No. 87 – March 1997

Important Events in Chile

R. GIACCONI, Director General of ESO

The political events foreseen in the December 1996 issue of The Messenger did take place in Chile in the early part of December 1996. On December 2, the Minister of Foreign Affairs of the Republic of Chile, Mr. Miguel Insulza, and the Director General of ESO, Professor Riccardo Giacconi, exchanged in Santiago Instruments of Ratification of the new "Interpretative, Supplementary and Amending Agreement" to the 1963 Convention between the Government of Chile and the European Southern Observatory. This agreement opens a new era of co-operation between Chilean and European Astronomers.

On December 4, 1996, the "Foundation Ceremony" for the Paranal Observatory took place on Cerro Paranal, in the presence of the President of Chile, Mr. Eduardo Frei Ruiz-Tagle, the Royal couple of Sweden, King Carl XVI Gustaf and Queen Silvia, the Foreign Minister of the Republic of Chile, Mr. José Miguel Insulza, the Ambassadors of the Member States, members of the of the ESO Executive, ESO staff and the Paranal contractors' workers.

The approximately 250 guests heard addresses by Dr. Peter Creola, President of the ESO Council, Professor Riccardo Giacconi, Director General of ESO, Foreign Minister José Miguel Insulza and President Eduardo Frei Ruiz-Tagle. The original language version of the four addresses follows this introduction. (A translation in English of the Spanish text is given on pages 58 and 59 in this issue of The Messenger.)

A time capsule whose contents are described in Dr. Richard West's article was then deposited by President Frei with the works being blessed by the Archbishop of Antofagasta, Monsignor Patricio Infante.

Both the formal and informal parts of the Ceremonies were de-

The Minister of Foreign Affairs of the Republic of Chile, Mr. Miguel Insulza, and the Director General of ESO, Prof. Riccardo Giacconi, signing the instruments of ratification on December 2, 1996, in the Ministry of Foreign Affairs in Santiago.

noted by great warmth. The event is seen as initiating a new period in the relations between ESO and its host country Chile and the harbinger of closer scientific co-operation between Chilean and European astronomers.

The ESO Council meeting took place in Santiago on December 5 and 6, 1996. Mr. Henrik Grage was elected President of Council as of January 1, 1997, and Dr. Bernard Fort as Vice-President as of January 1, 1998, at the end of Dr. Jean Pierre Swings' term.

The Council approved the ESO 1997 budget as recommended by the ESO Finance Committee and discussed in the December 1996 issue of The Messenger. More detailed discussion of this and other Council actions will appear in the June 1997 issue of The Messenger.

Speech by the President of the ESO Council, Dr. Peter Creola

Paranal, December 4, 1996

Your Excellency, President of the Republic of Chile, Don Eduardo Frei Ruiz-Tagle, your Majesties the King and Queen of Sweden, Carl XVI Gustaf and Queen Silvia, your Excellency, Minister of Foreign Affairs, Don José Miguel Insulza, Señor Intendente of the II Region, Don Cesar Castillo, honourable Senators, Ambassadors, authorities, colleagues of the ESO Executive and the ESO Council; friends, ladies and gentlemen,

It gives me great pleasure to welcome all of you on Cerro Paranal, the site of the world's largest optical observatory.

Our organisation's life in Chile started 33 years ago when the original agreement between ESO and its host country was signed under the government of President Jorge Alessandri Rodriguez, agreement which was to be supplemented later under President Eduardo Frei Montalva, who inaugurated in 1969 the La Silla Observatory with his son, now President of the Republic. For us it is then a special honour to welcome today members of both presidential families.

Nine years ago, in a historical meeting at the ESO headquarters in Garching, Germany, the 8 Member States of ESO united in the Council took the momentous decision to construct the Very Large Telescope. This decision followed a period of several years of intense discussions in the European Scientific Community; as well as in the various ministries and science committees of the ESO Member Countries.

The decision was not an easy one. Never before had a ground-based astronomical project of this size been proposed. Never before had the scientific community of Europe, together with the funding authorities, dared to consider a ground-based research facility to study the cosmos of this complexity and cost. The positive decision to engage in this project for the 21st century started a highly elaborate process on many fronts. Within ESO a gifted group of scientists and engineers began to work on the technical implementation, invoking the latest technologies available anywhere in the world. In many cities all over Europe, industrial engineers and technicians began the construction of the complex parts which would later come together as the VLT at the Paranal Observatory. In the ministries in the Member Countries, we began the long process of ensuring the steady funding and political support for this European flagship project.

Now, 9 years later, we are close to the goal of our common dreams. Despite many obstacles, we have succeeded in keeping to the plan and in just a year from now, the first of the four 8.2-metre VLT telescopes will open its eye towards the sky.

This project would not have been possible without the close and continued, extremely positive collaboration, not only between the individual ESO Member States but, in particular, with the host country of this organisation, the Republic of Chile.

Mr. President, thanks to your personal support, the continued efforts of your government and of many other authorities in Chile, we have succeeded in transforming this mountain into what will soon become the world's most modern optical observatory. This process has not been easy, many areas have been interlinked, and there were some stones on the road, pebbles as well as rocks, but we are now certain that soon Chilean scientists, together with their European colleagues, will reap the fruits of our joint labours. Thanks to this unique project, at the limit of today's technologies frontiers, Europe and Chile have come closer together than ever before.

The presence of ESO in Chile has given European scientists access to the clearest skies in the world and has provided Chilean scientists with the possibility to interact continuously with their colleagues in the front line of research and technology. We now look forward to the first exciting results from this collaboration at the Paranal Observatory. As I hear, there are already many discussions going on between European and Chilean researchers about how to best use this unique facility for the benefit of all involved.

The Members of the ESO Council and I are happy to be here today and to sense the enthusiasm which is evident in all quarters. We have no doubt that it was a wise decision by our countries to build the VLT and support this great project. The fruits will be not only in the fields of science and technology but, equally important, the understanding among peoples and nations will be furthered. It is a uniting aspect of all cultures to look up from our home planet towards the universe to admire its wonders and to grasp its origin and destiny. Our countries may be far apart in a geographical sense, but within this project we will labour together and thereby open new horizons for all of humanity.

Muchas gracias.

Speech by the Director General of ESO, Prof. Riccardo Giacconi

Paranal, December 4, 1996

Your Excellency President of the Republic of Chile, Don Eduardo Frei Ruiz-Tagle, your Majesties, King and Queen of Sweden, Carl XVI Gustaf and Queen Silvia, Minister of Foreign Affairs, Don José Miguel Insulza, Señor Intendente of the II Region, Don Cesar Castillo, honourable Congressmen, Senators, Ambassadors, authorities, Members of Council, friends and colleagues, ladies and gentlemen,

It is a great honour for us to welcome your Majesties on this very special occasion: There are certain events in the development of science, which mark important achievements, or a new promising departure towards, as yet, unexplored regions.

More than 30 years ago, I had the privilege of being part of an astronomical project that soon thereafter succeeded in opening the X-ray sky for scientists.

More recently, I was fortunate enough to be associated with the development and launching of the Hubble Space Telescope.

Today, I have a feeling of excitement equal to that on those occasions, as the ESO Very Large Telescope becomes a reality. No other project in ground-based astronomy has been more ambitious, more complex and, indeed, more demanding in resources. Few other projects in the history of astronomy have had a scientific potential of similar dimensions. Just one year from now, the first unit telescope of the VLT goes into operation and astronomers of the world will begin to open new vistas in this fundamental science. The VLT will deliver sharper images than any other optical telescope and, thanks to the enormous area of its mirrors, it will collect more photons and, therefore, reach fainter and more distant objects than any existing facility, either on the ground or in space.

As we are now approaching the end of the construction phase, astronomers in Europe, Chile and elsewhere, are preparing the exciting research projects they will soon undertake with their new observatory. Many of these will take us way beyond current horizons and will enable us to search for the answers to some of the deepest questions mankind has ever posed. The VLT has the capability of looking so far out in space and, therefore, so far back in time that we will ultimately reach the period, soon after the big bang explosion, when the matter in the universe had just begun to condense in the space islands we now observe as galaxies. The VLT will make it possible for us to look into the mysterious centres of galaxies where processes of unimaginable violence take place. The VLT will help us to understand the birth of stars, deep inside dense and, otherwise, impenetrable interstellar nebulae, enabling us to watch the processes that were the base of our own distant origins, 4.5 billion years ago. The VLT has the best potential of any telescope to search for, hitherto, unknown planets around other stars and, if they exist, to help us to discover other abodes of life in space.

The science of astronomy is a never-ending process which has drawn on the experience and ingenuity of countless individuals during the past millennia. Throughout the ages, scientists and engineers have put their faith in the latest technology and the VLT is no exception from this. We, as scientists, are deeply thankful to all those in- and outside ESO who have helped to realise this project and, in particular, to those authorities who have provided political and financial support for this project. Without their foresight, this moment would not have been possible.

During the coming years, it will be our privilege to share with them and the rest of mankind the excitement of new discoveries which will be made with the Very Large Telescope. The comprehension of our cosmic surroundings is one of the noblest goals of the human race. It enables us to understand and appreciate our niche in space and time, and it opens our minds towards fundamental truths which unite us all.

Las circunstancias me han llevado a leer el idioma de Chile, y hoy voy a aventurar algunas palabras en castellano.

Quiero decirles que nuestra organización no solo quiere hacer ciencia sino también participar en la vida cultural de Chile. Queremos apoyar el gran esfuerzo del gobierno del Presidente Frei para el desarrollo de la educación – en particular en la Segunda Región. Región donde la Cordillera, el desierto y su gente vive en una relación mas íntima con nuestro universo.

Muchas gracias.

Speech by the Minister of Foreign Affairs, Mr. José Miguel Insulza

Paranal, December 4, 1996

Señor Presidente de la República, don Eduardo Frei Ruiz-Tagle, sus Majestades los Reyes de Suecia, Karl XVI Gustaf y Reina Silvia, Señor Presidente del Consejo de la Organización para la Investigación Astronómica en el Hemisferio Austral, Señor Director General de ESO, Señores Senadores, autoridades civiles, militares y eclesiásticas, Señores miembros de la delegación de Suecia, Señores miembros del Consejo de la ESO, Señoras y Señores,

Para mi constituye un alto honor representar al Gobierno de Chile en esta ceremonia y compartir con todos ustedes la satisfacción y la esperanza que nos produce estar aquí participando en esta significativa ocasión por medio de la cual se inaugura el centro de observación de la ESO en Cerro Paranal. Esta satisfacción se origina, en primer lugar, en la importancia del proyecto que hoy inauguramos. El telescopio VLT/VLTI ya descrito por el Presidente del Consejo y el Director de ESO constituye no sólo una expresión de la más moderna tecnología puesta al servicio de las ciencias astronómicas, sino también una oportunidad de selección para profundizar en el conocimiento del Universo y responder así a las interrogantes que han preocupado a la humanidad desde sus orígenes. En este sentido, más allá del considerable valor económico de la inversión que hoy inauguramos, es evidente que nos encontramos participando en un hito en el desarrollo mundial y nacional de la astronomía.

Este sentimiento de satisfacción desde luego se acrecienta si consideramos el largo, y no siempre fácil, camino por el que debimos transitar en los últimos años para llegar hasta este lugar y hasta esta ocasión. Todos conocemos las dificultades heredadas de las incomprensiones hoy felizmente superadas que en un momento amenazaron la concreción de este proyecto.

Sin embargo, creo que es importante señalar que en todo este proceso, el Gobierno mantuvo, permanentemente, su apoyo a la ESO y a la posibilidad de que esta Organización continuara desarrollando y expandiendo sus actividades en Chile. Lo hicimos no sólo porque se trataba de un compromiso internacionalmente asumido por el Estado en lo cual nuestro país tiene una tradición de respeto riguroso a las obligaciones emanadas de tratados internacionales que comprometen el honor de la República, sino también porque apreciábamos que el desarrollo de las actividades de la ESO en nuestro país, en un marco jurídico claro, no sólo beneficiaría a la ciencia mundial, sino también al desarrollo científico de Chile y de importantes regiones de nuestro país.

La veracidad de este análisis queda hoy demostrada, pues el Centro de Observación de Paranal servirá no sólo a las actividades de la ESO, sino que redundará también en beneficio de los científicos chilenos, quienes dispondrán así de un instrumento de trabajo que, de otra manera, les sería absolutamente inaccesible.

Por ello, esta ceremonia, que es consecuencia del intercambio de Instrumentos de Ratificación del Acuerdo Interpretativo, Suplementario y Modificatorio del Convenio de 1963, que realizáramos el lunes pasado, es el punto final de un proceso difícil, y también es el inicio de una nueva relación de cooperación y entendimiento entre Chile y la ESO, que es una relación madura, consolidada, equitativa y de cooperación en mutuo provecho.

La consolidación de la relación jurídico-política de Chile con la ESO garantiza a esta Organización el desarrollo pacífico de sus actividades en un marco de mutuo provecho y constituye un aval importante para asegurar la expansión de las mismas en el futuro.

Al mismo tiempo, al otorgar a los sectores nacionales más directamente concernidos con la actividad de la ESO, un reconocimiento a sus legítimas aspiraciones, se consagra una relación equitativa, pues los derechos reconocidos a Chile y sus ciudadanos en materia científica y laboral, constituyen una adecuada contrapartida al aporte chileno a las actividades de la ESO en Chile.

Al establecer instancias permanentes de cooperación y de resolución de controversias entre Chile y la ESO, esta Organización se asocia estrechamente al desarrollo científico y tecnológico nacional.

Por último, esta relación es también pionera en numerosos aspectos, como la protección medioambiental, los derechos de trabajadores chilenos en entidades públicas extranjeras y los derechos de la comunidad científica nacional, y esperamos que constituirá un ejemplo para futuras acciones en convenios astronómicos que el país subscriba en los próximos años.

Dentro de este marco, deseo expresar la más cálida acogida del Gobierno a la iniciativa de creación de la “Fundación para el Desarrollo de la Astronomía”, iniciativa originada en los astrónomos chilenos que han obtenido Cátedras Presidenciales en ciencias y que ha contado con el apoyo del Director General de la ESO, Dr. Riccardo Giacconi. Creemos que esta fundación, que se complementará con la acción de otras entidades que vinculan a Chile con la ESO, está llamada a jugar un papel de gran importancia en la administración de recursos destinados al desarrollo astronómico de Chile y en la promoción de la cooperación internacional en esta importante ciencia.

Señor Presidente, Majestades, nos encontramos en este imponente lugar para participar en una ceremonia que ha sido el fruto de la decidida y visionaria cooperación entre el Gobierno del Presidente Frei y la ESO. Agradecemos también, esta es la ocasión de hacerlo, a los muchos científicos que han participado con su esfuerzo en este proyecto, a los trabajadores que lo han realizado y también al Congreso Chileno, representado aquí por los senadores de la Región por la comprensión que manifestó siempre hacia nuestro esfuerzo.

Esperamos que el Centro de Observación de Cerro Paranal entre pronto en funcionamiento, y que los frutos del trabajo que chilenos y extranjeros realicen en sus instalaciones, no sólo redunden en un mejor conocimiento del Universo, sino también en beneficios concretos para la ESO, para sus Estados miembros, entre los que se cuenta el Reino de Suecia, y para Chile. En esta esperanza expreso mis mejores deseos de éxito a esta nueva aventura de la ciencia.

Muchas gracias.

The President of Chile, Mr. Eduardo Frei Ruiz-Tagle, addressing the audience.

Speech by H.E. President Eduardo Frei

Paranal, December 4, 1996.

Sus Majestades los Reyes de Suecia, Señor Ministro de Relaciones Exteriores, Señores Senadores de la 2ª Región, Señor Intendente, Señores Embajadores, Señores Miembros del Consejo de la ESO, y un saludo muy especial para el Presidente del Consejo del Observatorio Europeo Austral, ESO, Don Peter Creola, y también para el Profesor Riccardo Giacconi, Director General, estimado amigo.

Al contemplar esta obra en medio del desierto chileno, hecha con el esfuerzo conjunto de un grupo de países europeos, de su comunidad científica de astrónomos, y de Chile, sus trabajadores, sus ingenieros y sus técnicos, siento no solo satisfacción, sino que también un legítimo orgullo.

Esta es una concreta señal de como estamos internacionalizando nuestro país e insertándolo cada día más en el mundo. Y no es solamente en materia económica.

Todos sabemos los logros que hemos obtenido este año al asociarnos con la Unión Europea, con Mercosur, al llegar a un acuerdo de libre comercio con Canadá.

Pero hay también otros aspectos en que nos estamos integrando positivamente al mundo. Hoy, nuestra relación política con la comunidad internacional se haya a un altísimo nivel, impensable hace algunos años. La democracia no solamente nos ha aproximado al mundo, sino que nos ha dado un prestigio que hoy es respetado en todo el globo.

Y también, en el plano de la cooperación científica hemos dado importantes pasos hacia una mayor cooperación internacional. El establecimiento de este observatorio es una muestra clara de ello: aquí vendrán astrónomos de Europa y de muchas naciones del mundo, y tendrán la oportunidad de llevar a cabo sus investigaciones los más destacados astrónomos Chilenos.

Esto abre múltiples oportunidades de colaboración y crea también una plataforma de gran valor para la formación de los jóvenes astrónomos chilenos. Nuestras principales universidades se verán beneficiadas, así como el país en su conjunto, que obtendrá el provecho de ser sede de uno de los lugares de observación astronómica de mayor concentración y más avanzado del mundo.

Otorgo vital importancia a estas actividades conjuntas con países industrial y científicamente desarrollados, porque nosotros enfrentamos como el reto de nuestra modernización, el desafío de construir nuestras propias capacidades en ciencia y en tecnología.

Chile no podrá proyectarse creativamente hacia el futuro, ni vamos a poder crear una sociedad más moderna, más justa, más equitativa, si junto al desarrollo y al crecimiento económico no generamos las oportunidades para sus ciudadanos, y no logramos simultáneamente producir y aplicar estos conocimientos avanzados en la industria, en la agricultura, en los servicios, en la gestión del Estado.

Quizás sea este uno de los desafíos más grandes que tenemos; esto requiere del esfuerzo de toda la comunidad nacional, del gobierno, de las empresas, de las universidades. Agradecemos el apoyo al esfuerzo de modernización de la educación. Sabemos que ese es el fundamento de todo el edificio que estamos construyendo: sin una educación de mayor calidad y más equitativa, no vamos a construir un país de oportunidades y no vamos a terminar con la marginación y la pobreza.

Quisiera al terminar, agradecer y dar un público reconocimiento a las autoridades que participan en la ESO, a sus ejecutivos, y decir que, poco después de asumir la Presidencia, como decía el Presidente, no solamente habían piedras sino que habían rocas en el camino. Pero tuvimos la voluntad política de destruir todos los obstáculos, porque no íbamos a permitir que una obra como ésta no se concretara en nuestro país.

Estamos felices además de contar hoy día con la presencia de sus Majestades los Reyes de Suecia. Queremos simbolizar en ellos también nuestro reconocimiento y expresarles también que nuestra comunidad académica tiene una deuda de solidaridad con su país por el apoyo prestado a centenares de investigadores y profesores Chilenos que vivieron durante largos años el exilio en Suecia, y el apoyo también dado a un importante número de instituciones nacionales que se han desarrollado gracias a la colaboración y cooperación internacional de esta generosa nación.

Por último, quiero hacer un recuerdo especial ya que el año 1969 le correspondió a mi padre, el entonces Presidente Eduardo Frei Montalva, inaugurar el primer centro astronómico en el Observatorio de La Silla. Lo hizo en compañía de un destacado hombre de Suecia, el Ex-Primer Ministro Olaf Palme, en esa época Ministro de Educación.

El mundo es pequeño, las historias se repiten, con gran alegría estamos hoy día dando el vamos a esta gran obra que significa, a futuro, desarrollo para nuestro país.

Muchas gracias.

The Time Capsule

During the December 4, 1996 event at Paranal, President Frei placed a Time Capsule with selected materials in the wall of the UT1 building. This capsule, an aluminium cylinder of 15 cm diameter and 45 cm long, was filled with nitrogen gas and sealed hermetically. A commemorative plaque was fixed in front of the cavity. In addition to the various papers listed below, the capsule also contains a list of contents etched on a metal plate which will survive virtually indefinitely in this environment, while it cannot be excluded that the papers may deteriorate with time.

Contents of the Time Capsule:

1. Document signed by President Frei on the occasion;
2. Copy of the Acuerdo between ESO and Chile;
3. One outstanding scientific paper from each of ESO's member countries (a list of the titles is available at the ESO Web-site)
4. Copy of December 4 issues of the Chilean newspapers *El Mercurio* and *La Epoca*;
5. Copies of the written version of the speeches delivered on the occasion;
6. Viewgraph and description of VLT, as presented at the exhibition;
7. List of VLT Team members;
8. Photos of Paranal before and after construction;
9. Photo of the VLT model at exhibition.

R.M. West

Paranal, December 1996

M. TARENGHI, ESO

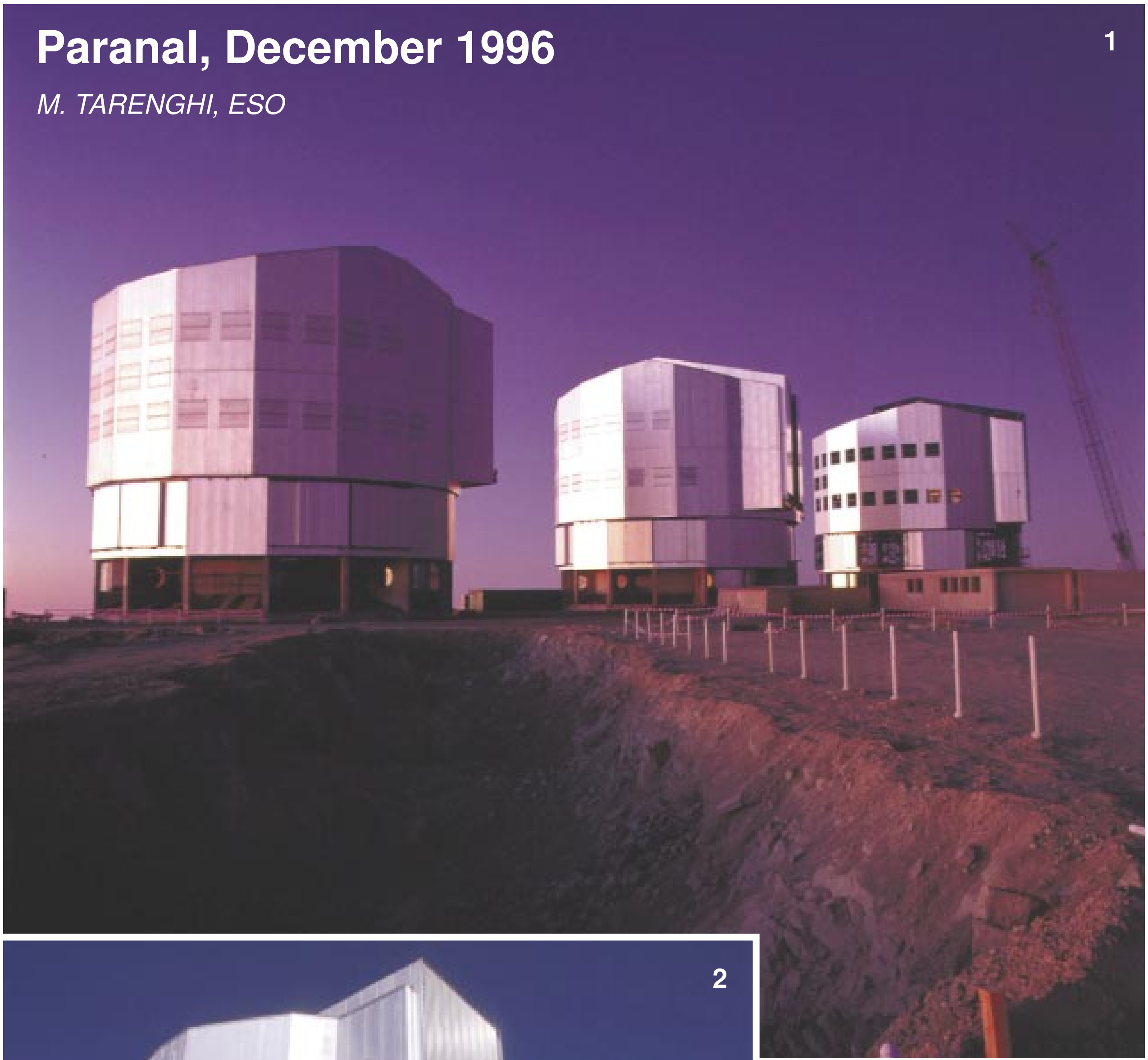
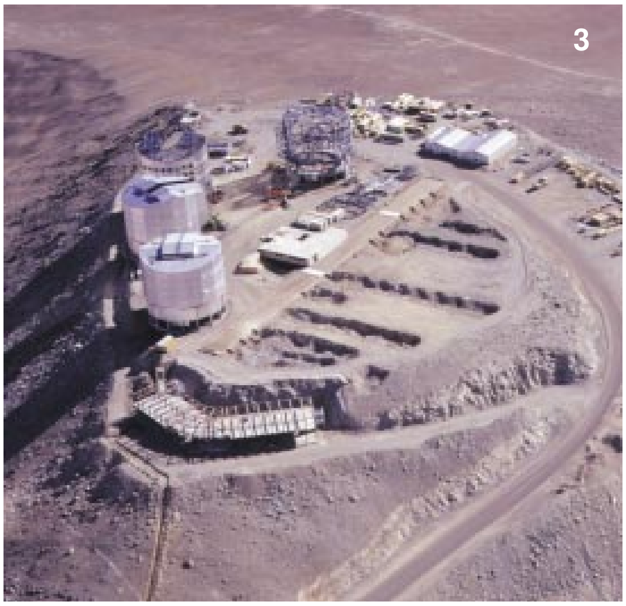


Figure 1: The enclosures for telescopes 1, 2 and 3 show the completion of the external cladding and the series of openings (louvers and doors) that were designed in the enclosure to be able to control ventilation and minimise dome seeing. The excavations in the foreground are for the foundations of one of the tracks that will be used by the auxiliary telescopes for the VLTI.

Figure 2: The enclosure of UT1 is shown in this picture as it will be used during observation. The slits and louvers are open, the large box in the lower part is one of the air conditioning/air treatment units. Above the small door in the concrete structure one can see the large sliding door 10 metre wide that will be used to integrate the 8.2 m diameter mirror with its cell.

Figure 3: This aerial picture taken early in the morning from the west side shows clearly the different phases of erection of

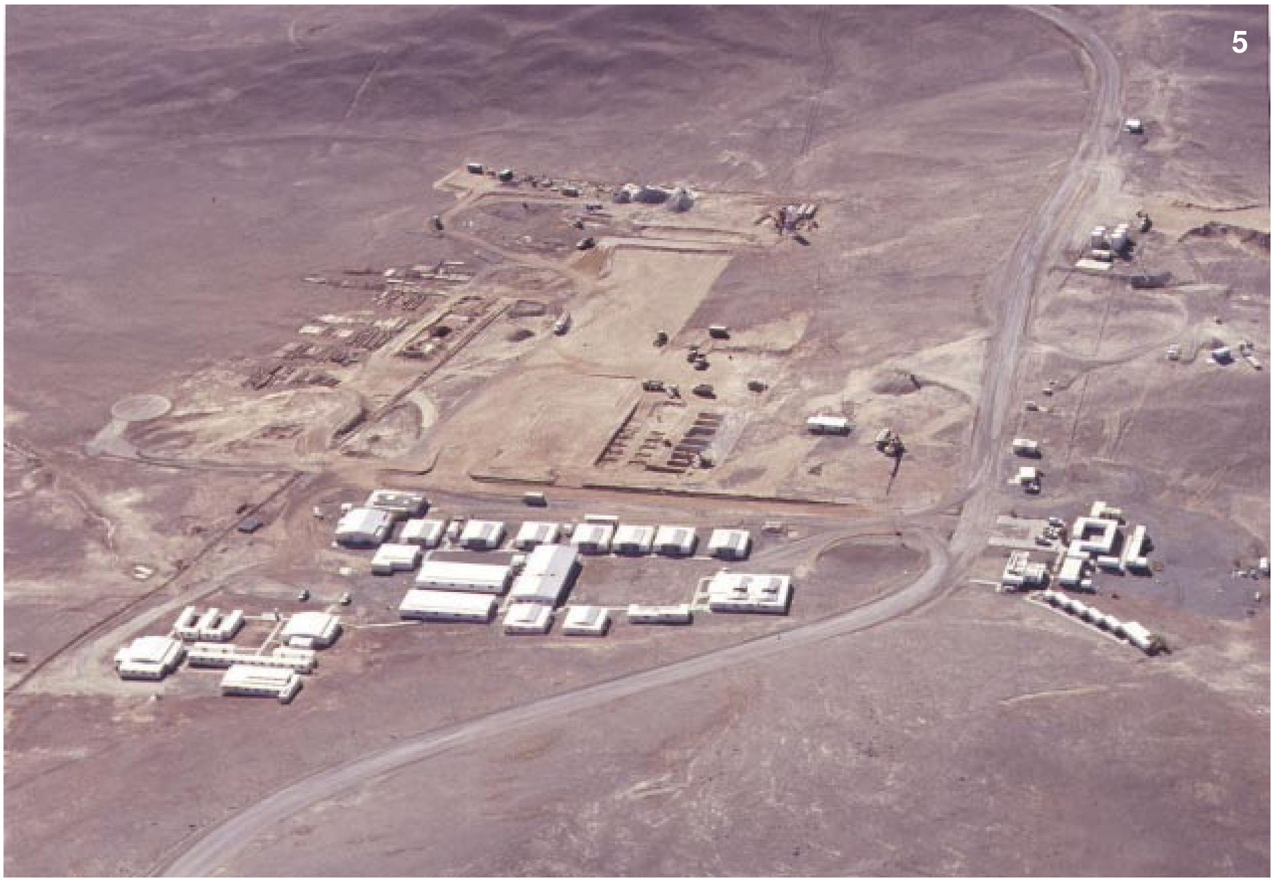


the four nclosures and the steel frame of the control building. In addition, it is possible to see the roof of the delay-line tunnel and the laboratory for interferometry located in the middle of the flat summit area.

Figure 4: A view of the interior of enclosure No. 1 during functional tests of the rotation of the upper part. The long exposure time used to take this picture shows clearly the movement of the rotating part. Visible above the electronic cabinets controlling the complex functions of the enclosure are some of the ducts and vents of the air conditioning system which are used during the day to control the temperature of the telescope.

Figure 5: This aerial view shows the three camps utilised by ESO and the contractors in this phase of construction. To the far right is the old ESO camp. In the centre is the camp erected by Skanska-Belfi and now used by SOIMI and ESO. At the far left is the in tial SOIMI camp. Clearly visible in the background are the excavations for the construction of the Mirror Maintenance Building, the power generation building, warehouse and all the other structures necessary for the operation of the observatory.

(Photographer: H.-H. Heyer)



TELESCOPES AND INSTRUMENTATION

A New Plan for the VLTI

O. VON DER LÜHE, D. BONACCINI, F. DERIE, B. KOEHLER, S. LÉVÊQUE, E. MANIL, A. MICHEL, M. VEROLA, ESO Garching

1. Introduction

Since the decision by the ESO Council in December 1993 to postpone the implementation of the VLTI (see *The Messenger* No. 74, December 1993), ESO has pursued a programme with the aim to develop all necessary designs to assure a fast implementation as soon as funds would become available. As a part of this programme, the Interferometry Science Advisory Committee (ISAC), a committee of astronomers who have a background in high angular resolution astrophysics and interferometry, was established. Its charge is to review the development of, to define a key science programme for, and to recommend necessary conceptual changes to, the VLTI. It has convened in May and October 1995 and in April 1996. The ISAC found a wealth of scientific topics which could be addressed favourably or uniquely with the VLTI. Some of them have been described in more detail (see *The Messenger* No. 83, March 1996). The top-level technical requirements which result from the ISAC scientific requirements are:

• The VLTI should acquire first fringes around the turn of the century in order to ensure competitiveness with other interferometry programmes.

• There should be a phased approach to the implementation of the VLTI. The first phase shall include the 8-m Unit Telescopes from the start, and shall focus on spectral regimes where telescopes can perform near the diffraction limit with a minimum of adaptive control. The capability, within the budget, to open the spectral ranges towards shorter wavelengths for all telescopes, in particular to the near-infrared regime with Unit Telescopes using higher-order adaptive optics systems, shall be investigated.

• Auxiliary Telescopes should have a diameter of order 1.8 m as a compromise between cost and sensitivity.

• A field of view for the science target of 2 arcseconds ("primary beam") is sufficient. In order to enable phase referencing as well as narrow-angle astrometry, the capability to do interferometry at a second field position ("secondary beam") within 1 arcminute radius from the science beam shall be included.

• VLTI shall have the capability to simultaneously combine four telescopes, including at least two 8-m Unit Telescopes and up to three Auxiliary Telescopes.

• Beam combination instruments shall operate in "single mode" (fringe detection on fields of the size of the Airy disk) in the red, near-infrared, and in the mid-infrared.

• VLTI should have narrow-angle astrometric capability with the a precision comparable to the atmospheric limit.

In view of the progress made in the scientific definition as well as of the growing competition, ESO decided in December 1995 that the time was right to reintroduce the implementation of the VLTI into the VLT programme, within funds available at ESO as well as in the community. We have developed a "New Plan" with a technical scope which is adapted to a limited budget, and a significantly modified technical concept which meets better the scientific needs. The main goal of the New Plan is to introduce the original VLTI capability, but in several phases with a modified schedule and sequence off supplies. However, there will be significant changes to the earlier concept (see J.M. Beckers, "Planning the VLT Interferometer", in *The Messenger* No. 60, June 1990). The new plan was endorsed by the Scientific-Technical Committee, Council has subsequently confirmed its authorisation to the Director General to proceed with parts of the VLTI programme. Also, additional funds of 10 million DM which were made available through an agreement on the enhancement of the interferometric

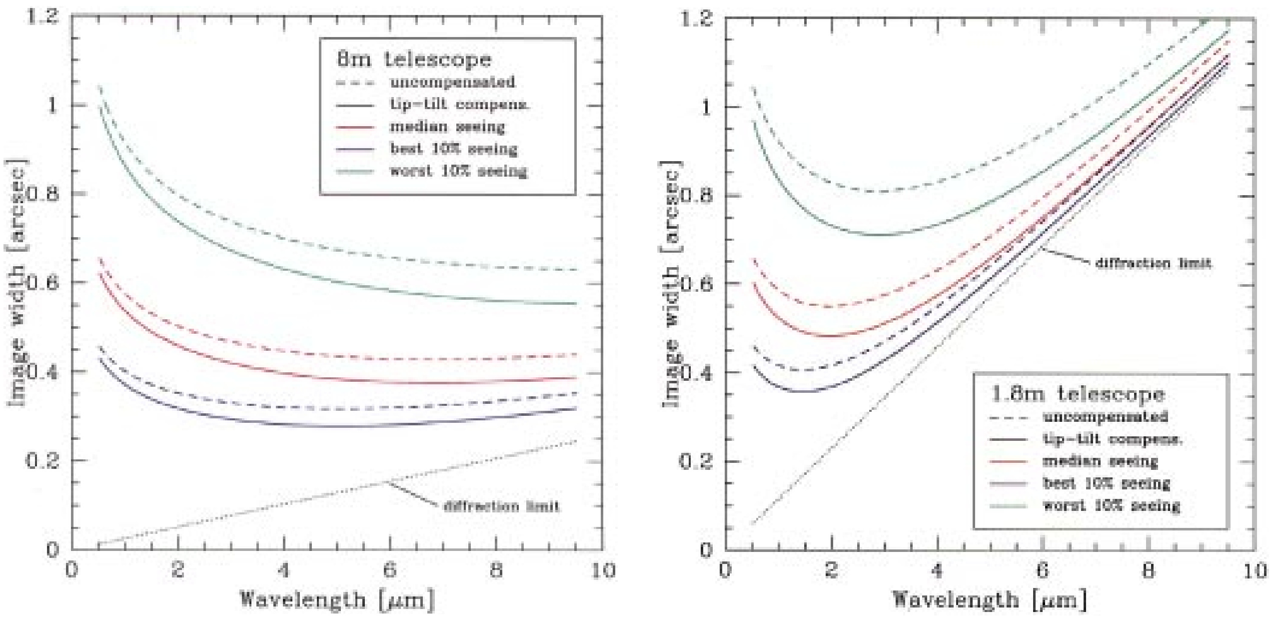


Figure 1: Resolut on of an 8-m telescope (left) and a 1.8-m telescope (right) with the seeing characteristics of Paranal. Median seeing refers to $r_{0,550}$ = 15.6 cm, best 10% of seeing to $r_{0,550}$ = 22.4 cm, and worst 10% seeing to $r_{0,550}$ = 9.8 cm.

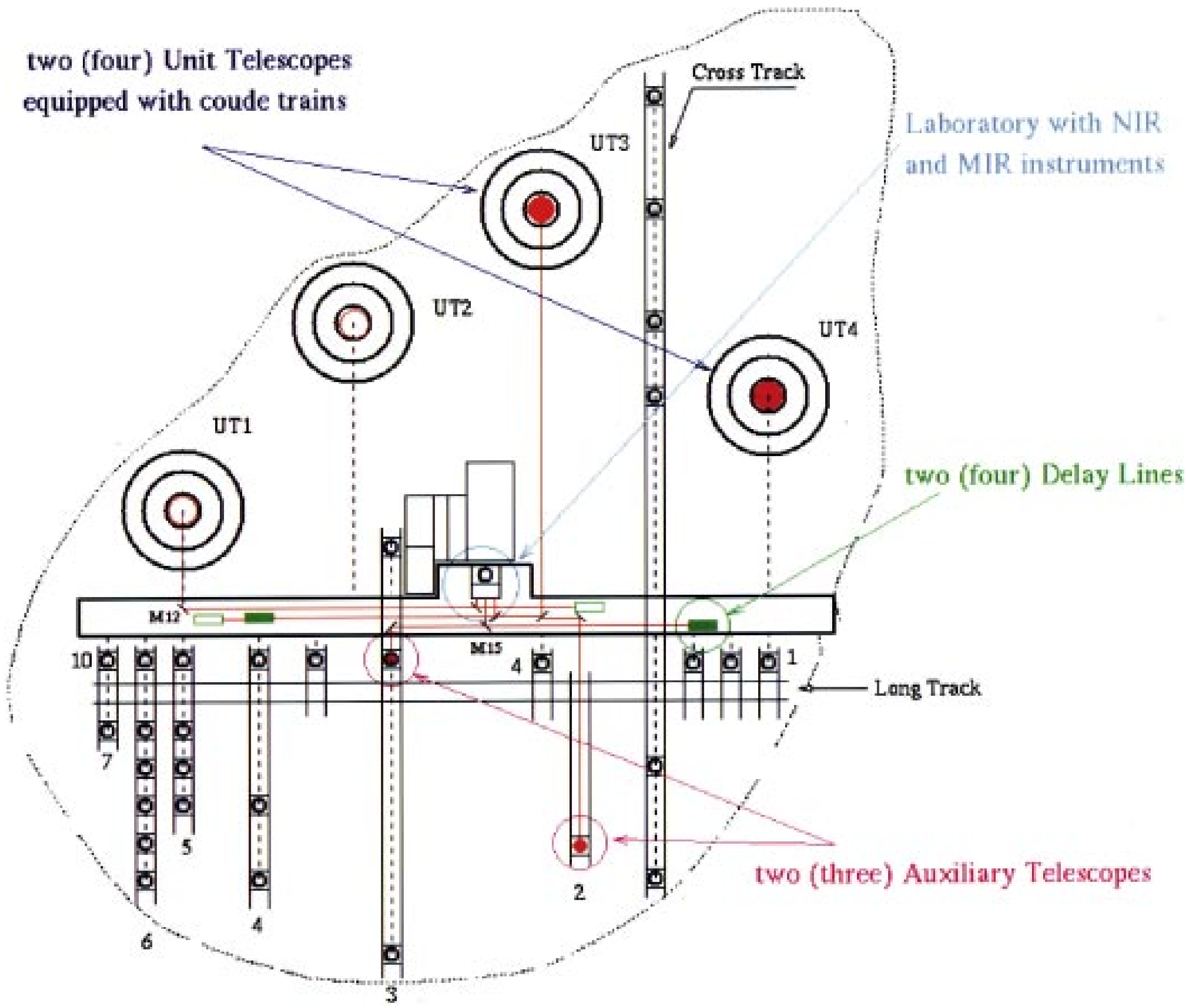


Figure 2: Layout of the VLT Interferometer on Paranal.

mode of the VLT, and which was signed by the CNRS, the MPG and ESO in 1992 (see *The Messenger* No. 71, March 1993), could be secured for the New Plan through an update which was signed by the three partners end of 1996. This article describes the essential elements of the New Plan and recent changes, as well as the current progress.

2. Consequences on the VLTI Concept

2.1. Wavelength range for early phases

ISAC recommended to focus for the earliest operational phases on the near and thermal infrared spectral regimes where Unit and Auxiliary Telescopes would be diffraction limited with tip-tilt compensation. Figure 1 shows the resolution attained by 8-m and 1.8-m telescopes on Paranal without and with fast tip-tilt only compensation. An 8-m Unit Telescope achieves the best resolution for wavelengths above 5 μm under median seeing conditions without any compensation, and is close to the diffraction limit for these wavelengths when image motion is controlled. A 1.8-m Auxiliary Telescope operates at the diffraction limit for wavelengths above 2 μm. Therefore, operation without higher-order adaptive optics will be optimum in the thermal IR (5 μm and longer) with the Unit Telescopes and in the near IR (1 μm … 2.4 μm) with the Auxiliary Telescopes. Without adaptive optics beyond tip-tilt compensation, the Unit Telescopes would not be significantly more sensitive in the near-IR than the Auxiliary Telescopes. ESO therefore currently pursues the development of low-cost adaptive-optics systems specifically tailored for interferometry with the Unit Telescopes in the near infrared.

Diffraction within the collimated beams inside the delay-line tunnel limits the suitability of the Auxiliary Telescopes for use in the N and Q bands. The implications of doing interferometry with Unit Telescopes in the thermal IR need further detailed investigations considering that beam combination occurs after more than 20 reflections at room temperature. However, fringes appear at precisely-known frequencies and their position can be modulated in time by small variations of optical delay. This should substantially facilitate their detection against the background.

2.2. Reduction of the field of view

The reduction of the field of view to 2 arcseconds makes a substantial reduction of the optics in the delay lines possible. The beam diameter which the delay line primary optics must accommodate is now at most 15 cm. The dimensions of the cat's eye primary mirror is reduced from a size of about one metre to 60 cm. Another consequence of the field reduction is that severe requirements on the lateral stability of the delay-line carriage motion could be relaxed substantially, making simpler drive concepts viable.

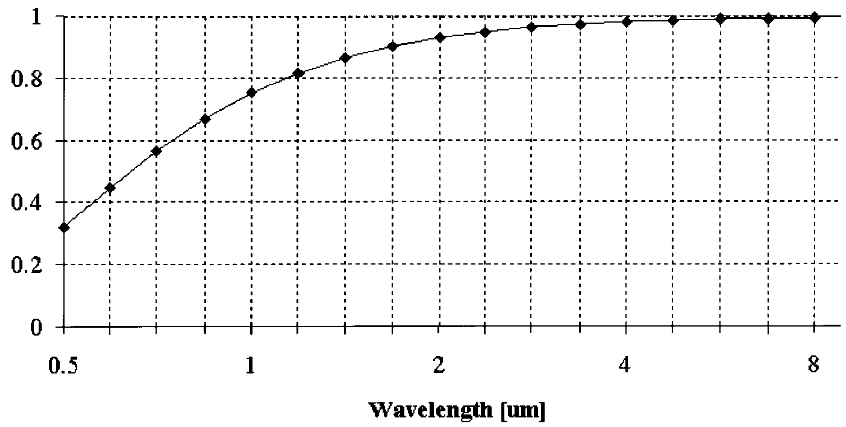


Figure 3: On-axis Strehl ratio as a function of wavelength for new UT coudé trains.

A reconstructed field of view of the VLTI is most likely limited by incomplete UV coverage, in particular when the number of baselines is initially small. The imaging beam combiner in the laboratory which was conceived for a co-phased field of view of 8 arcsec will therefore not be part of the early VLTI. Phase referencing, for which the field should be actually larger than 8 arcsec, is better implemented with a dual feed (see below). Beam combination will occur in the first phases within the instruments.

2.3. Dual feed

The desire for including narrow-angle astrometric capability (Shao et al., 1992) into VLTI (Léger et al., 1995, Quirrenbach, 1995, von der Lühe et al., 1995) eventually resulted in the decision to replace the original 8-arcsec continuous field with dual feeds. These allow selecting two positions at the coudé focus to be directed towards the delay lines and the laboratory. One beam will propagate the light from the science target, the other one will propagate the beam of a nearby phase reference (UTs and ATs) or an astrometric reference (ATs only). The concept behind the phase reference is similar to a reference star for adaptive optics, it serves for image and fringe tracking should the science target be too faint. There are limits to the field angle which come from atmospheric anisoplanatism.

The coudé foci of both Unit and Auxiliary Telescopes will be equipped with dual feeds. One position will be on the optical axis. The other position will be within a range of 5 to 60 arcsec from the axis anywhere within the coudé foci. The two beam lines will share the delay lines for any given telescope, making differential delay lines in the laboratory necessary. The design concept for the dual feed is still in the works. Although designs for dual feeds exist elsewhere, they are not easily adapted to VLTI because the requirements on spectral coverage and astrometric precision essentially exclude transmissive optics.

The requirements and engineering implications of narrow-angle astrometry are very severe and need thorough studies. The atmospheric limits to astrometric precision depend linearly on field angle and amount to about 10 µas with a 100-m baseline and 30 minutes of integration. Achieving this precision in practice requires the *knowledge* of the instrumental differential delay between the primary and secondary beam to 5 nm accuracy. At this time, the technical limits to determine the differential delay are not known.

3. VLTI Development

Budget limitations require an implementation of the VLTI in two phases (Phases A and B). The first and most expensive Phase A is covered by ESO's financial projections. Since Auxiliary Telescopes make up a large part of the cost, it was decided to build only two of them in Phase A and to defer the third one to Phase B. Because of the long lead times for the Auxiliary Telescopes, first fringes will be observed first with Unit Telescopes which we expect to be highly subscribed. To be able to exercise and test the interferometry subsystems with little impact on Unit telescope time, we intend to use simple siderostats on Auxiliary Telescope stations observing bright stars until the time Auxiliary Telescopes become available. Figure 2 shows the general layout of the VLTI and its major components for Phase A (for Phase B in parentheses). We discuss some major elements of the VLTI development in the following sections.

VLTI will consist of the following subsystems after the completion of Phase A:

1. Coudé optical trains on two Unit Telescopes
2. Two delay lines
3. Two test siderostats, to be replaced by
4. Two Auxiliary Telescopes, relocatable between 30 stations
5. Control system
6. Beam combination instruments

The following subsystems will be added during Phase B:

1. Third Auxiliary Telescope
2. Coudé optical trains on remaining Unit Telescopes
3. Two additional delay lines

Phase A has just begun and is expected to last until the end of 2001 when more or less regular science observations will begin. "First fringes" by the coherent combination of two Unit Telescopes would be observed early 2000 if the Phase A coudé trains are installed on Unit Telescopes 1 and 2, the delay lines are in place, and the first instrument is completed. First fringes with Auxiliary Telescopes are expected in the middle of 2001 after installation of Auxiliary Telescopes 1 and 2. The kick-off of Phase B, which represents about $^1/_4$ of the total cost, depends on the availability of additional funds. If started early 2000, interferometry with all four Unit Telescopes and three Auxiliary Telescopes would begin in 2003.

3.1. Unit Telescope Coudé Trains

The early use of 8-m Unit Telescopes with VLTI requires that coudé optical trains, which also were delayed in

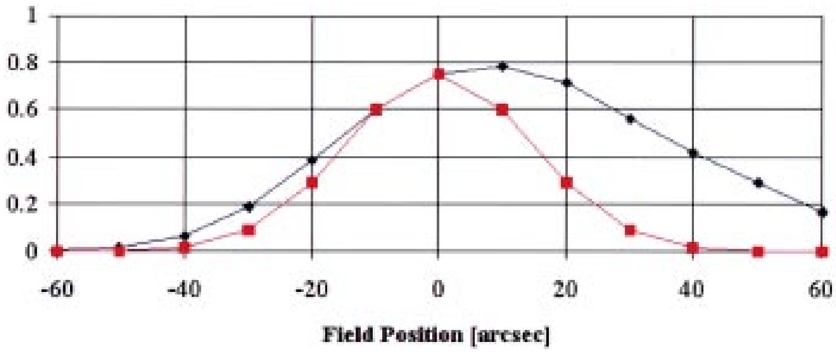


Figure 4: Field dependence of Strehl ratio of new UT coudé trains in two orthogonal directions at 1 µm.

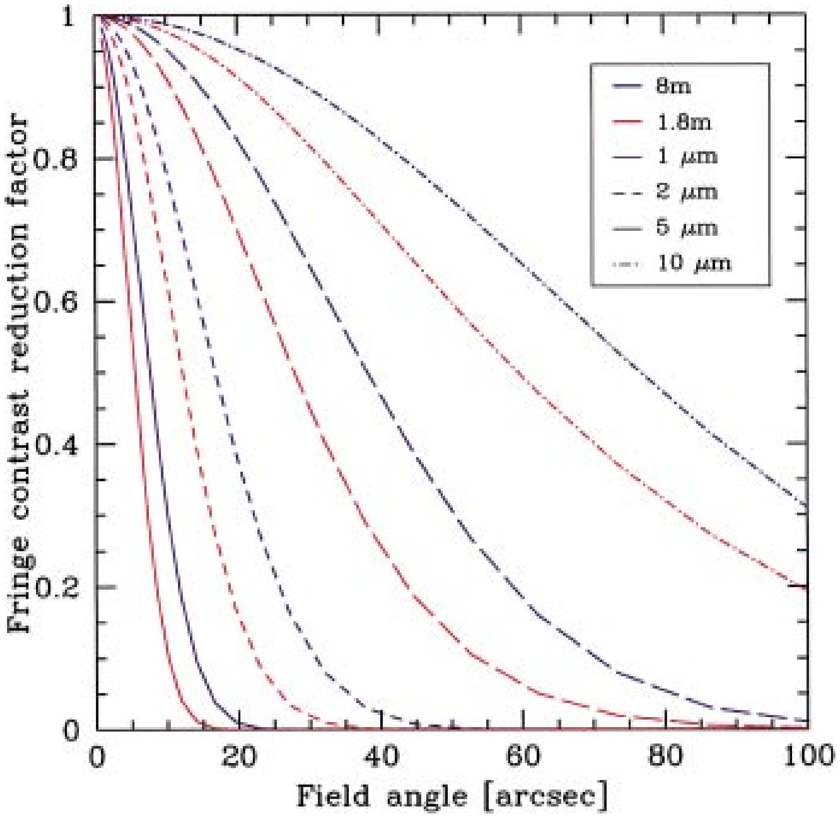


Figure 5: Fractional fringe contrast loss as a function of field position for a representative distribution of turbulence for Paranal, with 8-m and 1.8-m telescopes.

1993, be re-introduced into the technical and financial concept. Since the use of Unit Telescopes from Hα towards longer wavelengths is emphasised, we have investigated a simpler and cheaper optical design where large off-axis elliptical mirrors are replaced by spherical mirrors. The astigmatism and field scale anisotropy resulting from this change are compensated on-axis by replacing two flats with weak cylindrical mirrors. Figure 3 shows the on-axis Strehl ratio as a function of wavelength. The main contributing aberration is astigmatism. Figure 4 shows the Strehl ratio as a function of field angle in two directions for a wavelength of 1 μm.

The on-axis performance of the modified coudé optics is very satisfactory over a large spectral regime, including the visible, when atmospheric distortions are taken into account. The Strehl ratio degrades with increasing field angle but the resulting fringe contrast loss will always be small compared to the loss due to atmospheric piston anisoplanatism. This is shown in Figure 5, where the fringe contrast loss due to the differential piston variation between two field positions is shown. This effect is the interferometry analogue to the "isoplanatic patch" in adaptive optics. These curves were calculated based on measurements of the turbulence above Paranal by radio sondes in 1994.

Two out of the four Unit Telescopes will be equipped with coudé trains during the first phase. The decision which telescopes to equip will be influenced by scientific, schedule, and technical considerations.

3.2. Auxiliary Telescopes and Stations

The Conceptual Design of the Auxiliary Telescope System (ATS) was established in 1992 after a study performed by IRAM under ESO contract. It features 1.8-m telescopes in Alt-Az mount with mechanical bearings. The axes are controlled through optical encoders and friction coupled or direct drives. The optical layout is similar to that of the VLT 8-m telescope. It includes a coudé train with an intermediate pupil image to enable fast tip-tilt compensation (and possibly later adaptive optics). The coudé beam is collimated and sent horizontally to the Delay Line Tunnel through underground light ducts. The telescope is self-protected against wind and adverse weather conditions by built-in wind shield protective cover. The telescope is movable on a rail network and can be located on any of the 30 observing stations through a kinematic interface. Each telescope is equipped with a transporter which handles the telescope for the relocation and houses a number of auxiliary equipment. During observation, the transporter is anchored on separate foundations isolated from the ground to avoid transmission of vibrations from the wind shield and auxiliary equipment.

ESO has thoroughly reviewed during 1995 alternatives to the original design and development concept in an attempt to trade off technical scope and cost with scientific performance. This concerns mainly the diameter of the primary mirrors, as well as a trade between in-house design and industrial design. The conclusion was that the original ap-

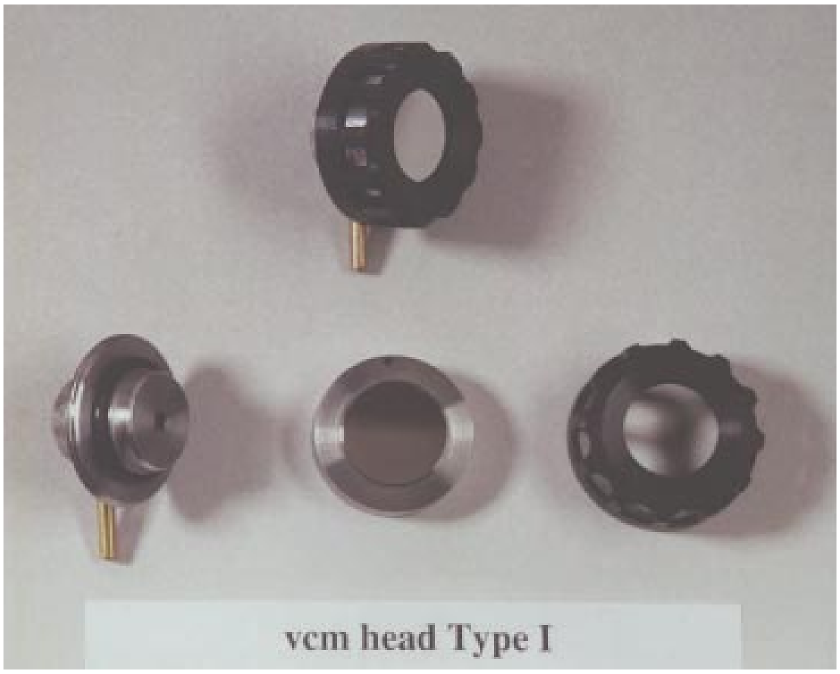


Figure 6: Variable curvature mirror head.

proach represents the best compromise. Based on the original concept, ESO will contract to industry the final design, manufacturing and testing of the ATS including optics, mechanics and control for the telescope and its transporter in 1997. Integration and testing of the Auxiliary Telescopes at the observatory will be performed by ESO staff.

3.3. Delay Lines

The purpose of the delay lines is twofold, to equalise optical path length differences (OPD) and to transfer a pupil at a fixed location inside the interferometry laboratory.

The delay lines equalise optical path length differences caused by the static geometric path length difference between telescopes in any given configuration, by the diurnal motion of the astronomical source during observation (sidereal motion of a star), and by the rapid fluctuations due to atmospheric disturbances and/or mechanical vibrations. To perform the compensation of the OPD, the delay lines include an optical retroreflector (cat's eye) which moves during observation with high precision. The range required for OPD equalisation is 120 m which implies a mechanical stroke of up to 60 m for each delay line. This motion must be very accurate and smooth in order not to distort the interference fringe pattern formed at the interferometry focus. The longitudinal position of the cat's eye must be continuously monitored and controlled by a fast metrology system; high dynamic stability and adequate drives and bearings are required to avoid vibrations which otherwise could blur the fringe contrast.

The second purpose of the delay lines is to image the pupil of the telescope at a fixed position inside the interferometry laboratory for beam management. A mirror with a variable curvature is used at the focus of the cat's eye which has been developed for this purpose by the Laboratoire d'Optique de l'Observatoire de Marseille (Figure 6).

Figure 7 shows a model of the delay line cat's eye according to a design study performed by ESO. The lower part shows a section of the 69 m long foundation. The cat's eye consists of a compact Cassegrain optical configuration with a 60 cm diameter primary mirror and an effective focal length of 3.5 m. The optics support the beams from two field positions which enter through the upper two holes and leave the cat's eye through the lower two holes on opposite sides. The delay line covers half of the support bench, the other half provides space for a second one. ESO will contract to industry the design, manufacturing and testing of the delay lines including optics, mechanics, control and metrology in 1997. The integration and testing of the delay lines at the observatory will be performed by ESO staff.

Figure 7: A model of the VLTI delay line. See text..

3.4. Beam Combination and Fringe Detection

The beam combination laboratory area provides the following functions during Phases A and B: beam alignment (image and pupil position alignment), calibration, fringe tracking, beam combination and fringe detection. Figure 8 shows an overview of the layout for Phase A. Stellar light beams enter the laboratory from below. A switchyard, which consists of dichroic and reflective mirrors, directs the light towards the instruments and to the image and pupil alignment and fringe sensor systems. A calibration unit which provides a number of sources in the visible and infrared feeds the alignment units and the beam combiner/fringe detector instruments and assures their intercalibration. Wide-band visible and laser light will be available for this purpose, as well as for the alignment of the beam combination/fringe detection instruments. Laser metrology beams feed the fringe tracking sensor for internal calibration. Another metrology beam travels back to the telescopes and determines the delay line zero position for the internal path during a set-up phase.

A prototype of the fringe sensor is currently under development at the Ob-

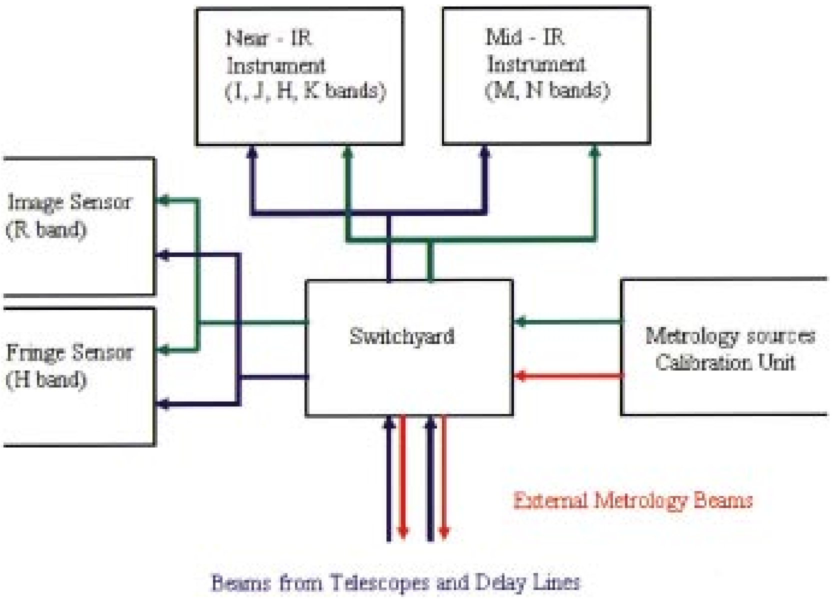


Figure 8: General interferometry laboratory layout.

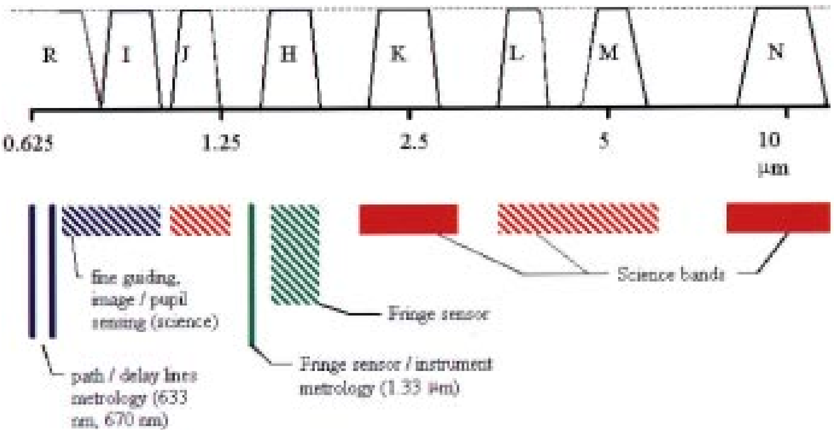


Figure 9: Allocation of spectral band usage for VLTI.

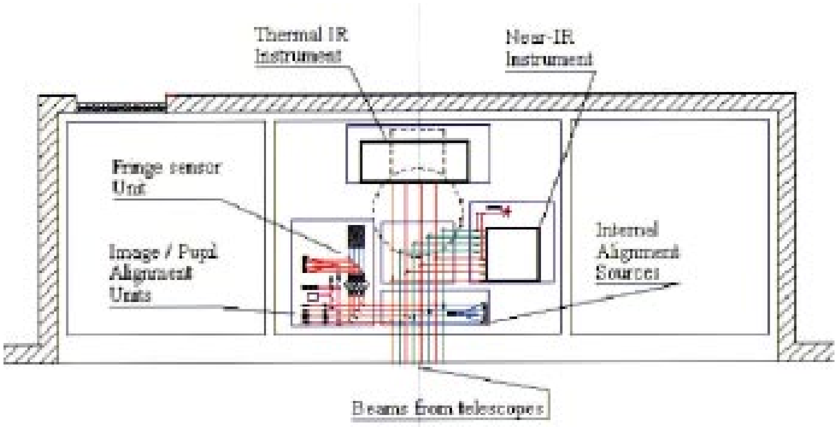


Figure 10: Preliminary configuration of interferometric laboratory.

servatoire de Côte d'Azur in Nice. This sensor uses a long stroke synchronous demodulation technique to detect both the presence and the position of stellar fringes in the H band. The error signal is fed back to the delay line control system to provide real-time fringe stabilisation. Figure 9 shows a provisional allocation of spectral bands for metrology, sensing, and science fringe detection purposes. We are developing a test bed for this metrology system in a nearby laboratory to validate the concept and its performance with an optical path of several hundred metres.

Figure 10 shows the central part of the tunnel and the laboratory with some more detail. Primary and secondary beams emerging from the delay line cat's eyes are directed towards the laboratory in the upper half. The switchyard is near the centre of the layout. Instruments are on the top and right. Fringe and image sensors are to the left. The structure to the lower right is the metrology beam launching system.

The two boxes represent the final beam combination and fringe detection stage for the near and thermal infrared. At this time, these areas are not yet defined. We expect to populate them with the help of the community. The functions needed here are beam combination (two beams in Phase A, three or four in Phase B), any dispersion required, detectors and associated read-out electronics, control electronics for mechanical functions as needed, cryogenics, and metrology sensors contained in the instrument. The interfaces to which the equipment should fit include a mechanical interface (optics bench), an optical interface (size and position of incoming stellar and metrology optical beams), and a control and data interface. The VLT Programme provides an extensive set of standards for electronic equipment whose use in encouraged, as well as general-purpose software packages which facilitate the integration into the VLT Observatory. ESO currently develops a computer model of the essential VLTI elements for engineering purposes (Fig. 11). It is planned to also use the simulated data to model in detail the fringe generation and detection with realistic astronomical sources and spectral band within the instruments to assess the performance of VLTI.

ESO's partners to the agreement on the enhancement of the VLTI, the CNRS

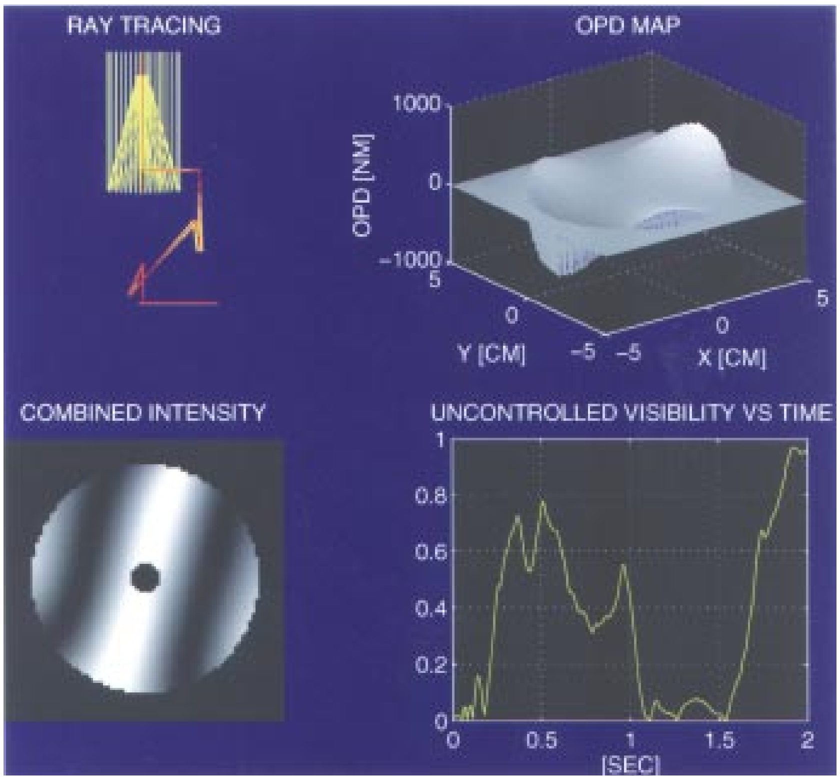


Figure 11: Sample output from the VLTI end-to-end model under development at ESO. Top left: ray tracing of an individual telescope, top right: resulting OPD map near the point of beam combination, bottom left: fringes in a combined pupil image, bottom right: time variation of fringe contrast with uncontrolled atmospheric, seismic and mechanical disturbances.

and the MPG, have already agreed to also contribute to the beam combination and fringe sensing instruments in the form of equipment and manpower. ESO invites the wider community to participate in this effort, and to help defining and developing the beam combination and fringe detection equipment.

4. Conclusions

We have described the new implementation plan for the interferometric mode of the ESO Very Large Telescope. ESO proceeds with VLTI with a larger effort in terms of manpower than ever before and involves a significant fraction of the ESO astronomical community into this endeavour. The development plan for the VLTI has been adapted to the difficult financial situation by substantial modification of the concept and by gradually increasing the capability. We feel that the modifications simplify the project in many areas while strengthening the scientific potential. However, introducing the astrometric capability is a new requirement which will certainly be difficult. When Phases A and B are completed, a large subset of the initial goals for VLTI will have been put into existence.

At this time, the VLTI will be far from complete, and one should prepare for further upgrades. An important capability will be the near-infrared capability of Unit Telescopes through adaptive optics. Another important capability would be extending the spectral regime towards the visible, opening a wide range of spectral diagnostics and even higher resolution. Similarly important would be adding a fourth Auxiliary Telescope and more delay lines to bring the number of beam lines up to a number of eight. VLTI will then unveil its full potential as an optical aperture synthesis array.

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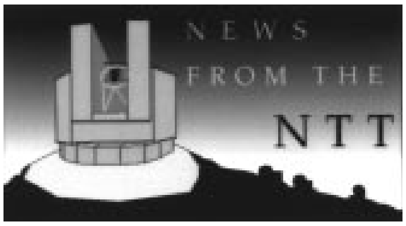

The NTT upgrade project has the following goals:

1. *Establish a robust operating procedure for the telescope to minimise down time and maximise the scientific output.*
2. *Test the VLT control system in real operations prior to installation on UT1.*
3. *Test the VLT operations scheme and the data flow from proposal preparation to final product.*

J. SPYROMILIO, ESO

Last time I wrote for *The Messenger*, the NTT upgrade was progressing well. We had been able to point and track with the telescope but still had some problems with telescope oscillations. The telescope realignment was about to start and the instruments had not as yet been used. Since then a huge amount of work and progress has taken place.

The alignment of the telescope, a practice run for the VLT Unit Telescopes, was successful. The telescope altitude axis was redetermined and the adapter-rotators were re-aligned to ensure that the mechanical and optical axes of the telescope were as close to each other as possible. We found that the telescope was within the specifications but nevertheless we decided to compensate for the small misalignment present. The adapter-rotators were moved by approximately 100 microns. In addition, the setting angle for the tertiary mirror was also redetermined. Here the change was somewhat larger, possibly explaining an effect found in the old NTT whereby when tracking in an unguided mode across the meridian the stars moved. This would not have affected guided exposures. In addition, the position of the secondary mirror was redetermined. M2 is within the specifications as well, although close to the limit. During the next months we shall be using the active optics results to determine if we should undertake to move the secondary mirror.

In December and January, an intense period of commissioning and integrating the software, the telescope was brought from an engineering mode to an operational state. The telescope oscillations proved very hard to fix. A combination of problems contributed to causing the telescope to misbehave at random intervals. Only in the very last days of January were the most critical problems really solved. The telescope now tracks very well in most areas of the sky. However, there seems to be significant friction, especially in the altitude axis, causing some problems as the telescope moves past the meridian (where the altitude speed slows down to zero before changing sign). The azimuth axis seems to behave very well but we have not been running the telescope long enough to be sure that all is well.

The telescope pointing is excellent, with the exception of a zone of avoidance around the zenith. This of course is a problem all alt-az telescopes have and is not new to the NTT. However, we hope with more detailed pointing models we will be able to make the zone of avoidance small enough so as not to impact any scientific programme. On other fronts the telescope control system is also improving. Image analysis is being run regularly and although as yet it is not robust, it is functioning and the telescope image quality is back to the excellent values we have come to expect from the NTT. Autoguiding is now working reasonably well, and automatic guide star selection by the control system is available either in blind mode (let the system select for you) or manual mode (let the system offer you a choice). Selection of the guide star to be used is a matter of clicking with the mouse on any suitable star seen on the guide camera output.

We believe that the new NTT is a telescope that is easy to use, with most of the complexity hidden from the user by the graphical user interfaces. No cryptic commands need any longer be issued and a fair amount of work has gone into the on-line help available.

On the instrumentation front, the new ACE controllers have now been commissioned and we have an improvement of a factor of 2 in readout time over the old VME controllers for the same noise figures. In addition, the re-aluminisation of the telescope mirrors and the refurbishment of the instruments have given us an improvement in throughput of a factor of 2 to 3 in most bands. In the case of SUSI we also replaced the detector with one which has high UV sensitivity. The early estimates suggest we may have improvements as high as a factor of 20 in the U band in SUSI. The SUSI control software is going through final testing and seems to work well, although some parts of the system, especially linked to the interaction of SUSI with the telescope, are still not fully tested. EMMI underwent a complete clean-up and has had a new grism wheel, the refurbished red camera, and the new RILD mirror re-installed. The new EMMI software, which is almost identical to that running in SUSI is also being tested.

The plan for the NTT upgrade which was approved by the STC and ESO management had the telescope returning to partial operations on the 1st of February. Some of you who submitted applications have already been through ESO and completed the Phase 2 Proposal Preparation process. After seven months of keeping to the daily NTT upgrade schedule religiously, I am sorry to say that the project has slipped. The first execution of a service programme took place 4 days later than planned for, on February 5th. The telescope is still in shared-risks mode and we have quite some way to go before the requirements set on the telescope and instrumentation are met. However, we believe we are close enough to be exercising the telescope and trying to do real science. I should emphasise that we are not guaranteeing any performance figures before the 27th of June when the NTT returns to full operations. However, we shall do out best to deliver science quality data to as many users as possible.

On the operations front, an enormous amount of progress has been made. The output of P2PP is now being passed to the control system in a transparent fashion and provides the parameters for the automatic execution of the programmes. The observing and target acquisition templates are running and some calibration templates are also available (e.g. automatic focusing and sky flat fields). In this way we can ensure to be doing exactly what the users specified. In December/January, we took delivery of the archive and pipeline data reduction workstations. They have been integrated into the NTT control system and while they are still running prototype software, the data do flow across the complete system and do get automatically reduced. The reductions right now are pretty rudimentary but there is no reason why this work cannot be expanded to provide the users with a first cut at their data.

As mentioned earlier, the NTT upgrade still has 5 months to run. For the time being we have been finding and solving the 1 in 1 bugs. Over the next months we have a lot of work to do. Not only do we have to acquire the necessary experience with service observing, but also find the 1 in 10 and hopefully the 1 in 100 bugs. We also have some maintenance we wish to do, which we did not wish to perform while the first phase of the upgrade was taking place. This was a decision based on various planning and technical reasons. We plan that the NTT shall continue over the next months to improve in reliability and expand the functionality of the telescope. In April we plan to start with some limited service observing using EMMI.

I would like to take the opportunity to thank all our colleagues in all the ESO divisions that have helped to make the new NTT a reality.

Staff Movements

I would like to welcome to the NTT team our new instrument operator Norma Hurtado.

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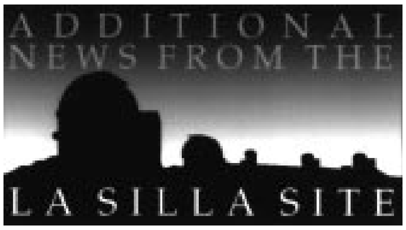

The La Silla News Page

The editors of the La Silla News Page would like to welcome readers of the sixth edition of a page devoted to reporting on technical updates and observational achievements at La Silla. We would like this page to inform the astronomical community of changes made to telescopes, instruments, operations, and of instrumental performances that cannot be reported conveniently elsewhere. Contributions and inquiries to this page from the community are most welcome. *(P. Bouchet, R. Gredel, C. Lidman)*

The Image Quality of the 3.6-m Telescope (Part V)

What Happens far from Zenith?

S. GUISARD, ESO-La Silla

Earlier articles about the Image Quality (IQ) at the 3.6-m telescope (part I to part IV, see previous Messenger issues) concerned the IQ near zenith. Final conclusions and improvements have been written already [1]. In this article we will present the results of the study since September, 1996, when we started to analyse the telescope behaviour far from zenith.

1. Introduction

The IQ of a telescope degrades as the telescope moves from zenith. For a mechanically perfect telescope, this degradation is due only to the natural seeing which worsens with increasing airmass. However, for real telescopes, mechanical flexures accelerate the degradation. These flexures affect the structure of the telescope itself and the mirror supports.

Flexures of the Serrurier struss misalign the two mirrors of the telescope and cause mainly decentring coma aberration. Malfunctionning of the mirror cell with zenith distance is more likely to create astigmatism and triangular coma. We shall see that the 3.6-m is no exception to this rule.

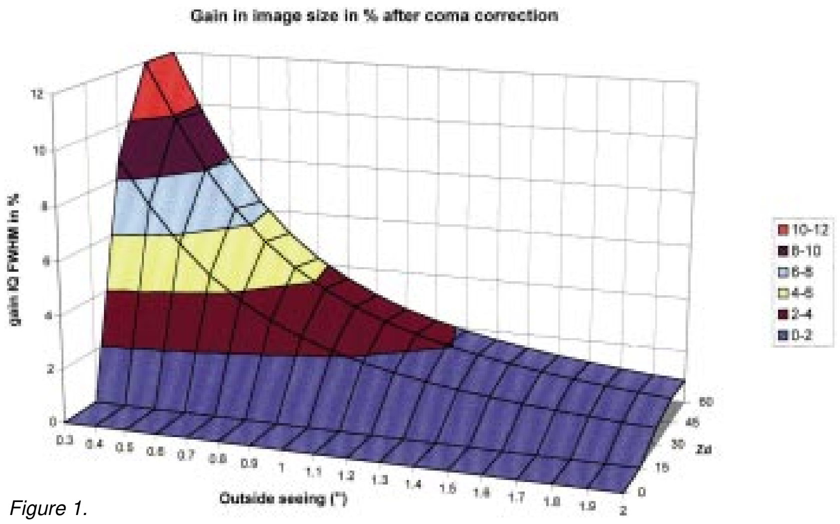

Figure 1.

2. Measuring the Optical Quality at Large Zenith Distances

This work started in September 1996 and is continuing. It is only because of a rigorous test scheme, involving many test nights, that the telescope aberrations are now understood. The aberrations are calculated from extra-focal and intra-focal images using the curvature sensing method.

Since September 1996, more than 1300 defocused images have been taken and analysed, with the distance from zenith ranging from 0 to 60 degrees and with the telescope pointing in different positions. Movement cycles were done also to study the hysteresis of the aberrations. Two detailed technical reports have been written [2], [3]. Here we will only summarise the main results.

Table 1 summarises the variation of each of the aberrations with zenith distance. The aberrations that change most are coma, astigmatism and triangular. The spherical aberrations (at the new focal plane [1]) and quadratic astigmatism are included in the row ‘other terms’ and do not change much with zenith distance. The values in this table are averaged over many azimuth positions. In practice, the telescope behaviour changes if it points South, East, West or North. The aberrations are given in arcsec d80% (diameter of the circle containing 80% of the light).

The aberration that was expected to change most was coma; however, the changes are much smaller than what had been reported several years ago. Indeed, the flexure of the telescope is much smaller than stated in the old reports. Gerardo Ihle (Mechanics Support Team, La Silla) confirmed this by a finite-element analysis of the telescope structure.

The surprise came from the astigmatism and triangular aberrations which have large changes with zenith distance. These aberrations are due to the primary mirror and its support.

The triangular aberration is in fact a fixed defect of the mirror after it was polished. But in order to compensate for this aberration, the polisher, twenty years ago, deliberately modulated the axial force on the astatic levers below the mirrors. The aberration is therefore compensated at zenith but reappears as a cosine function of zenith distance when the telescope is inclined. This is exactly what we measure.

Part of the astigmatism has the same cause; the other part is due to the pneumatic lateral supports of the mirror which do not work properly.

3. Solutions

3.1 “Semi-activation” of M2

Decentring coma can be corrected by moving the secondary mirror. In the case of the 3.6-m, we call it ‘semi-activation of M2’, as, unlike the NTT, the movements of the secondary mirror will de-point the telescope. Therefore, coma correction can only take place between exposures.

Successful tests of semi-activation have been done during test nights. Coma could be completely corrected for zenith distances of 45 and 60 degrees; however, this correction did not reduce significantly the image size because other terms, like astigmatism and triangular aberration, are as important as coma (see Table 1). Furthermore, the outside seeing depends on zenith distance and this makes the correction of coma less impressive than expected. For example, the IQ at 60 degrees zenith distance with a natural seeing of 0.60″ at zenith will be 1.22″ without coma correction and 1.15″ with the correction. Without degradation of the image by astigmatism and triangular aberration, this would be 1.05″.

Figure 1 gives the gain in IQ in % as a function of zenith distance and outside seeing (given at zenith) when only coma is corrected. On this graph, the other aberrations have the values given by Table 1. If we set the criteria for correcting the decentring coma as an improvement of 10% in the image size (which corresponds to a gain of 1.2 in exposure time), we see that it is worth semi-activating M2 only for outside seeing better than 0.4″ and zenith distances larger than 45 degrees. This situation may happen for a few hours in a year only!

Figure 2 also gives the gain induced by coma correction but assuming that astigmatism and triangular keep their values of 0.15″ for any position of the telescope. In that case semi-activating M2 becomes more attractive.

3.2 Eliminating the dependence of astigmatism and triangular aberrations on zenith distance

As we saw above, this correction is a necessity as it will improve images and make the correction of coma useful. It requires significant work on the primary mirror cell, mainly the axial supports. Solutions have been found already. The idea is to change the force distribution on the astatic levers below the mirror as if the mirror were perfect. This would of course introduce at zenith the constant triangular pattern of the mirror. This aberration has to be compensated by axial forces independent of zenith distance like springs for example.

Part of the astigmatism should also be corrected in this way, the other part of the astigmatism will be removed by improvements of the lateral pneumatic mirror support system.

Technical time has been requested for April 1997 to install load cells on all the mirror supports (33 axial and 21 lateral supports). This change involves the manufacturing of nearly 200 mechanical pieces, which has started already in the La Silla workshop, and 2 weeks of telescope time to install the axial load cells in April. The installation

TABLE 1

Zenithal distance (deg)	0	15	30	45	60
Coma (d80%)	0.20″	0.20″	0.35″	0.40″	0.45″
Astigmatism (d80%)	0.15″	0.15″	0.20″	0.30″	0.45″
Triangular (d80%)	0.15″	0.15″	0.15″	0.20″	0.30″
Other terms (d80%)	0.25″	0.25″	0.25″	0.25″	0.25″
Total (d80%)	0.40″	0.40″	0.50″	0.60″	0.75″

of the lateral load cells will follow, and we should be able to have full information on the support forces by the end of August this year. Time will be requested before the end of the year to change the force distribution below and around the mirror, and to install springs on the axial astatic levers.

A detailed planning of the intervention on the primary mirror support has been prepared by Roland Gredel. We hope that all the necessary work on the mirror cell can be done within the year.

4. Conclusions

The behaviour of the telescope at large zenith distance in terms of optical quality has been investigated carefully since September last year. Improvement plans have been proposed and work has started already. The phase we are entering now is very delicate as it involves the intervention on the mirror support itself. Everything will be done not to degrade the optical quality at zenith while changes are made. More technical time will be needed before the end of the year to decrease the aberrations for all telescope positions. The 3.6-m is getting better; however, much work still has to be done.

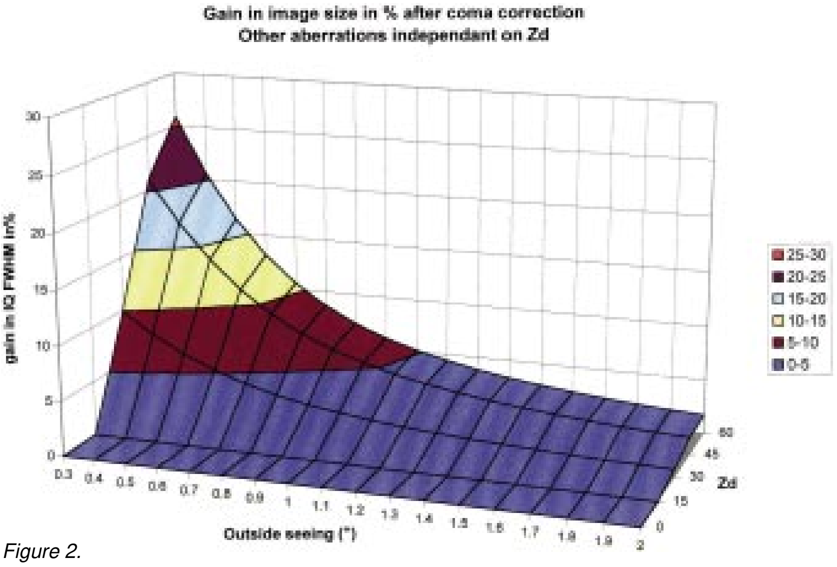

Figure 2.

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[2] S. Guisard: 3.6-m + CAT Upgrade, "Report on the test nights 7th and 8th October 1996", 3P6-TRE-ESO-032-009, October 1996.

[3] S. Guisard: 3.6-m + CAT Upgrade, "Report on the test nights 18/10/96 and 19, 20, 25, 26, 27/11/96", 3P6-TRE-ESO-032-010, December 1996.

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From the 3.6-m and 2.2-m Teams

During October 1997, EFOSC2, the imaging spectrograph now at the 2.2-m telescope, will be moved from the 2.2-m to the 3.6-m. The current spectrograph on the 3.6-m, EFOSC1, will be de-commissioned. EFOSC2 on the 3.6-m will have higher throughput, a larger field of view and significantly better image quality than what was possible with EFOSC1. The significantly smaller pixel scale of the EFOSC2 CCD, 0.18 arcsec per pixel at the 3.6-m telescope, compared to 0.61 arcsecond per pixel of EFOSC1, will allow observers to fully exploit the recent progress in the improvement of the 3.6-m image quality (see S. Guisard's reports in *The Messenger*, December 1996, March 1997). Multi-object spectroscopy will not be avaible with EFOSC2 during Period 60 but only in Period 61 and thereafter.

For ESO time during period 60, the 2.2-m will be dedicated to observations with the two infrared cameras, IRAC1 and IRAC2b.

2.2-m Telescope Upgrade Plan

With the 3.6-m upgrade in progress, the 2.2-m telescope will be the only major telescope on La Silla which still runs off an HP-1000 computer. To make sure that the 2.2-m telescope will be maintainable into the next decade, we are preparing an upgrade plan for the telescope which will be presented to the STC in the beginning of May. The upgrade plan will discuss both the possible replacement of much of the electronics and computers as well as possible modifications to the drive system and possible improvements of the image quality. This will be a good opportunity to address some long-standing problems with this otherwise excellent telescope. *J. Storm*

News from the Danish 1.54-m Telescope

J. BREWER and J. STORM

TCS User Interface Upgrade

A new TCS graphical user interface (GUI), written by Gaetano Andreoni using the VLT panel editor, is now in use at the Danish 1.54-m telescope. Observers will find that the frequently used telescope and adapter controls are now contained within a single window, while lesser-used functions are within a dismissable pop-up window. A 'virtual handset' can also be enabled from the main control window. The new interface retains the same functionality as the old interface, though it is simpler and more user friendly. The new interface also offers the advantages that it is significantly more robust than the old system and is easily modifiable.

DAISY

A new instrument GUI, based on the GUI at the Dutch telescope, is now in use at the Danish 1.54-m telescope. DAISY (Data Acquisition Integrated SYstem), written by Eduardo Robledo, combines the control of the CCD Camera, the DFOSC (Danish Faint Object Spectroscopic Camera), the FASU (Filter And Shutter Unit), and the telescope focus control all into one package. Observers will find that DAISY is very easy to use; the operation is intuitive and there is little to remember. The DAISY interface allows observers to define a sequence of exposures with each exposure having its own filter/grism/slit combination. In addition, it is possible to define a sequence of sequences. By combining the various controls into one package, DAISY both optimises and simplifies observations.

Focus Pyramid

During Danish time at the beginning of January, a new focusing device was tested and installed in DFOSC by Per Kjaergaard Rasmussen and Michael Andersen from Copenhagen University Observatory. The prism works in the same manner as focus wedges, which have been in use in the focal reducers at La Silla for many years. However, instead of splitting the telescope pupil into two images, as is done with a wedge, the focus pyramid splits it into four components. The advantage is that alignment is not critical for the resulting focus estimate, which makes it simpler to maintain.

A new observing batch has been developed for analysing the images and it is now possible to check the focus in less than a minute. This will enable a much more frequent refocusing of the telescope than has previously been feasible and thus help to improve the image quality.

Image Quality Improvements

Following the promising results which have been achieved at the 3.6-m telescope (see e.g. S. Guisard, *The Messenger* 86, p. 21), an investigation of the image quality of the Danish 1.54-m is also in progress in close collaboration with the group at Copenhagen University Observatory. It is clearly a complex problem and we must proceed one step at a time to achieve consistent results. The first step is to improve the monitoring of the current performance and ambient conditions to determine which are the major sources of the seeing. Apart from the atmospheric seeing there are probably significant contributions to the seeing from the dome, the telescope itself as well as from the finite size of the pixels of the detector.

The physical size of the pixels corresponds to 0.39 arcsec on the sky, but as the overthinned LORAL-CCD smears the charge, the effective pixel size is significantly larger, especially in the blue. Still, images with a seeing of 0.9 arcsec have been obtained with DFOSC so the potential for sub-arcsecond images is definitely there.

To investigate the effect of mirror seeing, the mirror cover has been lifted some 10 cm at the beginning of January and a couple of fans have been mounted following the example of the 3.6-m. The first tests suggest that the forced mirror ventilation reduces the typical FWHM of images by 0.2–0.3 arcsec. More tests under a wider range of external conditions will have to be carried out to derive a clearer picture.

The next step will be to assess the amount of dome seeing and the ways in which this contribution can be reduced.

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END OF LA SILLA NEWS PAGE

New CASPEC Manual and Simulator

S. RANDICH, ESO-Garching, and M. SHETRONE, ESO-Chile

1. CASPEC Operating Manual

A new operating manual for the Cassegrain Echelle Spectrograph (CASPEC) at the 3.6-m telescope is now available.

The manual can be retrieved from the 3.6-m & CAT WWW page: (http://www.ls.eso.org/lasilla/Telescopes/360cat/html/CASPEC/caspec.html).

Since 1989, when the last operating manual was written (ESO Operating Manual #2), CASPEC has undergone several modifications; the main ones being: the installation of two new (RED and BLUE) cross-dispersers; CCD upgrades; a new clamping system, which reduced the flexure in the spectrograph; and the addition of new colour filters to the CASPEC set. An update to the manual was written in 1993 by L. Pasquini. The major changes since then are the installation of a new high-efficiency CCD (ESO CCD #37) and the fact that only one grating (31.6 lines/mm) and only the Long Camera are presently offered.

The new manual describes CASPEC in its present status. This includes all the information reported in separate documents since 1989 (e.g., new cross-disperser efficiencies, 3.6 + CASPEC + CCD #37 overall efficiency, CCD #37 characteristics), plus new information; in particular, the inter-order separations for the 31.6 lines/mm echelle grating and the long camera for both the RED and BLUE cross-dispersers. Additionally, S/N estimates are given for the two standard configurations (31.6 lines/mm echelle + RED (BLUE) cross-disperser + Long Camera + CCD #37); new bright, 1.6 nm resolution flux standard stars have been added to the table of standards stars; reference exposure times for Quartz and Thorium-Argon lamps exposures with the different neutral density filters and colour filters are given; and, finally, a new Long Slit filter centred at 671.1 nm, which arrived very recently, have been added to the list of Long Slit filters.

The structure of the manual differs with the 1989 version. For example, a more comprehensive introductory chapter is given. It summarises the properties of CASPEC and compares it with the two other high-resolution spectrographs at La Silla, namely EMMI at the NTT and the CES at the 1.4-m CAT telescope. In this chapter, the CASPEC observing modes are listed and all the basic characteristics of the instrument are summarised. This first chapter should be read before writing the Observing Proposal; in particular, it should allow the observer to discern whether CASPEC is suitable or not for your scientific programme. Chapter 2 describes, in detail, the characteristics of the different components, and should allow one to choose the most suitable configuration for a given project. Chapter 3 (Instrument performance) should also be read when writing the proposal in order to ascertain the feasibility of the project and to estimate the number of nights needed to carry out the project. This Chapter is complemented by a simulator (see below). Finally, Chapters 4 and 5, may be skipped when preparing the proposal, but should be read before carrying out the observations.

CASPEC Exposure Time Calculator

The ESO 3.6-m CASPEC Exposure Time Calculator (Version 1.0) has been completed and is available on the 3.6-m Team CASPEC Homepage.

The calculator can simulate the most common observing set-ups for CASPEC; future versions may include Long Slit mode and the Zeeman Analyzer. It is based on both observed and theoretical parameters. The simulator will be used as a starting point for the CASPEC Physical Model.

This calculator takes into account many observing parameters not included in other simulators or S/N estimators (e.g. Chapter 3 of the CASPEC manual). For example, the phase of the moon, seeing slit losses, airmass corrections and basic colour terms in the assumed input magnitude are included. The calculator can either be used to estimate the S/N in the resulting spectra for a given exposure time or to

Figure 1: Exposure Time Calculator.

estimate the required exposure to obtain a spectrum with the given S/N.

For example, input parameters might include: a 15th V-magnitude star with an effective temperature of 5000K. The observations are to be taken during bright time at 1.5 airmasses and with 1.0 arcsec seeing. The wavelength of interest is 6000 Å employing the Red cross-disperser and a 1.2 arcsec slit (see Fig. 1).

With these input parameters S/N of 15 per pixel (in the summed spectra) can be achieved in an exposure of approximately 2600 seconds.

The simulator can be used to plan an observing run but should not be substituted for actual observing!

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The Eclipse Software

N. DEVILLARD, ESO

A Brief History

Adonis, the Adaptive Optics instrument on use on the 3.6-m telescope on La Silla, is available for the astronomical community since April 1993. Experience has been acquired by many users since then, and what Adonis needed most was to gather this experience, and then offer a set of data-reduction facilities and guidelines for observation and calibration procedures. To get all the expertise, a working group was created, dealing with High-Resolution Infra-Red Data Reduction. Its output was directly fed into software development to produce the *eclipse* software.

When we took the decision to develop *eclipse*, we had to set up how far it should go when reducing the data, and which language/platform should be host. By questioning Adonis users, we found out that writing the Data Reduction Software within a standard reduction package such as MIDAS, IRAF, or IDL, would certainly reduce the number of potential users. Furthermore, high-resolution data reduction techniques are constantly evolving, and it is not always easy or even possible to add up brand new algorithms to most standard software packages. The result had to work simultaneously under most other data-processing software packages, and modifications should be easy to quickly add new methods as they come out of the Working Group.

The decision was taken to develop in ANSI C, which acts as a *lingua franca* for Unix-based workstations. The set of supported machines is: any machine running a Unix Operating System. In this way, we ensure portability, code reusability, and integration into all major data-reduction software packages.

Overview

eclipse offers an open environment for data-reduction algorithm development and simple pipeline processings. At the highest level, the user will find a manual describing how to observe and calibrate data using Adonis in its different modes, with associated example reduction scripts ready to be called from within standard software or directly from the Unix command line. So far, covered reduction aspects are:

- pixel gain map creation
- dead pixel detection and correction
- simple data classification from FITS information
- sky-subtraction and flat-field division
- shift-and-add
- data extraction and merging
- statistics computation
- cube arithmetic
- spatial filtering
- Fourier transform
- image resampling

All of these high-level procedures are running without user interaction, which is typical of a pipeline, number-crunching approach.

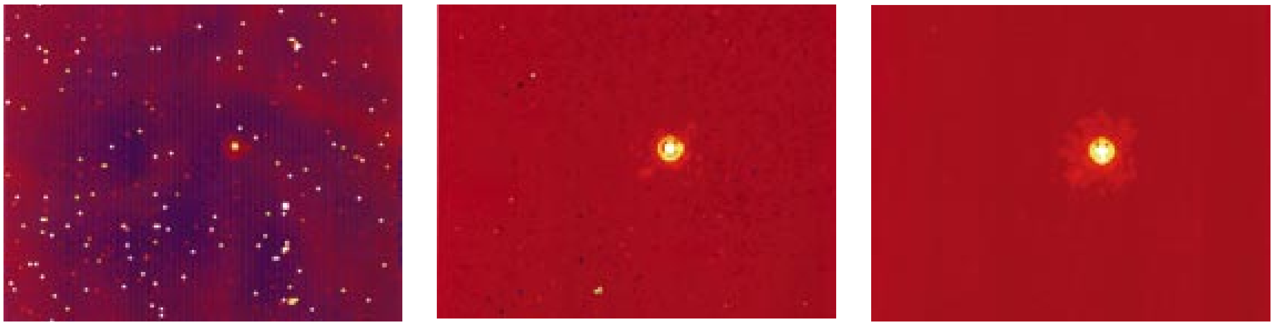

Figure 1: From left t right: Figure (a) is a raw frame, Figure (b) is sky-substracted, Figure (c) is bad pixel corrected and flat-fielded. The whole process used 1.26 seconds CPU time on the La Silla main server, including flat-field creation from a set of sky images and bad pixel detection. The total amount of involved data is about 5 megabytes.

Going one layer down reveals that *eclipse* is made of 32 Unix commands, each of them delivered with a manual page containing explanations about algorithms, input parameters and files, and several examples. By combining these commands into scripts, it is possible to create simple pipelines handling basic calibration and cosmetic procedures in a fast and efficient way. Notice that commands are scriptable from any high-level programming language, e.g. *MIDAS*, *IRAF*, *IDL*, *perl*, *tcl*, or standard Unix shells. Most of all, feedback from the working group allows a fast development of the latest algorithms, specific to Adonis.

Going to the very heart of *eclipse* means getting into 30,000 lines of documented ANSI C code. Written in an object-oriented way, it provides the programmer with a set of typical objects (images, cubes, pixel maps . . .) to develop with. From this level, it is possible to embed validated algorithms, which allows strong optimisations both in terms of speed and disk space, and encapsulation of these algorithms for higher-level processes. Notice that optimisation in the case of Adonis is a major concern: with data cubes reaching sizes of several hundred megabytes, it is easy to overflow disks, saturate memory, or in the best case monopolise computing power for several hours, preventing any other computer work! And the situation is likely to get worse on these aspects, with ever increasing detector sizes… Nearly all algorithms included in the *eclipse* code have been especially designed to handle these aspects in the best possible way, making use of automatic disk swapping and delicate memory handling routines.

Notice that a link to off-line data-processing software is essential. *eclipse* does not provide any complex post-processing algorithm such as deconvolution, nor does it contain any image or data displayer. Global data analysers such as MIDAS provide the full range of functionality needed for evolved post-processing and analyses; *eclipse* is to be used as a pre-processor, a signal-processing engine.

The Adonis Pipeline

A set of scripts and Unix commands has been especially designed to take care of most basic data reductions for Adonis. This has been set up during August 1996 on La Silla, with help from observers, telescope and Adonis teams.

The following set of operations has been automated:

- flat-field creation
- bad pixel detection
- sky extraction from data cube, averaging, and subtraction from object frames
- average of the result

There is a preparation phase, during which the observers have to identify their files according to their logbook, and sort them out, preferably in separate directories. It is then possible to design quickly a Unix script to launch a unique reduction command on all directories, and get cleaned data in a very short time.

Let us browse through an example:

Figure 1(a) shows a raw image of an object taken in thermal infrared. Noise is dominant, the object is barely visible among the noisy background. Figure (b) shows the same image after subtraction of the closest (in time) averaged sky. On Figure (c), bad pixels have been cleaned, and a flat-field division has been applied. The star is now cleaned, ready for deeper analysis.

The whole process applied on the La Silla main server (kila) took 1.26 seconds CPU time, and 12.73 seconds user time with 70 active users, for a total amount of more than 5 megabytes of data. The given figure includes processing time for flat-field creation and bad pixel detection. Such processing speed implies that data cleaning takes place in less time than needed for acquisition, which makes such a pipeline a good candidate for on-line display.

Future Developments

For the moment, *eclipse* handles directly all imaging modes in all wavelengths for Adonis. By combining its low-level functionalities, it is certainly possible to develop new modules, specific to other instrumental modes (coronography, spectro-imaging with Fabry-Perot, polarimetry, astrometry, . . .). Christian Drouet D'Aubigny (ESO-Garching) is right now working on the Fabry-Perot extension for Adonis, together with Patrice Corporon (ESO-Chile), both coopérants.

Julian Christou's deconvolution software: *idac*, has been recently linked to *eclipse*. In this way, the user also has an iterative blind deconvolution algorithm readily available in La Silla's machines. Though it would probably not be used as on-line software, *idac* may need some of *eclipse* functionalities to provide default start-up estimation images, create bad pixel maps, or apply cube arithmetics.

eclipse is covered by the MIDAS GNU public general license, which allows us to distribute it on the World Wide Web. It should be included in the future in MIDAS distribution as a contribution for Adonis. MIDAS has been enhanced to support data cube manipulations, viewing, and direct FITS access, which ensures that a complete toolbox is available to the Adonis user for data reduction.

Finally, portability made it possible to install *eclipse* in many other observatories and institutes, for data reduction of eventually other instruments on other telescopes.

I would like to thank all people participating in the High-Resolution Data Reduction Working Group for their kind help and patience in explaining to me the secrets of infrared data processing. Note that for 16 months the development team consisted of a single person (N.D.), but, in fact, many people worked on the algorithms, and it would be hard to acknowledge them all here. The goal has been reached: Adonis is now provided to the astronomical community together with a documented and dedicated data reduction package.

Most eclipse documentation is available on-line on the ESO server at the following address: http://www.eso.org/~ndevilla/adonis/eclipse.

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The VLT Science Cases: a Test for the VLT

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Introduction

In preparation for VLT operations, ESO is gearing up its interaction with its astronomical community. It is important for ESO to understand the needs and requirements of future users and to accomplish as high a standard of service as possible. In addition, we have got to know the most demanding needs of the community in order to *verify* at the earliest possible stage that the VLT will actually meet such expectations. To this end, we have been actively seeking input from future observers.

We asked several astronomers to provide us with ‘VLT Science Cases’ (SC), potential programmes of high scientific interest and especially demanding in terms of required performance. In parallel, a set of ‘Reference Observing Proposals’ (ROP) have been created at ESO to cover some more technical aspects. The SC and ROP are used as a conceptual test of the VLT, of its first-generation instrumentation (ESO Technical Preprint No. 72), and of the VLT science data flow (P. Quinn, *The Messenger* No. 84). They are meant to help us to achieve a quantitative understanding of the expectations concerning the scientific performance of the VLT, and identify possible improvements of the project. This should provide an early appreciation of potential shortcomings that could be eliminated before the VLT is offered to the community, and/or an early identification of needs that may be satisfied by appropriate upgrades in the instrumentation plan and VLT operations. The ROP were also established for tests of the VLT operational system (cf. P. Quinn, *The Messenger* No. 84, and J. Spyromilio, *The Messenger* No. 85). The SC were analysed by the ‘Science Performance Group’ co-ordinated by the VLT Programme Scientist (A. Renzini) with the goal to identify actions which could improve the scientific performance of the VLT. This approach is complementing the other user interaction channels through the standing oversight ESO Committees, and the VLT/VLTI workshops held over the last few years.

Up to now 28 SC and 7 ROP have been completed (Tables 1 and 2). The collection of VLT Science Cases illustrates the wide involvement of ESO’s user community. More than 90 astronomers from all ESO member countries have contributed in one form or another. To this are added over 20 ESO/ECF staff astronomers in Garching and in Chile. The effect is to strengthen the ties between ESO and its scientific community on a rather informal, but direct, level. In effect, through the SC a ‘network’ has started to be established within the community which can be rapidly accessed for specific scientific questions and to explore the relative effectiveness of various options concerning the VLT. We are very grateful to all the astronomers that have participated in the SC, and believe they deserve the gratitude of the community for having spent some of their time for the common benefit. There will be indeed no privilege or tangible reward for them, with the exclusion perhaps of what may come from having started thinking about VLT observations in a more precise and practical way. With VLT first light being already so close, the VLT has to become a much stronger reality in many European astronomers’ mind in this and the coming year. The SC were also meant to stimulate and assist this process.

The size of this SC network has been so far limited only by our capacity to maintain interactions with it and to fruitfully analyse its input. Yet, the exercise is not over and we plan to “call” for a new set of SC this year. The selection of the topics of the SC was done to cover some of the most active areas of astronomical research for which we believe the VLT will become a major contributor. To this we added observational techniques we

TABLE 1: VLT Science Cases

- Evolution of galaxies from z = 0.6 to z = 4.3
- Testing the redshift evolution of potential wells and scaling relations of galaxies
- The evolution of cluster galaxies
- A search for binaries in globular cluster cores
- High redshift radio galaxies:
  - (a) Their stellar content and surrounding clusters
  - (b) Gas kinematics and jet/cloud interactions
  - (c) Imaging- and spectro-polarimetry to identify and separate the scattered component
  - (d) UV nebular diagnostics of the extended gas
  - (e) Absorption studies of Lyα and C IV as probes of the circumnuclear gas particularly the cold component
- Distant cluster of galaxies
- Measuring Ω with weak gravitational lensing
- Dark matter searches with weak gravitational lensing from a drift-scan image
- Measuring Ω_Λ from (weak and strong) lensing modelling of rich clusters
- The star formation history of ultra-low surface-brightness galaxies
- Extending extragalactic PN as probes of galaxies out to 50 Mpc
- Astronomy of isolated neutron stars
- Spectroscopy and photometry of very distant supernovae
- Chemical evolution and star formation history in nearby galaxies
- A complete sample of 1000 active galactic nuclei to $R = 23.5$
- Dynamics of the Carina dwarf spheroidal galaxy
- Properties of compact emission line galaxies up to $z = 1.2$: velocity dispersions and emission line ratios
- Chemical abundances of stars in globular clusters
- Physics of main-sequence and slightly evolved stars in young open clusters
- RR Lyrae stars in the LMC: tracers of the structure and the metallicity of the old population
- The galaxy population in the redshift interval $0.5 < z < 5$
- Redshift evolution of chemical abundances in damped Lyman-α system
- Dynamics of galaxies at the VLT with FUEGOS/ARGUS
- Optical identification of gamma-ray burst sources

TABLE 2: VLT Reference Observing Proposals

- Quasar absorption lines
- Gravitational arcs in clusters of galaxies
- The nature of AGNs
- Dynamics of dwarf galaxies
- Stellar winds on the AGB
- Comet impact on Jupiter
- Gravitational shear in clusters of galaxies

expect to be essential for the success of VLT observation, i.e. demanding programmes in terms of preparations and observational skills. We are fully aware that the current set of SC does not cover all of astronomy, but it is the purpose of the next rounds to start filling in the gaps. The scientific contents of the SC are treated confidentially.

The VLTI has been excluded from the current science cases. The Interferometry Science Advisory Group has indeed provided very valuable input to the definition of the VLTI programme (cf. Paresce et al., *The Messenger* No. 83), and further science cases at this stage would have unnecessarily duplicated this effort. One emerging field of astronomy, extra-solar planets, has also been set aside as this area has been judged so rapidly expanding and crucial for the VLT/VLTI that a special working group was created at the beginning of 1996. The reports of this working group are complementary to the SC.

While several useful indications for further improvements have been produced by the SC exercise, it is reassuring to note that no major drawback has emerged, while most SC can be served adequately with the telescopes and instruments as they are specified at this point. In a few cases with very special requirements (e.g. fast reaction time to targets of opportunity – possibly through direct outside access) the proposed experiment does not lie within the specifications for the telescope. Such cases are studied further to explore the possibility of future implementation.

Almost all SC demonstrate that VLT science will not be possible without the preparatory and supporting work at other telescopes. This is true for target selection as well as target characterisation. A direct response to this need is the ESO Imaging Survey which is to be carried out at the NTT (cf. Renzini and da Costa article in this *Messenger*, see also the ESO WEB site).

The extraordinary advantages of the connection with HST has been amply demonstrated by results combining Keck and HST data. The presence of the ECF at ESO/Garching offers the ESO community a unique opportunity for productive combination of VLT and HST data, and several SC are directly built up on such combinations.

Perhaps not surprisingly, it has been found that most demands from the SC have been placed on the instrumentation. This may be due to a self-imposed limitation of many astronomers to currently available telescope hardware. The VLT science cases offer the possibility to ask for more than just the proposed instrumentation and possibly refine the instrumentation programme. It is clearly understandable that most people restrict themselves to the possible rather than develop dreams; however, it is also evident that only by asking for the 'ideal' experiment can we try to push hardware to the limit and learn what to do next.

Many SC need massive multiplexing capabilities for the VLT to be competitive in the corresponding scientific areas. Besides this, capabilities to be included in the instrumentation programme highlighted by the SC are adaptive optics supported by artificial guide stars, integral field spectroscopy in the optical and IR, high-speed CCD photometry, and coronography. There are other parts of the instrumental parameter space which are not covered by the VLT instrumentation. However, no SC was designed to demand a capability which could not be served within the current instrumentation plan.

The Science Cases
Pseudo-proposals

The VLT Science Cases solicited by the SPG were meant to address fundamental problems in different areas of astronomical research. By no means is it expected that these SC cover all of the most relevant current astrophysical issues, but they are rather indicative of the type of scientific operations the VLT will be asked to perform. Each PI was asked to fill out a standard VLT Science Case form to obtain relevant and detailed information about the VLT requirements for the proposed research. The form – nicknamed *pseudo-proposal* – was split into five main sections.

(1) The scientific rationale, also addressing the possible impact of current research before the VLT will start operating; (2) a description of the proposed observations, including an estimate of the total observing time required to achieve the scientific goal (preparatory La Silla observations were also mentioned and quantified); (3) a detailed list of the technical requirements to accomplish the scientific goal (e.g., pointing, tracking, image quality, throughput, etc.); (4) identification and a quantitative discussion of the performance of the VLT and the instruments required to achieve the science goal and the associated calibration requirements; and finally (5) proposers were asked to briefly identify the limits of first-generation instruments for the specific SC, all the way from simple items (e.g., the filter list) to the whole instrumentation plan.

In a parallel development, several ROP were created in house. Their purpose was specifically to test the operational concepts proposed for the VLT. To provide a semirealistic scenario, they also contain a scientific rationale appropriate for an 8-m project, but the emphasis was put on the technical aspects of the proposals. Since they were planned for realistic checks of the data flow and the operational system, they assumed the approved instrumentation and were developed to cover as wide a parameter space as possible. Operationally simple observations are included as well as complicated and delicate projects which require a very high level of planning and agility of the system, even the combination of individual telescopes for the simultaneous coverage of particular events. There is some overlap between VLT science cases and the reference proposals. We included the reference proposals as they describe the operational requirements in greater detail.

Each SC and ROP was analysed by a member of the SPG. The main observational elements and their requirements were addressed. All proposed observations were assessed with a particular view on technological and operational aspects. The results are now currently used in discussions on the scientific needs of the VLT project, and to quantitatively investigate instrumental options, optimisation, and telescope/instrument combinations.

Discussion

All VLT science cases were broken down to the level of individual types of observation and the relative instrument(s) (imaging, spectroscopy, optical, near-IR, high-resolution, low-resolution, etc.). We have concentrated the investigation on some specific topics, since we are interested on the impact of the realistic programmes on the observing modes and the operations. All observations were assessed for the image quality requirements, the importance of temporal resolution, spectral resolution and coverage, and typical flux levels to judge the amount of observing time.

On the operations side we checked from where the target catalogues for the proposal would be drawn. The VLT will work at flux levels for which no whole sky survey is available. Preparation is the key to the success of VLT observations. Almost all SC are based on extensions of current data sets (e.g. the ESO Imaging Survey) and only very few projects will build their catalogues directly from VLT imaging data. The requirement for the logistic support of the VLT in terms of object catalogues and supporting observations at other (smaller) telescopes is evident. The need to find faint and/or rare but interesting objects for study with the VLT in statistically significant quantities has spawned the ESO Imaging Survey, and many other observatories are gearing up for large-field-of-view instruments. The wide-field capabilities planned at ESO will become crucial for the VLT. Multi-object spectroscopy depends on very good positional information which has to be provided ahead of the VLT observations (to set up slitlet arrays in FORS, fiber positioning for FUEGOS, or provide masks for VMOS and NIRMOS). This information has to be available either from observations with smaller telescopes or imaging with the VLT itself.

There are many different factors which determine the detailed scheduling of an observation. All SC were assessed for their constraints on the schedule. Exceptional atmospheric conditions (e.g. seeing, low IR background) can be critical as well as the absolute timing (co-ordination with other observatories), or the dependence on earlier observations. Most importantly for VLT operations, such factors directly influence whether a programme can be carried out by means of service observations, or whether the presence of the astronomer at the telescope is required. This will still be possible in the 'classical' observing mode. Note that there might be programmes which require excellent conditions, yet are delicate enough to demand the astronomer's direct interaction. Situations like these will have to be resolved and it was one of the aims to learn how many such programmes might emerge in a realistic schedule. Another aspect of importance for the VLT operations is the data rate which will have to be handled at the observatory. Estimates of typical data volumes were derived for each SC. A related topic is the format in which data are archived. For certain observations it will be impossible to maintain all raw data and some preliminary reduction procedures will have to be applied (typically IR data will have to be combined 'on the fly'). Data storage and handling will not pose a critical problem with the possible exception of some special programmes (speckle, high-speed photometry). The current data-flow schemes should be able to cope with the amount of data delivered by the instruments. The SC provide ground examples for decisions to be taken soon. A few SC require specialised observing techniques, e.g. drift scans offer flatfield quality which may be essential for some applications.

The available VLT science cases span a wide range in project size. There are a few SC which, if implemented at the proposed scale, would take up a major fraction of the available time, while other programmes are estimated to take only a few nights for completion. Interestingly, the majority of the projects would request more than 100 hours observing time. Thus it should not be expected that observing projects at the VLT will be of smaller scale or be completed in less time than current programmes at La Silla.

Many projects are suitable for service observing, some completely depend on it to catch the excellent image quality required for the experiment. The option to make full use of co-ordinated observations, however, is not explored yet. Only few projects try to combine various observing techniques for a more complete picture of the science object.

There are certainly limitations in the current set of SC. There is an obvious bias towards observational cosmology. The large statistical samples of faint objects required for this type of research drives the demand for high multiplexing facilities at the large telescopes. Another often requested facility is outstanding imaging quality stable for very weak objects over a large wide-field of view (weak gravitational lensing, statistical lensing).

A few science areas are missing completely, e.g. there are no SC for the thermal IR or adaptive optics with IR wavefront sensor. No studies of the interstellar medium or of gas in general have been provided. High-resolution studies of stars, mapping of stellar surfaces (e.g. through Doppler mapping), stellar outflow, stellar environments, or the whole area of star formation and pre-main-sequence evolution have not yet been considered. Other stellar topics, like initial mass functions, low-metallicity stars, stars in nearby galaxies, will have to be addressed in the future. No science case for the solar system (e.g. trans-Neptunian objects) is available.

Summary

The VLT Science Cases have opened a new channel of user interaction with ESO. They were meant to have a two-way effect; first to raise the awareness within the community by stimulating European astronomers to think about the forthcoming capabilities of the VLT 8-m telescopes and entice them to prepare for the exciting opportunities they will provide. Besides this, they were meant to set elements for a concrete scientific platform for future developments in the VLT project. They also were meant to better identify what the astronomical community is expecting from ESO.

It is gratifying to see that there seem to be no major shortcomings in the VLT programme, and the instrumental resources for most planned observations will become available in due time. Yet we have identified improvements in the instrumentation plan like the massive multiplexing spectroscopy needs or the possible fiber feed boosting the multiplex capability of the high-resolution instruments (e.g. UVES).

With the experience gained from this first set of SC we now feel confident to ask interested astronomers to submit a science case to ESO. While we cannot guarantee that every pseudo-proposal can be included into our list, we do encourage all ESO astronomers to think about their plans for VLT observing, whether they submit a science case to us or not. Anybody interested in providing a VLT Science Case should contact one of the authors of this article. We are particularly interested in projects which cover research areas not represented in the current sample, and instrumental capabilities which are poorly represented in the first set of SC. These include the mid-infrared spectral range, near-infrared high resolution spectroscopy, and projects which require adaptive optics with and without artificial reference star.

We believe it is timely to think about the capabilities of the VLT now and ask for the necessary preparatory observations with La Silla telescopes. The OPC has specifically set guidelines to devote some of the available time to preparatory programmes (cf. Call for Proposals). The work on a Science Case may also provide stimulus to check out the developments in the VLT project (see the WWW VLT page http://www.eso.org/vlt/ and the descriptions of the instruments). It certainly will prepare you for the occasions when the VLT will be 'your' telescope. On the other hand, soon real VLT proposals will take the place of SC pseudo-proposals, and some of the questions in the pseudo-proposals may be transferred to real ones, for ESO to keep active an ongoing monitoring of the needs and expectations of the community.

The ESO Imaging Survey

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1. Introduction

During 1997 (July–November), ESO plans to carry out a wide-angle, multicolour imaging survey using EMMI on the NTT, followed by a deeper, narrow-angle survey using SUSI2 and SOFI, early in 1998. A summary of the expected characteristics of the survey is shown in Table 1. This project, hereafter referred to as the ESO Imaging Survey (EIS), is meant to generate moderate-size statistical samples for a variety of astronomical applications, ranging from candidate objects at the outer edge of the Solar System all the way to galaxies and quasars at extremely high redshift. EIS data should provide a suitable database from which targets can be drawn for observations with the VLT, in its early phase of scientific operation (from the third quarter of 1998 to approximately the end of 2000). EIS has been conceived as a service to the ESO community, with all the data becoming public immediately after its completion. Here we provide information that may help astronomers in the ESO community plan their initial VLT programmes, taking advantage of this survey.

The main motivation for EIS was the general recognition of the urgent need to prepare suitable target lists for the VLT, essential for it to soon play a leading role in ground-based optical/IR astronomy. By the year 2000, the competition will be fierce with many 8-m-class telescopes in operation. The main goal of EIS is, therefore, to foster the scientific productivity of the early VLT, and maximise its scientific impact. There was also the understanding that a co-ordinated effort was required in order to optimise the preparatory work at the La Silla telescopes as well as to guarantee the homogeneity and quality of the data. The ambitiously tight timetable and the large volume of data to be processed and analysed also implied the need for extensive collaboration between ESO and the community. Finally, there was the perception that no individual team would be able to fully exploit a survey similar to EIS in a timely fashion, were the data to remain *proprietary,* even if only for a limited period. Instead, with this *co-ordinated* effort most of the short-term survey needs will be met in a more efficient way, while the competition for VLT observing time will take place at the appropriate moment.

In order to insure the involvement of the community, a Working Group (WG) was created to design and supervise the survey. Following the recommendation of the OPC, the WG members were selected on the basis of their expertise in different research areas that could most directly benefit from the survey. The EIS Working Group has not concluded its activity with the submission of the EIS proposal and its endorsement by the OPC. It will, instead, continue to oversee all EIS activities, from the final selection of some of the survey parameters to the distribution of the data.

With the parameters listed in Table 1, the survey is expected to include 150 candidate clusters with $z > 0.6$, up to 50 candidate quasars at $z > 3$ brighter than $V = 21$ and about 200 down to $I = 22.5$. These candidates will represent natural targets for follow-up work with ISAAC, FORS and UVES, as soon as they come into operation at the VLT. The deep, narrow-angle part of the survey, covering 250 square arcminutes, should contain about 10,000 objects to I 26, with at least 30% of them being expected to lie at z 1, and at least 200 at z 3. The 25 square arcminutes imaged also in the J band should lead to the identification of a similar number of galaxies with 1 z 2.8. For more details and updates please check the EIS web site "http://www.eso.org/vlt/eis/".

One aspect worth emphasising is the *experimental* nature of EIS, which introduces a novel approach to large surveys. With EIS both ESO and the ESO community will gain additional experience which will be valuable for the scientific planning and operation of future surveys, such as those that are likely to take place using the ESO/MPIA 2.2-m telescope with the new wide-field camera scheduled for the second semester of 1998.

Finally, it is worth pointing out that EIS is not meant to be the only preparatory work for the VLT, nor to meet the long-term needs of the community. Other set-ups may be required for scientific goals not addressed by EIS. Other optical surveys are also likely to be needed in the future, in support of VLT research and of various space missions. The aim of EIS is just to bridge the gap between now and the early VLT era, focusing on topics that are likely to be mainstream in the time frame considered.

2. Scientific Rationale

The WG has agreed on the necessity of identifying a set of science drivers used to optimise the survey. The study of objects in the high-redshift universe has then been singled out as the field most in need of a preparatory survey. Correspondingly, the main science drivers used to optimise the survey have been identified to be the searches for: *(1) Distant Clusters of Galaxies; (2) Quasars; (3) High-Redshift Galaxies***.** With this selection, the WG has paid attention to include all classes of high-redshift objects, so as to place all research teams on a condition of parity while fostering the overall productivity of the VLT. Although the WG felt that it was essential to optimise the survey for a limited number of goals, this should not overshadow the fact that the survey will have almost countless applications in virtually every field of astronomy. In particular, it will provide a unique stellar database for studies of *Galactic structure and stellar populations***,** by detecting several hundred very low metallicity stars, M dwarfs, white dwarfs and by setting strong limits on the local density of brown dwarfs (possibly detecting some of them).

The urgency of the proposed survey comes from the necessity of providing suitable scientific targets to be observed by the VLT as early as the second semester of 1998. In designing the survey, the following timetable for the availability of VLT instruments was taken into account: ISAAC (1998/Q3); FORS (1999/Q1); CONICA (1999/Q2); UVES (1999/Q3). Adopting this specific timetable as a constraint proved to be extremely useful in designing the size of the survey which requires a balance between the need for enough targets to generate statistical samples and the availability of time to allow them to be observed with the early VLT, between 1998 (Q4) and 2000 (Q4).

While some of the targets will be immediately used in VLT observations as early as 1998, others will require further observations at the NTT or the 3.6-m to provide "clean" samples for the VLT (e.g. to confirm candidate high-redshift quasars). This lead time has to be taken into account in order to insure the *immediate* competitiveness of the VLT in some research areas in a way that it is consistent with the existing instrumentation plans for the VLT.

In order to achieve the main scientific goals and to reconcile the need for wide-angle coverage and depth, the survey will consist of two parts. A wide-angle survey to search for clusters and quasars, complemented by deep-pointed observations of a smaller area to search for high-redshift galaxies. For all the scientific goals the parameters of the survey were set to generate samples of about 200 targets each, the minimal size suitable for statistical analysis.

3. Background

In the summer of 1995, a small Panel was set up at the ESO headquarters to investigate and make recommendations about the scientific needs and the technical requirements for wide-field imaging capabilities in support of the VLT. The Panel was composed by ESO staff, visiting scientists and scientists in the Garching area, including: T. Broadhurst. S. Cristiani, L. da Costa, R. Gilmozzi, B. Leibundgut, R. Mendez, G. Monnet, A. Renzini (chair), P. Schneider and J. Villumsen. The Panel first identified a set of topics that required extensive imaging observations either in preparation for either VLT or stand-alone programmes. Among the topics considered were: search for primeval galaxies; high-redshift QSOs; distant clusters; low-surface-brightness galaxies; weak gravitational lensing by galaxies, clusters, and large-scale structures; galaxy inventory of low redshift clusters; search for high-redshift supernovae; search and study of individual objects in nearby galaxies (globular clusters, planetary nebulae, massive stars, HII regions, etc.); stellar-population studies in the Milky Way, the Magellanic Clouds and the dwarf spheroidal galaxies; and finally the search for exo-planets by gravitational microlensing. The Panel reviewed all these science cases thoroughly, as well as all the possible options for wide-field imaging. The Panel concluded that to ensure a competitive use of the VLT in several research areas required both a very wide field imager at a 2–4-m-class telescope, and a moderately-wide field imager at the VLT.

Since then, several positive develop-

Table 1. EIS General Characteristics

Science Driver	Area	t_{int}	Filters	Hours	$m_{lim}(5\sigma)$
Wide-Angle Survey					
Distant clusters	18 sq. degree	300s	*V*	96	24.7
	—	300s	*I*	96	23.8
Quasars	—	150s	*B*	48	24.5
	10 sq. degree	50s	*Gun-z*	16	22.3
Narrow-Angle Survey					
High-*z* galaxies	250 sq. arcmin.		*UGrIK*	104	26, K = 21.5
	25 sq. arcmin.		*J*	24	24
Total				384	

ments have taken place thanks to the continuous effort of ESO as well as the initiative of individual institutes in the ESO Community. The Max-Planck-Institut für Astronomie (Heidelberg, MPIA) has offered financial and technical support to equip the ESO-MPIA 2.2-m telescope with a wide-field camera ($35' \times 35'$), while the Osservatorio Astronomico di Capodimonte (Napoli) has offered financial and technical support for the development of the 8K × 8K CCD detector for the same camera. While this initiative is now well underway, the Osservatorio di Capodimonte has also offered to ESO a 2.5-m telescope optimised for wide-field imaging, a proposal now under evaluation at ESO. In addition, the STC has recently approved the construction of two new, highly-competitive instruments for the VLT, the optical and near-infrared multiobject spectrographs (VMOS and NIRMOS, respectively), each with imaging cameras with a field of view $14' \times 14'$.

Despite these important developments, none of these facilities will be available before the VLT is offered to the community. In order to cope with the short-term needs, a group of ESO astronomers was set up (L. da Costa (chair), A. Baker, J. Beletic, D. Clements, S. Coté, W. Freudling, E. Huizinga, R. Mendez, and J. Ronnback) to investigate other alternatives. During several months, this group investigated the possibility of conducting an imaging survey at the NTT during the second semester of 1997 (about one year before the beginning of the VLT scientific operations) and making the data available to the ESO community. On 12 May 1996, the Group released its final document describing the conclusions of this feasibility study, which included a careful analysis of the science drivers of the survey and its technical, observational, and operational aspects. The document also included contributions on specific topics by H. Böringer, S. Cristiani, P. Schneider, and J. Villumsen.

On 31 May 1996, the ESO Director General and the VLT Programme Scientist illustrated to the OPC the benefits that an imaging survey would have for the early VLT observations. The OPC fully endorsed the notion, and recommended the formation of a Working Group to elaborate a formal proposal for the imaging survey to be discussed at the following meeting of the OPC on 29 November 1996. Being recognised as an integral part of the VLT Programme, the VLT Programme Scientist was asked to organise and chair the Working Group. On 10/11 July 1996, the WG had its first meeting in Garching, with the presence of G. Chincarini, S. Cristiani, J. Krautter, K. Kuijken, Y. Mellier, D. Mera, H. Röttgering and P. Schneider. From ESO, besides the authors of the present article, several other astronomers attended the meeting, including J. Bergeron, S. D'Odorico, W. Freudling and R. Gilmozzi. As the starting point of the discussions, the WG adopted the da Costa et al. document, complemented by additional input from S. D'Odorico on the deep observations. The WG soon endorsed the concept, goals, and general design of the proposed survey. This was followed by a very productive discussion about the various trade-offs, such as depth versus sky coverage, length versus width and filter selection, among others. As a result of the discussion, important improvements were made to the original design, and the ESO astronomers were requested to prepare a revised and more concise proposal to be circulated in advance of the next meeting.

The draft of the EIS proposal was distributed to the WG members in September 1996, and on 4 October 1996 the WG met again, this time with the presence of S. Charlot and R. Saglia, and thoroughly discussed the proposal. While the wide-angle part of the EIS proposal was unanimously endorsed by all the WG members, a few among them expressed some reservation concerning the pointed observations. Although fully acknowledging the outstanding scientific value of this part of the proposal, some argued that individual teams from the community could have submitted a regular proposal on their own to conduct the corresponding observations, while maintaining proprietary data rights for some time. The WG finally endorsed both parts of the survey, and issued a set of recommendations to the OPC ("http://www.eso.org/vlt/eis/eis_wgr.html").

An additional and independent endorsement to EIS came from the ESO VLT Key Programme Working Group in Extragalactic Astronomy that stated in its final report: "The working group strongly endorses the OPC policy to reserve substantial amounts of NTT time for programmes that are preparatory to VLT programmes. In particular, the working group expresses very strong support for the important initiative of the ESO Imaging Survey on the NTT as a vital preparation for the first few years of the VLT".

In the letter to the OPC accompanying the EIS proposal and the WG recommendations, the VLT Programme Scientist stressed the following additional point:

"The ESO scientists appearing as PI and Co-I of the EIS proposal commit themselves to avoid any personal use of the survey data before they become public. If appropriate, the time limit of this commitment can be extended at the discretion of the OPC. A similar commitment will be asked to all those members of the community that may come to ESO to handle the data."

The EIS proposal was formally submitted to the OPC on 31 October 1996 as planned, with the VLT Programme Scientist as PI, and L. da Costa, W. Freudling, S. D'Odorico, P. Quinn, J. Spyromilio, and J. Beletic as Co-Is. Since the proposal was not intended to provide data rights to the team, the team composition reflected exclusively the functional aspects of the Survey. In practice, a much larger number of people has been and will be directly or indirectly involved in the EIS project.

On 29 November 1996, the OPC reviewed the EIS proposal and as of February 1997, the wide-angle section of the survey has been scheduled for period 59. Funds have been allocated to the project and a visitors programme has been established to sponsor short- and long-term visits of scientists from the community that can contribute with specific skills to the preparation and execution of the survey. The survey has also received high priority within all other ESO divisions, thus securing the necessary support.

4. Recent Developments and Future Work

In early February 1997, it became apparent that a FIERA controller could not be implemented on EMMI in time for the survey to use this facility. This has led to the decision to abandon the drift-scan mode of observations, that was originally recommended by the WG, in favour of the shift-stare mode with the EMMI-ACE system. Using recent estimates of the readout time, we expect an overhead of about 100 seconds per exposure which will imply an efficiency of 60% relative to that expected for the drift-scan. This has already been taken into account in Table 1. The implication is a reduction of the area covered during the Chilean winter-spring period, unless more time is allocated to the project. On the positive side, the EMMI-ACE system will be fully tested by the time EIS observations get underway. The system is also VLT-compliant, and as so EIS will serve as a prototype for the service-mode observations and the development of the archive research environment. Another advantage of the shift-stare mode is that it gives more flexibility in the choice of the survey regions.

Given these changes, the WG is currently evaluating the possibility of still covering a wide range of right ascensions, thus allowing for an even distribution of VLT targets. For example, the survey may be conducted in 3 patches of about 6 square degrees each, separated by 3^h and spread over the right ascension range 21^h to 3^h. The exact pointings and the format of each patch (e.g., $1° \times 6°$ or $0.5° \times 12°$) are still under consideration. The EIS home page will be updated as soon as the WG makes its final recommendation.

Since receiving the endorsement of the OPC, the EIS team has initiated its work on several fronts:

• Preparation and distribution of the Announcement of Opportunities for the EIS visitor programme.

• The preparation of the EIS home page ("http://www.eso.org/vlt/eis/") which so far has been accessed over 1000 times.

• Orders have been placed for a set of wide-band filters and computer hardware.

• ESO fellows are already at work in a variety of tasks related to the survey.

• Interviews are being conducted to select the first group of visitors who will work on the development of the data-processing pipeline.

• The general plan for EIS is being elaborated in collaboration with other ESO Divisions to establish the necessary interfaces between EIS and the User Support Group, the NTT team, the Data Management Division and the ECF.

Some of the main tasks of the EIS team are:

• Selection of the survey regions to be presented to the WG for final approval.

• Phase II Proposal Preparation (P2PP) and production of the Observational Blocks.

• Implementation of data-processing pipeline.

• Implementation of EIS database, data archive, and procedures for data distribution.

• Development of algorithms for the production of catalogues of candidate clusters, quasars, high-redshift galaxies and galactic objects.

The EIS team is also following closely the progress of SUSI2 and SOFI, with which the deep observations will be conducted.

Given the large amount of work ahead and the ambitious timetable of the survey the involvement of the community in EIS is an essential ingredient for its success.

5. Participation of the Community

The involvement of the ESO community is essential for two reasons. First, it is appropriate that this "service to the community" is carried out with the direct control and participation of the community itself. Second, the tight timetable of the survey and the fact that the ESO staff already have other commitments make it necessary to rely on the participation of scientists from the community. ESO is committed to provide the necessary support to make this participation possible.

The involvement of the community is already present through the EIS Working Group. However, to expand this participation, we urge interested scientists to interact either directly with the EIS team at ESO or with the members of the EIS Working Group which will remain active until the completion of the survey.

ESO also envisions a more active participation of the community via the direct involvement of scientists and students in the observations, data reduction and analysis. For this purpose a special ("http://www.eso.org/adm/personnel/ann/eis.html") visitors programme has been established to sponsor short- and long-term visits of scientists/programmers/data assistants willing to contribute to EIS. As EIS will operate in a very tight schedule, the priority will be determined by the most pressing needs of the survey which will evolve in time.

So far we have received over 70 applications for the visitors programme from all over Europe and abroad. We are currently selecting visitors who will help us implement the data reduction pipeline.

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The Deep Near-Infrared Southern Sky Survey (DENIS)

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1. The DENIS Project

Since the middle of 1994, the ESO 1-metre telescope has been dedicated on a full-time basis to a long-term project whose main objective is to survey the entire southern sky in 3 bands of the near-infrared regime, namely I, J, and K_s. The routine observations of the DENIS project began in December 1995, after a long period of tests of the instruments and telescope optics, observational pilot programmes, and an unexpected delay due to the implementation of the new read-out electronics of the I channel.

Extensive catalogues of stars, galaxies, and other celestial objects constitute a fundamental tool of astronomy. Statistics of any class of objects requires data as complete and as well-calibrated as possible. Before making any deep investigation of a particular region, a large-scale map of the surrounding area is essential to establish the general context. For these simple reasons, the sky has been surveyed at almost all wavelengths accessible from the Earth's surface and for which the appropriate technology is available; and soon after man had escaped the Earth's atmosphere, or discovered new ways of detecting radiation thus unveiling new spectral ranges, explorations quickly commenced in quest of new celestial objects and unknown physical processes.

The 2.2-micron window is of particular astrophysical interest. It is the longest wavelength window not much hampered by extinction in the Earth's atmosphere, and is also a band quite free of background thermal emission. The interstellar medium is quite transparent at 2.2 microns. The astrophysical importance of the band lies in the fact that this wavelength corresponds to the maximum in the emission spectrum of evolved stars.

At the end of the 1980's, it had become clear that an all-sky survey was technically possible which would yield an improvement by more than 4 orders of magnitude in the K band, at 2.2 microns, over what had been achieved by the extraordinarily valuable Two-Micron Sky Surveys (TMSS) (Neugebauer and Leighton, 1969). Obviously, crucial was the release from military classification of infrared detectors suitable for astronomical work; also important were the advances in computer technology which would allow the enormous amount of data to be processed and distributed in a feasible manner.

Two major efforts to map the infrared sky began more or less simultaneously. In Europe, several laboratories, under the leadership of the Paris Observatory in Meudon, started to consider pooling efforts which led to a proposal for the DENIS project, aimed at covering the entire southern sky from the ESO site at La Silla, making full-time use of the ESO 1-metre telescope. In the US, following the initiatives of the University of Massachusetts, the 2MASS project was put forward, which proposed to use two custom-built telescopes to observe both hemispheres of the sky. Operating with somewhat different wavelength bands, and in particular without the CCD-camera coverage of the I band, the 2MASS project is in some ways complementary and in other ways competitive with the DENIS survey of the southern sky.

Although not originally designed for infrared observations, the ESO 1-metre telescope has been used successfully over a two-decade period to carry out photometric observations from 1 to 20 microns. In fact, many of the most well-known "infrared objects" populating the southern sky, including very young massive stars, extreme AGB stars, active galactic nuclei, and actively star-forming systems, were discovered with this instrument.

The DENIS efforts started in earnest in 1990 to generate the necessary funds and manpower. The French Education Ministry provided the initial funding which supported the preliminary feasibility studies. The *Département de Recherche Spatiale* of Paris Observatory at

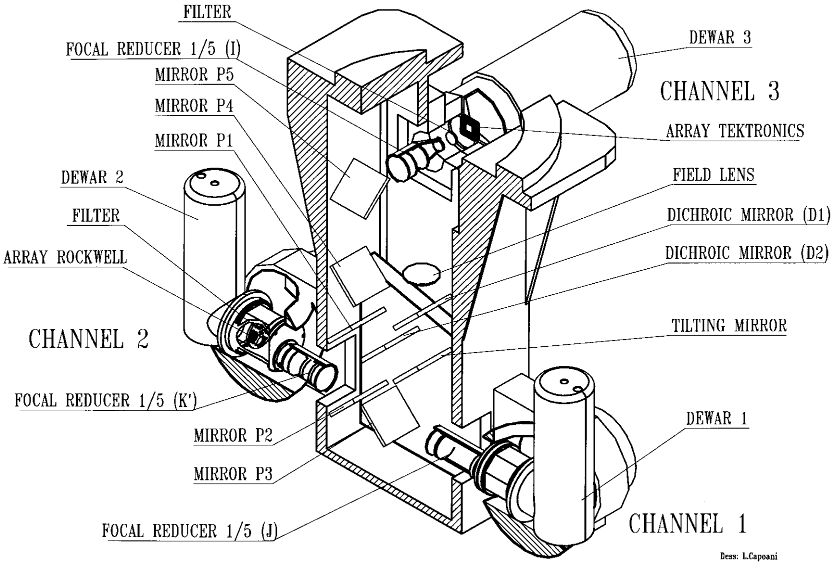

Figure 1: Sketch of the DENIS focal instrument (from L. Capoani).

Meudon had established expertise in building IR cameras during the CIRCUS and ISOCAM short-wavelength projects, and this allowed a prompt design of the two DENIS infrared cameras. At the same time, several European laboratories pooled their manpower resources and technical expertise to propose a project which was first granted funding within the context of the *Science* plan of the European Commission, then subsequently as a network in the *Human Capital and Mobility* programme.

The ambition of the DENIS project is to produce the first directly-digitised astronomical sky survey, and the largest infrared star catalogue ever produced. It is a long-range project that will extend over the full decade of the 1990's, from the initiation of the design studies to the final exploitation of the data. The basic DENIS objective is to explore the entire sky at $\delta < +2°$ in three spectral bands of the near-infrared, namely the I, J, and K_s, bands centred at 0.85, 1.25, and 2.15 µm, respectively. DENIS will thus produce and deliver to the community a set of fundamental astronomical documents, including a point-source catalogue of almost 1 billion stars in the I band, an extended-source catalogue containing some 250,000 galaxies, and an atlas of 1 million elementary images of $12' \times 12'$ size, in three colours. This material, which will amount to some 4 Terabytes of data, will be of direct value and will also support statistical investigations (star and galaxy counts) in a newly explored spectral range; it will also support the preparation and subsequent exploration of the planned and on-going space missions such as the Infrared Space Observatory (ISO) mission of the European Space Agency, the Near-Infrared Camera and Multi-Object Spectrometer (NICMOS) project on the Hubble Space Telescope, and the Space Infrared Telescope Facility (SIRTF), as well as ground-based projects including in particular some of those to be carried out with the ESO Very Large Telescope.

The DENIS material will support a range of investigations in several important astronomical fields, including those dealing with the structure of our galaxy, specifically with the distribution of various stellar populations, the investigation of the missing mass in our galaxy, the formation and evolution of stars, and the local structure of the Universe.

The DENIS project incorporates state-of-the-art technologies in several different areas, including IR-array detectors, electronics, real-time computing, and data-base management, each of which require a different sort of expertise. For this reason, the design and implementation of the DENIS project has required the pooling of funding and human resources in a number of different European institutes. No less than 20 institutes, located in 8 countries[1], are involved in the DENIS project, together with the European Southern Observatory (ESO). The technological requirements and the realities of the funding problems have led to a somewhat cumbersome organisational structure, but has had the advantage of stimulating new collaborations for the scientific exploitation of the data.

[1] Contributing countries and institutes are Austria (Universities of Innsbruck and Vienna) Brazil (University of São Paulo), France (Paris, Lyon, Grenoble and Besançon Observatories and Institut d'Astrophysique de Paris), Germany (Landessternwarte, Heidelberg), Hungary (Konkoly Observatory, Budapest), Netherlands (Leiden Observatory), Italy (Istituto di Astrofisica Spaziale, Frascati) and Spain (Instituto Astrofísica de Canarias).

2. The DENIS Instrument and the Observing Strategy

The DENIS focal instrument is a completely new and specially designed 3-channel camera including its dedicated data-handling system (Fig. 1, Fig. 2). It consists of 3 independent cameras attached to a main structure that is set up at the Cassegrain focus of the 1-metre telescope. The I-band camera is equipped with a Tektronix array of 1024 × 1024 pixels; the J- and K_s-band cameras are each outfitted with Rockwell NICMOS-3 detector arrays of 256 × 256 pixels. Installing such a substantial instrument at the focus of a relatively small

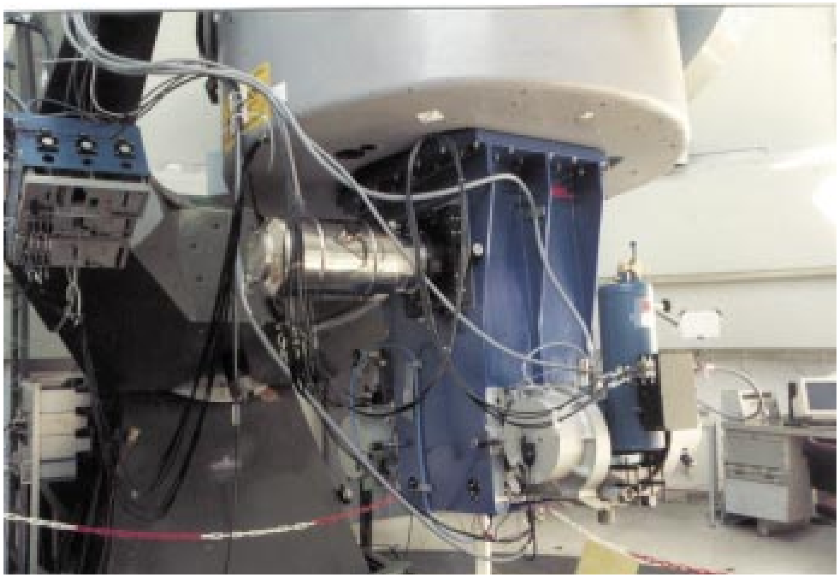

Figure 2: The DENIS focal instrument installed at the Cassegrain focus of the 1-metre telescope at La Silla. The stainless steel dewar seen on the left of the main structure contains the CCD array. The infrared NICMOS arrays are set up in 2 cryostats, one of which (K band) is seen on the right of the picture (blue vertical cylinder), the other is hidden by the structure. Part of the read-out electronics is hanged on the fork of the telescope.

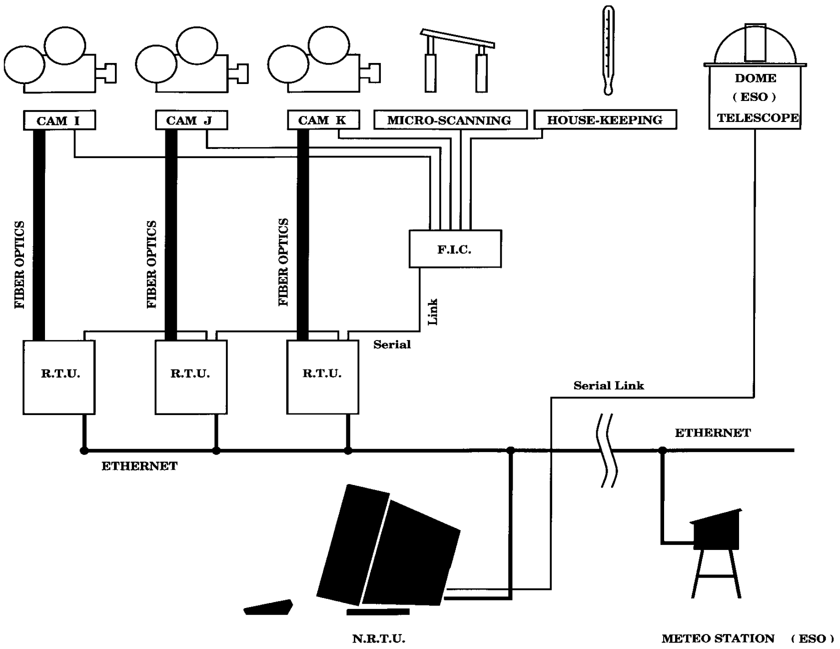

Figure 3: The DENIS computer network (from F. Lacombe).

telescope was quite challenging; for example, due to weight limitations, the main instrumental structure had to be made of magnesium. The f/15 beam coming from the telescope is split into three beams, corresponding to the three survey wavelengths, using dichroic beam splitters. Three focal reducers, each optimised for the respective wavelengths, transform the f/15 focal ratio to f/3. They provide a field of view of 12′ × 12′ on the sky for the three arrays and a scale of 3″ per pixel on the J and K_s channels and 1″ on the I channel. A microscanning mirror is inserted in the infrared beams which can be tilted by piezoelectric actuators in the right ascension and declination directions in small steps corresponding to fractions of pixels.

The purpose of this microscanning mirror is to optimise the sampling of the J and K_s images and to minimise the effect of bad pixels on the NICMOS arrays. An elementary DENIS image in the J and K_s bands results from combining and interlacing 9 sub-images obtained by moving the microscanning mirror by 1/3 of a pixel in α and $2^1/_3$ pixels in δ, in both negative and positive directions. Because of this optimised sampling of the DENIS images, each of the three channels is characterised by similar astrometric accuracy, of the order of 1″.

The DENIS project will survey the entire sky between δ = +2° and –88°. The sky-coverage strategy involves dividing the sky into three zones, each covering 30° of declination; each zone is itself divided into narrow *strips,* 12′ wide in α and 30° long in δ. Each strip is scanned by moving the telescope in the so-called *step and stare mode.* The integration time on each position of the telescope is approximately 10 seconds; after this duration, the telescope is moved 10′ in declination in order to allow for an overlap of 2′ between two consecutive images. One strip contains 180 images of 12′ × 12′ and takes approximately 1.5 hours to be completed. This includes the time spent on photometric and astrometric calibrations and the overhead delays required by the movement and stabilisation of the telescope, by the data read-out of the cameras, by data transfer between computers, as well as by the actions of shutters and filter wheels. Flat-fielding observations are performed in the three colours at dusk and at dawn.

The data handling at the telescope is controlled by three “Real-Time Units” (RTU), one per channel, each consisting of a pair of 68040 processors. A special processor (the Focal Instrument Controller or FIC) controls the hardware (including filter-wheel rotation on the IR channels, the movement of the CCD shutter and microscanning mirror, etc.) as well as general housekeeping (including temperature probes, etc.) and the sequence of observations. Finally, an HP 9720 workstation (NRTU) is used as the observer interface; it manages the survey strategy automatically, by choosing the right strip to be observed at a given time, and displays all necessary information regarding telescope control and the status of the cameras and progress of the survey. This workstation is also interfaced with the HP 1000 of the Telescope Control System (TCS) (see Fig. 3).

The focal instrument was designed and constructed under the leadership of the *Département de Recherche Spatiale* of Paris Observatory at Meudon, where D. Rouan, D. Tiphène, F. Lacombe, B. de Batz, N. Epchtein, L. Capoani, S. Pau and E. Copet contributed to the design and implementation of the hardware and software, and in partnership with the *Institut d’Astrophysique* in Paris, where J.C. Renault served as project manager. The *Istituto di Astrofisica Spaziale* in Frascati, Italy, the *Instituto Astrofísica de Canarias* in Spain, and the Observatories of Lyon and Haute-Provence in France, each contributed optical and mechanical parts for the focal instrument. The real-time data-handling software was implemented by a collaboration between F. Lacombe at the Meudon Observatory, S. Kimeswenger at the University of Innsbruck, and T. Forveille at the Grenoble Observatory.

A preliminary version of the DENIS instrument, equipped only with the J and K_s channels, was mounted on the ESO telescope for the first time in December 1993. The I-band CCD channel was delivered to La Silla in July 1995, and put in full operation soon after. The performance characteristics (see Table 1) of the cameras are in agreement with the design specifications. During

TABLE 1: Characteristics of the DENIS Channels.

Channel	*I*	*J*	K_s
Central wavelength (μm)	0.80	1.25	2.15
Array manufacturer	*Tektronix*	*Rockwell*	*Rockwell*
Number of pixels	1024 × 1024	256 × 256	256 × 256
Array quantum efficiency	0.65	0.81	0.61
Pixel size (μm, arcsec)	24, 1	40, 3	40, 3
Number of bad pixels	a few	216	254
Largest defect (pixels)	none	16	73
Read-out noise *(e^-)*	6.7	38	39
Read-out time *(second)*	2.98	0.13	0.13
Exposure time *(second)*	9	8.8	8.8
Storage capacity (e^-)	$1.5 10^5$	$2.0 10^5$	$2.0 10^5$
Achieved limiting magnitude *(point source 5σ)*	18.0	16.0	13.5
Magnitude of saturation	10.3	8.0	6.5

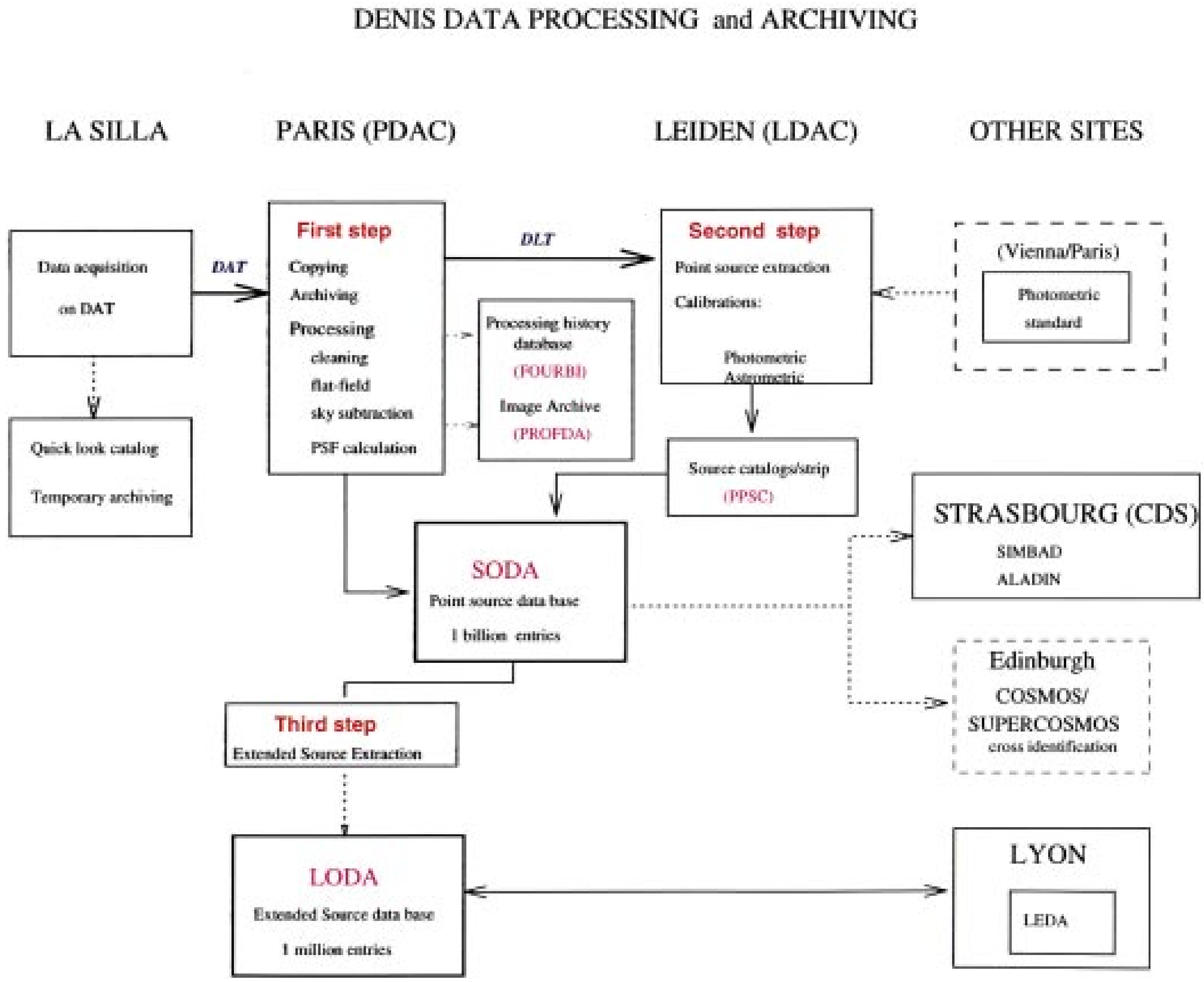

Figure 4: The DENIS data pipeline. Users will access the image archives (PROFDA) that will be installed on a jukebox of DLTs at PDAC, and the sourc catalogues in the SODA and LODA databases. The FOURBI database already provides the consortium members with information on the current status of observations (observed areas). The connections with the CDS in Strasbourg and ROE are under discussion.

the commissioning phase, hardware subsystems and software were tested and improved in order to optimise the image quality, the data reduction procedures, and the survey strategy. Because no major change in the instrumental configuration nor in the survey strategy will be possible during the lifetime of the survey, in order to ensure homogeneity of the data, all the parameters that define this strategy were carefully reviewed during the commissioning phase of the project.

The series of pilot-programme observations *(protosurvey)* of selected areas of the sky chosen for specific scientific reasons, has been fully completed and has resulted in a sky coverage of about 2000 square degrees, in either two or three colours, depending on whether the pilot programme in question was completed before or after the CCD channel had been installed. Scientific analysis of these data is now underway (see section 5).

3. The Off-Site Data-Analysis Centres in Leiden and in Paris

The data processing and archiving is performed as a joint task between the Paris Data Analysis Centre (PDAC), operating out of the *Institut d'Astrophysique* and the Paris Observatory under the supervision of J. Borsenberger, and the Leiden Data Analysis Centre (LDAC) operating at the Leiden Observatory under the supervision of E. Deul. The data pipeline is schematised in Figure 4.

The PDAC is responsible for archiving and preprocessing the raw data in order to provide a homogeneous set of images suitable for the subsequent data-analysis streams in both Leiden and Paris. The LDAC is extracting objects, ranging from point sources to small extended sources, and then parameterising them and entering the results into an archive constituting a preliminary point source catalogue (PPSC). The PDAC also extracts and archives images for those sources found to be extended, and will thus create a catalogue of galaxies. Both DAC's are working in close collaboration, supplementing each other, to perform a coherent and complete data reduction analysis task.

3.1 The Paris Data Analysis Centre (PDAC)

The PDAC performs a number of steps necessary to prepare the data for further processing and analysis. The steps involve the flat-fielding and sky-emission corrections of the strip images using flat-fields derived during the real-time processing on the mountain and through sunrise/sunset observations. Subsequently, a sorting of the frames is done to obtain colour-grouped sets of data for each pointing position. At PDAC, the incoming data stream is inspected thoroughly to assess the quality of each and every image of the strips.

Figure 5: DENIS image of the molecular cloud OMC2 as seen in J and K_s (false colours, blue = J, red = K_s, processed by E. Copet).

This information is relayed back to La Silla to allow re-observations when necessary. This procedure ensures a homogeneous survey.

The processed frames (strips) are stored in the Processed Frame Database (PROFDA) and also sent to the LDAC for further processing. The PROFDA will allow mosaicking the individual images. Access to the PROFDA is provided through a database produced and maintained at the PDAC. This database allows verification of the observing strategy goals aimed at full mapping of the southern sky, and also keeps track of the data quality and storage administration.

Upon return of source and calibration information from LDAC, the PDAC examines the processed frames for extended objects. These non-stellar objects are parametrised and archived in the extended-source database. For each extended object a postage stamp image is extracted and stored.

3.2 The Leiden Data Analysis Centre (LDAC)

The LDAC concentrates on the extraction of "small objects" from the DENIS images, at all three wavelength bands. Production of a catalogue is done during the course of the survey data acquisition and should result in an incremental first-order data product tracing the observations with a delay period of approximately one year. Access to the "protosurvey" data is open to the DENIS Science Working Groups.

The derivation of object parameters is based solely on image properties; no *a priori* astronomical information will enter this catalogue. Object parameters are corrected for instrumental effects in the final catalogue. Apart from the usual extraction parameters, information about the local image environment and extraction characteristics are also retained. All objects above the 5-σ noise level are extracted. The objects are de-blended and their positions calculated using the frame centres and plate parameters computed with the help of cross-identifications with the DENIS Input Catalogue sources. In order to improve the positional accuracy, strip wide astrometric solutions are computed utilising the overlap information inherent to the observing strategy. The small objects are photometrically calibrated using a set of DENIS standards widely distributed over the southern sky. The list of standard stars used for DENIS has been divided into two parts, one for the I band and the other for the J and K bands. The I-band standards come from the set of UBVRI standards used at ESO and at CTIO (Landolt, 1992). For the J and K bands, a list of standards has been compiled from those in use at CTIO, ESO, MSSSO, SAAO, and UKIRT. At LDAC, a working database stores all the raw and derived extraction parameters along with the most recent calibration parameters. At regular intervals, the raw information is transformed into astronomically meaningful parameters using the best available calibration.

3.3 Quality estimates and final databases

The photometric accuracy of the DENIS data can be assessed using the photometric standard stars as a local reference frame. The standard deviation in the photometric parameter derived from the protosurvey data shows that high accuracy is achieved over a large range in magnitudes. The photometric accuracy of the object extraction (rms error) has been shown to be about 0.03 mag, just below the saturation limit, and 0.02 mag at the faint cut-off. The DENIS instrument has so far been very stable in time. As a result of the large amount of data produced by DENIS, we will define our own photometric system and provide transformation formulae to most other standard photometric systems. Our system, however, will increase in accuracy with time and can only be finalised at the end of the survey.

The positional accuracy is influenced mainly by the systematic errors of the GSC, which on average are about 1″. In fact, the DENIS input catalogue used is a combination of several catalogues, the GSC v1.2, the PPM catalogue, the HIPPARCOS input catalogue and eventually also the Tycho catalogue, each appropriately weighted in the astrometric solution. The relative rms errors (within a DENIS frame) are of the order of 0.1″. After the TYCHO catalogue becomes available (we expect one TYCHO star per DENIS frame), the positional errors can be reduced to a few tenths of arcseconds. Current positional errors are about 0.3″. Once the data have passed the quality tests, they will be gathered into final databases, one containing the small sources (SODA) the other the extended sources (LODA). These databases will result from a collaboration between both DACs and the CDS in Strasbourg. Cross-identifications with the optical SUPERCOSMOS data are also envisaged to eventually provide 5-colour photometric catalogues.

4. DENIS Operations in Chile

The survey operations in Chile involve a major effort, requiring the presence of at least one person every night, all the year round, at the observing site for an expected total duration of 4.5 years. The project maintains a dedicated team, resident in Chile and now fully operational. The team involves a survey astronomer, P. Fouqué, who supervises the observations; an operations engineer, formerly B. Jansson; and a young scientist, generally a French "coopérant", E. Bertin for the 1994–95 year, P.-A. Duc for the 1995–96 year, and presently R. Moliton. In addition, visiting astronomers and engineers come from Europe to reinforce the local staff, to make urgent hardware or software modifications, and to provide the necessary link between the operations in Chile and the data analysis centres in Paris and Leiden.

The mountain operations are conducted under the responsibility of the survey astronomer. All commissioning tests have been done under his supervision in close interaction, via daily e-mail connections, with the instrument team based in Meudon and with the two data analysis centres. The primary responsibilities of the operations engineer involve maintenance of all aspects of the instrumentation, mainly the electronics and hardware devices; as with any new and complex instrument, maintenance of the complete DENIS facility is an important and demanding task.

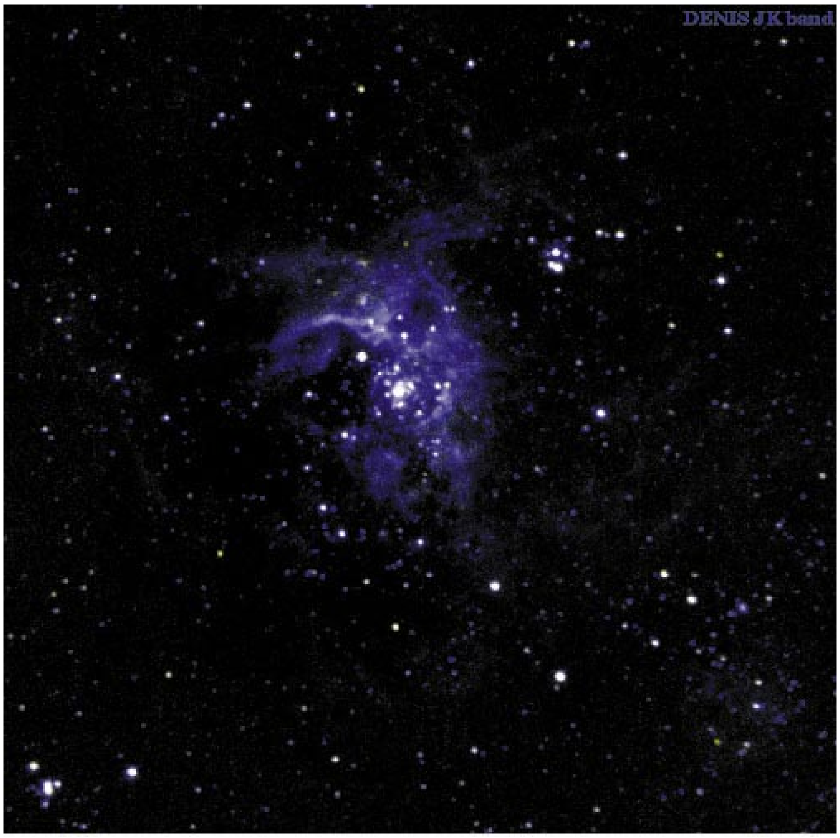

Figure 6: DENIS two-colour (J, K_s) image of the Tarantula Nebula in the Large Magellanic Cloud (false colours, blue =J, yellow = K_s, processed by E. Copet).

5. First Scientific Results from the DENIS Project

5.1 Organisation of the scientific data analysis

The scientific interpretation of the data obtained during the pilot-survey period has now started, under the responsibility of five dedicated Science Working Groups set up for this purpose. They involve astronomers from the different institutes of the consortium, including a number of graduate students and post-doctoral fellows, several of whom are supported by the European Community through a network of the *Human Capital and Mobility* programme, as well as through other individual and institutional fellowships. The five working groups are dedicated to the principal areas to which DENIS is expected to contribute: (i) late-type and AGB stars, chaired by H. Habing, Leiden; (ii) low-mass stars, chaired by T. Forveille, Grenoble; (iii) galactic structure, chaired by A. Robin, Besançon; (iv) star formation, chaired by P. Persi, Frascati; and (v) extragalactic systems and cosmology, chaired by G. Mamon, IAP, Paris.

A data-release policy group (DRPG) defines and regulates the access to the data and the authorship of the publications. The main rule is in accordance with ESO policy, that once the data have been processed and certified regarding quality, they are put at the disposal of the consortium members for the duration of one year after archival in the DACs; subsequently the data are released to the community at large. The first such general release of DENIS data is expected in spring 1997. The DENIS consortium has been actively pursuing its goals. Twice a year progress review meetings are held, involving the entire consortium and chaired by the PI. More frequently, in practice at least five times a year, the data processing specialists meet in Data Analysis Meetings, or DAMs, chaired by E. Deul, in order to discuss and optimise the data processing techniques and methods. The DENIS project has been the focus of several national and international conferences. A *Les Houches School* was held on the subject of Science with Astronomical Near-Infrared Surveys (Epchtein et al., 1994). Two Euroconferences, supported by a grant from the EC, have been dedicated to presenting and discussing the first scientific results from DENIS. The first of these was organised in Italy (Persi et al., 1995), and the second in Spain (Garzon et al., 1997). Several scientists from 2MASS and IPAC have participated in these workshops, thus maintaining contacts and collaborations between the two infrared survey projects.

A couple of DENIS images obtained during the now-routine period of observations are shown in Figure 5 and Figure 6. These images illustrate the quality of the data and the results of the reduction pipeline; the images involve the nominal integration times of 10 seconds, and each represents a field of $12' \times 12'$ area.

Several Ph.D. theses based on the exploitation of DENIS data acquired during the protosurvey period have been recently defended or are currently in progress. Eric Copet (Meudon, DESPA), the first graduate student involved in DENIS since its beginning, in addition to contributing to the implementation of parts of the real-time data handling software, studied the luminosity function of young stars in the Orion region based on the early DENIS observations. He investigated the nature of some 2000 objects detected in J and K_s in an area covering $2° \times 0.5°$ around the Trapezium (Copet, 1996). Most of them are likely to be associated with the Orion complex. Stephanie Ruphy (Meudon, DESPA), has performed large-scale DENIS star counts, mainly in J and K_s, in various directions of the Galaxy, and compared them with the predictions of currently available models of stellar populations synthesis. She is particularly involved in a study of the anticentre direction. In these directions, all current existing models disagree with DENIS star counts in the sense that there are fewer stars observed than the models predict. At low galactic latitudes, colour diagrams are successfully used to separate giant and dwarf stellar populations (Fig. 7) (Ruphy, 1996). New revised values of the scale length and of the cut-off distance of the

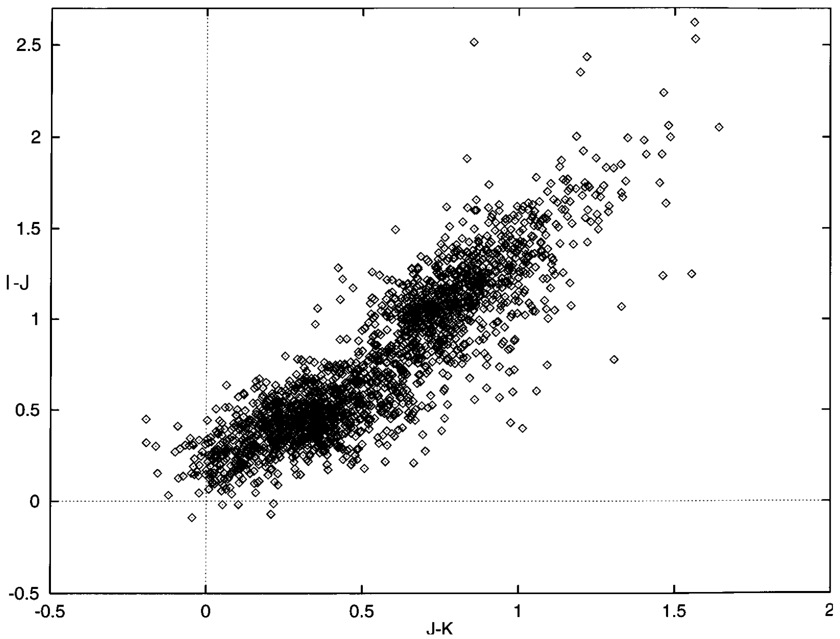

Figure 7: DENIS colour-colour diagram of 3800 point sources detected in an area of one half square degree at b = 1° and l = 238° at K < 13.5. This diagram shows two main concentrations of sources, the blue one corresponds mainly to dwarf stars and the redder one mainly to giants. At low latitude, the interstellar extinction efficiently separates the two populations.

stellar distribution in the Galaxy have been derived (Ruphy et al., 1996).

Another study in progress involves a search for low-mass stars at high galactic latitudes. Xavier Delfosse, at Grenoble, is preparing a Ph.D. thesis based on the analysis of DENIS images taken far from the galactic disk. A first analysis of several tens of strips at high galactic latitude resulted in the discovery of several very late (M8 to M10) red dwarfs. Other results have been already obtained by Y. Dabrowski who has combined DENIS images with optical data coming from Schmidt plates digitised with the COSMOS machine (Fig. 8). Most of the DENIS source extractions were done using the *sextractor* software developed by Emmanuel Bertin.

Extensive investigations involving the combination of DENIS and ISO images have already started. A. Omont (IAP, Paris) is leading a large-scale ISO open-time programme, entitled "ISOGAL" and aimed at probing the galactic bulge populations at 7 and 15 μm. Several areas located in the range $+45° > l > -45°$ and $|b| \leq 0.5°$ are currently being observed by ISO and by DENIS almost simultaneously, giving a wide spectral coverage and allowing much easier population separation in colour-colour diagrams (Perault et al., 1996). Other DENIS and ISO collaborations have begun, aimed e.g. at exploring nearby star formation regions, and the evolved giant and supergiant populations of the Magellanic Clouds. P. Persi (IAS, Frascati) and collaborators are studying the star-formation rate in several nearby molecular clouds such as the Chameleon clouds. L. Cambresy is drawing out a high spatial resolution and large-scale mapping of the extinction towards this nearby dust and molecular complex on the basis of star counts and [I – K] reddening. C. Loup and collaborators are characterising the DENIS colours of late-type giants (e.g., O-rich vs. C-rich) and identifying new such stars in the Magellanic Clouds.

Gary Mamon (IAP, Paris) and his collaborators have made simulations for star-galaxy separation and have estimated that the number of galaxies that will be detected by DENIS in the K_s band would be around 250,000, while in the I band, this number could be close to 1 million. As an illustration of the capability of detecting reddened galaxies in the Zone of Avoidance, an edge-on galaxy, IRAS 07395-2224, as seen by DENIS in its three bands is shown in Figure 9. Although the galaxy is barely seen on Schmidt plates (SRCJ) and is still rather faint in I, it appears prominently in K_s, where the density of field stars is much lower. A long-range programme to detect highly-obscured galaxies in the Zone of Avoidance is planned in collaboration with Renée Kraan-Korteweg (Meudon). G. Paturel and I. Vauglin from Lyon Observatory are currently cross-identifying DENIS sources with the galaxies of the *Lyon-Meudon Extragalactic Data Base (LEDA)* using the deep I images, and are drawing up a list of still uncatalogued galaxies detected by DENIS. Thousands of new galaxies have been already identified on the DENIS images.

Although DENIS has been operating in its routine mode only for one year, covering about one quarter of the southern sky, the project has already resulted

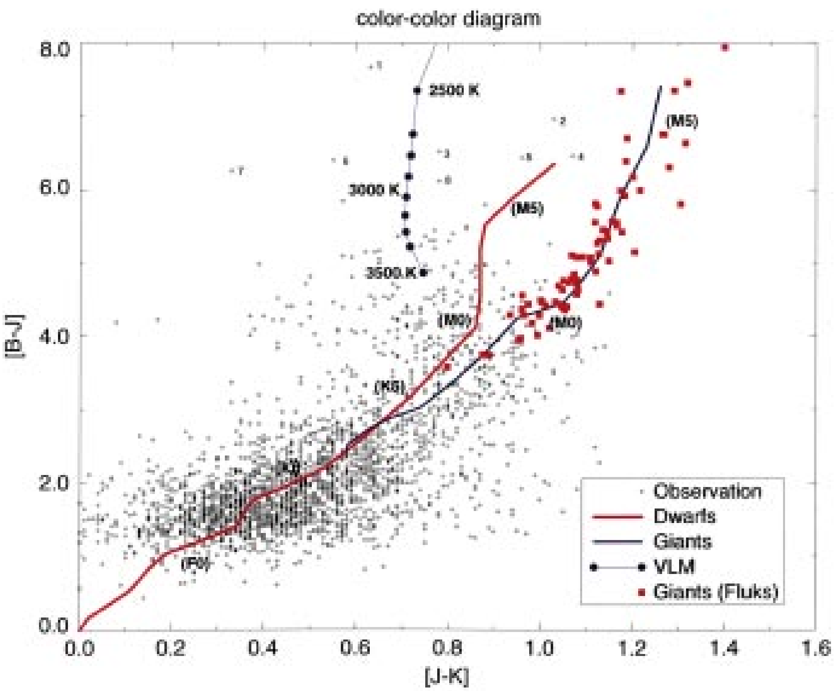

Figure 8: [B-J] vs. [J-K] colour diagram obtained by cross-identifying hundreds of objects detected by DENIS with optical sources extracted from a Schmidt SRCJ plate with the COSMOS machine at high galactic latitudes. This diagram illustrates the extremely promising breakthrough that the combination of optical and near-IR data at large scale will provide in the quest for very low mass stars. According to the recent models of VLM stars, (e.g. Allard and Hauschildt), they should appear much bluer in [J-K] than the normal main-sequence dwarfs, and thus good candidates could be easily recognised in this diagram.

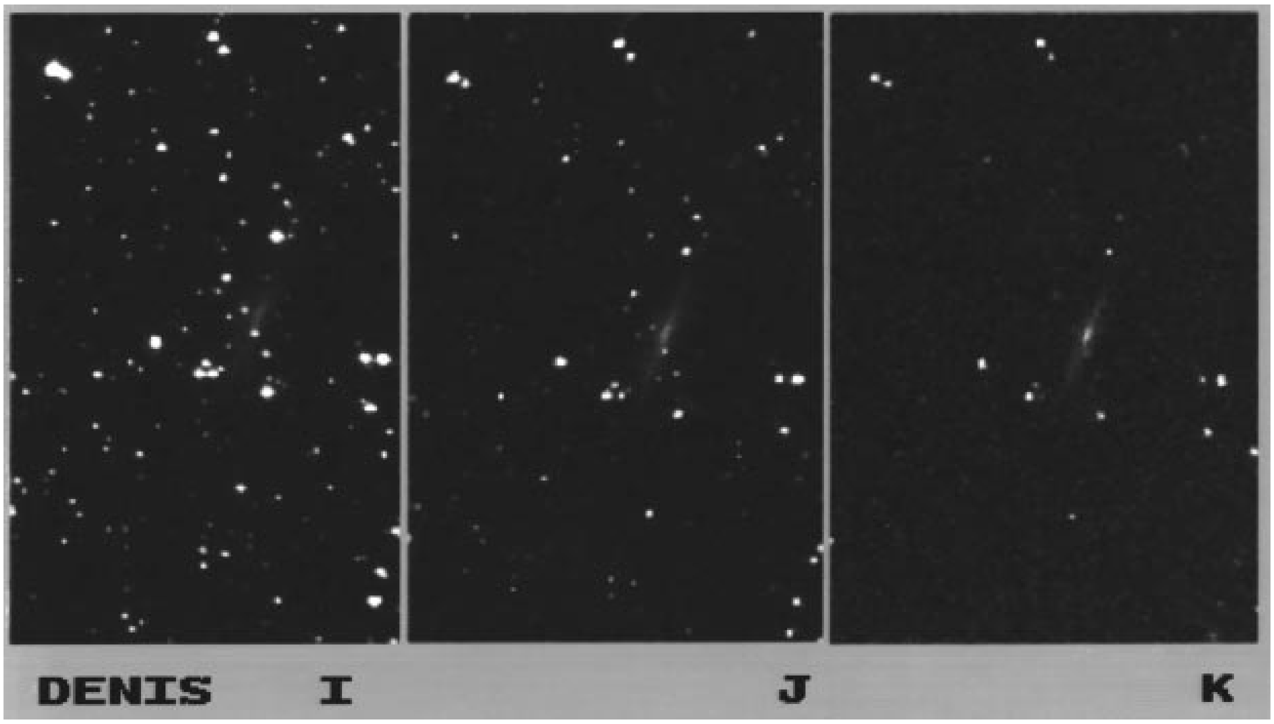

Figure 9: The galaxy IRAS 07395-2224, located at b = 0.2° as seen in the 3 DENIS bands from left to right: I, J, K_s. Notice that this edge-on spiral appears prominently in the K_s band. DENIS is expected to pick up many such galaxies in the zone of avoidance.

in a number of promising results. A small fraction of the archived data has been exploited, so far. Several fruitful collaborations have started within the consortium institutes and with ISO teams. Owing to the huge amount of data to analyse, we expect that the interest in DENIS products in the astronomical community at large, and in particular within the ESO community, will grow as the survey progresses; we also expect that the 2-micron point source catalogue will be available, at least partly, for the first light of the VLT.

Acknowledgements

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R Doradus: the Biggest Star in the Sky

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What is the biggest star in the sky? Here we are not speaking of absolute size in kilometres, but in apparent size as seen from the Earth. The obvious answer is the Sun, which has an angular diameter of half a degree. But which star comes next? The answer has long been assumed to be Betelgeuse (alpha Orionis), which appears to be about 35,000 times smaller than the Sun (depending on the wavelength at which you observe). In fact, Betelgeuse was the first

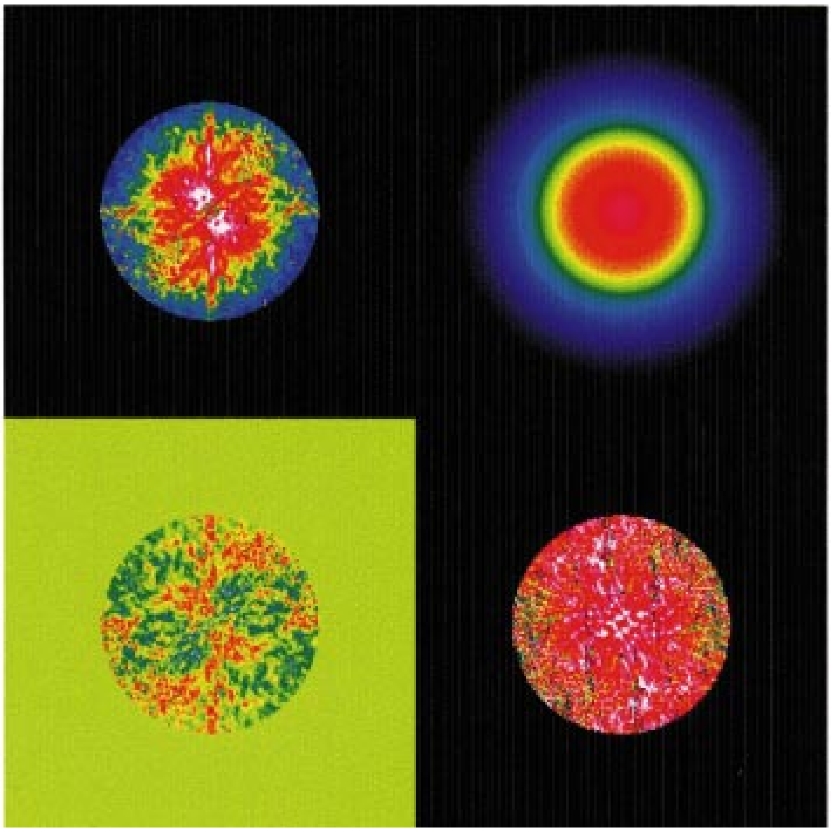

Figure 1.

star apart from the Sun to have its angular diameter measured (Michelson & Pease, 1921).

Betelgeuse is a red supergiant and its large apparent size is due both to its extremely large physical diameter (about 700 times that of the Sun) and to its relative closeness (about 200 pc). Several other nearby red giant and supergiant stars are resolvable with diffraction-limited 4-m-class telescopes. Not only can the angular diameter of these stars be measured directly (e.g., Tuthill et al., 1994b), but in some cases (e.g., Betelgeuse) features on the stellar surface have been detected (Buscher et al., 1990). In the case of some Mira stars, significant elongation has been found (Wilson et al., 1992, Haniff et al., 1992, Tuthill et al., 1994a).

Here we report observations of the star R Doradus, which has not previously been observed at high angular resolution. R Dor is an M8 giant and is the brightest, and presumably closest, star with such a late spectral type. Based on its infrared brightness, Wing (1971) predicted that R Dor (HR 1492) could be larger than Betelgeuse. We observed R Dor with SHARP on the NTT (infrared) using the technique of aperture masking. Other results, not presented here, were obtained with MAPPIT on the AAT. We indeed find that R Dor exceeds Betelgeuse in angular size.

Sequences of short (0.1s) exposures were taken of R Dor and two near-by unresolved stars, α and γ Ret (HD 27256 and HD 27304), using the SHARP camera on the NTT in the Johnson J band. The NTT entrance aperture was covered with an annular mask (see Bedding et al., 1993). The purpose of the mask is to reduce the effects of seeing on the accuracy of the measurement, with the beneficial side effect of attenuating the flux to a level which can be managed by the detector. The moduli squared of the Fourier transforms of 300 frames were averaged for each star. Calculating the ratio of the mean spectra from R Dor and the unresolved stars calibrates for instrumental and atmospheric attenuation of the mean spectra. The result is the two-dimensional visibility function squared of R Dor: it shows a decrease towards larger angular frequencies which indicate that the source is resolved. Figure 1 shows a sample calibrated visibility function (top-left panel). A non-linear least-squares fit of a model of the visibility function for a uniformly illuminated disk, with the apparent diameter as the only parameter, is applied. The top-right panel shows the model fitted to the data shown in the top left panel. The difference between observations and model is seen in the lower-left panel: the curved features are instrumental residuals from the spiders of the telescope, the remainder being the noise. For comparison, the bottom-right panel shows the visibility of one of the reference stars calibrated by the other one.

The mean diameter of R Dor we obtain from these data is 0.0587 ± 0.0026 (1 sigma) arcsec, uniform disk equivalent. This is the average of 11 model fits

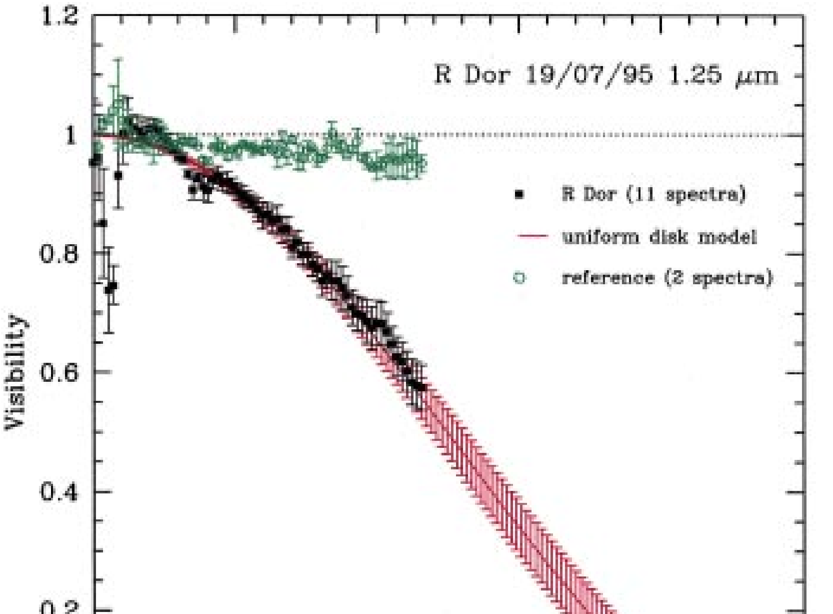

Figure 2.

to the corrected mean power spectra which result from all but one combinations between 3 sets of observations of R Dor and 4 sets of reference-star observations. There is no significant indication of a deviation from circular symmetry of more than 2 per cent. Smaller deviations are easily explained by residual artifacts in the visibility data.

Figure 2 shows radial plots (averages over the azimuth) of the compensated spectra. The black, heavy dots are the azimuth averages of the R Dor spectra. The origin of the dip near 1 lp/arcsec may be related to seeing variations; this region was excluded from the fitting process. The red curve shows the average and the variation of the non-linear fits to the data. The green, open circles show azimuth averages of inter-calibrated reference data to demonstrate the significance of the R Dor measurements.

The observed angular diameter of an M star can be strongly affected by the atmospheric extensions. Within bands of high opacity (such as the TiO bands) the star can appear 50 per cent larger than in continuum regions of the spectrum. It is therefore important to compare diameters for different stars only for measurements made in the continuum. A limb-darkening correction may also have to be applied, but this correction is somewhat ad-hoc due to the lack of reliable model atmospheres. Opacity effects and limb darkening are smallest in the infrared and stellar diameter measurements should preferably be taken in this region of the spectrum.

The uniform-disk diameter of Betelgeuse at 2.2 microns has been measured to be 44 mas (Dyck et al., 1992). Thus, R Dor appears to be the largest star in the sky.

Despite its classification as semi-regular, R Dor is in many ways closer to the Miras than to other SRb stars. Its period is near the peak of the Mira period distribution function (250–350 days), while SRb stars almost always have much shorter periods (e.g., Kerschbaum & Hron, 1992). Its late spectral type and large J–K are also more typical of Miras than other M-type stars (Feast, 1996). Using a bolometric magnitude at the epoch of our measurement of –0.96, we derive an effective temperature of 2740 ± 190 K from the measured diameter. Assuming that R Dor is closely related to the Mira variables, as seems likely, we can apply the period-luminosity relations for Miras in the LMC given by Feast 1996. We obtain a distance of 61 ± 7 pc and a luminosity for R Dor of 6500 ± 400 L . Our distance for R Dor agrees with estimates of 60 pc by Judge & Stencel, 1991, and 51 pc by Celis, 1995. This distance, together with our observed angular diameter, implies a stellar radius of 370 ± 50 L . From the pulsation equation $\bar{Q} = \bar{P}\ (\bar{M}/M\ )^{1/2}\ (\bar{R}/R\ )^{-3/2}$ and assuming Q = 0.04 days (appropriate for first overtone pulsation), we derive a mass of 0.7 ± 0.3 M . All the derived parameters are consistent with a classification of this star as Mira-like, with the effective temperature being slightly higher than the average for Miras.

All previous measurements of the radii of Miras fall in the range 400–500 R , which is taken by Haniff et al., 1995, as evidence that Miras are associated with a well-defined instability strip. The fact that R Dor shows a more irregular pulsation behaviour but with many characteristics of a Mira is consistent with it lying near the edge of such a strip. Miras have been found to show surface structures and/or ellipticity: if R Dor is related to the Miras, it may be expected that it also shows these effects. MAPPIT/AAT observations of R Dor indeed show non-zero closure phases, indicative of asymmetries or surface structure. R Dor is clearly an excellent candidate for more detailed observations with the VLT and VLTI.

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Molecular Hydrogen Towards T Tauri Observed with Adaptive Optics

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1. Introduction

Although T Tauri is the prototype of a large class of pre-main-sequence objects (the T Tauri stars), it is actually very peculiar. First, the optical primary (T Tau N) has an infrared companion (T Tau S) at a separation of 0.7″, which is completely obscured at visible wavelengths, but may dominate the bolometric luminosity of the system (Dyck et al., 1982, Ghez et al., 1991). Infrared companions have been found near a number of other pre-main-sequence stars, but their presence seems to be the exception rather than the rule (Zinnecker and Wilking, 1992). Second, and even more surprisingly, strong extended 2.121 µm H_2 (v = 1 – 0) S(1) ro-vibrational emission was found from T Tau (Beckwith et al., 1978). Despite extensive searches, H_2 emission with comparable strength has been found in very few other pre-main-sequence stars (e.g. Carr, 1990). Finally, there are two Herbig-Haro objects at right angles associated with T Tau (Schwartz, 1975, Bührke et al., 1986), giving rise to the suspicion that two misaligned pairs of jets emanate from the two components of the binary.

Taking a closer look at the environment of T Tau, and at the relation of the gas to the two stellar components requires spectral line imaging with the highest possible angular resolution. Van Langevelde et al. (1994) present an image of T Tau in the H_2 (v = 1 – 0) S(1) line with a resolution of 0.8″, but the central region of this image had to be blanked because of saturation[1]. More recently, Herbst et al. (1996) observed T Tau with the MPE imaging spectrometer 3D; these observations cover a field of 8″ × 8″ with a resolution of 0.7″. A complicated structure was detected on this scale, which was interpreted as an

[1]Note that Figure 1 in van Langevelde et al. (1994) is labelled incorrectly. The correct image size is 26″, rather than 52″.

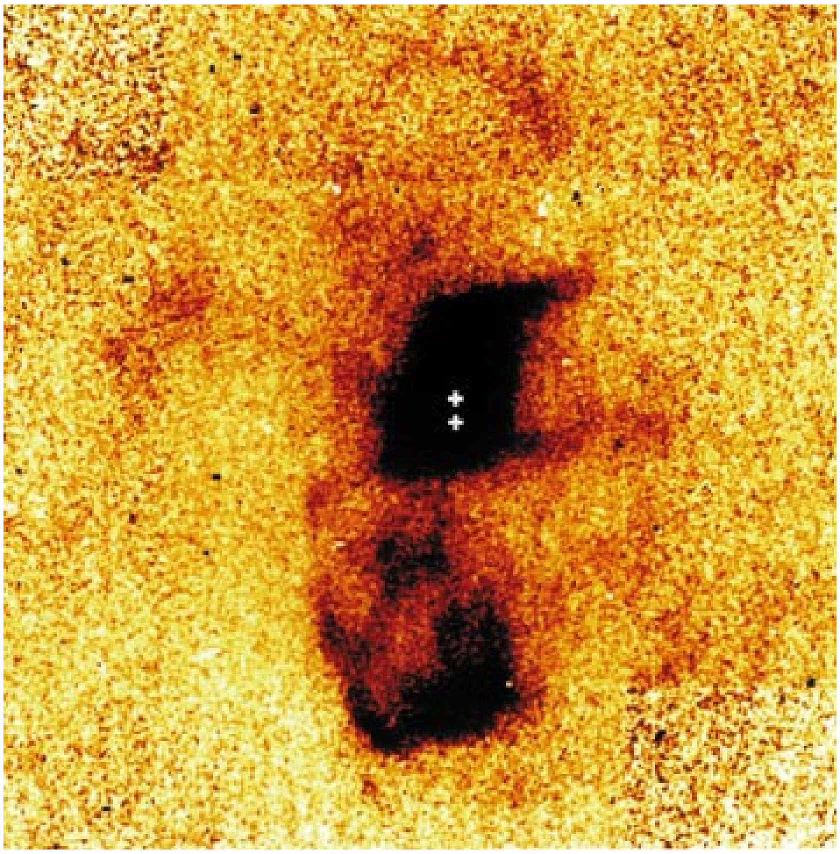


Figure 1: 2.121 μm H_2 (v = 1 – 0) S(1) ro-vibrational emission towards T Tauri. The field size is 25″ × 25″, North is up, and East is left. The positions of the two components of the T Tauri binary are marked with crosses. The continuum emission has been subtracted. The colour table has been chosen to emphasise low surface brightness emission. The most prominent features are the central "Z"-shaped emission region, and the complex structure in the south towards Burnham's nebula. In the north, a faint arc is seen at a position nearly mirror-symmetric to Burnham's nebula. In addition, three filaments are seen extending from the NW tip of the "Z", from its SW corner, and from its eastern side.

indication for two outflow systems, one of them oriented roughly N-S and associated with T Tau N, the other at a nearly perpendicular direction and emanating from the infrared companion. To test this picture, and to get even more detailed information, higher angular resolution is required, which provided the motivation for our adaptive optics observations.

2. Observations and Data Analysis

T Tauri was observed in the (v = 1 – 0) S(1) transition of molecular hydrogen at 2.121 μm with the SHARP II camera attached to the ADONIS adaptive optics system on January 15, 1996. To obtain optimum contrast between the faint line emission and the bright background from the stellar continuum and from the sky, it is necessary to use high spectral resolution. Therefore, we did not use an H_2 line filter, but rather SHARP II's high-resolution Fabry-Perot etalon, which provides a spectral resolution R 2500 (i.e. 120 km/s). With an image scale of 0.1″ per pixel, we could cover a field of 25″ in each exposure. Positioning T Tauri successively in the four quadrants of the detector, we obtained a small 35″ × 35″ mosaic centred on the star.

Each data set contains a short sequence of two observations at the wavelength of the emission line, bracketed by two frames in the adjacent continuum at –600 km/s and +600 km/s, respectively. On the one hand, it is desirable to execute these Fabry-Perot sequences as quickly as possible, to minimise the seeing variations between the line and continuum images. On the other hand, with the relatively small pixel scale and the high spectral resolution of our observations, detector noise dominates over the sky background for integration times up to several minutes, which calls for long exposures. As a compromise between these conflicting requirements, we settled for a frame integration time of 60 seconds. On January 15, 1996, we spent a total of 20 minutes integrating on the 2.121 μm line in 0.7″ seeing. The results from these observations are presented here; additional data taken on the previous day in substantially poorer seeing (1.4″ to 1.9″) were discarded.

The raw data were corrected for bad pixels and flatfielded with exposures of the sky taken before sunset. (Because of strong wavelength-dependent fringes caused by interference in the detector substrate and the circular variable filter (CVF), which is used as an order sorter, we took sky flats at exactly the same wavelengths that we used for the astronomical observations.) All images were then resampled on a 0.05″ grid and recentred, before the continuum frames were subtracted from the line exposures. It turned out that this procedure did not only remove the continuum light from the stars, but it also resulted in an excellent cancellation of the sky background, because of the small wavelength difference between the line and continuum channels. The resulting images were coadded to form the final image of the v = 1 – 0 S(1) transition of H_2 towards T Tauri (see Figs. 1 and 2).

3. The Morphology of the 2.121 μm H_2 Emission Towards T Tauri

Perhaps the most striking property of the H_2 emission from the T Tau system is its unusual complexity. This may be partly due to the presumed nearly pole-on orientation, which would cause polar outflows and material in the equatorial plane to be projected on top of each other, and bends and misalignments to be exaggerated by projection effects. Therefore, we start with a purely morphological description of the results of our observations, before we proceed with the interpretation.

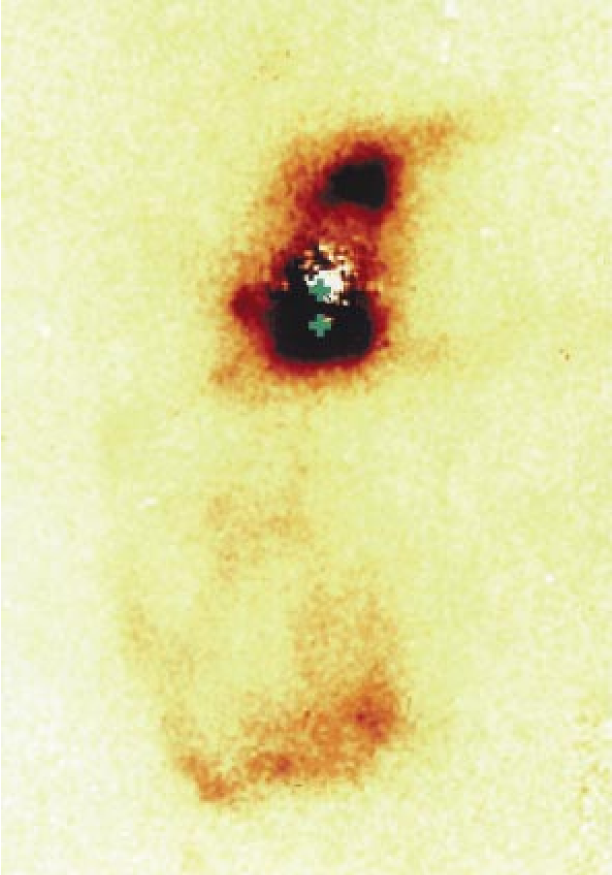
First, we are interested in the question whether most of the bright H_2 emission from the innermost star is associated with the visual primary or with the infrared companion. While observations with a scanning Fabry-Perot, in which line and continuum data are not taken simultaneously, are not optimum for the detection of line emission close to bright continuum sources, Figure 2 suggests that most of the compact H_2 emission comes from the infrared companion and that the emission region is resolved in the east-west direction. The next obvious features are a very bright knot 2– 3″ NW of the primary and an elongated filament at a position angle of 290° (measured from N through E) extending from this knot. A second filament with nearly the same orientation is seen 4.5″ further south, apparently pointing towards a position 0.7″ south of the IR companion. A third filament at position angle 60° is found in the east, connecting another bright knot 1.5″ east of the stars with an extended region of enhanced emission 9″ to the east. It should be pointed out that none of the filaments appears to be pointing back to either of the stellar components. A complex region of fairly bright hydrogen emission lies 4″ to 10″ south of the stars, towards Burnham's nebula. This emission region contains several knots and filaments; it appears to end abruptly in a bright southern rim. A corresponding, albeit much weaker, structure can be seen faintly in the north. It is worth noting that these features are all present at lower resolution in the lowest contours of Figure 1 in van Langevelde et al. (1994); this gives us confidence that they are all real. The bright NW knot, the western filament, and the northernmost knots of the southern emission region were also detected by Herbst et al. (1996).

4. Interpretation

The H_2 data are suggestive of at least one collimated outflow in the T Tau system, roughly in the north-south direction: Burnham's nebula a few arcsec to the south of T Tau appears as a bright bow-shock projected close to the line of sight, while its arc-like counterpart symmetrically placed a few arcsec to the north of T Tau appears much fainter. This flow direction is about the same as the direction of the superjet seen in Hα as a series of 3 bow-shocks north and south of T Tau up to a distance of 20′ (1 pc) from the source (Reipurth, Bally, & Devine, in preparation). It is not clear whether the collimated flow traced in H_2 originates from T Tau N (the optical star) or T Tau S (the IR companion). On one hand, Solf et al. (1988) have found a jump in velocity in [SII] emission on the optical star, interpreted as a jet-like feature. On the other hand, the generally presumed connection between accretion and ejection tends to favour the IR companion as the jet source, as IR companions are considered as temporary accretors (Koresko et al., 1997). Herbst et al. (1996) argue that there are two outflow systems, one of them comprised by the NW knot and the southern emission region, and the other one by the SW and E filaments. Our finding that none of the filaments seems to emanate from either star, and the detection of an apparent counter-structure to Burnham's nebula, appear to contradict this picture. However, it must be kept in mind that precession and motion of the jet footpoints in the binary system might lead to strong bends and misalignments. Furthermore, the near-IR emission traces shocked hydrogen and not the bulk of the material, which may render the observed morphology misleading.

The fact that it is the IR companion rather than the optical star on which the H_2 emission is concentrated is taken to imply that matter is falling onto the circumstellar disk of the IR companion whereby it is shock-excited. Infall velocities of the order of 5–10 km/s are needed to produce the H_2 v = 1 – 0 excitation around 2000 K (Smith & Brand, 1990).

Figure 2: Same as Figure 1, but 12.5″ × 18″ field and different colour table. Artefacts from the non-perfect continuum subtraction are seen at the positions of the stars, but it is obvious that most of the compact H_2 emission is associated with the southern (IR) component. Two bright knots, which are well detached from the stars, are visible in the NW and E, at the footpoints of filaments 1 and 3. The complex structure in the south ends abruptly in a bright rim.



This infall could arise from the inner edge of a circumbinary disk (Artymowicz & Lubow, 1996), which is detected both in CO interferometric observations (Weintraub et al., 1989, Momose et al., 1996) and in scattered IR light (Weintraub et al., 1992). There is no question that a fair amount of dusty disk and envelope gas (of the order of 0.01 M) likely to be bound to T Tau is present.

There are more H_2 features in our map than can be explained by H_2 jets. The filaments or fingers (one to the east and two to the west) may have nothing to do with jets whatsoever but rather come from material in the equatorial (disk) plane. We suggest two possible alternative origins for these features:

(1) Tidal tails caused by the interaction of the two star-disk systems (T Tau N and T Tau S), much like in interacting disk galaxy pairs. In this case, the expected shock velocities are of the order of the Keplerian orbital velocity of the binary system (around 5 km/s).

(2) Spiral shocks in the circumbinary disk of the T Tau binary system. These would arise as the binary drives spiral waves into the circumbinary disk with a pattern speed of the order of the orbital speed (5 km/s). Although the gas in the circumbinary disk has only a small orbital velocity (less than 1 km/s at radial distances in excess of 300 AU), the gas could be shock excited to emit in H_2, while running into the externally excited spiral potential well with a difference speed of a few km/s. These spiral shocks could be associated with accretion streams from the inner edge of the circumbinary disk, which also cause the shock excitation of the H_2 in the circumstellar disks.

Finally let us discuss the origin of the bright H_2 knot 2–3″ NW of T Tau N. We speculate that it might be related to a spiral shock which might be strongest right at the inner edge of the circumbinary disk. It is likely a density enhancement, because this knot is also visible in coronographic I-band images (Nakajima & Golimowski, 1995) as a reflection nebula (also seen in Hα but not in [SII], Robberto et al., 1995). It is noteworthy that the whole H_2 emission in the immediate vicinity of the binary system (including the NW knot and the IR companion and its respective H_2 fingers) are "Z" shaped as is the associated optical reflection nebula. Thus there is a strong similarity between dense gas and dust seen in reflected optical light and shocked H_2 emission, which has not been noticed before. Perhaps this could indicate some shock interaction of a diffuse outflow with the remnant material in the circumbinary environment.

In summary, we stress that the H_2 features seen in the T Tau system very likely have different origins. The fact that the T Tau system is almost unique in showing extended H_2 emission could (a) be related to the presence of a jet interacting with the local environment (Burnham's Nebula and its northern counterpart), and (b) be related to a relatively massive circumbinary disk and a binary system with a component orbital speed of the same order as is necessary to shock excite molecular hydrogen (5 km/s) in this disk.

5. Future Prospects

The high angular resolution afforded by SHARP II and ADONIS has enabled us to study the distribution of warm molecular hydrogen in the T Tauri system in considerably more detail than has been possible before. With multi-line observations it is possible to determine the excitation mechanism. The ratio of the (v = 1 – 0) S(1), (v = 2 – 1) S(1), and e.g. (v = 9 – 7) 0(3) near-IR lines can be taken to distinguish between UV fluorescence and shock excitation, and to determine the gas temperature in the latter case. From their integral field spectroscopy with 3D, Herbst et al. (1996) conclude that the bulk of the material is shock excited with a typical temperature of 2000 K. Future observations of the (v = 2 – 1) S(1) and (v = 9 – 7) O(3) with SHARP II and ADONIS could be used to map the gas temperature at higher spatial resolution, and to search for fluorescent H_2, whose presence is expected on the basis of IUE observations of UV fluorescence (Brown et al., 1981). Even more efficiently, such observations could be performed with the 3D integral field spectrometer, which will be coupled to the ALFA adaptive optics system on Calar Alto in the course of 1997. In addition to the multiplex advantage of 3D, the strictly simultaneous spectra will allow a much better continuum subtraction, and thus a better definition of the emission close to the two bright stars.

Acknowledgements

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Examples of High-Resolution Imaging and Polarimetry of R Monocerotis and NGC 2261

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1. Introduction

High angular resolution polarisation and surface brightness images of R Monocerotis (R Mon) and its associated reflection nebulae NGC 2261 (Hubble's variable nebula), have been obtained. Ground-based optical imaging and near-infrared polarimetric data as well as HST optical polarisation measurements are presented as examples of current high-resolution imaging capabilities.

R Mon is a variable semi-stellar object, which has never been resolved into a single star. It is presumed to be a very young star in the process of emerging from its parent cloud and the source of illumination of the nebula. For decades the variability of both R Mon, and NGC 2261, has been observed both in brightness and polarisation (Hubble, 1916; Lightfoot, 1989). The apparent cometary nebula NGC 2261 extends, in the optical 3′ northward of R Mon. CO mapping (Canto et al., 1981) reveals that it is indeed one lobe of a bipolar nebula; the southern lobe being obscured by the presumed tilted disk around R Mon. Some 7′ north of R Mon there are a group of associated Herbig-Haro objects (HH39). A faint loop extending between HH39 and the eastern extremity of NGC 2261 has been interpreted by Walsh & Malin (1985) as evidence of a stellar wind driven flow between R Mon and HH39. Imhoff & Mendoza (1974) derived a luminosity of 660 L for R Mon, assuming a distance of 800 pc (Walker, 1964), which is atypical of the low luminosity normally observed for Herbig-Haro exciting sources. There is also a faint jet-like feature south of R Mon (Walsh & Malin, 1985); this is not a true jet but dust illuminated by radiation escaping from the dusty disk around R Mon (Warren-Smith et al., 1987).

In this article we present new observational data at high spatial resolution and discuss some possible explanations of the features revealed. These data serve to illustrate the state of the art in high angular resolution polarimetry. The observations have been acquired both from the ground with SUSI and ADONIS at ESO-Chile and from space with the Hubble Space Telescope. In section 2 we present in some detail the observational procedures. Some results are shown in section 3 and we end by a short discussion on R Mon and NGC 2261 together with some comments on the potential of high-resolution polarimetry.

2. Observations

NGC 2261 has been adopted as an HST polarisation calibrator (Turnshek et al., 1990), since it is extended, has high polarisation (10%) and has been well observed from the ground (see e.g. Aspin et al., 1985 and Minchin et al., 1991). The ADONIS and HST polarimetric data of R Mon and NGC 2261 presented here were acquired in order to calibrate polarimetric data of other

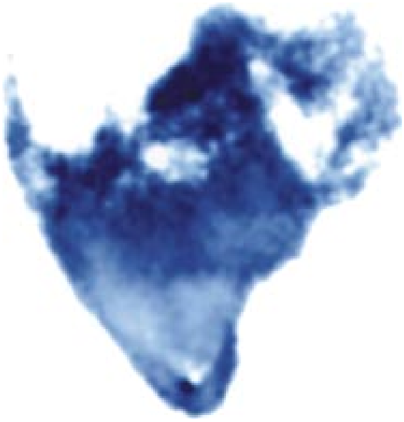

Figure 1: Hα – V SUSI colour map. In this figure, white corresponds to blue physical colour and black to redder colour. North is to the top and east to the left. The size of the image is 2′ × 2′. North is to the top and east to the left.

astronomical sources; however, we show that the high resolution of the data reveals new details of this fascinating source.

2.1 Ground-based optical observations

Ground-based optical observations were made with the SUperb Seeing Imager (SUSI) of ESO, at the NTT in April 1996. The Tek CCD chip of SUSI has 1024 × 1024 pixels, each with a size of 0.13″, giving a 2′ field of view. These observations are typical of 'passive' imaging. An advantage is that a large field can be observed, but the disadvantage is that the spatial resolution is at the mercy of the seeing variations. Indeed the V and Hα band data presented here have been acquired under the worst seeing conditions (average 1.2″) compared to the other data and thus have the lowest resolution.

Images in V and a narrow-band (60 Å wide) Hα filter with exposure times of 60 seconds were obtained. The data have been flat fielded and then flux calibrated in MIDAS. In the absence of a real flux calibrator observed during these observations, and in order to be able to create the colour (Hα–V) map, the integrated flux in a 5″ aperture centred on R Mon was compared with the equivalent magnitudes from Aspin, McLean & Coyne (1991). This calibration does not allow accurate photometric information to be derived, since R Mon is known to be variable (e.g. 4 magnitudes in 1 year – Matsumara & Seki, 1995) on short and long time scales. The calibration is however sufficient for the purposes of scaling the colour map.

2.2 Near-infrared observations

The near-infrared polarimetric data were acquired in March 1996 with the ESO adaptive optics instrument, ADONIS, on the 3.6-m telescope. The camera is a 256 × 256 pixels NICMOS3 array and a pixel scale of 0.05″/pixel was used for the observations, giving a field of 25″ × 25″ (see the ADONIS home page
http://www.ls.eso.org/lasilla/Telescopes/360cat/html/ADONIS/
for details). In the case of these observations, the resulting images are only partially affected by the seeing effects. The data presented are the first example of scientific use of polarisation measurements coupled with the ADONIS adaptive optics system.

As point spread function (PSF) and polarisation calibrator, the nearby unpolarised star HD 64299 was employed. Table 1 indicates the number of frames observed, per position of the polariser, for a given wavelength and integration time for both the reference star and R Mon. Nine positions of the polariser were used for each series of observations: from 0° to 157.5° in steps of 22.5° and 0° again to finish the sequence. The first and last images were compared in order to check the photometric stability. The basic data reduction (dead pixel correction, flat fielding, sky subtraction, stacking of images) were performed with ECLIPSE – an image-processing engine developed at ESO for astronomical data reduction in general and ADONIS data in particular. For further information on ECLIPSE see: http://www.eso.org/~ndevilla/adonis/eclipse. At each pixel, or set of binned pixels, a cosine function was fitted to the values as a function of polariser position angle, and maps of the mean signal, linear polarisation and polarisation position angle were computed for both the R Mon and HD 64299 data using a dedicated MIDAS programme. A value of the instrumental polarisation of 2.7% ± 0.2% at 158 ± 2° was derived at J, with the errors based on the image statistics. We consider this as a preliminary value until all the calibration data on unpolarised and polarised standard stars have been analysed. The polarisation and position angle of the polarisation vectors shown in the maps will change slightly upon adoption of an improved instrumental polarisation.

2.3 Optical HST observations

The WFPC2 imager aboard HST consists of four 800^2 CCD chips – three Wide Field (0.1″ pixels) and one Planetary Camera (0.046″ pixels). There is a polariser filter which is a quad of four polarisers oriented at different angles (see the WFPC2 Instrument Handbook for details). Data can be taken by either rotating the filter over a single chip or by taking images in successive chips. The advantage of space observations is that the PSF is constant in time, but, in the case of WFPC2, it is spatially varying (on account of the correction for the spherical aberration of the telescope). The resolution is therefore high but not diffraction limited since the PC pixels undersample the PSF.

As part of the calibration programme for this instrument, images of R Mon and NGC 2261 were taken in February 1995 in both modes, together with an unpolarised standard (G191B2B) and a polarised standard (BD+64°106). The PI was W. Sparks (Programme ID 5574). Images taken with the POLQ filter (in which each chip is imaged by the polariser at a different rotation 0,45, 90 and 135°) were studied. A set of F555W (V band) and F675W (R band) filter images were analysed, all with 300s exposure. The field of the three WFC chips is 80 × 80″ but the field of the PC chip is 35 × 35″ and, since the data from all four chips were used, the image area was restricted. The polarisation in R Mon and the brightest portions of NGC 2261 was mapped. However, the HST polarisation maps do not give adequate data over R Mon itself since R Mon occurs close to the edge of the PC chip in a region where there is cross-talk between the polariser quad filters.

3. Results

3.1 SUSI data

Figure 1 shows an Hα–V colour map of NGC 2261 from the SUSI images. The map has been convolved by a 3 pixel wide Gaussian to smooth the observed structures. The colour map shows a region of redder colour (coded in black in Fig. 1) just to the south of R Mon and two spikes of bluer colour extending NE and NW, with the bluer one to the NE. There are some small spatial colour changes in the NGC 2261 nebula in addition.

3.2 ADONIS data

On account of their short integration times, the total flux ADONIS images, at J, H and K, do not show much detail of NGC 2261. Some extension north-east of the bright source appears with de-

	R Mon		HD 64299	
	# Frames	τ (s)	# Frames	τ (s)
J	10	1	10	5
H	20	0.4	10	3
K	10	0.1	10	3

TABLE 1: Observational details of the ADONIS data taken for R Mon and the unpolarised reference star HD 64299. Columns 2 and 4 indicate the total number of frames acquired per position of the polariser; columns 3 and 5 the respective integration time per frame.

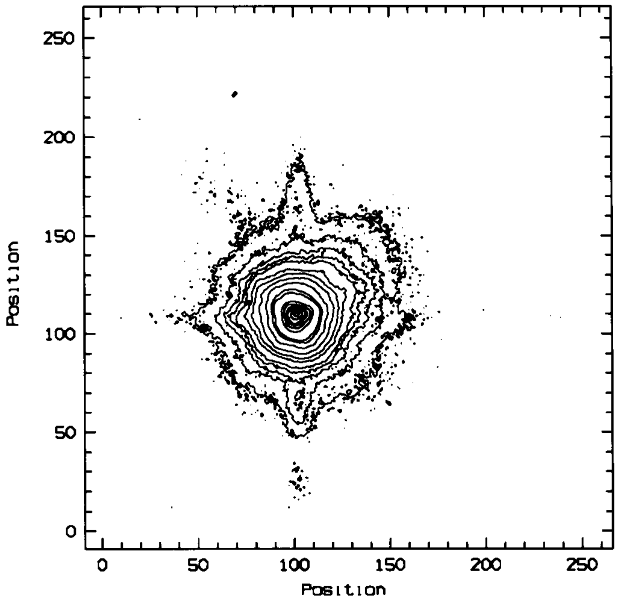

Figure 2: Intensity contour plot of the observed ADONIS K band averaged image of R Mon. North is to the top and left to the east. The scale is in pixels (0.05″/pixel). The trace of the telescope spider is well seen at the lowest plotted contour level. The central contours point out the residual coma in our data as well as a slight East-West elongation.

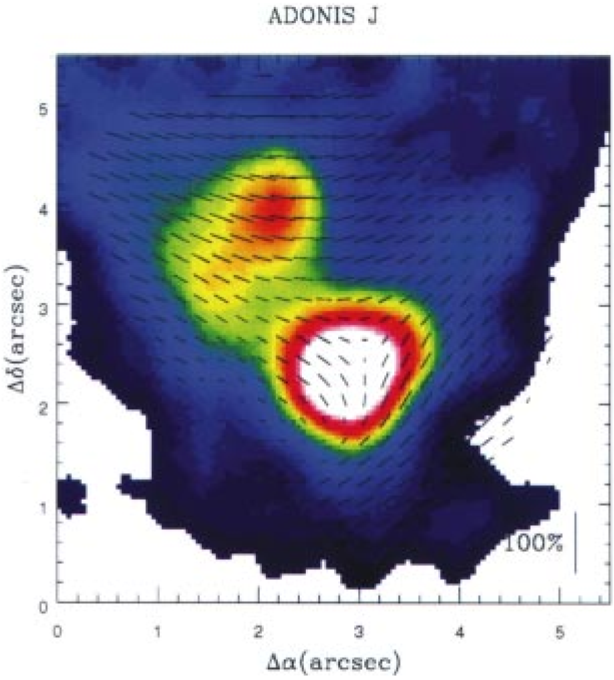

Figure 3: ADONIS J band restored image with the polarisation vector plot superposed. For this plot the polarisation vectors have been calculated in square apertures of 0.4″ radius.

creasing wavelength. In the K band image (see Fig. 2) the spider of the telescope is clearly recognisable at a level of up to 0.09% of the peak intensity. Two other optical effects can be noticed in this image: an elongation along the X-axis, which results from a vibration in this direction, whose origin is not clear; the triangular shape of the PSF, which is a residual triangular coma. This last effect, linked to a servo-loop problem, appears at poor correction level and is not repeatable.

In order to increase the effective resolution of the images, deconvolution with the star HD 64299 used as PSF calibrator, by the Lucy-Richardson algorithm (Lucy, 1974) was applied. After only 10 iterations, the nebular structure around R Mon is apparent at a level of 0.14% of the peak intensity in J Band for example. Figures 3, 4, 5 show colour plots of the restored J, H and K images. Two distinct ‘knots’ north-east of R Mon are revealed in all IR images and another to the NW in the J band image. These knots are also seen in the HST V and R images; the NW knot is the same as the NW spike mentioned in section 3.1.

3.3 HST data

The WFPC2 data for R-Mon had to be recalibrated since the original data were

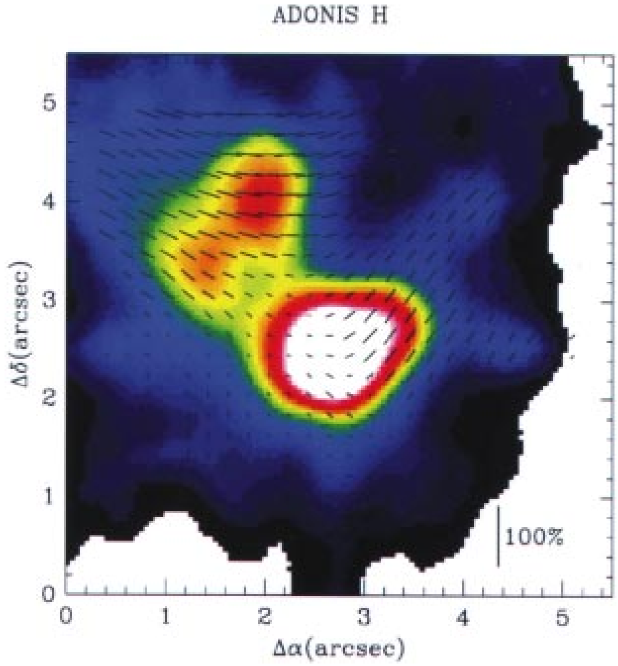

Figure 4: Same as Figure 3 but in H band.

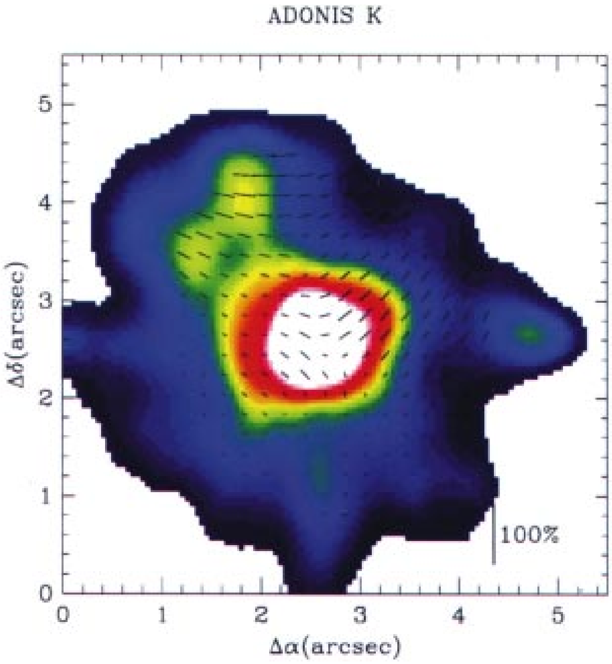

Figure 5: Same as Figure 3 but in K band.

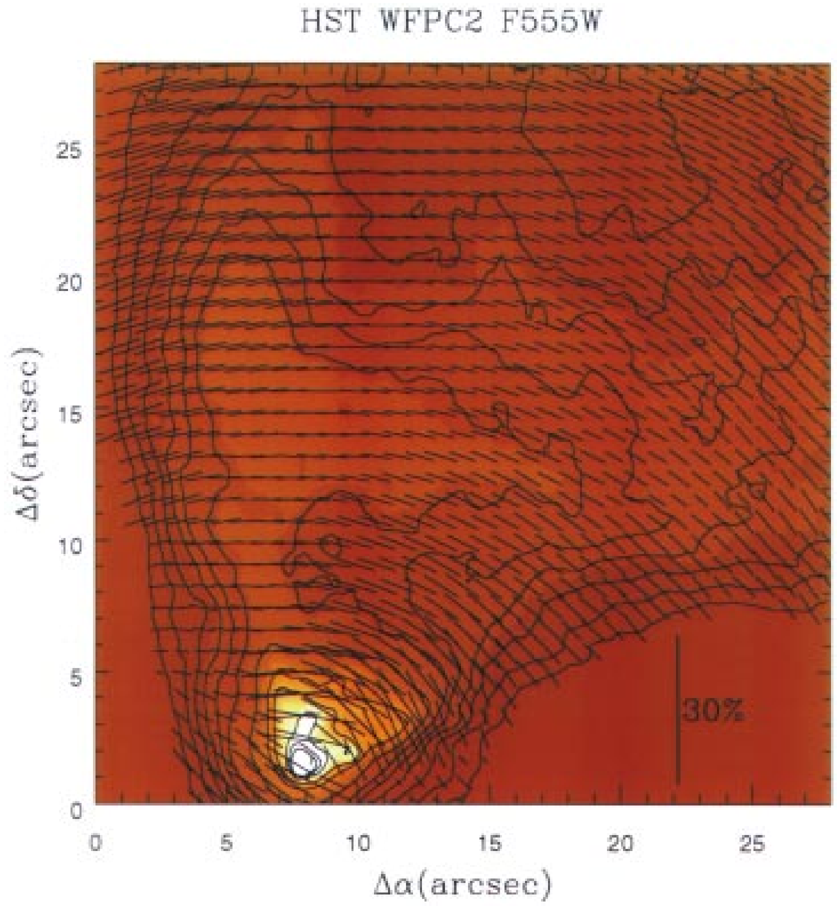

Figure 6: HST V band polarisation map, convolved to a 0.8″ resolution, overplotted on an intensity map of 0.1″ resolution. The orientation in this image is tilted at position angle 15° compared to the previous images, where north is to the top and east to the left.

taken before flat fields with the polariser filters were available. The WFPC2 Web pages give full details of flat fielding WFPC2 polariser images and understanding the data
(http: //www.stsci.edu/ftp/instrument_news/WFPC2/Wfpc2
_pol/wfpc2_pol_cal.html).

The images were corrected for the geometrical distortion and difference in pixel size for the different chips using the standard WFPC2 software in IRAF/STSDAS (wmosaic). The data were handled in the conventional manner: Stokes Q and U parameters were calculated from the difference of the 0 and 90° frames and the 45 and 135° frames respectively. The total flux (sum of polarised and unpolarised), linear polarisation and polarisation position angle were calculated from the Stokes parameters. The errors on the Stokes parameters were calculated based on the image statistics and propagated to the polarisation and position angle. The data for the polarized and unpolarised standards were treated in the same way. The deduced instrumental polarisation is about 2.5% for F555W. Dedicated software (written in MIDAS) produces the polarisation maps allowing the data to be binned to increase the signal-to-noise per pixel and cosmic rays to be rejected. Figures 5 and 6, respectively, show the V and large R band total flux image and the deduced polarisation map as a vector plot.

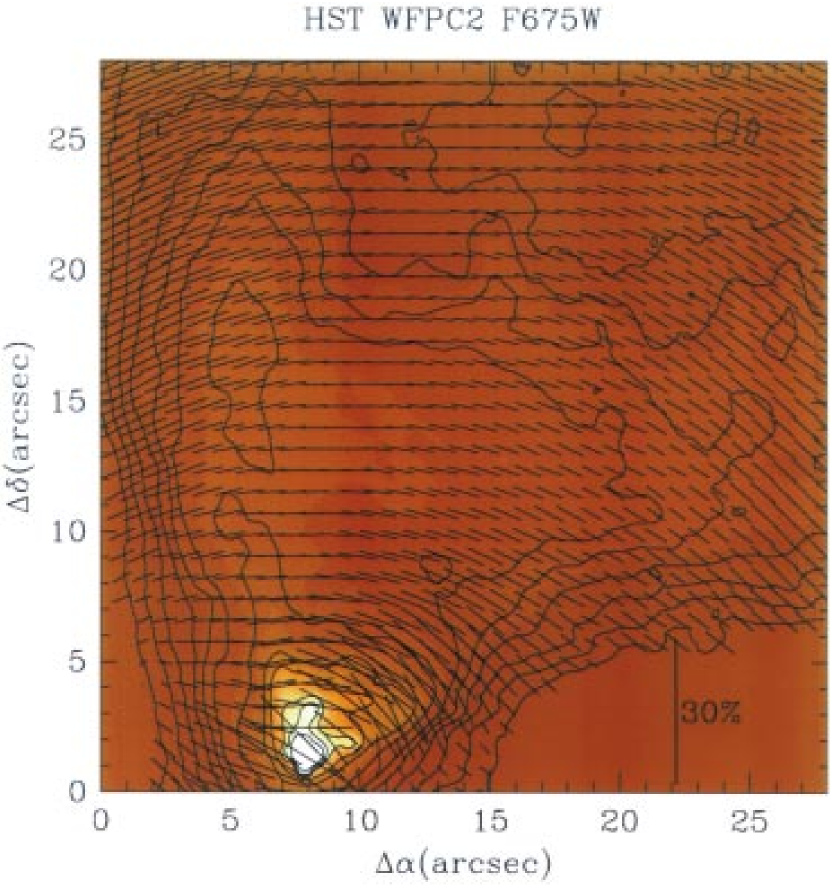

Figure 7: Same as Figure 6 but in large R band.

4. Discussion

R Mon is known to have Hα emission (e.g. Stockton et al., 1975) which is then scattered by dust in the reflection nebula; there is no convincing evidence for intrinsic line emission in the nebula and the polarisation is very similar at Hα and V (Aspin et al., 1985). The SUSI Hα – V colour map (Fig. 1) then traces small differences in extinction through the nebula, differences in scattered flux arising from different scattering angles and possibly also multiple scattering in the near vicinity of R Mon itself. Interpretation of these colour changes is complex since R Mon itself also shows temporal colour changes and these then propagate through reflection over the nebula. The ‘structural’ changes observed in

NGC 2261 are considered to be due to the movement of obscuring clouds in the near vicinity of the embedded stellar source which modulate the illumination escaping in the direction of NGC 2261 ("shadowplay" – Lightfoot, 1989).

The most prominent features on the HST images are the lack of a resolved stellar source to R Mon and the two spikes emanating from it. The eastern spike is present at all wavelengths in the images presented here from V to K band. It is clearly a dust feature or a tunnel of lower obscuration from R Mon into the nebula. The polarisation behaviour of these two spikes could prove useful in studying their origin. The NE spike, extended both in length and width, shows higher linear polarisation (25% at V integrated over its area) with a trend to increased polarisation outwards from R Mon. The NW spike, has lower polarisation (12% at V, and fairly constant along its length), is narrow (0.3″) and not visible in the H and K ADONIS images; Figs. 4, 5). The polarisation position angles of both features are quite consistent with illumination by R Mon. An interpretation of the lower polarisation (of the NW knot) could be in terms of the (single) scattering angle of the radiation from R Mon, reflected off the dust features towards the observer. The NE spike then is more tilted away from the observer than the NW spike. The features could be either 'tubes' relatively free of dust within the extended dust disk about R Mon or individual clumps. An extended cloud would reflect light at different angles giving rise to differing polarisation along its length whilst a radial feature should produce similar polarisation along its whole length (assuming single Mie scattering). However, Scarrott et al. (1989) have studied the polarisation behaviour of the disk around R Mon and suggest that scattering of polarised light and perhaps magnetically aligned grains may play a role. Detailed modelling is required to resolve these differing interpretations but the long wavelength coverage and comparable high resolution (0.2″) polarimetry offered by HST and ADONIS bring critical data to this problem.

Polarisation mapping has been applied to a great variety of astronomical sources: reflection nebulae around young stars, AGB stars, proto-planetary and planetary nebulae; to galactic scale extended emission-line regions in radio galaxies and normal and dusty galaxies; synchrotron sources in supernova remnants and quasars and AGN. Most studies have been at modest spatial resolution dictated by ground-based seeing. However, the application of adaptive optics to polarimetry brings a powerful tool to study the nearby regions of dusty sources enabling the study of dust structures around AGN, non-axially symmetric outflows near AGB stars and dust disks around young stars for example. NICMOS will also enable high-resolution polarimetry to be achieved in J and H bands. HST with WFPC2 allows high-resolution optical imaging in the optical and with the Advanced Camera for Surveys (ACS, see http://jhufos.phajhu.edu/ for details) installed into HST in 1999, even higher resolution polarimetry over a longer wavelength range (2500 to 8200 Å) will be achievable. Polarimetry brings critical data related to orientation that cannot be gained in other ways, and is therefore an important tool for deeper understanding of structures surrounded by dust.

5. Acknowledgements

We would like to thank the ADONIS team for their excellent assistance at the telescope and for the smooth working of the instrument. We also thank John Biretta, at STScI, for helpful discussions on WFPC2 polarimetry.

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Proper Motion as a Tool to Identify the Optical Counterparts of Pulsars: the Case of PSR0656+14

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1. Introduction

Up to now, about 1% of Isolated Neutron Stars (INS) have been observed in the optical domain (Caraveo, 1996). From an observational point of view, INSs are challenging targets owing to their intrinsic faintness. Young (τ 10^4 yrs) pulsars like the Crab, PSR 0540-69 and Vela are relatively bright, powered by magnetospheric processes, and easily identified through the detection of optical pulsations. However, such magnetospheric emission fades away rapidly in the optical domain, giving way to the star's surface thermal emission. It is the case of the so-called "Middle-Aged" (τ 10^5 yrs) Isolated Neutron Stars (MINSs) that, with a temperature T 10^5–10^6 K, can be detected at optical wavelengths as thermal emitters. However, since neutron stars are extremely compact objects (10 km in radius), the optical luminosity of MINSs turns out to be very faint, preventing the timing of their optical emission.

Thus, for MINSs the optical identification generally relies on the positional coincidence with a candidate as well as on its peculiar colours. This is how the candidate counterparts of Geminga (Bignami et al, 1987), PSR 1509-58 (Caraveo et al., 1994b), PSR 0656 +14 (Caraveo et al., 1994a) and PSR 1055-52 (Mignani et al., 1997a; Mignani et al., 1997b) were singled out. However, for some of the closer objects (d $\leq$ 500 pc) other, independent, pieces of evidence can be collected.

Isolated Neutron Stars are known to be high-velocity objects (Lyne and Lorimer, 1994; Caraveo, 1993), moving in the sky with transverse velocities v_T 100–400 km/s. A tentative optical identification can thus be confirmed, or, at least made much more compelling, by measuring the proper motion, if any, of the optical counterpart. Indeed, this is how the optical identification of Geminga was confirmed by Bignami et al. (1993). In the case of a radio pulsar, with known

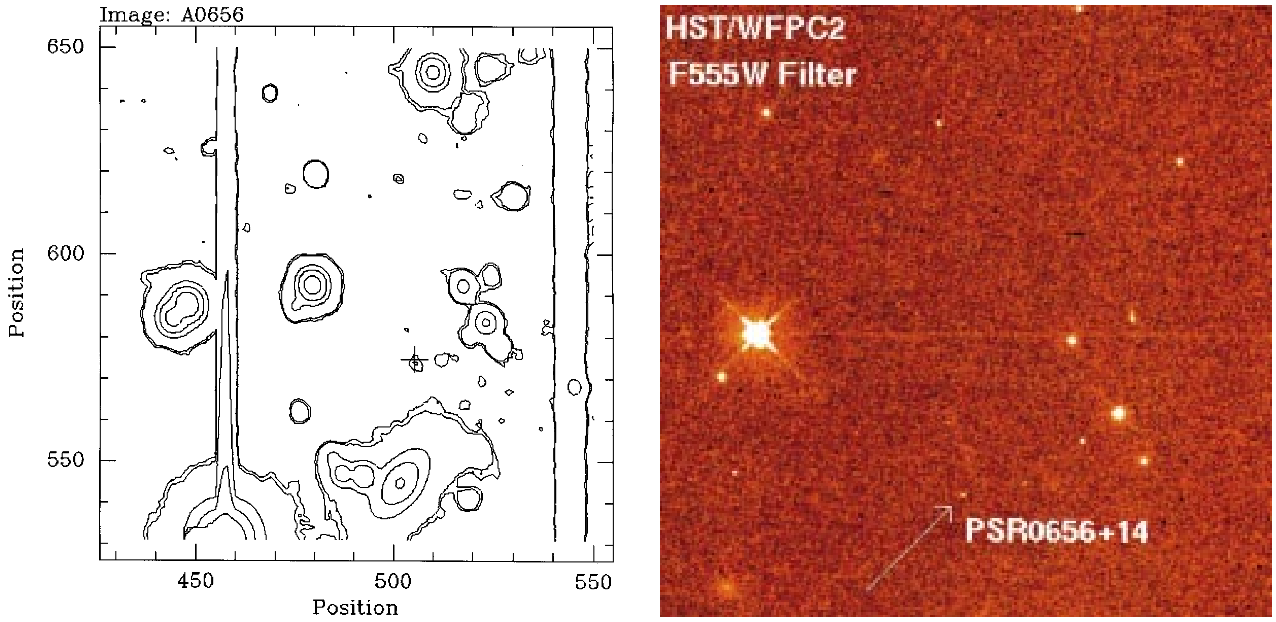

Figure 1: (a) Image of the field of PSR 0656 +14 taken in 1991 with the NTT/EMMI (from Caraveo et al., 1994a); the proposed optical counterpart is marked by a cross. (b) Image of the same region, taken in January 1996 with the WFPC2 onboard HST. The proposed optical counterpart of the pulsar is indicated by an arrow. The image size is about 35 × 35 arcsec.

proper motion, this would indeed secure the optical identification with a degree of confidence comparable to that obtained through detection of pulsed emission.

This strategy gains much more power when exploiting the high precision positioning of the target, presently achievable with the imaging facilities onboard HST and, in the near future, with the VLT.

2. PSR 0656 +14: A Middle-Aged Neutron Star

PSR 0656 +14 is one of the INSs still waiting for a confirmation of the optical identification. It is a “Middle-Aged” (τ 10^5 yrs) radio (P = 385 ms) as well as a soft X-ray pulsar (Finley et al., 1992) with a thermal spectrum consistent with the surface temperature ($T \leq 8 \times 10^5$ K) expected on the basis of its age (Becker, 1996). Recently, PSR 0656 +14 has been tentatively observed as γ-ray pulsars by EGRET (Ramanamurthy et al., 1996). It is thus, with PSR1055-52, a pulsar of the “Geminga class” (Mignani et al., 1997a). PSR 0656 +14 is also characterised by a 70 mas/yr proper motion (Thompson and Cordova, 1994) towards SE (position angle 114°), corresponding to a transverse velocity V_T 250 km/s at the assumed radio distance (760 pc).

Images of the field were obtained at ESO in 1989 and 1991 and a probable optical identification of PSR 0656 +14 was proposed by Caraveo et al. (1994a). A faint (m_V 25) point source was detected in both observations, coincident, within a few tenths of arcsec, with the pulsar’s radio co-ordinates (see Fig. 1a). This object was later tentatively associated by Pavlov et al. (1996) with a point source detected with the HST/FOC. However, the data presently available do not provide a firm optical identification of PSR 0656 +14. Since the object’s faintness renders extremely difficult the search for optical pulsations, the optical identification must rely on the *a priori* knowledge of the pulsar’s proper motion. We, thus, needed a new, high-resolution image, containing enough reference stars to allow very accurate relative astrometry to unveil, if at all present, its expected angular displacement (0.5 arcsec in 7 years). As shown for the measure of Geminga’s parallax (Caraveo et al., 1996) the WFPC2, operated in the PC mode, is presently the ideal instrument to measure tiny angular displacements since it offers a high angular resolution (0.0455″/px) coupled with a 35 × 35 arcsec field of view.

3. The Observations

As a starting point to measure the object’s proper motion, we used our 1989 and 1991 ESO images, dating back sufficiently to provide the required time baseline. The observations were performed with the 3.6-m and with the NTT, respectively, using EFOSC2 and EMMI (see Table 1 for details). These images also provided a useful reference to plan the upcoming HST observations.

The target was observed in January 1996 with the PC, equipped with the wide band F555W filter (λ = 5252 Å; Δλ = 1222.5 Å) i.e. the one closer to the Johnson’s V which was used to obtain our 1989/1991 images. The final image (Fig. 1b) clearly confirms the previous 3.6-m/NTT detection of Caraveo et al. (1994a). The object magnitude was computed to be 25.1 ± 0.1, consistent with our previous ground-based measurements, but with a considerably smaller error. We then computed the centroids for our target and for the reference stars in the field, fitting their profiles with a 3-D gaussian using different centring areas. This procedure yielded the stars’ relative co-ordinates with a precision of a few hundredths of a PC pixel (0.0455 arcsec). We have then compared the present position of PSR 0656 +14 with the ones corresponding to our ESO 1989 and 1991 observations rebinned and tilted to match the PC reference frame. While

TABLE 1: Ground-based plus HST observations of PSR 0656 +14 used for the measure of the proper motion.

Date	Telescope	Filter	Pixel size	Seeing	Exposure time
1989.01	3.6-m/EFOSC2	V	0.675″	1.5″	60 min
1991.01	NTT/EMMI-RED	V	0.44″	1.0″	70 min
1996.01	HST/WFPC	F555W	0.0455″	—	103 min

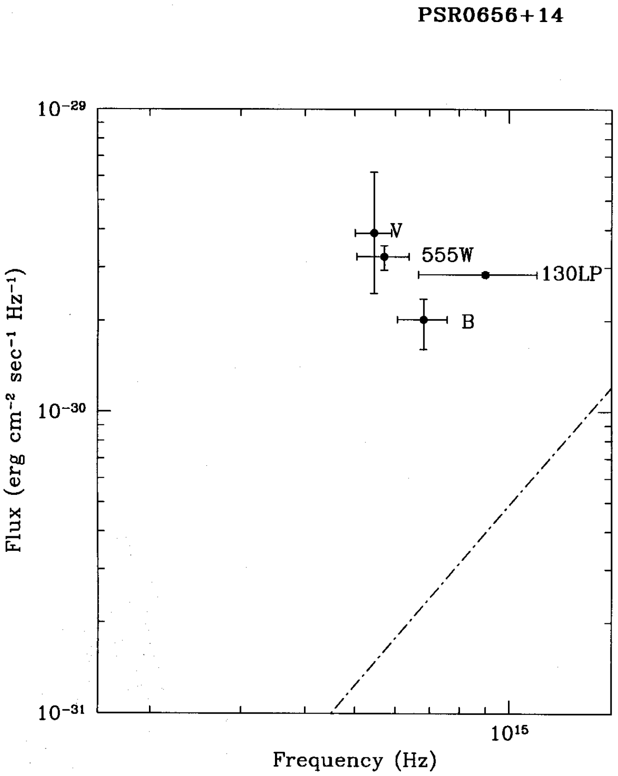

Figure 2: Colours of PSR 0656 +14 compared with the Rayleigh-Jeans extrapolation of the soft X-ray spectrum (T $8 \cdot 10^5$ K) as observed by the ROSAT/PSPC (Finley et al., 1992). The optical/UV fluxes have been corrected for the interstellar extinction using the N_H best fitting the ROSAT data (N_H 10^{20} cm^{-2}) and correspond to the original detection in the V band (Caraveo et al, 1994a), to the HST observation in the 555W filter (see text), to the FOC observation of Pavlov et al. (1996) in the 130LP filter and to the B photometry of Shrearer et al. (1996). The points are at least 2 magnitudes above the expectations.

the position of the reference stars does not change noticeably, a trend is recognisable for the proposed candidate.

Unfortunately, the factor of ten difference in the pixel size between the ESO images and the PC one translates into a large error of the object relative position as computed in the 1989 and 1991 frames, thus making it difficult to reliably compute its displacement. After fitting the object positions at different epochs, we obtain a value $\mu = 0.107 \pm 0.044$ arcsec/yr with a corresponding position angle of 112° ± 9° to be compared with the radio values obtained by Thompson and Cordova (1994). Although not statistically compelling, a hint of proper motion is certainly present in our data.

4. Conclusions

Proper motion appears to be a powerful tool to secure optical identifications of candidate counterparts of INSs, as successfully shown for Geminga (Bignami et al., 1993). Its application is straightforward, just relying on deep, high-quality imaging.

Following this strategy, we have used our ESO 3.6-m/NTT images plus a more recent HST/PC one, to measure the proper motion of the candidate counterpart of PSR 0656 +14. Although promising, this case is not settled yet. The significant uncertainty makes the present result tantalising but certainly far from being conclusive. Of course, new high-resolution observations, could easily say the final word. Again, these could be obtained with the PC or, from the ground, using the VLT.

A firm optical identification of PSR 0656 +14 would be important to establish its emission mechanism in the optical domain and, thus, to complete the multiwavelength phenomenology of this source. The multicolour data presently available (Pavlov et al., 1996; Mignani et al., 1997a), are not easily compatible with the Rayleigh-Jeans extrapolation of the soft X-ray Planckian, even considering the spectral distortion induced by an atmosphere around the neutron star (Meyer et al., 1994). New, as yet unpublished FOC observations in the B/UV (Pavlov, 1996, private communication) seem to confirm this finding which appears to be further substantiated by the possible detection of optical pulsations (Shrearer et al., 1996), accounting for almost 100% of the flux in the B band (B 25.9) More colours of the counterpart are needed to understand the optical behaviour of the source. Now that the FOC has explored the B side of the spectrum, it is mandatory to concentrate on the Red part seeking for an R or I detection. NTT time has been granted for this project and the observations are currently underway.

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On the Nature of the High-Redshift Universe

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One of the most debated arguments of recent astronomy is the understanding of the physical conditions of the Intergalactic Medium (IGM) at high redshift since it represents a unique probe of the young Universe. The state of the diffuse matter, the formation and distribution of the first collapsed objects, their nature and evolution with redshift are all open questions strongly related to the origin of the Universe. The most distant and powerful sources, the quasars, offer the opportunity to explore this side of the Universe.

The optical part of high redshift quasar spectra (z > 2) manifests the presence of a high number of Lyα absorption lines due to neutral hydrogen. For very distant objects, suitable observations are guaranteed only by 4-m-class or larger telescopes. In this paper, new results on the z 4 Universe obtained with EMMI observations (the high-resolution echelle spectrograph mounted at the ESO New Technology Telescope) of the high-redshift quasar Q0000-26 will be presented. These data are part of a sample of high-redshift QSO observations obtained during the ESO Key Programme 2-013-49K devoted to study the Intergalactic Medium at high redshift (P.I. S. D'Odorico).

The light emitted by Q0000-26 (at a redshift of $z = 4.12$) scans the Universe starting at an epoch when it was only 10% of its present age (for a flat Universe with $q_0 = 0.5$). Since it is one of the most distant and intrinsically brightest objects, it has been observed several times in the past. Recently, new observations at high resolution and signal-to-noise ratio have been presented almost simultaneously by two different groups of astronomers: by Lu et al. (1996) using the 10-m Keck Telescope and by Savaglio et al. (1996) with the ESO 3.5-m NTT. In Figure 1, an interesting comparison between the two spectra is shown. In that spectral range, the Keck spectrum has a resolution of FWHM = 6.6 km s^{-1} for a total exposure time of 12,000 seconds. The NTT observations in the same spectral range have a resolution of FWHM = 13 km s^{-1} and a total exposure time of 27,600 seconds. One may notice that all the information contained in the Keck observations can be found in the NTT ones, even if the resolution is considerably better in the former. This means that higher resolution does not help in overcoming an intrinsic limitation of the high-redshift QSO observations due the confusion of the absorption lines. The signal-to-noise ratio is similar in the two spectra, which is what one would expect comparing the exposure times and the different collecting areas. Remarkable differences in the interpretations of the data are due to the line-fitting procedure used.

The majority of the very numerous lines seen in QSO spectra has HI column densities below N_{HI} 10^{15} cm^{-2}. Higher HI column density systems (N_{HI} 10^{16} cm^{-2}) frequently show associated metal lines which probably have origin in protogalactic halo or disk clouds. In the past, astronomers have raised a still unresolved question on the nature of the low HI column density (N_{HI} 10^{15} cm^{-2}) clouds, commonly referred to as Lyα forest. In particular, they have been thought for a long time to be intergalactic gas clouds of primordial chemical composition not associated with galaxies. Only the recent performances of optical telescopes allowed to see in more detail the QSO spectra at the expected positions of the metal lines associated with the Lyα lines and to give new constraints on the chemical composition and evolutionary state of those clouds. The NTT observations revealed the presence of C IV and Si IV in three optically thin HI clouds in the redshift range 3.5 z 3.8 (Savaglio et al., 1996). The age of these clouds, assum-

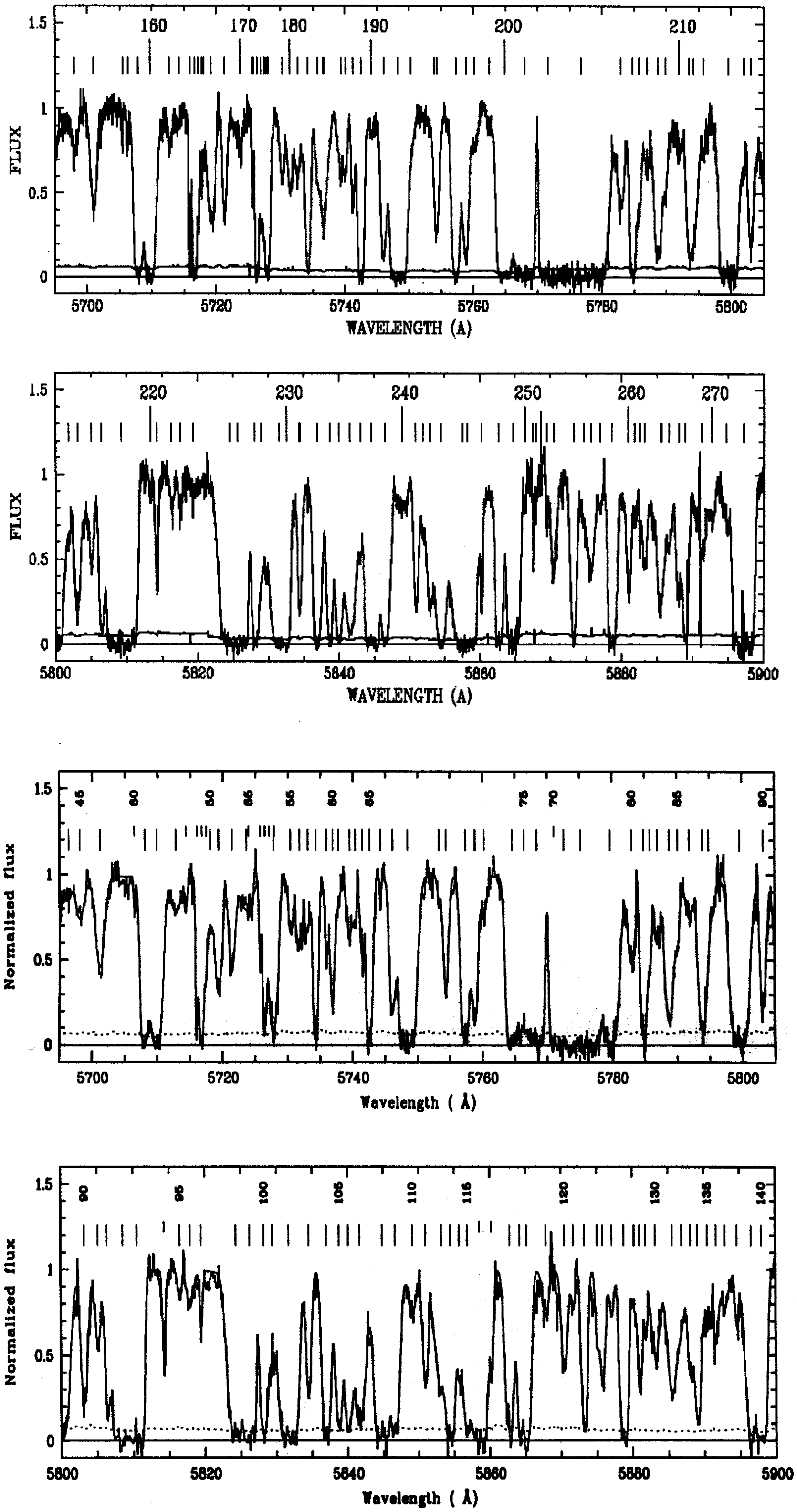

Figure 1: Spectrum of the high redshift quasar Q0000-26 (z = 4.12). The two upper panels have been obtained with the 10-m Keck telescope (Lu et al., 1996) at a resolution of FWHM = 6.6 km s^{-1} and an exposure time of 12,000 seconds. The two lower panels are NTT data (Savaglio et al., 1996) in the same spectral range at a resolution of FWHM = 13 km s^{-1} and an exposure time of 27,600 seconds.

ing that they are connected to galaxy formation and the redshift of galaxy formation is not beyond $z_f = 10$, is lower than 1.4 Gyr (for H_0 = 75 km s^{-1} Mpc^{-1} and q_0 = 0.1) or 0.9 Gyr (for H_0 = 50 km s^{-1} Mpc^{-1} and $q_0 = 0.5$).

To investigate the physical state of these systems, namely their ionisation state, density and size, it is possible to model the observed parameters of the clouds. Optically thin systems at high redshift with metal absorption lines are particularly interesting by themselves, not only because they are related to the early phases of galaxy evolution, but also because their ionisation state is probably dominated by the UV background flux, thus providing indirect information on the IGM.

The UV background (UVB) radiation field at high redshift is the result of the integrated light of the collapsed objects at early epoch once the absorption due to both diffuse IGM and discrete clouds is taken into account. Its shape, intensity and redshift dependence ($J_\nu(z)$) is a subject of controversy both from the theoretical and observational point of view. Direct estimates at the Lyman limit wavelength λ_{LL} = 912 Å as a function of redshift ($J_{912}(z)$) can be given by comparing the ionisation state of the clouds close to the quasar with those far from the quasar and presumably ionised by the UVB. Modelling of $J_\nu(z)$ has been mostly done considering the quasar integrated light only (Haardt & Madau, 1996). The effects of the presence of a population of young galaxies have been discussed by Miralda-Escude & Ostriker (1990). The soft spectrum of young galaxies would cause an increase of the jump of the UVB at the two edges of the Lyman limit wavelengths for H I and He II, namely $S_L = J_{912}/J_{228}$. The same effect would be obtained if an absorption of He II in the diffuse IGM were considered. The amount of He II in the IGM has not been firmly established yet and it will necessitate further efforts with HST observations for more significant estimates.

Figure 2 shows the details of possible UVB spectra. For three different values of log S_L = 2, 2.9, 3.5, three different spectral shapes in the range 1 ν/ν_{LL} 4 (912 Å λ 228 Å) can be considered. Also indicated as dotted vertical lines are the ionisation potential of the most interesting species. It is clear that the abundances of these species depends not only on S_L but also on the shape of J_ν for 4 ν/ν_{LL} 1.

Given the shape and intensity of the UVB, it is possible to explore the parameter space using the observed ion abundances. Figure 3 shows the results of photoionisation calculations using CLOUDY (Ferland, 1993) applied to one of the optically thin systems in Q0000-26 at z = 3.8190 observed with the NTT. The UVB spectra used as ionising sources are those indicated in Figure 2.

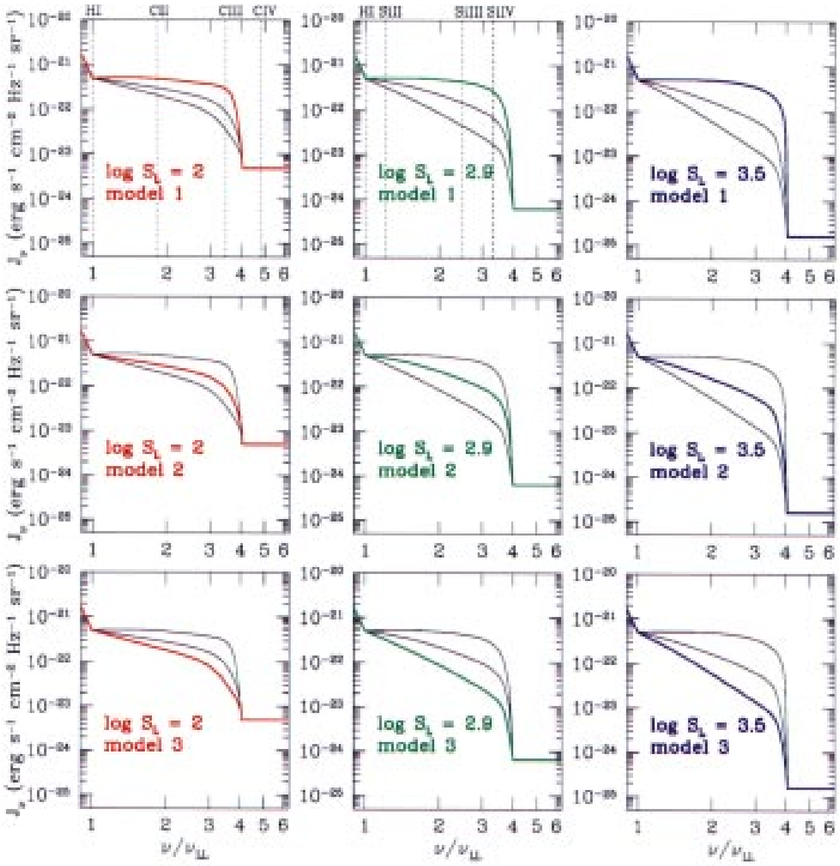

Figure 2: Models of the UV ionising background as a function of the frequency. The red, green and blue curves indicate the models with log S_L = 2, 2.9 and 3.5, respectively. For each value of S_L three different shapes of J_ν in the frequency interval 1 ν/ν_{LL} 4 are shown. The vertical dotted lines indicate the values of ionisation potential for species of interest.

The values of silicon-to-carbon ratios are shown as a function of the carbon abundances [C/H] for different values of the gas density obtained forcing the code to reproduce the observed H I and C IV column densities.

In the study of the heavy element abundances of the Interstellar Medium (ISM) and stars, the abundance measurements are usually reported as a function of the iron-to-hydrogen ratio since the iron content is usually considered an age estimator (Timmes et al., 1995). The evolution of carbon in disk and halo stars follows that of iron. In fact, iron is mainly produced by type Ia Supernovae, while carbon is supposed to be mainly produced by intermediate-mass stars and these two processes have similar time scales. The silicon history is different being higher than in the sun for low metallicity, since the intermediate-mass α-chain elements are formed early by type II Supernova events. In QSO absorption lines, carbon is easier to detect than iron, therefore, normally, in absence of iron, carbon is considered for metallicity evaluations assuming that carbon abundance evolution follows that of iron. This is justified by models of chemical evolution, even though observations show a large spread with no particular trend (Timmes et al., 1995). Comparisons with the local ISM abundances are complicated by the fact that iron is strongly depleted into dust grains, both in warm and cold gas (–1.4 *dex* in the first and –2.2 *dex* in the second, Lauroesch et al., 1996) whereas carbon is much less hidden into dust grains, its depletion being around –0.3 *dex*. Therefore, considering the carbon abundance as metallicity indicator has the advantage that depletion in low-density gas is negligible, especially at high redshift when the dust formation is probably in an early phase. The red lines in Figure 3 represent the silicon overabundance with respect to carbon as a function of metallicity as found by chemical evolution models.

Another interesting parameter which can be explored by photoionisation calculations is the physical size of the absorbing cloud. The regions with R 50 kpc and R 1 kpc are represented by the left and right shaded regions, respectively, in Figure 3. The green dot in each panel represents the result for a gas density of n_H = 10$^{-3.1}$ cm^{-3}. Dots towards lower metallicity represent gas densities decreasing by steps of 0.2 *dex*, and vice versa for dots towards higher metallicities.

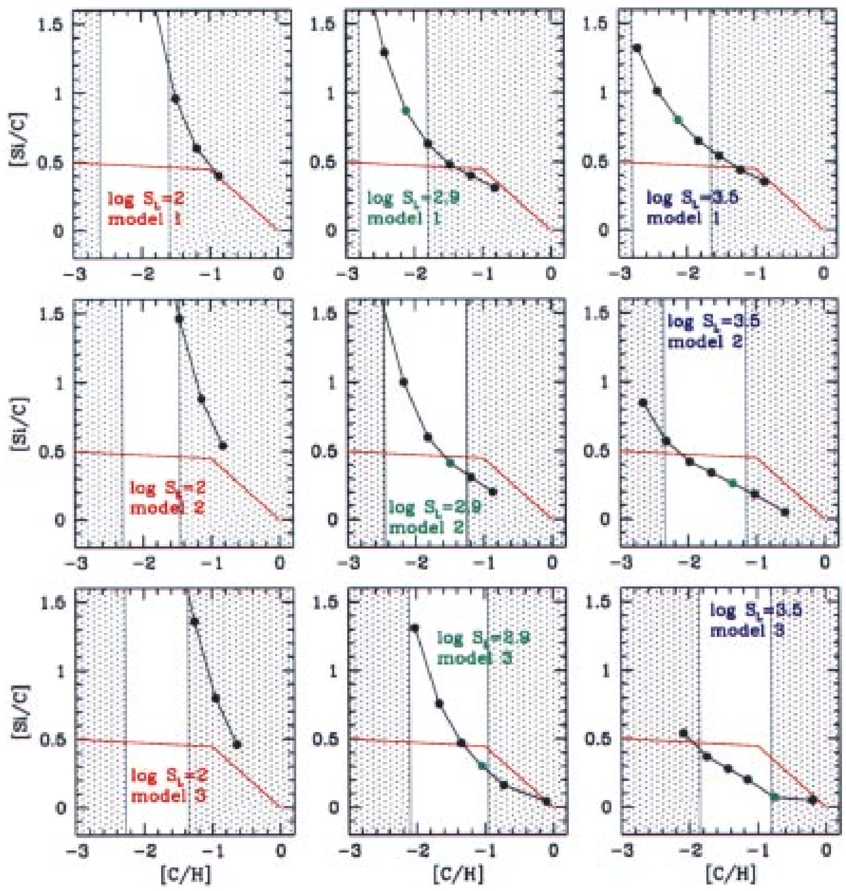

Figure 3: Silicon-to-carbon ratio as a function of the carbon-to-hydrogen ratio for the absorbing system at z = 3.8190 observed in Q0000-26 ([X/Y] = log(X/Y) – log(X/Y)). Both values are compared to the solar values. The dots are results of CLOUDY calculations obtained varying the gas density n_H with a 0.2 dex step. The green dot indicates the result for log n_H = –3.1. Lower densities have higher [C/H] values, while higher densities have lower [C/H] values. The shaded areas indicate the regions where the cloud sizes become smaller than 1 kpc (right side) or larger than 50 kpc (left side). The results are shown for three different models of J_ν and three different S_L values.

The expected values of [Si/C] can be reproduced by the models with log S_L = 2 only assuming a cloud size by far smaller than 1 kpc and this would give a metallicity for this cloud larger than 1/10 of solar. Therefore, observations can be better explained only if log S_L 2. The metallicity in log S_L = 2.9 models is in the range 2.2 [C/H] 1, while the density spread is 3.5 log n_H 2.9. A similar spread in metallicity is obtained for the log S_L = 3.5 models, whereas the upper limit to the density is log n_H 3.7. Metallicities lower than 1/10 of solar found in this cloud, suggest ages lower than 1 Gyr. The size inferred by the calculations indicates that the cloud is smaller than typical clouds of the Lyα forest for which lower limits to the size have been found to be 70 kpc (for H_0 = 70 km s^{-1} Mpc^{-1}) at redshift z 2 (Smette et al., 1995). The difference is also in the gas density which is always lower than the typical value of $n_H = 10^{-4}$ cm^{-3} found in the Lyα forest clouds. Thus we are still far from concluding that all the optically thin Lyα lines have the same intergalactic origin.

Metal systems optically thin to the HI ionising photons are an important probe of the shape of the UV background radiation. If this is the main ionising source, the quasar light contribution only absorbed by H I of the discrete Lyα clouds and Lyman limit systems (which implies log S_l 1.5) cannot explain the observations. This means that either an additional source of ionisation is necessary, or intergalactic diffuse He II is responsible for the spectral shape of J_ν at wavelengths lower than 228 Å, or both. Further detailed analysis of N_{HI} 10^{15} cm^{-2} absorption systems with metal lines will hopefully clarify this situation. Challenging results can be obtained by dedicated observations with 4-m-class telescopes and do not need to wait for the VLT to be operational.

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Optical Observations Provide a New Measure of the Vela Pulsar's Proper Motion

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1. Introduction

Isolated Neutron Stars (INSs) move in the sky with high (≥ 100 km s^{-1}) tangential velocities (Lyne & Lorimer, 1994). Indeed, proper motions have been measured for several INSs, mainly in the radio domain (Harrison et al., 1993). In addition, for two (possibly three) INSs proper motions have been measured in the optical domain through relative astrometry of their optical counterparts.

TABLE 1: This table summarises the published values of the Vela pulsar proper motion obtained from radio as well as optical observations.

Optical				Radio	
	Bignami & Caraveo 1988	Ögelman et al. 1989	Markwardt & Ögelman 1994	Bailes et al.* 1989	Fomalont et al. 1992
μ	< 60 mas	38 ± 8 mas	49 ± 4 mas	59 ± 5 mas	116 ± 62 mas
μ_α		–26 ± 6 mas	–41 ± 3 mas	–48 ± 4 mas	–67 ± 20 mas
μ_δ		28 ± 6 mas	26 ± 3 mas	34 ± 2 mas	–95 ± 75 mas

*After correction for the motion of the Sun and for the rotation of the Galaxy they obtain $\mu_\alpha = -40 \pm 4$ mas and $\mu_\delta = 28 \pm 2$ mas.

These NSs are Geminga (Bignami et al., 1993), the Vela pulsar (Bignami and Caraveo, 1988; Ögelman et al., 1989; Markwardt and Ögelman, 1994) and, possibly, PSR 0656 +14 (Mignani et al., 1997). In the case of Geminga, because of its radio quietness, optical observations are the only way to measure such proper motion. In particular, proper-motion measures in the radio and optical bands are a valuable strategy to confirm optical identifications of pulsars that, in the optical domain, are far too faint for fast photometry observations (Mignani et al., 1997).

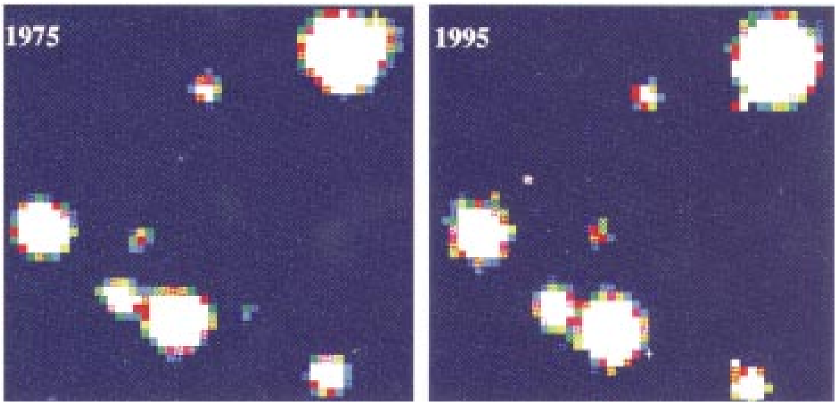

Figure 1: Images of the Vela pulsar field taken in 1975 with the CTIO 4-m and in 1995 with NTT/EMMI.

2. The Vela Pulsar

Optical observations represent a real alternative to measure proper motions since they are independent from timing irregularities. This is specially true in the case of the Vela pulsar, well known for its gigantic glitches. Indeed, a comparison between published values of the Vela pulsar proper motion shows significant differences between radio and optical measurements (see Table 1 for a summary) with angular displacements going from a minimum of 38 mas yr^{-1} (Ögelman et al., 1989) to a maximum of 116 mas yr^{-1}(Fomalont et al., 1992). Thus, although the Vela pulsar moves in the sky, the actual value of its displacement is still to be measured.

3. The Observations

For the measure of the proper motion we have used a set of four images collected over several years with the ESO telescopes, 3.6 m and NTT (see Table 2). To obtain a reliable measure of the pulsar's proper motion, we have selected only those images obtained in the Johnson's B filter. This overcomes shifts of the object's centroid induced by differential refraction of the Earth's atmosphere (Filippenko, 1982 and references therein). Our data set was later integrated by the original image, taken in 1975, which lead to the discovery of the Vela optical counterpart (Lasker, 1976). Since the 1975 image is recorded on a broad-band blue IIIa-J plate, it has been digitised in order to allow an immediate comparison with other, more recent images, taken with CCD detectors.

To compute the pulsar's proper motion, the different images have been rebinned and rotated in order to match exactly the same scale and orientation.

As a reference frame we used the most recent image of the field which is also the one obtained under the best seeing conditions (0.8 arcsec). Rebinning and rotating were applied using the standard alghorithms available in MIDAS. After this procedure, all the reference stars were seen to overlap within a few hundredths of the reference pixel.

Table 2: Data set used for the proper-motion measure. The displacements of Vela are computed with respect to the 1975 frame. The quoted uncertainties include stars' centring errors as well as errors in the rebinning/rotation procedures.

Epoch	Telescope	Pixel size	Exp. time	$\Delta\alpha$	$\Delta\delta$
1975.2	CTIO 4-m	—	45 min.	0 ± 0.05	0 ± 0.05
1987.1	ESO 3.6-m	0.67″	30 min.	–0.46 ± 0.06	0.21 ± 0.06
1988.1	ESO 3.6-m	0.67″	30 min.	–0.52 ± 0.09	0.31 ± 0.05
1990.1	ESO NTT	0.26″	85 min.	–0.73 ± 0.05	0.40 ± 0.05
1995.1	ESO NTT	0.36″	30 min.	–0.92 ± 0.02	0.45 ± 0.02

4. The Proper Motion

Contour plots of all the images were later prepared in order to provide an immediate guess on the source's displacement (Fig. 2). As it is clearly seen from the figure, while the position of the reference stars does not change, the pulsar exhibits a displacement of about 1 arcsec to NE. The angular displacement of Vela was then computed using the 1975 position as starting point and fitting linearly the pulsar's position at the different epochs.

The resulting proper motion is

$$\mu_\alpha = -47 \pm 3 \text{ mas yr}^{-1}$$
$$\mu_\delta = 22 \pm 3 \text{ mas yr}^{-1}$$

for a total annual displacement of 52 ± 5 mas yr^{-1} with a corresponding position angle   295°, which appears completely unrelated to the soft X-ray jet observed by Markwardt and Ögelman (1995) to protrude south from the pulsar.

5. Conclusions

Our measurements make a final case for the Vela pulsar proper motion to be around 50 mas/yr. Since our proper-motion study covers a period of 20 years, the present result can be

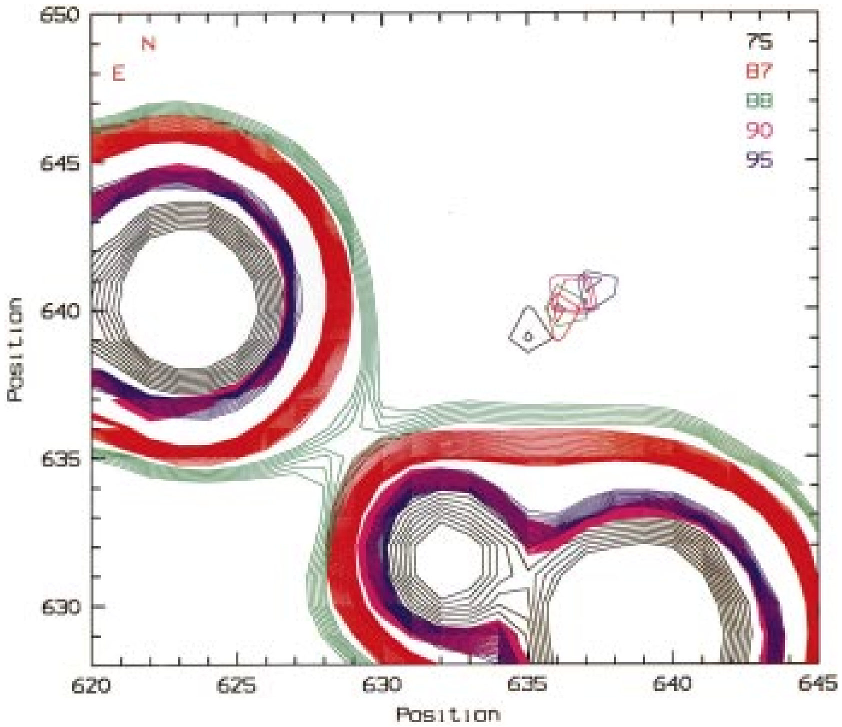

Figure 2: Contour plots of the five images available. While the position of the reference stars does not change, the overall displacement (~ 1 arcsec) of the Vela Pulsar over a time span of 20 yr is evident.

considered reliable. In particular, our value is compatible with the previous measurements of Markwardt and Ögelman (1994) and Bailes et al. (1989), while it is clearly incompatible with the ones of Ögelman et al. (1989) and Fomalont et al. (1992). A better assessment will only be possible through accurate HST astrometry, currently in progress, which could also yield a measurable annual parallax, ending the current debate on the Vela pulsar/SNR distance. Indeed, a reanalysis of ROSAT data by Page et al. (1996) suggests that the pulsar could be as close as 285 pc, while radio measurements (Taylor et al., 1993) provide a distance of 500 pc.

Acknowledgements

We wish to thank C. Markwardt and H. Ögelman, who kindly made available a copy of the poster presented at the 1994 AAS meeting. We would also like to thank B. Lasker for providing the 1975 plates.

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Bavarian Prime Minister at La Silla

In the afternoon of March 9, 1997, the Bavarian Prime Minister, Dr. Edmund Stoiber, on the invitation of the Director General of ESO, Professor Riccardo Giacconi, visited the ESO La Silla Observatory.
The photograph shows the Prime Minister and Mrs. Karin Stoiber on the platform near the ESO 3.6-m telescope with the lower observatory area in the background.

The Astronomy On-Line Project

R. WEST and C. MADSEN, ESO

A major Web-based educational programme, known as Astronomy On-Line, has just taken place in close collaboration between the European Association for Astronomy Education (EAAE), the European Southern Observatory and the European Union.

During a period of two months, from early October to late November 1996, a comprehensive network of astronomy-oriented educational Web-pages was built up at various European sites, including the ESO Headquarters in Garching. Throughout this period, astronomy-interested groups of mostly young people from all over Europe registered with Astronomy On-Line; in the end, 720 groups with approximately 5000 participants from 39 countries took part.

The Astronomy On-Line Web-site at ESO received up to 100,000 hits per day. All pages were mirrored once per day or more frequently to about 25 mirror sites in other European countries. No accurate statistics are available for the number of entries at these sites, but there is little doubt that Astronomy On-Line quickly developed into what the organisers early claimed: the World's Biggest Astronomy Event on the World-Wide Web.

Background

Astronomy On-Line took place under the auspices of the European Union within the yearly European Week for Scientific and Technological Culture. This Programme was first conceived in April 1996 and presented to the European Commission during a special meeting in Brussels early that month. From the beginning, it was carried out under the direct responsibility of the newly established European Association for Astronomy Education, with technical support by ESO and financial support by the European Commission.

The main goal was to create a system which would attract young people, in particular students in Europe's high schools, to participate in an exciting, well-structured "astronomical" Web event. The benefits from such a Programme would be many-fold: interest in the science of astronomy and astrophysics, useful knowledge about the efficient use of the nearly unlimited possibilities on the Web and, not the least, the establishment of personal contacts across Europe's borders. There is no doubt that all three goals were amply fulfilled.

Throughout the summer of 1996, discussions were held between the involved parties at EAAE and ESO, in particular during an intensive one-day meeting that took place at the ESO Headquarters in mid-June. At that time it was decided to set up an International Steering Committee of eight key persons and also National Steering Committees in all participating countries. The latter would be responsible for all Astronomy On-Line-related activities, including the establishment and subsequent operation of national Astronomy On-Line Web sites.

The Programme

The basic Web structure was available at the beginning of August. This

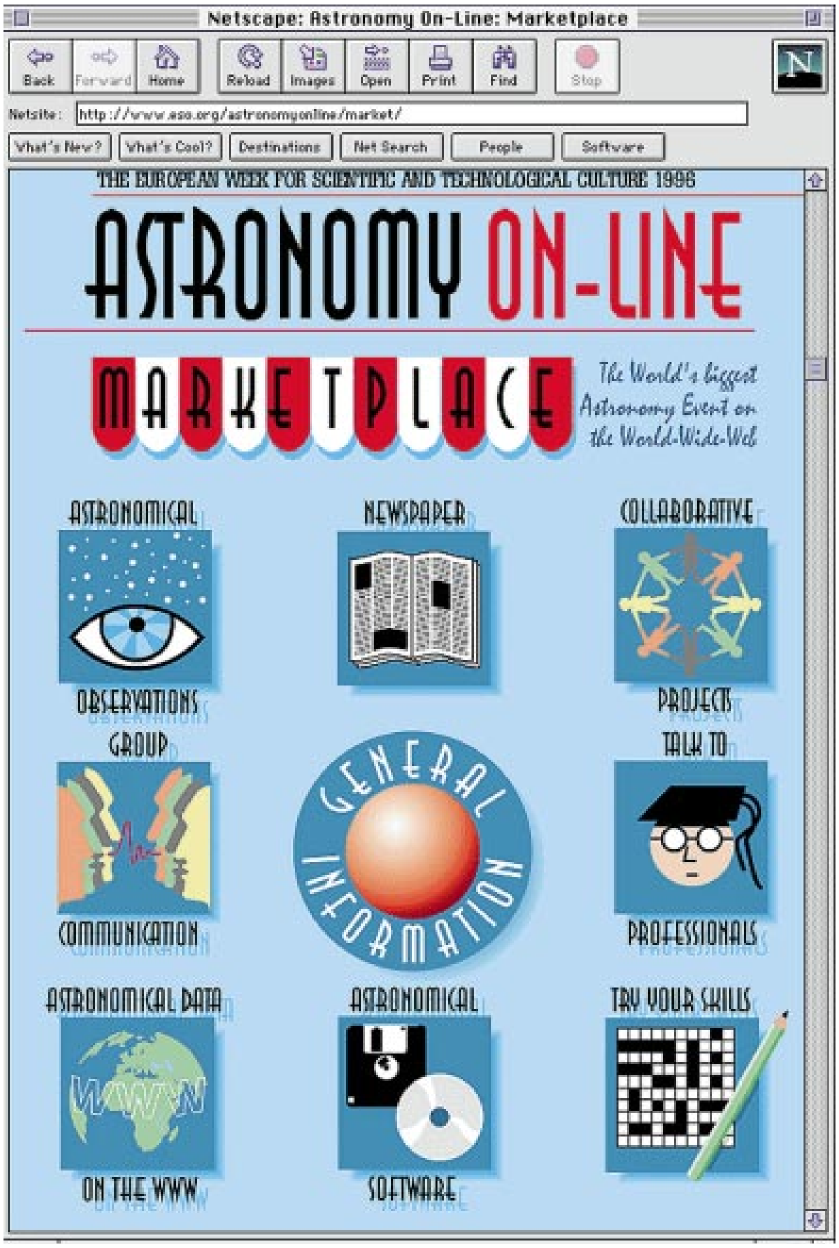

Figure 1: The virtual marketplace was the focal point of Astronomy On-Line.

involved a very welcome and effective support by the ESO Data Management Division staff. From then on, many European astronomy teachers contributed actively to the development with information, exercises, images, texts, etc. which were progressively inserted into the Astronomy On-Line structure. In fact, this process continued until the last few days in November, providing a steady inflow of new possibilities for the participants and thereby ensuring that their interest continued at a high level.

No other project of this scope and volume had ever been attempted anywhere in the world, and Astronomy On-Line, as a pilot project, had to be set up with comparatively little previous experience available. Thus, it was natural that various modifications took place during its implementation. The organisers were also pleased to obtain advice from many sides.

In view of the relatively short time available, a simple and efficient strategy was adopted. It took the form of a "Market Place". According to this concept, the participants were able to access a central Web page with nine different "Shops", each representing different activities. The corresponding URL is: http://www.eso.org/astronomyonline/market/

For instance, one much visited "Shop" enabled the students to join a series of "Collaborative Projects". This included observations of the Lunar Eclipse on 27 September and the Solar Eclipse on 12 October. These two events could be followed live on the Web, thanks to diligent observers among the participants who made their images available in real time. In the follow-up activities, the measurements made by the students were among others used to calculate the distance to the Moon and thereby the physical size of our satellite. Considering the comparative simple observational tools employed, the achieved accuracy was quite impressive.

In another Collaborative Project, the participants made measurements of the length of a gnomon shadow at local noon, repeating the historical experiment of Eratosthenes and, when these values were compared, the circumference of the Earth was calculated to within 5 percent of the correct value.

Another Shop permitted participants to submit requests for observations from several professional observatories in Bulgaria, Denmark, France, Germany, Great Britain, Portugal, Slovenia, Spain and La Silla in Chile. These had kindly made a substantial number of nights available for this purpose. Many excellent observing proposals were received and, although the weather – as expected at this time in Europe! – was not equally good in all places, most of the requests could be satisfied. The data files were transmitted through the Web to the proposers, and groups of students at many schools have since been busy reducing their observations of galaxies, stellar clusters, comets, etc. A group of ESO fellows provided great support for this part of the Astronomy On-Line Programme.

In order to promote knowledge about Web techniques, specific information was inserted into the Astronomy On-Line structure with the appropriate Web links, e.g. about how to search on the Web. "Treasure Hunts" were established in support, with visits to various astronomy related-sites, for instance the ESO VLT pages. And, not the least, the students had the opportunity to communicate via e-mail and during the last few days of the project, also by "Whiteboard" and "Chat".

The ESO Astronomy On-Line Team

James Brewer, Jacques Breysacher, Fernando Comeron, Vanessa Doublier, Christian Drouet d'Aubigny, Gregory Dudziak, Hans-Hermann Heyer, Edmund Janssen, Lex Kaper, Kurt Kjär, Jacco van Loon, Claus Madsen, Karen Müller, Michael Naumann, Resy de Ruijsscher, Elisabeth Völk, Rein Warmels, R. West, Albert Zijlstra, Herbert Zodet

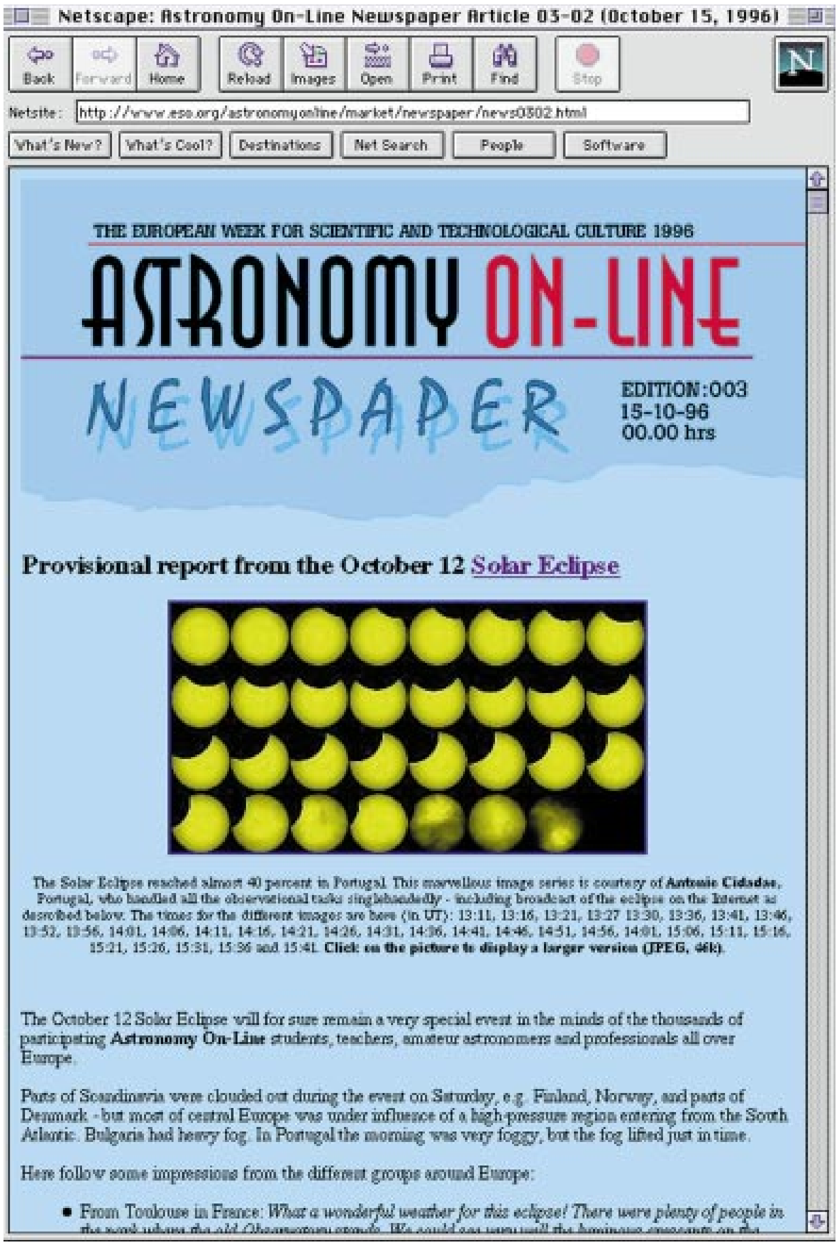

Figure 2: Activities around the partial solar eclipse on October 12 became a prelude to the many collaborative projects, carried out during the Astronomy On-Line peak phase.

In many observatories professional astronomers agreed to answer questions. Reports to the Steering Committee reveal they were positively impressed by the quality and depth of many of the inquiries submitted by the young participants.

An Astronomy On-Line "Newspaper" kept the participants informed about the latest developments. This not only included information by the observatories, but also reports of the related activities from the participants themselves.

Reaching the Public

The success of a programme such as Astronomy On-Line obviously lies in the effective organisation of the work and tasks. Equally important, however, is to reach as many potential participants as possible.

This was achieved through a combination of information meetings for teachers (at the national level), the distribution to secondary schools of attractive posters as well as press releases and video news reels to the media both by ESO and the National Steering Committees. Thus Astronomy On-Line found its way into newspapers, magazines, radio and TV.

Also a big effort on the part of the National Steering Committees went into finding suitable sponsors, e.g. network providers and hardware companies, as well as maintaining close contact to the national ministries of education, who in many cases provided extremely valuable help.

Astronomy On-Line maintained a very high visibility during the peak phase of the programme. At the same time it was a pilot programme and as such, the experience from it is of great interest to experts in network-based learning. For this reason Astronomy On-Line was followed very closely by Dr. Jari Multisilta from Tampere University of Technology. At the end of the programme (22 November 1996), all participants were invited to fill in a detailed questionnaire about their own background and personal experience with Astronomy On-Line. Following the evaluation of the incoming replies, it is the intention to publish the results in the journal *Education & Information Technologies*. A provisional report, however, is already available on the Internet (http://www.eso.org/astronomyonline/market/newspaper/news1703.html)

Current Status

The entire Astronomy On-Line structure is still available at the Web, for instance from the central ESO site URL: http://www.eso.org/aol/. Although the daily number of hits is considerably lower than during the "Hot Phase" in November, it is still obvious that it is being used extensively.

The EAAE organisers of Astronomy On-Line early decided that it would be desirable to continue this programme and to establish it on a more permanent basis. Indeed, it has already become an important tool for the exchange of information among Europe's astronomy educators. Few doubt that it will again be used extensively when particular events as Solar and Lunar Eclipses offer the opportunity of joint projects among astronomy-interested students in Europe's schools.

Early 1997, the EAAE made a formal approach to the EU for continued support of Astronomy On-Line. If granted, this would ensure the maintenance and further development of the Astronomy On-Line Web sites, thus enhancing the usefulness of this unique educational tool. Meanwhile, the Astronomy On-Line site at ESO will be kept running.

Conclusion

Apart from its educational aspects, Astronomy On-Line proved to be a powerful vehicle for stimulating the interest in astronomy. Reports filed by the National Steering Committees show the huge number of national activities, that were prompted by the very existence of the programme. These activities ranged from popular talks by professional astronomers, visits to local observatories, joint (and public) observations – in particular in connection

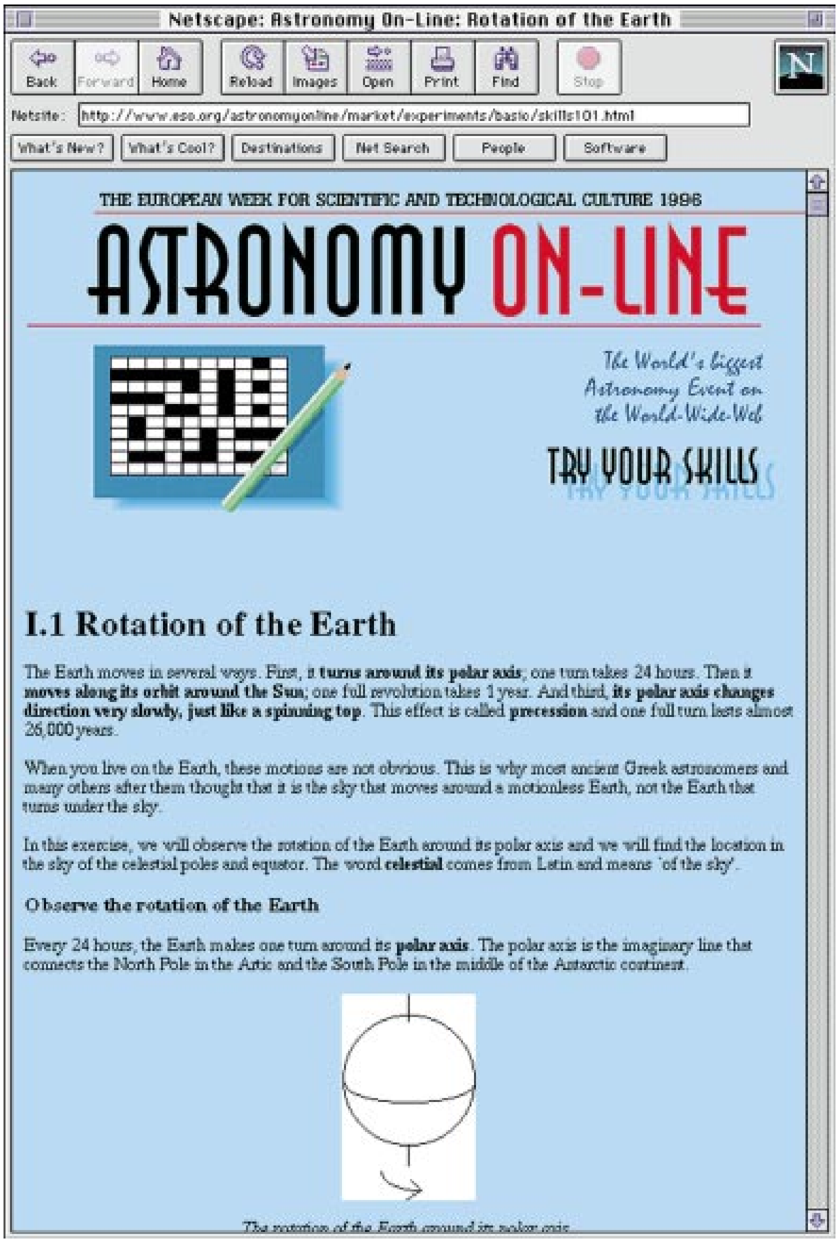

Figure 3: The "Try your skills" shop had a wide range of exciting exercises on offer.

with the lunar eclipse and the partial solar eclipse – to dedicated, often highly successful, efforts to accelerate school plans for getting an Internet connection.

We at ESO have been pleased to be involved in this project from the beginning and thereby to contribute to the three goals mentioned above. We are also confident that Astronomy On-Line will provide a stimulus to young people to become more interested in natural sciences, especially at a time when worries have been expressed at many European Universities about the dwindling number of young people who are considering to pursue a career in these fields.

The European Week for Scientific and Technological Culture

The objective for the European Week for Scientific and Technological Culture is to improve European citizens' knowledge and understanding of science and technology, particularly in their European dimension: it addresses both pan-European scientific and technological co-operation, as well as science and technology in each European country.

"The Week" is organised every autumn by the European Commission in collaboration with national and international research organisations, universities, museums, TV, etc.

EUROPEAN WEEK FOR SCIENTIFIC AND TECHNOLOGICAL CULTURE

Acknowledgements

Astronomy On-Line was made possible by the active personal involvement of a large number of dedicated people all over Europe and, indeed, on several continents. Thanks to their unremitting efforts, it became possible to implement in an extremely short time, a project which will undoubtedly serve as a very useful example for similar events within other subject areas.

Richard West, e-mail: rwest@eso.org

Availability of IDL at ESO/ST-ECF

R. ALBRECHT, W. FREUDLING, R. THOMAS,
Space Telescope – European Coordinating Facility

Introduction

The range of astronomical computing has become so broad that there is no one single data-processing system which covers all possible aspects. Thus, in addition to the indigenous data analysis system MIDAS (Munich Image Data Analysis System) ESO supports a number of other analysis systems. The two most important ones are, at this time, IRAF (Interactive Reduction and Analysis Facility), and IDL (Interactive Data Language).

For many years now, IDL has played a significant role in astronomical data analysis. Originally developed by Dave Stern of Research Systems Inc. in the late seventies, IDL has survived many transitions of hardware platforms and operating systems, all the time improving the functionality while retaining full backward compatibility. This is a truly remarkable achievement.

For Space Telescope data analysis, IDL has been an important tool since the very early days. Since it had been used for the analysis of IUE data, and staff of the IUE centre at GSFC was heavily involved in the development of the Goddard High Resolution Spectrograph (GHRS), a large amount of spectroscopic analysis software was available in IDL. In addition, IDL provided the possibility to read the HST native data format, GEIS (Generic Edited Information Set). Because of its importance for HST data analysis, ST-ECF has been supporting IDL since 1984. More recently, IDL has been made available for the full ESO community.

An often heard objection to the use of IDL is its commercial nature, i.e. license fees have to be paid. However, there are several aspects to consider: the costs are quite moderate in comparison with the other computer system related costs (hardware, operating system, utility software), and buying an IDL license opens up an enormous amount of astronomical application software which has been developed over the years, representing an effort of hundreds of person-years; and, IDL has the potential of considerable cost savings by increasing the efficiency and productivity of software developers.

IDL is available on the ESO local area network to staff and visiting astronomers. Copies of the most important astronomical libraries are available locally, or they can be downloaded through the Internet.

Application Programme Development

Experience shows that it is very difficult to incorporate contributed software written by astronomers for their own research into systems like IRAF and MIDS. The reason for this is that the requirements for adherence to standards, level of documentation, testing, quality control and configuration management have to be so strict that researchers are unwilling and/or incapable of following them. On the other hand, such requirements are absolutely necessary in order to keep the system transportable, maintainable, and reliable. As a consequence, we can hardly ever incorporate "contributed" software into MIDAS or IRAF as is. Instead, we have to take the research software (which may or may not run under one of those systems), re-design and re-code it in the proper manner, and then incorporate it into the target system.

We have found this process to be very smooth when IDL is used. IDL allows quick and easy, step-by-step prototyping by the researcher or by the s/w developer. A large function library encourages modularity. The code is eminently readable, making the process of re-casting it into a different target language very easy. In fact, IDL can be considered a powerful detailed level design language with the advantage that it actually executes.

Of course, there is a penalty for all this: although IDL is very fast as far as interactive languages go, and it can actually be pre-compiled to speed up the execution, it cannot compete with Fortran or C when it comes to pure number crunching involving a large number of

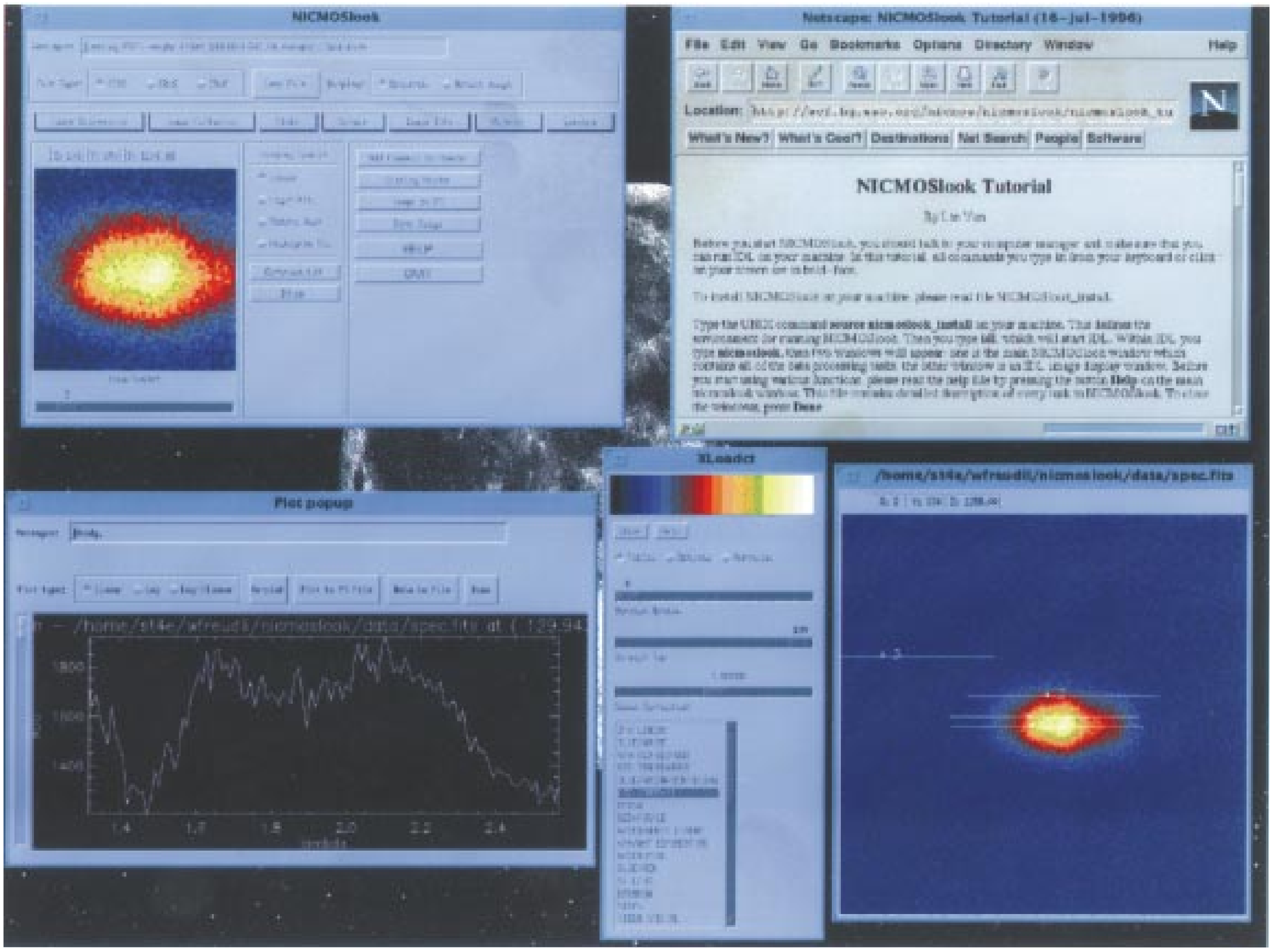

Figure 1: NICMOSLook screen shot, showing the graphical user interface, display panels, and on-line documentation implemented in html.

large data sets. This is one of the reasons why it is necessary to re-code application programmes. Another reason is the fact that sophisticated data analysis systems offer enormous functionality which, however, can only be used if the application programme is compatible within the system.

Example: NICMOSLook and NICMOS grism extraction pipeline

A recent example of the use of IDL at ESO/ST-ECF is the development of a pipeline for the extraction and calibration of NICMOS grism spectra. NICMOS (Near Infrared Camera and Multi-Object Spectrometer) was installed in the Hubble Space Telescope (HST) during the 2nd Servicing Mission in February 1997. Software is being developed at the Space Telescope Science Institute (STScI) to ensure the proper calibration of data obtained with NICMOS. Software is also being developed within the NICMOS Investigation Definition Team (IDT, Principal Investigator Roger Thompson) to support the IDT science programme.

Among the operating modes of NICMOS is a grism spectrum mode. While this mode is not being considered one of the primary operating modes, it nonetheless provides a very important scientific capability and has the highest potential for serendipitous discovery.

NicmosLook is an interactive tool to extract spectra for individual sources on a NICMOS grism image. A matching direct image of the same field is used to determine the location of sources and therefore the zero point for the wavelength scale for each individual spectrum.

The tool is implemented as an IDL widget. After loading both the grism image and the direct image, both images can individually be displayed and manipulated. Objects can be located by the user using the cursor, by supplying object co-ordinates or by supplying a threshold for an automatic object search.

Spectra can be extracted for any user-selected object or for all objects at once. The dispersion and distortion spectra are read from a database. There are several options for the spatial weighting of the spectra. The output of NICMOSLook is wavelength calibrated spectra, which are plotted on the screen and can be saved as postscript files or ASCII data files (Fig. 1).

NICMOSLook is a convenient tool to extract spectra from small numbers of grism images. However, the routine extraction of spectra from large numbers of NICMOS grism images requires a tool which extracts spectra without human intervention. Establishing the requirements for such a software package, we quickly found that we did not have the resources to write it from scratch. On the other hand, it soon became evident that most of the individual steps needed for the reduction have been coded before in one way or the other. The challenge was to harvest as much as possible of this available functionality and to combine it into a package which would meet the requirements of minimum human intervention and operational resilience.

The resulting IDL programme, calnicc, uses the SExtractor programme to identify objects and classifies them as stars or galaxies using a neural network approach (Bertin & Arnouts, 1996). The wavelength calibration of the extracted spectra is performed using the position of the objects as determined by the SExtractor programme as the zero point, and using parameterised dispersion relations. After background subtraction and extractions of the spectra, they

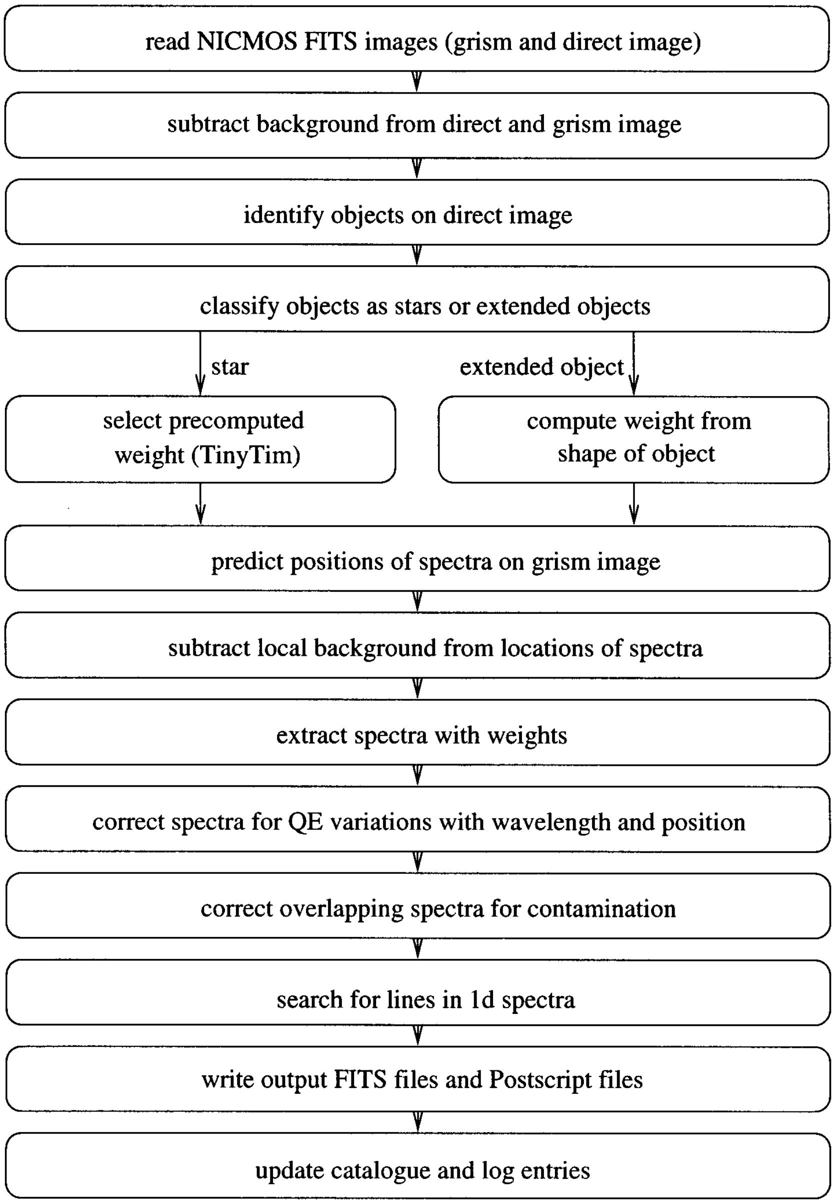

Figure 2: NICMOS grism spectrum extraction pipeline processing steps.

are corrected for the wavelength dependence of the quantum efficiency of the detector. The flux scale is then computed using the standard NICMOS flux calibration data. The extracted spectra are automatically checked for artifacts from bad data and contamination from nearby objects. An attempt is made to correct spectra for the contamination. All spectra are automatically searched for emission and absorption lines. In addition, the continuum emission is determined. The final data product consists of binary FITS tables with the spectra, error estimates, object parameters derived from the direct imaging and details of the spectrum extraction process (Fig. 2).

IDL allowed the quick merging of components written by different authors, including components written in different languages. This was an important aspect of our project as the object extraction software is only available in C.

The software will be used for the extraction and calibration of NICMOS grism spectra during the orbital verification and initial science programme of NICMOS. We expect to have to do considerable changes in response to in-orbit performance. Once the software is stable and the data volume increases, we are in a position to speed up the processing by re-casting the software as an IRAF task and executing it in the HST calibration pipeline system, using the existing software as the detailed design.

Conclusions

IDL in many ways combines the advantages of an interactive and a compiled language. The speed penalty mentioned above is not significant considering the speeds afforded today even by low-cost hardware.

IDL is a traditional language as far as syntax and usage mode is concerned. It is thus usable by astronomers, which is to say by users with a minimum computer science background, who do not easily adapt to state-of-the-art object oriented paradigms. However, recent add-ons to IDL make it possible for the professional programmer to use object-oriented concepts.

By using IDL, it was possible to develop a software package consisting of about 5000 lines of IDL and C code in about 3 person-months. The total effort, including requirements definition, reviewing, testing, documentation, and integration was about twice that. This fast-track development, which was made possible by the use of IDL, enabled us to produce the required software on time. The portability of the code made delivering it to the NICMOS IDT and the STScI very easy. It was mainly due to the demonstrated availability and capability of this software package that a major NICMOS grism survey proposal was approved by the HST Time Allocation Committee.

Reference

Bertin, E., Arnouts, S., 1995, *A&A Suppl.*, **117**, 393.

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Gerhard Bachmann (1931–1996)

Gerhard Bachmann, who for many years as Head of Administration played an essential role in the development of ESO, died on 9 December 1996. Through his wisdom, dedication, integrity and persistence many problems were solved, ESO's relations with the member countries were excellent and ESO's internal organisation functioned smoothly. He always had a willing ear for complaints from the staff and, if justified, would see to it that the necessary corrective action was taken.

Born in Berlin on 24 May 1931, he held various positions in the German civil service, before joining the NATO Maintenance and Supply Agency in France and Luxembourg (1963–1970). In 1970 he joined the ESO Administration which he headed since 1972. He retired in May 1996. During this time, ESO has developed into a major European research organisation. Mr. Bachmann's leadership has done much to inspire confidence among member state governments that ESO could be entrusted with substantially increased funds, that it had the management ability to deal with large projects, and that it could conduct diplomatic negotiations at the highest level. He successfully established the Personnel Statutes for International and Local Staff, the financial and contractual procedures of ESO, the adherence of ESO to many of the procedures of the Co-ordinated Organisations, even though the fickleness of the European governments led to deviations from these soon thereafter. All ESO's pensioners can be grateful to him for the way he integrated ESO into the CERN pension fund. He played an essential role in the delicate negotiations about the increase of the membership of ESO, which led to Italy and Switzerland joining the Organisation. His diplomatic abilities in smoothing out probl ms with the member states avoided many difficulties. More than anywhere this diplomacy was required in Chile, where he managed to maintain appropriate relations with governments ranging over the whole political spectrum. Unfortunately, he could not be present anymore at the signing of the Acuerdo that put an end to a period of some difficulties between Chile and ESO.

Mr. Bachmann had a strong personality and at the same time a great loyalty to ESO. He strongly defended his point of view, but it was always possibl to have a rational discussion and to come to a positive conclusion. Once arrived at, there was no doubt that it would be fully respected, even in the rare cases where his personal preference might have been slightly different.

Ger ard Bachmann always had time for what was needed, whatever the hour of the day or the day of the week. In the course of time we became very good friends, and I remember with particular pleasure the many travels we made together, most of all the first discovery trip to Paranal which turned out to have such far-reaching consequences. Between his various activities, Mr. Bachmann could perfectly relax, and I have fond memories of the many evenings we spent at the Casa Schuster at La Silla.

Mr. Bachmann was looking forward to spending more time at his home near Bordeaux that he had spent much effort to develop. Unfortunately, fate was different. His many friends in Europe and in Chile will miss him. All feel that he had merited better. Our sympathy goes to Mrs. Bachmann and his two daughters.

L. Woltjer

(7215) Gerhard = 1977 FS

Asteroid discovered 1977 March 16 by H.-E. Schuster at the European Southern Observatory.

Named in memory of Gerhard Bachmann (1931–1996), who came to the European Southern Observatory in 1970 and was head of administration at the organisation from 1972 to 1996. Throughout this time he greatly contributed to ESO's success. His unusual diplomatic abilities and thorough knowledge of the interaction of science and politics ensured the smooth running of the observatory and efficient interaction with the member countries and the European Union. The naming marks his retirement from ESO and subsequent untimely death. Name proposed by the discoverer. Citation prepared by R.M. West.

ESO Studentship Programme

Th European Southern Observatory research student programme aims at providing the opportunities and the facilities to enhance the post-grad ate programmes of the member-state universities by bringing young scientists in close contact with the instruments, activities, and people at one of the world's foremost observatories.

Students in the programme work on an advanced research degree under the formal tutelage of their home university and department, but come to either Garching or Vitacura/La Silla to do their studies under the supervision of an ESO Staff Astronomer. Candidates and their supervisors should agree on a research project together with the potential ESO local supervisor.

ESO has positions available for 12 to 14 research students. Students normally stay at ESO up to two years, so that each year a total of 6–7 new studentships are available either at the ESO Headquarters in Garching or in Chile at the Vitacura Quarters and the La Silla Observatory. These positions are open to students enrolled in a Ph.D. programme in the ESO member states and exceptionally at a university outside the ESO member states.

The closing date for applications is June 15, 1997.

For further information on the programme, the scientific interests of the ESO astronomers, and application forms please contact:

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Karl-Schwarzschild-Str. 2
D-85748 Garching bei München, Germany
e-mail: ksteiner@eso.org

or look up: http://www.eso.org/adm/personnel/students

F I R S T   A N N O U N C E M E N T

ESO Workshop on

Cyclical Variability in Stellar Winds –

recent developments and future applications

14–17 October 1997

ESO Headquarters
Garching bei München, Germany

Variability is a fundamental property of stellar winds. In recent years it has become clear that in many cases the observed variations show a cyclical behaviour. This is a property that **hot- and cool-star winds** seem to have in common, although the physical mechanism driving the wind is different.

Topics to be covered include:

- Wind acceleration mechanisms
- Observations of cyclical wind variability (hot and cool stars)
- Latest solar wind results
- Variability in pre-main-sequence winds
- Processes affecting the emergence of the wind
- Modelling time-dependent behaviour stellar winds
- MUSICOS 1996 results
- Future developments

Scientific Organising Committee: T. Böhm (Germany), A. Cameron (UK), C. Catala (France), L. Hartmann (USA), H. Henrichs (The Netherlands), L. Kaper (Germany), H. Lamers (The Netherlands), K. MacGregor (Chair, USA), S. Owocki (USA), J. Puls (Germany), O. Stahl (Germany) **Local Organising Committee:** A. Fullerton, L. Kaper (Chair), C. Stoffer.

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Please contact: windvar@eso.org

New ESO Preprints

(November 1996 – February 1997)

Scientific Preprints

1198. J. Manfroid and G. Mathys: Variations of the Ap Star HD 208217. *AA.*
1199. L. Kaper, J.Th. van Loon, T. Augusteijn, P. Goudfrooij, F. Patat, L.B.F.M. Waters, A.A. Zijlstra: Discovery of a Bow Shock Around Vela X-1. *ApJ* Letters.
1200. R. Gredel: Interstellar CH^+ in Southern OB Associations. *AA.*
1201. J. Rönnback and P.A. Shaver: A Distant Elliptical Galaxy Seen Through a Foreground Spiral. *AA.*
1202. P. Ferruit, L. Binette, R.S. Sutherland and E. Pécontal: Modeling Extragalactic Bowshocks. I. The Model. *AA.*
1203. G. Mathys and S. Hubrig: Spectropolarimetry of Magnetic Stars. VI. Longitudinal Field, Crossover and Quadratic Field: New Measurements. *AA.*
1204. M. Victoria Alonso and D. Minniti: Infrared Photometry of 487 Sources in the Inner Regions of NGC 5128 (Cen A). *ApJ Suppl.*
1205. I.J. Danziger and R. Gilmozzi: The Final Optical Identification Content of the Einstein Deep X-Ray Field in Pavo. *AA.*
1206. G. De Marchi and F. Paresce: The IMF of Low Mass Stars in Globular Clusters. *ApJ* Letters.
1207. G. Mathys and T. Lanz: The Variations of the Bp Star HD 137509. *AA.*
1208. P.-A. Duc, I.-F. Mirabel and J. Maza: Southern Ultraluminous Infrared Galaxies: an Optical and Infrared Database. *AA.*
1209. A.A. Zijlstra, A. Acker and J.R. Walsh: Radial Velocities of Planetary Nebulae Towards the Galactic Bulge. *AA.*
1210. T.R. Bedding, A.A. Zijlstra, O. von der Lühe, J.G. Robertson, R.G. Marson, J.R. Barton and B.S. Carter: The Angular Diameter of R Doradus: a Nearby Mira-like Star. *M.N.R.A.S.*
1211. S. Randich, N. Aharpour, R. Pallavicini, C.F. Prosser and J.R. Stauffer: Lithium Abundances in the Young Open Cluster IC 2602. AA.
1212. D. Baade and H. Kjeldsen: A Spectroscopic Search for High Azimuthal-Order Pulsation in Broad-Lined Late F- and Early G-Stars. *AA.*

PERSONNEL MOVEMENTS

International Staff (1 January – 31 March 1997)

ARRIVALS

EUROPE

WICENEC, Andreas (D), Archive Information Designer & Engineer
WOLFF, Norbert (D), Control Engineer
SILVA, David (USA), Head of User Support Group
BARZIV, Orly (GR), Student
ROSATI, Piero (I), Fellow
DUDZIAK, Gregory (F), Coopérant
PIEPER, Holger (D), UpA Optical Detector Team

CHILE

CANNON, Russell (GB/AUS), Senior Visitor

DEPARTURES

EUROPE

VAN DEN BRENK, John, Detector Engineer
VON DER LÜHE, Oskar (D), Experimental Physicist/ Astronomer
SACRÉ, Philippe (F), Mechanical Engineer
DUDZIAK, Gregory (F), Student
VAN LOON, Jacobus (NL), Student
PIEPER, Holger (D), Student
CÔTÉ, Stéphanie (CDN), Fellow

Translation of Speech by Foreign Minister Mr. José Miguel Insulza

Your Excellency, Don Eduardo Frei Ruiz-Tagle, Your Majesties King Karl XVI Gustaf and Queen Silvia of Sweden, Mr. President of the ESO Council, Mr. Director General of ESO, Senators, civil, military and church officials, Members of the Swedish delegation, Members of the ESO Council, ladies and gentlemen,

It is a great honour for me to represent the Chilean Government in this ceremony and to share with you my feeling of excitement and hope as we take part in this foundation ceremony of ESO's at Cerro Paranal. This feeling is, first of all, based upon the importance of the project that we inaugurate today. The VLT/VLTI telescope already described by the President of the ESO Council and by the Director General of ESO, is not only an expression of the most modern technology ever used in astronomy. It is also an opportunity to deepen our knowledge of the Universe and thus be able to answer the questions that have occupied mankind since its origin. In this sense, over and above the significant cost entailed by the project, it will be a milestone for the development of astronomy at a national and global level.

My satisfaction becomes even greater, when considering the long and winding path that Chile and ESO had to follow these last years, to reach this place and this occasion. We all know of the difficulties encountered and the misunderstandings, which have now been happily overcome, but which at some point threatened the completion of this project.

However, I believe it is important to say that during that process the Government permanently supported ESO, in order to enable the Organisation to continue developing and extending its activities in Chile. We did this not only because of the international commitment undertaken by the State and to follow Chilean tradition in honouring engagements of international treaties but also because we thought that the development of ESO's activities in the country, within a clear legal frame, would not only benefit world science, but also Chile's scientific development in its most important regions.

Our point of view is validated today, since the Paranal Observatory will not only benefit ESO's activities but will also redound to the benefit of Chilean scientists who will thus have access to a facility which would otherwise have been completely beyond their reach.

For this reason, this ceremony, which follows the signing of the Instruments of Ratification and Approval of the Interpretative, Supplementary and Amending Agreement of the 1963 Convention, constitutes not only the end of a difficult process, but also the beginning of a new relationship of co-operation and understanding between Chile and ESO, which is a mature, consolidated and equal relationship in which both parties benefit.

The consolidation of the legal-political relationship between Chile and ESO warrants a steady development for ESO's activities, within a framework of mutual benefit and also warrants the extension of these activities in the future.

Furthermore, through the recognition of the legitimate aspirations of the national sectors more directly involved in ESO's activities, an equal relationship is established, because the acknowledgement of the rights of Chile and its citizens in labour and scientific matters constitute an adequate counterpart to Chile's contribution to ESO.

By establishing permanent bodies of co-operation and for the resolution of controversies between Chile and ESO, the Organisation becomes closely linked to the scientific and technological development of the country.

Finally, this relationship has pilot character in several aspects, such as environmental protection, rights of Chilean workers in foreign public organisations and the rights of the national scientific community. We trust that it will set an example for future agreements related to astronomy, subscribed by the country in the next years.

In this context, I would like to express that the Government welcomes the establishment of the „Foundation for the Advancement of Astronomy". This initiative was started by Chilean astronomers who have obtained awards in sciences, and it is supported by the Director General of ESO, Prof. Riccardo Giacconi. We believe that this foundation, complemented by the action of other organisations that bring Chile and ESO together, will play an important role in administering resources for the advancement of astronomy in Chile and will promote international co-operation in this field.

Mr. President, Your Majesties, we are gathered in this impressive scenery to take part in a ceremony which has resulted from the strong and visionary co-operation between the Government of President Frei and ESO. We also take this opportunity to thank the many scientists who have participated in this project with all their effort, the workers who have accomplished it and also the Chilean Congress, represented here by Senators of the Region, for the continuous support. We hope that the Cerro Paranal Observation Centre may soon become operational and that the work carried out on these premises, both by Chilean and foreign guests, may redound to a greater knowledge of the Universe, as well as to clearer benefits for ESO, for its Member States, one of which is the Kingdom of Sweden, and for Chile. In this spirit I would like to express my best wishes for the success of this new adventure in science.

Thank you very much.

Translation of Speech by H.E. President Eduardo Frei

Your Majesties, Excellencies, Ambassadors, authorities, and a very special greeting to the President of the ESO Council, Dr. Peter Creola, and the Director General, Prof. Giacconi, esteemed friend.

As I contemplate this enterprise, in the middle of the desert, made possible through the joint effort of a group of European countries, their scientific communities and astronomers, on one hand, and of the Chilean nation, its workers, engineers and scientists, on the other, I feel not only deeply gratified but, also, extremely proud.

This is a concrete signal of how our country is becoming increasingly inserted in the international community. And not only in economic terms.

It is certainly true that our country is, nowadays, closely linked to international trade. This year we have completed our association with the MERCOSUR, we have achieved strong ties with the European Union and, for the first time in history, we have signed a Free Trade Agreement with an industrialised country: Canada.

But there are other aspects as well, where we are becoming positively integrated to the rest of the world. Today, our political relations with the community of nations are at a very high level, which would have seemed unfeasible a few years ago. Democracy has brought us closer to the rest of the world and has restored the prestige historically enjoyed by the nation.

In the field of scientific co-operation we have also made progress. The establishment of this observatory is a good example of it. Astronomers from Europe and other countries will come and work here, and the most prominent Chilean astronomers will be given the opportunity of carrying out their research projects.

This opens multiple opportunities for collaboration and creates an extremely valuable platform for training young Chilean astronomers. Our main universities will benefit, as well as the country as a whole, since we will become the seat of one of the most advanced astronomical observatories in the world.

I believe that all these joint activities with industrially and scientifically advanced countries are vitally important, since our own challenge, as far as modernisation is concerned, is the challenge of upgrading our own capabilities in the fields of science and technology.

Chile would not be able to project itself creatively towards the future, nor to create a modern society, if economic growth and the generation of opportunities for people are not simultaneously coupled with the application of frontier technologies in production, in industry, in agriculture, in services and State management.

Perhaps this is one of the greatest challenges we face. The successful achievement of this goal calls for the joint effort of universities, enterprises and the Government. We are working every day towards this end, through the modernisation of education, which is the very basis of the building we must construct. Without education, there would be no future, nor democracy, nor growth, nor competitiveness and we would be unable to create a fairer and more equitable society.

Finally, I would like to take this occasion to publicly express our appreciation to the ESO Member States, to the Organisation itself, its executives and to all those in Chile who have contributed in this task and to say that when I took office there were not only stones, but rocks on the path, but there was also the political will to overcome them, since we could not allow hindrances in the construction of this great enterprise.

At the same time, I would like to avail myself of the presence of Their Majesties, the King and Queen of Sweden, to express our gratitude to them. And also, to tell them that our academic community is deeply indebted to their country, for the support provided to hundreds of Chilean researchers and professors, during their years of exile in Sweden, as well as for the support given to a great number of national institutions that have sustained and developed in Chile, thanks to international collaboration, which was particularly generous and active, in the case of Sweden.

Finally, a special remembrance to the fact that in 1969 my father, President Eduardo Frei Montalva, inaugurated the La Silla Observatory, in the presence of a distinguished personality, former Prime Minister Olaf Palme. The world is small and history is repeating itself. Today, with great joy we are saying "go ahead" to this great enterprise which points to the future and will foster development in our country.

Thank you very much.

ESO, the European Southern Observatory, was created in 1962 to . . . establish and operate an astronomical observatory in the southern hemisphere, equipped with powerful instruments, with the aim of furthering and organising collaboration in astronomy . . . It is supported by eight countries: Belgium, Denmark, France, Germany, Italy, the Netherlands, Sweden and Switzerland. It operates the La Silla observatory in the Atacama desert, 600 km north of Santiago de Chile, at 2,400 m altitude, where fourteen optical telescopes with diameters up to 3.6 m and a 15-m submillimetre radio telescope (SEST) are now in operation. The 3.5-m New Technology Telescope (NTT) became operational in 1990, and a giant telescope (VLT = Very Large Telescope), consisting of four 8-m telescopes (equivalent aperture = 16 m) is under construction. It is being erected on Paranal, a 2,600 m high mountain in northern Chile, approximately 130 km south of Antofagasta. Eight hundred scientists make proposals each year for the use of the telescopes at La Silla. The ESO Headquarters are located in Garching, near Munich, Germany. It is the scientific, technical and administrative centre of ESO where technical development programmes are carried out to provide the La Silla observatory with the most advanced instruments. There are also extensive facilities which enable the scientists to analyse their data. In Europe ESO employs about 200 international Staff members, Fellows and Associates; at La Silla about 50 and, in addition, 150 local Staff members.

The ESO MESSENGER is published four times a year: normally in March, June, September and December. ESO also publishes Conference Proceedings, Preprints, Technical Notes and other material connected to its activities. Press Releases inform the media about particular events. For further information, contact the ESO Information Service at the following address:

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On January 12, 1997, his Holiness Pope John Paul II. graciously received in private audience the participants to the international Conference "the Three Galileos: the Man, the Spacecraft and the Telescope". The Pope was introduced to the astronomers and their families, and among others to the ESO Director General, Professor Riccardo Giacconi and his wife Mirella.

Contents