cited H_2 emission toward NGC 6334 I(N) (cf. Fig. 4). Thus, NGC 6334 I(N) now appears to harbour ongoing star formation, which explains the previously enigmatic presence of masers toward I(N). We suggest that I(N) is in an interesting transition phase, transforming from a chemically quiescent to a shock/outflow-dominated molecular core. Assuming that its southernly companion, NGC 6334 I, passed through a similar transition phase before entering the observed hot core chemistry, these two molecular cores, embedded within the same parental molecular cloud and separated by less than 0.5 pc, will allow for a unique case study of the chemical and physical evolution of molecular cores in their earliest phases after the onset of star formation (Megeath & Tieftrunk, Tieftrunk & Megeath, in preparation).

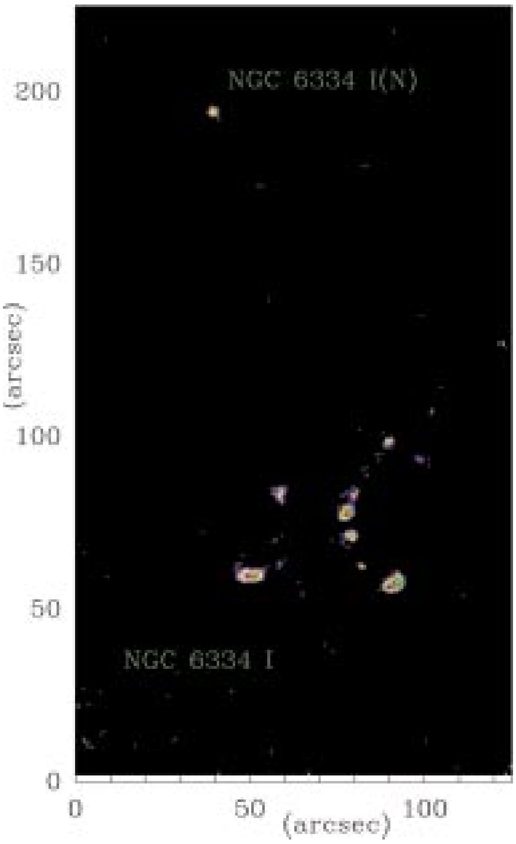

Figure 4: $H_2$1-0 S(1) emission toward NGC 6334 I and I(N) from our Fabry-Perot imaging with the 2.2-m in July 1998. The lower part of this figure shows the same H_2 emission knots as Figure 2, but with higher dynamic range. Relative offsets are given in arcseconds from an arbitrary off-position, chosen to align the two FP-fields. We caution the reader that the registration of the data in this figure is preliminary and may have absolute errors of several arcseconds. Note that no *continuum and* no *Brγ emission could be detected toward the shock-excited H_2 emission knots.*

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Molecular Gas in 30 Doradus

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Introduction

The Large Magellanic Cloud (LMC) contains numerous star-forming regions (SFRs) in an environment considerably different from the Galaxy. As in our Milky Way, SFRs in the LMC include complexes of ionised gas, patches of dust, and clusters of young stars and share the same markers of star formation: protostellar objects (Jones et al. 1986; Hyland et al. 1992), compact infrared sources (Schwering & Israel 1990; Rubio et al. 1992), OH and H_2O masers (Whiteoak & Gardner 1986; Caswell 1995), etc. They show, however, significant differences: the ionising radiation is stronger, the luminous stars are less deeply embedded, there is a lack of far-IR brightness peaks, and substantially less cold molecular gas (Cohen et al. 1988; Israel et al. 1993; Kutner et al. 1997; Johansson et al. 1998). The SFRs in the LMC should be important stepping stones between Galactic SFRs and those in more distant galaxies. In particular, the giant H II region 30 Doradus is thought to be a keystone object for understanding the "starburst" phenomenon in active galaxies (cf. Walborn 1991). Much larger than any Galactic SFR, the 30 Doradus region contains luminous clusters of massive young stars emitting intense UV radiation and powerful stellar winds which have created loops and shells of ionised gas, and shows evidence for a highly efficient formation mechanism unmatched in Galactic molecular clouds (Massey and Hunter 1998). We summarise here the results of an ongoing investigation of the characteristics of the highly excited molecular gas and cold molecular gas toward the centre of the 30 Doradus region, made through observations of H_2 and CO(2$\rightarrow$1) line emission, respectively.

Cold Molecular Gas

CO emission from the 30 Doradus region was first detected, using the Columbia millimetre radio telescope, by Melnick & Rubio (1985). Their pointed, low angular resolution (8.8′) observations showed a weak CO line emission with several velocity components. Higher sensitivity CO mapping of a region of $\sim 1^\circ$ centred near the exciting cluster of the H II region (hereafter the R136 cluster), made with the same instrument, were reported by Garay et al. (1993). They suggested that the CO emission from the 30 Doradus region arises from small, dense molecular clumps that are embedded in a mainly atomic but partly molecular interclump medium where CO has been destroyed by photodissociation due to the strong UV radiation field present in the area.

As part of the ESO-SEST Key Programme: CO in the Magellanic Clouds, Johansson et al. (1998) mapped the CO(1$\rightarrow$0) line emission from the 30 Doradus region with a tenfold higher angular resolution (45″) than in previous works. They identified more than 30 molecular clouds within a region of $24' \times 24'$, having typically sizes of 10 pc and masses of $\sim 2 \times 10^4$ $M_\odot$, confirming the suggestion made by Garay et al. (1993). In particular, close to the R136 cluster, Johansson et al. (1998) detected two CO clouds located toward the north-east and west of R136 (clouds # 10 and 13, respectively) and which lie close to the edg-

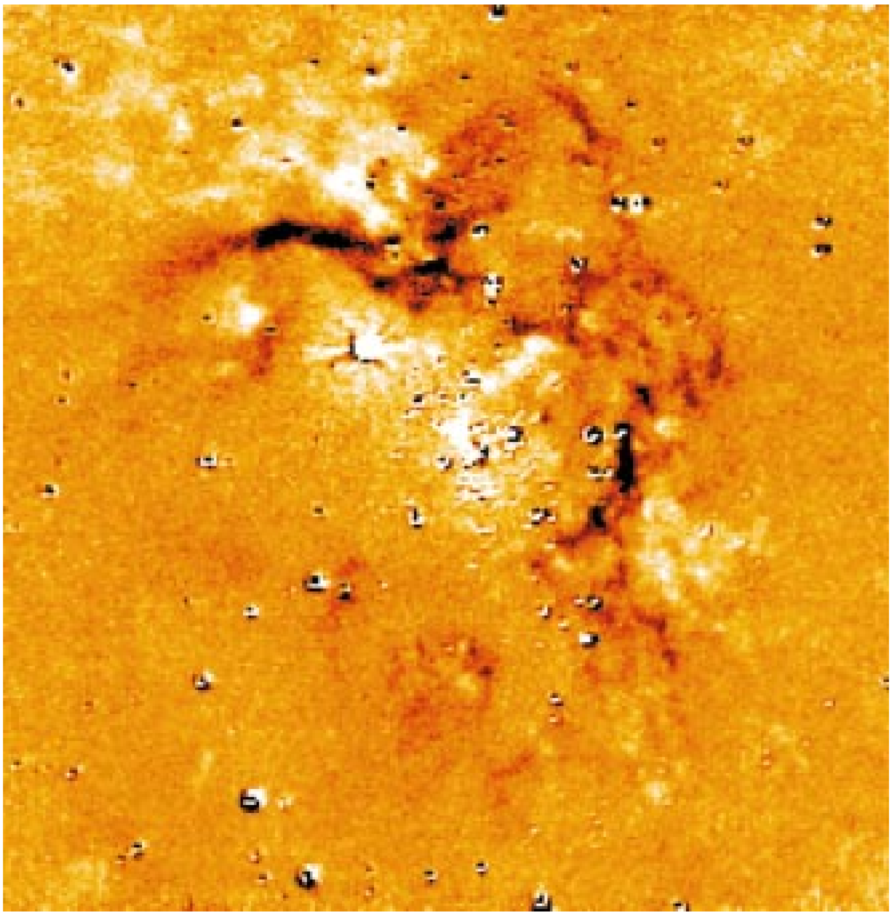

Figure 1: Composite image of the 30 Doradus Nebula, using the 2.12µ and 2.16µ narrow-filter images taken with CIRIM (Nicmos III, 256 × 256 IR camera) at the 1.5-m telescope at Cerro Tololo Inter-American Observatory. The individual images cover an area of 5′ × 5′ centred in R136 and the exposures times are 1 hour and 30 minutes for the 2.12µ H_2 and 2.16µ Brγ, respectively. The Brγ image has been subtracted from the H_2 image. Red-brown colours indicate Brγ emission while yellow-white colours indicate H_2 emission. The scale is 1.16″/pix and the field shown is 4.4′ × 4.5′. North is at top, east to the left.

es of filaments of ionised gas characteristic of this giant HII region. Cloud 10 is the most luminous and massive cloud of the region surveyed, having a CO luminosity of 9.9×10^3 K km s^{-1} pc^2 and a virial mass of 3.8×10^5 $M_\odot$. Near IR images show the presence of an IR cluster towards Cloud 10 and a chain of knot-like features towards Cloud 13 (Rubio et al. 1992). The knots seem to be associated with early-type (O3) massive stars, suggesting that massive star formation is currently taking place within dense molecular clumps embedded in the ionised gas. Further evidence for a new stellar generation of young massive stars in the 30 Doradus Nebula is presented by Rubio et al. (1998).

Excited Molecular Gas

Recently we undertook deep imaging, in the 2.12µ 1-0 S(1) line of H_2 and 2.16µ Brγ recombination line of hydrogen using the CTIO 1.5-m telescope, of several LMC SFRs in order to investigate the spatial distribution of H_2 and ionised gas with respect to the CO molecular clouds (Probst & Rubio 1998). Toward the 30 Doradus region a 5′ × 5′ area was imaged, with 1.16″/pix resolution, showing that the H_2 emission is clumpy, with numerous knots and with a reticulated pattern in contrast to the ionised gas which shows a filamentary structure in Brγ. These near-IR images are considerably more sensitive than those reported by Poglistch et al. (1995) and have considerably higher angular resolution than the low-surface-brightness line emission observations of Pak et al. (1998). Figure 1 shows a composite image, made using the 2.12µ and 2.16µ narrow-filter images (1-hour and 30-min exposures, respectively) in which the Brγ image has been subtracted from the H_2 image. The Brγ emission (shown in red-brown colours) clearly shows filaments and arc structures of ionised gas towards the west and north-east of the central cluster, as well as the filamentary structure of the nebula. On the other hand, the distribution of H_2 (shown in yellow-white colours) is characterised by compact knots of strong emission, near the centre of the image, and two extended areas of weaker emission, one toward the NE and the other toward the

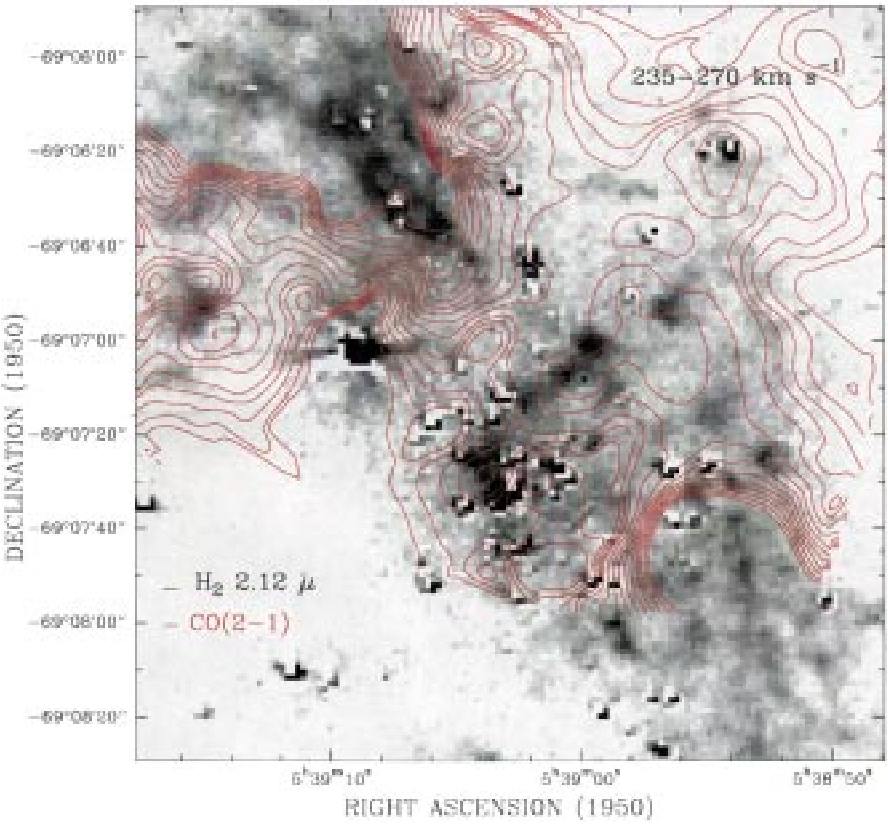

Figure 2: Contour map of velocity integrated CO(2→1) line emission from the 30 Doradus region, superimposed on the 2.12µ H_2 image taken with CIRIM at the 1.5-m telescope at CTIO. The velocity interval of integration ranges from 235 to 270 km s^{-1}. The contour levels are from 0.8 K km s^{-1} (~ 4σ) to 2.4 K km s^{-1} in steps of 0.4 K km s^{-1} and from 3.2 to 10 K km s^{-1} in steps of 0.8 K km s^{-1}.

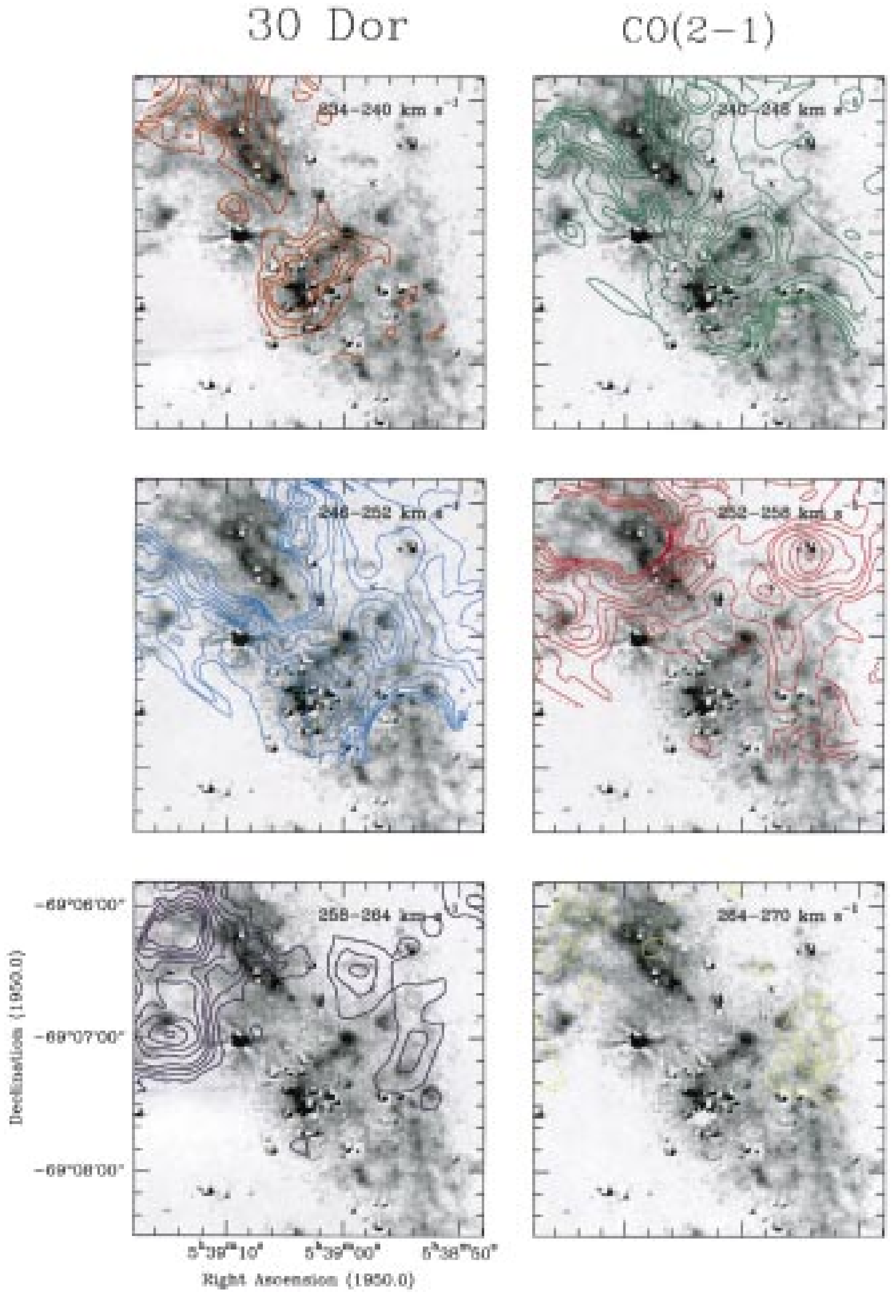

Figure 3: Channel maps of the integrated CO(2→1) line emission over velocity intervals of 6 km s^{-1}, in the velocity range from 234 to 270 km s^{-1}, superimposed on the same H_2 image shown in Figure 2. The contour levels are from 0.25 K km s^{-1} (~ 4σ) to 1.0 K km s^{-1} in steps of 0.25 K km s^{-1} and from 1.5 to 3.0 K km s^{-1} in steps of 0.5 K km s^{-1}. The position of R136 is indicated by a white star symbol in the lower-right panel.

SW of R136. The extended emission is found projected toward the CO clouds detected in the near vicinity of R136 by Johansson et al. (1998). Projected toward the NE H_2 region are known protostars and an $H_2$0 maser feature. The extended SW H_2 region exhibits a peculiar bubble structure apparently unrelated to the Brγ emission. These bubbles have roughly the same linear dimensions as those seen in the Orion SFR (Tanaka et al. 1989), but unlike the latter do not contain hot young stars or ionised gas, and show a more clumpy structure. The nature of the bright H_2 knots seen in the vicinity of R136 is particularly intriguing; they are not associated with stars, ionised gas, nor with CO emission as reported by the Key Programme survey (Johansson et al. 1998).

Observations and Results

The presence of concentrations of excited molecular gas, as revealed by the 2.12μ emission, in regions near the central cluster R136 where no CO(1→0) had been detected by Johansson et al. (1998) clearly calls for more sensitivity CO observations of the region. Hence, we undertook a deep survey of the CO(2→1) line emission towards the H_2 knots and bright structures. This line was chosen in order to benefit from the higher angular resolution provided by SEST at the frequency of 230 GHz (23″ or 6 pc at the distance of the LMC). The aim of the observations was to search for weak CO emission, tracing cold molecular gas, that might be associated with the hot molecular gas of the H_2 knots, and to study the physical conditions of molecular clouds in the presence of an intense ultraviolet radiation field.

The observations were made during two observing runs (March 1997 and January 1998) using the SEST telescope on La Silla, and performed in the position-switching mode using a nearby reference position free of CO(2→1) emission. Only linear baseline fits were needed to reduce the data. The rms noise achieved in a single channel 0.054 km s^{-1} wide, is 0.07 K. We fully mapped, with 10″ spacings, a region between Clouds 10 and 13 which encompasses the H_2 knots found in the near IR. Emission is detected in most of the mapped region, but with an intensity of typically 3–4 times lower than that of the emission mapped by Johansson et al. (1998).

Figure 2 shows a contour map of the CO(2→1) emission integrated over the velocity interval from 235 km s^{-1} to 270 km s^{-1}, superimposed on the 2.12μ H_2 image. Besides the strong emission from Cloud 10 (NE region of the map) and Cloud 13 (SW region of the map), particularly notable is the detection of emission from a clumpy structure, located between Clouds 10 and 13, having an elongated morphology along a SE-NW direction. In addition, at least two other CO(2→1) clumps are clearly detected, one located in the east and the other in the north-west region of the map. The central, clumpy CO(2→1) structure is closely associated with the H_2 knots and roughly follows their morphology. However, the peak of the CO clumps are in general not exactly coincident with the peaks of the H_2 knots.

The velocity structure of the CO(2→1) emission from the 30 Doradus region is presented in Figure 3, which shows channel maps of the emission integrated over velocity intervals of 6 km s^{-1}, superimposed on the 2.12μ H_2 image. The strong emission from Cloud 10 is clearly seen in all, but the last, channel maps, while emission from Cloud 13 is seen in the range from 240 to 258 km s^{-1}. Note that the CO emission above 10 K km s^{-1} is not contoured in Figure 3 to allow a clear display of the weaker emission pertained to this work. From an analysis of the channel maps we have identified seven molecular clumps in the mapped region (other than Clouds 10 and 13), with velocities ranging from 236.7 km s^{-1} to 268.8 km s^{-1}. The radii of the clumps range from 4 to 7 pc, the line widths range from 2.4 to 7.9 km s^{-1}, and the CO luminosities range from 0.5×10^2 to 4.3×10^2 K km s^{-1} pc^2. Compared to the average parameters of LMC molecular clouds, derived from a total of about 100 CO clouds mapped with the SEST under the CO Key programme (Rubio 1997), these clumps are smaller in size by a factor of ~ 4 and

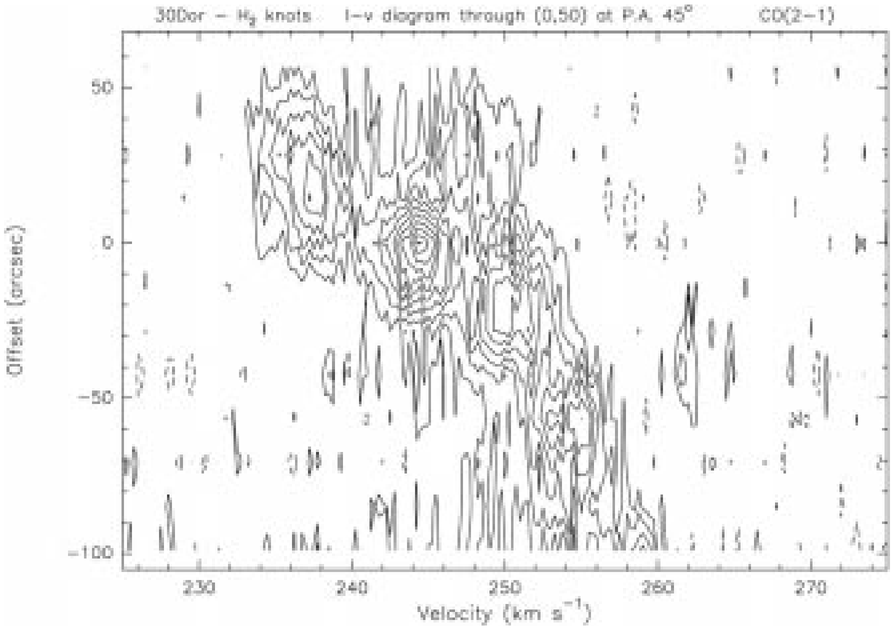

Figure 4: Position-velocity diagram of the CO(2→1) line emission from the central region of 30 Doradus along a direction with a position angle of 45° passing through α (1950) = $5^h39^m00.2^s$, δ (1950) = –69°07′10″. Contour levels are –0.07, and 0.07 to 0.7 K in steps of 0.07 K. The spectral data used to make this diagram have been smoothed to a velocity resolution of 0.25 km s^{-1}.

have CO luminosities lower by a factor of ~ 10^2. Assuming that the CO clumps are in virial equilibrium, we estimate clumps masses in the range from 5×10^3 to 5×10^4 $M_\odot$. This hypothesis is, however, arguable for clouds in the 30 Doradus region due to the large amount of mechanical energy that has been deposited in the region by the recently formed massive stars.

Discussion

The CO(2→1) emission associated with the chain of H_2 emission shows a clear gradient in velocity along a SE-NW direction. In the lowest velocity interval (234–240 km s^{-1}) the CO emission arises from a region associated with the south-eastern most H_2 knots, in the next velocity interval (240–246 km s^{-1}) it peaks near the strongest H_2 knot, while in the velocity interval 246–252 km s^{-1} it is mainly associated with the north-western most H_2 knot in the chain. The velocity gradient is best appreciated in Figure 4 which shows a position velocity plot of the emission along a direction with a position angle of 45° passing through α (1950) = $5^h39^m00^s.2$, δ (1950) = –69°07′10″. From this figure we measured, for the CO emission associated with the H_2 chain, a velocity gradient of ~ 0.37 km s^{-1} $arcsec^{-1}$ (or 1.4 km s^{-1} pc^{-1} at the distance of 55 kpc) over a region of ~ 50″ in length. If these motions are due to gravitationally bound rotation around a core of mass M_c, then the observed velocity gradient implies that $M_c \sim 1.4 \times 10^5$ $M_\odot$ within a 7 pc core radius (cf. Armstrong, Ho, & Barret 1985).

While the presence of such a massive core cannot be ruled out at present, we believe that the observed velocity field in the 30 Doradus region is most likely produced by the expansion of molecular gas driven by the powerful stellar winds from the luminous stars located in the central part of 30 Doradus. The interaction of stellar winds with the ambient interstellar medium has been extensively studied by Castor et al. (1975) and Weaver et al. (1977). Assuming that the characteristic velocity of expansion of the clumps is 16.7 km s^{-1} (equal to the largest observed relative velocity of the clumps with respect to the ambient cloud velocity) and that they are located at a characteristic radius of ~ 16 pc (equal to the radius of the region encompassing the seven clumps), then the stellar wind power required to form the observed structure, assuming a medium with an initial ambient density of 10^4 cm^{-3}, is 4×10^{39} ergs s^{-1}. The power of the stellar wind originating in R136 is estimated to be 4×10^{39} ergs s^{-1} (Cox & Deharveng 1983), hence it alone is sufficient to explain the expansion motions of the CO clumps in 30 Doradus.

The detection of compact H_2 knots projected close to R136 seems to indicate that dense molecular structures can survive the strong winds and intense ionising radiation produced by the luminous young stars of the compact R136 cluster. The peak intensities in the 1-0 S(1) line from the three strong H_2 knots of the chain range from ~ 4×10^{-5} to 6×10^{-5} ergs s^{-1} cm^{-2} str^{-1}. If this H_2 emission is produced in a photodissociation region exposed to a UV radiation field with an intensity ~ 3500 times larger than the average intensity of the Galactic interstellar field (Werner et al. 1978), then the observed intensity in the 1-0 S(1) line implies that the emitting region has a density of ~ 2×10^5 cm^{-3} (Sternberg & Dalgarno 1989). To compute the total intensity in H_2 from the intensity in the 1-0 S(1) line we used a scale factor of 50 (cf. Goldshmidt & Sternberg 1995).

Conclusions and Outlook

We suggest that the weak CO clumps found projected toward the R136 region correspond to dense fragments of gas that are remnants of the original molecular cloud in which the young massive cluster R136 was born. Due to the strong winds from the massive stars and the large UV radiation field generated by them, the parental molecular cloud was fragmented and dispersed, and a cavity has been blown. The question arises as to the spatial location of the H_2 knots: Are they embedded within the giant H II region or are they rather located in their outskirts? If the dense fragments of molecular cold gas are within the hot cavity it implies that they have not been photoevaporated by the strong ionising radiation that has destroyed the rest of molecular gas. There are several arguments against this hypothesis, however. The velocities of the clumps are not close to the ambient cloud velocity, as expected in this scenario, but displaced by typically 10 km s^{-1}. Further, the clumps should exhibit an externally ionised envelope which, however, is not detected in the Brγ image. Most likely the CO clumps are remnants or fragments of a supershell of molecular gas that has been driven by the powerful stellar winds from the cluster of luminous young stars. This hypothesis is supported by the observed velocity field of the clumps. We envisage that the cold and dense fragments are exposed to the strong photodissociating UV radiation field from the central cluster and hence are being heated on their periphery. The molecular gas is being excited and emits by fluorescence in the 1-0 S(1) infrared line as seen in the 2.12μ images. Alternatively, the CO clumps could be undergoing shock interaction with the strong winds of the massive stars in the central cluster and thus, emitting in the NIR. The molecular/ionised gas interface will be investigated through a spectroscopic follow up to determine the excitation mechanism, temperature, and column density of the excited H_2.

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OTHER ASTRONOMICAL NEWS

A Fresh Look at the Future: "La Silla 2000++"

B. NORDSTRÖM, Chair, ESO Users' Committee

Background

Investments in observational facilities on a European scale, whether on a VLT or LSA scale or in telescopes of more modest size, must be based on careful medium- and long-term planning. As scientific priorities and external conditions (e.g. budgets!) change, so the plans must be revised periodically.

In 1995, a joint STC/ESO/UC Working Group presented a plan for the midterm future of La Silla, Scientific Priorities for La Silla in the VLT Era (ESO/STC-174; see also *The Messenger* 83, p. 48, 1996). This report made a first attempt to chart the complementary roles of the Paranal and La Silla observatories in the commissioning phase of the VLT, based on an ESO-wide questionnaire survey of the plans and priorities of the user community.

From an analysis of the replies, recommendations were derived for additions to and reductions in the facilities offered by ESO on La Silla, with the aim to optimise the scientific returns of the resources that could be realistically expected to be available. It was also recommended to revise such planning roughly every three years.

La Silla 1998: Current Status

Three years later, First Light on UT1 has been achieved with tremendous success (see the last issue of *The Messenger*!). The whole schedule for commissioning the VLT telescopes is thus firmly consolidated. Meanwhile, a new set of powerful VLT instruments has been approved for construction on an accelerated schedule. Many of us are already eagerly preparing applications for VLT observing time.

At the same time, many of the chief recommendations for the future of La Silla have been implemented, as evident from the last several issues of *The Messenger*.

Most importantly, the refurbished NTT is back in operation as a superb 3.5-m telescope with much-improved performance and equipped with new instruments (SOFI and SUSI2) which are second to none in their fields. In the process, invaluable lessons have been learned for the commissioning and operation of the VLT.

The 3.6-m telescope has achieved an image quality never seen during its previous 20 years of operation, and will soon receive a new, powerful mid-infrared instrument, TIMMI2. Its control system is also being upgraded. Moreover, the CES has been upgraded to a new class of high-resolution science with the new Very Long Camera, and is being provided with a permanent fibre link to the 3.6-m.

Among the smaller telescopes, the 2.2-m is receiving a new control system as well as a powerful Wide Field Imager based on an 8 k × 8 k CCD array. The 1.52-m ESO telescope will be equipped with the new FEROS spectrograph later this year, and a dome upgrade programme at the 1.54-m Danish should lead to improved image quality there. Moreover, the DENIS and EROS2 projects are going ahead full blast and producing lots of exciting science.

A top priority need for the future, wide-field imaging with high spatial resolution, is being addressed through the Napoli-ESO project to construct a 2.5-m VLT Survey Telescope on Paranal, covering a 1-degree field on a 16k × 16k CCD array from about 2001. And on the down side, the Schmidt, the CAT 1.4-m and the ESO 50-cm telescopes have been closed as general ESO facilities.

Last, but not least, ESO is rapidly moving into a welcome position of leadership as regards CCD detector and controller technology, with new 2k × 4k chips being fielded at a rapid pace with the new, lightning fast and low-noise FIERA controller.

A Fresh Start

The developments outlined above make this an opportune time to give the 1995 plans a thorough overhaul. Accordingly, the Director General has asked the Users' Committee to poll the user community in the ESO countries regarding their wishes for the future of La Silla, and the order of priority of these wishes. The replies must be evaluated on the background of an uncertain, but likely level or even decreasing budget for La Silla, cf. also the policy paper "The Role of ESO in European Astronomy" in the March-98 issue of *The Messenger*.

As before, synergy with the VLT is an important consideration: For many projects, the smaller telescopes (below 4 metres) are the platform we need to plan and prepare VLT projects. For some, the VLT will outperform any likely La Silla facility by a large factor. However, pressure on available VLT time will be great and other programmes can or even must be conducted on smaller telescopes than the VLT.