International Workshop on

First Decadal Review of the Edgeworth-Kuiper Belt: Toward New Frontiers

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On March 11 to 14, 2003, an international conference on the Minor Bodies in the Outer Solar System was held in Antofagasta, Chile. The conference, which was organized by ESO and Universidad Catolica del Norte (UCN) of Antofagasta, gathered about 70 participants from 20 countries. Originally, it was supposed to take place on the UCN campus. However, a student strike forced us to relocate at the last minute to the Carrera Club Hotel. Thanks to the efforts of A. Lagarini, the conference secretary (and ESO/Chile Science secretary) and to the Hotel staff, this did not cause any disruption. The traditional group photo (opposite) was shot in front of the Geological Museum of UCN. This short summary highlights some of the results presented at this conference; the proceedings, which are currently being edited, will be published as a special issue of "Earth, Moon and Planets."

Just over 10 years ago, the first Trans-Neptunian Object (TNO), 1992 QB_1, was discovered by Jewitt and Luu (IAUC 5611). This was the first of about 700 TNOs known today. They are believed to be remnants of the proto-planetary nebula, the largest objects of the Edgeworth-Kuiper Belt (EKB), extending beyond ~ 30 AU from the Sun, which is also the reservoir of Short Period Comets.

Thanks to more and more detailed numerical simulations, which are supported by a continuously growing number of objects with well determined orbits, the broad lines of the dynamical history of these objects now begins to be fairly clear. Morbidelli presented a review of the latest results. The TNOs are distributed as follow:

• A large fractions are located in the main belt (the "Classical Objects"), which includes objects with fairly circular orbits of low inclination.

• Others have been trapped in stable motion resonances with Neptune, constituting the Resonant Population, also known as Plutinos (named after Pluto, the largest member). One of the very promising theories explaining the number of objects in these resonances involves the outward migration of Neptune, a migration caused by the ejection of proto-planetesimals by this planet, during the early days of the Solar System. In that process, the stable resonances swept the inner Kuiper belt, trapping the objects encountered, and exciting their eccentricities and inclination.

• A third population is constituted by objects that have been ejected by interactions with Neptune. They are now on very eccentric and inclined orbits, constituting the "Scattered Disc."

One of the puzzling problems was that the "Classical Objects" appear to be distributed in a very dynamically cold population (low inclination), mixed with a secondary population of higher inclination. Gomez and Morbidelli demonstrated how this can be explained by interactions of objects of the inner edge of the Edgeworth Kuiper belt with Neptune, which would slightly "kick out" these objects. Malhotra and Kuchner further studied, from the theoretical point of view, the evolution of dust in the EKB, and compared it with other observed dust discs, suggesting some similarities.

Many other results were presented; for instance, Chiang performed extensive numerical simulations of the resonant objects, showing how they tend to cluster at preferred positions leading and trailing Neptune. Wyatt showed how similar effects could possibly be observed in extra-solar Edgeworth-Kuiper belts (also known as circumstellar discs). For instance, the disc around Vega displays some striking similarity with his simulations; if confirmed, this would imply the presence of (proto-) planet around that star. Fernandez, who is one of the founding fathers of the EKB as a reservoir of comets, made some promising connections between the Scattered Disc and the Oort cloud. Koebert discussed the possibility of a perturbation in the EKB as the origin of the "Late Heavy Bombardment" that the inner planets suffered 3.8 Gyr ago. Jancart presented a generic model that considers dissipative force combined with the effects of the orbital resonances.

After a session full of numerical simulations of dynamical processes, the observers presented the results of ongoing surveys. While over the past years, many "generic" surveys discovered the bulk of the currently known objects, we see now a specialization of these surveys. Buie et al presented the "Deep Ecliptic Survey," which aims at discovering many TNOs of intermediate brightness, with special care in securing the orbits by carefully planned (and time consuming) follow up. This follow up is critical, as about half of the known objects do not have orbits reliable enough to ensure their recovery. Moody, and Trujillo and Brown performed extremely wide, shallow surveys aimed at discovering all the brightest TNOs. Unfortunately, they did not detect any new Pluto, although there is still a possibility to have a couple of objects of that size out there. The survey by Moody et al has the very sad peculiarity of having been terminated by the destruction of its telescope, at Mount Stromlo. Fortunately, the data are not lost. Kinoshita, Holman and Hainaut have performed some deep to extremely deep surveys (with Subaru, VLT and HST) in order to study the faint end of TNO luminosity function. Kinoshita, with his results down to mag ~ 27.7 reported a bent in that luminosity function at mag ~ 24. The two other surveys (which should be even deeper, possibly beyond mag 30 by combining 3 nights of data on 2 VLTs in parallel) will soon check and refine this result. Indeed, such a bend is expected, as the power-law luminosity function cannot extend down to dust size. Otherwise, the resulting dust cloud would have been detected by IRAS. The size at which it happens will give direct constraints on the importance of disruptive/aggregating collisions and accretion in the early solar system. Also, we hope that these deep surveys will reveal what lies beyond 45 AU, where absolutely no object has been discovered so far, while the protoplanetary nebula is expected to have extended out to several hundred AU, making this lack of distant objects one of the most puzzling questions of the field.

The observers continued with physical studies of TNOs. It is worth reminding the reader that TNOs are faint (typically in the 20–25 mag range) making their physical studies quite challenging, especially for spectroscopy, where the expected absorption features are very shallow. In order to get a grasp of the whole population, large photometric surveys have been performed, collecting colours of almost 100 objects in total. They reveal a broad distribution ranging from neutral (solar) to very red colours, the large majority of objects having a fairly linear reflectivity spectrum. Dorressoundiram and Boehnhardt presented such a survey, performed in the framework of a VLT large program (which was concluded during the conference). Dorressoundiram and Thebault analysed them by comparing them with a model of collisions affecting the TNOs. Indeed, collisions, by resurfacing the objects, are expected to have an effect on their colours. Fulchignoni split the objects in families using multivariate analysis of their colours, as done 30 years ago with the main belt asteroids, resulting in taxonomic families that were later related to the physical nature of the objects. Stephens (who presented a large HST-based colour survey) and Peixinho performed various statistical tests in order to reveal possible correlations between the colours of the objects and their other parameters (orbital elements, size, etc). Sheppard, Jewitt and Ortiz have obtained light curves of several objects, which reveal their rotational periods and constrain their elongations. While most objects do not display significant magnitude variations (which is interpreted as almost spherical objects), about a quarter of them have light curves with full amplitude greater than 0.15 mag. Also, the measurements of 1995 SM_{55} (by Sheppard and Jewitt) displayed a strong dispersion – a controversial result, to which a controversial interpretation is attached: this could be the evidence of cometary activity. Cometary activity, caused at these distances by the sublimation of super-volatile ices such as CO, should in theory be possible, but has never been observed. It would be an interesting process for resurfacing the objects, possibly explaining (part of) their colour diversity. In the same line, Meech obtained some extremely deep images of TNO 24952 with Subaru, in order to search for direct evidence of a coma surrounding the object; her results are negative. The first phase functions of TNOs were presented by Sheppard and Jewitt, and Roussellot; they observed a phase dependency of the brightness much steeper than expected for icy bodies. Bagnulo obtained the first polarimetric measurements of a TNO–another challenge for the VLT. The phase function (which describes the variation of brightness of the object with the solar phase angle) and the polarimetric characteristics of an object can be interpreted in terms of surface properties. Barucci, De Bergh and Dotto analysed spectra of TNOs, some of them revealing variable surface features on some objects.

Recently, binary TNOs have been discovered. While binary asteroids tend to be formed by a main body and a small satellite, binary TNOs appear as pairs of fairly similar objects. Noll summarized the general properties of these objects, while Kern, Osip and Takato presented physical studies of some pairs.

The surface of TNOs is expected to be composed by a mixture of dust and ices. In order to understand the observations, various groups are performing laboratory experiments involving the irradiation of ices by high energy particles, in order to simulate the effect of cosmic rays on the TNOs. Moore and Brucato presented the latest results of such work. Cooper and Moroz presented their studies of irradiation of KBO surfaces; Cooper detailed the effects of the various high-energy particles that are expected to affect objects in the outermost parts of the Solar System. This "space weathering" is considered one of the most important processes explaining the diversity of colours observed in TNOs. Levasseur-Regourd has performed other laboratory experiments to study the formation of regoliths in microgravity.

Pluto, the largest TNO, caused some stellar occultations in 2002; these were the first ones observed since 1985 when its atmosphere was discovered. Roques (representing the European team, that was known as the "Pluto Flying Circus" because of its impressive deployment in South America) and Elliot presented the interpretations of these occultations, which demonstrate that the atmosphere of Pluto has significantly changed since 1985. A space mission to Pluto, which has already been cancelled several times for budgetary reasons, is now finally secured (under designation of New Horizon Mission), to be launched in 2006, for a Pluto/Charon fast fly-by around 2015. As it would be frustrating to go that far for only one (pair of) object, astronomers are now looking for suitable TNOs located on the track of the space probe. Unfortunately, these hypothetical candidates are now located in front of the Milky Way, appearing close to the galactic centre. The field crowding makes the discovery of TNOs in these regions very challenging. In the mean time, theoretical studies of that object continue: McKinnon presented models of the interior of Pluto and other large TNOs. The very small TNOs were also considered by Keller, who summarized the physical properties of cometary nuclei.

Future survey projects – including new methods – were discussed: Alcock, Cooray and Roques plan to discover objects by stellar occultations. While such an event is not very probably, observing many stars – or observing for a long time – should lead to many discoveries, leading to some information on the size and distance of the object. This is a very promising way to discover the smallest bodies of the EKB, and the

Panoramic view of the Monturaqui meteoritic crater. Photo by John Davies.

only way to observe comets in the Oort Cloud. Sekiguchi and Stansberry discussed the observations that will be possible with ASTE (the Japanese counterpart to APEX) and SIRTF (resp.). Jewitt presented a very ambitious project, Pan-STARRS, that will be installed on Mauna Kea and scan the whole sky on a weekly basis. This programme, originally targeted at Near Earth Objects, will discover and follow up all TNOs down to mag 24.

Having 70 astronomers in Antofagasta, a trip to the VLT was a must. Bus-loads invaded Paranal on the Saturday following the conference. Finally, on Sunday, 25 brave adventurers went into the deep Atacama Desert, lead by L. Barrera from UCN, in order to inspect the Monturaqui meteoritic crater. This 300-m diameter crater is located South of the large Salar de Atacama, a 6 hours drive from Antofagasta.

Amazingly, none of the participants was lost on the way, which goes against the legend that astronomers cannot be disciplined when needed.

In 1998, a conference on the same topic was held at ESO/Garching. At that meeting, we were confident that we were on the way to understanding the TNO formation, evolution, composition, etc, with the enthusiasm of a field that was only a few years old. The broad lines were traced, the general picture was in place. The feeling left by this new conference is that we have now enough information to reveal the weaknesses of this general picture, and that even some fundamental questions are still unanswered, such as the reason (or the reality) of a sharp edge terminating the EKB at 45 AU, or the nature of the processes leading to the observed colour distribution.

Finally, during the final discussion session, it was unanimously decided that the branch of science devoted to the study of the TNOs, also designated as Edgeworth-Kuiper belt Object, will be known as EKOlogy.

Fellows at ESO

Stefano Ettori

In October 2001, I started my fellowship in ESO, after 6 years spent at IoA in Cambridge (England) doing my PhD and first Post-Doc in the X-ray Group headed by Andrew Fabian. My area of research is clusters and superclusters of galaxies, with particular interest on the cosmological implications of their observed properties. To study these objects that are the largest virialized structures in the Universe, I look in the optical (with VLT) and X-ray (through XMM and Chandra) wavebands. These observations allow me to determine densities and temperatures of the hot plasma collapsed in the dark matter halo and to recover the cluster baryonic and gravitational masses. With my collaborators here at ESO, I do this at different redshifts from moderate $z = 0.3$, where the X-ray masses can be directly compared to those obtained from weak lensing analyses, up to 1.2 where few clusters are known through X-ray detection. Of these systems, I have recently used their baryonic mass fraction as cosmological tool to put stringent constraints on the energy constituents of the cosmos.

My duties at ESO are to support the release to the community of the ground based data of the Chandra Deep Field South as part of the Great Observatories Origin Deep Survey (GOODS) project, to represent the Fellows and Students in the Computer Co-ordination Group in Garching and to maintain X-ray software for the few of us that are interested in it.

I am really enjoying my time here: ESO is a perfect place to work both in terms of hard/software assistance and of motivations, it promotes the interaction with other researchers with several lunch/tea talks, informal discussions and crowded offices (sic!) and is big enough to find anytime the right person to discuss with. For my family and myself, it was a debated question whether to accept this fellowship, but now, and also considering the difficulties in changing social life in a country with such a strange language (still originating from Ur-germanic but nothing to do with English...), we think we made the right choice.

Lisa Germany

Having arrived at ESO Chile in September 2000, I truly feel like one of the veterans of La Silla now. There has been an almost complete turnover of support astronomers since I arrived, and I have met many of the visiting astronomers on several previous occasions! But this is part of the great thing about working at La Silla - you get to talk to astronomers from all over the world, learn about different areas of astronomy and instrumentation, build collaborations, and make new friends.

I came here straight from my PhD, which I completed at Mount Stromlo Observatory in Canberra, Australia. I was the 3rd person from Stromlo working here at ESO Chile in 2000/2001, and all three of us actually lived in the same house while we were students! I'm one of these Supernova people who, along with the Gamma Ray Burst people, are the bane of visiting astronomers (all those Targets of Opportunity stealing valuable telescope time). My biggest claim to fame during my PhD is my contribution to the discussion about whether Supernovae and Gamma Ray Bursts are connected.

I am currently investigating the fields around apparently "hostless" supernovae (i.e. supernovae which did not appear to have a host galaxy) to look for faint hosts and, if they exist, investigate their properties. So far, all the supernovae do appear to have hosts, and in one case, we can still see the supernova itself three years after the event! For a supernova to be visible after such a long time is highly unusual, and makes this particular supernova a very interesting object to study – stay tuned for more on that one!

My other main interest is public outreach and taking science to the people. Before starting my PhD I completed a Graduate Diploma in Scientific Communication and have always wanted to pursue this further. To my great joy, ESO is developing an exhibition to go into the science centre here in Santiago, and I am very happy to be part of the team of people working on that.

Linda Schmidtobreick

When I performed my first observations in La Silla in February 1997, I immediately fell in love with the place and decided I wanted to work here someday. In September 2001 after finishing my PhD, working for a year at MPIA Heidelberg, and spending two years as a Postdoc in Padova, I indeed started as an ESO Fellow – with