Issue No. 52 *May 2007*

DISTANT EKOs

The Kuiper Belt Electronic Newsletter

Edited by: Joel Wm. Parker

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CONTENTS

NEWS & ANNOUNCEMENTS

There were no new TNO discoveries announced since the previous issue of *Distant EKOs* and 1 new Centaur/SDO discovery:

2006 AO101

Objects recently assigned names:

2001 QT297 = Teharonhiawako

Current number of TNOs: 1026 (including Pluto)
Current number of Centaurs/SDOs: 196
Current number of Neptune Trojans: 5

Out of a total of 1227 objects:

512 have measurements from only one opposition
470 of those have had no measurements for more than a year
252 of those have arcs shorter than 10 days

(for more details, see: `http://www.boulder.swri.edu/ekonews/objects/recov_stats.gif`)

PAPERS ACCEPTED TO JOURNALS

A Collisional Family of Icy Objects in the Kuiper Belt

M.E. Brown[1], K.M. Barkume[1], D. Ragozzine[1], and E.L. Schaller[1]

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The small bodies in the solar system are thought to have been highly affected by collisions and erosion. In the asteroid belt, direct evidence of the effects of large collisions can be seen in the existence of many separate families of asteroids, where each family consists of many asteroids with similar orbits and, frequently, similar surface properties, and is the remnant of a single catastrophic impact. In the region beyond Neptune, in contrast, no collisionally created families have hitherto been found. The third largest known Kuiper belt object (KBO), 2003 EL61, however, is thought to have experienced a giant impact that created its multiple satellite system, stripped away much of an overlying ice mantle, and left it with a rapid rotation. Here we report the discovery of a family of KBOs with nearly identical surface properties and orbits as 2003 EL61. This family appears to be fragments of the ejected ice mantle of 2003 EL61. 2003 EL61, its two satellites, and its family of collisional remnants provide a new window into the physical, dynamical, and chemical effects of giant impacts in the solar system.

Published in: Nature, 446, 294, (2007 March 15)

Preprints available on the web at `http://www.gps.caltech.edu/~mbrown/papers`

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Properties of the Icy Surface of the TNO 136108 (2003 EL_{61})

F. Merlin[1], A. Guilbert[1], C. Dumas[2], M.A. Barucci[1], C. de Bergh[1], and P. Vernazza[1]

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Context. Spectroscopic observations of numerous trans-Neptunian objects (TNOs), considered to be among the most pristine objects of the solar system, have revealed the presence of several kinds of surface ices. The high-sensitivity spectra that can be measured for the brightest objects also provide constraints on the physical properties of the surface (e.g. ice phase, temperature).

Aims. We observed one of the largest and brightest TNOs, 136108 (2003 EL_{61}), to determine its surface composition properties and to constrain its surface properties.

Methods. We obtained new visible spectra with EMMI on the ESO-NTT and near-infrared spectra with the new 3D spectrograph SINFONI at the ESO-VLT. Our analysis consists of radiative transfer modelling to constrain composition and surface properties and to identify the precise minimum of the 1.65 micron band to constrain the surface temperature.

Results. The observations reveal a surface essentially composed of water ice. An absorption feature at 1.65 micron clearly indicates the presence of ice in the crystalline phase. Spectral modelling suggests that a small fraction of the surface ice is in the amorphous state. We also derive the temperature of the crystalline ice at the surface.

Published in: Astronomy & Astrophysics, 466, 1185 (2007 May)

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Ices on (90377) Sedna: Confirmation and Compositional Constraints

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We report measurements of reflectances of 90377 Sedna at $\lambda > 2.5$ μm using the Infrared Array Camera (IRAC) on the Spitzer Space Telescope. Sedna orbits well beyond even the Kuiper Belt, with a perihelion distance of 76 AU, and is therefore very faint as viewed from Earth, despite its relatively large size. Previously published near-infrared spectra show possible signatures of CH_4 and N_2 at $\sim$2.3 and $\sim$2.15 μm, respectively. These and other ices also exhibit much stronger absorptions at $\lambda > 2.5$ μm, providing the motivation for the present work. We detected flux from Sedna at 3.6 and 4.5 μm, but not at 5.8 or 8.0 μm. The measured IRAC fluxes are converted to geometric albedos and combined with previous measurements of the visible and near-infrared spectra. Strong absorption at both 3.6 and 4.5 μm (relative to the 2.0–2.5 μm region) is readily apparent, confirming the presence of ices on the surface of Sedna. Spectral modeling of the full wavelength range (0.4–4.5 μm) provides further constraints. We find that CH_4 is required to fit the new data points, but that these new data points can not be adequately described with models containing CH_4 and N_2 as the only ices. We suggest that H_2O ice is also present. Several characteristics of the spectrum of Sedna suggest an absence of atmospheric volatile transport, in contrast to the large objects Eris and 2005 FY_9.

Published in: Astronomy & Astrophysics, 466, 395(April 2007)
For reprints, contact jemery@mail.arc.nasa.gov

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Search for Cometary Activity in Three Centaurs [(60558) Echeclus, 2000 FZ_{53} and 2000 GM_{137}] and two Trans-Neptunian Objects [(29981) 1999 TD_{10} and (28978) Ixion]

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We have searched for evidence of a dust coma around three Centaurs [(60558) Echeclus (or 174P/Echeclus), 2000 FZ_{53} and 2000 GM_{137}] and two trans-Neptunian objects [(28978) Ixion and (29981) 1999 TD_{10}]. Despite the recent discovery of a coma around (60558) Echeclus, none of these objects, observed with a 3.5- and an 8-m telescope, presents any evidence of cometary activity at the time of observation. Upper limits for the $Af\rho$ parameters and dust production rates are presented.

Published in: Monthly Notices of the Royal Astronomical Society, 376, 881 (2007 April)

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The Water Ice Rich Surface of (145453) 2005 RR43: A Case for a Carbon-depleted Population of TNOs?

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Recent results suggest that there is a group of trans-Neptunian objects (TNOs) (2003 EL_{61} being the biggest member), with surfaces composed of almost pure water ice and with very similar orbital elements. These objects provide exciting laboratories for the study of the processes that prevent the formation of an evolved mantle of organics on the surfaces of the bodies in the trans-Neptunian belt (TNb).

We study the surface composition of another TNO that moves in a similar orbit, (145453) 2005 RR_{43}, and compare it with the surface composition of the other members of the group.

We report visible and near-infrared spectra in the 0.53-2.4μm spectral range, obtained with the 4.2m William Herschel Telescope and the 3.58m Telescopio Nazionale Galileo at the "Roque de los Muchachos" Observatory (La Palma, Spain). Scattering models are used to derive information about its surface composition. We also measure the depth D of the water ice absorption bands and compare with those of the other members of the group.

The spectrum of 2005 RR_{43} is neutral in color in the visible and dominated by very deep water ice absorption bands in the near infrared (D= 70.3$\pm$2.1% and 82.8 $\pm$4.9% at 1.5 μm and 2.0 μm respectively). It is very similar to the spectrum of the group of TNOs already mentioned. All of them present much deeper water ice absorption bands (D >40 %) than any other TNO except Charon. Scattering models show that its surface is covered by water ice, a significant fraction in crystalline state with no trace (5% upper limit) of complex organics. Possible scenarios to explain the existence of this population of TNOs are discussed: a giant collision, an originally carbon depleted composition, or a common process of continuous resurfacing.

2005 RR_{43} is member of a group, may be a population, of TNOs clustered in the space of orbital parameters that show abundant water ice and no signs of complex organics and which origin needs to be further investigated. The lack of complex organics in their surfaces suggests a significant smaller fraction of carbonaceous volatiles like CH_4 in this population than in "normal" TNOs. A carbon depleted population of TNOs could be the origin of the population of carbon depleted Jupiter family comets already noticed by A'Hearn et al. (1995).

To appear in: Astronomy & Astrophysics

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An Exploration of the Kozai Resonance in the Kuiper Belt

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The Kozai resonance of Kuiper Belt objects is explored using a model of a circular-restricted three-body problem. We use an analytical approach to find the topological structure of the plane of the eccentricity and the argument of perihelion. We find that objects inside the 2:3 and 1:2 resonances can be inside the Kozai resonance, with their arguments of perihelion ω librating around 90° or 270°. This is consistent with the fact that Pluto is inside both the 2:3 resonance and the Kozai resonance. Furthermore, objects outside the mean-motion resonances are also found to be inside the Kozai resonance. We discover that there are stable equilibrium points of ω at 90° and 270°, but not at 0° and 180° as was shown in the work of Thomas & Morbidelli. To verify our results, numerical experiments are carried out with various longitudes of the node and mean anomalies. In these experiments, some test particles are found to be in the Kozai resonance around 90° for one billion years, and the libration amplitudes of their arguments of perihelion are small. This is in agreement with our analytical results. No particles are found to stay inside the Kozai resonance around = 0 or 180, although some particles exist temporarily in the Kozai resonance around = 0 or 180. We conclude that the Kozai resonance around $\omega = 90°$ or 270° exists both inside and outside the mean-motion resonance for Kuiper Belt objects.

Published in: Monthly Notices of the Royal Astronomical Society, 377, 133 (2007 May)

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Light Curves of Dwarf Plutonian Planets and other Large Kuiper Belt Objects: Their Rotations, Phase Functions and Absolute Magnitudes

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I report new time-resolved light curves and determine the rotations and phase functions of several large Kuiper Belt objects, which includes the dwarf planet Eris (2003 UB_{313}). Three of the new sample of ten Trans-Neptunian objects display obvious short-term periodic light curves. (120348) 2004 TY_{364} shows a light curve which if double-peaked has a period of 11.70 ± 0.01 hours and a peak-to-peak amplitude of 0.22 ± 0.02 magnitudes. (84922) 2003 VS_2 has a well defined double-peaked light curve of 7.41 ± 0.02 hours with a 0.21 ± 0.02 magnitude range. (126154) 2001 YH_{140} shows variability of 0.21 ± 0.04 magnitudes with a possible 13.25 ± 0.2 hour single-peaked period. The seven new KBOs in the sample which show no discernible variations within the uncertainties on short rotational time scales are 2001 UQ_{18}, (55565) 2002 AW_{197}, (119979) 2002 WC_{19}, (120132) 2003 FY_{128}, (136108) Eris 2003 UB_{313}, (90482) Orcus 2004 DW, and (90568) 2004 GV_9. Four of the ten newly sampled Kuiper Belt objects were observed over a significant range of phase angles to determine their phase functions and absolute magnitudes. The three medium to large sized Kuiper Belt objects 2004 TY_{364}, Orcus, and 2004 GV_9 show fairly steep linear phase curves ($\sim$ 0.18 to 0.26 mags per degree) between phase angles of 0.1 and 1.5 degrees. This is consistent with previous measurements obtained for moderately sized Kuiper Belt objects. The extremely large dwarf planet Eris (2003 UB_{313}) shows a shallower phase curve (0.09 ± 0.03 mags per degree) which is more similar to the other known dwarf planet Pluto. It appears the surface properties of the largest

dwarf planets in the Kuiper Belt maybe different than the smaller Kuiper Belt objects. This may have to do with the larger objects ability to hold more volatile ices as well as sustain atmospheres. Finally, it is found that the absolute magnitudes obtained using the measured phase slopes are a few tenths of magnitudes different from those given by the Minor Planet Center.

To appear in: The Astronomical Journal (2007 August)
For preprints, contact sheppard@dtm.ciw.edu
or on the web at http://www.arxiv.org/abs/0704.1636

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Short Term Rotational Variability in the Large TNO 2005 FY_9

J.L. Ortiz[1], P. Santos Sanz[1], P.J. Gutierrez[1], R. Duffard[1], and F.J. Aceituno[1]

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Despite the fact that 2005 FY_9 is one of the largest transneptunian objects (TNOs), and a dwarf planet candidate, little is known about this object apart from surface composition constraints. The goal of this work is the study of 2005 FY_9's short term variability in order to determine the amplitude of the lightcurve, which can be linked to the degree of elongation of the body or to the degree of albedo heterogeneity on the surface. Besides, the rotation period can be determined. CCD photometric observations of the transneptunian object 2005 FY_9 in R band on 21 nights spanning several months have been carried out using the 1.5m telescope at Sierra Nevada Observatory and the 2.2m telescope at Calar Alto Observatory. The time series analysis results in confident detection of short-term variability. The most significant periodicities are 11.24 $\pm$ 0.01 h and its double, but other possibilities cannot be ruled out. The 22.48 h double peaked rotational phase curve is slightly preferred from our analysis. As for the amplitude of the lightcurve, we get a peak to peak variability of 0.03 $\pm$ 0.01 mag. This result is compatible with a nearly spherical body that has a very homogeneous surface. There is also the possibility that the body is rotating nearly pole on, but we believe this is less likely. Very weak constraints are obtained for the density and internal strength based on the rotational properties derived from the photometry.

To appear in: Astronomy and Astrophysics
For preprints, contact ortiz@iaa.es

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Spin Limits of Solar System Bodies: From the Small Fast-rotators to 2003 EL61

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Holsapple [Holsapple, K.A., 2001. Icarus 154, 432448; Holsapple, K.A., 2004. Icarus 172, 272303] determined the spin limits of bodies using a model for solid bodies without tensile or cohesive strength, but with the pressure-induced shear strengths characteristic of dry sands and gravels. That theory included the classical analyses for fluid bodies given by Maclaurin, Jacobi and others as a special case. For the general solid bodies, it was shown that there exists a very wide range of permissible shapes and spin limits; and explicit algebraic results for those limits were given. This paper gives an extension of those analyses to include geological-like materials that also have tensile and cohesive strength. Those strengths are necessary to explain the smaller, fast-rotating asteroids

discovered in the last few years. I find that the spin limits for these more general solids have two limiting regimes: a strength regime for bodies with a diameter < 3 km, and a gravity regime for the larger bodies with a diameter > 10 km (which is the case covered by the earlier papers). I derive explicit algebraic forms for the dependence of the spin limits on shape, mass density and material strength properties. The comparison of the theory to the database for the spins of asteroids and trans-neptunian objects (TNO's) objects shows excellent agreement. For large bodies (diameter $D > 10$ km), the presence of cohesive and/or tensile strength does not permit higher spin rates than would be allowed for rubble pile bodies. Thus, the fact that the spin rates of all large bodies is limited to periods greater than about 2 h does not imply that they are rubble piles. In contrast, for small bodies ($D < 10$ km) the presence of even a very small amount of strength allows much more rapid spins. Small bodies might then be rubble piles but require a small amount of bonding. Finally, I make some remarks about the application of the theory to the TNO's and large asteroids, and question whether a common assumption by researchers that those bodies must take on relaxed fluid shapes is warranted. If not, then the densities and shapes required by that assumption are not valid. I use 2003 EL61 as a prime example.

Published in: Icarus, 187, 500 (2007 April)
For preprints, contact holsapple@aa.washington.edu

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The Orbit, Mass, Size, Albedo, and Density of (65489) Ceto/Phorcys: A Tidally-evolved Binary Centaur

W.M. Grundy[1], J.A. Stansberry[2], K.S. Noll[3], D.C. Stephens[4], D.E. Trilling[2], S.D. Kern[3], J.R. Spencer[5], D.P. Cruikshank[6], and H.F. Levison[5]

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Hubble Space Telescope observations of Uranus- and Neptune-crossing object (65489) Ceto/Phorcys (provisionally designated 2003 FX_{128}) reveal it to be a close binary system. The mutual orbit has a period of 9.554±0.011 days and a semimajor axis of 1840±48 km. These values enable computation of a system mass of $(5.41\pm0.42)\times10^{18}$ kg. Spitzer Space Telescope observations of thermal emission at 24 and 70 μm are combined with visible photometry to constrain the system's effective radius (109^{+10}_{-11} km) and geometric albedo ($0.084^{+0.021}_{-0.014}$). We estimate the average bulk density to be $1.37^{+0.66}_{-0.32}$ g cm^{-3}, consistent with ice plus rocky and/or carbonaceous materials. This density contrasts lower densities recently measured with the same technique for three other comparably-sized outer Solar System binaries (617) Patroclus, (26308) 1998 SM_{165}, and (47171) 1999 TC_{36}, and is closer to the density of the saturnian irregular satellite Phoebe. The mutual orbit of Ceto and Phorcys is nearly circular, with an eccentricity $\leq$0.015. This observation is consistent with calculations suggesting that the system should tidally evolve on a timescale shorter than the age of the solar system.

To appear in: Icarus
Preprints available from http://www.lowell.edu/~grundy/abstracts/2007.Ceto-Phorcys.html

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Visible Spectroscopic and Photometric Survey of Jupiter Trojans: Final Results on Dynamical Families

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We present the results of a visible spectroscopic and photometric survey of Jupiter Trojans belonging to different dynamical families. The survey was carried out at the 3.5m New Technology Telescope (NTT) of the European Southern Observatory (La Silla, Chile) in April 2003, May 2004 and January 2005. We obtained data on 47 objects, 23 belonging to the L5 swarm and 24 to the L4 one. These data together with those already published by Fornasier et al. (2004a) and Dotto et al. (2006), acquired since November 2002, constitute a total sample of visible spectra for 80 objects.

The survey allows us to investigate six families (Aneas, Anchises, Misenus, Phereclos, Sarpedon, Panthoos) in the L5 cloud and four L4 families (Eurybates, Menelaus, 1986 WD and 1986 TS6). The sample that we measured is dominated by D-type asteroids, with the exception of the Eurybates family in the L4 swarm, where there is a dominance of C- and P-type asteroids.

All the spectra that we obtained are featureless with the exception of some Eurybates members, where a drop-off of the reflectance is detected shortward of 5200 Å. Similar features are seen in main belt C-type asteroids and commonly attributed to the intervalence charge transfer transition in oxidized iron.

Our sample comprises fainter and smaller Trojans as compared to the literature's data and allows us to investigate the properties of objects with estimated diameter smaller than 40–50 km. The analysis of the spectral slopes and colors versus the estimated diameters shows that the blue and red objects have indistinguishable size distribution, so any relationship between size and spectral slopes has been found.

To fully investigate the Trojans population, we include in our analysis 62 spectra of Trojans available in literature, resulting in a total sample of 142 objects. Although the mean spectral behavior of L4 and L5 Trojans is indistinguishable within the uncertainties, we find that the L4 population is more heterogeneous and that it has a higher abundance of bluish objects as compared to the L5 swarm.

Finally, we perform a statistical investigation of the Trojans's spectra property distributions as a function of their orbital and physical parameters, and in comparison with other classes of minor bodies in the outer Solar System. Trojans at lower inclination appear significantly bluer than those at higher inclination, but this effect is strongly driven by the Eurybates family. The mean colors of the Trojans are similar to those of short period comets and neutral Centaurs, but their color distributions are different.

To appear in: Icarus

Preprints available on the web at `http://arxiv.org/abs/0704.0350` and `http://dx.doi.org/10.1016/j.icarus.2007.03.033`

PAPERS RECENTLY SUBMITTED TO JOURNALS

On the Atmospheres of Objects in the Kuiper Belt

S. Alan Stern[1] **and Laurence M. Trafton**[3]

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Submitted to: Space Science Series Volume "Kuiper Belt Objects"

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Production of Trans-Neptunian Binaries through Chaos-assisted Capture

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Submitted to: Monthly Notices of the Royal Astronomical Society

Preprints available on the web at `http://arxiv.org/abs/0705.0475`

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Detectability of Occultation of Stars by Objects in the Kuiper Belt and Oort Cloud

T.C. Nihei[1,2], **M.J. Lehner**[2], **F.B. Bianco**[1,2], **S.-K. King**[3], **J.M. Giammarco** [4], **and C. Alcock**[2]

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[3] Dept. of Physics, Temple University, Barton Hall, Philadelphia, PA 19122, USA

Submitted to: The Astronomical Journal

Preprints on the web at `http://arxiv.org/abs/astro-ph/0703460`

OTHER PAPERS OF INTEREST

Extrasolar Planet Taxonomy: A New Statistical Approach

S. Marchi[1]

[1] Department of Astronomy, Padova University, Italy

The Astrophysical Journal

For preprints, contact `simone.marchi@unipd.it`

BOOKS

Below are a more chapters from the "Kuiper Belt" book (M.A. Barucci, H. Boehnhardt,D. Cruikshank, and A. Morbidelli, eds.; U. Arizona Press, Tucson, 2007). Other chapters were included in issue #51 of this newsletter, and I will include more chapters in later issues of the newsletter if they are submitted to me, as well as an outline of the full book when it is published.

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The Dynamical Structure of the Kuiper Belt and its Primordial Origin

A. Morbidelli[1], H.F. Levison[2], and R. Gomes[3]

[1] Observatoire de la Côte d'Azur, France

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[3] Observatório Nacional/MCT, Brazil

This chapter discusses the dynamical properties of the Kuiper belt population. Then, it focuses on the characteristics of the Kuiper belt that cannot be explained by its evolution in the framework of the current solar system. We review models of primordial solar system evolution that have been proposed to reproduce the Kuiper belt features, outlining advantages and problems of each of them.

For preprints, contact morby@obs-nice.fr
or on the web at http://arxiv.org/abs/astro-ph/0703558

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Formation and Collisional Evolution of Kuiper Belt Objects

Scott J. Kenyon[1], Benjamin C. Bromley[2], David P. O'Brien[3], and Donald R. Davis[3]

[1] Smithsonian Astrophysical Observatory, USA

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This chapter summarizes analytic theory and numerical calculations for the formation and collisional evolution of KBOs at 20–150 AU. We describe the main predictions of a baseline self-stirring model and show how dynamical perturbations from a stellar flyby or stirring by a giant planet modify the evolution. Although robust comparisons between observations and theory require better KBO statistics and more comprehensive calculations, the data are broadly consistent with KBO formation in a massive disk followed by substantial collisional grinding and dynamical ejection. However, there are important problems reconciling the results of coagulation and dynamical calculations. Contrasting our current understanding of the evolution of KBOs and asteroids suggests that additional observational constraints, such as the identification of more dynamical families of KBOs (like the 2003 EL61 family), would provide additional information on the relative roles of collisional grinding and dynamical ejection in the Kuiper Belt. The uncertainties also motivate calculations that combine collisional and dynamical evolution, a 'unified' calculation that should give us a better picture of KBO formation and evolution.

Preprints available on the web at http://arxiv.org/abs/0704.0259

CONFERENCE CONTRIBUTIONS

Cometary Diversity and Cometary Families

J. Crovisier[1]

[1] Observatoire de Paris, 5 Place Jules Janssen, F-92195 Meudon, France

To appear in:
Proceedings of the XVIII Rencontres de Blois: *Planetary Science: Challenges and Discoveries*
(2006 May 28 – June 2 2006, Blois, France)
Preprint available on the web at `http://arxiv.org/abs/astro-ph/0703785`

CONFERENCE INFORMATION

First Workshop on Binaries in the Solar System

2007 August 20-23
Steamboat Springs, Colorado, USA

The goal of this workshop is to bring together various ideas on detection, characterization, and formation of binary and multiple objects among the NEO, main-belt, Trojan, and TNO populations. The format will be in a true workshop style, with all talks being invited, reviewing major aspects of the field, with substantial time for discussion after each talk. Poster papers will allow presentation of more specific results. The venue is a small (pop. 10,000) ski-resort village in the Colorado Rocky Mountains.

A developing web page, with the first announcement, which contains more details and the method of indicating interest, can be found at: `http://www.boulder.swri.edu/binary-mtg/` or send email to: `binary-mtg@boulder.swri.edu`

The *Distant EKOs* Newsletter is dedicated to provide researchers with easy and rapid access to current work regarding the Kuiper belt (observational and theoretical studies), directly related objects (e.g., Pluto, Centaurs), and other areas of study when explicitly applied to the Kuiper belt.

We accept submissions for the following sections:
⋆ Abstracts of accepted papers
⋆ Titles of submitted (but not yet accepted) papers and conference articles
⋆ Thesis abstracts
⋆ Short articles, announcements, or editorials
⋆ Status reports of on-going programs
⋆ Requests for collaboration or observing coordination
⋆ Table of contents/outlines of books
⋆ Announcements for conferences
⋆ Job advertisements
⋆ General news items deemed of interest to the Kuiper belt community

A LaTeX template for submissions is appended to each issue of the newsletter, and is sent out regularly to the e-mail distribution list. Please use that template, and send your submission to:

`ekonews@boulder.swri.edu`

The *Distant EKOs* Newsletter is available on the World Wide Web at:

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Recent and back issues of the newsletter are archived there in various formats. The web pages also contain other related information and links.

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Moving ... ??

If you move or your e-mail address changes, please send the editor your new address. If the newsletter bounces back from an address for three consecutive issues, the address will be deleted from the mailing list. All address changes, submissions, and other correspondence should be sent to:

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