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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*, but there was 1 new Centaur/SDO discovery:

2012 QQ14

and 1 new Neptune Trojan discovery:

2011 HM102

Reclassified objects:

2010 RF43 (SDO → TNO)

Objects recently assigned numbers:

2010 NV1 = (336756)

Current number of TNOs: 1252 (including Pluto)
Current number of Centaurs/SDOs: 356
Current number of Neptune Trojans: 9

Out of a total of 1617 objects:

642 have measurements from only one opposition
626 of those have had no measurements for more than a year
320 of those have arcs shorter than 10 days

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

PAPERS ACCEPTED TO JOURNALS

The La Silla - QUEST Kuiper Belt Survey

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We describe the instrumentation and detection software and characterize the detection efficiency of an automated, all-sky, southern-hemisphere search for Kuiper Belt objects brighter than R mag 21.4. The search relies on Yale University's 160-Megapixel QUEST camera, previously used for successful surveys at Palomar that detected most of the distant dwarf planets, and now installed on the ESO 1.0-m Schmidt telescope at La Silla, Chile. Extensive upgrades were made to the telescope control system to support automation, and significant improvements were made to the camera. To date, 63 new KBOs have been discovered, including a new member of the Haumea collision family (2009 YE7) and a new distant object with inclination exceeding 70 deg (2010 WG9). In a survey covering $\sim$7500 deg^2, we have thus far detected 77 KBOs and Centaurs, more than any other full-hemisphere search to date. Using a pattern of dithered pointings, we demonstrate a search efficiency exceeding 80%. We are currently on track to complete the southern-sky survey and detect any bright KBOs that have eluded detection from the north.

To appear in: The Astronomical Journal

Preprints available on the web at `http://arxiv.org/abs/1205.5214`

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The Effect of Orbital Evolution on the Haumea (2003 EL_{61}) Collisional Family

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The Haumea family is currently the only identified collisional family in the Kuiper belt. We numerically simulate the long-term dynamical evolution of the family to estimate a lower limit of the family's age and to assess how the population of the family and its dynamical clustering are preserved over Gyr timescales. We find that the family is not younger than 100 Myr, and its age is at least 1 Gyr with 95% confidence. We find that for initial velocity dispersions of 50-400 m/s, approximately 20-45% of the family members are lost to close encounters with Neptune after 3.5 Gyr of orbital evolution. We apply these loss rates to two proposed models for the formation of the Haumea family, a graze-and-merge type collision between two similarly sized, differentiated KBOs or the collisional disruption of a satellite orbiting Haumea. For the graze-and-merge collision model, we calculate that >85% of the expected mass in surviving family members within 150 m/s of the collision has been identified, but that one to two times the mass of the known family members remains to be identified at larger velocities. For the satellite-break-up model, we estimate that the currently identified family members account for $\sim$50% of the expected mass of the family. Taking observational incompleteness into account, the observed number of Haumea family members is consistent with either formation scenario at the 1σ level, however both models predict more objects at larger relative velocities (>150 m/s) than have been identified.

Published in: Icarus, 221, 106 (2012 September)

For preprints, contact `kvolk@lpl.arizona.edu`

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(309239) 2007 RW_{10}: a Large Temporary Quasi-satellite of Neptune

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Context. Upon discovery, asteroid (309239) 2007 RW_{10} was considered a Neptune Trojan candidate. The object is currently listed by the Minor Planet Center as a Centaur but it is classified as a scattered disk or trans-Neptunian object by others. Now that its arc-length is 8154 d and has been observed for more than 20 yr, a more robust classification should be possible.

Aims. Here we explore the orbital behaviour of this object in order to reveal its current dynamical status.

Methods. We perform N-body simulations in both directions of time to investigate the evolution of its orbital elements. In particular, we study the librational properties of the mean longitude.

Results. Its mean longitude currently librates around the value of the mean longitude of Neptune with an amplitude of nearly 50° and a period of about 7.5 kyr. Our calculations show that it has been in its present dynamical state for about 12.5 kyr and it will stay there for another 12.5 kyr. Therefore, its current state is relatively short-lived. Due to its chaotic behaviour, the object may have remained in the 1:1 mean motion resonance with Neptune for several 100 kyr at most, undergoing transitions between the various resonant states.

Conclusions. (309239) 2007 RW_{10} is currently a quasi-satellite, the first object of this dynamical class to be discovered around Neptune. With a diameter of about 250 km, it is the largest known co-orbital in the solar system. Although it is not a Centaur now, it may become one in the future as it appears to move in an unstable region. Its significant eccentricity (0.30) and inclination (36°), strongly suggest that it did not form in situ but was captured, likely from beyond Neptune. With an apparent magnitude of 21.1 at opposition (October), it is well suited for spectroscopic observations that may provide information on its composition and hence eventually its origin.

Published in: Astronomy and Astrophysics, 545, L9 (2012 September)
For preprints, contact `nbplanet@fis.ucm.es`
or on the web at `http://adsabs.harvard.edu/abs/2012A%26A...545L...9D`

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The Color Differences of Kuiper Belt Objects in Resonance with Neptune

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The optical colors of 58 objects in mean motion resonance with Neptune were obtained. The various Neptune resonant populations were found to have significantly different surface color distributions. The 5:3 and 7:4 resonances have semi-major axes near the middle of the main Kuiper Belt and both are dominated by ultra-red material (spectral gradient: $S \gtrsim 25$). The 5:3 and 7:4 resonances have statistically the same color distribution as the low inclination "cold" classical belt. The inner 4:3 and distant 5:2 resonances have objects with mostly moderately red colors ($S \sim 15$), similar to the scattered and detached disk populations. The 2:1 resonance, which is near the outer edge of the main Kuiper Belt, has a large range of colors with similar numbers of moderately red and ultra-red objects at all inclinations. The 2:1 resonance was also found to have a very rare neutral colored object showing that the 2:1 resonance is really a mix of all object types. The inner 3:2 resonance, like the outer 2:1, has a large range of objects from neutral to ultra-red. The Neptune Trojans (1:1 resonance) are only slightly red ($S \sim 9$), similar to the Jupiter Trojans. The

inner 5:4 resonance only has four objects with measured colors but shows equal numbers of ultra-red and moderately red objects. The 9:5, 12:5, 7:3, 3:1 and 11:3 resonances do not have reliable color distribution statistics since few objects have been observed in these resonances, though it appears noteworthy that all three of the measured 3:1 objects have only moderately red colors, similar to the 4:3 and 5:2 resonances. The different color distributions of objects in mean motion resonance with Neptune are likely a result from the disruption of the primordial Kuiper Belt from the scattering and migration of the giant planets. The few low inclination objects known in the outer 2:1 and 5:2 resonances are mostly only moderately red. This suggests if the 2:1 and 5:2 have a cold low inclination component, the objects likely had a significantly different origin than the ultra-red dominated cold components of the cold classical belt and 5:3 and 7:4 resonances.

To appear in: The Astronomical Journal
For preprints, contact sheppard@dtm.ciw.edu
or on the web at http://arxiv.org/abs/1210.0537

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Polarimetry of Transneptunian Objects (136472) Makemake and (90482) Orcus

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Context. We study the surface properties of transneptunian populations of solar system bodies.

Aims. We investigate the surface characteristics of the dwarf planet (136472) Makemake and the resonant object (90482) Orcus.

Methods. Using the FORS2 instrument of the ESO-VLT, we carried out linear polarisation measurements of Makemake and Orcus.

Results. Polarisation of Orcus is similar to that of smaller-sized objects. The polarimetric properties of Makemake are very close to those of Eris and Pluto. We did not find any significant differences in the polarisation properties of transneptunian objects (TNOs) from different dynamical classes. However, there are significant differences in the polarisation of the large objects and the smaller ones and between large TNOs with water-ice and methane-ice dominated surfaces.

Conclusions. We confirm the different types of polarisation phase behaviour for the largest and smaller-sized TNOs. To explain subtle surface polarisation of Pluto, Makemake and Eris, we assume that their surfaces are covered by a thin layer of hoarfrost masking the surface structure.

To appear in: Astronomy and Astrophysics
For preprints, contact irina@astron.kharkov.ua
or on the web at http://arxiv.org/abs/1209.6025

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Constraints on Dust Production in the Edgeworth-Kuiper Belt from Pioneer 10 and New Horizons Measurements

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Impact ejecta and collisional debris from the Edgeworth-Kuiper Belt are the dominant source of micron-sized grains in the outer solar system, as they slowly migrate inwards through the outer solar system before most grains are ejected during close encounters with Jupiter. These grains drive several phenomena in the outer solar system, including the generation of impact ejecta clouds at airless bodies, the formation of ionospheric layers and neutral gases in the atmospheres of the giant planets due to meteoric ablation, the generation of tenuous outer planetary ring systems and the spatial and compositional alteration of Saturn's main rings. Previous analyses have offered estimates of the net mass production rate from the Edgeworth-Kuiper Belt both theoretically and observationally. In order to improve upon these estimates, we compare measurements of the interplanetary dust density in the outer solar system by both the Pioneer 10 meteoroid detector and the New Horizons Student Dust Counter with a dynamical dust grain tracing model. Our best estimates for the net mass production rate and the ejecta mass distribution power law exponent are $(8.9 \pm 0.5) \times 10^5$ g/s and 3.02 ± 0.04, respectively.

Published in: Geophysical Research Letters, 38, L24102 (2011 December)

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On the Edgeworth-Kuiper Belt Dust Flux to Saturn

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Dust grains originating from the Edgeworth-Kuiper Belt (EKB) are believed to be the dominant species of dust in the outer solar system. These grains, evolving inward from the EKB under the influence of a variety of forces, will encounter the giant planets or their ring and moon systems. At Saturn, this influx drives several physical processes including the generation of tenuous dusty exospheres and rings, the spatial and compositional evolution of Saturn's main planetary ring system, and the generation of ionospheric and neutral gas layers in the atmospheres of Saturn and Titan. Recent comparisons between in-situ dust density measurements in the outer solar system and a dynamical dust grain tracing model have placed experimental limits on the mass production rate and power-law exponent of EKB-generated grains. Using this model and the experimental constraints, we make predictions for the influx of micron-sized, EKB-generated grains into the saturnian system, where the Cosmic Dust Analyzer onboard the Cassini mission is currently making measurements of both endogenous and exogenous dust populations.

Published in: Geophysical Research Letters, 39, L15104 (2012 August)

For preprints, contact poppe@ssl.berkeley.edu

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Methanol Ice on the Surface of Minor Bodies in the Solar System

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Spectral analyses of trans-Neptunan objects (TNOs) and of the linked Centaurs, which are supposed to be among the most primitive minor bodies in the solar system, reveal some chemical and physical properties of their surface. To determine the surface composition of these objects and their surface evolution is essential for gaining clues on the conditions under which the solar system has been formed. Chemical composition and physical properties of the surface of three objects have been constrained by computing the depth of the absorption features of the spectra in the near-infrared, running spectral models based on radiative transfer theory in the [0.4-2.3] μm range, and analyzing new laboratory measurements of the spectral behavior of thin samples of H_2O-CH_3OH mixtures. Our investigations allow us to confirm the presence of CH_3OH ice on the surface of the Centaur (5145) Pholus and the resonant TNO (55638) 2002 VE_{95}. It may also possibly be found on the classical TNO (120348) 2004 TY_{364}. Our laboratory experiments indicate that the behavior of the methanol and water ice absorption bands is dependent on the ambient temperature and the dilution level of the mixture. These results also suggest that methanol may be diluted in water ice on the surface of the Centaur Pholus. Formation and destruction processes of methanol suggest that a part (at least) of the surface of these objects is younger than the solar system age. If confirmed, this shows that primordial ices could still be detected on the surface of objects that are submitted to irradiation and rejuvenation processes.

Published in: Astronomy & Astrophysics, 544, 20

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Electron Irradiation of Kuiper Belt Surface Ices: Ternary N_2-CH_4-CO Mixtures as a Case Study

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The space weathering of icy Kuiper Belt Objects was investigated in this case study by exposing methane (CH_4) and carbon monoxide (CO) doped nitrogen (N_2) ices at 10 K to ionizing radiation in the form of energetic electrons. Online and in situ Fourier transform infrared spectroscopy was utilized to monitor the radiation-induced chemical processing of these ices. Along with isocyanic acid (HNCO), the products could be mainly derived from those formed in irradiated binary ices of the N_2-CH_4 and CO-CH_4 systems: nitrogen-bearing products were found in the form of hydrogen cyanide (HCN), hydrogen isocyanide (HNC), diazomethane (CH_2N_2), and its radical fragment (HCN_2); oxygen-bearing products were of acetaldehyde (CH_3CHO), formyl radical (HCO), and formaldehyde (H_2CO). As in the pure ices, the methyl radical (CH_3) and ethane (C_2H_6) were also detected, as were carbon dioxide (CO_2) and the azide radical (N_3). Based on the temporal evolution of the newly formed products, kinetic reaction schemes were then developed to fit the temporal profiles of the newly formed species, resulting in numerical sets of rate constants. The current study highlights important constraints on the preferential formation of isocyanic acid (HNCO) over hydrogen cyanide (HCN) and hydrogen isocyanide (HNC), thus guiding the astrobiological and chemical evolution of those distant bodies.

Published in: The Astrophysical Journal, 758, 37 (2012 October 10)

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Survival of Amorphous Water Ice on Centaurs

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Centaurs are believed to be Kuiper Belt Objects in transition between Jupiter and Neptune, before possibly becoming Jupiter Family Comets. Some indirect observational evidence is consistent with the presence of amorphous water ice in Centaurs. Some of them also display a cometary activity, probably triggered by the crystallization of the amorphous water ice, as suggested by Jewitt (2009) and this work. Indeed, we investigate the survival of amorphous water ice against crystallization, using a fully 3D thermal evolution model. Simulations are performed for varying heliocentric distances and obliquities. They suggest that crystallization can be triggered as far as 16 AU, though amorphous ice can survive beyond 10 AU. The phase transition is an efficient source of outgassing up to 10-12 AU, which is broadly consistent with the observations of the active Centaurs. The most extreme case is 167P/CINEOS which barely crystallizes in our simulations. However, amorphous ice can be preserved inside Centaurs in many heliocentric distance-obliquity combinations, below a ∼5-10 m crystallized crust. We also find that outgassing due to crystallization cannot be sustained for a time longer than 10^{4-5} years, leading to the hypothesis that active Centaurs might have recently suffered from orbital changes. This could be supported by both observations (although limited) and dynamical studies.

Published in: The Astronomical Journal, 144, 97 (2012 October)
For preprints, contact `aguilber@rssd.esa.int`

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Was the Sun Born in a Massive Cluster?

Donald Dukes[1] **and Mark R. Krumholz**[1]

[1] Department of Astronomy & Astrophysics, University of California, Santa Cruz, CA 95064, USA

A number of authors have argued that the Sun must have been born in a cluster of no more than several thousand stars, on the basis that, in a larger cluster, close encounters between the Sun and other stars would have truncated the outer solar system or excited the outer planets into eccentric orbits. However, this dynamical limit is in tension with meteoritic evidence that the solar system was exposed to a nearby supernova during or shortly after its formation; a several-thousand-star cluster is much too small to produce a massive star whose lifetime is short enough to have provided the enrichment. In this paper, we revisit the dynamical limit in the light of improved observations of the properties of young clusters. We use a series of scattering simulations to measure the velocity-dependent cross-section for disruption of the outer solar system by stellar encounters, and use this cross-section to compute the probability of a disruptive encounter as a function of birth cluster properties. We find that, contrary to prior work, the probability of disruption is small regardless of the cluster mass, and that it actually decreases rather than increases with cluster mass. Our results differ from prior work for three main reasons: (1) unlike in most previous work, we compute a velocity-dependent cross-section and properly integrate over the cluster mass-dependent velocity distribution of incoming stars; (2) we recognize that ∼90% of clusters have lifetimes of a few crossing times, rather than the 10-100 Myr adopted in many earlier models; and (3) following recent observations, we adopt a mass-independent surface density for embedded clusters, rather than a mass-independent radius as assumed many earlier papers. Our results remove the tension between the dynamical limit and the meteoritic evidence, and suggest that the Sun was born in a massive cluster. A corollary to this result is that close encounters in the Sun's birth cluster are highly unlikely to truncate the Kuiper Belt unless

the Sun was born in one of the unusual clusters that survived for tens of Myr. However, we find that encounters could plausibly produce highly eccentric Kuiper Belt objects such as Sedna.

Published in: The Astrophysical Journal, 754, 54 (2012 July 20)
For preprints, contact krumholz@ucolick.org
or on the web at http://www.ucolick.org/~krumholz/publications.html

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PAPERS RECENTLY SUBMITTED TO JOURNALS

A 3D General Circulation Model for Pluto and Triton with Fixed Volatile Abundance and Simplified Surface Forcing

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Submitted to: Icarus
For preprints, contact Angela Zalucha angela@boulder.swri.edu

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CONFERENCE INFORMATION

Workshop on "Ice and Planet Formation"

Lund Observatory, Lund, 15–17 May 2013

This workshop in Lund focuses on ice(s) and planet formation. Astrophysical ice has become an increasingly popular topic in the past years, inspired and driven by new observations of ices in molecular clouds and protoplanetary discs, models of dust coagulation and planet formation where ice plays an important role and current and upcoming laboratory experiments on ice collisions and ice deposition.

The goal of the workshop is to bring together observers, experimentalists and theorists to discuss the present state-of-the-art of the field as well as future directions. The workshop will consist of contributed talks and posters, with ample time for discussion during extended breaks and poster sessions.

The Ice and Planet Formation workshop will be held 15 – 17 May 2013 at Lund Observatory in Lund in Sweden. The workshop will start after lunch on Wednesday 15 May and end after lunch on Friday 17 May.

Scientific organising committee:
Jürgen Blum (University of Braunschweig)
Ewine van Dishoeck (Leiden University)
Carsten Dominik (Amsterdam University)
Cornelis Dullemond (Heidelberg University)
Thomas Henning (Max Planck Institute for Astronomy)
Michiel Hogerheijde (Leiden University)
Anders Johansen (Lund University)
Klaus Pontoppidan (Space Telescope Science Institute)

Local organising committee:
Anders Johansen (Lund University)
Katrin Ros (Lund University)
Michiel Lambrechts (Lund University)

Website: `http://www.astro.lu.se/~anders/IPF2013/`

Registration closes on 15 February 2013.

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:

`http://www.boulder.swri.edu/ekonews`

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

Distant EKOs is not a refereed publication, but is a tool for furthering communication among people interested in Kuiper belt research. Publication or listing of an article in the newsletter or the web page does not constitute an endorsement of the article's results or imply validity of its contents. When referencing an article, please reference the original source; *Distant EKOs* is not a substitute for peer-reviewed journals.

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:

`ekonews@boulder.swri.edu`