Issue No. 40 *April 2005*

DISTANT EKOs

The Kuiper Belt Electronic Newsletter

Edited by: Joel Wm. Parker

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CONTENTS

NEWS & ANNOUNCEMENTS

This issue of the newsletter unfortunately was delayed by more than a month due to unusually intense time demands on me by other projects. Rather than compress the schedule for the next issue, I will just go with the flow and shift the regular schedule to the right by a month. The next issue will be published in June, and announcements for submissions will be sent out at the end of May.

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There were 18 new TNO discoveries announced since the previous issue of *Distant EKOs*:

2005 EB318, 2005 EC318, 2005 ED300, 2005 EE296, 2005 EF298, 2005 EF304, 2005 EH305, 2005 EJ300, 2005 EK298, 2005 EM303, 2005 EN302, 2005 EO296, 2005 EO297, 2005 EO302, 2005 EO304, 2005 EP296, 2005 EX297, 2005 EZ296

and 2 new Centaur/SDO discoveries:

2005 EB299, 2005 EZ300

Reclassified objects:
2004 TF282 (TNO $\rightarrow$ SDO)

Current number of TNOs: 865 (and Pluto & Charon, and 12 other TNO binary companions)
Current number of Centaurs/SDOs: 152
Current number of Neptune Trojans: 1

Out of a total of 1018 objects:
494 have measurements from only one opposition
418 of those have had no measurements for more than a year
206 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

The Deep Ecliptic Survey: A Search for Kuiper Belt Objects and Centaurs. II. Dynamical Classification, the Kuiper Belt Plane, and the Core Population

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The Deep Ecliptic Survey (DES)—a search optimized for the discovery of Kuiper belt objects (KBOs) with the Blanco and Mayall 4 m telescopes at the Cerro Tololo Inter-American Observatory and Kitt Peak National Observatory—has covered 550 square degrees from its inception in 1998 through the end of 2003. This survey has a mean 50% sensitivity at *VR* magnitude 22.5. We report here the discoveries of 320 designated KBOs and Centaurs for the period 2000 March through 2003 December and describe improvements to our discovery and recovery procedures. Our data and the data products needed to reproduce our analyses in this paper are available through the NOAO survey database. Here we present a dynamical classification scheme, based on the behavior of orbital integrations over 10 Myr. The dynamical classes, in order of testing, are "Resonant," "Centaur," "Scattered-Near," "Scattered-Extended," and "Classical." (These terms are capitalized when referring to our rigorous definitions.) Of the 382 total designated KBOs discovered by the DES, a subset of 196 objects have sufficiently accurate orbits for dynamical classification. Summary information is given for an additional 240 undesignated objects also discovered by the DES from its inception through the end of 2003. The number of classified DES objects (uncorrected for observational bias) are Classical, 96; Resonant, 54; Scattered-Near, 24; Scattered-Extended, 9; and Centaur, 13. We use subsets of the DES objects (which can have observational biases removed) and larger samples to perform dynamical analyses on the Kuiper belt. The first of these is a determination of the Kuiper belt plane (KBP), for which the Classical objects with inclinations less than 5 from the mean orbit pole yield a pole at R.A.=273.92±0.62 degrees and decl.=66.7±0.20 degrees (J2000), consistent with the invariable plane of the solar system. A general method for removing observational biases from the DES data set is presented and used to find a provisional magnitude distribution and the distribution of orbital inclinations relative to the KBP. A power-law model fit to the cumulative magnitude distribution of all KBOs discovered by the DES in the *VR* filter yields an index of 0.86±0.10 (with the efficiency parameters for the DES fitted simultaneously with the population power law). With the DES sensitivity parameters fixed, we derive power-law indices of 0.74±0.05, 0.52±0.08, and 0.74±0.15, respectively, for the Classical, Resonant, and Scattered classes. Plans for calibration of the DES detection efficiency function and DES magnitudes are discussed. The inclination distribution confirms the presence of "hot" and "cold" populations; when the geometric $\sin i$ factor is removed from the inclination distribution function, the cold population shows a concentrated "core" with a full width at half-maximum of approximately 4.6 degrees, while the hot population appears as a "halo," extending beyond 30 deg. The inclination distribution is used to infer the KBO distribution in the sky, as a function of latitude relative to the KBP. This inferred latitude distribution is reasonably consistent with the latitude distribution derived from direct observation, but the agreement is not perfect. We find no clear boundary between the Classical and Scattered classes either in their orbital inclinations with respect to the KBP or in their power-law indices in their respective magnitude distributions. This leaves open the possibility that common processes have shaped the distribution of orbital parameters for the two classes.

Published in: The Astronomical Journal, 129, 1117 (2005 February)
For preprints, contact jle@mit.edu

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Exploring the 7:4 Mean Motion Resonance. I. Dynamical Evolution of Classical Transneptunian Objects

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In the transneptunian classical region (42 AU< a <48 AU) it is observed an unexpected orbital excitation in eccentricity and inclination, dynamically distinct populations and the presence of chaotic regions. For instance, the 7:4 mean motion resonance ($a \sim 43.7$ AU) appears to have been causing unique dynamical excitation according to observational evidences. Namely, an apparent shallow gap in number density and anomalies in the color distribution, both features enhanced near the 7:4 mean motion resonance location. In order to investigate the resonance dynamics, we present extensive computer simulation results totalizing almost 10000 test particles under the effect of the four giant planets for the age of the solar system. A chaotic diffusion experiment was also performed to follow tracks in phase space over 4–5 Gyr. The 7:4 mean motion resonance is weakly chaotic causing irregular eccentricity and inclination evolution for billion of years. Most 7:4 resonant particles suffered significant eccentricities and/or inclinations excitation, an outcome shared even by those located in the vicinity of the resonance. Particles in stable resonance locking are rare and usually had $0.25 < e < 0.3$. For other regions, 7:4 resonants had quite large mobility in phase space typically leaving the resonance (and being scattered) after reaching a critical $e \sim 0.2$. The escape happened in $10^8 - 10^9$ yr time scales. Concerning the inclination dependence for 7:4 resonants, we found strong instability islands for approximately $i > 10$ degrees. Taking into account those particles still locked in the resonance at the end of the simulations, we determined a retainability of 12–15% for real 7:4 resonant TNOs. Lastly, our results demonstrate that classical TNOs associated with the 7:4 mean motion resonance have been evolving continuously until present with non-negligible mixing of populations.

To appear in: Planetary and Space Science
For preprints, contact patryk@kobe-u.ac.jp
or on the web at http://harbor.scitec.kobe-u.ac.jp/~patryk/index-uk.html

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Stellar Perturbations on the Scattered Disk

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We present a statistical model for estimating the effects of stellar encounters on orbits in the outer Solar System, focussing on the scattered disk at $\lesssim 10^3$ AU from the Sun. We describe a Monte Carlo simulation using those results and apply it to the evolution of the scattered disk over 4 Gyr, finding that a final perihelion distance distribution with an extended tail reaching to very large values is to be expected. This would likely result from a single close stellar encounter, in agreement with the conclusion by Morbidelli & Levison (2004). We estimate that the newly discovered minor planet (90377) Sedna may be a typical representative of such an extended scattered disk and that a few more objects of the same size may reside at similar heliocentric distances. There is a possibility that the bulk of the population, which should have smaller perihelion distances, contains some very large objects that may have contributed to sculpting the Kuiper Belt. We also find that the creation of an extended scattered disk by a stellar encounter should have been accompanied by a huge influx of large objects into the inner Solar System, but the timing of the encounter is constrained by the fact that the scattered disk must still have been quite massive. Thus it likely happened long before the purported late heavy bombardment of the terrestrial planets.

Published in: Astronomy & Astrophysics, 428, 637 (2004 December)

For preprints, contact `hans.rickman@astro.uu.se`
or on the web at
`http://www.edpsciences.org/articles/aa/abs/2004/47/aa1109/aa1109.html`

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The Kuiper Belt and the Solar System's Comet Disk

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Our planetary system is embedded in a small-body disk of asteroids and comets, vestigial remnants of the original planetesimal population that formed the planets. Once formed, those planets dispersed most of the remaining small bodies. Outside of Neptune, this process has left our Kuiper belt and built the Oort cloud, as well as emplacing comets into several other identifiable structures. The orbits in these structures indicate that our outer solar system's comet disk was shaped by a variety of different physical processes, which teach us about how the giant planets formed. Recent work has shown that the scattered disk is the most likely source of short-period comets. Moreover, a growing body of evidence indicates that the sculpting of the Kuiper belt region may have involved large-scale planetary migration, the presence of other rogue planetary objects in the disk, and/or the close passage of other stars in the Sun's birth cluster.

Published in: Science, 307, 71 (2005 January 07)

For preprints, contact `gladman@astro.ubc.ca`
or on the web at `http://www.sciencemag.org/cgi/content/abstract/307/5706/71`

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Diverse Albedos of Small Trans-Neptunian Objects

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Discovery of transneptunian object (TNO) satellites and determination of their orbits has recently enabled estimation of the size and albedo of several small TNOs, extending the size range of objects having known size and albedo down into the sub-100 km range. In this paper we compute albedo and size estimates or limits for 20 TNOs, using a consistent method for all binary objects and a consistent method for all objects having reported thermal fluxes. As is true for larger TNOs, the small objects show a remarkable diversity of albedos. Although the sample is limited, there do not yet appear to be any trends relating albedo to other observable properties or to dynamical class, with the possible exception of inclination. The observed albedo diversity of TNOs has important implications for computing the size-frequency distribution, the mass, and other global properties of the Kuiper belt derived from observations of objects' apparent magnitudes and may also point the way toward an improved compositional taxonomy based on albedo in addition to color.

To appear in: Icarus

For preprints, contact W.Grundy@lowell.edu

or on the web at: http://arxiv.org/abs/astro-ph/0502229

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A Shape-and-Density Model of the Putative Binary EKBO 2001 QG298

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Recent observations of the Edgeworth-Kuiper belt object (EKBO) 2001 QG_{298} (Sheppard & Jewitt 2004) have shown that the lightcurve of this object has a very large amplitude (1.14±0.04 mag), indicating that it is either of an elongated shape or of a binary structure with two components of similar sizes nearly in contact with each other. On the basis of these interesting published data, we employed Roche binary lightcurve simulations to construct a shape model of EKBO 2001 QG_{298}. The shape parameters of the best-fitted model were $260(164) \times 205(130) \times 185(116)$ km for the primary, and $265(168) \times 160(102) \times 150(94)$ km for the secondary in the case of an albedo of 0.04(0.10). An additional result of this calculation is that the average bulk density of the contact binary system could be estimated to be 630 kg m^{-3}. This value is similar to that of several icy moons of Saturn with a diameter of less than 200 km. We have also used the Jacobi ellipsoidal approximation to compute the shape of one of the largest EKBOs, Varuna. The corresponding shape parameters are $a : b : c = 1.00 : 0.76 : 0.50$. The lower limit of the bulk density is $\rho \geq 1000$ kg m^{-3}. These results are in good agreement with the published values of Jewitt and Sheppard (2002), and are consistent with their suggestion that larger icy bodies have higher densities (Sheppard & Jewitt 2002).

Published in: Publications of the Astronomical Society of Japan, 56, 1099

For preprints, contact shigeru@astro.ncu.edu.tw

or on the web at http://pasj.asj.or.jp/v56/n6/560614/560614a.html

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Shaping the Kuiper Belt Size Distribution by Shattering Large but Strengthless Bodies

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The observed size distribution of Kuiper belt objects (KBOs)—small icy and rocky Solar System bodies orbiting beyond Neptune—is well described by a power law at large KBO sizes. However, recent work by Bernstein et al. (2004, Astron. J. 128, 1364–1390) indicates that the size distribution breaks and becomes shallower for KBOs smaller than about 70 km in size. Here we show that we expect such a break at KBO radius ∼40 km since destructive collisions are frequent for smaller KBOs. Specifically, we assume that KBOs are gravity-dominated bodies with negligible material strength. This gives a power-law slope $q \simeq 3$, where the number $N > r$ of KBOs larger than a size r is given by $N_{>r} \propto r^{1-q}$; the break location follows from this slope through a self-consistent calculation. The existence of this break, the break's location, and the power-law slope we expect below the break are consistent with the findings of Bernstein et al. (2004, Astron. J. 128, 1364–1390). The agreement with observations indicates that KBOs as small as ∼40 km are effectively strengthless.

Published in: Icarus, 173, 342 [2005 February]

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A Giant Impact Origin of Pluto-Charon

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Pluto and its moon, Charon, are the most prominent members of the Kuiper belt, and their existence holds clues to outer solar system formation processes. Here, hydrodynamic simulations are used to demonstrate that the formation of Pluto-Charon by means of a large collision is quite plausible. I show that such an impact probably produced an intact Charon, although it is possible that a disk of material orbited Pluto from which Charon later accumulated. These findings suggest that collisions between 1000-kilometer-class objects occurred in the early inner Kuiper belt.

Published in: Science, 307, 546 [2005 January 28]

For preprints, contact `robin@boulder.swri.edu`

or on the web at `http://www.boulder.swri.edu/~robin/rcpapers.html`

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Search for Nonmethane Hydrocarbons on Pluto

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We have carried out infrared high-resolution spectroscopy of the Pluto-Charon system in the L band with the adaptive optics system on the Subaru telescope. The spectrum is dominated by the strong and broad absorption features of methane but includes some additional features. Comparing the spectrum with model calculations, we suggest that absorption features around 3.1, 3.2, and 3.35 mum could be an indication of nonmethane hydrocarbons on Pluto's uppermost surface. Implications of the estimated mass ratio between hydrocarbons for the formation and evolution of Pluto are discussed.

Published in: The Astrophysical Journal Letters, 618, L57 [2005 January]

For preprints, contact `takanori@eps.s.u-tokyo.ac.jp`

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The Structure of Pluto's Atmosphere from the 2002 August 21 Stellar Occultation

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We have observed the 2002 August 21 occultation by Pluto of the $R = 15.7$ mag star P131.1, using 0.5 s cadence observations in integrated white light with the Williams College frame-transfer, rapid-readout CCD at the 2.24 m University of Hawaii telescope. We detected an occultation that lasted 5 minutes, 9.1 ± 0.7 s between half-light points. The "kinks" in the ingress and egress parts of the curve that were apparent in 1988 had become much less pronounced by the time of the two 2002 occultations that were observed, indicating a major change in the structure of Pluto's atmosphere. Analysis of our light curves shows that the pressure in Pluto's atmosphere has increased at all the altitudes that we probed. Essentially, the entire pressure scale has moved up in altitude, increasing by a factor of 2 since 1988. Spikes in our light curve reveal vertical structure in Pluto's atmosphere at unprecedentedly high resolution. We have confirmation of our spikes at lower time resolution as part of observations of the emersion made at 1.4 s and 2.4 s cadence with the 3.67 m AEOS telescope on Maui.

Published in: The Astronomical Journal, 129, 1718 [2005 March]

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Neptune Trojans as a Testbed for Planet Formation

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The problem of accretion in the Trojan 1:1 resonance is akin to the standard problem of planet formation, transplanted from a star-centered disk to a disk centered on the Lagrange point. The newly discovered class of Neptune Trojans promises to test theories of planet formation by coagulation. Neptune Trojans resembling the prototype 2001 QR_{322} ("QR")—whose radius of ∼100 km is comparable to that of the largest Jupiter Trojan—may outnumber their Jovian counterparts by a factor of ∼10. We develop and test three theories for the origin of large Neptune Trojans: pull-down capture, direct collisional emplacement, and *in situ* accretion. These theories are staged after Neptune's orbit anneals: after dynamical friction eliminates any large orbital eccentricity and after the planet ceases to migrate. We discover that seeding the 1:1 resonance with debris from planetesimal collisions and having the seed particles accrete *in situ* naturally reproduces the inferred number of QR-sized Trojans. We analyze accretion in the Trojan sub-disk by applying the two-groups method, accounting for kinematics specific to the resonance. We find that a Trojan sub-disk comprising decimeter-sized seed particles and having a surface density $\sim 10^{-3}$ that of the local minimum-mass disk produces ∼10 QR-sized objects in ∼1 Gyr, in accord with observation. Further growth is halted by collisional diffusion of seed particles out of resonance. In our picture, the number and sizes of the largest Neptune Trojans represent the unadulterated outcome of dispersion-dominated, oligarchic accretion. Large Neptune Trojans, perhaps the most newly accreted objects in our Solar System, may today have a dispersion in orbital inclination of less than ∼10 degrees, despite the existence of niches of stability at higher inclinations. Such a vertically thin disk, born of a dynamically cold environment necessary for accretion, and raised in minimal contact with external perturbations, contrasts with the thick disks of other minor body belts.

To appear in: The Astrophysical Journal
For preprints, contact `echiang@astron.berkeley.edu`
or on the web at `astron.berkeley.edu/~echiang/ppp/ppp.html`

OTHER PAPERS OF INTEREST

New Horizons Pluto-Kuiper Belt Mission: Design and Simulation of the Pluto-Charon Encounter

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Published in: Acta Astronautica, 56, 421 (2005 February)

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Submillimeter Images of a Dusty Kuiper Belt Around eta Corvi

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Published in: The Astrophysical Journal, 620, 492 (2005 February 10)

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 ... ??

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`ekonews@boulder.swri.edu`