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DISTANT EKOs

The Kuiper Belt Electronic Newsletter

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NEWS & ANNOUNCEMENTS

There were 8 new TNO discoveries announced since the previous issue of *Distant EKOs*:

2013 FA28, 2013 FB28, 2013 FC28, 2013 FD28, 2013 JV63, 2013 JW63, 2014 FP43, 2014 FX61

and 6 new Centaur/SDO discoveries:

2013 JU63, 2014 FU61, 2014 FB62, 2014 KL84, 2014 LR14, 2014 LJ9

Reclassified objects:
2014 FB62 (Centaur → TNO)

Objects recently assigned numbers:
2012 GN12 = (395699)

Current number of TNOs: 1272 (including Pluto)
Current number of Centaurs/SDOs: 398
Current number of Neptune Trojans: 9

Out of a total of 1679 objects:
648 have measurements from only one opposition
631 of those have had no measurements for more than a year
327 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

De-biased Populations of Kuiper Belt Objects from the Deep Ecliptic Survey

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The Deep Ecliptic Survey (DES) was a survey project that discovered hundreds of Kuiper Belt objects from 1998–2005. Extensive follow-up observations of these bodies has yielded 304 objects with well-determined orbits and dynamical classifications into one of several categories: Classical, Scattered, Centaur, or 16 mean-motion resonances with Neptune. The DES search fields are well documented, enabling us to calculate the probability on each frame of detecting an object with its particular orbital parameters and absolute magnitude at a randomized point in its orbit. The detection probabilities range from a maximum of 0.32 for the 3:2 resonant object 2002 GF_{32} to a minimum of 1.5×10^{-7} for the faint Scattered object 2001 FU_{185}. By grouping individual objects together by dynamical classes, we can estimate the distributions of four parameters that define each class: semi-major axis, eccentricity, inclination, and object size. The orbital element distributions (a, e, and i) were fit to the largest three classes (Classical, 3:2, and Scattered) using a maximum likelihood fit. Using the absolute magnitude (H-magnitude) as a proxy for the object size, we fit a power law to the number of objects vs. H magnitude for 8 classes with at least 5 detected members (246 objects). The Classical objects are best fit with a power-law slope of $\alpha = 1.02 \pm 0.01$ (observed from $5 \leq H \leq 7.2$). Six other dynamical classes (Scattered plus 5 resonances) have consistent magnitude distributions *slopes* with the Classicals, provided that the *absolute number* of objects is scaled. Scattered objects are somewhat more numerous than Classical objects, while there are only a quarter as many 3:2 objects as Classicals. The exception to the power law relation is the Centaurs, which are non-resonant objects with perihelia closer than Neptune and therefore brighter and detectable at smaller sizes. Centaurs were observed from $7.5 < H < 11$, and that population is best fit by a power law with $\alpha = 0.42 \pm 0.02$. This is consistent with a knee in the H-distribution around $H = 7.2$ as reported elsewhere (Bernstein et al. 2004, Fraser et al. 2014). Based on the Classical-derived magnitude distribution, the total number of objects ($H \leq 7$) in each class are: Classical (2100 ± 300 objects), Scattered (2800 ± 400), 3:2 (570 ± 80), 2:1 (400 ± 50), 5:2 (270 ± 40), 7:4 (69 ± 9), 5:3 (60 ± 8). The independent estimate for the number of Centaurs in the same H range is 13 ± 5. If instead all objects are divided by inclination into "Hot" and "Cold" populations, following Fraser et al. (2014), we find that $\alpha_{Hot} = 0.90 \pm 0.02$, while $\alpha_{Cold} = 1.32 \pm 0.02$, in good agreement with that work.

To appear in: The Astronomical Journal

For preprints, contact `adams@psi.edu`

or on the web at `http://arxiv.org/abs/1311.3250`

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New Horizons: Long-range Kuiper Belt Targets Observed by the Hubble Space Telescope

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We report on Hubble Space Telescope (HST) observations of three Kuiper Belt Objects (KBOs), discovered in our dedicated ground-based search campaign, that are candidates for long-range observations from the New Horizons spacecraft: 2011 JY_{31}, 2011 HZ_{102}, and 2013 LU_{35}. Astrometry with HST enables both current and future critical accuracy improvements for orbit precision, required for possible New Horizons observations, beyond what can be obtained from the ground. Photometric colors of all three objects are red, typical of the Cold Classical dynamical population within which they reside; they are also the faintest KBOs to have had their colors measured. None are observed to be binary with HST above separations of ~ 0.02 arcsec (~ 700 km at 44 AU) and $\Delta m \leq 0.5$.

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For preprints, contact susank@psi.edu

or on the web at arxiv.org/abs/1405.7181

and at http://dx.doi.org/10.1016/j.icarus.2014.04.014

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A Study of the High-inclination Population in the Kuiper Belt – II. The Twotinos

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As the second part of our study, in this paper we proceed to explore the dynamics of the high-inclination Twotinos in the 1:2 Neptune mean motion resonance (NMMR). Depending on the inclination i, we show the existence of two critical eccentricities $e_a(i)$ and $e_c(i)$, which are lower limits of the eccentricity e for the resonant angle σ to exhibit libration and asymmetric libration, respectively. Accordingly, we have determined the libration centres σ_0 for inclined orbits, which are strongly dependent on i. With initial $\sigma = \sigma_0$ on a fine grid of (e, i), the stability of orbits in the 1:2 NMMR is probed by 4-Gyr integrations. It is shown that symmetric librators are totally unstable for $i \geq 30°$; while stable asymmetric librators exist for i up to $90°$.

We further investigate the 1:2 NMMR capture and retention of planetesimals with initial inclinations $i_0 \leq 90°$ in the planet migration model using a long time-scale of 2×10^7 yr. We find that: (1) the

capture efficiency of the 1:2 NMMR decreases drastically with the increase of i_0, and it goes to 0 when $i_0 \geq 60°$; (2) the probability of discovering Twotinos with $i > 25°$, beyond observed values, is roughly estimated to be ≤ 0.1 per cent; (3) more particles are captured into the leading rather than the trailing asymmetric resonance for $i_0 \leq 10°$, but this number difference appears to be the opposite at $i_0 = 20°$ and is continuously varying for even larger i_0; (4) captured Twotinos residing in the trailing resonance or having $i > 15°$ are practically outside the Kozai mechanism, like currently observed samples.

To appear in: Monthly Notices of the Royal Astronomical Society
Preprints available on the web at `http://arxiv.org/abs/1402.5924`

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Extreme Trans-Neptunian Objects and the Kozai Mechanism: Signaling the Presence of Trans-Plutonian Planets?

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The existence of an outer planet beyond Pluto has been a matter of debate for decades and the recent discovery of 2012 VP_{113} has just revived the interest for this controversial topic. This Sedna-like object has the most distant perihelion of any known minor planet and the value of its argument of perihelion is close to 0°. This property appears to be shared by almost all known asteroids with semimajor axis greater than 150 au and perihelion greater than 30 au (the extreme trans-Neptunian objects or ETNOs), and this fact has been interpreted as evidence for the existence of a super-Earth at 250 au. In this scenario, a population of stable asteroids may be shepherded by a distant, undiscovered planet larger than the Earth that keeps the value of their argument of perihelion librating around 0° as a result of the Kozai mechanism. Here, we study the visibility of these ETNOs and confirm that the observed excess of objects reaching perihelion near the ascending node cannot be explained in terms of any observational biases. This excess must be a true feature of this population and its possible origin is explored in the framework of the Kozai effect. The analysis of several possible scenarios strongly suggest that at least two trans-Plutonian planets must exist.

To appear in: Monthly Notices of the Royal Astronomical Society, Letters
For preprints, contact `nbplanet@fis.ucm.es`
or on the web at `http://arxiv.org/abs/1406.0715`

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Large Retrograde Centaurs: Visitors from the Oort Cloud?

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Among all the asteroid dynamical groups, Centaurs have the highest fraction of objects moving in retrograde orbits. The distribution in absolute magnitude, H, of known retrograde Centaurs with semi-major axes in the range 6–34 AU exhibits a remarkable trend: 10% have $H < 10$ mag, the rest have $H > 12$ mag. The largest objects, namely (342842) 2008 YB_3, 2011 MM_4 and 2013 LU_{28}, move in almost polar, very eccentric paths; their nodal points are currently located near perihelion and aphelion. In the group of retrograde Centaurs, they are obvious outliers both in terms of dynamics and size. Here, we show that these objects are also trapped in retrograde resonances that make them unstable. Asteroid 2013 LU_{28}, the largest, is a candidate transient co-orbital to Uranus and it may

be a recent visitor from the trans-Neptunian region. Asteroids 342842 and 2011 MM_4 are temporarily submitted to various high-order retrograde resonances with the Jovian planets but 342842 may be ejected towards the trans-Neptunian region within the next few hundred kyr. Asteroid 2011 MM_4 is far more stable. Our analysis shows that the large retrograde Centaurs form an heterogeneous group that may include objects from various sources. Asteroid 2011 MM_4 could be a visitor from the Oort cloud but an origin in a relatively stable closer reservoir cannot be ruled out. Minor bodies like 2011 MM_4 may represent the remnants of the primordial planetesimals and signal the size threshold for catastrophic collisions in the early Solar System.

To appear in: **Astrophysics and Space Science**
For preprints, contact `nbplanet@fis.ucm.es`
or on the web at `http://arxiv.org/abs/1406.1450`

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On the State of Methane and Nitrogen Ice on Pluto and Triton: Implications of the Binary Phase Diagram

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Compositional analyses of Pluto's surface ice in the literature typically include large areas on the body where CH_4 and other volatiles are segregated in the pure form from the solid solution N_2:CH_4 in which CH_4 is diluted. However, the existence of continent-size areas of pure CH_4 are in conflict with both of the alternative models that successfully explain the enhancement of CH_4 in Pluto's atmosphere, the Detailed Balancing thermal equilibrium model and the Hot Methane Patch model. Pluto's spectrum includes an apparently unshifted CH_4 component while Triton's does not, and 93% of the concentration range of the binary phase diagram at 38 K shows that these species exist as a mixture of two saturated solid solution phases. Recognizing this, we propose that both of these saturated phases are present on Pluto and the CH_4-rich phase of the mixture, CH_4:N_2, is the source of the relatively unshifted CH_4 spectrum attributed to pure CH_4. We also propose that CH_4 is less abundant in Triton's ice to the point where either the ice is not saturated or the saturated CH_4:N_2 phase has not been detected. In this scenario, the partial vapor pressures do not change when the relative proportions of these saturated phases are varied in the mixture. Thus, the partial vapor pressures are independent of N_2–CH_4 concentrations if both saturated phases are present. Accordingly, the longitudinal and seasonal variations of CH_4 and N_2 features in Pluto's spectrum would be attributed to spatial variations in the relative proportions of these species. This may occur during volatile transport in the sublimation wind through extensive influences. The lower, unsaturated, values of the mole fraction of CH_4 in the ice reported by Owen et al. (1993) and Cruikshank et al. (1998), and by Doute et al. (1999) based on a compositional analysis of Pluto's surface, were not obtained using optical constants for components consistent with the constraints of the phase diagram.

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For preprints, contact `lmt@astro.as.utexas.edu`

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Gas Transfer in the Pluto-Charon System: A Charon Atmosphere

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Recent hybrid fluid/molecular kinetic models demonstrated that Plutos upper atmosphere is warmer and more extended than previously thought (Erwin et al., 2013; Tucker et al. 2012). Here we examine the effect of Charon on the molecular escape rate from Plutos extended atmosphere, simulate the spatial distribution of N_2 in this binary system, and describe the resulting accumulation of N_2 on Charon. These Monte Carlo simulations are carried out for approximate solar medium conditions at $\sim$33 AU. Including Charons gravity and orbital motion,the atmosphere on the Plutos Charon-facing hemisphere is more strongly bound to the system and is more extended than the atmosphere on Plutos anti-Charon hemisphere. Accounting for Charons gravity the net escape from the system is reduced by $\sim$5%. Most of the loss is direct from Plutos exobase region with $\sim$1-2% due to scattering by Charon. About $\sim$0.2% of the flux from Plutos exobase impinges on Charon: $\sim 5.7 \times 10^{25}$ N_2/s at nominal solar medium conditions. This is a source of condensed N_2 for Charons night side and forms a tenuous atmosphere. For the approximate range of surface temperatures, the residence time of N_2 on the surface can range from a fraction of a second to 10s of years with the near surface line of sight column densities varying from $\sim 3 \times 10^{18}$ N_2/m^2 up to $> 6 \times 10^{19}$ N_2/m^2. Such an atmosphere could be detectable during the solar occultation that will occur during the New Horizon encounter providing a measure of the transfer of gas between bodies in this binary system.

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or on the web at http://dx.doi.org/10.1016/j.icarus.2014.05.002

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The Effect of Rayleigh-Taylor Instabilities on the Thickness of Undifferentiated Crust on Kuiper Belt Objects

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Previous calculations of the internal structure and thermal evolution of Kuiper Belt Objects (KBOs) by Desch et al. (Desch, S.J., Cook, J.C., Doggett, T.C., Porter, S.B. [2009]. Icarus 202, 694-714) have predicted that KBOs should only partially differentiate, with rock and ice separating into a rocky core and icy mantle, below an undifferentiated crust of ice and rock. This crust is thermally insulating and enhances the ability of subsurface liquid to persist within KBOs. A dense rock/ice layer resting on an icy mantle is gravitationally unstable and prone to Rayleigh-Taylor (RT) instabilities, and may potentially overturn. Here we calculate the ability of RT instabilities to act in KBOs, and determine the thickness of undifferentiated crusts. We have used previously calculated growth rates of the RT instability to determine the critical viscosity of ice needed for the RT instability to operate. We calculate the viscosity of ice at the cold temperatures and long timescales relevant to KBOs. We find that crustal overturn is only possible where the temperature exceeds about 150 K, and that RT instabilities cannot act on geological timescales within about 60 km of the surfaces of a KBO like Charon. Although this crustal thickness is less than the 85 km previously calculated by Desch et al. (Desch, S.J., Cook, J.C., Doggett, T.C., Porter, S.B. [2009]. Icarus 202, 694-714), it is still significant, representing $\sim$25% of the mass of

the KBO. We conclude that while RT instabilities may act in KBOs, they do not completely overturn their crusts. We calculate that Saturns moon Rhea should only partially differentiate, resulting in a moment of inertia $C/MR^2 \approx 0.38$.

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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
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⋆ 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:

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