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DISTANT EKOs

The Kuiper Belt Electronic Newsletter

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CONTENTS

NEWS & ANNOUNCEMENTS

There were 2 new TNO discoveries announced since the previous issue of *Distant EKOs*:

2008 LD18, 2012 HH2

and 5 new Centaur/SDO discoveries:

2004 VM131, 2012 GM12, 2012 GU11, 2012 GX17, 2012 KU50

Reclassified objects:

2012 BX85 (SDO → TNO)
2012 FZ78 (SDO → Centaur)

Objects recently assigned numbers:

2010 LJ109 = (328884)
2009 HW77 = (330836)

Deleted/Re-identified objects:

2012 GN12 = 2010 FY28 = 2011 GP61

Current number of TNOs: 1250 (including Pluto)
Current number of Centaurs/SDOs: 354
Current number of Neptune Trojans: 8

Out of a total of 1612 objects:

642 have measurements from only one opposition
624 of those have had no measurements for more than a year
319 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 Bimodal Colors of Centaurs and Small Kuiper Belt Objects

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Ever since the very first photometric studies of Centaurs and Kuiper Belt Objects (KBOs) their visible color distribution has been controversial. That controversy gave rise to a prolific debate on the origin of the surface colors of these distant icy objects of the Solar System. Two different views attempt to interpret and explain the large variability of colors, hence surface composition. Are the colors mainly primordial and directly related to the formation region, or are they the result of surface evolution processes? To date, no mechanism has been found that successfully explains why Centaurs, which are escapees from the Kuiper Belt, exhibit two distinct color groups, whereas KBOs do not. In this letter, we readdress this issue using a carefully compiled set of $B-R$ colors and $H_R(\alpha)$ magnitudes (as proxy for size) for 253 objects, including data for 10 new small objects.

We find that the bimodal behavior seen among Centaurs is a size related phenomenon, common to both Centaurs and small KBOs, *i.e.* independent of dynamical classification. Further, we find that large KBOs also exhibit a bimodal behavior of surface colors, albeit distinct from the small objects and strongly dependent on the 'Haumea collisional family' objects. When plotted in $B-R$, $H_R(\alpha)$ space, the colors of Centaurs and KBOs display a peculiar $\mathcal{N}$ shape.

To appear in: Astronomy & Astrophysics

For preprints, contact peixinho@mat.uc.pt

or on the web at http://arxiv.org/abs/1206.3153

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The Resonant Trans-Neptunian Populations

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The transneptunian objects (TNOs) trapped in mean-motion resonances with Neptune were likely emplaced there during planet migration late in the giant-planet formation process. We perform detailed modelling of the resonant objects detected in the Canada-France Ecliptic Plane Survey

(CFEPS) in order to provide population estimates and, for some resonances, constrain the complex internal orbital element distribution. Detection biases play a critical role because phase relationships with Neptune make object discovery more likely at certain longitudes. This paper discusses the 3:2, 5:2, 2:1, 3:1, 5:1, 4:3, 5:3, 7:3, 5:4, and 7:4 mean-motion resonances, all of which had CFEPS detections, along with our upper limit on 1:1 Neptune Trojans (which is consistent with their small population estimated elsewhere). For the plutinos (TNOs in the 3:2 resonance) we refine the orbital element distribution given in Kavelaars *et al.* (2009) and show that steep H-magnitude distributions ($N(H) \propto 10^{\alpha H}$, with α =0.8–0.9) are favoured in the range H_g=8–9, and confirm that this resonance does not share the inclination distribution of the classical Kuiper Belt. We give the first population estimate for the 5:2 resonance and find that, to within the uncertainties, the population is equal to that of the 3:2 ($\simeq$ 13,000 TNOs with $H_g < 9.16$), whereas the 2:1 population is smaller by a factor of 3–4 compared to the other two resonances. We also measure significant populations inhabiting the 4:3, 5:3, 7:3, 5:4, 7:4, 3:1, and 5:1 resonances, with $H_g < 9.16$ (D >100 km) populations in the thousands. We compare our intrinsic population and orbital-element distributions with several published models of resonant-TNO production; the most striking discrepancy is that resonances beyond the 2:1 are in reality more heavily populated than in published models.

Published in: Astronomical Journal 144, 23 (2012 July)
Preprints available on the web at `http://arxiv.org/abs/1205.7065`

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Stability of Higher Order Resonances in the Restricted Three-Body Problem

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Third and fourth order mean motion resonances are studied in the model of the restricted three-body problem by numerical methods for mass parameters corresponding approximately to the Sun-Jupiter and Sun-Neptune systems. In the case of inner resonances, it is shown that there are two regions of libration in the 8:5 and 7:4 resonances, one at low, the other at high eccentricities. In the 9:5 and 7:3 resonances libration can exist only in one region at high eccentricities. The 5:2 and 4:1 resonances are very regular, with one librational zone existing for all eccentricities. There is no visible region of libration at any eccentricities in the 5:1 resonance, the transition between the regions of direct and retrograde circulation is very sharp. In the case of outer resonances, the 8:5 and 7:4 resonances have also two regions of libration, but the 9:5 resonance has three, the 7:3 resonance two librational zones. The 5:2 resonance is again very regular, but it is parted for two regions of libration at high eccentricities. Libration is possible in the 4:1 resonance only at high eccentricities. The 5:1 resonance is very symmetric. In the case of outer resonances, a comparison is made with trans-Neptunian objects (TNO) in higher order mean motion resonances. Several new librating TNOs are identified.

Published in: Celestial Mechanics and Dynamical Astronomy 113, 95 (2012 May)
For preprints, contact `B.Erdi@astro.elte.hu`

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Trailing (L5) Neptune Trojans: 2004 KV18 and 2008 LC18

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The population of Neptune Trojans is believed to be bigger than that of Jupiter Trojans and that of asteroids in the main belt, although only eight members of this far distant asteroid swarm have been observed up to now. Six leading Neptune Trojans around the Lagrange point L_4 discovered earlier have been studied in detail, but two trailing ones found recently around the L_5 point, 2004 KV18 and 2008 LC18, have not been investigated yet. In this paper, we report our investigations on the dynamical behaviors of these two new Neptune Trojans. Our calculations show that the asteroid 2004 KV18 is a temporary Neptune Trojan. Most probably, it was captured into the trailing Trojan cloud no earlier than 2.03×10^5 yr ago, and it will not keep this identity no later than 1.65×10^5 yr in future. Based on the statistics on our orbital simulations, we argue that this object is more like a scattered Kuiper belt object. On the contrary, the orbit of 2008 LC18 is much more stable. Among the clone orbits spreading within the orbital uncertainties, a considerable portion of clones may survive on the L_5 tadpole orbits for 4 Gyr. The strong dependence of the stability on the semimajor axis and resonant angle suggests that further observations are badly required to confine the orbit in the stable region. We also discuss the implications of the existence and dynamics of these two trailing Trojans on the Solar system history.

To appear in: Research in Astronomy and Astrophysics
For preprints, contact `zhouly@nju.edu.cn`
or on the web at `http://arxiv.org/abs/1205.2206`

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Physical Properties of Trans-Neptunian Binaries (120347) Salacia–Actaea and (42355) Typhon–Echidna

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We report new *Hubble Space Telescope* and *Spitzer Space Telescope* results concerning the physical properties of the trans-Neptunian Object (TNO) binaries (120347) Salacia–Actaea (formerly 2004 SB_{60}), and (42355) Typhon–Echidna (formerly 2002 CR_{46}). The mass of the (120347) Salacia–Actaea system is $4.66 \pm 0.22 \times 10^{20}$ kg. The semi-major axis, period, and eccentricity of the binary orbit are $a = 5619 \pm 87$ km, $P = 5.49380 \pm 0.00016$ days, and $e = 0.0084 \pm 0.0076$, respectively. In terms of the ratio of the semimajor axis to the radius of the Hill sphere, a/r_H, (120347) Salacia–Actaea is the tightest TNO binary system with a known orbit. Based on hybrid Standard Thermal Model (hybrid-STM) fits to the data, the effective diameter and V-band geometric albedo of the system are $D = 954 \pm 109$ km (making it one of the largest known TNOs), and $p_V = 3.57^{+1.03}_{-0.72}\%$. Thermophysical models for (120347) Salacia suggest that it probably has a thermal inertia ≤ 5 J m$^{-2}s^{-1/2}K^{-1}$,

although we can not rule out values as high as 30 $\mathrm{J\,m^{-2}s^{-1/2}K^{-1}}$. Based on the magnitude difference between Salacia and Actaea, $\delta = 2.37 \pm 0.06$, we estimate their individual diameters to be $d_1 = 905 \pm 103$ km and $d_2 = 303 \pm 35$ km. The mass density of the components is $\rho = 1.16^{+0.59}_{-0.36}\,\mathrm{g/cm^3}$. Hybrid-STM fits to new Spitzer data for Typhon–Echidna give an effective diameter and V-band geometric albedo for the system of $D = 157 \pm 34$ km, and $p_V = 6.00^{+4.10}_{-2.08}\%$. Thermophysical models for (42355) Typhon suggest somewhat lower albedos (probably no higher than about 8.2%, as compared to the hybrid-STM upper limit of 10.1%). Taken together with the previously reported mass, this diameter indicates a density of $\rho = 0.60^{+0.72}_{-0.29}\mathrm{g/cm^3}$, consistent with the very low densities of most other TNOs smaller than 500 km diameter. Both objects must have significant amounts of void space in their interiors, particularly if they contain silicates as well as water-ice (as is expected). The ensemble of binary-TNO densities suggests a trend of increasing density with size, with objects smaller than 400 km diameter all having densities less than $1\,\mathrm{g/cm^3}$, and those with diameters greater than 800 km all having densities greater than $1\,\mathrm{g/cm^3}$. If the eccentricity of the binary orbit of (42355) Typhon–Echidna is not due to recent perturbations, considerations of tidal evolution suggest that (42355) Typhon–Echidna must have a rigidity close to that of solid water ice, otherwise the orbital eccentricity of the system would have been damped by now.

Published in: Icarus 219, 676 (2012 June)
For preprints, contact `stansber@as.arizona.edu`

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Circumbinary Chaos: Using Pluto's Newest Moon to Constrain the Masses of Nix & Hydra

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The Pluto system provides a unique local laboratory for the study of binaries with multiple low mass companions. In this paper, we study the orbital stability of P4, the most recently discovered moon in the Pluto system. This newfound companion orbits near the plane of the Pluto-Charon binary, roughly halfway between the two minor moons Nix and Hydra. We use a suite of few body integrations to constrain the masses of Nix and Hydra, and the orbital parameters of P4. For the system to remain stable over the age of the Solar System, the masses of Nix and Hydra likely do not exceed 5×10^16 kg and 9×10^16 kg, respectively. These upper limits assume a fixed mass ratio between Nix and Hydra at the value implied by their median optical brightness. Our study finds that stability is more sensitive to their total mass and that a downward revision of Charon's eccentricity (from our adopted value of 0.0035) is unlikely to significantly affect our conclusions. Our upper limits are an order of magnitude below existing astrometric limits on the masses of Nix and Hydra. For a density at least that of ice, the albedos of Nix and Hydra would exceed 0.3. This constraint implies they are icy, as predicted by giant impact models. Even with these low masses, P4 only remains stable if its eccentricity $e \lesssim 0.02$. The 5:1 commensurability with Charon is particularly unstable, Combining stability constraints with the observed mean motion places the preferred orbit for P4 just exterior to the 5:1 resonance. These predictions will be tested when the New Horizons satellite visits Pluto. Based on the results for the Pluto-Charon system, we expect that circumbinary, multi-planet systems will be more widely spaced than their singleton counterparts. Further, circumbinary exoplanets close to the three-body stability boundary, such as those found by Kepler, are less likely to have other companions nearby.

To appear in: The Astrophysical Journal
Preprints available on the web at `http://arxiv.org/abs/1205.5273`

Volatile Transport on Inhomogeneous Surfaces: I. Analytic Expressions, with Application to Pluto's Day

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An analytic expression for the variation in surface and sub-surface temperature is developed for worlds whose surface pressures are nearly constant with latitude and longitude and whose atmospheres are in vapor-pressure equilibrium with the dominant surface volatiles. Such worlds include the current Pluto and Triton, and other volatile-covered Kuiper Belt Objects during some portion of their heliocentric orbit. The expressions also apply on airless worlds with negligible horizontal heat flow, such as asteroids. Temperature variations in volatile-covered or bare areas as a function of time is derived in terms of three thermal parameters relating to (1) the thermal wave within the substrate, (2) the energy needed to heat an isothermal volatile slab, and (3) the buffering by the latent heat needed to change the atmospheric surface pressure. For Pluto's current surface pressure ($\sim$17 μbar), atmospheric buffering dominates over subsurface effects on diurnal timescales, and should keep the surface pressure over a Pluto day constant to within 0.2%.

To appear in: Icarus

For preprints, contact `layoung@boulder.swri.edu`
or on the web at
`http://www.boulder.swri.edu/~layoung/eprint/LYoung2012_VolXferI_rev2full.pdf`

Comparison of a Simple 2D Pluto General Circulation Model With Stellar Occultation Light Curves and Implications for Atmospheric Circulation

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We use a simple Pluto general circulation model (sPGCM) to predict for the first time the wind on Pluto and its global, large-scale structure, as well as the temperature and surface pressure. Wind is a fundamental atmospheric variable that has previously been neither measured nor explicitly modeled on Pluto. We ran the sPGCM in 2D mode (latitude, height, and time varying) using the Massachusetts Institute of Technology general circulation model dynamical core, a simple radiative-convective scheme, and no frost cycle. We found that Pluto's atmosphere is dynamically active in the zonal direction with high-speed, high-latitude jets that encircle the poles in gradient wind balance and prograde with Pluto's rotation. The meridional and vertical winds do not show evidence for a Hadley cell (or other large-scale structure), due to the low altitude temperature inversion. The horizontal variation in surface pressure is a small fraction of the previously derived inter-annual variation in surface pressure. The sGCM output was validated with stellar occultation light curve data from the years 1988, 2002, 2006, and 2007. For 2006 and 2007, the best-fit global mean surface

pressure was 24 microbar, in 2002 it was 22 microbar, while in 1988 it was 12 microbar (1 microbar error bars). For all years the methane mixing ratio was 1% (0.2% error bars). This work is a first step for future Pluto, Triton, and KBO atmosphere general circulation models that will also include longitudinal variations and a volatile cycle.

Published in: Journal of Geophysical Research, 117, E05002 (2012 May)
For preprints, contact angela@boulder.swri.edu
or on the web at http://www.boulder.swri.edu/~angela/zalucha2012JGR.117.E05002.pdf

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OTHER PAPERS OF INTEREST

On the Relation of the Sizes of Trans-Neptunian Dwarf Planets Pluto and Eris

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The discovery of the largest trans-neptunian object 2003 UB313 (dwarf planet Eris) was made more than 5 years ago, but the question on the true relation of the sizes of Pluto and Eris (and according to of their densities) remains debatable in view of a sizable scatter of their size's estimates obtained by the various methods. Here, we first used a semi-empirical approach to deduce the expression linking the orbital parameter eccentricity to the physical properties of the trans-neptunian dwarf planets and have applied it to determining the mean size of these planets. In doing so is proved that the mean Eris' size should be about 9% larger than of Pluto's. Based on the published photometric data and the derived mean diameter the possible estimates of the minimum and maximum diameters of Pluto and Eris on the assumption of a deviation their form from spherical are provided. The probable reason for an occurrence of such an aspherical form of these dwarf planets is briefly discussed.

Preprint available on the web at http://arxiv.org/abs/1203.0524

CONFERENCE INFORMATION

First Workshop on Experimental Laboratory Astrophysics

February 25-27, 2013
Poipu, Kauai, Hawaii,

http://www.chem.hawaii.edu/Bil301/Ice2013.html

During the last decade, significant new experimental techniques have been developed to investigate the interaction of ionizing radiation (UV, VUV, gamma rays, charged particles) and of neutrals (atoms, radicals, molecules, grains) with surfaces of solids (ices, minerals, carbonaceous compounds) in the Solar System and in the Interstellar Medium (ISM). These processes provide new fundamental insights – sometimes on the molecular level – into the processes that are critical to the chemistry in the ISM, star and planet forming regions, and on/in icy objects in the Solar System from the formation of the simplest molecule (molecular hydrogen) to astrobiologically important species such as amino acids and sugars. There is an increasing convergence of interests of these fields, so a 'united', bi-annual workshop is highly desired.

The first workshop features invited (senior and junior researchers) as well as contributed talks focusing on the interaction of ionizing radiation (UV, VUV, gamma rays, charged particles) and neutrals (atoms, radicals, molecules, grains) with low temperature solids (ices, minerals, organics). The talks can be extended to observations, modeling, and electronic structure calculations, but only if these topics can be directly linked – as evident from the abstract – to laboratory experiments. Poster submissions are highly encouraged; this will allow a broad participation of newcomers to the field (Ph.D. students, postdocs).

Accommodation: The workshop will take place in the Sheraton Kauai Resort in Poipu, Kauai, Hawaii, starting with a reception and registration on February 24, 2013, at 6 pm. The hotel will allocate a block of rooms for workshop participants. Reservations must be made by December 1, 2012. Group rates are available three days pre and post group arrival and departure dates. Additional information will be posted soon.

Transportation: Sheraton Kauai Resort is a short drive (20 minutes) from the airport (LIH). LIH can be reached from LAX, SFO, or HNL.

Registration: The registration deadline is November 1, 2012. The registration fee of $250 includes the reception, snacks, and a book-of-abstracts.

Additional information available at: http://www.chem.hawaii.edu/Bil301/Ice2013.html If you have additional questions, please email Ralf Kaiser (ralfk@hawaii.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:

`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`