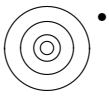
Issue No. 72 *December 2010*

DISTANT EKOs



The Kuiper Belt Electronic Newsletter

Edited by: Joel Wm. Parker

ekonews@boulder.swri.edu www.boulder.swri.edu/ekonews

CONTENTS

NEWS & ANNOUNCEMENTS

It is with much sadness to report the death of Brian Marsden on November 18, 2010. Most people who get this newsletter are familiar with Brian both personally and through his work at the CBAT/MPC, his work in celestial mechanics, his encouragement and advice to amateur and professional astronomers alike for obtaining high-quality astrometry, and entertaining discussions of mythology and historical astronomy.

`http://www.minorplanetcenter.org/mpec/K10/K10W10.html`
`http://www.cfa.harvard.edu/iau/cbet/002500/CBET002554.txt`

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

2010 SB41, 2010 TJ, 2010 TR19, 2010 TY53, 2010 VQ11, 2010 VR11, 2010 VS11, 2010 VZ98

and 1 new Centaur/SDO discovery:

2010 WG9

Reclassified objects:

2007 OC10 (SDO → TNO)
2010 RO64 (SDO → TNO)
2010 VR11 (TNO → SDO)

Current number of TNOs: 1164 (including Pluto)
Current number of Centaurs/SDOs: 289
Current number of Neptune Trojans: 7

Out of a total of 1460 objects:

634 have measurements from only one opposition
577 of those have had no measurements for more than a year
324 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

A Mid-term Astrometric and Photometric Study of Trans-Neptunian Object (90482) Orcus

J.L. Ortiz[1], A. Cikota[2], S. Cikota[2], D. Hestroffer[3], A. Thirouin[1], N. Morales[1], R. Duffard[1], R. Gil-Hutton[5], P. Santos-Sanz[1,4], and I. de la Cueva[6]

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From time series CCD observations of a fixed and large star field that contained the binary trans-Neptunian object (90482) Orcus (formerly 2004 DW), taken during a period of 33 days, we have been able to derive high-precision relative astrometry and photometry of the Orcus system with respect to background stars. The right ascension residuals of an orbital fit to the astrometric data revealed a periodicity of 9.7±0.3 days, which is what one would expect to be induced by the known Orcus companion (Vanth). The residuals are also correlated with the theoretical positions of the satellite with regard to the primary. We therefore have revealed the presence of Orcus' satellite in our astrometric measurements, although the residuals in declination did not show the expected variations. The oscillation in the residuals is caused by the photocenter motion of the combined Orcus plus satellite system around the barycenter along an orbital revolution of the satellite. The photocenter motion is much larger than the motion of Orcus around the barycenter, and we show here that detecting some binaries through a carefully devised astrometric technique might be feasible with telescopes of moderate size. We discuss the prospects for using the technique to find new binary trans-Neptunian objects (TNOs) and to study already known binary systems with uncertain orbital periods. We also analyzed the system's mid-term photometry in order to determine whether the rotation could be tidally locked to the satellite's orbital period. We found that a photometric variability of 9.7±0.3 days is clear in our data, and is nearly coincident with the orbital period of the satellite. We believe this variability might be induced by the satellite's rotation. In our photometry there is also a slight hint for an additional very small variability in the 10 hr range that was already reported in the literature. This short-term variability would indicate that the primary is not tidally locked and therefore the system would not have reached a double synchronous state. Implications for the basic physical properties of the primary and its satellite are discussed. From angular momentum considerations we suspect that the Orcus satellite might have formed from a rotational fission. This requires that the mass of the satellite would be around 0.09 times that of the primary, close to the value that one derives by using an albedo of 0.12 for the satellite and assuming equal densities for both the primary and secondary.

Published in: Astronomy and Astrophysics, 525, 31 (2011 January)

For preprints, contact ortiz@iaa.es

or on the web at http://arxiv.org/abs/1010.6187/

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Runaway Growth During Planet Formation: Explaining the Size Distribution of Large Kuiper Belt Objects

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Runway growth is an important stage in planet formation during which large protoplanets form, while most of the initial mass remains in small planetesimals. The amount of mass converted into large protoplanets and their resulting size distribution are not well understood. Here, we use analytic work, that we confirm by coagulation simulations, to describe runaway growth and the corresponding evolution of the velocity dispersion. We find that runaway growth proceeds as follows: Initially all the mass resides in small planetesimals, with mass surface density σ, and large protoplanets start to form by accreting small planetesimals. This growth continues until growth by merging large protoplanets becomes comparable to growth by planetesimal accretion. This condition sets in when $\Sigma/\sigma \sim \alpha^{3/4} \sim 10^{-3}$, where Σ is the mass surface density in protoplanets in a given logarithmic mass interval and α is the ratio of the size of a body to its Hill radius. From then on, protoplanetary growth and the evolution of the velocity dispersion become self-similar and Σ remains roughly constant, since an increase in Σ by accretion of small planetesimals is balanced by a decrease due to merging with large protoplanets. We show that this growth leads to a protoplanet size distribution given by $N(>R) \propto R^{-3}$ where $N(>R)$ is the number of objects with radii greater than R (i.e., a differential power-law index of 4). Since only the largest bodies grow significantly during runaway growth, Σ and thereby the size distribution is preserved. We apply our results to the Kuiper Belt, which is a relic of runaway growth where planet formation never proceeded to completion. Our results successfully match the observed Kuiper belt size distribution, they illuminate the physical processes that shaped it and explain the total mass that is present in large Kuiper belt objects (KBOs) today. This work suggests that the current mass in large KBOs is primordial and that it has not been significantly depleted. We also predict a maximum mass-ratio of Kuiper belt binaries that formed by dynamical processes of $\alpha^{-1/4} \sim 10$, which explains the observed clustering in binary companion sizes that is seen in the cold classical belt. Finally, our results also apply to growth in debris disks, as long as frequent planetesimal-planetesimal collisions are not important during the growth.

To appear in: The Astrophysical Journal

For preprints, contact `hilke@ucla.edu`

or on the web at `http://arxiv.org/abs/1011.0201`

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The Populations of the Trans-Neptunian Small Bodies from the Simulation of the Oort-cloud Formation

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Considering the model of the initial disc of planetesimals consisting of 14799 test particles, we simulated the formation of the populations of small bodies in the outer region of the solar system for an initial 2 Gyr period. We aimed to provide a common reference model of the formation of all inner and outer parts of the Oort cloud. In this paper, we deal with a picture of the trans-Neptunian-belt

populations which can be outlined within our simple model. The dynamical evolution of massless test particles is followed via numerical integration of their orbits. We consider perturbations by four giant planets in their current orbits and with their current masses, as well as perturbations by the Galactic tide and passing stars. Our simulation qualitatively reproduces almost all structural features observed in the trans-Neptunian region. Unfortunately, there are a lot of quantitative discrepancies between our model and observed reality implying the main conclusion that the assumption of a dynamically very cold initial proto-planetary disc (with eccentricity $\sim$0.01 and inclination $\sim$0.01 rad), which extends beyond the heliocentric distance of about 34 AU, is inconsistent with the observed structure of trans-Neptunian population of small bodies. A big discrepancy is the survival of an almost untouched initial model population beyond $\sim$34 AU which is not observed. Two following positive observed details of the TN-population structure can, perhaps, be explained with the help of our simple model. Concerning the first, we showed that the outer border of the range of Neptune's perturbation on the dynamically cold orbits is identical with the outer border of 2:1 mean-motion resonance with this planet, where a sharp decrease of the number density of bodies belonging to the classical Edgeworth-Kuiper belt is observed. Most probably, this decrease is related to Neptune's ability to significantly influence the motion of small bodies, if we assume that these bodies formed closer to the Sun and were transported into the belt by Neptune. Second, the outer border of the objects of the so-called detached subpopulation is approximately at the same heliocentric distance of 100 AU in both model and observational samples.

Published in: Contributions of the Astronomical Observatory Skalnatè Pleso, 40, 107
For preprints, contact mjakubik@ta3.sk
or on the web at
http://www.ta3.sk/caosp/Eedition/Abstracts/2010/Vol_40/No_2/pp107-129_abstract.html

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Origin and Dynamical Evolution of Neptune Trojans – II: Long Term Evolution

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Following our earlier work studying the formation of the Neptunian Trojan population during the planet's migration, we present results examining the eventual fate of the Trojan clouds produced in that work. A large number of Trojans were followed under the gravitational influence of the giant planets for a period of at least 1 Gyr. We find that the stability of Neptunian Trojans seems to be strongly correlated to their initial post-migration orbital elements, with those objects that survive as Trojans for billions of years displaying negligible orbital evolution. The great majority of these survivors began the integrations with small eccentricities ($e < 0.2$) and small libration amplitudes ($A < 30 - 40$ deg). The survival rate of "pre-formed" Neptunian Trojans (which in general survived on dynamically cold orbits ($e < 0.1$, $i < 5 - 10$ deg)) varied between $\sim$5 and 70%, depending on the precise detail of their initial orbits. By contrast, the survival rate of "captured" Trojans (on final orbits spread across a larger region of e-i element space) were markedly lower, ranging between 1 and 10% after 4 Gyr. Taken in concert with our earlier work and the broad i-distribution of the observed Trojan population, we note that planetary formation scenarios which involve the slow migration (a few tens of millions of years) of Neptune from an initial planetary architecture that is both resonant

and compact ($a_N < 18$ AU) provide the most promising fit of those we considered to the observed Trojan population. In such scenarios, we find that the current day Trojan population would number $\sim$1% of that which was present at the end of the planet's migration (i.e., survival rate of $\sim$1%), with the bulk being sourced from captured, rather than pre-formed objects. We note, however, that even those scenarios still fail to reproduce the currently observed portion of the Neptune Trojan population moving on orbits with $e < 0.1$ but $i > 20$ deg. Dynamical integrations of the currently observed Trojans show that five out of the seven are dynamically stable on timescales comparable to the age of the Solar system, while 2001 QR322, exhibits significant dynamical instability on timescales of less than 1 Gyr. The seventh Trojan object, 2008 LC18, was only recently discovered, and has such large orbital uncertainties that only future studies will be able to determine its stability.

To appear in: Monthly Notices of the Royal Astronomical Society
For preprints, contact patryksan@gmail.com
or on the web at http://sites.google.com/site/patryksofialykawka/

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The Dynamics of Neptune Trojans - II. Eccentric Orbits and Observed Objects

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In a previous paper, we presented a global view of the stability of Neptune Trojans (NTs hereafter) on inclined orbits. As the continuation of the investigation, we discuss in this paper the dependence of the stability of NT orbits on the eccentricity. For this task, high-resolution dynamical maps are constructed using the results of extensive numerical integrations of orbits initialized on fine grids of initial semimajor axis (a_0) versus eccentricity (e_0). The extensions of regions of stable orbits on the (a_0, e_0) plane at different inclinations are shown. The maximum eccentricities of stable orbits in the three most stable regions at low $(0°, 12°)$, medium $(22°, 36°)$ and high $(51°, 59°)$ inclination are found to be 0.10, 0.12 and 0.04, respectively. The fine structures in the dynamical maps are described. Via the frequency-analysis method, the mechanisms that portray the dynamical maps are revealed. The secondary resonances, at the frequency of the librating resonant angle $\lambda - \lambda_8$ and the frequency of the quasi 2:1 mean-motion resonance (MMR hereafter) between Neptune and Uranus, are found to be deeply involved in the motion of NTs. Secular resonances are detected and they also contribute significantly to the triggering of chaos in the motion. In particular, the effects of the secular resonance ν_8, ν_{18} are clarified.

We also investigate the orbital stabilities of six observed NTs by checking the orbits of hundreds of clones generated within the observing error bars. We conclude that four of them are deeply inside the stable region, with 2001 QR322 and 2005 TO74 being the exceptions. 2001 QR322 is in the close vicinity of the most significant secondary resonance. 2005 TO74 is located close to the boundary separating stable orbits from unstable ones, and it may be influenced by a secular resonance.

To appear in: Monthly Notices of the Royal Astronomical Society
For preprints, contact zhouly@nju.edu.cn
or on the web at http://arxiv.org/abs/1007.5362 and
http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2966.2010.17566.x/pdf

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Near-Infrared Spectroscopy of Trojan Asteroids: Evidence for Two Compositional Groups

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The Trojan asteroids, a very substantial population of primitive bodies trapped in Jupiters stable Lagrange regions, remain quite poorly understood. Because they occupy these orbits, the physical properties of Trojans provide unique perspective on chemical and dynamical processes that shaped the Solar System. The current study was therefore undertaken to investigate surface compositions of these objects. We present 66 new near-infrared (NIR; 0.7 to 2.5 μm) spectra of 58 Trojan asteroids, including members of both the leading and trailing swarms. We also include in the analysis previously published NIR spectra of 13 Trojans (3 of which overlap with the new sample). This data set permits not only a direct search for compositional signatures, but also a search for patterns that may reveal clues to the origin of the Trojans. We do not report any confirmed absorption features in the new spectra. Analysis of the spectral slopes, however, reveals an interesting bimodality among the NIR data. The two spectral groups identified appear to be equally abundant in the leading and trailing swarms. The spectral groups are not a result of family membership; they occur in the background, non-family population. The average albedos of the two groups are the same within uncertainties (0.051±0.016 and 0.055±0.016). No correlations between spectral slope and any other physical or orbital parameter are detected, with the exception of a possible weak correlation with inclination among the less-red spectral group. The NIR spectral groups are consistent with a similar bimodality previously suggested among visible colors and spectra. Synthesizing the present results with previously published properties of Trojans, we conclude that the two spectral groups represent object with different intrinsic compositions. We further suggest that while the less-red group originated near Jupiter or in the main asteroid belt, the redder spectral group originated farther out in the Solar System. If this suggestion is correct, the Trojan swarms offer the most readily accessible large reservoir of Kuiper Belt material as well as a unique reservoir for the study of material from the middle part of the solar nebula.

Published in: The Astronomical Journal, 141, 25 (2011 January)
For preprints, contact `jemery2@utk.edu`
or on the web at `http://arxiv.org/abs/1012.1284`

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Sedna: Investigation of Surface Compositional Variation

M.A. Barucci[1], C. Morea Dalle Ore[2,3], A. Alvarez-Candal[4], C. de Bergh[1], F. Merlin[1], C. Dumas[4] and D. Cruikshank[2]

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The dwarf planet (90377) Sedna is one of the most remote solar system objects accessible to investigations. To better constrain its surface composition and to investigate the possible heterogeneity of the surface of Sedna, several observations have been carried out at ESO-VLT with the powerful spectrometer SINFONI observing simultaneously the H and K bands. The analyzed spectra (obtained in 2005, 2007, and 2008) show a non-uniform spectral signature, particularly in the K band. Spectral modeling using the Shkuratov radiative transfer code for surface scattering has been performed using

the various sets of data, including previous observations at visible wavelengths and photometry at 3.6 and 4.5 μm by the Spitzer Space Telescope. The visible and near-IR spectra can be modeled with organic materials (triton and titan tholin), serpentine, and H_2O ice in fairly significant amounts, and CH_4, N_2 and C_2H_6 in varying trace amounts. One of the spectra obtained in October, 2005, shows a different signature in the K-band and is best modeled with CH_3OH in place of CH_4, with reduced amounts of serpentine and with the addition of olivine. The compositional surface heterogeneity can give input on the past history as well clues to the origin of this peculiar, distant object.

Published in: The Astronomical Journal, 140, 2095 (2010 December)
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Methane and Nitrogen Abundances On Pluto and Eris

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We present spectra of Eris from the MMT 6.5 meter telescope and Red Channel Spectrograph (5700−9800 Å; 5 Å pix^{-1}) on Mt. Hopkins, AZ, and of Pluto from the Steward Observatory 2.3 meter telescope and Boller and Chivens spectrograph (7100−9400 Å; 2 Å pix^{-1}) on Kitt Peak, AZ. In addition, we present laboratory transmission spectra of methane-nitrogen and methane-argon ice mixtures. By anchoring our analysis in methane and nitrogen solubilities in one another as expressed in the phase diagram of Prokhvatilov & Yantsevich (1983), and comparing methane bands in our Eris and Pluto spectra and methane bands in our laboratory spectra of methane and nitrogen ice mixtures, we find Eris' bulk methane and nitrogen abundances are $\sim 10\%$ and $\sim 90\%$ and Pluto's bulk methane and nitrogen abundances are $\sim 3\%$ and $\sim 97\%$. Such abundances for Pluto are consistent with values reported in the literature. It appears that the bulk volatile composition of Eris is similar to the bulk volatile composition of Pluto. Both objects appear to be dominated by nitrogen ice. Our analysis also suggests, unlike previous work reported in the literature, that the methane and nitrogen stoichiometry is constant with depth into the surface of Eris. Finally, we point out that our Eris spectrum is also consistent with a laboratory ice mixture consisting of 40% methane and 60% argon. Although we cannot rule out an argon rich surface, it seems more likely that nitrogen is the dominant species on Eris because the nitrogen ice 2.15 μm band is seen in spectra of Pluto and Triton.

Published in: The Astrophysical Journal, 725, 1296-1305 (2010 December 10)
For preprints, contact Stephen.Tegler@nau.edu
or on the web at http://arxiv.org/abs/1010.4821

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Chemical and Physical Properties of the Variegated Pluto and Charon Surfaces

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We present new photometric and spectroscopic observations of the PlutoCharon system carried out at the VLT-ESO (Chile) with two 8-m telescopes equipped with the FORS2, ISAAC and SINFONI instruments. The spectra were obtained in the 0.6-2.45 μm range with a spectral resolution from 300 to 1500. The SINFONI data were obtained using adaptive optics, allowing a complete separation of the two bodies. We derive both objects' magnitudes in the near infrared and convert them into albedo values. These first near infrared photometric data allow to adjust the different parts of Pluto's spectrum, provided by the three instruments. We run spectral models in order to give chemical and physical constraints on the surface of Pluto and Charon. We discuss the dilution properties of the methane ice and its implications on Pluto's surface. The heterogeneities of the pure and diluted methane ice on Pluto's surface is also investigated. The high signal-to-noise level of the data and our analyses may support the presence of ethane ice on the surface of Pluto, which is one of the main products of the methane irradiation and photolysis. The analyses of the spectra of Charon suggest that the water ice is almost completely in its crystalline form and that the ammonia compound is hydrated on the surface of this satellite.

Published in: Icarus, 210, 930 (2010 December)

PAPERS RECENTLY SUBMITTED TO JOURNALS

Physical Properties of Trans-Neptunian Binaries (120347) 2004 SB_{60} and (42355) Typhon–Echidna

J.A. Stansberry[1], W.M. Grundy[2], M. Mueller[3], S.D. Benecchi[4], G.H. Rieke[1], K.S. Noll[5], M.W. Buie[6], H.F. Levison[6], S.B. Porter[2], and H.G. Roe[2]

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Submitted to: Icarus

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OTHER PAPERS OF INTEREST

On the Existence of Distant Solar Companion and Its Possible Effects on the Oort Cloud and the Observed Comet Population

Julio A. Fernández[1]

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The Astrophysical Journal

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Microwave Emission from the Edgeworth-Kuiper Belt and the Asteroid Belt Constrained from WMAP

Kazuhide Ichikawa[1] **and Masataka Fukugita**[1,2,3]

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Preprints on the web at http://arxiv.org/abs/1011.4796

THESES

Chasing Shadows in the Outer Solar System

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The characteristics of the populations of objects that inhabit the outer solar system carry the fingerprint of the processes that governed the formation and evolution of the solar system. Occultation surveys push the limit of observation into the very small and distant outer solar system objects, allowing us to set constraints on the structure of the Kuiper belt, Scattered disk and Sedna populations. I collected, reduced, and analyzed vast datasets looking for occultations of stars by outer solar system objects, both working with the Taiwanese American Occultation Survey (TAOS) collaboration and leading the MMT/Megacam occultation effort. Having found no such events in my data, I was able to place upper limits on the Kuiper belt, scattered disk and Sedna population. These limits and their derivation are described here.

Dissertation directed by C. R. Alcock
Ph.D. awarded on March 2010 from the University of Pennsylvania
For copies, contact fbianco@lcogt.net

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`