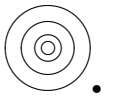
Issue No. 58 *May 2008*

DISTANT EKOs



The Kuiper Belt Electronic Newsletter

Edited by: Joel Wm. Parker

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

CONTENTS

NEWS & ANNOUNCEMENTS

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

2007 PS45, 2008 CS190

and 4 new Centaur/SDO discoveries:

2008 FC76, 2004 VP112, 2005 UN524, 2008 CT190

Objects recently assigned numbers:

1993 FW = (181708)
1998 WT31 = (181855)
1999 CG119 = (181868)
1999 CO153 = (181871)
1999 CV118 = (181867)
1999 HW11 = (181874)
1999 RD215 = (181902)
2000 YC2 = (182223)
2000 YU1 = (182222)
2001 KU76 = (182294)
2001 QW297 = (182397)
2002 FU6 = (182926)
2002 GJ32 = (182934)
2002 GZ31 = (182933)
2003 TG58 = (183595)
2004 DJ64 = (183963)
2004 DJ71 = (183964)
2004 PB112 = (184212)
2005 EO302 = (184314)

Current number of TNOs: 1076 (including Pluto)
Current number of Centaurs/SDOs: 227
Current number of Neptune Trojans: 6

Out of a total of 1309 objects:

557 have measurements from only one opposition
536 of those have had no measurements for more than a year
281 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

A Study of Photometric Variations on the Dwarf Planet (136199) Eris

R. Duffard[1], J.L. Ortiz[1], P. Santos Sanz[1], A. Mora[2], P.J. Gutiérrez[1], N. Morales[1], and D. Guirado[1]

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Eris is the largest dwarf planet currently known in the solar system. Knowledge about its physical parameters is necessary to interpret the characteristics of these kinds of bodies. The goal of this work is to study Eris' short-term and long-term variability in order to determine the amplitude of the lightcurve, which can be linked to the degree of elongation of the body or to the degree of albedo heterogeneity on the surface of the dwarf planet. In addition, the rotation period can be determined. CCD photometric observations of the trans Neptunian object Eris in R band on 16 nights spanning two years were carried out using the 1.5m telescope at Sierra Nevada Observatory (OSN), the 2.5m Isaac Newton Telescope (INT) telescope at the Roque de los Muchachos Observatory, and the 2.2m Telescope at Calar Alto Observatory. The time-series analysis leads to indications of a short-term variability whose nature is not clear. It could be real or a result of data-reduction artifacts, such as contamination by close, faint-background stars. The most significant periodicities are 14 h or its double, but other possibilities cannot be ruled out, like a 32 h weaker peak in the periodogram. As for the amplitude of the lightcurve, we get a peak-to-peak variability of 0.01±0.01 mag. The study of the long-term variability indicates that a long rotation period cannot be rejected, but the amplitude would be smaller than 0.06 mag. These results are compatible with a nearly spherical body that has a homogeneous surface.

Published in: Astronomy & Astrophysics, 479, 877, (2008 March)

For preprints, contact duffard@iaa.es

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Pluto's Light Curve in 1933–1934

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The Pluto-Charon system has complex photometric variations on all time scales; due to rotational modulations of dark markings across the surface, the changing orientation of the system as viewed from Earth, occultations and eclipses between Pluto and Charon, as well as the sublimation and condensation of frosts on the surface. The earliest useable light curve for Pluto is from 1953–1955 when Pluto was 35 AU from the Sun. Earlier data on Pluto has the potential to reveal properties of the surface at a greater heliocentric distance with nearly identical illumination and viewing geometry. We are reporting on a new accurate photographic light curve of Pluto for 1933-1934 when the heliocentric distance was 40 AU. We used 43 B-band and V-band images of Pluto on 32 plates taken on 15 nights from 19 March 1933 to 10 March 1934. Most of these plates were taken with the Mount Wilson 60-inch and 100-inch telescopes, but 7 of the plates (now at the Harvard College Observatory) were taken with the 12-inch and 16-inch Metcalf doublets at Oak Ridge. The plates were measured with an iris diaphragm photometer, which has an average one-sigma photometric error on these plates of 0.08 mag

as measured by the repeatability of constant comparison stars. The modern B and V magnitudes for the comparison stars were measured with the Lowell Observatory Hall 1.1-m telescope. The magnitudes in the plate's photographic system were converted to the Johnson B- and V-system after correction with color terms, even though they are small in size. We find that the average B-band mean opposition magnitude of Pluto in 1933–1934 was 15.73±0.01, and we see a roughly sinusoidal modulation on the rotational period (6.38 days) with a peak-to-peak amplitude of 0.11±0.03 mag. With this, we show that Pluto darkened by 5% from 1933–1934 to 1953–1955. This darkening from 1933–1934 to 1953–1955 cannot be due to changing viewing geometry (as both epochs had identical sub-Earth latitudes), so our observations must record a real albedo change over the southern hemisphere. The later darkening trend from 1954 to the 1980s has been explained by changing viewing geometry (as more of the darker northern hemisphere comes into view). Thus, we now have strong evidence for albedo changes on the surface of Pluto, and these are most easily explained by the systematic sublimation of frosts from the sunward pole that led to a drop in the mean surface albedo.

To appear in: Icarus
For preprints, contact schaefer@lsu.edu
or on the web at http://arxiv.org/abs/0805.2097

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Nereid: Light Curve for 1999–2006 and a Scenario For Its Variations

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Nereid is a small irregular moon of Neptune that displays large-, moderate-, and small-amplitude photometric variations on both fast and slow time scales. The central mystery of Nereid is now to explain the physical mechanism of these unique brightness changes and why they change with time. To characterize Nereid's variability, we have been using the SMARTS telescopes on Cerro Tololo for synoptic monitoring from 1999 to 2006. We present a well-sampled photometric time series of 493 magnitudes on 246 nights mostly in the V-band. In combination with our earlier data (for 774 magnitudes over 362 nights), our 20-year data set is the most comprehensive for any small icy body in our Solar System. Our yearly light curves show that Nereid displays various types of behaviors: large amplitude brightenings and fadings (1987 to 1990); moderate-amplitude variation about the average phase curve (1993–1997, 2003, 2005), moderate-amplitude variation and systematically brighter by roughly one-quarter magnitude throughout the entire season (2004); and nearly constant light curves superimposed on a surprisingly large-amplitude opposition surge (1998, 1999, 2000, 2006). Other than in 2004, Nereid's variations were closely centered around a constant phase curve that is well fit with a Hapke model for the coherent backscattering opposition surge mechanism with angular scale of 0.7±0.1 degrees. In our entire data set from 1987–2006, we find no significant periodicity. We propose that the year-to-year changes in the variability of Nereid are caused by forced precession (caused by tidal forces from Neptune) on the spin axis of a nonspherical Nereid, such that cross-sectional areas and average albedos change as viewed from Earth.

To appear in: Icarus
For preprints, contact schaefer@lsu.edu
or on the web at http://arxiv.org/abs/0804.2835

Production of Millisecond Dips in Sco X-1 Count Rates by Dead Time Effects

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Chang and coworkers reported millisecond duration dips in the X-ray intensity of Sco X-1 and attributed them to occultations of the source by small trans-Neptunian objects (TNOs). We have found multiple lines of evidence that these dips are not astronomical in origin, but rather the result of high-energy charged particle events in the *RXTE* PCA detectors. Our analysis of the *RXTE* data indicates that at most 10% of the observed dips in Sco X-1 could be due to occultations by TNOs, and, furthermore, we find no positive or supporting evidence for any of them being due to TNOs. We therefore believe that it is a mistake to conclude that any TNOs have been detected via occultation of Sco X-1.

Published in: The Astrophysical Journal, 677, 1241 (2008 April)
Preprint available on the web at `http://arxiv.org/abs/0710.0837`

Millisecond Dip Events in the 2007 RXTE/PCA Data of Sco X-1 and the TNO Size Distribution

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Millisecond dips in the RXTE/PCA archival data of Sco X-1 taken from 1996 to 2002 were reported recently. Those dips were found to be most likely caused by instrumental dead time but may also contain some true astronomical events, which were interpreted as the occultation of X-rays from Sco X-1 by Trans-Neptunian Objects (TNO) of 100-m size. Here we report the results of search for millisecond dip events with the new RXTE/PCA data of Sco X-1 taken in year 2007. Adopting the same selection criteria as that in the previous study, we found only 3 dip events in 72-ks data, much fewer than the 107 events found in the 560-ks data taken from 1996 to 2002 reported earlier. The new data provides more detailed information of individual 'very large events' (VLEs), which is not available in the old archival data. Although the number of VLEs does not obviously increase during the occurrence of dip events, all the 3 dip events are coincident in time with VLEs that have no flags set for any of the propane or the 6 main xenon anodes. It is a strong indication of instrumental effects. No significant dips which might be real occultation by 60–100 m TNOs were observed. With only 72-ks data, however, the previously proposed possibility that about 10% of the dip events might not be instrumental still cannot be strictly excluded. Using the absence of those anomalous VLEs as the criterion for identifying non-instrumental dip events, we found, at a lower confidence level, 4 dip events of duration 8–10 ms in the 72-ks data. Upper limits to the size distribution of TNOs at the small size end are suggested.

To appear in: Monthly Notices of the Royal Astronomical Society
For preprints, contact `hkchang@phys.nthu.edu.tw`

(42355) Typhon-Echidna: Scheduling Observations for Binary Orbit Determination

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We describe a strategy for scheduling astrometric observations to minimize the number required to determine the mutual orbits of binary transneptunian systems. The method is illustrated by application to Hubble Space Telescope observations of (42355) Typhon-Echidna, revealing that Typhon and Echidna orbit one another with a period of 18.971 ± 0.006 days and a semimajor axis of 1628 ± 29 km, implying a system mass of $(9.49 \pm 0.52) \times 10^{17}$ kg. The eccentricity of the orbit is 0.526 ± 0.015. Combined with a radiometric size determined from Spitzer Space Telescope data and the assumption that Typhon and Echidna both have the same albedo, we estimate that their radii are 76^{+14}_{-16} and 42^{+8}_{-9} km, respectively. These numbers give an average bulk density of only $0.44^{+0.44}_{0.17}$ g cm^{-3}, consistent with very low bulk densities recently reported for two other small transneptunian binaries.

To appear in: Icarus

Preprints available at `http://arxiv.org/abs/0804.2495`

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Resonant Motion of Trans-Neptunian Objects in High-eccentricity Orbits

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A substantial fraction of the Edgeworth-Kuiper belt objects are presently known to move in resonance with Neptune (the principal commensurabilities are 1/2, 3/5, 2/3, and 3/4). We have found that many of the distant (with orbital semimajor axes $a > 50$ AU) trans-Neptunian objects (TNOs) also execute resonant motions. Our investigation is based on symplectic integrations of the equations of motion for all multiple-opposition TNOs with $a > 50$ AU with allowance made for the uncertainties in their initial orbits. Librations near such commensurabilities with Neptune as 4/9, 3/7, 5/12, 2/5, 3/8, 4/27, and others have been found. The largest number of distant TNOs move near the 2/5 resonance with Neptune: 12 objects librate with a probability higher than 0.75. The multiplicity of objects moving in 2/5 resonance and the longterm stability of their librations suggest that this group of resonant objects was formed at early formation stages of the Solar system. For most of the other resonant objects, the librations are temporary. We also show the importance of asymmetric resonances in the large changes in TNO perihelion distances.

Published in: Astronomy Letters, 34, 271 (2008 April)

For preprints, contact `kleo@susu.ac.ru`

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The Warped Plane of the Classical Kuiper Belt

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By numerically integrating the orbits of the giant planets and of test particles for four billion years, we follow the evolution of the location of the midplane of the Kuiper belt. The Classical Kuiper belt conforms to a warped sheet that precesses with a 1.9 Myr period. The present-day location of the Kuiper belt plane can be computed using linear secular perturbation theory: the local normal to the plane is given by the theory's forced inclination vector, which is specific to every semi-major axis. The Kuiper belt plane does not coincide with the invariable plane, but deviates from it by up to a few degrees in stable zones. A Kuiper belt object keeps its free inclination relative to the Kuiper belt plane nearly constant, even while the plane departs from the trajectory predicted by linear theory. The constancy of free inclination simply reflects the undamped amplitude of free oscillation. Current observations of Classical Kuiper belt objects are consistent with the plane being warped by the giant planets alone, but the sample size will need to increase by a few times before confirmation exceeds 3σ in confidence. In principle, differences between the theoretically expected plane and the observed plane could be used to infer as yet unseen masses orbiting the Sun, but carrying out such a program would be challenging.

To appear in: The Astronomical Journal
For preprints, contact `echiang@astro.berkeley.edu`
or on the web at `http://arxiv.org/abs/0804.4687`

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Physical and Dynamical Properties of (12929) 1999 TZ1 Suggest that it is a Trojan

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Context: Small body (12929) 1999 TZ1 is listed by the Minor Planet Center (MPC) as a Centaur. However, its location close to the Lagrangian point L5 of Jupiter is typical of a Trojan object with large inclination.

Aims: The aim of this work is to provide a global physical and dynamical characterization of this object and to reassess its classification.

Methods: We obtained multi-wavelength observations with IRTF (Hawaii), OSN and IRAM-30 m (Spain), and performed a dynamical simulation of the evolution of its orbital parameters.

Results: Visible photometry monitoring shows a rotation curve with a period (if considered double-peaked) of 10.4 ± 0.1 h and an absolute R magnitude $H_R = 9.792 \pm 0.025$. Near-IR spectroscopy indicates a featureless reflectance spectra, with a low spectral slope of $7.2 \pm 0.11\%/100$ nm. Thermal observations at 250 GHz provide a 4.5σ detection with a flux of 1.22 ± 0.27 mJy. The combination of the visible and millimeter datasets, assuming a standard thermal model, leads to a geometric albedo $p_v = 0.053^{+0.015}_{-0.010}$ and a mean diameter of 51.5±5 km.

Conclusions: The low albedo and spectral slope measured are typical of Jupiter's Trojans, but cannot exclude a Centaur nature. However, the dynamical lifetime of the object was estimated to be

longer than 1 Gy, which is unlikely for a Centaur and suggests that (12929) 1999 TZ1 is a Trojan asteroid.

Published in: Astronomy & Astrophysics, 483, 17 (2008 May)
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A Subaru Archival Search for Faint TNOs

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We present the results of a survey for trans-neptunian objects (TNOs) based on Subaru archival images, originally collected by Sheppard et al. (2005) as part of a search for irregular satellites of Uranus. The survey region covers 2.8 deg^2, centered on Uranus and observed near opposition on two adjacent nights. Our survey reaches half its maximum detection efficiency at R=25.69 $\pm$ 0.01. The objects detected correspond to 82 TNOs, five Centaurs, and five irregular satellites. We model the cumulative number of TNOs brighter than a given apparent magnitude with both a single and double power law. The best fit single power law, with one object per square degree at magnitude R_0=$22.6^{+0.3}_{-0.4}$ and a slope of α=$0.51^{+0.5}_{-0.6}$, is inconsistent with the results of similar searches with shallower limiting magnitudes. The best fit double power law, with a bright-end slope α_1=$0.7^{+0.2}_{-0.1}$, a faint-end slope α_2=$0.3^{+0.2}_{-0.2}$, a differential number density at R=23 σ_{23}=$2.0^{+0.5}_{-0.5}$ and a magnitude break in the slope at R_{eq}=$24.3^{+0.8}_{-0.1}$, is more likely than the single power law by a Bayes factor of $\sim$26. This is the first survey with sufficient depth and areal coverage to identify the magnitude at which the break occurs without relying on the results of other surveys.

We estimate barycentric distances for the 73 objects that have 24 hr arcs; only two have heliocentric distances as large as $\sim$50 AU. We combine the distribution of observed distances with the size distribution that corresponds to a double power law luminosity function to set a tight constraint on the existence of a distant TNO population. We can exclude such a population at 60 AU, with 95% confidence, assuming it has the same size distribution and albedo as the observed TNOs, if it exceeds 8% of mass of the observed TNOs.

To appear in: The Astronomical Journal
For preprints, contact cfuentes@cfa.harvard.edu
or on the web at http://arxiv.org/abs/0804.3392

PAPERS RECENTLY SUBMITTED TO JOURNALS

Ejecta Exchange, Color Evolution in the Pluto System, and Implications for KBOs and Asteroids with Satellites

S. Alan Stern[1]

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Submitted to: Icarus

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The Youthful Appearance of the 2003 EL61 Collisional Family

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Submitted to: The Astronomical Journal

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or on the web at http://arxiv.org/abs/0804.2864

CONFERENCE INFORMATION

Great Planet Debate (GPD)

August 14 - 16, 2008

Johns Hopkins University Applied Physics Laboratory, Laurel, Maryland, USA

Scientists and educators will convene in Maryland this summer to explore a basic, but controversial, question: What is a planet?

The Great Planet Debate (GPD) conference includes two days (August 14-15) of scientific sessions to discuss and debate the processes leading to planet formation and the characteristics and criteria used to define and categorize planets. An open-to-the-public debate between Dr. Mark Sykes of the Planetary Science Institute and Dr. Neil deGrasse Tyson of the American Museum of Natural History is scheduled on the afternoon of August 14th.

During the first two days of the conference, speakers will present what we have learned about planetary bodies over more than 40 years of robotic exploration of the Solar System and what we are learning about planets around other stars. The IAU's dynamical definition of a planet will be presented, as well as an alternative geophysical definition. The utility of each will be debated, along with other potential planet definitions.

The invited speakers are leading researchers in the field of planetary system formation and evolution. The schedule of talks can be found at: http://gpd.jhuapl.edu/schedule/

The third day of the meeting will be an Educator Workshop to discuss how the question of "The Great Planet Debate" should be treated in schools and how that can be used as a springboard to discuss science as a process, as well as other topics in planetary science.

Deadline for Abstracts and Early Registration: June 27, 2008

To register go to: http://gpd.jhuapl.edu/

Meeting Organizers: Mark Sykes, Hal Weaver, and Keith Noll

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`