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DISTANT EKOs

The Kuiper Belt Electronic Newsletter

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CONTENTS

NEWS & ANNOUNCEMENTS

Names of the two most recently-discovered satellites of Pluto were announced in IAU Electronic Telegram #3575 based on approval from the IAU's Working Group for Planetary System Nomenclature and the Working Group on Small-Body Nomenclature:

- **Kerberos** = Pluto IV = S/2011 (134340) 1
- **Styx** = Pluto V = S/2012 (134340) 1

CBET 3575: `http://www.cbat.eps.harvard.edu/iau/cbet/003500/CBET003575.txt`

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Dear Distant EKOs Readers,

With the support and encouragement of Dr. James L. Green, Director of Planetary Science, NASA Headquarters, we are making a call for observations in support of the New Horizons mission.

We make this request because:
The July 2015 New Horizons encounter with Pluto presents a once-in-a-lifetime opportunity to directly link our Earth-based view of Pluto with 'ground truth' provided by in situ measurements.

To support the New Horizons encounter, our Campaign Goal is straightforward:
Establish an extensive Earth-based measurement context for the state of the Pluto system at the time of the flyby, including evolving trends in the system for at least one year prior- and post-flyby.

While near-simultaneous measurements at the highest possible resolution near the time of the July 14, 2015 flyby most directly complement New Horizons' measurements, there is a longer-term temporal context that must be addressed. A long record of observations shows Pluto to be a changing world, likely due to the insolation it receives decreasing by $\sim$2% per year on account of its eccentric orbit now carrying it rapidly away from perihelion. What's more, the obliquity of Pluto also causes a change of sub-solar latitude by more than 1 degree per year, bringing 105 km^2 of new surface area into sunlight for the first time in a century (while casting an equal and opposite polar area into arctic winter). These orbit-related effects on the atmosphere and surface of Pluto are on top of the well-known longitudinal variations measurable over the course Pluto's 6.387 day rotation.

A chart showing the New Horizons Earth-Based Campaign's Phases and a brief outline of priorities for a wide range of critically needed measurements is shown on the next page and is available on the "Campaign Objectives" tab on the website at `http://www.boulder.swri.edu/nh-support-obs/` .

We invite you to participate in this campaign. Please register your interest by sending an email to: nhobs "at" boulder.swri.edu In addition, informal workshops (information sessions) are being planned during the European Planetary Science Conference (EPSC)London 8-13 September and during the Division for Planetary Sciences Meeting (DPS) Denver 6-11 October.

For more information, please visit the Earth-Based Campaign website:
`http://www.boulder.swri.edu/nh-support-obs/`

With thanks for your support and consideration,
Richard P. Binzel (Professor of Planetary Science (MIT), New Horizons Lead, Earth-Based Campaign)
S. Alan Stern (New Horizons Principal Investigator)
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New Horizons Earth-Based Campaign: Calibration and Context of the Pluto System

http://www.boulder.swri.edu/nh-support-obs/

Campaign Phase	Date Range (MM/YY)	Measurement Theme	Measurement Required	Relative Priority *High ----------> Highest*
Phase I: Pre-Encounter	4/14 - 10/14	Occultations	Atmospheric profiles.	
		Spectral / Thermal (Global)	Atmospheric abundances & Surface mapping. Full rotational (global) coverage.	
		Photometry	Rotation lightcurve, phase function, & colors.	
Phase II: Immediate Approach	4/15 - 5/15	Occultations	Atmospheric profiles.	
		Spectral / Thermal (C/A Longitude)	Atmospheric abundances & Surface mapping. Longitude of closest approach (C/A).	
		Spectral / Thermal (Global)	Atmospheric abundances & Surface mapping. Full rotational (global) coverage.	
		Photometry.	Rotation lightcurve, phase function, & colors	
Phase III: Encounter	6/15 - 8/15 Closest Approach (C/A) date: 7/14/15	Occultations	Atmospheric profiles.	
		Spectral / Thermal (C/A Longitude)	Atmospheric abundances & Surface mapping. Longitude of closest approach (C/A).	
		Spectral / Thermal (Global)	Atmospheric abundances & Surface mapping. Full rotational (global) coverage.	
		Photometry	Rotation lightcurve, phase function, & colors	
Phase IV: Immediate Post-Encounter	9/15 - 10/15	Same as Phase II		
Phase V: Post-Encounter	4/16 - 10/16	Same as Phase I		

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There were no new TNO discoveries announced since the previous issue of *Distant EKOs* and 1 new Centaur/SDO discoveries:

2013 PH44

Objects recently assigned numbers:

2002 PQ145 = (363330)
2003 LB7 = (363401)
2006 JZ81 = (364171)

Objects recently assigned names:

2009 QV38 = Rhiphonos

Re-identified objects:

1996 TC68 = 2003 UY413
2002 JR146 = 2010 HE79

Deleted objects:

2004 PR107
2005 VD

Current number of TNOs: 1258 (including Pluto)
Current number of Centaurs/SDOs: 376
Current number of Neptune Trojans: 9

Out of a total of 1643 objects:
649 have measurements from only one opposition
634 of those have had no measurements for more than a year
323 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 Size, Shape, Albedo, Density, and Atmospheric Limit of Transneptunian Object (50000) Quaoar from Multi-chord Stellar Occultations

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We present results derived from the first multi-chord stellar occultations by the transneptunian object (50000) Quaoar, observed on 4 May 2011 and 17 February 2012, and from a single-chord occultation observed on 15 October 2012. If the timing of the five chords obtained in 2011 were correct, then Quaoar would possess topographic features (crater or mountain) that would be too large for a body of this mass. An alternative model consists in applying time shifts to some chords, to account for possible timing errors. Satisfactory elliptical fits to the chords are then possible, yielding an equivalent radius $R_{\rm equiv} = 555 \pm 2.5$ km and geometric visual albedo $p_V = 0.109 \pm 0.007$. Assuming that Quaoar is a Maclaurin spheroid with indeterminate polar aspect angle, we derive a true oblateness of $\epsilon = 0.087^{+0.0268}_{-0.0175}$, an equatorial radius of 569^{+24}_{-17} km and a density of 1.99 ± 0.46 g cm^{-3}. The orientation of our preferred solution in the plane of the sky implies that Quaoar's satellite Weywot cannot have an equatorial orbit. Finally, we detect no global atmosphere around Quaoar, considering a pressure upper limit of about 20 nbar for a pure methane atmosphere.

Published in: The Astrophysical Journal, 773, 26 (2013 August 10)
For preprints, contact `ribas@on.br`
or on the web at
`http://iopscience.iop.org/0004-637X/773/1/26/pdf/0004-637X_773_1_26.pdf`

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Limits on Quaoar's Atmosphere

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Here we present high cadence photometry taken by the Acquisition Camera on Gemini South, of a close passage by the $\sim$ 540 km radius Kuiper Belt Object, (50000) Quaoar, of a r'=20.2 background star. Observations before and after the event show that the apparent impact parameter of the event was 0.019 ± 0.004", corresponding to a close approach of 580 ± 120 km to the centre of Quaoar. No signatures of occultation by either Quaoar's limb or its potential atmosphere are detectable in the relative photometry of Quaoar and the target star, which were unresolved during closest approach. From this photometry we are able to put constraints on any potential atmosphere Quaoar might have. Using a Markov chain Monte Carlo and likelihood approach, we place pressure upper limits on sublimation supported, isothermal atmospheres of pure N_2, CO, and CH_4. For N_2 and CO, the upper limit surface pressures are 1 and 0.7 μbar respectively. The surface temperature required for such low sublimation pressures is $\sim$ 33 K, much lower than Quaoar's mean temperature of $\sim$ 44 K measured by others. We conclude that Quaoar cannot have an isothermal N_2 or CO atmosphere. We cannot eliminate the possibility of a CH_4 atmosphere, but place upper surface pressure and mean temperature limits of $\sim$ 138 nbar and $\sim$ 44 K respectively.

To appear in: The Astrophysical Journal Letters
For preprints, contact `wesley.fraser@nrc.ca`
or on the web at `http://arxiv.org/abs/1308.2230`

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The TAOS Project: Results From Seven Years of Survey Data

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The Taiwanese-American Occultation Survey (TAOS) aims to detect serendipitous occultations of stars by small ($\sim$1 km diameter) objects in the Kuiper Belt and beyond. Such events are very rare ($< 10^{-3}$ events per star per year) and short in duration ($\sim$200 ms), so many stars must be monitored at a high readout cadence. TAOS monitors typically $\sim$500 stars simultaneously at a 5 Hz readout cadence with four telescopes located at Lulin Observatory in central Taiwan. In this paper, we report the results of the search for small Kuiper Belt Objects (KBOs) in seven years of data. No occultation events were found, resulting in a 95% c.l. upper limit on the slope of the faint end of the KBO size distribution of $q = 3.34$ to 3.82, depending on the surface density at the break in the size distribution at a diameter of about 90 km.

Published in: The Astronomical Journal, 146, 14 (2013 July)

Preprints available on the web at `http://arxiv.org/abs/1301.6182`

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Kuiper Belt Occultation Predictions

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Here we present observations of 7 large Kuiper Belt Objects. From these observations, we extract a point source catalog with ~ 0.01" precision, and astrometry of our target Kuiper Belt Objects with 0.04–0.08" precision within that catalog. We have developed a new technique to predict the future occurrence of stellar occultations by Kuiper Belt Objects. The technique makes use of a maximum likelihood approach which determines the best-fit adjustment to cataloged orbital elements of an object. Using simulations of a theoretical object, we discuss the merits and weaknesses of this technique compared to the commonly adopted ephemeris offset approach. We demonstrate that both methods suffer from separate weaknesses, and thus, together provide a fair assessment of the true uncertainty in a particular prediction. We present occultation predictions made by both methods for the 7 tracked objects, with dates as late as 2015. Finally, we discuss observations of three separate close passages of Quaoar to field stars, which reveal the accuracy of the element adjustment approach, and which also demonstrate the necessity of considering the uncertainty in stellar position when assessing potential occultations.

Published in: Publications of the Astronomical Society of the Pacific, 125, 1000 (2013 August)

For preprints, contact `wesley.fraser@nrc.ca`
or on the web at `http://arxiv.org/abs/1306.6626`
and `http://www.jstor.org/stable/10.1086/672001`

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TNOs are Cool! : A Survey of the Trans-Neptunian Region. IX. Thermal Properties of Kuiper Belt Objects and Centaurs from Combined Herschel and Spitzer Observations

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The goal of this work is to characterize the ensemble thermal properties of the Centaurs / trans-Neptunian population.

Thermal flux measurements obtained with *Herschel*/PACS and *Spitzer*/MIPS provide size, albedo, and beaming factors for 85 objects (13 of which are presented here for the first time) by means of standard radiometric techniques. The measured beaming factors are influenced by the combination of surface roughness and thermal inertia effects. They are interpreted within a thermophysical model to constrain, in a statistical sense, the thermal inertia in the population and to study its dependence on several parameters. We use in particular a Monte-Carlo modeling approach to the data whereby synthetic datasets of beaming factors are created using random distributions of spin orientation and surface roughness.

Beaming factors η range from values <1 to ∼2.5, but high η values (>2) are lacking at low heliocentric distances ($r_h < 30\,\mathrm{AU}$). Beaming factors lower than 1 occur frequently (39% of the objects), indicating that surface roughness effects are important. We determine a mean thermal inertia for Centaurs/TNO of $\Gamma = (2.5\pm0.5)\,\mathrm{J\,m^{-2}\,s^{-1/2}\,K^{-1}}$, with evidence of a trend toward decreasing Γ with increasing heliocentric (by a factor ∼2.5 from 8–25 AU to 41–53 AU). These thermal inertias are 2-3 orders of magnitude lower than expected for compact ices, and generally lower than on Saturn's satellites or in the Pluto/Charon system. Most high-albedo objects are found to have unusually low thermal inertias. Our results suggest highly porous surfaces, in which the heat transfer is affected by radiative conductivity within pores and increases with depth in the sub-surface.

To appear in: Astronomy and Astrophysics

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On a Possible Size/Color Relationship in the Kuiper Belt

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Color measurements and albedo distributions introduce non-intuitive observational biases in size-color relationships among Kuiper Belt Objects (KBOs) that cannot be disentangled without a well characterized sample population with systematic photometry. Peixinho et al. report that the form of the KBO color distribution varies with absolute magnitude, H. However, Tegler et al. find that KBO color distributions are a property of object classification. We construct synthetic models of observed KBO colors based on two $B-R$ color distribution scenarios: color distribution dependent on H magnitude (H-Model) and color distribution based on object classification (Class-Model). These synthetic $B-R$ color distributions were modified to account for observational flux biases. We compare our synthetic $B-R$ distributions to the observed 'Hot' and 'Cold' detected objects from the Canada-France Ecliptic Plane Survey and the Meudon Multicolor Survey. For both surveys, the Hot population color distribution rejects the H-Model, but is well described by the Class-Model. The Cold objects reject the H-Model, but the Class-Model (while not statistically rejected) also does not provide a compelling match for data. Although we formally reject models where the structure of the color distribution is a strong function of H magnitude, we also do not find that a simple dependence of color distribution on orbit classification is sufficient to describe the color distribution of classical KBOs.

To appear in: The Astronomical Journal

Preprints are on the web at `http://arxiv.org/abs/1308.0014`

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A Portrait of the Extreme Solar System Object 2012 DR_{30}

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2012 DR_{30} is a recently discovered Solar System object on a unique orbit, with a high eccentricity of 0.9867, a perihelion distance of 14.54 AU and a semi-major axis of 1109 AU, in this respect outscoring the vast majority of trans-Neptunian objects. We performed Herschel/PACS and optical photometry to uncover the size and albedo of 2012 DR_{30}, together with its thermal and surface properties. The body is 185 km in diameter and has a relatively low V-band geometric albedo of ∼8%. Although the colours of the object indicate that 2012 DR_{30} is an RI taxonomy class TNO or Centaur, we detected an absorption

feature in the Z-band that is uncommon among these bodies. A dynamical analysis of the target's orbit shows that 2012 DR_{30} moves on a relatively unstable orbit and was most likely only recently placed on its current orbit from the most distant and still highly unexplored regions of the Solar System. If categorised on dynamical grounds 2012 DR_{30} is the largest Damocloid and/or high inclination Centaur observed so far.

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For preprints, contact pkisscs@konkoly.hu
or on the web at http://arxiv.org/abs/1304.7112

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Perspectives on Effectively Constraining the Location of a Massive Trans-Plutonian Object with the New Horizons Spacecraft: A Sensitivity Analysis

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The radio tracking apparatus of the New Horizons spacecraft, currently traveling to the Pluto system where its arrival is scheduled for July 2015, should be able to reach an accuracy of 10 m (range) and 0.1 mm/s (range-rate) over distances up to 50 au. This should allow to effectively constrain the location of a putative trans-Plutonian massive object, dubbed Planet X (PX) hereafter, whose existence has recently been postulated for a variety of reasons connected with, e.g., the architecture of the Kuiper belt and the cometary flux from the Oort cloud. Traditional scenarios involve a rock- ice planetoid with $m_X \approx 0.7 m_{\oplus}$ at some 100–200 au, or a Jovian body with $m_X \lesssim 5\, m_J$ at about 10,000–20,000 au; as a result of our preliminary sensitivity analysis, they should be detectable by New Horizons since they would impact its range at a km level or so over a time span 6 years long. Conversely, range residuals statistically compatible with zero having an amplitude of 10 m would imply that PX, if it exists, could not be located at less than about 4,500 au ($m_X = 0.7\, m_{\oplus}$) or 60,000 au ($m_X = 5\, m_J$), thus making a direct detection quite demanding with the present-day technologies. As a consequence, it would be appropriate to rename such a remote body as Thelisto. Also fundamental physics would benefit from this analysis since certain subtle effects predicted by MOND for the deep Newtonian regions of our Solar System are just equivalent to those of a distant pointlike mass.

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THESES

Study of Trans-Neptunian Objects using Photometric Techniques and Numerical Simulations

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More than 1,400 Trans-Neptunian Objects (TNOs) have been detected since the discovery of 1992 QB_1 (Jewitt and Luu 1992). The Trans-Neptunian belt is the largest and relatively stable reservoir of small bodies in the Solar System. Due to their distances from the Sun, the TNOs are considered the least evolved bodies of the Solar System and therefore, their studies provide us with information about the composition and properties of the primitive solar nebula. The study of these bodies provide us clues about the origin and the evolution of the early Solar System. In addition, the Trans-Neptunian belt provides a natural connection to the study of the protoplanetary disks observed around some stars.

The main objective of this thesis was to determine and analyze, for a large sample of objects, the ranges of variability, their rotational periods, as well as other physical parameters that can be derived from short-term variability. The aim was to derive physical parameters such as axis ratios, phase coefficients, albedos, density, porosity, etc., for a good sample of TNOs and centaurs because only few studies were published prior to this thesis. Short-term variability studies allow us to determine the rotational, dynamical and physical evolution of these objects. But a lot of observing time is required to provide reliable short-term variability studies. In addition, it is thought that large objects are less collisionally evolved, so they probably retain the distribution of the primitive angular momentum of the early stages of the Solar System (Davis and Farinella 1997).

At the beginning of this PhD, the sample of objects with measured rotational periods and lightcurve amplitudes was very limited. Only ∼50 objects with short-term variability were reported and many published rotational periods were uncertain or erroneous. In addition, Sheppard et al. (2008) noticed an observational bias towards large amplitudes and short rotational periods. Increasing the sample size, improving rotational periods, lightcurves, and trying to overcome some observational biases were some of the objectives of this study. On the other hand, binary objects required a special treatment, with the objective to derive relevant physical parameters, some of them from the tidal effects in such systems.

Another motivation to carry out photometry observations was the support to the Herschel Space Observatory (HSO) key project "TNOs are cool!". HSO is a mission of the European Space Agency (ESA) and of the National Aeronautics and Space Administration (NASA). "TNOs are cool!" is a key-project of HSO dedicated to the observations of thermal emission from 130 TNOs and centaurs in ∼400 h of observing time (Müller et al. 2009). This key project was the largest key-project of HSO and required a large international effort with more than 40 team members. For the analysis and interpretation of the thermal data from HSO, thermal models or thermophysical models (Müller et al. 2009, Vilenius et al. 2012, Mommert et al. 2012) are required. To derive diameters and albedos, all these models require input parameters such as absolute magnitudes and spin periods or constraints on them, all of which require ground based photometry.

As a result of early findings during the project, a new model from a numerical point of view to explain the formation of the Haumea system is developed. By extension, this model is also able to explain the formation of some binary/multiple systems, and even the formation of unbound pairs of TNOs that was not considered as a possibility in the Trans-Neptunian belt. Haumea is a large object with very peculiar characteristics. Several models have been proposed by different authors to explain the formation of this object and its "family" as well as the peculiar characteristics of Haumea, but all of them have some inconsistencies.

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