Issue No. 69 *June 2010*

DISTANT EKOs

The Kuiper Belt Electronic Newsletter

Edited by: Joel Wm. Parker

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CONTENTS

NEWS & ANNOUNCEMENTS

The abstracts and webcast of the talks from the workshop "Nix and Hydra: Five Years After Discovery" held last month are now available online.
Titles and abstracts:

`http://www.stsci.edu/institute/conference/nix-hydra/talksList`

Webcast talks (select "Recent Webcasts" then scroll to find them all on May 11 and 12):

`http://webcast.stsci.edu/webcast/`

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There were no new TNO or Centaur/SDO discoveries announced since the previous issue of *Distant EKOs*.

Current number of TNOs: 1130 (including Pluto)
Current number of Centaurs/SDOs: 256
Current number of Neptune Trojans: 6

Out of a total of 1392 objects:
584 have measurements from only one opposition
570 of those have had no measurements for more than a year
321 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 Edgeworth-Kuiper Debris Disk

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The Edgeworth-Kuiper belt (EKB) and its presumed dusty debris is a natural reference for extrsolar debris disks. We re-analyze the current database of known transneptunian objects (TNOs) and employ a new algorithm to eliminate the inclination and the distance selection effects in the known TNO populations to derive expected parameters of the "true" EKB. Its estimated mass is $M_{\rm EKB} = 0.12 M_\oplus$, which is by a factor of ~ 15 larger than the mass of the EKB objects detected so far. About a half of the total EKB mass is in classical and resonant objects and another half is in scattered ones. Treating the debiased populations of EKB objects as dust parent bodies, we then "generate" their dust disk with our collisional code. Apart from accurate handling of destructive and cratering collisions and direct radiation pressure, we include the Poynting-Robertson (P-R) drag. The latter is known to be unimportant for debris disks around other stars detected so far, but cannot be ignored for the EKB dust disk because of its much lower optical depth. We find the radial profile of the normal optical depth to peak at the inner edge of the classical belt, ≈ 40 AU. Outside the classical EKB, it approximately follows $\tau \propto r^{-2}$ which is roughly intermediate between the slope predicted analytically for collision-dominated ($r^{-1.5}$) and transport-dominated ($r^{-2.5}$) disks. The size distribution of dust is less affected by the P-R effect. The cross section-dominating grain size still lies just above the blowout size ($\sim 1 \ldots 2 \mu$m), as it would if the P-R effect was ignored. However, if the EKB were by one order of magnitude less massive, its dust disk would have distinctly different properties. The optical depth profile would fall off as $\tau \propto r^{-3}$, and the cross section-dominating grain size would shift from $\sim 1 \ldots 2 \mu$m to $\sim 100 \mu$m. These properties are seen if dust is assumed to be generated only by known TNOs without applying the debiasing algorithm. An upper limit of the in-plane optical depth of the EKB dust set by our model is $\tau = 2 \times 10^{-5}$ outside 30 AU. If the solar system were observed from outside, the thermal emission flux from the EKB dust would be about two orders of magnitude lower than for solar-type stars with the brightest known infrared excesses observed from the same distance. Herschel and other new-generation facilities should reveal extrasolar debris disks nearly as tenuous as the EKB disk. We estimate that the Herschel/PACS instrument should be able to detect disks at a $\sim 1 \ldots 2 M_{\rm EKB}$ level.

To appear in: Astronomy & Astrophysics
Preprints available on the web at `http://arxiv.org/abs/1006.2220`

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Systematic Biases in the Observed Distribution of Kuiper Belt Object Orbits

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The orbital distribution of Kuiper Belt objects (KBOs) provides important tests of solar system evolution models. However, our understanding of this orbital distribution can be affected by many observational biases. An important but difficult to quantify bias results from tracking selection effects; KBOs are recovered or lost

depending on assumptions made about their orbital elements when fitting the initial (short) observational arc. Quantitatively studying the effects and significance of this bias is generally difficult, because only the objects where the assumptions were correct are recovered and thus available to study "the problem," and because different observers use different assumptions and methods. We have used a sample of 38 KBOs that were discovered and tracked, bias-free, as part of the Canada-France Ecliptic Plane Survey to evaluate the potential for losing objects based on the two most common orbit and ephemeris prediction sources: the Minor Planet Center (MPC) and the Bernstein and Khushalani (BK) orbit fitting code. In both cases, we use early discovery and recovery astrometric measurements of the objects to generate ephemeris predictions that we then compare to later positional measurements; objects that have large differences between the predicted and actual positions would be unlikely to be recovered and are thus considered "lost." We find systematic differences in the orbit distributions which would result from using the two orbit-fitting procedures. In our sample, the MPC-derived orbit solutions lost slightly fewer objects (five out of 38) due to large ephemeris errors at one year recovery, but the objects which were lost belonged to more "unusual" orbits such as scattering disk objects or objects with semimajor axes interior to the 3:2 resonance. Using the BK code, more objects (seven out of 38) would have been lost due to ephemeris errors, but the lost objects came from a range of orbital regions, primarily the classical belt region. We also compare the accuracy of orbits calculated from one year arcs against orbits calculated from multiple years of observations and find that two-opposition orbits without additional observations acquired at least two months from opposition are unreliable for dynamical modeling.

Published in: The Astronomical Journal, 139, 2249 (2010 June)

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Unbiased Inclination Distributions for Objects in the Kuiper Belt

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Using data from the Deep Ecliptic Survey (DES), we investigate the inclination distributions of objects in the Kuiper Belt. We present a derivation for observational bias removal and use this procedure to generate unbiased inclination distributions for Kuiper Belt objects (KBOs) of different DES dynamical classes, with respect to the Kuiper Belt Plane. Consistent with previous results, we find that the inclination distribution for all DES KBOs is well fit by the sum of two Gaussians, or a Gaussian plus a generalized Lorentzian, multiplied by $\sin i$. Approximately 80% of KBOs are in the high-inclination grouping. We find that Classical object inclinations are well fit by $\sin i$ multiplied by the sum of two Gaussians, with roughly even distribution between Gaussians of widths 2.0 (+0.6, -0.5) deg. and 8.1 (+2.6, -2.1) deg. Objects in different resonances exhibit different inclination distributions. The inclinations of Scattered objects are best matched by $\sin i$ multiplied by a single Gaussian that is centered at 19.1 (+3.9, -3.6) deg. with a width of 6.9 (+4.1, -2.7) deg. Centaur inclinations peak just below 20°, with one exceptionally high-inclination object near 80○. The

currently observed inclination distribution of the Centaurs is not dissimilar to that of the Scattered Extended KBOs and Jupiter-family comets, but is significantly different from the Classical and Resonant KBOs. While the sample sizes of some dynamical classes are still small, these results should begin to serve as a critical diagnostic for models of Solar System evolution.

To appear in: The Astronomical Journal
For preprints, contact amanda@saao.ac.za
or on the web at http://arxiv.org/abs/1005.1719

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Towards Initial Mass Functions for Asteroids and Kuiper Belt Objects

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Our goal is to understand primary accretion of the first planetesimals. Some examples are seen today in the asteroid belt, providing the parent bodies for the primitive meteorites. The primitive meteorite record suggests that sizeable planetesimals formed over a period longer than a million years, each of which being composed entirely of an unusual, but homogeneous, mixture of mm-size particles. We sketch a scenario that might help explain how this occurred, in which primary accretion of 10–100 km size planetesimals proceeds directly, if sporadically, from aerodynamically-sorted mm-size particles (generically "chondrules"). These planetesimal sizes are in general agreement with the currently observed asteroid mass peak near 100 km diameter, which has been identified as a "fossil" property of the pre-erosion, pre-depletion population. We extend our primary accretion theory to make predictions for outer solar system planetesimals, which may also have a preferred size in the 100 km diameter range. We estimate formation *rates* of planetesimals and explore parameter space to assess the conditions needed to match estimates of both asteroid and Kuiper Belt Object (KBO) formation rates. For parameters that satisfy observed mass accretion rates of Myr-old protoplanetary nebulae, the scenario is roughly consistent with not only the "fossil" sizes of the asteroids, and their estimated production rates, but also with the observed spread in formation ages of chondrules in a given chondrite, and with a tolerably small radial diffusive mixing during this time between formation and accretion. As previously noted, the model naturally helps explain the peculiar size distribution of chondrules within such objects. The optimum range of parameters, however, represents a higher gas density and fractional abundance of solids, and a smaller difference between keplerian and pressure-supported orbital velocities, than "canonical" models of the solar nebula. We discuss several potential explanations for these differences. The scenario also produces 10-100km diameter primary KBOs, and also requires an enhanced abundance of solids to match the mass production rate estimates for KBOs (and presumably the planetesimal precursors of the ice giants themselves). We discuss the advantages and plausibility of the scenario, outstanding issues, and future directions of research.

To appear in: Icarus
For preprints, contact jeffrey.cuzzi@nasa.gov
or on the web at http://arxiv.org/abs/1004.0270

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Short-term Variability of a Sample of 29 Trans-Neptunian Objects and Centaurs

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We attempt to increase the number of Trans-Neptunian objects (TNOs) whose short-term variability has been studied and compile a high quality database with the least possible biases, which may be use to perform statistical analyse.

We performed broadband CCD photometric observations using several telescopes.

We present results for 6 years of observations, reduced and analyzed with the same tools in a systematic way and completely new data for 15 objects (1998 SG_{35}, 2002 GB_{10}, 2003 EL_{61}, 2003 FY_{128}, 2003 MW_{12}, 2003 OP_{32}, 2003 WL_7, 2004 SB_{60}, 2004 UX_{10}, 2005 CB_{79}, 2005 RM_{43}, 2005 RN_{43}, 2005 RR_{43}, 2005 UJ_{438}, 2007 UL_{126} (or 2002 KY_{14})), for 5 objects we present a new analysis of previously published results plus additional data (2000 WR_{106}, 2002 CR_{46}, 2002 TX_{300}, 2002 VE_{95}, 2005 FY_9) and for 9 objects we present a new analysis of data already published (1996 TL_{66}, 1999 TZ_1, 2001 YH_{140}, 2002 AW_{197}, 2002 LM_{60}, 2003 AZ_{84}, 2003 CO_1, 2003 VS_2, 2004 DW). Lightcurves, possible rotation periods and photometric amplitudes are reported for all of them. The photometric variability is smaller than previously thought: the mean amplitude of our sample is 0.1 mag and only around 15% of our sample has a larger variability than 0.15 mag. The smaller variability than previously thought seems to be a bias of previous observations. We find a very weak trend of faster spinning objects towards smaller sizes, which appears to be consistent with the fact that the smaller objects are more collisionally evolved, but could also be a specific feature of the Centaurs, the smallest objects in our sample. We also find that the smaller the objects, the larger their amplitude, which is also consistent with the idea that small objects are more collisionally evolved and thus more deformed. Average rotation rates from our work are 7.5 h for the whole sample, 7.6 h for the TNOs alone and 7.3 h for the Centaurs. All of them appear to be somewhat faster than what one can derive from a compilation of the scientific literature and our own results. Maxwellian fits to the rotation rate distribution give mean values of 7.5 h (for the whole sample) and 7.3 h (for the TNOs only). Assuming hydrostatic equilibrium we can determine densities from our sample under the additional assumption that the lightcurves are dominated by shape effects, which is likely not realistic. The resulting average density is 0.92 g/cm^3 which is not far from the density constraint that one can derive from the apparent spin barrier that we observe.

To appear in: Astronomy and Astrophysics

For preprints, contact thirouin@iaa.es

or on the web at http://arxiv.org/abs/1004.4841

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Searching for Sub-kilometer TNOs using Pan-STARRS Video Mode Lightcurves: Preliminary Study and Evaluation using Engineering Data

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We present a pre-survey study of using the Panoramic Survey Telescope and Rapid Response System (Pan-STARRS) high sampling rate video mode guide star images to search for trans-Neptunian objects (TNOs).

Guide stars are primarily used by Pan-STARRS to compensate for image motion and hence improve the point spread function. With suitable selection of the guide stars within the Pan-STARRS 7 $\deg^2$ field of view, the lightcurves of these guide stars can also be used to search for occultations by TNOs. The best target stars for this purpose are stars with high signal-to-noise ratio (S/N) and small angular size. In order to do this, we compiled a catalog using the S/N calculated from stars with $m_V < 13$ mag in the Tycho2 catalog then cross matched these stars with the Two Micron All Sky Survey catalog and estimated their angular sizes from $(V - K)$ color. We also outlined a new detection method based on matched filter that is optimized to search for diffraction patterns in the lightcurves due to occultation by sub-kilometer TNOs. A detection threshold is set to compromise between real detections and false positives. Depending on the theoretical size distribution model used, we expect to find up to *a hundred events* during the three-year life time of the Pan-STARRS-1 project. The high sampling (30 Hz) of the project facilitates detections of small objects (as small as 400 m), which are numerous according to power law size distribution, and thus allows us to verify various models and further constrain our understanding of the structure in the outer reach of the Solar System. We have tested the detection algorithm and the pipeline on a set of engineering data (taken at 10 Hz in stead of 30 Hz). No events were found within the engineering data, which is consistent with the small size of the data set and the theoretical models. Meanwhile, with a total of ~ 22 star-hours video mode data ($|\beta| < 10^\circ$), we are able to set an upper limit of $N(> 0.5 \text{ km}) \sim 2.47 \times 10^{10} \deg^{-2}$ at 95% confidence limit.

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Preprints available on the web at `http://arxiv.org/abs/0910.5598`

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Colors of Inner Disk Classical Kuiper Belt Objects

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We present new optical broadband colors, obtained with the Keck 1 and Vatican Advanced Technology telescopes, for six objects in the inner classical Kuiper Belt. Objects in the inner classical Kuiper Belt are of interest as they may represent the surviving members of the primordial Kuiper Belt that formed interior to the current position of the 3:2 resonance with Neptune, the current position of the plutinos, or, alternatively, they may be objects formed at a different heliocentric distance that were then moved to their present locations. The six new colors, combined with four previously published, show that the 10 inner belt objects with known colors form a neutral clump and a reddish clump in $B - R$ color. Nonparametric statistical tests show no significant difference between the $B - R$ color distribution of the inner disk objects compared to the color distributions of Centaurs, plutinos, or scattered disk objects. However, the $B - R$ color distribution of the inner classical Kuiper belt objects does differ significantly from the distribution of colors in the cold (low inclination) main classical Kuiper belt. The cold main classical objects are predominately red, while the inner classical belt objects are a mixture of neutral and red. The color difference may reveal the existence of a gradient in the composition and /or surface processing history in the primordial Kuiper Belt, or indicate that the inner disk objects are not dynamically analogous to the cold main classical belt objects.

To appear in: The Astronomical Journal
For preprints, contact `wromanishin@ou.edu`
or on the web at `http://arxiv.org/abs/1004.3059`

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TNOs are Cool: A Survey of the Trans-Neptunian Region I. Results from the *Herschel* Science Demonstration Phase (SDP)

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The goal of the *Herschel* Open Time Key programme *"TNOs are Cool!"* is to derive the physical and thermal properties for a large sample of Centaurs and trans-Neptunian objects (TNOs), including resonant, classical, detached and Scattered Disk objects. We present results for 7 targets either observed in PACS point-source, or in mini scan-map mode. For 3 objects *Spitzer*-MIPS observations were included. The sizes of these targets range from 100 km to almost 1000 km, 5 have low geometric albedos below 10%, (145480) 2005 TB_{190} has a higher albedo above 15%. Classical thermal models driven by an intermediate beaming factor of η=1.2 or η-values adjusted to the observed colour temperature fit the multi-band observations well in most cases. More sophisticated thermophysical models give very similar diameter and albedo values for thermal inertias in the range 0-25 $J\,m^{-2}\,s^{-0.5}\,K^{-1}$, consistent with very low heat conductivities at temperatures far away from the Sun. The early experience with observing and model strategies will allow us to derive physical and thermal properties for our complete *Herschel* TNO sample of 140 targets as a benchmark for understanding the solar system debris disk, and extra-solar ones as well.

To appear in: Astronomy and Astrophysics Letters (Herschel special issue)

For preprints, contact `tmueller@mpe.mpg.de`

or on the web at `http://arxiv.org/abs/1005.2923`

"TNOs are Cool": A Survey of the Trans-Neptunian Region. II. The Thermal Lightcurve of (136108) Haumea

E. Lellouch, C. Kiss, P. Santos-Sanz, T.G. Müller, S. Fornasier, O. Groussin, P. Lacerda, J.L. Ortiz, A. Thirouin, A. Delsanti, R. Duffard, A.W. Harris, F. Henry, T. Lim, R. Moreno, M. Mommert, M. Mueller, S. Protopapa, J. Stansberry, D. Trilling, E. Vilenius, A. Barucci, J. Crovisier, A. Doressoundiram, E. Dotto, P.J. Gutiérrez, O. Hainaut, P. Hartogh, D. Hestroffer, J. Horner, L. Jorda, M. Kidger, L. Lara, M. Rengel, B. Swinyard, and N. Thomas

Thermal emission from Kuiper Belt object (136108) Haumea was measured with Herschel-PACS at 100 and 160 micrometers for almost a full rotation period. Observations clearly indicate a 100 micrometer thermal lightcurve with an amplitude of a factor of ∼2, which is positively correlated with the optical lightcurve. This confirms that both are primarily due to shape effects. A 160 micrometer lightcurve is marginally detected. Radiometric fits of the mean Herschel and Spitzer fluxes indicate an equivalent diameter $D \sim 1300$ km and a geometric albedo $p_v \sim 0.70$–0.75. These values agree with inferences from the optical lightcurve, supporting the hydrostatic equilibrium hypothesis. The large amplitude of the 100 micrometer lightcurve suggests that the object has a high projected a/b axis ratio (∼1.3) and a low thermal inertia as well as possible variable infrared beaming. This may point to fine regolith on the surface, with a lunar-type photometric behavior. The quality of the thermal data is not sufficient to clearly detect the effects of a surface dark spot.

To appear in: Astronomy & Astrophysics
For preprints, contact emmanuel.lellouch@obspm.fr
or on the web at http://arxiv.org/abs/1006.0095

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The Formation of the Collisional Family around the Dwarf Planet Haumea

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Haumea, a rapidly rotating elongated dwarf planet (∼ 1500 km in diameter), has two satellites and is associated with a "family" of several smaller Kuiper Belt objects (KBOs) in similar orbits. All members of the Haumea system share a water ice spectral feature that is distinct from all other KBOs. The relative velocities between the Haumea family members are too small to have formed by catastrophic disruption of a large precursor body, which is the process that formed families around much smaller asteroids in the Main Belt. Here we show that all of the unusual characteristics of the Haumea system are explained by a novel type of giant collision: a graze-and-merge impact between two comparably sized bodies. The grazing encounter imparted the high angular momentum that spun off fragments from the icy crust of the elongated merged body. The fragments became satellites and family members. Giant collision outcomes are extremely sensitive to the impact parameters. Compared to the Main Belt, the largest bodies in the Kuiper Belt are more massive and experience slower velocity collisions; hence, outcomes of giant collisions are dramatically different between the inner and outer solar system. The dwarf planets in the Kuiper Belt record an unexpectedly large number of giant collisions, requiring a special dynamical event at the end of solar system formation.

Published in: The Astrophysical Journal, 714, 1789 (2010 May 10)
For preprints, contact Zoë M. Leinhardt at Z.M.Leinhardt@damtp.cam.ac.uk
or on the web at http://arxiv.org/abs/1003.5822
and http://www.damtp.cam.ac.uk/user/zml20/Zoe/Publications.html

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Size and Albedo of Kuiper Belt Object 55636 from a Stellar Occultation

J.L. Elliot[1,2,3], M.J. Person[1], C.A. Zuluaga[1], A.S. Bosh[1], E.R. Adams[1], T.C. Brothers[1], A.A.S. Gulbis[1,4], S.E. Levine[1,5,6], M. Lockhart[1], A.M. Zangari[1], B.A. Babcock[7], K. DuPre[8], J.M. Pasachoff[8], S.P. Souza[8], W. Rosing[9], N. Secrest[10], L. Bright[3], E.W. Dunham[3], S.S. Sheppard[11], M. Kakkala[12], T. Tilleman[5], B. Berger[13], J.W. Briggs[13,14], G. Jacobson[13], P. Valleli[13], B. Volz[13], S. Rapoport[15], R. Hart[16], M. Brucker[17], R. Michel[18], A. Mattingly[19], L. Zambrano-Marin[20], A.W. Meyer[21], J. Wolf[22], E.V. Ryan[23], W.H. Ryan[23], K. Morzinski[24], B. Grigsby[24], J. Brimacombe[25], D. Ragozzine[26], H.G. Montano[27], and A. Gilmore[28]

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The Kuiper belt is a collection of small bodies (Kuiper belt objects, KBOs) that lie beyond the orbit of Neptune and which are believed to have formed contemporaneously with the planets. Their small size and great distance make them difficult to study. KBO 55636 (2002 TX_{300}) is a member of the water-ice-rich Haumea KBO collisional family. The Haumea family are among the most highly reflective objects in the Solar System. Dynamical calculations indicate that the collision that created KBO 55636 occurred at least 1 Gyr ago. Here we report observations of a multi-chord stellar occultation by KBO 55636, which occurred on 9 October 2009 UT. We find that it has a mean radius of 143±5 km (assuming a circular solution). Allowing for possible elliptical shapes, we find a geometric albedo of $0.88^{(+0.15,-0.06)}$ in the V photometric band, which establishes that KBO 55636 is smaller than previously thought and that, like its parent body, it is highly reflective. The dynamical age implies either that KBO 55636 has an active resurfacing mechanism, or that fresh water-ice in the outer Solar System can persist for gigayear timescales.

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Quaoar: A Rock in the Kuiper Belt

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Here we report WFPC2 observations of the Quaoar-Weywot Kuiper belt binary. From these observations we find that Weywot is on an elliptical orbit with eccentricity of 0.14 ± 0.04, period of 12.438 ± 0.005 days, and a semi-major axis of $1.45 \pm 0.08 \times 10^4$ km. The orbit reveals a surprisingly high Quaoar-Weywot system mass of $1.6 \pm 0.3 \times 10^{21}$ kg. Using the surface properties of the Uranian and Neptunian satellites as a proxy for Quaoar's surface, we reanalyze the size estimate from Brown and Trujillo (2004). We find, from a mean of available published size estimates, a diameter for Quaoar of 890 ± 70 km. We find Quaoar's density to be $\rho = 4.2 \pm 1.3$ g cm^{-3}, possibly the highest density in the Kuiper belt.

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For preprints, contact `fraserw@gps.caltech.edh`
or on the web at `http://arxiv.org/abs/1003.5911`

A Spectroscopic Analysis of Jupiter-coupled Object (52872) Okyrhoe, and TNOs (90482) Orcus and (73480) 2002 PN_{34}

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Aims: We present new visible and near-infrared photometric measurements and near-infrared spectroscopic measurements for three outer Solar System small bodies, the Jupiter-coupled object (52872) Okyrhoe and the TNOs (90482) Orcus and (73480) 2002 PN_{34}. We analyzed their surface compositions by modeling their spectra in the visible and near-infrared wavelength ranges. We then compared this new data with previous measurements of Okyrhoe and Orcus to search for heterogeneity on their surfaces.

Methods: All observations were performed at the European Southern Observatory 8 m Very Large Telescope, UT1 and UT4 at the Paranal Observatory in Chile.

Results: We find varying amounts of H_2O ice among these bodies, Okyrhoe shows no trace of it in our spectrum, 73480 has small amounts, and Orcus has large quantities. While we do clearly see for Orcus that a significant fraction of the H_2O ice is in crystalline form from the 1.65-μm feature, we cannot detect the 2.21-μm feature supposedly due to ammonia hydrate, because of the low signal-to-noise of the data. We also do not see any indication of ices more volatile than H_2O, such as CH_4 or CO_2, in the spectrum, so we limit their presence to no more than about 5% based on the data presented here and on high-quality data from Barucci et al. (2008; A&A, 479:L13).

To appear in: Astronomy & Astrophysics

Methane, Ammonia and Their Irradiation Products at the Surface of an Intermediate-size KBO? A Portrait of Plutino (90482) Orcus

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Orcus is an intermediate-size 1000 km-scale Kuiper Belt Object (KBO) in 3:2 mean motion resonance with Neptune, in an orbit very similar to that of Pluto. It has a water ice dominated surface with solar-like visible colors. We present visible and near-infrared photometry and spectroscopy obtained with Keck 10 m telescope (optical) and Gemini 8 m telescope (near infrared). We confirm the unambiguous detection of crystalline water ice as well as absorption in the 2.2 μm region. These spectral properties are close to those observed for Pluto's larger satellite Charon, and for Plutino (208996) 2003 AZ_{84}. Both in the visible and near-infrared Orcus' spectral properties appear to be homogeneous over time (and probably rotation) at the resolution available. From Hapke radiative transfer models involving intimate mixtures of various ices we find for the first time that ammonium (NH_4^+) and traces of ethane (C_2H_6), which are most probably solar irradiation products of ammonia and methane, and a mixture of methane *and* ammonia (diluted or not) are the best candidates to improve the description of the data with respect to a simple water ice mixture (Haumea type surface). The possible more subtle structure of the 2.2 μm band(s) should be investigated thoroughly in the future for Orcus and other intermediate size Plutinos to better understand the methane and ammonia chemistry at work, if any. We investigated the thermal history of Orcus with a new 3D thermal evolution model. Simulations over 4.5×10^9yrs with an input 10% porosity, bulk composition of 23% amorphous water ice and 77% dust (mass fraction), and cold accretion show that even with the action of long-lived radiogenic elements only, Orcus should have a melted core and most probably suffered a cryovolcanic event in its history which brought large amounts of crystalline ice to the surface. The presence of ammonia in the interior would strengthen the melting process. A surface layer of a few hundred meters to a few tens of kilometers of amorphous water ice survives, while most of the remaining volume underneath contains crystalline ice. The crystalline water ice possibly brought to the surface by a past cryovolcanic event should still be detectable after several billion years despite the irradiation effects, as demonstrated by recent laboratory experiments.

To appear in: Astronomy & Astrophysics

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Dynamical Evolution of Escaped Plutinos

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Weakly chaotic orbits that diffuse very slowly have been found to exist in the plutino population. These orbits correspond to long-term plutino escapers and represent the plutinos presently escaping from the resonance. We perform numerical simulations to explore the dynamical evolution of plutinos that have recently escaped from the resonance. The numerical simulations were divided into two parts. In the first, we evolved 20,000 test particles in the resonance to detect and select the long-term escapers. In the second, we numerically integrated the selected escaped plutinos to study their dynamical post escaped behavior. We characterize the escape routes of plutinos and their evolution in the Centaur zone. We derive a present rate of escape of plutinos of between 1 and 10 every 10 years. The escaped plutinos would have a mean lifetime in the Centaur zone of 108 Myr and their contribution to the Centaur population would be a fraction of smaller than 6% of the total Centaur population. In this way, escaped plutinos would be a secondary source of Centaurs.

To appear in: Astronomy & Astrophysics
For preprints, contact romina@fcaglp.unlp.edu.ar

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The Capture of Trojan Asteroids by the Giant Planets During Planetary Migration

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Of the four giant planets in the Solar system, only Jupiter and Neptune are currently known to possess swarms of Trojan asteroids – small objects that experience a 1:1 mean motion resonance with their host planet. In Lykawka et al. (2009), we performed extensive dynamical simulations, including planetary migration, to investigate the origin of the Neptunian Trojan population. Utilising the vast amount of simulation data obtained for that work, together with fresh results from new simulations, we here investigate the dynamical capture of Trojans by all four giant planets from a primordial trans-Neptunian disk. We find the likelihood of a given planetesimal from this region being captured onto an orbit within Jupiter's Trojan cloud lies between several times 10^{-6} and 10^{-5}. For Saturn, the probability is found to be in the range $< 10^{-6}$ to 10^{-5}, whilst for Uranus the probabilities range between 10^{-5} and 10^{-4}. Finally, Neptune displays the greatest probability of Trojan capture, with values ranging between 10^{-4} and 10^{-3}. Our results suggest that all four giant planets are able to capture and retain a significant population of Trojan objects from the disk by the end of planetary migration. As a result of encounters with the giant planets prior to Trojan capture, these objects tend to be captured on orbits that are spread over a wide range of orbital eccentricities and inclinations. The bulk of captured objects are to some extent dynamically unstable, and therefore the populations of these objects tend to decay over the age of the Solar System, providing an important ongoing source of new objects moving on dynamically unstable orbits among the giant planets. Given that a huge population of objects would be displaced by Neptune's outward migration (with a potential cumulative mass a number of times that of the Earth), we conclude that the surviving remnant of the Trojans captured during the migration of the outer planets might be sufficient to explain the currently known Trojan populations in the outer Solar system.

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or on the web at http://sites.google.com/site/patryksofialykawka/

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Capture of the Sun's Oort Cloud from Stars in its Birth Cluster

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Oort cloud comets are currently believed to have formed in the Sun's proto-planetary disk, and to have been ejected to large heliocentric orbits by the giant planets. Detailed models of this process fail to reproduce all of the available observational constraints, however. In particular, the Oort cloud appears to be substantially more populous than the models predict. Here we present numerical simulations that show that the Sun captured comets from other stars while it was in its birth cluster. Our results imply that a substantial fraction of the Oort cloud comets, perhaps exceeding 90%, are from the proto-planetary disks of other stars.

To appear in: Science

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PAPERS RECENTLY SUBMITTED TO JOURNALS

Gravitational Effects of Nix and Hydra in the External Region of the Pluto-Charon System

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Impacts onto H_2O Ice: Scaling Laws for Melting, Vaporization, Excavation, and Final Crater Size

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OTHER PAPERS OF INTEREST

Locating the Planetesimals Belts in the Multiple-planet Systems HD 128311, HD 202206, HD 82943 and HR 8799

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In addition to the Sun, six other stars are known to harbor multiple planets and debris disks: HD 69830, HD 38529, HD 128311, HD 202206, HD 82943 and HR 8799. In this paper we set constraints on the location of the dust-producing planetesimals around the latter four systems. We use a radiative transfer model to analyze the spectral energy distributions of the dust disks (including two new it Spitzer IRS spectra presented in this paper), and a dynamical model to assess the long-term stability of the planetesimals' orbits. As members of a small group of stars that show evidence of harboring a multiple planets and planetesimals, their study can help us learn about the diversity of planetary systems.

To appear in: The Astrophysical Journal

For preprints, contact `amaya@cab.inta-csic.es`

or on the web at `http://www.astro.princeton.edu/~amaya/publications/publications.html`

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Diagnosing Circumstellar Debris Disks

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A numerical model of a circumstellar debris disk is developed and applied to observations of the circumstellar dust orbiting β Pictoris. The model accounts for the rates at which dust is produced by collisions among unseen planetesimals, and the rate at which dust grains are destroyed due to collisions. The model also accounts for the effects of radiation pressure, which is the dominant perturbation on the disk's smaller but abundant dust grains. Solving the resulting system of rate equations then provides the dust abundances versus grain size and over time. Those solutions also provide the dust grains' collisional lifetime versus grain size, and the debris disk's optical depth and surface brightness versus distance from the star. Comparison to observations then yields estimates of the unseen planetesimal disk's radius, and the rate at which the disk sheds mass due to planetesimal grinding. The model can also be used to measure or else constrain the dust grain's physical and optical properties, such as the dust grains' strength, their light scattering asymmetry parameter, and the grains' efficiency of light scattering Q_s.

The model is then applied to optical observations of the edge-on dust disk orbiting β Pictoris, and good agreement is achieved when the unseen planetesimal disk is broad, with $75 \lesssim r \lesssim 150$ AU. If it is assumed that the dust grains are bright like Saturn's icy rings ($Q_s = 0.7$), then the cross section of dust in the disk is $A_d \simeq 2 \times 10^{20}$ km^2 and its mass is $M_d \simeq 11$ lunar masses. In this case the planetesimal disk's dust production rate is quite heavy, $\dot{M}_d \sim 9$ M$_\oplus$/Myr, implying that there is or was a substantial amount of planetesimal mass

there, at least 110 earth-masses. But if the dust grains are darker than assumed, then the planetesimal disk's mass-loss rate and its total mass are heavier. In fact, the apparent dearth of any major planets in this region, plus the planetesimal disk's heavy mass-loss rate, suggests that the $75 \lesssim r < 150$ AU zone at β Pic might be a region of planetesimal destruction, rather than a site of ongoing planet formation.

To appear in: The Astrophysical Journal
Preprint available on the web at `http://arxiv.org/abs/1006.4311`

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Detection of CO in Triton's Atmosphere and the Nature of Surface-atmosphere Interactions

E. Lellouch, C. de Bergh, B. Sicardy, S. Ferron, and H.-U. Käufl

Triton possesses a thin atmosphere, primarily composed of nitrogen, sustained by the sublimation of surface ices. We aim at determining the composition of Triton's atmosphere to constrain the nature of surface-atmosphere interactions. We perform high-resolution spectroscopic observations in the 2.32–2.37 μm range, using CRIRES at the VLT.

From this first spectroscopic detection of Triton's atmosphere in the infrared, we report (i) the first observation of gaseous methane since its discovery in the ultraviolet by Voyager in 1989 and (ii) the first ever detection of gaseous CO in the satellite. The CO atmospheric abundance is remarkably similar to its surface abundance, and appears to be controlled by a thin, CO-enriched, surface veneer resulting from seasonal transport and/or atmospheric escape. The CH_4 partial pressure is several times higher than inferred by Voyager. This confirms that Triton's atmosphere is seasonally variable and is best interpreted by the warming of CH_4-rich icy grains as Triton passed southern summer solstice in 2000. The presence of CO in Triton's atmosphere also affects its temperature, photochemistry, and ionospheric composition. An improved upper limit

To appear in: Astronomy and Astrophysics, 512, L8 (2010 March-April)
Preprints available on the web at `http://arxiv.org/abs/1003.2866`

JOB ANNOUNCEMENTS

Postdoctoral position — Minor Bodies of the Solar System

Portuguese Foundation for Science and for Technology
Geophysics and Astrophysics Group of the Center for Computational Physics

The Portuguese Foundation for Science and for Technology
(FCT: `http://alfa.fct.mctes.pt/index.phtml.en`)
has opened the 2010 call for applications for postdoctoral individual grants (deadline September 6th). These are 3 year grants with the possibility of being renewed for further 3 years.

The Geophysics and Astrophysics Group of the Center for Computational Physics
(CFC: `http://cfc.fis.uc.pt/`),
University of Coimbra, Portugal, will support applications related with Minor Bodies of the Solar System. For further inquires and information please contact: Nuno Peixinho (`peixinho@mat.uc.pt`).

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:
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⋆ Titles of submitted (but not yet accepted) papers and conference articles
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⋆ 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

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