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# DISTANT EKOs

## The Kuiper Belt Electronic Newsletter

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## CONTENTS

# NEWS & ANNOUNCEMENTS

It is still December (at least in my time zone), so I'm getting this issue out just in time. Now we can look forward to what 2015 will bring to the Kuiper belt: The flyby of Pluto on July 14th by the New Horizons spacecraft. I note that the 100th issue of the *Distant EKOs* newsletter will come out at that time, and I expect there will be lots of Pluto news and science coming out before and long after that day.

Happy New Year!

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The 2015 January 15th issue of Icarus (volume 246, pages 1-374) is a special issue: "The Pluto System on the Eve of New Horizons". The abstracts of some of those papers were submitted to and included in this issue of the newsletter. You can find abstracts and downloadable reprints of all the papers in this link to the issue of Icarus:
`http://www.sciencedirect.com/science/journal/00191035/246`

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There were 62 new TNO discoveries announced since the previous issue of *Distant EKOs*:

2011 UA411, 2011 UA412, 2011 UB411, 2011 UB412, 2011 UC411, 2011 UC412, 2011 UD411, 2011 UD412, 2011 UE411, 2011 UE412, 2011 UF411, 2011 UF412, 2011 UG411, 2011 UG412, 2011 UH411, 2011 UH412, 2011 UJ411, 2011 UJ412, 2011 UK411, 2011 UK412, 2011 UL411, 2011 UL412, 2011 UM411, 2011 UM412, 2011 UN411, 2011 UN412, 2011 UO411, 2011 UO412, 2011 UP410, 2011 UQ410, 2011 UR410, 2011 US410, 2011 US412, 2011 UT410, 2011 UT412, 2011 UU410, 2011 UU411, 2011 UU412, 2011 UV410, 2011 UV411, 2011 UV412, 2011 UW410, 2011 UW411, 2011 UX410, 2011 UX411, 2011 UX412, 2011 UY410, 2011 UY411, 2011 UY412, 2011 UZ410, 2011 UZ411, 2012 UG177, 2012 UH177, 2012 UL177, 2012 UM177, 2012 UN177, 2012 UO177, 2012 UP177, 2012 UT177, 2012 UU177, 2012 VU113, 2012 VV113

and 16 new Centaur/SDO discoveries:

2011 UP411, 2011 UP412, 2011 UQ411, 2011 UQ412, 2011 UR411, 2011 UR412, 2011 US411, 2011 UT411, 2011 UW412, 2012 UJ177, 2012 UK177, 2012 UQ177, 2012 UR177, 2012 US177, 2012 WD36, 2014 HU195

Current number of TNOs: 1346 (including Pluto)
Current number of Centaurs/SDOs: 423
Current number of Neptune Trojans: 9

Out of a total of 1778 objects:
658 have measurements from only one opposition
633 of those have had no measurements for more than a year
328 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

## Reassessing the Formation of the Inner Oort Cloud in an Embedded Star Cluster II: Probing the Inner Edge

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The detached object Sedna is likely at the inner edge of the Oort cloud, more precisely the inner Oort cloud (IOC). Until recently it was the sole member of this population. The recent discovery of the detached object 2012 VP113 has confirmed that there should be more objects in this region. Three additional IOC candidates with orbits much closer to Neptune have been proposed in the past decade since Sedna's discovery: 2000 CR105, 2004 VN112 and 2010 GB174. Sedna and 2012 VP113 have perhelia near 80 AU and semi-major axes over 250 AU. The latter three have perihelia between 44 AU and 50 AU and semi-major axes between 200 AU and 400 AU. Here we determine whether the latter three objects belong to the IOC or are from the Kuiper Belt's Extended Scattered Disc (ESD) using numerical simulations. We assume that the IOC was formed when the Sun was in its birth cluster. We analyse the evolution of the IOC and the Scattered Disc (SD) during an episode of late giant planet migration. We examine the impact of giant planet migration in the context of four and five planets. We report that the detached objects 2004 VN112 and 2010 GB174 are likely members of the IOC that were placed there while the Sun was in its birth cluster or during an episode of Solar migration in the Galaxy. The origin of 2000 CR105 is ambiguous but it is likely it belongs to the ESD. Based on our simulations we find that the maximum perihelion distance of SD objects is 41 AU when the semi-major axis is higher than 250 AU. Objects closer in are subject to mean motion resonances with Neptune that may raise their perihelia. The five planet model yields the same outcome. We impose a conservative limit and state that all objects with perihelion distance $q > 45$ AU and semi-major axis $a > 250$ AU belong to the inner Oort cloud.

**To appear in: Monthly Notices of the Royal Astronomical Society**
*For preprints, contact R. Brasser at* `brasser_astro@yahoo.com`
*or on the web at* `http://arxiv.org/abs/1411.1844`

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## Dynamical Implantation of Objects in the Kuiper Belt

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Several models have been suggested in the past for the dynamical formation of hot Kuiper belt objects (hereafter Hot Classicals or HCs for short). Here we discuss a dynamical mechanism that allows orbits to evolve from the primordial planetesimal disk at $\lesssim$35 AU to reach the orbital region now occupied by HCs. We performed three different sets of numerical simulations to illustrate this mechanism. Two of these simulations were based on modern theories for the early evolution of the solar system (the Nice and jumping-Jupiter models). The third one was done with the purpose

to increase the resolution at 41-46 AU. The common aspect of these simulations is that Neptune scatters planetesimals from $\lesssim$35 AU to $>$ 40 AU, and then undergoes a long phase of slow residual migration. Our results show that, to reach a HC orbit, a scattered planetesimal needs to be captured in a mean motion resonance (MMR) with Neptune, where the perihelion distance can be risen by the Kozai resonance (that occurs in MMRs even for moderate inclinations). Finally, while Neptune is still migrating, the planetesimal is released from the MMR on a stable HC orbit. We show that the orbital distribution of HCs expected from this process provides a reasonable match to observations. The capture efficiency and the mass deposited into the HC region appears to be sensitive to the maximum eccentricity reached by Neptune during the planetary instability phase. Additional work will be needed to resolve this dependency in detail.

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## The Evolution of a Pluto-Like System During the Migration of the Ice Giants

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The planetary migration of the Solar System giant planets in the framework of the Nice model (Tsiganis, K., Gomes, R., Morbidelli, A., Levison, H.F. [2005]. Nature 435,459461; Morbidelli, A., Levison, H.F., Tsiganis, K., Gomes, R. [2005]. Nature 435, 462465; Gomes, R., Levison, H.F., Tsiganis, K., Morbidelli, A. [2005]. Nature 435, 466469) creates a dynamical mechanism which can be used to explain the distribution of objects currently observed in the Kuiper belt (e.g., Levison, H.F., Morbidelli, A., Vanlaerhoven, C., Gomes, R., Tsiganis, K. [2008]. Icarus 196, 258273). Through this mechanism the planetesimals within the disk, heliocentric distance ranging from beyond Neptunes orbit to approximately 34 AU, are delivered to the belt after a temporary eccentric phase of Uranus and Neptunes orbits. We reproduced the mechanism proposed by Levison et al. to implant bodies into the Kuiper belt. The capture of Pluto into the external 3:2 mean motion resonance with Neptune is associated with this gravitational scattering model. We verified the existence of several close encounters between the ice giants and the planetesimals during their outward radial migration, then we believe that the analysis of the dynamical history of the plutonian satellites during this kind of migration is important, and would provide some constrains about their place of formation - within the primordial planetesimal disk or in situ. We performed N-body simulations and recorded the trajectories of the planetesimals during close approaches with Uranus and Neptune. Close encounters with Neptune are the most common, reaching approximately 1200 in total. A Pluto similarly sized body assumed the hyperbolic trajectories of the former primordial planetesimal with respect to those giant planets. We assumed the current mutual orbital configuration and sizes for Plutos satellites, then we found that the rate of destruction of systems similar to that of Pluto with closest approaches to Uranus or Neptune $<$ 0.10 AU is 40%, i.e. these close approaches can lead to ejections of satellites or to changes in the satellites eccentricities at least 1 order of magnitude larger than the currently observed. However, we also found that the number of closest approaches which the minimum separation to Uranus or Neptune $<$ 0.10 AU is negligible, reaching 6%. In the other 60% of close encounter histories with closest approaches $>$ 0.10 AU, none of the systems have been destroyed. The latter sample concentrates 94% of closest approaches with the ice giants. Recall

that throughout the early history of the Solar System giant impacts were common (McKinnon, W.B. [1989]. Astrophys. J. 344, L41L44; Stern, A. [1991]. Icarus 90; Canup, R.M. [2005]. Science 307, 546550). Also, impacts capable of forming a binary like Pluto-Charon can occur possibly prior to 0.51 Gyr (Kenyon, S.J., Bromley, B.C. [2014]. Astron. J. 147, 8), and small satellites such as Nix and Hydra can grow in debris from the giant impact (e.g., Canup, R.M. [2011]. Astron. J. 141, 35). Thus, we conclude that if Pluto and its satellites were emplaced into the KB from lower heliocentric orbits, then the Pluto system could survive the encounters that may have happened for emplacement of the Plutinos through the mechanism proposed by Levison et al.

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## On the Origin of Pluto's Small Satellites by Resonant Transport

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The orbits of Pluto's four small satellites (Styx, Nix, Kerberos, and Hydra) are nearly circular and coplanar with the orbit of the large satellite Charon, with orbital periods nearly in the ratios 3:1, 4:1, 5:1, and 6:1 with Charon's orbital period. These properties suggest that the small satellites were created during the same impact event that placed Charon in orbit and had been pushed to their current positions by being locked in mean-motion resonances with Charon as Charon's orbit was expanded by tidal interactions with Pluto. Using the Pluto-Charon tidal evolution models developed by Cheng et al., we show that stable capture and transport of a test particle in multiple resonances at the same mean-motion commensurability is possible at the 5:1, 6:1, and 7:1 commensurabilities, if Pluto's zonal harmonic $J_{2P} = 0$. However, the test particle has significant orbital eccentricity at the end of the tidal evolution of Pluto-Charon in almost all cases, and there are no stable captures and transports at the 3:1 and 4:1 commensurabilities. Furthermore, a non-zero hydrostatic value of $J_{2P}$ destroys the conditions necessary for multiple resonance migration. Simulations with finite but minimal masses of Nix and Hydra also fail to yield any survivors. We conclude that the placing of the small satellites at their current orbital positions by resonant transport is extremely unlikely.

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## Flipping Minor Bodies: What Comet 96P/Machholz 1 can Tell Us about the Orbital Evolution of Extreme Trans-Neptunian Objects and the Production of Near-Earth Objects On Retrograde Orbits

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Nearly all known extreme trans-Neptunian objects (ETNOs) have argument of perihelion close to 0°. An existing observational bias strongly favours the detection of ETNOs with arguments of perihelion close to 0° and 180° yet no objects have been found at 180°. No plausible explanation

has been offered so far to account for this unusual pattern. Here, we study the dynamical evolution of comet 96P/Machholz 1, a bizarre near-Earth object (NEO) that may provide the key to explain the puzzling clustering of orbits around argument of perihelion close to 0° recently found for the population of ETNOs. Comet 96P/Machholz 1 is currently locked in a Kozai resonance with Jupiter such that the value of its argument of perihelion is always close to 0° at its shortest possible perihelion (highest eccentricity and lowest inclination) and about 180° near its shortest aphelion (longest perihelion distance, lowest eccentricity and highest inclination). If this object is a dynamical analogue (albeit limited) of the known ETNOs, this implies that massive perturbers must keep them confined in orbital parameter space. Besides, its future dynamical evolution displays orbital flips when its eccentricity is excited to a high value and its orbit turns over by nearly 180°, rolling over its major axis. This unusual behaviour, that is preserved when post-Newtonian terms are included in the numerical integrations, may also help understand the production of NEOs on retrograde orbits.

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## The Mass Disruption of Jupiter Family Comets

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I show that the size-distribution of small scattered-disk trans-Neptunian objects when derived from the observed size-distribution of Jupiter Family comets (JFCs) and other observational constraints implies that a large percentage (94-97%) of newly arrived active comets within a range of 0.2 to 15.4 km effective radius must physically disrupt, i.e., macroscopically disintegrate, within their median dynamical lifetime. Additional observational constraints include the numbers of dormant and active nuclei in the near-Earth object (NEO) population and the slope of their size distributions. I show that the cumulative power-law slope (-2.86 to -3.15) of the scattered-disk TNO hot population between 0.2-15.4 km effective radius is only weakly dependent on the size-dependence of the otherwise unknown disruption mechanism. Evidently, as JFC nuclei from the scattered disk evolve into the inner solar system only a fraction achieve dormancy while the vast majority of small nuclei (e.g., primarily those with effective radius $< 2$ km) break-up. The percentage disruption rate appears to be comparable with that of the dynamically distinct Oort cloud and Halley type comets (Levison et al. 2002, Science, 296, 2212-2215) suggesting that all types of comet nuclei may have similar structural characteristics even though they may have different source regions and thermal histories. The typical disruption rate for a 1 km radius active nucleus is $\sim 5 \times 10^{-5}$ disruptions/year and the dormancy rate is typically 3 times less. We also estimate that average fragmentation rates range from 0.01 to 0.04 events/year/comet, somewhat above the lower limit of 0.01 events/year/comet observed by Chen and Jewitt (1994, Icarus, 108, 265-271).

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# Updated Taxonomy of Trans-neptunian Objects and Centaurs: Influence of Albedo

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We present updated classification of 258 Trans-neptunian objects (TNOs) and Centaurs based on their visible and near-infrared colors. With increasing quality and quantity of color measurements we distinguished again four classes of objects confirming the previous classification into the BB, BR, IR, and RR taxonomic groups. Increasing accuracy of color measurements results in smaller scatter on color-color plots and better separation of classes. Albedos do not have any noticeable impact on the classification except for the separation of a sub-group of the brightest bodies inside the BB group. On the other side, all the BR objects for which albedo estimations are available have dark surfaces, while the IR and RR groups contain objects both with dark and moderate albedos. Analysis of the distribution of the groups with respect to their orbital parameters confirmed previous findings. The BB and RR groups are populated mainly with classical objects having generally high or low orbital inclinations, respectively. Any Centaur belongs to the IR group and only one Centaur is classified as BB: this is a confirmation of the existence of two separate classes in this population.

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# Evidence for Longitudinal Variability of Ethane Ice on the Surface of Pluto

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We present the results of an investigation using near-infrared spectra of Pluto taken on 72 separate nights using SpeX/IRTF. These data were obtained between 2001 and 2013 at various sub-observer longitudes. The aim of this work was to confirm the presence of ethane ice and to determine any longitudinal trends on the surface of Pluto. We computed models of the continuum near the 2.405 $\mu$m band using Hapke theory and calculated an equivalent width of the ethane absorption feature for six evenly-spaced longitude bins and a grand average spectrum. The 2.405 $\mu$m band on Pluto was detected at the 7.5-$\sigma$ level from the grand average spectrum. Additionally, the band was found to vary longitudinally with the highest absorption occurring in the $N_2$-rich region and the lowest absorption occurring in the visibly dark region. The longitudinal variability of $^{12}CO$ does not match that of the 2.405 $\mu$m band, suggesting a minimal contribution to the band by $^{13}CO$. We argue for ethane production in the atmosphere and present a theory of volatile transport to explain the observed longitudinal trend.

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## Spectral Variability of Charon's 2.21-$\mu$m Feature

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The clear angular separation of Pluto and Charon from ground-based telescopes has been enabled by improved technology, particularly adaptive optics systems. Near-infrared spectral data have revealed Charon's surface to be rich in crystalline water ice and ammonia hydrates. In this work, we search for spectral differences across Charon's surface with new near-infrared spectral data taken in the K-band (2.0-2.4 $\mu$m) with SINFONI on the VLT and NIRI on Gemini North as well as with previously published spectral data. The strength of the absorption band of ammonia hydrate is dependent on the state of the ice, concentration in $H_2O$, grain size, temperature and exposure to radiation. We find variability of the band center and band depth among spectra. This could indicate variability of the distribution of ammonia hydrate across Charon's surface. If the spectral variation is due to physical properties of Charon, the New Horizons flyby could find the concentration of ammonia hydrate heterogeneously distributed across the surface. Comparison between this work and New Horizons results will test the limits of ground-based reconnaissance.

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## On the Roles of Escape Erosion and the Relaxation of Craters on Pluto

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Pluto and its satellites will be the most distant objects ever reconnoitered when NASA's New Horizons spacecraft conducts its intensive flyby of this system in 2015. The size-frequency distribution (SFD) of craters on the surfaces in the Pluto system have long been expected to provide a useful measure of the size distribution of Kuiper Belt Objects (KBOs) down to much smaller size scales than presently observed. However, currently predicted escape rates of Pluto's atmosphere suggest that of order one-half to several kilometers of nitrogen ice has been removed from Pluto's surface over geologic time. Because this range of depths is comparable to or greater than most expected crater depths on Pluto, one might expect that many craters on Plutos surface may have been removed or degraded by this process, biasing the observed crater SFD relative to the productionfunction crater SFD. Further, if Pluto's surface volatile layer is comparable to or deeper than crater depths, and if the viscosity of this layer surface ice is low like the viscosity of pure $N_2$ ice at Pluto's measured 35 K surface temperature (or as low as the viscosity of $CH_4$ ice at warmer but plausible temperatures on isolated pure-$CH_4$ surfaces on Pluto), then craters on Pluto may also have significantly viscously relaxed, also potentially biasing the observed crater SFD and surface crater retention age. Here we make a first exploration of how these processes can affect the displayed cratering record on Pluto. We find that Pluto's surface may appear to be younger owing to these effects than it actually is. We also find that by comparing Pluto's cratering record to Charon's, it may be possible to estimate the total loss depth of material from Pluto's surface over geologic time, and therefore to estimate Pluto's time-averaged escape rate.

**To appear in: Icarus**

*Preprints available on the web at* `http://arxiv.org/abs/1412.1405`

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## Craters and Ejecta on Pluto and Charon: Anticipated Results From the New Horizons Flyby

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We examine the flux of bodies striking Pluto and Charon, and the nature of the crater populations that will form as a result of these impacts. Assuming impact speeds of 2 km/s and an impact angle of 45 deg, a 1 km impactor will form a 4.2 km diameter transient crater on Pluto, and a 5.0 km crater on Charon, as compared with 8-13 km for several mid-sized saturnian satellites and 8-10 km for the icy Galilean satellites. We predict that secondary craters will be present in the crater size-frequency distribution (SFD) for Pluto and Charon at sizes less than a few km, at spatial densities comparable to the range seen on the mid-sized saturnian satellites and distinctly less than seen on the icy Galilean satellites. Pluto should have more secondary craters formed per primary impact than Charon, so if neither crater population on these bodies is in saturation, Charon's crater SFD should be the "cleanest" reflection of the primary, impacting SFD. Ejecta from Pluto and Charon escape more efficiently from the combined system, relative to ejecta from a satellite in orbit around a giant planet, due to the absence of a large central body. We estimate that Kuiper Belt Objects (KBOs) with diameters larger than 1 km should strike Pluto and Charon on (nominal) timescales of 2.2 and

10 million years, respectively. These estimates are uncertain because the numbers of small KBOs are poorly constrained. Our estimated rates are smaller than earlier predictions of impact rates, primarily because we assume a KBO size distribution that is shallower overall than previous studies did. The impact rate, combined with the observed crater SFD, will enable estimates of relative and absolute age of different geologic units, should different geologic units exist. We explore two scenarios in regards to the crater population: (1) a shallow (differential power-law index of $p \sim 2$, i.e. for $dN/dD \propto D^p$), based on the crater SFD observed on young terrains of Galilean and saturnian satellites; and (2) a slightly steeper SFD ($p \propto 3$), based on extrapolations of larger ($\sim$ 100 km) KBOs from ground-based surveys. If the observed primary crater SFD, at diameters less than a few tens of km, is consistent with a differential power-law index $p \sim 2$, that will confirm that KBOs are deficient in small bodies relative to extrapolations from known $\sim$ 100 km KBOs, consistent with expectations derived from examination of crater populations in young terrains on the Galilean and saturnian satellites. If the crater SFD has $p \geq 3$ over all observed sizes, then that power-law index applies across the KBO population over at least two orders of magnitude (1 km to 100 km objects), and there must be some process that erodes the small KBOs when they migrate to the Jupiter-Saturn region of the Solar System. Whatever SFD is observed, the primary crater population on Pluto and Charon will provide the strongest constraint on the SFD of small KBOs, which will be beyond the observational reach of ground- and space-based telescopes for years to come. This, in turn, will provide a fundamental constraint for further understanding of the evolution of this distant and compelling population of bodies beyond Neptune.

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## Astrometry of Pluto from 1930-1951 Observations: the Lampland Plate Collection

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We present a new analysis of 843 photographic plates of Pluto taken by Carl Lampland at Lowell Observatory from 1930-1951. This large collection of plates contains useful astrometric information that improves our knowledge of Plutos orbit. This improvement provides critical support to the impending flyby of Pluto by New Horizons. New Horizons can do inbound navigation of the system to improve its targeting. This navigation is capable of nearly eliminating the sky-plane errors but can do little to constrain the time of closest approach. Thus the focus on this work was to better determine Plutos heliocentric distance and to determine the uncertainty on that distance with a particular eye to eliminating systematic errors that might have been previously unrecognized. This work adds 596 new astrometric measurements based on the USNO CCD Astrograph Catalog 4. With the addition of these data the uncertainty of the estimated heliocentric position of Pluto in Developmental Ephemerides 432 (DE432) is at the level of 1000 km. This new analysis gives us more confidence that these estimations are accurate and are sufficient to support a successful flyby of Pluto by New Horizons.

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## Limits of Astrometric and Photometric Precision on KBOs

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We present photometric and astrometric measurements of the Kuiper Belt Objects (KBO) Haumea and Makemake obtained between 2013 June 5 and 2013 July 31 with the 14-inch Wallace Astrophysical Observatory (WAO) telescopes. Using photometry, we determined that Haumea and Makemake have $R$ magnitudes $17.225 \pm 0.347$ and $16.850 \pm 0.107$, respectively. We obtained rotational light curves for Haumea and Makemake over eight separate nights. Astrometry yielded mean residuals with respect to the JPL ephemeris of $0.0095 \pm 0.027$" with an rms residual of 0.480" in R.A. and $0.261 \pm 0.019$" with an rms residual of 0.335 in decl. for Makemake, and $0.219 \pm 0.090$" in R.A. with an rms residual of 0.748", and $0.223 \pm 0.068$" in decl. with an rms residual of 0.571" for Haumea. Additionally, we calculated that observing Haumea with two 14-inch telescopes and Makemake with four 14-inch telescopes could resolve their periodicity. With improved observing techniques and modern CCD cameras, it is possible to utilize small telescopes in universities around the world to observe large KBOs.

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## MegaPipe Astrometry for the New Horizons Spacecraft

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The New Horizons spacecraft, launched by NASA in 2006, will arrive in the Pluto-Charon system on July 14, 2015. There, it will spend a few hours imaging Pluto and its moons. It will then have a small amount of reserve propellant which will be used to direct the probe on to a second, yet to be discovered object in the Kuiper Belt. Data from the MegaPrime camera on CFHT was used to build a precise, high density astrometric reference frame for both the final approach into the Pluto system and the search for the secondary target. Pluto currently lies in the galactic plane. This is a hindrance in that there are potential problems with confusion. However, it is also a benefit, since it allows the use of the UCAC4 astrometric reference catalog, which is normally too sparse for use with MegaCam images. The astrometric accuracy of the final catalogs, as measured by the residuals, is 0.02 arcseconds.

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## Stellar Occultation by (119951) 2002 KX14 on April 26, 2012

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*Context*. Trans-Neptunian objects (TNOs) are important bodies, but very little is known about their basic physical properties such as size, density, and albedo.

*Aims*. We intend to determine sizes, albedos, and even densities of a good sample of TNOs, especially those of the largest TNOs because they can be studied the best with different observational techniques.

*Methods*. We took advantage of a stellar occultation by (119951) 2002 KX14 to obtain valuable information by means of high temporal resolution CCD imaging using ULTRACAM at the 4.2 m William Herschel Telescope on La Palma (Spain).

*Results*. Thanks to the high time resolution of ULTRACAM and the large aperture provided by the telescope, we recorded the most accurate chord ever obtained for an occultation by a TNO, with a length of 415±1 km. This is a lower limit to the diameter of (119951) 2002 KX14 assuming that it has a spherical shape. For ellipsoidal objects we developed a method for obtaining equivalent diameters by combining single-chord occultations and accurate astrometry at the time of occultation. By applying this method to (119951) 2002 KX14, we estimate an equal-area equivalent diameter of at least $365^{+30}_{-21}$ km. A possible upper limit is 455±27 km, obtained via thermal data. No atmosphere is detected. We obtain a surface temperature higher than 40 K, which precludes the existence of ices, other than water ice, upon the surface, which is consistent with the featureless spectrum of (119951) 2002 KX14. There are no secondary occultation events that could reveal whether there is a ring system, as recently found for the Centaur (10199) Chariklo.

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## On the Use of Cherenkov Telescopes for Outer Solar System Body Occultations

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Imaging Atmosphere Cherenkov Telescopes (IACT) are arrays of very large optical telescopes that are well-suited for rapid photometry of bright sources. I investigate their potential in observing stellar occultations by small objects in the outer Solar System, Transjovian Objects (TJOs). These occultations cast diffraction patterns on the Earth. Current IACT arrays are capable of detecting

objects smaller than 100 metres in radius in the Kuiper Belt and 1 km radius out to 5000 AU. The future Cherenkov Telescope Array (CTA) will have even greater capabilities. Because the arrays include several telescopes, they can potentially measure the speeds of TJOs without degeneracies, and the sizes of the TJOs and background stars. I estimate the achievable precision using a Fisher matrix analysis. With CTA, the precisions of these parameter estimations will be as good as a few percent. I consider how often detectable occultations occur by members of different TJO populations, including Centaurs, Kuiper Belt Objects (KBOs), Oort cloud objects, and satellites and Trojans of Uranus and Neptune. The great sensitivity of IACT arrays means that they likely detect KBO occultations once every O(10) hours when looking near the ecliptic. IACTs can also set useful limits on many other TJO populations.

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## Search for Sub-Kilometer Trans-Neptunian Objects Using CoRoT Asteroseismology Data

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We present the search for sub-kilometer Trans-Neptunian Objects (TNOs) by re-examining the CoRoT (Convection Rotation and Planetary Transits) asteroseismology observations. The total observation time employed in this work is about 144,000 star hours with SNR larger than 1000 computed on 30-second intervals. 13 Possible Occultation Events (POEs) were found from the deviation method. These detections gives a density in the ecliptic sky plane of TNOs larger than 400-meter radius of $N(R > 400\ m) = 1.4^{+4.2}_{-0.7} \times 10^7 deg^{-2}$. The fit of the density of TNOs with the believed break $r_{break} = 45\ km$ provides a power-law size distribution index q larger than 3.5. This value is consistent with the detection of 2 potential events from HST/Fine Guidance Sensor (FGS) observations that found $q = 3.8 \pm 0.2$. However, fitting the 13 POEs with the HST/FGS result alone gives a power-law size distribution index of $q = 4.5 \pm 0.2$ in the size range of 0.2-2.0 km. This value is then compared with evolution models of the Kuiper Belt.

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## Interplanetary Dust Influx to the Pluto-Charon System

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The influx of interplanetary dust grains (IDPs) to the Pluto-Charon system is expected to drive several physical processes, including the formation of tenuous dusty rings and/or exospheres, the deposition of neutral material in Pluto's atmosphere through ablation, the annealing of surface ices, and the exchange of ejecta between Pluto and its satellites. The characteristics of these physical mechanisms are dependent on the total incoming mass, velocity, variability, and composition of interplanetary dust grains; however, our knowledge of the IDP environment in the Edgeworth-Kuiper Belt has, until recently, remained rather limited. Newly-reported measurements by the New Horizons Student Dust Counter combined with previous Pioneer 10 meteoroid measurements and a dynamical IDP tracing model have improved the characterization of the IDP environment in the outer Solar System, including at Pluto-Charon. Here we report on this modeling and data comparison effort, including a discussion of the IDP influx to Pluto and its moons, and the implications thereof.

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## Conditions for Liquid or Icy Core Existence in KBO Objects: Numerical Simulations for Orcus and Quaoar

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In this article, we present a model describing the thermal evolution and structure of Kuiper-belt objects (KBO) as a function of the intensity of radiogenic heat sources, mean density and the object's formation time. We have studied numerically the dependence of the interior composition and structure of a forming body on the accretion rate and radionuclide content in the dust particles, as well as the impact of the radiogenic heat generation rate on the water phase transition dynamics. The model is applied to predict the present internal structure of Plutino (90482) Orcus and KBO (50000) Quaoar with special emphasis on the possibility of cryovolcanism.

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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.

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