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DISTANT EKOs

The Kuiper Belt Electronic Newsletter

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CONTENTS

NEWS & ANNOUNCEMENTS

New Horizons Kuiper Belt Extended Mission Science Planning Opportunity

The centerpiece of the proposed New Horizons Kuiper Belt Extended Mission (NH-KEM) is the very close flyby of the 20-40 km wide KBO 2014 MU69 on 1 January 2019. NH-KEM will also observe 20 other KBOs at phase angles and/or at resolutions not otherwise possible, producing a unique database of KBO phase curves, satellite searches, and ring searches.
If NH-KEM is approved, mission schedules require that both distant KBO observations and MU69 close flyby planning must begin almost immediately.
The New Horizons team plans to use a portion of its Science Team Meeting being held near NASA's Ames Research Center during the week of September 19 to gather community input to NH-KEM observation plans.
Those who are interested in listening to, or potentially presenting, at this activity should complete the indication of interest form at: `http://pluto.jhuapl.edu/kem-workshop-1/index.php`

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There were 39 new TNO discoveries announced since the previous issue of *Distant EKOs*:
2014 FA72, 2015 GO50, 2016 FA59, 2016 FA60, 2016 FB59, 2016 FB60, 2016 FC59, 2016 FC60, 2016 FD59, 2016 FD60, 2016 FE59, 2016 FE60, 2016 FF59, 2016 FG59, 2016 FH59, 2016 FJ59, 2016 FK59, 2016 FL59, 2016 FM59, 2016 FN59, 2016 FO59, 2016 FP59, 2016 FQ59, 2016 FR59, 2016 FS59, 2016 FT58, 2016 FT59, 2016 FU58, 2016 FU59, 2016 FV58, 2016 FV59, 2016 FW58, 2016 FW59, 2016 FX58, 2016 FX59, 2016 FY58, 2016 FY59, 2016 FZ58, 2016 FZ59
and 14 new Centaur/SDO discoveries:
2012 FH84, 2013 FQ28, 2014 FZ71, 2015 FJ345, 2015 GP50, 2015 RR245, 2016 EB195, 2016 EX, 2016 FD14, 2016 FH13, 2016 GC241, 2016 GR206, 2016 GZ251, 2016 LS
and 5 new Neptune Trojan discoveries:
2010 TS191, 2010 TT191, 2011 SO277, 2011 WG157, 2013 KY18

Reclassified objects:
2016 FL59 (TNO → SDO)

Objects recently assigned numbers:
2012 VU85 = (463368)
2014 HY123 = (463663)
2013 LU28 = (468861)
2000 FA8 = (468422)

Deleted/Re-identified objects:
2000 GQ148
2011 GY61 = 2014 GE45
2013 BN45 = 2015 DX155 = 2016 EX

Current number of TNOs: 1491 (including Pluto)
Current number of Centaurs/SDOs: 501
Current number of Neptune Trojans: 17

Out of a total of 2009 objects:
692 have measurements from only one opposition
636 of those have had no measurements for more than a year
326 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

Surface Compositions Across Pluto and Charon

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The New Horizons spacecraft mapped colors and infrared spectra across the encounter hemispheres of Pluto and Charon. The volatile methane, carbon monoxide, and nitrogen ices that dominate Pluto's surface have complicated spatial distributions resulting from sublimation, condensation, and glacial flow acting over seasonal and geological time scales. Pluto's water ice "bedrock" was also mapped, with isolated outcrops occurring in a variety of settings. Pluto's surface exhibits complex regional color diversity associated with its distinct provinces. Charon's color pattern is simpler, dominated by neutral low latitudes and a reddish northern polar region. Charon's near-infrared spectra reveal highly localized areas with strong ammonia absorption tied to small craters with relatively fresh-appearing impact ejecta.

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Preprint available at `http://science.sciencemag.org/content/351/6279/aad9189`

An Atmospheric General Circulation Model for Pluto with Predictions for New Horizons Temperature Profiles

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Results are presented from a 3-D Pluto general circulation model (GCM) that includes conductive heating and cooling, non-local thermodynamic equilibrium (non-LTE) heating by methane at 2.3 and 3.3 microns, non-LTE cooling by cooling by methane at 7.6 microns, and LTE CO rotational line cooling. The GCM also includes a treatment of the subsurface temperature and surface-atmosphere mass exchange. An initially 1 m thick layer of surface nitrogen frost was assumed such that it was large enough to act as a large heat sink (compared with the solar heating term) but small enough that the water ice subsurface properties were also significant. Structure was found in all three directions of the 3-D wind field (with a maximum magnitude of order 10 m/s in the horizontal directions and $10^{-}5$ microbar/s in the vertical direction). Prograde jets were found at several altitudes. The direction of flow over the poles was found to very with altitude. Broad regions of up-welling and down-welling were also found. Predictions of vertical temperature profiles are provided for the Alice and REX instruments on New Horizons, while predictions of light curves are provided for ground-based stellar occultation observations. With this model methane concentrations of 0.2% and 1.0% and 8 and 24 microbar surface pressures are distinguishable. For ground-based stellar occultations, a detectable difference exists between light curves with the different methane concentrations, but not for different initial global mean surface pressures.

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For preprints, contact azalucha@seti.org
or on the web at http://arxiv.org/abs/1501.02848
and http://mnras.oxfordjournals.org/content/459/1/902

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Rotational Properties of the Haumea Family Members and Candidates: Short-term Variability

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Haumea is one of the most interesting and intriguing transneptunian objects (TNOs). It is a large, bright, fast rotator, and its spectrum indicates nearly pure water ice on the surface. It has at least two satellites and a dynamically related family of more than ten TNOs with very similar proper orbital parameters and similar surface properties. The Haumean family is the only one currently known in the transneptunian belt. Various models have been proposed but the formation of the family remains poorly understood. In this work, we have investigated the rotational properties of the family members and unconfirmed family candidates with short-term variability studies, and report the most complete review to date. We present results based on five years of observations and report the short-term variability of five family members, and seven candidates. The mean rotational

periods, from Maxwellian fits to the frequency distributions, are 6.27±1.19 h for the confirmed family members, 6.44±1.16 h for the candidates, and 7.65±0.54 h for other TNOs (without relation to the family). According to our study, there is a suggestion that Haumea family members rotate faster than other TNOs, however, the sample of family member is still too limited for a secure conclusion. We also highlight the fast rotation of 2002 GH32. This object has a 0.36±0.02 mag amplitude lightcurve and a rotational period of about 3.98 h. Assuming 2002 GH32 is a triaxial object in hydrostatic equilibrium, we derive a lower limit to the density of 2.56 g cm^{-3}. This density is similar to Haumea's and much more dense than other small TNO densities.

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For preprints, contact thirouin@lowell.edu
or on the web at http://arxiv.org/abs/1603.04406

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Interpreting the Densities of the Kuiper Belt's Dwarf Planets

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Kuiper Belt objects with absolute magnitude less than 3 (radius $\gtrsim$500 km), the dwarf planets, have a range of different ice/rock ratios, and are more rock-rich than their smaller counterparts. Many of these objects have moons, which suggests that collisions may have played a role in modifying their compositions. We show that the dwarf planets fall into two categories when analysed by their mean densities and satellite-to-primary size ratio. Systems with large moons, such as Pluto/Charon and Orcus/Vanth, can form in low-velocity grazing collisions in which both bodies retain their compositions. We propose that these systems retain a primordial composition, with a density of about 1.8 g/cm^3. Triton, thought to be a captured KBO, could have lost enough ice during its early orbital evolution to explain its rock-enrichment relative to the primordial material. Systems with small moons, Eris, Haumea, and Quaoar, formed from a different type of collision in which icy material, perhaps a few tens of percent of the total colliding mass, is lost. The fragments would not remain in physical or dynamical proximity to the parent body. The ice loss process has not yet been demonstrated numerically, which could be due to the paucity of KBO origin simulations, or missing physical processes in the impact models. If our hypothesis is correct, we predict that large KBOs with small moons should be denser than the primordial material, and that the mean density of Orcus should be close to the primordial value.

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or on the web at http://arxiv.org/abs/1603.06224
and http://dx.doi.org/10.1093/mnras/stw1052

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The Rings of Chariklo under Close Encounters with the Giant Planets

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The Centaur population is composed by minor bodies wandering between the giant planets and that frequently perform close gravitational encounters with these planets, which leads to a chaotic orbital evolution. Recently, the discovery of two well-defined narrow rings was announced around the Centaur 10199 Chariklo. The rings are assumed to be in the equatorial plane of Chariklo and to have circular orbits. The existence a well-defined system of rings around a body in such perturbed orbital region poses an interesting new problem. Are the rings of Chariklo stable when perturbed by close gravitational encounters with the giant planets? Our approach to address this question consisted of forward and backward numerical simulations of 729 clones of Chariklo, with similar initial orbits, for a period of 100 Myrs. We found, on average, that each clone suffers along its lifetime more than 150 close encounters with the giant planets within one Hill radius of the planet in question. We identified some extreme close encounters able to significantly disrupt or to disturb the rings of Chariklo. About 3% of the clones lose the rings and about 4% of the clones have the ring significantly disturbed. Therefore, our results show that in most of the cases (more than 90%) the close encounters with the giant planets do not affect the stability of the rings in Chariklo-like systems. Thus, if there is an efficient mechanism that creates the rings, then these structures may be common among these kinds of Centaurs.

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Photometry of Centaurs and Trans-Neptunian Objects: 2060 Chiron (1977 UB), 10199 Chariklo (1997 CU_{26}), 38628 Huya (2000 EB_{173}), 28978 Ixion (2001 KX_{76}), and 90482 Orcus (2004 DW)

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Both Centaurs and trans-Neptunian objects (TNOs) are minor bodies found in the outer Solar System. Centaurs are a transient population that moves between the orbits of Jupiter and Neptune, and they probably diffused out of the TNOs. TNOs move mainly beyond Neptune. Some of these objects display episodic cometary behaviour; a few percent of them are known to host binary companions. Here, we study the light-curves of two Centaurs — 2060 Chiron (1977 UB) and 10199 Chariklo (1997 CU_{26}) — and three TNOs — 38628 Huya (2000 EB_{173}), 28978 Ixion (2001 KX_{76}), and 90482 Orcus (2004 DW) — and the colours of the Centaurs and Huya. Precise,

$\sim$1%, R-band absolute CCD photometry of these minor bodies acquired between 2006 and 2011 is presented; the new data are used to investigate the rotation rate of these objects. The colours of the Centaurs and Huya are determined using $BVRI$ photometry. The point spread function of the five minor bodies is analysed, searching for signs of a coma or close companions. Astrometry is also discussed. A periodogram analysis of the light-curves of these objects gives the following rotational periods: 5.5±0.4 h for Chiron, 7.0±0.6 h for Chariklo, 4.45±0.07 h for Huya, 12.4±0.3 h for Ixion, and 11.9±0.5 h for Orcus. The colour indices of Chiron are found to be $B-V = 0.53 \pm 0.05$, $V-R = 0.37\pm0.08$, and $R-I = 0.36\pm0.15$. The values computed for Chariklo are $V-R = 0.62\pm0.07$ and $R-I = 0.61 \pm 0.07$. For Huya, we find $V-R = 0.58 \pm 0.09$ and $R-I = 0.64 \pm 0.20$. Our rotation periods are similar to and our colour values are consistent with those already published for these objects. We find very low levels of cometary activity (if any) and no sign of close or wide binary companions for these minor bodies.

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For preprints, contact gcarraro@eso.org
or on the web at http://arxiv.org/abs/1605.08251

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Beyond the Kuiper Belt Edge: New High Perihelion Trans-Neptunian Objects With Moderate Semi-major Axes and Eccentricities

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We have been conducting a survey for distant solar system objects beyond the Kuiper Belt edge ($\sim$50 AU) with new wide-field cameras on the Subaru 8 meter and CTIO 4 meter telescopes. We are interested in the orbits of objects that are decoupled from the giant planet region in order to understand the structure of the outer solar system, including whether a massive planet exists beyond a few hundred AU as first reported by Trujillo and Sheppard (2014). In addition to discovering extreme trans-Neptunian objects detailed elsewhere, we have found several objects with high perihelia ($q > 40$ AU) that differ from the extreme and inner Oort cloud objects due to their moderate semi-major axes ($50 < a < 100$ AU) and eccentricities ($e \lesssim 0.3$). Newly discovered objects 2014 FZ71 and 2015 FJ345 have the third and fourth highest perihelia known after Sedna and 2012 VP113, yet their orbits are not nearly as eccentric or distant. We found several of these high perihelion but moderate orbit objects and observe that they are mostly near Neptune mean motion resonances and have significant inclinations ($i > 20$ degrees). These moderate objects likely obtained their unusual orbits through combined interactions with Neptune's mean motion resonances and the Kozai resonance, similar to the origin scenarios for 2004 XR190. We also find the very distant 2008 ST291 has likely been modified by the MMR+KR mechanism through the 6:1 Neptune MMR. We discuss these moderately eccentric, distant objects along with some other interesting low inclination outer classical belt objects like 2012 FH84 discovered in our ongoing survey.

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For preprints, contact sheppard@dtm.ciw.edu
or on the web at http://home.dtm.ciw.edu/users/sheppard/pub/

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Finding Planet Nine: A Monte Carlo Approach

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Planet Nine is a hypothetical planet located well beyond Pluto that has been proposed in an attempt to explain the observed clustering in physical space of the perihelia of six extreme trans-Neptunian objects or ETNOs. The predicted approximate values of its orbital elements include a semimajor axis of 700 au, an eccentricity of 0.6, an inclination of 30°, and an argument of perihelion of 150°. Searching for this putative planet is already under way. Here, we use a Monte Carlo approach to create a synthetic population of Planet Nine orbits and study its visibility statistically in terms of various parameters and focusing on the aphelion configuration. Our analysis shows that, if Planet Nine exists and is at aphelion, it might be found projected against one out of four specific areas in the sky. Each area is linked to a particular value of the longitude of the ascending node and two of them are compatible with an apsidal anti-alignment scenario. In addition and after studying the current statistics of ETNOs, a cautionary note on the robustness of the perihelia clustering is presented.

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or on the web at http://adsabs.harvard.edu/abs/2016MNRAS.459L..66D

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Dynamical Impact of the Planet Nine Scenario: *N*-body Experiments

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The Planet Nine hypothesis has now enough constraints to deserve further attention in the form of detailed numerical experiments. The results of such studies can help us improve our understanding of the dynamical effects of such a hypothetical object on the extreme trans-Neptunian objects or ETNOs and perhaps provide additional constraints on the orbit of Planet Nine itself. Here, we present the results of direct N-body calculations including the latest data available on the Planet Nine conjecture. The present-day orbits of the six ETNOs originally linked to the hypothesis are evolved backwards in time and into the future under some plausible incarnations of the hypothesis to investigate if the values of several orbital elements, including the argument of perihelion, remain confined to relatively narrow ranges. We find that a nominal Planet Nine can keep the orbits of (90377) Sedna and 2012 VP_{113} relatively well confined in orbital parameter space for hundreds of Myr, but it may make the orbits of 2004 VN_{112}, 2007 TG_{422} and 2013 RF_{98} very unstable on time-scales of dozens of Myr, turning them retrograde and eventually triggering their ejection from the Solar system. Far more stable orbital evolution is found with slightly modified orbits for Planet Nine.

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or on the web at http://adsabs.harvard.edu/doi/10.1093/mnrasl/slw078

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The Outer Solar System Origins Survey: I. Design and First-Quarter Discoveries

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We report the discovery, tracking and detection circumstances for 85 trans-Neptunian objects

(TNOs) from the first 42 deg^2 of the Outer Solar System Origins Survey (OSSOS). This ongoing r-band Solar System survey uses the 0.9 deg^2 field-of-view MegaPrime camera on the 3.6 m Canada-France-Hawaii Telescope. Our orbital elements for these TNOs are precise to a fractional semi-major axis uncertainty $< 0.1\%$. We achieve this precision in just two oppositions, as compared to the normal 3–5 oppositions, via a dense observing cadence and innovative astrometric technique. These discoveries are free of ephemeris bias, a first for large trans-Neptunian surveys. We also provide the necessary information to enable models of TNO orbital distributions to be tested against our TNO sample. We confirm the existence of a cold "kernel" of objects within the main cold classical Kuiper belt, and infer the existence of an extension of the "stirred" cold classical Kuiper belt to at least several AU beyond the 2:1 mean motion resonance with Neptune. We find that the population model of Petit et al. (2011) remains a plausible representation of the Kuiper belt. The full survey, to be completed in 2017, will provide an exquisitely characterized sample of important resonant TNO populations, ideal for testing models of giant planet migration during the early history of the Solar System.

To appear in: The Astronomical Journal
Preprints available on the web at `http://arxiv.org/abs/1511.02895`

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OSSOS III – Resonant Trans-Neptunian Populations: Constraints from the First Quarter of the Outer Solar System Origins Survey

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The first two observational sky "blocks" of the Outer Solar System Origins Survey (OSSOS) have significantly increased the number of well-characterized observed trans-Neptunian objects (TNOs) in Neptune's mean motion resonances. We describe the 31 securely resonant TNOs detected by OSSOS so far, and we use them to independently verify the resonant population models from the Canada-France Ecliptic Plane Survey (CFEPS; Gladman et al. 2012), with which we find broad agreement. We confirm that the 5:2 resonance is more populated than models of the outer Solar System's dynamical history predict; our minimum population estimate shows that the high eccentricity ($e > 0.35$) portion of the resonance is at least as populous as the 2:1 and possibly as populated as the 3:2 resonance. One OSSOS block was well-suited to detecting objects trapped at low libration amplitudes

in Neptune's 3:2 resonance, a population of interest in testing the origins of resonant TNOs. We detected three 3:2 objects with libration amplitudes below the cutoff modeled by CFEPS; OSSOS thus offers new constraints on this distribution. The OSSOS detections confirm that the 2:1 resonance has a dynamically colder inclination distribution than either the 3:2 or 5:2 resonances. Using the combined OSSOS and CFEPS 2:1 detections, we constrain the fraction of 2:1 objects in the symmetric mode of libration to be 0.2–0.85; we also constrain the ratio of leading to trailing asymmetric librators, which has been theoretically predicted to vary depending on Neptune's migration history, to be 0.05–0.8. Future OSSOS blocks will improve these constraints.

To appear in: The Astronomical Journal
For preprints, contact kat.volk@gmail.com
or on the web at https://arxiv.org/abs/1604.08177

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Commensurabilities between ETNOs: a Monte Carlo Survey

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Many asteroids in the main and trans-Neptunian belts are trapped in mean motion resonances with Jupiter and Neptune, respectively. As a side effect, they experience accidental commensurabilities among themselves. These commensurabilities define characteristic patterns that can be used to trace the source of the observed resonant behaviour. Here, we explore systematically the existence of commensurabilities between the known ETNOs using their heliocentric and barycentric semimajor axes, their uncertainties, and Monte Carlo techniques. We find that the commensurability patterns present in the known ETNO population resemble those found in the main and trans-Neptunian belts. Although based on small number statistics, such patterns can only be properly explained if most, if not all, of the known ETNOs are subjected to the resonant gravitational perturbations of yet undetected trans-Plutonian planets. We show explicitly that some of the statistically significant commensurabilities are compatible with the Planet Nine hypothesis; in particular, a number of objects may be trapped in the 5:3 and 3:1 mean motion resonances with a putative Planet Nine with semimajor axis ∼700 au.

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The Research and Education Collaborative Occultation Network: A System for Coordinated TNO Occultation Observations

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We describe a new system and method for collecting coordinated occultation observations of trans-Neptunian objects (TNOs). Occultations by objects in the outer solar system are more difficult to predict due to their large distance and limited span of the astrometric data used to determine their orbits and positions. This project brings together the research and educational community into a unique citizen-science partnership to overcome the difficulties of observing these distant objects. The goal of the project is to get sizes and shapes for TNOs with diameters larger than 100 km. As a result of the system design it will also serve as a probe for binary systems with spatial separations as small as contact systems. Traditional occultation efforts strive to get a prediction sufficiently good to place mobile ground stations in the shadow track. Our system takes a new approach of setting up a large number of fixed observing stations and letting the shadows come to the network. The nominal spacing of the stations is 50 km so that we ensure two chords at our limiting size. The spread of the network is roughly 2000 km along a roughly north-south line in the western United States. The network contains 56 stations that are committed to the project and we get additional ad hoc support from International Occultation Timing Association members. At our minimum size, two stations will record an event while the other stations will be probing the inner regions for secondary events. Larger objects will get more chords and will allow determination of shape profiles. The stations are almost exclusively sited and associated with schools, usually at the 9-12 grade level. We present a full description of the system we have developed for the continued exploration of the Kuiper Belt.

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PAPERS RECENTLY SUBMITTED TO JOURNALS

Past Epochs of Significantly Higher Pressure Atmospheres on Pluto

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Pluto is known to have undergone thousands of cycles of obliquity change and polar precession. These variations have a large and corresponding impact on the total average solar insolation reaching various places on Pluto's surface as a function of time. We show here that such changes produce changes in Pluto's atmospheric pressure, in many cases exceeding 1 millibar, and in some cases reaching 10s to 100s of millibars. Such past epochs of high pressure may help explain certain features observed by New Horizons on Pluto's surface.

Submitted to: Icarus

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New Horizons Constraints on Charon's Present Day Atmosphere

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New Horizons used a variety of standard techniques including a solar ultraviolet occultation, ultraviolet airglow searches, and high phase look back particulate search imaging to search for an atmosphere around Pluto's large moon Charon during its flyby in July 2015. Data from these observations have been sent to Earth and are examined here. No evidence for a present day atmosphere has been found for 14 potential atomic and molecular species, all of which are now constrained to have pressures below 0.3 nanobar, much more stringent upper limits than the previously available 15–100 nanobar constraints; for example, the 3σ upper limit for an N_2 atmosphere on Charon is 4.2 picobars and the 3σ upper limit for the brightness of any atmospheric haze layer on Charon is $I/F = 9 \times 10^{-5}$

Submitted to: Icarus

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First Direct Size Measurement of a Detached Object: Results from a Triple Chord Occultation and Far-infrared Photometry of (229762) 2007 UK_{126}

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Context. A passage of a trans-Neptunian object (TNO) in front of a star provides an opportunity to probe the size and shape of these distant, pristine objects in our Solar System. In the past six years, several occultations by TNOs could be observed. However, most events have been observed from a single location. Not counting the Pluto system, only five objects have been sampled simultaneously from multiple locations, and sufficient data for a fully determined ellipse fit could be obtained for only two objects.

Aims. Here we present the first observation of an occultation by the TNO 2007 UK_{126} on 15 November 2014, measured by three observers located almost symmetrically to and nearly on the shadow's center line (176.8 km north, 7.1 km north and 199.6 km south). Our work presents the first observation of an occultation of a so-called "detached object", a subgroup with perihelion distances so large that Neptune and the other giant planets have likely not perturbed their orbits. We comprehensively characterize 2007 UK_{126} by combining the results from the occultation with a radiometric analysis.

Methods. We use freely available software to reduce data from two commercial video camera systems and an EMCCD camera. While shadow sizes are typically estimated by direct ellipse fitting, we use an error-in-variable regression approach that allows us to solve the non-linear problem to propagate timing errors into uncertainties of the geometric ellipse parameters. We have revisited existing Herschel/PACS far-infrared data for this object and applied a new reduction method to improve the accuracy of the measured fluxes compared to previously published values. A thermo-physical model (TPM) code is used to predict model fluxes based on thermal and geometrical properties.

Results. The fortunate geographical locations, combined with zero dead-time imaging and precise GPS time measurements, allow for an accurate determination of the projected shadow size (686.03 ± 60.23 km $\times$ 593.63 ± 61.91 km). We estimate a geometric albedo of $p_V = 14.3 \pm 2.5\%$. From the shadow geometry, we derive plausible shapes and sizes of 2007 UK_{126}, and use these estimates as an additional constraint for a subsequent radiometric analysis. Via a parametric study, we can discard a pole-on viewing geometry at the time of the occultation and find that 2007 UK_{126} must have been observed rather near the equator. Matching modeled with observed fluxes while using physically plausible values for thermal inertia and surface roughness constrains the effective diameter of 2007 UK_{126} to $d_{\rm eff} = 536 - 656$ km. We conclude that subsolar surface temperatures are on the order of $\approx\ 50 - 55$ K.

Submitted to: Astronomy & Astrophysics

Results from the 2014 November 15th Multi-chord Stellar Occultation by the TNO (229762) 2007 UK_{126}

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We present results derived from the first multi-chord stellar occultation by the trans-Neptunian object (229762) 2007 UK_{126}, observed on 2014 November 15. The event was observed by the RECON project and IOTA collaborators throughout the United States. Use of two different data analysis methods obtain a satisfactory fit to seven chords, yielding an elliptical fit to the chords with an equatorial radius of $R = 338^{+15}_{-10}$ km and equivalent radius of $R_{eq} = 319^{+14}_{-7}$ m. A circular fit also gives a radius of $R = 324^{+30}_{-23}$ km. Assuming that the object is a Maclaurin spheroid with indeterminate aspect angle, and using two published absolute magnitudes for the body, we derive possible ranges for geometric albedo between $p_V = 0.159^{+0.007}_{-0.013}$ and $p_R = 0,189^{+0,009}_{-0,015}$, and for the body oblateness between $\epsilon = 0.105^{+0.050}_{-0.040}$ and $\epsilon = 0.118^{+0.055}_{-0.048}$. For a nominal rotational period of 11.05 h, an upper limit for density of $\rho = 1740$ kg m^{-3} is estimated for the body.

Submitted to: The Astrophysical Journal

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Red, Rough, Fast, and Perturbed: New Horizons Observations of KBO (15810) 1994 JR_1 from the Kuiper Belt

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The 3:2 resonant KBO (15810) 1994 JR_1 was observed by NASA's New Horizons spacecraft on November 2, 2015 from a distance of 1.85 AU, and again on April 7, 2016 from a distance of 0.71 AU. Acquired using the LOng Range Reconnaissance Imager (LORRI), these were the first close observations of any KBO other than Pluto, and the first ever of a small KBO. Combining ground-based and HST observations at small phase angles and the LORRI observations at higher phase angles, we produced the first disk-integrated solar phase curve of a typical KBO from α=0.6-58°. Observations at these geometries, attainable only from a spacecraft in the outer Solar System, constrain surface properties such as macroscopic roughness and the single particle phase function. 1994 JR_1 has a rough surface with a 37±5° mean topographic slope angle and has a relatively rapid rotation period of 5.47±0.33 hours. 1994 JR_1 is currently 2.7 AU from Pluto; our astrometric points enable high-precision orbit determination and integrations which show that it comes this close to Pluto every 2.4 million years, causing Pluto to perturb 1994 JR_1. During the November spacecraft observation, the KBO was simultaneously observed using the Hubble Space Telescope in two colors, confirming its very red spectral slope. These observations have laid the groundwork for numerous potential future distant KBO observations in the proposed New Horizons-Kuiper Belt Extended Mission.

Submitted to: The Astrophysical Journal Letters

Preprints on the web at `http://arxiv.org/abs/1605.05376`

OTHER PAPERS OF INTEREST

TRIPPy: Trailed Image Photometry in Python

W. Fraser[1], M. Alexandersen[2], M. Schwamb[2], M. Marsset[3], R. Pike[4], JJ Kavelaars[5], M. Bannister[4], S. Benecchi[6], and A. Delsanti[7]

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Photometry of moving sources typically suffers from reduced signal-to-noise (SNR) or flux measurements biased to incorrect low values through the use of circular apertures. To address this issue we present the software package, TRIPPy: TRailed Image Photometry in Python. TRIPPy introduces the pill aperture, which is the natural extension of the circular aperture appropriate for linearly trailed sources. The pill shape is a rectangle with two semicircular end-caps, and is described by three parameters, the trail length and angle, and the radius. The TRIPPy software package also includes a new technique to generate accurate model point-spread functions (PSF) and trailed point-spread functions (TSF) from stationary background sources in sidereally tracked images. The TSF is merely the convolution of the model PSF, which consists of a moffat profile, and super sampled lookup table. From the TSF, accurate pill aperture corrections can be estimated as a function of pill radius with a accuracy of 10 millimags for highly trailed sources. Analogous to the use of small circular apertures and associated aperture corrections, small radius pill apertures can be used to preserve signal-to-noise of low flux sources, with appropriate aperture correction applied to provide an accurate, unbiased flux measurement at all SNR.

To appear in: The Astronomical Journal

For preprints, contact `wes.fraser@qub.ac.uk`

or on the web at `http://arxiv.org/abs/1604.00031`

JOB ANNOUNCEMENTS

Research Fellow in Solar System Astrophysics

School of Mathematics and Physics
Queen's University Belfast

This post is available for 1.5 years from 1 October 2016 to work as part of the Solar System Group within the Astrophysics Research Centre. Faculty members of the QUB Solar System Group are current leaders of large telescope surveys, including an ESO large program on Kuiper Belt Object lightcurves (PI: Pedro Lacerda), the Colours of the Outer Solar System Origins Survey using the Gemini-North and Canada-France-Hawaii Telescopes (PI Wesley Fraser), and the Pan-STARRS Solar System Survey (Co-lead Alan Fitzsimmons).

The successful candidate will exploit these three datasets to study outer Solar System targets. Analysis of these data will focus on the following projects: searches for activity, photometric variability, and colour studies.

Informal enquiries may be directed to Dr. Wesley Fraser (telephone: +44 02890976354; email: `wes.fraser@qub.ac.uk`). More information at:
`https://star.pst.qub.ac.uk/wiki/doku.php/public/postdoc_fraser/start`
(Ref. 16/104687)

Application closing date: 11 July 2016
Anticipated interview date: 27 July 2016
Salary: £31,656 - £41,255 per annum

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⋆ Table of contents/outlines of books
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⋆ Job advertisements
⋆ General news items deemed of interest to the Kuiper belt community

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