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DISTANT EKOs

The Kuiper Belt Electronic Newsletter

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CONTENTS

NEWS & ANNOUNCEMENTS

Icarus is sponsoring a special issue on results related to the exploration of the Pluto system, the Kuiper Belt, and Kuiper Belt Objects by New Horizons. Papers are solicited from authors inside and outside the New Horizons team. The deadline for this special issue is 15 September 2019.

Alan Stern
Principal Investigator, New Horizons

Rosaly Lopes
Editor, Icarus

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EPSC-DPS Session SB5:
Trans-Neptunian objects and their dust environment, Pluto, 2014 MU69, and Centaurs

This session welcomes papers about the trans-Neptunian objects and their environment, including investigations of space weathering. We encourage scientific investigations based on both space and Earth-based observations as well as theoretical and laboratory investigations. Papers based on observations and measurements obtained from within the Kuiper Belt are particularly encouraged including those focusing on 2014 MU69 (a target of the New Horizons mission). We also welcome papers about the Pluto system including investigations of the geology, composition, atmosphere, climate and environment. Papers on processes that may be active in the Pluto system are particularly encouraged and include topics such as formation of organics in Pluto's atmosphere and surface, or seasonal/climatic models of volatile transports.
This session will also welcome abstracts devoted to studies of the Centaurs, in particular on their structure, composition, dynamics and activity patterns. We invite studies that describe observations, theory, experimental work, and future spacecraft encounters related to: (i) the onset and provenance of activity beyond Jupiter's orbit, and (ii) the nature of surface modification at these heliocentric distances (including, but not limited to, solar radiation, space weathering and impacts).

The abstract submission deadline is May 8, 2019, 13:00 CEST.

`https://meetingorganizer.copernicus.org/EPSC-DPS2019/session/34462`

Please join us in Geneva, Sept. 15-20 2019, for what is sure to be a great meeting.

Conveners: Kelsi Singer, Maria Teresa Capria, Heather Elliott, Sonia Fornasier, Walter Harris, Rodrigo Leiva, Catherine Olkin, Davide Perna, Simon Porter, Silvia Protopappa, Gal Sarid, Bernard Schmitt, Anne Verbiscer, Laura Woodney

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There were 56 new TNO discoveries announced since the previous issue of *Distant EKOs*:

2009 XM26, 2009 YR26, 2009 YS26, 2009 YT26, 2010 AV153, 2010 DF106,
2010 JF210, 2010 JH210, 2010 JJ210, 2010 NF146, 2010 RJ190, 2010 RK190,
2010 TR195, 2010 TS195, 2010 TT195, 2010 WN75, 2011 BO170, 2011 BQ170,
2011 EY90, 2011 EZ90, 2011 GZ61, 2011 HN104, 2011 LJ29, 2011 OC61, 2011 SW281,
2012 BZ159, 2012 DQ106, 2012 FN87, 2012 JD68, 2012 PU45, 2012 UE185,
2012 VB116, 2012 WD37, 2012 XW159, 2012 YF12, 2012 YG12, 2013 CF229,
2013 PE84, 2014 AF61, 2014 BD70, 2014 GK65, 2014 JQ92, 2014 JR92, 2014 KF113,
2014 OX415, 2014 SA365, 2014 WC536, 2014 WW535, 2014 WZ535, 2015 AQ293,
2015 DZ250, 2015 KG178, 2015 KK178, 2016 AN278, 2016 NZ90, 2017 FD163

and 55 new Centaur/SDO discoveries:

2010 AW153, 2010 BP153, 2010 CD270, 2010 JG210, 2010 NG146, 2010 OE153, 2010 PC88, 2010 QQ7, 2010 UU110, 2010 WM75, 2011 BM170, 2011 BN170, 2011 BP170, 2011 MV11, 2011 QY100, 2011 VZ24, 2012 AZ25, 2012 FM87, 2012 GT41, 2012 HW87, 2012 HX87, 2012 LB27, 2012 PV45, 2013 GW141, 2013 LZ36, 2013 ME14, 2013 NT33, 2013 NU33, 2013 PD84, 2014 BE70, 2014 BF70, 2014 GJ65, 2014 HO211, 2014 KE113, 2014 PM82, 2014 WA536, 2014 WB536, 2014 WV535, 2014 WX535, 2014 WY535, 2015 AR293, 2015 BE568, 2015 BF568, 2015 BG568, 2015 FG415, 2015 RQ281, 2015 XW379, 2016 CN323, 2016 SE56, 2017 OK69, 2017 VO34, 2018 AZ18, 2018 GT12, 2018 JT6, 2018 JU6

Current number of TNOs: 2499 (including Pluto)
Current number of Centaurs/SDOs: 921
Current number of Neptune Trojans: 22

Out of a total of 3442 objects:
693 have measurements from only one opposition
686 of those have had no measurements for more than a year
368 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

Impact Craters on Pluto and Charon Indicate a Deficit of Small Kuiper Belt Objects

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The flyby of Pluto and Charon by the New Horizons spacecraft provided high-resolution images of cratered surfaces embedded in the Kuiper belt, an extensive region of bodies orbiting beyond Neptune. Impact craters on Pluto and Charon were formed by collisions with other Kuiper belt objects (KBOs) with diameters from ~40 kilometers to ~300 meters, smaller than most KBOs observed directly by telescopes. We find a relative paucity of small craters less than approximately 13 kilometers in diameter, which cannot be explained solely by geological resurfacing. This implies a deficit of small KBOs (less than 1 to 2 kilometers in diameter). Some surfaces on Pluto and Charon are likely greater than 4 billion years old, thus their crater records provide information on the size-frequency distribution of KBOs in the early Solar System.

Published in: Science, 363, 955 (2019 March 1)
Available online at `http://adsabs.harvard.edu/abs/2019Sci...363..955N`

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Col-OSSOS: Color and Inclination are Correlated Throughout the Kuiper Belt

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Both physical and dynamical properties must be considered to constrain the origins of the dynamically excited distant Solar System populations. We present high-precision (g-r) colors for 25 small (H_r>5) dynamically excited Trans-Neptunian Objects (TNOs) and centaurs acquired as part of the Colours of the Outer Solar System Origins Survey (Col-OSSOS). We combine our dataset with previously published measurements and consider a set of 229 colors of outer Solar System objects on dynamically excited orbits. The overall color distribution is bimodal and can be decomposed into two distinct classes, termed 'gray' and 'red', that each has a normal color distribution. The two color classes have different inclination distributions: red objects have lower inclinations than the gray ones. This trend holds for all dynamically excited TNO populations. Even in the worst-case scenario, biases in the discovery surveys cannot account for this trend: it is intrinsic to the TNO population. Considering that TNOs are the precursors of centaurs, and that their inclinations are roughly preserved as they become centaurs, our finding solves the conundrum of centaurs being the only outer Solar System population identified so far to exhibit this property (Tegler et al. 2016). The different orbital distributions of the gray and red dynamically excited TNOs provide strong evidence that their colors are due to different formation locations in a disk of planetesimals with a compositional gradient.

Published in: The Astronomical Journal, 157, 94 (2019 March)

For preprints, contact `mmarsset@mit.edu`

or on the web at `http://adsabs.harvard.edu/abs/2019AJ....157...94M`

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Long-term Photometric Monitoring of the Dwarf Planet (136472) Makemake

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We studied the rotational properties of the dwarf planet Makemake. The photometric observations were carried out at different telescopes between 2006 and 2017. Most of the measurements were acquired in $BVRI$ broad-band filters of a standard Johnson-Cousins photometric system. We found that Makemake rotates more slowly than was previously reported. A possible lightcurve asymmetry suggests a double-peaked period of P = 22.8266±0.0001 h. A small peak-to-peak lightcurve amplitude in R-filter A = 0.032±0.005 mag implies an almost spherical shape or near pole-on orientation. We also measured $BVRI$ colours and the R-filter phase-angle slope and revised the absolute magnitudes. The absolute magnitude of Makemake has remained unchanged since its discovery in 2005. No direct evidence of a newly discovered satellite was found in our photometric data; however, we discuss the possible existence of another larger satellite.

To appear in: Astronomy & Astrophysics
For preprints, contact hromakina@astron.kharkov.ua
or on the web at http://arxiv.org/abs/1904.03679

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Lightcurves and Rotational Properties of the Pristine Cold Classical Kuiper Belt Objects

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We present a survey on the rotational and physical properties of the dynamically low inclination Cold Classical trans-Neptunian objects. The Cold Classicals are primordial planetesimals and contain relevant information about the early phase of our Solar System and planet formation over the first 100 million years after the formation of the Sun. Our project makes use of the Magellan and the Lowell's Discovery Channel Telescopes for photometric purposes. We obtained partial/complete lightcurves for 42 Cold Classicals. We use statistical tests to derive general properties about the shape and rotational frequency distributions of the Cold Classical population, and infer that the Cold Classicals have slower rotations and are more elongated/deformed than the other trans-Neptunian objects. Based on the available full lightcurves, the mean rotational period of the Cold Classical population is 9.48±1.53 h whereas the mean period of the rest of the trans-Neptunian objects is 8.45±0.58 h. About 65% of the trans-Neptunian objects (excluding the Cold Classicals) have a lightcurve amplitude below 0.2 mag compared to the 36% of Cold Classicals with small amplitude. We present the full lightcurve of one new likely contact binary: 2004 VC_{131} with a potential density of 1 g cm^{-3} for a mass ratio of 0.4. We also have hints that 2004 MU_8 and 2004 VU_{75} are maybe potential contact binaries based on their sparse lightcurves but more data are needed to confirm such a find. Assuming equal-sized binaries, we find that only ∼10-25 % of the Cold Classicals could be contact binaries, suggesting that there is a deficit of contact binaries in this population compared to previous estimates and compared to the abundant (∼40-50%) possible contact binaries in the 3:2 resonant (Plutino) population. This estimate is a lower limit and will increase if non equal-sized contact binaries are also considered. Finally, we put in context the early results of the *New Horizons* flyby of (486958) 2014 MU_{69}.

To appear in: The Astronomical Journal
For preprints, contact `thirouin@lowell.edu` or `ssheppard@carnegiescience.edu`
or on the web at `https://arxiv.org/abs/1904.02207`

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Using the Density of Kuiper Belt Objects to Constrain their Composition and Formation History

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Telescopic observations of Kuiper Belt objects have enabled bulk density determinations for 18 objects. These densities vary systematically with size, perhaps suggesting systematic variations in bulk composition. We find this trend can be explained instead by variations in porosity arising from the higher pressures and warmer temperatures in larger objects. We are able to match the density of 15 of 18 KBOs within their 2σ errors with a constant rock mass fraction of 70%, suggesting a compositionally homogeneous, rock-rich reservoir. Because early ^{26}Al would have removed too much porosity in small (∼100 km) KBOs we find the minimum formation time to be 4 Myr after solar system formation. This suggests that coagulation, and not gravitational collapse, was the dominant mechanism for KBO formation, or the gas disk lingered in the outer solar system. We also use this model to make predictions for the density of Makemake, 2007 OR_{10}, and MU_{69}.

Published in: Icarus, 326, 10 (2019 July 1)
For preprints, contact `cthomas1@ucsc.edu`
or on the web at `http://adsabs.harvard.edu/abs/2019Icar..326...10B`

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Dynamical Analysis of Three Distant Trans-Neptunian Objects with Similar Orbits

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This paper reports the discovery and orbital characterization of two extreme trans-Neptunian objects (ETNOs), 2016 QV_{89} and 2016 QU_{89}, which have orbits that appear similar to that of a previously known object, 2013 UH_{15}. All three ETNOs have semi-major axes $a \approx 172$ AU and eccentricities $e \approx 0.77$. The angular elements (i, ω, Ω) vary by 6, 15, and 49 deg, respectively between the three objects. The two new objects add to the small number of TNOs currently known to have semi-major axes between 150 and 250 AU, and serve as an interesting dynamical laboratory to study the outer realm of our Solar System. Using a large ensemble of numerical integrations, we find that the orbits are expected to reside in close proximity in the (a, e) phase plane for roughly 100 Myr before diffusing to more separated values. We find that an explanation for the orbital configuration of the bodies as a collision product is disfavored. We then explore other scenarios that could influence their orbits. With aphelion distances over 300 AU, the orbits of these ETNOs extend far beyond the classical Kuiper Belt, and an order of magnitude beyond Neptune. As a result, their orbital dynamics can be affected by the proposed new Solar System member, referred to as Planet Nine in this work. With perihelion distances of 35–40 AU, these orbits are also influenced by resonant interactions with Neptune. A full assessment of any possible, new Solar System planets must thus take into account this emerging class of TNOs.

Published in: The Astronomical Journal, 156, 273 (2018 December)

For preprints, contact `talikh@umich.edu`

or on the web at `http://adsabs.harvard.edu/abs/2018AJ....156..273K`

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A New High Perihelion Trans-Plutonian Inner Oort Cloud Object: 2015 TG387

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Inner Oort Cloud objects (IOCs) are Trans-Plutonian for their entire orbits. They are beyond the strong gravitational influences of the known planets yet close enough to the Sun that outside forces are minimal. Here we report the discovery of the third known IOC after Sedna and 2012 VP113, called 2015 TG387. 2015 TG387 has a perihelion of 65 ± 1 au and semi-major axis of 1170 ± 70 au. The longitude of perihelion angle, $\bar{\omega}$, for 2015 TG387 is between that of Sedna and 2012 VP113, and thus similar to the main group of clustered extreme trans-Neptunian objects (ETNOs), which may be shepherded into similar orbital angles by an unknown massive distant planet, called Planet X or Planet Nine. 2015 TG387's orbit is stable over the age of the solar system from the known planets and Galactic tide. When including outside stellar encounters over 4 Gyrs, 2015 TG387's orbit is usually stable, but its dynamical evolution depends on the stellar encounter scenarios used. Surprisingly, when including a massive Planet X beyond a few hundred au on an eccentric orbit that is anti-aligned

in longitude of perihelion with most of the known ETNOs, we find 2015 TG387 is typically stable for Planet X orbits that render the other ETNOs stable as well. Notably, 2015 TG387's argument of perihelion is constrained and its longitude of perihelion librates about 180 deg from Planet X's longitude of perihelion, keeping 2015 TG387 anti-aligned with Planet X over the age of the solar system. We find a power law slope near 3 for the semi-major axis distribution of IOCs, meaning there are many more high than low semi-major axis IOCs. There are about 2 million IOCs larger than 40 km, giving a mass of 10^{22} kg. The IOCs inclination distribution is similar to the scattered disk, with an average inclination of 19 deg.

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For preprints, contact `sheppard@dtm.ciw.edu`
or on the web at `http://adsabs.harvard.edu/abs/2019AJ....157..139S`

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JWST/NIRSpec Prospects on Transneptunian Objects

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The transneptunian region has proven to be a valuable probe to test models of the formation and evolution of the solar system. To further advance our current knowledge of these early stages requires an increased knowledge of the physical properties of Transneptunian Objects (TNOs). Colors and albedos have been the best way so far to classify and study the surface properties of a large number TNOs. However, they only provide a limited fraction of the compositional information, required for understanding the physical and chemical processes to which these objects have been exposed since their formation. This can be better achieved by near-infrared (NIR) spectroscopy, since water ice, hydrocarbons, and nitrile compounds display diagnostic absorption bands in this wavelength range. Visible and NIR spectra taken from ground-based facilities have been observed for ~80 objects so far, covering the full range of spectral types: from neutral to extremely red with respect to the Sun, featureless to volatile-bearing and volatile-dominated (Barkume et al., 2008; Guilbert et al., 2009; Barucci et al., 2011; Brown, 2012). The largest TNOs are bright and thus allow for detailed and reliable spectroscopy: they exhibit complex surface compositions, including water ice, methane, ammonia, and nitrogen. Smaller objects are more difficult to observe even from the largest telescopes in the world. In order to further constrain the inventory of volatiles and organics in the solar system, and understand the physical and chemical evolution of these bodies, high-quality NIR spectra of a larger sample of TNOs need to be observed. JWST/NIRSpec is expected to provide a substantial improvement in this regard, by increasing both the quality of observed spectra and the number of observed objects. In this paper, we review the current knowledge of TNO properties and provide diagnostics for using NIRSpec to constrain TNO surface compositions.

Published in: Frontiers in Astronomy and Space Sciences, 6, 8 (2019 February)
Available online at `http://adsabs.harvard.edu/abs/2019FrASS...6....8M`

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A Software Roadmap for Solar System Science with the Large Synoptic Survey Telescope

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The 8.4-m Large Synoptic Survey Telescope (LSST) will provide an unprecedented view of the Solar System. LSST will detect millions of asteroids and tens of thousands of distant Solar System bodies, within approximately 16 and 24.5 mag (in r-band). Over a ten year period, most of these minor planets will receive hundreds of observations divided between 6 filters (ugrizy). What specifically LSST project will deliver for Solar System detections will soon be updated in the LSST Data Products Definition Document. The LSST Solar System Science Collaboration (SSSC; `http://www.lsstsssc.org`) produced a science roadmap which outlines the collaboration's highest ranked research priorities utilizing LSST. To achieve these science goals, the SSSC has identified crucial software products and tools that will be required but will not be provided by the LSST project. These will have to be developed by the SSSC and the broader planetary community. To spur this effort, we present this list of LSST community software development tasks.

Published in: Research Notes of the American Astronomical Society, 3, 51 (2019 March)

Available online at `http://adsabs.harvard.edu/abs/2019RNAAS...3c..51S`

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Kuiper Belt: Formation and Evolution

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This chapter reviews accretion models for Kuiper belt objects (KBOs), discussing in particular the compatibility of the observed properties of the KBO population with the streaming instability paradigm. Then it discusses how the dynamical structure of the KBO population, including the formation of its 5 sub-components (cold, hot, resonant, scattered and fossilized), can be quantitatively understood in the framework of the giant planet instability. We also establish the connections

between the KBO population and the Trojans of Jupiter and Neptune, the irregular satellites of all giant planets, the Oort cloud and the D-type main belt asteroids. Finally, we discuss the collisional evolution of the KBO population, arguing that the current size-frequency distribution below 100 km in size has been achieved as a collisional equilibrium in a few tens of My inside the original massive trans-Neptunain disk, possibly with the exception of the cold population sub-component.

To appear in: "The Transneptunian Solar System"
(D. Prialnik, M.A. Barucci, L. Young eds., Elsevier)
For preprints, contact `morby@oca.eu`
or on the web at `http://arxiv.org/abs/1904.02980`

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The Dynamics of Rings around Centaurs and Trans-Neptunian Objects

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Since 2013, dense and narrow rings are known around the small Centaur object Chariklo and the dwarf planet Haumea. Dense material has also been detected been around the Centaur Chiron, although its nature is debated. This is the first time ever that rings are observed elsewhere than around the giant planets, suggesting that those features are more common than previously thought. The origins of those rings remain unclear. In particular, it is not known if the same generic process can explain the presence of material around Chariklo, Chiron, Haumea, or if each object has a very different history. Nonetheless, a specific aspect of small bodies is that they may possess a non-axisymmetric shape (topographic features and/or elongation) that are essentially absent in giant planets. This creates strong resonances between the spin rate of the object and the mean motion of ring particles. In particular, Lindblad-type resonances tend to clear the region around the corotation (or synchronous) orbit, where the particles orbital period matches that of the body. Whatever the origin of the ring is, modest topographic features or elongations of Chariklo and Haumea explain why their rings should be found beyond the outermost 1/2 resonance, where the particles complete one revolution while the body completes two rotations. Comparison of the resonant locations relative to the Roche limit of the body shows that fast rotators are favored for being surrounded by rings. We discuss in more details the phase portraits of the 1/2 and 1/3 resonances, and the consequences of a ring presence on satellite formation.

To appear in: "The Transneptunian Solar System"
(D. Prialnik, M.A. Barucci, L. Young eds., Elsevier)
Preprints available on the web at `https://arxiv.org/abs/1904.04851`

The *Distant EKOs* Newsletter is dedicated to provide researchers with easy and rapid access to current work regarding the Kuiper belt (observational and theoretical studies), directly related objects (e.g., Pluto, Centaurs), and other areas of study when explicitly applied to the Kuiper belt.

We accept submissions for the following sections:
⋆ Abstracts of papers submitted, in press, or recently published in refereed journals
⋆ Titles of conference presentations
⋆ Thesis abstracts
⋆ Short articles, announcements, or editorials
⋆ Status reports of on-going programs
⋆ Requests for collaboration or observing coordination
⋆ Table of contents/outlines of books
⋆ Announcements for conferences
⋆ Job advertisements
⋆ General news items deemed of interest to the Kuiper belt community

A LaTeX template for submissions is appended to each issue of the newsletter, and is sent out regularly to the e-mail distribution list. Please use that template, and send your submission to:

`ekonews@boulder.swri.edu`

The *Distant EKOs* Newsletter is available on the World Wide Web at:

`http://www.boulder.swri.edu/ekonews`

Recent and back issues of the newsletter are archived there in various formats. The web pages also contain other related information and links.

Distant EKOs is not a refereed publication, but is a tool for furthering communication among people interested in Kuiper belt research. Publication or listing of an article in the newsletter or the web page does not constitute an endorsement of the article's results or imply validity of its contents. When referencing an article, please reference the original source; *Distant EKOs* is not a substitute for peer-reviewed journals.

Moving ... ??

If you move or your e-mail address changes, please send the editor your new address. If the newsletter bounces back from an address for three consecutive issues, the address will be deleted from the mailing list. All address changes, submissions, and other correspondence should be sent to:

`ekonews@boulder.swri.edu`