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DISTANT EKOs

The Kuiper Belt Electronic Newsletter

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CONTENTS

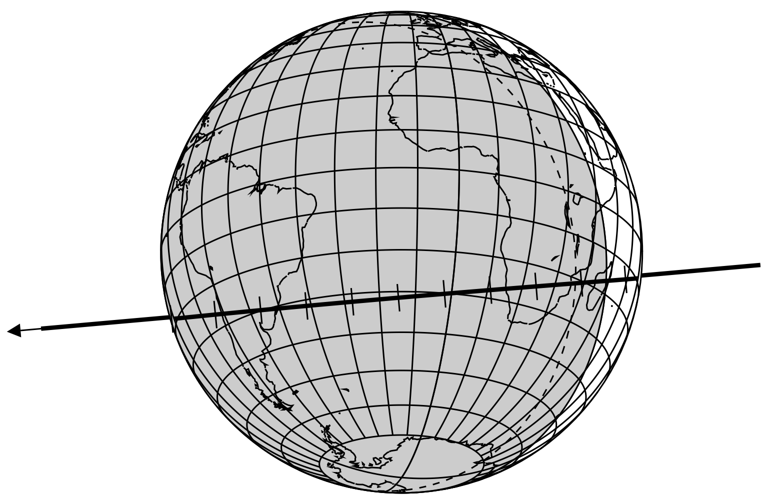
NEWS & ANNOUNCEMENTS

Occultation Observation Support for New Horizons KBO Encounter

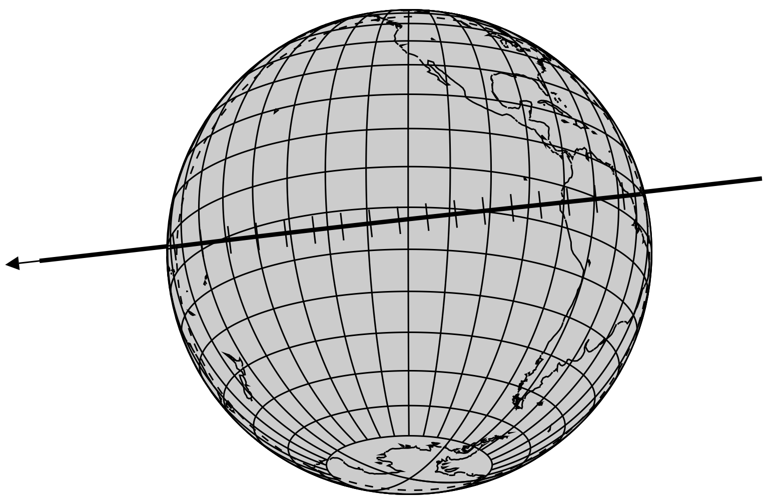
Having completed its successful flyby of the Pluto system, the New Horizons spacecraft is on a trajectory for a January 2019 encounter with the 2014 MU69, an approximately 40 km diameter member of the cold classical Kuiper Belt. Earth-based observers have an opportunity to probe the Hill sphere of MU69 and potentially constrain its position and diameter through upcoming stellar occultation events. Three events are forecast in 2017: June 3, July 10, and July 17. Each event is depicted in detail below. These figures are the best available solution as of 2016 December 11 and are provided by Eliot Young with credit to Marc Buie, Larry Wasserman, and Simon Porter. Ongoing updates will be available at `www.boulder.swri.edu/nh-support-obs`

For ground-based observers, particular focus is being directed toward the 2017 June 3 event, for two reasons:
- It crosses two continents (Africa and South America) at locations that have reasonable prospects in terms of setting up a picket fence of observers.
- A detection by ground-based observers on 2017 June 3 will greatly refine the position, thereby greatly improving the chances of SOFIA getting in the shadow path on for the 2017 July 10 and July 17 events.

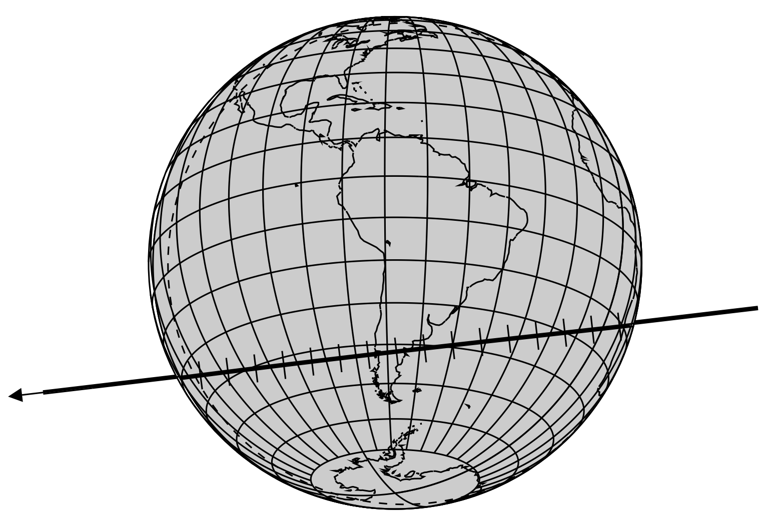
Interested observers willing to conduct and coordinate their measurements should contact `azangari@boulder.swri.edu`



NH -08194514G by 14MU69 Gaia *, MWB-H-PM
2017/06/03 03:11:50
RA: 19 03 34.493 DEC: -20 34 39.34
Diam: 75.0 = 0.002as Max Duration: 3.7s Q: 82.1 Solar elongation: 147.6
Lunar elongation: 103.3 Illuminated: 66.3%
Sun altitude at -12.0 shown dotted
Ticks from: 03:07:00 to 03:17:00 every 1 min



NH -07659414G by 14MU69 Gaia * MWB-H-PM
2017/07/10 07:45:52
RA: 19 00 41.620 DEC: -20 38 44.53
Diam: 75.0 = 0.002as Max Duration: 3.1s Q: 81.8 Solar elongation: 175.7
Lunar elongation: 16.7 Illuminated: 98.7% Sun altitude at -12.0 shown dotted
Ticks from: 07:42:00 to 07:50:00 every 30 sec



NH -07544526G by 14MU69 Gaia * MWB-H-PM
2017/07/17 03:49:50
RA: 19 00 08.292 DEC: -20 39 37.97
Diam: 75.0 = 0.002as Max Duration: 3.1s Q: 81.8 Solar elongation: 169.3
Lunar elongation: 105.1 Illuminated: 46.2%
Sun altitude at -12.0 shown dotted
Ticks from: 03:46:00 to 03:53:30 every 30 sec

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Exploration Missions to the Kuiper Belt And Oort Cloud

With the 2015 flyby of Pluto and the planned 2019 flyby of KBO 2014 MU69, the New Horizons mission has only undertaken the very earliest reconnaissance phase of the exploration of the Kuiper Belt.

The overall science strategy for incrementing knowledge of solar system objects was articulated by the Committee on Planetary and Lunar Exploration (COMPLEX) in the 1970's; it begins with flyby reconnaissance and progresses exploration with orbiters and then landers.

The Kuiper Belt and Oort Cloud will next require a series of flyby missions to explore the diversity of phenomenology and origins of the objects found in these vast, primordial reservoirs. Additionally, Pluto system orbiters or landers are also needed to understand its unexpectedly complex surface geology, atmospheric dynamics and volatile transport, its satellite system, and the possibility and characteristics of its suspected interior ocean.

Anyone interested in potentially joining a Pluto follow-on mission interest group should contact Alan Stern at `astern@swri.edu`

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There were 19 new TNO discoveries announced since the previous issue of *Distant EKOs*:

2013 VJ24, 2014 SB350, 2014 SE350, 2014 SF350, 2014 SH350, 2014 SJ350, 2014 SL350, 2014 SM350, 2014 SN350, 2014 ST349, 2014 SX349, 2014 TE86, 2014 UB225, 2014 UC225, 2014 XY40 2014 XZ40, 2015 DB225, 2015 DC225, 2016 BP81

and 12 new Centaur/SDO discoveries:

2012 FN84, 2014 SC350, 2014 SG350, 2014 SK350, 2014 SO350, 2014 UA225, 2014 UZ224, 2014 YL50, 2015 DA225, 2015 FW392, 2015 UK84, 2015 VT152

Reclassified objects:
2014 YY49 (SDO → Centaur)
2015 FW392 (SDO → TNO)

Objects recently assigned numbers:
2004 VN112 = (474640)
2014 QB442 = (480017)

Current number of TNOs: 1789 (including Pluto)
Current number of Centaurs/SDOs: 689
Current number of Neptune Trojans: 17

Out of a total of 2495 objects:
713 have measurements from only one opposition
676 of those have had no measurements for more than a year
311 of those have arcs shorter than 10 days
(for more details, see: `http://www.boulder.swri.edu/ekonews/objects/recov_stats.jpg`)

PAPERS ACCEPTED TO JOURNALS

The Formation of Charon's Red Poles From Seasonally Cold-trapped Volatiles

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A unique feature of Pluto's large satellite Charon is its dark red northern polar cap. Similar colours on Pluto's surface have been attributed to tholin-like organic macromolecules produced by energetic radiation processing of hydrocarbons. The polar location on Charon implicates the temperature extremes that result from Charon's high obliquity and long seasons in the production of this material. The escape of Pluto's atmosphere provides a potential feedstock for a complex chemistry. Gas from Pluto that is transiently cold-trapped and processed at Charon's winter pole was proposed as an explanation for the dark coloration on the basis of an image of Charon's northern hemisphere, but not modelled quantitatively. Here we report images of the southern hemisphere illuminated by Pluto-shine and also images taken during the approach phase that show the northern polar cap over a range of longitudes. We model the surface thermal environment on Charon and the supply and temporary cold-trapping of material escaping from Pluto, as well as the photolytic processing of this material into more complex and less volatile molecules while cold-trapped. The model results are consistent with the proposed mechanism for producing the observed colour pattern on Charon.

Published in: Nature, 539, 65 (2016 November 3)

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Detection of CO and HCN in Pluto's Atmosphere with ALMA

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Observations of the Pluto-Charon system, acquired with the ALMA interferometer on June 12-13, 2015, have led to the detection of the CO(3-2) and HCN(4-3) rotational transitions from Pluto (including the hyperfine structure of HCN), providing a strong confirmation of the presence of CO, and the first observation of HCN in Pluto's atmosphere. The CO and HCN lines probe Pluto's atmosphere up to ~450 km and ~900 km altitude, respectively, with a large contribution due to limb emission. The CO detection yields (i) a much improved determination of the CO mole fraction, as 515 ± 40 ppm for a 12 microbar surface pressure (ii) strong constraints on Pluto's mean atmospheric dayside temperature profile over ~50-400 km, with clear evidence for a well-marked temperature decrease (i.e., mesosphere) above the 30-50 km stratopause and a best-determined temperature of 70 ± 2 K at 300 km, somewhat lower than previously estimated from stellar occultations (81 ± 6 K), and in agreement with recent inferences from New Horizons / Alice solar occultation data. The HCN line shape implies a high abundance of this species in the upper atmosphere, with a mole fraction $> 1.5 \times 10^{-5}$ above 450 km and a value of 4×10^{-5} near 800 km. Assuming HCN at saturation, this would require a warm (> 92 K) upper atmosphere layer; while this is not ruled out by the CO emission, it is inconsistent with the Alice-measured CH_4 and N_2 line-of-sight column densities. Taken together, the large HCN abundance and the cold upper atmosphere imply supersaturation of HCN to a degree (7-8 orders of magnitude) hitherto unseen in planetary atmospheres, probably due to a lack of condensation nuclei above the haze region and the slow kinetics of condensation at the low pressure and temperature conditions of Pluto's upper atmosphere. HCN is also present in the bottom ~100 km of the atmosphere, with a $10^{-8} - 10^{-7}$ mole fraction; this implies either HCN saturation or undersaturation there, depending on the precise stratopause temperature. The HCN column is $(1.6 \pm 0.4) \times 10^{14}$ cm^{-2}, suggesting a surface-referred vertically-integrated net production rate of $\sim 2 \times 10^7$ cm^{-2} s^{-1}. Although HCN rotational line cooling affects Pluto's atmosphere heat budget, the amounts determined in this study are insufficient to explain the well-marked mesosphere and upper atmosphere's ~70 K temperature, which if controlled by HCN cooling would require HCN mole fractions of $(3 - 7) \times 10^{-4}$ over 400-800 km. We finally report an upper limit on the HC_3N column density ($< 2 \times 10^{13}$ cm^{-2}) and on the $HC^{15}N/HC^{14}N$ ratio ($< 1/125$).

To appear in: Icarus

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or on the web at `http://arxiv.org/abs/1606.03293`

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The Puzzling Detection of X-rays From Pluto by Chandra

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Using *Chandra ACIS-S*, we have obtained low-resolution imaging X-ray spectrophotometry of the Pluto system in support of the New Horizons flyby on 14 July 2015. Observations were obtained in a trial "seed" campaign conducted in one visit on 24 Feb 2014, and a follow-up campaign conducted soon after the New Horizons flyby that consisted of 3 visits spanning 26 Jul to 03 Aug 2015. In a total of 174 ksec of on-target time, in the 0.31 to 0.60 keV passband, we measured 8 total photons in a co-moving 11 x 11 pixel^2 box (the 90% flux aperture determined by observations of fixed background sources in the field) measuring ~121,000 x 121,000 km^2 (or ~100 x 100 $R_{\rm Pluto}$) at Pluto. No photons were detected from 0.60 to 1.0 keV in this box during the same exposures. Allowing for background, we find a net signal of 6.8 counts and a statistical noise level of 1.2 counts, for a detection of Pluto in this passband at >99.95% confidence. The Pluto photons do not have the spectral shape of the background, are coincident with a 90% flux aperture co-moving with Pluto, and are not confused with any background source, so we consider them as sourced from the Pluto system. The mean 0.31-0.60 keV X-ray power from Pluto is 200^{+200}_{-100} MW, in the middle range of X-ray power levels seen for other known Solar System emission sources: auroral precipitation, solar X-ray scattering, and charge exchange (CXE) between solar wind (SW) ions and atmospheric neutrals. We eliminate auroral effects as a source, as Pluto has no known magnetic field and the New Horizons Alice UV spectrometer detected no airglow from Pluto during the flyby. Nano-scale atmospheric haze particles could lead to enhanced resonant scattering of solar X-rays from Pluto, but the energy signature of the detected photons does not match the solar spectrum and estimates of Pluto's scattered X-ray emission are 2 to 3 orders of magnitude below the $3.9 \pm 0.7 \times 10^{-5}$ cps found in our observations. Charge-exchange-driven emission from hydrogenic and heliogenic SW carbon, nitrogen, and oxygen (CNO) ions can produce the energy signature seen, and the 6×10^{25} neutral gas escape rate from Pluto deduced from New Horizons data (Gladstone et al. 2016) can support the $\sim 3.0^{+3.0}_{-1.5} \times 10^{24}$ X-ray photons/s emission rate required by our observations. Using the solar wind proton density and speed measured by the Solar Wind Around Pluto (SWAP) instrument in the vicinity of Pluto at the time of the photon emissions, we find a factor of 40^{+40}_{-20} lower SW minor ions flowing planarly into an 11 x 11 pixel^2, 90% flux box centered on Pluto than are needed to support the observed emission rate. Hence, the SW must be somehow significantly focused and enhanced within 60,000 km (projected) of Pluto for this mechanism to work.

To appear in: Icarus

Preprints available on the web at http://arxiv.org/abs/1610.07963

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Upper Limits to the Number of Oort Cloud Objects Based on Serendipitous Occultation Events Search in X-Rays

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Using all the RXTE archival data of Sco X-1 and GX 5-1, which amount to about 1.6 Ms in total, we searched for possible occultation events caused by Oort Cloud objects. The detection efficiency of our searching approach was studied with simulation. Our search is sensitive to object size of about 300 m in the inner Oort Cloud, taking 4000 au as a representative distance, and of 900 m in the outer Oort Cloud, taking 36,000 au as the representative distance. No occultation events were found in the 1.6 Ms data. We derived upper limits to the number of Oort Cloud objects, which are about three orders of magnitude higher than the highest theoretical estimates in the literature for the inner Oort Cloud, and about six orders higher for the outer Oort Cloud. Although these upper limits are not constraining enough, they are the first obtained observationally, without making any model assumptions about comet injection. They also provide guidance to such serendipitous occultation event search in the future.

Published in: Monthly Notices of the Royal Astronomical Society, 462, 1952

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or on the web at http://arxiv.org/abs/1607.05797

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The Inclination of the Planetary System Relative to the Solar Equator may be Explained by the Presence of Planet 9

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We evaluate the effects of a distant planet, commonly known as planet 9, on the dynamics of the giant planets of the Solar System. We find that, given the large distance of planet 9, the dynamics of the inner giant planets can be decomposed into a classic Lagrange-Laplace dynamics relative to their own invariant plane (the plane orthogonal to their total angular momentum vector) and a slow precession of said plane relative to the total angular momentum vector of the Solar System, including planet 9. Under some specific configurations for planet 9, this precession can explain the current tilt of $\sim 6^\circ$ between the invariant plane of the giant planets and the solar equator. An analytical model is developed to map the evolution of the inclination of the inner giant planets' invariant plane as a function of the planet 9's mass, inclination, eccentricity and semimajor axis, and some numerical simulations of the equations of motion of the giant planets and planet 9 are performed to validate our analytical approach. The longitude of the ascending node of planet 9 is found to be linked to the longitude of the ascending node of the giant planets' invariant plane, which also constrain the longitude of the node of planet 9 on the ecliptic. Some of the planet 9 configurations that allow explaining the current solar tilt are compatible with those proposed to explain the orbital confinement of the most distant Kuiper belt objects. Thus, this work on the one hand gives an elegant explanation for the current tilt between the invariant plane of the inner giant planets and the solar equator and, on the other hand, adds new constraints to the orbital elements of planet 9.

Published in: The Astronomical Journal, 153, 27 (2017 January)

For preprints, contact rodney@on.br

or on the web at http://arxiv.org/abs/1607.05111v1

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Preliminary Constraints on the Location of the Recently Hypothesized New Planet of the Solar System from Planetary Orbital Dynamics

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It has been recently proposed that the observed grouping of either the perihelia and the orbital planes of some observed distant Kuiper Belt Objects (KBOs) can be explained by the shepherding influence of a remote (150 au $\lesssim q_X \lesssim$ 350 au), still unseen massive object PX having planetary size (5 $m_\oplus \lesssim m_X \lesssim$ 20 $m_\oplus$) and moving along an ecliptically inclined (22 deg $\lesssim I_X \lesssim$ 40 deg), eccentric (380 au $\lesssim a_X \lesssim$ 980 au) Heliocentric bound orbit located in space at 80 deg $\lesssim \Omega_X \lesssim$ 120 deg and which is anti-aligned (120 deg $\lesssim \omega_X \lesssim$ 160 deg) with those of the considered KBOs. The trajectory of Saturn is nowadays known at essentially the same accuracy level of the inner planets due to the telemetry of the Cassini spacecraft. Thus, the expected perturbations $\dot{\varpi}$, $\dot{\Omega}$ due to PX on the Kronian apsidal and draconitic orbital motions are theoretically investigated to tentatively constrain the configuration space of PX itself. To this aim, we compare our predictions $\dot{\varpi}_{\rm theo}$, $\dot{\Omega}_{\rm theo}$ to the currently available experimental intervals of values $\Delta\dot{\Omega}_{\rm obs}$, $\Delta\dot{\varpi}_{\rm obs}$ determined by astronomers in the recent past without explicitly modeling and solving for PX itself. As such, our results, despite being plausible and in agreement to a large extent with other constraints released in the literature, should be regarded as proof-of-principle investigations aimed to encourage more accurate analyses in future. It turns out that the admissible region in its configuration space is moderately narrow as far as its position along its orbit, reckoned by the true anomaly f_X, is concerned, being concentrated around approximately 130 deg $\lesssim f_X \lesssim$ 240 deg. PX is certainly far from its perihelion ($f_X = 0$ deg), in agreement with other recent studies. The future analysis of the data from the ongoing New Horizons mission might be helpful in further constraining the scenario considered here for PX. Its impact on the spacecraft's range over a multi-year span is investigated with a preliminary sensitivity analysis.

Published in: Astrophysics and Space Science, 362, 11 (2017 January)
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The Very Homogeneous Surface of the Dwarf Planet Makemake

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The dwarf planet (136472) Makemake is one of the largest trans-Neptunian objects discovered to date. Noteworthy, the size and surface temperature of this celestial body put it in a transition region where nitrogen is preferentially lost, while the less volatile methane is retained. Indeed, literature spectra clearly show that the surface of Makemake is dominated by methane ice, though the presence of nitrogen and of irradiation products of methane has been inferred by several authors, and a debate is still open about the eventual rotational variability of the surface composition. In this work we present new visible and near-infrared spectra of Makemake obtained with the TNG telescope (La Palma, Spain) in the time span 2006-2013. Our data sample different rotational phases, covering about 80% of the surface. All of the obtained spectra look very similar, suggesting an overall homogeneous composition. No secular variations appear when comparing our data to literature results (as expected, considering the quite short orbital arc travelled by Makemake since its discovery in 2005). The presence of methane diluted in nitrogen is evidenced by the shift of the observed absorption bands with respect to those of pure methane, with a dilution state looking homogeneous over the surface. We modelled a complete visible and

near-infrared spectrum of Makemake using the Shkuratov formalism, and found that adding irradiation products of methane like ethane and ethylene seems indeed improving the fit of the synthetic spectrum to our data. We found no hints of a localized/temporary atmosphere.

To appear in: Monthly Notices of the Royal Astronomical Society
(DOI: 10.1093/mnras/stw3272)
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The Short Rotation Period of Hi'iaka, Haumea's Largest Satellite

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Hi'iaka is the larger outer satellite of the dwarf planet Haumea. Using relative photometry from the Hubble Space Telescope and Magellan and a phase dispersion minimization analysis, we have identified the rotation period of Hi'iaka to be ~ 9.8 hrs (double-peaked). This is ~ 120 times faster than its orbital period, creating new questions about the formation of this system and possible tidal evolution. The rapid rotation suggests that Hi'iaka could have a significant obliquity and spin precession that could be visible in light curves within a few years. We then turn to an investigation of what we learn about the (presently unclear) formation of the Haumea system and family based on this unexpectedly rapid rotation rate. We explore the importance of the initial semi-major axis and rotation period in tidal evolution theory and find they strongly influence the time required to despin to synchronous rotation, relevant to understanding a wide variety of satellite and binary systems. We find that despinning tides do not necessarily lead to synchronous spin periods for Hi'iaka, even if it formed near the Roche limit. Therefore the short rotation period of Hi'iaka does not rule out significant tidal evolution. Hi'iaka's spin period is also consistent with formation near its current location and spin up due to Haumea-centric impactors.

Published in: The Astronomical Journal, 152, 195 (2016 December)
Preprints available on the web at http://arxiv.org/abs/1610.04305

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:

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Moving ... ??

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