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DISTANT EKOs

The Kuiper Belt Electronic Newsletter

Edited by: Joel Wm. Parker

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NEWS & ANNOUNCEMENTS

Frontiers journal has set up an online Research Topic: "From Comets to Pluto and Beyond: Kuiper Belt Objects and Investigations"
`http://journal.frontiersin.org/researchtopic/5809/from-comets-to-pluto-and-beyond-kuiper-belt`
We hope that the distinguished researchers who kindly wish to contribute to this Research Topic will provide the community of interested readers with the latest developments at the forefront of the research in this fascinating and rapidly evolving field. Contributions based on theory/modeling, observations, and experiments are highly welcomed.

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There were 9 new TNO discoveries announced since the previous issue of *Distant EKOs*:

2013 SP99, 2013 SQ99, 2013 UL15, 2013 UM15, 2013 UN15, 2013 UO15, 2013 UP15, 2014 UD225, 2014 UE225

and 3 new Centaur/SDO discoveries:

2013 RO98, 2017 AB5, 2017 CX33

Objects recently assigned numbers:

2013 XC26 = (482824)
2014 QS441 = (483002)

Objects recently assigned names:

1994 JR1 = Arawn

Current number of TNOs: 1798 (including Pluto)
Current number of Centaurs/SDOs: 692
Current number of Neptune Trojans: 17

Out of a total of 2507 objects:

709 have measurements from only one opposition
671 of those have had no measurements for more than a year
310 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

Haze in Pluto's Atmosphere

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Haze in Pluto's atmosphere was detected in images by both the Long Range Reconnaissance Imager (LORRI) and the Multispectral Visible Imaging Camera (MVIC) on New Horizons. LORRI observed haze up to altitudes of at least 200 km above Pluto's surface at solar phase angles from $\sim 20^\circ$ to $\sim 169^\circ$. The haze is structured with about ~ 20 layers, and the extinction due to haze is greater in the northern hemisphere than at equatorial or southern latitudes. However, more haze layers are discerned at equatorial latitudes. A search for temporal variations found no evidence for motions of haze layers (temporal changes in layer altitudes) on time scales of 2 to 5 hours, but did find evidence of changes in haze scale height above 100 km altitude. An ultraviolet extinction attributable to the atmospheric haze was also detected by the ALICE ultraviolet spectrograph on New Horizons. The haze particles are strongly forward-scattering in the visible, and a microphysical model of haze is presented which reproduces the visible phase function just above the surface with 0.5 μm spherical particles, but also invokes fractal aggregate particles to fit the visible phase function at 45 km altitude and account for UV extinction. A model of haze layer generation by orographic excitation of gravity waves is presented. This model accounts for the observed layer thickness and distribution with altitude. Haze particles settle out of the atmosphere and onto Pluto's surface, at a rate sufficient to alter surface optical properties on seasonal time scales. Pluto's regional scale albedo contrasts may be preserved in the face of the haze deposition by atmospheric collapse.

To appear in: Icarus

For preprints, contact `andrew.cheng@jhuapl.edu`

or on the web at `https://arxiv.org/abs/1702.07771`

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3D Modeling of Organic Haze in Pluto's Atmosphere

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The New Horizons spacecraft, which flew by Pluto on July 14, 2015, revealed the presence of haze in Pluto's atmosphere that were formed by CH_4/N_2 photochemistry at high altitudes in Pluto's atmosphere, as on Titan and Triton. In order to help the analysis of the observations and further investigate the formation of organic haze and its evolution at global scales, we have implemented a simple parametrization of the formation of organic haze in our Pluto General Circulation Model. The

production of haze in our model is based on the different steps of aerosol formation as understood on Titan and Triton: photolysis of CH_4 in the upper atmosphere by Lyman-α UV radiation, production of various gaseous species, and conversion into solid particles through accumulation and aggregation processes. The simulations use properties of aerosols similar to those observed in the detached haze layer on Titan. We compared two reference simulations ran with a particle radius of 50 nm: with, and without South Pole N_2 condensation. We discuss the impact of the particle radius and the lifetime of the precursors on the haze distribution. We simulate CH_4 photolysis and the haze formation up to 600 km above the surface. Results show that CH_4 photolysis in Pluto's atmosphere in 2015 occurred mostly in the sunlit summer hemisphere with a peak at an altitude of 250 km, though the interplanetary source of Lyman-α flux can induce some photolysis even in the Winter hemisphere. We obtained an extensive haze up to altitudes comparable with the observations, and with non-negligible densities up to 500 km altitude. In both reference simulations, the haze density is not strongly impacted by the meridional circulation. With no South Pole N_2 condensation, the maximum nadir opacity and haze extent is obtained at the North Pole. With South Pole N_2 condensation, the descending parcel of air above the South Pole leads to a latitudinally more homogeneous haze density with a slight density peak at the South Pole. The visible opacities obtained from the computed mass of haze, which is about 2-4$\times10^{-7}$ g cm^{-2} in the summer hemisphere, are similar for most of the simulation cases and in the range of 0.001-0.01, which is consistent with recent observations of Pluto and their interpretation.

Published in: Icarus, 287, 72 (2017 May 1)
For preprints, contact tanguy.bertrand@lmd.jussieu.fr
or on the web at https://arxiv.org/abs/1702.03783

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The Fate of Debris in the Pluto-Charon System

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The Pluto-Charon system has come into sharper focus following the fly by of *New Horizons*. We use N-body simulations to probe the unique dynamical history of this binary dwarf planet system. We follow the evolution of the debris disc that might have formed during the Charon-forming giant impact. First, we note that in-situ formation of the four circumbinary moons is extremely difficult if Charon undergoes eccentric tidal evolution. We track collisions of disc debris with Charon, estimating that hundreds to hundreds of thousands of visible craters might arise from 0.3–5 km radius bodies. *New Horizons* data suggesting a dearth of these small craters may place constraints on the disc properties. While tidal heating will erase some of the cratering history, both tidal and radiogenic heating may also make it possible to differentiate disc debris craters from Kuiper belt object craters. We also track the debris ejected from the Pluto-Charon system into the Solar System; while most of this debris is ultimately lost from the Solar System, a few tens of 10–30 km radius bodies could survive as a Pluto-Charon collisional family. Most are plutinos in the 3:2 resonance with Neptune, while a small number populate nearby resonances. We show that migration of the giant planets early in the Solar System's history would not destroy this collisional family. Finally, we suggest that identification of such a family would likely need to be based on composition as they show minimal clustering in relevant orbital parameters.

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For preprints, contact rsmullen@email.arizona.edu
or on the web at https://arxiv.org/abs/1609.08635
or https://doi.org/10.1093/mnras/stw3386

Observational Signatures of a Massive Distant Planet on the Scattering Disk

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The orbital element distribution of trans-Neptunian objects (TNOs) with large pericenters has been suggested to be influenced by the presence of an undetected, large planet at >200 AU from the Sun. To find additional observables caused by this scenario, we here present the first detailed emplacement simulation in the presence of a massive ninth planet on the distant Kuiper Belt. We perform 4 Gyr N-body simulations with the currently known Solar System planetary architecture, plus a 10 $M_\oplus$ planet with similar orbital parameters to those suggested by Trujillo & Sheppard or Batygin & Brown, and 10^5 test particles in an initial planetesimal disk. We find that including a distant superearth-mass planet produces a substantially different orbital distribution for the scattering and detached TNOs, raising the pericenters and inclinations of moderate semimajor axis ($50 < a < 500$ AU) objects. We test whether this signature is detectable via a simulator with the observational characteristics of four precisely characterized TNO surveys. We find that the qualitatively very distinct Solar System models that include a ninth planet are essentially observationally indistinguishable from an outer Solar System produced solely by the four giant planets. We also find that the mass of the Kuiper Belt's current scattering and detached populations is required to be 3–10 times larger in the presence of an additional planet. We do not find any evidence for clustering of orbital angles in our simulated TNO population. Wide-field, deep surveys targeting inclined high-pericenter objects will be required to distinguish between these different scenarios.

Published in: The Astronomical Journal, 153, 33 (2017 January)

The Structure of the Distant Kuiper Belt in a Nice Model Scenario

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This work explores the orbital distribution of minor bodies in the outer Solar System emplaced as a result of a Nice model migration from the simulations of Brasser & Morbidelli (2013). This planetary migration scatters a planetesimal disk from between 29-34 AU and emplaces a population of objects into the Kuiper belt region. From the 2:1 Neptune resonance and outward, the test particles

analyzed populate the outer resonances with orbital distributions consistent with trans-Neptunian object (TNO) detections in semi-major axis, inclination, and eccentricity, while capture into the closest resonances is too efficient. The relative populations of the simulated scattering objects and resonant objects in the 3:1 and 4:1 resonances are also consistent with observed populations based on debiased TNO surveys, but the 5:1 resonance is severely underpopulated compared to population estimates from survey results. Scattering emplacement results in the expected orbital distribution for the majority of the TNO populations, however the origin of the large observed population in the 5:1 resonance remains unexplained.

Published in: The Astronomical Journal, 153, 3 (2017 March)
Preprints available on the web at `http://adsabs.harvard.edu/abs/2017AJ....153..127P`

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Constraining the Giant Planets' Initial Configuration from Their Evolution: Implications for the Timing of the Planetary Instability

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Recent works on planetary migration show that the orbital structure of the Kuiper belt can be very well reproduced if before the onset of the planetary instability Neptune underwent a long-range planetesimal-driven migration up to ∼28 au. However, considering that all giant planets should have been captured in mean motion resonances among themselves during the gas-disk phase, it is not clear whether such a very specific evolution for Neptune is possible, nor whether the instability could have happened at late times. Here, we first investigate which initial resonant configuration of the giant planets can be compatible with Neptune being extracted from the resonant chain and migrating to ∼28 au before that the planetary instability happened. We address the late instability issue by investigating the conditions where the planets can stay in resonance for about 400 My. Our results indicate that this can happen only in the case where the planetesimal disk is beyond a specific minimum distance δ_{stab} from Neptune. Then, if there is a sufficient amount of dust produced in the planetesimal disk, that drifts inwards, Neptune can enter in a slow dust-driven migration phase for hundreds of Mys until it reaches a critical distance δ_{mig} from the disk. From that point, faster planetesimal-driven migration takes over and Neptune continues migrating outward until the instability happens. We conclude that, although an early instability reproduces more easily the evolution of Neptune required to explain the structure of the Kuiper belt, such evolution is also compatible with a late instability.

To appear in: The Astronomical Journal
For preprints, contact `rogerio.deienno@gmail.com`
or on the web at `https://arxiv.org/abs/1702.02094`

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Initial Mass Function of Planetesimals Formed by the Streaming Instability

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The streaming instability is a mechanism to concentrate solid particles into overdense filaments that undergo gravitational collapse and form planetesimals. However, it remains unclear how the initial mass function of these planetesimals depends on the box dimensions of numerical simulations. To resolve this, we perform simulations of planetesimal formation with the largest box dimensions to date, allowing planetesimals to form simultaneously in multiple filaments that can only emerge within such large simulation boxes. In our simulations, planetesimals with sizes between 80 km and several hundred kilometers form. We find that a power law with a rather shallow exponential cutoff at the high-mass end represents the cumulative birth mass function better than an integrated power law. The steepness of the exponential cutoff is largely independent of box dimensions and resolution, while the exponent of the power law is not constrained at the resolutions we employ. Moreover, we find that the characteristic mass scale of the exponential cutoff correlates with the mass budget in each filament. Together with previous studies of high-resolution simulations with small box domains, our results therefore imply that the cumulative birth mass function of planetesimals is consistent with an exponentially tapered power law with a power-law exponent of approximately -1.6 and a steepness of the exponential cutoff in the range of $0.3 - 0.4$.

Published in: Astronomy & Astrophysics, 597, A69

For preprints, contact urs.schaefer@hs.uni-hamburg.de

or on the web at https://arxiv.org/abs/1611.02285

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Visible Spectra of (474640) 2004 VN_{112}–2013 RF_{98} with OSIRIS at the 10.4 m GTC: Evidence for Binary Dissociation Near Aphelion among the Extreme Trans-Neptunian Objects

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The existence of significant anisotropies in the distributions of the directions of perihelia and orbital poles of the known extreme trans-Neptunian objects (ETNOs) has been used to claim that trans-Plutonian planets may exist. Among the known ETNOs, the pair (474640) 2004 VN_{112}–2013 RF_{98} stands out. Their orbital poles and the directions of their perihelia and their velocities at perihelion/aphelion are separated by a few degrees, but orbital similarity does not necessarily imply common physical origin. In an attempt to unravel their physical nature, visible spectroscopy of both targets was obtained using the OSIRIS camera-spectrograph at the 10.4 m Gran Telescopio Canarias (GTC). From the spectral analysis, we find that 474640–2013 RF_{98} have similar spectral slopes (12 vs. 15 %/0.1 μm), very different from Sedna's but compatible with those of (148209) 2000 CR_{105} and 2012 VP_{113}. These five ETNOs belong to the group of seven linked to the Planet Nine hypothesis. A dynamical pathway consistent with these findings is dissociation of a binary asteroid during a close encounter with a planet and we confirm its plausibility using N-body simulations. We thus conclude

that both the dynamical and spectroscopic properties of 474640–2013 RF_{98} favour a genetic link and their current orbits suggest that the pair was kicked by a perturber near aphelion.

To appear in: Monthly Notices of the Royal Astronomical Society, 467, L66
For preprints, contact jmlc@iac.es
or on the web at https://arxiv.org/abs/1701.02534

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The Bimodal Color Distribution of Small Kuiper Belt Objects

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We conducted a two-night photometric survey of small Kuiper Belt objects (KBOs) near opposition using the wide-field Hyper Suprime-Cam instrument on the 8.2 m Subaru Telescope. The survey covered about 90 deg^2 of sky, with each field imaged in the g and i bands. We detected 356 KBOs, ranging in absolute magnitude from 6.5 to 10.4. Filtering for high-inclination objects within the hot KBO population, we show that the $g - i$ color distribution is strongly bimodal, indicative of two color classes — the red and very red subpopulations. After categorizing objects into the two subpopulations by color, we present the first dedicated analysis of the magnitude distributions of the individual color subpopulations and demonstrate that the two distributions are roughly identical in shape throughout the entire size range covered by our survey. Comparing the color distribution of small hot KBOs with that of Centaurs, we find that they have similar bimodal shapes, thereby providing strong confirmation of previous explanations for the attested bimodality of Centaurs. We also show that the magnitude distributions of the two KBO color subpopulations and the two color subpopulations observed in the Jupiter Trojans are statistically indistinguishable. Finally, we discuss a hypothesis describing the origin of the KBO color bimodality based on our survey results.

To appear in: The Astronomical Journal
For preprints, contact iwong@caltech.edu
or on the web at http://arxiv.org/abs/1702.02615

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Assessment of Different Formation Scenarios for the Ring System of (10199) Chariklo

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The discovery that the centaur (10199) Chariklo possesses a ring system opens questions about its origin. To asses the plausibility of different scenarios for the origin of the observed ring system. We first consider the possibility that the material of the ring is originated by the disruption of a satellite reaching a critical distance from the centaur. We discuss the conditions for the putative satellite to approach the centaur as a consequence of tidal interaction. A 3-body encounter is also considered as a transport mechanism. In addition, we study the case in which the ring is formed

by the ejecta of a cratering collision on the centaur and we constraint the collision parameters and the size of the resulting crater of the event. Finally, we consider that the ring material originates from a catastrophic collision between a background object and a satellite located at a distance corresponding to the the current location of the ring. We compute the typical timescales for these scenarios. We estimate that –in order to be tidally disrupted– a satellite should have been larger than approximately 6.5 km at the location of the rings. However the tidal interaction is rather weak for objects of the size of outer Solar System bodies at the rings location, therefore we considered other more effective mechanisms by which a satellite approaches the centaur. Collisonal scenarios are both physically plausible for the formation, but semi-analytical estimations indicate that the probability of the corresponding collisions is low under current conditions.

To appear in: Astronomy & Astrophysics
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Physical Properties of Centaur (54598) Bienor from Photometry

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We present time series photometry of Bienor in four observation campaigns from 2013 to 2016 and compare them with previous observations in the literature dating back to 2000. The results show a remarkable decline in the amplitude of the rotational light curve and in the absolute magnitude. This suggests that the angle between the rotation axis and the line of sight has changed noticeably during the last 16 years as Bienor orbits the Sun. From the light curve amplitude data we are able to determine the orientation of the rotation axis of Bienor ($\beta_p = 50 \pm 3°$, $\lambda_p = 35 \pm 8°$). We are also able to constrain the b/a axial ratio of a triaxial Jacobi ellipsoidal body (with semi-axis $a > b > c$). The best fit is for $b/a = 0.45 \pm 0.05$, which corresponds to a density value of 594^{+47}_{-35} kg m^{-3} under the usual assumption of hydrostatic equilibrium and given that Bienor's rotational period is 9.17 h. However, the absolute magnitude of Bienor at several epochs is not well reproduced. We tested several explanations such as relaxing the hydrostatic equilibrium constraint, a large North-South asymmetry in the surface albedo of Bienor or even a ring system. When a ring system of similar characteristics to those of Chariklo and Chiron is included, we can fit both the light curve amplitude and absolute magnitude. In this case the derived axial ratio is modified to $b/a = 0.37 \pm 0.10$. The implied density is 678^{+209}_{-100} kg m^{-3}. Also the existence of a ring is consistent with the spectroscopic detection of water ice on Bienor. Nevertheless the other explanations cannot be discarded.

To appear in: Monthly Notices of the Royal Astronomical Society
For preprints, contact estela@iaa.es
or on the web at https://arxiv.org/abs/1612.02626

PAPERS RECENTLY SUBMITTED TO JOURNALS

Obliquity Evolution of the Minor Satellites of Pluto and Charon

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New Horizons mission observations show that the small satellites Styx, Nix, Kerberos and Hydra, of the Pluto-Charon system, have not tidally spun-down to near synchronous spin states and have high obliquities with respect to their orbit about the Pluto-Charon binary (Weaver et al. 2016). We use a damped mass-spring model within an N-body simulation to study spin and obliquity evolution for single spinning non-round bodies in circumbinary orbit. Simulations with tidal dissipation alone do not show strong obliquity variations from tidally induced spin-orbit resonance crossing and this we attribute to the high satellite spin rates and low orbital eccentricities. However, a tidally evolving Styx exhibits intermittent obliquity variations and episodes of tumbling. During a previous epoch where Charon migrated away from Pluto, the minor satellites could have been trapped in orbital mean motion inclination resonances. An outward migrating Charon induces large variations in Nix and Styx's obliquities. The cause is a commensurability between the mean motion resonance frequency and the spin precession rate of the spinning body. As the minor satellites are near mean motion resonances, this mechanism could have lifted the obliquities of all four minor satellites. If so the high obliquities of Pluto and Charon's minor satellites imply that this system experienced orbital migration and all satellites were at one time captured into mean motion resonances.

Submitted to: Icarus

For preprints, contact `alice.quillen@rochester.edu`

or on the web at `https://arxiv.org/abs/1701.05594`

OTHER PAPERS OF INTEREST

Asteroid 2014 YX_{49}: A Large Transient Trojan of Uranus

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In the outer Solar system, primordial Trojan asteroids may have remained dynamically stable for billions of years. Several thousands of them accompany Jupiter in its journey around the Sun and a similarly large population may be hosted by Neptune. In addition, recently captured or transient Jovian and Neptunian Trojans are not uncommon. In contrast, no Trojans of Saturn have been found yet and just one Uranian Trojan is known, 2011 QF_{99}. Here, we discuss the identification of a second Trojan of Uranus: 2014 YX_{49}. Like 2011 QF_{99}, 2014 YX_{49} is a transient L_4 Trojan although it orbits at higher inclination (25.55° vs. 10.83°), is larger (absolute magnitude of 8.5 vs. 9.7) and its libration period is slightly shorter (5.1 vs. 5.9 kyr); contrary to 2011 QF_{99}, its discovery was not the result of a targeted survey. It is less stable than 2011 QF_{99}; our extensive N-body simulations show that 2014 YX_{49} may have been following a tadpole trajectory ahead of Uranus for about 60 kyr and it can continue doing so for another 80 kyr. Our analysis suggests that it may remain as co-orbital for nearly 1 Myr. As in the case of 2011 QF_{99}, the long-term stability of 2014 YX_{49} is controlled by Jupiter and Neptune, but it is currently trapped in the 7:20 mean motion resonance with Saturn. Consistently, the dynamical mechanism leading to the capture into and the ejection from the Trojan state involves ephemeral multibody mean motion resonances.

To appear in: Monthly Notices of the Royal Astronomical Society, 467, 1561
For preprints, contact `nbplanet@ucm.es`
or on the web at `https://arxiv.org/abs/1701.05541`

CONFERENCE INFORMATION

Planet Formation and Evolution 2017

25-27 September 2017
Jena, Germany

The German community of researchers working in the fields of planet formation, exoplanets and planetary systems, protoplanetary and debris disks, astrobiology, and planetary research in general has organized the "Planet Formation and Evolution" workshops since 2001. The meetings in the series are typically held every 1.5 years at different German universities that host research groups actively working on these topics. This workshop is the 11th in the series. PFE meetings are usually attended by scientists from all parts of Germany with a broad international participation. Following the spirit of the previous very stimulating meetings, the goal of this workshop is to provide a common platform for scientists working in the fields listed above. Most importantly, this workshop is aimed at stimulating and intensifying the dialogue between researchers using various approaches - observations, theory, and laboratory studies. In particular, students and postdocs are encouraged to present their results and to use the opportunity to learn more about the main questions and most recent results in adjacent fields.

TOPICS:
- Dust, Pebbles, Planetesimals
- Protoplanetary and Transitional Disks
- Exoplanet Observations
- Exoplanet Interiors, Atmospheres, and Habitability
- Planetary System Dynamics
- Debris Disks
- Solar System

CONFIRMED INVITED SPEAKERS:
Anthony Boccaletti (Paris)
Carsten Guettler (Goettingen)
Grant Kennedy (Cambridge)
Zoe Leinhardt (Bristol)
Nadine Nettelmann (Rostock)
Ilaria Pascucci (Arizona)
Sean Raymond (Bordeaux)
Ignas Snellen (Leiden)

REGISTRATION AND ABSTRACT SUBMISSION:
Registration and abstract submission through the workshop website are now open. Make sure to register early, as the number of participants is limited to 150. Final deadline is 1st June.

WEBSITE:
`http://www.astro.uni-jena.de/ pfe2017`

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.

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Moving ... ??

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