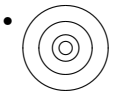
*Issue No. 97* *February 2015*

# *DISTANT EKOs*



*The Kuiper Belt Electronic Newsletter*

*Edited by: Joel Wm. Parker*

ekonews@boulder.swri.edu www.boulder.swri.edu/ekonews

## CONTENTS

# NEWS & ANNOUNCEMENTS

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

2011 UA413, 2011 UZ412, 2013 FH28, 2013 FO28, 2013 RD98, 2014 SZ348, 2014 TT85, 2014 TU85, 2014 UF224

and 11 new Centaur/SDO discoveries:

2012 UW177, 2013 FG28, 2013 FJ28, 2013 RF98, 2013 RG98, 2013 SE99, 2014 FC69, 2014 WT69, 2015 BF515, 2015 BQ311, 2015 CM3

and 3 new Neptune Trojan discoveries:

2012 UV177, 2014 QO441, 2014 QP441

Reclassified objects:

2014 FW (SDO → Centaur)
2014 UH192 (TNO → SDO)

Objects recently assigned numbers:

1999 RU215 = (415720)
2003 UZ117 = (416400)
2009 MS9 = (418993)
2012 BX85 = (420356)
2002 DH5 = (427507)
2003 QB92 = (427581)
2003 SR422 = (427614)

Current number of TNOs: 1354 (including Pluto)
Current number of Centaurs/SDOs: 435
Current number of Neptune Trojans: 12

Out of a total of 1801 objects:

663 have measurements from only one opposition
635 of those have had no measurements for more than a year
328 of those have arcs shorter than 10 days

(for more details, see: `http://www.boulder.swri.edu/ekonews/objects/recov_stats.jpg`)

# PAPERS ACCEPTED TO JOURNALS

## Reanalyzing the Visible Colors of Centaurs and KBOs: What is There and What we Might be Missing

**N. Peixinho[1], A. Delsanti[2], and A. Doressoundiram[3]**

[1] Unidad de Astronomía, Fac. de Ciencias Básicas, Universidad de Antofagasta, Avda. U. de Antofagasta 02800, Antofagasta, Chile

[2] Aix Marseille Université, CNRS, LAM (Laboratoire d'Astrophysique de Marseille) UMR 7326, 13388 Marseille, France

[3] Observatoire de Paris, Site de Meudon, 5 place Jules Janssen, 92190 Meudon, France

Since the discovery of the Kuiper Belt, broadband surface colors were thoroughly studied as a first approximation to the object reflectivity spectra. Visible colors ($BVRI$) have proven to be a reasonable proxy for real spectra, which are rather linear in this range. In contrast, near-IR colors ($JHK$ bands) could be misleading when absorption features of ices are present in the spectra. Although the physical and chemical information provided by colors are rather limited, broadband photometry remains the best tool for establishing the bulk surface properties of KBOs and Centaurs.

In this work, we explore for the first time general, recurrent effects in the study of visible colors that could affect the interpretation of the scientific results: i) how a correlation could be missed or weakened as a result of the data error bars, ii) the "risk" of missing an existing trend because of low sampling, and the possibility of making quantified predictions on the sample size needed to detect a trend at a given significance level — assuming the sample is unbiased, iii) the use of partial correlations to distinguish the mutual effect of two or more (physical) parameters, and iv) the sensitivity of the "reddening line" tool to the central wavelength of the filters used.

To illustrate and apply these new tools, we have compiled the visible colors and orbital parameters of about 370 objects available in the literature — assumed, by default, as unbiased samples — and carried out a traditional analysis per dynamical family.

Our results show in particular how a) data error bars impose a limit on the detectable correlations regardless of sample size and that therefore, once that limit is achieved, it is important to diminish the error bars, but it is pointless to enlarge the sampling with the same or larger errors; b) almost all dynamical families still require larger samplings to ensure the detection of correlations stronger than $\pm 0.5$, that is, correlations that may explain $\sim 25\%$ or more of the color variability; c) the correlation strength between $(V-R)$ vs. $(R-I)$ is systematically lower than the one between $(B-V)$ vs. $(V-R)$ and is not related with error-bar differences between these colors; d) it is statistically equivalent to use any of the different flavors of orbital excitation or collisional velocity parameters regarding the famous color-inclination correlation among classical KBOs — which no longer appears to be a strong correlation — whereas the inclination and Tisserand parameter relative to Neptune cannot be separated from one another; and e) classical KBOs are the only dynamical family that shows neither $(B-V)$ vs. $(V-R)$ nor $(V-R)$ vs. $(R-I)$ correlations. It therefore is the family with the most unpredictable visible surface reflectivities.

**To appear in: Astronomy & Astrophysics**

*For preprints, contact* `nuno.peixinho@uantof.cl`

*or on the web at* `http://arxiv.org/abs/1502.04145`

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# The Hubble Wide Field Camera 3 Test of Surfaces in the Outer Solar System: Spectral Variation on Kuiper Belt Objects

**Wesley C. Fraser[1,2], Michael E. Brown[2], and Florian Glass[3,4]**

[1] Herzberg Institute of Astrophysics, 5071 W. Saanich Rd. Victoria, BC V9E 2E7, Canada

[2] California Institute of Technology, 1200 E. California Blvd. Pasadena, CA 91101, USA

[3] Observatoire de Genve, Universit de Genve, 51 chemin des Maillettes, CH-1290 Sauverny, Switzerland

[4] Dept. of Physics and Astronomy, University of Victoria, Victoria, BC V8W 3P6, Canada

Here we present additional photometry of targets observed as part of the Hubble Wide Field Camera 3 Test of Surfaces in the Outer Solar System. 12 targets were re-observed with the Wide Field Camera 3 in optical and NIR wavebands designed to compliment those used during the first visit. Additionally, all observations originally presented by Fraser and Brown (2012) were reanalyzed through the same updated photometry pipeline. A reanalysis of the optical and NIR colour distribution reveals a bifurcated optical colour distribution and only two identifiable spectral classes, each of which occupies a broad range of colours and have correlated optical and NIR colours, in agreement with our previous findings. We report the detection of significant spectral variations on 5 targets which cannot be attributed to photometry errors, cosmic rays, point spread function or sensitivity variations, or other image artifacts capable of explaining the magnitude of the variation. The spectrally variable objects are found to have a broad range of dynamical classes, absolute magnitudes, exhibit a broad range of apparent magnitude variations, and are found in both compositional classes. The spectrally variable objects with sufficiently accurate colours for spectral classification maintain their membership, belonging to the same class at both epochs. 2005 TV189 exhibits a sufficiently broad difference in colour at the two epochs that span the full range of colours of the neutral class. This strongly argues that the neutral class is one single class with a broad range of colours, rather than the combination of multiple overlapping classes.

**To appear in: The Astrophysical Journal**

*Preprints available on the web at* `http://arxiv.org/abs/1502.06612v1`

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# Limits on Pluto's Ring System from the June 12 2006 Stellar Occultation and Implications for the New Horizons Impact Hazard

**H.B. Throop[1,2], R.G. French[3], K. Shoemaker[4], C.B. Olkin [5], T.R. Ruhland[5], and L.A. Young[5]**

[1] Planetary Science Institute, 1700 E Fort Lowell Rd. #106, Tucson, AZ 85719, USA

[2] University of Pretoria, Hatfield, Pretoria, South Africa

[3] Wellesley College, Wellesley, MA, 02481, USA

[4] Shoemaker Labs, 2225 Hwy A1A, #311, Indian Harbour Beach, FL 32937, USA

[5] Southwest Research Institute, 1050 Walnut St, Boulder, CO 80302, USA

The Pluto system passed in front of a 15th magnitude star on 12 June 2006. We observed this occultation from the 3.9 m Anglo-Australian Telescope (AAT), and took photometric observations every 100 ms for 3 h. Our three-hour baseline of data provides among the longest and highest-quality occultation dataset of the Pluto system ever taken. Results on Pluto's atmospheric structure from these data have been previously reported (Young, E.F. [2008]. Astron. J. 136, 1757-1769). Here we report on limits for rings, ring arcs, and small satellites within the system. We find a $3\sigma$ upper limit on the normal optical depth of $\tau < 0.07$ for narrow rings of width 2.4 km, and $\tau < 5 \times 10^{-3}$ for rings of width 1500 km. We also detect no discrete objects of radius 220 m or larger along the occultation path. Motivated by the upcoming flyby of New Horizons through the Pluto system, we estimate the

dust impact hazard to the spacecraft based on our optical depth limits and those derived from imaging with the Hubble Space Telescope.

**Published in: Icarus, 246, 345 (2015 January 15)**
*For preprints, contact* henry.throop@gmail.com

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## Possible Ring Material Around Centaur (2060) Chiron

**J.L. Ortiz[1], R. Duffard[1], N. Pinilla-Alonso[2], A. Alvarez-Candal[3], P. Santos-Sanz[1], N. Morales[1], E. Fernández-Valenzuela[1], J. Licandro[4,5], A. Campo Bagatin[6], and A. Thirouin[7,1]**

[1] Instituto de Astrofísica de Andalucía, CSIC, Apt 3004, 18080, Granada, Spain

[2] Department of Earth and Planetary Sciences, University of Tennessee, Knoxville, TN, 37996, USA

[3] Observatório Nacional, Rua General José Cristino 77, Rio de Janeiro 20921-400, Brazil

[4] Instituto de Astrofísica de Canarias, c/Vía Lactea s/n, 38200 La Laguna, Tenerife, Spain

[5] Departamento de Astrofísica, Universidad de La Laguna (ULL), 38205 La Laguna, Tenerife, Spain

[6] Departamento de Física, Ingeniería de Sistemas y Teoría de la Señal, Universidad de Alicante, Carretera San Vicente del Raspeig S/N, 03690 San Vicente del Raspeig, Alicante, Spain

[7] Lowell Observatory, 1400 W Mars Hill Rd, 86001, Flagstaff, Arizona, USA

We propose that several short duration events observed in past stellar occultations by Chiron were produced by rings material. Some similarities between these events and the characteristics of Chariklo's rings could indicate common mechanisms around centaurs. From a reanalysis of the stellar occultation data in the literature we determined two possible orientations of the pole of Chiron's rings, with ecliptic coordinates $\lambda = (352 \pm 10)^\circ$, $\beta = (37 \pm 10)^\circ$ or $\lambda = (144 \pm 10)^\circ$, $\beta = (24 \pm 10)^\circ$. The mean radius of the rings is $(324 \pm 10)$ km. One can use the rotational lightcurve amplitude of Chiron at different epochs to distinguish between the two solutions for the pole. The two solutions imply a lower lightcurve amplitude in 2013 than in 1988, when the rotational lightcurve was first determined. We derived Chiron's rotational lightcurve in 2013 from observations at the 1.23 m CAHA telescope and indeed its amplitude is smaller than in 1988. We also present a rotational lightcurve in 2000 from images taken at CASLEO 2.15 m telescope that is consistent with our predictions. Out of the two poles the $\lambda = (144 \pm 10)^\circ$, $\beta = (24 \pm 10)^\circ$ solution provides a better match to a compilation of rotational lightcurve amplitudes from the literature and those presented here. We also show that using this preferred pole orientation, Chiron's long term brightness variations are compatible with a simple model that incorporates the changing brightness of the rings as the tilt angle with respect to the Earth changes with time. Also, the variability of the water ice band in Chiron's spectra in the literature can be explained to a large degree by an icy ring system whose tilt angle changes with time and whose composition includes water ice, analogously to the case of Chariklo. We present several possible formation scenarios for the rings from qualitative points of view and speculate on the reasons why rings might be common in centaurs. We also speculate on whether the known bimodal color distribution of the centaurs could be due to centaurs with rings and centaurs without rings.

**To appear in: Astronomy & Astrophysics**
*For preprints, contact* ortiz@iaa.es
*or on the web at* http://arxiv.org/abs/1501.05911

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# Absorption Coefficients of the Methane-Nitrogen Binary Ice System: Implications for Pluto

**S. Protopapa[1], W.M. Grundy[2], S.C. Tegler[3], and J.M. Bergonio[4]**

[1] University of Maryland, Department of Astronomy, College Park, MD, USA

[2] Lowell Observatory, Flagstaff, AZ, USA

[3] Department of Physics and Astronomy, Northern Arizona University, Flagstaff, AZ, USA

[4] Department of Physics and Astronomy, University of Hawai'i, Manoa Honolulu, HI, USA

The methane-nitrogen phase diagram of Prokhvatilov and Yantsevich (1983) indicates that at temperatures relevant to the surfaces of icy dwarf planets like Pluto, two phases contribute to the methane absorptions: nitrogen saturated with methane $\overline{\mathbf{N_2}}$:$CH_4$ and methane saturated with nitrogen $\overline{\mathbf{CH_4}}$:$N_2$. No optical constants are available so far for the latter component limiting construction of a proper model, in compliance with thermodynamic equilibrium considerations. New optical constants for solid solutions of methane diluted in nitrogen ($N_2$:$CH_4$) and nitrogen diluted in methane ($CH_4$:$N_2$) are presented at temperatures between 40 and 90 K, in the wavelength range 1.1–2.7 $\mu$m at different mixing ratios. These optical constants are derived from transmission measurements of crystals grown from the liquid phase in closed cells. A systematic study of the changes of methane and nitrogen solid mixtures spectral behavior with mixing ratio and temperature is presented.

**To appear in: Icarus**

*For preprints, contact* protopapa@astro.umd.edu

*or on the web at* http://arxiv.org/abs/1503.00703

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# Irradiation Products On Dwarf Planet Makemake

**M.E. Brown[1], E.L. Schaller[1], and G.A. Blake[1]**

[1] Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA 91125, USA

The dark, reddish tinged surfaces of icy bodies in the outer solar system are usually attributed to the long term irradiation of simple hydrocarbons leading to the breaking of C-H bonds, loss of hydrogen, and the production of long carbon chains. While the simple hydrocarbon methane is stable and detected on the most massive bodies in the Kuiper Belt, evidence of active irradiation chemistry is scant except for the presence of ethane on methane-rich Makemake and the possible detections of ethane on more methane-poor Pluto and Quaoar. We have obtained deep high signal-to-noise spectra of Makemake from 1.4 to 2.5 $\mu$m in an attempt to trace the radiation chemistry in the outer solar system beyond the initial ethane formation. We present the first astrophysical detection of solid ethylene and evidence for acetylene and high-mass alkanes — all expected products of the continued irradiation of methane, and use these species to map the chemical pathway from methane to long-chain hydrocarbons.

**Published in: The Astronomical Journal 149, 105 (2015 March)**

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# Does the Presence of Planets Affect the Frequency and Properties Of Extrasolar Kuiper Belts? Results from the Herschel DEBRIS and DUNES Surveys

**A. Moro-Martín[1,2], J.P. Marshall[3,4,5], G. Kennedy[6], B. Sibthorpe[7], B.C. Matthews[8,9], C. Eiroa[5], M.C. Wyatt[6], J.-F. Lestrade[10], J. Maldonado[11], D. Rodriguez[12], J.S. Greaves[13], B. Montesinos[14], A. Mora[15], M. Booth[16], G. Duchêne[17,18,19], D. Wilner[20], and J. Horner[21,4]**

[1] Space Telescope Science Institute, 3700 San Martin Dr., Baltimore, MD 21218, USA.

[2] Center for Astrophysical Sciences, Johns Hopkins University, Baltimore MD 21218, USA.

[3] School of Physics, University of New South Wales, Sydney, NSW 2052, Australia.

[4] Australian Centre for Astrobiology, University of New South Wales, Sydney, NSW 2052, Australia

[5] Depto. Física Teórica, Universidad Autónoma de Madrid, Cantoblanco, 28049, Madrid, Spain.

[6] Institute of Astronomy (IoA), University of Cambridge, Madingley Rd., Cambridge, CB3 0HA, UK.

[7] SRON Netherlands Institute for Space Research, NL-9747 AD, Groningen, The Netherlands.

[8] Herzberg Astronomy & Astrophysics, National Research Council of Canada, 5071 West Saanich Rd, Victoria, BC V9E 2E7, Canada.

[9] University of Victoria, Finnerty Road, Victoria, BC, V8W 3P6, Canada.

[10] Observatoire de Paris, CNRS, 61 Av. de l'Observatoire, F-75014, Paris, France.

[11] INAF - Osservatorio Astronomico di Palermo, Piazza Parlamento 1, 90134 Palermo, Italy.

[12] Universidad de Chile, Camino el Observatorio 1515, Las Condes, Santiago, Chile.

[13] SUPA, School of Physics and Astronomy, University of St. Andrews, North Haugh, St. Andrews KY16 9SS, UK.

[14] Centro de Astrobiología (CAB, CSIC-INTA), ESAC Campus, P.O. Box 78, 28691 Villanueva de la Cañada, Madrid, Spain.

[15] ESA-ESAC Gaia SOC. P.O. Box 78 E-28691 Villanueva de la Cañada, Madrid, Spain.

[16] Instituto de Astrofísica, Pontíficia Universidad Católica de Chile, Vicuña Mackenna 4860, 7820436 Macul, Santiago, Chile.

[17] Astronomy Department, University of California, Berkeley, CA 94720, USA.

[18] Univ. Grenoble Alpes, IPAG, F-38000 Grenoble, France.

[19] CNRS, IPAG, F-38000 Grenoble, France.

[20] Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA.

[21] Computational Engineering and Science Research Centre, University of Southern Queensland, West Street, Toowoomba Qld 4350, Australia.

The study of the planet-debris disk connection can shed light on the formation and evolution of planetary systems, and may help "predict" the presence of planets around stars with certain disk characteristics. In preliminary analyses of subsamples of the *Herschel DEBRIS* and *DUNES* surveys, Wyatt et al. (2012) and Marshall et al. (2014) identified a tentative correlation between debris and the presence of low-mass planets. Here we use the cleanest possible sample out these *Herschel* surveys to assess the presence of such a correlation, discarding stars without known ages, with ages <1 Gyr and with binary companions <100 AU, to rule out possible correlations due to effects other than planet presence. In our resulting subsample of 204 FGK stars, we do not find evidence that debris disks are more common or more dusty around stars harboring high-mass or low-mass planets compared to a control sample without identified planets. There is no evidence either that the characteristic dust temperature of the debris disks around planet-bearing stars is any different from that in debris disks without identified planets, nor that debris disks are more or less common (or more or less dusty) around stars harboring multiple planets compared to single-planet systems. Diverse dynamical histories may account for the lack of correlations. The data show a correlation between the presence of high-mass planets and stellar metallicity, but no correlation between the presence of low-mass planets or debris and stellar metallicity. Comparing the observed cumulative distribution of fractional luminosity to

those expected from a Gaussian distribution in logarithmic scale, we find that a distribution centered on the Solar system's value fits well the data, while one centered at 10 times this value can be rejected. This is of interest in the context of future terrestrial planet detection and characterization because it indicates that there are good prospects for finding a large number of debris disk systems (i.e. with evidence of harboring planetesimals, the building blocks of planets) with exozodiacal emission low enough to be appropriate targets for an *ATLAST*-type mission to search for biosignatures.

**To appear in: The Astrophysical Journal**
*For preprints, contact* amaya@stsci.edu *or on the web at* http://arxiv.org/abs/1501.03813

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## A Serendipitous All Sky Survey for Bright Objects in the Outer Solar System

**M.E. Brown[1], M.T. Bannister[2,3], B.P. Schmidt[3], A.J. Drake[1], S.G. Djorgovski[1], M.J. Graham[1], A. Mahabal[1], C. Donalek[1], S. Larson[4], E. Christensen[4], E. Beshore[4], and R. McNaught[3]**

[1] California Institute of Technology, Pasadena, CA, USA

[2] University of Victoria, Victoria, BC, Canada

[3] The Australian National University, Canberra, Australia

[4] The University of Arizona, Lunar and Planetary Laboratory, Tucson, AZ, USA

We use seven year's worth of observations from the Catalina Sky Survey and the Siding Spring Survey covering most of the northern and southern hemisphere at galactic latitudes higher than 20 degrees to search for serendipitously imaged moving objects in the outer solar system. These slowly moving objects would appear as stationary transients in these fast cadence asteroids surveys, so we develop methods to discover objects in the outer solar system using individual observations spaced by months, rather than spaced by hours, as is typically done. While we independently discover 8 known bright objects in the outer solar system, the faintest having $V = 19.8 \pm 0.1$, no new objects are discovered. We find that the survey is nearly 100% efficient at detecting objects beyond 25 AU for $V \lesssim 19.1$ ($V \lesssim 18.6$ in the southern hemisphere) and that the probability that there is one or more remaining outer solar system object of this brightness left to be discovered in the unsurveyed regions of the galactic plane is approximately 32%

**Published in: The Astronomical Journal, 149, 69 (2015 February)**
*Preprints available on the web at* http://arxiv.org/abs/1501.00941v1

# PAPERS RECENTLY SUBMITTED TO JOURNALS

## An Atmospheric General Circulation Model for Pluto with Predictions for New Horizons

**A.M. Zalucha[1]**

SETI Institute, 189 Bernardo Ave, Mountain View, CA, 94043, USA

Submitted to: The Astrophysical Journal
*For preprints, contact* azaucha@seti.org
*or on the web at* http://arxiv.org/abs/1501.02848

# CONFERENCE INFORMATION

## Highlights in the Exploration on Small Worlds

**Focus meeting FM9, IAU General Assembly**
**Honolulu, Aug 11-13, 2015**

http://astronomy2015.org/focus_meeting_9

This focus meeting will highlight results obtained from various ongoing space missions to small Solar System bodies (Rosetta, Dawn, New Horizons, Cassini-Huygens, HERSCHEL, Gaia, ...), as well as recent achievements obtained from other space facilities, including past space missions, ground-based telescopes, and geochemical analyses. The meeting aims at discussing aspects of the Solar System formation and evolution,through studies on the complex and rich evolution of the diverse small bodies of the Solar system. The meeting will also address the cosmo-chemistry and physical properties across the continuum of small bodies (asteroids, comets, planetary satellites, dwarf planets, main-belt comets), with the objective to better understand their interrelations in the context of planetary formation.

Sessions

Recent results and news will be presented by key speakers and additional contributions (oral and posters) distributed over the following sessions:

- highlights from space missions
- chemical and physical properties of small worlds
- hotspots of the triennium
- the asteroid-comet continuum
- the ISM/Solar System connection
- future missions will be covered by the poster session

Some confirmed invited speakers

Claudia Alexander (USA), C. Russel (USA), A. Mainzer (USA), T. Müller (DE), N. Peixinho (CI), N. Biver (FR), K. Stephan (DE), N. Pinilla-Alonso (USA), Z. Martins (UK), M. Cordiner (USA), K. Battams (USA), J. Borovička (CZ), A. Morbidelli (FR), H. Hsieh (TW), B. Carry (FR), C. Engrand (FR), K. Oberg (USA), K. Altwegg (CH), E. Wirstroem (SW), J. Castillo-Rogez (USA)

For more information: http://astronomy2015.org/focus_meeting_9

There is room for contributed talks as well as posters. Contributors are invited to submit abstract at http://astronomy2015.org/abstracts (deadline is March 18)

Grant applications are encouraged, in particular for young participants (PhD. and post-docs), before April 1st, 2015.

http://www.iau.org/science/grants_prizes/iau_grants/ga_events/ga_application_form/

The Organising Committee
D. Bockelé-Morvan, Paola Casetti, D. Hestroffer

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 accepted papers
⋆ Titles of submitted (but not yet accepted) papers and conference articles
⋆ 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`