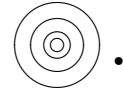


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DISTANT EKOs
The Kuiper Belt Electronic Newsletter



Edited by: Joel Wm. Parker

`ekonews@boulder.swri.edu`

`www.boulder.swri.edu/ekonews`

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NEWS & ANNOUNCEMENTS

There were *no* new TNO/Centaur/SDO discoveries announced since the previous issue of *Distant EKO*s.

Objects recently assigned numbers:

2003 AZ84 = (208996)

Current number of TNOs: 1093 (including Pluto)

Current number of Centaurs/SDOs: 242

Current number of Neptune Trojans: 6

Out of a total of 1341 objects:

556 have measurements from only one opposition

543 of those have had no measurements for more than a year

288 of those have arcs shorter than 10 days

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

Pluto's Lower Atmosphere Structure and Methane Abundance from High-Resolution Spectroscopy and Stellar Occultations

E. Lellouch¹, B. Sicardy^{1,2}, C. de Bergh¹, H.U. Käuff³, S. Kassi⁴, and A. Campargue⁴

¹LESIA, Observatoire de Paris, 92195 Meudon, France

²Université Pierre et Marie Curie, 75005 Paris, France

³European Space Observatory, D-85748 Garching bei München, Germany

⁴Laboratoire de Spectrométrie Physique, 38402 St-Martin d'Hères Cedex, France

Context. Pluto possesses a thin atmosphere, primarily composed of nitrogen, in which the detection of methane has been reported.

Aims. The goal is to constrain essential but so far unknown parameters of Pluto's atmosphere such as the surface pressure, lower atmosphere thermal structure, and methane mixing ratio.

Methods. We use high-resolution spectroscopic observations of gaseous methane, and a novel analysis of occultation light-curves.

Results. We show that (i) Pluto's surface pressure is currently in the 6.5–24 μ bar range (ii) the methane mixing ratio is 0.5 ± 0.1 %, adequate to explain Pluto's inverted thermal structure and ~ 100 K upper atmosphere temperature (iii) if Pluto has a troposphere, its depth is at most 17 km, i.e. less than one pressure scale height, and methane is supersaturated in most of it. The atmospheric and bulk surface abundance of methane are strikingly similar, a possible consequence of the presence of a CH₄-rich top surface layer.

To appear in: *Astronomy and Astrophysics Letters*, 495, L17 (2009 March)

For preprints, contact emmanuel.lellouch@obspm.fr

or on the web at <http://fr.arxiv.org/abs/0901.4882>

See also <http://www.eso.org/public/outreach/press-rel/pr-2009/pr-08-09.html>

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Stratification of Methane Ice on Eris' Surface

**F. Merlin¹, A. Alvarez-Candal¹, A. Delsanti¹, S. Fornasier¹, M.A. Barucci¹,
F.E. DeMeo¹, C. de Bergh¹, A. Doressoundiram¹, E. Quirico², and B. Schmitt²**

¹ Observatoire de Paris-Laboratoire d' Études Spatiales et d' Instrumentation en Astrophysique. 5, Place Jules Janssen 92195 Meudon Cedex, France

² Laboratoire de Planetologie de Grenoble, Bâtiment D de Physique, Domaine Universitaire B.P. 53 38041 Grenoble Cedex 9, France

We present new photometric and spectroscopic data of the dwarf planet Eris obtained on 2006 October and 2007 December with the Very Large Telescopes at ESO, Chile. We use three different instruments (FORs, ISAAC, and SINFONI) covering the 0.4–2.4 μ m wavelength range. We show that N₂ ice is not directly detected, but the wavelength positions of the bands of CH₄ measured on the complete wavelength range seem to indicate that, as already suggested by Brown et al. and Licandro et al., a part of CH₄ ice is diluted in N₂. Spectral modeling using the Hapke theory reveals that a segregation of small and large particles of methane ice could exist on the surface. The presence of water ice and nitrogen is not completely excluded even if the respective absorption bands

of these ices have not been directly detected. We present in this paper our methods to determine the wavelength shifts of the methane bands and the chemical composition from spectral modeling.

Published in: The Astronomical Journal, 137, 315 (2009 January)

For preprints, contact frederic.merlin@obspm.fr

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The Active Centaurs

David Jewitt¹

¹ Institute for Astronomy, University of Hawaii, 2680 Woodlawn Drive, Honolulu, HI 96822, USA

The Centaurs are recent escapees from the Kuiper belt that are destined either to meet fiery oblivion in the hot inner regions of the Solar system or to be ejected to the interstellar medium by gravitational scattering from the giant planets. Dynamically evolved Centaurs, when captured by Jupiter and close enough to the Sun for near-surface water ice to sublimate, are conventionally labeled as “short-period” (specifically, Jupiter-family) comets. Remarkably, some Centaurs show comet-like activity even when far beyond the orbit of Jupiter, suggesting mass-loss driven by a process other than the sublimation of water ice. We observed a sample of 23 Centaurs and found nine to be active, with mass-loss rates measured from several kg s^{-1} to several tonnes s^{-1} . Considered as a group, we find that the “active Centaurs” in our sample have perihelia smaller than the inactive Centaurs (median 5.9 AU vs. 8.7 AU), and smaller than the median perihelion distance computed for all known Centaurs (12.4 AU). This suggests that their activity is thermally driven. We consider several possibilities for the origin of the mass-loss from the active Centaurs. Most are too cold for activity at the observed levels to originate via the sublimation of crystalline water ice. Solid carbon monoxide and carbon dioxide have the opposite problem: they are so volatile that they should drive activity in Centaurs at much larger distances than observed. We consider the possibility that activity in the Centaurs is triggered by the conversion of amorphous ice into the crystalline form accompanied by the release of trapped gases, including carbon monoxide. By imposing the condition that crystallization should occur when the crystallization time is shorter than the orbital period we find a qualitative match to the perihelion distribution of the active Centaurs and conclude that the data are consistent with the hypothesis that the Centaurs contain amorphous ice.

To appear in: The Astronomical Journal

Preprints available on the web at

<http://www.ifa.hawaii.edu/faculty/jewitt/papers/2009/J09.pdf>

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Jupiter - Friend or Foe? II: The Centaurs

J. Horner¹ and B.W. Jones¹

¹ Astronomy Group, Physics & Astronomy, The Open University, Milton Keynes, MK7 6AA, UK

It has long been assumed that the planet Jupiter acts as a giant shield, significantly lowering the impact rate of minor bodies upon the Earth, and thus enabling the development and evolution of life in a collisional environment which is not overly hostile. In other words, it is thought that thanks to Jupiter, mass extinctions have been sufficiently infrequent that the biosphere has been able to diversify and prosper. However, in the past, little work has been carried out to examine the validity of this idea. In the second of a series of papers, we examine the degree to which the impact

risk resulting from objects on Centaur-like orbits is affected by the presence of a giant planet, in an attempt to fully understand the impact regime under which life on Earth has developed. The Centaurs are a population of ice-rich bodies which move on dynamically unstable orbits in the outer Solar system. The largest Centaurs known are several hundred kilometres in diameter, and it is certain that a great number of kilometre or sub-kilometre sized Centaurs still await discovery. These objects move on orbits which bring them closer to the Sun than Neptune, although they remain beyond the orbit of Jupiter at all times, and have their origins in the vast reservoir of debris known as the Edgeworth-Kuiper belt that extends beyond Neptune. Over time, the giant planets perturb the Centaurs, sending a significant fraction into the inner Solar System where they become visible as short-period comets. In this work, we obtain results which show that the presence of a giant planet can act to significantly change the impact rate of short-period comets on the Earth, and that such planets often actually increase the impact flux greatly over that which would be expected were a giant planet not present.

To appear in: International Journal of Astrobiology

For preprints, contact `j.a.horner@open.ac.uk`

or on the web at <http://arxiv.org/abs/0903.3305>

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The Trans-Neptunian Object Size Distribution at Small Sizes

R. Gil-Hutton¹, J. Licandro², N. Pinilla-Alonso³, and R. Brunetto⁴

¹ Complejo Astronómico El Leoncito - CONICET and Universidad Nacional de San Juan, Av. España 1512 sur, J5402DSP - San Juan, Argentina

² Instituto de Astrofísica de Canarias, c/Vía Láctea s/n, E38205, La Laguna, Tenerife, Spain

³ Fundación Galileo Galilei & Telescopio Nazionale Galileo, P.O.Box 565, E-38700, S/C de La Palma, Tenerife, Spain

⁴ Institut d'Astrophysique Spatiale, Université Paris-Sud, bâtiment 121, 91405 Orsay Cedex, France

Aims. The aim of this work is to estimate the size distribution of small Trans-Neptunian objects.

Methods. We simulate the irradiation and collisional processes affecting the surface of a Trans-Neptunian object using for the first time as constraint the peculiar crystalline to amorphous water ice ratio observed on (136108) 2003 EL₆₁.

Results. We find that the size distribution changes its exponent from $q_0 = 4.2$ at larger sizes to $q_1 = 2.40 \pm 0.3$ at the smaller ones, with a break radius of $r_1 = 35 \pm 15$ km. If this size distribution is applied to study the collisional surface evolution of (136108) 2003 EL₆₁, we find that the object must be covered by a thin ice crust of ≈ 0.12 cm, while the original composition of the object is still present at 1.61 cm or more below the surface. This result is not affected by a collision with a large projectile that occurred by chance more than 10^9 yr ago since after a short time the mean value obtained for the crystalline to amorphous water ice ratio is indistinguishable from that obtained without a collision with a large projectile. Since the simulations are not sensitive to the effects of very small projectiles ($r_p < 10\text{--}30$ m), it is possible that the exponent of the size distribution for these very small objects change again approaching a Donhanyi's size distribution.

To appear in: Astronomy & Astrophysics

For preprints, contact `rgilhutton@casleo.gov.ar`

Considerations on the Magnitude Distributions of the Kuiper Belt and of the Jupiter Trojans

Alessandro Morbidelli¹, Harold F. Levison², William F. Bottke², Luke Dones² and David Nesvorný²

¹ Observatoire de la Côte d’Azur, Nice, France

² Southwest Research Institute, Boulder, CO, USA

By examining the absolute magnitude (H) distributions (hereafter HD) of the cold and hot populations in the Kuiper belt and of the Trojans of Jupiter, we find evidence that the Trojans have been captured from the outer part of the primordial trans-Neptunian planetesimal disk. We develop a sketch model of the HDs in the inner and outer parts of the disk that is consistent with the observed distributions and with the dynamical evolution scenario known as the ‘Nice model’. This leads us to predict that the HD of hot population should have the same slope of the HD of the cold population for $6.5 < H < 9$, both as steep as the slope of the Trojans’ HD. Current data partially support this prediction, but future observations are needed to clarify this issue. Because the HD of the Trojans rolls over at $H \sim 9$ to a collisional equilibrium slope that should have been acquired when the Trojans were still embedded in the primordial trans-Neptunian disk, our model implies that the same roll-over should characterize the HDs of the Kuiper belt populations, in agreement with the results of Bernstein et al. (2004) and Fuentes and Holman (2008). Finally, we show that the constraint on the total mass of the primordial trans-Neptunian disk imposed by the Nice model implies that it is unlikely that the cold population formed beyond 35 AU.

To appear in: Icarus

For preprints, contact `morby@oca.eu`

or on the web at <http://www.oca.eu/morby/papers/Note-SFD3.pdf>

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The Colors of Cometary Nuclei – Comparison with Other Primitive Bodies of the Solar System and Implications for their Origin

P. Lamy¹ and I. Toth^{1,2}

¹ Laboratoire d’Astrophysique de Marseille, UMR6110 CNRS/Université de Provence, Technopôle de Marseille-Etoile, 38 rue Frédéric Joliot-Curie, 13388 Marseille cedex 13, France,

² Konkoly Observatory, Budapest, P.O. Box 67, H-1525, Hungary

We present new color results of cometary nuclei obtained with the Hubble Space Telescope (HST) whose superior resolution enables us to accurately isolate the nucleus signals from the surrounding comae. By combining with scrutinized available data obtained with ground-based telescopes, we accumulated a sample of 51 cometary nuclei, 44 ecliptic comets (ECs) and 7 nearly-isotropic comets (NICs) using the nomenclature of Levison (1996). We analyze color distributions and color-color correlations as well as correlations with other physical parameters. We present our compilation of colors of 232 outer solar system objects – separately considering the different dynamical populations, classical KBOs in low and high-inclination orbits (respectively CKBO-LI and CKBO-HI), resonant KBOs (practically Plutinos), scattered-disk objects (SDOs) and Centaurs – of 12 candidate dead comets, and of 85 Trojans. We perform a systematic analysis of all color distributions, and conclude by synthesizing the implications of the dynamical evolution and of the colors for the origin of the minor bodies of the solar system. We find that the color distributions are remarkably consistent

with the scenarios of the formation of TNOs by Gomes (2003) generalized by the "Nice" model (Levison et al., 2008), and of the Trojans by Morbidelli et al. (2005). The color distributions of the Centaurs are globally similar to those of the CKBO-HI, the Plutinos and the SDOs. However the potential bimodality of their distributions allows to possibly distinguish two groups based on their $(B - R)$ index: Centaurs I with $(B - R) > 1.7$ and Centaurs II with $(B - R) < 1.4$. Centaurs I could be composed of TNOs (prominently CKBO-LI) and ultra red objects from a yet unstudied family. Centaurs II could consist in a population of evolved objects which have already visited the inner solar system, and which has been scattered back beyond Jupiter. The diversity of colors of the ECs, in particular the existence of very red objects, is consistent with an origin in the Kuiper belt. Candidate dead comets represent an ultimate state of evolution as they conspicuously appear more evolved than the Trojans and Centaurs II.

To appear in: Icarus

For preprints, contact Philippe Lamy: philippe.lamy@oamp.fr

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A Search for Distant Solar System Bodies in the Region of Sedna

Megan E. Schwamb¹, Michael E. Brown¹, and David L. Rabinowitz²

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

² Department of Physics, Yale University, P.O. Box 208121, New Haven, CT 06520, USA

We present the results of a wide-field survey for distant Sedna-like bodies in the outer solar system using the 1.2-m Samuel Oschin Telescope at Palomar Observatory. We searched $\sim 12,000$ deg² down to a mean limiting magnitude of 21.3 in R. A total number of 53 Kuiper belt objects and Centaurs have been detected, 25 of which were discovered in this survey. No additional Sedna-like bodies with perihelia beyond 70 AU were found despite a sensitivity to motions out to ~ 1000 AU. We place constraints on the size and distribution of objects on Sedna orbits.

Published in: The Astrophysical Journal Letters, 694, L45 (2009 March 20)

For preprints, contact mschwamb@gps.caltech.edu

or on the web at <http://www.iop.org/EJ/abstract/1538-4357/694/1/L45/>

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Kuiper Belt Object Occultations: Expected Rates, False Positives, and Survey Design

S.J. Bickerton¹, D.L. Welch², and J.J. Kavelaars³

¹ Princeton University, Princeton NJ, 08544, USA

² McMaster University, Hamilton ON, L8S 4M1, Canada

³ Herzberg Institute of Astrophysics, Victoria BC, V9E 2E7, Canada

A novel method of generating artificial scintillation noise is developed and used to evaluate occultation rates and false positive rates for surveys probing the Kuiper Belt with the method of serendipitous stellar occultations. A thorough examination of survey design shows that: (1) diffraction-dominated occultations are critically (Nyquist) sampled at a rate of 2 Fsu^{-1} , corresponding to 40 s^{-1} for objects at 40 AU, (2) occultation detection rates are maximized when targets are observed at solar opposition, (3) Main Belt Asteroids will produce occultations lightcurves identical to those of Kuiper Belt Objects if target stars are observed at solar elongations of: $116^\circ < \varepsilon < 125^\circ$,

or $131^\circ < \varepsilon < 141^\circ$, and (4) genuine KBO occultations are likely to be so rare that a detection threshold of $> 7 - 8\sigma$ should be adopted to ensure that viable candidate events can be disentangled from false positives.

To appear in: The Astronomical Journal

For preprints, contact `bick@astro.princeton.edu`

or on the web at `arXiv.org/abs/0902.3457`

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The Taiwanese-American Occultation Survey: The Multi-Telescope Robotic Observatory

M.J. Lehner^{1,2,3}, C.-Y. Wen¹, J.-H. Wang^{1,7}, S.L. Marshall^{4,5}, M.E. Schwamb⁶,
Z.-W. Zhang⁷, F.B. Bianco^{2,3}, J. Giammarco⁸, R. Porrata⁹, C. Alcock³, T. Axelrod¹⁰,
Y.-I. Byun¹¹, W.P. Chen⁷, K.H. Cook⁵, R. Dave¹², S.-K. King¹, T. Lee¹, H.-C. Lin⁷,
S.-Y. Wang¹, J.A. Rice¹³ and I. de Pater¹⁴

¹ Institute of Astronomy and Astrophysics, Academia Sinica. P.O. Box 23-141, Taipei 106, Taiwan

² Department of Physics and Astronomy, University of Pennsylvania, 209 S. 33rd St., Philadelphia, PA 19104, USA

³ Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA

⁴ Kavli Institute for Particle Astrophysics and Cosmology, 2575 Sand Hill Road, MS 29, Menlo Park, CA 94025, USA

⁵ Institute for Geophysics & Planetary Physics, Lawrence Livermore National Laboratory, Livermore, CA 94550, USA

⁶ Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA 91125, USA

⁷ Institute of Astronomy, National Central University, No. 300, Jhongda Rd, Jhongli City, Taoyuan County 320, Taiwan

⁸ Department of Astronomy and Physics, Eastern University 1300 Eagle Road Saint Davids, PA 19087, USA

⁹ Department of Physics, University of California at Berkeley, Berkeley, CA 94270, USA

¹⁰ Steward Observatory, 933 North Cherry Avenue, Room N204 Tucson AZ 85721, USA

¹¹ Department of Astronomy, Yonsei University, 134 Shinchon, Seoul 120-749, Korea

¹² Initiative in Innovative Computing, Harvard University, 60 Oxford St, Cambridge, MA 02138, USA

¹³ Department of Physics, University of California at Berkeley, Berkeley, CA 94270, USA

¹⁴ Department of Physics, University of California at Berkeley, Berkeley, CA 94270, USA

The Taiwanese-American Occultation Survey (TAOS) operates four fully automatic telescopes to search for occultations of stars by Kuiper Belt Objects. It is a versatile facility that is also useful for the study of initial optical GRB afterglows. This paper provides a detailed description of the TAOS multi-telescope system, control software, and high-speed imaging.

Published in: Publications of the Astronomical Society of the Pacific, 121, 138

Preprints available on the web at `http://arxiv.org/abs/0802.0303`

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NICMOS Photometry of the Unusual Dwarf Planet Haumea and its Satellites

W.C. Fraser¹ and M.E. Brown¹

¹ Division of Geological and Planetary Sciences, California Institute of Technology, MC 150-21, 1200 E. California Blvd. Pasadena, CA 91125, USA

We present here HST NICMOS F110W and F160W observations of Haumea, and its two satellites Hi'iaka and Namaka. From the measured (F110W-F160W) colours of -1.208 ± 0.004 , -1.48 ± 0.06 , and -1.4 ± 0.2 mag for each object, respectively, we infer that the $1.6 \mu\text{m}$ water-ice absorption feature depths on Hi'iaka and Namaka are at least as deep as that of Haumea. The light-curve of Haumea is detected in both filters, and we find that the infrared colour is bluer by $\sim 2 - 3\%$ at the phase of the red spot. These observations suggest that the satellites of Haumea were formed from the collision that produced the Haumea collisional family.

Published in: The Astrophysical Journal Letters, 695, L1 (2009 April)

For preprints, contact fraserw@gps.caltech.edu

or online at <http://arxiv.org/abs/0903.0860>

The Surface of (136108) Haumea (2003 EL₆₁), the Largest Carbon-depleted Object in the Trans-Neptunian Belt

N. Pinilla-Alonso¹, R. Brunetto^{2,3}, J. Licandro⁴,
R. Gil-Hutton⁵, T.L. Roush⁶ and G. Strazzulla³

¹ Fundación Galileo Galilei & Telescopio Nazionale Galileo, P.O.Box 565, E-38700, S/C de La Palma, Tenerife, Spain

² Institut d'Astrophysique Spatiale, Université Paris-Sud, bâtiment 121, 91405 Orsay Cedex, France

³ INAF-Osservatorio Astrofisico di Catania, Via S. Sofia 78, I-95123, Catania, Italy

⁴ Instituto de Astrofísica de Canarias, c/Vía Láctea s/n, E38205, La Laguna, Tenerife, Spain

⁵ Complejo Astronómico El Leoncito (Casleo) and San Juan National University, Av. España 1512 sur, J5402DSP, San Juan, Argentina

⁶ NASA Ames Research Center, MS 245-3, Moffett Field, CA 94035-1000, USA

Context. Previously known as 2003 EL₆₁, (136108) Haumea, is the largest member of a group of trans-Neptunian objects (TNOs) with similar orbits and ‘unique’ spectral characteristics in the form of a neutral slope in the visible and the deepest water ice absorption bands observed in the trans-neptunian belt (TNb). Studying the surface of 2003 EL₆₁ provides useful constraints of the origin of this particular group of TNOs and about the outer Solar System’s history.

Aims. In this work we attempt to study the composition of the surface of 2003 EL₆₁.

Methods. We present visible and near-infrared spectra of 2003 EL₆₁ obtained with the 4.2m WHT and the 3.6m TNG telescopes at the “Roque de los Muchachos” Observatory (Canary Islands, Spain). Near-infrared spectra were obtained at different rotational phases covering almost one complete rotational period. Spectra are fitted using scattering models based on Hapke theory and constraints on the surface composition are derived.

Results. The observations confirm previous results that the 2003 EL₆₁ spectrum is neutral in color and exhibits deep water-ice absorption bands. They also provide new facts about the surface of this object: the lack of significant variations in the spectral slope (in the near-infrared) and the depth of the water-ice absorption bands at different rotational phases clearly evident in the data, suggest that the surface of 2003 EL₆₁ is homogeneous. The scattering models indicate that a 1:1 intimate mixture of crystalline and amorphous water ice is the most probable surface composition

of this big TNO, and constrain the presence of other minor constituents to a maximum traction of 8%.

Conclusions. The derived composition suggests that: a) cryovolcanism is unlikely to be the resurfacing process that retains the surface of this TNO, and the other members of this population, covered mainly by water ice; b) the surface is older than 10^8 yr, which constrains the timescale of any catastrophic event, such as the collision suggested to be the origin of this population, to at least 10^8 yr; c) the surface of 2003 EL₆₁ is depleted of carbon-bearing species. According to the orbital parameters of the population, this implies that is a possible source of carbon-depleted, Jupiter-Family comets.

Published in: *Astronomy & Astrophysics* 496, 547 (2009 March)

For preprints, contact npinilla@tng.iac.es

or on the web at <http://arxiv.org/abs/0803.1080>

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Orbits and Masses of the Satellites of the Dwarf Planet Haumea (2003 EL61)

D. Ragozzine¹ and M. E. Brown¹

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

Using precise relative astrometry from the Hubble Space Telescope and the W. M. Keck Telescope, we have determined the orbits and masses of the two dynamically interacting satellites of the dwarf planet (136108) Haumea, formerly 2003 EL61. The orbital parameters of Hi'iaka, the outer, brighter satellite, match well the previously derived orbit. On timescales longer than a few weeks, no Keplerian orbit is sufficient to describe the motion of the inner, fainter satellite Namaka. Using a fully-interacting three point-mass model, we have recovered the orbital parameters of both orbits and the mass of Haumea and Hi'iaka; Namaka's mass is marginally detected. The data are not sufficient to uniquely determine the gravitational quadrupole of the non-spherical primary (described by J_2). The nearly co-planar nature of the satellites, as well as an inferred density similar to water ice, strengthen the hypothesis that Haumea experienced a giant collision billions of years ago. The excited eccentricities and mutual inclination point to an intriguing tidal history of significant semi-major axis evolution through satellite mean-motion resonances. The orbital solution indicates that Namaka and Haumea are currently undergoing mutual events and that the mutual event season will last for the next several years.

To appear in: *The Astronomical Journal*

For preprints, contact darin@gps.caltech.edu

or on the web at <http://arxiv.org/abs/0903.4213>

OTHER PAPERS OF INTEREST

Isotropic Gamma-Ray Background: Cosmic-Ray-Induced Albedo from Debris in the Solar System?

Igor V. Moskalenko^{1,3} and Troy A. Porter²

¹ Hansen Experimental Physics Laboratory, Stanford University, Stanford, CA 94305, USA

² Santa Cruz Institute for Particle Physics, University of California, Santa Cruz, CA 95064, USA

³ Also Kavli Institute for Particle Astrophysics, and Cosmology, Stanford University, Stanford, CA 94309, USA

We calculate the γ -ray albedo due to cosmic-ray interactions with debris (small rocks, dust, and grains) in the Oort Cloud. We show that under reasonable assumptions a significant proportion of what is called the “extragalactic γ -ray background” could be produced at the outer frontier of the solar system, and may be detectable by the Large Area Telescope, the primary instrument on the Fermi Gamma-ray Space Telescope. If detected, it could provide unique direct information about the total column density of material in the Oort Cloud that is difficult to access by any other method. The same γ -ray production process takes place in other populations of small solar system bodies, such as Main Belt asteroids, Jovian and Neptunian Trojans, and Kuiper Belt objects. Their detection can be used to constrain the total mass of debris in these systems.

Published in: The Astrophysical Journal Letters, 692, L54 (2009 February 10)

Preprints, on the web at <http://arxiv.org/abs/0901.0304>

The *Distant EKO*s 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 L^AT_EX 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 EKO*s 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 ... ??

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`