Issue No. 90 *December 2013*

DISTANT EKOs

The Kuiper Belt Electronic Newsletter

Edited by: Joel Wm. Parker

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

CONTENTS

NEWS & ANNOUNCEMENTS

An Icarus special issue on Pluto system science will be published in 2014. The pace of discovery about the Pluto system has accelerated continually since its discovery in 1930, and we are now on the doorstep of the most dramatic advances yet, with the system's exploration by NASA's New Horizons probe in 2015. New Horizons, equipped with a powerful suite of scientific instruments, will explore Pluto and its complex system of moons and potential rings/dust assemblages. The encounter will herald the exploration of the newly recognized planetary class called ice dwarfs, prevalent in the outer solar system. This special issue sets the stage for the encounter, with scientific papers on:

- New results from observations, theoretical modeling, and laboratory studies relevant to the Pluto system
- Pre-encounter predictions of Pluto system properties and processes
- Investigations into the implications of Pluto system science for broader outer Solar System studies

Many of the papers in the special issue originated in a conference held last summer at APL, but contributions are not restricted to conference participants.
The submission deadline is December 20, through the normal Icarus submission site
`http://ees.elsevier.com/icarus`
(select "Special Issue: The Pluto System" under manuscript type). The usual Icarus guidelines for authors apply.
Special issue editors: Will Grundy, Alan Stern, Fran Bagenal, Randy Gladstone, and Bonnie Buratti.

. . . .

There was 1 new TNO discovery announced since the previous issue of *Distant EKOs*:

2013 SA87

and 4 new Centaur/SDO discoveries:

2013 UL10, 2013 VE2, 2013 WV107, 2013 XZ8

Reclassified objects:
2002 CP154 (TNO $\rightarrow$ SDO)

Objects recently assigned numbers:
2010 RM64 = (382004)

Current number of TNOs: 1259 (including Pluto)
Current number of Centaurs/SDOs: 382
Current number of Neptune Trojans: 9

Out of a total of 1649 objects:
643 have measurements from only one opposition
628 of those have had no measurements for more than a year
324 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 Pluto's Low Mass Satellites

S.J. Kenyon[1] and B.C. Bromley[2]

[1] Smithsonian Astrophysical Observatory, 60 Garden Street, Cambridge, MA 02138, USA

[2] Department of Physics, University of Utah, 201 JFB, Salt Lake City, UT 84112, USA

Motivated by the *New Horizons* mission, we consider how Pluto's small satellites – currently Styx, Nix, Kerberos, and Hydra – grow in debris from the giant impact that forms the Pluto-Charon binary. After the impact, Pluto and Charon accrete some of the debris and eject the rest from the binary orbit. During the ejection, high velocity collisions among debris particles produce a collisional cascade, leading to the ejection of some debris from the system and enabling the remaining debris particles to find stable orbits around the binary. Our numerical simulations of coagulation and migration show that collisional evolution within a ring or a disk of debris leads to a few small satellites orbiting Pluto-Charon. These simulations are the first to demonstrate migration-induced mergers within a particle disk. The final satellite masses correlate with the initial disk mass. More massive disks tend to produce fewer satellites. For the current properties of the satellites, our results strongly favor initial debris masses of 3–10$\times 10^{19}$ g and current satellite albedos $A \approx$ 0.4–1. We also predict an ensemble of smaller satellites, $R \lesssim$ 1–3 km, and very small particles, $R \approx$ 1–100 cm and optical depth $\tau \lesssim 10^{-10}$. These objects should have semimajor axes outside the current orbit of Hydra.

To appear in: The Astronomical Journal

Preprints available at `http://arxiv.org/abs/1303.0280`

. . . .

Astrometry and Orbits of Nix, Kerberos, and Hydra

Marc W. Buie[1], William M. Grundy[2], and David J. Tholen[3]

[1] Southwest Research Institute, 1050 Walnut Street, Suite 300, Boulder, CO 80302, USA

[2] Lowell Observatory, 1400 West Mars Hill Road, Flagstaff, AZ 86001, USA

[3] Institute for Astronomy, University of Hawaii, 2680 Woodlawn Drive, Honolulu, HI 96822, USA

We present new Hubble Space Telescope observations of three of Pluto's outer moons, Nix, Kerberos, and Hydra. This work revises previously published astrometry of Nix and Hydra from 2002 to 2003. New data from a four-month span during 2007 include observations designed to better measure the positions of Nix and Hydra. A third data set from 2010 also includes data on Nix and Hydra as well as some pre-discovery observations of Kerberos. The data were fitted using numerical point-spread function (PSF) fitting techniques to get accurate positions but also to remove the extended wings of the Pluto and Charon PSFs when working on these faint satellites. The resulting astrometric data were fitted with two-body Keplerian orbits that are useful for short-term predictions of the future positions of these satellites for stellar occultation and for guiding encounter planning for the upcoming New Horizons flyby of the Pluto system. The mutual inclinations of the satellites are all within 0.2° of the plane of Charon's orbit. The periods for all continue to show that their orbits are near but distinct from integer period ratios relative to Charon. Based on our results, the period ratios are Hydra:Charon = 5.98094 ± 0.00001, Kerberos:Charon = 5.0392 ± 0.0003, and Nix:Charon = 3.89135 ± 0.00001. Based on period ratios alone, there is a trend of increased distance from an integer period ratio with decreasing distance from Charon. Our analysis shows that orbital

uncertainties for Nix and Hydra are now low enough to permit useful stellar occultation predictions and for New Horizons encounter planning. In 2015 July, our orbits predict a position error of 60 km for Nix and 38 km for Hydra, well below other limiting errors that affect targeting. The orbit for Kerberos, however, still needs a lot of work as its uncertainty in 2015 is quite large at 22,000 km based on these data.

Published in: The Astronomical Journal, 146, 152 (2013 December)
For preprints, contact buie@boulder.swri.edu

. . . .

On the Dynamics and Origin of Haumea's Moons

M. Cuk[1], D. Ragozzine[2], and D. Nesvorny[3]

[1] SETI Institute, Mountain View, CA, USA

[2] University of Florida, Gainesville, FL, USA

[3] Southwest Research Institute, Boulder, CO, USA

The dwarf planet Haumea has two large satellites, Namaka and Hi'iaka, which orbit at relatively large separations. Both moons have significant eccentricities and inclinations, in a pattern that is consistent with a past orbital resonance (Ragozzine and Brown, 2009). Based on our analysis, we find that the present system is not consistent with satellite formation close to the primary and tidal evolution though mean-motion resonances. We propose that Namaka experienced only limited tidal evolution, leading to the mutual 8:3 mean-motion resonance which redistributed eccentricities and inclinations between the moons. This scenario requires that the original orbit of Hi'iaka was mildly eccentric; we propose that this eccentricity was either primordial or acquired though encounters with other TNOs. Both dynamical stability and our preferred tidal evolution model imply that the moons' masses are only about one half of previously estimated values, suggesting high albedos and low densities. As the present orbits of the moons strongly suggest formation from a flat disk close to their present locations, we conclude that Hi'iaka and Namaka may be second-generation moons, formed after the breakup of a past large moon, previously proposed as the parent body of the Haumea family (Schlichting and Sari, 2009). We derive plausible parameters of that moon, consistent with the current models of Haumea's formation (Leinhardt et al., 2010). An interesting implication of this hypothesis is that Hi'iaka and Namaka may orbit retrograde with respect to Haumea's spin. Retrograde orbits of Haumea's moons would be in full agreement with available observations and our dynamical analysis, and could provide a unique confirmation the "disrupted satellite" scenario for the origin of the family.

Published in: The Astronomical Journal, 146, 89 (2013 October)
For preprints, contact mcuk@seti.org
or on the web at http://www.people.fas.harvard.edu/~cuk/papers/haumea.pdf

. . . .

The Density of Mid-sized Kuiper Belt Object 2002 UX25 and the Formation of the Dwarf Planets

Michael E. Brown[1]

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

The dramatic difference in density between the ~350 km diameter and smaller objects in the Kuiper belt, which all have densities consistent with values below 1 g cm^{-3}, and the ~850 km and larger objects, which all have densities above this value, is difficult to explain in any standard coagulation scenario. An important clue to the cause of this density bifurcation could come from the measurement of the density of mid-sized Kuiper belt objects with diameters in between the two measured regimes. Here we report the orbital characterization, mass, and density determination of the 2002 UX25 system in the Kuiper belt. For this object, with a diameter of ~650 km, we find a density of 0.82 ± 0.11 g cm^{-3}, making it the largest solid known object in the solar system with a measured density below that of pure water ice. None of the currently proposed explanations for the high density of large Kuiper belt objects is supported by the existence of such a large low density system in the Kuiper belt. If the currently measured densities of Kuiper belt objects are a fair representation of the sample as a whole, standard pairwise accretion cannot build the ~1000 km and larger Kuiper belt objects with densities of ~2 g cm^{-3} from smaller objects with densities below 1 g cm^{-3}.

Published in: The Astrophysical Journal Letters, 778, 34 (2013 Dec 1)
Preprints on the web at `www.gps.caltech.edu/~mbrown/papers/pubs.html`

. . . .

The Unusual Kuiper Belt Object 2003 SQ_{317}

P. Lacerda[1], **A. McNeill**[1], **and N. Peixinho**[2,3]

[1] Astrophysics Research Centre, Queen's University Belfast, Belfast BT7 1NN, Northern Ireland, UK

[2] Center for Geophysics of the University of Coimbra, Geophysical and Astronomical Observatory of the University of Coimbra, Almas de Freire, 3040-004 Coimbra, Portugal

[3] Unidad de Astronomía, Universidad de Antofagasta, Avenida Angamos 601, Antofagasta, Chile

We report photometric observations of Kuiper belt object 2003 SQ_{317} obtained between 2011 August 21 and 2011 November 1 at the 3.58 m New Technology Telescope, La Silla. We obtained a rotational lightcurve for 2003 SQ_{317} with a large peak-to-peak photometric range, $\Delta m = 0.85 \pm 0.05$ mag, and a periodicity, $P = 7.210 \pm 0.001$ hr. We also measure a nearly neutral broadband colour $B - R = 1.05 \pm 0.18$ mag and a phase function with slope $\beta = 0.95 \pm 0.41$ mag/deg. The large lightcurve range implies an extremely elongated shape for 2003 SQ_{317}, possibly as a single elongated object but most simply explained as a compact binary. If modelled as a compact binary near hydrostatic equilibrium, the bulk density of 2003 SQ_{317} is near 2670 kg m^{-3}. If 2003 SQ_{317} is instead a single, elongated object, then its equilibrium density is about 860 kg m^{-3}. These density estimates become uncertain at the 30% level if we relax the hydrostatic assumption and account for solid, "rubble pile"-type configurations. 2003 SQ_{317} has been associated with the Haumea family based on its orbital parameters and near-infrared colour; we discuss our findings in this context. If confirmed as a close binary, 2003 SQ_{317} will be the second object of its kind identified in the Kuiper belt.

To appear in: Monthly Notices of the Royal Astronomical Society
For preprints, contact `pedro.lacerda@mps.mpg.de`
or on the web at `http://lacerdapedro.wordpress.com/publications/`

. . . .

A Possible Mechanism to Explain the Lack of Binary Asteroids among the Plutinos

A. Compère[1], D. Farrelly[2], A. Lemaître[1], and D. Hestroffer[3]

[1] naXys, University of Namur, Rempart de la Vierge 8, 5000 Namur, Belgium

[2] Utah State University, 0300 Old Main Hill, Logan, UT 84322-0300, USA

[3] IMCCE, Observatoire de Paris, UPMC, CNRS, 77 av. Denfert Rochereau 75014 Paris, France

Context. Binary asteroids are common in the Solar System, including in the Kuiper belt. However, there seems to be a marked disparity between the binary populations in the classical part of the Kuiper belt and the part of the belt in the 3:2 resonance with Neptune – i.e., the region inhabited by the Plutinos. In particular, binary Plutinos are extremely rare.
Aims. We study the impact of the 3:2 resonance on the formation of Kuiper belt binaries, according to the Nice model, in order to explain such phenomenon.
Methods. Numerical simulations are performed within the 2+2 body approximation (Sun/Neptune + binary partners). The MEGNO chaos indicator is used to map out regular and chaotic regions of phase space. Residence times of test (binary) particles within the Hill sphere are compared inside and outside of the 3:2 resonance. The effect of increasing the heliocentric eccentricity of the centre of mass of the binary system is studied. This is done because mean-motion resonances between a planet and an asteroid usually have the effect of increasing the eccentricity of the asteroid.
Results. The stable zones in the MEGNO maps are mainly disrupted in the resonant, eccentric case: the number of binary asteroids created in this case is significantly lower than outside the 3:2 resonance.
Conclusions. In the 2+2 body approximation, the pumping of the eccentricity of the centre of mass of a potential binary destabilizes the formation of binaries. This may be a factor in explaining the scarcity of binaries in the Plutino population.

Published in: Astronomy & Astrophysics, 558, A4, 2013

For preprints, contact `audrey.compere@unamur.be`

. . . .

On the Dynamical Evolution and End States of Binary Centaurs

A. Brunini[1,2]

[1] Facultad de Ciencias Astronomicas y Geofisicas, Universidad Nacional de La Plata, Argentina

[2] Instituto de Astrofisica de La Plata. CCT CONICET La Plata, Argentina

In this paper we perform a numerical integration of 666 fictitious Binary Centaurs coming from the trans Neptunian space. Our population is restricted to tight binaries whose components have sizes between 30 and 100 km. We included the dynamical perturbations from the giant planets, Kozai Cycles induced by the Sun, and tidal friction on the orbits of the binaries. We found that most binaries are disrupted during one of the close planetary encounters, making the mean lifetime of Binary Centaurs of less than 1 Myr. Nearly 10 per cent of the binaries reach a very small circular orbit, arguing in favor of the existence of a non-negligible population of contact Centaurs. Another 10 per cent survive as a binary during their lifetime as Centaur. Our simulations favour the existence of a small population of very tight Binary Centaurs.

To appear in: Monthly Notices of the Royal Astronomical Society

. . . .

Statistics of Encounters in the Trans-Neptunian Region

A. Dell'Oro[1], A. Campo Bagatin[2,3], P.G. Benavidez[2,3], and R.A. Alemañ[2,3]

[1] INAF - Osservatorio Astrofisico di Arcetri, Largo Enrico Fermi, 5, 50125 Firenze, Italy

[2] Departamento de Física, Ingeniera de Sistemas y Teorá de la Señal. Universidad de Alicante, Carretera San Vicente del Raspeig S/N, 03690 San Vicente del Raspeig (Alicante), Spain

[3] Instituto Universitario de Física Aplicada a las Ciencias y la Tecnologa. Universidad de Alicante, Carretera San Vicente del Raspeig S/N, 03690 San Vicente del Raspeig (Alicante), Spain

The inventory of the populations of trans-Neptunian objects (TNO) has grown considerably over the last decade. As for other groups of small bodies in our solar system, TNOs are expected to have experienced a collisional evolution owing to their mutual impacts. The knowledge of the statistics of collisions, including determination of the rate of mutual collisions and the distribution of the impact velocity, is indeed a fundamental prerequisite for developing models of collisional evolution. We revised the evaluation of those statistical parameters for TNOs provided more than ten years ago on the basis of a much more limited sample of objects than currently available. We used the Canada-France Ecliptic Plane Survey (CFEPS) L7 model to extract an unbiased sample of orbits for TNOs, while the statistical parameters of impact are computed using a statistical tool. We investigated the statistics of impacts among TNOs for the whole population and for different dynamical subgroups. Moreover, we investigated the statistics of collisions between subgroups with crossing orbits. The peculiar dynamical behavior of objects in resonant orbits is taken into account. Our present computation of the probabilities of collision are 20% to 50% lower than previous estimates, while mean impact velocities turn out to be about 70% higher. For instance, the rate of collisions among Plutinos, expressed in terms of the so-called *mean intrinsic probability of collision*, results to be $(3.90 \pm 0.01) \times 10^{-22}$ km^{-2} yr^{-1} and the mean impact velocity is 2.46 ± 0.01 km/s. We also find that the distributions of impact velocities seem to be quite different from pure Maxwellian distributions. These results can be useful in developing models of the collisional evolution in the trans-Neptunian region.

Published in: Astronomy & Astrophysics, 558, A95 (2013 October)

For preprints, on the web at `http://dx.doi.org/10.1051/0004-6361/201321461`

. . . .

The Size-distribution of Scattered Disk TNOs from that of JFCs between 0.2 and 15 km Effective Radius

Michael J. S. Belton[1]

[1] Belton Space Exploration Initiatives, LLC. 430 S Randolph Way, Tucson, AZ, USA

We investigate the differential size-frequency distribution (SFD) of Jupiter Family comets (JFCs) in order to determine whether they are primordial accreted objects or collisional fragments as suggested by current models of the evolution of Trans-Neptunian Objects (TNOs). We develop a list of effective radii and their uncertainties for 161 active JFCs from published sources and compute the observed differential size-frequency distribution using a Probability Index technique. The radii range from 0.2 to 15.4 km and average 1.9 km. The peak of the distribution is near 1.0 km. This is then corrected for the effects of observational selection using a model published earlier by Meech et al. (Icarus 170, 463-491, 2004). We estimate that the total number of active JFCs between 0.2 and 15.4 km is approximately 2300 indicating that our current sample of the of active JFC population is far from complete. The active JFC size-frequency distribution, over the range from 0.6 to 10 km where it is best defined, is found to be closer to an exponential distribution in character than a power-law. We then develop a statistical model, based on the assumption of a steady state, for converting the distribution of active JFCs to the SFD of the source population among the TNOs. The model includes the effects of devolatization (that produces a large sub-class of defunct nuclei) and surficial mass-loss. Comparison with available TNO observations shows that to simultaneously attain continuity with the data on objects in the hot TNO population (Fuentes et al. (Astrophys.J 722,1290-1304; 2010), satisfy constraints on the number of TNOs set by the occultation detections of Schlichting et al. (Ap.J. 761:150; 2012), and to remain within upper limits set by the Taiwanese-American Occultation Survey (TAOS; Zhang et al, Astron. J. 146, Id 14, 10pp) the total JFC population must contain a large fraction of small defunct nuclei. The effective power-law index of the inferred TNO differential SFD between 1 and 10 km is -4.5±0.5 indicating a population in this range that is not in fully relaxed collisional equilibrium. We conclude that the cometary nuclei so far visited by spacecraft and many JFCs are primordial accreted objects relatively unaffected by collisional evolution. We find a turndown in the slope of the predicted TNO cumulative distribution near 1 km radius rather than near 10 km that is seen in many TNO evolutionary calculations. This may or may not represent the onset of a collisional cascade.

To appear in: Icarus
Preprints available on the web at `http://arXiv.org/abs/1312.1424`

. . . .

$^{14}N^{15}N$ Detectability in Pluto's Atmosphere

Kandis Lea Jessup[1], G.R. Gladstone[2], A.N. Heays[3,4], S.T. Gibson[4], B.R. Lewis[4], and G. Stark[5]

[1] Southwest Research Institute, 1050 Walnut Street, Suite 300, Boulder, CO 80302, USA
[2] Southwest Research Institute, 6220 Culebra Rd., San Antonio, TX 78238, USA
[3] Leiden Observatory, Leiden University, P.O. Box 9513, 2300 RA Leiden, The Netherlands
[4] Research School of Physics and Engineering, The Australian National University, Canberra, ACT 0200, Australia
[5] Department of Physics, Wellesley College, 106 Central Street, Wellesley, MA 02481, USA

Based on the vapor pressure behavior of Pluto's surface ices, Pluto's atmosphere is expected to be predominantly composed of N_2 gas. Measurement of the N_2 isotopologue $^{15}N/^{14}N$ ratio within Pluto's atmosphere would provide important clues to the evolution of Pluto's atmosphere from the time of formation to its present state. The most straightforward way of determining the N_2 isotopologue $^{15}N/^{14}N$ ratio in Pluto's atmosphere is via spectroscopic observation of the $^{14}N^{15}N$ gas species. Recent calculations of the 80–100 nm absorption behavior of the $^{14}N_2$ and $^{14}N^{15}N$ isotopologues by Heays et al. (Heays, A.N. et al. [2011]. J. Chem. Phys. 135, 244301), Lewis et al. (Lewis, B.R., Heays, A.N., Gibson, S.T., Lefebvre-Brion, H., Lefebvre, R. [2008]. J. Chem. Phys. 129, 164306); Lewis et al. (Lewis, B.R., Gibson, S.T., Zhang, W., Lefebvre-Brion, H., Robbe, J.-M. [2005]. J. Chem. Phys. 122, 144302), and Haverd et al. (Haverd, V.E., Lewis, B.R., Gibson, S.T., Stark, G. [2005]. J. Chem. Phys. 123, 214304) show that the peak magnitudes of the $^{14}N_2$ and $^{14}N^{15}N$ absorption bandhead cross-sections are similar, but the locations of the bandhead peaks are offset in wavelength by ∼0.05–0.1 nm. These offsets make the segregation of the $^{14}N_2$ and $^{14}N^{15}N$ absorption signatures possible. We use the most recent N_2 isotopologue absorption cross-section calculations and the atmospheric density profiles resulting from photochemical models developed by Krasnopolsky and Cruickshank (Krasnopolsky, V.A., Cruickshank, D.P. [1999]. J. Geophys. Res. 104, 21979–21996) to predict the level of solar light that will be transmitted through Pluto's atmosphere as a function of altitude during a Pluto solar occultation. We characterize the detectability of the isotopic absorption signature per altitude assuming $^{14}N^{15}N$ concentrations

ranging from 0.1% to 2% of the $^{14}N_2$ density and instrumental spectral resolutions ranging from 0.01 to 0.3 nm. Our simulations indicate that optical depth of unity is attained in the key $^{14}N^{15}N$ absorption bands located between 85 and 90 nm at altitudes ∼1100–1600 km above Pluto's surface. Additionally, an $^{14}N^{15}N$ isotope absorption depth ∼4–15% is predicted for observations obtained at these altitudes at a spectral resolution of ∼0.2–0.3 nm, if the N_2 isotopologue $^{15}N/1^{14}N$ percent ratio is comparable to the 0.37–0.6% ratio observed at Earth, Titan and Mars. If we presume that the predicted absorption depth must be at least 25% greater than the expected observational uncertainty, then it follows that a statistically significant detection of these signatures and constraint of the N_2 isotopologue $^{15}N/^{14}N$ ratio within Pluto's atmosphere will be possible if the attainable observational signal-to noise (S/N) ratio is ≥9. The New Horizons (NH) Mission will be able to obtain high S/N, 0.27–0.35 nm full-width half-max 80–100 nm spectral observations of Pluto using the Alice spectrograph. Based on the NH/Alice specifications we have simulated 0.3 nm spectral resolution solar occultation spectra for the 1100–1600 km altitude range, assuming 30 s integration times. These simulations indicate that NH/Alice will obtain spectral observations within this altitude range with a S/N ratio ∼25–50, and should be able to reliably detect the $^{14}N^{15}N$ gas absorption signature between 85 and 90 nm if the $^{14}N^{15}N$ concentration is ∼0.3% or greater. This, additionally, implies that the non-detection of the $^{14}N^{15}N$ species in the 1100–1600 km range by NH/Alice may be used to reliably establish an upper limit to the N_2 isotopologue $^{15}N/^{14}N$ ratio within Pluto's atmosphere. Similar results may be derived from 0.2 to 0.3 nm spectral resolution observations of any other N_2-rich Solar System or exoplanet atmosphere, provided the observations are attained with similar S/N levels.

Published in: Icarus, 226, 1514 (2013 November)
For preprints, contact jessup@boulder.swri.edu

. . . .

The Density and Thermal Structure of Pluto's Atmosphere and Associated Escape Processes and Rates

Xun Zhu[1], Darrell F. Strobel[2], Justin T. Erwin[3]

[1] The Johns Hopkins University, Applied Physics Laboratory, 11100 Johns Hopkins Road, Laurel, MD 20723, USA

[2] Department of Earth and Planetary Sciences, Johns Hopkins University, Baltimore, MD 21218, USA

[3] Department of Materials Science and Engineering, University of Virginia, Charlottesville, VA 22904, USA

The original Strobel et al. (Strobel, D.F., Zhu, X., Summers, M.E., Stevens, M.E. [1996]. Icarus 120, 266–289) model for Pluto's stratospheric density and thermal structure is augmented to include a radial momentum equation with radial velocity associated with atmospheric escape of N_2 and in the energy equation to also include the solar far ultraviolet and extreme ultraviolet (FUV–EUV) heating in the upper atmosphere and adiabatic cooling due to hydrodynamic expansion. The inclusion of radial velocity introduces important negative feedback processes such as increased solar heating leading to enhanced escape rate and higher radial velocity with stronger adiabatic cooling in the upper atmosphere accompanied by reduced temperature. The coupled set of equations for mass, momentum, and energy are solved subject to two types of upper boundary conditions that represent two different descriptions of atmospheric escape: Jeans escape and hydrodynamic escape. For the former which is physically correct, an enhanced Jeans escape rate is prescribed at the exobase and parameterized according to the direct simulation Monte Carlo kinetic model results. For the latter, the atmosphere is assumed to remain a fluid to infinity with the escape rate determined by the temperature and density at the transonic point subject to vanishing temperature and pressure at infinity. For Pluto, the two escape descriptions approach the same limit when the exobase coincides

with the transonic level and merge to a common escape rate $\sim 10^{28}$ N_2 s^{-1} under elevated energy input. For Pluto's current atmosphere, the hydrodynamic approach underestimates the escape rate by about 13%. In all cases, the escape rate is limited by the solar FUV–EUV power input.

Specific results for the New Horizons Pluto flyby July 2015 are escape rate $\sim 3.5 \times 10^{27}$ N_2 s^{-1}, exobase at $8r_0 \sim 9600$ km, with Jeans $\lambda \sim 5$ for a reference Pluto atmosphere model. With Pluto's highly elliptic orbit and variable solar activity affecting its atmosphere, Pluto's escape rates' range is $(1 - 10) \times 10^{27}$ N_2 s^{-1}, exobase radius is bounded by $\sim (5 - 13)r_0$, and at the exobase Pluto is locked in the enhanced Jeans regime with $\lambda \sim (6 - 4)$.

Finally, a systematic review of previous approximate hydrodynamic escape models is presented to compare the constraints which determine the escape rate in each model.

Published in: Icarus, 228, 301 (2014 January)
For preprints, contact Xun.Zhu@jhuapl.edu

. . . .

The 2011 June 23 Stellar Occultation by Pluto: Airborne and Ground Observations

M.J. Person[1], E.W. Dunham[2], A.S. Bosh[1], S.E. Levine[1,2], A.A.S. Gulbis[1,3], A.M. Zangari[1], C.A. Zuluaga[1], J.M. Pasachoff[4], B.A. Babcock[4], S. Pandey[4], D. Amrhein[4,5], S. Sallum[1,6], D.J. Tholen[7], P. Collins[2], T. Bida[2], B. Taylor[8], L. Bright[2], J. Wolf[9,10], A. Meyer[1]0, E. Pfueller[9,10], M. Wiedemann[9,10], H.-P. Roeser[9], R. Lucas[4], M. Kakkala[11], J. Ciotti[12], S. Plunkett[12], N. Hiraoka[12], W. Best[6], E.J. Pilger[13], M. Micheli[7], A. Springmann[1], M. Hicks[14], B. Thackeray[15], J.P. Emery[16], T. Tilleman[17], H. Harris[17], S. Sheppard[18], S. Rapoport[19], I. Ritchie[20], M. Pearson[20], A. Mattingly[21], J. Brimacombe[22], D. Gault[23], R. Jones[24], R. Nolthenius[25], J. Broughton[26], and T. Barry[27]

[1] Department of Earth, Atmospheric, and Planetary Sciences, Massachusetts Institute of Technology (MIT), Cambridge, MA 02139-4307, USA

[2] Lowell Observatory, Flagstaff, AZ, USA

[3] South African Astronomical Observatory, Cape Town, South Africa

[4] Williams College-Hopkins Observatory, Williamstown, MA, USA

[5] Wesleyan University, Middletown, CT, USA

[6] Steward Observatory, University of Arizona, Tucson, AZ, USA

[7] Institute for Astronomy, University of Hawaii, Manoa, HI, USA

[8] Boston University, Boston, MA, USA

[9] Deutsches SOFIA Institut, Universitaet Stuttgart, Pfaffenwaldring 29, D-70569 Stuttgart, Germany

[10] SOFIA Science Center, NASA Ames Research Center, MS 211-1, Moffett Field, CA 94035, USA

[11] Leeward Community College, Pearl City, HI, USA

[12] Windward Community College, Kaneohe, HI, USA

[13] Hawaii Geophysics & Planetology, Honolulu, HI, USA

[14] Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA

[15] Jet Propulsion Laboratory, Pasadena, CA, USA

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

[17] United States Naval Observatory Flagstaff Station, Flagstaff, AZ, USA

[18] Carnegie Institute of Washington, Washington, DC, USA

[19] Research School of Astronomy and Astrophysics, Mt. Stromlo Observatory, Weston Creek, Australia

[20] EOS Space Systems, New South Wales, Australia

[21] IBM, St. Leonards, New South Wales, Australia

[22] James Cook University, Cairns, Queensland, Australia
[23] International Occultation Timing Association, Sydney, New South Wales, Australia
[24] Running Springs, CA, USA
[25] Cabrillo Observatory, Aptos, CA, USA
[26] Reedy Creek, Queensland, Australia
[27] University of Western Sydney, Penrith Observatory, Australia

On 2011 June 23, stellar occultations by both Pluto (this work) and Charon (future analysis) were observed from numerous ground stations as well as the Stratospheric Observatory for Infrared Astronomy (SOFIA). This first airborne occultation observation since 1995 with the Kuiper Airborne Observatory resulted in the best occultation chords recorded for the event, in three visible wavelength bands. The data obtained from SOFIA are combined with chords obtained from the ground at the IRTF, the U.S. Naval Observatory Flagstaff Station, and Leeward Community College to give the detailed state of the Pluto-Charon system at the time of the event with a focus on Pluto's atmosphere. The data show a return to the distinct upper and lower atmospheric regions with a knee or kink in the light curve separating them as was observed in 1988, rather than the smoothly transitioning bowl-shaped light curves of recent years. The upper atmosphere is analyzed by fitting a model to all of the light curves, resulting in a half-light radius of 1288 ± 1 km. The lower atmosphere is analyzed using two different methods to provide results under the differing assumptions of particulate haze and a strong thermal gradient as causes for the lower atmospheric diminution of flux. These results are compared with those from past occultations to provide a picture of Pluto's evolving atmosphere. Regardless of which lower atmospheric structure is assumed, results indicate that this part of the atmosphere evolves on short timescales with results changing the light curve structures between 1988 and 2006, and then reverting these changes in 2011 though at significantly higher pressures. Throughout these changes, the upper atmosphere remains remarkably stable in structure, again except for the overall pressure changes. No evidence of onset of atmospheric collapse predicted by frost migration models is seen, and the atmosphere appears to be remaining at a stable pressure level, suggesting it should persist at this full level through New Horizon's flyby in 2015.

Published in: The Astronomical Journal, 146, 83 (2013 October)
For reprints, contact mjperson@mit.edu

OTHER PAPERS OF INTEREST

Optimized Herschel/PACS Photometer Observing and Data Reduction Strategies for Moving Solar System Targets

C. Kiss[1], T.G. Müller[2], E. Vilenius[2], A. Pál[1], P. Santos-Sanz[3], E. Lellouch[4], G. Marton[1], E. Verebélyi[1], N. Szalai[1], P. Hartogh[5], J. Stansberry[6], F. Henry[4], and A. Delsanti[4]

[1] Konkoly Observatory, MTA CSFK, Budapest, Hungary

[2] Max-Planck-Institut für extraterrestrische Physik, Garching, Germany

[3] Instituto de Astrofísica de Andalucía-CSIC, Granada, Spain

[4] LESIA, Observatoire de Paris, Meudon, France

[5] Max-Planck-Institut für Sonnensystemforschung, Katlenburg-Lindau, Germany

[6] Space Telescope Science Institute, Baltimore, MD, USA

The "TNOs are Cool!: A survey of the trans-Neptunian region" is a Herschel Open Time Key Program that aims to characterize planetary bodies at the outskirts of the Solar System using PACS and SPIRE data, mostly taken as scan-maps. In this paper we summarize our PACS data reduction scheme that uses a modified version of the standard pipeline for basic data reduction, optimized for faint, moving targets. Due to the low flux density of our targets the observations are confusion noise limited or at least often affected by bright nearby background sources at 100 and 160 μm. To overcome these problems we developed techniques to characterize and eliminate the background at the positions of our targets and a background matching technique to compensate for pointing errors. We derive a variety of maps as science data products that are used depending on the source flux and background levels and the scientific purpose. Our techniques are also applicable to a wealth of other Herschel solar system photometric observations, e.g. comets and near-Earth asteroids. The principles of our observing strategies and reduction techniques for moving targets will also be applicable for similar surveys of future infrared space projects.

To appear in: Experimental Astronomy
For preprints, contact `pkisscs@konkoly.hu`
or on the web at `http://arxiv.org/abs/1309.4212`

JOB ANNOUNCEMENTS

Postdoctoral Research Associate
National Research Council of Canada

The NRC Herzberg Astronomy and Astrophysics Program (NRC Herzberg) requires a Postdoctoral Research Associate (RA) at the Dominion Astrophysical Observatory (DAO) in Victoria, BC. The successful candidate will be an outstanding recent doctoral graduate in astrophysics or a closely related discipline who is highly motivated to contribute to projects led by NRC Herzberg staff members and exploiting facilities administered by NRC for Canadian astronomers.
The successful candidate will:

- Work independently and perform original research in collaboration with NRC Herzberg staff members associated with the projects that are most relevant to the applicant's area of expertise; in particular, he/she will help lead the scientific exploitation of projects that utilize the astronomical facilities and infrastructure whose Canadian access is administered by NRC-Herzberg, including:

    1. High contrast imaging of exoplanets and debris disks (Principal contact: Christian Marois)
    2. Characterization and multi-wavelength observations of Kuiper Belt Objects (Principal contact: JJ Kavelaars)
    3. Study of planet or star formation processes (Principal contact: Brenda Matthews)
    4. Resolved stellar population analysis of the Galaxy and its nearest neighbours (Principal contact: Alan McConnachie)
    5. Scientific exploitation of data taken as part of the Next Generation Virgo Cluster Survey (NGVS) (Principal contact: Laura Ferrarese)

- Keep an active engagement with the community to advance NRC Herzberg's mandate. In particular, NRC Herzberg is a leading developer of instrumentation for ground and space-based telescopes (e.g., ALMA, CFHT, Gemini, JCMT, JWST, SKA, TMT), and is at the forefront of scientific data preservation, distribution and analysis techniques. The CADC, which is home to the Canadian Virtual Observatory, the CANFAR cloud computing network, and data archives including, e.g., CFHT, CGPS, Gemini, HST and JCMT, is also located at NRC Herzberg.

- Share with other RAs the organization of the weekly seminar series which runs September–April

Applicants must have acquired their PhD within the last five years or expect to receive the degree within the next 6 months.
Applications should be made by 17 February 2014 via the process described at the URL provided.
Further project information available at : `http://tinyurl.com/p5em7ya`
Closing date: 17 February

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`