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DISTANT EKOs

The Kuiper Belt Electronic Newsletter

Edited by: Joel Wm. Parker

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CONTENTS

NEWS & ANNOUNCEMENTS

The *Distant EKOs Newsletter* just broke the 500 subscriber mark, with readers from at least 35 countries. It has been running for 13 years with 78 issues (coincidentally the 100th issue should come out when New Horizons flies past Pluto). Thanks to all of you for your interest and submissions.

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There were 21 new TNO discoveries announced since the previous issue of *Distant EKOs*:

2009 DK143, 2009 DL143, 2009 DN143, 2009 DO143, 2009 DP143, 2009 DQ143, 2009 DR143, 2009 DS143, 2009 DT143, 2009 JA19, 2009 JB19, 2009 JD19, 2009 JE19, 2009 JF19, 2009 JT18, 2009 JV18, 2009 JW18, 2009 KT36, 2009 KU36, 2009 KV36, 2009 KW36

and 14 new Centaur/SDO discoveries:

2009 DJ143, 2009 DM143, 2009 JC19, 2009 JU18, 2009 JX18, 2009 JY18, 2009 JZ18, 2009 KA37, 2009 KX36, 2009 KY36, 2009 KZ36, 2011 SR250, 2011 UD63, 2011 WR74

Objects recently assigned numbers:

2005 QU182 = (303775)
2008 QY40 = (305543)
2005 PR21 = (303712)
2006 XQ51 = (309139)
2007 RW10 = (309239)
2008 SJ236 = (309737)
2008 UZ6 = (309741)
2010 KR59 = (310071)
2004 PG115 = (307982)
2006 SQ372 = (308933)
2001 KQ77 = (306792)
2002 KW14 = (307251)
2002 MS4 = (307261)
2002 VU130 = (307463)
2003 QW90 = (307616)
2005 CB79 = (308193)
2005 RS43 = (308379)
2005 SC278 = (308460)
2005 XU100 = (308634)

Deleted/Re-identified objects:

1999 TZ1
2008 HG67
2000 SN331

Current number of TNOs: 1248 (including Pluto)
Current number of Centaurs/SDOs: 333
Current number of Neptune Trojans: 8

Out of a total of 1589 objects:
- 641 have measurements from only one opposition
  - 619 of those have had no measurements for more than a year
    - 315 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

Integral-field Spectroscopy of (90482) Orcus-Vanth

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We seek to constrain the surface composition of the Trans-Neptunian Object (90482) Orcus and its small satellite Vanth, as well as their mass and density.

We acquired near-infrared spectra (1.4–2.4 μm) of (90482) Orcus and its companion Vanth using the adaptive-optics-fed integral-field spectrograph SINFONI mounted on Yepun/UT4 at the European Southern Observatory Very Large Telescope. We took advantage of a very favorable appulse (separation of only 4") between Orcus and the UCAC2 29643541 star ($m_R = 11.6$) to use the adaptive optics mode of SINFONI, allowing both components to be spatially resolved and Vanth colors to be extracted independently from Orcus.

The spectrum of Orcus we obtain has the highest signal-to-noise ratio to date, and we confirm the presence of H_2O ice in crystalline form, together with the presence of an absorption band at 2.2 μm. We set an upper limit of about 2% for the presence of methane, and 5% for ethane. Because the methane alone cannot account for the 2.2 μm band, the presence of ammonia is suggested to the level of a couple of percent. The colors of Vanth are found slightly redder than those of Orcus, but the large measurement uncertainties forbid us from drawing conclusions on the origin of the pair (capture or co-formation). Finally, we reset the orbital phase of Vanth around Orcus, and confirm the orbital parameters derived by Brown et al. (2010, AJ 139).

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For preprints, contact `benoit.carry@esa.int`
or on the web at `http://benoit.carry.free.fr/science/article/2011-AA-534-Carry.pdf`

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2007 TY430: A Cold Classical Kuiper Belt Type Binary in the Plutino Population

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Kuiper Belt object 2007 TY430 is the first wide, equal-sized, binary known in the 3:2 mean motion resonance with Neptune. The two components have a maximum separation of about 1 arcsecond and are on average less than 0.1 magnitudes different in apparent magnitude with identical ultra-red colors ($g-i = 1.49 \pm 0.01$ mags). Using nearly monthly observations of 2007 TY430 from 2007–2011, the orbit of the mutual components was found to have a period of 961.2 ± 4.6 days with a semi-major axis of 21000 ± 160 km and eccentricity of 0.1529 ± 0.0028. The inclination with respect to the ecliptic is 15.68 ± 0.22 degrees and extensive observations have allowed the mirror orbit to be eliminated as a possibility. The total mass for the binary system was found to be $7.90 \pm 0.21 \times 10^{17}$ kg. Equal-sized, wide binaries and ultra-red colors are common in the low inclination "cold" classical part of the Kuiper Belt and likely formed through some sort of three body interactions within a much denser Kuiper Belt. To date 2007 TY430 is the only ultra-red, equal-sized binary known outside of the classical Kuiper belt population. Numerical simulations suggest 2007 TY430 is moderately unstable in the outer part of the 3:2 resonance and thus 2007 TY430 is likely an escaped "cold" classical object that later got trapped in the 3:2 resonance. Similar to the known equal-sized, wide binaries in the cold classical population, the binary 2007 TY430 requires a high albedo and very low density structure to obtain the total mass found for the pair. For a realistic minimum density of 0.5 g/cm^3 the albedo of 2007 TY430 would be greater than 0.17. For reasonable densities, the radii of either component should be less than 60 km, and thus the relatively low eccentricity of the binary is interesting since no tides should be operating on the bodies at their large distances from each other. The low prograde inclination of the binary also makes it unlikely the Kozai mechanism could have altered the orbit, making the 2007 TY430 binary orbit likely one of the few relatively unaltered primordial binary orbits known. Under some binary formation models, the low inclination prograde orbit of the 2007 TY430 binary indicates formation within a relatively high velocity regime in the Kuiper Belt.

To appear in: The Astronomical Journal

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Collisional Evolution of Ultra-Wide Trans-Neptunian Binaries

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The widely-separated, near-equal mass binaries hosted by the cold Classical Kuiper Belt are delicately bound and subject to disruption by many perturbing processes. We use analytical arguments and numerical simulations to determine their collisional lifetimes given various impactor size distributions, and include the effects of mass-loss and multiple impacts over the lifetime of each system. These collisional lifetimes constrain the population of small ($R \gtrsim 1$ km) objects currently residing in the Kuiper Belt, and confirm that the size distribution slope at small size cannot be excessively steep

— likely $q \lesssim 3.5$. We track mutual semi-major axis, inclination, and eccentricity evolution through our simulations, and show that it is unlikely that the wide binary population represents an evolved tail of the primordially-tight binary population. We find that if the wide binaries are a collisionally-eroded population, their primordial mutual orbit planes must have preferred to lie in the plane of the solar system. Finally, we find that current limits on the size distribution at small radii remain high enough that the prospect of detecting dust-producing collisions in real-time in the Kuiper Belt with future optical surveys is feasible.

To appear in: The Astrophysical Journal
For preprints, contact alexhp@uvic.ca
or on the web at http://arxiv.org/abs/1111.2046

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The Origin of TNO 2004 XR190 as a Primordial Scattered Object

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Numerical integrations of the equations of motion of the giant planets and scattering particles show that there is a possible orbital itinerary that a particle may follow from a scattering mode up to a stable position near the orbit of 2004 XR190. This orbital evolution requires that the particle gets trapped in a mean motion resonance with Neptune coupled with the Kozai resonance. Imposing migration on Neptune while a particle is experiencing both resonances can entail an escape from resonance at a low particle's eccentricity. This eccentricity and the associated inclination are always similar to those of 2004 XR190. I conclude that 2004 XR190 was most likely a scattered object that went through those resonance processes and was eventually deposited at its current position. By the same argument, it is expected that there must exist several other objects with similar semimajor axis, eccentricity and inclination as those of 2004 XR190.

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For preprints, contact rodney@on.br

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Dynamically Excited Outer Solar System Objects in the Hubble Space Telescope Archive

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We present the faintest mid ecliptic latitude survey in the second part of HST archival search for outer Solar System bodies. We report the discovery of 28 new trans-Neptunian objects and 1 small centaur ($R \sim 2$ km) in the band $5° - 20°$ off the ecliptic. The inclination distribution of these excited objects is consistent with the distribution derived from brighter ecliptic surveys. We suggest that the size and inclination distribution should be estimated consistently using suitable surveys with calibrated search algorithms and reliable orbital information.

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For preprints, contact cesar.i.fuentes@nau.edu
or on the web at http://arxiv.org/abs/1108.5213

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An Oort Cloud Origin for the High-inclination, High-perihelion Centaurs

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We analyse the origin of three Centaurs with perihelia in the range 15 AU to 30 AU, inclinations above 70° and semi-major axes shorter than 100 AU. Based on long-term numerical simulations we conclude that these objects most likely originate from the Oort cloud rather than the Kuiper Belt or Scattered Disc. We estimate that there are currently between 1 and 200 of these high-inclination, high-perihelion Centaurs with absolute magnitude $H < 8$.

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For preprints, contact `brasser_astro@yahoo.com`
or on the web at `http://arxiv.org/abs/1111.7037`

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Neptune on Tiptoes: Dynamical Histories that Preserve the Cold Classical Kuiper Belt

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The current dynamical structure of the Kuiper belt was shaped by the orbital evolution of the giant planets, especially Neptune, during the era following planet formation, when the giant planets may have undergone planet-planet scattering and/or planetesimal-driven migration. Numerical simulations of this process, while reproducing many properties of the belt, fail to generate the high inclinations and eccentricities observed for some objects while maintaining the observed dynamically "cold" population. We present the first of a three-part parameter study of how different dynamical histories of Neptune sculpt the planetesimal disk. Here we identify which dynamical histories allow an *in situ* planetesimal disk to remain dynamically cold, becoming today's cold Kuiper belt population. We find that if Neptune undergoes a period of elevated eccentricity and/or inclination, it secularly excites the eccentricities and inclinations of the planetesimal disk. We demonstrate that there are several well-defined regimes for this secular excitation, depending on the relative timescales of Neptune's migration, the damping of Neptune's orbital inclination and/or eccentricity, and the secular evolution of the planetesimals. We model this secular excitation analytically in each regime, allowing for a thorough exploration of parameter space. Neptune's eccentricity and inclination can remain high for a limited amount of time without disrupting the cold classical belt. In the regime of slow damping and slow migration, if Neptune is located (for example) at 20 AU, then its eccentricity must stay below 0.18 and its inclination below 6°.

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For preprints, contact `rdawson@cfa.harvard.edu`
or on the web at `http://arxiv.org/abs/1112.1954`

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Late Orbital Instabilities in the Outer Planets Induced by Interaction with a Self-gravitating Planetesimal Disk

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We revisit the issue of the cause of the dynamical instability during the so-called *Nice model*, which describes the early dynamical evolution of the giant planets (Tsiganis et al. 2005, Gomes et al. 2005). In particular, we address the problem of the interaction of planets with a distant planetesimal disk in the time interval between the dispersal of the proto-solar nebula and the instability. In contrast to previous works, we assume that the inner edge of the planetesimal disk is several AUs beyond the orbit of the outermost planet, so that no close encounters between planets and planetesimals occur. Moreover, we model the disk's viscous stirring, induced by the presence of embedded Pluto-sized objects. The four outer planets are assumed to be initially locked in a multi-resonant state that most likely resulted from a preceding phase of gas-driven migration (Morbidelli et al. 2007). We show that viscous stirring leads to an irreversible exchange of energy between a planet and a planetesimal disk even in absence of close encounters between the planet and disk particles. The process is mainly driven by the most eccentric planet, which is the inner ice giant in the case studied here. If in isolation, this would cause this ice giant to migrate inward. However, because it is locked in resonance with Saturn, its eccentricity increases due to adiabatic invariance. During this process, the system crosses many weak secular resonances — many of which can disrupt the mean motion resonance and make the planetary system unstable. We argue that this basic dynamical process would work in many generic multi-resonant systems — forcing a good fraction of them to become unstable. Because the energy exchange proceeds at a very slow pace, the instability manifests itself late, on a time scale consistent with the epoch of the Late Heavy Bombardment (LHB, ~ 700 My). In the migration mechanism presented here, the instability time is much less sensitive to the properties of the planetesimal disk (particularly the location of its inner edge) than in the classic Nice-model mechanism.

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Adding Particle Collisions to the Formation of Asteroids and Kuiper Belt Objects via Streaming Instabilities

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Modelling the formation of super-km-sized planetesimals by gravitational collapse of regions over-dense in small particles requires numerical algorithms capable of handling simultaneously hydrodynamics, particle dynamics and particle collisions. While the initial phases of radial contraction are dictated by drag forces and gravity, particle collisions become gradually more significant as filaments contract beyond Roche density. Here we present a new numerical algorithm for treating momentum and energy exchange in collisions between numerical superparticles representing a high number of physical particles. We adopt a Monte Carlo approach where superparticle pairs in a grid cell collide statistically on the physical collision time-scale. Collisions occur by enlarging particles until they touch and solving for the collision outcome, accounting for energy dissipation in inelastic collisions. We demonstrate that superparticle collisions can be consistently implemented at a modest computational cost. In protoplanetary disc turbulence driven by the streaming instability, we argue that the relative Keplerian shear velocity should be subtracted during the collision calculation. If it is not subtracted, density inhomogeneities are too rapidly diffused away, as bloated particles exaggerate collision speeds. Local particle densities reach several thousand times the mid-plane gas density. We find efficient formation of gravitationally bound clumps, with a range of masses corresponding to contracted radii from 100 to 400 km when applied to the asteroid belt and 150 to 730 km when applied to the Kuiper belt, extrapolated using a constant self-gravity parameter. The smaller planetesimals are not observed at low resolution, but the masses of the largest planetesimals are relatively independent of resolution and treatment of collisions.

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For preprints, contact anders@astro.lu.se
or on the web at http://arxiv.org/abs/1111.0221

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Thermally Driven Escape from Pluto's Atmosphere: A Combined Fluid/Kinetic Model

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A combined fluid/kinetic model is developed to calculate thermally driven escape of N2 from Pluto's atmosphere for two solar heating conditions: no heating above 1450 km and solar minimum heating conditions. In the combined model, one-dimensional fluid equations are applied for the dense part of the atmosphere, while the exobase region is described by a kinetic model and calculated by the direct simulation Monte Carlo method. Fluid and kinetic parts of the model are iteratively solved in order to maintain constant total mass and energy fluxes through the simulation region. Although the atmosphere was found to be highly extended, with an exobase altitude at 6000 km at solar minimum, the outflow remained subsonic and the escape rate was within a factor of two of the Jeans rate for the exobase temperatures determined. This picture is drastically different from recent predictions obtained solely using a fluid model which, in itself, requires assumptions about atmospheric density, flow velocity and energy flux carried away by escaping molecules at infinity. Gas temperature, density, velocity and heat flux versus radial distance are consistent between the hydrodynamic and kinetic model up to the exobase, only when the energy flux across the lower boundary and escape rate used to solve the hydrodynamic equations is obtained from the kinetic model. This limits the applicability of fluid models to atmospheric escape problems. Finally, the recent discovery of CO at high altitudes, the effect of Charon and the conditions at the New Horizon encounter are briefly considered.

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For preprints, contact ojt9j@virginia.edu
or on the web at http://arxiv.org/abs/1111.2808

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A Pluto-Like Radius and a High Albedo for the Dwarf Planet Eris from an Occultation

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The dwarf planet Eris is a Trans-Neptunian Object (TNO) with an elongated orbit (eccentricity 0.44), a large inclination (44 degrees) relative to the ecliptic plane, and a surface composition very similar to Pluto. It presently resides at 95.7 astronomical units (1 AU is the Earth-Sun distance) from Earth, near its aphelion and more than three times farther than Pluto. Owing to this great distance, measuring its size or detecting a putative atmosphere is difficult. Here we report the observation of a multi-chord stellar occultation by Eris on November 6, 2010 UT. The event is consistent with a spherical shape for Eris, with radius $R_{\mathsf{E}} = 1,163 \pm 6$ km, density $\rho = 2.52 \pm 0.05$ g cm^{-3} and a high visible geometric albedo $p_{\mathsf{V}} = 0.96^{+0.09}_{-0.04}$. No nitrogen, argon or methane atmospheres are detected with surface pressure larger than $\sim$1 nbar, about 10,000 times more tenuous than Pluto's present atmosphere. As Pluto's radius is estimated between 1,150 and 1,200 km, Eris appears as a Pluto-twin, with a bright surface possibly caused by a collapsed atmosphere, owing to its cold environment. We anticipate that this atmosphere may periodically sublimate as Eris approaches its perihelion, at 37.8 AU from the Sun.

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For preprints, contact `Bruno.Sicardy@obspm.fr`

PAPERS RECENTLY SUBMITTED TO JOURNALS

Neptune's Wild Days: Constraints from the Eccentricity Distribution of the Classical Kuiper Belt

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THESES

Ultra-Wide Trans-Neptunian Binaries: Tracers of the Outer Solar System's History

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Ultra-wide Trans-Neptunian Binaries (TNBs) are extremely sensitive to perturbation, and therefore make excellent probes of the past and present dynamical environment of the outer Solar System. Using data gathered from a host of facilities we have determined the mutual orbits for a sample of seven wide TNBs whose periods exceed one year. This characterized sample provides us with new information about the probable formation scenarios of TNBs, and has significant implications for the early dynamical and collisional history of the Kuiper Belt. We show that these wide binaries have short collisional lifetimes, and use them to produce a new estimate of the number of small (∼1 km) objects in the Kuiper Belt. Additionally, these systems are susceptible to tidal disruption, and we show that it is unlikely that they were ever subjected to a period of close encounters with the giant planets. We find that the current properties of these ultra-wide Trans-Neptunian Binaries suggest that planetesimal growth in the Cold Classical Kuiper Belt did not occur through slow hierarchical accretion, but rather through rapid gravitational collapse.

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