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DISTANT EKOs

The Kuiper Belt Electronic Newsletter

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NEWS & ANNOUNCEMENTS

Dear Colleague,

We are pleased to announce that at the national ACS meeting in Philadelphia, the ACS-PHYS division established a new Astrochemistry Subdivision. Astrochemistry is the study of the abundances and chemical reactions of atoms, molecules, and ions and how they interact with radiation in both gas and condensed phases in Solar Systems and in the Interstellar Medium. The new Subdivision provides an interdisciplinary "home" for individuals interested in this growing research area. In addition, the Subdivision contributes to PHYS Division programs in areas of special interest to Astrochemists.

We would like to invite you and the undergraduate students, graduate students, and postdoctoral fellows in your group to join the ACS Astrochemistry Subdivision to connect to an exciting research endeavor and to further promote the Astrochemistry Subdivision at (international) meetings, in your university, and in your department. Additional information on joining the Subdivision may be found at:

`http://www.chem.hawaii.edu/Bil301/ACSAstrochemistry.html`

`http://www.chem.hawaii.edu/Bil301/ACSAstrochemistryjoin.html`

An inaugural Astrochemistry Symposium will be held at the Fall ACS National Meeting in Indianapolis, IN, September 8-12, 2013.

Please also email us (`ralfk@hawaii.edu`, `asuits@chem.wayne.edu`, `mhg@cchem.berkeley.edu`) suggestions for forthcoming ACS Astrochemistry Symposia and nominations for officers for the Astrochemistry subdivision.

We would also like to thank those of you who supported the establishment of the Astrochemistry Subdivision! We hope that the new Subdivision will effectively serve this thriving scientific community.

Best regards,

Ralf Kaiser (Chair), Arthur Suits (Chair-Elect), Martin Head-Gordon (Vice-Chair)

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There were 6 new TNO discoveries announced since the previous issue of *Distant EKOs*:
2009 UF156, 2010 TP182, 2011 HZ102, 2011 JW31, 2011 JX31, 2011 JY31
and 4 new Centaur/SDO discoveries:
2012 GN12, 2012 UT68, 2012 UY174, 2012 VU85

Reclassified objects:
2012 VU85 (SDO → Centaur)

Objects recently assigned numbers:
2007 RG283 = (341275)
2007 TY430 = (341520)
2008 YB3 = (342842)
2009 QV38 = (346889)
2009 YF7 = (349933)

Deleted objects:
2012 QQ14

Current number of TNOs: 1258 (including Pluto)
Current number of Centaurs/SDOs: 359
Current number of Neptune Trojans: 9

Out of a total of 1626 objects:
640 have measurements from only one opposition
628 of those have had no measurements for more than a year
321 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 Hill Stability of Triple Minor Planets in the Solar System

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The triple asteroids and triple Kuiper belt objects (collectively called triple minor planets) in the Solar system are of particular interest to the scientific community since the discovery of the first triple asteroid system in 2004. In this paper, the Hill stability of the nine known triple minor planets in the Solar system is investigated. Seven of the systems are of large size ratio, that is, they consist of a larger primary and two moonlets, while the other two systems have components of comparable size. Each case is treated separately. For the triple minor planets that have large size ratio, the sufficient condition for Hill stability is expressed in a closed form. This is not possible for the systems with comparable size components, for which the Hill stability is assessed by a combination of analytical and numerical means. It is found that all the known triple minor planets are Hill stable, except 3749 Balam, for which the incomplete orbital parameters make the Hill stability of the system uncertain. This suggests that there might be more such stable triple minor planets in the Solar system yet to be observed. It is also shown that the Hill stability regions increase as the mutual inclination between the inner and outer orbits decreases, the semimajor axis ratio of the inner orbit with respect to the outer orbit decreases, and the mass ratio of the outer satellite with respect to the inner satellite increases. This study therefore provides useful information about dynamical properties of the triple minor planets in the Solar system.

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For preprints, contact `baoyin@tsinghua.edu.cn`

or on the web at `http://arxiv.org/abs/1211.4096`

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Plutino (15810) 1994 JR_1, an Accidental Quasi-satellite of Pluto

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In the Solar system, quasi-satellites move in a 1:1 mean motion resonance going around their host body like a retrograde satellite but their mutual separation is well beyond the Hill radius and the trajectory is not closed as they orbit the Sun, not the host body. Although they share the semi-major axis and the mean longitude of their host body, their eccentricity and inclination may be very different. So far, minor bodies temporarily trapped in the quasi-satellite dynamical state have been identified around Venus, the Earth, the dwarf planet (1) Ceres, the large asteroid (4) Vesta, Jupiter and Saturn. Using computer simulations, Tiscareno & Malhotra have predicted the existence of a small but significant population of minor bodies moving in a 1:1 mean motion resonance with Pluto. Here we show using N-body calculations that the plutino (15810) 1994 JR_1 is currently an accidental quasi-satellite of Pluto and it will remain as such for nearly 350,000 years. By accidental we mean that the quasi-satellite phase is triggered (or terminated) not by a direct gravitational influence in the form of a discrete close encounter, but as a result of a resonance. The relative mean longitude of the plutino (15810) 1994 JR_1 circulates with a superimposed libration resulting from the oscillation of the orbital period induced by the 2:3 mean motion resonance with

Neptune. These quasi-satellite episodes are recurrent with a periodicity of nearly 2 Myr. This makes the plutino (15810) 1994 JR_1 the first minor body moving in a 1:1 mean motion resonance with Pluto and the first quasi-satellite found in the trans-Neptunian region. It also makes Pluto the second dwarf planet, besides Ceres, to host a quasi-satellite. Our finding confirms that the quasi-satellite resonant phase is not restricted to small bodies orbiting major planets but is possible for dwarf planets/asteroids too. Moreover, the plutino (15810) 1994 JR_1 could be considered as a possible secondary target for NASA's Pluto-Kuiper Belt Mission New Horizons after the main Pluto flyby in 2015. This opens the possibility of studying at first hand and for the first time a minor body in the quasi-satellite dynamical state.

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Four Temporary Neptune Co-orbitals: (148975) 2001 XA_{255}, (310071) 2010 KR_{59}, (316179) 2010 EN_{65}, and 2012 GX_{17}

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Context. Numerical simulations suggest that Neptune primordial co-orbitals may significantly outnumber the equivalent population hosted by Jupiter, yet the objects remain elusive. Since the first discovery in 2001 just ten minor planets, including nine Trojans and one quasi-satellite, have been positively identified as Neptune co-orbitals. In contrast, Minor Planet Center (MPC) data indicate that more than 5000 objects are confirmed Jupiter co-orbitals. On the other hand, some simulations predict that a negligible fraction of passing bodies are captured into the 1:1 commensurability with Neptune today.

Aims. Hundreds of objects have been discovered in the outer solar system during the various wide-field surveys carried out during the past decade, and many of them have been classified using cuts in the pericentre and other orbital elements. This leads to possible misclassifications of resonant objects. Here, we explore this possibility to uncover neglected Neptune co-orbitals.

Methods. Using numerical analysis techniques, we singled out eleven candidates and used N-body calculations to either confirm or reject their co-orbital nature.

Results. We confirm that four objects previously classified as Centaurs by the MPC currently are temporary Neptune co-orbitals. (148975) 2001 XA_{255} is the most dynamically unstable of the four. It appears to be a relatively recent (50 kyr) visitor from the scattered disk on its way to the inner solar system. (310071) 2010 KR_{59} is following a complex horseshoe orbit, (316179) 2010 EN_{65} is in the process of switching from L_4 to L_5 Trojan, and 2012 GX_{17} is a promising L_5 Trojan candidate in urgent need of follow-up. The four objects move in highly inclined orbits and have high eccentricities. These dynamically hot objects are not primordial 1:1 librators, but are captured and likely originated from beyond Neptune, having entered the region of the giant planets relatively recently.

Conclusions. Casting doubt over claims by other authors, our results show that Neptune can still efficiently capture co-orbitals for short periods of time and that the cuts in the orbital elements are unreliable criteria to classify objects orbiting in the outer solar system. As in the case of Jupiter Trojans, our results suggests that Neptune's L_5 point is less stable than L_4, in this case perhaps due to the influence of Pluto.

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Albedo and Atmospheric Constraints of Dwarf Planet Makemake from a Stellar Occultation

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Pluto and Eris are icy dwarf planets with nearly identical sizes, comparable densities and similar surface compositions as revealed by spectroscopic studies. Pluto possesses an atmosphere whereas Eris does not; the difference probably arises from their differing distances from the Sun, and explains their different albedos. Makemake is another icy dwarf planet with a spectrum similar to Eris and Pluto, and is currently at a distance to the Sun intermediate between the two. Although Makemake's size (1,420±60 km) and albedo are roughly known, there has been no constraint on its density and there were expectations that it could have a Pluto-like atmosphere. Here we report the results from a stellar occultation by Makemake on 2011 April 23. Our preferred solution that fits the occultation chords corresponds to a body with projected axes of 1,430±9 km (1σ) and 1,502±45 km, implying a V-band geometric albedo p_v=0.77±0.03. This albedo is larger than that of Pluto, but smaller than that of Eris. The disappearances and reappearances of the star were abrupt, showing that Makemake has no global Pluto-like atmosphere at an upper limit of 4-12 nanobar (1σ) for the surface pressure, although a localized atmosphere is possible. A density of 1.7±0.3 g cm^{-3} is inferred from the data.

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For preprints, contact `ortiz@iaa.es`

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Measuring the Abundance of Sub-kilometer Sized Kuiper Belt Objects using Stellar Occultations

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We present here the analysis of about 19,500 new star hours of low ecliptic latitude observations ($|b| \leq 20^\circ$) obtained by the Hubble Space Telescope's Fine Guidance Sensors over a time span of more than nine years; which is an addition to the $\sim 12,000$ star hours previously analyzed by Schlichting et al. Our search for stellar occultations by small Kuiper belt objects (KBOs) yielded one new candidate event corresponding to a body with a 530 ± 70 m radius at a distance of about 40 AU. Using bootstrap simulations, we estimate a probability of $\approx 5\%$, that this event is due to random statistical fluctuations within the new data set. Combining this new event with the single KBO occultation reported by Schlichting et al. we arrive at the following results: 1) The ecliptic latitudes of 6.6° and 14.4° of the two events are consistent with the observed inclination distribution of larger, 100 km-sized KBOs. 2) Assuming that small, sub-km sized KBOs have the same ecliptic latitude distribution as their larger counterparts, we find an ecliptic surface density of KBOs with radii larger than 250 m of $N(r > 250\,m) = 1.1^{+1.5}_{-0.7} \times 10^7\,\mathrm{deg}^{-2}$; if sub-km sized KBOs have instead a uniform ecliptic latitude distribution for $-20^\circ < b < 20^\circ$ then $N(r > 250\,m) = 4.4^{+5.8}_{-2.8} \times 10^6\,\mathrm{deg}^{-2}$. This is the best measurement of the surface density of sub-km sized KBOs to date. 3) Assuming the KBO size distribution can be well described by a single power law given by $N(> r) \propto r^{1-q}$, where $N(> r)$ is

the number of KBOs with radii greater than r, and q is the power law index, we find $q = 3.8 \pm 0.2$ and $q = 3.6 \pm 0.2$ for a KBO ecliptic latitude distribution that follows the observed distribution for larger, 100-km sized KBOs and a uniform KBO ecliptic latitude distribution for $-20° < b < 20°$, respectively. 4) Regardless of the exact power law, our results suggest that small KBOs are numerous enough to satisfy the required supply rate for the Jupiter family comets. 5) We can rule out a single power law below the break with $q > 4.0$ at 2σ, confirming a strong deficit of sub-km sized KBOs compared to a population extrapolated from objects with $r > 45$ km. This suggests that small KBOs are undergoing collisional erosion and that the Kuiper belt is a true analogue to the dust producing debris disks observed around other stars.

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or on the web at http://iopscience.iop.org/0004-637X/761/2/150/

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Ground-based Exploration of the Outer Solar System by Serendipitous Stellar Occultations

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Serendipitous stellar occultation technique provides a powerful and unique tool to probe the outer Solar system matter, e.g. Kuiper disc and Oort cloud. We present the results of a serendipitous occultation observation campaign carried out with ULTRACAM, mounted on the ESO-VLT telescope, during 2005 May 17-20. The data are processed using the variability index (VI) method modified. The two-colour data set and the VI method allow searching for occulting objects in term of their distance (50, 200 and 5000 AU). The analysis of 34 star-hours provide a working data set for assessing an instrumental approach to search for occultation events by trans-Neptunian objects. We performed recovery tests by implanting synthetic profiles in the data and defining the size of detectable objects to achieve a detection rate of 100%. We propose a Fast Multi-Object Photometer (F-MOP) mounted on a 8-m class telescope and examine its performances. Such instrumental approach from the ground is able to exploit the occultation method for the exploration of the trans-Neptunian region, with a high efficiency.

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Search for Serendipitous TNO Occultation in X-rays

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To study the population properties of small, remote objects beyond Neptune's orbit in the outer solar system, of kilometer size or smaller, serendipitous occultation search is so far the only way. For hectometer-sized Trans-Neptunian Objects (TNOs), optical shadows actually disappear because of diffraction. Observations at shorter wave lengths are needed. Here we report the effort of TNO occultation search in X-rays using RXTE/PCA data of Sco X-1 taken from June 2007 to October 2011. No definite TNO occultation events were found in the 334 ks data. We investigate the detection efficiency dependence on the TNO size to better define the sensible size range of our approach and suggest upper limits to the TNO size distribution in the size range from 30 m to 300 m. A list of X-ray sources suitable for future larger facilities to observe is proposed.

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or online at http://arxiv.org/abs/1211.4650

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Surface Composition and Dynamical Evolution of Two Retrograde Objects in the Outer Solar System: 2008 YB_3 and 2005 VD

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Most of the objects in the trans-Neptunian belt (TNb) and related populations move in prograde orbits with low eccentricity and inclination. However, the list of icy minor bodies moving in orbits with an inclination above 40° has increased in the last years. The origin of these bodies, and in particular of those objects in retrograde orbits, is not well determined and different scenarios are considered, depending on their inclination and perihelion. In this paper we present new observational and dynamical data of two objects in retrograde orbits, 2008 YB_3 and 2005 VD. We find that the surface of these extreme objects is depleted of ices and does not contain the 'ultra-red' matter typical of some Centaurs. Despite small differences, these objects share common colors and spectral characteristics with the Trojans, comet nuclei and the group of grey Centaurs. All of these populations are supposed to be covered by a mantle of dust responsible for their reddish to neutral color. To investigate if the surface properties and dynamical evolution of these bodies are related we integrate their orbits for 10^8 years to the past. We find a remarkable difference in their dynamical evolutions: 2005 VD's evolution is dominated by a Kozai resonance with planet Jupiter while that of 2008 YB_3 is dominated by close encounters with planets Jupiter and Saturn. Our models suggest that the immediate site of provenance of 2005 VD is the in the Oort cloud whereas for 2008 YB_3 it is in the trans-Neptunian region. Additionally, the study of their residence-time shows that 2005 VD has spent a larger lapse of time moving in orbits in the region of the Giant Planets than 2008 YB_3. This fact, together with the small differences in color between these two objects, being 2005 VD more neutral than 2008 YB_3, suggest that the surface of 2005 VD has suffered a higher degree of processing probably related to cometary activity episodes.

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A Compositional Interpretation of Trans-neptunian Objects Taxonomies

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Trans-Neptunian Objects (TNOs) are a population of small objects orbiting the Sun beyond Neptune. Because of their distance they are difficult to observe spectroscopically, but a large body of photometric observations is available and growing. TNOs are important tracers of the evolution of the outer Solar System and key when testing current dynamical evolution theories. Previous statistical studies of the colors of TNOs have yielded useful but limited results regarding the chemical history and evolution of these bodies.

With the aim at obtaining compositional information on the small and distant TNOs we introduce a statistical cluster analysis (labelled *albedo*) based on colors and published albedos of TNOs. We compare it to a previous taxonomy, to illustrate the significance of including the albedo information when determining the composition of the objects. When the albedo contribution is removed from the data, the new taxonomy (now labelled *classical*) is in general agreement with the published ones, supporting the applicability of our approach. Making use of modeled reflectance spectra of a variety of plausible mixtures found on the surface of TNOs, we extract the average surface composition of each taxon, for both the *classical* and the *albedo* taxonomy, in a statistically consistent fashion.

Differently from previous and *classical*, the *albedo* taxonomy establishes a direct link between the colors and albedos of the objects and their surface composition, allowing, for the first time, a quick assessment of the chemical history of TNOs. In fact, under closer examination the taxa show trends in composition that might be evolutionary in nature. If a simple 'snow lines' model is adopted, we can infer that *albedo* taxa relate the current objects' locations to their original ones, prior to the migration of the outer planets. We regard the large population that characterizes the darkest classes spread at a variety of semi-major axis distances as one of the intriguing results of this work.

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For preprints, contact `Cristina.M.DalleOre@nasa.gov`

or online at `http://dx.doi.org/10.1016/j.icarus.2012.11.015`

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Possible Origin of the Damocloids: The Scattered Disk or a New Region?

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The Damocloids are a group of unusual asteroids that recently added a new member: 2010 EJ104. The dynamical evolution of the Damocloids may reveal a connection from the Main Belt to the Kuiper Belt and beyond the scattered disk. According to our simulations, two regions may be considered as possible origins of the Damocloids: the scattered disk, or a part of the Oort cloud, which will be perturbed to a transient region located between 700 AU and 1000 AU. Based on their potential origin, the Damocloids can be classified into two types, depending on their semi-major axes, and about 65.5% of the Damocloids are classified into type I which mainly originate from the Oort cloud. Whether the Damocloids are inactive nuclei of the Halley Family of Comets may depend on their origin.

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Discovery, Observational Data and the Orbit of the Centaur Asteroid 2012 DS85

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A project for astrometric and photometric observations of asteroids at Mt. Graham Observatory with the VATT telescope is described. One of the most important results is a discovery of the Centaur 2012 DS85. Astrometric and photometric data on the asteroid are presented. The orbit of the asteroid was computed from 67 observations. Combined with its apparent brightness, the orbit gives an absolute magnitude of 9.43. Using a typical albedo value of 0.08 for Centaurs and TNOs (Moullet et al. 2011), we get a diameter of 2012 DS85 at about 61 km.

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For preprints, contact `Kazimieras.Cernis@tfai.vu.lt`

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OSS (Outer Solar System): A Fundamental and Planetary Physics Mission to Neptune, Triton and the Kuiper Belt

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The present OSS (Outer Solar System) mission continues a long and bright tradition by associating the communities of fundamental physics and planetary sciences in a single mission with ambitious goals in both domains. OSS is an M-class mission to explore the Neptune system almost half a century after the flyby of the Voyager 2 spacecraft.

Several discoveries were made by Voyager 2, including the Great Dark Spot (which has now disappeared) and Triton's geysers. Voyager 2 revealed the dynamics of Neptune's atmosphere and found four rings and evidence of ring arcs above Neptune. Benefiting from a greatly improved instrumentation, a mission as OSS would result in a striking advance in the study of the farthest planet of the solar system. Furthermore, OSS would provide a unique opportunity to visit a selected Kuiper Belt object subsequent to the passage of the Neptunian system. OSS would help consolidate the hypothesis of the origin of Triton as a Kuiper Belt object captured by Neptune, and to improve our knowledge on the formation of the solar system.

The OSS probe would carry instruments allowing precise tracking of the spacecraft during the cruise. It would facilitate the best possible tests of the laws of gravity in deep space. These objectives are important for fundamental physics, as they test General Relativity, our current theoretical description of gravitation, but also for cosmology, astrophysics and planetary science, as General Relativity is used as a tool in all these domains. In particular, the models of solar system formation uses General Relativity to describe the crucial role of gravity.

OSS is proposed as an international cooperation between ESA and NASA, giving the capability for ESA to launch an M-class mission towards the farthest planet of the solar system, and to a Kuiper Belt object. The proposed mission profile would allow to deliver a 500 kg class spacecraft. The design of the probe is mainly constrained by the deep space gravity test in order to minimize the perturbation of the accelerometer measurement.

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OTHER PAPERS OF INTEREST

Comet-like Mineralogy of Olivine Crystals in an Extrasolar Proto-Kuiper Belt

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Nature, 490, 74 (2012 Oct 4)

Preprints on the web at `http://arxiv.org/abs/1211.2626`

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Can Residuals of the Solar System Foreground Explain Low Multipole Anomalies of the CMB?

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Journal of Cosmology and Astroparticle Physics, 10, 59 (2012 October)

Preprints on the web at `http://arxiv.org/abs/1206.6981`

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Improved Physical Properties Database of Trans-Neptunian Dwarf Planets

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For preprints, contact yrogozin@gmail.com
or online at http://arxiv.org/abs/1210.3052

THESES

A Search for Volatile Ices on the Surfaces of Cold Classical Kuiper Belt Objects

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The surprisingly complex dynamical distribution of small bodies among and beyond the orbits of the planets has changed our understanding of Solar System evolution and planetary migration. Compositional information about the small bodies in the Solar System provides constraints for models of Solar System formation. According to most models, the Kuiper Belt population known as the cold classicals formed at distances far enough from the Sun for these objects to be composed of an appreciable fraction of volatile ices of diverse composition (H_2O, CO_2, CH_4, light hydrocarbons, e.g. CH_3OH) and their orbits have remained stable. Cold classical objects should still be volatile rich. Broadband data from the *Spitzer Space Telescope* Infrared Array Camera (IRAC) can detect and distinguish between absorptions of relevant ices in the 3-5 μm infrared region. Of the 46 cold classical Kuiper Belt Objects in this study, 35 (78%) objects' surfaces exhibit absorptions from ices or organics in IRAC channel 1 (3.6 μm). The combination of data from IRAC channels 1 and 2 (4.5 μm) provides gross surface composition for six objects with secure observations in both channels. These six objects are observed to have ices or organics on their surfaces; this is the first detection of ices on four of these objects. The surface of 20000 Varuna contains organic material. The surface of 50000 Quaoar is confirmed to be rich in water ice. The surface composition of 19521 Chaos is mixed ice and organics. Mixed ices, with a high fraction of water ice, and other components are on the surface of (119951) 2002 KX14. The surface of 66652 Borasisi is methane rich. Methanol or light hydrocarbons are on the surface of (138537) 2000 OK67. Cold classical objects are found to be volatile rich and of diverse surface composition. The presence of ices and organics indicate these objects formed far from the Sun.

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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.

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