Issue No. 6 *July 1999*

DISTANT EKOs

The Kuiper Belt Electronic Newsletter

Edited by: Joel Wm. Parker

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

CONTENTS

NEWS & ANNOUNCEMENTS

Well, in some form of historical revisionism, the number of objects found in 1998 continues to climb, and in mid-May temporarily surpassed the number of objects found so far in 1999. Similarly, "new" objects from as far back as 1995 are being reported.

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The scattered disk is finally making a stronger appearance. New discoveries and revised orbital elements for some objects discovered earlier this year now puts the list of assumed SDOs at five:

Object	a	e	i
1996 TL66	85	0.59	24
1999 CF119	115	0.69	20
1999 CV118	57	0.39	6
1999 CY118	95	0.64	26
1999 DG8	82	0.60	40

Note in particular the impressive semi-major axis for 1999 CF119, the new record-holder. Also, 1998 DG8 was discovered at a heliocentric distance of 61 AU; as quoted in M.P.E.C. 1999-M30, "it is clear that 1999 DG8 was being observed at a distance that is substantially greater than that at which any other solar-system object has been observed."

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A feature characteristic of water ice has been detected in a spectrum of 1996 TO66. The abstract for that ApJ article is in this issue.

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Request for Collaboration: Joel Parker has a number of observing runs in the following semester for recoveries of EKOs and Centaurs. Dates are: August 5–6, September 16–17, November 29–30, and December 27–30. If you are interested in coordinating with him for followup observations of newly discovered objects or contemporaneous observations (e.g., lightcurves or visible-IR colors), please contact him at: `joel@boulder.swri.edu` or by phone at 303-546-0265.

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There were 38 new EKO discoveries announced since the previous issue of the *Distant EKOs* Newsletter:
1995 SM55, 1995 TL8, 1996 GQ21, 1996 TC68, 1998 HJ151, 1998 HK151, 1998 HL151, 1998 HM151, 1998 HN151, 1998 HO151, 1998 HP151, 1998 HQ151, 1998 HR151, 1998 SM165, 1999 DB8, 1999 DC8, 1999 HA12, 1999 HB12, 1999 HC12, 1999 HR11, 1999 HS11, 1999 HT11, 1999 HU11, 1999 HV11, 1999 HW11, 1999 HX11, 1999 HY11, 1999 HZ11, 1999 DD8, 1999 DE8, 1999 DF8, 1999 DG8, 1999 JA132, 1999 JB132, 1999 JC132, 1999 JD132, 1999 JE132, 1999 JF132

and 5 new Centaur discoveries:
1995 SN55, 1998 BU48, 1998 TF35, 1999 HD12, 1999 JV127

Current number of EKOs: 174 (and Pluto & Charon)
Current number of Centaurs: 14

PAPERS ACCEPTED TO JOURNALS

Water Ice on Kuiper Belt Object 1996 TO_{66}

Robert H. Brown[1], **Dale P. Cruikshank**[2], **& Yvonne Pendleton**[3]

[1] Lunar and Planetary Laboratory and Steward Observatory, University of Arizona, Tucson, AZ 85721
[2] Mail Stop N245-6, NASA/Ames Research Center, Moffett Field, CA 94035
[3] Mail Stop N245-3, NASA/Ames Research Center, Moffett Field, CA 94035

The 1.40–2.45 μm spectrum of Kuiper Belt object 1996 TO_{66} was measured at the Keck Observatory in 1998 September. Its spectrum shows the strong absorptions near 1.5 and 2.0 μm that are characteristic of water ice—the first such detection on a Kuiper Belt object. The depth of the absorption bands and the continuum reflectance of 1996 TO_{66} suggest the presence of a black- to slightly blue-colored, spectrally featureless particulate material as a minority component mixed with the water ice. In addition, there is evidence that the intensity of the water bands in the spectrum of 1996 TO_{66} varies with rotational phase, suggesting a "patchy" surface.

Published in: The Astrophysical Journal, 519, L101
For preprints, contact `rhb@abante.lpl.arizona.edu`

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Evolution of Orbits at the 2:3 Resonance with Neptune

S.I. Ipatov[1] **and J. Henrard**[2]

[1] Institute of Applied Mathematics, Miusskaya sq. 4, Moscow 125047, Russia
[2] Deptartement de Mathematique, Facultes Universitaires Notre-Dame de la Paris, Rempart de la Vierge 8, B-5000, Namur, Belgium

Results of numerical investigations of the evolution of orbits at the 2:3 resonance with Neptune are presented. The gravitational influence of four giant planets was taken into account. For identical initial values of semimajor axes, eccentricities and inclinations but for different initial orbital orientations and initial positions in orbits, we obtained various types of variations in the difference $\Delta\Omega = \Omega - \Omega_N$ in the longitudes of the ascending node of the body and Neptune and the argument of perihelion ω. If $\Delta\Omega$ decreases and ω increases during evolution, then most of bodies leaves the resonance in 20 Myr. In the case of an increase of $\Delta\Omega$ and a decrease of ω, bodies stay in the resonance for much longer time. Regions of eccentricities and inclinations, for which some bodies were in the η_{18} secular resonance ($\Delta\Omega \approx$ const) and the Kozai resonance ($\omega \approx$ const) were obtained to be larger than those predicted for small variations in the critical angle. Some bodies can be at the same time in both these resonances.

To appear in: Solar System Research, No. 4, 1999
For preprints, contact `ipatov@spp.keldysh.ru`

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Migration of Trans-Neptunian Objects to The Earth

Sergei I. Ipatov[1]

[1] Institute of Applied Mathematics, Miusskaya sq. 4, Moscow 125047, Russia

Migration of trans-Neptunian objects under their mutual gravitation influence and the influence of the giant planets is investigated. These investigations are based on computer simulation results and on some formulas. We estimated that about 20% of near-Earth objects with diameter $d \geq 1$ km may have come from the Edgeworth-Kuiper belt.

To appear in: Celest. Mech. & Dyn. Astronomy, in press
For preprints, contact `ipatov@spp.keldysh.ru`

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Keck Pencil-beam Survey For Faint Kuiper Belt Objects

E. I. Chiang[1] **and M. E. Brown**[1]

[1] California Institute of Technology

We present the results of a pencil-beam survey of the Kuiper Belt using the Keck 10-m telescope. A single 0.01 square degree field is imaged 29 times for a total integration time of 4.8 hr. Combining exposures in software allows the detection of Kuiper Belt Objects (KBOs) having visual magnitude $m_V \leq 27.9$. Two new KBOs are discovered. One object having $m_V = 25.5$ lies at a probable heliocentric distance $R \approx 33$ AU. The second object at $m_V = 27.2$ is located at $R \approx 44$ AU. Both KBOs have diameters of about 50 km, assuming comet-like albedos of 4%.

Data from all surveys are pooled to construct the luminosity function from $m_R = 20$ to 27. The cumulative number of objects per square degree, $\Sigma(< m_R)$, is fitted to a power law of the form $\log_{10} \Sigma = \alpha(m_R - 23.5)$, where the slope $\alpha = 0.52 \pm 0.02$. Differences between slopes reported in the literature are due mainly to which survey data are incorporated in the fit, and not to the method of analysis. The luminosity function is consistent with a power-law size distribution for objects having diameters $s = 50$–500 km; $dN \propto s^{-q}\, ds$, where the differential size index $q = 3.6 \pm 0.1$. The distribution is such that the smallest objects possess most of the surface area, but the largest bodies contain the bulk of the mass. We estimate to order-of-magnitude that $0.2 M_\oplus$ and 1×10^{10} comet progenitors lie between 30 and 50 AU. Though our inferred size index nearly matches that derived by Dohnanyi (1969), it is unknown whether catastrophic collisions are responsible for shaping the size distribution. Impact strengths may increase strongly with size from 50 to 500 km, whereas the derivation by Dohnanyi (1969) assumes impact strength to be independent of size. In the present-day Belt, collisional lifetimes of KBOs having diameters 50–500 km exceed the age of the Solar System by at least 2 orders of magnitude, assuming bodies consist of solid, cohesive rock. Implications of the absence of detections of classical KBOs beyond 50 AU are discussed.

To appear in: Astronomical Journal, September 1999
For preprints, contact `echiang@tapir.caltech.edu`
or on the web at `www.its.caltech.edu/~eugene/ppp/ppp.html`

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Accretion in the Early Outer Solar System

Scott J. Kenyon[1] **and Jane X. Luu**[2]

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[2] Leiden Observatory, PO Box 9513, 2300 RA Leiden, The Netherlands

We describe calculations of the evolution of an ensemble of small planetesimals in the outer solar system. In a solar nebula with a mass of several times the Minimum Mass Solar Nebula, objects with radii of 100-1000 km can form on timescales of 10-100 Myr. Model luminosity functions derived from these calculations agree with current observations of bodies beyond the orbit of Neptune (Kuiper Belt objects). New surveys with current and planned instruments can place better constraints on the mass and dynamics of the solar nebula by measuring the luminosity function at red magnitudes $m_R \geq 28$.

To appear in: Astrophysical Journal
E-mail contact: `skenyon@cfa.harvard.edu`
Preprints on the web at: `http://xxx.lanl.gov/abs/astro-ph/9906143`

PAPERS RECENTLY SUBMITTED TO JOURNALS

Uranus and Neptune: Refugees from the Jupiter-Saturn Zone?

Edward W. Thommes[1], **Martin J. Duncan**[1], **& Harold F. Levison**[2]

[1]Department of Physics, Queen's University, Kingston, Ontario, Canada K7L 3N6

[2]Space Studies Department, Southwest Research Institute, Boulder, CO 80302

Submitted to: Nature
E-mail contact: `thommes@astro.queensu.ca`

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Near-Infrared Spectroscopy of Centaurs and Irregular Satellites

Michael E. Brown[1]

[1]Division of Geological and Planetary Sciences, California Institute of Technology

Submitted to: The Astronomical Journal
Preprints on the web at `www.gps.caltech.edu/~mbrown/papers/pubs.html`

CONFERENCE CONTRIBUTIONS

On-line preprints of all the chapters in the Protostars and Planets IV conference proceedings book can now be downloaded from:

`http://astro.caltech.edu/ vgm/ppiv/`

The book is divided into the following eight sections:

1. Molecular Clouds and Star Formation
2. Circumstellar Envelopes and Disks
3. Young Binaries
4. Jets and Outflows
5. Early Solar System and Planet Formation
6. Comets and The Kuiper Belt
7. Extrasolar Planets and Brown Dwarfs
8. Initial Conditions for Astrobiology

Below are the abstracts of three articles regarding the Kuiper Belt.

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Physical Nature of The Kuiper Belt

David Jewitt[1] **and Jane Luu**[2]

[1] Institute for Astronomy, University of Hawaii
[2] Sterrewacht, Leiden University

Recent ground-based observations have unveiled a large number of bodies in orbit beyond Neptune, in a region now widely known as the Kuiper (or, less commonly, Edgeworth-Kuiper) Belt. About 10^5 Kuiper Belt Objects (KBOs) with diameters larger than 100 km exist in the 30 AU to 50 AU trans-Neptunian region. Their combined mass is about 10% of that of Earth. The orbits of KBOs fall into at least three distinct dynamical classes (the "Classical" objects, the Plutinos and the "Scattered" objects). Each throws light on physical processes operating in the solar system prior to and during the formation of the planets. The Kuiper Belt is significant both as the likely source of the short-period comets (and the dynamically intermediate Centaurs), and as a repository of the solar system's most primitive (least thermally processed) material. KBOs show an unexpected and presently unexplained diversity of surface colors, possibly reflecting intrinsic compositional variations and transient resurfacing by impacts. The present-day Kuiper Belt is probably the surviving remnant of a once much more massive ($10M_\oplus$?) preplanetary disk. It is very likely that collisions and disk-planet interactions played a major role in shaping this early precursor. While the collisional production of dust is presently modest ($\sim 10^3$ kg s^{-1}), and the optical depth small ($\sim 10^{-7}$), the early Belt was probably very dusty and may have sustained a disk analogous to those reported around some nearby main-sequence stars.

To appear in: Protostars and Planets IV, University of Arizona Press
Preprints available on the web at `www.ifa.hawaii.edu/faculty/jewitt/papers/PPIV`

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Dynamics of The Kuiper Belt

R. Malhotra[1], M. Duncan[2], and H. Levison[3]

[1] Lunar and Planetary Institute
[2] Queen's University
[3] Southwest Research Institute

Our current knowledge of the dynamical structure of the Kuiper Belt is reviewed here. Numerical results on long term orbital evolution and dynamical mechanisms underlying the transport of objects out of the Kuiper Belt are discussed. Scenarios about the origin of the highly non-uniform orbital distribution of Kuiper Belt objects are described, as well as the constraints these provide on the formation and long term dynamical evolution of the outer Solar system. Possible mechanisms include an early history of orbital migration of the outer planets, a mass loss phase in the outer Solar system and scattering by large planetesimals. The origin and dynamics of the scattered component of the Kuiper Belt is discussed. Inferences about the primordial mass distribution in the trans-Neptune region are reviewed. Outstanding questions about Kuiper Belt dynamics are listed.

To appear in: Protostars and Planets IV, University of Arizona Press
For preprints, contact `renu@lpi.jsc.nasa.gov`
or on the web at `http://xxx.lanl.gov/ps/astro-ph/9901155`

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Formation and Collisional Evolution of The Edgeworth-Kuiper Belt

Paolo Farinella[1], Donald R. Davis[2], and S. Alan Stern[3]

[1] Department of Astronomy, University of Trieste, Italy
[2] Planetary Science Institute, Tucson, USA
[3] Southwest Research Institute, Boulder, USA

We provide a summary of current research concerning the formation and the collisional history of the Edgeworth-Kuiper belt. Collisions appear to have first built up sizable (up to Pluto-sized) bodies in a primordial, massive planetesimal population. Then, following the formation of Neptune, collisional grinding has been eroding the population at diameters smaller than about 100 km, at a variable extent depending on heliocentric distance. In both phases collisional evolution has interacted in a complex way with a variety of subtle dynamical processes, and this interplay has been responsible for stopping accretion and for ejecting bodies (including the currently observed Jupiter-family comets) from the stable regions of orbital element space. We compare the properties and history of the transneptunian belt to those of main–belt and Trojan asteroids, and discuss the recent evidence for similar disks of planetesimals and debris around both newly-formed and main-sequence stars.

To appear in: Protostars and Planets IV, University of Arizona Press
Preprints available on the web at `http://astro.caltech.edu/~vgm/ppiv/preprints.html`

BOOKS

This is a contents of a book which is in press in Russian. The publication of the book was in the plan for 1998, but as the Russian Foundation for Basic Research had no money in 1998 for publications, it moved to 1999. Now the Publishing company URSS has received money from the Foundation and began preparing the book. So, probably, the book will be published in 1999.

Migration of Celestial Bodies in the Solar System

S.I. Ipatov

INTRODUCTION

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§ 4. Formation of the 5:2 Kirkwood gap
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§ 7. Types N_π of interrelations of the variations in the eccentricity and longitude of perihelion when the periods of these variations are the same
§ 8. Transitions between different types N_π

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`