JD4

The Transneptunian Population

Chairpersons: C. Froeschlé & H. Rickman

Editors: A. Lemaître & H. Rickman

https://doi.org/10.1017/S153929960001323X Published online by Cambridge University Press

Highlights of Astronomy, Vol. 12
International Astronomical Union, 2002
H. Rickman, ed.

Joint Discussion 4: Foreword

When Edgeworth and Kuiper first conjectured the existence of a belt of small bodies beyond Neptune – the presently called Edgeworth-Kuiper or Kuiper belt – they certainly were imagining a disk of planetesimals preserving the pristine conditions of the proto-planetary disk. But, since the first discoveries of Kuiper belt objects (1992), astronomers have realized that it is not so: the disk has been labored by a number of still not completely understood processes which altered its original structure. The orbital distribution of the bodies discovered so far is not trivial: the Kuiper belt is not a disk of particles on quasi–circular and coplanar orbits, as it was generally expected. On the contrary, it looks like the mirror image of the asteroid belt.

In the inner belt (semi-major axis smaller than 40 AU) all the known objects have large eccentricity and are associated with first order mean motion resonances with Neptune. Actually, all but one of the objects with well determined orbits in the inner Kuiper belt are in the 2/3 resonance – like the "planet" Pluto – and are therefore called Plutinos. Beyond 42 AU the "classical" belt begins, where the discovered objects are not specifically related to any mean motion resonance. Although the eccentricities and inclinations are generally smaller than in the inner belt, again the classical belt does not look like a proto-planetary disk, since the latter should be made of planetesimals on quasi-circular and coplanar orbits. In particular, a few objects have a surprisingly high inclination, despite the observational biases not favoring their discovery.

In addition to the inner and the classical Kuiper belts, theoretical considerations and the discovery of the object 1996 TL66 argue for the existence of a third population of bodies, which evolve under the effects of sporadic close encounters with Neptune, forming a sort of scattered disk.

Our knowledge of the present structure of the Kuiper belt is nevertheless very preliminary. At the present time (March 5, 1999), only 102 bodies have been discovered. The rate of discovery has been dramatically increasing since 1992. However, only 35 bodies have well determined orbits, having been observed during at least three oppositions. Several observational campaigns are presently ongoing with the double goal of discovering new bodies and allowing an accurate orbital determination of the already discovered objects. Telescopes ranging from 2 meters to 10 meters are used all over the world for this task. It becomes more and more evident, however, that the efforts need to be coordinated in order to optimize their efficiency.

The peculiar orbital distribution of the trans-neptunian objects may provide decisive clues for an improved understanding of the formation and primordial evolution of the outer Solar System. The present day dynamics, in fact, allows to explain some, but certainly not all the observed features. For instance, the overabundance of objects in the 2/3 resonance and the large eccentricities and inclinations of the bodies in the classical belt must be the result of some process that occurred during the primordial era. Three main scenarios have been proposed so far to explain the primordial sculpting of the Kuiper belt. These include the sweeping of the belt by mean motion resonances due to the radial migration of Neptune, the displacement of the secular resonances due to a gradual mass loss of the trans-neptunian regions, and the primordial existence of "Large Scattered Planetesimals" on orbits crossing the Kuiper belt. Any of these scenarios, if confirmed true, would provide important information on the primordial formation and subsequent evolution of the outer Solar System. The physical properties of the trans-neptunian objects are also of fundamental importance to understand the composition of the Solar nebula, its temperature etc. Information can be obtained through the spectroscopic analysis of the brightest Kuiper belt objects, but also from the physics of Jupiter-family comets, once the link between the latter and the Kuiper belt is well understood. Many believe that Jupiter-family comets come from the trans-neptunian region, but it is not clear yet which parts of the Kuiper belt are the most active sources.

Recent observations of bright comets have thrown new light on the pristinity of their material and the likely existence of certain "mineral" phases such as amorphous H_2O and crystalline olivine in cometary nuclei. Of great interest in this regard is the close similarity between the IR spectra of Comet Hale–Bopp and circumstellar disks, as revealed by ISO. This raises important questions about early processing of such material and the associated role of collisional evolution.

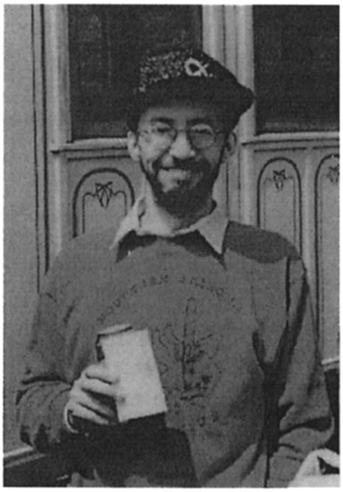
Finally, the observed structure of the Kuiper belt also provides new hints on the origin and the evolution of circumstellar dust disks. According to the statistics of discoveries per unit area of searched sky, about 70,000 objects bigger than 100 km should exist in the Kuiper belt up to 48 AU. The total mass of the belt up to 48 AU seems to be $\sim$ 0.3 Earth masses (M_E). This is much lower than its estimated primordial mass of about 30 M_E. The present population seems to imply that collisions among Kuiper belt objects are not rare, and the mass deficiency of the belt suggests that the collisional evolution has been much more intense in the primordial phases, when most of the mass has been ground to dust and eventually lost from the Kuiper belt. Based on theoretical calculations, the population of grains in the early Kuiper belt looked very much like the dust disk around the famous Vega-excess star Beta Pictoris (age from several tens to $\sim 10^2$ Myr). Beta Pic's circumstellar dust is known to be replenished or second-generation dust, i.e., one produced in collision and/or evaporation of parent bodies (planetesimals) rather than primordial. Planetesimals, perhaps comets, are located in a disk resembling, even though spatially more extended than the currently known Kuiper belt. Some become star-grazing, causing frequent spectroscopic line variations. (Other recently imaged examples of dusty disks are HR4796 and HD141569.) The inferred population of Beta Pictoris planetesimals corresponds to primordial Kuiper belt with a mass of order 100 M_E. The analogy between Kuiper and extrasolar dust belts seems close. The study of these objects provides complementary information on large vs. small-size end of the distribution of bodies in disks.

This science is still young and rapidly evolving, but it is evidently a very interdisciplinary one. The goal of this J.D. is to inventory the state of the art and animate the debate among the communities of dynamicists, observers, experts of cometary physics, Solar System formation and circumstellar disks.

Alessandro Morbidelli
Observatoire de la Côte d'Azur, B.P. 4229, 06304 Nice Cedex 4, France

In Memoriam Paolo Farinella (1953-2000)

Paolo Farinella was planning to deliver an invited review on the Collisional Evolution of the Kuiper Belt in the IAU General Assembly in Manchester, England, in August, 2000. However, when he was hospitalized and placed on the heart transplant waiting list in the autumn of 1999, he realized that he might not be able to fulfill this goal due to uncertainties surrounding the transplant procedure. He asked if I would serve as an alternate in case events precluded his fulfilling this commitment. I certainly agreed but privately thought that he would certainly be fully recovered and active by IAU time. After all, there is a major heart transplant center in my home town of Tucson, Arizona, and there are frequent stories about the successes of the program. The Italian heart transplant center in Bergamo is one of the best in Italy, so I believed that Paolo's would be another success story in what has now become almost a routine medical procedure. This happy outcome was not to be: the career of Paolo Farinella, 47, was prematurely ended when he died on March 25, 2000, of complications following congestive heart failure.



Farinella received his education at the Scuola Normale Superiore in Pisa where he was a student of the outstanding Italian dynamicist Giuseppe Colombo. With colleagues Andrea Milani and Anna Nobili, he established the Space Mechanics Group at the University of Pisa, which soon became one of the outstanding research centers in planetary science in Italy. Paolo won a position as Assistant Professor at the University of Trieste in 1998 and he held this position until the time of his death.

His contributions to the understanding of the origin and evolution of small bodies of the Solar System were fundamental and enduring. Farinella and coworkers were the first to point out that most asteroids injected into strong resonances actually fall into the Sun instead of being left on planet-crossing orbits as scientists had previously believed. This result led to our current understanding of the role of dynamics in the asteroid belt which is more comprehensive and subtle than previously believed. He advocated the view that most short-period comets are collisional fragments from larger bodies rather than the primordial objects as was widely believed. One of his last major areas of investigation was to show that the Yarkovsky effect played a significant rôle in transporting small asteroids to resonant locations where they began their journey to Earth as well as other planets. This insight resolved a long-standing contradiction in the age of meteorites as inferred from their cosmic ray exposure vs. the time it takes them to reach Earth based on dynamical calculations. Of the more than 250 scientific papers he authored (an additional 125 or so articles were on popular science or disarmament), 200 were on the topics of small body dynamics and collisional evolution of asteroids, Trojans, comets, and Kuiper Belt objects.

Asteroid 3248 was named Farinella in recognition of his pioneering work on dynamical and collisional evolution of small body populations..

Farinella's interests ranged far beyond the sphere of planetary science. Always concerned with the connections between science and society, he applied the tools and methodology of asteroid science to the threat that space debris poses for Earth orbiting satellites. Paolo had a passionate commitment to work towards a major reduction in weapons of mass destruction among the nations of the world. His efforts through the Italian organization USPID (Unione Scienziati Per Il Disarmo) and Pugwash were driven by a rational perspective on the issues of arms control for the benefit of humanity, not narrow nationalistic perspectives.

The scientific accomplishments of Farinella were matched by his humanism and personal warmth. He was a dedicated teacher who sought to find better, more effective ways to motivate and teach students who seemed frustratingly uninterested in the fascinating material that was presented them. Paolo's ability to work with a wide range of colleagues on a variety of problems demonstrated the range and vitality of his interests. His passion for justice and equality among nations, together with an interest in promoting stable and equitable economic systems that would ultimately benefit the human race, was apparent in his activities. His powerful intellect was limited by his frail physique which resulted in part from his heart condition, though early surgery gave him nearly four more decades of life. He accomplished much in the time that he had and his contributions to human knowledge will remain his legacy. He will be missed by all who knew him.

Donald R. Davis
Planetary Science Institute, 620 N. 6th Avenue
Tucson, Arizona 85705 USA