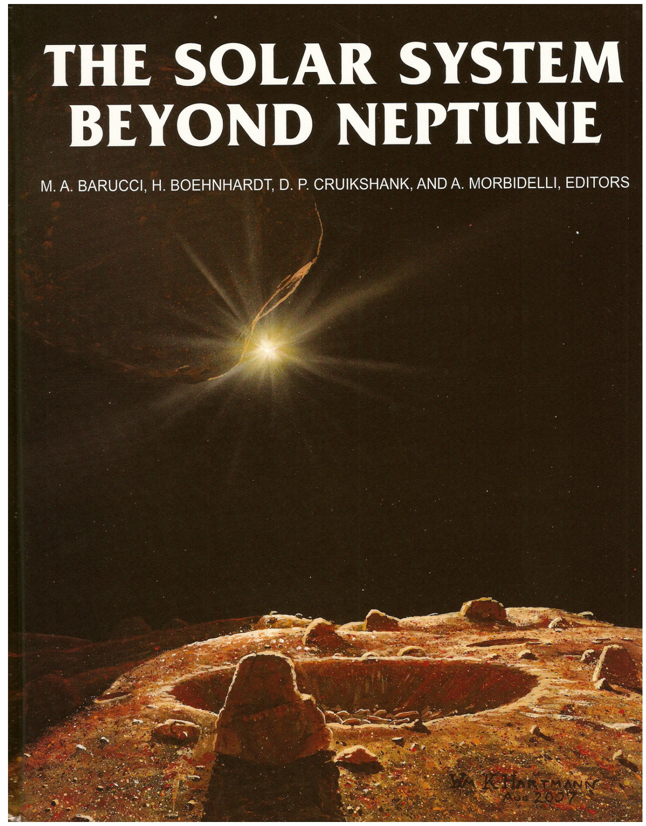
The Meteoritical Society

Meteoritics & Planetary Science 44, Nr 3, 463–464 (2009)
http://meteoritics.org

Book Review

The solar system beyond Neptune, edited by M. A. Barucci, H. Boehnhardt, D. P. Cruikshank, and A. Morbidelli. Tucson, Arizona: The University of Arizona Press, 2008, 592 p. $70, hardcover (ISBN #978-0-8165-2755-7).



Four and a half billion years after the formation of our solar system scientists are on the verge of decoding the mysteries of its primordial evolution. The link between past and present is being revealed within the surprisingly complex populations of transneptunian objects. This research is the astronomical equivalent of sequencing dinosaur DNA. Such is the impression I get from reading *The solar system beyond Neptune*.

Tipping the scales at just 1.66 kg, *The solar system beyond Neptune* is a light-weight in the University of Arizona Space Science series. The record[1] is held by *Protostars and planets V*, at 2.44 kg. Don't judge this book by its mass though, or its title! *The solar system beyond Neptune* reviews the clues that transneptunian objects are telling us about mysteries all over the solar system and far beyond it. From the cratered surfaces of Mercury, the Moon, and Mars, to planets around distant stars, and pretty much everything in between. To put it a different way, most of the chapters in *The solar system beyond Neptune* could have found homes among the previous 34 books in the Space Science series.

The first six chapters of the book are dedicated to perspectives and broad overviews, for instance, on nomenclature and distributions (size, spatial, and orbital). Most of the authors of these and the other chapters refer to transneptunian objects as Kuiper belt objects, named after Gerard Kuiper, who contributed to a theory of their existence in the 1950s. However, after reading the historically oriented second chapter by Davies et al., I could not help but think that the term "Kuiper belt object" (KBO) thrives in the literature merely for the sake of convenience over the more appropriate but cumbersome "Edgeworth-Kuiper belt object" (EKBO). Based on what Davies et al. discuss, I would have naively thought that observers might prefer "Tombaugh belt" (my apologies to D. J. and J. L.) and theoreticians "Campbell-Aitken-Leuschner-Leonard-Edgeworth-Kuiper belt." The editors appear equally uncomfortable with the currently accepted nomenclature and quickly advocate (3rd paragraph of entire book, see p. 3) for use of the more neutral "Transneptunian object" (TNO), going so far as having the index entries for KBOs and EKBOs merely referring readers to the entry for TNOs.

The early chapter on TNO populations by Gladman et al. is especially useful in helping understand the dynamical diversity of TNOs discussed in subsequent chapters. It is shocking that just 17 years after the discovery of 1992 QB1 there are already enough TNOs cataloged[2] to easily discern four distinct dynamical populations: resonant TNOs (like Pluto and Orcus), scattered TNOs, detached TNOs (like Eris and Sedna), and classical TNOs (like 1992 QB1 and Haumae). The orbital phase space of resonant TNOs is filled to such an extent that 21 sub-populations have been identified. In Gladman et al., you will find descriptions of these and other sub-populations, as well as a dynamical recipe and handy flowchart to help you classify new discoveries.

[1] I use mass rather than page count as the series formatting changed to larger pages in 2000. *PPIII* holds the record in page count, at 1596, but it is in the smaller format and has less total mass than *PPV.*

[2] There are now well over 1000. To put that number in context, 17 years after Ceres was discovered there were 4 known main belt asteroids.

As we have come to expect from the Arizona Space Science series, there is a vast abundance of data reviewed in this book. Sixteen chapters are devoted to discussing TNO bulk properties (colors, compositions, etc.), TNO physical processes (collisions, differentiation, etc.), and laboratory analogs of TNO surface material. In these chapters, you begin to get the feel for how TNOs are related to other solar system objects, in terms of what they are made of. Historically speaking, the earliest connections were made to Centaurs and comets and the physical relationships between TNOs and these objects enjoy widespread discussion in the book.

Observational and laboratory data are all fine and good. However, I would argue that nothing in *The solar system beyond Neptune* makes sense except in the light of dynamical evolution. Thus, it is the chapters by the dynamicists that begin to decipher the primordial record that is fossilized within the TNO populations. In a must-read chapter, Morbidelli et al. lay out their remarkable "Nice Model" of early solar system evolution (see page 285 to learn why they didn't call it the Naughty Model). Herein lie the connections between the many traits observed among the TNOs and the dynamical "genes" responsible for them. Not only do these dynamical genes explain the observed TNOs, but they also give rise to seemingly distinct traits observed elsewhere in the solar system. For instance, the current orbits of Neptune, Uranus, Saturn, and Jupiter, characteristics of the irregular satellites and Trojan companions of the giant planets, and also the long-standing notion of a late heavy bombardment (LHB) of the inner solar system some 3.8 billion years ago. In terms of this new dynamical gene for the LHB, it is remarkable that within just the next few years two spacecraft nearly 5 billion km apart may be independently exploring a source and a sink of the LHB at essentially the same time. MESSENGER researchers will be counting craters on Mercury as New Horizons gives us our first close-up look at a TNO. You won't find MESSENGER in *The solar system beyond Neptune*, but Weaver and Stern do provide a nice overview of the New Horizons mission. Additional dynamics chapters provide more details on key aspects of the Nice Model as well as other topics, including the link between TNOs and Halley-type and Jupiter-family comets, possible links between TNOs and meteorites collected on Earth, and the role our Sun's galactic neighborhood may have played in shaping the TNO populations (environmental mutations on our dynamical genes?). Venturing even farther out into the galaxy, chapters by Moro-Martin et al. and Liou and Kaufmann draw connections between a transneptunian dusty debris disk (formed by collisional erosion of TNOs) and structure that we observe in similar disks around other stars. Hidden planets embedded within these extrasolar debris disks may be deduced from the visible structure that their gravity imparts on the disks.

If you explore *The solar system beyond Neptune* from front to back, then near the end you may be feeling confident enough for a little quiz. True or false? With a current heliocentric distance of 97 AU, the dwarf planet Eris is the most distant known object in the solar system. False! Richardson and Schwadron remind us that, at nearly 110 AU, the Voyager I spacecraft is farther. Exploring the boundary between the heliosphere and the interstellar medium, Voyager I informs us that detached TNOs like Sedna spend most or all of their orbits exposed to space weathering by interstellar ions rather than the solar wind. Hudson et al. subsequently explain how Voyager I's exploration of the diverse space environment encountered by TNOs is helping us understand the different surface chemistries inferred for their various dynamical populations.

Finally, IAU definitions notwithstanding, there are plenty of planets in *The solar system beyond Neptune*. Although readers seeking a mash-up on the "Pluto is (not) a planet!" imbroglio will be disappointed. Yes, the IAU vote is mentioned in passing and the term dwarf planet appears in a few places. But this is a science book so you should rather expect to encounter esoteric terms such as Plutino, Plutoid, and Pluto-class, instead of a debate about what, exactly, Pluto is. However, chapters by Brown, Trujillo, and McKinnon et al. suggest that the cultural controversy surrounding Pluto will likely stick around for a while. Brown analyzes the completeness of current sky surveys and suggests that a couple more Pluto-size objects may be hiding in the classical, resonant, and scattered TNO populations, and potentially hundreds may exist as detached TNOs with Sedna-like orbits. Trujillo lays out a timetable of sorts for how long it might take to find these super-Sednas in sky surveys conducted using new observatories coming on line in the next decade. McKinnon et al. argue, based on current theories needed to explain certain observed traits of the solar system (binaries like Pluto-Charon, captured irregulars like Triton, etc.), that we should not be surprised to see record setting TNO discoveries continue, with perhaps even Earth-size or larger detached TNOs still waiting to be found. In other words, long live the Great Planet Debate!

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