

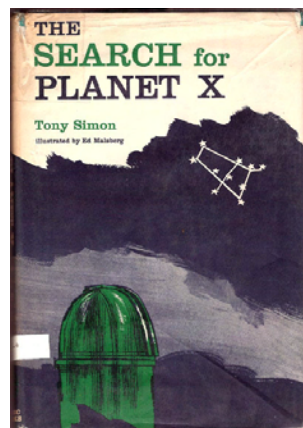
Hubble Observations of Ceres and Pluto: A Closer Look at the “Ugly Ducklings” of the Solar System

by Max Mutchler
Space Telescope Science Institute

Introduction

I regret that my 4th Grade teacher, Mrs. Hadley, doesn't know that she provided me with the very first astronomy book that I ever read, because it had a profound impact on me. In our classroom, she maintained a small shelf with a rotating selection of books from the library, designed to pique our interest. A book about the discovery of Pluto in 1930, titled “The Search for Planet X”, caught my eye. The storyline is a rich mixture of scientific sleuthing and folklore. It sparked my fascination with the universe beyond Earth, and my admiration for clever and tenacious astronomers, like [Clyde Tombaugh](#)¹, who discovered Pluto. I became motivated to study astronomy, and today I work on the [Hubble Space Telescope](#).² In particular, I'm an expert on Hubble's main camera. I'm involved in keeping it well-calibrated, designing optimal observing strategies, and extracting as much information as possible from the resulting images.

Hubble has made important contributions in almost every area of astronomy — most famously in the realm of cosmology, the scientific study of the origin, evolution, and future of the Universe as a whole. But Hubble has also furthered our understanding of the Solar System, our local neighborhood. Pluto and Ceres are two recent

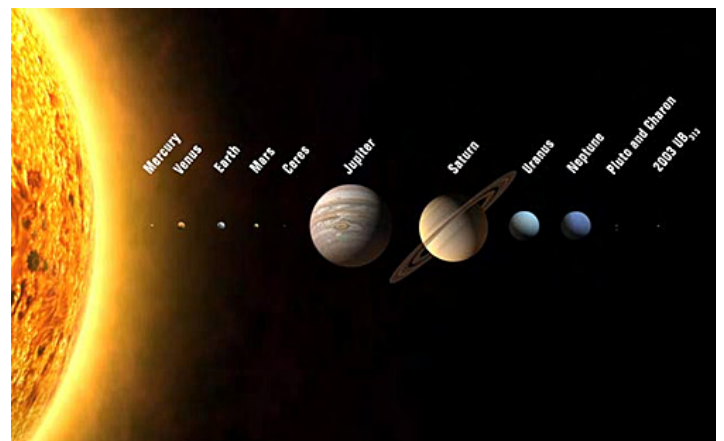


The book that sparked the author's interest as a child.

Image credit: Simon, Tony, 1962, “The Search for Planet X”, Basic Books Publishing Company, Inc., New York

examples. Neither have given up their secrets very easily since their discoveries, and they have both suffered through protracted periods of being misunderstood. So in the last year, it has been particularly satisfying to be involved with some breakthrough Hubble observations of them, and in the process, see my primal interest in “Planet X” come full circle.

Pluto and lesser-known Ceres share strikingly similar histories, played out a century apart. At present, you could say Pluto appears doomed to repeat the history of Ceres, but perhaps that sounds too glum. Better to say their histories may forever be interrelated, and for good reason. They share the distinction of being the first members of an entire class of objects: the swarms of smaller worlds



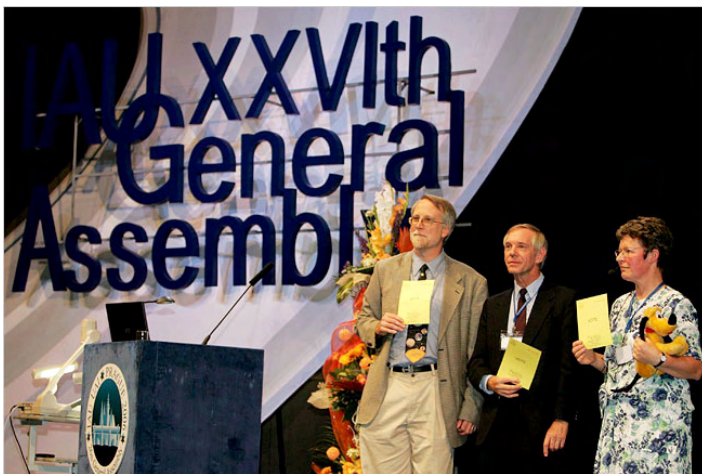
The Solar System, including the objects in question during the IAU's recent planet definition debate : Ceres, Pluto-Charon, and Eris.

Image credit: The International Astronomical Union/Martin Kornmesser

which are the left-over building blocks of the larger planets, and collectively form the largest structures in the Solar System. Understanding them and their kin is critical to understanding the structure of planetary systems on many scales, including those being discovered around other stars. Being mindful of the histories of Pluto and Ceres allows us to digest the latest information from Hubble in the broadest context, and fully appreciate and anticipate how the “ugly duckling” storylines of Ceres and Pluto will continue to unfold in the coming years.

Planet X becomes just another ex-planet

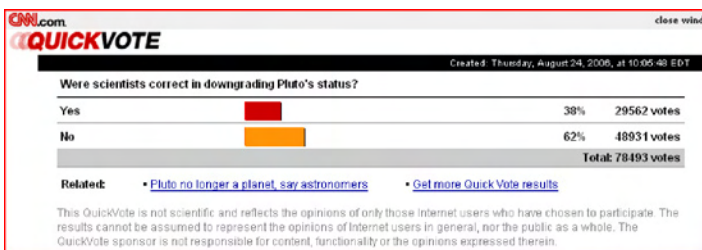
But first, unless you moved into a cave last summer, by now you are well aware of the sociological phenomenon that was the vote by the International Astronomical Union



Astronomers vote on the definition

Image credit: The International Astronomical Union/Lars Holm Nielsen

(IAU) on the definition of a planet, where a main result was that Pluto and Ceres were re-classified as “[dwarf planets](#)”,³ along with Eris, which had been temporarily referred to as the 10th planet. Not content to leave the voting to the IAU, many public opinion surveys showed a strong negative reaction to the “demotion” of Pluto.



Results of a public opinion poll on CNN’s website: Bring Pluto back!

Image credit: CNN.com

The intense reaction from the public was somewhat fueled by sentiment, and also the air of finality that a vote creates. But this debate isn’t purely sentimental or final. It has been

going on since shortly after Pluto was discovered, and there continue to be good scientific arguments being made by prominent planetary scientists on both sides.

I’m not an expert on planetary science, and I don’t have a strong opinion on the definition of a planet. So I will focus on some relevant history and data here, not the voting. While science is a never-ending cycle of discovery and debate, perhaps this debate is still premature, and we simply need more discoveries before we can arrive at a robust definition of a planet.

The IAU vote was rather euphemistically dubbed a “teachable moment”: an example of scientific debate and classification in progress. I’m not convinced that it was a prime example for students, but I was curious to see whether my 7-year-old son, after considering the issue, would want to leave Pluto among the planets hanging from his bedroom ceiling. He decided to leave it there, essentially arriving at the same bottom line as Clyde Tombaugh after a lifetime of enduring this debate, “It’s there. Whatever it is. It is there”.



Here to stay: the author’s son points out Pluto on his bedroom ceiling

Image credit: M. Mutchler

How many planets are there?

The answer to this question has never been particularly straightforward. The number has gone up with new discoveries, of course. But it has gone down before, too — and not because the Solar System has ejected any planets. The initial and most dramatic change, of course, was the Copernican paradigm shift from a geocentric (Earth-centered) to a heliocentric (Sun-centered) system. But following that, the other two downsizings had to do with the discovery and understanding of the [Asteroid Belt](#)⁴ (a region between the orbits of Mars and Jupiter) and [Kuiper Belt](#)⁵ (a region beyond the orbit of Neptune), and a desire to

Table 1: “Planet Count” History

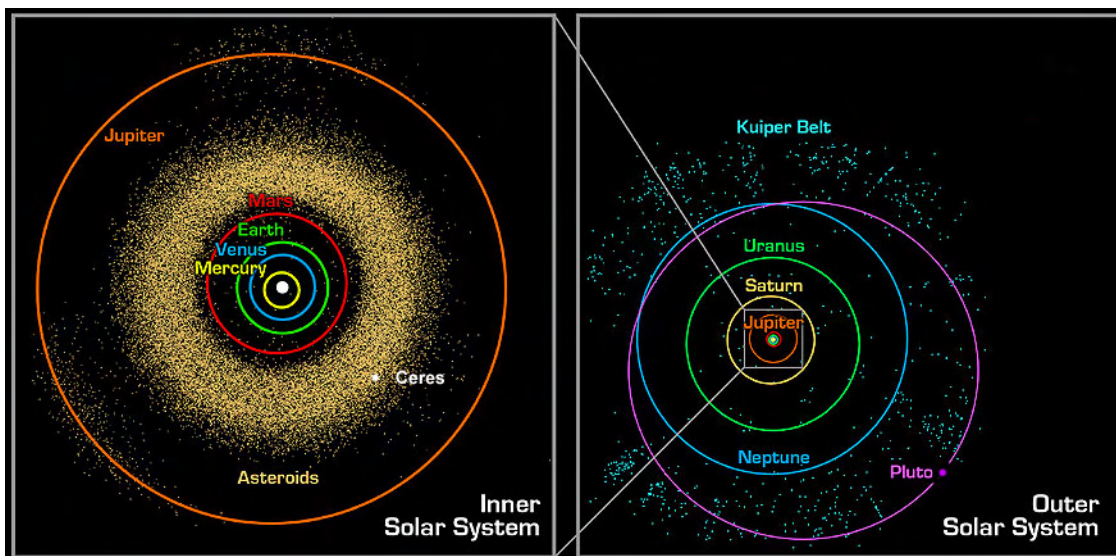
Year	Discoveries, classifications, and relevant events	Planet count
Since antiquity	Geocentric system (Ptolemy) counted the Moon and Sun as planets, along with Mercury, Venus, Mars, Jupiter, and Saturn	7
1550	Heliocentric system (Copernicus) properly classifies Earth, Moon, Sun	6
1781	Discovery of Uranus	7
1801-1807	Discovery of Ceres, Pallas, Juno, Vesta	11
1845	Discovery of Astraea	12
1846	Discovery of Neptune	13
1851	Classification of Ceres, etc., as “minor planets” with many other Asteroid Belt objects being discovered	8
1930	Discovery of Pluto	9
1978	Discovery of Charon*	9?
1992-1999	Discovery of 1992 QB1 and many other Kuiper Belt objects (KBOs)	9?
2000-2005	Discovery of several large KBOs: most notably Eris, larger than Pluto	9?
2006	Classification of Pluto, Eris, Ceres, etc., as “dwarf planets”; Charon too?	8

* An issue that was not clearly resolved by the IAU vote is the unique status of Pluto-Charon as a gravitational double system, [a binary planet](#)⁶. If Pluto is a dwarf planet, is Charon also?

keep the number of objects we call planets manageably low (see Table 1 for a complete history of the “planet count”). Ceres and Pluto both ushered in paradigm shifts, being the first objects discovered in their respective belts. But that’s just the beginning. As astronomers continue to discover planets outside our Solar System and to characterize the more than 200 that have been located already, we can expect even more changes to come.

Ceres: the original Pluto

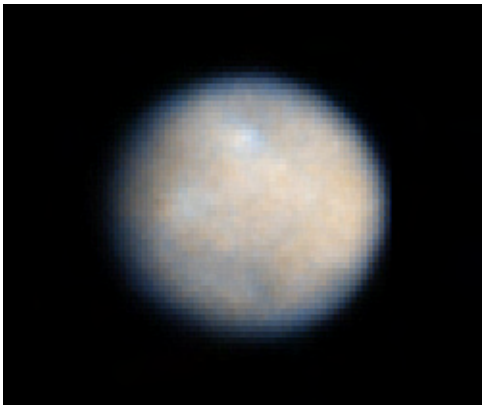
We are typically biased by the history we have personally experienced. For most people living today, Pluto’s story and status has been emblazoned in our minds since our school days. None of us was alive when the story of Ceres began playing out in the early 19th Century, but brace yourself for some déjà vu, because Ceres is an ideal case-study which illuminates the current planet debate. It may change the way you think about Pluto and the other dwarf planets.



The inner and outer solar system, including the Asteroid belt and the Kuiper Belt

Image credit: A. Feild (STScI)

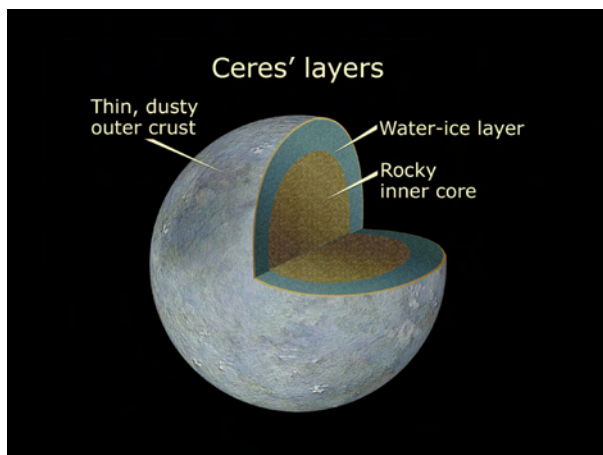
Ceres was discovered in 1801 by Giuseppe Piazzi, where an empirical “Bode’s Law” (later discredited with the discovery of Neptune) crudely predicted a heretofore missing planet between Mars and Jupiter. Ceres was therefore dubbed a planet, and referred to as such for 50 years. During that time, however, many other small worlds were discovered in similar orbits, and estimates of their sizes kept trending downwards. So arguments arose, initiated by William Herschel (discoverer of Uranus), that Ceres and the other star-like “asteroids” were too small to be planets. Perhaps they were just fragments of a planet disrupted by nearby Jupiter. In 1851, Ceres and its cohorts were therefore re-classified as minor planet members of the [Asteroid Belt](#)⁷.



Hubble image of Ceres

Image credit: NASA, ESA, J. Parker (Southwest Research Institute), P. Thomas (Cornell University), L. McFadden (University of Maryland, College Park), and M. Mutchler and Z. Levay (STScI)

For most of its history, Ceres was a barely-resolved point of light. Only recently have the best ground-based images hinted that, although very small, Ceres is still massive enough for its self-gravity to round out its shape. [Hubble observations of Ceres](#)⁸ reveal it to be even more planet-like – unlike the mental picture we have of most asteroids



Hubble observations have been used to suggest that Ceres may have a layered composition

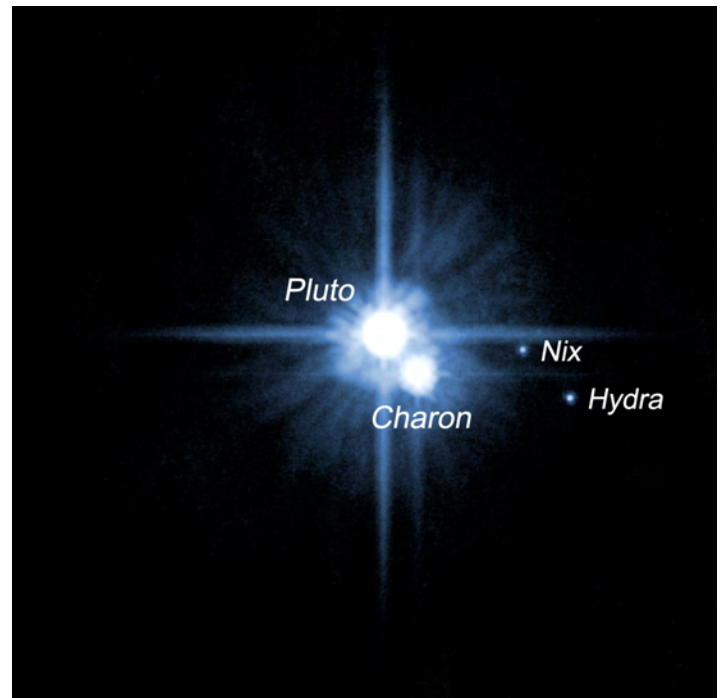
Image credit: NASA, ESA, and A. Feild (STScI)

as potato-shaped hunks of lifeless solid iron. Hubble has verified that Ceres is very round. Roundness implies a differentiated interior. Like the Earth, it probably has a core and interior layers — one of the hallmarks of planethood. Additionally, the highest-resolution color images from Hubble show many as of yet unidentified surface features rotating in and out of view throughout Ceres 9-hour-long “day”. [Learn more about Ceres here](#)⁹.

Pluto: doomed to repeat the history of Ceres?

Like Ceres, Pluto initially seemed to show up right where a missing planet was predicted to be, but like the unscientific Bode’s Law before it, Percival Lowell’s predictions of a trans-Neptunian “Planet X” were based on flawed calculations of perturbations in Neptune’s orbit. So both Ceres and Pluto were discovered for the wrong reason, and the flawed predictions led them to be unhesitatingly heralded as new planets.

But for decades, the more we learned about Pluto, the less it seemed like the other 8 planets. It had an eccentric tilted orbit, which crosses Neptune’s orbit. Initially, it was thought to be perhaps as large as Earth, but each subsequent estimate was smaller. On the other hand, discoveries since



The Pluto system

Image credit: H. Weaver (JHU/APL), S. A. Stern (SwRI), M. Mutchler (STScI), A. Steffl (SwRI), W. Merline (SwRI), M. Buie (Lowell Obs.), J. Spencer (SwRI), E. Young (SwRI), L. Young (SwRI)

the 1970s have also made Pluto seem more complex and planet-like: its atmosphere, its large moon Charon (and the fact that together they form a unique binary planet), and



A giant collision about 4 billion years ago probably created the Pluto “quadruple system”

Image credit: Don Davis

a [complex surface with contrasting features](#)¹⁰. Then last year, two small moons, [Nix and Hydra](#)¹¹, were unexpectedly found in Hubble images. The existence of more moons of Pluto, Charon-like in both their orbits and colors, fit the collision theory of the formation of Pluto-Charon — the same theory we have to explain our Earth-Moon system. The gray colors measured for Nix and Hydra earlier this year further support the [collision-formation theory](#)¹².

Pluto is located in a region of the solar system known as the [Kuiper \(rhymes with “viper”\) Belt](#)¹³. This is a disk-shaped region beyond the orbit of Neptune, extending out 50 A.U. (7.5 billion km, or 4.7 billion miles). Before 1992, a belt of planetary debris beyond Neptune was only a decades-old theory. Following the discovery of 1992 QB1 by Dave Jewitt and Jane Luu (Univ. Hawaii), the floodgates opened wide and we now know of over 800 [Kuiper Belt objects](#)¹⁴ (KBOs), with many more surely awaiting discovery. After the turn of the millenium, several KBOs approaching the size of Pluto were discovered by the team of Mike Brown (Caltech), Chad Trujillo (Gemini Observatory), and David Rabinowitz (Yale). And although their penultimate discovery of Eris (formerly referred to as the “tenth planet”), a KBO larger than Pluto, has triggered recent plot twists for Ceres and Pluto, entirely new and unpredictable chapters will soon be written into their respective storylines by two intrepid visitors.

More information about Pluto is available on the following websites:

- [The Planetary Society – Pluto and Charon](#)¹⁵
- [New Horizons Mission](#)¹⁶ — What We Know About Pluto, Charon, and the Kuiper Belt
- [Hubble Space Telescope Observations of Pluto](#)¹⁷

Waiting for their spaceships to come in

As much as we have learned from these recent observations of Ceres and Pluto, even the remarkable clarity of the mighty Hubble is only scratching at the surface of these fascinating worlds. These Hubble observations were

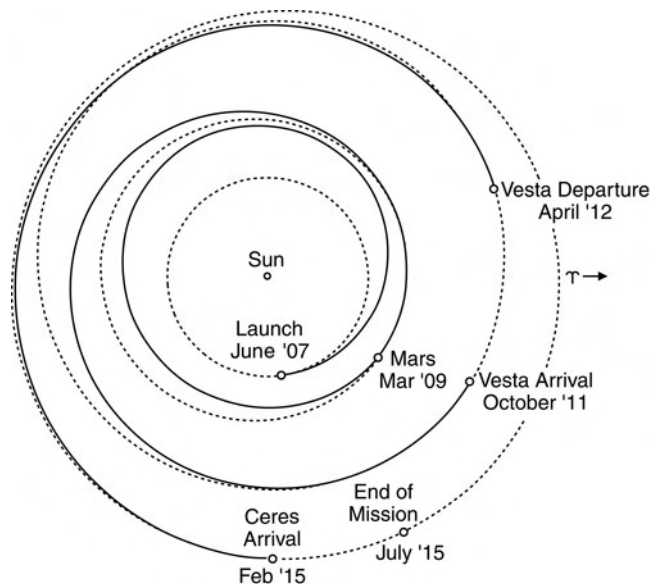


Image credit: NASA/Dawn



Image credit: William K. Hartmann Courtesy of UCLA

The Dawn spacecraft will be launched in June 2007. It will encounter Vesta in 2011, and Ceres in 2015

conducted in support of two exciting space missions which will improve our understanding of these small worlds and planet formation in general. The observations of Ceres were made by the [Dawn](#)¹⁸ mission science team, and the discovery data containing Nix and Hydra were made by the [New Horizons](#)¹⁹ mission science team. Mark your calendar for 2015, when these two small but groundbreaking space probes will encounter Ceres and Pluto, and significantly add to our understanding of the Solar System. These spacecraft will study their respective targets with a host of scientific instruments, which will expand our knowledge of their compositions, dynamics, surface features, and history. These encounters will be dazzling, and should greatly inform and clarify the planet definition debate.

The *Dawn* spacecraft is set to launch in June 2007. First it will encounter the second-largest asteroid Vesta in 2011, then on to Ceres in 2015. They are like two baby planets, whose growth was stunted by their proximity to their gigantic neighbor, Jupiter. As such, they represent the building blocks from which all the terrestrial planets are formed. Differences in their subsequent evolution and the role of size and water give insight into the various forces at play in the early Solar System, which shaped all the planets. Ceres may have seasonal polar caps of water frost, and a thin atmosphere which would distinguish it from the

other minor planets. Vesta may have rocks more strongly magnetized than on Mars.

Check out [Dawn's education programs and materials](#)²⁰.

The *New Horizons* mission to Pluto and the Kuiper Belt was launched from Cape Canaveral on January 19, 2006. The fastest spaceship ever launched — it is already beyond Mars and the Asteroid Belt, and it has an encounter with Jupiter coming up on February 28, 2007. Not bad for it's first year of flight, right? But the long haul to Pluto will take another 8 years — yes, the Solar System is really, really big.

The *New Horizons* science team wants to reach the Pluto system as soon as possible. Pluto is swinging farther out on it's eccentric orbit, getting less sunlight all the time, and less of its surface can be mapped. As Pluto gets colder, its atmosphere will likely “freeze out” or condense onto the surface, so the team wants to arrive while there is a chance to see a the thin atmosphere. They will compile maps and gather spectral measurements and check for changes over a Pluto day, as might be caused by new snows — essentially creating a daily weather report for Pluto. It will also take spectral maps in the near infrared, telling the science team about Pluto's and Charon's surface compositions and locations and temperatures of these materials.

Even after the spacecraft passes Pluto and its moons, *New Horizons* will look back at the mostly dark side of Pluto and Charon, to spot haze in the atmosphere, to look for rings, and to figure out whether their surfaces are smooth or rough. Also, the spacecraft will fly through the shadows cast by Pluto and Charon. It can look back at the Sun and Earth, and watch the light from the Sun or the radio waves from transmitters on Earth. The best time to measure the

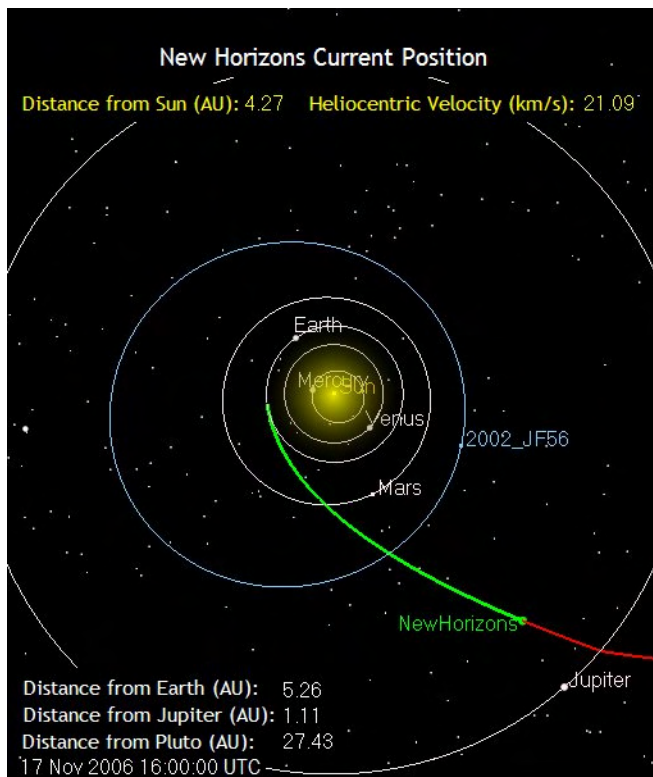


Image credit: NASA/New Horizons

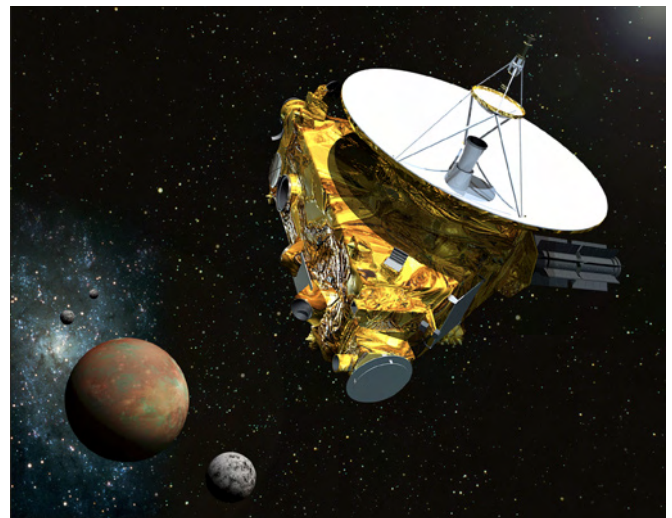


Image credit: Johns Hopkins University Applied Physics Laboratory/Southwest Research Institute (JHUAPL/SwRI)

The *New Horizons* spacecraft was launched in January 2006. It will encounter Jupiter on February 28, 2007, and Pluto in July 2015. [Click here](#)²¹ to see where *New Horizons* is now.

atmosphere happens as the spacecraft watches the Sun and Earth set behind Pluto and Charon. After passing Pluto and Charon, the spacecraft could be rerouted for an encounter with another Kuiper Belt object.

Check out [New Horizons' education programs and materials](#)²².

Beyond the Solar System

So far, only information from objects in our own Solar System have been influencing the definition of a planet. For example, recent Hubble images have confirmed that Eris is larger than Pluto, although not by as much as originally thought. While this fact may be forcing the planet debate right now, yet other Hubble observations remind us we are still in the early naïve stages of understanding planets. Beyond our solar system, Hubble has shown a warped disk around the star [Beta Pictoris](#)²³. This disk is the equivalent of a Kuiper Belt, implying unseen planets closer in to that nearby star.

Over 200 extrasolar planets have been confirmed, mostly by indirect methods, and Hubble recently added to the tally by finding evidence for possibly [16 Jupiter-sized planets](#)²⁴ in a small patch of sky towards the galactic center. By extrapolation across the entire sky, this is strong evidence for the existence of approximately 6 billion Jupiter-sized planets in our Milky Way galaxy alone!

Conclusion

Recent and upcoming observations of Ceres and Pluto are undeniably moving them towards the next chapter in

our understanding of them. These “ugly ducklings” of the Solar System, regardless of how we classify them, are truly the “swans” of their respective zones. Their common historical roles will continue as they form a critical bridge of understanding between the rocky minor planets of the inner Solar System, and the icy dwarf planets of the outer Solar System.

The exciting discoveries in the outer Solar System are more than matched by the discovery of so many other planets scattered around our vaster home, the Milky Way galaxy. Obviously, we must ultimately arrive at a planet definition which encompasses all of them, and in doing so, we will begin to fully grasp the link between our Solar System, and the larger galaxy (full of other planetary systems) that it is in.

*“We shall not cease from exploration
And the end of all our exploring
Will be to arrive where we started
And know the place for the first time.”*

— T. S. Eliot, *Little Gidding*

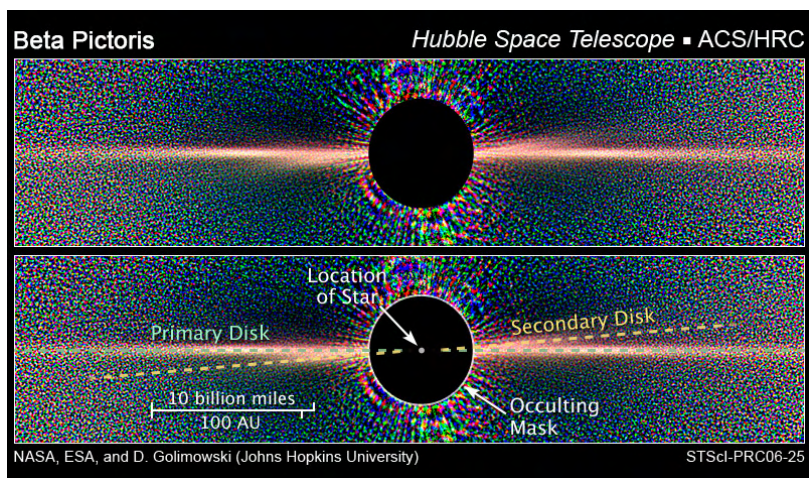


Image credit: NASA, ESA, D. Golimowski (Johns Hopkins University), D. Ardila (IPAC), J. Krist (JPL), M. Clampin (GSFC), H. Ford (JHU), and G. Illingworth (UCO/Lick) and the ACS Science Team

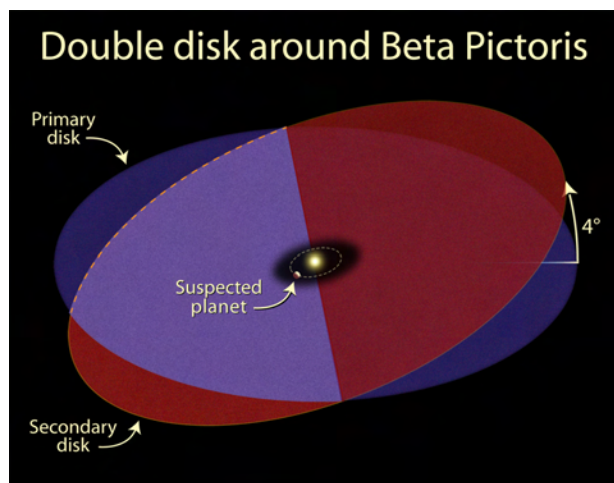


Image credit: NASA, ESA, and A. Feild (STScI)

Hubble has discovered a disk similar to the Kuiper belt around the star Beta Pictoris

About the author

Max Mutchler has been working at the Space Telescope Science Institute in Baltimore since the Hubble Space Telescope was launched in 1990. He is currently a science instrument specialist for Hubble's Advanced Camera for Surveys (ACS), and a member of the Hubble Heritage Team. Asteroid "6815 Mutchler" was recently named in honor of his work on the Pluto observations described in this article (*Minor Planet Circular* citation below).



The Hubble Space Telescope
in orbit around the Earth

Image credit: NASA

M.P.C. 56612

2006 APR. 13

(6815) Mutchler = 1979 MM₅

Discovered 1979 June 25 by E. F. Helin and S. J. Bus at Siding Spring.

Max J. Mutchler (b. 1965), an astronomer at the Space Telescope Science Institute in Baltimore, Maryland, in June 2005 was the first person to identify Pluto's second and third satellites, using Hubble Space Telescope images.

More about the Hubble Space Telescope:

- [Hubble Space Telescope: http://hubblesite.org](http://hubblesite.org)
- [The Space Telescope Science Institute: http://www.stsci.edu/hst/](http://www.stsci.edu/hst/)
- [Hubble Heritage Team: http://heritage.stsci.edu/](http://heritage.stsci.edu/)

Activity 1: Sorting the Solar System

developed by Anna Hurst

This activity has students explore some of the different objects in the Solar System and create their own categories for them. They then have a discussion about what categories scientists currently assign to each object.

Pass out a set of the 24 [Solar System Cards](#)²⁵ to each group of students, available here for download as a PDF. Together, they should sort their cards into a number of groups using whatever criteria they choose. Each card has an image of an object and information about its size, its distance from the Sun, what object it orbits, and its composition, but it does not identify the object. Encourage students to invent their own categories, rather than using categories they have already heard. For example, they might create a “lumpy potato-like” category, rather than “asteroids”. Have students list the criteria they used to create the categories, so that if they were given a new object, they could easily place it into one of the categories.

Another variation would be to have each group sort according to different criteria, such as appearance, size, composition, etc. You could then have the groups circulate and guess what criteria each other group used to sort the cards.

After they have finished sorting, you can facilitate a discussion with students about their categories and how they chose them. Write a few categories on the board. What criteria did they use? Were there other criteria they could have used? Were there any that didn't quite fit into a category? Choose a card and ask a group in which of their categories the object belongs.

Now lead a discussion of how scientists currently classify these objects. Explain that in many sciences there are collections of objects that get sorted and classified: birds, plants, bacteria, rocks, etc. Scientists come up with lists of questions or criteria to help determine which group an object will ultimately belong to. As new objects are discovered, these questions can help decide if they are like other things that we already know something about, or, if they are unique. Of course, sometimes new discoveries make us think about our definitions in new ways, so that sometimes revisions need to be made. The discovery of Eris (the “tenth planet”) forced astronomers to give a fresh look at their definition of a planet and make revisions. As they discover ever more planets around other stars, they will probably have to revise it again.

There are six types of objects represented on the cards: star, planet, dwarf planet, moon, comet, and asteroid. The identity of each object and a definition of each of the categories is also provided in the Solar System Cards PDF. You may want to define the categories and have students try to sort the cards again, in small groups or together as a class. Are there any that don't fit these categories? Could any of the definitions be improved? What if we wanted to use these definitions for a system around another star?

Activity 2: How Big? How Far? A Scale Model of the Solar System

based on an activity developed by Guy Ottewell

After students have become familiar with the different types of objects in the Solar System, you may want to create a scale model so that they can get a feel for how big and how far away these objects are. We recommend the [Earth As A Peppercorn](#)²⁶ model, which has both size and distance to scale. In this model, the Sun is an 8-inch ball, the Earth is a peppercorn, and students end up pacing out 1,000 yards to reach Pluto! Though this model focuses on the planets, you can make the following additions:

- **Dwarf planets:** Pluto is already represented in the model. Ceres would be less than 1/100 of an inch in diameter — about 0.1 mm — a tiny speck of dust 71 yards from the 8-inch Sun, or 31 yards from Mars. Eris would be slightly larger than Pluto and located another 1,000 – 2,500 yards beyond Pluto, depending on where it is in its orbit. So you'll have to walk just as far from Pluto as you just walked from the Sun to get to Pluto, if not farther! Rather than having students walk all this way, you could look at a map of your town or city together and point out where you would end up if you were to walk the whole distance. Would you have to walk all the way to the library, the supermarket, or the high school?
- **Moons:** Jupiter's satellite Ganymede is the largest moon in the Solar System. In this model, it would be 0.03 inches in diameter (slightly larger than Mercury) and located 6 inches from Jupiter. To find the scaled sizes and distances of other moons, use the Exploratorium's ["Build A Solar System" calculator](#)²⁷. This is also useful for creating solar system models using different scales — just plug in the size of your Sun and this calculator does the rest!
- **Comets:** Although we wouldn't be able to see a comet's nucleus at this scale, we would be able to see its tail. Comet tails can reach 6 million miles in length, which would be five feet on this scale!
- **Asteroids:** In this model, the main asteroid belt would extend from about 53 yards from the Sun to about 84 yards from the Sun. The asteroids themselves would be far too small to see. Imagine taking the tiniest grain of salt, crushing it into hundreds of thousands of pieces, and spreading it over the area just described!

Resources

1. Clyde Tombaugh, discoverer of Pluto
<http://www.klx.com/clyde/>
2. Hubble Space Telescope
<http://hubblesite.org>
3. International Astronomical Union vote on the definition of a planet
<http://www.iau.org/iau0603.414.0.html>
4. Asteroids and Comets
http://www.planetary.org/explore/topics/near_earth_objects/asteroids_and_comets/facts.html
5. Kuiper Belt Objects
http://www.planetary.org/explore/topics/trans_neptunian_objects/
6. Pluto-Charon as a binary planet:
http://www.windows.ucar.edu/tour/link=/pluto/binary_planet.html&edu=mid
7. Asteroids and Comets
http://www.planetary.org/explore/topics/near_earth_objects/asteroids_and_comets/facts.html
8. Hubble Observations of Ceres
<http://hubblesite.org/newscenter/archive/releases/2005/27/>
9. Ceres
http://www.planetary.org/explore/topics/near_earth_objects/asteroids_and_comets/ceres.html
10. Hubble Observations of Ceres
<http://hubblesite.org/newscenter/archive/releases/1996/09>
11. Nix & Hydra
http://www.planetary.org/news/2005/1103_Hubble_Observations_Add_Two_New_Moons.html
12. Collision Formation Theory
<http://hubblesite.org/newscenter/archive/releases/2006/15/>
13. Kuiper Belt
<http://www.nineplanets.org>
14. Kuiper Belt Objects
http://www.planetary.org/explore/topics/trans_neptunian_objects/facts.html#kbos
15. Pluto & Charon
http://planetary.org/explore/topics/our_solar_system/pluto/
16. Overview of Pluto, Charon, and the Kuiper Belt:
<http://pluto.jhuapl.edu/science/whatWeKnow.html>
17. Hubble Observations of Pluto
<http://hubblesite.org/newscenter/archive/releases/1996/09>
18. Dawn mission to Ceres
<http://dawn.jpl.nasa.gov/>

19. New Horizons mission to Pluto

<http://pluto.jhuapl.edu/>

20. Dawn Education and Public Outreach

<http://dawn.jpl.nasa.gov/education/index.asp>

21. Where New Horizons is now

http://pluto.jhuapl.edu/mission/whereis_nh.php

22. New Horizons Education & Outreach

<http://pluto.jhuapl.edu/education/>

23. Hubble observations of disk around Beta-Pictoris

<http://hubblesite.org/newscenter/archive/releases/2006/25/full/>

24. Hubble observations of Jupiter-sized extrasolar planets

<http://hubblesite.org/newscenter/archive/releases/2006/2006/34/>

25. Solar System Cards

<http://www.astrosociety.org/education/publications/tnl/70/solarsystemcards.pdf>

26. Earth As A Peppercorn Model

<http://www.noao.edu/education/peppercorn/pcmain.html>

27. “Build a Solar System” calculator

http://www.exploratorium.edu/ronh/solar_system/all_bodies.html

Additional Resources: How are educators reacting to the new planet definition?

“Teaching What a Planet Is: A Roundtable on the Educational Implications of the New Definition of a Planet”, edited by A. Fraknoi, Astronomy Education Review

<http://aer.noao.edu/cgi-bin/article.pl?id=207>

Pluto’s demotion not a cause for classroom panic from CNN

<http://www.cnn.com/2006/EDUCATION/08/25/pluto.reaction/index.html>

Use Pluto’s dwarf status to think big from Newsday

<http://toto.plymouth.edu/pipermail/nhsci-ed/2006-August/000721.html>

Bill Nye’s reaction: “Science Guy’ Likes Pluto Change” from ABC News

<http://abcnews.go.com/ThisWeek/Science/story?id=2362119>