



Historical overview	Personal anecdotes
<ul style="list-style-type: none"> <li>Discovery of Pluto and it's "moon" Charon</li> <li>Discovery of Kuiper Belt and Eris, the 10<sup>th</sup> planet?</li> <li>"Great Planet Debates" of 1851, 2006, 2008</li> <li>Ceres, Vesta and the Asteroid Belt: déjà vu</li> <li>Ongoing discovery: <i>Hubble</i>, <i>New Horizons</i>, and <i>Dawn</i> missions</li> </ul>	<ul style="list-style-type: none"> <li>"Planet X" books</li> <li><i>Hubble</i> imaging of Pluto, Ceres, and Vesta</li> <li>Discovery of Pluto's moons Nix &amp; Hydra</li> <li>Coming full circle, and "teachable moments"</li> <li>Semantics: names, classifications</li> <li>Basketballs and gorillas, imagination and blissful ignorance</li> </ul>

*Every journey begins with one small step...*

Excerpt from *The Search for Planet X*, by Tony Simon, 1962

No one can say that we have come to the end of discoveries in the Solar System.

New tools and methods – such as computing machines...and **observatories in space** outside the Earth's atmosphere, man(kind) will get much better views of the far reaches of the Solar System.

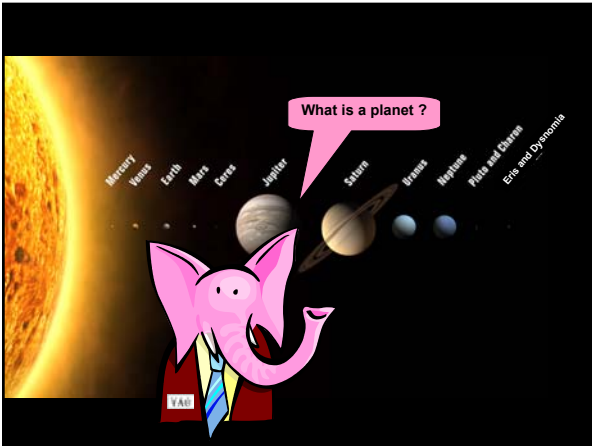
Standing on the shoulders of the scientists of centuries past, *patient and brilliant* astronomers of the future will surely **discover more new worlds...** and have the fun of debating what to name it.

4<sup>th</sup> Grade (1974)

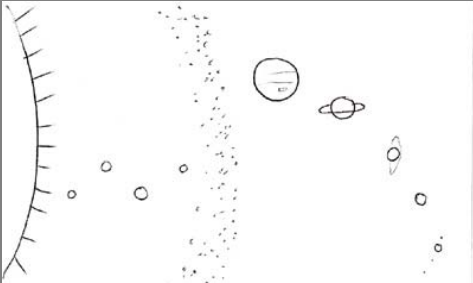


### Hubble and the Space Shuttle: launch and servicing missions

1990  
1993  
1997  
1999  
2002  
2008 !  
????



A thousand childhood doodles...



A comforting, familiar *incomplete* bedtime story

### The discovery of Pluto in 1930



FIG. 6. A SECTION OF ONE OF THE DISCOVERY PLATES THAT OF JANUARY 23, 1930. THE ARROW NEAR THE CENTER ARE POINTING TO THE LITTLE IMAGE OF PLUTO.

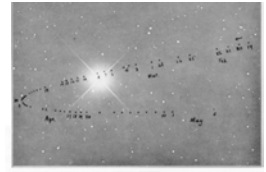
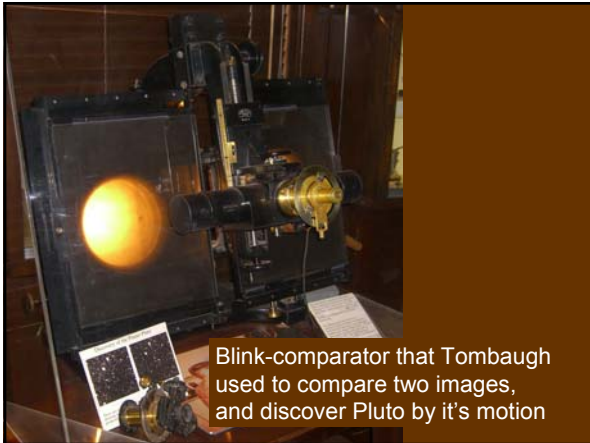


FIG. 8. PLUTO. APPROXIMATE PATH OF THIS PLANET AROUND THE SUN. PHOTOGRAPHED ON MARCH 20, 1930, AND PUBLISHED MARCH 4, 1931. THE ORBITAL PERIOD OF THIS PLANET IS 248 EARTH YEARS. THE DISTANCE FROM THE SUN TO PLUTO IS 39.5 AU.



FIG. 7. MR. C. W. TOMBAUGH THE CAREFUL-WORKING AND KEEN-EYED YOUNG MAN WHO WAS FIRST TO FIND THE RECORD OF PLUTO ON THE PHOTOGRAPHIC PLATES.

Clyde Tombaugh



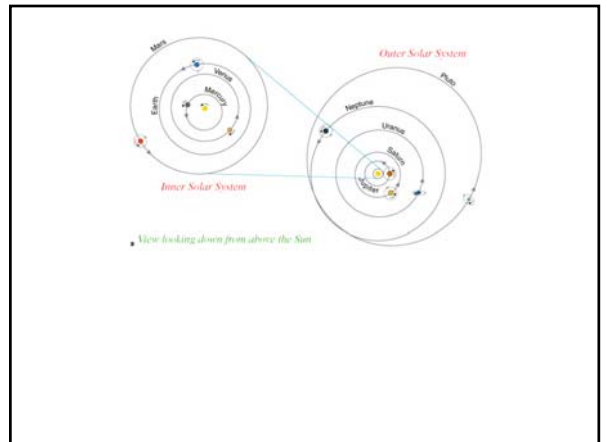
Blink-comparator that Tombaugh used to compare two images, and discover Pluto by it's motion



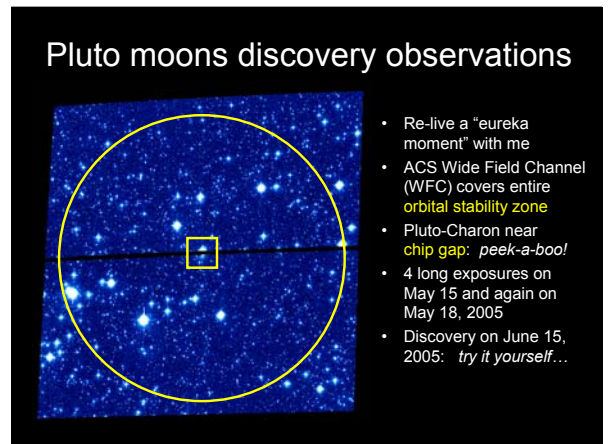
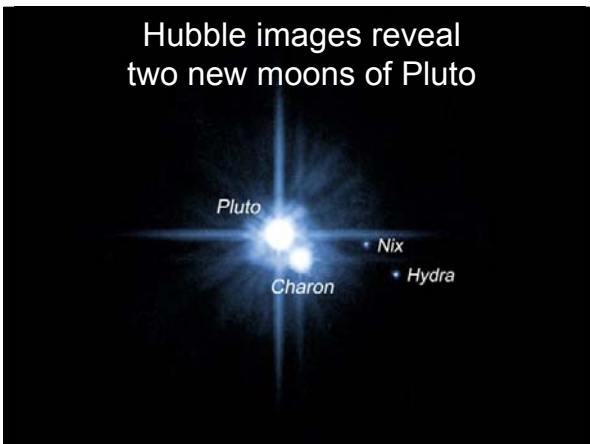
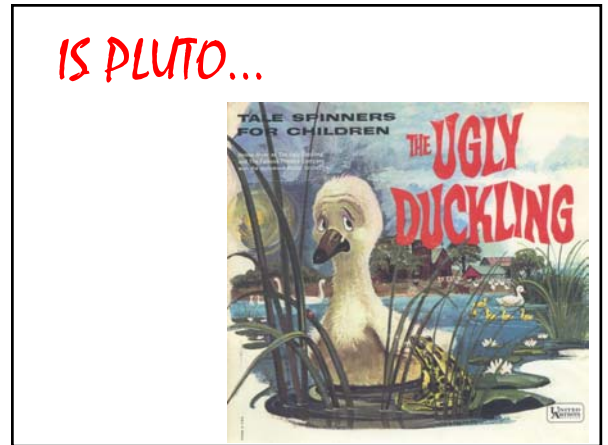
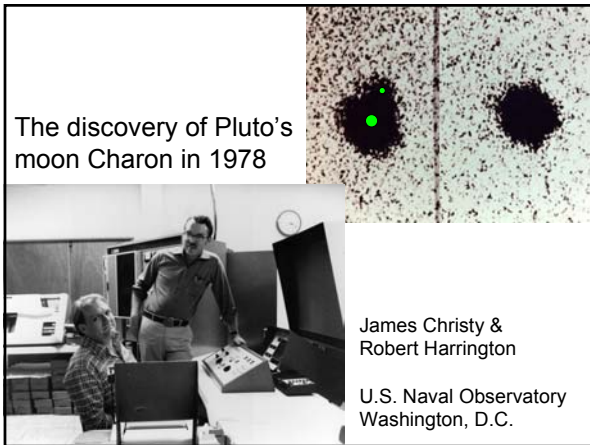
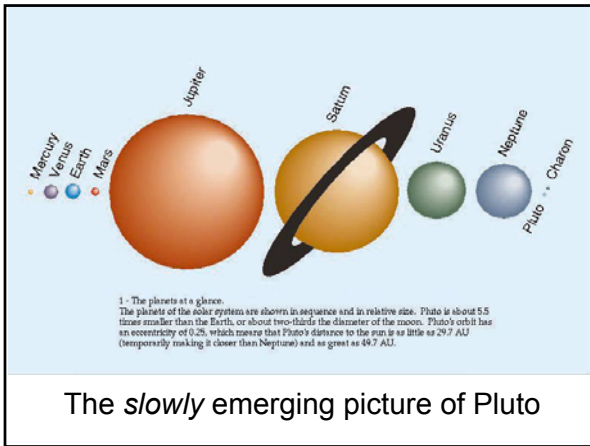
Pluto discovery images  
January 23, 1930

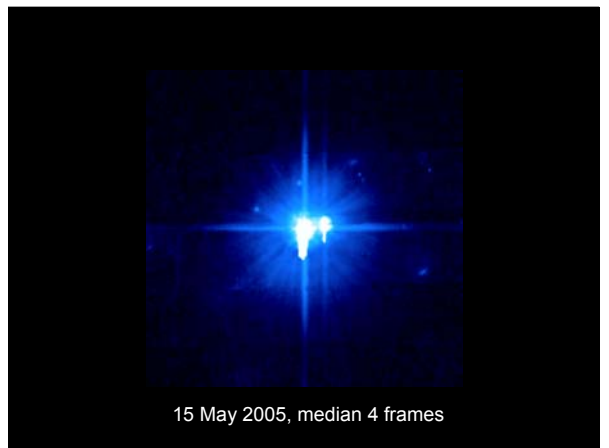
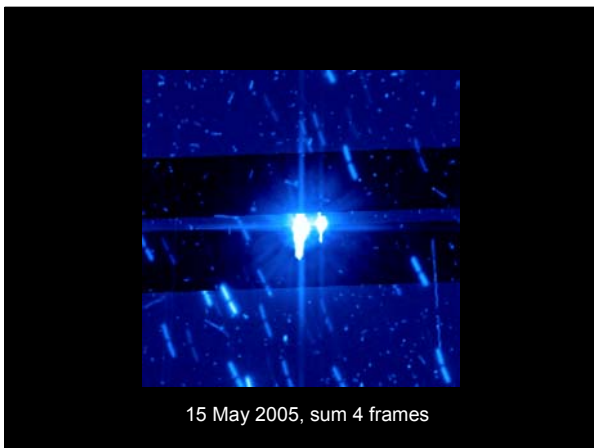
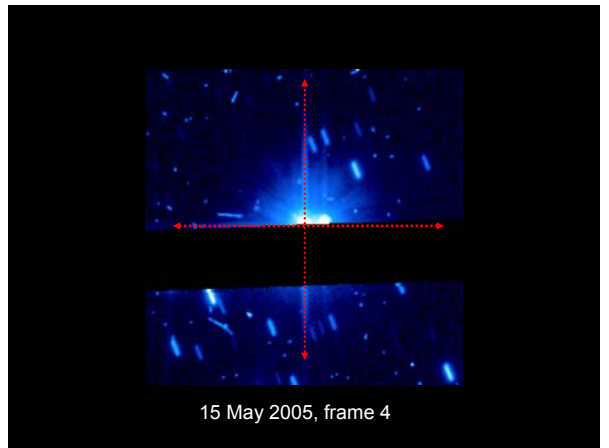
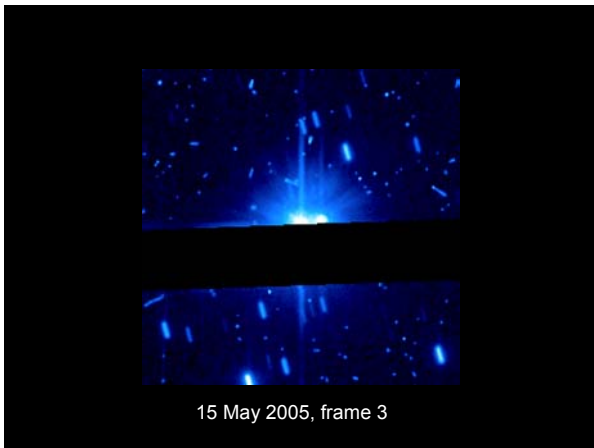
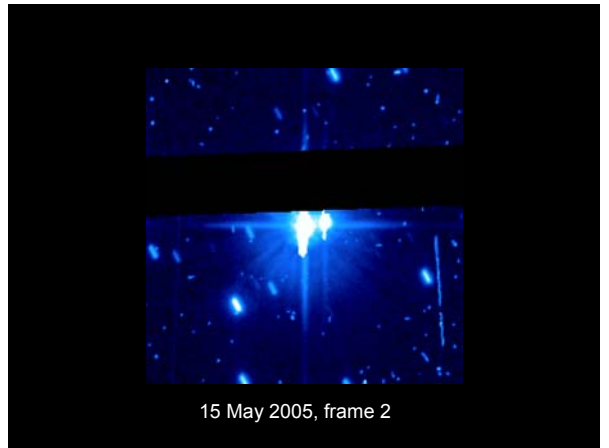
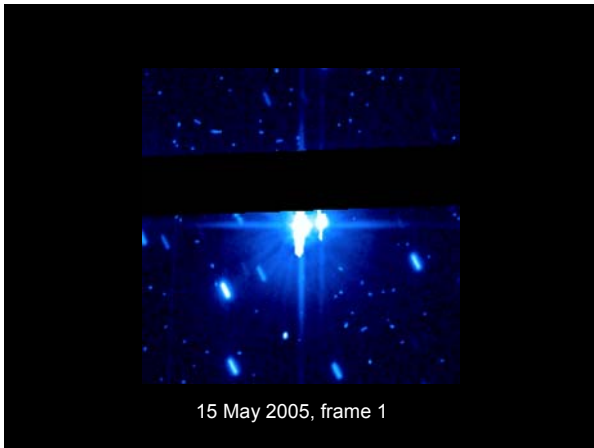


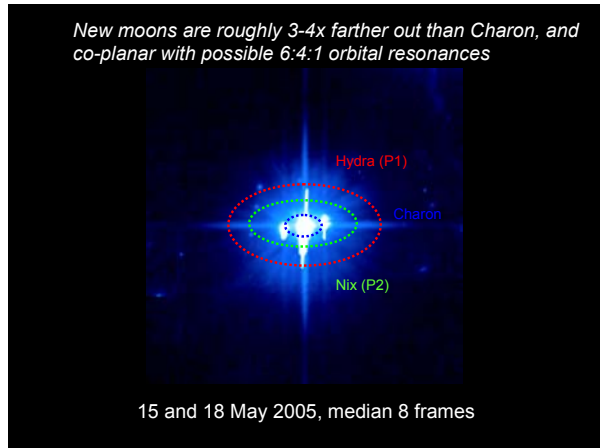
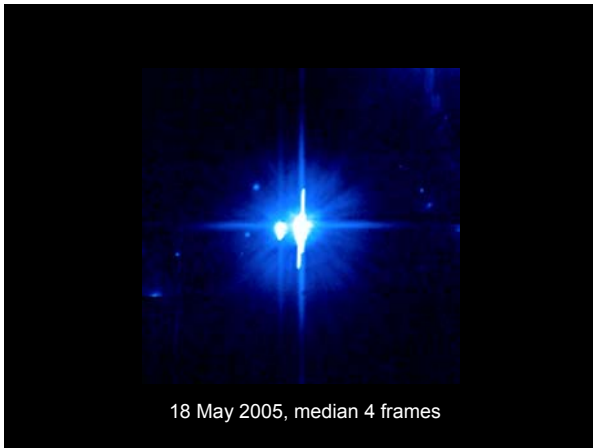
Pluto discovery images  
January 29, 1930



View looking down from above the Sun







### Pre-discovery observations in 2002

Pluto System • June 14, 2002 HST • ACS/HRC

Yellow light (555nm)  
Blue light (475nm)

NASA, ESA, and M. Bue (Lowell Observatory)

- Why weren't these moons discovered earlier?
- Now knowing exactly where to look: new moons marginally detected
- Additional points for orbit determinations

### Relative sizes of Pluto, Charon, and new moons (P1 and P2)

PLUTO 2300 km  
CHARON 1200 km  
Nix ~100 km  
Hydra ~100 km


The new moons are roughly 12x smaller and 600x fainter than Charon, and 4000x fainter than Pluto

Annette and Patsy Tombaugh

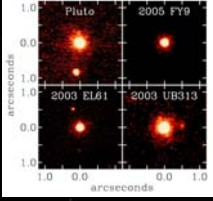

Jim Christy

New Horizons launch  
19 January 2006


## Eris (was "Xena") discovery announced in July 2005




Forcing the question:  
is this the 10<sup>th</sup> planet?

## The planet vote of 2006... and the *reaction*



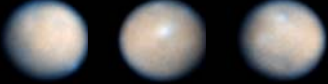
<http://www.iau2006.org>  
**Draft Resolution 5 for GA-XXVI:  
 Definition of a Planet**  
 16 August 2006 (initial proposal)



- (1) A planet is a celestial body that (a) has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (**nearly round**) shape<sup>1</sup>, and (b) is in orbit around a star, and is neither a star nor a satellite of a planet.
- (2) We distinguish between the eight classical planets discovered before 1900, which move in nearly circular orbits close to the ecliptic plane, and other planetary objects in orbit around the Sun. All of these other objects are smaller than Mercury. We recognize that **Ceres is a planet** by the above scientific definition. For historical reasons, one may choose to distinguish Ceres from the classical planets by referring to it as a "**dwarf planet**."
- (3) We recognize **Pluto to be a planet** by the above scientific definition, as are one or more recently discovered large Trans-Neptunian Objects. In contrast to the classical planets, these objects typically have highly inclined orbits with large eccentricities and orbital periods in excess of 200 years. We designate this category of planetary objects, of which Pluto is the prototype, as a new class that we call "**plutons**".
- (4) All non-planet objects orbiting the Sun shall be referred to collectively as "Small Solar System Bodies".


For two or more objects comprising a multiple object system, the primary object is designated a planet if it independently satisfies the conditions above. A secondary object satisfying these conditions is also designated a planet if the system barycentre resides outside the primary. Secondary objects not satisfying these criteria are "satellites". Under this definition, Pluto's companion **Charon is a planet**, making Pluto-Charon a double planet. If **Pallas, Vesta, and/or Hygeia** are found to be in hydrostatic equilibrium, they are also planets, and may be referred to as "dwarf planets".

## Three different faces of Ceres



## High resolution images of Ceres reveal roundness, surface features, and colors

## Three different faces of Ceres



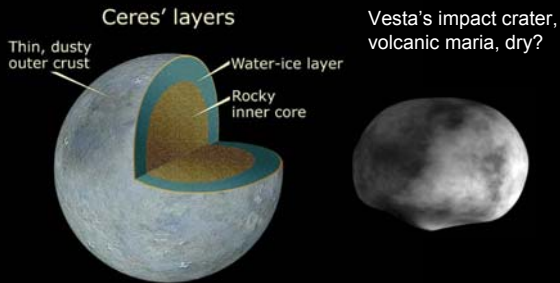
## High resolution images of Ceres reveal roundness, surface features, and colors

## Why does roundness matter ?

Hubble image of Ceres, the largest asteroid in the main asteroid belt, compared with four other asteroids and Mars.  
 (Longest dimension for each body in parentheses.)

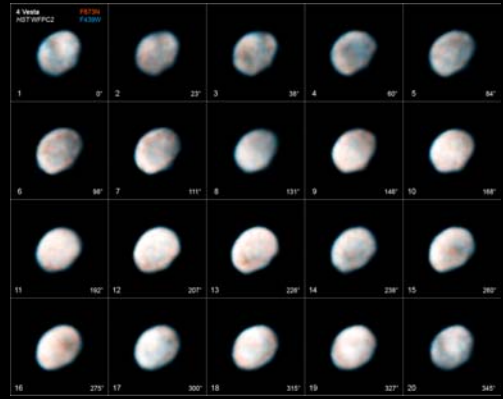


Same initial conditions, but different subsequent evolutions

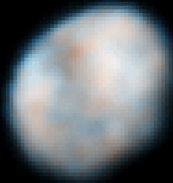


Thomas, P. et al., 2005, "Differentiation of the asteroid Ceres as revealed by its shape", *Nature Letters*, Vol 437  
 Thomas, P. et al., 1997, "Impact excavation on asteroid 4 Vesta: Hubble Space Telescope results", *Science*, Vol 277

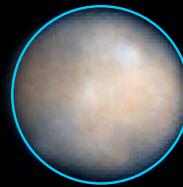
**Vesta color composites, in phase sequence**



Hubble WFPC2 images of asteroid Vesta in May 2007: color composite movie



**dwarf planet**



Ceres • January 24, 2004  
 HST ACS/HRC  
 with dither / drizzle

**asteroid**

(small solar system body)



*Hey, no fair!*

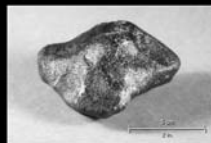
Vesta • May 14, 2007  
 HST WFPC2  
 with MEM deconvolution

Big collisions in the early Solar System:

Earth-Moon formation

Pluto and moons

Vesta impact: created 50 smaller asteroids, and 20% of meteorites



Meteorite - Fragment of Vesta  
 Left Photograph: Russell Kempton, New England Meteoritical Services  
 Right: NASA/JPL-Caltech, NASA/JPL-Caltech, NASA/JPL-Caltech

**Vesta was discovered in 1807... why not thousands of years ago?**



**"Naked eye" in May 2007**

<http://www.iau2006.org>

### Final Resolution for GA-XXVI: Definition of a Planet 24 August 2006



The IAU therefore resolves that planets and other bodies in our Solar System, except satellites, be defined into three distinct categories in the following way:

- (1) A "planet" is a celestial body that (a) is in orbit around the Sun, (b) has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape, and (c) has cleared the neighbourhood around its orbit.
- (2) A "dwarf planet" is a celestial body that (a) is in orbit around the Sun, (b) has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape, (c) has not cleared the neighbourhood around its orbit, and (d) is not a satellite.
- (3) All other objects, except satellites, orbiting the Sun shall be referred to collectively as "Small Solar System Bodies".

Pluto is a "dwarf planet" by the above definition and is recognized as the prototype of a new category of trans-Neptunian objects. For now, Charon is considered just to be Pluto's moon. The idea that Charon might qualify to be called a dwarf planet on its own, may be considered later.

## Largest known Kuiper Belt objects ...and Ceres are "dwarf planets"?

Dysnomia  
Nix  
Charon  
Eris (2003 UB313)  
Pluto  
2005 FY9  
2003 EL61  
Sedna  
Quaoar

### LIVE VOTE

Do you think Pluto should have retained its planetary characterization? \* 1535 responses

Yes	67%
No	24%
I don't know	9.5%

Not a scientific survey. [Click to learn more.](#) Results may not total 100% due to rounding.

Vote for Pluto. I ♥ PLUTO

### CNN.com QUICKVOTE

Created: Wednesday, February 01, 2006, at 13:46:21 EDT

Should Pluto keep its status as a planet?

Yes	74%	12132 votes
No	26%	4166 votes
Total: 16298 votes		

### CNN.com QUICKVOTE

Created: Tuesday, August 24, 2006, at 10:05:40 EDT

Were scientists correct in downgrading Pluto's status?

Yes	38%	29562 votes
No	62%	48931 votes
Total: 78493 votes		

Related: [Pluto no longer a planet, say astronomers](#) [Get more Quick Vote results](#)

This QuickVote is not scientific, and reflects the opinions of only those Internet users who have chosen to participate. The results cannot be assumed to represent the opinions of Internet users in general, nor the public as a whole. The QuickVote sponsor is not responsible for content, functionality or the opinions expressed therein.

### And now there are 8

Leading astronomers today declared that Pluto is no longer a planet, approving new guidelines that reclassify the solar system from nine planets to eight. The International Astronomical Union (IAU) passed the planetary status of what had been since its discovery in 1930.

### THE PROSPECTS OF BIN LADEN

Bin Laden's capture is a major step in the war on terror. It is also a major step in the war on terrorism.

### PEOPLE WHO MATTERED 2006

THE YEAR'S CHOICE PEOPLE WHO MATTERED A HOME FAREWELL PREY CHOICE

### Pluto

Back from the Minors After 18 Years

Deep down, Pluto had never been abandoned. It was on the way to becoming a planet again. It was on the way to becoming a planet again. It was on the way to becoming a planet again.

### Pluto's revenge: 'Word of the Year' award

PROBLED: 10:10 AM EST, January 1, 2007

STORY HIGHLIGHTS

- "Pluto" was named "Word of the Year" by the American Dialect Society.
- "Pluto" was named "Word of the Year" by the American Dialect Society.
- "Pluto" was named "Word of the Year" by the American Dialect Society.

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## Planet X becomes... just an ex-planet

On Sept. 7, the former 9th planet was assigned the asteroid number 134340 by the Minor Planet Center, the official organization responsible for collecting data about asteroids and comets in our solar system.

Pluto's companion satellites, Charon, Nix and Hydra are considered part of the same system and will not be assigned separate asteroid numbers, instead they will be called 134340 I, II and III, respectively.

There are currently 136,563 asteroid objects recognized by the MPC; 2,224 new objects were added last week, of which Pluto was the first.

Other notable objects to receive asteroid numbers included 2003 UB313, also known as "Xena," and the recently discovered Kuiper Belt objects 2003 EL61 and 2005 FY9. Their asteroid numbers are 136199, 136108 and 136472, respectively.

Circular No. 6747

Central Bureau for Astronomical Telegrams  
INTERNATIONAL ASTRONOMICAL UNION

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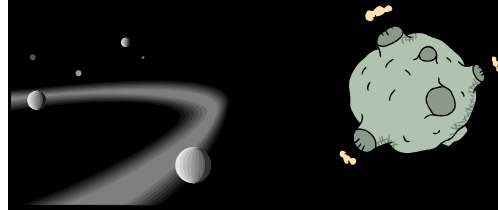
(134340) 2006 ER15 AND (134340) ERIS I (DYNORIDA)

Following the Aug. 24 resolution by the IAU to the effect that the solar system contains eight "planets" (Mercury, Neptune), with (1) Ceres, Pluto (cf. IAU 2003), and 2003 UB313 (cf. IAU 2007) to be considered representative "dwarf planets", the Minor Planet Center included Pluto and 2003 UB313 (along with two other new potential dwarf-planet candidates) in its standard catalogue of numbered objects with well-determined orbits on (134340) and (134340) respectively (see MPC 57252). Following unanimous acceptance by both the Committee on Small-Body Nomenclature and the Working Group on Planetary-System Nomenclature (in consultation with the discovery team), the IAU Executive Committee has now approved the name Eris for (134340) and Demos for its satellite (134340) Eris I (January 9, 2006 (2003 UB313) 1; cf. IAU 2003).



**Asteroid 134340  
(alias Pluto)**

## Citation from IAU *Minor Planet Circular* 56612 on the naming of Asteroid "6815 Mutchler"



M.P.C. 56612

2006 APR. 13

(6815) Mutchler = 1979 MM<sub>5</sub>

Discovered 1979 June 25 by E. F. Helein 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.



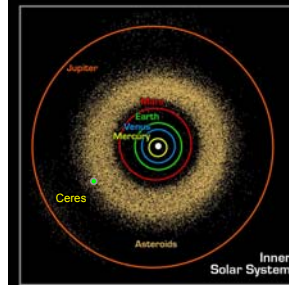
## Historical perspective: how many planets are there?

- **Antiquity** -- 7 planets in geocentric model (Moon, Mercury, Venus, Sun, Mars, Jupiter, Saturn)
- **1550** -- 6 planets in heliocentric model (add Earth, remove Moon and Sun)
- **1781** -- 7 planets (add Uranus)
- **1807** -- 11 planets (add Ceres, Pallas, Juno, Vesta)
- **1845** -- 12 planets (add Astraea)
- **1846** -- 13 planets (add Neptune)
- **1851** -- 8 planets (too many objects in Asteroid Belt to include them all)
- **1930** -- 9 planets (add Pluto)
- **1992** -- Discovery of 1992 QB<sub>1</sub>...the Kuiper Belt!
- **2005** -- Discovery of Eris (UB<sub>313</sub>)
- **2006** -- 8 planets (remove Pluto; *don't* add Ceres, Charon, Eris or other "dwarf planets")

## Ceres and Pluto: The "ugly duckling" problem of being the first of an entire class

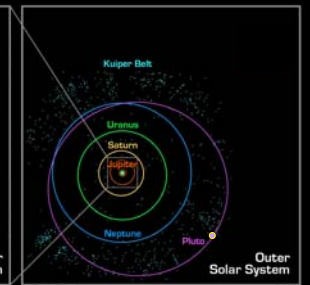
### Asteroid Belt

Discovered 1801-1851

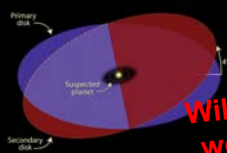


### Kuiper Belt

Discovered in 1992...or 1930?

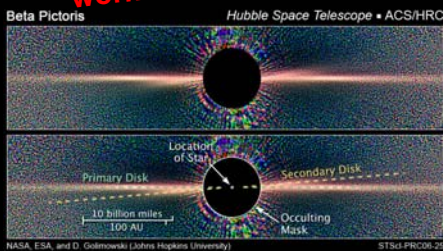


### Double disk around Beta Pictoris



Inferring planets from extra-solar Kuiper Belt's (vice versa): where planetary meets stellar astronomy

**Will our planet definition work here? Elsewhere?**



NASA, ESA, and D. Golimowski (Johns Hopkins University) STScI.PRC06.26

Dawn mission to Vesta and Ceres

Launched September 27, 2007



