Planets, Asteroids, Comets...

Cosmic Cleanup

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What exactly is a planet? Back when mankind only knew five roaming celestial bodies visible to the naked eye, the answer was simple. But the recent discovery of more and more planets circling our own Sun as well as distant stars has made it necessary to reconsider the meaning of the term...

Planets, asteroids, comets... such cosmic notions have recently made their way into the limelight. The media has been reporting about astronomers discovering more and more planets circling distant stars, pondering the issue of how many planets the Sun really has, debating whether Pluto is actually a planet or asteroid, and trying to assess the likelihood that a asteroid might one day strike the Earth. We struggle to imagine what the consequences of such a catastrophe might be like, take pleasure in reading that a space probe has brought a sample of a comet back to Earth, are concerned to learn that another probe smashed headlong into a comet, and try to understand just what exactly asteroids and comets are and why they are now the subject of such intense research. This barrage of information about extraordinary objects in the Earth's cosmic environs and astonishing events in Solar System research needs to be sorted out and put into some sort of perspective. And so, let take a step back and broadly consider how our picture of the Solar System has been affected by all these fascinating discoveries and discussions.

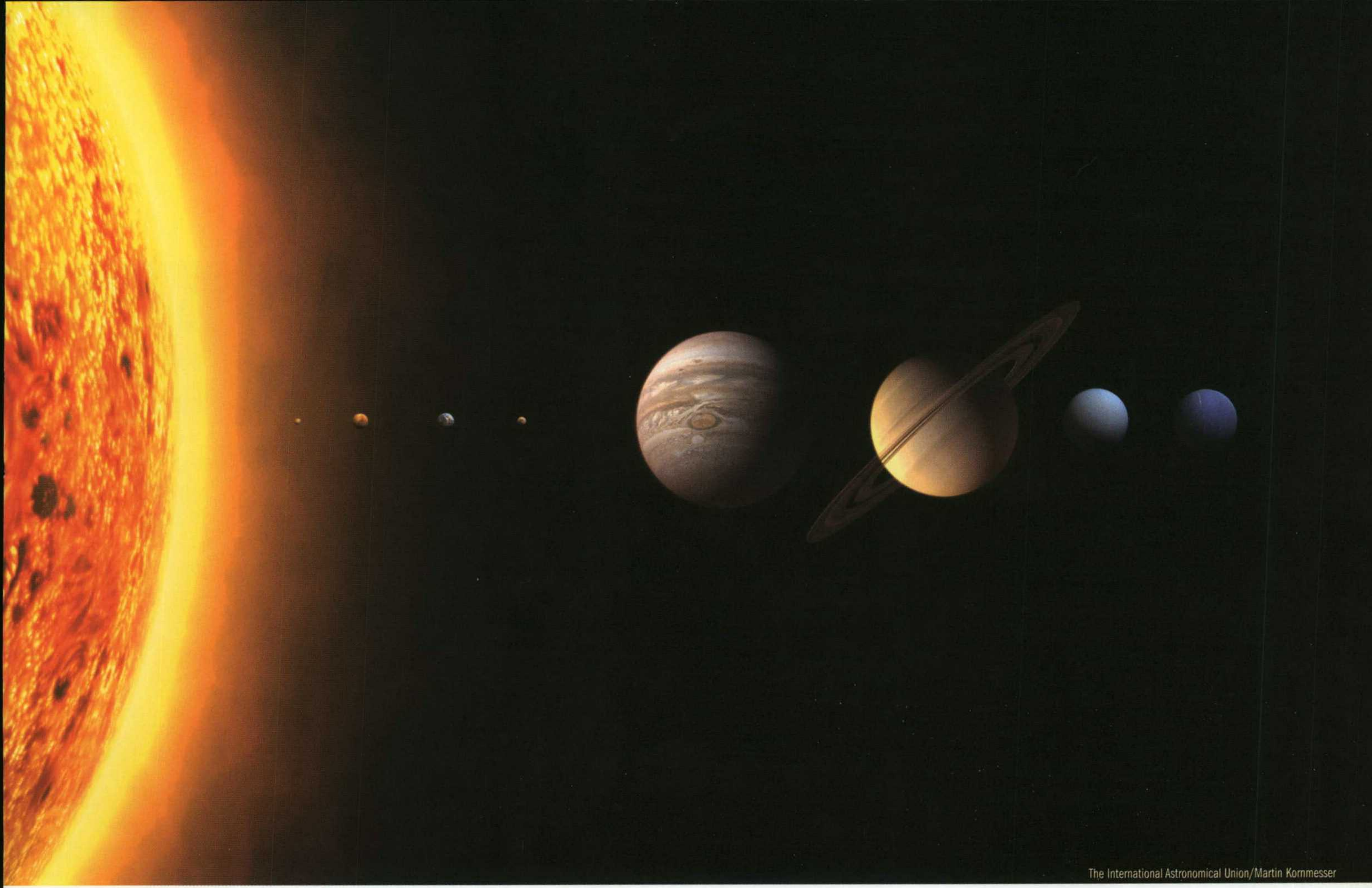
Adam Block/(NOAO), AURA, NSF

While comets, such as Comet Machholz seen here, differ from the asteroids in terms of their appearance in the sky (like a star with a "tail"), they are even more distinct in terms of their chemical composition

The concept of "planet" has evolved through history. It was first used by the ancient Greeks to describe 5 celestial objects that differed in appearance from the stars, and which, like the Sun and Moon, regularly changed their position against the fixed stellar backdrop. Centuries of studying the movements of these planets culminated in the work of Nicolaus Copernicus, who laid the foundation of modern astronomy. After Copernicus, the term "planet" came to encompass not only Mercury, Venus, Mars, Jupiter, and Saturn, but also the Earth, which ceased to be considered the center of the Universe. Subsequently the category also came to include the newly-discovered Uranus and Neptune, invisible to the naked eye.

An epoch of discoveries

Aside from these 8 planets, in the early 19th century numerous small objects called asteroids (or planetoids) began to be observed. They, too, cannot be seen with the unaided eye, being significantly smaller than the planets, but by the end of the 19th century ever more powerful observation tools and methods had led to the discovery and cataloging of several hundred such asteroids, moving around the Sun in the same direction and in nearly the same plane as the planets, in almost circular orbits located between Mars and Jupiter in what is known as the asteroid belt. One hundred years ago, therefore, our picture of the Solar System was quite straightforward: there were 4 planets of similar size and composition circling nearest the Sun (Mercury, Venus, Earth, Mars) plus 4 much larger gas giants at greater distances (Jupiter, Saturn, Uranus, Neptune), with a


The International Astronomical Union/Martin Kornmesser

band of numerous asteroids orbiting between these two clearly distinct groups.

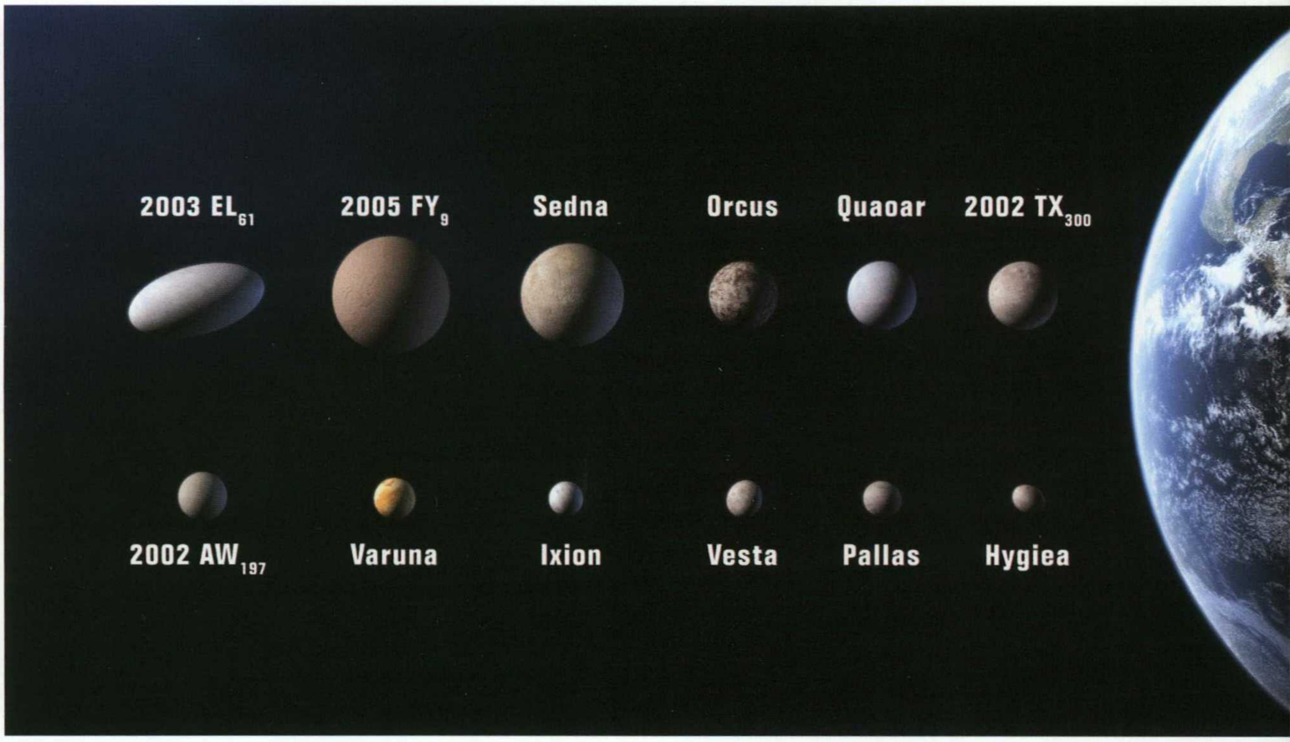
This lucid picture was first upset in 1930, with the discovery of an object even more distant from the Sun than Neptune, which was hailed as the ninth planet and named Pluto. Although Pluto differs from the other planets in terms of the path of its orbit, its size, and its mass (being even smaller than our Moon), these facts did not impede astronomers from treating it as yet another planet, albeit a somewhat unusual one. The ease with which Pluto was classified among the large "planets" despite its distinctness is perhaps more understandable if we consider the fact that various atypical objects were at that time also starting to be discovered within the "asteroid" group as well.

These other objects that further upset the image of the Solar System in the first half of the 20th century were asteroids found to have orbits outside the asteroid belt, often quite significantly so. First, asteroids were discovered orbiting closer to the Sun, where some of them could come close to the inner planets or even collide with them (leading mankind to realize the threat they might pose to the Earth). Next, asteroids located significantly more distant were also identified, among the four outer planets. When the 1990s brought a wave of discoveries of asteroids located even further out, we came to understand that there were a large number of such asteroids orbiting the Sun on the fringes of the planetary system, beyond the orbit of Neptune (thus dubbed "Trans-Neptunian Objects"), in a structure similar to the asteroid belt, discovered two centuries previously. This new band was called the Kuiper belt, in honor of the astronomer who had predicted its existence nearly 50 years earlier.

In August 2006, the International Astronomical Union adopted a resolution naming only eight Solar System bodies as planets: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune

Suspicious planet

Observational confirmation of the existence of a second belt of asteroids on the outskirts of the planetary system, beyond the zone of the 8 large planets, raised the question of whether Pluto, orbiting within the Kuiper belt, should still be treated as the ninth planet or simply as one of the asteroids, albeit perhaps the largest of them. Heated debate on this issue was initially cut off when the International Astronomical Union decided in 1999 not to change Pluto's status as a planet, chiefly on historical grounds. Yet the same dispute flared up again several years later when an object with the provisory name "2003 UB313" - Eris, and was discovered, orbiting the Sun along an even more atypical orbit than Pluto, yet being somewhat



The International Astronomical Union/Martin Kommesser

A new concept of "dwarf planet" has been set up to encompass such objects as Pluto, the somewhat larger 2003 UB313 (officially named Eris), and Ceres, the largest asteroid in the asteroid belt. Other candidates for the status of "dwarf planet" are portrayed here

larger than the latter. Should it rightfully be declared the tenth planet of the Solar System, as its discoverers were urging? In August 2006, the International Astronomical Union decided otherwise, adopting a resolution depriving Pluto of its status as the ninth planet of the Solar System and introducing a new concept of "dwarf planet" to encompass such objects as Pluto, the somewhat larger 2003 UB313, and also the largest asteroid in the asteroid belt, Ceres.

A new order emerging

But how exactly does a planet differ from a asteroid? There is no clear-cut answer to this question. Asteroids are much, much smaller objects than planets - although no precise limits of size or mass have been fixed to clearly delimit the two groups, which would enable us to settle whether Pluto is still a planet or only a asteroid. Even so, the latest discoveries and research are increasingly giving rise to a new overall picture of the Solar System, one that is as simple as the earlier one but also in agreement with contemporary concepts about its formation and evolution.

The matter in the original protoplanetary disk, encircling the Sun as it was formed 4.5 billion years ago, eventually coalesced into the 8 large objects we now know as planets. The material left over from the process of planet formation, in the form of significantly smaller lumps of matter now called asteroids, became grouped together - as a result of the evolution of their orbit paths under the dominant influence of the nascent planets' gravitational pull - in the zone between the four earthlike planets nearest the Sun and the four Jovian planets situated farther out, forming what is now called the asteroid belt. Even further away from the Sun, beyond the orbit of the farthest planet Neptune, remnants of the outer edge of the protoplanetary disk formed the structure known as the second asteroid belt or the Kuiper belt.

But asteroids are not the only remnants of the material from which the planets were formed - such remains are also to be found in another class of objects sporadically observed in the sky since very ancient times, which were until recently perhaps the most mysterious of all celestial bodies: what the ancient Greeks called comets. While comets of course differ from the asteroids in terms of their appearance in the sky (like a star with a "tail"), but they are even more distinct in terms of their chemical composition. Comets are icy objects chiefly composed of simple compounds of light elements (such as water), whereas the rocky asteroids are generally composed of minerals containing heavier elements (silicates, metals). When such icy bodies move closer to Sun, where temperatures are higher than in more distant regions of the Solar System, their surface layers give off gaseous substances which form a vast cloud of gas and dust enveloping the comet's small nucleus, usually only several kilometers across. The appearance of such a cloud of gas and dust and its dissipation of solar light are what make it possible for us to see a comet, and some of the matter blown out of the cloud by the solar wind and radiation pressure forms a tail, making comets particularly intriguing and picturesque in the night sky. Asteroids, on the other hand, lack such gaseous substances and can only be observed in the same way as the planets: owing to the solar radiation reflected from their surface.

Remnants from the past

Moreover, unlike asteroids, comets orbit the Sun along very diverse, variously oriented paths. Comets are presumed to originate in the Kuiper belt, as well as in a hypothetical collection of remnants of the protoplanetary disk known as the Oort cloud (after the Dutch astronomer who hypothesized its existence in the mid 20th century), spherically encircling the Sun at tens of thousands of times the distance between the Sun and the Earth. These remnants of the matter that formed the Sun and planets were probably cast off into regions so distant from the Sun at a late stage in the Solar System's formation. Another interesting and as-yet-unresolved problem lies in the mechanisms which first of all led to the formation of the Oort cloud, and second of all cause certain objects to leave it - just like other objects are pushed out of the Kuiper belt or the main asteroid belt and sent in a more sunward direction. This slow diffusion of smaller Solar System bodies towards the Sun is a characteristic element in the evolution of the material gathered around our star. Resolving this phenomenon is one of the key issues in contemporary astronomy.

The meaning of the word "planet" was expanded yet again at the end of the 20th century, when observational evidence was found for the existence of objects circling stars other than our Sun, with masses comparable to those of the planets in our Solar System. Astronomy now defines the "planet" category as including celestial bodies that are gravitationally bound to stars but which do not, like stars, have their own productive sources of energy. This means that they can only be observed in the light of their nearby star. So far, only the planets in the Solar System itself have actually been observed and studied in detail, as existing observational methods are as yet unable to directly observe extrasolar planets. For now we can only deduce their existence on the basis of various observable intermittent phenomena, such as the wobbling of a star around its common center of mass with an accompanying planet, or a dimming in the light from a star (as perceived from the Earth) when it becomes momentarily obscured by a circling planet. These days such methods can only be used to detect the presence of large and massive planets, relatively close to the stars they circle. Yet better and faster techniques and methods of observation are constantly being developed, brining hope that soon we will find evidence for the existence of extrasolar planets similar in size and mass to those in our Solar System - and perhaps even observe them directly. ■

Further reading:

Blondel Ph., Mason J., (2006). *Solar System Update.* Germany: Springer.

http://nssdc.gsfc.nasa.gov/planetary/planetfact.html

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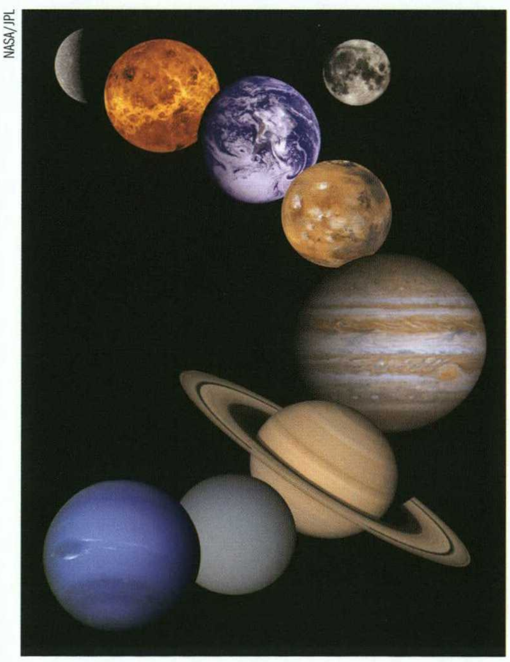
NASA/JPL



A montage of planetary images taken by spacecraft, including (top to bottom): Mercury, Venus, Earth (and the Moon), Mars, Jupiter, Saturn, Uranus and Neptune