

# THE COMPLETE COSMOS

## Chapter 12: Uranus and Neptune

*The outer giants. Uranus - a crazy tilt and a chaotic moon called Miranda. Neptune - tempests and a moon spurting geysers.*

### Outline

Seventh planet from the Sun, Uranus is a gas giant far larger than Earth - but modest in size compared to Jupiter. Uranus has an 84-year orbit, a day of 17 hours 48 minutes, a strangely tilted axis, and a magnetic field that is offset by 60 degrees to the rotation axis.

That Uranus has rings was discovered in 1977, when a star was observed winking several times before and after it passed behind the planet. In 1986, Voyager 2 made the first fly-by, but saw very little in the way of clouds and weather. Later, the Hubble Space Telescope revealed three hazy layers of atmosphere. A description of probable internal structure of Uranus.

Uranus has 17 moons - Miranda, Ariel, Umbriel, Oberon and Titania being the most important. Miranda, which has a chaotic surface and ice cliffs 15 kilometers high, may be the rough reassembly of a moon shattered in an ancient collision.

By observing the movement of Uranus, astronomers discovered that it was being perturbed by another, more distant planet. They correctly predicted its position - the planet now known as Neptune. Very slightly smaller than Uranus, Neptune has a 165-year orbit and a day of 16 hours seven minutes.

Compared to the almost featureless blur of Uranus, Neptune has plenty of clouds and weather. At the equator, winds roar at 2,000 kilometers an hour. The planet's atmosphere and internal structure are described.

Neptune also has rings and eight known moons. The largest moon, Triton, is icy and extremely cold at -238 degrees Celsius. Triton has geysers that shoot blackened nitrogen eight kilometers high. It may not always have been a moon - but a planetesimal captured by Neptune.

### Sub-chapters

#### *Strange Tilted Uranus*

- Spectacular fly-around of Uranus - its system of rings revealing the planet's strangely tilted axis. Close-up of the strange moon Miranda, the rough diamond of the Solar System.
- The remoteness of Uranus, 19 times further from the Sun than Earth.
- Discovery of the rings of Uranus when a star is seen to wink several times before and after it passes behind the planet. They emphasize the severe tilt of the planet - all of 98 degrees. Uranus orbits on its side.
- Size with both Earth and Jupiter. Uranus is far larger than Earth but modest compared to Jupiter.

#### *Magnetic Field and Atmosphere*

- In 1986, the Voyager spacecraft shows Uranus as an apparently featureless ball.
- With infra-red, the Hubble Space Telescope reveals three hazy layers of atmosphere and hints of weather.
- The magnetic field through Uranus is demonstrated by a moving arrow. The planet's

magnetic axis is shown to be strangely tilted by 60 degrees to the rotational axis. On Earth this tilt is only 11 degrees.

- Composition of the atmosphere of Uranus - mainly hydrogen, with helium and a touch of methane.
- The planet's internal structure - layer by layer - down to the rocky core. The magnetic field is probably generated within the mantle of ices.

#### *Weird Moons*

- Introduction to the most unusual moon of Uranus - Miranda - a chaotic world less than 500 kilometers across.
- A massive impact shatters Miranda early in its life. Miranda reassembles, but some of the debris forms the rings of Uranus.
- Miranda's ice cliffs, up to 15 kilometers high.
- Close-ups of another four of the 17 known moons of Uranus:
- Ariel, dull compared with Miranda, but twice the size, with canyons, faults and frost.
- Umbriel, a little bigger than Ariel, but with an ancient surface pock-marked by craters.
- Titania, the largest moon of Uranus, with a canyon comparable to the East African Rift Valley.
- Finally Oberon, the outermost large moon.
- The length of the day on Uranus, and the length of its year - 84 Earth years.

#### *Neptune: Outermost Giant*

- Fly-out from Uranus until to Neptune - last of the gas giant planets.
- The remoteness of Neptune, 4,500 million kilometers from the Sun, and length of its year - 165 Earth years.
- Problems in predicting the position of Uranus lead to the discovery of Neptune.
- Something is perturbing Uranus, pulling the planet out of position. Using these disturbances, astronomers discover a new planet - now called Neptune - in 1846.
- Neptune compared in size with Uranus - very slightly larger - and with both Earth and Jupiter. Like Uranus, Neptune is far bigger than Earth but modest compared to Jupiter.

#### *Turbulent Atmosphere*

- After the blandness of Uranus, Voyager finds plenty of weather on Neptune, driven by heat from within the planet.
- Neptune's clouds, storms, and winds which roar at up to 2,000 kilometers an hour.
- The Great Dark Spot, a tempest the size of Earth, seen by Voyager, but shown to have disappeared by the Hubble Space Telescope seven years later.
- Length of the day on Neptune, composition of the planet's atmosphere – mainly hydrogen, with helium and a touch of methane. Internal structure - layer by layer – down to the rocky core.

#### *Rings and Geysers*

- Neptune's two main rings are seen in close-up - plus their particles of icy dust.
- The planet's eight moons, six of them discovered by Voyager, but focusing on the largest, Triton, which has the coldest known surface.
- Erupting geysers on Triton spurring blackened nitrogen eight kilometers high.
- Possibility that Triton is a captured planetesimal, and perhaps similar to Pluto, the tiny planet beyond.

## **Background**

### *Moons of Uranus*

The five largest moons of Uranus were known before the Voyager 2 spacecraft encountered the planet in 1986. In order of decreasing distance from the planet, the five are Oberon, Titania, Umbriel, Ariel and Miranda. The names, borrowed from English literature (the works of William Shakespeare and Alexander Pope), were suggested by John Herschel, son of the astronomer William Herschel. The names broke with the tradition of using names from Greek or Roman mythology.

Ten new, smaller Uranian moons were discovered by Voyager 2, all of them closer to the planet than Miranda. Their names (in order of decreasing distance from the planet) are Puck, Belinda, Cressida, Portia, Rosalind, Desdemona, Juliet, Bianca, Ophelia, and Cordelia. The naming followed the precedent set by John Herschel. More recently, two new more distant moons (as yet unnamed) have been discovered, bringing the total to 17. The two largest moons, Oberon and Titania, are each less than half the diameter of Earth's Moon. Both moons have average densities between 1.6 and 1.7 times that of water, surprisingly high compared to Saturn's icy moons. The pair are a mixture of ice and rock, but scientists had anticipated the bodies would be icier and, therefore, have lower densities.

Titania, the largest of the Uranian moons, has plenty of craters, many with bright rays. There are also complex rift valleys and fault lines hundreds of kilometers long. Smooth sections indicate where volcanic resurfacing has taken place. Titania's surface fractures may have been caused by the expansion of frozen water beneath the surface. Oberon, however, shows no signs of internal activity since visible rift valleys and fault lines are virtually absent from its heavily cratered surface.

Umbriel and Ariel are roughly three-quarters the size of Oberon and Titania. Umbriel is the darkest of the large Uranian moons. It has a reflectivity of just 19 per cent. Huge craters pockmark its surface. Unlike the other large moons, Umbriel has a dark, relatively bland surface with a lack of bright, younger ray craters. The surface is probably extremely ancient. In contrast, the surface of Ariel, the brightest of the Uranian moons, has spectacularly deep rift valleys, together with broad, smooth valleys. Its surface certainly appeared "younger" than those of Oberon and Titania.

The smallest of the large Uranian moons, Miranda, has been described as the most bizarre body in the Solar System. It has a remarkable variety of surface terrain, with rolling, heavily cratered plains next to three huge, 200-300 kilometer oval-to-trapezoidal regions known as "coronae". They have networks of concentric canyons but the regions are less cratered than the plains. Miranda has grooves, craters, valleys and ice cliffs towering up to 15 kilometers. There is also a corona region shaped like a chevron and another nicknamed "the racetrack". Various theories offer explanations of Miranda's odd features. One is that at some time in the past the moon was impacted, shattered and haphazardly fell together again under the influence of its own gravity.

### *Strange Magnetic Fields*

Five days before its closest approach to the planet in January, 1986, Voyager 2 found that Uranus has a magnetic field. The extreme tilt of its rotation axis - 98 degrees - was already known, so that Uranus orbits on its side. The great surprise was the discovery that the planet's magnetic axis - an imaginary line joining its north and south magnetic poles - is tilted by 59 degrees with respect to the planet's rotation axis. This is by far the greatest offset of any of the planet. For example, Earth's magnetic axis is tilted by just over 11 degrees to its rotation axis, and Saturn has the smallest tilt of all, zero degrees. The inclination of the Uranian magnetic axis causes the magnetic

field to wobble back and forth as the planet rotates. Another strange feature is that the magnetic field is not centered at the very core of Uranus, but is shifted by nearly one third of the planet's radius from its center. On Earth, this displacement is only eight hundredths of the planet's radius. The probably reason is that on Uranus, the magnetic field is generated within an electrically-conducting layer deep inside, but not at the core.

When Voyager 2 arrived at Neptune in 1989, it found a magnetic field almost as strange as that of Uranus. The tilt of Neptune's rotation axis is only about 29 degrees - far less than Uranus, and more like that of the Earth. Neptune's magnetic axis, however, is inclined by 47 degrees to the planet's rotation axis - only slightly less than Uranus. Even more remarkably, the magnetic axis is shifted by 55 per cent of the planet's radius from its center. Clearly, Neptune's magnetic field must again be generated within an electrically-conducting layer deep within, but located some way from the planet's core. Once again, the magnetic field wobbles back and forth as the planet rotates.

#### *Triton - Neptune's Remarkable Moon*

Five hours after Voyager 2 had swooped above the north pole of Neptune in August, 1989, the craft made a close pass of the planet's largest moon, Triton. What surprises! Triton turned out to be smaller than anticipated, with a diameter of just over 2,700 kilometers - considerably smaller than our Moon.

Triton was also more reflective and much colder than expected, with a surface temperature of - 238 degrees Celsius. Its density is about twice that of water. The moon seems to be composed of about one-third ice and two-thirds rock. It has a very tenuous atmosphere consisting mainly of nitrogen, with traces of methane and carbon monoxide. The surface pressure is just 14 microbars - 70,000 times less than Earth's air at sea level. Winds at the surface blow at around 20 kilometers an hour, westward.

Triton's surface is greatly varied. It's coated with water ice - so cold it must be as hard as steel at such low temperatures - overlaid by methane and nitrogen ices. Triton is remarkably flat - with few normal craters and no mountains or deep valleys. The coloring of parts of the surface is surprisingly vivid. A large pinkish ice cap covers the south pole - resembling strawberry ice-cream in color and thought to consist of nitrogen snow and ice.

It is in this region that astronomers have identified nitrogen ice geysers. Presumably, Triton has a layer of liquid nitrogen under pressure a few tens of meters below the surface. Finding its way upwards through cracks in the crust, the material explodes through the surface as a shower of ice and gas. It spurts at up to 150 meters per second, rising to a height of several kilometers. It then blows downwind producing dark 80 kilometer streaks.

North of the pink polar ice cap, are two regions of equatorial terrain, with a well defined edge. The eastern region is partly covered by relatively smooth terrain, but also with hummocky and knobby areas. There are low-walled plains as flat and smooth as frozen lakes. The western equatorial region is criss-crossed by fissures with central ridges. It resembles a melon skin - hence the name "cantaloupe terrain".

Triton, without doubt, is a remarkable world. Southern midsummer falls in about 2006, so major changes in the pinkish ice cap may be expected. So too, in the northern polar region which at the time of the Voyager encounter was plunged into winter. Unfortunately, no new space probes to Neptune are planned in the near future.

### **Links for Further Information**

A page about the Voyager spacecraft and its mission, including images acquired at both Uranus and Neptune.

<http://www.star.le.ac.uk/edu/solar/voyager.html>

Overall information on Uranus, with key facts, images and animations.

<http://www.star.le.ac.uk/edu/solar/uranus.html>

Overall information about Neptune, with key facts, images and animations.

<http://www.star.le.ac.uk/edu/solar/neptune.html>

All that we have learned so far about Uranus, presented in a simple and easy to understand way.

<http://www.crystalinks.com/uranus.html>

A page with many links leading to various sites relating to the planet Neptune.

[http://www.astro.ku.dk/~lars\\_c/tbp/solar/eng/neptune.htm](http://www.astro.ku.dk/~lars_c/tbp/solar/eng/neptune.htm)

### **Questions and Activities for the Curious**

1. If Uranus and Neptune are both represented by the size of tennis balls, how big would Jupiter be on the same scale? How big would the Sun be, and how far would Uranus and Neptune be from the Sun using this scale?
2. Describe the technique that was used to discover the rings of Uranus in 1977.
3. Discuss the similarities and differences between the five largest moons of Uranus.
4. The moons of Uranus are named after characters in plays by William Shakespeare and Alexander Pope. For each of the moons, identify the play from which the name comes. If two new moons were discovered, suggest names for these moons, and say why you chose them.
5. Research and explain why the planet Uranus was originally called "Georgium Sidus" by the man who discovered it, William Herschel.
6. Both John Couch Adams, in England, and Urbain-Jean-Joseph Le Verrier, in France, predicted the existence of an eighth planet beyond Uranus. Research what you can about this astronomical detective story.
7. Compare the visible appearance, atmospheres and internal structures of the planets Uranus and Neptune.
8. Describe the axial tilts and magnetic fields of Uranus and Neptune, and the similarities and differences between them.