Understanding Uranus

No, it is not Saturn, although it does have rings. It is not Neptune, although it does have bright clouds and obvious bands. This is URANUS (pronounced "YOUR-a-nuss" by most scientists) as imaged by the Hubble Space Telescope in 1998. Uranus is undergoing remarkable atmospheric changes right now, and scientists are using all means possible to decipher the causes of the change.

Uranus - The First "Modern" Planet

Since antiquity, some stars were seen to move through the heavens. These "planets" ("wandering stars") were Venus, Mars, Jupiter, and Saturn. Uranus is just bright enough to be seen with the naked eye, and indeed had appeared in some early star charts as an unidentified star. But it was not until 1781 that English astronomer William Herschel recognized it as a planet. Uranus travels in a nearly circular orbit at an average distance of almost 3 billion kilometers (1.9 billion miles) from the Sun (about nineteen times the distance from Earth to the Sun).

The earliest observations of the planet's shape and the orbits of its moons led to a startling conclusion. Sometime in Uranus's past, a massive collision had wrenched the young planet, knocking it over onto its side.[1] As a result, the rotation pole of Uranus is now tilted more than 90 degrees from the plane of the planet's orbit.

William Herschel

Uranus Discovery Telescope

Another thing that makes Uranus so different from other giant planets[2] is that it does not appear to be radiating heat from its interior. In comparison, the other three giant planets radiate significantly more heat than they receive from the sun. The heat is thought to be left over from the time of the planets' formation and from continuing gravitational contraction. Why does Uranus appear to have none? Scientists theorize that perhaps the event that knocked Uranus over on

[1] GAVRT Science Advisor Heidi Hammel watched in 1994 as a small wayward comet struck Jupiter; the ensuing celestial fireworks were documented by the Hubble Space Telescope and by observers all over Earth. Yet within just a month, Jupiter's ugly bruises had faded, and the planet spun serenely on as if nothing untoward had happened. Thus, one can only imagine what must have happened to poor Uranus to twist it completely off its normal spin axis.

[2] There are four giant planets in the solar system: Jupiter, Saturn, Uranus, and Neptune. Uranus is a somewhat small giant: at its equator, its radius is about 25,559 kilometers (15,847 miles).

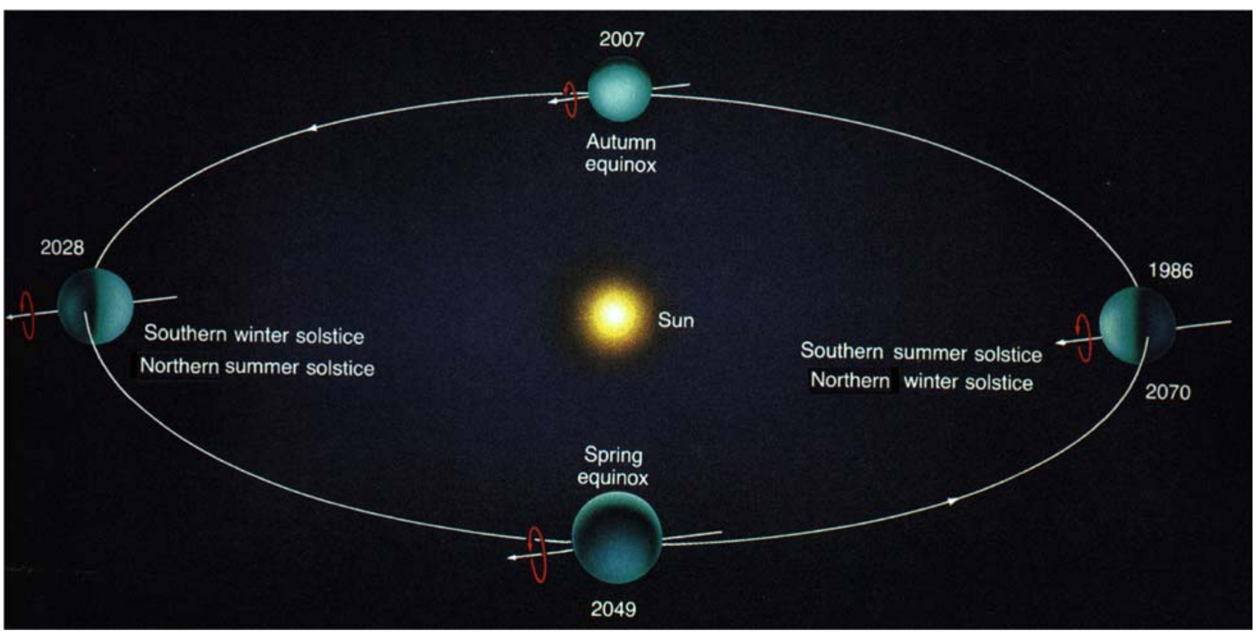
its side somehow caused much of the heat to be released early in the planet's history, or perhaps the heat is there but is trapped by stable layers in the atmosphere which block transport from the interior outward.

The composition of Uranus is similar to that of the other giant planets and the Sun, consisting predominantly of hydrogen (about 80 percent) and helium (15 percent). The remainder of Uranus's atmosphere is methane (less than 3 percent), hydrocarbons (mixtures of carbon, nitrogen, hydrogen, and oxygen), and other trace elements. Uranus's color is caused by the methane, which preferentially absorbs red light, rendering the remaining reflected light a greenish-blue color.

What Causes Seasons?

On Earth, energy from the Sun drives the weather. Sunlight, combined with the Earth's axial tilt, creates the seasons. The tilt causes different regions on the Earth to receive different amounts of sunlight depending on the time of year. The varying amount of sunlight creates temperature differences that in turn affect atmospheric circulation. These variations in temperature and circulation are the changing seasons.

Uranus has the most extreme seasonal variation in the solar system, thanks to its large tilt. One Uranian "year" (the time it takes Uranus to travel around the Sun) lasts 84 Earth years. Thus each season lasts 21 years! It is now approaching equinox in 2007; at that time its equator will be pointing toward the sun. The last time this happened was 1965!



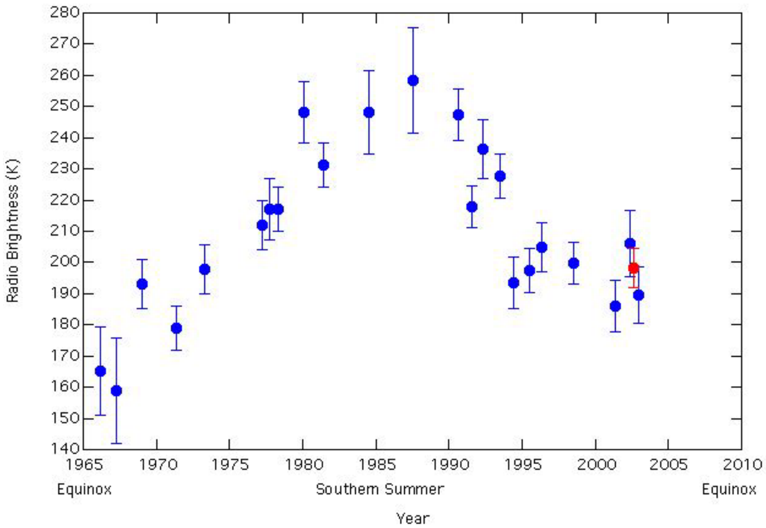
Uranus Through the Eyes of Voyager

The atmosphere of Uranus has often been called bland, and even boring. These epithets are a consequence of fate and unfortunate timing. It was fate that caused that early collision of Uranus with a large body, creating the planet's extreme axial tilt, which in turn created extreme seasons. It was unfortunate timing that the Voyager 2 encounter (which gave us our highest resolution pictures) occurred in 1986 at peak southern summer, when we had a view of only the southern half of the planet. This season is when Uranus has appeared blandest in the past.

Uranus as seen by Voyager

Radio Observations of Uranus

Radio observations of Uranus have been made since the 1960s. They show something unusual: the planet can change rapidly (from year to year and perhaps even faster), and the changes occur deep in the atmosphere, far below the clouds we see at visible wavelengths.[3]



[3] Mike Klein, Project Scientist of the GAVRT program, was one of the first scientists to recognize this and report it, back in 1978.

The rapid change is surprising. They are probably seasonal, but sunlight is relatively weak out at Uranus, and we didn't expect it to penetrate far below the cloud tops. Thus, we expected seasonal changes to be sluggish and weak, but that is not what the observations are showing us! Our hope is that by studying Uranus carefully, we will learn why our expectations were wrong. That could help us understand how the seasons and weather work on all the giant planets.

But what exactly does the radio brightness tell us about the planet? It tells us the composition and temperature of the atmosphere. By looking at any one time, we therefore learn about the weather at that specific time. Where are the clouds today? Where is it warm and where is it cold? If we look at the weather for many years, however, we learn about the seasons. How different are summer and winter? When are storms most likely to occur? We have to look for many years to figure this out because each season on Uranus lasts for 21 terrestrial years.

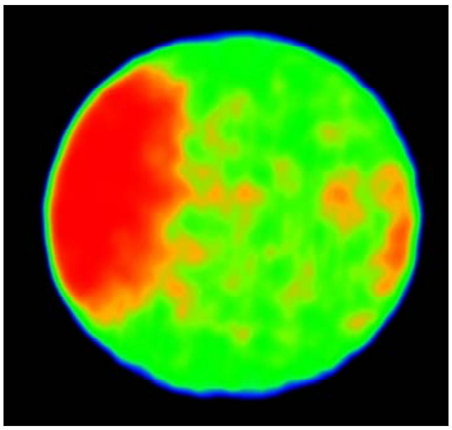
What is Happening on Uranus Now?

As Uranus continues its 84-year-long progression around the Sun, its equatorial region is now receiving sunlight again, and parts of its northern hemisphere are being bathed in solar radiation for the first time in decades. For this reason, astronomers at many observatories will be looking at Uranus now and over the coming years. Observations are being made at the Keck 10-m telescope in Hawaii, from the Hubble Space Telescope in Earth orbit, and at the Very Large Array, a giant radio telescope in New Mexico, to name just a few of the places turning their instruments toward this distant planet.

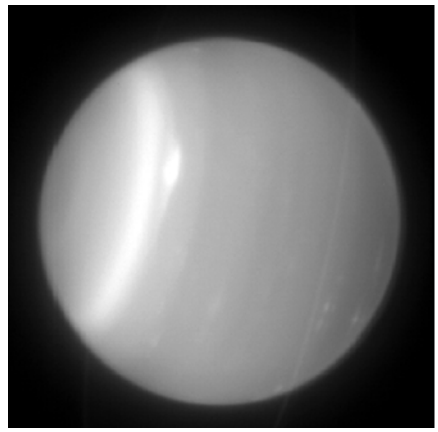
VLA, Soccoro, New Mexico

Observatory, Mauna Kea, Hawaii

We are watching Uranus carefully, in the hopes that answers to some of our questions might be revealed as we probe the planet's seasonal change with modern astronomical equipment. To visible and infrared telescopes, it appears that the northern hemisphere (in its spring) differs quantitatively from the southern (fall) in terms of overall haziness and number of bright cloud features. Images from Hubble and Keck reveal multiple bright cloud features and stunning banded structures on Uranus. It is not yet clear how the northern and southern hemispheres differ at radio wavelengths, which sense far below the clouds seen at visible and infrared wavelengths. Radio maps from the VLA show a bright south pole and perhaps the first hint of a bright northern pole.



Uranus with the VLA
July 2003, M. Hofstadter and B. Butler



Uranus with the Keck 10-m
October 2003, H. Hammel

With each visit to the telescope, we hold our breath just a little, because we are not quite sure what the planet will look like. It is fascinating to speculate how Uranus will appear to us by the time it reaches its next equinox in 2007.

Why Study Uranus with GAVRT?

If all these observatories are watching Uranus, why is GAVRT important? Because YOU can do things a professional astronomer cannot! There are many interesting things to look at in our universe, thus telescopes like the VLA or Hubble Space Telescope only have time to check up on Uranus every year or two. What if something starts to change when the VLA is not looking? GAVRT, by observing several times a year, might see something happening first, and warn us to look with other telescopes!

Another important contribution from GAVRT is the continuation of the 40-year record of seasonal change. It is critical to maintain a consistent record; the GAVRT observations are especially valuable in this sense, because the equipment and observational techniques used by the GAVRT observers are similar to those used to take measurements in the 1960s and 1970s, though more sensitive.

With GAVRT's help, we hope to answer questions such as:

- What does the northern hemisphere of Uranus look like?
- What is the weather like there?
- How does it change with the seasons?
- What can Uranus teach us about weather and seasons on other planets?

Sign up for the Uranus GAVRT Campaign, and find out the important role that you can play in determining the answers to these questions!

Uranus experts Mike Klein, Heidi Hammel, and Mark Hofstadter (in center) meet with teacher Debby Salter (far right), her GAVRT student team, and other GAVRT staff during a January 2003 visit to their school in the state of Washington.

Heidi B. Hammel, Mark D. Hofstadter, and Michael J. Klein
December 2003