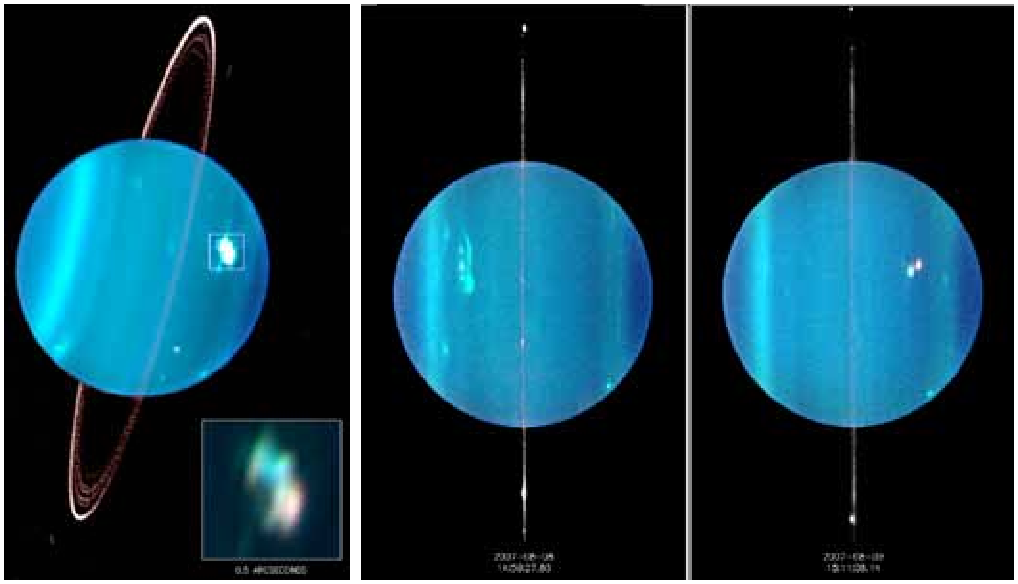
Uranus: A Puzzling Cloud Distribution

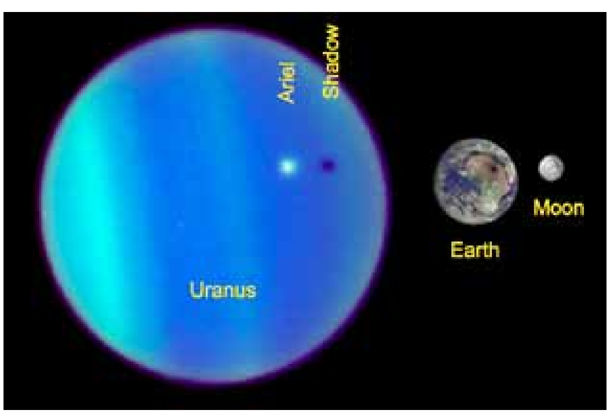


Far left image shows the brightest feature yet seen on Uranus. Later images show Uranus at the 2007 equinox, with its rings viewed directly edge-on.

When Voyager 2 flew by Uranus in 1986, its radio-based images showed a rather featureless planet. It was a surprise when, a decade later, the Hubble Space Telescope's (HST) near infrared detectors revealed many previously unseen cloud features. The brightest features were in the northern hemisphere, a latitude range on the planet that had just come into sunlight after having been in darkness for over 40 years. Since the late 1990s HST has observed the planet regularly, joined in 2000 by the 10-meter Keck telescope on Mauna Kea in Hawaii.

Uranus has an 84-year orbital period and a spin-axis tilt of 97° from its orbit normal, so that its poles alternate between 42 years of sunlight and 42 years of darkness, providing the largest fractional seasonal forcing of any planet in our solar system. On average its poles receive more sunlight than its equator. For comparison, the Earth's spin axis tilt is only 23.5°.

Discrete cloud features in the southern hemisphere of Uranus are generally much deeper than those in the northern hemisphere and likely of a different composition.



2006 HST observations captured the first image of a solar eclipse on Uranus, this one by the moon Ariel. Earth and Moon shown for size comparison.

From analysis of reflected spectra, the main cloud layer on Uranus appeared to be centered much deeper than expected from Voyager 2 radio occultation results (collected in its fly-by in 1986), strongly suggesting that the main cloud could not be composed of methane, in spite of the fact that methane is by far the most abundant condensable gas on the planet.

In observations from 1994 through its 2007 equinox, Principal Investigator Larry Sromovsky at SSEC saw asymmetry in Uranus's cloud structure, with the southern hemisphere, recently coming out of a long summer, being generally brighter than the northern hemisphere. This would not be surprising if it was a long-delayed response to seasonal forcing, but changes were occurring faster than expected.

The bright band at 45°S was beginning to fade, while a new bright band was beginning to form at 45°N.

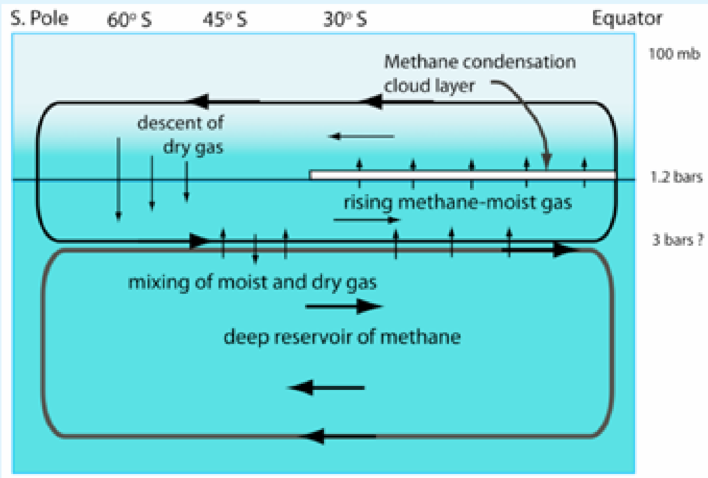
Another interesting asymmetry was the continued complete absence of discrete cloud features south of 45°S, while discrete cloud features were observed north of 45°N (which were only visible in high-pass filtered near-IR images taken by the Keck Observatory telescope). Some mechanism seemed to be inhibiting convection at high southern latitudes but not at high northern latitudes.

In 2009, complex calibration issues were finally resolved allowing observations made in 2002 by the Hubble Space Telescope (HST) Space Telescope Imaging Spectrograph (STIS) to be thoroughly analyzed by Erik Kartoschka of the University of Arizona. They revealed a puzzling lack of methane concentrations in the southern hemisphere of Uranus.

Reanalysis of the Voyager occultation and of the CCD spectra measured by the STIS, which uses two compact cloud layers instead of one diffuse layer for the main layer, produced more consistent results between occultation and spectral results for the upper compact layer.

Sromovsky confirmed that at high southern latitudes methane must be strongly decreased in the upper troposphere, suggesting a down-welling at high latitudes and slow rising motions at low latitudes.

A current question is whether the circulation pattern extends to the northern hemisphere. Is methane depleted in the north as it is in the south? Or does the northern convective activity enhance methane? The methane depletion anomalies suggest a meridional circulation pattern on Uranus.



Schematic of methane depletion through condensation that dries ascending air at low latitudes, leading to depleted methane in descending regions at high latitudes.

An upwelling at low latitudes brings about condensation, depleting the methane gas. Gas above the condensation layer flows toward the pole. At mid- to high-latitudes the dry gas descends and pushes the upper tropospheric methane deeper into the atmosphere, which then mixes with methane rich gases at lower altitudes and flows back toward the lower latitudes, restoring the mixing ratio.

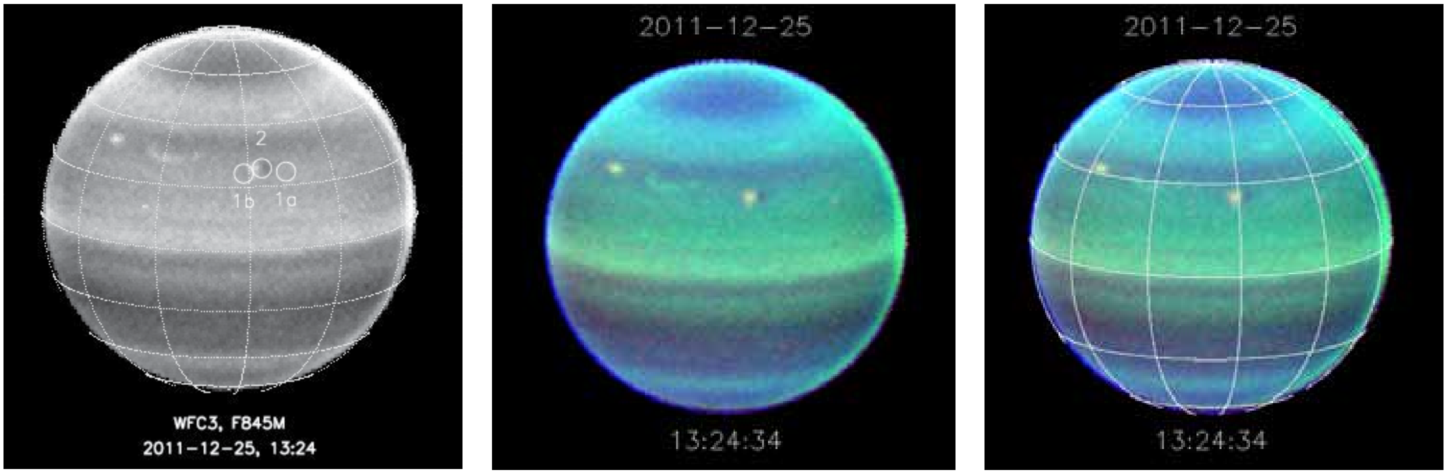
Sromovsky surmises that a lower cloud was not seen by radio measurements because it does not produce a significant change in atmospheric refractivity. The methane cloud layer was missed by spectral analysis because the vertical resolution of near IR spectra is too low to distinguish two compact layers from one diffuse layer.

When radio and reflected spectra were combined, it was possible to reach consistent results.

Mark Hobson

Holiday Treat from the 7th Planet

Holiday season observations in 2011 revealed a new dark spot (and a bright companion spot) at the predicted position of the close approach of two previously observed bright spots. Given that only one other dark spot was ever seen on Uranus, this is an important result. It appears from images taken on 20 December 2011 that the first bright spot, the one that was seen to be increasing in brightness during October, may have dissipated sometime after 16 December.



The black and white image above shows predicted spot positions on the image made with the HST F845M filter. Two predictions are given for the first spot to illustrate the range of uncertainty in its drift rate. The color images show an ungridded image on the left and a gridded image as observed by the HST on Christmas Day.