

Weather in the Solar System

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Space Science and Engineering Center

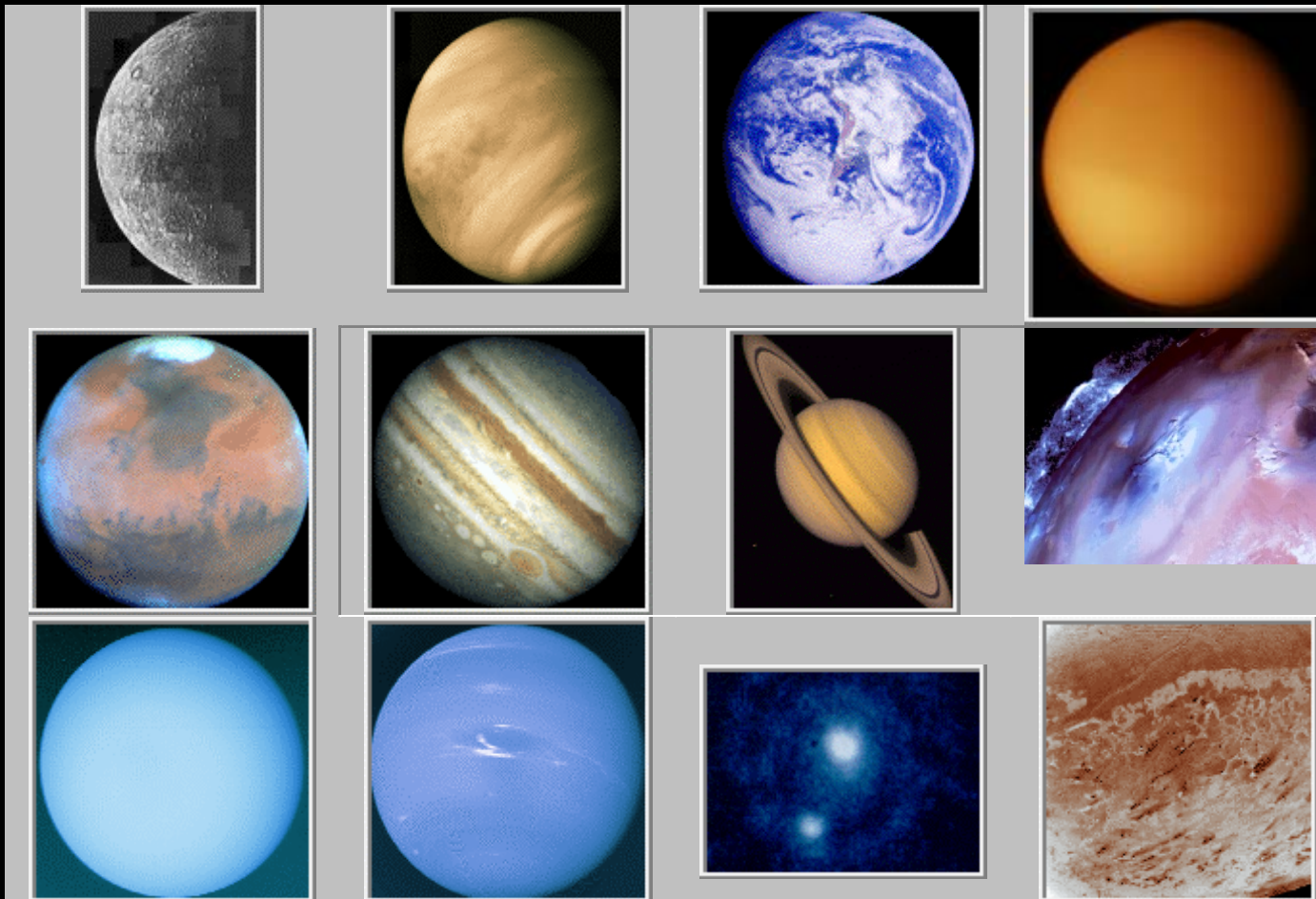
University of Wisconsin-Madison

8 February 2002

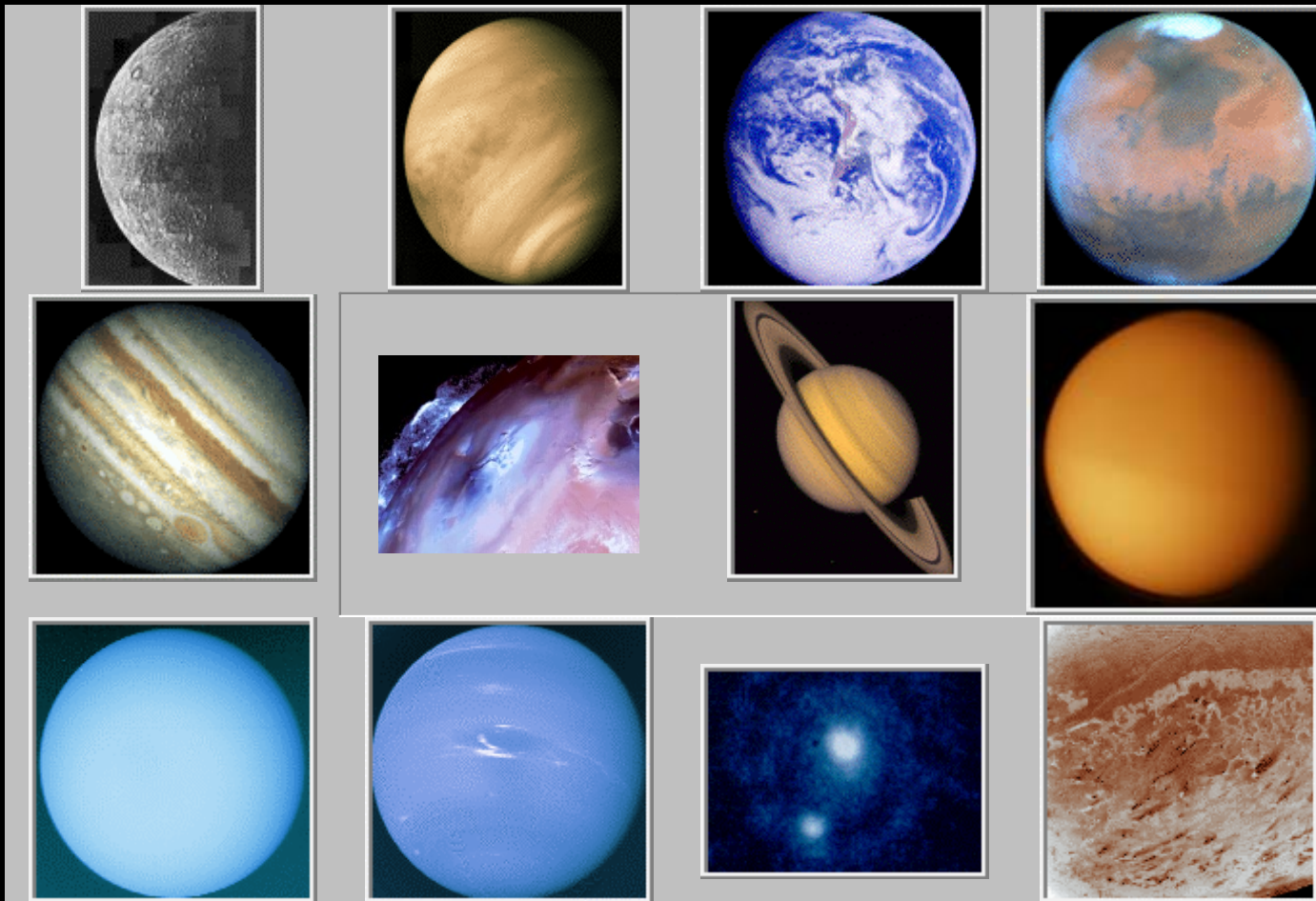
What is Weather?

- Webster's New Collegiate Dictionary:
“state of the atmosphere with respect to heat or cold, wetness or dryness, calm or storm, clearness or cloudiness”
- GLOBE: *“By weather we mean what is happening in the atmosphere today, tomorrow, or even next week.”*

Weather, Weather Everywhere!



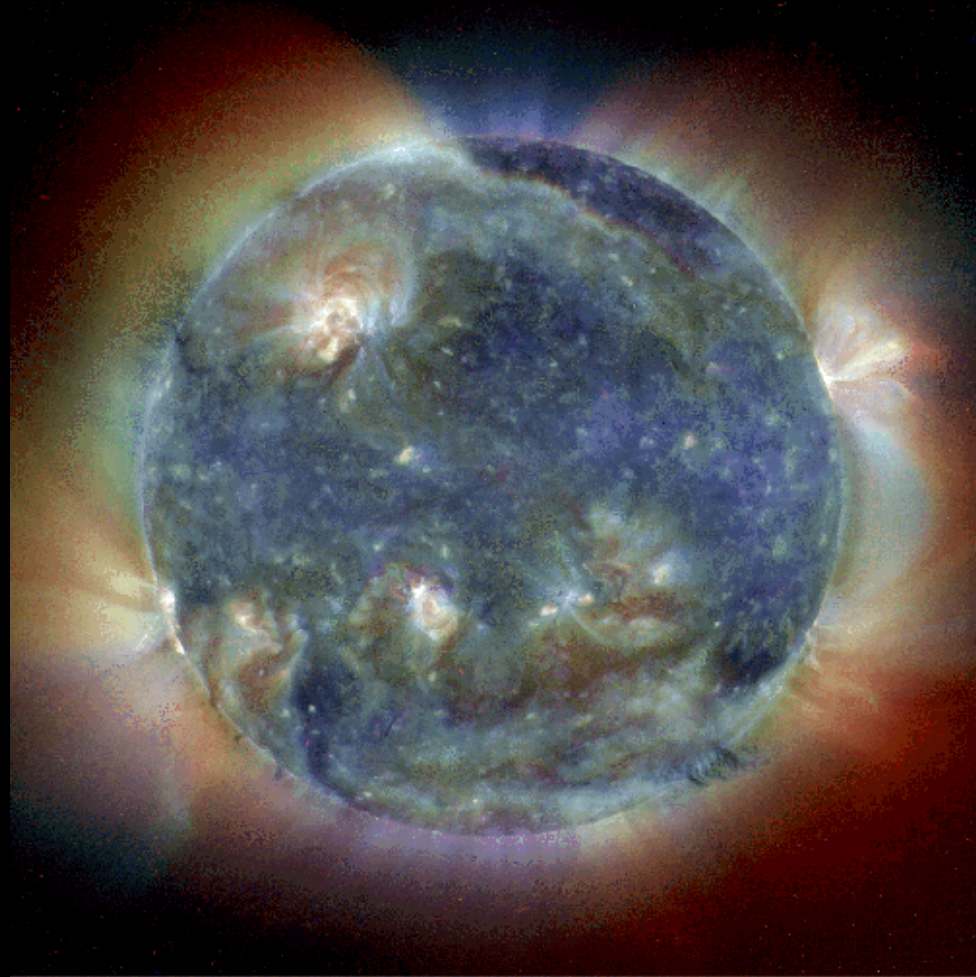
Weather, Weather Everywhere!



Ingredients for Making Weather

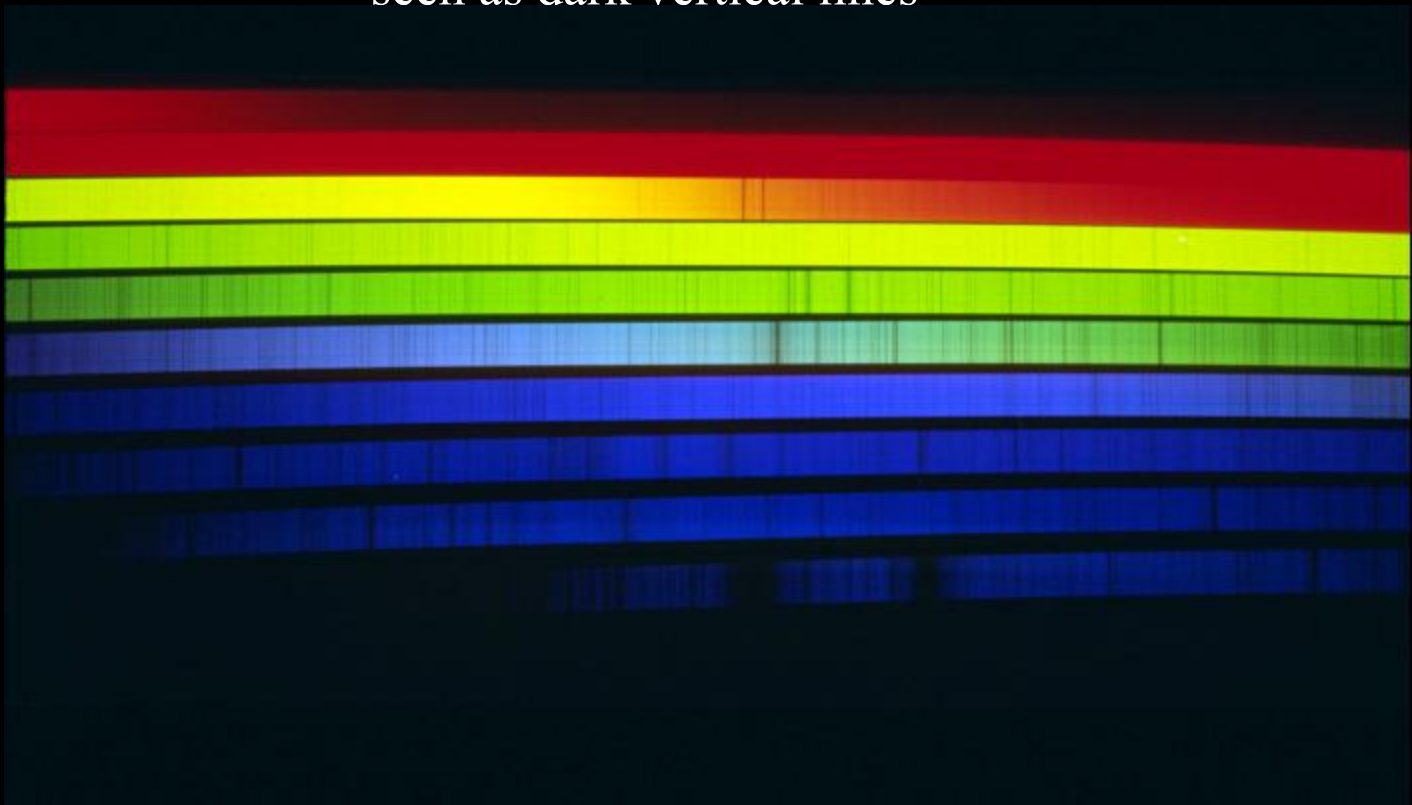
- ✧ A nice, thick atmosphere
- ✧ A variable energy source (*for heating and cooling changes*)
- ✧ A condensate (on earth it is water; on other planets methane, ammonia, carbon dioxide and other compounds)

Weather, Even on the Sun!



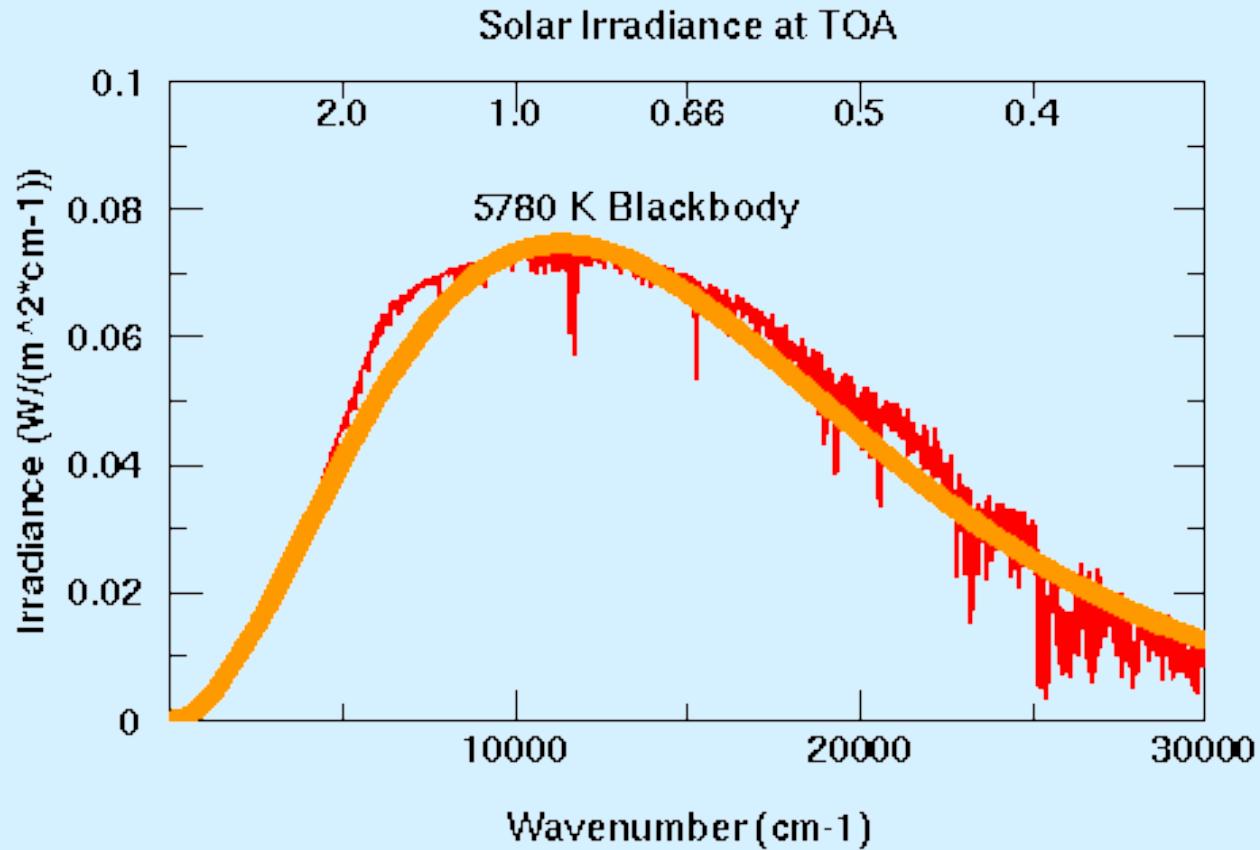
The Solar (Visible) Spectrum:

Fraunhofer Lines (absorption lines) characteristic of different elements seen as dark vertical lines

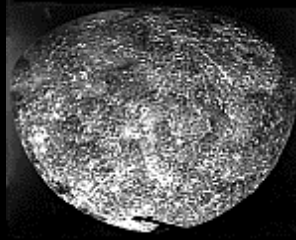


Solar Radiation Spectrum

<http://climate.gsfc.nasa.gov/~cahalan/Radiation/>



Weather, weather everywhere!



Venus

Earth

Mars

Jupiter

Io

Saturn

Titan

Neptune

Triton

Pluto

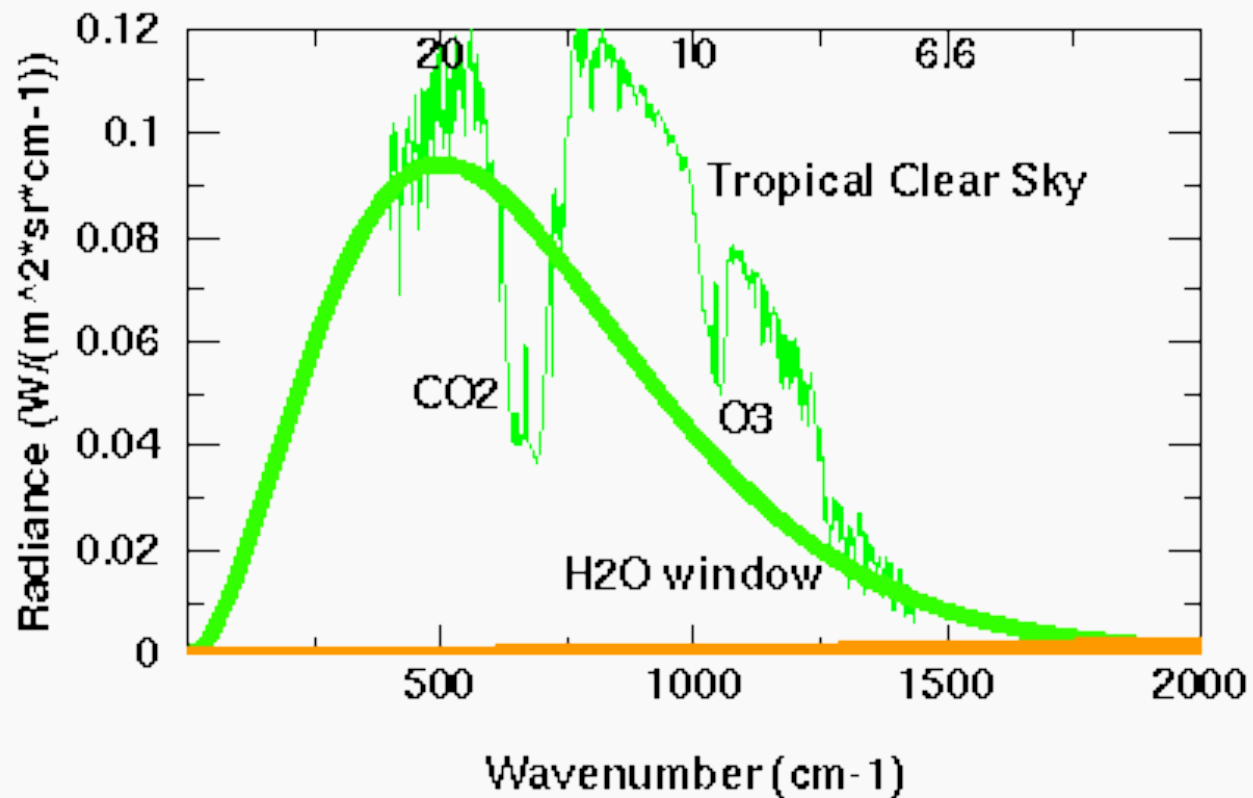
Greenhouses Everywhere!

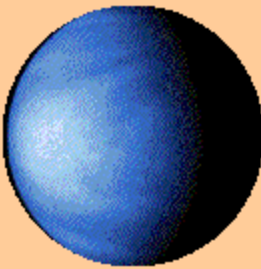


Planet	Avg Distance from the Sun (Million miles)	Avg Distance in Million Km	Avg Distance relative to earth (AU)	Albedo (Amount of Incident Sunlight Reflected back to space)	Effective Temperature	Actual Temperature	Length of Year (years)	Length of Day (days)	Inclination of Rotation Axis (Degrees)
Mercury	36	57.6	0.39	0.12	436.0		0.241	58.65	2
Venus	67.1	107.36	0.72	0.76	230.8	750	0.615	243.01	177.3
Earth	92.9	148.64	1.00	0.32	254.4	288	1	1	23.45
Mars	141.5	226.4	1.52	0.25	211.3	220	1.881	1.029	25.19
Jupiter	483.4	773.44	5.20	0.34	110.7	144	11.862	0.411	3.12
Saturn	886.7	1418.72	9.54	0.34	81.7		29.458	0.428	26.73
Titan	886.7	1418.72	9.54	0.3	83.0	115	29.458	15.95	26.73
Uranus	1782.7	2852.32	19.19	0.3	58.5		84.01	0.748	97.86
Neptune	2794.3	4470.88	30.08	0.29	46.9	58	164.79	0.802	29.6
Pluto	3666.1	5865.76	39.46	0.4	39.3		248.54	6.387	122.46

- Gaseous envelopes around solid planets provide an insulating layer through the selective absorption of incident solar and/or emitted radiation by the planet

Earth Radiation Spectrum

Earth Radiance (Tropical Clear Sky)



	VENUS	EARTH	MARS
SURFACE PRESSURE	100,000 mb	1,000 mb	6 mb
	COMPOSITION		
CO ₂	>98%	0.03%	96%
N ₂	1%	78%	2.50%
A	1%	1%	1.50%
O ₂	0.00%	21%	2.50%
H ₂ O	0.00%	0.10%	0-0.1%
			
	12,140 km	12,753 km	6,785 km

Weather on the Planets is influenced by:

- planet's orbit,
- inclination,
- rotation rate, and

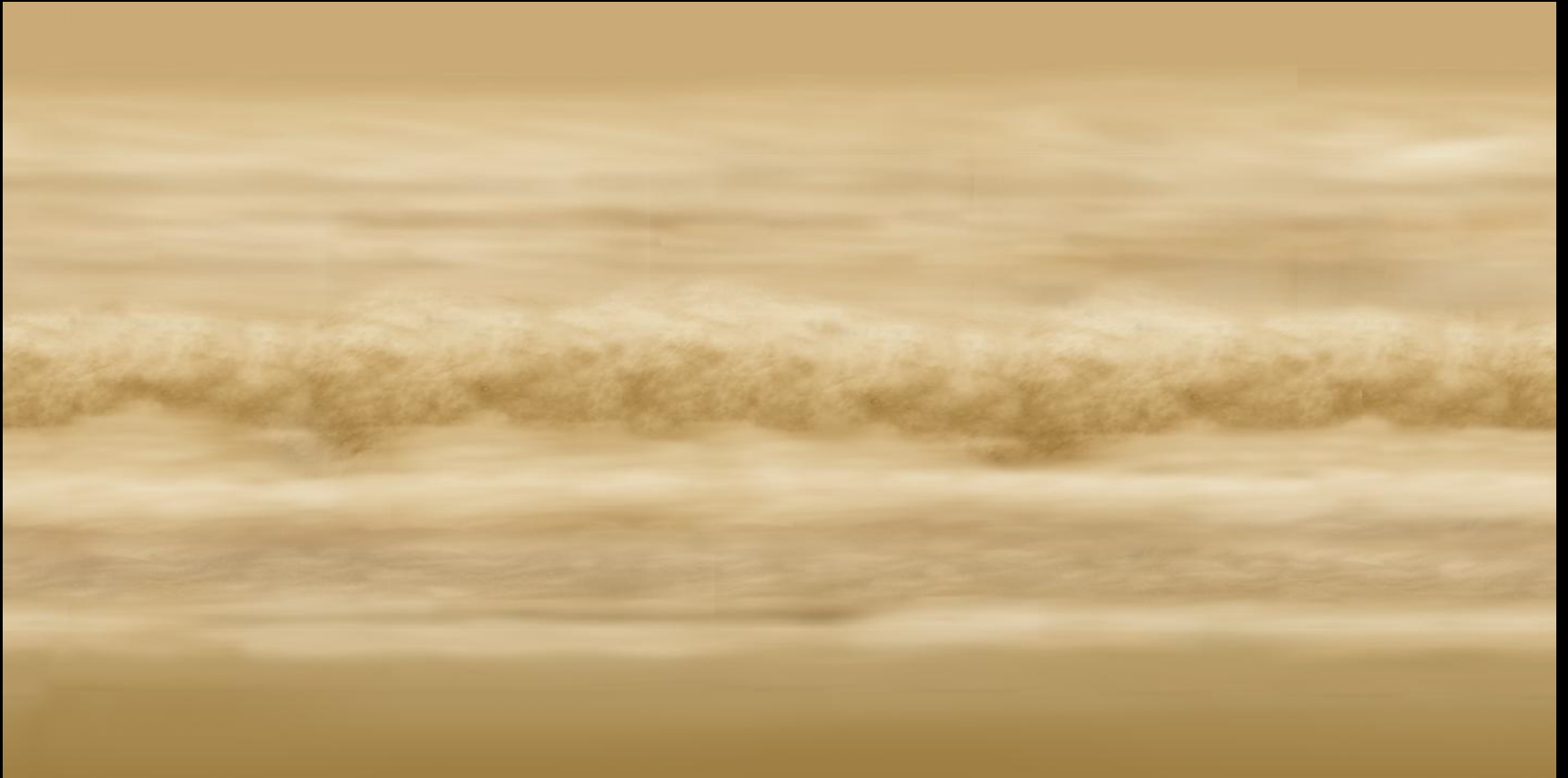
Determined by:

- atmosphere - composition, amount
- surface characteristics - topography, oceans

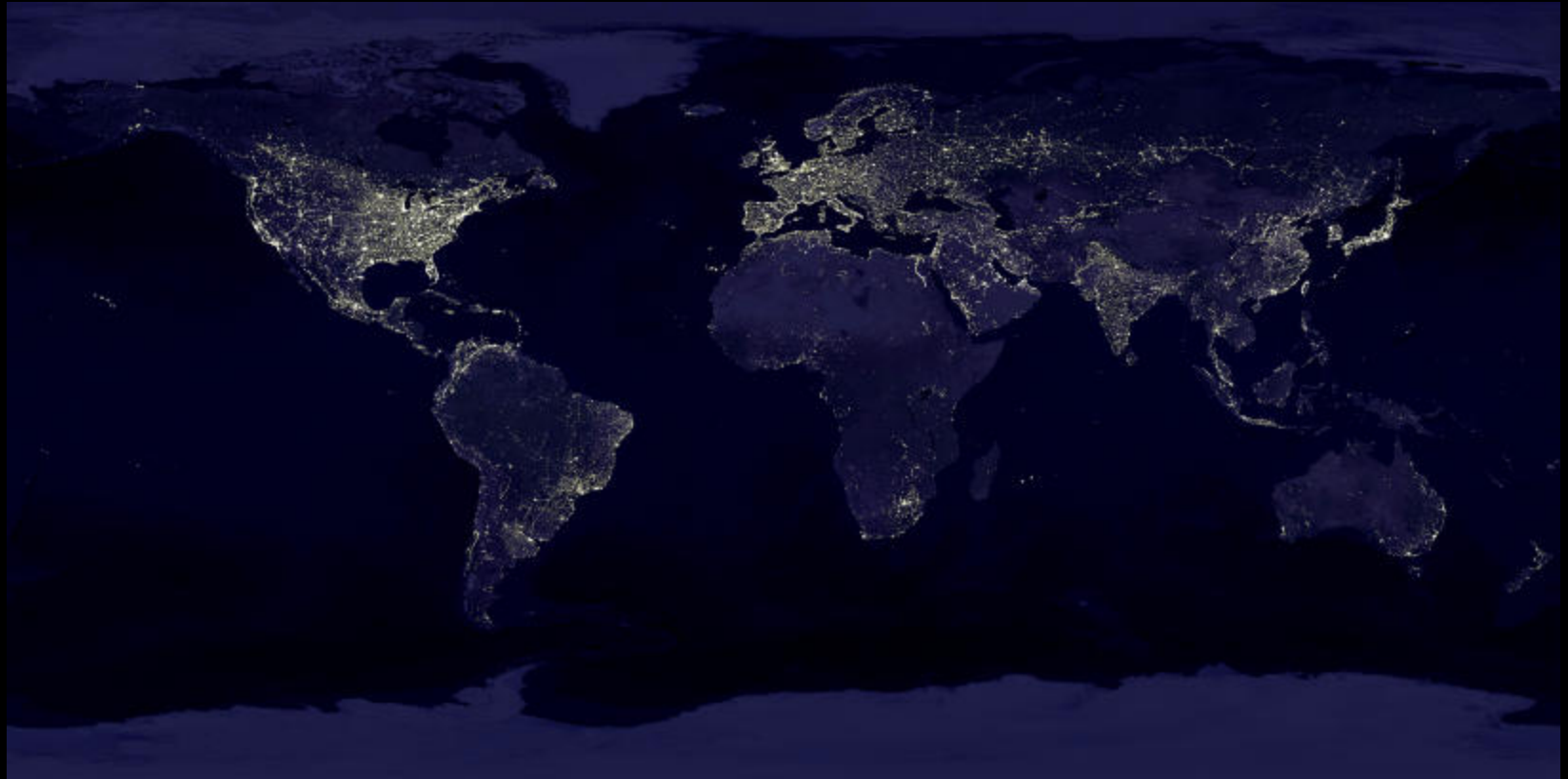




South Hemisphere of Venus: A Polar View

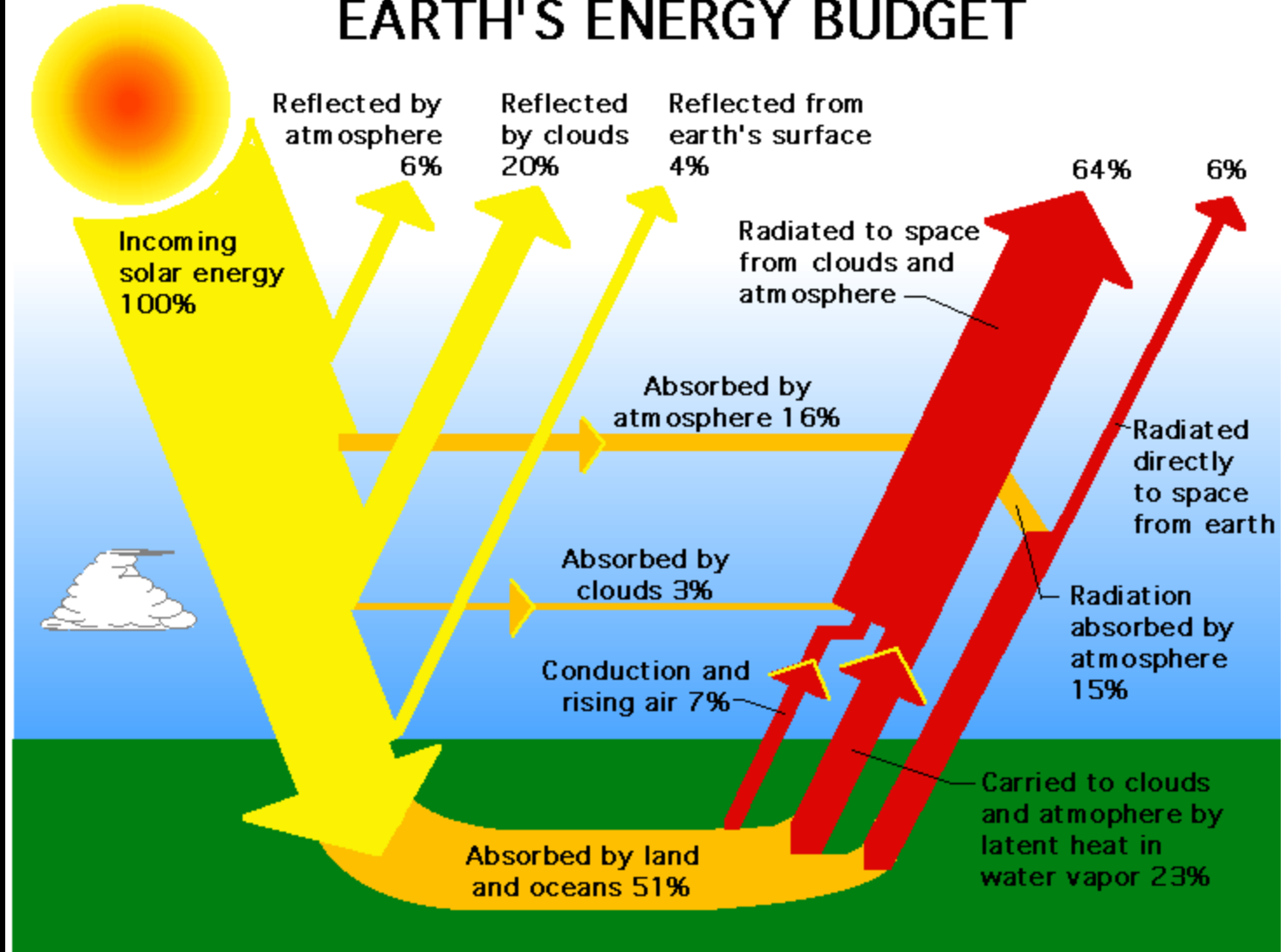


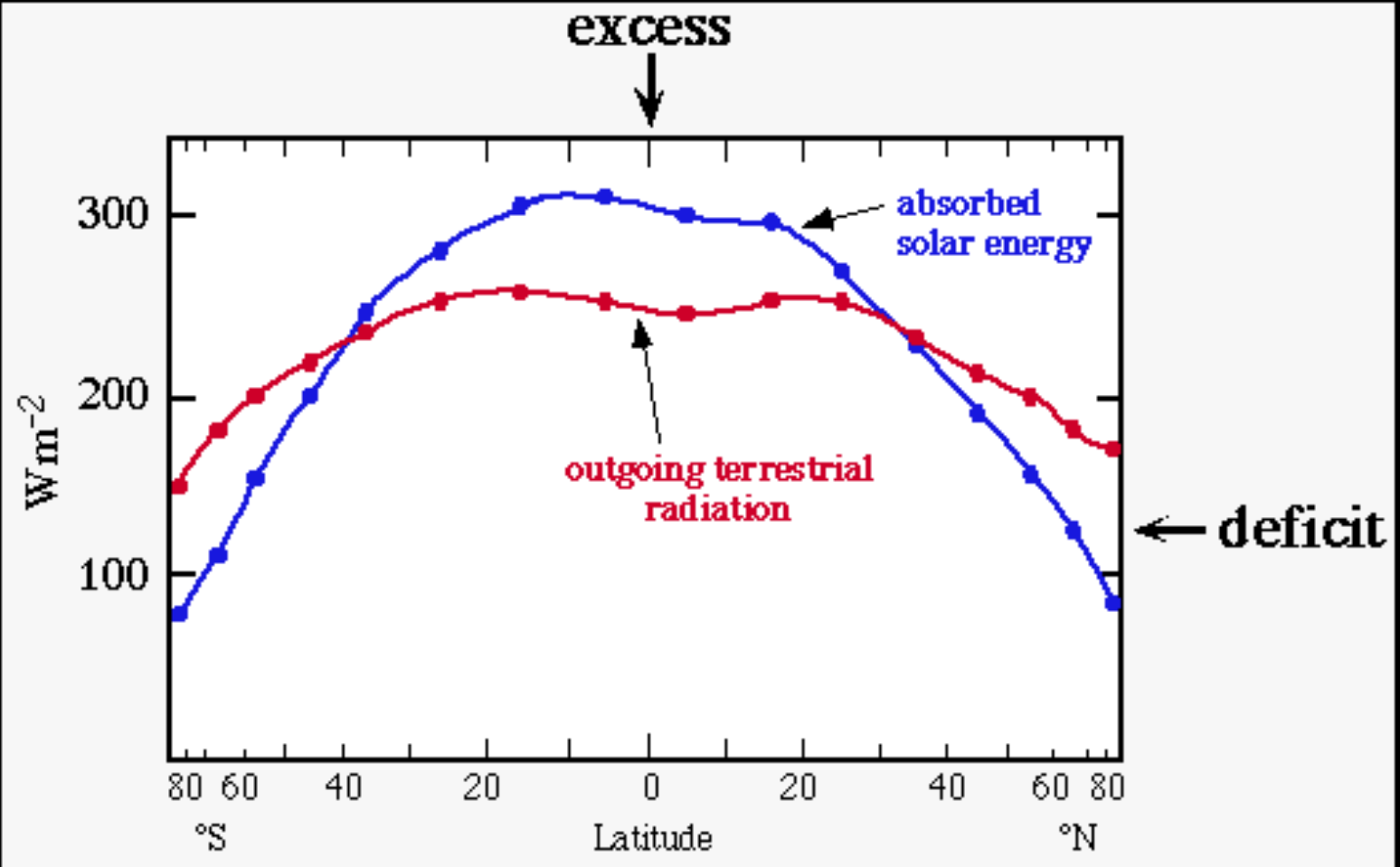
Pole-to-Pole Latitude-Longitude Map of Venus

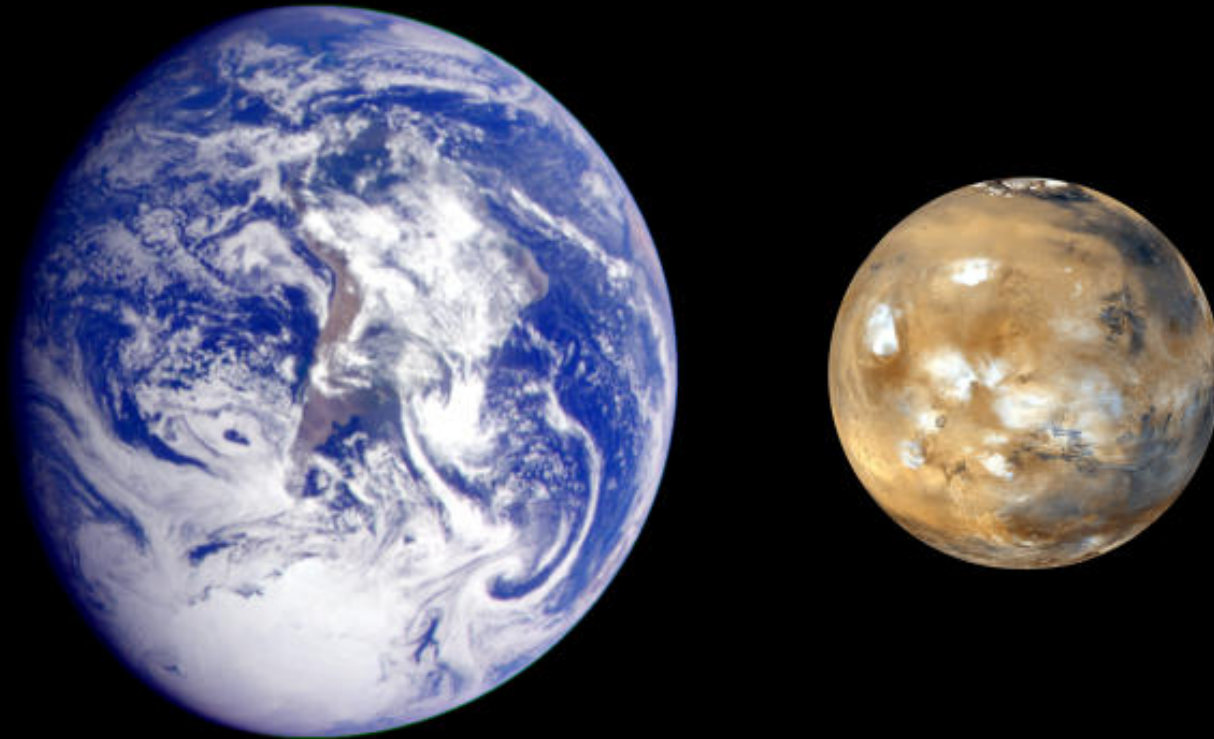


Earth at Night in Visible Light - Emission to Space!

EARTH'S ENERGY BUDGET



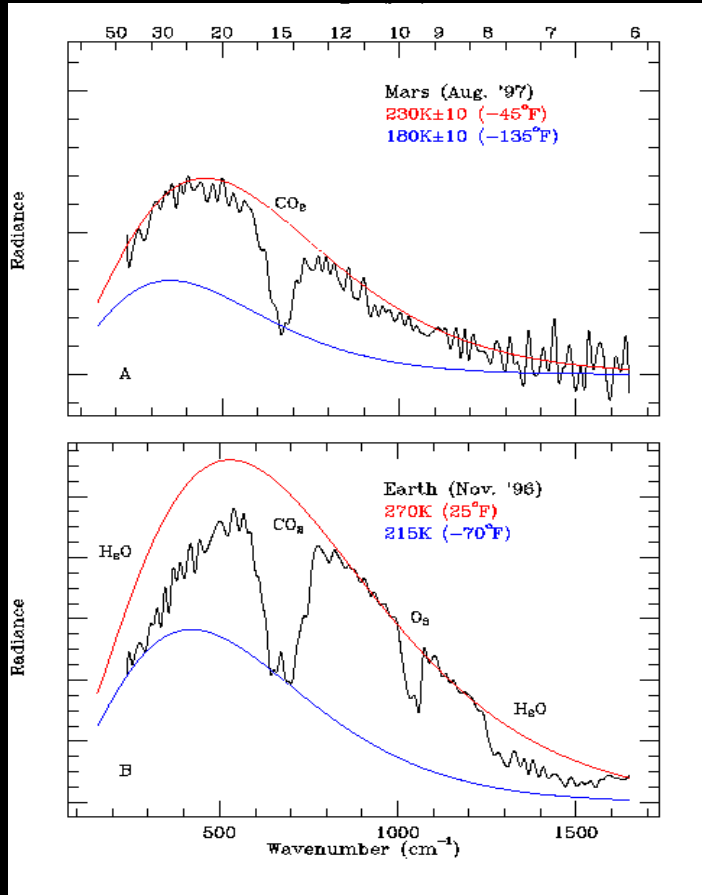




Relative size of Earth and Mars

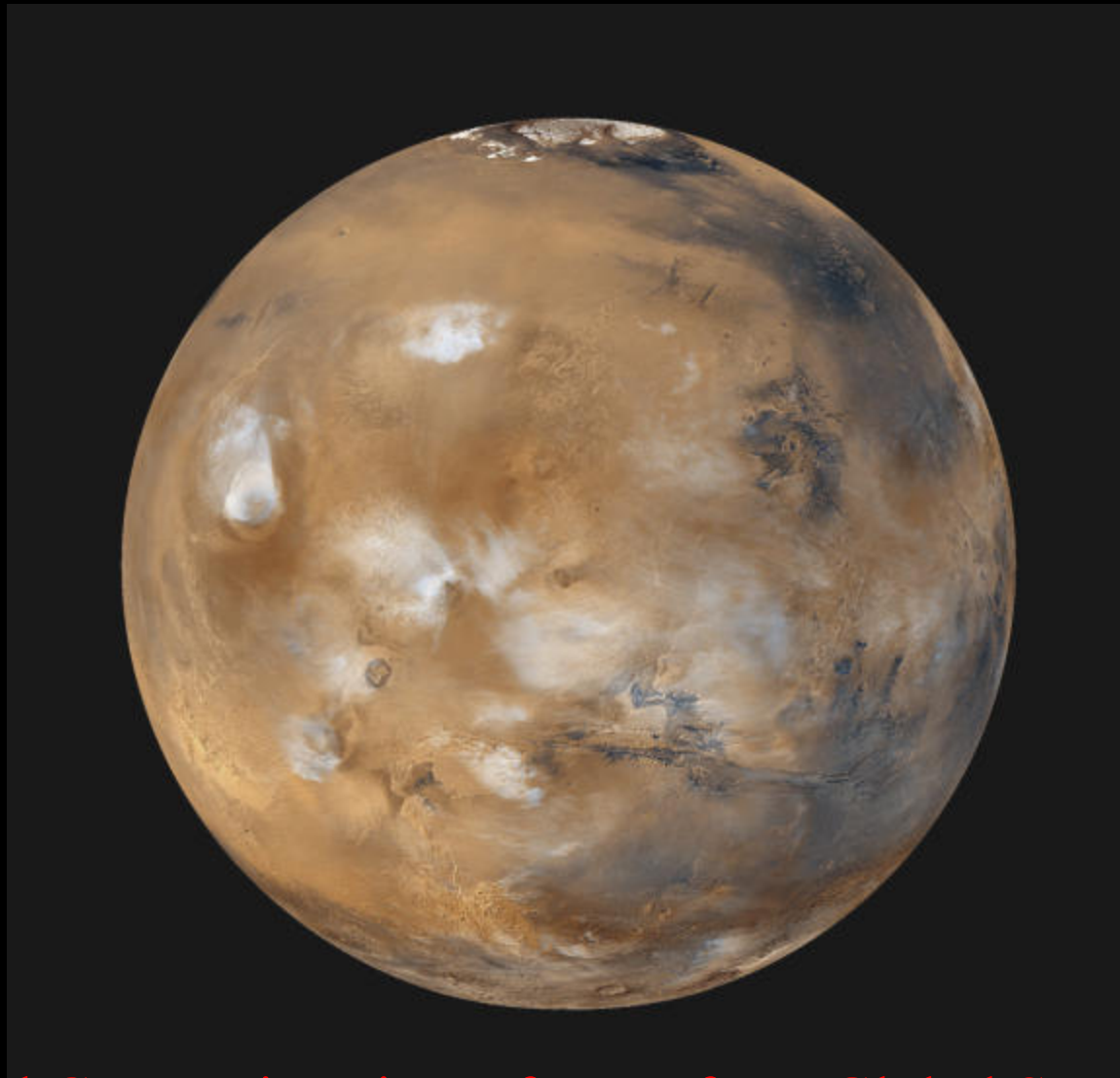
Earth & Mars Radiation Spectra

<http://emma.la.asu.edu/TESSCruise/marscruise.html>

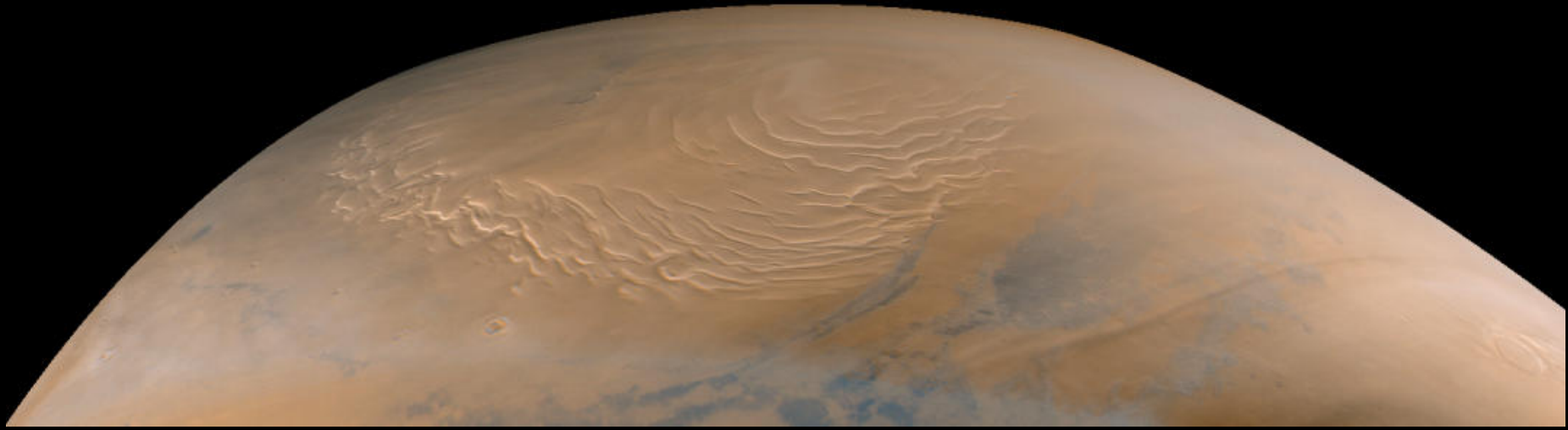


Earth and Mars spectra show similarities due to CO_2 and differences in H_2O and O_3 abundances.

Colored lines show Black Body temperature curves for different temperatures.

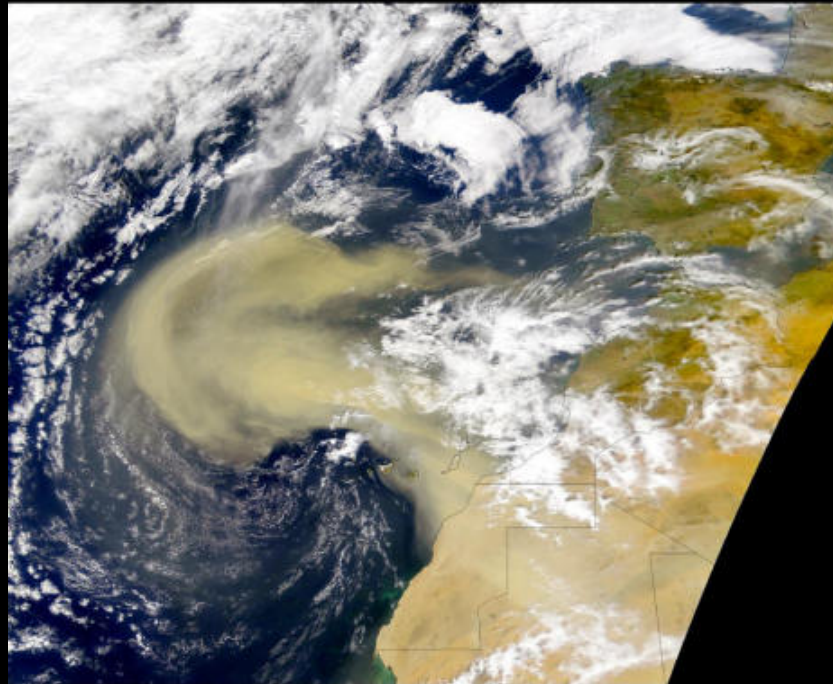
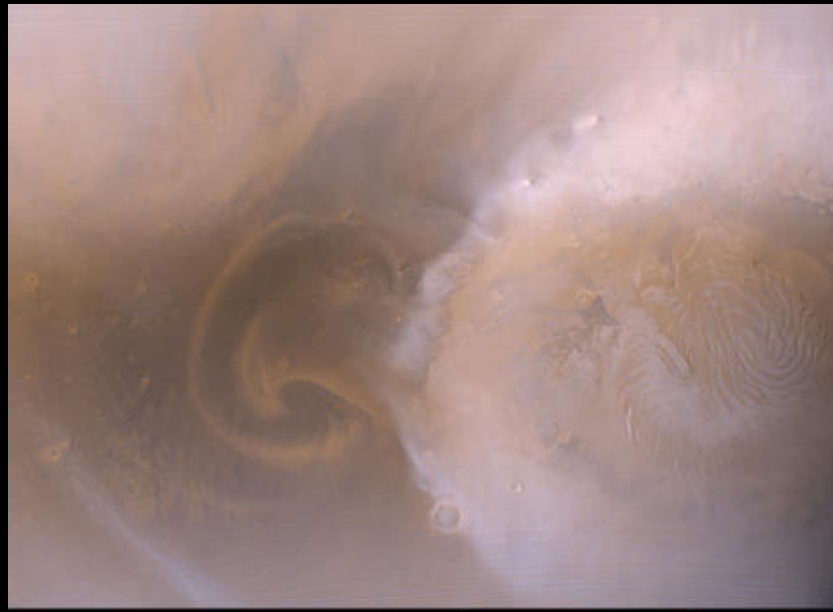


Global Composite View of Mars from Global Surveyor



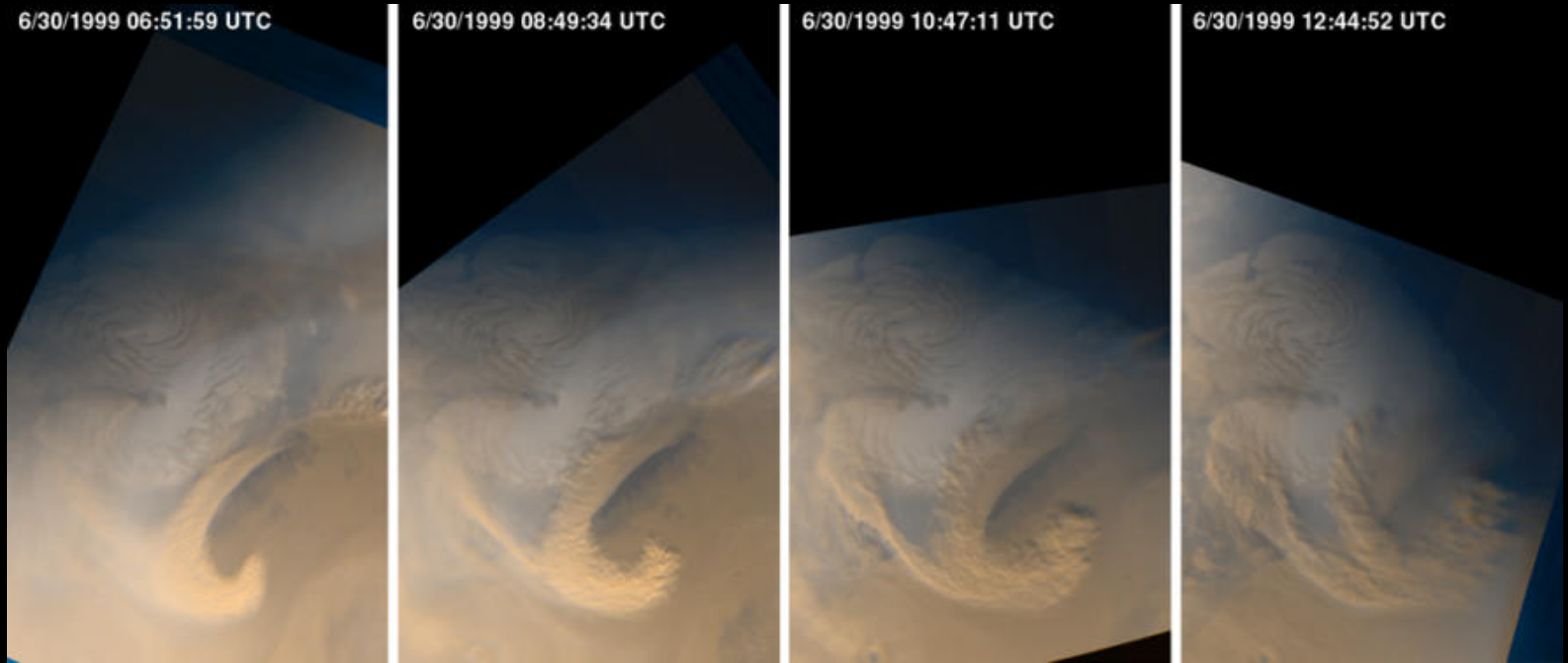
Northern Polar Region of Mars

**Martian Dust
Storm near the
Northern Pole**

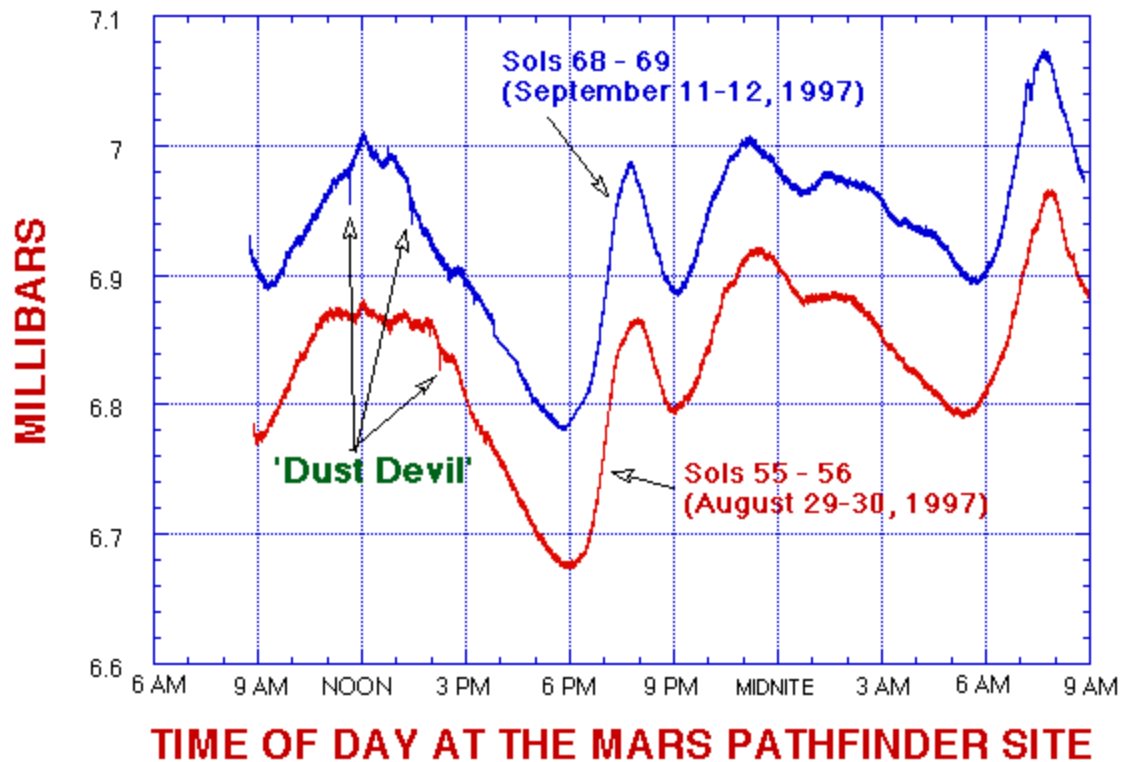


**Dust storm off
Sahara on Earth**

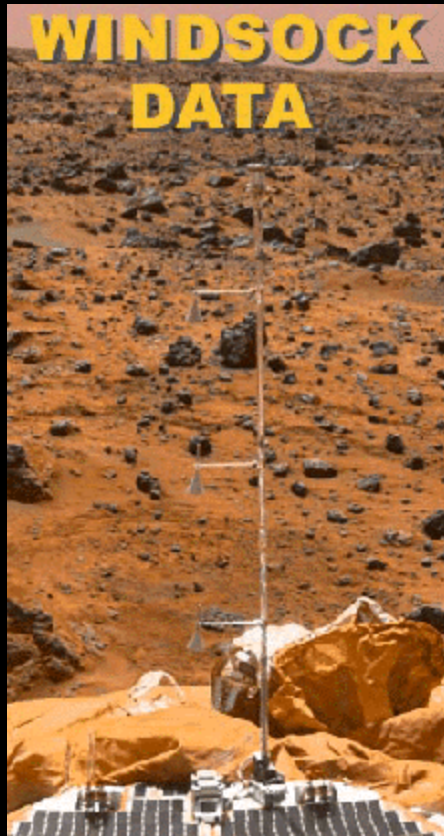
Storms on Mars - similar to Earth



MARS PATHFINDER LANDER MEASURED SURFACE PRESSURE



[Surface Pressure Movie](#)



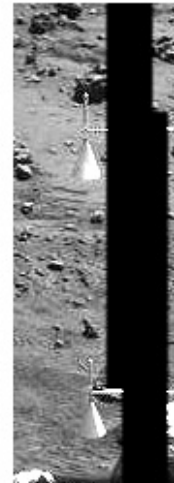
Sol 82 Morning Wind Profile Sequence



t = 0 sec



t = 7 sec



t = 35 sec



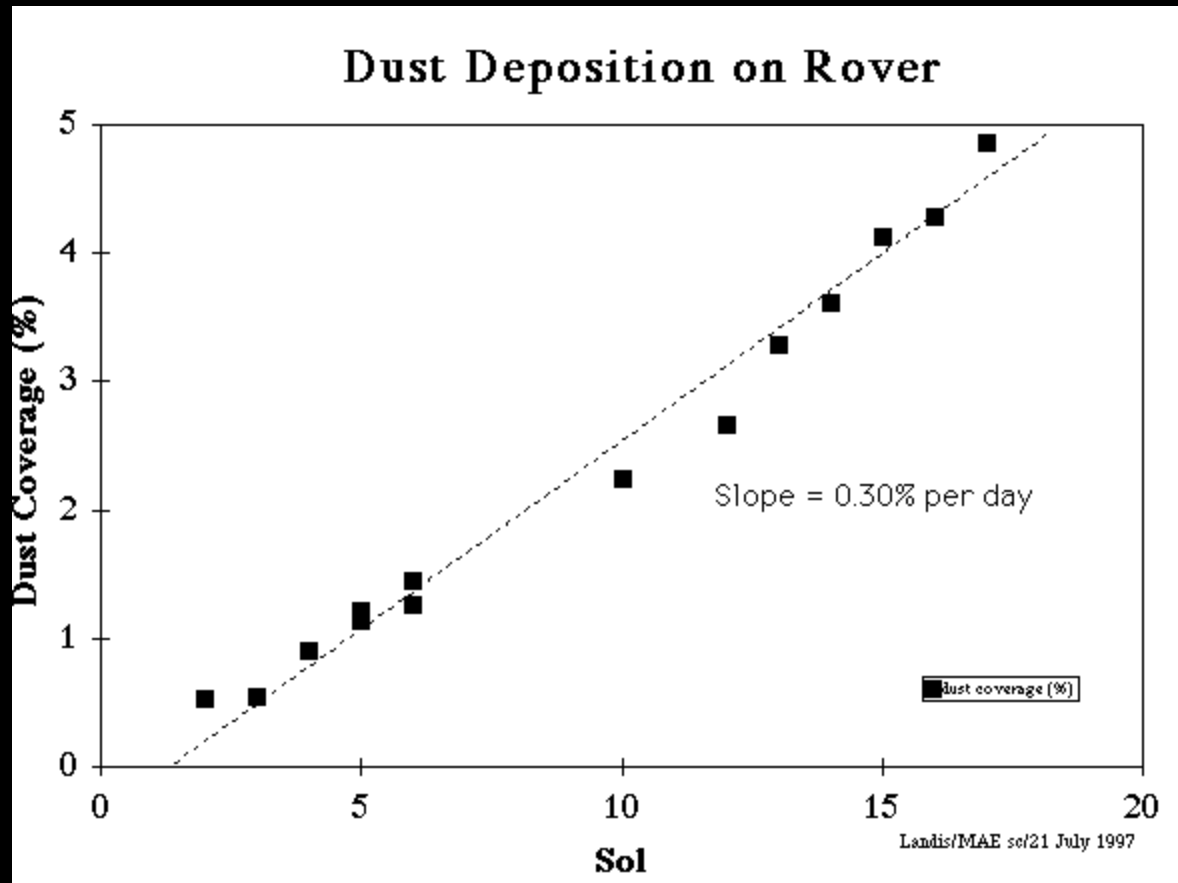
t = 49 sec

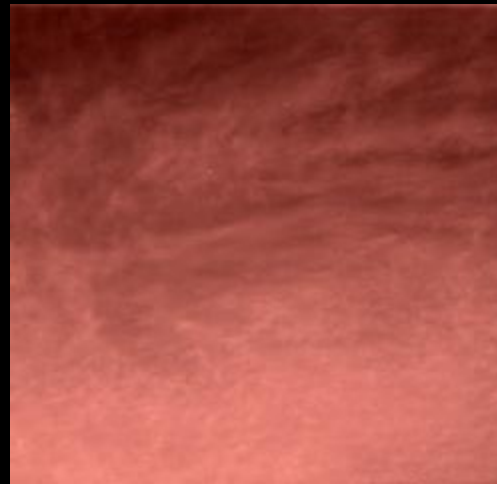


t = 63 sec



t = 70 sec

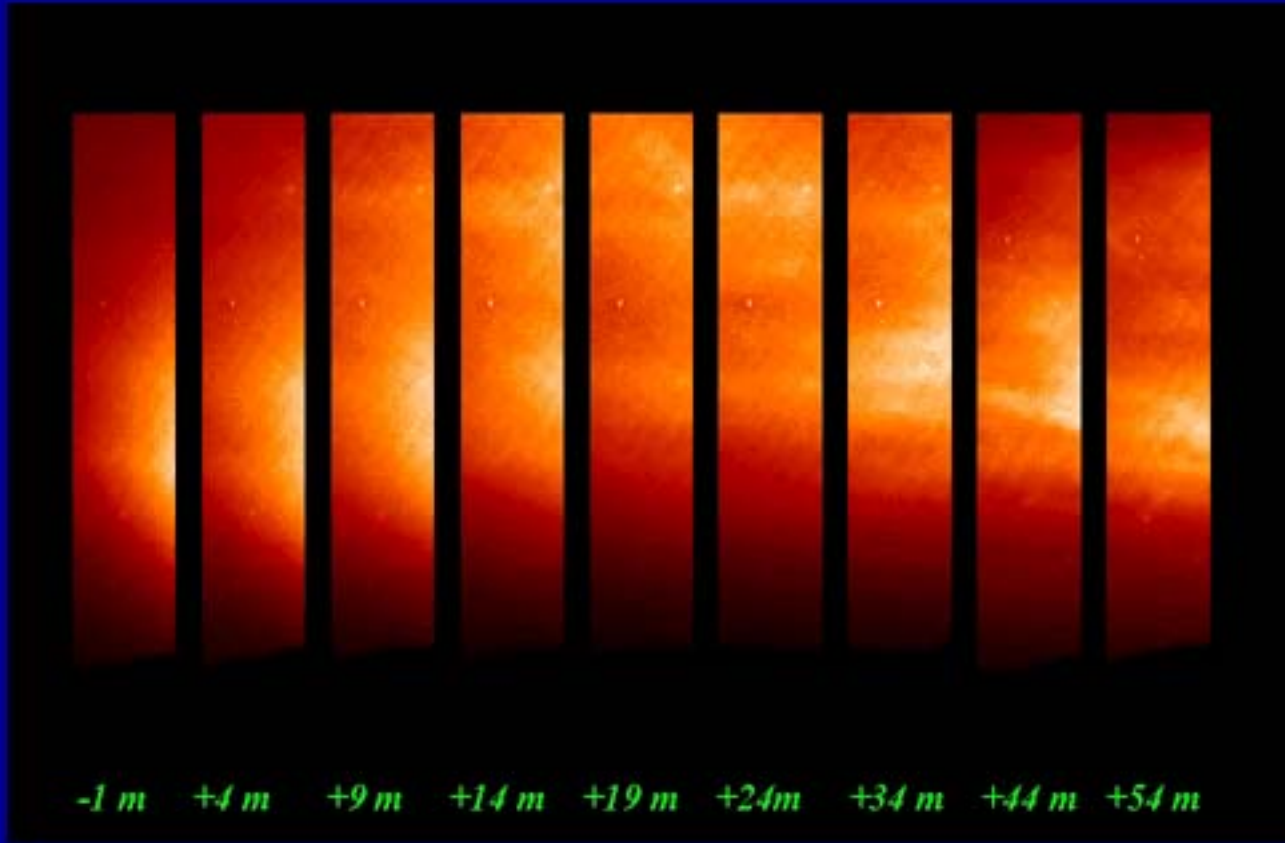




Clouds seen from Sagan Station - Mars Pathfinder

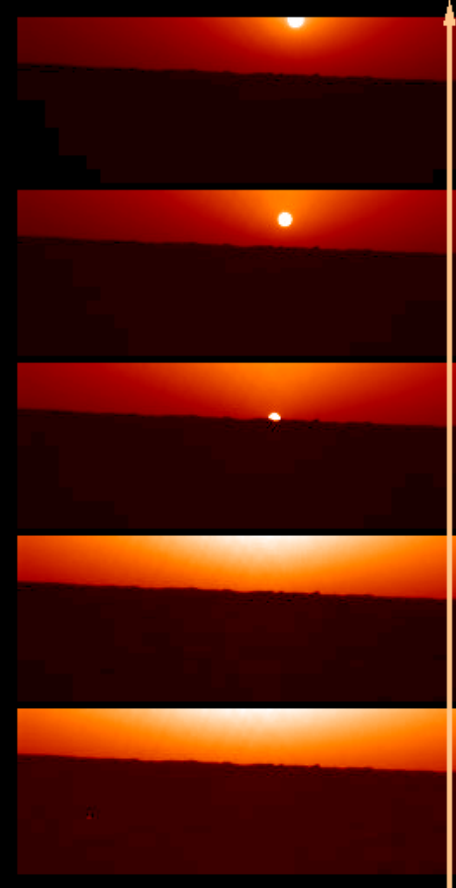


Clouds at Sunset



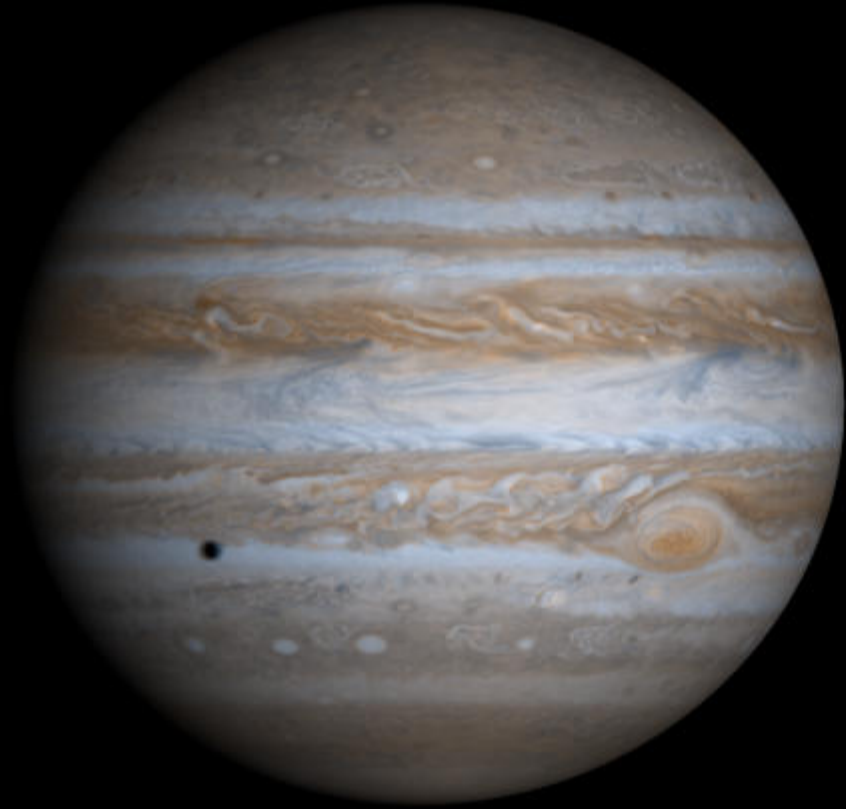
Time relative to Sunset

Sunrise

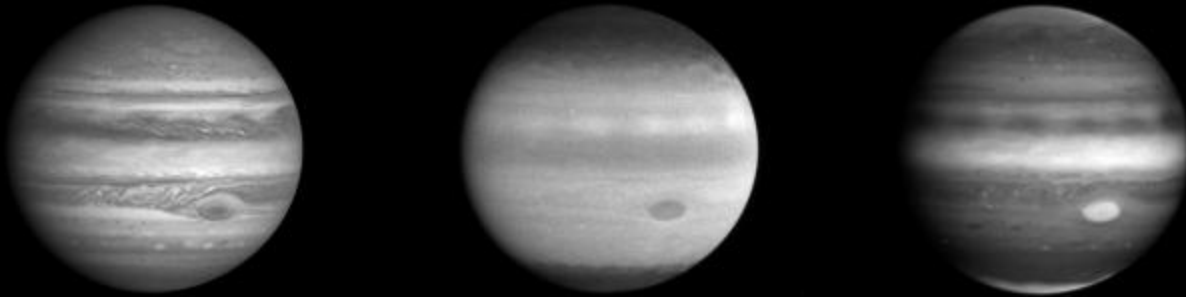




Sunset on Mars over the Sagan Station (Mars Pathfinder)



Jupiter in blue, ultraviolet and near infrared

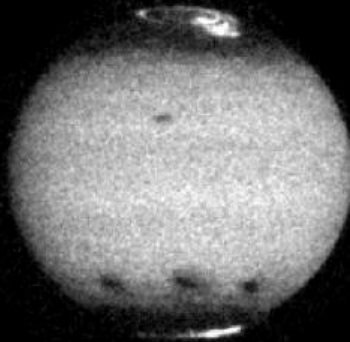


Jupiter

July 17, 1994



Violet (3660 Å)

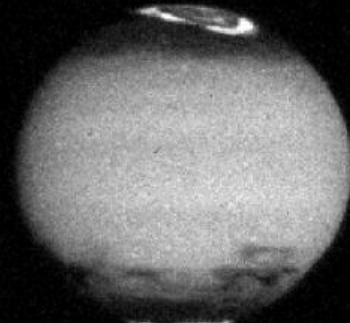


Far UV (1600 Å)

July 29-30, 1994



Violet (3660 Å)



Far UV (1600 Å)

Hubble Space Telescope
Wide Field Planetary Camera 2

These four NASA Hubble Space Telescope images of Jupiter, as seen in visible (violet) and far-ultraviolet (UV) wavelengths, show the remarkable spreading of the clouds of smoke and dust thrown into the atmosphere after the impacts of the fragments of comet P/Shoemaker-Levy 9. These dark regions provide the only information ever obtained on the wind direction and speed in Jupiter's upper atmosphere.

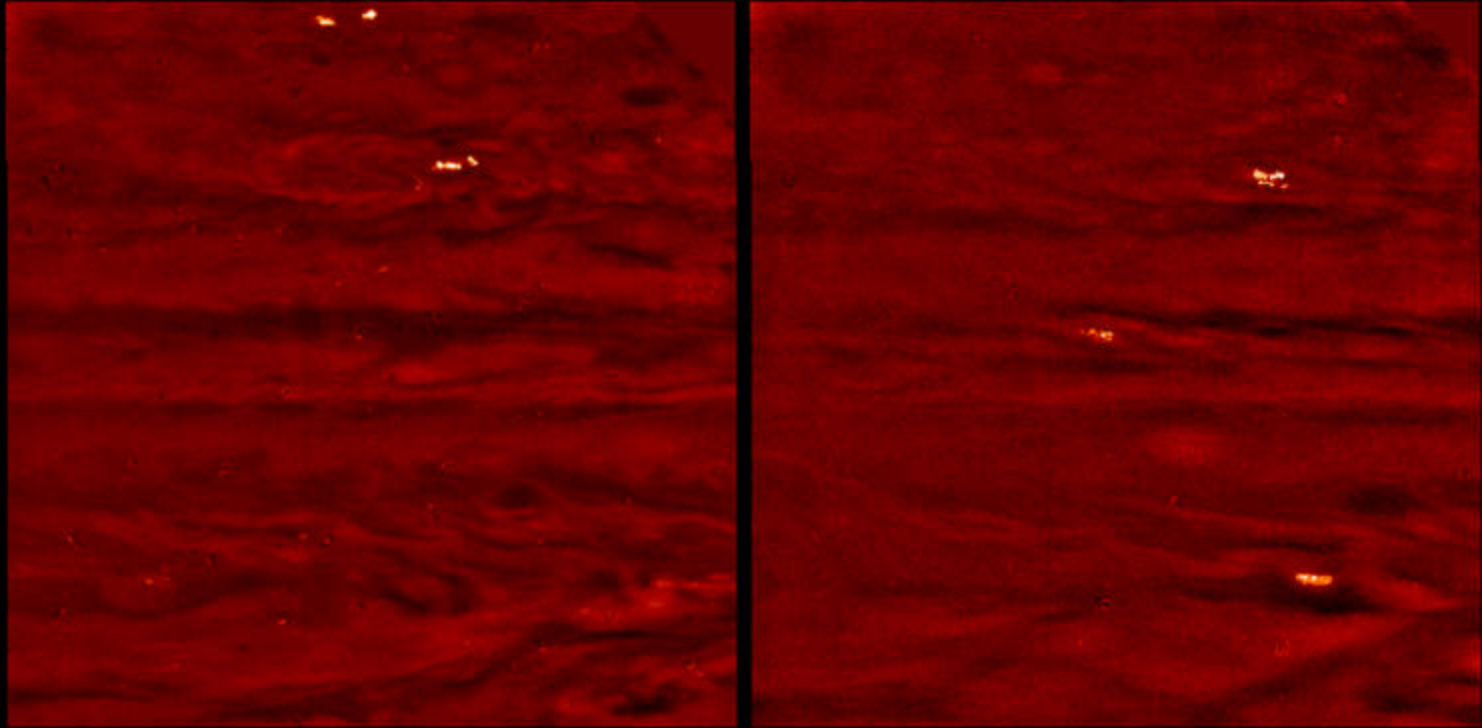
TOP

Three impact sites appear as dark smudges lined up along Jupiter's southern hemisphere (from left to right, sites C, A, and E). This pair of images was obtained on 17 July, several hours after the E impact. These 3 impact sites appear strikingly darker in the far-ultraviolet images to the right. This is because the smoke and dust rising from the fireballs absorbs UV light more strongly than violet light, so that the clouds appear both darker and larger in the UV images. Apparently, the fireball and plume threw large amounts of material completely above the atmosphere. This material diffused back down through the atmosphere with the smaller and lighter particles suspended at high altitudes.

BOTTOM

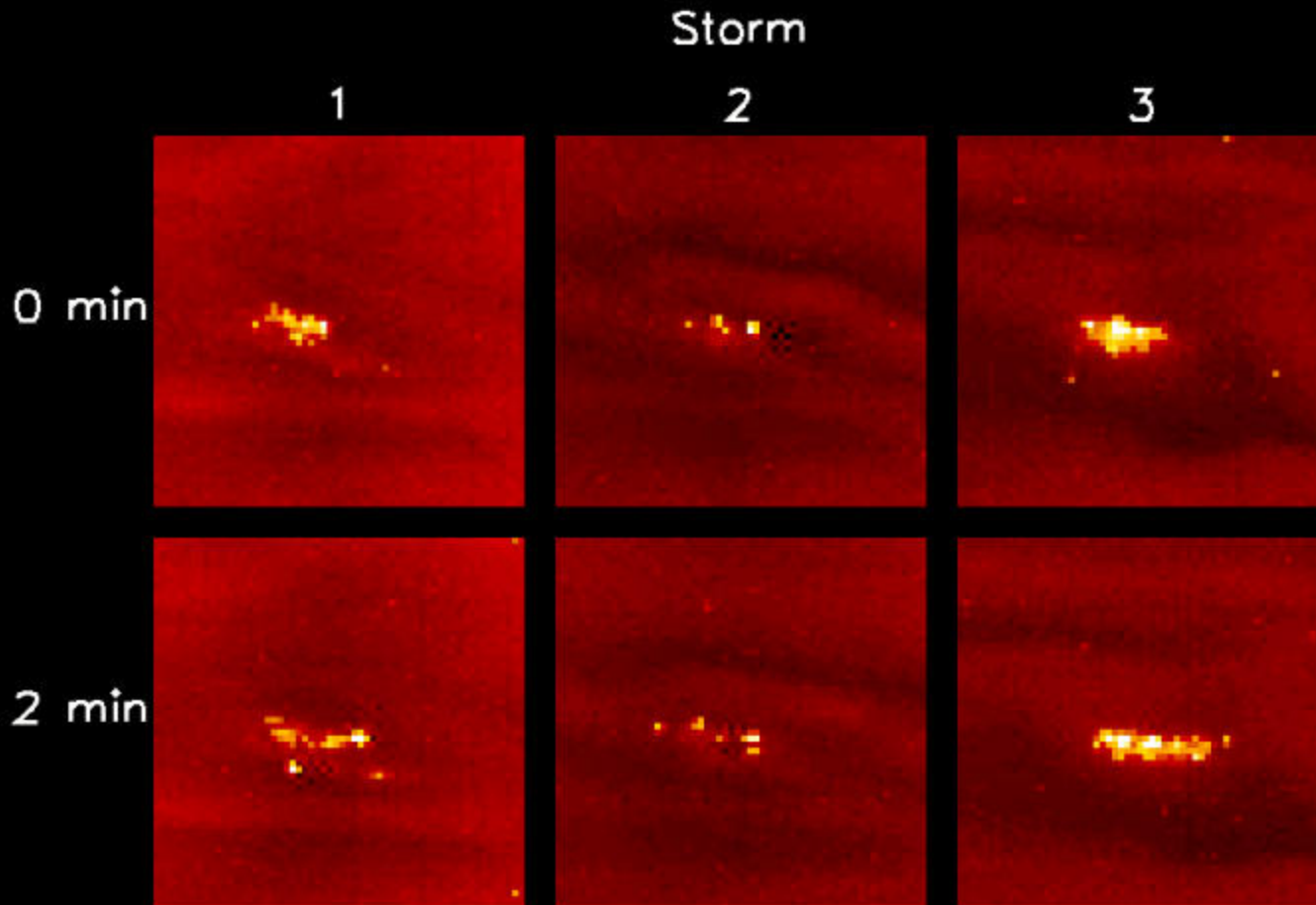
Hubble's view of the same hemisphere of Jupiter 12-13 days later shows that the smoke and dust have now been spread mainly in the east/west direction by the prevailing winds at the altitude where the dark material is suspended or "floating" in the atmosphere.

Credit: J.T. Clarke, G.E. Ballester (University of Michigan), and J.T. Trauger (Jet Propulsion Laboratory), and NASA

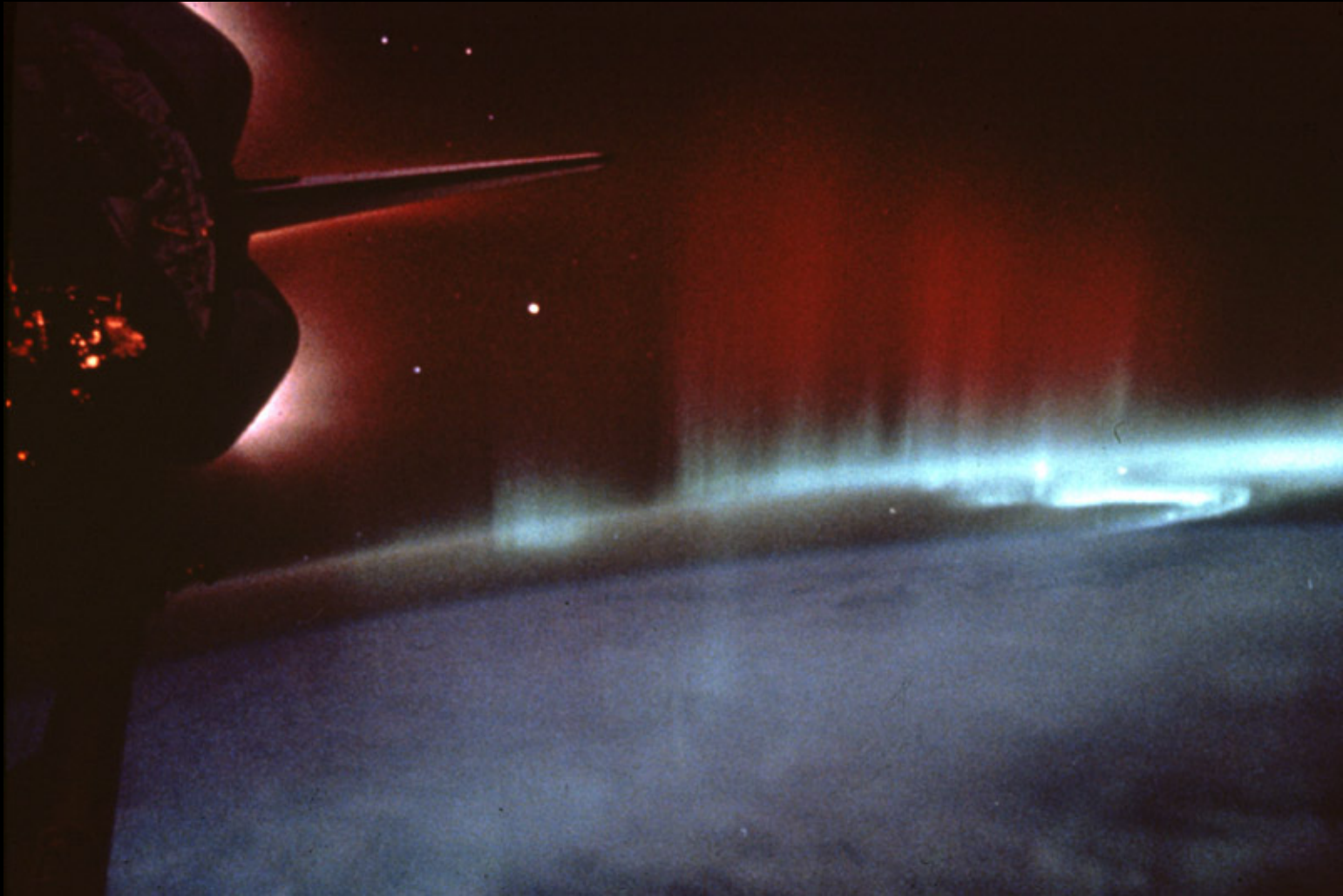


Lightning on Jupiter in clouds lit by light from Io

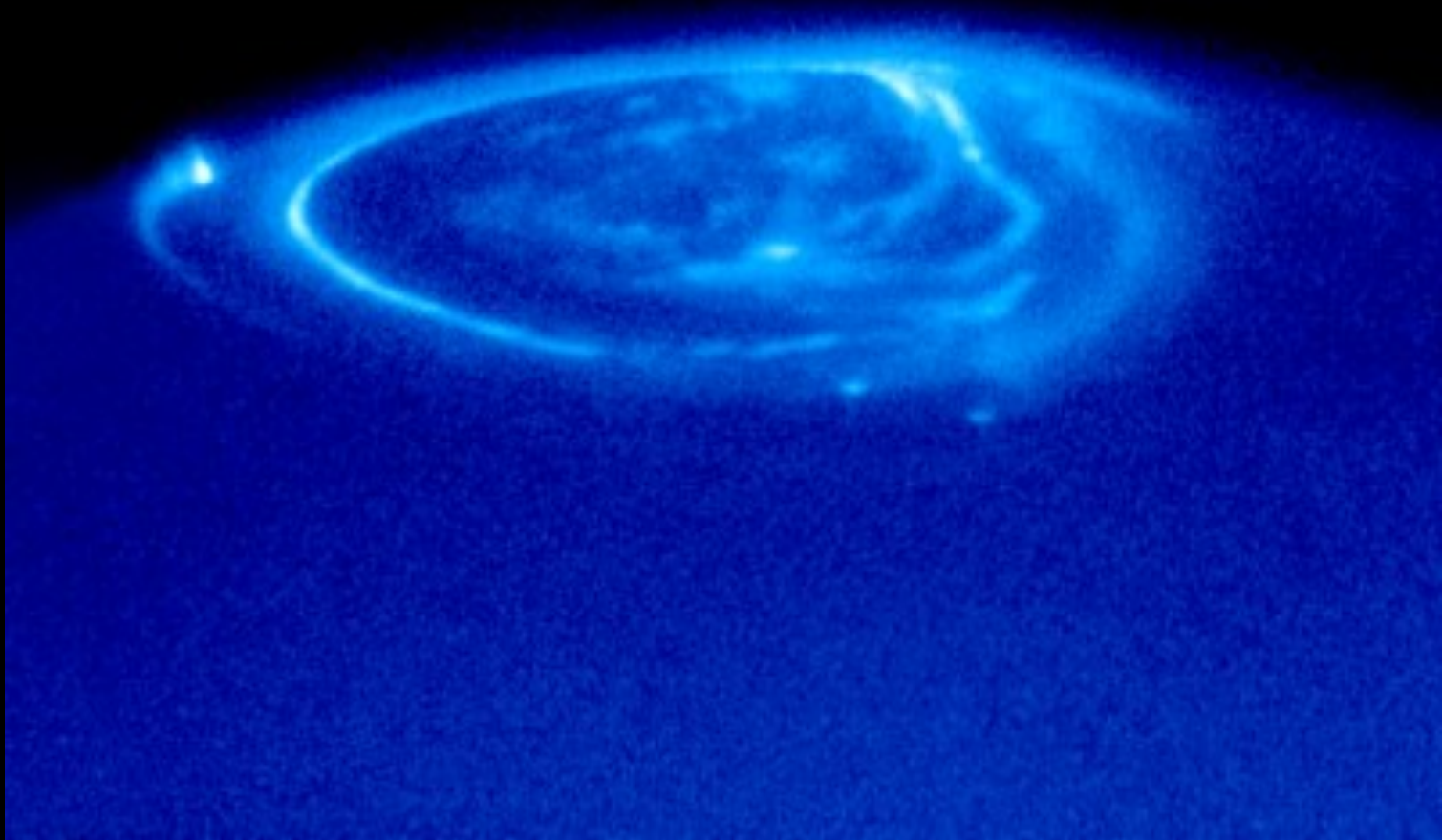
PIA01096



Space Shuttle View of Aurora



Jupiter Aurora as imaged by the Hubble Space Telescope

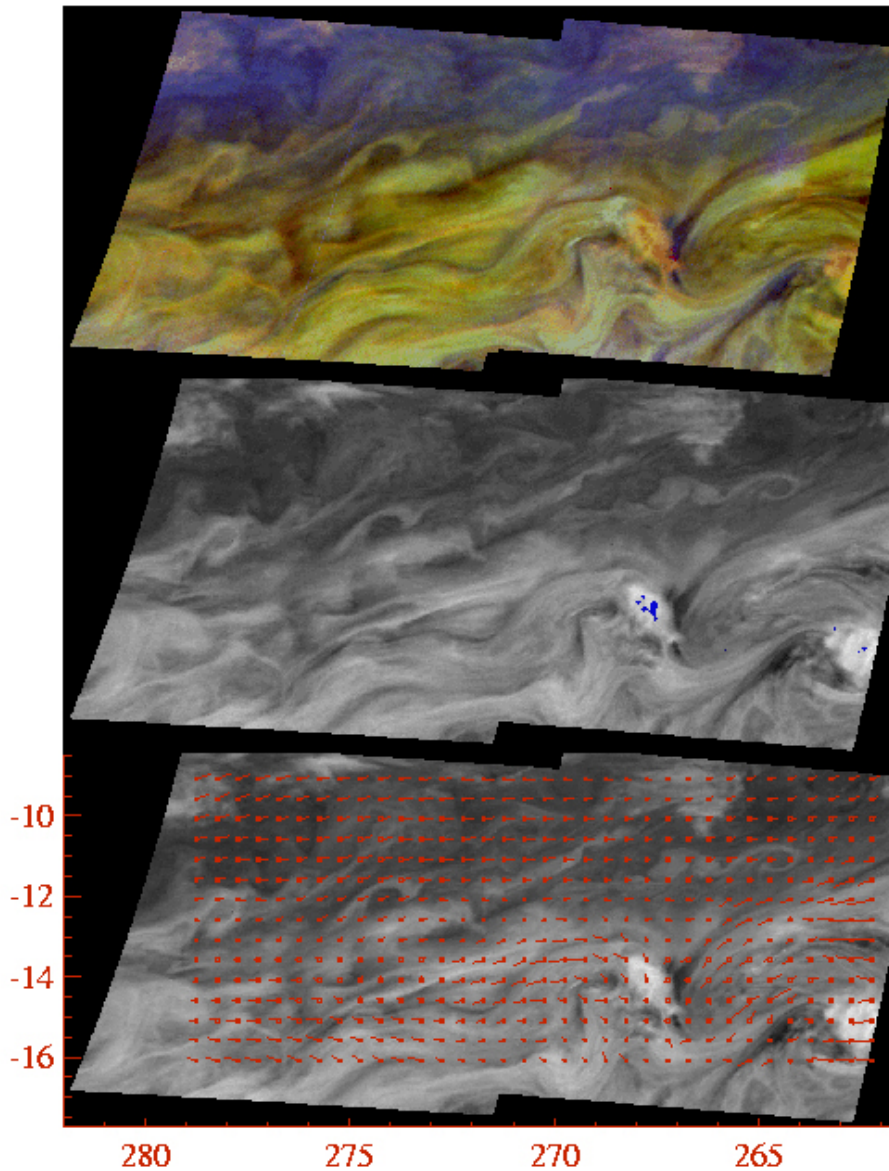


Images of the storm region composited from Galileo spacecraft images. There are two storm centers, located at latitude 14S, longitude 268W and latitude 15S, longitude 263W.

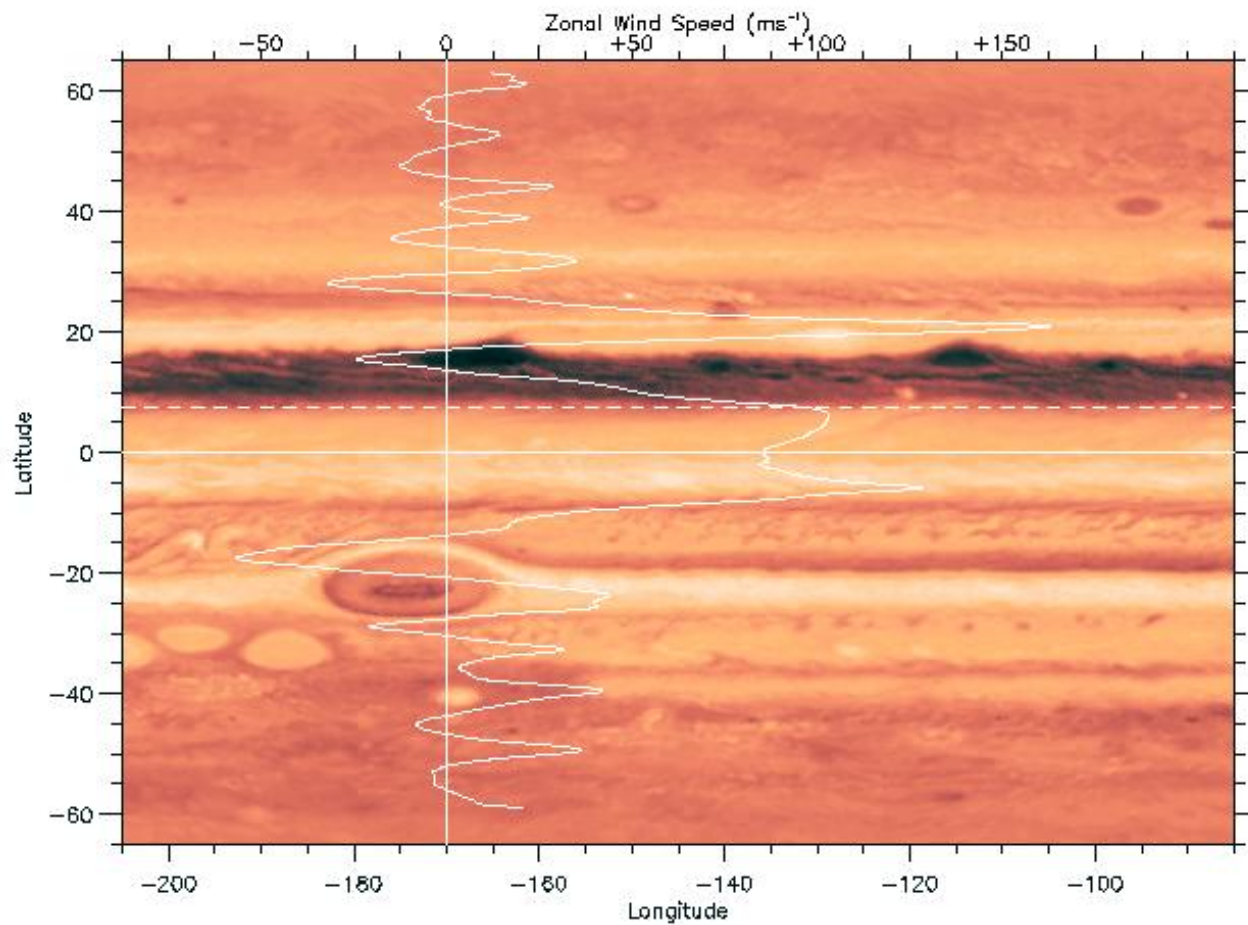
The color image at the top was made by superimposing images at two different wavelengths that are absorbed by methane and one where there is little absorption; these represent pressures (i.e., depths in the atmosphere) of about .5 bar (blue), 3 bar (green) and deeper than 3 bar (red).

In the middle black and white image a lightning strike, photographed while the same storm was on the night side of the planet, is overlaid.

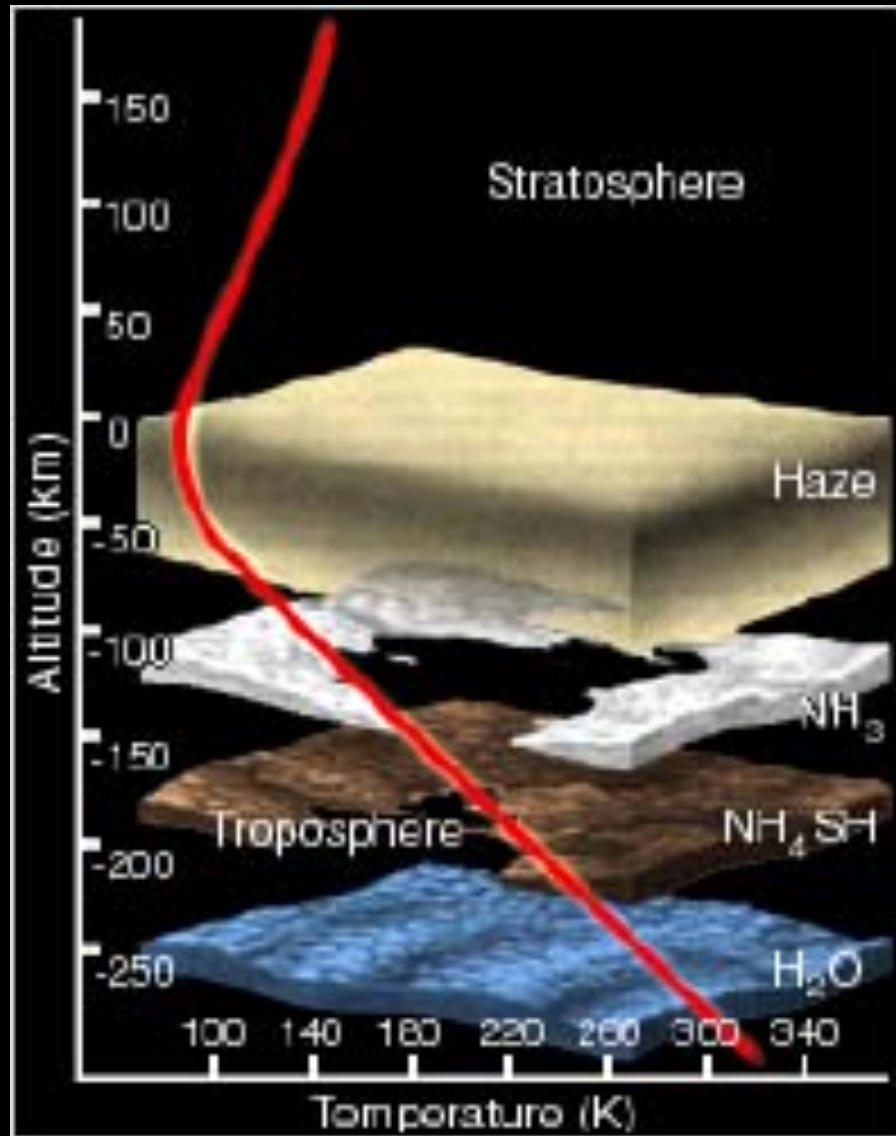
Wind vectors are overlaid on the bottom image.



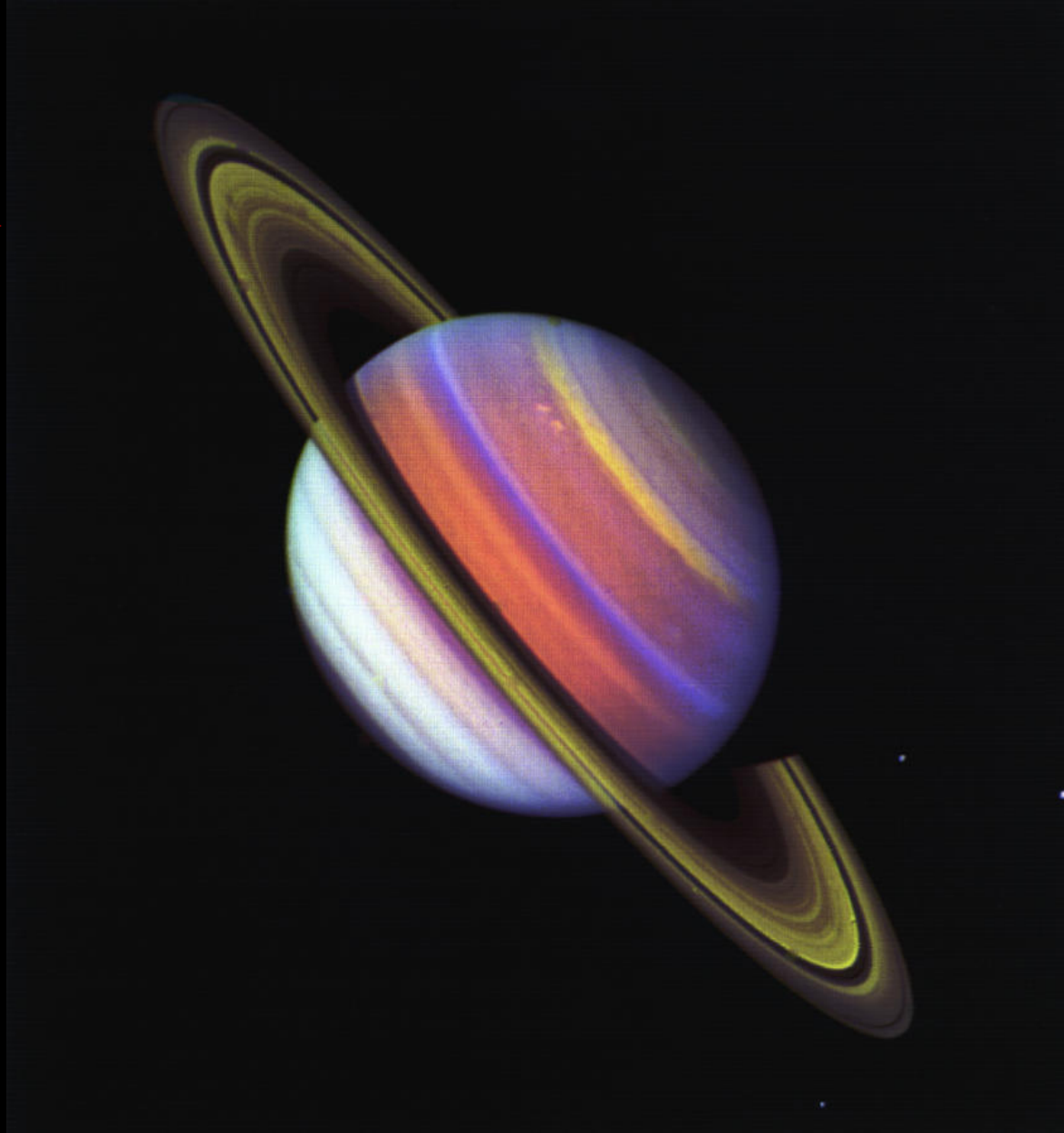
Cloud Level East-West Winds on Jupiter (*Limaye, Icarus, 1986*)

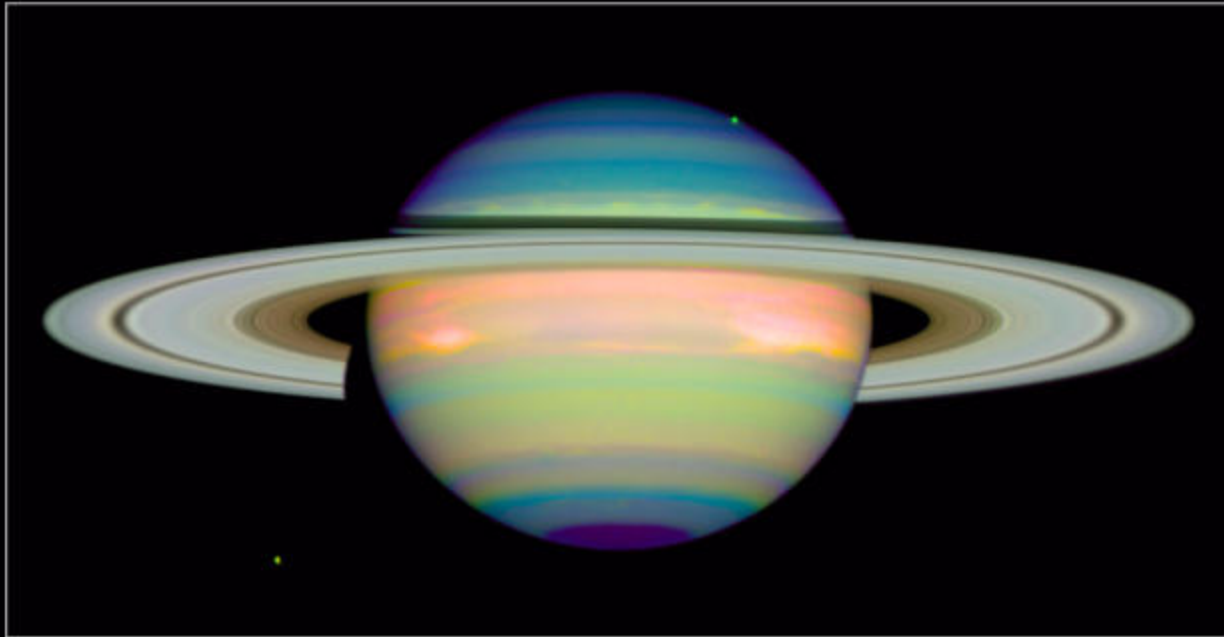


Jupiter:
Vertical
Structure



Saturn - A
multi-spectral
view from
Voyager 2

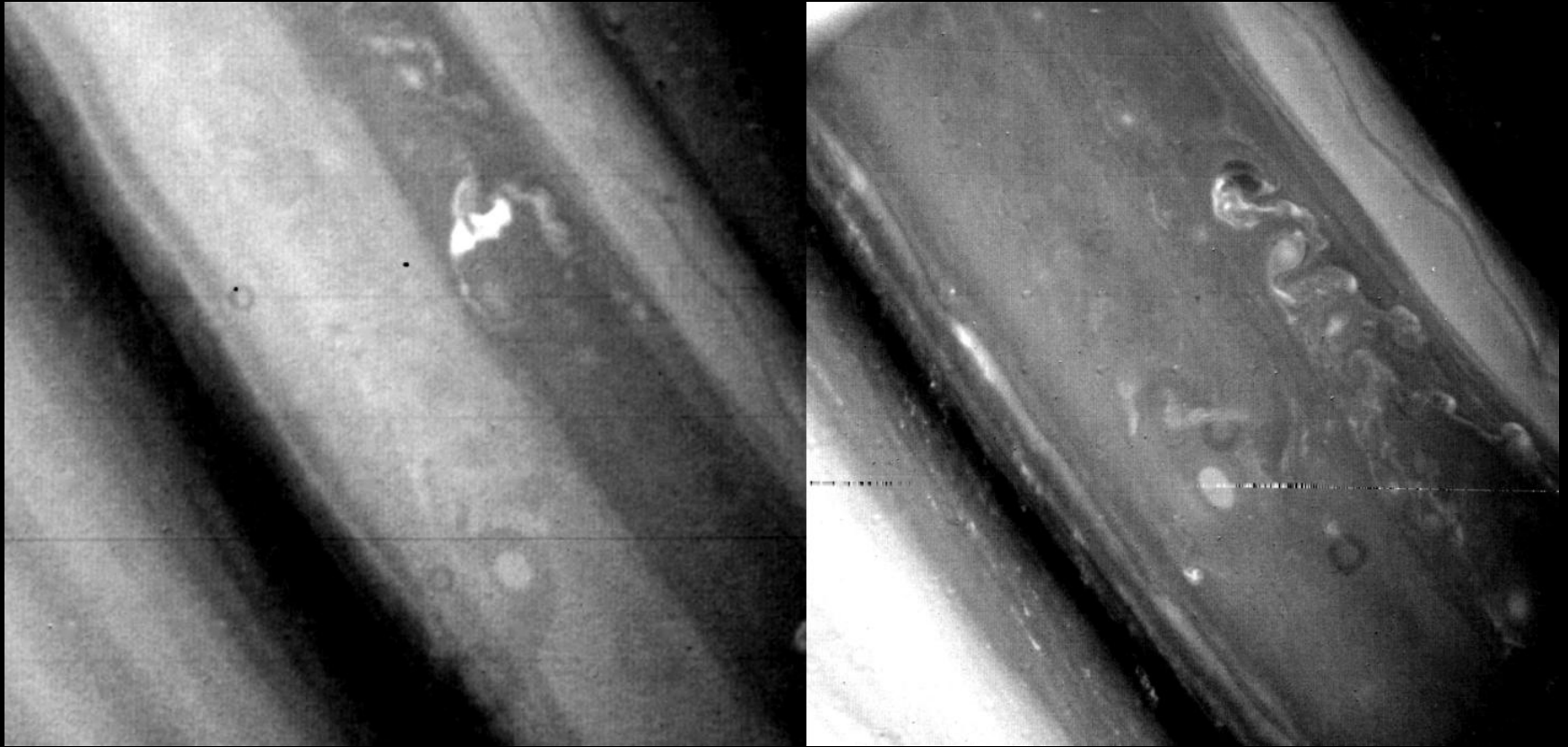




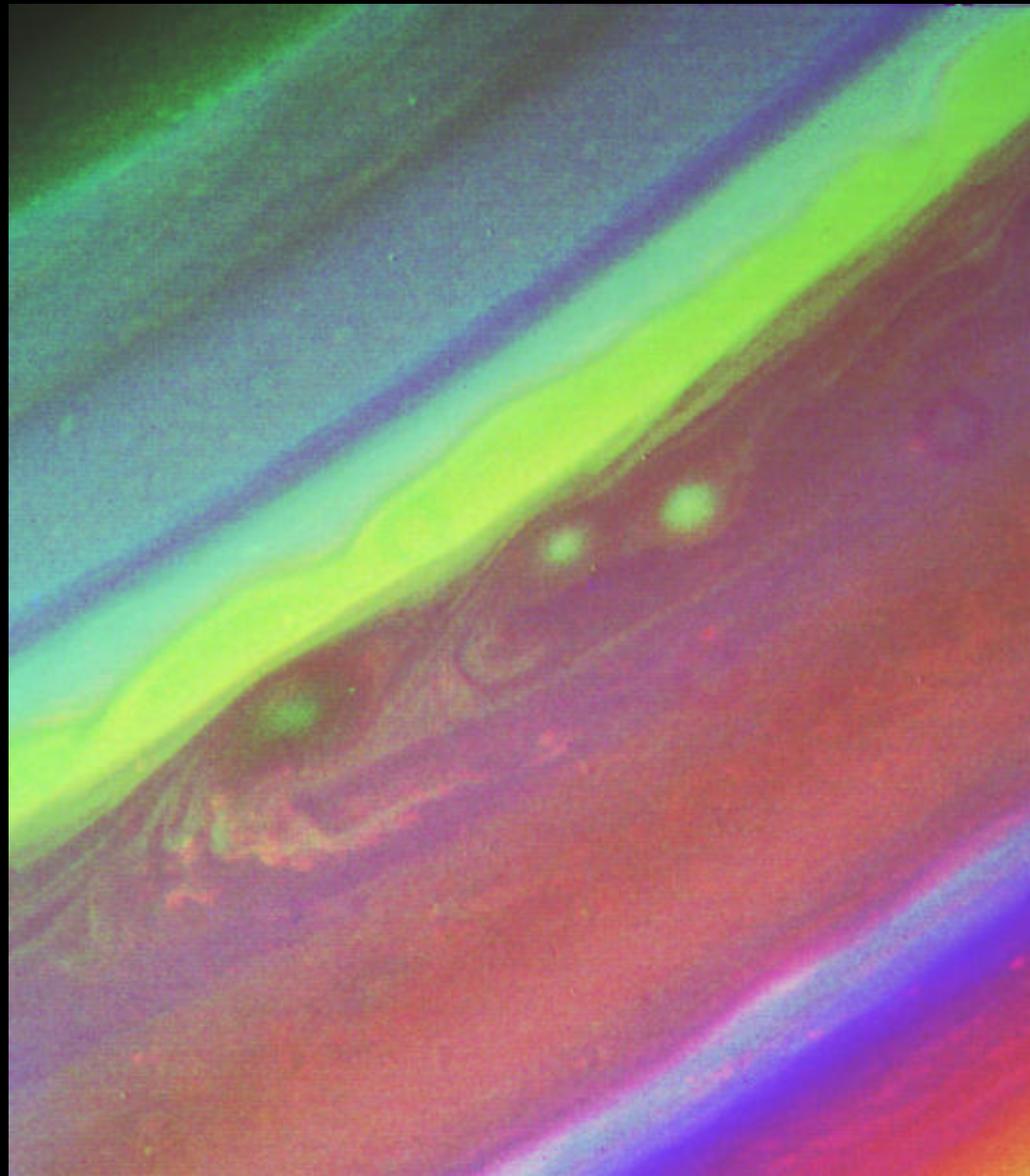
Saturn • January 4, 1998
Hubble Space Telescope • NICMOS

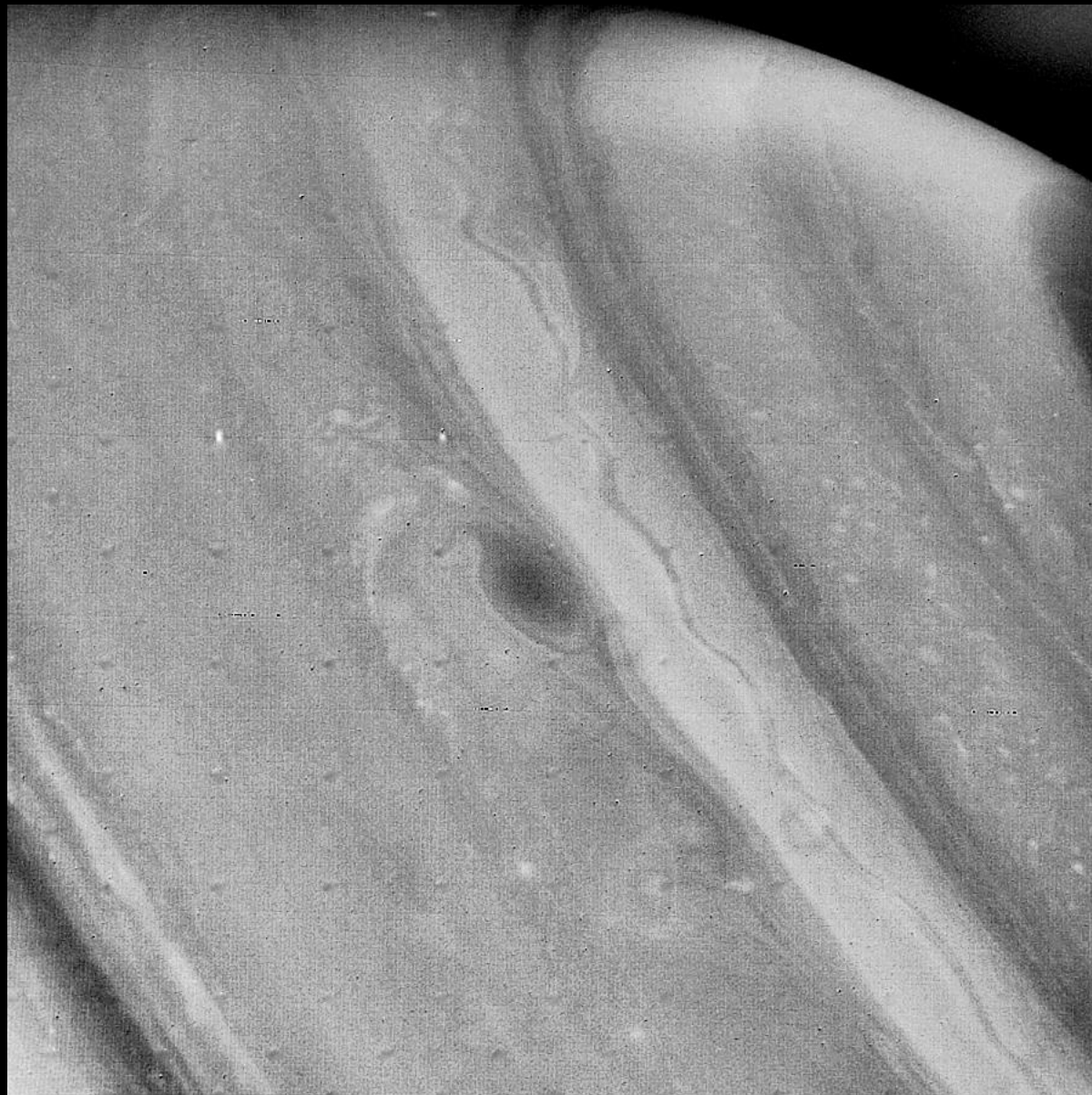
PRC98-18 • April 23, 1998 • ST ScI OPO • E. Karkoschka (University of Arizona) and NASA

Storms on Saturn

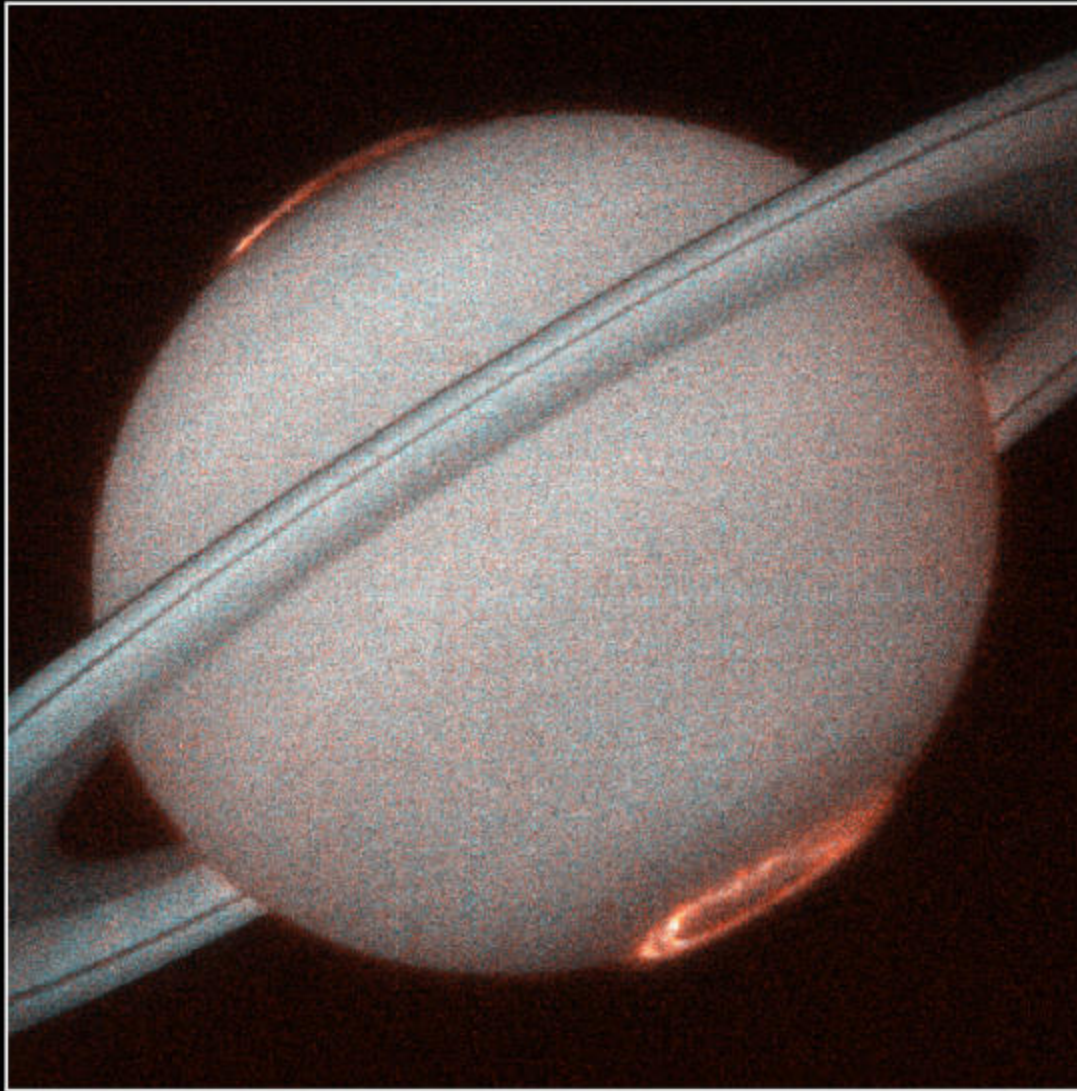


Storms and
Latitudinal
Cloud
Structure on
Saturn





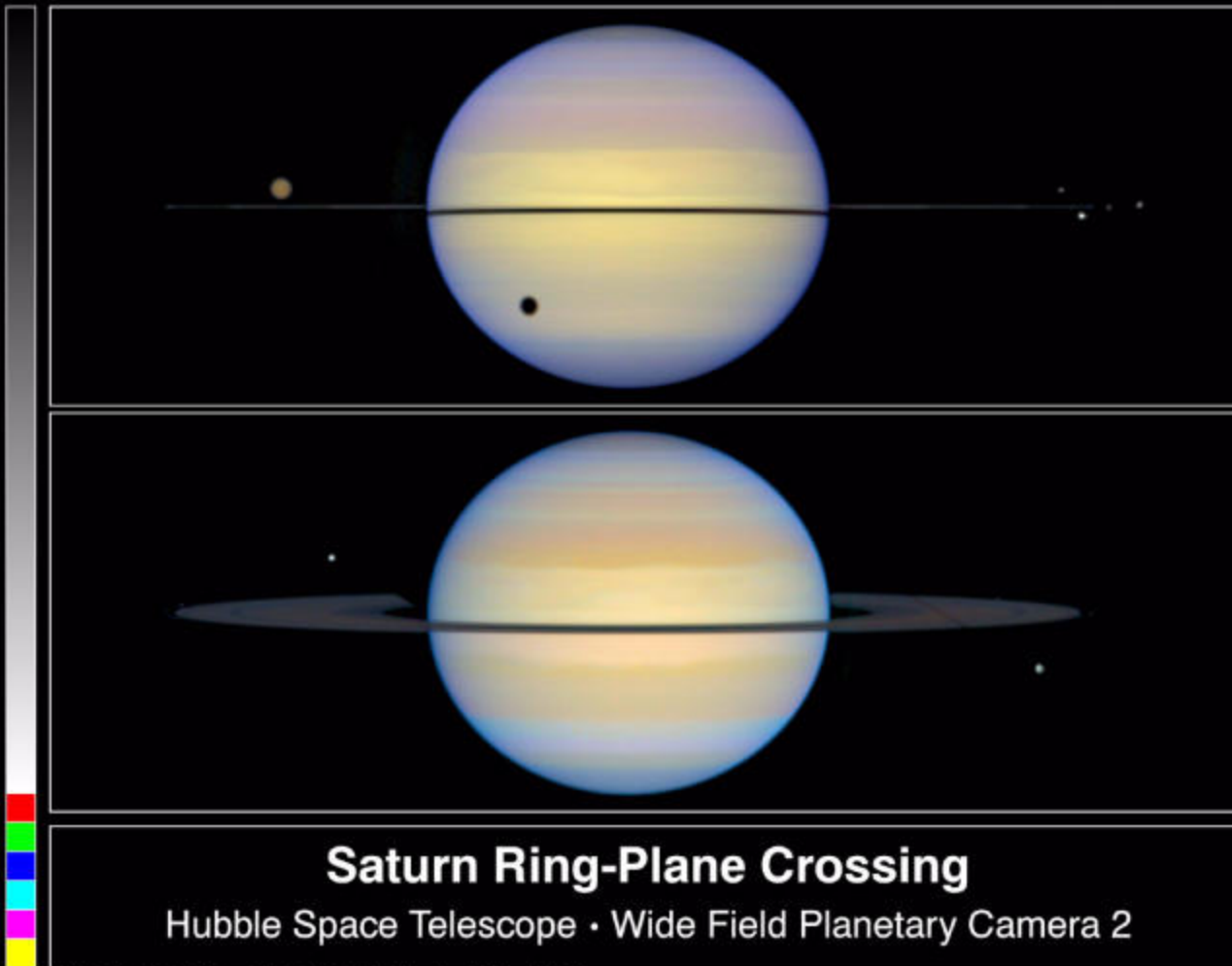
Aurora
over
Saturn's
Polar
regions -
Hubble
Space
Telescope



Saturn Aurora

HST • STIS

PRC98-05 • ST Sci OPO • January 7, 1998 • J. Trauger (JPL) and NASA

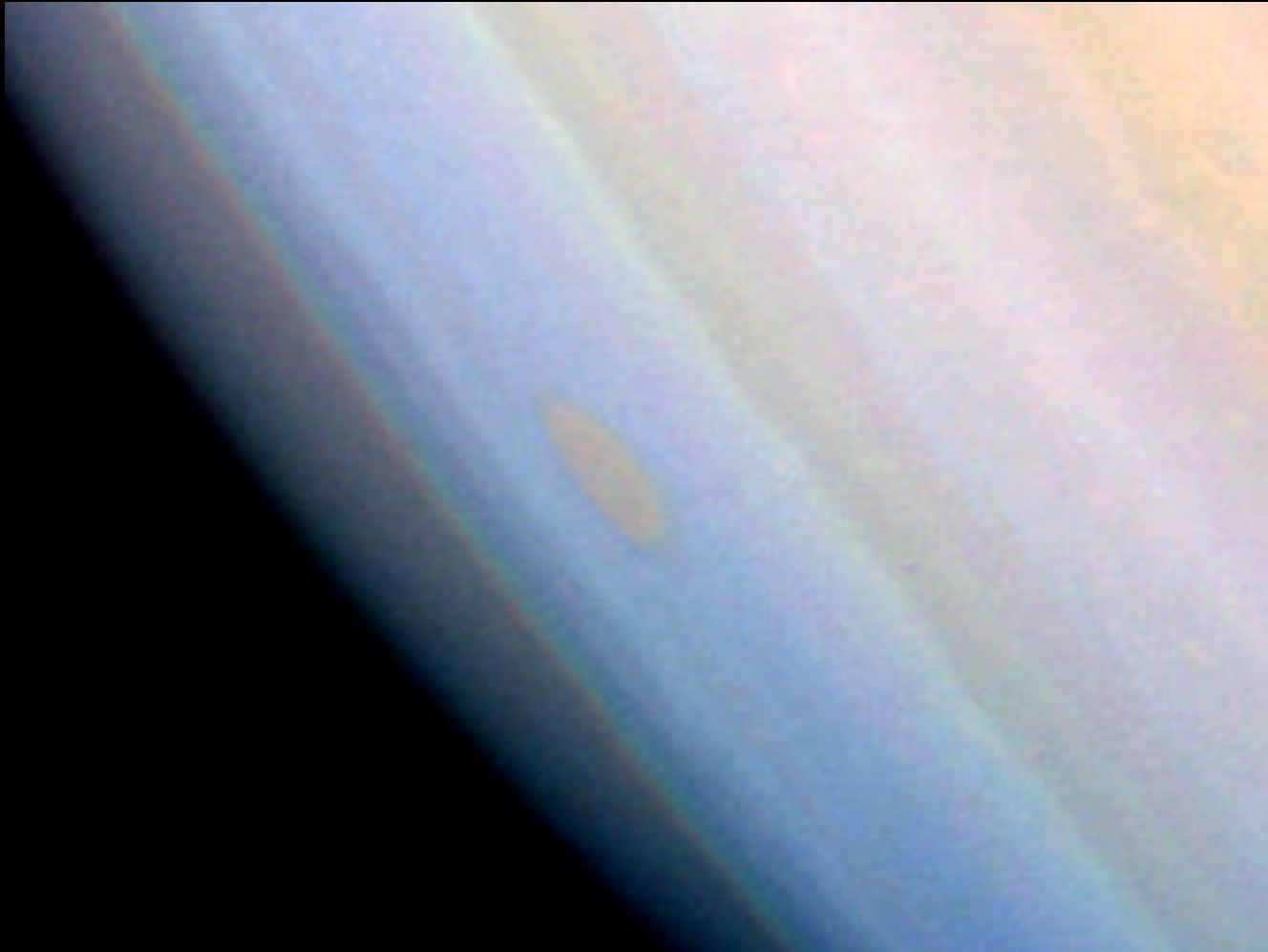


Saturn Ring-Plane Crossing

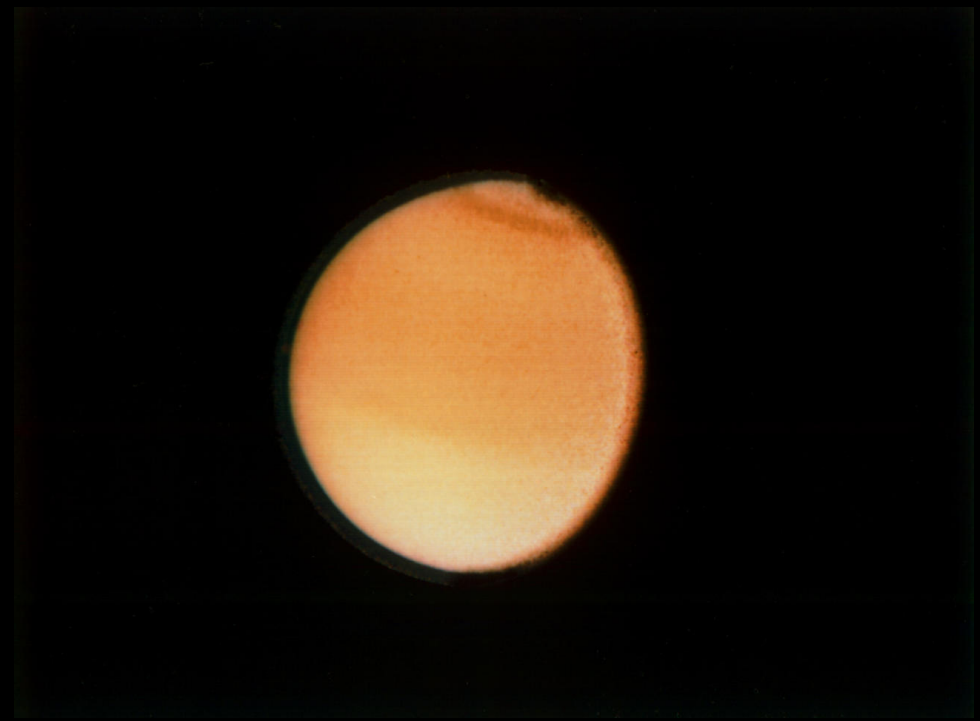
Hubble Space Telescope · Wide Field Planetary Camera 2

PRC96-16 · ST ScI OPO · April 24, 1996 · E. Karkoschka (LPL) and NASA

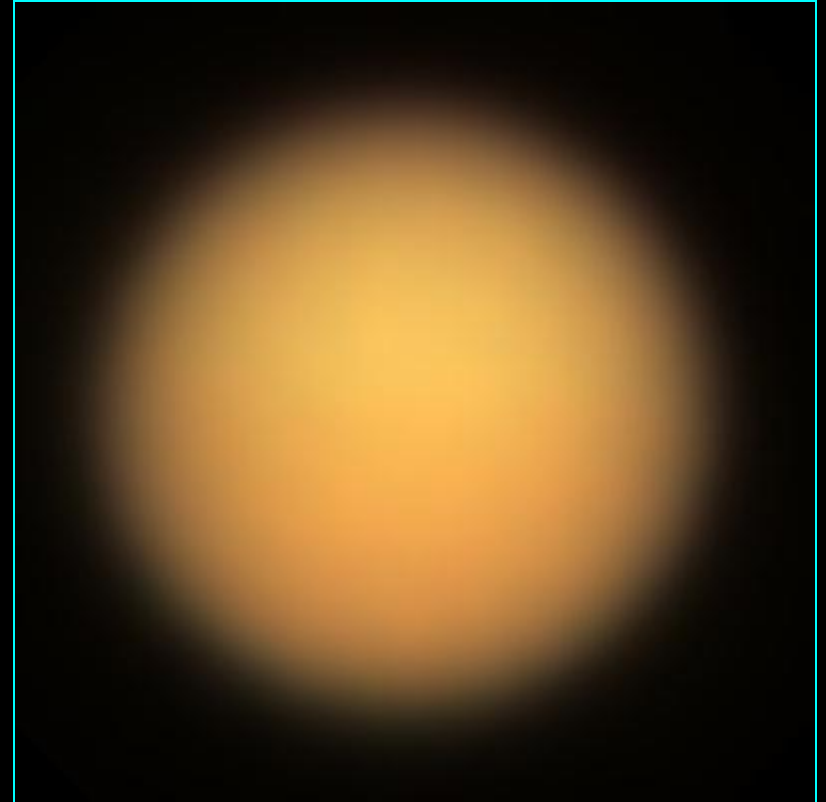
Red Spot on Saturn

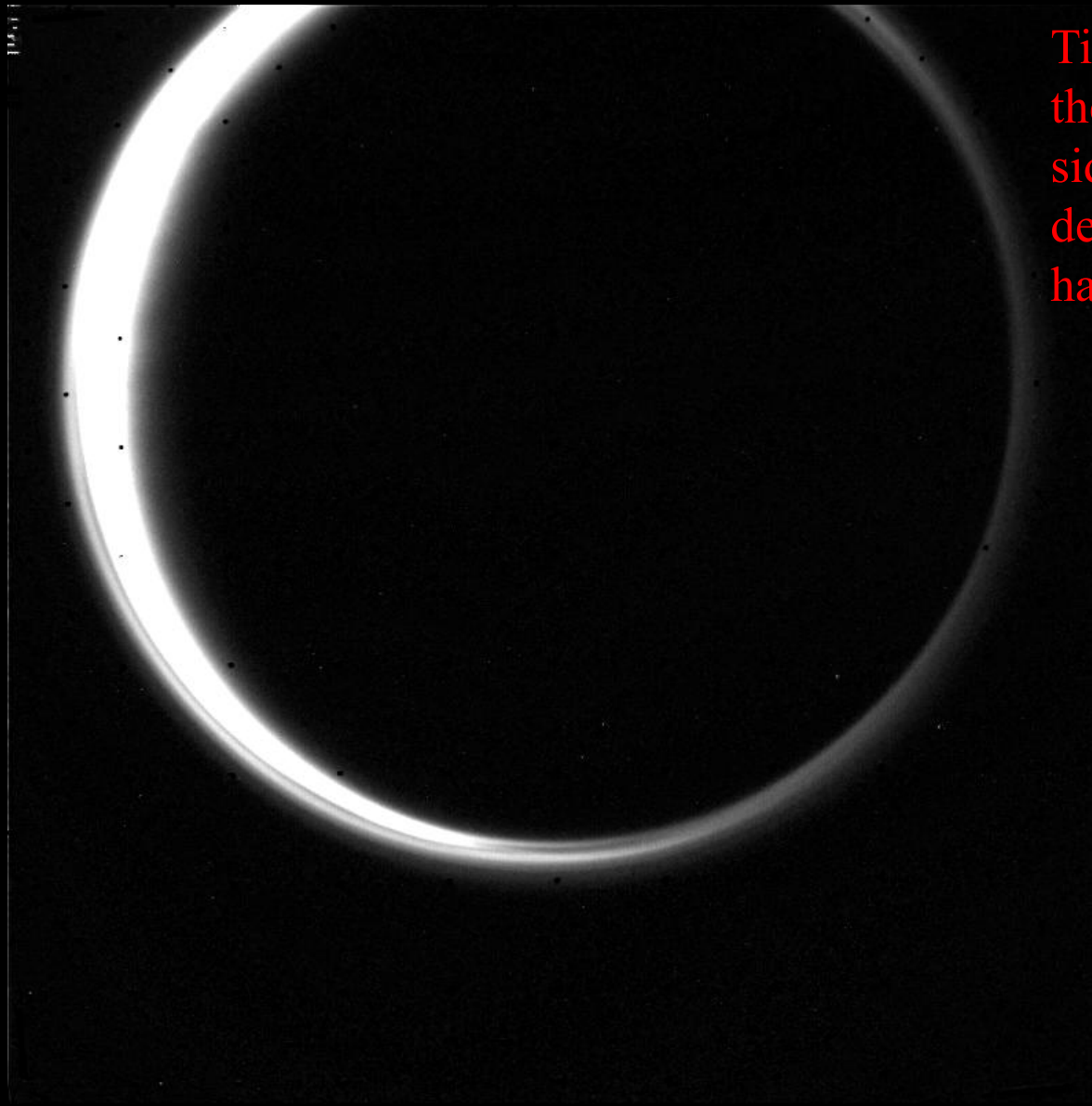


Titan - Moon with an atmosphere: *Hemispheric
Seasonal Appearance of Cloud Cover*



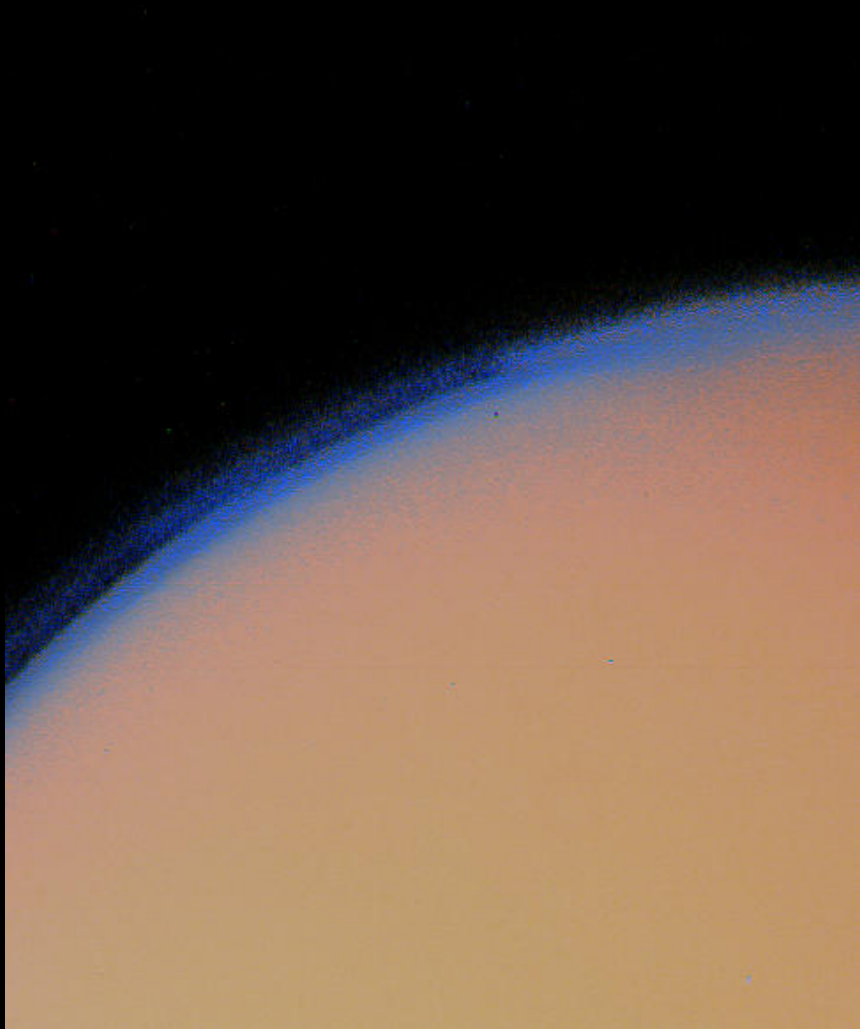
Titan - November 1980 (left) and in October 1994
Seasonal Variations in Clouds





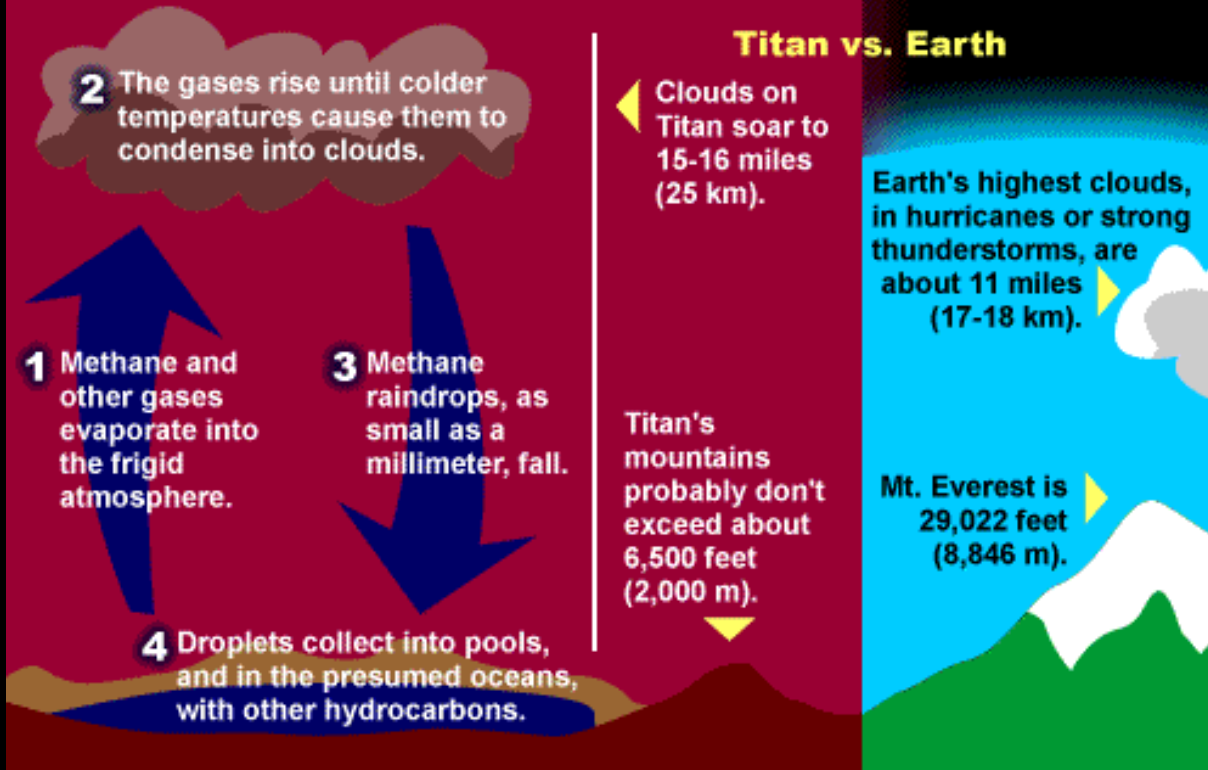
Titan from
the night-
side showing
detached
haze layer





Titan's Weather: The new picture

Weather on Earth and Titan have much in common. But Titan's low gravity creates an atmosphere that extends much higher. And Titan's atmosphere of methane is thought to be replenished by giant methane seas.



What makes weather?

On Titan, where the Sun's energy is 100 times weaker than on Earth, energy released during condensation drives much of the weather.

On Earth, the Sun is the main driving force for weather, creating temperature differences that force wind.

SPACE.COM GRAPHIC / ROBERT ROY BRITT

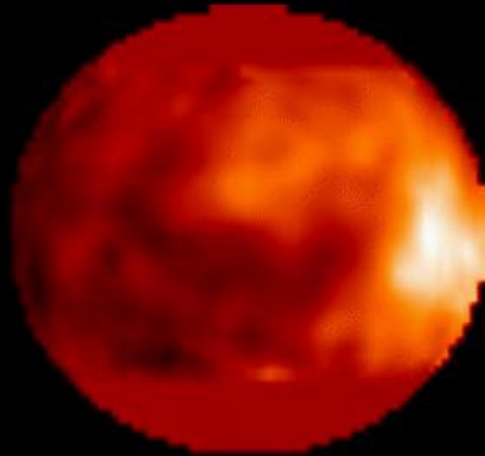
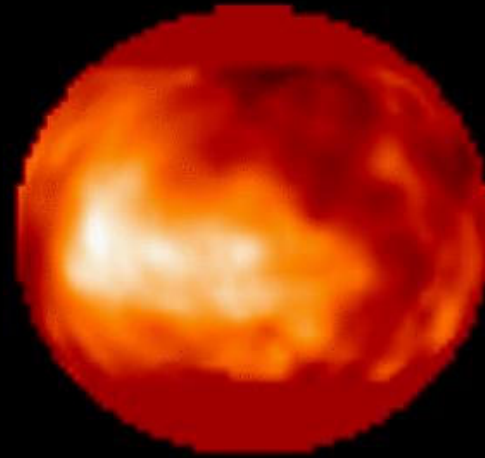
SOURCE: CAITLIN GRIFFITH

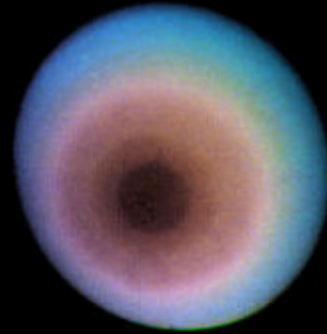


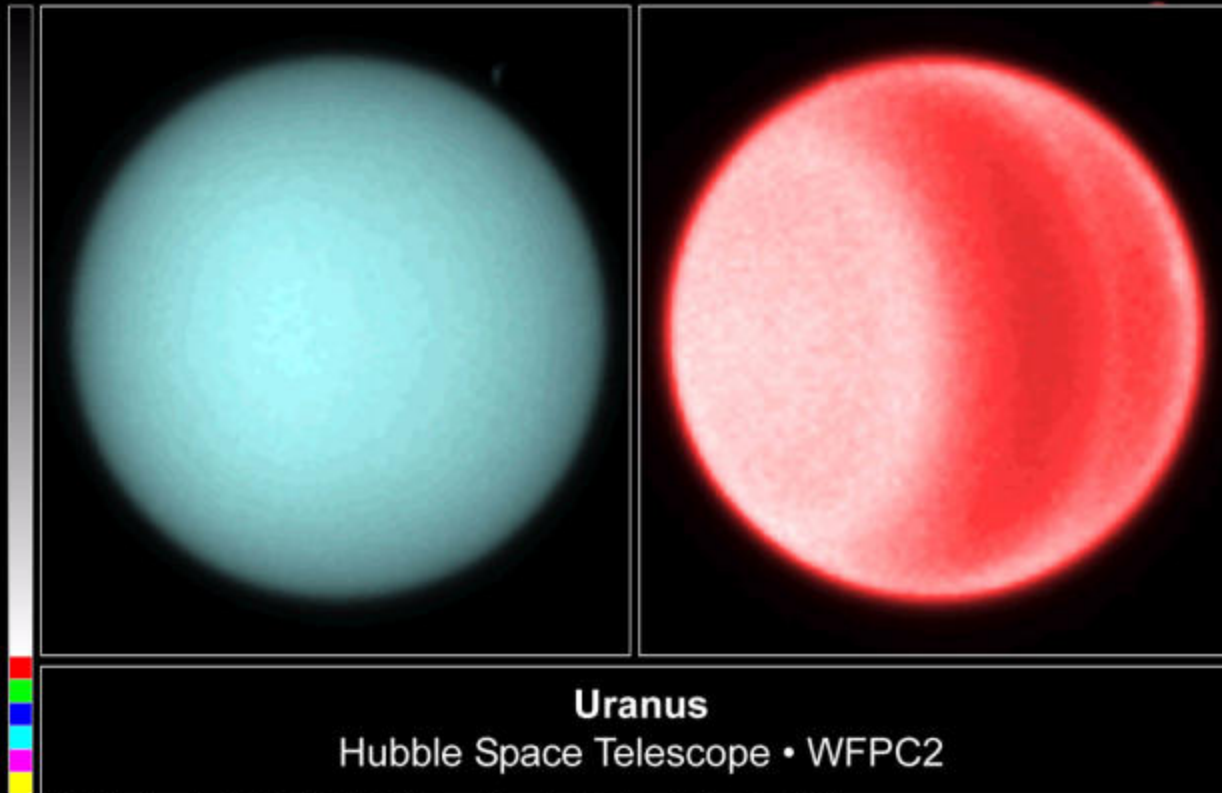
ESA

Surface of Titan

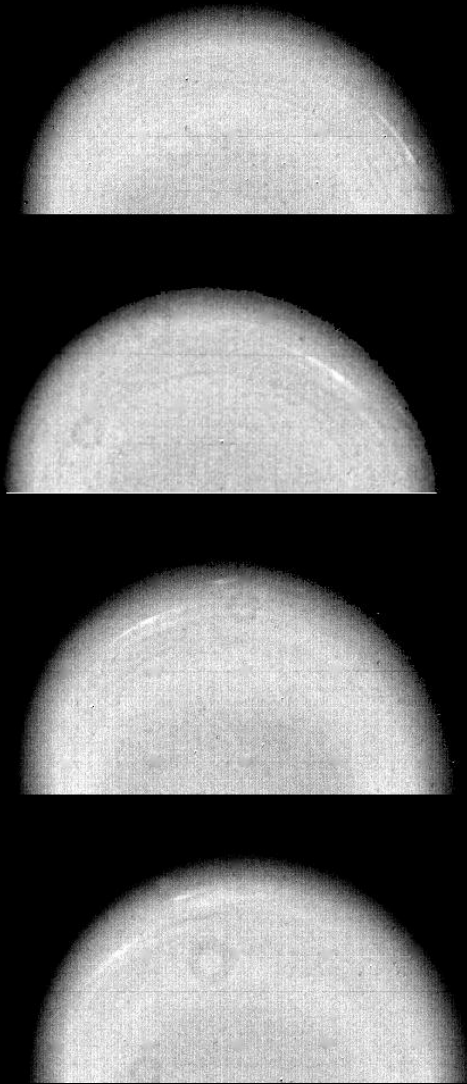
HST · WFPC2





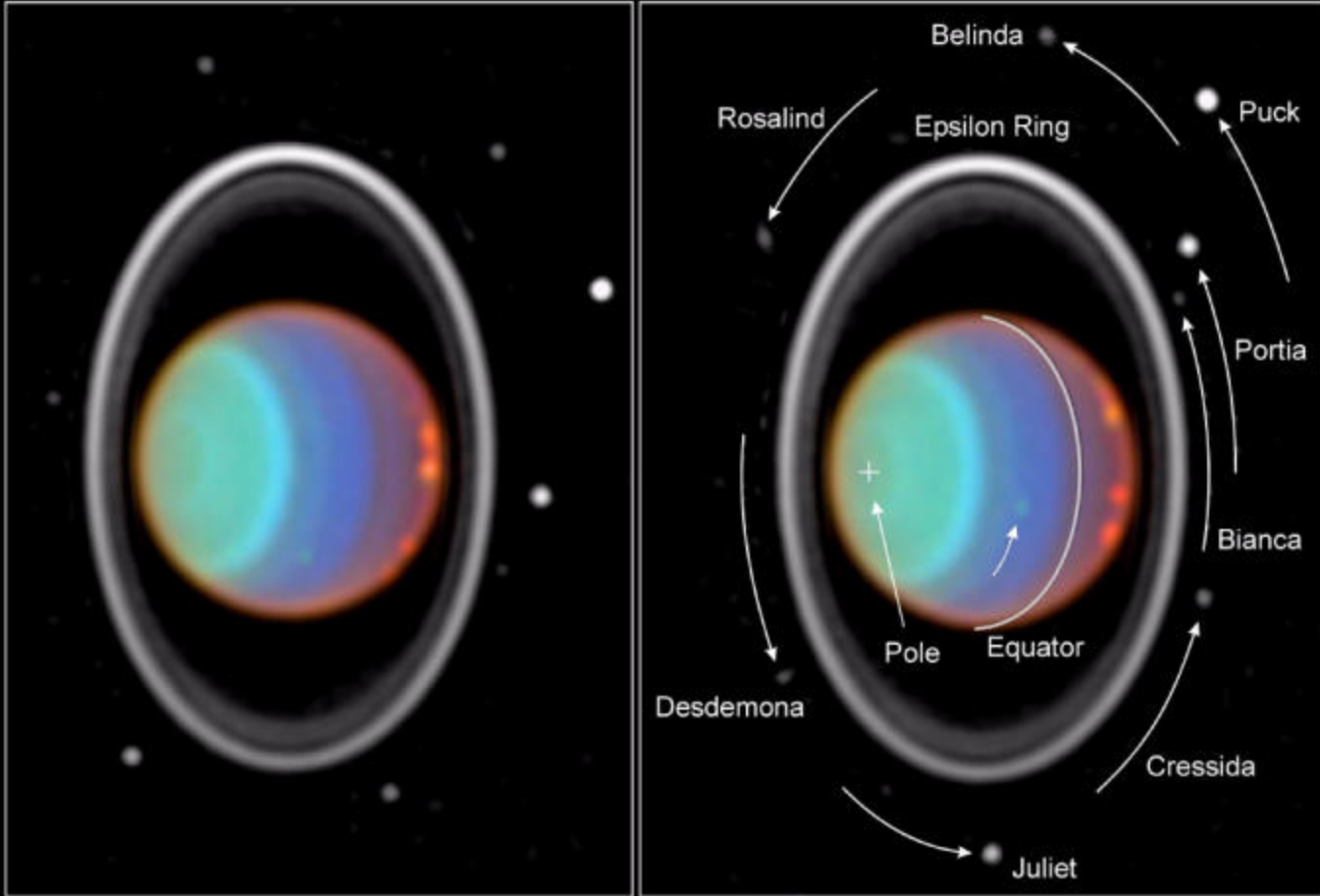


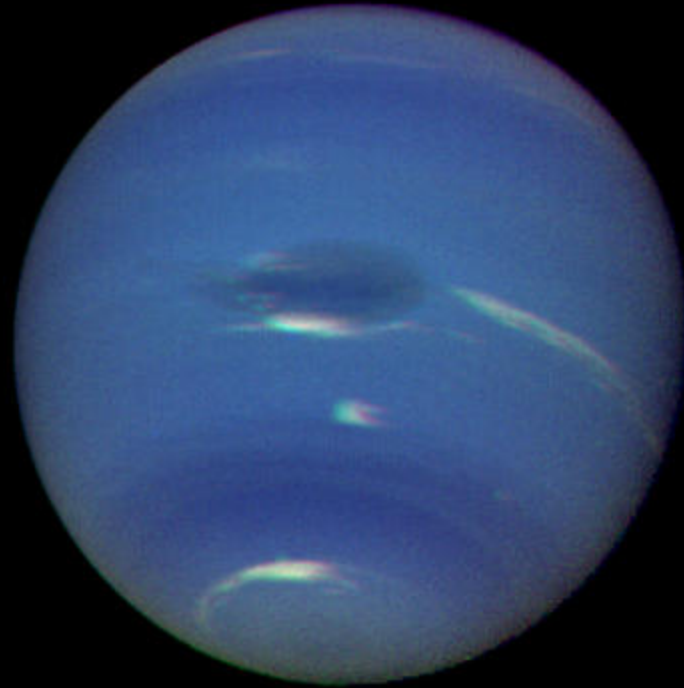
PRC97-36b • November 20, 1997 • ST ScI OPO • H. Hammel (Massachusetts Institute of Technology) and NASA

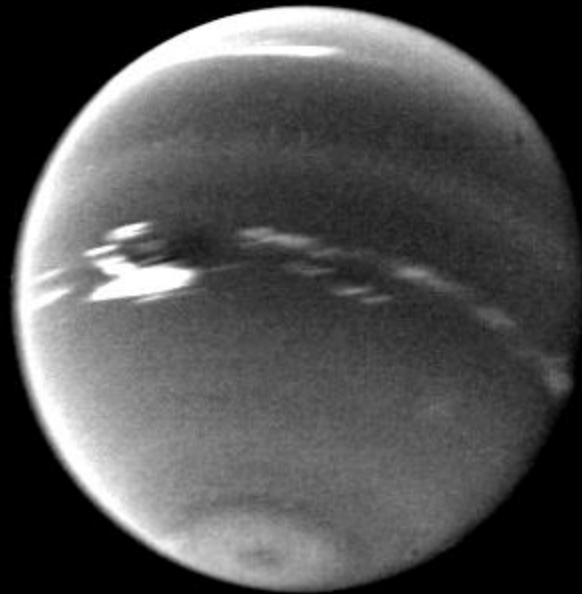


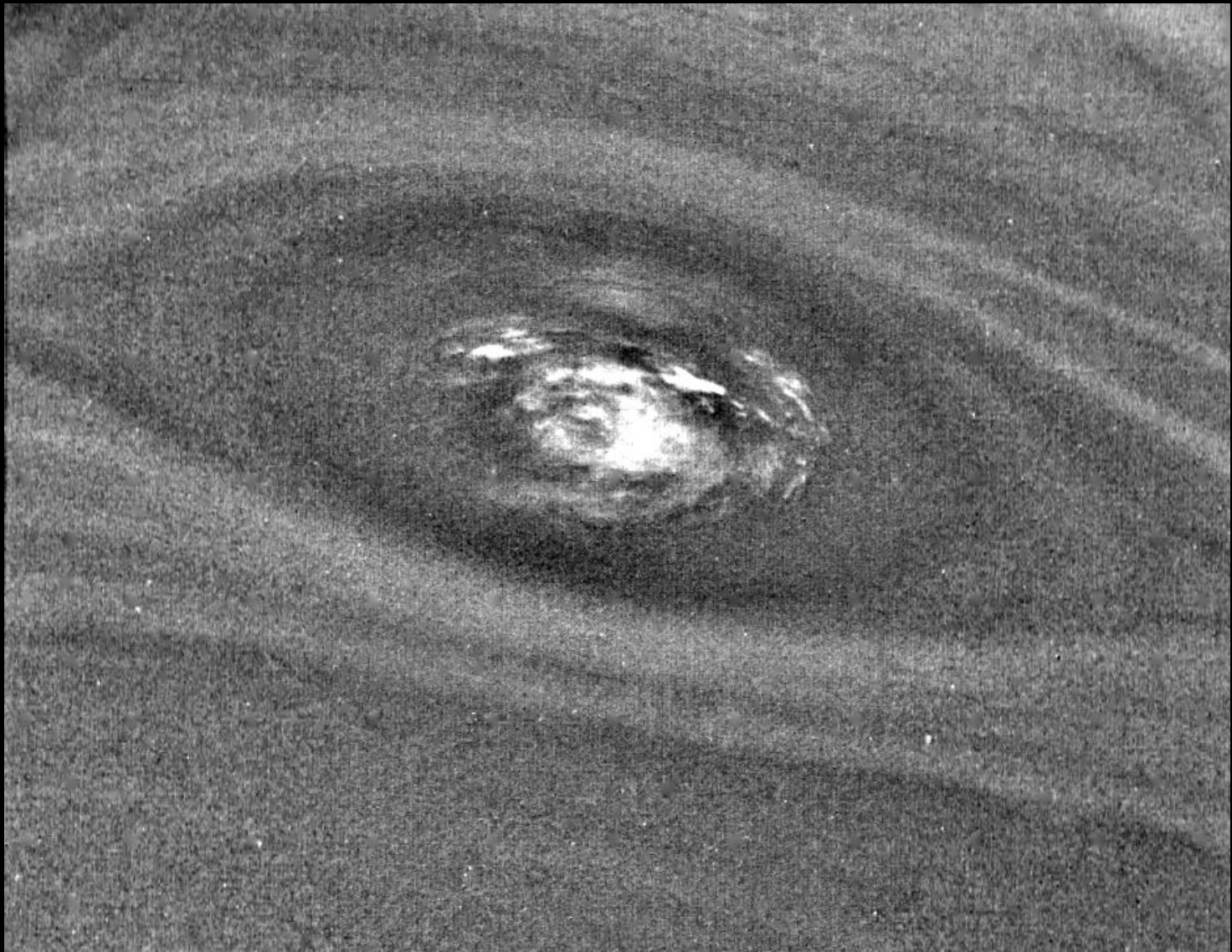
Time-lapse Voyager 2 images of Uranus show the movement of two small, bright, streaky clouds -- the first such features ever seen on the planet. The clouds were detected in this series of orange-filtered images taken Jan. 14, 1986, over a 4.6-hour interval (from top to bottom). At the time, the spacecraft was about 12.9 million kilometers (8.0 million miles) from the planet, whose pole of rotation is near the center of each disk. Uranus, which is tipped on its side with respect to the other planets, is rotating in a counterclockwise direction, as are the two clouds seen here as bright streaks. (The occasional donut-shaped features that show up are shadows cast by dust in the camera optics. The processing necessary to bring out the faint features on the planet also brings out these camera blemishes.)

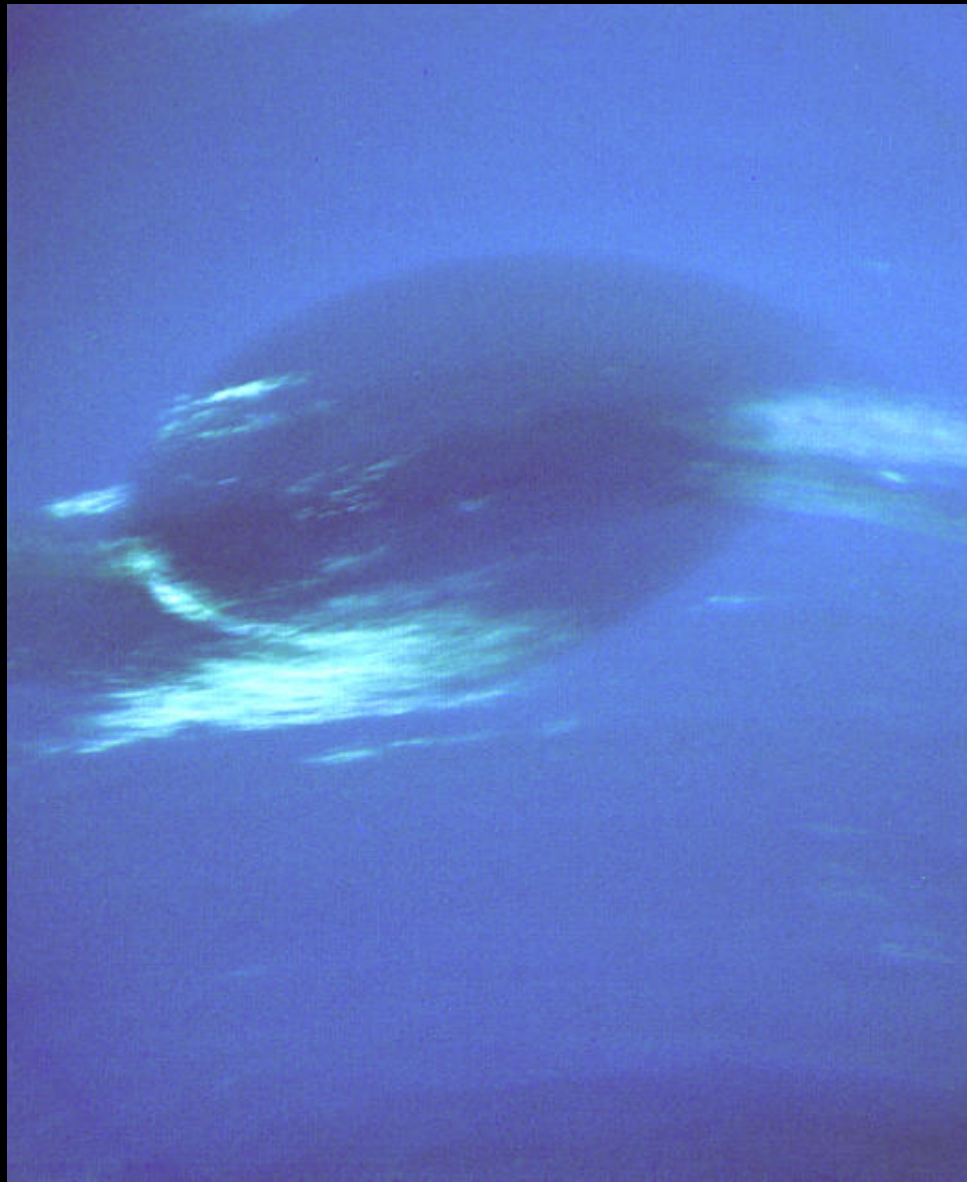
The larger of the two clouds is at a latitude of 33 degrees; the smaller cloud, seen faintly in the three lower images, lies at 26 degrees (a lower latitude and hence closer to the limb). Their counterclockwise periods of rotation are 16.2 and 16.9 hours, respectively. This difference implies that the lower-latitude feature is lagging behind the higher-latitude feature at a speed of almost 100 meters per second (220 mph). Latitudinal bands are also visible in these images. The faint bands, more numerous now than in previous Voyager images from longer range, are concentric with the pole of rotation -- that is, they circle the planet in lines of constant latitude. The Voyager project is managed for NASA by the Jet Propulsion Laboratory.









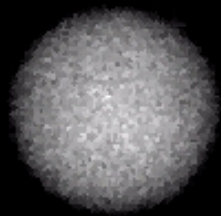




Neptune's Global Cloud Cover - A Latitude-Longitude View from Voyager 2 (1989)

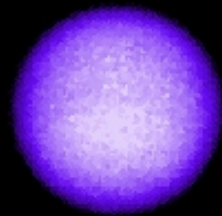


Neptune in Visible and Infrared Light (HST WFPC2 and NICMOS)



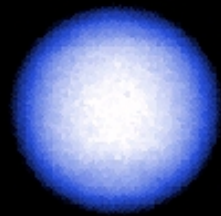
F255W

13/08/95, 23:19



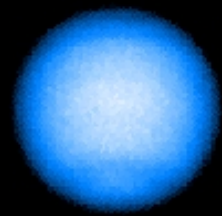
F336W

14/08/96, 01:01



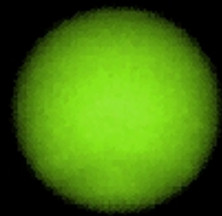
F410M

14/08/95, 01:09



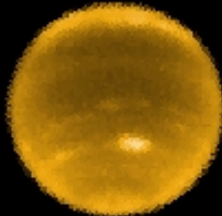
F467M

14/08/96, 00:30



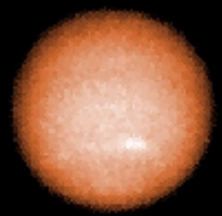
F588N

14/08/95, 01:04



FQCH4N-B

13/08/96, 21:58



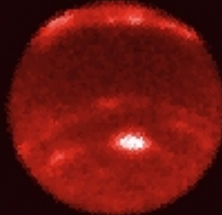
F631N

13/08/95, 22:05



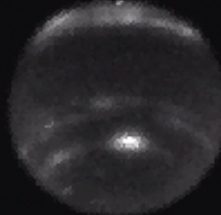
F673N

13/08/95, 21:30



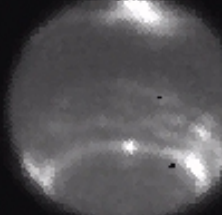
F850LP

13/08/96, 21:52



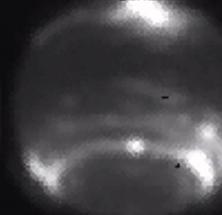
FQCH4N-D

13/08/95, 21:42



F110M

11/08/98, 08:33



F160W

11/08/98, 08:34



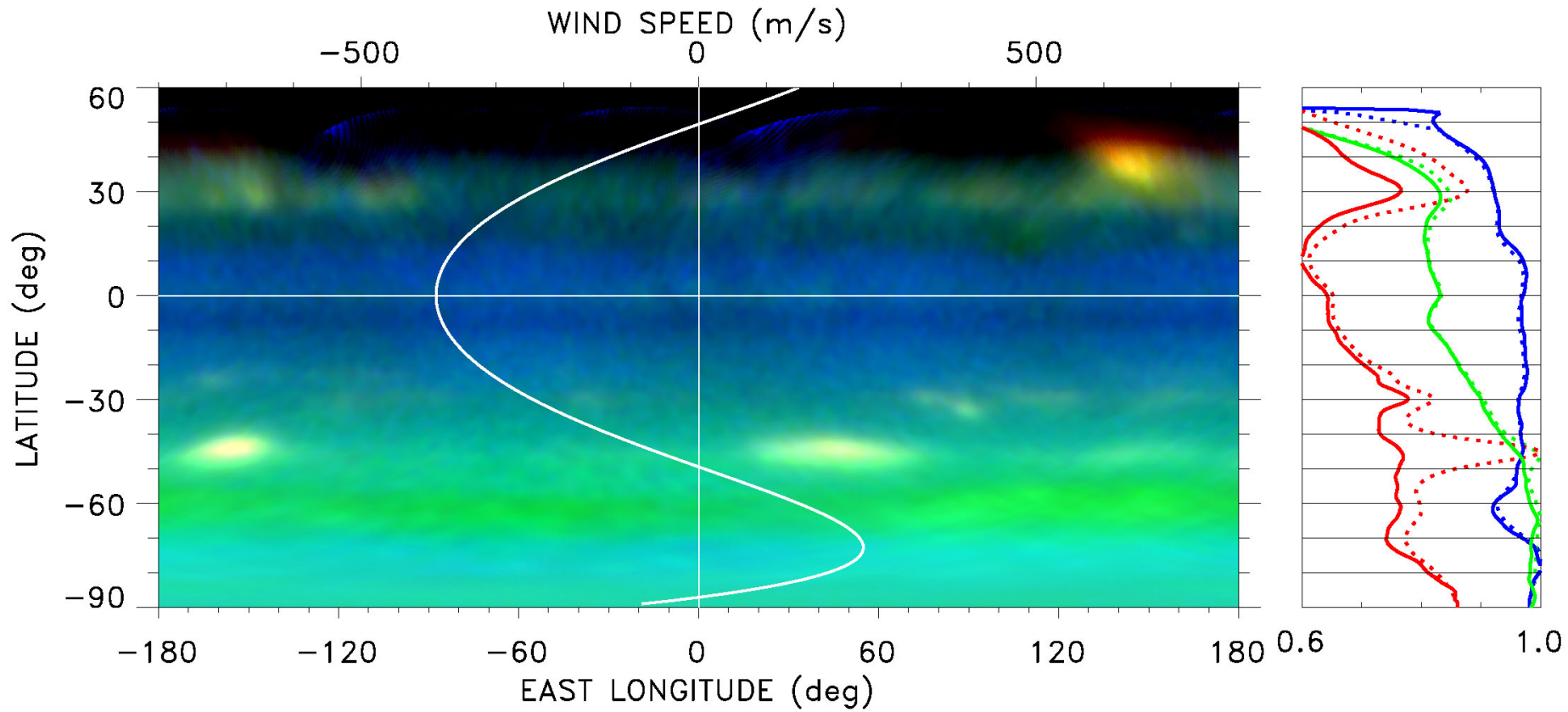
F205W

11/08/98, 13:30



F212N

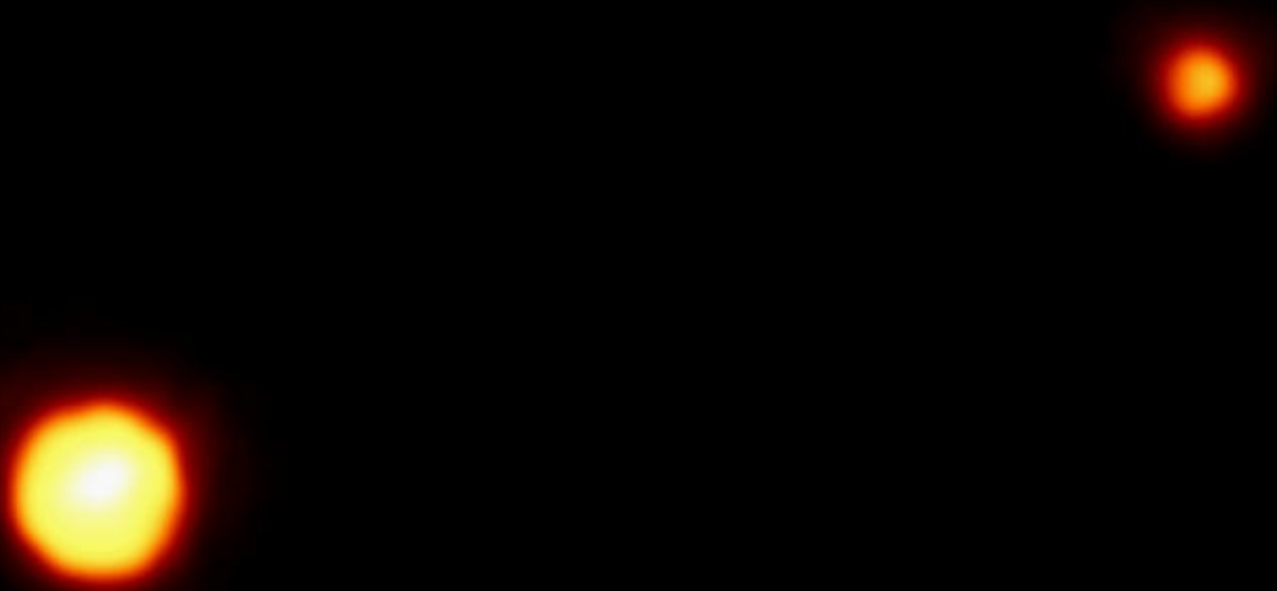
11/08/98, 13:33

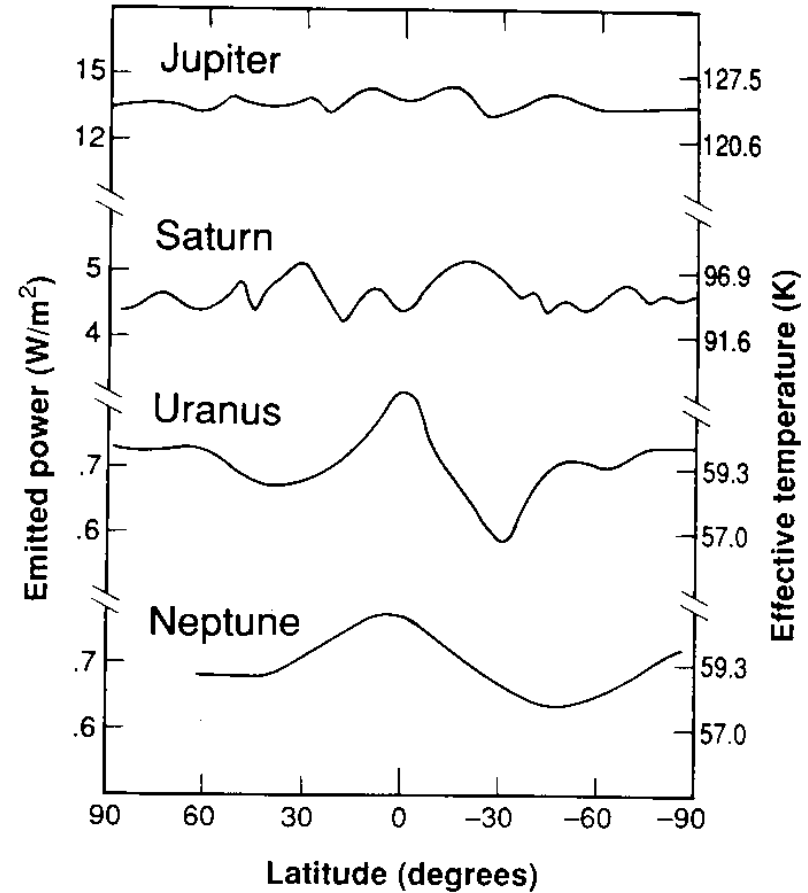
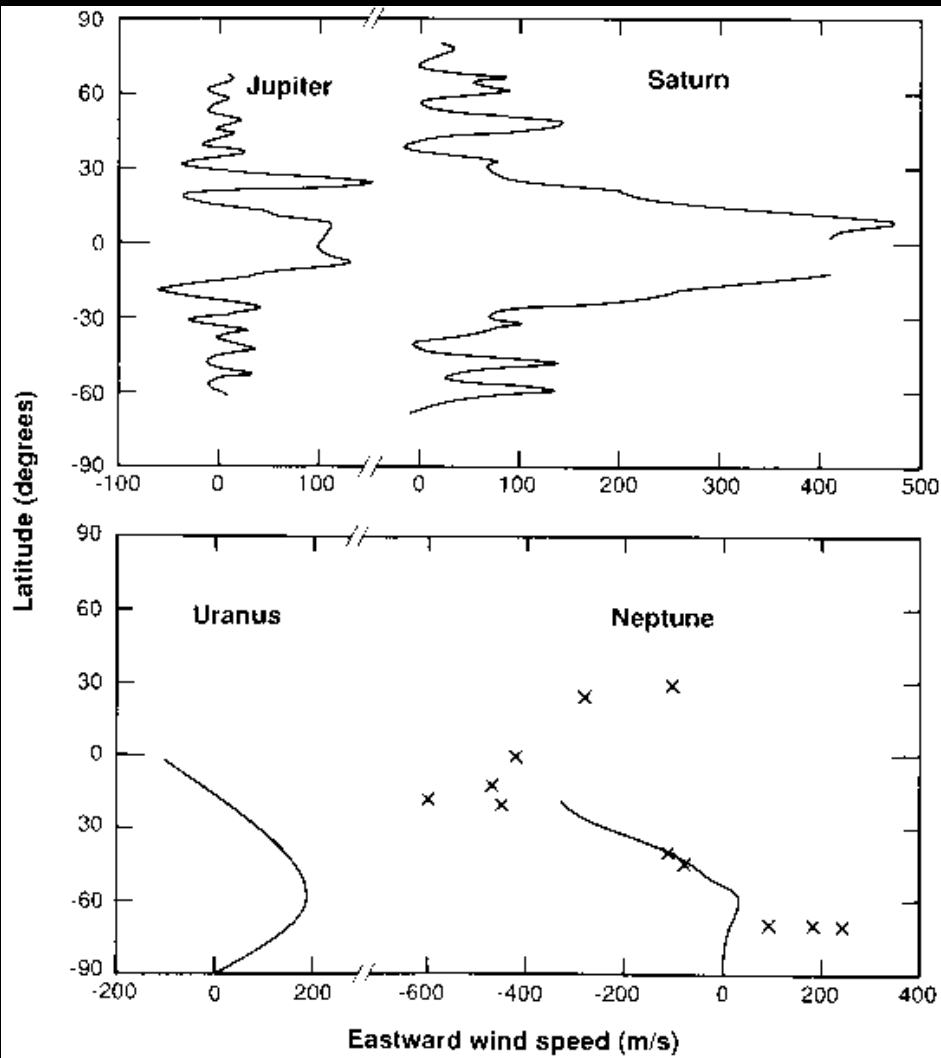


Plumes on Triton - Ice Volcanism?



Pluto and Sharon as imaged by the Nordic Optical Telescope





Parameter, symbol	Jupiter	Saturn	Uranus	Neptune
Equatorial radius, r_e (10^3 km)	74.1	60.3	25.6	24.8
Rotation period, $2\pi/\Omega$ (hour)	9.92	10.66	17.24	16.11
Equatorial gravity, g (m/s^2)	22.9	9.1	8.8	11.1
Orbital period, $2\pi/\Omega_o$ (year)	11.9	29.5	84.0	164.8
Obliquity of spin axis, i (degree)	3	27	98	29
Helium mole fraction, f_{He}	0.10	0.03	0.15	0.15*
Emitted/absorbed power, f_e	1.7	1.8	1.0	2.7*
Emission temperature, T_e (K)	124	95	59	59*
Emission pressure, P_e (bar)	0.4	0.3	0.4	0.5
Scale height, H (km)	20	39	25	20
Speed of sound, c_s (m/s)	810	705	560	560