

"The Planets"

Astro/EPS C12 (CCN 17045 or 32505)

Dr. Michael H. Wong

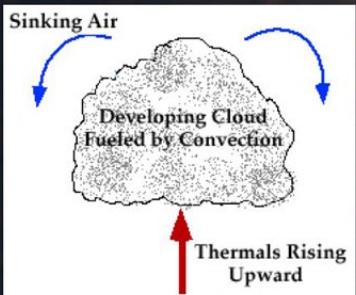


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astro.berkeley.edu/~mikewong/C12.html

LEC: 2 LeConte TWTh, 2:40–5:00pm
Office Hours: 419 Campbell Hall,
Mon 3–4 and Tue 5–6

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CONVECTION



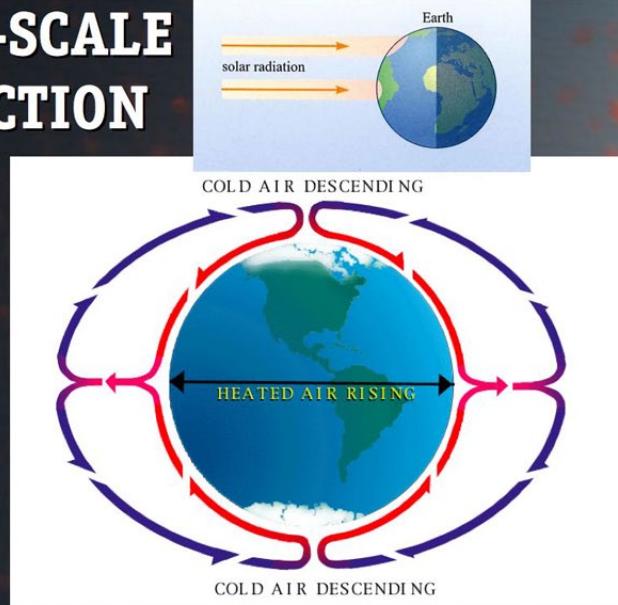
- heating --> buoyancy
- buoyancy --> motion, transport of heat

HEAT TRANSPORT MECHANISMS

- radiation: heat carried by light
 - the Sun
 - greenhouse effect
- conduction: heat transported by contact
- advection: physically moving heat from one place to another
- convection: heat transported by buoyancy and motion
 - plate tectonics

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LARGE-SCALE CONVECTION



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ANGULAR MOMENTUM

- angular momentum is rotational inertia
 - angular momentum is a “conserved” quantity: it doesn’t change unless a torque is applied
- for a point mass rotating around an axis, angular momentum L is:

$$L = m v r$$

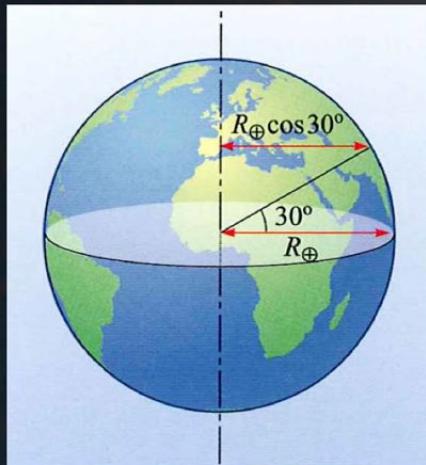
m is mass, v is velocity, r is distance from object to rotational axis

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CORIOLIS EFFECT

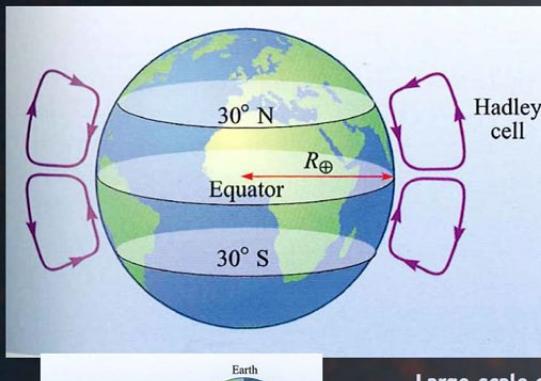
Conservation of angular momentum:

- everything at the surface has angular momentum due to the Earth’s rotation
- a “coriolis force” pushes to the right (N hemisphere) or left (S hemisphere) of any large-scale surface motion
- toilets are not large-scale



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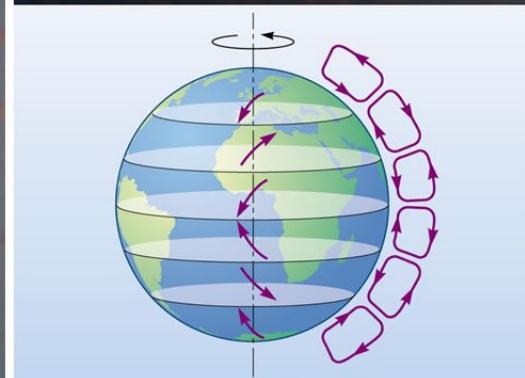
HADLEY CELL



Large-scale convective heat transport by convection

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HADLEY CIRCULATION

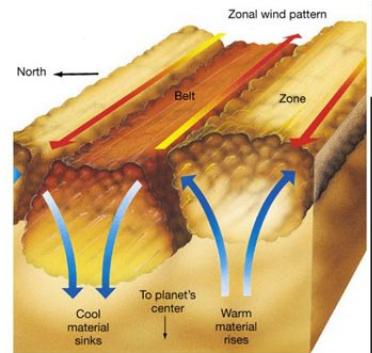


involves several concepts:

- convection
- coriolis effect
- equator-to-pole variation in sunlight intensity

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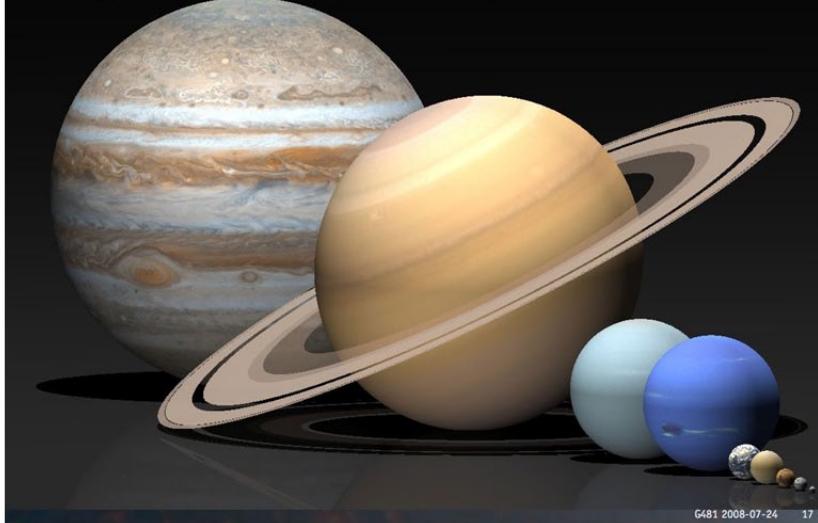
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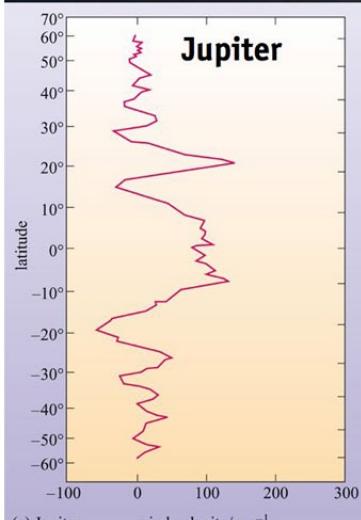
(a)



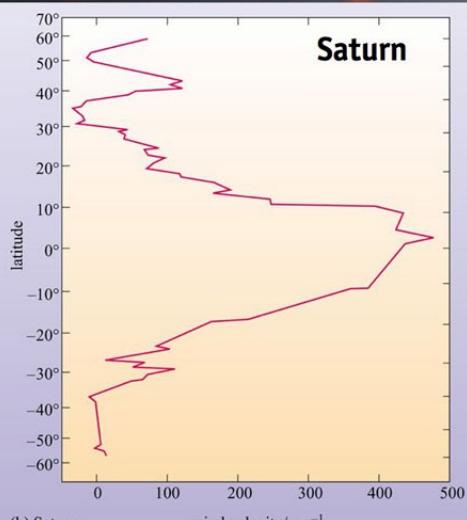
GIANT PLANETS



ZONAL WIND PROFILES

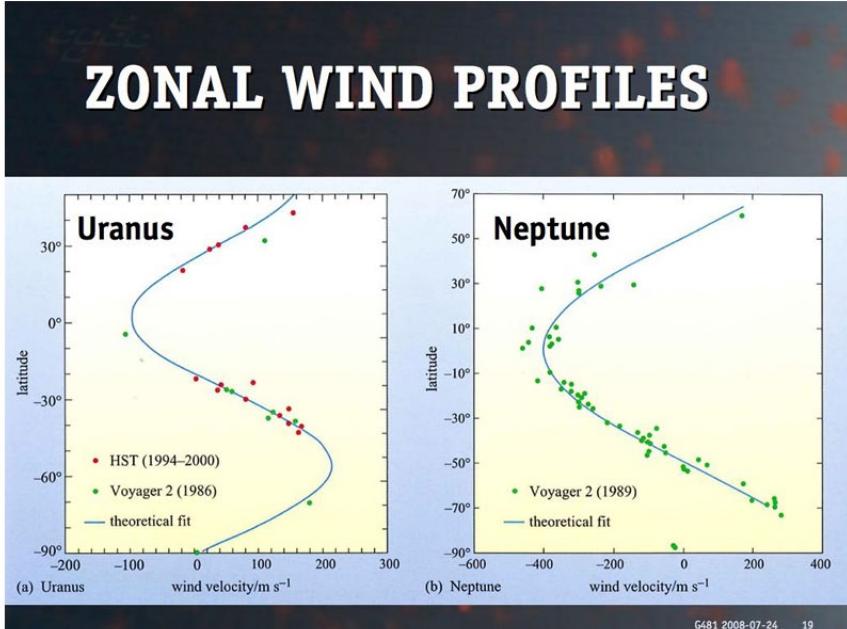


(a) Jupiter

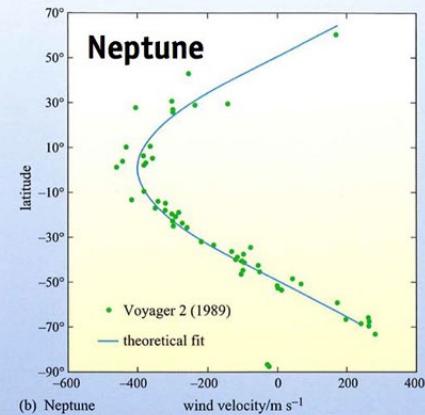


(b) Saturn

ZONAL WIND PROFILES



(a) Uranus



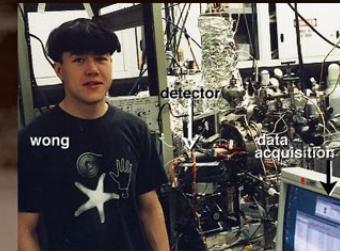
(b) Neptune

HEAT EXCESS

- giant planets typically radiate more heat than they receive from the Sun
- heat source: gravitational contraction
- Saturn may also be differentiating by "helium raindrops"
- Uranus is the exception: it does not have a "heat excess," although similar-sized Neptune radiates 2.6 times as much heat as it receives from the Sun

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GPMS



7 December 1995

ATMOSPHERIC COMPOSITION

	Protosolar	Jupiter	Saturn	Uranus	Neptune
H ₂	0.84	0.86	0.88	0.83	0.80
He	0.16	0.14	0.12	0.15	0.18
CH ₄	4.6x10 ⁻⁴	2.0x10 ⁻³	4.9x10 ⁻³	0.018	0.02
H ₂ O	8.6x10 ⁻⁴	4.2x10 ⁻⁴	?	?	?
NH ₃	1.1x10 ⁻⁴	5.7x10 ⁻⁴	6x10 ⁻⁴ ?	?	?
H ₂ S	2.6x10 ⁻⁵	7.7x10 ⁻⁵	?	?	?
Ne	1.3x10 ⁻⁴	2.0x10 ⁻⁵	?	?	?

*units are volume ratios

ATMOSPHERIC COMPOSITION

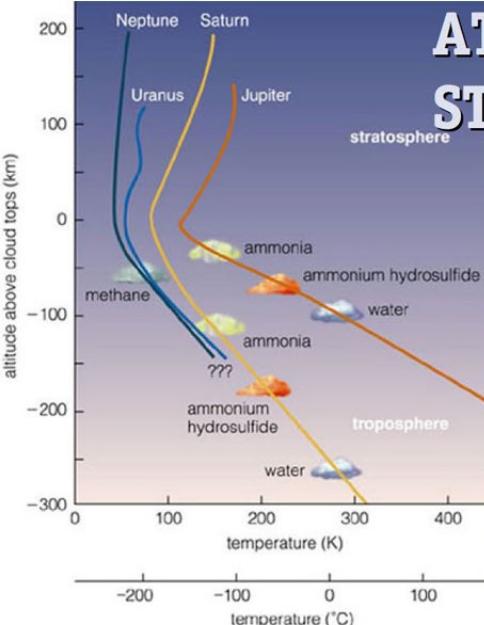
	Jupiter	Saturn	Uranus	Neptune
H ₂	1.0	1.0	1.0	1.0
He	0.83	0.89	0.94	1.2
CH ₄	4.4	9.7	39	43
H ₂ O	0.49	?	?	?
NH ₃	5.1	4.4?	?	?
H ₂ S	3.0	?	?	?
Ne	0.15	?	?	?

*relative to protosolar values

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ATMOSPHERIC STRUCTURE



- where do clouds condense?
depends on:
 - temperature
 - amount of cloud-forming gas

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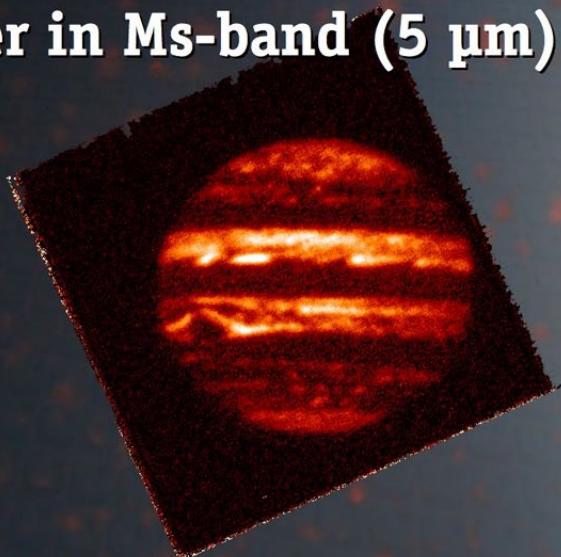
CLOUDS



- Jupiter + Saturn
 - ammonia
 - something with sulfur
 - water
 - photochemical haze
- Titan
 - hydrocarbon hazes
 - methane?
 - ethane?
- Uranus + Neptune
 - methane
 - ammonia
 - sulfur
 - water

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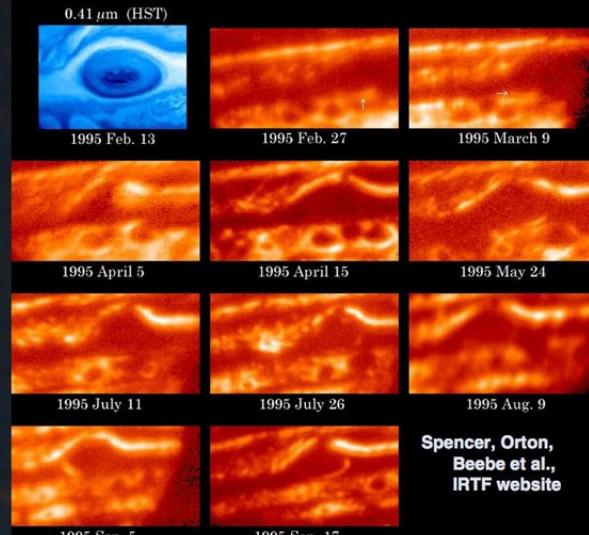
Jupiter in Ms-band (5 μm)

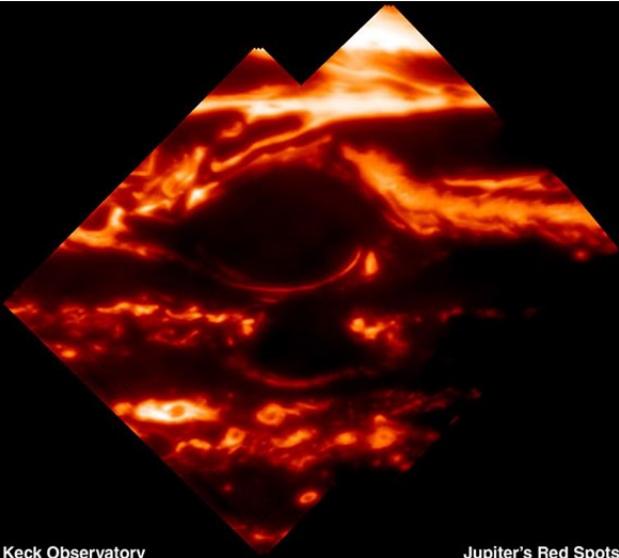


Wong et al. (2006), from IRTF data

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Jupiter: Great Red Spot, 4.8 μm
NASA Infrared Telescope Facility



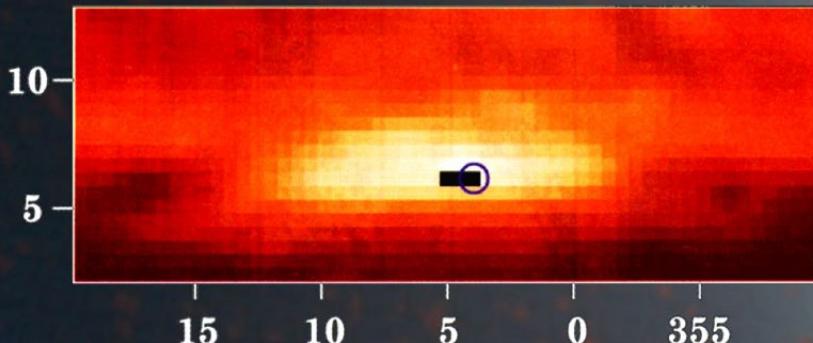


Keck Observatory
NIRC2 LGS-AO
Imke de Pater, Mike Wong, Al Conrad

Jupiter's Red Spots
M-band thermal IR
21 July 2006 UT

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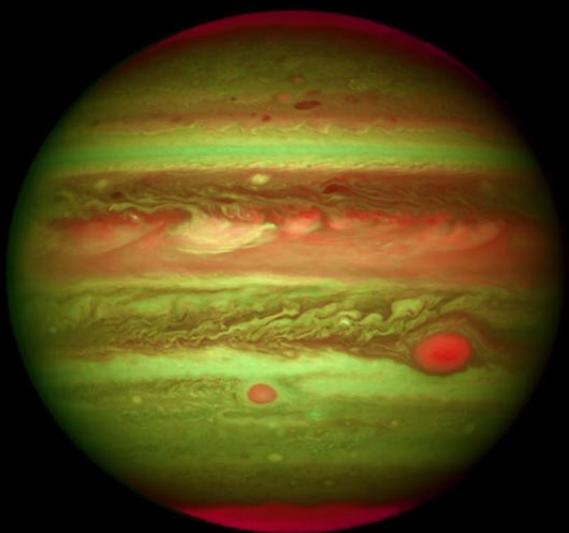
Probe entry site at 5 μ m



Orton et al. (1998), from IRTF data

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SATURN STORMS

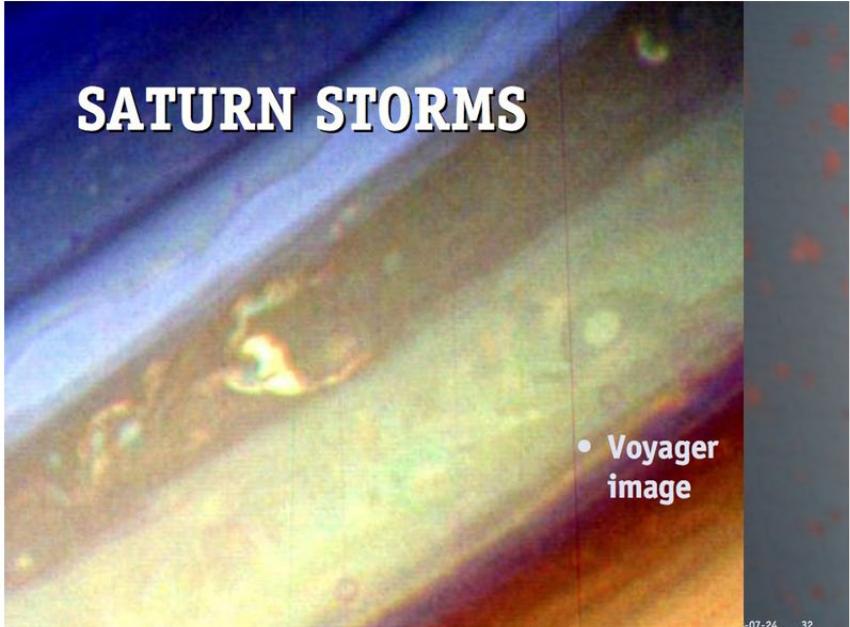


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Saturn's "Dragon Cloud"

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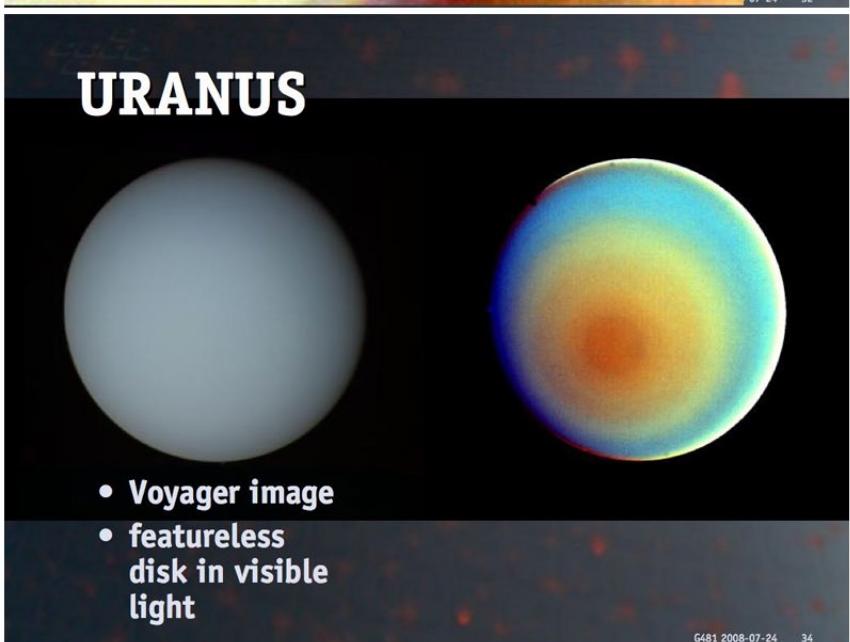
SATURN STORMS



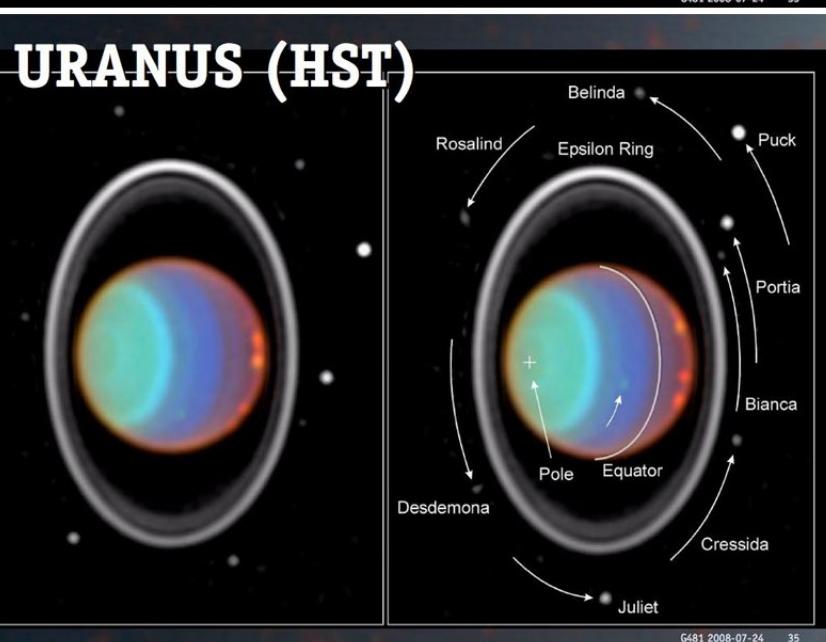
SATURN



URANUS



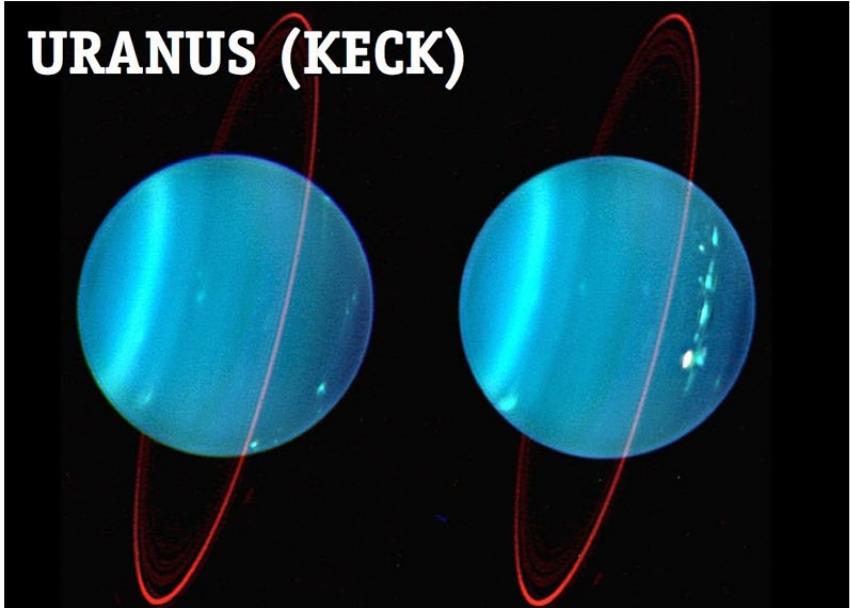
URANUS (HST)



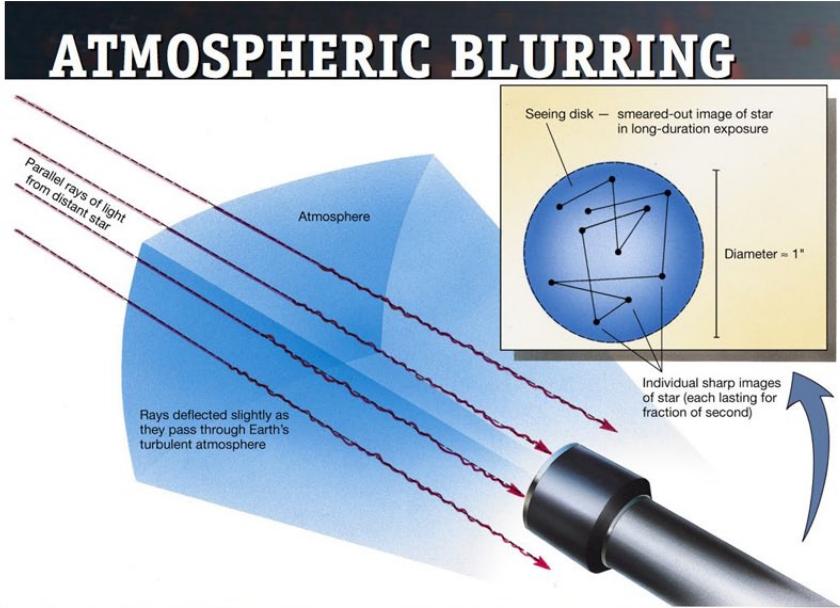
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URANUS (KECK)



ATMOSPHERIC BLURRING



ADAPTIVE OPTICS



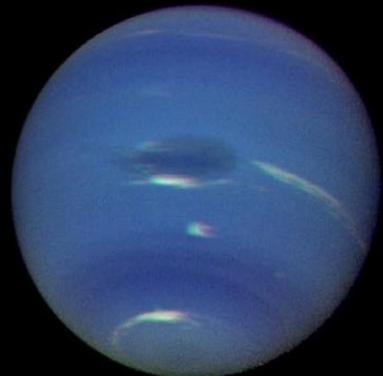
Laser-guided adaptive optics at Lick Observatory



NEPTUNE: KECK AO



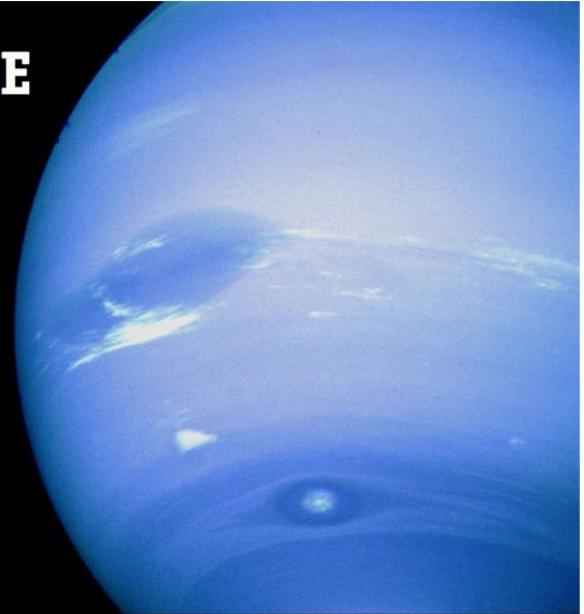
NEPTUNE



- Voyager image, 1989

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NEPTUNE



- Voyager image

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NEPTUNE

- Voyager image

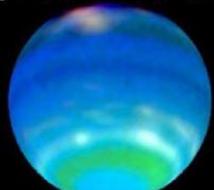
18-07-24 42

NEPTUNE

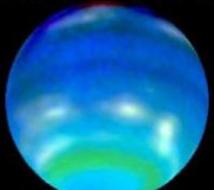
- Voyager image
- white high altitude methane clouds leave dark shadows

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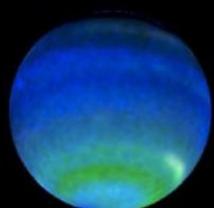
WEATHER ON NEPTUNE



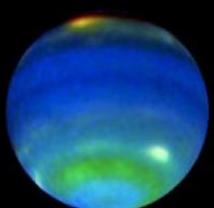
August 11, 1998



- cloud patterns and albedos (reflectivities) vary over time



August 13, 1996

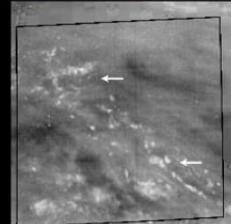


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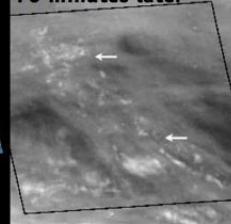
STORMS



Jupiter's Great Red Spot



70 minutes later

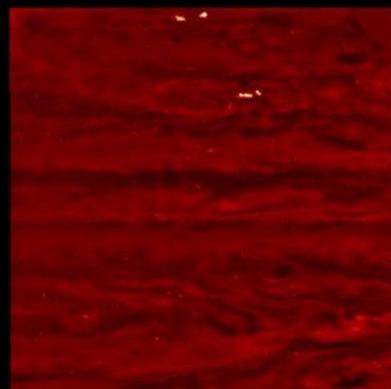


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STORMS



Lightning



Galileo spacecraft

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Lightning



Convective storms

- Cassini ISS images
- red clouds are at $P > 2\text{--}5 \text{ bar}$

Porco et al. (2003)

