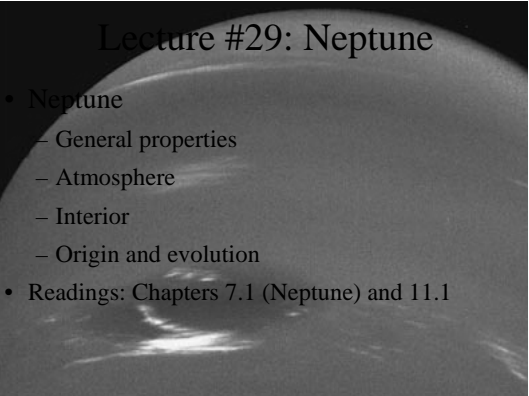


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Lecture #29: Neptune

- Neptune
 - General properties
 - Atmosphere
 - Interior
 - Origin and evolution
- Readings: Chapters 7.1 (Neptune) and 11.1



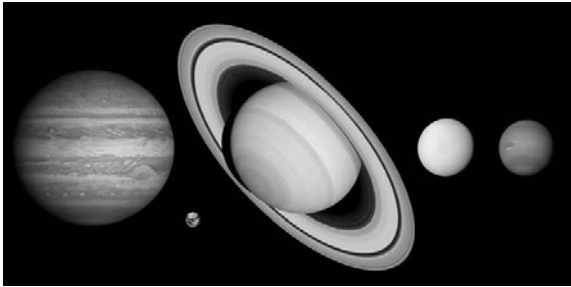
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The Main Point

Neptune, the second planet discovered by telescope, is a mid-sized Jovian planet made mostly of hydrogen, helium, and methane and possessing a strong internal heat source

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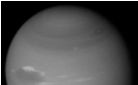
The Jovian Planets



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Basic Properties of Neptune







- Average Distance from Sun: 4.5 billion km ($a=30.1$ AU)
- Orbital period: 165 years; eccentricity: 0.01
- Period of Spin around axis: ~16 hours
- Tilt of Neptune's spin axis: 29° (*seasons*)
- Mass: 1.0×10^{26} kg = $17 M_E$; Radius: 24,750 km = $3.9 R_E$
- Density = 1.6 g/cm^3 (mostly "rocky/icy")
- No "surface" like the terrestrial planets: clouds/haze visible
- Gravity = 11.6 m/sec^2 (1.18 times Earth's)
- Cloud-top temperature: 60 K (-213°C) [same as Uranus!]
- Atmosphere: Mostly H, He, CH_4
- Moons: 8 presently known
- Neptune has a set of thin, dark rings

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Discovery

Le Verrier Adams d'Arrest


- Neptune was discovered by telescope in 1846
 - Galileo saw Neptune in 1613, but thought it was a star!
- Neptune's existence was *predicted* based on mathematical studies of small perturbations in the orbits of Uranus, Saturn, and Jupiter
 - Mathematicians John C. Adams and Urbain Jean Joseph Le Verrier independently predicted Neptune's position
 - Johann Gottfried Galle and Heinrich Louis d'Arrest found the planet independently at different telescopes
- Lots of nasty business about who got the credit! 5

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A Triumph of Newtonian physics!

"Monsieur, the planet of which you indicated the position really exists."
Galle to Le Verrier on 25 Sept., 1846

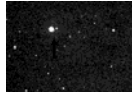
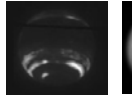
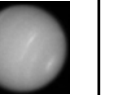
"I thank you for the alacrity with which you applied my instructions. We are thereby, thanks to you, definitely in possession of a new world."
Le Verrier's reply



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Observations of Neptune


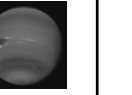
small telescope Keck IR HST

- Neptune's disk is only about 2 arcsec diameter
 - You need a telescope to see Neptune
 - Even then, it's challenging to see any details
- Neptune appears slightly blue through telescopes
- More detail can be seen in higher resolution HST images, or using telescopes in the infrared
- Features in Neptune's atmosphere can be seen
 - More subtle than those on Jupiter or Saturn
 - But much more visible than those on Uranus

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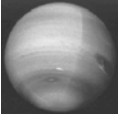
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Space Missions

- Only one encounter:
 Voyager 2

Mission	Date	Goals and Results
Voyager 2	1989	Flyby; high resolution imaging and other studies



Future Mission:
 Neptune/Triton Orbiter
 Launch: 2035

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Features in Neptune's Atmosphere

- Zones & belts stronger than Uranus'
- Smaller clouds, storms apparent
- Clouds, storms *changed* during the past decade

Neptune rotation
1996 HST Images

"Great Dark Spot"
1989 Voyager Images

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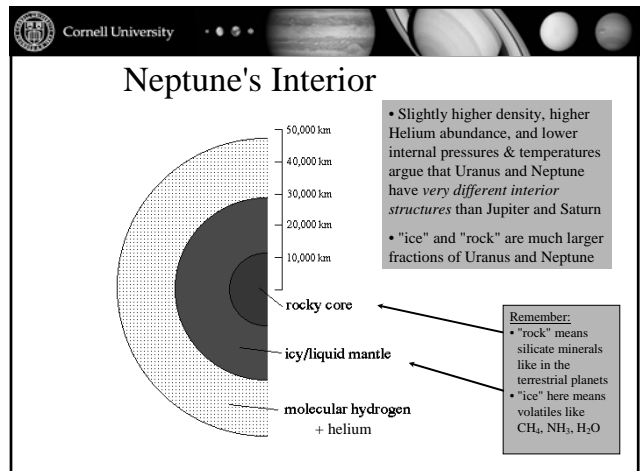
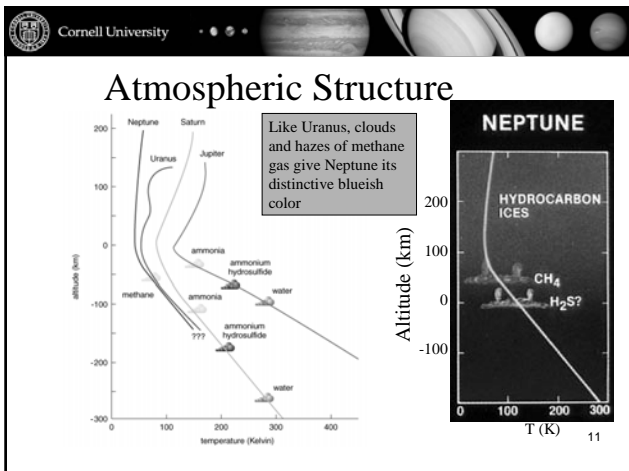
Atmospheric Composition

- Determined by spectroscopy from telescopes and spacecraft
- Observed (upper) composition very "solar"

Name	Symbol	% Volume
Hydrogen	H ₂	85
Helium	He	13
Methane	CH ₄	.01 to 1?
Water	H ₂ O	???
Carbon Monoxide	CO	~1 x 10 ⁻⁶
	C ₂ H ₆	1.5 x 10 ⁻⁶
	C ₂ H ₂	6 x 10 ⁻⁸
	HCN	~1 x 10 ⁻⁹

- The ratio of H₂/He in Neptune's atmosphere is close to the Sun's
- Much more He than Jupiter & Saturn, but comparable CH₄
- Neptune's atmosphere differs from Uranus'; different internal heating/mixing?

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Internal vs. External Heat Sources

- What is Neptune's energy balance?
- For Neptune: $\text{Outgoing} = 3 \times \text{Incoming}$
- Neptune generates its own internal heat!
 - Primordial heat of formation?
 - More radioactive "rocky" materials?
 - But why is Uranus so different?
- May explain the greater variety and variability of clouds compared to Uranus

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Neptune has a strong magnetic field

- Like Uranus, Neptune has no metallic H in its interior...why does it have a field?
- Same theory: Field is generated in the core by high pressure ionization of ices/rock (making them conductive)

- Neptune's field is tilted and offset relative to its spin axis, like Uranus'
- Supports the idea that the field is generated in the rocky/ice mantle?

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Satellites of Neptune

- 1 large satellite, Triton
 - Also discovered in 1846
 - Similar size as Earth's Moon
 - But orbits *backwards* compared to Neptune's spin...!
 - Has an *atmosphere* and *active geysers* on the surface!
- 1 mid-size satellite, Nereid
 - Nereid has a very eccentric orbit ($e=0.75$)
- 6 smaller moons discovered by Voyager 2
- 5 irregular outer satellites

More details: Lecture 30

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Neptune's irregular moons

Halimede, Sao, Laomedeia, and Neso discovered in 2002 at Cerro Tololo

Psamathe discovered in 2003 at Mauna Kea

These extremely faint moons with diameters of 30 to 50 km were presumably captured by Neptune. Two of the five irregular moons of Neptune have prograde and three have retrograde orbits.

Cerro Tololo is a complex of astronomical telescopes located 70 km east of La Serena, Chile.

More information at:
<http://planetarynames.wr.usgs.gov/append7.html#NeptunianSystem>

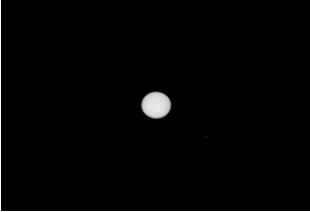
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A time-lapse movie of Neptune...

... assembled from combining NASA Hubble Space Telescope images taken over a 15-hour period. The animation has four sections:

- Neptune and its largest satellite Triton, which is about as large as our moon.
- Colors enhanced to better show the subtle detail of clouds in Neptune's atmosphere.
- Spectral region of light changed from the visible to special methane bands in the near infrared.
- Traces the satellite orbits.

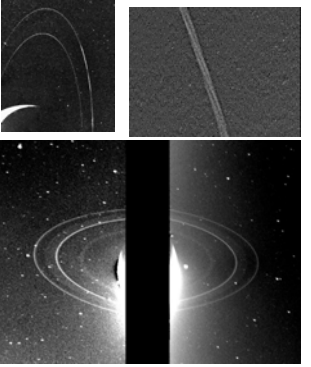


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Rings!

- Neptune has rings
 - 4 main rings
 - 3 narrow, 1 diffuse
 - all very dark
- Discovered from Earth by star occultations
- Once thought to be "arcs" not complete rings
- But Voyager images showed them to be full rings, with "clumps"
- Made of organics+ices?

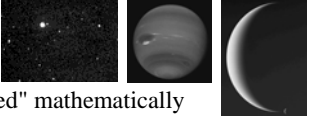


More details in Lecture 31...

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Summary

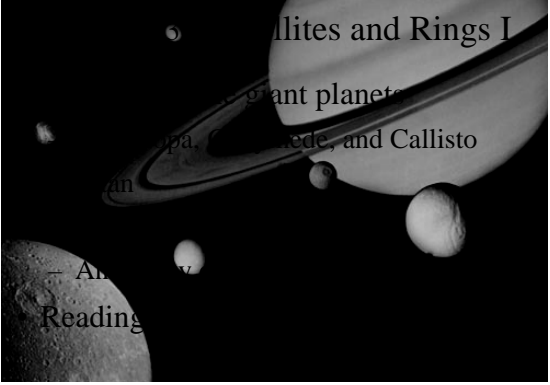


- Neptune was "discovered" mathematically
- Neptune is a gas giant planet with a thick H, He, and CH₄ atmosphere
- Neptune's atmosphere has clouds and other features that change rapidly like Jupiter's or Saturn's
 - Neptune generates its own internal heat
- Neptune's interior consists mostly of "icy" and "rocky" materials at high pressure and temperature
 - Strong & offset magnetic field like Uranus
- Neptune has 13 known satellites and a ring system

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Satellites and Rings I



giant planets
 pa. Callisto, and Callisto
 an
 - An
 Reading