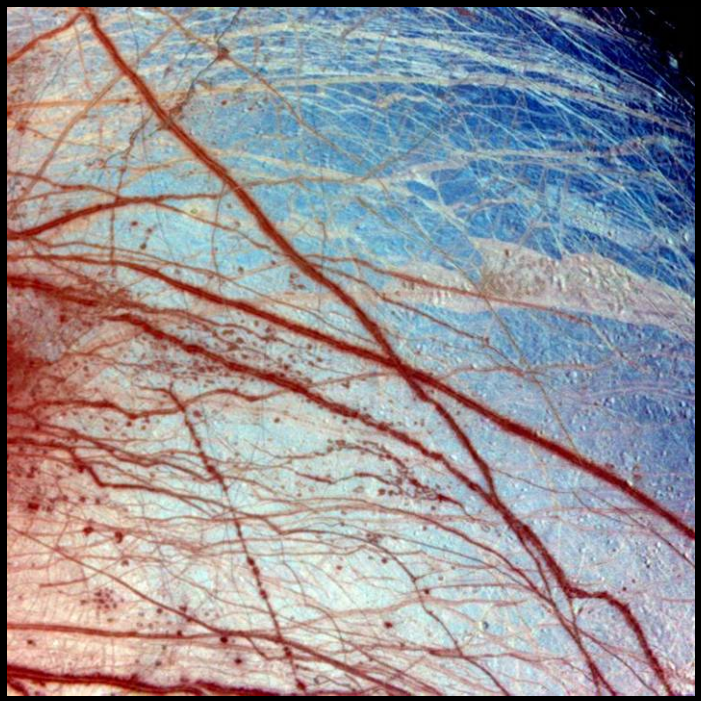
12.001 Introduction to Geology
Spring 2008

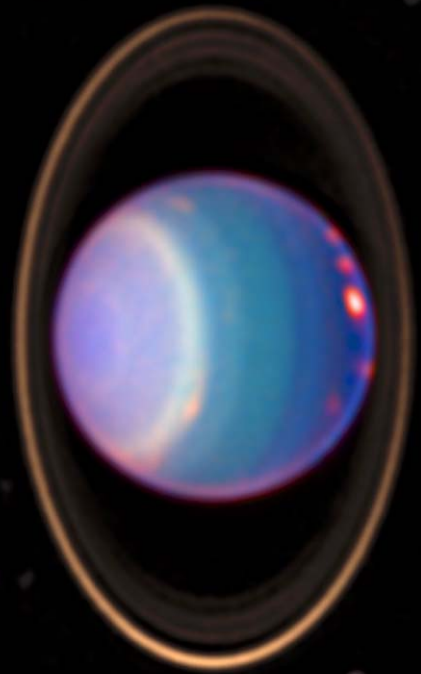
Comparative planetology

With many thanks to NASA, JPL, and the mission teams, and your tax dollars!



Icy surface of Jupiter's moon Europa

G-impact of comet Shoemaker-Levy into Jupiter, 1994



Uranus' spin axis lies almost in the ecliptic plane

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Rocks

Dating: Radiodecay and paleontology

Rock deformation: Folds, faults, brittle vs. ductile

Field techniques

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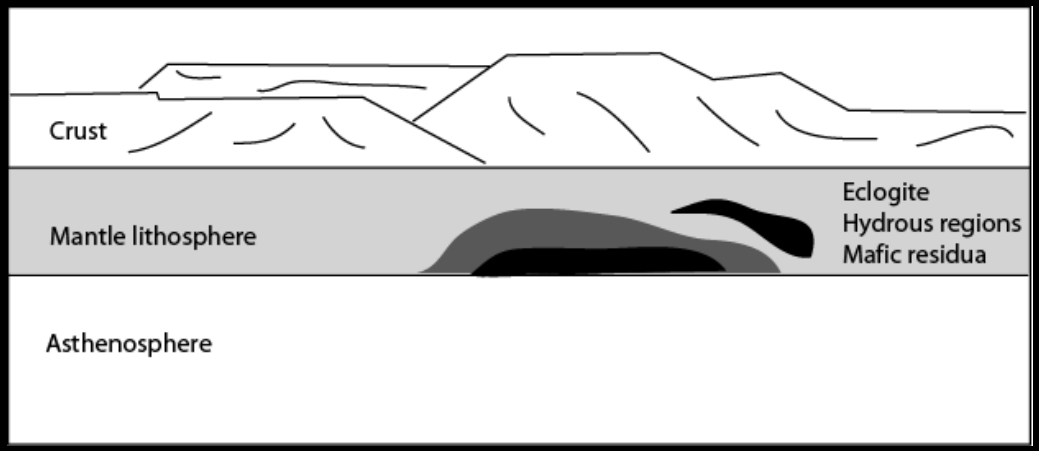
What kinds of rocks are these?

	Venusian compositions
SiO_2	45 – 49
Al_2O_3	16 – 18
TiO_2	0 – 2
FeO	8 – 9
CaO	7 – 10
MgO	8 – 12
K_2O	0 – 4
Na_2O	na

Published in Surkov (1990); Several of the USSR's *Venera* landers in the 1960s and 1970s took compositional measurements.

Gravitational instabilities



Elkins-Tanton (2006)

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(e.g. Houseman *et al*., 1981; Fleitout and Froidevaux, 1982; Conrad and Molnar, 1997; Schott and Schmeling, 1998; Neil and Houseman, 1999; Schott *et al*., 2000; Elkins-Tanton and Hager, 2000; Morency *et al*., 2002)

Venus

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Elkins-Tanton et al. (2007) JGR Planets

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Samples to date

Apollo 12 sample

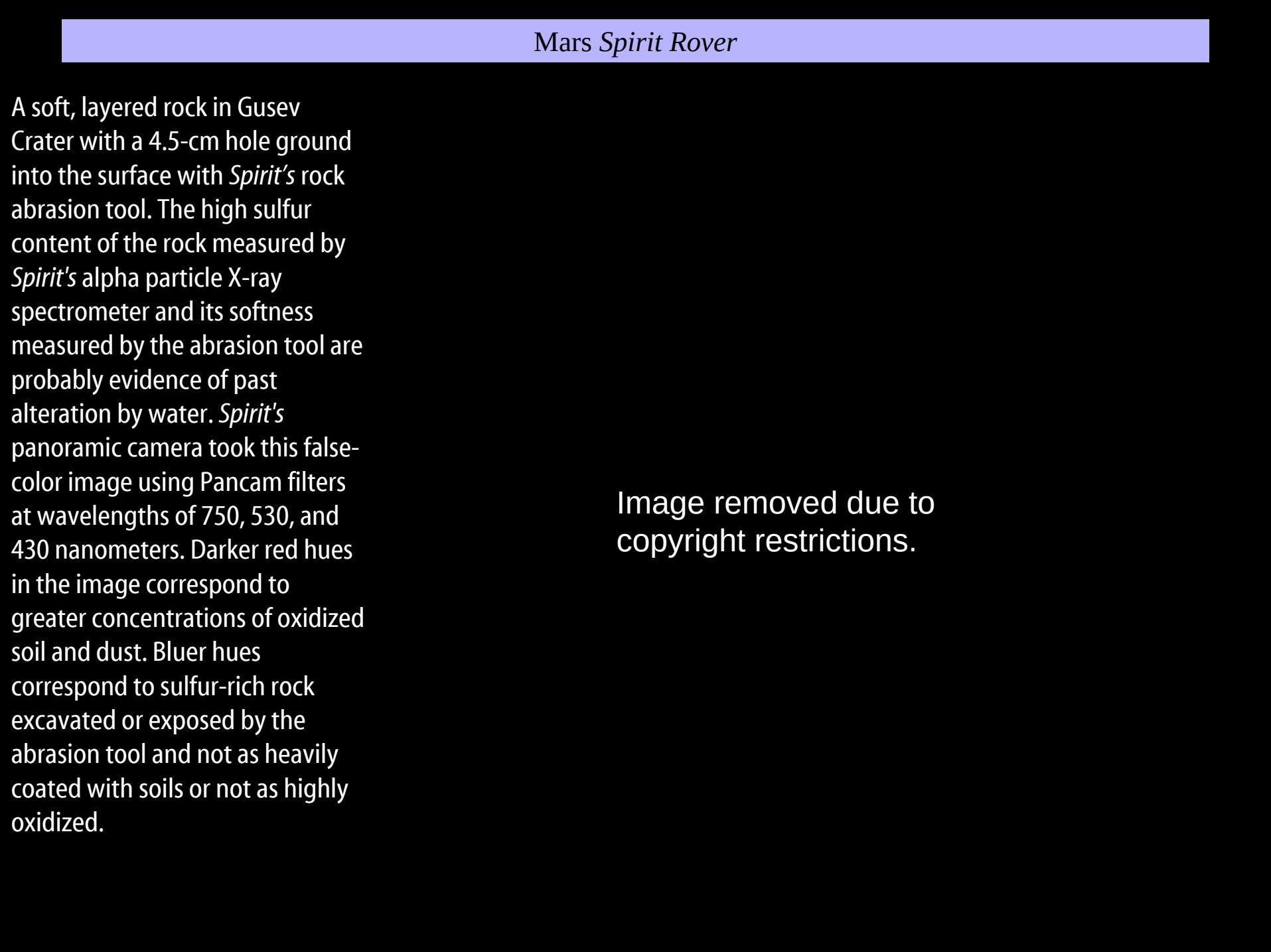
382 kg of lunar material returned by *Apollo* missions

Meteorites from Mars and the Moon, plus asteroidal material

Images removed due to copyright restrictions.

Mars *Spirit Rover*

A soft, layered rock in Gusev Crater with a 4.5-cm hole ground into the surface with *Spirit's* rock abrasion tool. The high sulfur content of the rock measured by *Spirit's* alpha particle X-ray spectrometer and its softness measured by the abrasion tool are probably evidence of past alteration by water. *Spirit's* panoramic camera took this false-color image using Pancam filters at wavelengths of 750, 530, and 430 nanometers. Darker red hues in the image correspond to greater concentrations of oxidized soil and dust. Bluer hues correspond to sulfur-rich rock excavated or exposed by the abrasion tool and not as heavily coated with soils or not as highly oxidized.



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Moon: False color

In 1990 *Galileo* took infrared spectrometer images that show composition: Pinkish areas are highlands materials, and blue to orange indicate lava flows.

Image removed due to copyright restrictions.

Ground truth: Moon and Mars

MER Opportunity's wheel is free at last.

Images removed due to copyright restrictions.

Harrison Schmidt at Taurus Littrow, *Apollo 17*

Martian soil samples with hematite concretions. *MER* team.

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Enceladus, Saturn's moon, spurts water geysers

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Before the Cassini mission only the Earth, Io (Jupiter), and Triton (Neptune) were confirmed to be geologically active - though Mars really has to be, too.

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Moonquakes

Apollo 11, 12, 14, 15, and *16* passive seismic experiments;

Active seismic experiments on *A14, 15*, and *17*

11,800 events from 1969 – 1977

(Some seismology for Mars from *Viking Lander 2*, 1976-1978)

Images removed due to copyright restrictions.

Sunquakes formed by solar flare eruption in the photosphere

Waves accelerated from 14,000 km/hour to more than ten times that speed

SOHO mission

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Mars

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Olympus Mons: 600 km in diameter and 21,283 m high (Everest = 8,848 m). Caldera is 80 km in diameter and is active.

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Io: One of Jupiter's Galilean satellites

Volcanism photographed by *Voyager 2* in 1979

Caused redesign of mission

Volcanic plumes reach 600 km

Higher heat flux than the Earth

Magma is sulfur- and silica-based, reaching 1600C

500 km^3 of lava erupted every year (Earth = ~15 km^3)

If this volume was the same in the past, the planet has melted its crust and mantle 80 times and erupted its own volume 40 times

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Io

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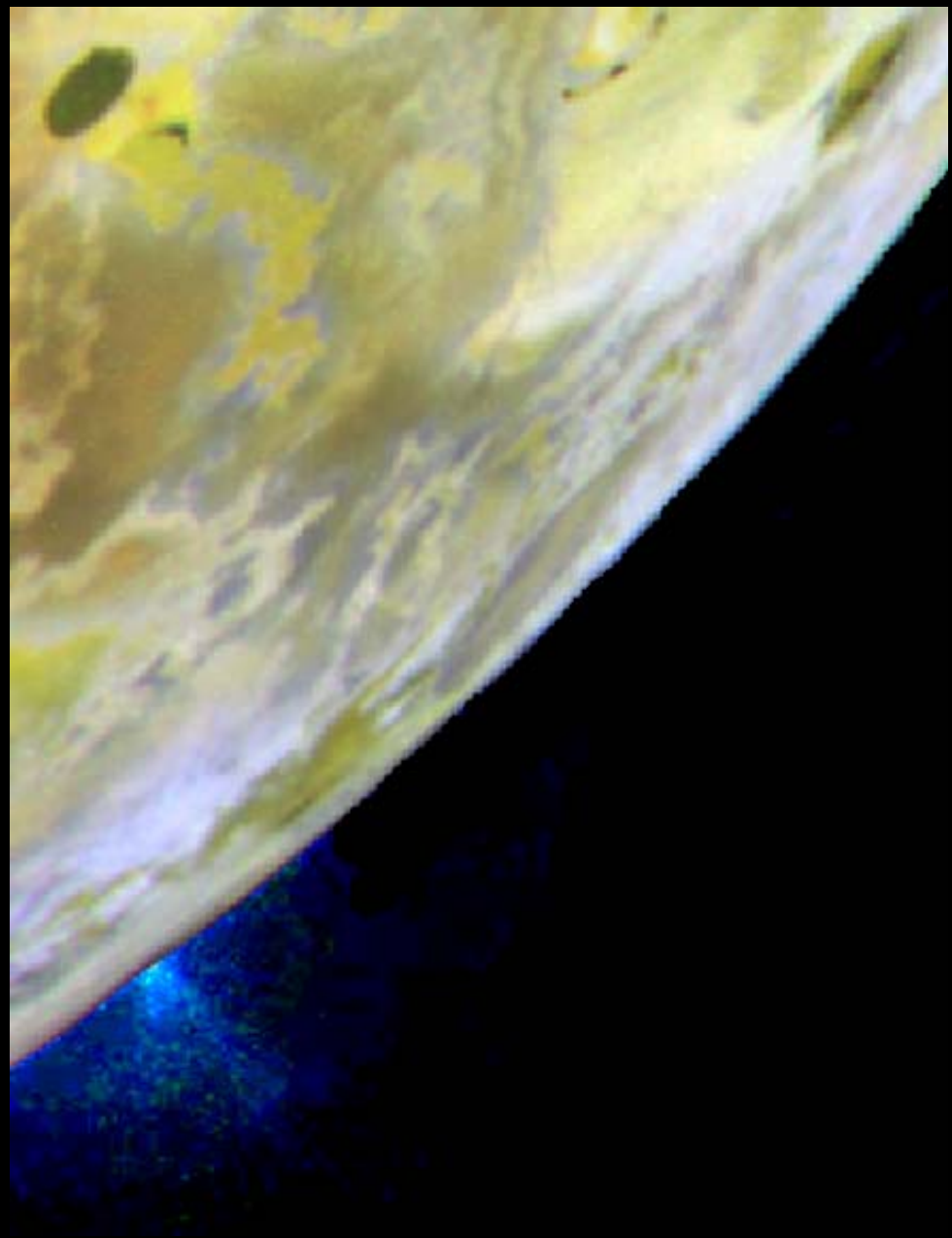
Fallout from the plume
covered an area equivalent to
Alaska

Io



NASA/Magellan/Galileo/International Space Station

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Venus

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The Dali and Diana Chasma system is 4,588 miles (7,400 km) long

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Same delta from *Mars Global Surveyor*, 2003. Max resolution: 12 m/pixel.

Delta in Eberswalde, HI-RISE, 2007. Max resolution: 25 cm/pixel.

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Europa

One of the brightest objects in the solar system, with an albedo of 0.64 (Moon is 0.07)

Icy surface is mostly water, and liquid water exists below its crust (life??)

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Enceladus, Saturn's moon

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The highest albedo object in the solar system at ~0.99

Consists primarily of water with ammonia

Recently shown to be geologically active

Smooth surface indicates recent resurfacing

Ariel, Uranus' moon

Youngest and brightest of Uranus' major moons

Voyager 2 took this image from 130,000 km

Image removed due to copyright restrictions.

Triton, Neptune's moon

Image removed due to copyright restrictions.

2,706 km in diameter (far larger than the Moon)

Retrograde orbit causes the moon to spiral toward Neptune and will collide in tens to 100 Myr, creating a fabulous ring system

Has a nitrogen atmosphere (among moons, only Jupiter's Io and Saturn's Titan also have atmospheres)

Coldest known surface, at -235C

Geysers 8 km high

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Solar weather

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Solar prominence

Coronal mass ejection from the *Solar Terrestrial Relations Observatory*

Move at 1,000 km/sec and sometimes collide with Earth

Initial at 3- 6,000,000C

Image removed due to copyright restrictions.

Jupiter

Ammonium hydrosulfide and thin water clouds colored by sulfur and phosphurus

Lightning storms

Visible surface 1000 km into atmosphere

Zonal winds average 150 m/sec (!) in the cloud tops, and affect the planet's rotation

Red spot may have developed in the 1600s?

Images removed due to copyright restrictions.

Neptune

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A trace of methane in the atmosphere absorbs red light, making the planet this intense blue color

Atmosphere is 16 – 22% He, 2% methane, remainder H

Some winds reach 2000 km/sec, highest in the solar system

More usual winds are 250 – 400 km/sec

Great Dark Spot, like Great Red Spot on Jupiter, is a high-pressure anti-cylcone

Saturn’s moon Titan

Last object in the solar system with an unknown surface

Contains 90% of the mass orbiting Saturn

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