

Jovian system
Massive, gas giant planet,
~0.001 Solar masses


Orbital radius: 5.2 AU - distance beyond snowline where rock and water ice dominates

4 large *Galilean* moons:

- Io (period 3.55 days)
- Europa
- Ganymede
- Callisto

1:2:4 *resonance* between the orbital periods of the inner 3 satellites

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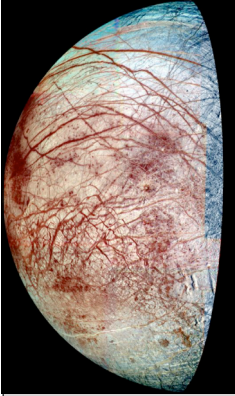


Europa: radius 1560km

Gradient of mean density:

- Io 3530 kg/m³ ← density of rock (silicates)
- Europa 3018 kg/m³
- Ganymede 1936 kg/m³
- Callisto 1851 kg/m³ ← mixture of rock plus lower density ice (~920 kg/m³)

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Surface of Europa is made of water ice

Mean density would be consistent with a 6% fraction of water by mass:

e.g. 1450km rocky interior with a 110km thick layer of water (liquid or ice) at the surface

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Evidence for an ocean on Europa

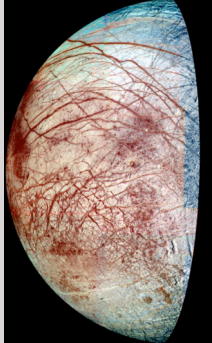
(1) Global surface appearance

Europa surface has very few impact craters - only 3 with diameter > 3km

Young surface

Cratering rate in the outer Solar System is not well determined: models suggest an age between 10 million and 1 billion years

Resurfacing must involve melting at least some of the ice

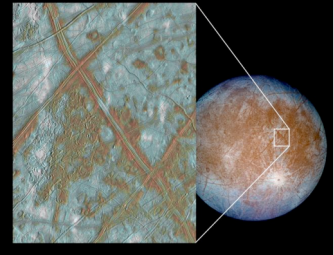


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(2) Local surface features

Galileo images of the surface show blocks of ice, km-10s km in size, separated by ridges

Crust has been fractured and then refrozen in place

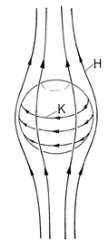


Appearance resembles pack ice floating on the ocean at the North Pole and off the coast of Antarctica

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(3) Magnetic field measurements

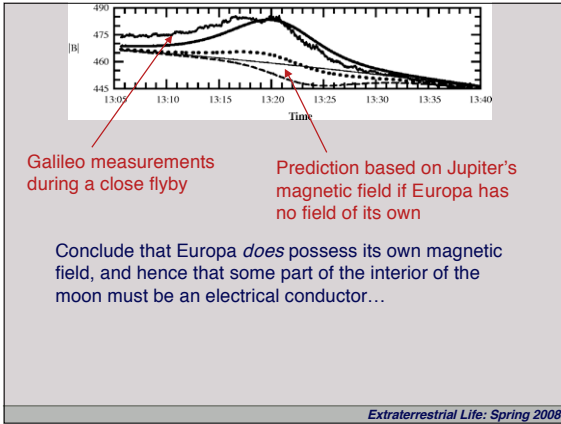
Jupiter has a strong magnetic field, which Europa is orbiting through. Magnetic fields are generated by currents - flows of charged particles.



If Europa's interior does not conduct electricity, the moon cannot generate its own magnetic field and the field measured near the surface should be that of Jupiter alone

If Europa's interior conducts electricity, then the motion of the moon through Jupiter's field induces a current, which distorts the Jovian field near the moon.

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What could the conductor be?

Rock and ice are both poor conductors

A salty ocean beneath the ice would be a good conductor: explains the Galileo magnetic field measurements quite well

An iron core would also be a good conductor: can't exclude this possibility and if one exists, analysis is much more complicated...

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Heat source for Europa

Internal heat of small bodies (Moon, Mars, Mercury) is not enough to sustain geological activity for the life of the Solar System

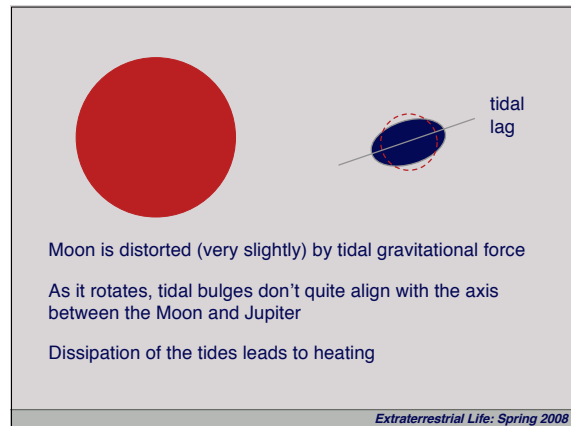
Tidal heating

Tides are raised on Europa by the different gravitational force from Jupiter on the near / far side of the moon

Stress and try to crack the surface

Dissipation of the tidal energy results in heat in the moon's interior

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Possible oceans

Current data provides little constraint on the thickness of the ice layer overlying the ocean. Two models:

- (1) Thin ice layer (~1km), fractured by tidal forces as Europa orbits Jupiter, or local heating from volcanic events at the silicate / water boundary
- (2) Thick ice layer (at least 20km) fractured by convection in the ice heated by tides

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If Europa indeed has an ocean, are the basic conditions for life met?

- **Water:** yes
- **Carbon:** yes - surface of the other Galilean moons show abundant impact craters... meteorites on Earth deliver organic material and the same must be true for Europa
- **Energy:** *possibly*... unknown whether hydrothermal vents or volcanic activity occurs at the bottom of the ocean

If energy is available, conditions in Europa's ocean (T ~ 0C, probably quite salty water) fall within the range for which extremophiles survive on Earth...

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Europa exploration

No current spacecraft in the Jovian system, and no funded mission to return by NASA or ESA

High priority for "outer planets" science, but expensive and difficult to fly to Europa (distance, low Solar flux, radiation environment near Jupiter)

Europa orbiter could definitively establish the presence or absence of an ocean, and measure the depth of the ice

Lander could sample the ice near the surface, and conceivably drill through to the ocean

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