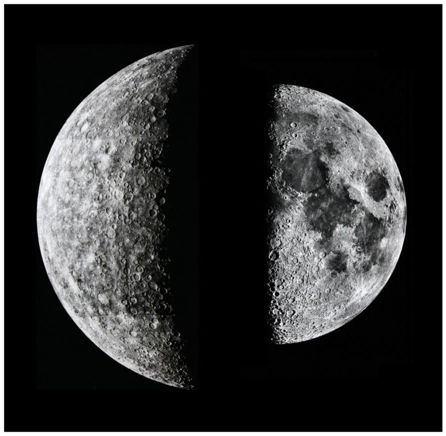
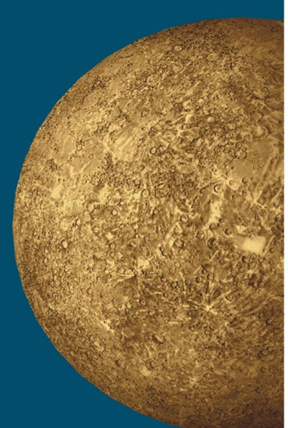
Mercury



A Moon-like surface but an Earth-like interior!

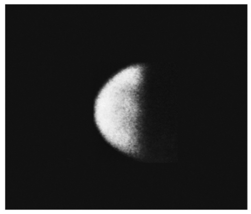
Table 10-1 Mercury Data

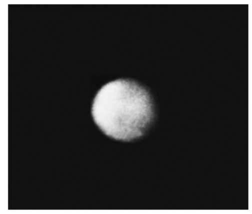
Average distance from Sun:	0.387 AU = 5.79×10^7 km
Maximum distance from Sun:	0.467 AU = 6.98×10^7 km
Minimum distance from Sun:	0.307 AU = 4.60×10^7 km
Eccentricity of orbit:	0.206
Average orbital speed:	47.9 km/s
Orbital period:	87.969 days
Rotation period:	58.646 days
Inclination of equator to orbit:	0.5°
Inclination of orbit to ecliptic:	7° 00′ 16″
Diameter (equatorial):	4880 km = 0.383 Earth diameter
Mass:	3.302×10^{23} kg = 0.0553 Earth mass
Average density:	5430 kg/m^3
Escape speed:	4.3 km/s
Surface gravity (Earth = 1):	0.38
Albedo:	0.12
Average surface temperatures:	Day: 350°C = 662°F = 623 K Night: −170°C = −274°F = 103 K



(Astrogeology Team, U.S. Geological Survey)

Earth-Based Views



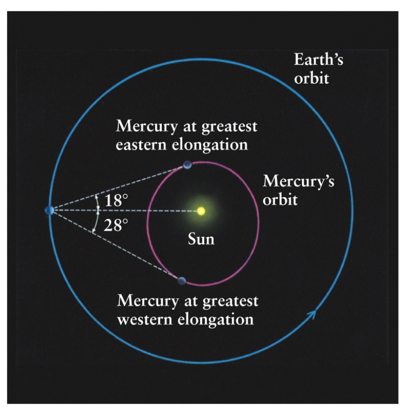


Until 1974, we knew very little about the smallest planet that formed in the inner regions of the solar nebula. Information about Mercury was difficult to obtain for two simple reasons: (1) Mercury is very small, and (2) it is very near the Sun.

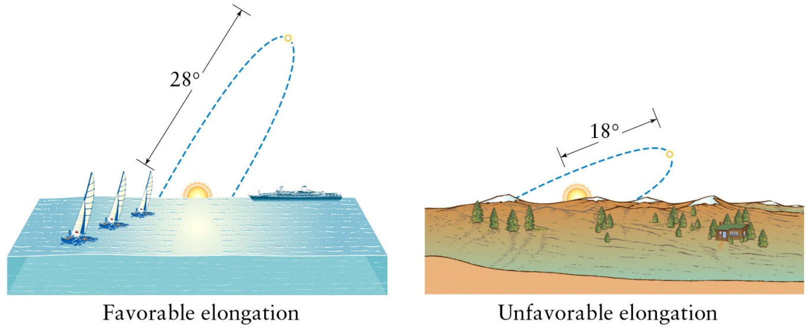
Orbit

Mercury's orbit is more eccentric than the orbit of any other planet except Pluto's. It varies by 24 million km, from 0.306 to 0.467 AU. Maximum elongation is 28°.

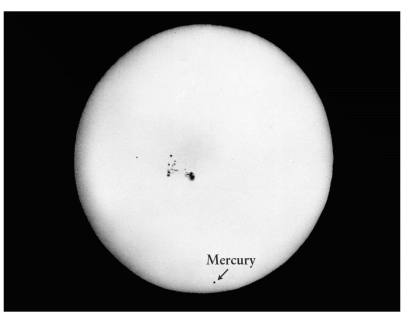
Some elongations are "favorable," whereas others are not.



Types of Elongations



Transits



Mercury's orbit has an inclination of 7° with respect to the ecliptic.

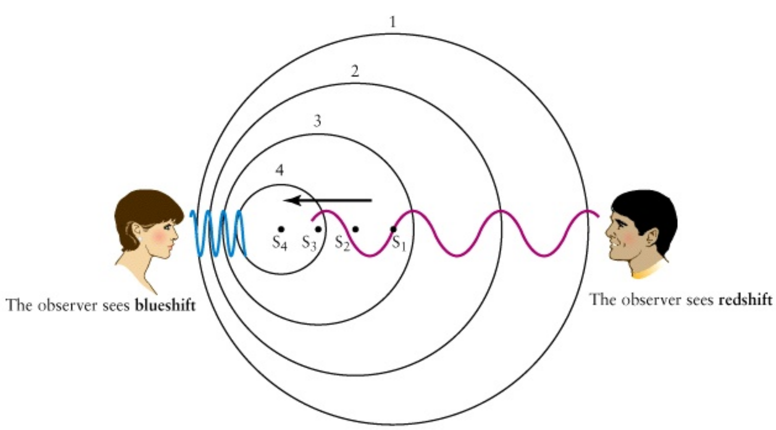
Transits are rare – The next will occur on November 13, 2032.

Studying Mercury

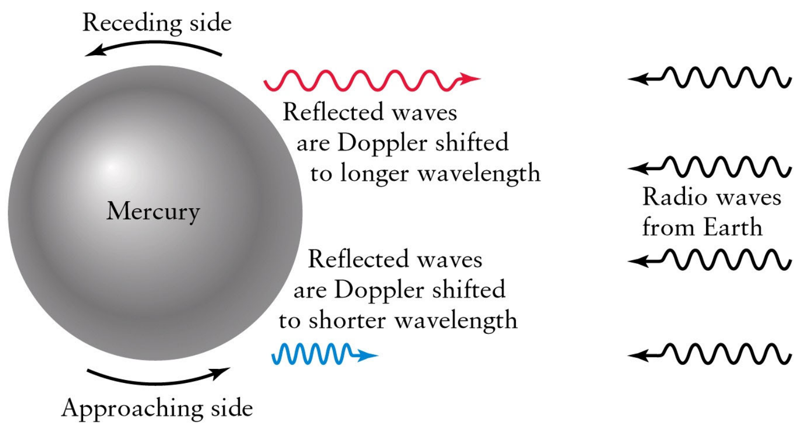
Because it has been difficult to study Mercury due to the glare of the Sun, astronomers turned to other types of observations.

Radio and radar observations can determine temperature information and rotation rate.

Doppler Shift



Rotation Rate Technique

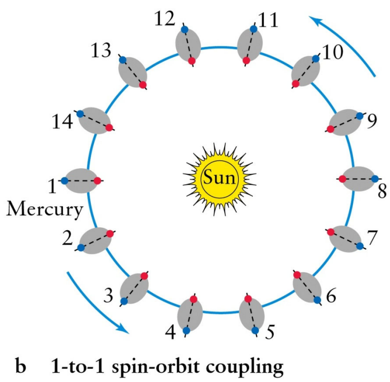


Rotation Rate

Year – 88 Earth days
Day – 58 Earth days

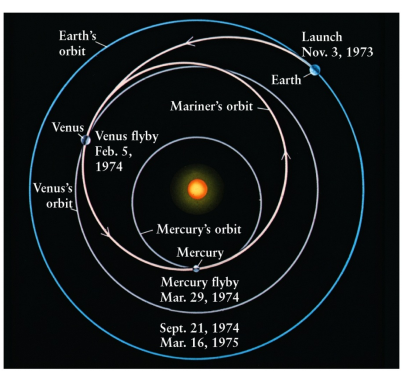
Rotation rate: 3-to-2 spin-orbit coupling

Spin-Orbit Coupling



[*show animations*]

Mariner 10 Flybys



Total of three flybys in 1974-75 collected data. The flight path of **Mariner 10** carried the spacecraft through Mercury's shadow. No television pictures could be taken of the non-illuminated hemisphere.

[176 day period = 2 Mercurial years].

The photography was divided into two parts: "incoming views" taken prior to closest approach, and out-going "views" taken after Mariner 10 emerged from the shadow.

MESSENGER Spacecraft

The MErcury Surface, Space ENvironment, GEochemistry and Ranging (MESSENGER) probe was a NASA spacecraft, orbited from 2011 - 2015. Specifically, the mission was to characterize

(a) the chemical composition of Mercury's surface,

(b) the geologic history,

(c) the nature of the magnetic field,

(d) the size and state of the core,

(e) the volatile inventory at the poles, and

(f) the nature of Mercury's exosphere and magnetosphere over a nominal orbital mission of one Earth year.

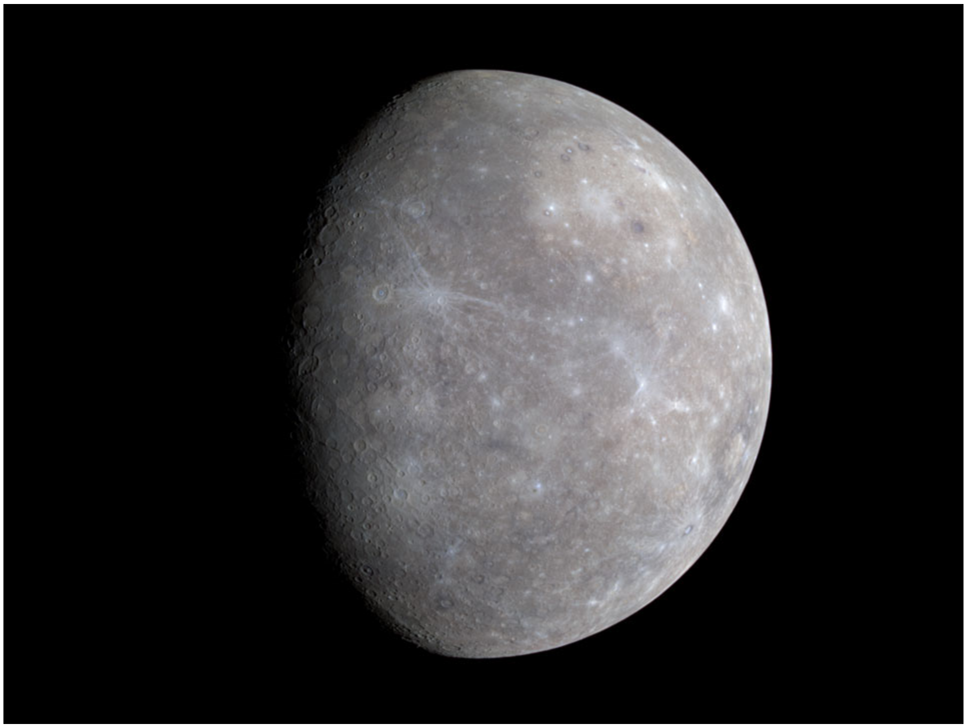
(The contrived acronym MESSENGER was chosen because Mercury was the messenger of the gods according to Roman mythology.)

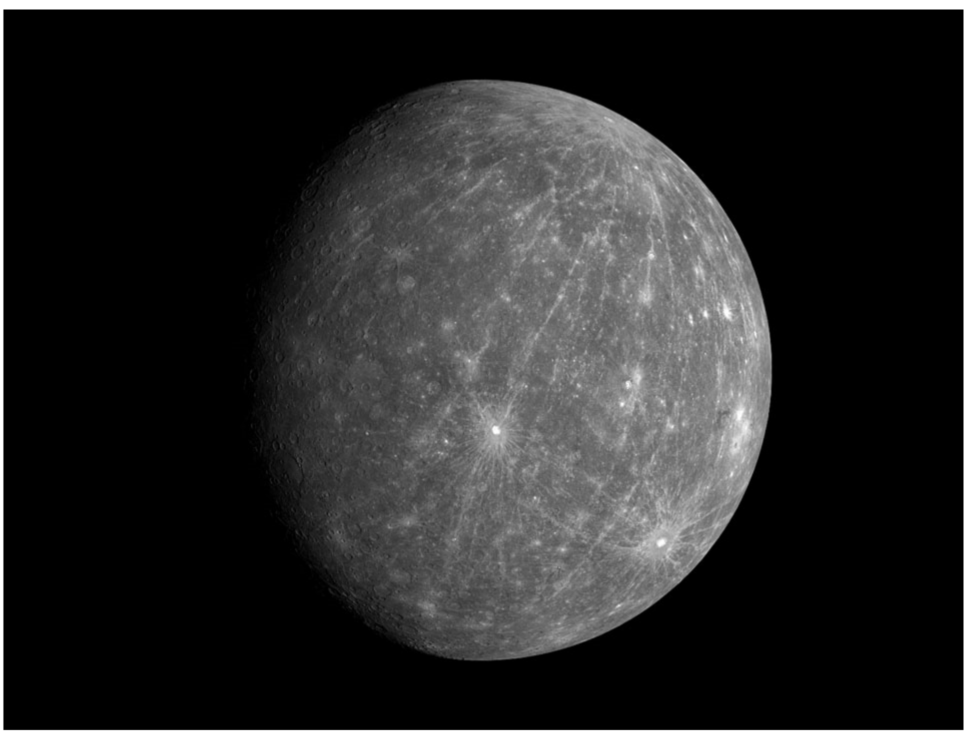
BepiColombo Spacecraft

The European Space Agency (ESA) and the Japan Aerospace Exploration Agency (JAXA) launched a joint mission to Mercury in 2018 that is named **BepiColombo**.

It is made up of two spacecraft: the Mercury Planetary Orbiter and the Mercury Magnetospheric Orbiter.

BepiColombo captured its first views of Mercury during a flyby on Oct. 1, 2021. A total of nine flybys are planned to help steer the spacecraft into orbit in late 2025. It will begin its primary science mission in early 2026.





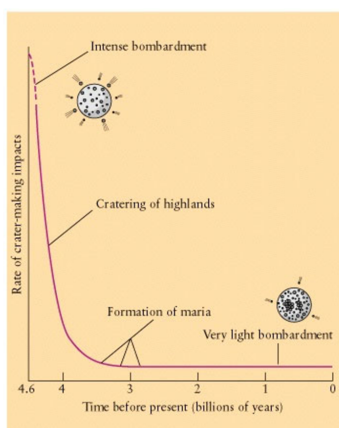
Mercury's Crust

The terrestrial planets and the Moon must have been completely molten spheres of liquid at first. After only a few hundred million years, their surfaces solidified as the rock cooled.

Nevertheless, large meteoroids easily punctured the thin cooling crusts, allowing molten lava to well up from the interiors. Older craters were obliterated as seas of molten rock flooded across portions of the surfaces.

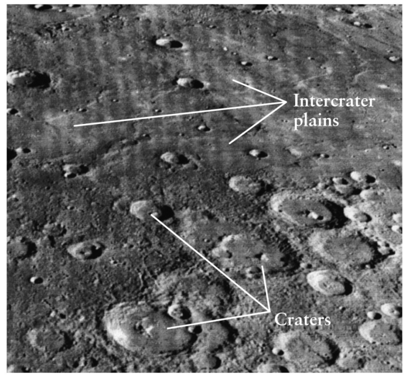
Craters

Astronomers believe that most of the craters on both Mercury and the Moon **were produced during a period of 700 million years** immediately after the planets formed. The strongest evidence comes from direct analysis and dating of Moon rocks brought back by the Apollo astronauts.



Craters

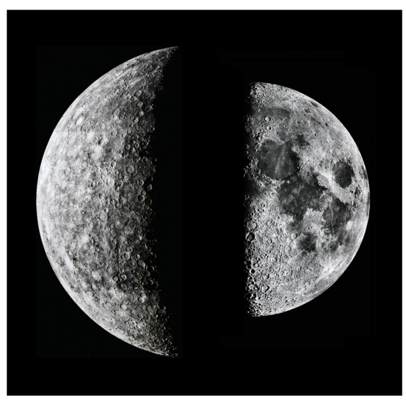
As Mariner 10 closed in, scientists were surprised by the Moon-like pictures. Although the first views were of a lunar landscape, closer scrutiny revealed some significant non-lunar characteristics. Mercury's surface has extensive **intercrater plains** – not maria.



Crust

The planets did not, however, cool down at the same rate. The **volume of a planet is proportional to the CUBE of its radius**, whereas **the surface area is proportional to the SQUARE of the radius.**

Consequently, a small planet has a higher ratio of surface area to volume. This means that a small planet can more easily radiate its internal heat into space and cool off more rapidly than a big planet.

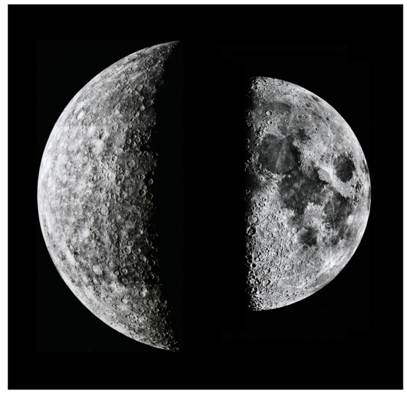


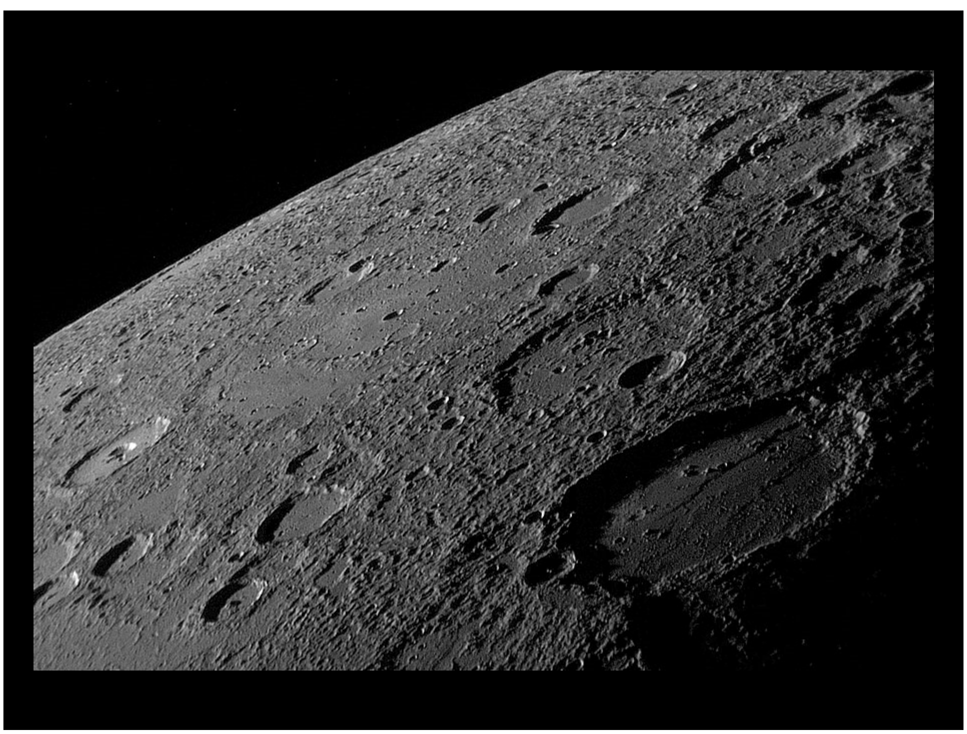
Crust

Because Mercury is larger than the Moon, it took longer for a thick protective crust to form.

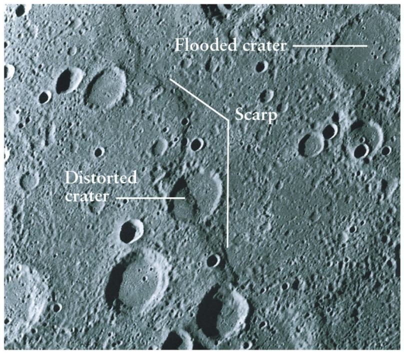
Throughout its early history, molten rock seeped up through cracks and fissures in its young, frail crust, and volcanism was pervasive.

The resulting lava flows inundated many older craters, leaving behind broad, smooth **intercrater plains**.





Scarps



Mariner 10 also saw numerous long cliffs called **Scarps** meandering across the surface (up to 2 km high).

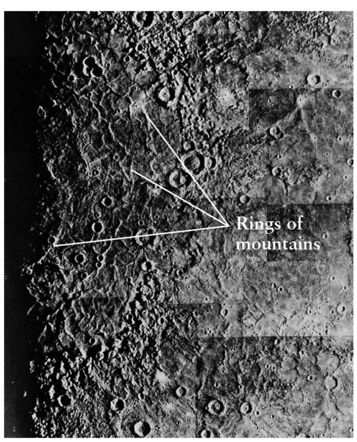
These scarps formed as the planet cooled from its initial molten state.

As the **interior solidified**, Mercury contracted, causing the **crust to wrinkle**.

The scarps are ridges and wrinkles thrust up by compressions.

[Scarps are named after famous sailing ships.]

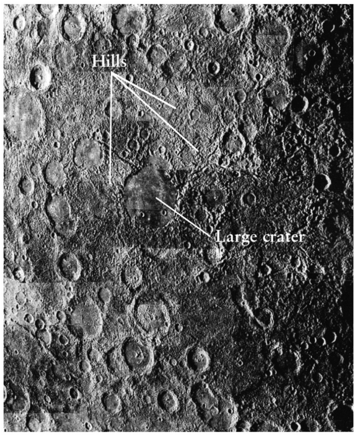
Caloris Basin



Caloris Basin (1300 km) is so named because the Sun shines directly down on this region when Mercury is at perihelion – it is therefore probably the hottest place on the planet.

It was formed by the impact of a very large meteoroid near the end of the crater-making period. (There are relatively few craters on it; hence, it is one of the last basins formed).

Caloris Basin

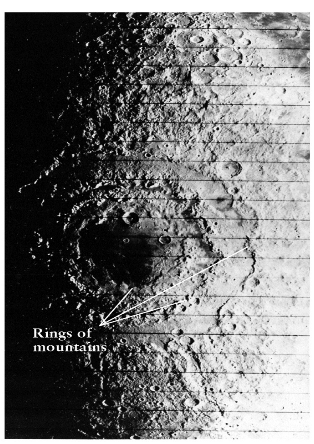


The Caloris impact must have been a violent event that shook the entire planet with seismic waves.

Geologists contend that these waves from the Caloris impact were focused as they passed through the planet.

Jumbled hills (**chaotic terrain**) were pushed up as this concentrated seismic energy reached the far side.

Caloris Basin



Features similar to the Caloris Basin exist on our Moon. The best example is the **Orientale Basin (**900 km). The scarcity of fresh craters attests to its late formation.

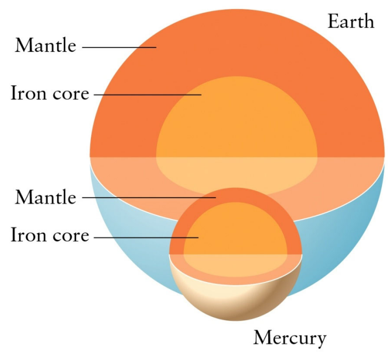
The seismic up-thrusting of jumbled hills on Mercury is supported by the fact that similar (although less extensive) chaotic hills are found on the opposite side of the Moon from the **Orientale Basin**.

Interior of Mercury

Mercury's density is 5.4 g/cm^3 (Earth is 5.5 g/cm^3). Mercury's average density is very slightly less than the Earth's, but the Earth is 18 times more massive than Mercury. This larger mass pushing down on the Earth's interior compresses the Earth's core much more than Mercury's core is compressed.

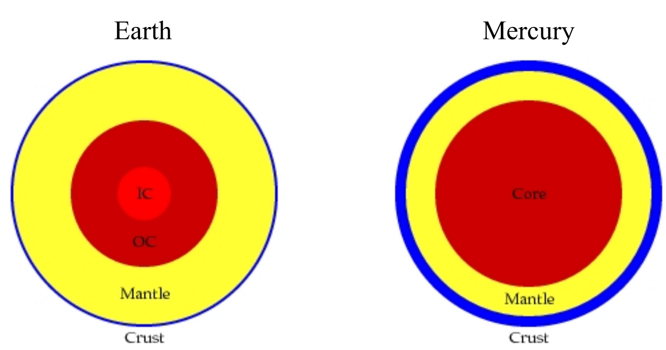
The **uncompressed density** of the Earth is about 4.5 g/cm^3, whereas for Mercury it is 5.3 g/cm^3.

Interior of Mercury



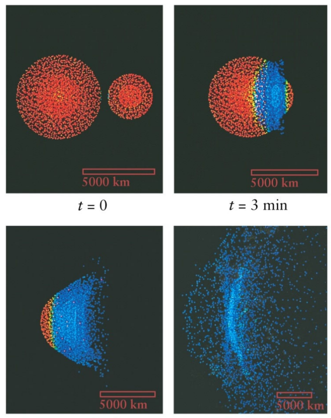
Mercury is the most iron-rich planet in the Solar System, with iron accounting for 65 to 70% of the planet's mass.

Comparison of Mercury



Why the large difference? Theories?

Impact Theory



t = 0　*t* = 3 min

t = 6 min　*t* = 30 min

Magnetic Field of Mercury

Independent evidence of a large iron core came from Mariner 10's magnetometers, which discovered that Mercury has a weak magnetic field.

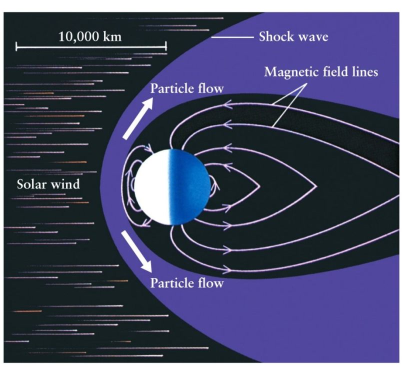
Iron is the only common element that could account for the magnetic field.

Magnetic Field of Mercury

Many geologists suspect that the Earth's magnetic field originates with electric currents flowing in the liquid outer core. These currents are carried around by the Earth's rotation and create the planet-wide magnetic field. This process, in which rotation of a planet with an iron core produces an magnetic field, is called the **Dynamo Theory**.

Scientists were surprised to find that Mercury also has a magnetic field, since it rotates much slower than does the Earth. Mercury's core may be completely solid, and its magnetic field may be a "fossil field" frozen into the core when it solidified. Another theory states that there may be a mixture of sulfur with the iron, keeping some of the core in a liquid state.

Atmosphere of Mercury



The only atmosphere Mariner 10 detected was a thin scattering of particles that may have been captured from the solar wind. The magnetic field of a planet will repel and deflect impinging particles, thereby forming an elongated "cavity" in the solar wind, called the **magnetosphere**.

Temperature

Although the temperature of Mercury had been measured from the Earth, better data came from the Mariner 10 flybys. The daylight temperature on the surface ranges up to about **700 K at noontime**.

Just after sunset, however, the temperature drops quickly to about 150 K, and then it slowly descends to about **100 K just before dawn**. The range in temperature on Mercury is thus 600 K, more than on any other planet.