SPACE PHYSICS

Lecture 3

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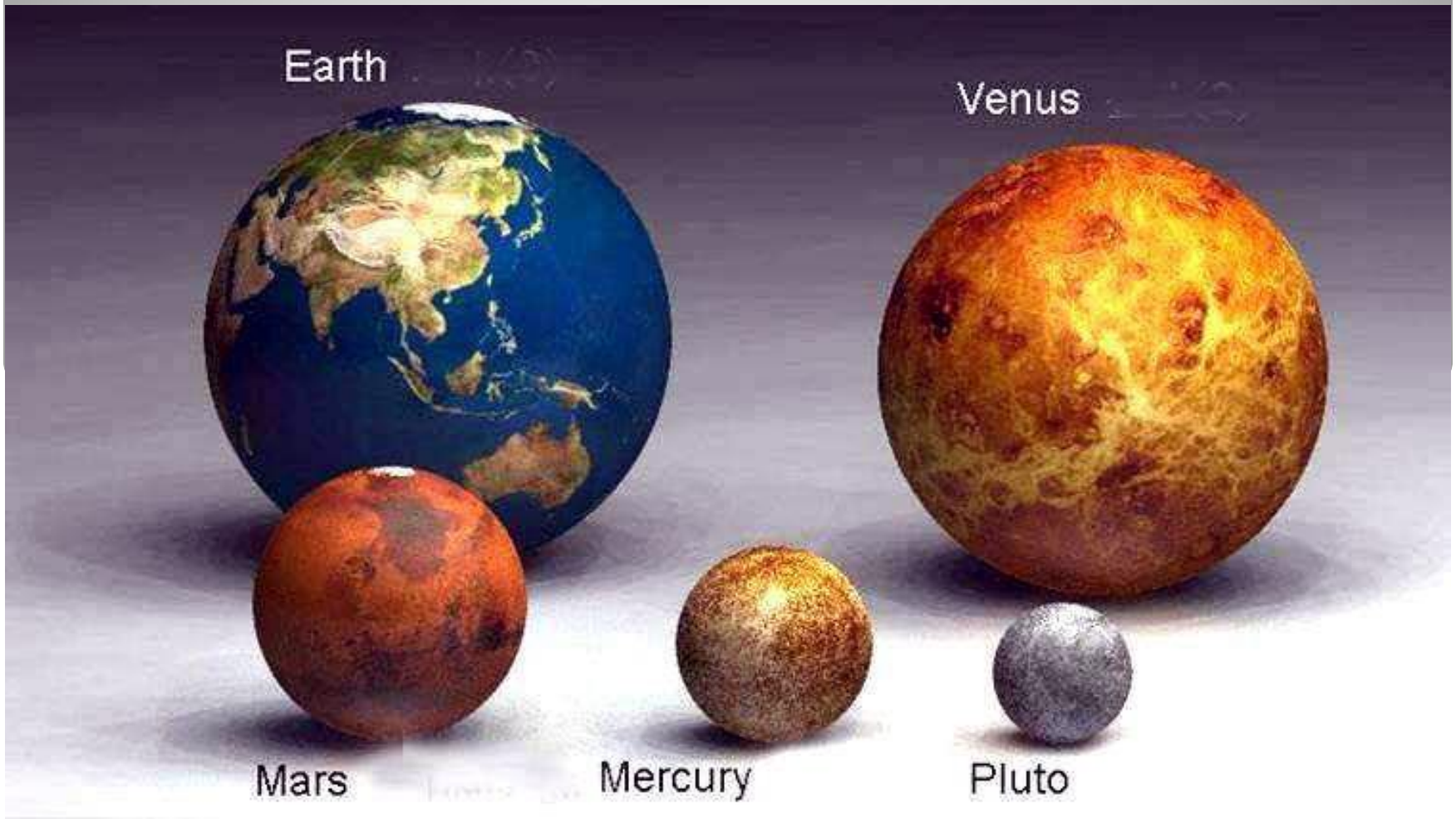
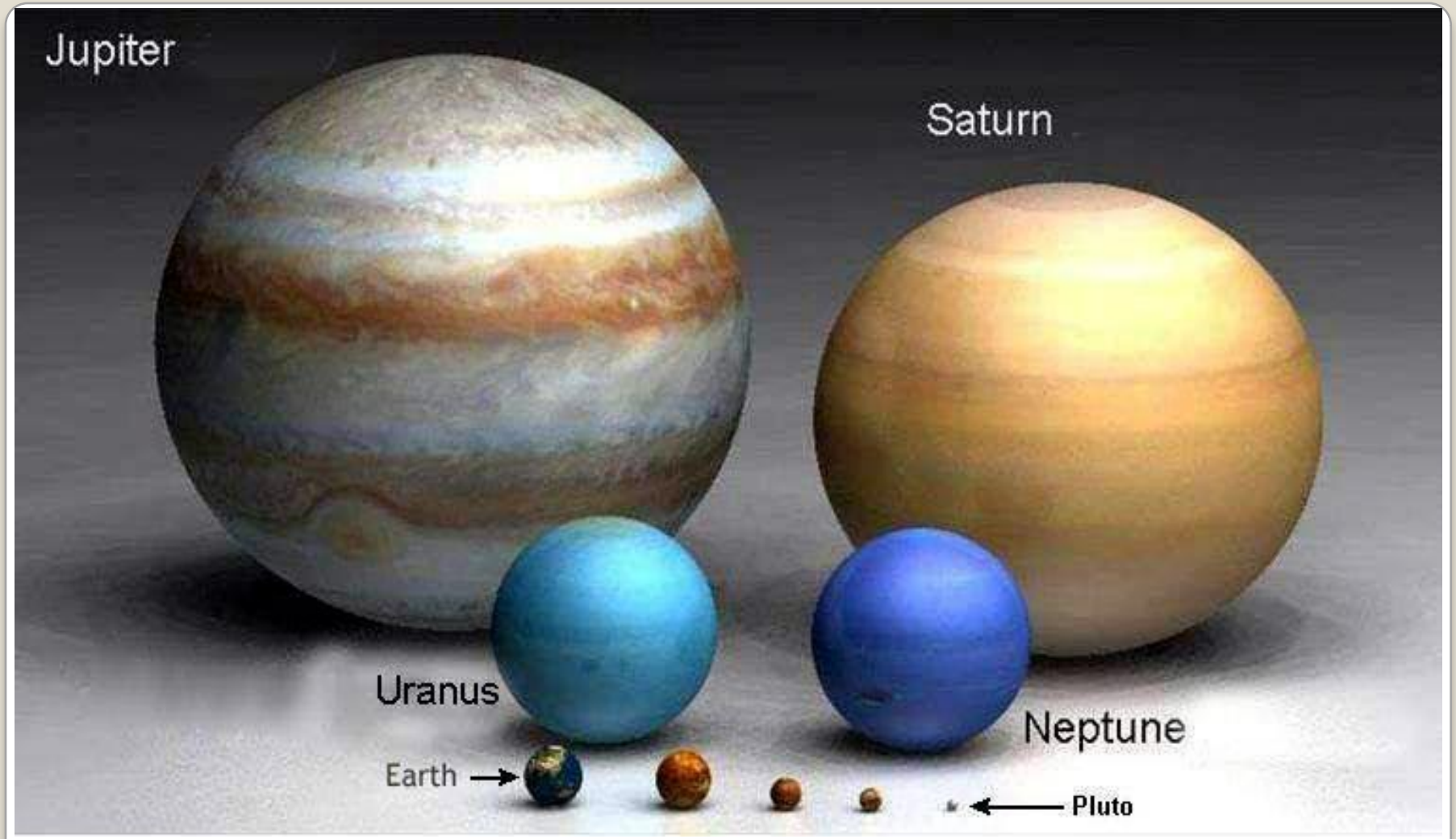
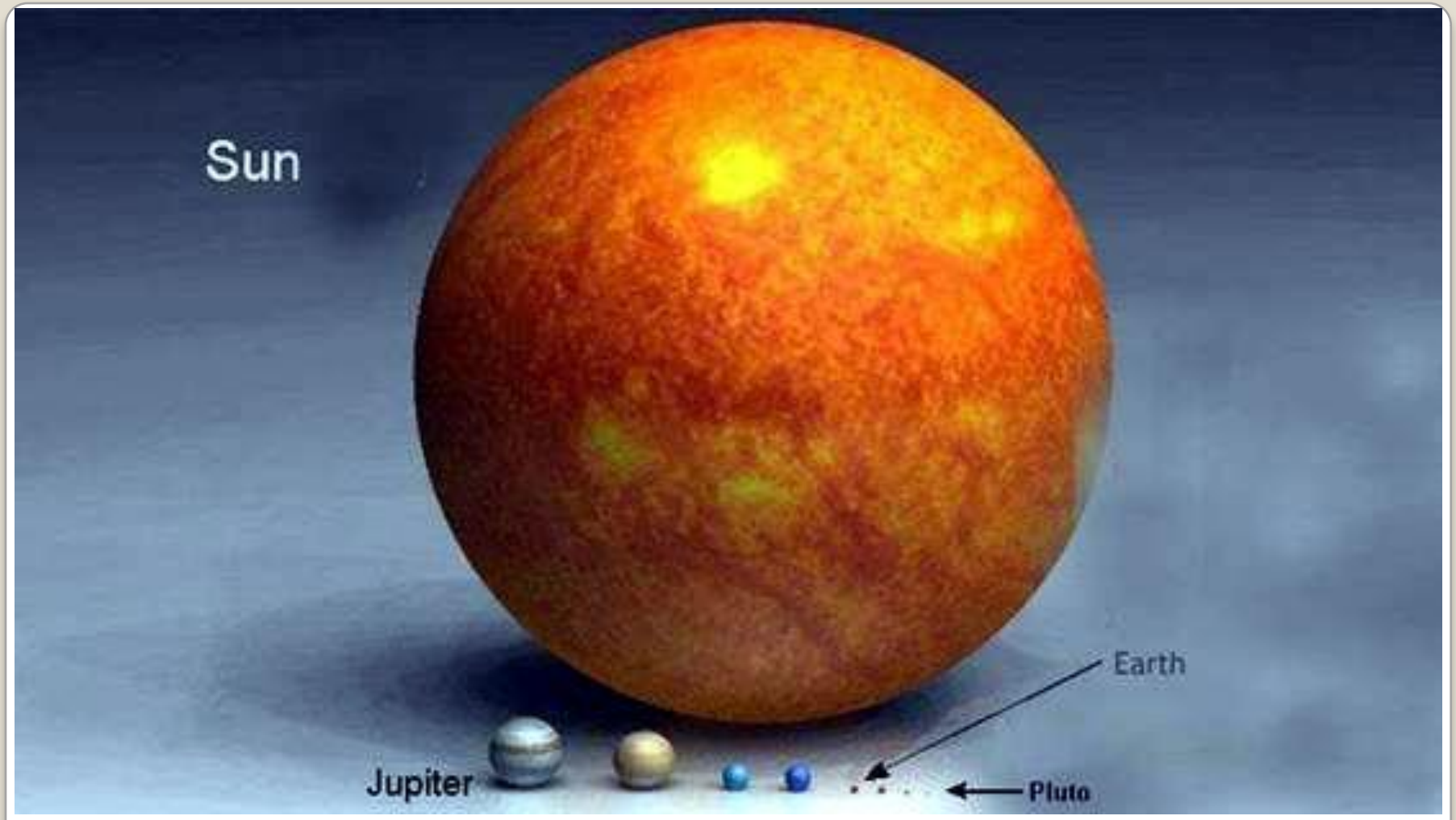
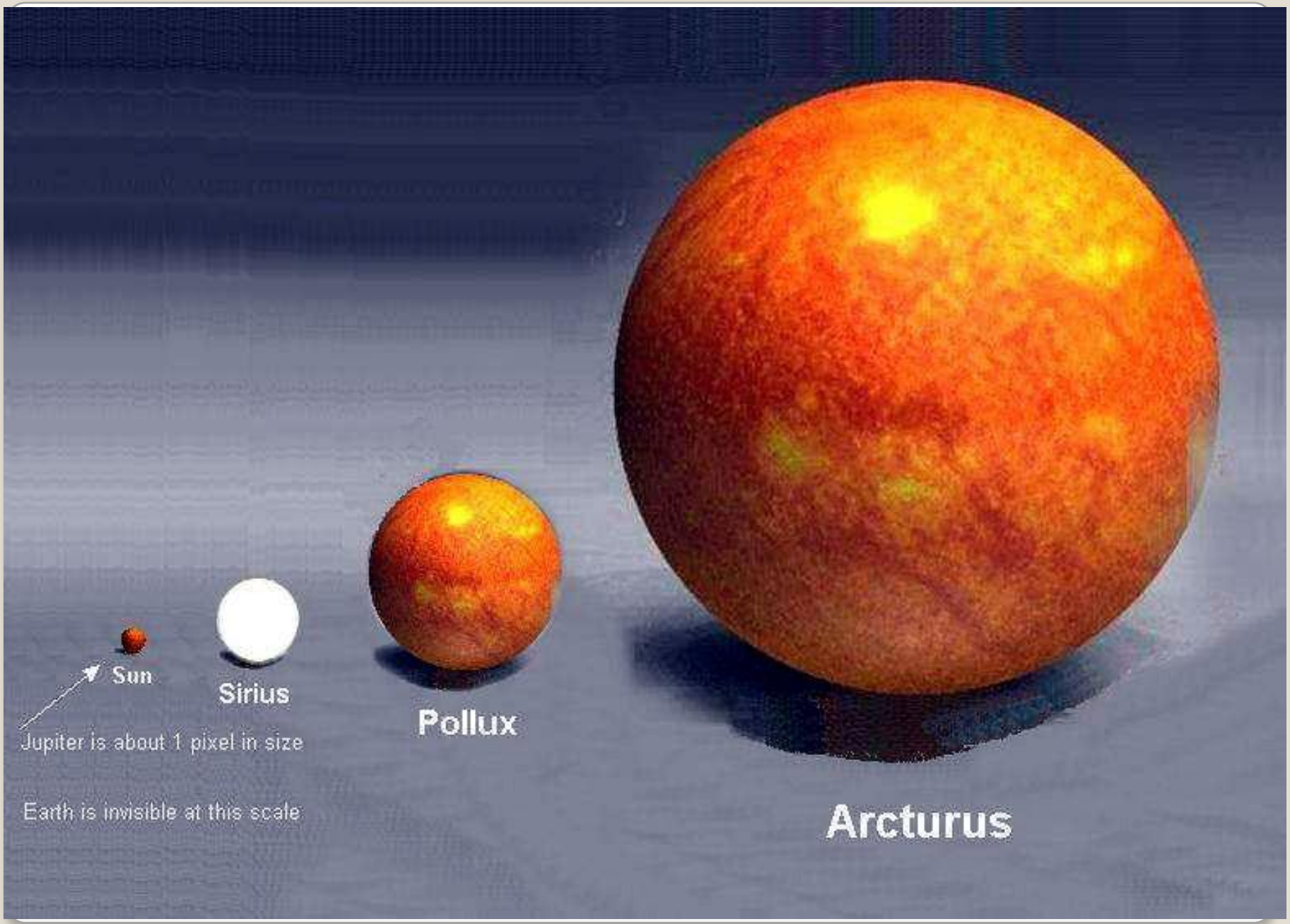
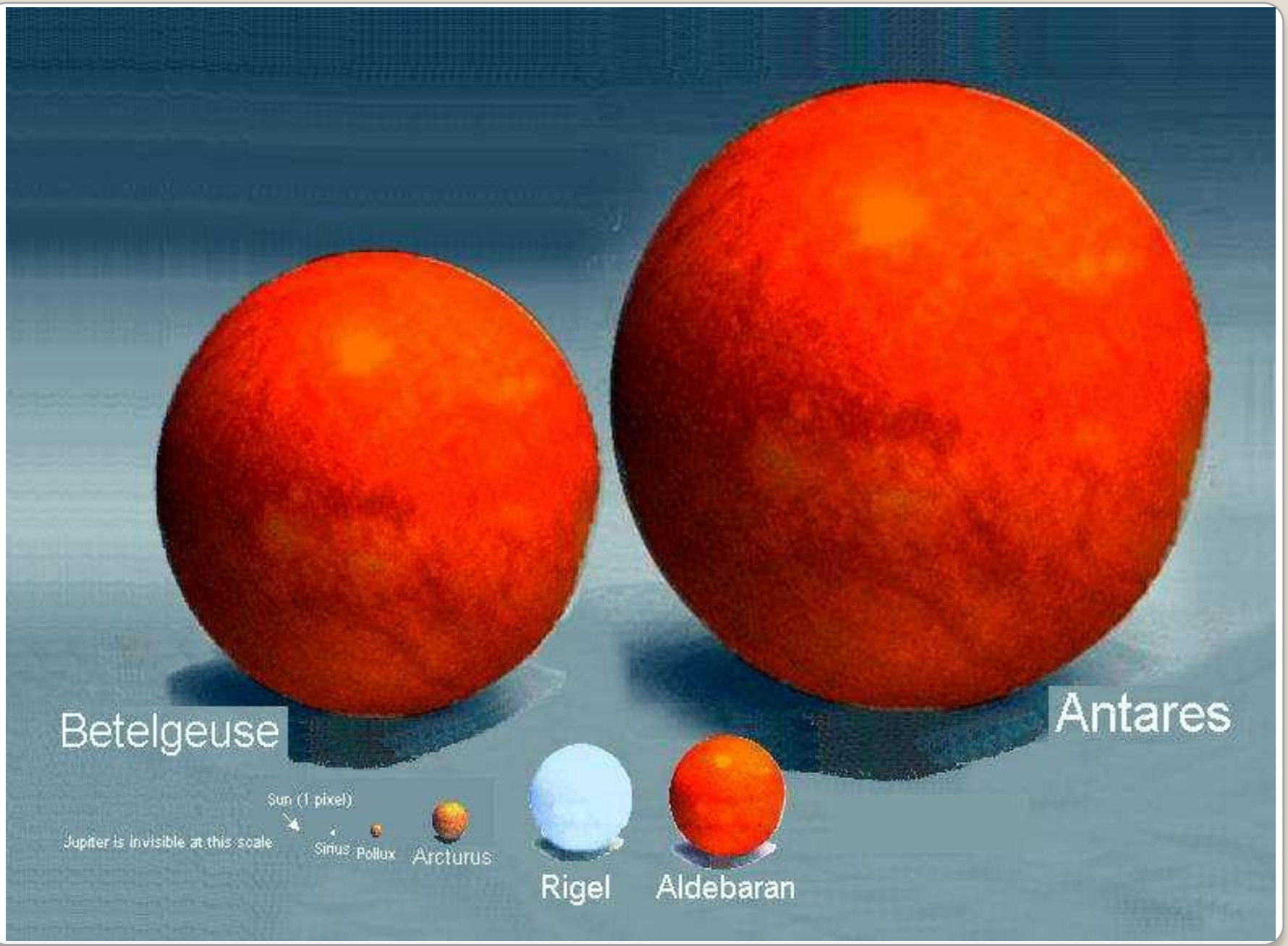
Sun and Planets in the Solar System




Jupiter
Saturn
Uranus
Neptune
Earth
Pluto

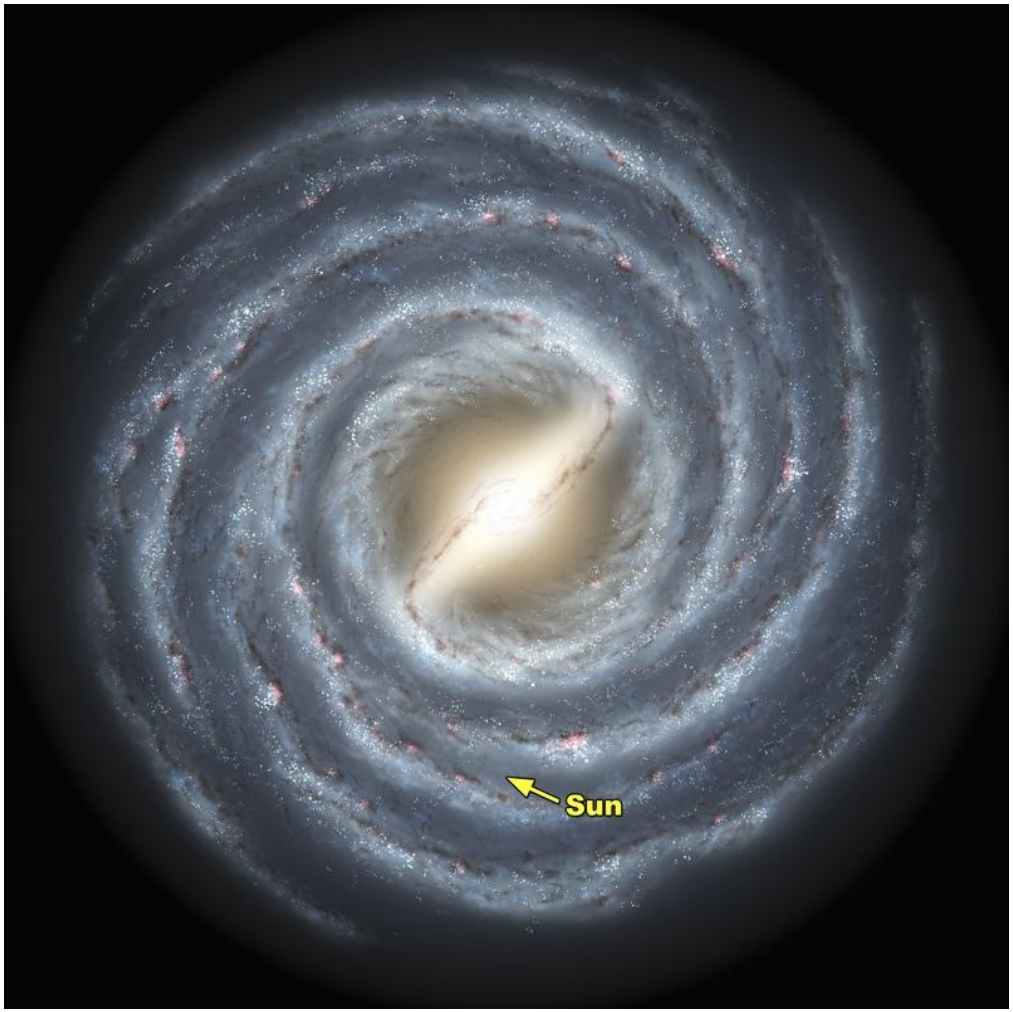

Sun
Earth
Jupiter
Pluto

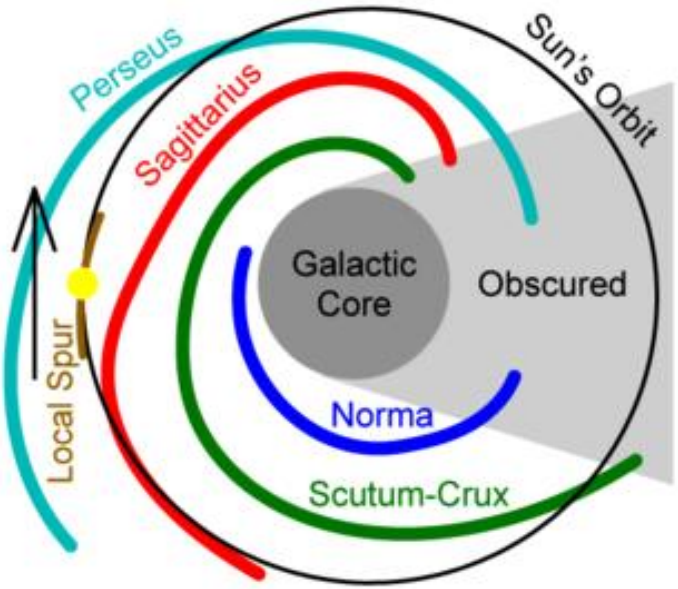

Sun
Sirius
Pollux
Arcturus
Jupiter is about 1 pixel in size
Earth is invisible at this scale


Betelgeuse
Antares
Sun (1 pixel)
Jupiter is invisible at this scale
Sirius
Pollux
Arcturus
Rigel
Aldebaran

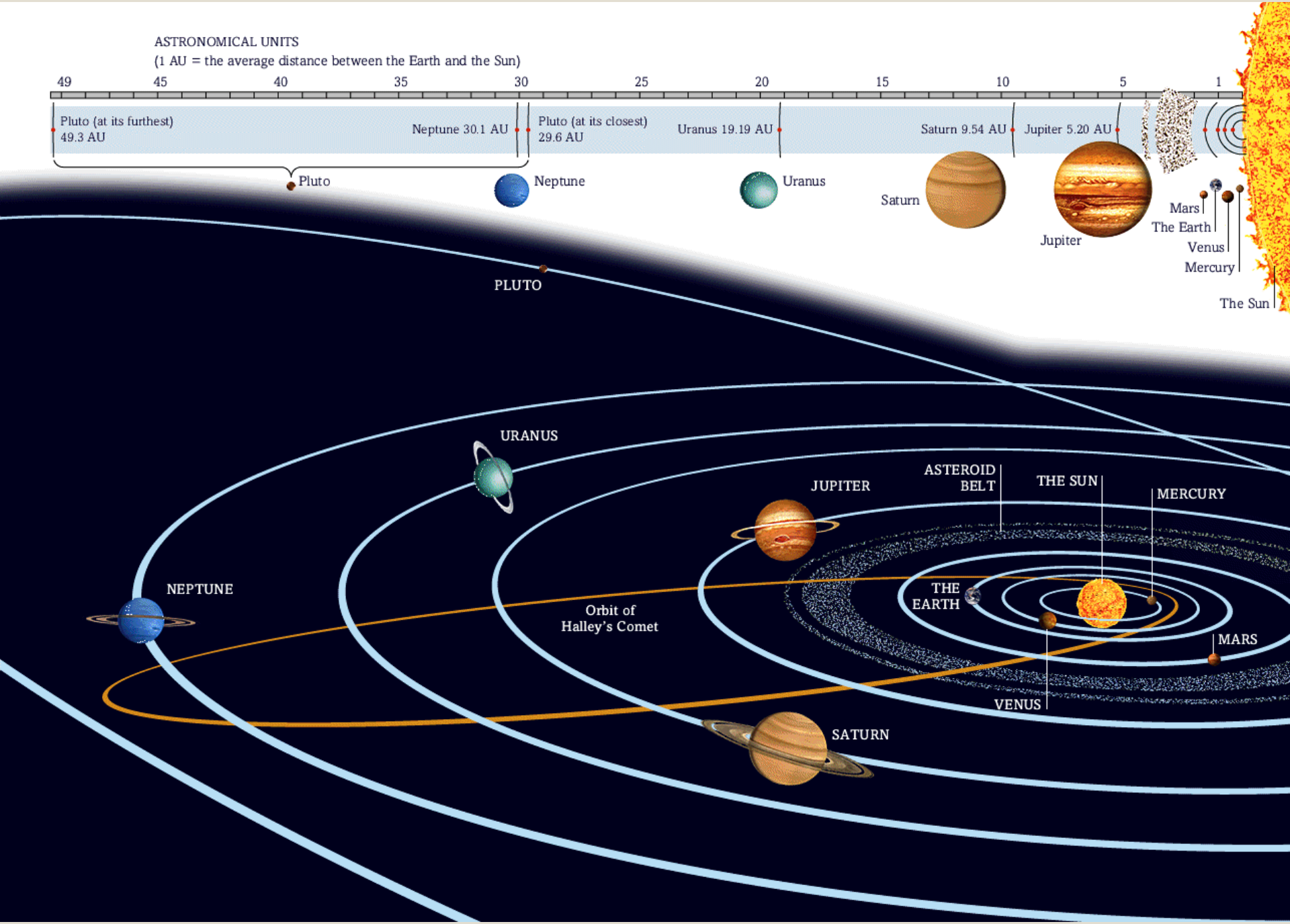
The location of the Solar System in the Milky way Galaxy

Milky way Galaxy diameter = 100,000 ly





Milky way Galaxy depth = 2000 ly


ASTRONOMICAL UNITS
(1 AU = the average distance between the Earth and the Sun)
49
45
40
35
30
25
20
15
10
5
1
Pluto (at its furthest)
49.3 AU
Neptune 30.1 AU
Pluto (at its closest)
29.6 AU
Uranus 19.19 AU
Saturn 9.54 AU
Jupiter 5.20 AU
Pluto
Neptune
Uranus
Saturn
Jupiter
Mars
The Earth
Venus
Mercury
The Sun
PLUTO
URANUS
JUPITER
ASTEROID BELT
THE SUN
MERCURY
NEPTUNE
Orbit of Halley's Comet
THE EARTH
MARS
VENUS
SATURN

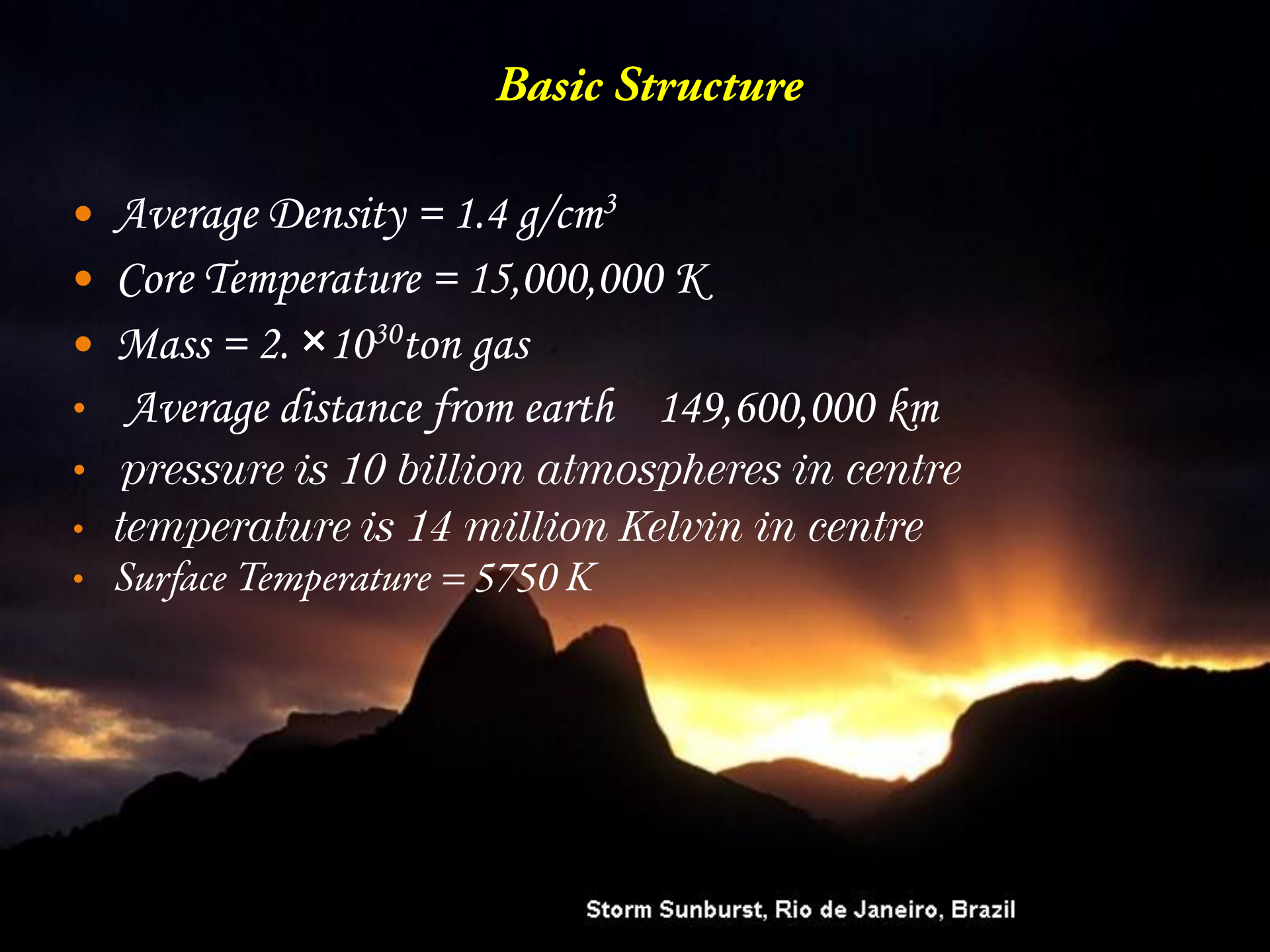
The Sun

Our sun is a star located in our Solar System. It is a huge, spinning ball of hot gas that lights up the Earth and provides us with heat.

- *The sun is the biggest, brightest, and hottest object in the solar system.*
- *The sun is an ordinary star.*
- *Sun converts hydrogen to helium in its core*
- *Differential rotation*
  - *equator the surface rotates once every 25.4 days*
  - *near the poles it's as much as 36 days*

Basic Structure

- *Average Density = 1.4 g/cm^3*
- *Core Temperature = 15,000,000 K*
- *Mass = 2. × 10^{30} ton gas*
- *Average distance from earth 149,600,000 km*
- *pressure is 10 billion atmospheres in centre*
- *temperature is 14 million Kelvin in centre*
- *Surface Temperature = 5750 K*



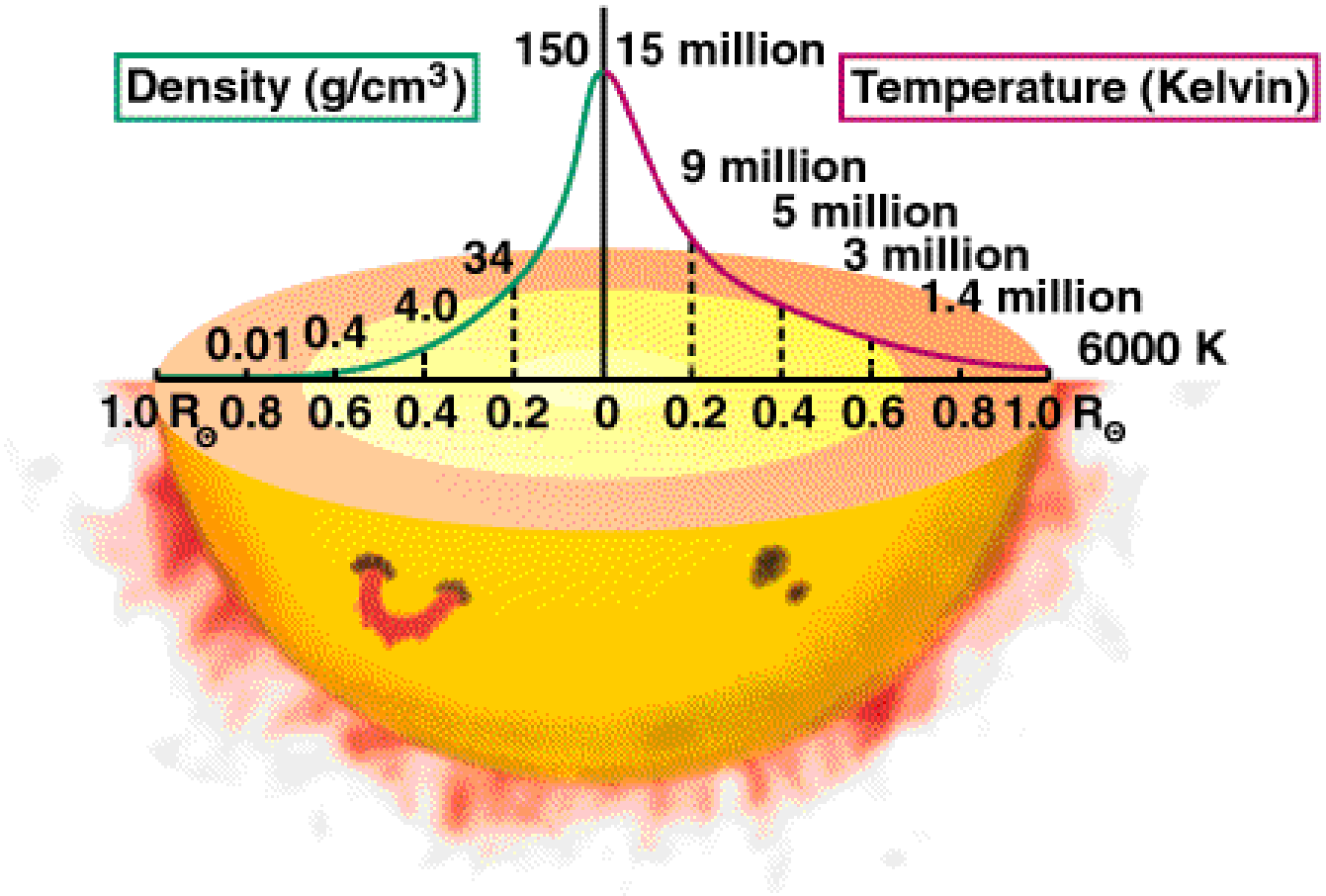
Storm Sunburst, Rio de Janeiro, Brazil

Chemical Composition of the Sun

Here is a table of the 10 most common elements in the Sun:

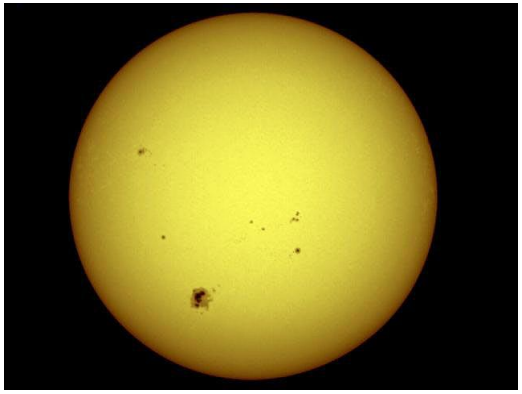
Element	Abundance (% of total number of atoms)	Abundance (% of total mass)
Hydrogen	91.2	71.0
Helium	8.7	27.1
Oxygen	0.078	0.97
Carbon	0.043	0.40
Nitrogen	0.0088	0.096
Silicon	0.0045	0.099
Magnesium	0.0038	0.076
Neon	0.0035	0.058
Iron	0.0030	0.014
Sulfur	0.0015	0.040

How Temperature and Density Vary Inside the Sun



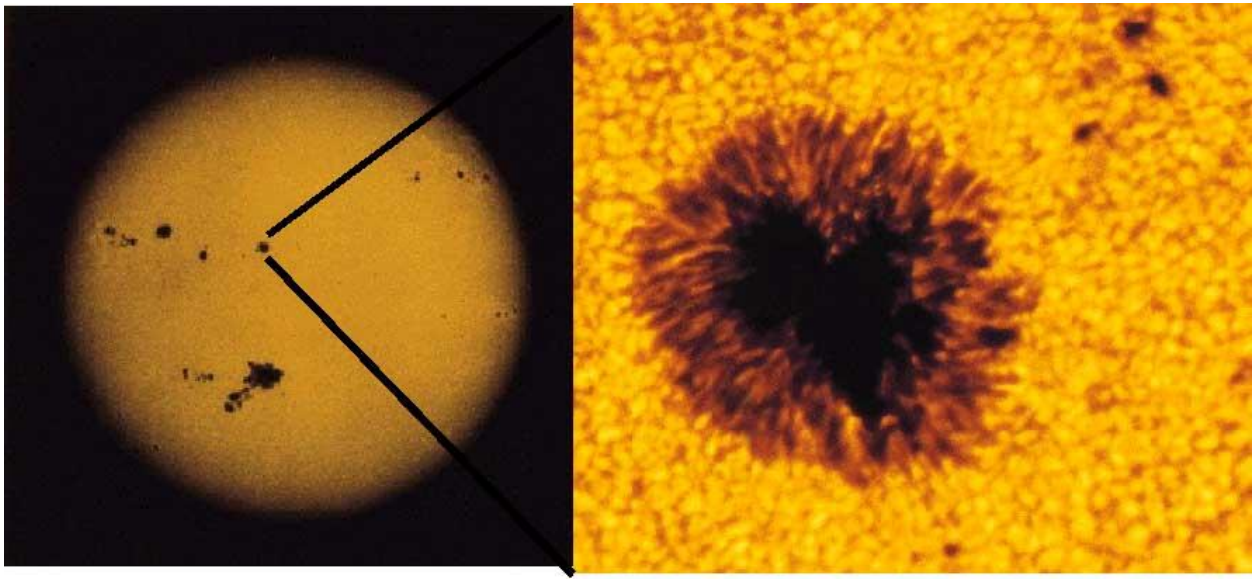
Solar Characteristic

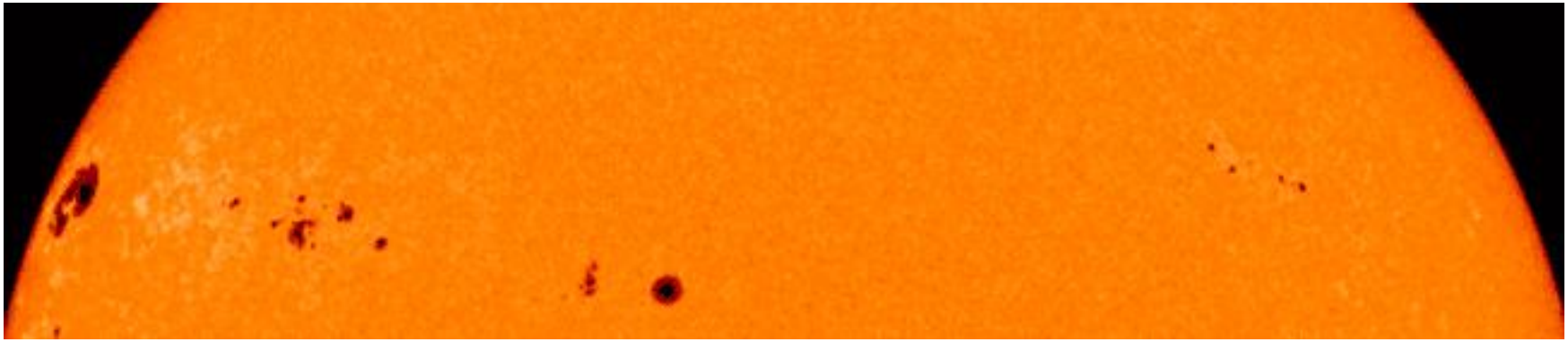
Photosphere: "sphere of light", the visible surface of the Sun.



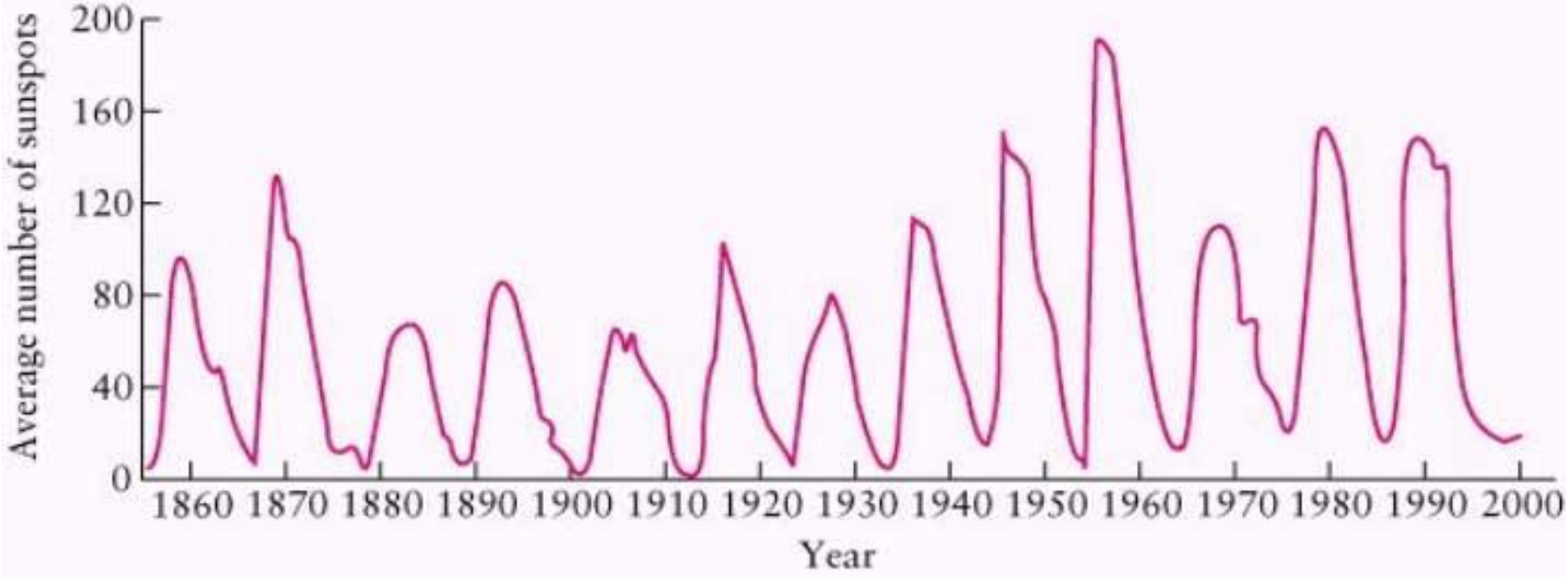
$T = 5750\ K$

SUNSPOTS

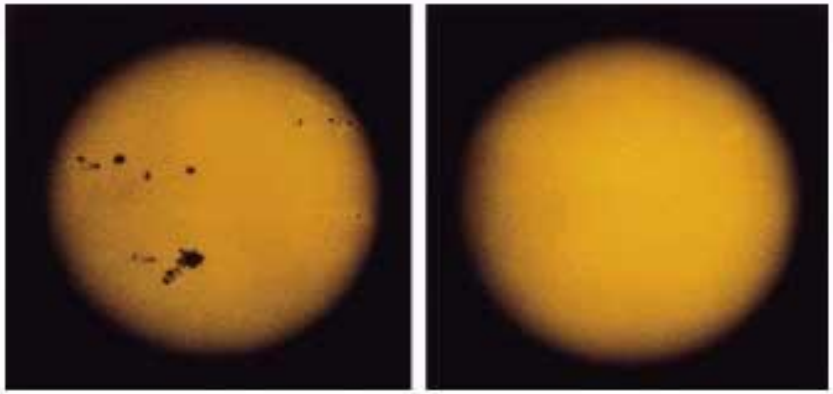




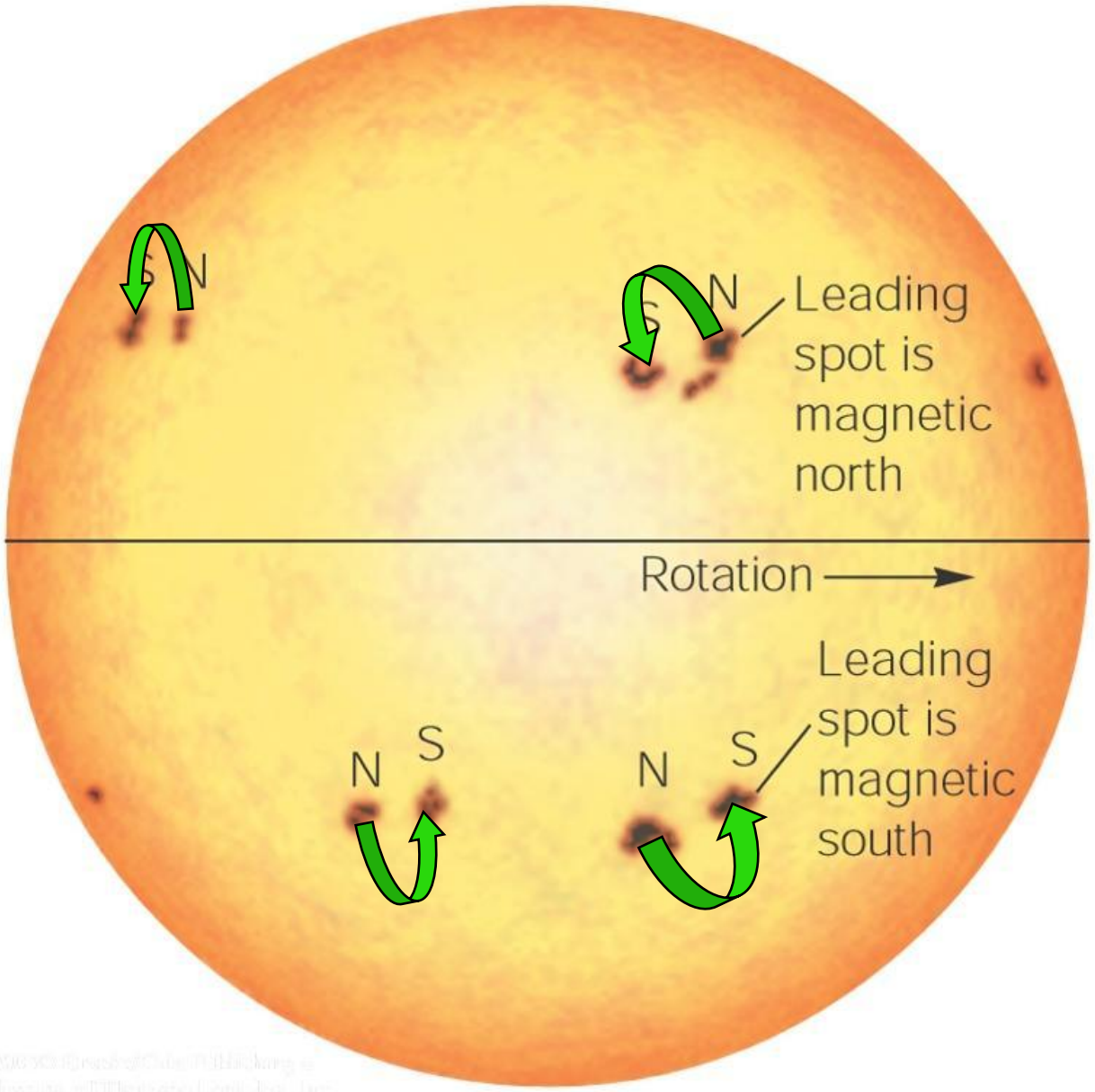
The annual change in numbers of **sunspots** reveals that the Sun experiences an 11-year solar cycle.



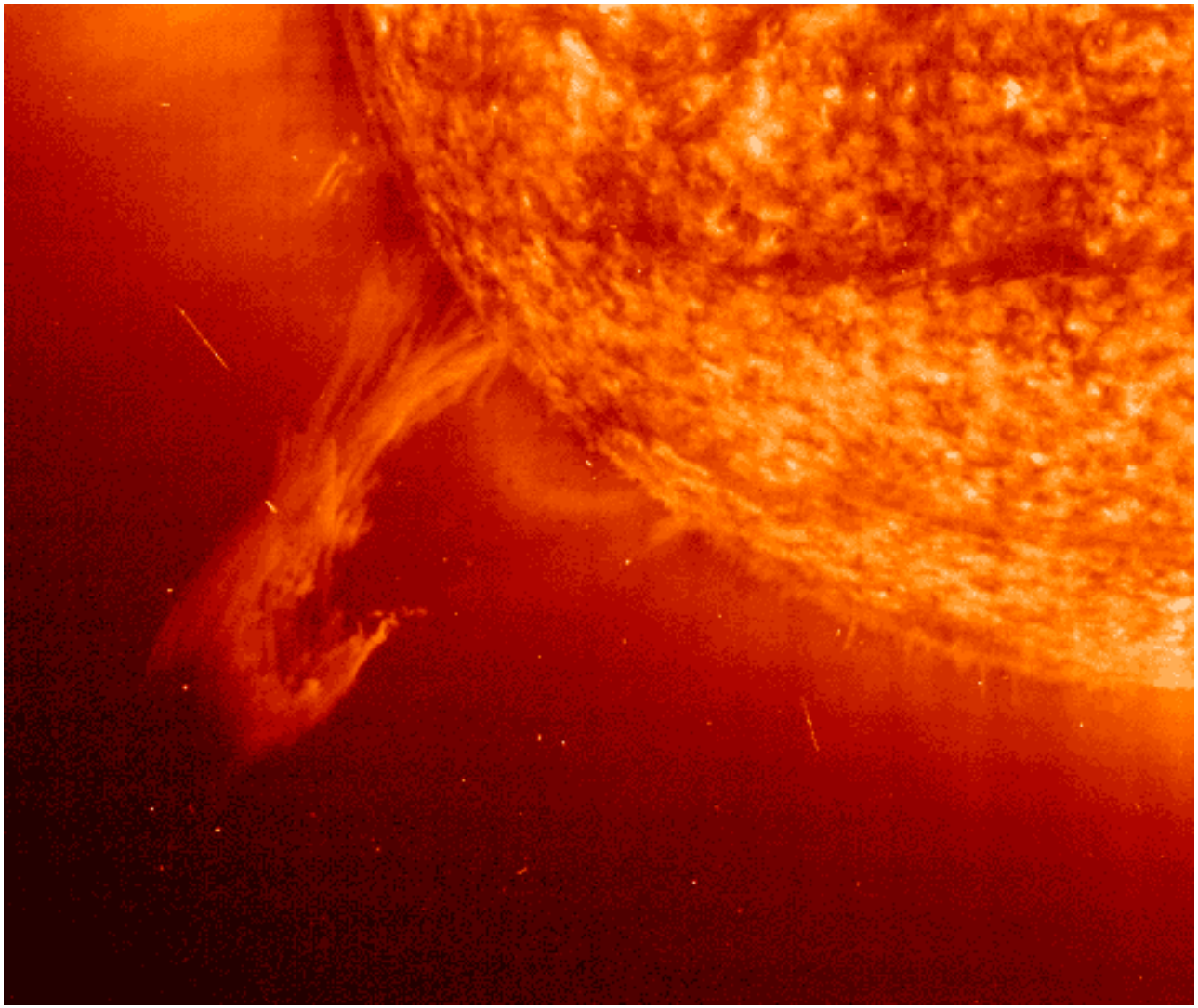
Maximum number



Minimum number


S N
N S
Leading spot is magnetic north
Rotation
N S
N S
Leading spot is magnetic south

Prominence



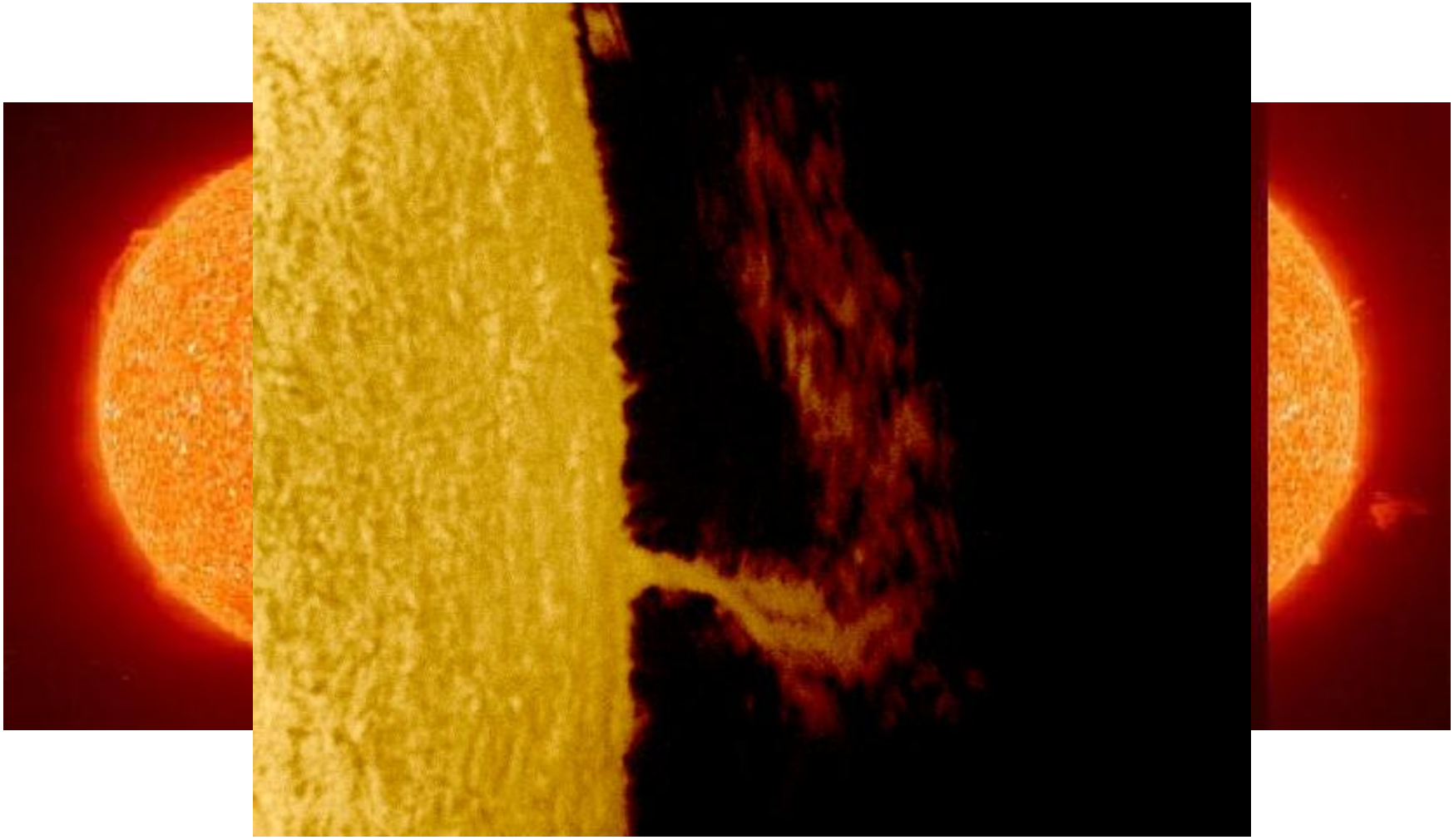
Chromosphere: "sphere of color", visible during solar eclipses

just outside of photosphere

hot gas

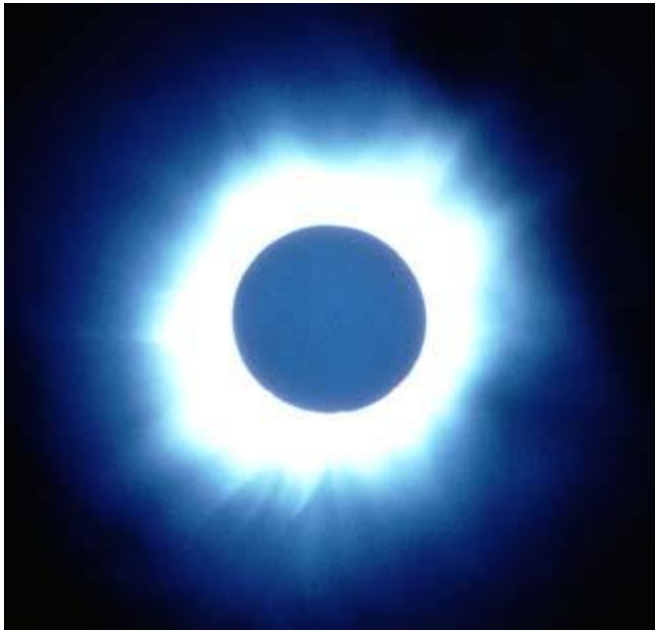
T = 10,000 K

Solar Flare



Corona - the Sun's outermost atmosphere.

The outflow of gas in this region is called the solar wind, which is protons and electrons that have escaped the Sun's gravity.

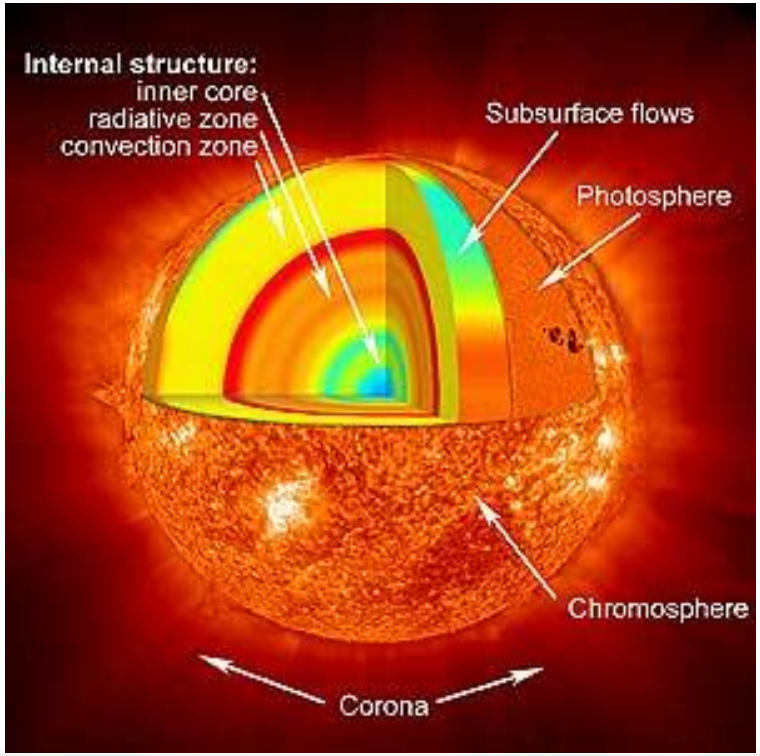


Very hot (few million degrees) visible during eclipse.

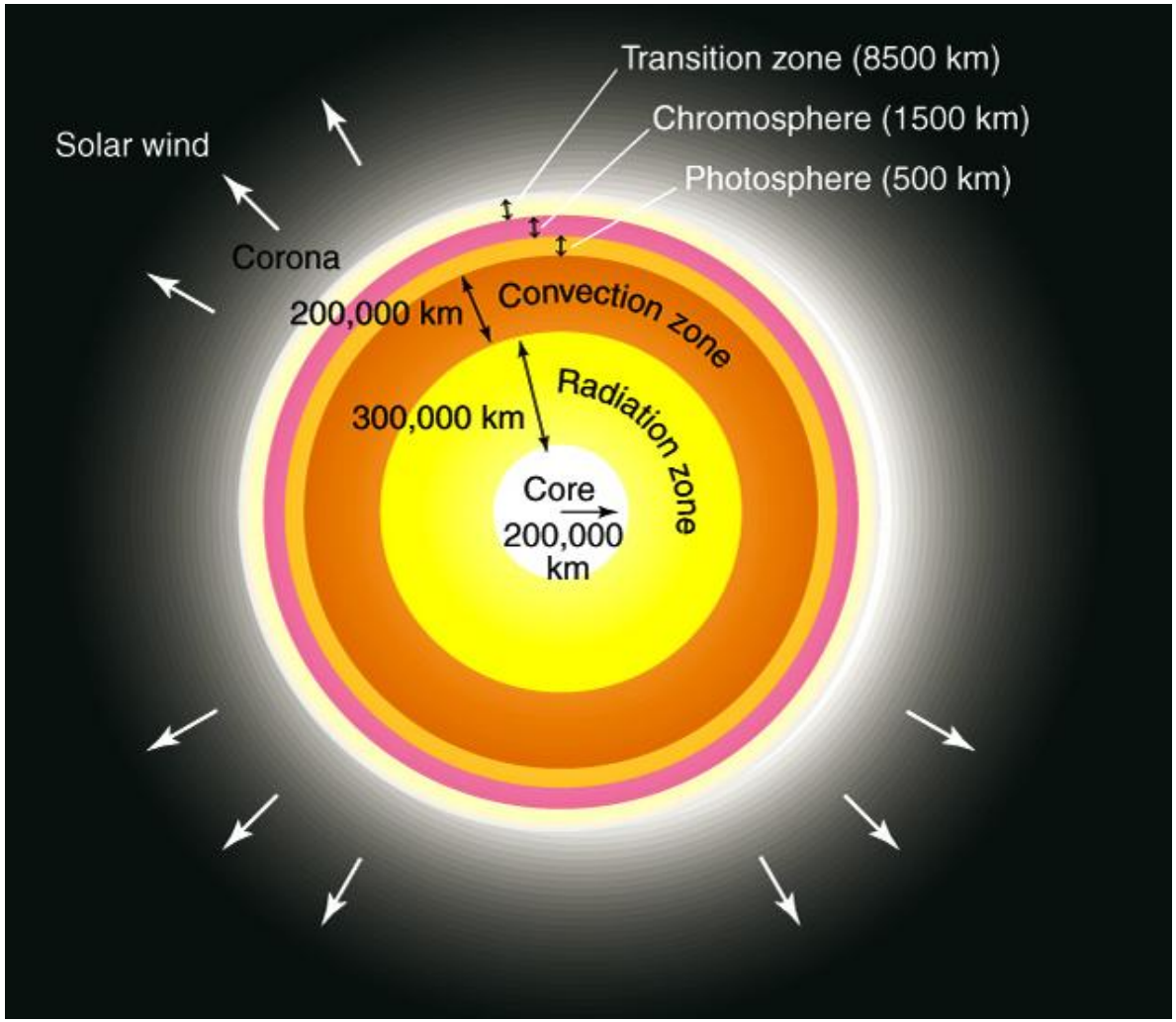
The sun's corona, or extended outer layer, is a region of plasma that is heated to over 1000000 celcius. the mean velocity of these particles is about 145km/s, which is below the solar escape velocity of 618km/s.

The Sun's Interior

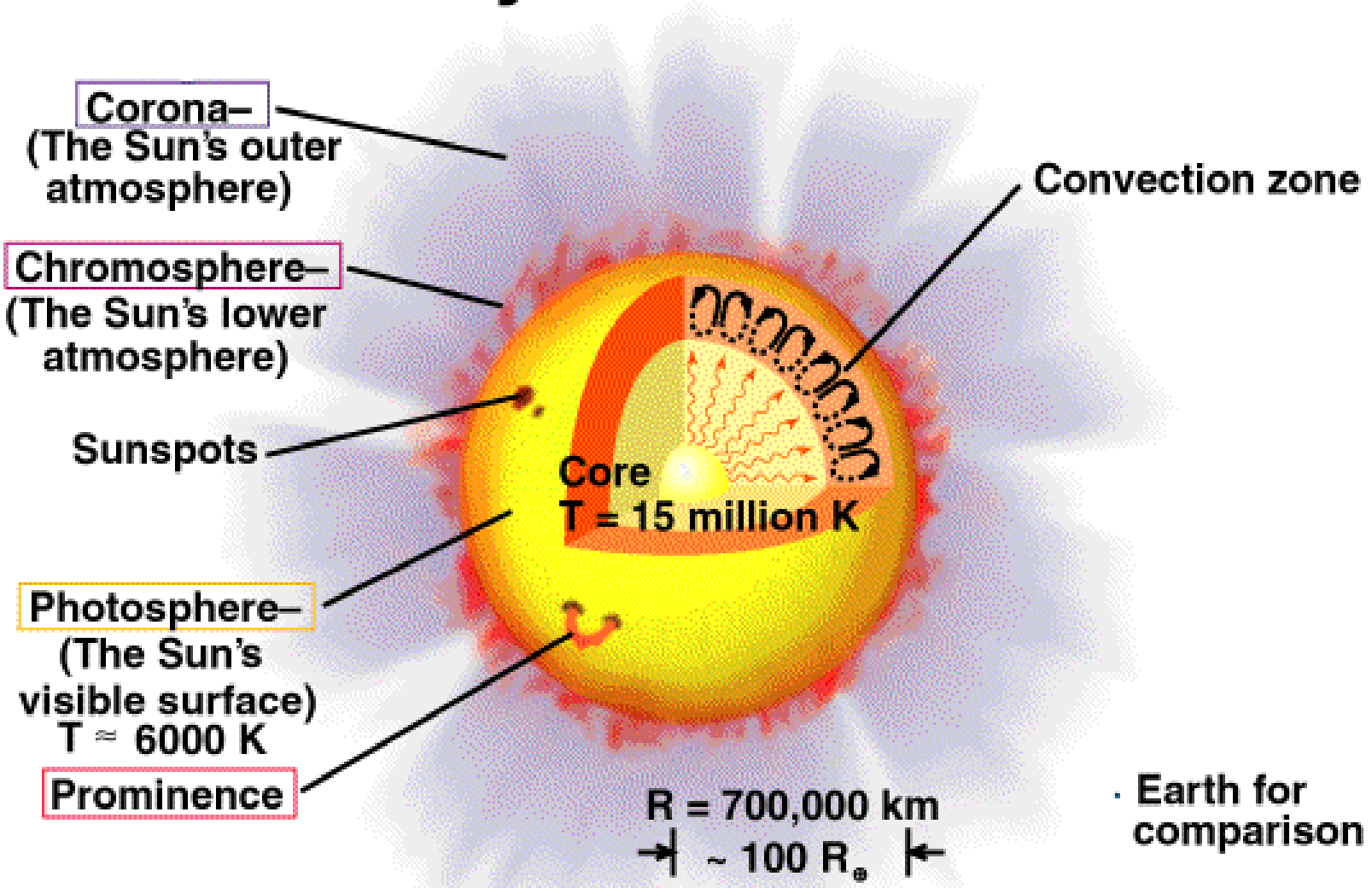
- *Radiative zone - a region inside a star where energy is transported outward by the movement of photons.*
- ***Convective zone - a layer inside a star where energy is transported outward by means of heat flow through the gasses of the star (convection).***



Layers of the Sun



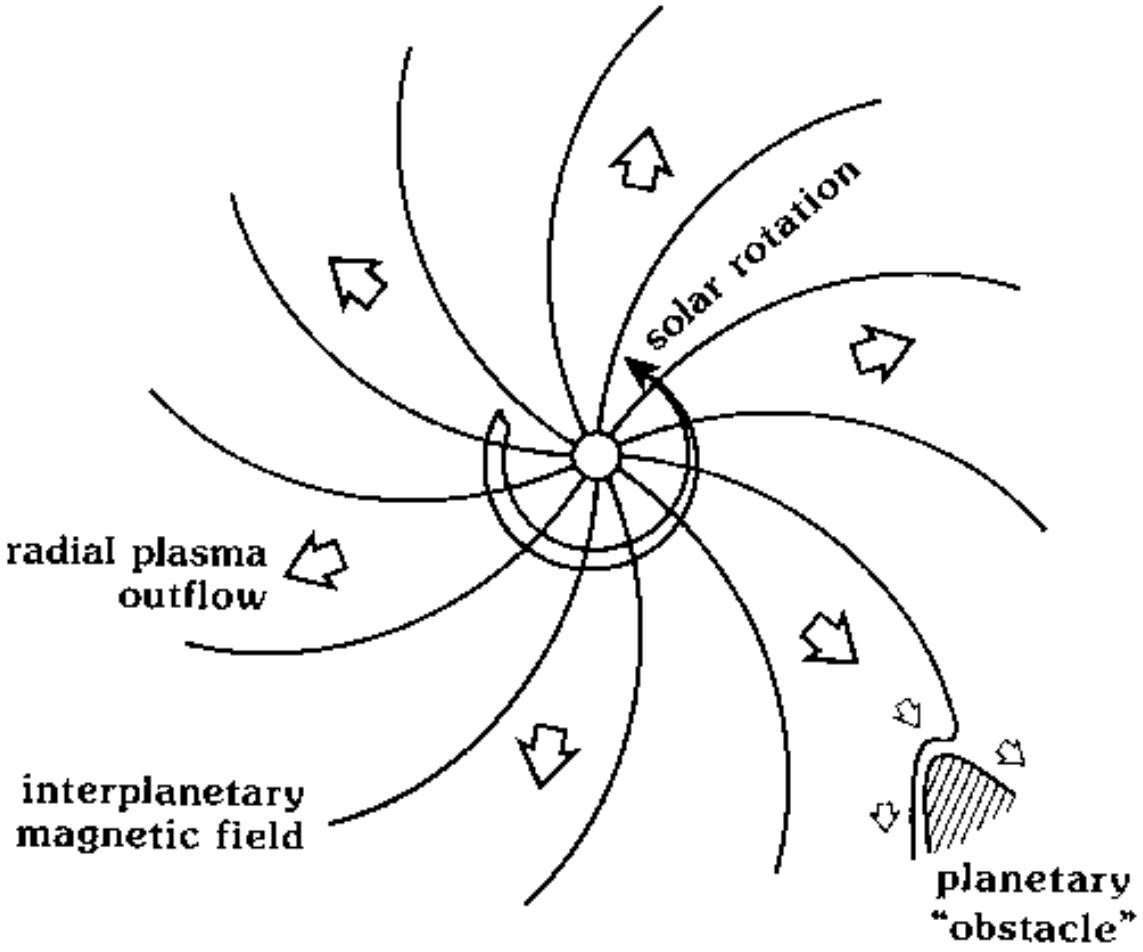
Cut Away View of the Sun



The Solar Corona: Source of the solar wind

The solar wind is a stream of charged particals-plasma-ejected from the upper atmosphere of the sun.
It contains electons & protons with energies of about 1kv

The Solar Wind and Interplanetary Magnetic Field



Fusion of Hydrogen into Helium
The Suns' Source of Energy

- ***Nuclear Reactions:*** *The Sun's energy comes from nuclear reactions in its core.*
  More specifically, the energy comes from the fusion (joining) of nuclei of hydrogen atoms into nuclei of helium atoms. The actual fusion process takes place in several steps, which may be summarized as follows:

Four hydrogen nuclei get fused into one helium nucleus, accompanied by the emission of neutrinos and release of energy:

$$4\ {}^{1}H \Rightarrow {}^{4}He + \text{neutrinos} + \text{energy}$$

${}^{1}H$ = nucleus of hydrogen atom

${}^{4}He$ = nucleus of helium atom

Neutrinos are subatomic particles that travel close to the speed of light and only rarely interact with matter.

Where Does the Energy Come from in the Fusion of Hydrogen into Helium?

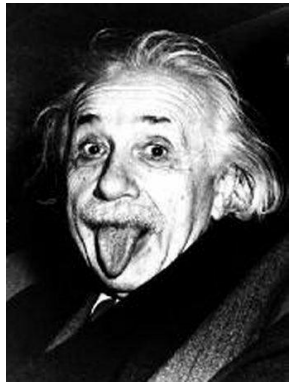
During the fusion of hydrogen, approximately 0.7% of the mass of hydrogen is converted into energy. This means that the resulting helium has 0.7% less mass than the original hydrogen. Einstein's famous formula tells us how much energy this loss of mass generates:

Hydrogen + Hydrogen = Helium + energy

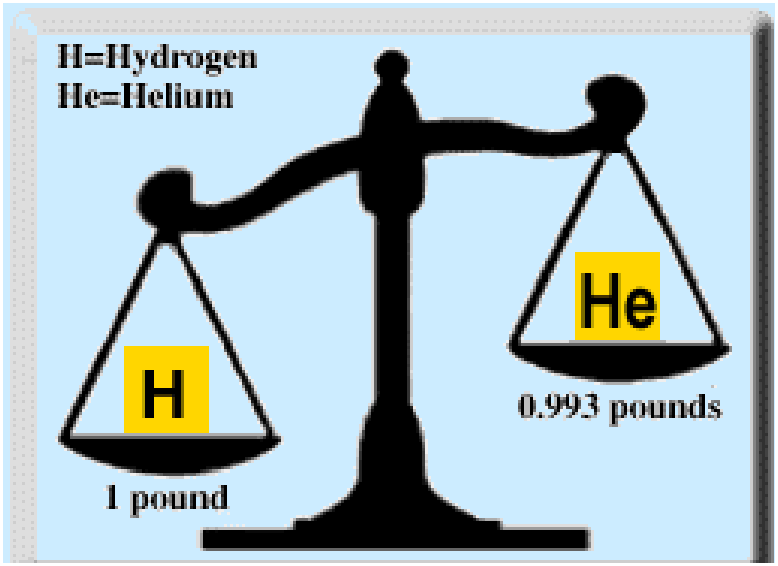
difference in mass converted to energy

$E=mc^2$

famous Einstein ***mass=energy***



Since the speed of light (c) is very large and comes in squared, the amount of energy generated by the fusion of hydrogen is very large, even though the amount of mass that disappears is very small.



If we could weigh the helium produced by the fusion of 1 pound of hydrogen, we'd find it weighs only 0.993 pounds. The difference, namely 0.007 pounds, has been converted into energy.

NUCLEAR "ENERGY" is the conversion of mass to energy