Origin of the Earth, Ocean, and Atmosphere

Topics:

- Formation of Earth & Solar System - Nebular Theory
- the Earth & the Moon
- Formation of Earth's Layered Structure
- Origin of the Earth's Atmosphere
- Origin of Earth's Oceans

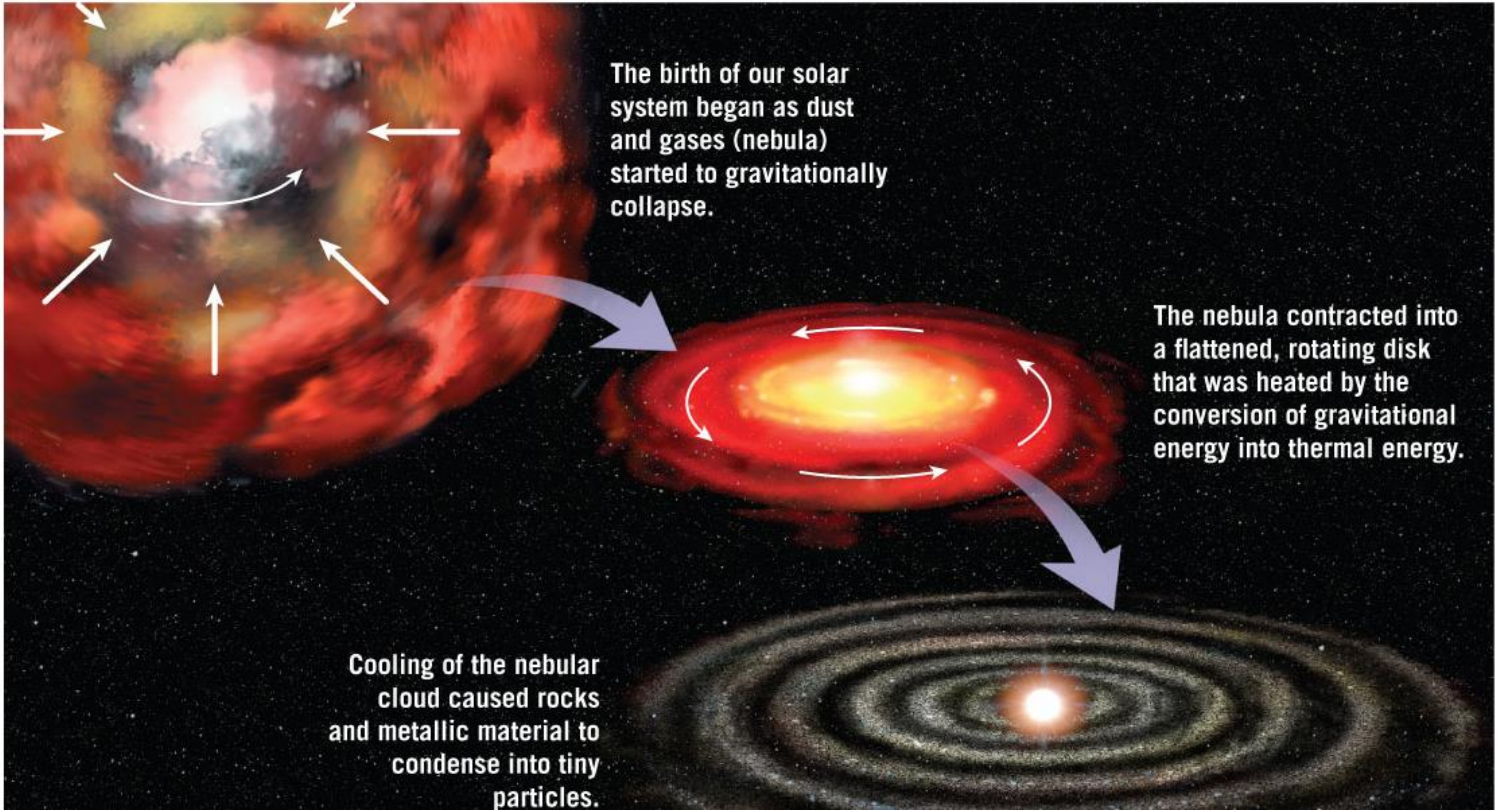
Formation of Earth and the Solar System

Solar system formed from solar nebula

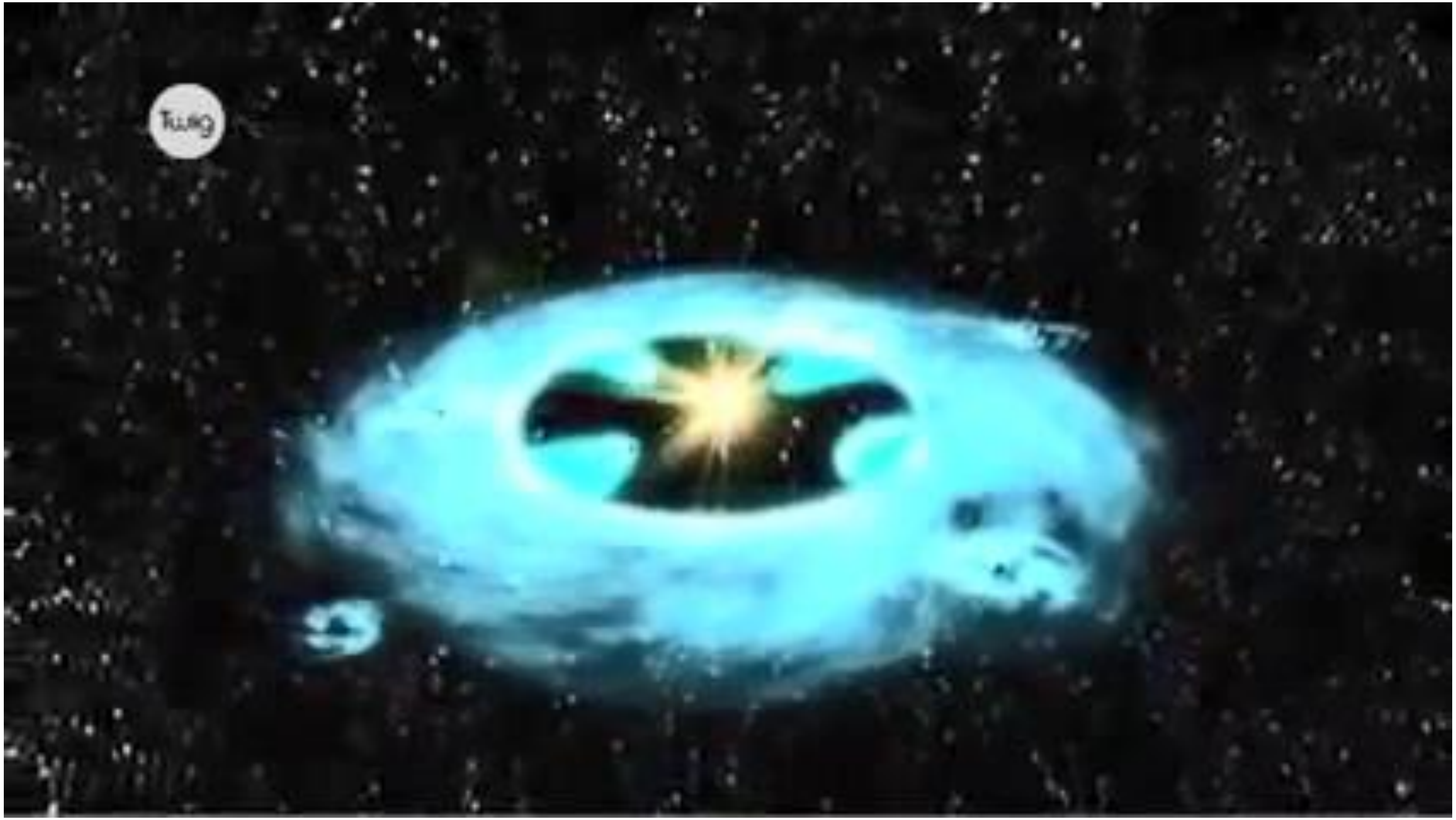
(mostly H & He)

NASA’s Hubble Space Telescope image of Ghost Head Nebula

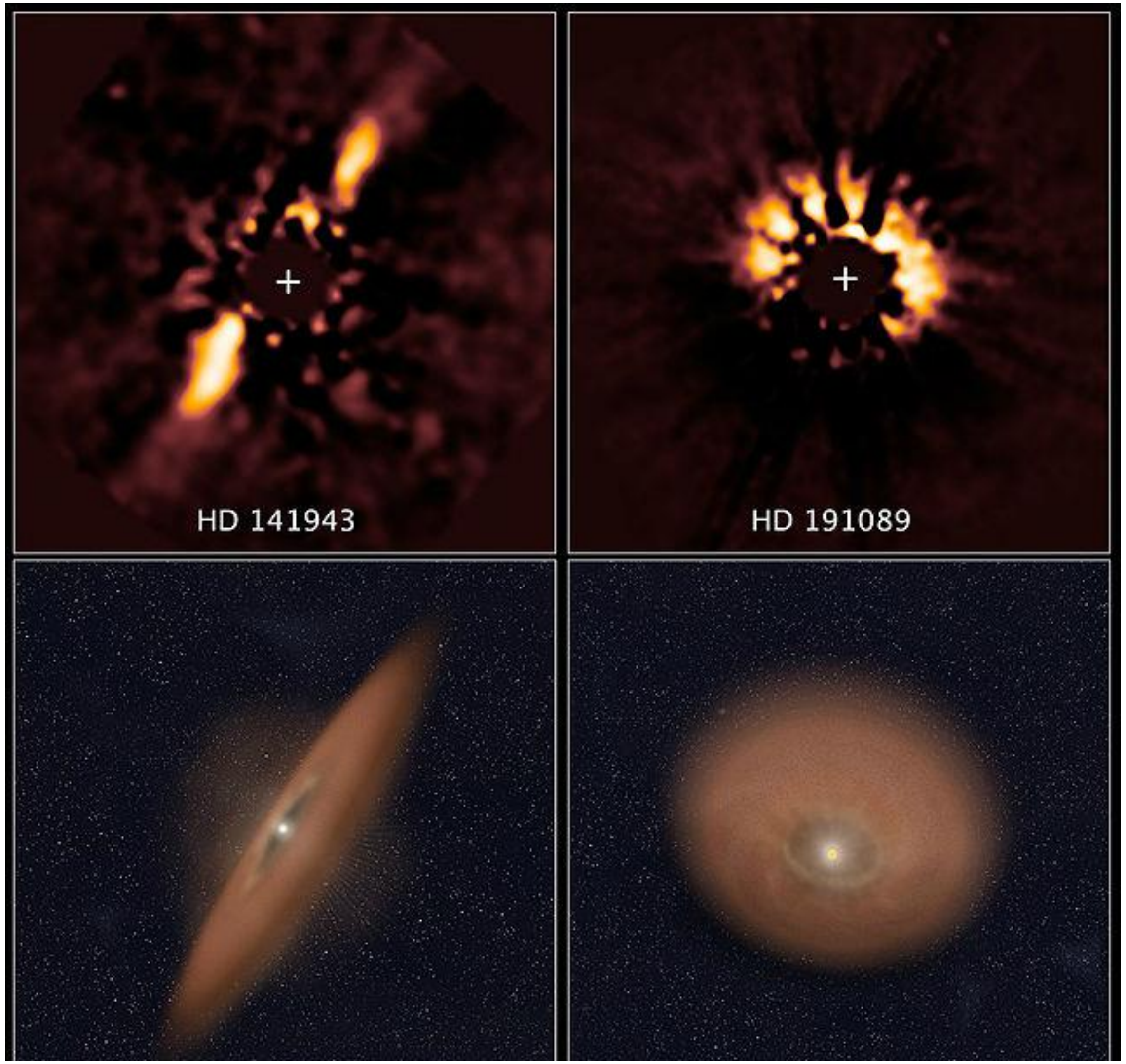
Nebular Theory



The Nebular Theory



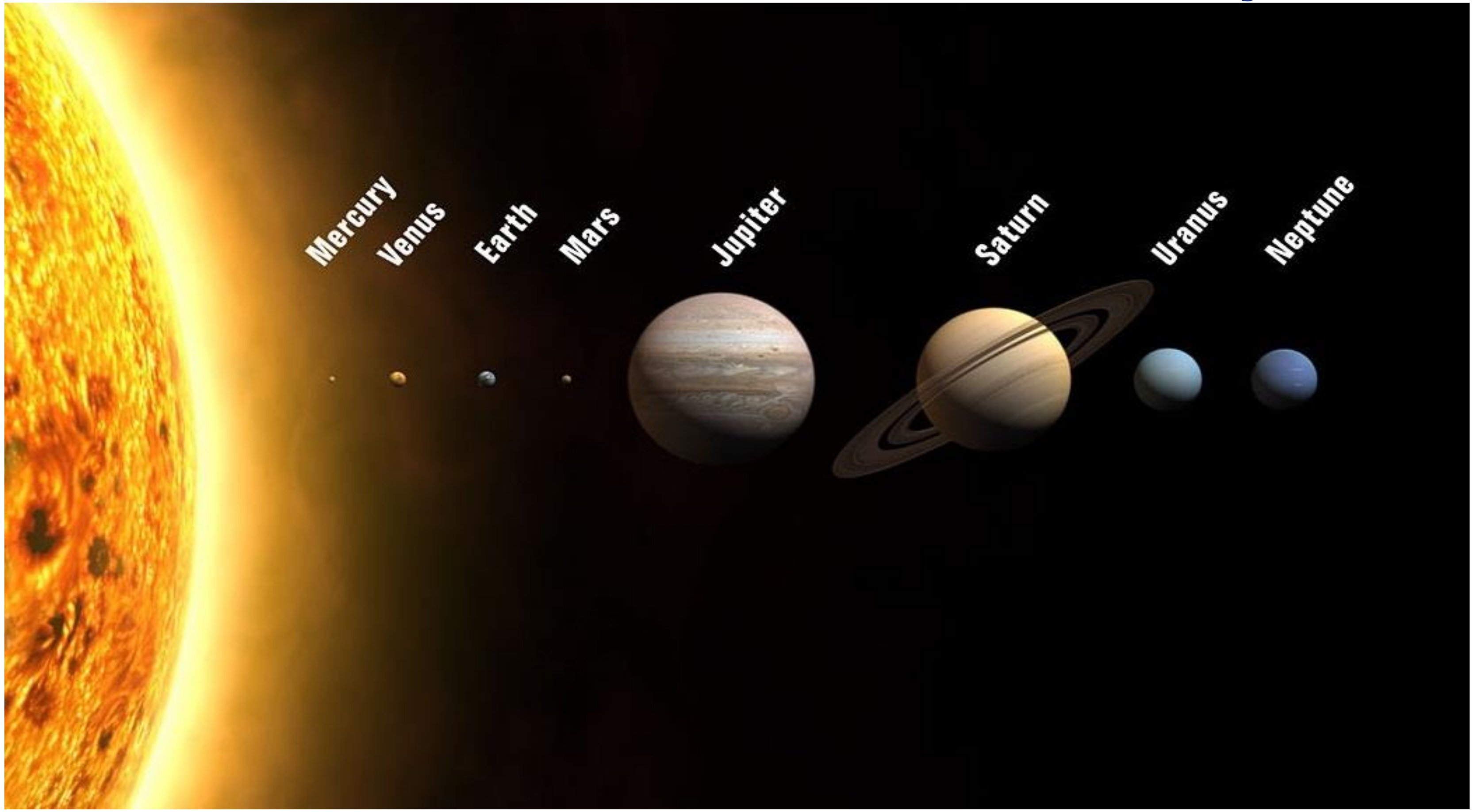
- How many years ago the nebula of our solar system formed?
- What were the main gas of the nebula?
- What process made the core of this cloud densier and hotter?
- What process formed planets?
- What are the rocky planets in the solar system?



Debris disks detected in Hubble Space Telescope archival images of two young stars, using improved imaging processes (24 April 2014)

A Hubble Space Telescope view of a small portion of the Orion Nebula

Formation of the Earth and the Solar System



- **Inner planets: mostly silicates and metal density ~ 3.3-5.5 g/cm^3**
- **Outer planets: mostly H, He, H_2O, CH_4** (Methan**e), & NH_3** (Ammonia)**; density < 2**

the Earth & the Moon

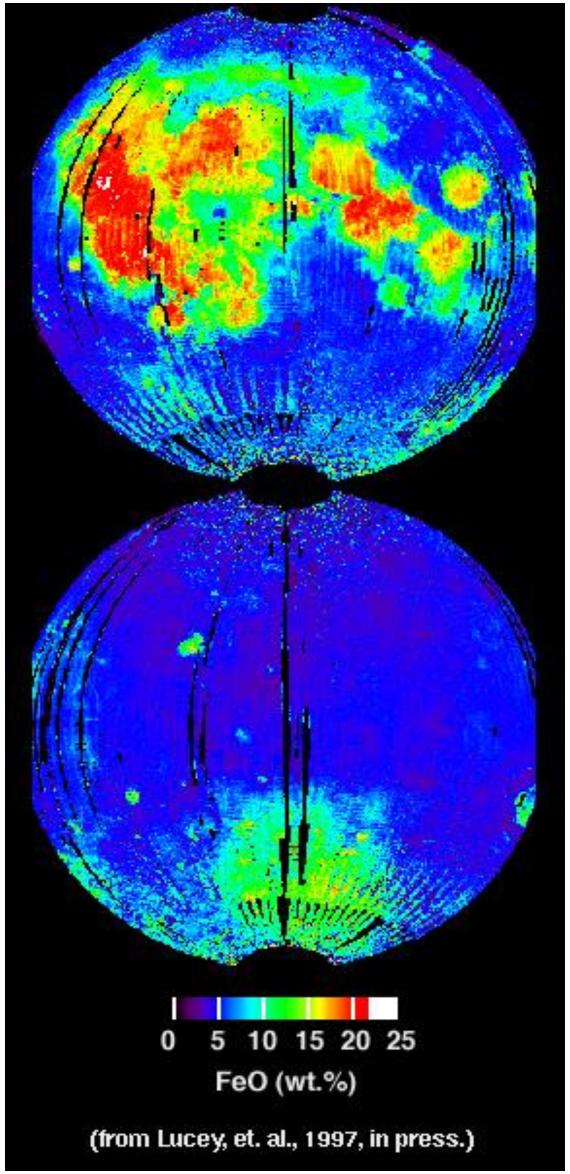
Hypotheses

- **Fission**
- **Captured body**
- **Accretion** **(**Two-object system)
- **Giant impact**

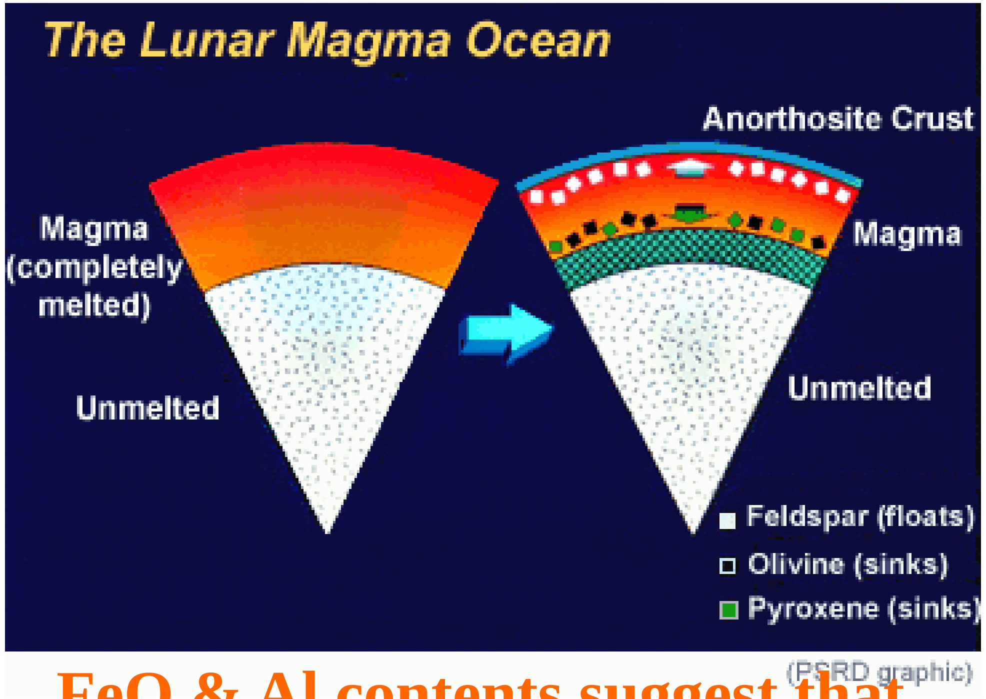
Earth's Moon (photo from NASA)

Evolution of the Moon (video)

Video: http://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=10930



FeO concentration on the nearside (top) and the farside (bottom) of the Moon



FeO & Al contents suggest that the highlands crust formed initially from a globe-encircling layer of molten rock, the lunar magma ocean, in which plagioclase floated and denser minerals sank.

Recent Geochemical Studies

Consistent with **giant impact hypothesis:**
Zn isotopes study (2012) – shows large scale evaporation of Zn in lunar samples

Studies that show Lunar samples have same chemical signatures as Earth rocks (conflict with giant impact hypothesis; **favor accretion hypothesis**)**- Oxygen isotopes** (2001, 2007)
Titanium isotopes (2012)

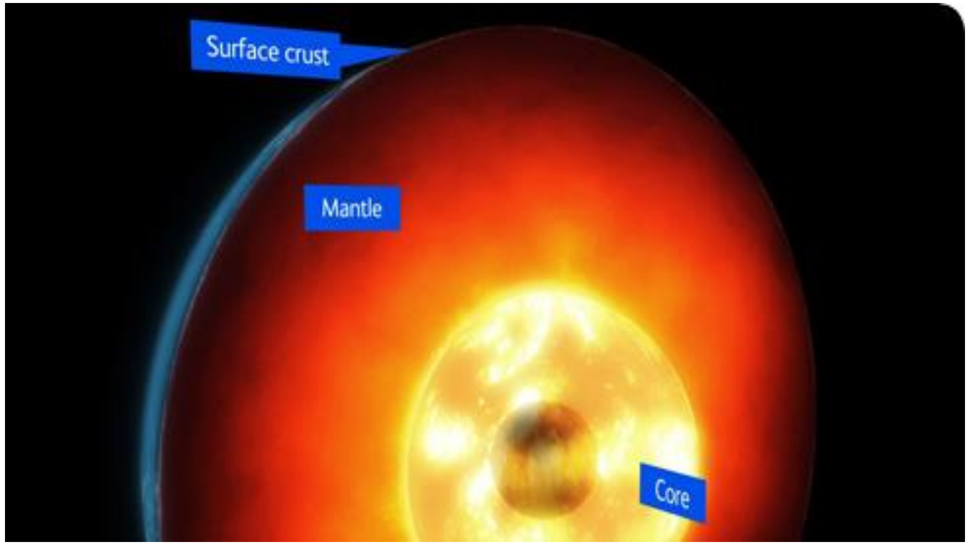
Hydrogen Isotopes of water in lunar volcanic glasses and melt Inclusions (2013) same as Earth rocks.

Revised **giant impact hypothesis** (2012): two bodies five-times the size of Mars collided, then re-collided, forming a large disc of debris that eventually formed the Earth and Moon.

Formation of Earth’s Layered Structure

Heat from **gravitational contraction, high-velocity meteorite impacts,** & **decay of radioactive elements** caused temperature of the Earth to increase

- **Iron** and **nickel** began to melt and sink toward the center
- **Lighter rock components** floated outward, toward the surface



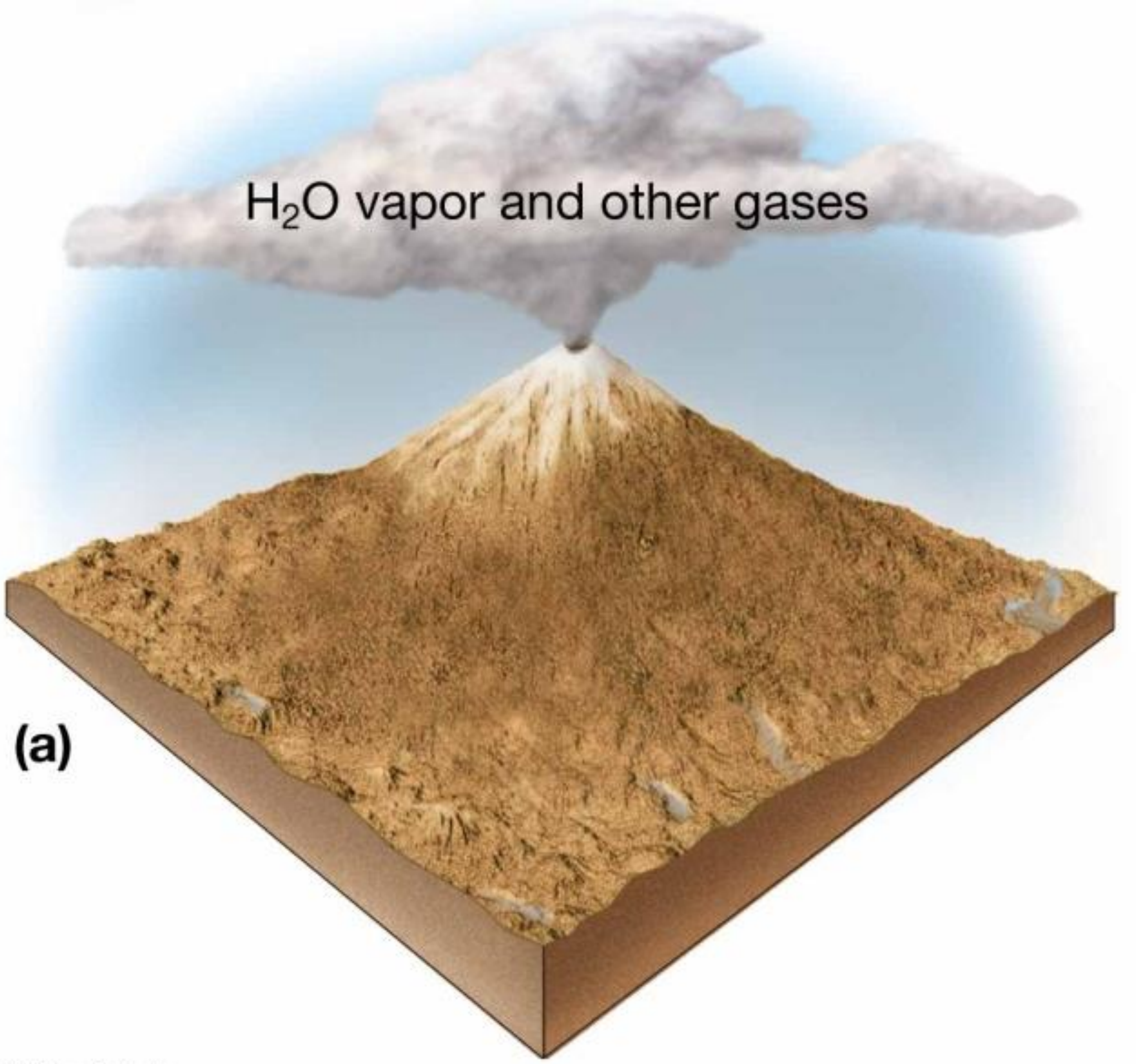
Origin of the Earth's Atmosphere

- mostly by **outgassing** process

Origin of Earth's Atmosphere

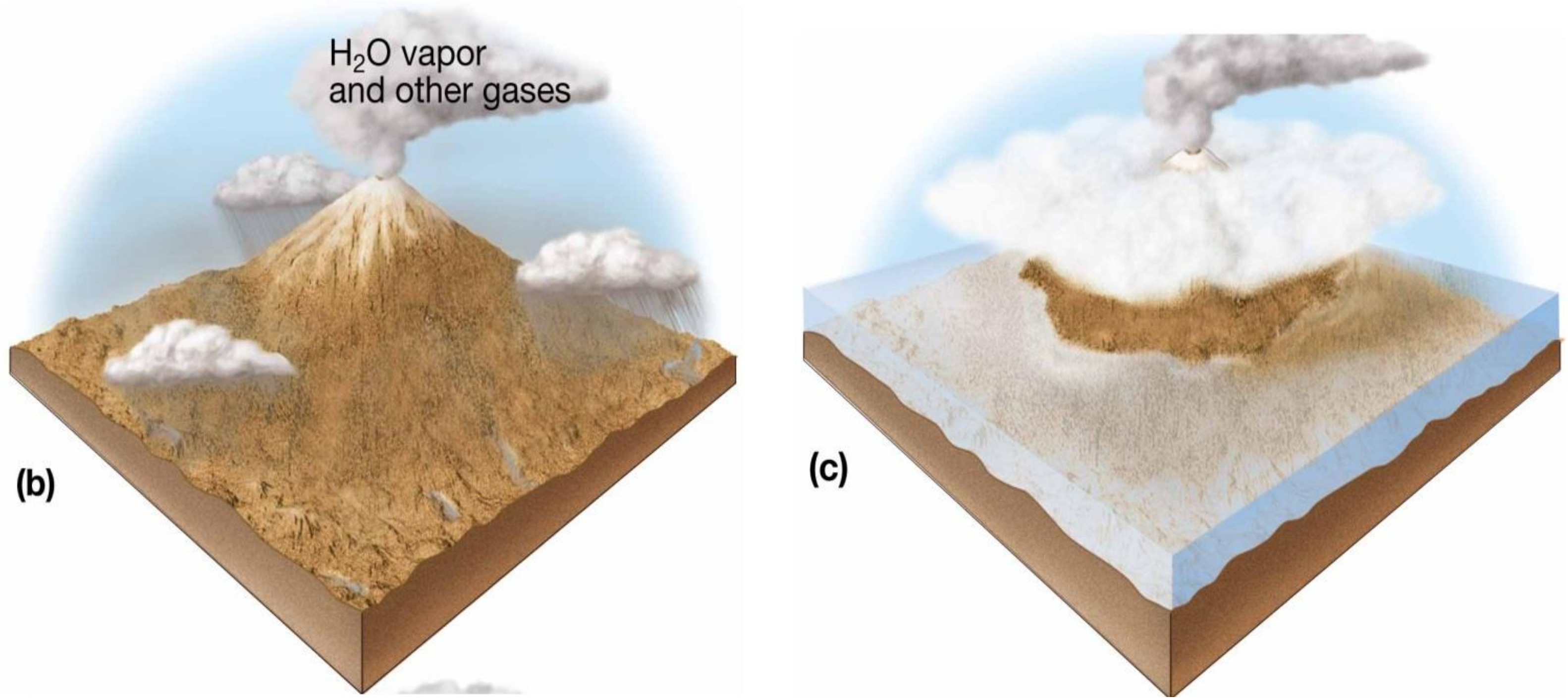
Outgassing

- Water vapor (H_2O)
- Carbon dioxide (CO_2)
- Other gases (N_2, Ar, H_2, S, Cl, CH_4, NH_3, etc.)



Origin of Earth's Oceans

- Outgassed vapor in the air condensed to form clouds and rainwater → formed the oceans

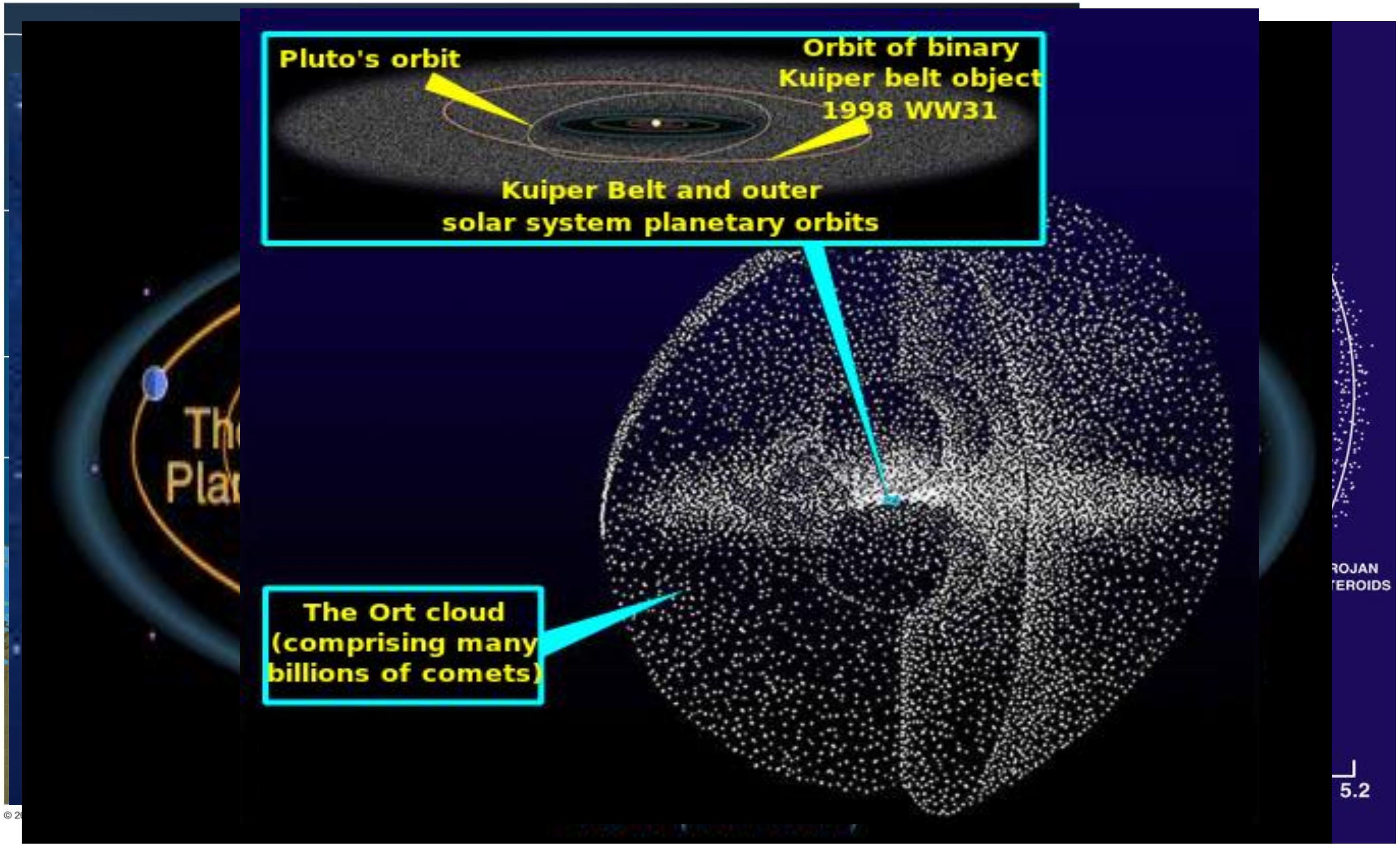


- **Other origin of water:** from **comets/asteroids?**

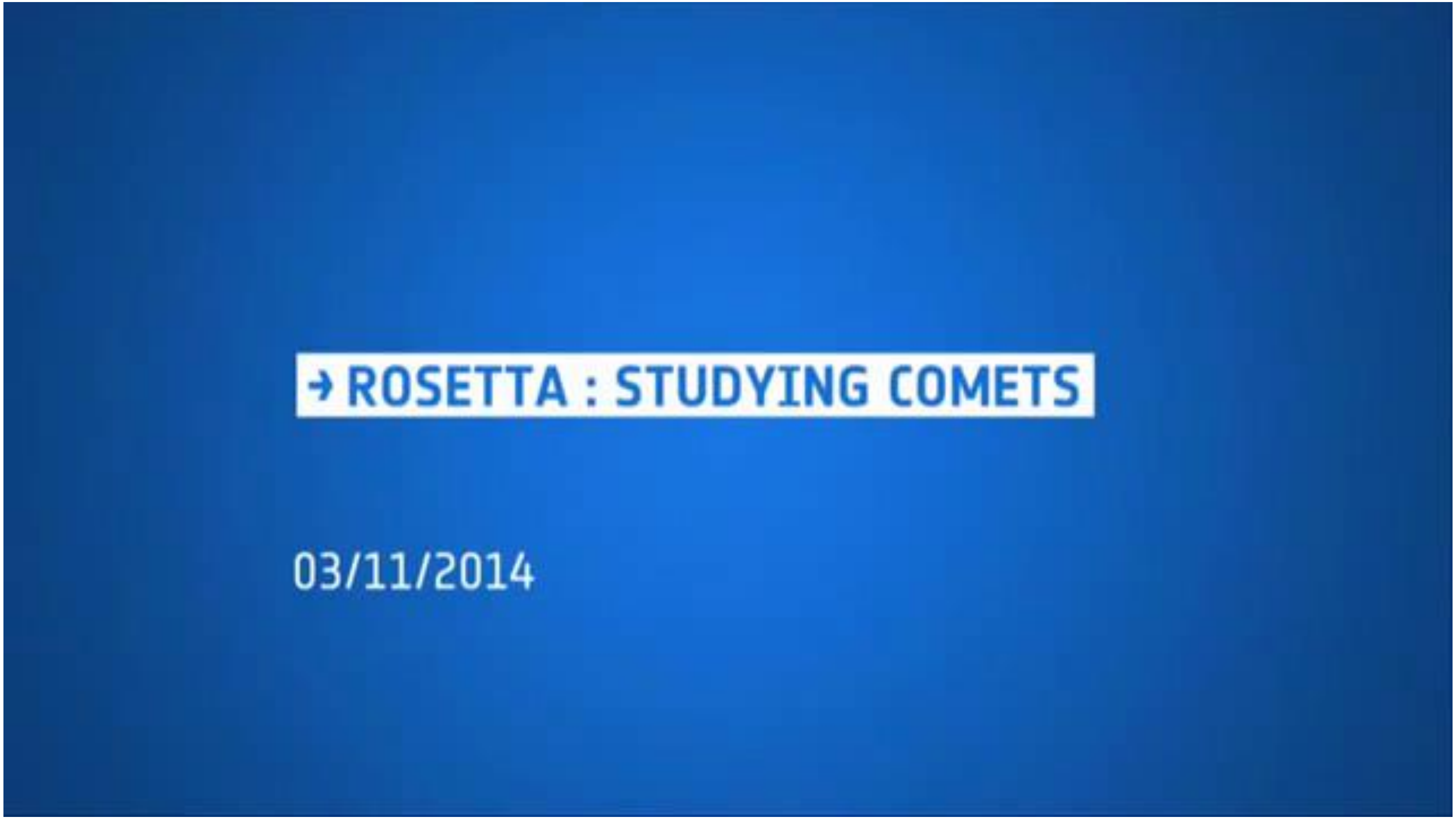
Hydrogen isotopes studies, (D/H ratio) i.e., Deuterium (^2H) to Protium (^1H) ratio

Sidebar

Meteor, meteorite, asteroid, asteroid belt, comet



Rosetta studying comets (67P by esa)



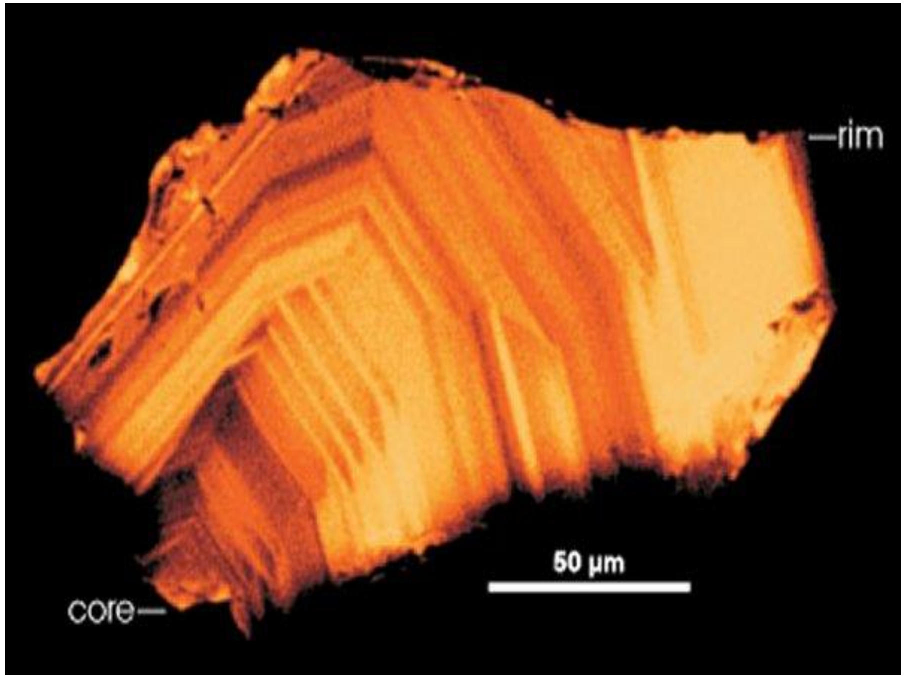
Timing of Events

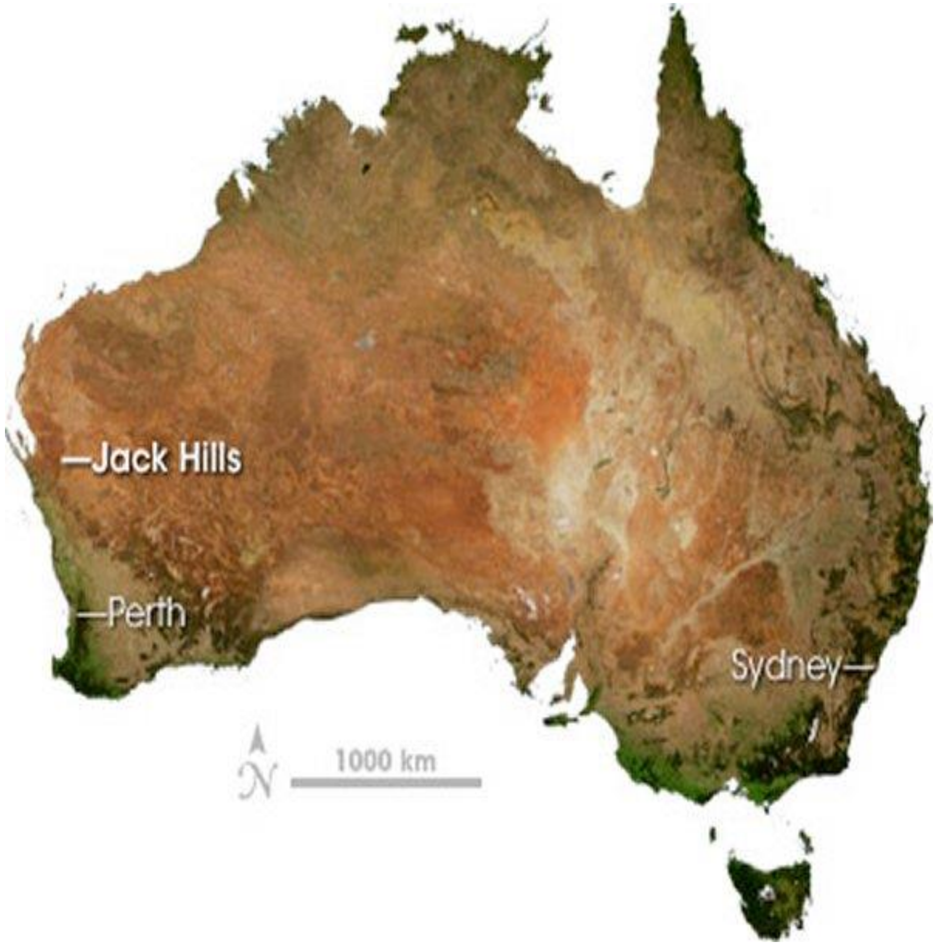
Earth’s Oldest Known Rocks: 4.03 Billion Years Old
Acasta Gneiss , Canada

Timing of Events

Earth's Oldest Known Minerals: 4.4 Billion Years Old

Zircon grains in metamophosed sandstone in Western Australia





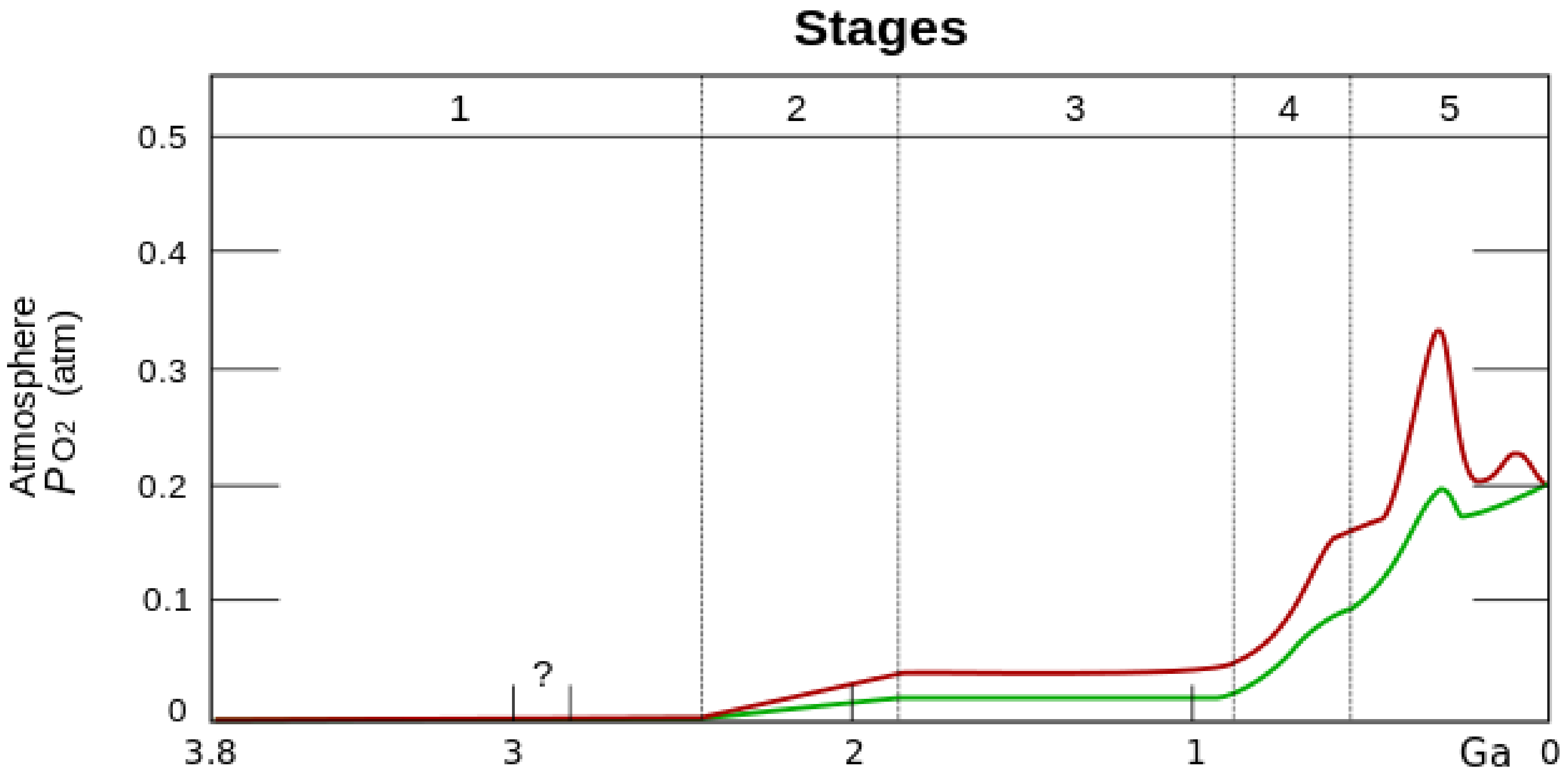
Life's Possible Ocean Origins

- The earliest evidence for life found so far is in a 3.8 billion-year-old rock, the Isua sediments, found in western Greenland
- Earth's earliest known life forms: 3.5-billion-year-old bacteria fossilized in ocean rocks

Stromatolites, Western Australia

Earth's early atmosphere different from today

Early Earth's atmosphere: No O_2 ; higher H_2O & CO_2



O_2 build-up in the Earth's atmosphere. **Great Oxygenation Event** happened around 2.3 billion years ago. Red and green lines represent the range of the estimates;

Atmosphere characteristics in early Earth (~ 4.5 to 3.5 billion years ago) and current Earth

	Early Earth	Current Earth
$T_{average}$ (^oC)	290	16
P (bars)	60	1
CO_2 Abundance	98%	0.039%

What happened to the huge amount of CO_2 gas that was in the early Earth's atmosphere ?

$H_2O + CO_2 \leftarrow \rightarrow H_2CO_3$

$H_2CO_3 \leftarrow \rightarrow H^+ + HCO_3^- \leftarrow \rightarrow 2\ H^+ + CO_3^{-2}$

Chemical weathering:

e.g., $CaSiO_3 + 2\ H^+ <-> Ca^{2+} + SiO_2 + H2O$

Formation of Calcite in the ocean

$Ca^{2+} + CO_3^{2-} \leftarrow\rightarrow CaCO_3$

Most of the CO_2 from the early Earth are now bounded in mineral **Calcite and stores in limestone.**