

EESC 2200
The Solid Earth System

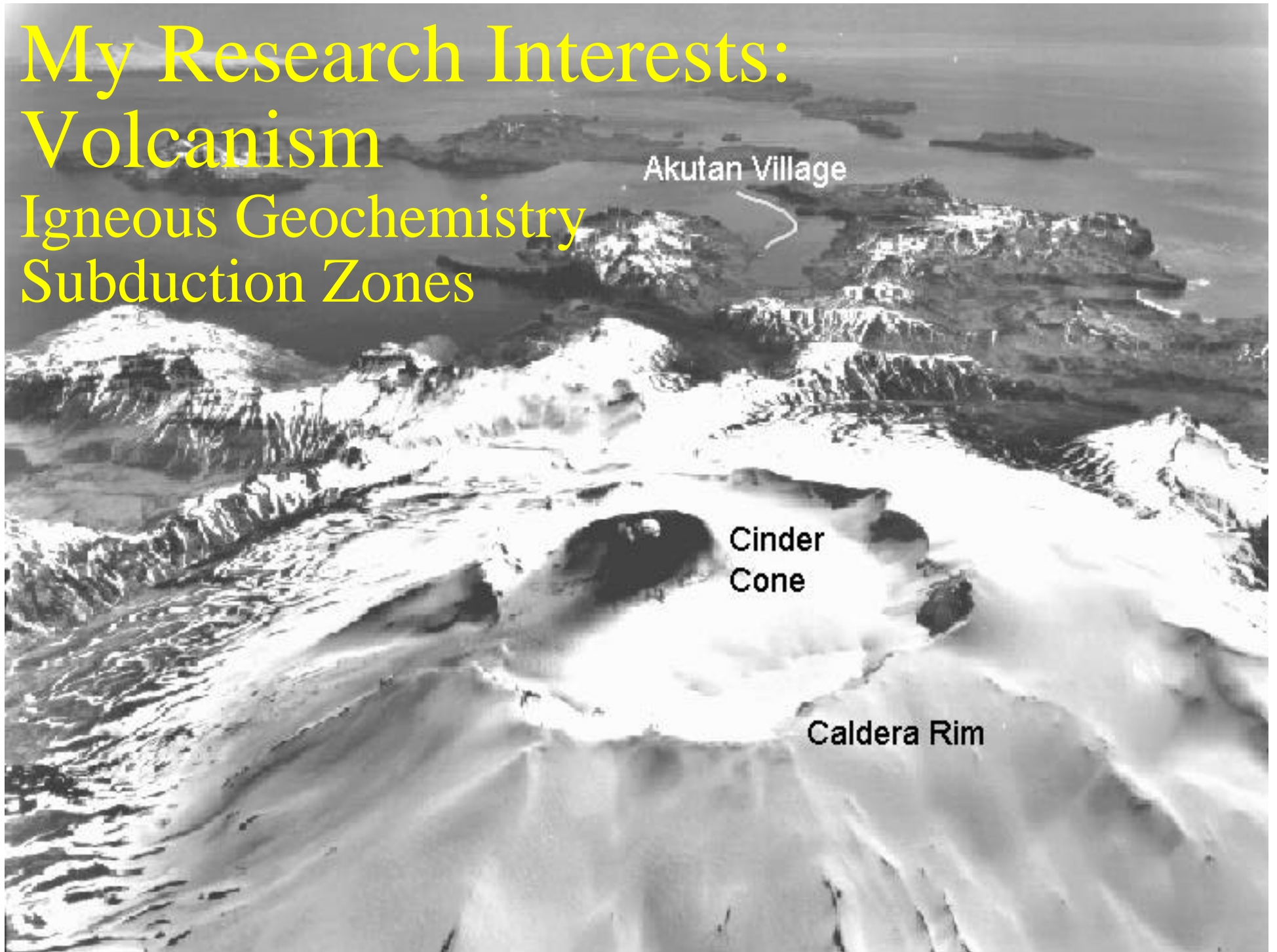
Office Hours: before class, faculty or student lounge

Questionnaire

Volcano field work in Alaska

My Research Interests: Volcanism

Igneous Geochemistry
Subduction Zones





Bering
Sea

Seguam
island





1977 Eruption on Seguam Island, Alaska



US Coast Guard photo; Pyre Peak; 1054 m

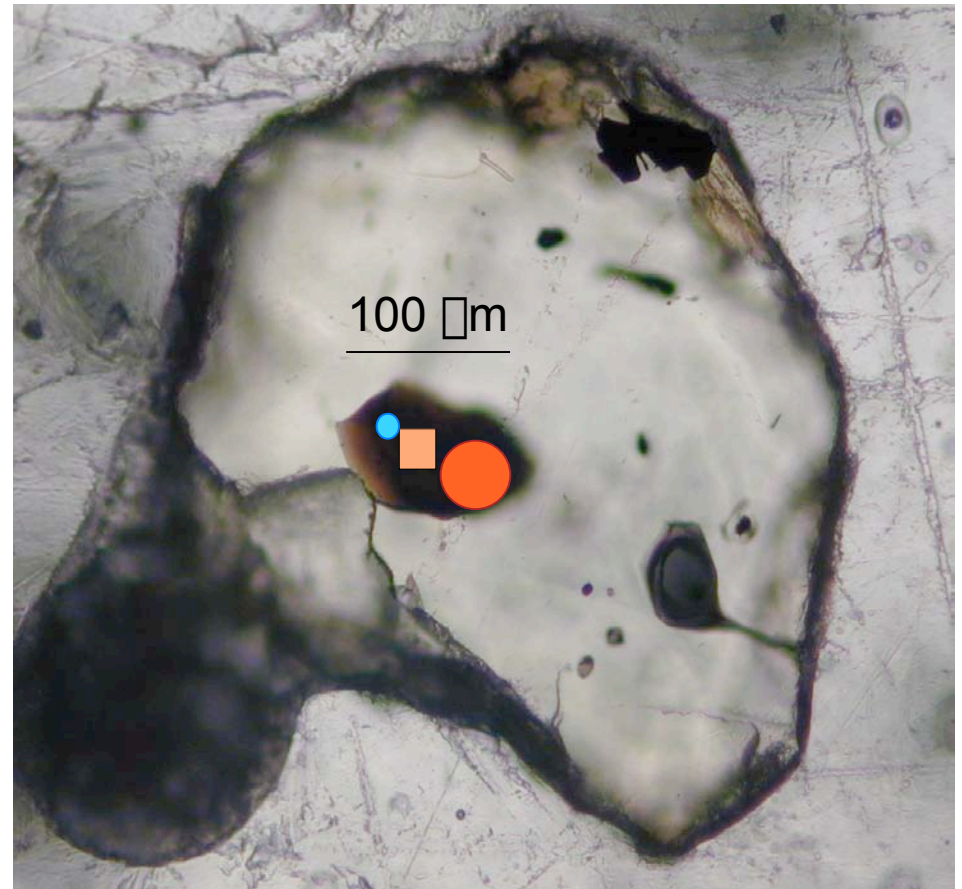
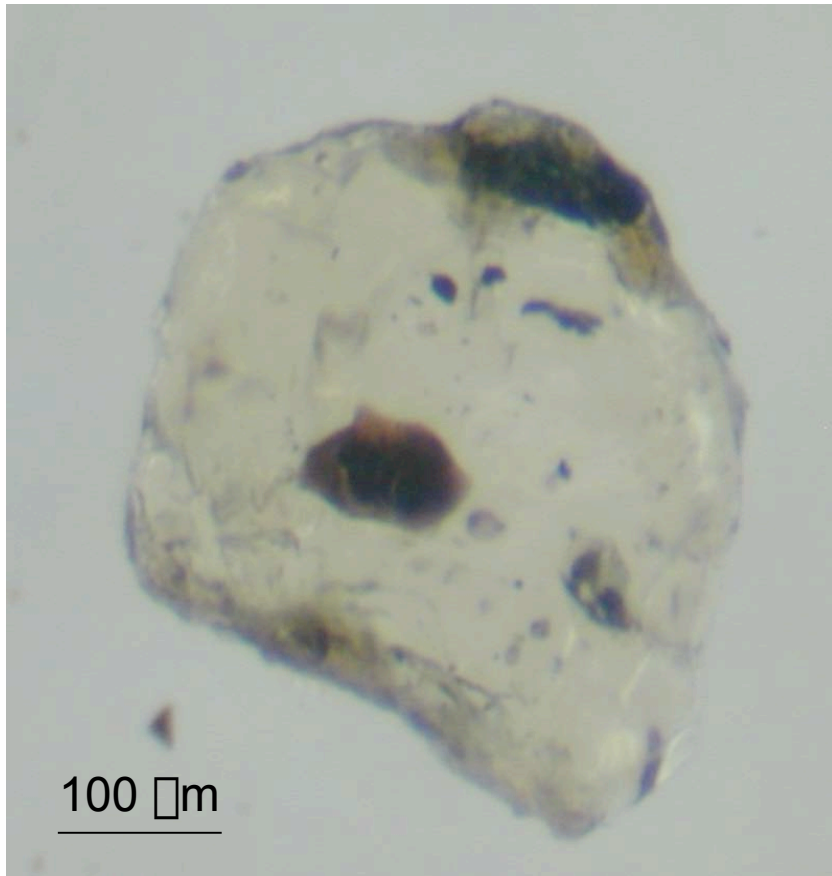






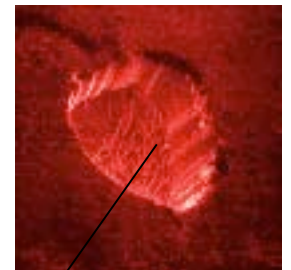
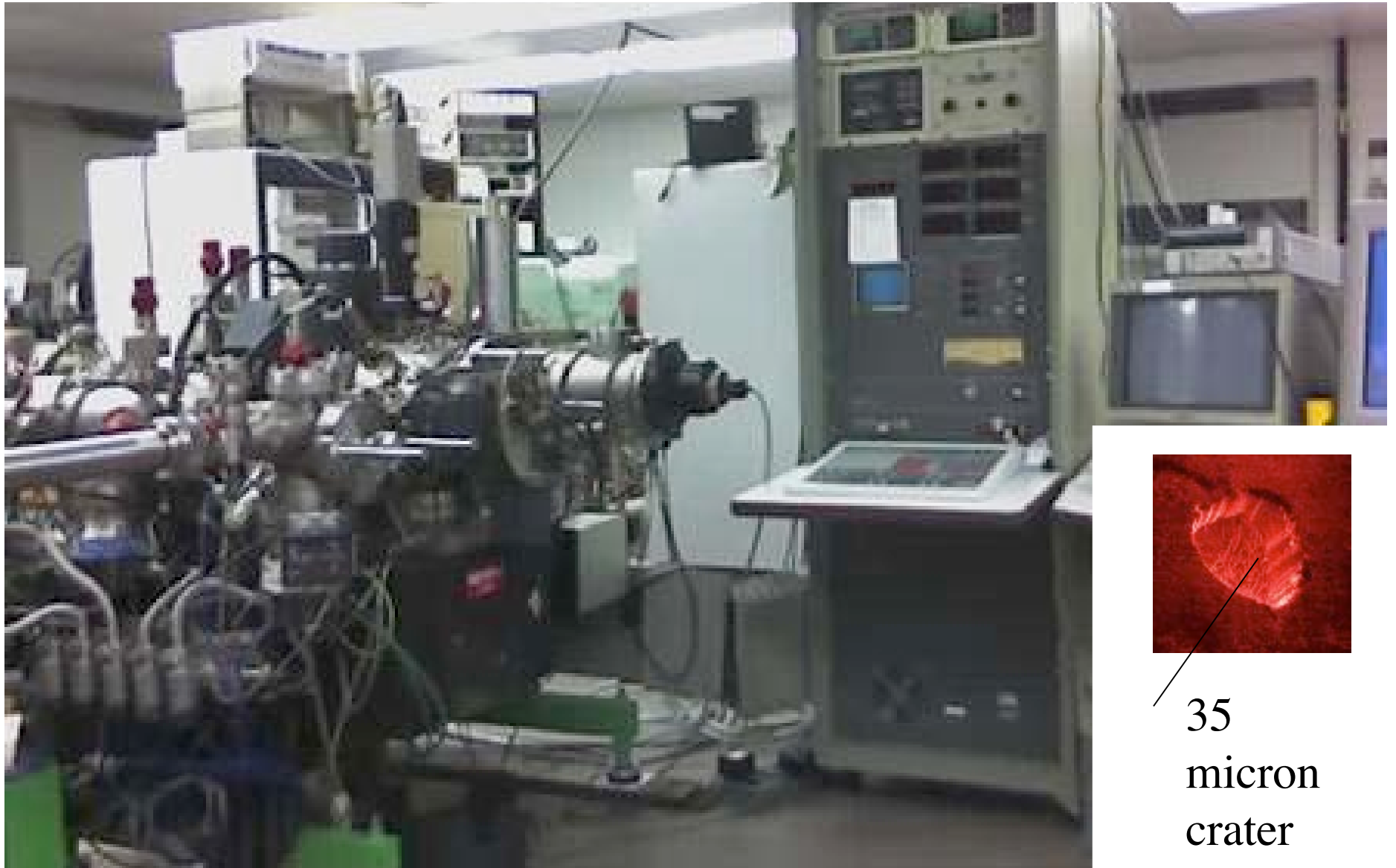


Olivine crystal
With melt inclusion



Spots analyzed with
ion microprobe, electron microprobe,
and laser ablation ICPMS

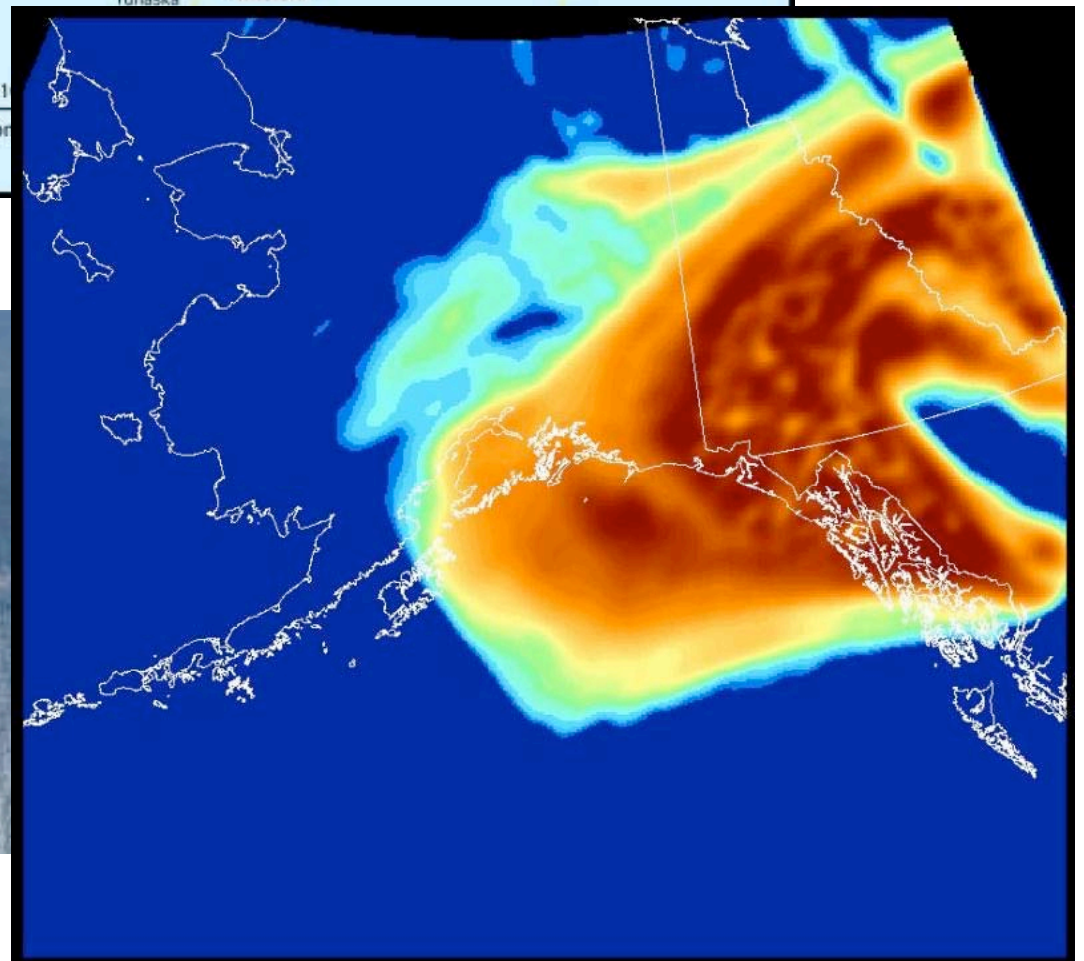
Ion Microprobe, Carnegie Institution of Washington



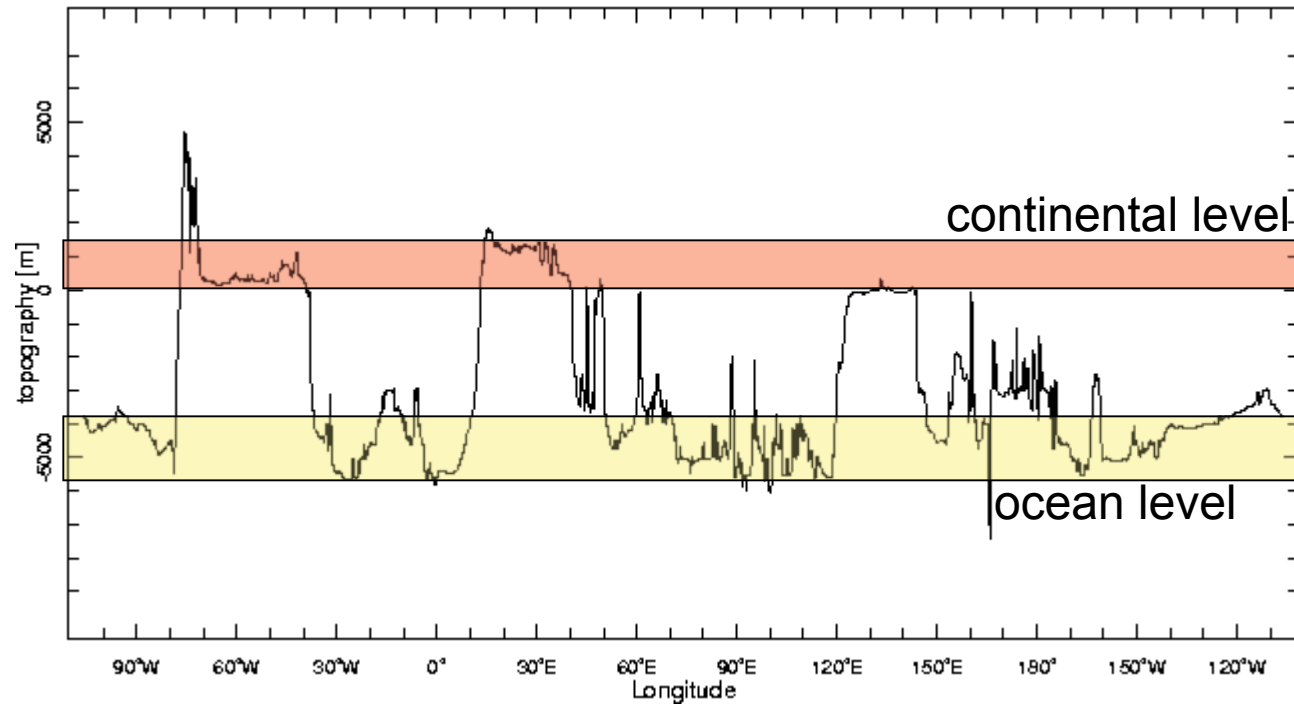
35
micron
crater



August 2008 eruption of Kasatochi



Earth Hypsometry

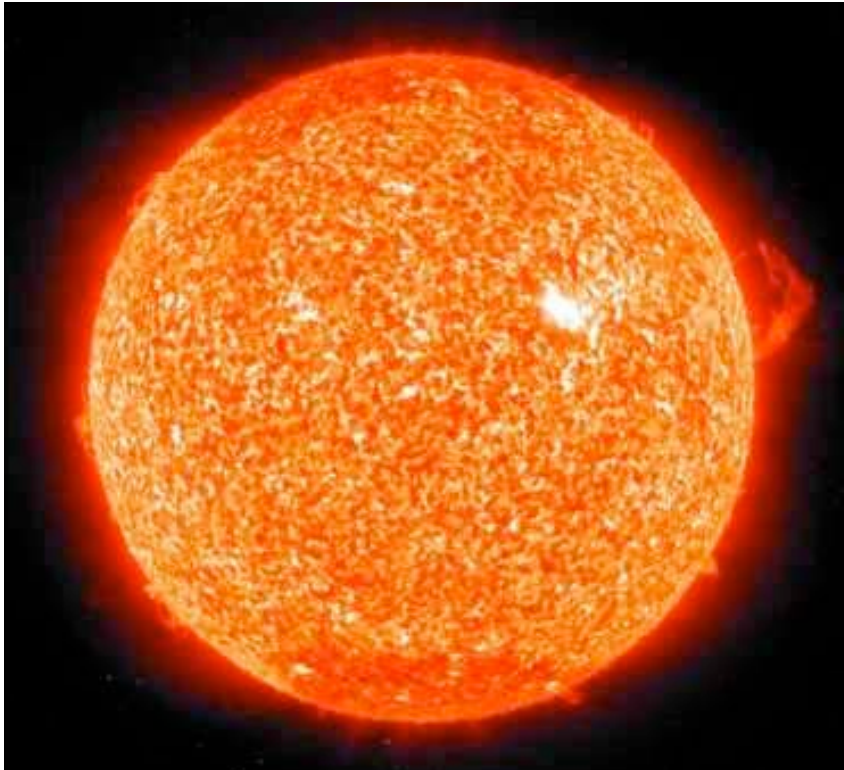


Simple observation.....complex cause



Composition and Structure of the Earth

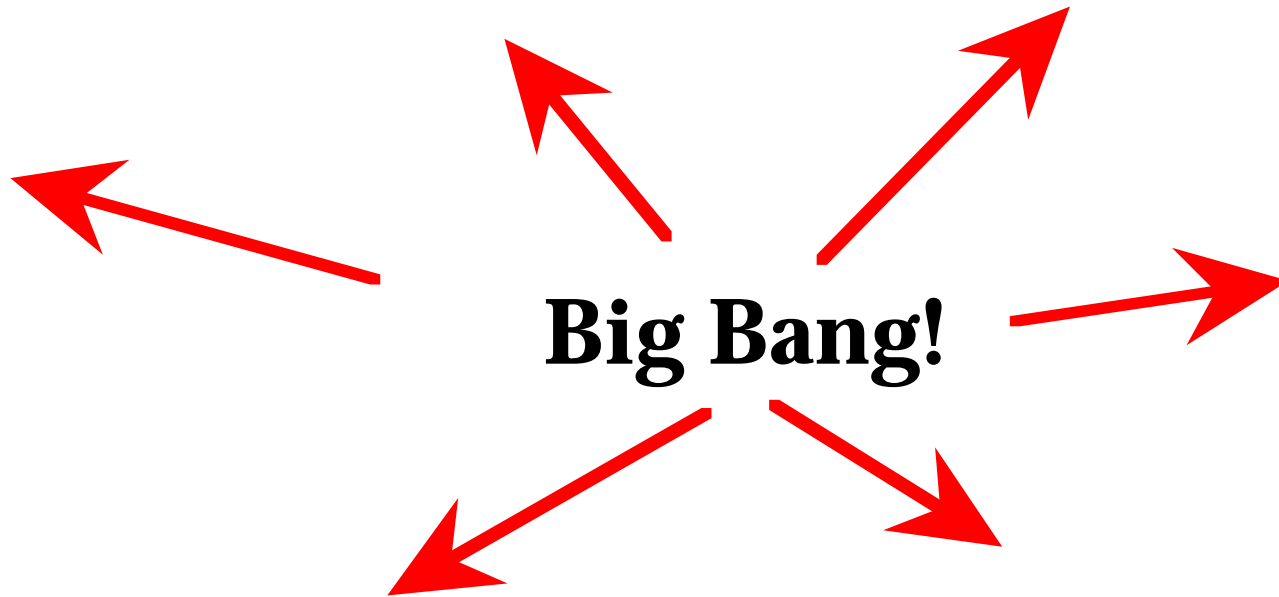
What is the Sun made of?



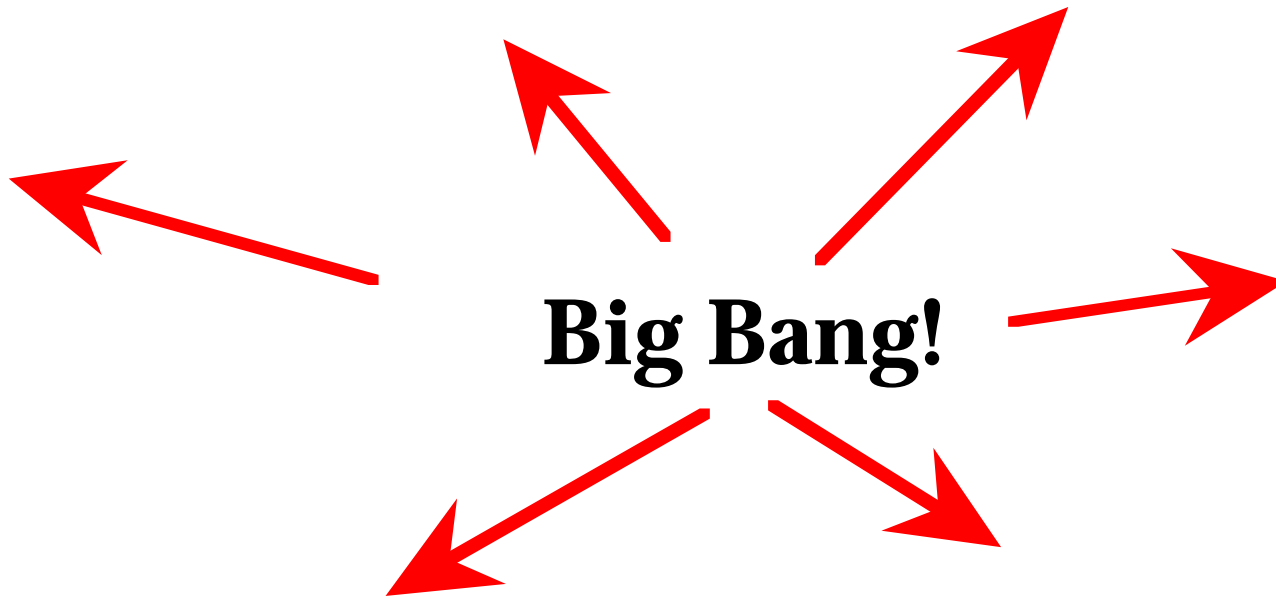
What is the Earth made of?



Top elements are.....



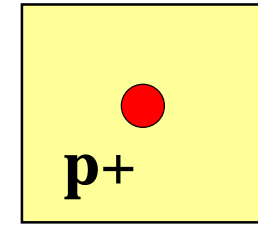
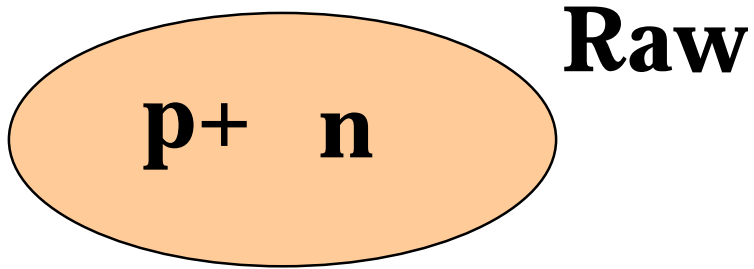
~ 14 Ga
All matter
expanding universe



neutrons



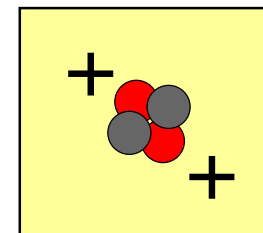
half life = 12 min



**Hydrogen
nucleus**

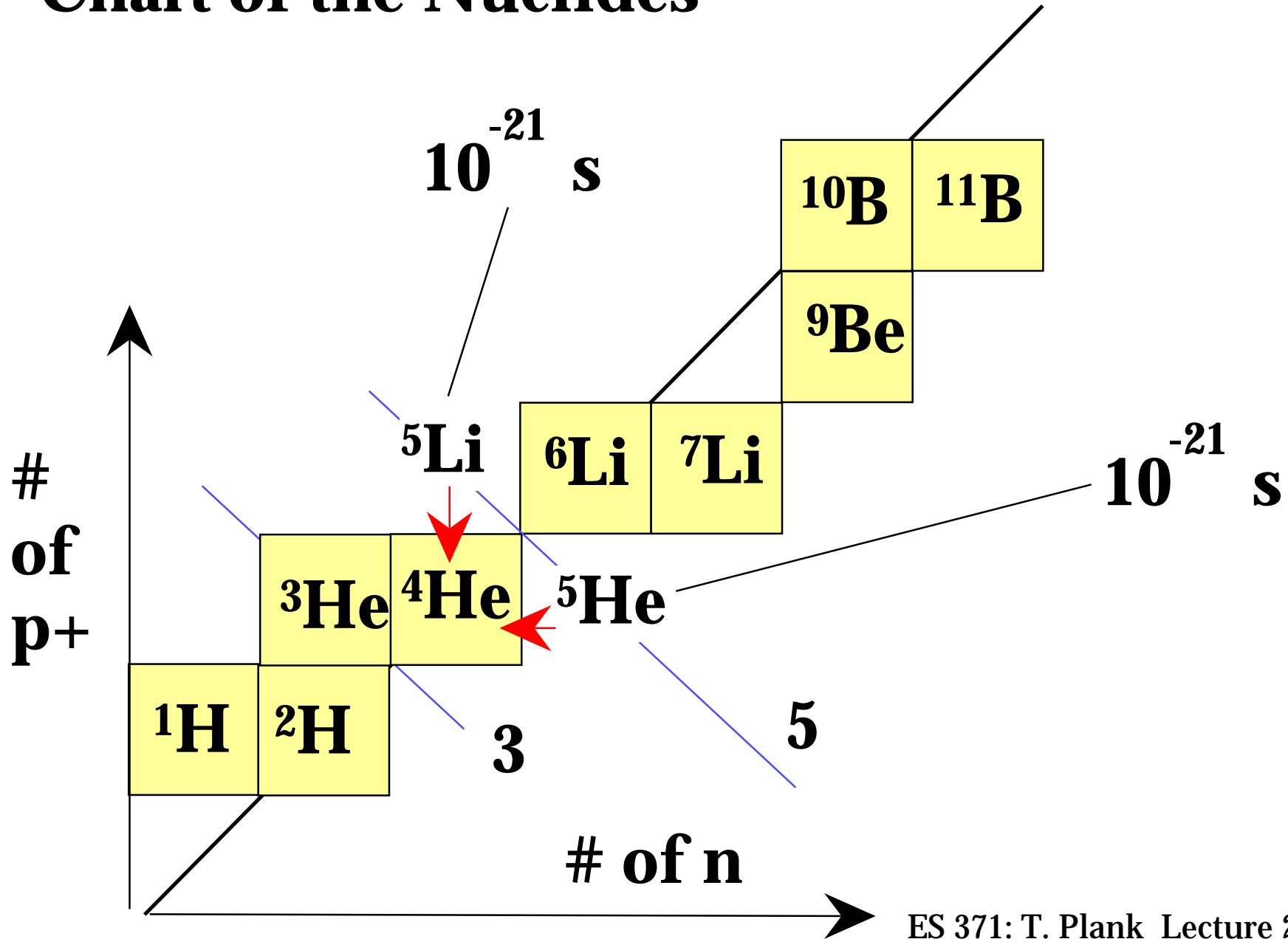


**Helium
nucleus**



why not keep going?

Chart of the Nuclides



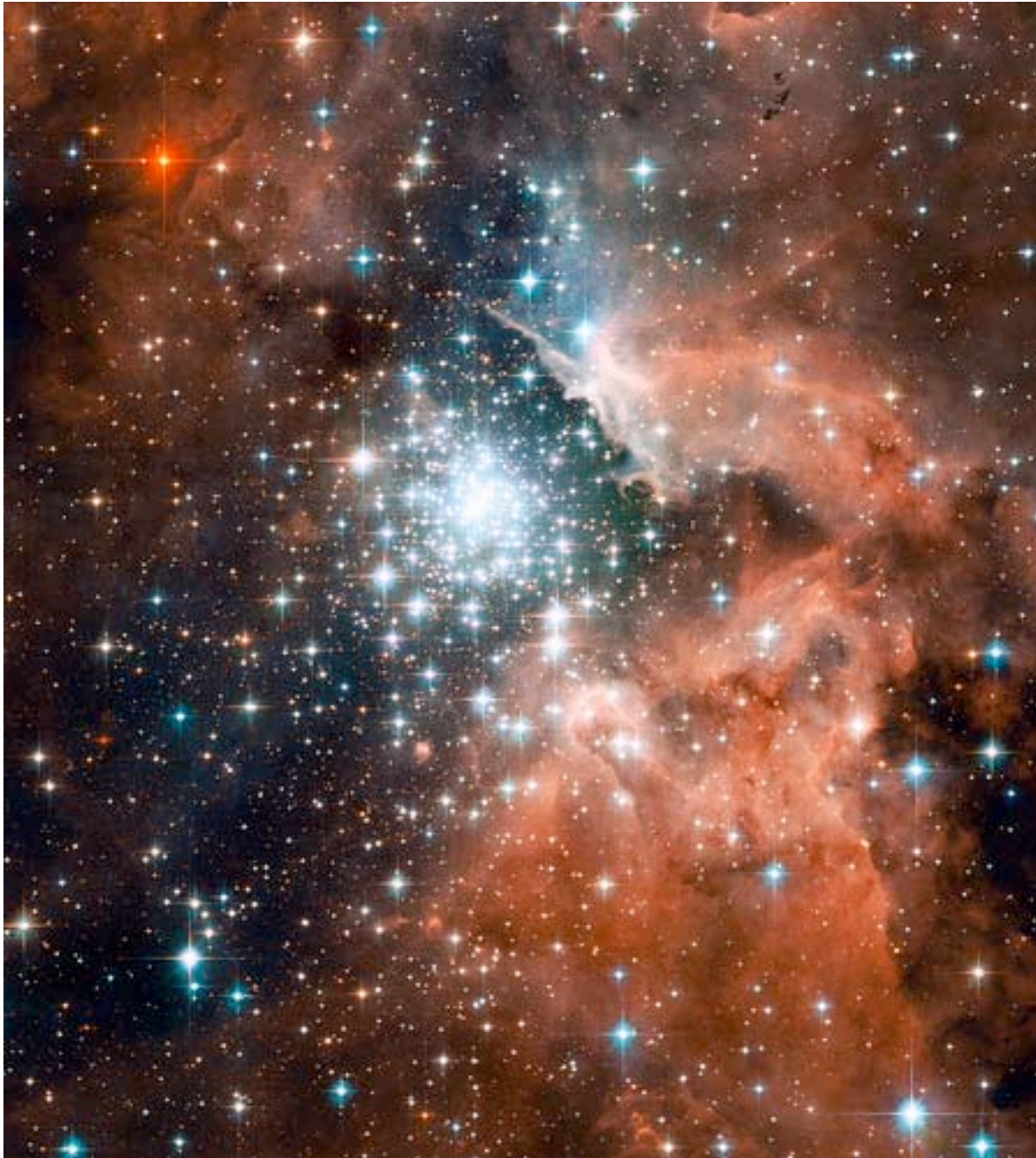
Day One

75% H nuclei

25% He nuclei

Interstellar Gas Clouds



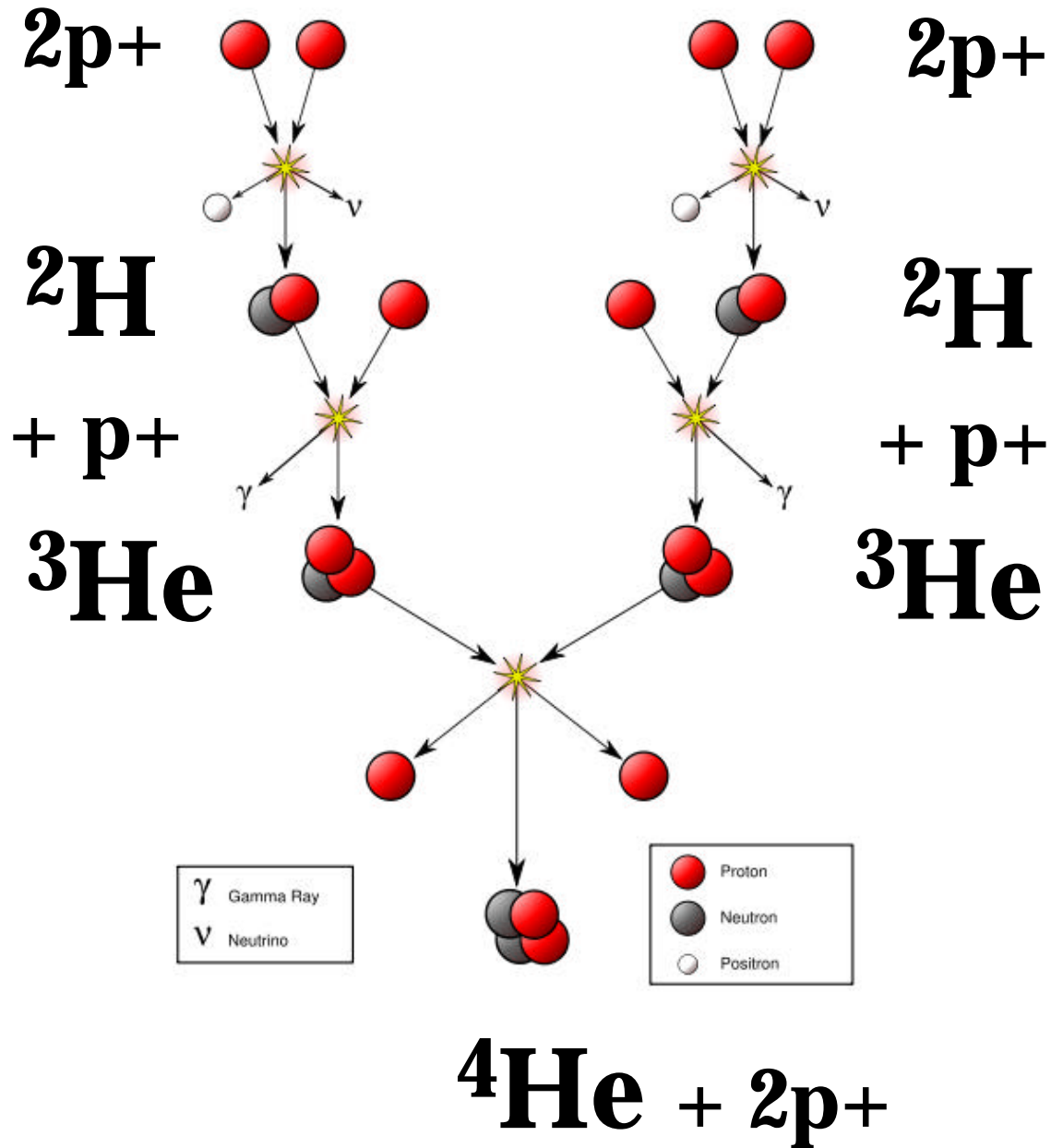


Gas clouds
coalesce
to form
first stars

Density
increases ->
 $T > 60 \text{ M K}$

Fusion!

H burning



net: $4p^+ \rightarrow {}^4\text{He}$

H burning

"Nuclear fire"

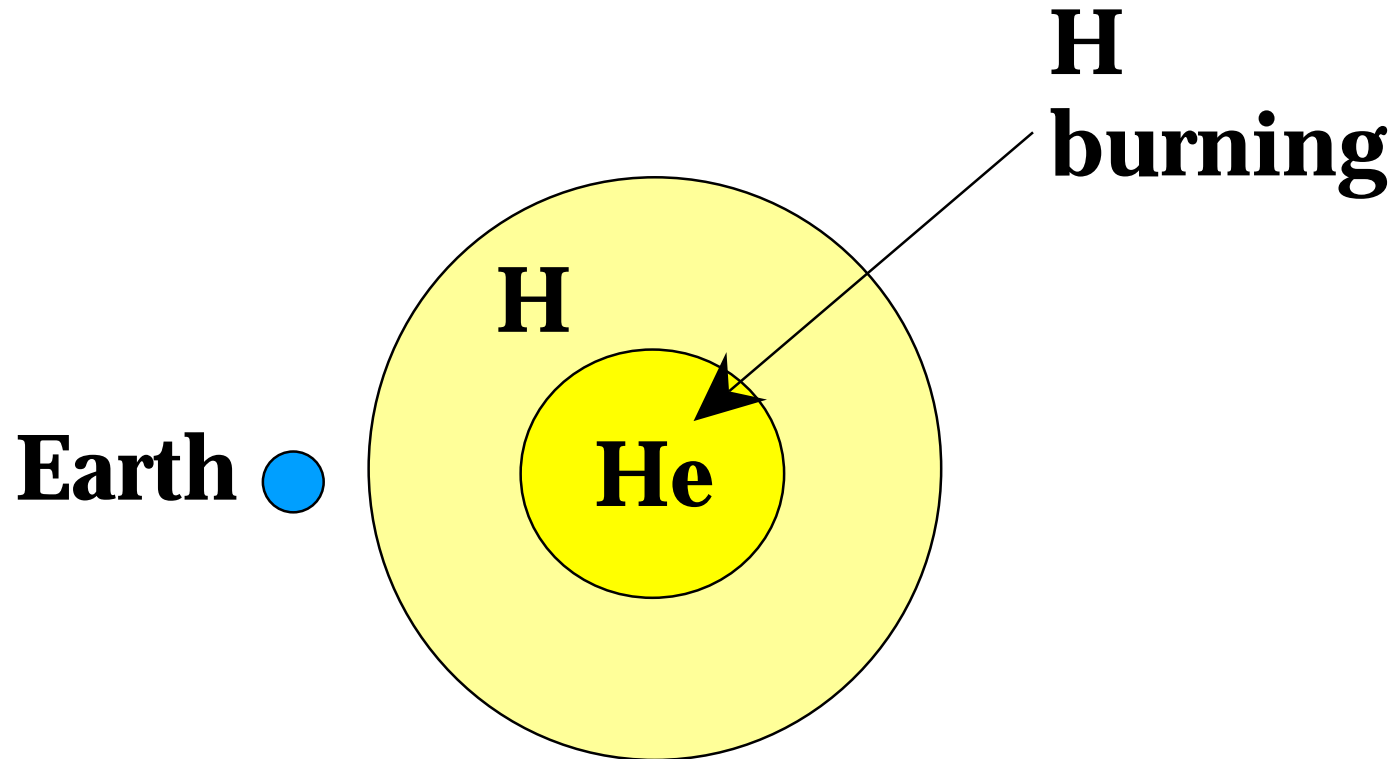
net: $4 p^+ \rightarrow {}^4\text{He}$

$$4 \times {}^1\text{H} = 6.696 \times 10^{-24} \text{ g}$$
$$1 \times {}^4\text{He} = 6.648 \times 10^{-24} \text{ g}$$

$$\mathbf{E = mc^2 !!}$$

$$\mathbf{+ 26.7 \text{ MeV}}$$

our Sun



but what happens eventually?

**Super
Giant**

**Unburned
H**

**He
burning**

**C
burning**

**Ne
burning**

**O
burning**

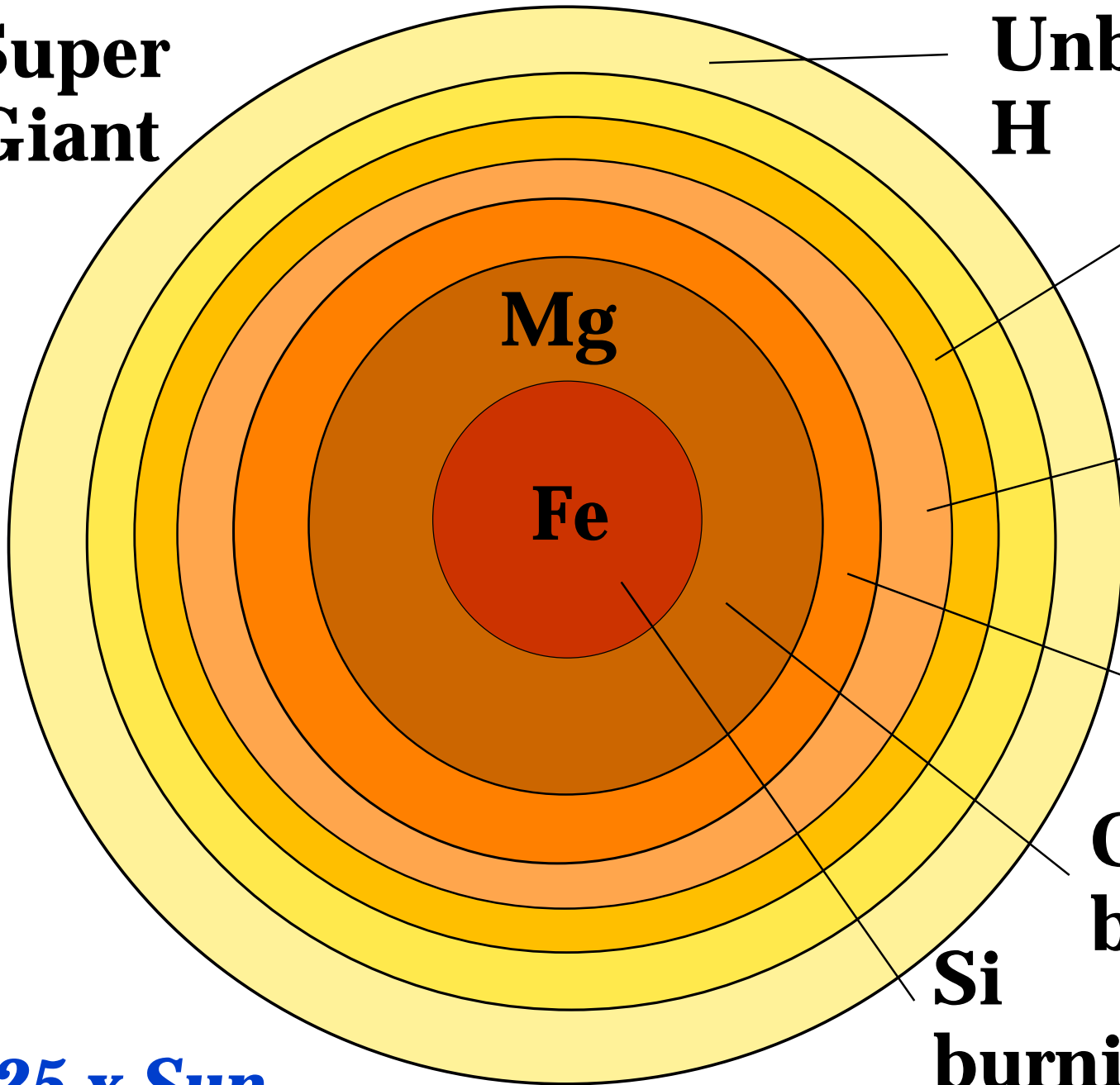
**Si
burning**

Mg

Fe

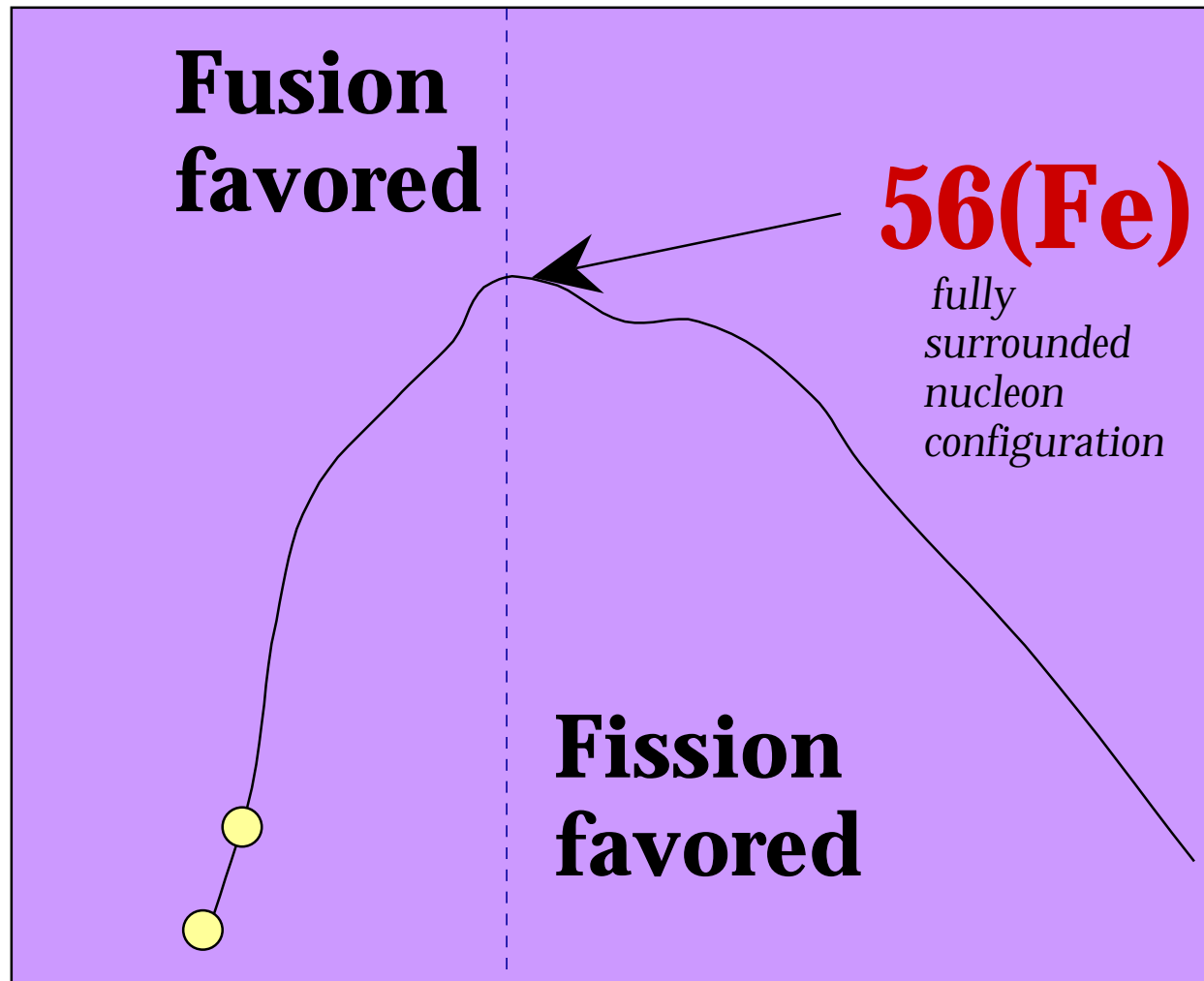
25 x Sun

ES 371: T. Plank Lecture 2



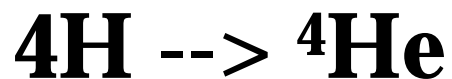
Binding Energy per Nucleon

E needed to pull a nucleon from the nucleus



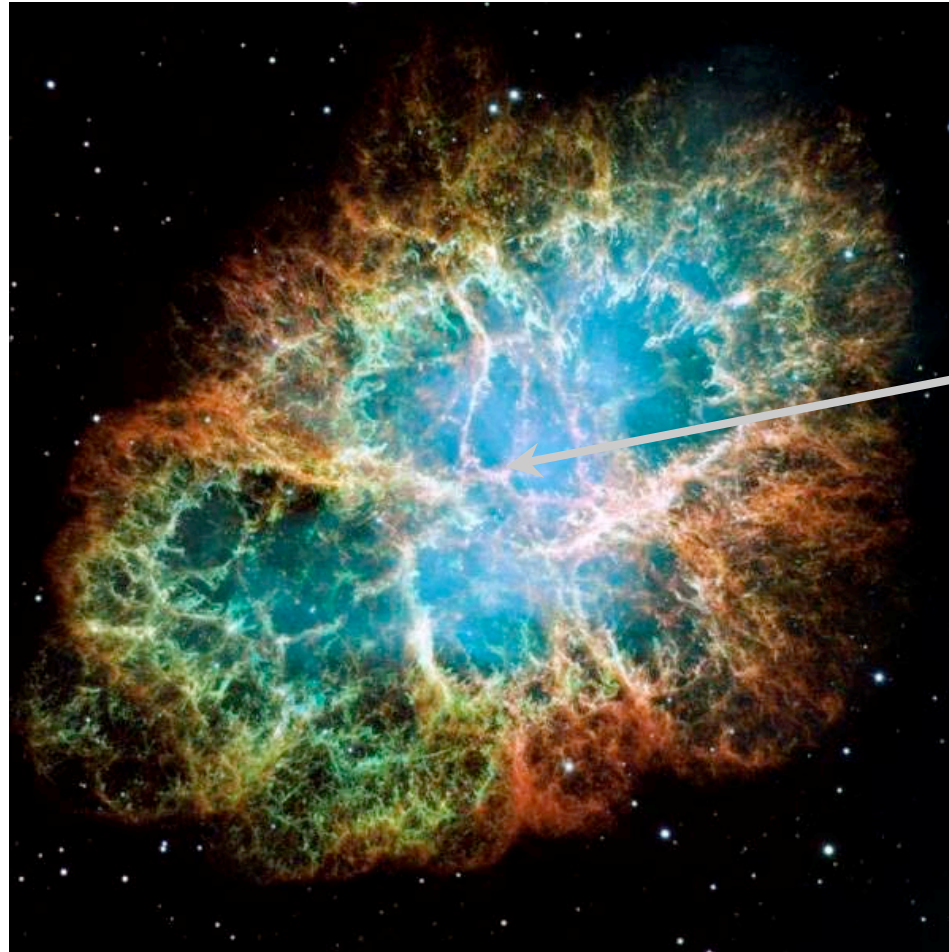
A (p+n)

Strong nuclear force vs. electrostatic force



Supernova!

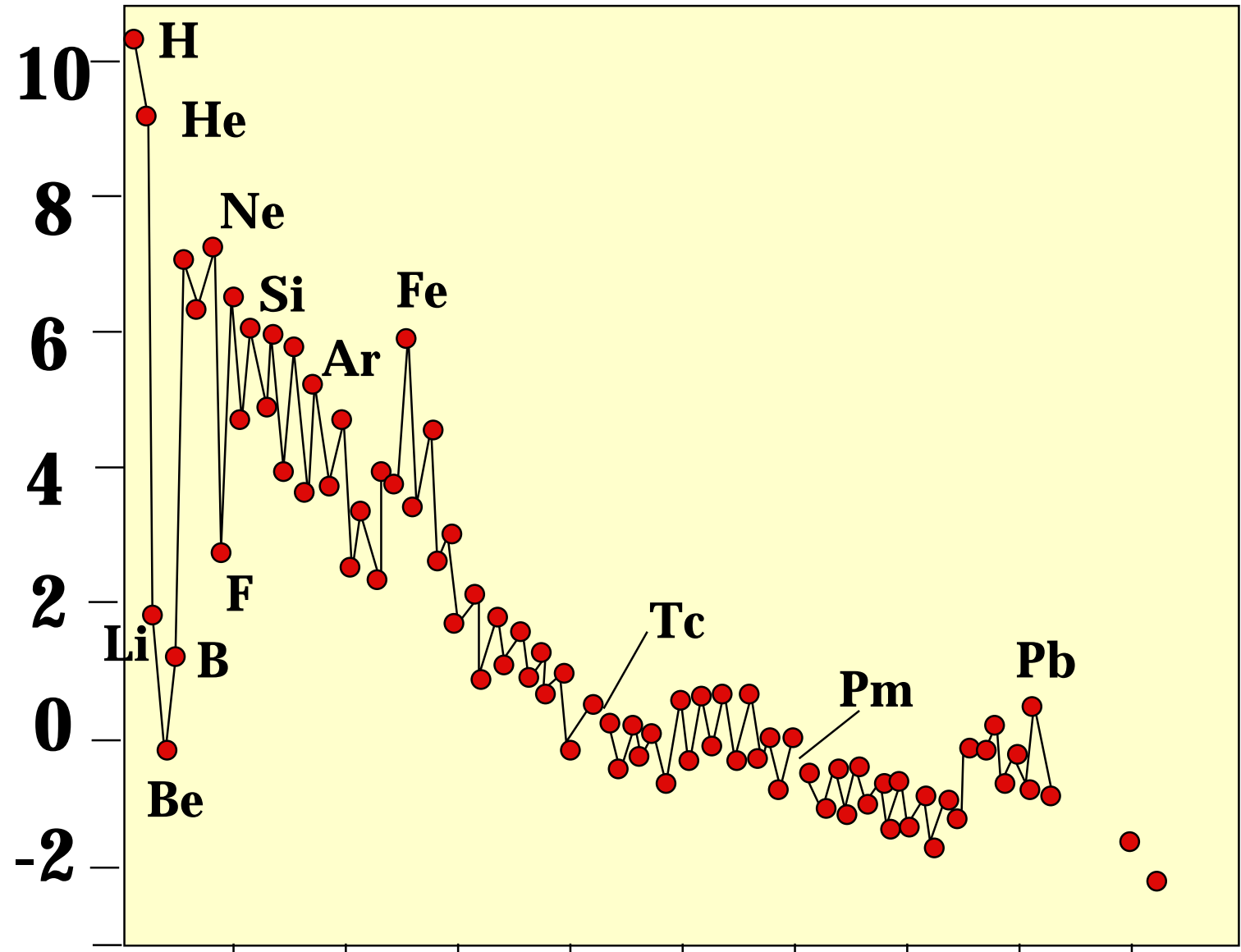
- *Heavy element factory*
- *Element dispersal system*



Original star
is just tiny
dot center

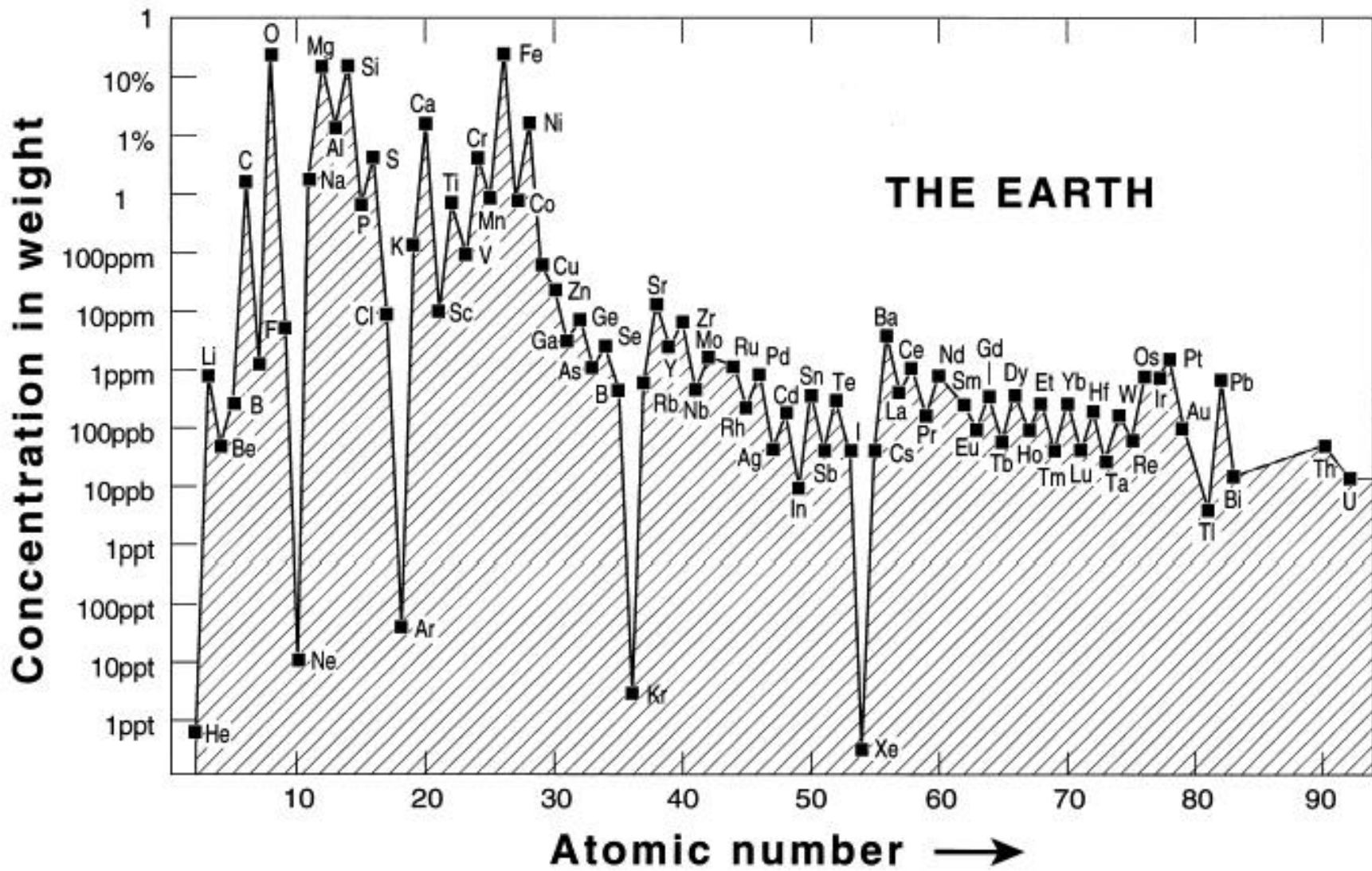
*Crab Nebula: Supernova Remnant 6,500 light years away
seen by Chinese and Japanese astronomers (with naked eye!) in 1054*

Log Abundance (solar)



10 30 50 70 90

Atomic # (Z)

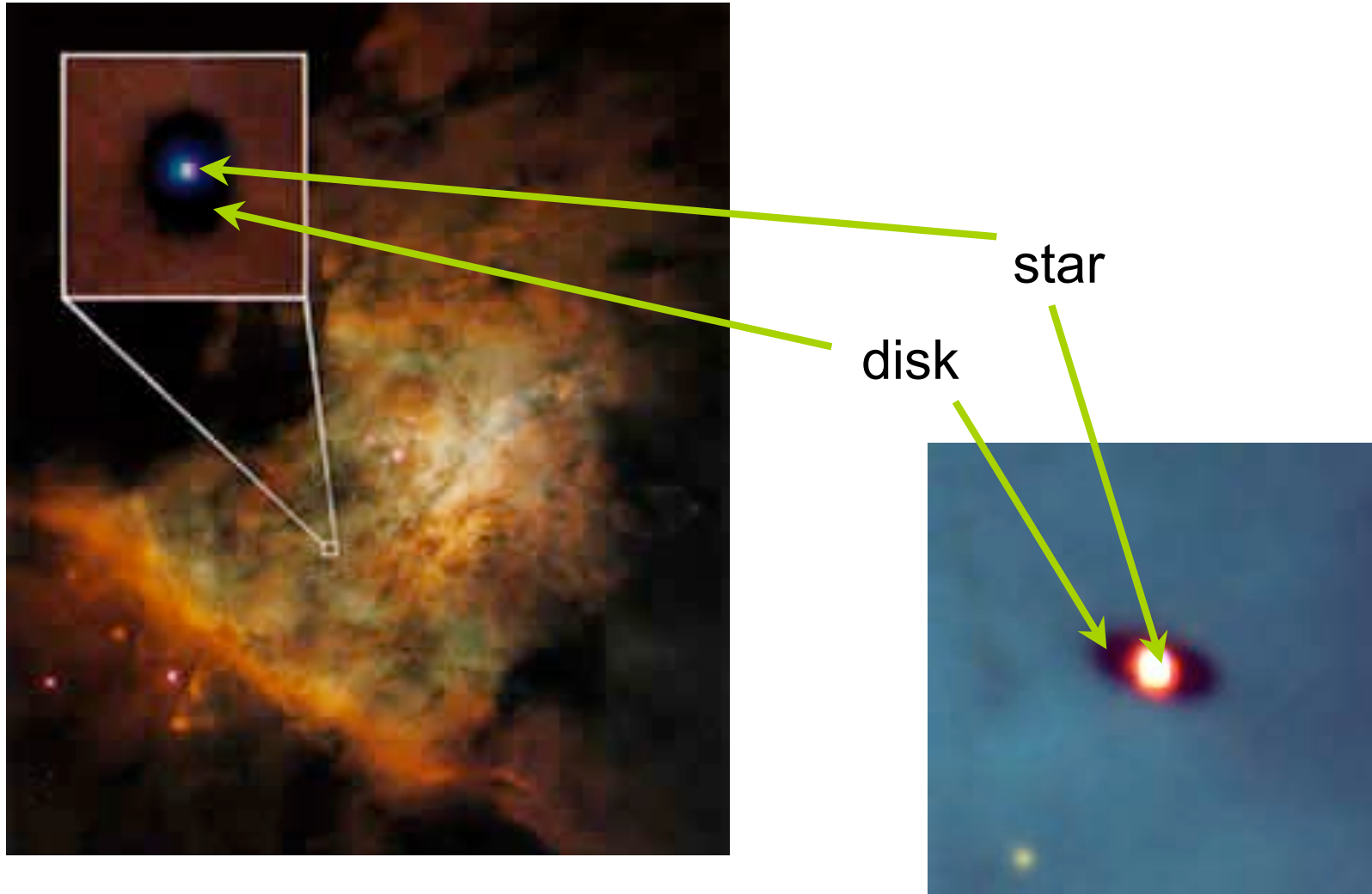


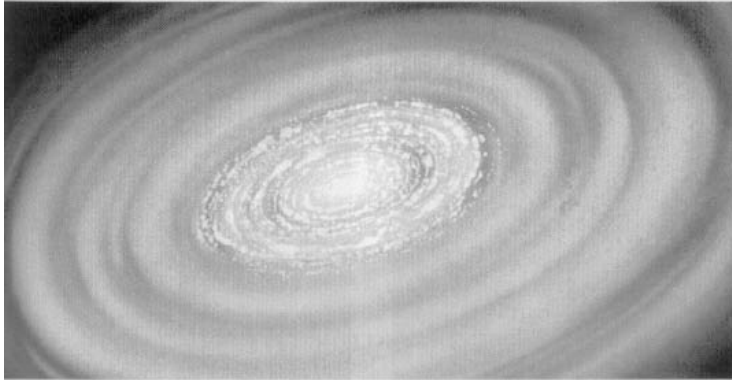
Birth of a solar system



Hubble Space Telescope view of a portion of the Orion Nebula showing five young stars surrounded by gas and dust trapped as the stars formed, that might evolve to planets.

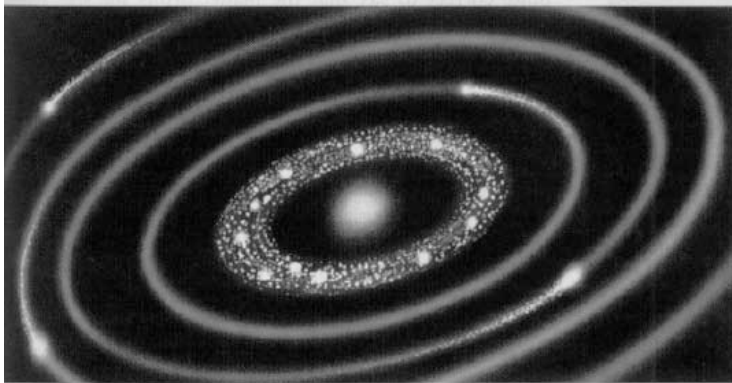
Accretion disk and star



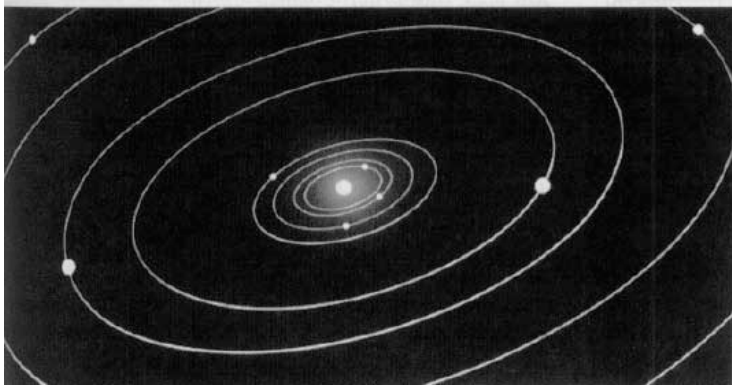


4.56 Ga

Evolution of the accretion disk into the sun and planets

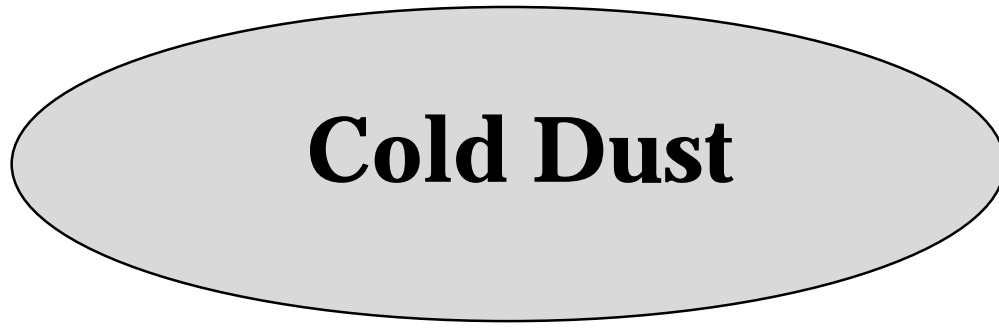


Explains why all planets orbit in the same plane and in the same direction



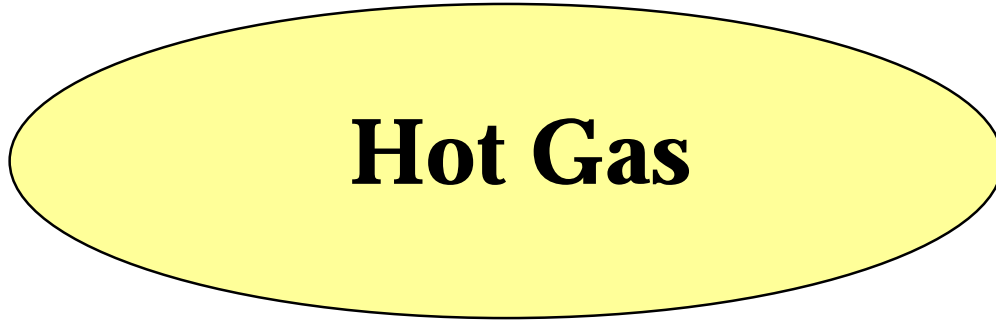
solar wind blows light elements away from inner solar system, explains their low abundance in inner solar system

time



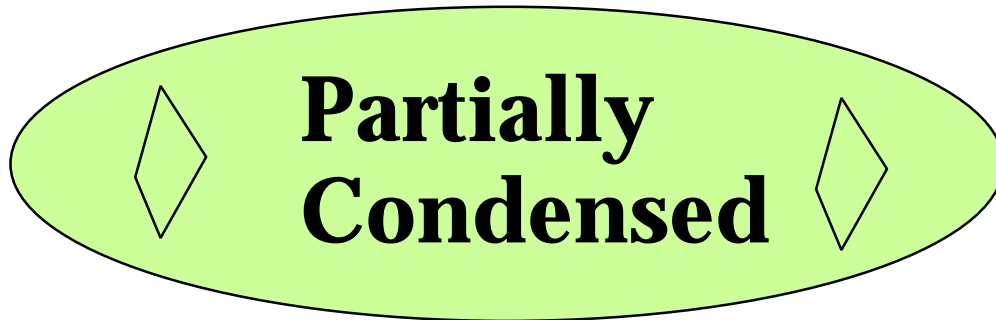
Cold Dust

initial



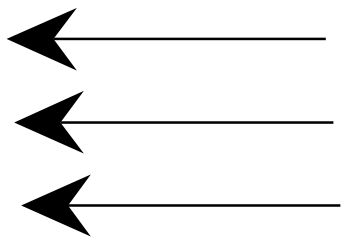
Hot Gas

**grav.
heating**

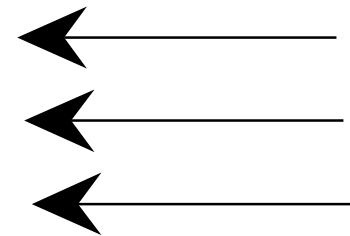


**Partially
Condensed**

cooling



**solar wind
leaves condensates**



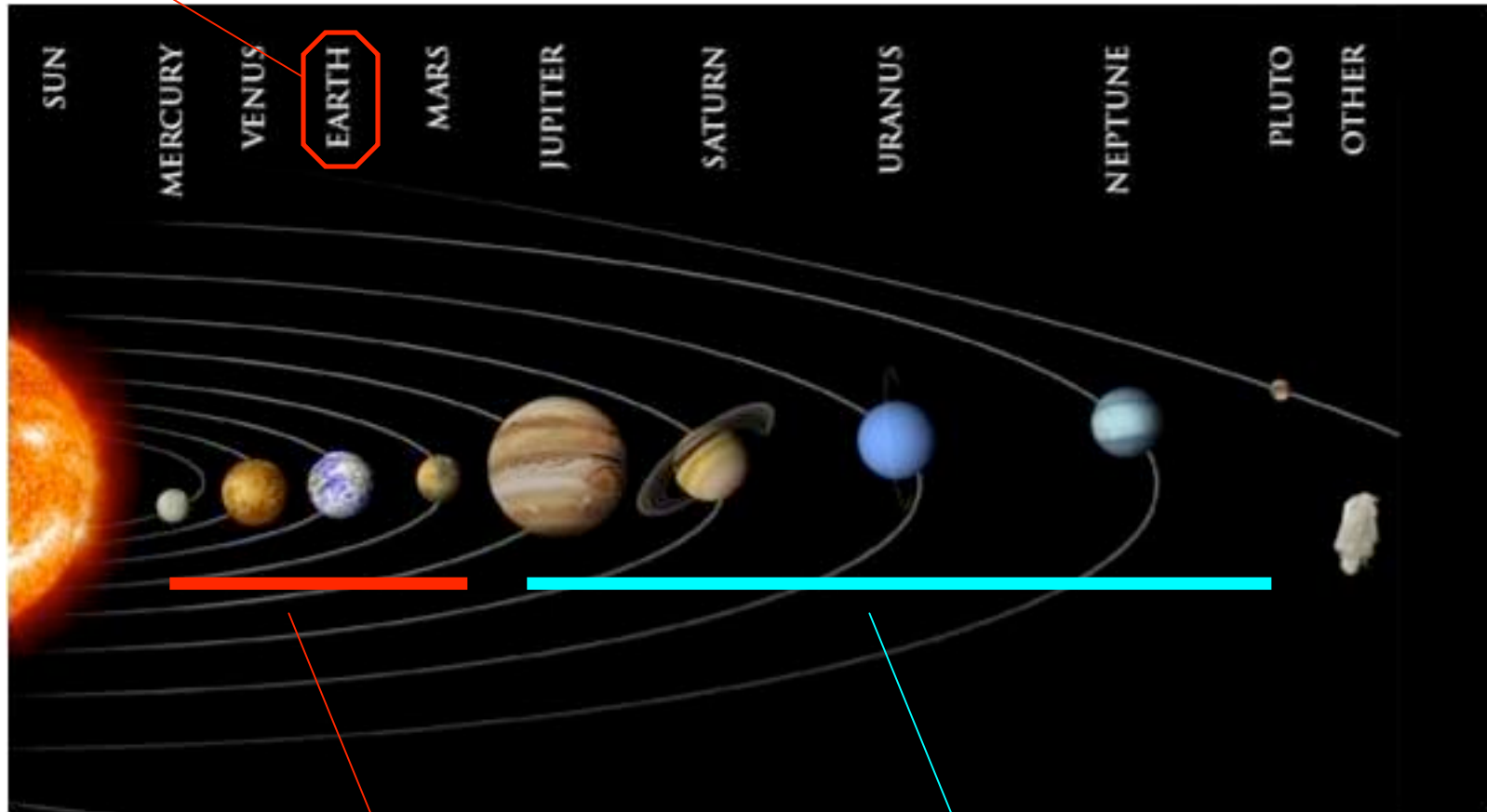
Composition of the Terrestrial Planets

85% = ^{16}O , ^{24}Mg , ^{28}Si , ^{56}Fe

- **Primary solar abundances**
- **Solid vs. Gas**

home sweet home

our solar system



Terrestrial planets

Mostly heavy nuclei

Outer solar system

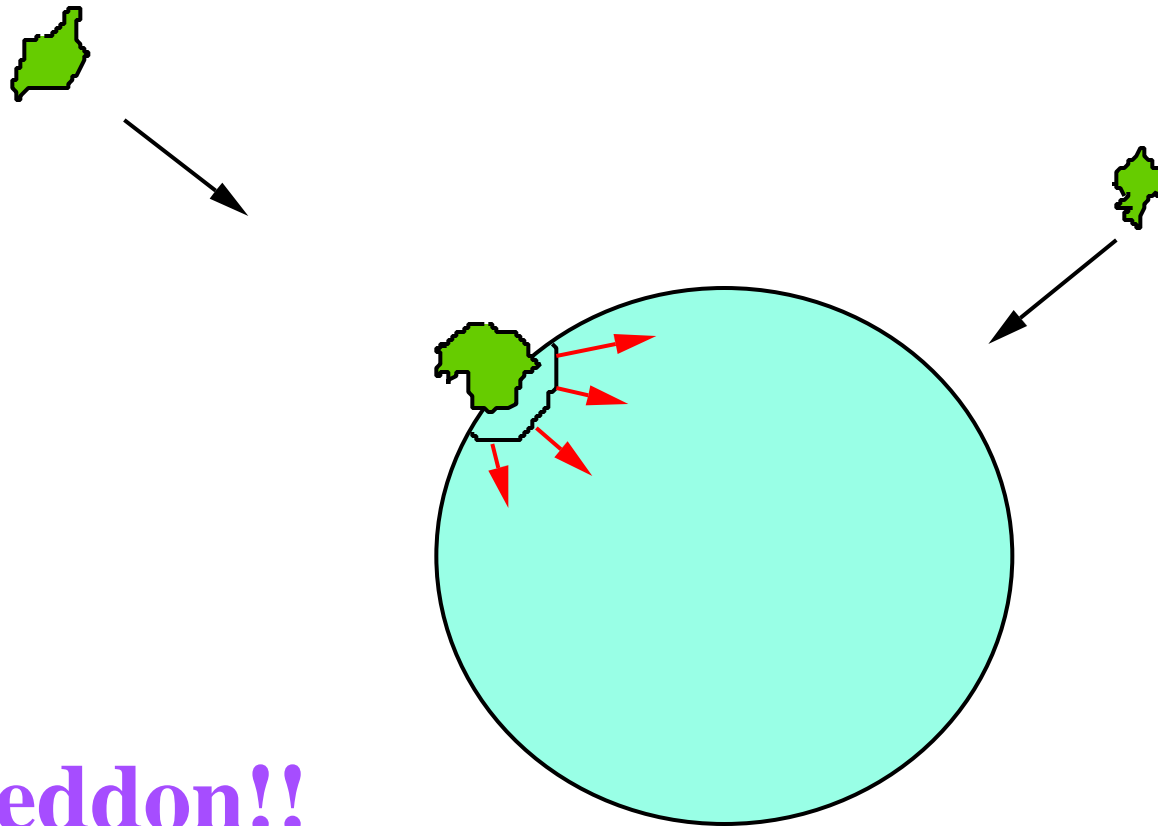
Lots of H and He

Eris (Xena): New Dwarf Planet '06



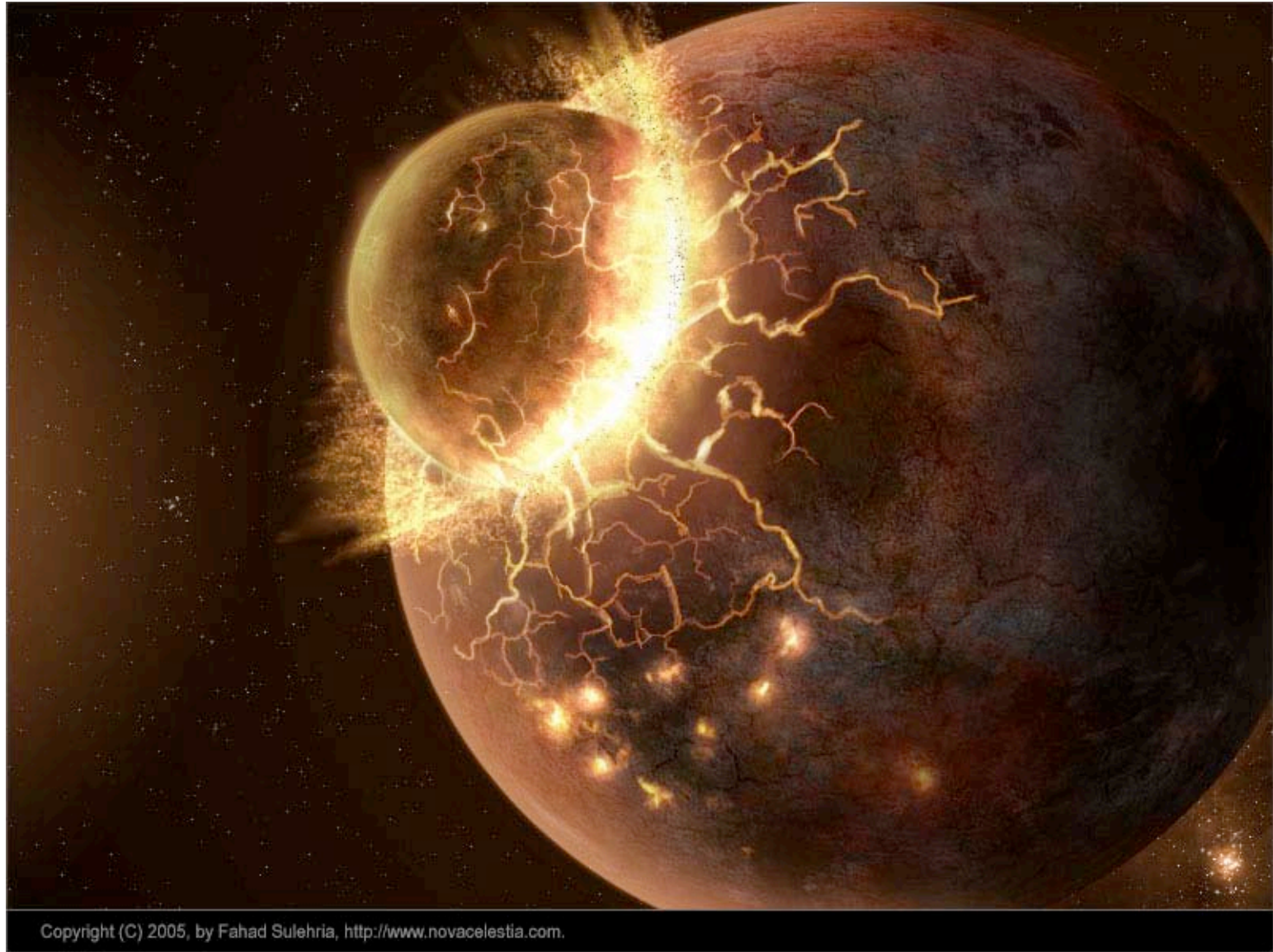
Accretion = sticking together

1. *impact heating*



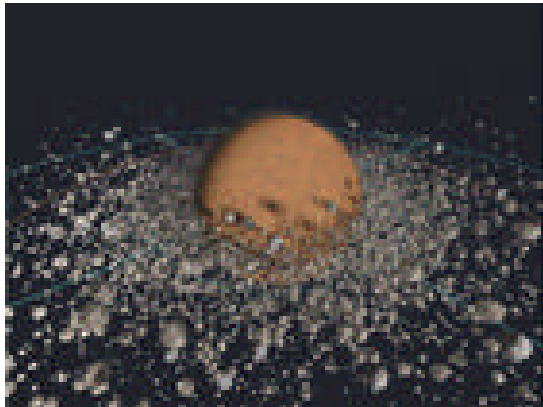
Armageddon!!

One Giant Impact Formed the Moon!

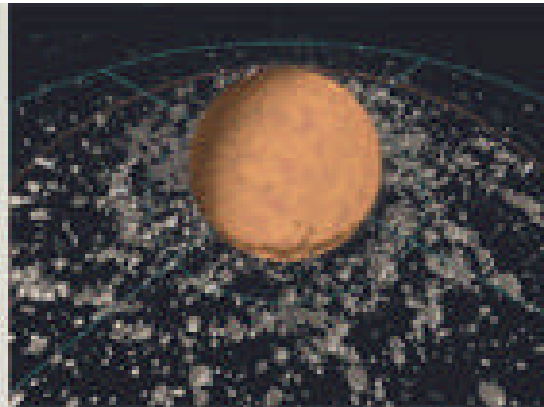


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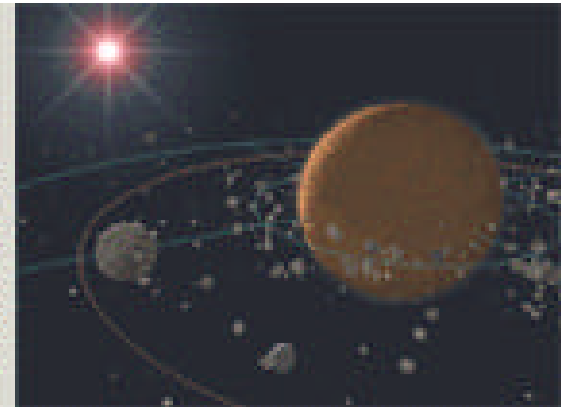
Giant Impact Theory



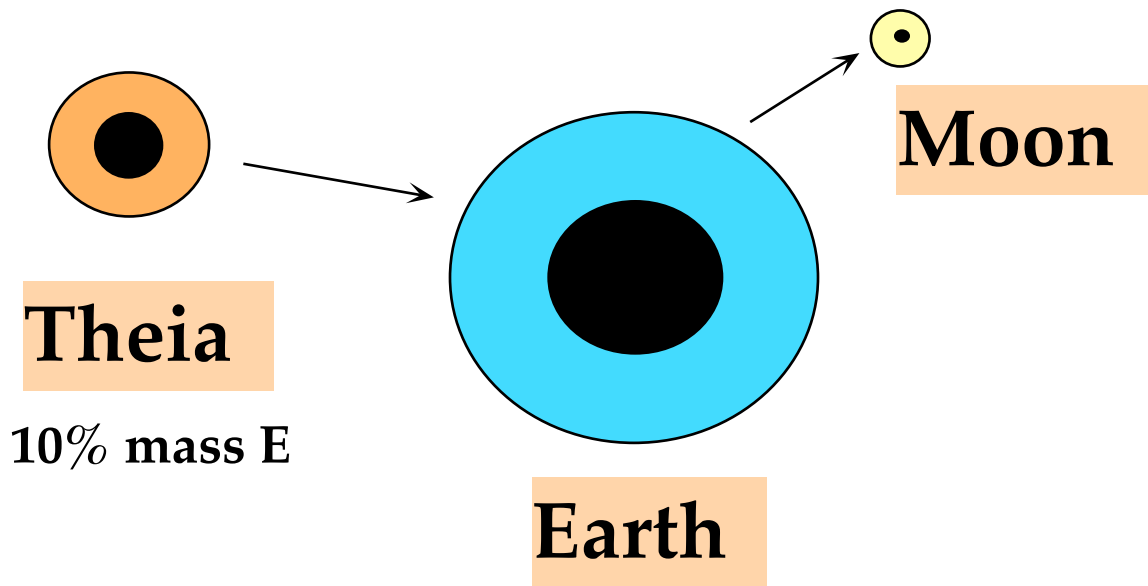
debris disk
from
collision
of
Theia



20 hrs later -
spiral arm
structure

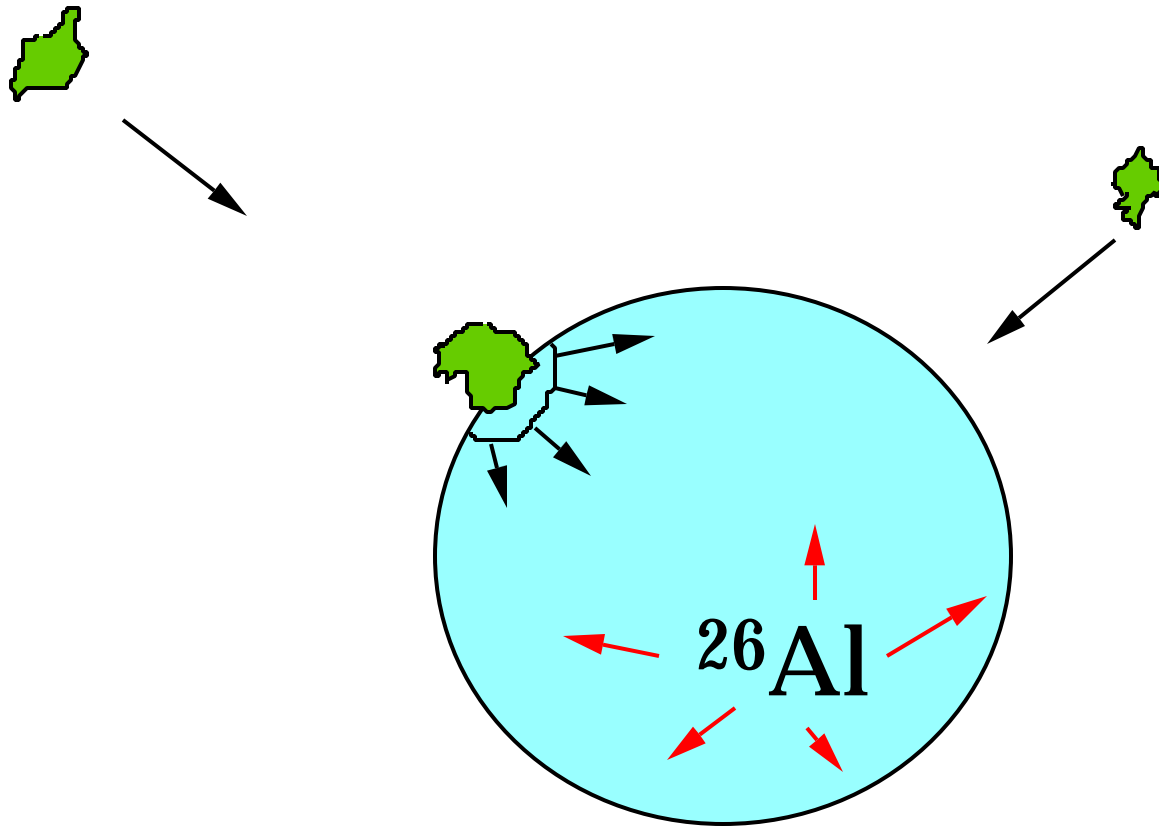


200 hrs later -
a single large
moon



1. *impact heating*

2. *Radioactive heating*



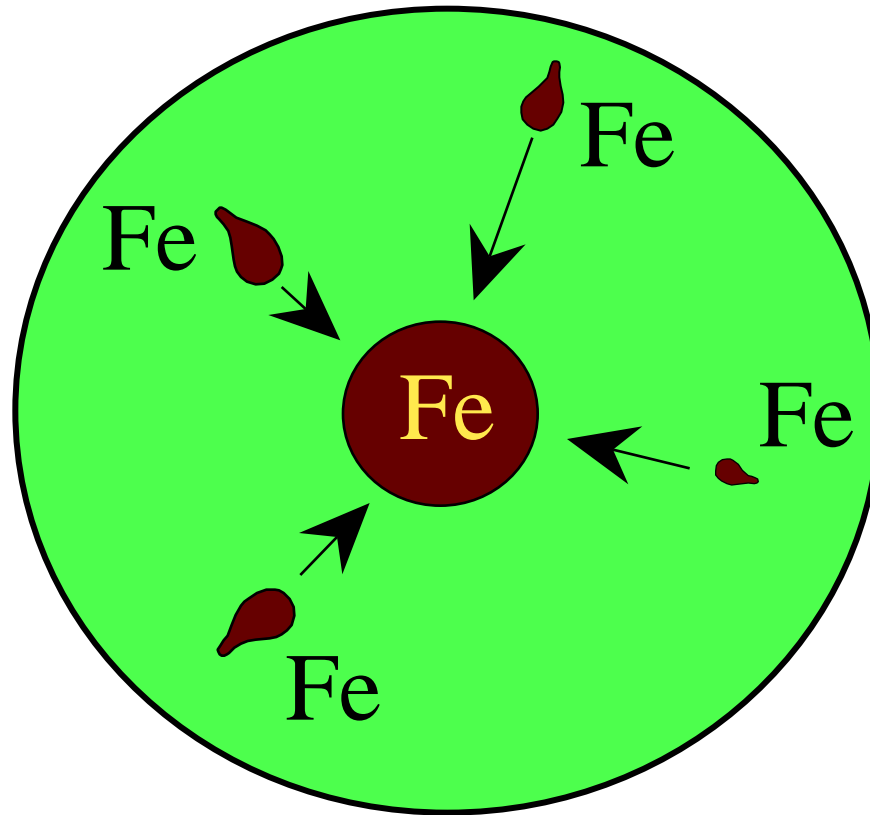
earth started with magma ocean



(artist's rendition)

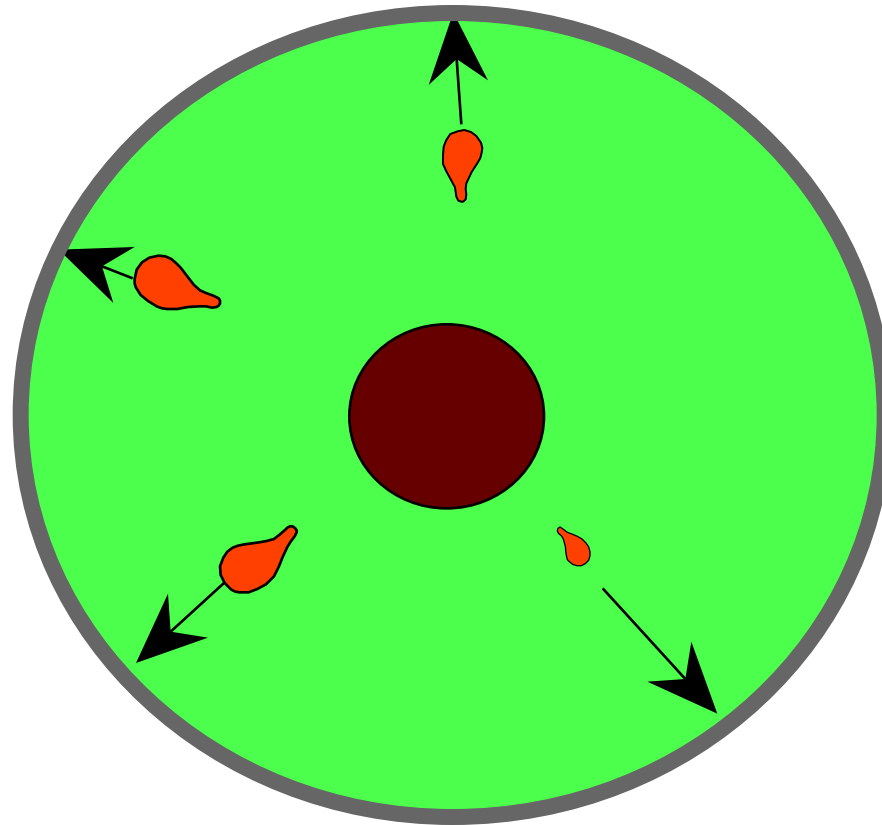
Earth Heats Up and Differentiates

oil and
vinegar



Iron liquid forms and sinks

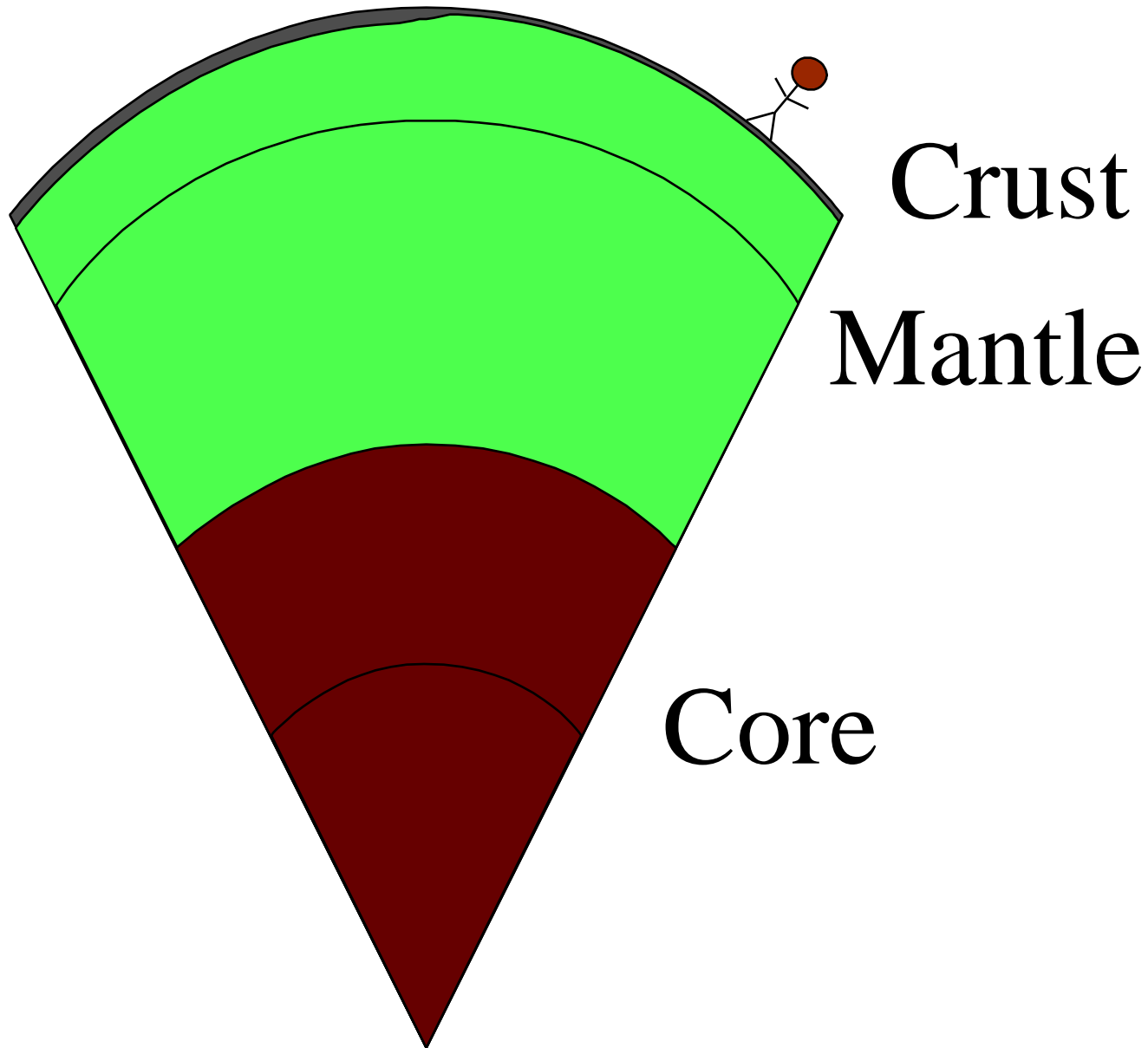
Earth Heats Up and Differentiates



*Density
Driven*

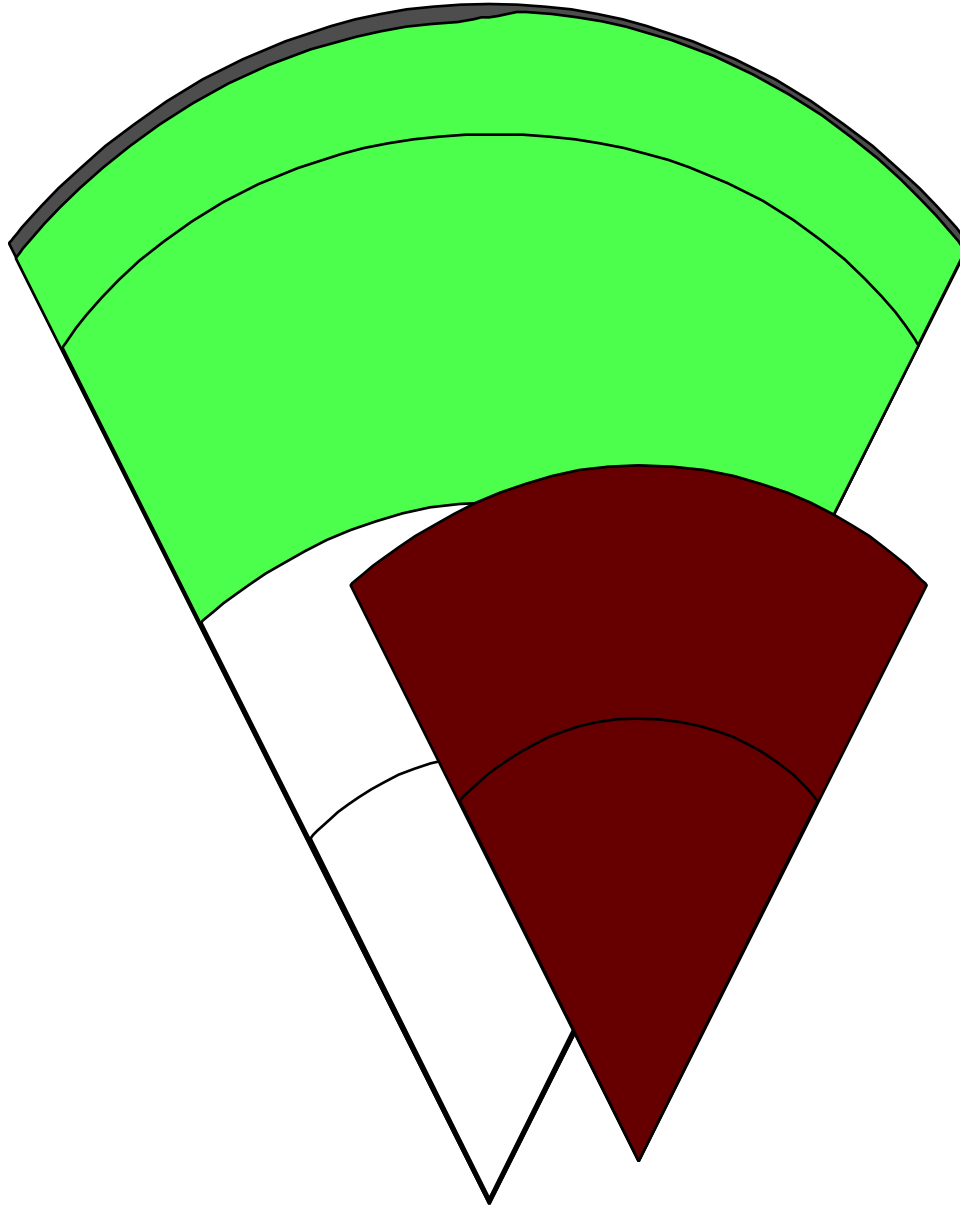
Silica-rich melt rises and forms crust

Differentiation-> Compositional Layering



peach

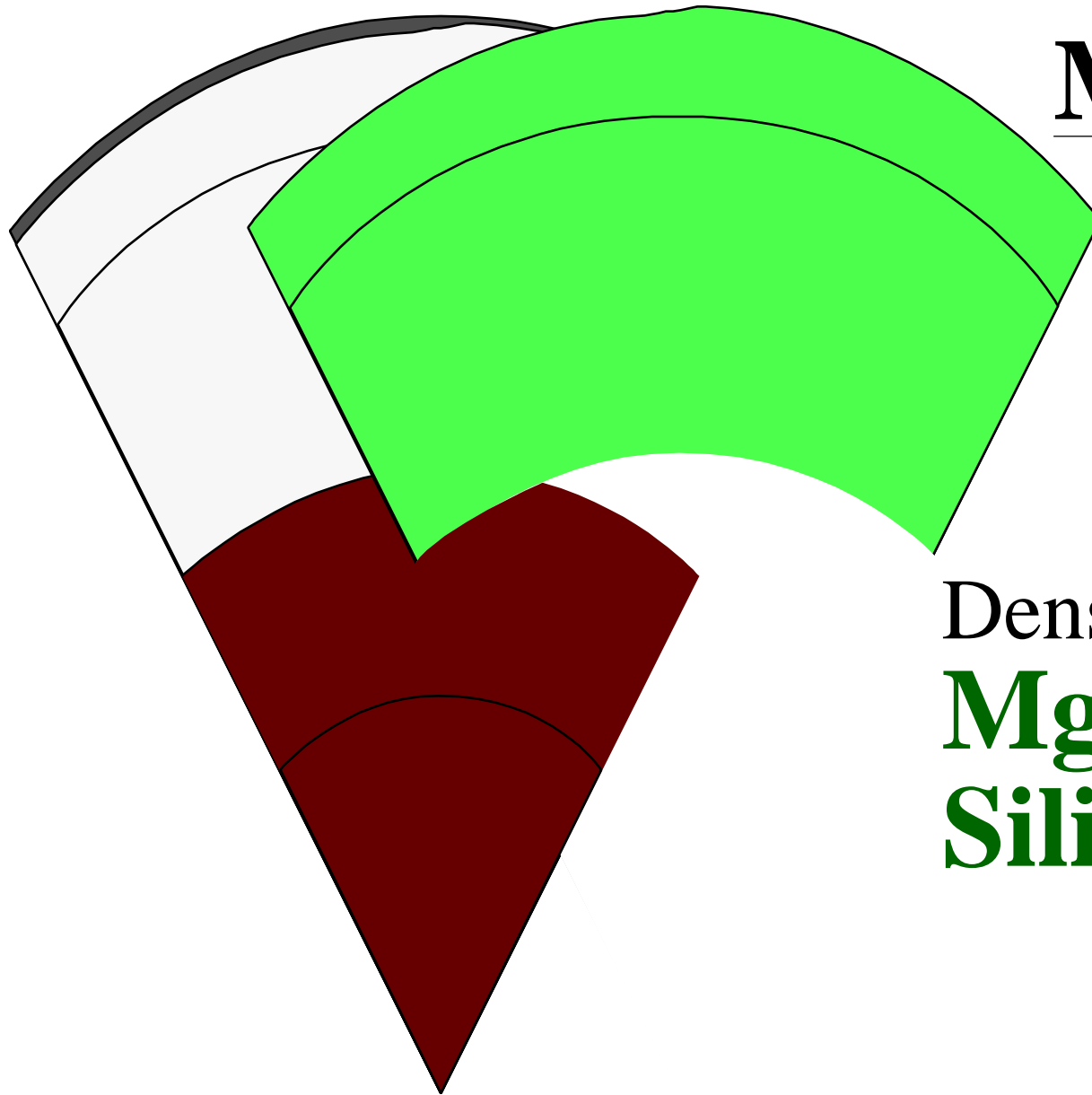
Compositional Layering



Core

Mostly **Iron**
Some Nickel

Compositional Layering



Mantle

Dense
Mg+Fe
Silicate

Pieces of Earth's mantle (green) caught in basaltic lava

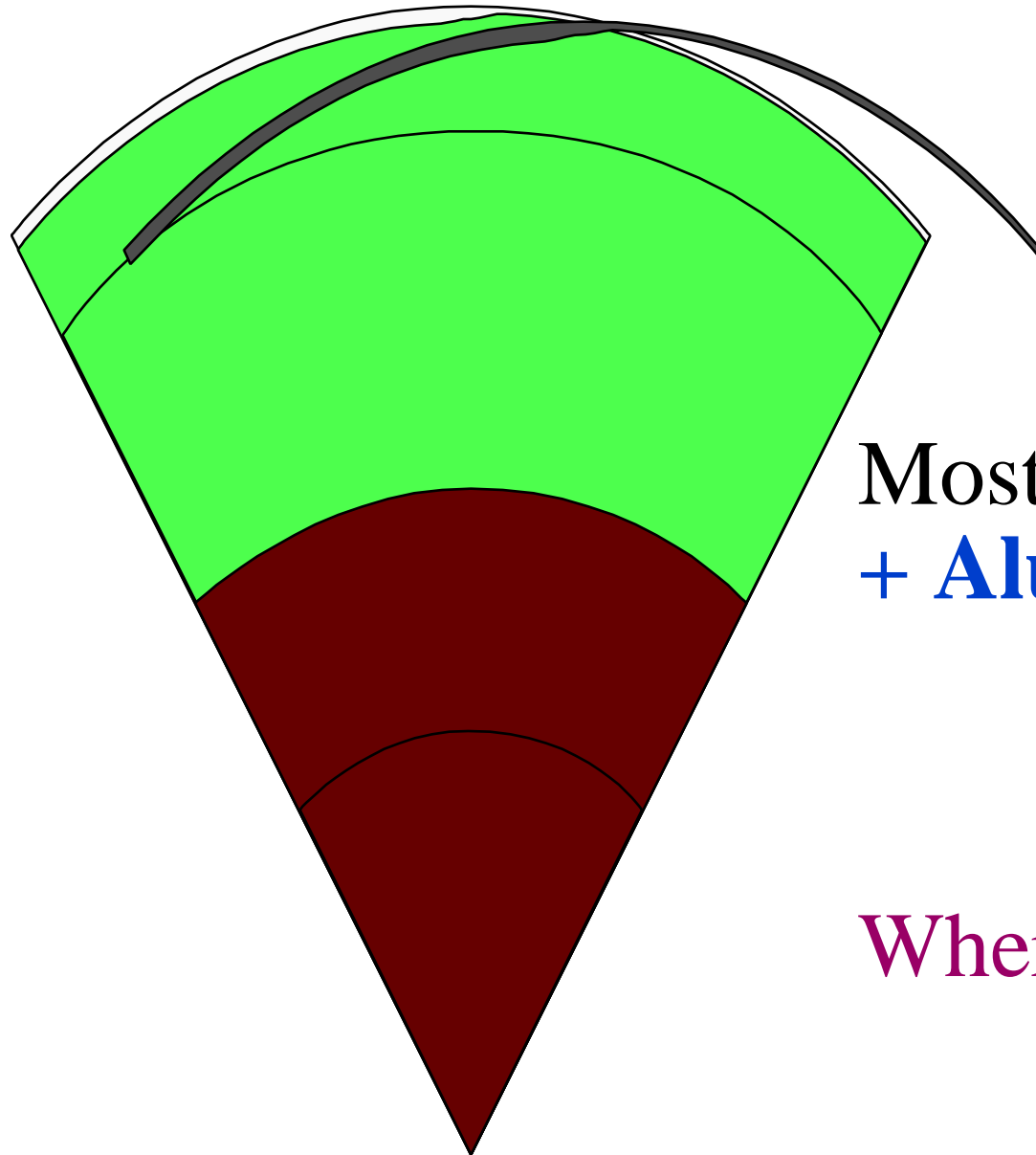


Core-mantle boundary of Asteroid

Mantle minerals in
Fe matrix



Compositional Layering



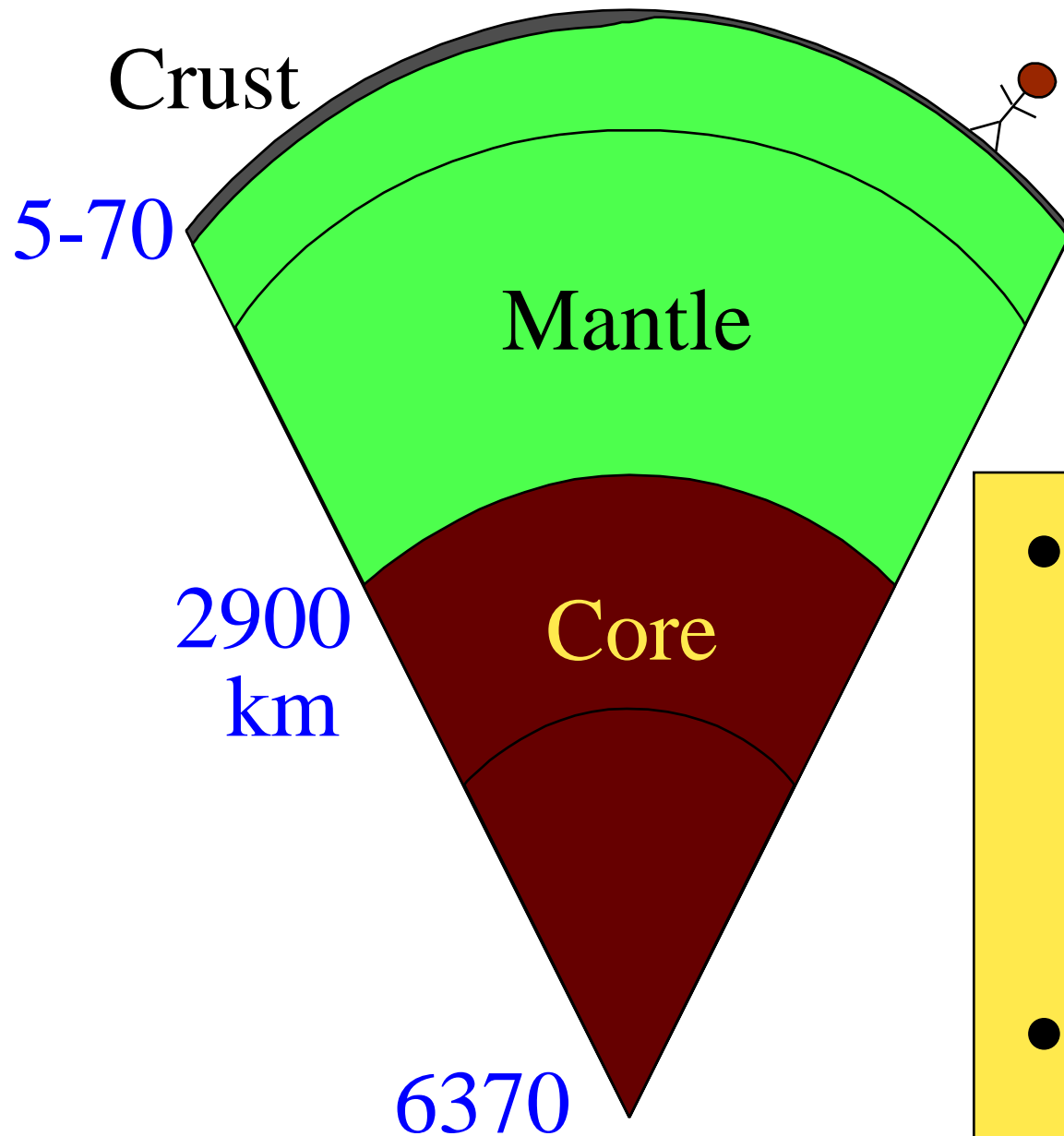
Crust

Mostly **Silica**
+ **Aluminum**

Where we live

How do we know?

How do we Know this?



- seismic wave velocities
- meteorites

Compositional Layering
VS.
Mechanical Layering
How Strong or Weak?