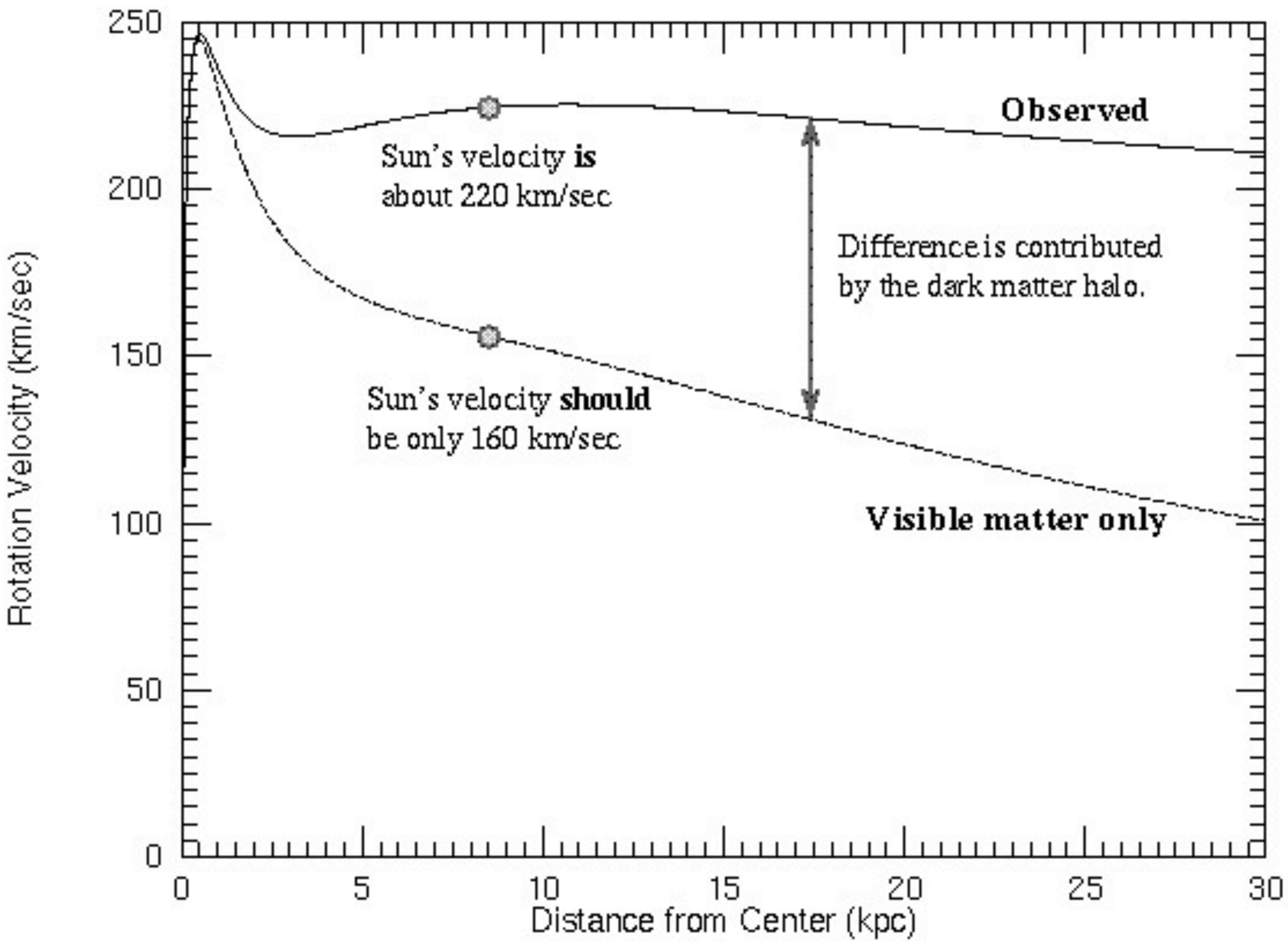
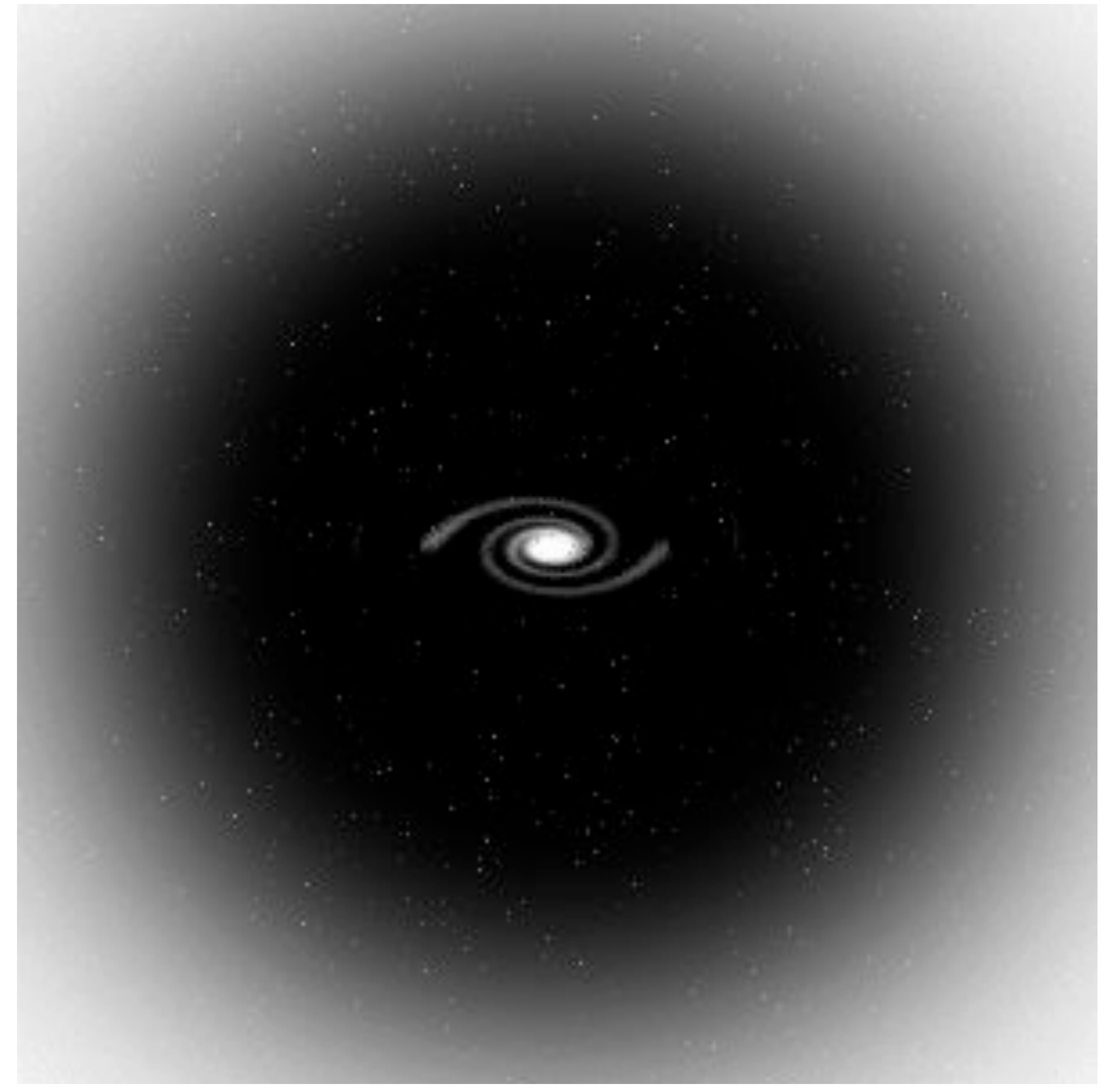
Stars @ the centre, dark matter further out.





When falling into the potential well of a galaxy,

gas: collides and loses angular momentum, forms disk/bulge in the inner part of the galaxy

dark matter: no collision, can not lose angular momentum, orbit further out with nearly isotropic velocity dispersion (halo)

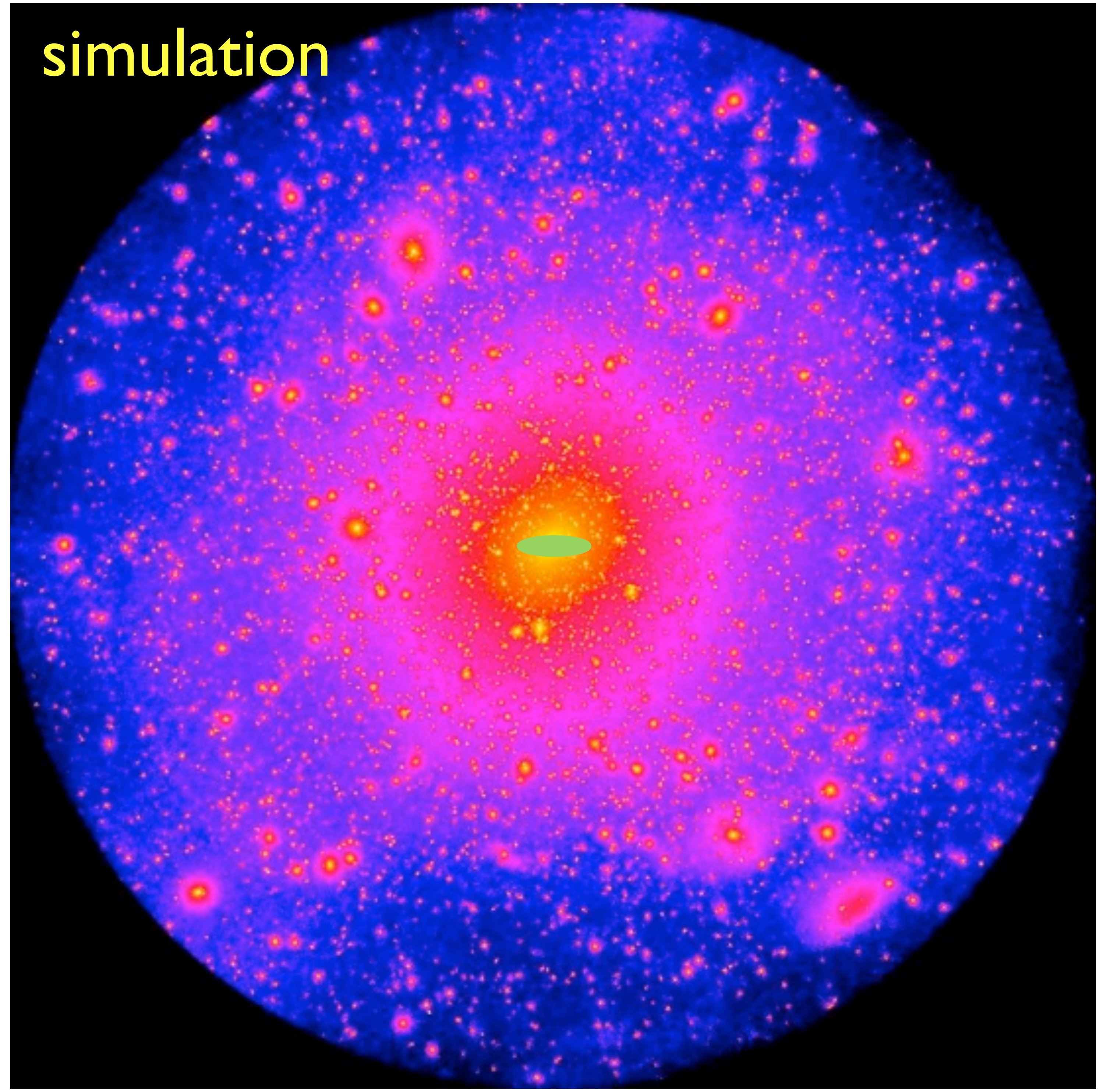
•the Milky Way has absorbed many smaller galaxies along the way

•newly absorbed galaxies bring along their dark matter,

•dark matter can't dissipate

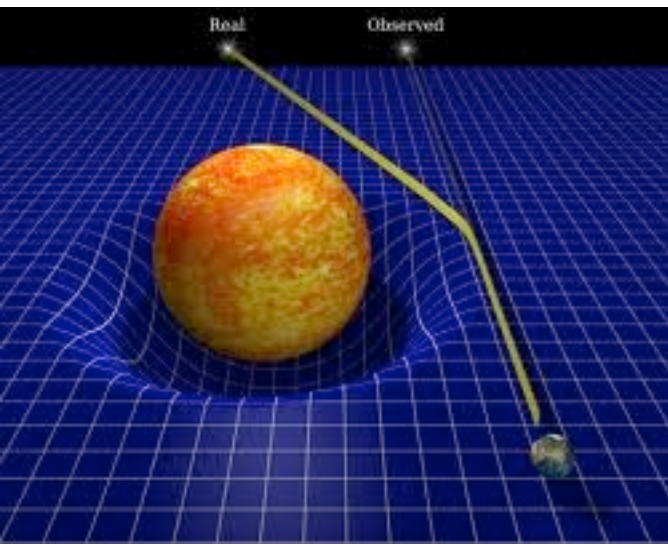
•the Milky Way acquires a dark matter halo that's full of structure, and memory of the past

•it can be triaxial, it can be lumpy, it can have many streams...

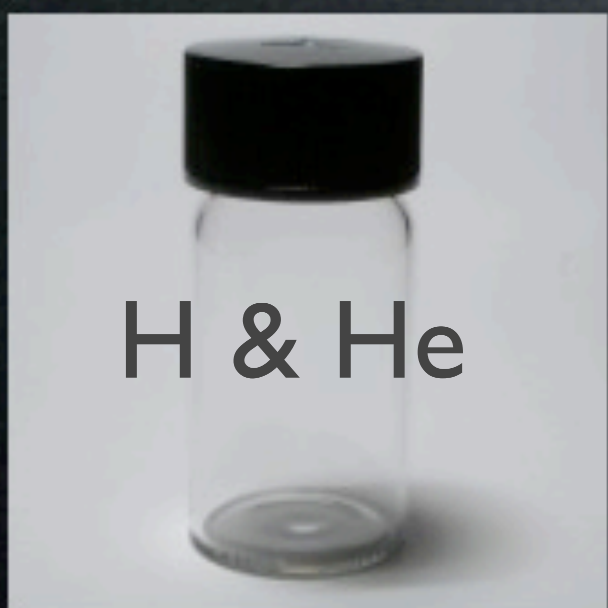


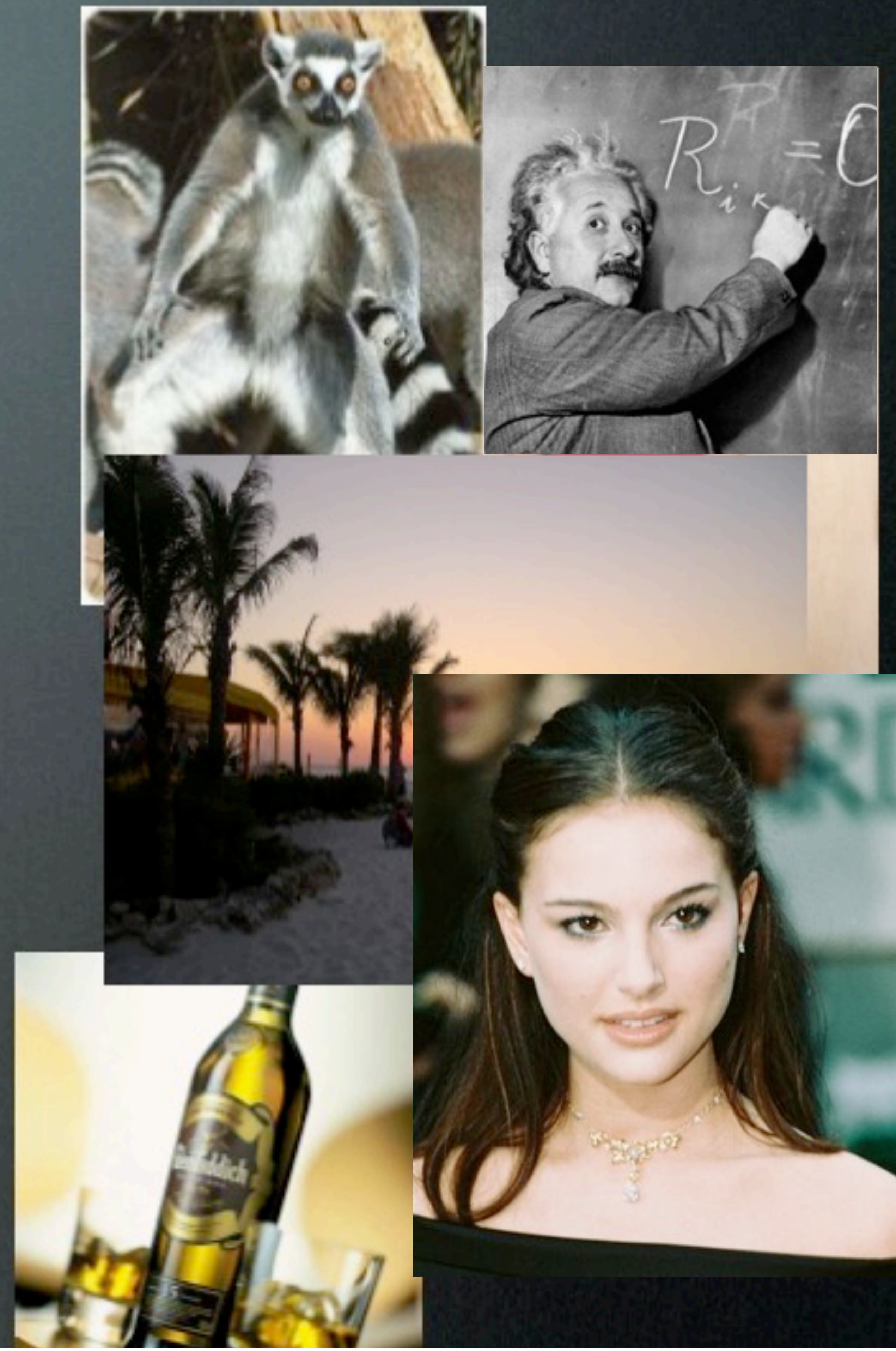
Would be nice to 'see' the dark matter

Seeing dark matter using 'gravitational lensing'



galaxy cluster Cl0024+17, blue halo --> dark matter map


H & He

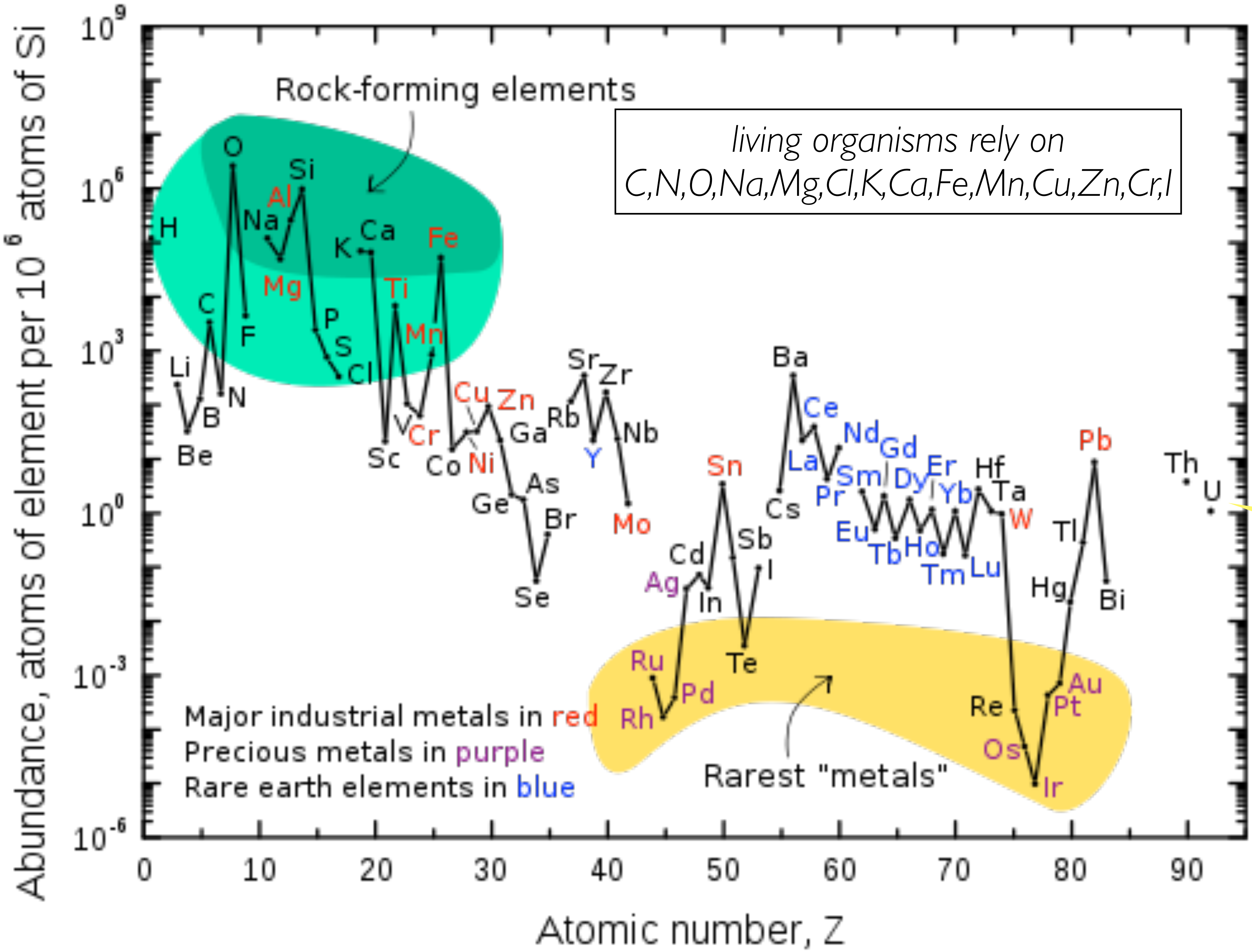


Chemical Abundances on Earth

H/He depleted -- escaped

Carbon poor -- never accreted much

pollution = giant stars + type II SN + type Ia SN



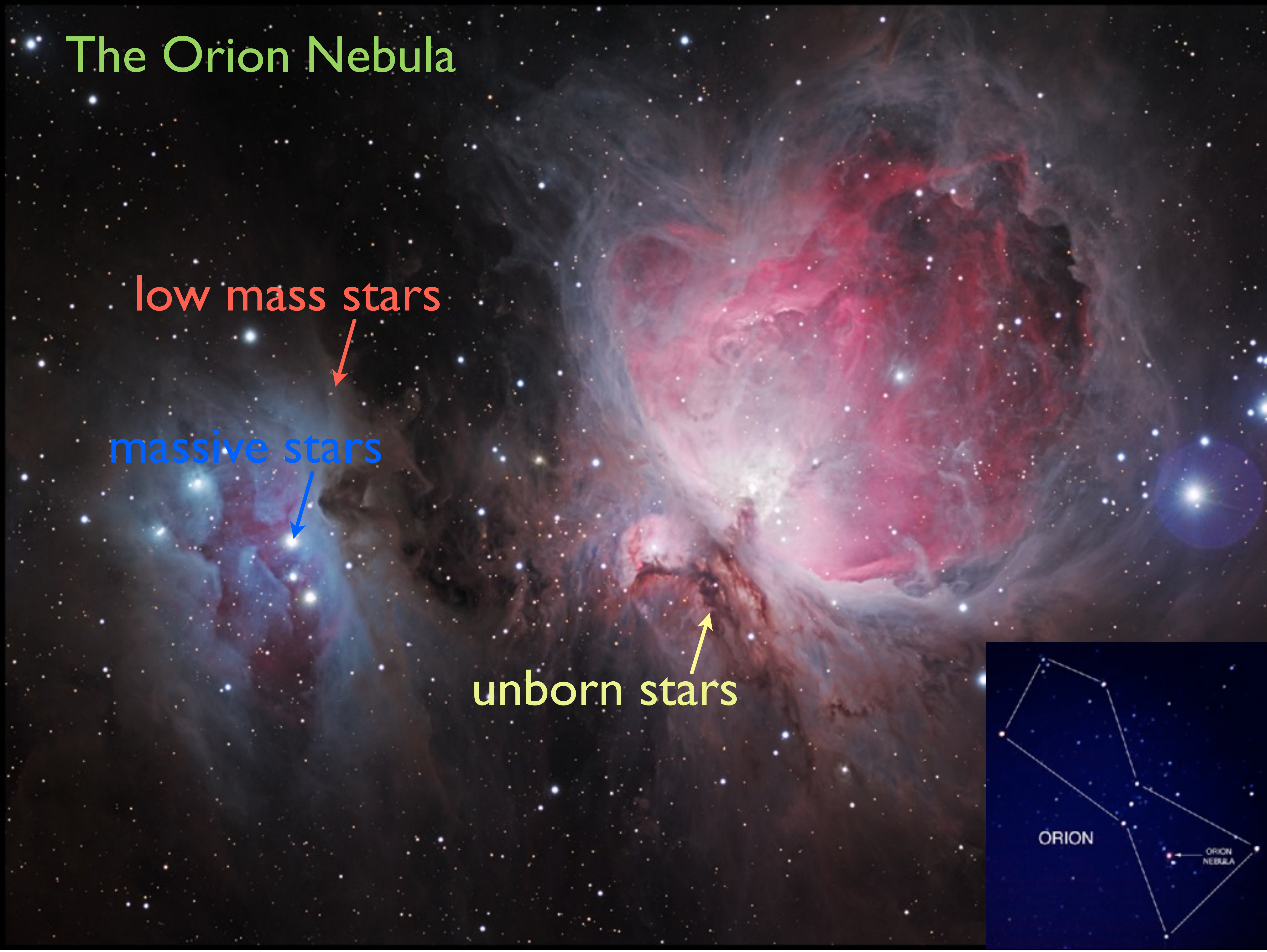
Both high and low mass stars are essential:

C/N/O: low mass stars

Fe: massive stars (supernova)

Uranium: supernova

The Orion Nebula

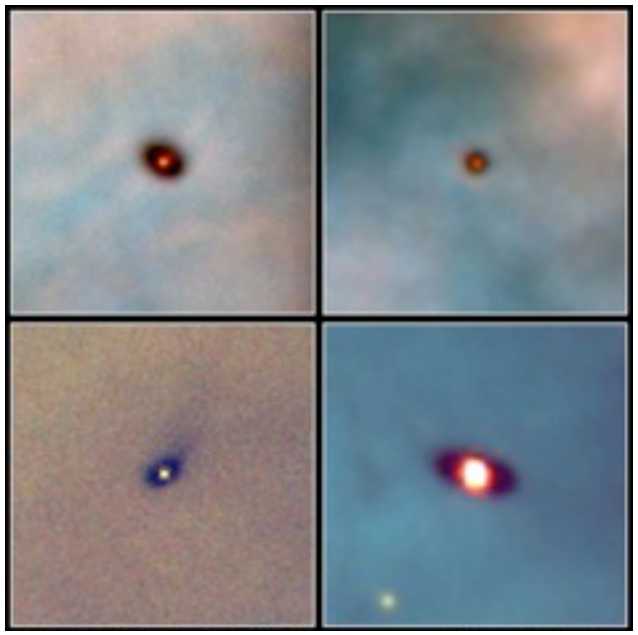


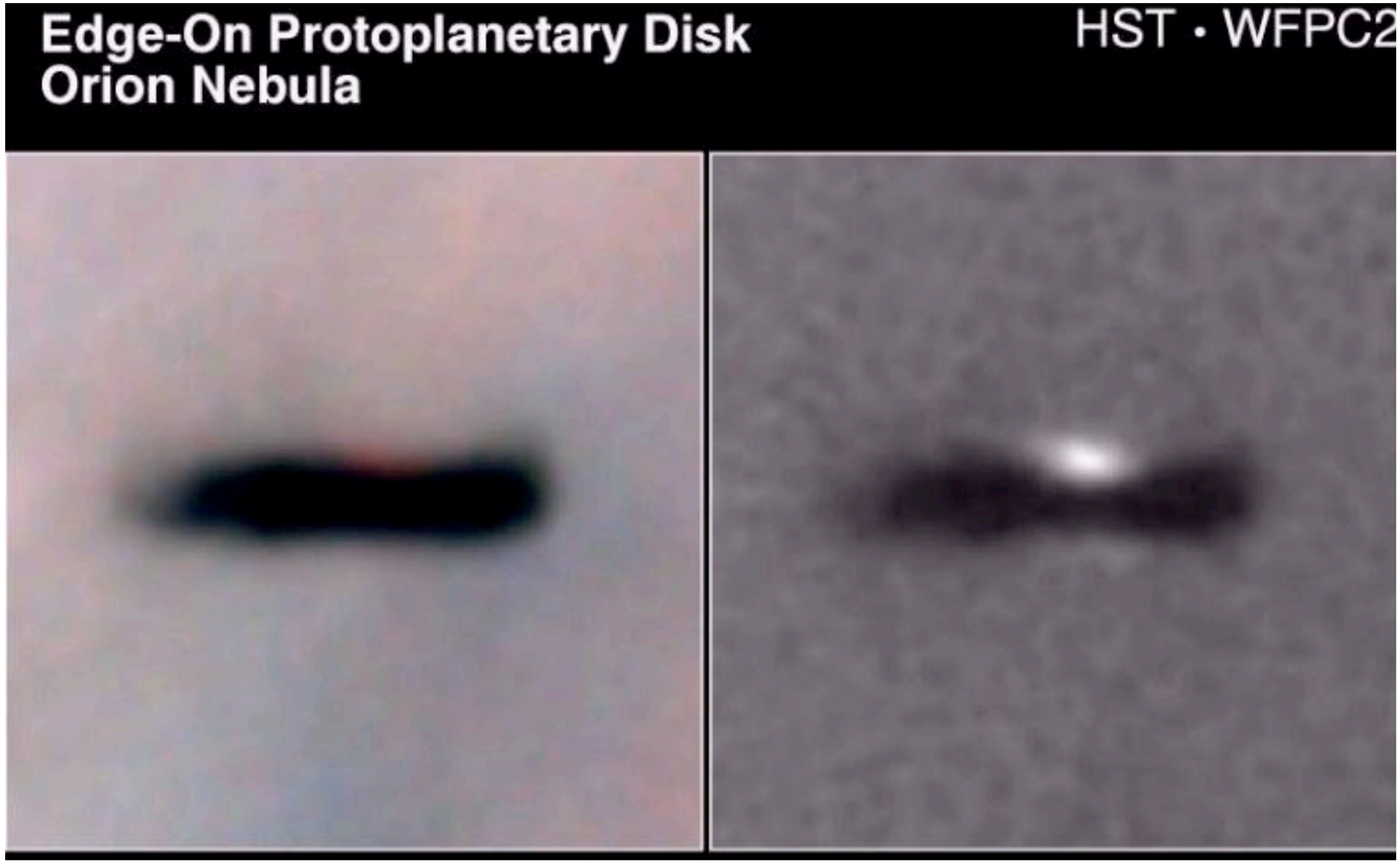
star formation: gravity wins

Orion Nebula with cocoons (star formation sites)

- stars form by collapsing dense clouds
- gravity pulls gas inward, but rotation & pressure support resist
  (from ~ light-year ~ 10^{18} cm --> light second, ~ 10^{11} cm)
- needs to dissipate most angular momentum and heat
- stars usually form as groups or clusters
  (evidence for nearby SN when Sun was forming)
- this takes ~ a few million years

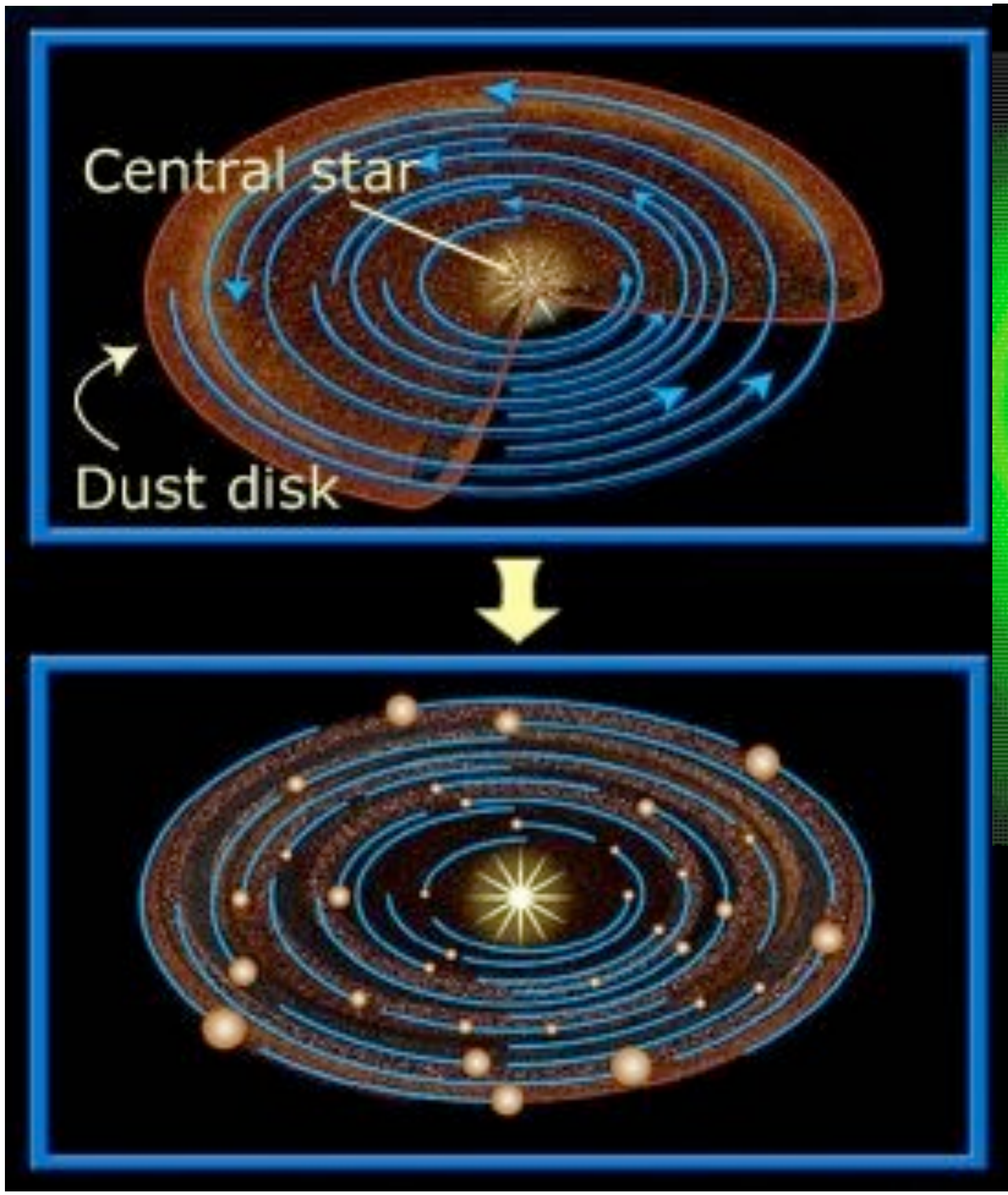
Planets form in residual disks surrounding young stars (proto-planetary disks)

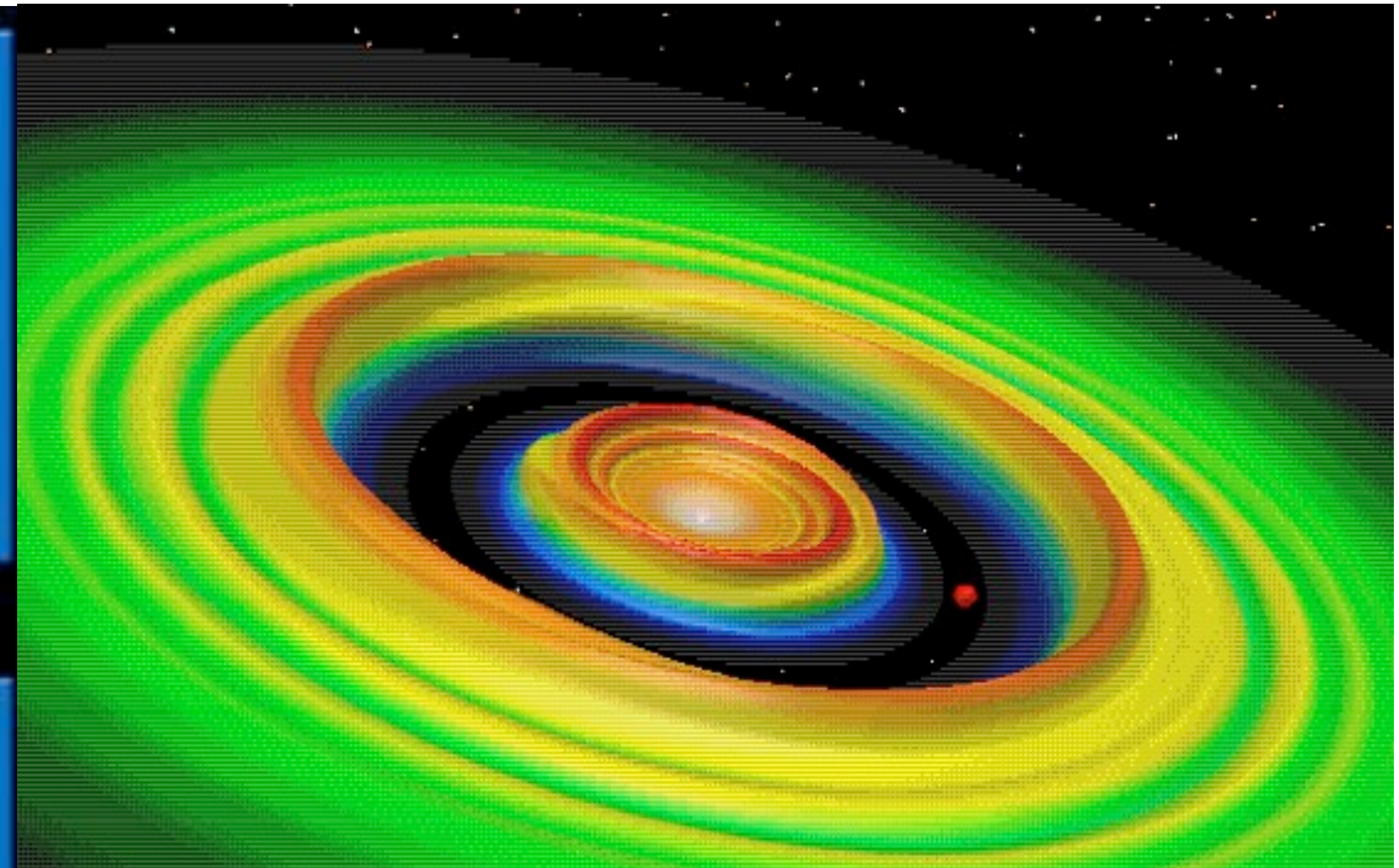




- we oftenly see these disks around young stars
- disks ~ 1% stellar mass, same composition as star
  (mostly gaseous, but dust condensing out)

planet formation requires metal.



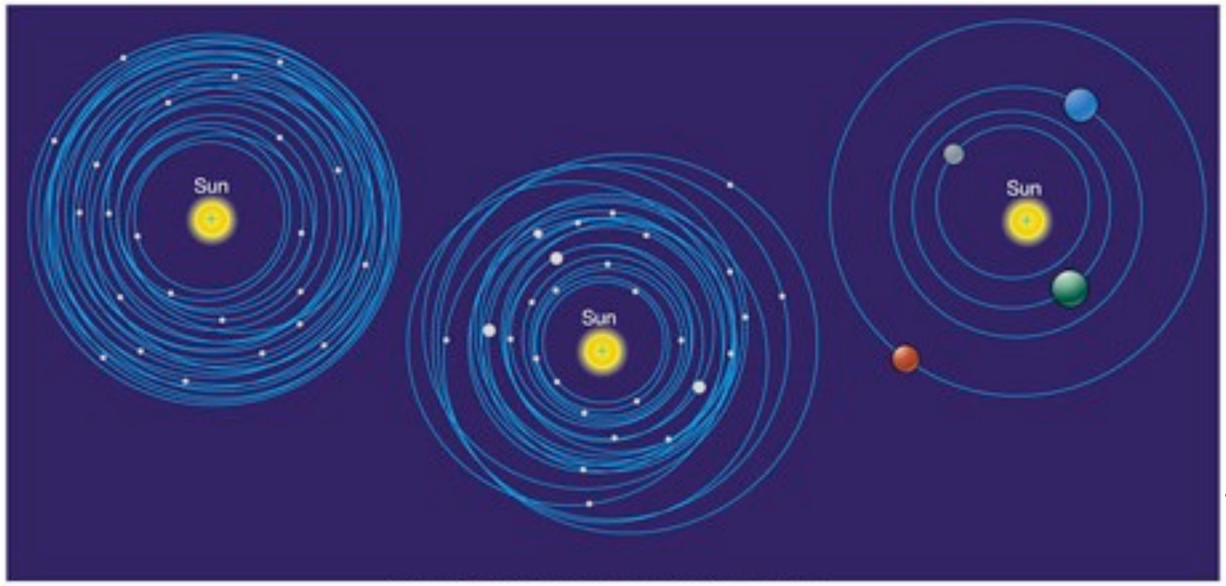


In proto-planetary disks,

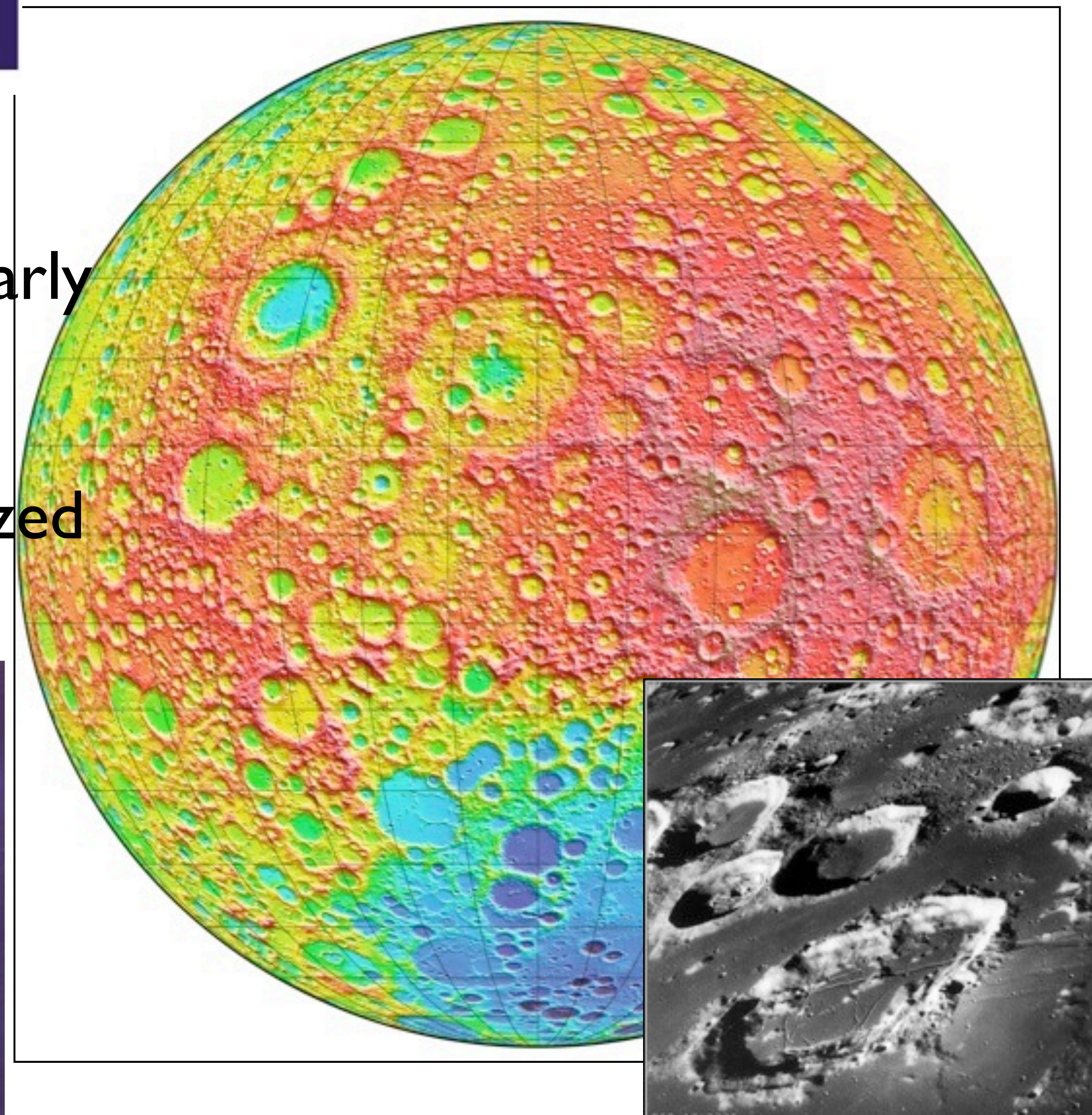
•solids condense, grows, forming into cores

•cores accrete gas forming gaseous giant planets (Jupiter & Saturn)

•after gas removal, smaller cores form terrestrial planets

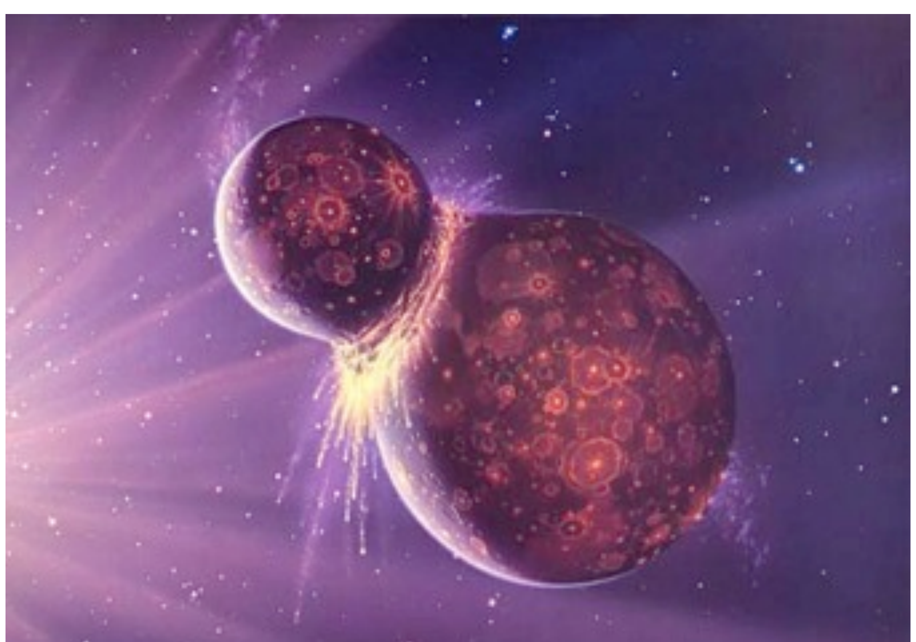


Early solar system: very violent. lots of collisions. clearing of 'bad' planets; extremely heavy bombardment on Earth

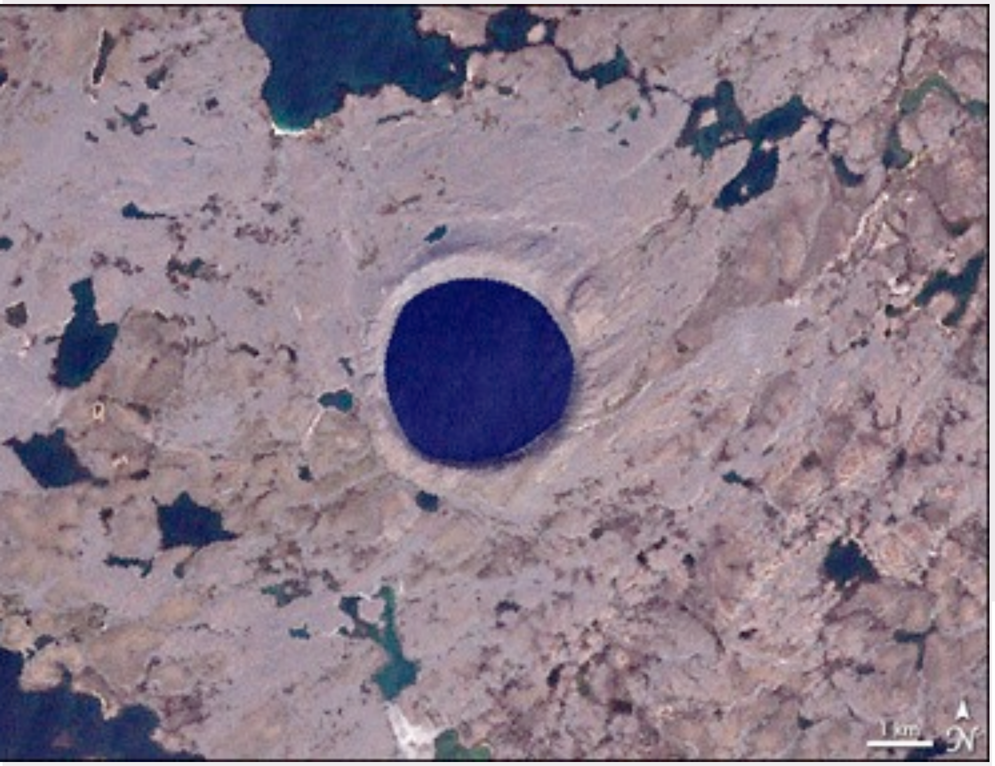


Lacking weathering, the Moon kept some records of these early bombardments.

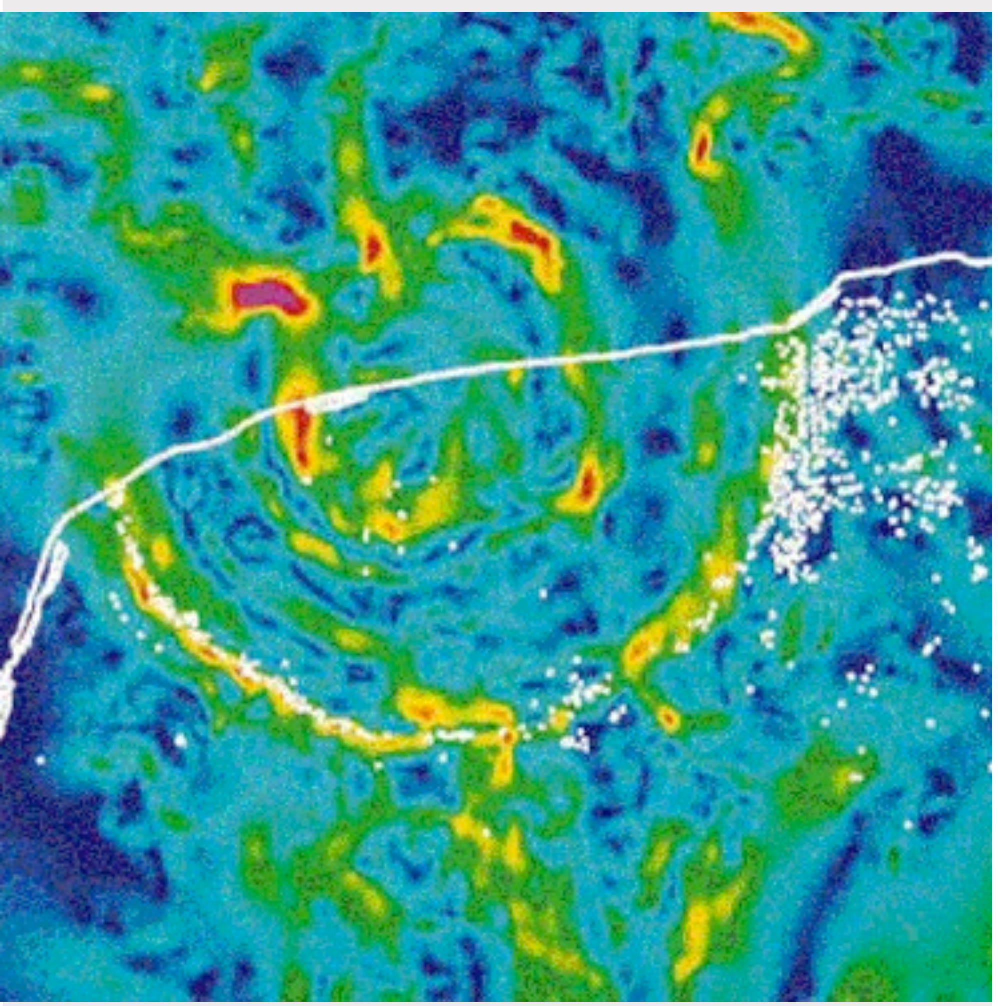
In fact, the Moon is hypothesized to be bombarded out of the Earth.

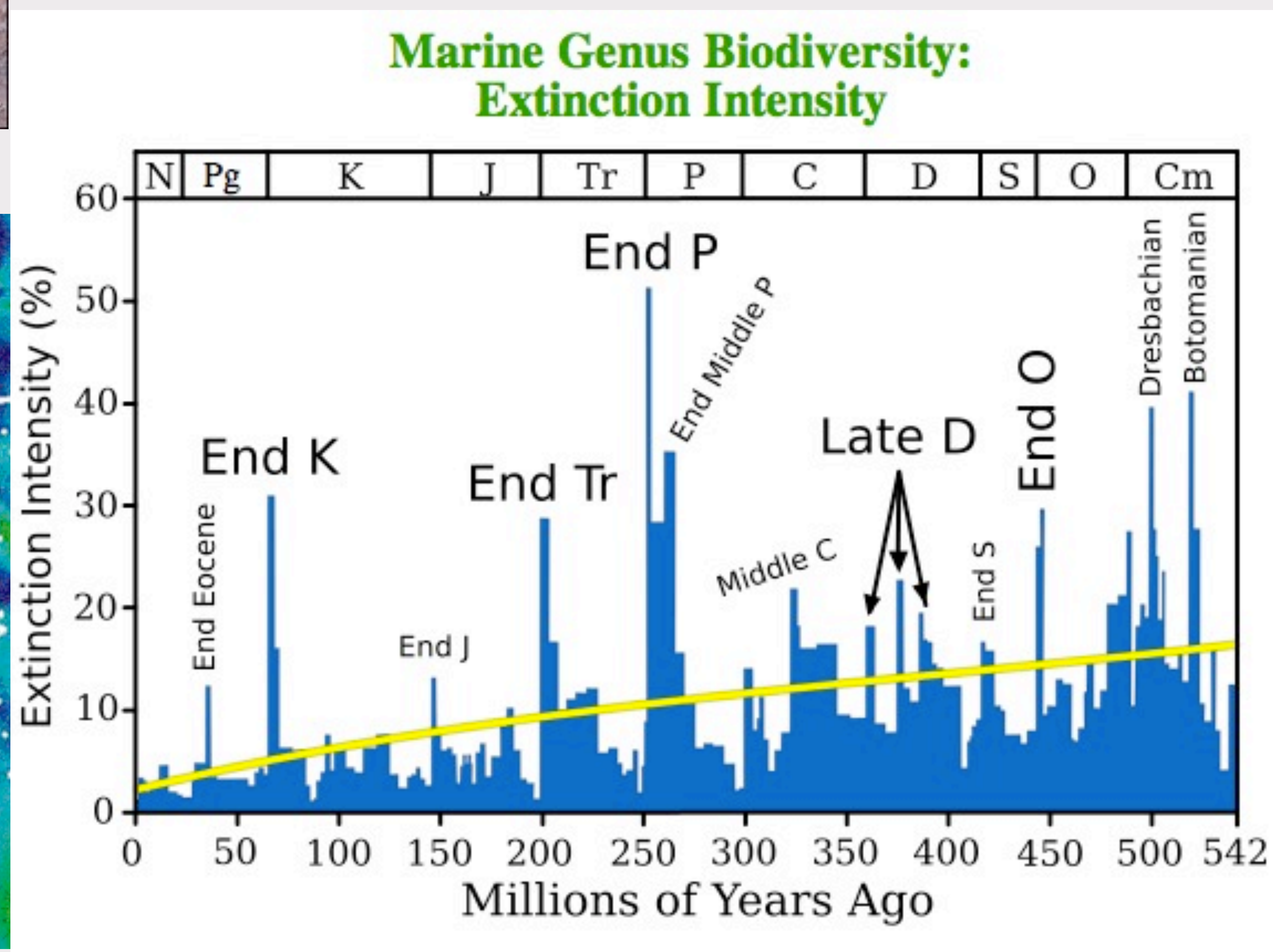


clearing going on even today...



global catastrophe-class impact, ~1/10^8 yrs, may be related to ~ periodic extinction event on Earth?

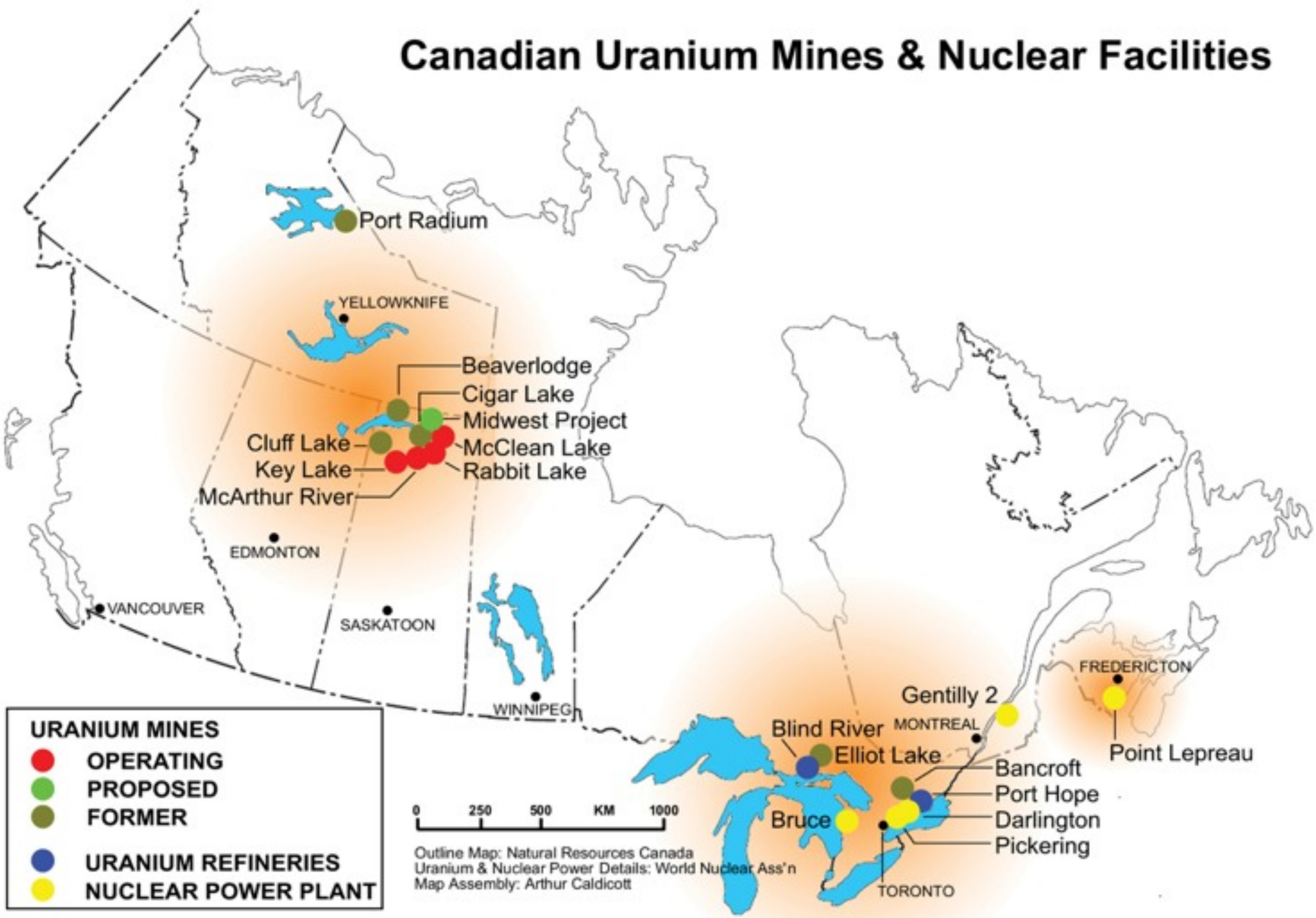




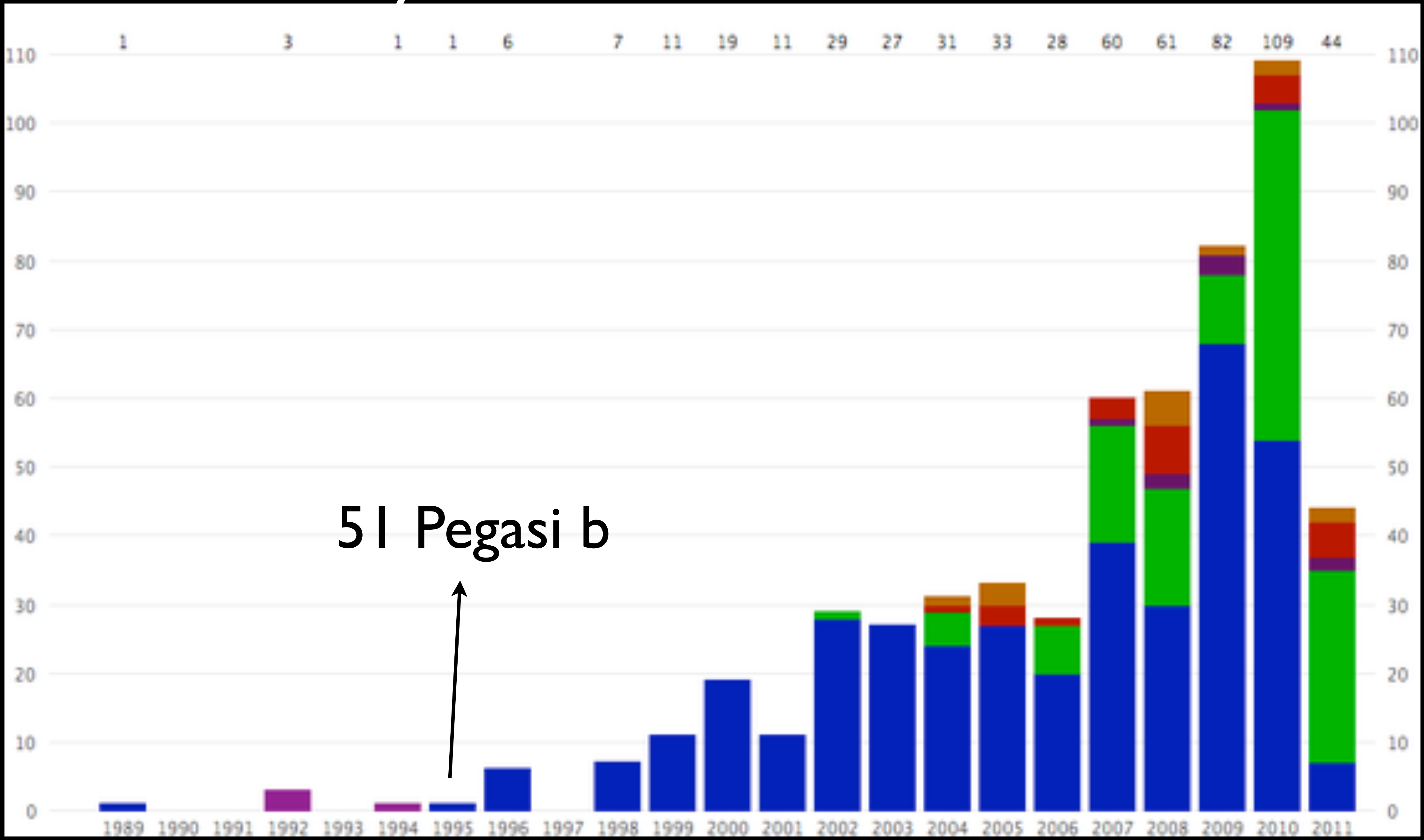
Uranium is made in massive stars.

It's buried deep in Earth, but leaked up when crust impacted.

Canada is world's top 1 producer of Uranium



Life likely lives on planets.
-- Discovery of Extra-solar Planets



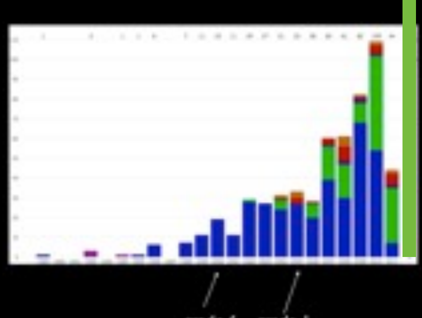
born

high school

year 2012 2300 planets found,
many Earth-sized

Over the last few years, we have inferred that at least 50% stars have planets around them.

The galaxy has 10^{11} stars....



The Drake Equation

$$\boxed{N = R_* \times f_p \times n_e \times f_l \times f_i \times f_c \times L}$$

Is there alien out there? Let's turn it into a scientific question...

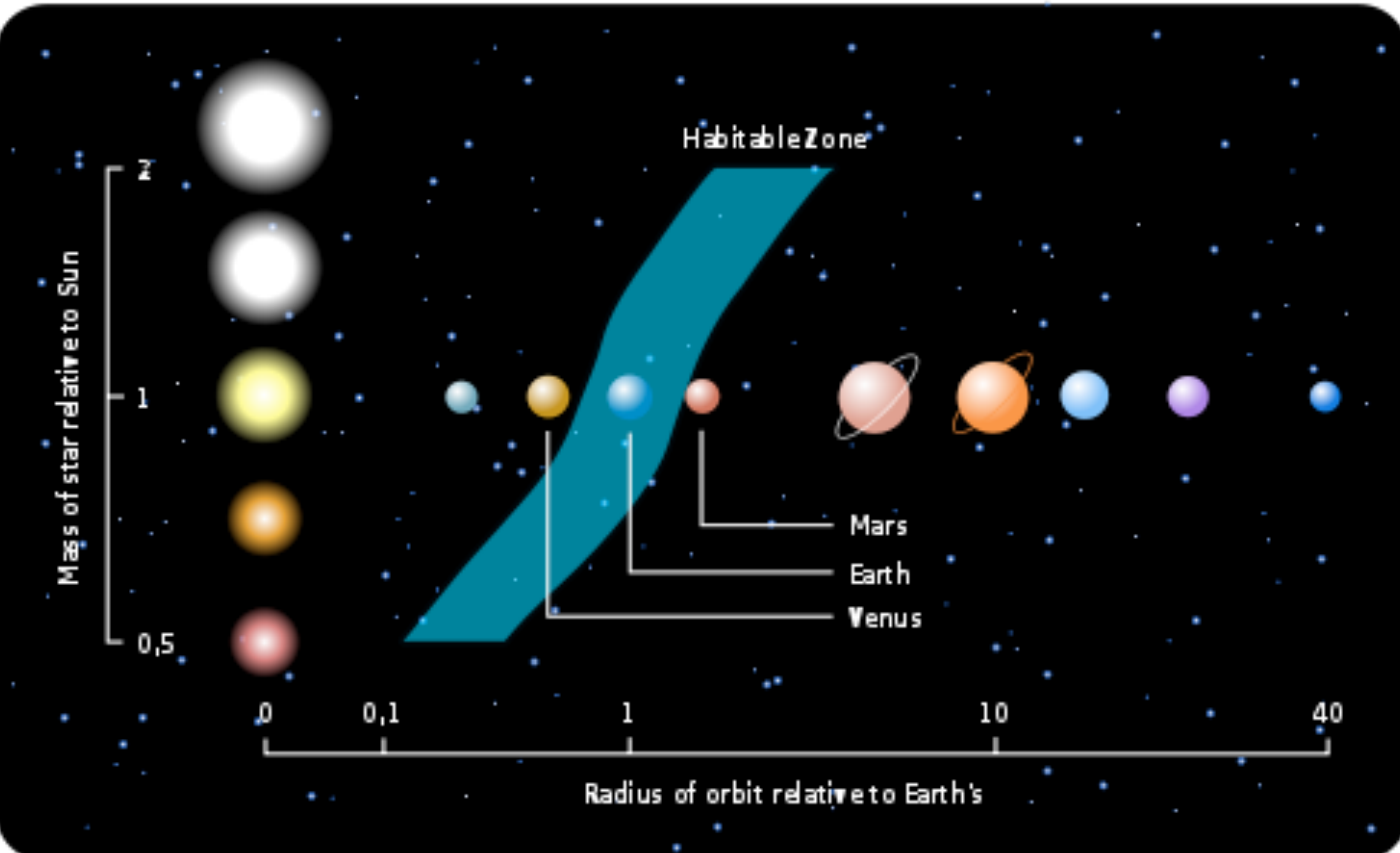
What we want:

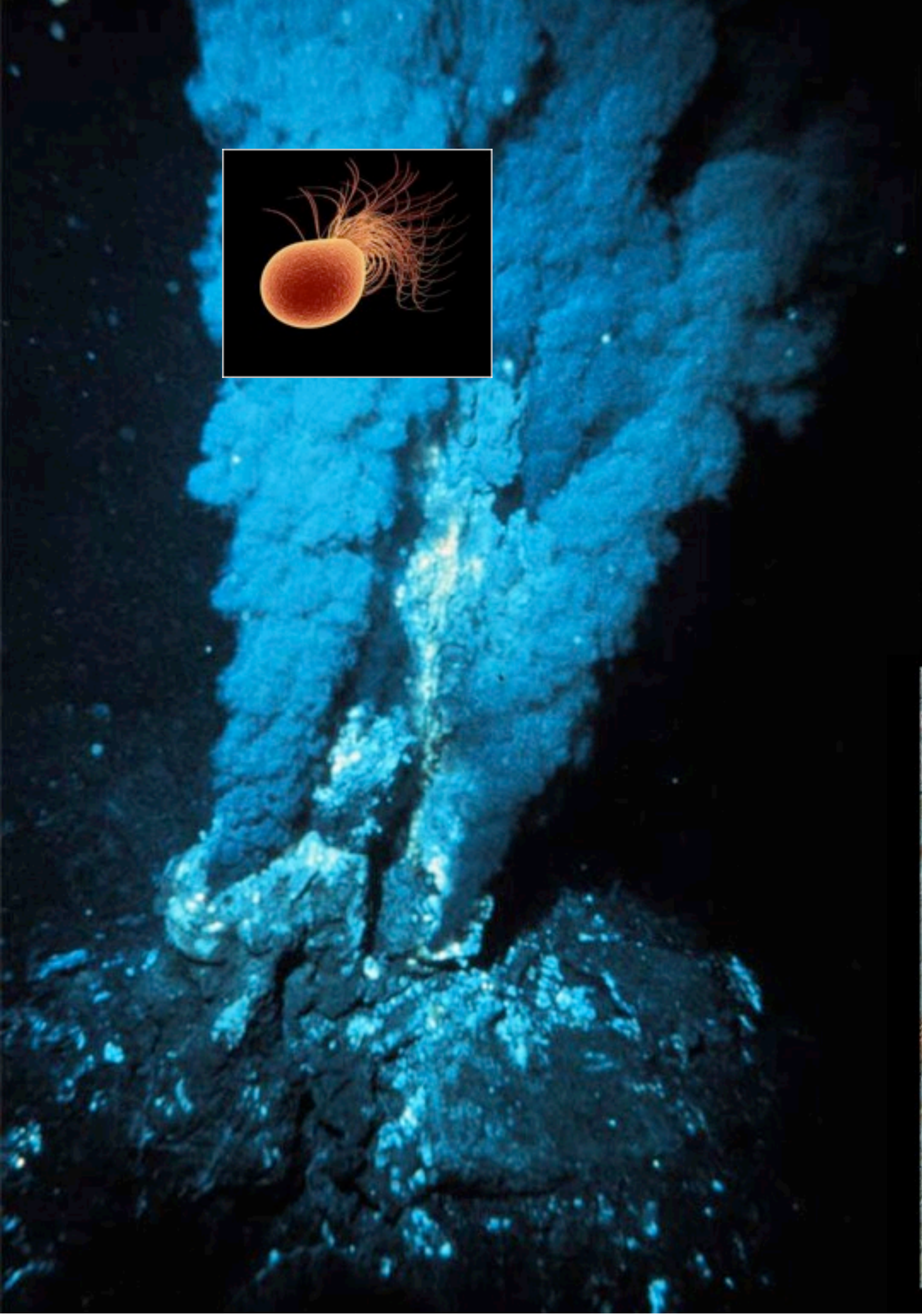
N=number of communicative civilizations

What we're going to assume it depends on:

	optimistic	pessimistic
R^*=number of suitable stars with habitable zones		
f_p=fraction of those stars with planets	all stars	1%
n_e=number of earths per planetary system	100%	1%
f_l=fraction of those planets where life develops	100%	1%
f_i=fraction of life sites where intelligence develops	100%	1%
f_c=fraction of planets where technology develops	100%	1%
L=lifetime of communicating civilization, divided by the age of the galaxy	100%	1%
	10^9 yrs	10^3 yrs

Not every planet may be suitable for life.
“habitable zone”: at right distance from star to have surface ocean





extremophiles: organism that thrive on extreme environments

- extreme temperature/pressure
- hydrothermal vent in ocean floor
- acidic/alkalic lake
- dry desert
- inside rocks

Jupiter’s moon Europa -- maybe life as well?