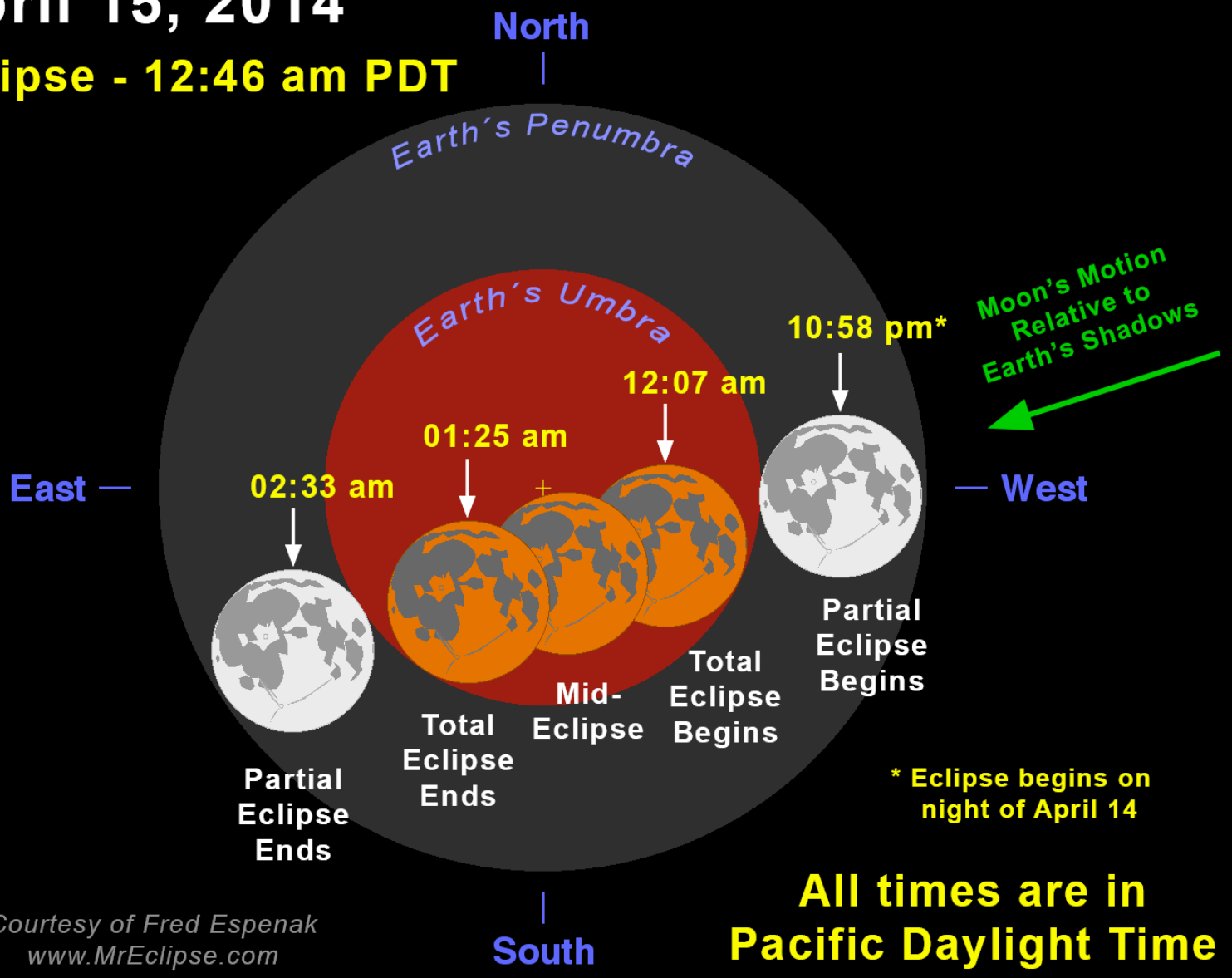
Total Eclipse of the Moon

April 15, 2014

Mid-Eclipse - 12:46 am PDT



* Eclipse begins on night of April 14

All times are in Pacific Daylight Time

Courtesy of Fred Espenak
www.MrEclipse.com

The Search for Extraterrestrial Intelligence (SETI)

Our goals for learning

- What is the Drake equation?
- How many habitable planets have life?
- How many civilizations are out there?
- How does SETI work?

How many civilizations are out there?

The Drake Equation

Number of civilizations with whom we could potentially communicate $= N_{HP} \times f_{life} \times f_{civ} \times f_{now}$

N_{HP} = total # of habitable planets in galaxy

f_{life} = fraction of habitable planets with life

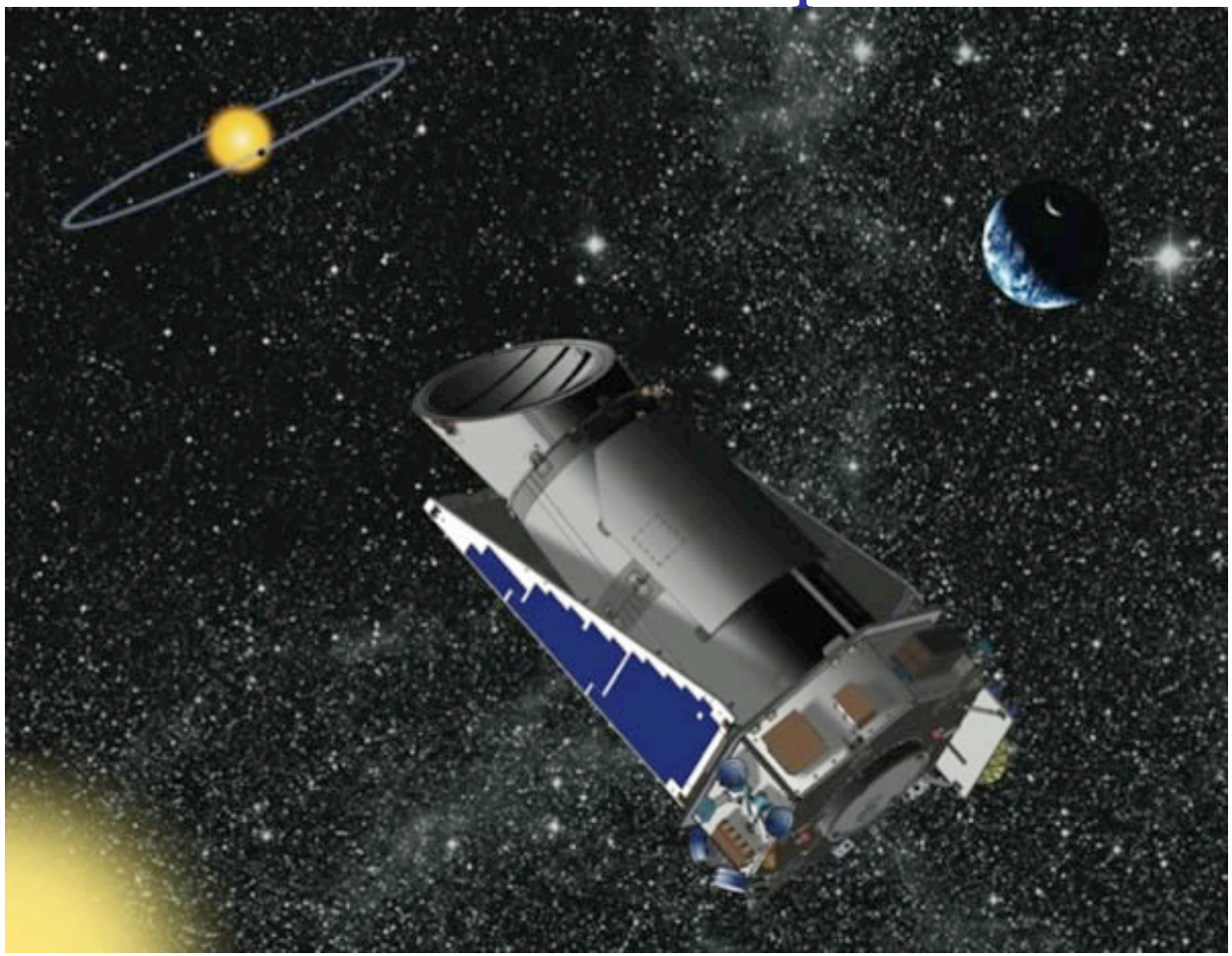
f_{civ} = fraction of life-bearing planets with civilizations at some time

f_{now} = fraction of civilizations around *now*.

How many Habitable Planets in Milky Way?

$$N_{HP} \times f_{life} \times f_{civ} \times f_{now}$$

Best estimates come from Kepler observations:



How many Habitable Planets in Milky Way?

$$N_{HP} \times f_{life} \times f_{civ} \times f_{now}$$

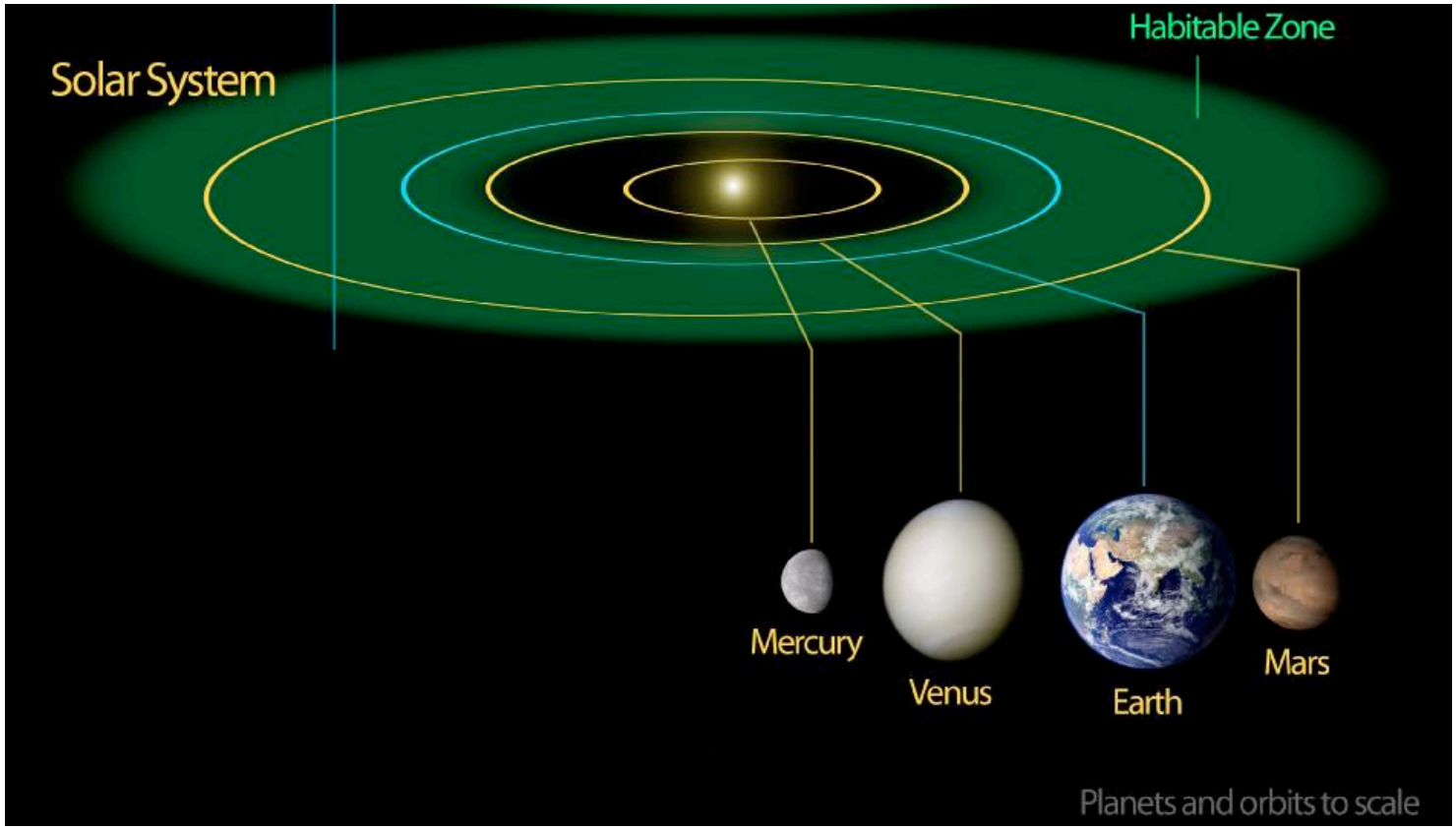
Initial ***extrapolations*** from Kepler observations:

N_{stars} in the Galaxy with planets ~ 100 billion

What fraction of our Solar System in Habitable Zone ?

Solar System Habitable Zone from 0.7 – 3.0 AU
Orbit of Neptune (farthest planet) is ~ 30 AU

$$\text{Fraction of H.Z.} = \frac{\text{Area of H.Z.}}{\text{Area of Sol. Sys.}} = \frac{\pi\,(3^2 - 0.7^2)}{\pi\ 30^2} \sim 0.01$$



How many Habitable Planets in Milky Way?

$$N_{HP} \times f_{life} \times f_{civ} \times f_{now}$$

Initial extrapolations from Kepler observations:

N_{stars} in the Galaxy with planets ~ 100 billion

But if only ~ 1:100 of those stars has a planet in a Habitable Zone (perhaps a pessimistic estimate!)

$N_{HP} \sim 1$ billion

How many Habitable Planets have life?

$$N_{HP} \times f_{life} \times f_{civ} \times f_{now}$$

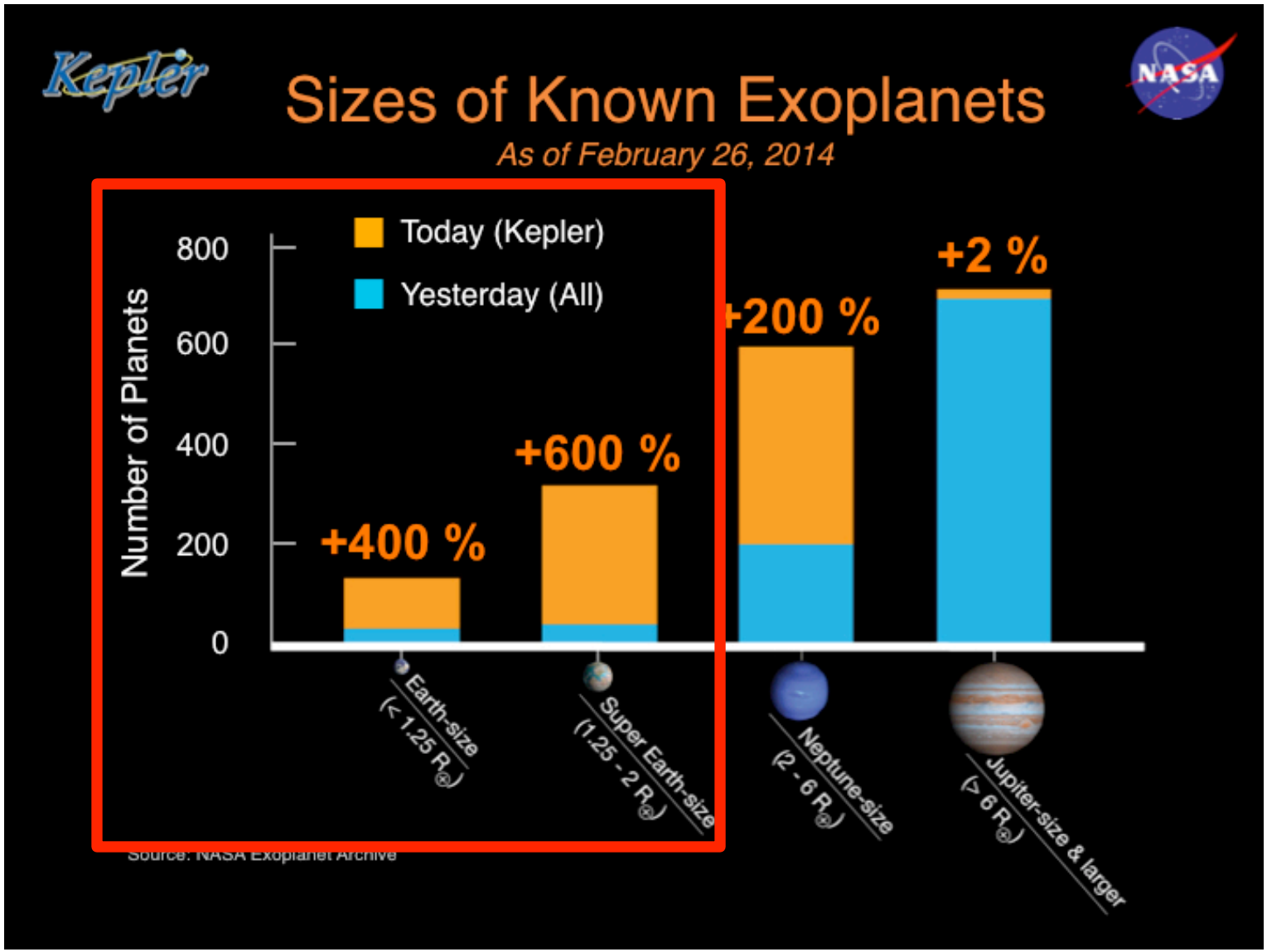
To date, we only know of 1 example:

Most Pessimistic Estimate:

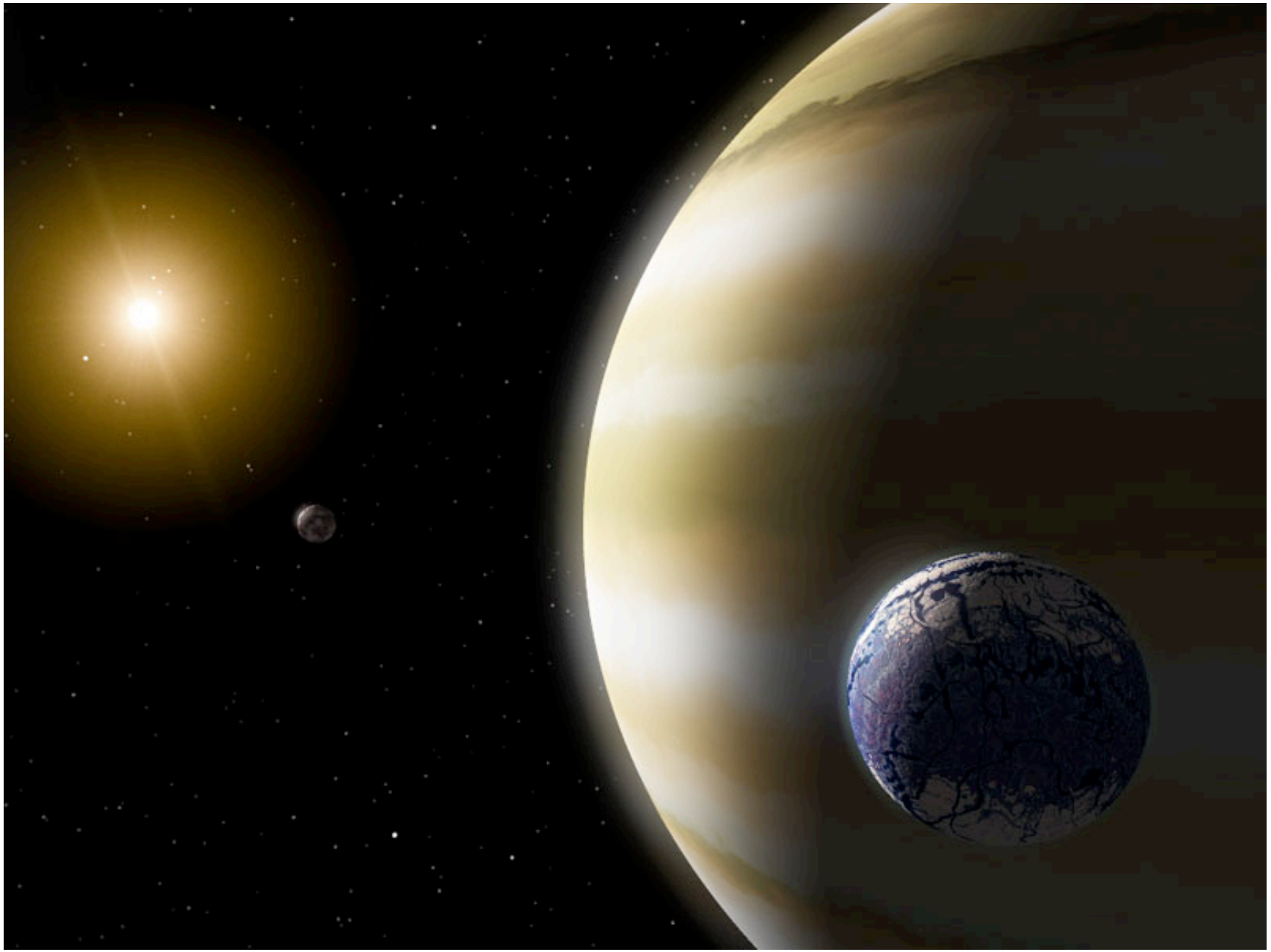
$f_{life} \sim 1 / 1$ billion

Solid surface with atmosphere conducive to life

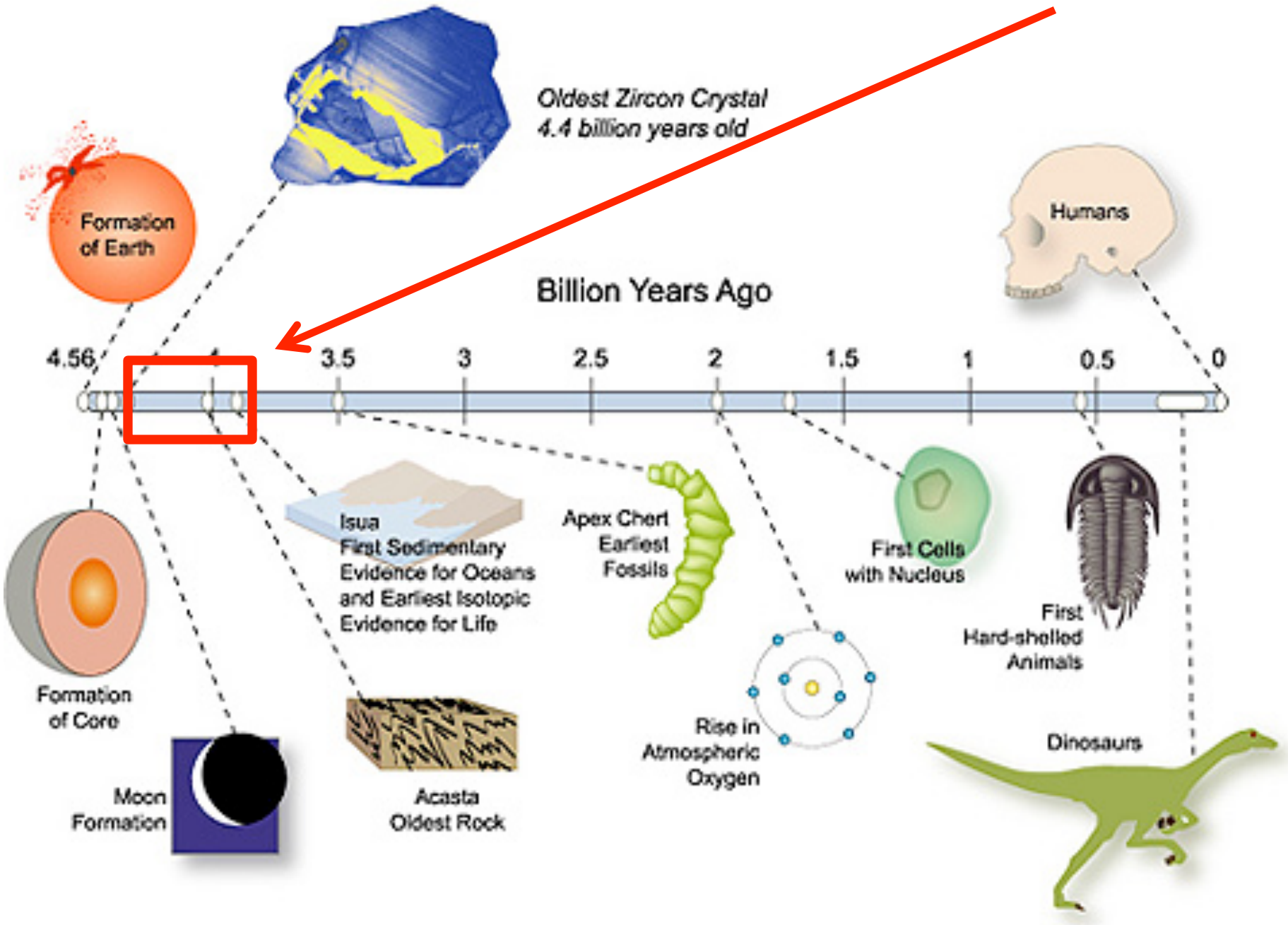
40% of Kepler-discovered planets are Super-Earths or smaller



However - Moon of Gas Giants Could be Habitable

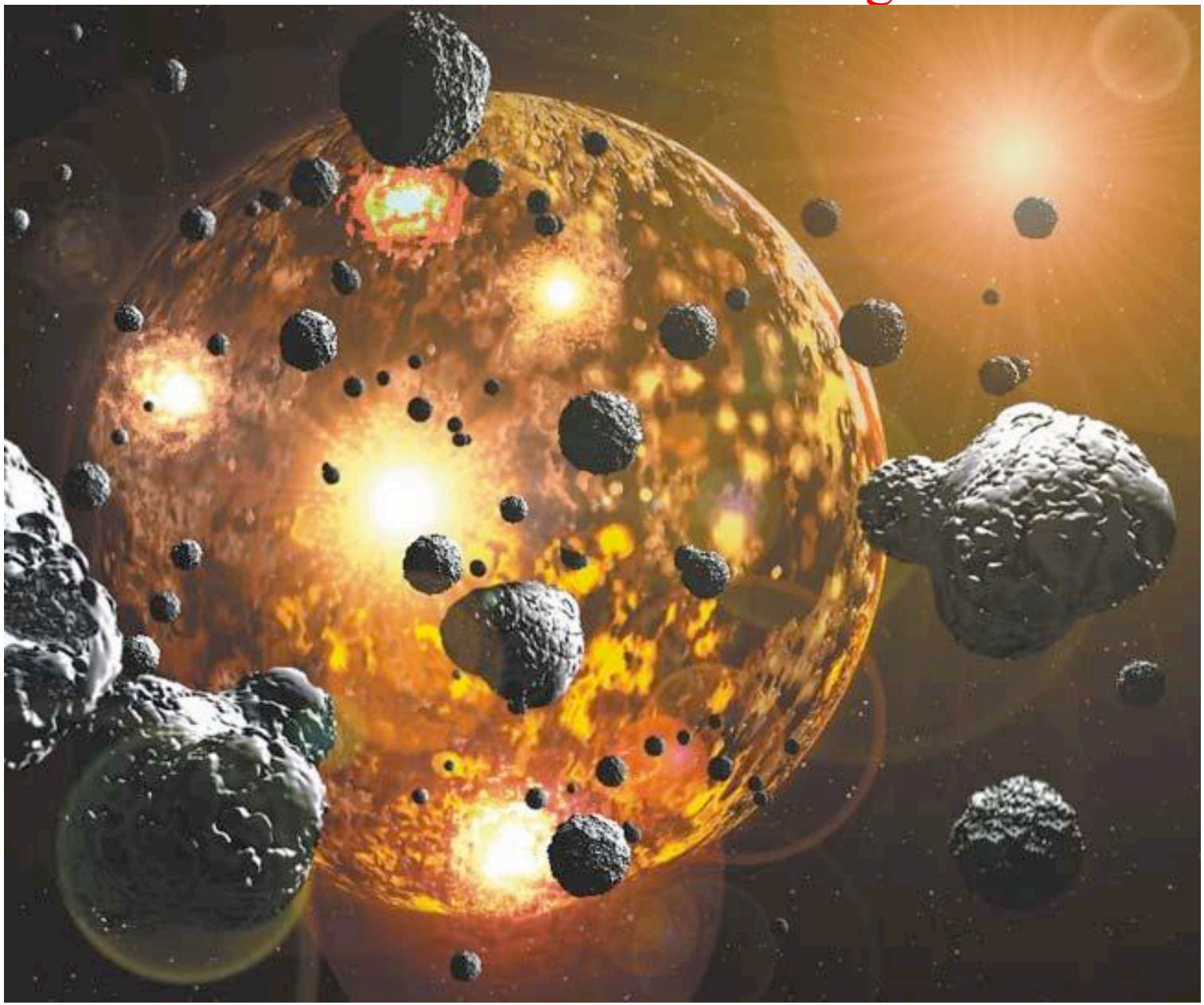


Development of life happened in few 100 million years

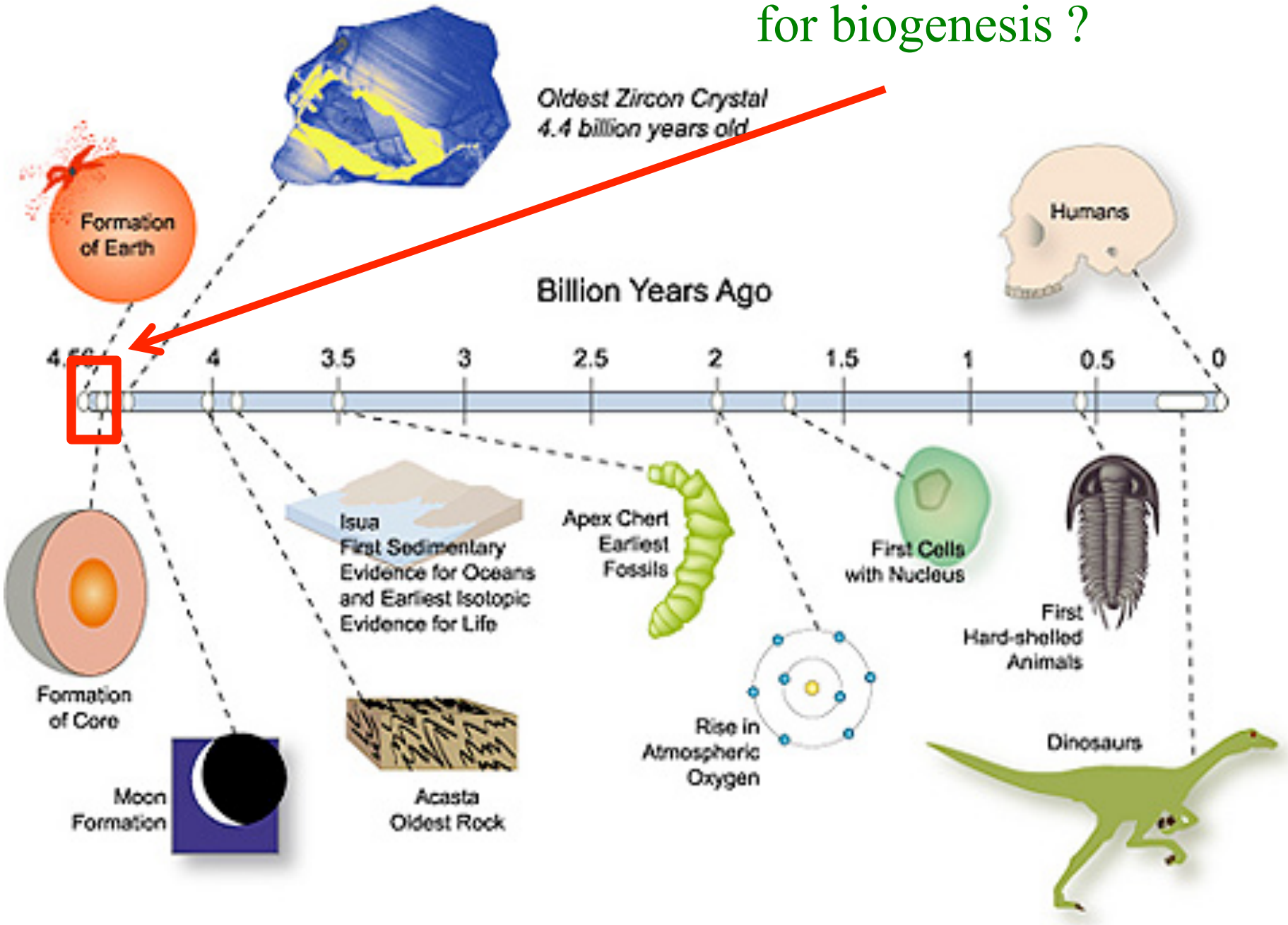


Earth was heavily bombarded with rocks/comets

Possible sterilization of biogensis



Impacts may have sterilized early Earth shortening time for biogenesis ?

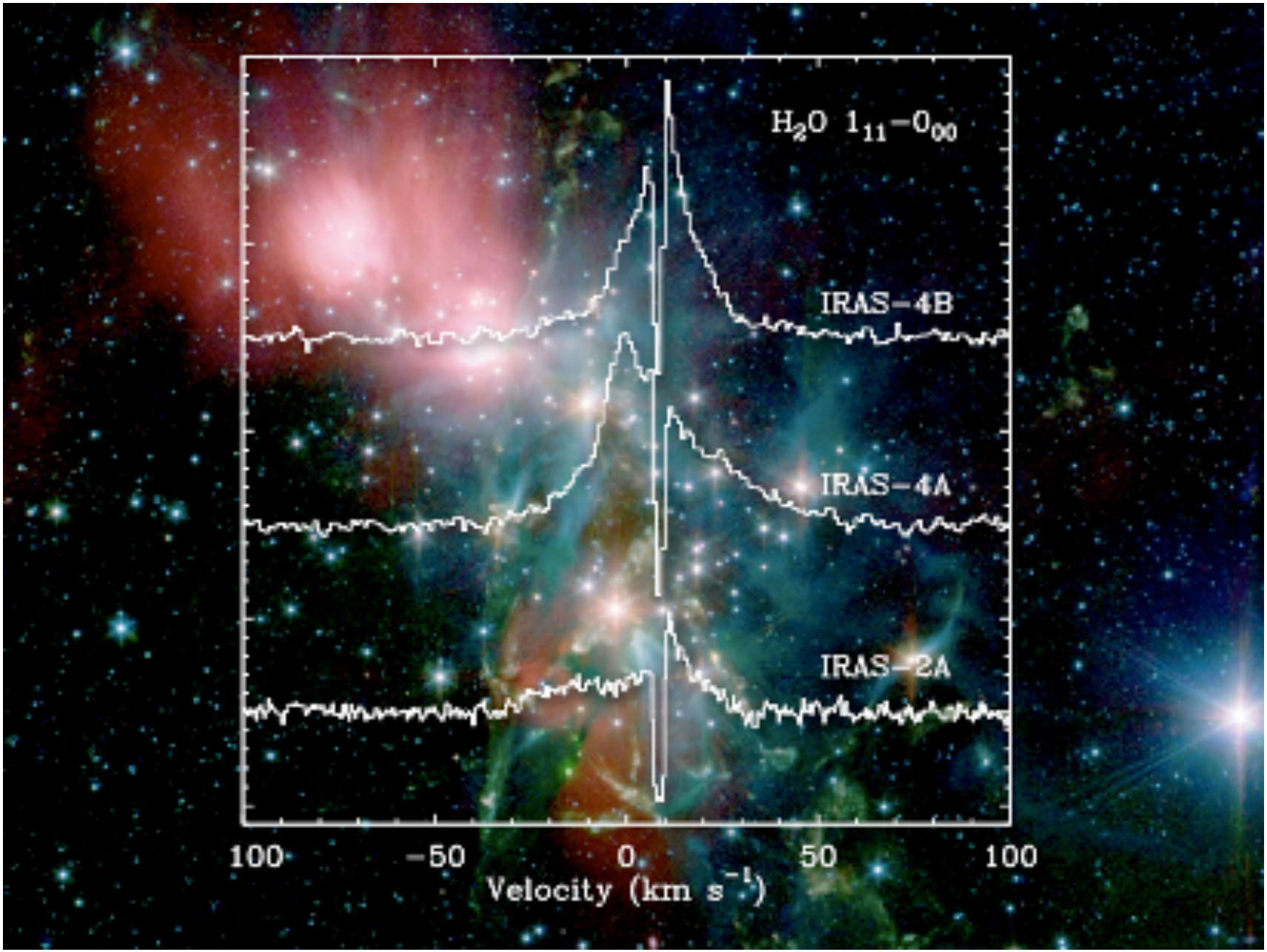


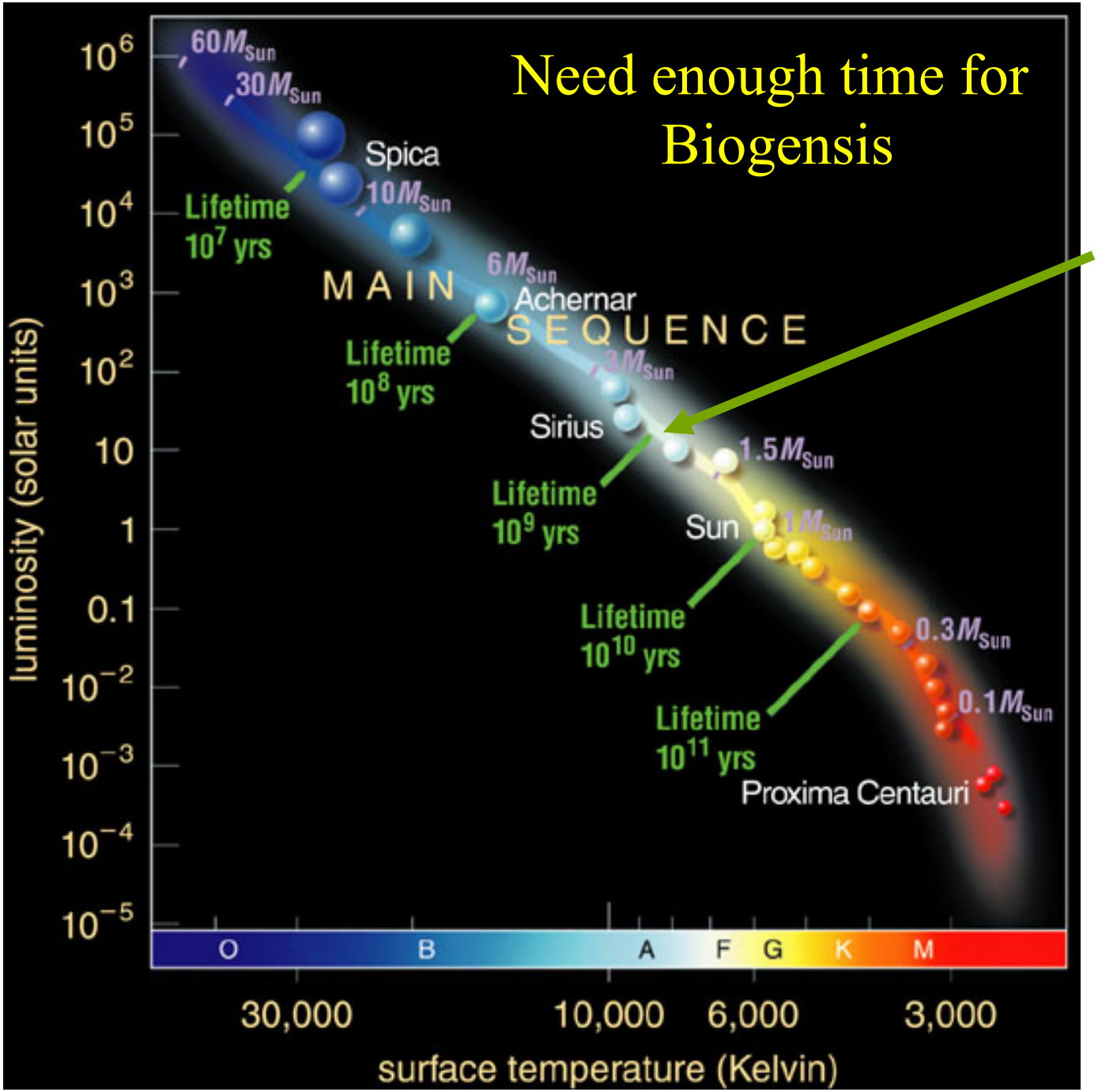
Is Biogensis Common ??

If yes, then optimistic estimate:

$f_{life} \sim 0.5 - 1$

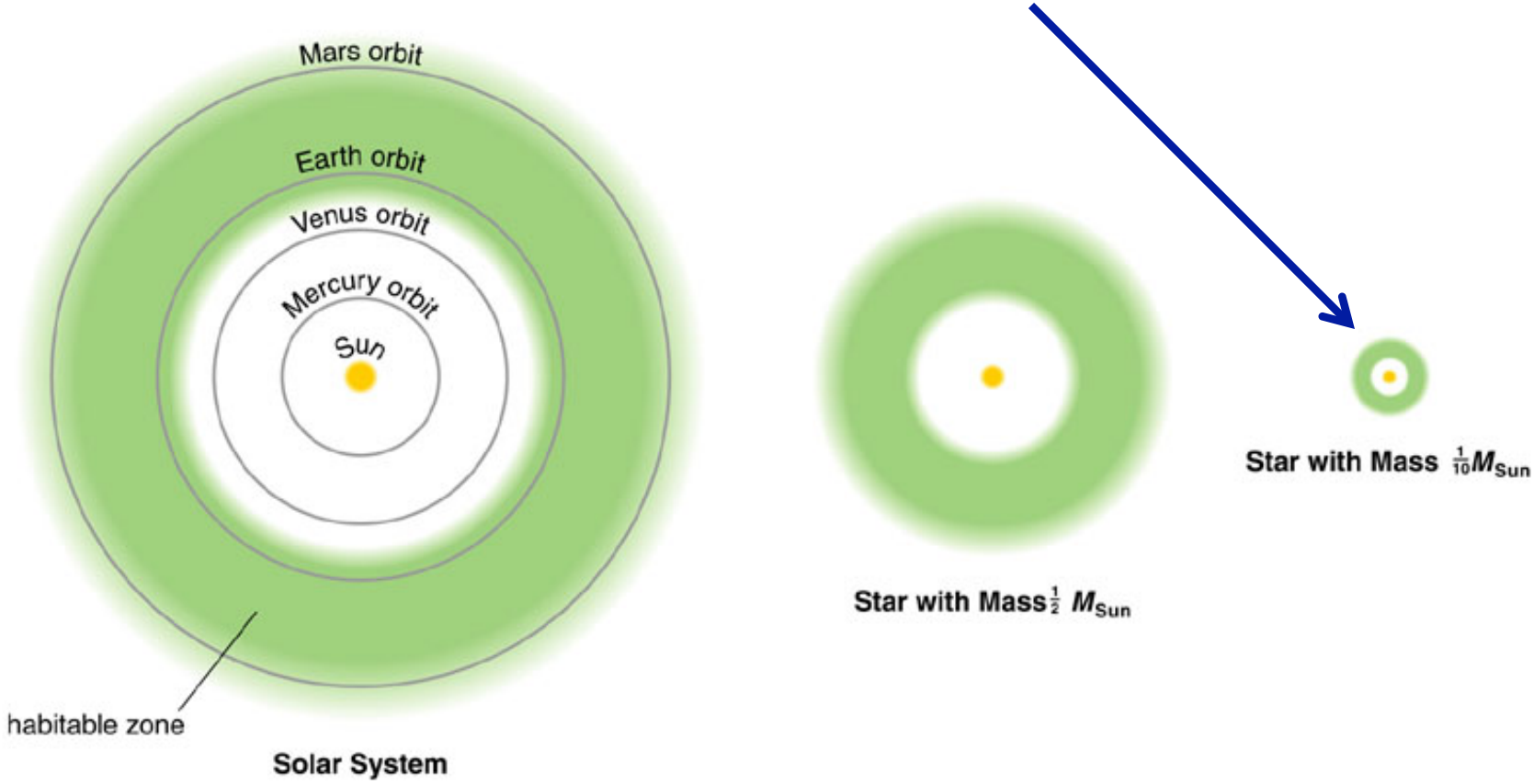
Water is ***common*** in all Star-Forming Regions





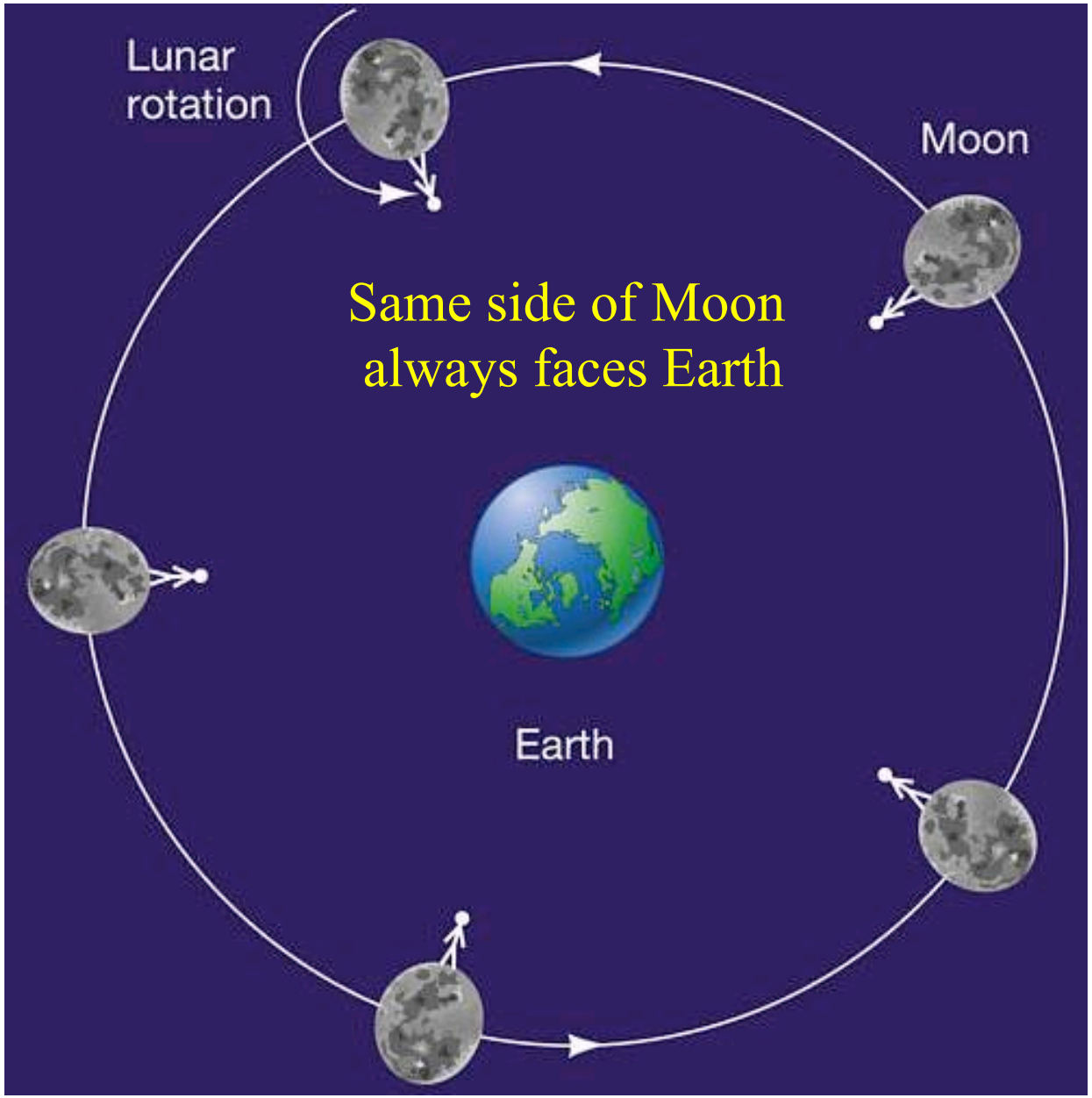
High mass limit of 2 times solar mass for lifetime to be at least 1 billion years for development of life.

Red dwarfs are most numerous stars in Milky Way (~90%)
But they have the smallest Habitable Zones



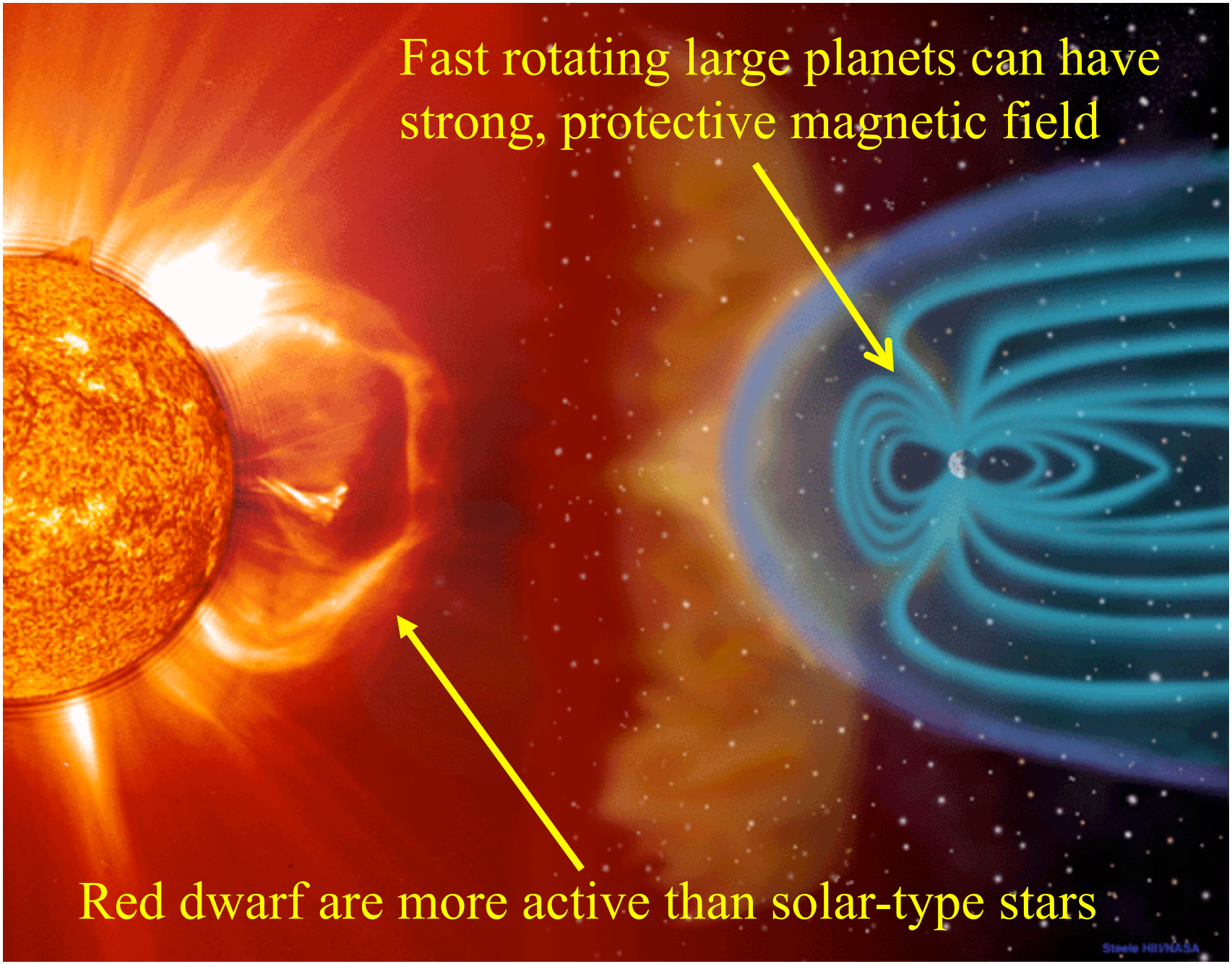
The less massive the star is, the smaller the habitable zone.

Tidal locking can occur with strong interaction (being close)

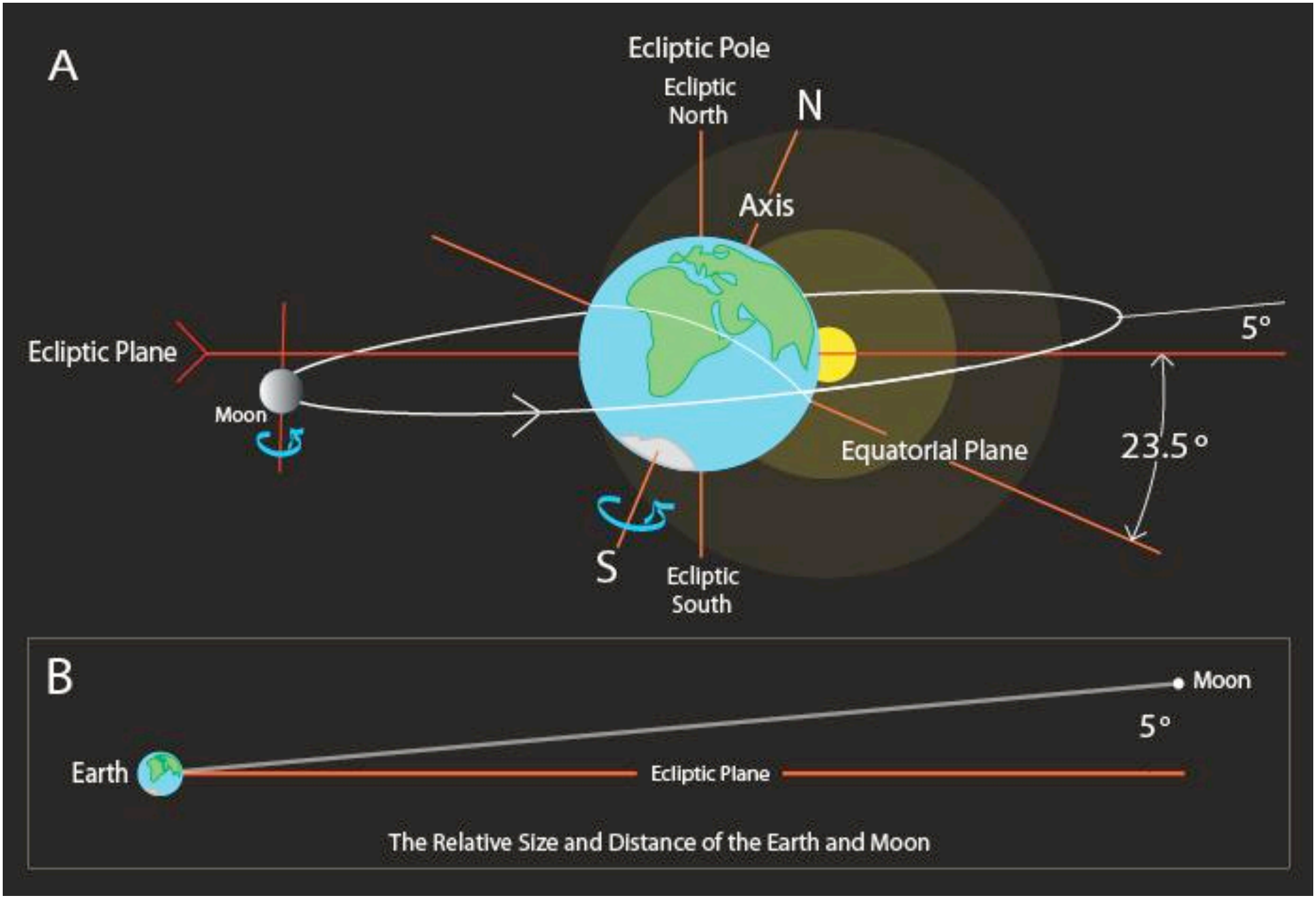


Tidal locking should occur for planets close to stars

Stellar Flares can be detrimental to life

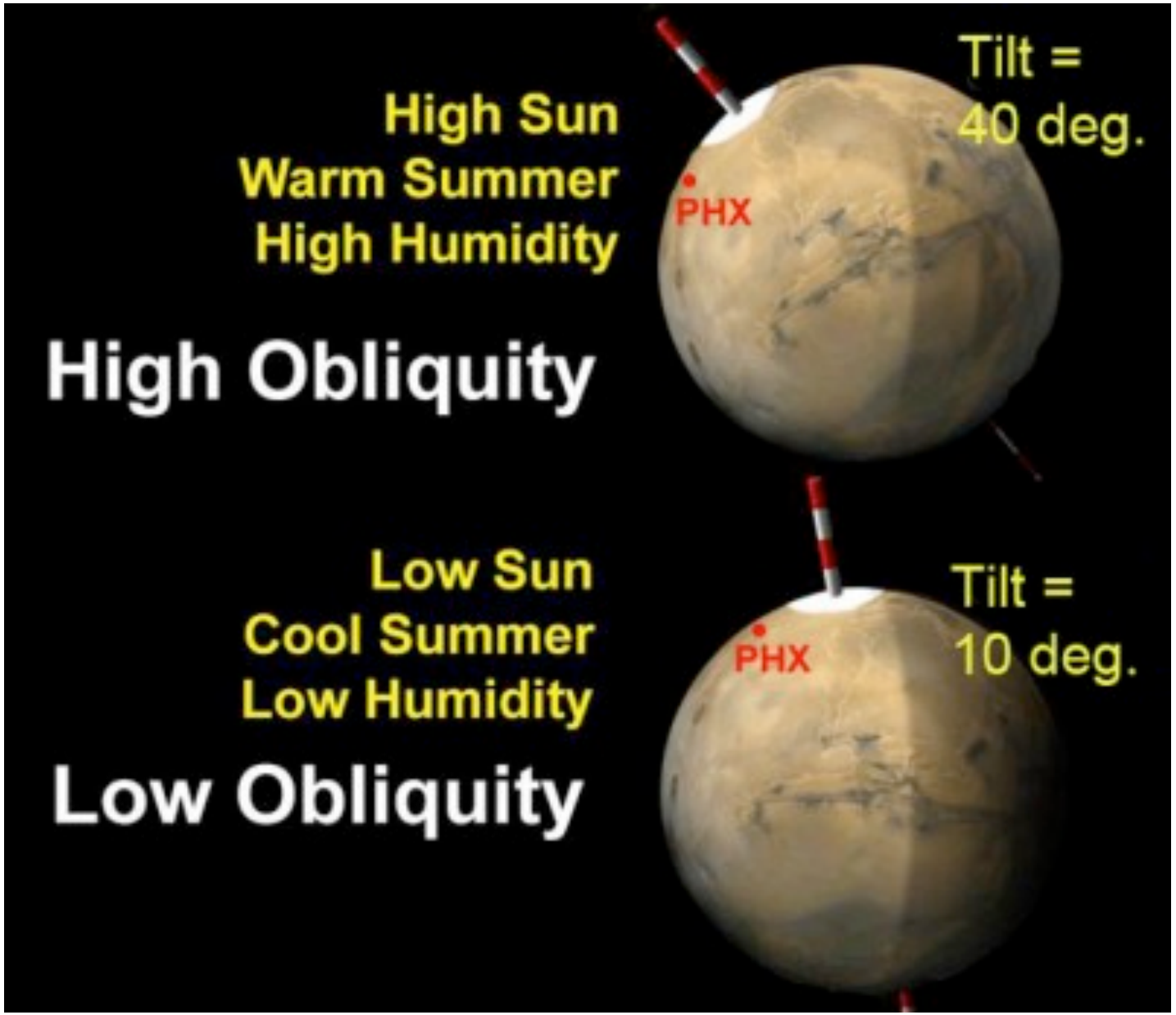


Earth's Moon has stabilized tilt of orbital axis



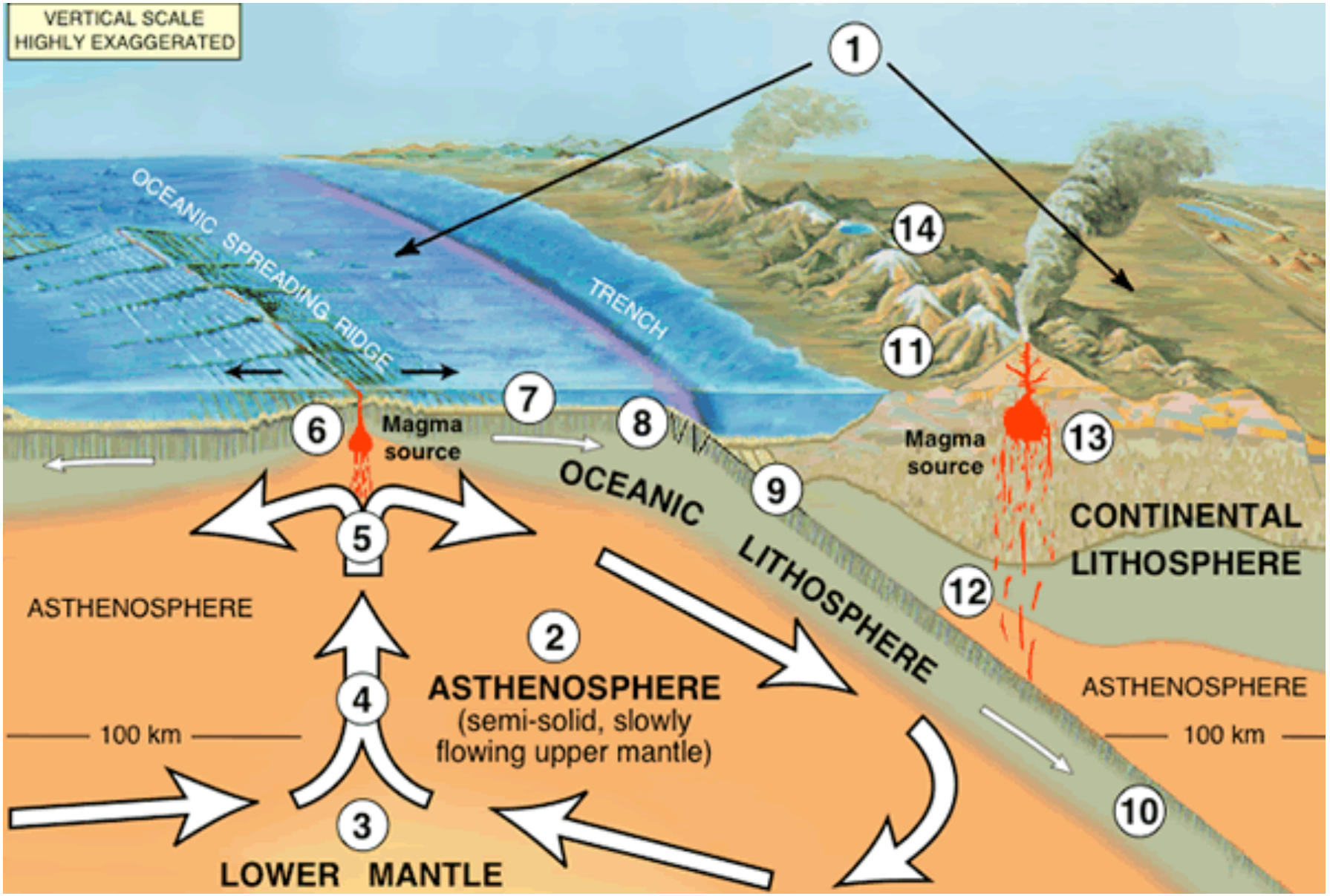
Mars has no moon to stabilize its rotation axis

Climatic variability – how does this affect life?



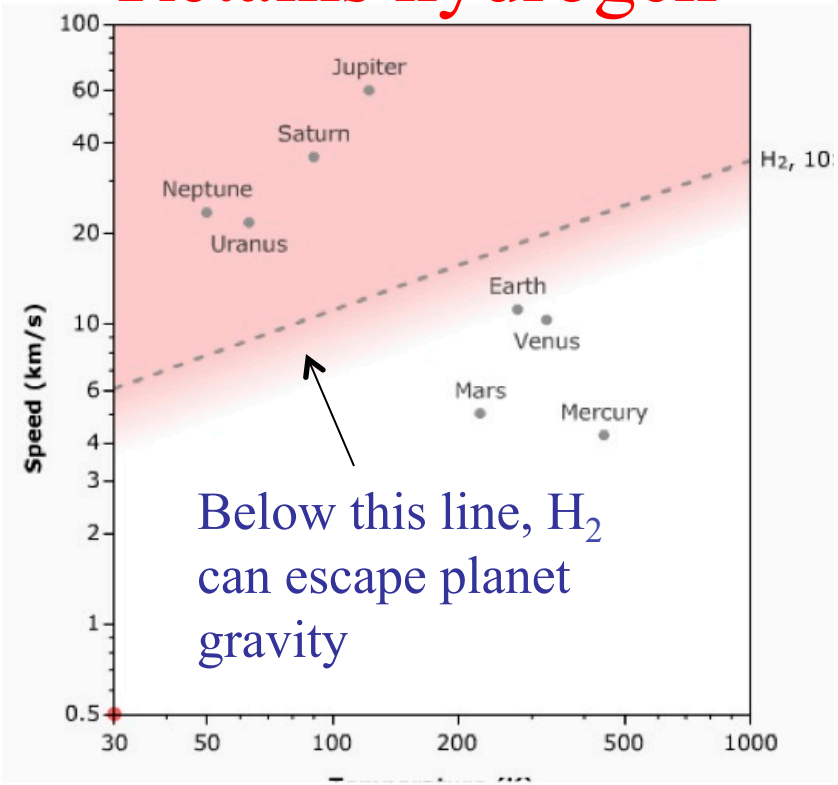
Earth has plate tectonics which cycles Carbon

Plate tectonics favor larger planets?

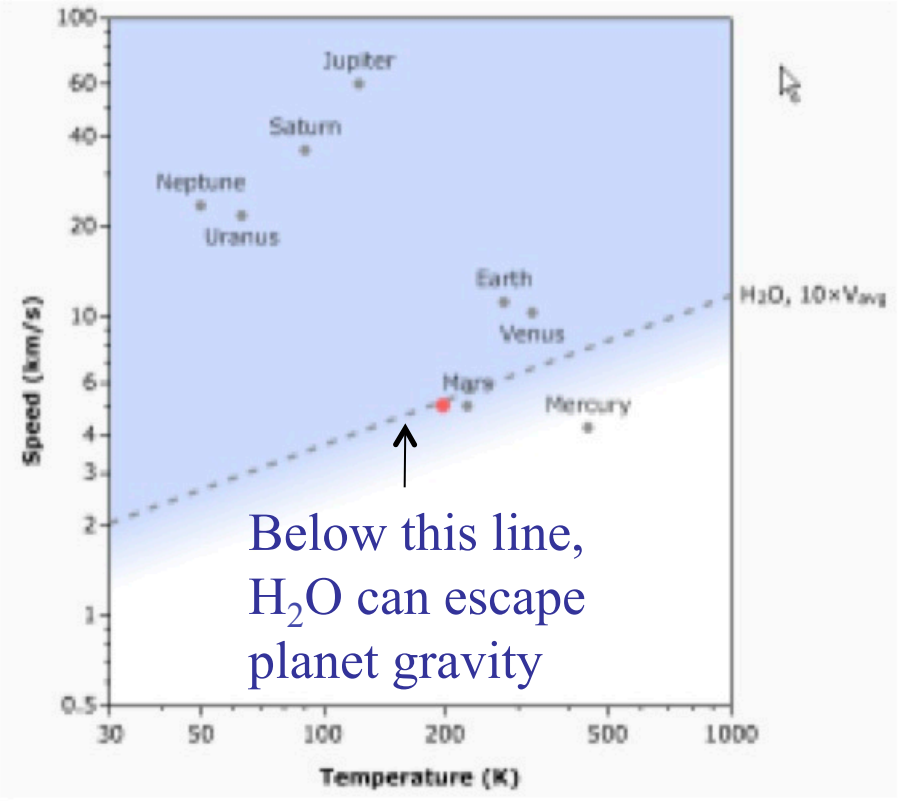


More evidence size matters : retaining an atmosphere

Retains hydrogen



Retains water



Gas Speed (km/s)

Temperature (K)

How many Habitable Planets have life?

$$N_{HP} \times f_{life} \times f_{civ} \times f_{now}$$

Bottom line is that we don't know and the answer could be anywhere between ~ 0 and 1

Most Pessimistic Estimate:

$f_{life} \sim 1 / 1\text{billion}$

Is Biogensis Common ??

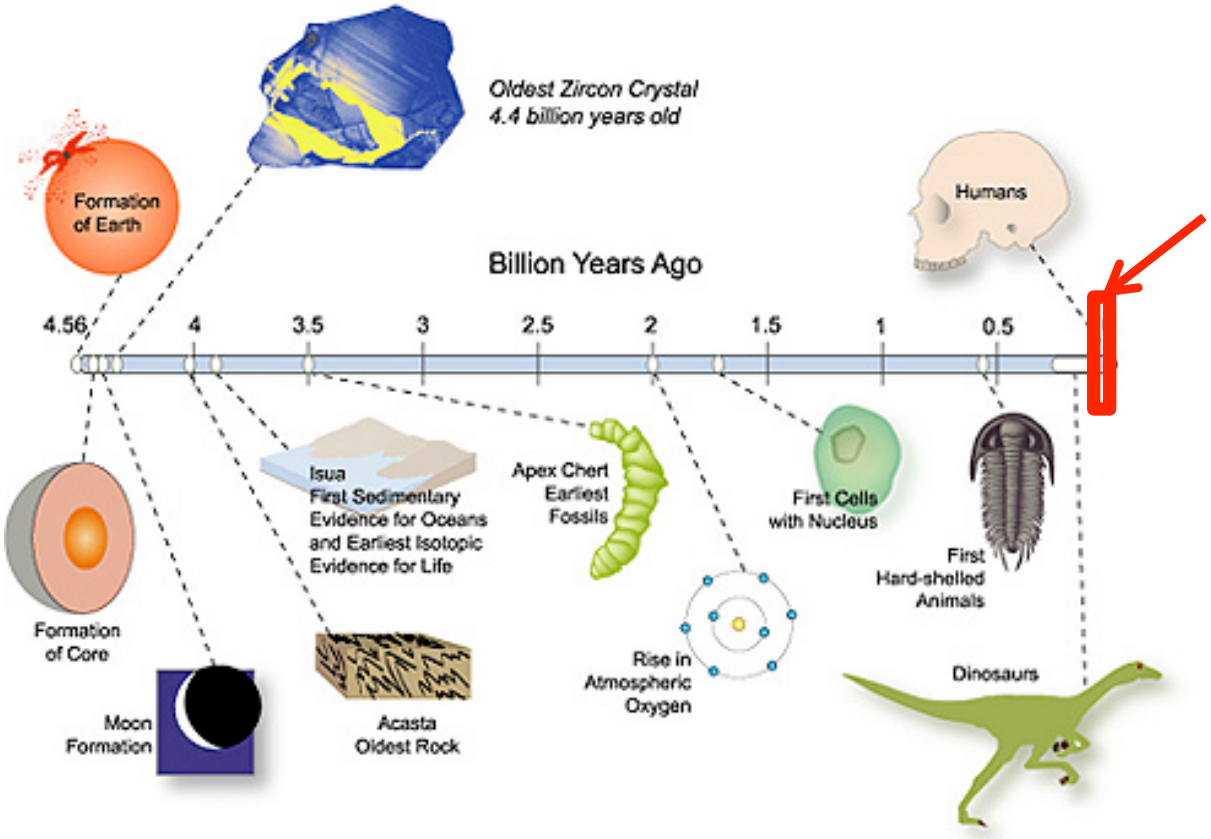
If yes, then Optimistic Estimate:

$f_{life} \sim 0.5 - 1$

How many planets with life develop intelligence?

$$N_{HP} \times f_{life} \times f_{civ} \times f_{now}$$

To date, we only know of 1 example and it took 4.5 billion years:



How many planets have intelligent life now?

$$N_{HP} \times f_{life} \times f_{civ} \times f_{now}$$

Major extinction events have occurred in the past

How many planets have intelligent life now?

$$N_{HP} \times f_{life} \times f_{civ} \times f_{now}$$

Ends of civilizations may be self-inflicted

We do not know the values for the Drake Equation

N_{HP} : ~ 1 billion (estimates will improve next few yrs)

f_{life} : ??? Hard to say (near 0 or near 1)

f_{civ} : ??? It took 4.5 billion years on Earth

f_{now} : ??? Can civilizations survive long-term?

For "optimistic" values of the factors, the proximity of aliens depends on the longevity of their civilizations.

How many planets have communicating civilizations?

$$N_{HP} \times f_{life} \times f_{civ} \times f_{now} \times f_{communicate}$$

Humans have had radio communication for only ~ 100 years

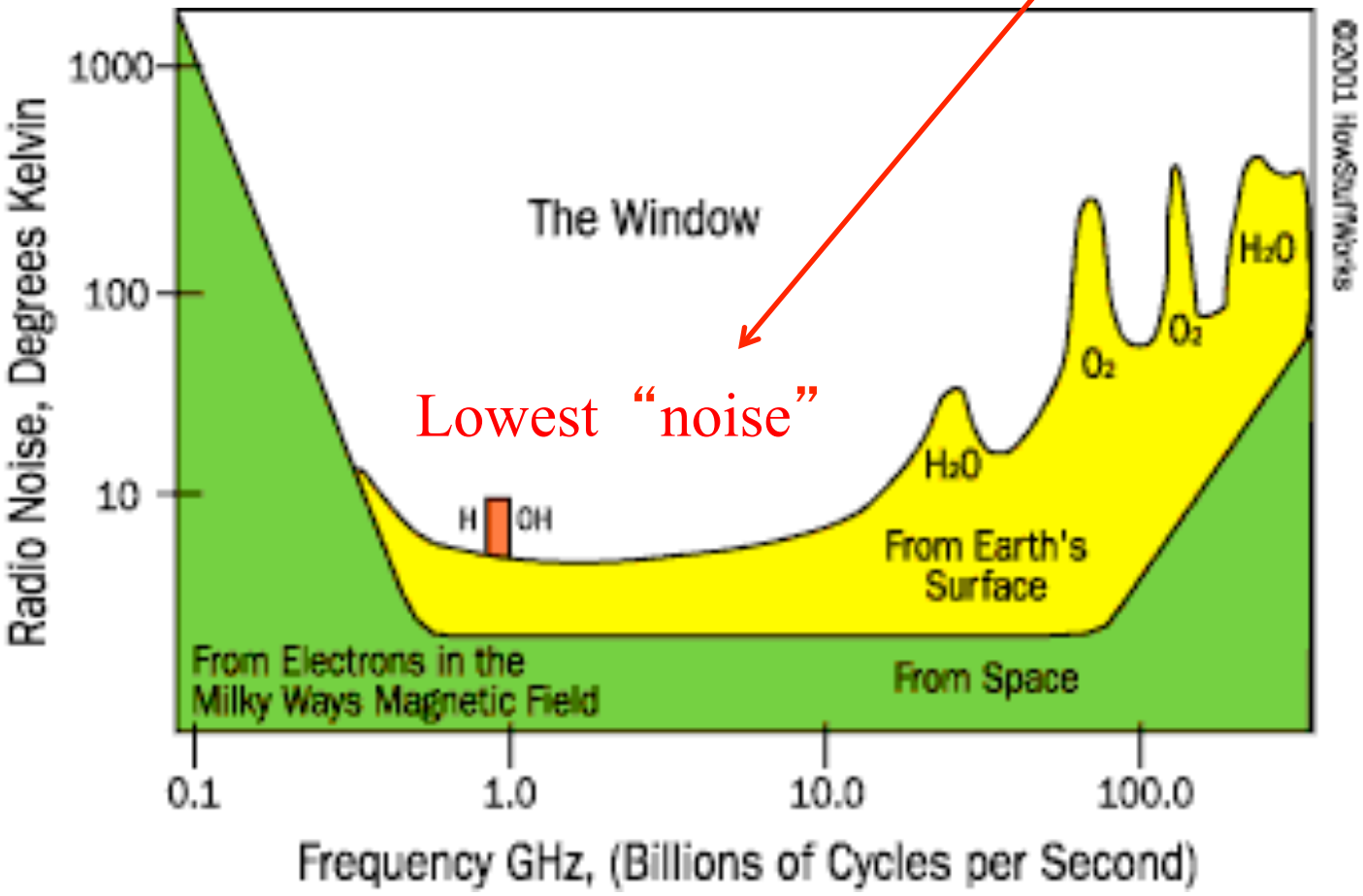
We've even sent a few deliberate signals ourselves…

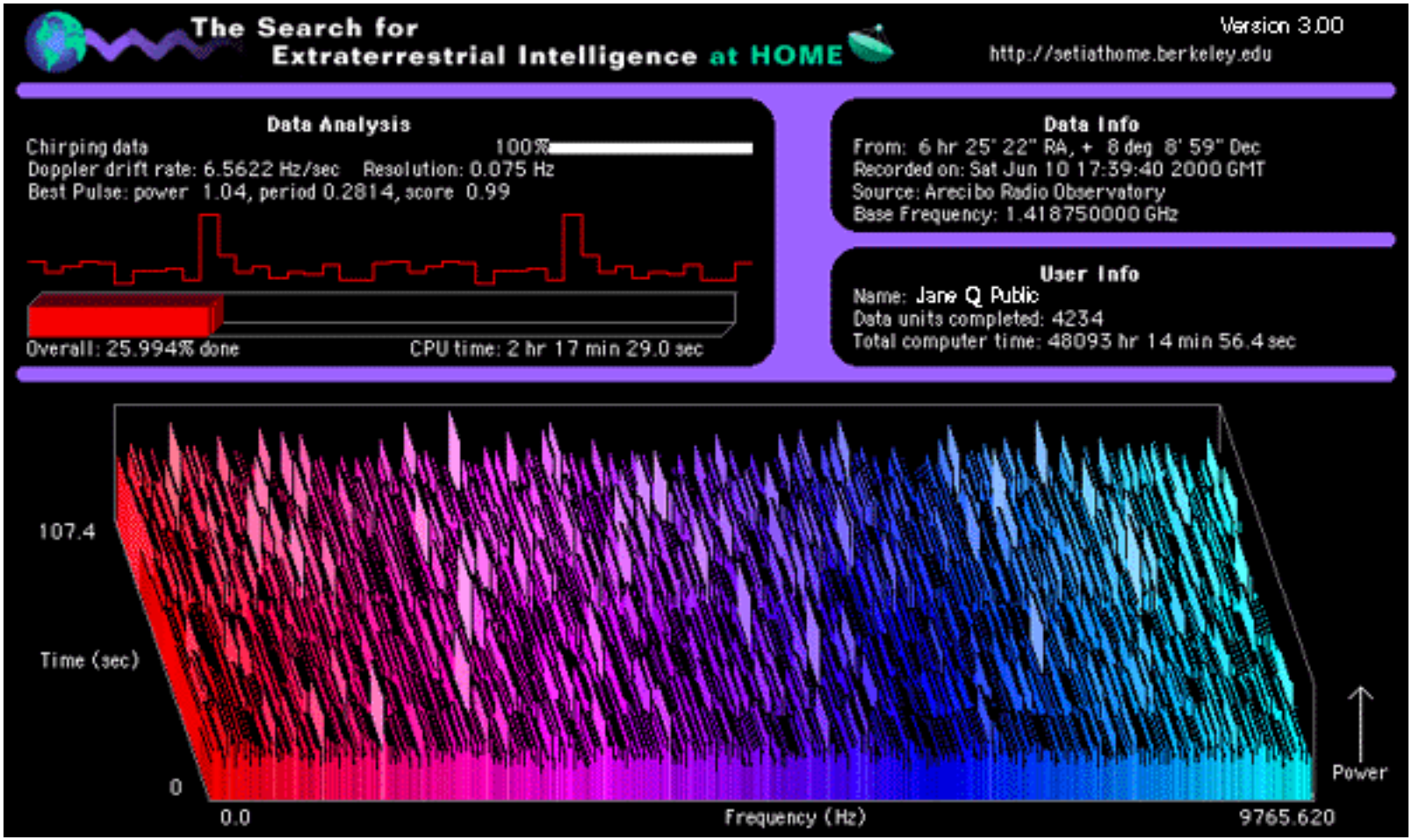
Earth to globular cluster M13: Hoping we'll hear back in about 50,000 years!

How does SETI work?

Looking for ***deliberate*** signals from E.T.

Best Frequency to search is in ***Radio***





Your computer can help! SETI @ Home: a screensaver with a purpose, looking for signals in radio data (mostly just noise).