News and Reminders

End of semester proposal due dates:

- Proposal review: today
- Proposal review write-ups: Monday, Dec. 9

Please complete the **course evaluations**

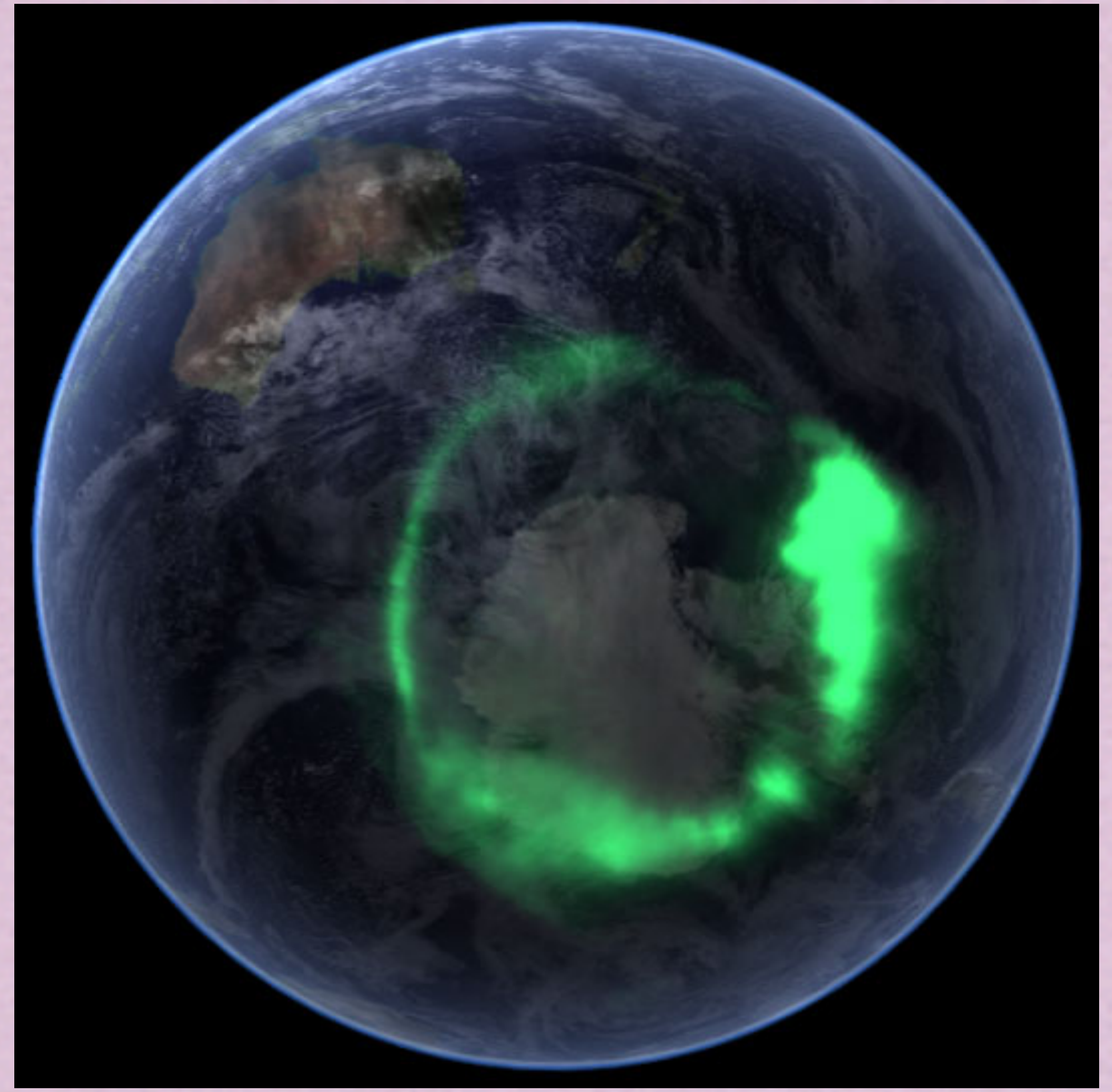
Detecting Magnetic Fields on Exoplanets

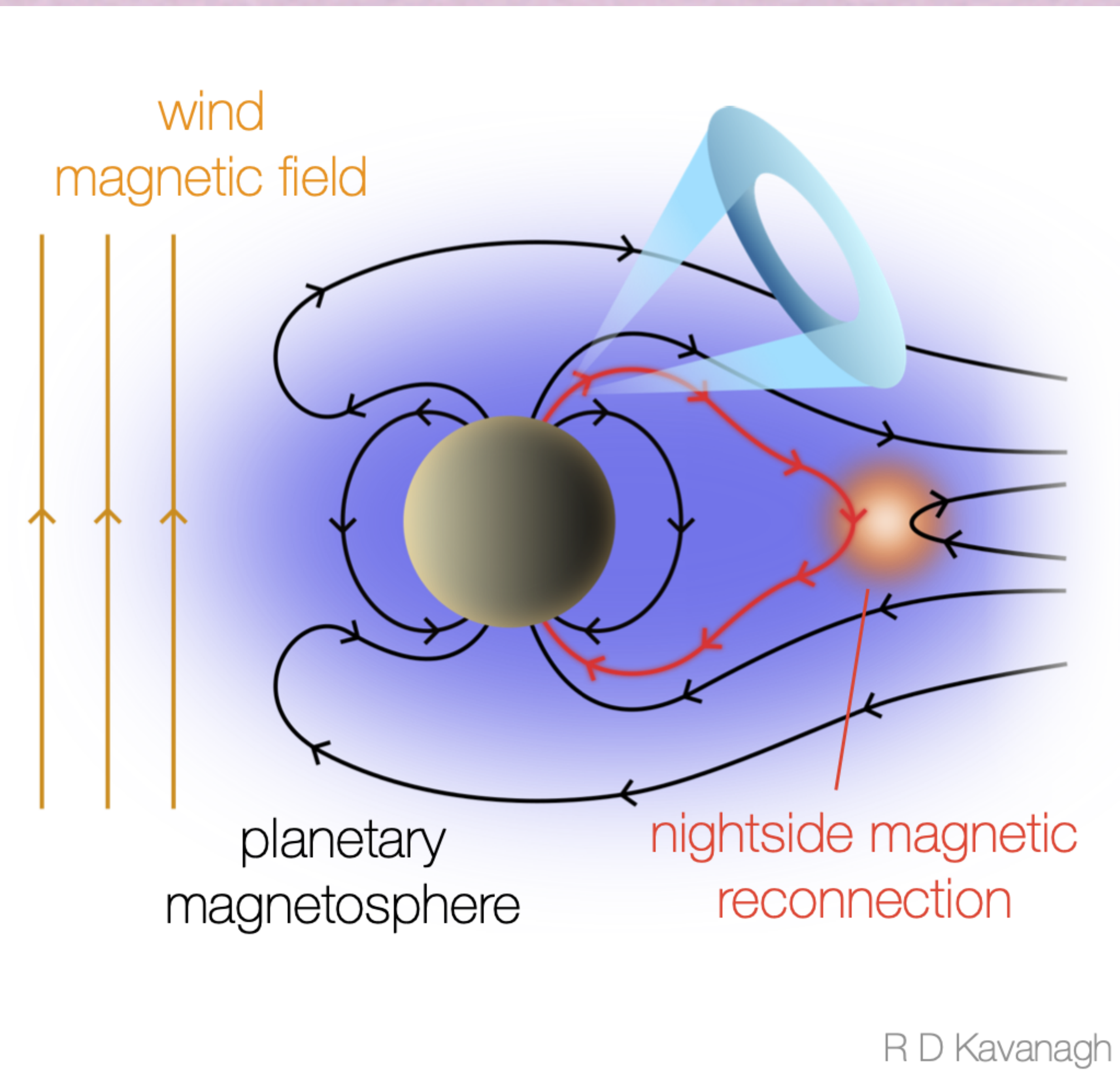
Table 2. Summary of exoplanet magnetic field measurement methods.

Method	Planet type	Information
Direct		
Exoplanet aurorae	all	local strength
He 1083 nm spectropolarimetry	transiting hot Jupiter	l.o.s. averaged strength
Radiation belt emission	all	dipole magnetic component
Indirect		
Star-planet interactions	close-in	magnetopause size
Ohmic dissipation	transiting hot Jupiter	
Magnetospheric bow shocks	transiting	magnetopause size
Atmospheric outflow transit spectroscopy	transiting close-in	strongly or weakly magnetized

Brain et al. (2024)

Aurorae in the Solar System - Earth





Saturn, Uranus and Neptune get aurorae through the same mechanism, but the radio emission is fainter because the solar wind power is lower.

Detecting Magnetic Fields on Exoplanets

Aurorae:

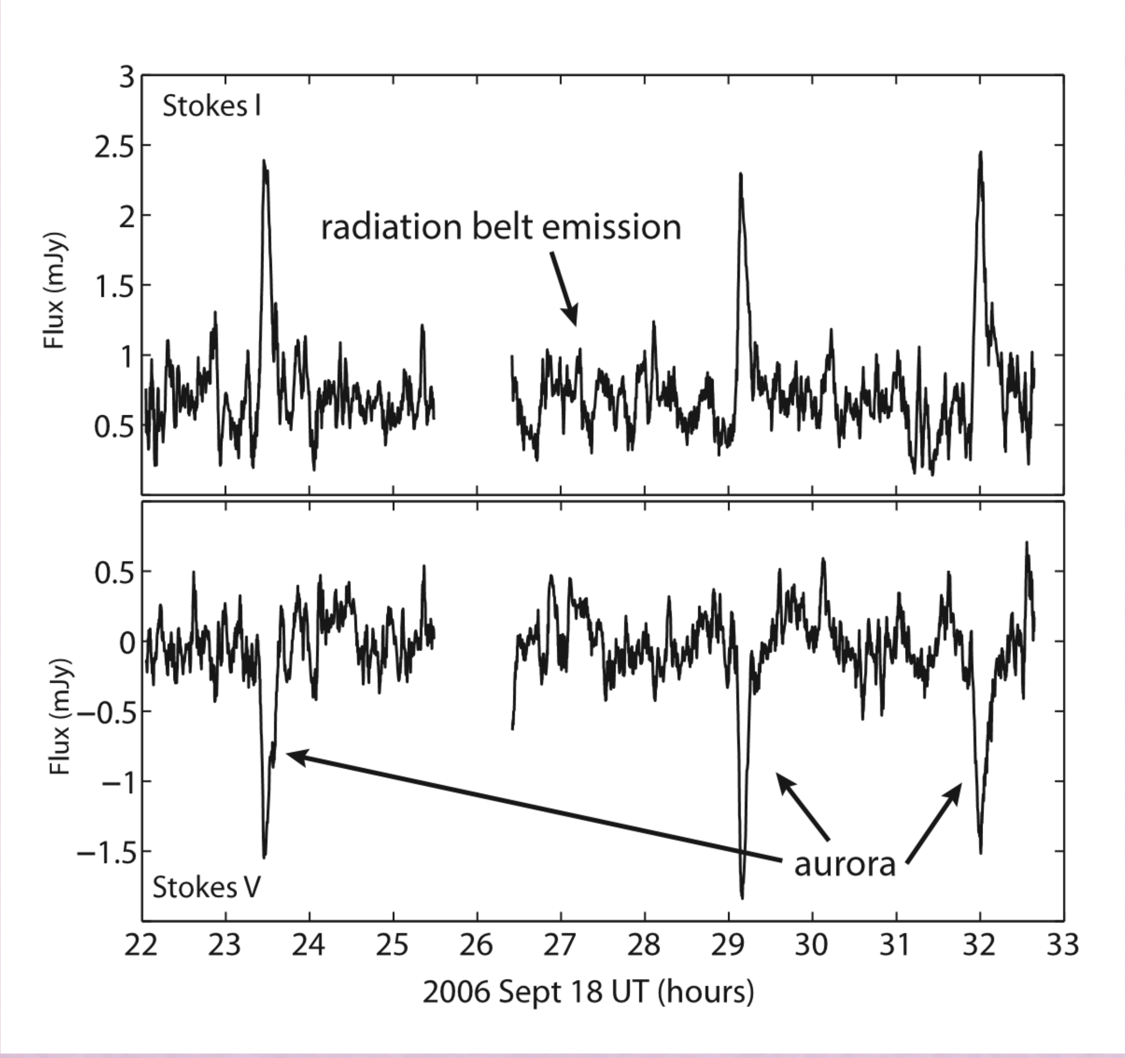
- no detections on exoplanets so far
  - hot Jupiters may suffer from dense, plasma-filled magnetospheres that inhibit electron cyclotron maser emission?

- however, detections have been made on brown dwarfs and low-mass M dwarfs

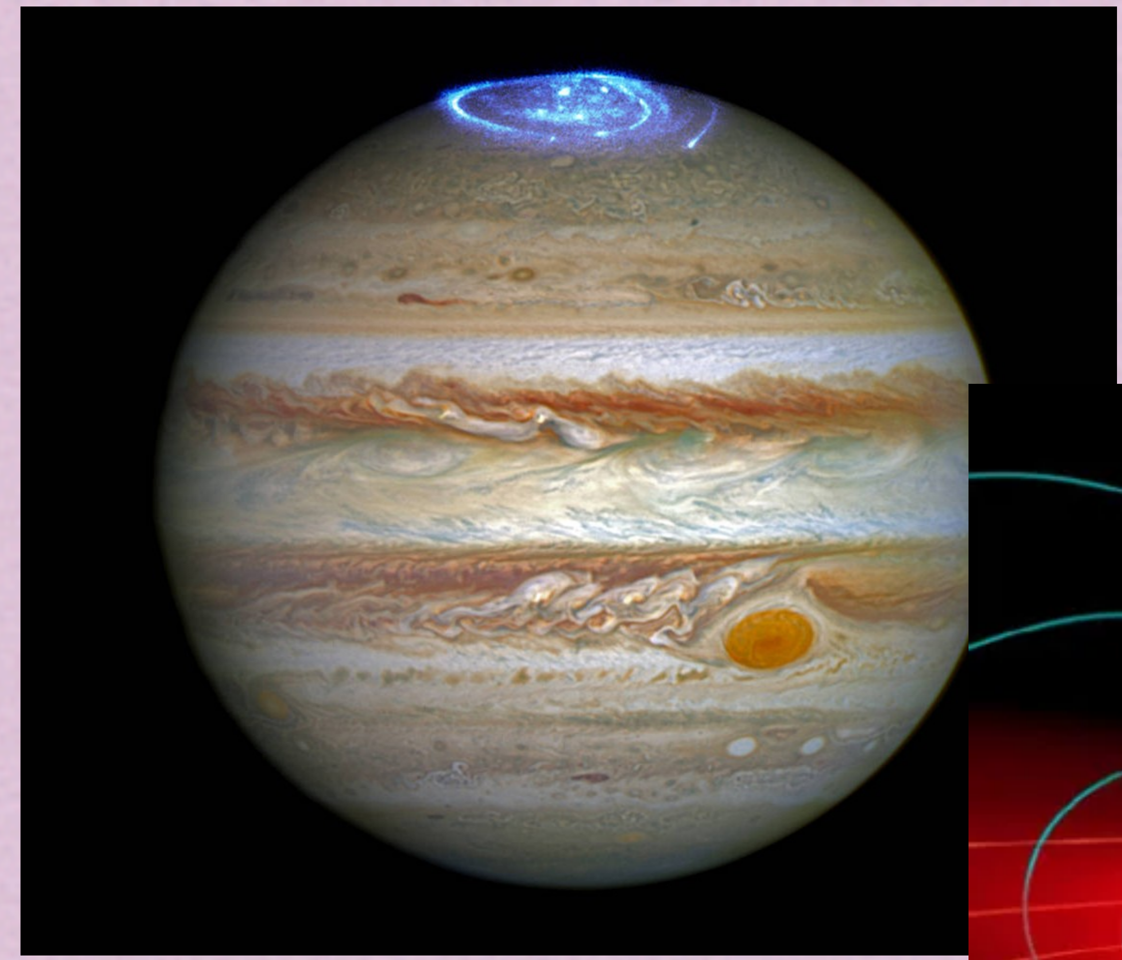
Very low-mass dwarf
LSR J1835+3259

Rotation period = 2.84 hours

Hallinan et al. (2008)



Aurorae in the Solar System



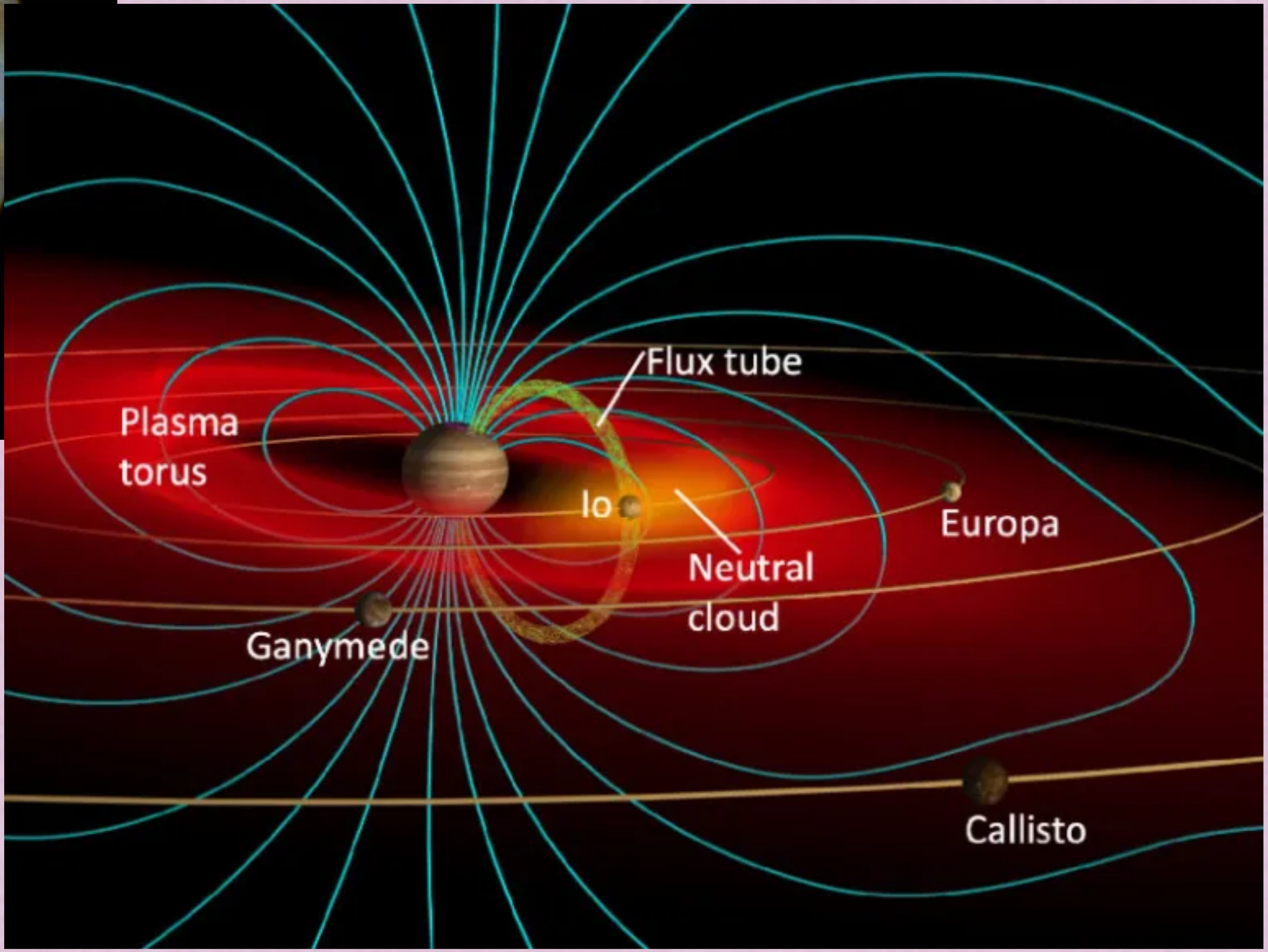
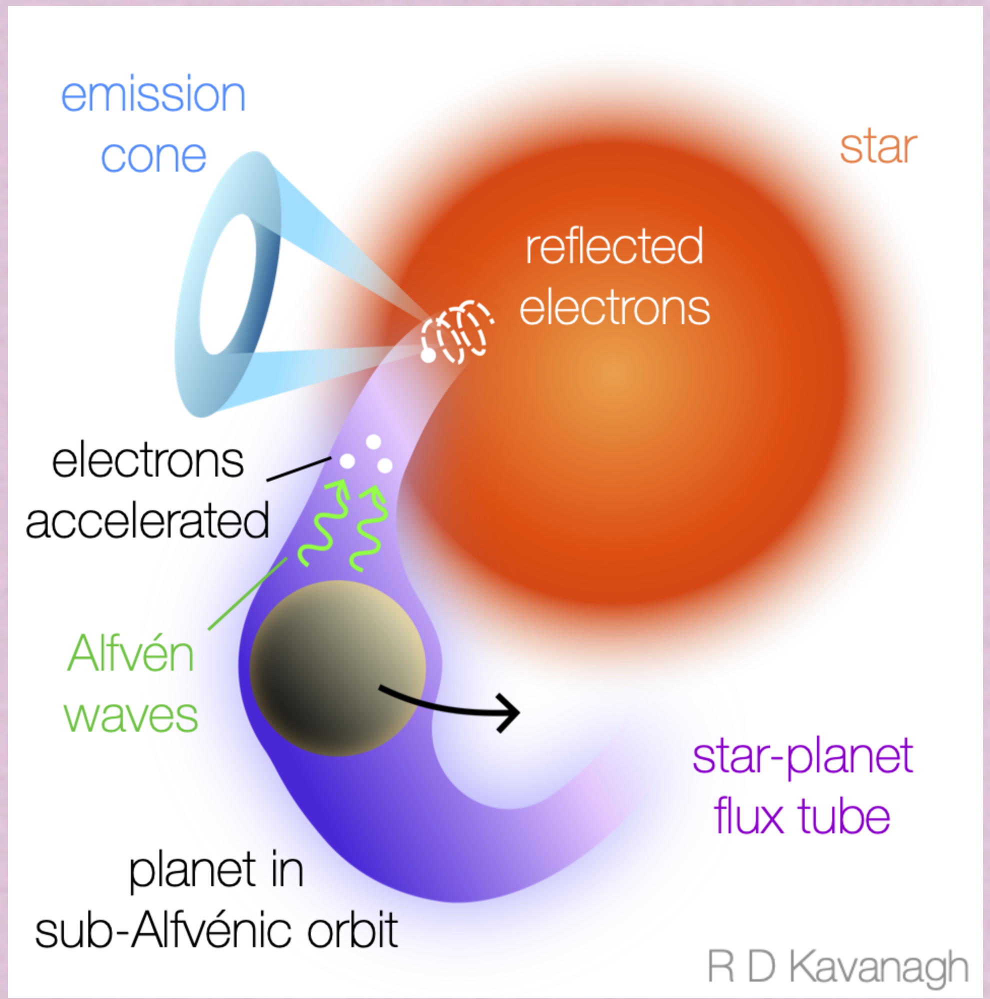


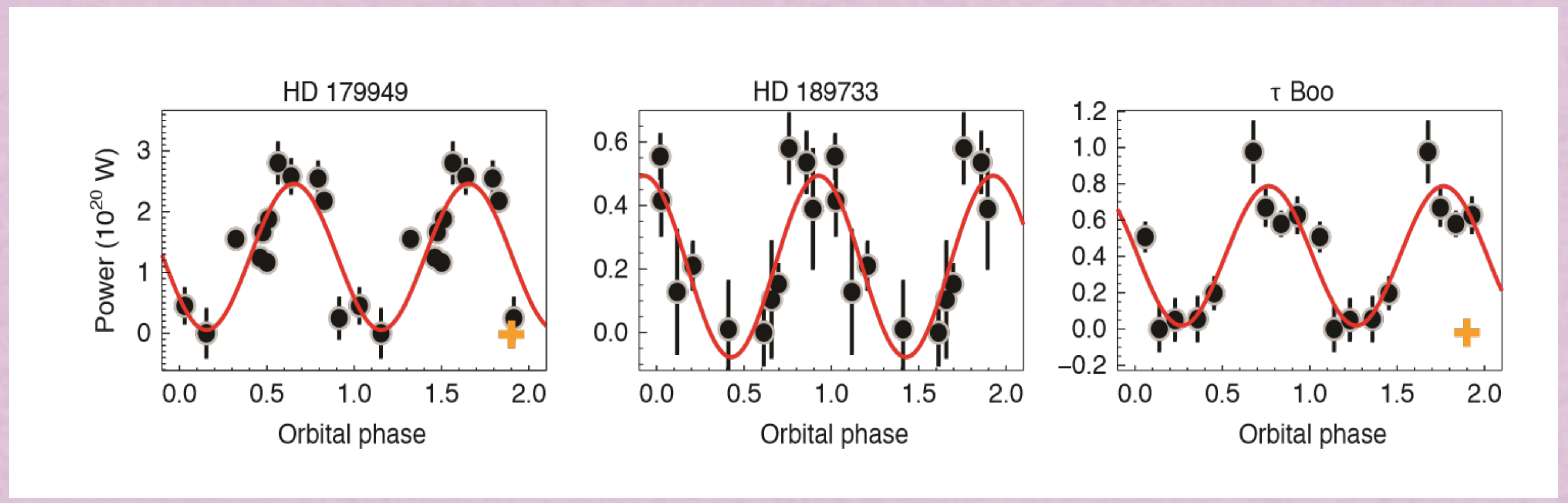
Image credit: J. Spencer,
Southwest Research Institute

Detecting Magnetic Fields on Exoplanets

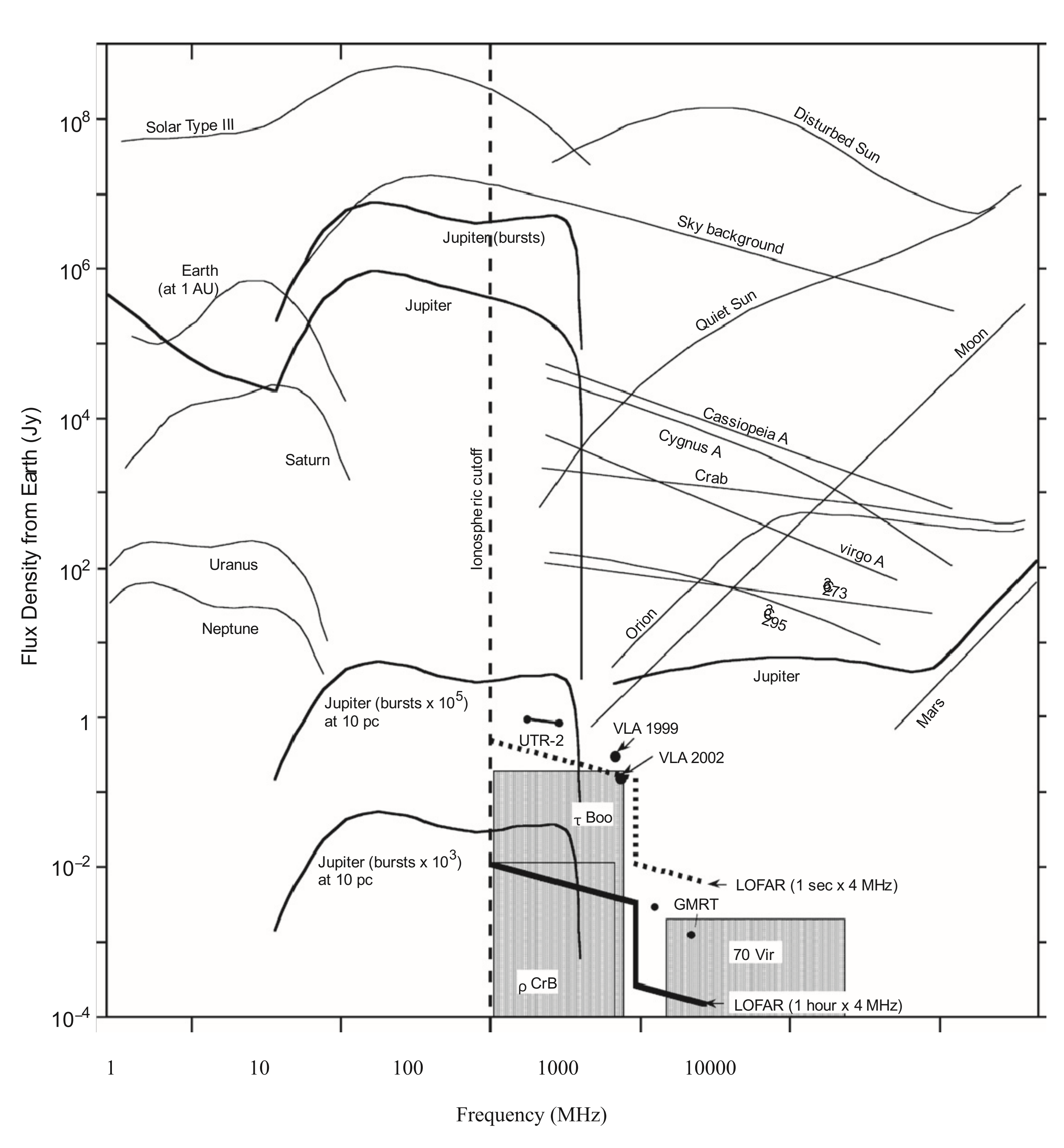
Star-planet interaction



Aurorae on the *star*!

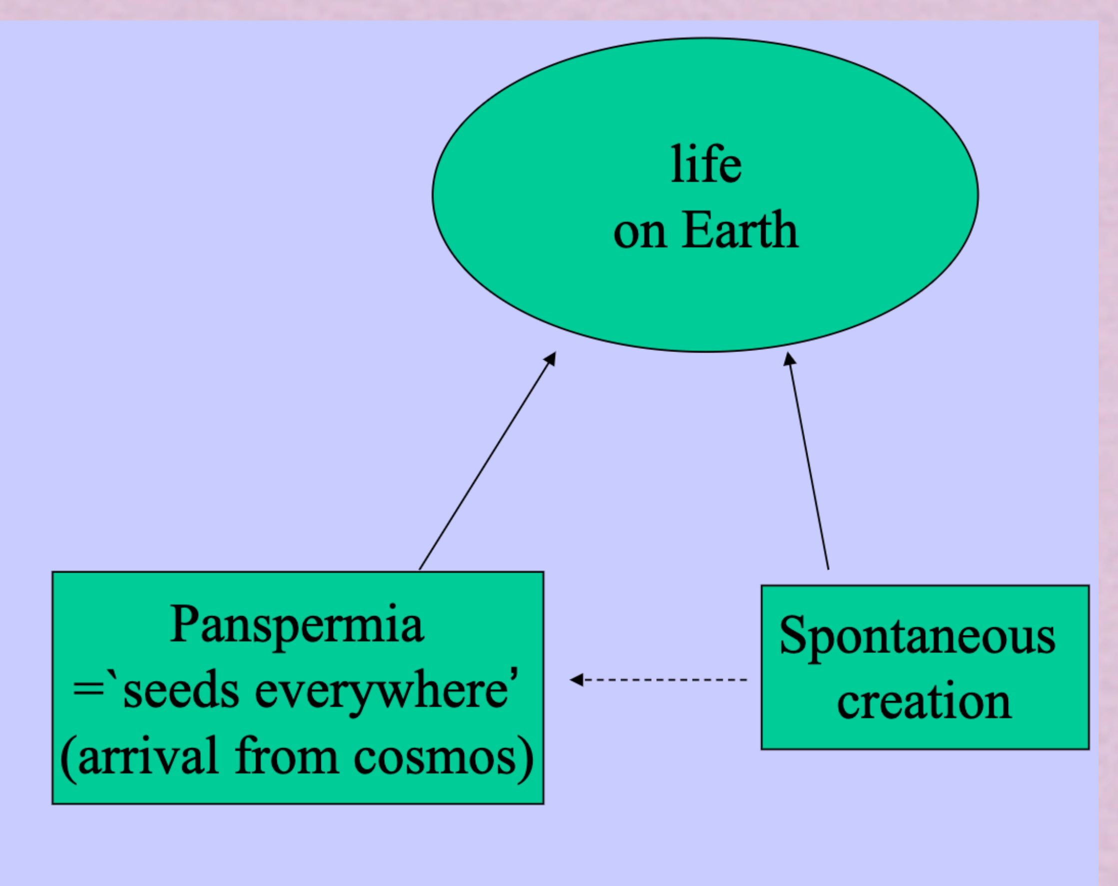


Detecting Magnetic Fields on Exoplanets



Zarka (2007)

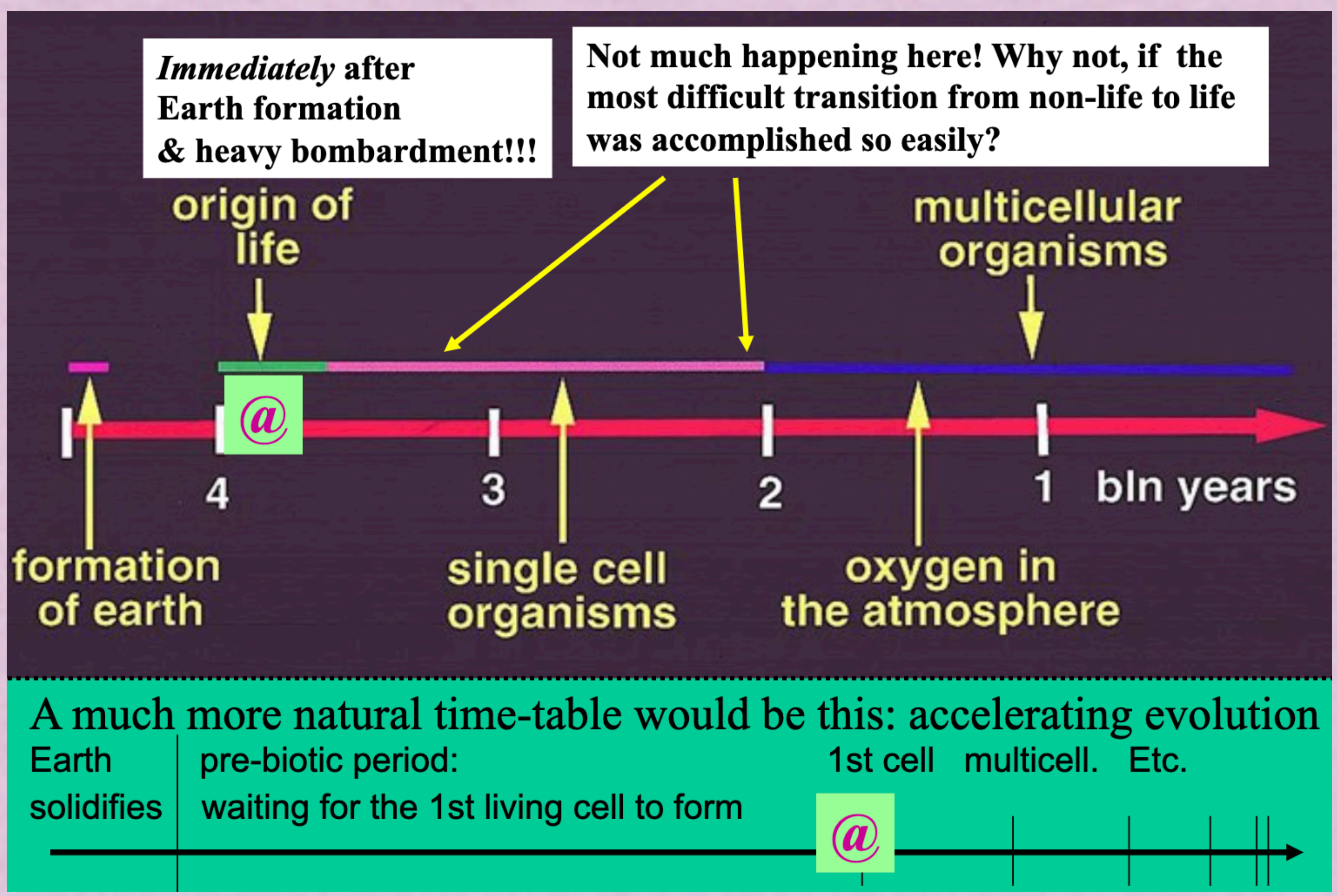
Life on Earth



panspermia: "seeds everywhere"

-> life arrives, ready-made, on the surface of planets from space (meteorites, asteroids, comets, space dust…)

-> can life survive the trip? bacterial spores: ~1 in 100,000 have been shown to survive brief exposure to the 3,000°C flame (e.g. rocket exhaust), while others have survived a bath in liquid helium at -269°C



Life on Earth

More likely, meteors impacting Earth generated HCN (hydrogen cyanide) and H_2S (hydrogen sulfide). HCN is also abundant in comets many of which impacted Earth for the first several hundred Myr of its history

- -> these molecules + UV radiation kickstarted the production of amino acids and other organic building blocks;
- -> amino acids react with energy (sunshine, volcanic) to make the specific polypeptide chains (precursors to proteins) needed for life.
- -> DNA communicates the "blueprints" for making proteins, but cells can't copy these molecules without proteins. So which came first?
    - -> Studies find that HCN + H_2S + UV can, over time, make RNA
    - -> Perhaps first life was only based on RNA and DNA appeared later
    - -> Recent research suggests that it may be possible to go from RNA to DNA in just a few chemical reaction steps *without* cells

But a key element is liquid water, which acts as a solvent for prebiotic reactions to take place.

To date, life has not been created in the lab.

Drake Equation

$$N = N_s \times F_p \times F_l \times F_i \times L_c / L_s$$

N is the number of civilizations in the Milky Way today.

N_s is the number of stars in the Milky Way.

F_p is the fraction of stars with habitable planets.

F_l is the fraction of habitable planets with life.

F_i is the fraction of life-bearing planets where intelligent civilizations arise.

L_c is the typical lifetime of a civilization in years.

L_s is the typical lifetime of a star (10 billion years for Sun-like stars).

Ns = 100 x 10^9

Fp = 0.1?

Fl = 1?

Fi = 0.01?

Lc = 300 000 y ?

Ls = 10 Gy

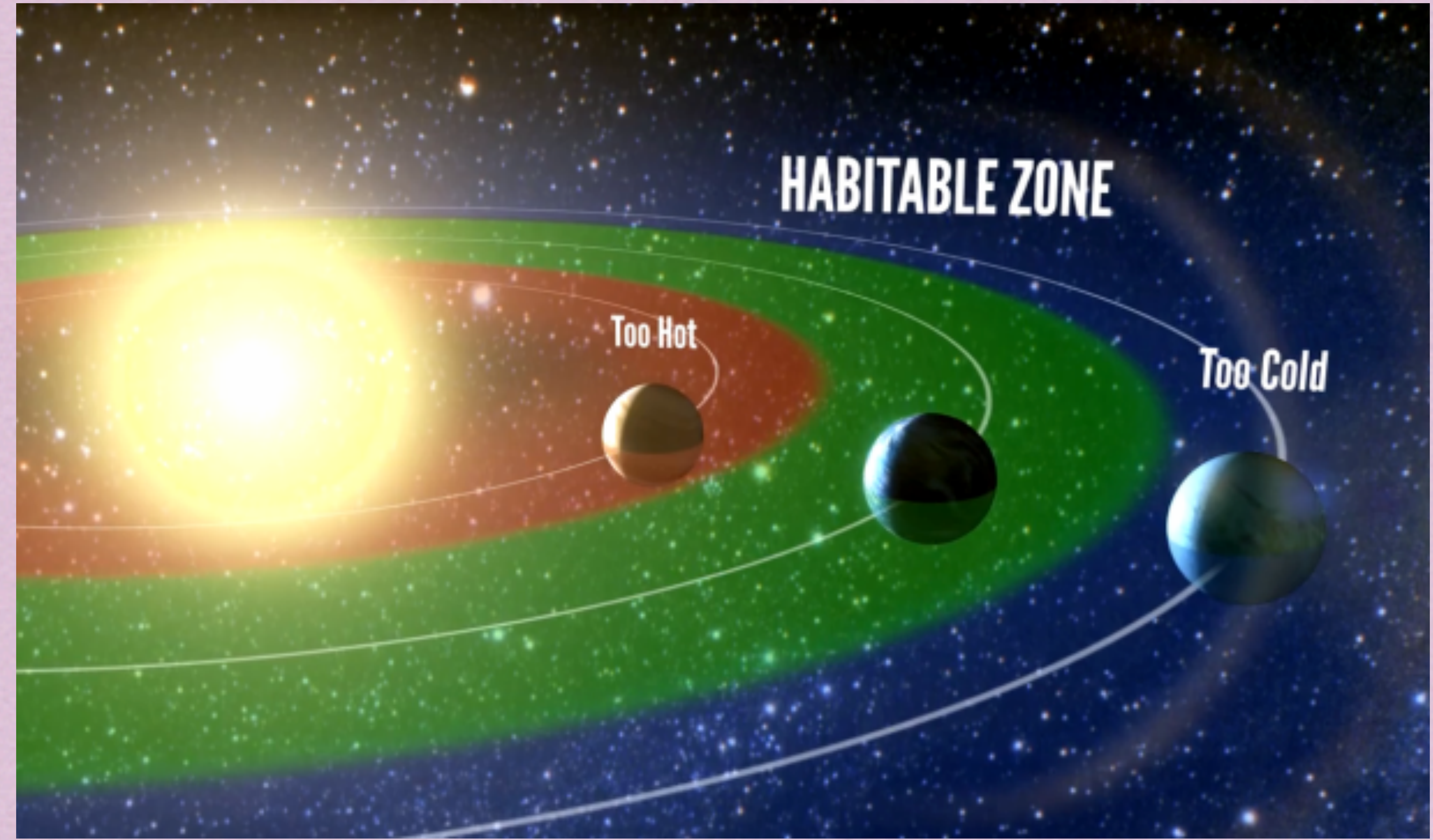
N = 3000

The first SETI meeting speculated N = 1000 to 100 000 000 in the Milky Way.

The Fermi Paradox

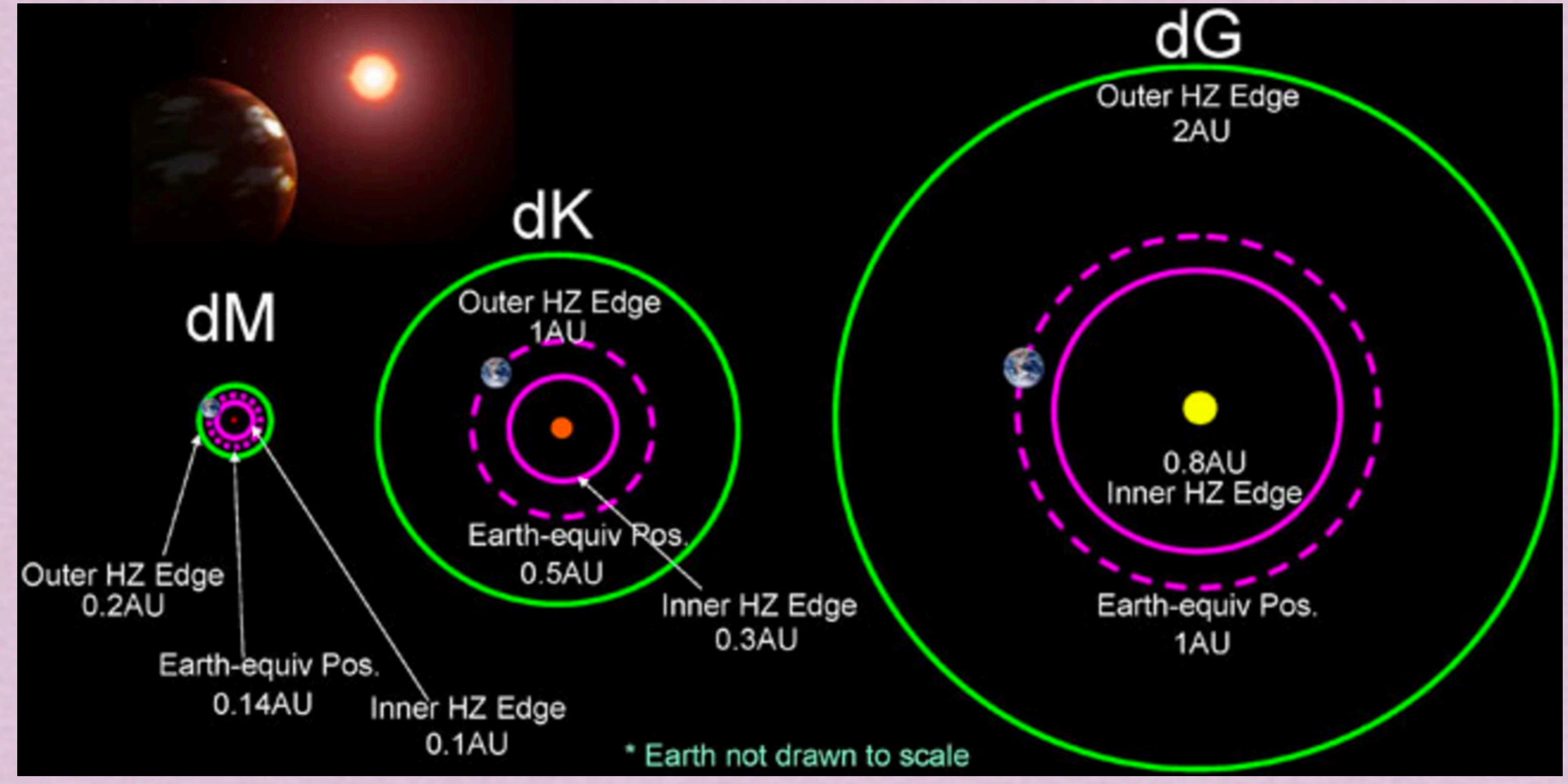
So where are they?

Where do we search?
"Habitable" Zones



(But is liquid water enough?)

Where do search? M Dwarfs



Pros

- Deeper transits (for radius and atmospheric measurements);
- More frequent transits of planets in the "habitable zone";
- Stronger radial velocity signal (for mass measurements);
- M dwarfs live longer -> more time for (advanced) life to develop?

Cons

- Stellar activity (e.g. flares) give off a lot of UV and XRay light

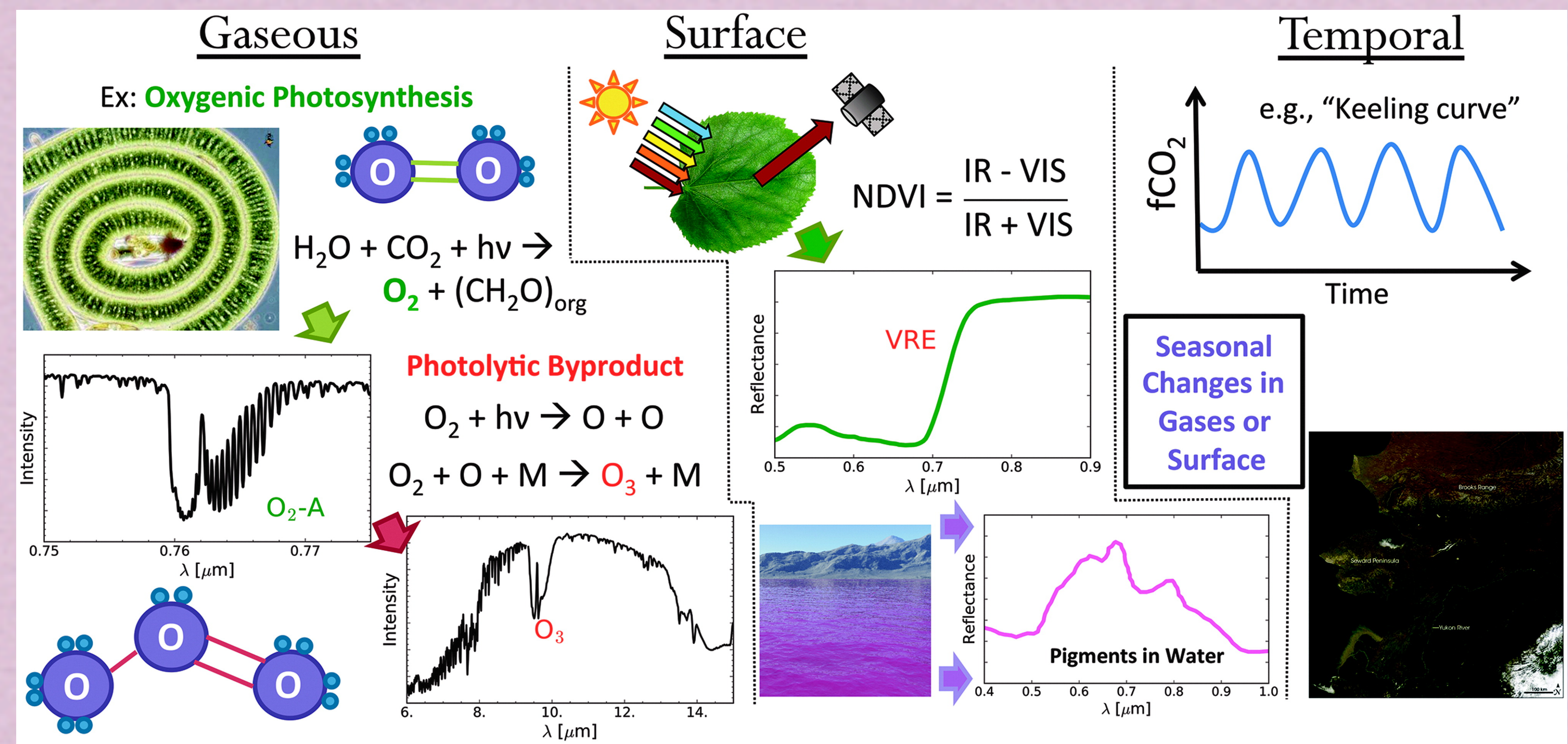
  -> can strip planetary atmospheres

  -> bad for the development of biological life

How do we search?

Best options right now:

- spectral features of biosignatures (e.g. oxygen AND methane) and technosignatures



- SETI