An introduction to

Habitability

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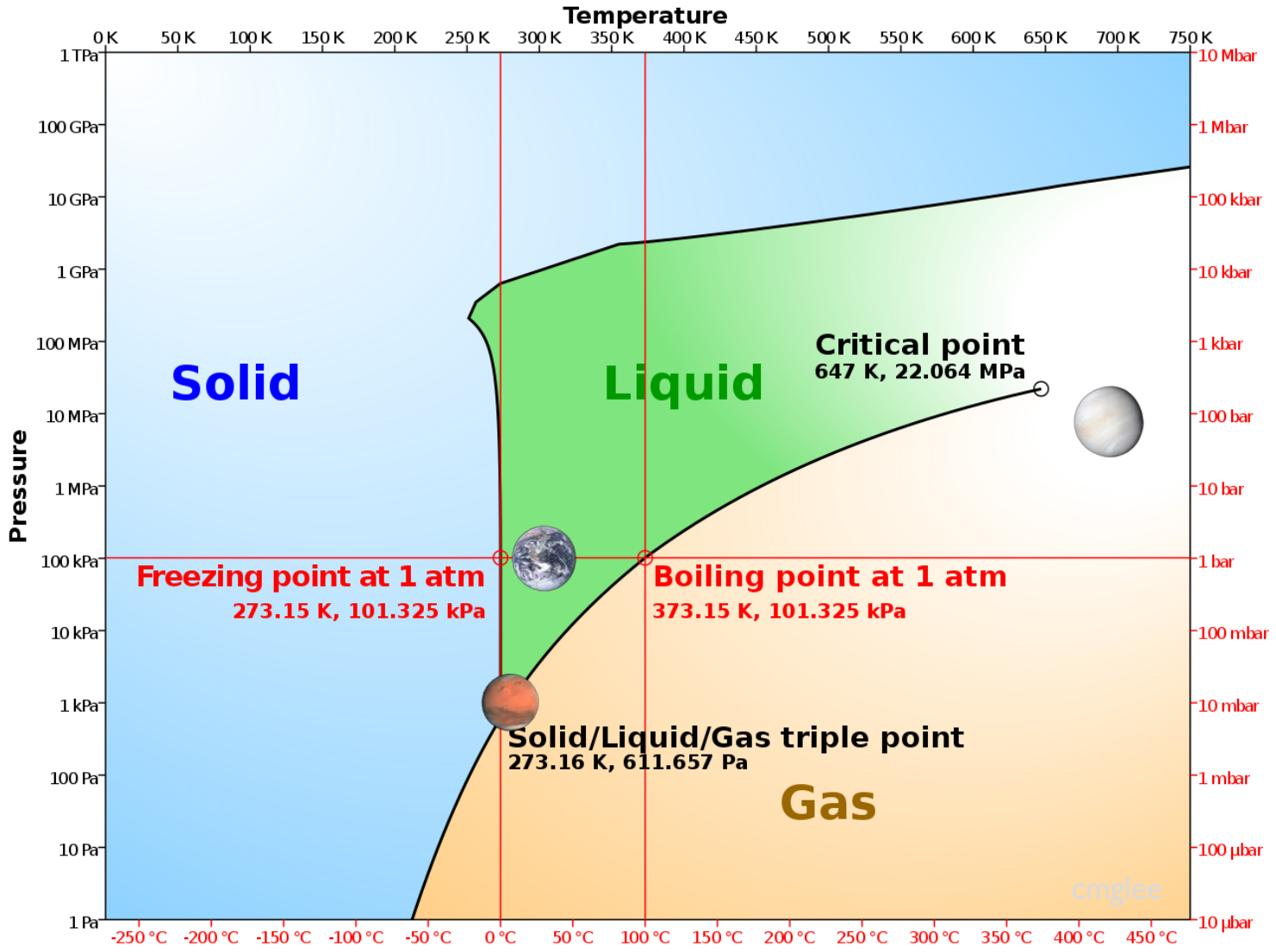
Habitability

- **Habitability** is the capability of an environment to host life.
- "Life" is pretty hard to define, considering we have one sample set (Earth),
  so our working criterion is:
  - liquid water
  - chemical building-blocks for carbon-based life: C, H, N, O, P, S
- Being habitable *does not* imply being inhabited,
  i.e. this is a separate question from extraterrestrial life, let alone intelligent life
- Not limited to planets, but also includes moons
- Could include an object covered in water, or a subterranean ocean where heat comes from the object's interior

NASA/Apollo 17

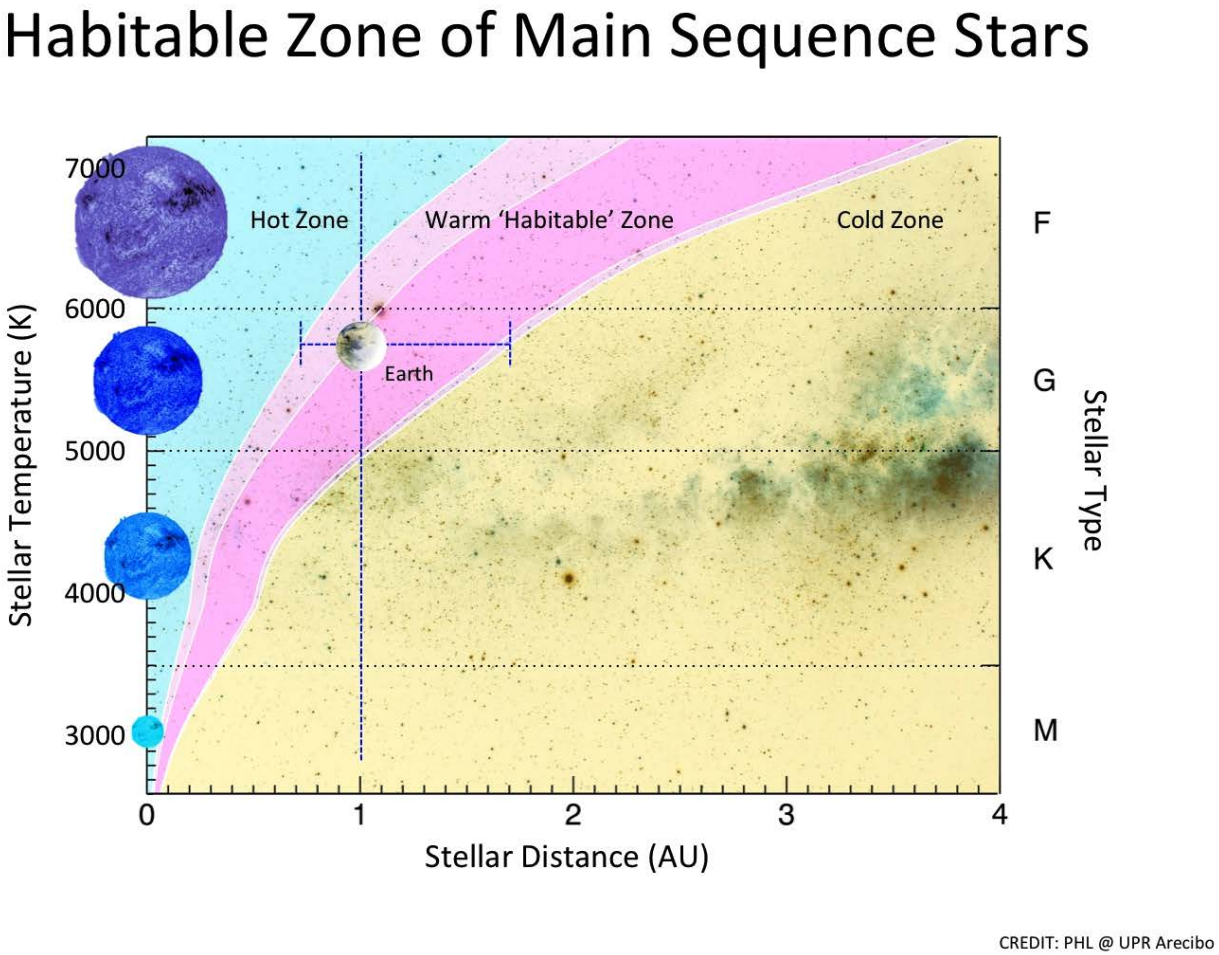
Water

- Will exist as a solid (ice), liquid ("water"), or gas ("water vapor"), depending on the temperature and pressure of an environment
- Higher-pressure conditions than on Earth (like on a super-Earth) enable liquid water at higher surface temperatures
- Greenhouse gas conditions can lead to higher temperatures, which could be good (Mars) or could be bad (Venus)



Habitable Zone

- The habitable zone varies by star type
- Typically we consider main-sequence stars only, because you would want a stable environment for a long enough time to make life interesting
- We also want UV radiation to not be too significant (see *Intro to Light* for the blackbody spectrum)
- There needs to be a wide enough range for liquid water that a planet could stay inside of the radius during its orbit. And can't be so close that it gets tidally locked.
- This limits cases to classes F, G, K, M
- Depending on proximity, an object also needs a magnetic field to shield from stellar winds

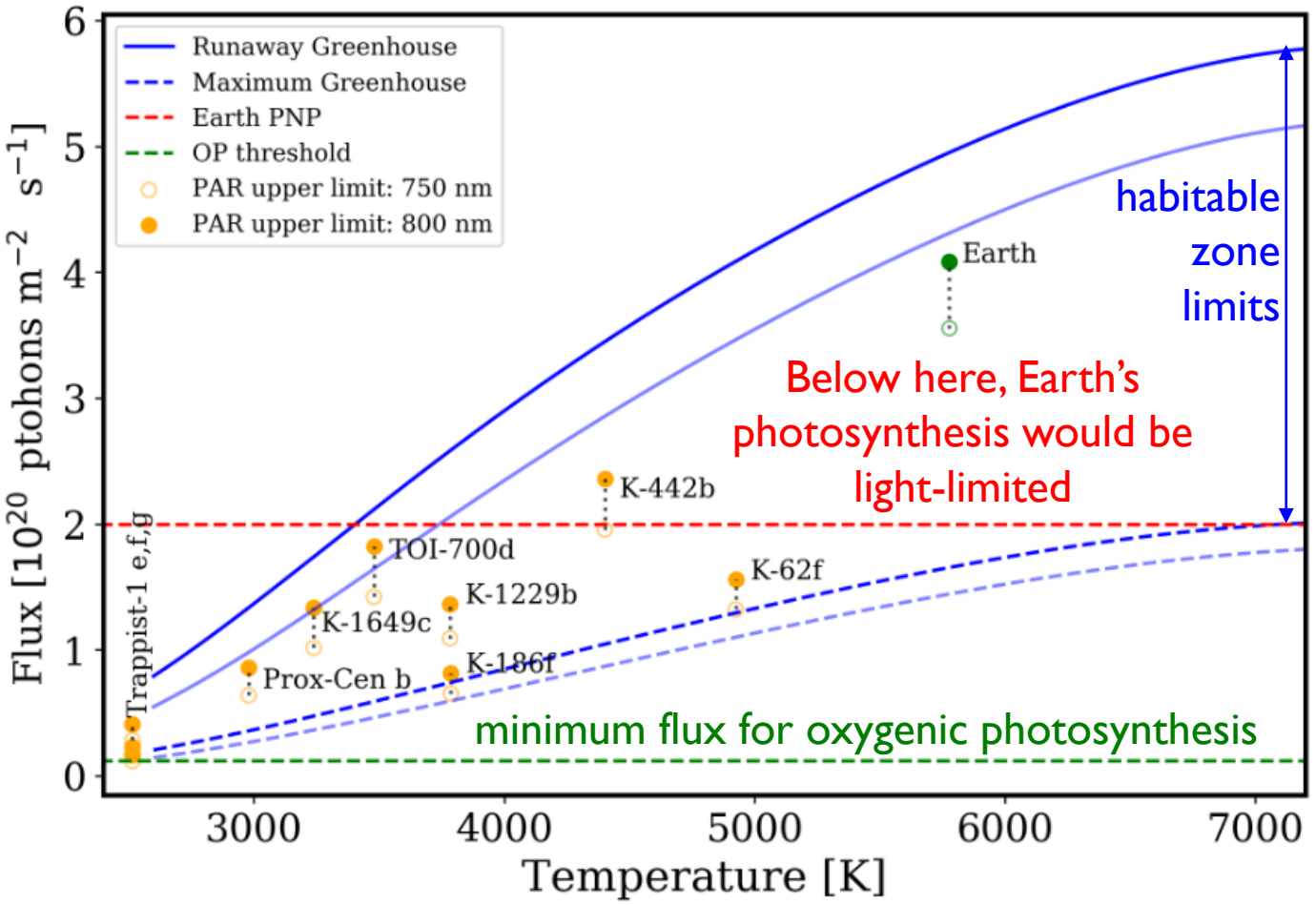


Requirements for photosynthesis

- For plant-based life on Earth, photosynthesis is often required
- On Earth, this requires light within the wavelength range ~400-700 nm, which can be called the "photosynthetically active region".
- To sustain a given amount of photosynthesis, enough light must be present. This will depend on:
  - distance to host star
  - host star type (blackbody spectrum)

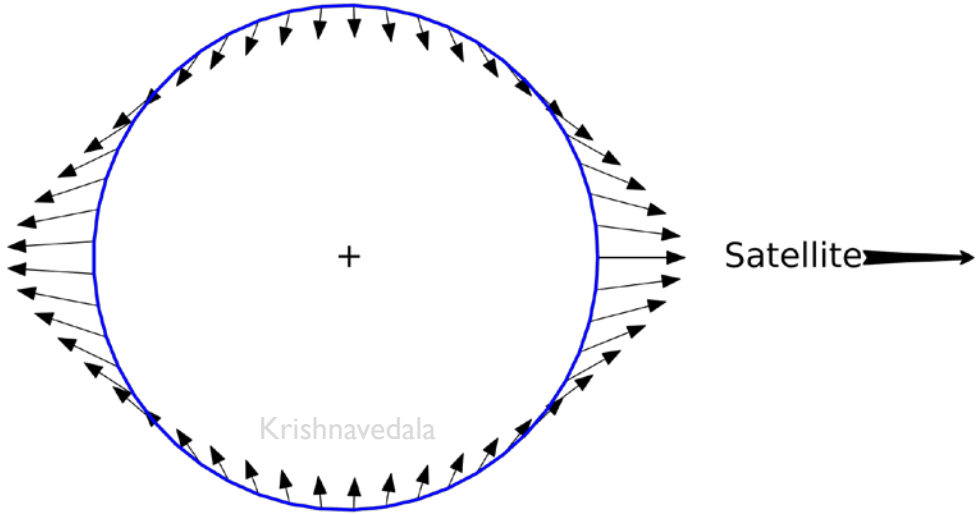
[see Intro to Light]

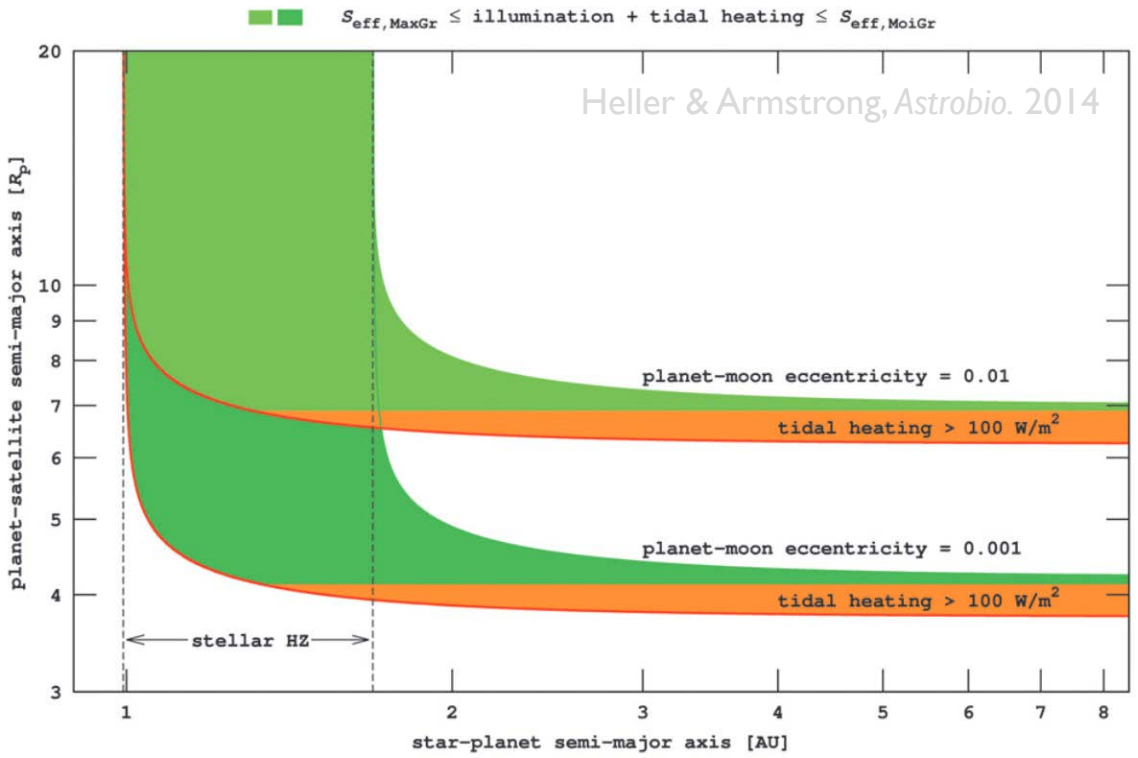
G. Covone MNRAS 2021



Getting more creative

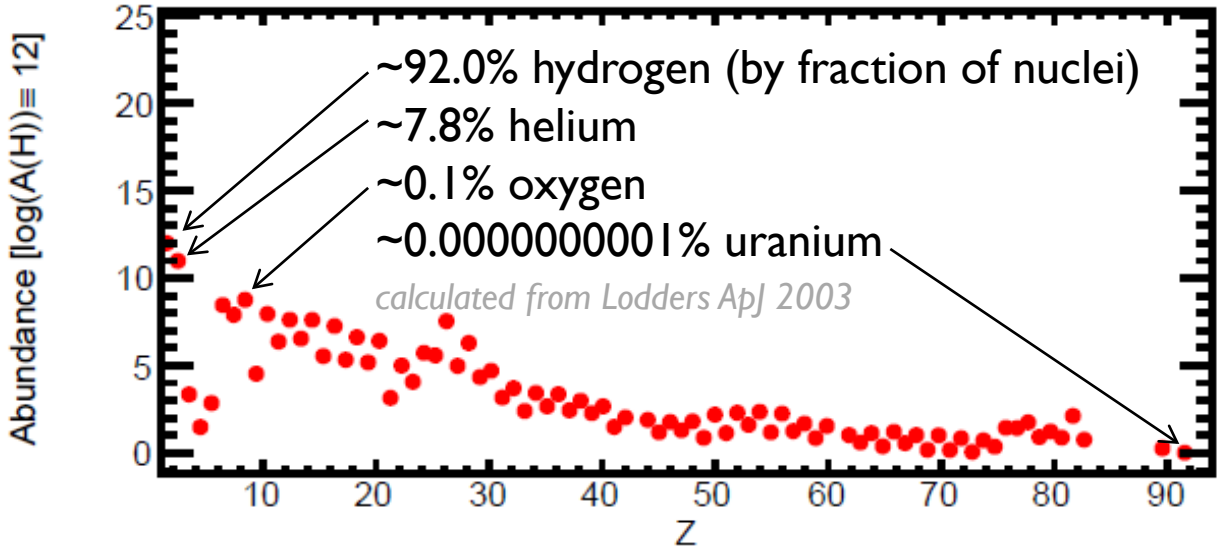
- Large moons could also host life, where the heat is provided by geothermal energy and tidal forces from the host planet on the moon
- Several solar system moons could fit the bill:
  - e.g. Saturn's Titan & Enceladus and Jupiter's Galilean moons
- This effectively extends the habitable zone far beyond the traditional stellar habitable zone based on surface temperature due to stellar radiation alone



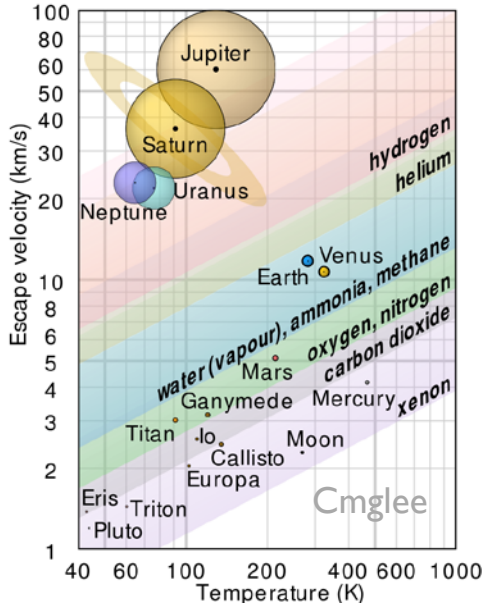


Cosmic Abundances: *raw ingredients*

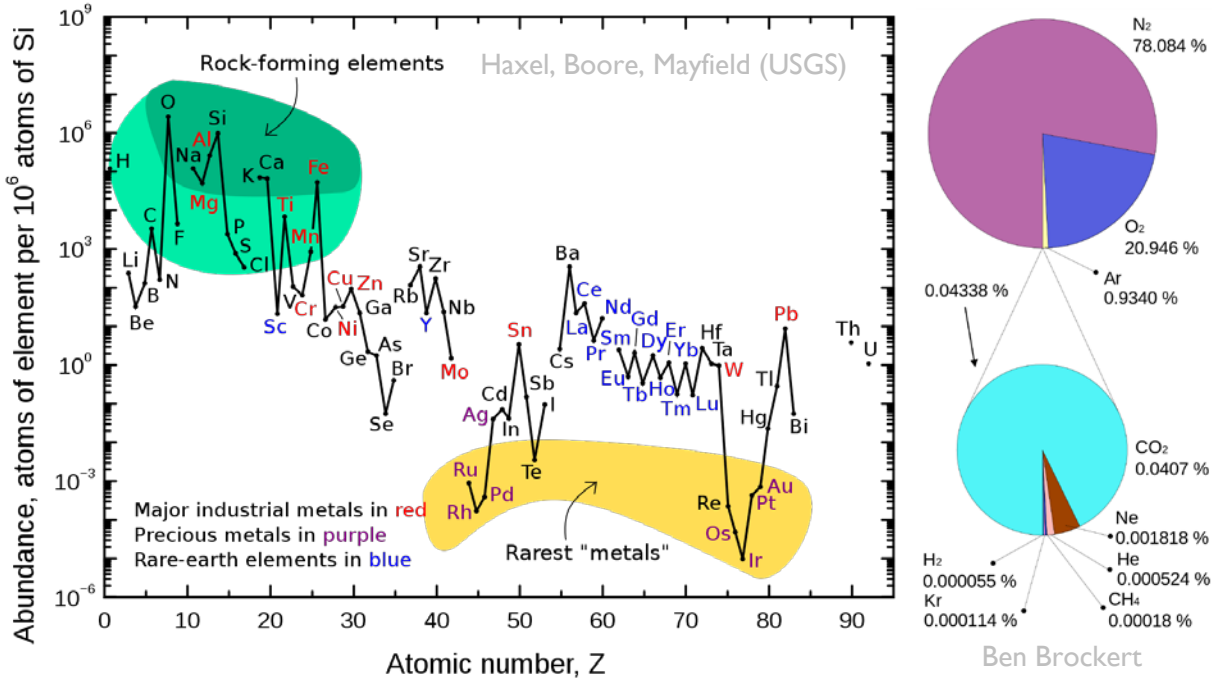
The solar system composition…



…gets modified by escape velocity of a planet



to arrive at the elements on a planet's surface



…and planetary differentiation:

- higher-mass atoms sink
- species chemically separate

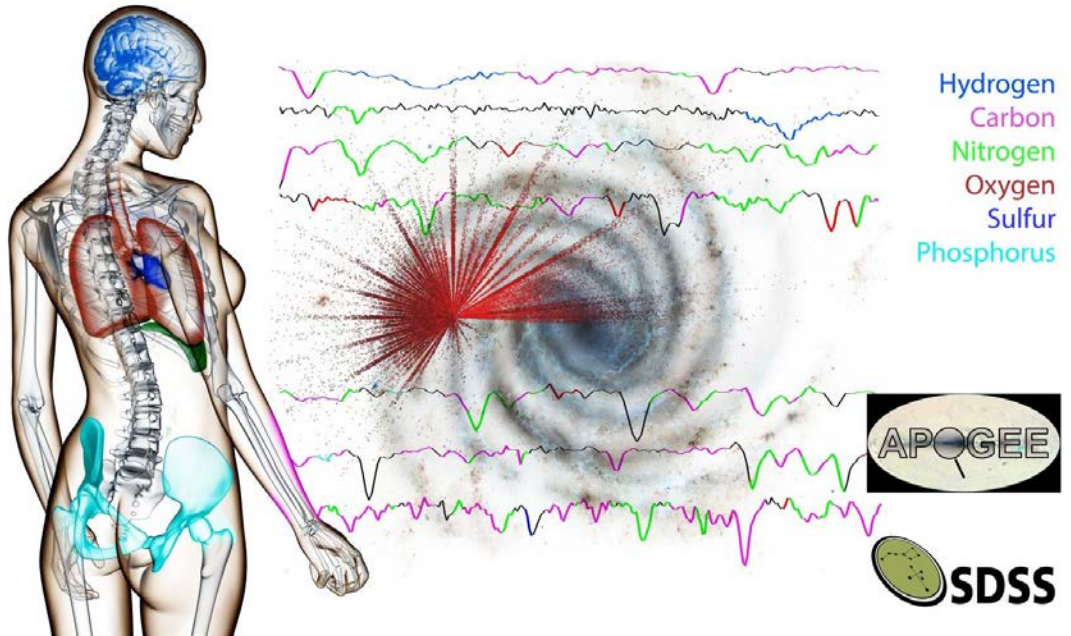
CHNOPS: *essential ingredients*

CHNOPS comprise most of the mass of plants & animals

Element	Mass in plants	Mass in animals	Biological uses
Carbon	12%	19%	Found in carbohydrates, lipids, nucleic acids, and proteins.
Hydrogen	10%	10%	Found in carbohydrates, lipids, nucleic acids, and proteins.
Nitrogen	1%	4%	Found in nucleic acids and proteins.
Oxygen	77%	63%	Found in carbohydrates, lipids, nucleic acids, and proteins.
Phosphorus	<1%	<1%	Found in lipids and nucleic acids.
Sulfur	<1%	<1%	Found in proteins.

~100% ~96%

and are rather prevalent within the Milky Way:



Astrobiology: *going from the ingredients for life to actual life*

- Astrobiology is the investigation of how one gets from CHNOPS in a habitable environment to an actual living thing
- Lots of organic molecules and even amino acids have been observed in extraterrestrial environments, such as meteorites & interstellar dust
- But, we don't know how matter undergoes **abiogenesis**, the leap from these building blocks to the chemicals of life: lipids, carbohydrates, amino acids, and nucleic acids
- Two approaches to study abiogenesis are direct experiments (e.g. Miller-Urey) and the study of the oldest fossils on Earth