European Research Council

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Habitable worlds:

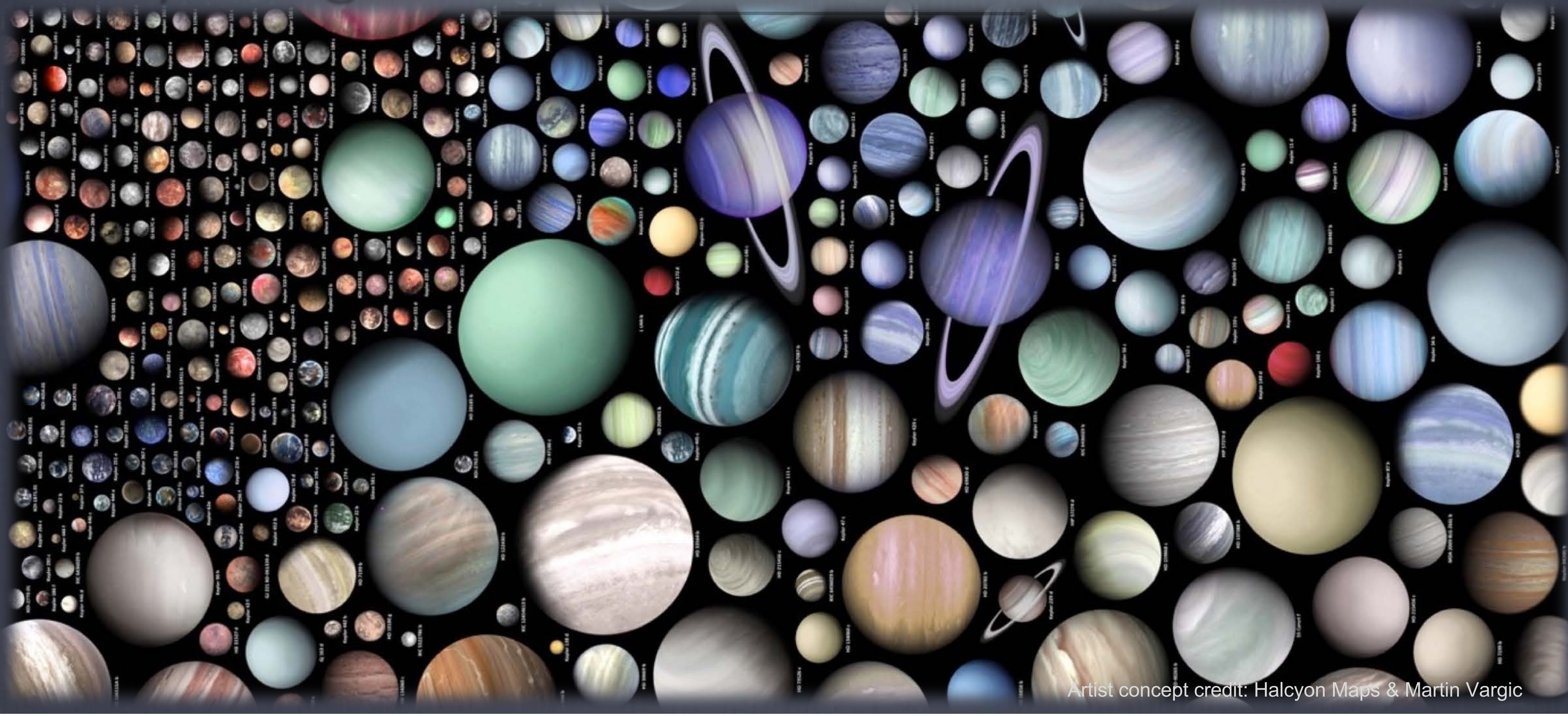
Can we discriminate them from their atmospheric composition?

Giovanna Tinetti

Presented by Göran Pilbratt

Image credit Hanno Rein

The search for exoplanets has often been driven by the goal to discover life in the Universe…



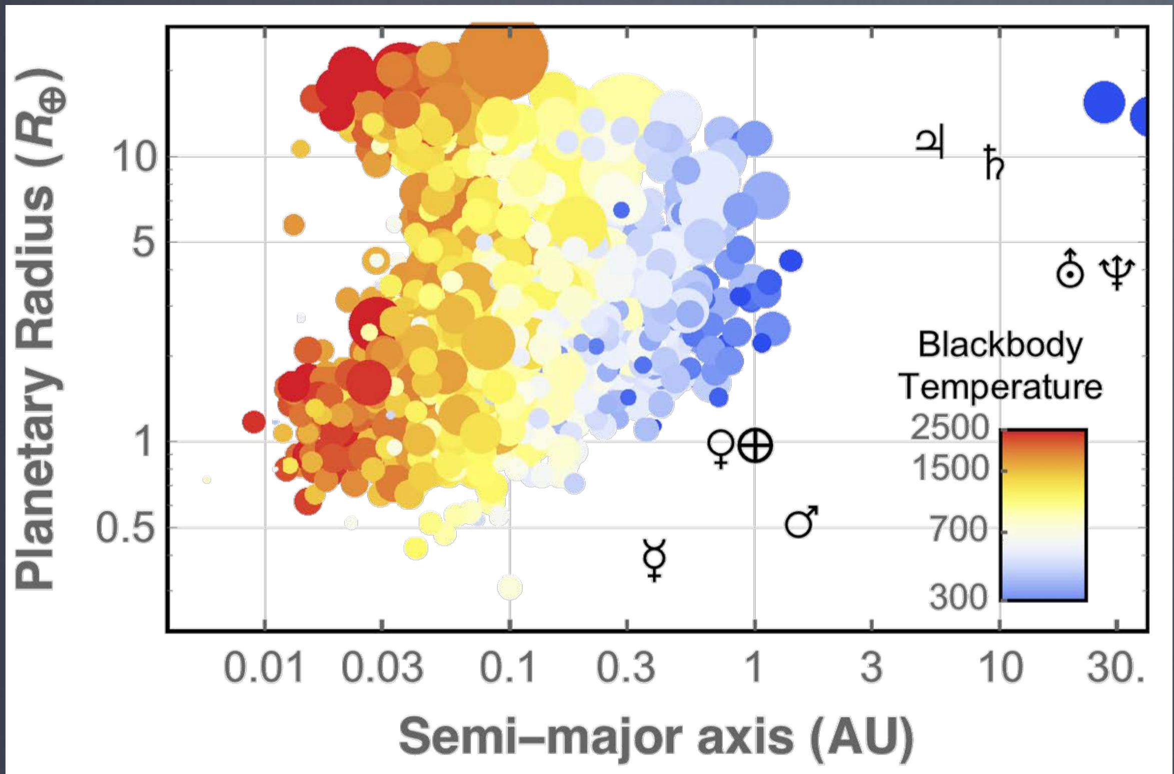
We know today that planets are ubiquitous…

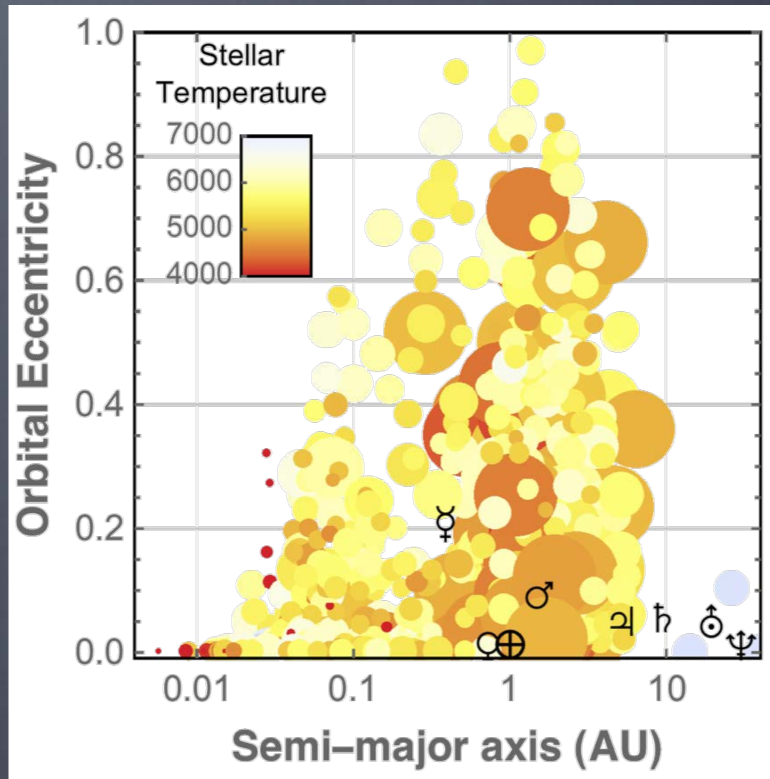
There are at least as many planets as stars

Cassan et al, 2012; Batalha et al., 2015

Huge diversity

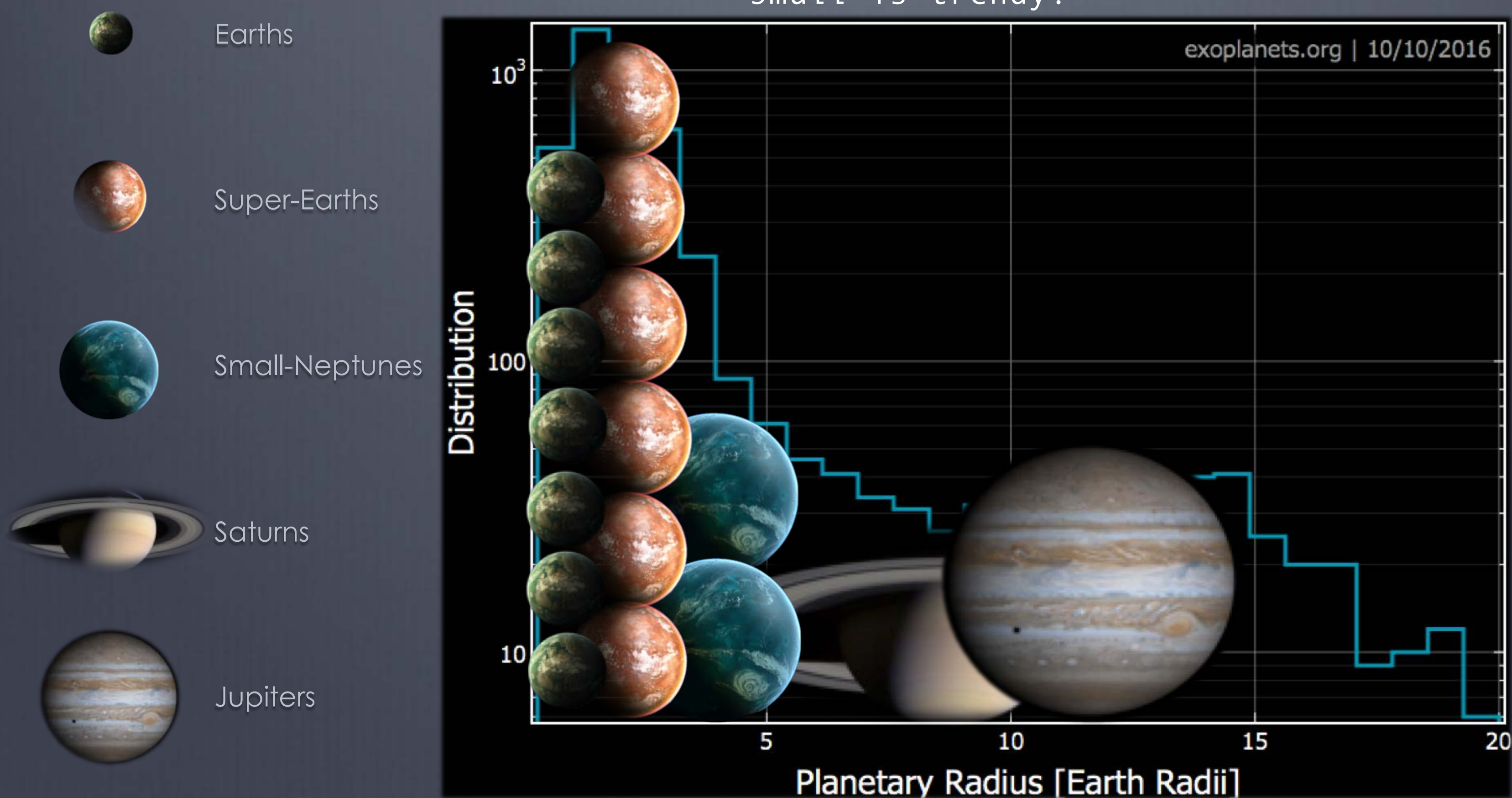
3700+ planets, 2700 planetary systems known in our galaxy





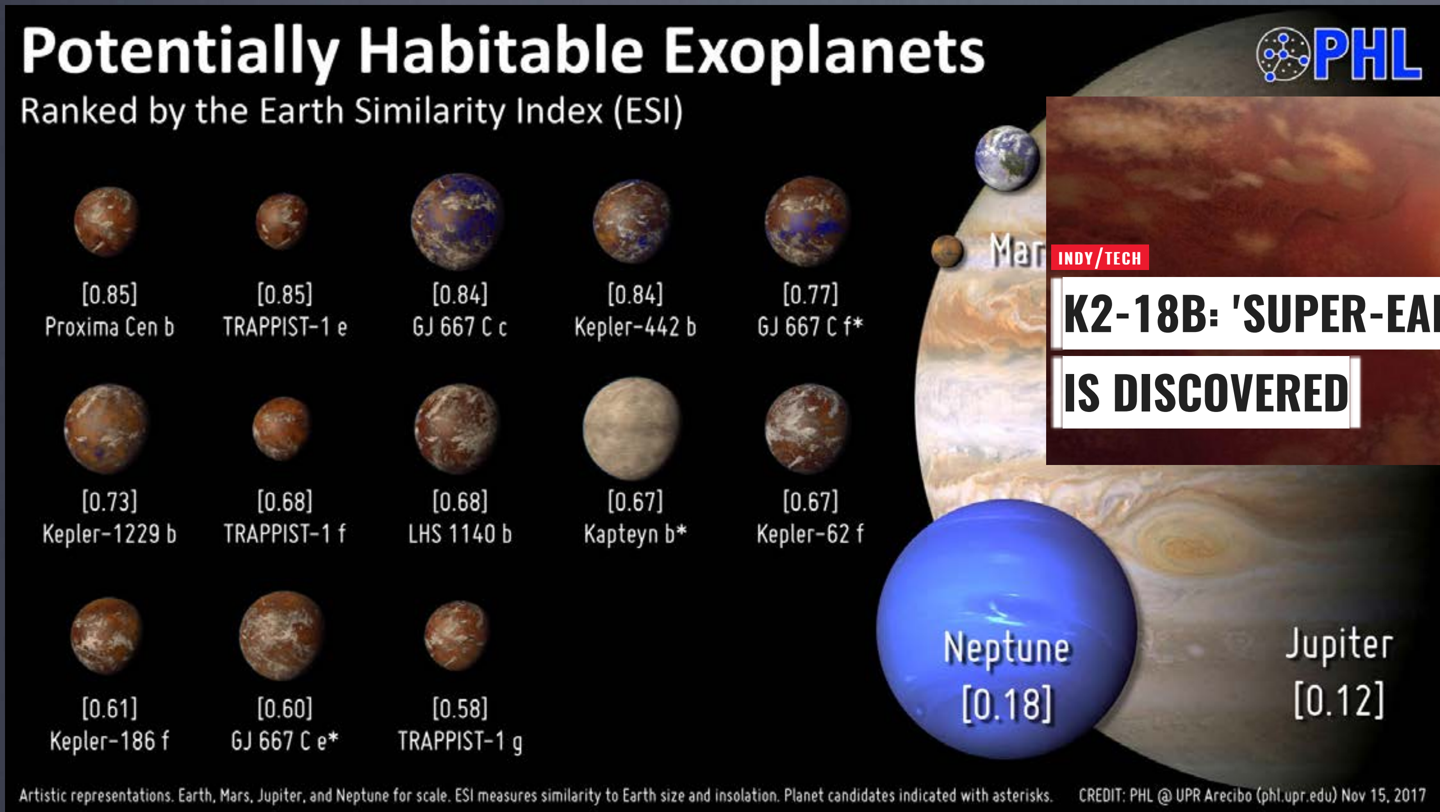
Most of them are small

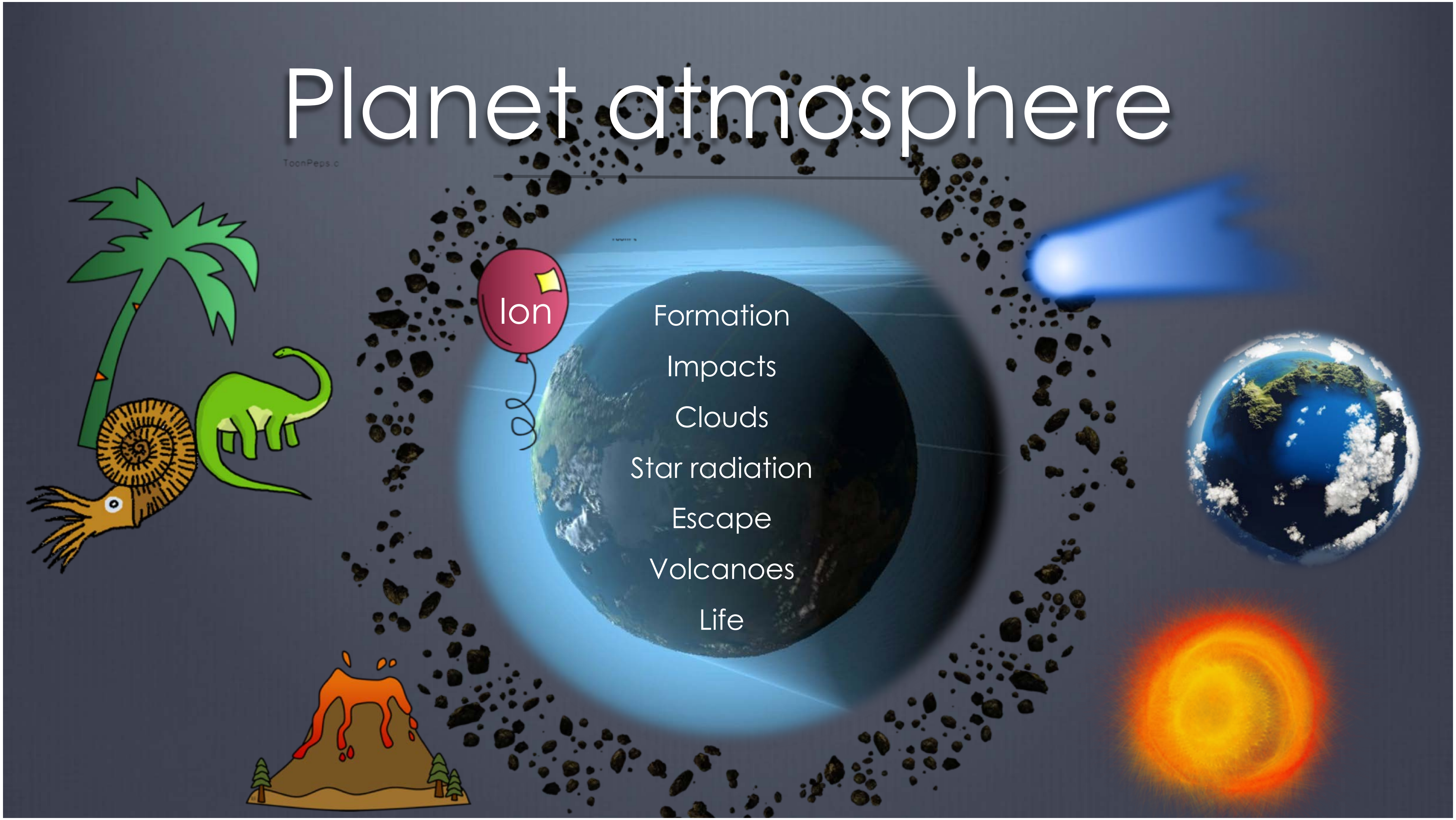
Small is trendy!



Some of them might be habitable

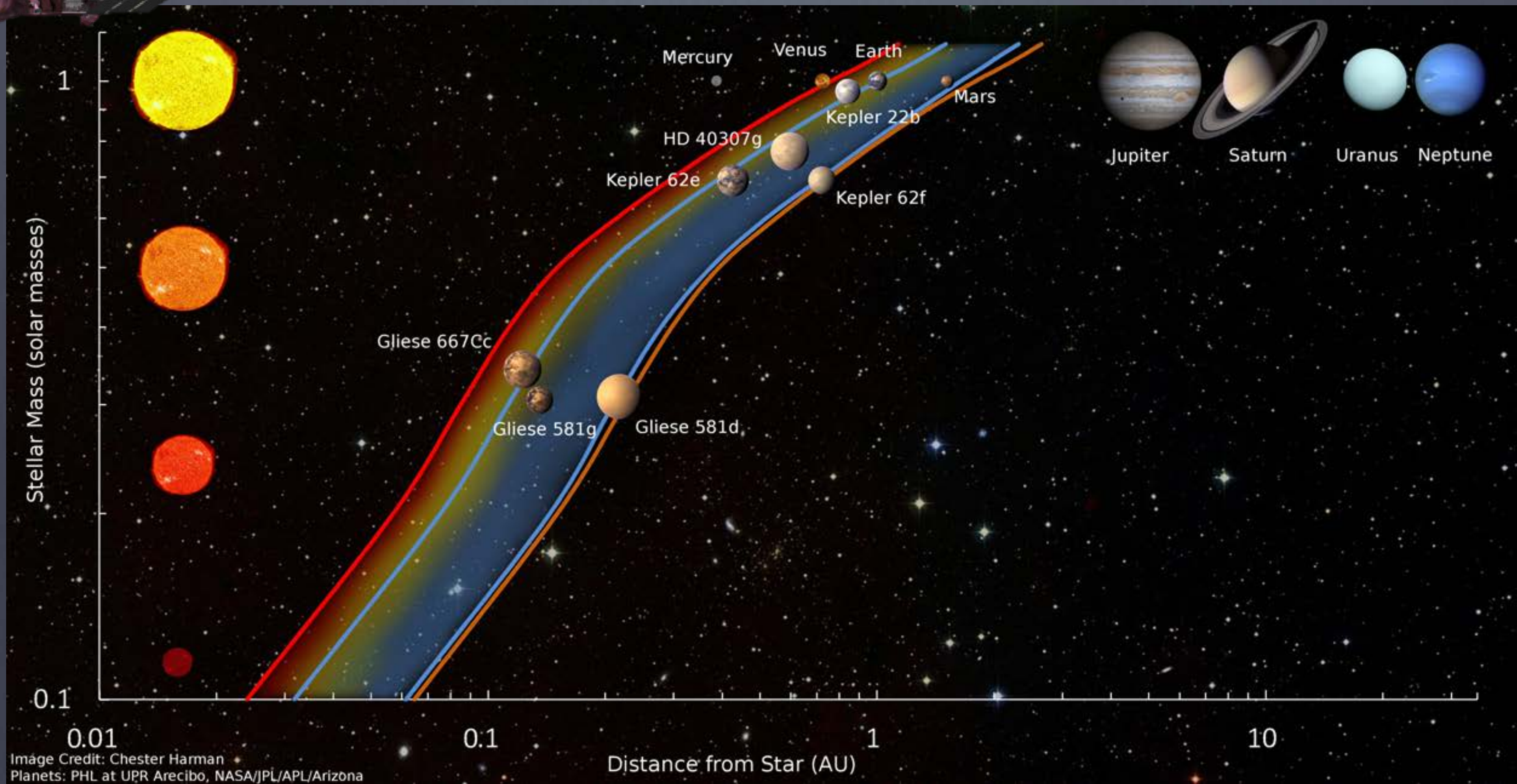
Are they really???? Do we have a better way to tell?




Planet atmosphere
Ion
Formation
Impacts
Clouds
Star radiation
Escape
Volcanoes
Life

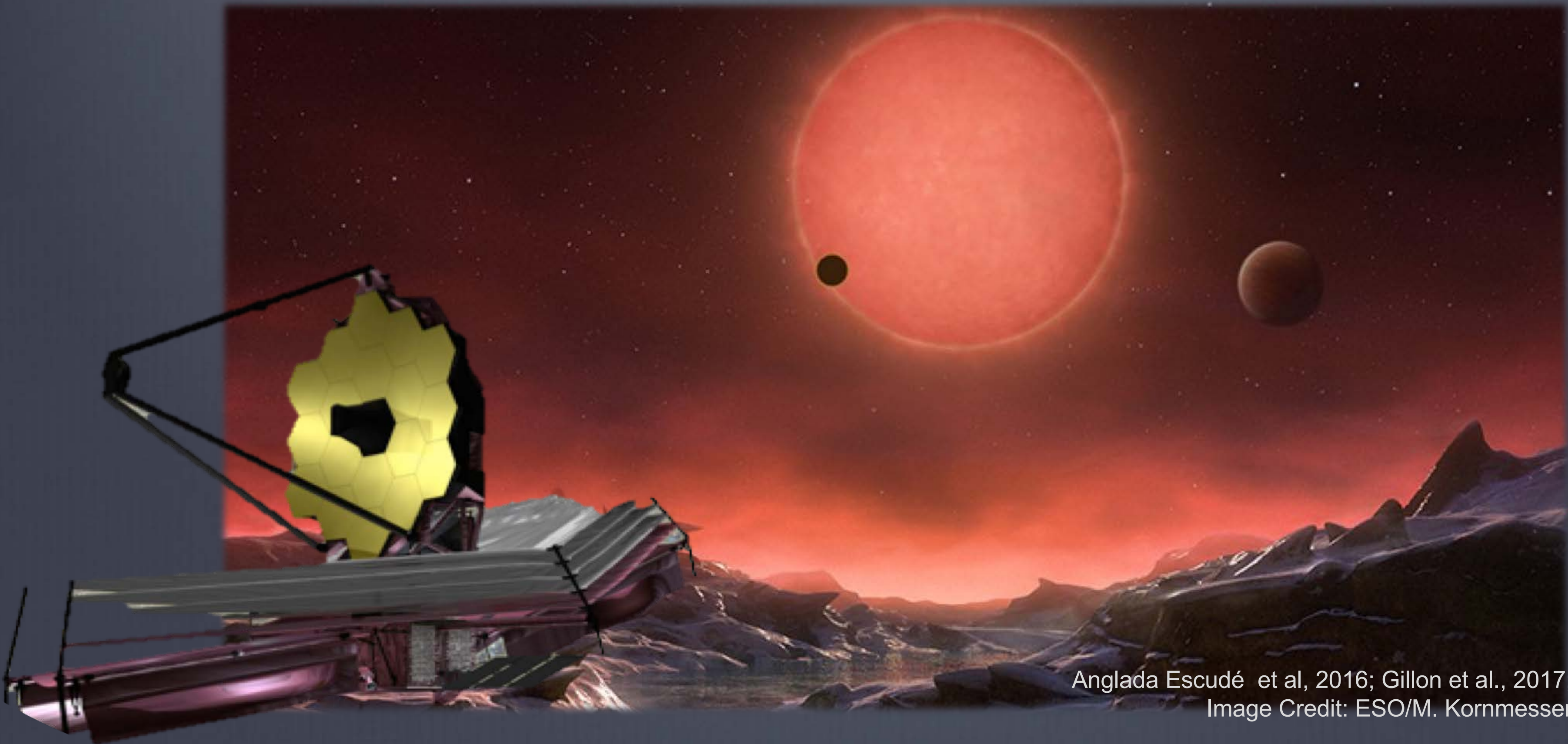
Habitable planets?

Transiting temperate super-Earths orbiting cool stars
best chance to study habitable planets in a foreseeable future



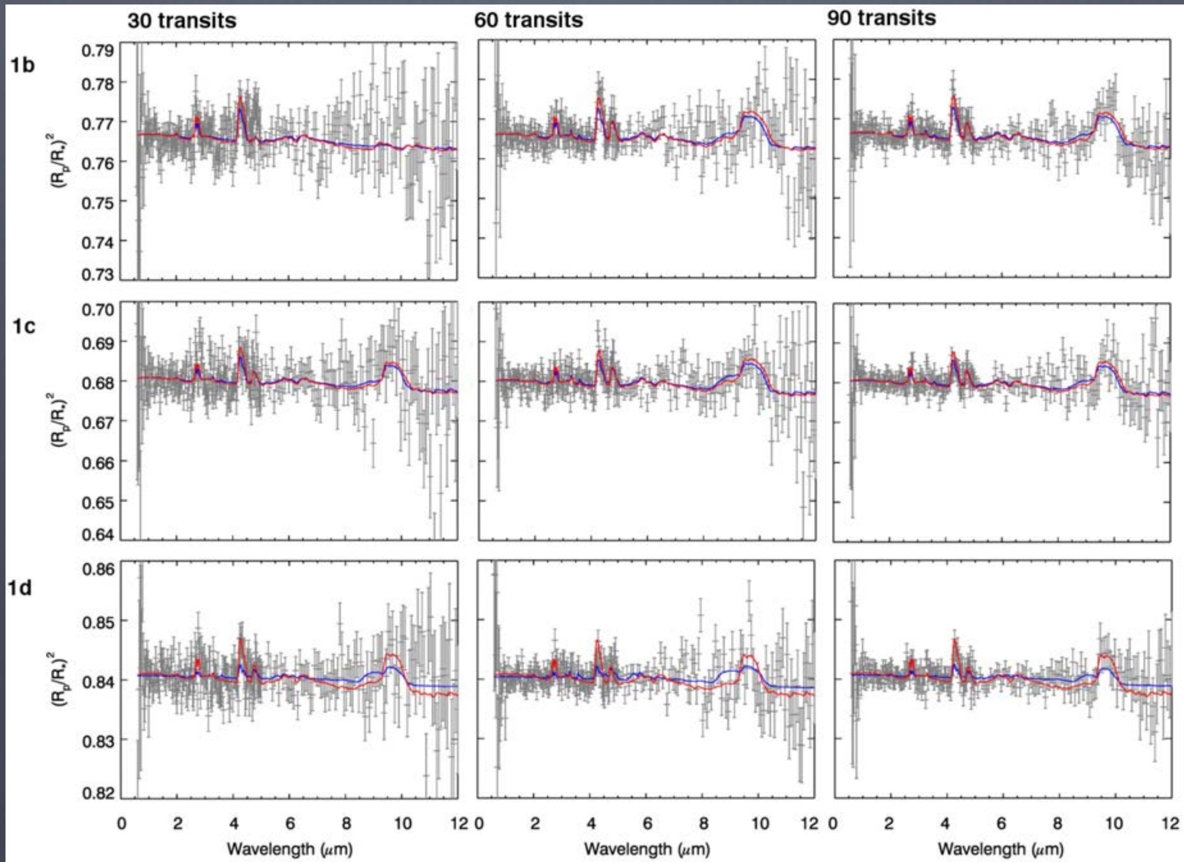
Worlds around cool stars

Can live survive to flares, effects of tidal-locking, red-shifted photons from star?



Habitable planets?

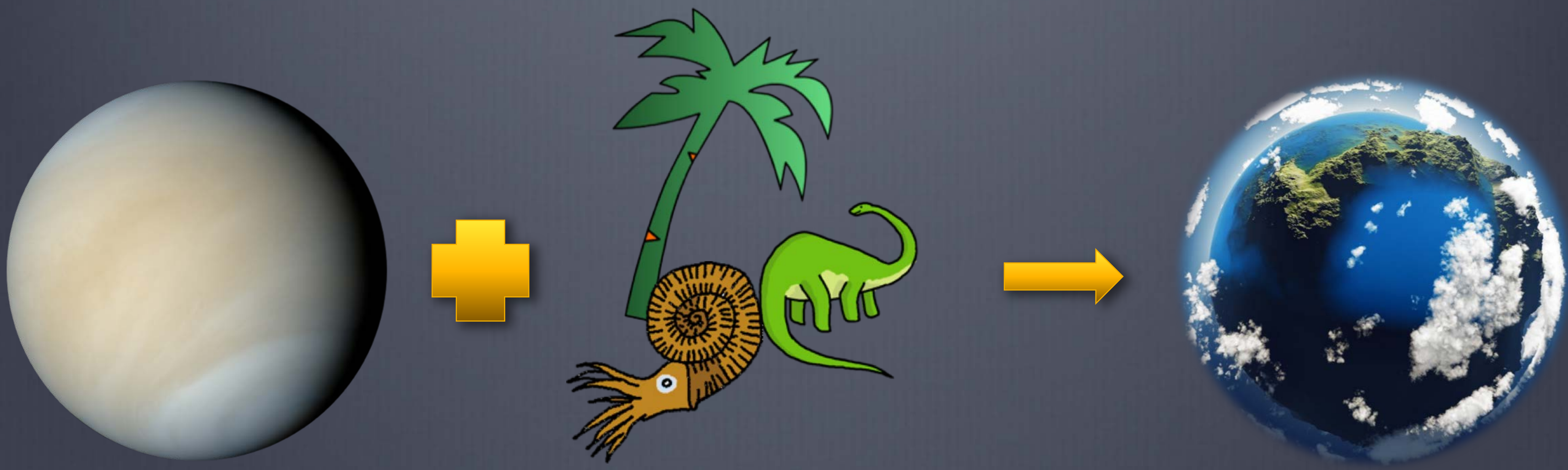
Temperate Earth-size planets, orbiting an ultra cool star: biosignatures?



Barstow & Irwin, 2016

James Lovelock

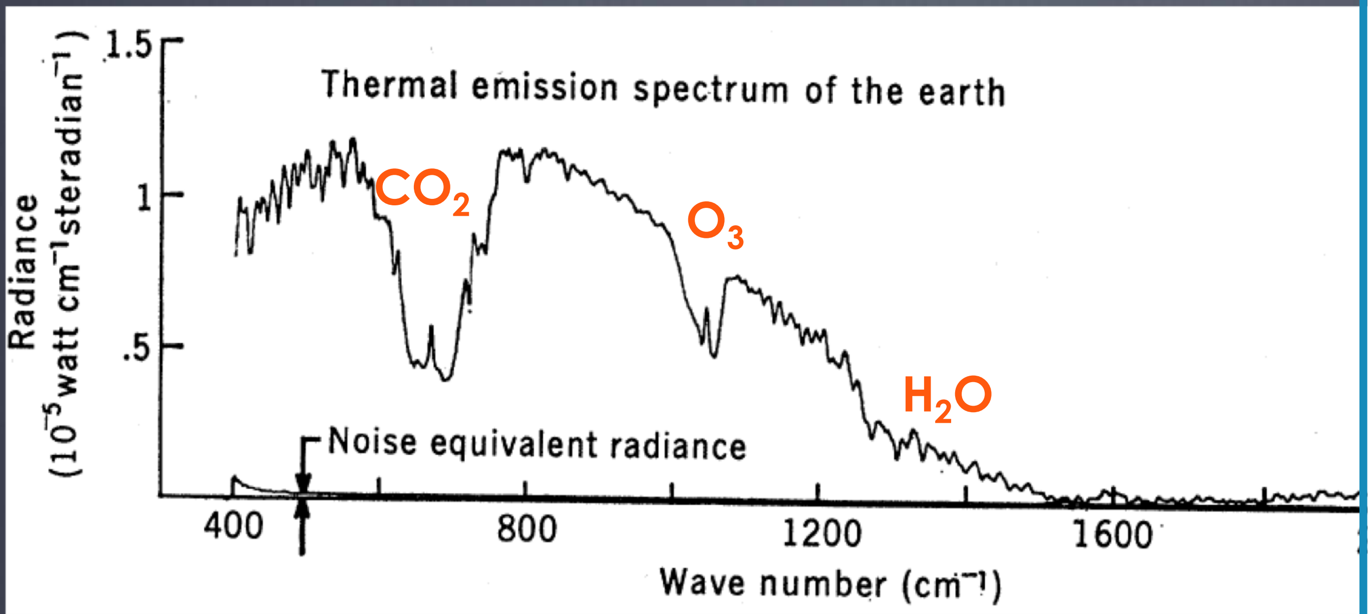
« The history of a planet can not be disentangled from the evolution of the organisms living on that planet »

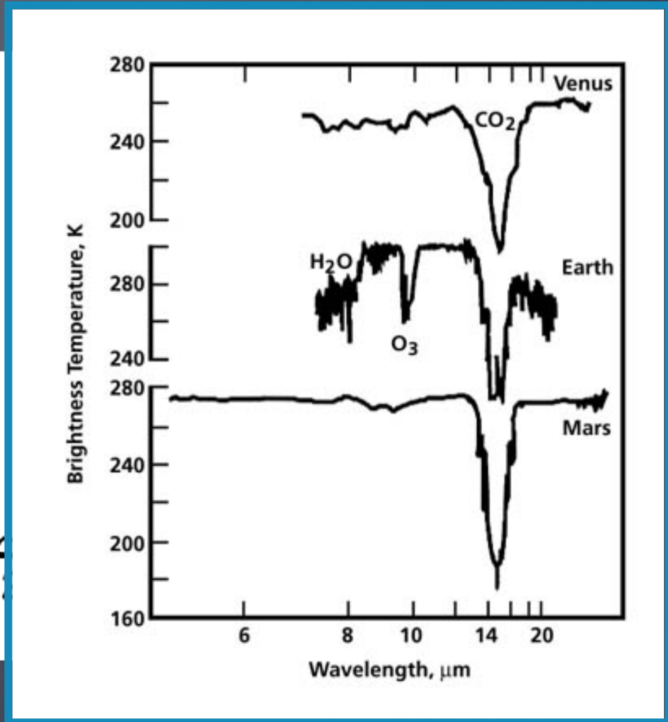


Gaia A new look at life on Earth, publ. Oxford University Press 1979.

Biosignature

« The presence of chemically based life on a planet would change the composition of its atmosphere away from the abiological steady state
The change would be recognizable even at astronomical distances »

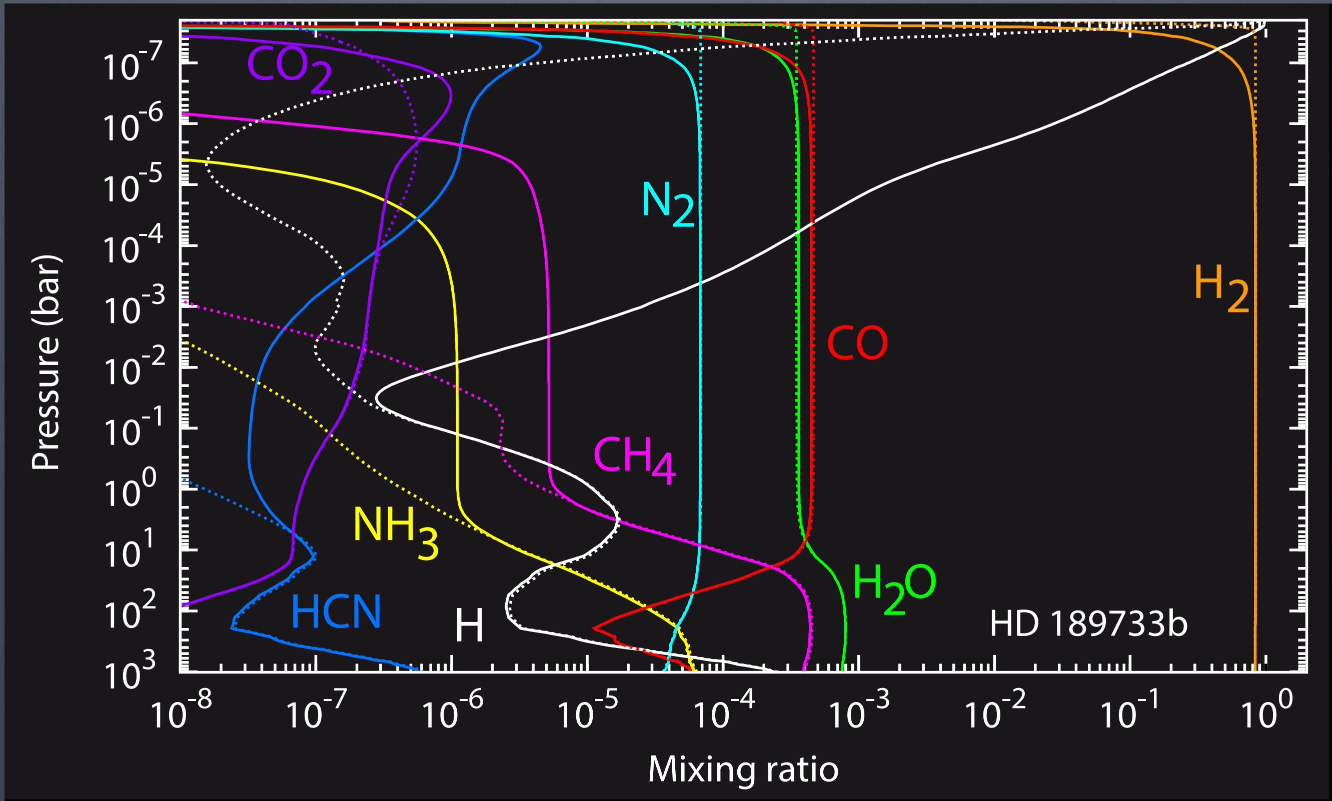




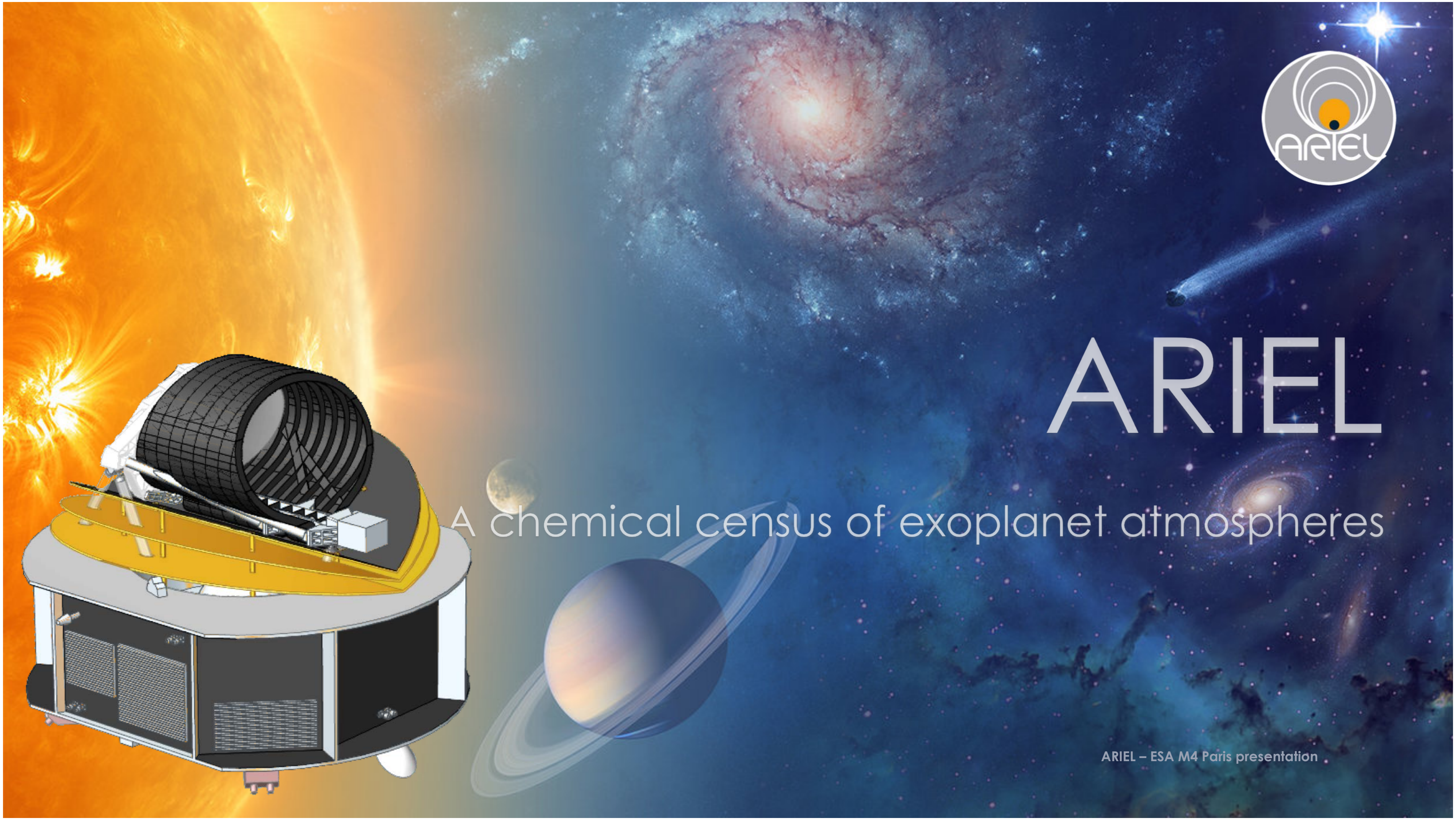
Gaia A new look at life on Earth, publ. Oxford University Press 1979; Nimbus 3 observations, Galileo observations

Chemical disequilibrium: is it a robust biosignature?

Below 1500K atmospheres are likely to be in disequilibrium!

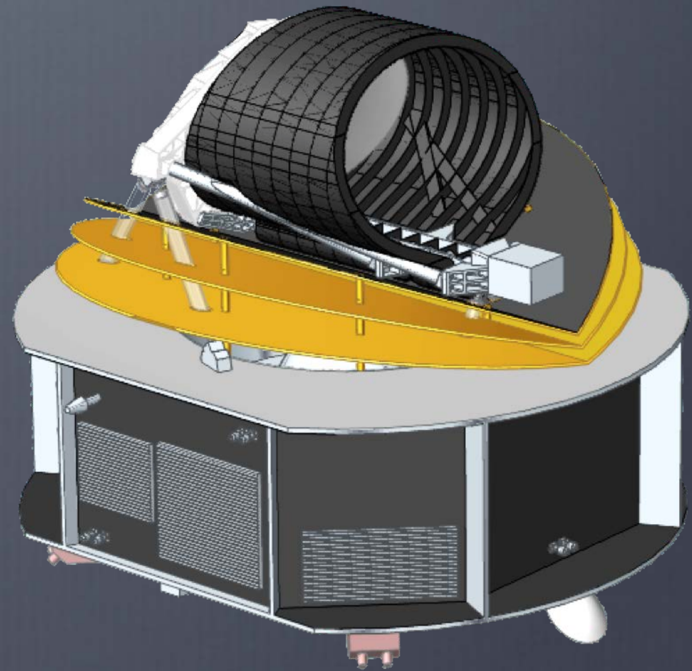


Venot et al., 2015


ARIEL
A chemical census of exoplanet atmospheres
ARIEL – ESA M4 Paris presentation

ARIEL – key facts

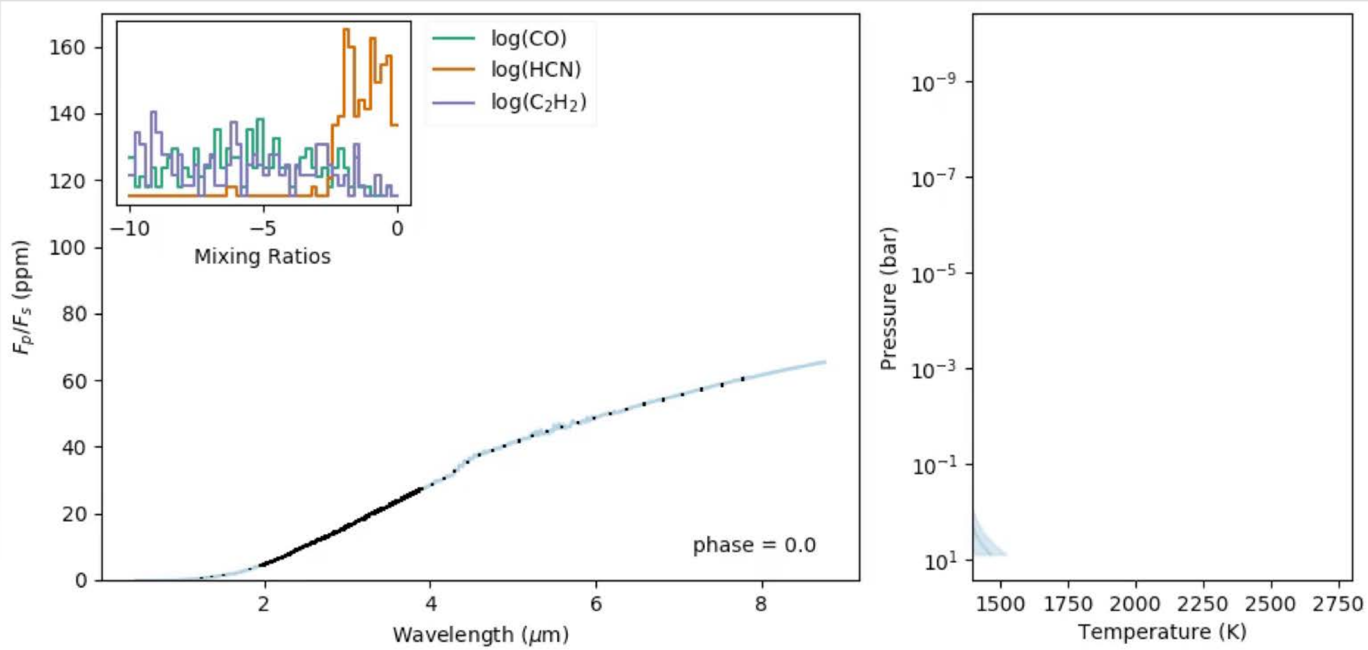
- 1-m telescope, spectroscopy from VIS to IR
- Satellite in orbit around L2
- Chemical census of ~1000 exoplanets (rocky + gaseous), primarily warm & hot
- Simultaneous coverage 0.5-7.8 micron
- Payload consortium: 11 ESA countries



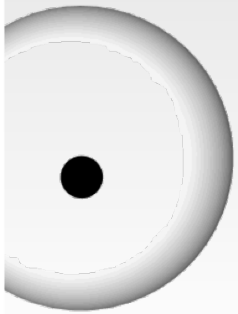
INSTANT & SHORT-TERM VARIABILITY: 55 CNC e

(NON)-EQUILIBRIUM CHEMISTRY? ATMOSPHERIC CIRCULATION? CLOUD PATTERN?

ARIEL phase-curve spectra, chemical composition & thermal profile



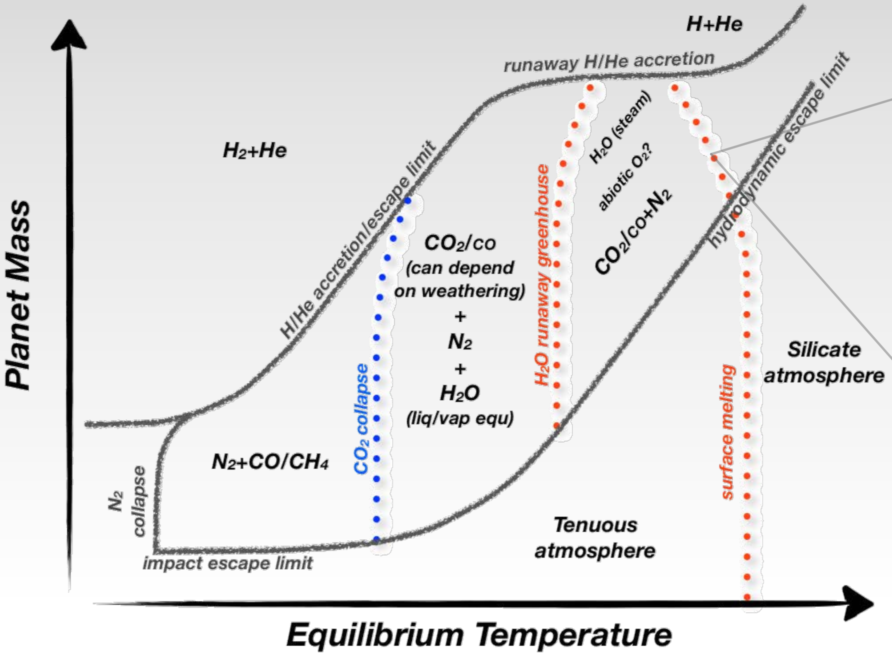
Planet orbiting around the star



CHEMICAL DIVERSITY

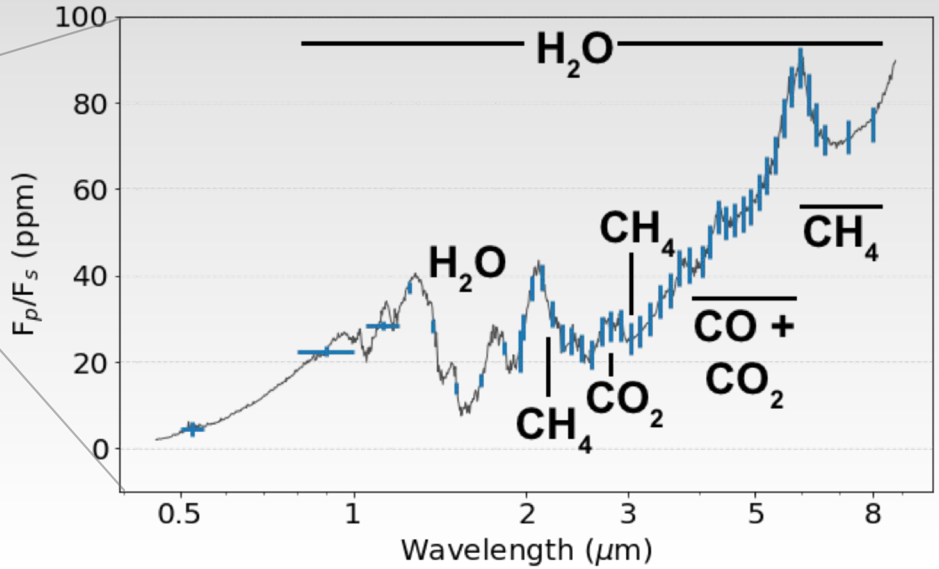
CORRELATION WITH ANY OTHER KEY PARAMETERS?

Is this plot true? Where are the transitions?



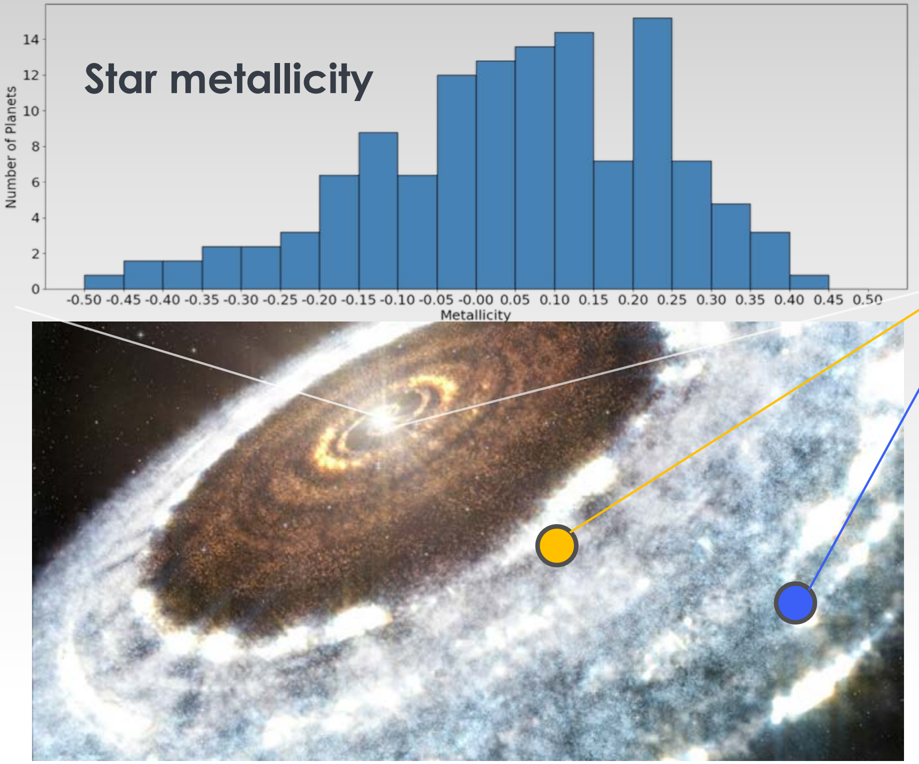
Forget & Leconte, 2013

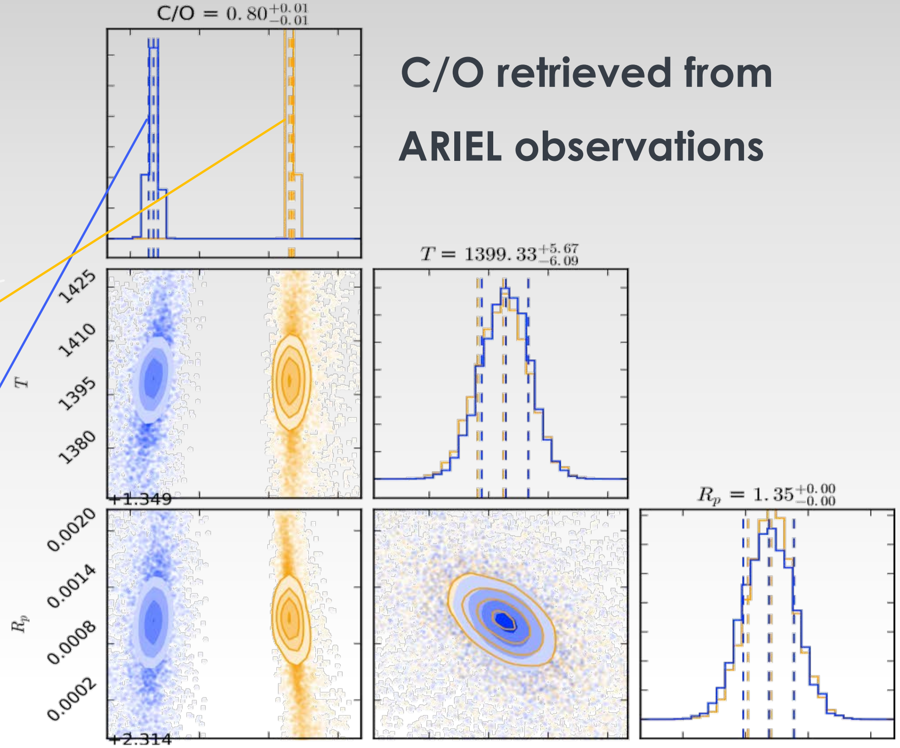
ARIEL observations x 1000 planets



IS ELEMENTAL COMPOSITION CORRELATED …

…TO EXOPLANET PROVENANCE OR STELLAR METALLICITY?





C/O retrieved from ARIEL observations

Some thoughts to conclude

- The search for exoplanets has been driven by the goal to discover life in the Universe
- We know today there are billions of worlds out there, and small planets are the most numerous…so there is hope!
- Basic planetary and orbital parameters suggest the Solar System is not the paradigm of planetary system in the galaxy
- Our definition of biosignature did not change from the seventies
- Although Lovelock's recipe to search for chemical disequilibrium as sign of life is still valid, there are issues
- The chemistry of planets colder than 1500 K is expected to be increasingly driven by disequilibrium processes, are we able to recognize life?

Some thoughts to conclude

- Recipe for the next decade:
  - Complete a chemical census of NON-habitable planets probing the parameter space of planet temperature, mass, stellar metallicity, stellar type (ARIEL mission)
  - Use the opportunity to observe planets in the habitable zone of cool stars (JWST)
  - Is Lovelock's recipe of biosignature still useful?

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