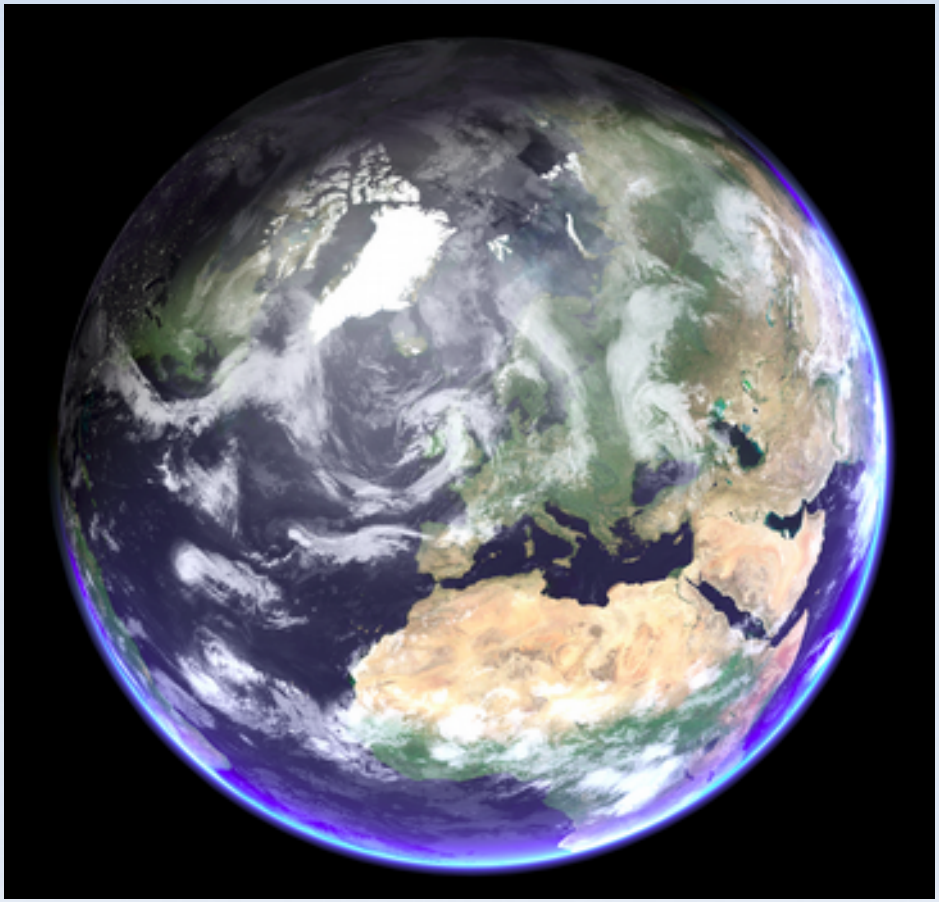
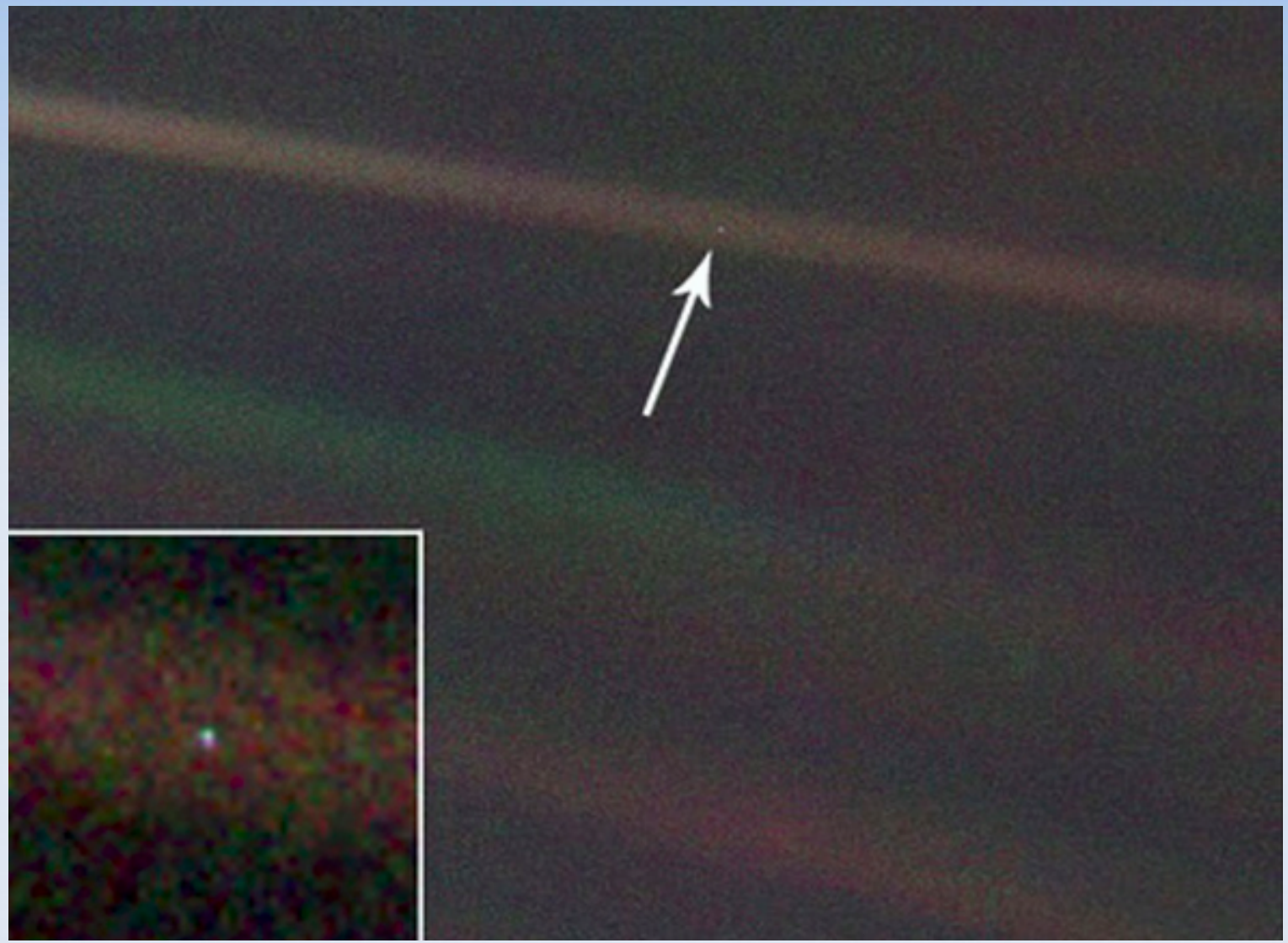
Biosignatures: What on Earth ?

- Observable or combination of observables that are compatible with biological processes and **cannot be explained otherwise.**



- Biological pigments
- Out of chemical equilibrium atmosphere

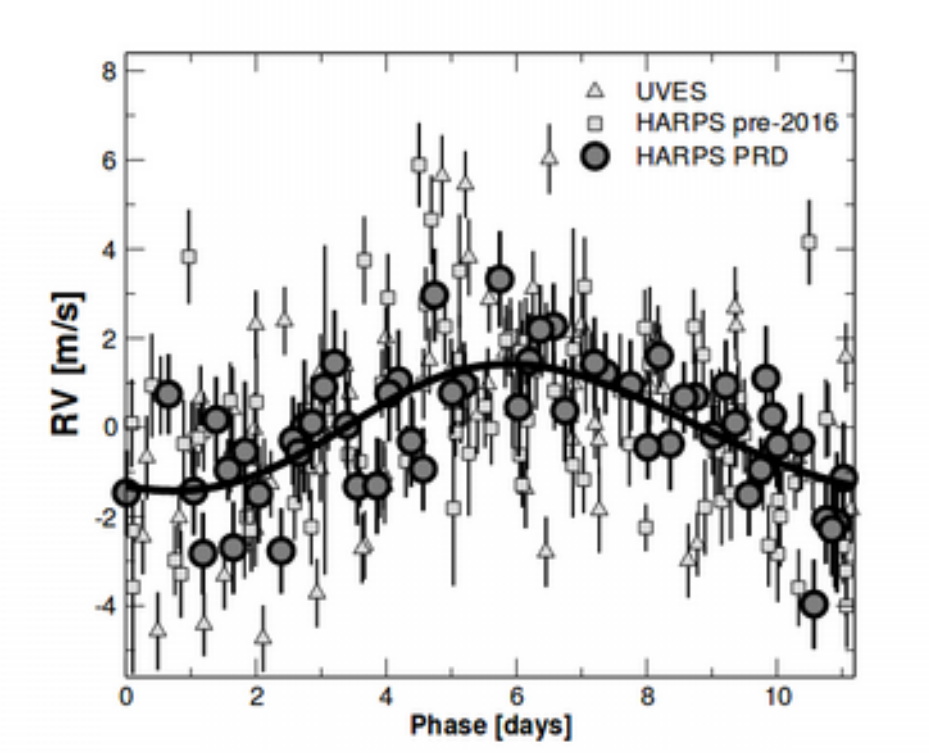
Biosignatures of Earth a little farther away…



“Pale blue dot” view from the outer Solar System

Biosignatures of exoplanets 10^5 times farther away...

- Closest star to Sun has “habitable” planet but...



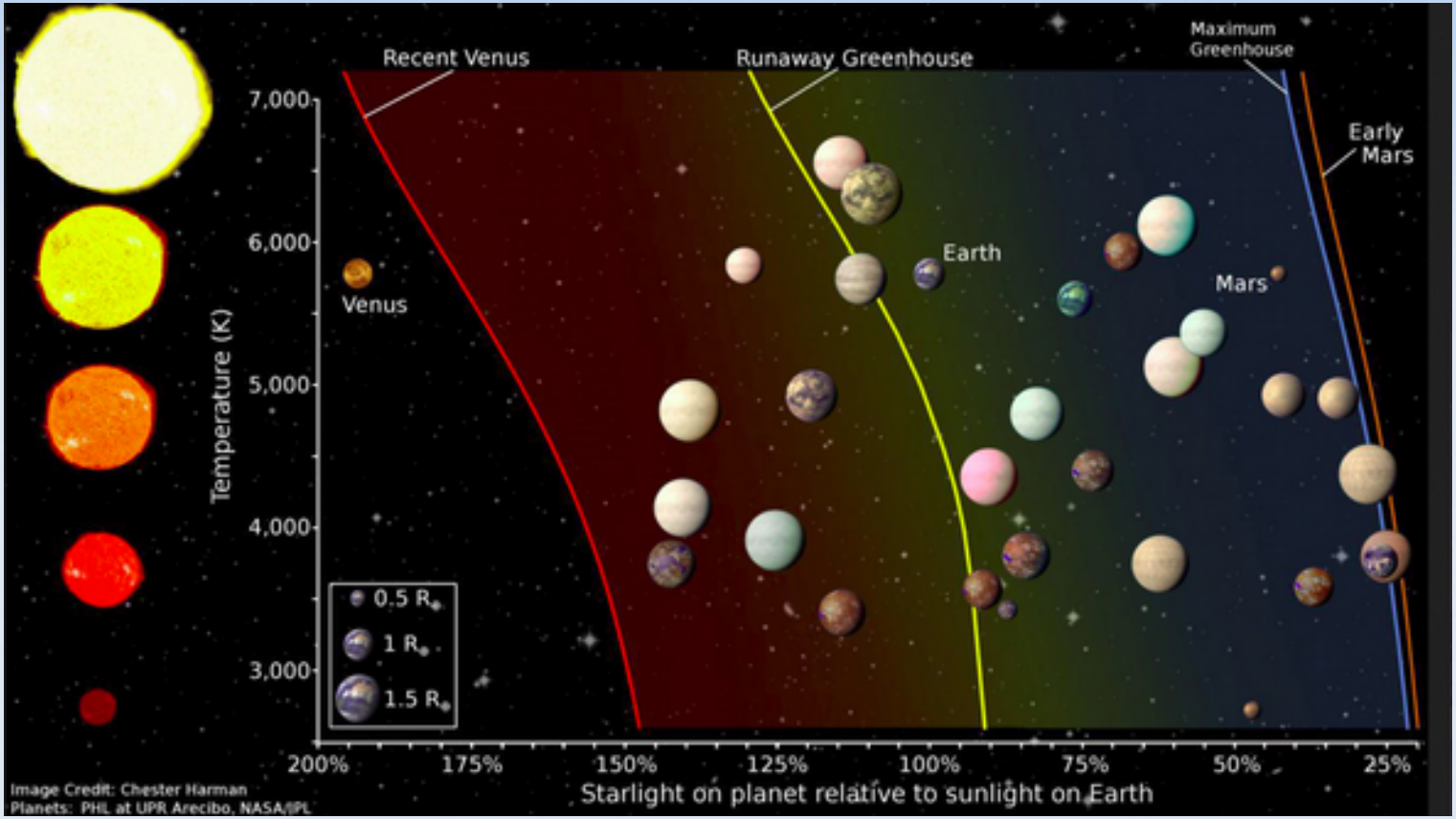
- Anglada-Escude et al. 2016

- Low SNR
- Indirect detection

- No plan for spatially resolved images before long long term future.

Biosignatures on “habitable” exoplanets

- We know several **“habitable”** exoplanets



From press release of Kane et al.2016

- What can be observed for now ?

At best stellar illumination, radius+mass, no spectra of habitable planets yet

Habitable exoplanets

- Cf Xavier Delfosse's talk

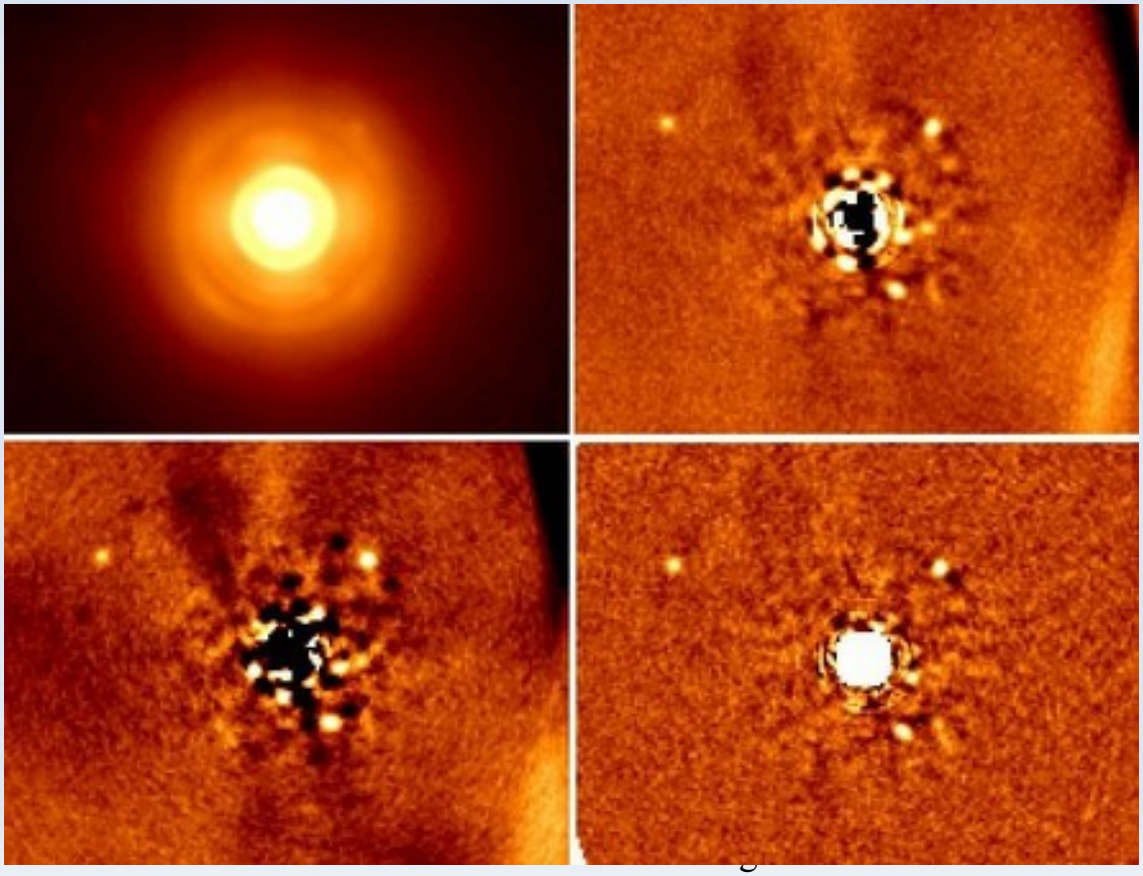
- Significant fraction of nearby stars do host "Habitable" exoplanets
- Several new space and ground based instruments (TESS, Extra, PLATO,Spirou, …) are dedicated to finding them
- We will detect many in the near term future

Characterising exoplanets

- The challenges are:

  Weak signal from habitable exoplanets

  Very high contrast with nearby host star

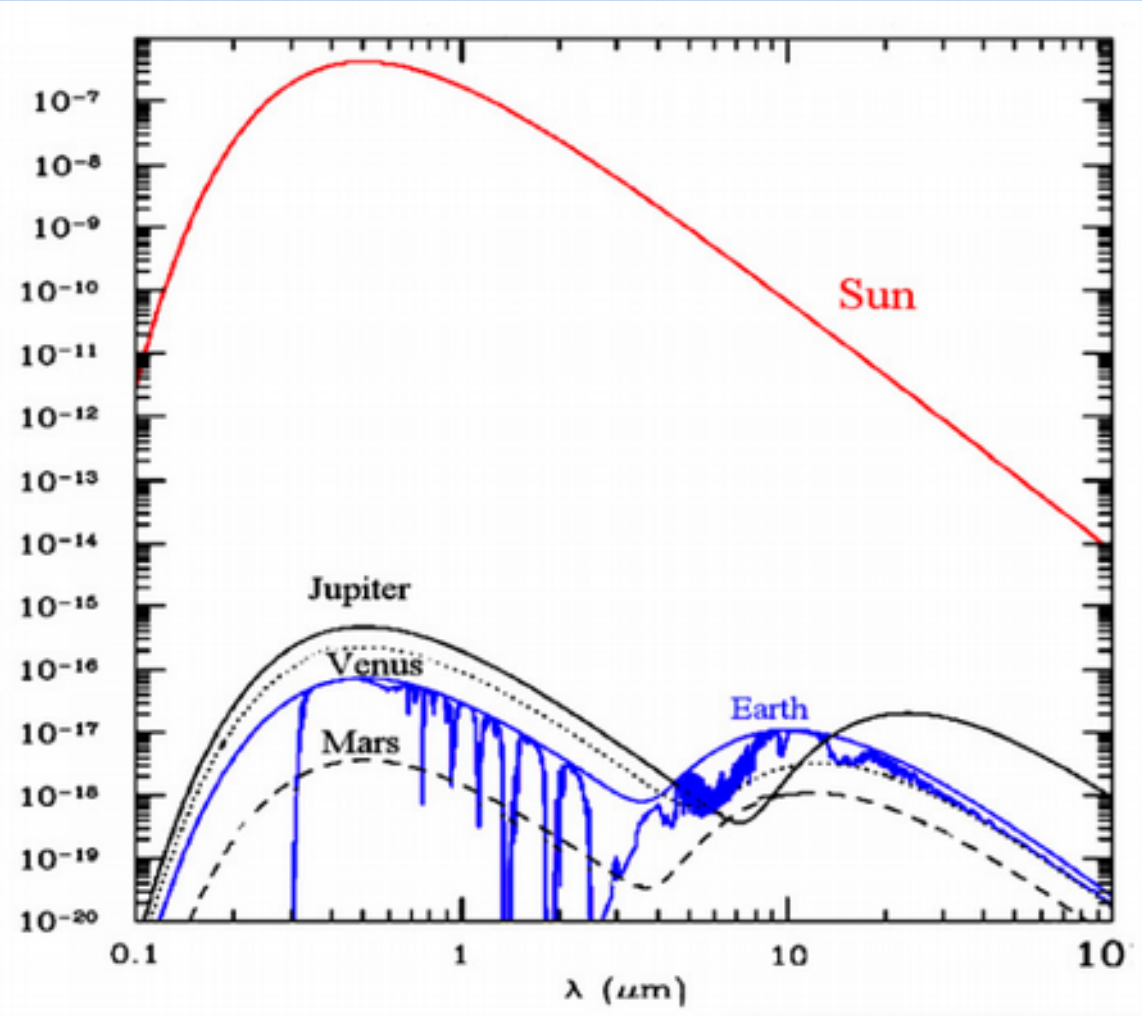


Easier case of young giant exoplanets

HR8799 planetary system

Characterising exoearths: the issue of contrast

- Depends on wavelength: from 10^{-9} to 10^{-6} around the Sun, but 10 to 100 more favourable around M dwarfs



Flux of Earth-like planets close to Earth's, regardless of host star !

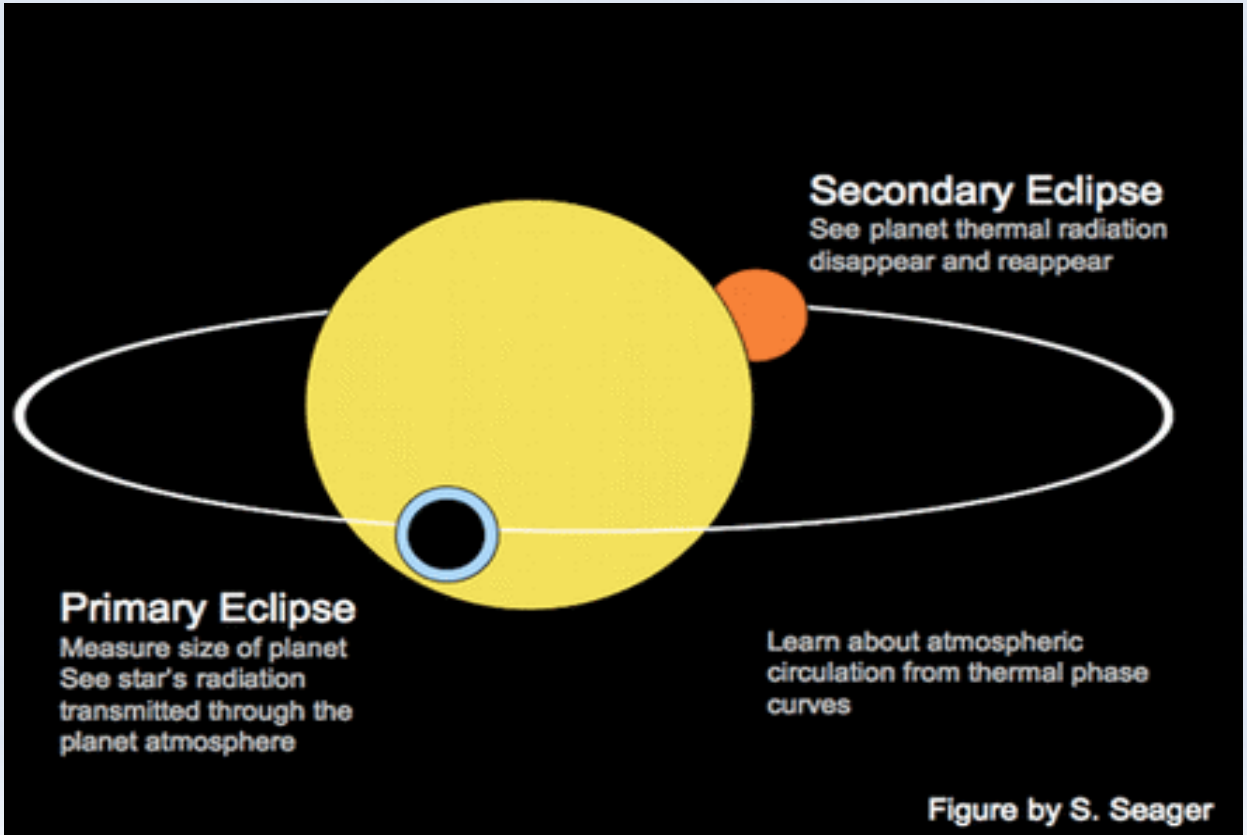
Contrast best in infrared.

Resolution best in visible

From Kaltenegger et al. 2011

Transit photometry/Spectroscopy

- Similar observables as direct photometry/spectroscopy
- **Contrast is not an issue** since it uses the star's photons
- **Resolution is not an issue**
- **Atmospheric signal is also weak** ~10^{-6} around solar-type stars and 5.10^{-5} around small M dwarfs
- **Fewer targets**
- **Timing constraints**

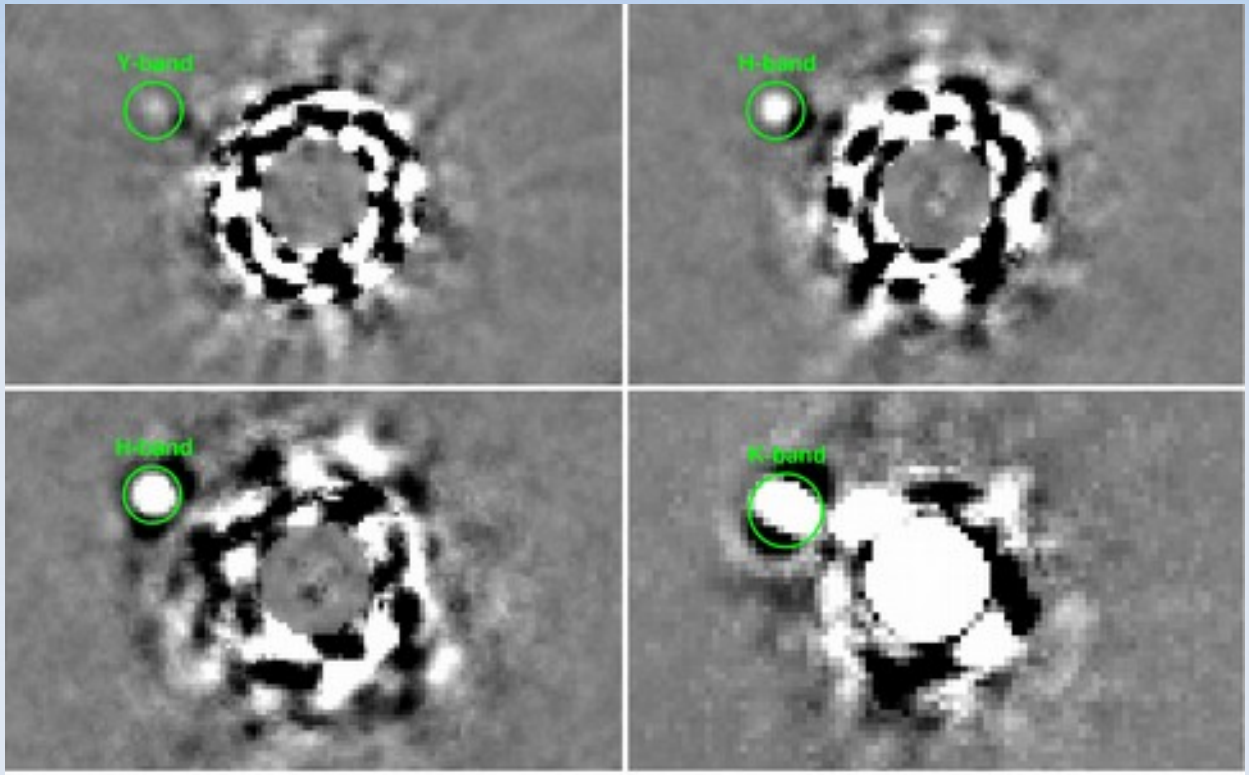


Currently : direct photometry

- Instance of young substellar object HD206893B
- SPHERE instrument

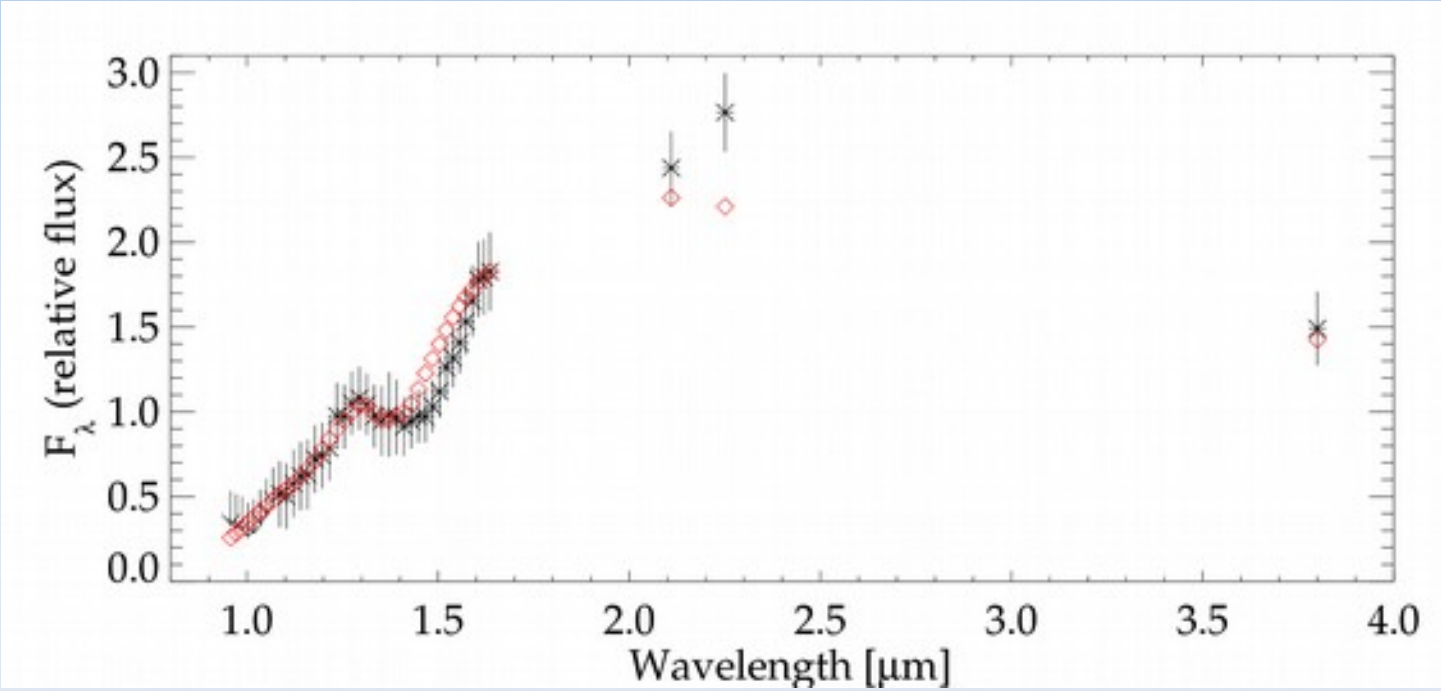
  Still issue with speckles

  => ***Very red !***
- ***Quantitatively gives constraint on effective temperature (~1400K)***
- ***Needs dust***



From Delorme et al. 2017.

Currently : Spectroscopy and model fitting



From Delorme et al. 2017.
***Black** : observation*
***Red**: model*

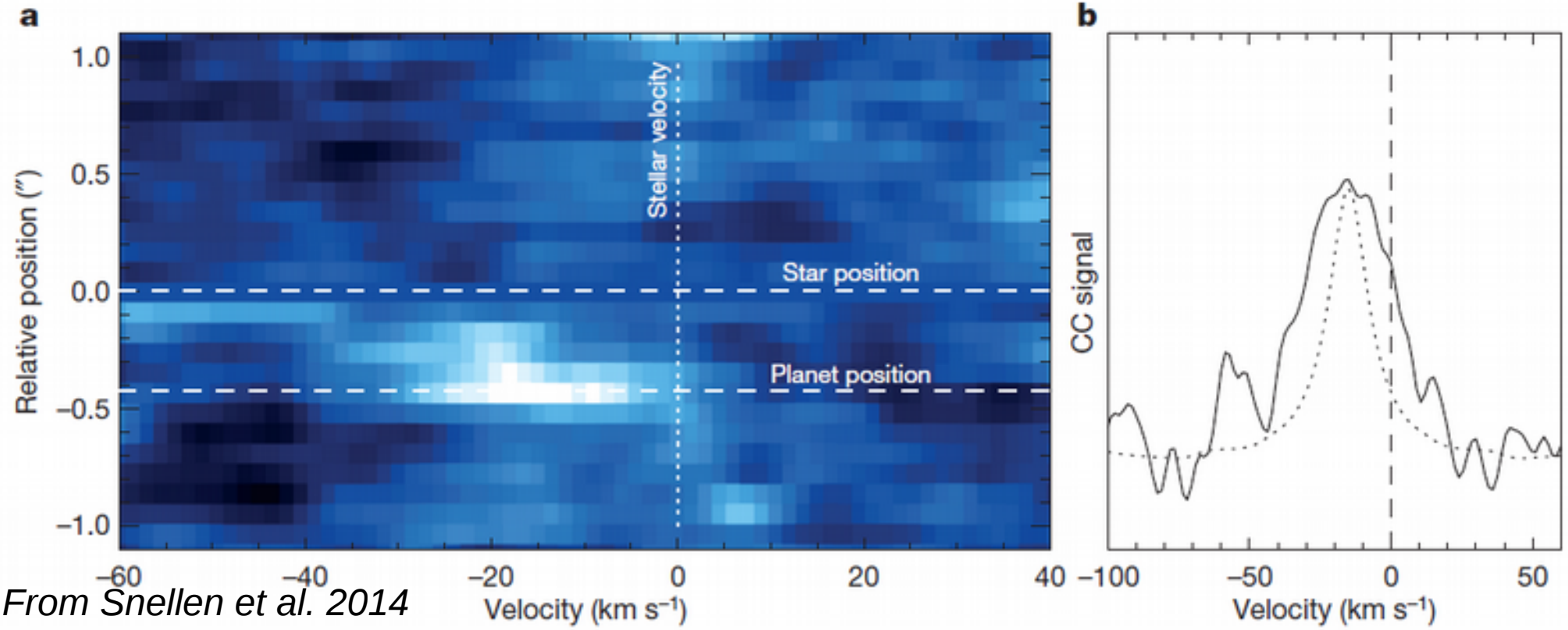
Best fit: log g=4.4 ; Teff =1300K ; M/H=0 χ^2=0.98

Consistent with a 12-20Mjup object aged 100-200Myr

But several models provide $\chi^2 \sim 1$ …

Direct spectroscopy of giant planets

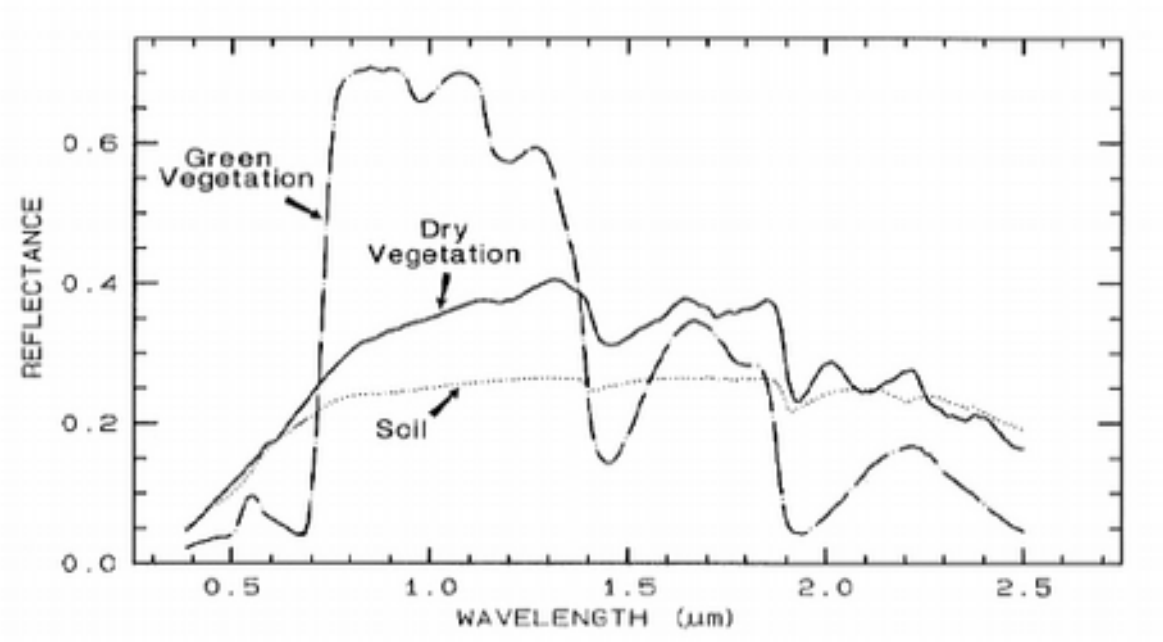
- Improve contrast using molecular lines and keplerian motions to disentangle planet from star
- Planets have molecules, stars don't or different ones. Here correlation with CO+H20 line template
- Planets spectral lines are shifted by Keplerian motion



From Snellen et al. 2014

Biosignatures: Pigments

- See the distinct photometric/spectroscopic signal from photosynthesis: the vegetation red-edge

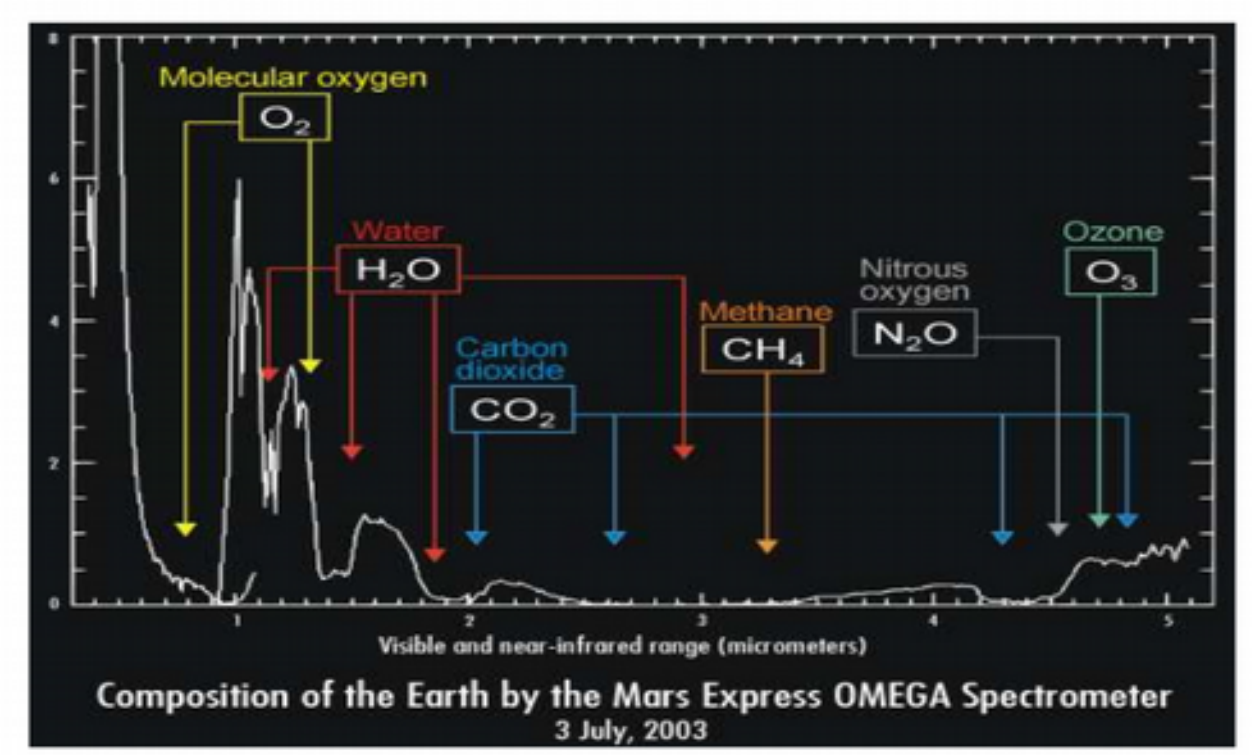


From Arnold et al. 2008

- Detectable in Earthsine if you look for it, but also possible to fit it with combination of mineral spectra
- Pigments with different stellar flux ?

Biosignatures: out-of equilibrium atmosphere

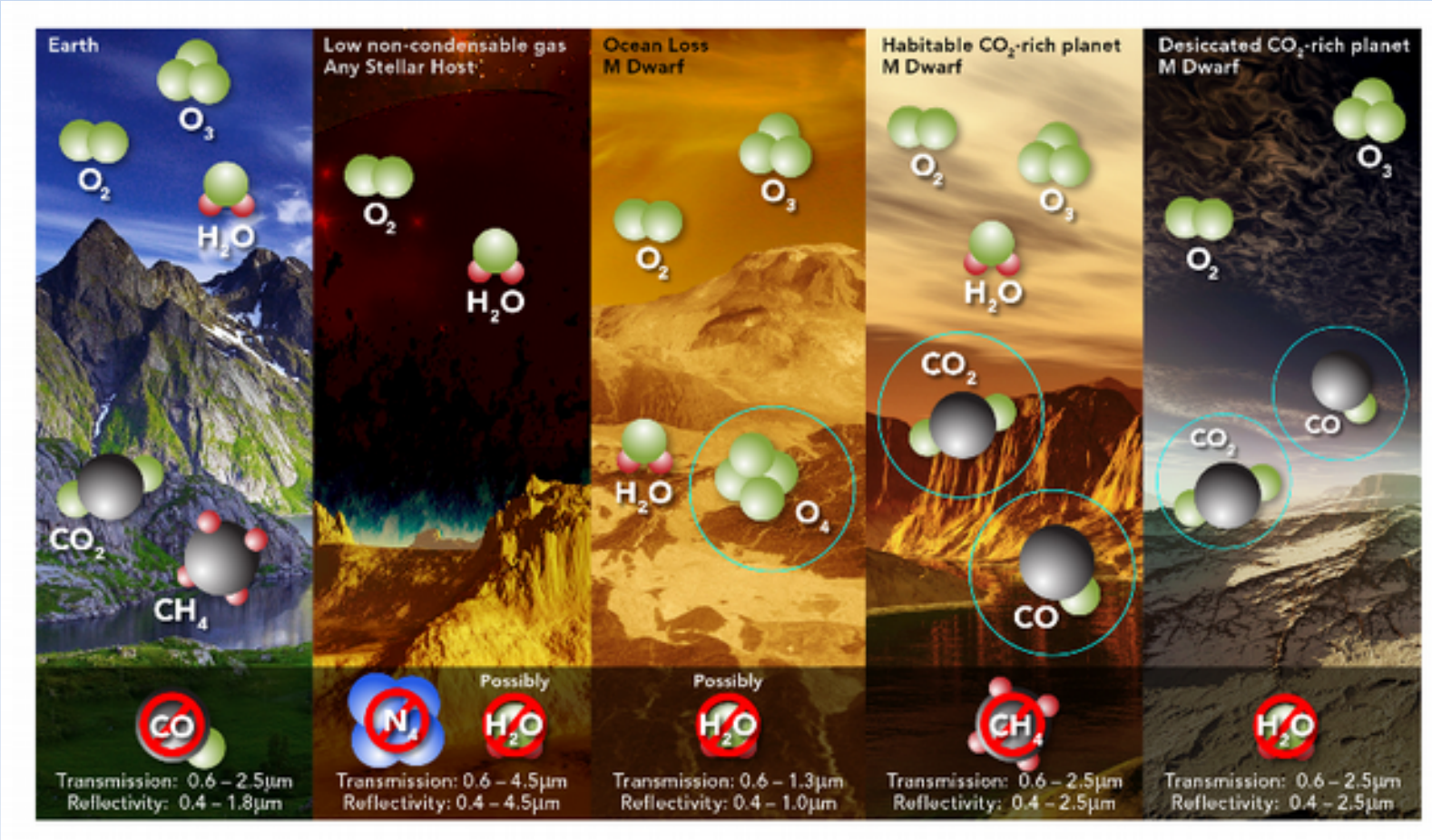
- Instance of Earth



- O_2 alone good tracer : very reactive => easily removed. But false positives are possible (water loss)
- CH_4+CO_2 or O_2 oxidising atmosphere ?

Biosignatures: issue of false positives

- Instance of O_2



From Meadows et al. 2017

How to detect biosignatures: my best guess at the moment

Target the closest habitable exoplanets, likely around M dwarfs

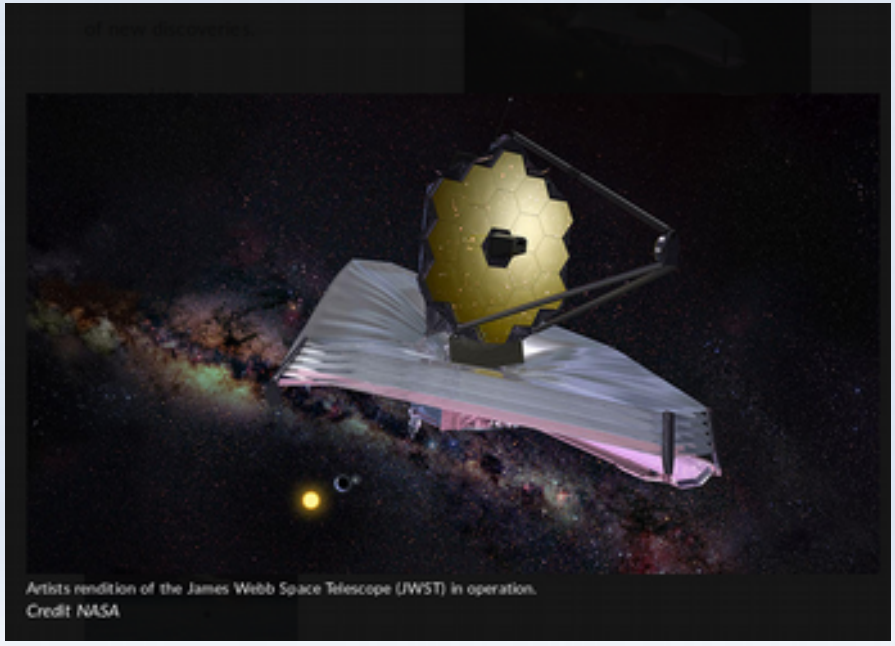
Use dedicated instruments on the largest telescopes available

~100 hours of cumulated observation per target

Transit or combine high angular resolution and high spectral resolution to target molecules combination like CH_4 + (O_2 or CO_2 or O_3)

Characterising exoplanets in the near future

- Transit photometry/spectroscopy around M dwarfs with James Webb Space Telescope in 2020
- Plausible direct spectroscopy of Proxima b after 2020. Need improved instrumentation on existing telescope
- Spectro: characterisation of multiple habitable exoplanets atmospheres in late 2020's with Extremely Large Telescopes



Artists rendition of the James Webb Space Telescope (JWST) in operation.
Credit NASA

Biosignatures: roadmap in Origin Of Life CDP

- Define combination of molecules to target
- Determine optimal wavelength range (signal, number of lines, instrumental capabilities)
- SPHERE upgrade: how to detect molecules in Proxima b atmosphere.
- Detect molecules on brown dwarfs, giant exoplanets and measure abundances and degeneracies.
- Application on habitable exo-earths with JWST data. Simulation of ELT's capabilities.