LIFE

Large Interferometer For Exoplanets

Detecting and characterizing terrestrial exoplanet atmospheres in the mid-infrared

Sascha P. Quanz & the LIFE team
(special thanks to Maurice Ottiger, Bjoern Konrad, Emile Fontanet, Franziska Menti, Jens Kammerer, Eleonora Alei)

www.life-space-mission.com

@LIFE_Telescope

PlanetS
National Centre of Competence in Research

ETH zürich

How to characterize dozens of temperate rocky worlds

Reflected light (UV - NIR)

Thermal emission (MIR)

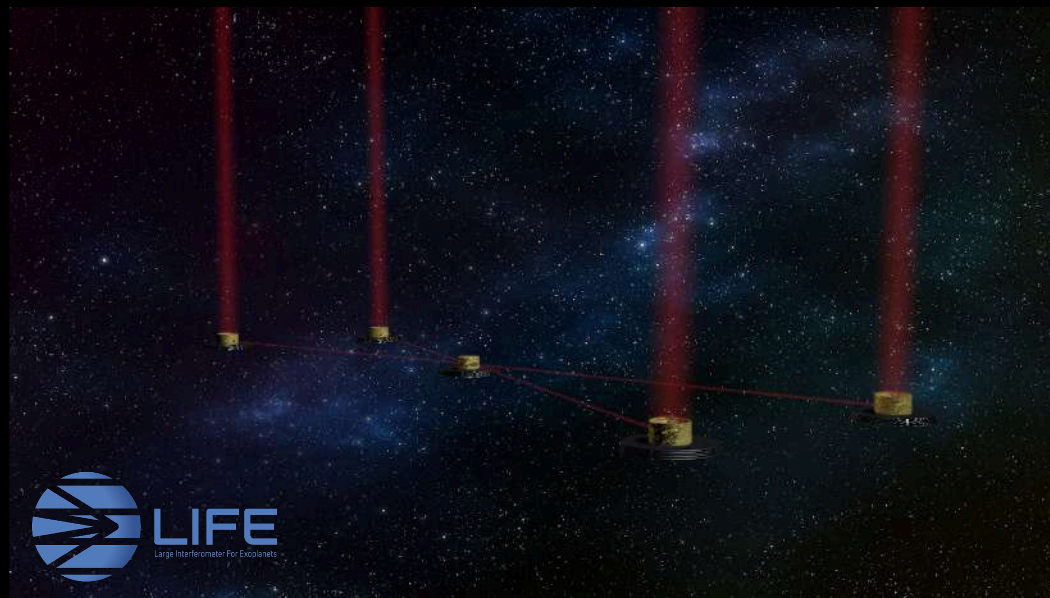
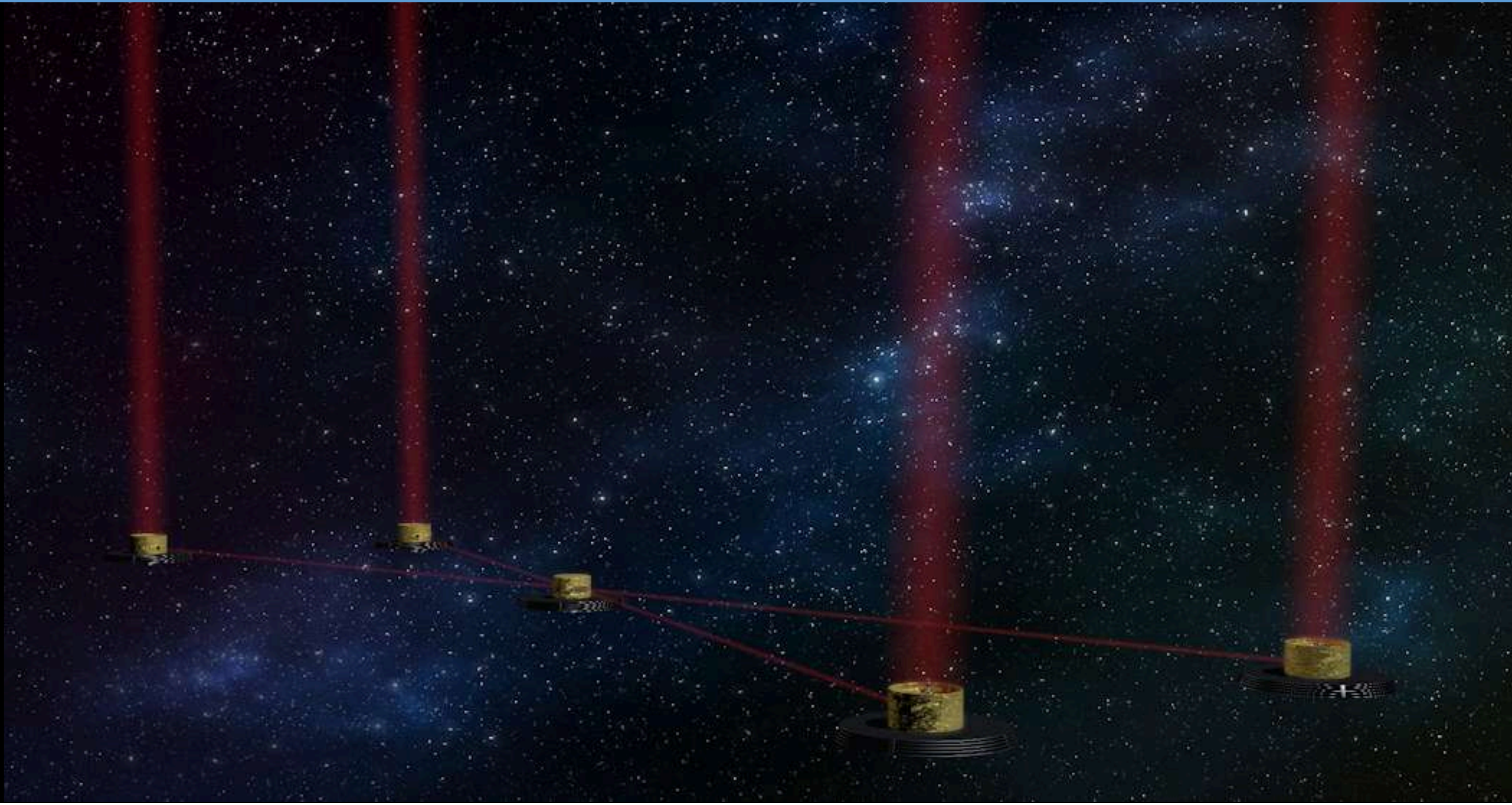


Image credit: NASA/NOAA; NASA/NOAA GOES Project; NASA; LIFE initiative

How to characterize dozens of temperate rocky worlds



DETECTION YIELD

(~2.5 years search phase)

Approach and assumptions for Monte Carlo simulations

Planet population:

- Sample of main-sequence stars within 20 pc from GAIA (incl. wide-separation binaries)
- Occurrence rates and period and radius distributions from Kepler:
  - NASA's SAG 13 report (for FKG stars); Dressing & Charbonneau 2015 (for M stars)
- Dynamical stability criterion for systems with multiple planets
- Exozodi level distribution as found by HOSTS (Ertl et al. 2020, nominal case)
- Circular orbits, random albedos (A_B [0, 0.8], A_g [0,0.1] in the MIR), random inclination, random orbital phase
- Planet treated as black bodies w/ equilibrium temperature
- 500 systems generated per star

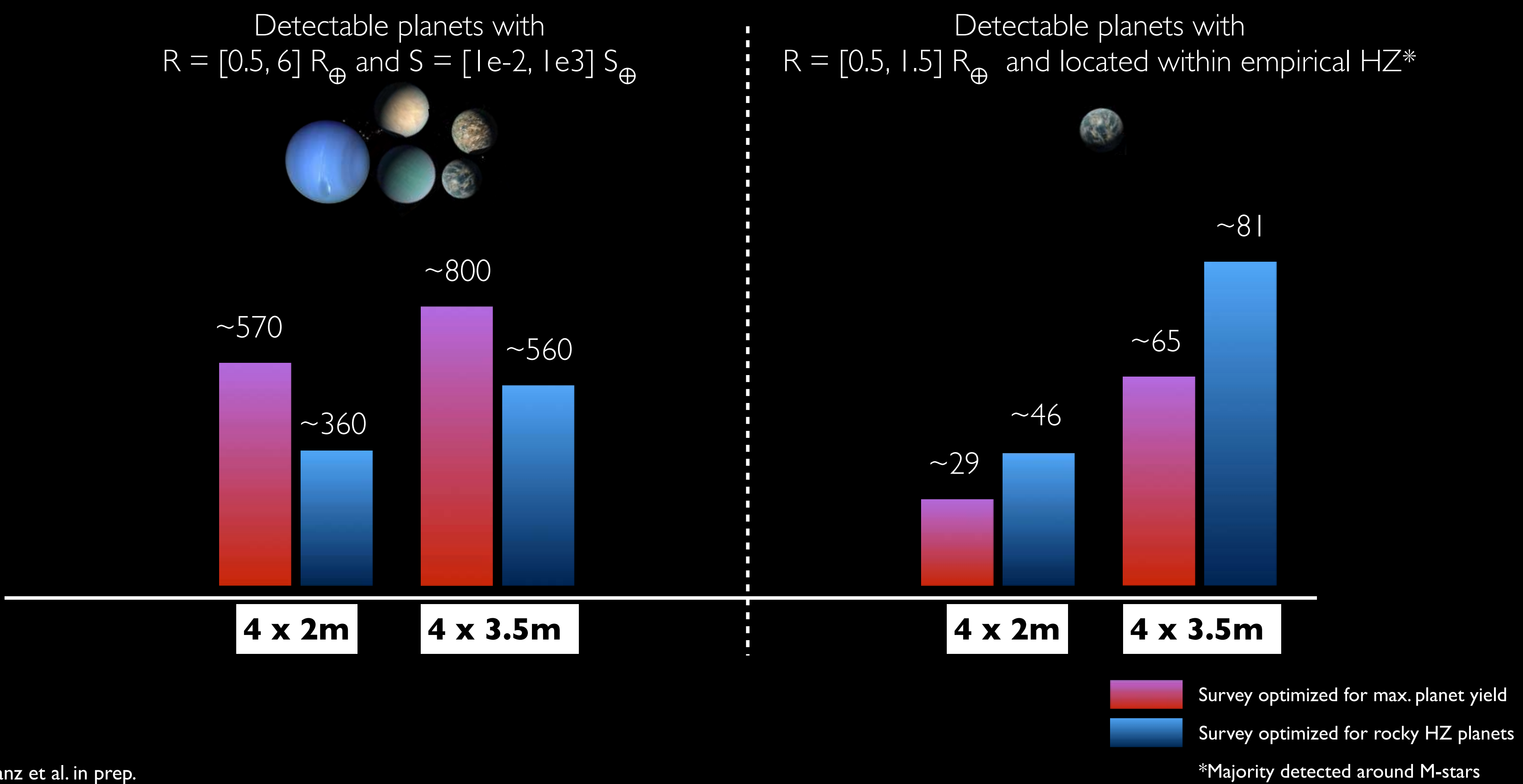
Spacecraft & mission parameter:

- 4-telescope array with 6:1 baseline ratio
- Length of nulling baselines adapted for each star so that center of HZ is located in first transmission maximum at 15 micron
- Maximum/minimum allowed separation: 600 m / 10 m
- 2 years of on-source time available (-> 2.5 years for the search phase assuming 25% general overhead)
- Slew time to new target: 10 hours
- Integration time per star optimized either for (expected) maximum planet yield or (expected) maximum number of rocky planets in HZ

Instrument & noise parameter:

- Wavelength range: 3 - 20 micron
- Quantum efficiency of detector: 70% (constant over full wavelength range)
- Instrument throughput: 5% (same for all interferometric channels)
- Photon noise from exoplanets
- Photon noise from stellar leakage
- Photon noise from local zodi (2-D dust distribution matched to empirical data)
- Photon noise from exozodi disks
- Detection criterion: integrated SNR >7

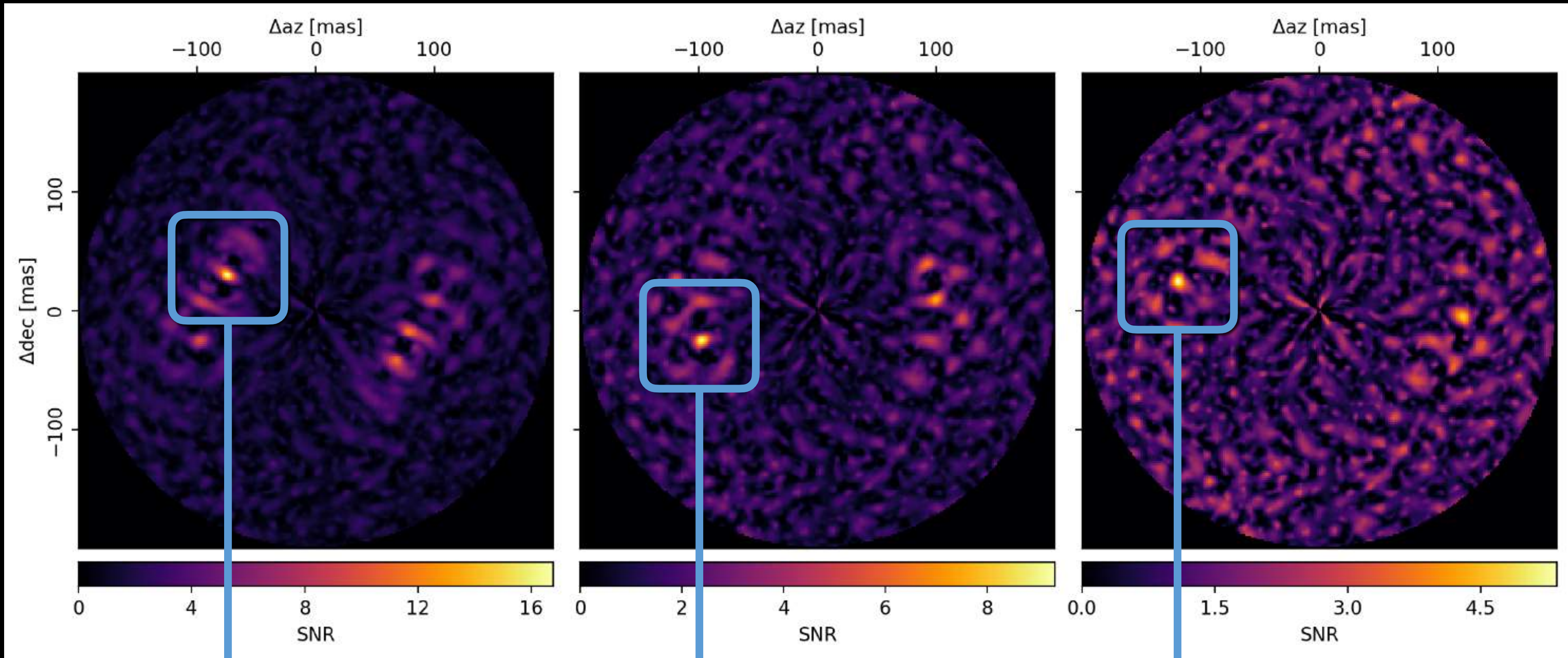
Expected LIFE detection yield for 2.5 years search phase



Quanz et al. in prep.

Obtaining radii and effective temperatures of rocky planets

Signal extraction of multi-planet systems from single epoch (data created with *LIFESim*)



1 R_{Earth}, 10 pc, 0.8, 1.0 & 1.2 AU, 3 exozodis, 35 h on-source (4 x 2m apertures)

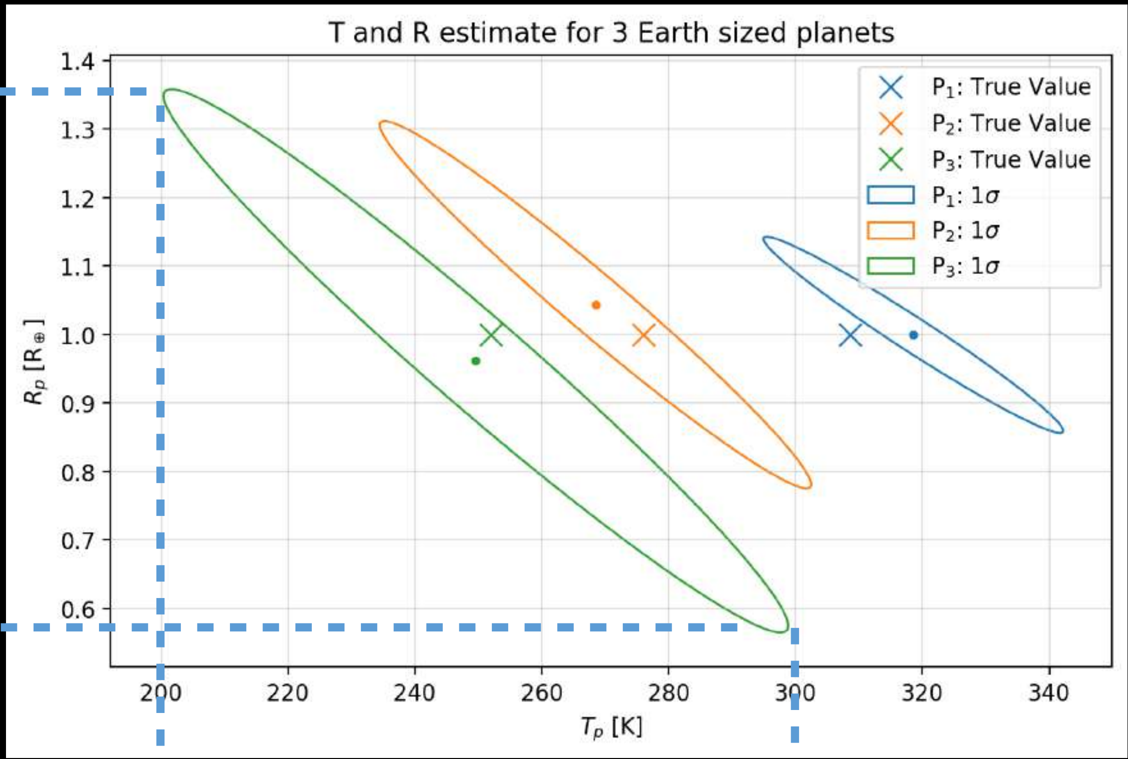
Ottiger et al. (in prep.)

Obtaining radii and effective temperatures of rocky planets

Signal extraction of multi-planet systems from single epoch (data created with *LIFESim*)

For the faintest signal w/ SNR ~ 5

Radius error: +/- 0.35 R_{Earth}



Temperature error: +/- 50 K

Analysis of full sample from "search phase" ongoing

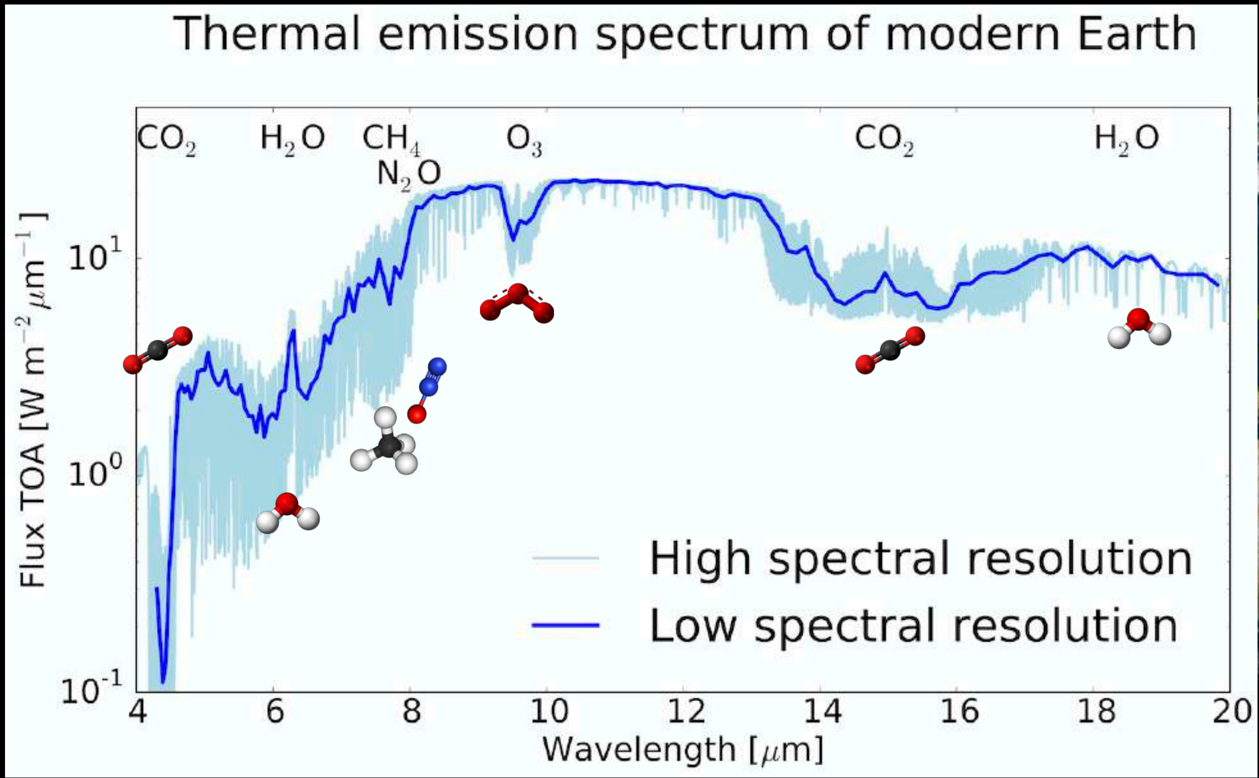
Ottiger et al. (in prep.)

Characterization potential

(~2.5 years characterization phase)

Atmospheric characterization of temperate rocky planets

Spectral retrieval case study: Earth twin at 10 pc

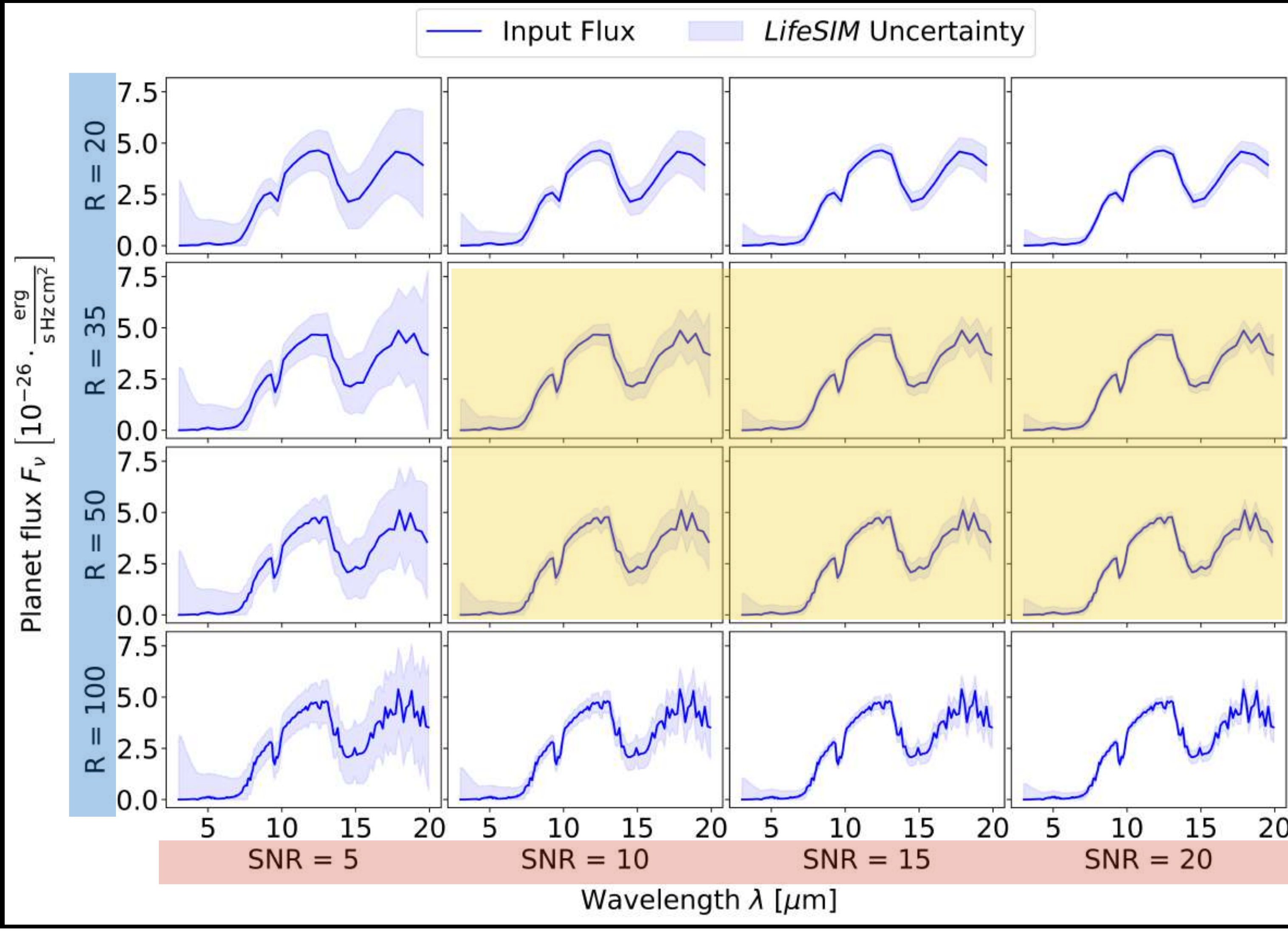


….many more molecules in MIR (e.g., CO, PH_3,….)

Atmospheric characterization of temperate rocky planets

Spectral retrieval case study:

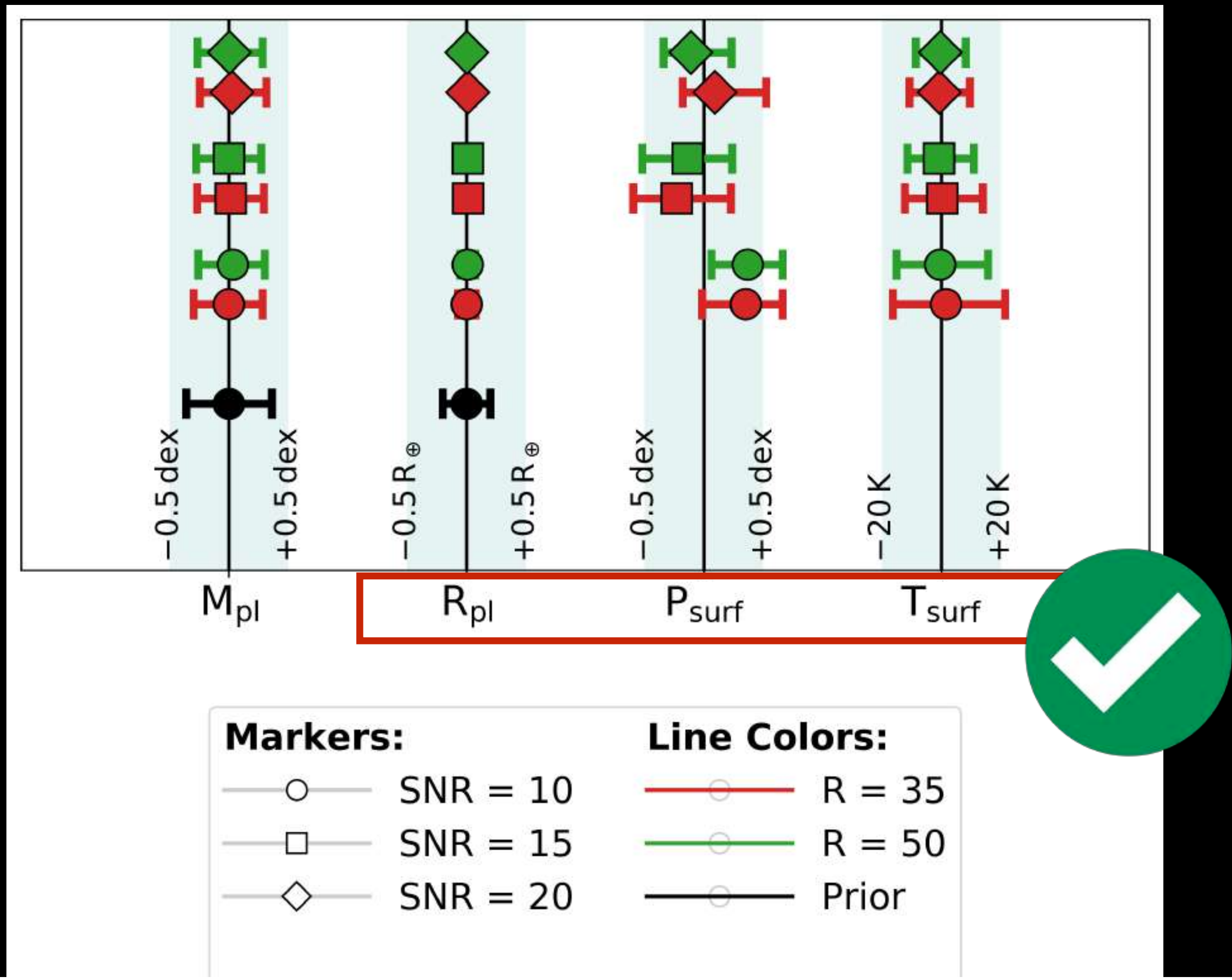
- Earth twin at 10 pc
- 0.5 or 3 exozodis
- Grid in
  - R: 20, 35, 50, 100
  - SNR: 5, 10, 15, 20
  - Wavelength range:
    - 3-20 micron
    - 4-18.5 micron
    - 6-17 micron



Konrad, Alei et al. (in prep.)

Atmospheric characterization of temperate rocky planets

Case study: Earth twin at 10 pc; 0.5 exozodis; 4-18.5 micron



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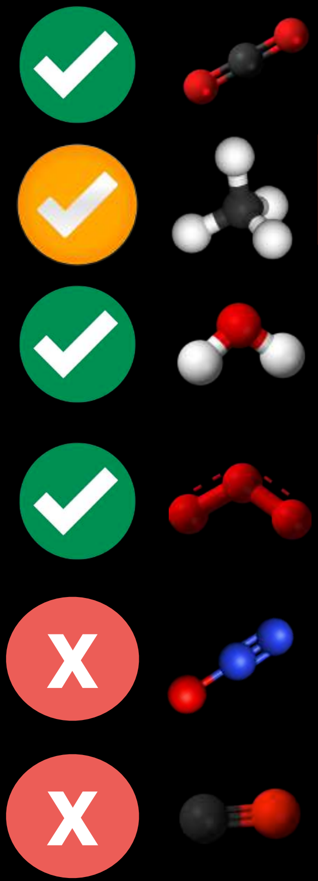

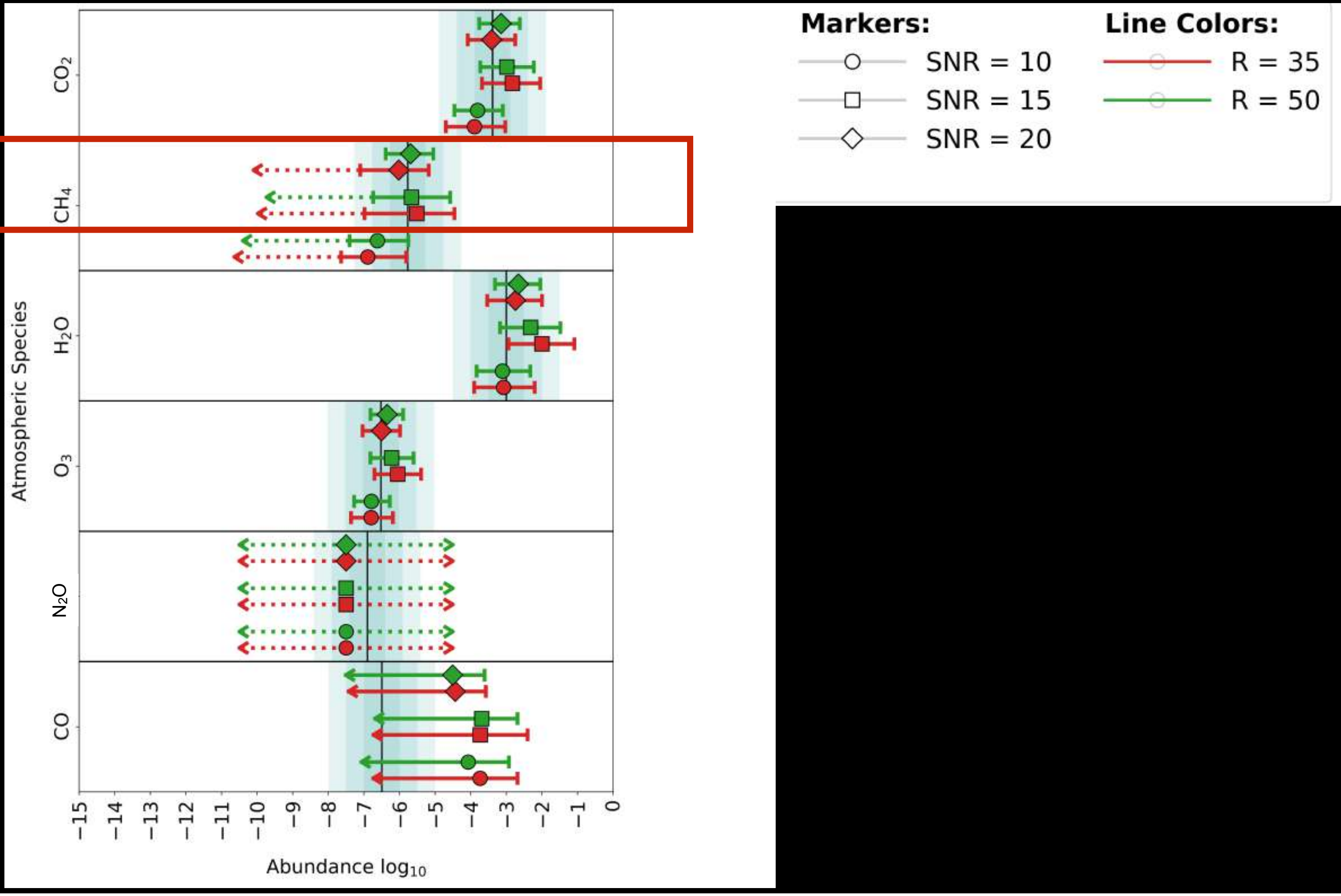

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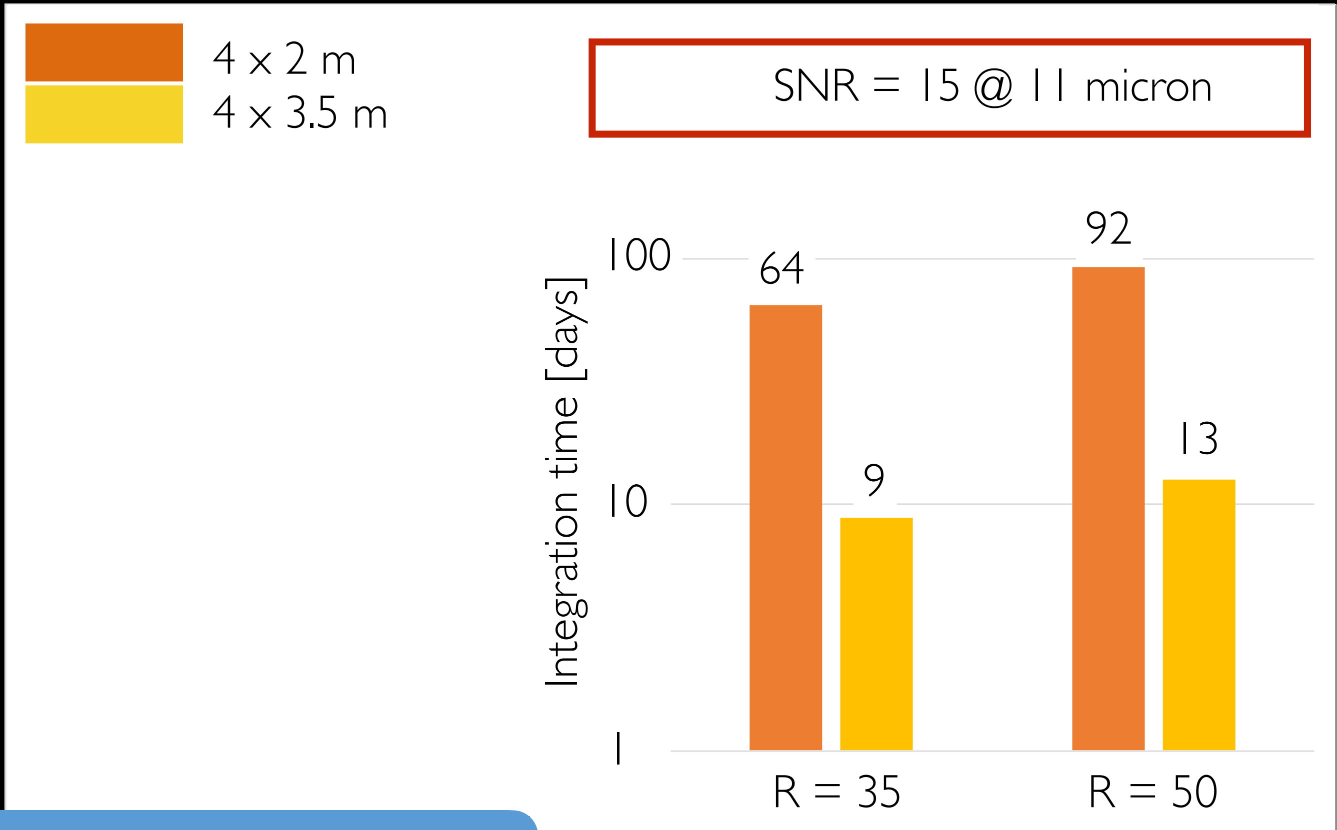


Times are factor ~2 lower / higher for SNR = 10 / 20

WHERE DO WE STAND

LIFE

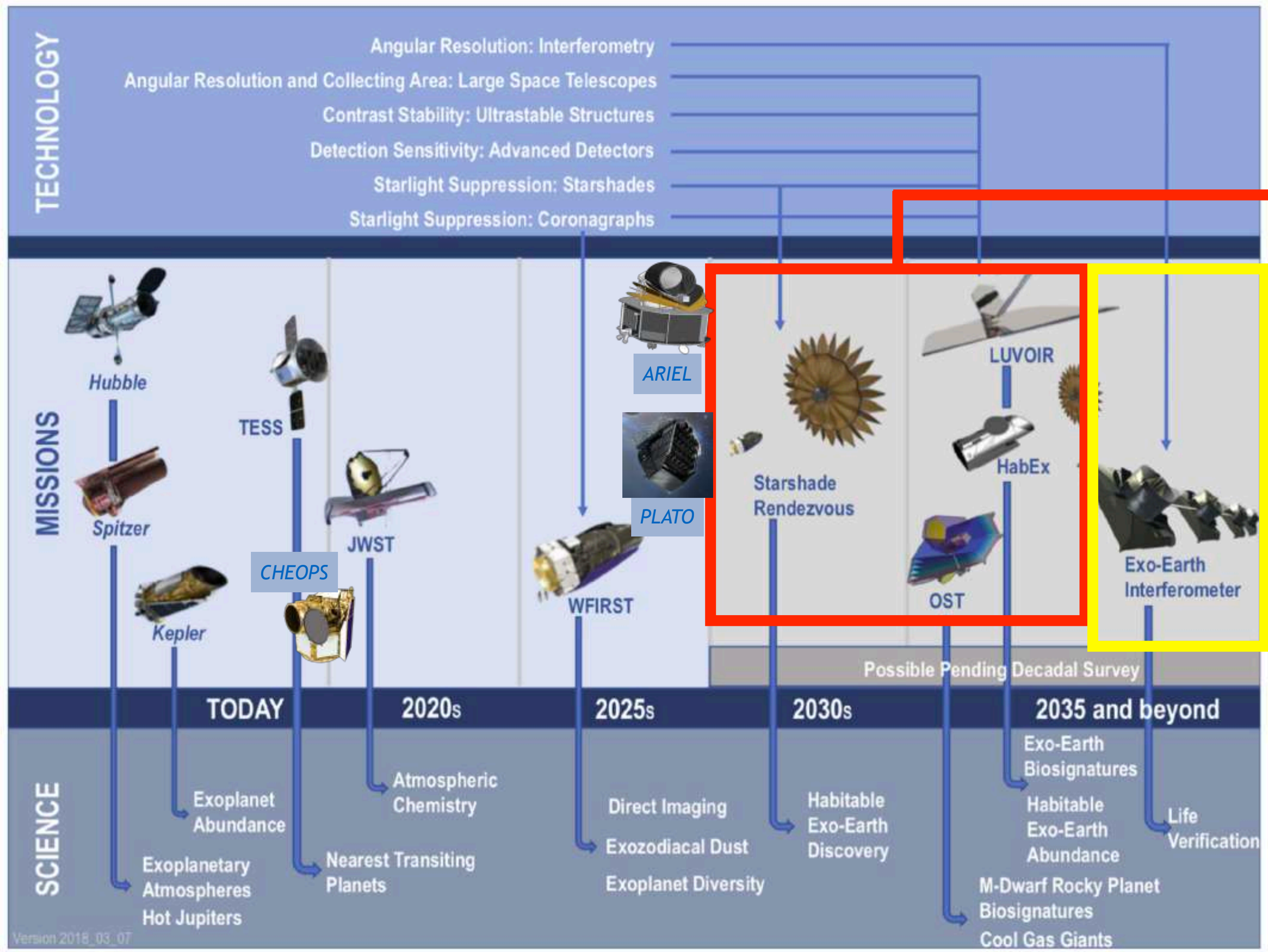
First steps done…much more to do…

- Ongoing quantification of science cases (ideas very welcome!) and science requirements

- Ramping up of lab activities:
  - Nulling Interferometry Cryogenic Experiment (NICE for LIFE) at ETH Zurich to enhance TRL of broadband "nullers"
  - Concept and design studies for new (MIR) VLTI nulling instruments
    (e.g., Hi-5 (Defrère et al. 2018) and VIKING (Martinache and Ireland 2018))
  - Concept studies for demonstration / pre-cursor missions

- Ongoing selection process at European Space Agency for Large Missions in 2035-2050 timeframe (first results some time early next year)

Our vision…



NASA - led

esa - led

Image credit: (adapted from) NASA/JPL/Caltech; https://exoplanets.nasa.gov/exep/technology/technology-overview/ (accessed July 4, 2019)

Summary

LIFE is a free-flying mid-infrared (nulling) interferometer (4 x 2-3.5 m)

Wavelength range: ~4 - 17-18 μm (tbc)

Spectral resolution: R ~ 35 - 50 (tbc)

Total mission lifetime (requirement) 5-6 years:
- search phase: detection of hundreds of planets
- characterization phase: detailed investigation of dozens of planets (priorities have to be defined!)
- other science

Lots of heritage exist and significant progress has been made since mid-2000s (also on the technical side)

In the context of the "ESA Voyage 2050" process there is a chance to get a mission like this on the roadmap in the 2035-2050 timeframe!

Image credit:NASA Ames/JPL-Caltech/T. Pyle