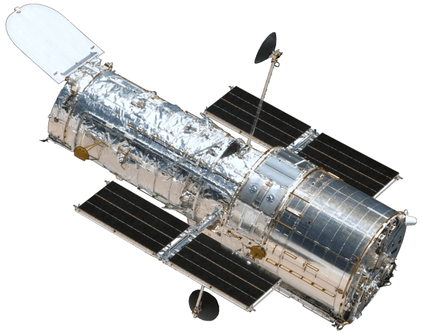
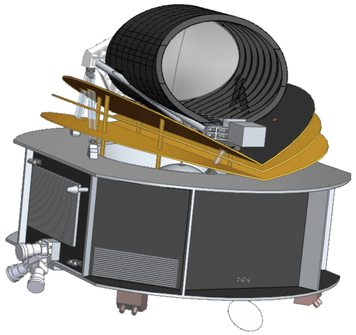
Journée ARIEL France 2024

Combining space- and ground-based data to optimise exoplanet atmospheric characterisation

Thea Hood
PhD supervisors: Florian Debras, Claire Moutou

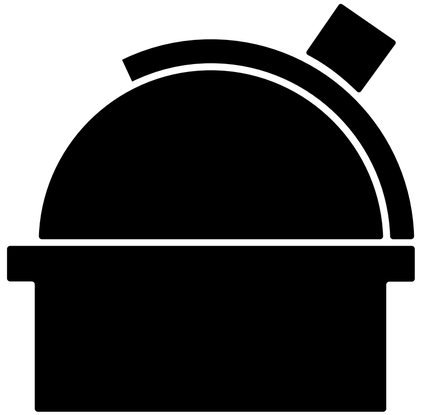
Space-based observations





VS

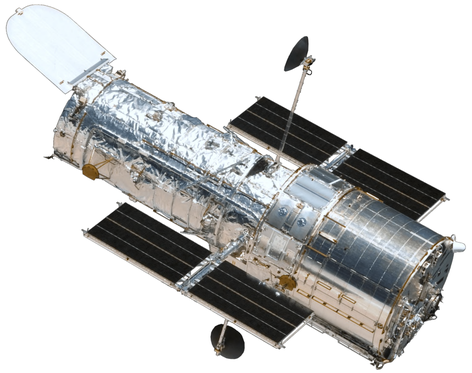
Ground-based observations

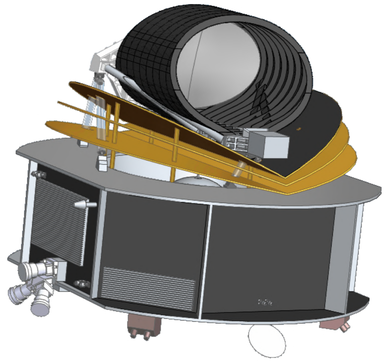


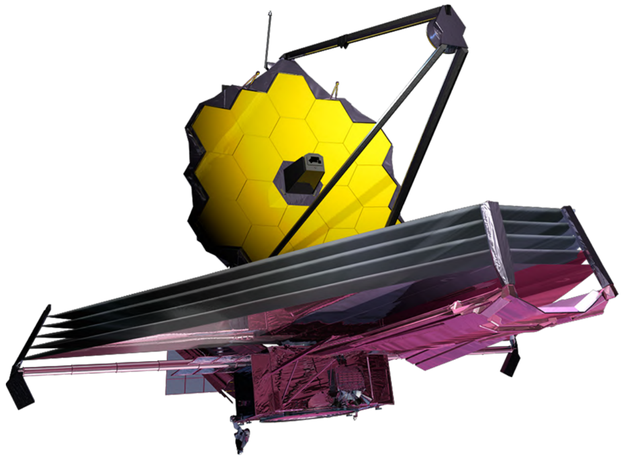
Space-based observations

<u>Low-resolution spectroscopy:</u>

- Broad wavelength coverage
- No tellurics
- Global slope of the spectrum







Ground-based observations

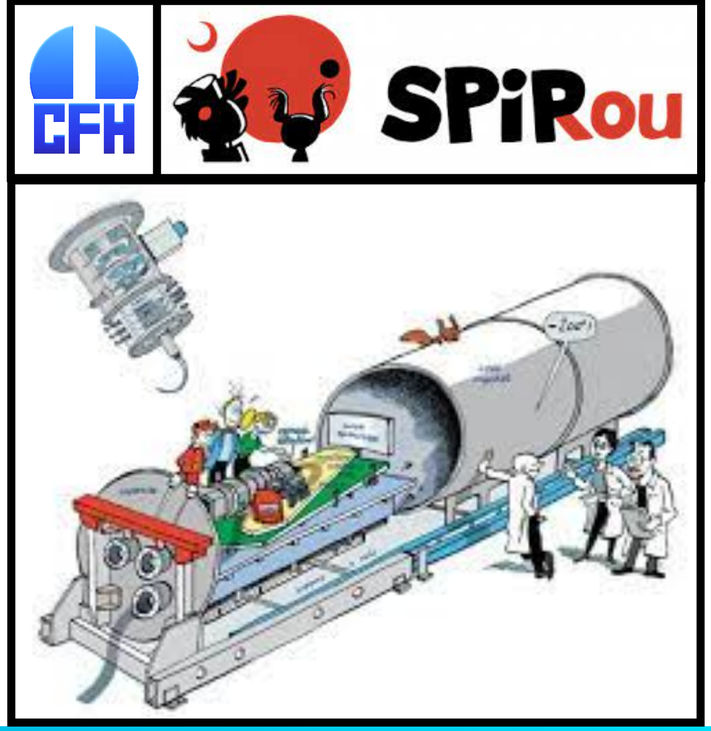
<u>High-resolution spectroscopy:</u>

- ➢ Resolution of individual lines
- ➢ Can detect above clouds
- ➢ Access to wind dynamics

Ground-based observations

<u>Precise mass measurements:</u>

➢ SPIRou (**Sp**ectropolarimètre **I**nfra**rou**ge[1]): radial velocity accuracy ~ meters/second over several years



[1] Donati et al. 2020

Combining data sets

➢ Highly complementary observables

LRS	HRS
Broad wavelength coverage	Most instruments with narrow or non-continuous wavelength coverage
No tellurics	Tellurics
Global slope of the spectrum	Loss of continuum information
Probes lower atmosphere	Probes higher atmosphere
Can be “blocked” by clouds	Can detect above clouds
Resolution too low for individual lines	Resolution of individual lines
Resolution too low for access to wind dynamics	Access to wind dynamics

Combining data sets

Previous work:

- Brogi et al. 2017 (HD 209458b)
- Brogi & Line 2019 (HD 209458b, HD 189733b)
- Ghandhi et al. 2019 (HD 209458b)
- Khalafinejad et al. 2021 (WASP-69b)
- Kasper et al. 2023 (KELT-20b/MASCARA-2b)
- Boucher et al. 2023 (WASP-127b)
- Smith et al. 2023 (WASP-77b)

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Combining low- and high-resolution provides more powerful probes of exoplanetary atmospheres, and lifts degeneracies affecting retrievals


ATMOSPHERIX

ATMOSPHERIX

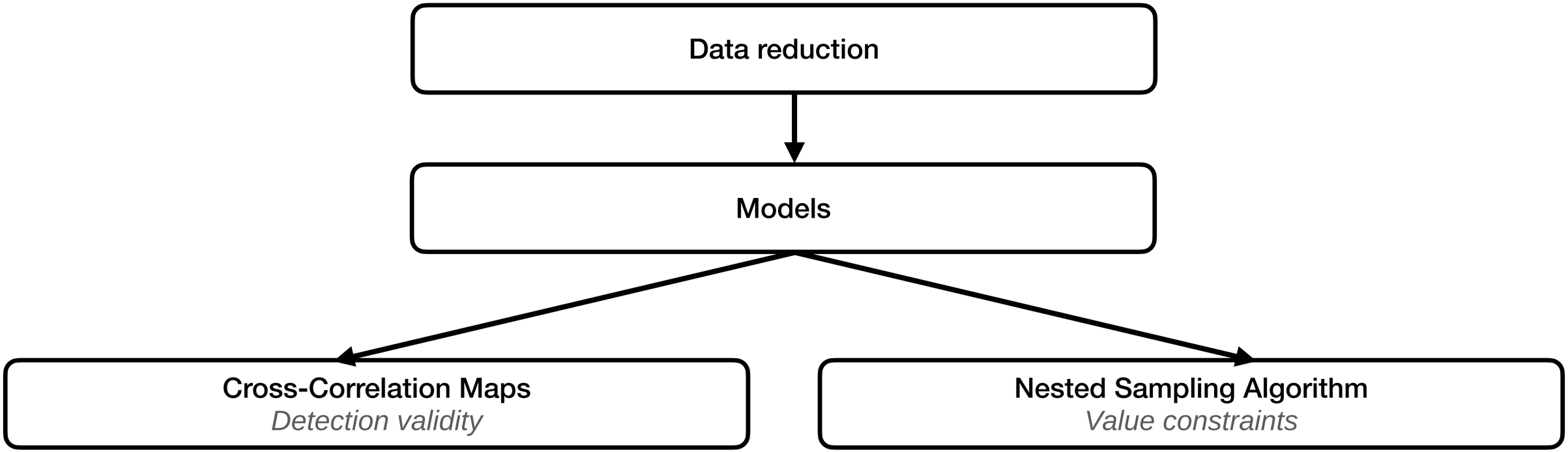
30 members

5 PhD

11 universities or institutes

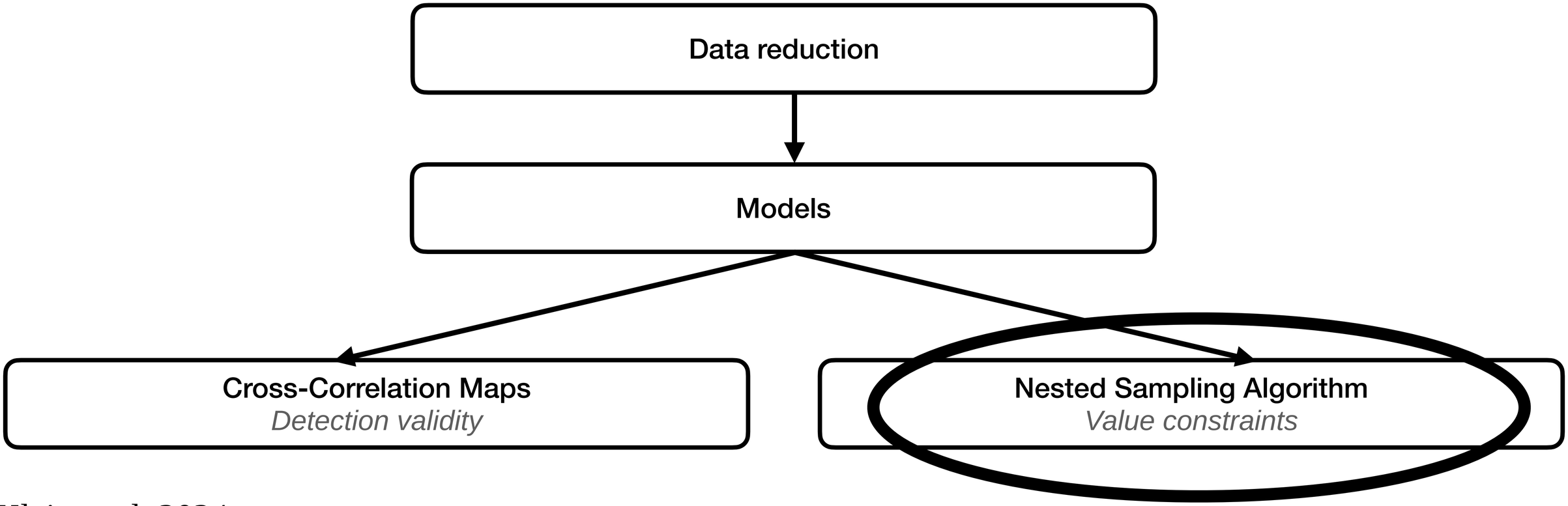
2 papers accepted, 3 submitted, contribution to 2 other papers, few targets waiting

Pipeline[1,2,3]*:*



[1] Klein et al. 2024
[2] Debras et al. 2024
[3] https://github.com/baptklein/ATMOSPHERIX_DATA_RED

Pipeline[1,2,3]*:*



[1] Klein et al. 2024
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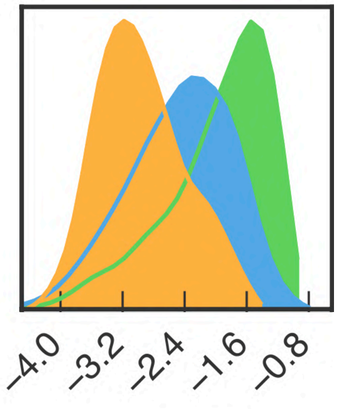
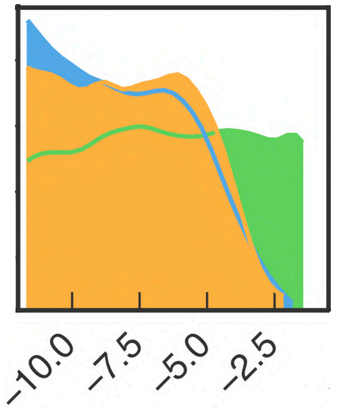
Joint retrieval:

- High- and low-resolution models created with petitRADTRANS
- For each step:
  - Likelihood for high- and low-resolution models calculated seperately
  - Return sum of these likelihoods

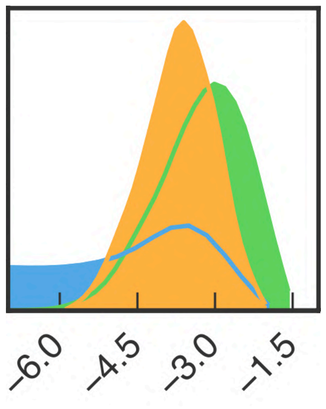
WASP-127 b:



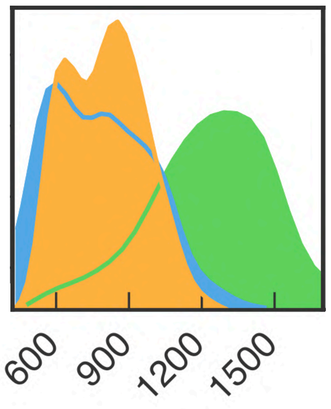
H_2O



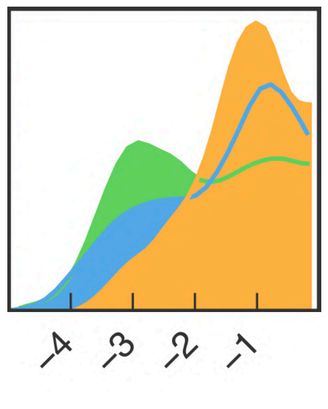
CO



CO_2



T_p



P_{cloud}

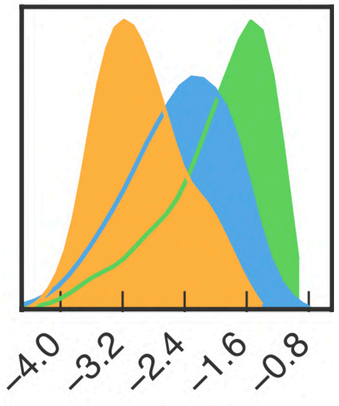
SPIRou

HST + Spitzer

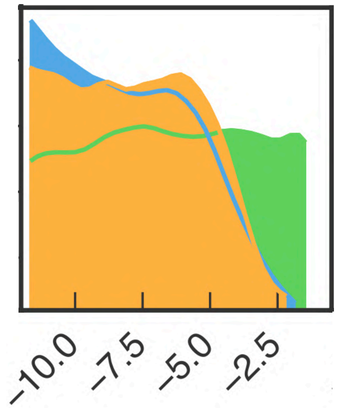
SPIRou + HST + Spitzer

(Boucher et al. 2023)

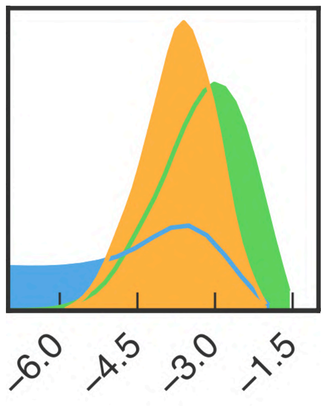
WASP-127 b:



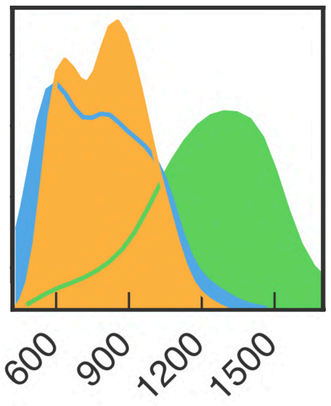
H_2O



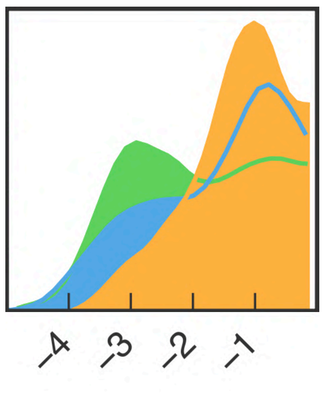
CO



CO_2



T_p



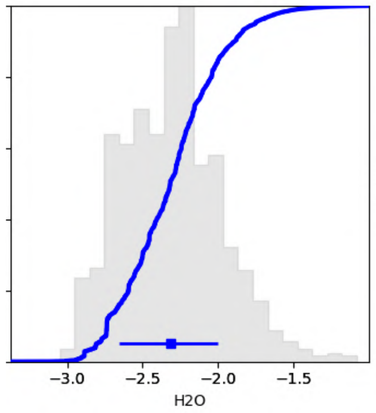
P_{cloud}

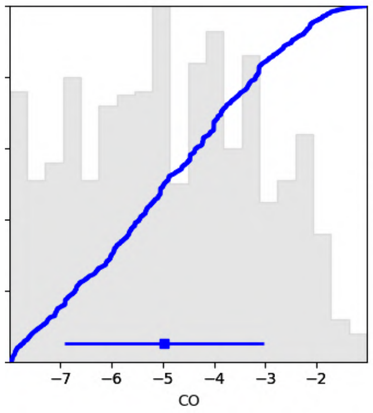
SPIRou

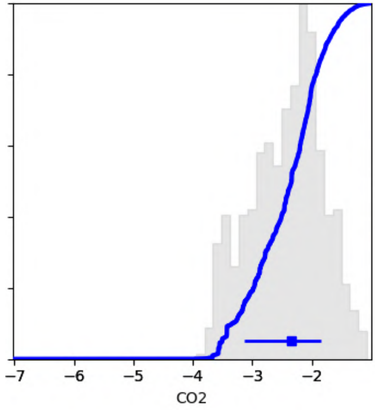
HST + Spitzer

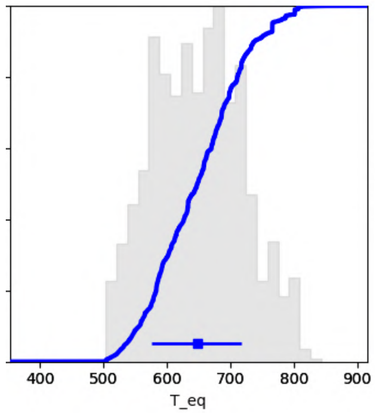
SPIRou + HST + Spitzer

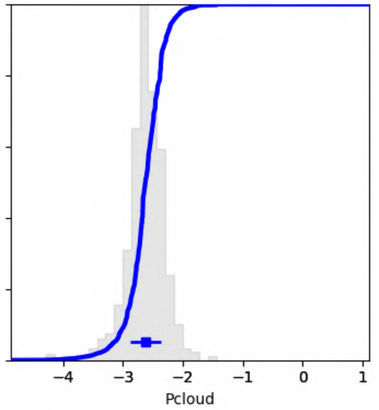
(Boucher et al. 2023)









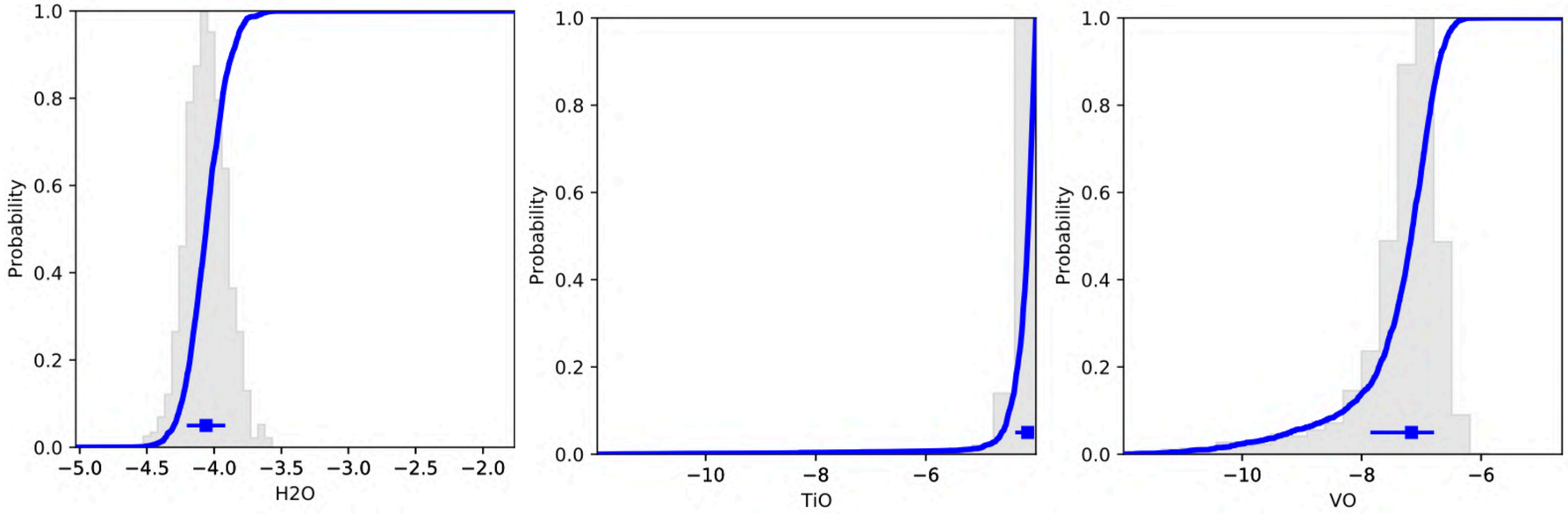


SPIRou + HST + Spitzer

(ATMOSPHERIX)

WASP-76 b:

- HST data: Tsiaras et al. 2018, Fisher & Heng 2018
- SPIRou data: Hood et al. submitted



Perspectives

- Improve joint likelihood calculation
- Implement more complex profiles for chemical abundances and temperature
- Apply to other exoplanets
- Extend wavelength coverage of data sets

Thank You

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(Currently searching for a post-doc)