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Supervised Machine Learning for Exoplanet Atmospheric Retrieval

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27/01/2020, AMLD

Our Collaboration

Medical Imaging

Pablo Marquez-Neila

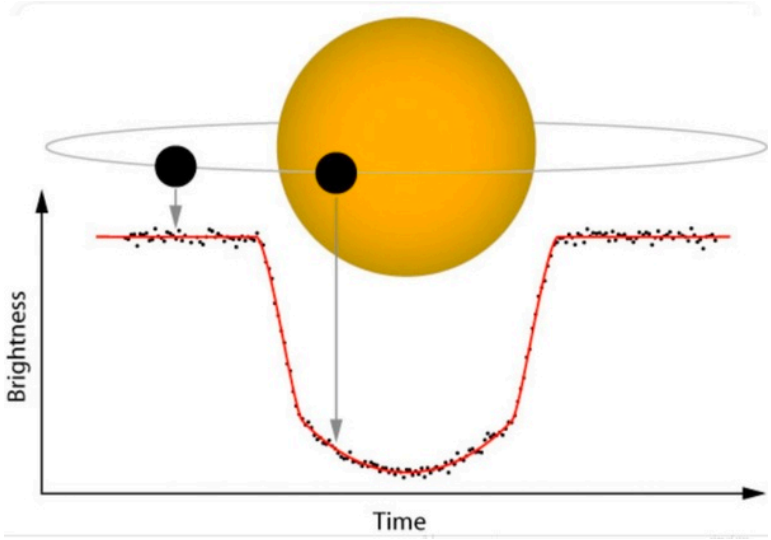
Raphael Sznitman

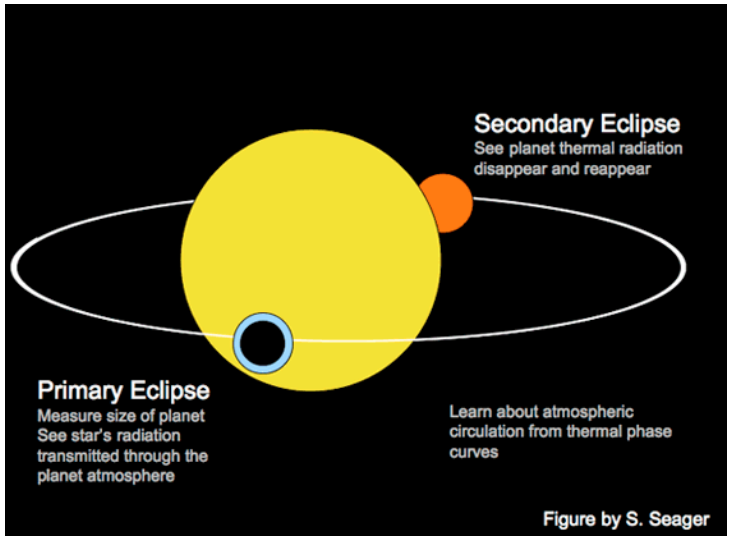
Astrophysics

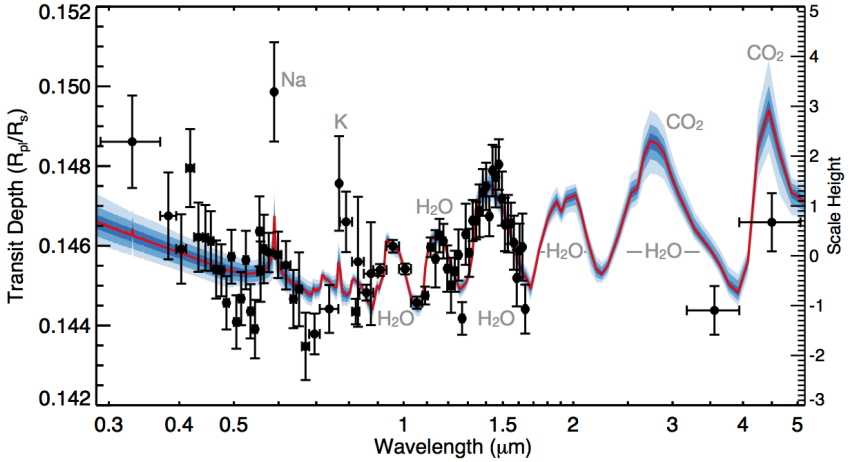
Chloe Fisher

Kevin Heng

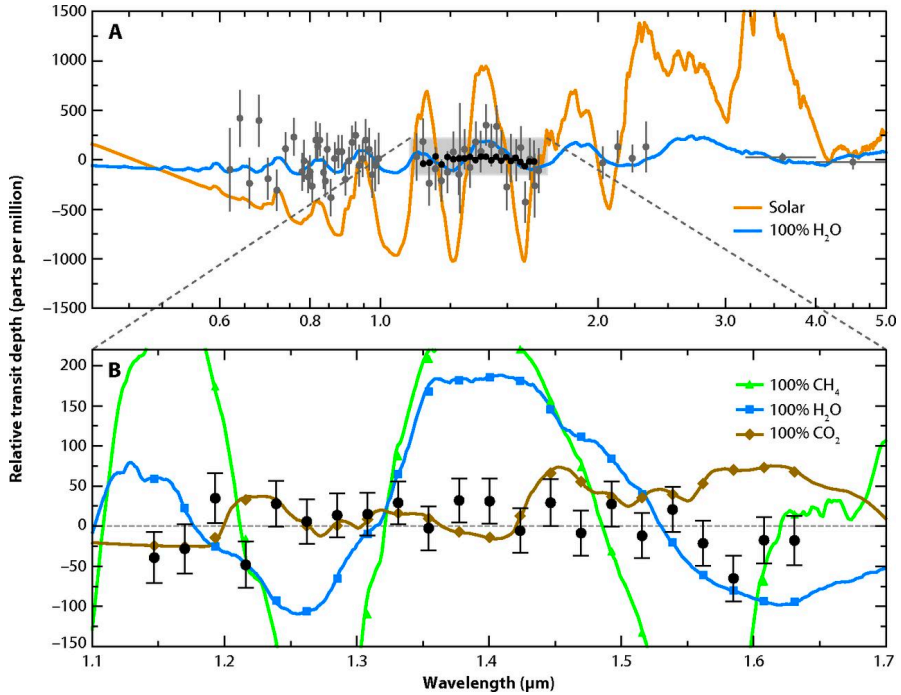
Intro to Transmission Spectra







Wakeford et al. 2017



Kreidberg et al. 2014

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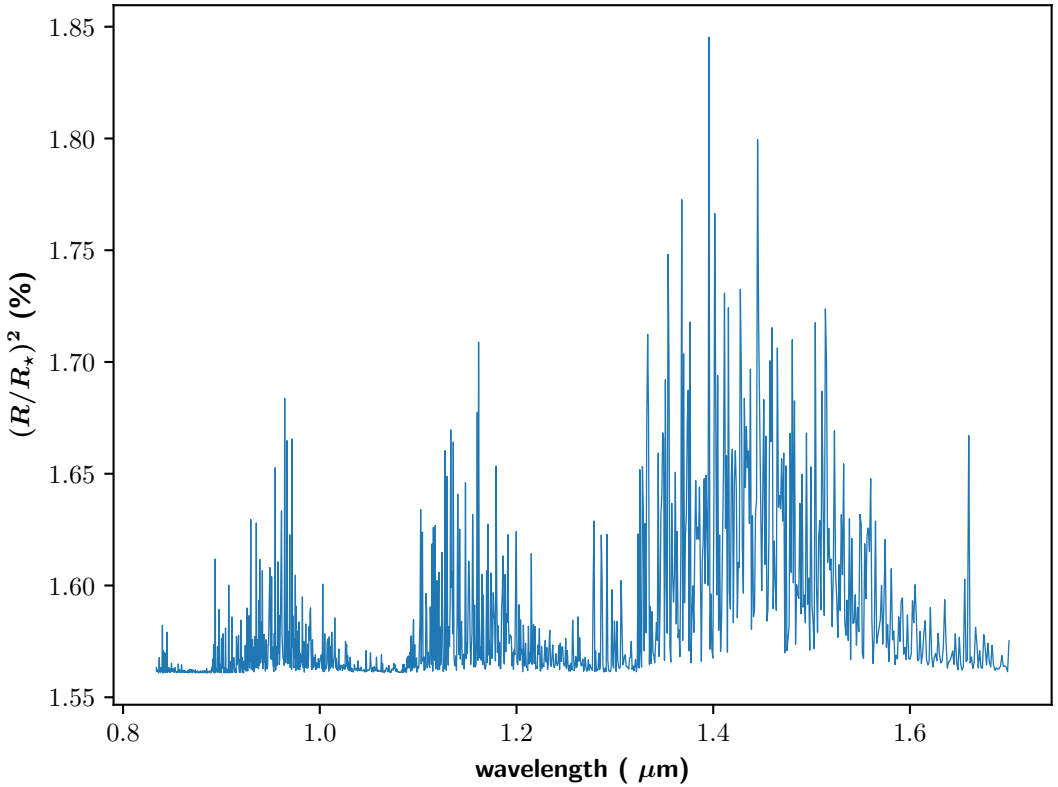
Analytical Model

$$R = R_0 + H\left[\gamma + \ln\left(\frac{\kappa P_0}{g}\sqrt{\frac{2\pi R_0}{H}}\right)\right]$$

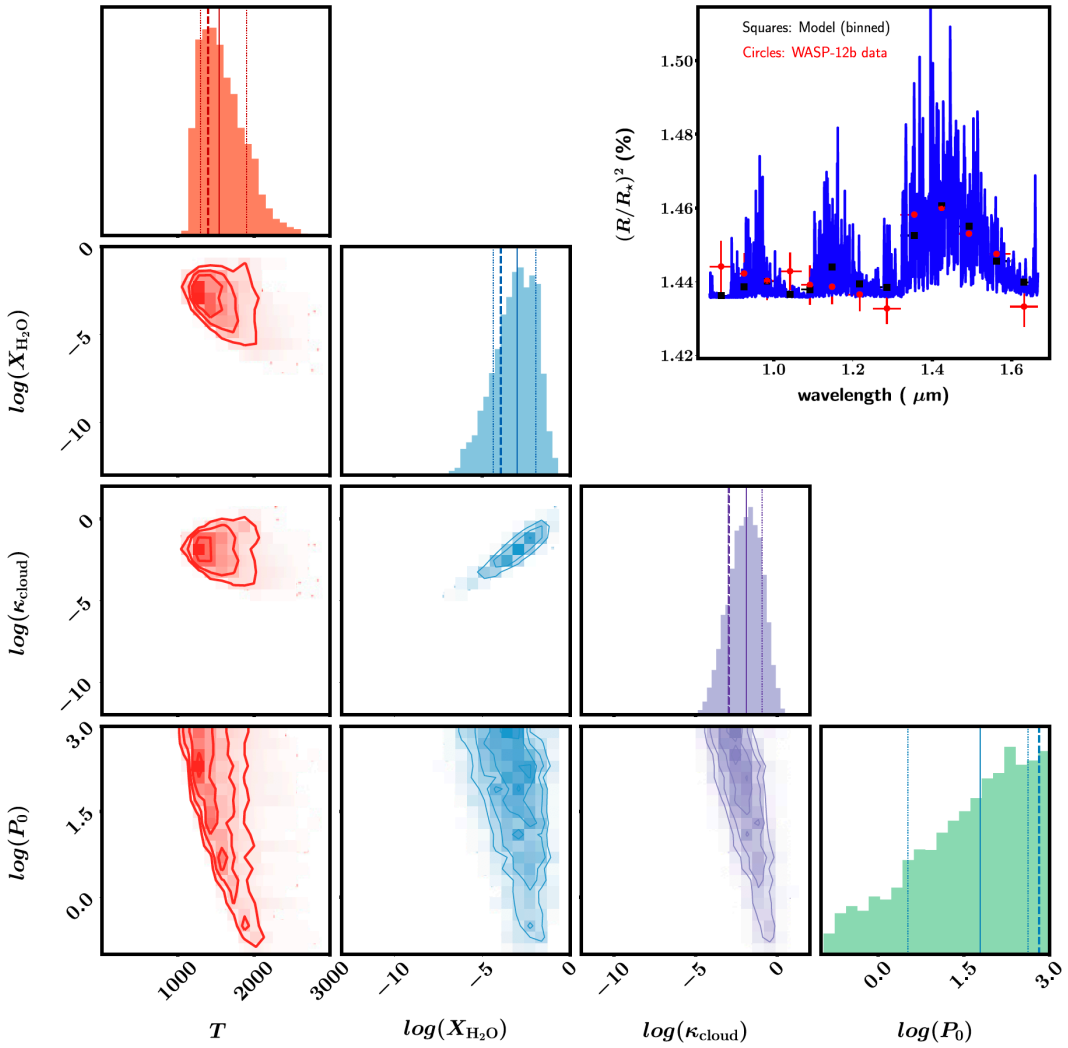
Heng & Kitzmann (2017)

- General shape caused by opacities in κ.
- Inputs: Temperature, abundance of molecules, clouds…



Traditional Atmospheric Retrieval

- Nested-Sampling/MCMC searches parameter space for best fitting model.
- Produces Bayesian posteriors.
- Requires analytical model to be run on the fly.
- A single retrieval is slow.

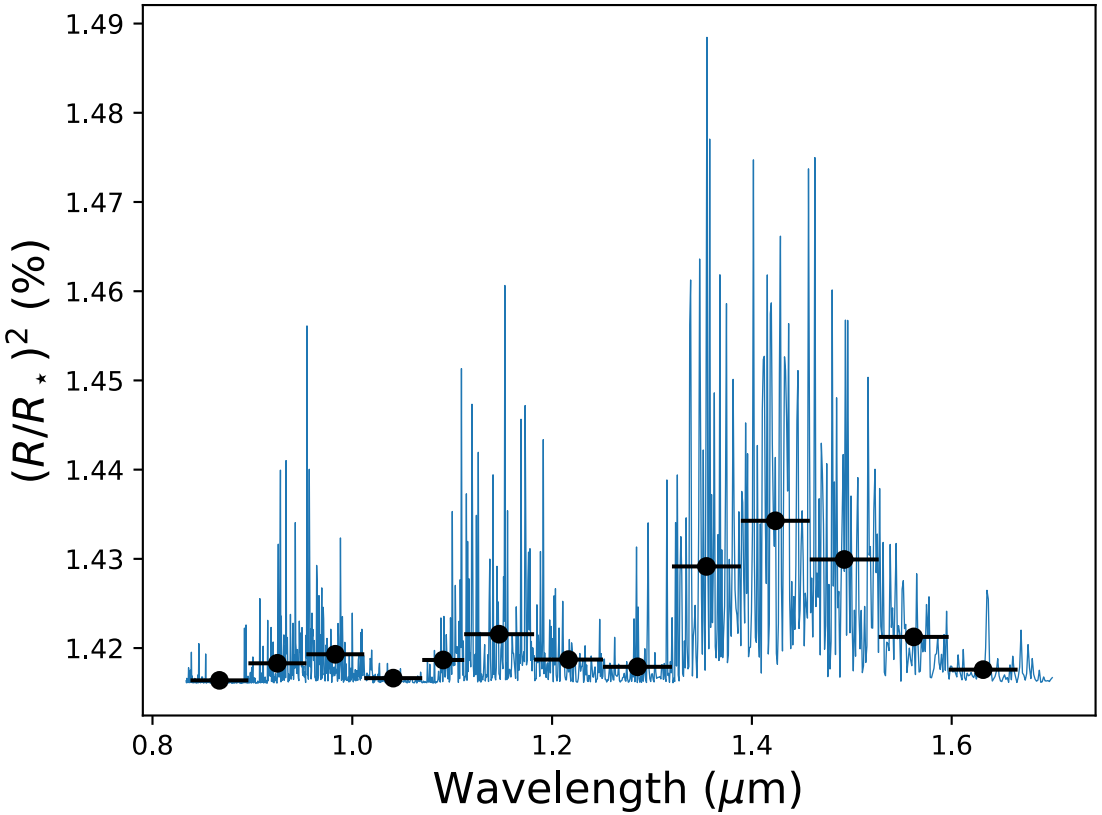


HELA

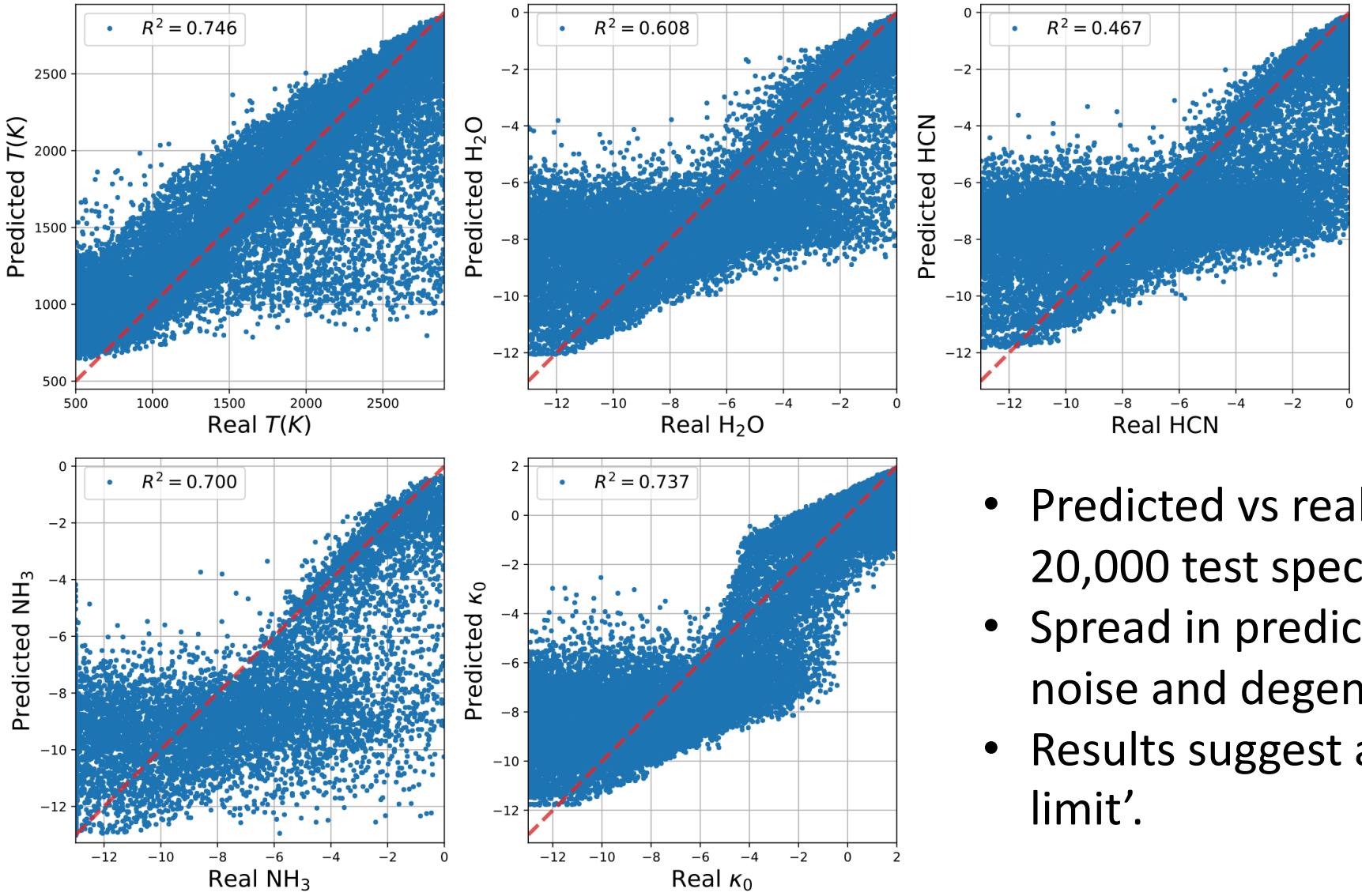
- HELA – an open source **random forest** algorithm for analyzing exoplanet spectra.
- https://github.com/exoclime/HELA
- Marquez-Neila, Fisher, Sznitman & Heng (2018, Nature Astronomy Letters)

Training Data

- 100,000 models, binned to HST WFC3 resolution
- 5 parameters: temperature, three molecular abundances, grey cloud
- Gaussian noise added
- Trained on 80,000 spectra.
- Tested on 20,000.



Predictions



- Predicted vs real computed for 20,000 test spectra.
- Spread in predictions indicate noise and degeneracies.
- Results suggest a ‘detectability limit’.

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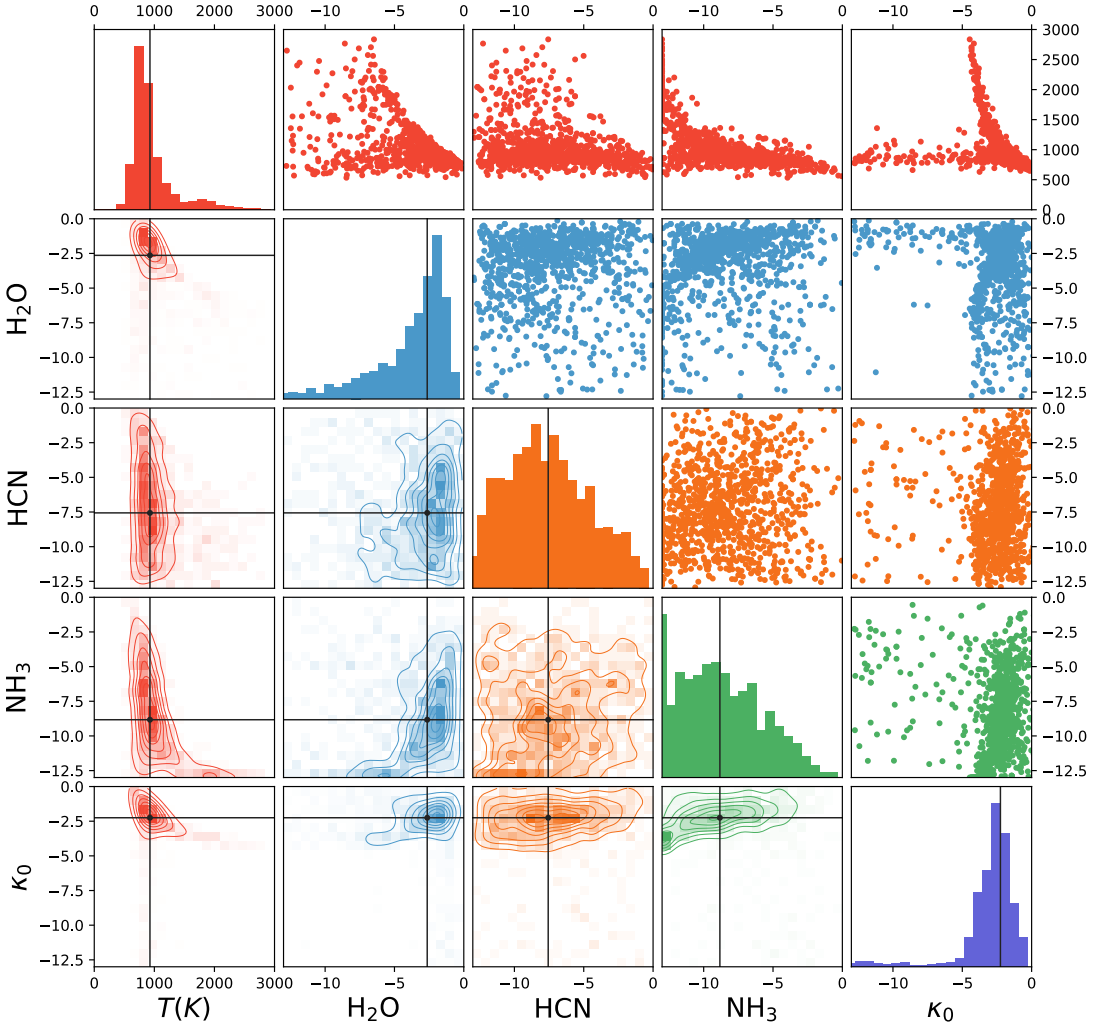
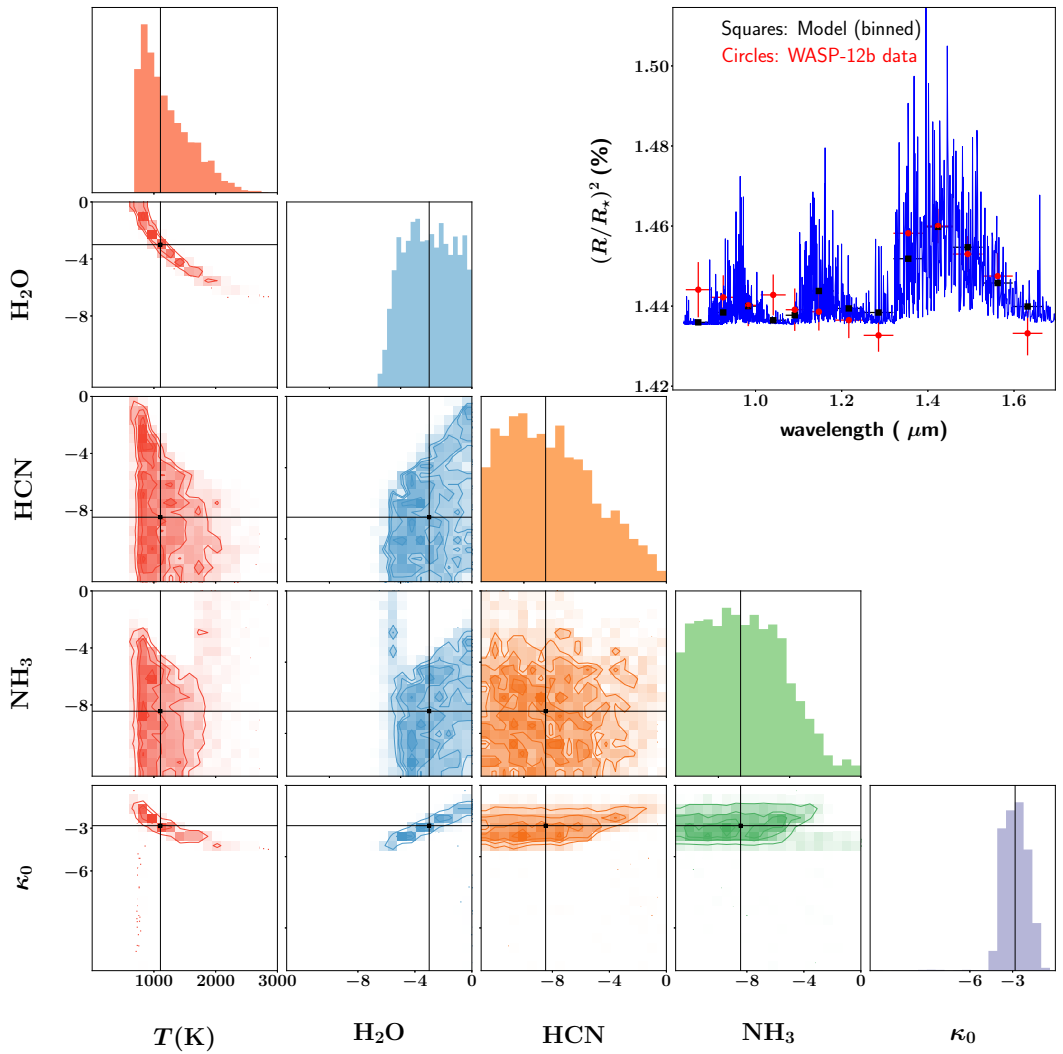
Marquez-Neila, Fisher, Sznitman & Heng (2018, Nature Astronomy Letters)

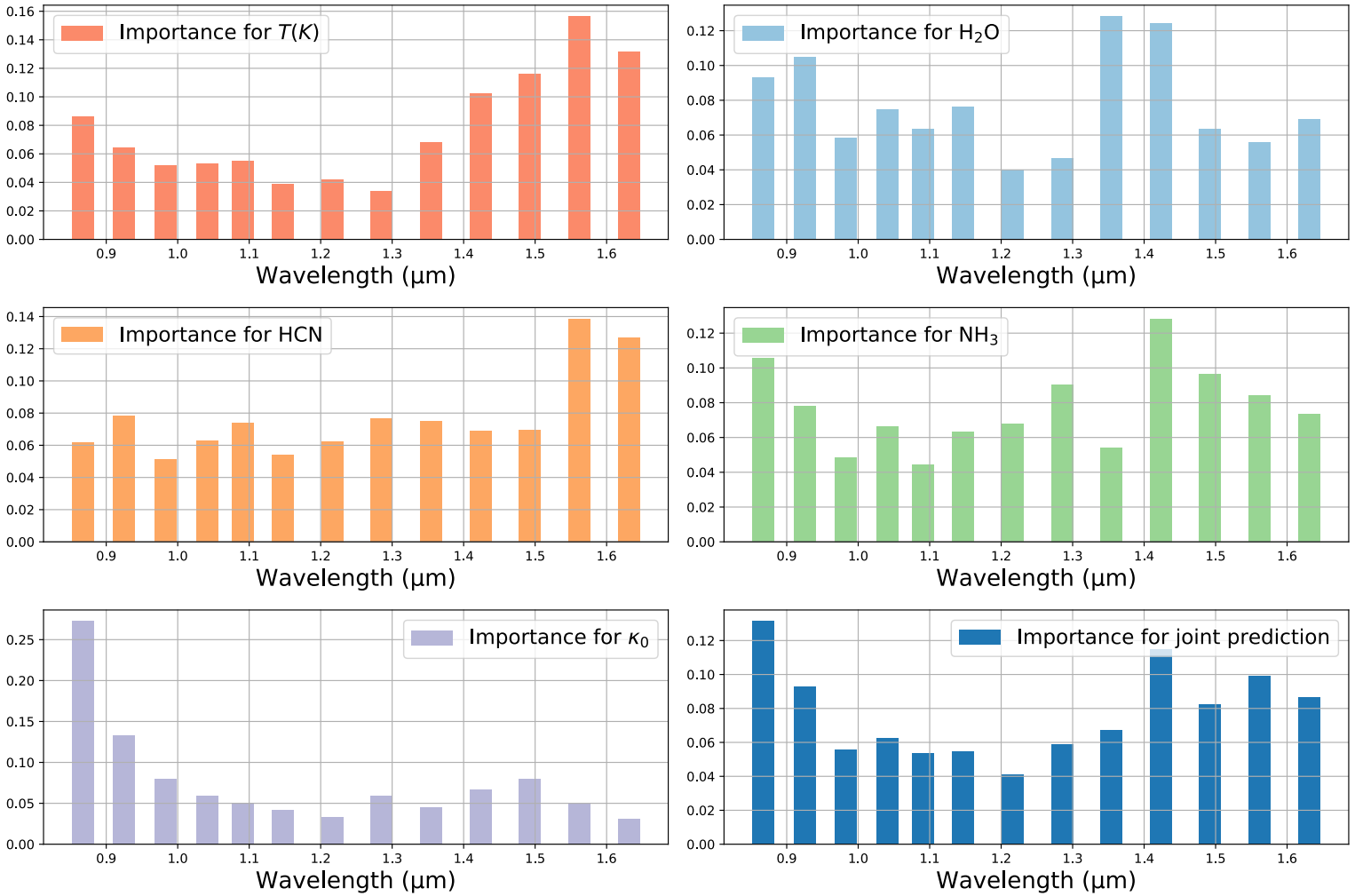
Random Forest vs Nested Sampling





Marquez-Neila, Fisher, Sznitman & Heng (2018, Nature Astronomy Letters)

Feature Importance

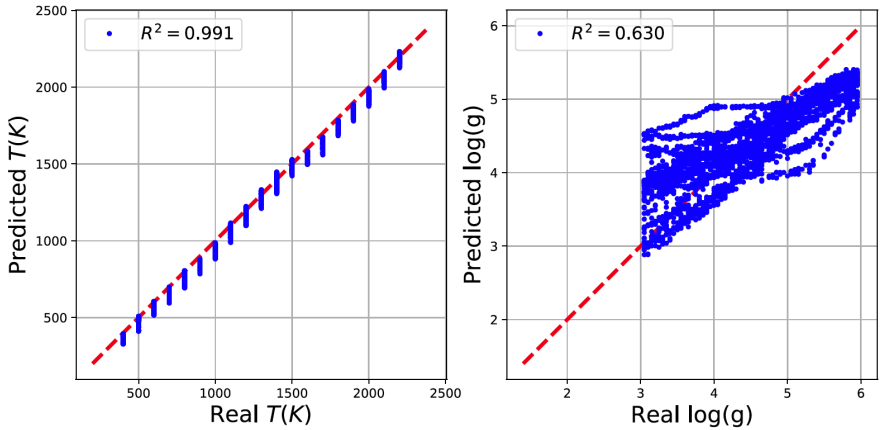


Marquez-Neila, Fisher, Sznitman & Heng (2018, Nature Astronomy Letters)

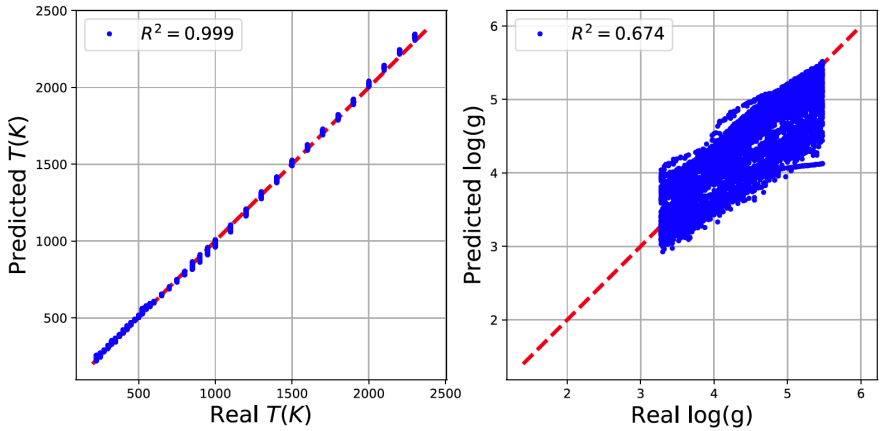
- Quantifies the information content of the wavebands.
- Goes beyond physical intuition.
- Could be used when applying for telescope time, or even when proposing new telescopes.

Other Applications

- Model grid comparison for Brown Dwarfs – Oreshenko et al. 2020
- High-resolution retrievals – Fisher et al., in review (on arxiv already)
- JWST information content analysis – Guzmán Mesa et al., in review



(b) Tested on `AMES-cond`, spectrum cut below 1.2 μm



(d) Tested on `Sonora`, spectrum cut below 1.2 μm

Oreshenko et al. (2020, AJ)

Conclusions

- Open source random forest algorithm “HELA” for retrieval on exoplanet atmospheres.
- Good posterior comparison with nested-sampling.
- Provides ability to test parameter prediction.
- Fast retrievals can give statistics in the future.
- Produces feature importance plots for information content analysis.
- Used so far on low-, mid- and high-res data, and to compare model grids.

🔗 https://cefisher.github.io/ @cfisher94