Atmospheric constraint of a close terrestrial exoplanet

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Introduction

Rocky terrestrial planets are frequently found orbiting GKM stars, yet their atmospheric properties remain largely unknown due to their diminutive sizes. However, exoplanets around nearby M dwarfs offer the most favorable samples for follow-up characterization. This is primarily due to their relatively brighter host stars, smaller stellar radii, and consequently, a higher transmission signal. Nonetheless, technically, it remains extremely challenging, and as of now, only very limited ground-based observations have been conducted on terrestrial planets around M dwarfs.

Why GJ 486b?

GJ 486b is the nearest transiting Earth-like planet around an M-type red dwarf, with a measured mass. Its remarkable characteristics include a brief orbital period of just 1.5 days and an elevated equilibrium temperature of 700K. It exhibits a robust transmission signal, outshining all terrestrial planets with a Transmission Spectroscopy Metric (TSM) value of 36 (Figure 1). The host star's minimal stellar activity, featuring faint Ca II H&K emission and a weak magnetic field further enhance GJ 486 b's standing as a prime candidate for atmospheric detection.

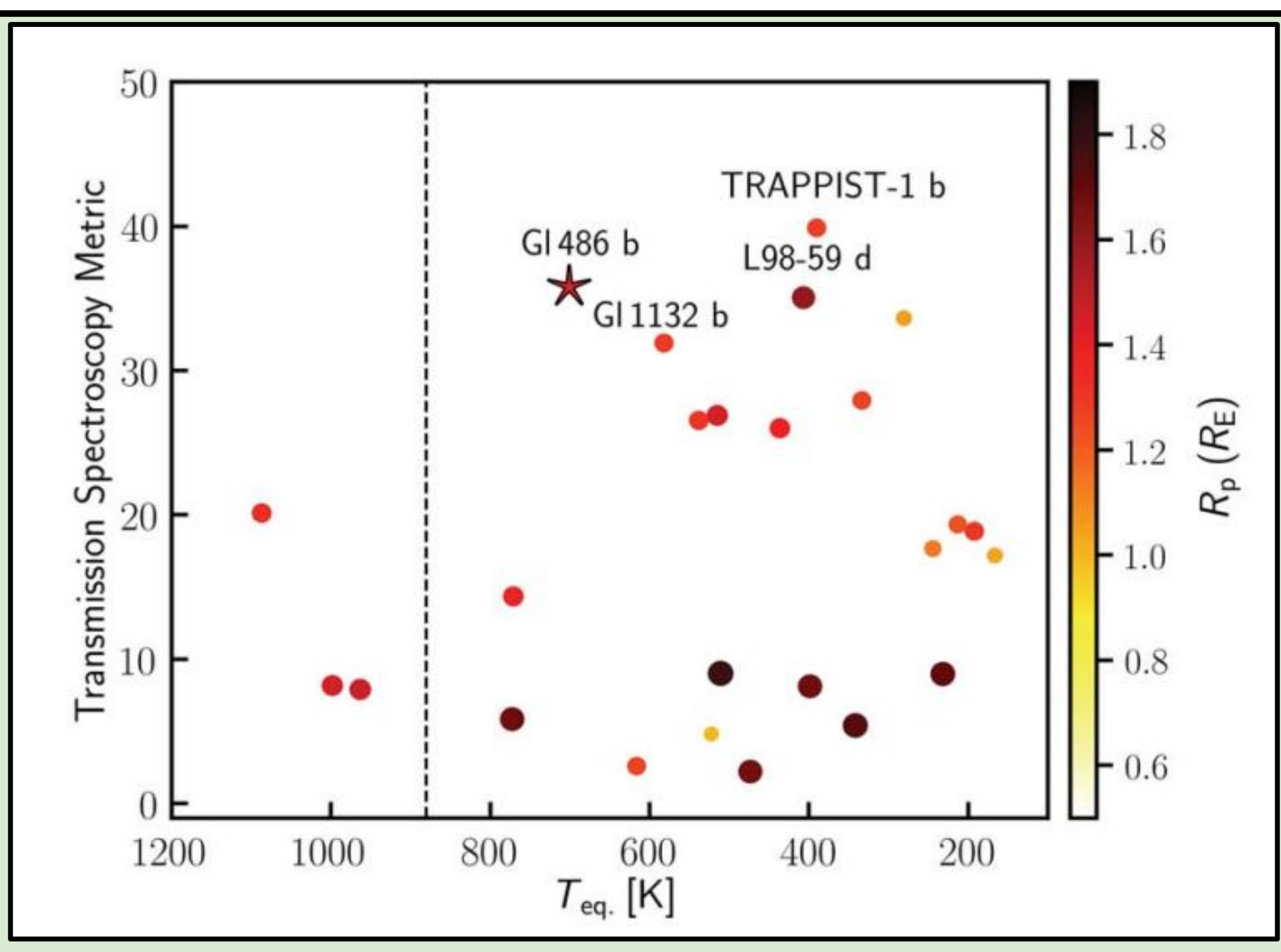

Figure 1. The transmission spectroscopy metric (computed homogeneously with a scale factor 0.190) as a function of T_{eq}.

Motivation

- The work was aimed towards reducing CR2RES raw data through the EsoRex pipeline.
- The work focused to comprehend molecfit, a telluric correction pipeline for transmission spectroscopy data related to exoplanets.

Observations and telluric correction

- GJ 486 b was observed during one of its transits by the CRIRES+ instrument, a high resolution cross dispersed spectroscope at the Very Large Telescope(VLT).
- CRIRES+ observed across the near infrared region, where it is contaminated largely by water and Methane lines from Earth's atmosphere.
- This led us to Molecfit, the ESO telluric removal tool, to correct for telluric absorption lines based on synthetic modelling of the Earth's atmospheric transmission.
- Running Molecfit, resulted in both under and over corrections (Figure 2), which was due to various reasons, such as wavelength misalignment (Figure 3) and bad pixels.

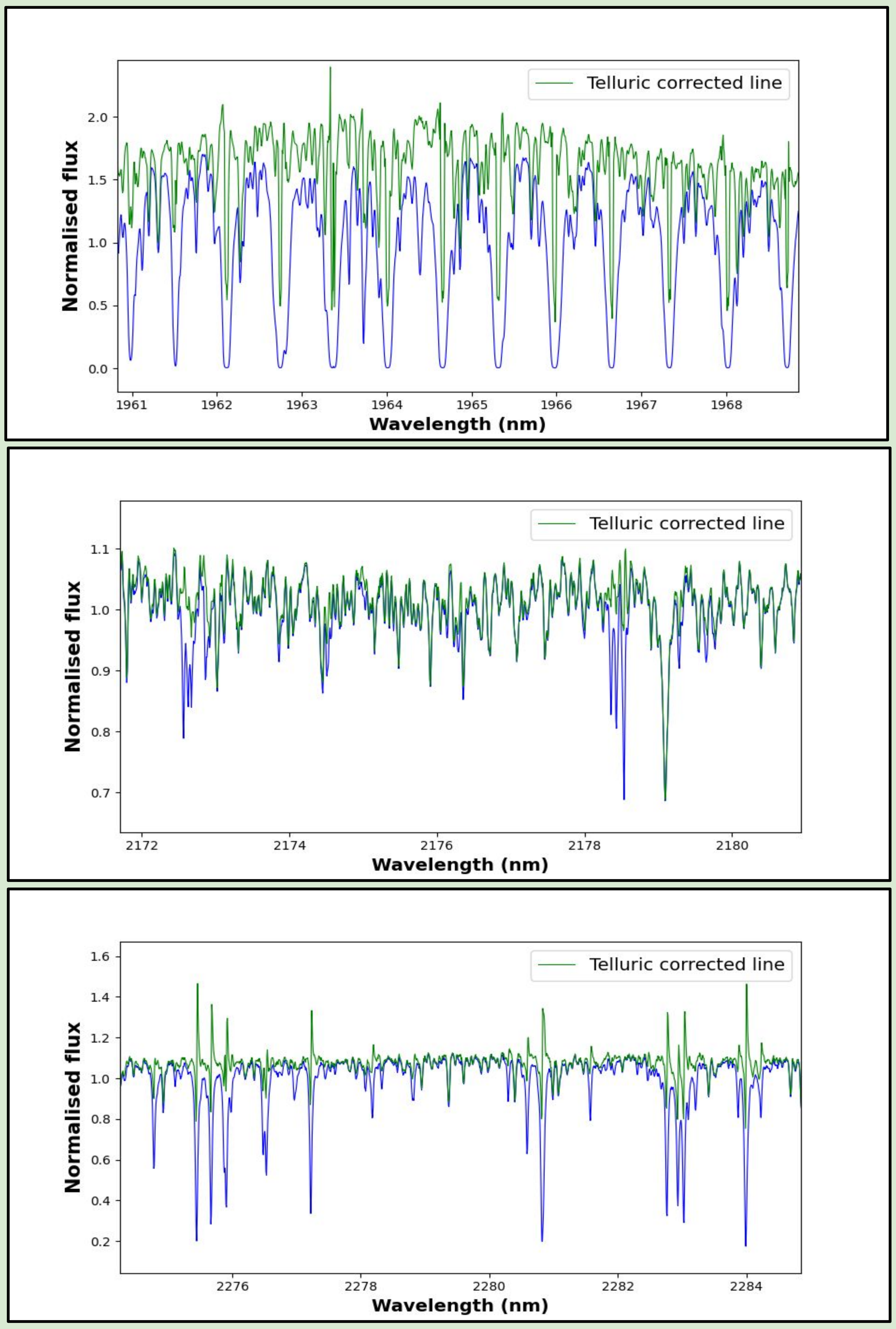

Figure 2. Selected spectra before and after Molecfit telluric correction.

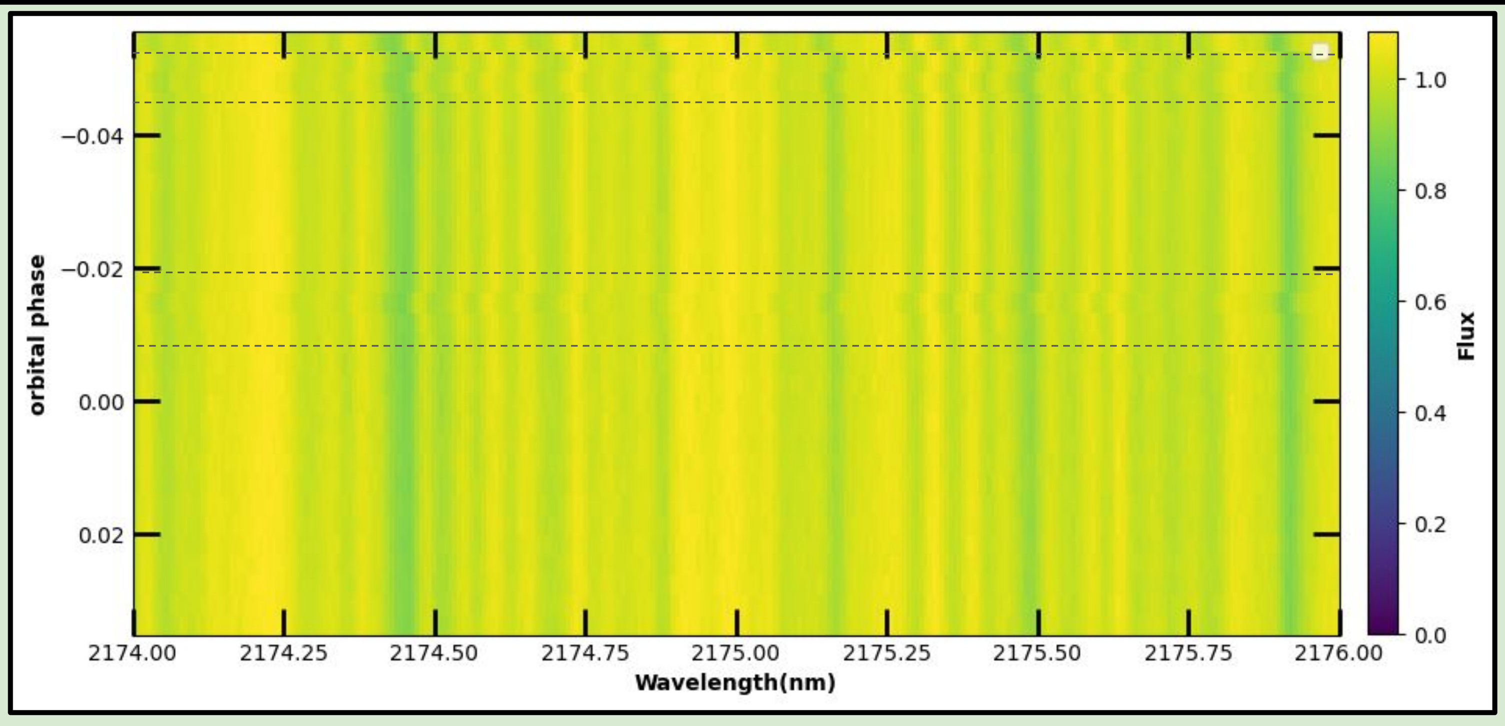

Figure 3. The wiggles in between the dotted lines indicate a few wavelength misalignments during observation.

Results and Future works

- Molecfit provided us with a good telluric correction after normalising the data.
- While executing Molecfit, certain improvements were made by excluding boundary pixels and addressing some bad pixels. However, there is still room for further enhancements.
- Along with Molecfit, Principal component analysis (PCA), can be used for a more precise telluric correction.
- The corrections from Molecfit and PCA can be compared and it is also possible to experiment with a combination of both approaches.

References

- Trifonov et al., Science 371, 1038–1041 (2021)
- J. A. Caballero et al. 2022
- M. C. Maimone et al. 2022

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