TOI-6478b

Scott et al (2025)

Building bridges between cold exo-Neptunes and the Solar System Ice Giants

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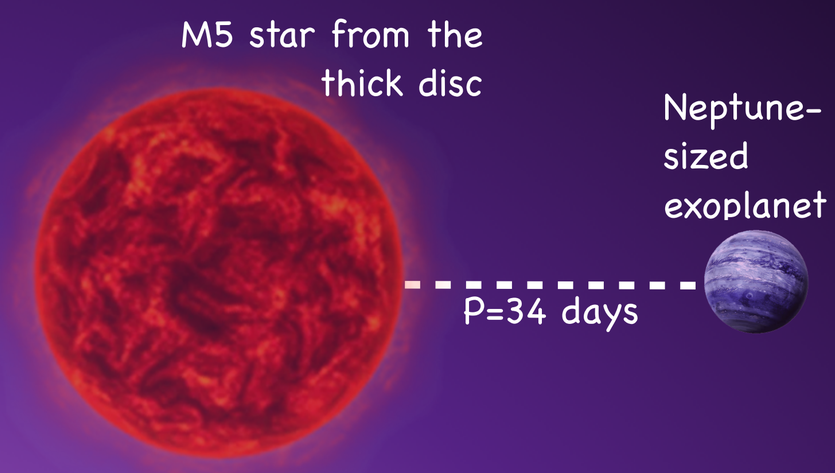
INTRODUCTION

Exoplanets are planets that orbit stars other than the Sun.
Observational biases -> most detected exoplanets are large (e.g. the size of Jupiter) and have short orbital periods (e.g. a year for the planet could be 7 days) => hot/warm planets. Therefore finding cold planets is challenging.
For smaller, cooler stars (M dwarfs-75% of stars in the Milky Way - Chabrier+2003, Henry+2006, Reylé+2021), cooler planets can have relatively shorter orbital periods.

TOI-6478b (Scott+2025) is a cold, Neptune-sized exoplanet that orbits its M dwarf host star on a 34d orbital period. It has an equilibrium temperature of 205K, comparable to Mars, which orbits ~every 2yrs.



METHODS

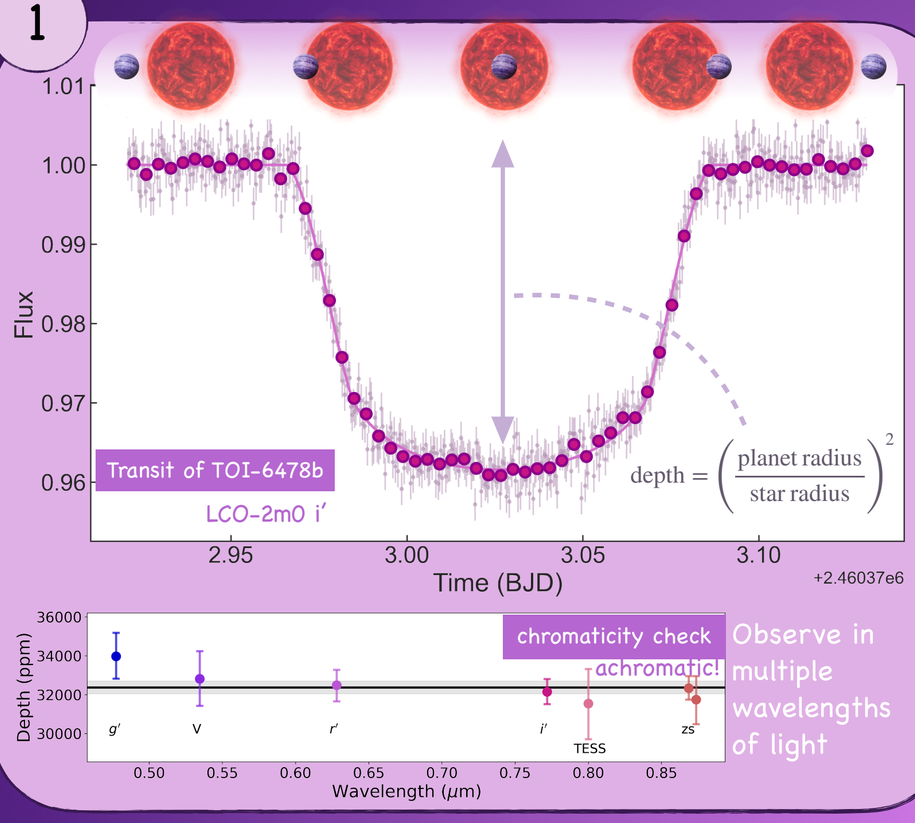
1 Photometry & Transits

When a planet passes in front of its star along our line of sight it causes a dip in the observed light from the star. From the depth of this transit, we obtain the planet's radius. Transits are observed in different colours to ensure consistent depths across wavelengths.

2 Spectra & Radial Velocities

As the planet and star orbit a common centre of mass, the planet will exert a "pull" on the star, causing it to wobble. This causes the observed spectral lines of the star to be periodically red- and blue-shifted. We can measure this as a velocity, which forms a sine wave across the planet's orbit. From the amplitude of this velocity, we obtain the planet's mass.

1



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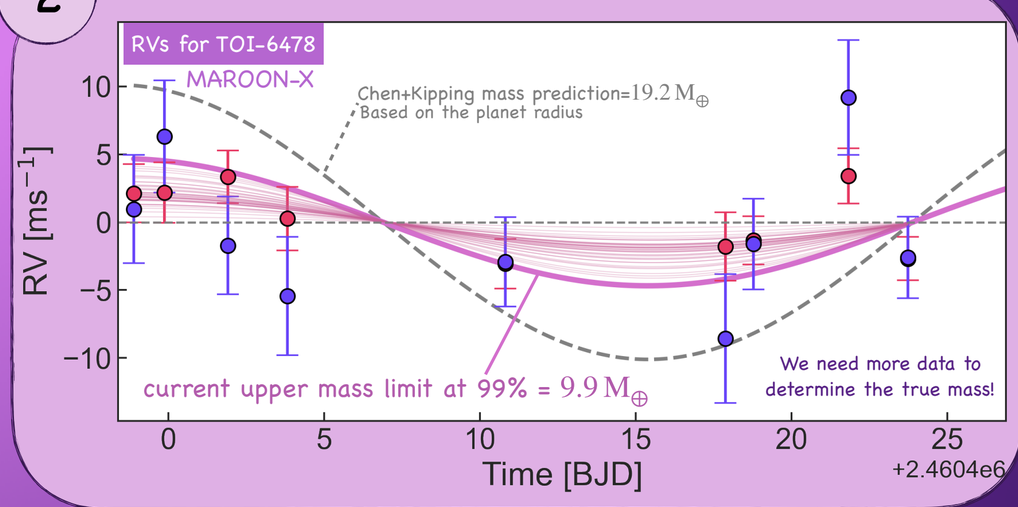


RESULTS

Modelling of both photometric 1 and RV 2 data using the python package allesfitter (Günther&Daylan2019) allows us to find the best fit model (using nested sampling) to the observational data, which we can then use to extract physical parameters of the exoplanet + the system as a whole.

Stellar parameters — from stellar spectra: optical spectroscopy-Shane/Kast (Miller&Stone1994)

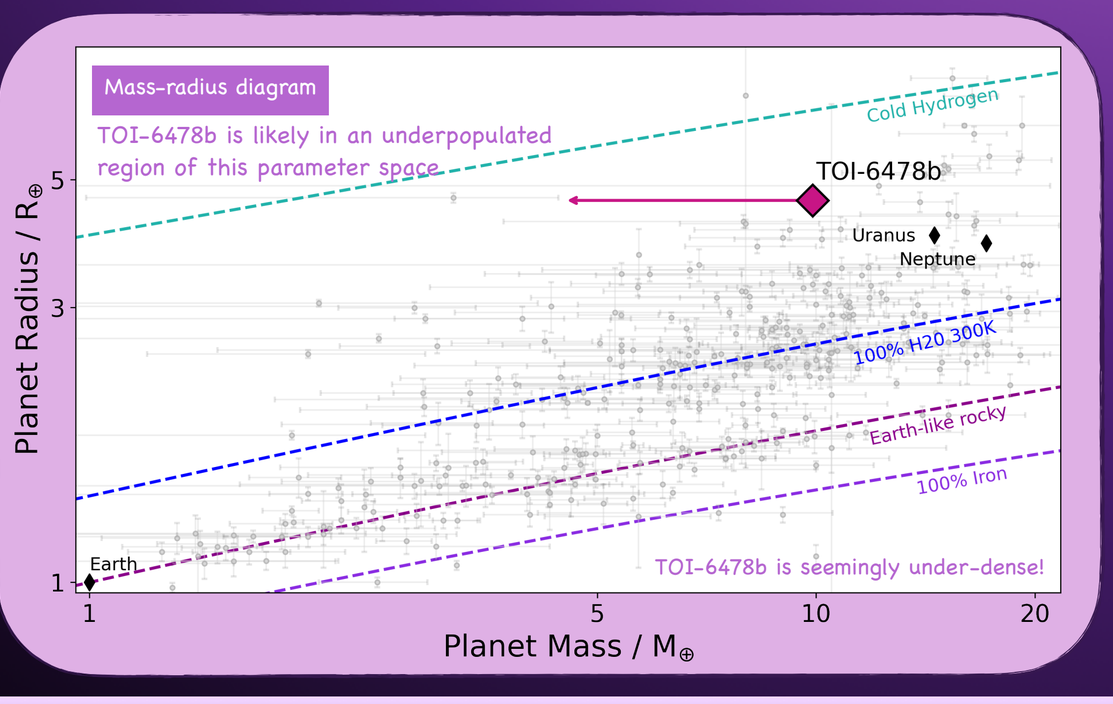
Radius / $R_\odot$	Mass / $M_\odot$	Teff / K
0.23	0.23	3230

Planet+Orbital parameters — from global modelling

Radius / $R_\oplus$	Mass / $M_\oplus$	Teq / K	Period / d
4.6	≤ 9.9	205	34.005

Comparison to known planets

	TOI-6478b	K2-18b	Mars	Neptune
Period / d	34	33	687	60195
T_{eq} / K	205	284	210	47
R_{planet} / $R_\oplus$	4.6	2.4	0.5	3.8
Semi-major axis / ice line	0.9	0.5	1	20



CONCLUSIONS

- TOI-6478b likely formed beyond the ice line.
- Thanks to its M5 host star, it has a cold temperature (205K) despite a relatively short orbital period of just 34d.
- Its seemingly low density further enhances its transmission signal, permitting detailed atmospheric characterisation with telescopes such as the James Webb Space Telescope.
- TOI-6478b can provide a clear window into the composition and dynamics of a cold, Neptune-like exo-atmosphere.
- TOI-6478b can therefore build a bridge between the cold exo-Neptune population and the Solar System Ice giants, something that up until now has rarely been studied due to observational limitations of typical cold exoplanets.

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