Characterization of sub-Neptune and rocky planets' atmosphere using high resolution NIR spectroscopy

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Introduction

- The atmospheric escape of close-in exoplanets have thought to be driven by the abundant high-energy radiation they receive from the host star.
- The X-rays and EUV stellar radiation at the base of planet's thermosphere leads to hydrodynamic expansion of hydrogen/helium atoms up to altitudes of several planetary radii.
- Ideal spectral types are K-dwarfs and early M-dwarfs.

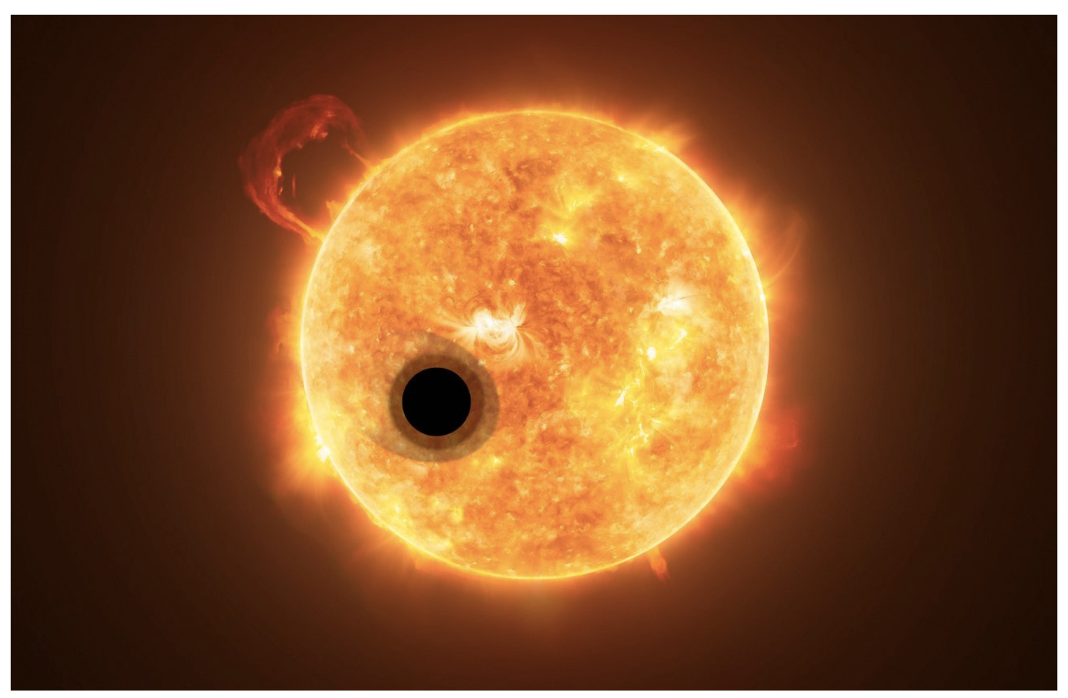


Figure 1: Close in exoplanet with its eroding atmosphere (artistic impression)

Origins of IR Helium line

- The EUV stellar radiation shortward of 50.4 nm will photoionize the neutral He atoms and they will recombine at the upper atmosphere of the planet.
- The recombination cascade is efficient for singlet states, but stops at 2^3S for triplet states which lack a fast radiative decay path to the ground state.

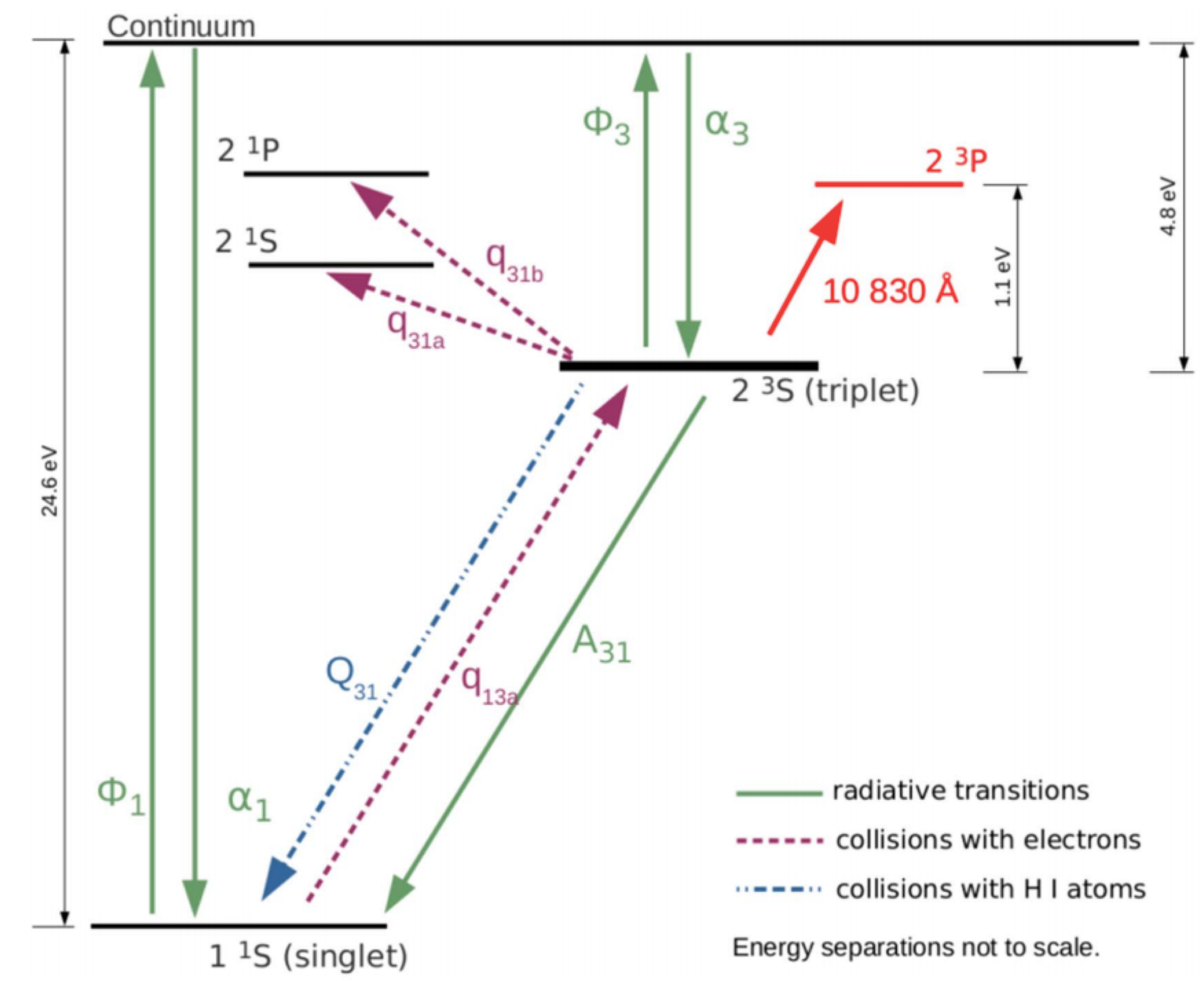
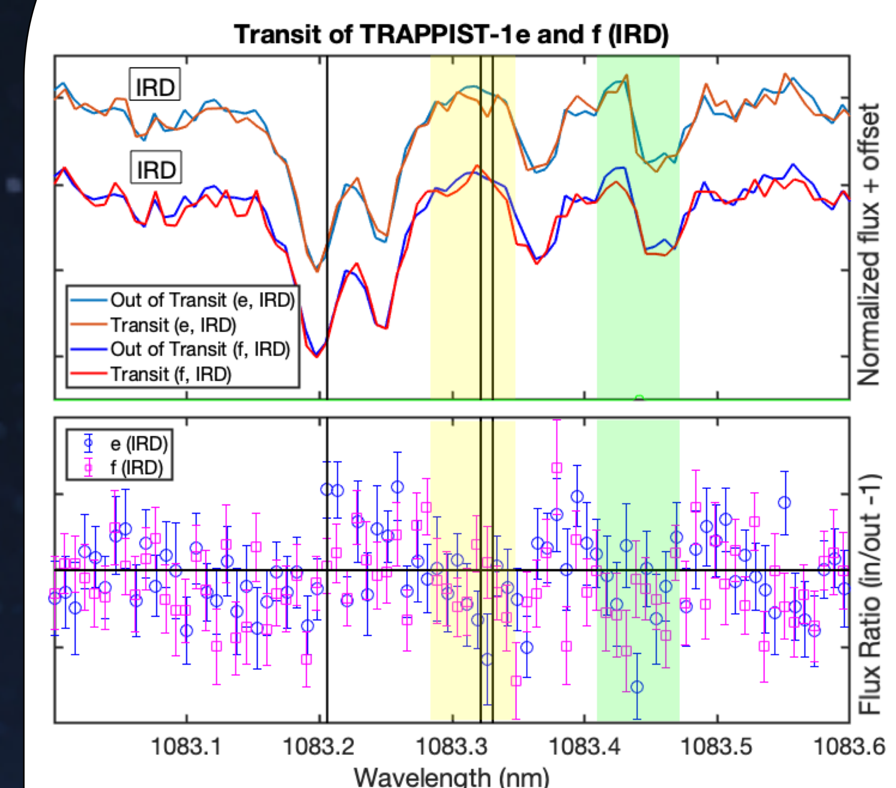


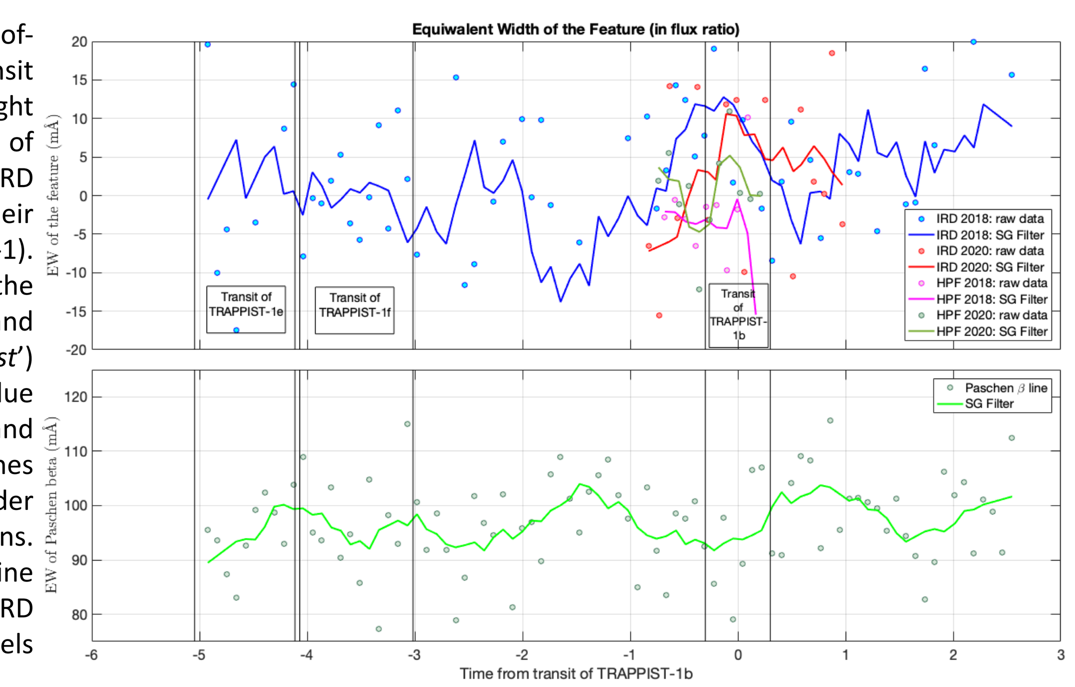
Figure 3: Helium excitation energy diagram (Oklopcic & Hirata, 2018)

TRAPPIST-1e and f



- We estimate an upper limit of 10.458 mÅ and 4.143 mÅ for planet 'e' and 'f' respectively, for any possible planet related absorption at 95% confidence.
- The Pa-β line weakly correlates with the feature, supporting the scenario of planetary absorption.

Figure 5*: **Top left**: in- and out-of-transit spectra during the transit of planet 'e' (orange and light blue) and during the transit of planet 'f' (red and blue) from IRD (Hirano et al. 2020b) and their respective flux ratios (in/out -1). **Bottom right**: Strength of the feature between 1083.285 and 1083.34 nm (*'region of interest'*) vs. time as measured in IRD (blue and red) and HPF (magenta and green) spectra. The solid lines represent 7-point, first-order Savitzky-Golay filtered versions. EW of Hydrogen Paschen beta line as (green) measured in IRD spectra in 2018. Both panels correlates negatively.



* Analysis of archival data from Hirano et al, 2020

Neptunian desert

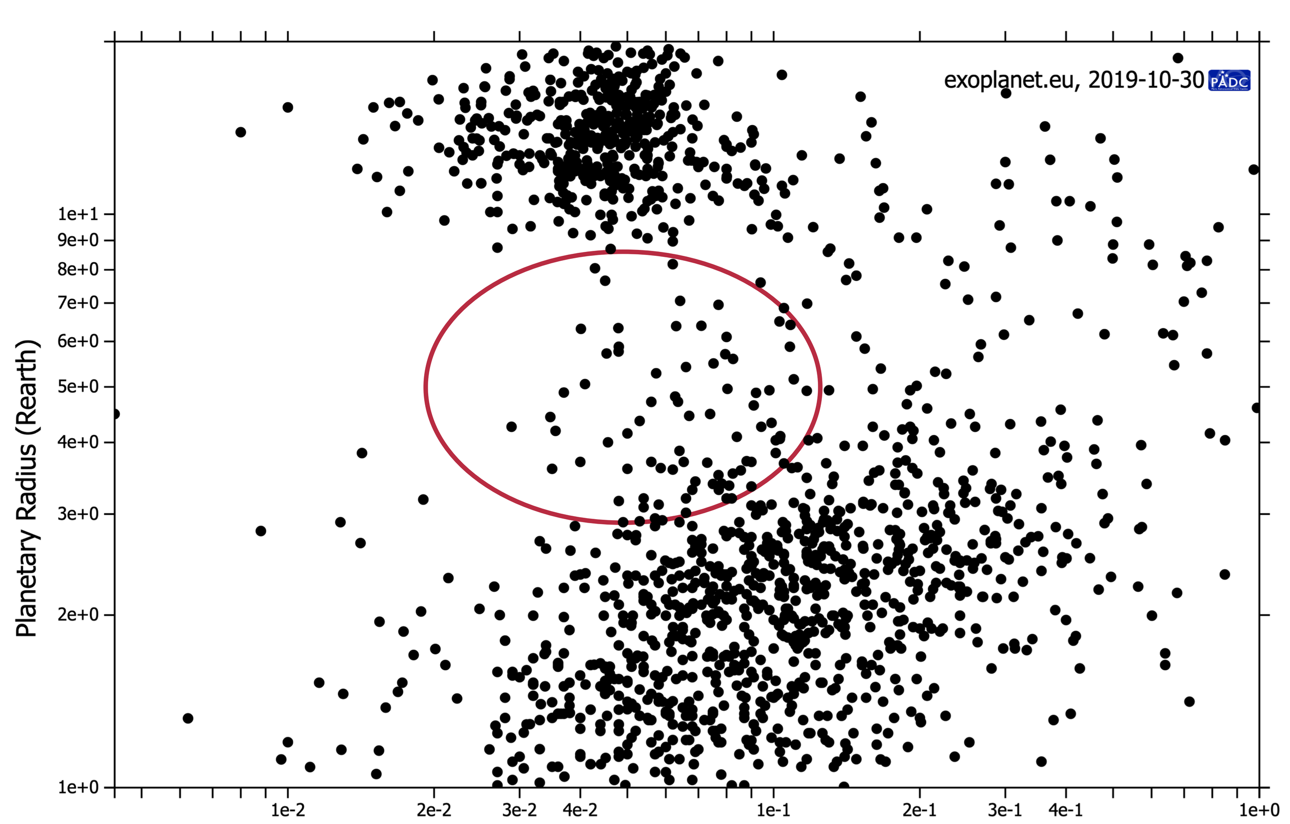


Figure 2: Planet distribution plot of known exoplanets showing the paucity of 'Neptune-sized' planets. Source: exoplanet.eu

- The paucity of planets in the region between hot Jupiters and rocky planets could be caused by the process of photoevaporation.

TRAPPIST-1b

- 4 transits; 2 from Subaru/IRD and 2 from HPF/HET

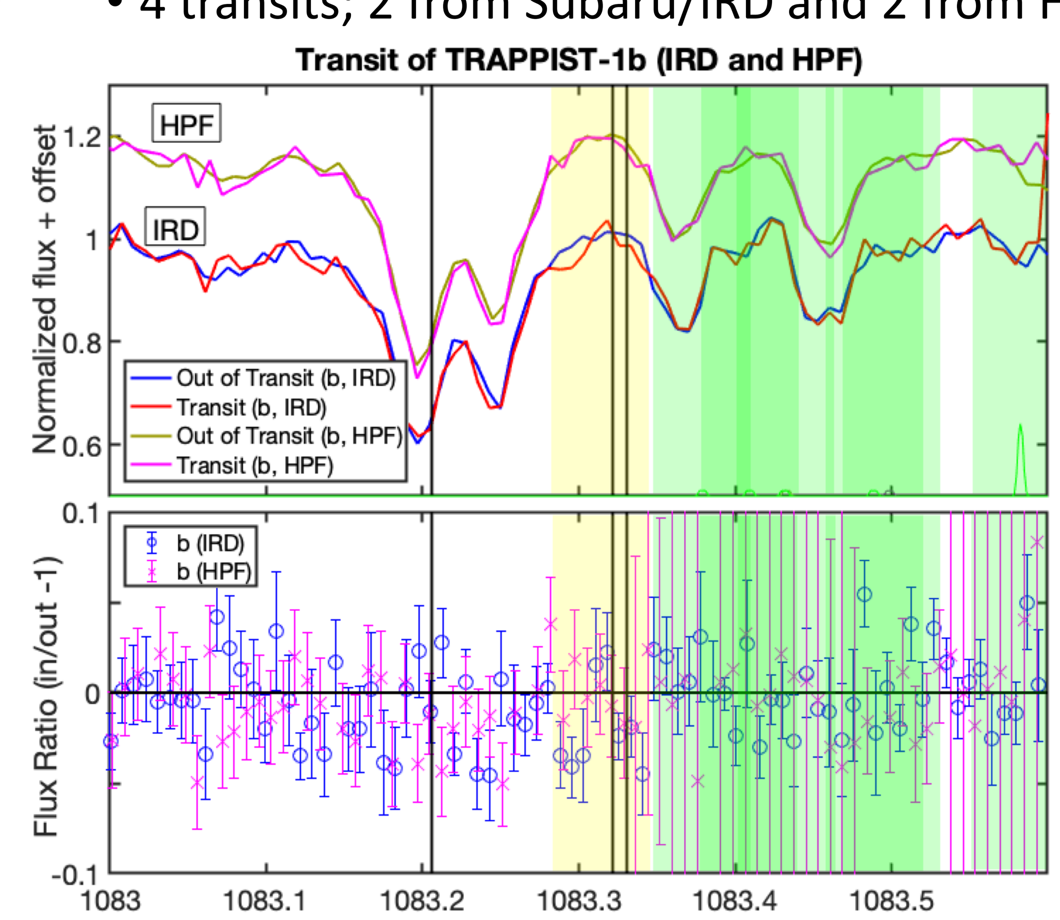


Figure 4#: Transmission spectra of TRAPPIST-1b. **Top**: The in- and out-of-transit spectra of planet 'b' from both IRD (red and blue) and HPF (magenta and light green). The yellow shaded region marks the *'region of interest'* (width: 0.55Å) where we attempt to estimate the upper limit from possible planet-related absorption. Green shaded region correspond to the telluric OH-lines contaminated region. **Bottom**: Their respective flux ratios (in/out -1).

- We estimate an upper limit of 7.754 mA and 3.467 mÅ from IRD and HPF respectively, for any possible planet-related absorption at 95% confidence.

IRD data from S19B-069 (PI: Krishnamurthy), S20A-UH104 (PI: Gaidos) and archival data from Hirano et al, 2020

Conclusion and discussion

- TRAPPIST-1 planets, although are expected to not have any Hydrogen-dominated atmospheres (Hori and Ogihara, 2020), they might still be hanging on to residual Helium which can produce such features.
- The stellar flares with are observed in TRAPPIST-1, can also mimic such features. Hence more observations are essential to characterize the upper atmosphere.

References

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