Probing exosphere of Neptune size planets around M-dwarf using He10830

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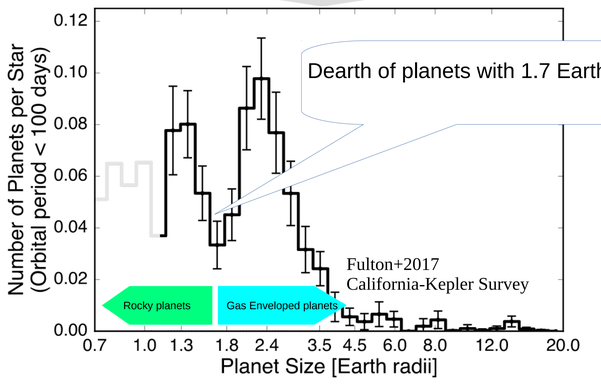
https://ui.adsabs.harvard.edu/abs/2020ApJ...894...97N/abstract

Motivation to study evaporating atmospheres



Could it be due to Photo- evaporation of the atmosphere?

How can we observe evaporating atmosphere?

Ly alpha in Transit observations

Pros:
- Hydrogen is most abundant.
- Very large absorption cross section for neutral hydrogen.

Cons:
- Need space based observation (HST).
- Neutral Hydrogen in Interstellar medium and Geo coronal contamination destroys all information in low velocity (base) of the exosphere.

Image Courtesy: ESO

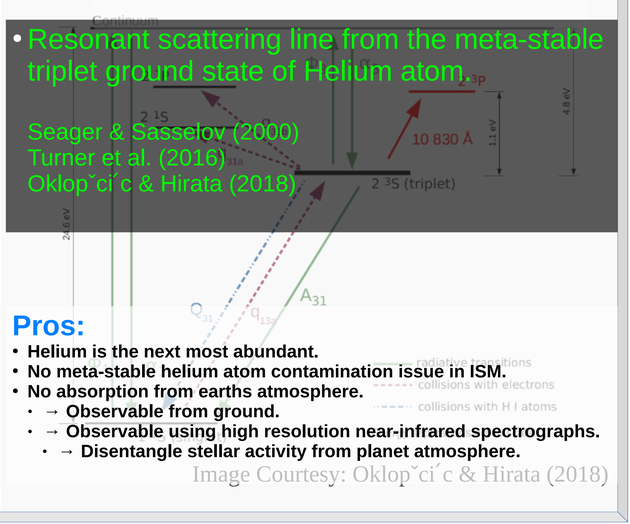
Vidal-Madjar+ 2003, 2004, 2008; Ben-Jaffel 2007; Ehrenreich+ 2008

A new better probe!

He 10830 in Transit observations

- Resonant scattering line from the meta-stable triplet ground state of Helium atom.

Seager & Sasselov (2000)
Turner et al. (2016)
Oklop˘ci´c & Hirata (2018)



Pros:
- Helium is the next most abundant.
- No meta-stable helium atom contamination issue in ISM.
- No absorption from earths atmosphere.
  - → Observable from ground.
  - → Observable using high resolution near-infrared spectrographs.
    - → Disentangle stellar activity from planet atmosphere.

Image Courtesy: Oklop˘ci´c & Hirata (2018)

Search for He10830 in Saturns and Neptunes around M-dwarfs using HPF at HET

Sample of hot/warm gas planets

Mass outflow rate

Temperature

Outflow: Parker wind model

Density field **Velocity field**

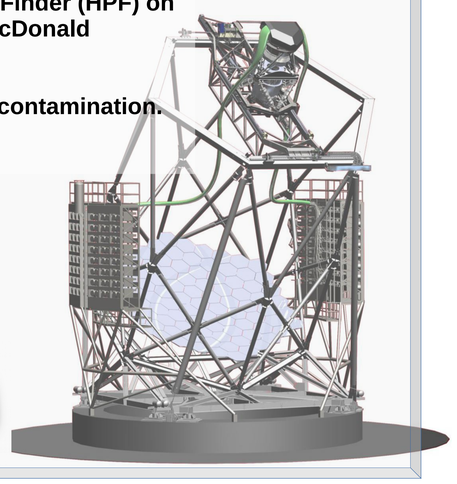
X-ray – EUV – UV Irradiation model spectrum

Integro-differential equation solver

Solves for number density of meta-stable Helium atoms as a function of altitude.

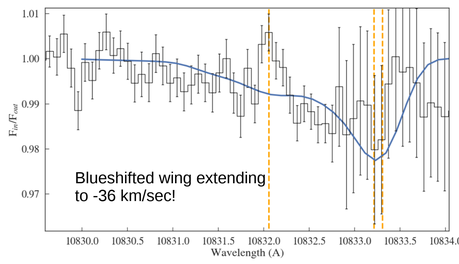
Calculate disc integrated expected absorption line profile strength during transit at 10830A.

Observations:
- Promising candidates are then observed in-tranist and out-of -transit using the Habitable-zone Planet Finder (HPF) on the 10m Hobby Eberly Telescope (HET) , McDonald Observatory, TX, USA
- Observations are panned to avoid Telluric contamination.
- Data reduced using the HPF pipeline



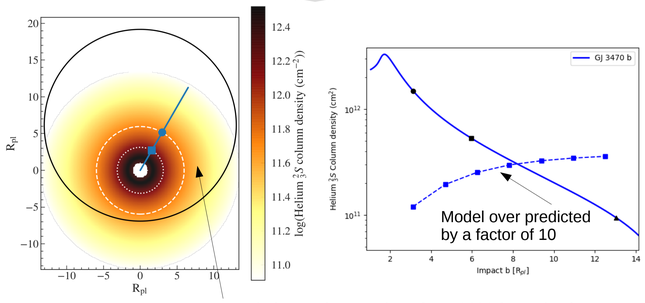
GJ3470b: First† detection of He10830 from a warm Neptune around an M-dwarf star

† An independent study by Pallé+ (2020) also reported detection soon after using CARMENES spectrograph



- Measured column density of metastable Helium = 2.4×10^{10} cm^{-2}

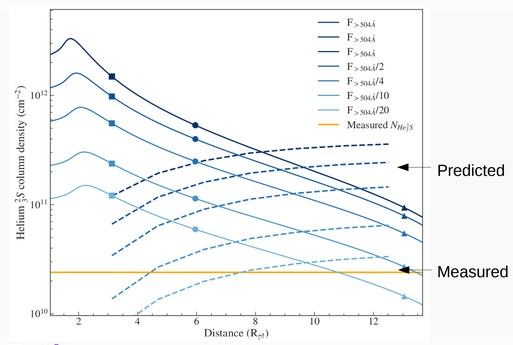
Factor of 10 lower than our model prediction based on Salz+ (2016) outflow and H/He ratio of 10:1



Extended exosphere region of He10830 formation in GJ3470b due to the low gravitational potential.

Possible ways to reconcile:

EUV Radiation:
- Error in empirically derived model predicted EUV irradiation.
  - Both the fraction of meta-stale Helium atoms and the mass outflow rate is proportional to EUV.



He/H Ratio:
- Model assumed a solar Helium abundance ratio of 10% Helium.
- Recent studies suggest the Helium in exospheres could be significantly depleted and can explain a factor of 10 less Helium abundance.
  Hu+ (2015), Shaikhislamov+ (2021), Lampón+ (2021)

3D model vs 1D model:
- Our model was 1D model ignoring many important 3D dynamics physics.
- These He10830 detection are now enabling 3D modeling of the atmosphere evaporation Eg: Shaikhislamov+ (2021)

References:

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Cool Stars 20.5

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