WASP-69b's Escaping Atmosphere Confined to a Tail Extending at Least 7 Planet Radii

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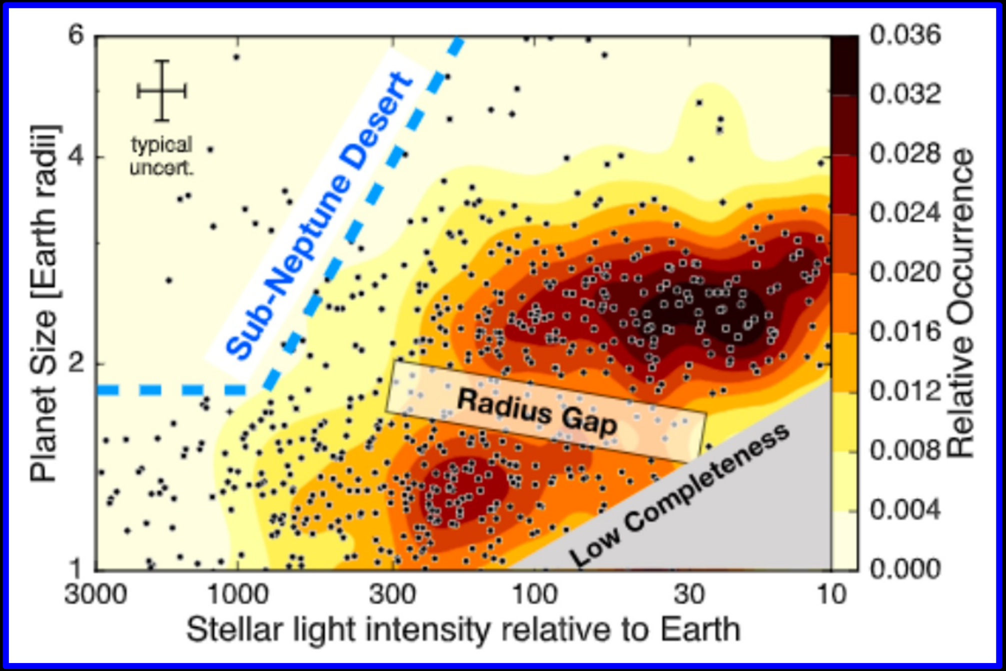
Observational Investigations of Mass-Loss for Close-In Exoplanets

- "Radius Gap" separating super-Earths and sub-Neptunes with few planets in between

- "Hot Neptune Desert" - dearth of sub-Jovians on short orbits

- Clearly mass-loss plays an important role in shaping the distribution of close-in planets

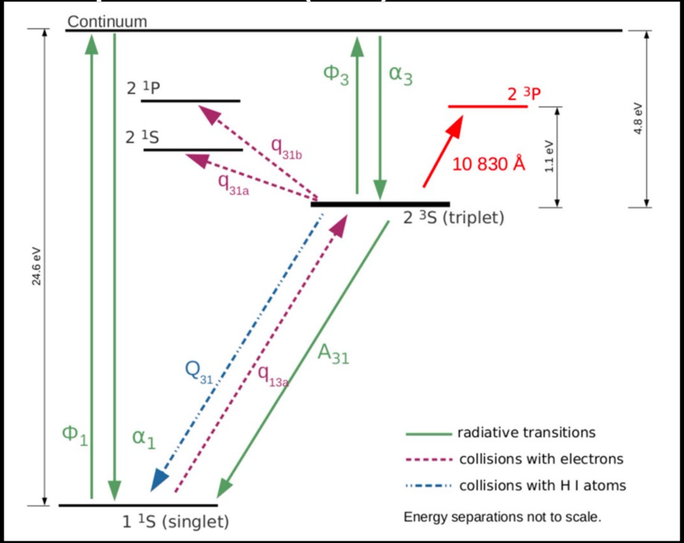
  - Photoevaporation and Core-Cooling are two leading theories



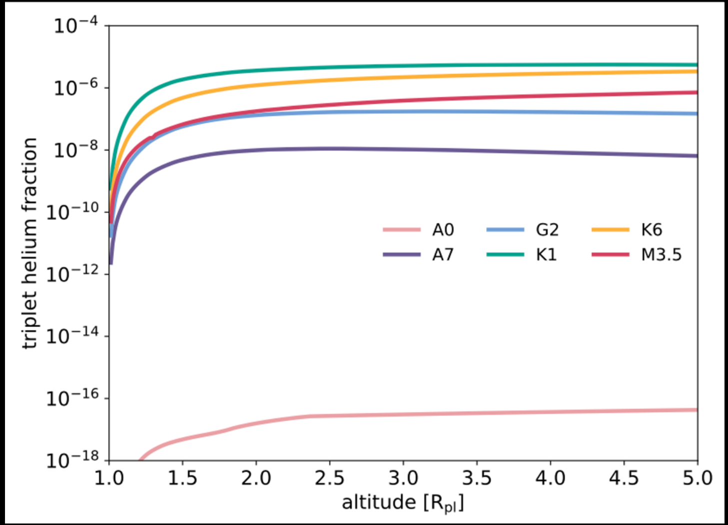
Fulton et al. 2017

Helium 10830 Å as a Mass-Loss Tracer

Oklopcic & Hirata (2018)



Oklopcic (2019)



- Metastable helium (He I 10830 Å) populated by recombination or collisional excitation

- EUV photons (hv = 10–100 eV) populate the 2^3S state, FUV photons (hv = 5–10 eV) ionize and destroy it
- K stars provide the optimal EUV/FUV ratio

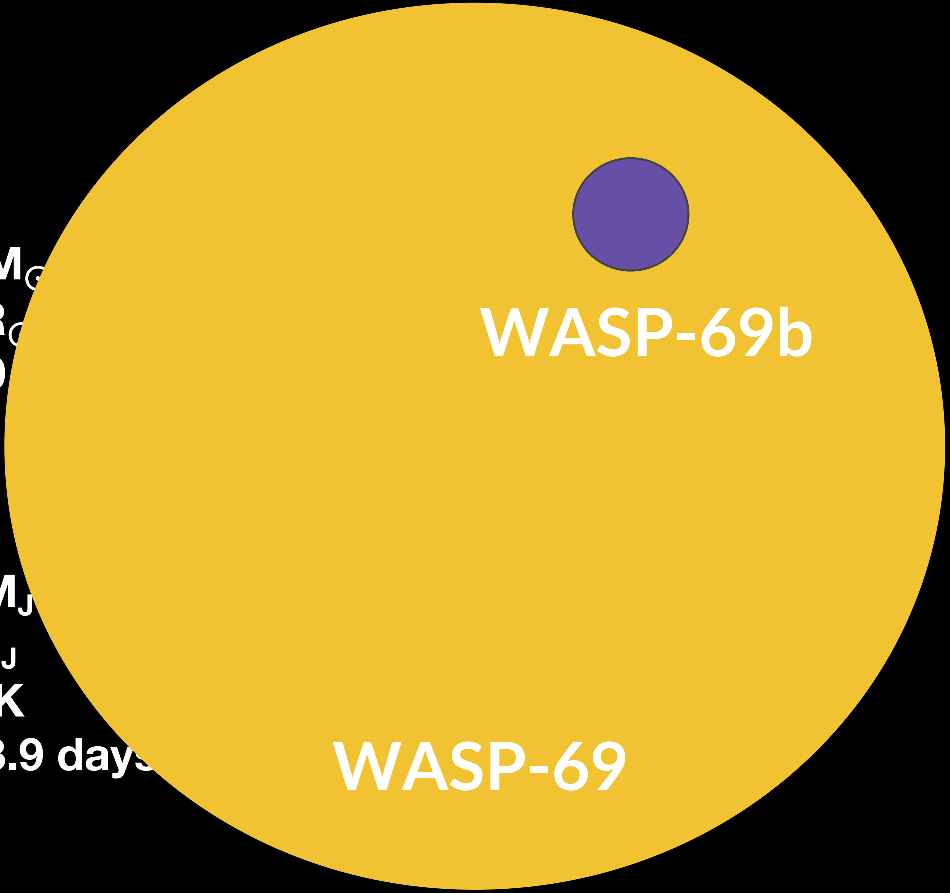
WASP-69 System

WASP-69 (K5-star)

$M_\star = 0.8\ M_\odot$
$R_\star = 0.8\ R_\odot$
T_{eff} = 4800

WASP-69b

$M_P = 0.3\ M_J$
$R_P = 1.1\ R_J$
T_{eq} = 960 K
Period = 3.9 days



Previously observed by:

Nortmann et al. 2018
CARMENES
Calar Alto - 3.5m

This work 2019
NIRSPEC
Keck - 10m

Vissapragada et el. 2020
WIRC
Hale - 5m

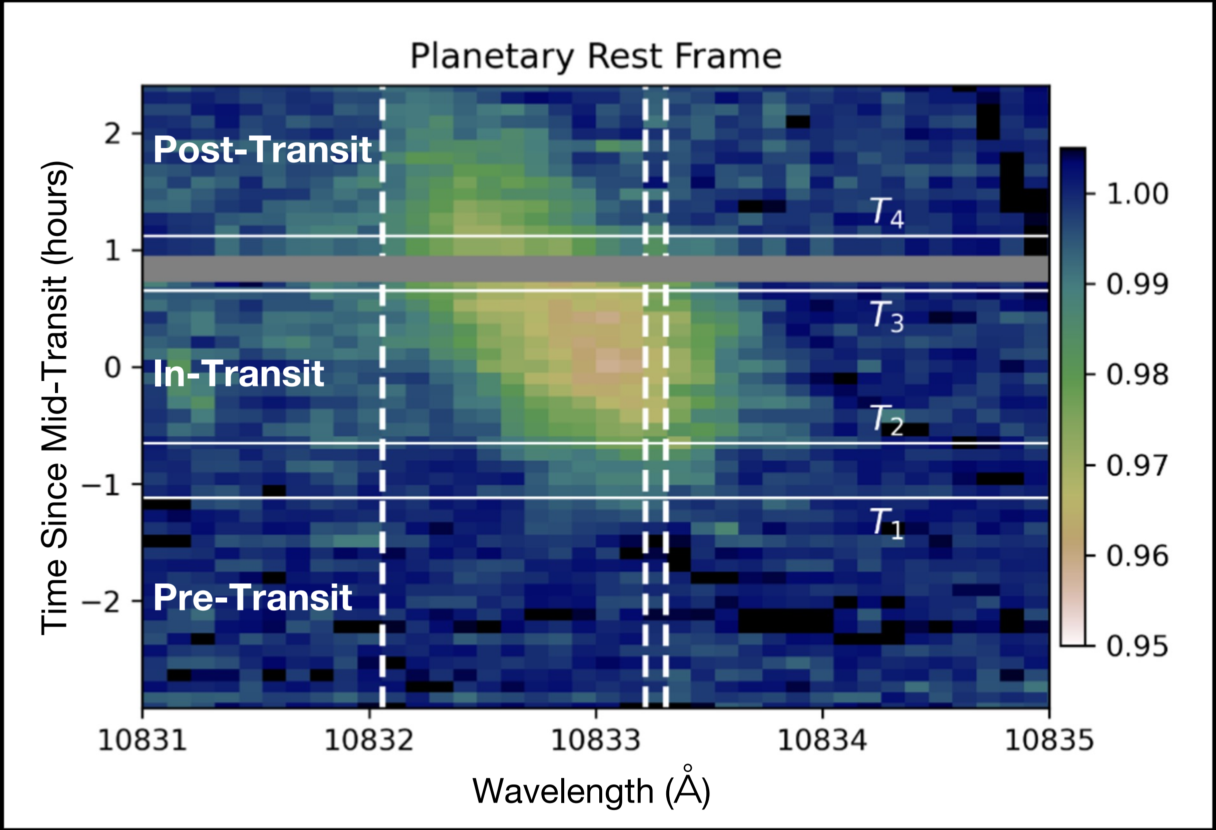
Relative Helium 10830 Å Absorption

In-Transit Helium:

- **Absorption**
  - **2.7 +/- 0.4%**
- **Blueshift**
  - **-5.9 +/- 0.8 km/s**

Post-Transit Helium:

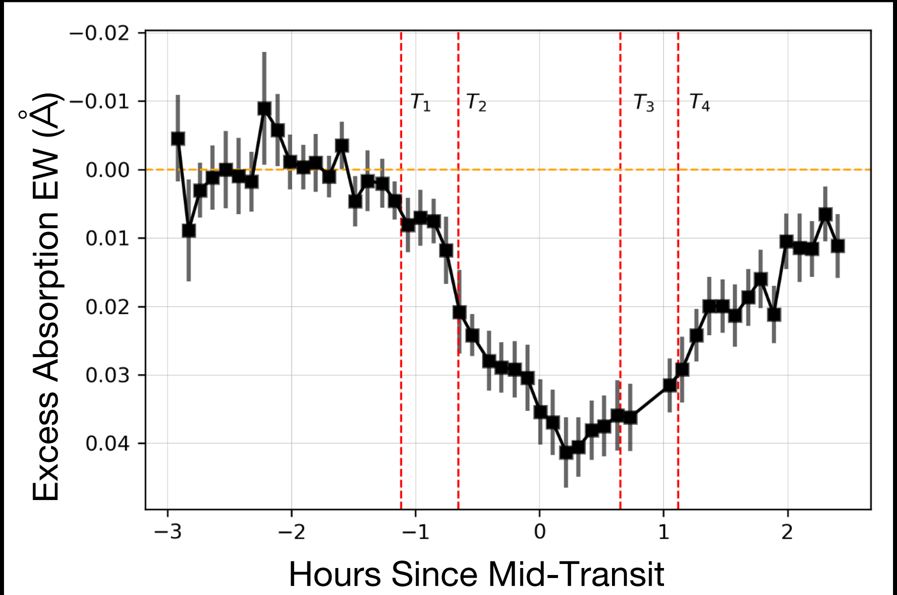
- **Absorption**
  - **1.5 +/- 0.3%**
  - **0.5% CARMENES****
- **Blueshift**
  - **-23.3 +/- 1 km/s**
  - **-10.7 km/s CARMENES****



Tyler et al. (2023)

Helium 10830 Å Light Curve

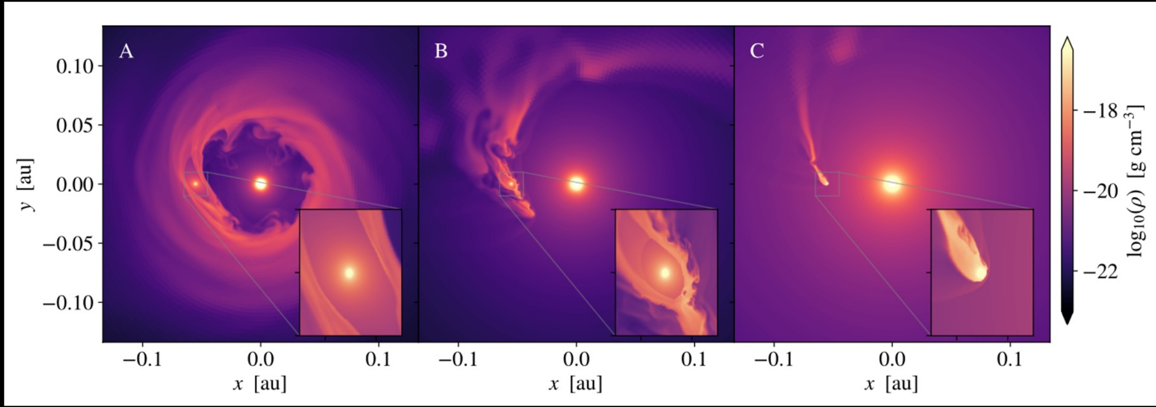
- **He I 10830 Å Equivalent Width for time series**
  - **Time asymmetry in helium light curve**
  - **Baseline never recovered - Excess absorption for 1.3 hours ~7.5 planet radii**
    - **Compare to Nortmann et al. return to baseline in 22 min ~2.2 planet radii**
  - **Maximal absorption depth is delayed relative to mid-transit**
  - **These effects show up in systems with extended atmospheric tails**



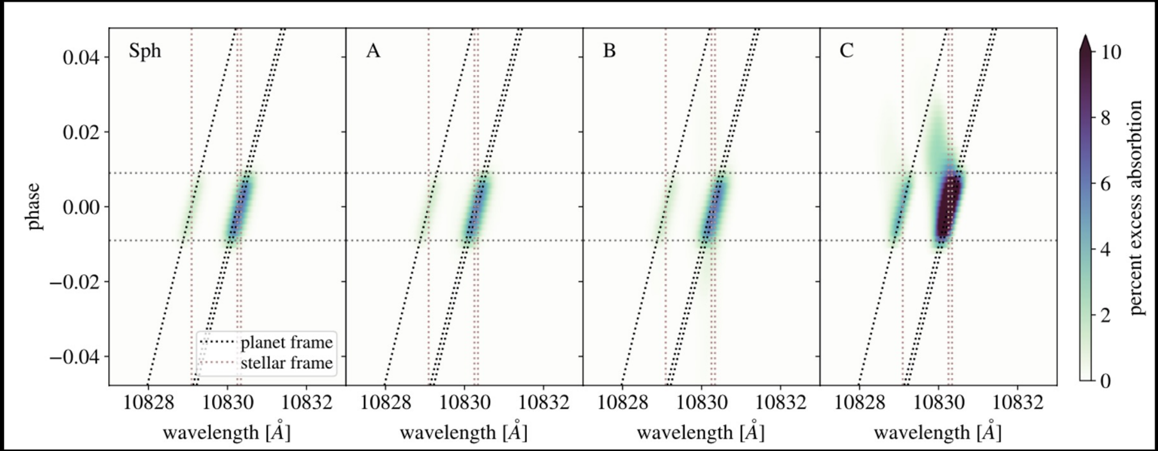
Tyler et al. (2023)

3D Hydrodynamic Stellar-Planetary Wind Interaction Models

These tails are produced by strong stellar winds



Predicted Excess He I 10830 Å Absorption



MacLeod & Oklopcic (2022)

Interpretation - Diagram to Scale

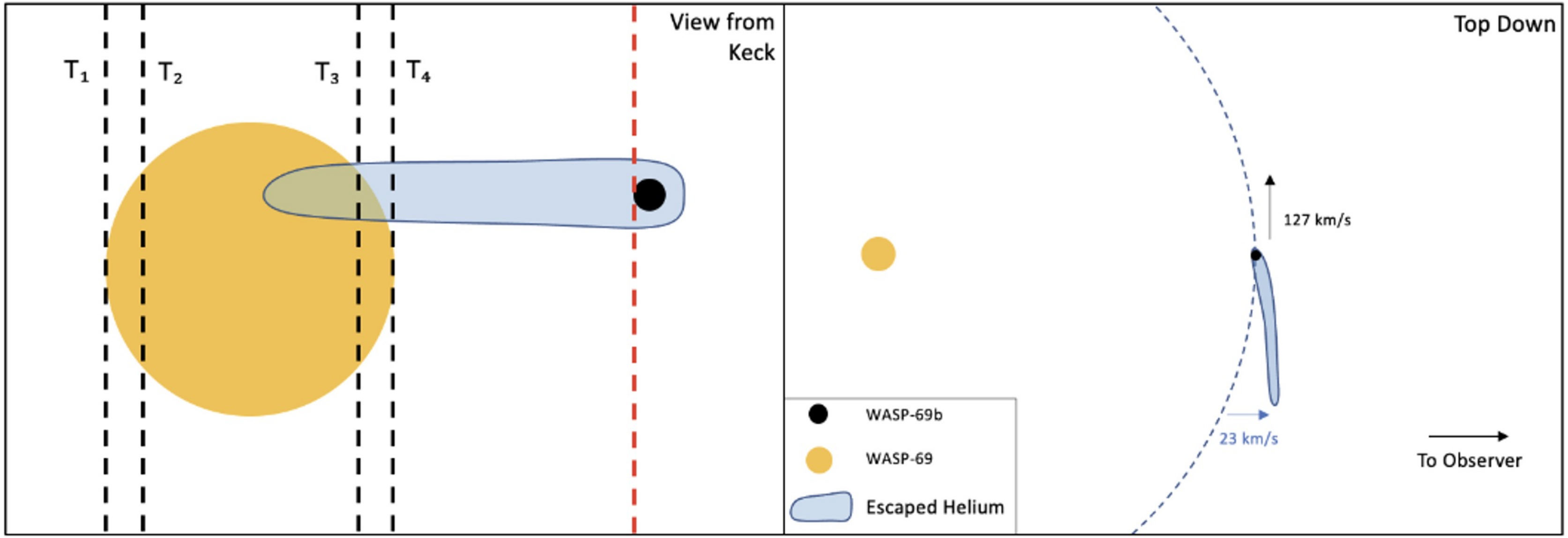


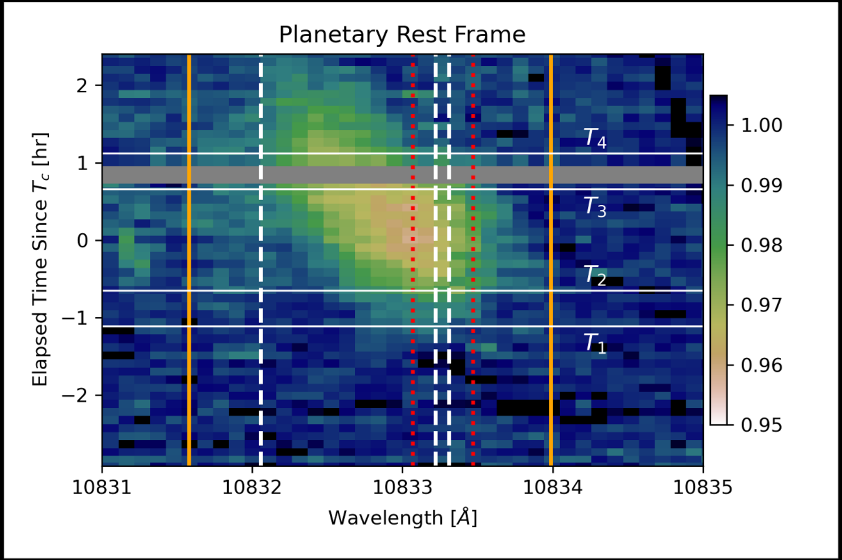
Figure 6. Transit chord and top down view of the WASP-69 system presented to scale. Left: Transit chord view from Keck. The four contact points, T_1, T_2, T_3, and T_4 are represented with vertical black dashed lines and the absorbing He I is light blue. The red dashed line represents the final predicted position of the planet corresponding to the last observation in the spectral time series after traveling over 7 R_p (1.28 hrs) beyond the disk of the star from the perspective of the observer. Right: Top down view of the system. The He I tail can be seen accelerating towards the observer on the lower right of the panel.

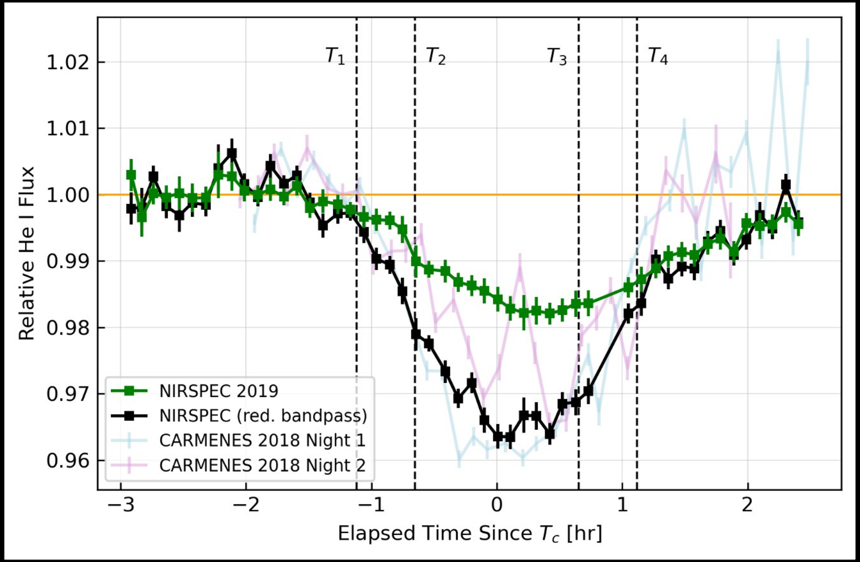
Tyler et al. (2023)

Potential Variability within Observations

- Instrumental Variability
    - CARMENES vs NIRSPEC vs WIRC
        - Resolution/Signal Strength
- Stellar Variability
    - Helium variability within the stellar atmosphere
        - Seems unlikely
    - Variability in the EUV/FUV stellar output
        - Changes amount of helium we can see
    - Varying stellar wind strength
        - Changes physical length of the tail

SNR Contributed Variations





Helium bandpass indicated:
Nortmann et al. 2018 (red)
This work (orange)

Tyler et al. 2023
& data from
Nortmann et al. 2018

Key Takeaways

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Thank You!!

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