Weather Report on Ross 458c

Jared Bull
Elena Manjavacas

September 4, 2025

STScI | SPACE TELESCOPE SCIENCE INSTITUTE

Image Credit: ESO-I. Crossfield-N. Risinger

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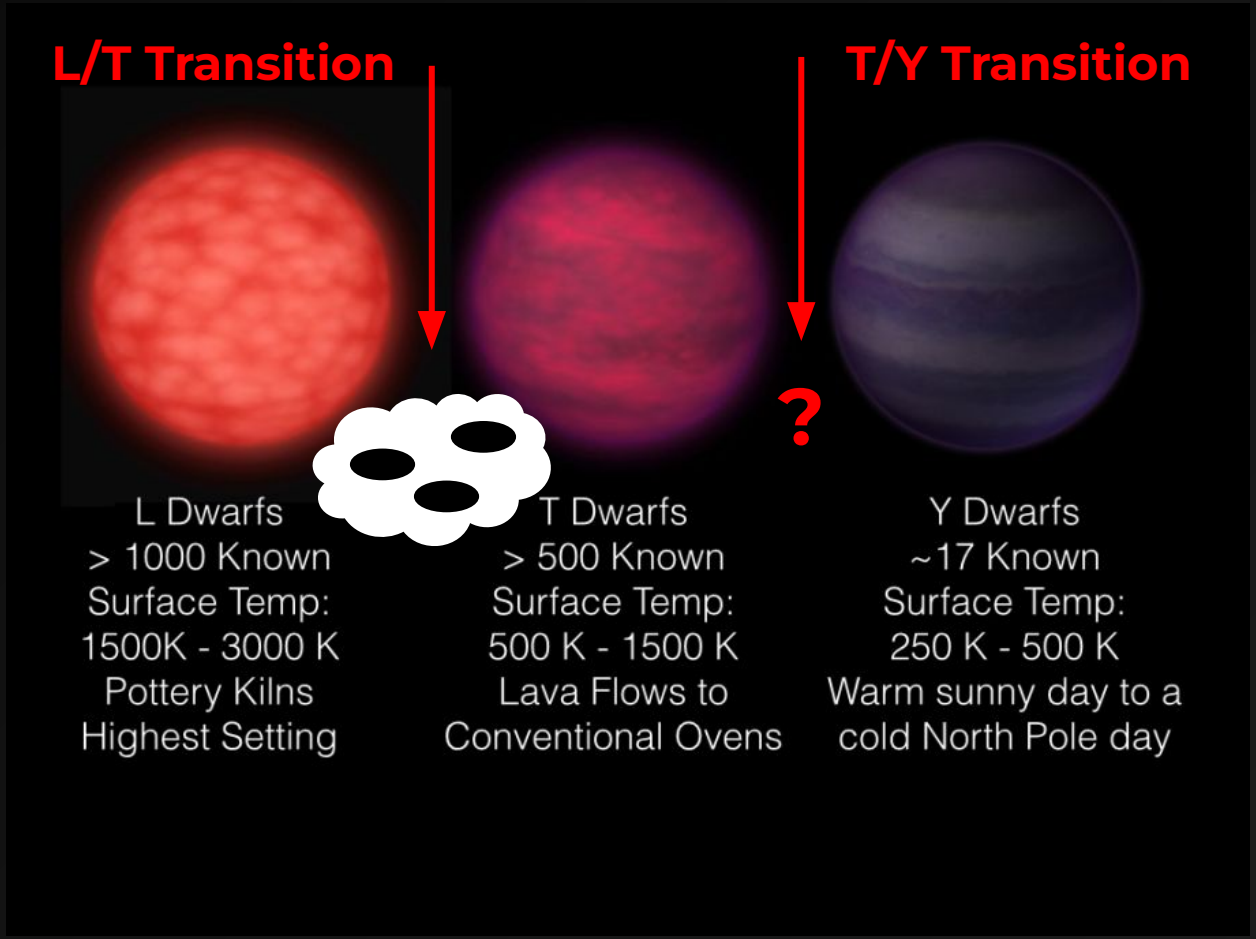

Ross 458c

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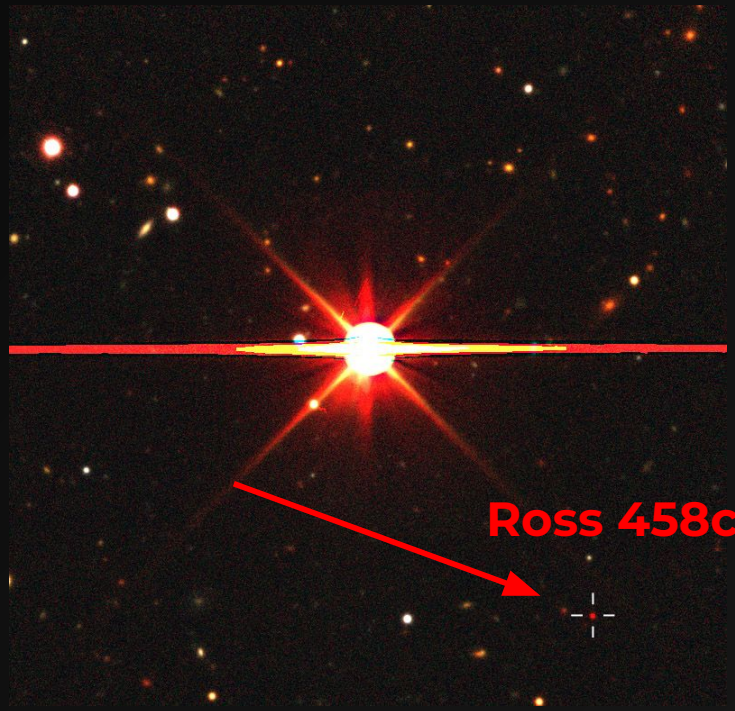

Image Credit: Legacy Surveys / D.Lang
(Perimeter Institute)

T-dwarf companion to binary M-dwarf primary system:

- Distance ~11 pc, Separation ~1200 AU, Age 200-800 Myr
- T8 spectral type (~700 K), Mass 9-16 M_{Jup}

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We should *expect* this object to be cloudless...

Modeling Woes

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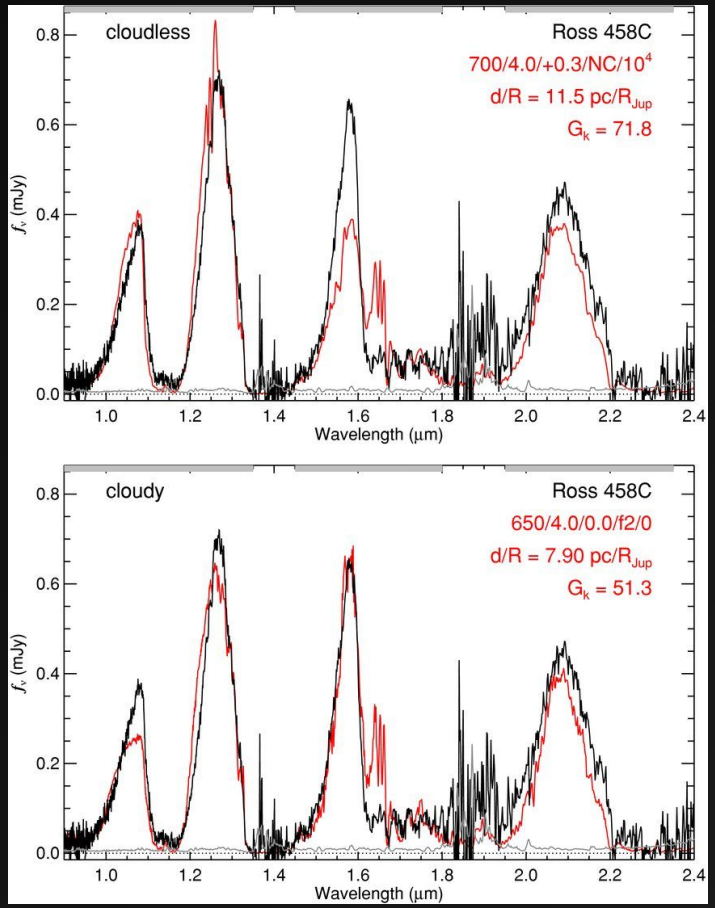

Burgasser et al. 2010

Modeling Woes

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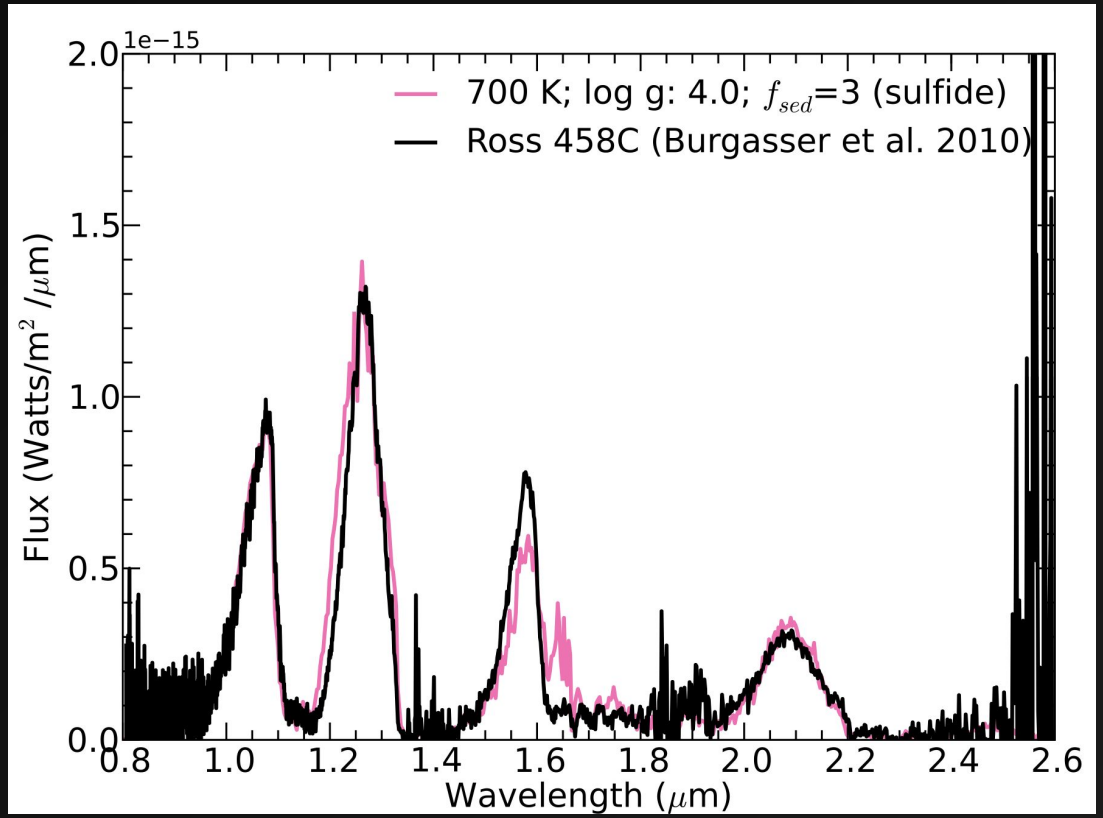

Morley et al. 2012

Modeling Woes

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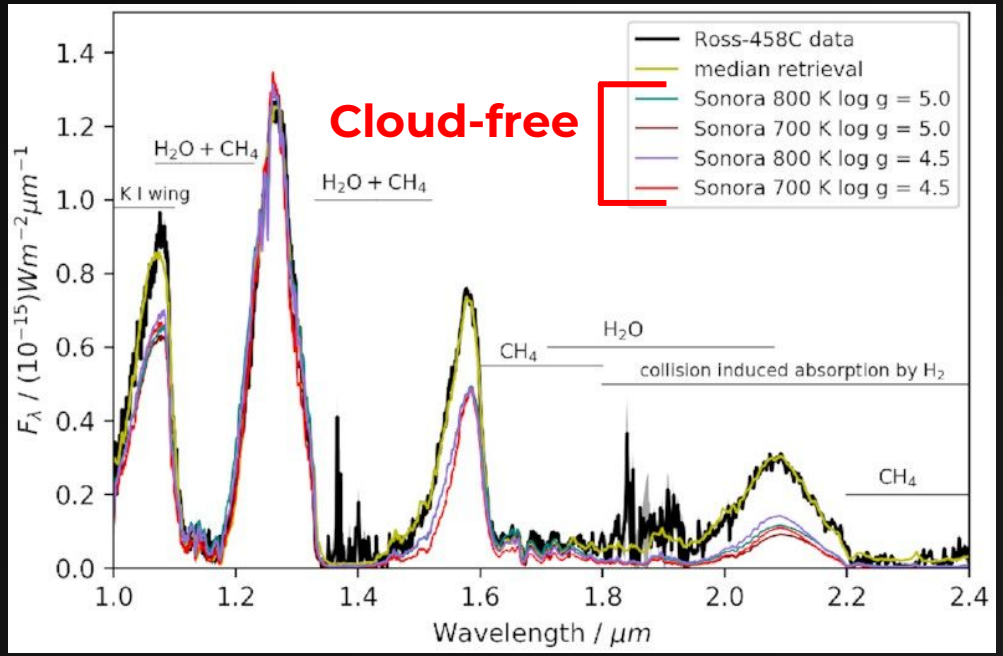
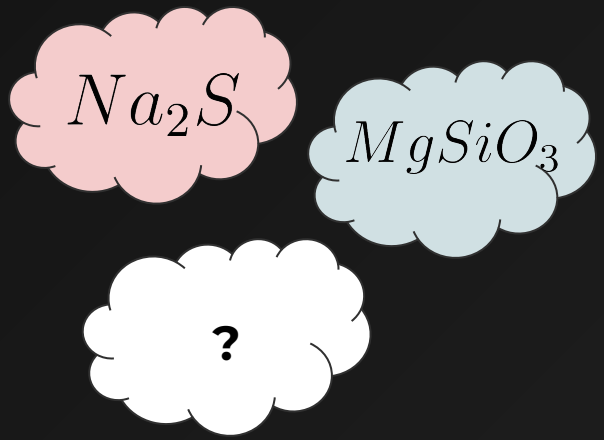


Gaarn et al. 2023

Is Ross 458c cloudy?

Mostly Clear Skies



More excitement...

Variability of Ross 458c (w/ HST)

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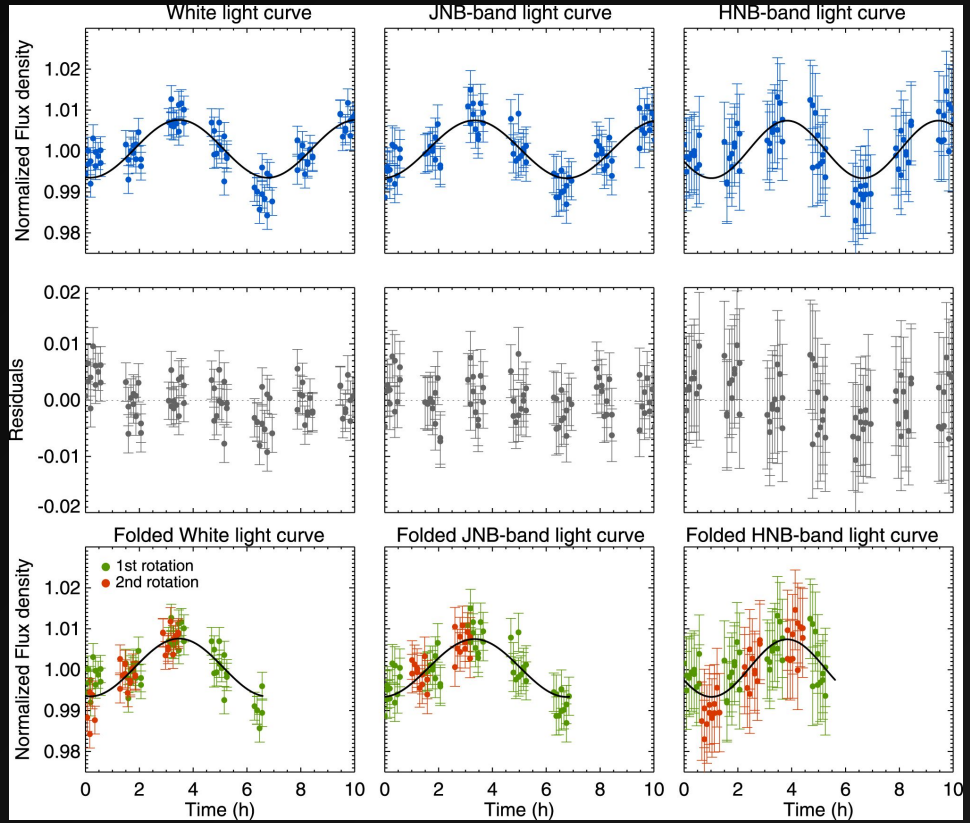


Manjavacas et al. 2019

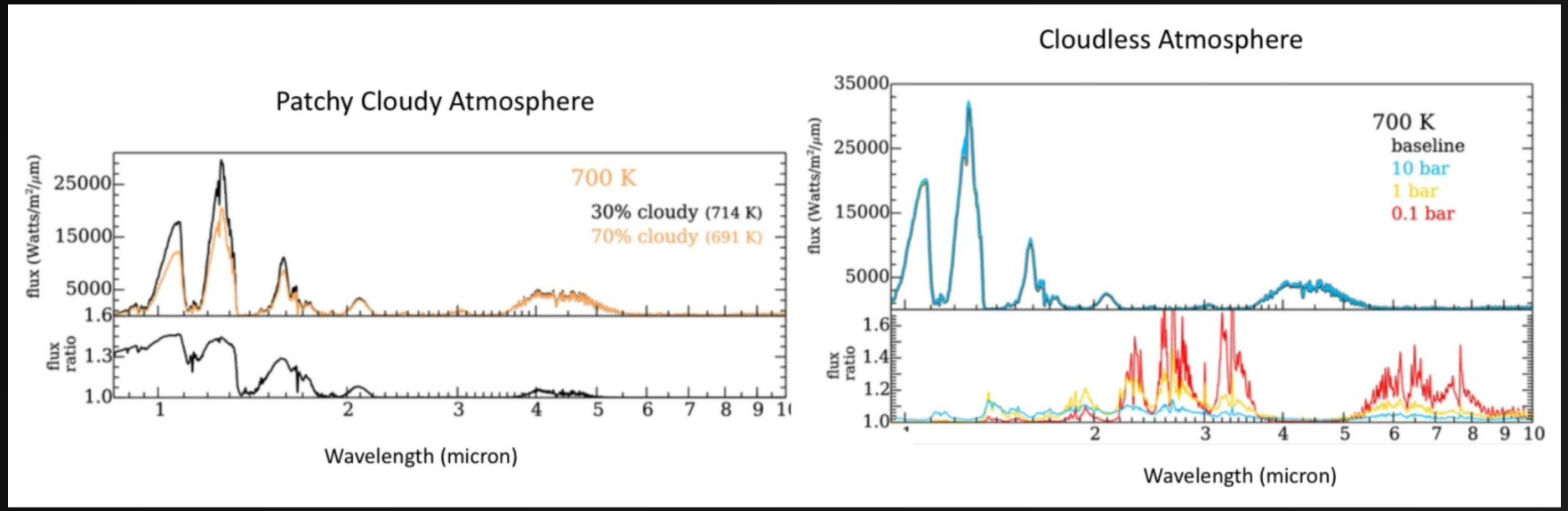
WFC3/G141 (1.05-1.7 um)

- Amplitude ~2%
- Period 6.75 +/- 1.58 hr

What is driving the variability on Ross 458c?*

Model Predictions

Analysis of wavelength-dependent amplitudes are key to uncovering present mechanisms



Morley et al. 2014

JWST NIRSpec PRISM is necessary!

JWST Cycle 3 GO Program 5226

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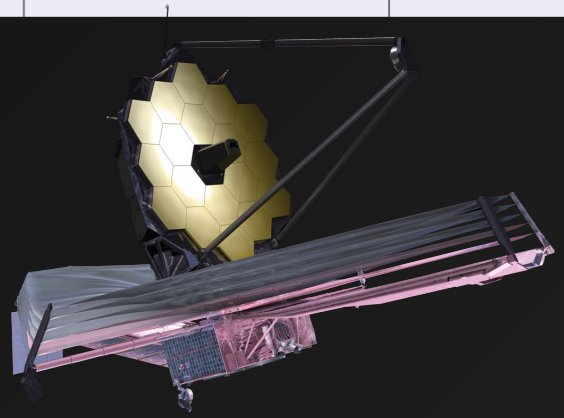
5226	The Weather Forecast in a Cloudy (or not) Cool Planetary-Mass Brown Dwarf	PI: Elena Manjavacas Co-PIs: Daniel Apai, Theodora Karalidi, Glenn Schneider, and Yifan Zhou	12	20.5/0.0	NIRSpec/BOTS	GO

- NIRSpec PRISM, BOTS observing mode
- 880 total integrations, 69 s per integration
- Cover a minimum of 2 full rotations (16.66 hr)



Time-Resolved Spectra

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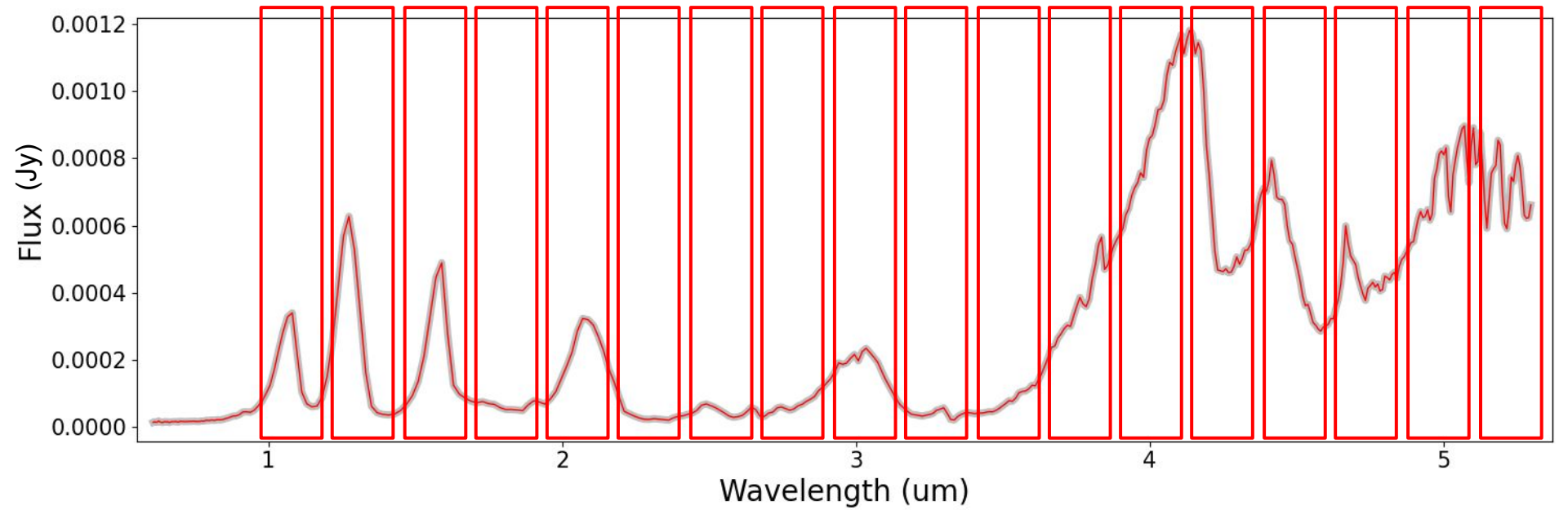

Binned LCs

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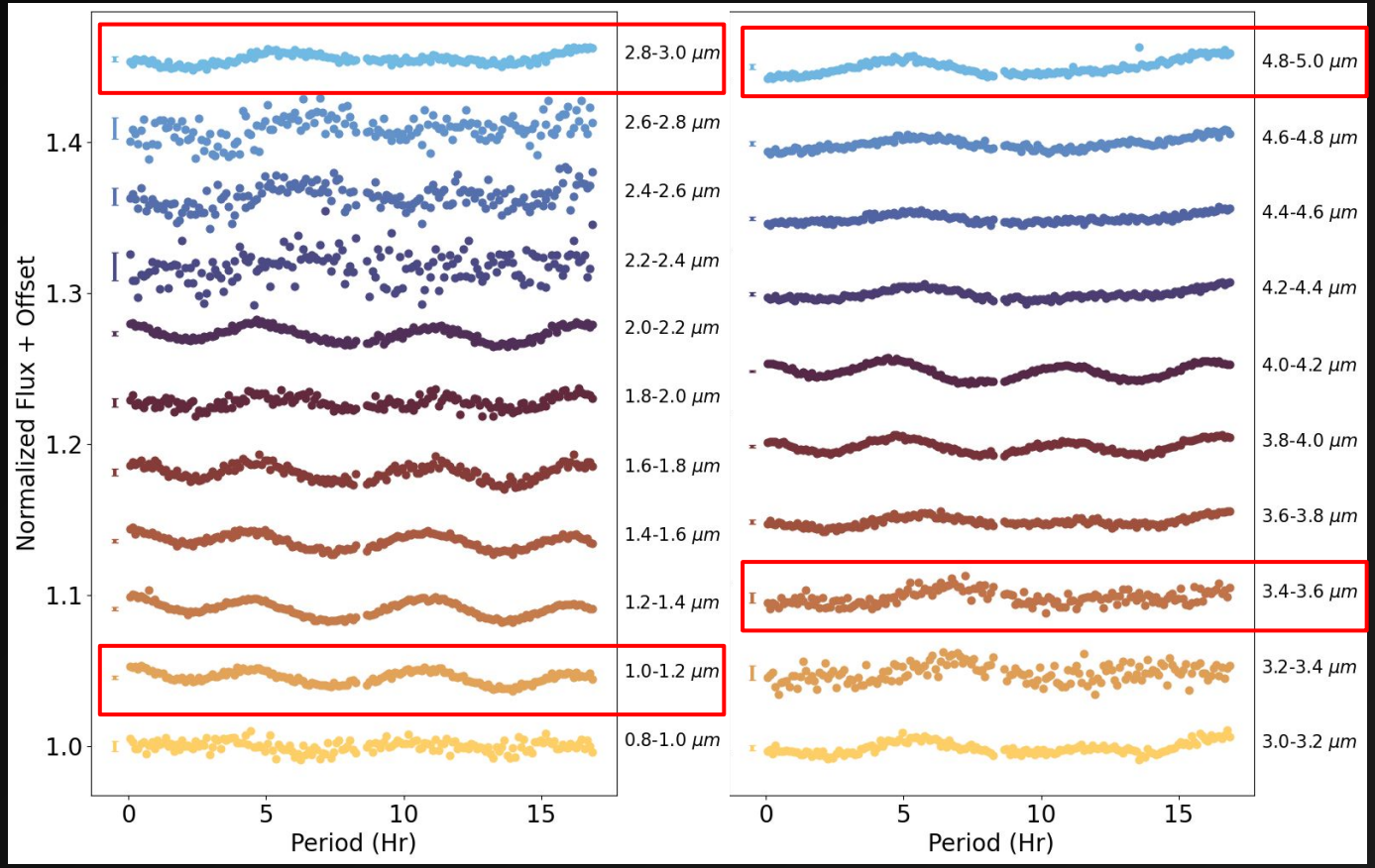

Distinct LC shapes across wavelengths!

Driven by:

- **Clouds?**
- **DEQ Chemistry?**
- **Spots?**

Can we constrain the period using one LC?

Rotational Period Constraint

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Methods from Manjavacas et al. 2019:

1) Lomb-Scargle Periodogram
2) Bayesian-Generalized Lomb-Scargle
3) Sine-model Fitting
4) MC + Prayer Bead + Bootstrap Methods

How well do these periods overlap?

Periodogram Analysis

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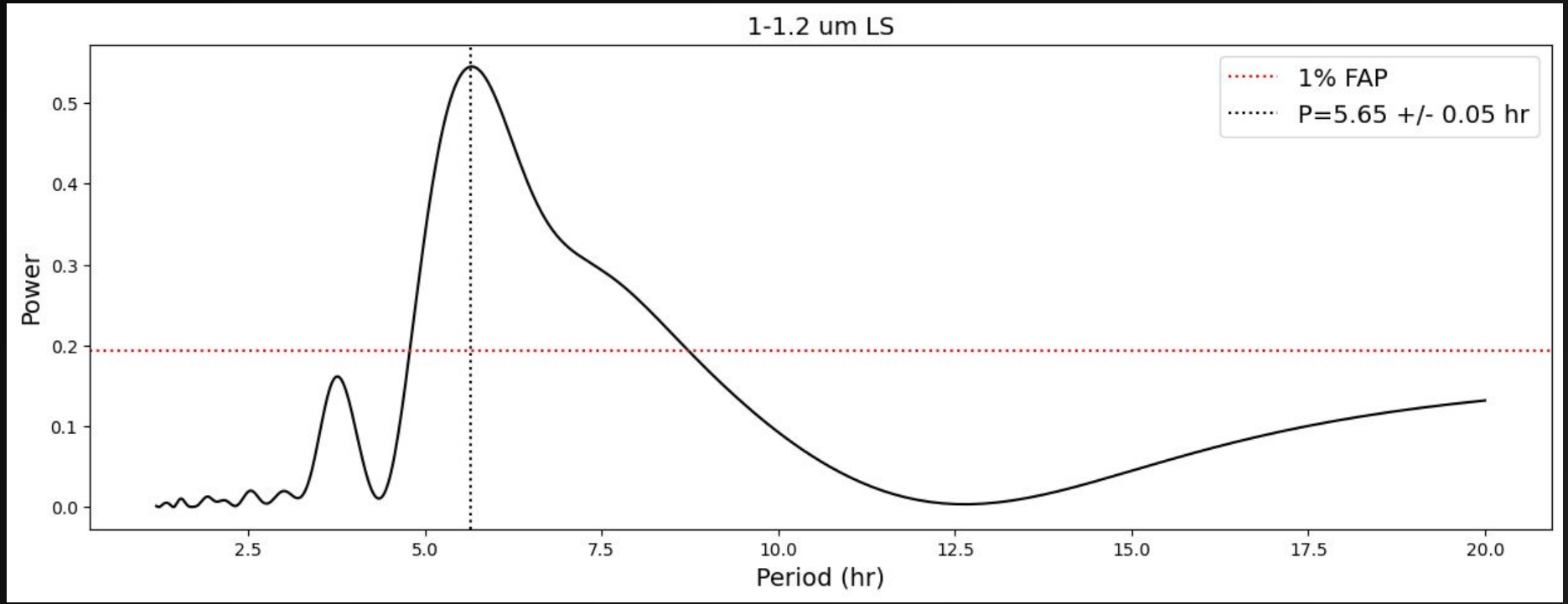

MC + Prayer Bead + Bootstrap

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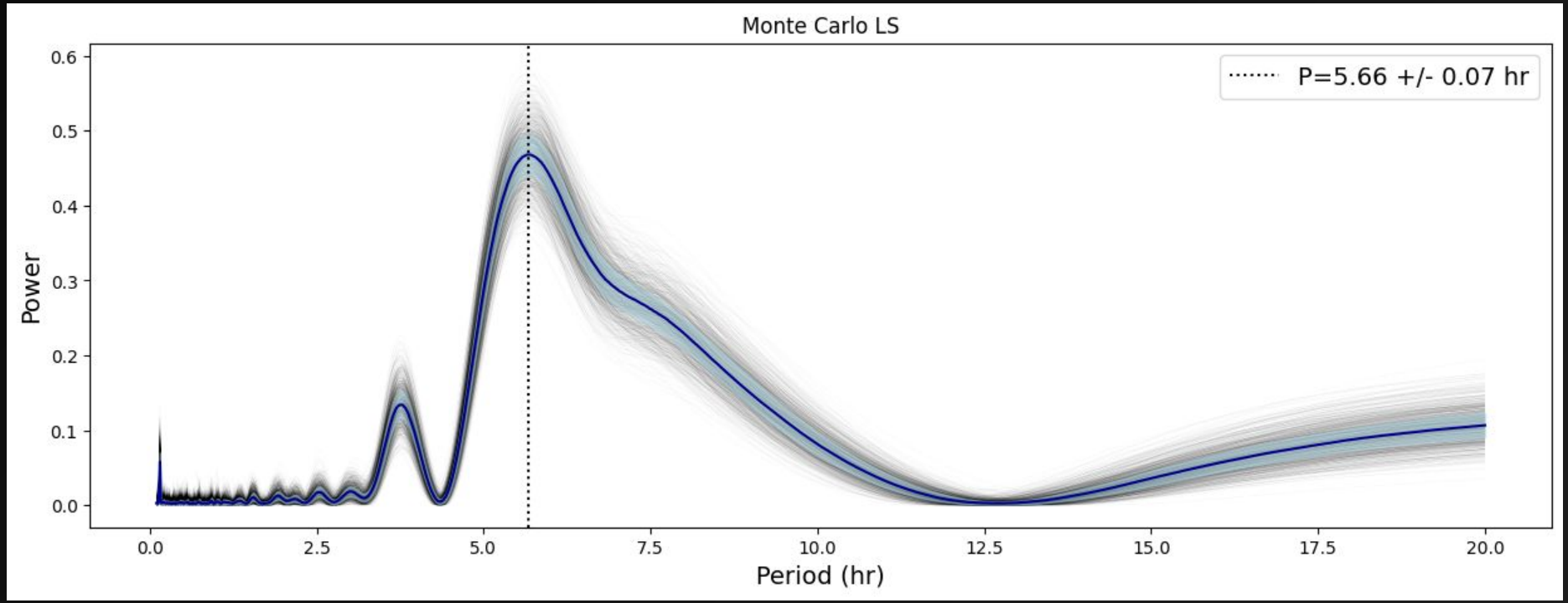

Rotational Period Constraint

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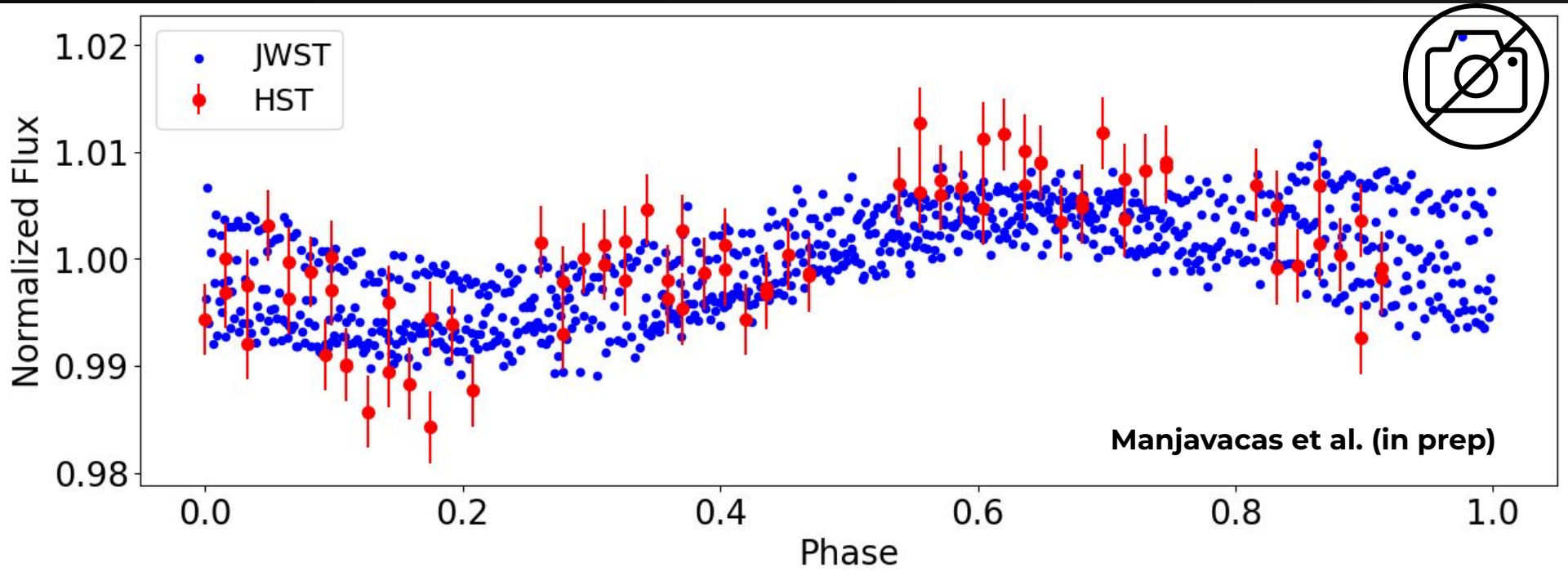
Method	Result
Manjavacas et al. 2019	6.75 +/- 1.58 hr
Lomb-Scargle	5.65 +/- 0.05 hr
BGLS	5.66 +/- 0.08 hr
Monte Carlo LS	5.66 +/- 0.07 hr
Prayer Bead LS	5.70 +/- 0.02 hr
Bootstrap LS	5.69 +/- 0.04 hr

All periods consistent & align w/ prior constraint

What happens if we compare LCs from HST and JWST?

Long-Term Stability of T-dwarf Variability

Stable across 6+ yr (472 rotations)!



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Summary

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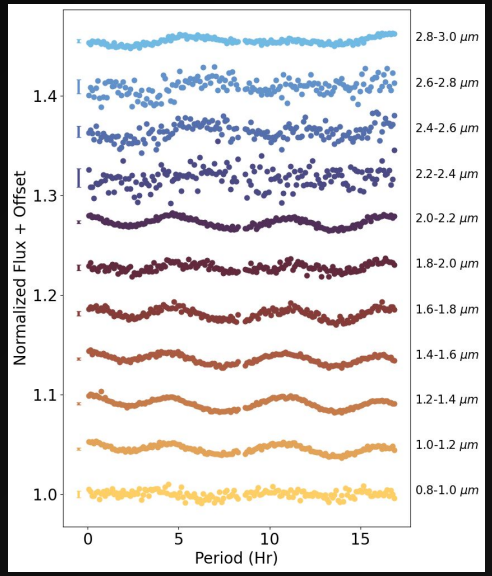
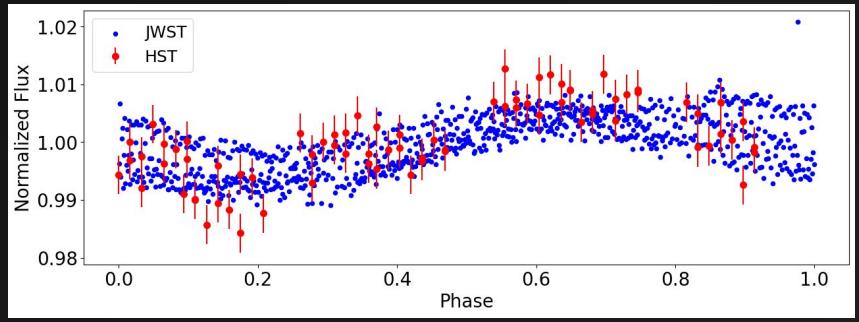


➔ **Distinct** LC behavior across wavelengths

- Multiple mechanisms at play?

➔ Variability **stable** across epochs (400+ rotations)

- Period constraint of **5.66 +/- 0.08 hr**



Obs. Window Function LS

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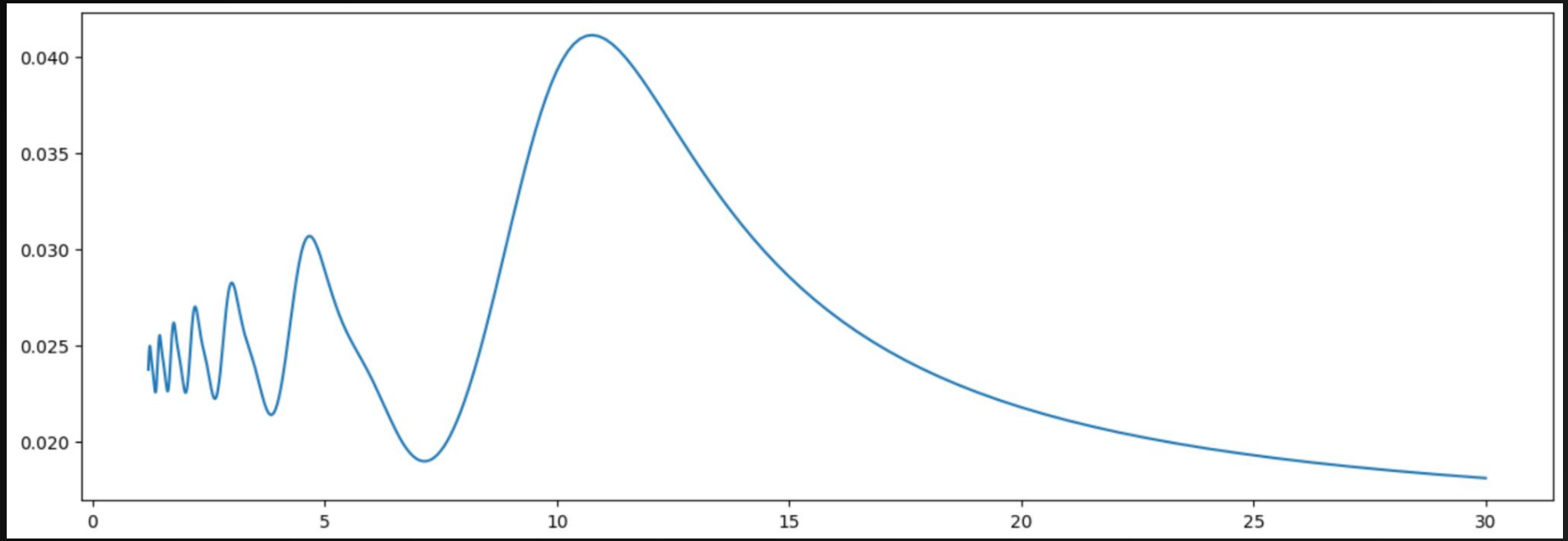

BGLS Analysis

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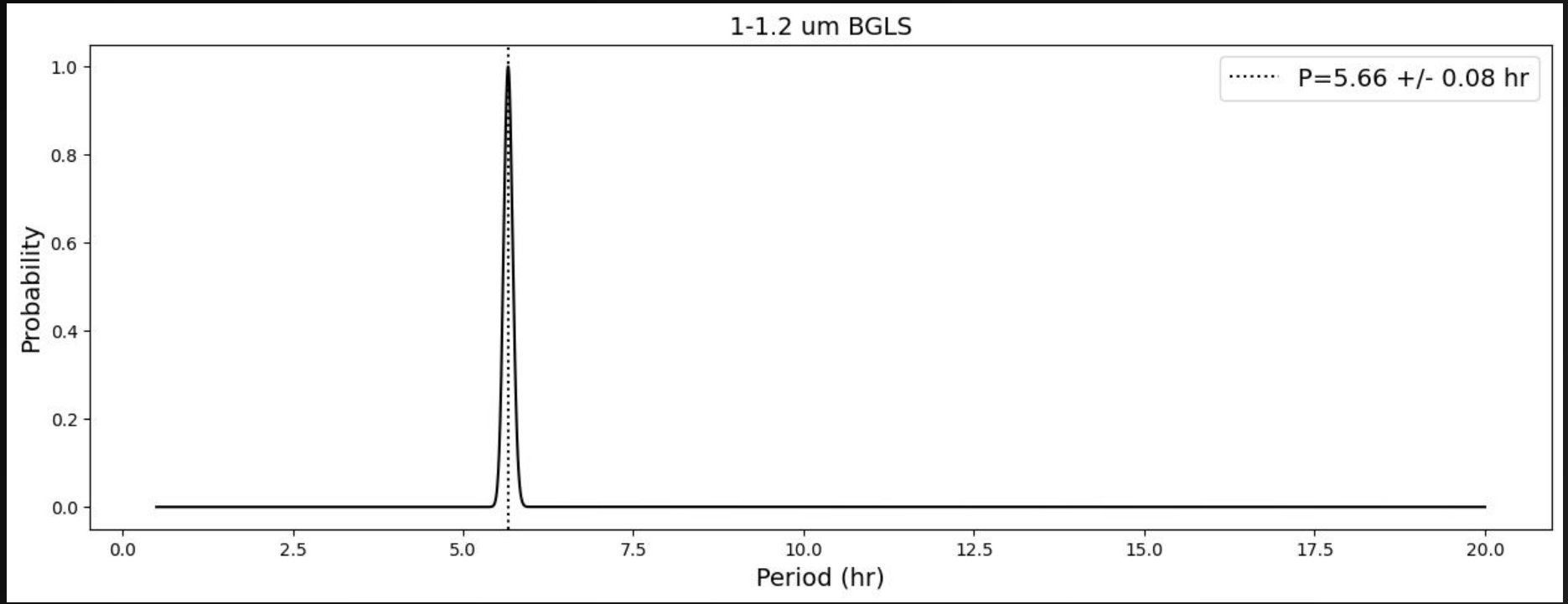

Model Fitting

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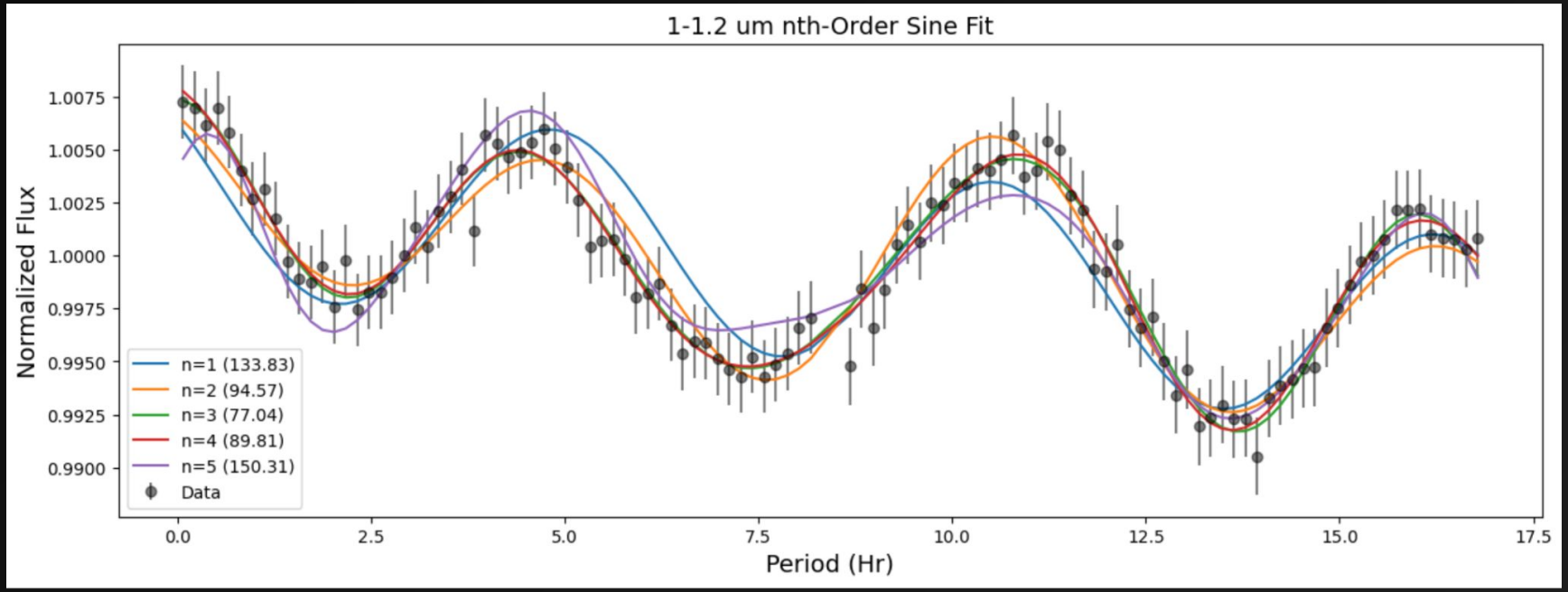
$$F(t) = C_0 + C_1 t + \sum_{i=1}^{N} \left[A_i \sin\left(\frac{2\pi t}{P_i} + \phi_i \right) \right]$$



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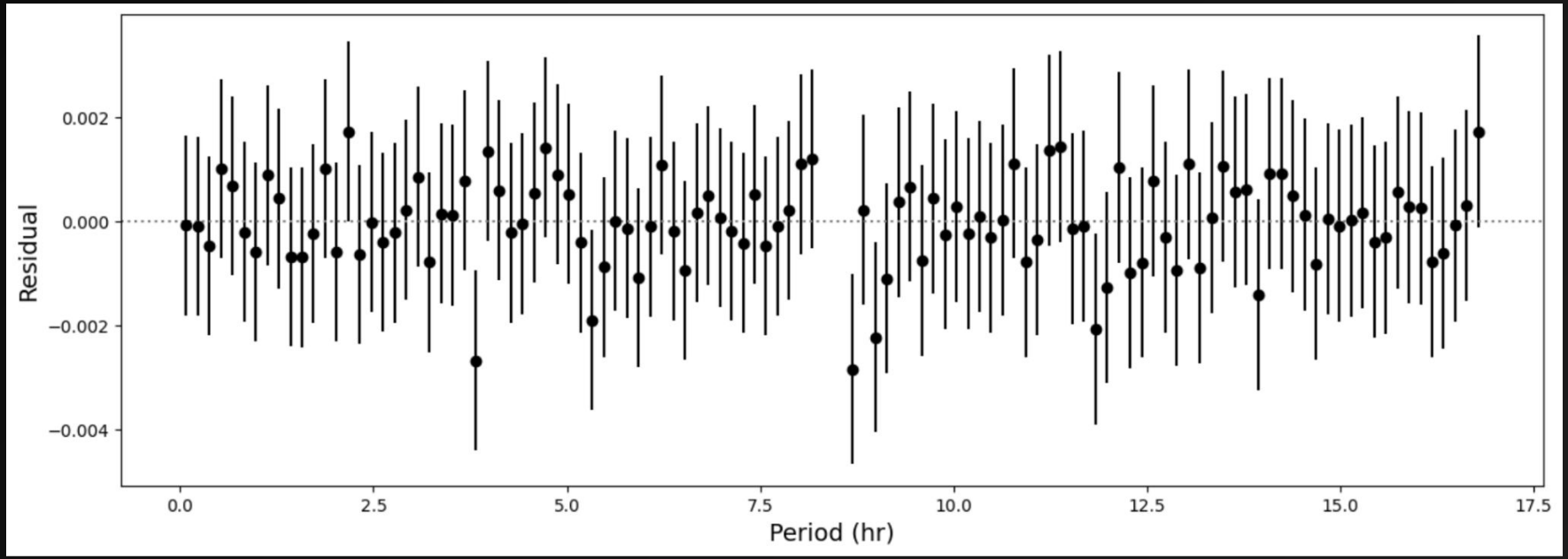

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Model Fitting Cont.

For n=3:

P_1 = ~5 hr (3% Amplitude)

P_2 = 7.98 +/- .64 hr (.3% Amplitude)

P_3 = ~5hr (3% Amplitude)