



# New Dimensions in Time-Series Analysis for Exoplanet Detection

**Jack Lubin**

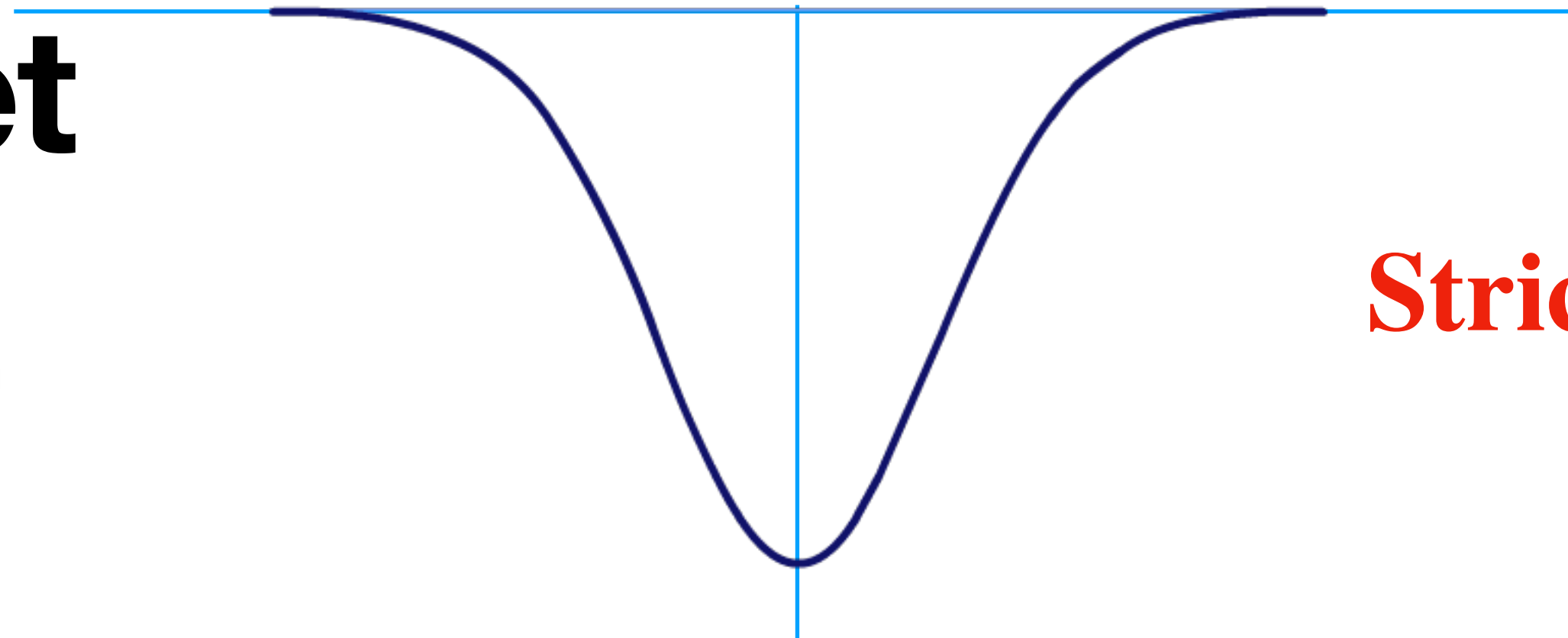
**June 16, 2023**



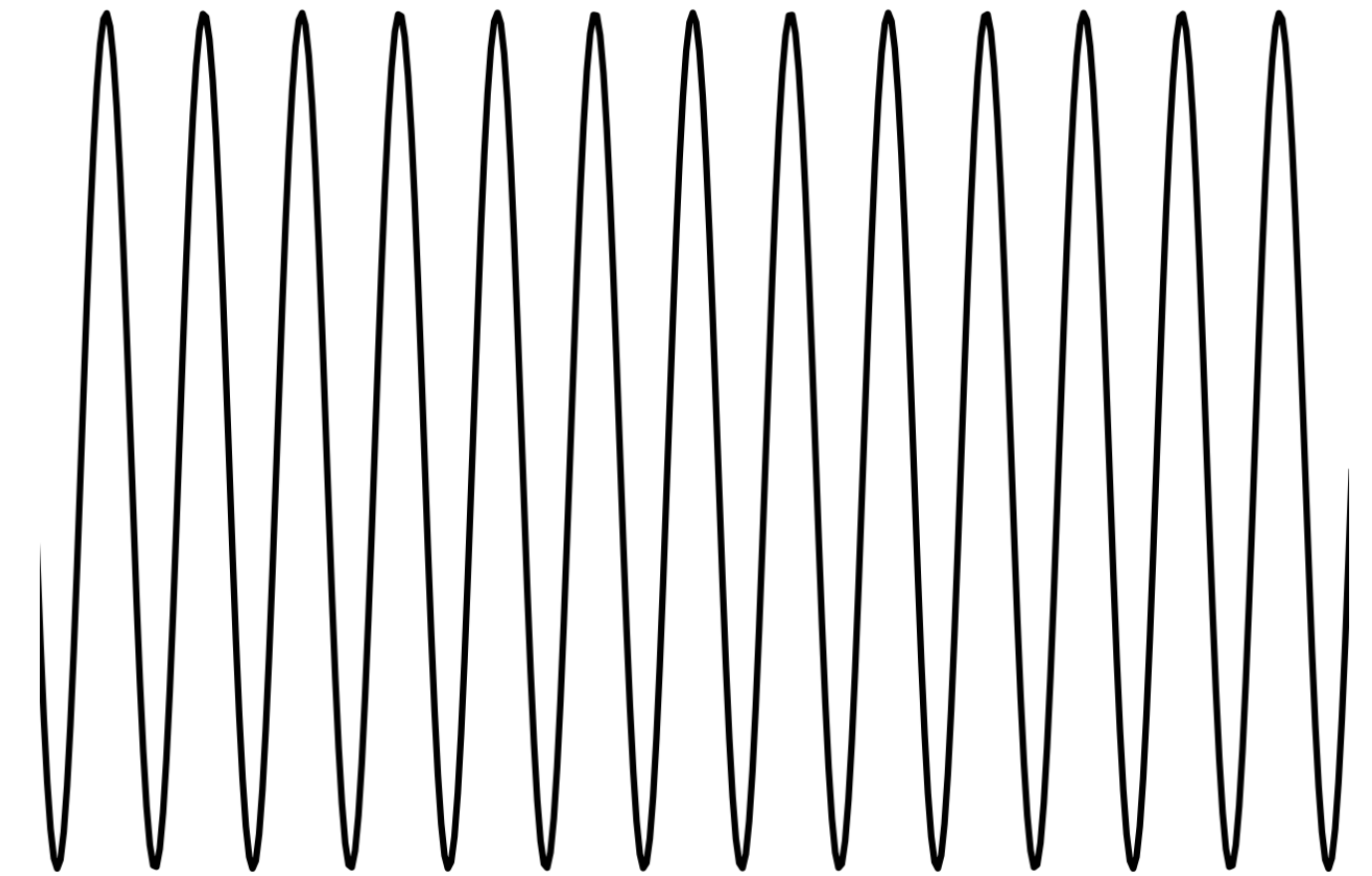
**@LubysLemmas**

# RVs and Activity

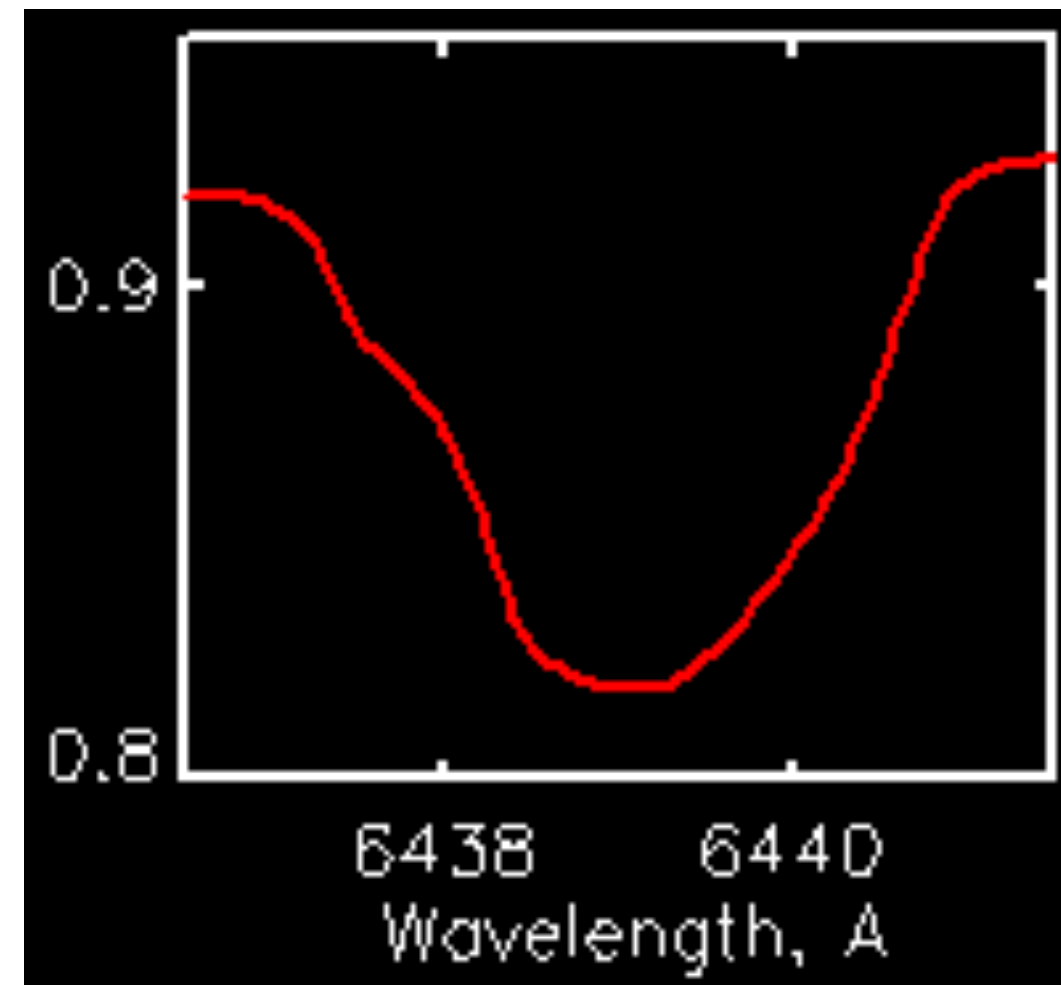
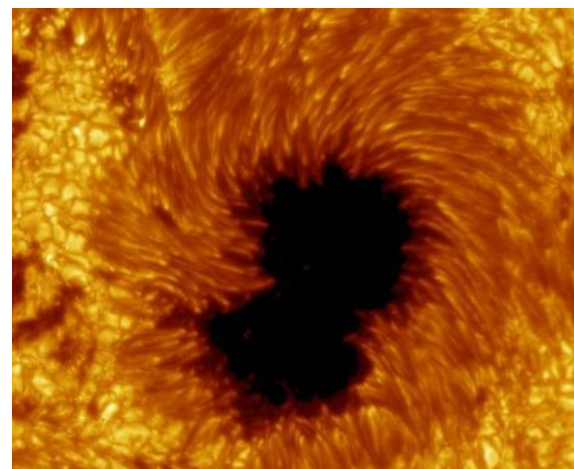
## Planet



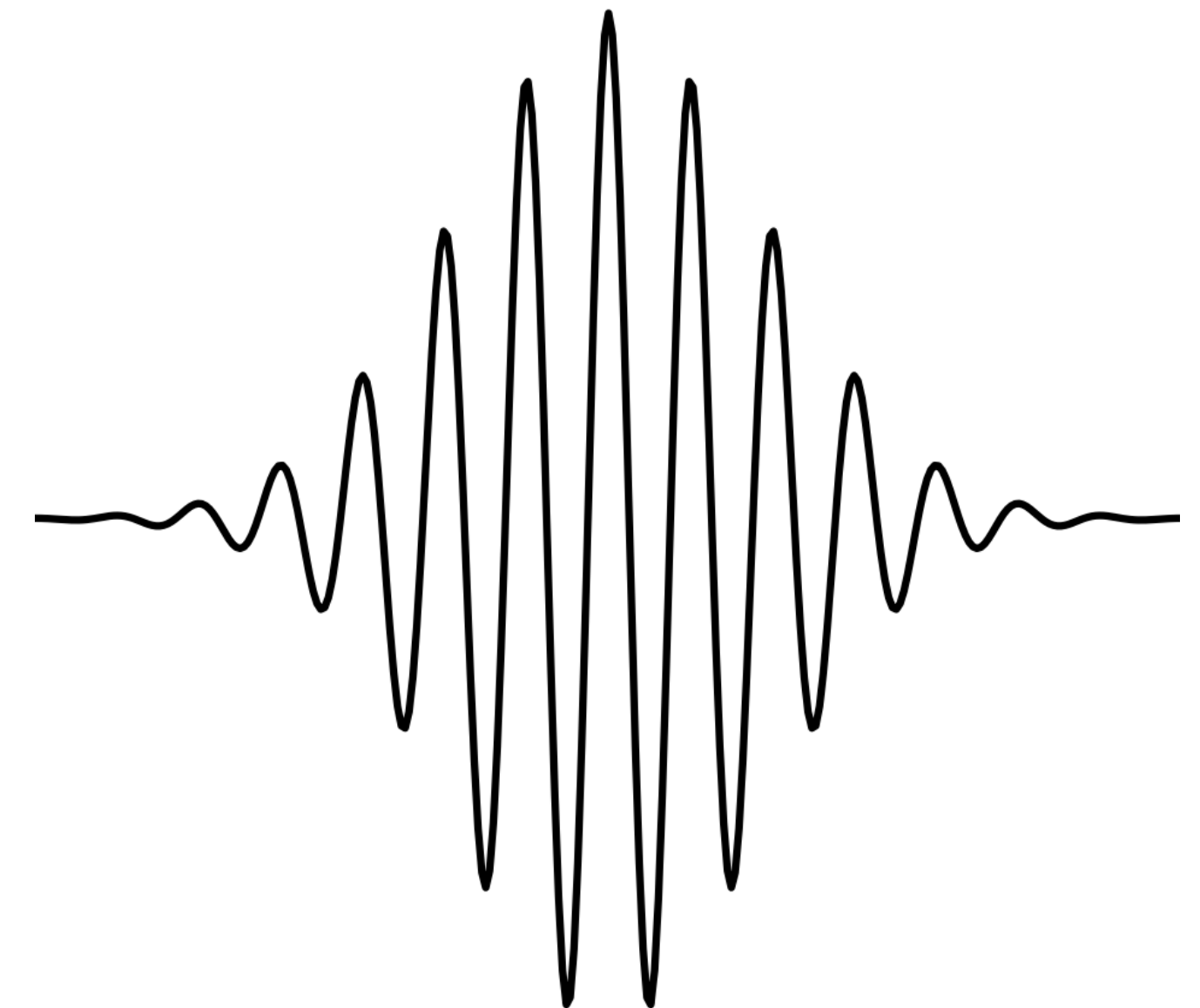
**Strictly Periodic**



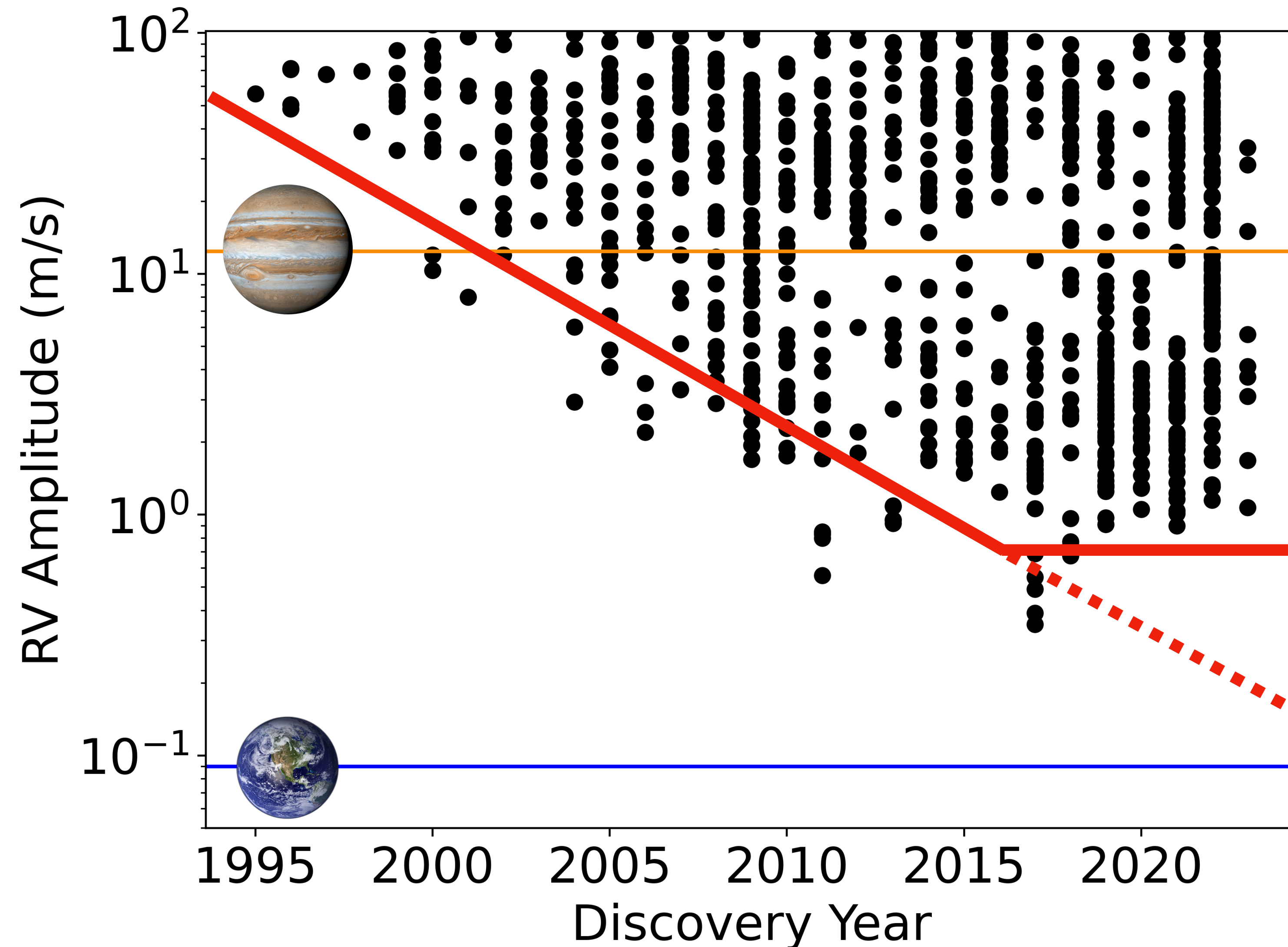
## Activity



**Quasi-Periodic**



# Pushing the Boundary



## Instrumentation



Build more precise spectrometers

=

Build a fast car

## Software



Understanding our data better

=

Learn to drive





## Scientists report a super-Earth orbiting Barnard's Star, a mere 6 light-years away

BY **ALAN BOYLE** on November 14, 2018 at 1:27 pm

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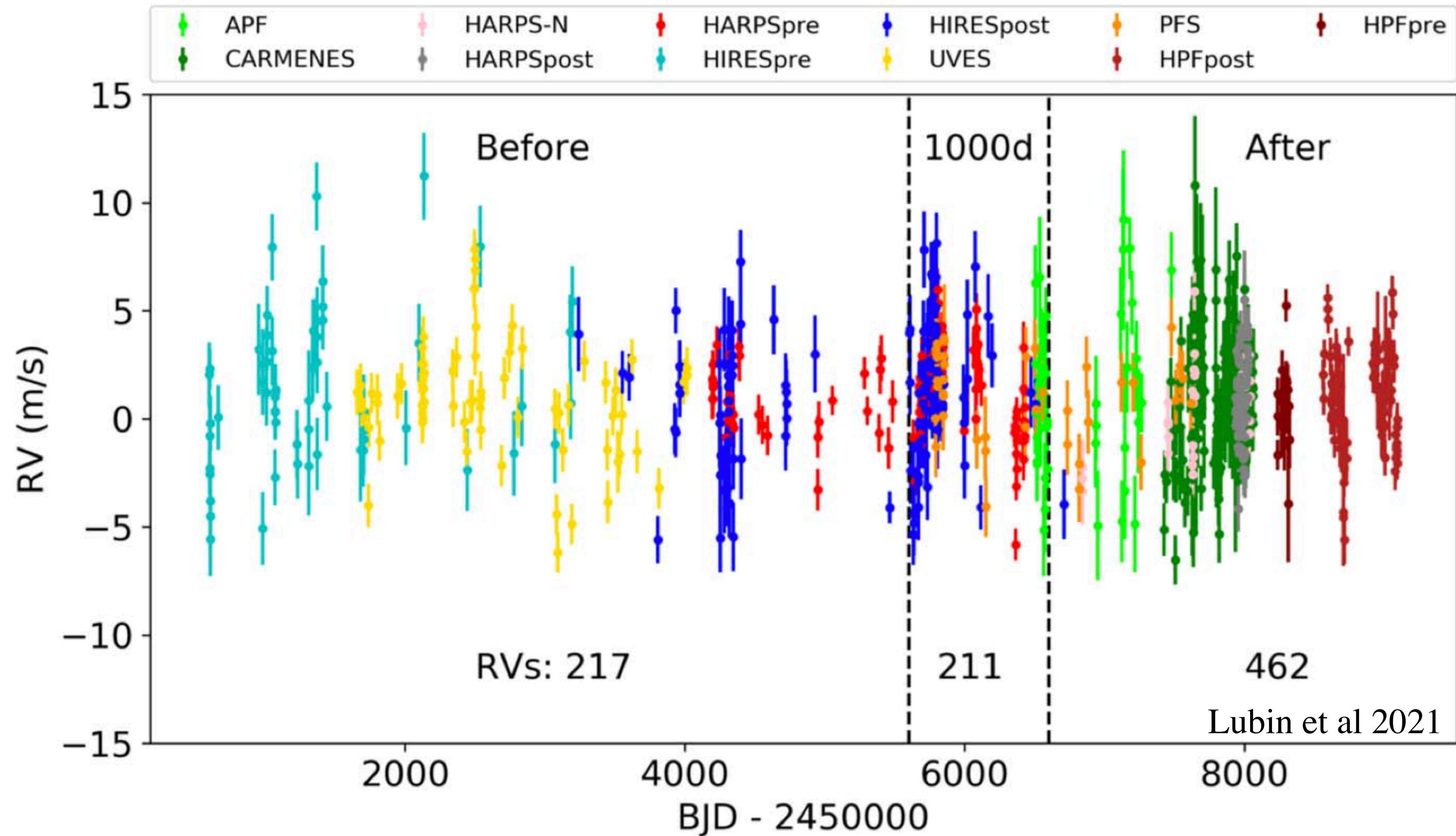
Email

## Stellar Activity Manifesting at a One-year Alias Explains Barnard b as a False Positive

Jack Lubin<sup>1</sup> , Paul Robertson<sup>1</sup> , Gudmundur Stefansson<sup>2,18</sup> , Joe Ninan<sup>3,4</sup> , Suvrath Mahadevan<sup>3,4</sup> , Michael Endl<sup>5</sup> ,  
Eric Ford<sup>3,4,6</sup> , Jason T. Wright<sup>3,4</sup> , Corey Beard<sup>1</sup> , Chad Bender<sup>7</sup> , William D. Cochran<sup>8</sup> , Scott A. Diddams<sup>9,10</sup> ,  
Connor Fredrick<sup>10,11</sup> , Samuel Halverson<sup>12</sup> , Shubham Kanodia<sup>3,4</sup> , Andrew J. Metcalf<sup>9,10,13</sup> , Lawrence Ramsey<sup>3,4</sup> ,  
Arpita Roy<sup>14,15</sup> , Christian Schwab<sup>16</sup> , and Ryan Terrien<sup>17</sup> 



# 23 Years of RVs

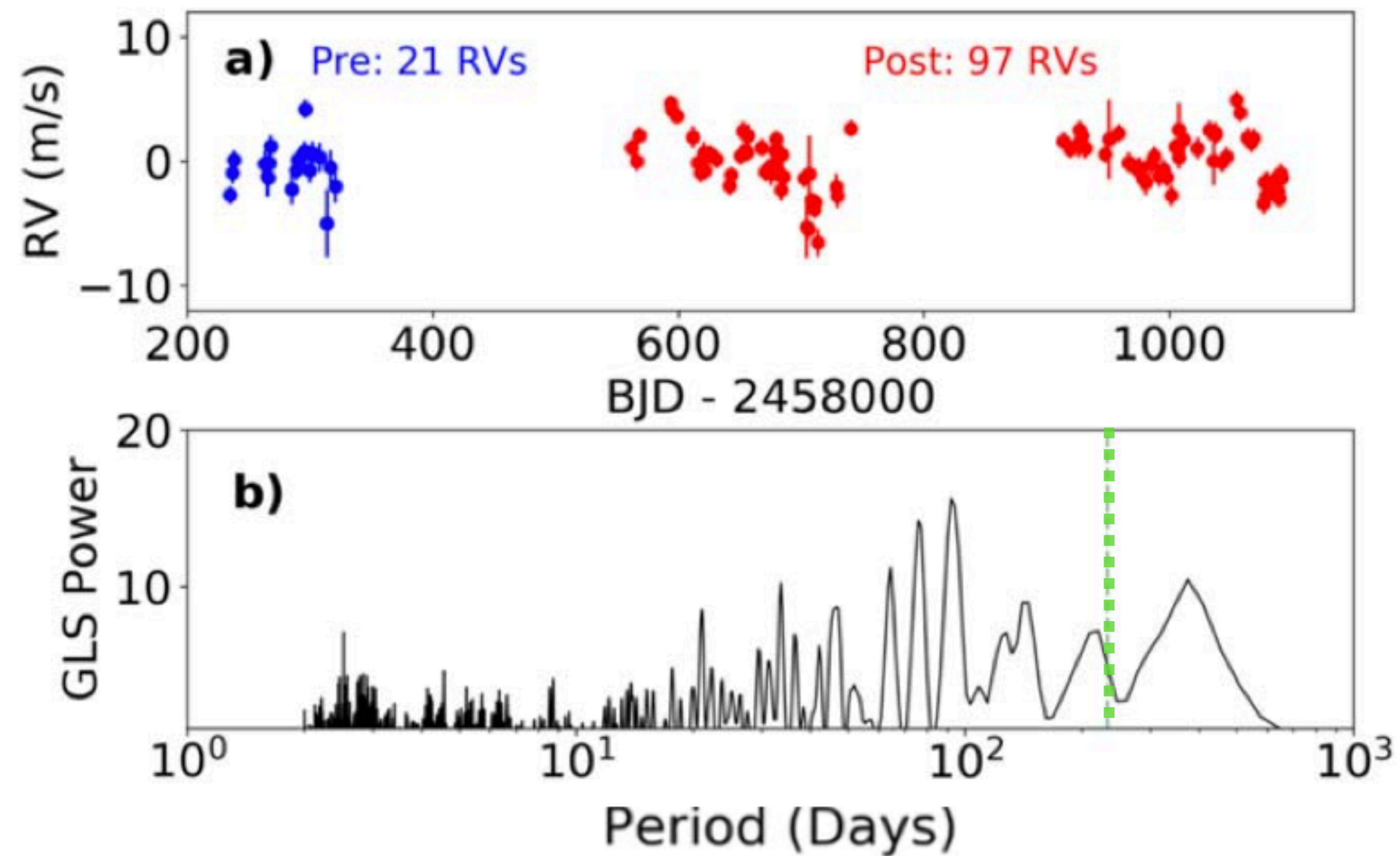




# No Planet in HPF Data



Credit: Marty Harris/McDonald Observatory.

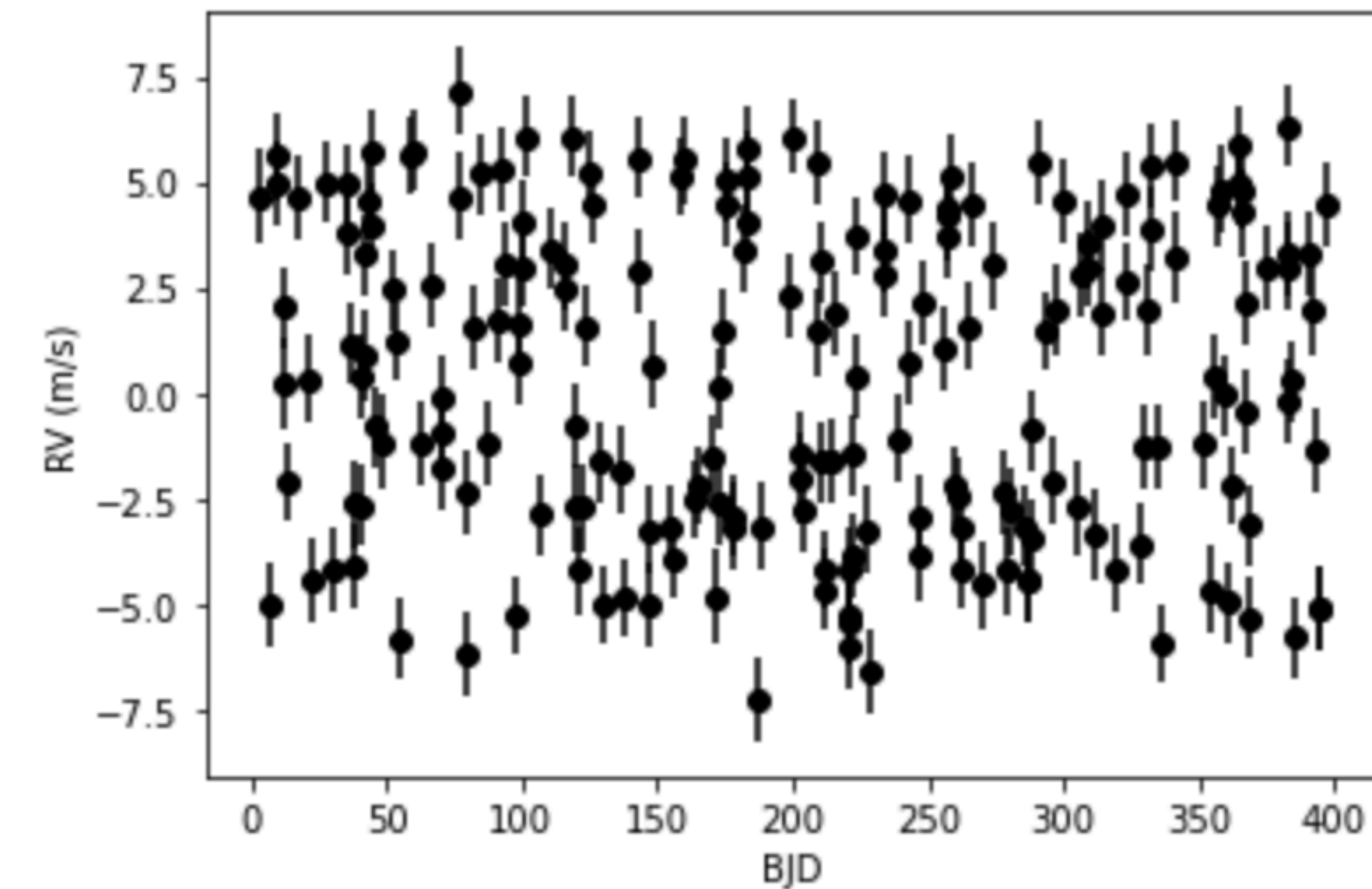


Lubin et al 2021



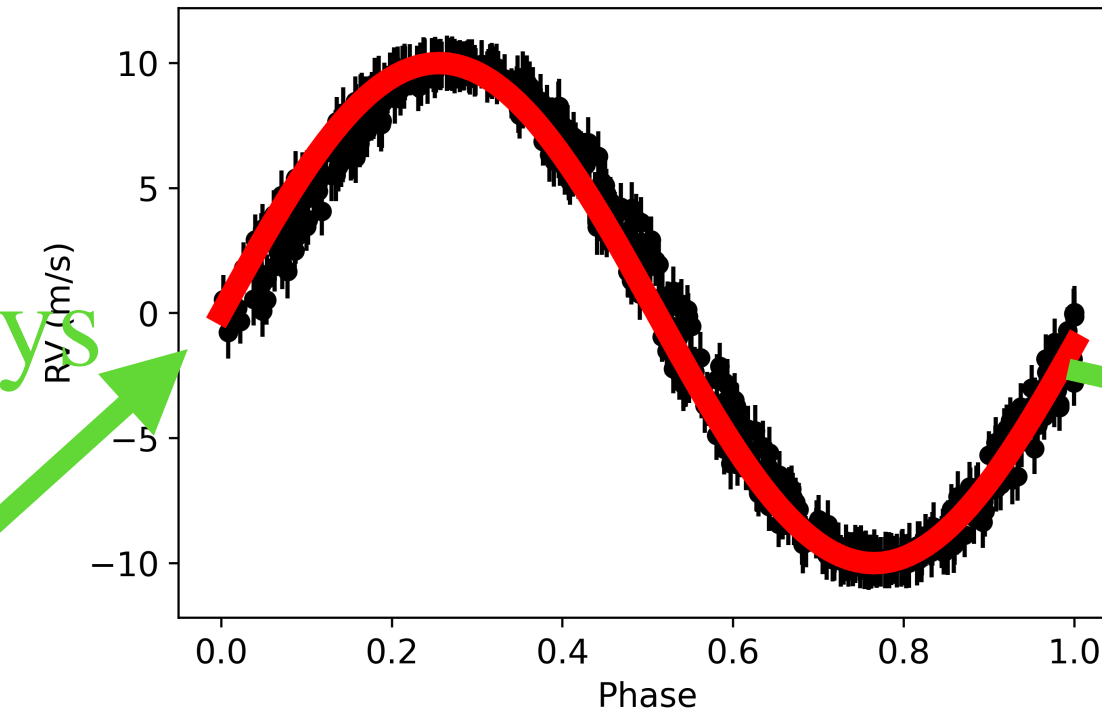
# Lomb-Scargle Periodograms

Original Data

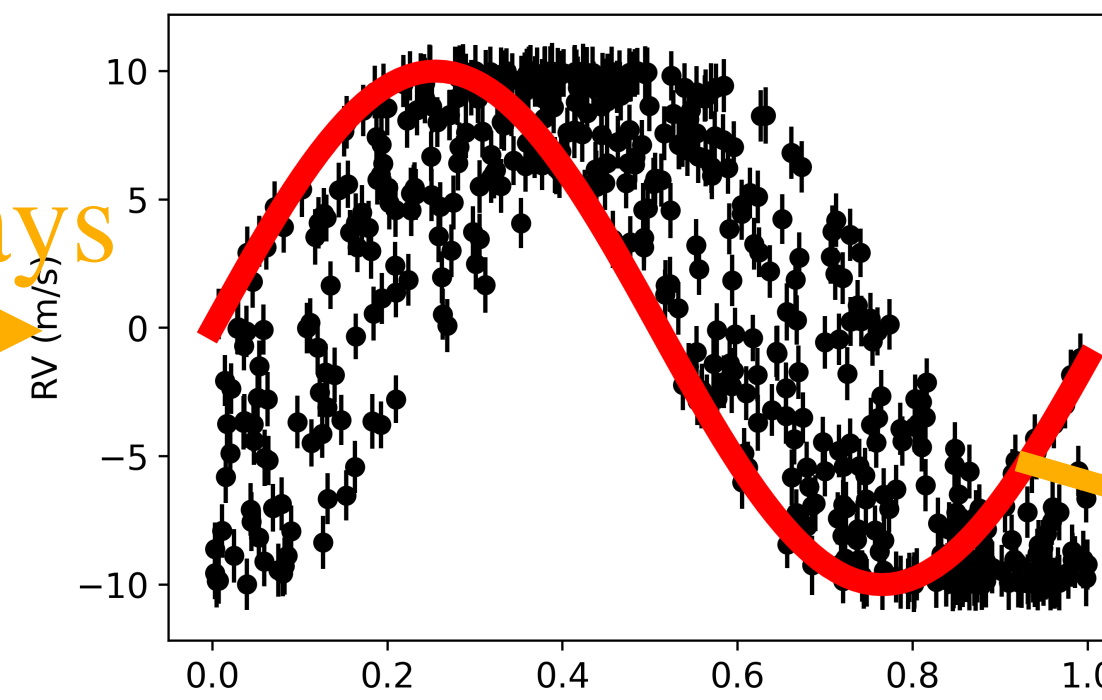


Various Phase-Folds

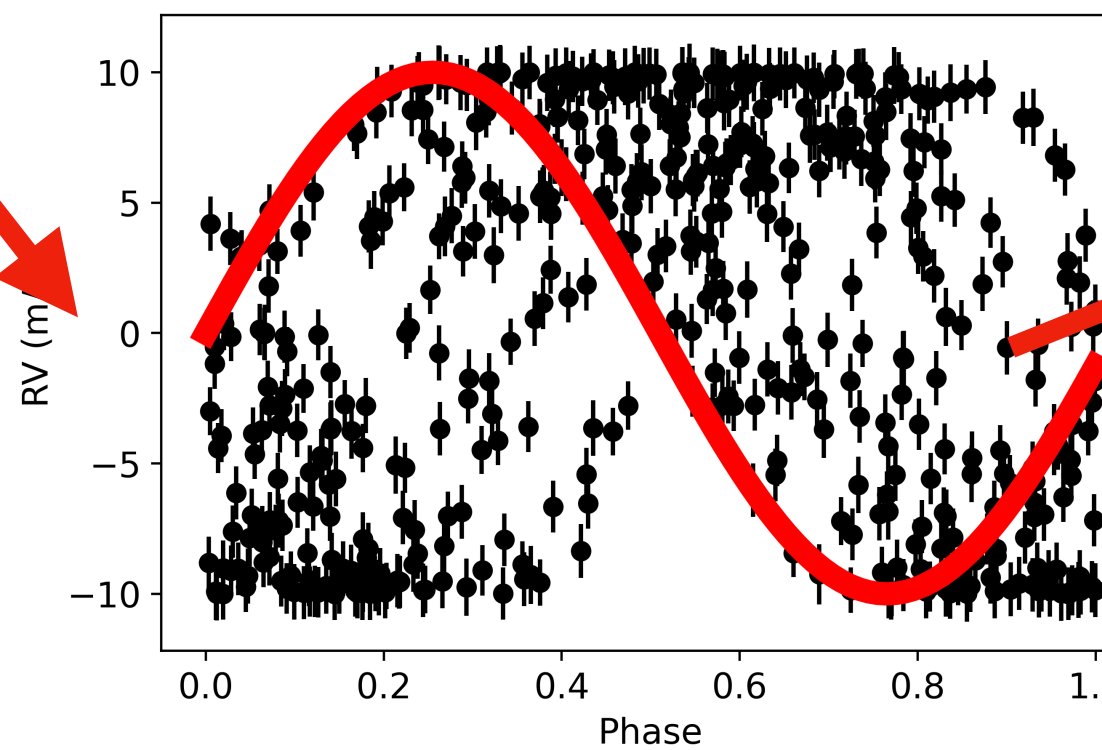
8.25 days



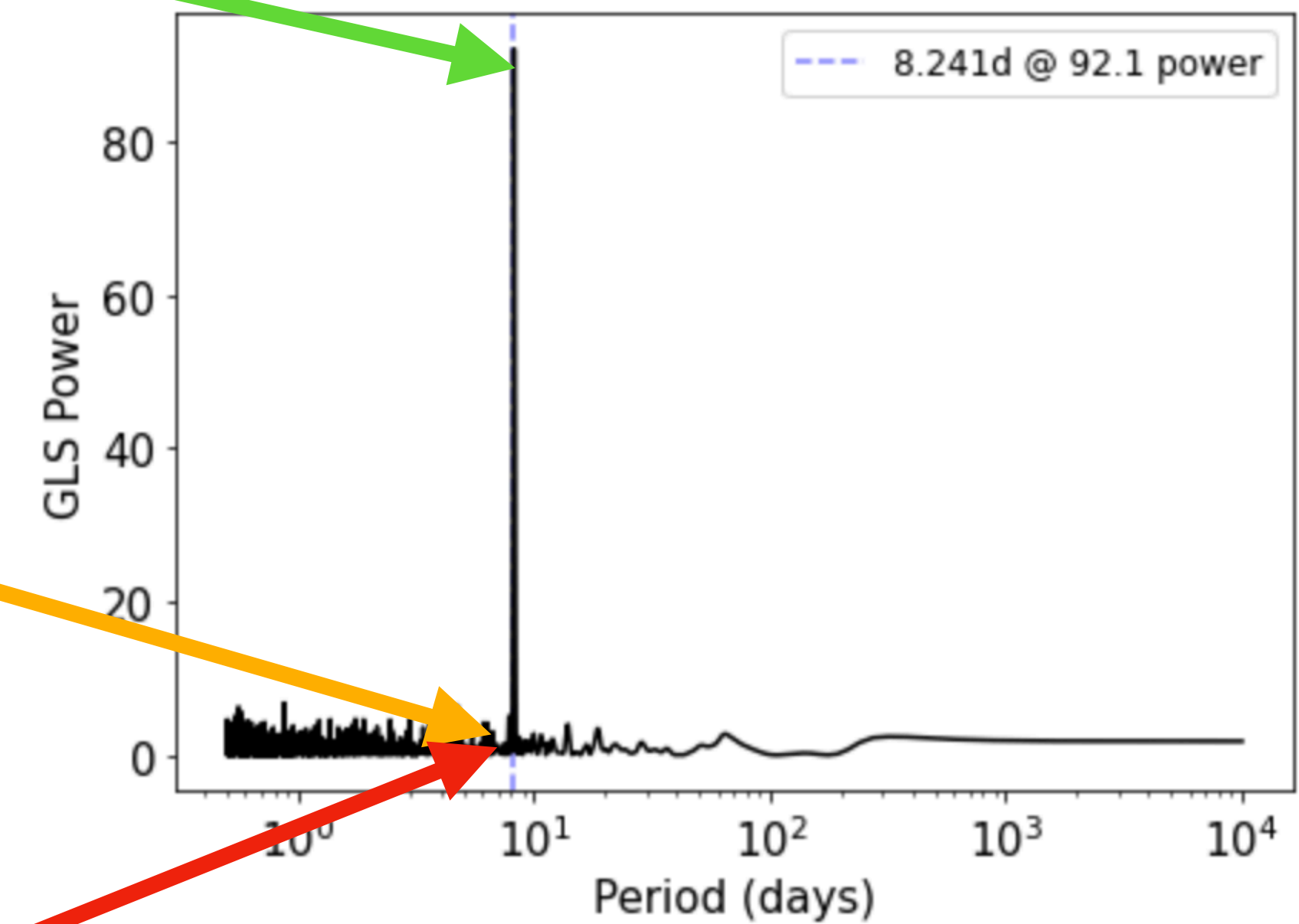
8.2 days



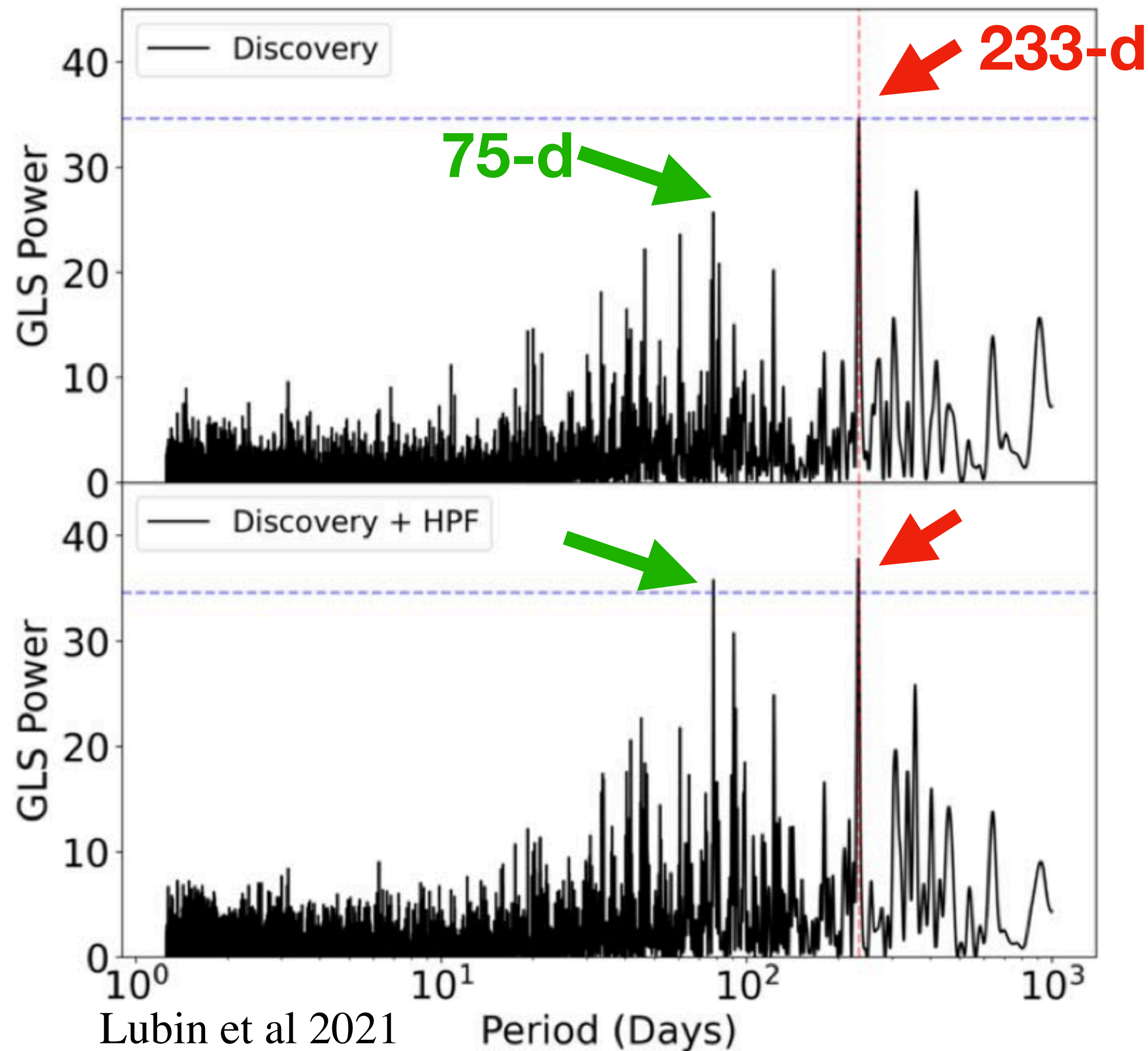
8.15 days



GLS Periodogram



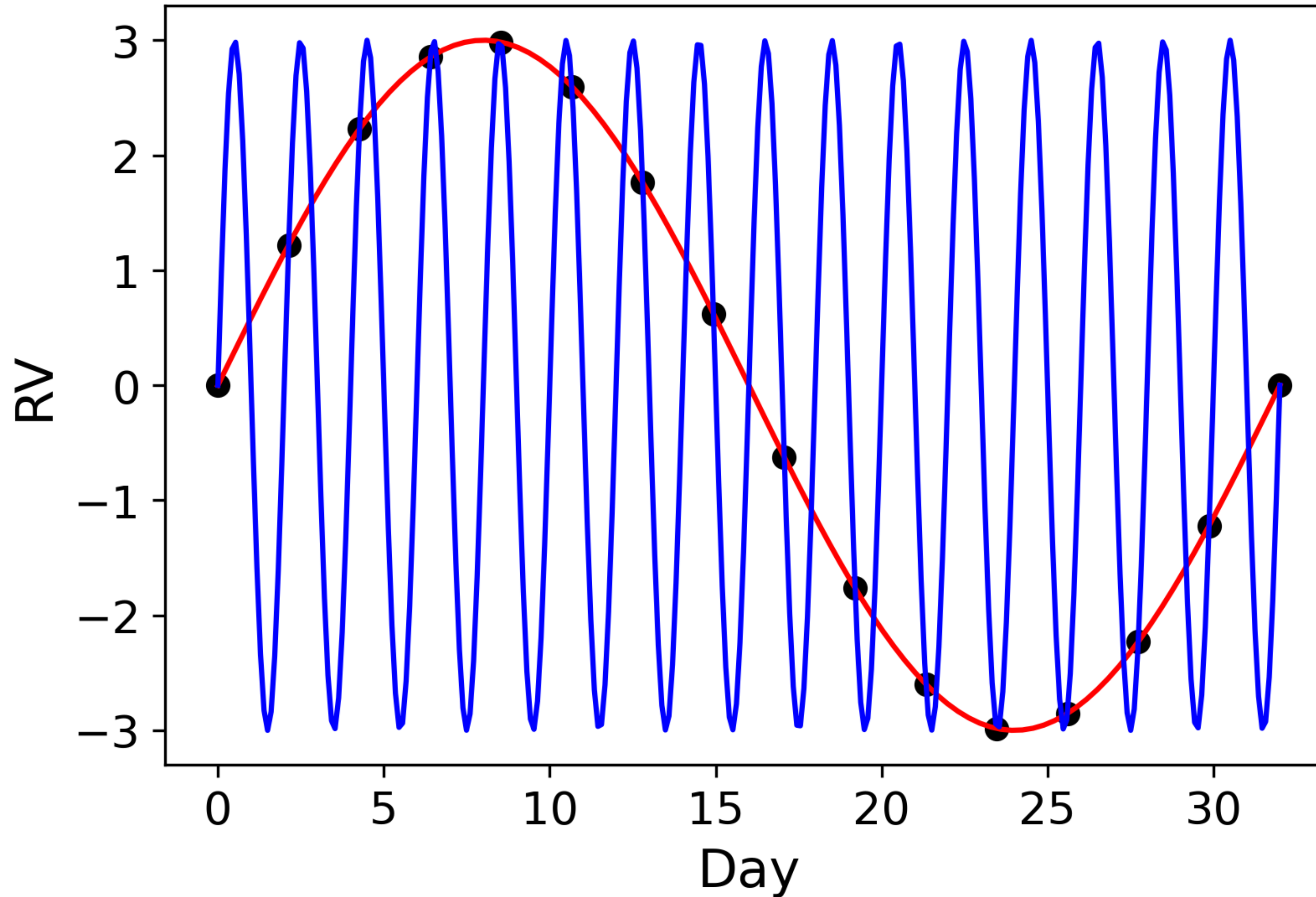
# More Data, Little Improvement



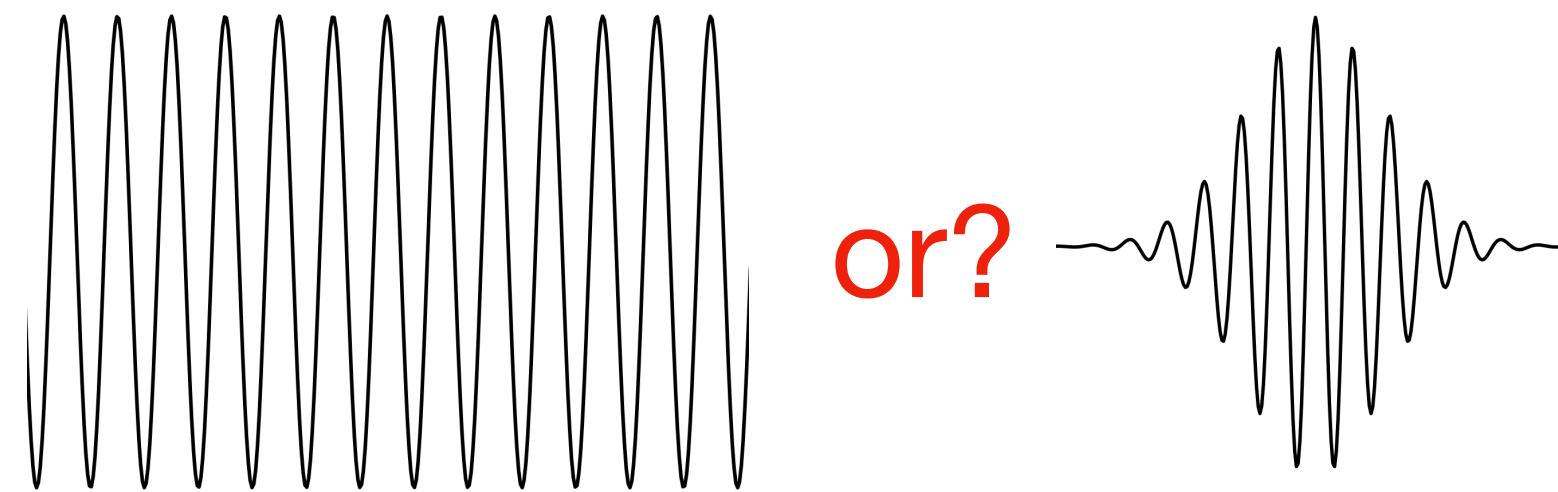
- With and Without HPF data
- 233-day peak hardly grows
- 75-day peak grows noticeably
  - 1st harmonic of the 145-day rotation period



# Aliasing



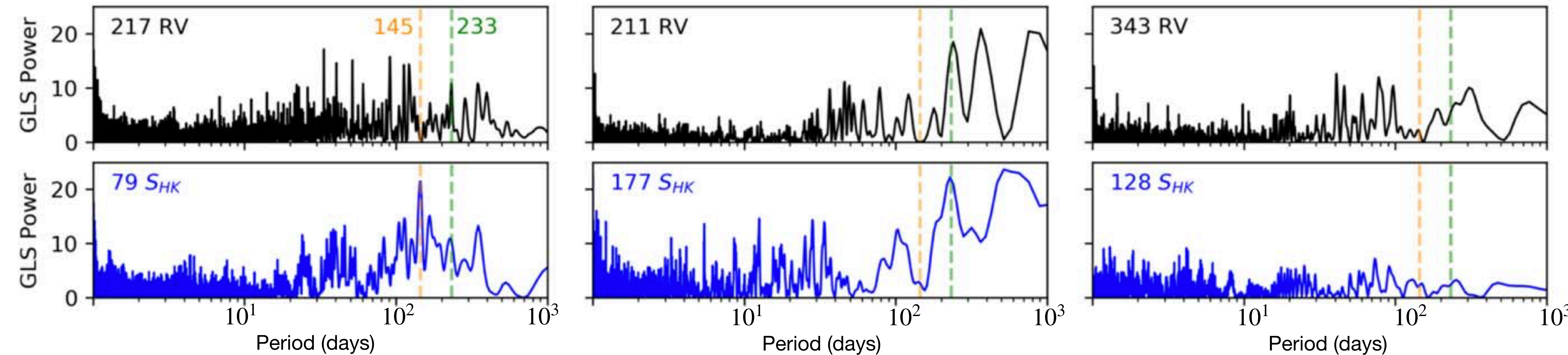
# Activity and Aliases



Pre-2011

2011 — 2013

Post-2013



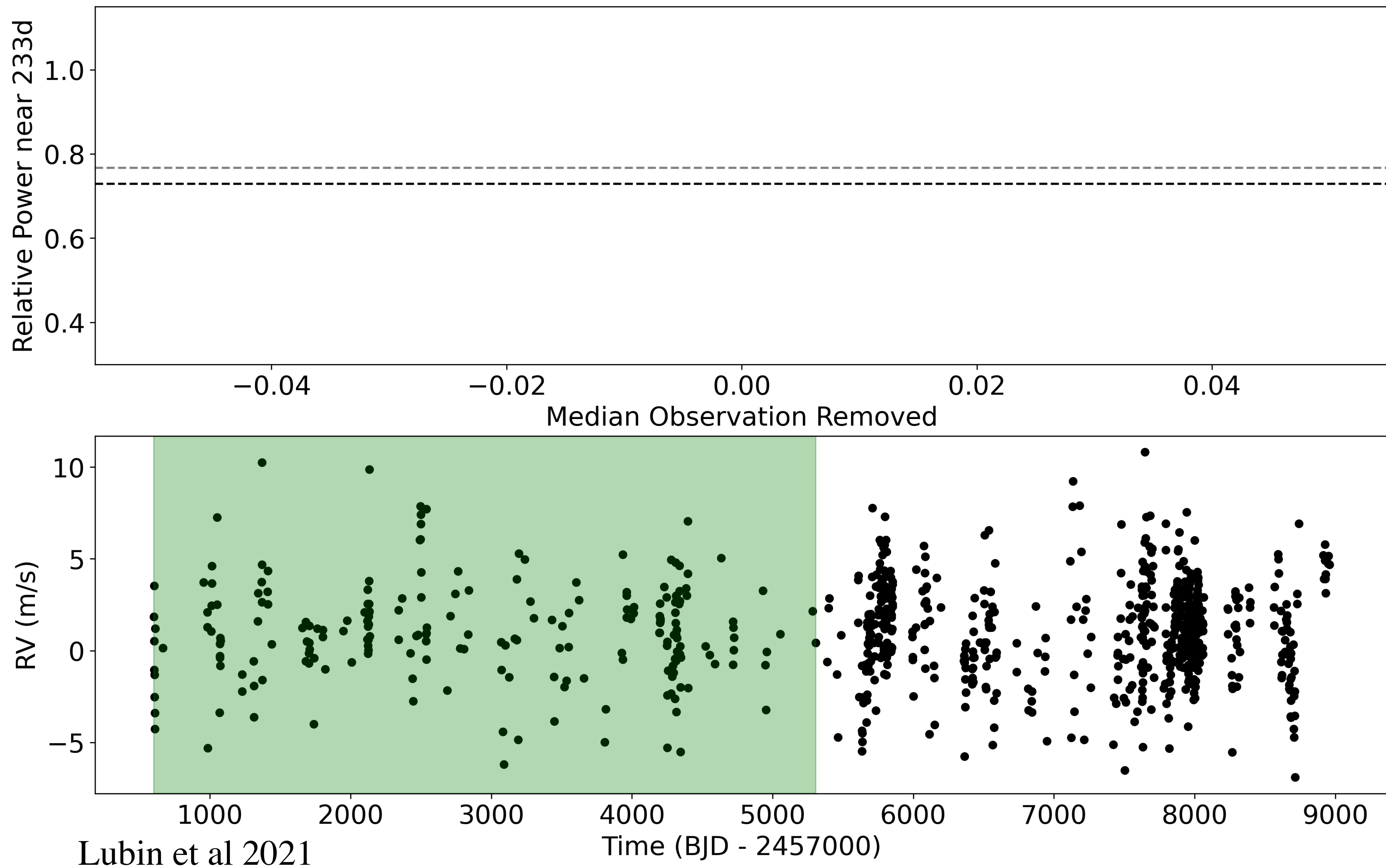
Lubin et al 2021

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Barnard's star

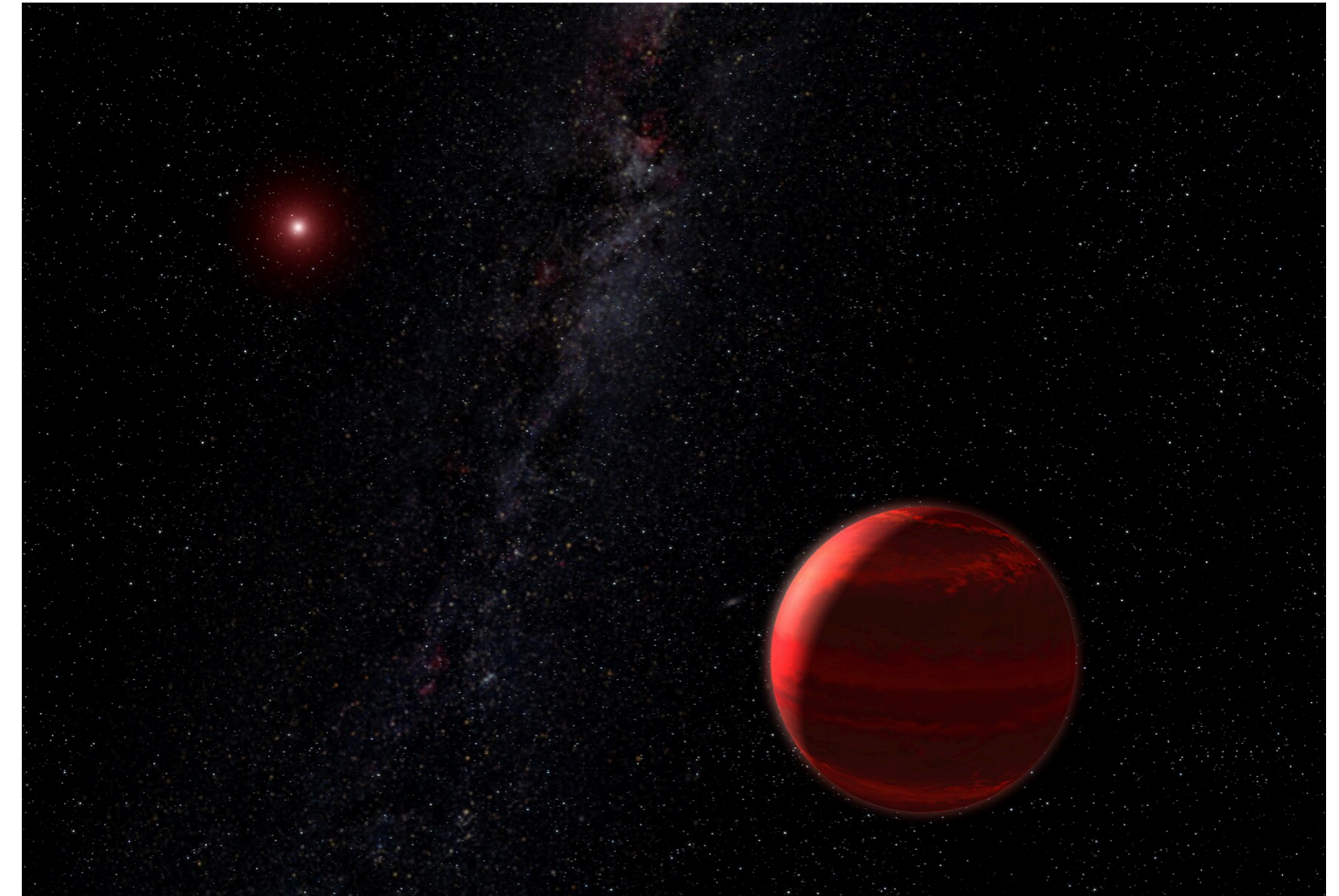


# Rolling Omission



# Conclusions

- The proposed planet is instead a false positive (also fails model comparison)
- A rotation period alias was strongest within a 1000d time window

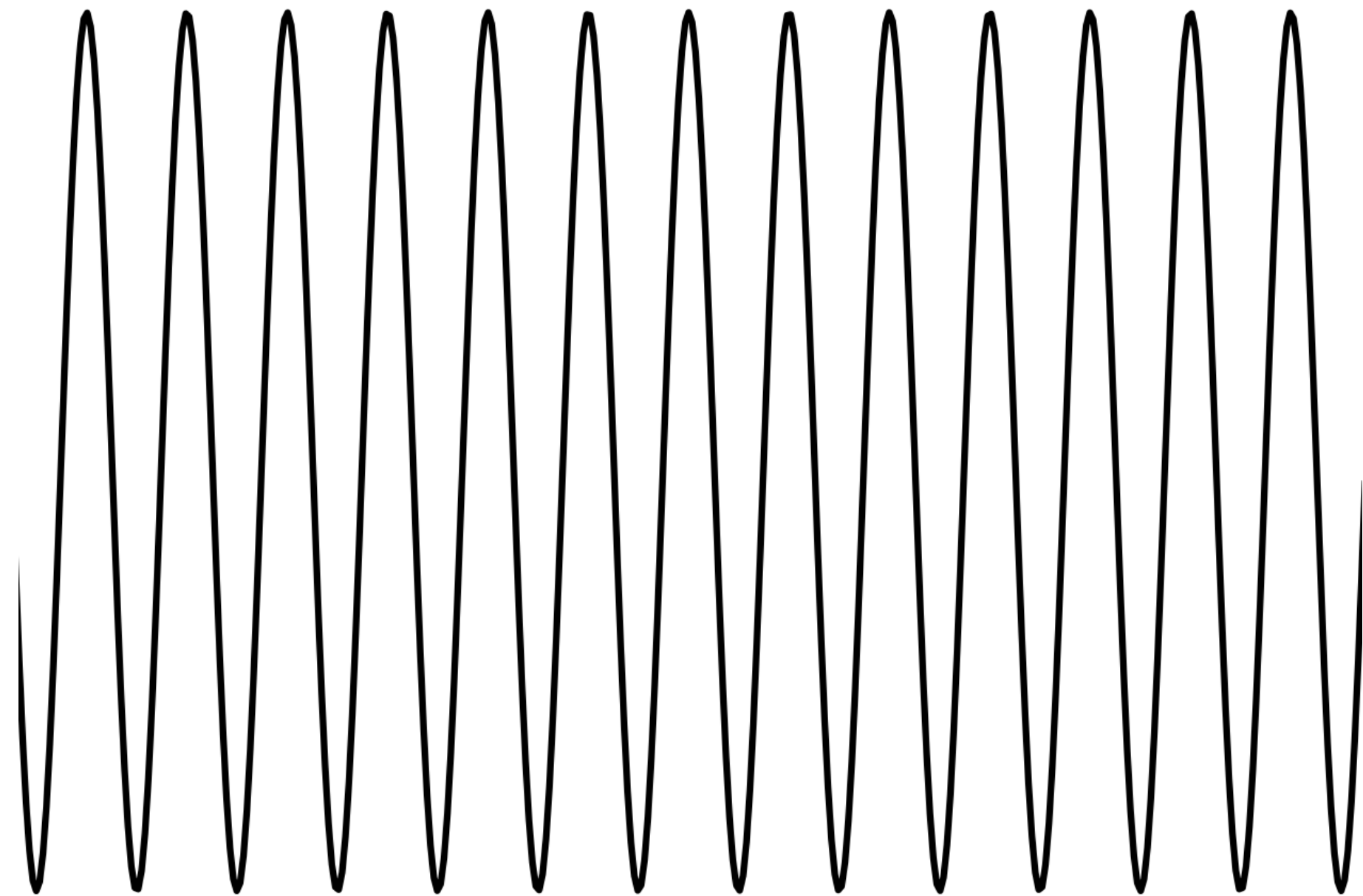


NASA, ESA and G. Bacon (STScI)

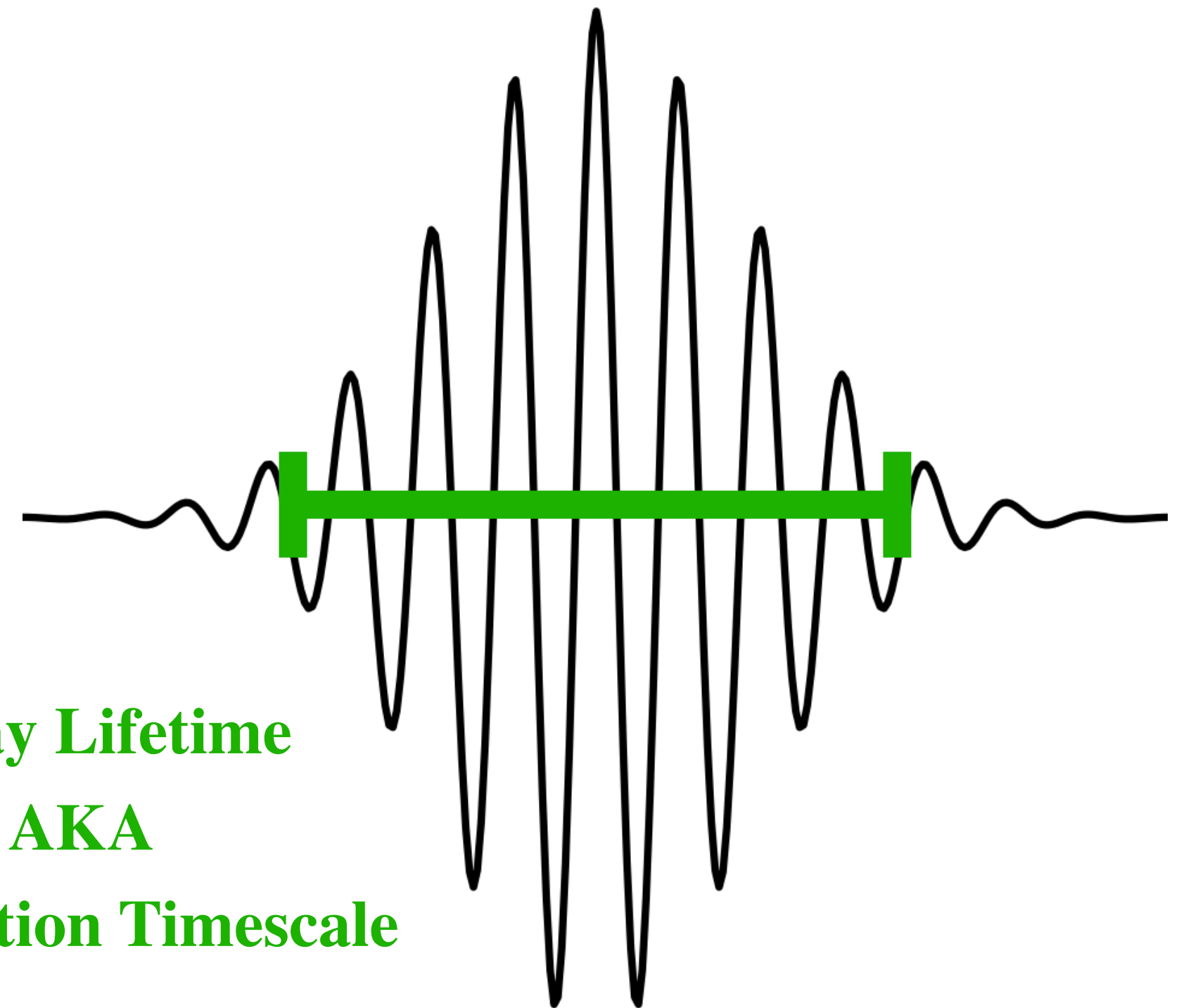


# Finding Time Localized Signals

**Strictly Periodic  
(Planet)**



**Quasi-Periodic  
(Activity)**



**Decay Lifetime  
AKA  
Apodization Timescale**

In Prep.

## Lia: Finding a Sparse Representation of an Exoplanet RV Time Series in the Time/Frequency Domain

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<sup>2</sup>*Observatoire Astronomique de l'Université de Genève, Chemin de Pegasi 51 b, 1290 Versoix, Switzerland*

$\ell_1$  Apodized

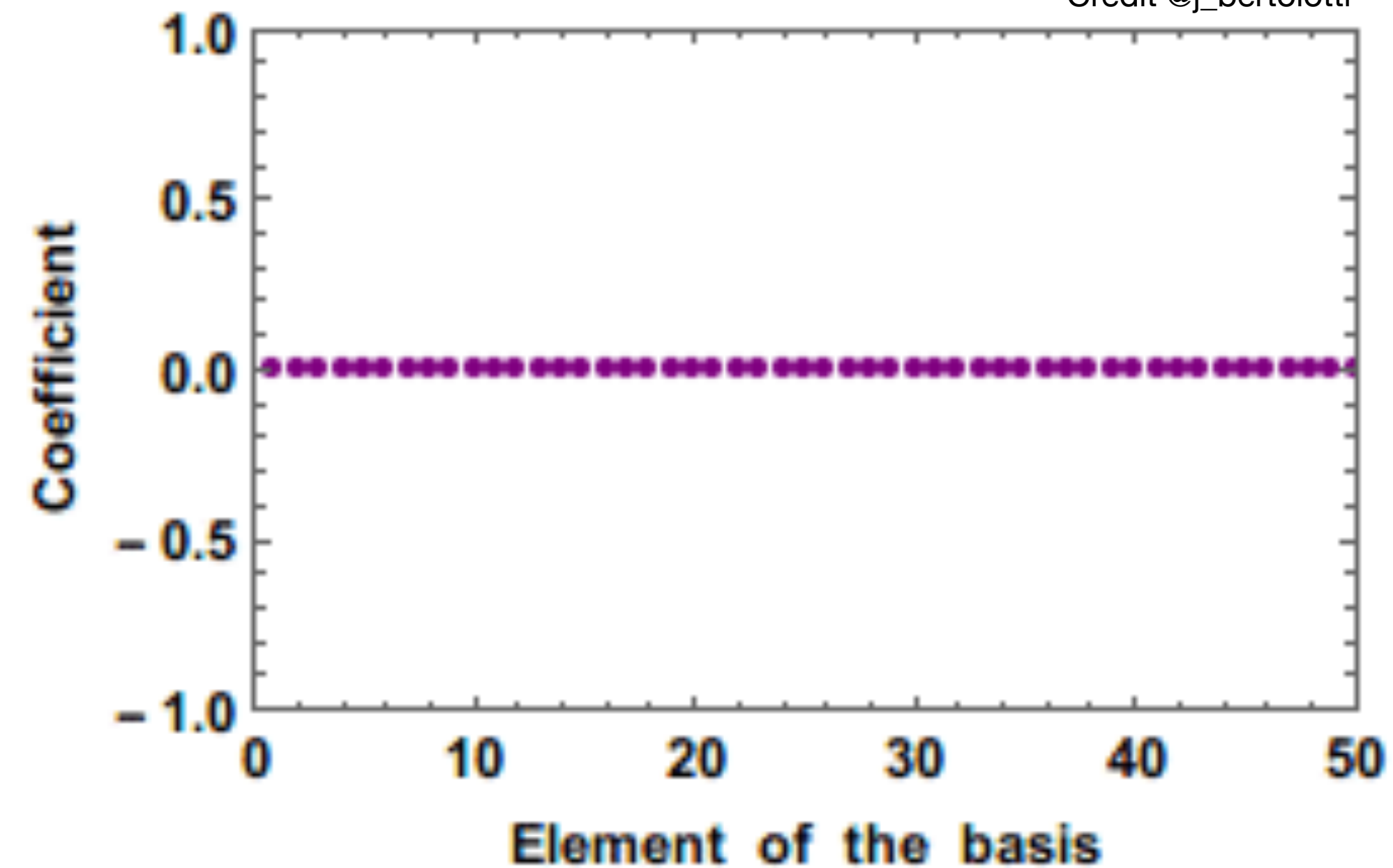
=

L1A or Lia



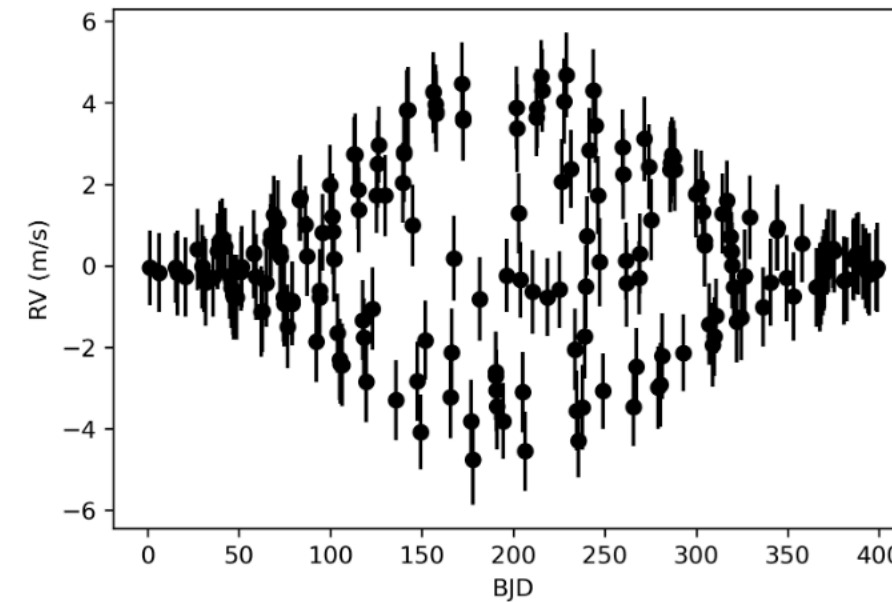
# The L1 Periodogram

Credit @j\_bertolotti

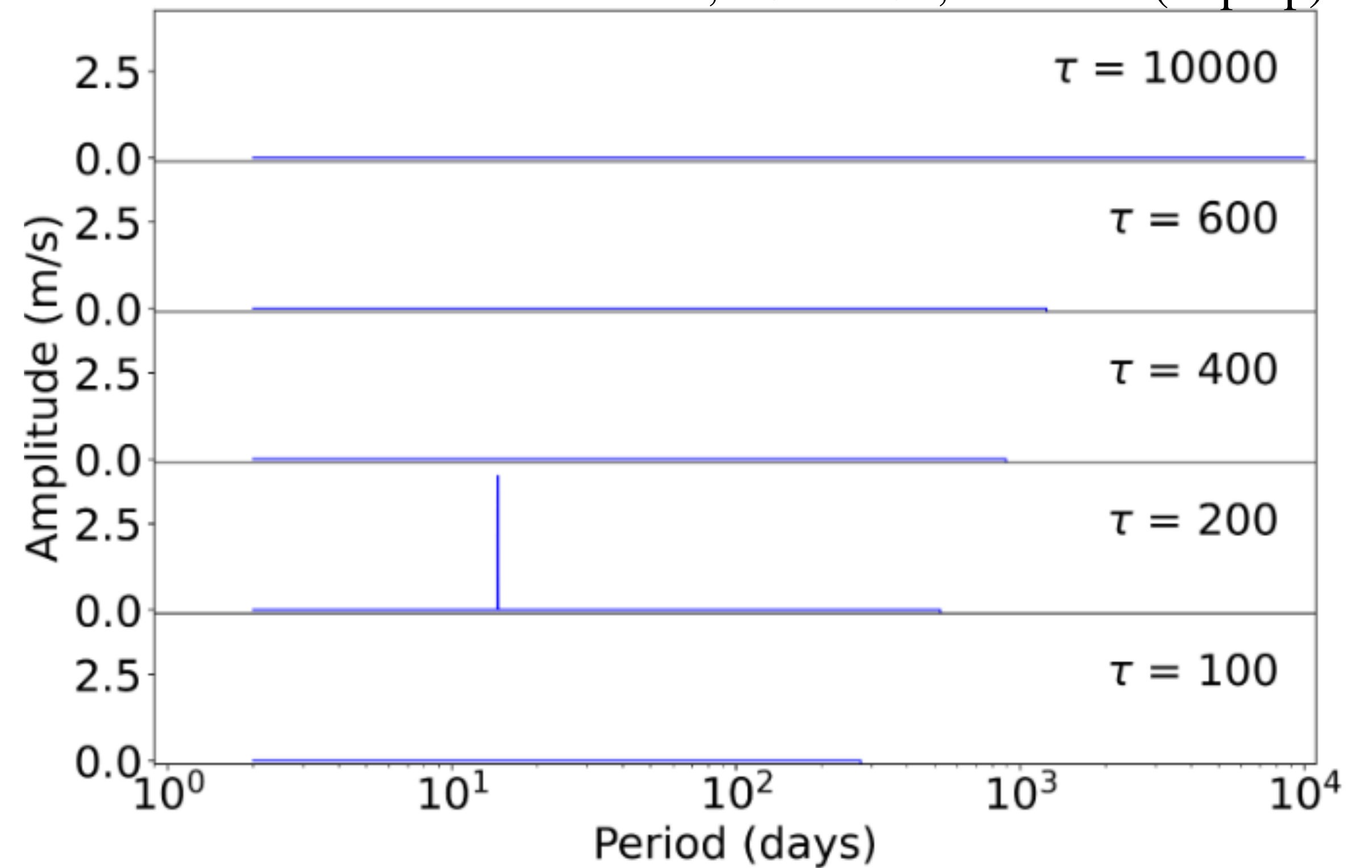
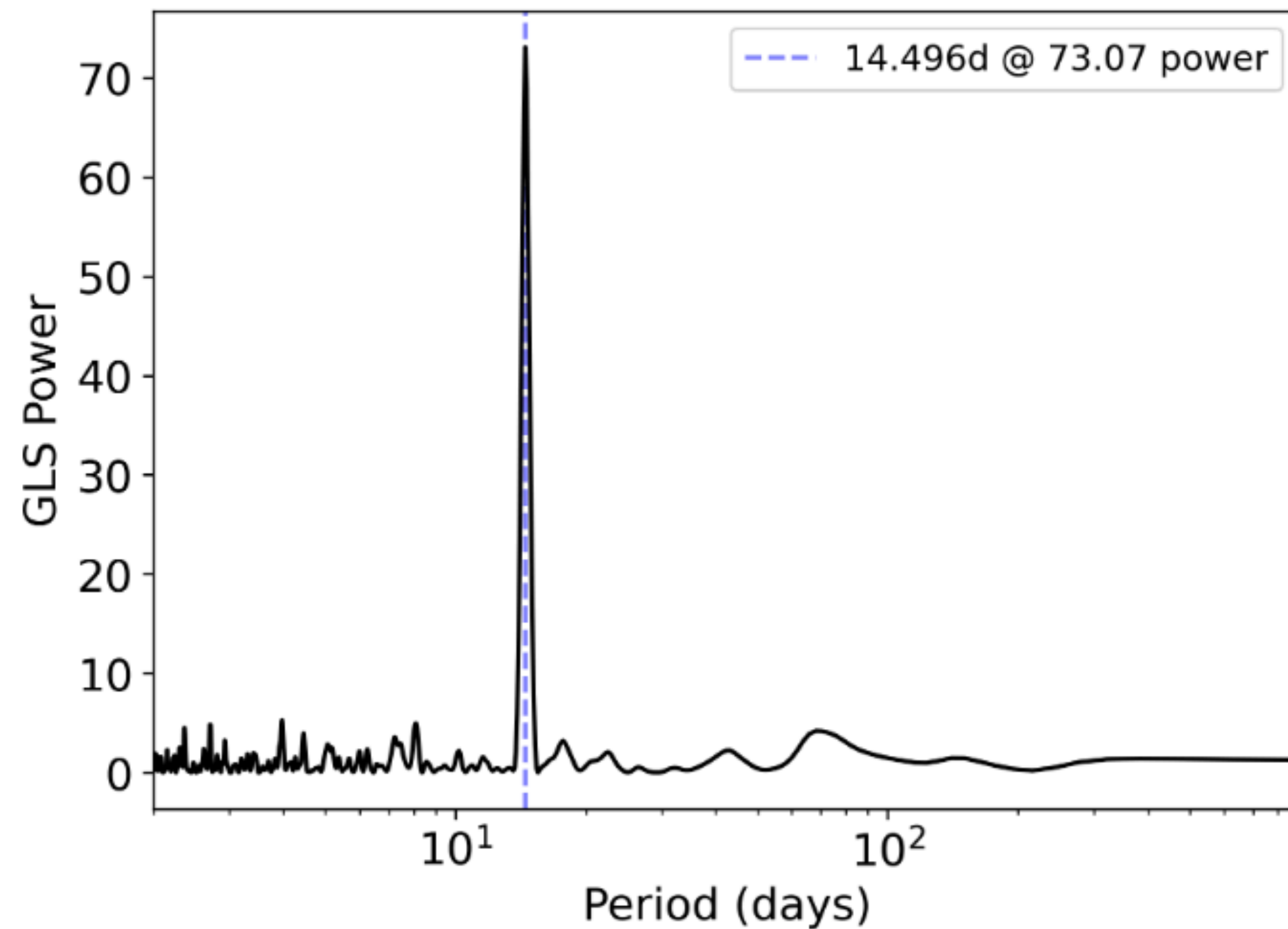


- From a large dictionary of functions (right), a small number of them might represent the data
- By turning up the strength of some functions (spikes), we can recreate the data

# Motivation

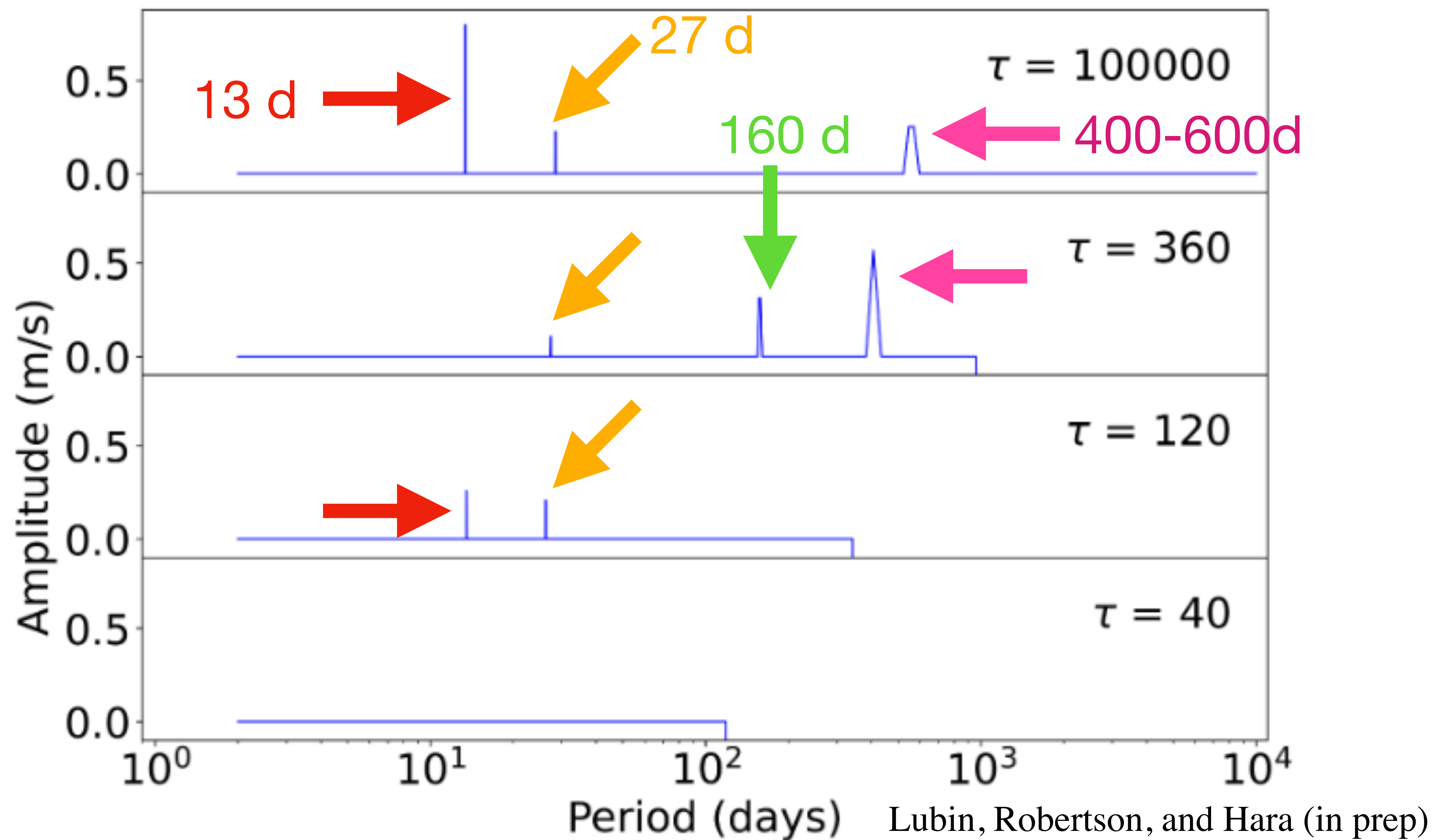


Lubin, Robertson, and Hara (in prep)

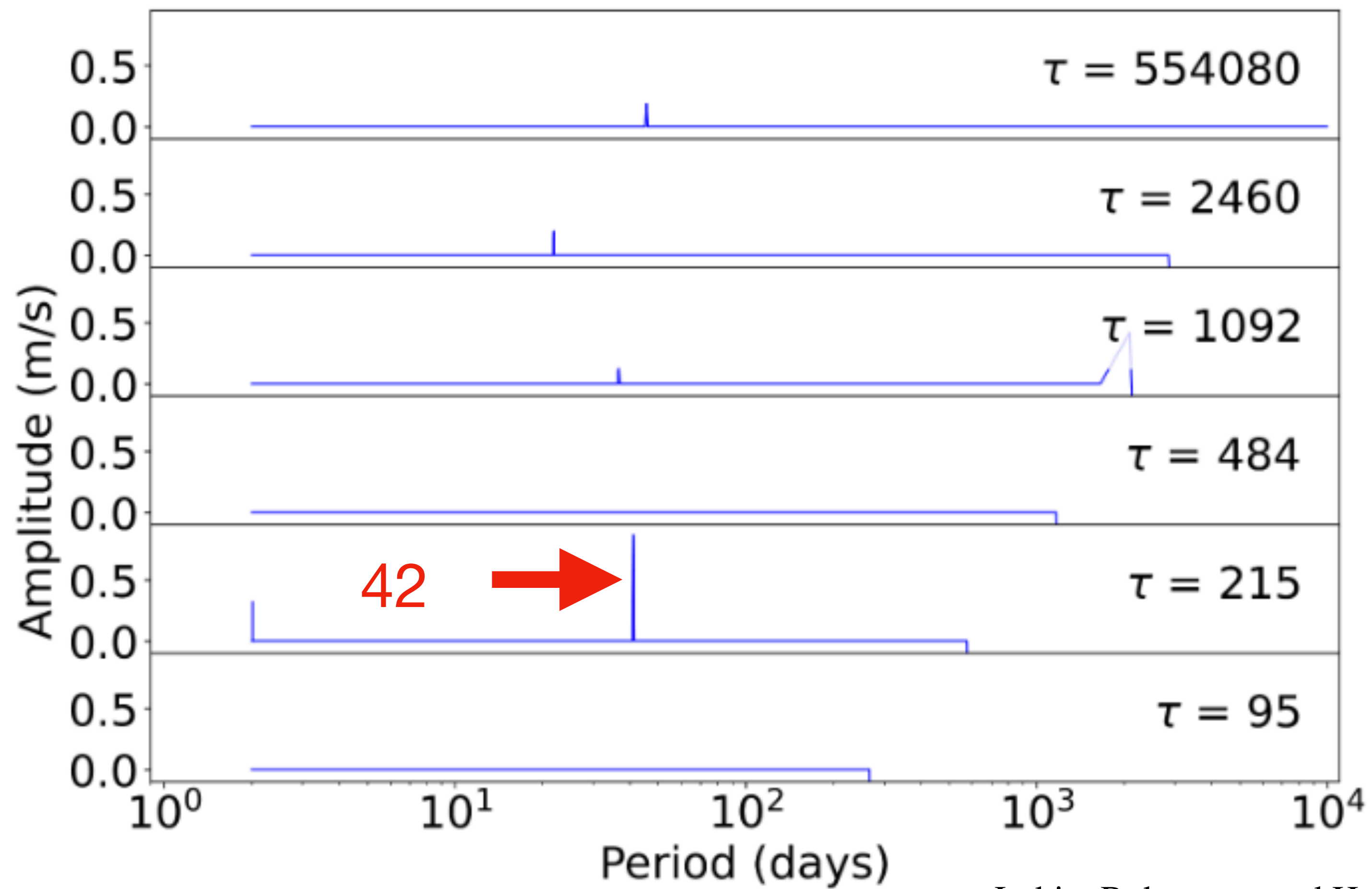
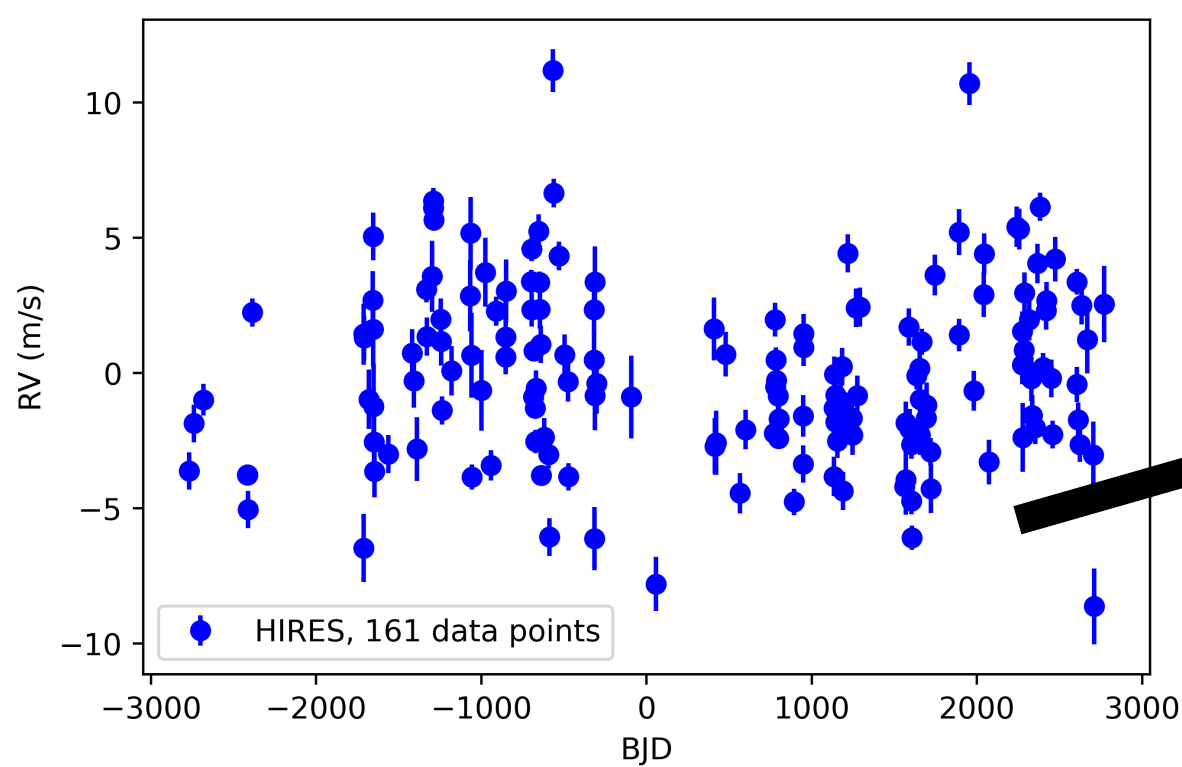
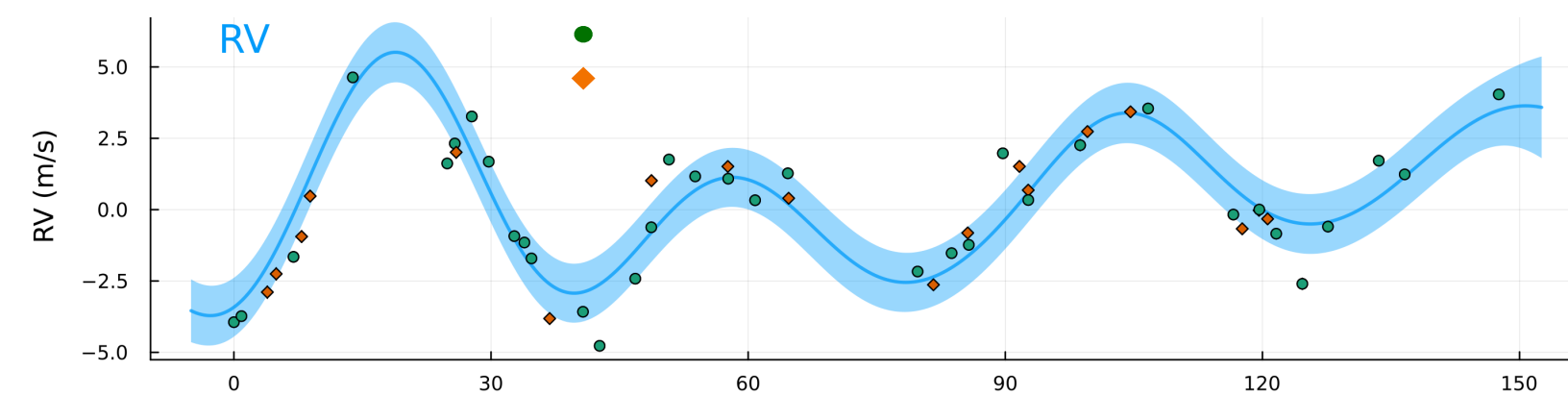




# HARPS-N Solar Data



# HD 26965 Results

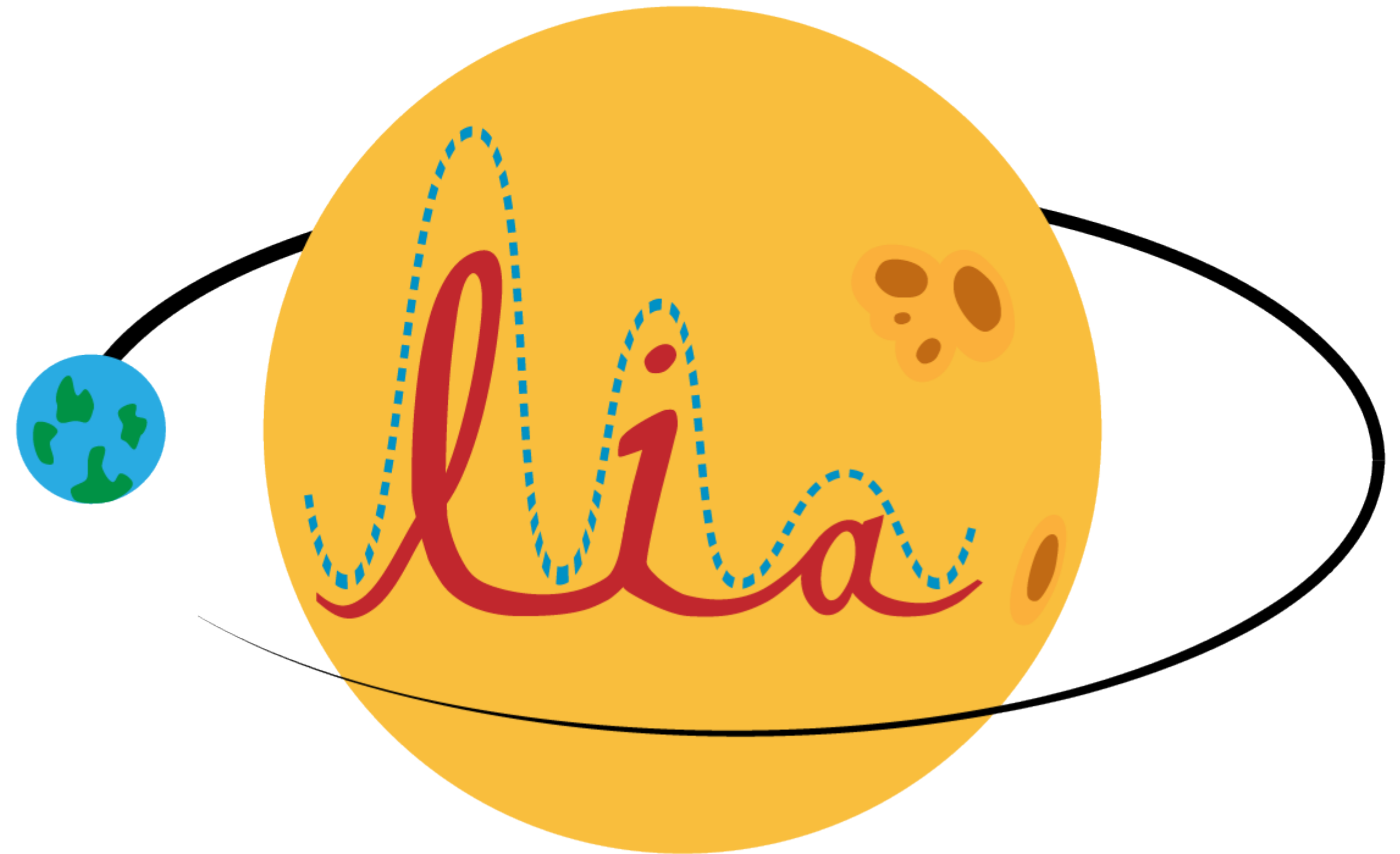


Lubin, Robertson, and Hara (in prep)



# Conclusions

- Lia is a new, fast and flexible framework, written in python with documentation and tutorials for all to use
- New software techniques can identify and characterize quasi-periodic signals
- What will we learn by looking at the data in new ways?



Thank you to Jacob Luhn for helping design and realize this logo!

# Conclusions

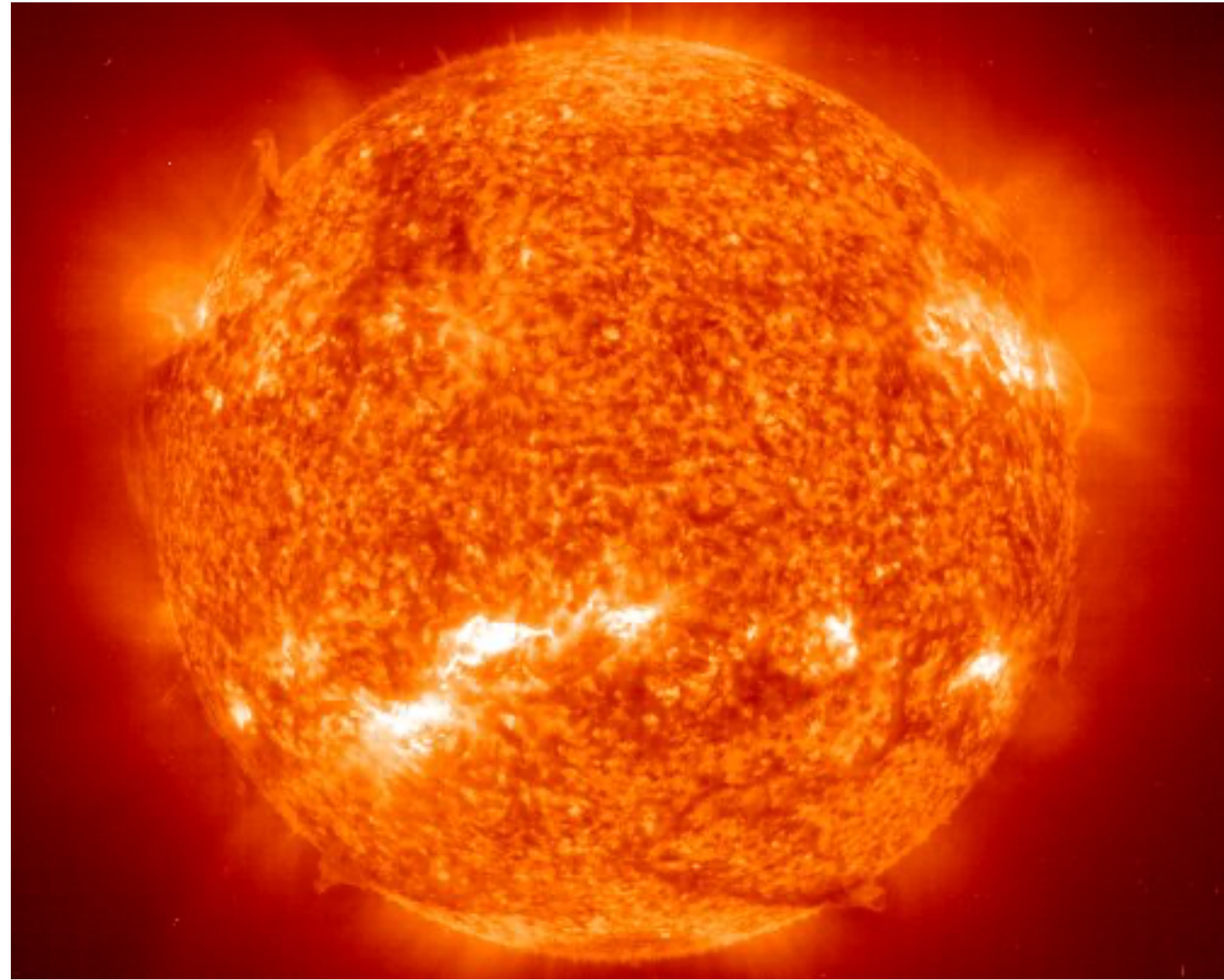


Image Credit: EIT - SOHO Consortium / ESA / NASA

Stellar Activity makes planet detection, and therefore mass measurement, more difficult

With sophisticated techniques, Stellar Activity is no longer only nuisance noise, rather a measurable signal

**Quasi-periodic signals are distinguishable!**



# Thank you!



**@LubysLemmas**