Detecting Jupiter Analogues

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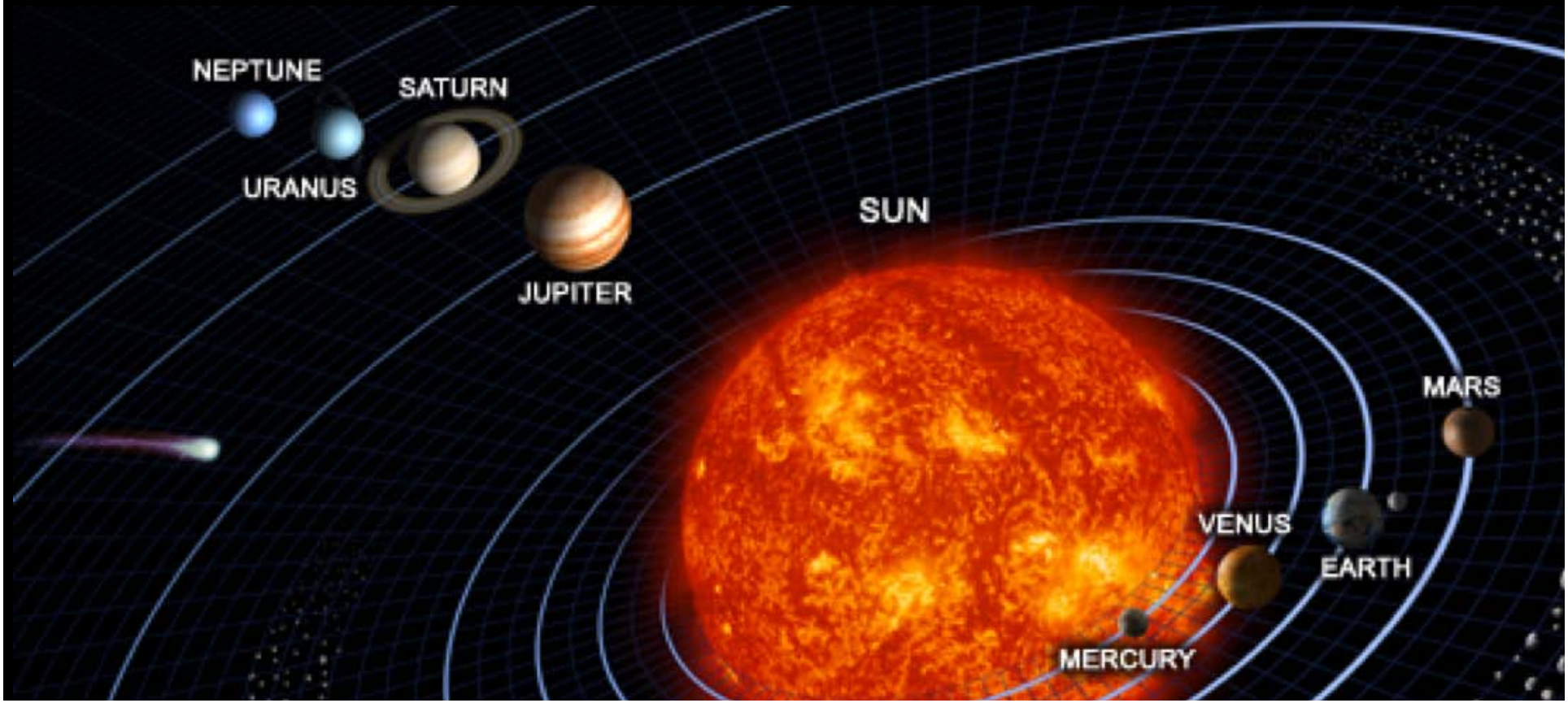
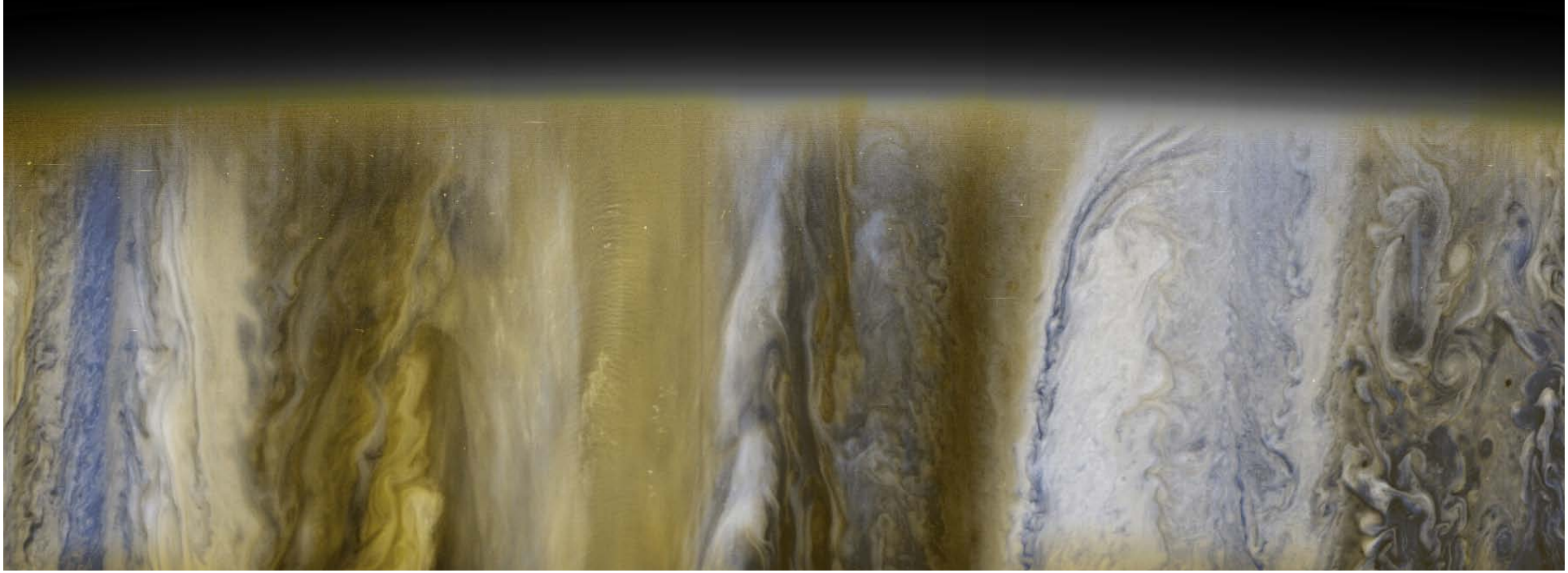
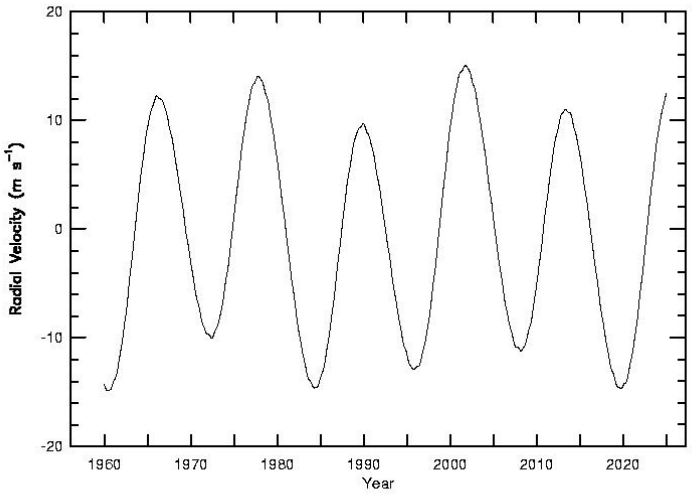
- Are there other solar systems like ours? – Solar System structure and evolution
- 12 years of observations
- How well can we detect Jupiter analogues?



Sample

All data was collected at the McDonald Observatory 2.7m Harlan J. Smith Telescope using the Tull High Resolution Spectrograph from 1998 to 2011. Our sample consists of 81 stars that do not have known companions. They have luminosity classifications near that of our sun (no giant stars), and at least a 4330 day (one Jupiter period) observation time line. Outlying observations and some with significantly high error have been removed on an individual, star-by-star basis. Linear or quadratic trends produced by binary stars have been removed when necessary.





Above, the radial velocity of the Sun from a point co-planar in our solar system.

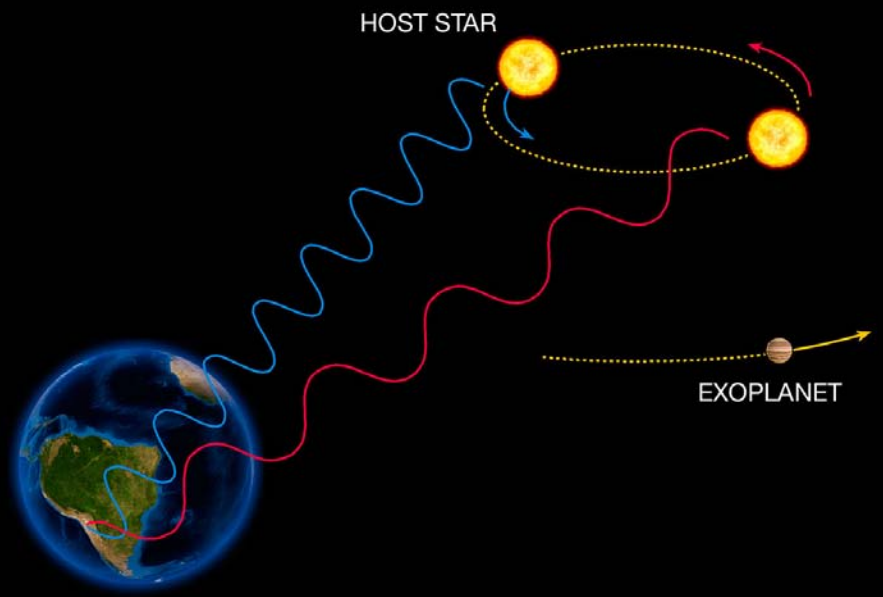
K (Jupiter) = 12.4 m/s
P (Jupiter) = 12 years
a (Jupiter) = 5 A.U.

The smaller perturbation in the signal is caused by Saturn.

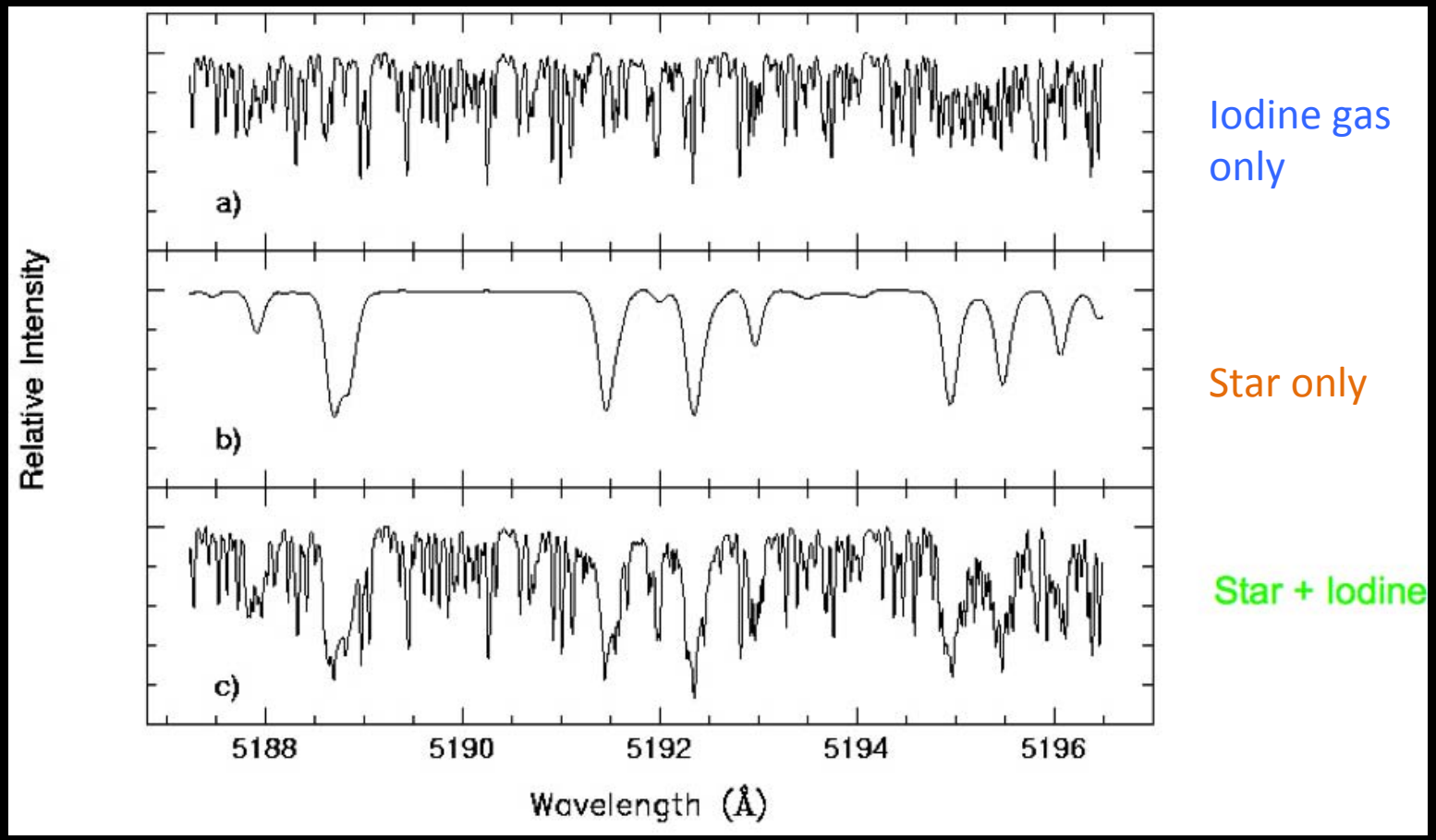
Radial Velocity

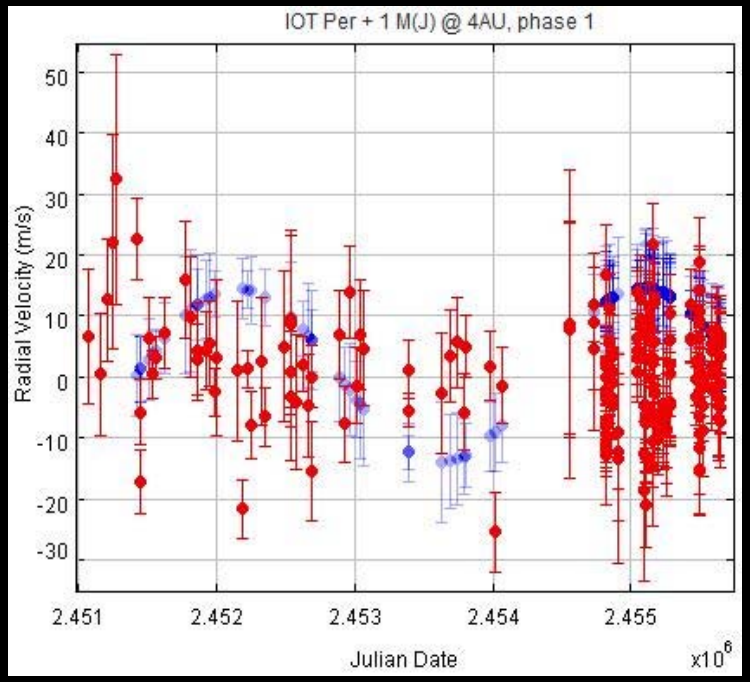
Doppler Shift Equation $F/F_{0} = c/(c \pm v_s)$

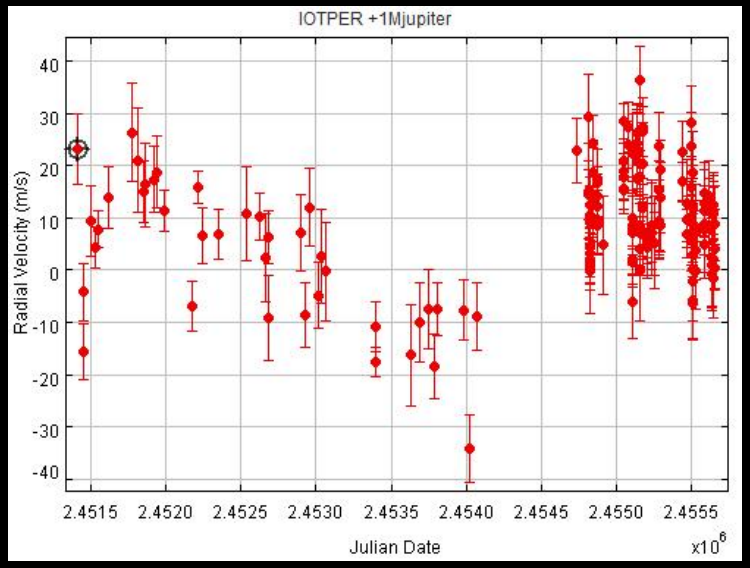
$K \equiv$ radial velocity semi-amplitude $= \frac{2\pi a \sin I}{P\sqrt{(1-e^2)}}$

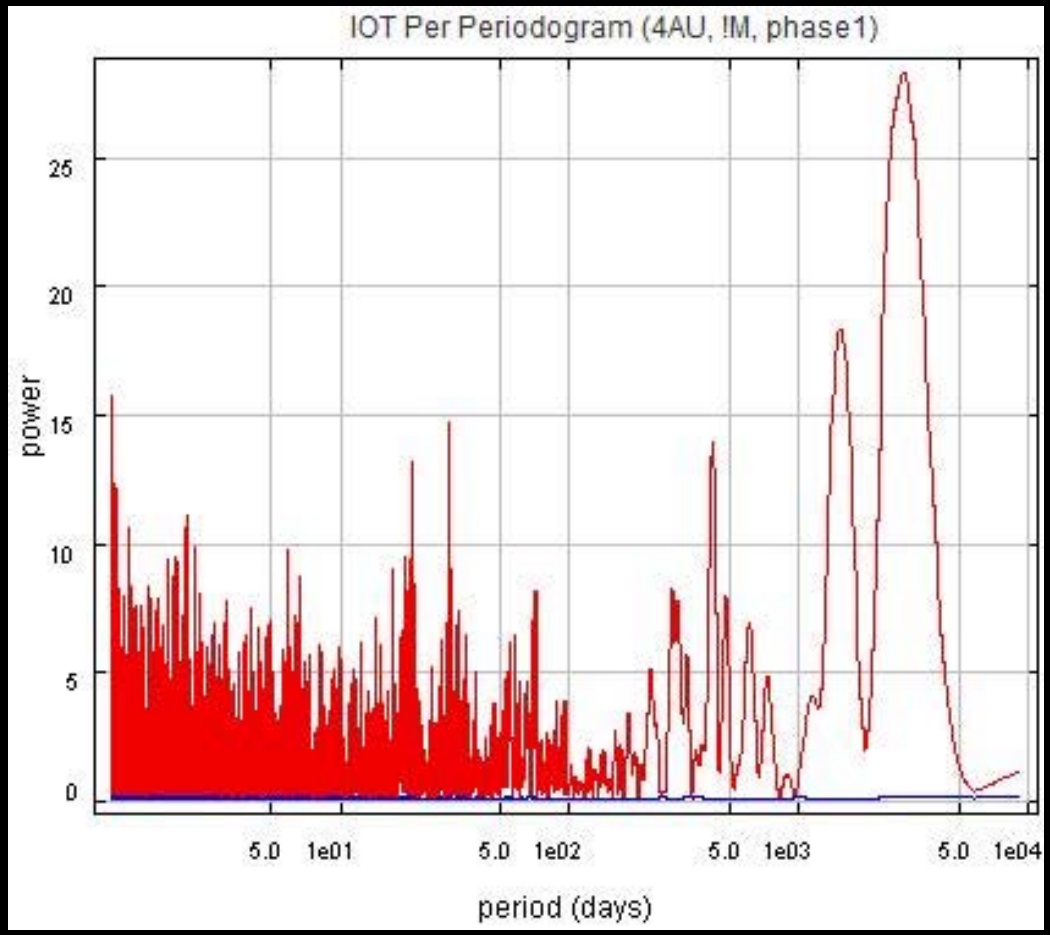


Star + Iodine = High Precision (a few m/s) Radial Velocity Measurements



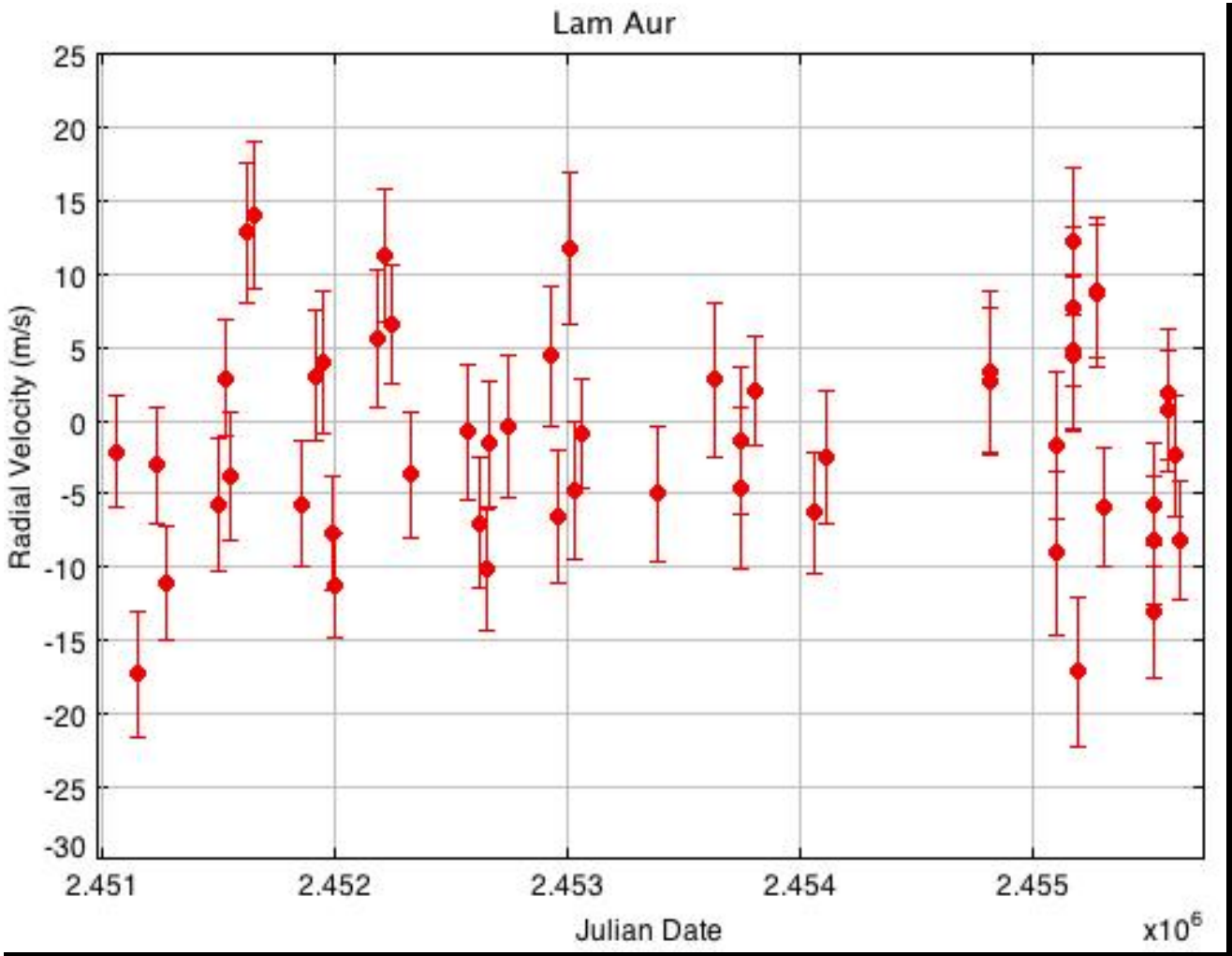






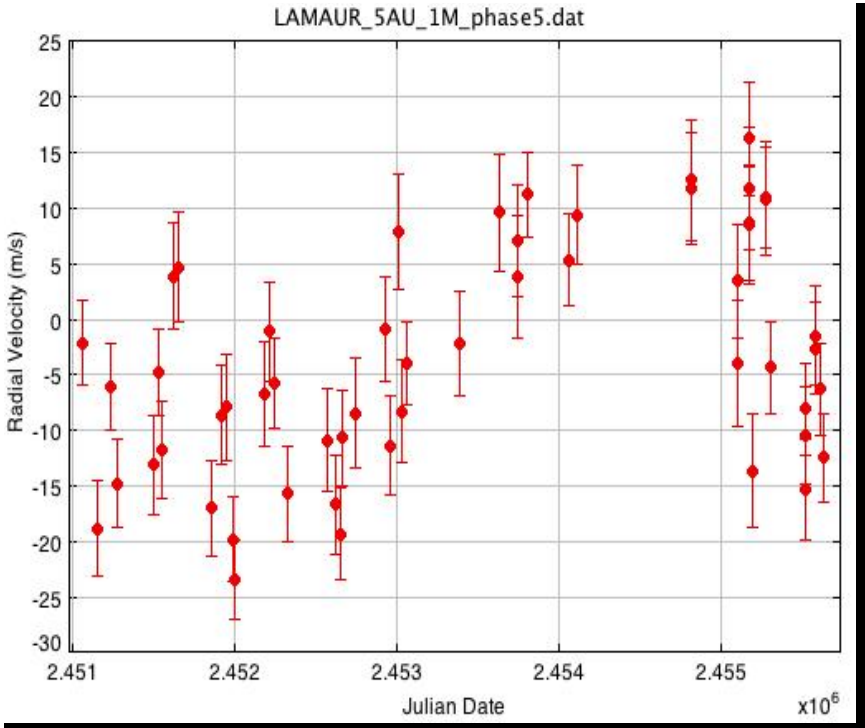
1. Add a “Jupiter signal” to the data.
   - Jupiter Signal=
   - 4 and 5 AU
   - 1, 2, 3, and 4 M (Jupiter)
   - 8 Phases

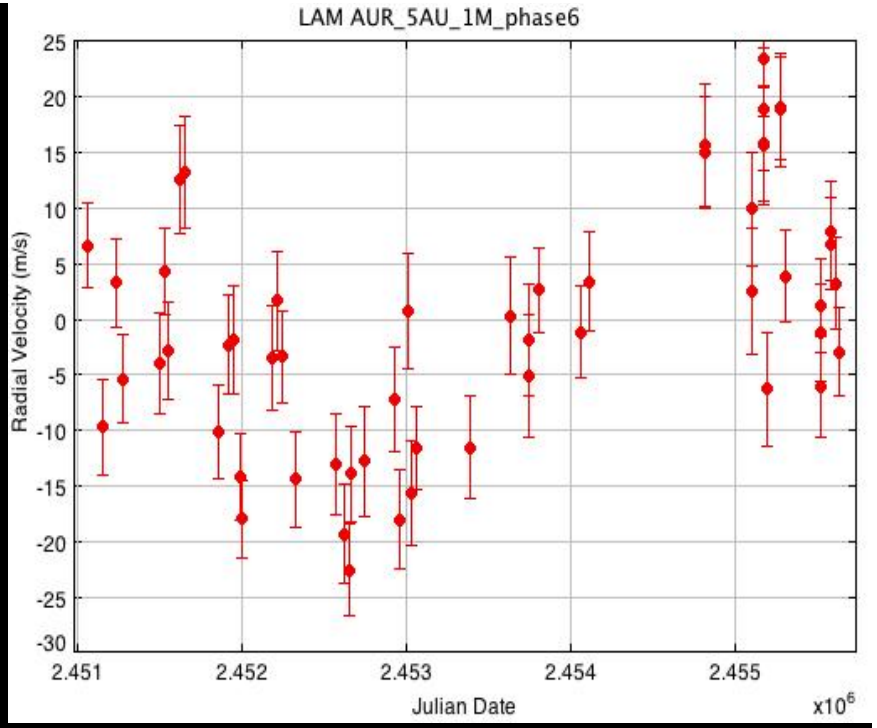
2. Detect period of injected signal with periodogram

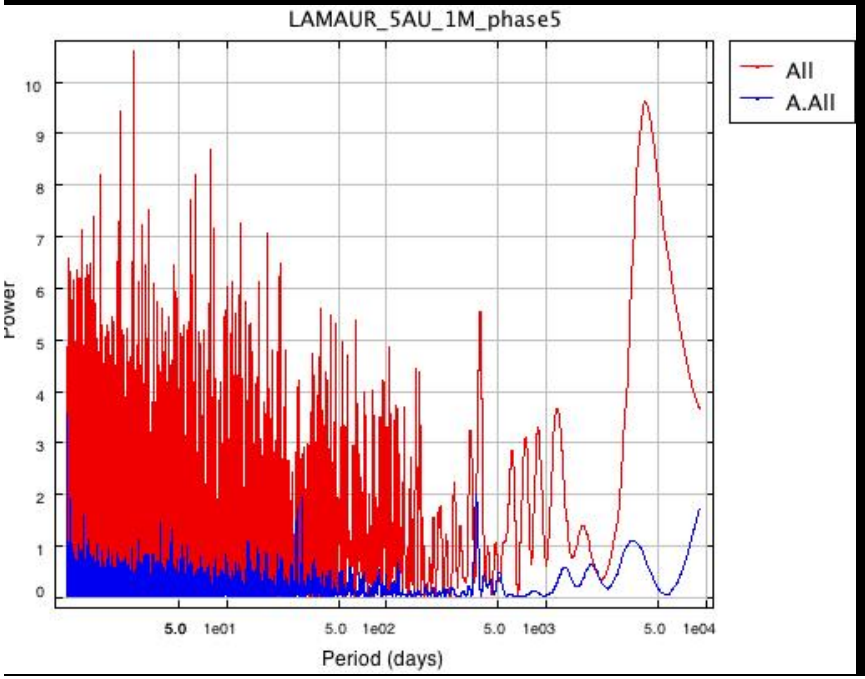


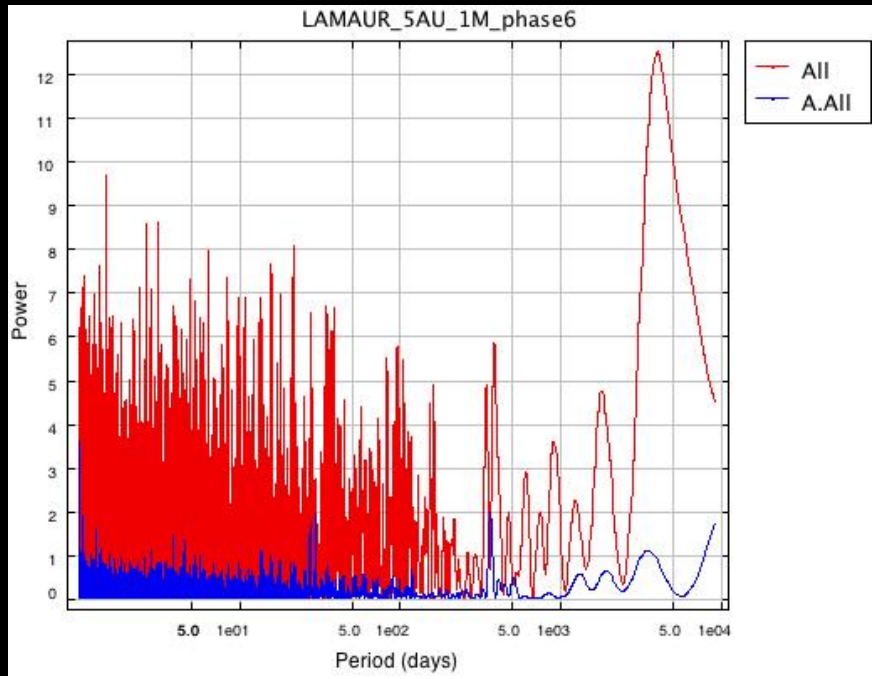
Injected Keplerian Orbit Parameters

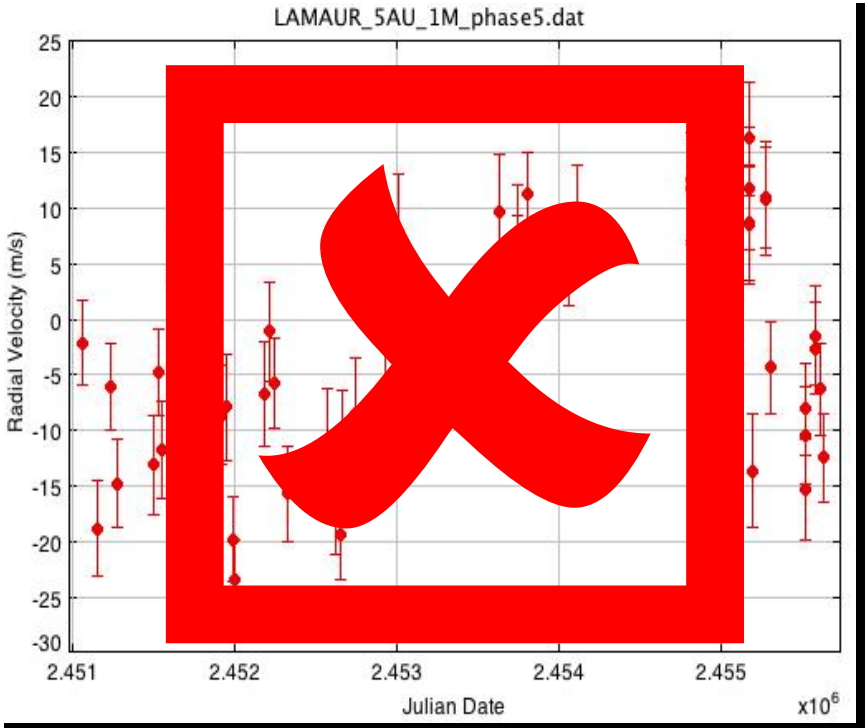
5AU	4AU
T= 4330 days	T=2930
v(1M)=12.4	v(1M)=14.2
v(2M)=25	v(2M)=28.4
v(3M)=37	v(3M)=42.6
v(4M)=51	v(4M)=56.8


LAMAUR_5AU_1M_phase5.dat
Radial Velocity (m/s)
Julian Date
x10^6


LAM AUR_5AU_1M_phase6
Radial Velocity (m/s)
Julian Date
x10^6


LAMAUR_5AU_1M_phase5
All
A.All
Period (days)


LAMAUR_5AU_1M_phase6
All
A.All
Power
Period (days)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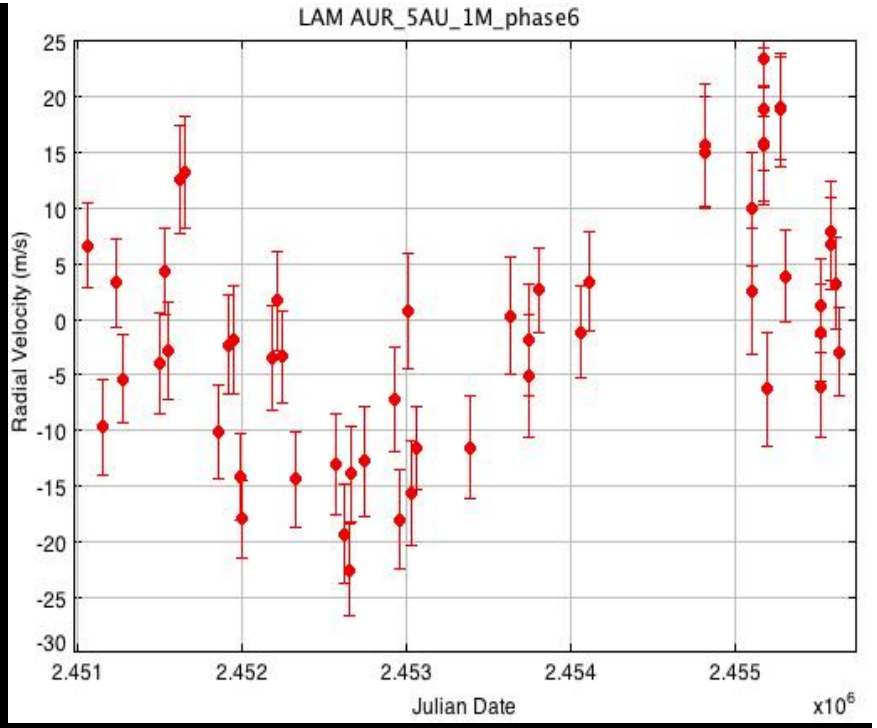
Julian Date
x10^6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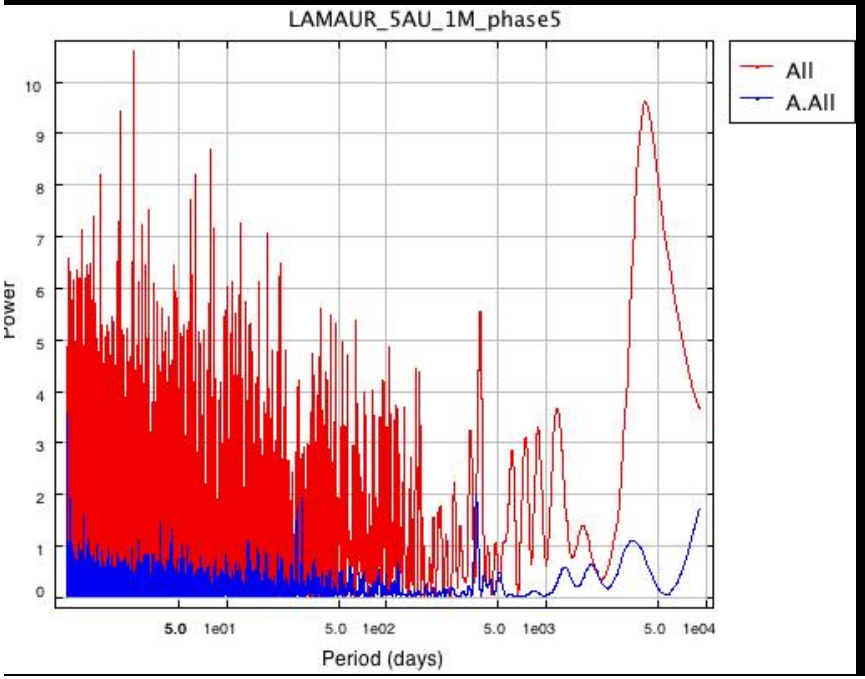
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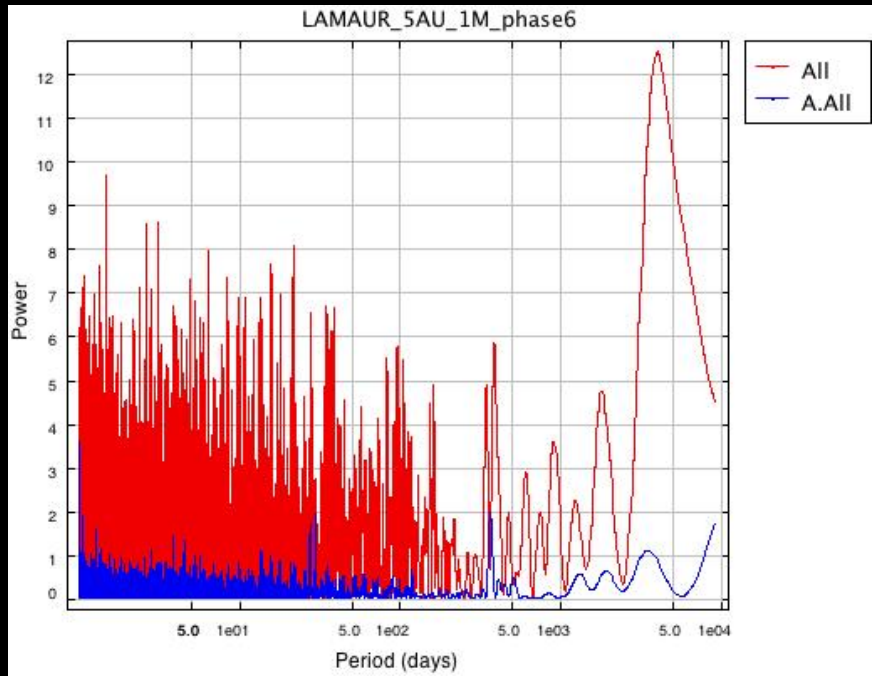
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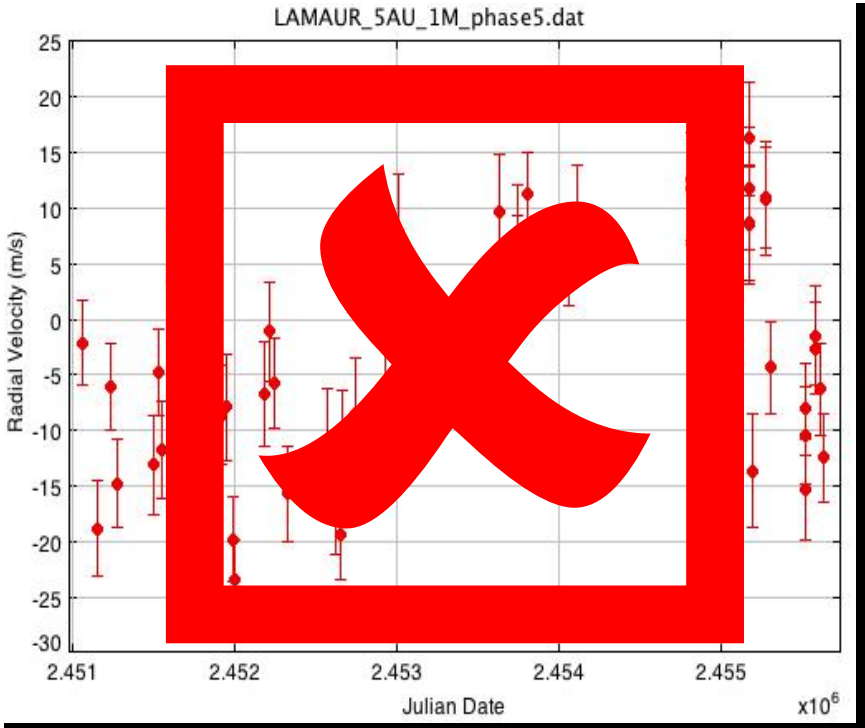
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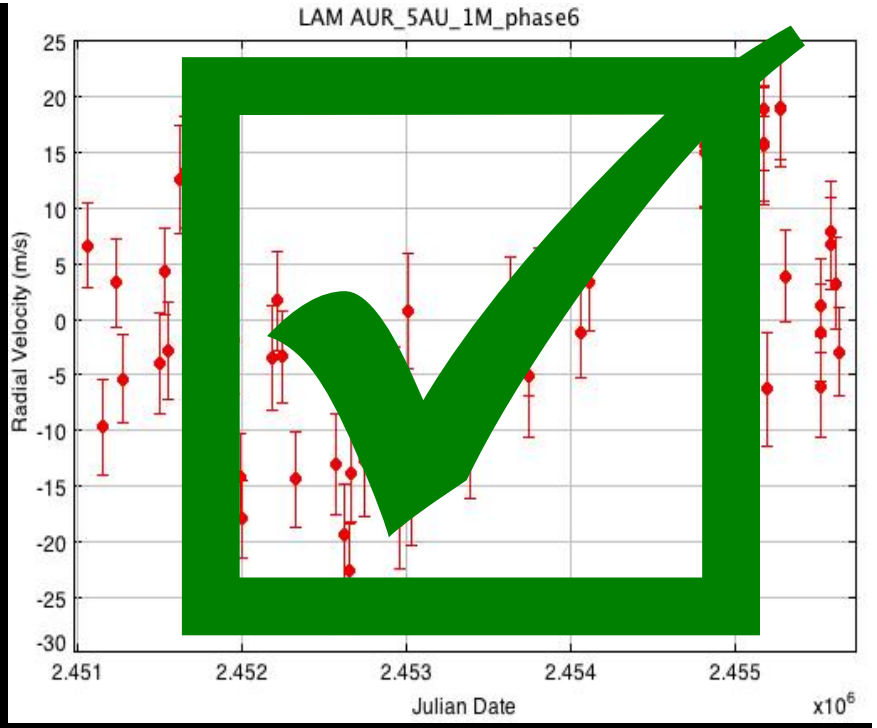
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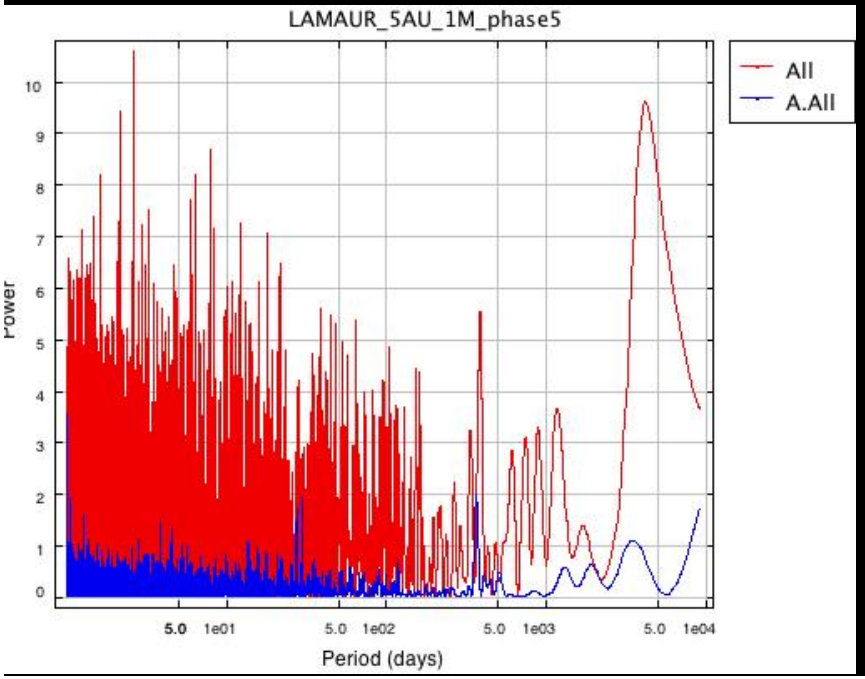
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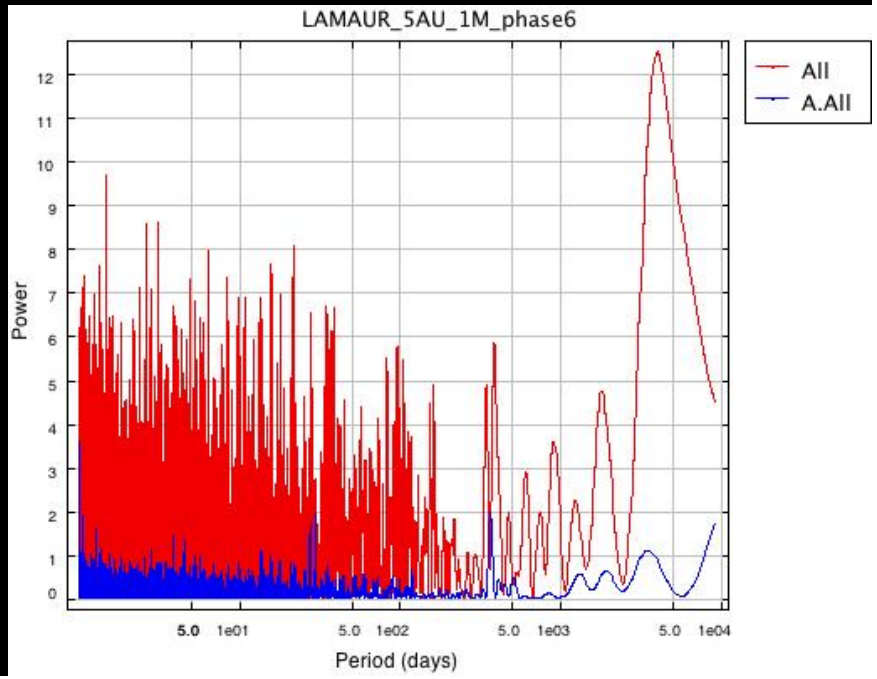
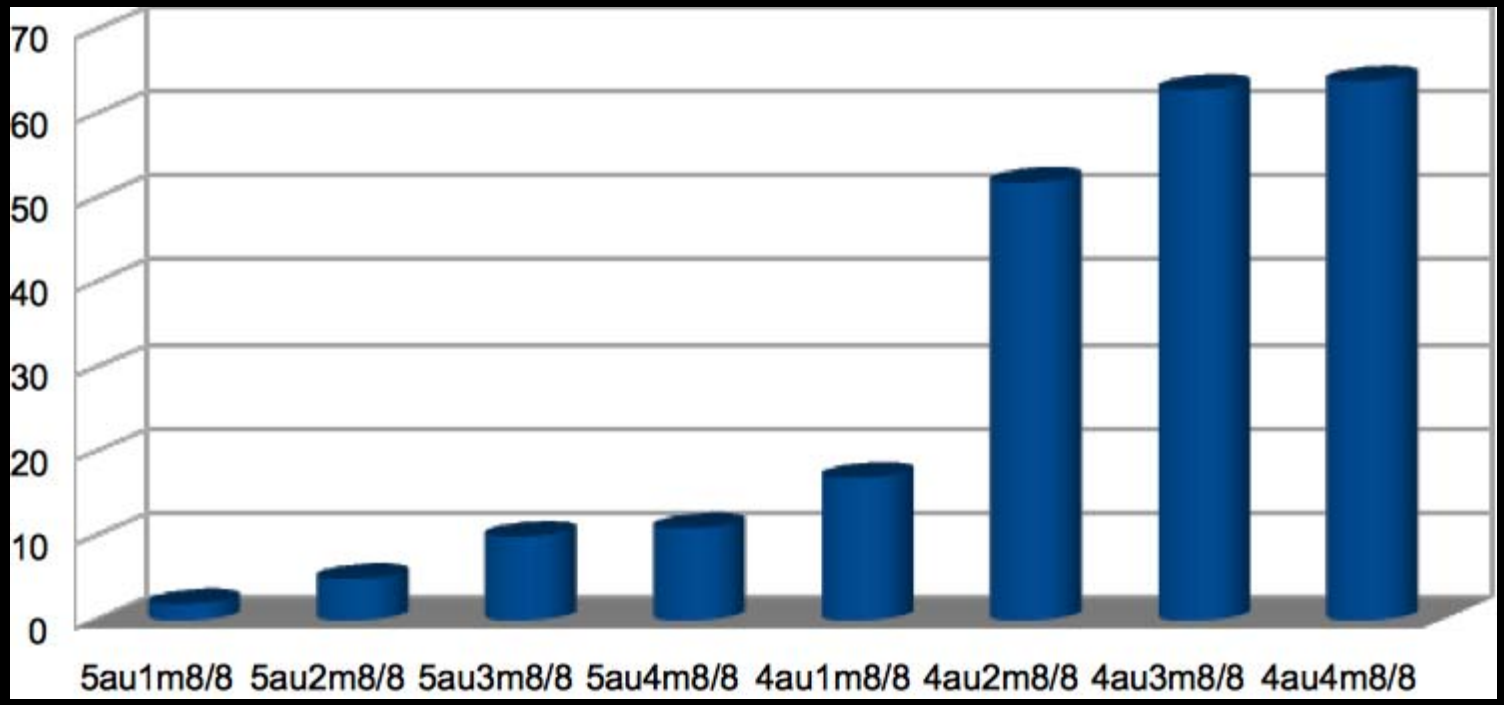
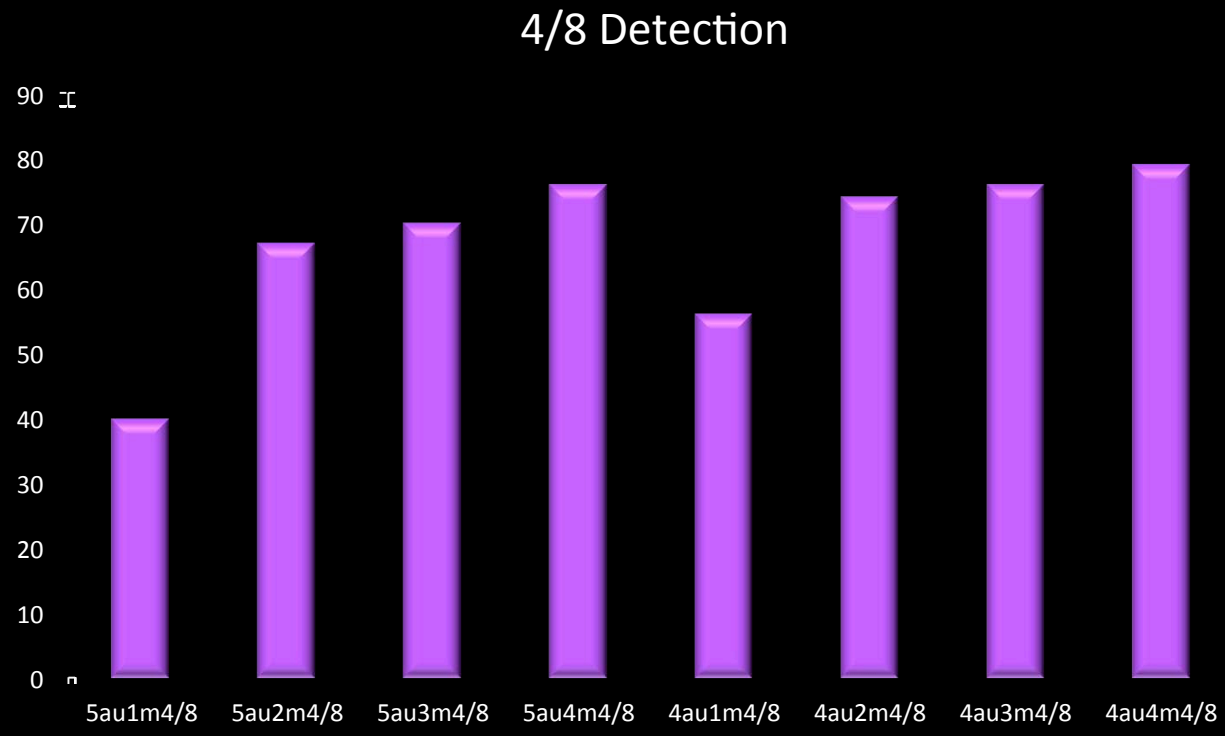

LAMAUR_5AU_1M_phase6
All
A.All
Power
Period (days)

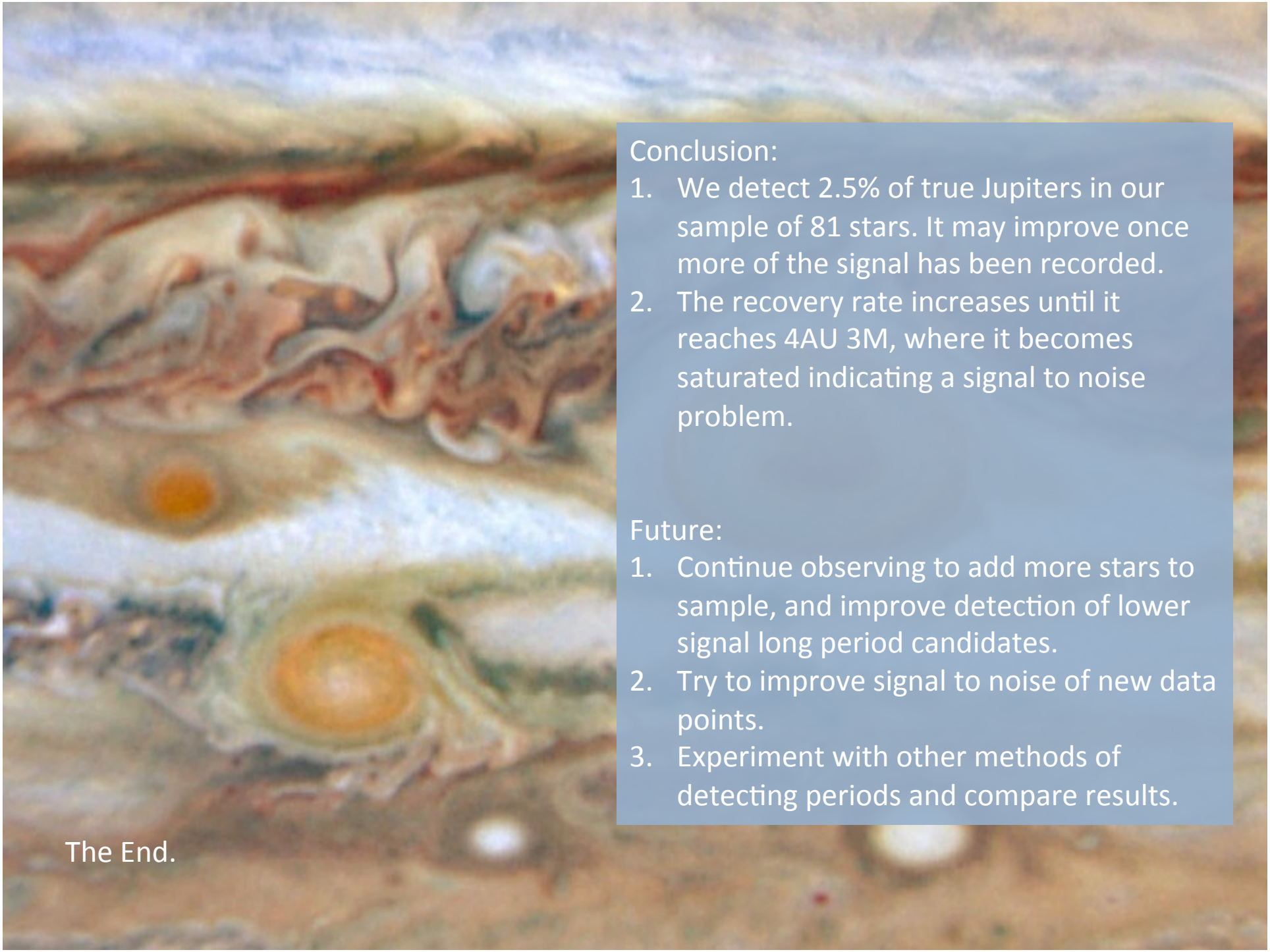
Detection Limits



- "True" Jupiter detection limit is 2.5%.
- 4AU, 3M limit is 75%.
- 5AU limit will be improved by extending the observational timeline. 4AU limit saturated by signal to noise.



- At the lowest level (5AU,1M) we recover %50 of the phases, %50 percent of the time.
- Still need to increase the observation time line and improve S/N.



Conclusion:

1. We detect 2.5% of true Jupiters in our sample of 81 stars. It may improve once more of the signal has been recorded.
2. The recovery rate increases until it reaches 4AU 3M, where it becomes saturated indicating a signal to noise problem.

Future:

1. Continue observing to add more stars to sample, and improve detection of lower signal long period candidates.
2. Try to improve signal to noise of new data points.
3. Experiment with other methods of detecting periods and compare results.

The End.