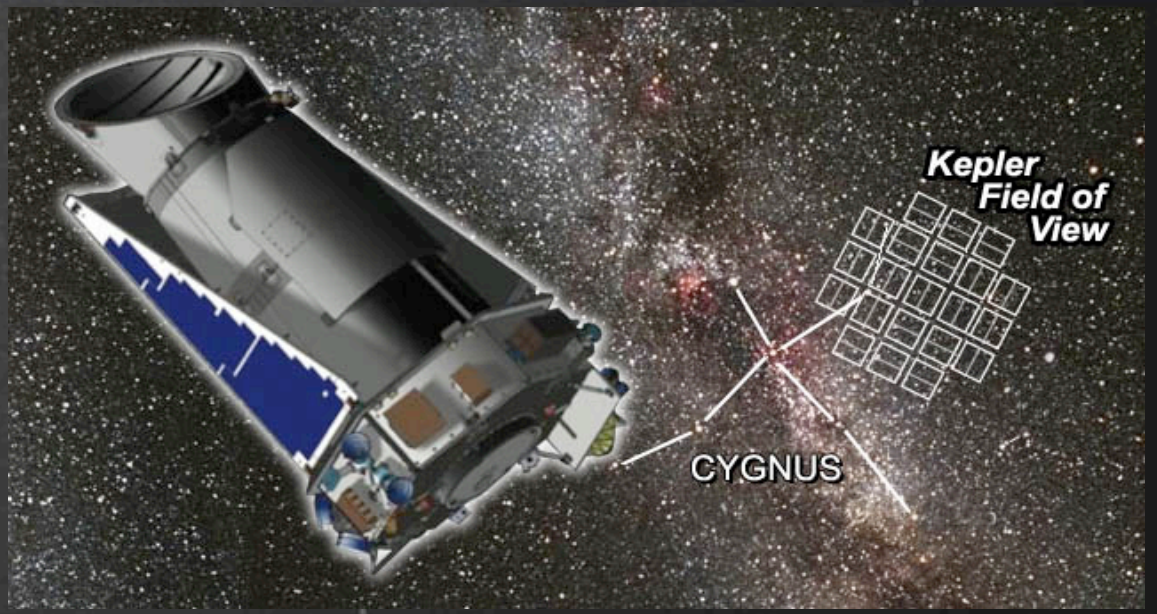
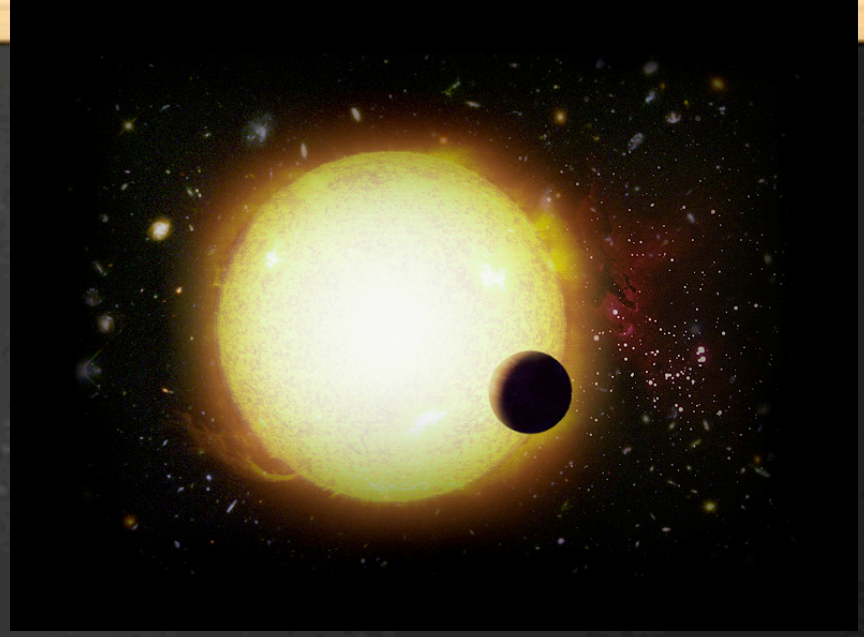


Planet Hunting with Kepler

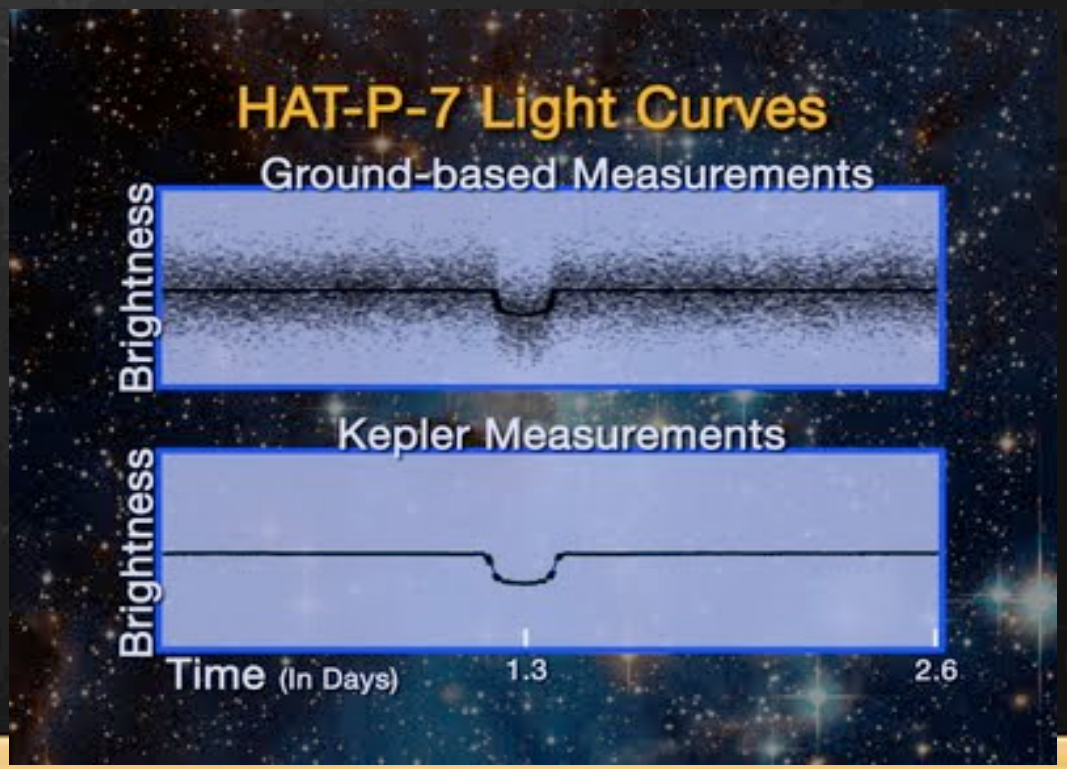
Group "AWESOME"
Mentor: Kaspar von Braun

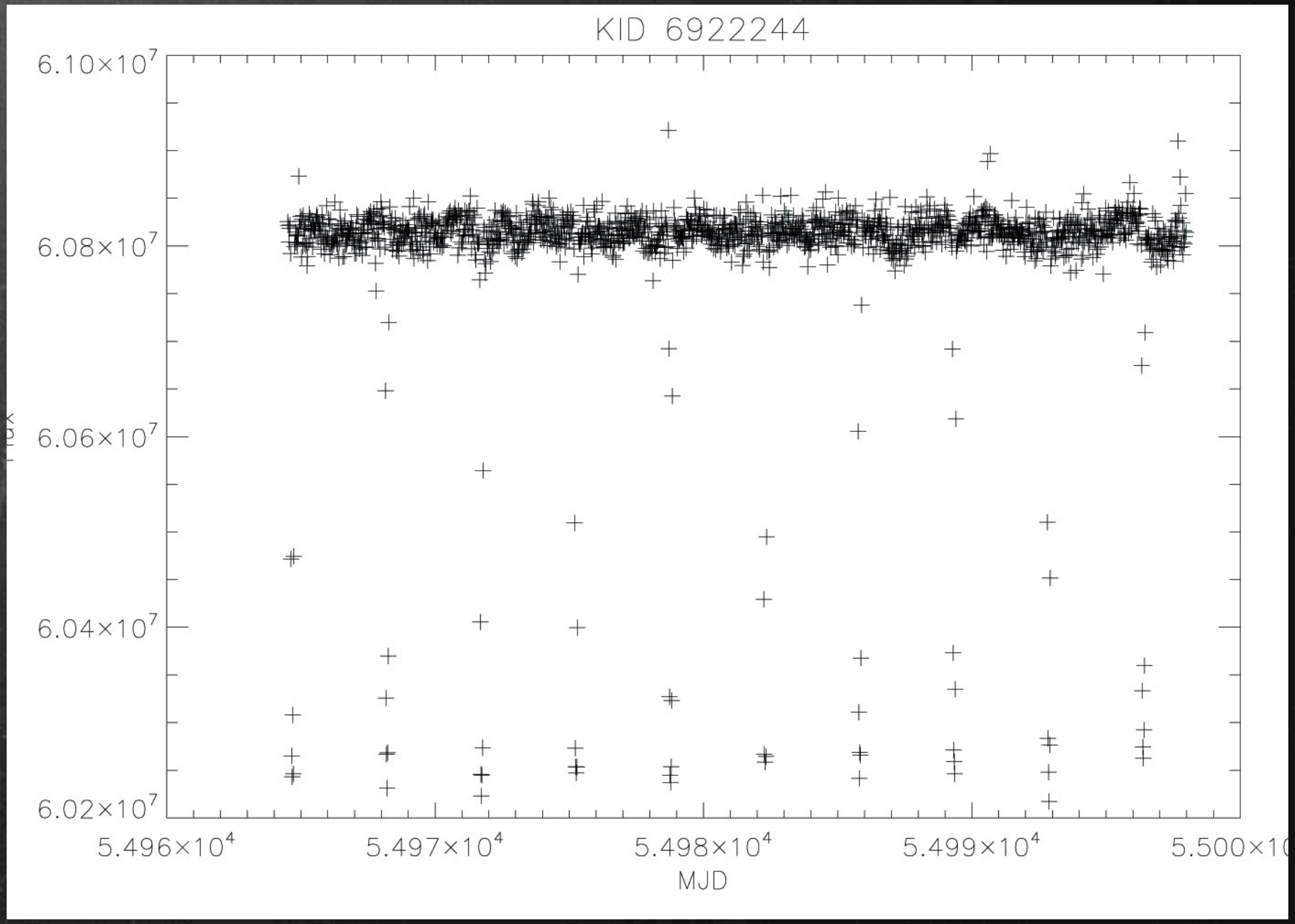

PLANET
SEASON
RABBIT SEAZON
Rabbit
RABBIT SEASON

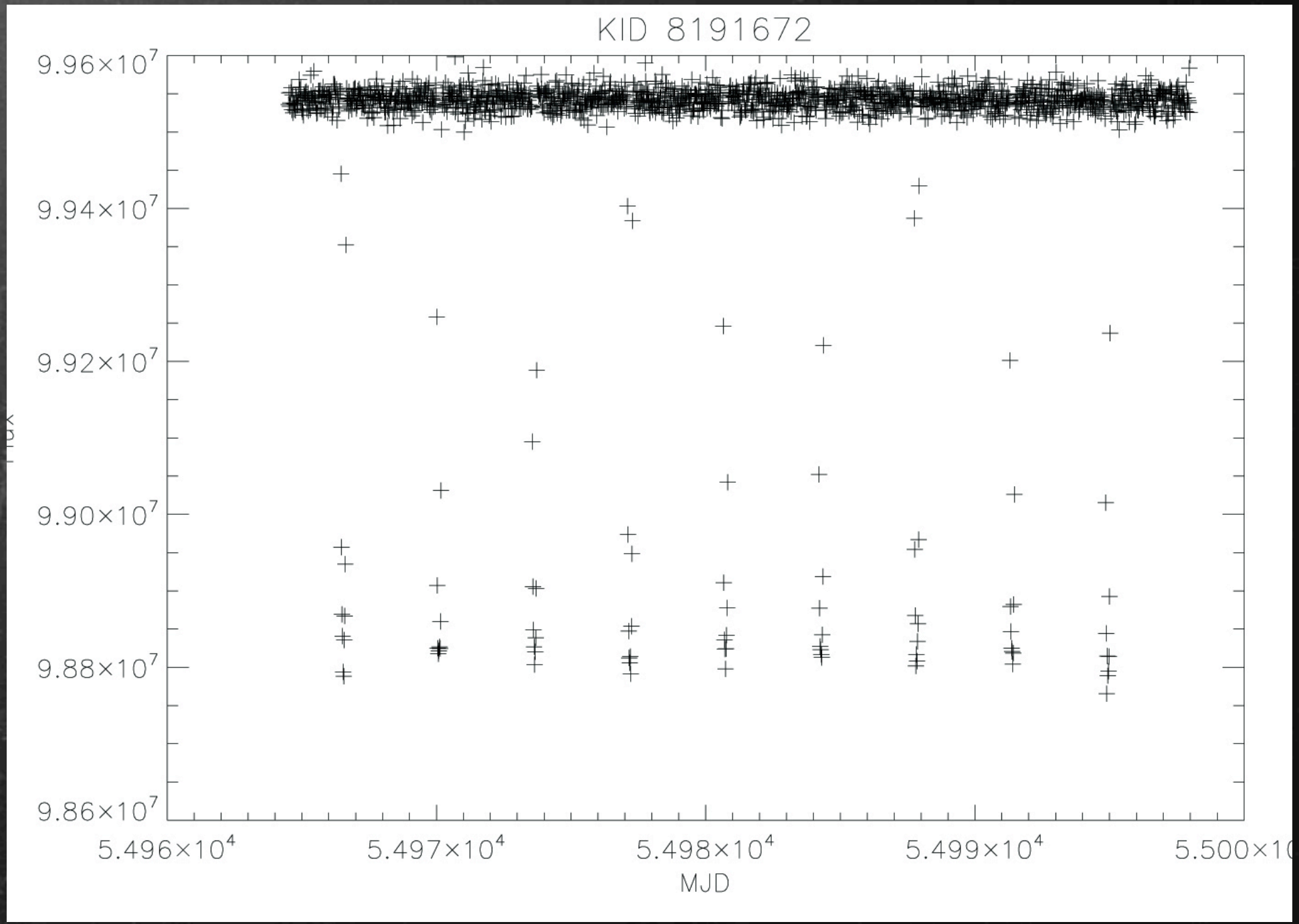
We decided to give up on light curves and just watch SETI @ Home to see the evidence of life in the universe



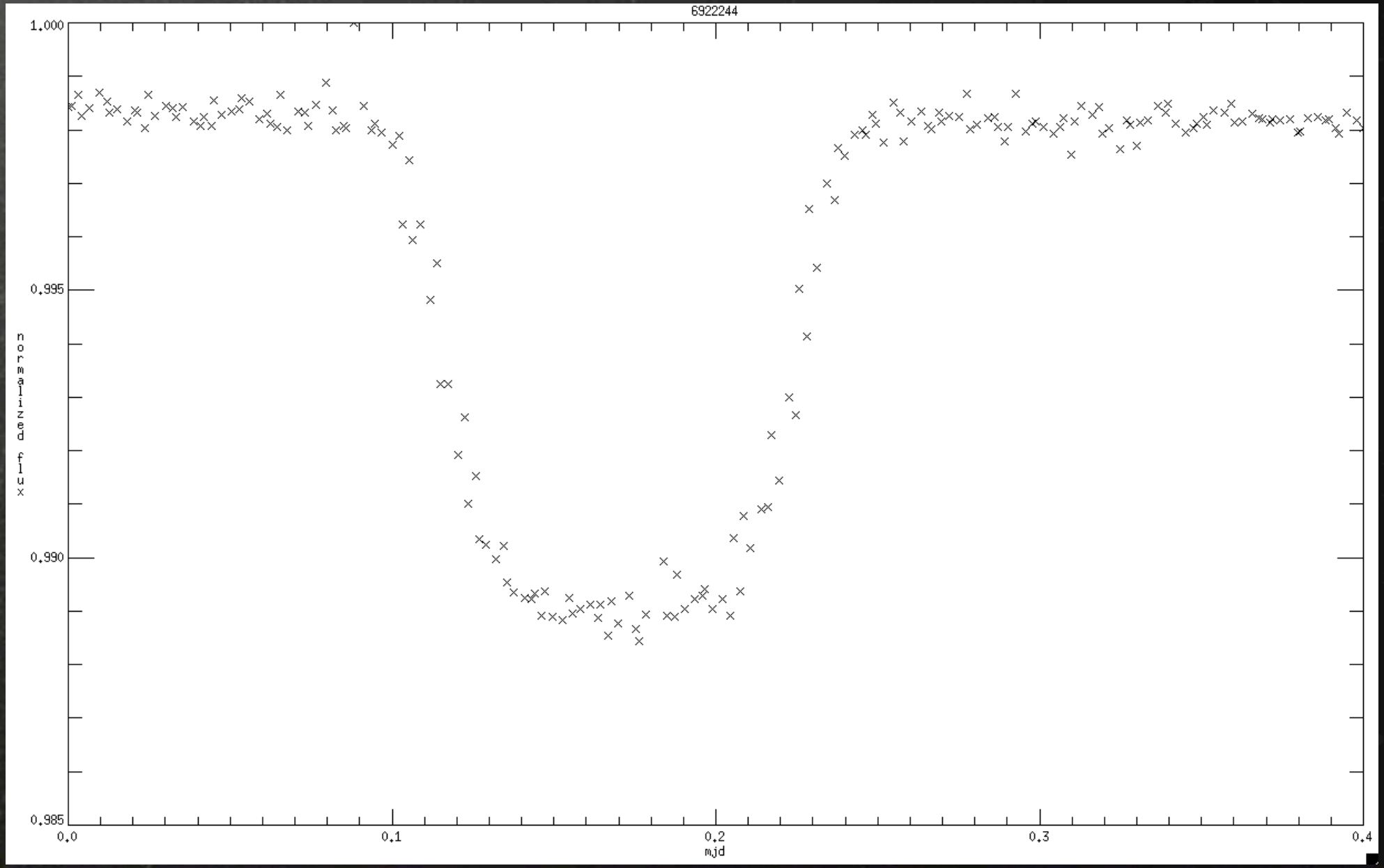
Fitting the Best Curves




KID 6922244
6.10×10^7
6.08×10^7
6.06×10^7
6.04×10^7
6.02×10^7
5.496×10^4
5.497×10^4
5.498×10^4
5.499×10^4
MJD

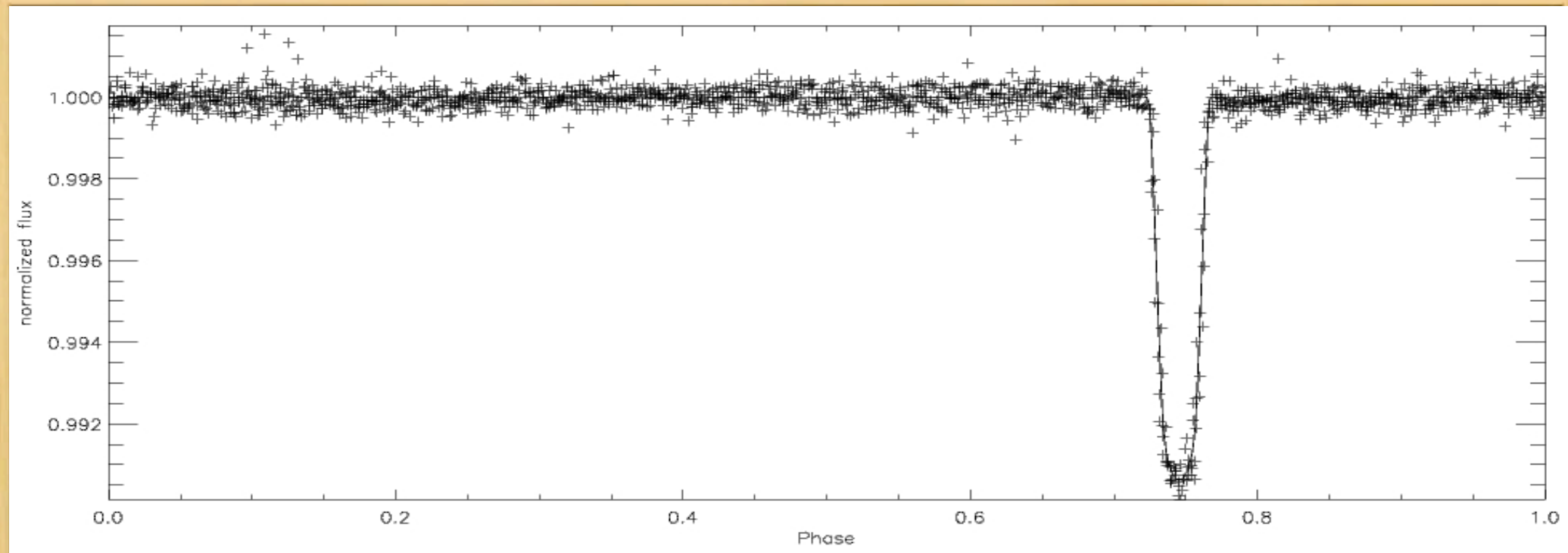

KID 8191672
9.96×10^7
9.94×10^7
9.92×10^7
9.90×10^7
9.88×10^7
9.86×10^7
5.496×10^4
5.497×10^4
5.498×10^4
5.499×10^4
MJD

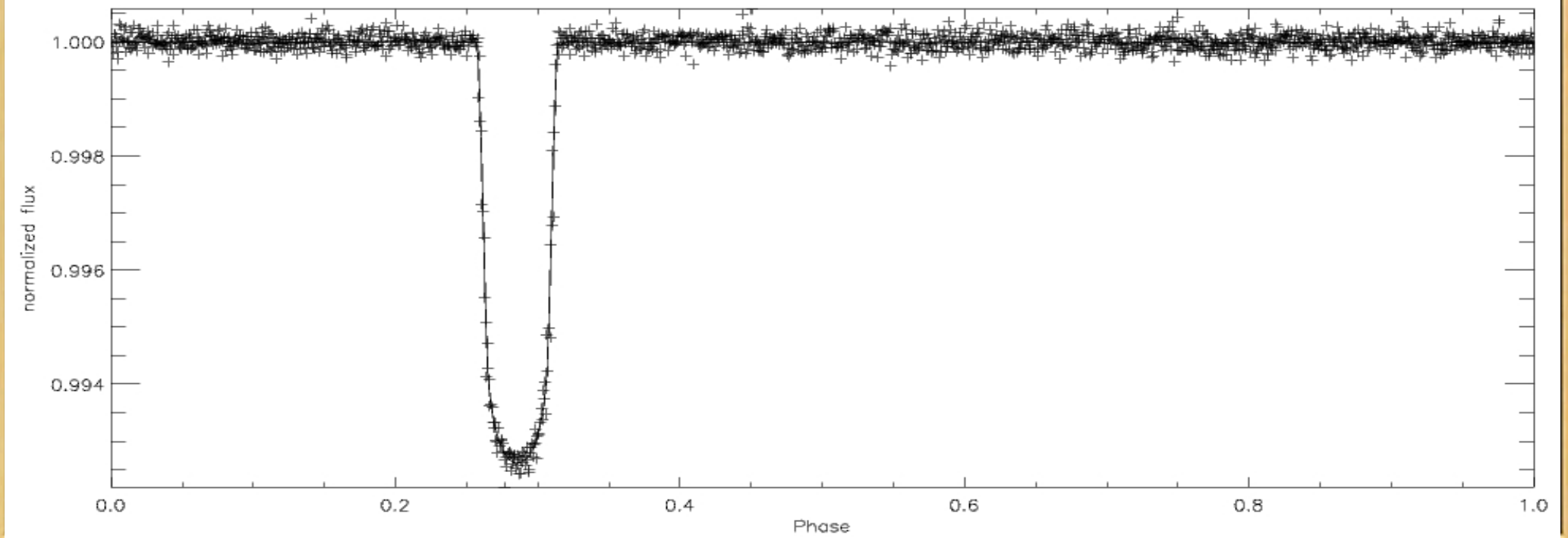
Zoomed-in Transit



Fitting Process

- Some tools available - still of limited use!
- Wrote own code and used Levenberg-Marquardt fitting
- Used periodograms to fix period
  - BLS much more effective for transits
- Also easiest to fix limb darkening parameters
- Program output --> b, i, R_p/R_*, a/R_*
- Used these parameters to derive absolute R_*, M_*, R_p
  - Model dependent
  - Still major uncertainties
- Alternative: "by eye" $t_{transit}$, t_{flat}, & dF $[=(R_p/R_*)^2]$


1.000
0.998
0.996
0.994
0.992
normalized flux
0.0
0.2
0.4
0.6
0.8
1.0
Phase


1.000
0.998
0.996
0.994
normalized flux
0.0
0.2
0.4
0.6
0.8
1.0
Phase

Two Sample Results

Kepler ID 6922244

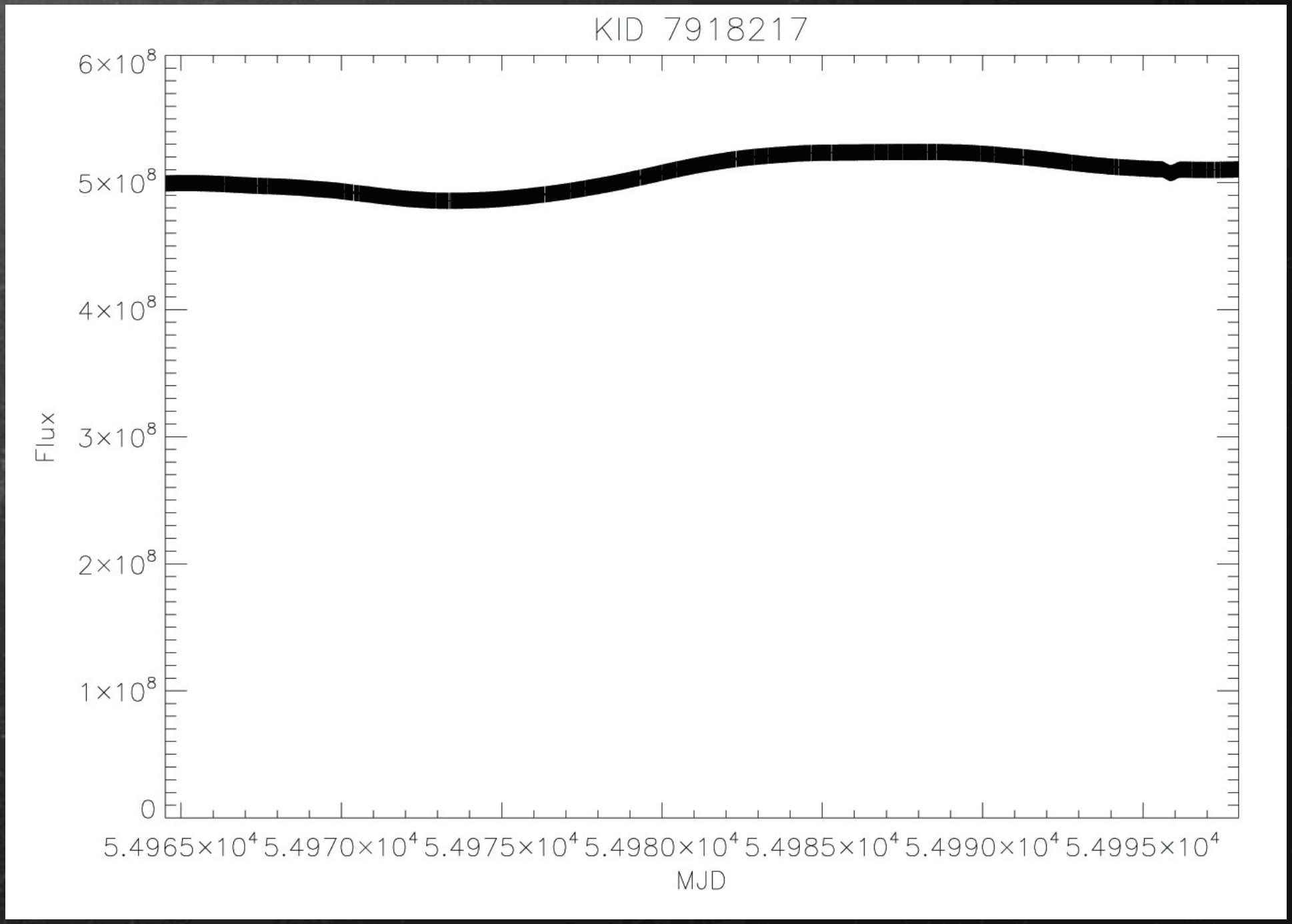
- Period 3.524 days
- Transit depth <~ 1%
- $a/R_* = 10.64$
- $R_p/R_* = 0.099$
- $i = 85.5^O$
- $R_* = 0.86R_{Sun}$
- $M_* = 0.83M_{Sun}$
- $R_p = 0.83R_{Jup}$

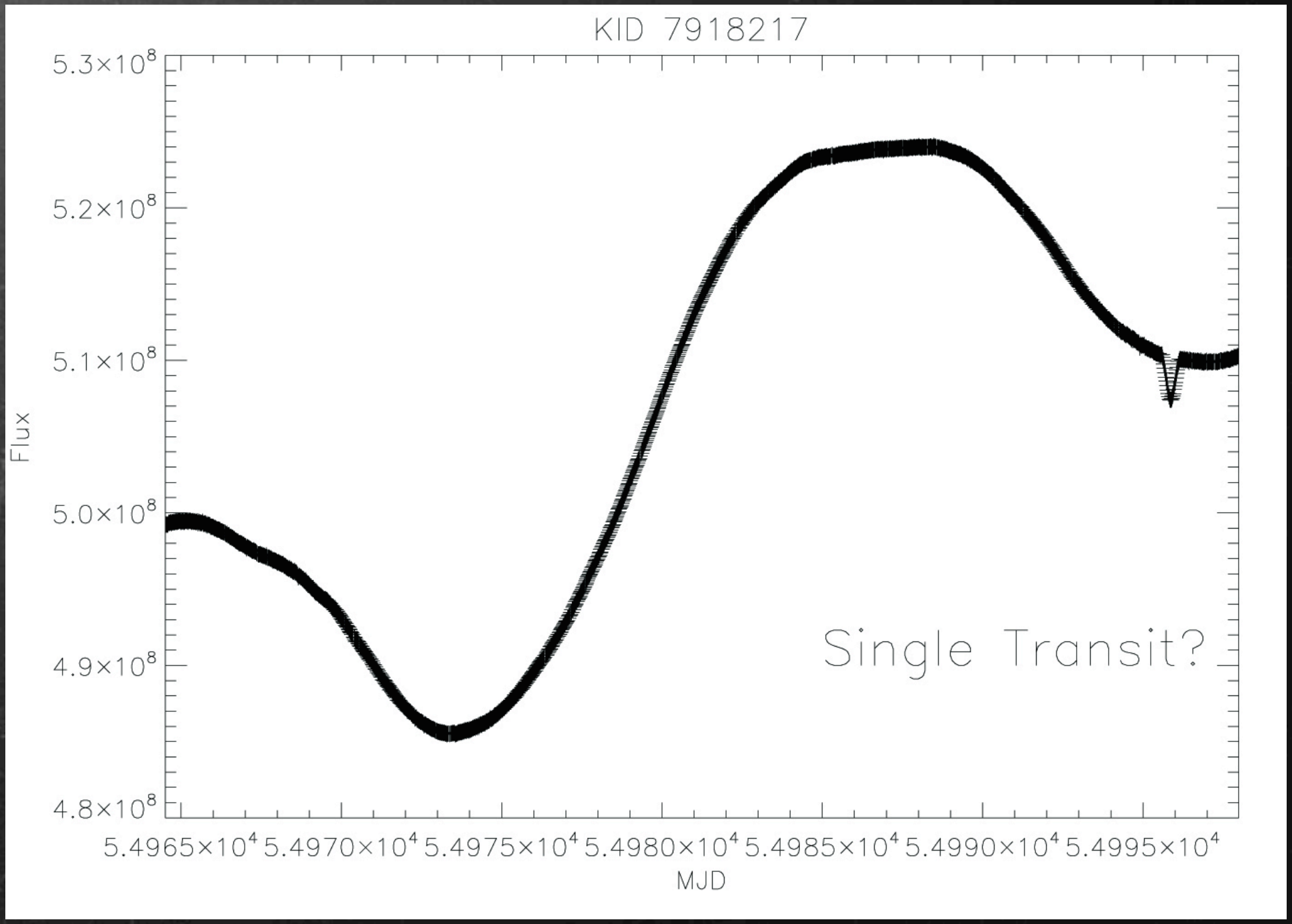
Kepler ID 8191672

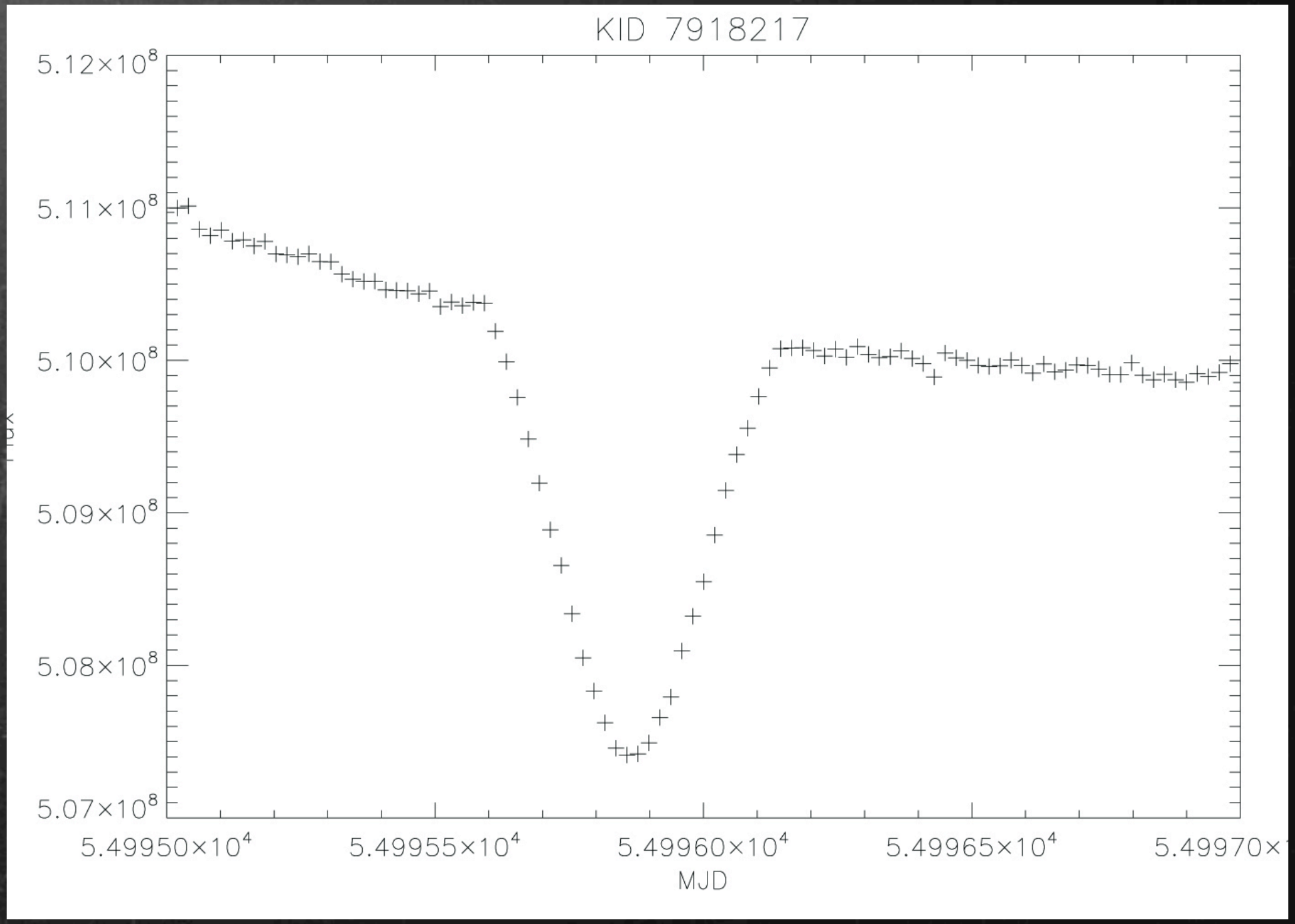
- Period 3.547 days
- Transit depth <~ 1%
- $a/R_* = 9.37$
- $R_p/R_* = 0.084$
- $i = 85.8^O$
- $R_* = 1.08R_{Sun}$
- $M_* = 1.10M_{Sun}$
- $R_p = 0.88R_{Jup}$

Challenges

- Finding which variables to fix and deriving those quantities
- Derivation of absolute quantities is very sensitive to measurements of the light curve - cannot necessarily do by eye
- Many light curves with only one suspected transit, need to wait for additional cycles to establish nature of variation and period, if applicable

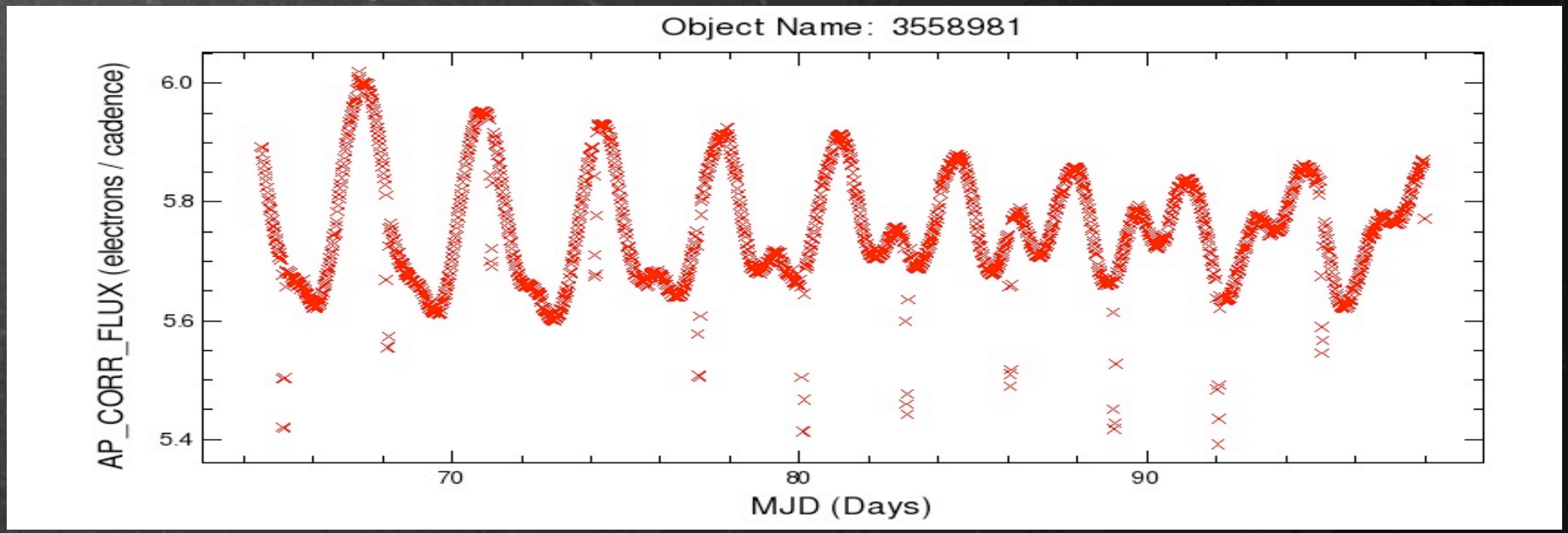

KID 7918217
6×10^8
5×10^8
4×10^8
3×10^8
2×10^8
1×10^8
0
Flux
5.4965×10^4
5.4970×10^4
5.4975×10^4
5.4980×10^4
5.4985×10^4
5.4990×10^4
5.4995×10^4
MJD


KID 7918217
5.3×10^8
5.2×10^8
5.1×10^8
5.0×10^8
4.9×10^8
4.8×10^8
Flux
5.4965×10^4 5.4970×10^4 5.4975×10^4 5.4980×10^4 5.4985×10^4 5.4990×10^4 5.4995×10^4
MJD
Single Transit?

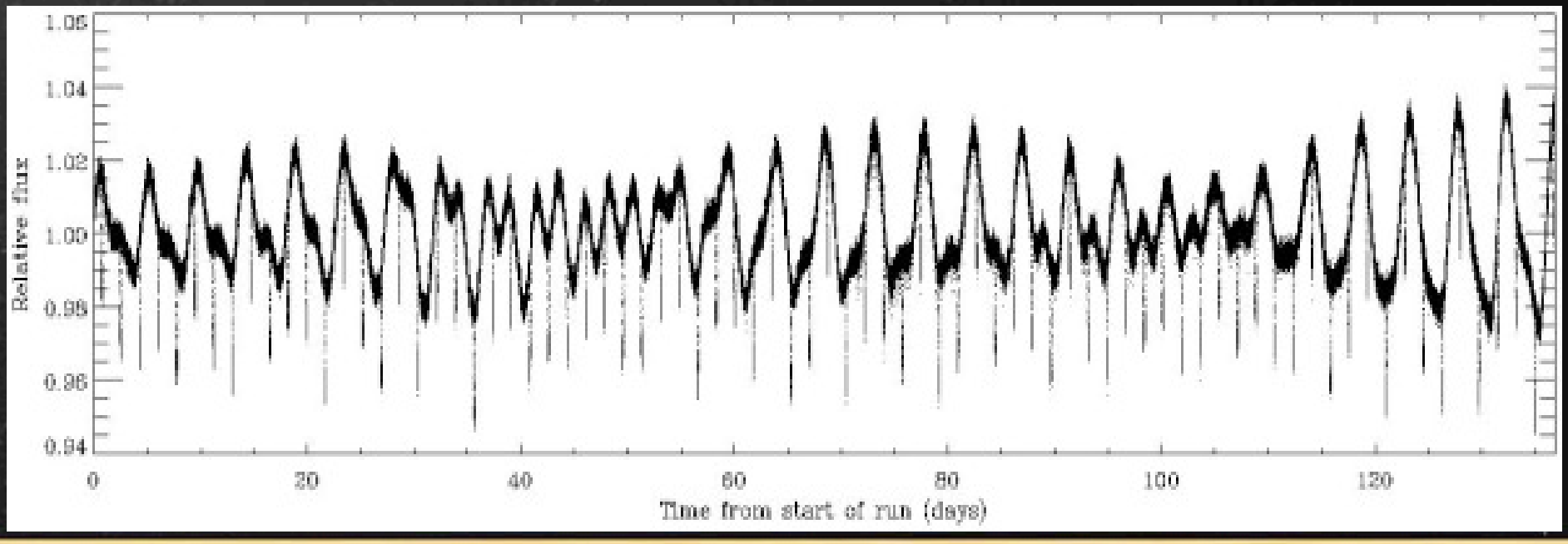

KID 7918217
5.12×10^8
5.11×10^8
5.10×10^8
5.09×10^8
5.08×10^8
5.07×10^8
5.49950×10^4
5.49955×10^4
5.49960×10^4
5.49965×10^4
MJD

The following images are REALLY REALLY COOL/unusual data from Kepler

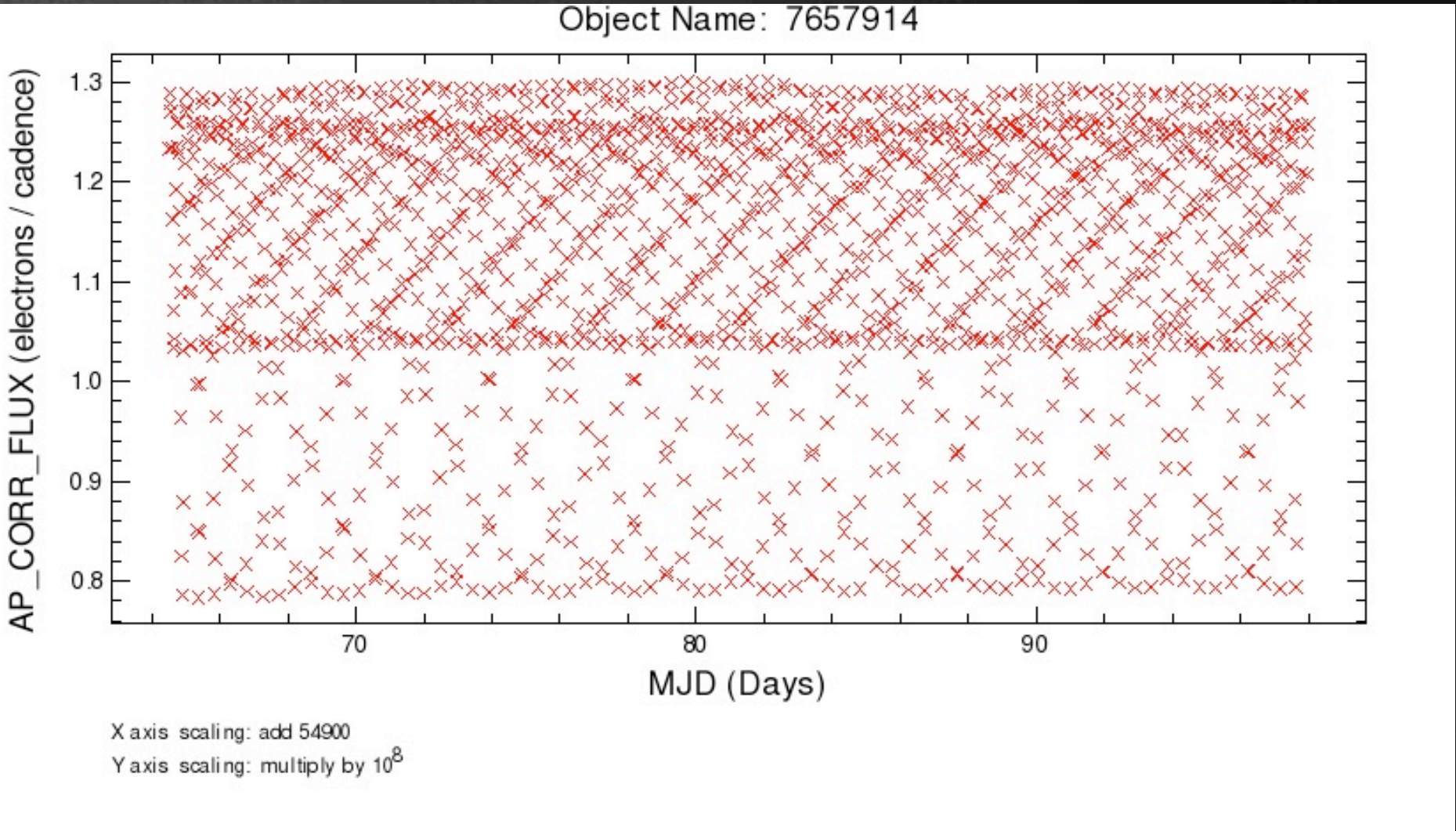
looks confusing... but similar to CoRoT 2b

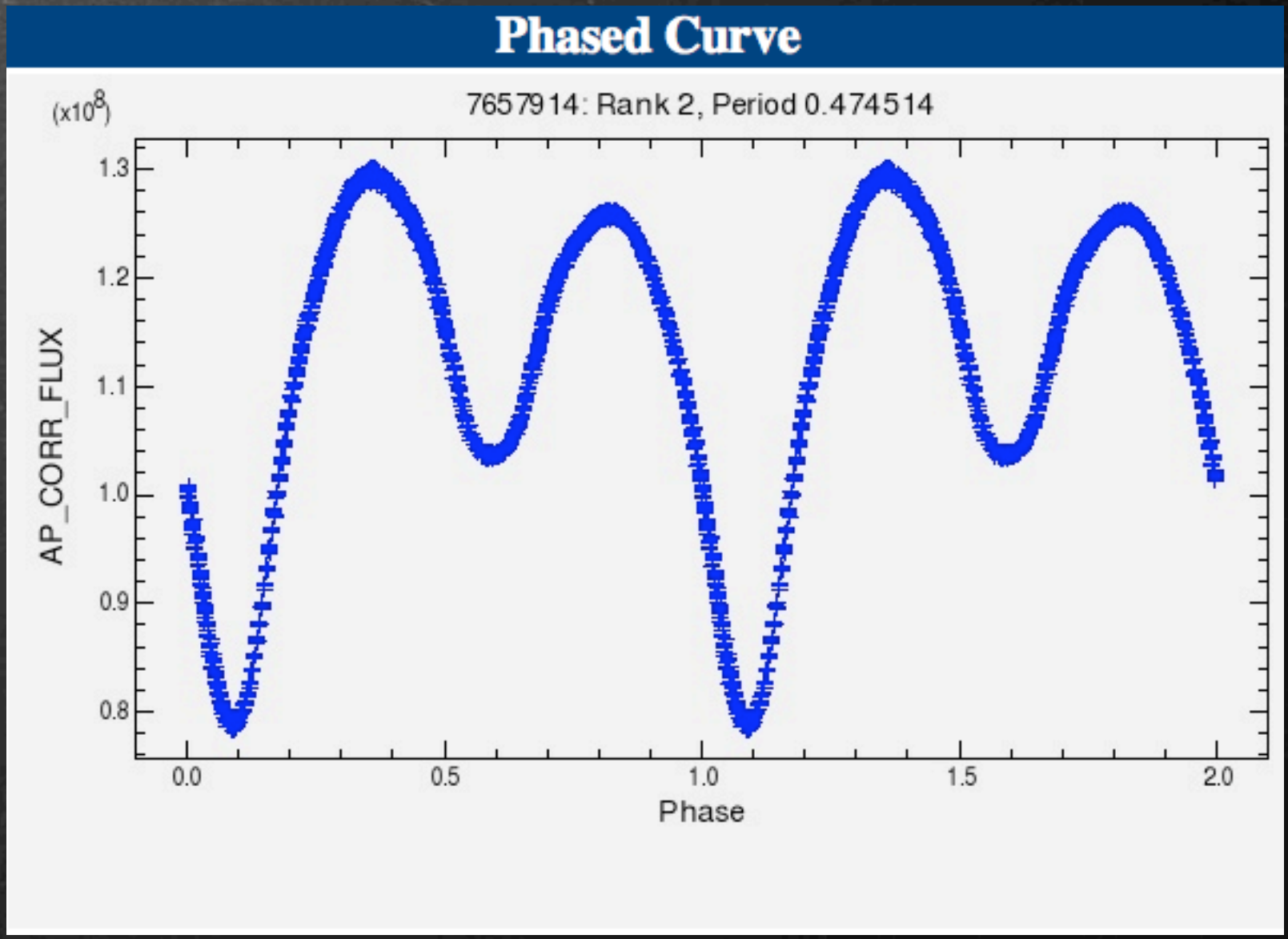


The planet is a large hot Jupiter, about 1.43 times the radius of Jupiter and approximately 3.3 times as massive.



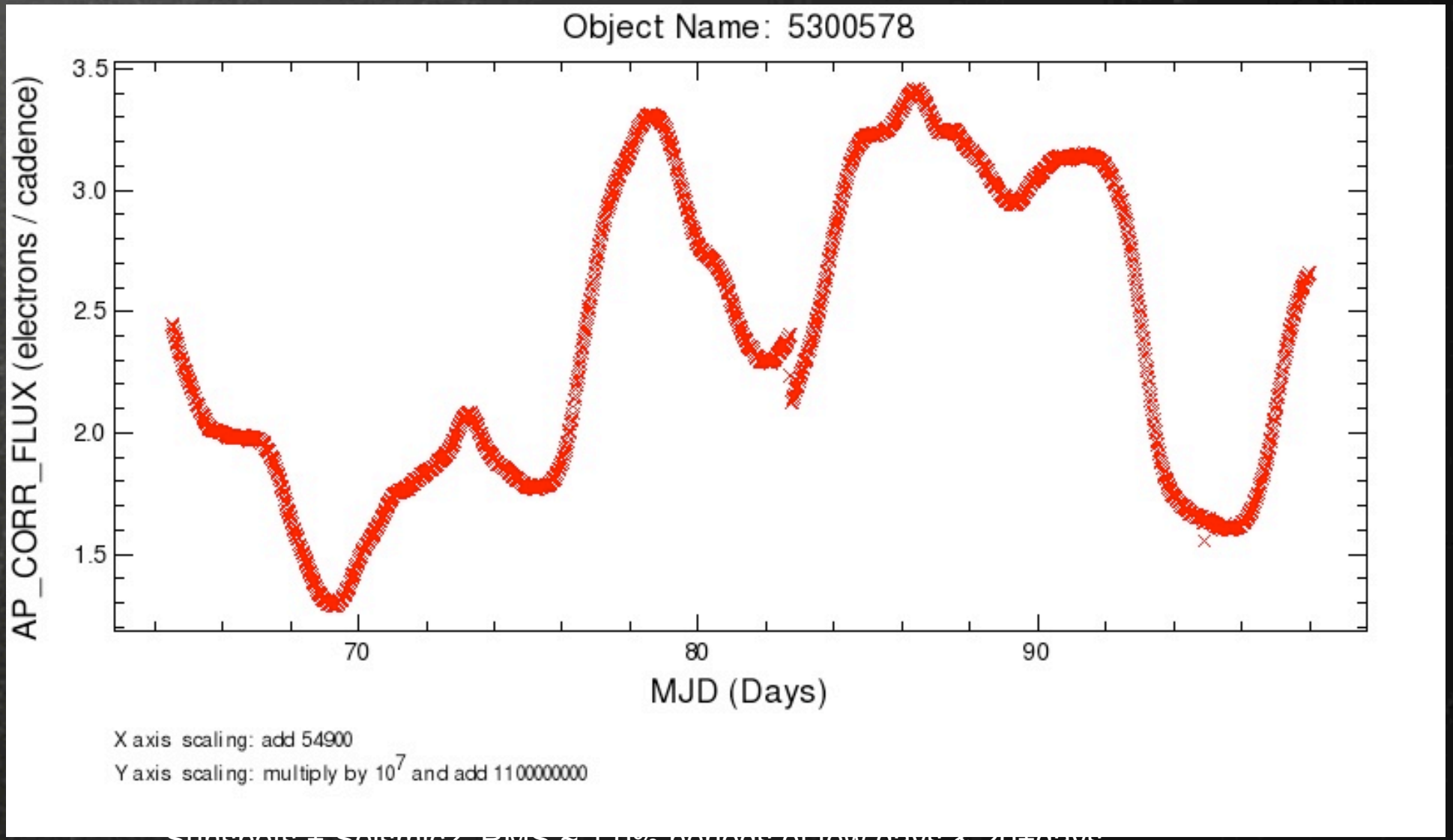
what is going on?! spirograph?





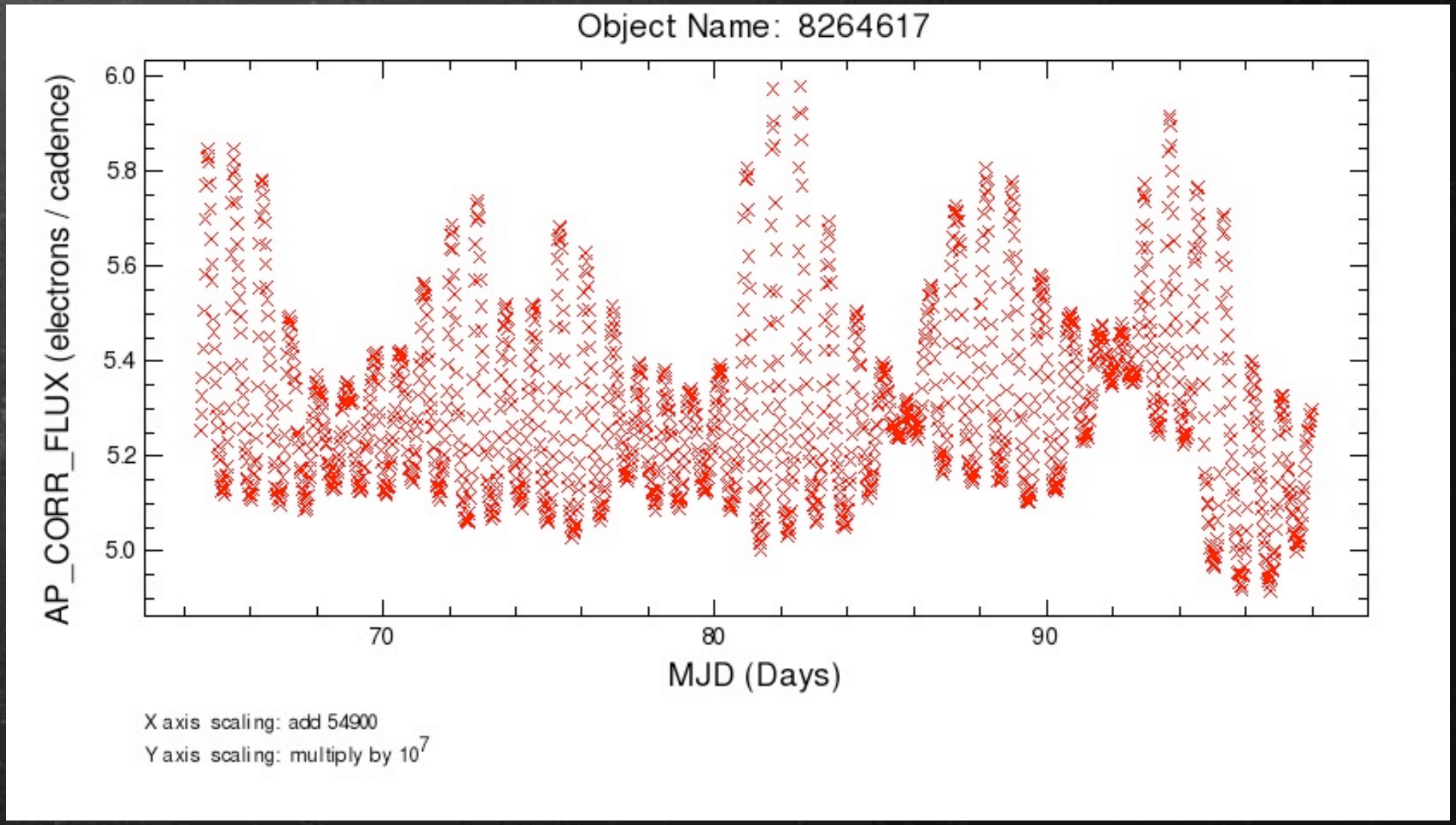
after phasing we can see it's an eclipsing binary

We titled this WTF?!



Sunspots + Seismic? RMS ~ 1.0% periods of few days & 20+days

PMS star



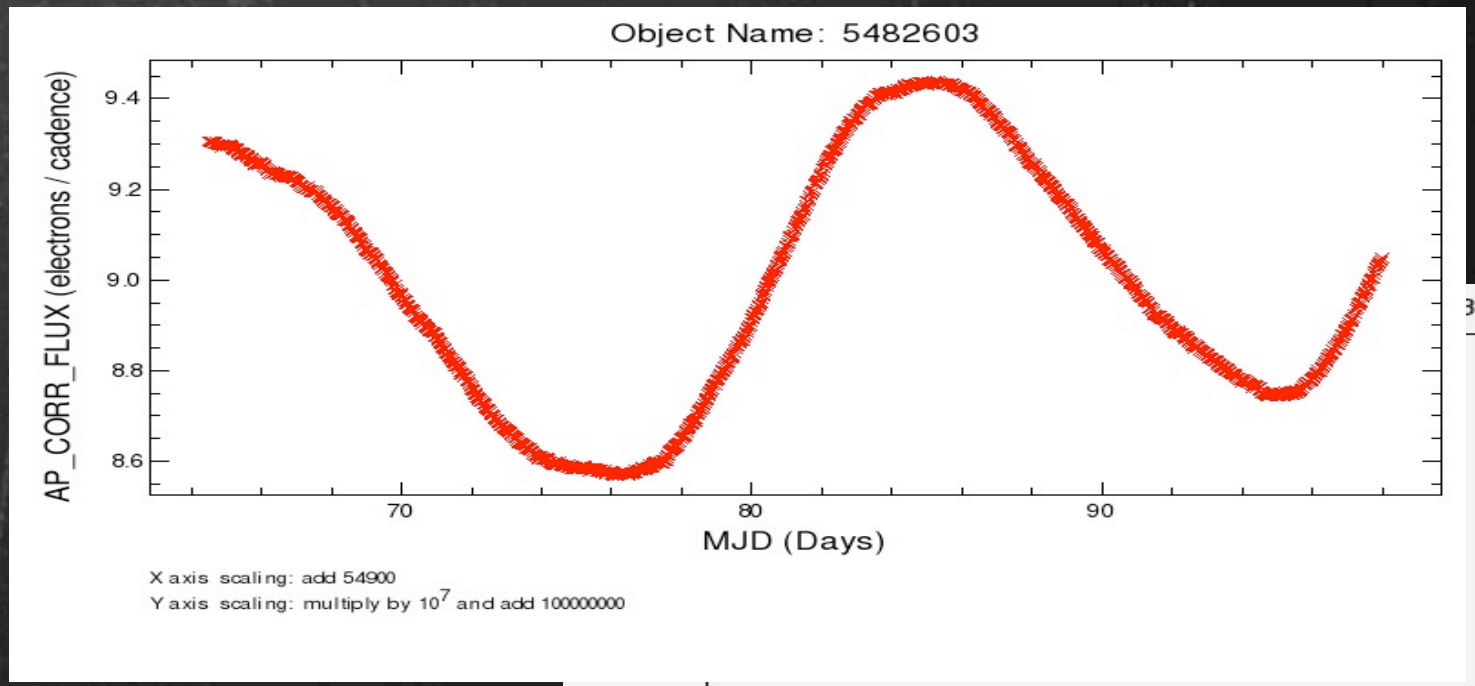
Or just stellar variability?

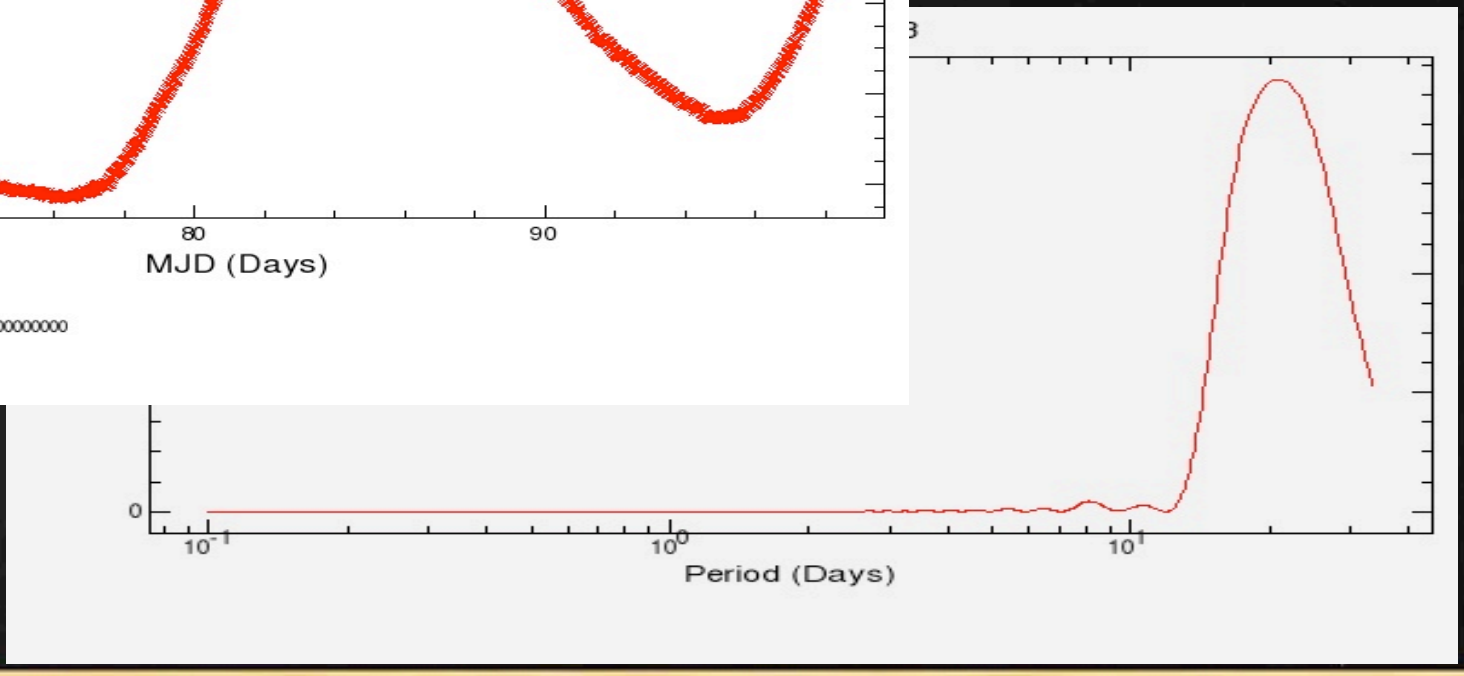
Staring at Static (Science in the Noise)

Non-Transit Light Curves
brought to you by Julia^2

Sunspots

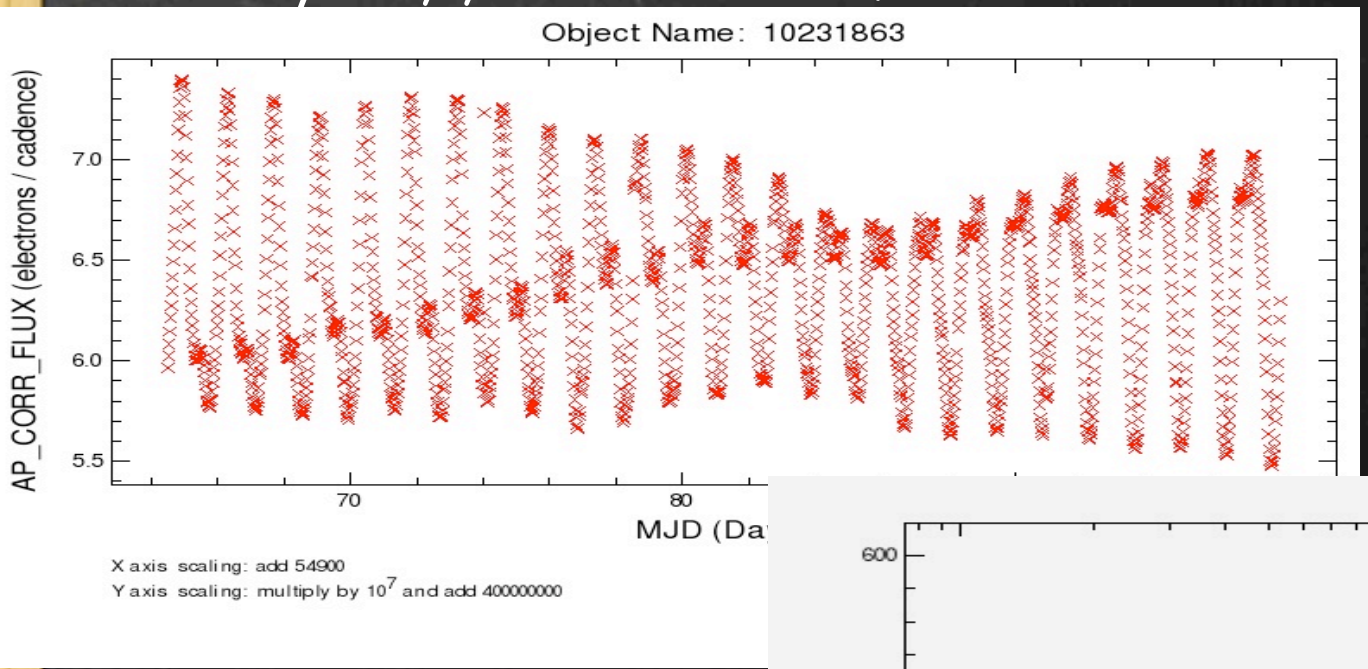
* ~ 8% of Sample
* ~ 1 to few% variation with 20-30 d Period
* Could check rotation & activity v. stellar type

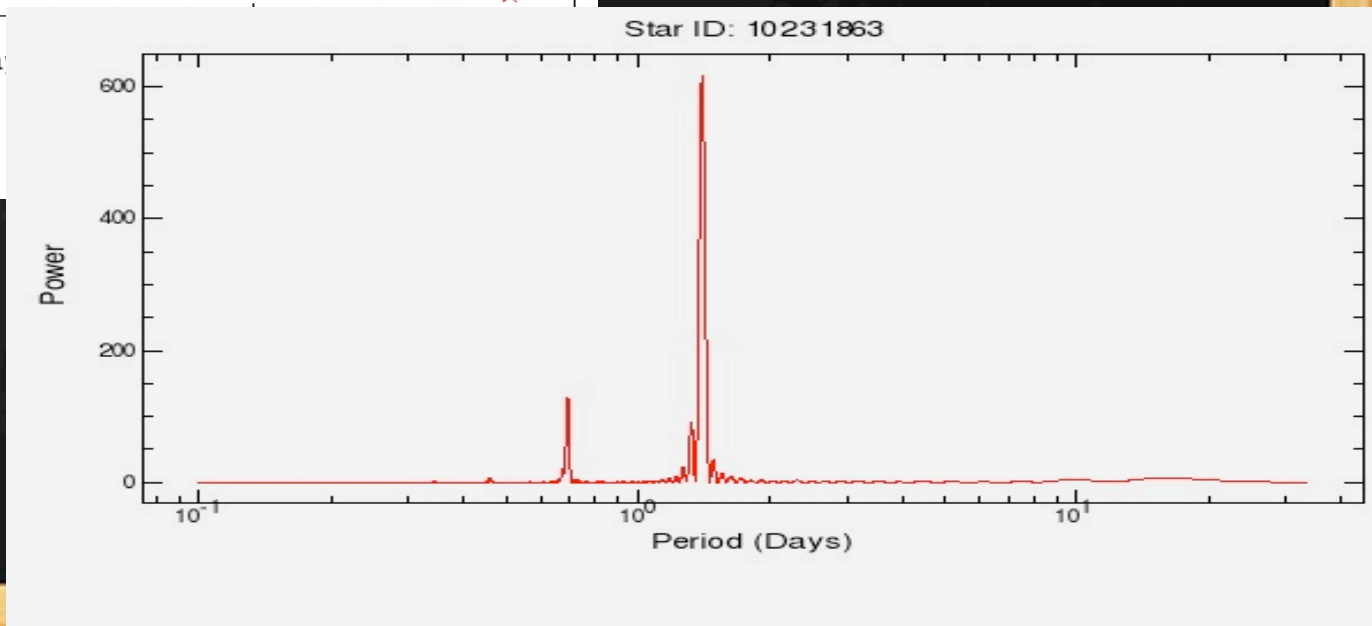




Seismic Activity?

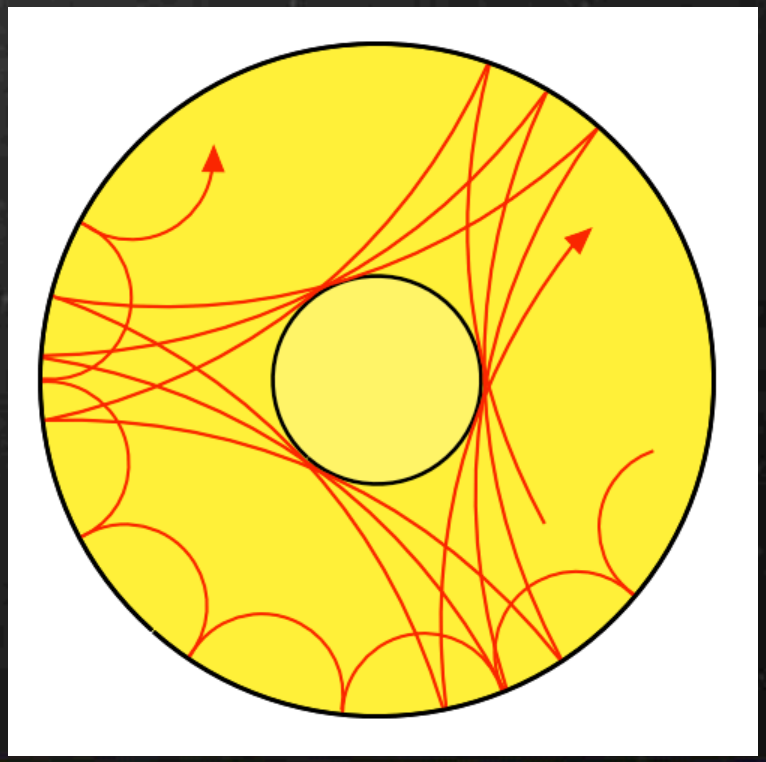
* ~ 3% of stars with clear seismic activity
* ~0.2% variability with 1.0 d period
* Possibly l=2,1,0 oscillations of a Gamma Doradus variable





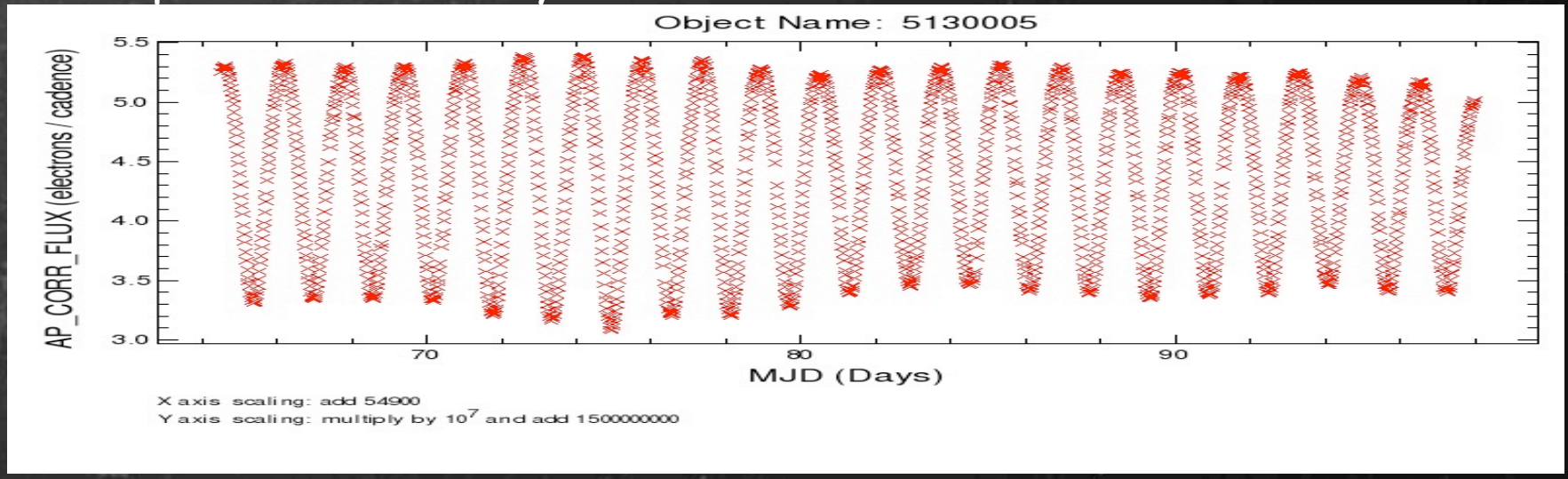
Asteroseismology

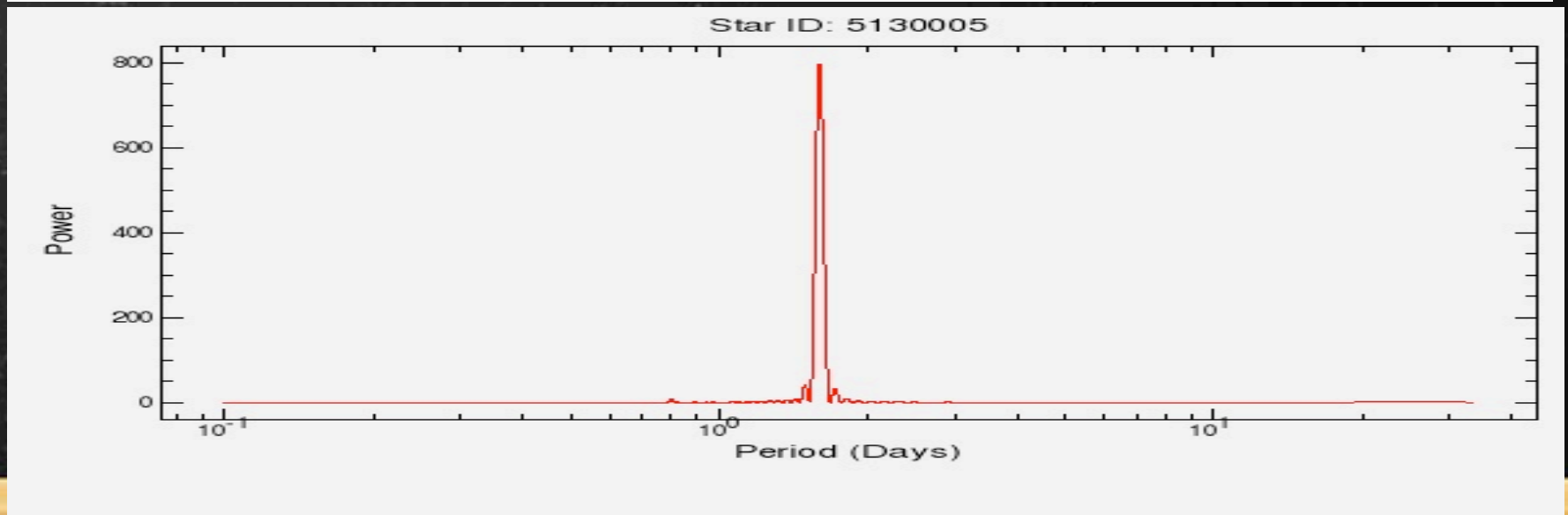
- Acoustic or pressure (p) modes, driven by internal pressure fluctuations within a star; their dynamics being determined by the local speed of sound.
- Gravity (g) modes, driven by buoyancy,
- Surface gravity (f) modes, akin to ocean waves along the stellar surface.



Periodic Unknowns

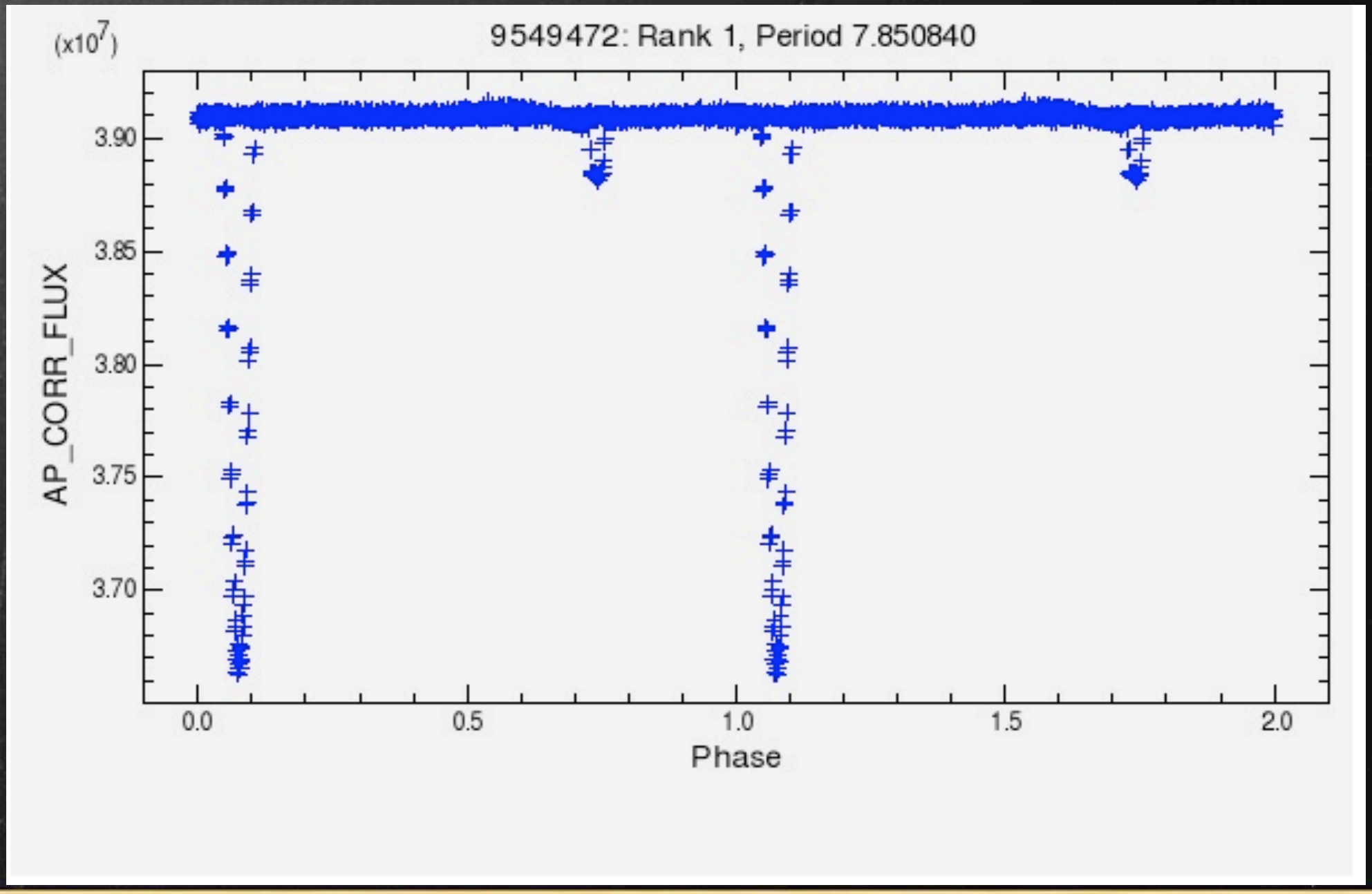
* Seismic Activity without multiple modes?
* Oblateness of Primary Induced by Companion's Gravity?
* Reflection of Primary off Secondary?
* Hot Spot on Secondary?



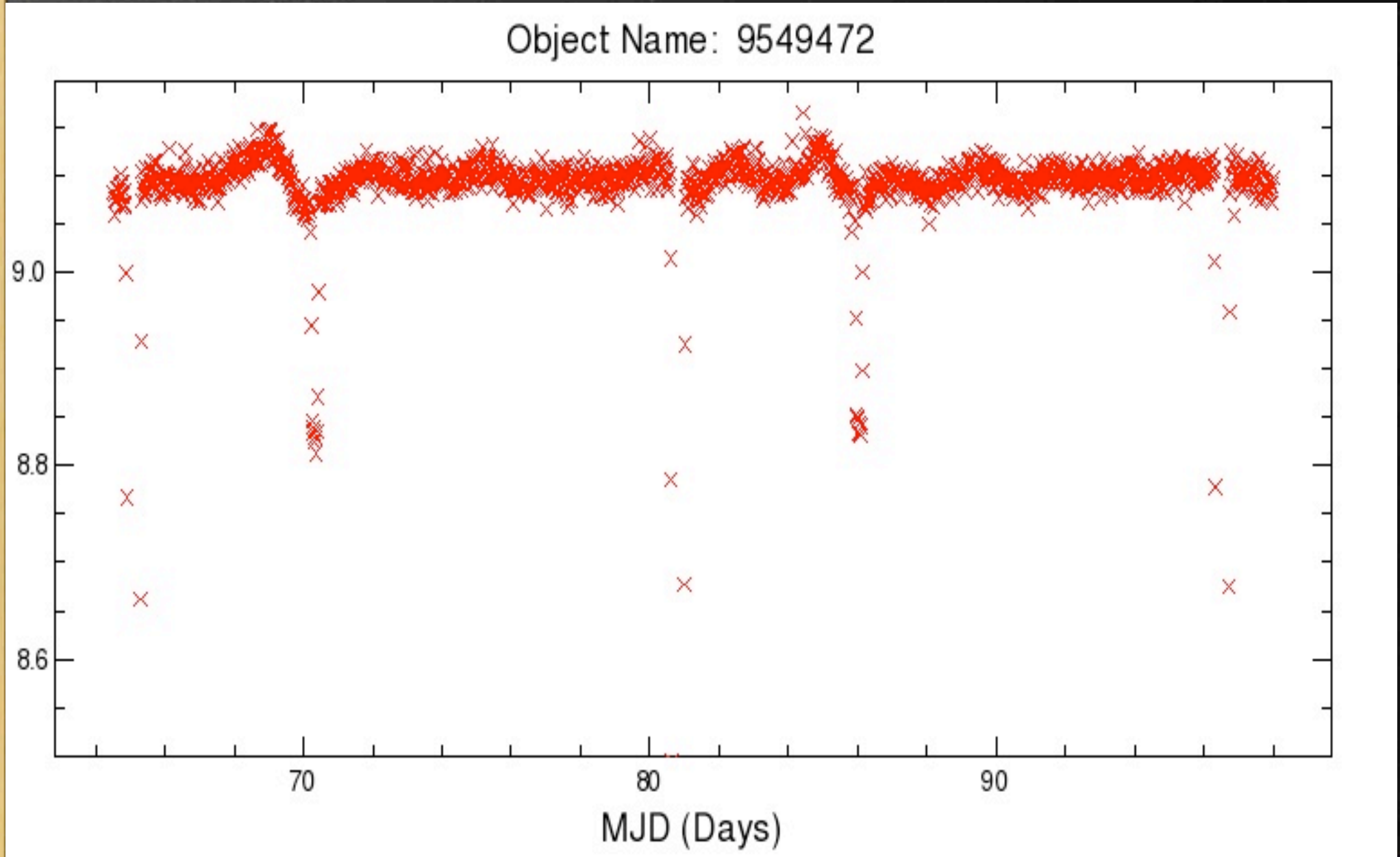


Transits + a Story

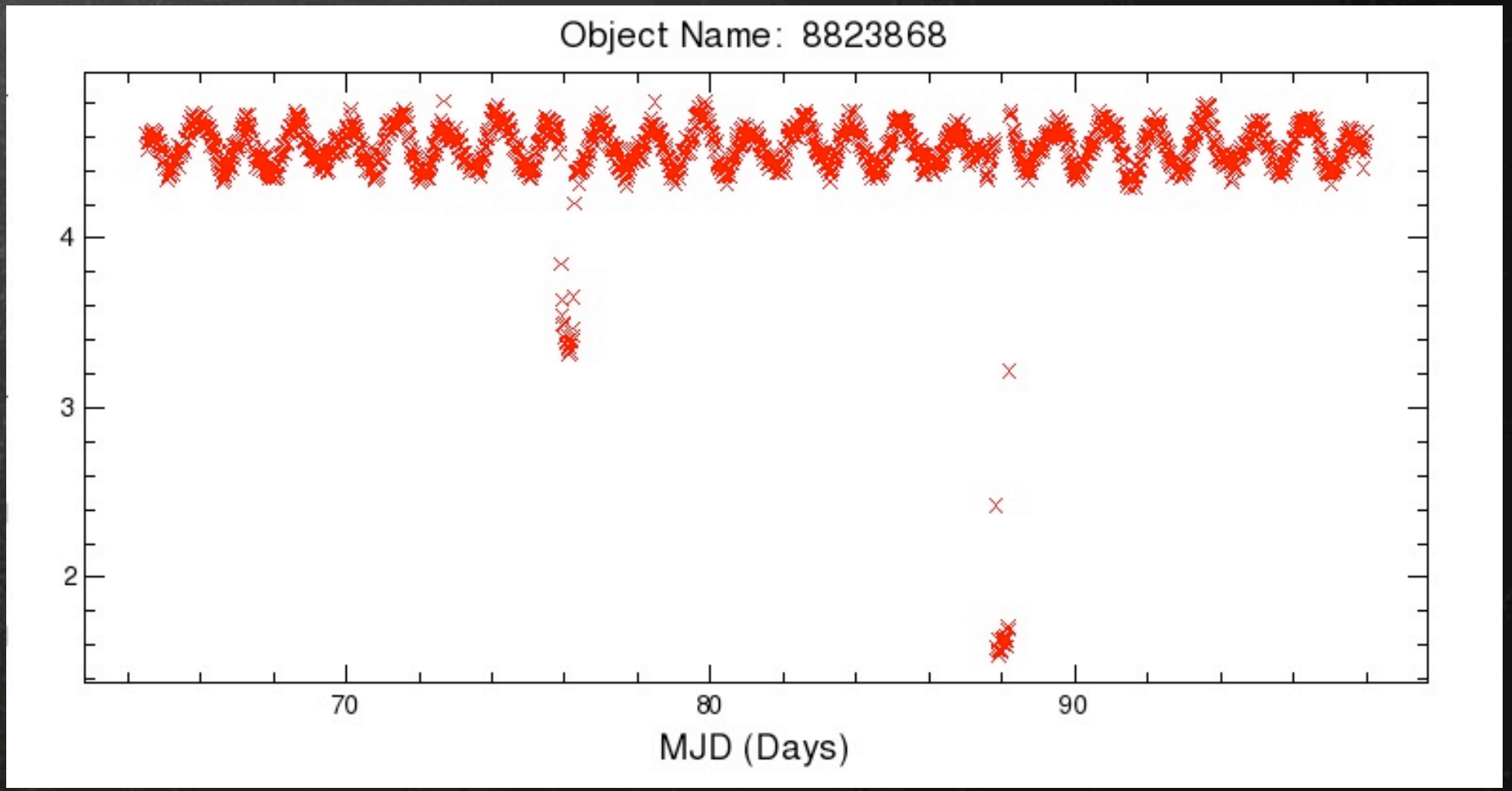
An Eccentric Eclipser



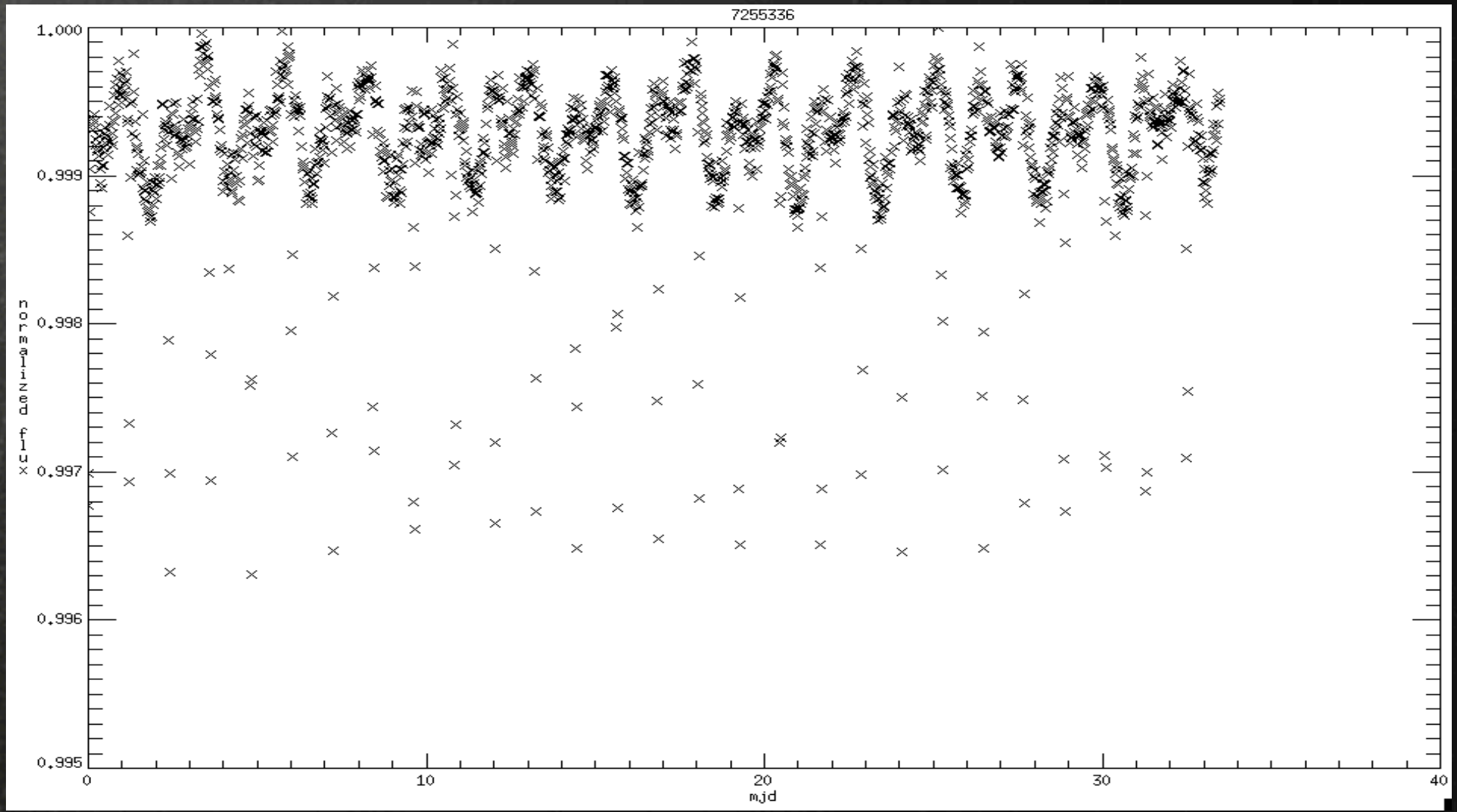
Heating/Refection near Secondary



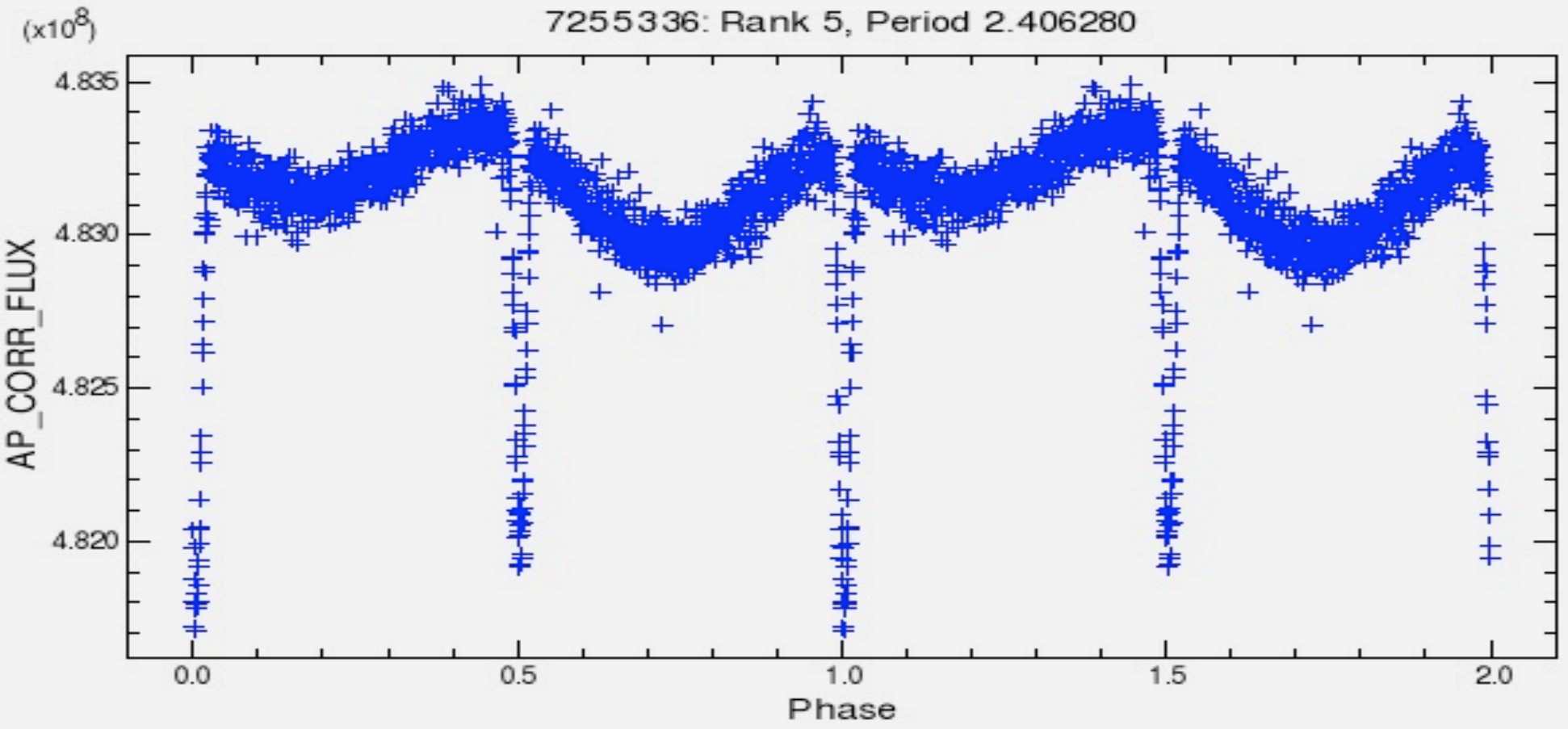
Red Herring



Primary-Secondary Interactions



Transit just AFTER peaks?



Red Noise

* Definition?
  - Most light curves have red (time-correlated) noise
    -Tracking/Guiding Errors
    - Flat-Field Errors
    - Comparison star noise
    -- But really, the star is just varying in hard to explain ways.
      -- Acoustic effects
      -- Companion noise
      -- Astrophysical sources

Statistical Properties

Chi Squared versus rms

-high chisq means pulsating star with high amplitude (seismic);
-chisq is more sensitive to a transit than rms is;
-high signal amplitude + low rms = transit;
-amplitude variations; fitting functions

Isn't NStED the coolest thing ever?

Like, totally! ZOMG LOL!

Summary

- ~8% of data set - sunspots
- ~3% of data set - possible seismic activity
- ~<15% of data set - (Binary or Planet) transit candidates
- Remaining % of data set - no obvious variability
- "Follow-up Needed"
  - Radial Velocity Measurements of Systems
  - Certainly learn more about planetary systems
- Stars Are Dynamic!!!
  - We will see scenarios that we've never fathomed (except maybe the astroseismologists)
- Automation is Very Necessary and Very Difficult!