>> Measure Orbital Period Derivative of OAO 1657-415

>> Calibrate Photomultiplier Tubes for Veritas

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>> Who am I?

>> For whom do I work?

>> And in what department?

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- *Joseph Street*

>> For whom do I work?

- Dr. John Finley

>> And in what department?

- High Energy Astrophysics

>> What is the Orbital Period Derivative ($\dot{P}$)?

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- $\dot{P}$ is the change in period of the orbiting bodies that comprise the binary system with respect to time.

>> Why do we care about this?

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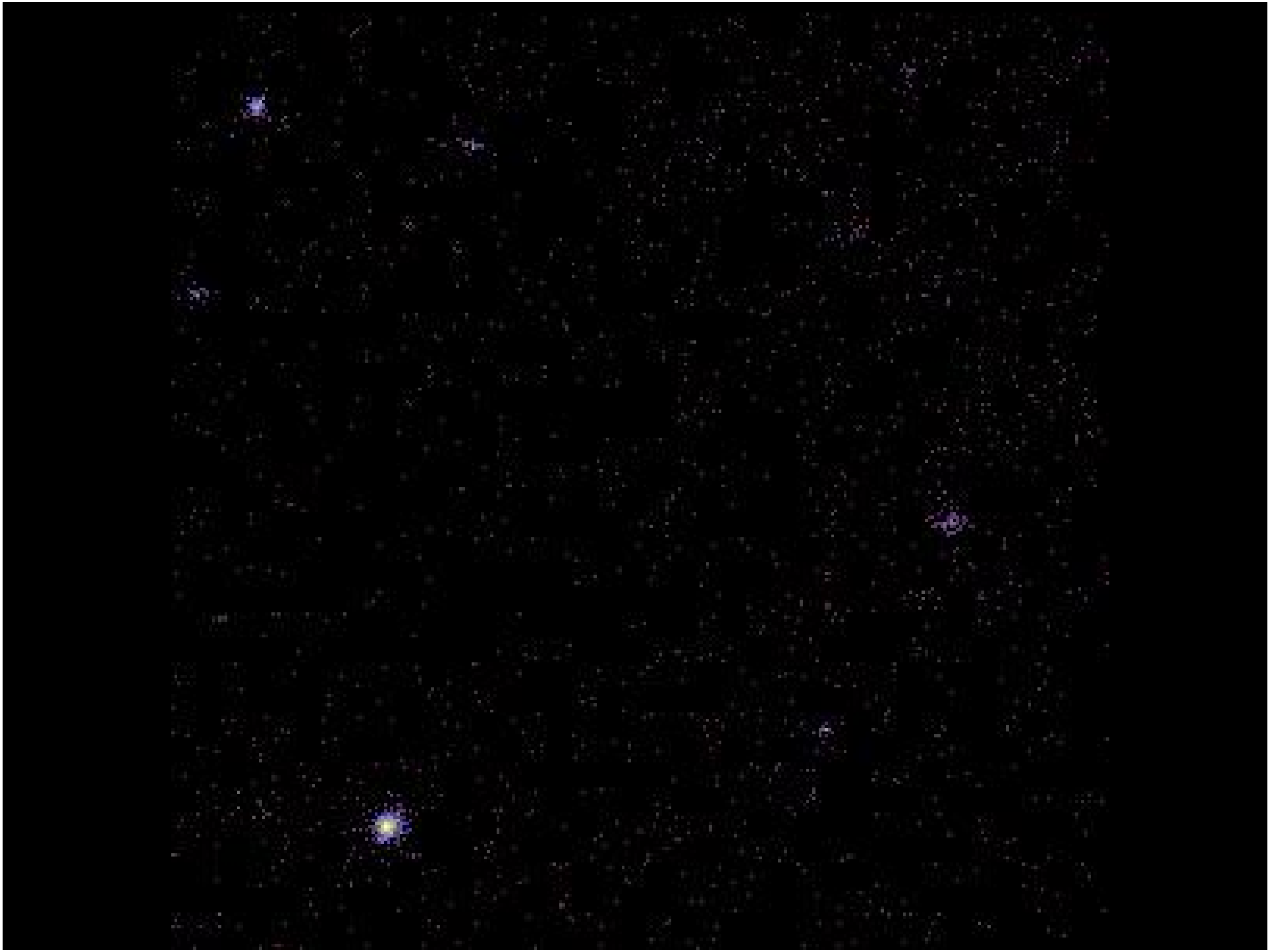
- To better understand the evolution of binary systems

>> What is the binary system, OAO 1657-415, like?



- 7^{th} eclipsing binary system found.
- P = 10.44809(30) days [1993]
- Mid-Eclipse Epoch at 48515.99 MJD [1993]
- About ~6.2kpc away from Earth
- Mass of neutron star $\sim 1.4 M_{\odot}$
- Mass of supergiant $\sim 13 M_{\odot}$
- Eccentricity of 0.104(5)

>> How is $\dot{P}$ measured?

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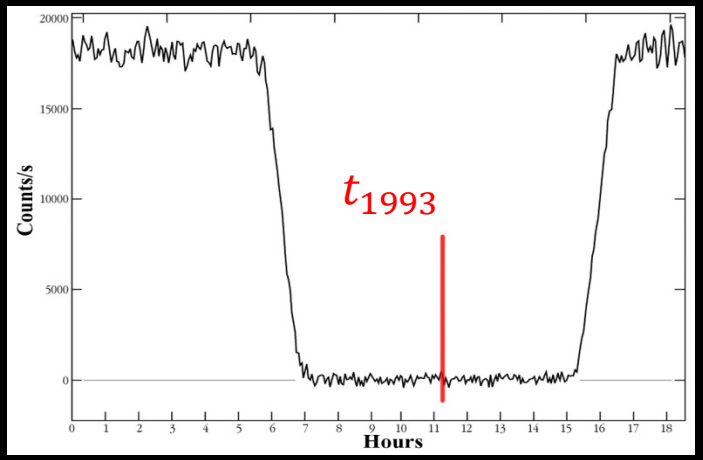
- Observe pulses from neutron star
- Supergiant eclipses neutron star ⇒ pulses cease

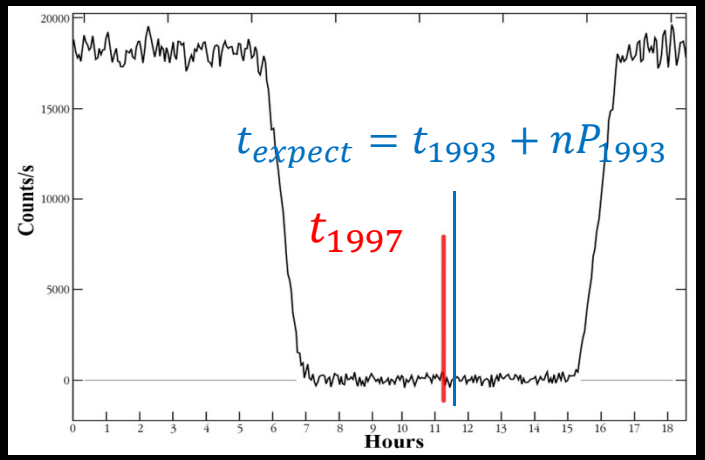
Since we know the previously measured Period and Mid-eclipse Epoch, we can do the following:

Data from 1993



$\Rightarrow$

Data from 1997



We would expect that the 1997 Epoch, say t_{expect}, would be t_{1993} plus an integer multiple of P_{1993}. If this is *not true*, than the period has changed.

Though software will likely do this for me, here is one way to get $\dot{P}$.

$$t_{1997} - t_{1993} = t'$$
$$t' \bmod P_{1993} \equiv t_o$$
$$\Rightarrow t_o < P_{1993}$$
$$\frac{P_{1993} - t_o}{t_{1997} - t_{1993}} \approx \frac{\Delta P}{\Delta t} \approx \dot{P}$$

I greatly doubt we will use a method this primitive.

>> How are X-Rays detected?

- The Rossi X-Ray Timing Explorer (RXTE)
- Period of 96 minutes at a Radius of 500,000 km

>> How is the data analyzed?

- NASA Provides software called FTOOLS which is used to sort data, create light curves, create spectra, and so on…

>> What do I actually do?

Most of my work looks like this:

```
jstreet@earth:/project/astro/jstreet/P20115/LC_ALL$ fmerge lastkey=TSTOP
List of FITS file to be merged[@list_filters_ALL.xdf]
Name of output merged FITS file[Merged_filters_ALL.xfl]
List of column names for the merged FITS file[@list_XTE_S2.txt]


jstreet@earth:/project/astro/jstreet/P20115/LC_ALL$ maketime
Name of FITS file and [ext#][filter_00A.xfl] Merged_filters_ALL.xfl
Name of output FITS file[basic_00A.gti] GTI_ALL.gti
Selection Expression[elv.gt.10.and.offset.lt.0.02.and.num_pcu_on.eq.5]
Flag, yes if HK format is compact[no]
Column containing HK parameter times[Time]
PREFR keyword not found, using prefr = 0.5
POSTFR keyword not found, using postfr = 0.5
```

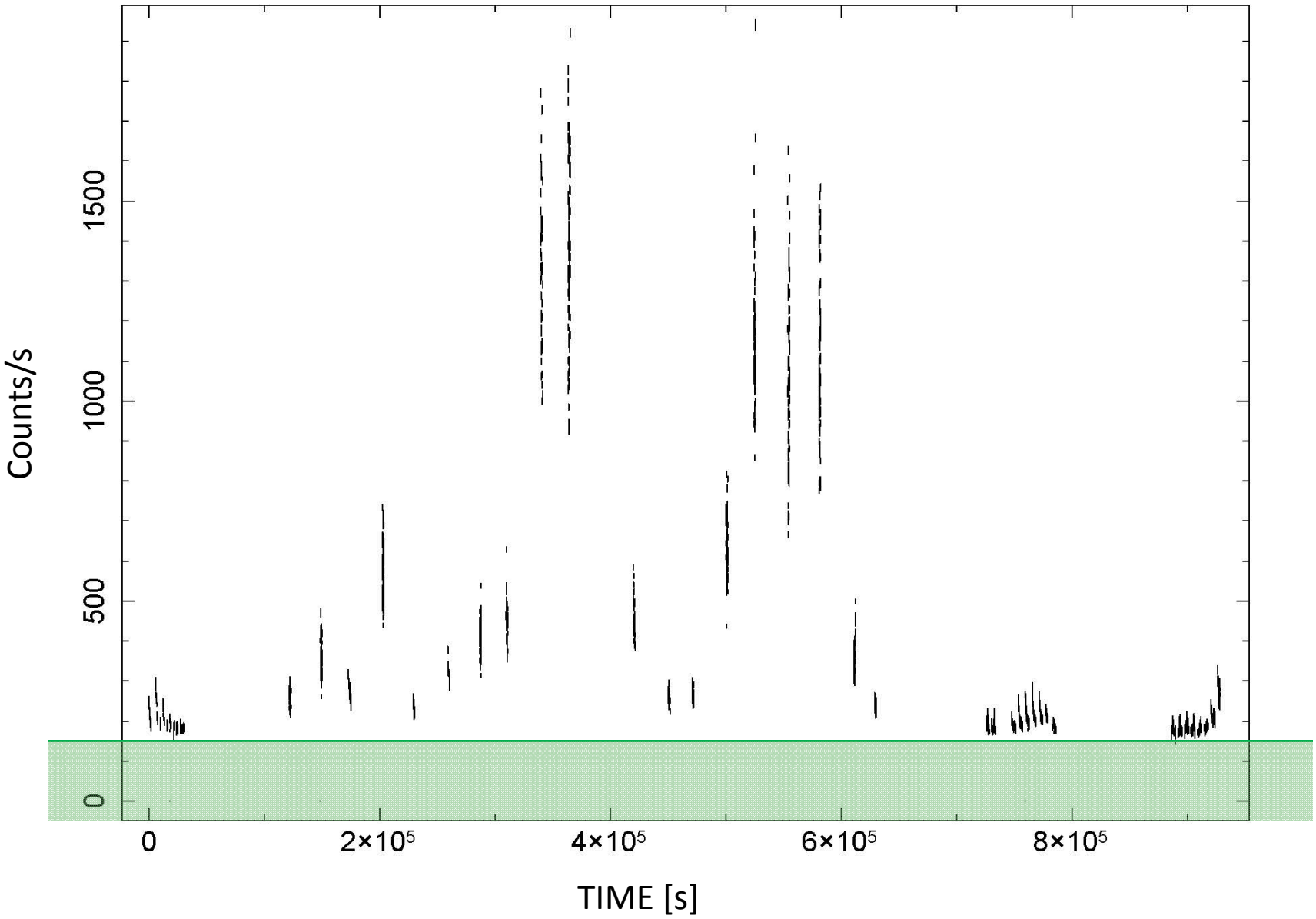
```
jstreet@earth:/project/astro/jstreet/P20115/LC_ALL$ make_se
Starting up MAKE_SE v.0.20

 > Give name of file containing FITS filelist [fits_files.txt] > list_GX_ALL.xdf
 > Give root for product (output) filenames [event] > Event_ALL

-------------------------------------------------
    Input file name: list_GX_ALL.xdf
    Output file root: Event_ALL
-------------------------------------------------

FS37_734a610-734b1f4    1.2089089600000000E+08   GoodXenon1_2s
FS37_734be00-734c876    1.2089702400000000E+08   GoodXenon1_2s
FS37_734d4f0-734def4    1.2090289600000000E+08   GoodXenon1_2s
FS37_734ed10-734f576    1.2090907200000000E+08   GoodXenon1_2s
FS3b_734a610-734b1f6    1.2089089600000000E+08   GoodXenon2_2s
FS3b_734be00-734c874    1.2089702400000000E+08   GoodXenon2_2s

(. . .)
```

```
jstreet@earth:/project/astro/jstreet/P20115/LC_ALL$ seextrct

Running SEEXTRCT version 4.2e
=============================================
Input file name or @file-of-filenames:[@Event_00A.txt] @Event_list.txt
Input GTI files to be OR'd with INFILE (-):[APPLY]
Input GTI file to be AND'd with INFILE (-):[basic_00A.gti] GTI_ALL.gti
Root name for output file:[sec]
Name of TIME column:[TIME]
Name of COLUMN to be accumulated:[Event]
Input the binsize in seconds, use 0.1 etc. if nec (INDEF):[16.0]
Chose print option, LIGHTCURVE, SPECTRUM, or BOTH:[lightcurve]
Type of binning for LIGHTCURVE: (SUM, RATE, MEAN):[RATE]
Type of binning for SPECTRUM (SUM, RATE, MEAN):[SUM]
Starting time for summation in seconds (INDEF):[INDEF]
Ending time for summation in seconds (INDEF):[INDEF]
Input time intervals t1-t2,t3-t4 in seconds (INDEF):[INDEF]
Minimum energy bin to include in Spectra (INDEF) or 0-255:[INDEF]
Maximum energy bin to include in Spectra (INDEF) or 0-255:[INDEF]
Input energy intervals to be retained 0-1,2-255 (INDEF):[INDEF]
Input channels for each bin 0-5,6-255 (INDEF):[INDEF]

(. . .)
```

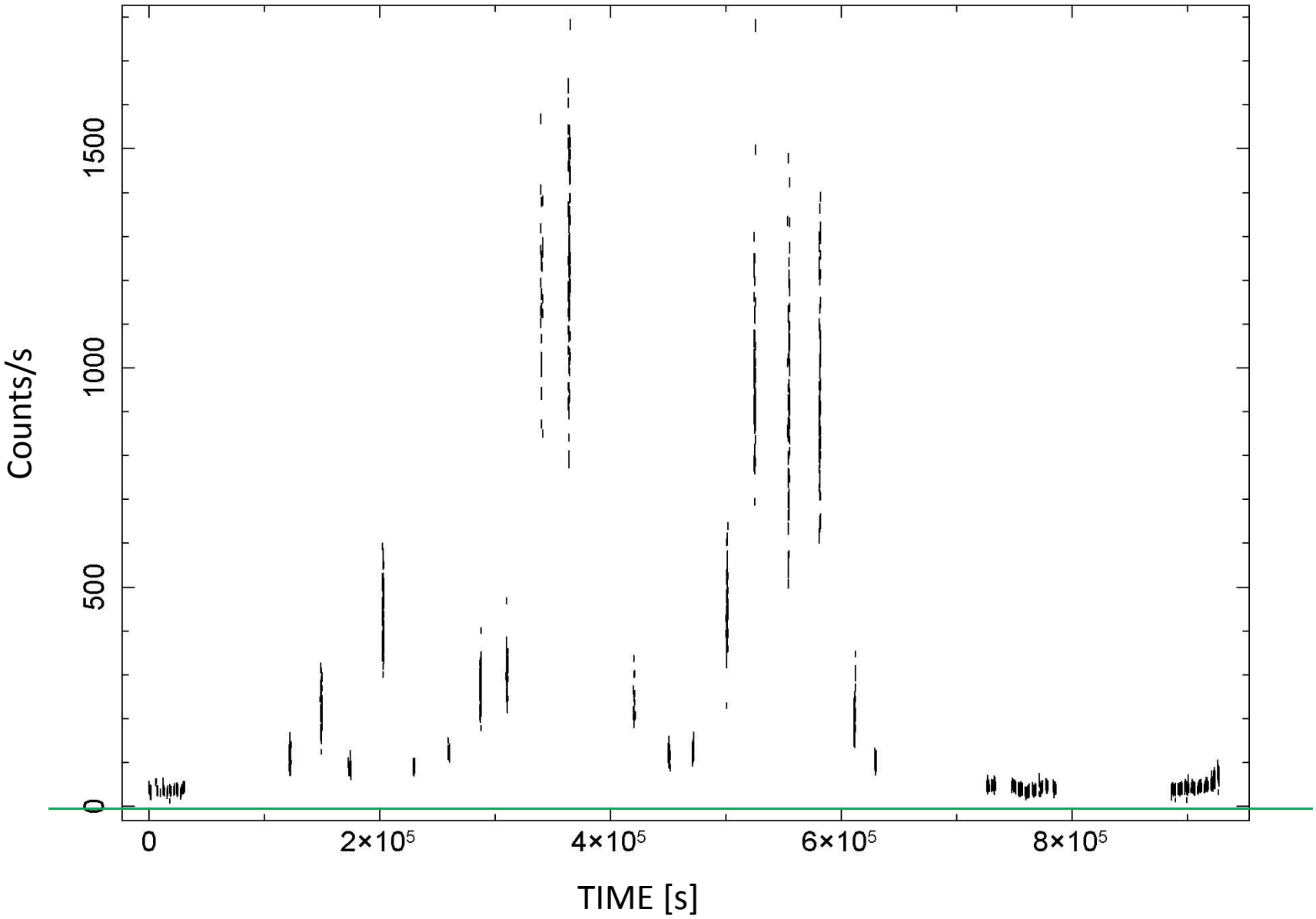
```
jstreet@earth:/project/astro/jstreet/P20115/LC_ALL$ fplot offset=yes sec.lc
Name of X Axis Parameter[error][Time]
Name of Y Axis Parameter[error] up to 8 allowed[ELV OFFSET NUM_PCU_ON] RATE[ERROR]
Lists of rows[-]
Device: /XWindow, /XTerm, /TK, /PS, etc[/PS]
Any legal PLT command[]
PLT>
```

And after all of this fun is done, we get…

Light Curve Before Background Subtraction



Light Curve After Background Subtraction



>> What's Next?

- Fold light curve I'm not totally clear on how this will work.
- Calculate Mid-Eclipse Epoch
- Compare Epochs as described earlier
- Calculate $\dot{P}$

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VERITAS = Very Energetic Radiation Imaging Telescope Array System