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?
Who am I?
- Joseph Street

For whom do I work?
- Dr. John Finley

And in what department?
- High Energy Astrophysics
What is the Orbital Period Derivative ($\dot{P}$)?
What is the Orbital Period Derivative ($\dot{P}$)?

$\dot{P}$ is the change in period of the orbiting bodies that comprise the binary system with respect to time.
Why do we care about this?
Why do we care about this?

- To better understand the evolution of binary systems
What is the binary system, OAO 1657-415, like?
• 7th eclipsing binary system found.
• \( P = 10.44809(30) \) days [1993]
• Mid-Eclipse Epoch at 48515.99 MJD [1993]
• About \( \sim 6.2 \) kpc 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?
How is $\dot{P}$ measured?

- Observe pulses from neutron star
- Supergiant eclipses neutron star $\Rightarrow$ pulses cease
Since we know the previously measured Period and Mid-eclipse Epoch, we can do the following:

Data from 1993

Data from 1997

$\scriptstyle \text{Counts}$$

$t_{1993}$

$t_{1997}$

$t_{\text{expect}} = t_{1993} + nP_{1993}$

We would expect that the 1997 Epoch, say $t_{\text{expect}}$, 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 $\dot{P}$.

$$
\begin{align*}
& t_{1997} - t_{1993} = t' \\
& t' \mod P_{1993} \equiv t_o \\
\Rightarrow & \quad t_o < P_{1993} \\
& \frac{P_{1993} - t_o}{t_{1997} - t_{1993}} \approx \frac{\Delta P}{\Delta t} \approx \dot{P}
\end{align*}
$$

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
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  1.208908960000000E+08  GoodXenon1_2s
FS37_734be00-734c876  1.208970240000000E+08  GoodXenon1_2s
FS37_734d4f0-734def4  1.209028960000000E+08  GoodXenon1_2s
FS37_734ed10-734f576  1.209090720000000E+08  GoodXenon1_2s
FS3b_734a610-734b1f6  1.208908960000000E+08  GoodXenon2_2s
FS3b_734be00-734c874  1.208970240000000E+08  GoodXenon2_2s

( . . )
Running SEEXTRACT 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

Counts/s

TIME [s]
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