Timing Analysis with *Chandra*

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(& thanks to Glenn Allen, Peter Ford, Herman Marshall …)

See help threads at:

http://cxc.harvard.edu/ciao/documents_threads_timing.html

And keep an eye on:

http://space.mit.edu/CXC

Hey?! Isn't That RXTE's Job? Yes, but … *Chandra* Can:

- Observe Crowded Fields
- Observe the 0.1 – 2 keV Energy Band
- Obtain 10^{-5} Hz – 10^{-3} Hz (not since EXOSAT!)
- Faint Objects (*Single* Photons Matter!)

And It Can do msec Timing Too!

Normalizing Power as $(\mathrm{RMS})^2/\mathrm{Hz}$:

$(\text{Noise Limit} * df)^{1/2} = (2/R)^{1/2} (1 + B/R)^{1/2} (df / T)^{1/4}$,

i.e., RMS limit in *averaged* frequency bin, where:

- R = Signal Count Rate
- B = *Constant* Background Count Rate
- T = Total Observation Length
- df = Width of Frequency Bin

Example: T = 40 ksec,

RMS Limit ~10% $R^{-1/2} (1 + B/R)^{1/2} (df / 1\ \mathrm{Hz})^{1/4}$

Reducing Background Can Really Help!

Fundamental Times: ACIS, Timed Exposure

- **Frame Time:**

  $$T\,(\text{msec}) = (41 + 0.040 * q)*m + 2.84*n + 5.2\ ,$$

  q = # of rows from readout

  m = # of active chips

  n = # of rows read

- **Reality: Frame Time is *Integer* Multiple of 0.1 sec (0.2 – 10 sec) + 41.04 msec**
- **Caveat: Images are Transferred to Frame Store (Quasi-) Serially, so up to a 5*41.04 msec Delay Between Chips**
- **Event Times are *Middle* of Frame Time**

Fundamental Times: ACIS, Timed Exposure

- **Frames Take 41.04 msec to Transfer to Frame Store, so a Given Amount of (Uniform) Deadtime is Expected**
- **Charge Moved at 40 μsec/row, which Gives the Potential for Very Fast Timing of Readout Streaks**
- **(Sources that bright will otherwise be difficult to deal with…)**

Fundamental Times: ACIS, Timed Exposure

- **Event Time is *Terrestrial Time*, Referenced to:**

  MJD = 50814.0 **(January 1, 1998)**

  MJD = Julian Date – 2,400,000.5

  (TJD = MJD – n * 10,000. *Don't Use!*)

- ***XMM*: Same Reference MJD**

- ***RXTE* Referenced to:**

  MJD = 49353.000696574074 **(January 1, 1994)**

  (fraction is ~ 1 minute, i.e. Terrestial Time vs. UTC)

- ***ASCA* is Referenced to:**

  MJD = 48988.0 **(January 1, 1993)**

Check FITS Headers!

None of These Times are Barycentered!

(Requires Orbital Ephemeris; *axbary*, *fxbary*)

- **Useful Links for Understanding/Converting:**
- **NIST Time Glossary -**

  http://www.bldroc.gov/timefreq/

- **Date Conversion Utility -**

  http://heasarc.gsfc.nasa.gov/cgi-bin/Tools/DateConv/dateconv.pl

- **Look at *ahelp* file for *axbary***

Fundamental Times: ACIS, Continuous Clocking

- **Rows are Read Out Every 2.85 msec**
- **Chips are Read in Parallel**
- **Time is Read Out Time, *Not* Arrival Time. (Read out delay from aim point, modulo dither, etc.) Tool (from G. Allen) to Correct This Almost Ready.**
- **Generalization to CC-Gratings Observation Should Be Straightforward**
- **40 μsec row shift "deadtime" still applies**

Fundamental Times: HRC-S

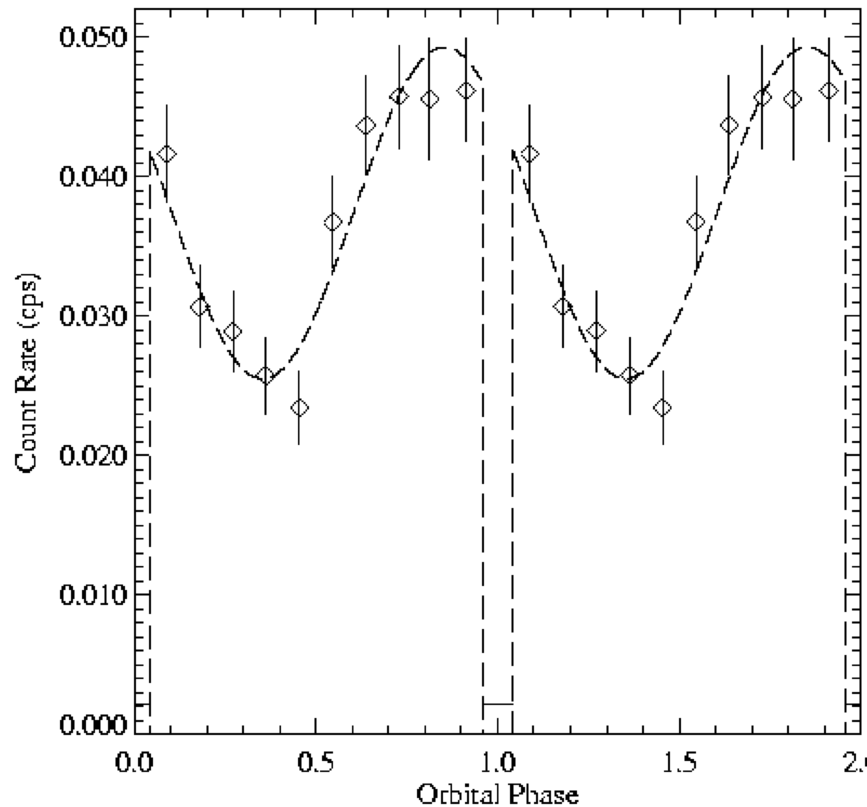
- HRC-I Wiring Problem Limits Time to ~ 4 msec on Average
- HRC-S Can Achieve 16 μsec Accuracy
- Faster Timing than ACIS, but more severe Telemetry Limits (184 cps), and Higher Backgrounds
- But, no Deadtime, and HRC-S is Linear Up to at Least 5 cps for a Point Source

Tools at Your Disposal:

- **CIAO Tools: *lightcurve*, *axbary*, threads on filtering lightcurves, creating phase-folded spectra**
- **Data products can be further analyzed with *XRONOS*, *IDL*, *S-Lang*, …**
- **More to be Developed. What Do Users Want?**

Self-Promoting Example:

- ***lightcurve*** **corrected with *axbary*, allowed comparison to previous observations**
- **Folded Spectrum Created with *CIAO* Tools, Following Threads**
- ***0 Background!***
  df **~ 5 x 10^{-5} Hz , RMS > 4%**
- ***Single photon events*** **used to determine rapidity of eclipse, yielding limits on source size**



Other Examples Have Included:

- **Crab Pulsar (Easily Detected)**
- **RX J185635-375 (astro-ph/0204159): Strong Upper Limits to Pulse Fraction**
- **Important Caveat/Strong Suggestion: Bin on Integer Multiples of “Natural” Time Unit, Watch Out for Instrumental Time Scales (dither, etc.)**