XTE J1807-294

one of the four accreting millisecond pulsars

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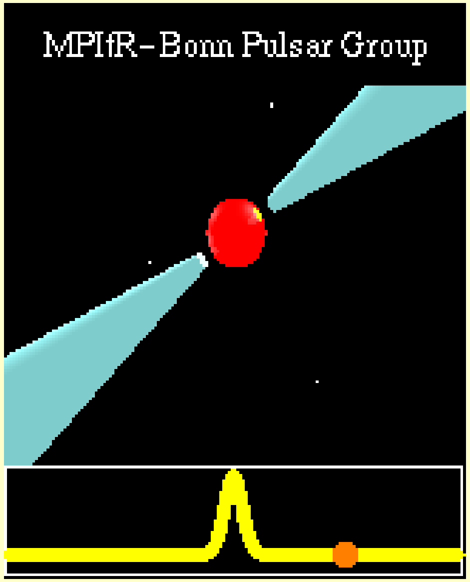
the question



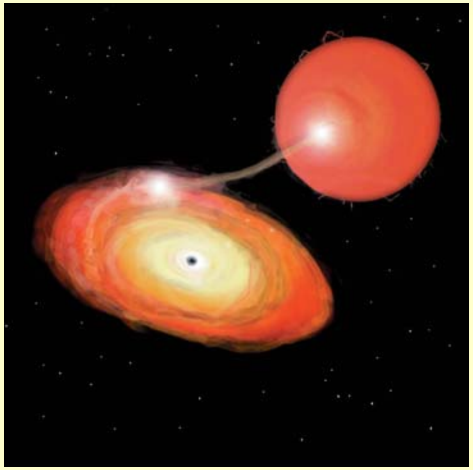
- ordinary radio pulsars: P=0.1-3 sec, B~10^{12} Gauss
- ms radio pulsars: B ~10^{9} Gauss

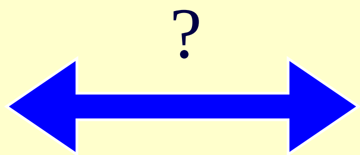
- energy for both is thought to be derived from the rotation of the neutron star

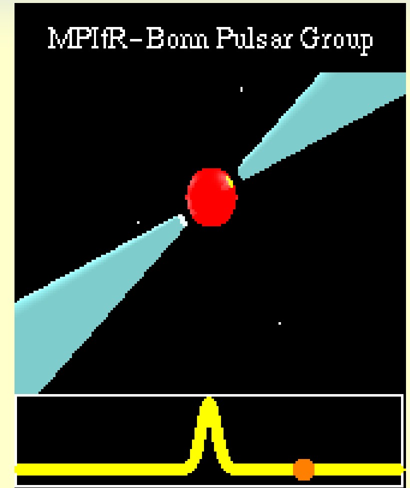
  → NS gradually spins down as energy is radiated away

how did they speed up again ?

accreting millisecond pulsars:







- missing link between X-ray binaries and ms radio pulsars
- ms pulsars possible end state of low-mass X-ray binary (LMXB) evolution
- neutron star in LMXB spin-up due to accretion toque to millisecond period while losing its magnetic field, due to accretion matter from its stellar companion
- at the end of accretion phase, it may turn on as a radio millisecond pulsar

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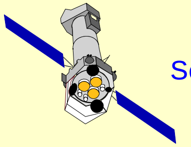
accreting millisecond pulsars:

- four objects
  - **SAX J1808.4-3658**: (Wijnands & van der Klis 1998), first evidence of spun-up neutron star by mass accretion in LMBX
    P_{spin}: 2.49 ms, P_{orb}: 120 min
  - **XTE J1751-305** P_{spin}: 2.30 ms, P_{orb}: 42.0 min
    (Markwardt & Swank 2002)
  - **XTE J0929-314** P_{spin}: 5.41 ms, P_{orb}: 43.6 min
    (Remillard, Swank & Strohmayer 2002)
  - **XTE J1807-294** P_{spin}: 5.25 ms, P_{orb}: 40.07 min
    (Markwardt, Smith & Swank 2003)



accreting millisecond pulsars:

features

- **short period**
- **X-ray transients**
- **ultra compact binary systems**, orbital period < 120 minutes
- binary parameters imply ~0.01 M_{sun} white dwarf donors with moderately high inclination
- **extremely low mass transfer rates** (M': 10^{-10} M_{sun}/year) provide easy detection, otherwise difficult to detect due to magnetic screening by freshly accreted matter on to the neutron star which can prevent the formation of persistent X-ray pulses when the accretion rate reaches a critical limit (Cumming, Zweibel & Bildsten 2001).
- **weak magnetic fields** (SAX J1808.4-3658 1-5 10^8 Gauss, Di Salvo & Burderi 2003, measured from source luminosity in quiescence)

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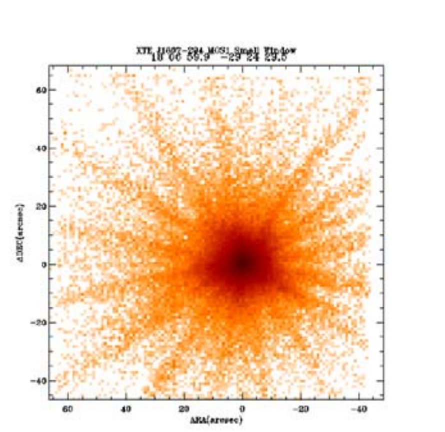
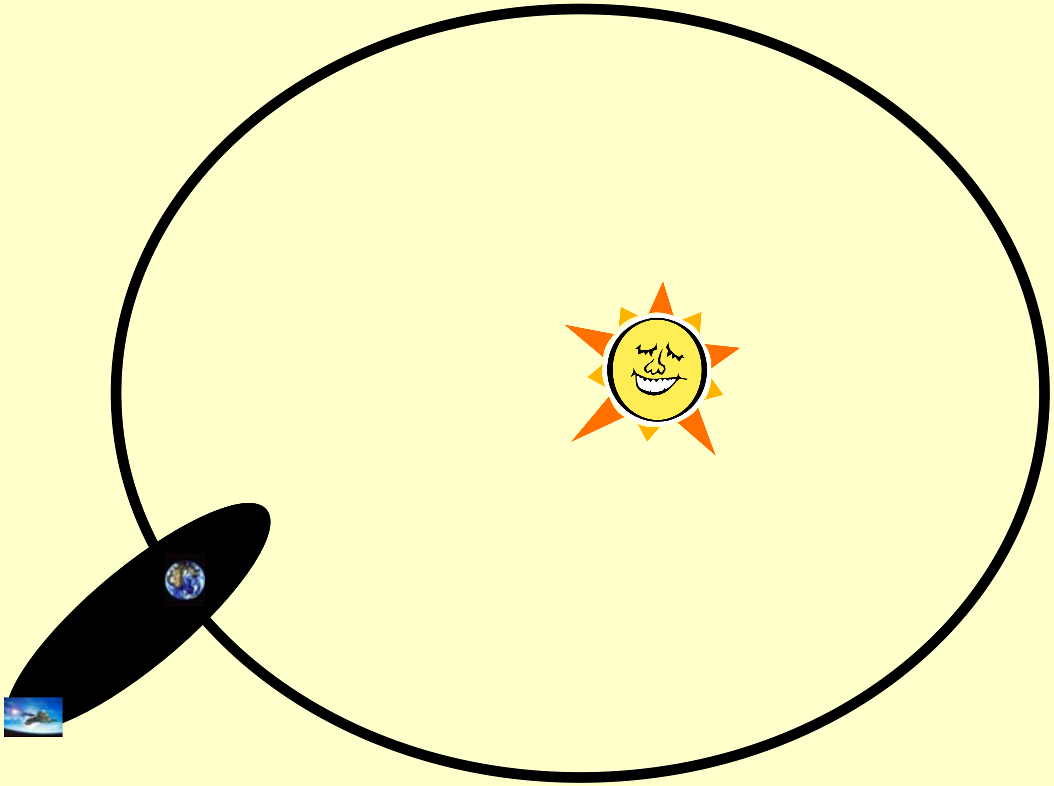
XTE J1807-294

- **Feb. 21 2003:**
  discovered by RXTE (Markwardt et al., IAUC/ 8080)
- **March 10:**
  Chandra best fit position R.A. = 18h06m59.80s,
  DEC= -29°24'30" (equinox 2000.0; uncertainty about 1")
- **March 16:**
  orbital period: 40.0741 +/- 0.0005 minutes (Markward et al.)→ shortest period of any of the four accreting millisecond pulsars
- **March 22:**
  ToO observation XMM-Newton (01579601)

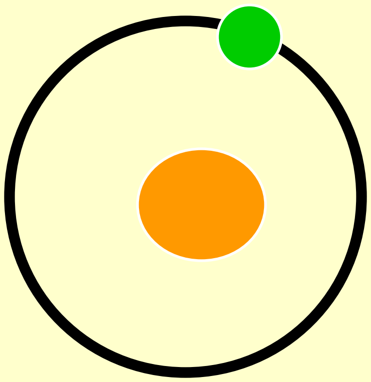


time correction

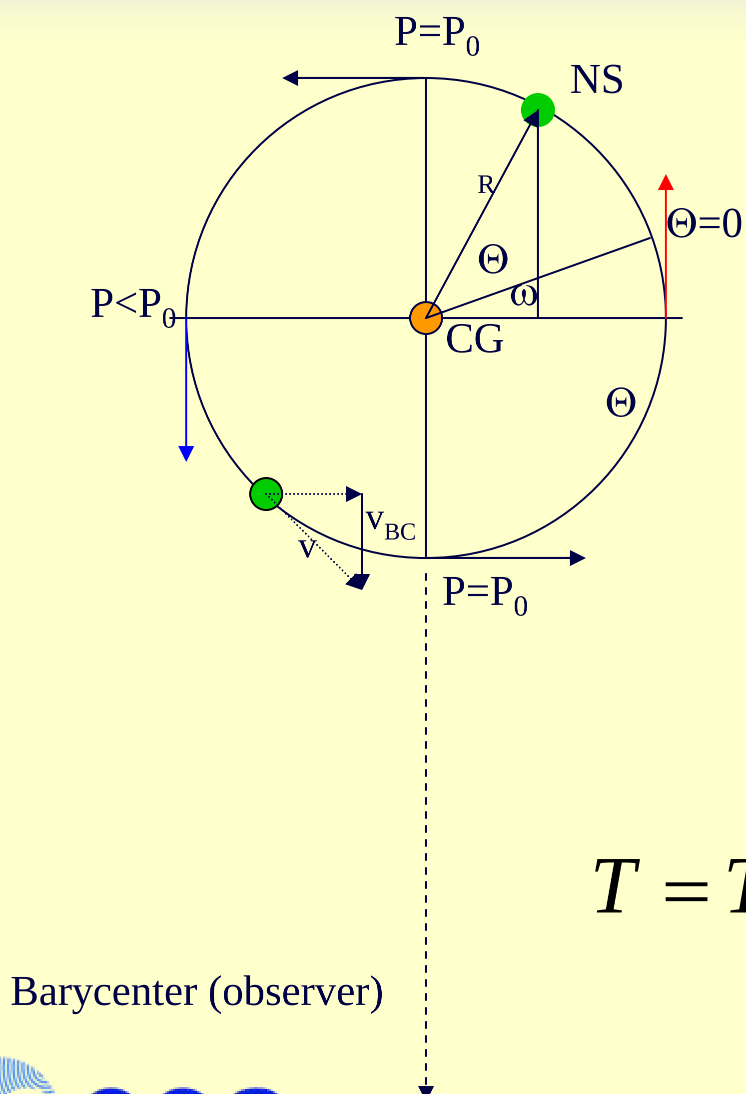
- correction of photon arrival time to the solar barycenter as a reference point



- correction for photon arrival time to the binary barycenter



binary correction



$$x(t) = x_0 \sin\left(\frac{2\pi}{P_{orb}}(t - t_0)\right)$$

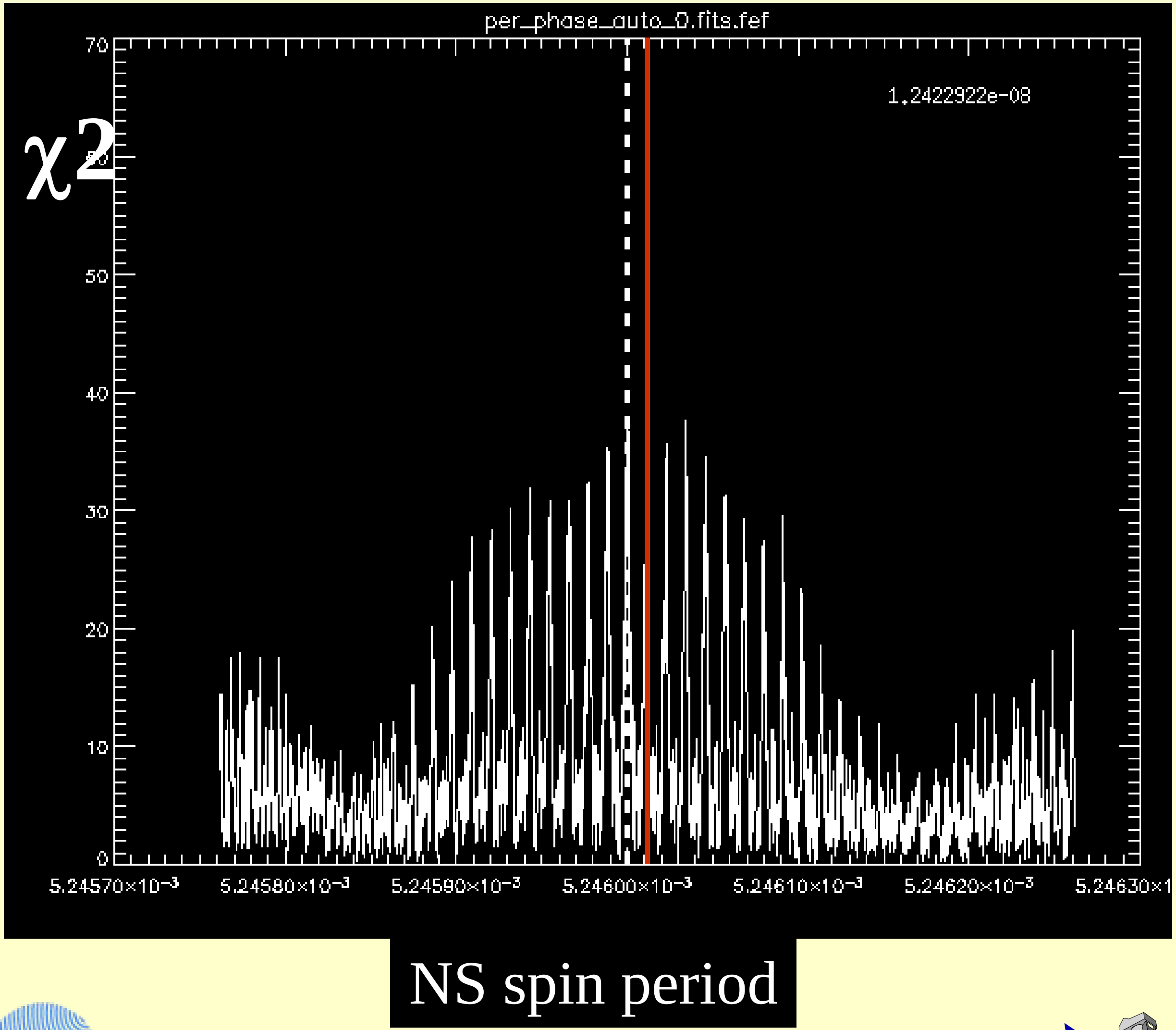
$$v(t) = x_0 \frac{2\pi}{P_{orb}} \cos\left(\frac{2\pi}{P_{orb}}(t - t_0)\right)$$

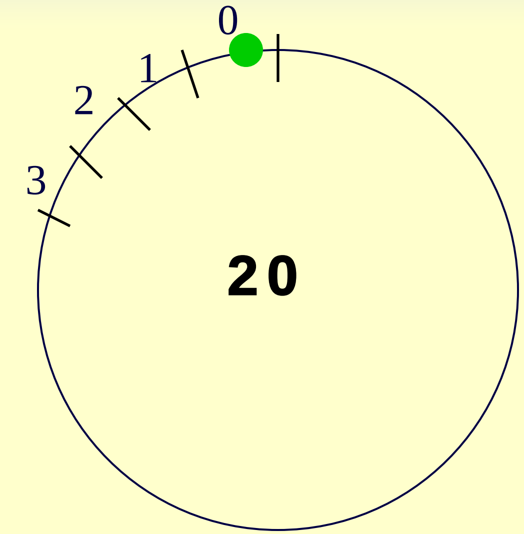
$$v_{\max} = x_0 \frac{2\pi}{P_{orb}} = \frac{c\left(P_{spin} - P_{spin0}\right)}{P_{spin}}$$

$$x_0 = a \cdot \sin i = \frac{c\left(P_{spin} - P_{spin0}\right)}{P_{spin}} \frac{P_{orb}}{2\pi}$$

$$T = T_{bc\_sun} - \frac{x_0}{c} \sin\left(\frac{2\pi}{P_{orb}}(t - t_0)\right)$$

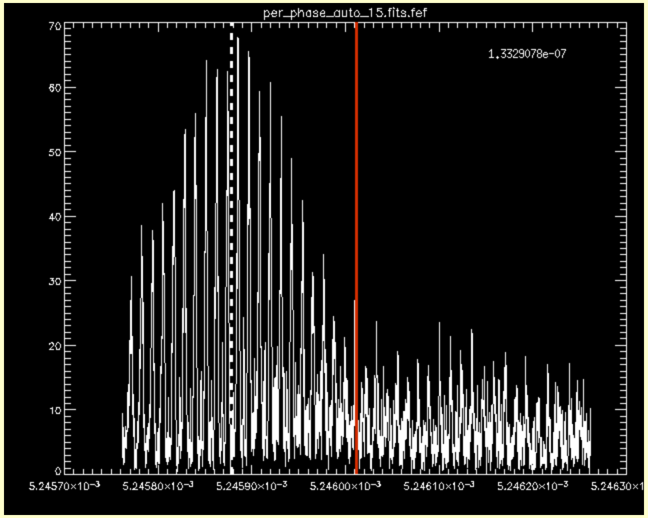
orbit phases

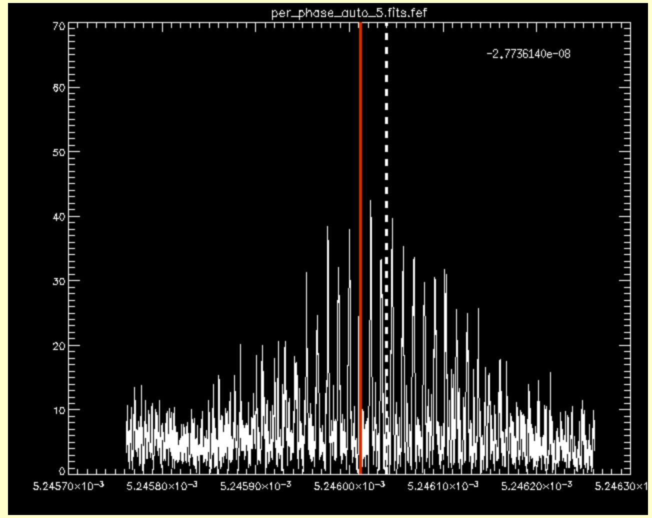




- divide orbit into n phases and determine best fit NS spin period for each phase

approximation of x_0 and t_0

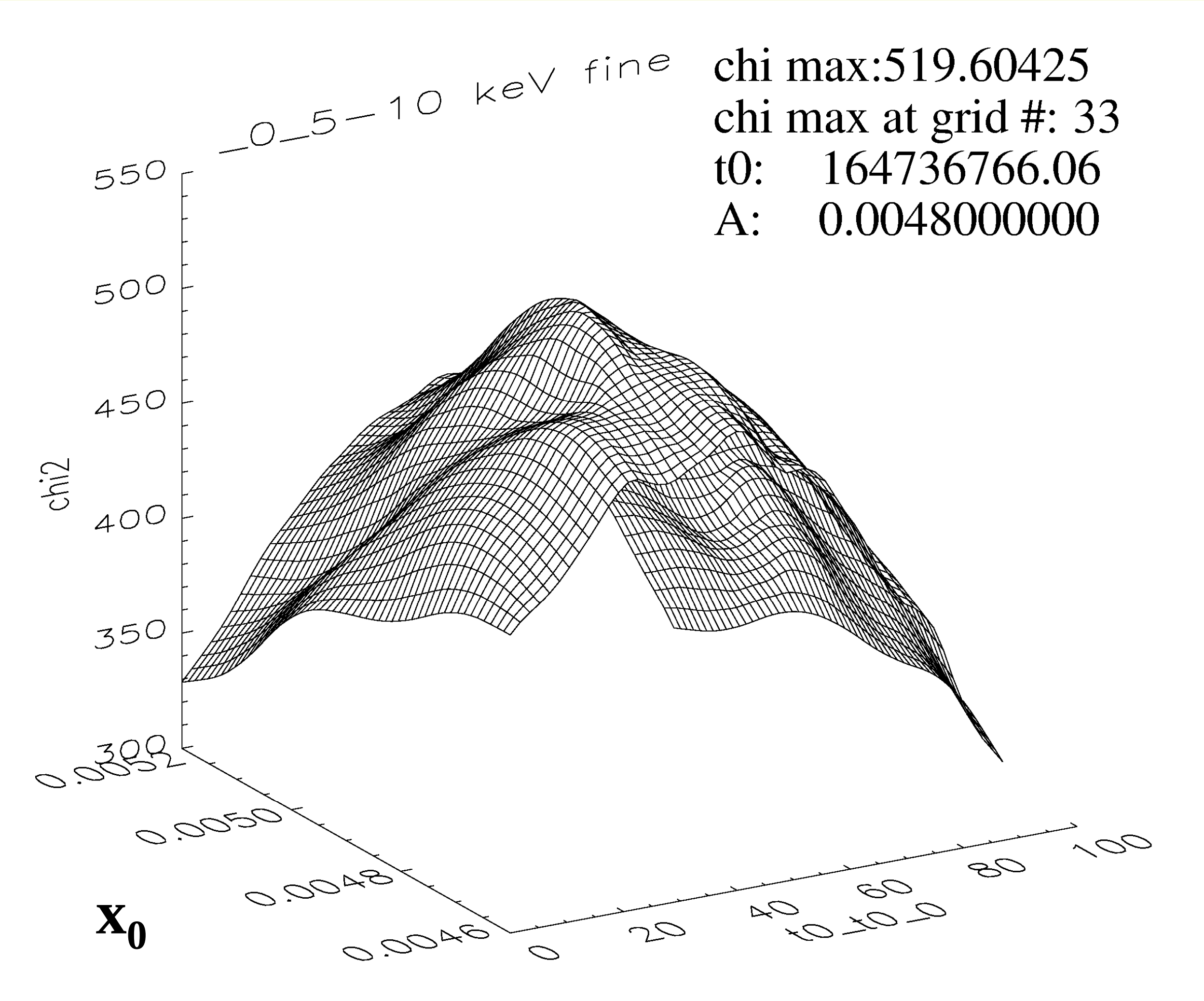




$$T = T_{bc\_sun} - \frac{x_0}{c}\sin\left(\frac{2\pi}{P_{orb}}(t - t_0)\right)$$

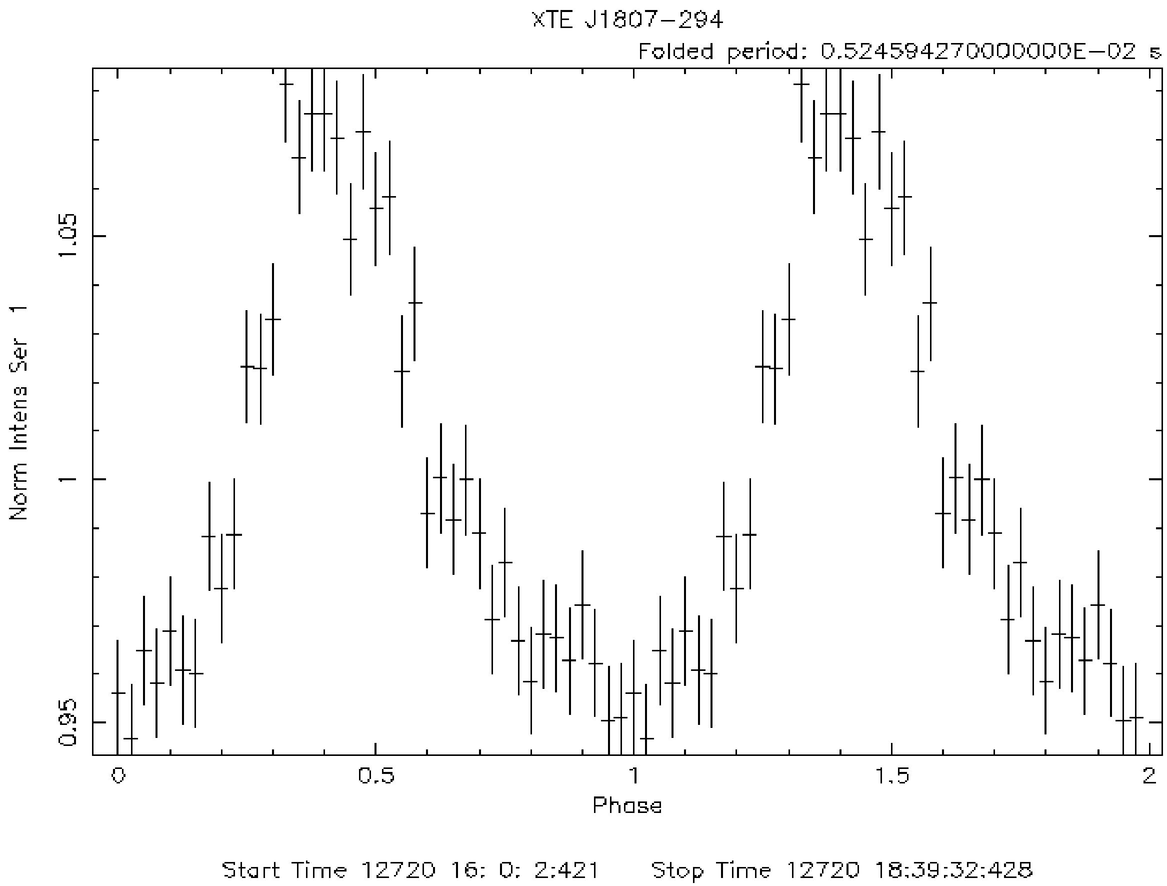
- orbit phase 5 and 15 give first start values for x_0 and t_0
- x_0 via ΔP_{spin}
- t_0 time of first photon in orbit phase 5

determination of x_0 and t_0



- correct photon arrival times to binary barycentre for a grid of different x_0 and t_0
- determine best fit NS spin period

folded light curve of NS



- pulse profile shows a single peak (~ 1.5 ms FWHM)
- combined pulse profile in the 0.5-10 keV band shows a modulation of 6.0 +/- 0.1 % (90-% confidence level).

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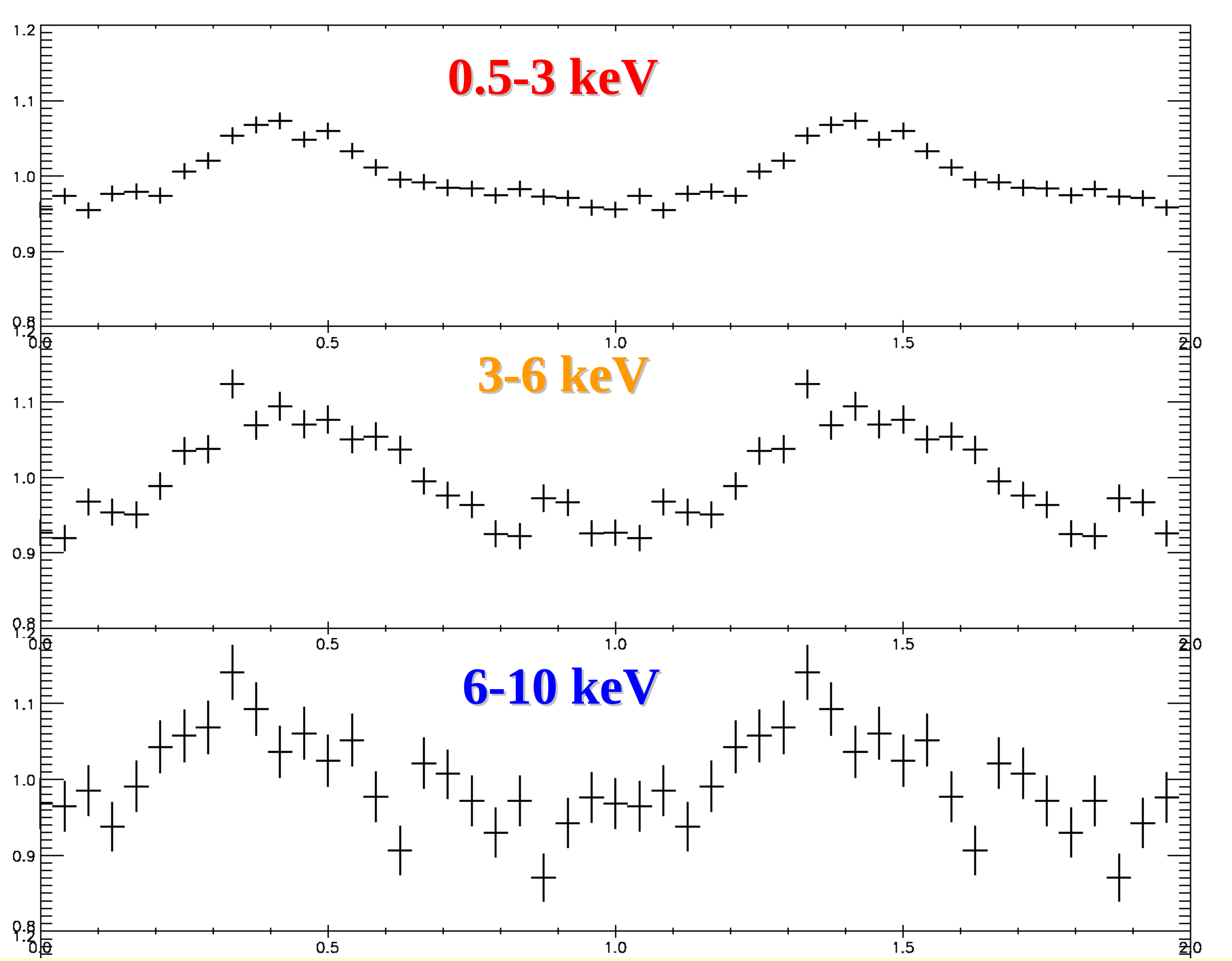
pulse profile at different energies



- modulation over the entire energy band from 0.5 to 10 keV
- lager pulsed fraction at higher energies

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summary

- P_{orb} = 40.04741 ± 0.0005 min

- P_{spin} = 5.2459427 ± 0.0000004 sec
- a·sin(i)/c=4.8 ms
- v_{max} = 13555.61 km/h

- modulation over the entire energy band from 0.5 to 10 keV
- pulse profile shows a single main peak (~ 1.5 ms FWHM)
- combined pulse profile in the 0.5-10 keV band shows a modulation of 6.0 +/- 0.1 percent (90-percent confidence level)

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