UNIVERSITY OF ALBERTA

47 Tuc W : Mysterious X ray Variable

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Introduction

Figure 1 : Chandra Observatory

The Chandra X-ray Observatory is a observatory launched by NASA on July 23, 1999. It is one of the best X-ray observatories, with excellent spatial resolution of less than an arc second. Since the Earth's atmosphere is opaque to X-rays, it's essential for X-ray observatories to be space based. Chandra is an Earth satellite in a 64 hr orbit and is working in perfect condition as of now.

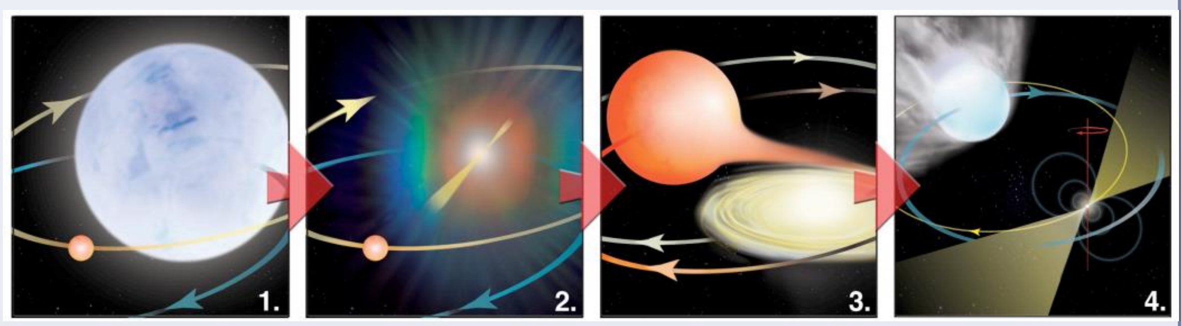


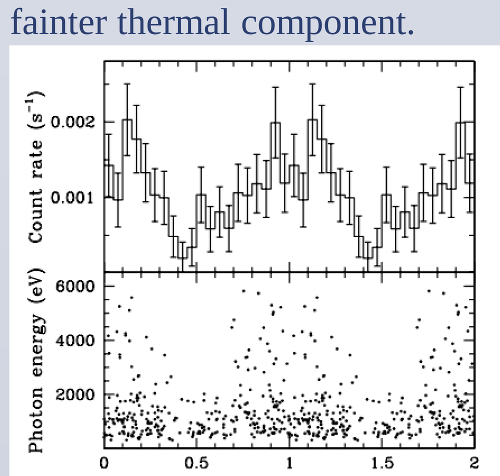
Figure 2: Evolution of millisecond pulsar

Radio pulsars are highly magnetized, spinning neutron stars that emit radio waves through their poles that sweep across us as they spin and appear as pulses. Radio millisecond pulsars (MSPs) are pulsars characterized by small spin periods (< 25ms). It is believed that these Neutron stars (NSs) were spun up to such high frequencies due to the angular momentum of the accreting matter from their companion stars during their active phase. Three systems have recently been observed to transition between accreting phases, and radio pulsar behaviour.

Figure 3: X ray image of 47 Tuc

In this project we study the X-ray properties of the binary system of the pulsar PSR J0024-7204W (henceforth 47 Tuc W). 47 Tuc W has a spin period of 2.35 ms and a binary period of 3.2 hrs. The optical counterpart of 47 Tuc W is a $\gtrsim 0.13\ M_{\odot}$ main sequence star. This implies that either the companion star has just finished spinning up the pulsar or the original secondary star has been exchanged. It was shown that 47 Tuc W coincided with the X-ray source W29. The X-ray spectrum of 47 Tuc W is relatively hard suggestive of a non thermal emission.

The detailed analysis of X-ray light curve and spectrum of 47 Tuc W was done by Bogdanov et al. 2005 which analysed the 2002 observations of 47 Tuc W by Chandra X-ray Observatory. The X-ray spectrum was decomposed into a dominant non thermal (power law) component and a fainter thermal component.



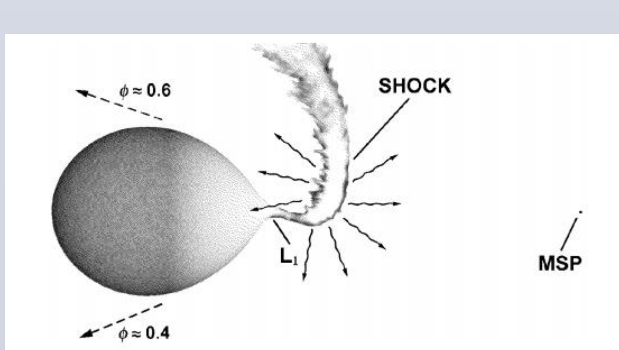


Figure 5 : 47 Tuc W system

Figure 4: (Top)Light curve of 47 Tuc W by Bogdanov et al.
(Below)Distribution of photons w.r.t energy and orbital phase

Based on these observations it was proposed that the non thermal component was emitted from an intra-binary shock and the thermal component was from the NS atmosphere.

Objectives

In 2007, Cameron et al. reported the absence of any transits in the light curve of 47 Tuc W in 2005- 06 HRC observations. The following light curve was reported. This raised the question whether the transits had disappeared, indicating a change in the system, such as might be expected in a system which transitions between accretion and a radio pulsar phase.

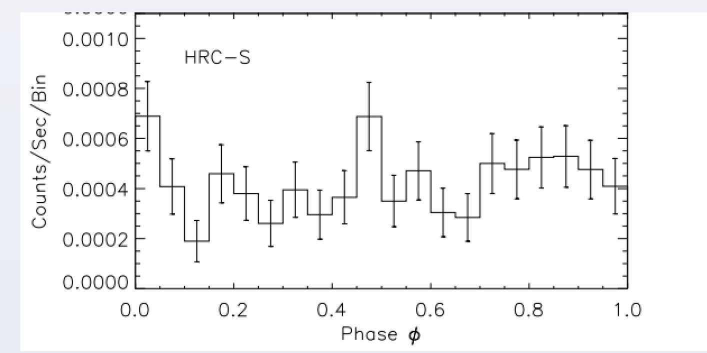
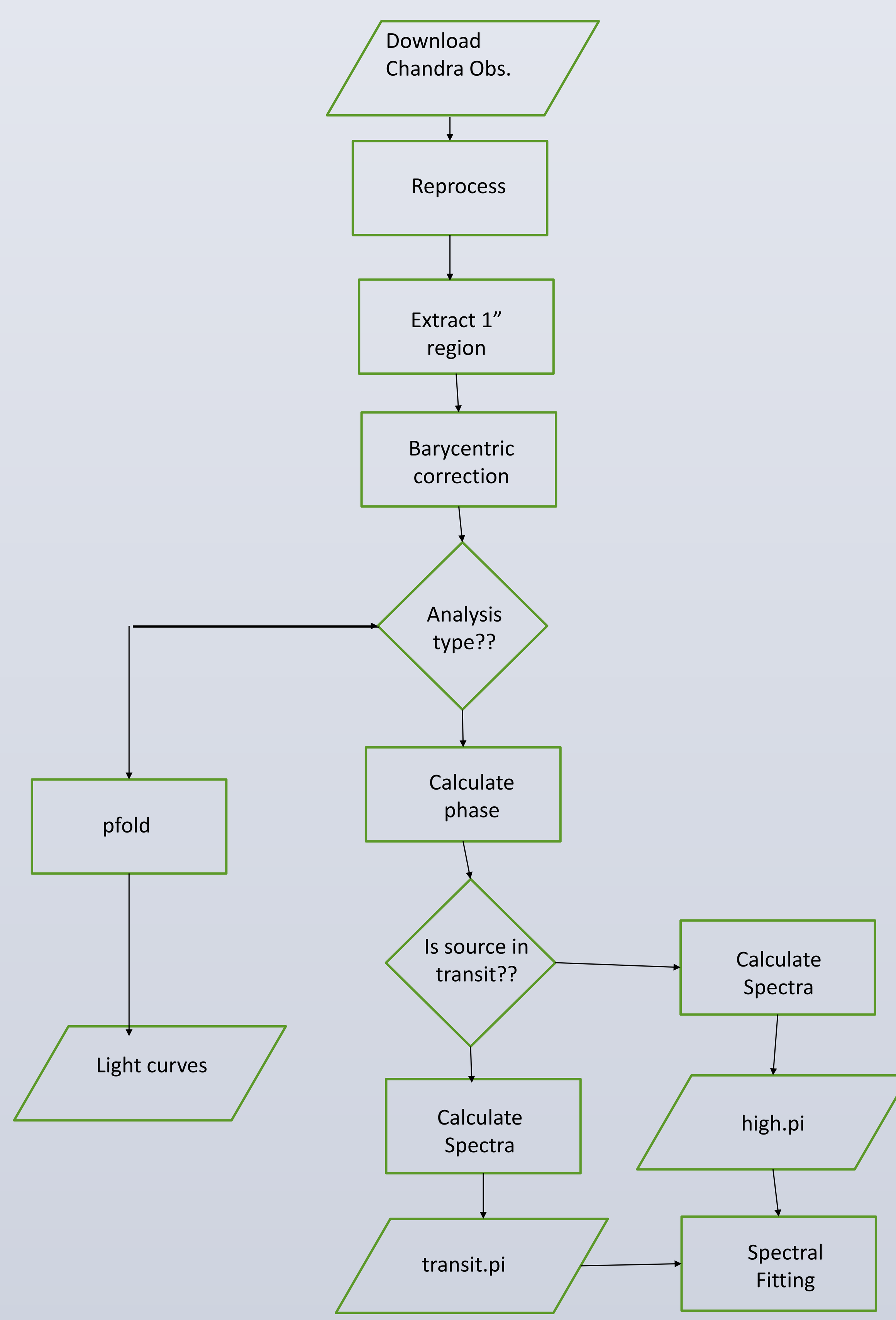


Figure 6: HRC light curve, by Camreon et al.

- In this project we looked at the light curves of 47 Tuc W in the latest Chandra observations of 2014 – 15 to verify the nature of the binary system.
- We also analyzed the spectroscopic data in order to look into the mechanism of X-ray emission and NS properties

Observations and Data analysis

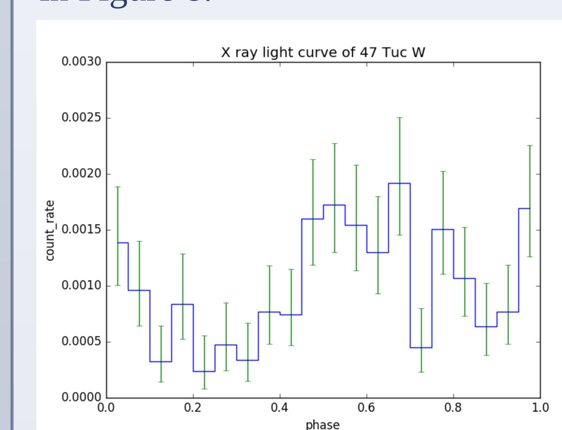
In this project we have primarily looked into the latest Chandra Observations of 47 Tuc W. We also analyzed the 2002 and the 2005- 06 observations for the purpose of comparison.



Results

Light curves

The background becomes significant at higher energies, therefore we filtered the photons from 0.3 – 6 keV to analyze the light curve. On folding the light curve using a period of 11486.4 s (Ridolfi et al. in prep.), we obtained the following light curve as shown in Figure 7. Since HRC is sensitive to soft X-rays, we also plotted the count rate v/s the phase for the photons of energy between 0.3 – 2 keV. The light curve obtained is shown in Figure 8.



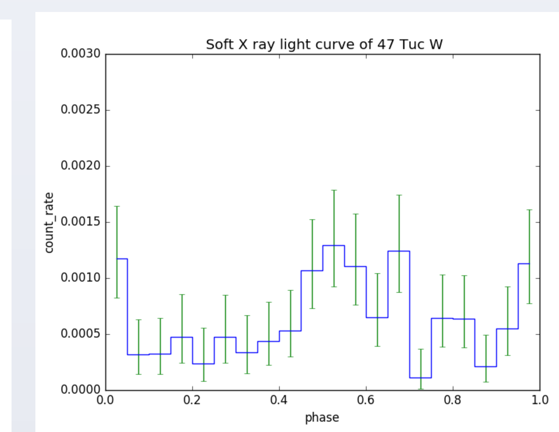


Figure 7: 2014 light curve of 47 Tuc W

Figure 8 : 2014 soft x-ray light curve

We see that the non thermal source is occulted from phase ~0.1 – 0.4. We also see that in case of soft X-rays the transit isn't significant as compared to the error bars. We also plot the light curve for hard photons with energies between 2 – 8 keV as shown in Figure 9. We see that the transits are more distinct implying that the transits are almost entirely due to obscuration of the non thermal source.

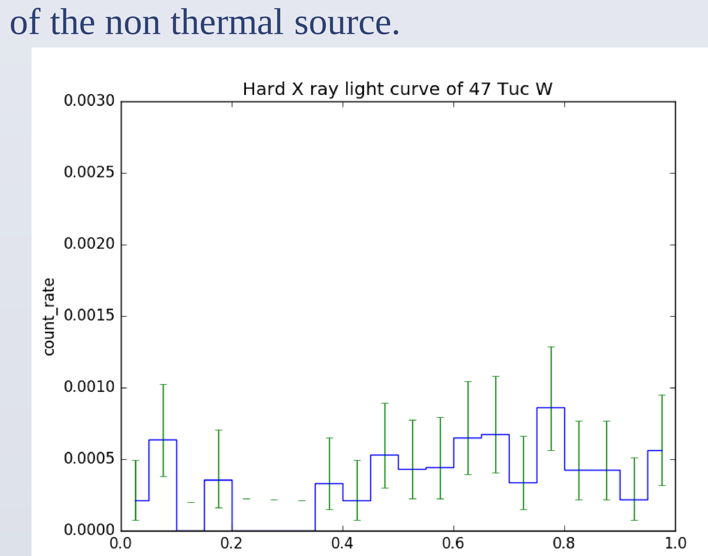


Figure 9 : 2014 hard x-ray light curve of 47 Tuc W

Spectral Fitting

For the purpose of spectral analysis we filtered the photons between 0.3 to 8 keV. To compensate for the bias in observed photons, we made two sets of data – one corresponding to times when the source was not in transit and other corresponding to phase 0.1 – 0.4. The former set of photons were grouped such that each group contains 15 photons and the latter set was grouped with 6 photons in each group. We used C-statistic for the fit using gehrels method to determine the errors. A hydrogen column density of 3.5 x 10^{20} was used.

On doing the spectral fit in Xspec, we saw that the spectrum could be fit by power law only with an index of $\Gamma = 1.52 \pm 0.22$. This is because of the low photon count (~ 180) photons. Introducing a BB/NSA spectrum did improve the fit, but the parameters could no longer be constrained in a reasonable range. Below is the power law fit to the spectrum.

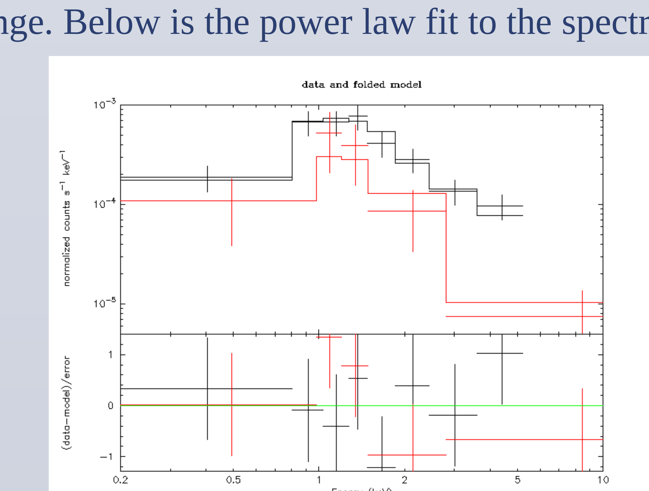


Figure 10 : Powerlaw fit to observed spectrum

Conclusions

From our observations we see that the 47 Tuc W system does show transits for about one-third of its orbit in the 2014 – 15 observations of 47 Tuc. The light curve obtained is similar to the light curves obtained by Bogdanov et al. 2005. Thus the system hasn't evolved much over the past 12 years. The absence of transits in the HRC observations of 2005 – 06 could most probably be due to the decreasing response of HRC instrument at higher energies. It could also be possible that the lack of transits could be linked to intrinsic change in the properties of the system, in which case it will be very interesting source to track. As of now, we cannot completely deny the evolution of the system.

We also see that the spectrum could be fit by a power law. It was observed that the normalization of the power law reduces to one third of its original value during transit which is consistent with similar decrease in the count rate. So, there needs to be a more extensive study of the object to determine its evolution with time.

References

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