

Episodic Torque-Luminosity Correlations and Anticorrelations of GX 1+4

M. M. Serim*

Middle East Technical University

E-mail: muhammed@astroa.physics.metu.edu.tr

Ş. Şahiner

Middle East Technical University

E-mail: seyda@astroa.physics.metu.edu.tr

D. Çerri-Serim

Middle East Technical University

E-mail: danjela@astroa.physics.metu.edu.tr

S. Ç. İnam

Başkent University

E-mail: inam@baskent.edu.tr

A. Baykal

Middle East Technical University

E-mail: altan@astroa.physics.metu.edu.tr

We analyse archival CGRO-BATSE X-ray flux and spin frequency measurements of GX 1+4 over a time span of 3000 days. We systematically search for time dependent variations of torque luminosity correlation. Our preliminary results indicate that the correlation shifts from being positive to negative on time scales of few 100 days.

11th INTEGRAL Conference Gamma-Ray Astrophysics in Multi-Wavelength Perspective, 10-14 October 2016
Amsterdam, The Netherlands

^{*}Speaker.

1. Introduction

GX 1+4 is an accretion powered pulsar of which optical companion is M6III type M giant V2116 Oph with slow stellar wind (Chakrabarty & Roche 1997; Davidsen et al. 1977; Hinkle et al. 2006). It was discovered with approximately \simeq 138 s pulsations (Lewin et al. 1971) and found to be spinning-up till it became undetectable during 1980s (Doty et al. 1981). Then the source detected again during late 1980s and it is found to be spinning-down indicating that source underwent a torque reversal during undetectable era (White et al. 1983;Makishima et al. 1988). The source shows an overall spin-down trend ever since (Gonzales-Galan et al. 2012).

Previous studies of GX 1+4 revealed correlations between frequency derivative and X-ray luminosity (Paul et al. 1997; Chakrabarty et al. 1997). Chakrabarty et al. (1997) investigated the torque and luminosity behaviour for 2000 days of BATSE measurements and reported that the frequency derivative and X-ray luminosity episodically shows both positive and negative correlations.

2. Observations

GX 1+4 was continuously monitored with Burst and Transient Source Experiment (BATSE) between MJD 48373 and 51348 for a time span of approximately 3000 days. We retrieved pulse frequency, frequency derivative and X-ray pulsed flux measurements of the observations from public archive of BATSE Pulsar Team¹. The pulse frequency measurements are initially carried out with searching the pulse signal via fast fourier transform. When the pulse frequency of a source is already known, more accurate measurements are implemented via other timing methods (such as epoch folding and pulse phase). The measurements are made with 5 days sampling and flagged either Y or N depending on the whether confidence level of the measurement is above the noise level (see BATSE pulsar team website for more information). In this study, we only used measurements flagged Y. The retrieved data are investigated for frequency derivative and X-ray pulsed flux correlations. In this work, we seek for such correlations on shorter time scales.

3. Time Dependent Torque-Luminosity Correlation

We analyse the data systematically for time dependent variations of correlation and anticorrelation episodes. Hence, we blindly search for correlation by calculating Pearson correlation coefficient between two parameters for time row number 0 to N. When the correlation coefficient systematically changes after row n, we accept the Pearson coefficient of this interval to be pre-break down value (between 0 and n) and repeat same procedure each time for next interval between row n and (n+N). The correlation coefficient value breaks down on time scales of 100 days (Serim et al 2017). Furthermore, correlations are generally weak (Pearson coefficient is ranging between -0.6 and 0.6). In figure 1, we represent frequency derivative and X-ray flux of each corresponding interval.

¹https://gammaray.nsstc.nasa.gov/batse/pulsar/

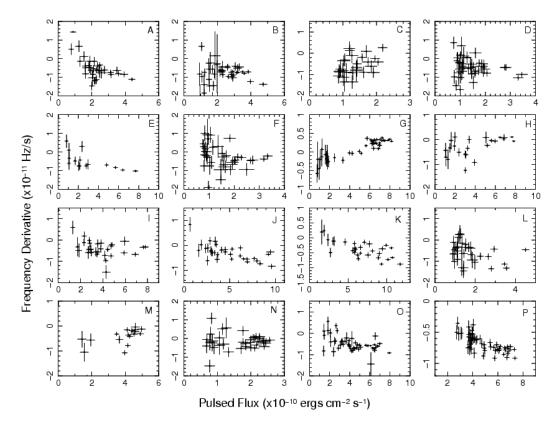


Figure 1: Frequency derivative vs pulsed flux correlation of each interval. MJD ranges of intervals are (A) 48364-48508; (B) 48512-48724; (C) 48728-48944; (D) 48948-49176; (E) 49180-49292; (F) 49296-49580; (G) 49584-49764; (H) 49768-49872; (I) 49876-49992; (J) 49996-50124; (K) 50128-50244; (L) 50276-50628; (M) 50632-50708; (N) 50720-50920; (O) 50924-51128; (P) 51132-51348, respectively.

4. Conclusion

We investigate daily CCRO-BATSE pulsed X-ray flux and pulse frequency derivative measurements of GX 1+4 in 20-60 keV energy band and search for time resolved correlations between these parameters. This correlation can be accepted as a sign of torque-luminosity variations under the assumption that bolometric luminosity is correlated with X-ray flux. We found that the source seems to undergo episodic variations of the correlation on time scales of $\simeq 100-200$ days.

An anti-correlation between torque and luminosity is hard to explain by standard prograde accretion disk models. However, formation of a transient prograde/retrograde disk by a stellar wind may account for both variation of correlation and observed timing noise behaviour (GX 1+4:Bildsten et al. 1997; Nelson et al. 1997; Serim et al. 2017, OAO 1657-415: Baykal 1997; Baykal 2000). The episodic interchange of correlations might be an indication of prograde/retrograde disk formation on time scales of few 100 days.

We acknowledge support from TÜBİTAK, the Scientific and Technological Research Council of Turkey through the research project MFAG 114F345.

References

- [1] Baykal, A., The torque and X-ray flux changes of OAO 1657-415, AAP 318, 515 (1997)
- [2] Baykal, A., Short-term pulse frequency fluctuations of OAO 1657-415 from RXTE observations, MNRAS 313, 637 (2000)
- [3] Bildsten, L. et al. Observations of Accreting Pulsars, ApJS 113, 367 (1997)
- [4] Chakrabarty, D. et al. On the Correlation of Torque and Luminosity in GX 1+4, ApJL 481, 101 (1997)
- [5] Chakrabarty, D. et al. Optical/IR Observations of the Low-Mass X-Ray Binaries GX 1+4 and 4U 1626-67, Bulletin of the American Astronomical Society 29, 840 (1997)
- [6] Davidsen, A. and Malina, R. and Bowyer, S., *The optical counterpart of GX 1 + 4 A symbiotic star*, ApJ 211, 866 (1977)
- [7] Doty, J. P. and Lewin, W. H. G. and Hoffman, J. A., *SAS 3 observations of GX 1 + 4*, ApJ 243, 257 (1981)
- [8] Hinkle, K. H. et al., Infrared Spectroscopy of Symbiotic Stars. IV. V2116 Ophiuchi/GX 1+4, The Neutron Star Symbiotic, ApJ 641, 479 (2006)
- [9] Lewin, W.H.G., Ricker, G.R., and McClintock, J.E. *X-Rays from a New Variable Source GX 1+4*, ApJ 169, 17 (1971)
- [10] Makishima, K. et al., *Spin-down of the X-ray pulsar GX1 +4 during an extended low state*, Nature 333, 746 (1988)
- [11] Nelson, R. W. et al. On the Dramatic Spin-up/Spin-down Torque Reversals in Accreting Pulsars, ApJL 488, 117 (1997)
- [12] Paul, B. and Rao, A. R. and Singh, K. P., *Torque-luminosity correlation and possible evidence for core-crust relaxation in the X-ray pulsar GX 1+4.*, AAP 320, 9 (1997)
- [13] White, N. E. and Swank, J. H. and Holt, S. S., Accretion powered X-ray pulsars, ApJ 270, 711 (1983)
- [14] Serim et al., Comprehensive Timing and Spectral Analysis of GX 1+4 to be submitted to MNRAS