Orbital phase spectroscopy of four high mass X-ray binary pulsars to study the stellar wind of the companion

Sachindra Naik a,*, U. Mukherjee b, B. Paul c, C.S. Choi d

a Astronomy & Astrophysics Division, Physical Research Laboratory, Navrangpura, Ahmedabad 380 009, India
b B.P. Poddar Institute of Management and Technology, 137 V.I.P Road, Poddar Vihar, Kolkata 700 052, India
c Astronomy & Astrophysics Group, Raman Research Institute, Sadashivnagar, C.V. Raman Avenue, Bangalore 560 080, India
d Center for Astrophysics, Korea Astronomy and Space Science Institute, 61-1, Hwaam-dong, Yuseong-gu, Daejeon 305 348, Republic of Korea

Received 8 January 2007; received in revised form 23 October 2008; accepted 13 December 2008

Abstract

Our work focuses on a comprehensive orbital phase-dependent spectroscopy of the four High Mass X-ray Binary Pulsars (HMXBPs) 4U 1538-52, GX 301-2, OAO 1657-415 and Vela X-1. We hereby report the measurements of the variation of the absorption column density and iron-line flux along with other spectral parameters over the binary orbit for the above-mentioned HMXBPs in elliptical orbits, as observed with the Rossi X-ray Timing Explorer (RXTE) and the BeppoSAX satellites. A spherically symmetric wind profile was used as a model to compare the observed column density variations. Out of the four pulsars, only in 4U 1538-52, we find the model having a reasonable corroboration with the observations, whereas in the remaining three the stellar wind seems to be clumpy and a smooth symmetric stellar wind model appears to be quite inadequate in explaining the data. Moreover, in GX 301-2, neither the presence of a disk nor a gas stream from the companion was validated. Furthermore, the spectral results obtained in the case of OAO 1657-415 and Vela X-1 were more or less similar to that of GX 301-2.

© 2008 COSPAR. Published by Elsevier Ltd. All rights reserved.

Keywords: Pulsars: individual (4U 1538-52, GX 301-2, OAO 1657-415 and Vela X-1); Stars: circumstellar matter; X-rays: stars

1. The pulsars, observations and analysis

4U 1538-52 was first detected with the Uhuru satellite (Giacconi et al., 1974). The spin period and orbital period of the pulsar were first estimated to be 529 s and 3.73 days, respectively, from the observations with Ariel 5 and OSO-8 (Davey et al., 1977). Using data from the RXTE, the eccentricity of the binary orbit was calculated to be ~0.18 (Mukherjee and Paul, 2004; Mukherjee et al., 2006). The X-ray spectrum has a prominent iron K-line (Makishima et al., 1987) and a pulse phase-dependent cyclotron resonance feature at 20 keV (Clark et al., 1990). It has a moderate X-ray luminosity of ~10^{36} erg s^{-1}. The optical counterpart was found to be an early B type supergiant star (QV Nor) with Hz emission lines (Parkes et al., 1978). The mass-loss rate and the terminal wind velocity were estimated as ~10^{-6} M_{⊙} yr^{-1} and ~1000 km s^{-1}, respectively.

GX 301–2 (4U 1223-62) was discovered by White et al. (1976). Using data from BATSE observations, the orbital period and eccentricity of the binary system were determined as ~41.5 days and ~0.46, respectively (Koh et al., 1997). The companion star Wray 977 has a B1 Ia+ spectral classification with a mass of 39 M_{⊙} (Kaper et al., 2006). The mass-loss rate and terminal velocity of the stellar wind are ~10^{-5} M_{⊙} yr^{-1} and 305 km s^{-1}, respectively. GX 301-2 shows a variable X-ray luminosity in the range (2–400) × 10^{35} erg s^{-1}, depending on the amount of the stellar wind captured, which in turn depends on the density and velocity of the wind.

OAO 1657–415 was discovered by the Copernicus satellite (Polidan et al., 1978). White et al. (1976) and White and...