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Constraining the mass of Galactic black hole GX 339-4

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Abstract. Observations of Galactic black hole candidates during their outburst phases have revealed Quasi-Periodic Oscillations (QPOs) and their dependence on the spectral parameters. We used the 2010 outburst data of GX 339-4 from Rossi X-ray Timing Explorer (RXTE) and modeled it based on evolution of QPO frequencies and spectro-temporal correlation to constrain the mass of the compact object.

Keywords : accretion – black hole physics – stars: individual:GX 339-4

1. Introduction

Having undergone five outbursts during the RXTE era, GX 339-4 is one of the most dynamic Galactic X-ray binary sources. Hynes et al. (2003) and Munoz et al. (2008) estimated a lower bound on the mass of GX 339-4 to be $5.8 \pm 0.3 M_\odot$ and $6 M_\odot$ respectively. We model the spectro-temporal features from X-ray observational data of the 2010 outburst of GX 339-4 to estimate the mass of the black hole candidate.

2. Methods and Results

We use two methods to indirectly estimate the mass of GX 339-4 as presented in Iyer et al. (2015) for the source IGR J17091-3624. The methods are discussed below.

2.1 Photon index - QPO correlation

A scaling method from an empirical relation for the Photon index - QPO correlation was developed by Shaposhnikov and Titarchuk (2007) based on Titarchuk and Fiorito (2004). The model gives Photon index, $\Gamma(\nu) = A - BD\, ln\left(exp\left(\frac{\nu_{tr} - \nu}{D}\right) + 1\right)$. For any two sources, we have $B_1/B_2 = \Delta\nu_1/\Delta\nu_2 = M_1/M_2$. Figure 1 (a) shows the result of modeling the photon index-QPO correlation for the 2010 outburst of GX 339-4.

2.2 QPO evolution

The Propagating Oscillatory Shock (POS) has been used to model the QPO evolution of 2010 outburst of GX 339-4 by (Debnath et al. (2010), Nandi et al. (2012)). In POS, QPOs are considered to be the result of oscillations of a propagating shock front and the model is described by $\nu_{qpo} = \frac{c}{2\pi\, R\, r_g\, r_s\, \sqrt{r_s - 1}}$, where $r_s = r_{so} - \frac{v_o t + \frac{1}{2} a t^2}{r_g}$ is the

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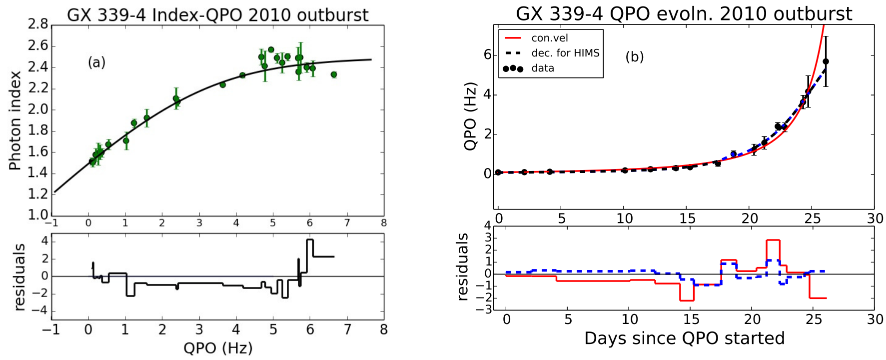

Figure 1. (a) Photon index-QPO correlation and (b) temporal evolution of QPO frequency modeled for the 2010 outburst of GX 339-4 to estimate the mass of its compact object.

instantaneous shock location in units of $r_g = \frac{2GM}{c^2}$ and R is the shock compression ratio, fixed to 2.5 for the present work. Figure 1 (b) shows POS model fit for 2010 outburst of GX 339-4 with and without deceleration.

3. Conclusion

Using dynamically measured mass ($9.5 \pm 1.1\ M_{\odot}$) of XTE J1550-564 from Orosz et al. (2002), we calculated the mass of GX 339-4 to be $6.8 \pm 1.64\ M_{\odot}$ based on the scaling method. The POS model based mass estimate is $4.5 \pm 0.5\ M_{\odot}$ ($r_{so} = 445\ r_g$) for a constant velocity propagation ($2.54\ m/s$) where as a deceleration of $2.58\ \mu m/s^2$ in the hard intermediate state resulted in $6.32 \pm 0.47\ M_{\odot}$ ($r_{so} = 479\ r_g$). Considering POS with deceleration and Photon index-QPO correlations, we computed the mass of GX 339-4 to be in the range $5.15\ M_{\odot}$ to $8.44\ M_{\odot}$. The disadvantages of both these methods are detailed in Iyer et al. (2015). Also our analysis suggests that a variable compression ratio may provide a better mass estimate. This will be attempted in future for modeling the spectro-temporal features of other outbursts of GX 339-4.

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References

Debnath D., Nandi A., Chakrabarti S. K., 2010, AA, 520, A98
Hynes R. I., Steeghs D., Casares J., Charles P.A., O'Brien K., 2003, ApJL, 583
Iyer N., Nandi A., Mandal S., 2015, ApJ, 807, 108
Munoz-Darias T., Casares J., Martinez-Pais I., 2008, MNRAS, 385, 2205
Nandi A., Debnath D., Mandal S., Chakrabarti S. K., 2012, A&A, 542, A56
Orosz J. A., Groot P. J., van der Klis M., McClintock J. E., Garcia M. R., Zhao P., Jain R. K., Bailyn Ch. D., Remillard R. A., 2002, ApJ, 568, p845
Shaposhnikov N., Titarchuk L., 2007, ApJ, 663, 445
Titarchuk L., Fiorito R., 2004, ApJ, 612, 988