Impact of Quasi-Periodic Oscillations on the energy spectrum

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Abstract:

The presence of QPOs in the Power Density Spectra of x-ray binaries is quite ubiquitous and is often modeled as a hot structure orbiting in the disk. While we have been using timing and PDS to determine the presence and explore the possible origin of QPOs, they are, up to now, absent from the spectral analysis. Here we are using a simple analytical model to mimic the hot structure of several QPO models in order to determine their impact on the energy spectrum.

Introduction

- When looking at the Power Density Spectrum of microquasars the most striking features are the presence of Quasi-Periodic Oscillations. Those Low-Frequency (< 30Hz) and High-Frequency (> 40Hz) QPOs cannot be neglected, indeed, the LFQPO alone can have a rms of up to 30%. Models often describe them as a warm/hot structure orbiting the disk.

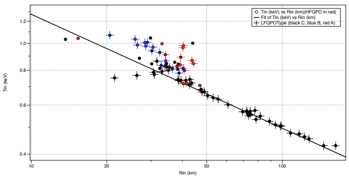
  → important timing feature that modulates the X-ray flux.

- Nevertheless, when looking at the same data through the energy spectrum the disk is considered smooth with a monotonic temperature profile. If such a featureless disk can easily model states where there is no QPO or even if the QPO has a low impact (hence low rms), it is incoherent to use it to describe states with prominent QPOs.

  → we need to check if the structure at the origin of QPOs also has a measurable impact on the energy spectrum and its fits.

Link between the disk parameters and QPOs

- It has been asserted early on that the properties of the LFQPOs, in particular its frequency, are related to parameters of the disk obtained through spectral fitting. As there is much less data for HFQPO, no similar study has been led yet.
- Using data from XTE J1550-564 outburst of 98-99 and 2000, we look at the behavior of the spectral paramaters depending if there is or not a QPO observed.

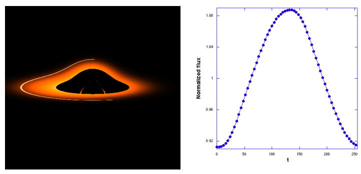


→ while most of the points seem to show a correlation between r_{in} and T_{in} there is a clear departure when HFQPOs or type A and B LFQPOs are detected

⇒ Is the departure from the correlation rooted by the presence of a QPO/warm structure which cause the fit by a smooth disk to fail?

simple model for the temperature profile

- Many QPO models tend to link the presence of the modulation with a hot structure in the disk such as an axisymmetric torus or other non-axisymmetric structures like hotspots and spirals. Here we do not focus on the origin of those structures but on their consequences on the emission. In that respect we decided to create a simple analytical model mimicking the perturbation of the temperature profile.



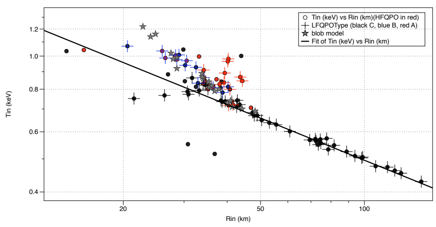
→ These simple models are able to reproduce several observables such as, for example, the rms amplitude of QPO (Varniere & Vincent, 2015).

- Using those parametrized temperature profiles we have created XSPEC models of disks having such structure (`disktor`, `diskblob`).

⇒ Using the procedure `fakeit` in XSPEC we created synthetic spectra of a power-law plus the disk emission taking into account the presence of a warm/hot structure.

impact on the energy spectrum fitting

- Using the physical parameters of XTE J1550-564 we ran several sets of parameters to reproduce a growing QPO in a regular, diskbb-like, disk which we then fitted with XSPEC following the standard procedure. We took the 'origin point', meaning the disk with a QPO amplitude of 0, to be $(45, 0.7)$ on the (r_{in}, T_{in}) diagram.



→ as soon as the QPO has a non-zero amplitude there is an error on the disk parameters.

- The error is growing with the QPO amplitude but already with a 5% rms for the QPO we get an error of about 14% on T_{in} and 12% on r_{in}

  ⇒ even with RXTE resolution neglecting the QPO in the spectral analysis leads to large errors.

- This set of simulated observations with a growing QPO occupy the same space as the HFQPO/type B LFQPO, strengthening the link between QPO, hot spot, and fit-difficulties. Other sets of parameters, not shown here, reach the type A LFQPOs.

  ⇒ this could be used to detect, purely from spectral analysis, the possible presence of HFQPO.

- With ATHENA it will be even more important to fully model the disk structure in presence of QPOs.

Conclusions:

We studied the impact on the energy spectrum of a non-monotonic disk temperature as it has been theorized to be the case in the presence of QPO.

⋆ our simulated observations are coherent with the departure from correlation seen in T_{in}-r_{in} in presence of HFQPO and LFQPOs B or A.

⋆ this could be used to narrow the search for HFQPOs and needs to be taken into account.

⋆ very small amplitude QPOs have a negligible impact on the energy spectrum and can be ignored but above 5% rms amplitude we cannot neglect the presence of the hot structure as it leads to significant errors in the fits

⋆ there is a need to improve the disk fitting by taking into account the structures at the origin of the QPOs.

References:

Remillard *et al.*, 2002, ApJ, 564, 962.

Varniere & Vincent, 2015, to be submitted to A&A.