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RWI IN DISK AROUND HIGH SPIN BLACK HOLE: HOW DOES IT IMPACT THE OBSERVABLES

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Abstract. The Rossby-Wave Instability (RWI) has been proposed as the source of the fast, high-frequency quasi-periodic oscillations (HFQPOs) in microquasars. Here we are using NOVAs, our Numerical Observatory of Violent Accreting systems, to follow the evolution of the RWI and obtain observables to compare with X-ray data.

The first aim is to prove the ability of the RWI to modulate the X-ray fluxes in a similar way as is observed. But, thanks to NOVAs we can go further and explore possible imprints of the RWI in other potential observables.

Keywords: microquasars, QPO, spin

1 NOVAs versus Observations

Fig.1 shows succinctly what the building blocks of `NOVAs` are and how they relate to standard observations.

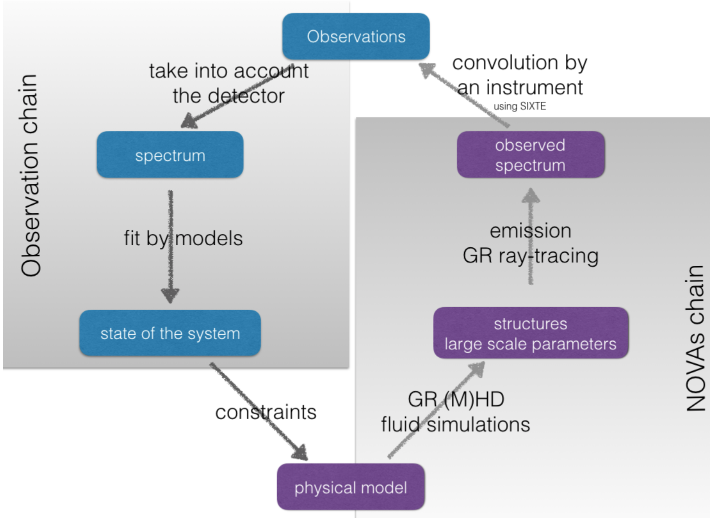

Fig. 1. The different building blocks that compose the `NOVAs` chain and the complementary observation chain.

- All the general relativistic (GR) fluid dynamics are done with the general relativistic version of MPI-AMRVAC: `GRAMRVAC` (Casse et al. 2017; Casse & Varniere 2018)
- For all the GR ray-tracing computations, we use the open-source code `GYOTO` (Vincent et al. 2011)
- In order to add instrumental effects we use the SIXTE package. It allows us to undertake instrument performance analyses and to produce simulated event files for mission and analysis studies.

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2 Time domain ‘observations’ of the RWI

We have performed two types of ‘observations’ related to time domain studies (Varniere et al. 2019). We computed the PDS of several disks with the RWI active. As can be seen on the the left of Fig.2, while a lot of our ‘observations’ have only one detectable peak, some exhibit two peaks in different integer ratios such as 3:2 and 3:4 which are also observed in microquasars (Varniere & Rodriguez 2018).

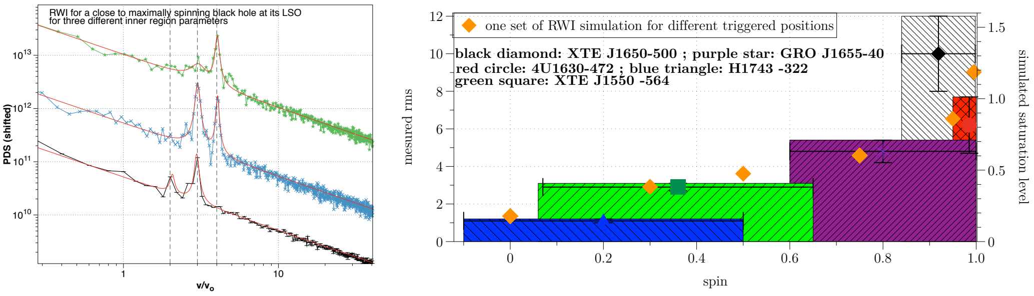

Fig. 2. Two type pf time domain ‘observations’ performed with NOVAs. On the Left three PDS associated with three distinct simulations for the same spin. On the right comparison between the observed rms versus spin behavior and the simulated vaues.

Using `NOVAs` we can follow the RWI in a similar setup while changing the spin. This allows us to see that the higher the spin of the black hole, the higher the rms of the HFQPO can become. Then we can compare with all the observations of HFQPOs in sources with known spins. The right of Fig.2 shows that the predicted behavior is coherent with limited known data.

This shows that the RWI is able to reproduce the time domain observations associated with HFQPOs and even offer other ways to further test the model.

3 Spectral domain ‘observations’ of the RWI

Beyond timing study, the `NOVAs` chain allows us to explore the impact of the RWI on the energy spectrum as well. The aim here is to explore new ways to detect the cause of the HFQPOs. As a first step we compute the energy spectrum of disk with the RWI active at different times along the HFQPO phase.

This allows us to see how much the RWI impacts the energy spectrum of the disk along one full phase. We need to look for good candidates to create energy spectrum binned per phase of the HFQPO. After adding comptonization by a corona, we can process our ‘observations’ through `xspec` and then we can obtain the fitted parameters for the system.

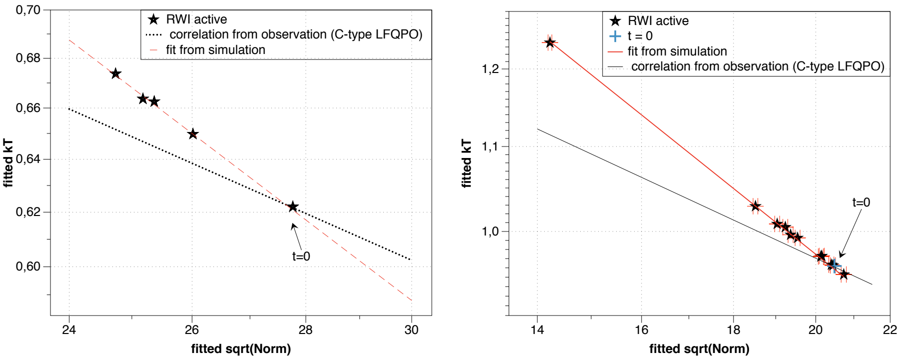

Fig. 3. Correlation between the inner edge position and temperature, as found by the fit when the RWI is active, for spin a=0.9 and a=0.75.

Fig.3 shows, for spin a=0.9 and a=0.75, the correlation between the inner edge position and temperature as found by the fit when the RWI is active.

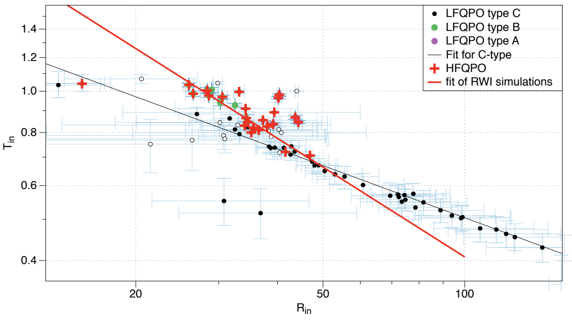

Fig. 4. Correlation between the inner edge position and temperature for XTE J1550-564. The red line represent the fit from the simulated RWI data shown above.

Those can in turn be compared to observations, here the case of XTE J1550-564 with data from both outbursts having known HFQPOs detections. As can be seen on Fig.4, a similar correlation as the one found in the RWI simulations seems to be present in the data when HFQPOs are present.

Those RWI 'numerical observations' are paving the way to further explore archival data as well as triggering new observations.

4 Conclusions

By combining smoothly two GR codes, one providing a full hydrodynamical solution and one providing the ray-tracing of the emission, we now have a fully functional numerical observatory which allows us to obtain spectrums and lightcurves of theoretical models with limited hypotheses.

It is now confirmed that the RWI is triggered at the inner edge of the disk and can modulate the X-ray flux in a similar way as is observed.

The RWI exhibits several sets of peaks in the PDS depending on the local condition in the inner region of the disk.

The impact on the energy spectrum of the RWI has consequences on the fit which is coherent with the observed deviation in presence of HFQPOs.

We now have all the tools necessary to start a more thorough comparison with observations.

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