Disentangling alternative models of microquasars quasi-periodic oscillations

F. Vincent[1,2], M. Abramowicz[1], P. Varniere[2], G. Mazur[1], H. Meheut[2,3], T. Paumard[4]

[1] CAMK, Bartycka 18, 00-716 Warsaw, Poland; [2] APC, Université Paris Diderot, 10 rue A. Domon et L. Duquet, 75205 Paris Cedex 13, France [3] SAp, Commissariat à l'Energie Atomique, Centre d'études de Saclay, Orme des Merisiers, 91191 Gif sur Yvette, France [4] LESIA, CNRS UMR 8109, Observatoire de Paris, 92195 Meudon cedex, France

fvincent@camk.edu.pl

Abstract

We study the observable signature of two models for high-frequency quasi-periodic oscillations of microquasars: the oscillating torus model developed from Abramowicz (2001) and Blaes et al. (2006); the Rossby wave instability model (Tagger & Varniere, 2006).
Our goal is to show that these two models are able of modulating the flux of microquasars. We take into account the relativistic effects on radiation via ray-tracing the emitted light from the source to a distant observer. We also progress towards model-specific observable signatures that may allow disentangling between these two models with future data.

The oscillating torus model

Oscillating slender tori and QPOs

- Slender (small cross-section) torus around a Schwarzschild black hole
- Oscillation modes computed by Blaes et al. (2006)
- Not (yet) taken into account here: only simple deformations
- First step: what is the observable signature of simple periodic deformations of the torus?
- Interest: first hint of observable signature for realistic oscillations; oscillations may be equivalent to a superimposition of simple deformations
- Radiation propagation taken into account by general relativistic ray-tracing (Vincent et al., 2011)

Observable signature of torus deformation

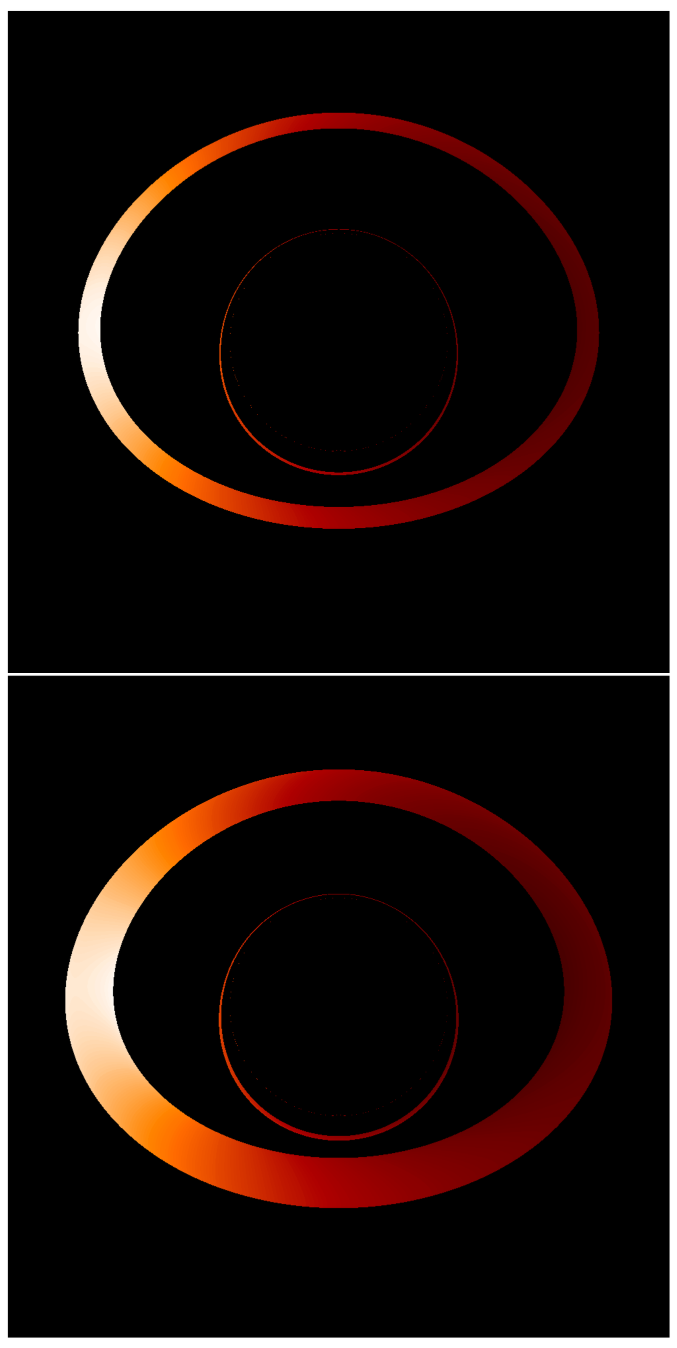


Figure 1: Image of a slender torus surrounding a Schwarzschild black hole seen with an inclination of 45°, with expanding cross-section, at two different times (change of projected area on sky).

- Schwarzschild metric
- Optically thick torus
- Emission is isotropic in emitter's frame, the same at any point of the surface
- Inclination is 45° on all figures

Simple periodic deformations

- Sinusoidal deformations of the torus cross-section
- Translation (radial, vertical), rotation, expansion, shear
- Emission inversely proportional to cross-section area (constant flux)
- Observed flux variation: change of projected area + relativistic effects

Light curves - Power spectra

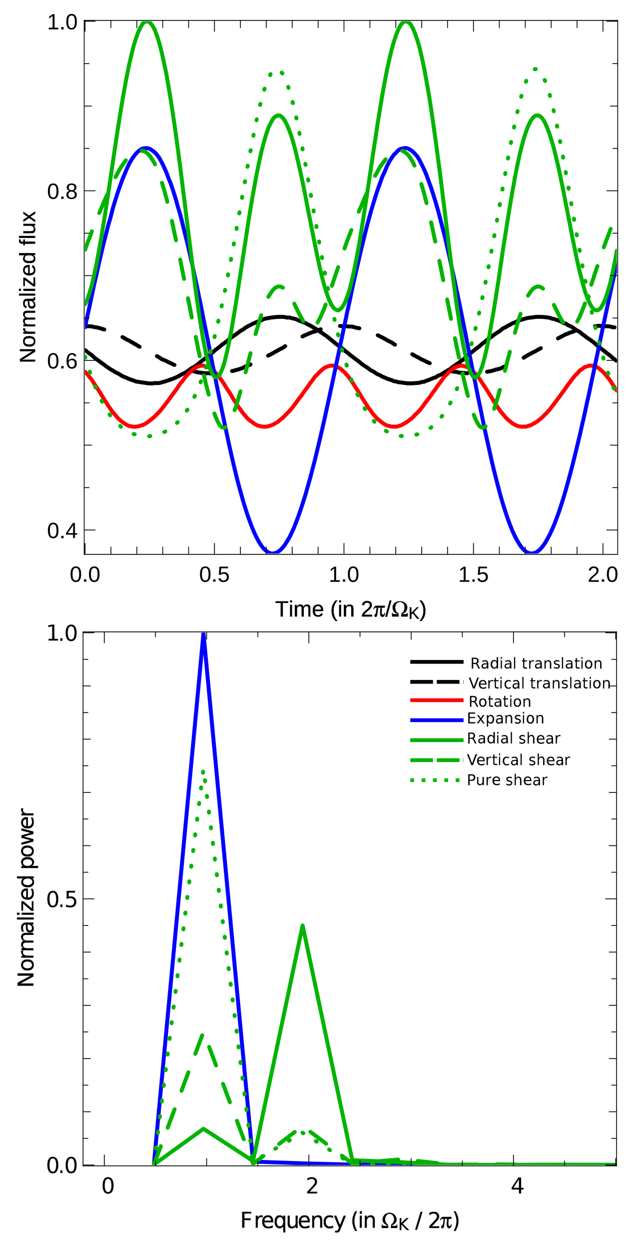


Figure 2: Light curves and power spectra for various deformations of the slender torus.

- Light curves are modulated for all deformations
- Power spectra are *very* different for different deformations
- Main reason: different variation of torus projected area on sky

Model-specific signature

- Power spectrum = probe of torus deformation
- Under development: can power spectra be used as a probe of the oscillating torus model?

The Rossby wave model

Rossby instability

- (M)HD instability of 2D/3D disks (Tagger & Varniere, 2006; Meheut et. al., 2010) proposed to model HFQPOs
- Triggered when $\mathcal{L} \propto \frac{\text{density}}{\text{epi.freq.}}$ shows an extremum, e.g. near ISCO of an accretion disk around a black hole
- Vortices and spiral waves develop
- The number of spiral arms evolves with time (mode evolution)
- Radiation propagation taken into account by general relativistic ray-tracing (Vincent et al., 2011)

Observable signature of Rossby instability

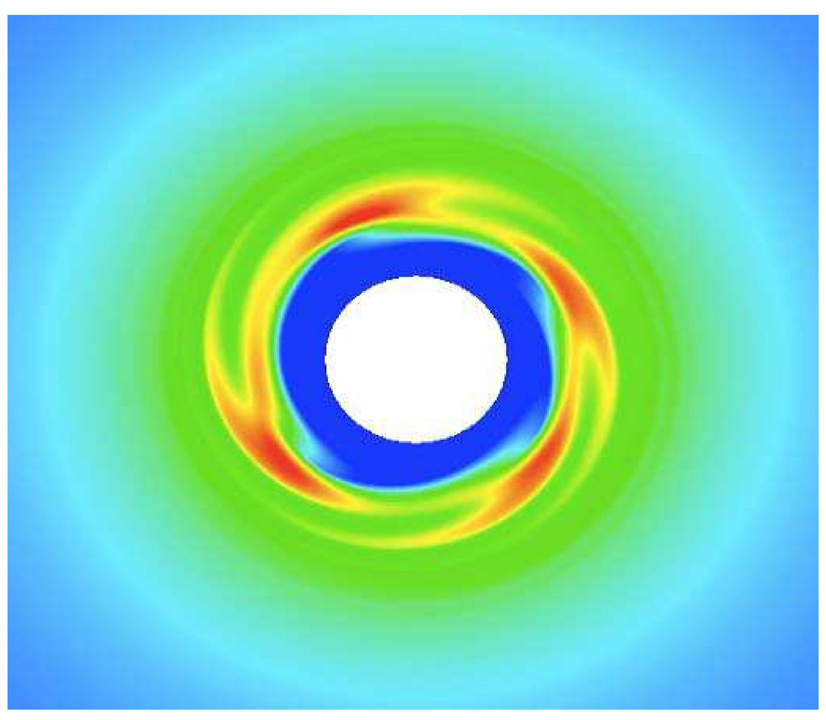
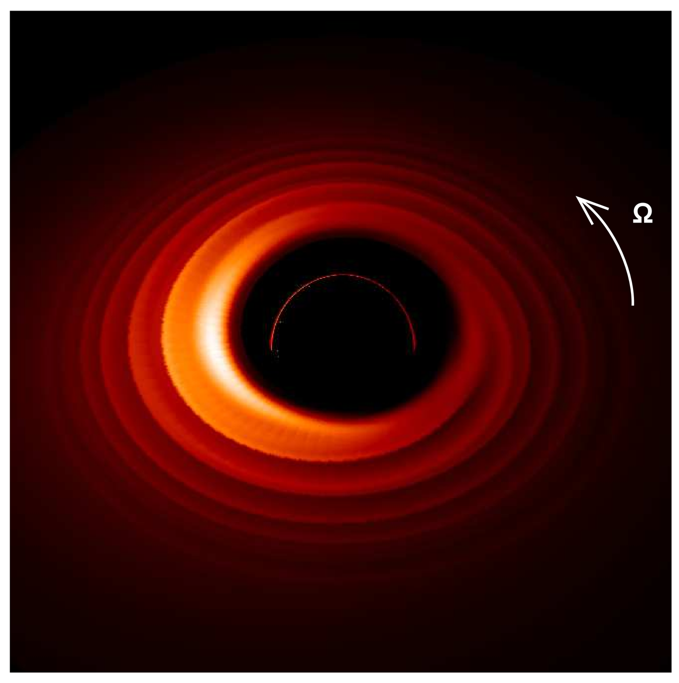


Figure 3: Density map of a 2D disk subject to the Rossby wave instability. Below, the image of the disk, seen with an inclination of 45°.



- Schwarzschild metric mimicked by pseudo-Newtonian potential (Paczynski & Wiita, 1980)
- 2D disk emitting blackbody radiation

Light curves - Rms evolution

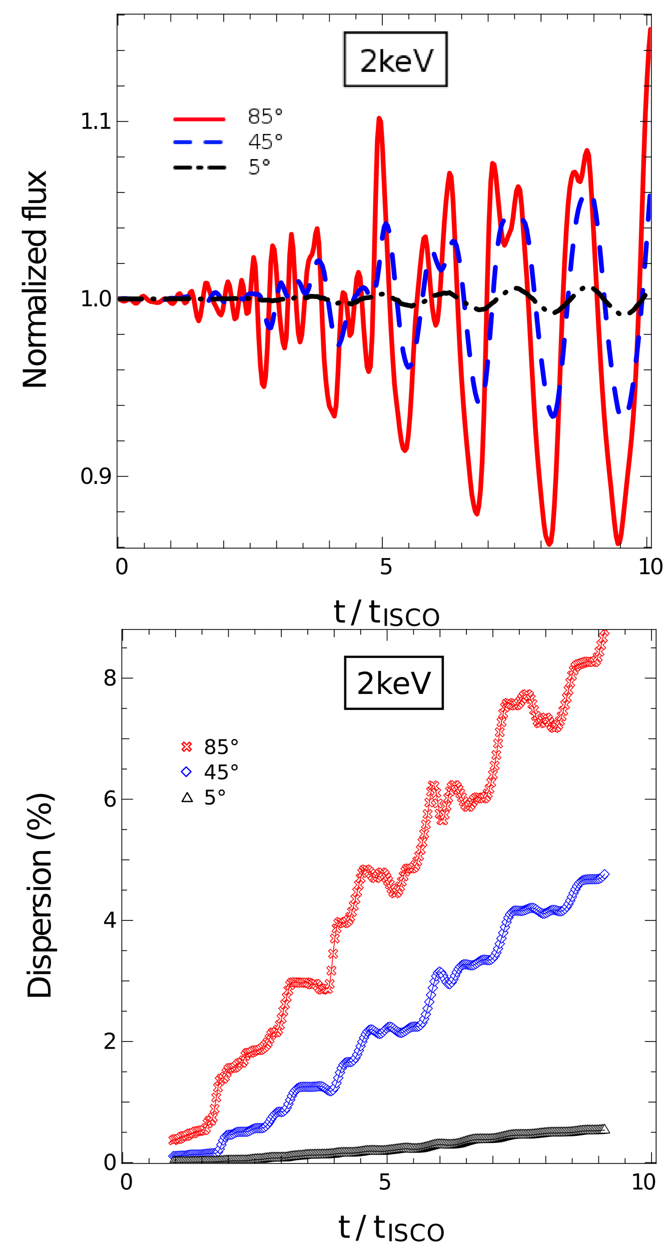


Figure 4: Light curves and rms evolution for the Rossby wave model.

- Light curves are modulated at a few % level
- Rms evolution depends on the inclination parameter in a way compatible with observations

Model-specific signature

- Mode evolution is imprinted in the light curve
- Number of peaks per period in the light curve = number of spiral arms of the instability
- Under development: can LOFT have access to this details of the light curve?

Future: differentiating with LOFT?

- Main motivation of this work: progress towards disentangling competing models for microquasars HFQPOs
- This work: model-specific observable signatures for both models
- Torus model: power spectrum; Rossby model: mode evolution
- Future work: develop LOFT data simulation for both models; determine whether these signatures are within reach of the instrument; determine whether the instrument will be able of disentangling the two models.

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