Observations of microquasars: giving strength to the AEI?

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What diagnostics do we have in hand?

Self absorbed or not synchrotron emission: very long λ -> infra red/Optical

Thermal emission black body: soft X-rays ~1keV

Non-thermal emission Inverse Compton (or synchrotron): Hard X-rays / soft gammaHigh and Low frequency Quasi Periodic Oscillations: global movements of disc? Coronal ? Instability?

Summary

o Timing:

o LFQPOs : what did we know about them in 2000
o The (inverted) correlation with the radius of the disc
o AEI & QPO how does it fit?
o QPO spectra: are we witnessing a "hot spot"?
o Spectral and multi wavelength:
o Ejection of coronal material in 1550-564 and 1915+105
o Appearance of LFQPO prior to spectral transitions
o How does this fit with the flood scenario?

We start with timing

AEI manifests itself by a rotating spiral An obvious effect is the modulation of flux <=>QPO

Definition of LFQPOs

Frequencies 0.05 ~ 20 Hz rms amplitude 1 - 30 % (RXTE/PCA range) Coherence (v / Δv) (def.>2) 3~20



LFQPOs & Spectral properties



Muno et al. '99

LFQPO frequency correlates with X-ray flux

LFQPOs & Spectral properties (2)



LFQPO frequency and diskbb flux (Jeff Mc Clintock's talk)

LFQPOs & Spectral properties (3)

LFQPO frequency correlated to disk flux

BUT 2 different types of variation of freq. vs. R_{col} in 2 objects



AEI in a modified potential

AEI <=> rotating spiral @ 0.1-0.3 $v_{\text{inner disk}}$ => $v_{\text{AEI}} \propto R_{\text{in}}^{-3/2}$ (in most cases, e.g. 1915, 1550)

If R_{in} close to R_{LSO}, then pseudo Newtonian potential formalism:

$$\Phi = -\frac{GM}{r} \left(1 - 3\frac{GM}{rc^2} + 12\left(\frac{GM}{rc^2}\right)^2 \right)$$

Leading to a modified expression of ν_{AEI}

$$\sqrt{GM}r^{-\frac{3}{2}}\left(1-\frac{r_{LSO}}{r}+\left(\frac{r_{LSO}}{r}\right)^{2}\right)^{\frac{1}{2}}$$

MAY EXPLAIN THE REVERSAL OF THE ν_{QPO} VS. R_{col} RELATION

AEI and QPO behavior

R_{col} returned from spectral fittings

- => problem of model dependence
- => problem of model when in SPL (Merloni et al. '00)

REVERSAL NEEDS CONFIRMATION!

=>Spectral fits when model is "valid"







Rodriguez, Varnière, Tagger & Durouchoux '02a

Varnière, Rodriguez & Tagger '02

Other sources



To go farther: QPO energy Spectra





1550 => disk flux not modulated
1915 => Hard X-rays not entirely modulated
 => 2 different emitting processes at
 interm. Energies: HOT SPOT ?

Conclusions (1)

IF rotating spiral identified as QPO: v_{QPO} vs. f_{disk} : expected v_{QPO} vs. r_{disk} : completely explained anticorrélation RMS_{QPO} vs. f_{disk} : disk is not source of modulated photons spectrum of QPO: hot spot + Comptonization ?

Spectral and multi wavelength approaches

Magnetic flood (Michel's talk)

Magnetic flood scenario in 1915:

accumulation of magnetic flux during X-ray dips (AEI, QPOs) reconnection at spike release of magnetic flux, ejection, return to MRI, no QPO (Tagger et al. '04) BUT

Mainly based on β classes (interm. spike)







XTE J1550-564 during the 2000 outburst



Re-appearance of LFQPO (C) before transition back to LHS

Ejection of corona and simultaneous disappearance of LFQPO



Magnetic flood in action?

Formerly: Corbel, Fender and collaborators=> ejection at the LHS to IS (SPL) transition

Our analysis => ejection at the spike

spike <=> analoguous to C->A transition in GRS 1915, with ejection of coronal material?

Magnetic flood?: Scenario can (qualitatively) be applied to 1550, although different time constants:

- \Rightarrow Accumulation of B flux during rise to outburst (LHS)
- approaching disk=>transition to SPL (coronal cooling), AEI still in action
- reconnection at spike=> ejection of corona and release of B flux
- \Rightarrow low magnetization => return to MRI, no QPO
- ⇒ accumulation of B flux after, reconstruction of corona => equipartition => AEI, QPOs (before transition back to LHS), heating of corona (Varnière & Tagger '03)=> transition to LHS

Difference with 1915: reservoir of material insufficient for several cycles?

Radio / X-ray connection

$\chi =>$ "Hard" steady X-ray state, compact jet, LFQPO

Belloni et al. '00; Klein-Wolt et al. '02



 $\alpha,\beta,\nu,\theta =>$ ejections of "bubble", X-ray dip/spike sequences (cycles), spectral transitions, HF and LFQPO

In class v: no spike a priori





- X-ray/radio correlation
- ✓ Amplitude QPO67 Hz <0.6%
 ✓ Dip amplitude fainter > 18 keV (R. et)
 - al. '02) => recession of disc?
- Presence of a precursor to main spike
 => real trigger of the ejection (as in e.g. class β)?

Spectral approach



"Monotonic" approach of the disc C dip <=> Compton flux_{3-50keV} divided 2.4

10.00

1.00

0.10

0.01

=> Ejection of «Corona»

Class λ : nothing known



<u>FOR THE 1st TIME</u>: Ejection during λ after a dip-spike cycle Presence of a "precursor" spike as well



Spectral approach



Disc ~ constant B, C, D (within errors) C dip <=> Compton flux_{3-50keV} divided > 2.7

=>Ejection of "Corona"

Timing with RXTE



LFQPO <-> X-ray dips: like other classes with cycles (α, β, ν, θ) QPO frequency follows (soft) X-ray flux (Markwardt et al. '99, R. et al. '02a,b, Vadawale et al. '04)

HFQPO <-> entire observation: 66.8 Hz, 0.85%, coherence ~10 Phenomena close to last stable orbit? Absent or weaker in v



Back to β





- ✓ Dips-spike ejection sequence
- ✓ Ejection of corona (Chaty `98) @ intermediate spike
- LFQPO with frequency correlated to flux
- ✓ HFQPO @ 65.2 Hz, Q~28, ~0.6%

Conclusions (2)

- Discrete ejections <u>always</u> associated with X-ray cycles
- Similar X to radio delay in all classes => identification of X-ray spike as trigger to ejections
- Soft X-ray spike <=> disappearance Compton component
- → Ejection of corona, & approach of disc : is 1 consequence of the other?
- Variable LFQPO during dips => link with ejection?
 HFQPO not necessarily linked

Conclusion (3): Magnetic flood in action?

- → In one case: possible appearance of LFQPO before transition to dip (need confirmation though)

as in 1550 if LFQPO<=> AEI, instability triggers the transition and is not its result.

Compatible (if not predicted) by the magnetic flood originally applied to β