# Accretion-Ejection Instability in X-ray binaries

a possible explanation for a range of phenomena occuring in X-ray binaries

P. Varnière[1], S. Caunt[1], M. Tagger[1]

[1]SAp, CEA Saclay

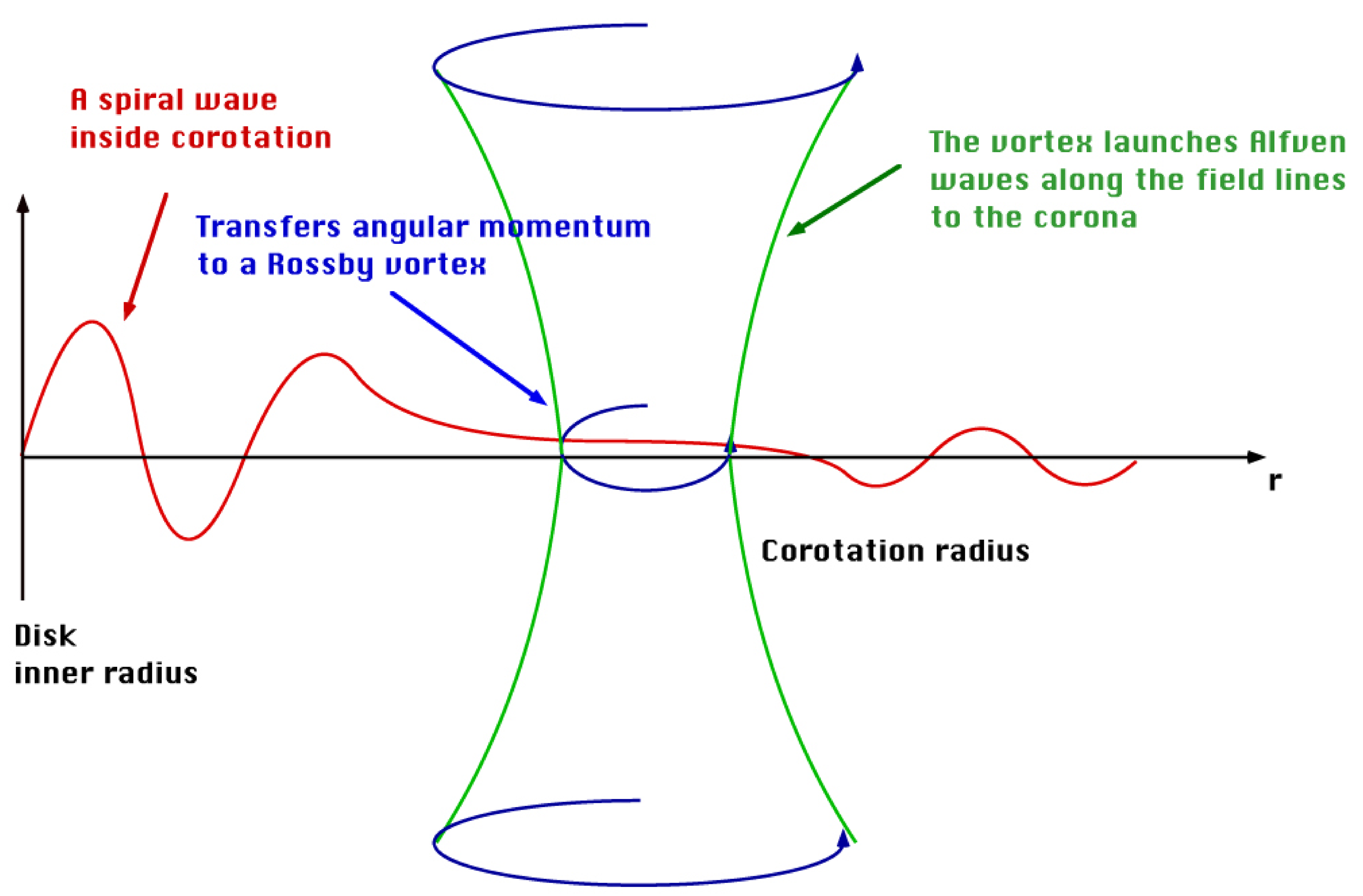
e-mail: varniere@cea.fr

## Introduction: Accretion-Ejection Instability

We present the Accretion-Ejection Instability as a possible explanation for the low-frequency (*"ubiquitous"*) QPO in microquasars. It occurs in the inner region of a disk threaded by a vertical magnetic field of the order of equipartition ($\beta \sim 1$ with $\beta = 8\pi/pB^2$ = gas pressure/magnetic pressure) This instability provides a way to connect accretion (in the inner region of the disk) with the ejection (energy for a jet or a wind).

## Scheme of the instability

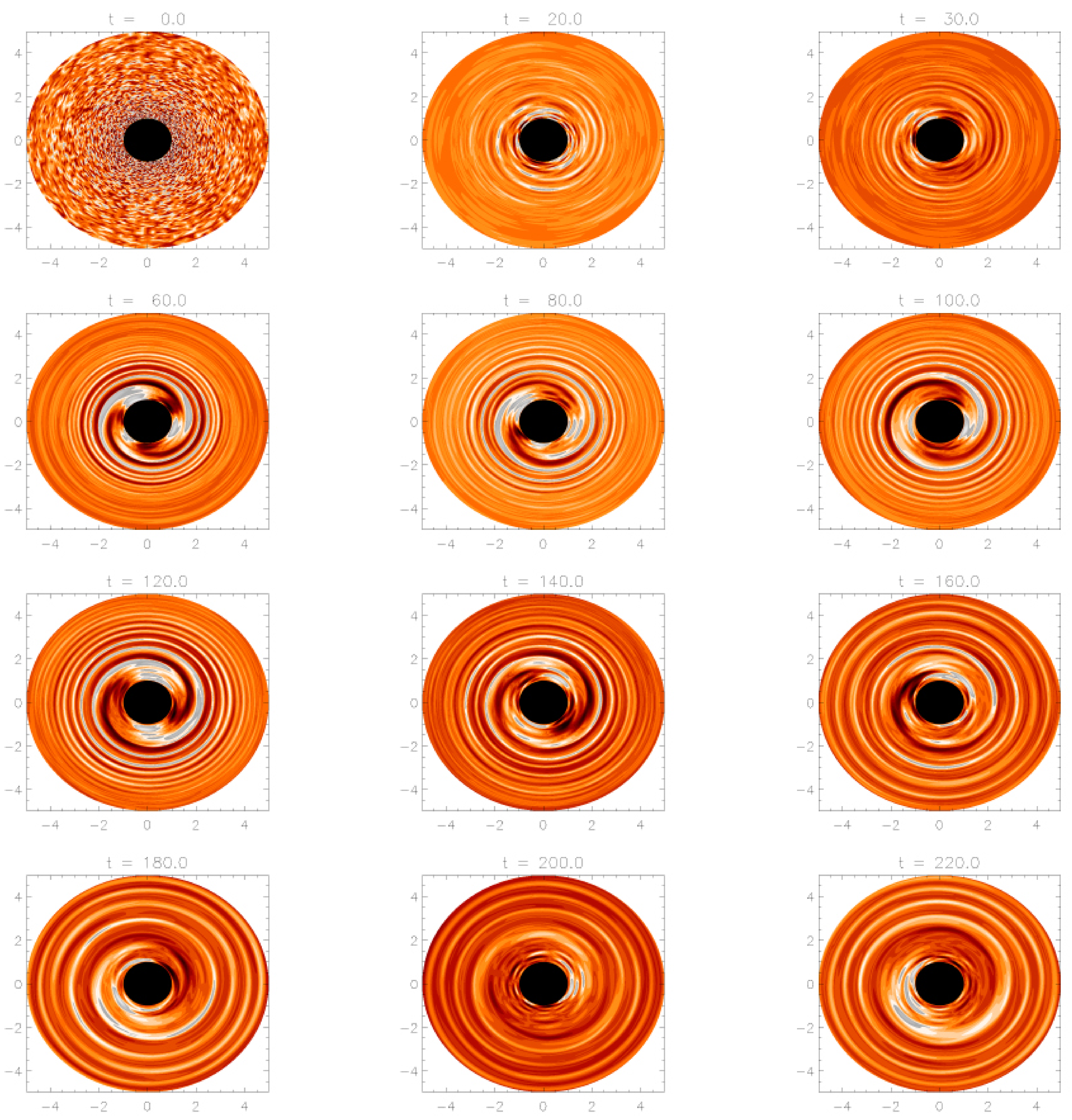
- The AEI is a spiral instability (∼ galactic spiral) driven by magnetic stresses (rather than self-gravity). It occurs in the inner region of an accretion disk threaded by a vertical magnetic field (in equipartition with gas pressure).




- The spiral extracts energy and angular momentum from the disk (⟶ accretion) and stores them in a Rossby vortex (∼ Great Red Spot) at its corotation radius.
- This vortex *leaks* energy and momentum to the corona as Alfven waves ⟶ power from accretion for a wind or a jet

## Numerical Simulation

2D, non linear MHD simulation of an infinitely thin accretion disk in vaccum thread by a vertical magnetic field of the order of the equipartition with gas pressure.



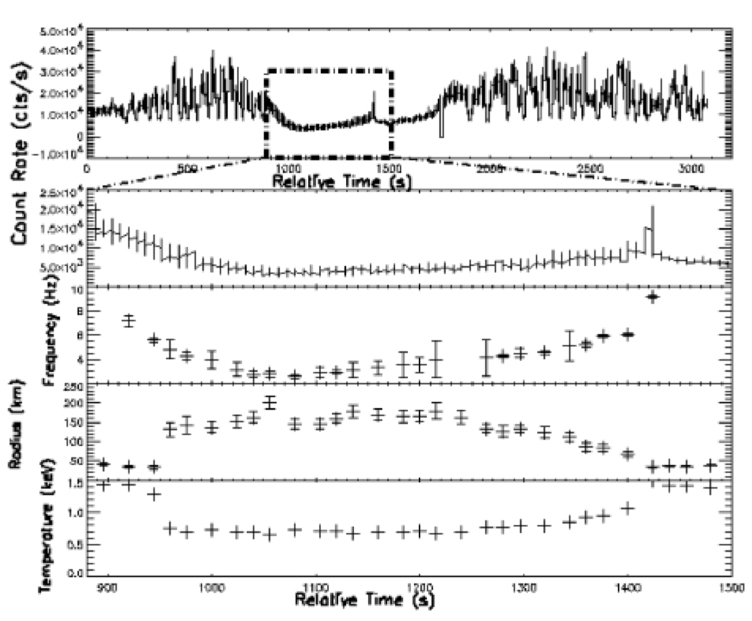

in agreement with theory, a spiral mode develops with initially 3 arms (depending on initial conditions) decreasing to 2 and finally 1 arm as magnetic flux piles up near the center.

## New Results

### 1) the AEI as a model for QPO

The AEI explains the QPO properties by spirals created in the disk. It can explain:

- the observed frequency of the QPO which is of the order of 0.1-0.3 $\Omega_{int}$ (the inner radius keplerien frequency)
- the long-life of the QPO by a quasi-steady spiral pattern (as seen in galaxies)
- why the QPO although its has its origin in the disk, can strongly affect the corona with the emission of Alfven Waves



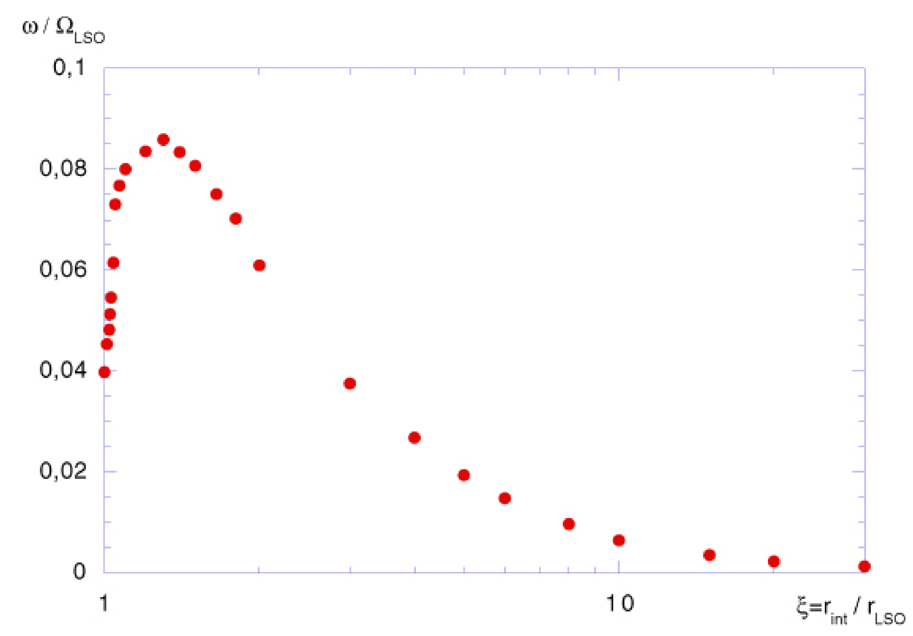

### 2) Relativistic Effects

Relativistic effects change the rotation curve of the disk near the last stable orbit.

⟶ It allows the existence of an Inner Lindblad Resonnance (ILR) for the $m = 1$ mode (the one associated with the QPO)

⟶ changes the properties of the armed spiral, and therefore the properties of the QPO frequency

We have solved numerically the equation for different inner radii of the disk $\xi = r_{int}/r_{LSO}$




⟶ the change in correlation appears about the radius where relativistic effects become important (.i.e where the ILR appear)

⟶ possible explanation for the different correlation found in GRO J1655 compared to other sources as seen by Sobczak *et al.*.

### 3) Emission of Alfven Waves:

The vortex twists the footpoint of the field lines threading the disk. If the disk has a low density corona:

twisting ⟶ emission of Alfven waves

⟶ energy and angular momentum extracted from the disk will be transfered to the corona where they can power a wind or jet

We work out a variational form:

$$F = [\text{energy of the waves}] + i\ (\text{outgoing spiral} + \text{coupling with vortex} + k_z\ \text{Alfven Wave})$$

imaginary terms ↔ amplification or damping

Alfven terms $\sim \left(\frac{\rho_{corona}}{\rho_{disk}}\right)^{\frac{1}{2}}$ (∼ magnetic breaking)

## Conclusions:

⋆ The AEI provides a possible explanation for the main properties of the QPO: its frequency, the frequency-radius correlation, the amplitude-energy correlation.

⋆ Numerical simulation confirm the expected behavior, namely a spiral wave and a Rossby vortex forming a steady rotating pattern.

⋆ We progress in the detailed theoretical understanding of the AEI and its role in the inner part of the disk.

⋆ Alfven waves can energize the corona ( + particle acceleration? )

Publications:

Caunt, S., Tagger, M., A&A, **367**, 1095-1111, 2001.

Rodriguez, J., Varnière, P., Tagger, M. (to be published by A&A)

Sobczak, G.J., McClintock, J.E., Remillard, R.A., Cui, W., Levine, A.M., Morgan, E.H., Orosz, J.A. and Bailyn, C.D. 2000, ApJ , **531**, 537.

Tagger, M. & Pellat, R. , A&A, **349**,1003-1016,1999.

Tagger, M., Varniere, P., Rodriguez, J., Physics of Accretion and Associated Outflows, Copenhagen, January 5-8, 2000

Varnière, P., Rodriguez, J., Tagger M. (submitted to A&A)