Probing the fast dynamics of disc-jet connection in GX 339-4 with the internal shock model

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Dissipation through shocks driven by rapid fluctuations of jet ejection Lorentz Factor.

Jamil et al. 2010, Malzac 2013

ISHEM code: simulate SEDs and light curves

Malzac 2014

SED sensitive to Fourrier PSD of input Lorentz factor fluctuations
Jet Lorentz factor fluctuations driven by accretion flow variability which is best traced by X-ray light curves

Fourier PDS of X-ray light curve

= Power spectrum of Lorentz factor fluctuations

Jet synchrotron

Irradiated accretion disc

corona

GX 339-4 hard state PDS

A dark jet in the soft state?

Drappeau et al. 2017

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**Soft state**

![Soft state diagram](image)

**Hard state**

![Hard state diagram](image)

Accretion flow $\mathcal{F}_j \sim 1'' \cdot \Theta_j = 1''$

Accretion flow $\mathcal{F}_j \sim 3'' \cdot \Theta_j = 3''$
$2 \times 10^{10}$ Hz  $2 \times 10^{12}$ Hz  $2 \times 10^{13}$ Hz  $2 \times 10^{14}$ Hz  $2 \times 10^{18}$ Hz

NIR Variability in Hard state

WISE light curves of GX339-4 (Gandhi et al. 2011)

Sample simulated light curve

1.36 × 10^{13} Hz

2.50 × 10^{13} Hz

6.52 × 10^{13} Hz

8.82 × 10^{13} Hz

Drappeau et al., MNRAS 2015
Fast variability from jets

Simulation

Casella et al. 2010

Observation

IR timing data of GX 339-4: First QPO detected in Infrared

Simultaneous IR / X timing data with VLT/ISAAC and RXTE (Kalamkar et al. 2016)

IR rms ~ X-ray rms ~ 20 %

IR QPO @ ~0.08 Hz
X-ray QPO @ ~0.16 Hz

Internal shock model predicts similar shape of IR PSD but model rms amplitude larger by factor of ~4.
Additional constant component from disc or jet?

Model lacks IR QPO.
IR QPO from jet precession

X-ray low frequency QPO caused by Lense-Thirring precession of the hot accretion flow?

Ingram, Done & Fragile 2009; Ingram et al. 2015

If jet launched by accretion flow, jet precesses with the hot flow → modulation of synchrotron emission
Jet precession at observed IR QPO frequency, precession angle: 5 deg.

X-ray QPO subtracted from input jet Lorentz factor fluctuations

QPO width: precession phase randomised every Q~10 cycles.

Depending on hot flow geometry and inclination and precession angle, X-ray QPO can be dominated by first harmonic (see Veledina et al. 2013).
Wavelength dependence of synthetic IR Fourier power spectrum
Fast IR /X-ray correlations in GX339-4

- IR vs X-ray Fourier coherence, and lags from Kalamkar et al. (2016) data

Model:
- IR light curve from same model used for SED and IR PSD.
- X-ray light curve: \( L_X(t) \propto \Gamma(t) - 1 \)
Effect of jet Lorentz factor

\[ \langle \Gamma \rangle < 3 \text{ favoured} \]
Effect of viewing angle

![Graph showing the effect of viewing angle on frequency response](image)
Jet disc coupling

\[ \Gamma(t) - 1 \propto L_X^g(t) \]

\( g = 1 \) favoured
There might be powerful radiatively inefficient jets in soft states.

Internal shock model predicts strong variability and IR/X-ray correlations similar to that observed in GX339-4.

IR QPO may be caused by jet precession.

Opt/IR/X-ray correlations could be used to constrain the jet parameters, unveil the dynamics of accretion and ejection physics, and also constrain the hot flow geometry (X-ray vs IR QPOs).

Need to combine accretion flow and jet models.