Evidence of Two component flows around the Galactic black hole candidates during their outbursts

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Abstract

It is already established in literature that Two component flow are necessary to explain the timing and spectral properties of black hole. We have studied the timing and spectral properties of a few Galactic black hole candidates (such as XTE J1550-564, GRO J1655-40, GX 339-4 etc.) during their outburst. We find that the spectral features of these black hole candidates could be clearly understood by a two component (Keplerian and sub-Keplerian) advective flow (TCAF). We choose the spectral data (PCA) from of the RXTE satellite and fit them quite satisfactorily using TCAF model and also calculate the disc parameters (Keplerian rate, the sub-Keplerian rate, shock location, inner edge of the Keplerian disc). From the timing analysis we find a systematic drifts (onset and in decline phase) in Quasi-Periodic Oscillations (QPOs) frequency during the outburst. This type of evolutions in QPO frequency was seen in the various black hole candidates such as GRO J1655-40, XTE J1550-564, GX 339-4 etc. We model the frequency drift with a propagatory oscillating shock solution where the post-shock region behaves as the Comptonized region. The smoothness of the variation of the QPO frequency over a period of weeks directly supports the view that it is due to the drifting of the Comptonizing region rather than the movements of a blob inside a differentially rotating disk. We conclude the presence of two independent component in the accretion flow.

Two Component Advective Flow model

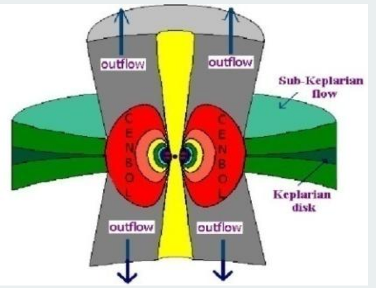
(Chakrabarti & Titarchuk 95)

Disk accretion: Keplerian and sub-Keplerian Flow
Soft state: Keplerian rate is high

Hard state: sub-Keplerian rate is high

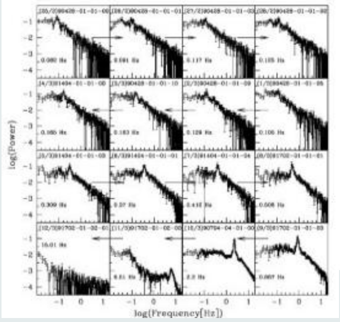
Intermediate state: both the rates are comparable

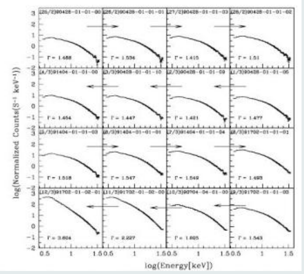
Timing Properties: Oscillations of Shock (CENBOL), movement of keplerian disk etc



Results and Discussions

Properties of GBHC GRO J1655-40





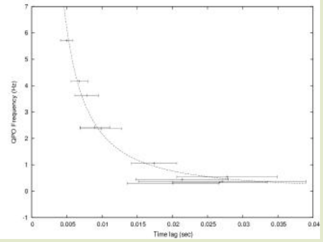
Variation of QPO frequency during the first two weeks of the outburst. Here we find a systematic movement of the QPO frequency with the time.

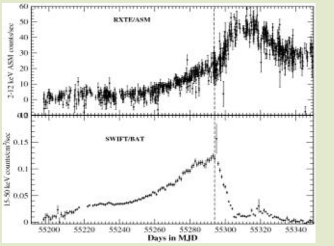
The spectral softening, together with the increase of QPO frequency fits well with the oscillating shock model. The shock is propagating towards the black hole with a constant velocity.

1. On the rising phase (from 25th Feb 2005 to 12th March) QPO frequency monotonically increased from 82 mHz to 17.78 Hz and it disappears within 15 hour. The drift velocity of shock was ~ 20 m/s.

2. The energy spectrum gradually became softer as shock proceeds close to black hole. The Keplerian disk follows the shock.

Properties of GBHC GX 339-4



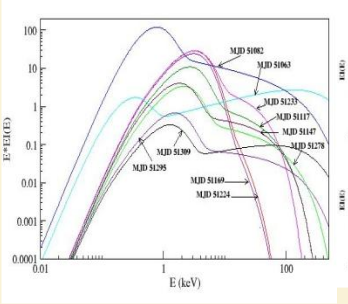


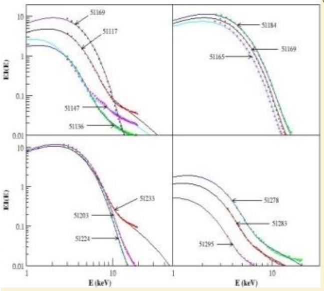
1. The outburst started with hard X-ray emission and these photons dominate up to MJD 55298, after that the system moves to the soft/intermediate state.

2.We find a clear point of intersection on MJD 55298 between the soft photons (2.0-3.7 keV) and hard photons (10.2-24.85 keV).

3. As frequency increses Phase lag between the soft and hard energy band also increases.

Properties of XTE J1655-40



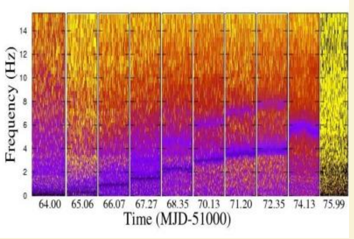


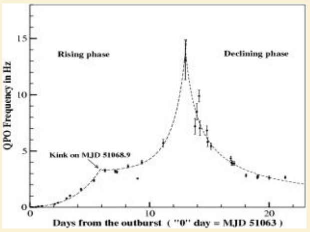
The overall view of fitted spectra with TCAF model for the whole outburst.

Three distinct spectral states low/hard, very high/intermediate and high/soft are observed.

A clear movement of the inner edge of the Keplerian disk

Fitted spectrum during the Intermediate state, transition to soft state and again transition to intermediate state.
The Keplerian rate, sub-Keplerian rate and CENBOL size governing the entire spectral states.





Variation of QPO frequency with time (in day) in the rising and decline phases of QPO since the beginning of the outburst. The dotted curves are the solutions from oscillating and propagating shocks.

Conclusions

1. The oscillation of the shock wave is responsible for QPOs (in XTE J1550-564, GX 339-4 & GRO J1655-40) and also explain the daily variation.

2. The smooth variation of the QPO frequency is due to the movement of the Comptonizing region itself.

3. In the rising phase, the excess cooling in the post-shock flow causes a steady drift of the shock towards the black hole, while in the decline phase the recession of the Keplerian disc causes the reduction of pressure in the pre-shock flow and the shock can propagate outward.

4. In XTE J1550-564 shock wave never reaches the horizon. But in case of GRO J1655-40, the shock wave moved closer to the black hole and ultimately disappeared behind the horizon.

5. For both the black holes the propagation speed of the shock is about 20m/s.

6. The outward propagatory shock in GRO 1655-40 & GX 339-4 started only after several months, indicating that matter supply was prolonged while in XTE J1550-564, the supply was erratic causing the receding shock to form immediately after the flare.

7. It is clear from the spectral fitting with TCAF model that in addition to Keplerian flow we need an another independent flow component called sub-Keplerian flow where both the components are present close to the black hole in the presence or absence of a shock.

References

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