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Compton cooling and the signature of Quasi Periodic Oscillations for the transient black hole candidate H 1743-322

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Abstract. In black hole accretion cooling of the Compton cloud has an enormous effect on the dynamics of post-shock flow. We demonstrate that the Compton cooling is highly responsible for the origin of Quasi Periodic Oscillations (QPOs) during the outburst time of the galactic black hole candidates (BHCs). Our study shows that the disk oscillation will take place when infall time from the shock roughly agrees with cooling time in the post-shock region i.e., the resonance condition. We believe that this oscillation is responsible for the origin of QPOs and will occur only when a particular disk condition (disk rate, halo rate and shock strength) satisfies. We also confirm that shock moves with an average velocity of a few meters/sec for the transient BHC H1743-322 due to the presence of Compton cooling.

Keywords : black hole physics, accretion, accretion disk, shock waves, hydrodynamics

1. Introduction

X-ray transient sources exhibit various types of Quasi Periodic Oscillations with frequencies ranging from mHz to a few hundreds of Hz (Morgan et al. 1997). Several models are there in the literature to explain the origin of QPOs. Trapped oscillations in gaseous disks around supermassive black holes and 100 days time variabilities in these objects were explained by Kato and Fukue (1980). ‘Diskoseismology’ model by Nowak and Wagoner (1991), used acoustic oscillations of the disk arising out of dispersion relation. Molteni et al. (1996), in the context of super massive black holes, mentioned that resonance caused by agreement of bremsstrahlung type cooling and infall time scale in the post-shock region of an advection flow is the cause of oscillation of the emitted radiation. Recently, Mondal et al. (2015) showed the monotonic increase of QPOs (mainly C-type, Casella et al. 2005) in presence of Compton cooling. In the present manuscript we show the origin of QPOs from the satisfaction of resonance condition using cooling (t_c) and infall (t_i) time scales.

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Table 1: Calculated parameters for H 1743-322

days	$\dot{m}_d$	$\dot{m}_h$	Λ_c (10^{-3})	QPOs (Hz)	α	τ	T_e	Q_{val}	t_c (s)	t_i (s)	$\frac{t_c}{t_i}$
1.00	0.131	0.353	0.339	0.919	0.625	0.730	0.261	11.15	4.164	5.714	0.729
2.17	0.156	0.376	0.364	1.002	0.661	0.779	0.221	16.01	3.343	4.763	0.702
2.84	0.120	0.400	0.380	1.045	0.685	0.814	0.201	14.10	2.790	4.249	0.657
4.00	0.352	0.445	0.405	1.174	0.819	1.100	0.163	24.46	2.920	3.516	0.831
5.78	0.524	0.279	0.426	1.789	1.209	0.760	0.111	25.59	1.057	1.889	0.560
6.96	0.740	0.379	0.448	2.947	2.315	0.143	0.120	8.954	0.044	0.053	0.840
7.81	0.976	0.456	0.516	4.796	2.401	0.075	0.118	9.620	0.059	0.063	0.936

In the table $\dot{m}_d$ and $\dot{m}_h$ are in Eddington unit ($\dot{M}_{Edd}$). The temperature T_e is in 10^{10} K unit, α and τ are the spectral index and optical depth, respectively.

2. Results and Discussions

In Table 1, we tabulate the summary of our results. For a particular observation of H1743-322 we obtain Keplerian disk rate ($\dot{m}_d$), sub-Keplerian rate ($\dot{m}_h$), location of the shock (X_s) and compression ratio (R) by TCAF fitting (Debnath et al. 2014, Mondal et al. 2014). These parameters determine the electron number density and temperature of the CENBOL (Chakrabarti and Titarchuk, 1995). Hydrodynamics of the flow is determined by the amount of cooling and Rankine-Hugoniot shock conditions. In Column 4 and 5, we see the increase in cooling rate (which we have calculated integrating the model fitted spectra) as well as QPOs frequency with progressive days. In Col 8 we tabulate the average temperature of the electron cloud. Sharpness of the QPOs are determined by the Q-values of the resonance oscillation. The Q-values are shown in Col 9 of Table 1. In Col 12, we show the ratio of cooling and infall time scales, which satisfies the condition of resonance. We consider only the raising phase of the outburst of H 1743-322 black hole candidate. On first observed day of the outburst, location of the shock (in $r_g = 2GM/c^2$ unit) was at 350.65 and at the end of our observation, it reaches at $\sim$ 64.99 with a velocity $\sim$ 13.11 ms^{-1}. From our result we conclude that the QPOs occur when resonance condition is satisfied (within 50%) during the outburst time of the BHCs (Chakrabarti et al. 2015).

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