New Astronomy 58 (2018) 84–89

Contents lists available at ScienceDirect

New Astronomy

journal homepage: www.elsevier.com/locate/newast

Modeling the response of a standard accretion disc to stochastic viscous fluctuations

Naveel Ahmad[a,*], Ranjeev Misra[b], Naseer Iqbal[a,b], Bari Maqbool[a], Mubashir Hamid[a]

[a] Department Of Physics, University of Kashmir, Srinagar 190006, India
[b] Inter-University Center for Astronomy and Astrophysics, Post Bag 4, Ganeshkhind, Pune 411007, India

HIGHLIGHTS

- The time-lag between the inner accretion rate variability with respect to that of the perturbation radius, depends on the time-period of the oscillation.
- The effect of perturbation is multiplicative in the inner regions, so the variability is stronger in the inner region than in the outer.
- The power spectra of the accretion rate in the inner regions has a power-law form.

ARTICLE INFO

Article history:
Received 22 June 2017
Accepted 27 July 2017
Available online 28 July 2017

Keywords:
Accretion
Accretion discs
Instabilities
Hydrodynamics
Methods: Numerical
X-Rays: Binaries

ABSTRACT

The observed variability of X-ray binaries over a wide range of time-scales can be understood in the framework of a stochastic propagation model, where viscous fluctuations at different radii induce accretion rate variability that propagate inwards to the X-ray producing region. The scenario successfully explains the power spectra, the linear rms-flux relation as well as the time-lag between different energy photons. The predictions of this model have been obtained using approximate analytical solutions or empirically motivated models which take into account the effect of these propagating variability on the radiative process of complex accretion flows. Here, we study the variation of the accretion rate due to such viscous fluctuations using a hydro-dynamical code for the standard geometrically thin, gas pressure dominated α-disc with a zero torque boundary condition. Our results confirm earlier findings that the time-lag between a perturbation and the resultant inner accretion rate variation depends on the frequency (or time-period) of the perturbation. Here we have quantified that the time-lag $t_{lag} \propto f^{-0.54}$, for time-periods less than the viscous time-scale of the perturbation radius and is nearly constant otherwise. This, coupled with radiative process would produce the observed frequency dependent time-lag between different energy bands. We also confirm that if there are random Gaussian fluctuations of the α-parameter at different radii, the resultant inner accretion rate has a power spectrum which is a power-law.

1. Introduction

Black hole X-ray binaries are powered by an accretion disc. The X-rays are emitted from the inner regions of the disc close to the black hole where the characteristic time-scales are expected to be of the order of less than seconds. Thus, it was rather surprising that the X-ray emission from these systems vary over a wide range of time-scales. It is now believed that this wide range occurs because viscous fluctuations with long characteristic time-scales occur in the outer parts of the disc and subsequently these variations propagate to the inner parts (Lyubarskii, 1997). Such a model qualitatively explains the power-law form of the power spectra of the X-ray emission. Moreover, these long time-scale fluctuations arising from large radii on propagating inwards gets superimposed on the smaller time-scale fluctuations arising there. Hence, this explains the linear positive relation between the *r.m.s* variability and the X-ray flux, that are observed in many X-ray binaries (Uttley and McHardy, 2001; Gaskell, 2004; Uttley, 2004; Uttley et al., 2005; Heil and Vaughan, 2010; Heil et al., 2011, 2012). Thus, the model provides a natural connection between the power spectra and the rms-flux relation which has been studied by several authors (e.g. Ingram and Done, 2011; Heil et al., 2012). Moreover, the same process should be acting on accreting systems such as Active Galactic Nuclei and hence in general can be used to obtain the size scale

* Corresponding author at: Department Of Physics, University of Kashmir, Srinagar 190006, India.
E-mail address: anaveel@gmail.com (N. Ahmad).

http://dx.doi.org/10.1016/j.newast.2017.07.011
1384-1076/