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Correlated X-ray/UV/optical emission and short-term variability in a Seyfert 1 galaxy NGC 4593

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ABSTRACT

We present a detailed multifrequency analysis of an intense monitoring programme of Seyfert 1 galaxy NGC 4593 over a duration of nearly for a month with *Swift* observatory. We used 185 pointings to study the variability in six ultraviolet/optical and two soft (0.3–1.5 keV) and hard X-ray (1.5–10 keV) bands. The amplitude of the observed variability is found to decrease from high energy to low energy (X-ray to optical) bands. Count–count plots of ultraviolet/optical bands with hard X-rays clearly suggest the presence of a mixture of two major components: (i) highly variable component such as hard X-ray emission, and (ii) slowly varying disc-like component. The variations observed in the ultraviolet/optical emission are strongly correlated with the hard X-ray band. Cross-correlation analysis provides the lags for the longer wavelengths compared to the hard X-rays. Such lags clearly suggest that the changes in the ultraviolet/optical bands follow the variations in the hard X-ray band. This implies that the observed variation in longer wavelengths is due to X-ray reprocessing. Though, the measured lag spectrum (lag versus wavelength) is well described by $\lambda^{4/3}$ as expected from the standard disc model, the observed lags are found to be longer than the predicted values from standard disc model. This implies that the actual size of the disc of NGC 4593 is larger than the estimated size of standard thin disc as reported in active galactic nuclei such as NGC 5548 and Fairall 9.

Key words: accretion, accretion discs – galaxies: active – galaxies: individual: NGC 4593 – galaxies: nuclei – X-rays: galaxies.

1 INTRODUCTION

Active galactic nuclei (AGNs) are normally considered to have accreting supermassive black holes (SMBHs) at the heart of the host galaxies. The radiation from these AGNs covers almost entire range of electromagnetic spectrum – starting from X-ray to Radio bands. The X-ray continuum emission from these objects is considered to be dominated by the power law model, which is known to be due to the inverse Compton scattering of soft photons in an optically thin i.e. $\tau \sim 1$ and hot electron plasma i.e. $kT_e \sim 100$ keV (Sunyaev & Titarchuk 1980; Haardt & Maraschi 1991). The soft photons observed in these sources are believed to be emitted from the accretion disc around the SMBH. The accretion disc, as proposed by Shakura & Sunyaev (1973), is assumed to be geometrically thin and optically thick. In the accretion disc, the energy loss due to the viscous heating is being emitted as blackbody emission corresponding to the temperature at a given radius. The temperature at a certain distance from the centre is inversely proportional to the three-fourth power of the distance. Depending on the temperature, the disc emits radiation in the range of ultraviolet (UV) to optical bands (Koratkar & Blaes 1999; Yuan & Narayan 2014). However, sometimes the inner disc becomes sufficiently hot and partly contributes at the soft X-ray band (e.g. Boller, Brandt & Fink 1996; Leighly 1999).

In Seyfert galaxies, radiation emitted from the accretion disc is dominated in the UV band. However, due to large Galactic absorption along the line of sight, the UV radiation peak is hardly detectable. The observed UV/optical emission shows different variabilities on various time-scales from days to years for 10^6–10^9 $M_\odot$ black hole mass range (e.g. Arévalo et al. 2008; Mehdipour et al. 2011; McHardy et al. 2014; Shappee et al. 2014; McHardy et al. 2016). However, the cause of observed variabilities in UV/optical emission from the accretion disc is not very clear. The observed UV/optical emission variabilities in Seyfert galaxies are thought to be associated with the fluctuation in the mass accretion (Arévalo et al. 2008; Marshall, Ryle & Miller 2008). However, such interpretation is unable to explain the observed disc variability on short (hours to days) time-scale. This variability time-scale is very much shorter compared to the expected time-scale of the density fluctuations in the accretion flow. The variations observed in X-ray emission are found to lead the variations in UV/optical band (McHardy et al. 2014; Shappee et al. 2014). This is difficult to explain by using the hypothesis that the cause of UV/optical variation is associated with accretion flow fluctuation.

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