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Correlated X-ray/ultraviolet/optical variability and the nature of accretion disc in the bare Seyfert 1 galaxy Fairall 9

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ABSTRACT

We study the multiwavelength variability of the bare Seyfert 1 galaxy Fairall 9 using *Swift* monitoring observations consisting of 165 usable pointings spanning nearly two years and covering six ultraviolet (UV)/optical bands and X-rays. Fairall 9 is highly variable in all bands though the variability amplitude decreases from X-ray to optical bands. The variations in the X-ray and UV/optical bands are strongly correlated. Our reverberation mapping analysis using the JAVALIN tool shows that the variation in the UV/optical bands lag behind the variations in the X-ray band by ∼2–10 d. These lag measurements strongly suggest that the optical/UV variations are mainly caused by variations in the X-rays, and the origin of most of the optical/UV emission is X-ray reprocessing. The observed lags are found to vary as $\tau \propto \lambda^{1.36 \pm 0.13}$, consistent with the prediction, $\tau \propto \lambda^{4/3}$, for X-ray reprocessing in a standard accretion disc. However, the predicted lags for a standard accretion disc with X-ray reprocessing using the black hole mass ($M_{\rm BH} \sim 2.6 \times 10^8\,{\rm M}_\odot$) estimated from the reverberation mapping of broad emission lines and the accretion rate relative to the Eddington rate ($\dot{m}_{\rm E} = 0.02$) are shorter than the observed lags. These observations suggest that the accretion disc in Fairall 9 is larger than that predicted by the standard disc model, and confirm similar findings in a few other Seyfert 1 galaxies such as NGC 5548.

Key words: accretion, accretion discs – radiation mechanisms: general – galaxies: active – galaxies: Seyfert – ultraviolet: galaxies – X-rays: galaxies.

1 INTRODUCTION

Active galactic nuclei (AGNs) are thought to contain an accreting supermassive black hole (SMBH) at the centre of the parent galaxy. Such sources emit over the entire electromagnetic spectrum from radio to X-rays. The main radiative component in the X-ray band is the power-law emission that is thought to arise due to the Compton upscattering of seed photons in an optically thin and hot corona (Sunyaev & Titarchuk 1980; Haardt & Maraschi 1991). The seed photons are thought to be associated with the material accreting towards the SMBH, forming an accretion disc. The popular standard accretion disc model, which describes an optically thick and geometrically thin disc, was proposed by Shakura & Sunyaev (1973). The dissipated energy in the accretion disc is considered to be radiated away locally as blackbody emission at each radius of the accretion disc. The temperature at each radius varies inversely as a three-fourths power of the radial distance from the centre. The emission from outer to inner regions of the accretion disc is observed in the optical to ultraviolet (UV) bands (e.g., Koratkar & Blaes 1999) and sometimes partly at the softest X-rays (e.g. Boller, Brandt & Fink 1996).

The emission from the accretion disc in Seyfert galaxies peaks in the UV regime, where the peak of the UV emission is hard to detect due to Galactic absorption along the line of sight. The observed UV/optical emission shows a variety of variability on various time-scales from hours to years for a range of black hole masses (e.g. MR 2251-178: Arévalo et al. 2008; Mrk 509: Mehdipour et al. 2011; NGC 5548: McHardy et al. 2014; NGC 2617: Shappee et al. 2014; NGC 4395: McHardy et al. 2016). However, the origin of the disc emission variability is less well understood. One can assume that the natural origin of the UV/optical emission variability is associated with the variations in the accretion flow (e.g. Arévalo et al. 2008; Marshall, Ryle & Miller 2008). Such models pose questions on the explanation of the observed disc variability. Sometimes the time-scale of observed fluctuations is of the order of hours to days, which is much faster than the expected time-scale of the accretion flow. Another problem is that the changes in the UV/optical emission lag the X-ray emission, which is unexplainable by the above assumption (e.g. McHardy et al. 2014; Shappee et al. 2014).

As suggested by Krolik et al. (1991), the variations in UV/optical emission can be delayed with respect to X-rays if the variations in

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