Disk-Jet Coupling in the Radio Source 4C +74.26

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Abstract

Disk-jet symbiosis is one of the challenging subjects in the study of active galactic nuclei (AGN). In this poster, we explore the disk-jet connection in the radio source 4C+74.26, a broad-line region galaxy with its jet oriented at an intermediate angle, utilizing the results of a multi-wavelength analysis involving long-term radio, optical and X-ray observations. While in blazar sources the disk/corona component is outshined by strongly beamed jet emission and in radio galaxies, it is typically heavily absorbed by the circumnuclear dust. In this radio-loud AGN we see directly the disk (optical), disk corona and disk outflows (X-rays), and relativistic jet (radio). In addition, all these components, i.e. the moderately beamed jet, the disk and the disk corona, are bright enough to be monitored simultaneously on a regular basis. In the cross-correlation between the optical and radio light curves, we found radio emission leading the optical emission by 250 d. Further, to relate the observed optical-radio correlation to the disk properties, we performed the spectral analysis on NuSTAR observations by modeling the reflection emission from the disk illuminated coronal emission and estimated the inner radius of the truncated disk to be ~ 35 ISCO. We interpret the results in the context of propagation of the magnetic instability around the innermost regions of a truncated disk of the AGN along the disk and into the jet. While there are numerous reports of strong correlation between the optical and gamma ray emission and the radio and the gamma ray emission, these observations provide first direct evidence of direct correlation between the optical and the radio. In such case, the result might be significant in constraining the disk-jet coupling in AGNs.

Introduction

4C+74.26 (z = 0.104) is a giant radio source with a projected linear size of ~ 1 Mpc. In the radio frequencies, it is classified as flat spectrum radio source whereas its optical emission is typical for a Seyfert I. The source is associated with giant radio lobes. The source is identified as having ultra-fast outflows (UFO) in X-ray and in optical spectropolarimetry. These findings strongly suggest that the X-ray and the optical emission originate close to the accretion disk. Very Large Array (VLA) observation reveal a kpc scale one-sided jet, From Very Long Baseline Interferometry (VLBI) observations, the angle between the jet axis and the line of sight was found to be $\lesssim 49°$. While the non-thermal emission from blazars completely swamp the thermal emission from the disk, and in Seyfert II type galaxies most of the jet emission is blocked from the view by the dusty torus. Sources with their jets inclined at an intermediate angle (around $45°$) are ideal to investigate the the disk-jet connection. In such source, the optical emission primarily being from the disk and the radio emission from the jets, any correlation between the emissions may help constrain the disk-jet coupling in AGNs. In this poster, we present our analysis focused on the correlation between the long term optical and the radio light curves of the source 4C+74.26 along with the spectral analysis of the NuSTAR observations. We discuss the results in the context of standard model of AGNs.

Observations Sample: Optical, OVRO, Swift/BAT and NuSTAR

The R-band optical observations were mainly gathered from the Mt. Suhora Observatory of the Pedagogical University in Krakow. The radio observations were taken from the 15 GHz monitoring performed with the 40-m telescope at the Owens Valley Radio Observatory (OVRO; Richards et al. 2011). The X-ray light curves were taken from the archive of Swift/BAT Hard X-ray Transient Monitor program in the 14–50 keV energy range, and were binned to a 50- day bin using the error weighted mean. From NuSTAR archive, we selected the longest exposure time (90925 s) observation on 2014-10-30 (ID 60001080006).

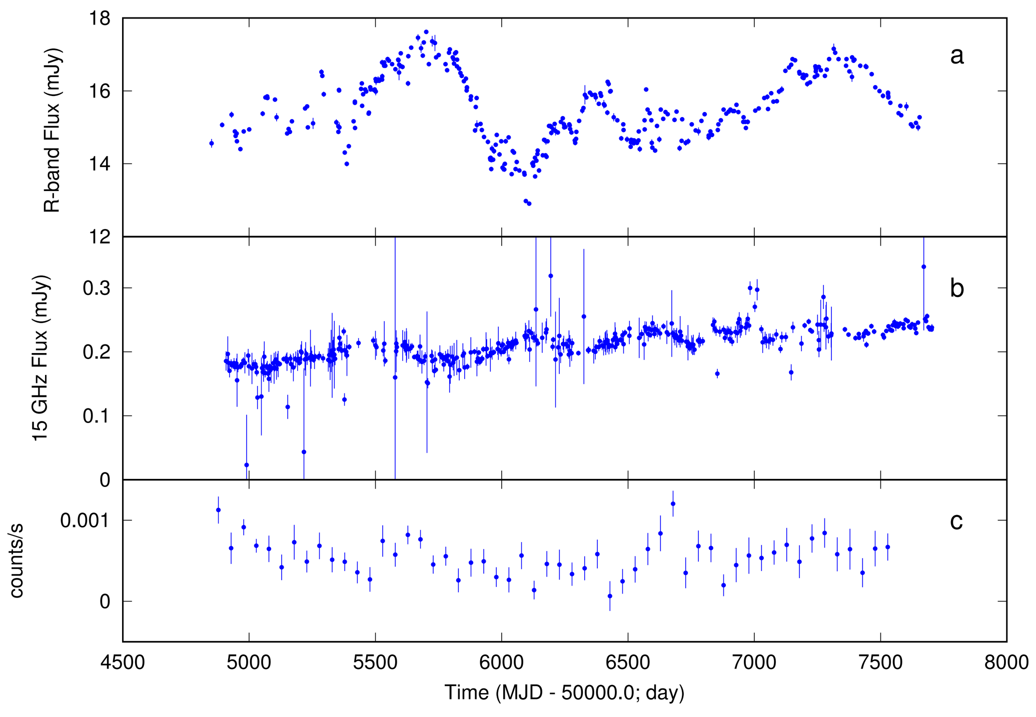
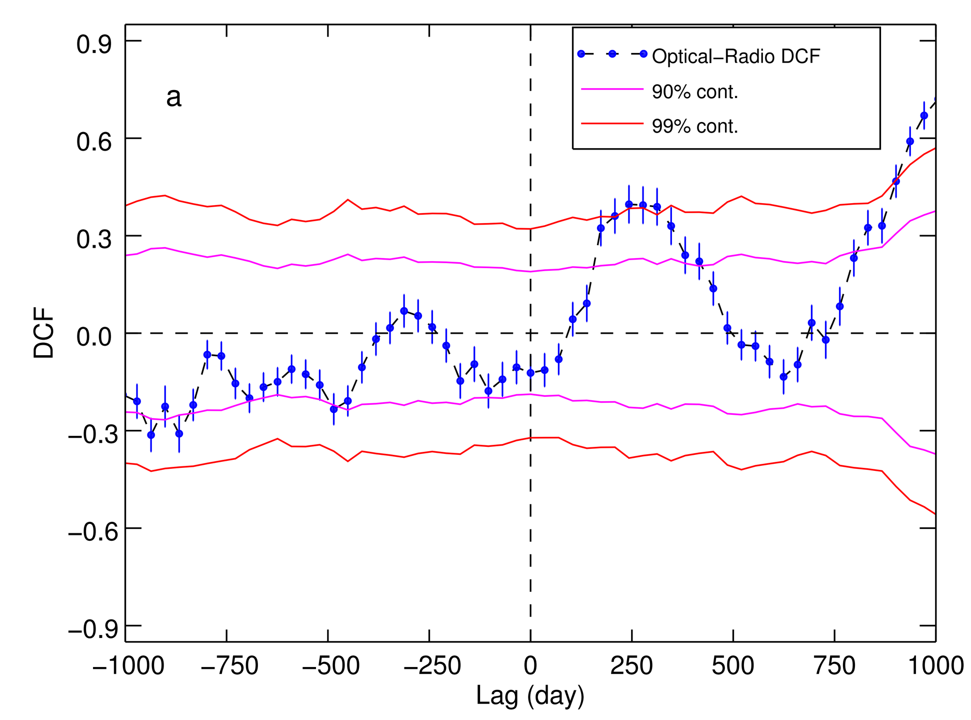


Figure 1: 4C+74.26 (J2042+7508) long-term light curves: R band optical observations (panel a), 15 GHz OVRO observations (panel b) and 50-d binned Swift/BAT observations (panel c)

Optical and Radio Light Curves Cross-correlation: Significance Estimation

We calculated the cross-correlation between the optical and the radio emission using the method described in Edelson & Krolik (1998). Figure 3 shows that the peak centered around +250 with the DCF values~ 0.4. Although, these values are less than 0.5, we tested their significance using a large number of simulated light curve as described in the method by Uttley et al. 2003. The details of the significance estimation method can be found in Bhatta et al. 2016b, c. To established the significance of the observed DCF peaks, the upper and lower 90th and 99th percentile, shown by the magenta and the red curves respectively, were evaluated from the DCF distribution of the correlation between the radio light curves and 10000 simulated light curves.



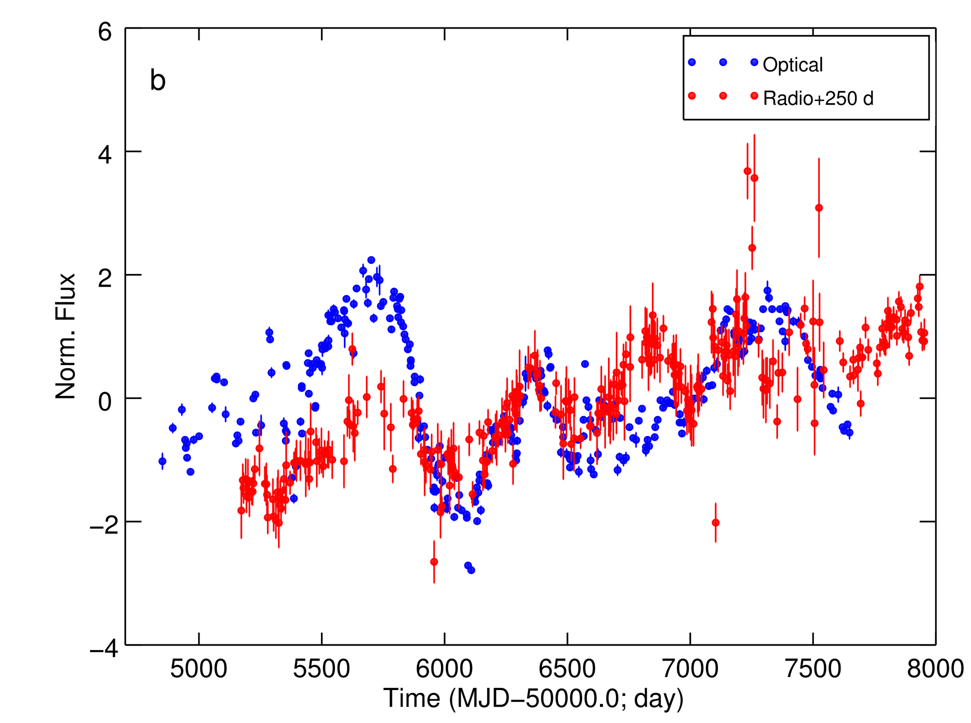


Figure 2: Top panel: The discrete cross-correlation function between the optical and radio observations (blue). The curves in magenta and red are the 90% and 99% confidence contour from MC simulations. Bottom panel: Optical (blue) and the radio observations shifted by +250 d (red) in the normalized units.

Spectral Modeling of NuSTAR Observations

We used a model of the form *tbabs*warmabs*relxill* (For relxill model see, Garcia & Kallman 2010; Garcia et al. 2013) to model disk reflection including the relativistic effects that occur near strong gravitational fields and to account for the presence of the warm absorber below 3 keV along with Galactic absorption. Our model included $N_{\rm H,Gal.} = 2.3\times10^{21}$ cm^{-2}, a single zone of ionized absorption with an outflow velocity of 3600 km s^{-1}, an ionization parameter log(ξ, erg cm s^{-1}) = 2.6 and a turbulent velocity $v_{\rm turb}$=100 km s^{-1}, a disk inclination of $45°$, black hole spin parameter a fixed at 0.998, outer radius $R_{\rm out} = 1000$ ISCO, and a high energy continuum cutoff of $E_{\rm cut} = 180$ keV. Our best-fit model had fit statistic $\chi^2/dof = 0.99$; the resulting output parameters include the inner radius of the accretion disk, $R_{\rm in} = 35\pm22$ ISCO, a disk ionization parameter at $R_{\rm in}$ of log(ξ, erg cm s^{-1}) = 2.29 ± 0.17, and FPMA/FPMB instrumental ratio of 1.03

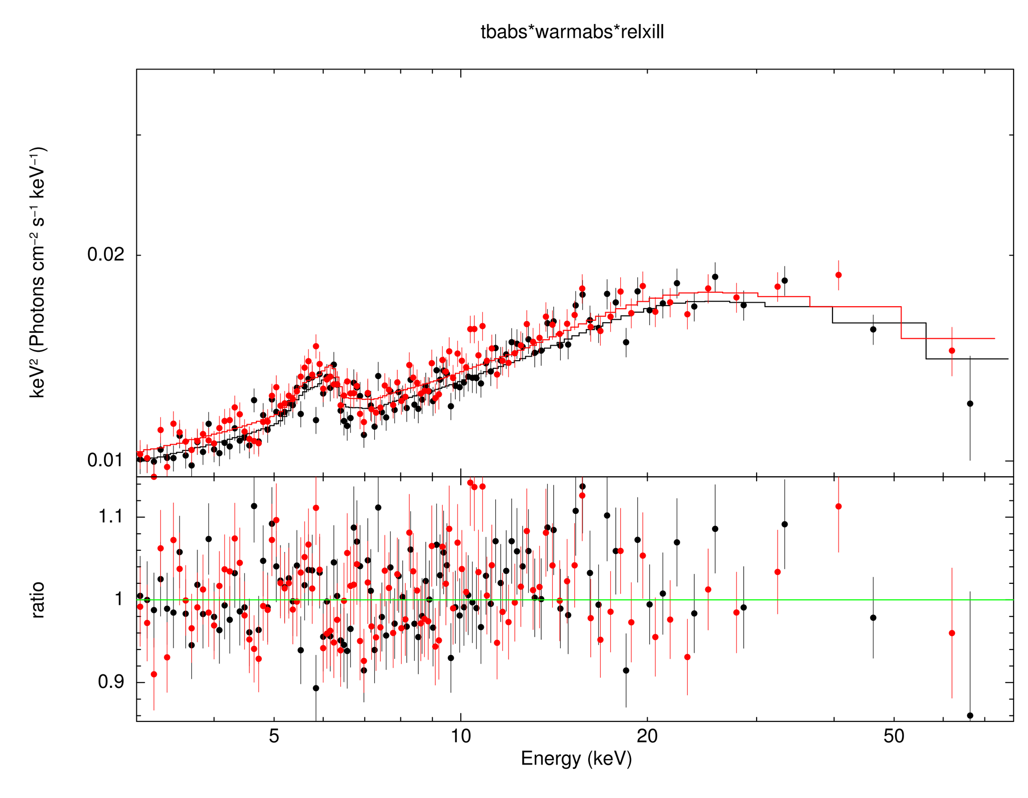


Figure 3: Spectral modeling of the NuSTAR observations using the convolved model tbabs*warmabs*relxill..

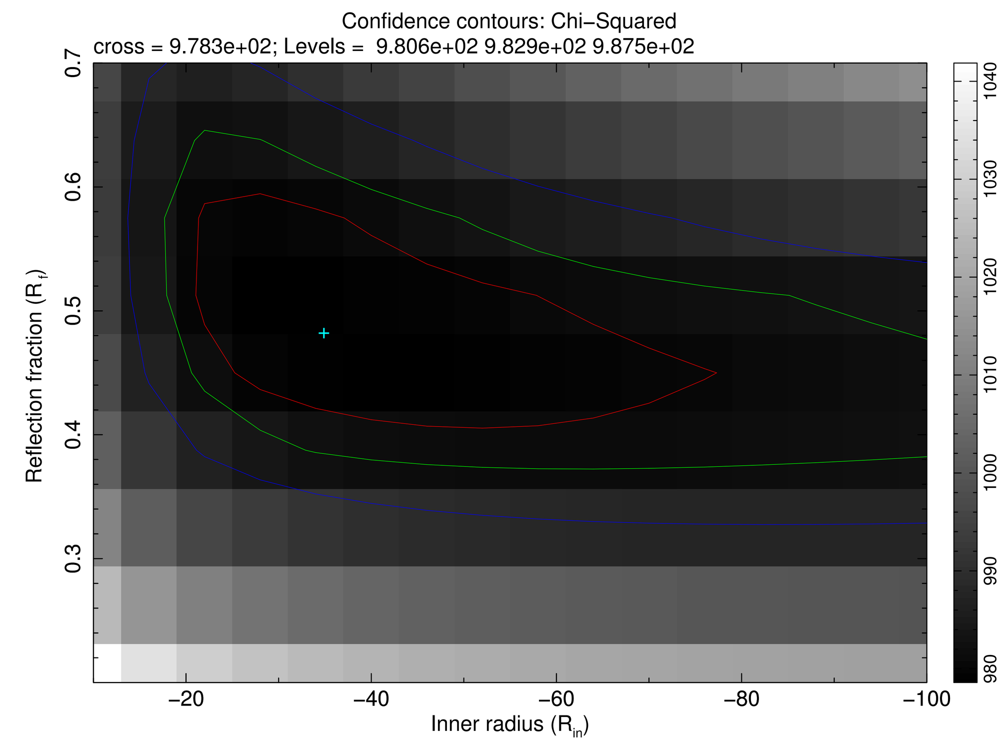


Figure 4: Contour plot of reflection fraction against inner disk radius. The blue, green and red contours represent the 1, 2 and 3 σ contours, respectively.

Conclusions

- The optical and the radio emission components appear strongly correlated such that optical lags behind the radio emission by ~ 250 days.
- From the spectral analysis of the NuSTAR observation using the model tbabs*warmabs*relxill, we estimate the inner disk radius of the truncated disk to be $R_{in} = 35^{+40}_{-16}$ ISCO along with the ionization parameter logξ $2.47^{+0.17}_{-0.19}$ and the reflection fraction $R_f = 0.48^{+1.3}_{-0.09}$.
- The results suggest a scenario where propagation of the magnetic instability around the innermost regions of a truncated disk of the AGN along the disk and into the jet.

References

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