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Connection between the X-ray, UV and optical emission line regions of AGN

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Abstract. In order to investigate the connection between the X-ray, UV and optical spectral line regions, we selected a sample of AGN which have the strong Fe Kα line and analyze the UV and optical spectral lines. Here we present an example of AGN NGC 3516. In this object it seems that geometries of all three emitting regions are similar, i.e. the broad line shapes can be explained by the multicomponent emitting line region with a disk emission. The disk emission contributes to the wings, while one (spherical) emitting region contributes to the line core. Concerning the Fe Kα, UV and Balmer line shapes it seems that these broad line emitting regions in NGC 3516 are geometrically similar, i.e. in all wavelengths the lines are emitted partly from the disk partly from a spherical region.

Key words. Active galactic nuclei – spectroscopy – spectral lines – accretion disk

1. Introduction

According to the standard model of Active Galactic Nuclei (AGNs), an AGN consists of a black hole surrounded by a (X-ray and optical) continuum emitting region probably with an accretion disk geometry, the Broad Line Region (BLR) and a larger region that usually is referred to as the Narrow Line Region (NLR). Variability studies of QSOs indicate that the size of the X-ray emission region is the order of 10^{14-15} cm (e.g. Oshima et al. 2001). An Fe Kα fluorescence line detected in several AGNs near 6.4 keV is thought to originate from within a few 10s of gravitational radii (Fabian et al. 1995). This line is thought to be a fluorescence line of Fe due to emission from a cold or ionized accretion disk that is illuminated from a source of hard X-rays originating near the central object.

On the other side, the BLR has also complex physics and kinematics. Kinematics in BLR is widely discussed (see Sulentic et al. 2000, and references therein); assuming spherical, cylindrical and disk geometry (see e.g. Popović et al. 2004, and references therein). Although the unified AGN model (e.g. Elvis 2000) seems to be appropriate to explain the nature of AGNs, the connection between different line emission regions is not yet clear, e.g. similarity between geometries of the X-ray line emitting region and the BLR. Possible relationships between the emission regions observed in different wavelengths, were investigated in

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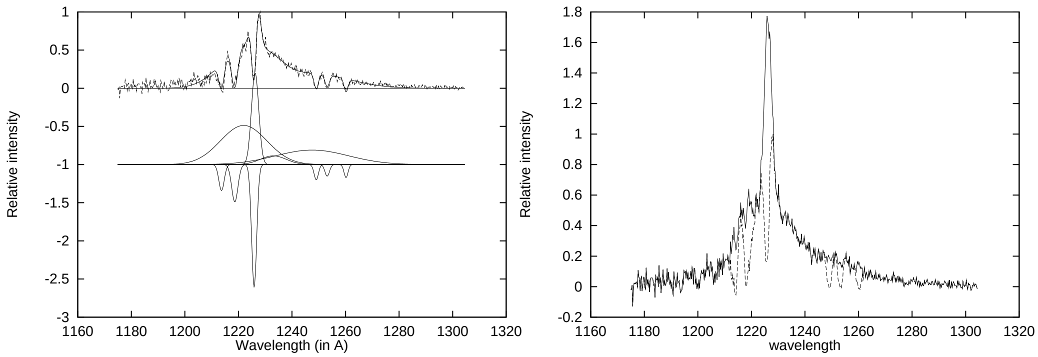

Fig. 1. it Left: The best fit of the Lyα line - the Gaussian components are presented at bottom. *Right*: The Lyα line after the absorption components were subtracted.

several works in the past: it was found that the steeper slopes of X-ray continua in AGNs are related to the presence of narrower optical lines (Boller et al. 1996). Furthermore, a correlation was found between the Hβ line width (narrower) and the ratio (higher) of the NV/CIV UV lines (Wills et al. 1999).

Here we present our analysis of the broad UV line shapes of NGC 3516. The aim of this work is to find any evidence of similar geometry between different emission line regions (X-ray, UV and optical).

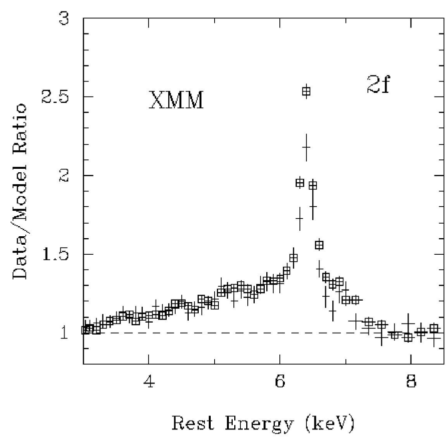

Fig. 2. The observed Fe Kα (squares) fitted with the multi component model (crosses) given by Turner et al. (2002)

2. The broad lines of NGC 3516

The existence of an accretion disc in NGC 3516 is supported by the shape of the Fe Kα line (Nandra et al. 1997, 1999, Turner et al. 2002). The Fe Kα line has been modeled according to a disc geometry. Nandra et al. (1997, 1999) fitted an integrated Fe Kα profile deriving the disc inclination for the Schwarzschild metric 35^{+1}_{-2} degrees and for the Kerr metric 0^{+19}_{-0} degrees. Also, Pariev et al. (2001) studied the Fe Kα emission obtaining a disc inclination of about 27 degrees. More recently, Turner et al. (2002) found that the Fe Kα shape has several peaks (5.6, 6.2, 6.4, 6.5, and 6.8) and alternatively they explained that peak at 5.6 keV could be the red horn of a disk line at 35R$_g$ (where a weak 6.8 keV peak may be the blue horn associated with this). Also, they supposed that the 6.2 and 6.5 keV peaks could be due to emission at 175R$_g$, and that these may be outside the disk structure. This model can well fit the Fe Kα line (Fig. 2).

On the other hand, the Hα line was fitted in an earlier work by Sulentic et al. (1998) with a model including a disc with an inclination about 20 degrees. Finally, Popović et al. (2002) found that all Balmer lines in NGC 3516 have disk-like wings. They fit all Balmer lines using the two-component model and found that the inclination of the optical disk is around 11 ± 5 degrees which is comparable with the results of Nandra (1999) and Sulentic (1998). Concerning these investigation the Balmer emission line disk is located from ∼ 400 R_g to ∼ 1500 R_g.

Here we present our investigations of the broad Lyα line.

2.1. The UV lines; observation and analysis

We use HST observations obtained with the FOS and STIS/FUV-MAMA, covering the wavelength ranges 1150-1730 Å. The observations were made in 1996 (FOS) and on Apr 13-18 1998 (STIS/FUV-MAMA), in the frame of the campaign monitoring of NGC 3516 with HST, RXTE and ASCA, for more details see Edelson et al. (2000). The spectra were reduced by the HST team. We transform the wavelength scale to zero redshifted taking into account the cosmological red-shift (z=0.00884). Absorption components are very often present in the UV lines. In order to subtract the absorption components, a multi-Gaussian analysis was used (see Fig. 1, left). Subtracting the absorption component we reconstruct the line profile (see e.g. for the Lyα, Fig. 1, right).

After that, the lines were fitted by two-component model described in Popović et al. (2002,2003,2004) assuming that the emissivity index $p = 3$.

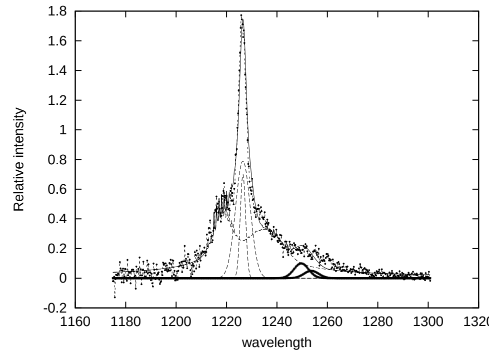

Fig. 3. The observed Lyα fitted with the two-component model. The central narrow component probably comes from NLR. The NV lines are present in the red wing.

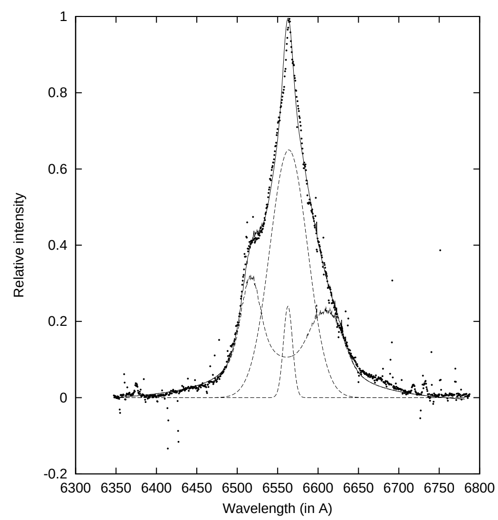

Fig. 4. The observed Hα line (dots) fitted with multicomponent model (solid line) given by Popović et al. (2002). With dashed lines the disk, broad and narrow spherical components are presented.

3. Results and discussion

The two-component model can very well fit the observed broad UV line profiles, but it is very hard to obtain the disk parameters without imposing at least one constraint because of the large number of parameters and the lack of two peaks in the line profiles. They can be only roughly estimated using fitting tests, but when we fixed $p = 3$ we found that the inclination is similar to the case of Balmer emission lines (Popović et al. 2002) $\approx 10^\circ$, and that the part of emission disk which emits in the UV lines seems to be located from ∼ 100 R_g to ∼ 900 R_g. As one can see in Fig. 3, the Lyα line can be well fitted with multi-component model, where one component, contributes to the wings, coming from disk. Moreover, the Fe Kα and Lyα wings are quit similar (see Fig. 2 and 3), they have an extended red side (that in the case of the Lyα cannot be explained by contribution of NV lines) in both of the lines. In Table 1 we give the estimated disk parameters for the Fe Kα, Lyα and Balmer lines.

Table 1. The disk parameters for the Fe Kα, Lyα and Balmer lines. Reference: (1)- Turner et al. 2002, (2)s,(2)k - Nandra et al. 1999 for Schwarzschild and Kerr metric, respectively, (3) - Popović et al. 2002. The inner (R_{inn}) and outer (R_{out}) disk radii are given in $R_g = GM/c^2$.

Line(s)	R_{inn}	R_{out}	i	Ref.
Fe Kα	3-5	35 (175)	38	(1)
Fe Kα	6	80	35	(2)s
Fe Kα	2.8	400	0-19	(2)k
Lyα	~ 100	900	~ 10	
Balmer	400	1500	11	(3)

As one can see from the Table 1. the Fe Kα disk region should be more compact than the UV/optical ones. On the other side, the inclination tends to be small ($i < 38°$) and it is in good agreement between the estimates given by Nandra et al. (1999) for the Kerr metric and our estimates, although one should not exclude the existence of a warped disk.

4. Conclusion

Here we present the investigation of the geometry of different emission line regions (Fe Kα, UV and optical) of NGC 3516. We found that the broad Lyα line can be well fitted by the two-component model. From this fit we found the parameters of the UV disk. These results, together with previous for the Fe Kα (Nandra et al. 1999; Turner et al. 2002, see Fig. 2) and Balmer lines (Popović et al. 2002, see Fig. 4) indicate that geometries of the broad X, UV and optical emission line regions in NGC 3516 are similar; i.e. that there is a disk component which contributes to the line wings and one component which contributes to the line core (see Figs. 2-4).

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