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Thomson-thick AGN— a Radio Emission View

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Abstract We have investigated the symmetric twin-jets related to innermost region of some AGNs, try to get their Thomson-thick properties. We propose to use radio method to obtain the column densities for 2 sources OQ208 and NGC 4261, the result for OQ208 is consistent with the estimate from X-ray method on average, and the column density for NGC 4261 is a bit less than that from X-ray. Other 2 sources NGC 1052 and Mrk 231 are also discussed. More compact symmetric sources with two-sided jets could be suitable to be used to study Thomson-thick/thin AGN properties in future.

Key words: galaxies: active — galaxies: jets — galaxies: individual: OQ208, NGC 4261

1 INTRODUCTION

Most AGNs are obscured in X-rays, i.e. the nucleus is hiding behind a screen of absorbing material (see Matt 2002 for a review).

If the absorbing matter is very thick, its column density exceeding the value $1.5\times10^{24}\,\mathrm{cm}^{-2}$, for which the Compton scattering optical depth equals unity, it is called a Compton-thick source. If the column density is smaller than that value but still in excess of the Galactic one ($\approx 10^{20}\,\mathrm{cm}^{-2}$), the source is called Compton-thin. For Compton-thick source, the nucleus is obscured. The spectrum of the reflected component depends on the ionization state of the matter.

If the matter is highly ionized, Compton scattering is the most important process and the spectrum (at least up to a few tens of keV, where Compton recoil becomes important) is very similar to the primary one. If instead the matter is neutral (and optically thick), the resulting spectrum is the so called Compton reflection with a broad bump between 10 and 100 keV. In both cases strong emission lines are also expected. More complex continuum and line spectra are expected for mildly ionized material. For Compton-thick source, their nucleus is obscured up to at least 10 keV, emission from off-nuclear regions is visible in these sources, providing the most favourable case for studying the circumnuclear matter.

The mixture of unobscured and obscured (with a spread of column densities) AGN is able to reproduce well the spectral shape of the Cosmic X-ray back-ground (CXRB). However, the luminosity we observed in the CXRB is only a fraction, probably of the order of 10%–20%,

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of the energy actually emitted, the remaining flux having been absorbed by the circumnuclear matter and re-emitted at longer wavelengths, mostly in the mid-IR (Matt 2002).

Some AGNs which are Compton-thick but do not show AGN-like optical lines, may have not been recognized as AGNs. Maybe a lot of AGNs have been missed by us as long as they have been heavily obscured. Heavy absorption is very common: about half of the optically selected Seyfert 2s in the local Universe are Compton-thick (Maiolino et al. 1998). A few Seyfert 1s have also been classified as Compton-thick sources, indicating their torus is spherical or they have very narrow opening angle of torus.

Both Compton-thin absorber and Compton-thick cold circumnuclear regions are present for some sources, they may have different locations. Compton-thick matter should be much closer to the nucleus, and associated with the torus of AGN. Compton-thick AGNs have been mostly found from X-ray detection of Seyfert 2 s.

2 FIND THOMSON-THICK AGN IN RADIO LOUD SOURCES

It is possible to find Thomson-thick AGN in radio loud sources. First, from the GHz-Peaked-Spectrum (GPS) radio sources, especially its subset: Compact Symmetric Objects (CSOs). They usually show two-sided radio emission in the core region of their host galaxies. CSOs are only marginally affected by beaming effect, and their small size is due to their youth and/or due to a dense circumnuclear matter. Second, from the Medium-size Symmetric Objects (MSOs), Seyferts, and FRI/II sources, they probably show jet and counterjet in their nuclear region.

Therefore, we propose to use the Thomson scattering of jet/counterjet to derive the column density in the core region of AGN with the formula (1) and Fig. 1 as following.

$$I_a = Ie^{-\sigma_T \overline{n}_2 l_2}, \quad I_r = Ie^{-\sigma_T (\overline{n}_1 \Delta l + \overline{n}_2 l_2)}, \quad I_a/I_r = e^{\sigma_T \overline{n}_1 \Delta l}\,, \tag{1}$$

where, I_a is flux density of the approaching jet, I_r is flux density of the receding jet, $\overline{n}_1$ is the average volume density between two lobes, $\overline{n}_2$ is the average volume density between the approaching lobe and the earth, Δl is the distance between two lobes along the line of sight, σ_T is the Thomson cross section.

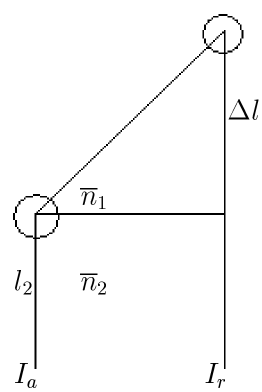

Fig. 1 A diagram for calculating the Thomson scattering.

2.1 OQ208

The Seyfert 1/broad line radio galaxy OQ208 (Mkn 668, 1404+286, z=0.077, $m_r = 14.6$) is a CSO, with viewing angle of about 45° (Stanghellini et al. 1997), and two mini lobes and a weak core (Fig. 2). It has been found that this is the youngest radio galaxy with jet proper motion speed of 0.07c (about 200 yr, Liu et al. 2000). The Thomson scattering has been calculated from the two-sided lobe emission in the optically thin regime of its convex spectrum (the lobe flux ratio is ≈ 10 at frequency greater than 5 GHz). We got the column density of $2.8 \times 10^{24}\,\mathrm{cm}^{-2}$, therefore this is a Thomson-thick source, with the formula (1), see Fig. 1. Note that we have considered the Doppler beaming effect, i.e. the lobe flux ratio I_a/I_r here equals to the observed flux ratio ≈ 10 divided by the factor 1.5 of beaming effect.

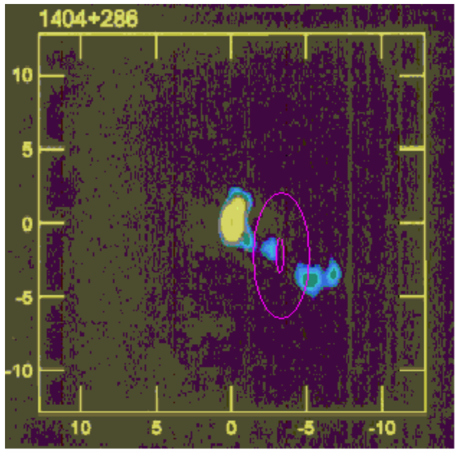

Fig. 2 The 15 GHz VLBA image of OQ208 (Kellermann et al. 1998) and possible disk/torus.

Our result is consistent, on average, with the findings of Guainazzi et al. (2004), who have found that the X-ray spectrum of OQ208 exhibits typical features of obscured AGN. From the spectral analysis of the XMM-Newton data the authors have suggested the presence of two different absorbing systems: the Compton-thick absorber with an estimated density of $3 \times 10^{25}\,\mathrm{cm}^{-2}$ and the Compton-thin absorber with a density of $1 \times 10^{21}\,\mathrm{cm}^{-2}$.

2.2 NGC 4261

NGC 4261 is a nearby elliptical galaxy with $z = 0.007465$ with a large (≈300 pc) near edge-on nuclear disk of gas and dust, revealed with HST. It is classified as a FR-I radio galaxy with a pair of highly symmetric kpc scale jets (Fig. 3).

An average electron density of $10^4\,\mathrm{cm}^{-3}$ at a disk radius 0.2 pc has been derived with free-free absorption (FFA, Jones et al. 2001), which indicates a column density of $0.62 \times 10^{22}\,\mathrm{cm}^{-2}$. This column density is a bit less than that measured with XMM-Newton by Sambruna et al. (2003) of $N_H = 4 \times 10^{22}\,\mathrm{cm}^{-2}$. With the electron density of $10^4\,\mathrm{cm}^{-3}$, we estimated an upper limit of the Thomson scattering contribution of jet/counterjet flux ratio, it is 1.1. Therefore, the FFA could be more responsible for the jet/counterjet flux ratio in the core region of NGC 4261.

2.3 NGC 1052 and Mrk 231

NGC 1052, a nearby elliptical galaxy with $z = 0.004903$, is a GPS radio source, which shows two-sided radio jets, and heavily obscured in the core region (Fig. 5). The jets are oriented near the plane of the sky, FFA opacity implies that dense ($n_e = 10^5\,\mathrm{cm}^{-3}$) plasma is associated with the central 0.5 pc (Guainazzi et al. 2000). We have not calculated the column density for

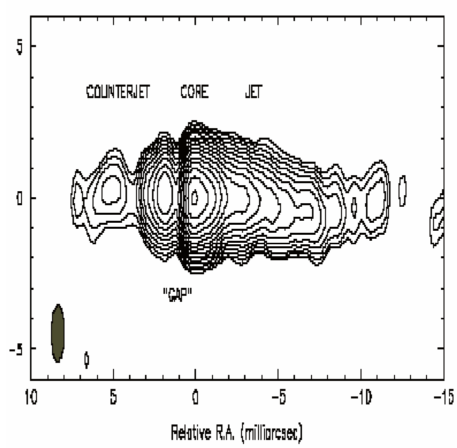

Fig. 3 The 8.4 GHz VLBA image of NGC 4261 (Jones et al. 2001).

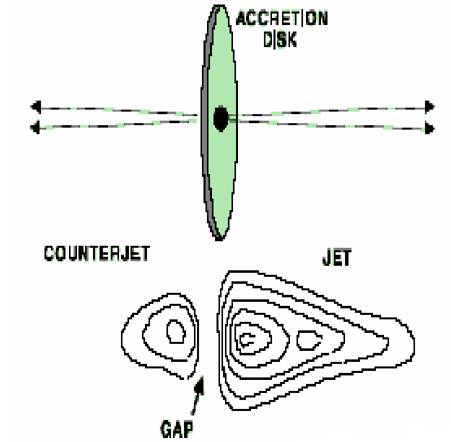

Fig. 4 The disk model for the central region of NGC 4261.

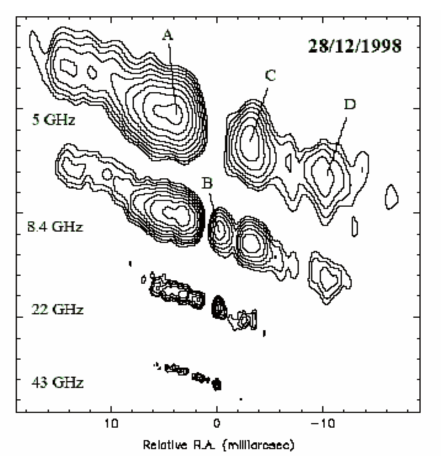

Fig. 5 The VLBA images of NGC 1052 (Kadler et al. 2002).

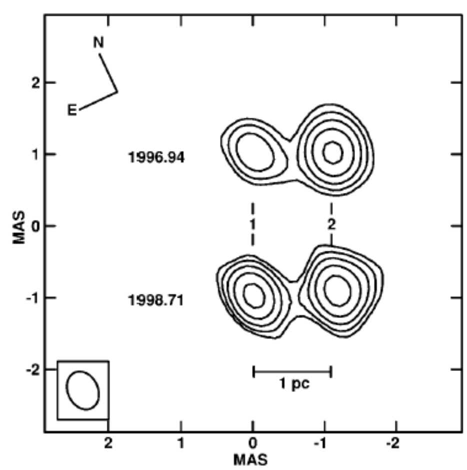

Fig. 6 The 15 GHz VLBA imges of Mrk 231 (Ulvestad et al. 1999).

this source since its radio jets are not so symmetric at high frequency and the viewing angle of the jets is not determined, but clearly there is a disk and/or torus between component A and B. An atomic column density of $\approx 10^{23}\,\mathrm{cm}^{-2}$ is derived from ROSAT and ASCA observations (Guainazzi et al. 2000).

Mrk 231, is a Seyfert 1 galaxy, redshift $z = 0.042$, with a heavily obscured nucleus. In the Fig. 6 there is on the left the core (1) and on the right the jet (2) at two different epochs. The average ionized density would be $n_e > 10^5\,\mathrm{cm}^{-3}$ at 0.5–1 pc from the nucleus estimated by Ulvestad et al. (1999) assuming that the jet/counterjet ratio is due to free-free absorption, resulting column density of about $10^{23}\,\mathrm{cm}^{-2}$, is remarkably consistent with the measured from X-ray absorption in Mrk 231. We think the Thomson scattering may also take a role in the contribution of the flux ratio, for the high electron volume density in the 1 pc region of the nucleus. However, we have not calculated it yet because the viewing angle of the jets is not well constrained.

3 CONCLUSIONS

We have investigated the symmetric twin-jets related to innermost region of some AGNs, try to get their Thomson-thick properties. We propose to use radio method to obtain the column densities for 2 sources OQ208 and NGC 4261. The result for OQ208 is consistent with the estimate from the X-ray method on average. The column density for NGC 4261 is a bit less than that from X-ray method. Other 2 sources NGC 1052 and Mrk 231 are also discussed. More compact symmetric sources with two-sided jets and with accretion disk diagnostic could be suitable to be used to study Thomson-thick/thin AGN properties in future, for example, the sources NGC 1275, NGC 4258, Cygnus A, Mrk348, 1946+708.

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