Thomson Scattering Effect on Broad Line Radio Galaxy OQ208

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Abstract We propose that the Thomson scattering could have observational effect in Compact Symmetric Objects(CSOs). We developed a 'semi-transparent screen' method for calculating the re-scattering back photons, by which we estimated that the Thomson scattering contributes a factor 1.7 to the lobe flux ratio in OQ208 and 2.5 to the component flux ratio in NGC4261.

Key words Thomson scattering, CSOs, OQ208, NGC4261

1 Introduction

Compact symmetric objects(CSOs) have been found to be young radio sources, probably in the early evolutionary stage of large double-lobed radio sources. CSOs are confined in less than $1kpc$ volume, VLBI morphologies of these objects have shown the double-lobed symmetric structure with a weak core between lobes. The typical lobe expansion speed of CSOs is about $0.2c$ (light speed) and the estimated kinematical ages of CSOs are less than 10^4 years.

The source OQ208 is a nearby radio galaxy (redshift 0.077). Its VLBI images at low frequency show a strong north-east lobe and a weak south-west lobe. Twin jets and a weak core were also detected at 15 GHz images. Stanghellini et al. (1997) suggested that the orientation of the jets is nearly 45 deg away from the line of sight. The 2 mini-lobes are separated by 6.6 milliarcseconds, i.e. $6.6h^{-1}pc$. The source has been confirmed as a CSO with lobe's proper motion velocity of $0.07h^{-1}c$ and age of ≈200 years (Liu et al. 2000; Stanghellini et al. 2000). Surprisingly, the flux densities of the 2 lobes in OQ208 have large differences, the flux ratio of the 2 lobes is 63, 11, 10 at 1.6, 5 and 8.4 GHz respectively (Kameno et al. 2000, Stanghellini et al. 1997, Fey et al. 1996).

The free-free absorption (FFA) has been found in the weak lobe of OQ208 (Kameno et al. 2000; Liu et al. 2002a), and the fitted turnover frequency of FFA in spectrum is 4 GHz. Therefore, the FFA could lead to the large flux ratio at 1.6 GHz. If the FFA is the only reason for the asymmetric flux densities in OQ208 the flux ratio should be near unity above 4 GHz. The beaming of jets in OQ208 can also cause the approaching lobe to have flux larger than the receding one, this effect is well known in small viewing-angle relativistic-beaming radio sources. However, the estimated flux ratio from the beaming effect in OQ208 is less than 1.5 (Liu 2002b). Considering this factor to the lobe flux ratio in OQ208 at 5 and 8.4 GHz, there is still a factor of 6.7 and it should be considered in view of other mechanisms.

2 Thomson scattering in the lobes of OQ208

For the broad line properties and the compactness of the radio source OQ208, it is possible that Thomson scattering could lead to an observational effect on the lobe flux ratio in OQ208.

As the first approximation, we assume that the lobe flux ratio 6.7 as mentioned above in OQ208 is due to Thomson scattering. As a result the mean medium density between lobes could be obtained; then the Thomson scattering can be calculated in detail by accounting for the re-scattering back photons, such that a more realistic lobe flux ratio caused by the Thomson scattering can be obtained.

For the distance between the 2 lobes in OQ208 along the line of sight, $\Delta l = 6.6h^{-1}pc$ (we use $h = 0.75$); the flux ratio of lobes $I_a/I_r = 6.7$, and the Thomson scattering section rate $\sigma_T = 6.65 \times 10^{-25}cm^2$, we have (see Fig.1)

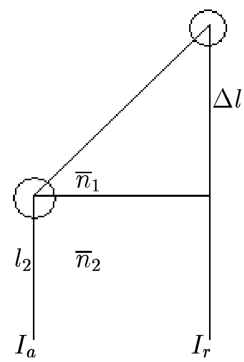

Fig. 1 The Thomson scattering as the first approximation

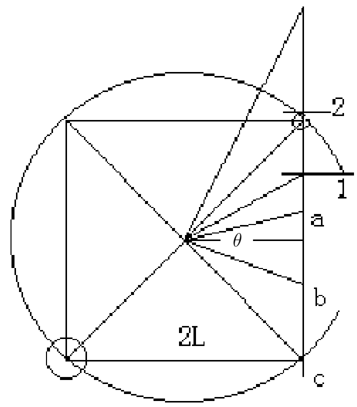

Fig. 2 A diagram for the calculation of the Thomson scattering in OQ208

$$I_a = I \times \exp(-\sigma_T \overline{n}_2 l_2)\,, \tag{1}$$

$$I_r = I \times \exp[-\sigma_T(\overline{n}_1 \Delta l + \overline{n}_2 l_2)]\,, \tag{2}$$

$$I_a/I_r = \exp(\sigma_T \overline{n}_1 \Delta l)\,. \tag{3}$$

The I is the intensity emitted by each lobe and we assume it is same for 2 lobes, then the mean medium density is $\overline{n}_1 = 1.1 \times 10^5 cm^{-3}$.

Assuming that the medium density varies with r as (Fanti 2000) $\rho = \rho_0(r_0/r)^2$, when $r > r_0$, ρ_0 (usually assumed as a constant) is the medium density inside r_0. Using the $\overline{n}_1$ above, the production $\rho_0 r_0^2$ can be determined. We integrate the column density from the weak lobe along the line of sight to the point 'a' in Fig.2 where a half flux from the weak lobe is just scattered,

$$\ln 0.5 = -\sigma_T \int_{45}^{\theta} \rho dl\,, \tag{4}$$

i.e. $\theta = 13.6\,\deg$ from the horizon line in Fig.2. A equivalent 'half transparent screen' scattering the half photons could be estimated as

$$< l >= \int_{45}^{13.6} l\rho dl / \int_{45}^{13.6} \rho dl = 0.418L\,, \tag{5}$$

$0.418L$ is at $\theta = 30.2\,\deg$ from the horizon line in Fig.2, is marked as '1'. The scattered photons will be partly re-scattering back. As above we integrate from the screen '1' up to the point where a half of the scattered ones will be reflected back, it is at $\theta = 61.6\,\text{deg}$; with equation (5) the equivalent 'half transparent screen' is at $\theta = 47.5\,\text{deg}$, is marked as '2', near the weak lobe.

Through the serial 'half-transparent screen' before point 'a', by a complete analysis and calculation we finally obtained the sum of photons arriving at the point 'a' with respect to the ones emitted (I) from the weak lobe is $\approx 0.80I$.

By the same approach we have the point 'b' where a half of the flux come from 'a' is scattered, the θ at 'b' is -18 degree. Again follow this way, the point 'c' is the place there a half of the flux from 'b' is scattered. Finally the sum photons come out from 'c' is $\approx 0.80 \times 0.83 \times 0.86I = 0.57I$. The flux ratio for the approaching lobe to the receding lobe is $\approx 1/0.59 = 1.7$ assuming the mean medium density is $1.1 \times 10^5 cm^{-3}$ in a few pc away from the center of OQ208, for the near broad line region of AGNs this medium density could be reasonable.

For a more realistic example, the source NGC4261, the viewing angle of its jets is 63 degree, the average medium density $\approx 1 \times 10^6 cm^{-3}$, and the separation $\approx 0.5pc$ between 2 bright components near its accretion disk (Jones et al. 2000). We found the receding component can be dimmed by $\approx 40\%$ through Thomson scattering, this can account for a part of the weakness of the receding jet in NGC4261, although free-free absorption was suggested for the weakness by Jones et al.(2000).

In summary, the beaming effect cannot fully account for the large flux ratio of lobes in near broad line region of CSOs, we propose that the Thomson scattering could cause observational effect in these compact sources. We have developed a 'semi-transparent screen' method for calculating the re-scattering back photons; we estimated that the Thomson scattering contributes a factor 1.7 to the lobe flux ratio in OQ208, and 2.5 to the component flux ratio in NGC4261.

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