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A Non-Mainstream Viewpoint on Apparent Superluminal Phenomena in AGN Jet

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Abstract. The group velocity of light in material around the AGN jet is acquiescently one (c as a unit), but this is only a hypothesis. Here, we re-derive apparent superluminal and Doppler formulas for the general case (it is assumed that the group velocity of light in the uniform and isotropic medium around a jet (a beaming model) is not necessarily equal to one, e.g., Araudo *et al.* (2010) thought that there may be dense clouds around AGN jet base), and show that the group velocity of light close to one could seriously affect apparent superluminal phenomena and Doppler effect in the AGN jet (when the viewing angle and Lorentz factor take some appropriate values).

Key words. Galaxies: active—galaxies: jets.

1. Introduction

Concerning the apparent superluminal motion, the most popular and classic viewpoint is the relativistic beaming model (Rees 1966). Figure S.6 in Rybicki & Lightman (2004) showed the simple geometry scenario of emission for a moving source, the observed transverse velocity of separation of a blob relative to the speed of light c (in this paper, all velocities are at c as a unit):

$$\beta_{\rm a} = \frac{\beta \sin\theta}{1 - \beta\cos\theta}, \tag{1}$$

where β is the true velocity, and θ is the angle of the line-of-sight. The corresponding Doppler factor δ (considering the effect of redshift) is:

$$\delta = [\Gamma(1+z)(1-\beta\cos\theta)]^{-1}, \tag{2}$$

where $\Gamma = (1-\beta^2)^{-1/2}$ is the Lorentz factor, and z is the redshift of this AGN.

For the 3C 273 jet ($z = 0.158$, Schmidt 1963), VLBI observations have detected apparent superluminal motions in the parsec-scale jet with apparent velocities $6 \sim 10$ (e.g., Unwin *et al.* 1985). We assume that the apparent velocity is 8, and the angle

to the line-of-sight is 10°. Then, based on the formulas (1) and (2), we could obtain the Doppler factor $\delta \sim 4.5$, and the true velocity ∼0.994 (Lorentz factor $\Gamma \sim 8.8$) which means the velocity of the 'ordinary' matter in AGN jet is extremely close to the speed of light.

The formulas (1) and (2) actually imply that the group velocity of light in the medium surrounding a blob in the AGN jet is equal to one, which is actually a hypothesis. In the following, we will consider a general scheme.

2. Model

We assume that the medium surrounding a blob is uniform, transparent, isotropic and stationary relative to the AGN core, and the group velocity of light is β_g which is not necessarily equal to one (β_g may be a function of frequency).

Then we could apply a derivation similar to Rybicki & Lightman (2004) and get the 'new' (modified) apparent velocity and Doppler formula:

$$\beta_a = \frac{\beta \sin\theta}{1 - n\beta\cos\theta}, \tag{3}$$

$$\delta = [\Gamma(1+z)(1 - n\beta\cos\theta)]^{-1}, \tag{4}$$

where $n = 1/\beta_g$ (if β_g is equal to the phase velocity of light in material, then n means the refractive index of the material).

3. Discussion

We apply formulas (3) and (4) to the 3C 273 jet (we assume that $\beta_a = 8$, $\theta = 10°$, $n = 1.01$ corresponding to $\beta_g = 0.99$) and obtain the Doppler factor $\delta \sim 7.2$, the true velocity ∼0.984 (Lorentz factor $\Gamma \sim 5.6$) which are clearly different from the ones in the case of $n = 1$ corresponding to $\beta_g = 1$.

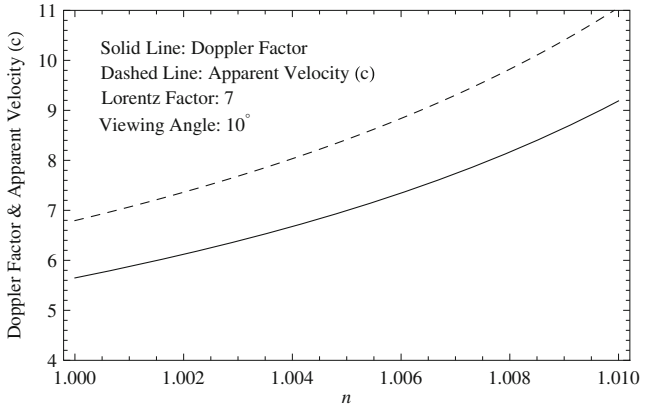

Figure 1. The plot shows that the apparent velocity and Doppler factor change with n from 1 to 1.01 (corresponding to the group velocity of light from 0.99 to 1). We assume $z = 0$, $\theta = 10°$ and $\Gamma = 7$.

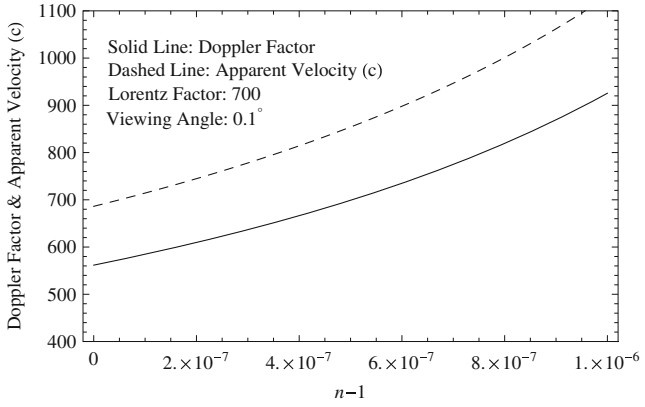

Figure 2. The plot shows that the apparent velocity and Doppler factor change with n from 1 to 1.000001 (corresponding to the group velocity of light from 0.999999 to 1). We assume $z = 0$, $\theta = 0.1°$ and $\Gamma = 700$.

Figures 1 and 2 show that the apparent velocity and Doppler factor change with n (in Fig. 1, we take $z = 0$, $\theta = 10°$ and $\Gamma = 7$; in Fig. 2, we assume that $z = 0$, $\theta = 0.1°$ and $\Gamma = 700$).

As shown, when the viewing angle and Lorentz factor take some appropriate values, the group velocity of light close to one could still seriously affect apparent superluminal phenomena and Doppler effect in the AGN jet, which may be verified by high-sensitivity observations in future.

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