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Doppler boosting and de-boosting effects in relativistic jets of AGNs and GRBs

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Abstract. It is widely accepted that the Doppler de-boosting effects exist in counter relativistic jets. However, people often neglect another important fact that both Doppler boosting and de-boosting effects could happen in forward relativistic jets. Such effects might be used to explain some strange phenomena, such as the invisible gaps between the inner and outer jets of AGNs, and the rapid initial decays and re-brightening bumps in the light curves of GRBs.

Keywords. Relativity – acceleration of particles – galaxies: jets – gamma rays: bursts

1. Doppler factors in relativistic jets

In the relativistic jets of AGNs or GRBs, the observed flux is related to their intrinsic flux by $F_{\rm obs} = \delta^{3+\alpha} F$, where δ is Doppler factor, $F_{\rm obs}$ and F are the observed and intrinsic flux respectively , and α is the spectral index (Blandford & Königl 1979). If δ is greater than 1, then the observed flux will be enhanced, which is called Doppler boosting effect. On the other hand, if *delta* is less than 1, the observed flux is attenuated, which is named to Doppler de-boosting effect.

The Doppler factor of a jet is

$$\delta = \frac{1}{\gamma(1 - \beta \cos\theta)} \tag{1.1}$$

where β is the velocity, γ is the Lorentz factor, and $0 \leqslant \theta \leqslant \pi$ is the viewing angle.

For a counter relativistic jet where $\theta > \pi/2$, the Doppler factor δ is always less than 1, which can easily be derived from equation 1.1. So a counter jet is always Doppler de-boosted. For a forward relativistic jet, the situation is more complex. Provided that the viewing angle of jet $\theta > 0$ (when $\theta = 0$, δ is always greater that 1), the Doppler factor can be greater than 1 as well as less than 1 (see figure 1 for detail). Therefore, both Doppler boosting and de-boosting effects could happen in forward jets.

2. Application to AGNs and GRBs

Some observational facts. In many radio loud AGNs, the large scale jets share some common features in their profiles. Firstly, there are compact and bright cores in the center of jets. Secondly, adjacent to the cores, the flux of the jets drops down very quickly, even form some gaps where the jets are undetectable. Thirdly, the jets will be re-brightened in the outer region.

Recently, the SWIFT found some interesting properties in GRBs. Five GRBs' X-ray light curves are characterized by a rapid fall-off for first few hundred seconds, followed

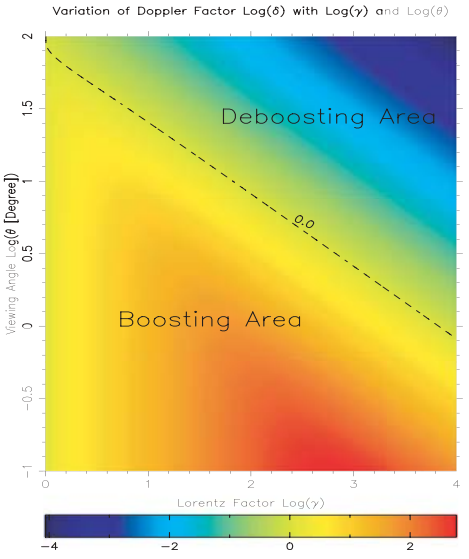

Figure 1. The function of Doppler factor in terms of viewing angle and Lorentz factor. Doppler factor, Lorenz factor and viewing angle are all plotted in the logarithmic scale. A contour line, corresponding to $\log \delta = 0$, is shown. This line cuts the figure into two areas, i.e. Doppler boosting area and de-boosting area.

by a less rapid decline lasting several hours. The light curves also show discontinuity (Tagliaferri *et al.* (2005)). Burrows *et al.* (2005) found that there were bright X-ray flares in GRB afterglows.

Explanation. To qualitatively explain the profiles of the jets in AGNs as well as the light curves in GRBs, we divide the evolution of the jets into four stages :

• Stage I : The jets are accelerating and boosting, which relates to the bright cores of AGNs and the bursts of GRBs. The initial acceleration of relativistic jets has been detected in 3C 273 by Krichbaum *et al.* (2001) and modeled by Zhou *et al.* (2004). In this stage, γ is usually less than a few tens, and δ increase very quickly.

• Stage II : The jets are accelerating but de-boosting. As the acceleration continues, γ will be very large (> 100). Therefore, the jets will enter into the de-boosting area, i.e. $\delta < 1$. In this stage, the observed flux of the jets decreases very quickly, and often forms the gaps between inner and outer jets in AGNs and the rapid decays and discontinuous light curves in GRBs.

• Stage III : The jets are decelerating and boosting. The acceleration, however, won't last forever because of radiation loss and the interaction between the jets and the surrounding medium. Thus, the jets will decelerate and their δ will increase again. Consequently, the Doppler boosted jets will appear again in the profiles of AGNs or in the light curves of GRBs.

• Stage IV : The jets are decelerating and de-boosting. Finally, due to the same reasons as in stage III, the jets will gradually disappear.

References

Blandford, R. D & Königl, A. 1979, ApJ, 232, 34
Burrows, D. N., Romana, P., Falcone, A. *et al.* 2005, Science, 309, 1833
Krichbaum, T. P., Graham, D. A., Witzel, A. *et al.* 2001, Particles and Fields in Radio Galaxies, ASP Conference Series
Tagliaferri, G., Goad, M., Ghincarini, G. *et al.* 2005, Nature, 436, 985
Zhou, J. F., Zheng, C., Li, T. P., Su, Y. & Venturi, T. 2004, ApJ, 616, L95

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