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Comments on "Polarimetric constraints on the optical afterglow emission from GRB 990123" by Hjorth et al.

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Abstract. Hjorth et al. (1999) reported an upper limit on the linear polarization of the optical afterglow for GRB 990123 ($P < 2.3\%$). One of the interpretations for this small value of P was that the emission was probably due a relativistic jet with ordered magnetic field, and the viewing angle in the lab frame $\theta' \lesssim \Gamma^{-1}$, where Γ is the bulk Lorentz factor of the jet. We point out that this conclusion is incorrect and resulted from a confusion between the angles measured in the lab frame (θ') and in the plasma rest frame (θ).

Key words: gamma rays: bursts – gamma rays: theory

Hjorth et al. (1999 HJ) imposed an upper limit on the degree of linear polarization ($P < 2.3\%$) for the optical afterglow of GRB 990123, and explored whether such a low value of P is consistent with emission from a narrow ultra relativistic jet. Specifically, they considered the possibility whether P could be very low if the jet is observed at an angle $\theta' \lesssim \Gamma^{-1}$. At the time of the optical emission, the estimated value of $\Gamma \sim 10$–20 and the corresponding $\theta' \sim 3^\circ - 6^\circ$. To seek an answer to the question, HJ banked on a work by Cellotti & Matt (1994, CM). From Figs. 2 & 3 of CM, HJ. concluded that the value of $P \approx 0$ for $\theta' \sim 3^\circ - 6^\circ$. Actually, the abscissa of Figs. 2 and 3 in CM is θ, and not θ', contrary to what has been considered by HJ. For small θ', these two angles are connected by the well known special relativistic formula

$$\sin\theta = \frac{2\Gamma\theta'}{1+\Gamma^2\theta'^2} \tag{1}$$

Thus for $\theta' \lesssim \Gamma^{-1}$, $\theta \lesssim \pi/2$! Then the Figs. 2 and 3 of CM would suggest a large value of $P \sim 22\%$ rather than $P \approx 0\%$. Thus, the interpretation given by HJ resulted from a confusion between θ and θ'. In the popular classification scheme of the Active Galactic Nuclei, θ' is smallest for the radio selected blazars and they are indeed found to have very high values of $P \sim 10$–40%. For the so-called galactic micro-quasars, it is believed that θ' is larger as compared to the radio selected blazars. The micro-quasars too display a fairly high value of $P \sim 10$–15% which is however, smaller than the average P observed by the radio-selected blazars (Mirabel & Rodriguez 1999). And thus these two objects broadly support a scheme in which the P increases with decreasing θ'. Physically this implies that a relativistic turbulent astrophysical jets may be endowed with some ordered magnetic field. However, it is possible that $P \approx 0$ for a very small θ' for the highly unusual case where there is no large scale ordered magnetic either along the axis of the jet or in a direction perpendicular to it.

If this is the case, we need to understand the following: If there is usually an ordered magnetic field, over and above small scale chaotic magnetic field, in relativistic turbulent plasma associated with blazars on scales of ~ 100 pc or more and for the so called micro-quasars, why the relativistic plamsa responsible for the emission of GRB 990123 was completely turbulent on all scales. And even if one assumes that there is no ordered magnetic field, if the jet is viewed off-axis, there would be a temporally variable finite P whose value can reach $\sim 10\%$ (Ghisellini & Lazzati 1999). Considering all such possibilities, it seems that GRB 990123 was more likely to be quasispherical because even in this case one may expect a $P < 10\%$ (Gruzinov & Waxman 1999) and further, the observed spectral break may be understood if it was propagating in a thick presupernova wind (Dai & Lu 1999).

References

Celotti A., Matt G., 1994, MNRAS 268, 451
Dai Z.G., Lu T., 1999, ApJ 519, L155
Ghisellini G., Lazzati D., 1999, MNRAS 309, L7
Gruzinov A., Waxman E., 1999, ApJ 511, 852
Hjorth J., et al., 1999, Sci. 283, 2073
Mirabel I.F., Rodriguez L.F., 1999, ARA&A, in press