The Interplay among Black Holes, Stars and ISM in Galactic Nuclei
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Soft X-ray precursors of the non-thermal flares in blazars

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Abstract. Popular internal shock models, developed to explain the production of high energy flares in blazar jets, involve collisions between local overdensities of matter being ejected by a central engine and moving along the jet with different velocities. Prior to such collisions, the matter is relatively cold and therefore does not produce intrinsic non-thermal radiation. However, due to Comptonization of external radiation by cold electrons, the presence of such matter should be apparent by prominent precursor soft X-ray flares. We discuss the predicted properties of such precursors.

1. Model and Results

The most popular blazar models invoke internal shocks, assumed to be produced by inhomogeneities moving down the jet with different velocities (Sikora, Begelman & Rees 1994; Spada *et al.* 2001). Prior to their collision, the inhomogeneities are cold, and they upscatter external UV photons up to soft X-ray energies, forming X-ray "precursors". We approximate the inhomogeneities by shells which propagate balistically, within the boundaries of a cone. We assume that the shells have equal masses and proper widths. We also assume that the conical angle, θ_j, is sufficiently small that the kinematics and dynamics of the ejecta can be described using a one-dimensional model. Cold electrons, carried by two neighboring relativistic shells through the external diffuse radiation field, u_{diff}, with their respective bulk Lorentz factors $\Gamma_2 > \Gamma_1 \gg 1$, upscatter the ambient photons. The scattered photons form the so-called *bulk Compton radiation*. One can find (see Moderski *et al.* 2004) that the maximum bulk Compton luminosity, L_{BC}, is

$$L_{BC,i} \simeq \frac{4}{3} c\sigma_T u_{diff} \Gamma_i^2 \mathcal{D}_i^4 N_e \,, \; i = 1,2\,, \quad N_e \simeq \frac{4t_{fl}(\nu L_\nu)}{3m_e c^2}\frac{\Gamma^2}{\mathcal{D}^5}\,, \tag{1.1}$$

where N_e is the number of electrons in the shell, t_{fl} and νL_ν are the non-thermal flare timescale and luminosity, respectively, $\mathcal{D}$ is the Doppler factor, and $\Gamma \simeq \sqrt{\Gamma_1\Gamma_2}$.

The EGRET instrument detected many prominent flares in blazars (von Montigny *et al.* 1995). In the 30 MeV - 10 GeV band, their apparent luminosities reach values $\nu L_\nu \sim 10^{48}$ erg s^{-1}, and their time scales, t_{fl}, are of the order of a few days. The light-curve of such a non-thermal flare, together with the lightcurves of soft X-ray precursors, are presented in Fig. 1.

2. Conclusions

Our results show that precursors produced by faster shells are typically 10 - 30 times less luminous than γ-ray flares. However, these precursors are predicted to dominate in the soft X-ray band. The presence of precursors can be verified by future polarimetric

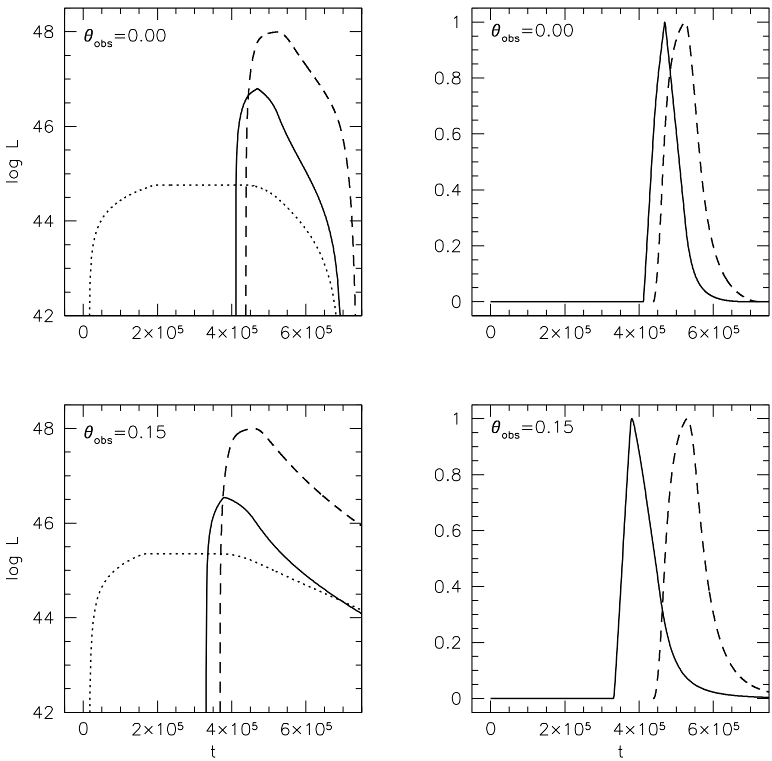

Figure 1. Light-curves of the two types of precursors and the non-thermal flares for $\theta_{obs} = 0$ (the upper left panel) and $\theta_{obs} = 0.15$ (the lower left panel) for $\theta_j = 1/\Gamma = 0.1$. The solid lines are the precursors produced by the faster shells; the dotted lines are the precursors produced by the slower shells; and the dashed lines are the non-thermal γ-ray flares. Those due to the faster shells and the flares are re-drawn in linear scale on the right panels with their peaks normalized to one.

measurements, as the bulk Compton radiation should be highly polarized, with the electric vector perpendicular to the jet axis. The lack of observational evidence for precursors by future observations will indicate that cold inhomogeneities originate *in situ*, at distances just prior to the formation of shocks, rather then resulting from the modulation of the outflow by a central engine. Their formation may be related to the transition from the Poynting flux to matter dominated flow.

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