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Magnetization of AGN jets as imposed by leptonic models of luminous blazars

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Abstract. Recent measurements of frequency-dependent shift of radio-core locations indicate that the ratio of the magnetic to kinetic energy flux (the σ parameter) is of the order of unity. These results are consistent with predictions of magnetically-arrested-disk (MAD) models of a jet formation, but contradict the predictions of leptonic models of γ-ray production in luminous blazars. We demonstrate this discrepancy by computing the γ-ray-to-synchrotron luminosity ratio (the q parameter) as a function of a distance from the black hole for different values of σ and using both spherical and planar models for broad-line region and dusty torus. We find that it is impossible to reproduce observed $q \gg 1$ for jets with $\sigma \geqslant 1$. This may indicate that blazar radiation is produced in reconnection layers or in spines of magnetically stratified jets.

Keywords. quasars: jets, radiation mechanisms: non-thermal, acceleration of particles

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1. Introduction

Measurements of radio core-shifts in core dominated luminous radio-loud AGN (Pushkarev *et al.* (2009)) were used by Zamaninasab *et al.* (2014) to estimate magnetic fluxes in parsec scale jets. The magnetic fluxes were found to be consistent with magnetic fluxes predicted to thread the black hole by the MAD model (McKinney *et al.* (2012)). These studies indicate also that magnetization of a jet plasma at parsec distances corresponds to $\sigma \sim 1$. While energetics of blazars seems to be consistent with the MAD model, having in the blazar zone $\sigma \sim 1$ was shown by Nalewajko *et al.* (2014) to contradict with popular, external-Compton-radiation (ERC) models of luminous, γ-ray dominant blazars. We verify analytical results of Nalewajko *et al.* (2014) by numerical studies of SEDs of luminous blazars.

2. The model

We calculate the quasi-steady-state electron distribution and produced radiation. Our one-zone leptonic model involves a source of non-thermal radiation propagating down the jet with bulk Lorentz factor $\Gamma = 15$ and $\theta_{jet} = 1/\Gamma$. Synchrotron and ERC radiation is $L_{syn} \propto u'_B$ and $L_{ERC} \propto u'_{ext}$, respectively, thus

$$q \propto \frac{u'_{ext}}{u'_B} = \frac{(1+\sigma)\Gamma^2 \zeta \eta_{disk}}{4\sigma \eta_{jet}}$$

where u'_B and u'_{ext} are the energy densities of magnetic field and external photons, respectively, $\eta_{disk} = L_{disk}/\dot{M}c^2$ is accretion disk radiative efficiency, $\eta_{jet} = L_{jet}/\dot{M}c^2$ is jet production efficiency, $\sigma = L_B/L_{kin}$ and $\zeta = 4\pi u'_{ext} r^2 c / L_{disk}\Gamma^2$. Sources of external seed photons in ERC process include broad line region (BLR, $0.1 r_{sub} < r_{BLR} < r_{sub}$), hot dust region (HDR, $r_{sub} < r_{HDR} < 10.0\, r_{sub}$) and accretion disk (where $r_{sub} \approx 1.0\,\mathrm{pc}$). We consider both planar and quasi-spherical geometries of BLR and HDR. Values of

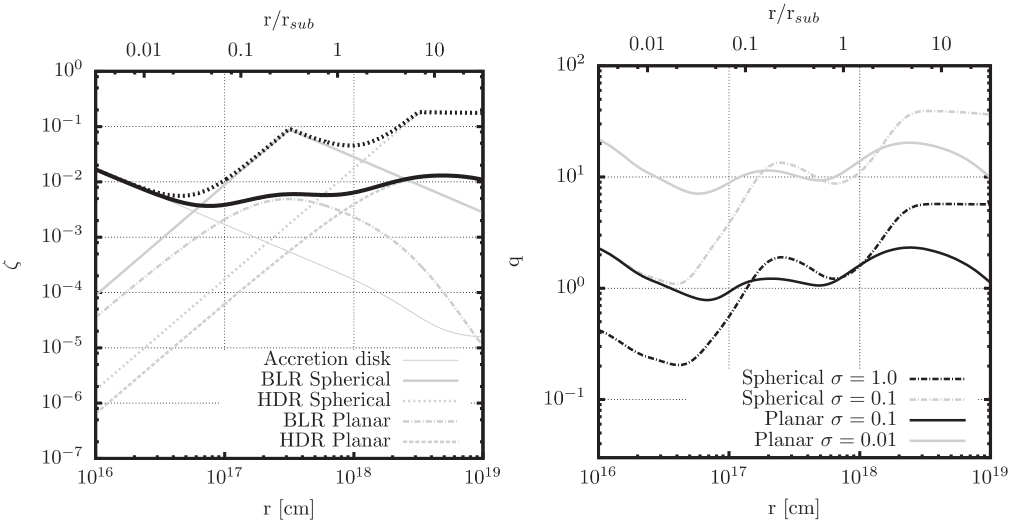

Fig. 1 *Left panel:* ζ vs radius for spherical and flat geometries of external radiation sources. Black dotted line is a total ζ for spherical case and black solid line presents a total ζ for planar geometry. *Right panel:* Compton dominance parameter q vs radius for different external source geometries and values of magnetization σ.

the Compton-dominance parameter $q = L_{ERC}/L_{syn}$ and ζ parameter are calculated for three distance decades, $10^{16} - 10^{19}$ cm and presented in Fig. 1.

3. Conclusions

- Modelling of radiation from blazar jets together with the assumption of high Compton dominance leads to $\sigma \ll 1$.
- Calculated values of u'_{ext} in the case of quasi-spherical geometry are much higher than for flat case. But even then $\sigma = 1.0$ is too high to reproduce $q > 10$ often observed in luminous blazars.
- Possible solution to presented discrepancy between $\sigma \sim 1$ determined by core-shift measurements and much smaller σ as indicated by blazar models with $q >> 1$ is non-uniformity of magnetic fields across the jet and production of blazar radiation in sites of lower magnetized plasma possibly associated with reconnection layers or with less magnetized jet spines.

Acknowledgements

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