Blazar emission from gradual magnetic dissipation: the jet as a multitude of communicating segments

S. Dimitrakoudis, M. Petropoulou — National and Kapodistrian University of Athens

Abstract:

AGN jets are sprawling entities, with structures of differing size and magnetic field strength extending from very close to supermassive black holes up to potentially over a hundred parsecs away. However, it has long been expedient to calculate their emission in one-zone models, which are effectively spheres. This is optimal for variability studies but also sidesteps the issue of irresolvable structure in what are, in the case of blazars, head-on jets. Here we treat blazar jets as a conical series of spherical segments, where energy is constantly being dissipated from magnetic reconnection in the current sheets that form from the alternating polarity of the jet's toroidal field. Within each segment we apply the LeHaMoC code to self-consistently calculate the photon emission from electrons that may be accelerated there, and we iteratively apply the effect of radiation spilling into the rest of the segments across the jet; that is, we treat radiation crossing through each segment from each other segment as an additional injection term in LeHaMoC's kinetic equations. In this way, we investigate the impact of such interactions between segments.

The spectral energy distribution (SED) of blazars has to be evaluated in the context of underlying emission models. One such model, laid out by **[1]**, posits that blazar emission is driven by magnetic reconnection along current sheets that form along the length of the jet in a stripy pattern. We have adopted the underlying assumptions of that model to compute the jet emission, using the radiative transfer code LeHaMoC **[2]**.

Photon propagation between segments along the jet (assumed spherical for LeHaMoC) happens as shown in Figure 1. Our free parameters are:

- the opening angle $\boldsymbol{\theta_j}$,
- power slope $\boldsymbol{\alpha}$ of the distribution of the jet's poloidal magnetic flux power spectrum, which determines magnetization σ for distance z,
- the jet terminal Lorentz Factor, $\boldsymbol{\Gamma_\infty}$,
- the black hole mass **M**,
- and accretion rate, $\boldsymbol{\dot{M}}$,
- as well as the electrons' power law slope and maximum energy.

This process is applied iteratively along the jet in both directions, until a steady state is reached.

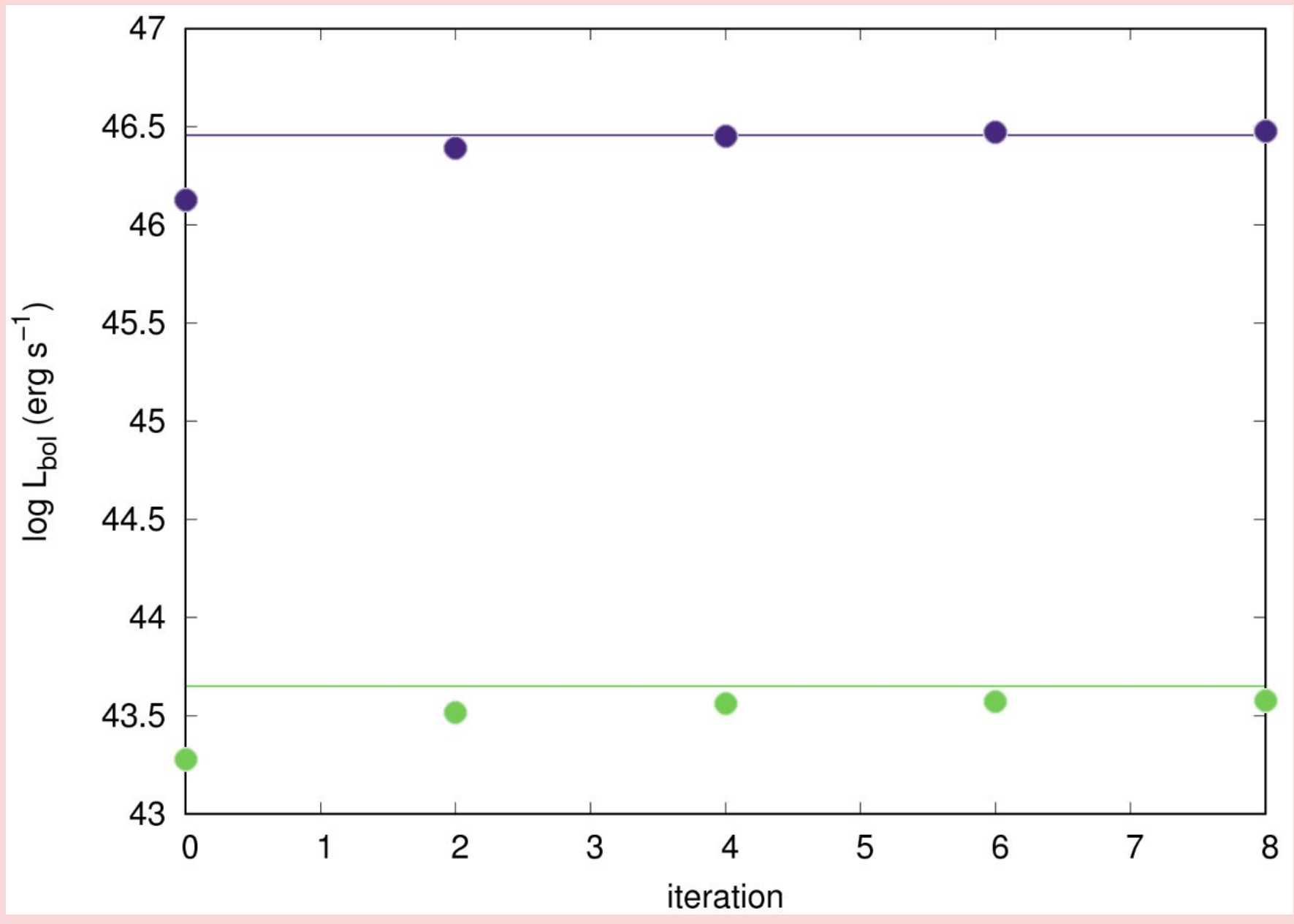

Figure 3: Bolometric luminosity calculated after each iteration, compared to that of all segments without photon spilling, for the values of Fig. 2 (a) (green) and (b) (purple).

Parameter	Values Fig.2 (a)	Fig.2 (b)
θ_j	2°	2°
$\dot{M}c^2$	10^{44}erg/s	10^{46}erg/s
a	1.4	1.4
z	$3\cdot10^{-4}$pc - $3\cdot10^{-3}$pc	5pc - 50pc

Table 1: Free parameter values used in Figure 2.

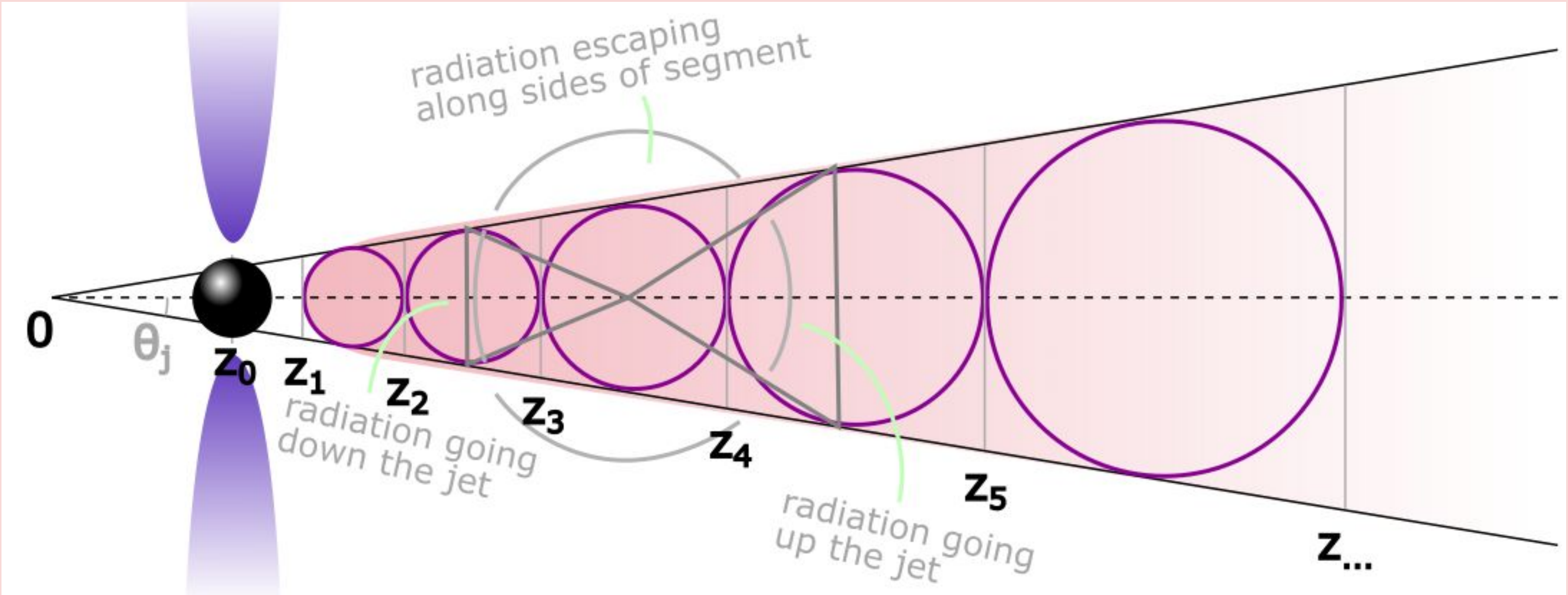

Figure 1: Sketch of a jet (in red) modeled as a series of spherical segments inscribed within a cone, with an initial pseudo-parabolic bulk flow acceleration region represented by the border of the first spherical segment. The black hole is at z_0.

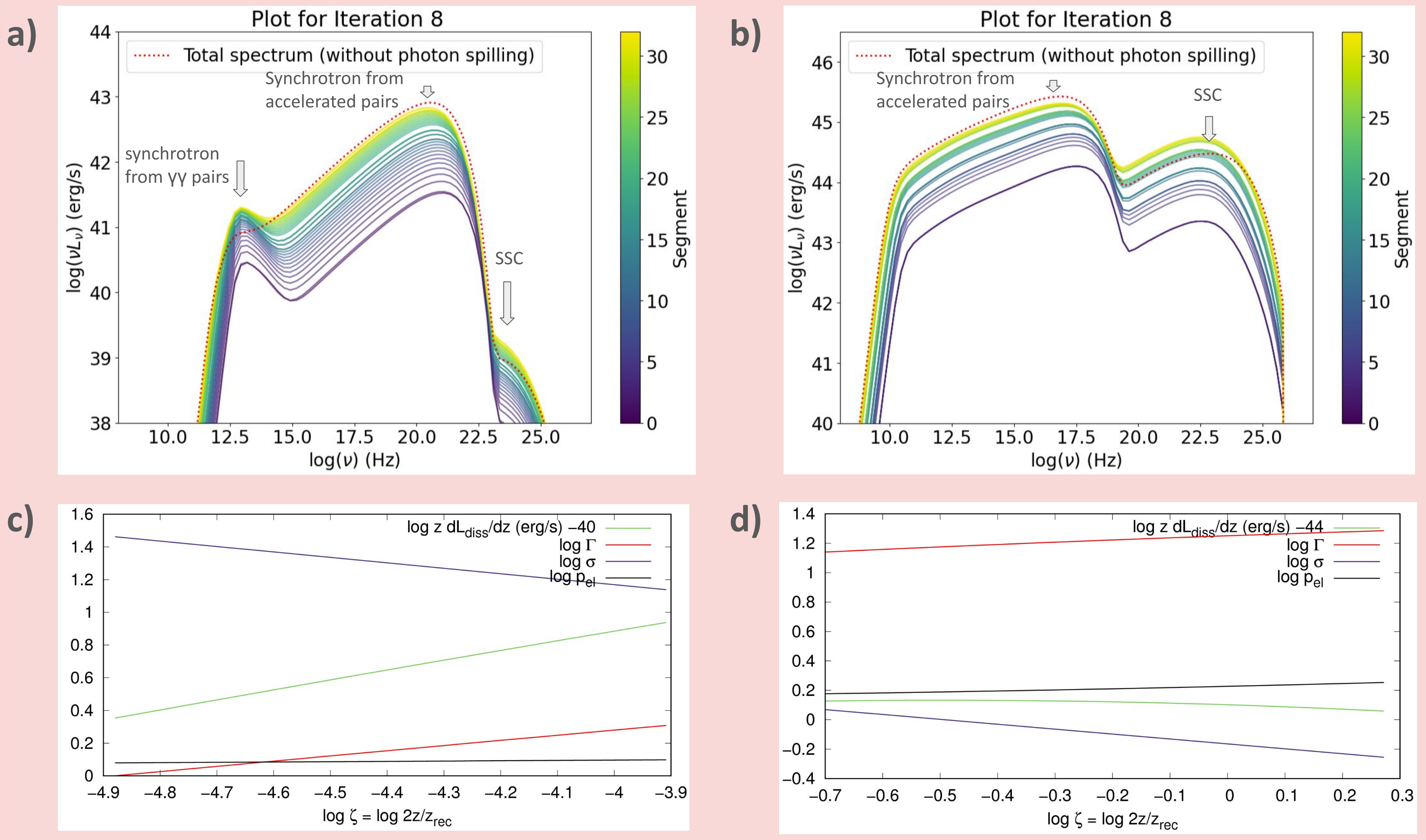

Figure 2: Total spectrum after eight iterations along all (33) segments in a part of the jet for **(a)** conditions of high γγ absorption at low z and **(b)** conditions of strong IC at high z. Parameter values are listed in Table 1. No doppler beaming has been applied yet. **(c)** and **(d)** show the dissipation profile, Γ, σ, and injected electron slope p_{el} for (a) and (b) respectively.

Conclusions and future work:

Inter-segment radiation spillage produces visible power transfer effects whenever processes that are sensitive to target photon density (γγ pair production, inverse Compton scattering) produce an output comparable to that of synchrotron.

For longer chains of segments we will have to take into account the relative Γ between them. Electron energies can also be constrained using the Hillas criterion.

While the movement of electrons between segments is hindered by their high synchrotron energy loss rates and small gyroradii, the same cannot be said of high energy protons. This will be investigated in future work.

References:

[1] Giannios, D. & Uzdensky, D. A. 2019, MNRAS, 484, 1378

[2] Stathopoulos, S. I., Petropoulou, M., Vasilopoulos, G., & Mastichiadis, A. 2024, A&A, 683, A225

Email: sdimis@phys.uoa.gr

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