The effect of plasma injection on Black Hole Activation

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Motivation

Accreting magnetized black holes (BHs) are theorized to power relativistic jets via the **Blandford-Znajek (BZ) mechanism**. The efficiency of the process depends on the amount of free charges in the BH magnetosphere screening the electric field and allowing for Poynting flow to carry energy away. As BHs don't have surfaces that can provide charges, the **origin of the plasma remains unknown**, where **two possible sources** are usually considered an external source, and local pair cascade episodes.

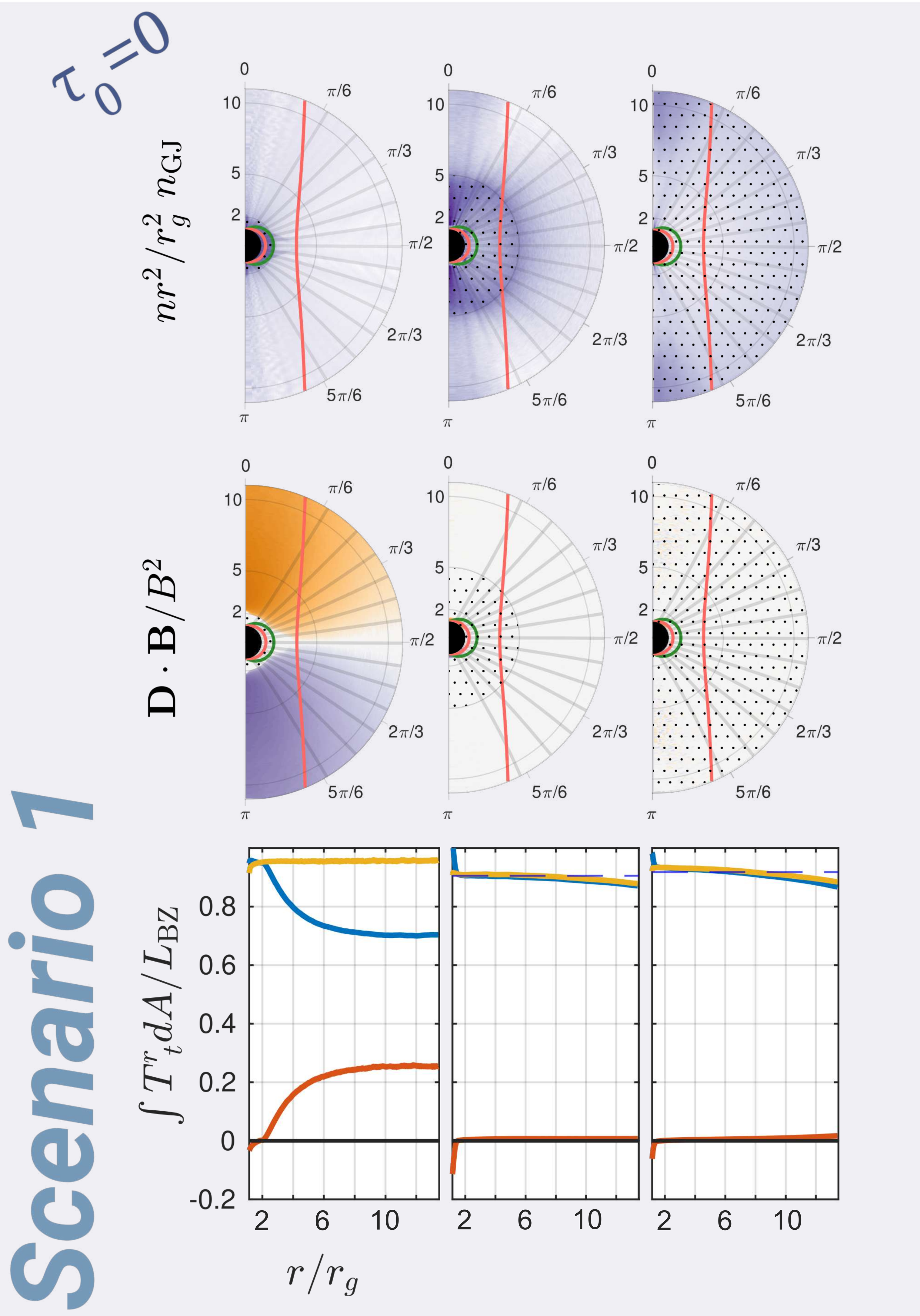
Setup

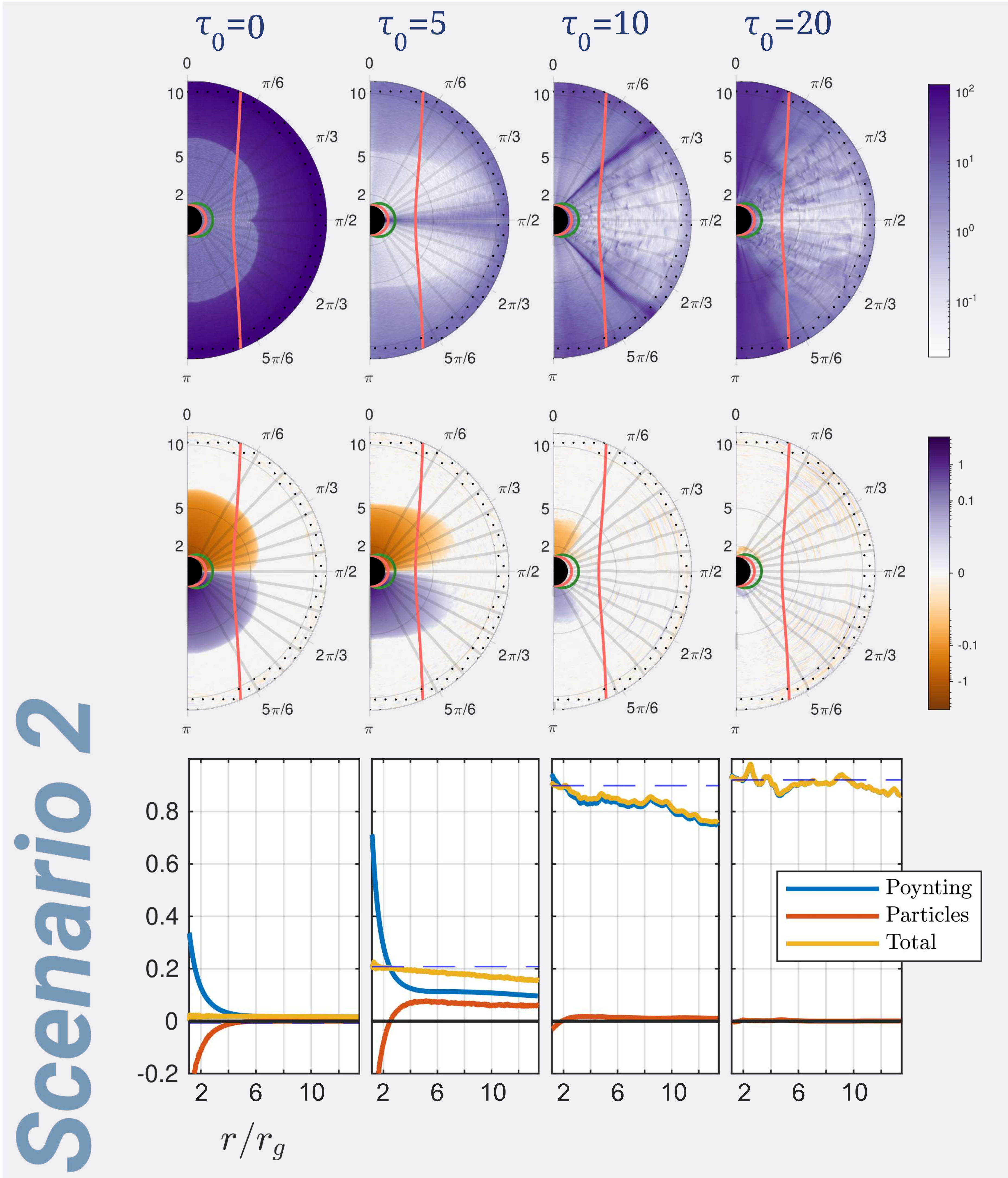
We ran a Particle-in-Cell (PIC) simulation of electron and positron plasma embedded in Kerr spacetime. The BH is threaded by radial magnetic fieldlines, fixing the BZ mechanism luminosity, L_{BZ}, to the monopole solution.

The system is engulfed by background of infrared (IR) photons, which can interact with gamma-rays through **pair production**, and with charges through **inverse-Compton (IC) scattering**. This leads to **pair cascades** filling the magnetosphere, and the rate of these interactions is controlled by τ_0 the fiducial opacity.

Whenever the charge density drops below the local Goldreich-Julian density, n_{GJ}, a radial electric field grows entailing more pair cascades. The degree of electric shielding is also directly related to the Poynting flux, $L_\infty = L_{BZ} - \int \vec{E}\cdot\vec{J}\,dV$.

To examine the possibility of an external source for the plasma screening the electric field, we conducted tests examining two scenarios. In the **first scenario**, no interactions and inject in a shell from the event horizon up to some outer radius. In the **second scenario**, we inject pairs at an outer radial shell and we allowing interactions. Pairs are injected hot and are **continuously injected** at a rate locally screening the field.





Results

We tested how the two scenarios affect the plasma density, electric field (notated by $\mathbf{D}$), and energy flux of the different components at each radial shell.The total flux plotted accounts for plasma and Poynting flux and does not account for radiative losses which result in negligible interaction; those include some of the IC and curvature radiation.

In scenario 1, the region between the light surfaces (colored in red) is important since plasma activating the BZ mechanism must reside in it. In the tests where the injection covers the outer light surface (OLS) we fully activate the BH.

In scenario 2, the screening efficacy with the opacity, and the plasma becomes more unstable to pair cascades.

Conclusions

- To activate BZ jet, need to inject plasma in the inner magnetosphere, inside the outer light surface.
- A strong electric field results with few percent of L_{BZ} radiative losses in the TeV range, suggesting this is not the case for AGNs such as M87* or Sagittarius A*.
- It seems unlikely that an external source could inject plasma into the inner magnetosphere; the case of local pair cascades seems more physical.
- Considering the case of pair cascades, the required soft photon density for electric shielding is determined. This case is associated with significantly lower TeV emissions than the alternative.

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