Magnetic Limits Redefined: Energy Dissipation and Extreme Efficiency in Black Hole Jets

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Outline

- How can we put radiation to GRMHD results
- 3D resistive simulations and dissipation
- Super MAD solutions



2020 MAD Magnetically Arrested Disk

Sea also Dexter et al. 2020, Nathanail et al. 2020, Ripperda et al. 2020, Chatterjee et a. 2021, Ripperda et al. 2022



Disk counterclockwise

Flux tube bends back ward (clockwise) depleted from mass

Particles ride on it

MAD

Sea Antonopoulou, Loules, Nathanail 2025



Salas et al. 2025

For radiation Common approach

 $\sigma > 1$

Excluded

Sea also Mościbrodzka et al. 2016, Fromm et al. 2021, Cruz-Osorio et al. 2021, Davelaar et al. 2023 and many others ...

State-of-the-art MAD simulations

Scepi et al. 2023 Identify current sheets

 $\mathcal{C}_{\min} =$

-5

5

5

-5

rg





Dimitropoulos, Nathanail, Petropoulou, Contopoulos, Fromm 2025

State-of-the-art Multiloop simulations



Identify the plasma expected to be accelerated

for SgrA*





Dimitropoulos, Nathanail, Petropoulou, Contopoulos, Fromm 2025



Dimitropoulos, Nathanail, Petropoulou, Contopoulos, Fromm 2025

M87: The base of the jet <u>New</u> Observations



Limb brightened + inner jet

Standard procedure: The funnel is excluded



Lu et al. 2023



Salas et al. 2025

For radiation Common approach

 $\sigma > 1$

Excluded

Sea also Mościbrodzka et al. 2016, Fromm et al. 2021, Cruz-Osorio et al. 2021, Davelaar et al. 2023 and many others ...

Micro-physics?





micro physics?

The boundary of the jet

 $\mathbf{E} \cdot \mathbf{J} / \mathbf{B}^2$

Nathanail, Fromm, Mizuno, Contopoulos, Cruz – Osorio, Moriyama, Rezzolla 2025 (submitted)

MAD 3D

accretion continues through Instabilities

Efficiency $\eta = (100) \times P_{jet} / m c^2 \sim 140 \%$

Narayan et al. 2003, Igumenshev 2008, Tchekhovskoy et al. 2011

MAD 3D

accretion continues through Instabilities

See Argyris's talk

Efficiency $\eta = (100) \times P_{jet} / II.$

Narayan et al. 2003, Igumenshev 2008, Tchekhovskoy et al. 2011





What about the Efficiency $\eta = (100) \times P_{jet} / m^{\circ}c^{2} \%$







MAD 3D

accretion can be stopped

efficiency 17000 %





Conclusions:

• We need to rethink how to put radiation in GRMHD simulations

non-thermal radiation 3D resistive

• Super MAD accretion can be stopped



