# Simulation of global resistive MHD accretion flows around spinning AGNs: the impact of resistivity on the MAD state

EAMA 11
The 11th East-Asian Meeting on Astronomy
TOKI MESSE, Niigata, Japan
December 8th-12th, 2025

**Mohammed Ramiz Aktar**[1], Kuo-Chuan Pan[2] & Toru Okuda[3]

[1]*Institute of Astronomy and Astrophysics, Academia Sinica (ASIAA)*

[2]*Department of Physics and Institute of Astronomy, National Tsing Hua University, 30013 Hsinchu, Taiwan*
[3] *Hakodate Campus, Hokkaido University of Education, Hachiman-Cho 1-2, Hakodate 040-8567, Japan*

## Abstract

We investigate the effect of resistivity on the dynamics of global MHD accretion flows around a spinning AGNs. Our study compares 2D and 3D resistive models around black holes. We propose an efficient and physically motivated approach to examine the magnetic state by estimating the spatial average plasma beta parameter. We observe signs of plasmoid formation in low-resistivity flows, in contrast to high-resistivity flows. Our findings suggest that models with low resistivity generate higher-power jets compared to those with higher resistivity.

**Keywords:** Accretion; Black hole physics, MHD, magnetic reconnection, Relativistic jets, AGNs.

## Introduction

- AGNs are commonly associated with jets and outflows.
- During the accretion process in a highly magnetized flow, magnetic flux builds up near the black hole's event horizon. This accumulation creates a magnetic pressure that balances the ram pressure in the disk, thereby preventing further mass accretion. This phenomenon is known as a 'magnetically arrested disk' (MAD).
- The EHT and GRAVITY Collaboration have confirmed the existence of the MAD state.
- Resistivity influences the behavior of accretion flows and their observable signatures, such as high-energy flares and variations in jets.

## Initial Torus set up

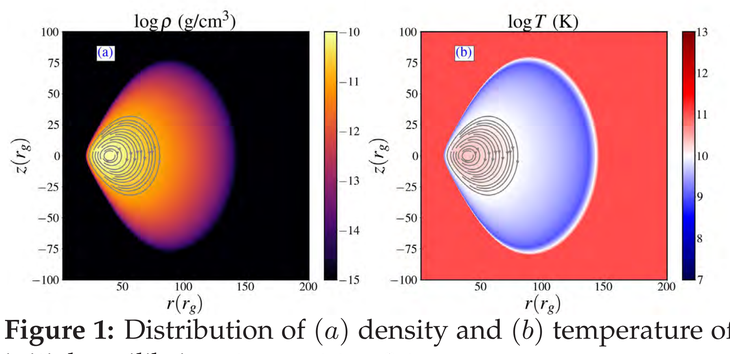



**Figure 1:** Distribution of $(a)$ density and $(b)$ temperature of the initial equilibrium torus at $t = 0\ t_g$

## Identifying MAD state

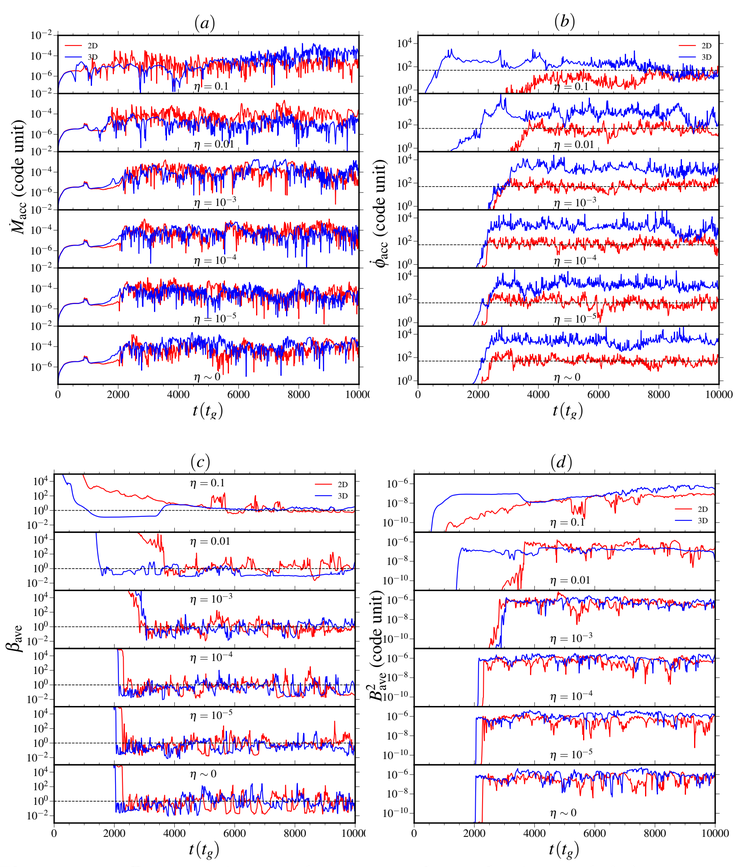



**Figure 2:** Comparison of temporal evolution of $(a)$: mass accretion rate ($\dot{M}_{\rm acc}$), $(b)$: normalized magnetic flux ($\dot{\phi}_{\rm acc}$) accumulated at the black hole horizon, $(c)$: spatial average plasma-$\beta$ ($\beta_{\rm ave}$) and $(d)$: spatial average magnetic energy ($B^2_{\rm ave}$) with the simulation time for different resistivity. Here, we consider the resistivity as $\eta = 0.1, 0.01, 10^{-3}, 10^{-4}, 10^{-5}$, and $\sim 0$.

## References

[1] Aktar et al. *MNRAS*, 527:1745, 2024a.

[2] Aktar et al. *ApJ*, 972:18, 2024b.

[3] Aktar et al. *ApJ*, 987:145, 2025.

[4] Narayan et al. *PASJ*, 55:L69, 2003.

## Distribution of flow variables

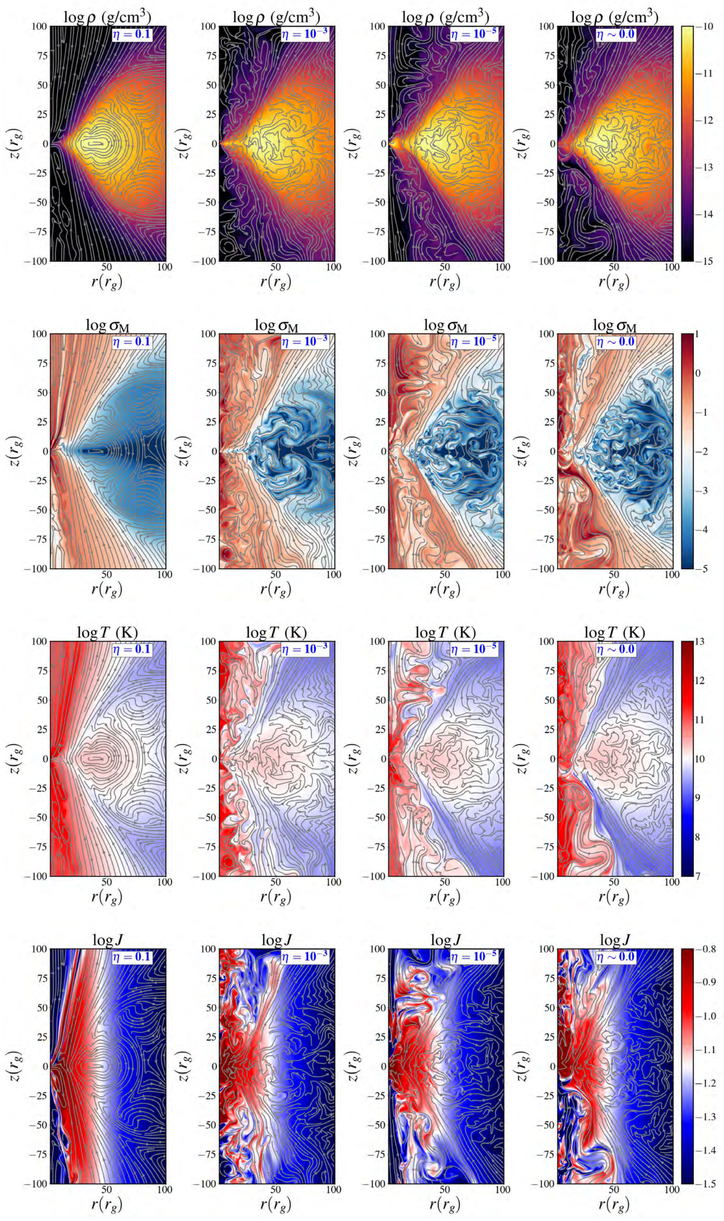



**Figure 3:** Distribution of gas density ($\rho$), magnetization parameter ($\sigma_{\rm M}$), temperature ($T$), and current density ($J$) in the first, second, third, and fourth rows, respectively. The gray lines represent the magnetic field lines. Here, we fix resistivity as $\eta = 0.1, 10^{-3}, 10^{-5}$ and $\sim 0$.

- We find that high-resistivity flow reduces MRI turbulence in the accretion flow, while the turbulence structures remain qualitatively similar in low resistivity flows.

## Plasmoid formation

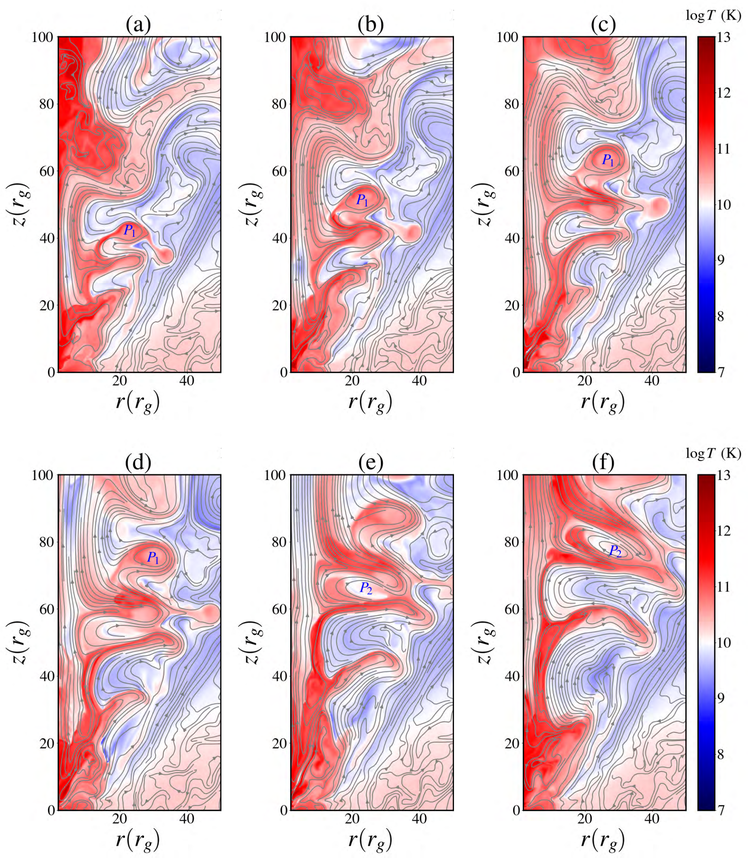



**Figure 4:** The plasmoid formation is shown for various time slices with resistivity of $\eta = 10^{-5}$. The specific time slices are as follows: $(a)\ t = 8200\ t_g$, $(b)\ t = 8300\ t_g$, $(c)\ t = 8400\ t_g$, $(d)\ t = 8500\ t_g$, $(e)\ t = 8600\ t_g$, and $(f)\ t = 8700\ t_g$. In the diagram, $P_1$ and $P_2$ denote the plasmoids.

- We observe the formation of a plasmoid at the location $(r, z) \sim (23, 42)\ r_g$, which we denote as $P_1$.
- The magnetic field lines appear to form a closed loop around this region.
- As time progresses, the plasmoid is advected along the jet.
- Plasmoid $P_1$ begins to dissipate, and a new plasmoid, $P_2$, starts to form.

## Magnetic field structure: MAD

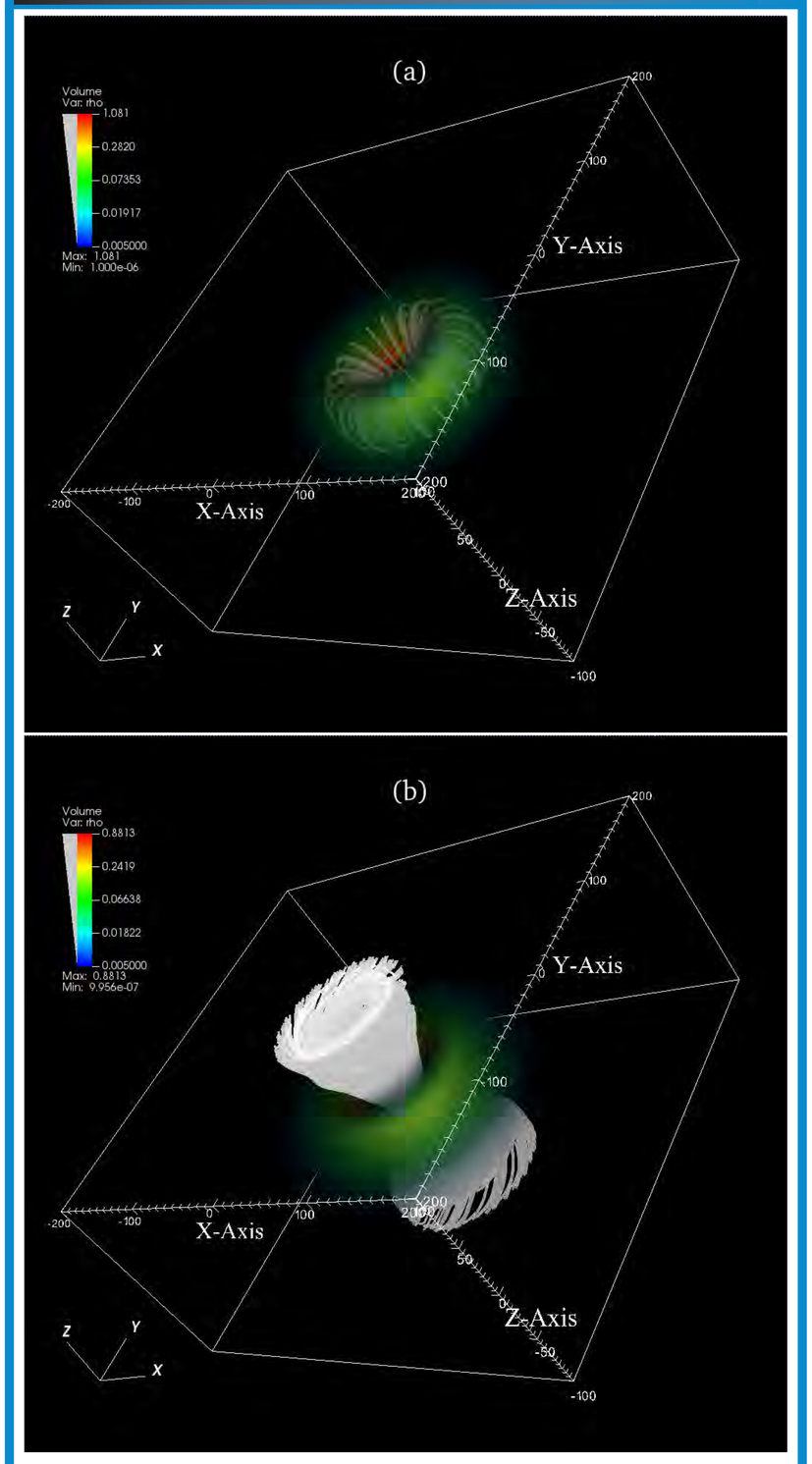



**Figure 5:** Volume rendering of density ($\log \rho$) with the magnetic field lines for the initial torus $(a)$ at $t = 0\ t_g$ and $(b)$ at $t = 8500\ t_g$.

## Jet vs resistivity

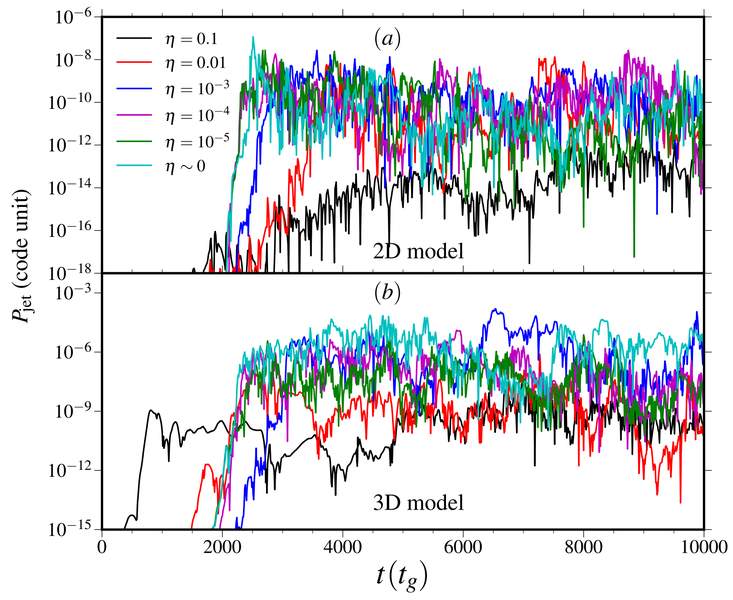



**Figure 6:** Jet power vs. resistivity of the flow for 2D and 3D models.

- We observe that the average jet power is significantly higher in low-resistivity flows compared to high-resistivity flows.

## Conclusion

- Resistivity plays a crucial role in the dynamics of the accretion flow.
- Plasmoids are formed in the low-resistivity accretion flow.
- Jet power is much greater in low-resistivity flows than in high-resistivity flows.

## Contact Information

**Web:** https://ramizaktar.wixsite.com/cinephileproduction
**Email:** ramizaktar@gmail.com