Shaping Jets with the Ambient Medium

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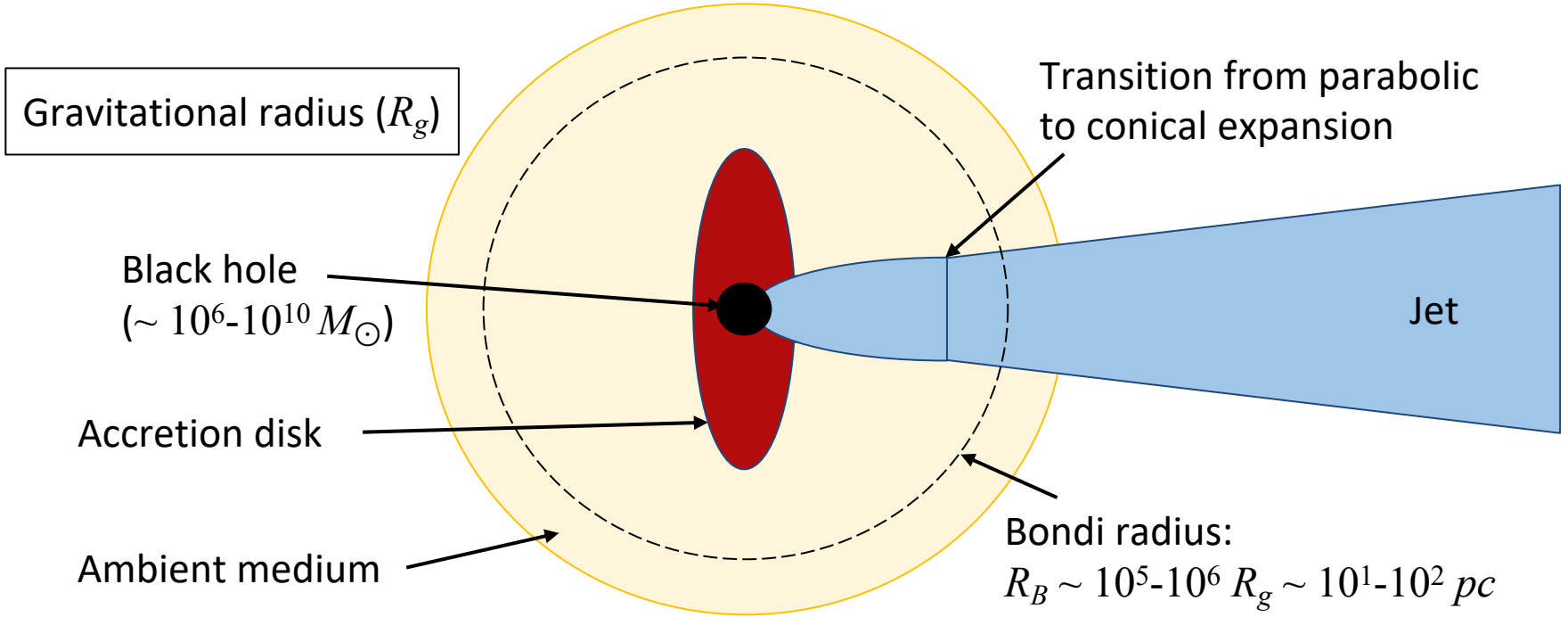
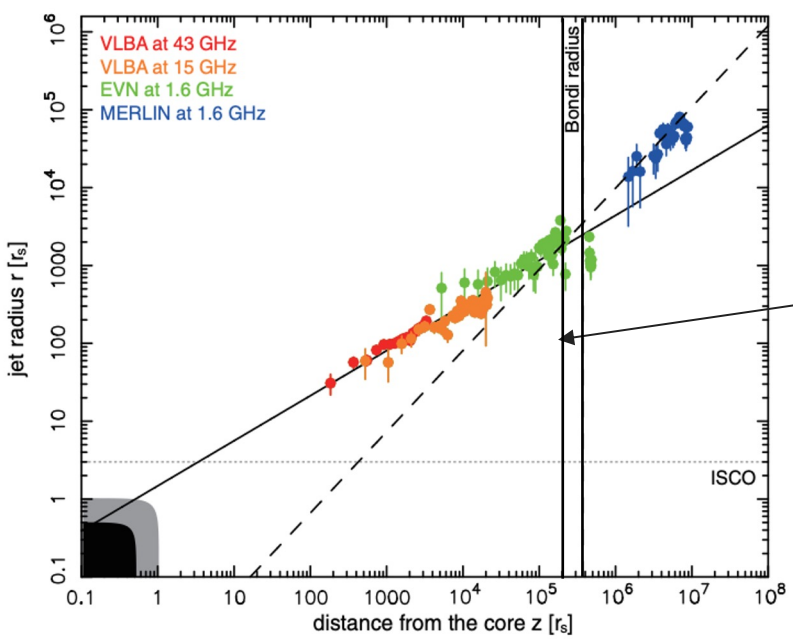
Jets = highly energetic outflows



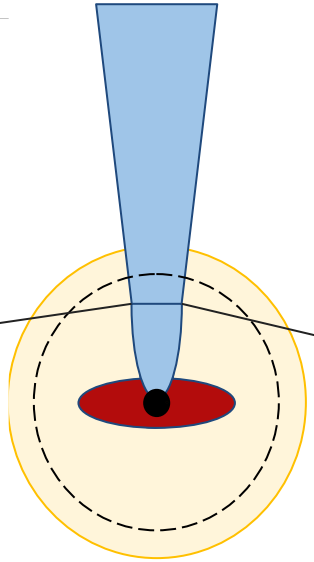
How does the surrounding environment shape these jets?

Observations show jet regime changes

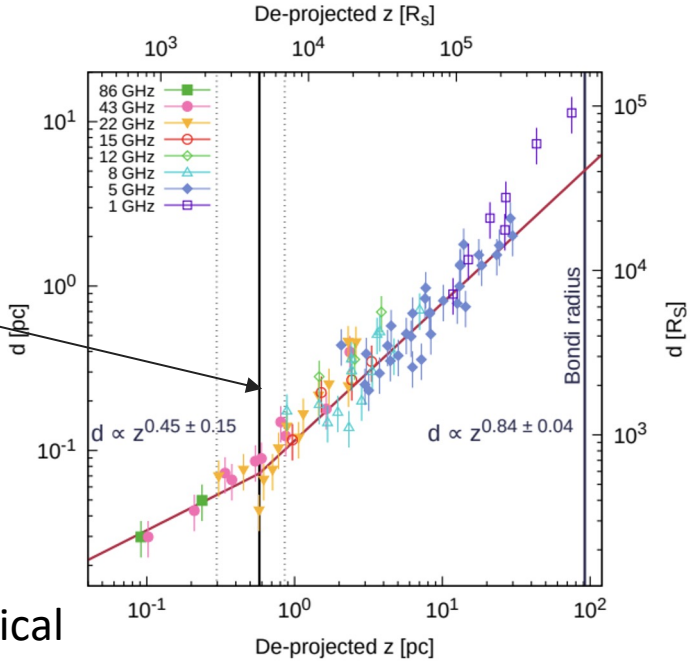


M87

Asada and Nakamura (2012)



Parabolic to conical transitions common in AGN Kovalev, et al. (2020)



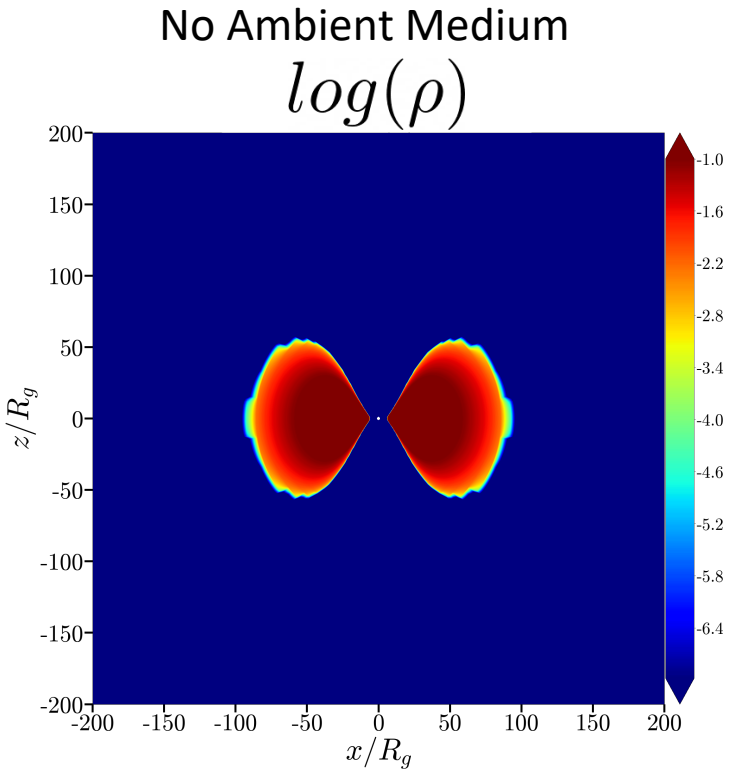
NGC 315

Boccardi, et al. (2021)

Cutting-edge numerical simulation

GPU-accelerated, 3D General Relativistic Magnetohydrodynamic code, *HAMR*

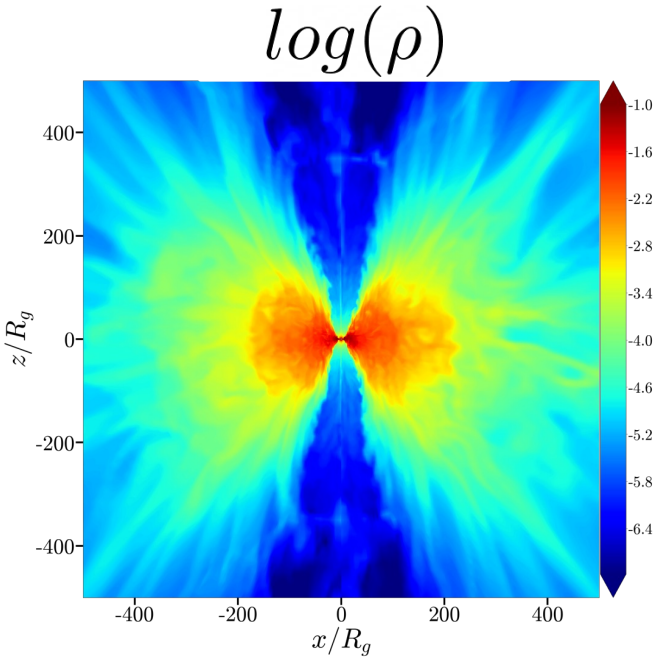
Magnetized torus launches powerful jets

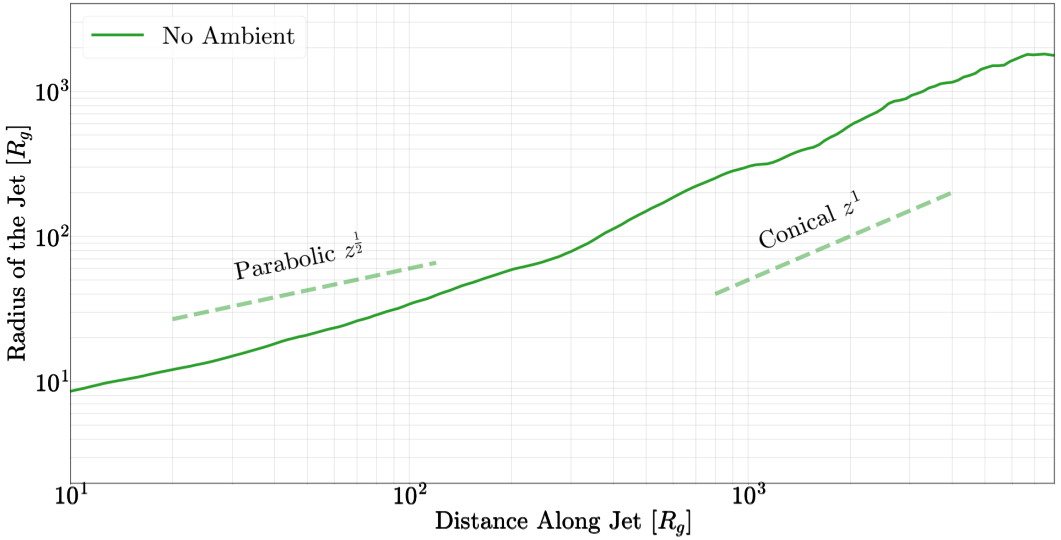


Liska, et al. (2019)

Disk winds create funnel near black hole

No Ambient Medium

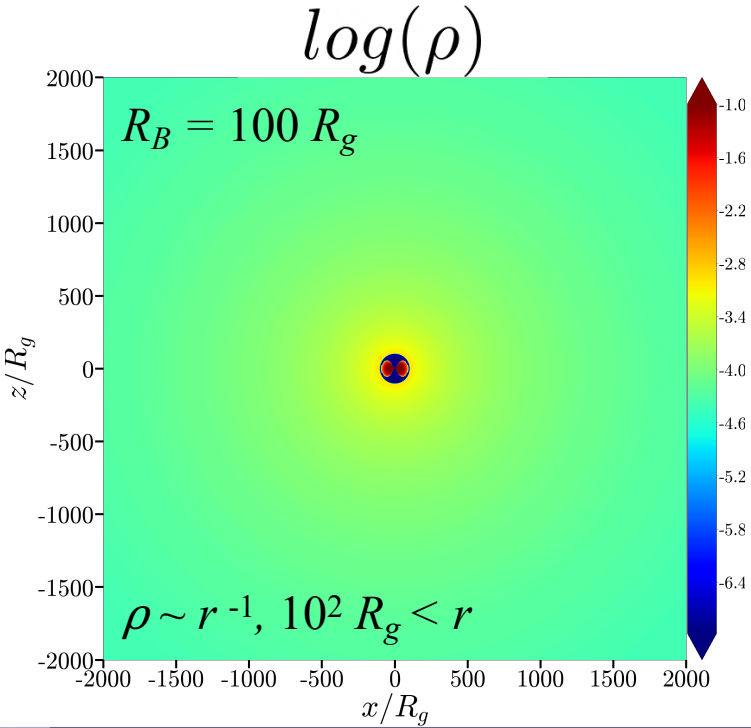




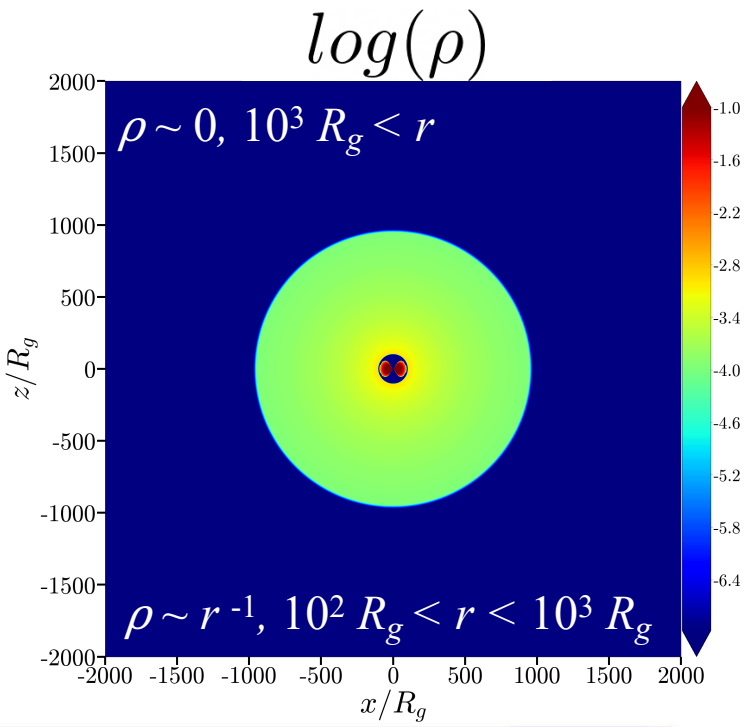
Pressure balance between disk and jet creates parabolic profile

Probing effects of the ambient medium

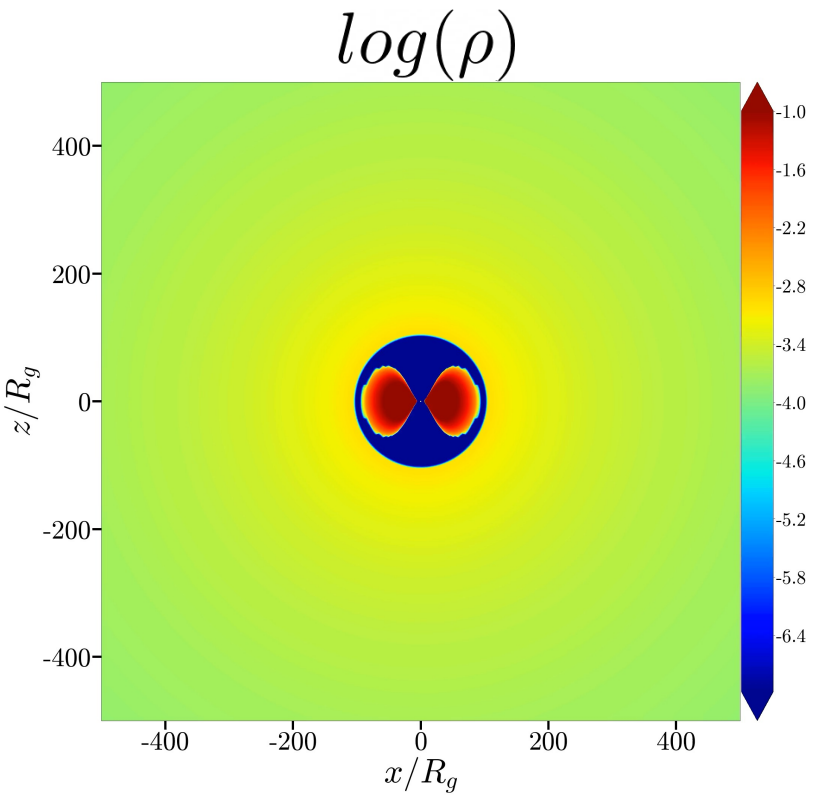
Infinite Ambient Medium



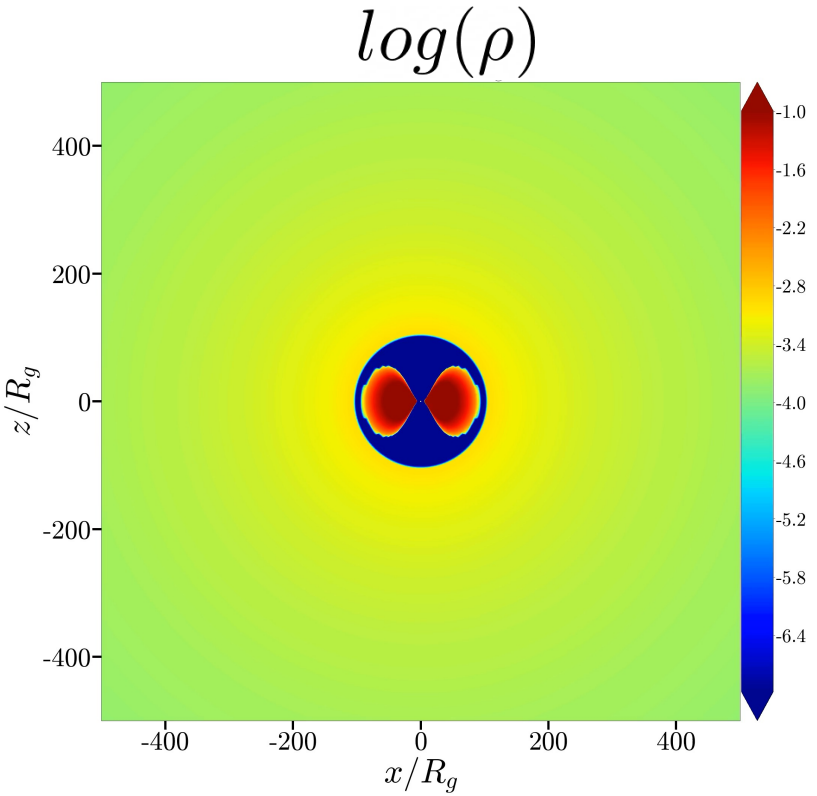
Cutoff Ambient Medium



Infinite Ambient Medium

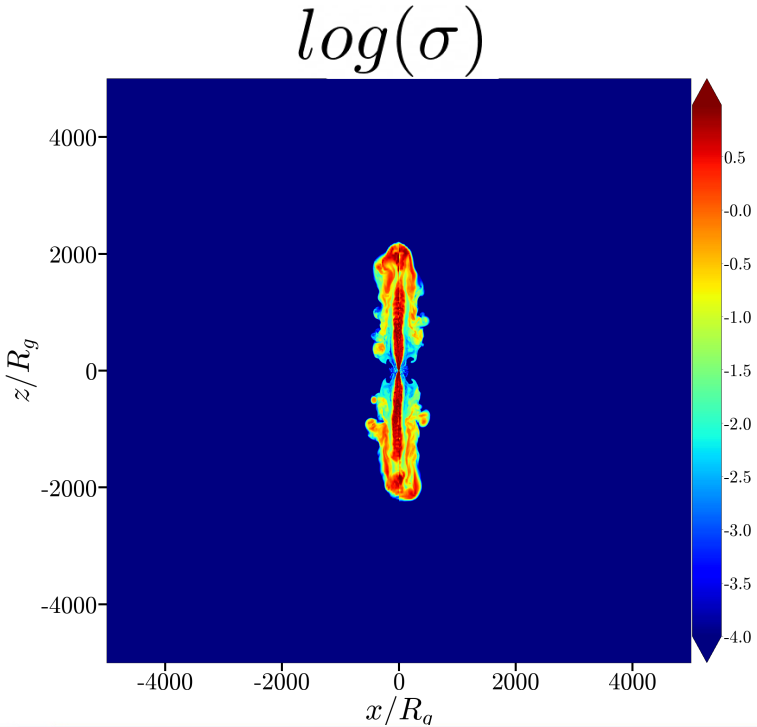


Cutoff Ambient Medium

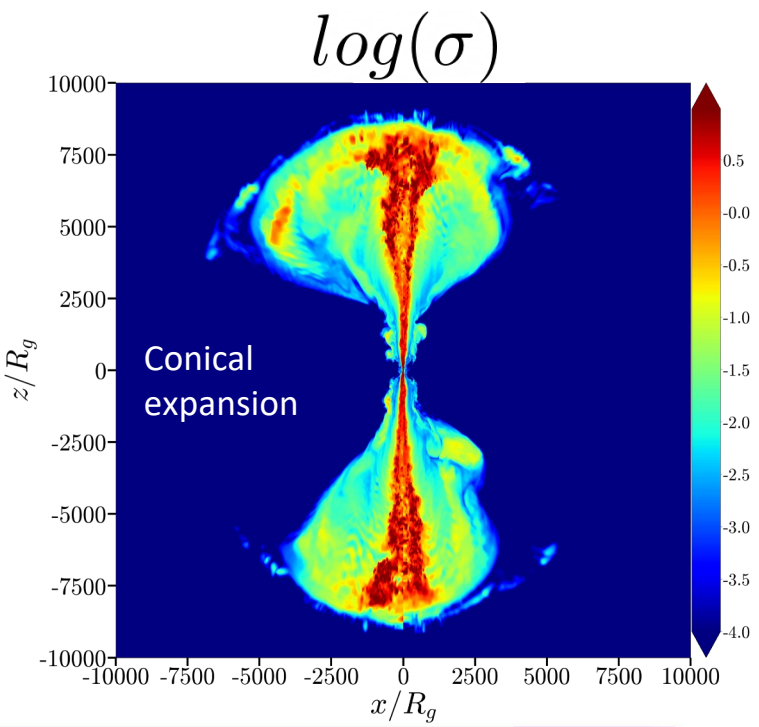


Rapid expansion of magnetization

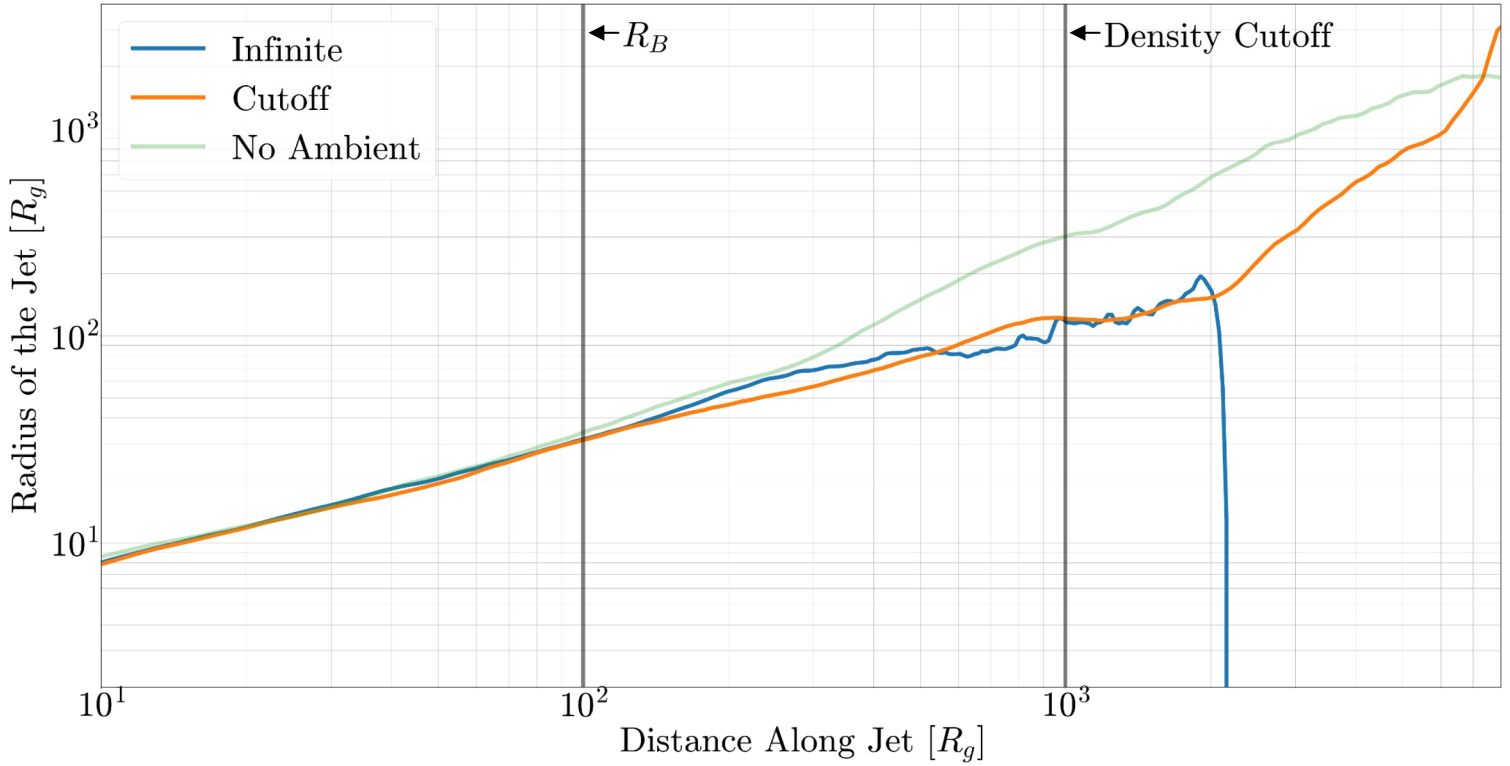
Infinite Ambient Medium



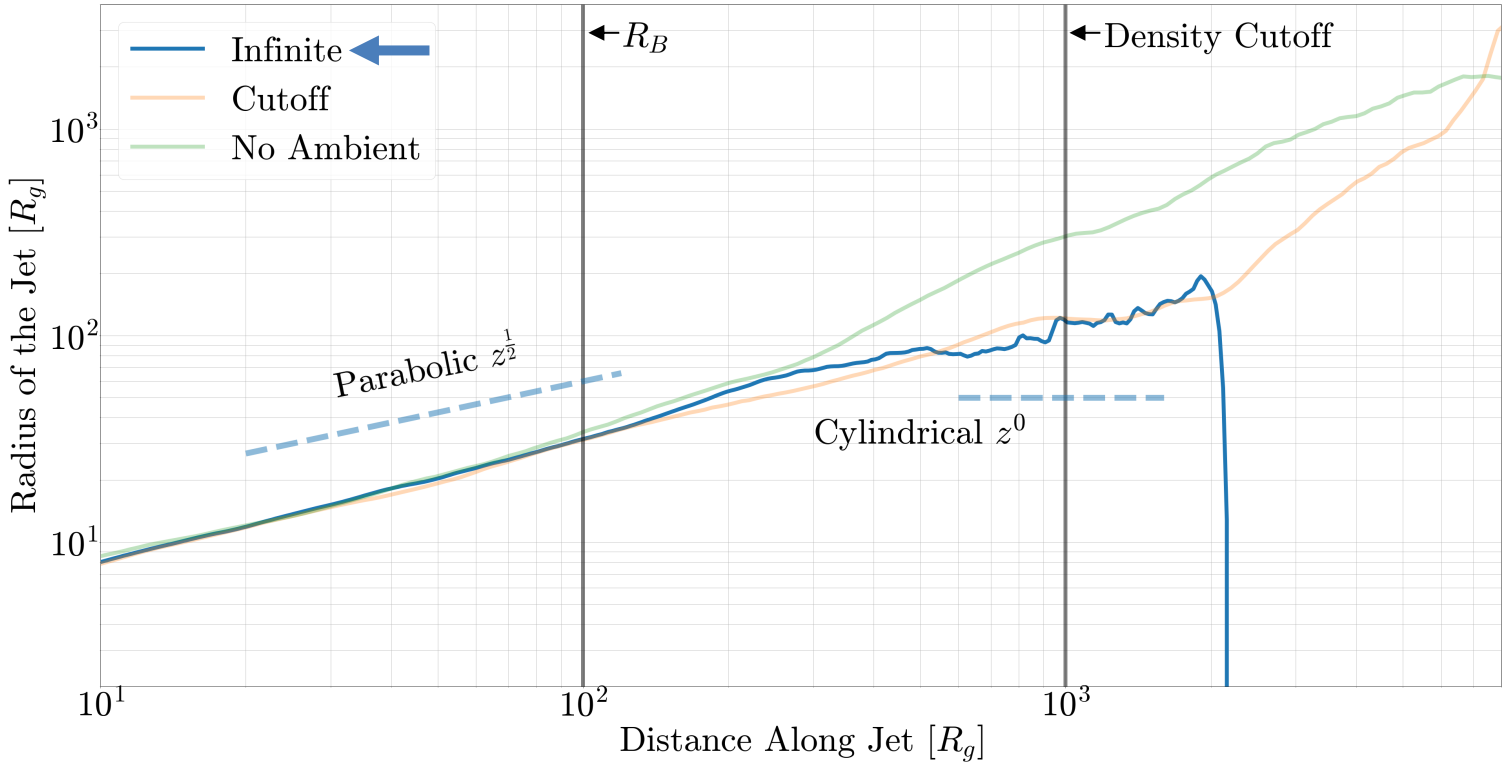
Cutoff Ambient Medium



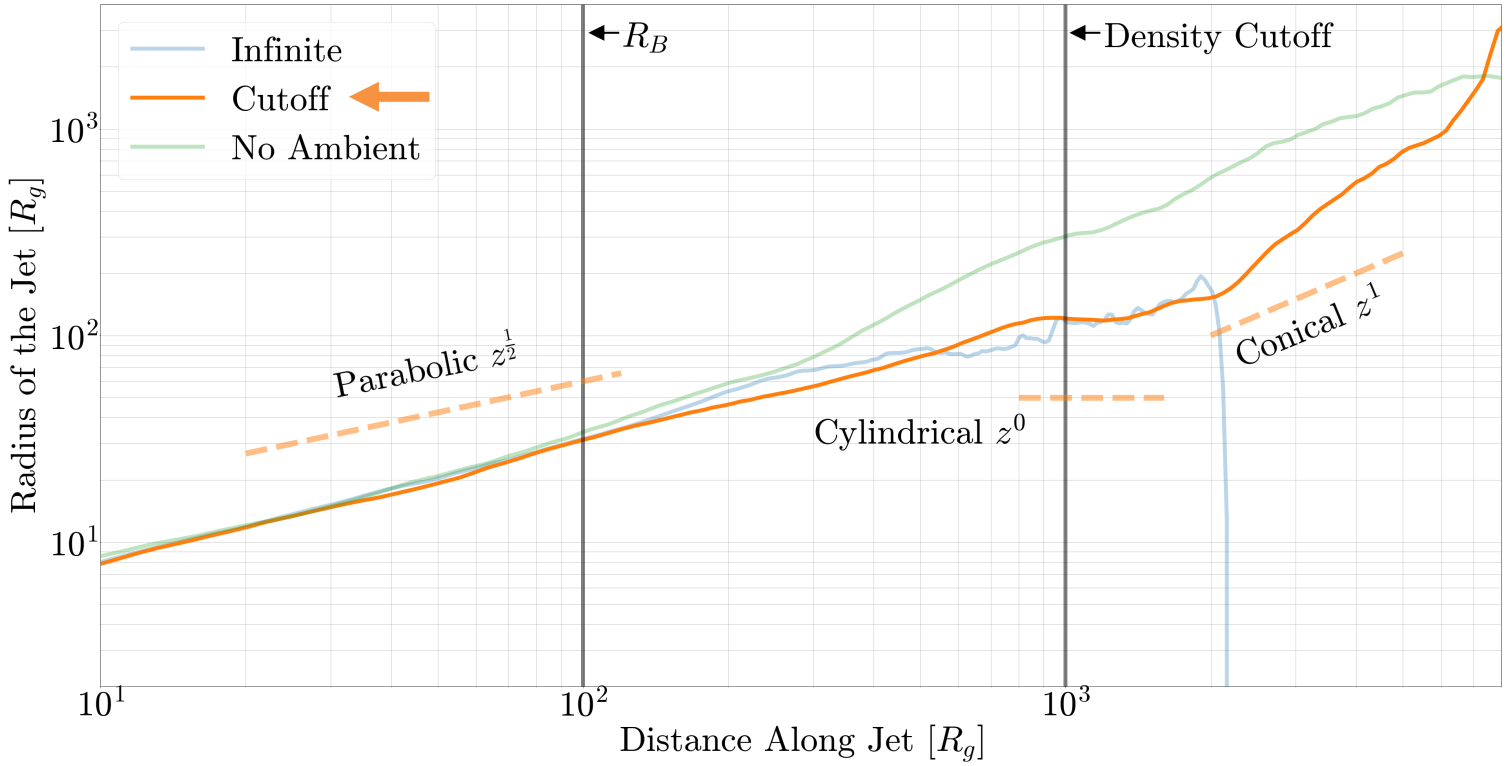
Jet shape in simulations



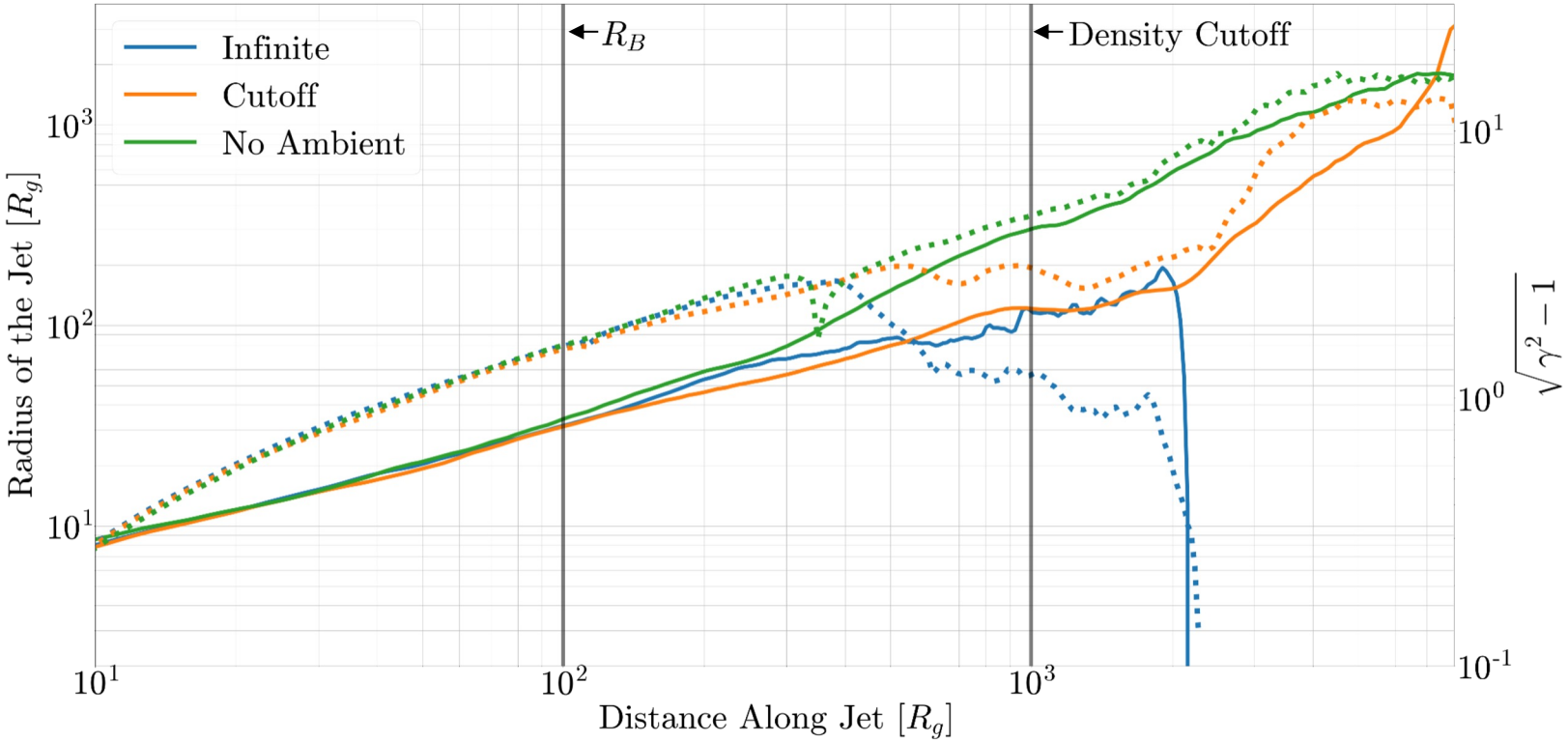
Infinite medium creates cylindrical jets



Jet regime changes drastically near cutoff



Expanding jets speed up



Takeaways

Disk winds shape jet into a parabola near the black hole.

A r^{-1} ambient density profile can provide sufficient pressure to **collimate jets into cylinders**.

Escaping regions of higher density allows for transition to a **conical free expansion regime**.

Future work:

- larger scale separations
- different ambient medium profiles

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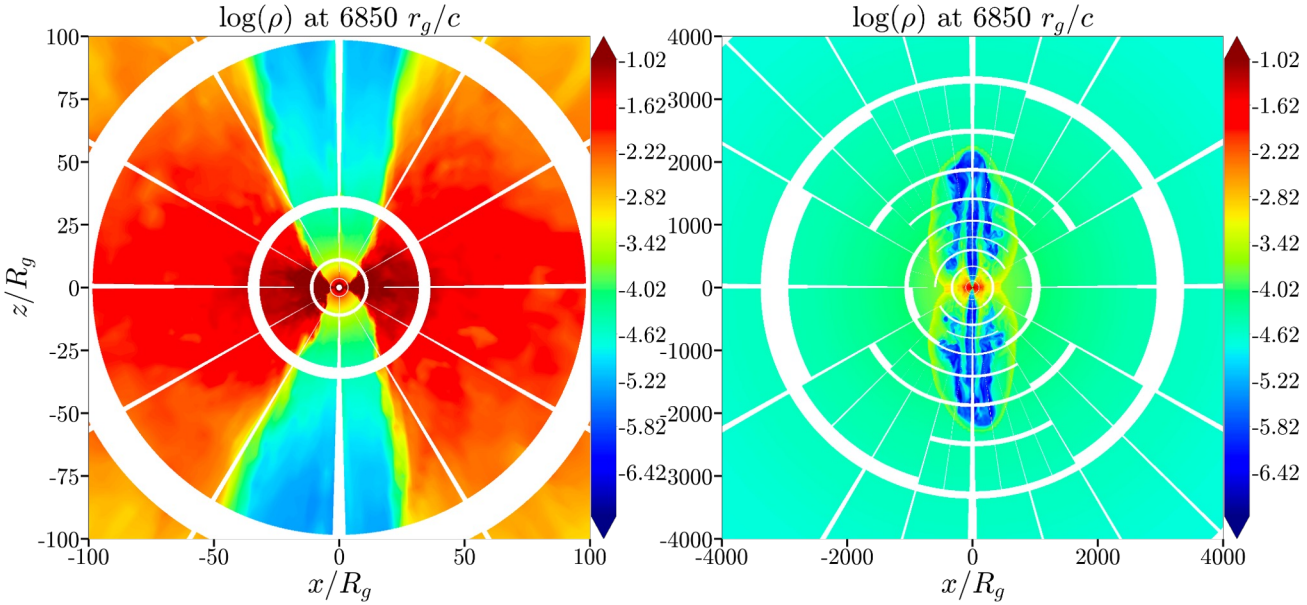
Resolving jets at large scale separation

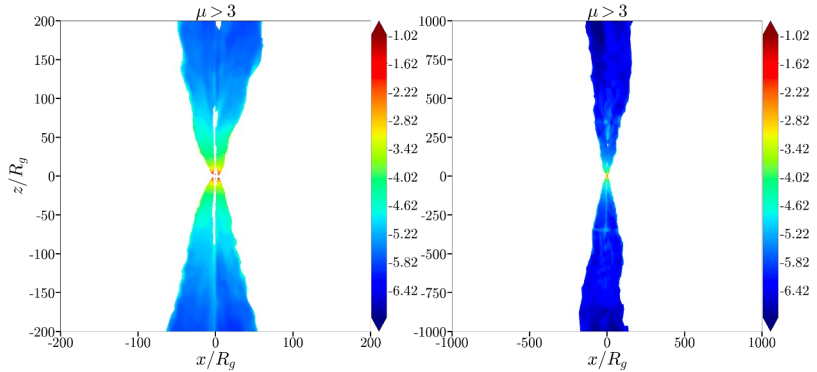


Base grid is (640 x 288 x 288) in spherical coordinates

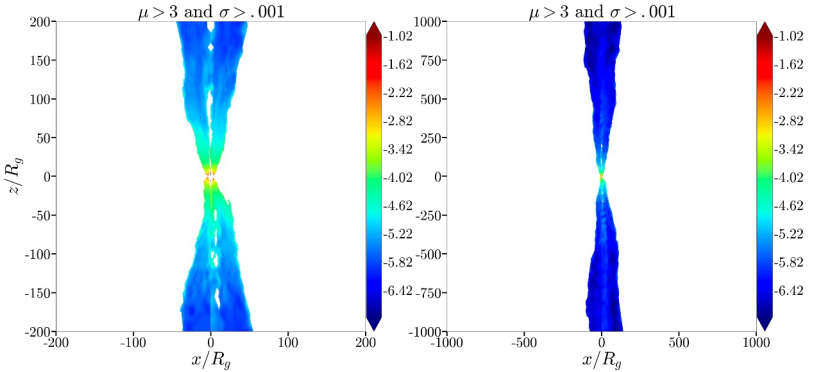
Adaptive Mesh Refinement allows jet to be resolved at large distances

How to pick out jets

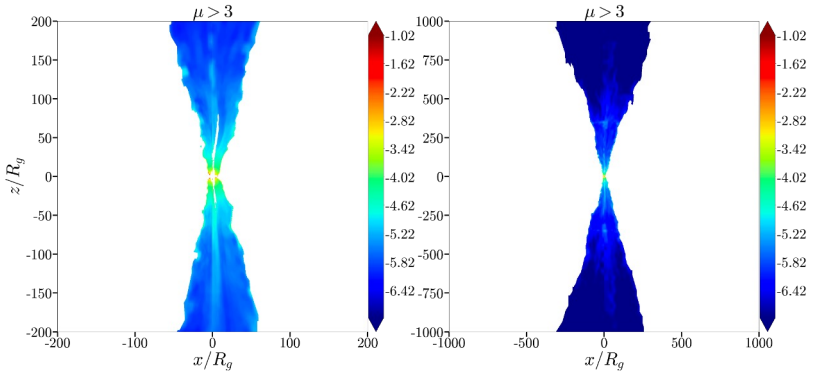
Infinite Ambient Medium



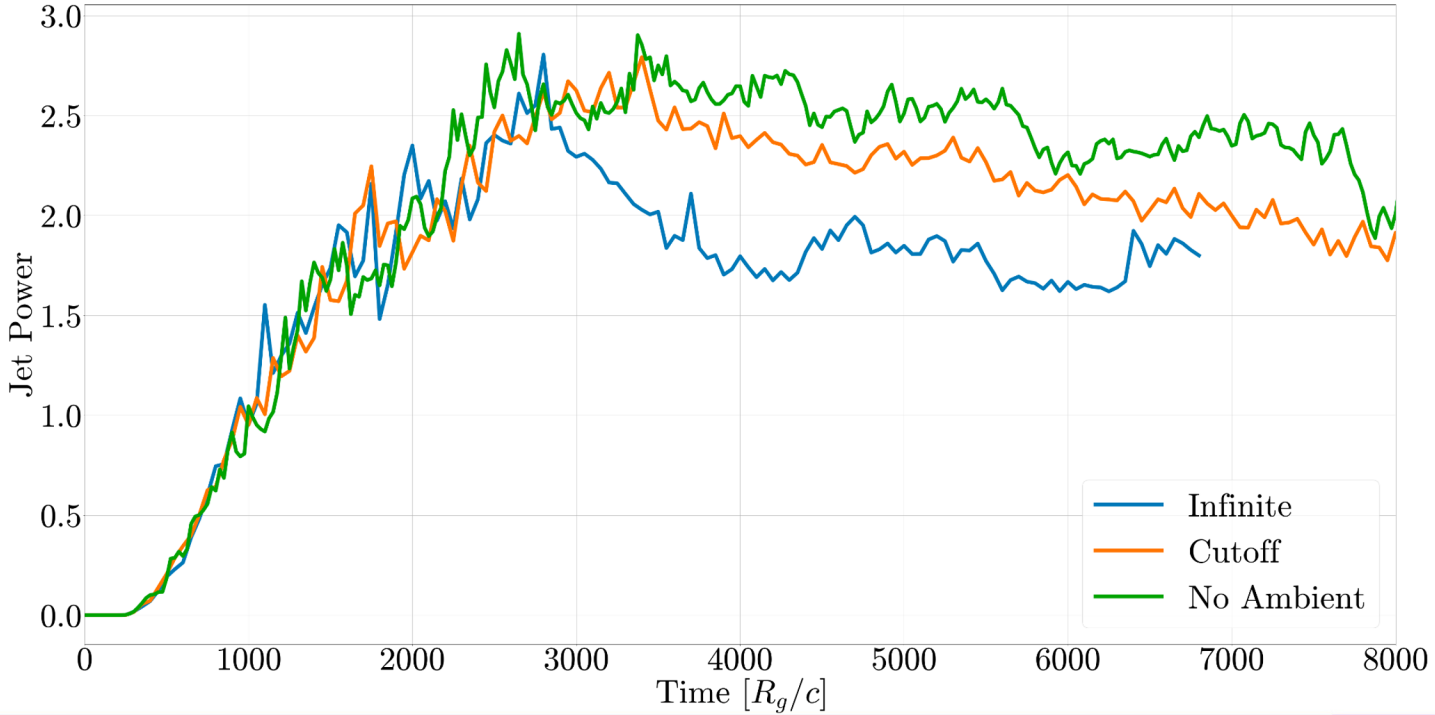
Cutoff Ambient Medium



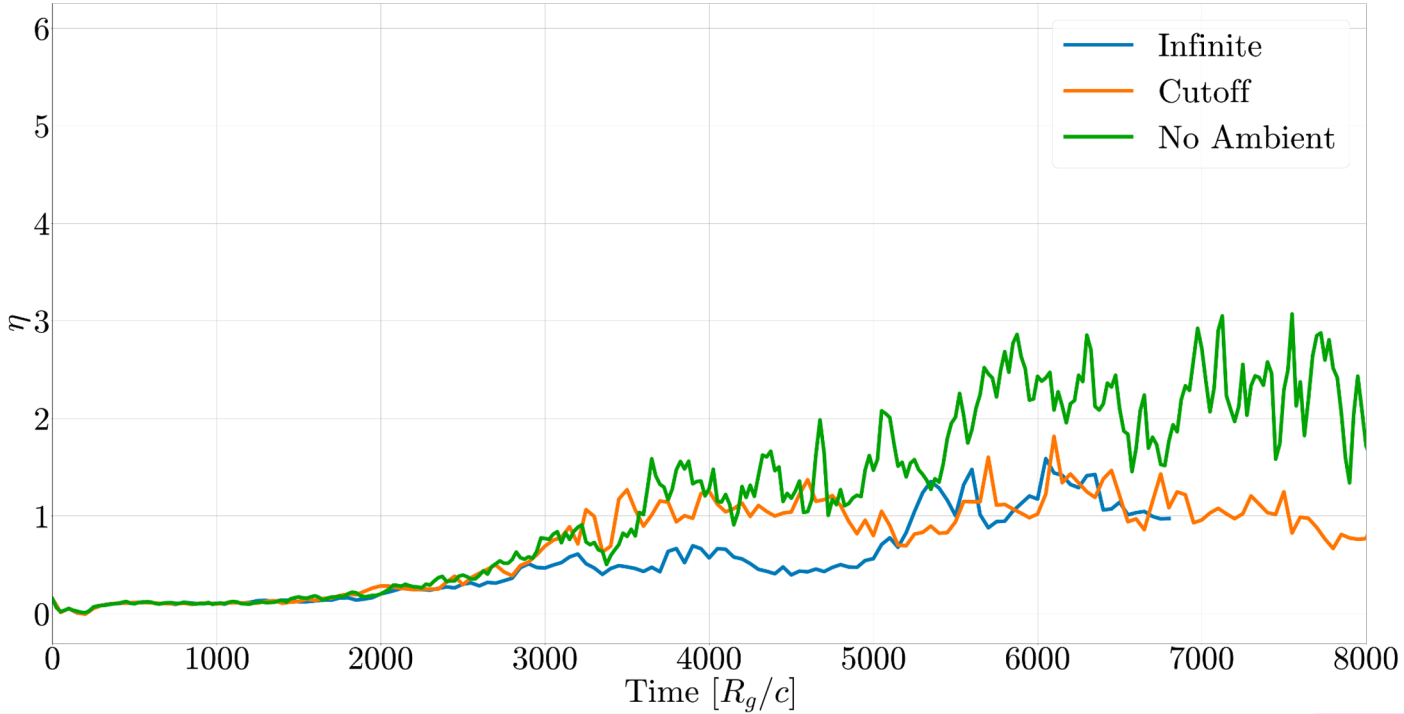
No Ambient Medium



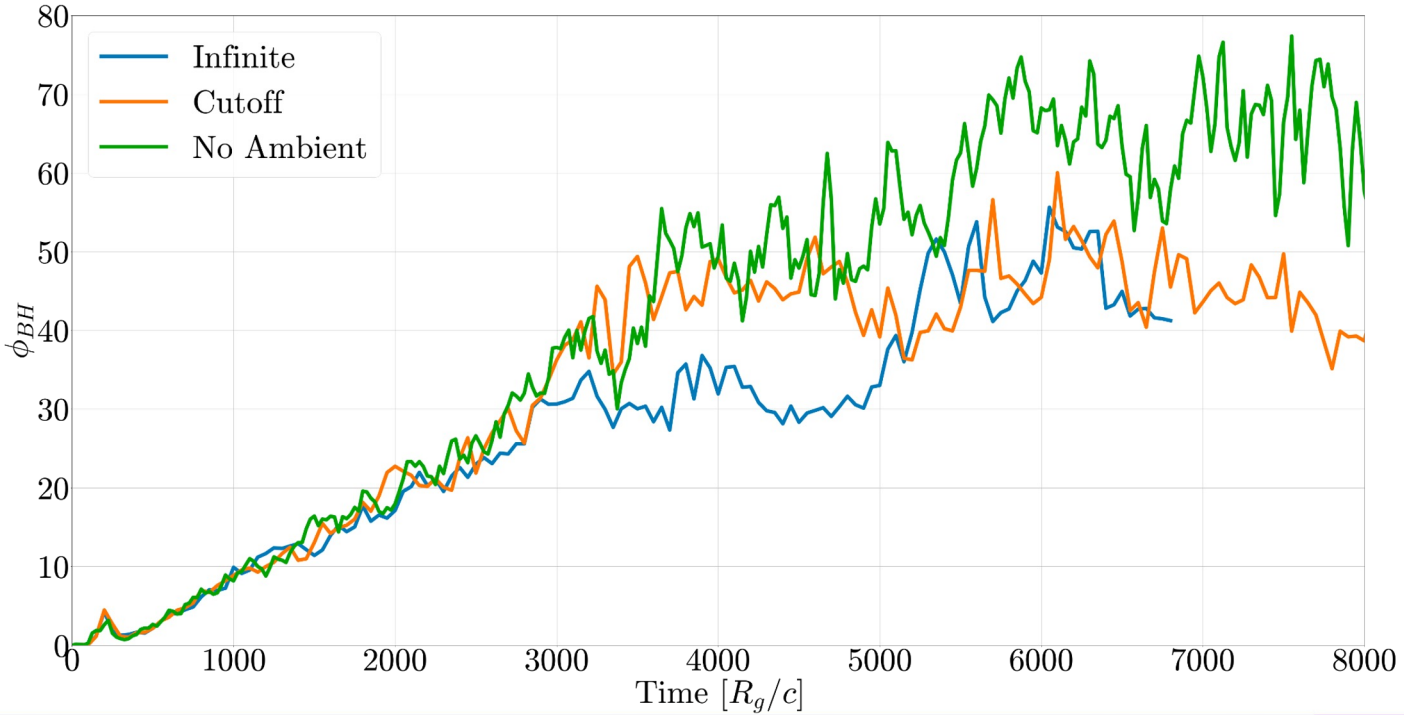
Jet power


3.0
2.5
2.0
1.5
1.0
0.5
0.0
Jet Power
0
1000
2000
3000
4000
5000
6000
7000
8000
Time $[R_g/c]$
Infinite
Cutoff
No Ambient

Jet efficiency



Magnetic flux on the black hole



Mass accretion rate