Numerical theory of accretion flow and jet launching:

A Study on the Galactic center.

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This project is financed by the European Community's 7th FP7/2007-2013 under the grant ITN 215212 "Black Hole Universe"

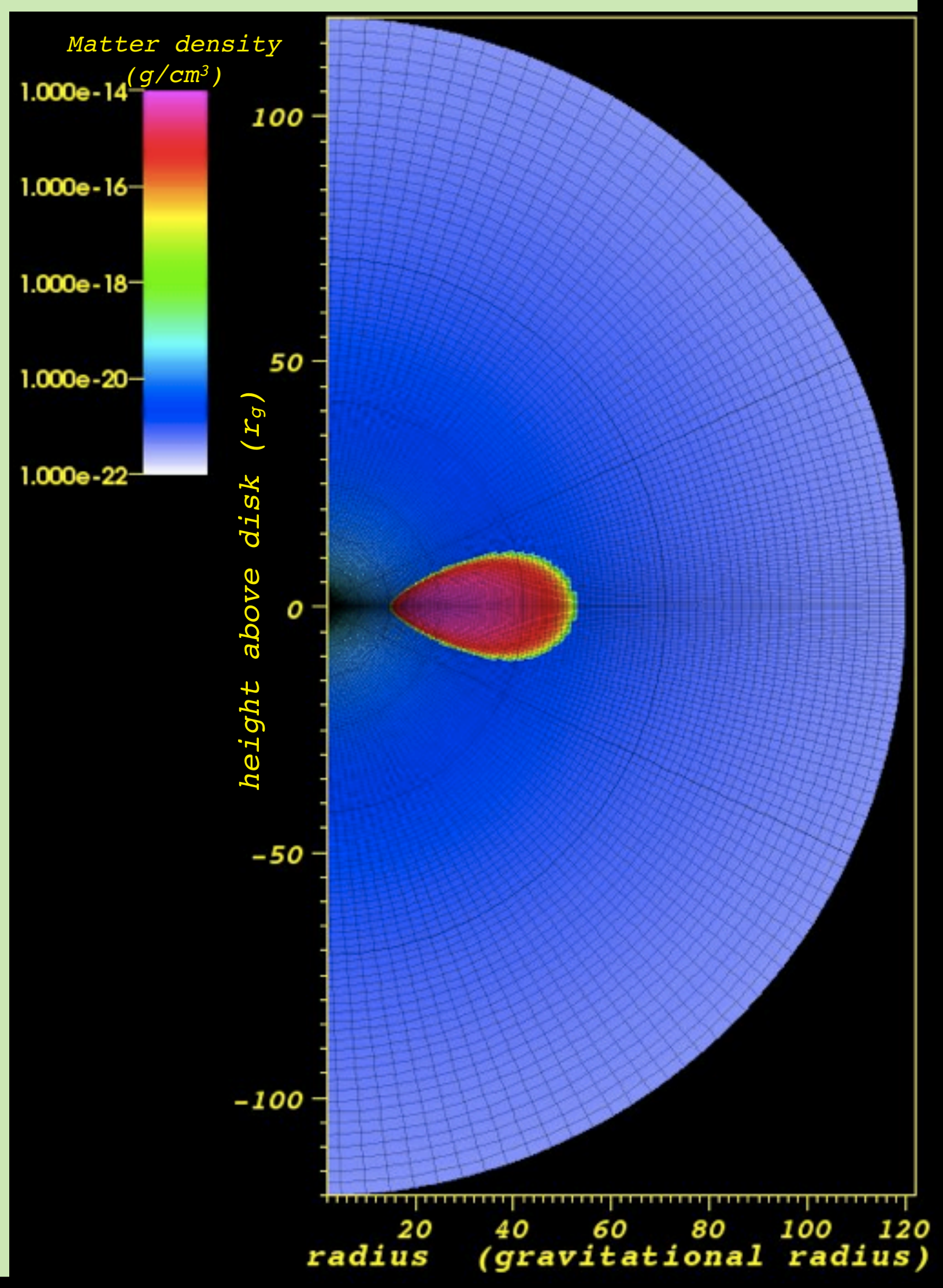
Introduction

We present preliminary results of a series of fully relativistic 2D magneto-hydrodynamic simulations (using Cosmos++ (Anninos ea. 2005)) of the accretion flow around a supermassive black hole (BH). Our simulations are some of the first that self-consistently include radiative cooling which allows us to compare our predictions to actual observations. In the present work we choose Sgr A* for our first tests as its accretion flow is relatively well constrained compared with other sources. We performed simulations with and without cooling, with and without spin, and for different initial configurations of the magnetic field. S. Drappeau (see her poster) has used our output to generate spectra to compare with observational data of the Galactic center.

Modeling Sgr A* with Cosmos++

We ran our simulation for 7 complete orbits which approximate a steady state. We discuss the consequences of changing the input conditions, especially for jet production. Even though these results can already give us insight into the jet launching structure, they should be confirmed in 3D. By exploring the parameter space we may place new constraints on the controversial question about the presence or not of a jet from Sgr A*.

The figure on the right shows the initial 2D state of the simulation (scale in density) for a 4.3×10^6 M$_\odot$ BH at (0,0). This is an edge-on view of the disk, the red shows the initial concentration of the material inside the accretion disk, set to values that capture the measured accretion rate onto Sgr A* (Bower ea. 2003; Marrone ea. 2006). Together with the matter density, the mesh grid domain used for the computation is represented. In addition, we assume axisymmetry.



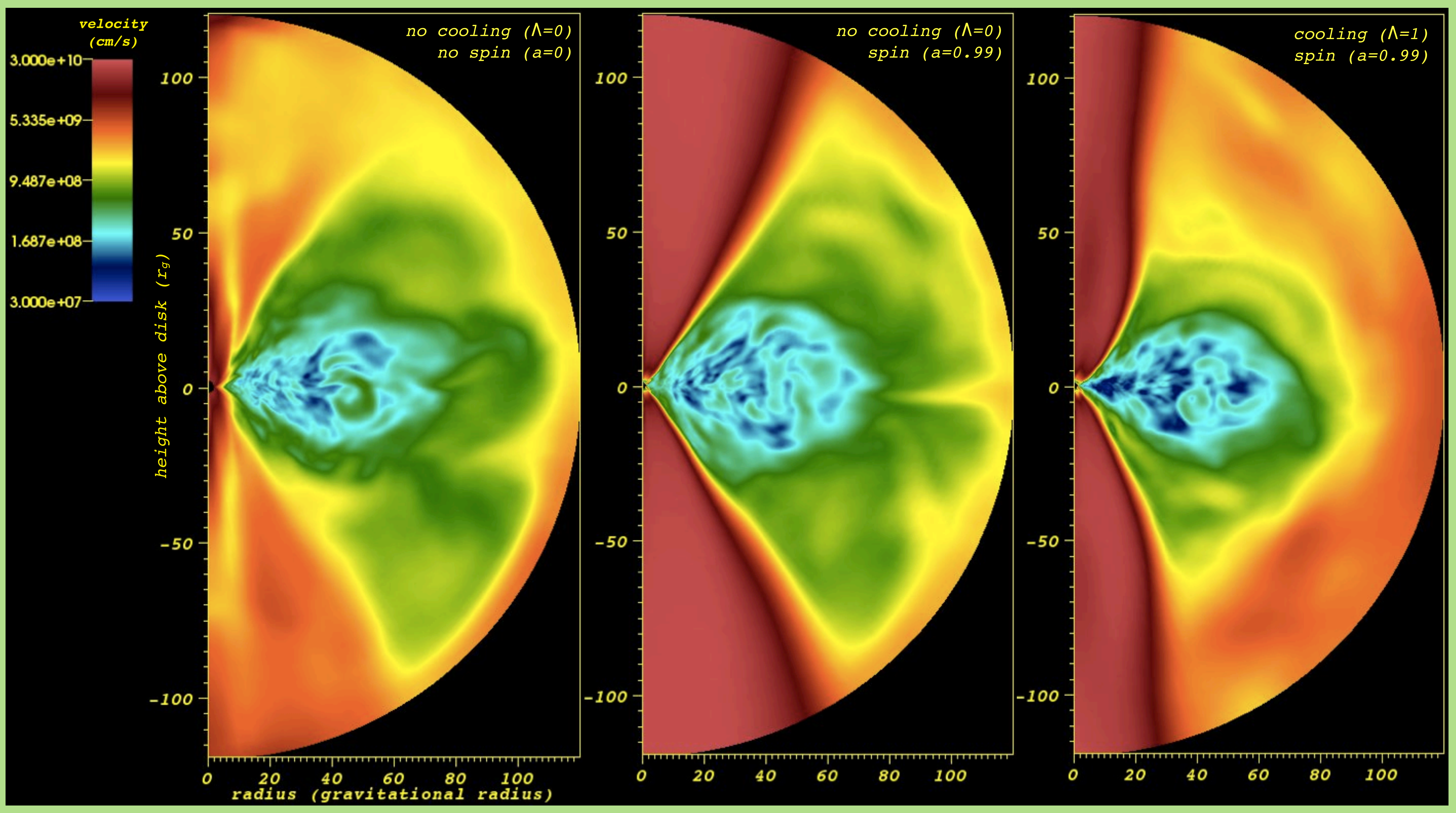
Results

• Influence of the initial parameters on the velocity magnitude of the outflows

These panels represent the time averaged velocity of the plasma over the last two orbits. We ran the models with the same initial magnetic field configuration (one poloidal loop crossing the disk, parameter B_p=1) to test the spin (parameter a) and the radiative cooling (parameter Λ).

•Spin influence:

As expected, the spin of the BH affects the structure of the jet. Even without spin, plasma is ejected along the axes, but it is less collimated and less relativistic. For the models with spin parameter of a=0.99, the jet is clearly more relativistic (Lorentz factor ≈ 3). For a non-rotating BH (a=0), the outflow is an order of magnitude slower which is not surprising as the magnetic field strength is also ten times weaker (see below).

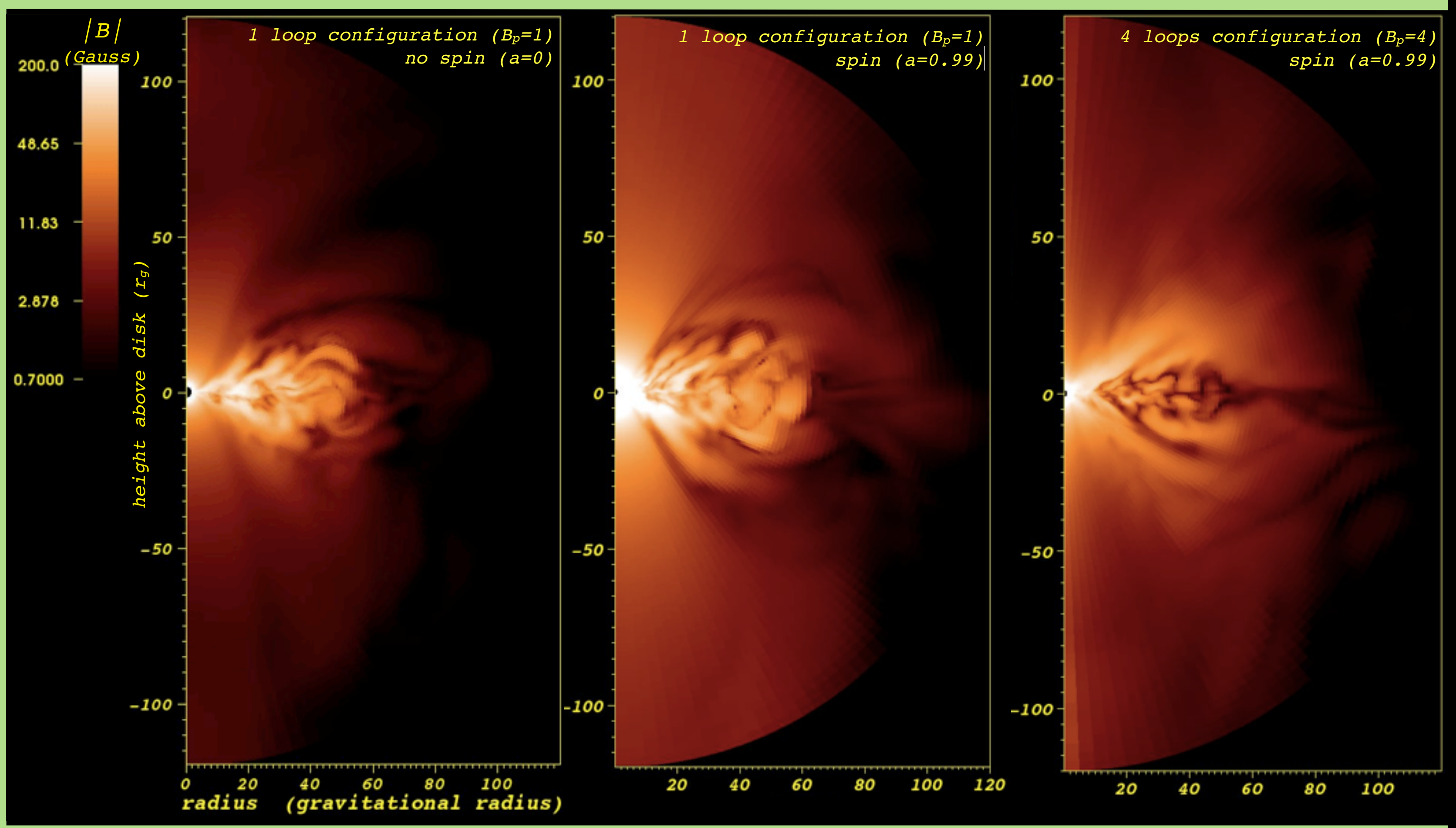


•Cooling influence

The presence of cooling also strongly influences the inner structure of the accretion disk and therefore affects jet launching. The model with cooling shows a more collimated jet likely due to a higher speed wind around the torus. The resulting inner accretion disk is flatter, because in the models without cooling the disk and jet are puffed up by gas pressure due to higher temperatures.

• Influence of the initial parameters on the magnetic field

In these three panels the colors represent the magnetic field magnitude (in Gauss) averaged over the last two orbits. We ran the simulation without radiative cooling and we adjusted the spin of the BH and the number of initial magnetic poloidal loops crossing the disk.



The magnetic field is an order of magnitude stronger in the spinning cases. The 4 poloidal loop configuration of the initial magnetic field seems in the end less organized and weaker inside the disk and away from the jet. But along the vertical axis its strength is comparable to the case with B_p=1 and a=0.99 in the middle panel and also launches a relativistic jet.

Conclusion & Future developments

- Radiative cooling, even in the very underluminous supermassive BH, Sgr A*, has a real visible influence on the accretion disk and the structure of the resulting jet.

- If those differences are also visible in the spectra, this is relevant for the interpretation of observations. For this reason we are working on producing spectra matching exactly the radiative cooling included in our simulations (see S. Drappeau's poster)

- Interesting results will be tested in future 3D simulations

Future Work

I will develop a semi-analytical outflow model to further extend the study of jet launching to the non steady state approximation. Such a model can only be tested with small BHs, whose variability timescales are directly observable. Thus, I have started a complementary project to study the evolution in the jet launching during the hard-to-soft state transition in accreting stellar mass BHs (X-ray binaries).

IAU Symposium 275: Jets at all Scales

Buenos Aires, Argentina, September 13-17, 2010