Long range RHD simulation of accretion disks of SMBH with inflow rate from high redshift cosmological simulations

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利用カテゴリ XC-Trial

Background & aim:

The objective of this project is to tackle the unknown origin of very large supermassive black holes (SMBH) in the early universe. Black holes as massive at $10^{9-10}M_{\odot}$ have been discovered all the way up to redshift z = 6–7 (Wu et al. 2015, Mortlock et al. 2011, Bañados et al. 2018). Their existence poses crucial questions on our understanding of black hole formation and growth. This objects are impossible to be created by accreting at the Eddington rate. Thus, there has been a lot of discussion around the different mechanisms and theoretical origins involved in their formation. The problem lies in that the study of this objects is very difficult due to these objects being embedded in early galaxies. This means that simulations of these objects need to account for the medium around them.

This is particularly problematic with our current technology, since cosmological simulations, that can study galaxy formations, lack the precision to study the AGNs (Shlosman et al. 2016). On the other hand astrophysical simulations for accretion disks don't go further than a few thousand Schwarzschild radii. Thus there is an information gap between the SMBH and the medium that feeds it.

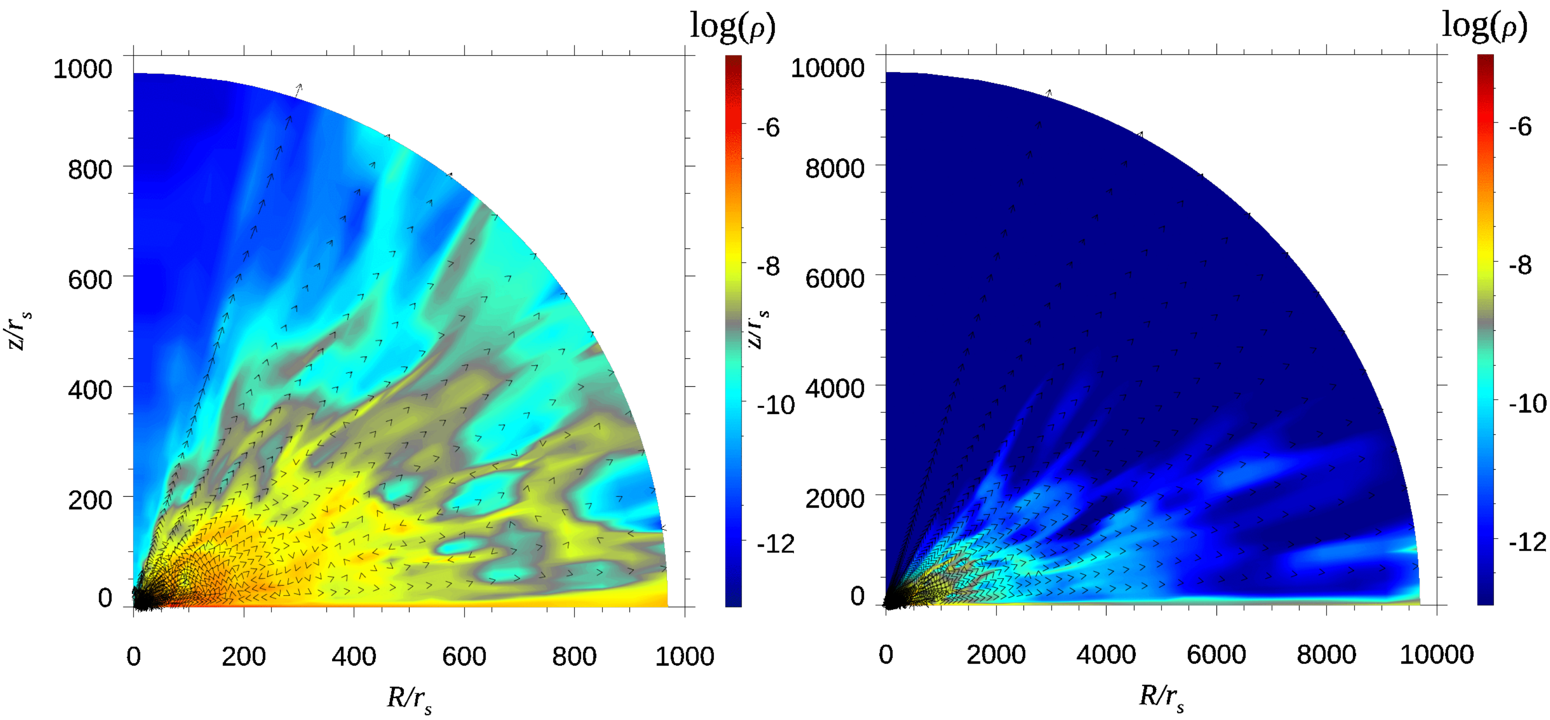
The aim if this project is to study the growth rate of SMBH under the outer conditions that cosmological simulations provide. This way we will obtain a floor value (constrain) for the initial seed mass needed in other to obtain a $10^{9-10}M_{\odot}$ BH at high redshifts. As a secondary goal, once we have a simulation that covers the area between cosmological and astrophysical simulations, we can also then provide more realistic jets data for the cosmological counterpart. This will help create a better, and more realistic, model of galactic formation at high-redshift with a very large embedded SMBH.

Methodology:

In order to achieve our goal we use the two-dimensional radiation-hydrodynamical (RHD) simulation model (Ohsuga et al. 2015). With it we solve the full set of RHD equations including the viscosity term. This approximation to the problem is specifically useful thanks to the use of the flux limited diffusion (FLD) approximation developed by Levermore and Pomraning (1981). Which allows us to study the quasi-steady structure of the super-critical disk accretion flows around our SMBH. These type of simulations have a high degree of free parameters that we can set to match the conditions determined by the cosmological simulations. The problem remains that cosmological simulations data stops at around 0.1pc ($\sim 10^8 r_s$ for a seed of $10^3 M_{\odot}$), and astrophysical simulations reach till around $10^3 r_s$. The problem of trying to expand high resolution simulations of the accretion disk is the high computational cost. Thus in order to study these cases without losing precision we broke the size of the box in smaller more manageable sizes. To do so we communicate the results of one box to the other through the inner and outer boundary conditions.

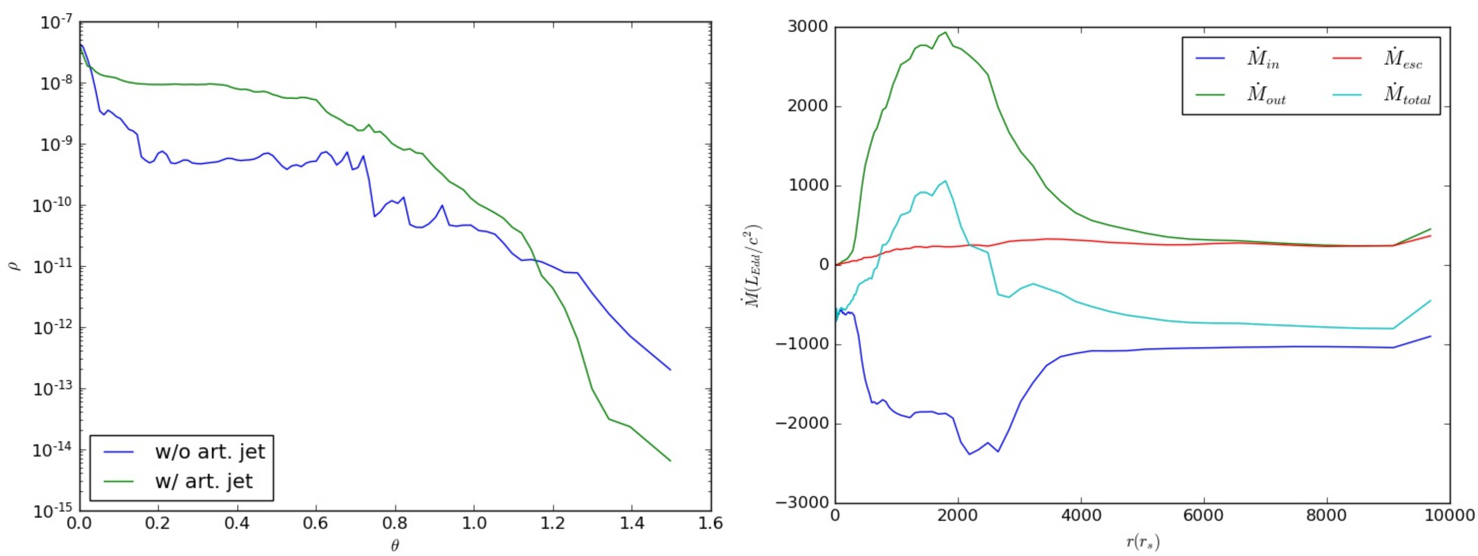
Results:

As a first stage we simulated from $2-10^3 r_s$, in this stage, once the quasi-steady state was reached, we say a bulge developing as shown in Fig. 1:



Figures 1 & 2: First step simulation (left) with a $10^3 M_\odot$ and an infall of $10^3 L_{\mathrm{Edd}}/c^2$. Second step (right) with an expanded box $20-10^4 r_s$.

In this stage we see the circular motion of gas spreading beyond the outer boundary which means that we need to extend the box. For the second stage we expand to a point where there was no more substructure (bulge) at the outer boundary, see Fig. 2. In this second stage we introduced an artificial jet to obtain the same results.



<u>Figures 3 & 4:</u> (Left panel) Mass flow rate ($\rho * v$) comparison between first step (blue line) and second step (green line) at $10^3 r_s$. (Right panel) Mass inflow of the second step as a function of the radius.

In Fig. 3 we can see that the addition of an artificial jet helps us recover the same trend in both simulation though the coverage is different. Further and more precise calibration will aid in recovering better matching results.

Now that we have a range for where no substructure is found, between $6000 - 8000 r_s$, see Fig. 4, we can expand from there to $10^6 r_s$ and check if in that area the matter behaves as expected which would allow us to extrapolate the results for farther areas. This is still a work in progress.