I. Vertical Shear Instability and Photoevaporative winds

L. Flores-Rivera[1], M. Flock[1] & R. Nakatani[2]

[1] MPIA, GERMANY
[2] RIKEN, JAPAN

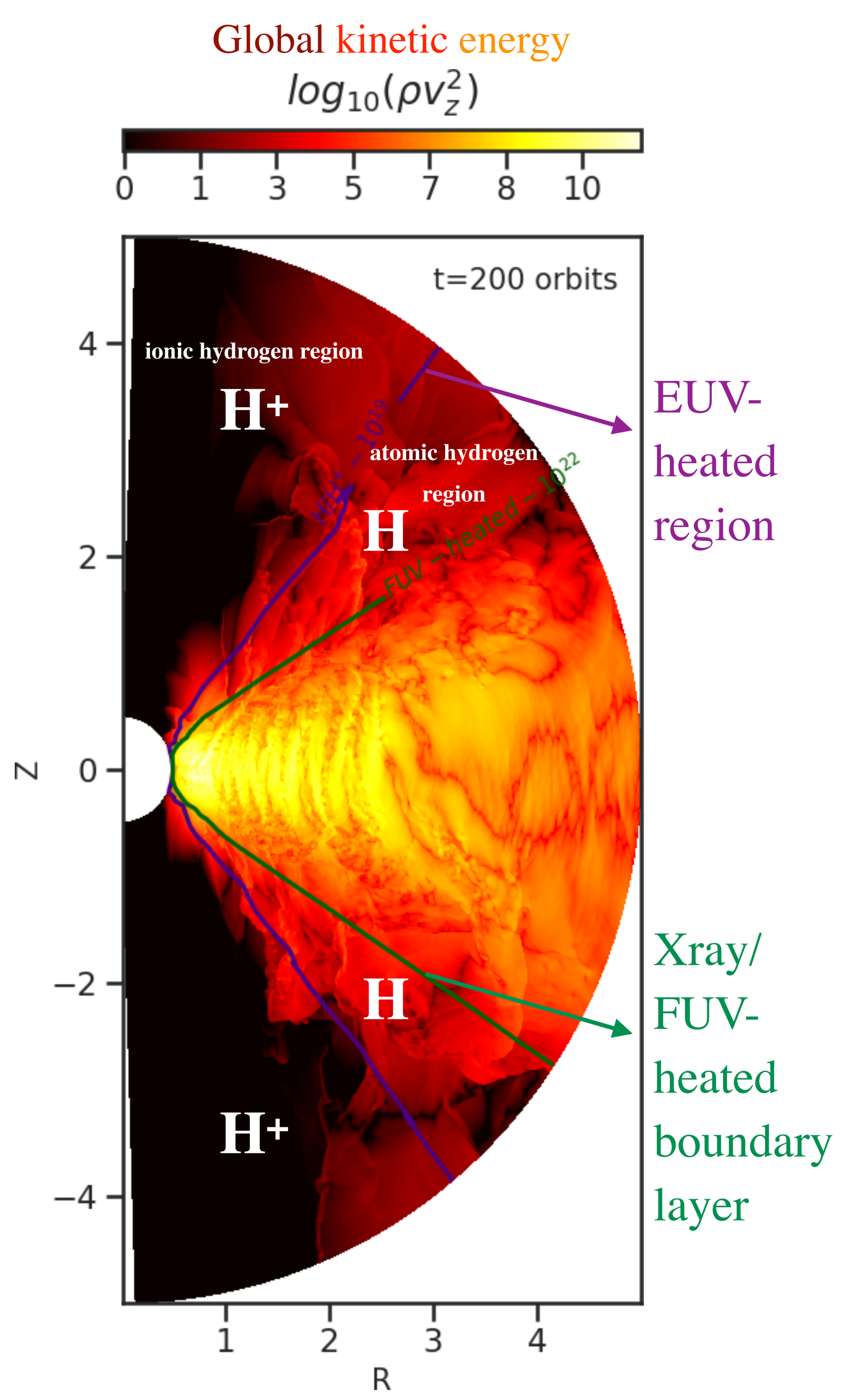
flores@mpia.de

Abstract

Aims. Our aim is to investigate how the Vertical Shear Instability (VSI) could influence the thermal photevaporation driven-winds on the surface of protoplanetary disks.
Methods. We perform a global HD simulations using the PLUTO code (Mignone+2007). We adopt a global isothermal accretion disk setup, 2.5D (2 Dimensions, 3 Components) which covers a radial domain from 0.5 to 5.0 AU and an approximately full meridional extension. In our simulations, the highest resolution covers 203 cells per scale height.
Results. Our results show VSI activity operating throughout the entire disk until reaching our density floor 0.003 cm^{-3} at $H_R = 13$. The location for the EUV-heated region is located at a column density of 10^{19} cm^{-2} and a $H_R = 9.7$. The X-ray/FUV-heated boundary layer is located at 10^{22} cm^{-2} and $H_R = 6.2$, making it necessary to introduce the need of a hot atmosphere. For the 203 cells per H_R we found the so-called 'body modes' to have a higher growth rate and a full saturation after 70 local orbits.

Background

In recent years Hydrodynamical (HD) models have become important to describe the gas kinematics in protoplanetary disks, especially in combination with models of photoevaporation and/or magnetic driven-winds. We expect the VSI to become important in regions where the gas is no longer coupled to the magnetic field (Turner et al 2014; Dzyurkevich et al. 2013). The effects of the VSI together with realistic thermal profile in the disk is not so well known.

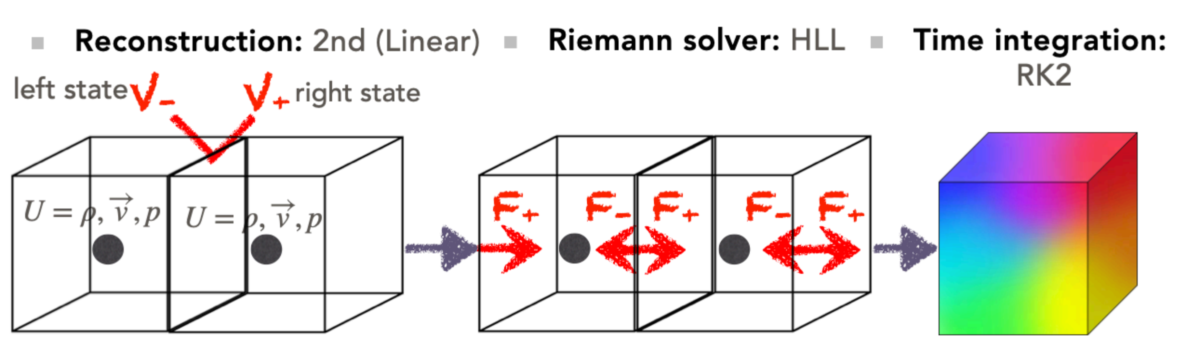


Model

The accretion disk setup in equilibrium in cylindrical coordinates (R, Z) are defined in Nelson et al. 2013.

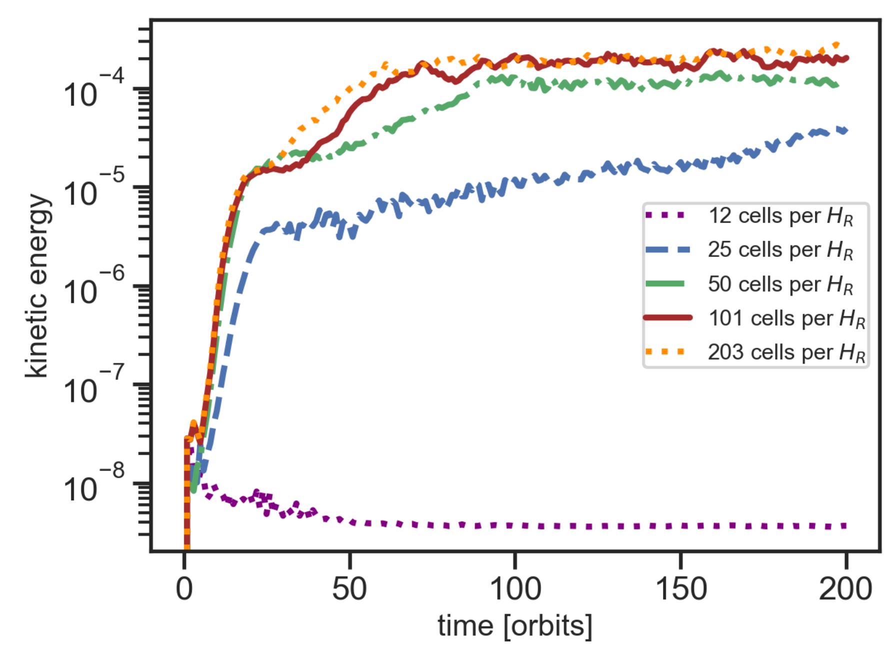
Resolution cases

Resolution cases
12 cells per H_R
25 cells per H_R
50 cells per H_R
101 cells per H_R
203 cells per H_R



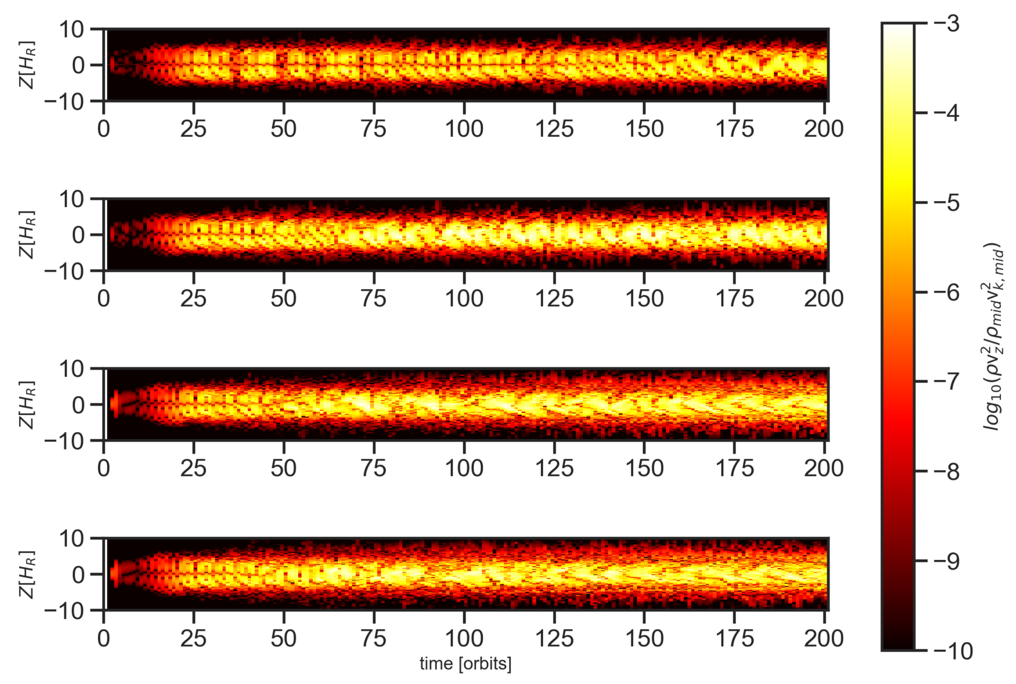
Results

I. How does the level of saturation for the **global kinetic energy** looks like at different resolutions?



— For the two highest resolutions, the body modes are growing faster until reaching saturation level after 90 orbits.

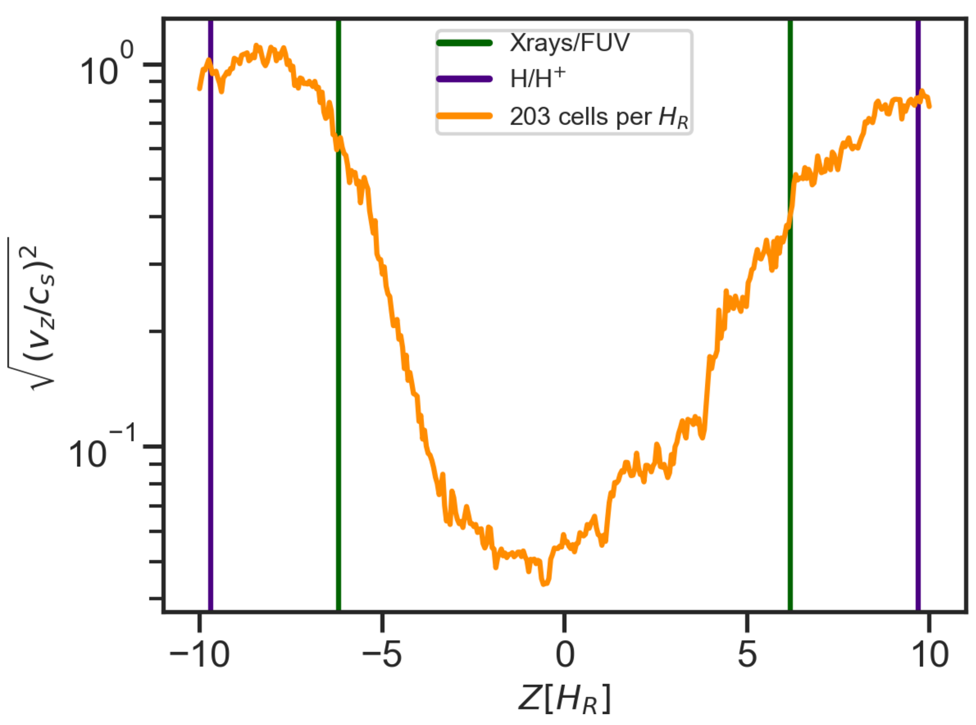
II. How does the **local kinetic energy** looks like at different resolutions?



— No VSI activity within the first 25 orbits due to the vanishing of the vertical shear in the midplane.

—The growth of the body modes increase with resolution, threatening the upper and lower hemisphere.

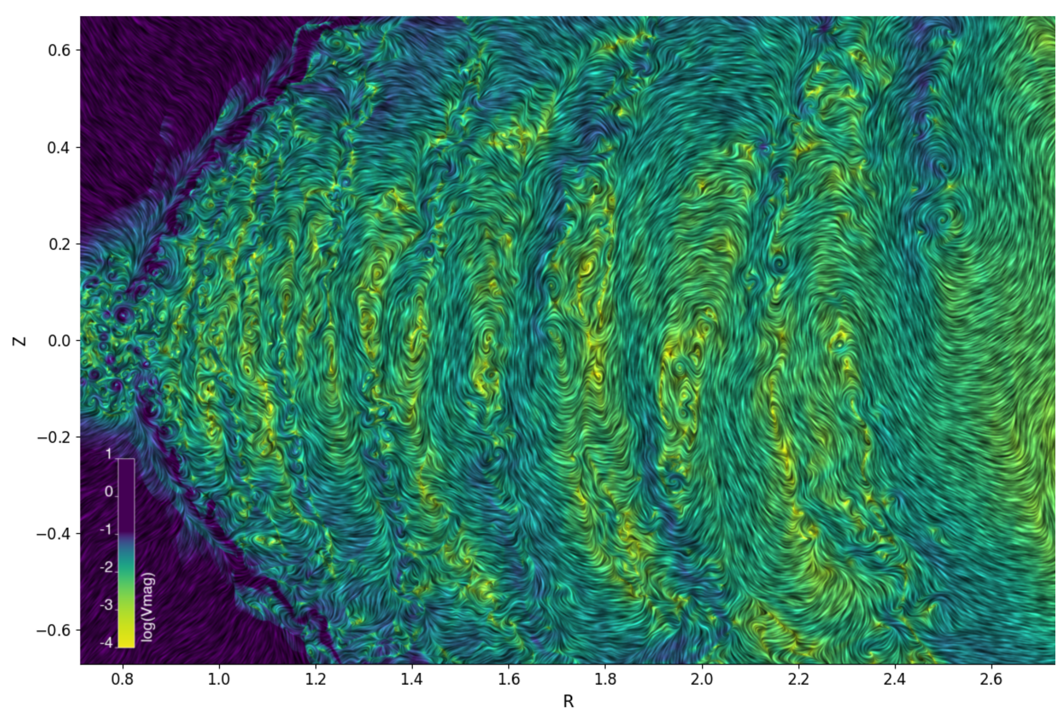
III. How does the averaged profile of the **vertical velocity** looks like for the highest resolution?



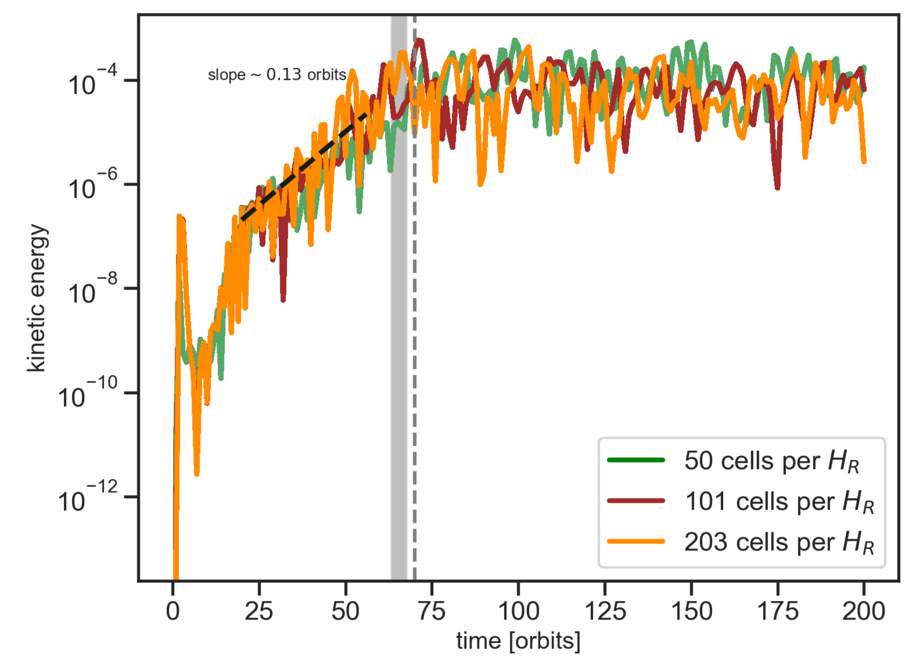
— The vertical velocity increases to levels of several tens of percent at the expect wind base at $H_R = 6.2$.

Discussion

When applying the Line Integral Convolution (LIC) method to visualize the gas flow, we notice small scale vortices in the *r-Z* plane. These happen at $H_R < 5$, therefore, being more important for dust evolution.



Time evolution of the local kinetic energy in the midplane (Fig. below) follows the same trend as the global one. The body modes have a growth rate of 0.13 orbits. The solid vertical gray lane represent the saturation of the 203 case, whereas, the dashed one represent the saturation for the 101 case. This confirms the early generation of the body modes for higher resolutions.



Conclusion

- Our VSI operates throughout the entire disk until reaching our density floor at $H_R = 13$.
- We see a clear dependence of the body modes on resolutions. For the highest resolution, the growth of the body modes saturates after 70 orbits.
- We encourage the use of high resolution (≥ 50 cells per H_R) to properly resolve for VSI.

References

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