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Gas flow into the vicinity of gas giants and formation of circumplanetary disks

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Abstract

We have performed radiation hydrodynamic simulations of the formation of circumplanetary disks (CPDs). In order to properly compute the temperature structure of the CPD, we employed an equation of states that considers effects such as dissociation of hydrogen and helium and hydrogen ionization. The region near the planet's deep potential well reached very high temperatures – yet, we still observe a disk-like structure to form in our simulations.

1. Introduction

The gas flow into the vicinity of a forming gas giant governs the formation of the planetary atmosphere as well as that of potential regular moons. Intuitively, a CPD is thought to form around a sufficiently massive planet due to the conservation of angular momentum. However, recent studies have shown that the circumplanetary gas can instead form an extended envelope rather than a thin, rotationally supported Keplerian disk. This was found in cases where the temperature is very high near the planet [1, 2]. Thus, calculating the temperature of the accretion flow properly is important to determine the disk structure.

2. Method

We performed three-dimensional radiation hydrodynamic simulations of a global protoplanetary disk section with an embedded Jupiter-mass planet. The planet is located at 3.5 AU away from the central solar-mass star and treated as a simple point-mass with a softened gravitational potential. The code used is a modified version of NIRVANA-III code [3, 4, 5]. We employed the static mesh refinement technique around the planet to provide sufficient resolution within the planet's Roche lobe, where the CPD forms.

We moreover adopted an equation of state with variable adiabatic index, γ [6, 7]. Notably, this includes the reduction of the effective γ via the endothermic reaction of hydrogen dissociation, which becomes important at around 2000 K in the density regime we are interested in. The ionization of atomic hydrogen and helium, that lower the adiabatic index at higher temperature, are also included. We adopted a fixed ortho-to-para ratio of 3:1 for molecular hydrogen.

3. Results

The peak temperature at the very center of the CPD can exceed 10,000 K when properly resolving the planet's gravitational well. The widely used adiabatic approximation with a constant adiabatic index of $\gamma = 1.4$ can be adopted for most of the planet's Hill sphere. We, however, found a small area where the adiabatic index drops to $\gamma \approx 1.1$ in the very inner part of the accretion region near the planet.

As found in previous hydrodynamic and radiation-hydrodynamic simulations [e.g., 1, 2, 5, 8], our simulations also exhibit the poloidal flow into the Hill sphere of the planet. Figure 1 shows the density profile of a vertical slice of the CPD region. The angular momentum profiles of the disks formed in our simulations show almost-Keplerian rotation when the softening-length is small enough. Unlike in isothermal hydrodynamic simulations, we observed a slight precession of the CPD, which we attribute to overturning motions (in regions where $\gamma \approx 1.4$), perturbing the otherwise regular poloidal flow pattern.

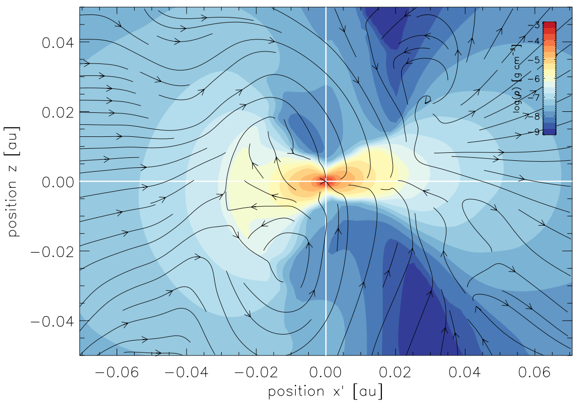

Figure 1: Edge-on view of the logarithmic density profile of the CPD region. The left side of the plot is the nearest to the central star.

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References

[1] Szulagyi, J., Masset, F., Lega, E. et al., 2016, MNRAS, 460, 2853

[2] Szulagyi, J. 2017, ApJ, 842, 103

[3] Ziegler, U. 2004, JCoPh, 196, 393

[4] Ziegler, U. 2011, JCoPh,, 230, 1035

[5] Gressel, O., Nelson, R. P., Turner, N. J., & Ziegler, U. 2013, ApJ, 779, 59

[6] Tomida, K., Okuzumi, S., & Machida, M. N. 2015, ApJ, 801, 117

[7] Tomida, K., Tomisaka, K., Matsumoto, T., et al. 2013, ApJ, 763, 6

[8] Tanigawa, T., Ohtsuki, K., & Machida, M. N., 2012, ApJ, 747, 47