DENSITY AND TEMPERATURE DISTRIBUTION OF MASSIVE CIRCUMSTELLAR DISKS USING FLUX LIMITED DIFFUSION APPROXIMATION.

Rogel Mari Sese, *Center for Computational Sciences, University of Tsukuba, Tsukuba City, Ibaraki Pref., JAPAN 305-8577 (rmdsese@ccs.tsukuba.ac.jp)*, Taishi Nakamoto, *Dept. of Earth and Planetary Sciences, Tokyo Institute of Technology, Meguro-ku, Tokyo, JAPAN 152-8551*, Masayuki Umemura, *Center for Computational Sciences, University of Tsukuba, Tsukuba City, Ibaraki Pref., JAPAN 305-8577*.

Background

Massive star formation is one of the major unsolved problems in astrophysics. Currently, there are two contending theories for massive star formation. The first involves a core-collapse scenario similar to low-mass stars, where material is accreted onto the protostar from a circumstellar disk. Due to the high radiation flux from the central protostar, such disks are predicted to have an unstable structure and would disappear within 1 Myr. On the other hand, the second theory involves the merging of several low and intermediate mass protostars and competitive accretion. However, the stability of these systems and the stellar merging are difficult to simulate due to the different processes involved.

Recent observational evidences revealed the existence of circumstellar disks around several massive protostars. In most observations, outflows are also present perpendicular to the disk plane. However, due to limited resolution, the disk structure itself was not fully resolved.

In this work, we simulate the disk density and temperature distribution by taking into account the radiative transfer along the disk structure. Obtaining a detailed disk structure is vital, both for theory and observations, in understanding the accretion mechanism and formation process of massive stars.

Disk Model and Numerical Method

We modeled the system using a 2D axisymmetric flared disk model in spherical coordinates (Figure 1). The density at each radial division was determined based on the hydrostatic equilibrium along the vertical direction. The inner radius was obtained from the stellar luminosity and dust sublimation temperature (1500K).

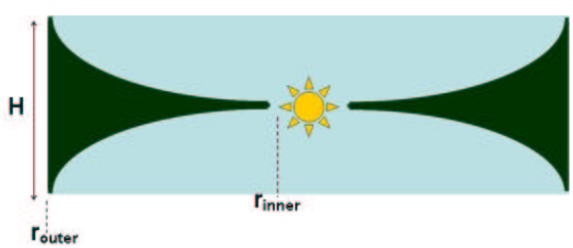

Figure 1: 2D Flared Disk Model

To solve the radiative transfer, we developed our own code using flux-limited diffusion (FLD) approximation proposed by Levermore and Pomraning. The FLD approximation introduces a flux limiter, λ, to solve the problem of causality, making it valid for both optically thick and thin regimes. We then solved the diffusion equation using finite difference methods to obtain the radiative equilibrium configuration of the disk.

Results of Test Calculations

We performed preliminary test simulations in 1D, similar to that of the disk midplane. The temperature distribution for both optically thin and thick case (Figure 2) were obtained by assuming a constant density distribution and using parameters similar to the Cepheus A HW2 protostar. In the optically thick regime, the computed temperature distribution provides an exact fit with the analytic solution. However, in the optically thin limit, discrepancies occurred between the analytic and computed values. The difference may be due to the expression for the flux limiter. It is possible that a more accurate solution can be obtained using a different flux limiter or by increasing the grid resolution. In both cases, dust vaporization was not considered.

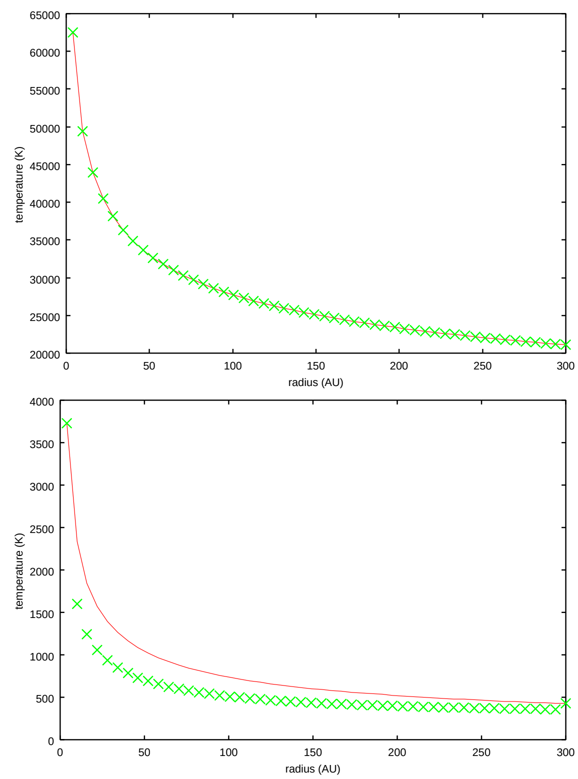

Figure 2: Temperature Distribution for optically thick (upper) and optically thin (lower) 1D disk. Solid lines denote the analytic solution.

Conclusion and Future Works

Currently, we are developing the 2D code in spherical coordinates. We have obtained the initial density distribution for a flared disk of similar parameters. In future works, we will consider the wavelength-dependent opacity and effect of different gas, dust vaporization and composition to obtain the spectral energy distribution of the disk. Developing such code is vital in understanding the disk dynamics and can serve as a basis for a full radiation hydrodynamic code in the future.