Japan Geoscience Union Meeting 2010
(May 23-28 2010 at Makuhari, Chiba, Japan)

PEM030-11 Room: 303 Time: May 26 10:04-10:17

Reference velocity method: a new scheme to solve a centrifugally supported disk

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Young stars are often associated with disks consiting of gas and dust. These disks are supported mainly by the centrifugal force against the gravity. Although pressure and magnetic force play essential roles in the evolution, they are weaker than the gravity. Thus it is not easy to compute these forces accurately, since truncation error in the centrifugal force is much larger. We have developed a new scheme named reference velocity method in order to overcome the difficulty.

The reference velocity method decompose the velocity into two components: reference velocity (known) and residual (unknown). We find that the centrifugal force due to the reference velocity appears as a source term in equation of motion for the residual velocity. We set the reference velocity so that the centrifugal
force reduces the effective gravity. We solve the modified hydrodynamical equation numerically and obtain much smooth and accurate solutions.

Besides the effective gravity, the modified hydrodynamical equations contain advection by the reference velocity and Coriolis-like force due to spatial change in the reference velocity. The advection velocity is evaluated at the cell surface without interpolation concerning the reference velocity. Thus the truncation error is elliminated and numerical errors are greatly reduced. This method is similar to Hada's method for magnetohydrodynamics. He decomposed magnetic field into a dipole component and the rest and succeeded in reducing numerical error in the current density derived as the derivative of the magnetic field.

This talk shows simulations of a protoplanetary disk with a planet. The planet is assumed to have a circular orbit. The computation box is 5 by 5 in area and 0.3 in the height, when meaured in unit of the orbital radius. The resolution is 0.5 % of the orbital radius. The planet mass is 1.4 % of the stellar mass. We also present simulations of an accreting binary and those of a spiral galaxy.

Keywords: protoplanetary disk, numerical hydrodynamics