# Binary Star Model

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## 1 Some General Concerns

Radiation pressure is on dust and dust drag gas. The motion of dust gas mixture will be decoupled when $n_d n_g$ is too small.

Geometrically thin dusty circumbinary disk need high resolution in equatorial plane. If the actually thickness of the disk is $0.2 - 1$ $AU$, the finest grid should be $0.05 - 0.25$ $AU$ at least.

Optically thick disk in UV/Optical range is a challenge. Especially for geometrically thin disk. Geometrically thin means that it is cold and its motion is more like Keplerian motion. To realize this feature in simulation, one need to add cooling. Optically thick implies that the dust in the outer region of the circumbinary disk does not experience radiation pressure thus one need to track the evolution of light - or radiation transfer equation - to get the right radiation pressure in optically thick case. No radiation pressure at large radii in the disk also implies that the disk is in Keplerian motion otherwise it will collapse.

To get a stellar wind that will not accelerate forever. The momentum added to the dust gas mixture is to vanish at some radii. This does not imply that the dust gas mixture will fall back because if the mixture has escape velocity at that time, it will escape. This two fate nature - fall back or escape - may suggest that circumbinary disk is sensitive to the wind condition and the existence of steady circumbinary dusty disk is a rare phenomenon. But the universality of circumbinary disk suggest that circumbinary disk is very sensitive to the wind condition and the existence of steady circumbinary disk is rare. But the universality of circumbinary disk suggest that there is some common physics behind it. For example: AGB star property like pulsation. Dust gas and radiation transfer. A loose requirement for the secondary.

## 2 A gas-dust one fluid model with cooling and primitive ray tracing method

Gas+dust:

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \vec{v}) = 0 \tag{1}$$

$$\frac{\partial \rho \vec{v}}{\partial t} + \nabla \cdot (\rho \vec{v} \vec{v}) = -\nabla p + \rho \vec{f}_{grav} + \vec{F}_{rad} \tag{2}$$

$$\frac{\partial \rho E}{\partial t} + \nabla \cdot [(p + \rho E)\vec{v}] = \rho \vec{f}_{grav} \cdot \vec{v} - \Lambda \tag{3}$$

$$\vec{F}_{rad} = \frac{\rho \kappa Q L \exp(-\tau)\vec{r}}{4\pi c r^3} \tag{4}$$

$\vec{F}_{rad}$ is the radiation pressure. Where $\vec{r}$ is the vector from the AGB star to the cell. $L$ is the luminosity of the AGB star. $\kappa$ is the constant mass weighted opacity and $Q$ is the radiation efficiency on the dust gas mixture. $\tau = \int_s \kappa(s)\rho(s)ds$

$\vec{f}_{grav}$ is the force due to gravity.

$E = \frac{1}{2}v^2 + \frac{3}{2}\rho RT$.

$\Lambda$ cooling of gas.

Cooling:

$$\Lambda = \Lambda_{H_2O} + \Lambda_{CO} \tag{5}$$

$$\Lambda_{H_2O} = \Pi n(H_2) n(H_2O) \tag{6}$$

$$\frac{1}{\Pi} = \frac{1}{L_0} + \frac{n(H_2)}{L_{LTE}} + \frac{1}{L_0}\left[\frac{n(H_2)}{n_{1/2}}\right]^{\alpha}\left(1 - \frac{n_{1/2}L_0}{L_{LTE}}\right) \tag{7}$$

Their meanings and values are in (1993 Neufeld & kaufman).

No regrid, no scattering, just interpolation. Not computationally intensive.

The advantage of this model is that it can easily be expanded to multispecies of dust, juts add a dust evolution equation (see 2006 Woitke)

## 3 Algorithm

Calculate $\vec{F}_{rad}$ on some specific lines and interpolate the others.

Calculate $\Lambda$ based on previous time information.

Advance with Riemann solver.