Volume Title
ASP Conference Series, Vol. **Volume Number**
Author

Hydrodynamics of mass transfer in binary star systems

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Abstract. No analytic formulation is currently available to correctly treat the exchange of mass and angular momentum between an AGB star and its low-mass main-sequence companion. The goal of our research is to derive prescriptions for the rates of mass and angular-momentum transfer by wind in long-period binary systems, based on 3D SPH simulations. In this poster, we present the first steps towards a consistent modeling of such mass transfer. A special attention is paid to the physics of mass loss by the giant star. One of the major achievements of our approach is the ability to fully reproduce for the first time in 3D the standard dust-driven wind model developed by Bowen.

1. 3D simulation of a dust-driven pulsating wind

We use the N-body SPH code Phantom developed by Daniel Price (Price & Federrath 2010). The wind is modeled by ejecting smooth (geodesic) spheres of gas particles in the SPH simulation. Rotations between two consecutive spheres avoid geometric artifacts.

The equations describing dust-driven winds derived by Bowen (1988) have been implemented in the Phantom code. These equations take into account the radiative acceleration and cooling due to the formation of dust, and the stellar pulsation is approximated by a piston. Figure 1 shows the comparison between the 1D simulation of Bowen and our 3D SPH simulation. We consider an AGB Mira-variable star with a pulsation period of 350 days ($M_* = 1.2\,\mathrm{M}_\odot$, $R_* = 1.26\,\mathrm{au}$). In this simulation, the wind is launched beyond the dust formation front at $r = 4.8\,\mathrm{au}$. The 3D SPH simulations can accurately reproduce the shock features, as well as the amplitudes and spatial variation of the wind velocity, pressure and temperature.

2. Binary system (Mira-like)

We simulated the interaction of the dust-driven wind with a binary companion. The system consists of a 1.2+0.6 $M_\odot$ binary with an orbital period of 67 years. As shown in Fig. 1, an accretion wake forms (Fig.1 right). A typical spiral structure develops as seen for example in R Sculptoris (Maercker et al. 2012) or AFGL 3068 (Mauron &

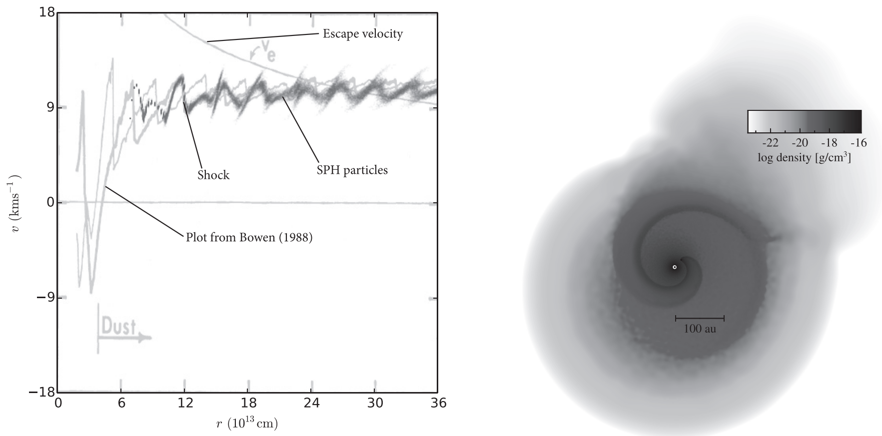

Figure 1. Left: the velocity structure of a Mira-like wind. The thick bold line represents the results of the 3D SPH simulation. The background plot comes from Bowen (1988). All parameters are the same as in Bowen's paper: $M_* = 1.2\,\mathrm{M}_\odot$, $R_* = 1.26\,\mathrm{au}$, $T_* = 3\,000\,\mathrm{K}$, $v_* = 8.6\,\mathrm{km\,s^{-1}}$, $\rho_* = 1.2 \times 10^{-16}\,\mathrm{g\,cm^{-3}}$. Right: the density cross section of the SPH simulation of a Mira-like binary system with Bowen's wind. There are about 10^6 particles in this simulation.

Huggins 2006). We estimate that for this system, of the order of a few percents of the ejected wind mass is accreted by the companion.

3. Future developments

We are currently developing tools to improve the description of the gas chemistry (molecule and dust formation) to have a consistent estimate of the opacity that is needed to calculate the radiative acceleration and the cooling. We are also working on an improved treatment of accretion using variable mass particles to provide more accurate estimates for mass- and angular momentum accretion by the wind. When Phantom is stabilized, we will investigate in more detail accretion via wind Roche lobe overflow (Mohamed & Podsiadlowski 2012), study how it depends on the input parameters and provide realistic prescriptions of the transferred quantities to be implemented in 1D stellar evolution codes such as Binstar (Siess et al. 2013).

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