ROTATION AND MIXING IN BINARY STARS

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Abstract. Rotation in massive stars plays a key role in the transport of nuclear-processed elements to the stellar surface. Although a large fraction of massive stars are binaries, most current models rely on the assumption that their mixing efficiency is the same as in single stars. This assumption neglects the perturbing effect of the binary companion. In this poster we examine the manner in which the rotation structure of an asynchronous binary star is affected by the presence of a companion. We use the TIDES code (Moreno & Koenigsberger 1999; 2017; Moreno et al. 2011) to solve for the spatially-resolved velocity of several concentric shells in a star that is tidally perturbed by its companion and focus on the azimuthal component of the velocity field, $v_\varphi(r,\theta,\varphi)$. The code includes gravitational, centrifugal, Coriolis, gas pressure and viscous forces. The input parameters for the example in this poster are: stellar masses $m_1 = 30M_\odot$, $m_2 = 20M_\odot$, equilibrium radius $R_1 = 6.44R_\odot$, eccentricity $e = 0.1$, orbital period $P = 6^d$, rotation velocity $v_{rot} = 0$, kinematical viscosity $\nu = 5.56$ cm$^2$/s, shell thickness $\Delta R = 0.06R_1$. The binary interaction produces time-dependent shearing flows in both the polar and in the radial directions which, we speculate, may lead to a more efficient transport of angular momentum and nuclear processed material in binaries than in their single-star analogues. Key unresolved issues concern the value that is adopted for the viscosity, the inner radius to which tidal forces are effective, and the interplay between tidal flows and convection.

Fig. 1. Left: Map of azimuthal velocity on surface of $m_1$ at periastron. Azimuth angle $\varphi=0$ is defined at the sub-binary longitude, indicated with the white line. Light (dark) colors represent flows in the same (opposite) sense as stellar rotation. Middle: plots of azimuthal velocity as a function of $\varphi$ at co-latitudes starting from the equator ($90^\circ$) toward the north pole (with vertical shifts of 0.2rad/d for clarity in the figure). The vertical dash line corresponds to the center of the map and the dotted lines enclose the longitudes that are displayed in the map. Right: plots of azimuthal velocities at the equator for the five shells that were modeled (with vertical shifts of 0.2rad/d for clarity in the figure).

Fig. 2. Same as Fig. 1 for apastron. The map corresponds to the same hemisphere as shown in Fig. 1.