MODELLING THE COMMON ENVELOPE PHASE IN CLASSICAL NOVAE

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ABSTRACT. Preliminary results of 1– and 2– dimensional hydrodynamical calculations of the common envelope phase in very slow classical novae are presented. We show that frictional deposition of orbital energy and angular momentum into the envelope can potentially induce mass loss. Specifically, we find that despite rapid initial spin–up of the envelope, ejection of mass in the orbital plane continues at a substantial rate.

1. INTRODUCTION

It is well known that classical novae display spectra resembling F–supergiants at visual maximum, implying photospheric radii of 10^{12}– 10^{13} cm. Typical nova binary separations of 10^{11} cm place the secondary deep inside this vastly extended "common" envelope. The secondary experiences a drag as it moves supersonically through the envelope, which dissipates both orbital energy and angular momentum. The possible hydrodynamic effects of the deposition of the drag energy in a torus located at the binary separation were discussed in the solitary work by MacDonald (1980). He was able to reproduce the mass loss characteristics of slow novae by including the drag energy (but not the angular momentum) in his 1–dimensional numerical calculations. Due to its potential consequences for the recently revised hibernation scenario for novae (Livio, this volume) and for the evolution of magnetic novae (Stockman, this volume), along with the inherent lack of spherical symmetry of deposition, the need to reproduce MacDonald's results in spherical symmetry and of multi–dimensional hydrodynamical calculations is clearly evident.

2. THE 1–D MODELS

To repeat the MacDonald (1980) calculations, first a hydrodynamical model for a very slow nova was generated using the Starrfield et al. (1985) 1–D spherically symmetric code, where no mass ejection occured. The input system parameters were chosen to be $M_{WD} = 1.0\ M_{\odot}$, $\dot{M}_{acc} = 10^{-9}\ M_{\odot}$, and $Z_{acc} = Z_{\odot}$. When the envelope expanded past the secondary, drag energy (calculated assuming the Bondi–Hoyle picture) was added to the zones at the location of the secondary. We included the energy released by accretion of matter onto the secondary in our calculations as well.

3. THE 2–D MODELS

The 2–D problem was set up in a manner similar to the one described by Bodenheimer and Taam (1984). The 1–D model for a very slow nova (see §2) near visual maximum was relaxed to hydrostatic equilibrium on a 30 × 20 spherical polar grid. The gravitational potentials of the primary (as a point mass) and the secondary (smeared over a ring located at the binary

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separation) were included. Drag energy and angular momentum were deposited self consistently in this initially non-rotating, hydrostatic slow nova envelope at the position of the secondary, within roughly an accretion radius. The resulting evolution was followed in time until a quasi-steady state was achieved.

4. RESULTS

For the input parameters described in §2 above, the 1-D models implied hydrodynamic ejection of the matter outside the orbit. Typical velocities achieved were several hundred km s^{-1}. Since no rotation was included in these calculations, the results represent an upper limit only. Note that the results of MacDonald (1980) were confirmed by our calculations.

The 2-D results provide for the first time the exact geometry of the flow. After a few orbital periods, matter at the edge of the grid in the orbital plane ($R = 5 \times 10^{11}$ cm) reaches escape velocity. The deposition of angular momentum caused a rapid spin-up of the envelope in the vicinity of the secondary. The flow of matter down the density gradient in the orbital plane kept advecting the angular momentum downstream, which prevents a corotating region from forming near the secondary. The drag luminosity decreased due to envelope rotation, but the combined effect of the remaining drag luminosity, the centrifugal force due to rotation, and a density gradient in the orbital plane maintained an outflow. This outflow was found to be confined to an opening angle of roughly 15 degrees from the orbital plane at an average outflow rate that approaches $2 \times 10^{-6} M_{\odot}\ yr^{-1}$ at the end of the calculation.

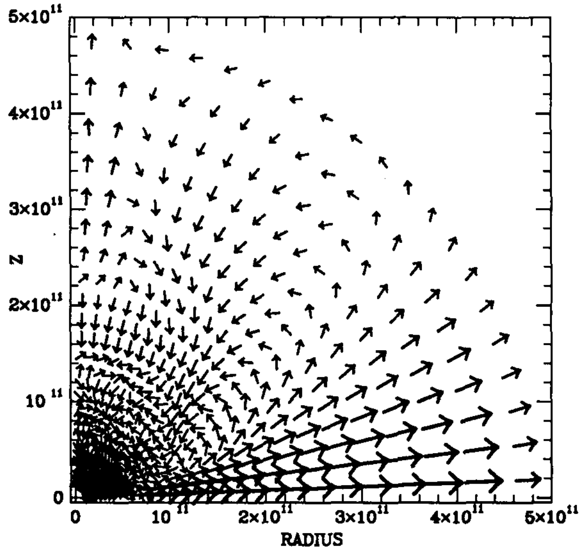

Fig. 1. Velocity field after 4 orbital periods. The circle denotes the position of the secondary. The velocity at the edge of the grid in the orbital plane is 800 km s^{-1}

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