NOVAE AS LOCAL THERMONUCLEAR RUNAWAYS

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Accretion occurs from a disc or possibly from polar caps in the case of magnetic novae: it is doubtful whether a spherically symmetric and homogeneous envelope configuration is eventually reached. A number of works (see in particular Kippenhahn & Thomas, 1978, King & Shaviv, 1978, Livio & Truran, 1988) adressed to this problem. Even if the matter can be almost homogeneously distributed - at least for high accretion rates - it is very likely that the chemical composition would not be uniform because of the shear mixing in the equatorial belt. Moreover, there can be temperature gradients. These and several non spherically symmetric factors (see the discussion of Tutokov & Yungelson, 1974, on the effects of rotation and magnetic fields) could lead to runaway only in a portion of the envelope. Instead of having a spherically symmetric explosion there would be a *local* thermonuclear runaway (LTNR). Estimates of Shara (1982) indicate that, with certain sets of parameters, the time for thermalization of the envelope would be much longer than the time to reach the conditions for the runaway and the outburst in such a case would occur only in a certain portion of the envelope. A non-spherically symmetric outburst could be the cause for the peculiar equatorial belts - polar caps geometry of the shells of many novae. There are other explanations (for instance interaction of the secondary with the expanding shell, like suggested by Livio and by Shankar et al. in this colloquium), but bidimensional spectroscopy seems to favour also difference in chemical composition in the envelope and in the polar caps (Duerbeck 1987) and high resolution H_α spectroscopy of Nova Cen 1986 hints that the blobs in the shell have formed at the time of the outburst (Bandiera & Focardi 1989) and cannot be explained by a spherically symmetric TNR model.

We studied the propagation of the thermal flows along the meridian in a hydrogen rich envelope accreted on a white dwarf (WD) assuming a 1D *quasistatic* model, including the effect of accretion that changes constantly the density. We tested the effects of inhomogeneities in temperature, with perturbations of different amplitudes and wavelengths, and also of small inhomogeneities in density and chemical composition - these, however, cause immediatly temperature gradients. The equations to be solved are the *continuity* equation (including a mass accretion rate, not necessarily uniform along the meridian), the *heat* equation, and one for the changes in chemical *composition* due to CNO burning. The exact form of these equations can be found in Orio, 1987. We included a simple form for the energy generation rate, a full equation of state from stellar evolution codes and the diffusion approximation for the radiative and conductive thermal flux. We did not include in this part of the work an equation of motion, because these calculations were stopped shortly before the onset of the TNR. At this point also propagation by convection becomes relevant (see Fryxell & Woosley, 1982, for the estimate of turbulent velocity close to the runaway). We take into account that not all the generated energy flows laterally parametrizing the fraction of radial thermal flux with a factor $(1 - \eta)$, the fraction of lateral flux being η. We suggest, on the basis of simple estimates, that its value should vary between 10^{-1} and 10^{-3}, but varied it even more. We are also presently analising with 2-D calculation what is the most reasonable range. We solved the equations with a fully explicit code, starting with a small envelope in place and assuming an inhomogeneity since the beginning of the calculation. This means imposing an arbitrary perturbation ΔT (or $\Delta\rho$ or $\Delta X(H)$) over a region of linear dimensions λ and following the evolution in time as a function of λ and ΔT (the results depend also on the size and wavelength of the perturbation). The burning layer is divided into cells subtending equal angles $\Delta\theta$. The difference equations are obtained after integrating the equations over the volume of each cell, to take the geometry of the problem into account. The full explanation of this method can be found in Orio & Shaviv, 1989.

The calculations were performed for different accretion rates, WD masses and for initial temperatures corresponding to very hot or to cooler WD's. Detailed results can be found in Orio, 1987. There is a range of parameters for which TNR would develop locally and expand on time scales of days (convection) or weeks (conduction): this could explain the slow rise to maximum of many novae observed since the beginning of the burst.

The most favourable conditions for a local TNR are:

a) high accretion rates,

b) hot and massive white dwarfs,

c) cooler white dwarfs of intermediate masses.

As a matter of fact most novae would be due to a *local* TNR and if it is not so this is due to *hibernation* that allows the envelope to thermalize during the phases of low accretion rate (see Shara et al., 1986). Our results also *exclude* that dwarf novae could be due to a TNR, because LTNR's are not favoured at very low accretion rates.

The next question and extremly important one is whether the LTNR extinguishes locally or propagates all over the surface and how it actually develops. 2-D calculations are being carried on with the explicit hydro-code SADIE (Arnold, 1985, modified by Müller, 1987), that can handle multidimensional problems in spherical coordinates (a description can be found in Mair et al., 1988, or Fryxell et al., 1989). The code has been further modified to handle our input physics, basically the same of the previous 1-D calculations. The variables in the equations are the total density, the density of hydrogen, helium and CNO, the energy density and the momenta in radial and meridional direction. For the cases close to the onset of the runaway the term of radiative fluxes and of accretion can be neglected.

We start with a density, temperature and chemical structure obtained by Starrfield et al. for a WD of 1.25 $M_\odot$ that has been accreting at a rate $10^{-9} yr^{-1}$, but modified it according to our 1-D results. The original temperature structure is maintained in a zone subtending 20° around the equator, but decreases by a factor that varies from the burning layer to the surface. There is a zone of transition from the high to the low temperature zone, but not very smooth, as the implicit 1-D code indicates unless $\eta << 10^{-3}$. This model has been evolved long enough in time to conclude that there is a definite delay between the expansion of material in the equatorial plane and in the other directions.

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