Nova ejecta Nova Proyect

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1 Introduction

Here we study the outburst of the nova, first looking for the general equations that describe the shock wave in the different phases and then getting closer to more sophisticated models and predictions of the interaction between the nova ejecta and the stellar wind companion in the case of SyRNe, that is, as we said, the objetive of this investigation.

2 Supernova/nova stages

In order to understand the expansion of the material we look for general equations that we can apply to both novae and supernovae, and then refine the application to SyRNe, so in order to understand the evolution of the nova ejecta, we will discuss the different phases and their characteristics.

2.1 Free expansion

As the expansion of the material begins the first phase is a free expansion, where we use energy conservation to describe some characteristics; we can make this approximation based on the light curves that we see, and that lead us to $E_0 = E_{SN}$, initial mass ejected $M_0 =\approx 2E_0/vo^2$ where the expansion takes place at $t = 0$, and initial velocity v_0, that are related trough:

$$E_0 = \frac{1}{2}M_0 v_*^2 + M_{ext}(R)(\frac{1}{2}v_*^2 + \frac{1}{\gamma - 1}\frac{P_*}{\rho_*})$$

Here the usual for supernovae is the condition $m_{ej} \gg$*swept up ISM*, that we have to prove if is still right for SyRNe, but in the case of SNe the energy losses are negligible because the *ISM* is not dense enough, so we can make the approximation $M_{ext} = (4/3)R^3 n m_p$ with $n \approx 1$ and we have the expansion at a constant velocity so $R \propto t$, also in the early expansion, we have $M_{ext}(R_{dec}) \approx M_0$ with R_{dec} the deceleration radius, that is to say, when the swept up mass is close to the ejected mass, radius that we can deduce from these equations that is:

$$R_{dec} \simeq (\frac{3E_0}{2\pi n m_p v_0^2})^{1/3}$$

and

$$t_{dec} = \frac{v_*}{R_{dec}}$$

This values evaluated for the typical kinetic energy of SNe $\sim 10^{50}$ erg and the typical velocities (tens of thousands km/s) leads us to R_{dec} of order of parsecs and t_{dec} that have order of one or a few hundred years.

So we have some initial features to describe the free expansion for SNe but **What happen with SyRNe?** In an attempt to reproduce the same procedure, we work with the same strategy but taking into account that the density of the surrounding medium is not homogeneous, so we describe the density with the mass loss rate and the wind velocity of the companion:

$$\rho(r) = \frac{\dot{M}}{4\pi r^2 v(r)}$$

and, for the wind velocity we use a beta law profile, that is: $v_{wind} = v_\infty(1 - \frac{R_*}{r})^\beta$ so mixing it together we look for an external mass M_{ext} integrating over this density profile, precisely from the radius of the RG to R_{dec}, to perform this integral we use $x = r/R_0$, $\alpha = R_*/R_0$ and $R_0 = 2R_*$, so doing the algebra we get to:

$$M_{ext} = \frac{\dot{M} R_0}{v_\infty} \int \frac{dx}{(1 - \alpha/x)^\beta}$$

The problem is that this integral have to be performed considering $\beta < 1$ because for larger values of beta there is no convergence.

2.2 Taylor-Sedov phase

This phase also knonw as the adiabatic phase, stands by the assumption that there is no heat exchange, the key condition is $m_{ej} \approx$*swept up mass* but here we keep seeing that energy is mostly conserved, and that is, the energy losses due to radiation by the accelerated particles in the process are neglected, which drives us to be concerned only in the adiabatic phase of the shock wave, evolution. So, to describe the radius of the shock for SNe we use the dimensionless shock coordinate $\xi_s = R^5 n m_p / E_0 t^2$ so the radius of the shock is given by:

$$R(t) = (\frac{\xi_s E_0 t^2}{\rho_1})^{1/5}$$

what leads us to:

$$v_s = \dot{R}(t) = \frac{2}{5}(\frac{\xi_s E_0}{\rho_1 t^3})^{1/5}$$

that is the velocity of the shock with ρ_1 the density carried by the shock. So, with this, we have that $R \propto t^{2/5}$ and for ξ_s we can get the value using the conservation equation and the value E_0 so $\xi_s = 2.03$, and form this we can study the age of SNe using $t = R/v$, but this is valid only if radiative losses are negligible, that is to say in the Sedov phase. So with this in mind, the question is **Can SyRNe reproduce this?** We don't know a priori if this will work in our context but we can assume that after the changes of the free expansion the nest stages should be more similar to the stages in SNe if we think that most of the interaction between the stellar wind of the RG and the nova ejecta is in the free expansion phase. So in order to have a clue of these, we will try to get the ages of some novae, either classical or recurrent ones, using particular values of ρ_1 that is, at this point, the most important variable that we are changing from one situation to the other.

So if we use ρ_1 evaluated at R_{dec} we can estimate the radius of the shock for novae at this phase and compare it to the SNe radius.