draft proyecto de investigacion

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1 Introduction/idea

This project is concerned on the symbiotic recurrent novae systems which are systems conformed by a white dwarf star from now on WD, and a red giant star (RG), in these kind of systems the RG transfer mass to the white dwarf by filling it's Roche lobe and tranfering mass into the inner Lagrangian point, and at this point the most common is to have an accretion disk around the WD sustained by the gravitational potential well of the WD....

More explanation and context...

2 What can we study from these systems?

In a first look we want to have a modest model of the interaction between the nova ejecta and the stellar wind by its companion, **bulk hydrodynamics**, but there are also other interesting concepts that we may want to study, maybe not deep enough to make models, but to make a review of the theoretical concepts related to the observational insights and in particular the **radiative transfer and photo-ionization models** which we would like to analyze to understand what kind of elements abundances and processes may be involved at this scales (ions, electrons and microphysics) in order to give a brief review of the main processes happening in these systems, all these with the global description of the outburst taking care about temperatures, densities and velocities and a little review of the observational aspects and the physics related.

The main systems that we want to study are T-CrB, RS Oph and V3890 Sagitarii, but the first two systems will be the principal subjects of analysis **the third one is actually just to have contrast and compare properties**.

3 Equations involved

In this section, we present some of the equations related to some phenomenological explanations. At the moment just for some standard variables of the system and some other that are just general equations that we need to adapt to the context.

For the fact that massive WD require less accreted material to drive an outburst, we have:

- Δm accreted layer of mass at the bottom of the disk (hydrogen rich)
- T_{ign} the temperature ignition threshold, it must be greater than $10^7 K$ (where CNO cycle ignites)
- r_b the radius where Δm is located.

Using the ED pressure and the ideal gas pressure, we can estimate a critical pressure: $P_{crit} = \frac{(RT_{ign})^{5/2}}{K_1^{3/2}}$ and then using the hydrostatic equation and the mass radius relations WD's: $R \propto M^{-1/3}$ we get to $\Delta m \propto M^{-7/3}$

The outburst recurrence time is given by:

$$P = \frac{\Delta m}{\dot{M}}$$

where $\dot{M}$ quantifies the mass loss rate from the companion star.

We can also make an estimation for the luminosity in the quiescent phase, because most of the luminosity comes from accretion, we can take $L \approx L_{acc}$ and $L_{acc} = \dot{E}_{grav} = \frac{GM\dot{M}}{R}$ and from the fact that at the peak of the nova outburst the luminosity approaches L_{Edd} we can estimate the amplitude of the outburst as the ratio of peak relative to quiescence, that is to say:

$$A \equiv log[\frac{L_{Edd}}{L_{acc}}] \approx log[\frac{4\pi c R(M)}{\kappa \dot{M}}]$$

It is important to have and precise idea of the distances in the system and that is to say the distance to the inner lagrangian point of both primary and secondary component for that relations we have:

$$l_1 = a[\frac{1}{2} - 0.227 log(\frac{M_2}{M1})]$$

and

$$l_2 = a[\frac{1}{2} - 0.227 log(\frac{M_1}{M2})]$$

where a is the distance from one star to the other... **ask Ileyk if the other equations that I have in the notebook are important to mention here**

The photosphere of the WD can be modeled initially with a radius that increases lineally with time **no eq here** until it reach a limit value:

$$R_\infty = \frac{3\bar{\kappa}\dot{M}_{ej}}{8\pi v}$$

and if L is assumed constant the effective temperature model T_{eff} for the photosphere expanding shell is:

$$T_\infty = (\frac{L}{4\pi\sigma})^{1/4} R_\infty^{-1/2}$$

ref: Carrol, Ostlie and D. Prialnik

Also for stellar wind we have a velocity profile given by:

$$v = v_\infty(1 - \frac{R_*}{r})$$

and we use that velocity profile to have an estimate description of the density of the wind in function of r that is given by:

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

ref: working with Ileyk

3.1 Stellar wind equations

3.2 Quiescence equations

Here we have some equations that are important to describe the system itself, that is, without thinking about the nova event, so here we describe the binary system and the accretion disk from the simpler to a little more sophisticated and further details to add to describe the system. The Euler equation in a

co-rotating frame is written:

$$\frac{\partial \mathbf{v}}{\partial t} + (\mathbf{v} \cdot \nabla)\mathbf{v} = -\nabla \Phi_R - 2\boldsymbol{\omega} \wedge \mathbf{v} - \frac{1}{\rho}\nabla P$$

This equation describes the any gas flow between the two stars. And in order to estimate the radius of the Roche lobe we can use:

$$\frac{R_2}{a} = \frac{0.49\, q^{2/3}}{0.6\, q^{2/3} + \ln\left(1 + q^{1/3}\right)}$$

This stands for an average analytic radius that is the radius of a sphere with the same volume as the Roche lobe, but there is a simpler expression we can use if we have $0.1 < q < 0.8$:

$$\frac{R_2}{a} = \frac{2}{3^{4/3}} \left(\frac{q}{1+q}\right)^{1/3} = 0.462 \left(\frac{M_2}{M_1 + M_2}\right)^{1/3}$$

also the ratio between the radius of the roche lobe from primary to secondary can be estimated with:

$$\frac{R_1}{R_2} = \left(\frac{M_1}{M_2}\right)^{0.45}$$

4 Phases of the nova

4.1 Fireball expansion phase

4.2 Optically thin phase

4.3 Dust formation phase

5 Ideas

We can plot the accretion mass rate vs the WD mass and have lines were the outburst recurrence time P is the same and then identify in that plot the systems that im studying with P and M_{WD} to estimate $\dot{M}$ and compare it to other methods and estimations

We can estimate the roche-lobe radius of the systems I want to study using the relations given by the quiescence equations and see how far it is from the estimations on the papers.

6 Draft material

apuntes de Supernovae Ryan Norton:

Las supernovas se dan cuando estrellas de main sequence queman todos sus metales hasta el hierro/Fe (Iron) y en este punto la masa de su núcleo supera el límite de Chandrasekhar: $1.4M_{\odot}$ y la presión de electrones degenerados no es capaz de sostener el colapso, core collapse into a white dwarf is necessary the result for stars with mass below this limit. El núcleo va a colapsar con una free fall timescale given by $t_{ff} = (\frac{3\pi}{32G\rho})^{\frac{1}{2}}$

En este contexto se suelen dar dos tranportes de energía: exothermic and endothermic reactions, while the first one release energy giving pressure support the last one does the opposite, there are two processes that can absorb energy: photodisintegration and electron capture processes.

Desintegración de qué? Del iron 56 que es el isotopo más común de hierro, en particular for the photodesintegration, se da con rayos gamma de alta energía que hacen que un núcleo de iron 56 se convierta en helio por ejemplo. Para entender la cantidad de energía absorbida en este proceso es necesario considerar los potenciales químicos. En cambio el otro proceso que es la captura de electrones se da si el gas tienen condiciones de densidad que lleven a una energía tal que el proceso se pueda dar.

When the iron core (remember that we hace an iron core and outer layers of oxigen, silicon, neon, etc) approaches nuclear densities the core can resist further compression and then the core rebound. Eso es lo que envía una onda la onda de choque que conocemos como supernova. El output optico de una supernova es del orden de $10^{47}J$ durante alrededor de un año.

Cómo podemos estimar roughly la energía que libera una supernova? Si usamos la energía potencial gravitacional E_{GR} para una estrella de masa M y considerando $E_{GR} = \frac{GM^2}{R_2} - \frac{GM^2}{R_1}$ y como $R_2 << R_1$ la energía es básicamente $\frac{GM^2}{R_2}$ Esta energía es al menos 10 veces la energía que se consigue con photodesintegration o con neutronization y dos ordenes de magnitud mayor a la enegía que vemos, so where does the energy go?

Se cree que hay una stage antes de la formación de una estrella de neutrones. What are the mains ways in which liberated energy is carried away from the supernova?

La menos efectiva es la energía transportada por los fotones del orden de $10^{42}J$ en cambio la energía cinética del material expelido es del orden de $10^{44}J$ pero de todas maneras queda mucha energía, esa energía es llevada por los neutrinos.

Tipos de supernova: SE clasifican como supernovas de tipo I si el hidrógeno está ausente, y II si está presente en su espectro visible

Table 7.1 Main types of supernovae

Supernovae type Ia (SN Ia)	**Supernovae type II (SN II)**
hydrogen *not* in visible spectrum	hydrogen in visible spectrum
associated with old stars	associated with young stars
standard lightcurve; used as distance indicator	less predictable lightcurve
probably leaves no compact remnant, only a fireball	leaves neutron star or black hole remnant
due to accretion on to white dwarf, which then exceeds Chandrasekhar mass ($1.4\,M_\odot$)	due to core collapse of massive star ($M_{ms} > 11\,M_\odot$)