Novae: The Astro-bombers!

Team Decoherence

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1 Introduction

Astrophysics is full of wonders and one of the great wonders are the "cosmic fireworks". Be it in supernovae, kilonovae or any similar boom-y event out there in sky, there are big explosions throwing out enormous amounts of matter in the universe. These explosions are super-bright and their spectra and lightcurves are treasures to astronomers and astrophysicists. The matter ejected are also the source of many heavy elements of the universe. Here, we will work with such a "boom" event, though at a very simple level.

2 Part A (40 marks)

Suppose there is a central object and it ejects some mass. Model this ejecta with all the beautiful physics-y approximations: spherically distributed and uniform density at every time and the sphere is expanding at some constant velocity. Also assume that the density and temperature are constant at all radii. It is also given that the radiation energy dominates over gas energy. Assume that this ejecta does not exchange either heat or mass with the surrounding or any other matter.

This ejecta will have radioactive elements. Consider that the rate of release per unit mass of energy by radioactivity is given by:

$$\epsilon = \frac{fc^2}{t}$$

where f is some constant factor, c is speed of light. Also take the ejecta luminosity to be given by the relation:

$$L = \frac{4\pi RcU}{3\kappa\rho}$$

where κ is opacity and constant everywhere and at all times, ρ is the density, R is the radius and U is the energy density, c is speed of light.

Given this whole scenario, the aim is to find a differential equation governing the total luminosity of the ejecta as function of time in terms of the known quantities, which are the velocity of expansion, the mass ejected, f and κ. There can be all other fundamental constants in the expressions. Consider the ejecta to be non-relativistic, and consider all classical thermodynamic laws to hold. After the equation is obtained, discuss how the light curve qualitatively looks like, either by solving the equation numerically or by using some analytical approximations or approaches.

3 Part B (20 marks)

Now, the above model seems too simplistic. Also it doesn't see the problem from an observer who may see things completely differently. But it turns out that coming out of this simple model is really difficult. What we will do here instead is to discuss the effects that should be included to make it more realistic. One very obvious lacking in the above model is taking the ejecta to be non-relativistic. There can be other issues too.

Discuss these issues and explain how they should be included in some better model and come up with some basic algorithm/pseudo codes as to how the effects can be included. To give a lead, consider the relativistic effect. Explain how the luminosity, now as observed by an observer, will get affected and how this can be computed (an algorithm or pseudo code and not hard coding). This question does not expect any mathematical derivations or numerical analysis. But the effects should be clearly described and the pseudo code should be proper and catch the essential steps of the effects you are including.