A Simple Estimation of Ejected Mass from PW Vul for the First Ejection after its Detection in the Radio Wavelengths, using Uniform Slab Model

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Abstract: A nova is a sudden drastic change in the luminous intensity of a star. The change in intensity is due to the explosion of the outer surface of the star, resulting in extreme temperatures and radiation throughout the space.. Nova occurs when a white dwarf engulfes mass on its surface from a binary companion red giant. This process get's continued till there is a breakdown of the mass that the white dwarf can carry on its surface. Many such nova systems have been found, yet this field is still a developing field in astronomy. In the year 1984, on July 28, PW Vul was discovered, it was later found to have a periodicity of about 15 days and thus a recurrent nova. The Parametrization of a nova is a crucial and important process, to state the process of before and after the nova situation. Not much study is done on PW Vul. In this paper, the ejected mass right after its detection is calculated by following the Uniform disk model. For this, the brightness temperature of the nova is calculated to be $6.1 \times 10^{6}K$, which is a strong suggestion of non-thermal synchrotron radiation from the nova. The ejected mass is calculated to be $1.12 \times 10^{-5}M_{\odot}$, which is under the expected range as suggested by of $10^{-7}M_{\odot} - 10^{-4}M_{\odot}$, by Steven N. Shore.

Keywords: Nova, PW Vul, recurrent nova, Uniform disk model, ejected mass.

1. Introduction

Stars are some of the most important components and elements in the universe, they provide the radiation energy available in the cosmos, a place for planets to sustain and a potential life system to form. The first categorization of stars happens in the form of generation of stars, i.e the order of forming after the big bang, set of stars formed after the big bang were termed as Population III stars. Population III stars, these stars have no metal in them, have not been detected observationally, although, the population II stars are detected with minimal metal's in them. The death of a star is decided a lot by its initial mass and metal content. The Sun is a third generation star and so, most of the stars in the Milky way, most of the stars in the cosmos today are third generation stars and it's very hard to detect second or first generation stars observationally [1].

Stars are gravitationally self bound objects, which means, the self gravitational attraction of these systems are enough to hold their structure. To neutralize their gravitational attraction, an opposite thermodynamic-temperature force acts on the object. For any star system, isolated, static, and spherically symmetric, there are four basic equations that describes the structure of the stars, these equations are (i) equation of hydrostatic equilibrium, (ii) conservation of mass, (iii) conservation of energy, and (iv) equation of energy transport, and all these quantities are locally defined and varies as one goes from the center to the surface boundary of the star [2]. The self gravitating balls are mostly hydrogen, the nucleus of the star, the center most, most dense and temperature part, converts this hydrogen into helium and higher elements, and generates energy. Stars come in a variety of shapes and sizes, even though to a large extent the luminosity of the star depends on the mass of the star, two same mass stars can have different luminosity and temperature, and thus, two different positions on HR diagram [3].

Death of stars can have varieties too, it’s again depends on the mass of the star, and if the mass of the star is above the Chandrasheker limit which is about $1.4\, M_{\odot}$ the star will die in a violent event, known as supernova, the core of the star will undergo a collapse and the result can be a neutron star or a black hole. But, when the mass is less than the Chandrasheker limit, the star dies peacefully and becomes what is known as a white hole. For a Nova to happen, a white dwarf and a red giant needs to be a binary companion [4].

A binary star system is a two star system orbiting around each other at their center of mass. The binary system can have one white dwarf and one red giant, this is known as the white dwarf to have red giant as the companion star. White dwarf is a dead star, highly dense, of the size of Earth, but as massive as Sun, thus, have very strong gravity on the surface, on the other end, a red giant could be massive in size and can range anywhere from 0.3 to 8 solar mass, and it's also at the end stage of its life. An event when the materials from the red giants are accelerated onto the surface of the white dwarf due to its strong gravity and accumulates on the surface. As this continues for days and months, the surface temperature of the white dwarf increases, and many chain reaction stars on the unreactive surface of the white dwarf, depending of the mass of the white dwarf and the mass accumulation rate the system undergoes a rundown, the surface of the white dwarf, exposed and ejects its outer surface, this phenomenon is known as nova, which means new in latin, it’s loosely means ‘new-light’ in sky [5] .

The PW Vul Nova also known as Nova Vul 1984 No. 1, was discovered by Wakuda in the year 1984, on July 28 [6]. It had a visual magnitude of 9.2. The maximum intensity was attained on August 4 th 1984. The decile was steep and follows a semi periodic brightness oscillation of about 15 days. Not many studies are done on PW Vul nova parametrization, in this paper, we will measure the ejecta mass of the Nova using a thin shell model approximation.

2. Methodology

This section discusses the methodology used to conduct the research.

2.1 Aim

To determine the ejected mass after the detection of PW Vul using the radiation data in the radio domain.

2.2 Research Design

The brightness temperature of the source is calculated to identify the type or radiation, i.e. thermal or non-thermal. Later, the flux peak day is identified and for this day, the angular displacement is calculated, followed by which the ejected mass is calculated.

2.3 Data collection procedure

The light curve is collected from Chomuk et al [7].

3. Discussion

Chomuk et al provides the light curve of the nova, the light curve is obtained for frequency 4.86 GHz, and the detection was a null detection till the first 600 days, see table no 1, which is also the day of peak flux day. After this day, the intensity of radiation decreases steeply (see table no 1).

Sr No	Time days	Detection Limit	Flux mJy	Flux error mJy
1	20.3	<	0.33	0.11
2	25.3	<	0.4	0.12
3	33.1	<	0.44	0.15
4	100	<	0.46	0.14
5	600.6		2.85	0.17
6	785.2		1.84	0.12

7	808.8		1.69	0.12
8	910.7		1.23	0.09
9	1084		0.45	0.07
10	1177		0.61	0.08
11	1218		0.82	0.14

Table no 1: Light curve of Nova PW Vul

The first column of the table represents the days after the detection, the second column, suggesting whether the detection was made or not if the sign is '<', it signifies that the flux is not recorded on the corresponding date. The third column represents the expected or detected flux, and the fourth column is the error in the flux measurement. The plotted light curve is shown in image no 1.

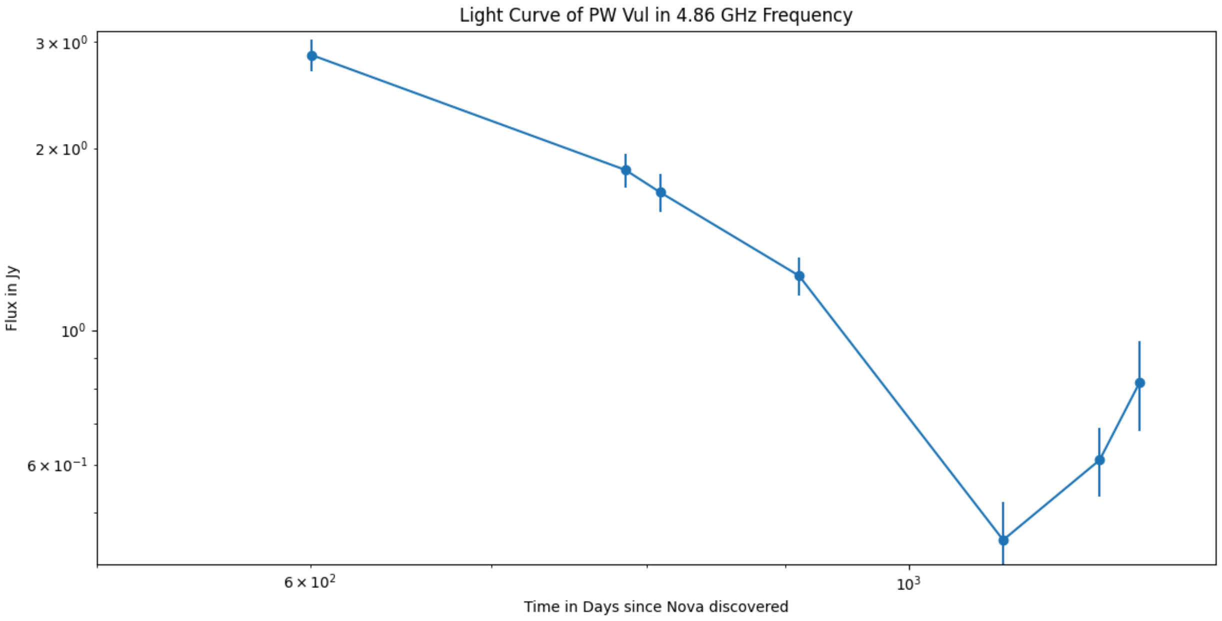

Image no 1: Light Curve of PW Vul at 4.86 GHz Frequency

Following L Rosino and T Iijima, the speed of the ejecta material has been used in this paper, spectroscopy measurements suggest that the speed of the ejecta to be on an average of 780 km/sec [8]. Another spectroscopic study of the source was done by F. A. Ringward and T. Naylor

[9]. The speed of the ejecta was calculated to be about 470 km/sec, this is the speed after a few years of the discovery of the nova. The distance of the nova from us, which is the parallax distance, is studied multiple times, the values are, see table no 2.

Sr No	Paper	Distance(kpc)
1	Ringwald	1.6
2	Duerbeck et al. [10]	1.2
3	Saizar et al. [11]	1.5 - 3.0

Table no 2: Parallax distance of Nova PW Vul

The parallax distance is measured to be 1.6 kpc, 1.2 kpc, 1.5 -1.3 kpc. The angular size of the object is the size the object covers in space, to calculate angular size, we need the distance of the object and the linear size of the object, then the angular size is defined as $\theta = S/D$, where ‘S’ is the linear size and ‘D’ is the parallax distance of the source. In this paper, we will assume the velocity of ejection to be a constant till the max peak flux day, this is because of less availability of the speed data, and we will find out the linear size of the object by $S = 2vt$, where ‘v’ is velocity and ‘t’ is the peak flux day.

4. Result

The brightness temperature of the system suggests whether the energy flux generated is due to thermal or non-thermal radiation, radiation in the radio wavelength is due to non-thermal synchrotron radiation. The calculated angular size for a parallax distance of 1.6 kpc, the nova is 0.0059 arcsecond, this will be used to measure the brightness temperature, which is given by.

$$T_B = 1765.8K(v/GHz)^{-2} \times (S_v/mJy) \times (\theta/arcsec)^2$$

The measured, brightness temperature is $6.1 \times 10^6 K$. For for thermal source, the temperature cannot exceeds $5 \times 10^4 K$ The brightness temperature of the source is a strong suggestion of non-thermal radiation.

Uniform Slab Model developed [12], assumes the radiation field surrounding the nova to be of the shape of a slab, and the field is uniformly distributed. The model suggests the ejected mass to be:

$$(M_{ej}/10^{-4}M_{\odot}) \quad = [\,(S_{max}/6.7\,mJy)\times(v/GHz)^{-1.16}\times(T_{B}/10^{4}K)^{-0.46}\times(d/kpc)^{2}]^{1/0.8}$$

For the S_{max} We used it for 2.85 mJy, which is for 600.6 days after the discovery. The ejected mass is about $1.12\times10^{-5}M_{\odot}$.

5. Comparison with Current Work

The ejected mass is $1.12\times10^{-5}M_{\odot}$, as there is no measurement on the ejected mass available, no comparison could be made, one can only comment that the measured ejected mass is in the range as suggested by Steven N. Shore [12].

6. Conclusion

In this paper, we estimated the brightness temperature of the nova named PW Vul and measured its ejected mass after its detection. The ejected mass is in the sensible range as suggested by Steven N. Shore and is equal to $1.12\times10^{-5}M_{\odot}$.

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