The Signature of Thermonuclear Supernovae

Resulting from Merging White Dwarf Stars

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Introduction

As one of the brightest objects in the cosmos, a thermonuclear supernova releases as much energy over the span of several seconds as the sun does in its entire lifetime. Though the progenitors of other types of supernovae are known, those of the thermonuclear supernova remain a mystery.

- What is a supernova?
- What defines a thermonuclear supernova?
- A proposed model
- A prediction for observing the double white dwarf model

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  - Type II do have hydrogen emission lines
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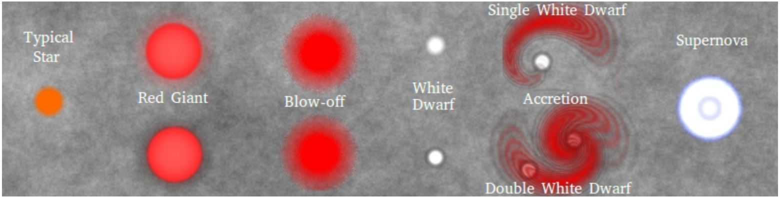
- **The Mystery of the Progenitor**
  - Pre-explosion data shows no star
  - No remnant or ex-companion star
  - Double degenerate white dwarf model

Single and Double White Dwarf Models

Leading Models

Two leading models for the thermonuclear supernova progenitor are the single white dwarf model and the double white dwarf model.



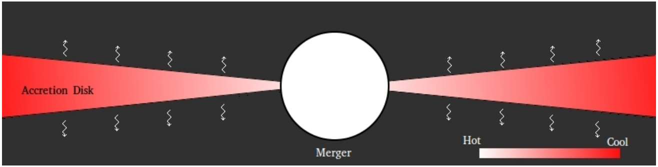
Top: a white dwarf accreting from a companion main sequence or red giant star. Bottom, a binary white dwarf system, drawn together and eventually merging.

Double White Dwarf Merger Model

Two white dwarf stars in a binary system being drawn together by gravitational radiation

- One white dwarf is disrupted by gravitational tides
- Torn apart
- Forms a hot accretion disk
- Combined mass exceeds Chandrasekhar limit
- Detonation
- Timescale on the order of 10 hours

Accretion Disk

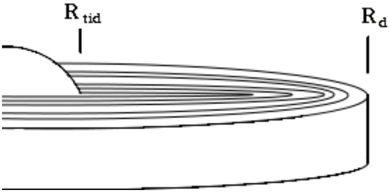


Side view of accretion disk around central white dwarf. Radiative flux is primarily emitted vertically from the disk.

Key Model Assumptions

- A supernova event occurs a viscous evolutionary timescale beyond the initial merger.
- α disk model – mass is transported inward and angular momentum outwards through the action of viscous torques, with the viscous dissipation energy locally deposited at each radius as heat.
- The mass accretion rate is steady.
- The disk is non self-irradiated.

Method



The accretion disk, evaluated as a series of rings. The radiative flux is primarily vertical. The inner disk is hot and radiates primarily in X-rays, and the outer disk cooler, and radiates in the optical and longer wavelengths.

Luminosity Cont.

By integrating over the flux as a function of the radially dependent temperature, we find the intensity [1]:

$$I_\nu = 4\pi \int_{R_{tid}}^{R_d} F_\nu[T_s(R)]RdR$$

Integrating between the frequencies ν_1 and ν_2 gives the luminosity[1]:

$$L_{opt} = \int_{\nu_1}^{\nu_2} I_\nu d\nu$$

For two 0.7 $M_\odot$ (solar masses) white dwarfs, the accretion disk produced a luminosity of 440.5 $L_\odot$ (solar luminosities) in the optical r-band.

[1] N. I. Shakura, R. A. Sunyaev(1972, June 6). Black Holes in Biary Systems. Observational Apearance

Distance Calculation

The distance to an object can be calculated using its luminosity. First, obtain its r-band absolute magnitude M:

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From this and a maximum apparent magnitude m that can be seen from Earth, its distance is
calculated:

$$d = (10pc)\sqrt{100^{\frac{(m-M)}{5}}}$$

The LSST will be capable of seeing an object with a minimum apparent magnitude of 24.5. A 440.5 $L_{\odot}$ accretion disk could be seen at a maximum distance of 1.93 million parsecs (1.93 Mpc).

Probability of Catching the Event

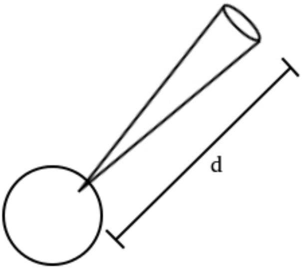
The supernova event rate can be calculated by volume. Two supernovae occur per one-thousand solar masses per age of the universe. Using the total mass in a sphere of radius 1.93 Mpc, the volume of interest will have a rate of .29 supernovae over the ten year survey.

Results

Each night, the LSST will be able to survey about 4% of the sky. The probability of the survey detecting a pre-explosion supernova given by

$$Probability = 1 - (1 - 4\%)^N$$

where N is the supernova rate within 2 Mpc, is a 1.2% chance.



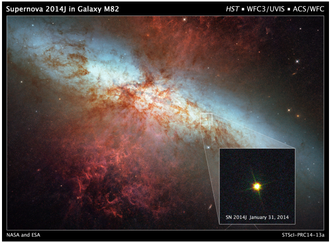
A cone of view out to a distance d representing the field of view out from a telescope on earth

Conclusions

- The luminosity prediction will refine the early supernova detection methods for the double white dwarf model
- The chances of pre-explosion observation remain low in the visual band
- Expect higher probabilities in UV and X-ray band
- Comparison to other models may explain their nature

Prospective Impact

Supernova 2014J was discovered inadvertently during a demonstration at the University of London Observatory. A telescope had been surveying the position a week prior, but the automated algorithms discarded the event.



Thank You

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Questions?