Modelling Type Ia supernovae with single white dwarf progenitors

PRESENTER:
Kate Blackham

ABSTRACT: This project sought to find a Galactic birth rate for Type Ia supernovae (SNe Ia) with progenitors that are a WD accreting mass from a companion non-WD. SNe Ia are used as 'standard candles' to measure intergalactic distances and occur when a white dwarf (WD) exceeds its maximum mass: the Chandrasekhar mass, $M_{Ch} = 1.44 M_{\odot}$ [1]. The accepted Galactic birth rate of SNe Ia is (4 ± 1) × 10^{-3} per year [2]. It is not known what proportion of SNe Ia occur via the potential progenitor types; if more SNe Ia are the result of a WD-WD collision than a single WD accreting matter from a companion, is our assumption that SNe Ia are standard candles valid?

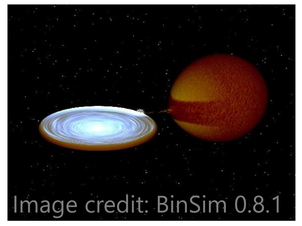


Image credit: BinSim 0.8.1

METHODS

1. Population synthesis simulations were performed using the Binary Star Evolution (BSE) code [3].
2. Models were created with parameters that maximized the production of SNe Ia from accreting WDs.
3. Fourteen models were created with 170 × 170 × 170 grid points, Z = 0.02 or 0.001, and a novae mass retention factor governing the amount of mass that is lost due to novae of $0.4 \leq \varepsilon \geq 1.0$, based on the findings of [4].

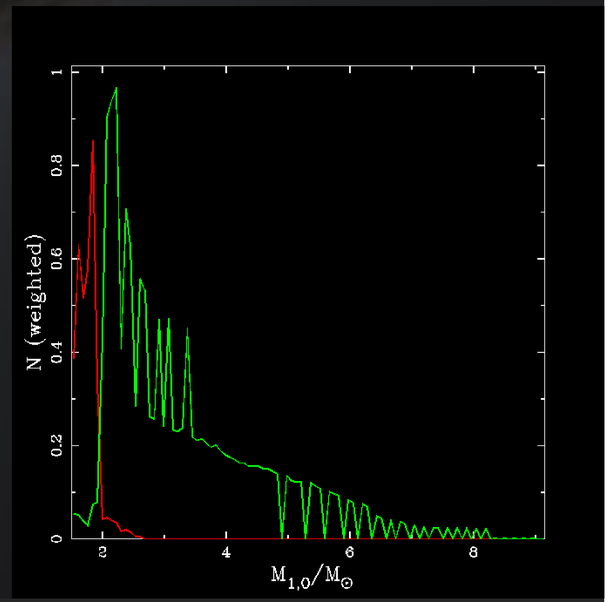
RESULTS

Spiral galaxies have these ELD SNe Ia birth rates:

Model no.	Z	ε	ELD SNe Ia birth rate / yr^{-1}
1	0.02	1.0	1.4910×10^{-3}
3	0.02	0.9	1.4832×10^{-3}
5	0.02	0.8	1.4755×10^{-3}
7	0.02	0.7	1.4681×10^{-3}
9	0.02	0.6	1.4608×10^{-3}
11	0.02	0.5	1.4536×10^{-3}
13	0.02	0.4	1.4470×10^{-3}

In spiral galaxies, **37%** of **Type Ia supernovae** may arise from the **edge-lit detonation** (ELD) of an accretion disk.

Image credit: ESA/Hubble



Normalized histogram of Type Ia supernovae by primary initial mass. Red: He white dwarfs; Green: C-O white dwarfs that accrete mass to the Chandrasekhar mass. The choice of initial parameters prevented the creation of significant numbers of SNe Ia via C-O WD collision within the models.

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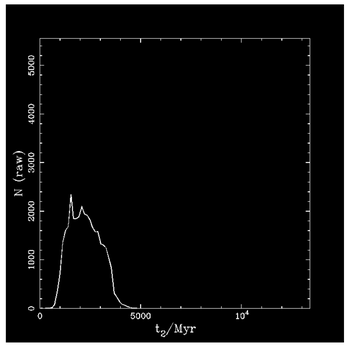
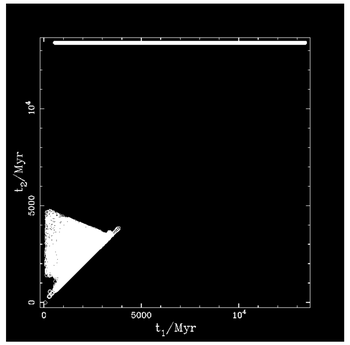
Elliptical galaxies with little gas and dust have a lower birth rate of ELD SNe Ia:

Model no.	Z	ε	ELD SNe Ia birth rate / yr^{-1}
2	0.001	1.0	8.7640×10^{-4}
4	0.001	0.9	8.7391×10^{-4}
6	0.001	0.8	8.7201×10^{-4}
8	0.001	0.7	8.7032×10^{-4}
10	0.001	0.6	8.6764×10^{-4}
12	0.001	0.5	8.6656×10^{-4}
14	0.001	0.4	8.6443×10^{-4}

The peak ELD SNe Ia birth rate occurs around 2 Gyr, making this a more common progenitor in young galaxies and spiral galaxies:



Once accretion begins, ε tends to 1 [5], accelerating the accretion. The BSE code does not allow a time-varying ε, but with ε=1, the accretion phase is short:



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