Pleasantness Review*

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Supernova Ia scenarios in 2019:
a rising demand for clean and symmetrical explosions

Lijiang 2019

Noam Soker

•**Dictionary translation of my name from Hebrew to English (real!):**

Noam = Pleasantness

Soker = Review

We (my wife, 3 kids, and I)
do not know what is the scenario
that works for SNe Ia, and so
we should be humble and
consider all 5 scenarios.

Too many papers mention only 2 or at most 3 scenarios.
This does not help, as it leads to wrong conclusions.

The Core Degenerate (CD) scenario

2 main sequence stars

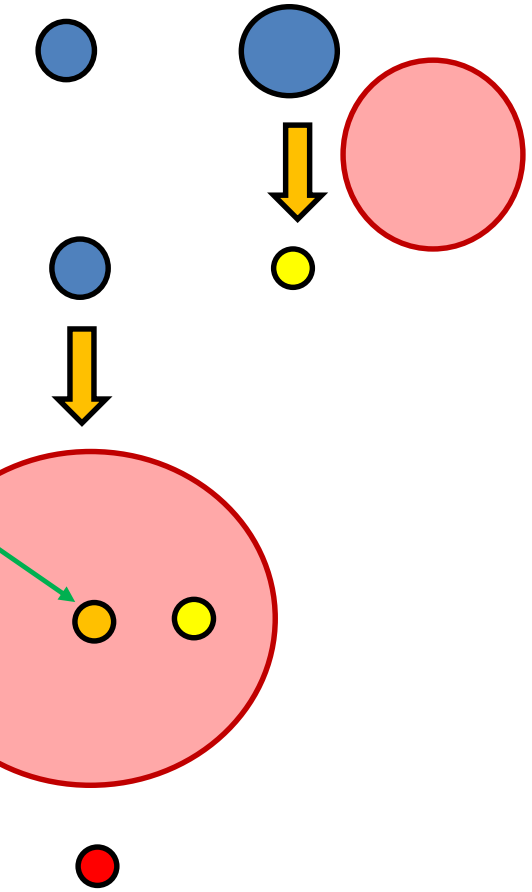
main sequence + WD

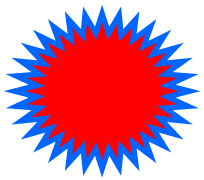
AGB core

AGB star + WD in a common envelope

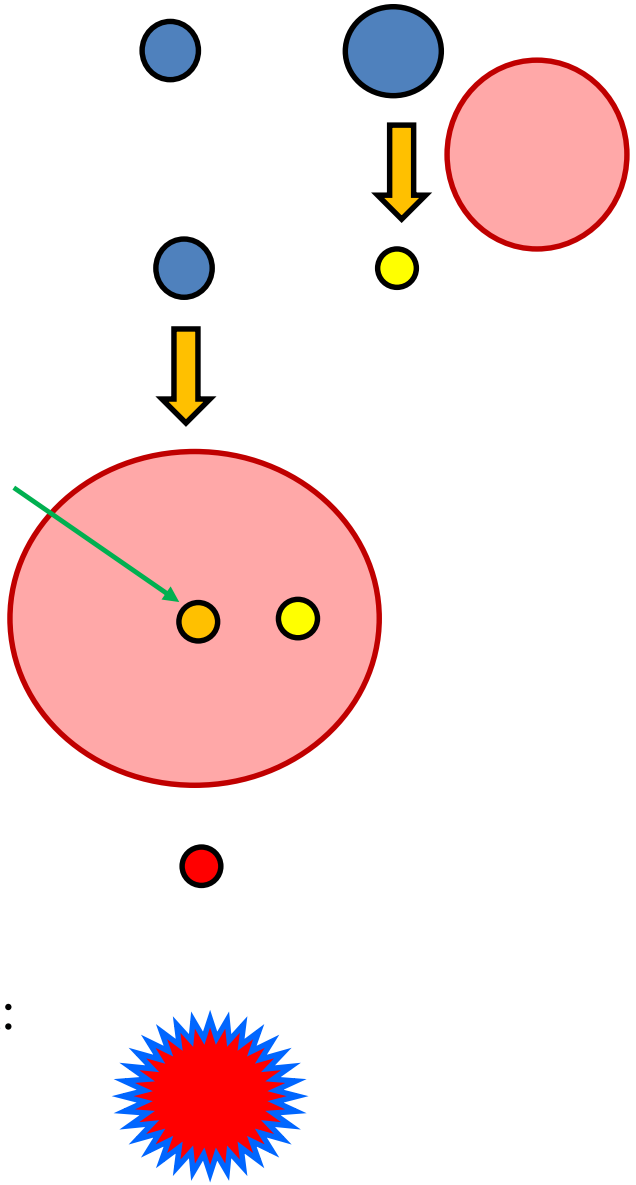
Core-WD merger and envelope ejection:
Merger product is a WD of Mch~1.4Mo

The WD explodes with a delay of years to billions of years ????





The Core Degenerate (CD) scenario



Main predictions:

(1) A single WD at explosion.
(2) A spherical explosion.
(3) In some cases massive circumstellar matter (CSM).

In a new paper I argue that ~20% of SNe have CSM within few pc.

(Soker, N. 2019, accepted for publication by astro-ph: **"Common envelope to explosion delay time of type Ia supernovae"**)

Examples of wrong conclusions

(1) If there is a circumstellar matter (CSM) it must be the single degenerate scenario.

NO! it is more likely a post-common envelope (Soker in several papers)

Post common envelope scenarios are:

- Core Degenerate
- Double Degenerate
- Double Detonation (some version)
- The common envelope wind single degenerate

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NO! it is more likely a post-common envelope (Soker in several papers)

(2) If there is an early emission (blue and UV excess) it is the single degenerate.
NO! it can be the double degenerate when the merger process launches jets and explosion occurs few days later
(Levanon & Soker 2017, 2019)

Explaining the Early Excess Emission of the Type Ia Supernova 2018oh by the Interaction of the Ejecta with Disk-originated Matter

Naveh Levanon[1] and Noam Soker[1,2]
Published 2019 February 8 •
The Astrophysical Journal Letters, Volume 872, Number 1

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(3) If there is no surviving companion it is the double degenerate scenario.
NO! it can also be the core degenerate scenario.

The five binary SN Ia scenarios

Core Degenerate (CD): WD-core merger during common envelope evolution.

1 star at explosion. 0 survive. [Chandrasekhar mass (Mch)] {1,0,Mch}

Double Degenerate (DD): WD-WD due to gravitational waves

2 bound sub-Mch WDs at explosion. 0 survives. [Sub-Mch] {2,0,S-Mch}

Including the hybrid model of **CO WD** + **HeCO WD** **(Yossef Zenati)**

Double Detonation (DDet): Helium ignites the WD. {2,1,S-Mch}

2: sub-Mch WD + helium-rich star at explosion. 1 helium-rich star survives. [Sub-Mch]

Including the D6 scenario of dynamical mass transfer of He **(Ken Shen)**

Single degenerate (SD): Hydrogen-rich companion {2,1,Mch}

2: Mch WD + hydrogen-rich star at explosion. 1 hydrogen-rich star survives. [Mch]

Including the common envelope wind SD **(Meng & Podsiadlowski 2017)**

WD-WD collision(WWC): Two WD collide and are ignited. {2,0,S-Mch}

2 unbound sub-Mch WDs at explosion. 0 survive. [Sub-Mch]

The five binary SN Ia scenarios

Core Degenerate (CD): {1,0,Mch}

Double Degenerate (DD): {2,0,S-Mch}

Double Detonation (DDet): {2,1,S-Mch}

Single degenerate (SD): {2,1,Mch}

WD-WD collision(WWC): {2,0,S-Mch}

Several studies showed that this cannot account for more than <1% of SNe Ia

However, it does challenge all other scenarios as the WD-WD clearly has **ignition** (Doron Kushnir)

The five binary SN Ia scenarios

Core Degenerate (CD): {1,0,Mch}

Double Degenerate (DD): {2,0,S-Mch}

Not easy to ignite, unless massive WDs.

But Yossef Zenati et al. showed in 2D simulations that the
He CO + CO WD (hybrid model) might work. But they must show ignition in 3D.

Double Detonation (DDet): {2,1,S-Mch}

In a recent study Robert Fisher et al. showed the helium does not ignite the CO WD in the D6 scenario. But it has several strong points (e.g., Ken Shen).

Single degenerate (SD): {2,1,Mch}

WD-WD collision(WWC): {2,0,S-Mch}

Several studies showed that this cannot account for more than <1% of SNe Ia

However, it does challenge all other scenarios as they have clearly showed **ignition** (Kushnor, D.)

The five binary SN Ia scenarios

Core Degenerate (CD): {1,0,Mch}

The core degenerate scenario has problems, like no calculations of ignition nor of the merger process inside the common envelope,

But it does challenge the other scenarios.

DO NOT IGNORE THESE CHALLANGES!

- Only scenario that predicts spherical supernova remnant as observed in many cases

Double Degenerate (DD): {2,0,S-Mch}

Double Detonation (DDet): {2,1,S-Mch}

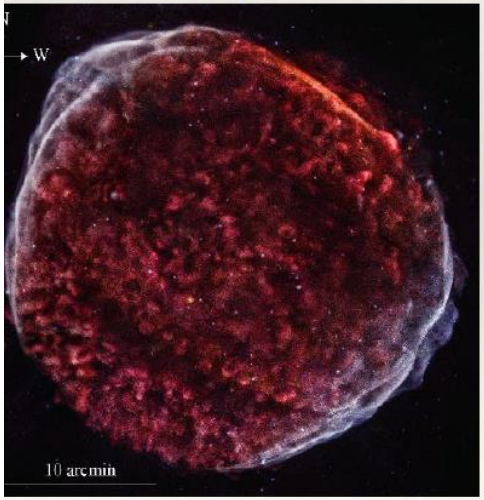
Single degenerate (SD): {2,1,Mch}

WD-WD collision(WWC): {2,0,S-Mch}

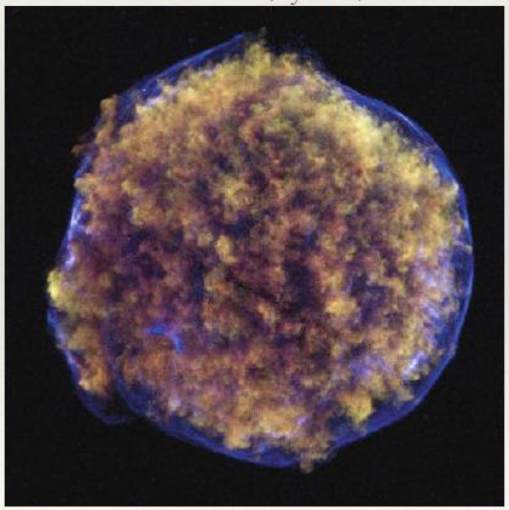
Supernova remnants

- Roughly spherical with some protrusions
- No surviving companion

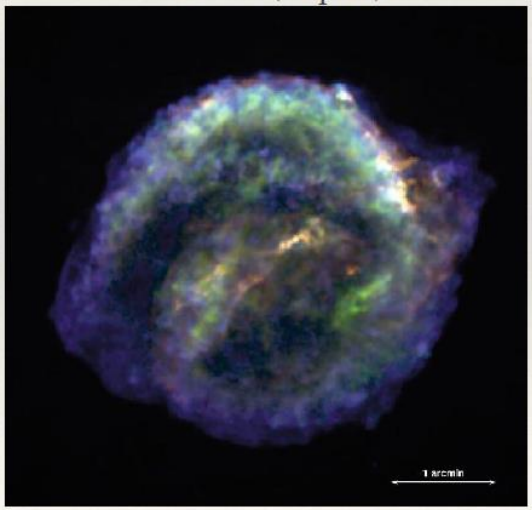
SN 1006



SN 1572 (Tycho)



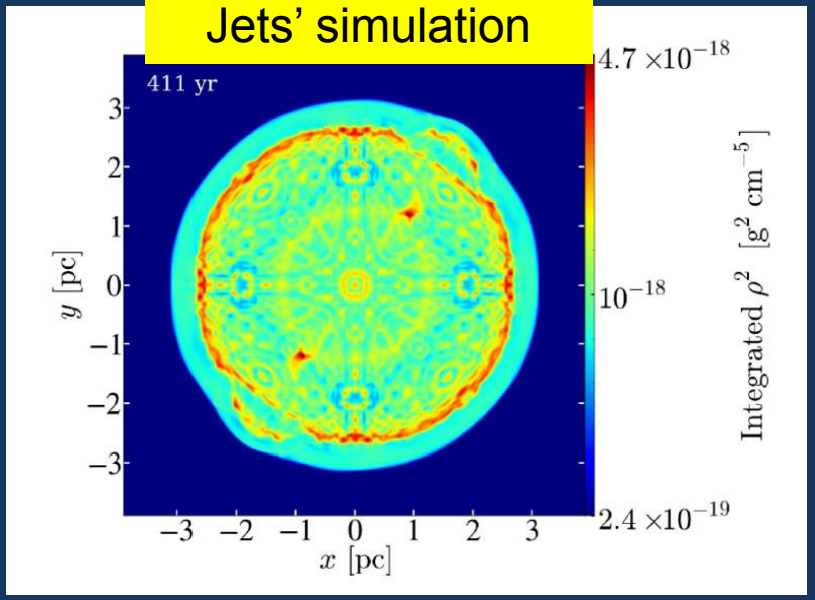
SN 1604 (Kepler)

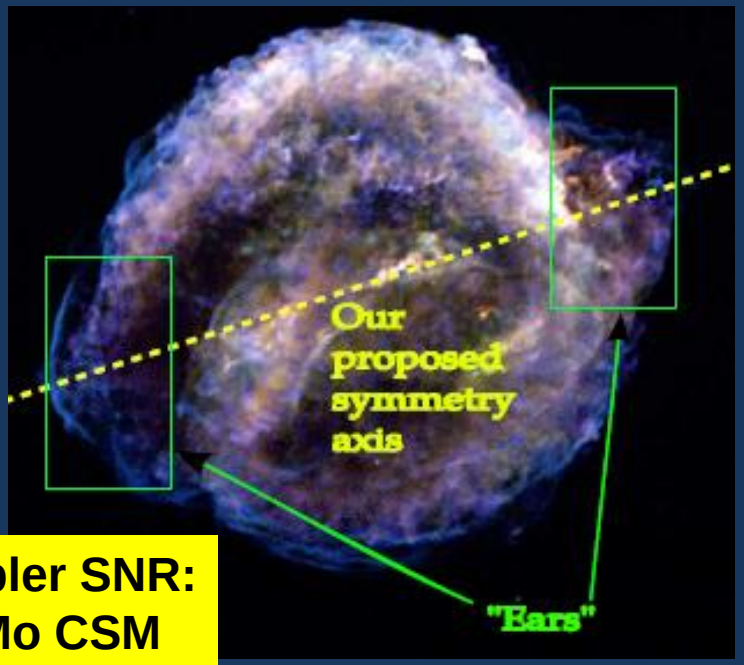


Source: *Chandra*

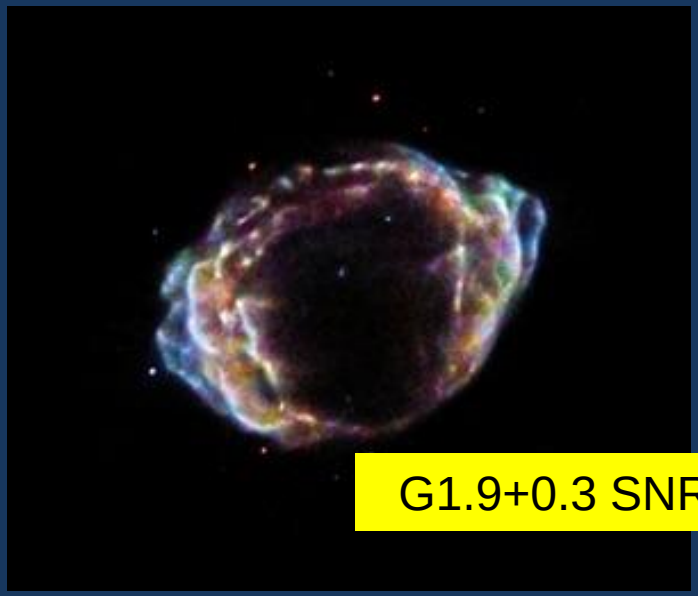
Ears in Type Ia SNRs

Jets' simulation

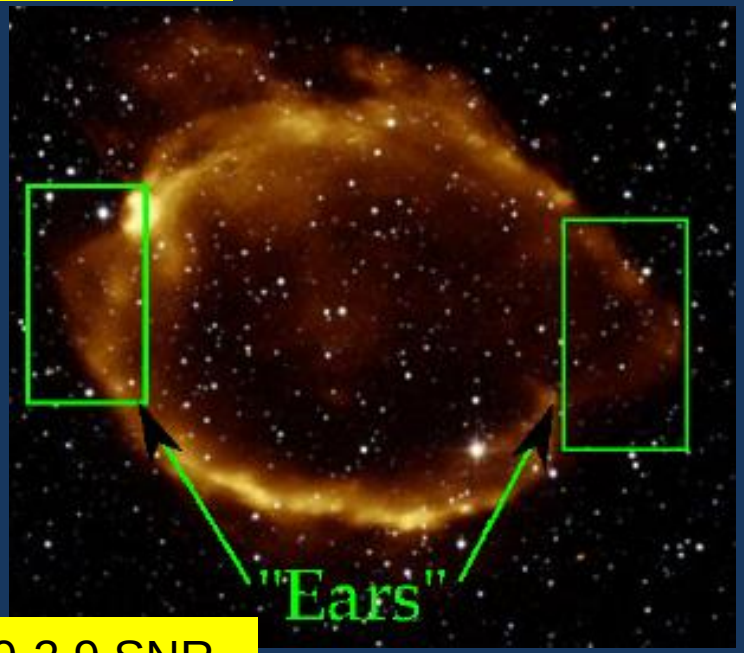




Kepler SNR: ~1Mo CSM

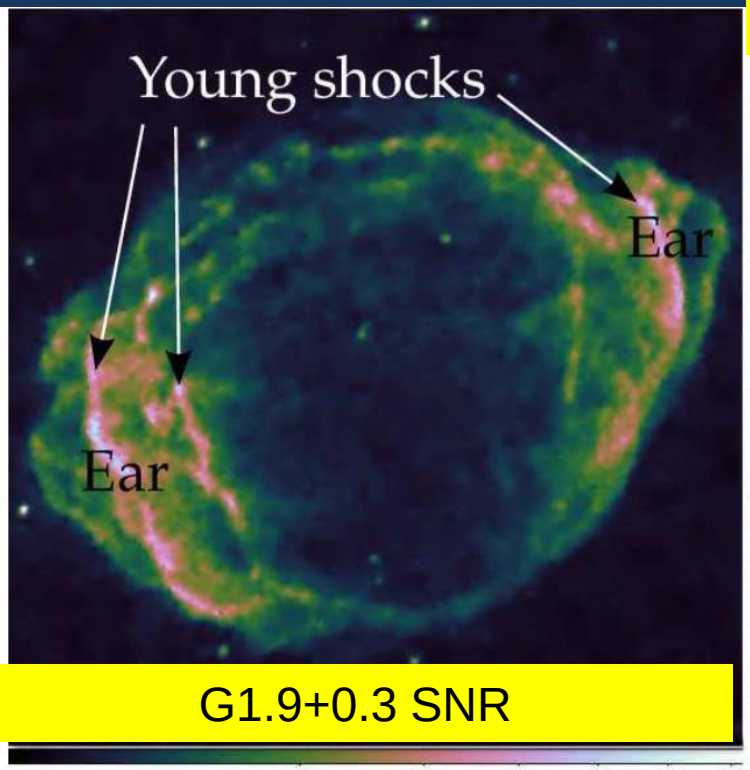


G1.9+0.3 SNR



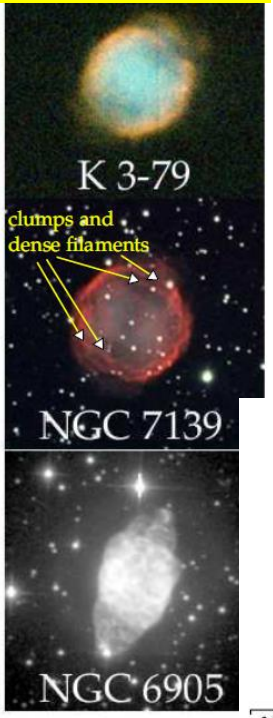
G299-2.9 SNR

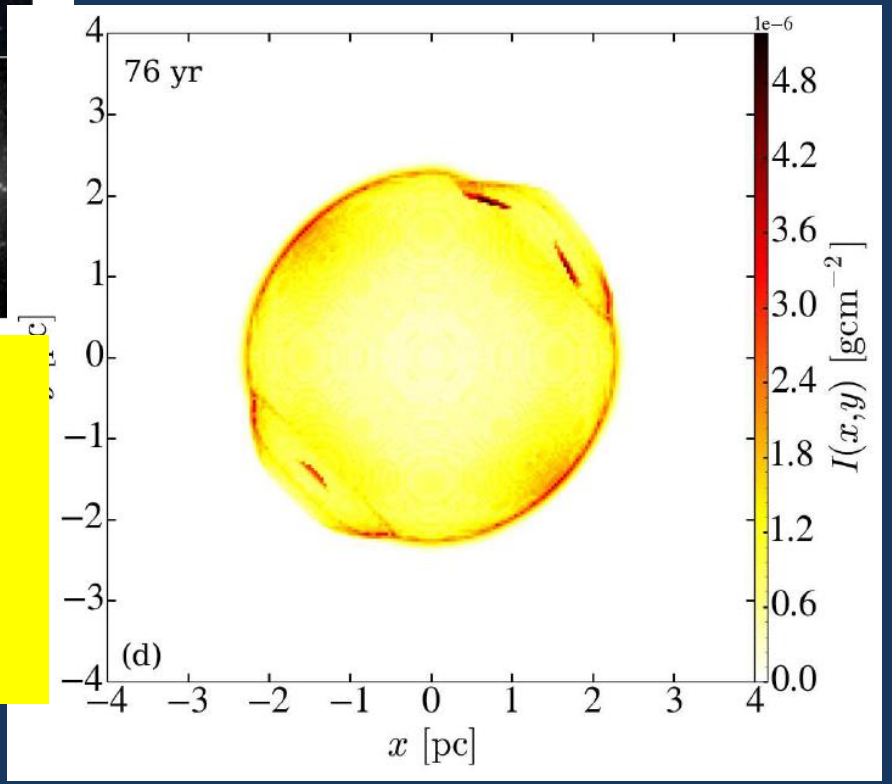
Ears in Type Ia SNRs



G1.9+0.3 SNR

Planetary nebulae

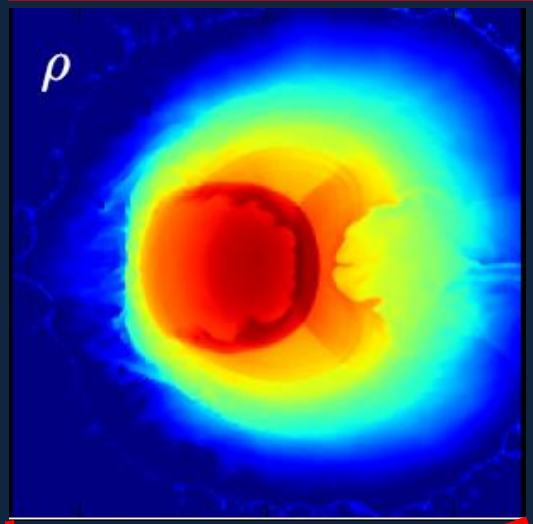


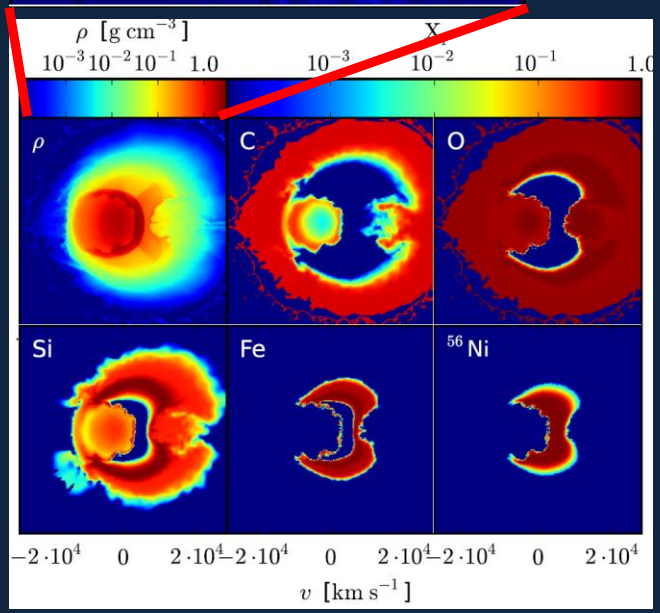


Numerical simulations of a
SN Inside a **P**lanetary nebula
(SNIP)
(from Tsebrenko, D. & Soker, N. 2015)

3D simulations of the DD scenario (Pakmor et al. 2012)

A highly non-spherical explosion





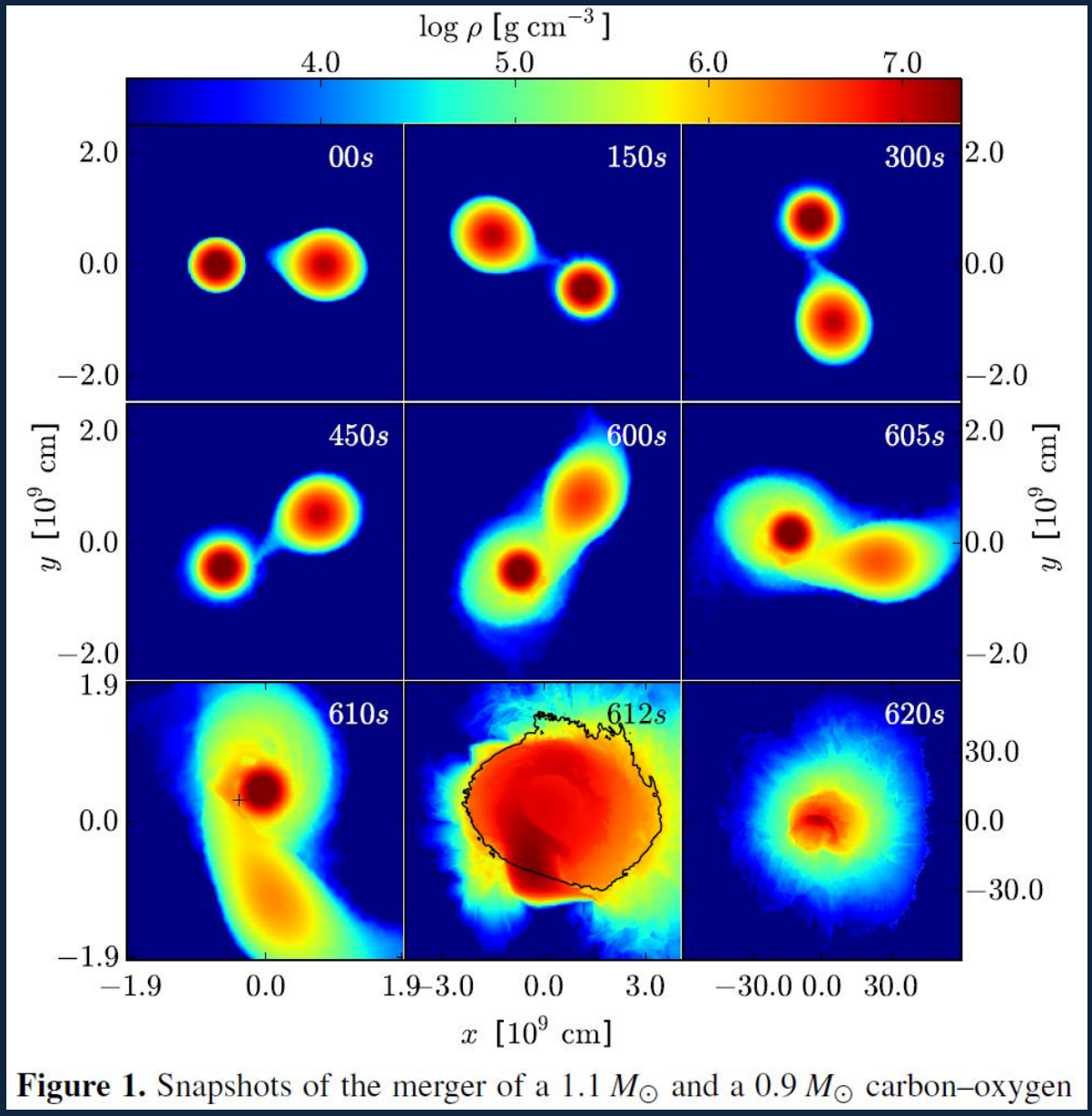
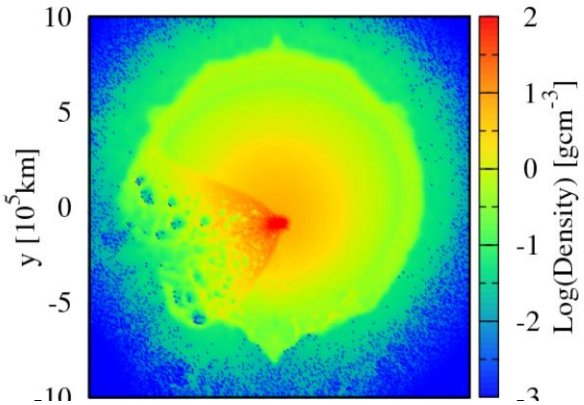
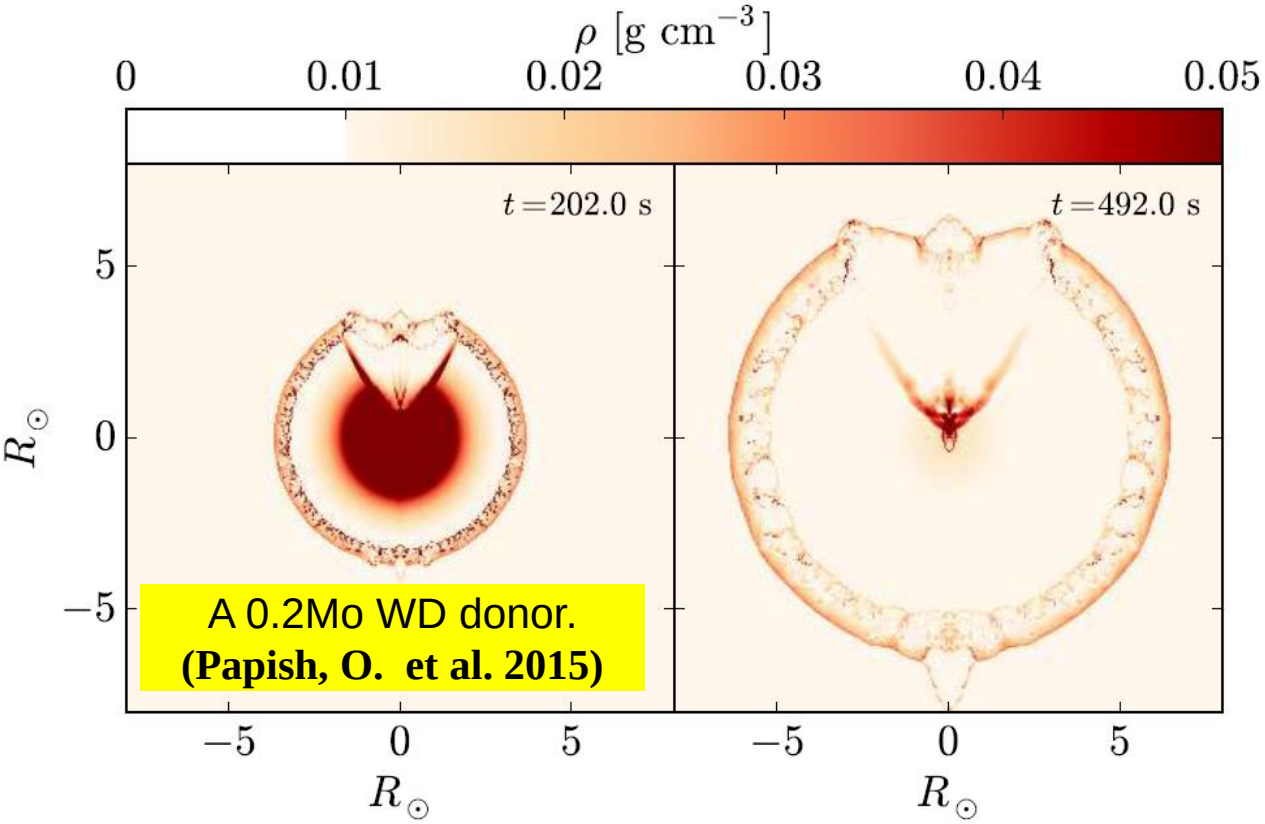


Figure 1. Snapshots of the merger of a 1.1 $M_\odot$ and a 0.9 $M_\odot$ carbon–oxygen

The globally symmetrical explosion is a problem to the Double Detonation (DDet including D6).



The D6 scenario
(Tanikawa, A. et al. 2018)



A 0.2Mo WD donor.
(Papish, O. et al. 2015)

Fig. 4.— Density maps in the meridional plane at 2 late times for the case in which a $0.2M_{\odot}$ WD is adopted. The computational grid was folded around the axis to present the entire meridional plane. A homologous expansion of the ejecta, with a Mach number > 10, has developed by the beginning of this evolutionary phase, with a dense conical surface surrounding a conical volume almost completely devoid of SN ejecta. The ambient gas

The five binary SN Ia scenarios

Core Degenerate (CD): {1,0,Mch}

The core degenerate scenario has problems, like no calculations of ignition nor of the merger process inside the common envelope,
But it does challenge the other scenarios.

DO NOT IGNORE THESE CHALLANGES!

- Only scenario that predicts spherical supernova remnant as observed in many cases
- Very small exploding star, as in SN 2011fe (also WWC)
- No surviving companion (also DD).
- Nucleosynthesis that requires Mch (also SD).

Prediction: When a WD will explode in our Galaxy, examination of old observations will reveal a single massive (Mch) WD.

Double Degenerate (DD): {2,0,S-Mch}
Double Detonation (DDet): {2,1,S-Mch}
Single degenerate (SD): {2,1,Mch}
WD-WD collision(WWC): {2,0,S-Mch}

“Common Envelope to Explosion Delay time of type Ia supernovae (CEED)”

Soker 2019 (accepted by astro-ph)

Posted on astro-ph Wed, 15 May 2019 08:24:15 UTC

Relevant to

Core-Degenerate (CD) (Soker, N. et al.)

Double Degenerate (DD) (all channels)

Double Detonation (Ddet) (most channels)

Common envelope channel of the SD scenario (Meng, & Podsiadlowski 2017)

There are three delay times

DTD (Delay Time Distribution): star formation to explosion.

Relevant to all scenarios.

CEED: Common Envelope to Explosion Delay time (Soker 2019)

Relevant to CD, DD, DDet and the common envelope channel of the SD scenario (Meng, & Podsiadlowski 2017).

MED: Merger/accretion to Explosion Delay time (Soker 2018)

Merger relevant to CD (MED=CEED), DD (DMED<CEED), WWC (MED=0)

Accretion relevant to DDet (MED=0) and SD

In my review paper from 2017

"Supernovae Ia in 2017: a long time delay from merger/accretion to explosion",

Science China Physics, Mechanics & Astronomy, 61(4), 049502, (2018)

"Common Envelope to Explosion Delay time of type Ia supernovae (CEED)"

Soker 2019 (accepted by astro-ph)

Posted on astro-ph Wed, 15 May 2019 08:24:15 UTC

About 20% of all SNe Ia occur within one million years after the common envelope (CEED<1e6 yr)

The expression for the SNe Ia rate as a function of time within a million years after the common envelope (CEED<1e6 yr) **cannot** be the one that is used for the Delay Time Distribution (DTD) long after star formation

The physical parameters of short CEED (CEED<1e6 yr) are different than those for much longer times (CEED > 1e7 yr), namely, those that determine the Delay Time Distribution (DTD)

SN Ia scenarios in the literature by alphabetical order

	Core Degenerate	Double Degenerate	Double Detonation	Single Degenerate	WD-WD collision
Two opposite Ears in some SNR Ia.					
SNR spherical					
≈ 1M⊙ CSM in Keplers SNR + Na lines					
Main Scenario Predictions					
General Strong Characteristics					
General Diffficulties					
Severe Difficulties					
This study: MED[f]					
This study: fraction of common SN Ia					
This study: fraction of peculiar SN Ia					

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Severe Difficulties					
This study: MED[f]					
This study: fraction of common SN Ia	~40% - 60%	~40% - 60%	~0% - 10%	~0% - 10%	0%
This study: fraction of peculiar SN Ia	< 10%	Several 10%: **Ca-rich** (Yossef Zenati)	Few 10%	Several 10%: All SNe Iax	< 1%

SN Ia scenarios in the literature by alphabetical order

	Core Degenerate	Double Degenerate	Double Detonation	Single Degenerate	WD-WD collision
Two opposite Ears in some SNR Ia.	Explained by SNIP (Supernovae inside planetary nebulae)	Low mass Ears if jets during merger (TS2013).	No Ears are expected for He WD companion.	Ears by jets from accreting WD.	No Ears are expected
SNR spherical	Expected	A problem	A problem	A problem	A large problem
≈ 1M⊙ CSM in Keplers SNR + Na lines	The massive CSM might be a planetary nebula.	No CSM shell	Any CSM is of a much lower mass	Might be explained by heavy mass loss from an AGB donor.	No CSM shell
Main Scenario Predictions	1. Single WD Exp. 2. Massive CSM in some cases (SNIP)	1. Sufficient WD-WD close binaries 2. DTD ∝ 1/t	1. Asymmetrical explosion 2. MWD < 1.2M⊙	1. Companion survives 2. MWD ≃ MCh	Asymmetrical explosion
General Strong Characteristics	1. Explains some SN Ia with H-CSM 2. Symmetric Exp.	Explains very well the delay time distribution (DTD)	Ignition achieved	1. Accreting massive WDs exist 2. Many with ~ MCh	1. Ignition easily achieved 2. compact object
General Diffficulties	More work on 1. Ignition process 2. DTD 3. Merge during CE	1. Ignition process 2. Inflated gas around WD 3. Asymmetrical	Ejected He in some sub-scenarios	1. Cannot do DTD 2. CSM of PTF 11kx too massive *The common envelope wind SD works (Meng, & Podsiadlowski 2017)	Cannot reproduce manganese
Severe Difficulties			1. MWD < 1.2M⊙ 2. Highly asymmetrical Exp.	1. Too few systems 2. No companions 3. No H observed	1. < 1% of SN Ia 2.Highly asymmetrical Exp.
This study: MED[f]	MED is built-in	Must include MED$\gtrsim 10^5$ yr	MED is problematic with helium accretion	2+3 are solved for MED$\gtrsim 10^7$ yr; problem 1 stays	MED is impossible
This study: fraction of common SN Ia	~40% - 60%	~40% - 60%	~0% - 10%	~0% - 10%	0%
This study: fraction of peculiar SN Ia	< 10%	Several 10%: **Ca-rich** (Yossef Zenati)	Few 10%	Several 10%: All SNe Iax	< 1%