Accretion-Induced Collapse (AIC)

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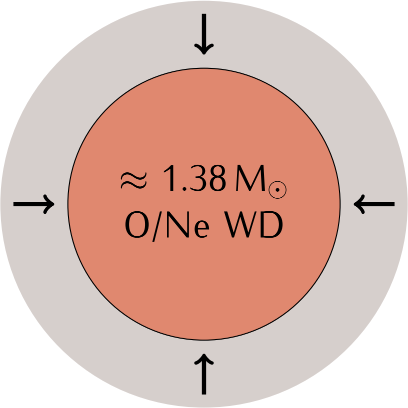
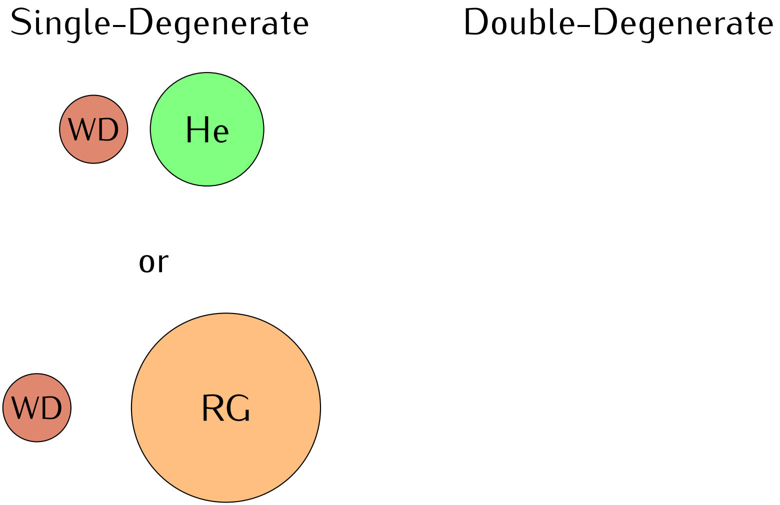
AIC occurs when an O/Ne WD grows in mass and reaches a critical central density.



The progenitors of AIC are the "classic" (super-) Chandrasekhar Type Ia progenitor systems.



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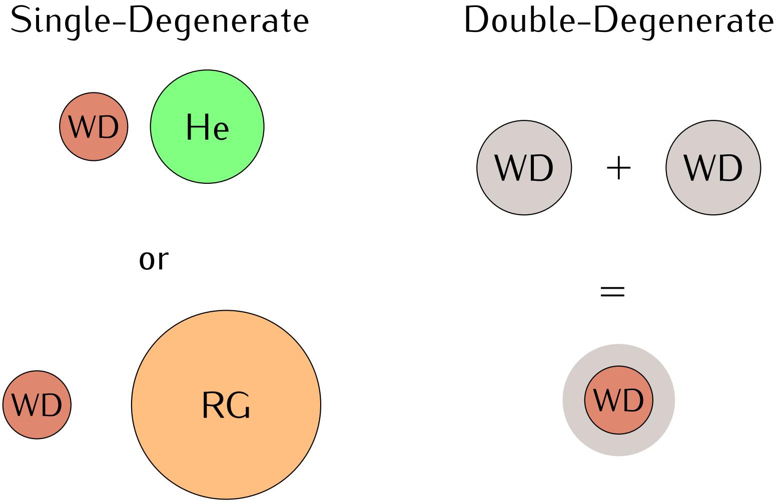

We've never observed an AIC event; however, the basic signature is predicted to be faint and fast.

- Models of the collapse of a massive WD to form a NS produce a weak explosion and $\sim 10^{-3}\,M_\odot$ of Ni-rich ejecta.

  Woosley & Baron (1992); Dessart et al. (2006)
- Those properties translate to a peak of $M_V \approx -13$ and a timescale of a few days. (And the rate is less than the Ia rate).

The strongest (indirect) evidence for AIC is the presence of young NSs in GCs.

Globular clusters have:

- old stellar populations ($\sim$ 10 Gyr)
- low escape velocities ($<$ 50 km/s)
- some young NSs ($P \sim 300$ ms, $B \sim 10^{11}$ G)

Lyne et al. (1996); Boyles et al. (2011)

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AIC:

- takes a long time
- is thought to produce NSs with low natal kicks

What is AIC?

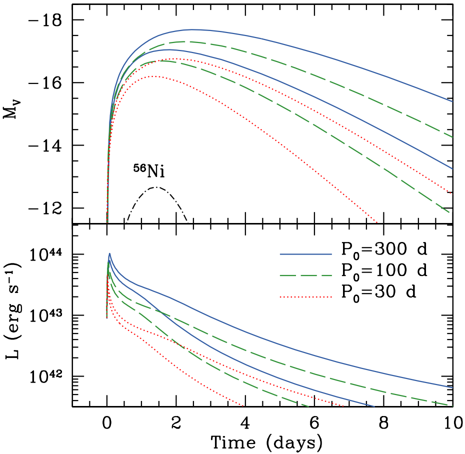
Why might things be brighter/longer?

How do we go from progenitor to NS?

What about the rates?

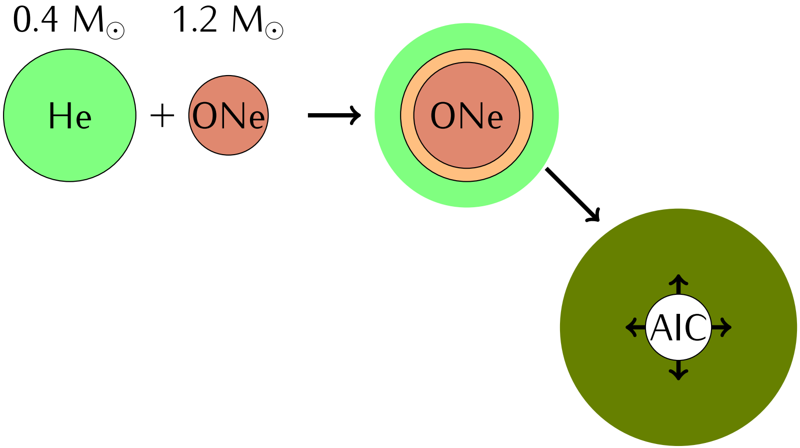
Summary

Single-degenerate systems can show signs of interaction with the companion.



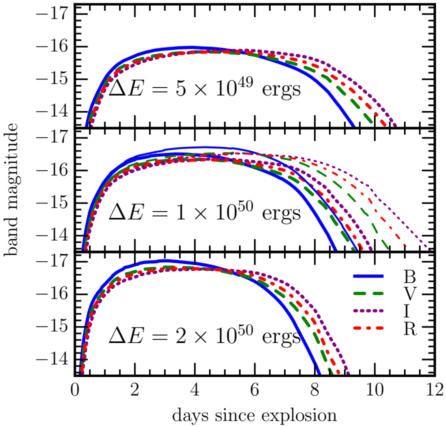
Piro & Thompson (2014); see also Moriya (2016)

The merger of a He WD & ONe WD with a super-Chandra total mass can collapse to an NS.



Brooks, JS et al. (2017b)

Material remaining from the double-degenerate merger can brighten and extend the signature.



Brooks, JS, et al. (2017b); see also Metzger et al. (2009)

Rotation (especially differential rotation) can significantly influence the AIC signature.

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- It is not clear that the WD can be differentially rotating during accretion (e.g., Piro 2008).
- It is not clear that the merger remnants will be rapidly rotating at the time of collapse (e.g., Shen et al. 2012).

Rapid rotation could imply
that the newly-formed NS will be a magnetar.

Energetic (magnetically-driven) explosion

Dessart et al. (2007)

Radio transient

- synchrotron from pulsar wind nebula

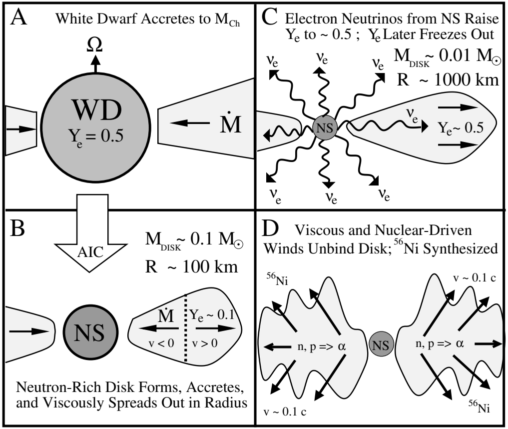
Piro & Kulkarni (2013)

Optical / X-ray transient

- reprocessed X-rays / ionization break-out

Metzger & Piro (2014)

Rapid rotation can lead to the formation of a disk that can create $\sim 10^{-2}\,M_\odot$ of Ni-rich ejecta.



Metzger et al. (2009); Darbha et al. (2010)

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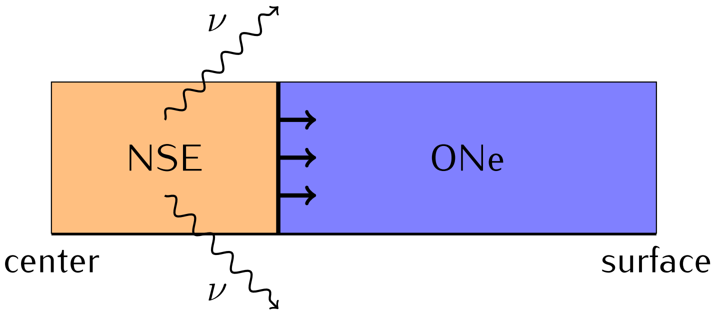
Summary

Multi-D simulations using parameterized initial models have followed the collapse to a NS.

- Collapsing ONe cores do not experience a prompt explosion, but do have successful, sub-energetic, neutrino-driven explosions.
- The formation of a massive disk around the NS requires differentially-rotating WD models.

Fryer et al. (1999); Kitaura et al. (2006);
Dessart et al. (2006); Abdikamalov et al. (2010)

Electron-capture reactions initiate an oxygen deflagration that begins to propagate outwards.



"Modern" models that explore the oxygen deflagration are just beginning to be performed.

- Simplified 1D models suggest collapse.

  Nomoto & Kondo (1991); Gutierrez et al. (1996)

- Multi-D simulations with better flame speeds provide a less clear picture.
  - Jones et al. (2016) find only their highest density models collapse to NSs, with other models leaving sub-Chandra bound remnants.
  - Leung & Nomoto (2017) emphasize that models flip between explosion and collapse within existing uncertainties in the initial model.

Stellar evolution calculations take growing ONe cores to the initiation of the oxygen deflagration.

- There's been recent progress in providing suitable weak reaction rates and incorporating them in stellar evolution codes.

  Jones et al. (2013); Martinez-Pinedo et al. (2014); JS et al. (2015); Suzuki et al. (2016)

- The stellar models still have challenges, especially associated with convection/mixing.

  e.g., Miyaji et al. (1987); JS et al. (2017)

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- There are now models with $\approx$ realistic thermal and composition profiles at oxygen ignition.

Thoughts on evolving single degenerate systems

- An (initially) ONe WD is not required for AIC; CO WD can convert during the accretion phase.

  Brooks, JS, et al. (2017a)

- Continuing the evolution beyond the AIC is necessary to understand the properties of the NS systems left behind.

Ivanova et al. (2008), Tauris et al. (2013), Liu & Li (2017)

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- Ia connection: We need to understand mass and angular momentum retention efficiencies during accretion.

Thoughts on evolving double degenerate systems

- Because material must cool before it can significantly compress the core, DD progenitors have delays between merger and collapse.
  - You need to evolve the systems post-merger for thermal/nuclear timescales.
  - There are $\sim$ few pre-AIC systems currently "waiting" in MW/M31.

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e.g., JS et al. (2016)

- Ia connection: We need to understand which super-Chandrasekhar systems explode at merger so we take them out of the AIC pool.

The rate of AIC is uncertain.

Theoretical predictions

- Pop syn gives $\sim 10^{-4}\,\mathrm{yr}^{-1}$ in the MW.
  - $10^{-6} - 10^{-4}\,\mathrm{yr}^{-1}$ (Yungelson & Livio 1998)
  - few $\times 10^{-4}\,\mathrm{yr}^{-1}$ (Ruiter et al. 2018)

Observational constraints

- Many Ia constraints can be re-interpreted as AIC rate constraints.
- If AIC produces r-process, then this also provides a limit on the rate.

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- AIC has many sub-channels. Given that the most prominent signature of the collapse may be channel-dependent, this makes identifying an AIC event tricky.
- For many of the predicted signatures, upcoming optical/radio surveys could observe $\sim 10\,\mathrm{yr}^{-1}$.