

# Binary nature of supernovae type Ic revealed by molecular gas observations of nearby galaxies

**Michał Michałowski**

/me-how me-how-off-skee/

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supernova type	observational definition	physical model
II	hydrogen lines	8–10 Solar mass star 

## Goals

- 1 Distinguish the very massive star and binary models for supernovae type Ib and Ic
- 2 Determine the conditions necessary for their progenitors to be born

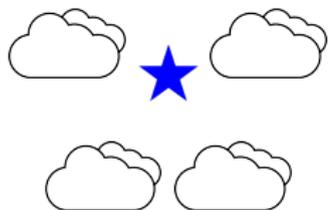
# Main goals

supernova type	observational definition	physical model	
II	hydrogen lines	8–10 Solar mass star	★
Ic	no hydrogen lines	binary 8–10 system??	★★
	no helium lines	30 Solar mass star??	★

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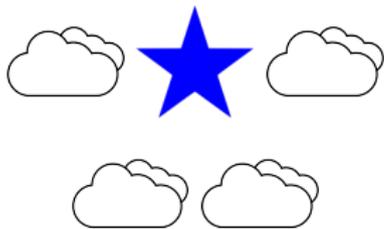
8 solar mass star (type II supernova)



binary 8 solar mass star system (type Ic supernova??)



30 solar mass star (type Ic supernova??)



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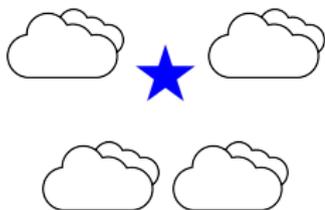
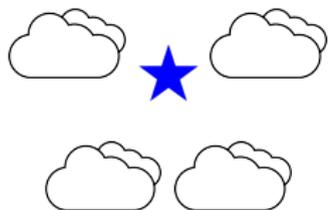


30 solar mass star (type Ic supernova??)



2 million years

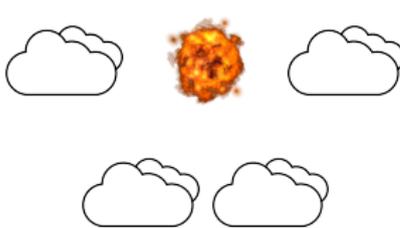
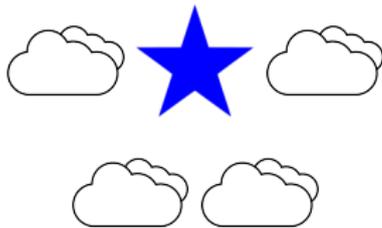
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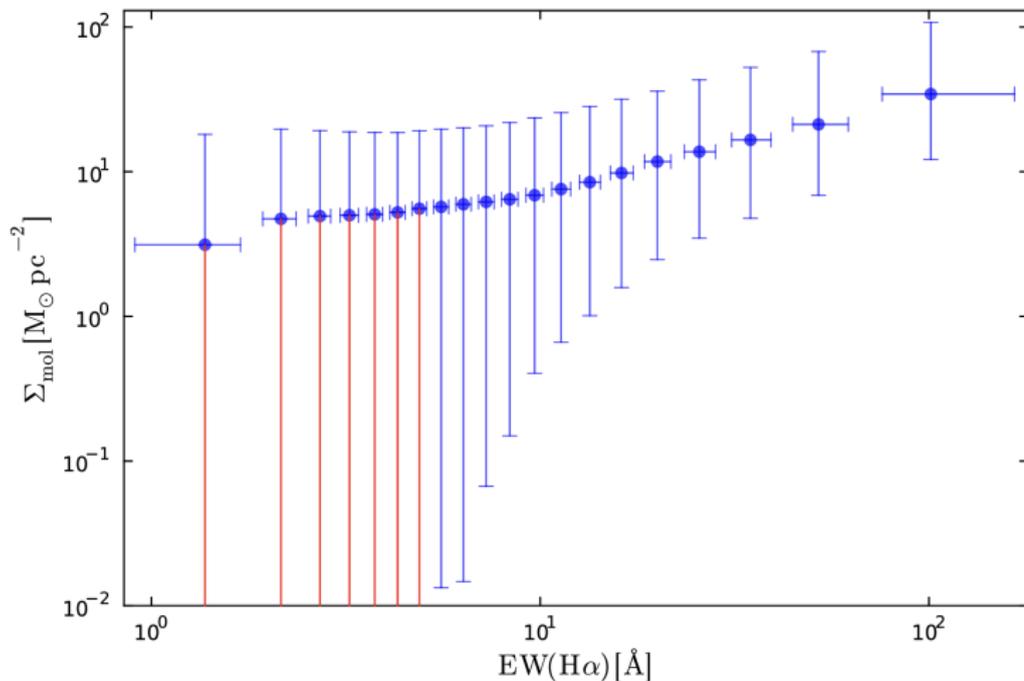
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2 million years

20 million years

# Molecular cloud timing

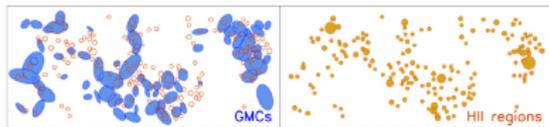
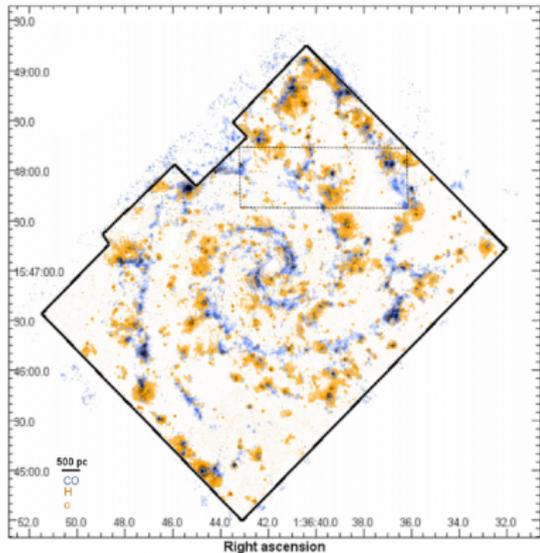


Gas density correlates with H $\alpha$  equivalent width - age proxy, so it can be used to time the evolution.

Solar et al. (2024, Nature Communications, 15, 7667)

# Why CO is needed in addition to $H\alpha$

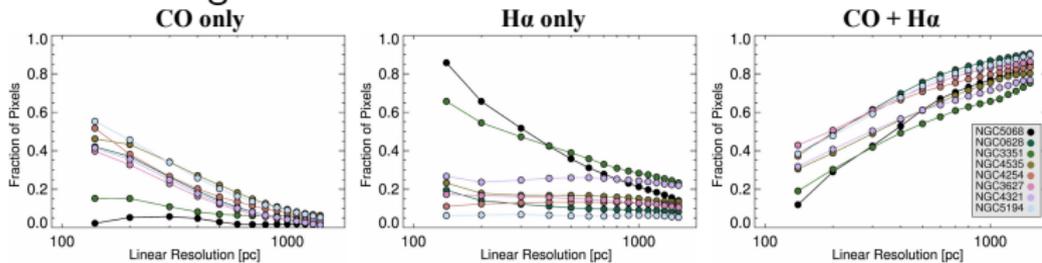
Most HII regions are not associated with CO and vice versa



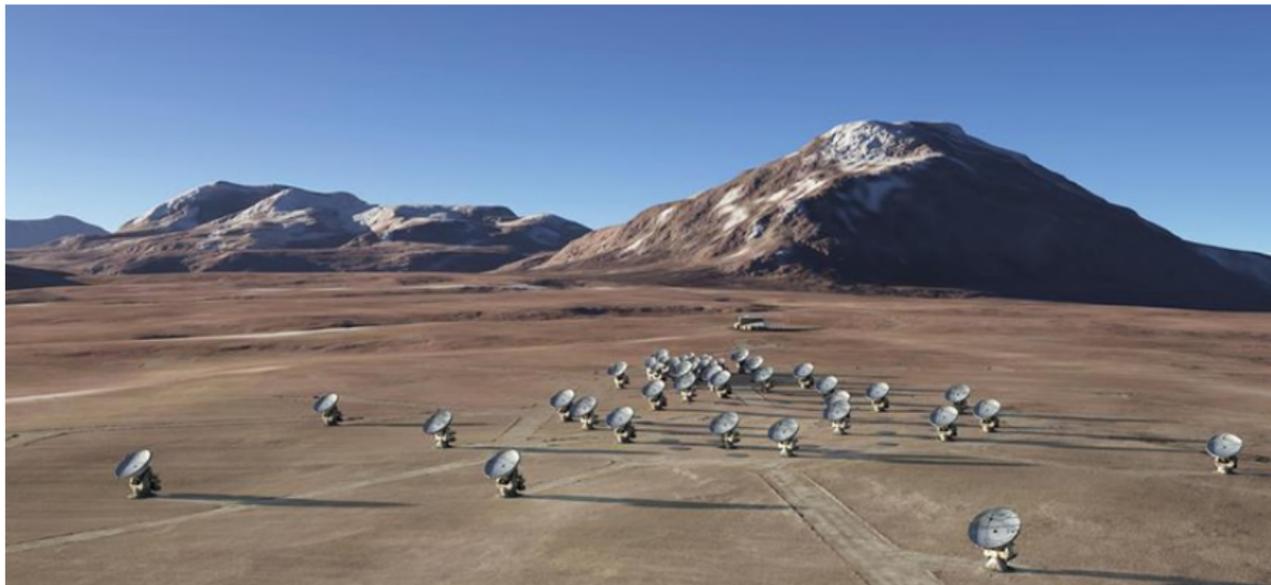
Kreckel et al. (2018, ApJL, 863, 21)

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Schinnerer et al. (2019, ApJ, 887, 49)



Matched to size of giant molecular clouds in which stars form

- PHANGS

Physics at High Angular resolution in Nearby Galaxies

<https://sites.google.com/view/phangs/home>

- 74 galaxies images by ALMA at 50-100 pc resolution
- 12 type Ia, 30 type II, and 5 type Ic

- ACOS

ALMA CO SN survey

- 16 type Ic SN host galaxies
- 50-100 pc resolution

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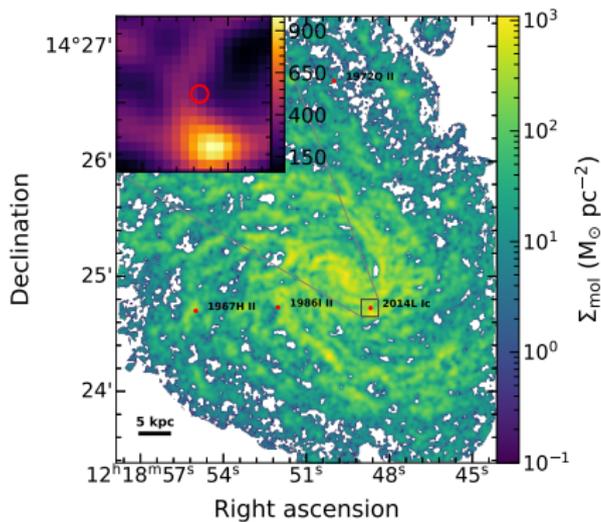
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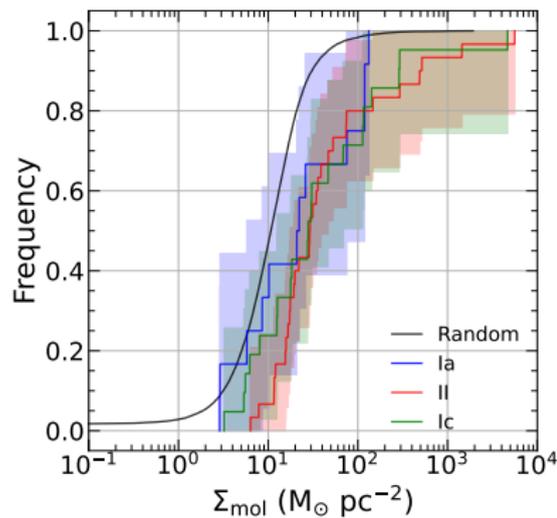
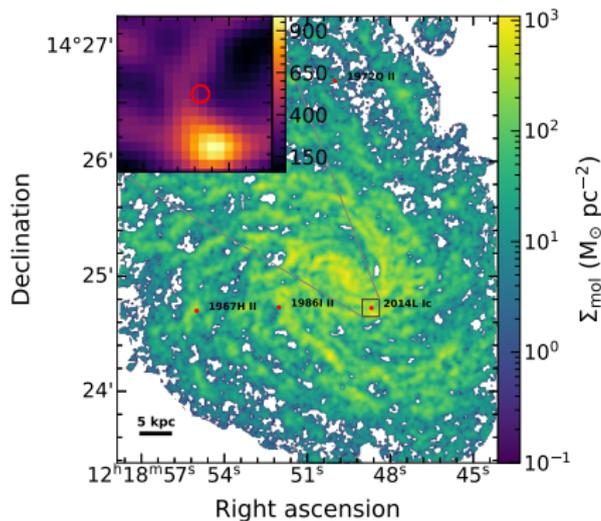
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# SN type Ic and II have similar molecular environments



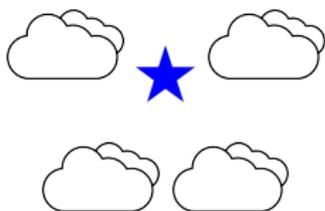
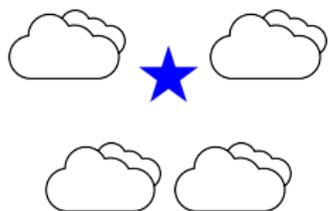
Solar et al. (2024, Nature Communications, 15, 7667)

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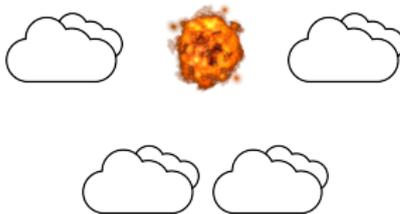
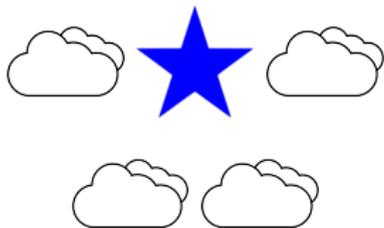
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2 million years

20 million years

# Constraints on the properties of progenitors of SNe type Ic

- Lifetime difference between progenitors of type II and Ic SNe:  $< 5$  Myr
- Confirmed type II progenitors masses:  $11 M_{\odot}$  and lifetimes: 25 Myr
- Hence, average type Ic progenitor masses: 10–12  $M_{\odot}$  and lifetimes: 20–29 Myr

- CO observations with a spatial scale of molecular clouds can constrain the SN progenitor nature
- Type Ic progenitor masses: 10–12  $M_{\odot}$
- Evidence for binary model of type Ic SNe
- This can be used to estimate their metal enrichment contribution and feedback
- Details in Solar et al. (2024, Nature Communications, 15, 7667)

# What can be done with the ALMA Band 2 upgrade

- CO(1-0) in order to trace colder gas component and investigate the excitation of gas
- Better line sensitivity to increase the sample size (higher redshifts)
- Better continuum sensitivity to investigate dust emission properties
- Search for other lines (e.g. SO<sub>2</sub>)