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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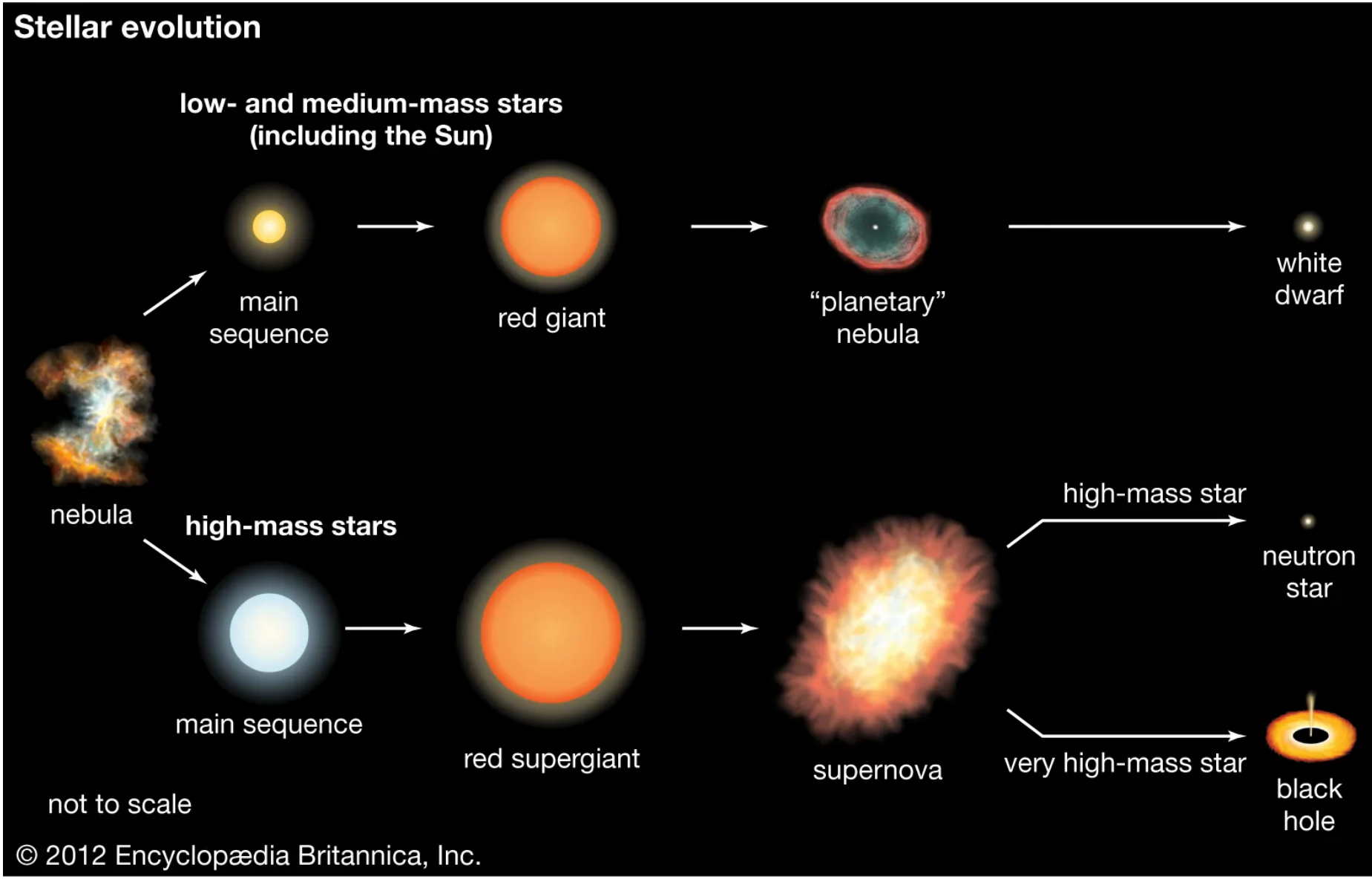
28.06.2023
Observing the Universe at millimetre wavelengths, Grenoble


Stellar evolution
low- and medium-mass stars
(including the Sun)
main
sequence
red giant
“planetary”
nebula
white
dwarf
nebula
high-mass stars
high-mass star
neutron
star
main sequence
red supergiant
supernova
very high-mass star
black
hole
not to scale
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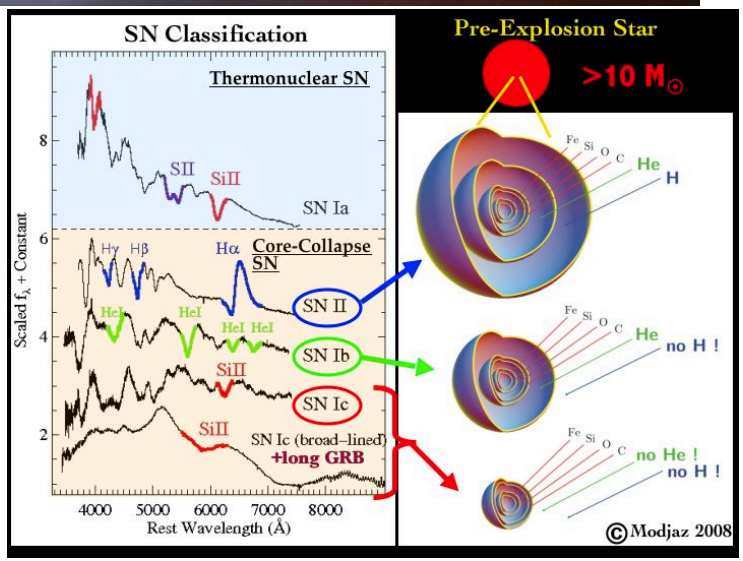
Supernova types

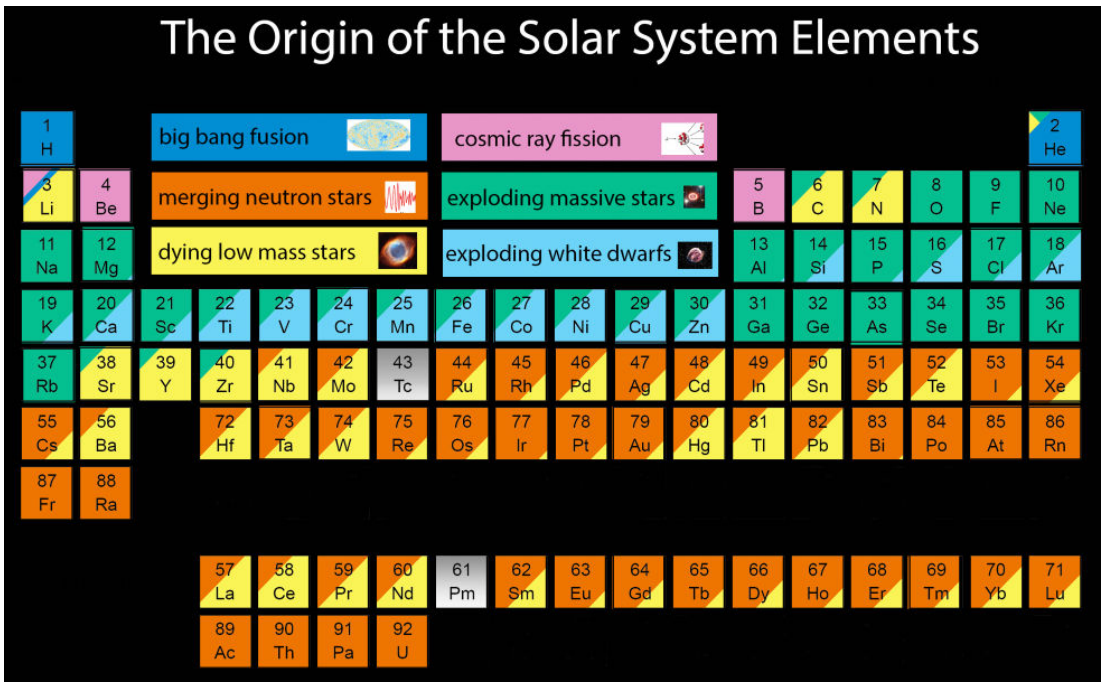
Supernovae type Ia



Supernovae type II
Supernovae type Ib
Supernovae type Ic

Why is the knowledge of SN progenitors important?

- To measure a fraction of metals produced by massive stars
- To determine how supernovae influence star formation through ionisation of gas
- These aspects need to be implemented by hand in numerical galaxy evolution simulations
- Understanding of the endpoints of massive stars is an important element of stellar evolution



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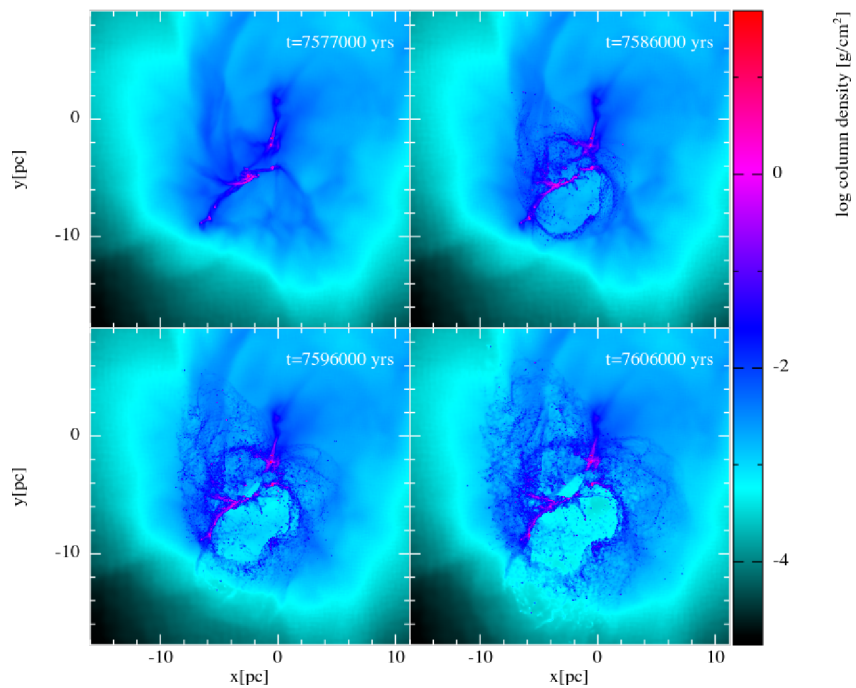

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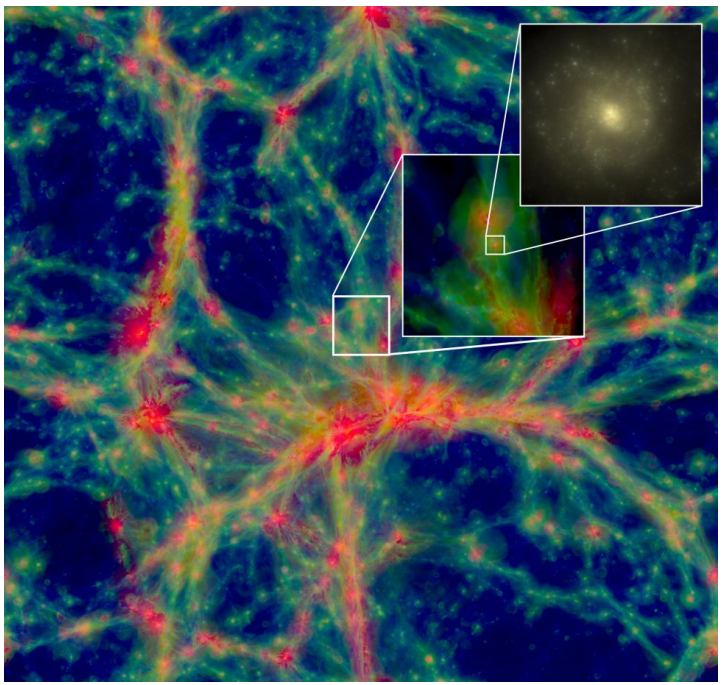

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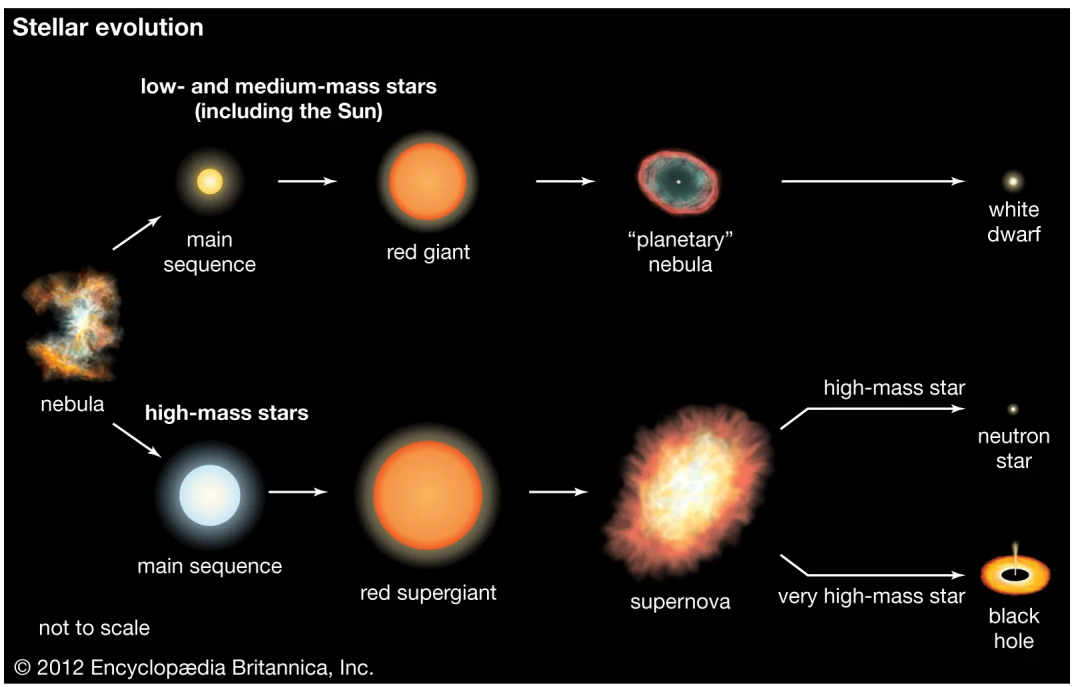


Main goals

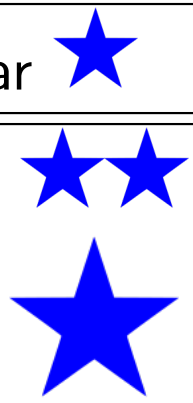
supernova type	observational definition	physical model
II	hydrogen lines	8–10 Solar mass star 

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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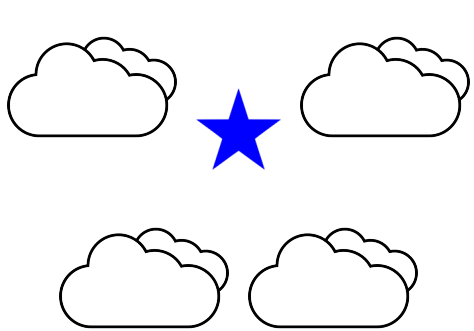
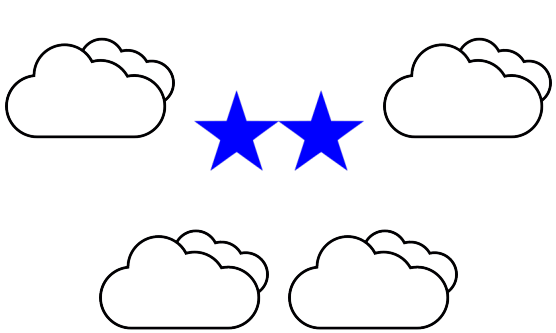
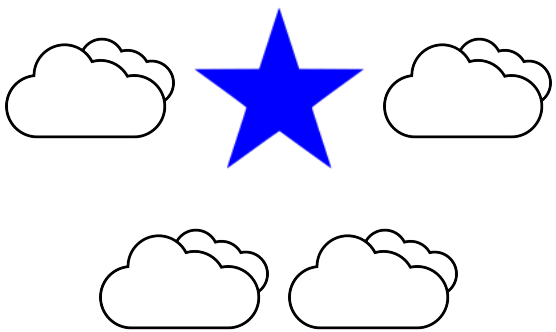
8 solar mass star (type II supernova)



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



30 solar mass star (type Ic supernova??)



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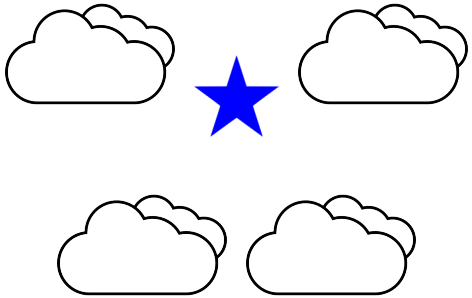

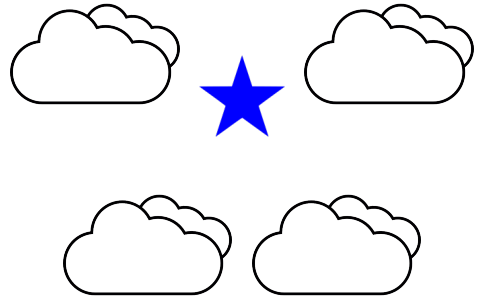

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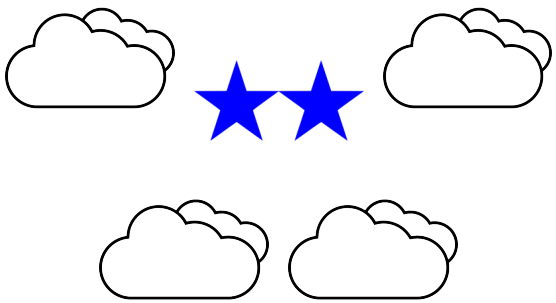

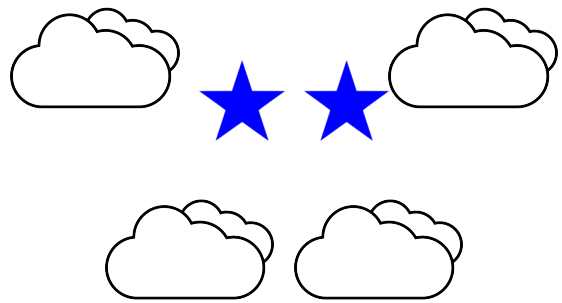

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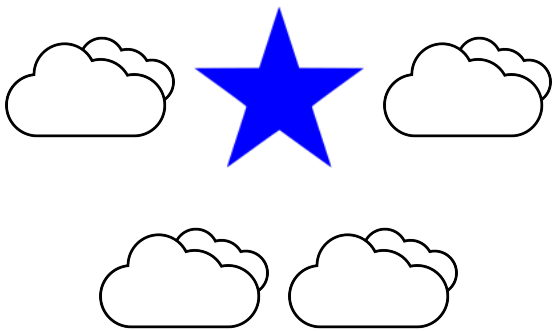

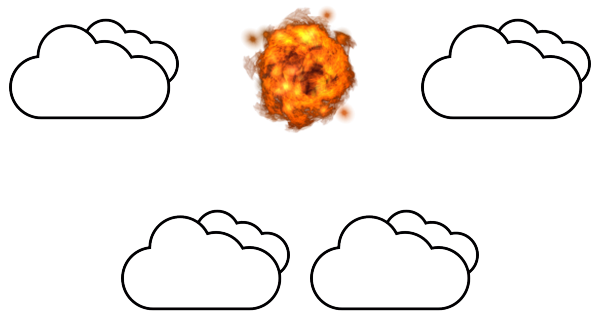

2 million years

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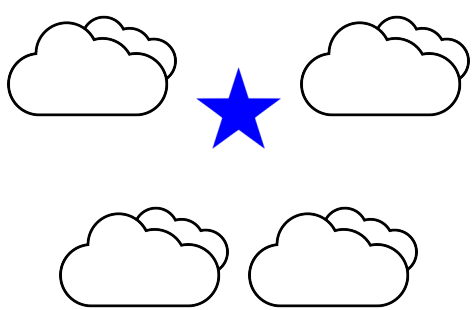

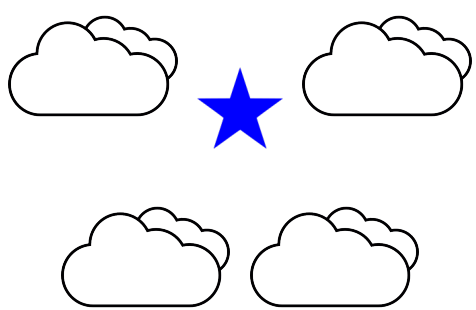

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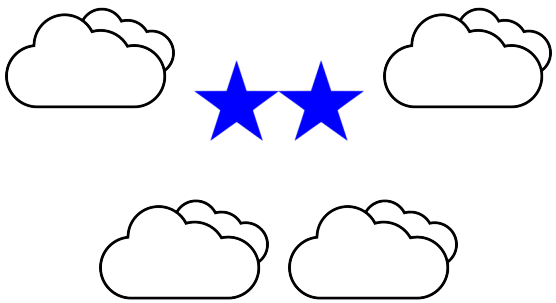

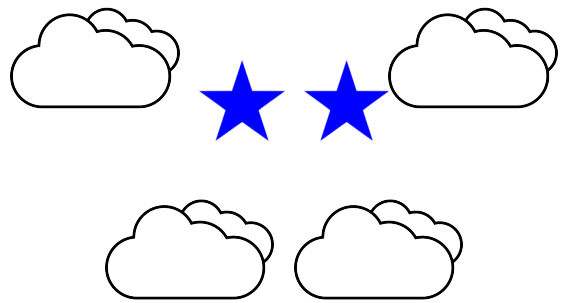

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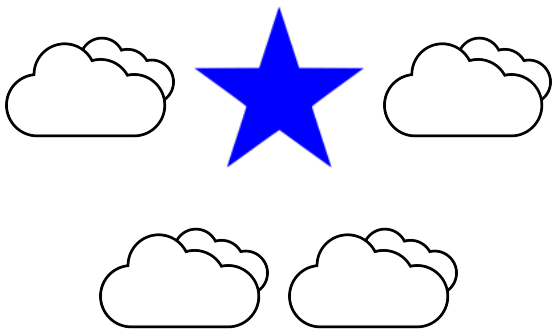
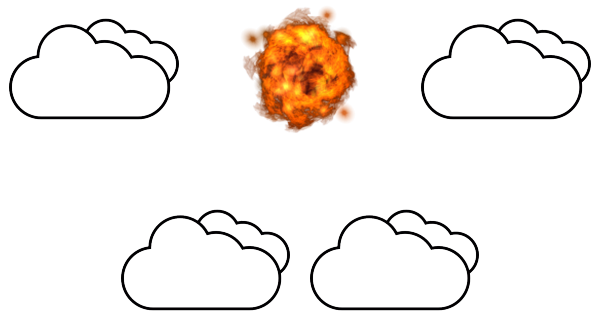
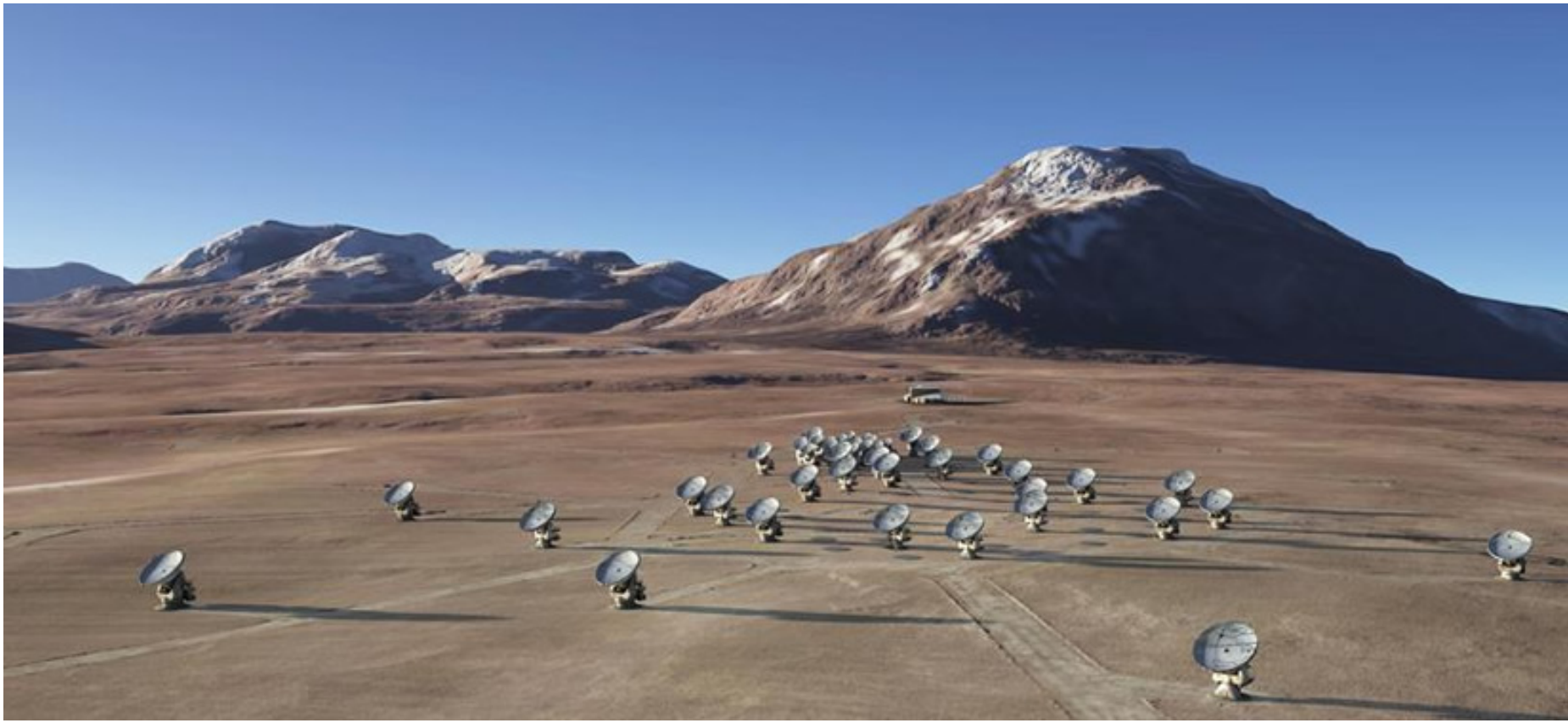




2 million years

20 million years

Resolution: ALMA



Matched to size of giant molecular clouds in which stars form

Data

- 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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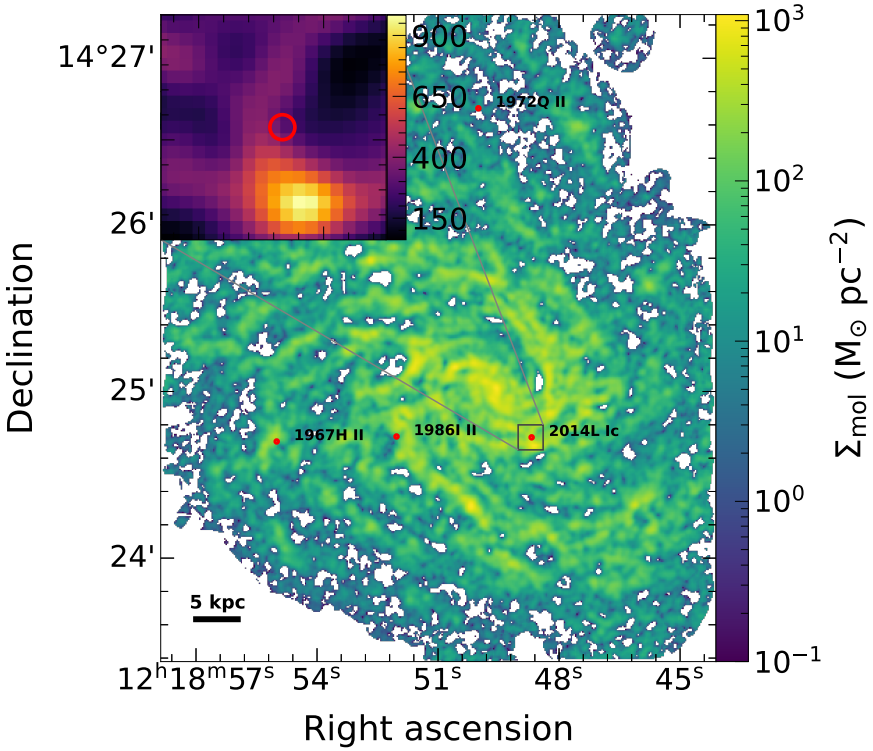
SN type Ic and II have similar molecular environments



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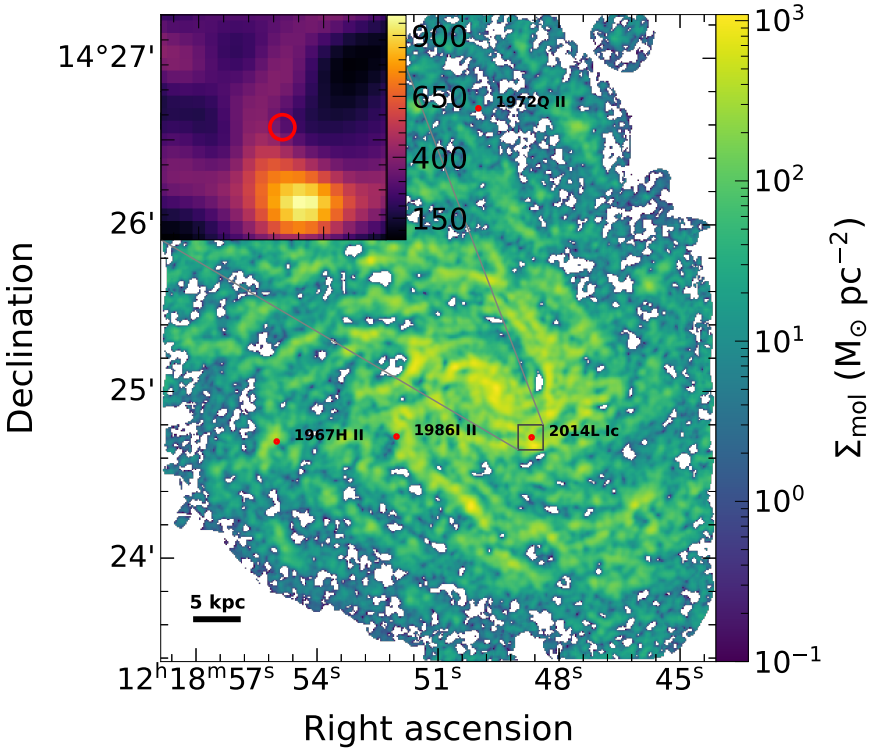

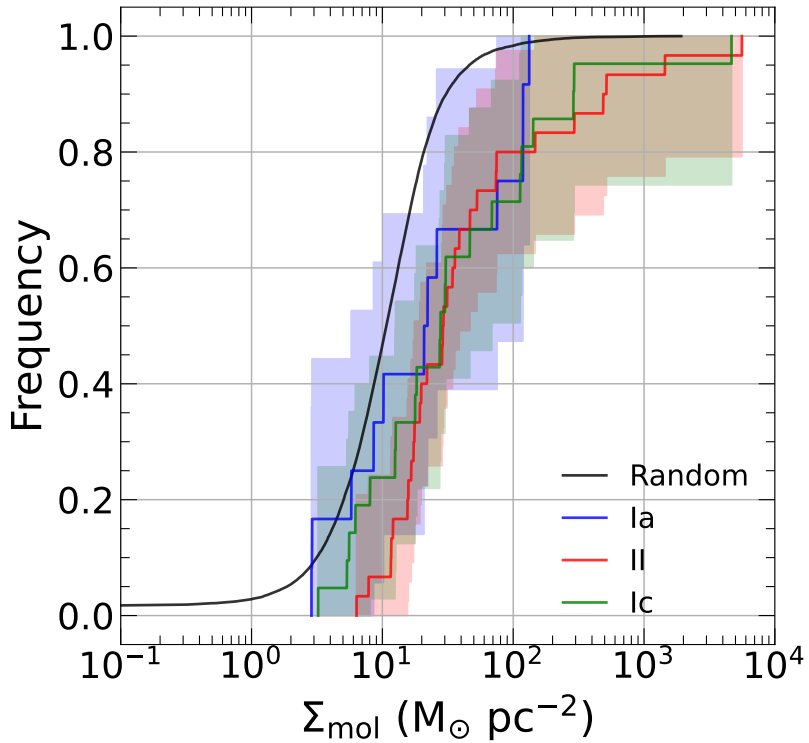

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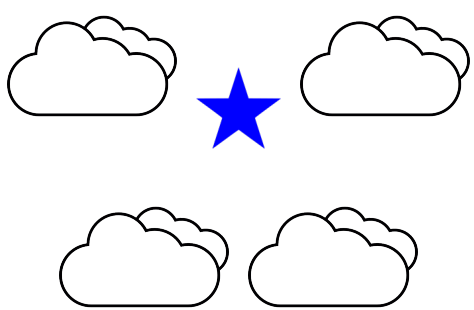

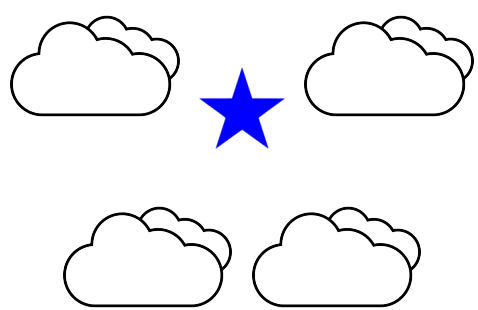

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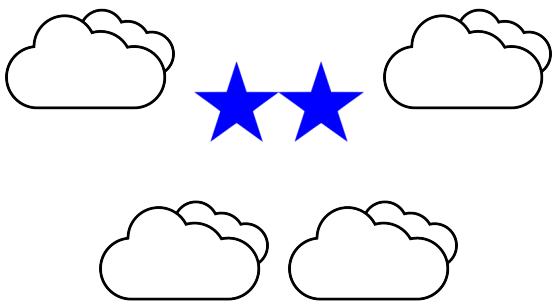

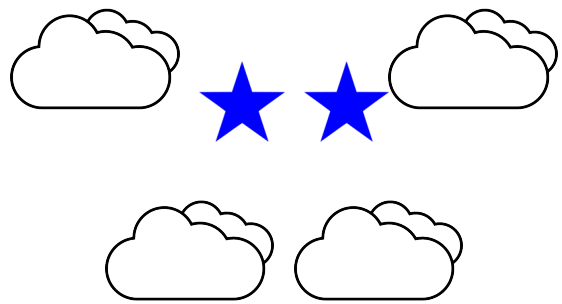

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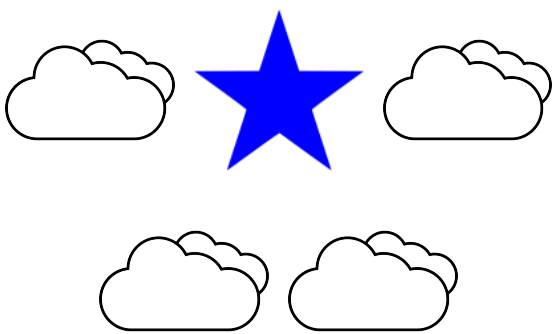
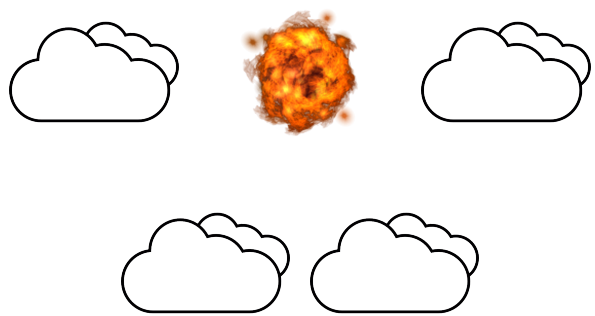




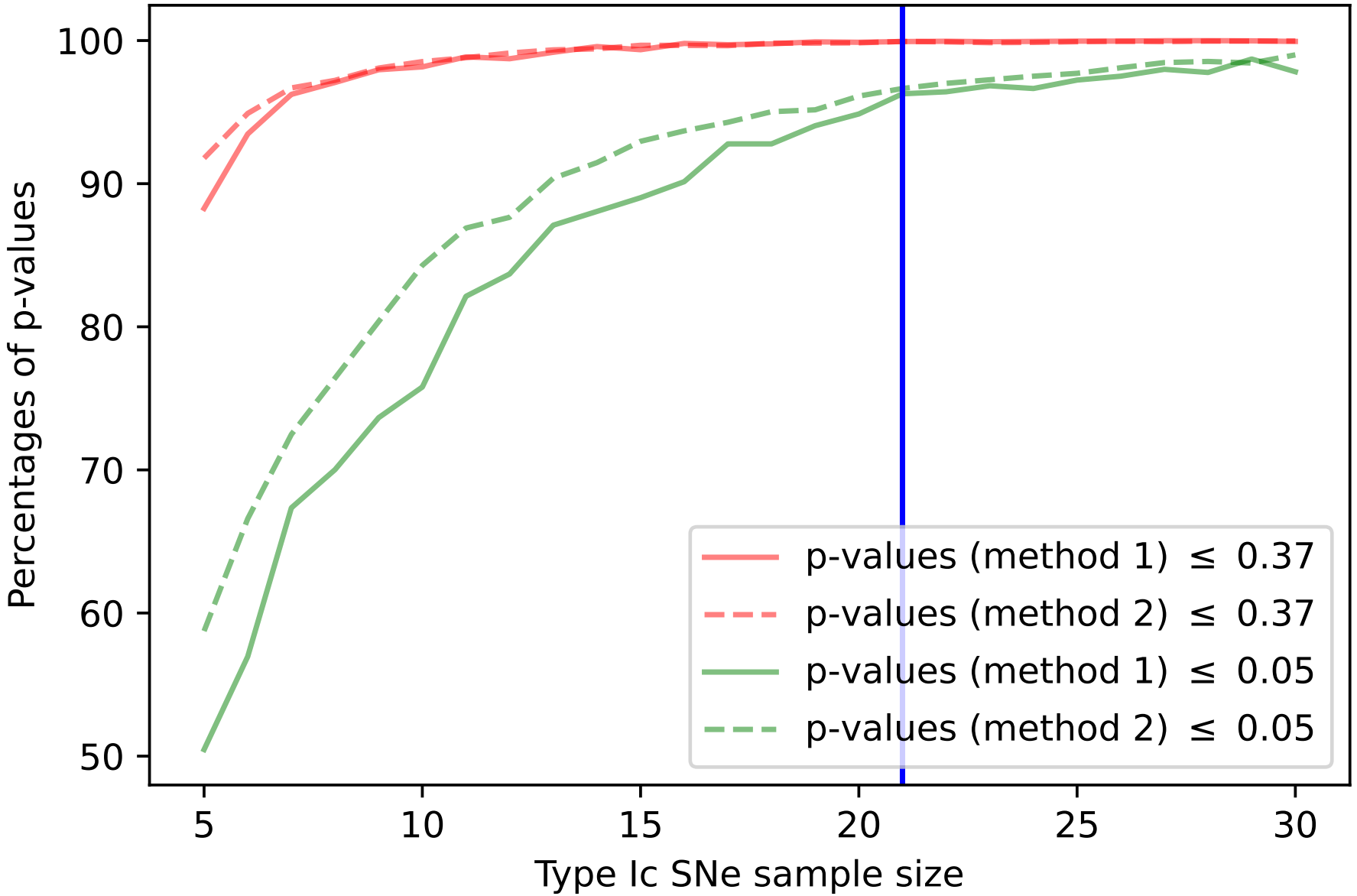
2 million years

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 $\mathrm{M}_{\odot}$ and lifetimes: 25 Myr
- Hence, average type Ic progenitor masses: 10–12 $\mathrm{M}_{\odot}$ and lifetimes: 20–29 Myr

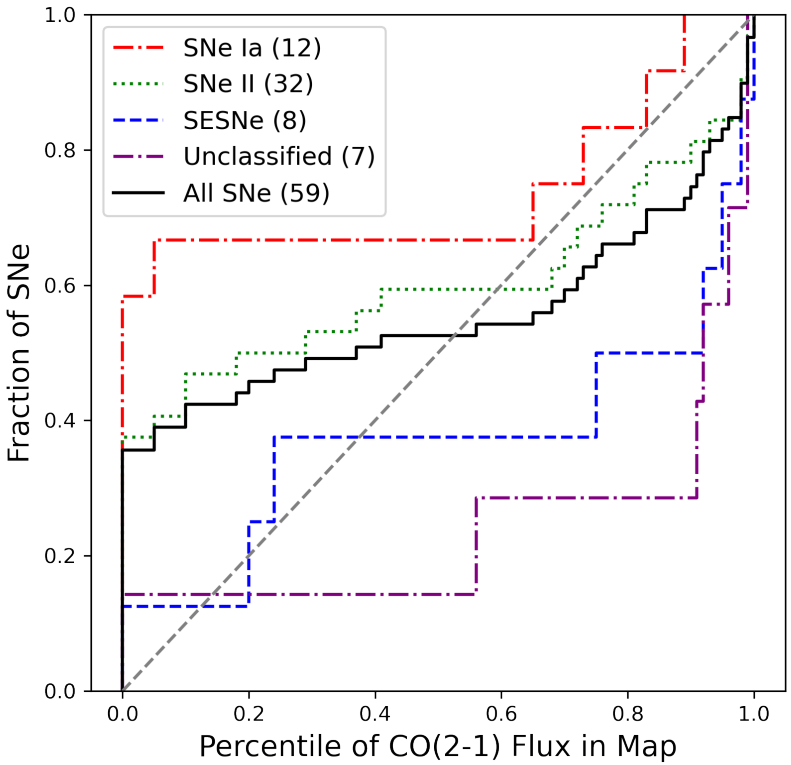
Statistical significance

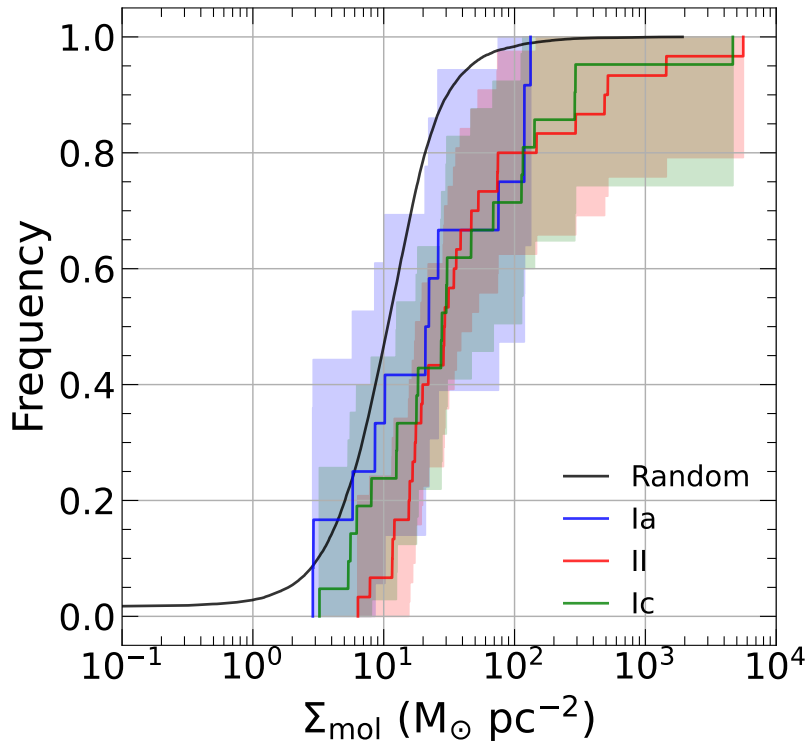


Conclusions

- CO observations with a spatial scale of molecular clouds can constrain the SN progenitor nature
- Type Ic progenitor masses: 10–12 $\mathrm{M}_{\odot}$
- 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. (submitted)

PHANGS collaboration results: sample size





Chen et al. (2023, ApJ, 944, 110)