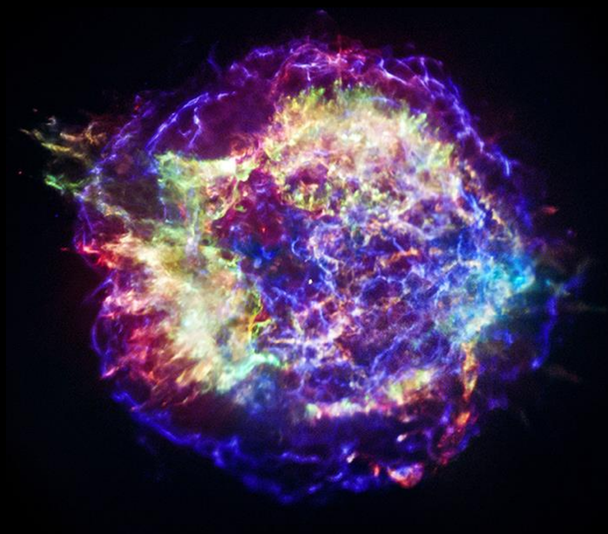
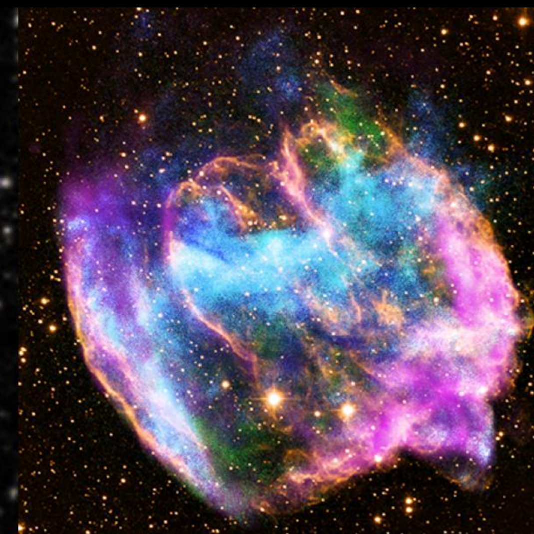
The imprint of their explosions:

Using supernovae to understand stellar death





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OzGrav
ARC CENTRE OF EXCELLENCE FOR GRAVITATIONAL WAVE DISCOVERY

Summary

- *Core-collapse supernovae (SNe) and their remnants (SNRs) are a useful means to test and constrain our understanding of how and which stars die.*

- *We can tie SNe and SNRs to their explosions origins and use their properties to understand many aspects of stellar death such as:*
  - *The mass of the stars that go supernova*
  - *Understanding the SN explosions that produce compact objects such as Neutron Stars*

Supernovae discovered everyday using a variety of optical surveys

ZTF | Pan-STARRS | atlas | ASAS-SN | YSE | Rubin Observatory

e.g.,

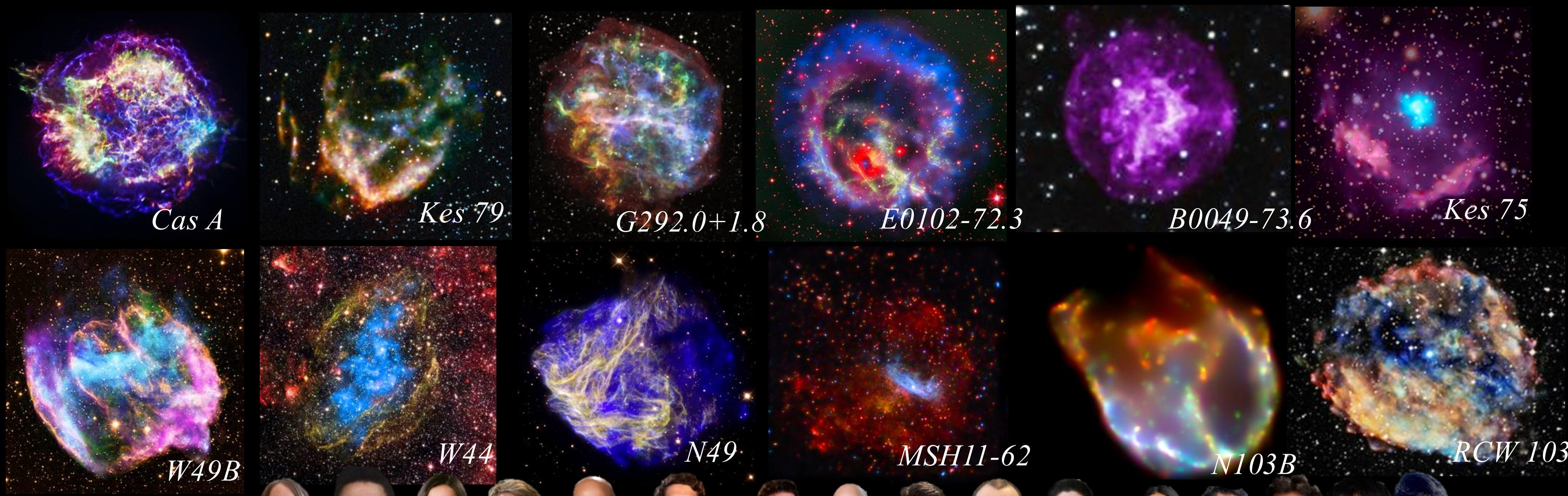
...and many others..

...but these supernovae are usually very far away

$\sim$1-100 Megaparsecs or

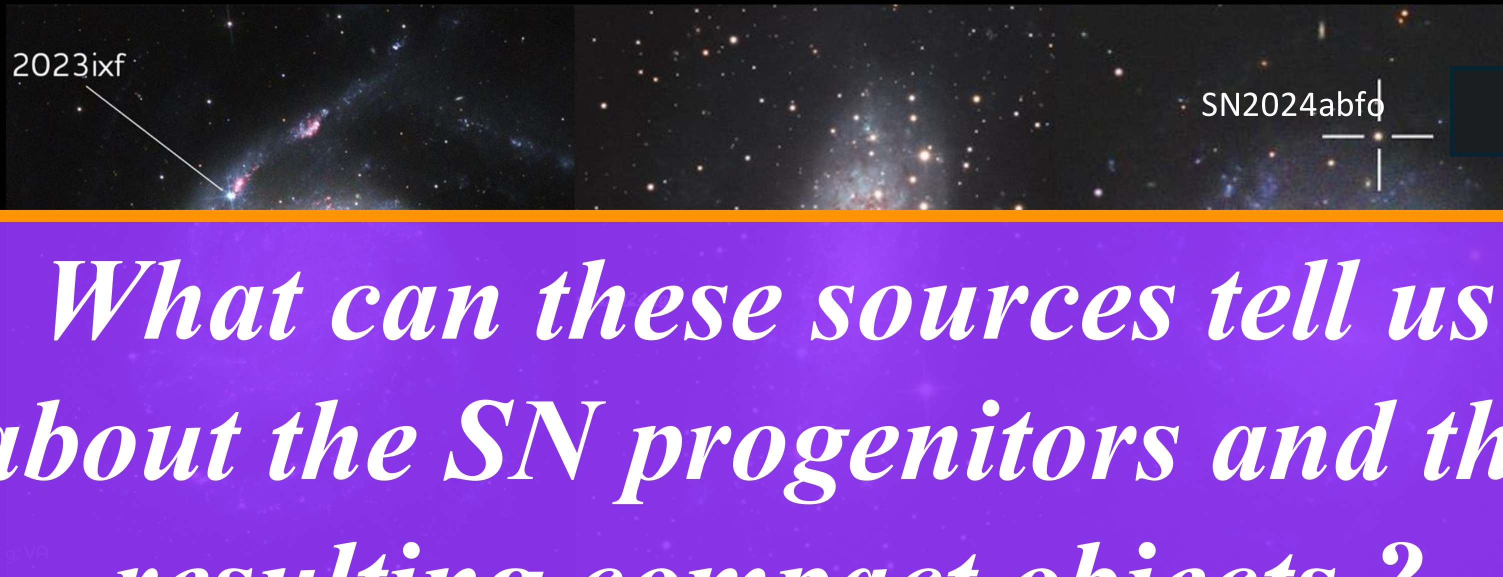
$\sim (3 - 300) \times 10^{19}$ km

Nearby supernova and their remnants

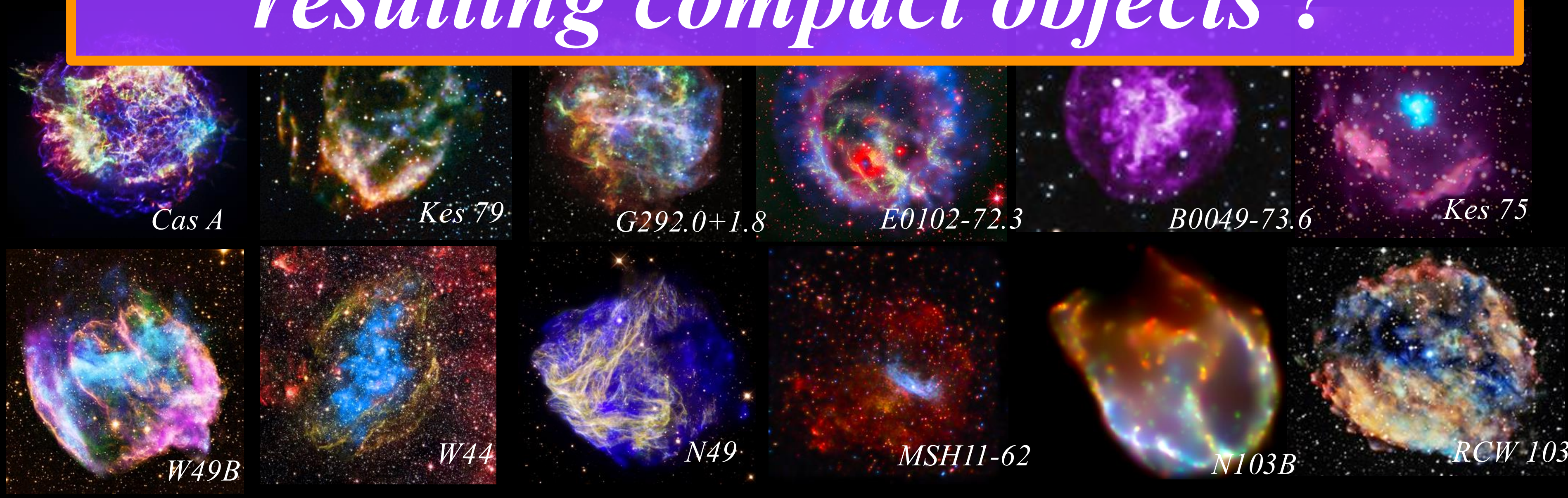


e.g.,

Nearby supernova and their remnants



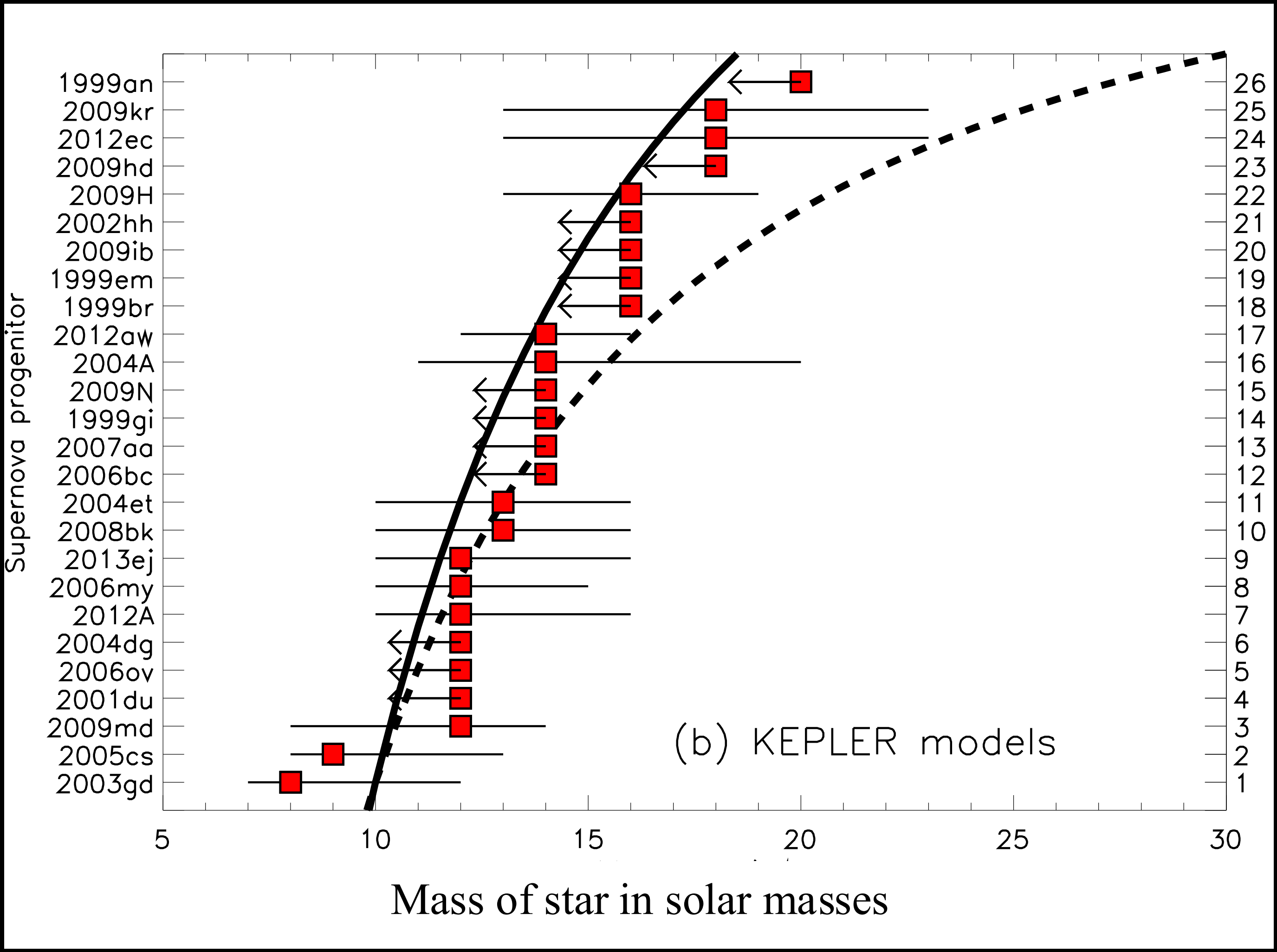
What can these sources tell us about the SN progenitors and the resulting compact objects ?



I. What are the masses of stars that undergo core-collapse?

Direct search for core collapse stars

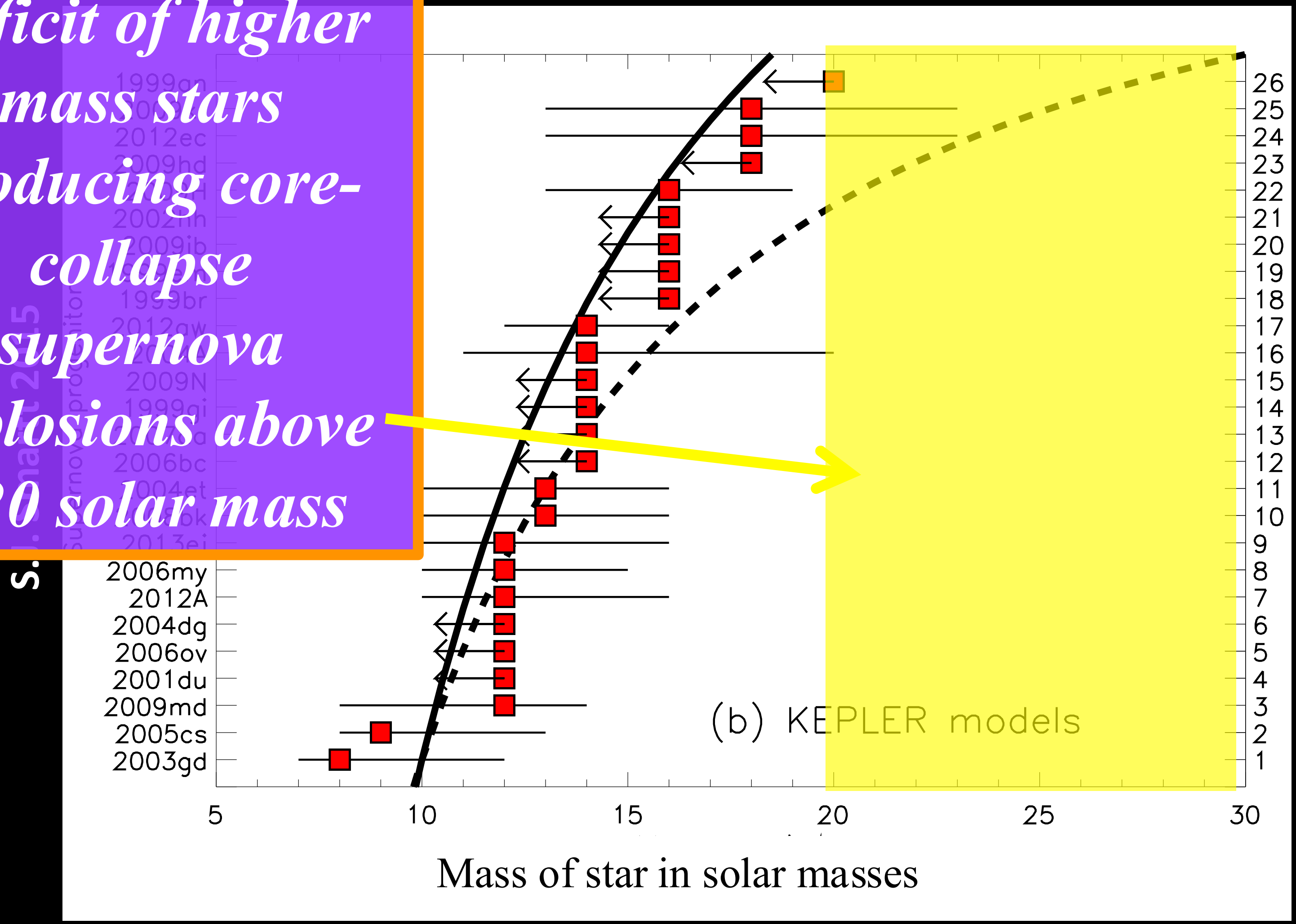
S.J. Smartt 2015



Masses of stars we saw explode ~8-20M_{sun}

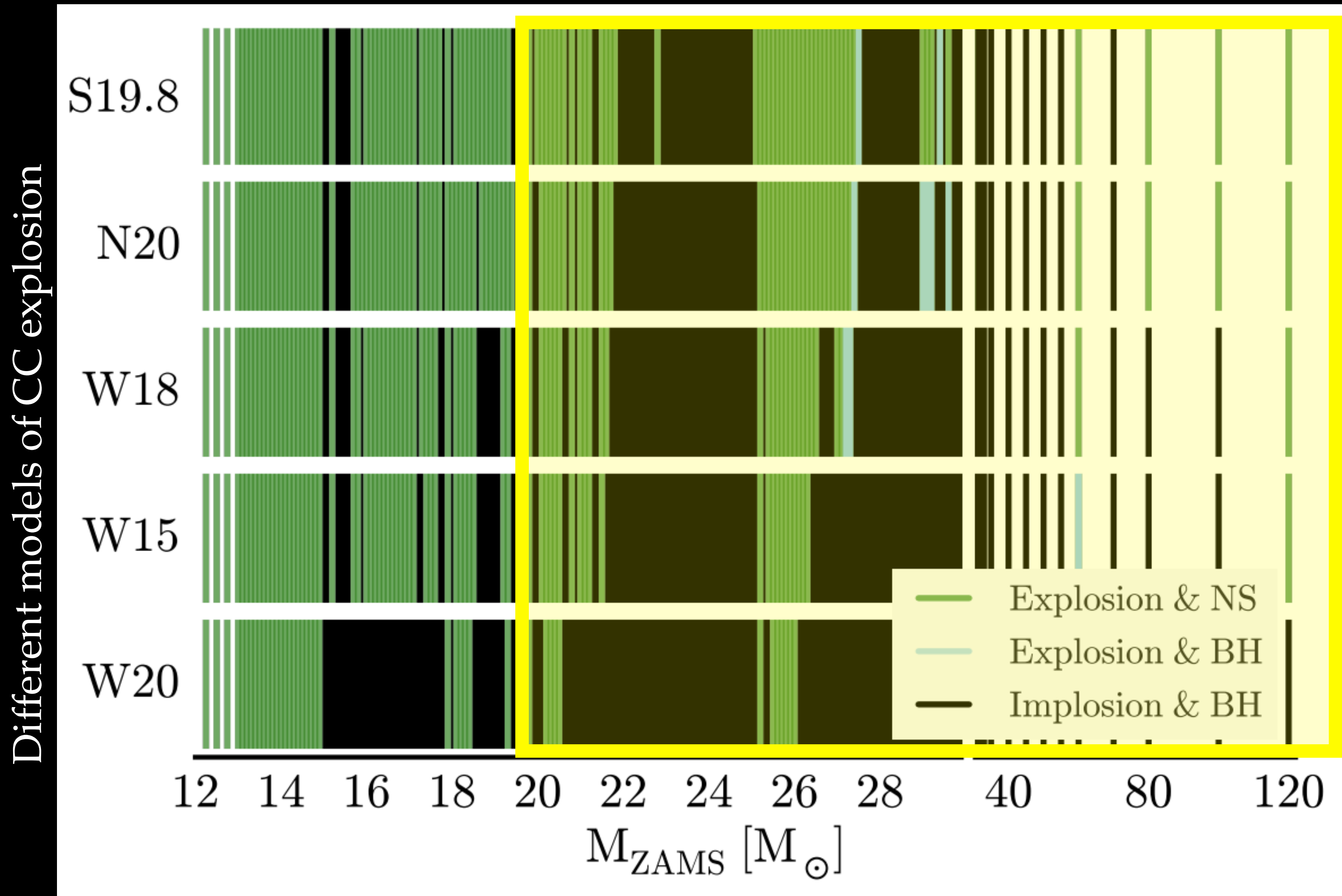
Direct search for core collapse stars

Deficit of higher mass stars producing core-collapse supernova explosions above ~20 solar mass



Masses of stars we saw explode ~8-20M_{sun}

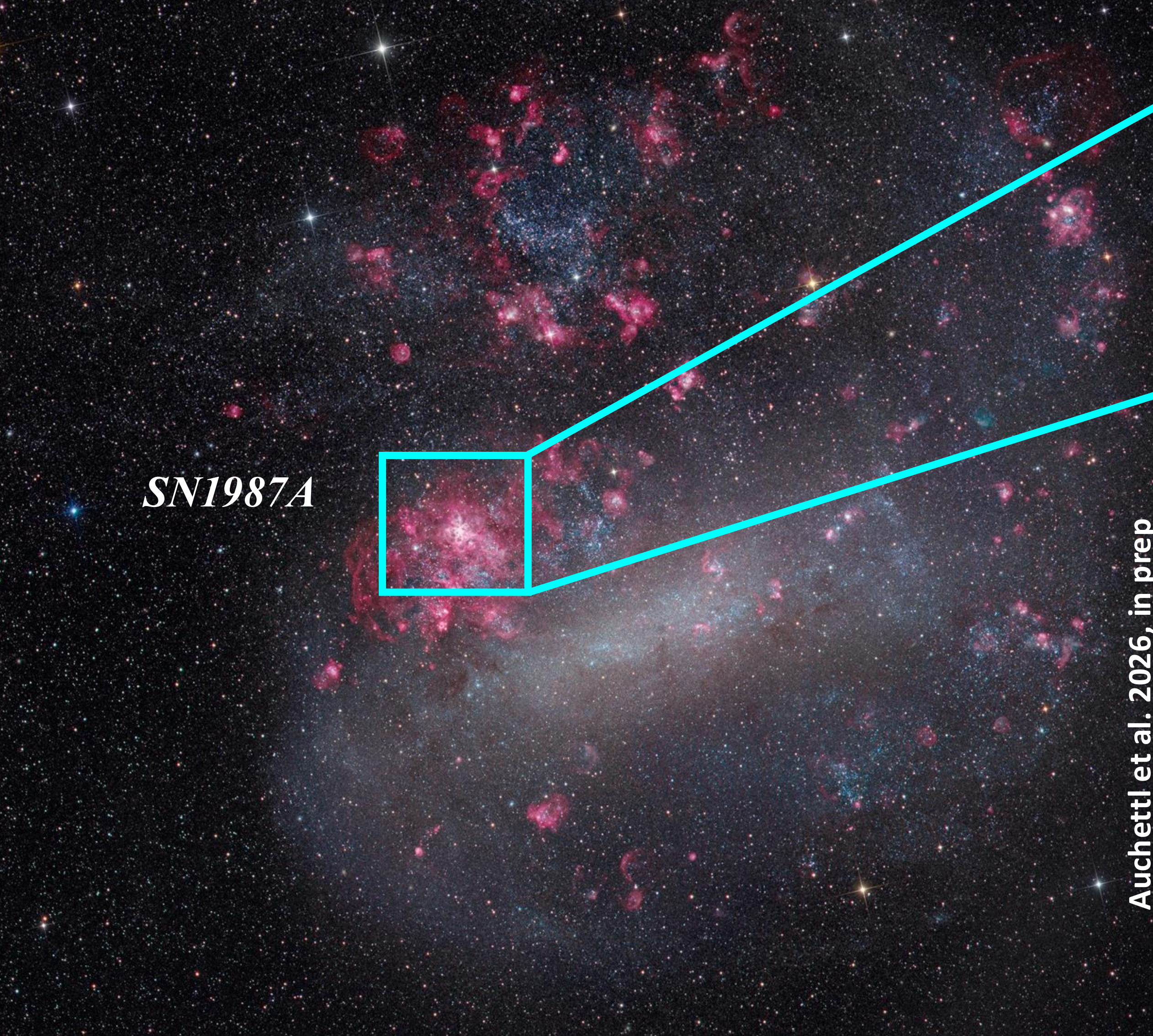
Theory predicts otherwise

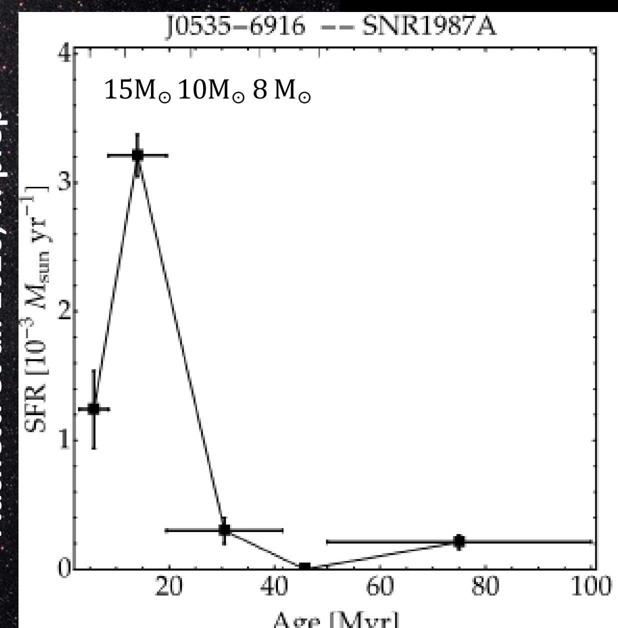


Sukhbold et al. 2015

Stellar masses from their neighbours

We can use the stars around a supernova remnant to determine the mass of the star that exploded!

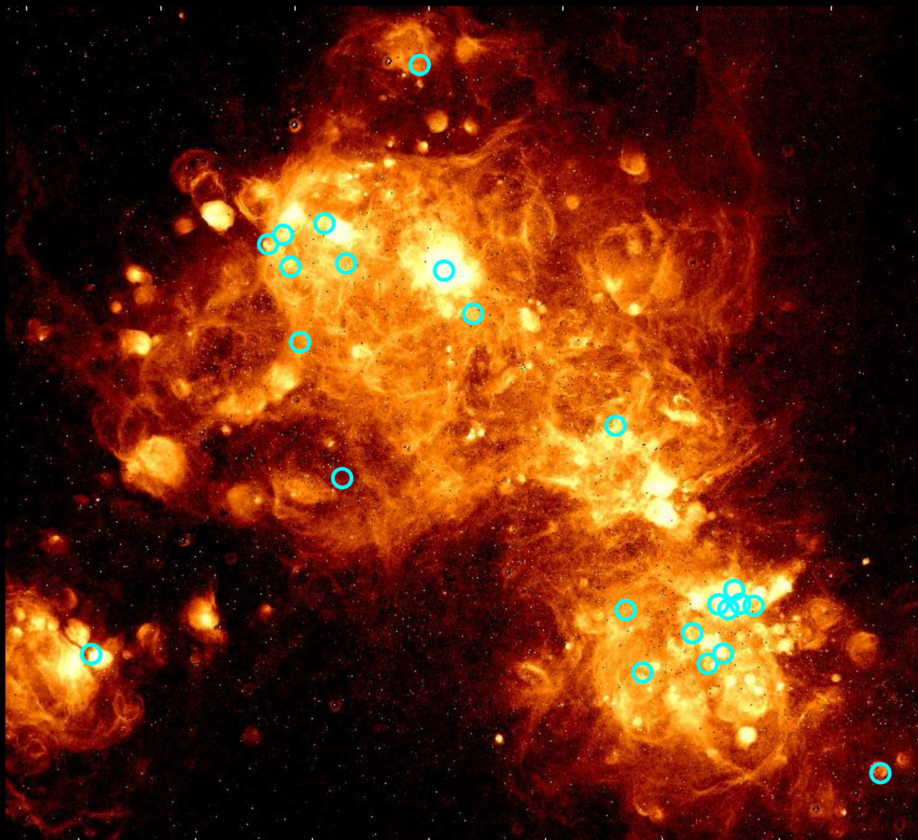


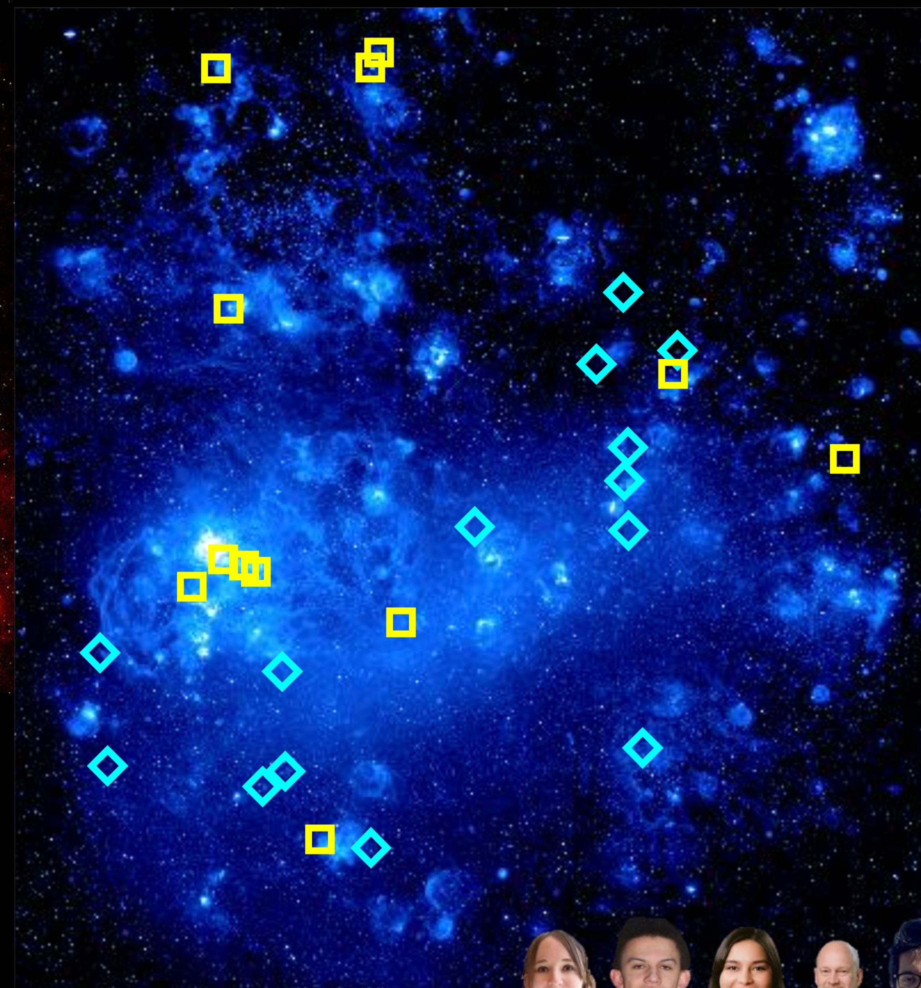


Auchettl et al. 2026, in prep

Stellar masses from their neighbours

..in the Small and Large Magellanic Cloud



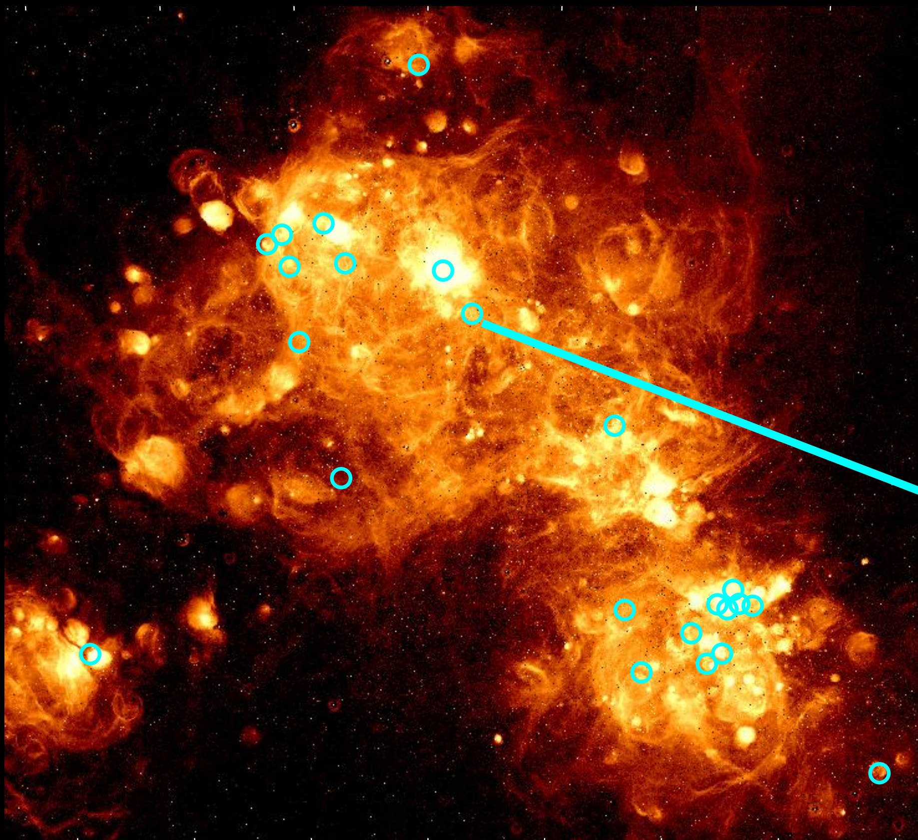


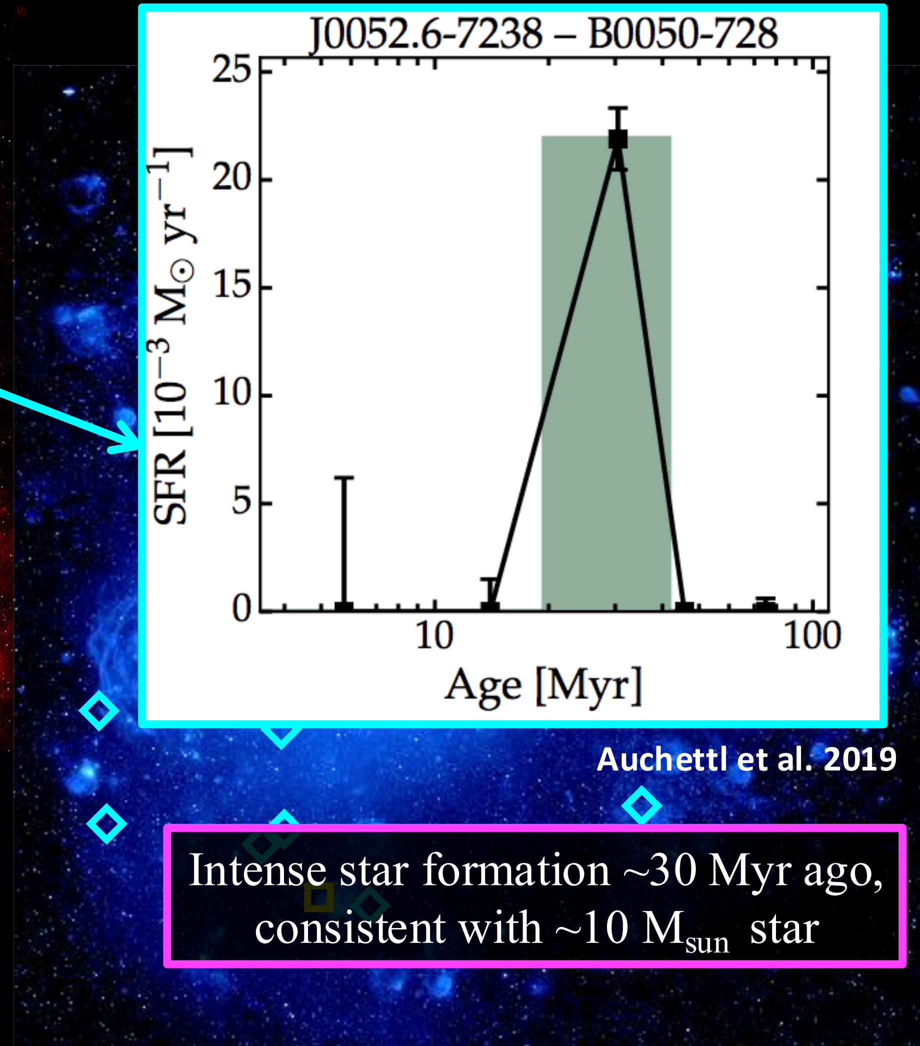
Locations of the supernova remnants:

- cyan circles (SMC)
- cyan diamonds and yellow squares (LMC).

Stellar masses from their neighbours

..in the Small and Large Magellanic Cloud





Auchettl et al. 2019

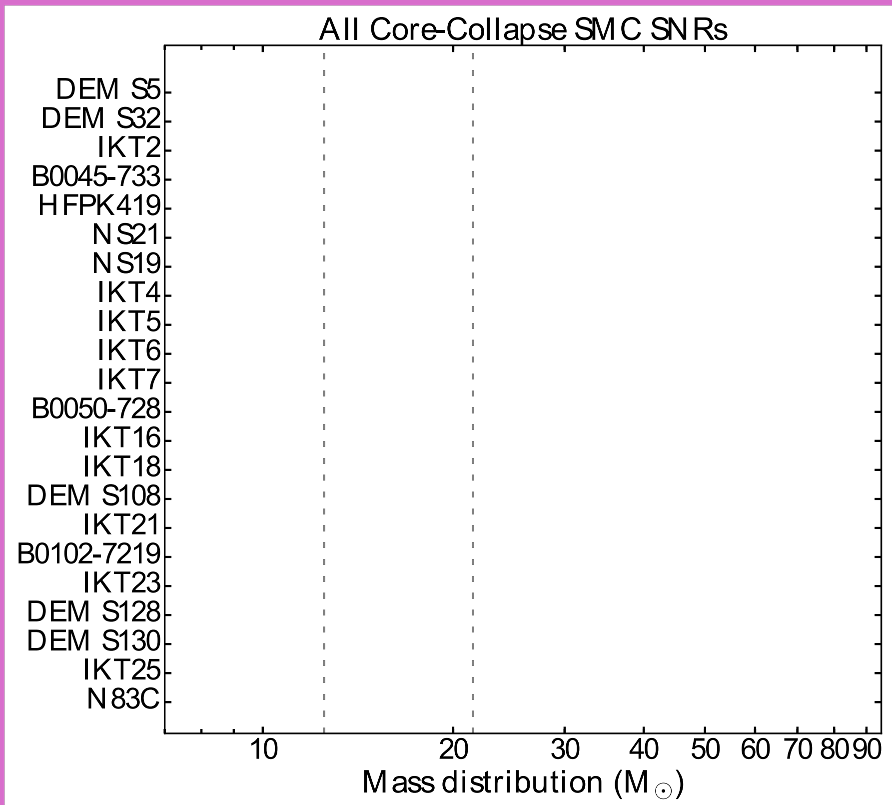
Intense star formation ~30 Myr ago, consistent with ~10 M_{sun} star

Locations of the supernova remnants:

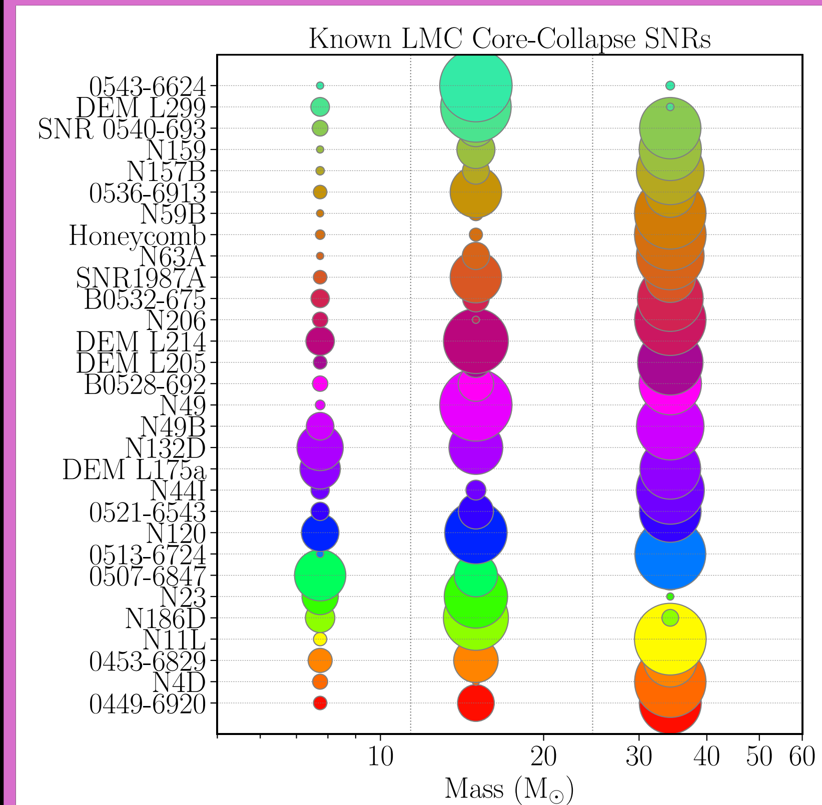
- cyan circles (SMC)
- cyan diamonds and yellow squares (LMC).

Masses of exploding stars

..in the Large and Small Magellanic Cloud



Auchettl et al. 2019



Auchettl et al. in prep

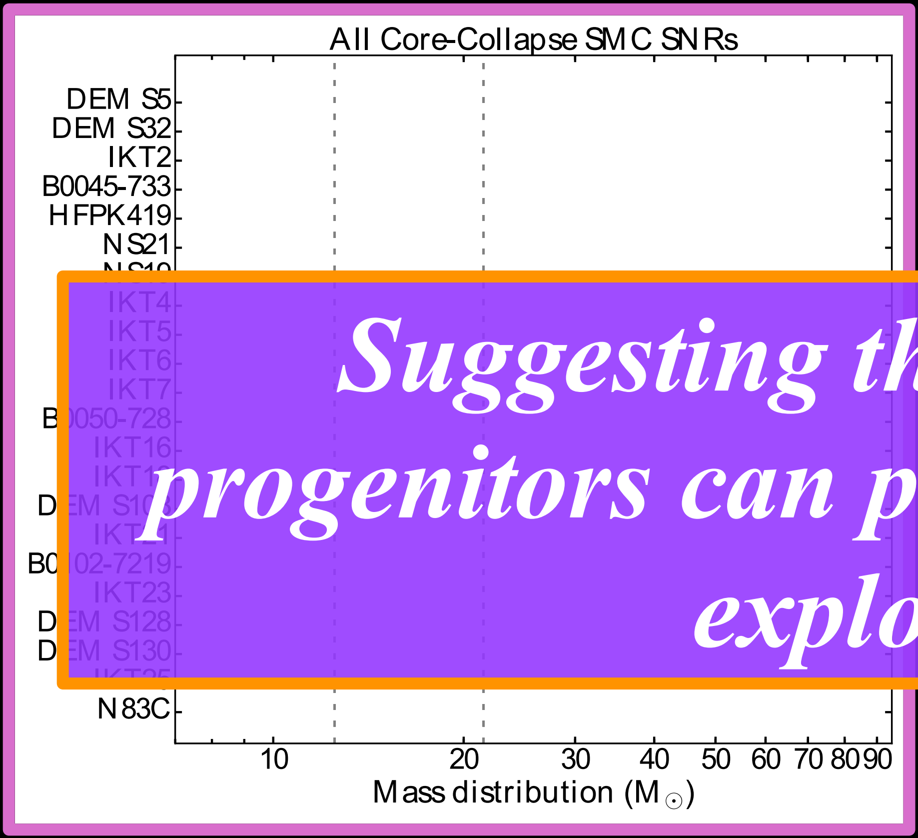
Larger Circle

=

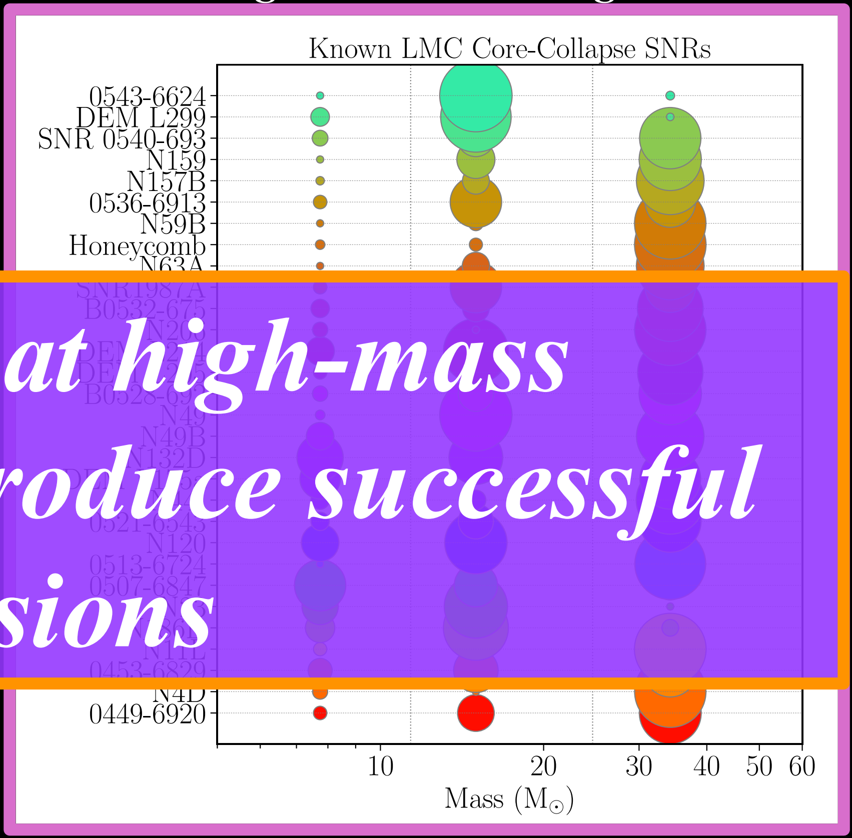
More likely that this SNR arose from that particular mass star

Masses of exploding stars

..in the Large and Small Magellanic Cloud



Auchettl et al. 2019



Auchettl et al. in prep

Suggesting that high-mass progenitors can produce successful explosions

Larger Circle

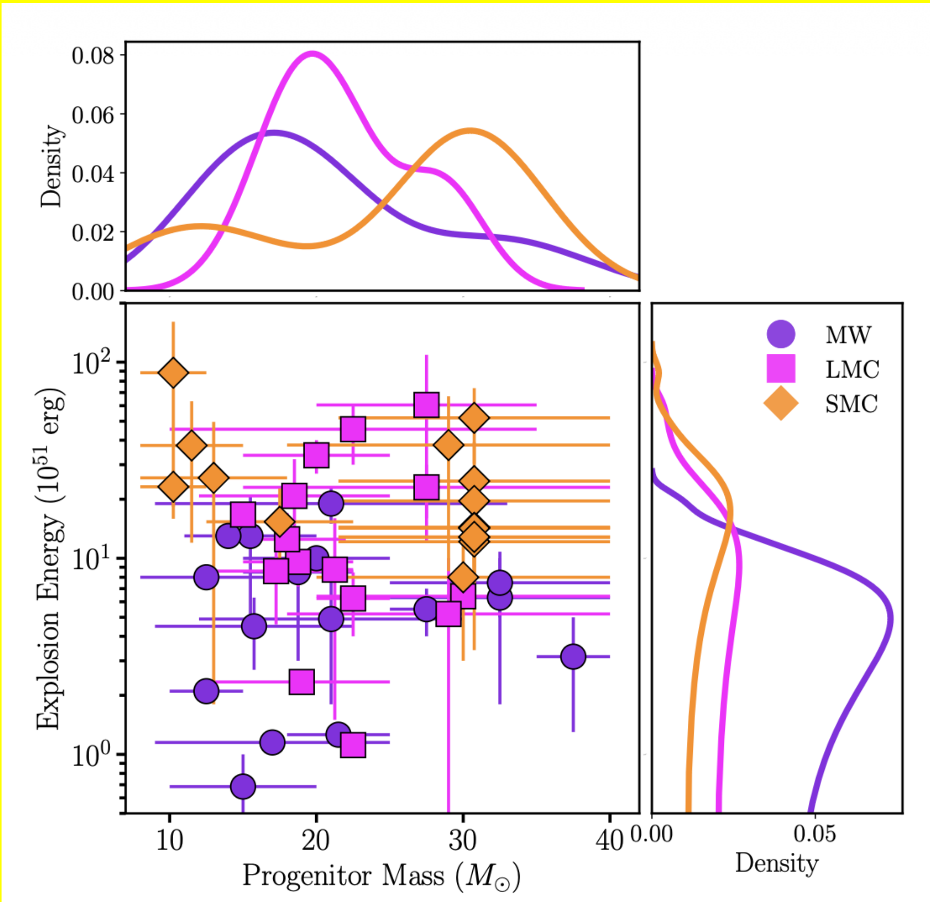
=

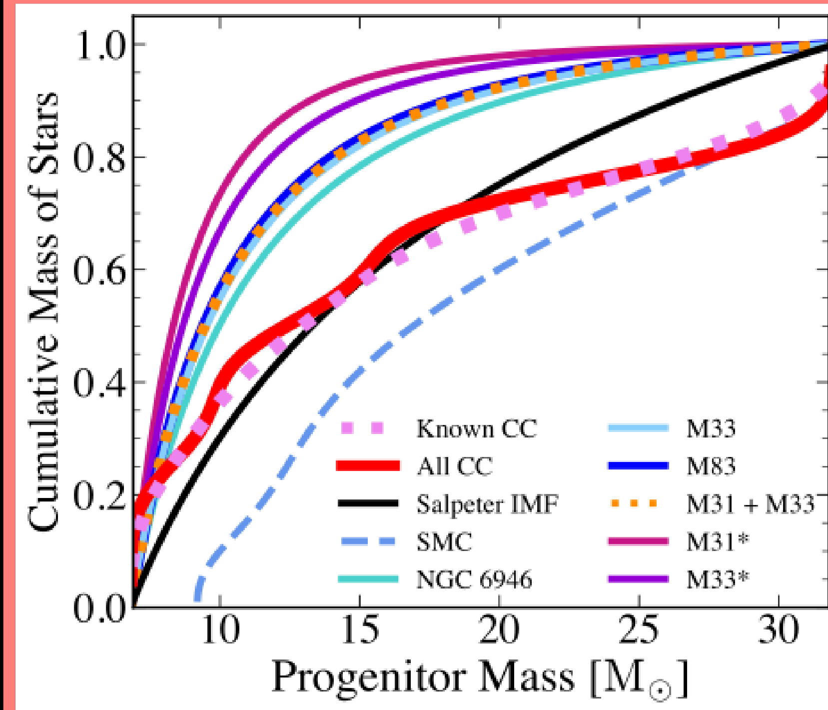
More likely that this SNR arose from that particular mass star

Mass distribution of CC SNRs

IMF is more top heavy in more metal poor galaxies.

Auchettl et al. in prep



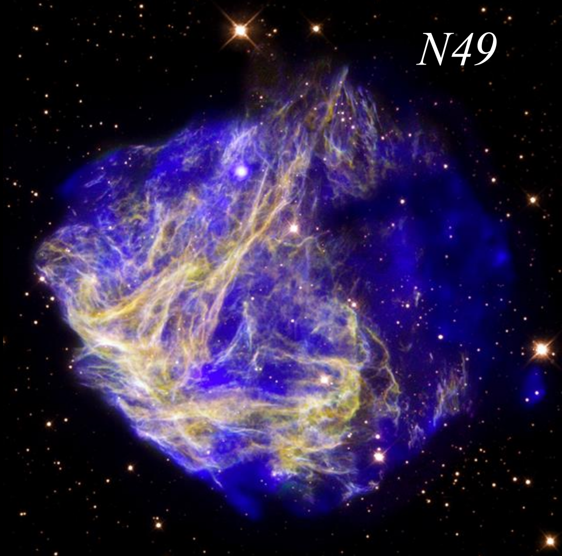


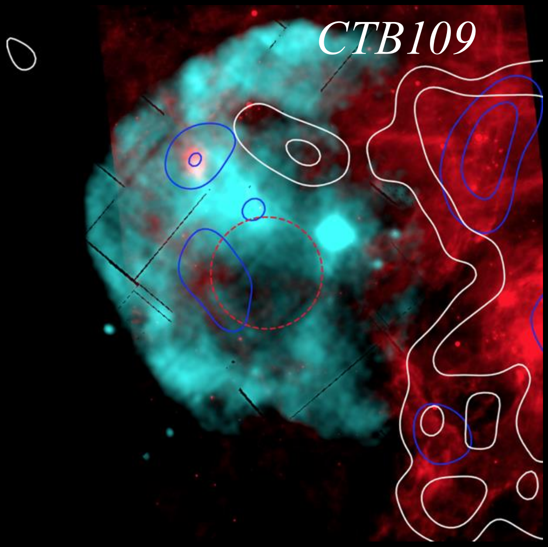
Massive progenitor production may be reduced in galaxies with metallicity > than LMC

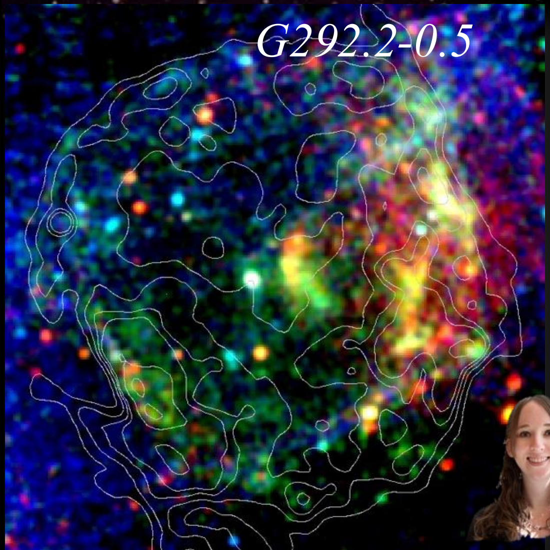
II. Connecting neutron stars to their core-collapse explosion.

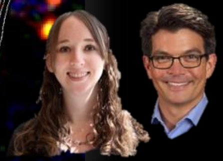
Magnetar's and their remnants

There are 37 known magnetars found in the Milky Way, LMC and SMC of which ~ 40% of these have secure SNR associations.









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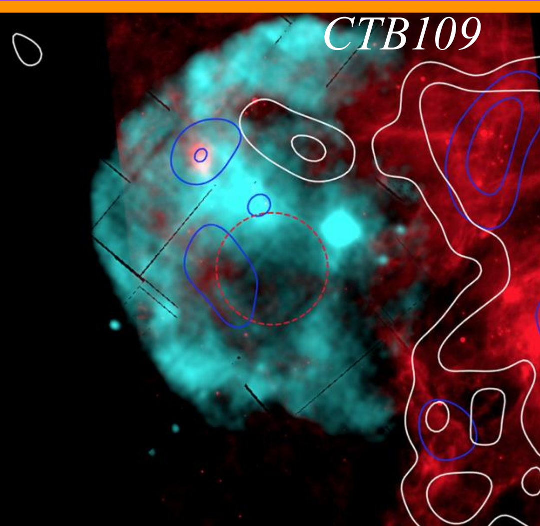
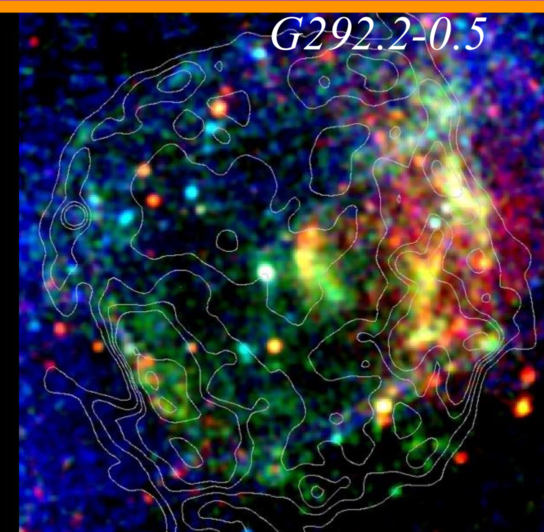
Do magnetars also affect their long-lived supernova remnants?

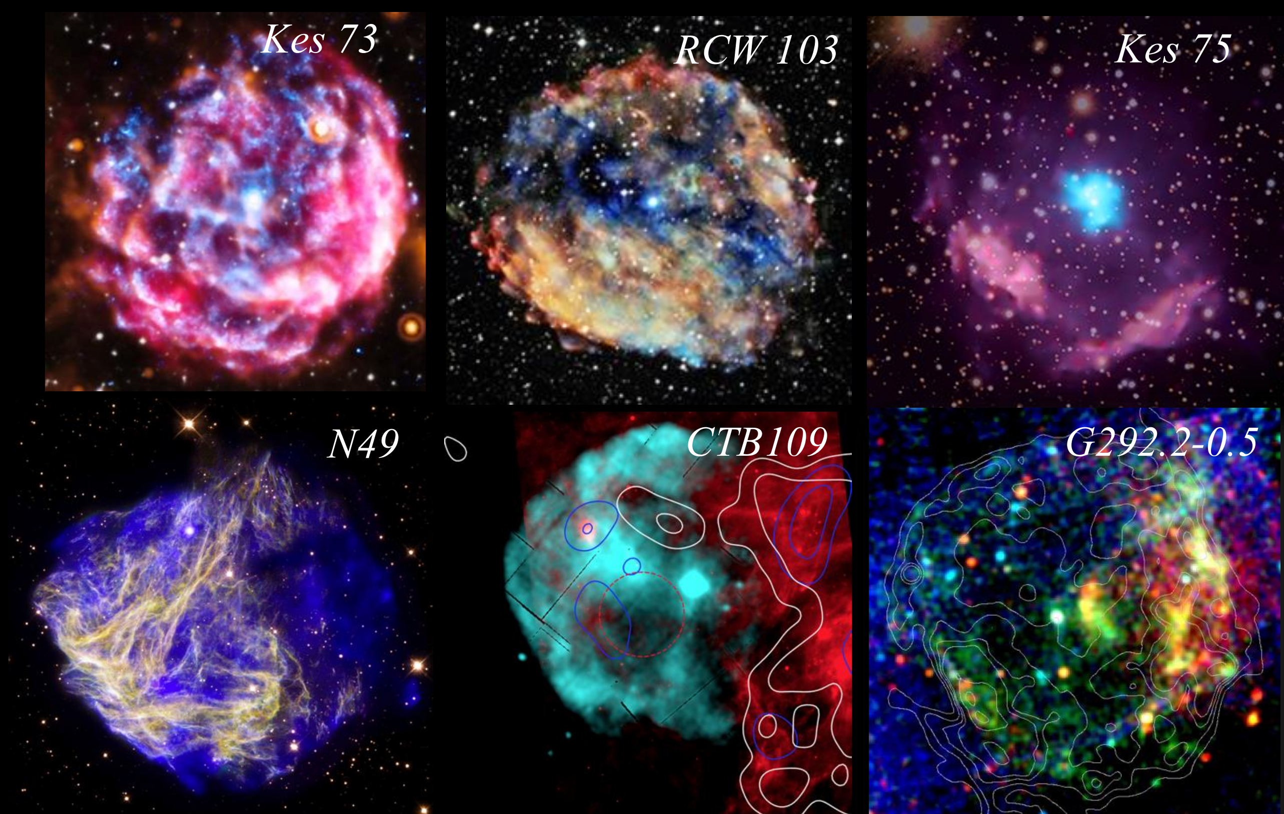




Predictions

Explosion energies exceeding the canconical 10^{51} erg

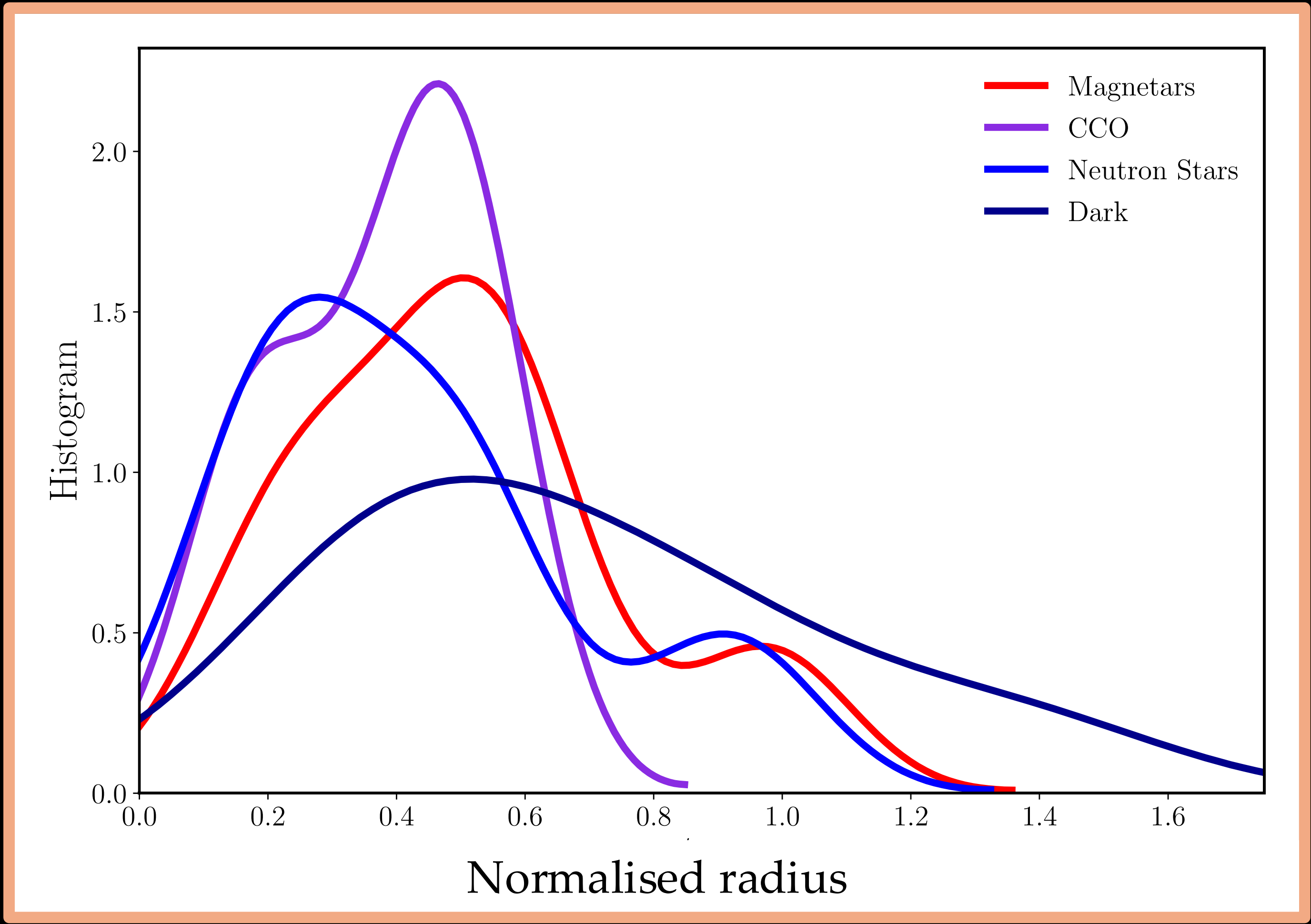
Extended compared to SNRs of similar environments



Sizes of magnetar SNRs

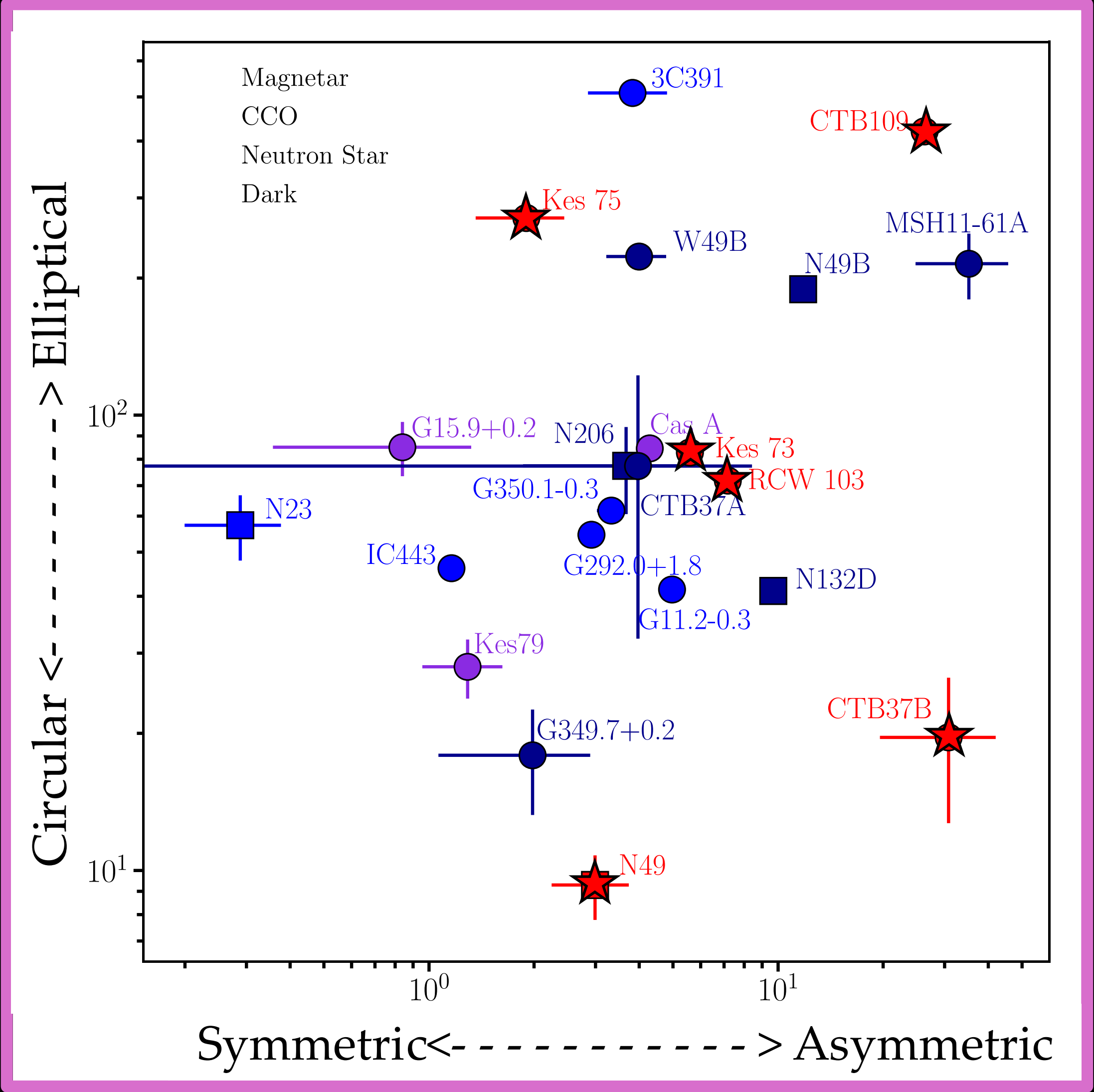
Magnetar SNRs are not significantly extended compared to other SNRs found in similar environments.

Auchettl et. al., in prep



Morphologies of magnetar SNRs

Magnetar SNRs have similar morphologies as other CC SNRs, suggesting that they are born in similar explosions.



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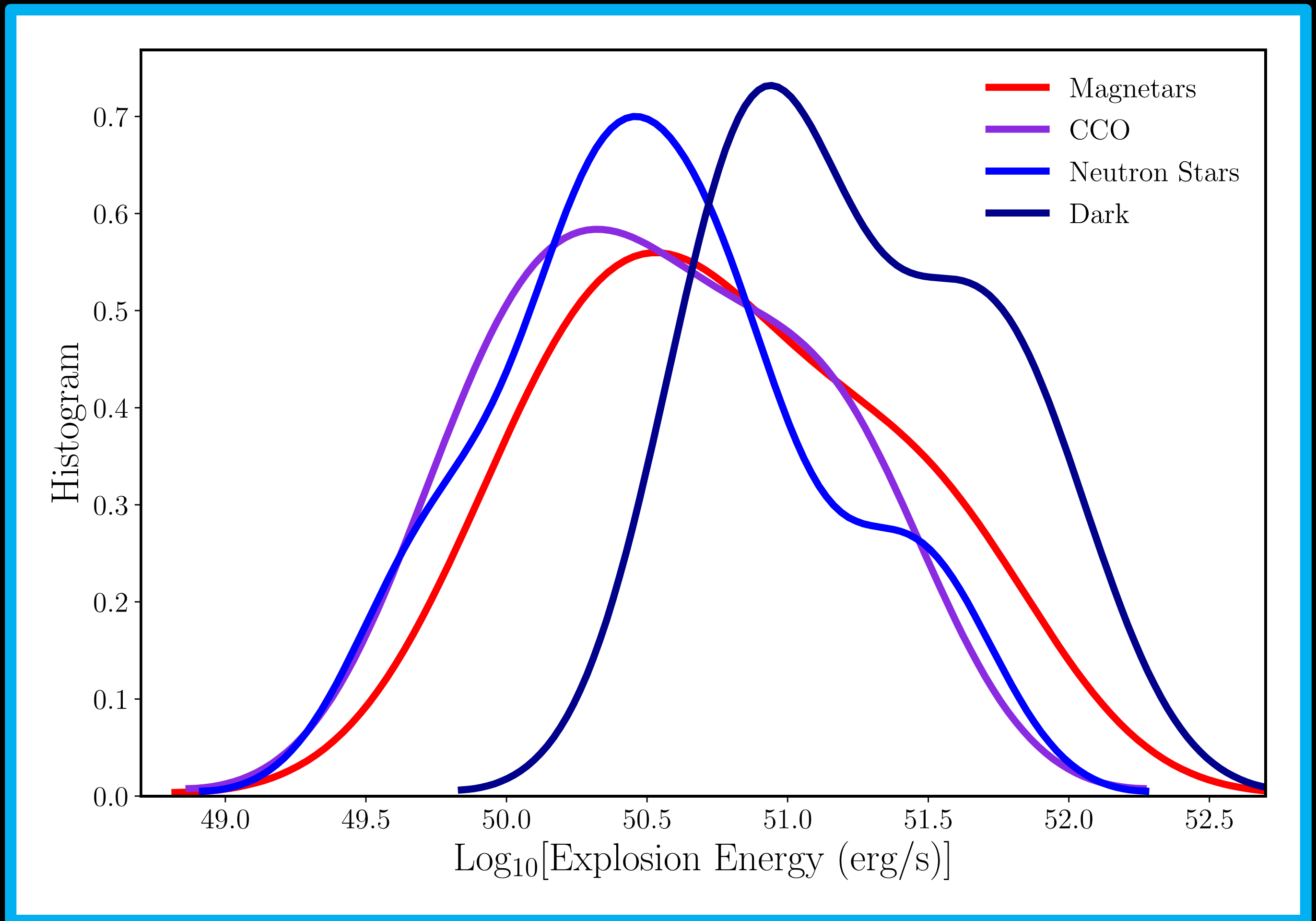
Energetics of magnetar SNRs

The energetics of magnetar SNRs does not deviate significantly from those of other CC SNRs.



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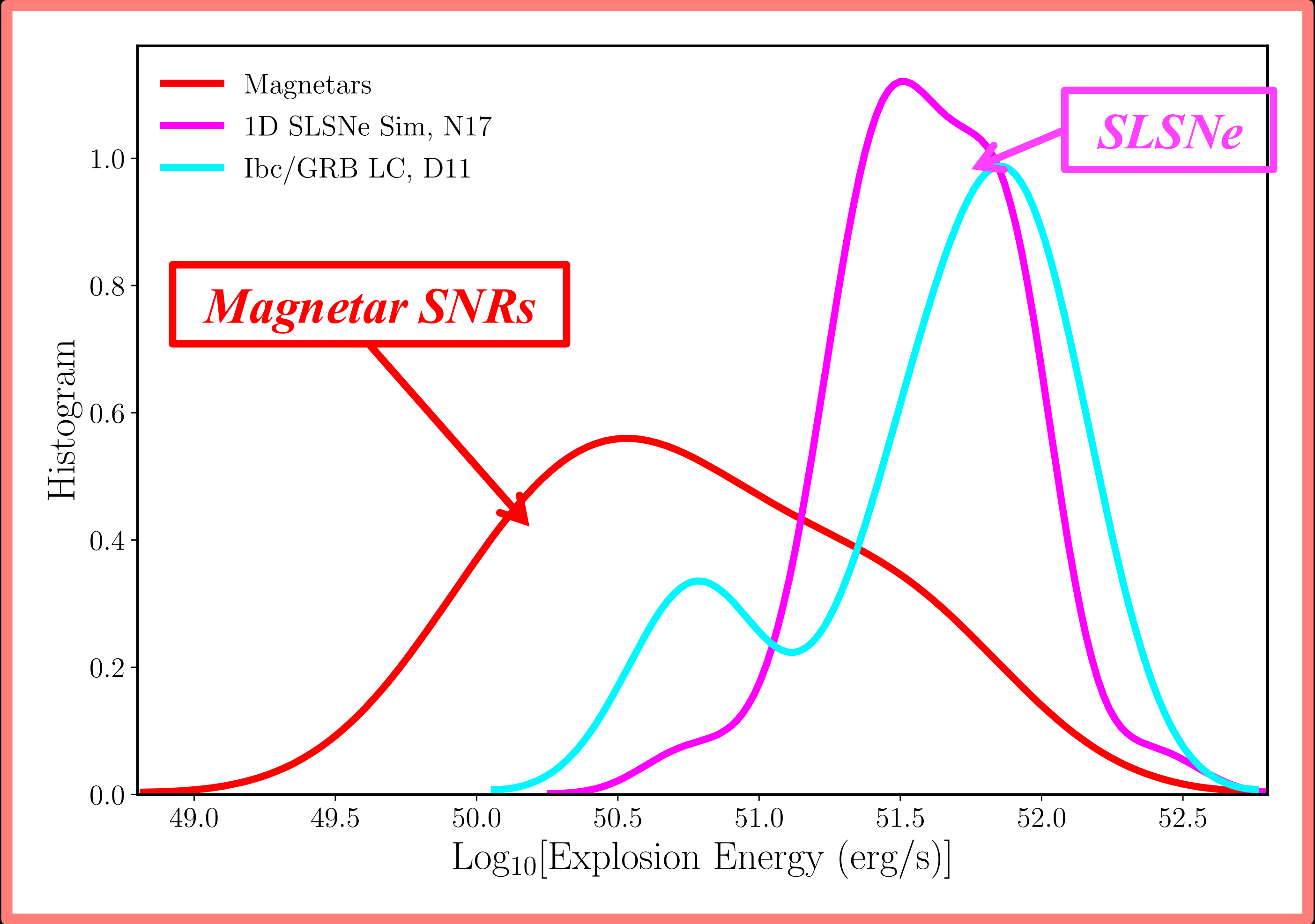
Energetics of magnetar SNRs

Magnetar SNRs are under-energetic vs SLSN, suggesting that not all magnetars are born rapidly rotating (or power SLSN).



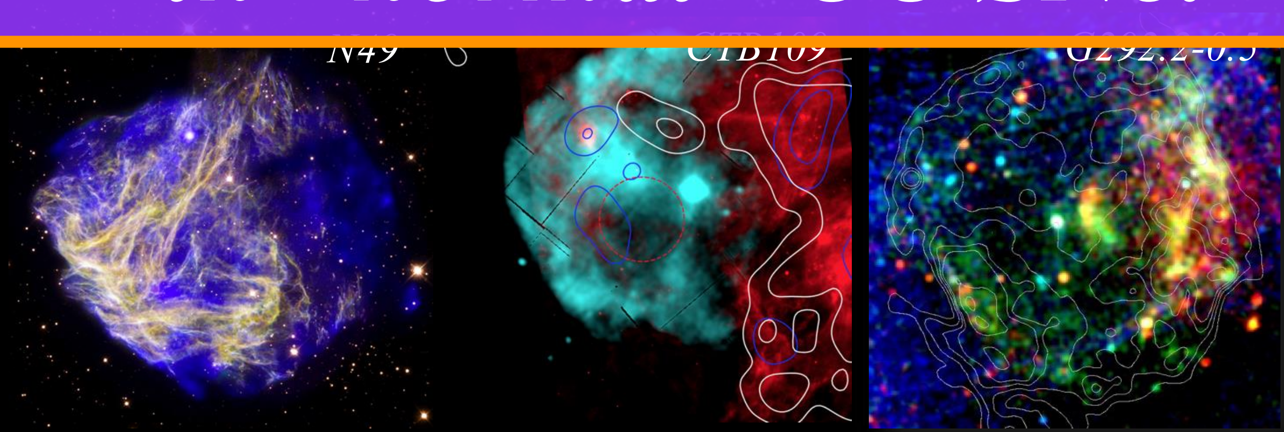
Auchettl et. al., in prep

Predictions

~~*Explosion energies exceeding the canonical 10^{51} erg*~~

~~*Extended compared to SNRs of similar environments*~~

Not all magnetars are formed by rapidly rotating proton-neutron stars and are produced in "normal" CC SNe.



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