Searching for Surviving Companions of Type Ia SNe in Five Balmer-Dominated SNRs in the LMC

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Abstract

We have been searching for surviving companions of Type Ia SNe in five young Type Ia SNRs in the LMC in order to assess their explosion mechanism. These young Type Ia SNRs are characterized by shells whose optical spectra are dominated by hydrogen Balmer lines. These Blamer-dominated spectra result from collisionless shocks moving into a partially neutral ambient medium. The five SNRs are 0509-67.5, 0519-69.0, 0548-70.4, DEM L71, and N103B. Only N103B is known to contain a dense circumstellar medium interior to the SNR shell, suggesting a single-degenerate nature of its SN progenitor.

We have used HST photometry of stars projected within the above five young Type Ia SNRs to produce color-magnitude diagrams (CMDs) and compare the stars to the post-impact evolution tracks of surviving companions from Pan et al. (2014) to identify candidates of surviving companions. We have also used VLT/MUSE observations of 0519-69.0, DEM L71, and N103B to extract spectra of stars projected within their SNR shells in order to use stellar radial velocities to identify candidates of surviving companions. In both methods, we find stars with unexpected behaviors that could be candidates of surviving companions of the SN progenitors.

Supernova progenitors

Two Origins of Supernovae (SNe):

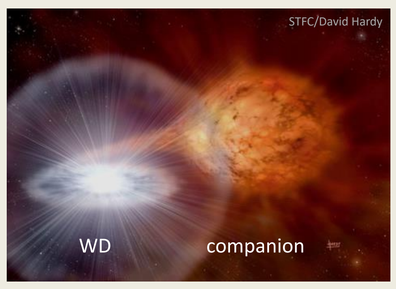
1. Core-collapse SNe – massive stars
2. Type Ia SNe – white dwarfs (WDs)

Luminous massive stars can be detected in pre-explosion images (Smartt+2004).

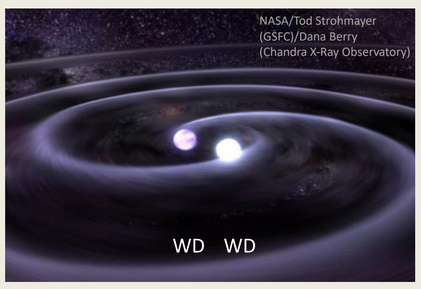
Progenitors of Type Ia SNe are too faint to be identified (Li2011; Kelly+2014; see also Foley+2010; McCully+2014).

Two main scenarios of Ia SNe progenitors

1. Single degenerate (SD)



2. Double degenerate (DD)



Question: SD and/or DD?

If a **surviving companion** or a **circumstellar medium** (CSM) is found, the SD origin is affirmed.

The surviving companion may be identified by its

- Faster rotation
- Chemical pollution
- Runaway velocities

(Vandenbergh+1973, 1977; Dennefeld+1982; Blair+1991; Marietta+2000; Pakmor+2008; Liu+2012; Williams+2012; Pan+2014; Kerzendorf+2014)

No confirmed surviving companion yet.

(Pilar Ruiz-Lapuente+2004; González Hernández+2009, 2012; Kerzendorf+2009, 2012, 2013; Shaefer+2012; Edwards+2012; Pagnotta+2015; Li+2017; Likte+2017; Pilar Ruiz-Lapuente+2018)

Large Magellanic Cloud (LMC)

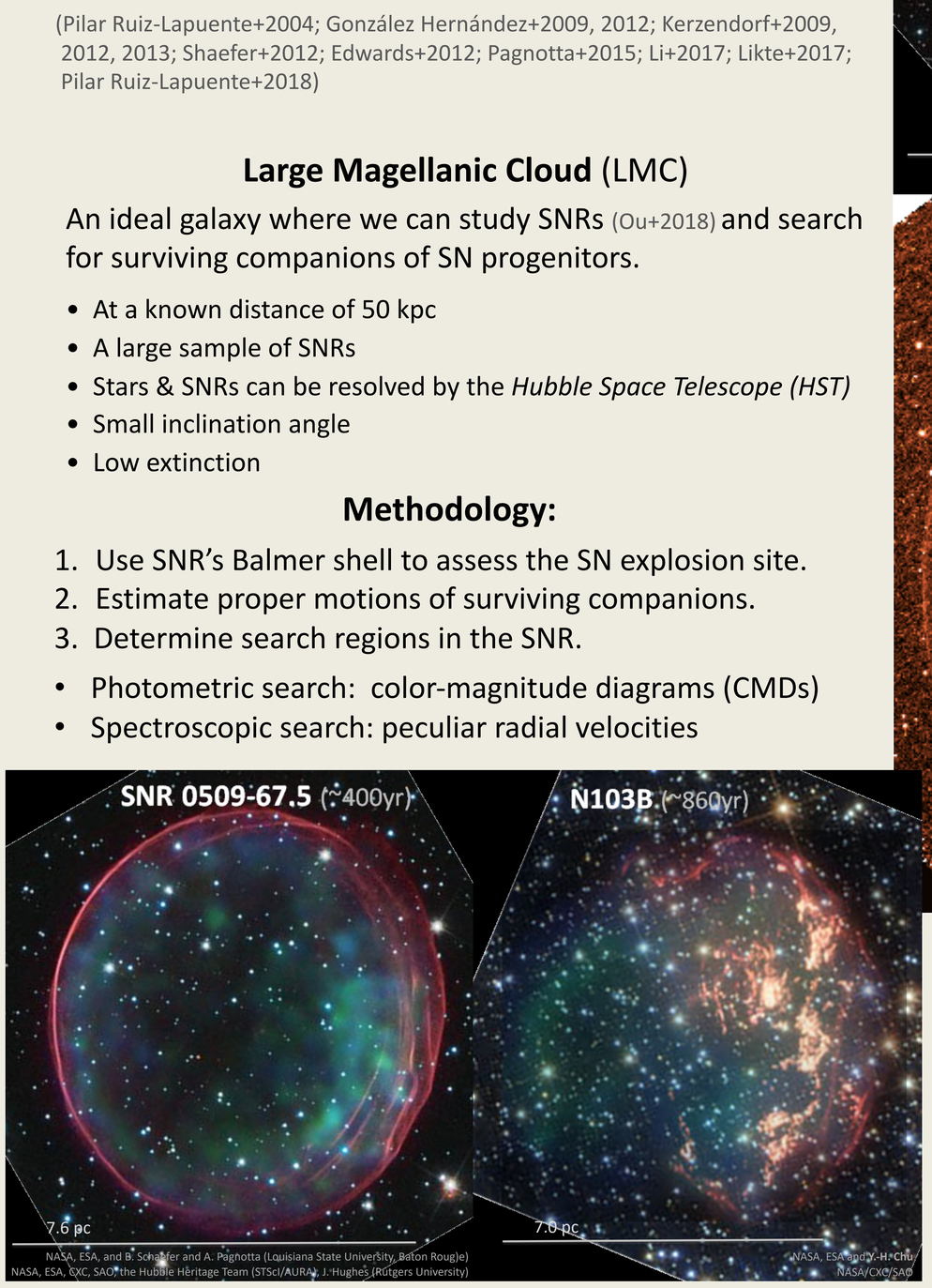
An ideal galaxy where we can study SNRs (Ou+2018) and search for surviving companions of SN progenitors.

- At a known distance of 50 kpc
- A large sample of SNRs
- Stars & SNRs can be resolved by the *Hubble Space Telescope (HST)*
- Small inclination angle
- Low extinction

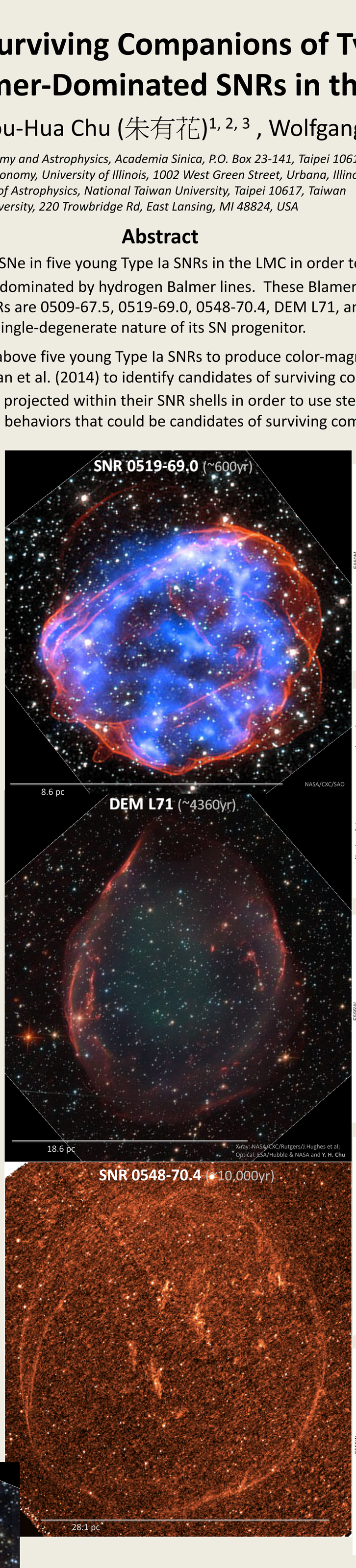
Methodology:

1. Use SNR's Balmer shell to assess the SN explosion site.
2. Estimate proper motions of surviving companions.
3. Determine search regions in the SNR.

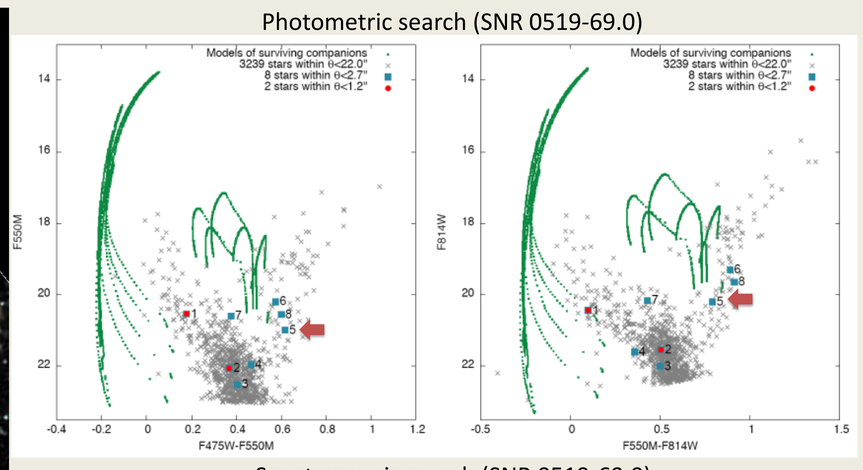
- Photometric search: color-magnitude diagrams (CMDs)
- Spectroscopic search: peculiar radial velocities



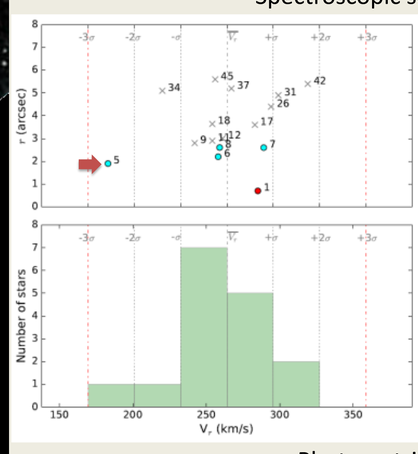
Litke+2017 Li+2017



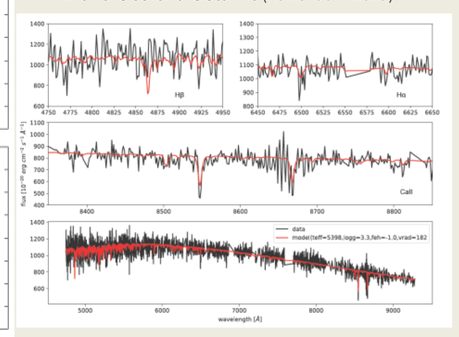
Photometric search (SNR 0519-69.0)



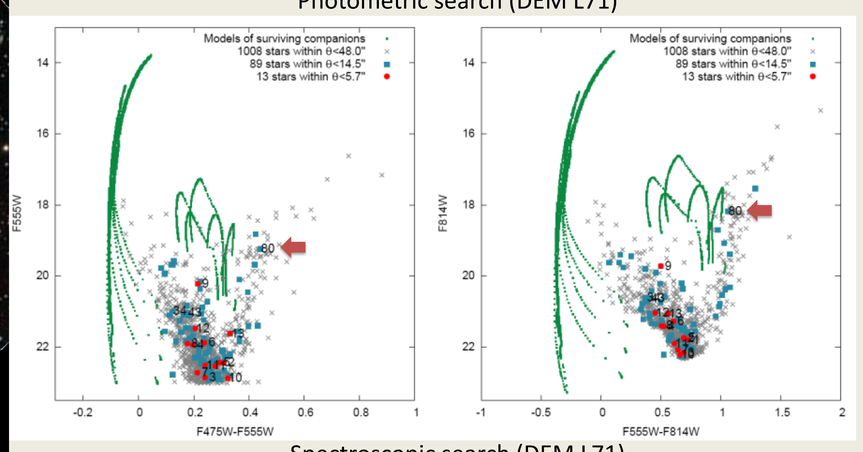
Spectroscopic search (SNR 0519-69.0)



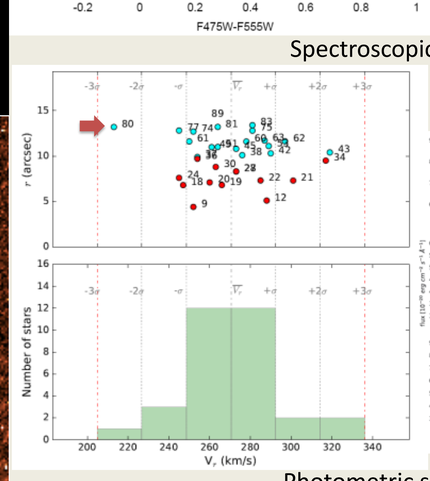
The VLT MUSE spectrum of star 5 and its model fit with the software *Starkit* (Kerzendorf+2015)



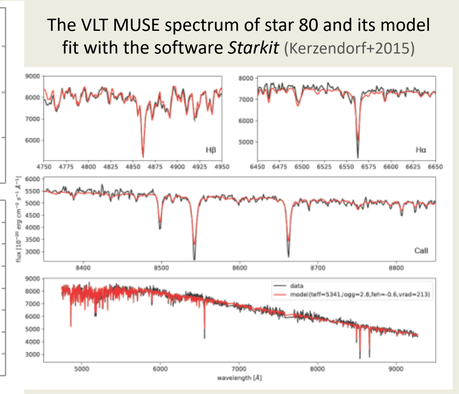
Photometric search (DEM L71)



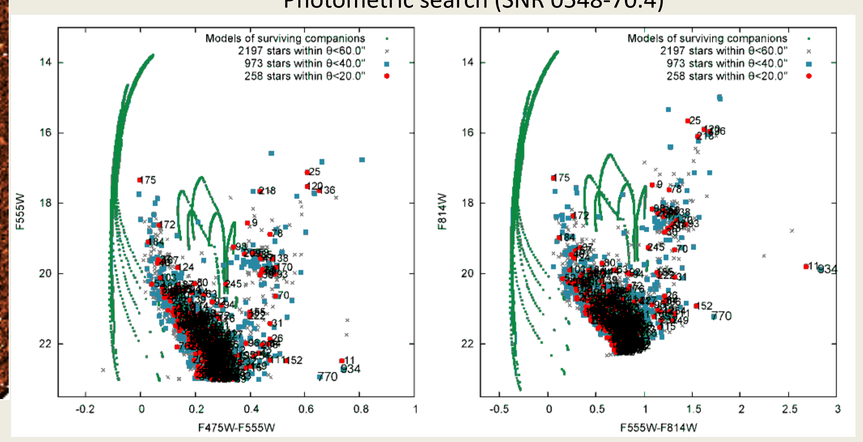
Spectroscopic search (DEM L71)



The VLT MUSE spectrum of star 80 and its model fit with the software *Starkit* (Kerzendorf+2015)



Photometric search (SNR 0548-70.4)



Li+2019 in prep

Discussions

From the positions of stars in the CMDs, no obvious surviving companion candidate is found in SNR 0548-70.4. Nevertheless, we spectroscopically find a type K and an A star within SNR 0519-69.0 and DEM L71, respectively, moving at a radial velocities that are close to 3 times standard deviations from the mean radial velocity of all stars within the runaway distance. Is it a mere coincidence? Follow-up abundance analyses are needed.