IFU spectroscopy of nearby SN sites: constraints on progenitor mass & metallicity

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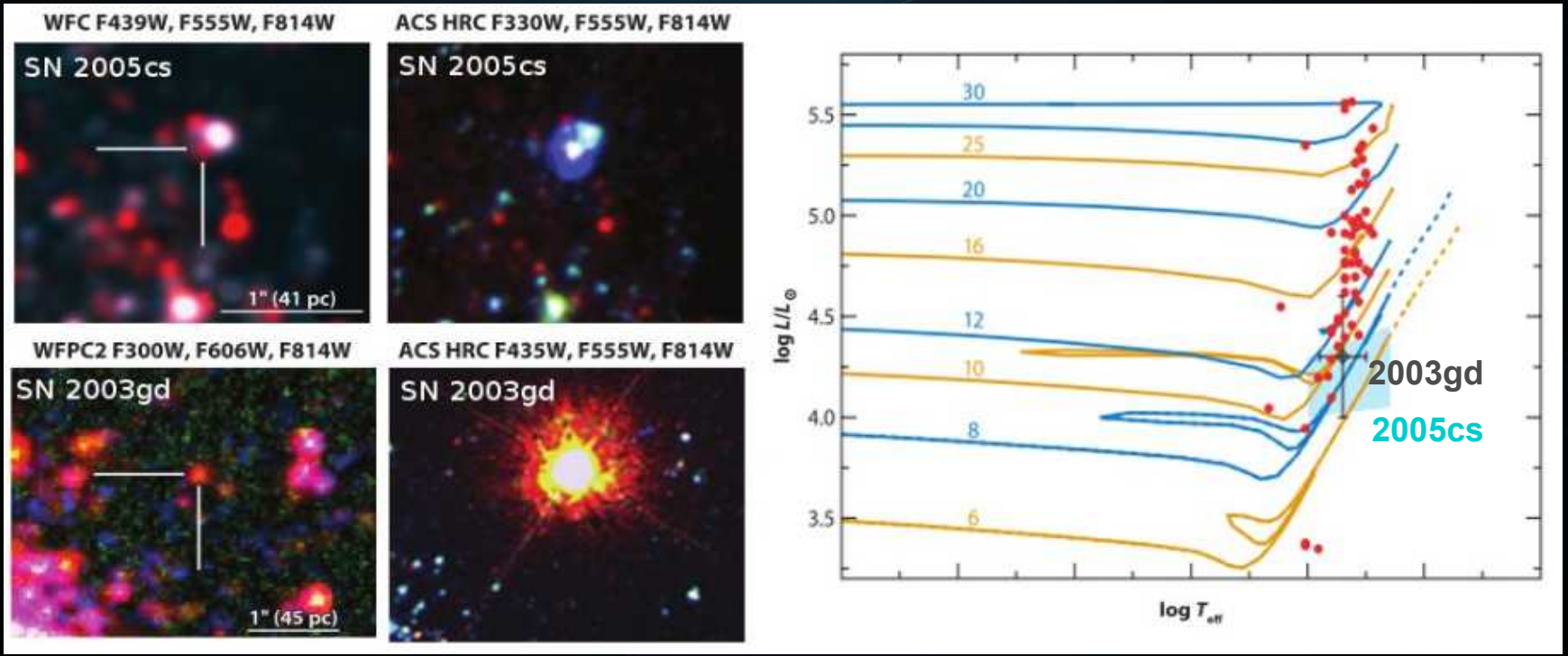
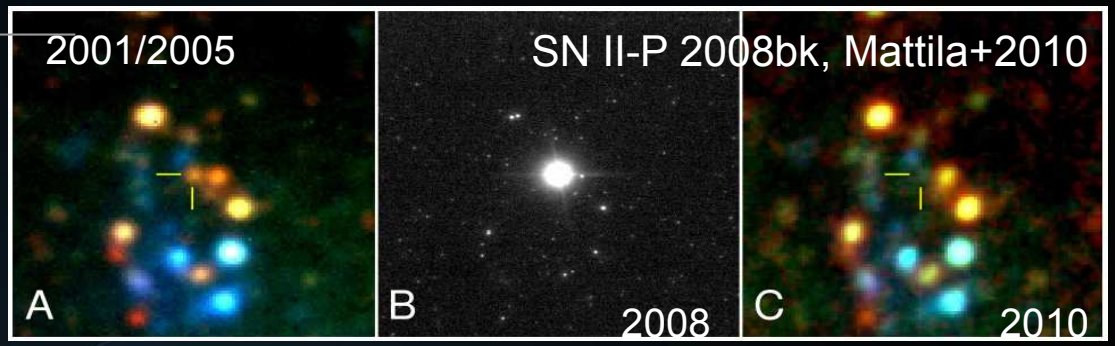
The hunt for SN progenitors in the recent years

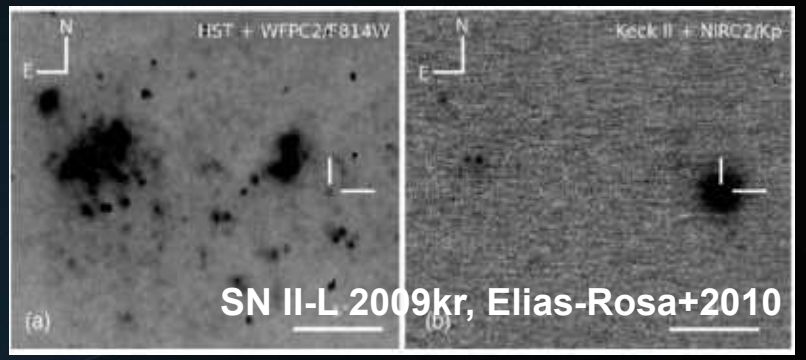
- Searching archival pre-explosion images for the progenitor star
- Made available by the advent of HST & AO
- Photometry of the star places it on the HR diagram → possible to determine initial mass
- Powerful and convincing, but very limited (*and sadly only very few of them have confirmation of progenitor disappearance after the explosion*)

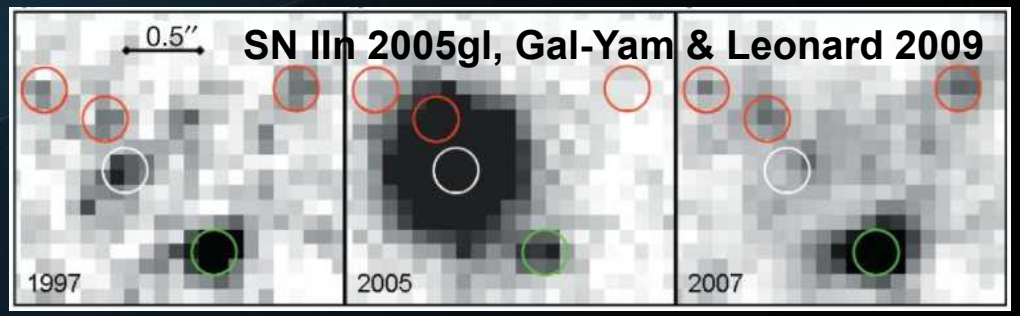


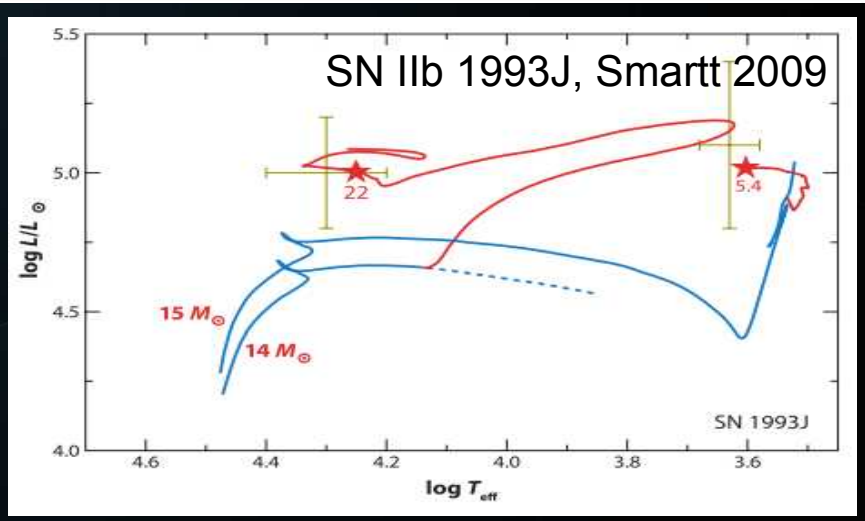
Discoveries of CCSN progenitors

- II-P: red supergiants
  - ~8.5-16.5 M⊙ (Smartt+09)
- II-L: yellow supergiants
  - 18-24 M⊙ (?)
- IIn: massive LBV
  - >30-50 M⊙ (?)
- IIb: binaries (?)
- Ib/c: Wolf-Rayet stars >25M⊙?? or binaries??









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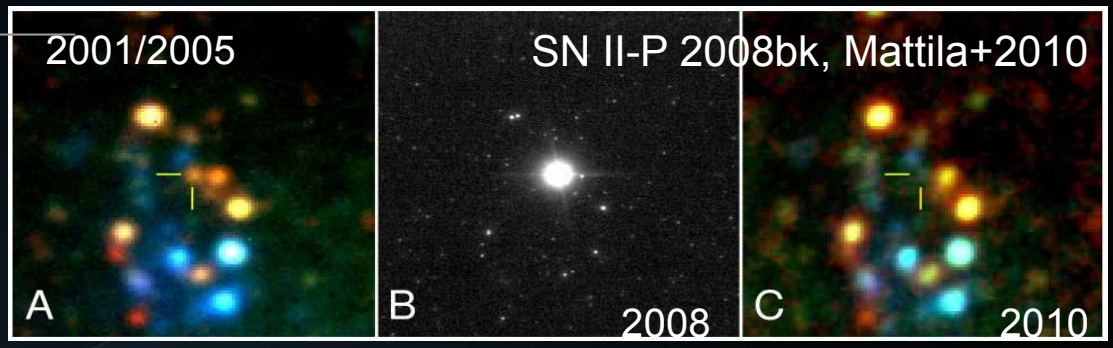
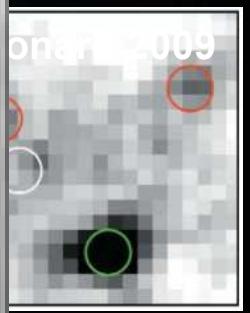
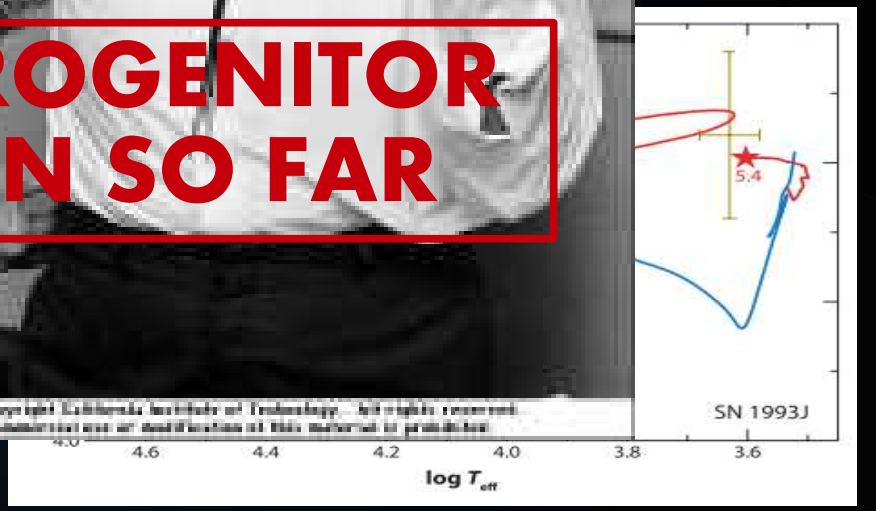


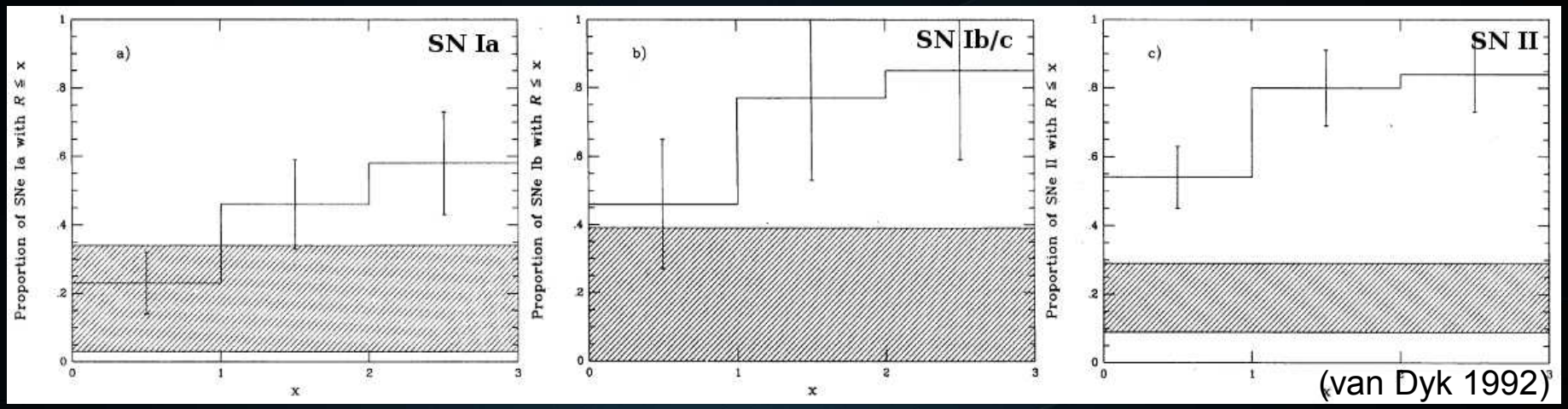


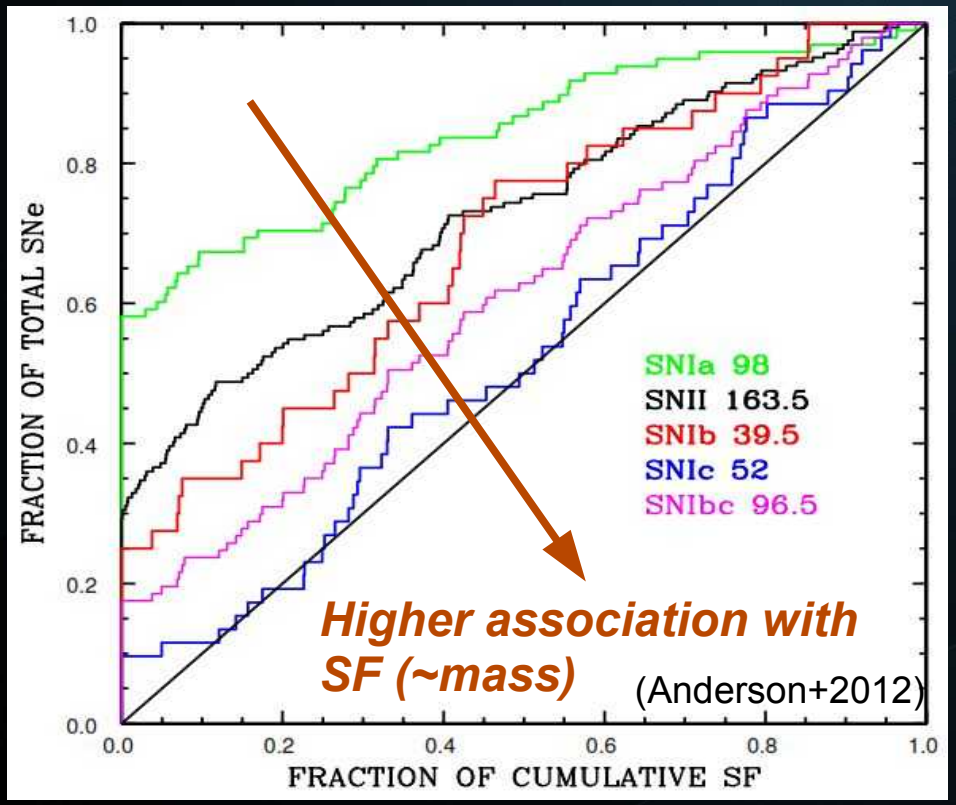
NO Ib/c PROGENITOR DETECTION SO FAR

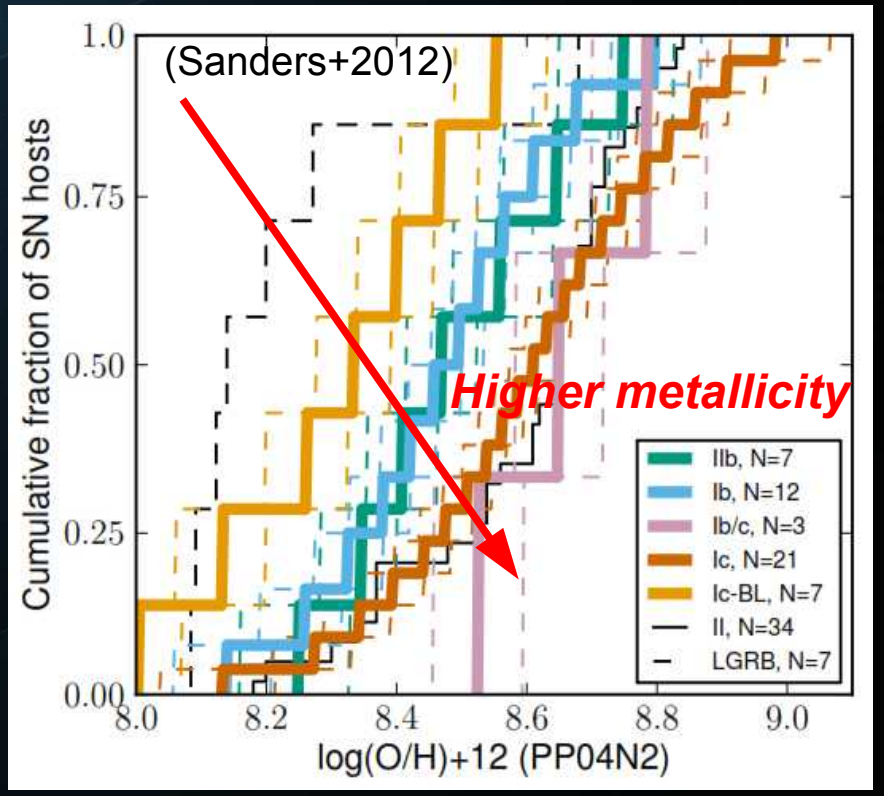


Clues from the environment

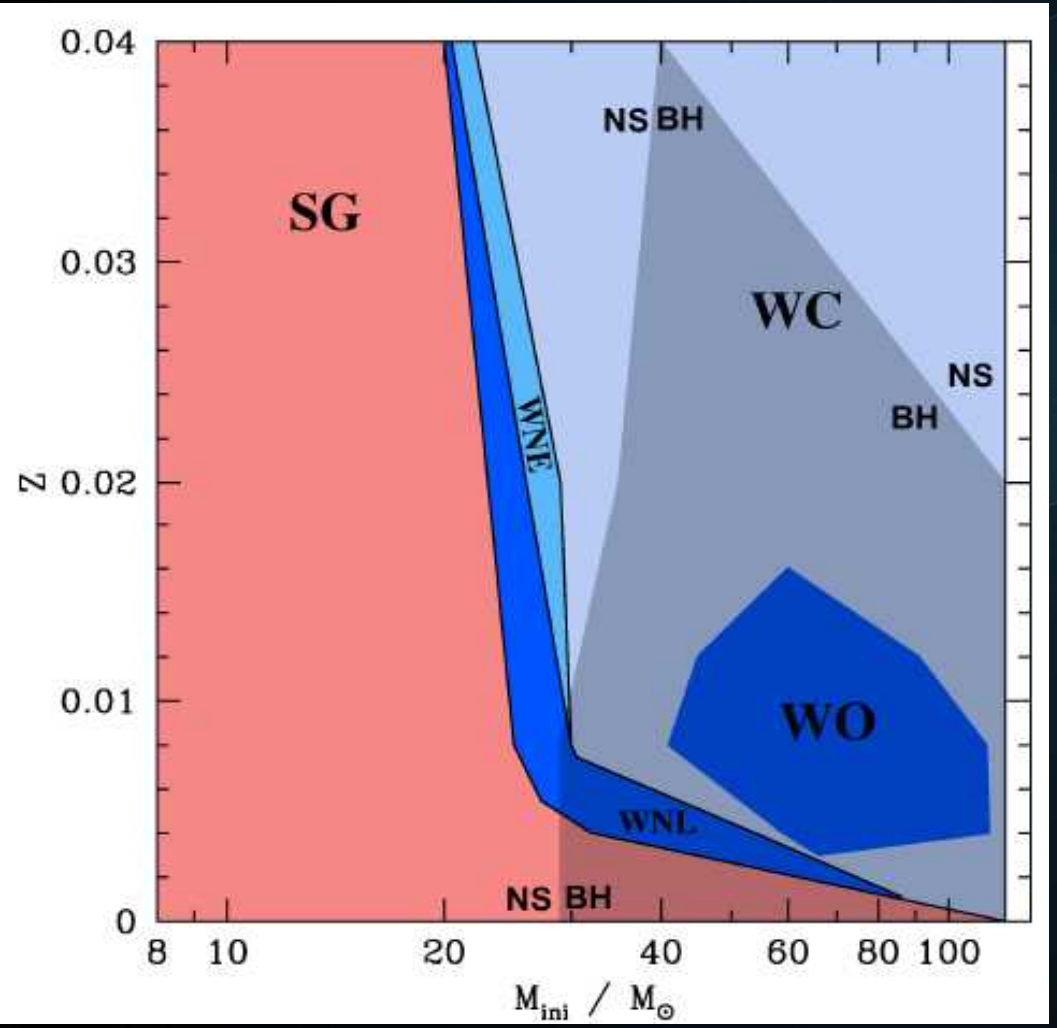
higher association with HII regions

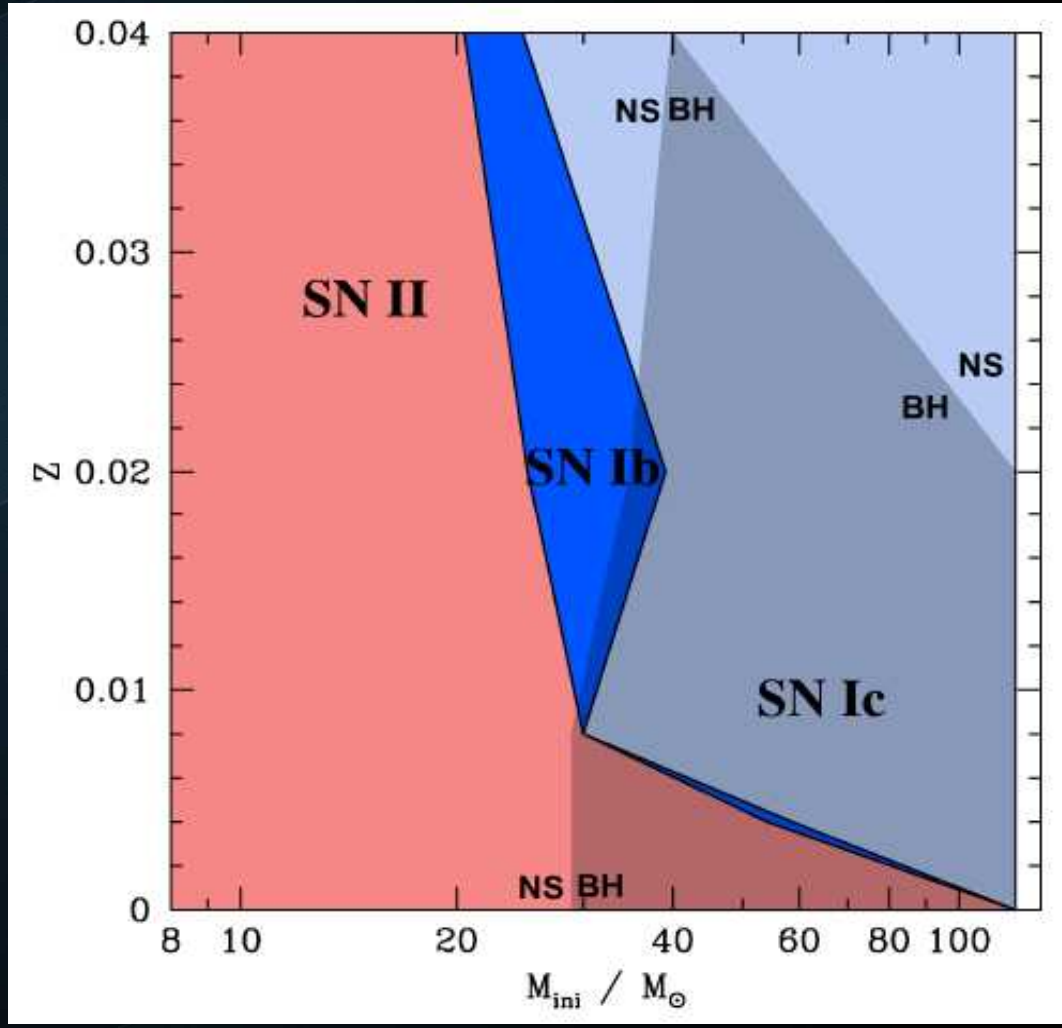






Theoretical predictions

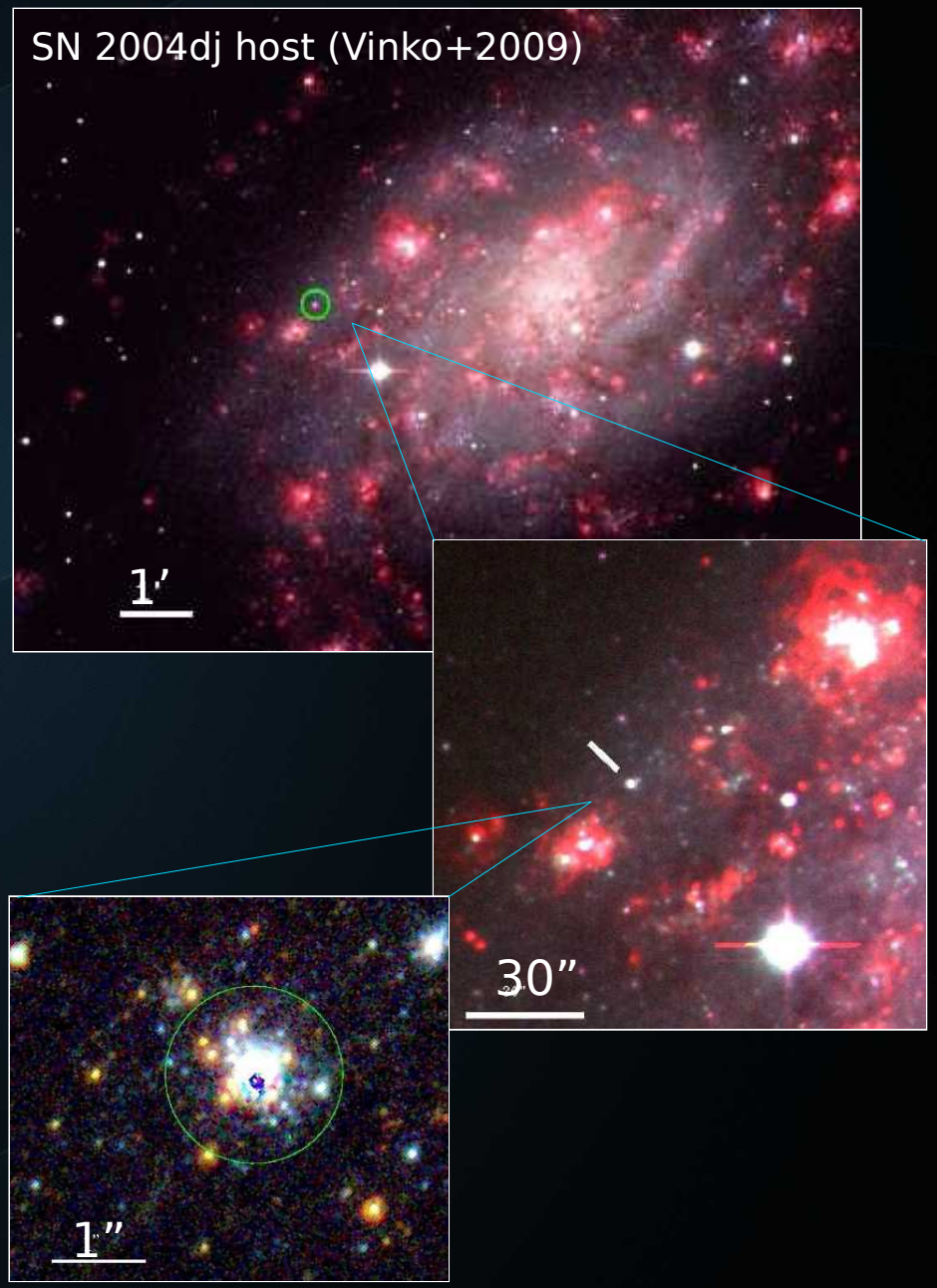




(Georgy+2009)

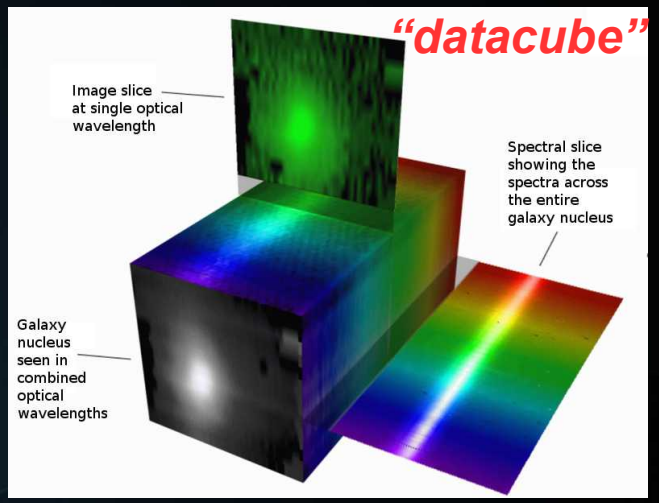
Strategy of the project

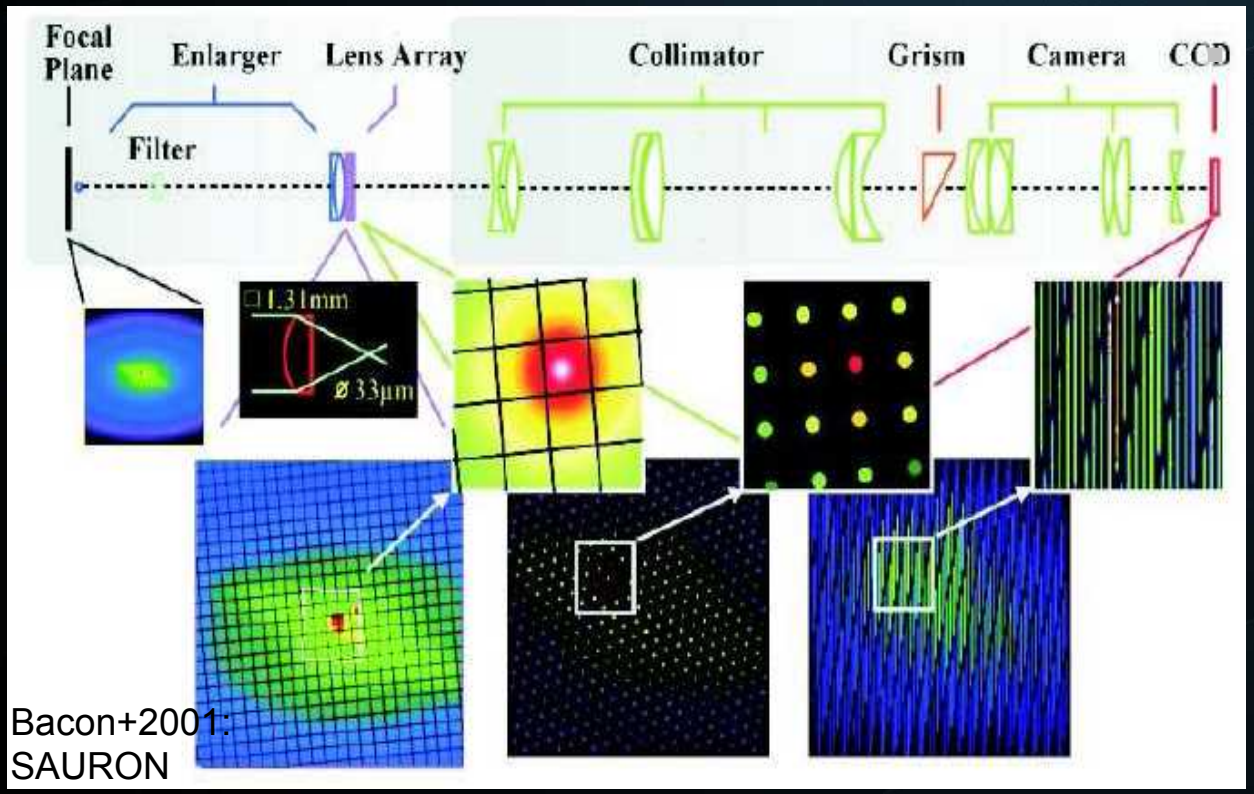
- Some SNe appear to be associated with bright sources → parent stellar population/star cluster (SC)
- Massive stars die first: SN progenitor must have been the most massive star in the parent SC
- SC age & metallicity = SN progenitor age & metallicity (star age~mass)
- Observe nearby SN sites with IFU spectroscopy → detect parent SC and extract spectrum
- Determine metallicity & age from the SC spectrum, adopt for SN progenitor
- Equally reliable mass estimate compared to direct imaging, but much easier to increase sample – plus metallicity could be derived



Integral field spectroscopy

- Spectra of each point in the sampled FoV → "3D spectroscopy", spatial + spectral information simultaneously
- Done using UH88/SNIFS and Gemini/GMOS





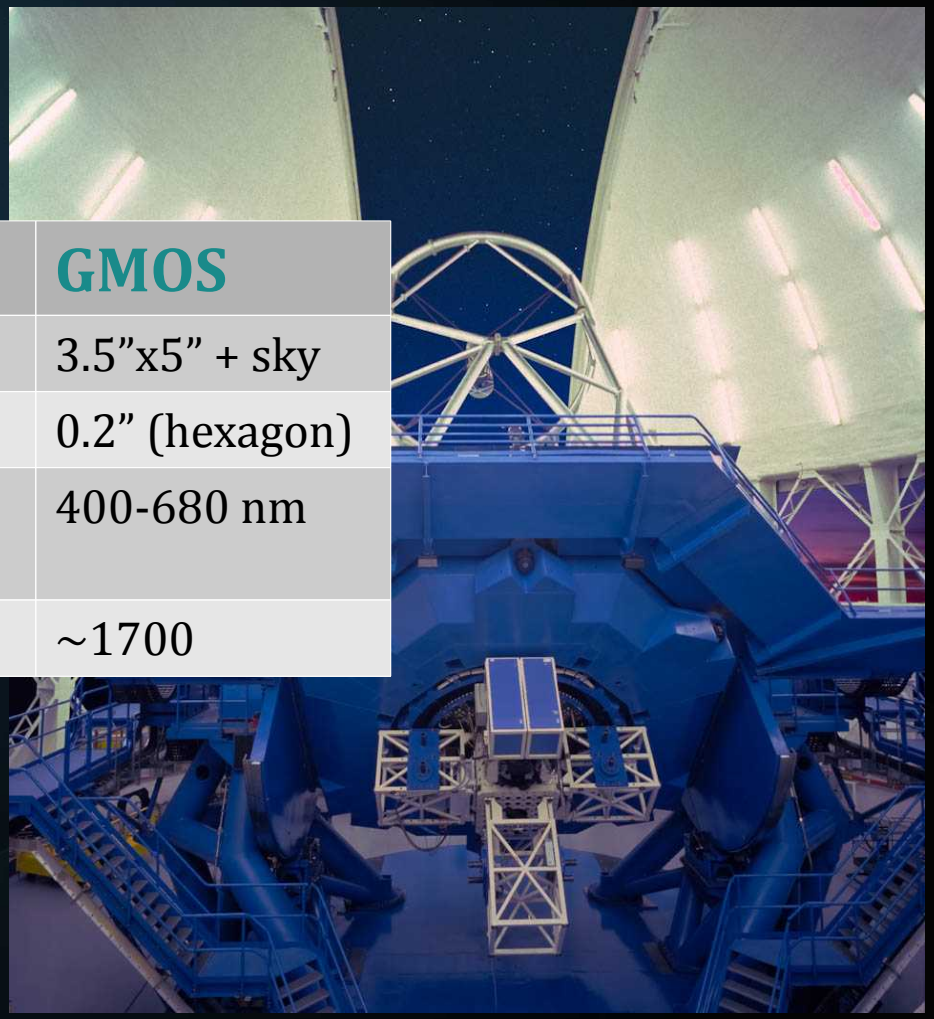
Bacon+2001: SAURON

If done with slit spectroscopy:

- Spatial information lost: cannot detect individual objects
- Integrating light from everything within the slit → contamination from other populations
- Inaccurate determination of age/metallicity

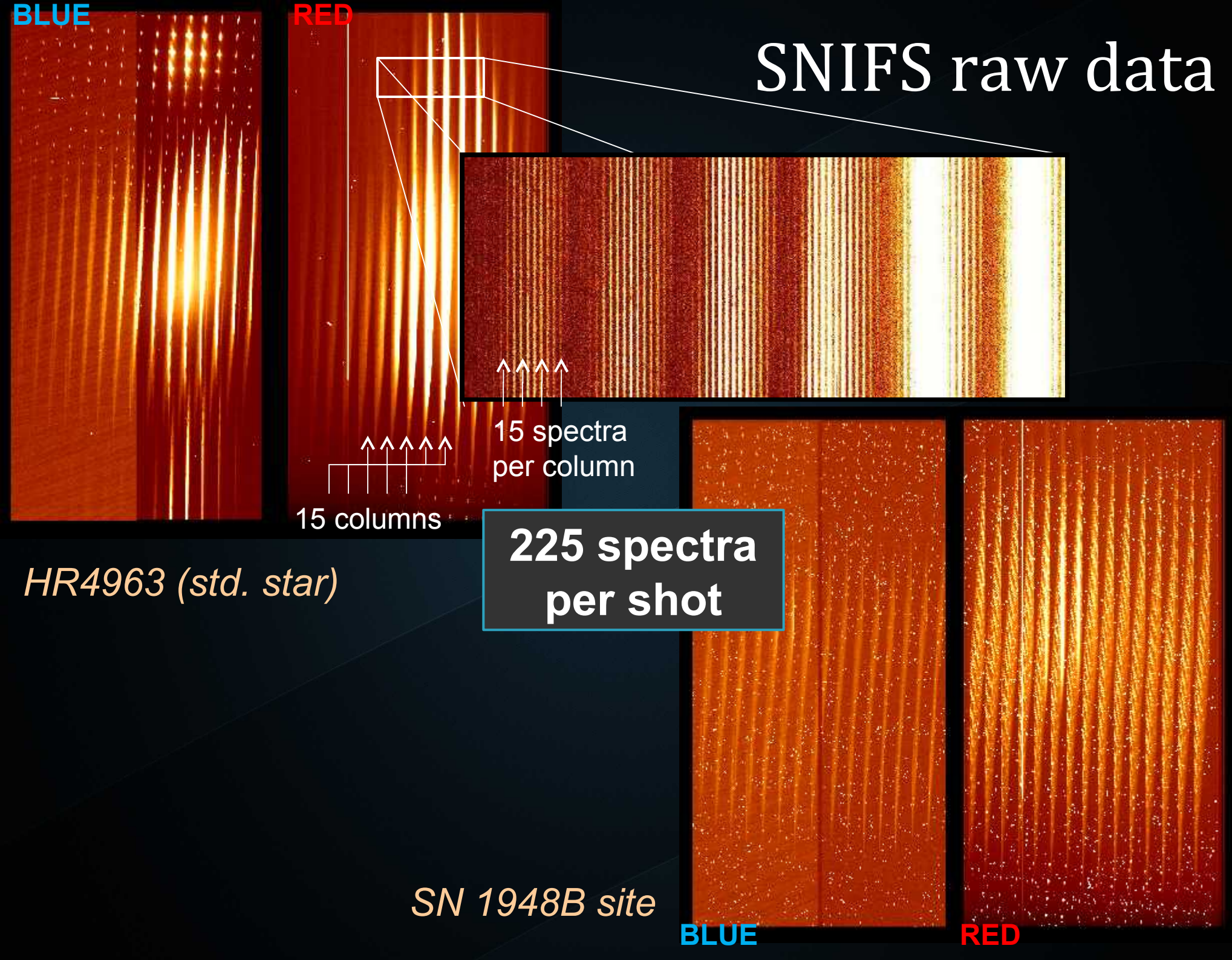
Data acquisition @ MKO

- UHawaii2.2m/SNIFS 2010-2011 (5 nights)
- Gemini-N/GMOS 2011 observations (1 nights)



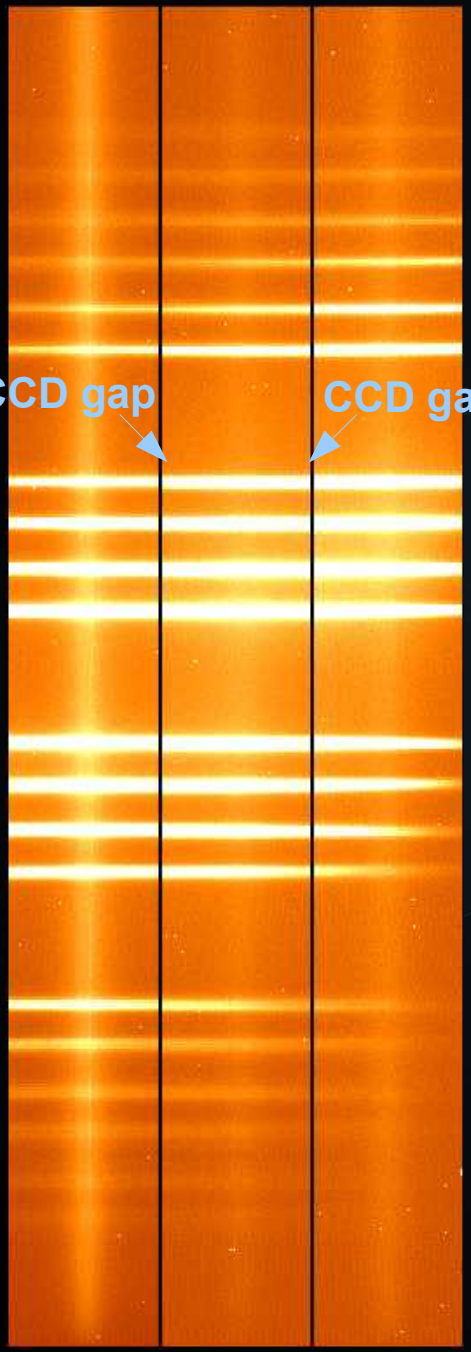
	SNIFS	GMOS
IFU FoV	6.4”x6.4”	3.5”x5” + sky
IFU sampling	0.43” (square)	0.2” (hexagon)
λ coverage	330-520 nm + 515-970 nm	400-680 nm
R	~1000	~1700

SNIFS raw data



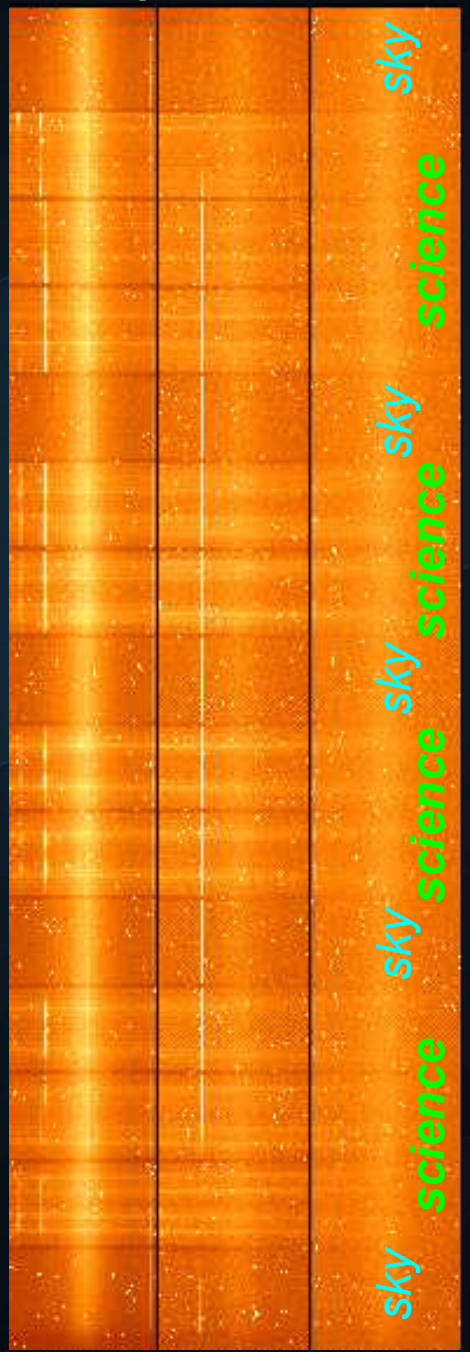
GMOS raw data

Standard star:
BD+284211

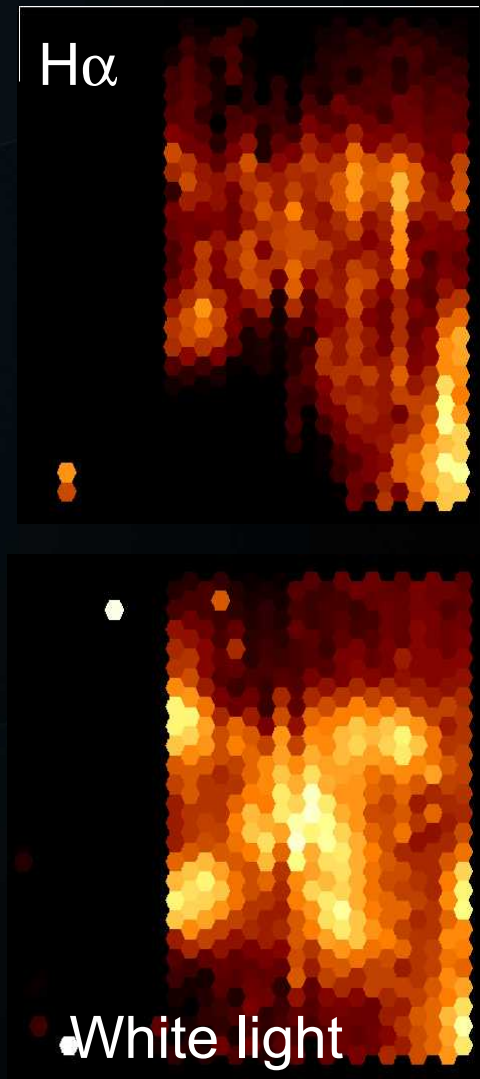


1500 spectra from different spatial positions

Science target:
SN 2007gr site

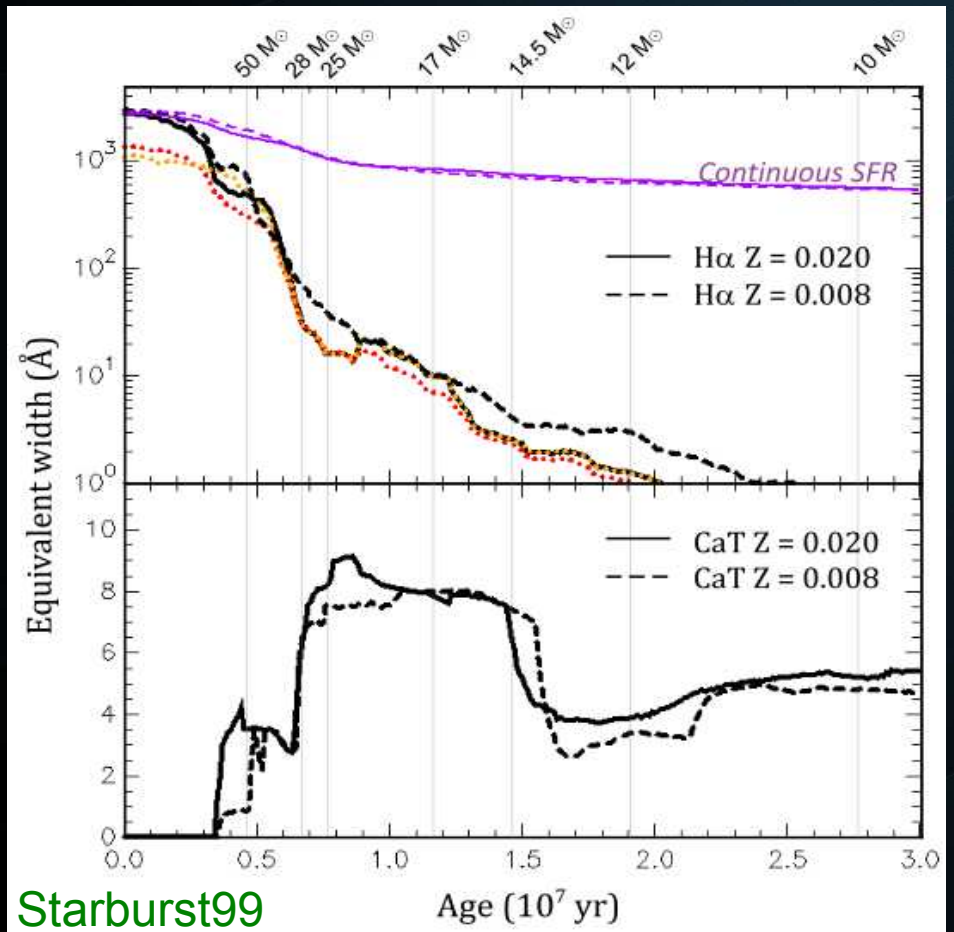


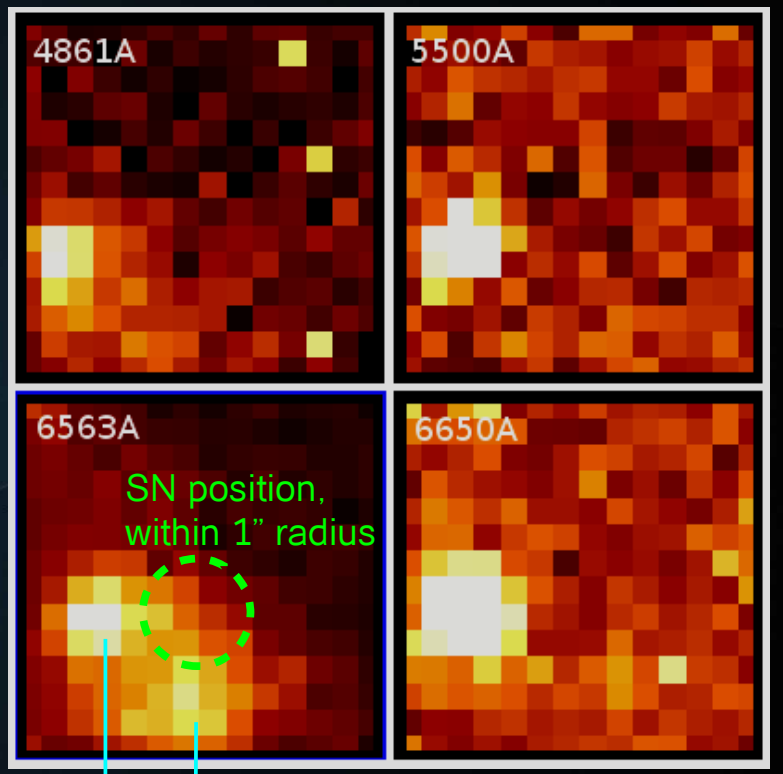
Reduction using IRAF,
gemini *package*



Analysis method

- Examine each site in 2-D
- Extract the 1-D spectra of all detected objects
- Analyze the spectra to determine:
  - Metallicity (strong-line method)
  - Age (Hα/CaT EW)



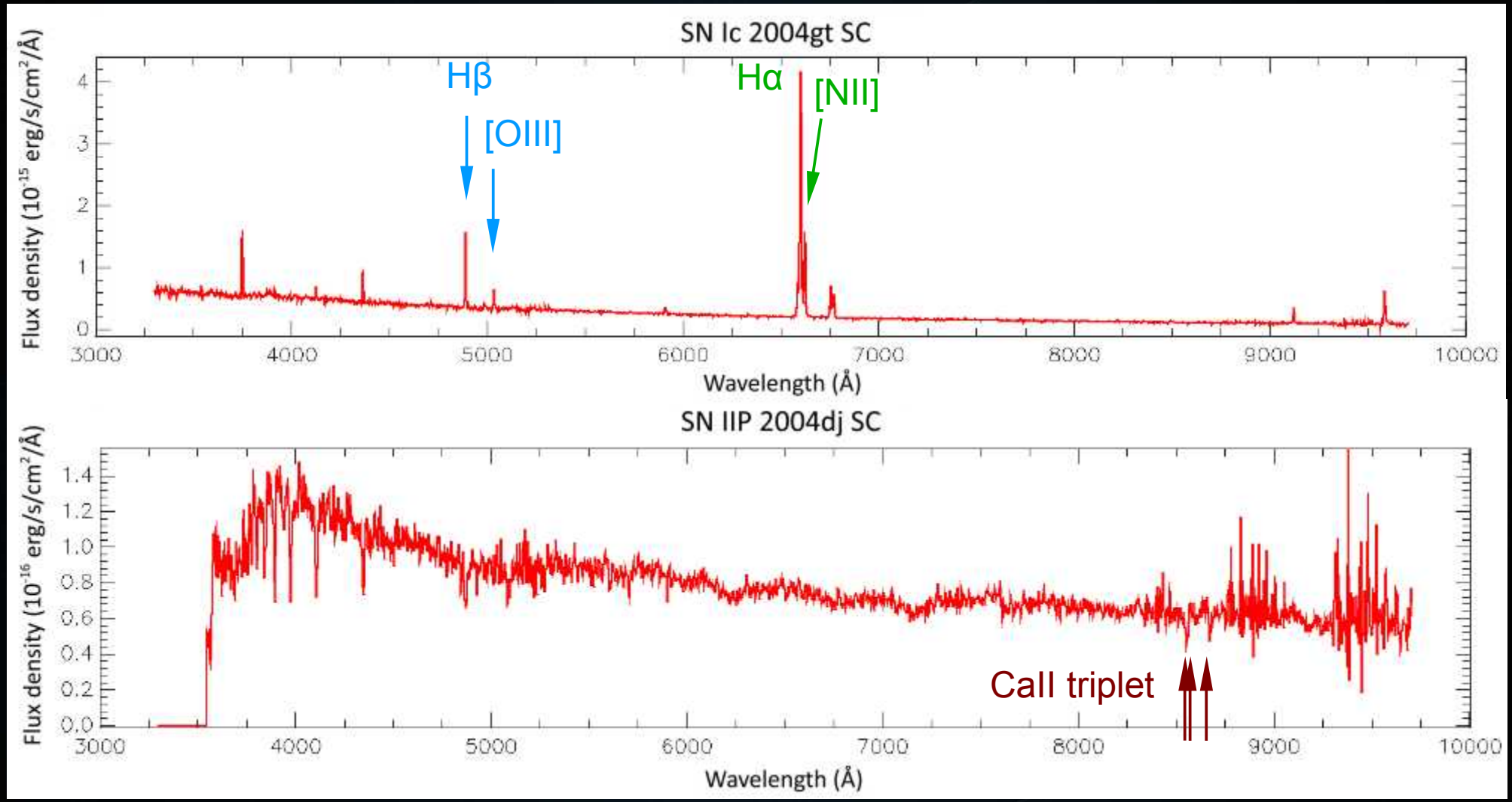


SNIFS,
SN 1948B site

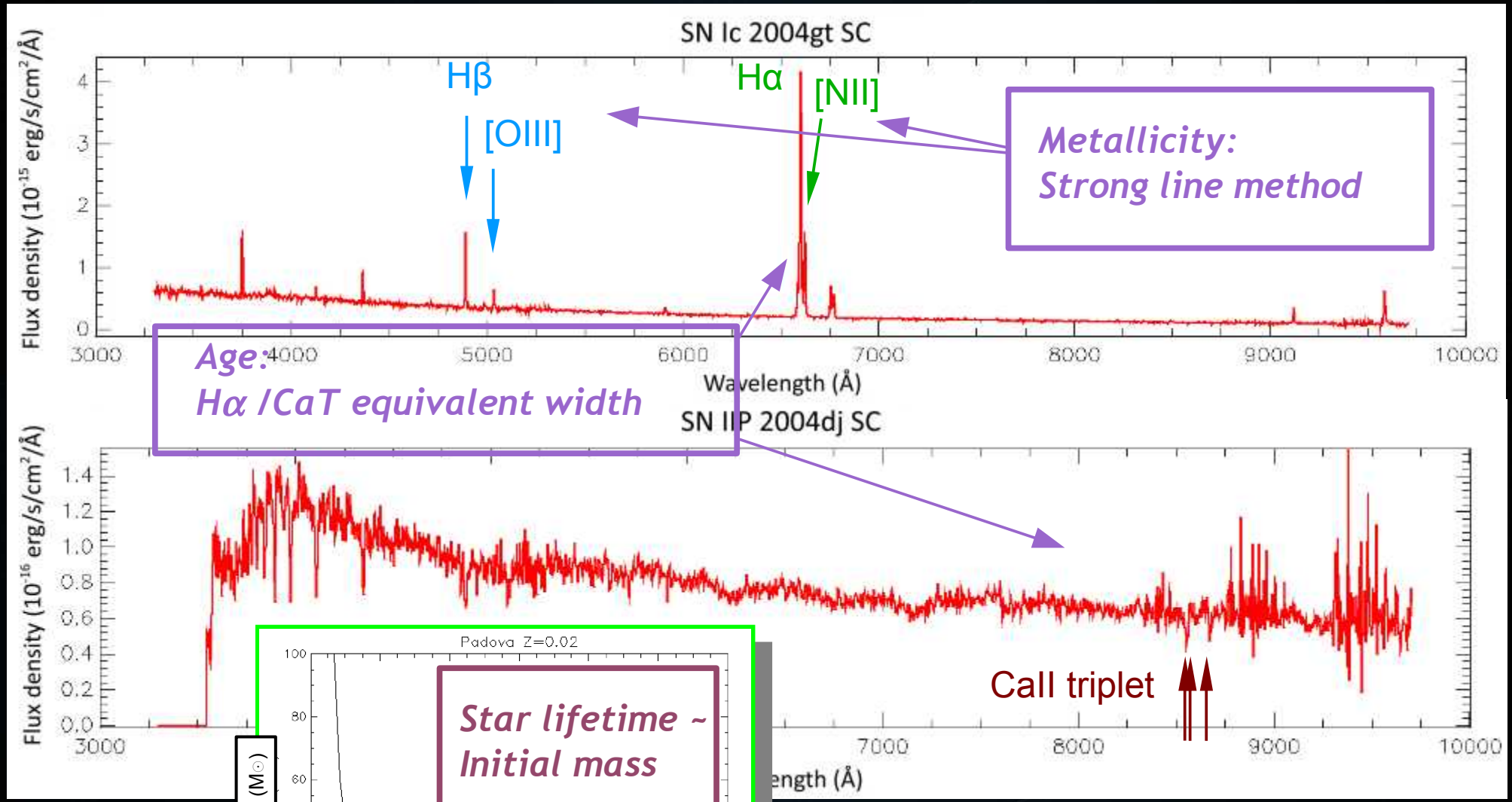
extract cluster

extract HII region

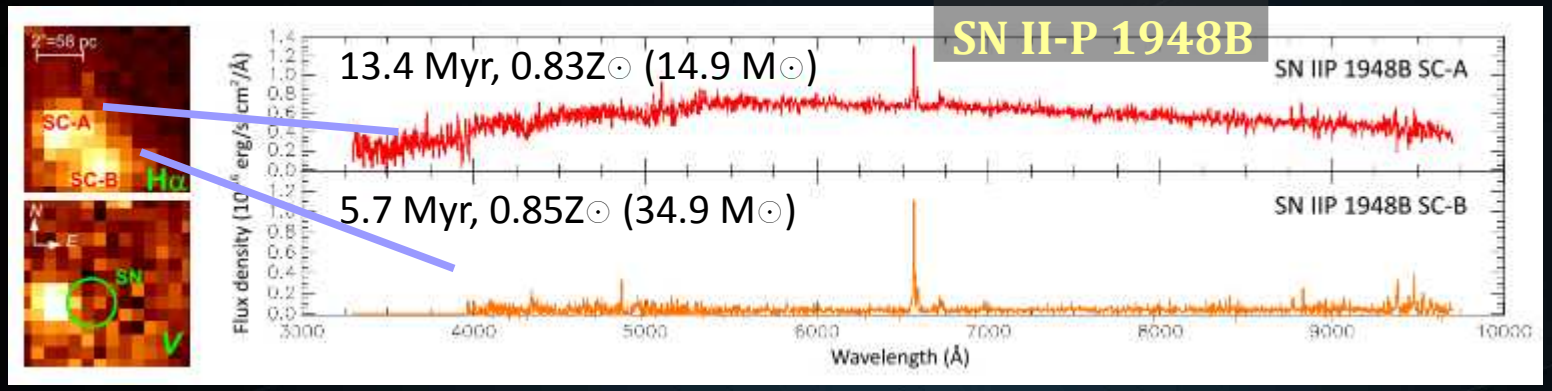
Sample spectra

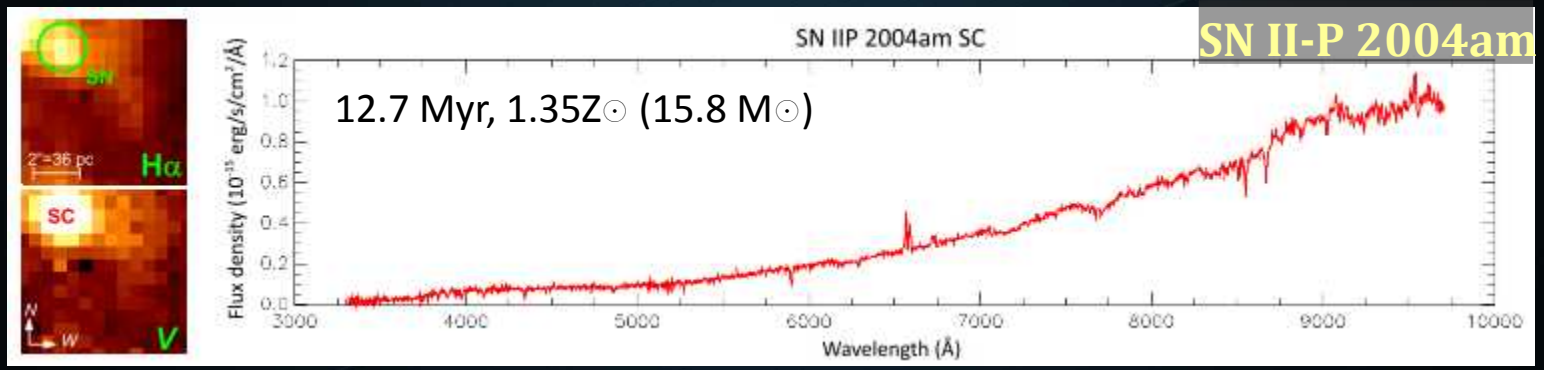


Sample spectra

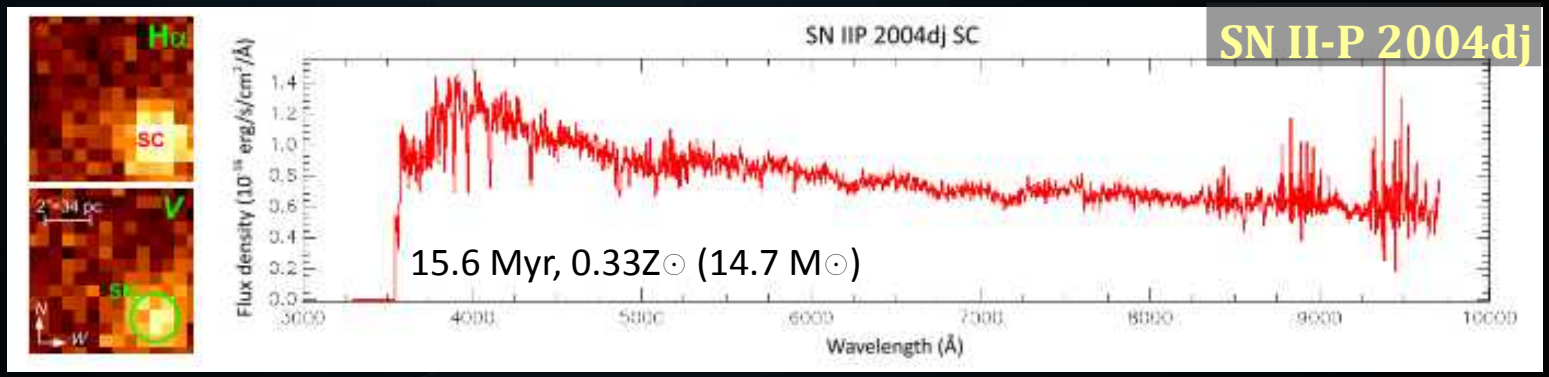


Some of the explosion sites

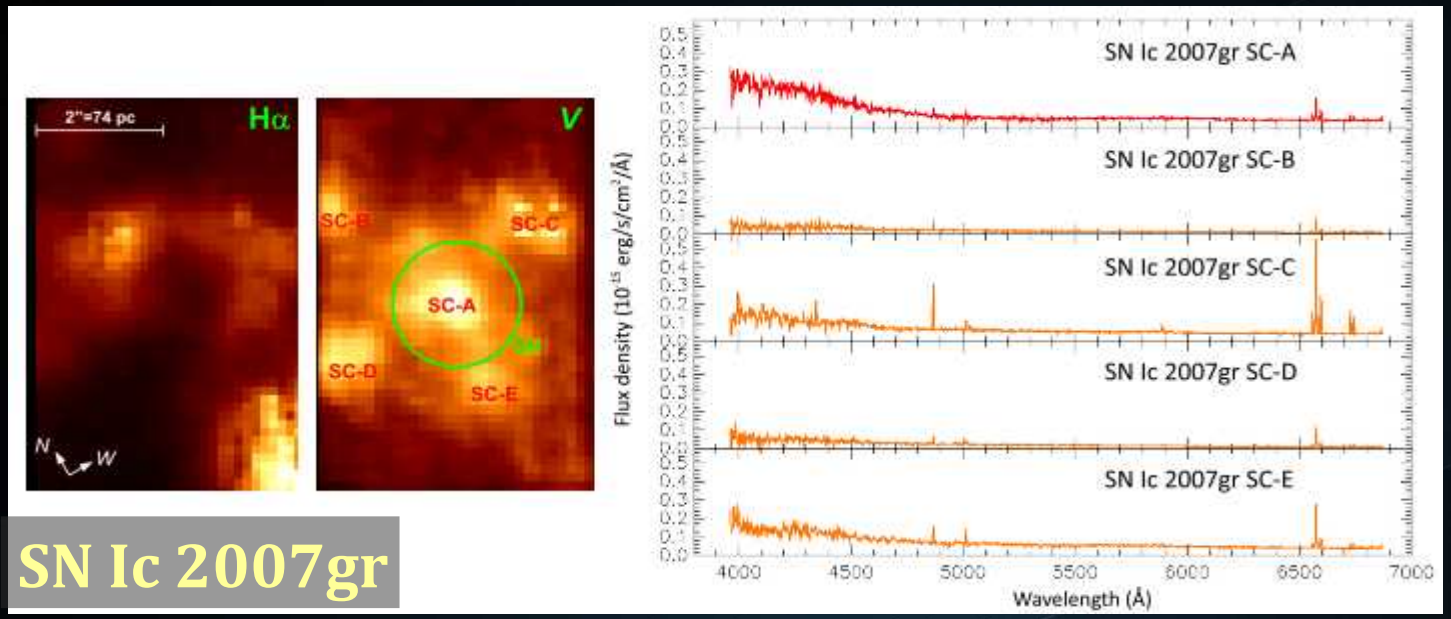




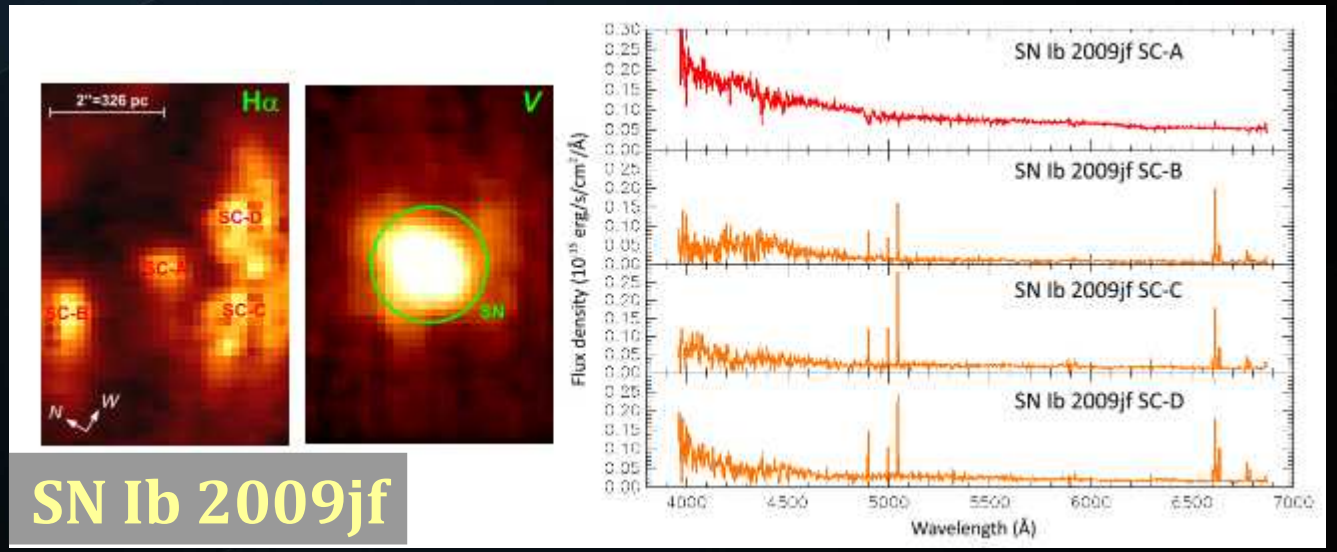
Ref → Smith+2006: 30-135 Myr; Lancon+2008: 10-35 Myr



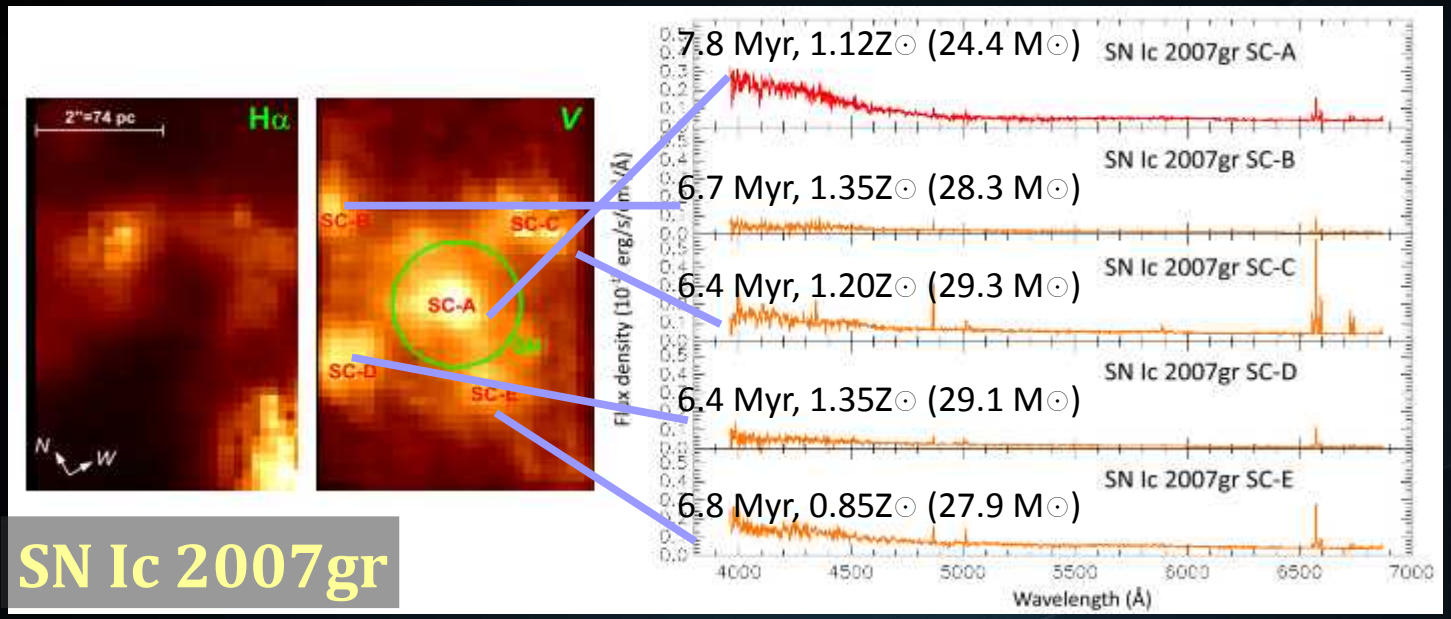
Ref → Maiz-Apellaniz+04: 13.6 Myr; Wang+05: ~20 Myr; Vinko+09: 10-16 Myr



SN Ic 2007gr

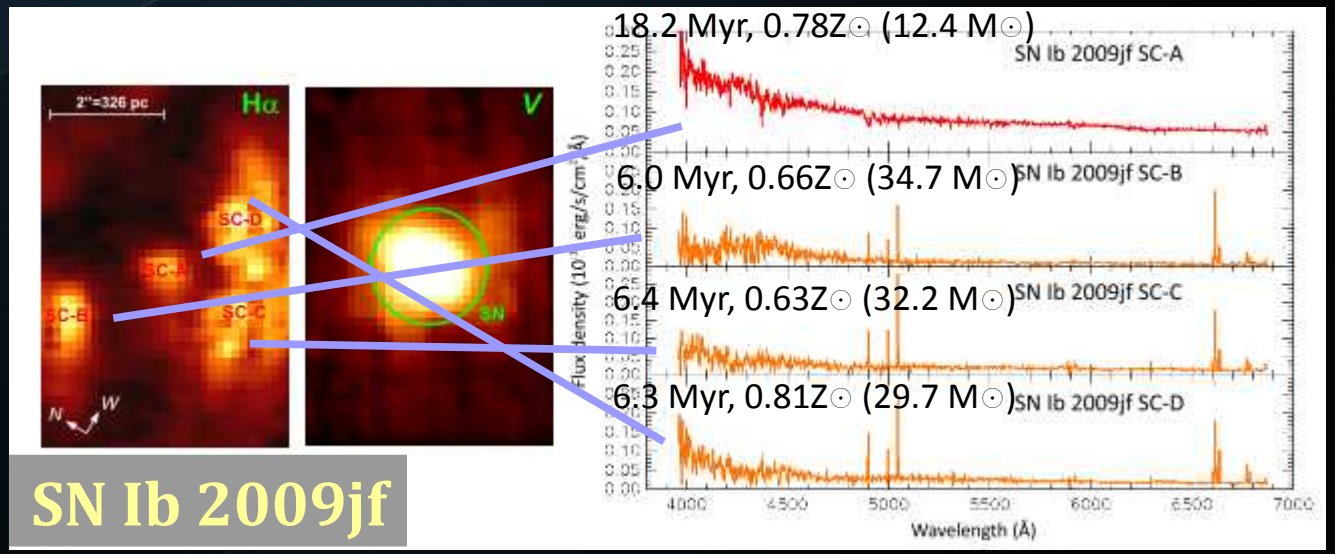


SN Ib 2009jf



SN Ic 2007gr

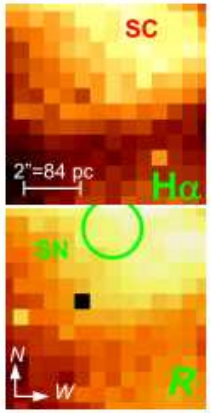
Ref → Crockett+2008: 7 or 20-30 Myr (SC-A)

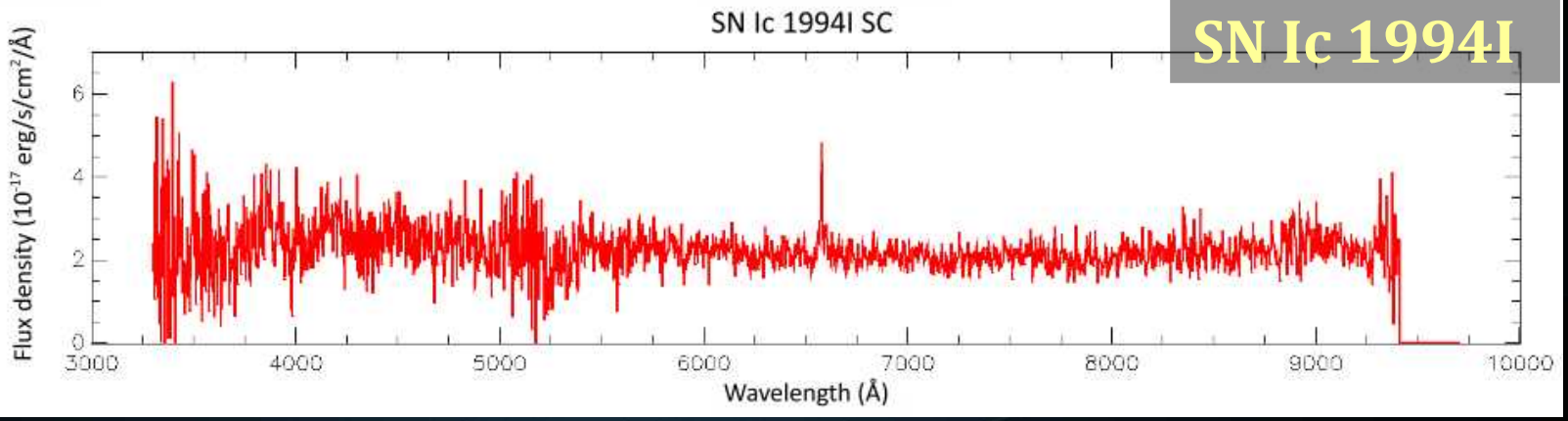


SN Ib 2009jf

Ref → Valenti+2011: 25-30 M⊙ (SN properties), but 8-25 M⊙ (SC-A)

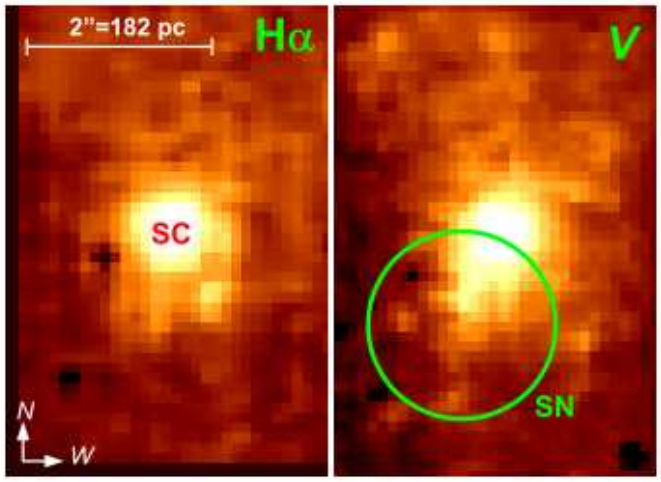
Sub-WR mass Ib/c progenitors → binaries?

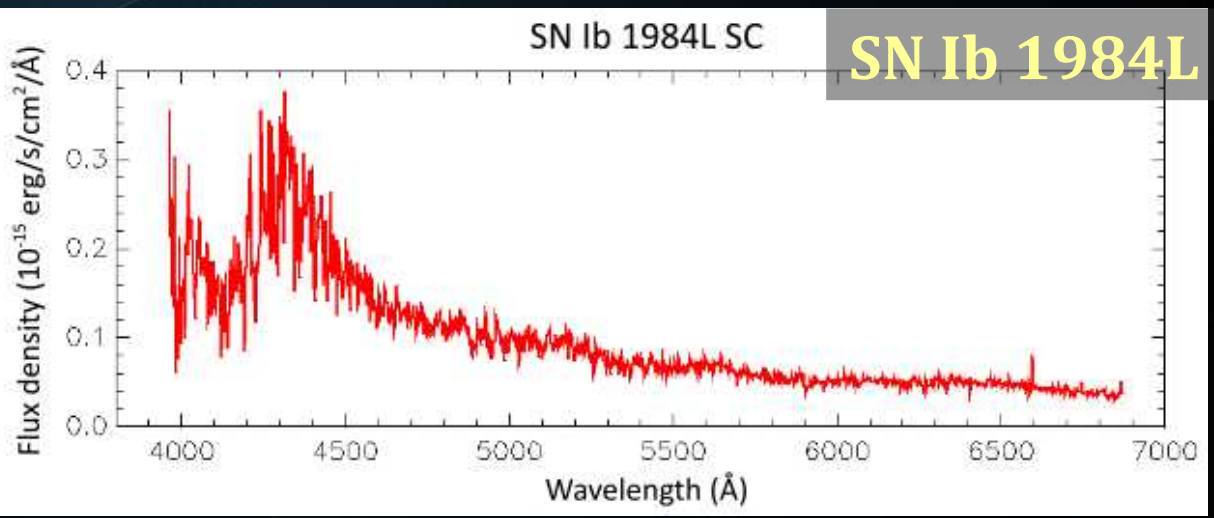




SN Ic 1994I

SC: 11.0 Myr, 0.83Z⊙: → **17.9 M⊙** progenitor Nomoto+94: 15 M⊙ binary progenitor



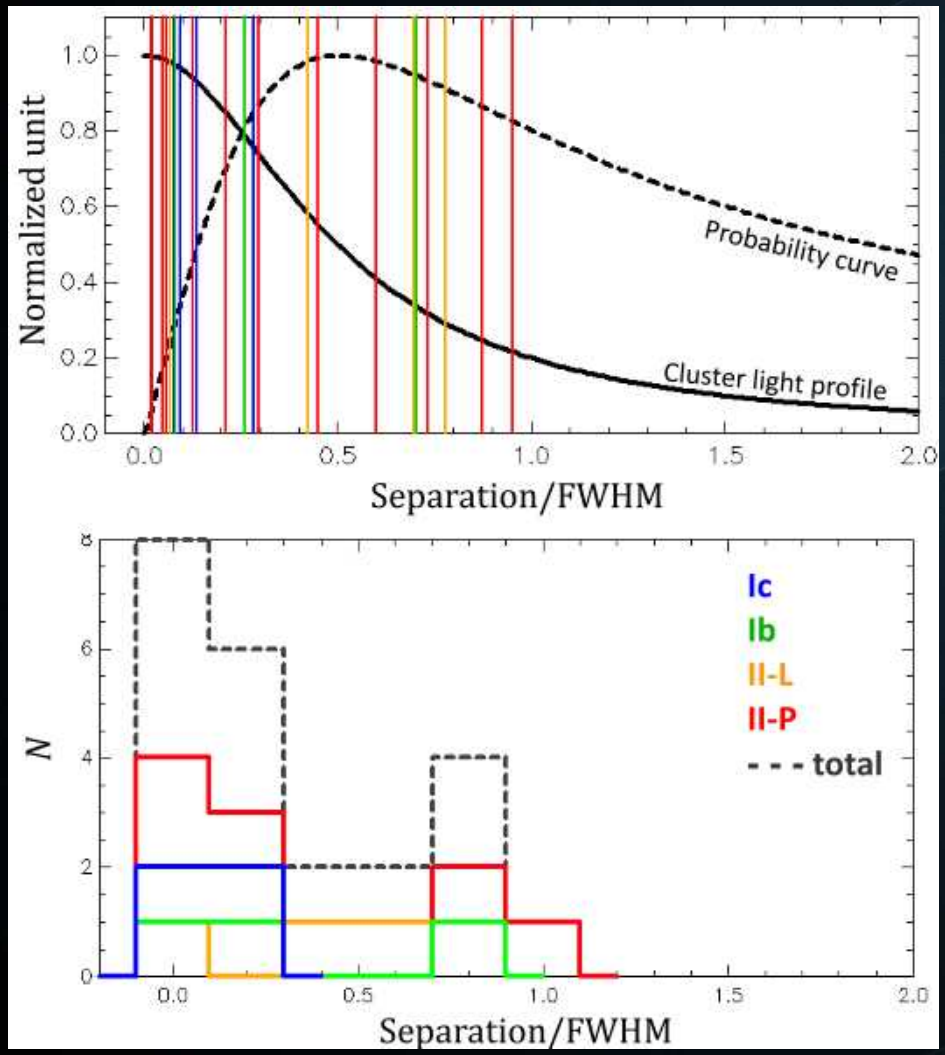


SN Ib 1984L

Metallicity:
12+log(O/H)= 8.67 (~Z⊙)

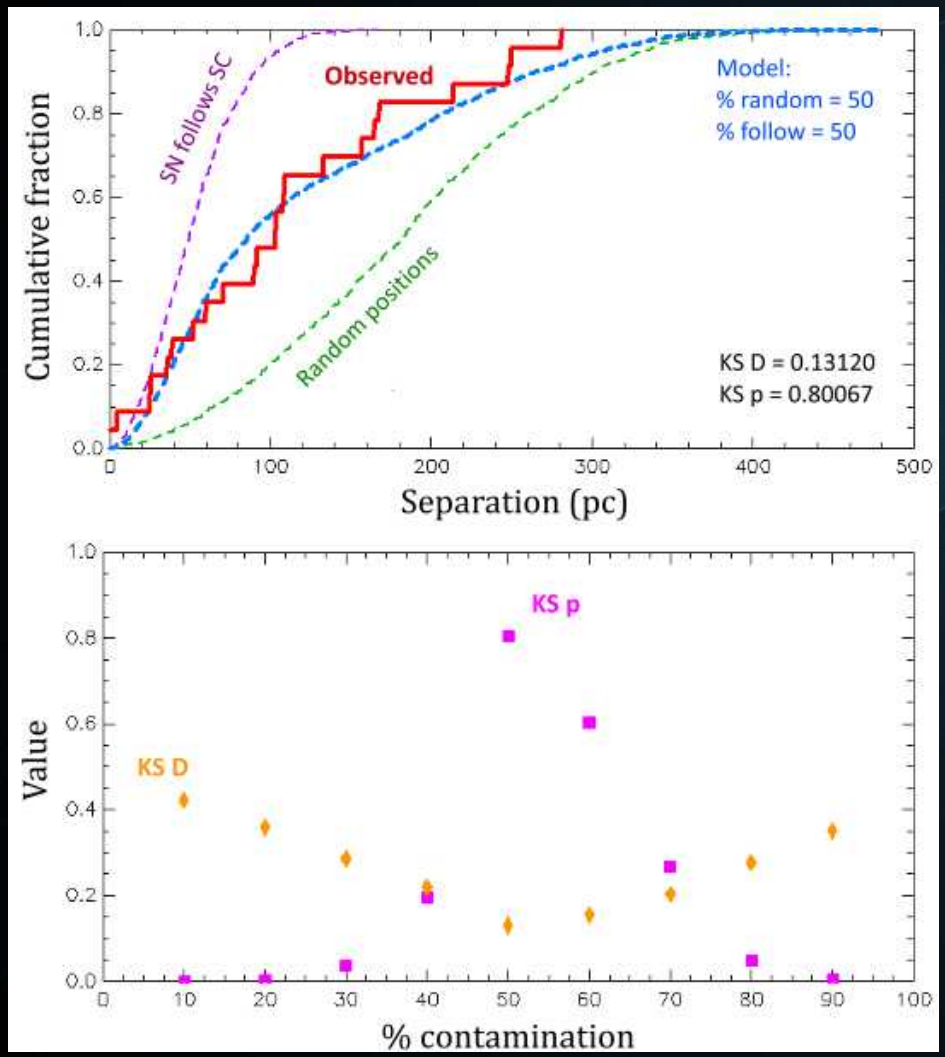
Cluster Hα EW age: 18.0 Myr → **13.5 M⊙** progenitor

Is that really the host cluster? Can we trust the apparent association?



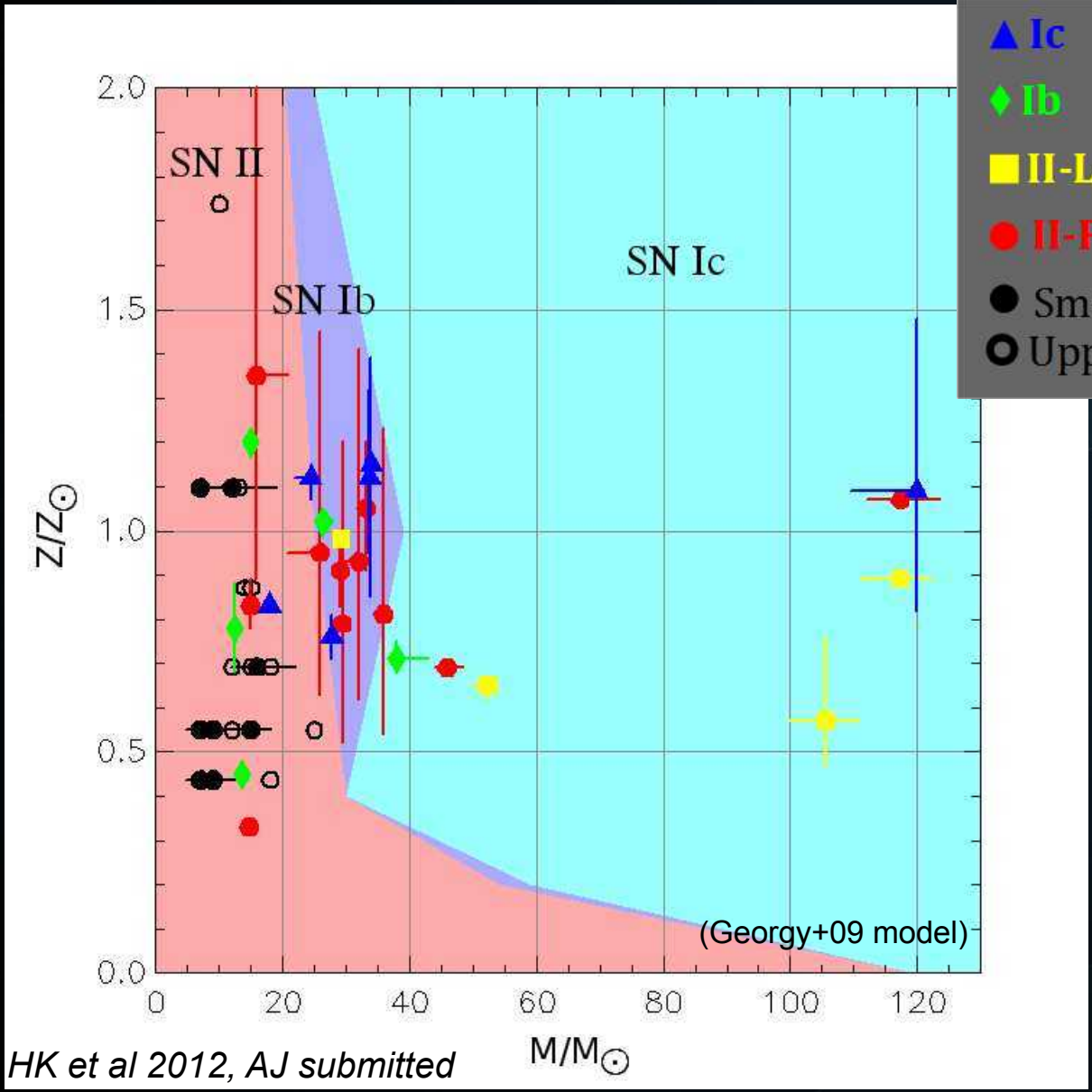
- Probably there are unseen clusters in the field (which may have been the real SN progenitor host) → but ~30% lower likelihood to host the SN, considering the luminosity & number
- How do the SNe follow host cluster light profile? → looks like they are associated

Simulating the FoV



- Perform a Monte Carlo simulation to check, compare observed distribution against models containing different levels of contamination
- Result: 50% contamination, 50% physical association

Final result on M-Z diagram



HK et al 2012, AJ submitted

- SN Ic more massive & metal rich than Ib
- There are sub-WR mass Ib/c progenitors → binaries
- Some SN II are massive

Resolving the caveats

- Insensitivity to low-mass progenitor (<12 M⊙) population
- Uncertain star formation history at the explosion sites

- Started IFU observation project using **VLT/SINFONI** (with J. Anderson & M. Hamuy)
- Near diffraction-limit *K*-band AO-assisted IFU → resolve explosion sites, detect older clusters & constrain SFH

Summary & future potentials

- IFU spectroscopy of nearby SN sites → progenitor mass & metallicity from parent stellar population
- Result indicates important implications to the current SN understanding:
  - Single+binary channel in SN Ib/c production
  - Higher mass & metallicity Ic > Ib
  - Probably some SN II progenitors are massive
- Still expecting more data from VLT/SINFONI to refine result & resolve caveats
- Increase sensitivity towards (fainter) older population, add farther SN sites & environments

Thank you very much