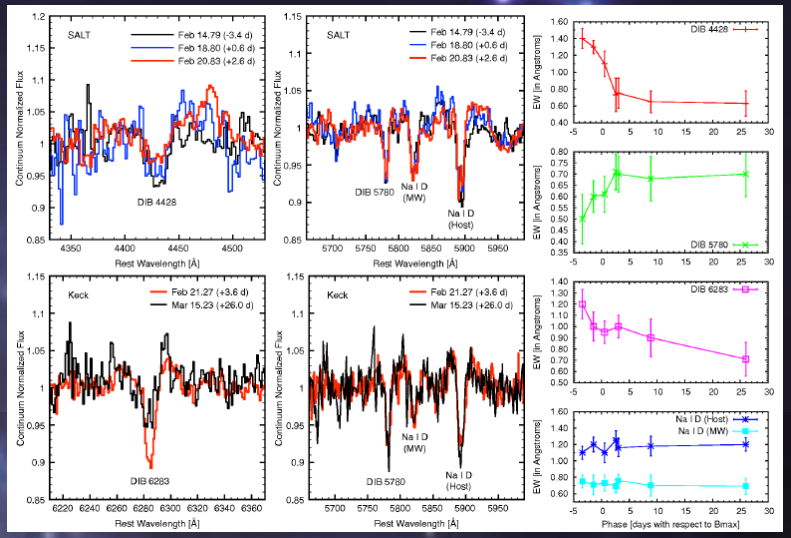
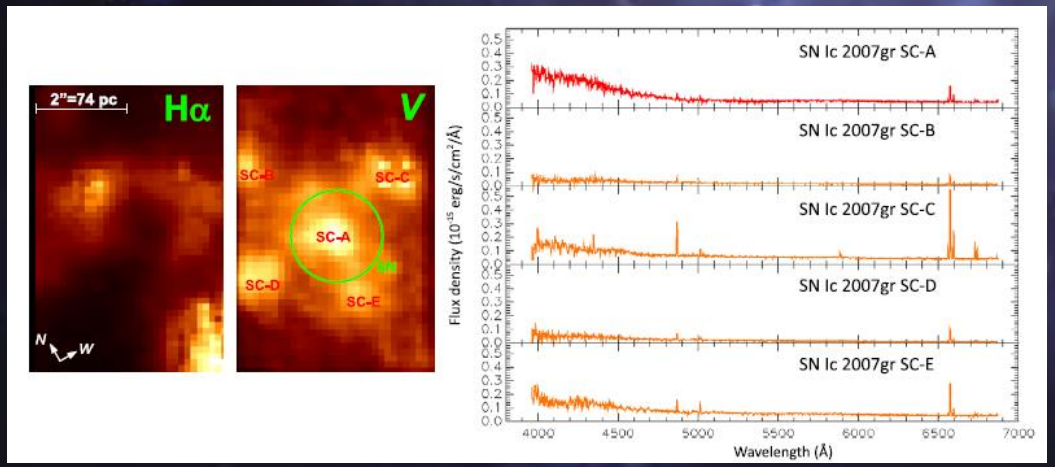
Evolution of absorption system



超新星(・爆発天体)の周辺環境

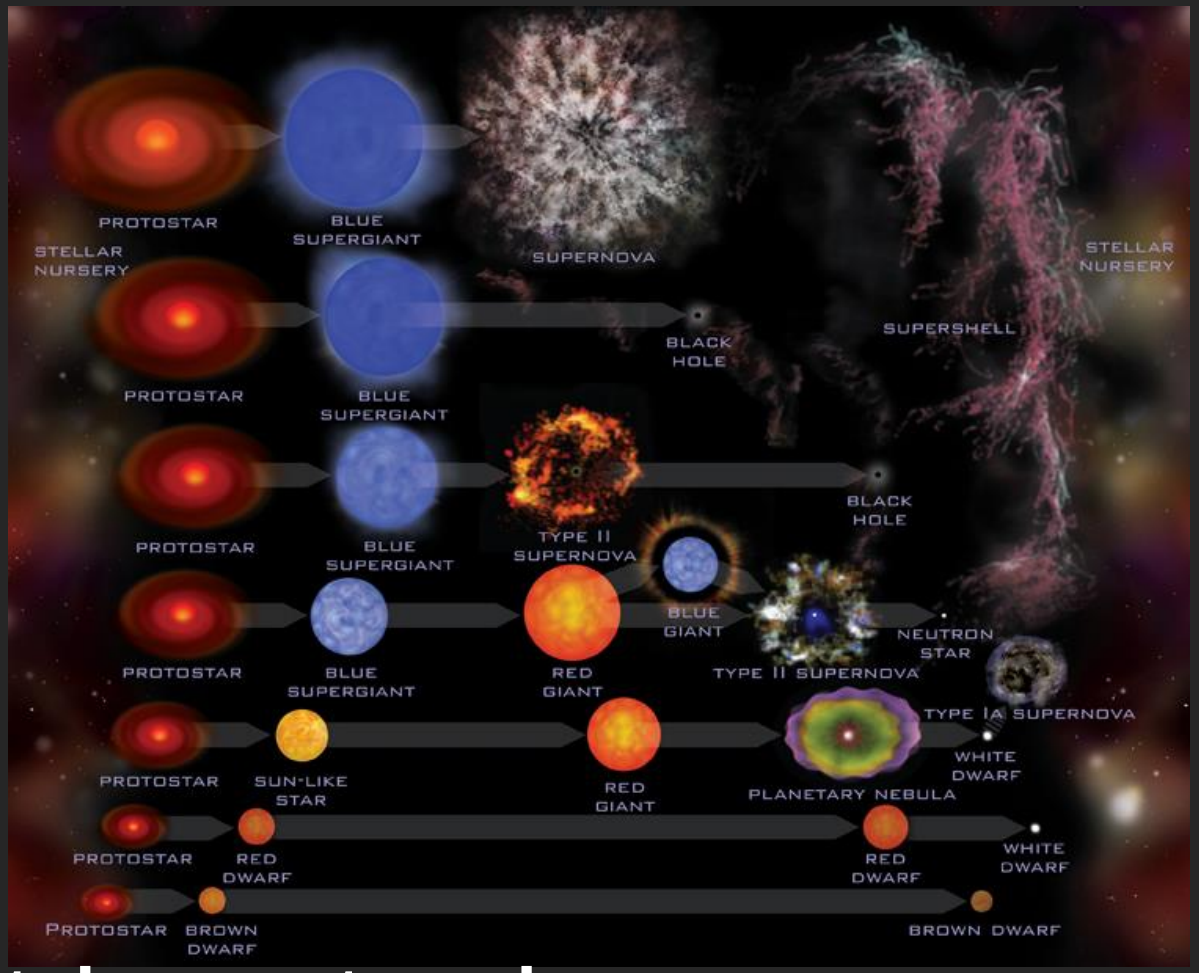
IFU SN-site



前田啓一
@京大宇物
（2013.9 -）

Stellar Evolution and SN explosions

Mass



We know it does not work.

Too much simplified, e.g., effects of banality?

SN Environment: A clue to stellar evolution

Stellar evolution toward SNe
in the last decades to centuries

An unresolved issue

Key:

Environment (age, metallicity, …)
CSM (mass loss)

Type Ia… Thermonuclear runaway of a white dwarf (WD).
Single White dwarf (dirty) or merging two WDs (clean)?

Type IIb/Ib/Ic… C+O star w/ small amount of H-envelope.
How to strip the envelope? CSM density not well known.

Type IIn… Strong CSM-SN hydrodynamic interaction.
How to make the huge CSM? Progenitor?

SN follow-up AND environment study

SN follow-up

Ejected mass
Ejecta composition
Energetics
Radioactivities
Explosion dynamics
Progenitor radius
…

Deep
Late

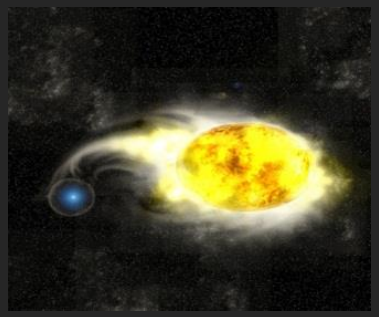
Quick
Early

Environment

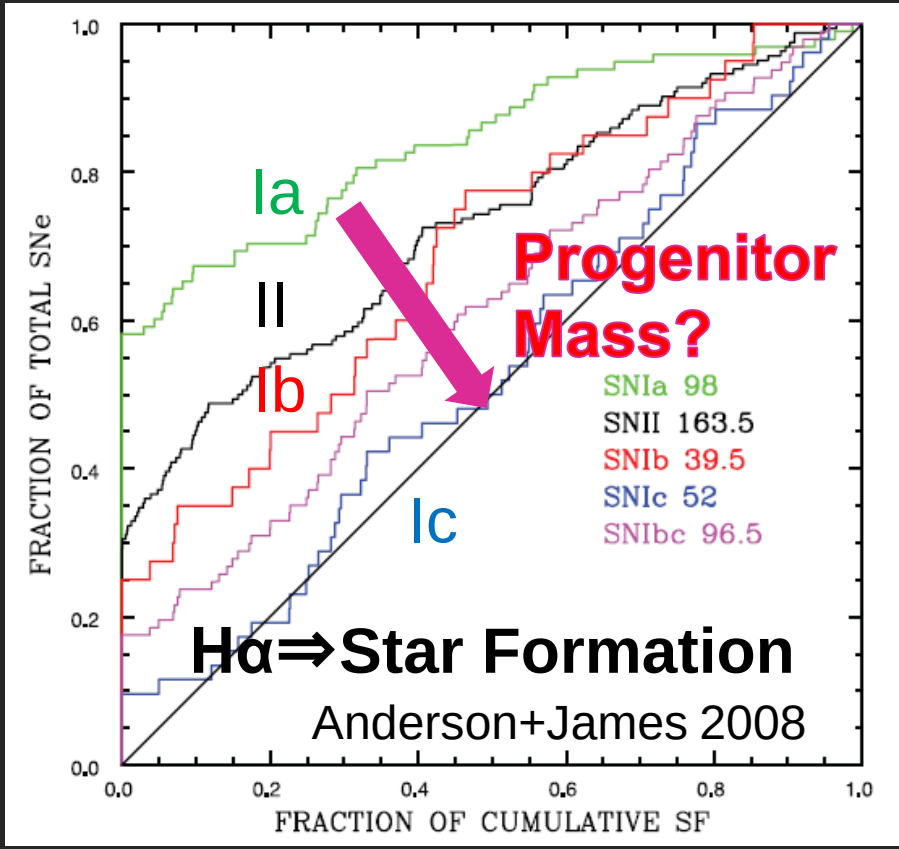
CSM/Mass loss
Metallicity
Age/Population
… at various scales
progenitor
host cluster
clusters
host galaxies

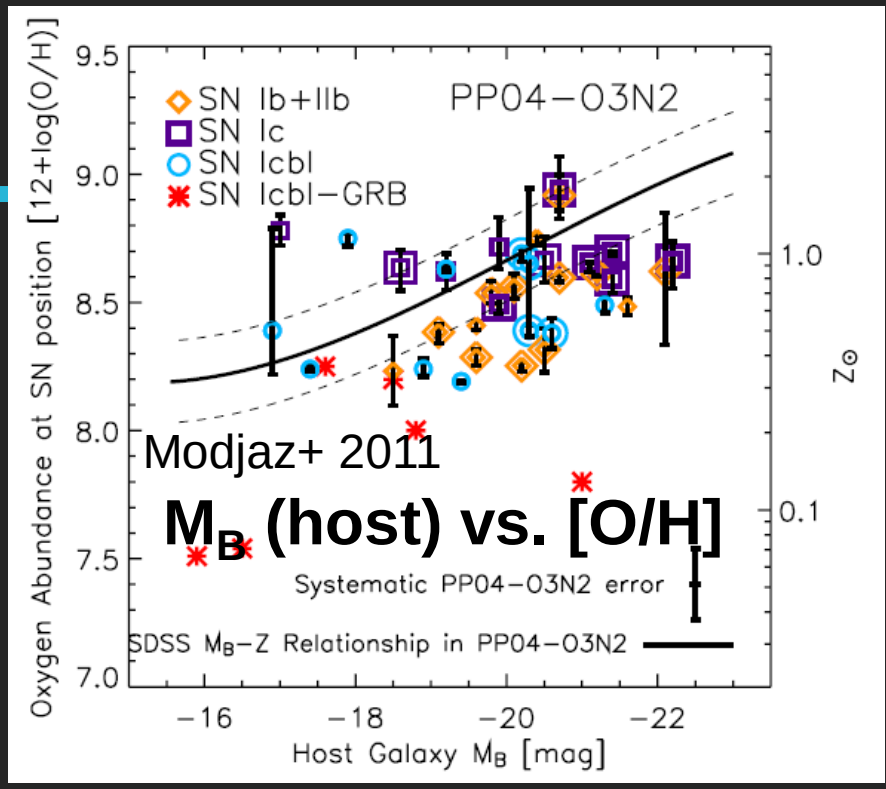
Quick
Early

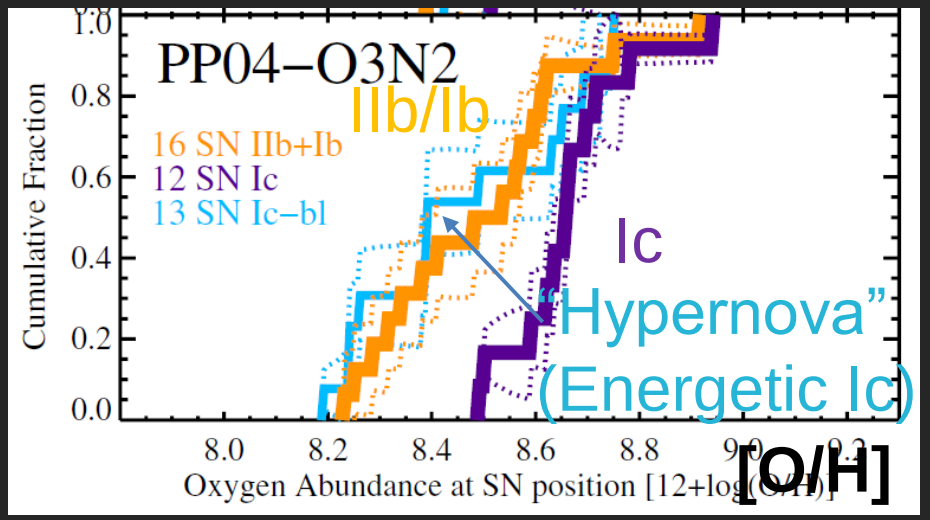
Deep
Late



SN-site environment



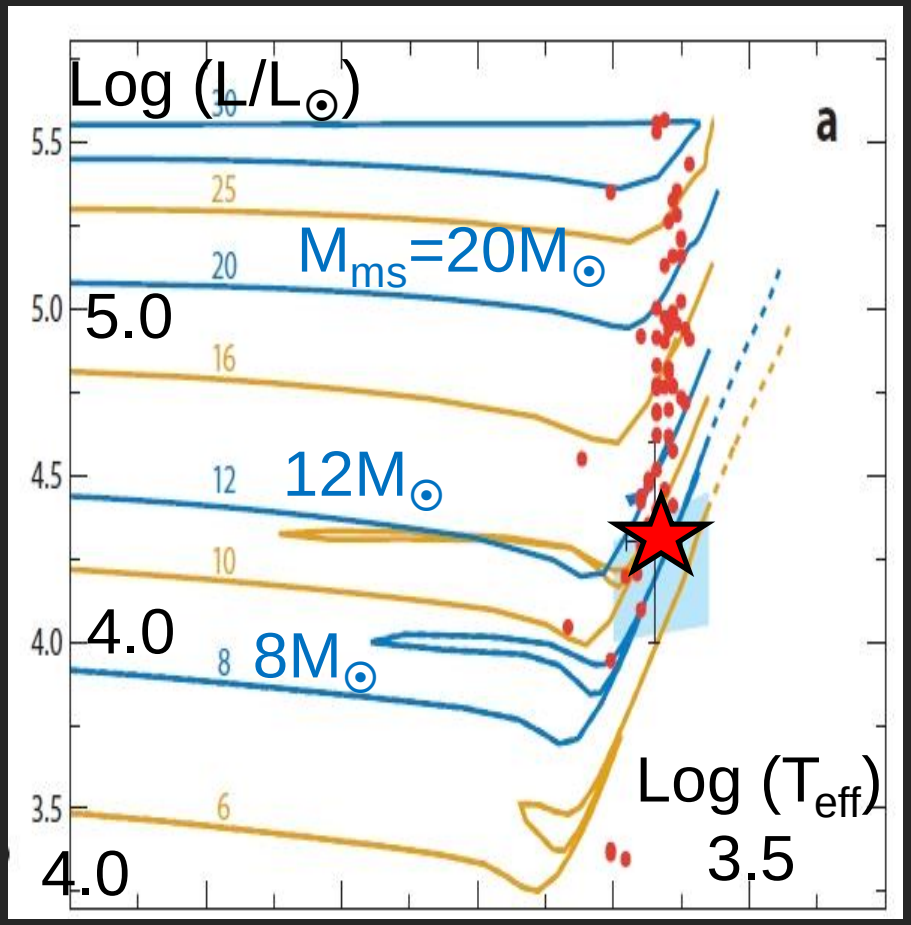




Need to go further

Not for 3.8m (but complementary) Smartt 2009 (Review)

Progenitor search in past images



Progenitor Detection

< ~ 10 Mpc with **HST**.

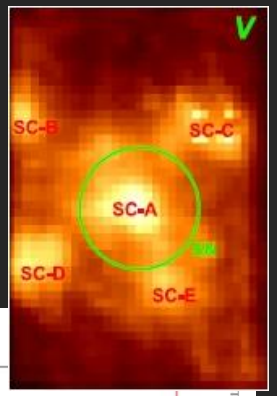
Good for SNe IIp (Giant, bright in optical)

Bad for SNe Ib/Ic (Wolf –Rayet, bright in UV, not in opt.)

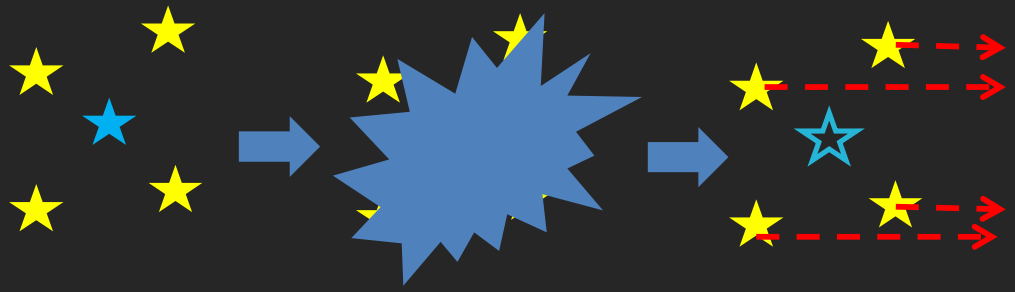
For 3.8m (collab. w/ H. Kuncarayakti, Doi, et al.)

Progenitor system search after SN

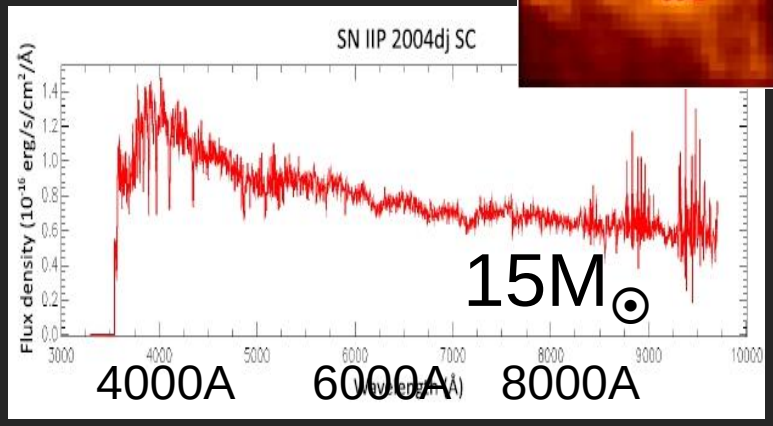
Kuncarayakti+ 2013ab



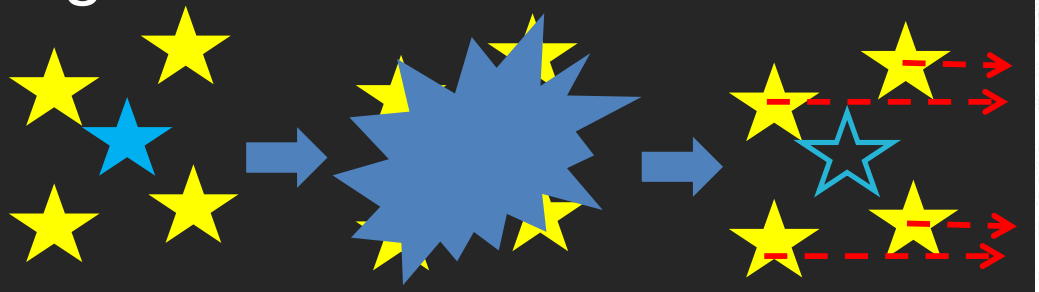
Low mass

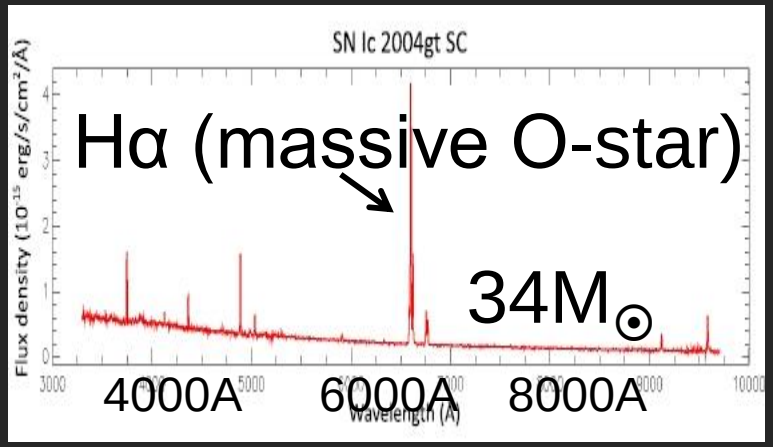


SN > A few yrs



High mass

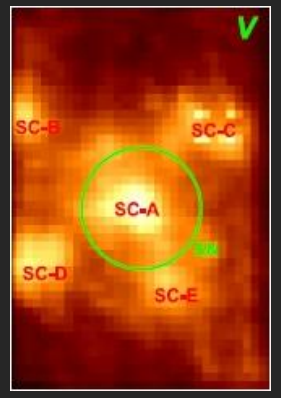




Byproduct:

Progenitor confirmation by disappearance (if pre-SN images)

IFU is an ideal tool



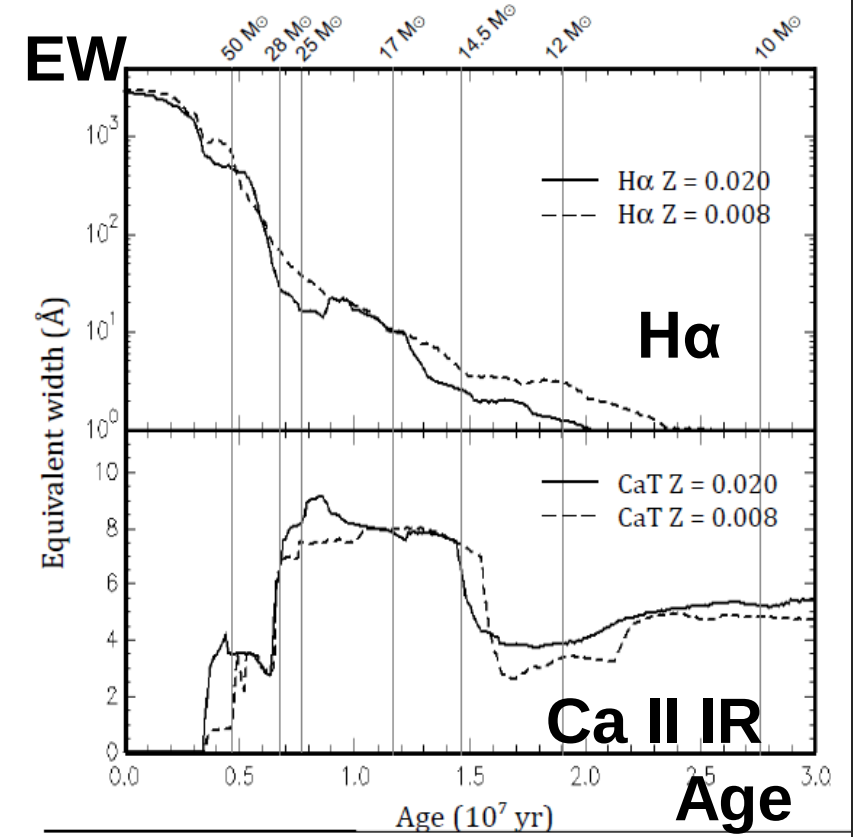
- The SN-vicinity is generally crowded with multiple stellar clusters.
- Frequently, it is not obvious which one hosted the SN (at least at the observatory).
  - As SN becomes faint, then faint and complicated environments show up.
- The clusters around the SN-host may contain the information on star-formation and stellar evolution.

Efficiency

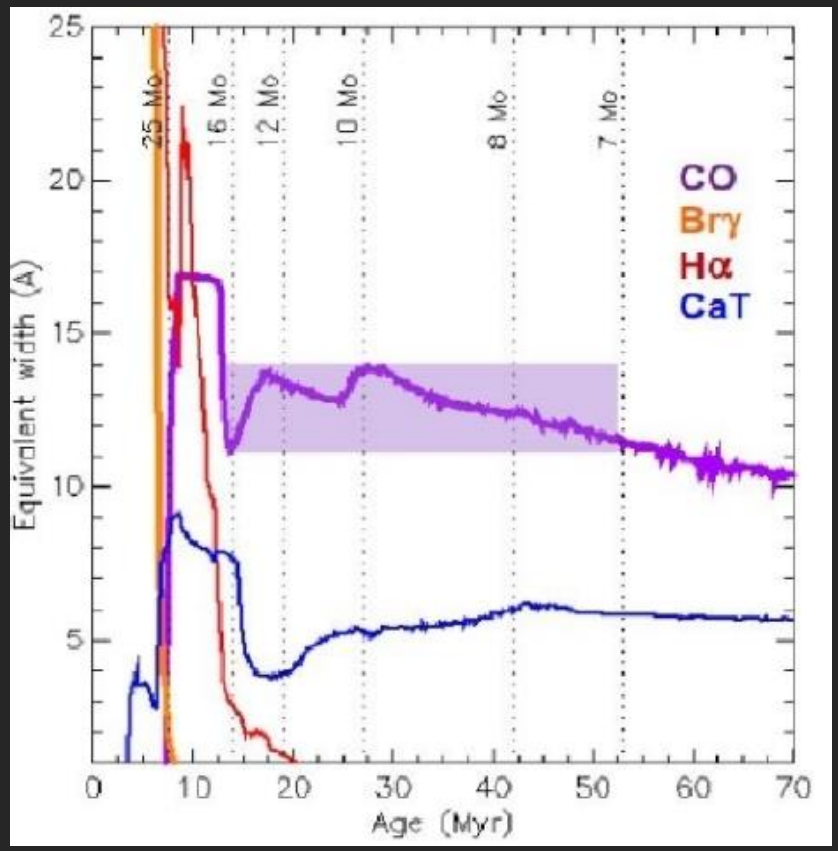
Larger scale environment

Cluster spectra ⇒ SN Progenitor

Optical (young pop.)



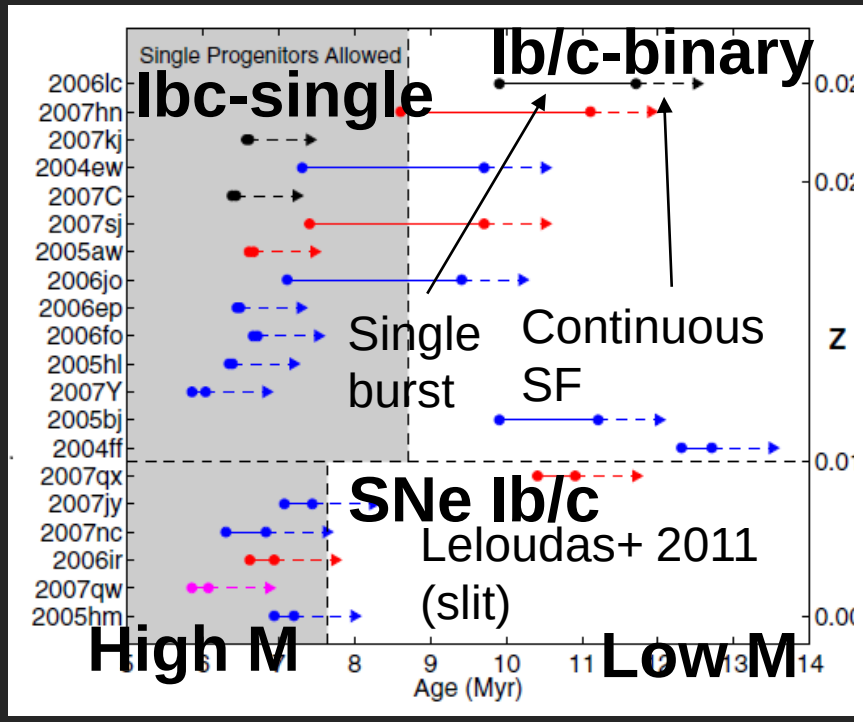
NIR (old pop.)

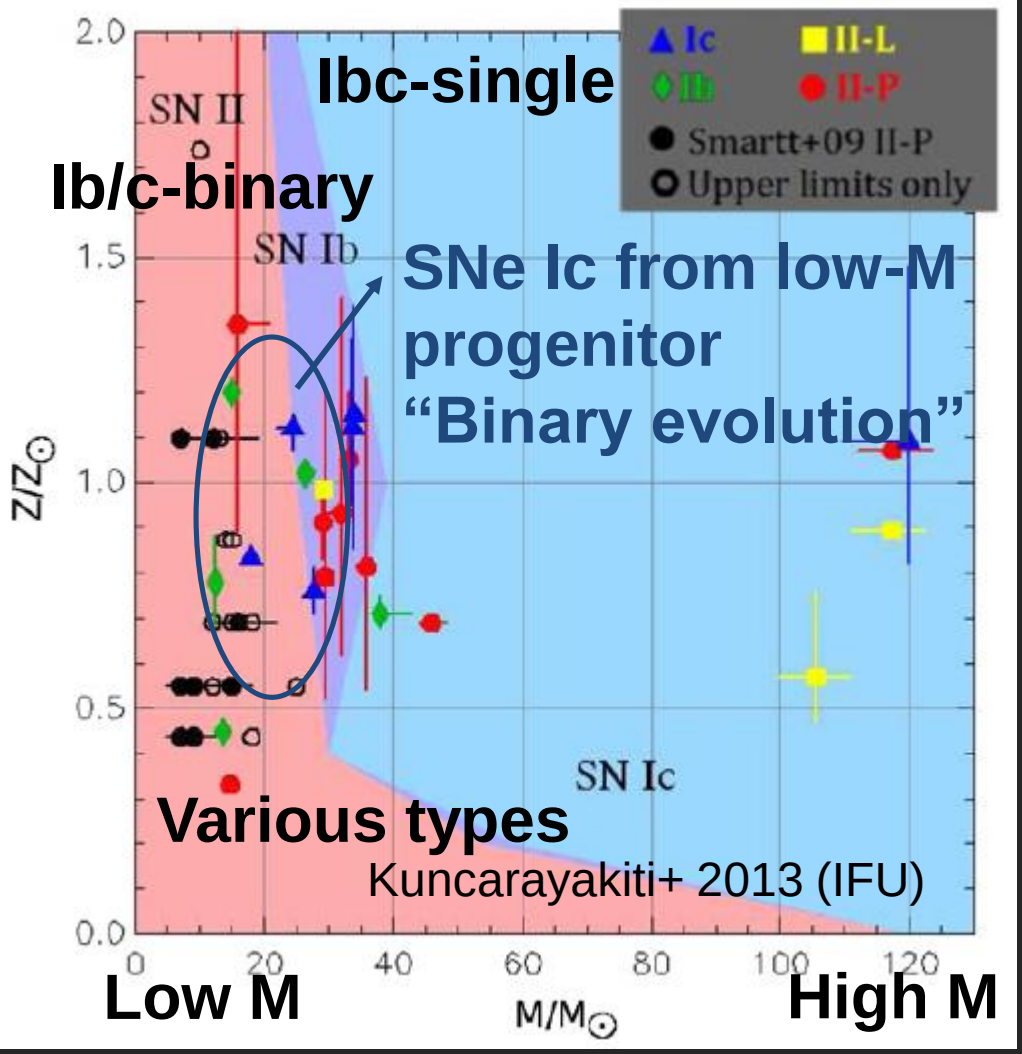


Age/Population ⇒ Progenitor mass

Statistics so far

Progenitor mass
(at least the upper limit)





Need

better theory

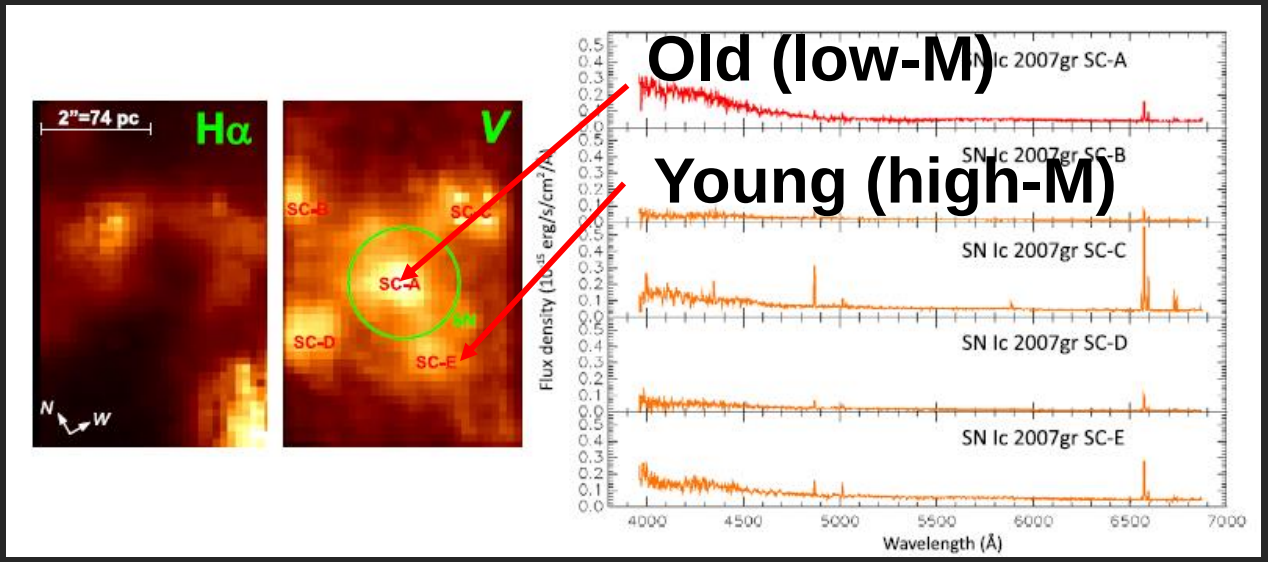
larger samples

SNe w/ good SN follow-up

to connect stellar evolution and explosion.

Some interesting cases

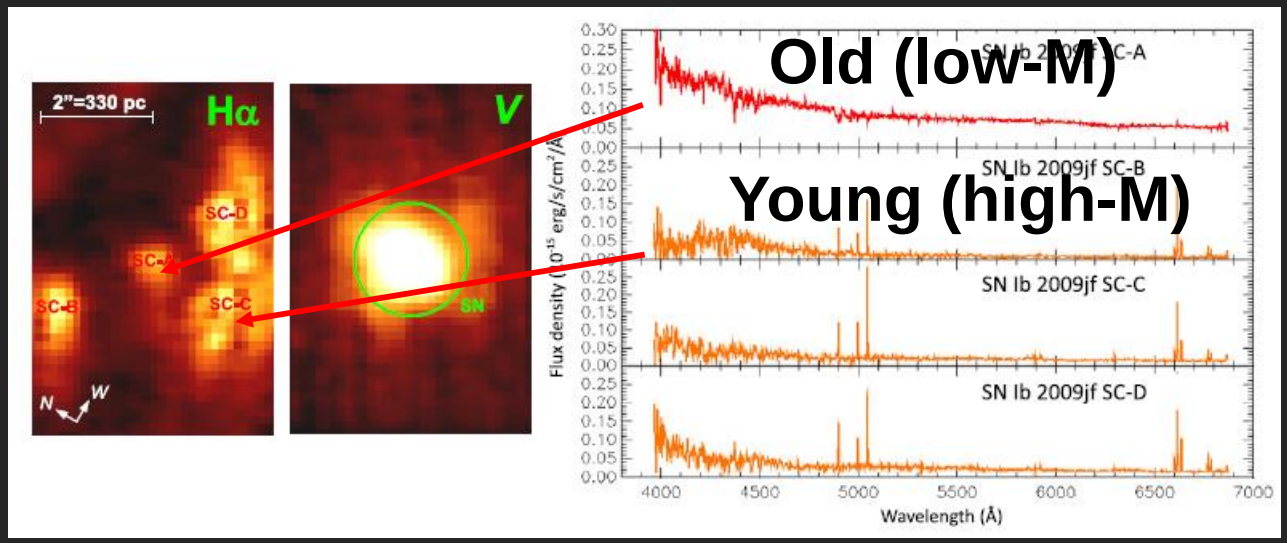
Kuncarayakti+ 2013ab



SN host
Older
Surroundings
Younger

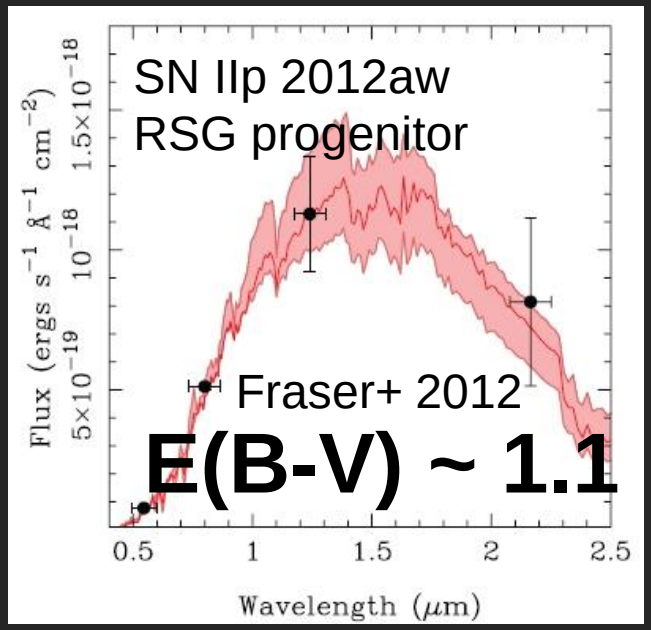
Triggered formation?

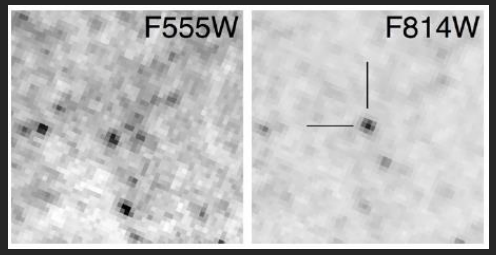
Pros: SN property in the "driving" cluster
= feedback.



Pre-SN vs. Post-SN environment

To understand the SN feedback on surroundings.

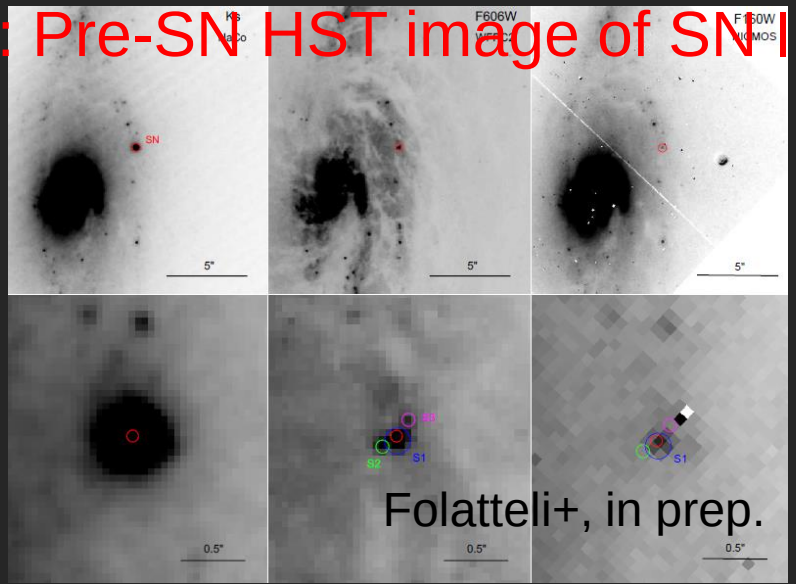




⇔ SN properties indicate E(B-V) ~ 0.1

⇔ Environment after the SN.

Example: Pre-SN HST image of SN Ib.



SN site environment

- Pre-SN⇔SN follow-up ⇔ post-SN environment.
  ←**3.8m**

- So far, most of the IFU data from UH 2.2m.
  - Biased toward the young/high-M population (V > 18).
  - Go deeper to construct the non-biased sample.
- So far, most of the data for "old" SNe w/o good SN data.
  - Natural extension of the SN follow-up by 3.8m.
  - Any single object can be interesting (←SN diversity).
    - e.g., "Super-Chandrasekhar SNe Ia".

SN Environment: A clue to stellar evolution

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Single White dwarf or merging two WDs?

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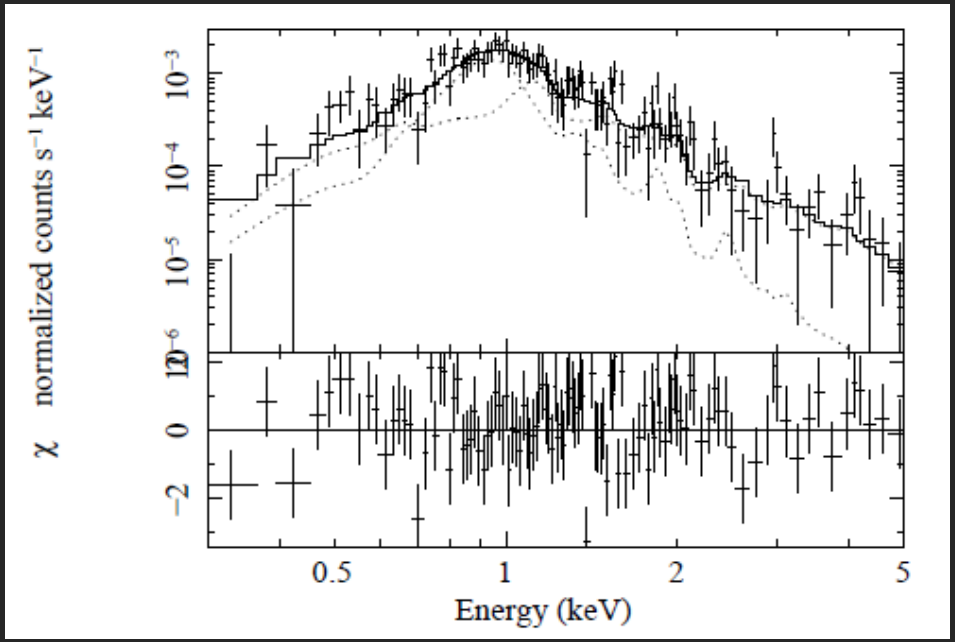
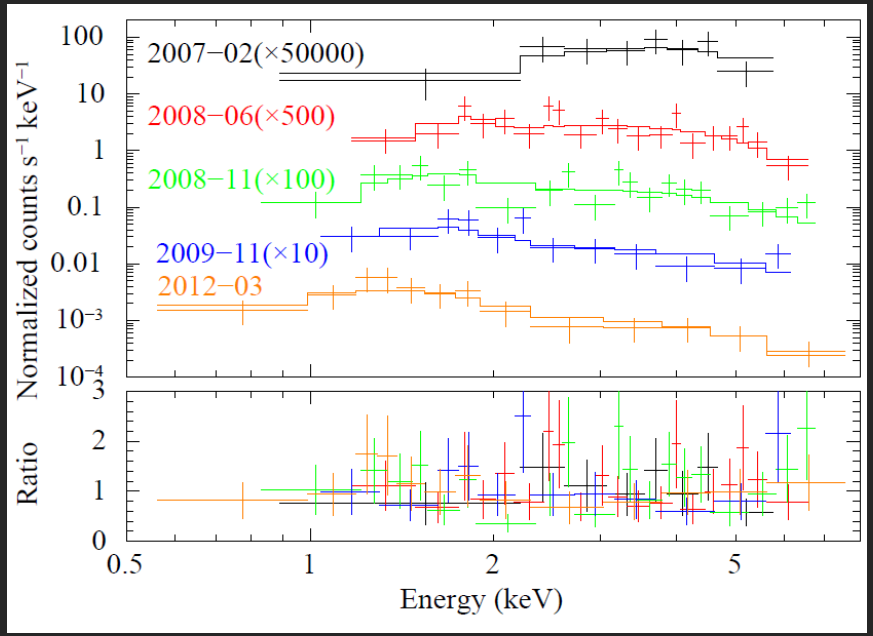
How to stripe the envelope? CSM density not well known.

Type IIn… Strong CSM-SN hydrodynamic interaction.
How to make the huge CSM? Progenitor?

CSM and mass loss

SN-CSM interaction (+ absorption)… Radio & X





SN IIb 2011dh (single or binary?)
Chandra
KM+ 2014, ApJ
Mass loss rate → binary

SN IIn 2005ip (mass-loss?)
SWIFT
Katsuda, KM+ 2014, ApJ
~ 10^{-2} $M_\odot$ / yr !!!

Ongoing/Submitted proposals

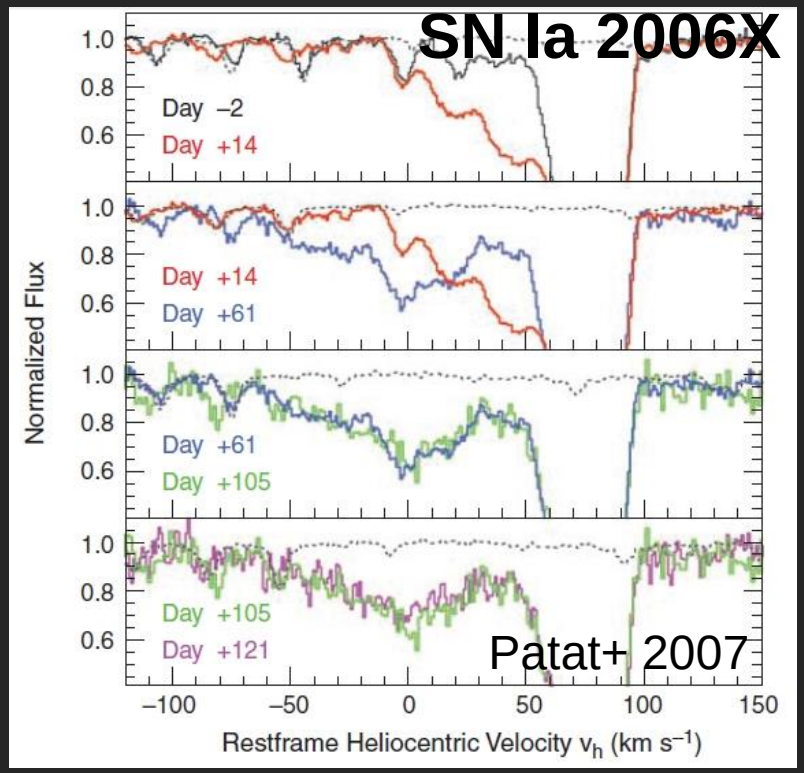
- ALMA, cycle 1+2 (2013-)
  - Approved (KM+).
- Suzaku A09 (2014-)
  - Approved (Katsuda, KM+).
- Chandra+VLA, cycle 15+16 (2013-)
  - Approved (Ray+), Submitted (Chakraborti+).
- Chandra, cycle 16 (2014-)
  - Submitted (KM+).

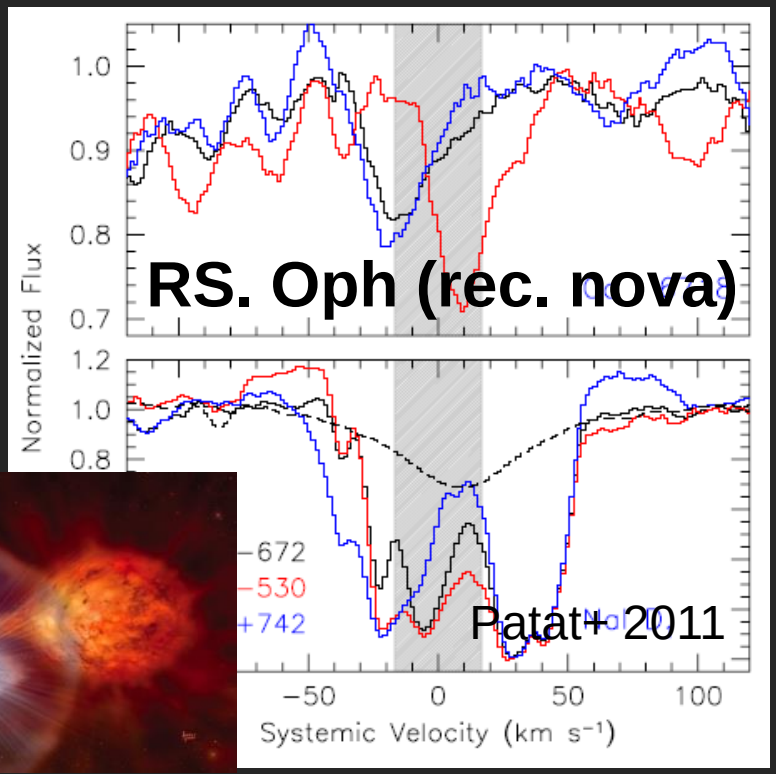
SN properties ⇔ CSM environment

Optical follow-up (3.8m!) Radio+X follow-up

CSM in optical

Time variability = CSM
(Generally) Need high-res.





High resolution spectroscopy

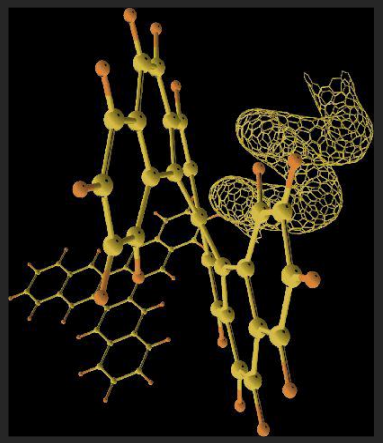
Required S/N per pix ~ 25
⇒ V < 14 w/ 3.8m (?) for weak Na ID + strong DIBs (according to Subaru proposal by KM, Phillips+).
⇒ a few SNe per year.

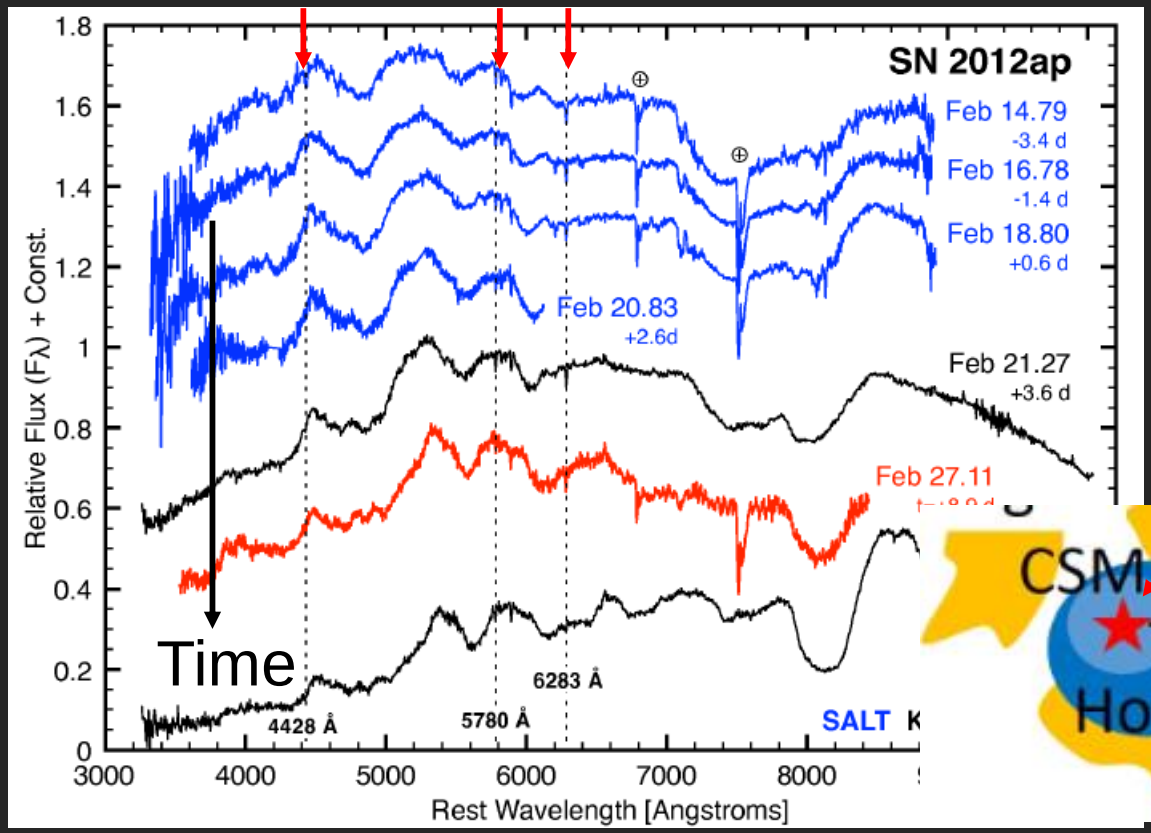
Pros. Dense sampling (not possible w/ 8m).

Example: SN Ia 2014J @ M101 (V = 11 - 12), 6 epochs in 2 months w/ Okayama & Gunma (ToO by Kawabata et al.).

Milisavljevic+ 2014, ApJL

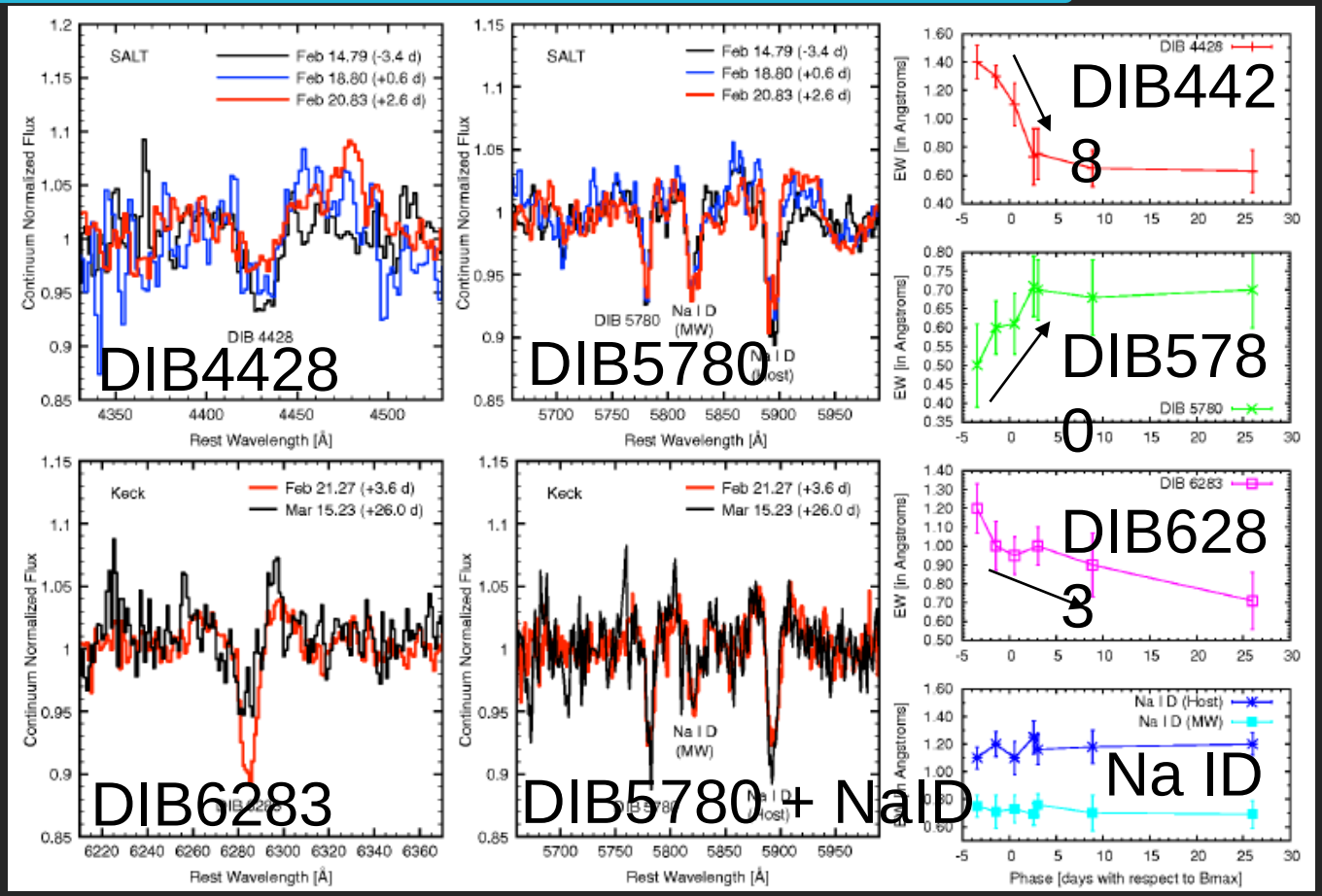
CSM/ISM Chemistry





- **Dense sampling (even w/ low-resolution: many "reddened" SNe).**
- **Example: Diffuse Interstellar Band (DIBs) + Molecules.**
  - **Origin of DIBs, CSM properties, CSM/ISM chemistry.**

CSM/ISM Chemistry



Variability

⬇

SN vicinity (CSM?)

DIBs in CSM or "hot" Star-forming region?

Low-resolution w/ SN ~ 25 （Na ID +DIBs in reddened SNe）.

⇒ V ~ 17 for 3.8m (?). V ~ 16 at peak ~ 100 SNe per year.

ISM/CSM through absorption

- Key = Dense sampling.
  - High-resolution: a few SNe per year (ToO).
  - Low-resolution: Many targets.
    - High S/N version for 2m-class targets.

- Pros.
  - Dense sampling (not for 8m's).
  - High S/N (not for 2m's).

Summary

SN follow-up

Ejected mass
Ejecta composition
Energetics
Radioactivities
Explosion dynamics
Progenitor radius
…

Deep
Late

Quick
Early

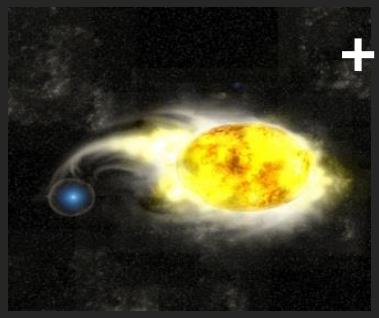
Environment

CSM/Mass loss
Metallicity
Age/Population
… at various scales
progenitor
host cluster
clusters
host galaxies

Quick
Early

Deep
Late

+ Multi-freq.
+ HST etc.



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