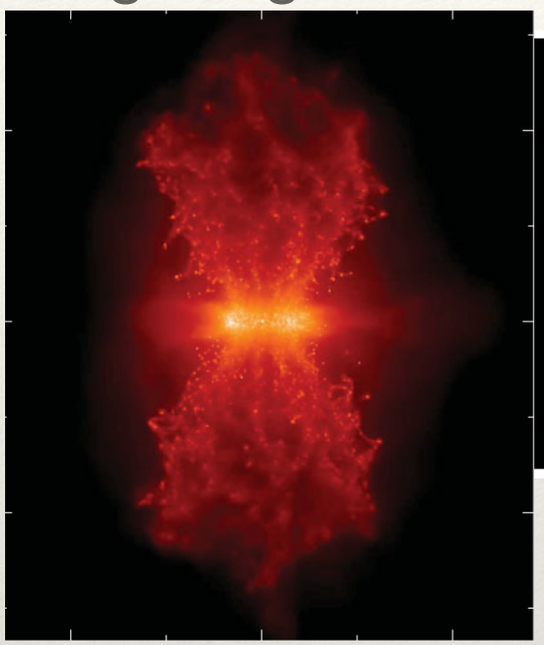
SN Ia Progenitor Workshop, Carnegie Observatories, August 2015

Constraining SN Ia progenitors using spectroscopic signatures

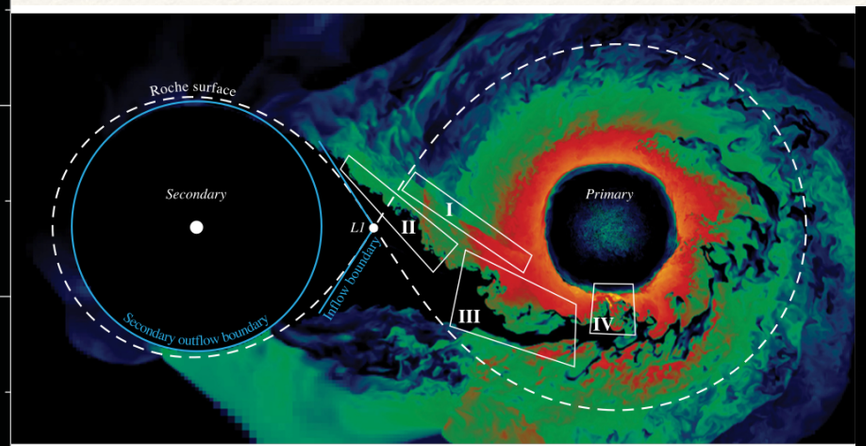
Kate Maguire

How can we distinguish explosion mechanisms?

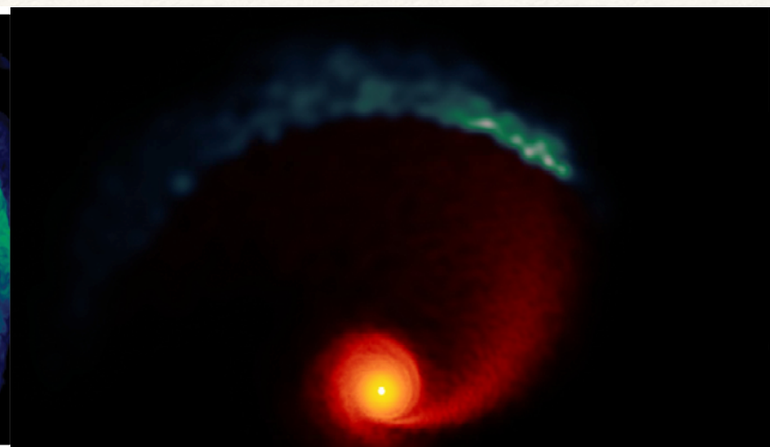
Single degenerate?



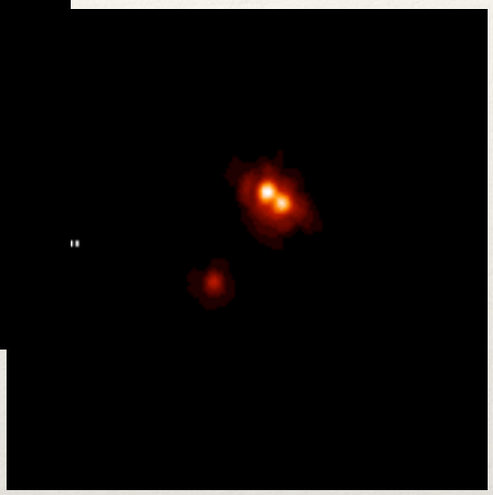
Double detonation?



Merger?



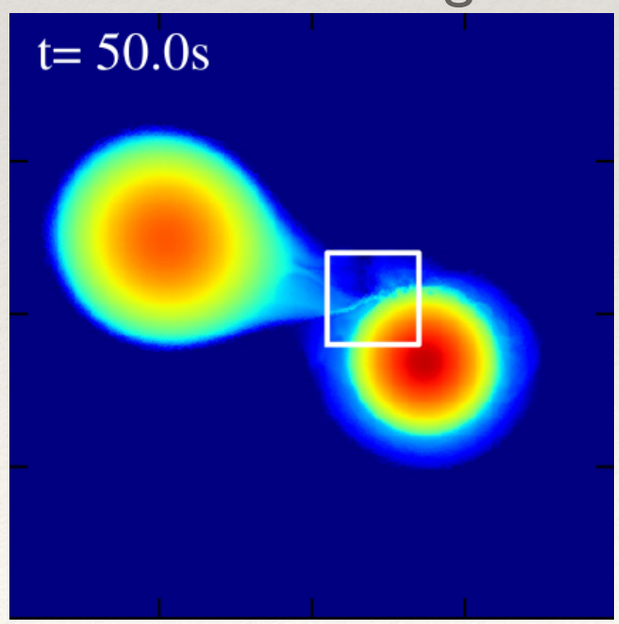
Triple system?



Single degenerate?

- Predict similar spectra
- Subtle signatures: Circumstellar material? Material stripped from a companion star?

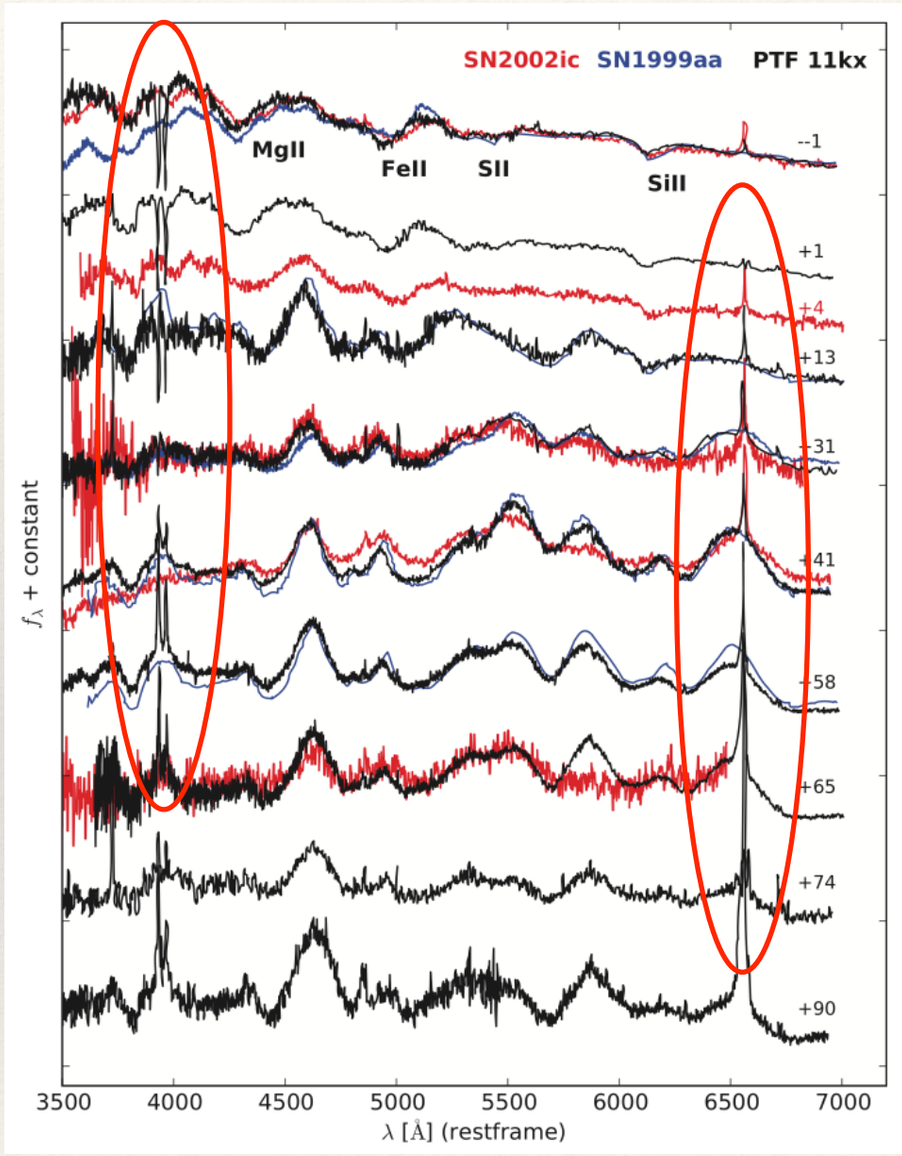
Violent merger?



1. Circumstellar material

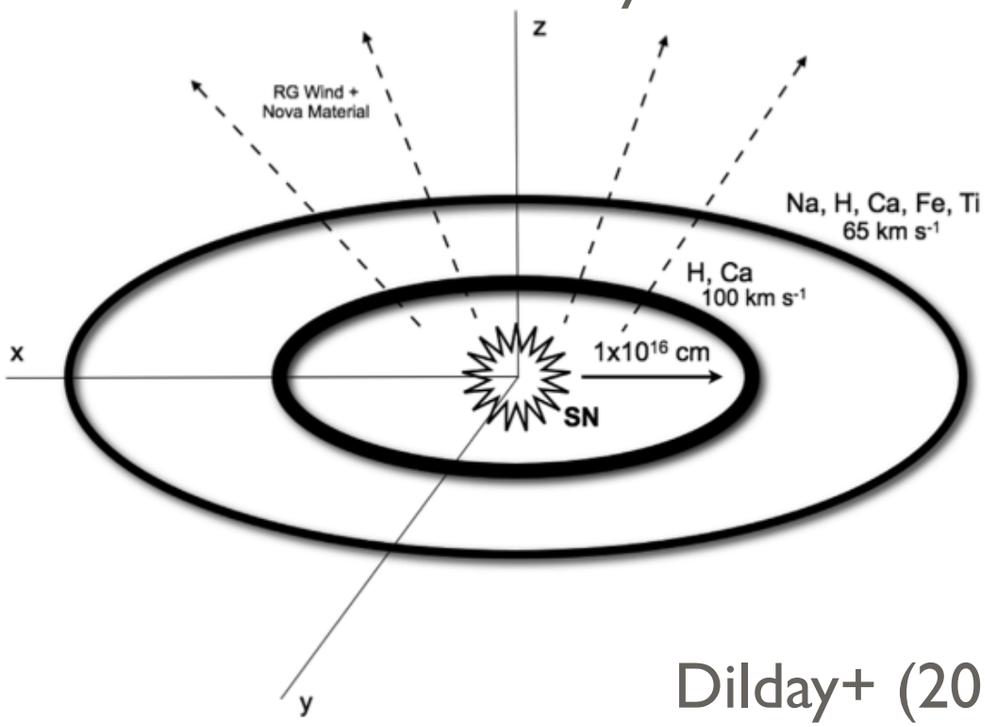
Extreme SNe Ia with CSM

- 'Diluted' SN Ia spectrum with narrow H lines - 'Ia-CSM'
- PTF11kx - interaction between SN ejecta and CSM



Dilday+ (2012)

Recurrent nova system?



Dilday+ (2012)

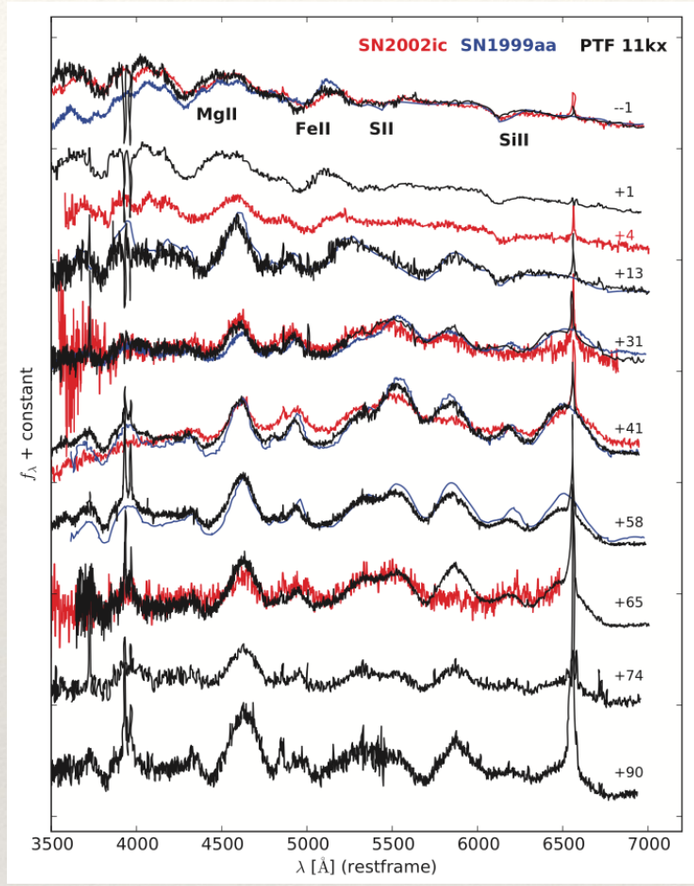
Signatures of circumstellar material

Examples **CSM signatures**

Ia-CSM

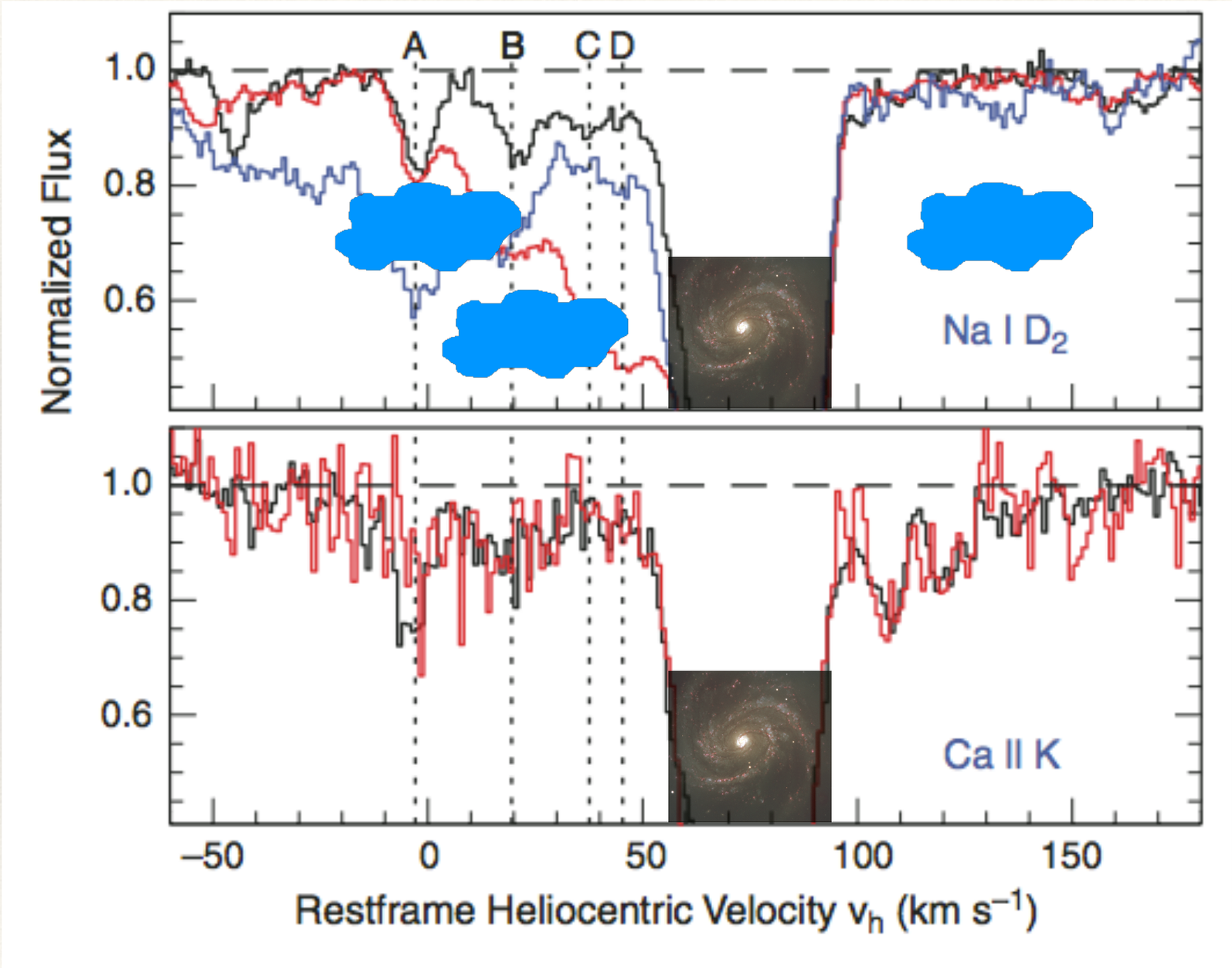
Narrow emission lines

Strength of CSM signatures



Dilday+ (2012)

SN 2006X: Time-varying Na I D



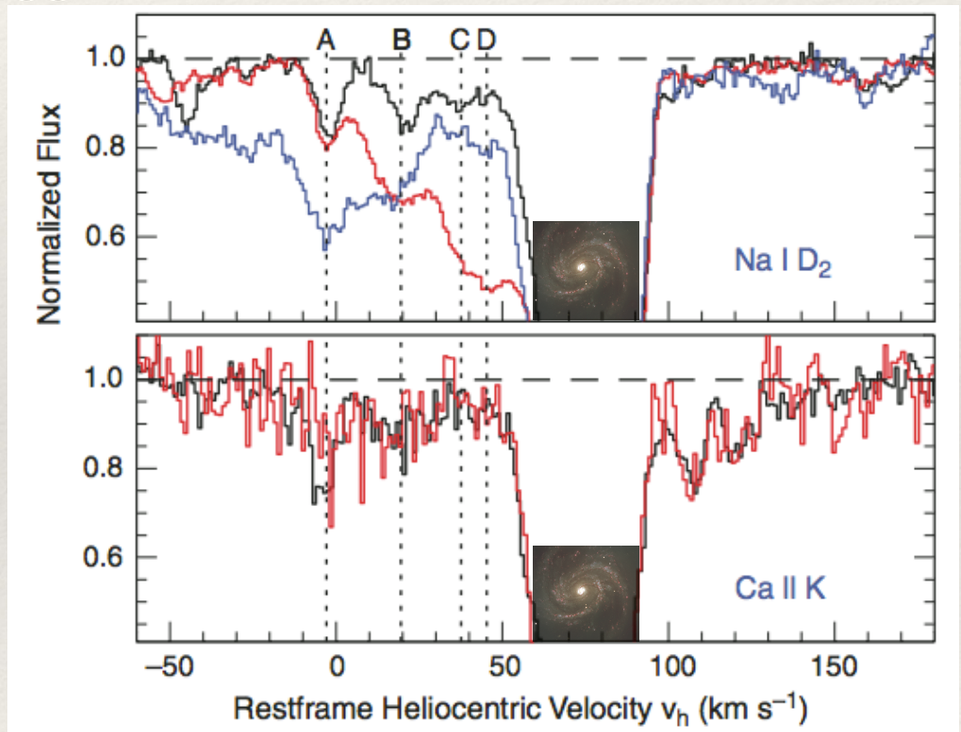
- Induced by variable SN radiation - varying features
- 10^{16} - 10^{17} cm
- Seen in ~20% SNe Ia (Sternberg+ 2014)

SN 2006X, Patat+ (2007)

Signatures of circumstellar material

Strength of CSM signatures

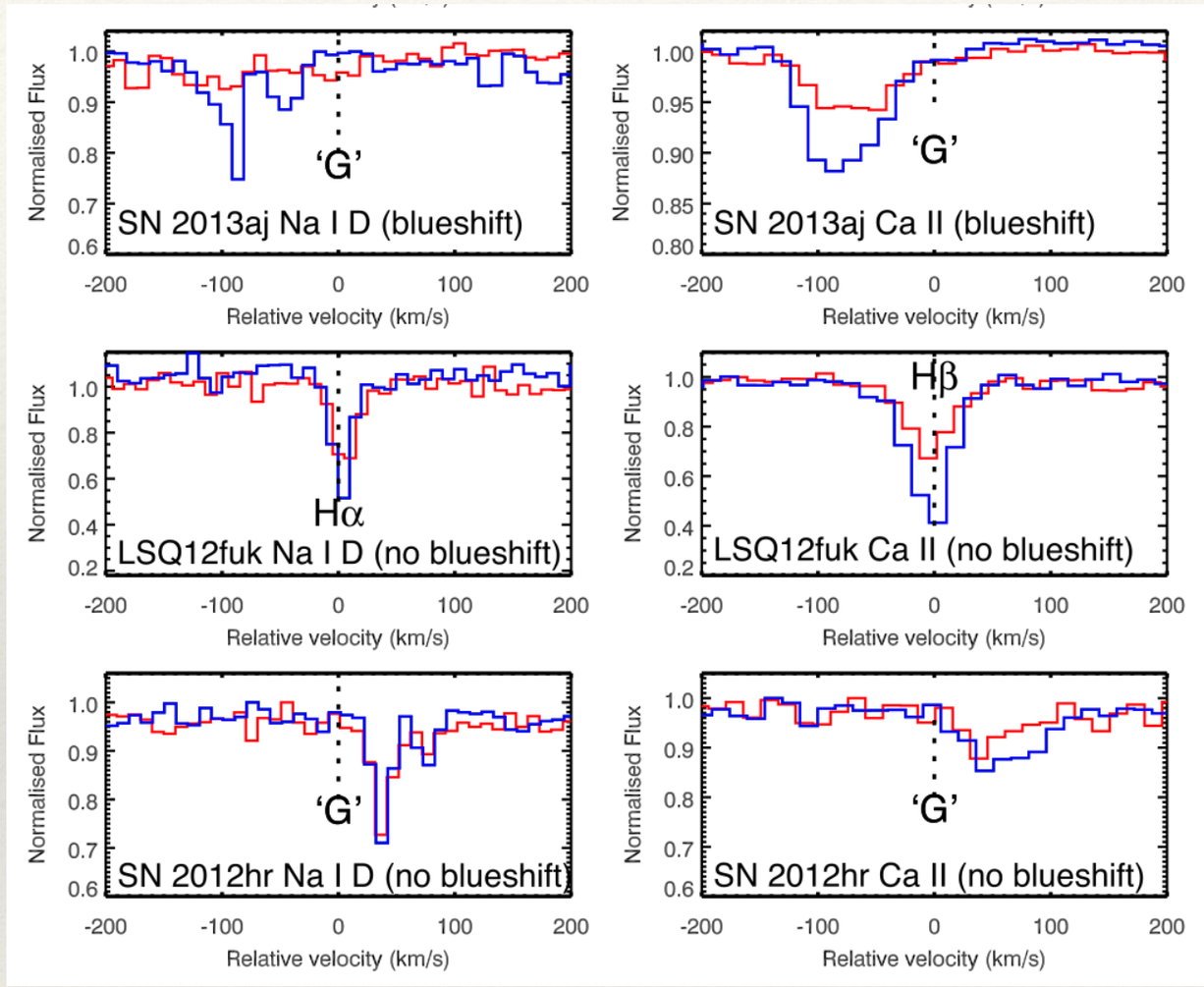
Examples	**CSM signatures**
Ia-CSM	**Narrow emission lines**
SN 2006X, ~20% of SNe Ia	**Variable Na I D**



SN 2006X, Patat+ (2007)

Excess of blueshifted Na I D features

- Multi-epoch high-resolution observations are expensive
- Material further out - no interaction expected
- If only galaxy absorption, expect redshifted = blueshifted Na I D features



Maguire+ (2013)

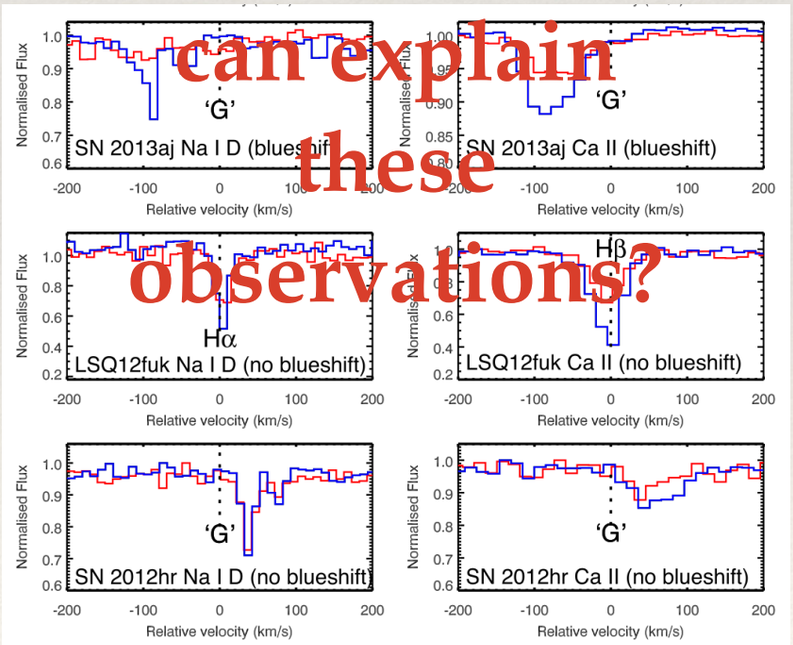
~20% of SNe Ia show signs of circumstellar material (Sternberg+ 2011, Maguire+ 2013)

Signatures of circumstellar material

Strength of CSM signatures

Examples	CSM signatures
Ia-CSM	Narrow emission lines
SN 2006X, ~20% of SNe Ia	Variable Na I D
~20% of SNe Ia	Excess of blueshifted Na I D
~80% of SNe Ia	No blueshifted Na I D

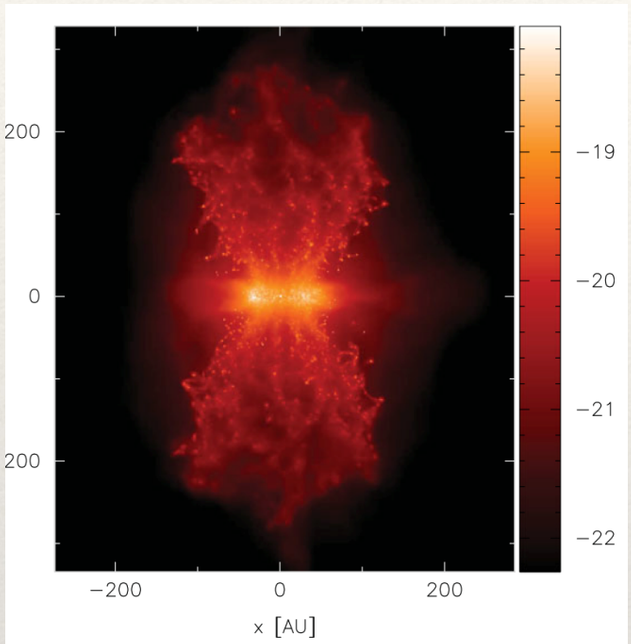
What explosion mechanisms can explain these observations?



Maguire+ (2013)

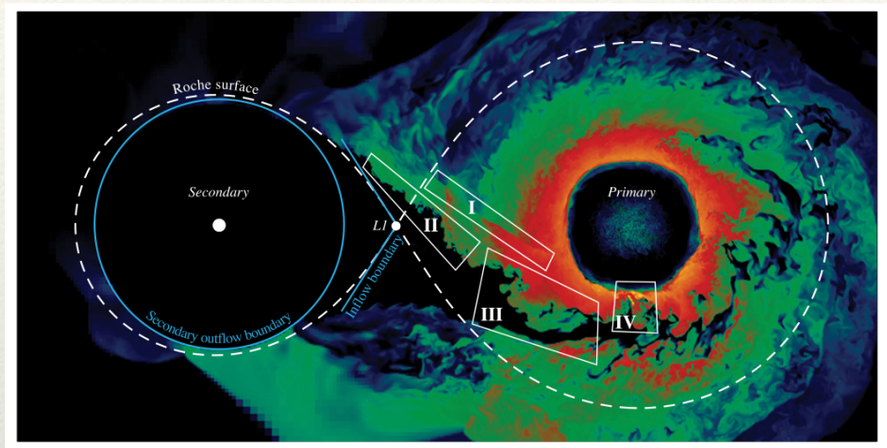
Na I D + explosion mechanisms

Recurrent novae?



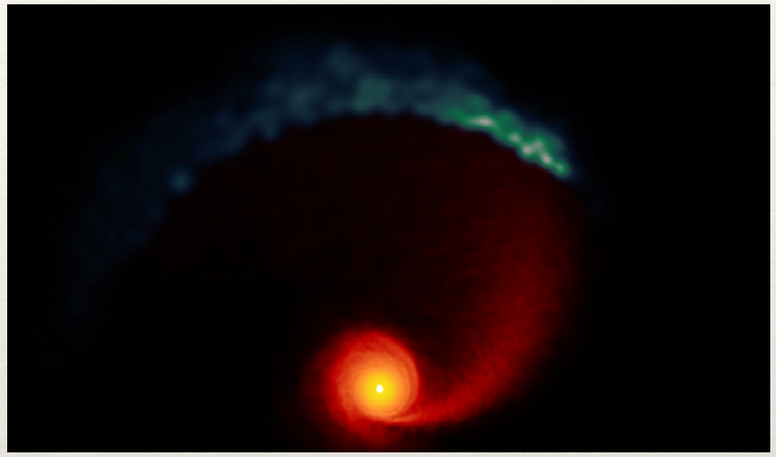
Mohamed+ (2010), Patat+ (2011)

Double-detonations?



Guillochon+ (2013), Shen+ (2013)

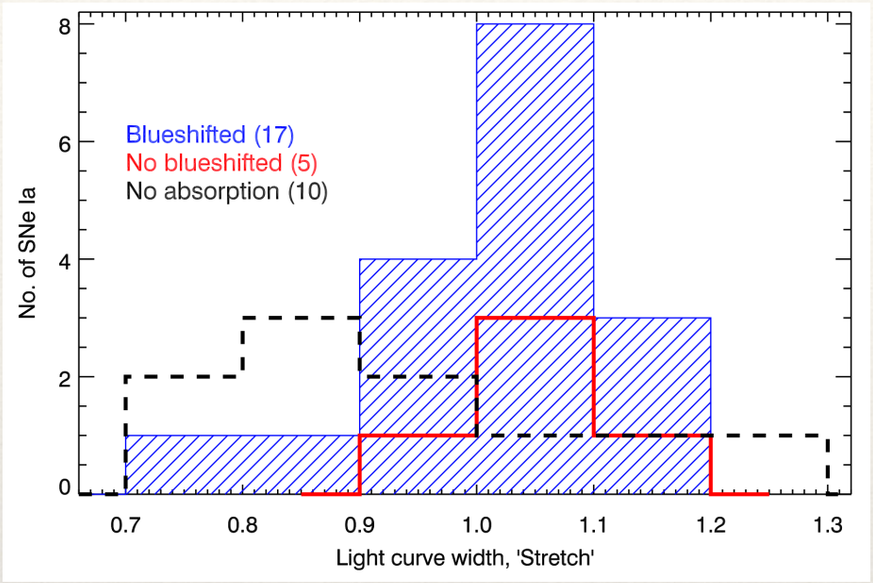
WD mergers?

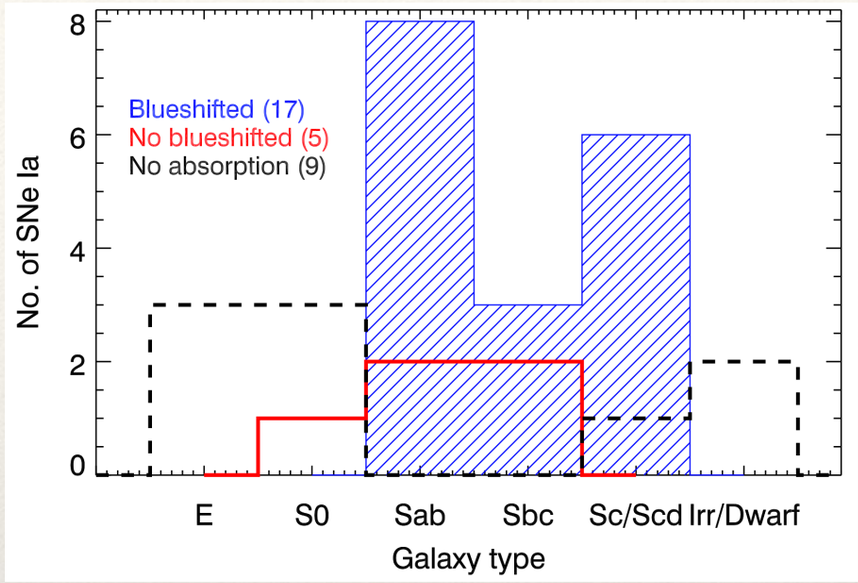


Raskin & Kasen (2013)

- Many progenitor scenarios can produced blueshifted Na I D
- Time-varying Na I D more difficult to explain
- Connection to host galaxy and SN properties?

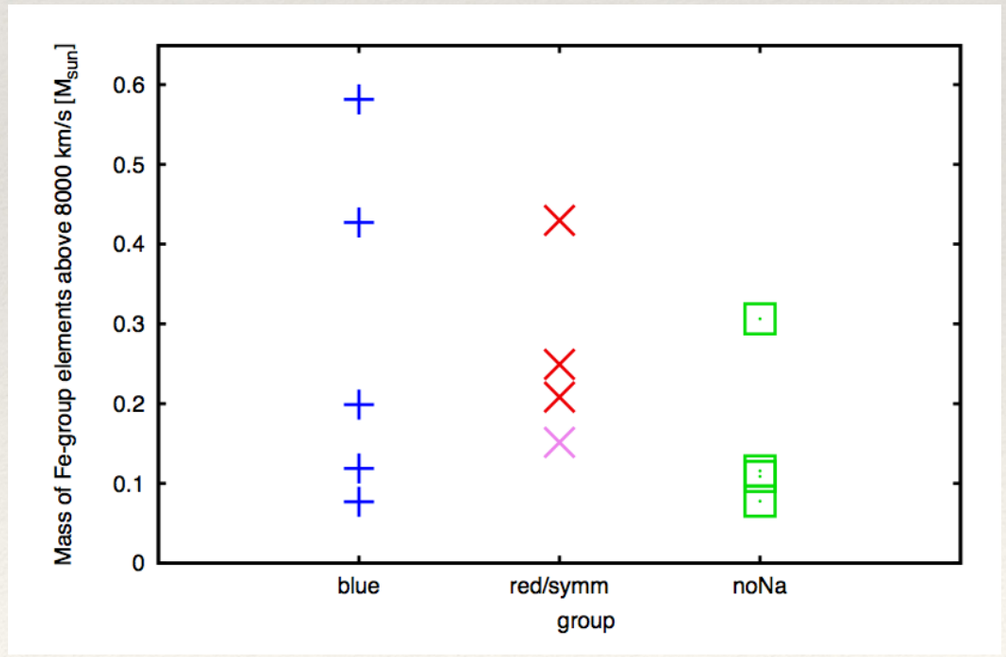
Na I D + (some) SN observables





Maguire+ (2013)

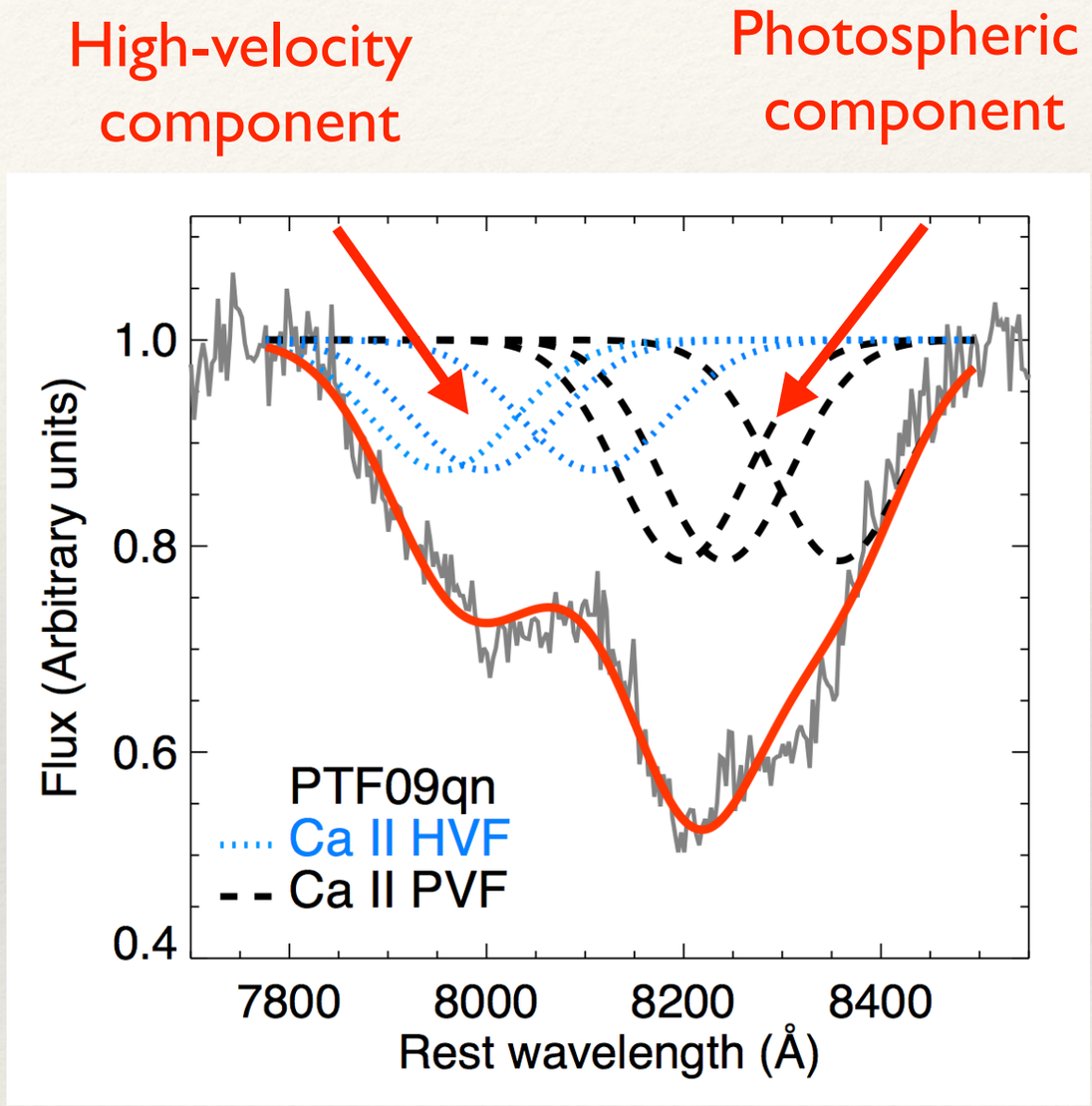
- More common in luminous SNe Ia
- More common in SNe Ia in late-type galaxies
- Abundance tomography - connection between Ni mass and Na I D?



Hachinger+ (in prep.)

High-velocity Ca II features

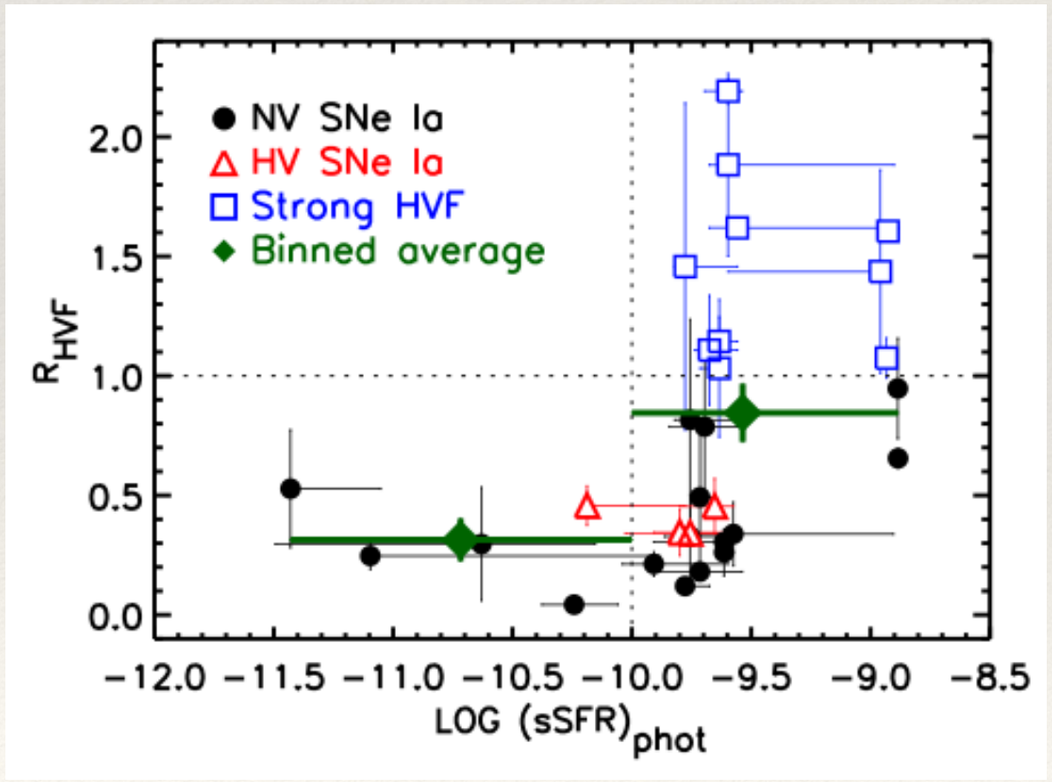
- Ca II HV features in >80-90% SNe Ia (Childress+ 2014, Maguire+ 2014, Silverman+ 2015)
- High-velocity features due to CSM or intrinsic to the SN?
- Different polarisation for high-velocity feature (Wang+ 2003)



Maguire+ (2014)

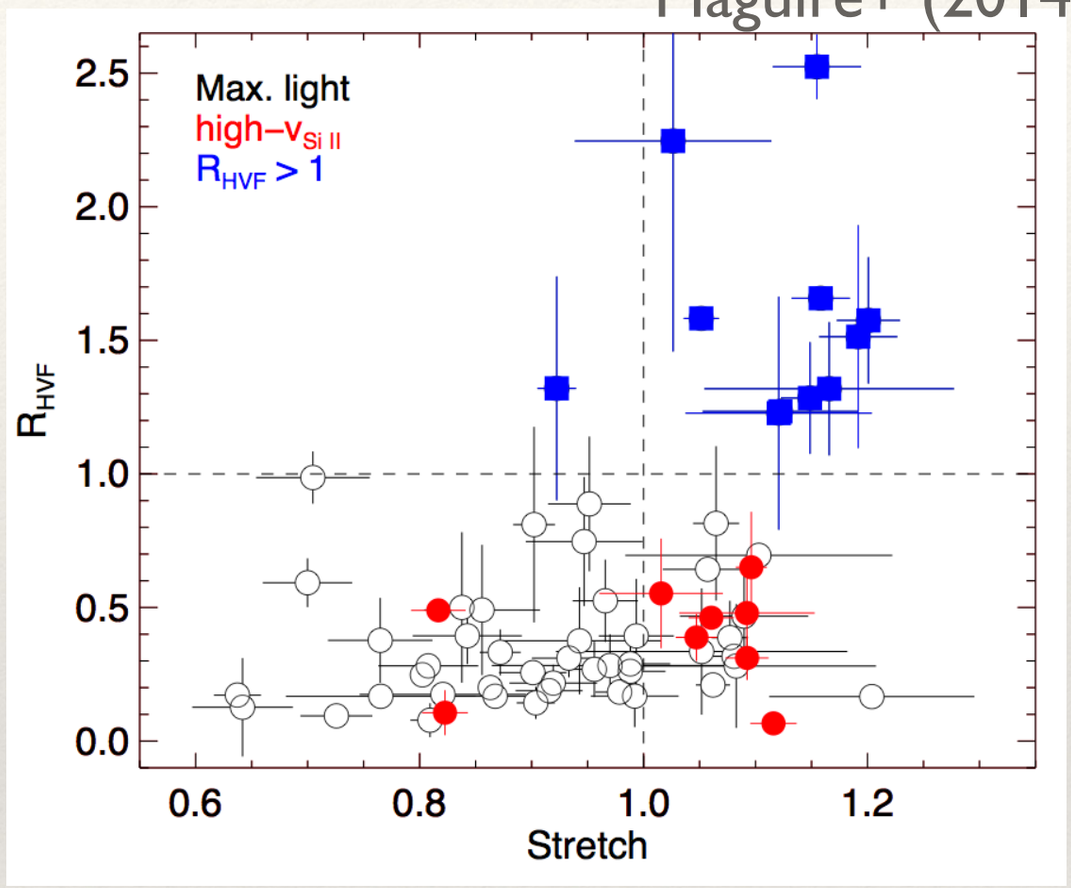
High-velocity Ca II features

- SNe Ia with stronger Ca II high-velocity features have broader light curves (Childress + 2013, Maguire+ 2014)



Pan+ (2014)

Maguire+ (2014)



Luminosity —>

- Found in strongly star-forming galaxies - younger population? (Pan+ 2014)

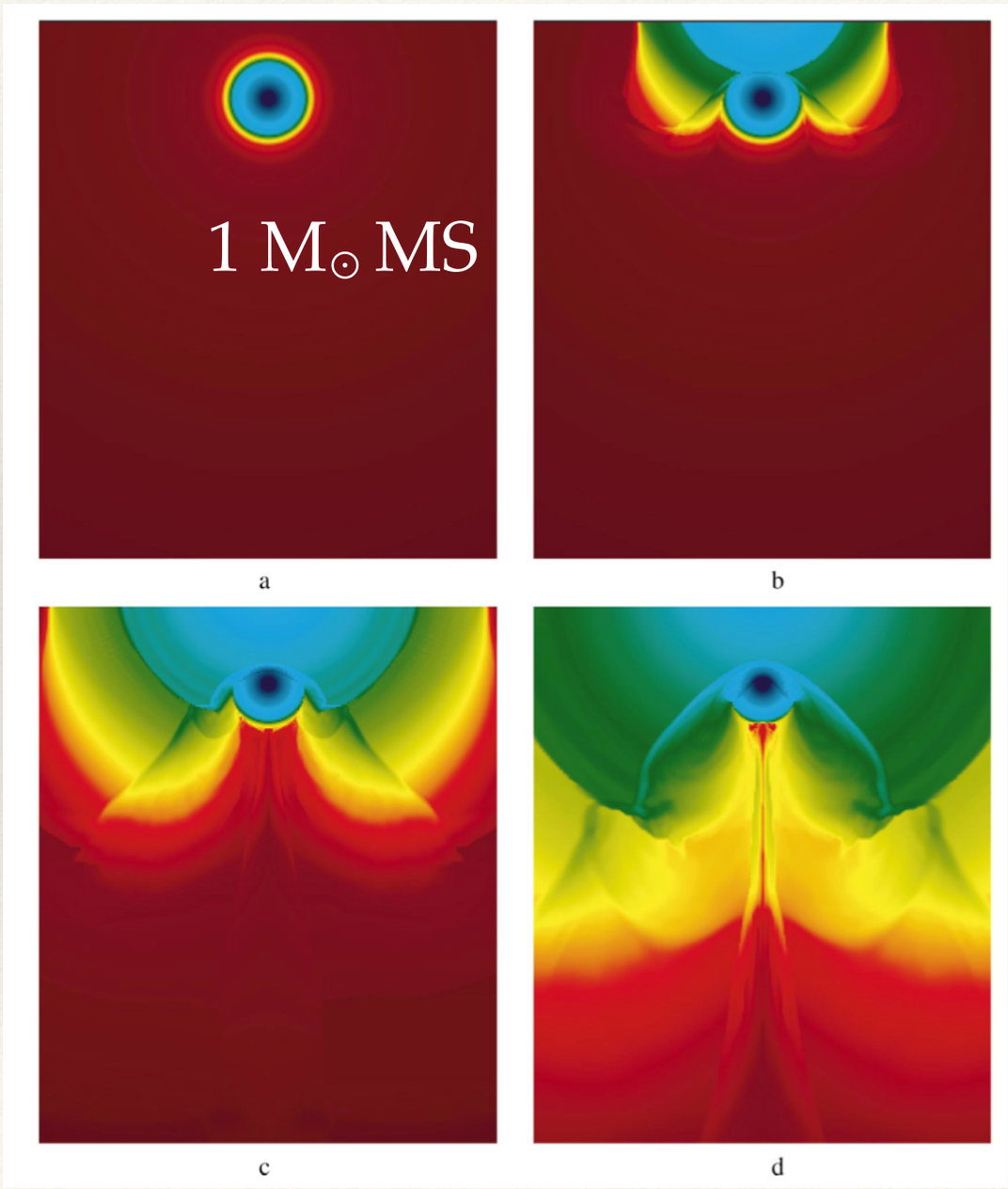
CSM + observables

- CSM features are more common in more luminous SNe Ia
- CSM features - more common in SNe Ia in late-type galaxies
  - Younger population?
  - Need ISM for interaction?
- Connection to high-velocity Ca II features
- What explosion models can explain high-velocity features?

Are there other spectral features that
can distinguish progenitor scenarios?

2. Searching for swept-up material in late-time spectra

Searching for companion material



Marietta+ (2000)

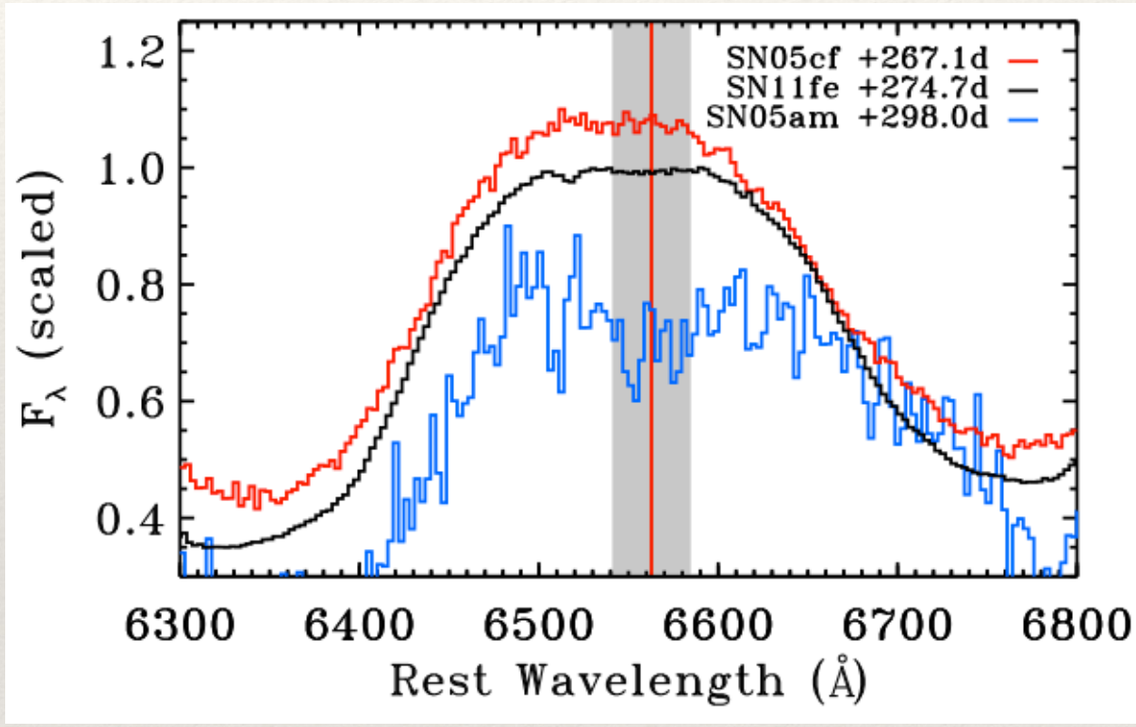
- Stripping of material from companion (first: Wheeler+ 1975)
- Low velocity emission features (< 1000 km/s)
- Stripped masses of 0.05-0.3 $M_\odot$ (Pan+ 2010,2012; Liu+ 2013)
- WD+He < WD+MS < WD+RG

Little mass lost

Nearly all envelope mass lost

Previous searches for Hydrogen

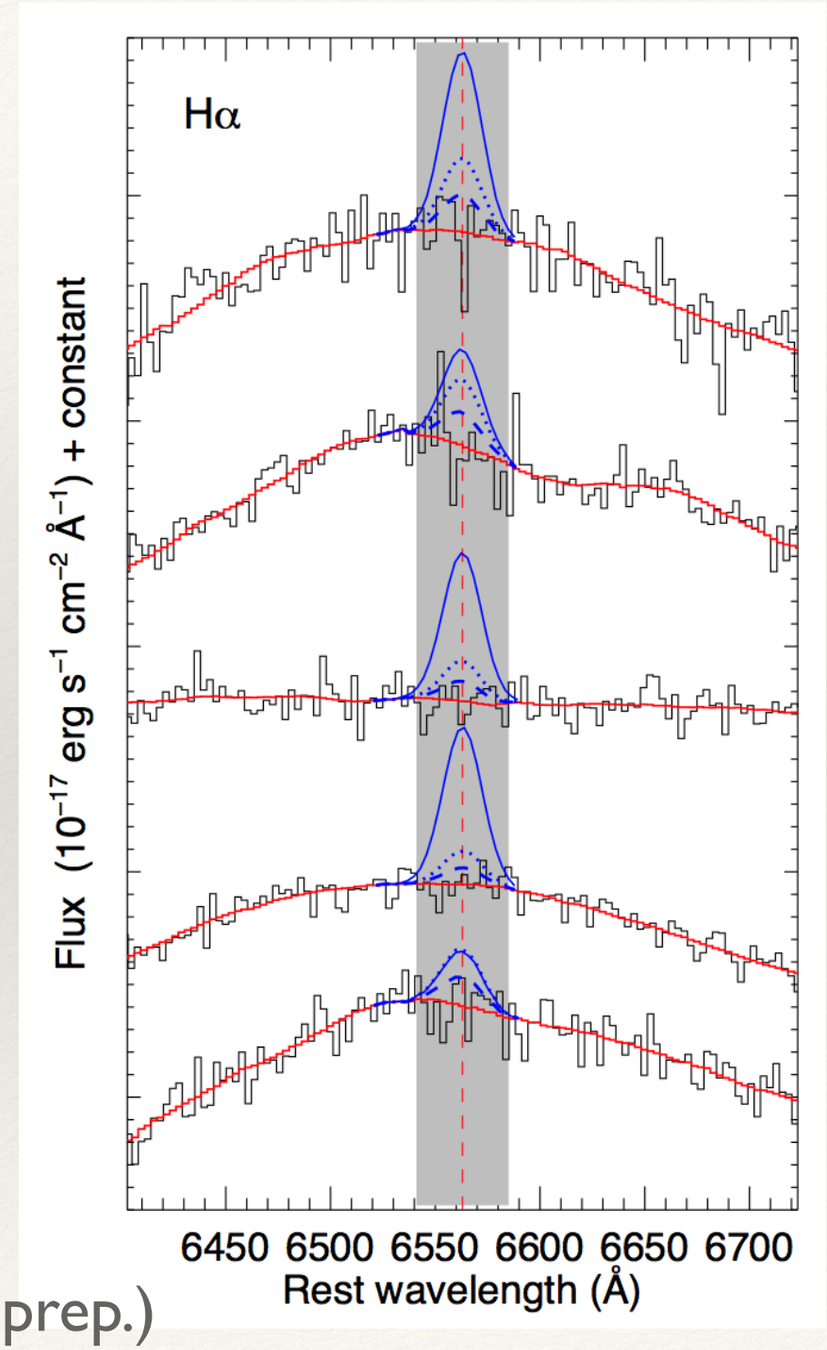
- Intermediate resolution - features are ~1000 km/s wide
- No detections for 7 normal SNe Ia (Mattila+ 2005, Leonard 2007, Shappee+ 2012, Lundqvist+ 2013)
- Using Mattila+ (2005) models rule out MS and RG via RLOF and stellar wind accretion



Shappee+ (2012)

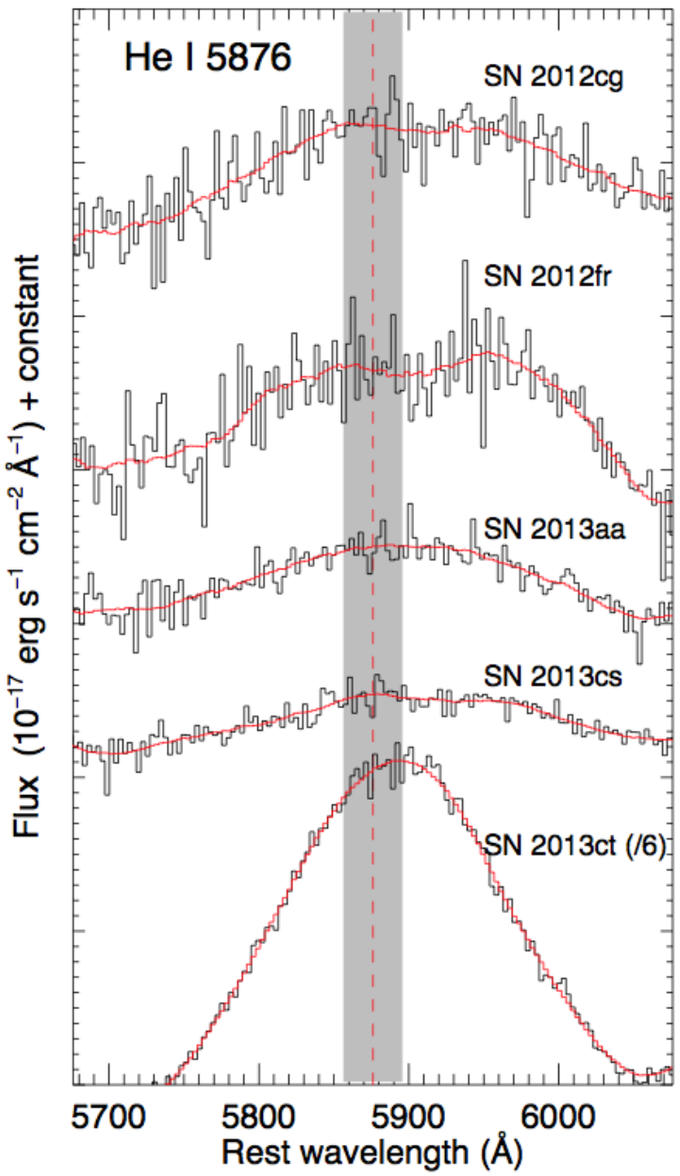
New late-time spectral sample

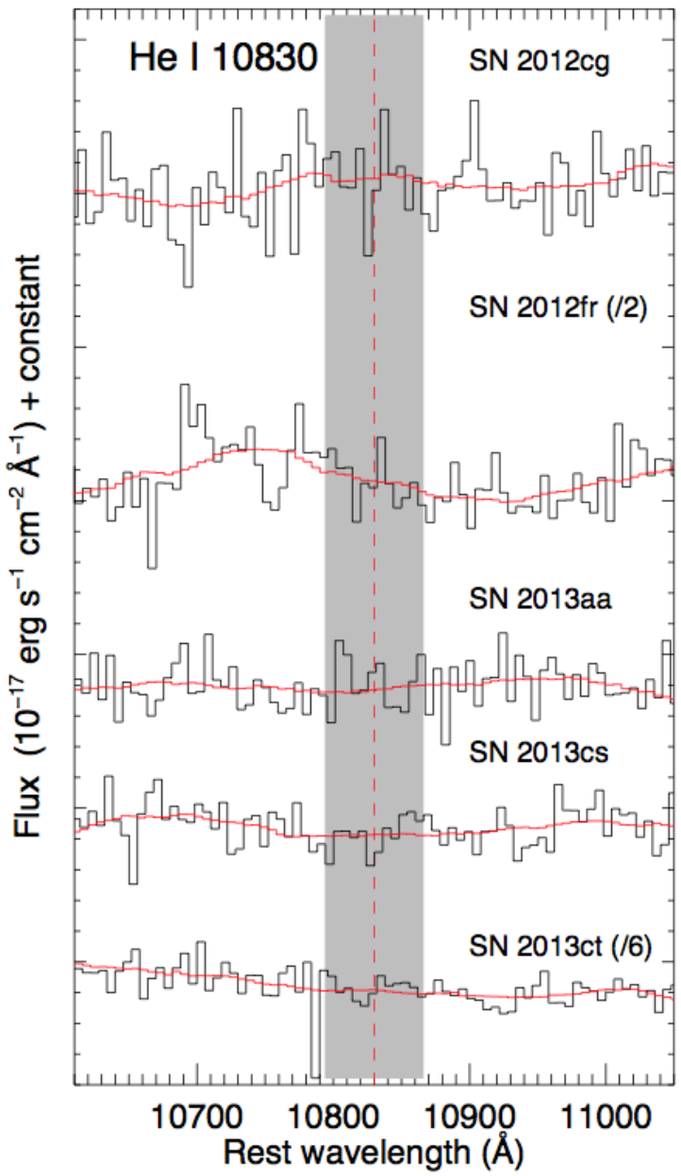
- 11 SN Ia spectra at >200 d
- XSH: R ~ 9000, FORS2: R ~ 800
- No detection of H in **10** SNe Ia
- Mass limits < 0.001-0.06 $M_\odot$ material
- SD systems in RLOF are ruled out
- Tentative detection in one SN Ia!

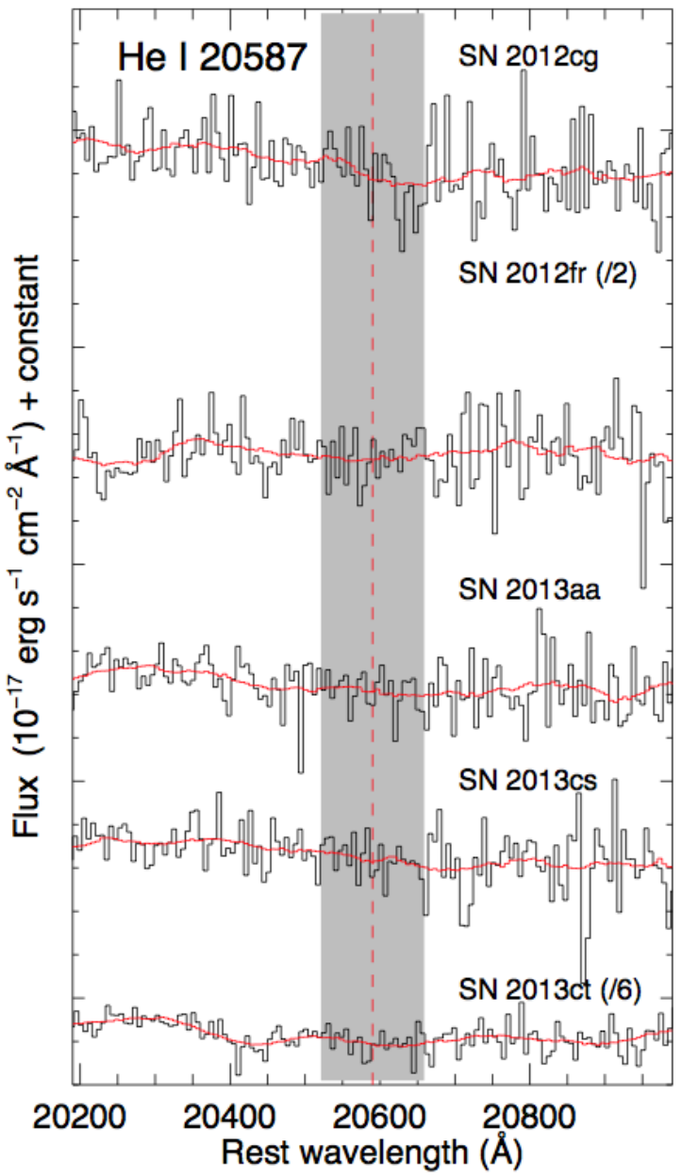


Maguire+ (in prep.)

No He I emission detected







Summary and Questions

- Variations in CSM strength - continuum?
- 20% of SNe Ia show signs of CSM
- Associated with more luminous SNe Ia
- Detection of H in one SN Ia at late times
- **IF** there are two (or more) progenitor channels, what are the relative rates?
- Can someone make new late-time H emission predictions?