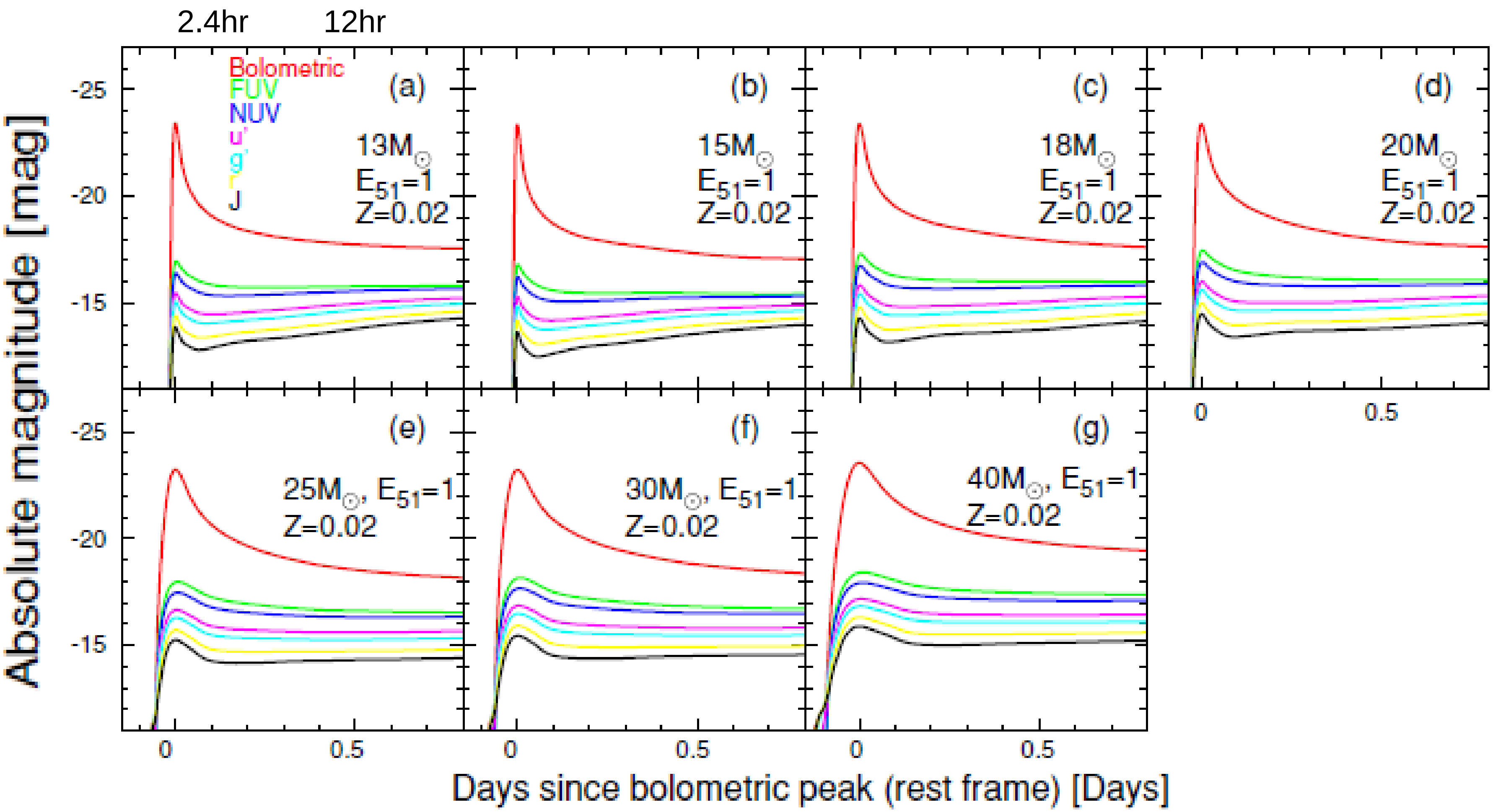
Early observations of supernovae

Major science goals

1. Shock breakouts of CCSNe (and SNe Ia)
2. Fraction of SNe with dense CSM
3. CSM surrounding AT2018cow-like objects
4. Early bump in SNe Ia

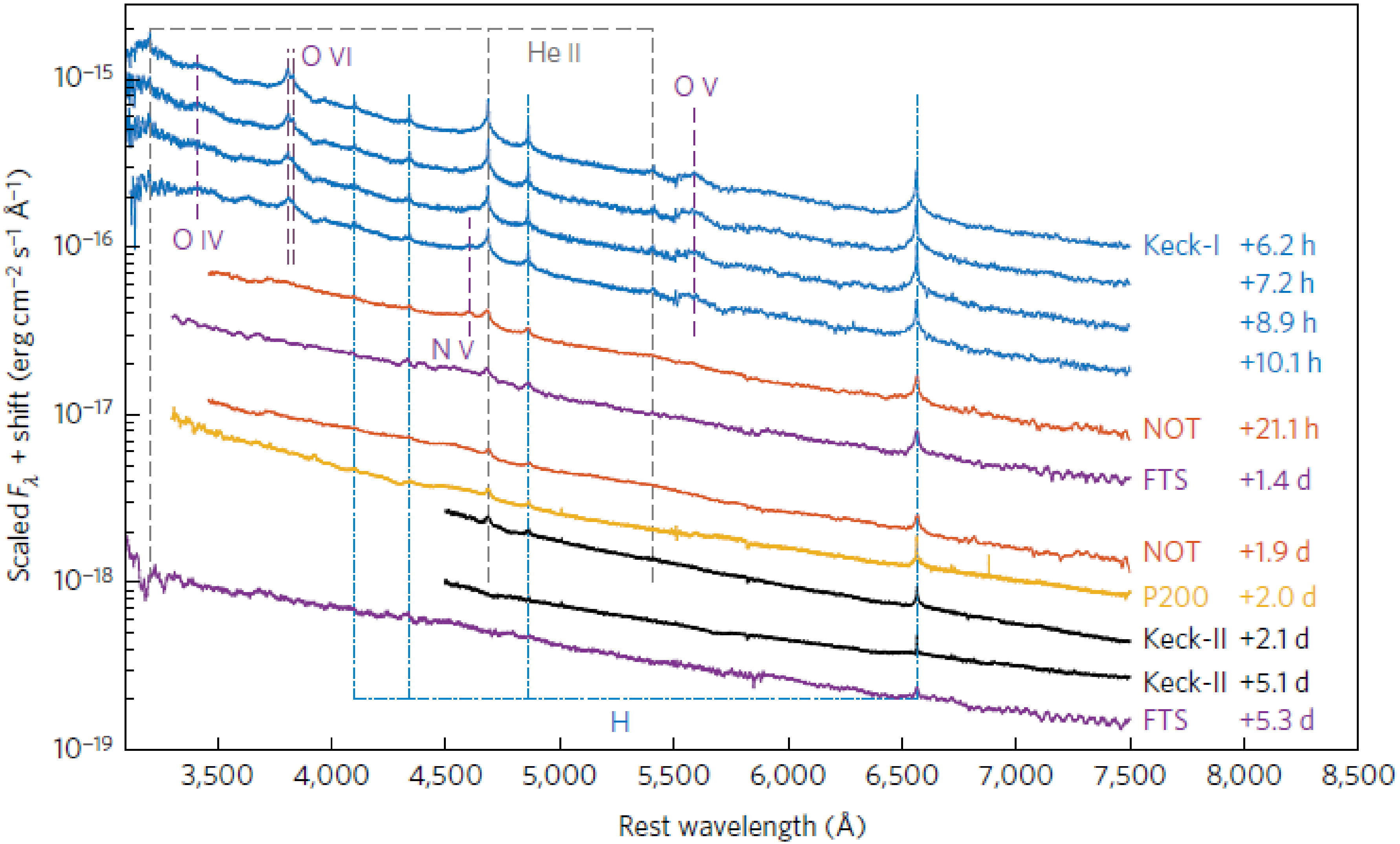
Shock breakout of CCSNe

Shock breakout at stellar surface



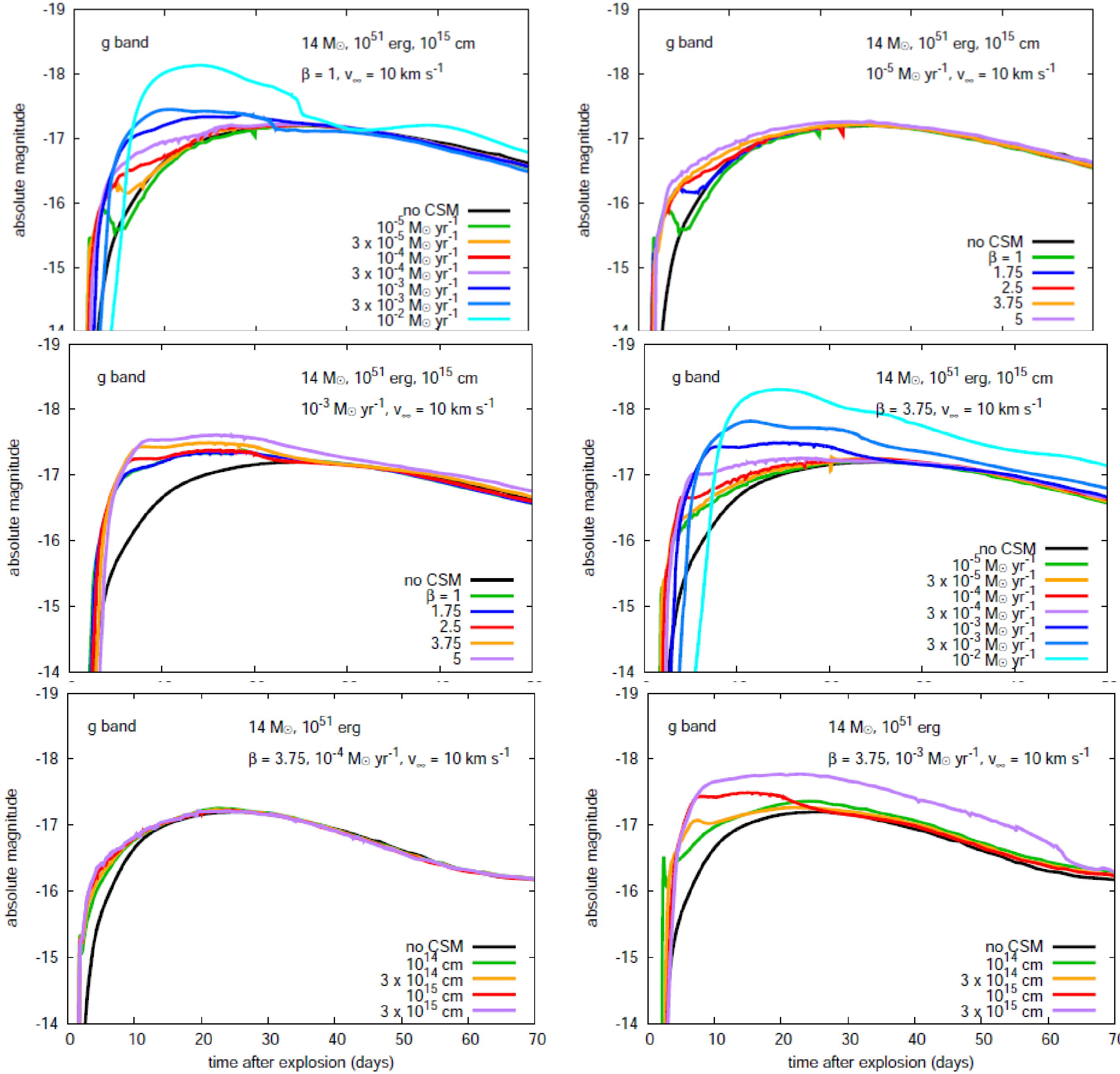
Tominaga + 11

Firm identification of dense CSM



Yaron + 18

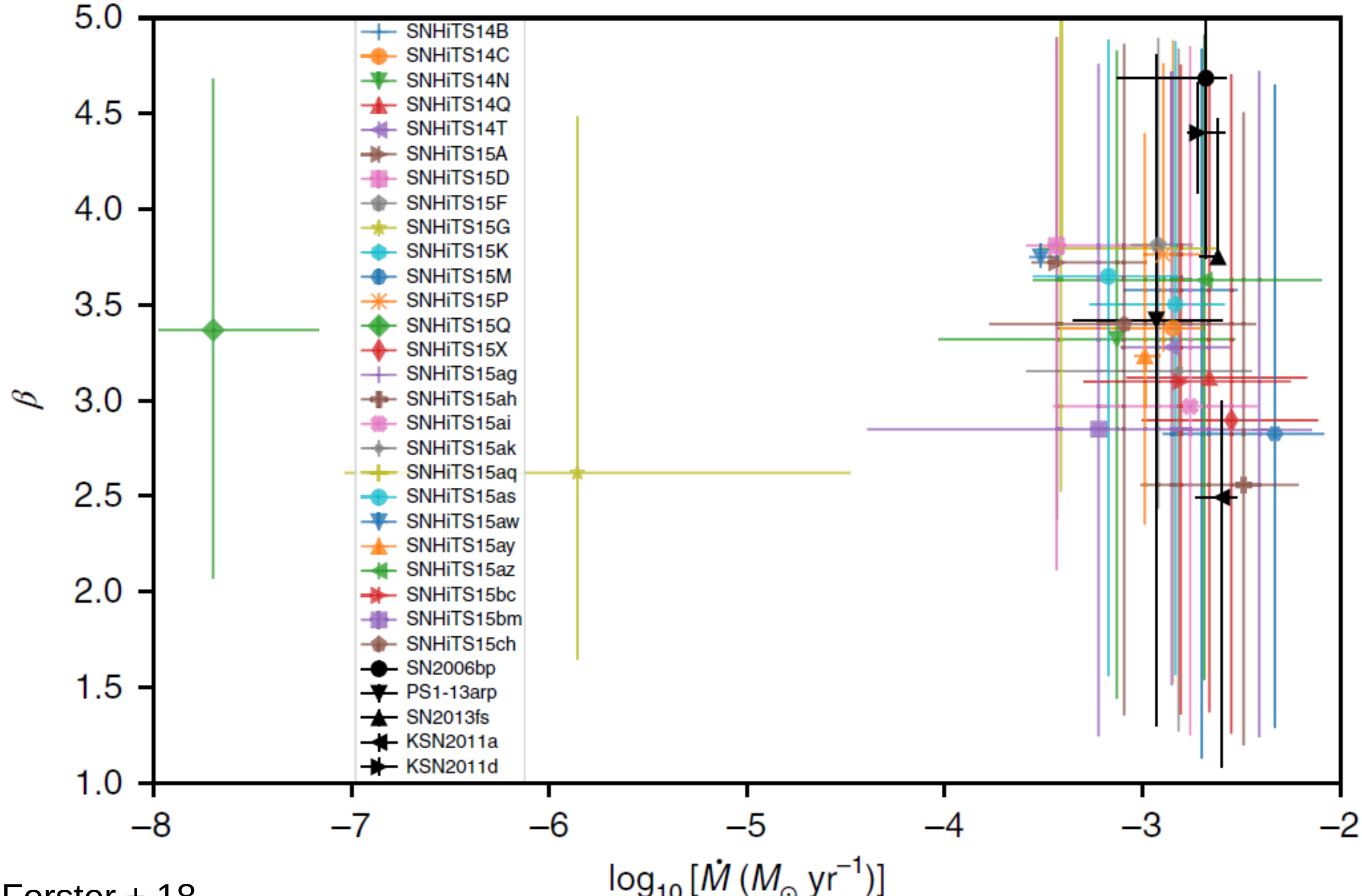
Early LC of SNe IIP with dense CSM



Moriya+18

Fraction of SNe IIP with dense CSM

Fraction of SNe with dense CSM to study the final stage of the stellar evolution



Forster + 18

24 out of 26 SNe IIP have dense CSM.

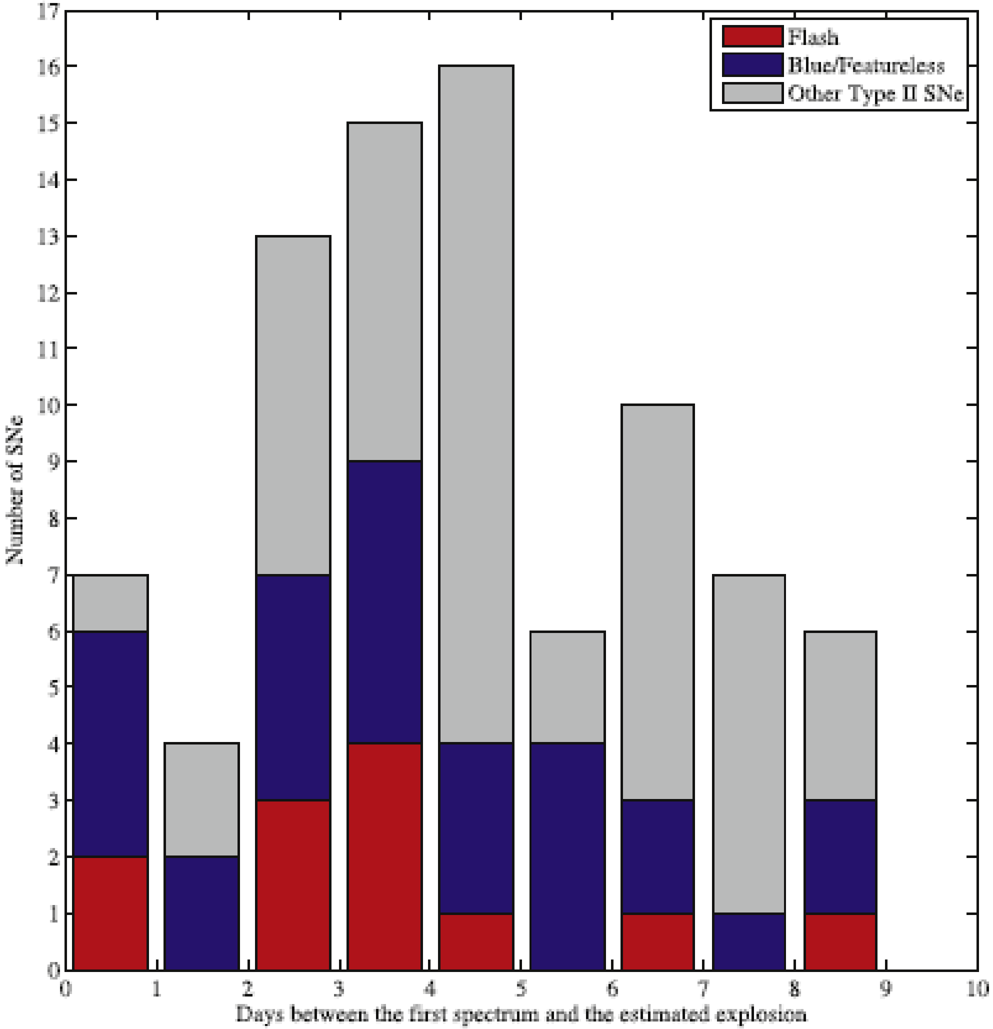
Significant observational bias to high mass loss rate.

The number of SNe are in a proportion of 28 to 72% between the low and large Mdot samples.

How high the intrinsic ratio of large Mdot?

It could be 1:4.5 for the low and large Mdot.

Fraction of SNe IIP with FI spectra

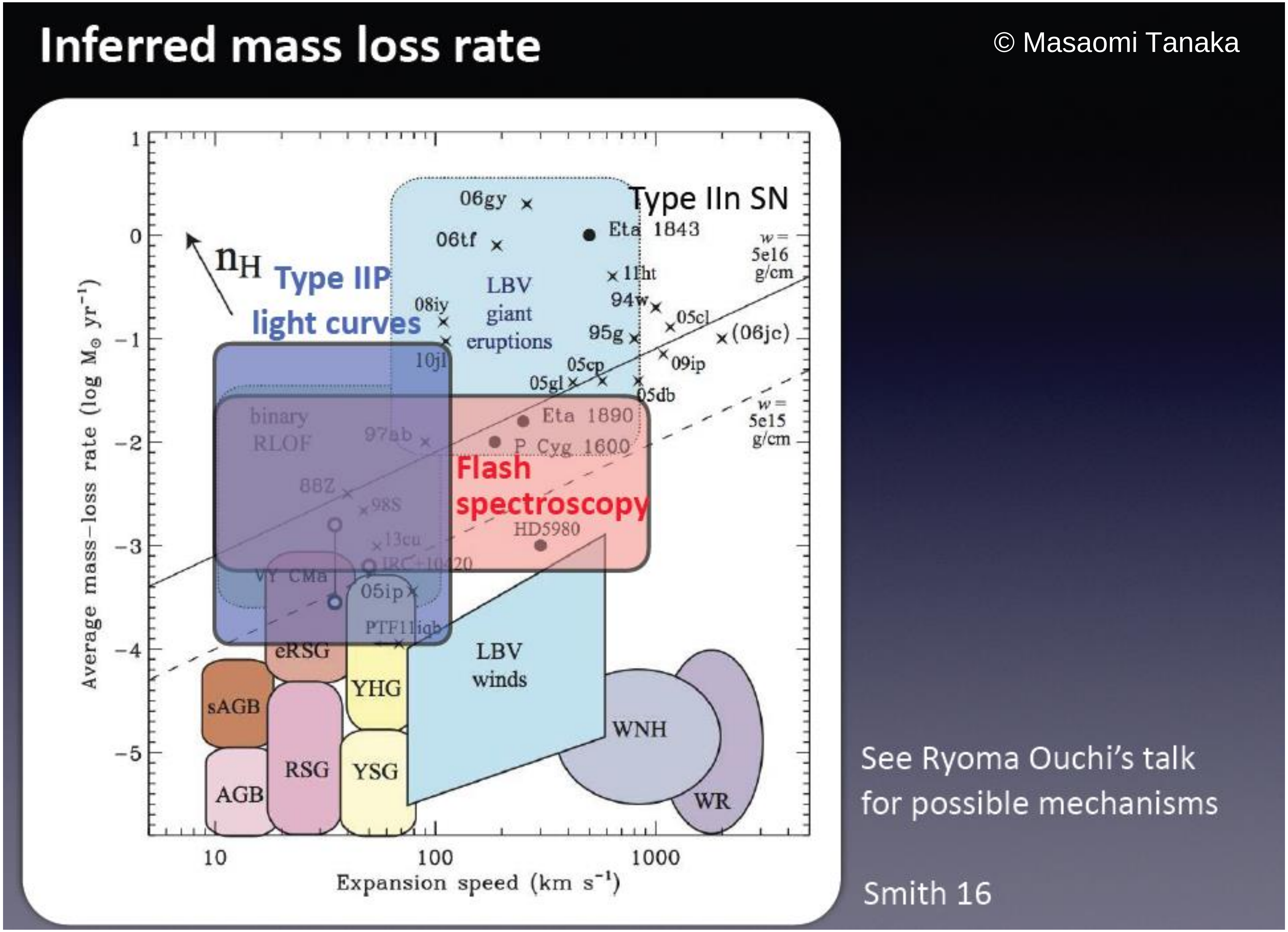


These events constitute 14% of all 84 SNe in our sample having a spectrum within 10 days from explosion, and 18% of SNeII observed at ages <5 days, thereby setting lower limits on the fraction of FI events.

19 out of 21 SNe brighter than an absolute magnitude MR=−18.2 belong to the FI or BF groups, and that all FI events peaked above MR=−17.6 mag, significantly brighter than average SNeII.

Khazov+16

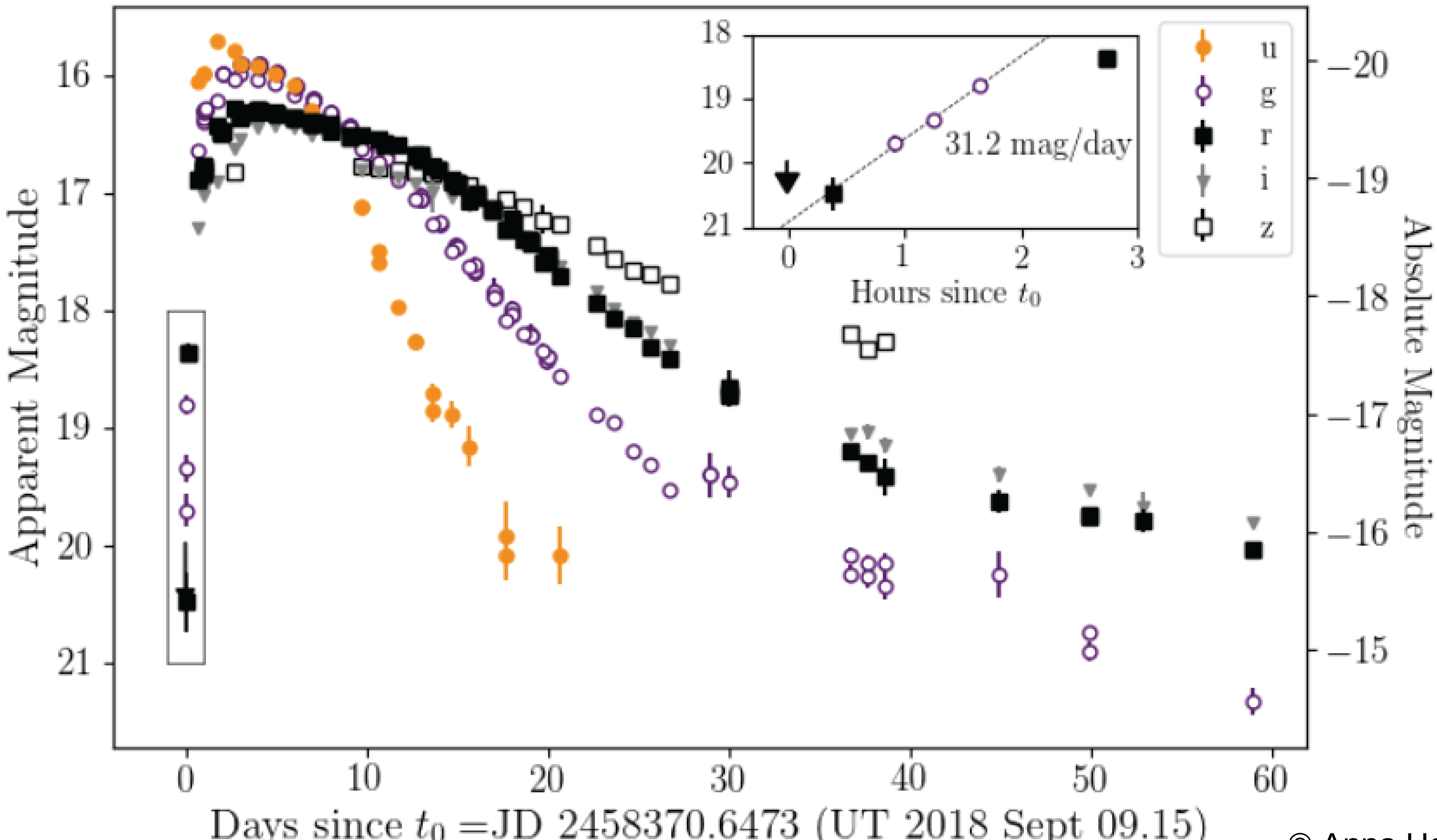
How dense the CSM is?



CSM surrounding AT2018cow-like objects

Early observations of SNe: a rapid rise as a diagnostic of recent mass-loss

ZTF18abukavn (SN 2018gep):
a Ic-BL dominated by shock cooling emission **(Ho et al. in prep)**



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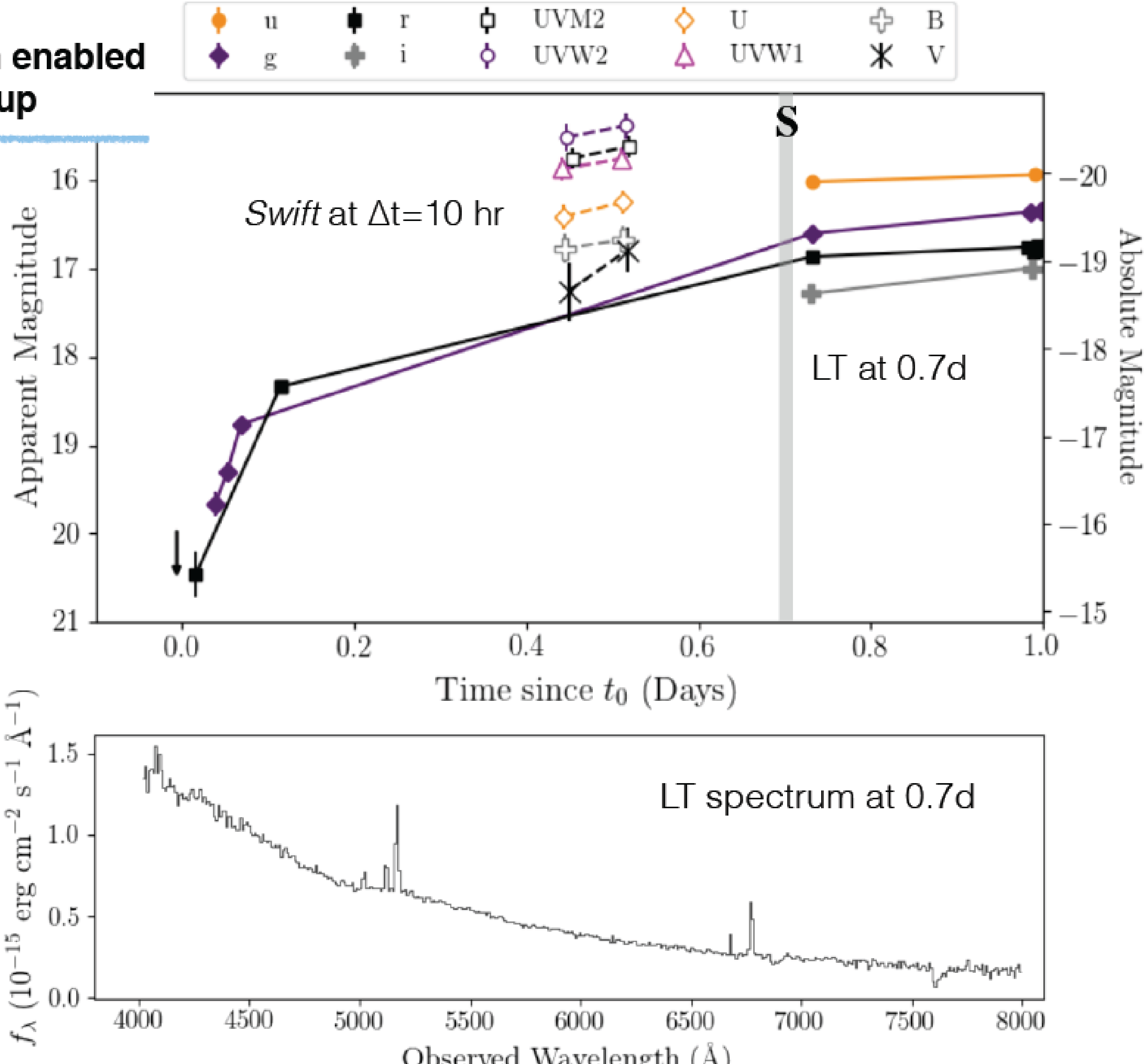
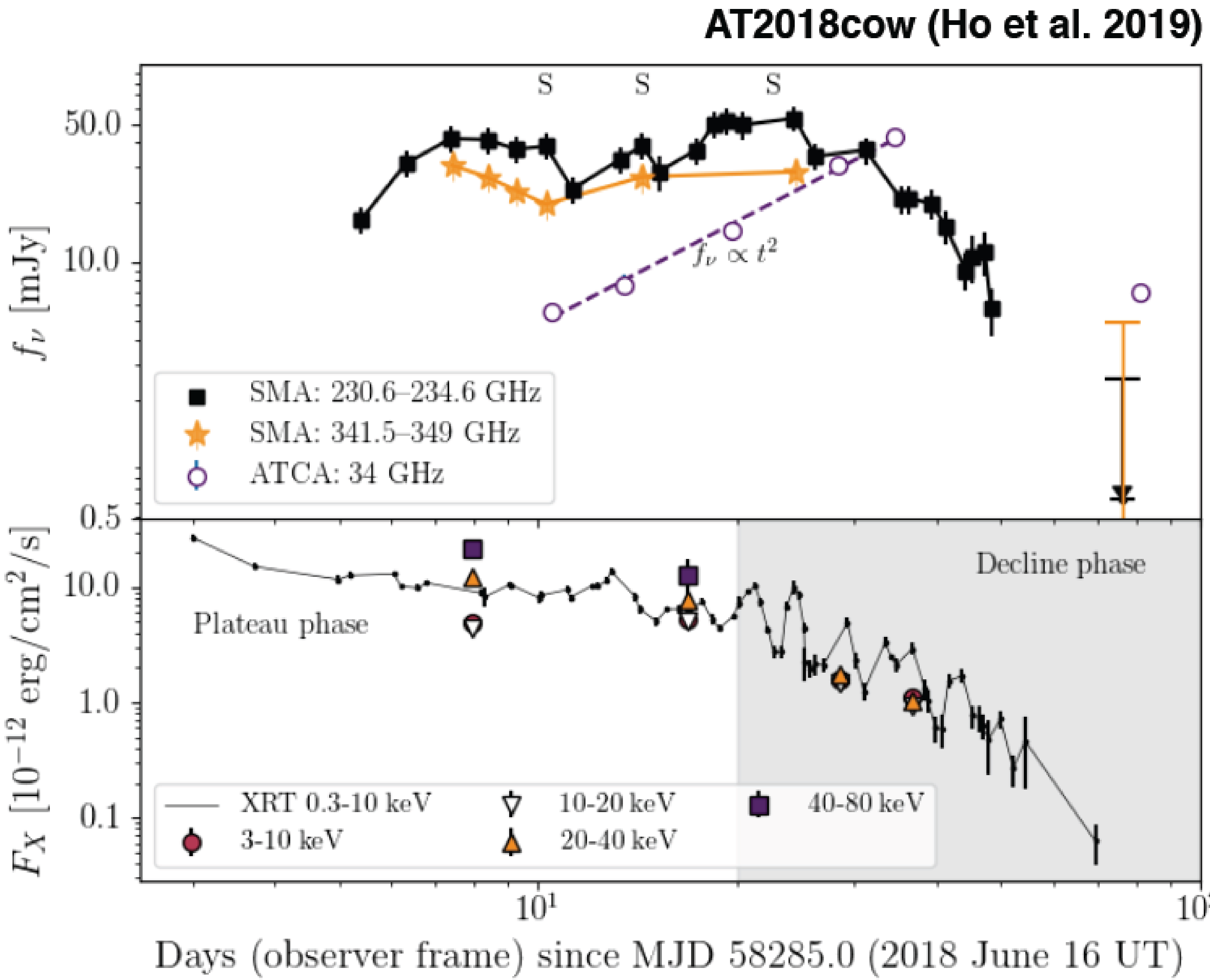
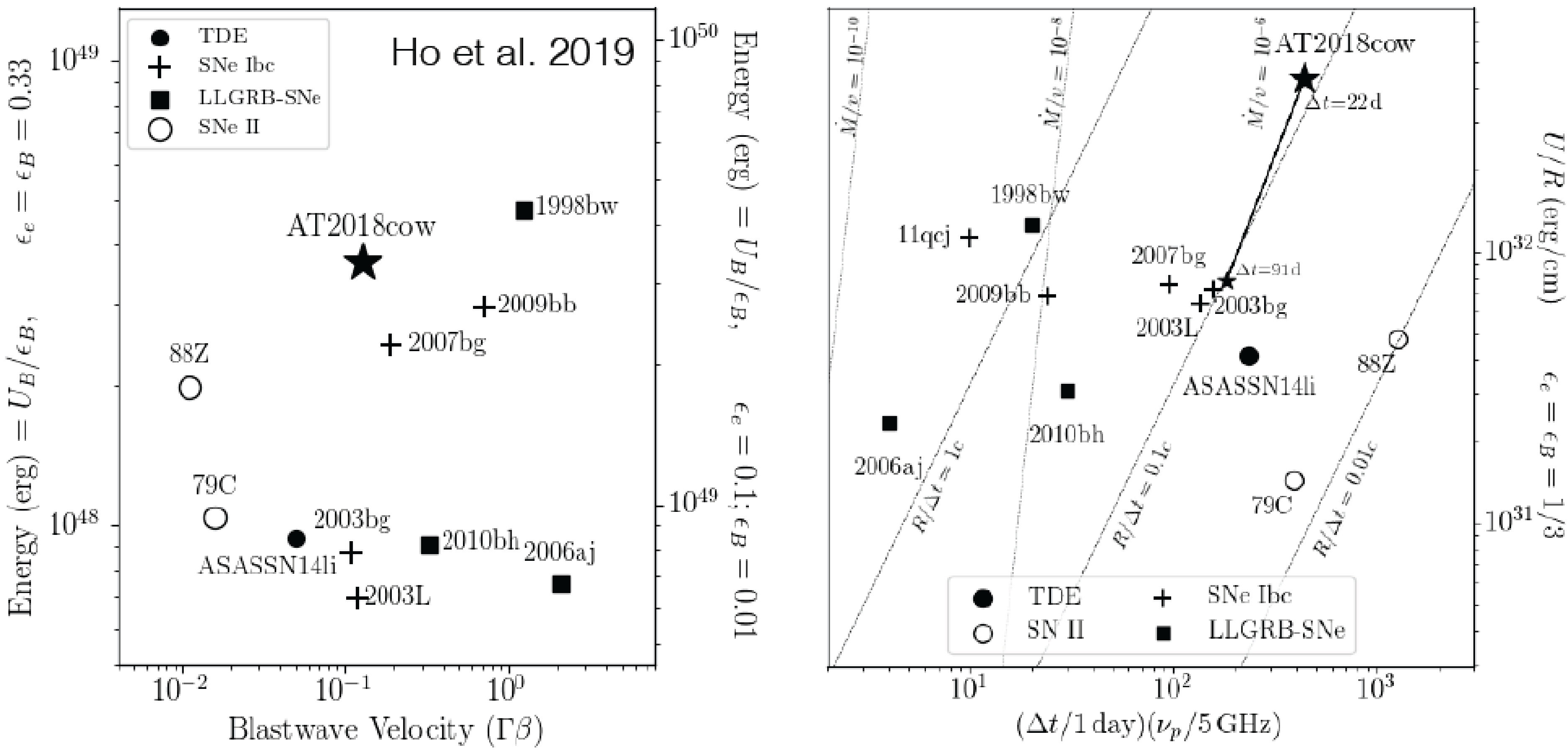
Early detection enabled prompt follow-up



Long-wavelength observations are an essential diagnostic of dense CSM

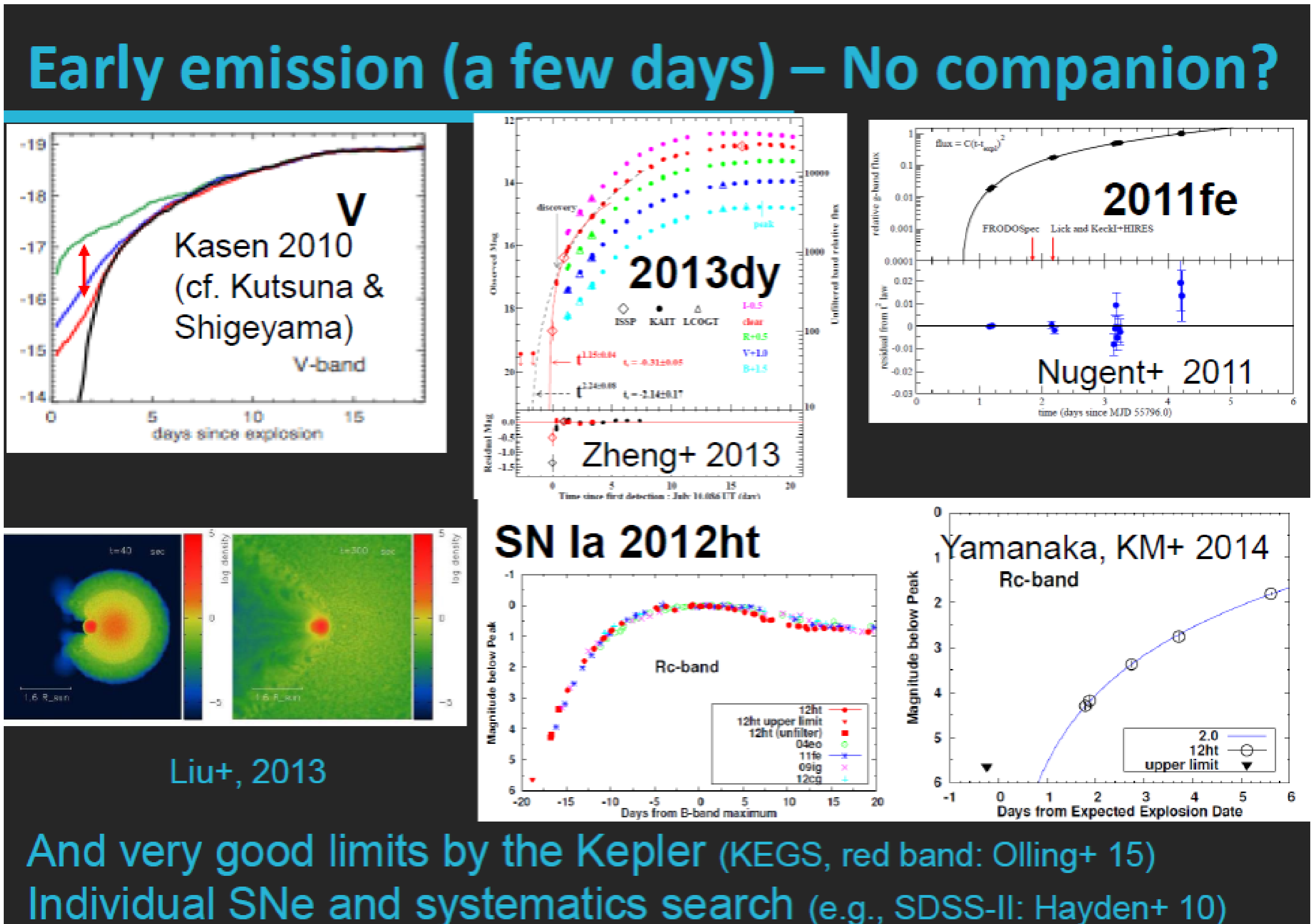


Long-wavelength observations are an essential diagnostic of dense CSM



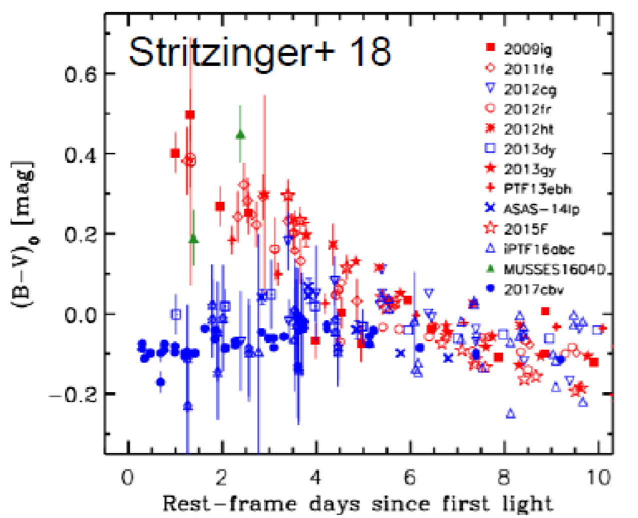
Early bump in SNe Ia

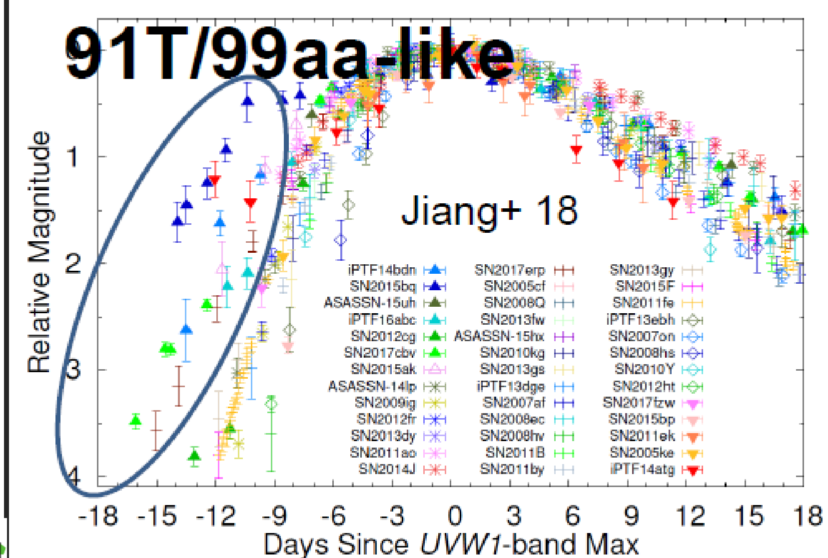
Early bump in SNe Ia to constrain the progenitor system and the explosion mechanism

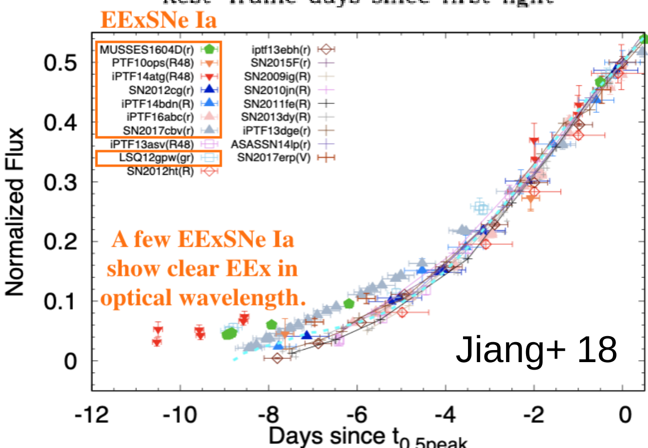


Early flash in SNe Ia

"Early flash" favors a specific sub class



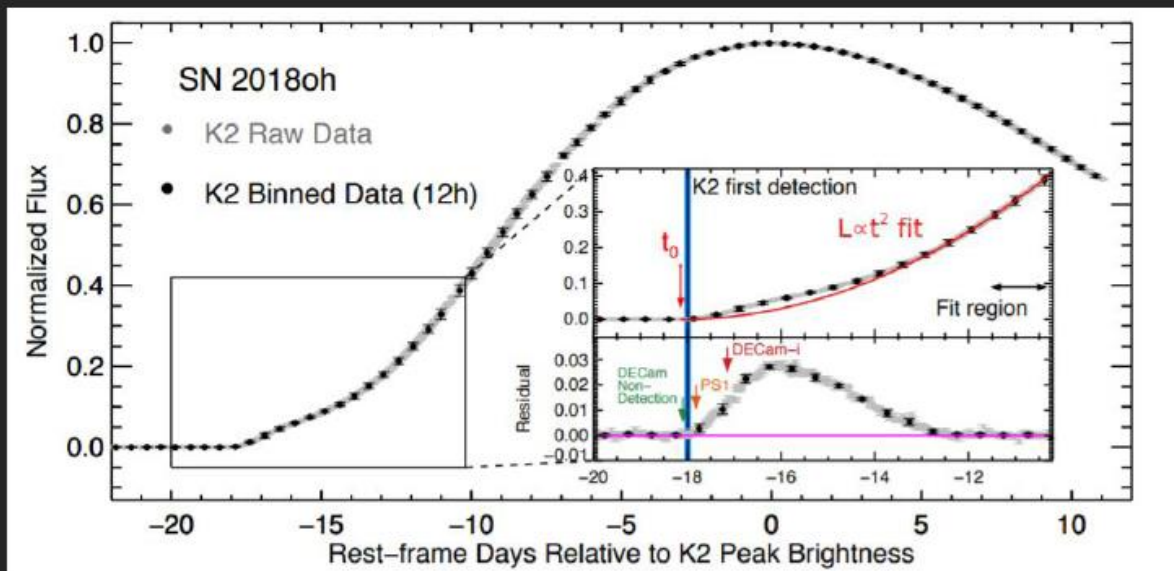




Except for iPTF14atg & MUSSES16D, they are ALL bright 91T/99aa-class.
No normal SNe with the flash.
Nearly all 91T/99a-lie shows the flash, if the early data are there.

Deviation from L∝t2 relation

Recent example: further diversity or not?

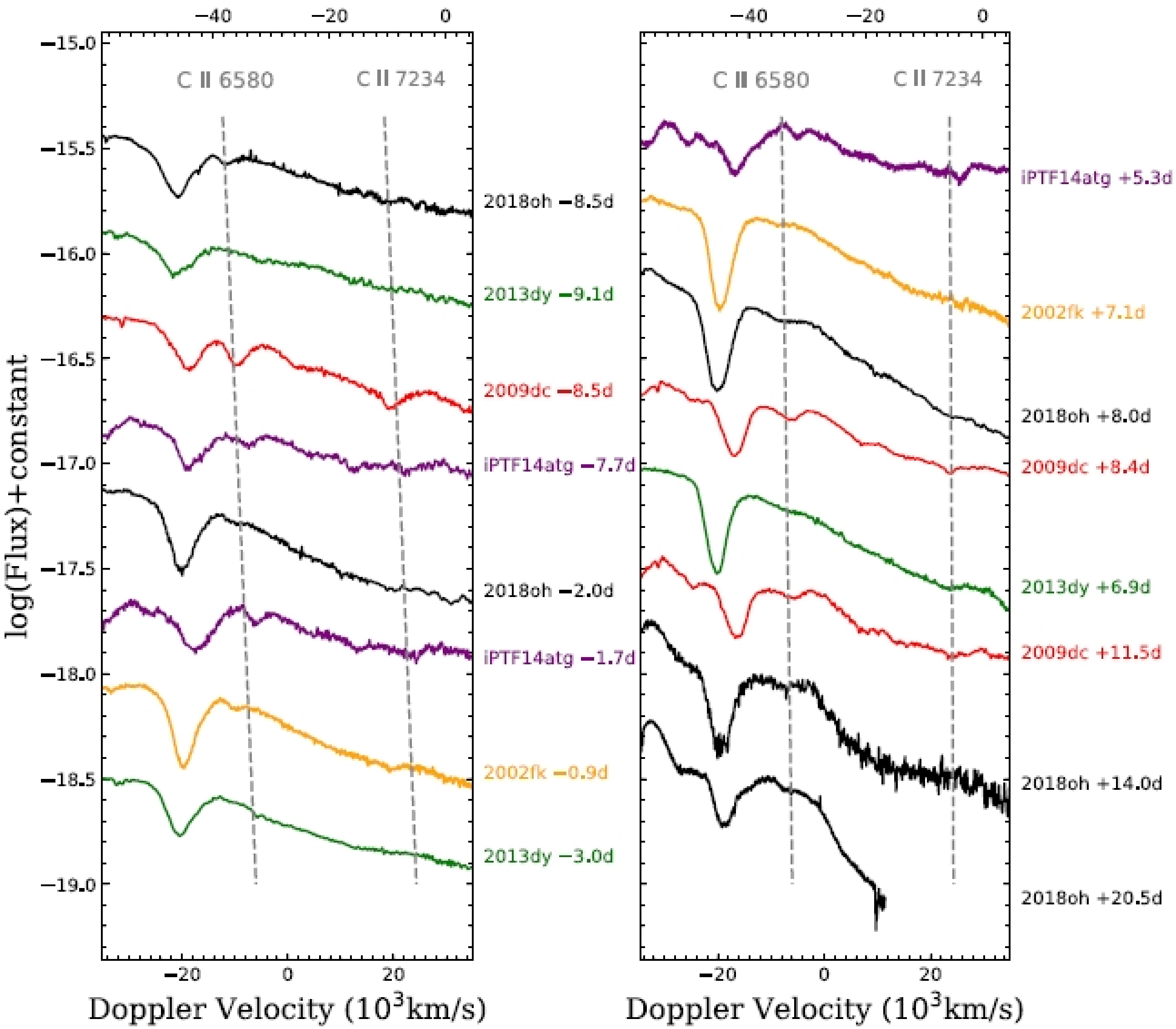


SN 2018oh/ASASSN-18bt w/ the KEPLER light curve.

Clear early excess, double power law? Dimitriadis+ 19a, Shappee+ 19
Spectroscopically ~91T-like or between 91T and normal. Li+ 19
No sign of stripped hydrogen in late phases. Dimitriadis+ 19b

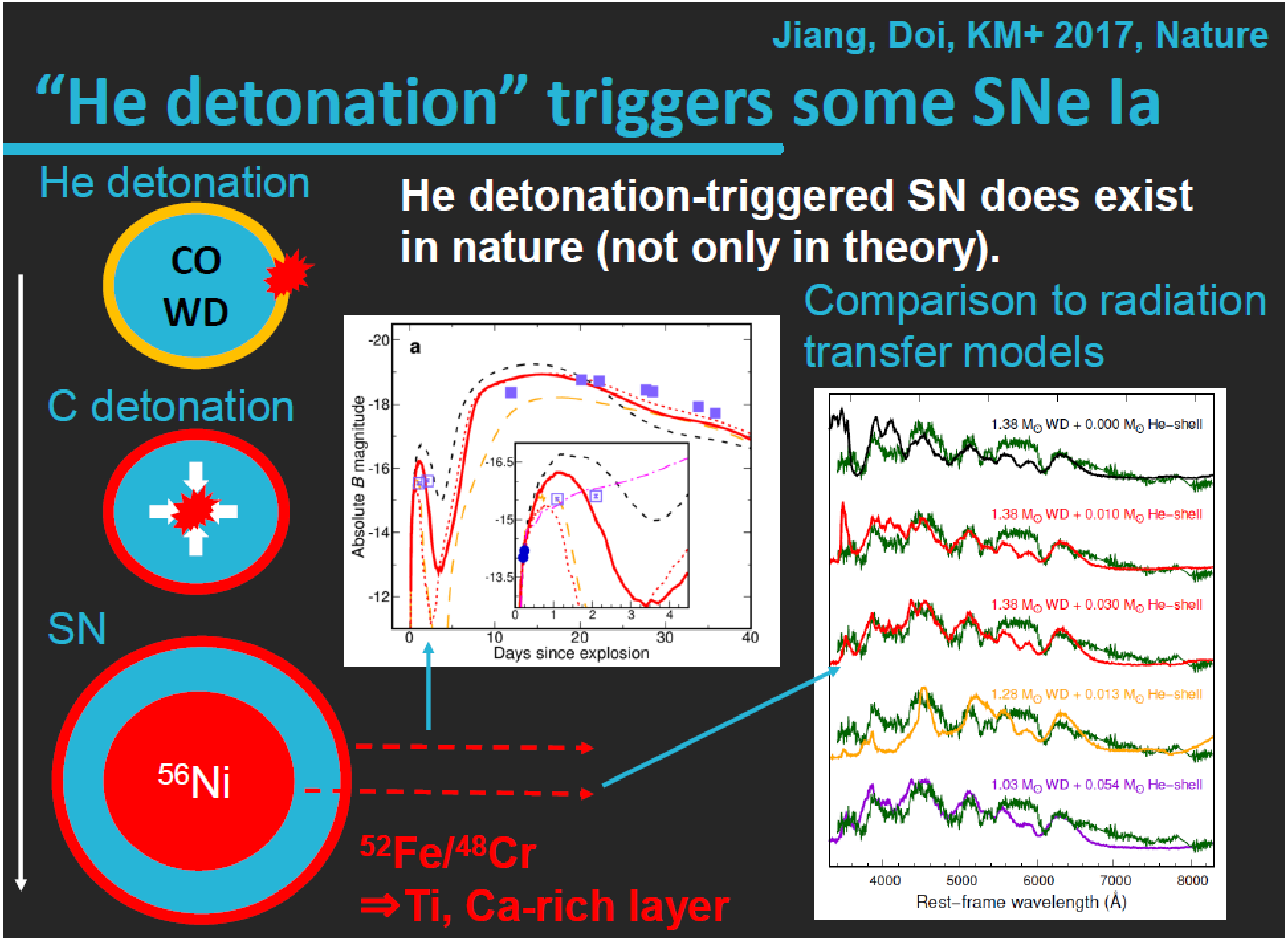
Spectra of SN2018oh

The spectra of SN 2018oh are somewhat different from the shallow-silicon/91T-like SNe Ia. The former is actually characterized by persistent carbon absorption feature as similarly seen in iPTF14atg.



Li+19

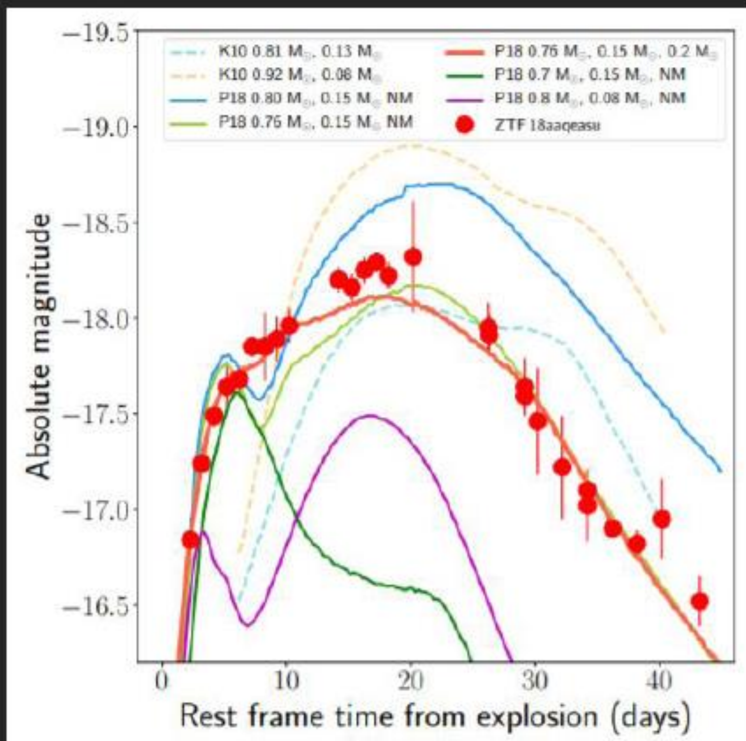
He detonation

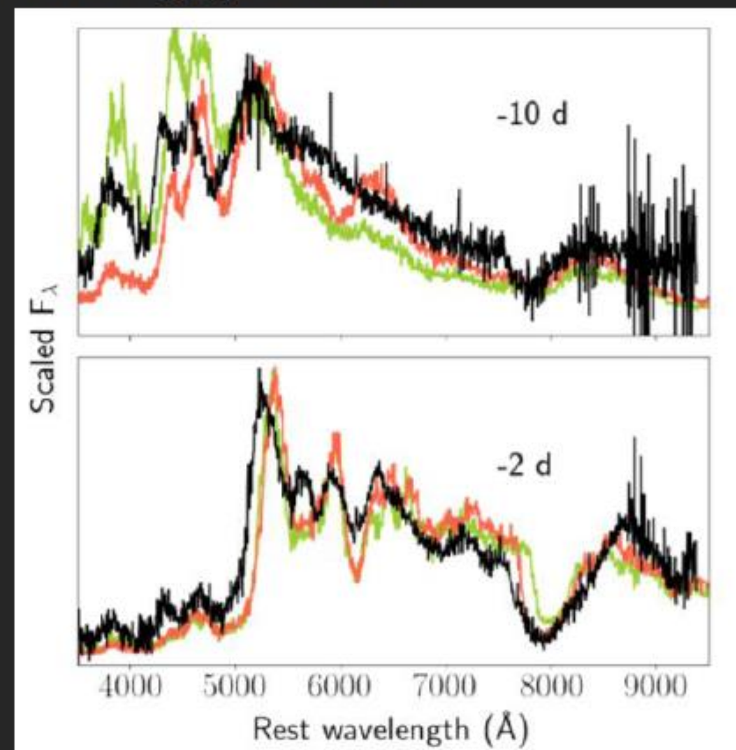


He detonation

Second robust example of the He detonation

ZTF 18aaqeasu (SN 2018byg): De+ 19



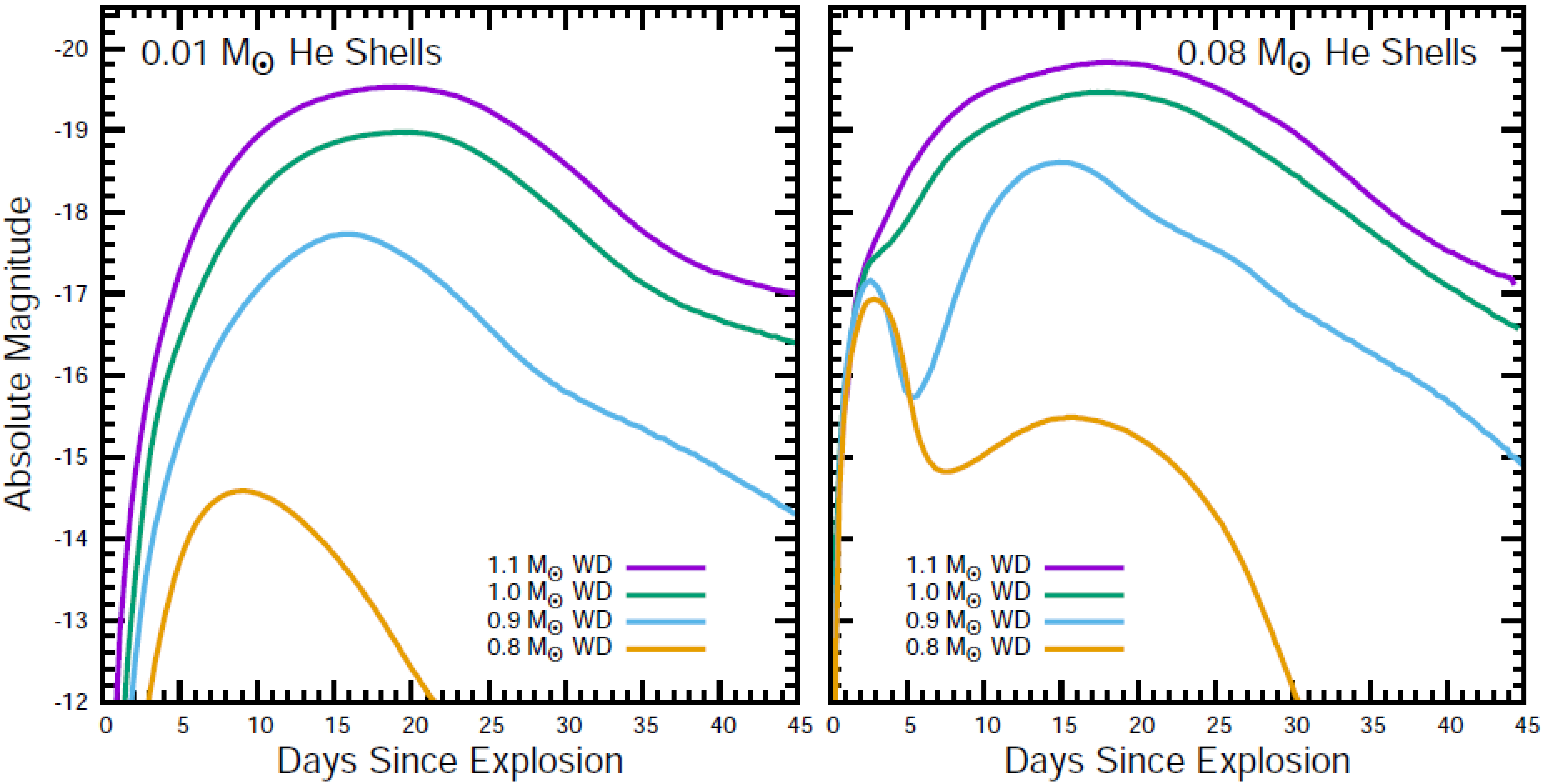


He detonation Model: Polin+ 18.

Predictions similar with a previous work by KM+ 18.

LCs depend on the He mass

g-band



Polin+18

Multiple Origins of Early flash

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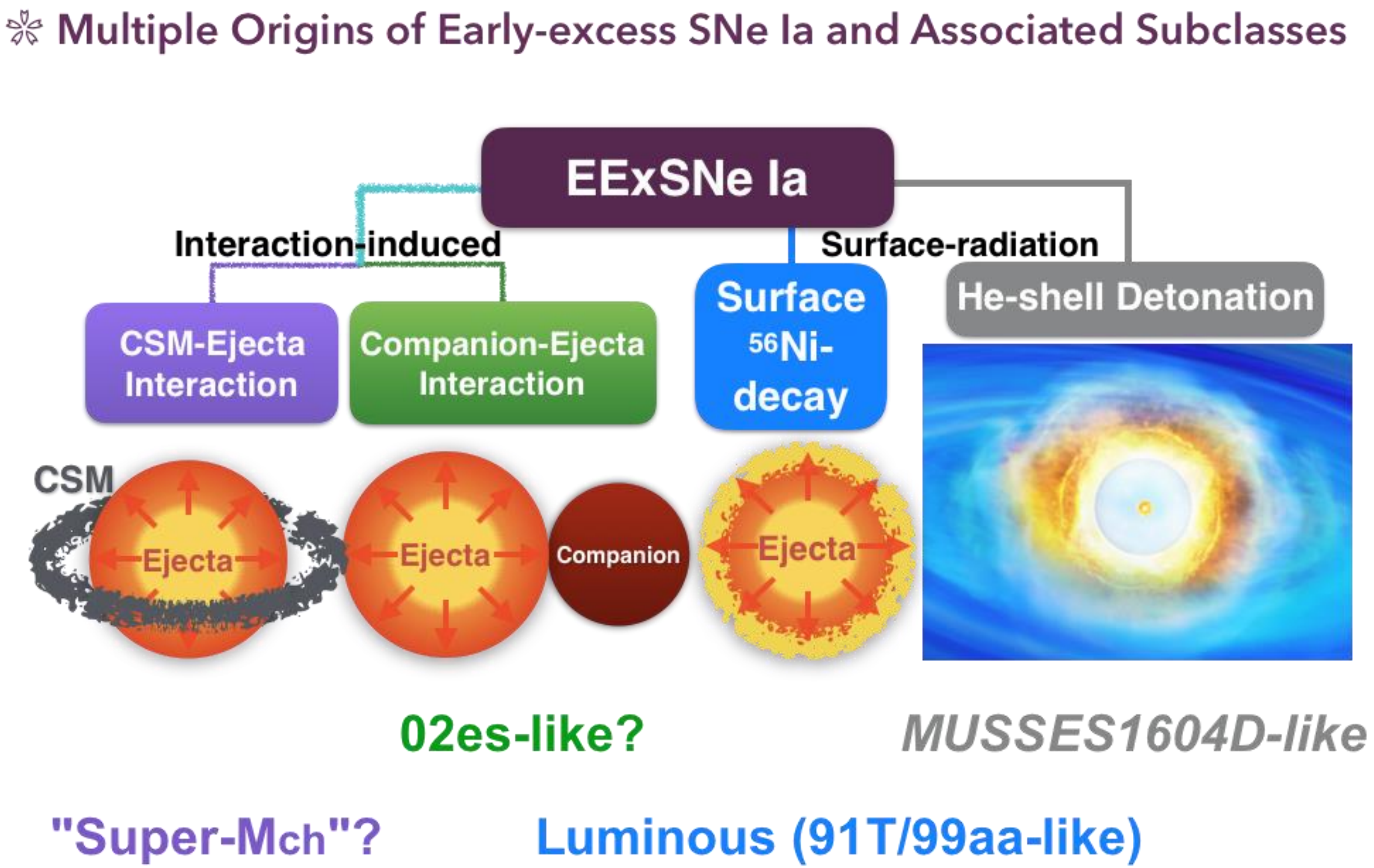

Suggested projects

1. Detection of shock breakouts
2. Intrinsic fraction of CCSNe with dense CSM
   a. How do we clarify observational biases?
   b. How is a difference between CSM density derived from LC and spectra solved? Acceleration of wind?
3. CSM of AT2018cow-like objects
   a. How frequently does cooling emission exist in normal SNe? (archival search)
   b. What is the optical “smoking gun” for luminous millimeter and radio emission?
4. Early bump of SNe Ia
   a. How robust are theoretical models for UV emission?
   b. Two possible strategies
      i. 1-day cadence to catch the real infant SNe. Dominated by normals?
      ii. wider, less cadance (1 week after the explosion ok). The large sample to include outliers (91T-like, etc).

Requirements

		Survey		Follow-up	
	Absolute magnitude	Cadence	Wavelength	Delay	Wavelength
Detection of shock breakout	-15mag -17mag	<1hr <1day	blue	<same night	flash spec
Fraction of CCSNe with dense CSM	-17mag	<1day	blue	<1-3day	flash spec w/ R~1000-3000 radio
CSM of AT2018cow-like object	-19mag	<1day shorter is better		<same night	X-ray, UV, radio spectra
Early bump of SNe Ia	-16mag	<twice per night several days	multicolor (g,r), UV	~1day several days	complete bolometric LC spec around maximum

High-cadence optical surveys and expected numbers

(0.1%? of CCSN)

Survey	Depth (mag)	Area (deg2)	Cadence	SBO at stellar surface (½ of # SNe/yr)	SBO in dense CSM (SNe/yr)	CSM of AT2018cow (SNe/yr)	Early bump in SNe Ia (SNe/yr)
BlackGEM	21.5	8.1	continuous	0.3	9	0.1	0.7
TMTS	~19	8000	1day		300	4	25
Tomo-e	17 18 19	5-20 7,000	0.5sec 2hr 1day	 2	 70 270	 1 4	 6 20
KMTnet	~21	~6,000	1 day (4 hr)		3300	45	300
ZTF	21	23,000 2,000 6,000	3day 1day 2hr	 100	 1100 340	 15 45	1100 100 300
PTSS	20.5	4,000	1day		1100	15	100
MOA	21	1,000	1day		560	7.5	50
ASAS-SN	17	40,000	1day		100	1.6	90
DLT40	20	600gal	1day		6	0.006	2
DECam	23.5	200 1,600	1hr 1day	100	2800 22000	30 230	260 2000
HSC	25	100 800	1hr 1day	370	8400 67000	70 560	800 7000

Follow-up observations

- Spectroscopic follow-up
  - Seimei 3.8m KOOLS-IFU
  - SED machine
- Other wavelengths
  - X-ray, UV, IR, radio
- Multi-object spectrograph
  - Observation of host galaxies