KOOLS-IFUによる
超新星・突発天体観測プログラム

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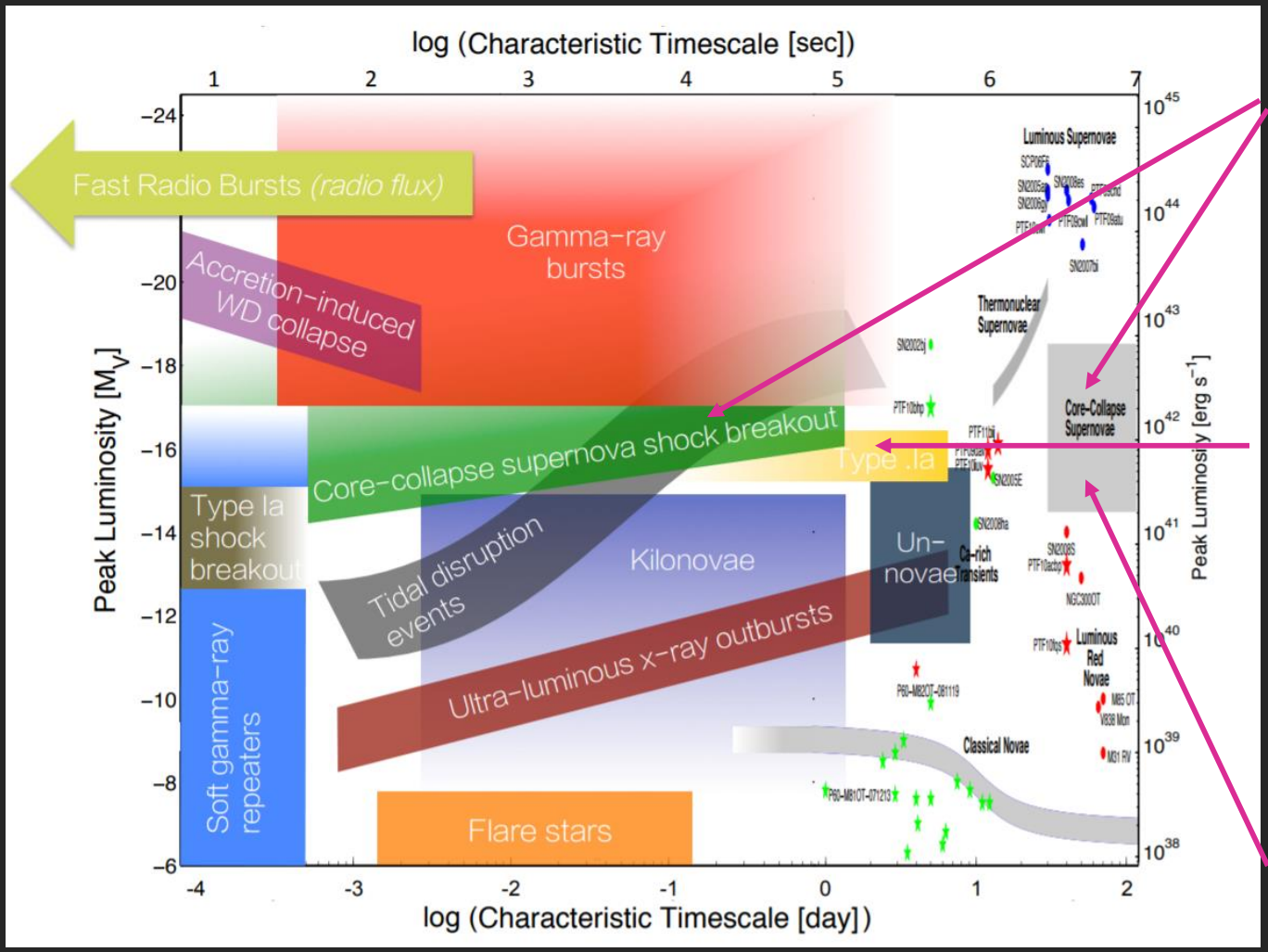
Supernova 2014J in Galaxy M82
Hubble Space Telescope ▪ WFC3/UVIS ▪ ACS/WFC

Plenty of Transient Targets for Kools-IFU



Cooke+ 2015

Higher cadence

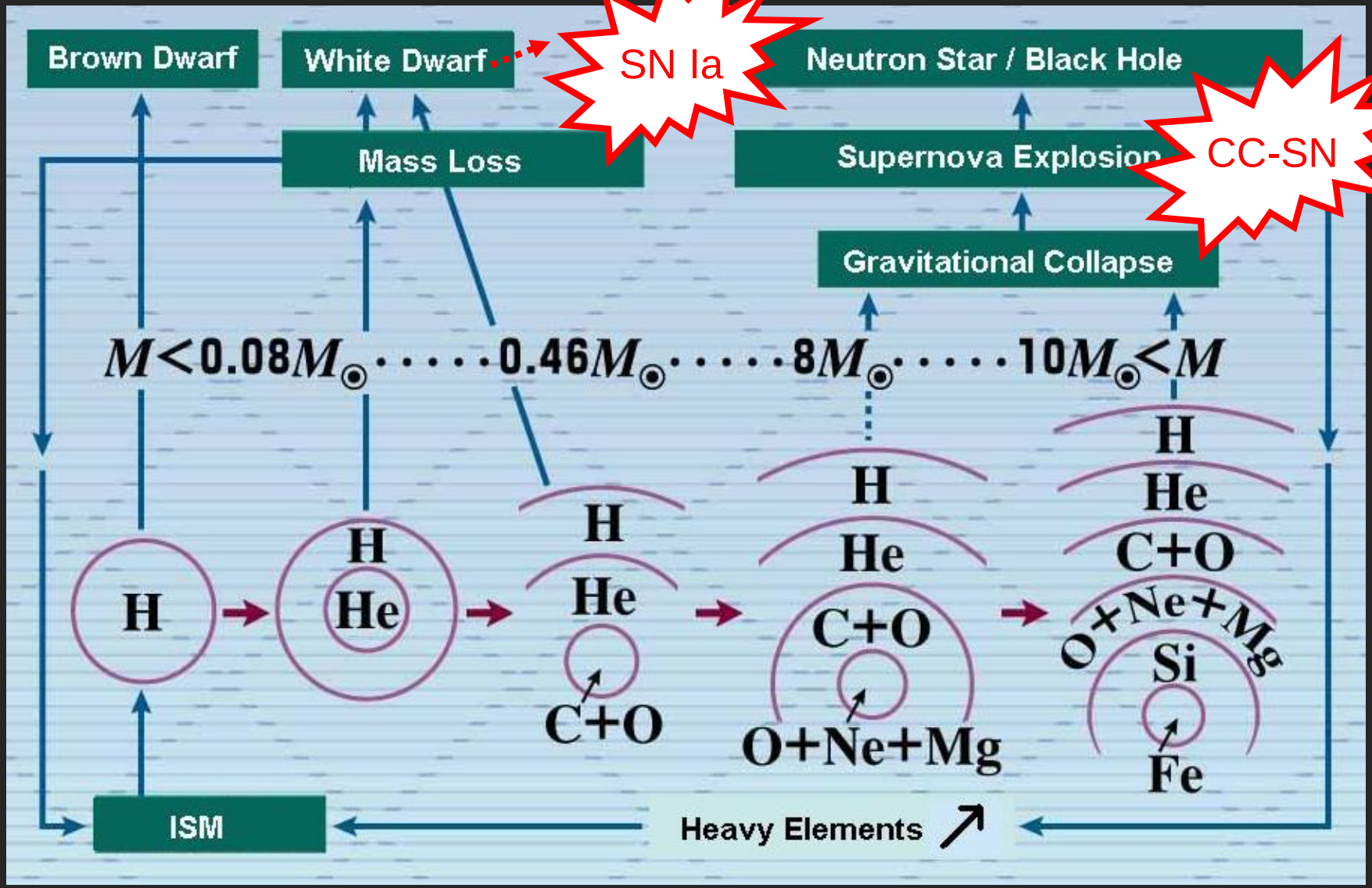
Known transients, but from the beginning

Unknown short-time scale objects

Larger samples

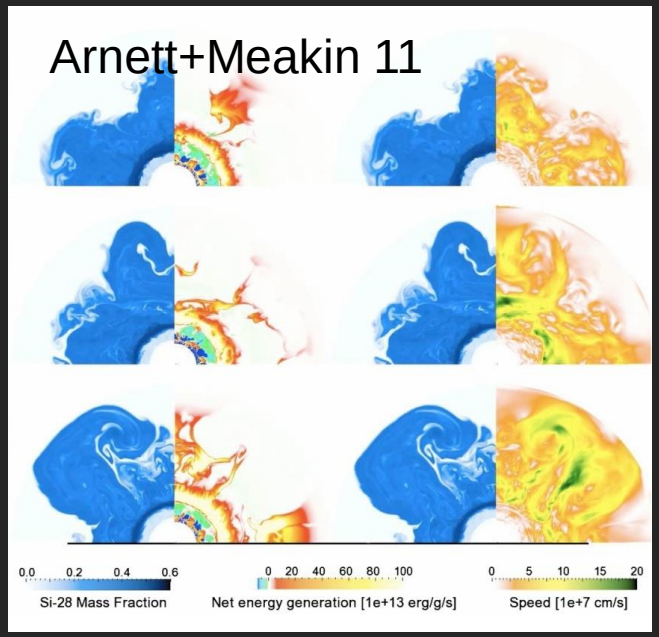
Rare types of explosions

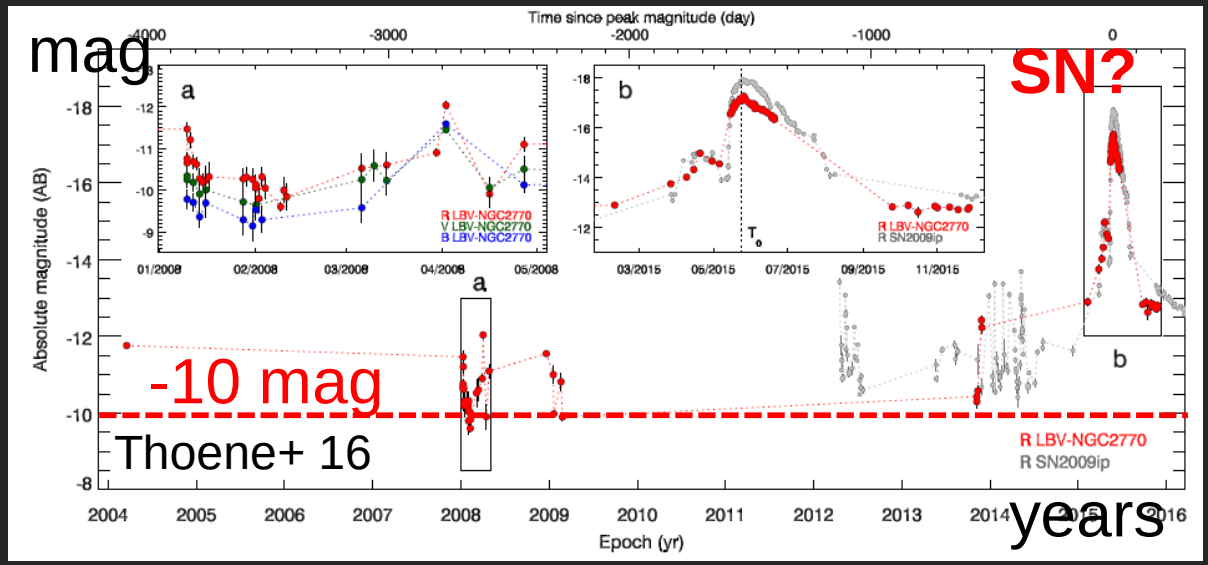
Stellar Evolution and Supernovae (SNe)



Unresolved problems for Core Collapse SNe (CC SNe)

- **Explosion mechanism.**
- **Final evolution of massive stars (single & binary).**
  - **Progenitor at the time of the explosion.**
  - **Mass loss in the final decades.**



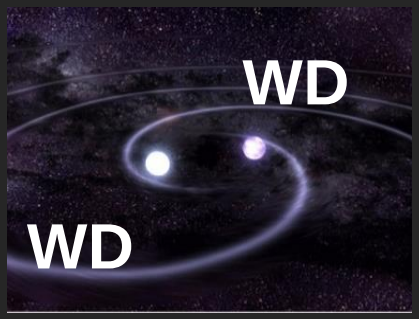


Unresolved problems for SNe Ia

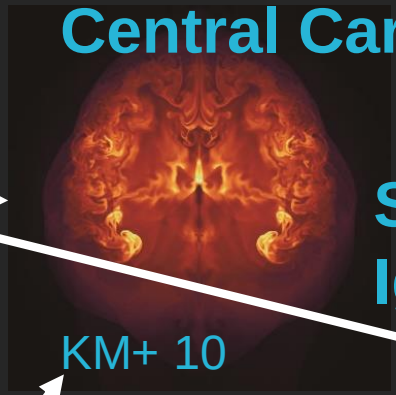
- **Explosion mechanism (multiple paths?).**
- **Progenitor systems.**

Single Degenerate (SD)

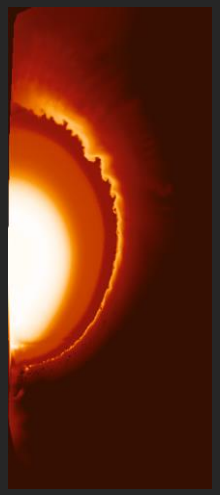
Double Degenerate (DD)



Central Carbon ignition



Surface Helium Ignition



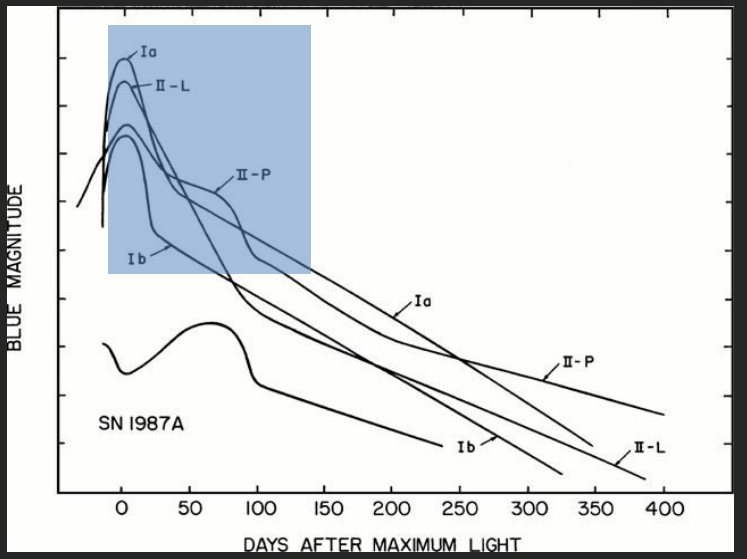
Surface Carbon Ignition

No more maximum-phase data alone (for "normal", if nothing special)

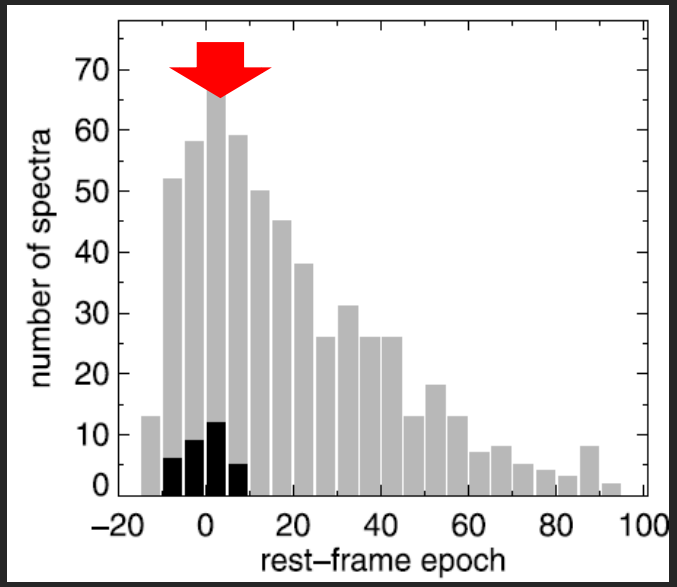
Adding another template example to already existing > 100 data set.

→ **No sense, forget it.**

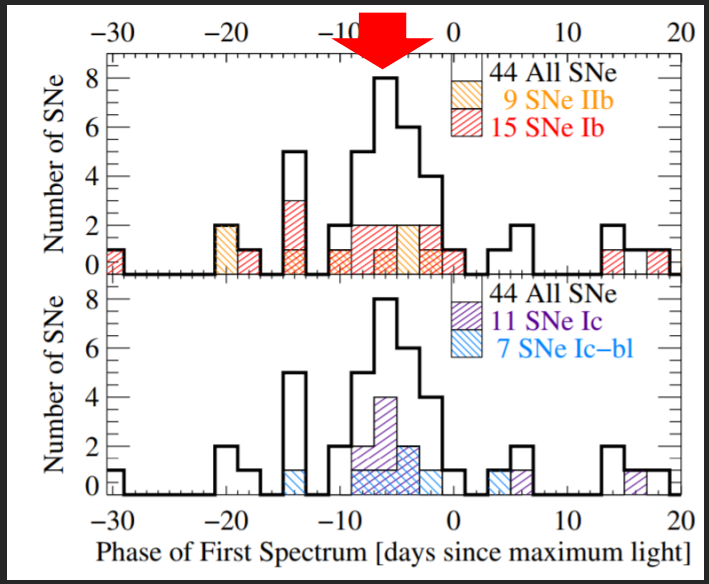
Do science w/ the archival data.



SNe Ia: "Hsiao Template"
Hsiao+ 2007



CC SNe (IIb/Ib/Ic): "CfA sample"
Modjaz+ 2014

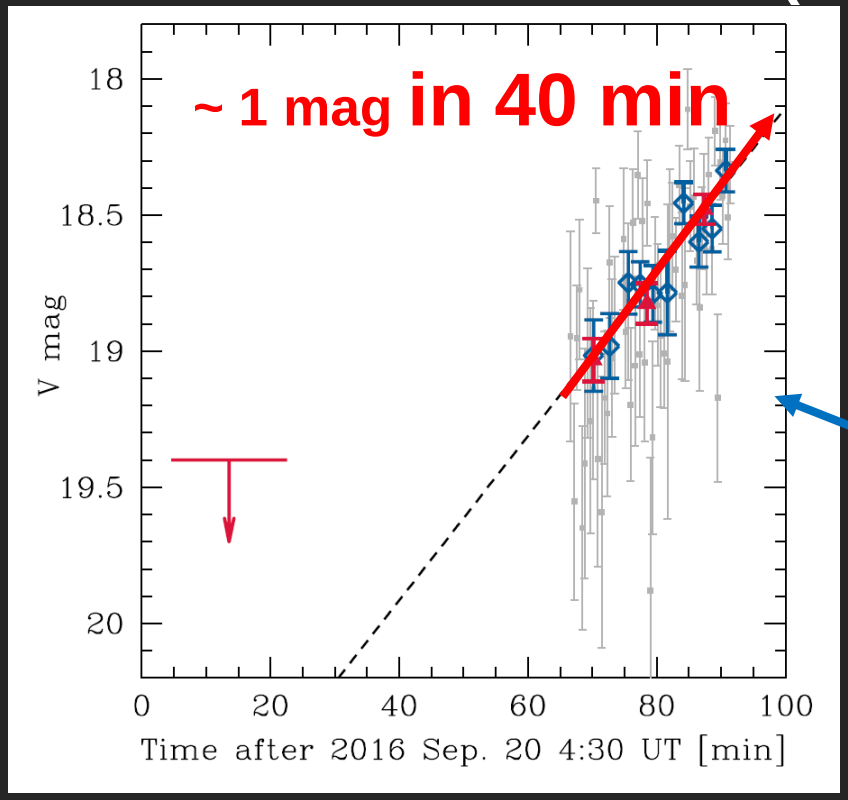


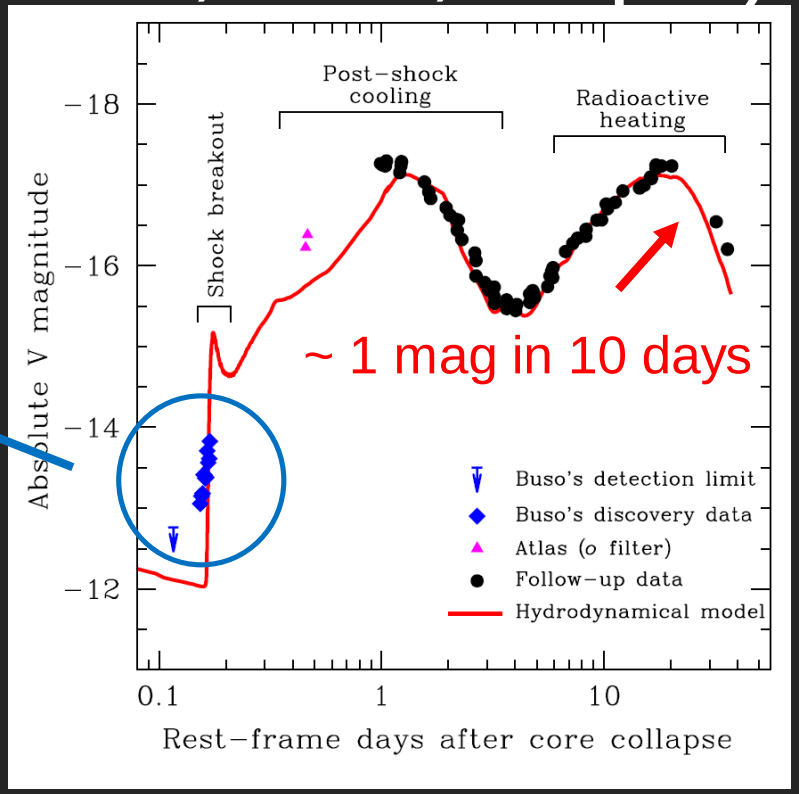
Why within a few days (ideally within a day)?

- **An SN is an expanding fireball (> 10,000 km/s).**
- Progenitor and explosion mechanism.
  - Will forget "initial configuration" in a few days.
  - e.g., $R = Vt + \mathbf{R_0} \rightarrow Vt$.
- Circumstellar material @ vicinity (→ progenitor).
  - Will sweep and hide the CSM in the vicinity of the SN.
  - e.g., the CSM created by the mass loss in the final 10 yrs will be lost in a few days (for the RSG wind velocity).

Examples: Core-collapse SNe

Shock Breakout! (Bersten+, Nature, accepted)





The first spectrum taken at 1.7 days after the discovery.

→**What would happen in the first day?**

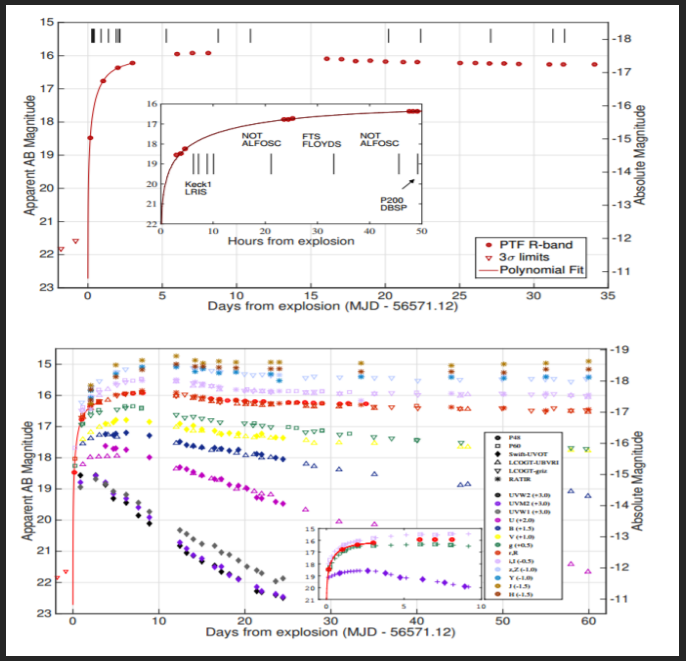
The maximum-phase follow-up also important.

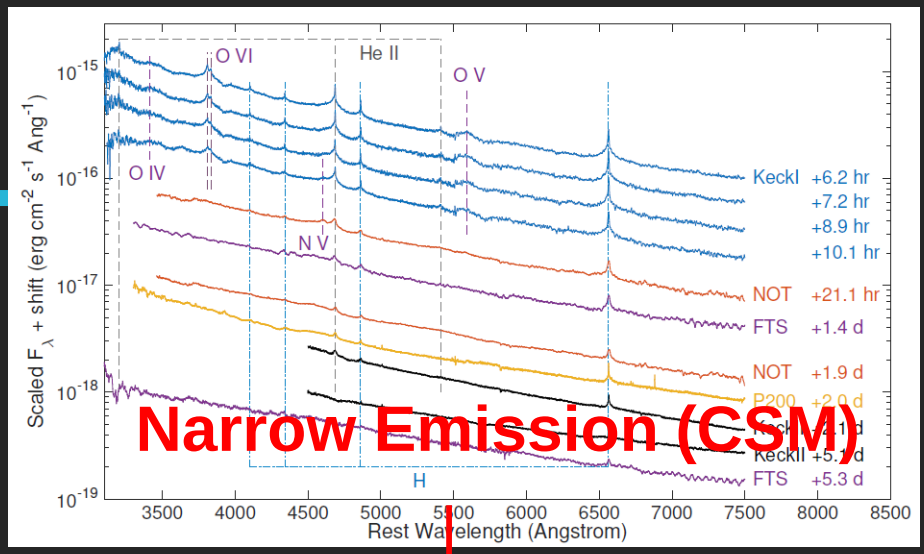
“Flash” spectroscopy

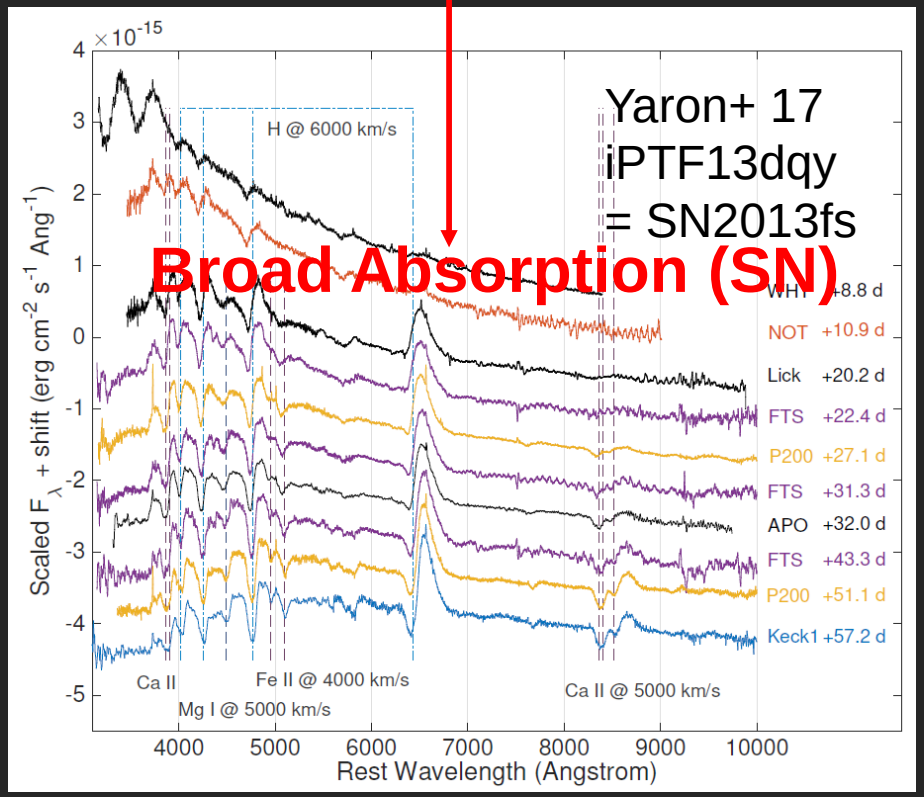
Recombination from the massive CSM near the SN???

（so far detected in one SN Ib and some SNe II）

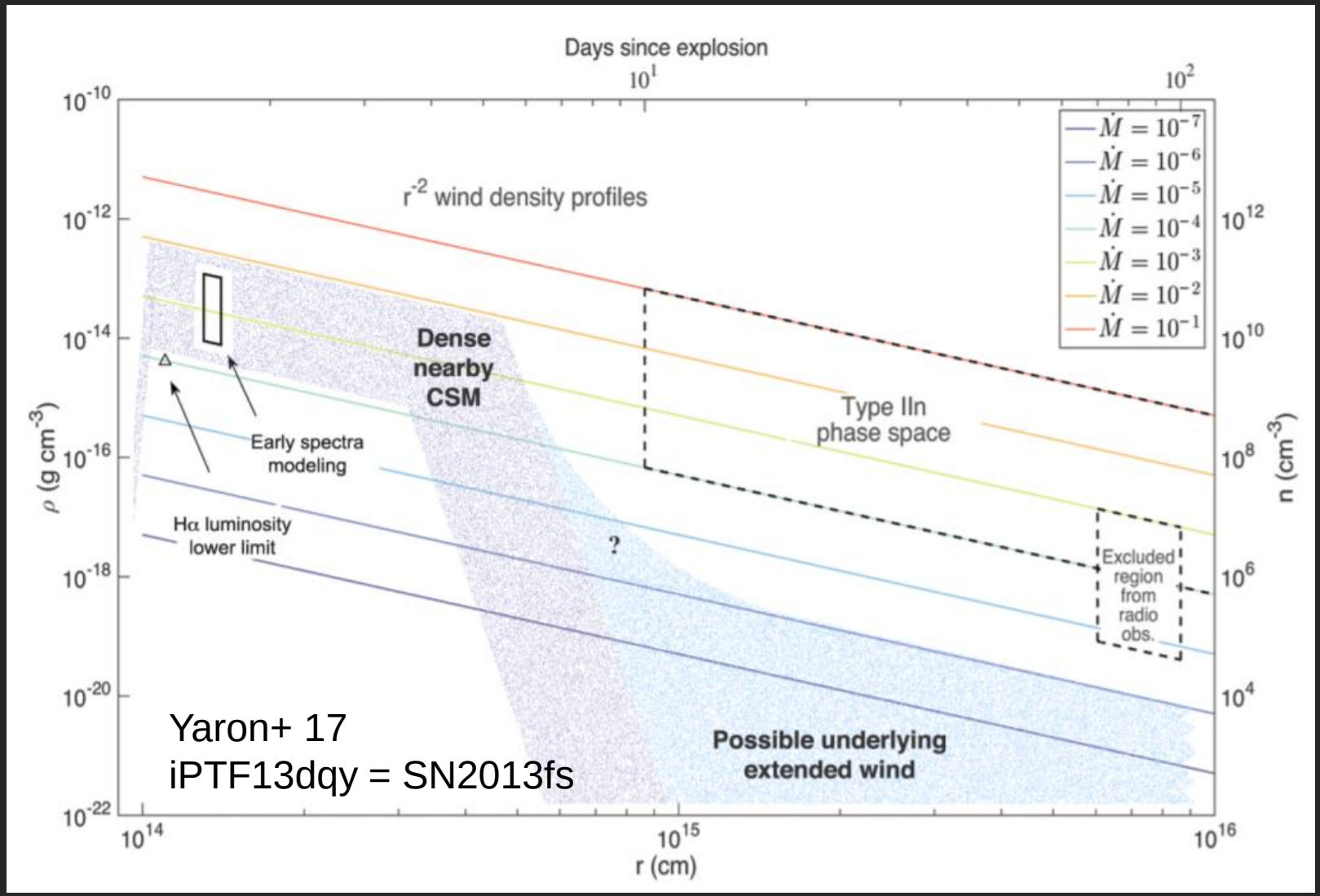
→ **New probe of CSM.**







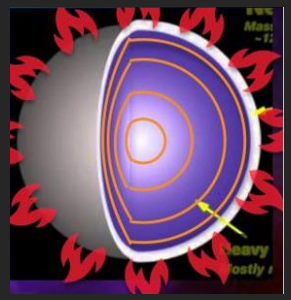
Mass loss in the final days to decades (< 10^{15}cm)



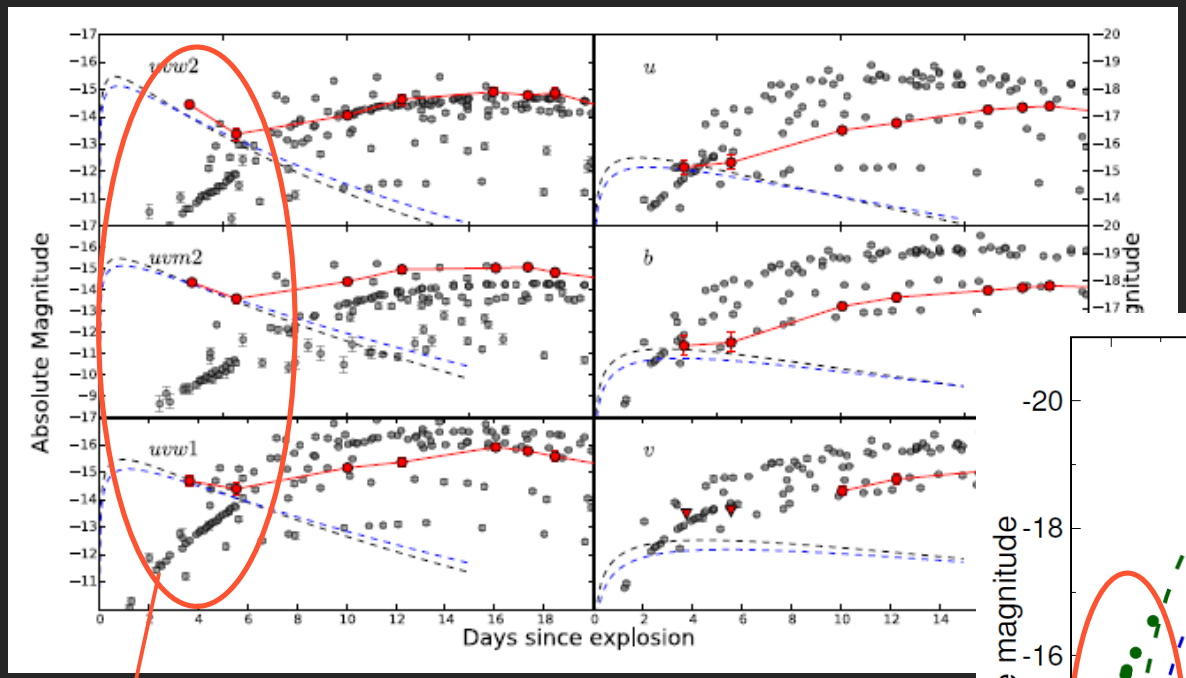
Yaron+ 17

iPTF13dqy = SN2013fs

Examples: SNe Ia

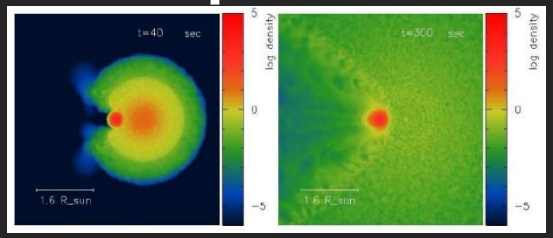


Surface He detonation trigger?

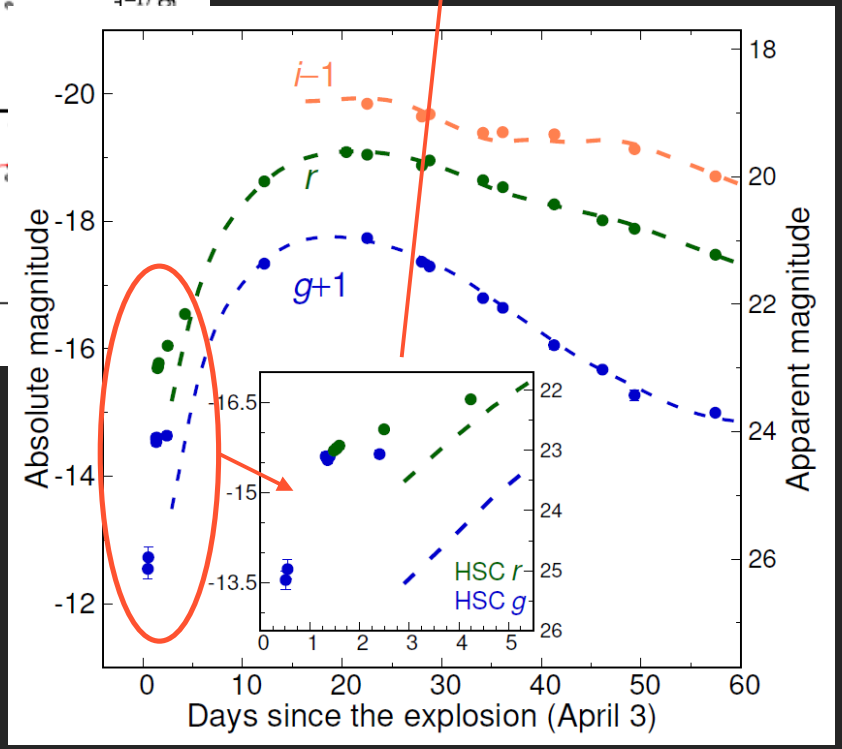


Cao+ 2015, Nature

Crush w/ a companion?



Liu, …, KM+, 2013



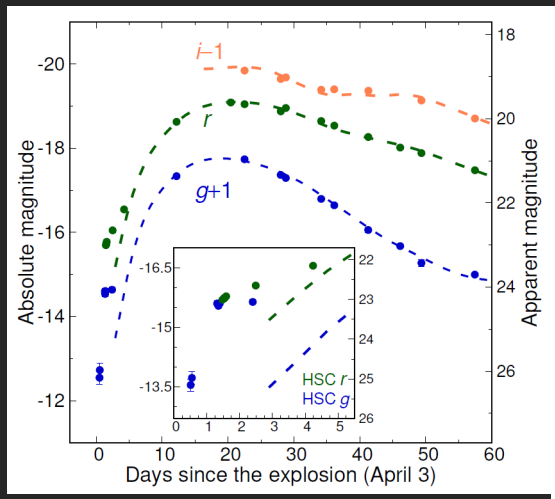
Jiang, Doi, KM+ 2017, Nature

MUSSES1604D: He detonation

He detonation

C detonation

SN



He detonation predictions:

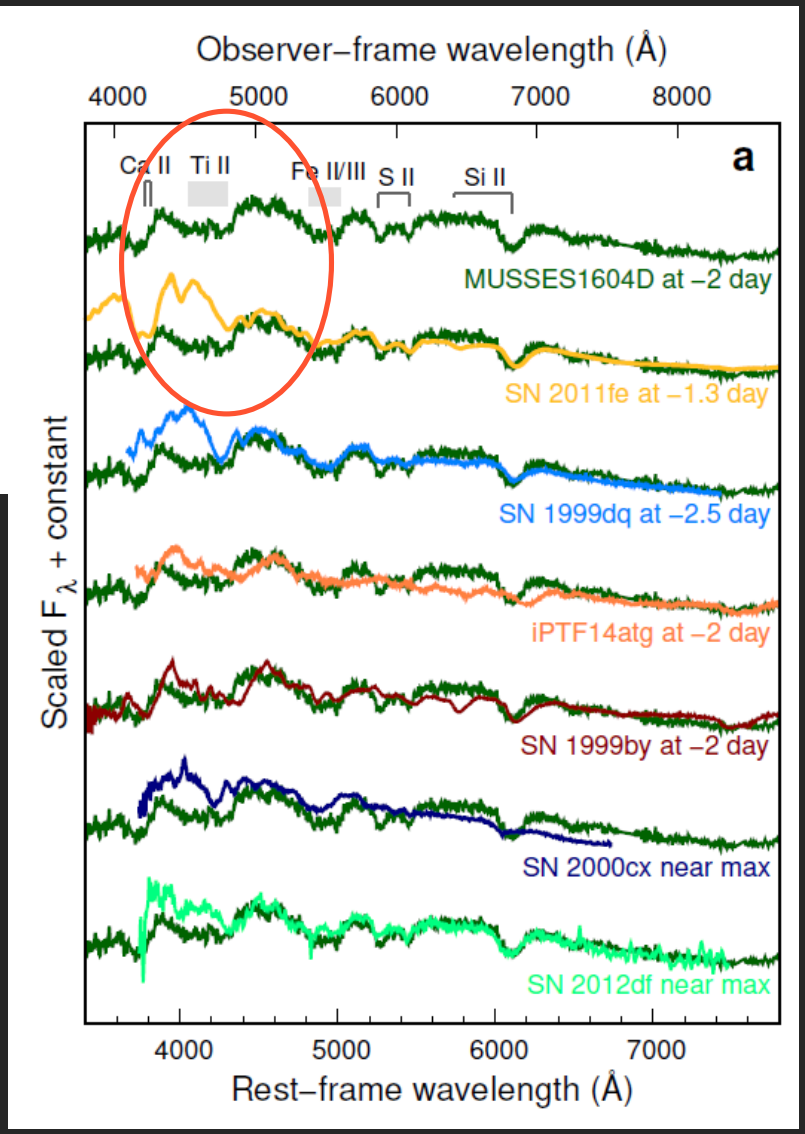
Early flash

+

Ti absorption @ maximum

Jiang+ 2017

KM+ 2018



Discovery within a few days becoming common

ASASSN-17gb (AT 2017dys) was discovered in images obtained on UT 2017-05-09.39 at V~17.0 mag. We also detect the object in images obtained on UT 2017-05-03.39 (V~17.5). We do not detect (V>18.0) the object in images taken on UT 2017-04-29.310 and before. An image obtained on 2017-

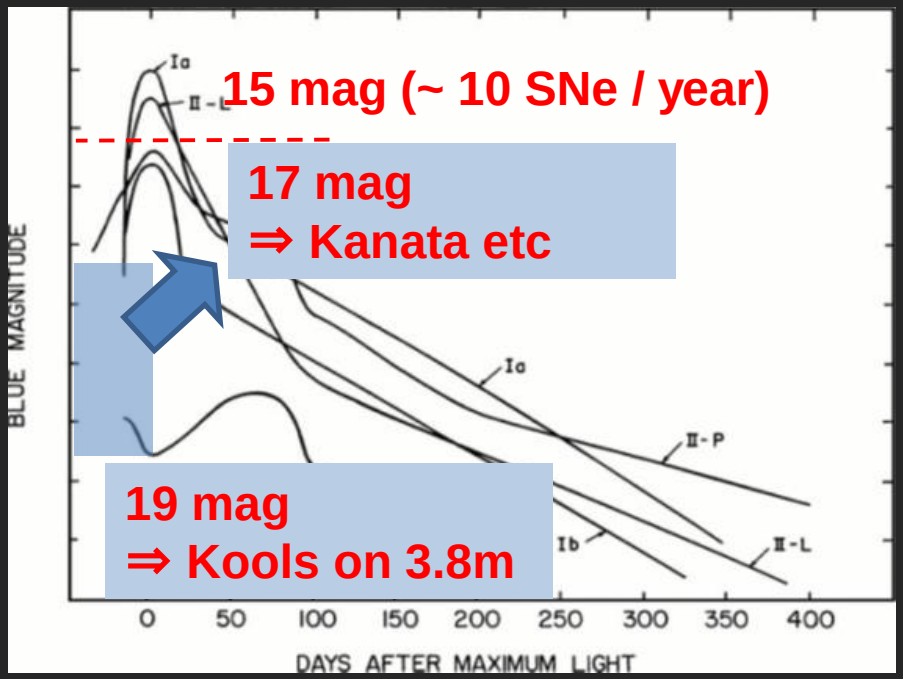
ASASSN-17fs (AT 2017dry) was discovered in images obtained on UT 2017-04-28.40 at V~17.2 mag. We do not detect (V>17.8) the object in images taken on UT 2017-04-25.310 and before. An

We report the discovery of DLT17aw/AT2017drh. The object was discovered on 2017-05-03.36 UT at R~17.9 mag, during the ongoing D<40 Mpc (DLT40) one day cadence supernova search, using data from the PROMPT 5 0.41m telescope located at CTIO. A PROMPT image taken on 2017-05-01.36 UT shows a clear, but low signal to noise, detection of the transient, with R~20. We do not detect the transient (R>20.5) on 2017-04-29.36 UT. All images were taken in a 'Clear' filter which was

Rapid spectroscopic follow-up still rare and limited.
→ **Excellent targets for 3.8m/Kools-IFU.**

Tomoe SN survey will find ~ 1000 SNe w < 1 day cadence

	Tomo-e SN Survey
instrument	Tomo-e Gozen
sensor	CMOS
readout time	~0 sec
period	2018/9-
survey area [deg2]	10,000
cadence	2 hours / 1 day
exposure time / visit	3 sec
depth	18 mag / 19 mag
filter	no (~g+r)
#(SBOs), #(SNe) / yr	5, 1000
data storage	daily-stacked image SN cutout images
reference	-



~15 mag @ peak: ~ 10 SNe

⇒ **Best targets (do not miss)**

~17 mag @ peak ~ 100 SNe

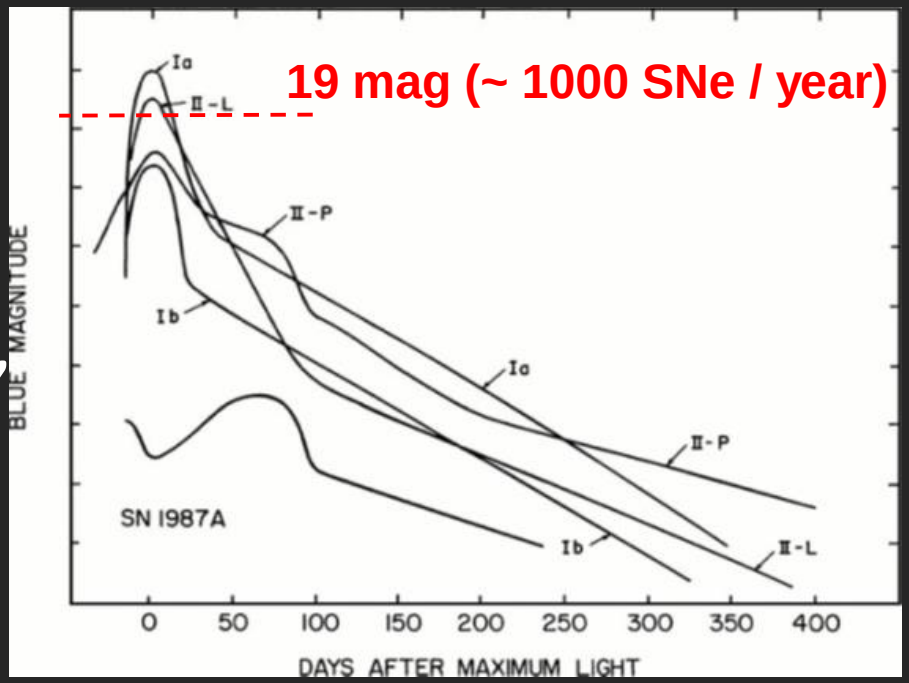
⇒ **Good targets (follow rare types)**

~19 mag @ peak ~ 1000 Sne

⇒ **Mess, forget them.**

Rapid Classification (~ 15 nights)

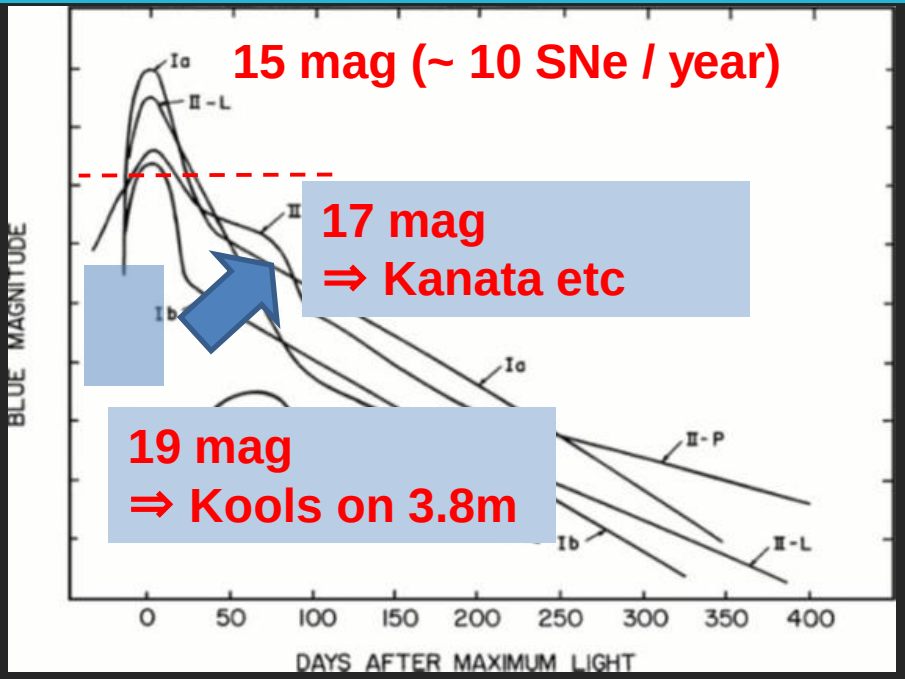
- Most of ~ 1000 / year discovered SNe are mess.
  - **~100 good SN targets.**
- Will find even more "non-SN" transients, may contain **"unknown" transients.**
  - **Will be useful for various projects (e.g., AGN, Novae).**
- **Will reject obviously useless ones, but often difficult.**
  - **May miss a chance as well.**

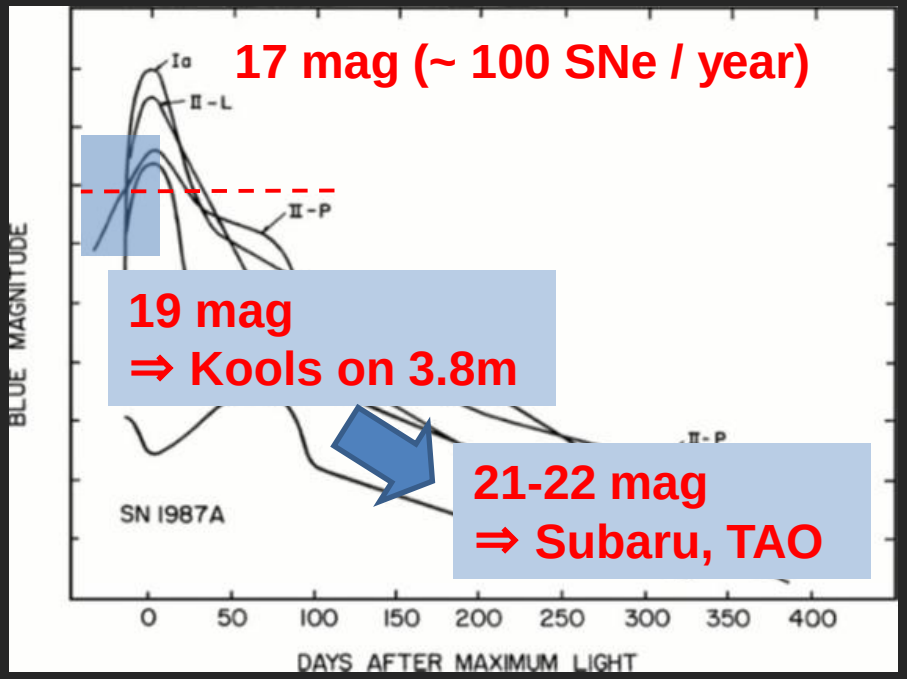


Rapid classification spec. for ~300 transients.

~ 15 nights / yr (30 min / each).

Follow-up observations (~ 15 nights)



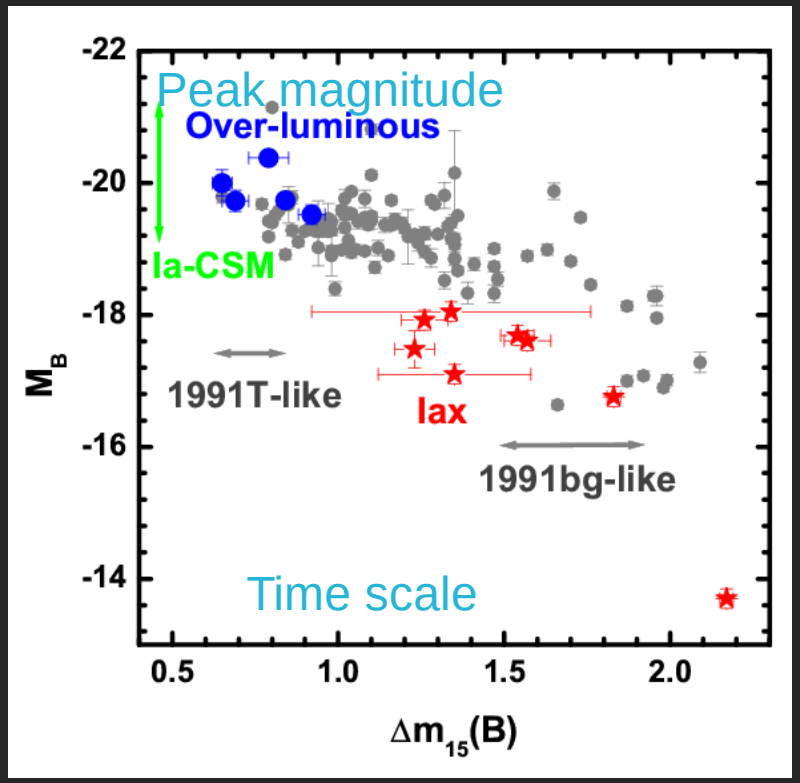


Spectroscopic follow up for
~ 10 "best" SNe from the first 1-2 days. Per year:
~ 10 epochs (+ Kanata etc)
→ ~ 5 nights (30min for each)

Spectroscopic follow up for
"selected" ~ 20 transients, out of ~ 300 classified ones.
~ 10 epochs
→ ~ 10 nights.

In total, ~ 15 nights / yr for follow-up.

More data for rare/new classes of objects



KM, Terada 2016

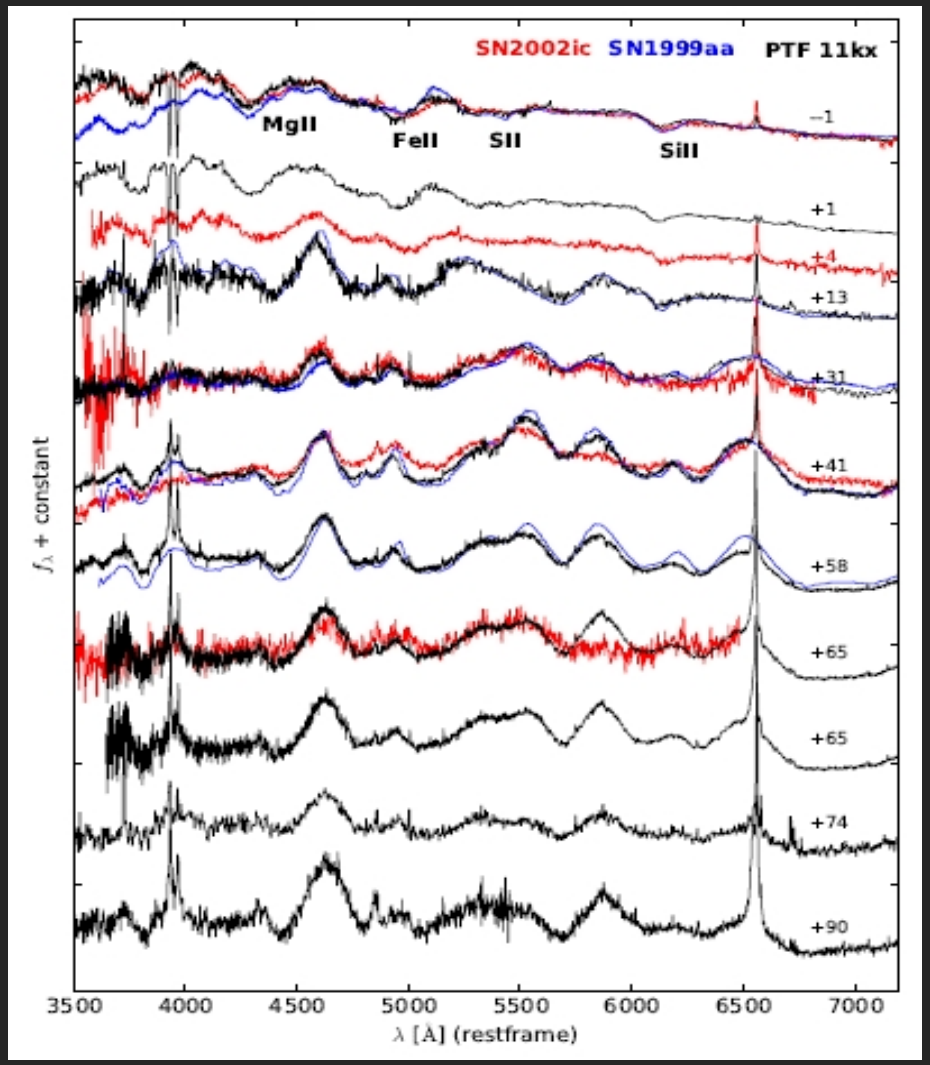
- Examples for “SNe Ia”.
- Huge diversity.
- **Understanding diversity⇒ progenitor & explosion.**

- **Excellent data set (only) for “normal” SNe, but lacking for “outliers”.**

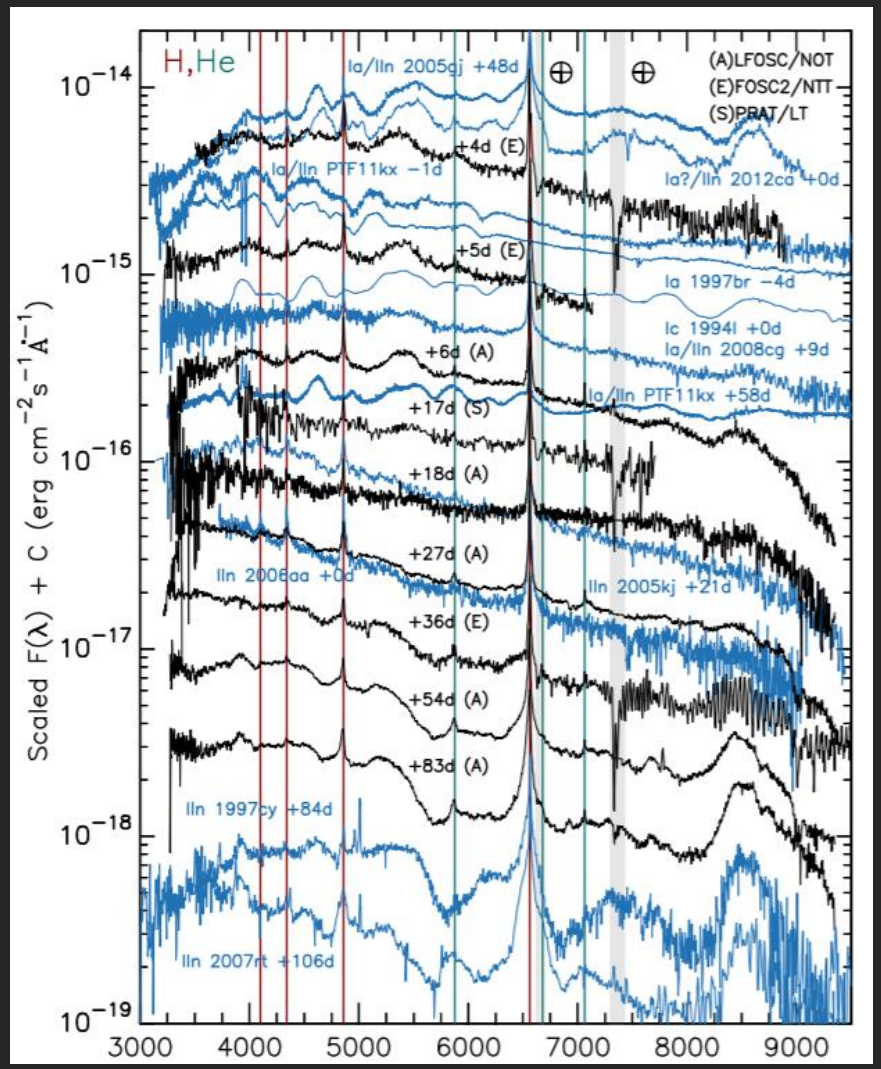
Example: developing CSM interaction

NUTS: Transient follow-up w/ NOT

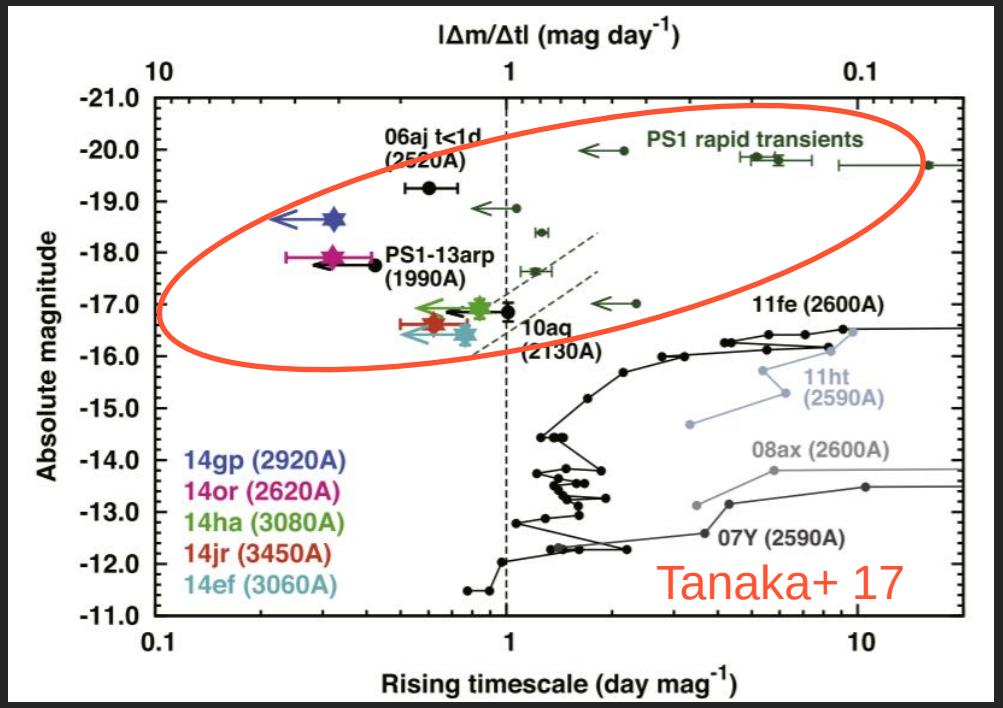
SN Ia (Dilday+ 2012)

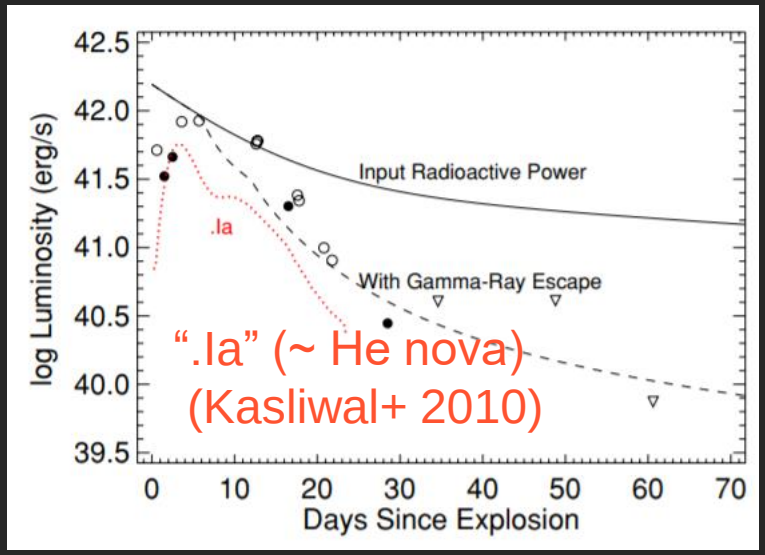


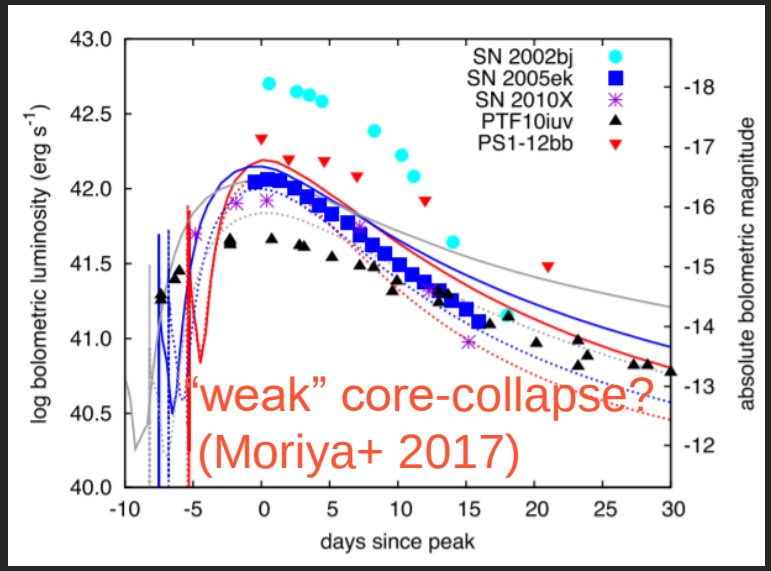
CC SN Ic (Kuncarayakti, KM+ 2018)



Example: Enigmatic short-time transients





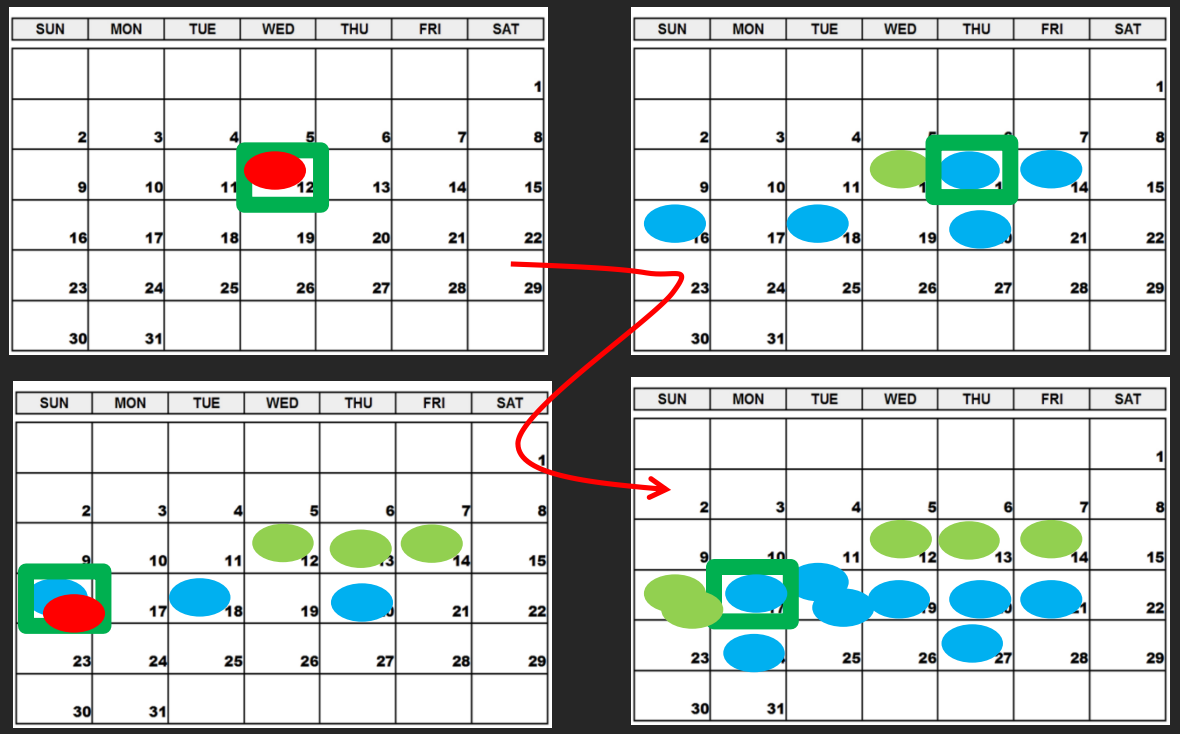


No good statistics yet, perhaps ~ 10% of CC SNe?

(then ~ 10 good targets / yr for Kools-IFU)

Observing modes (challenging)

- **Obs allocated in 0.5-1 hr block (~ 10-20 blocks for a night).**
- ~15 nights for rapid spectroscopy (~ 150-300 blocks).
  - **Genuine & rapid ToO.**
- ~15 nights for follow-up (~ 150-300 blocks).
  - **Essentially ToO, requires flexible que arrangement.**



怒られそうだ…

Follow-upの一部はFixed blocks (targets TBD)をあらかじめallocateする？
例：half night / week x 5 months (10 nights)
+ 5 ToO nights (to fill the gap)

自動化・単純なcriteriaの設定も重要（時間の節約）。

Organization (tentative)

Arrangement w/ other instruments

Tomoe… 諸隈、酒向、大澤

Kanata… 川端、山中

大学間連携… 山中

Science/Scheduling

前田、太田、野上、前原、諸隈、田中、松林、守屋、冨永、川端、山中＋to add

自動化・単純なcriteriaの設定も重要（時間の節約）。

Observing/Analysis/Science

京都・東京・広島ほか学生。

科研費研究員（希望…）。

＋to add

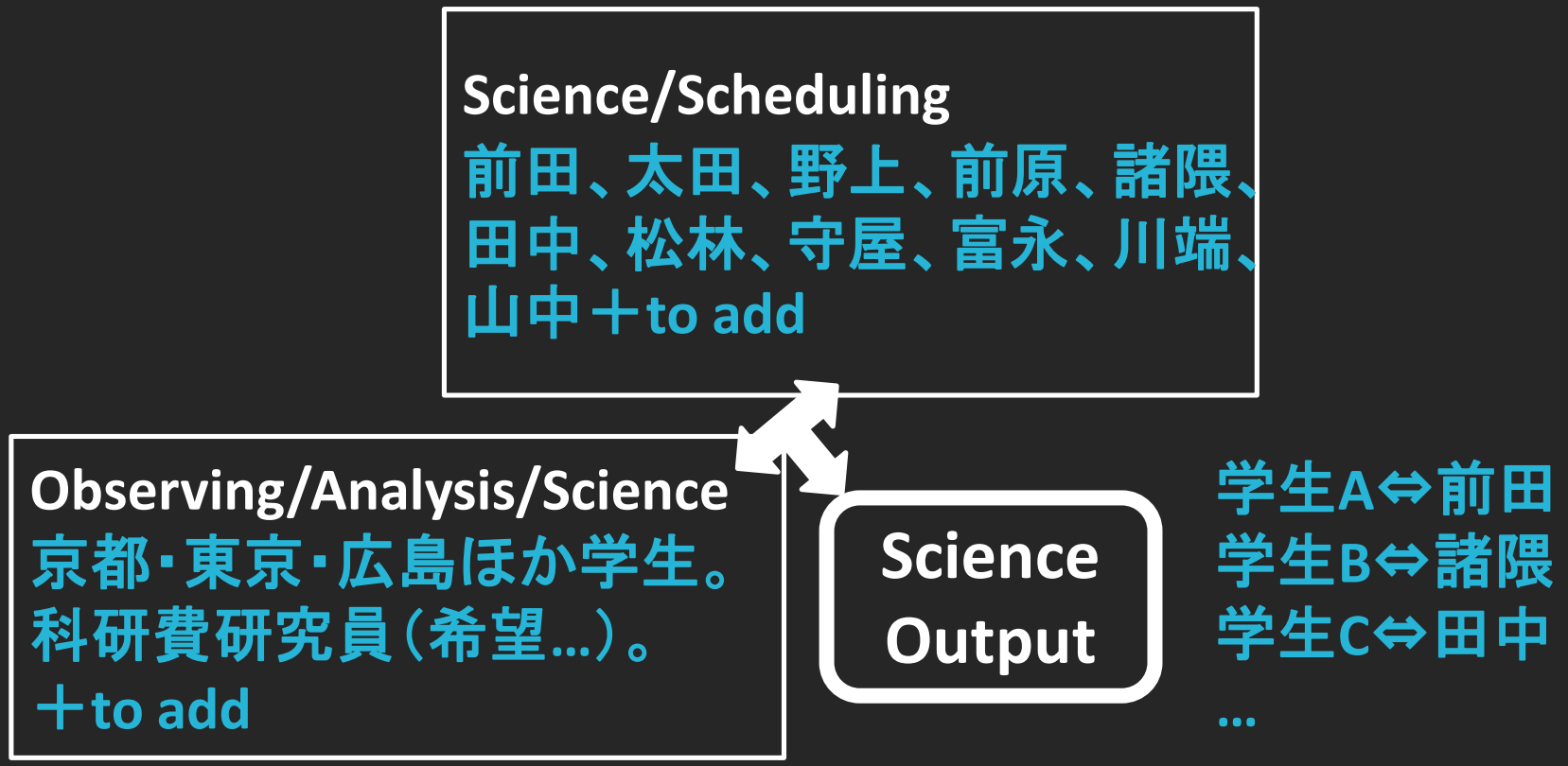
Science Output

Pipeline+database

Subaru/HSC、木曽、かなた等の資源を活用して…。

科研費研究員（希望…）。

Organization (tentative)



- All hand TV meeting / month or 2 weeks（広島かなたで実験中）。
- 1 projectにつき、その分野に詳しい一人の”mentor/adviser”をつける（教育＋science outputの加速）。

Summary and opinions for Tomoe-3.8m

- Many exciting scientific outcomes for transients.
- Early discovery + quick follow-up (esp. spec) is key.
  - **Frontier** in transient science.
- Long-term follow-up important as well.
  - We need a comprehensive view for **real science**.
- Possible/proposed Scheme:
  - **Flexible que necessary (0.5-1 hr block).**
  - (Equivalent) ~15 nights for rapid spec., ~ 15 nights for intensive follow-up.
- Efficient organization necessary (goal = science).