High-cadence transient surveys with Subaru/Hyper Suprime-Cam

Nozomu Tominaga

(Konan Univ./Kavli IPMU)

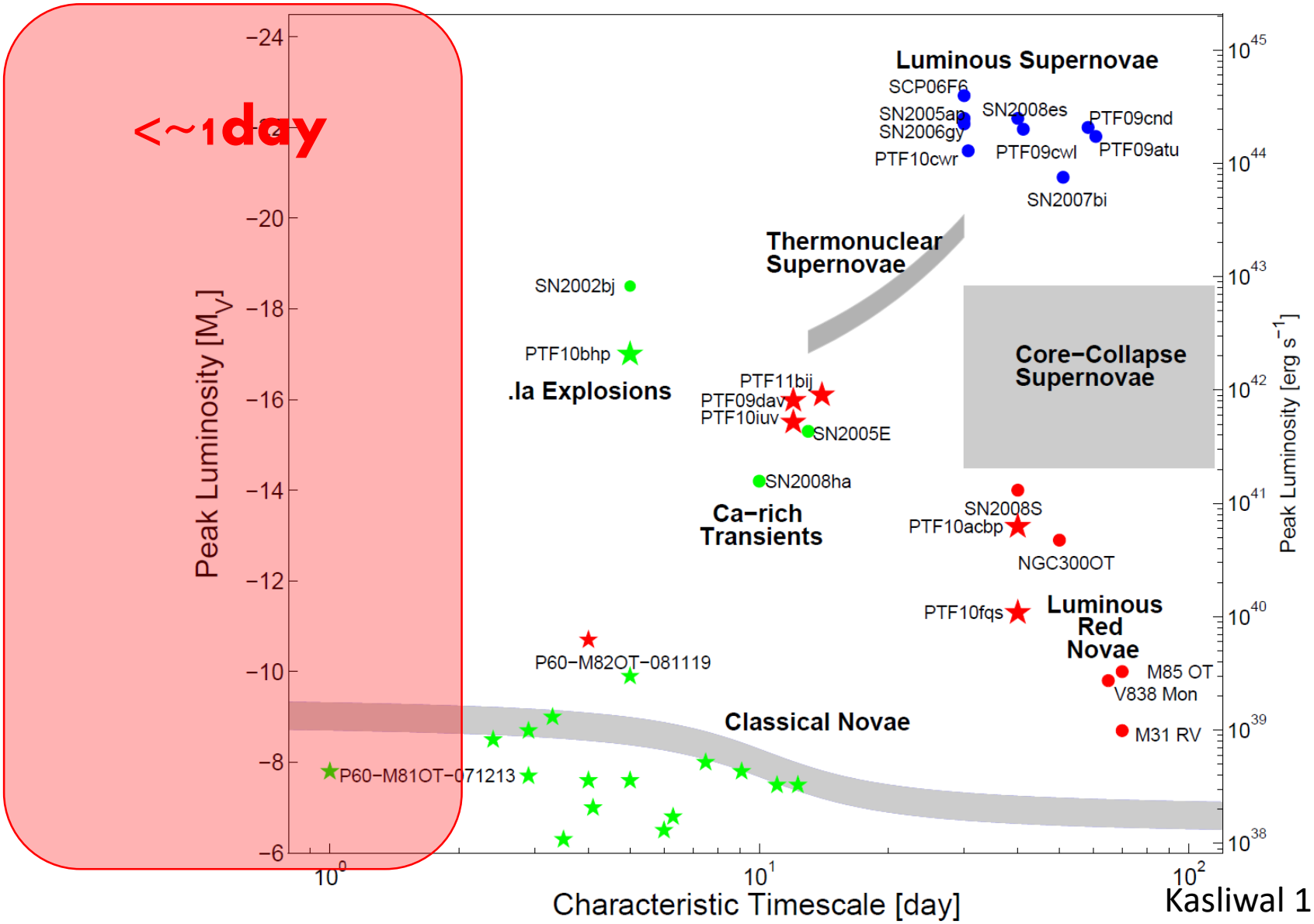
22nd Nov 2019

Subaru 20th Anniversary

Outline

- High-cadence survey & data analysis
- A rapidly declining transient
- Rapidly rising transients
- Event rates of rapidly varying transients
- Summary

Timescale of transients



Kasliwal 11

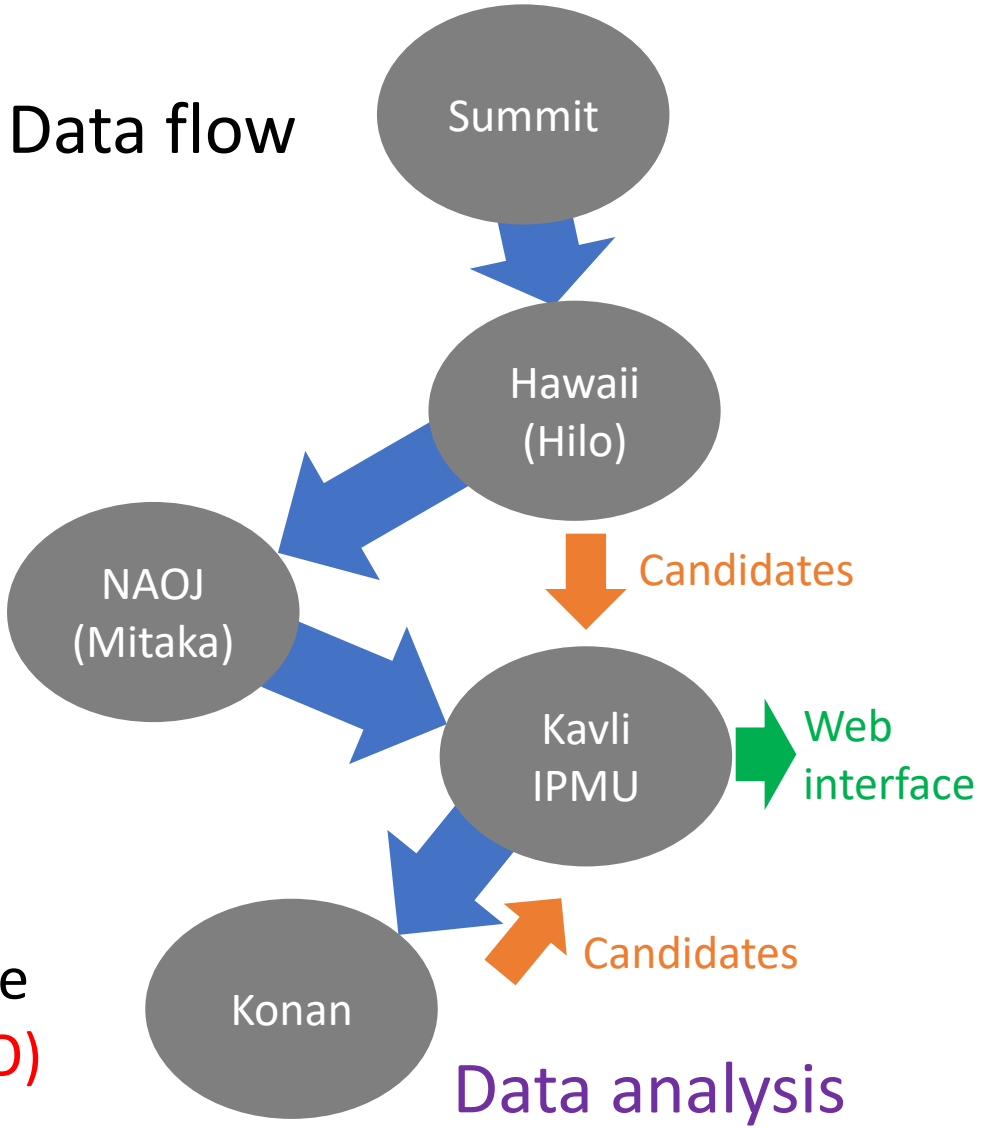
Data analysis for transient surveys

Transient finding system

- Hawaii observatory
  - CPU: 176 cores
  - Storage: 20TB
- Kavli IPMU
  - CPU: 1200 cores
  - Storage: 3.5PB
- Konan University
  - CPU: 800 cores
  - Storage: 500TB

The system is used for high-cadence surveys in openuse (survey and ToO) and SSP programs.

Data flow



Web interface for intranight transients

fits fits fits fits fits
ps1 diff diff diff diff

6849
(102104)

19akdk
2019-05-02
show
fastSN jiang
suzuki tominaga
intranight
tominaga
Star?
hamasaki

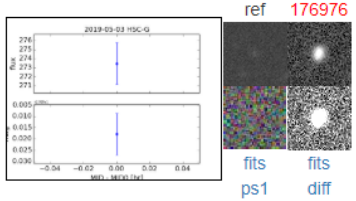
9862 (7,4)
798.5, 535.5

222.64084
2.15836
14:50:33.802
+02:09:30.092

0.28 (G = 21.68)
1.40 (G = 20.90)
1.40 (G = 20.90)

4
3
ph-z(D): 0.78
(dist: 0.00")
extend: -1.00
(dist: 0.01")
ext(PS): 0.0
(dist: 0.00")

2019-05-03 HSC-G
ds9 -zscale *.fits -pan to 222.64084 2.15836 wcs -zoom 0.5
ref 176976



fits fits
ps1 diff

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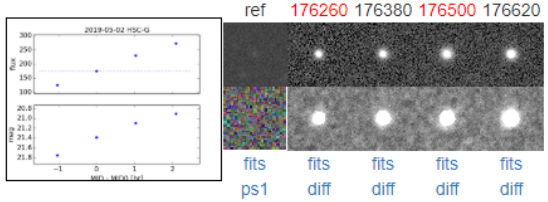
ref 176260 176380 176500 176620



fits fits fits fits fits
ps1 diff diff diff diff

fastSN fastSN?
normalSN AGN Star
normalSN? AGN? Star?
Bogus
Bogus
or submit

166
(2723)

19aagj
2019-05-02
show
fastSN?
ohgami yasuda
intranight
tominaga
early-phase? jiang
normalSN?
jiang

9608 (3,7)
3728.1,
1447.4

206.03659
1.27338
13:44:08.781
+01:16:24.162

0.26 (G = 23.65)
1.42 (G = 22.96)
1.42 (G = 22.96)

6
6
ph-z(M):
0.44
(dist: 0.00")
extend: -1.00
(dist: 0.35")
ext(PS): 0.0
(dist: 0.00")

2019-05-03 HSC-G
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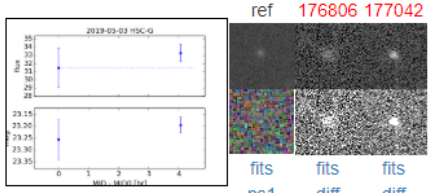
ref 176806 177042



fits fits fits
ps1 diff diff

2019-05-02 HSC-G
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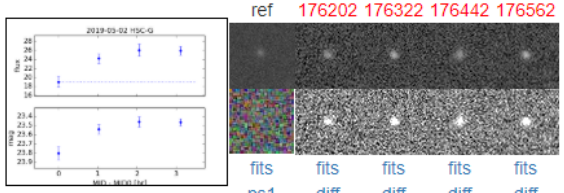
ref 176202 176322 176442 176562



fits fits fits fits fits
ps1 diff diff diff diff

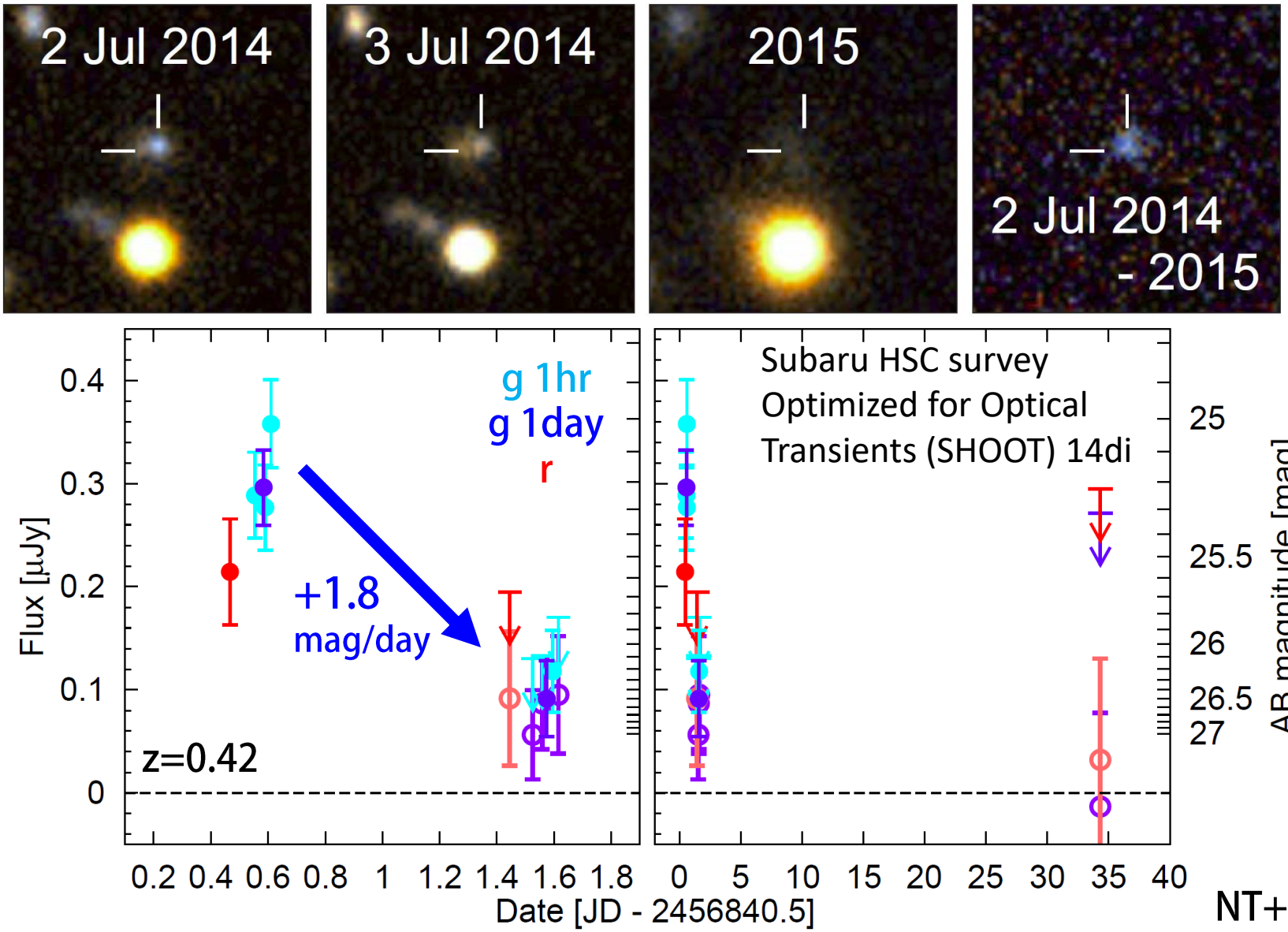
fastSN fastSN?
normalSN AGN Star
normalSN? AGN? Star?
Bogus
Bogus
or submit

165 **19aagi** 206.16221 5 2019-05-03 HSC-G

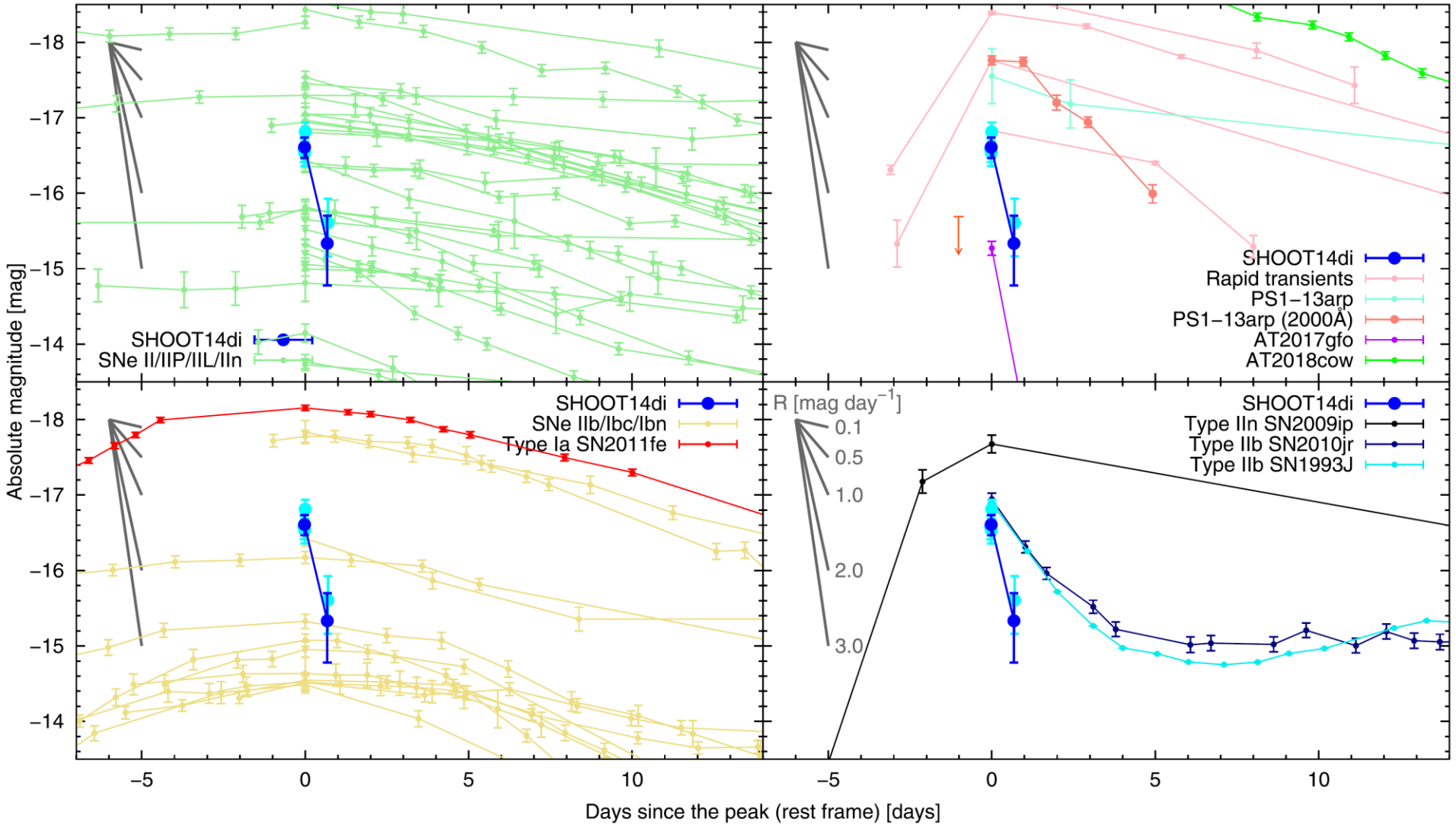
Rapidly declining transient

(NT+19, ApJ, 885, 13)

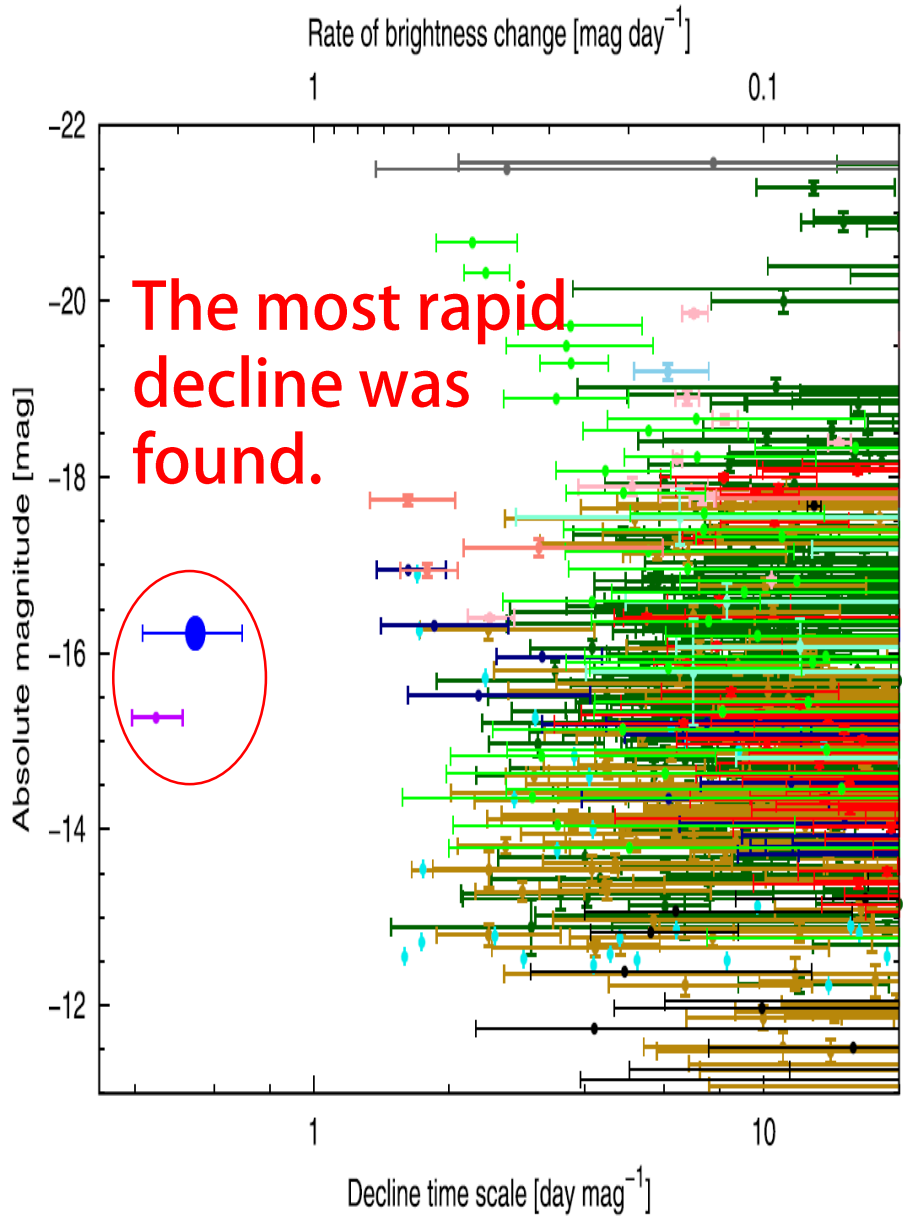
A rapid declining transient

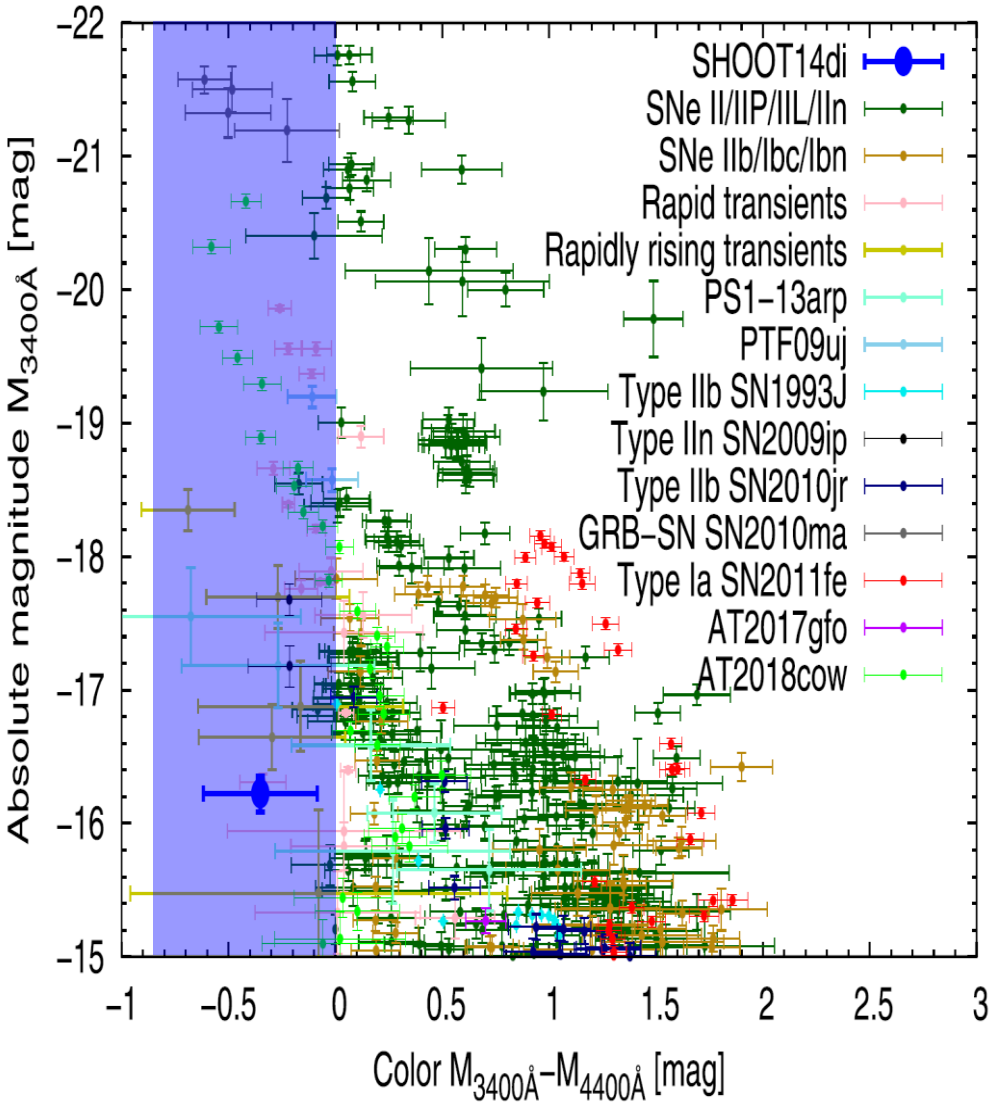


Comparison of rest u-band LCs



Decline rate and color





Origins of rapid decline

- Shock breakout at stellar surface (NT+11)
- Cooling envelope (Tsvestkov+12)
- Shock breakout in dense CSM (Moriya+18)

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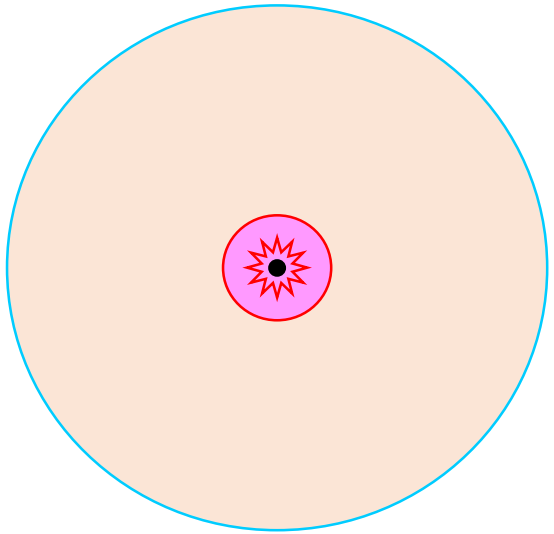

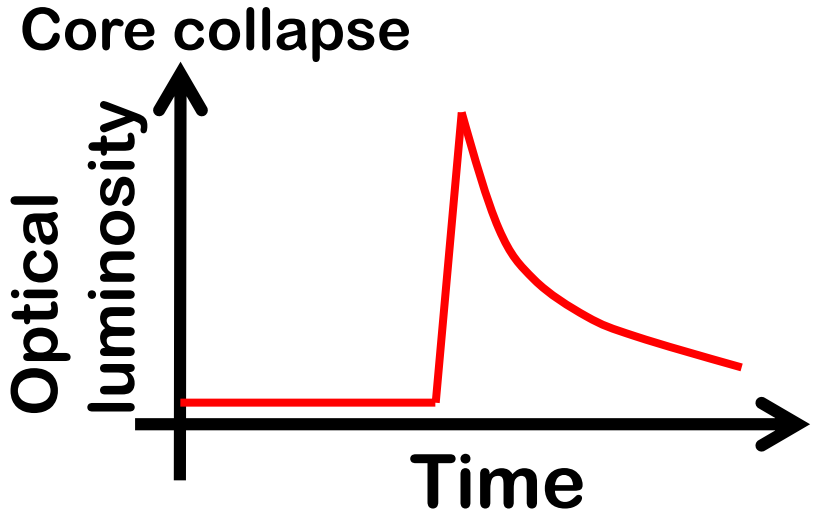

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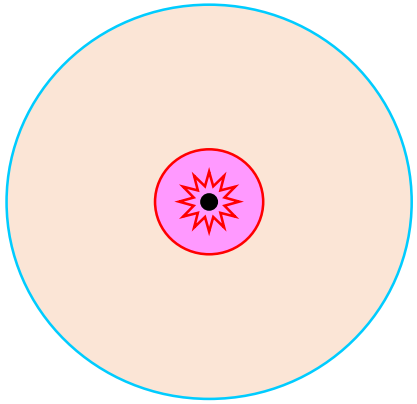

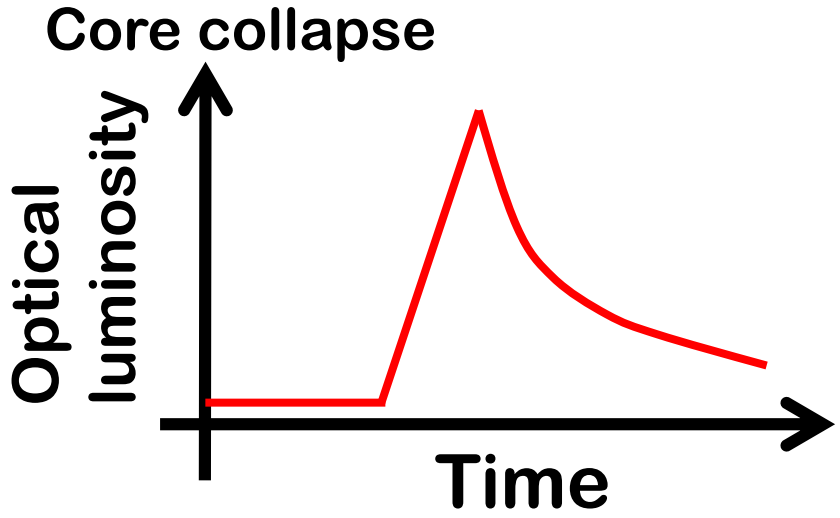

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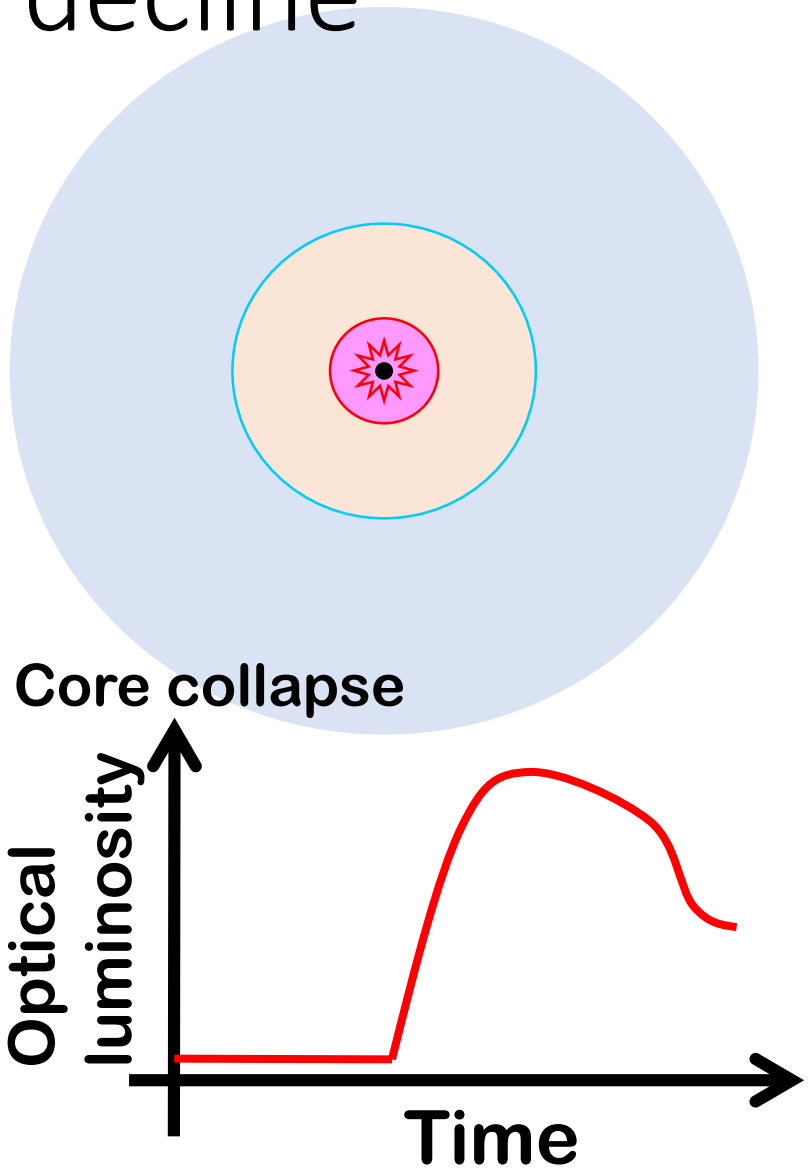
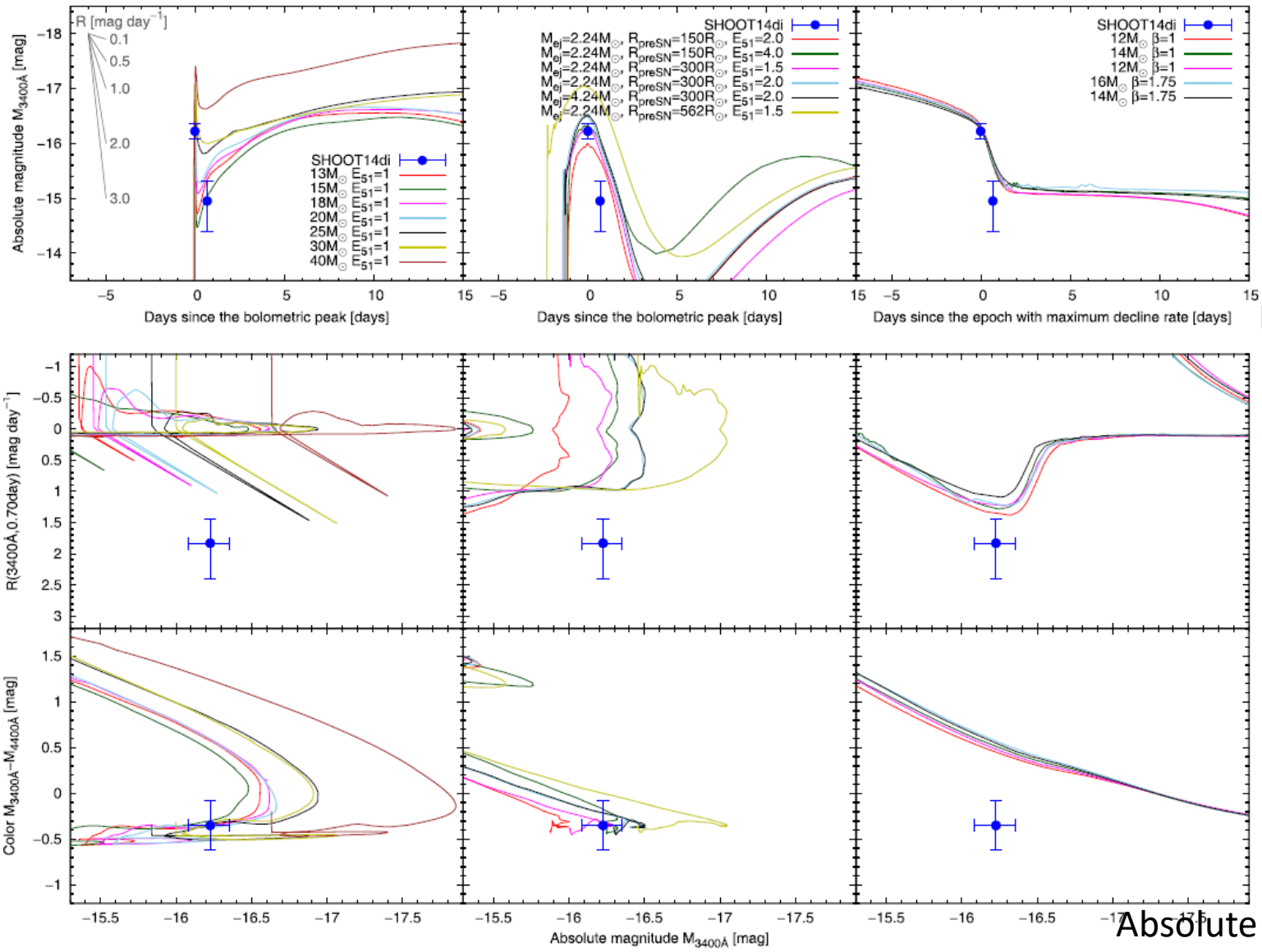


Comparison with published theoretical models

Shock breakout at stellar surface (NT+11)

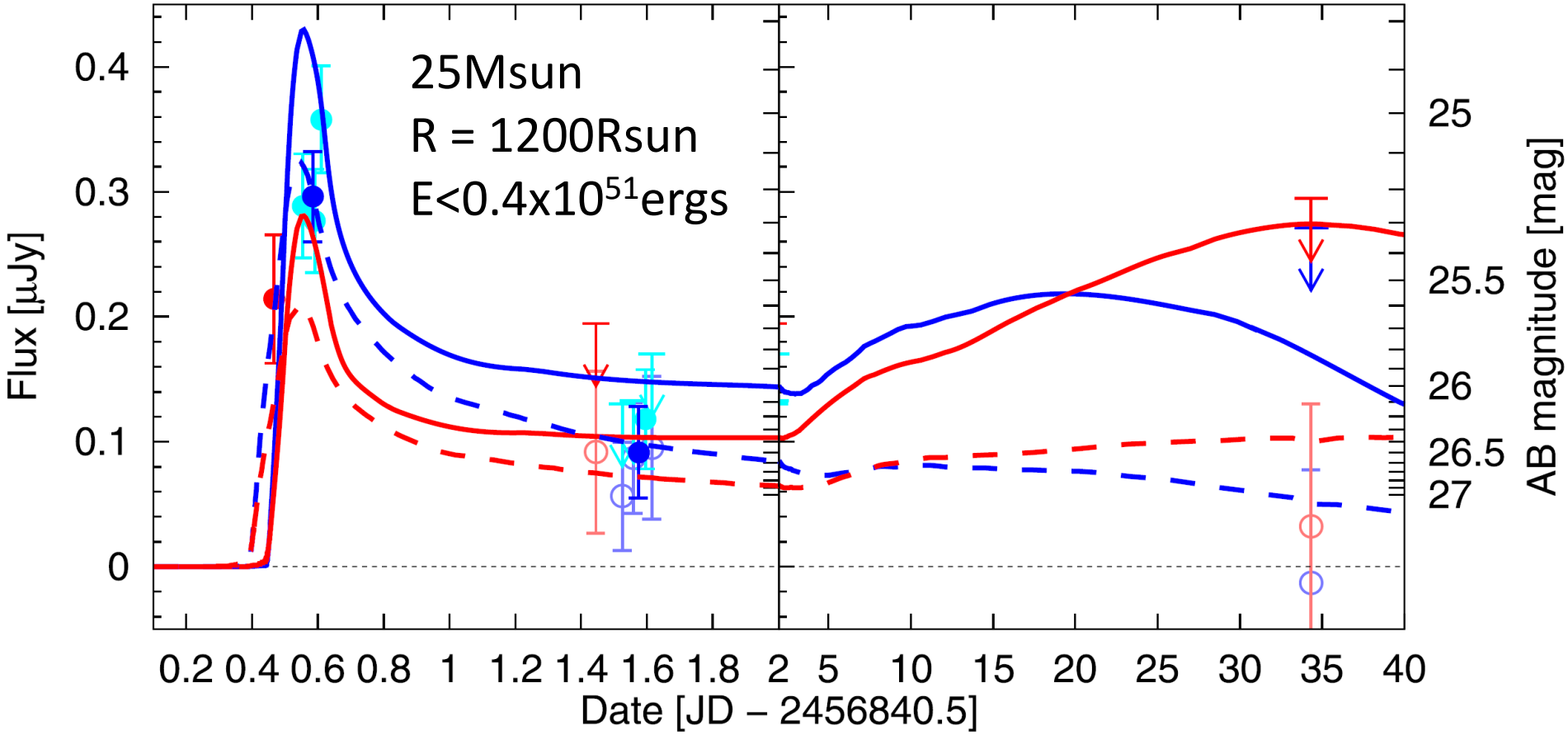
Cooling envelope (Tsvetkov+12)

Shock breakout in dense CSM (Moriya+18)



A shock breakout at the stellar surface of a low-E SN explosion

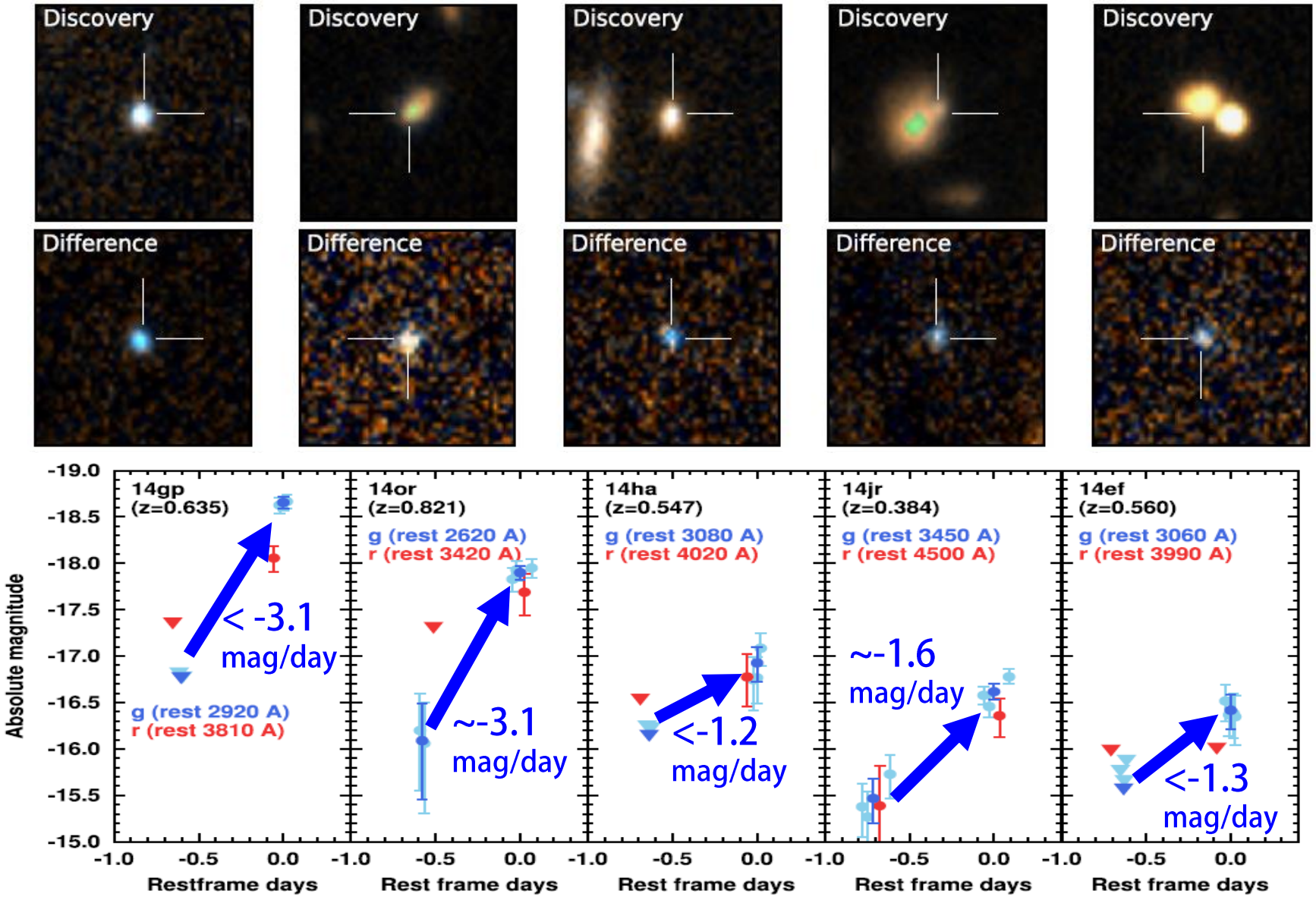
Metallicity of the host galaxy is 0.1-0.3Zsun.



Rapidly rising transients

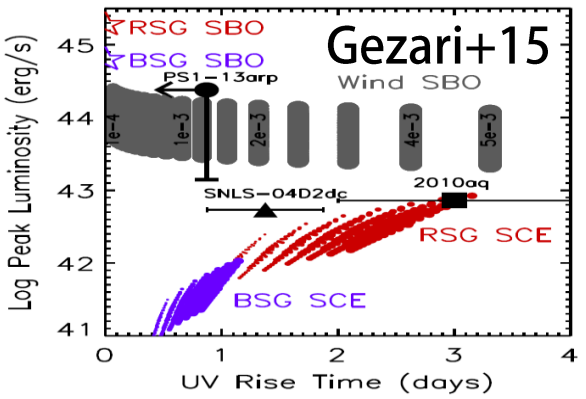
(Tanaka, NT+16, ApJ, 819, 5)

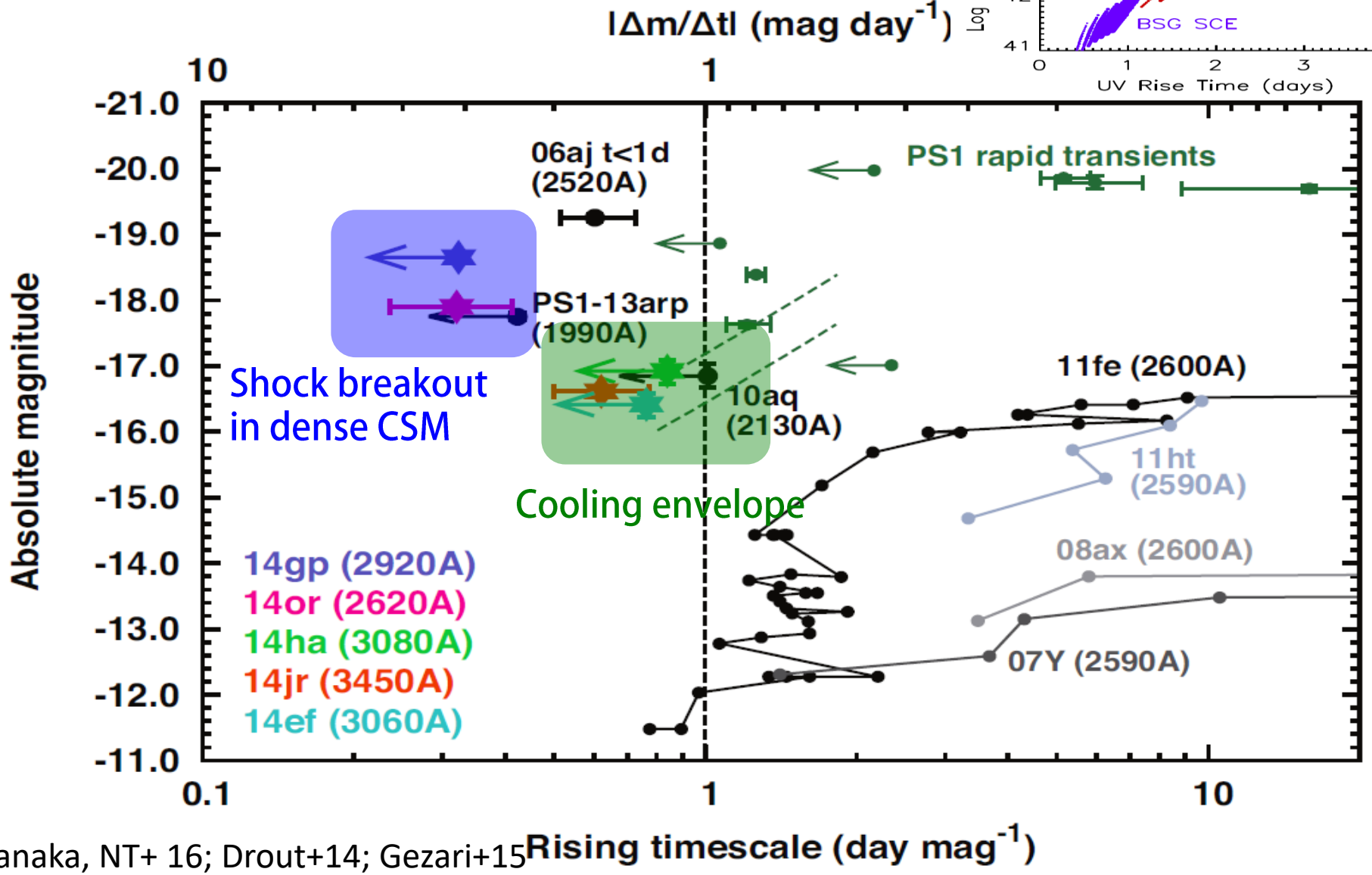
Rapidly rising transients



Tanaka, NT+ 16

Rising time scale





Tanaka, NT+ 16; Drout+14; Gezari+15

Rate of rapidly varying transients

Event rate: $R = 1/\tau\Omega V_{\rm max}$ Schmidt 1968; Eales 1993

$$\tau V_{\rm max} = \frac{1}{4\pi}\sum_{\rm field}\int_0^{z_{\rm max}} \max\left\{\tau_{\rm tran}, \frac{\tau_{\rm obs,field}}{1+z}\right\}\frac{dV}{dz}dz$$

1 rapidly declining transient and 5 rapidly rising transients (|dm/dt|>1mag/day)

~1 x 10^{-4} /yr/Mpc^3 NT+19

~6 x 10^{-5} (τ/1day)$^{-1}$ /yr/Mpc^3 Tanaka, NT+16

c.f. CCSN rate: (3-7) x 10^{-4} /yr/Mpc^3

High Cadence Transient Survey (HiTS) with CTIO/DECam (Forster+18)

26 rising transients (24 transients are rapid |dm/dt| > 0.2mag/day)

Detection efficiency: 28 % for low M_{dot}, 72% for high M_{dot}

1/5 of CCSNe could have a shock breakout at the stellar surface

Summary

- High-cadence transient surveys are performed in openuse and SSP programs.
- The high-cadence survey can prove the final fates of massive stars. The HSC observation probes them at **high redshift** and **low metallicity**.
- Our survey found 1 rapidly declining and 5 rapidly rising transients. **Declining transients** are also important.
- The fractions are roughly consistent with those from HiTS with CTIO/DECam. However, it is still **small** statistics. We need to increase the number of sample.