A rate study of Type Ia supernovae with Subaru/XMM-Newton Deep Survey

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Abstract

★ Our goal

Type Ia supernova rate at high redshift (z > 1.0)

★ Method

Classification of SNe → SNe Ia or CC SNe (Ib/c or II)

→Using light curves

★ SXDS Observations (Morokuma+2008a)

~1000 variable objects in SXDF (Subaru/XMM-Newton Deep Field)

(They include all of SXDF variable objects in 2002,03 and 05.)

→ ~200 are SN-like objects (found in 2002)

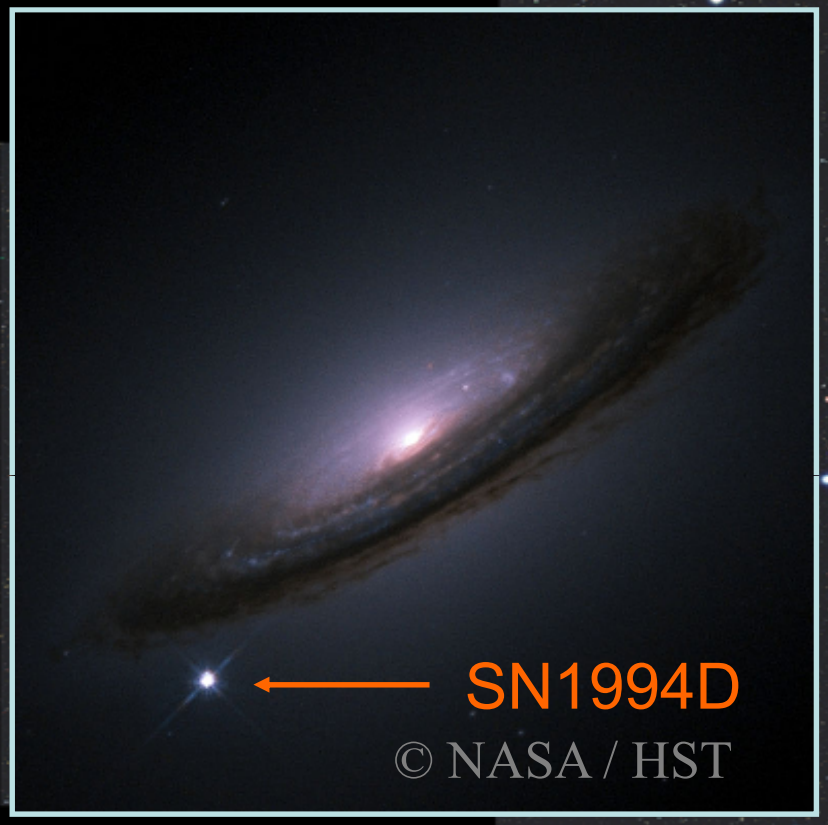
→ 50 SNe Ia (SXDF = 5 fields of view of Subaru/S-Cam)

★ Rates

Obtained SN Ia rates gradually increasing in higher redshift


Introduction

Type Ia supernovae



★ Unique properties

- Very bright (M_B~ -19 mag)

→ Observe SNe Ia at high-z (z~1)

- Very similar

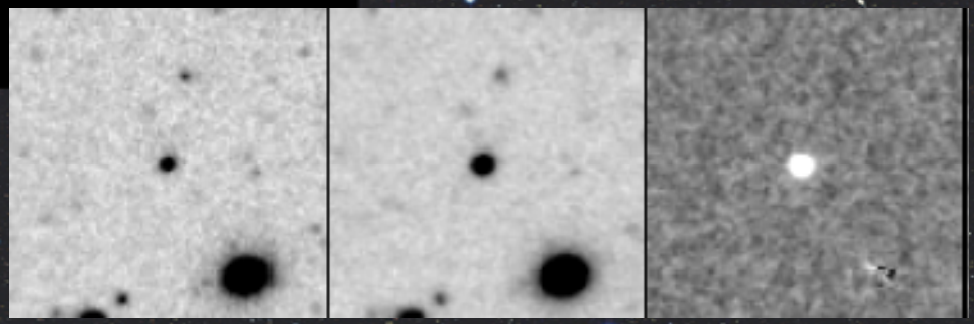
→ Every SN Ia has a similar light curve and a spectrum.

Type Ia supernovae are standard candles in the universe.
→ SNe Ia are useful to measure cosmological parameters !!

How to detect SNe ?

(1) Detect variable objects with repeat imaging observations

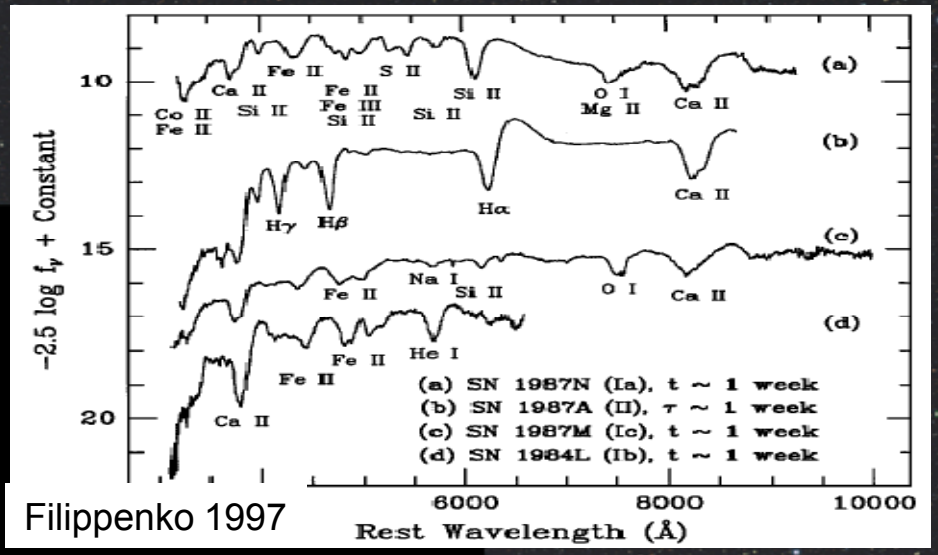
Example of a SN Ia at z=0.606 (Morokuma+2008)



Reference　Another Image　Subtracted Image

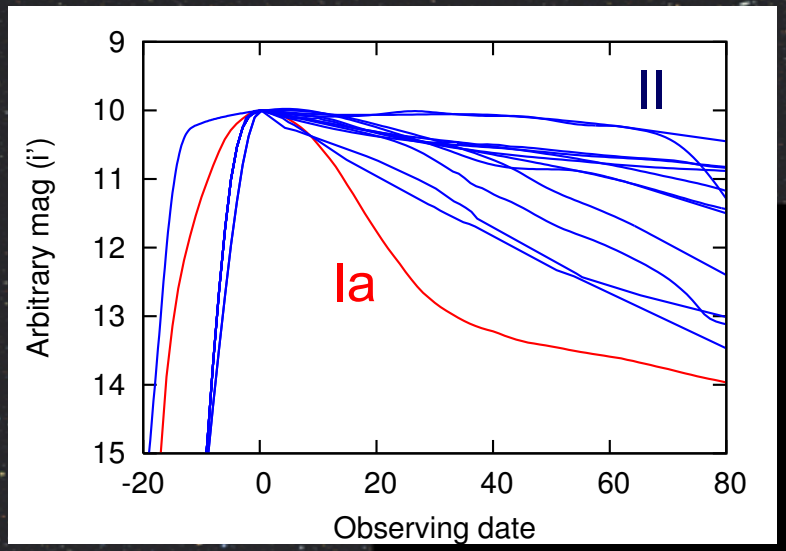
(2) Classify SNe

① From Spectra (Confirmed method)



Filippenko 1997

② From Light Curves (Our Method)



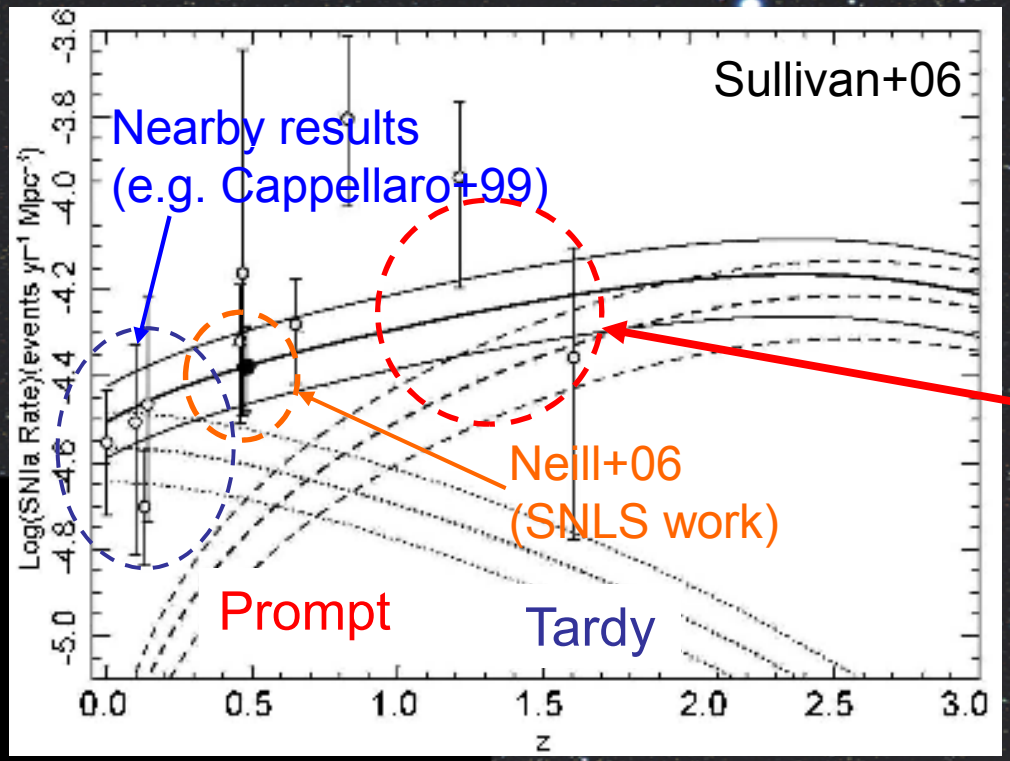
SN Ia rate study

Motivation

SN Ia rate is the clue of progenitors of SNe Ia

Recently, wide delay time distribution of SNe Ia are shown by rate studies.

("Delay time" → time interval between star formation and SN explosion)



★ Two populations of SNe Ia ?
(Mannucci+2005, 2006)

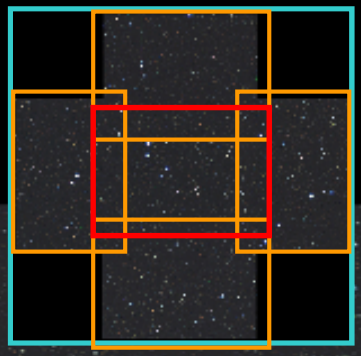
"Prompt" : Short delay time (~0.1-1Gyr)
"Tardy" : Long delay time (~1-10Gyr)

High-z rate is important!!
It is difficult to measure that from current SN surveys
→ SXDS data set is useful

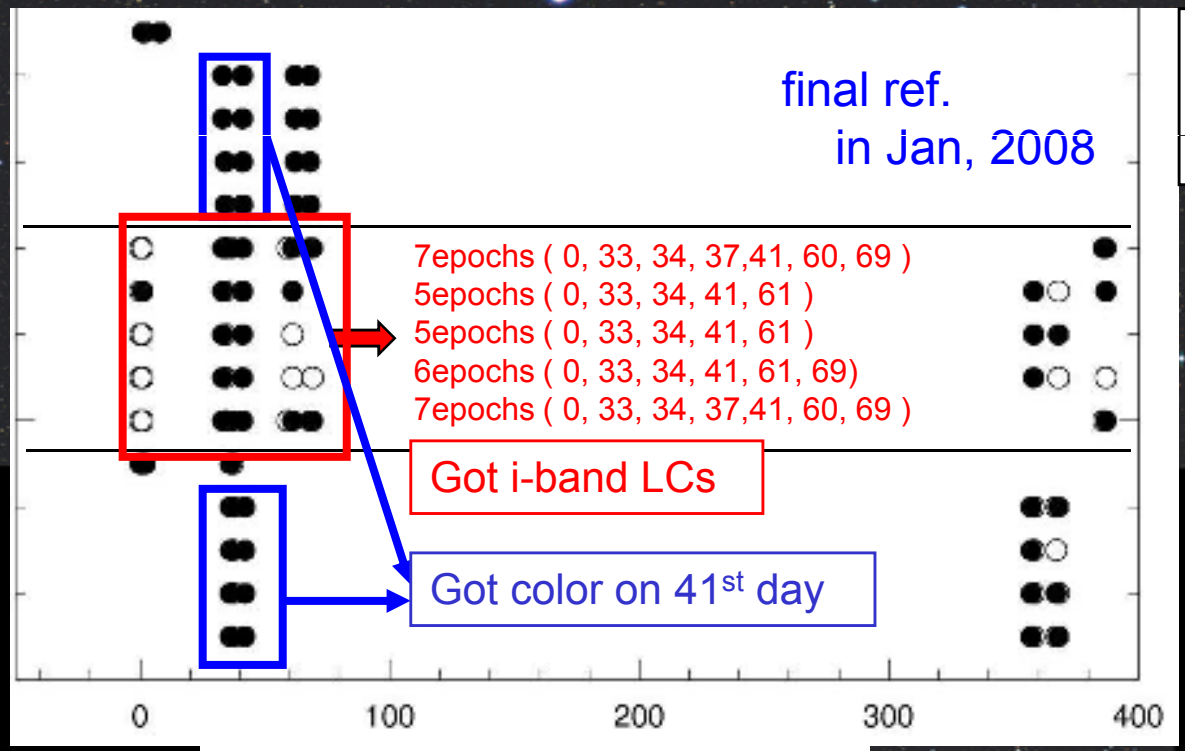

Our work

SXDS Subaru/Suprime-Cam observations

SXDF consists of 5 fields of view of Suprime-Cam
= 0.918 deg^2



Observing Date **2002.9.30.~12.10. = about 70days**
(i obs.) 5~7 epochs → Light curves
(R and z obs.) 2~4 epochs → Color



● **Exp.time>30min**
○ **Exp.time<=30min**

Method

$$N_{exp}(z) = \int \frac{r_V(z)}{1+z} CT(z)V(z)dz,$$

① Select SN-like light curves → Remove AGN, variable stars

Criteria
① Bright in 2002 and under detection limit in 2003 and 2005
② More than 3 points of light curves are >5σ limit

② Classify by LC fittings → Remove Type II supernovae

Type Ia supernovae are identified

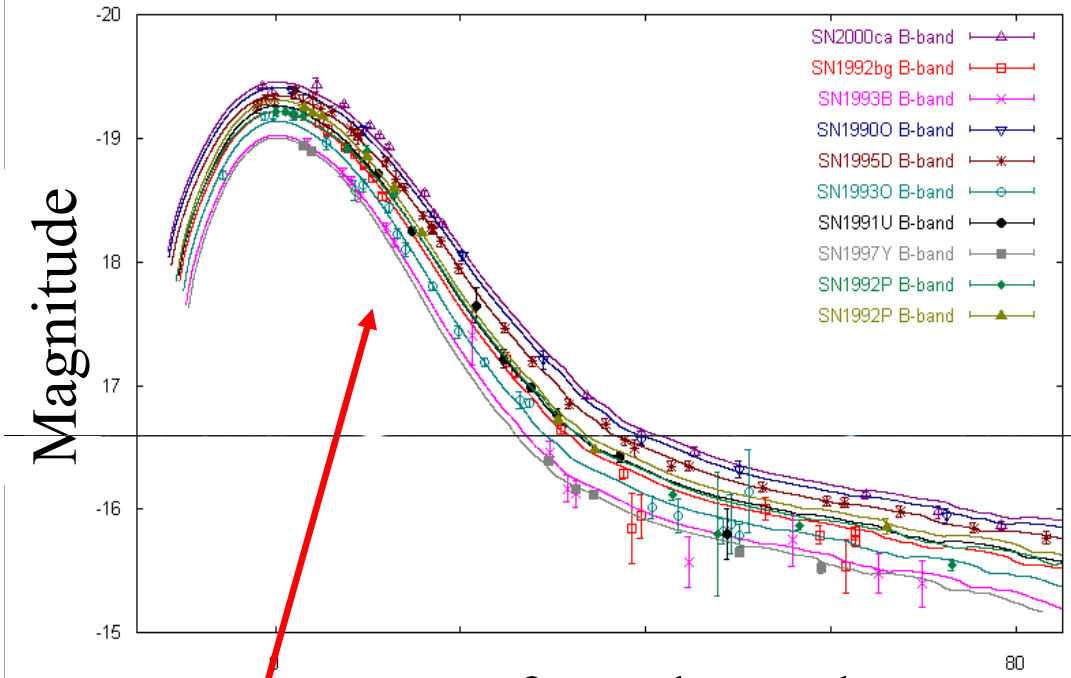
③ Correct the number of Type Ia supernovae

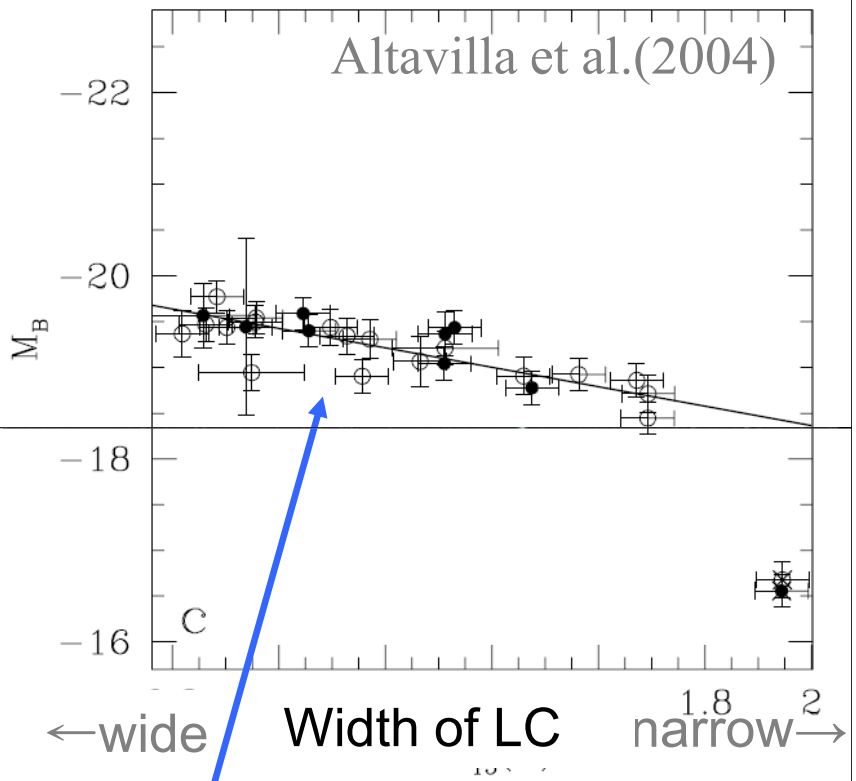
④ Time & Volume calculation

SN Ia rate


Results of LC fittings

Light curve





Every SN Ia has a similar LC

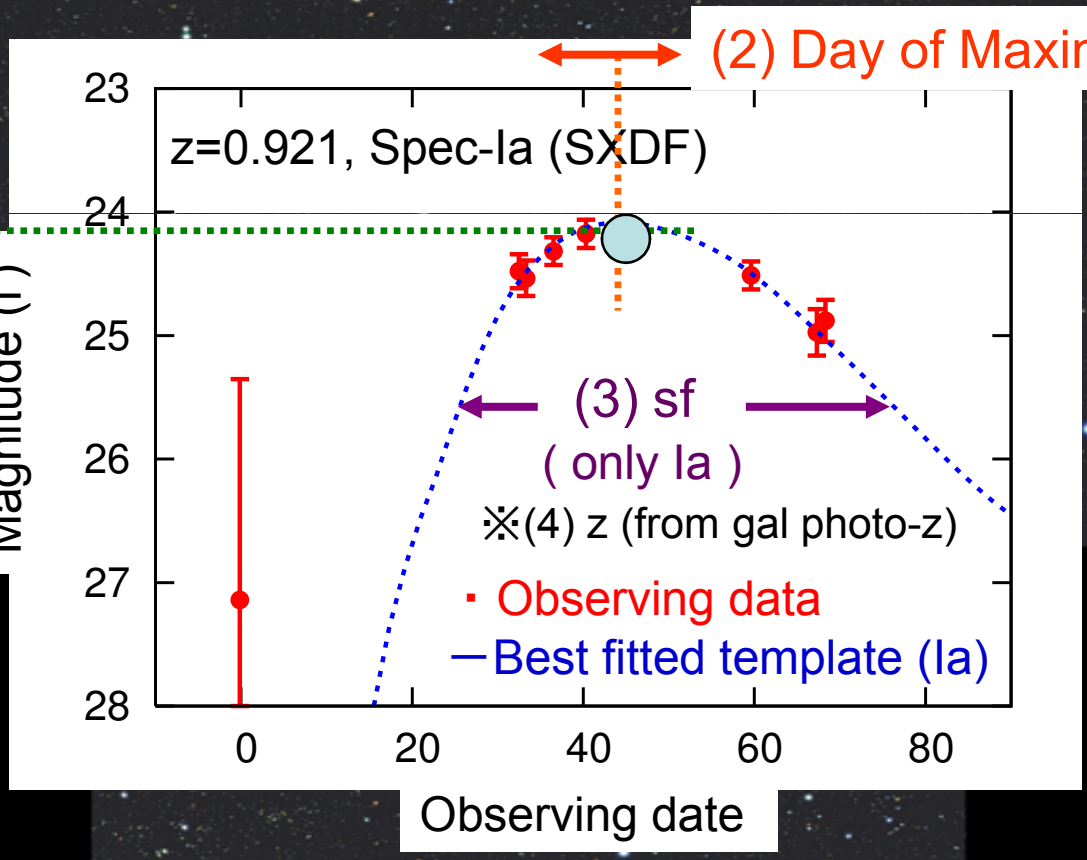
The relation of peak magnitude and width of LC

Width of LC = Stretch Factor

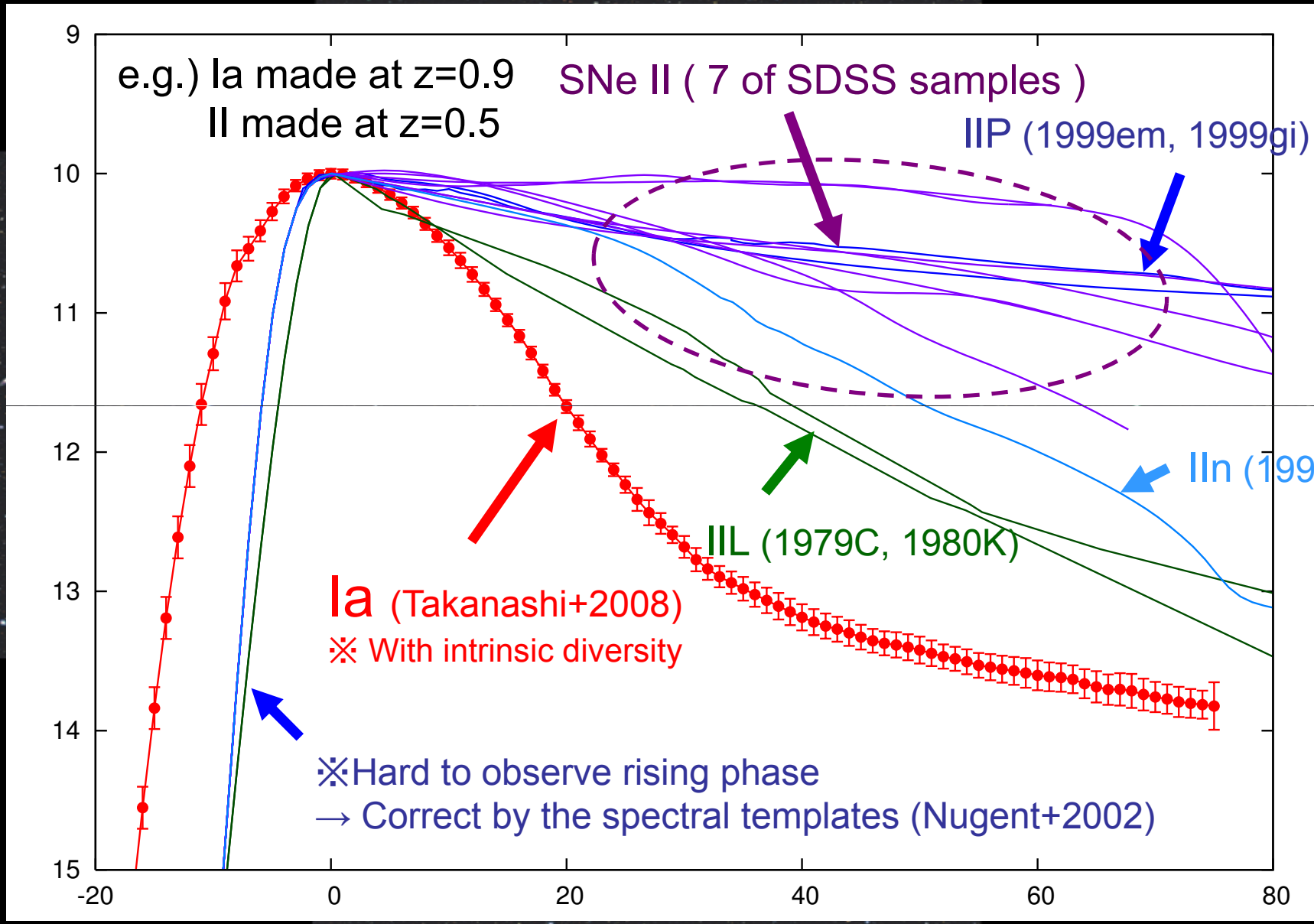
LC fitting Method

★ We classify SNe into type Ia and type II by fitting observed LCs with template LCs.

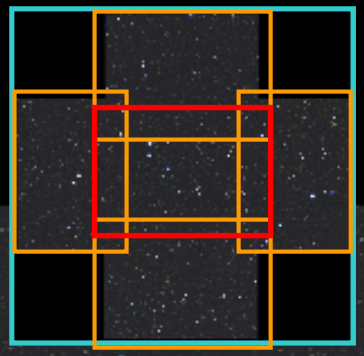
【 χ^2 fitting 】 Reduced $\chi^2 = \sum_n \left(\frac{\text{Obs.} - \text{Temp.}}{\text{error}} \right)^2$ / f.o.d.



Template(1 of Ia and 12 of II)



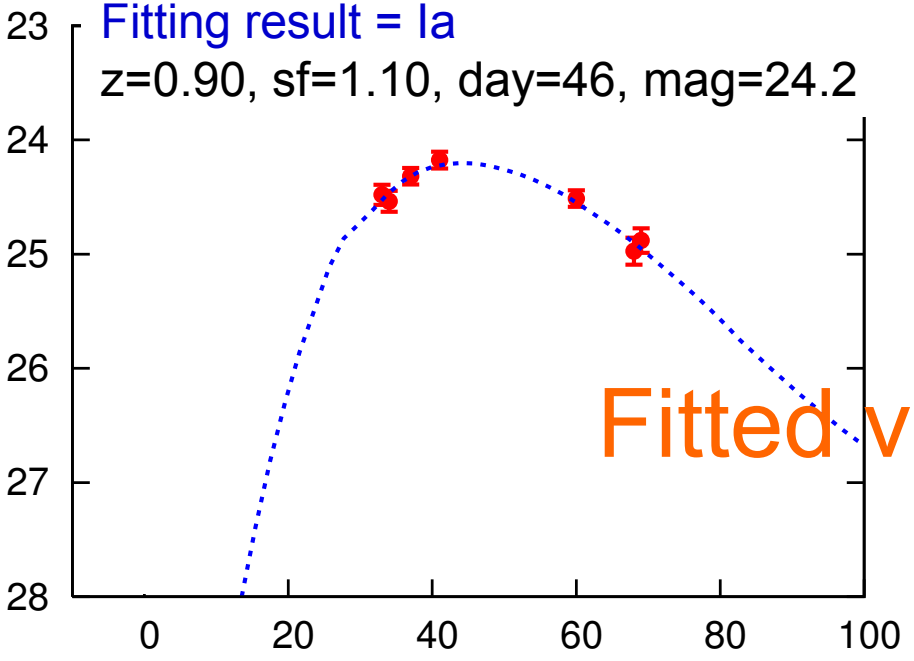
SNe in SXDF



~200 SN-like objects were discovered in 2002.
→50 are SNe Ia. The others are SNe II or AGN
(not yet classified)
All of 9 confirmed spec-Ia samples are identified as Type Ia by the LC fitting.

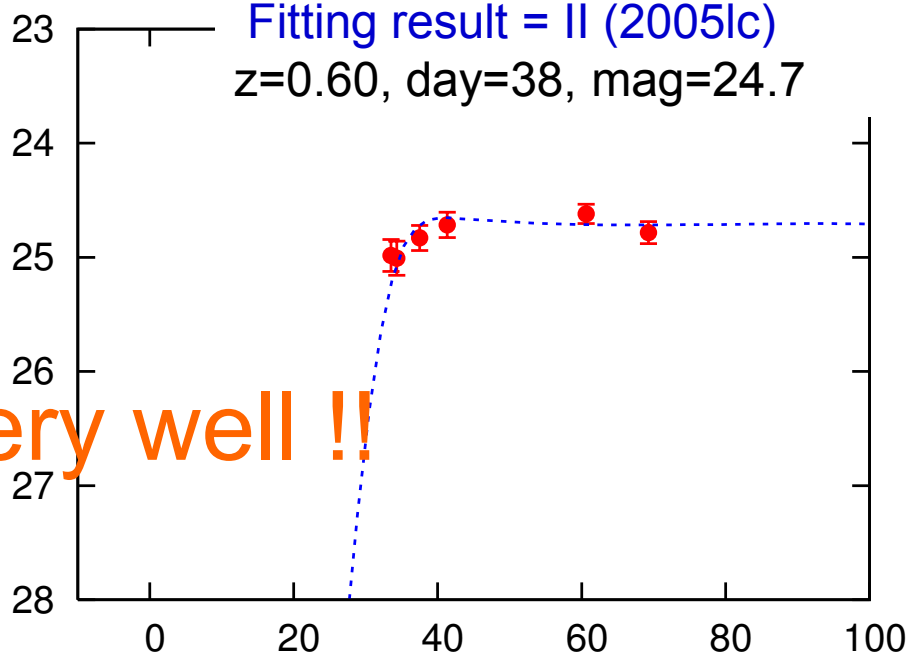
○ Type Ia

Ex.1 1-175 (spec-Ia)
z=0.921 i' max = 24.16



⊙ Type II

Ex.2 1-045 (?)
z=0.625 i' max = ?



Fitted very well !!

Raw number of SNe Ia in SXDF

	0.2-0.6	0.6-1.0	1.0-1.4	1.4-1.8
SXDF(50)	6	25	19	—
Poznanski+07(22) (SDF)	0 (<0.5)	9 (0.5-1.0)	10 (1.0-1.5)	3 (1.5-2.0)
Dahlen+08(56) (GOODS)	8	25	20	3


Completeness and Contamination

Simulation

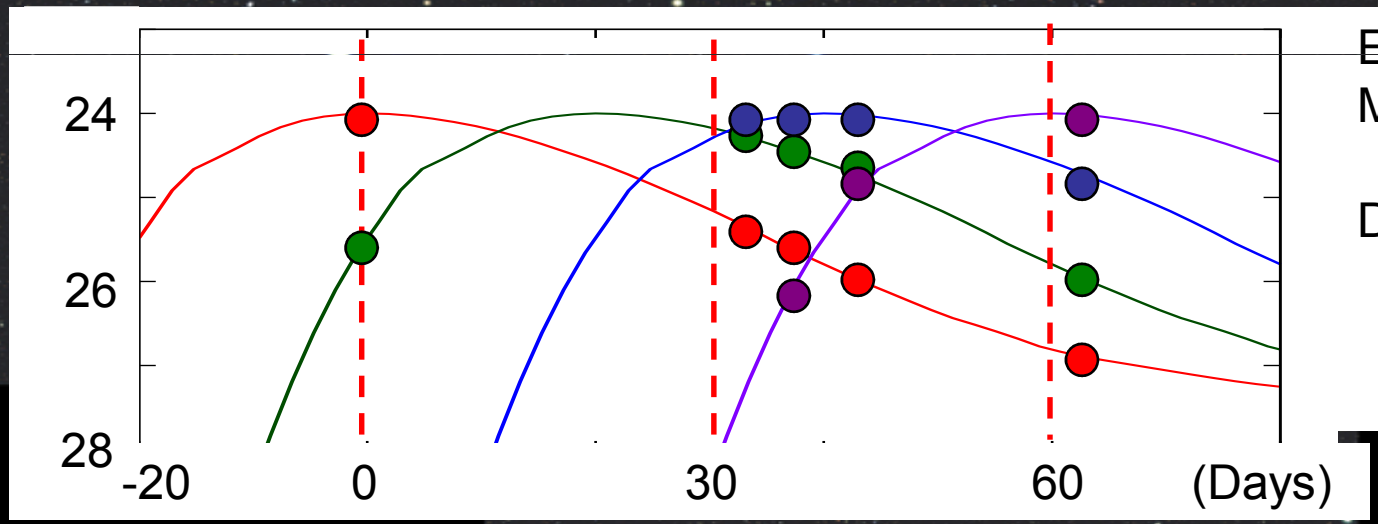
★ Make light curves in the observed i'-band using templates

- High-z SNe Ia (z~1). → observed i' = rest U - B
- Limiting magnitudes ~ 26 mag (5σ, 3600 sec exposure)
- Maximum magnitudes of SNe ~ 22.0~25.5 mag. → z=0.3~1.4

★ Input four parameters

Redshift, Maximum Magnitude、Date of Maximum、Stretch Factor

★ Example of artificial lightcurves



Make ~100,000 light curves of SNe Ia and II

→Check "Completeness" (ID confidence) and "Contamination"

Correct SN number from Contamination

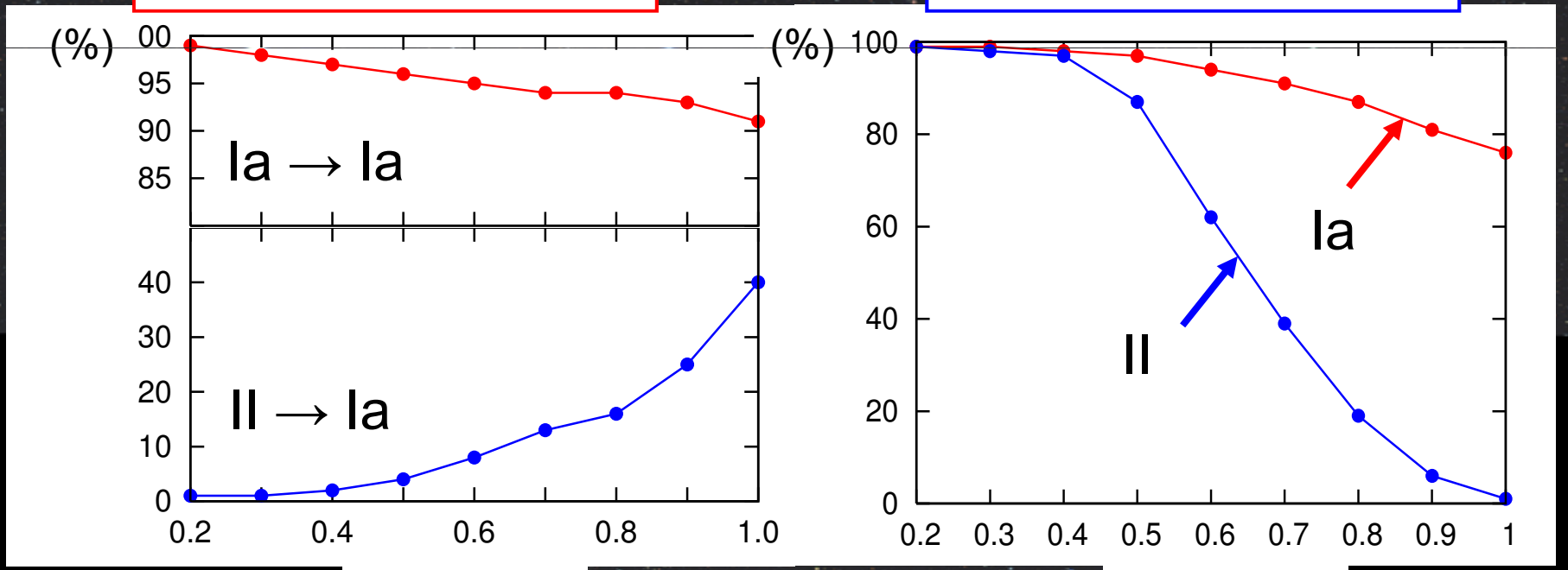
Type II rate (∝SFR) (Botticella+07)

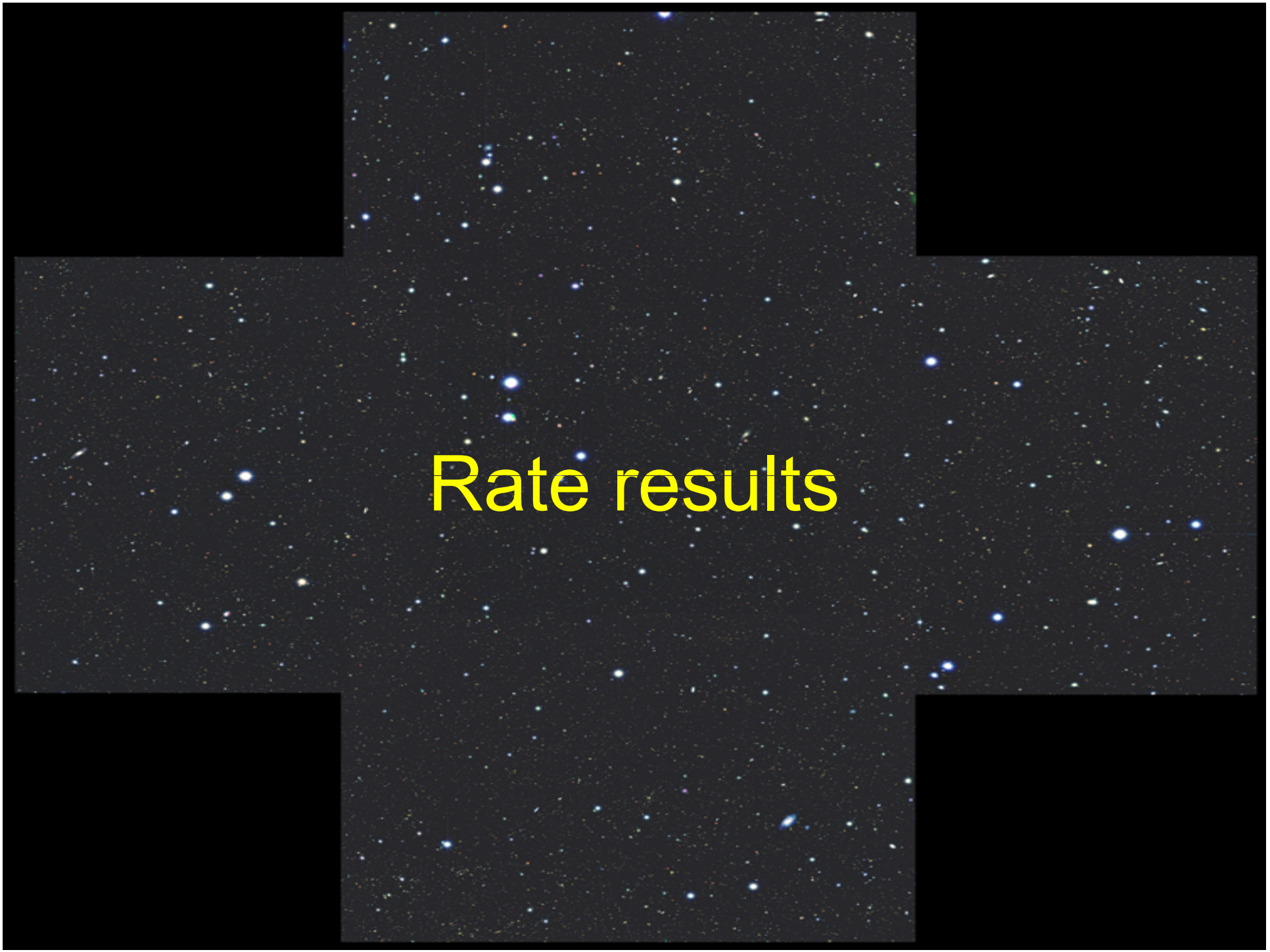
$$f(z) = \frac{0.55 \times 10^{-4}(1+z)^{3.9}}{r_0(1+z)^{\alpha}} \times \frac{LC_{II}}{LC_{Ia}} \times \frac{\epsilon_{II}}{\epsilon_{Ia}}$$

Type Ia rate (Fit later)

LC fitting accuracy

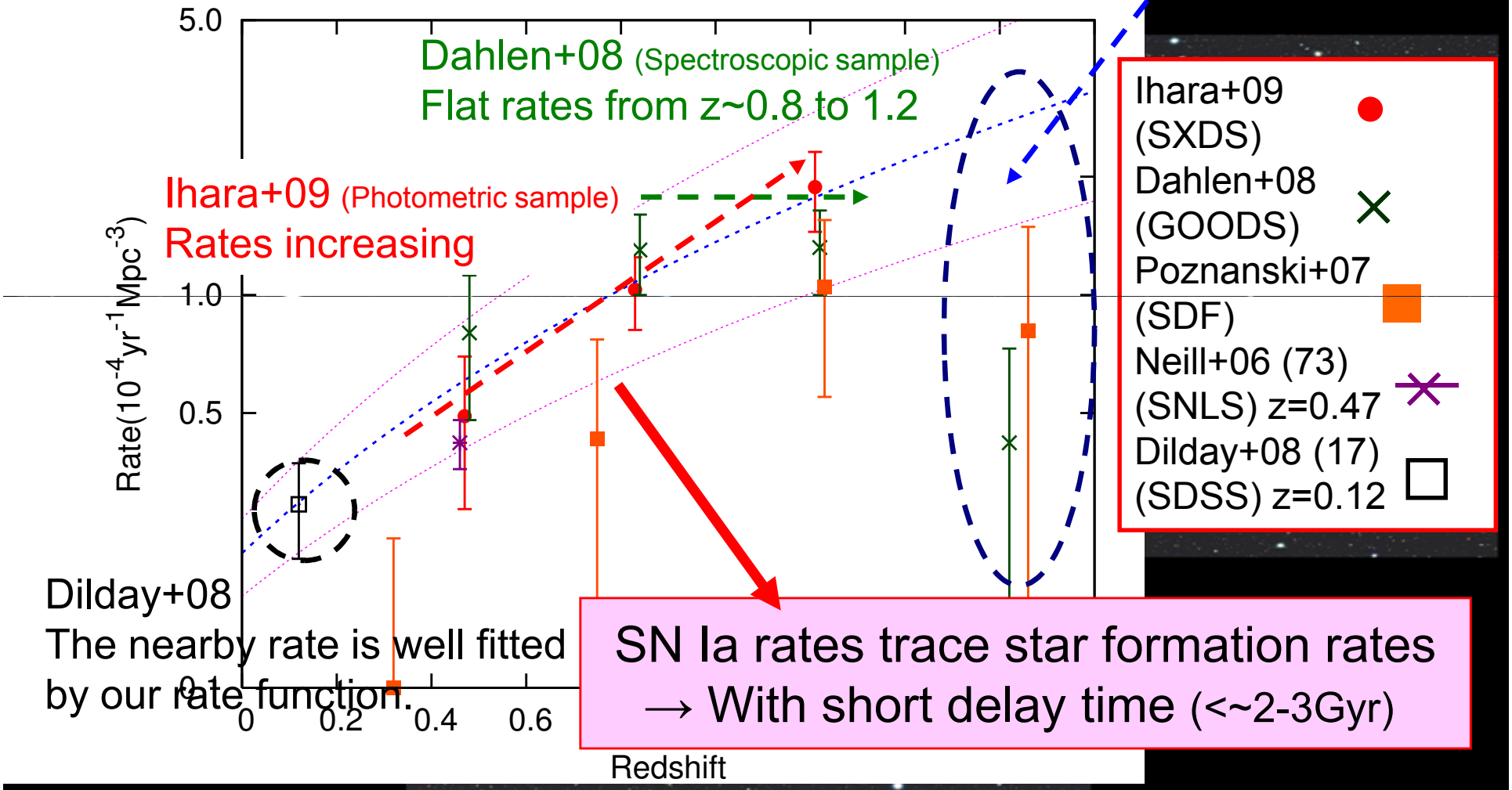
Detection efficiency




Rate results

Compared with the other results

At the highest redshift,
Not obtained by our results



Summary & Future Work

★ SNe Ia in SXDF

・We classified SNe in SXDF by light curve fitting.

・Out of 50 SNe Ia, 19 SNe Ia are high-z samples (z>1).

→ We can get high-z SNe Ia with a ground telescope (SUBARU) comparable by the search by HST (Dahlen+2008)

★ Rates

・We obtained the rates similar to Dahlen+08,
but the rates in SXDF are increasing to higher redshift.

→ Existence of SNe Ia with short delay time (<~2-3Gyr)

(Future Work)

・Suprime-Cam z'-band survey is on-going (P.I.:Furusawa).
(But the weather condition was very bad until now…)

→ We expect to obtain highest-z SNe Ia at z>1.4.


Fin