木曽シュミット望遠鏡を用いた超新星shock breakout探査

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木曽シュミットシンポジウム

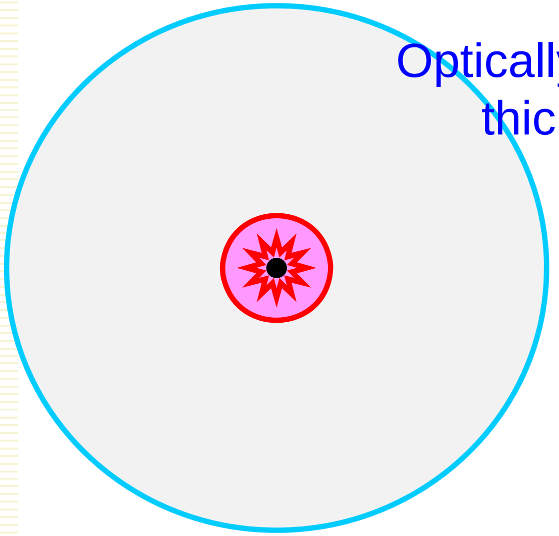
C: A. de Ugarte Postigo (ESO) et al.

Contents

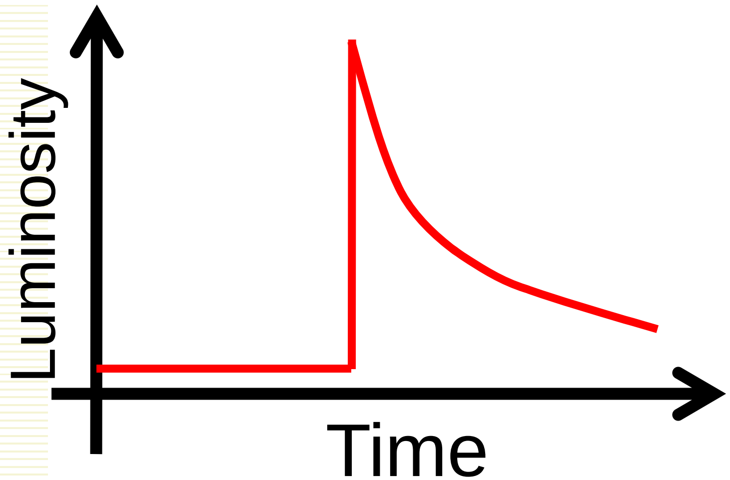
- **Shock breakoutとは?**
- 観測と理論モデル
- **Shock breakout survey with KWFC**

Reference
NT, Blinnikov, Baklanov, + 2009 ApJ 705 L10
NT, Morokuma, Blinnikov, + ApJ submitted

CCSNe & Shock breakout



Core collapse



Massive Star (>10M$_\odot$)

e^--capture SNe (8-10M$_\odot$)

Core collapse

Energy deposition

Shock formation

At the shock emergence,
a stored energy is released
as radiation.

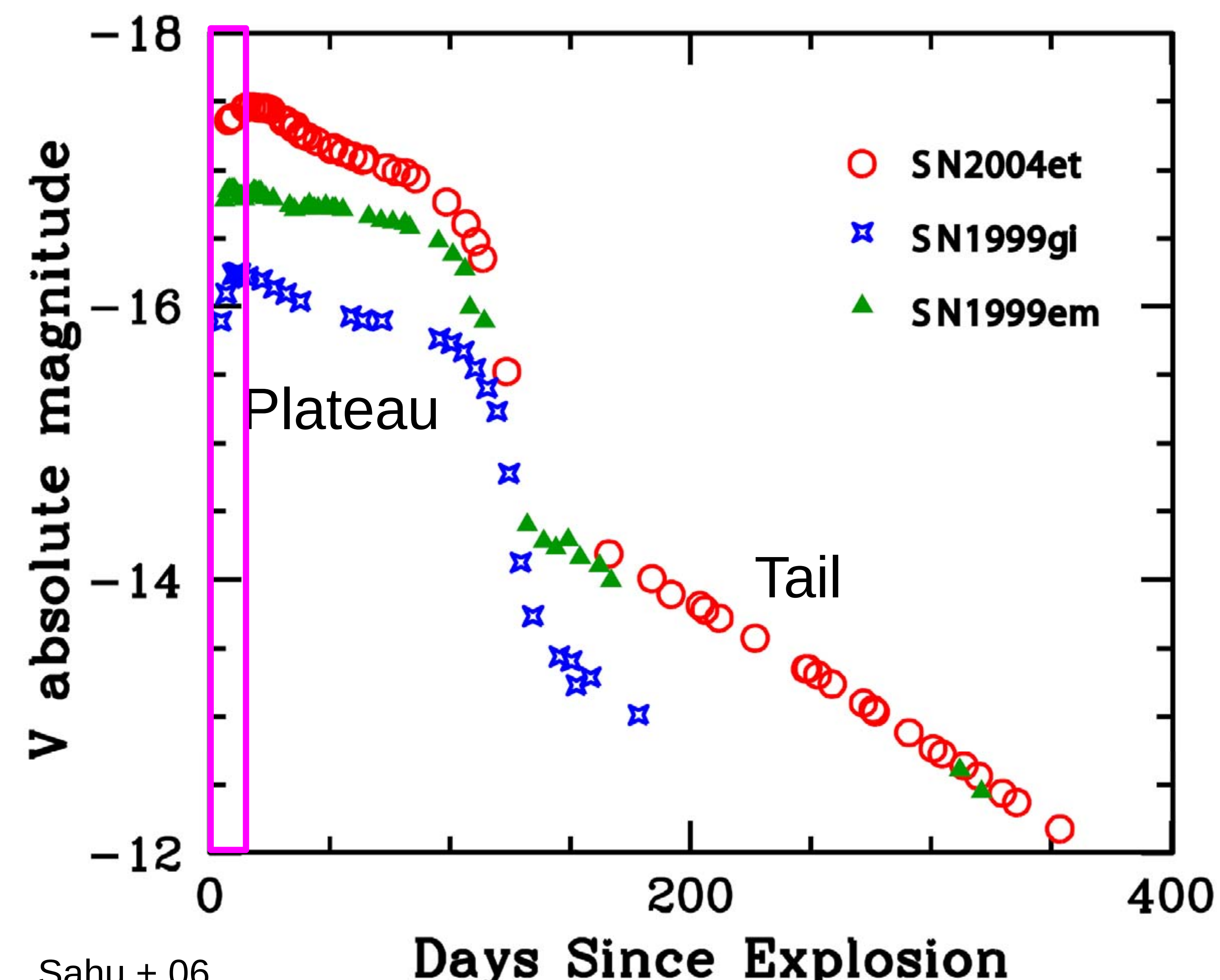
Spectra are quasi-blackbody

$$T \sim R^{-3/4}E^{1/4}$$

Multigroup radiation hydrodynamics code

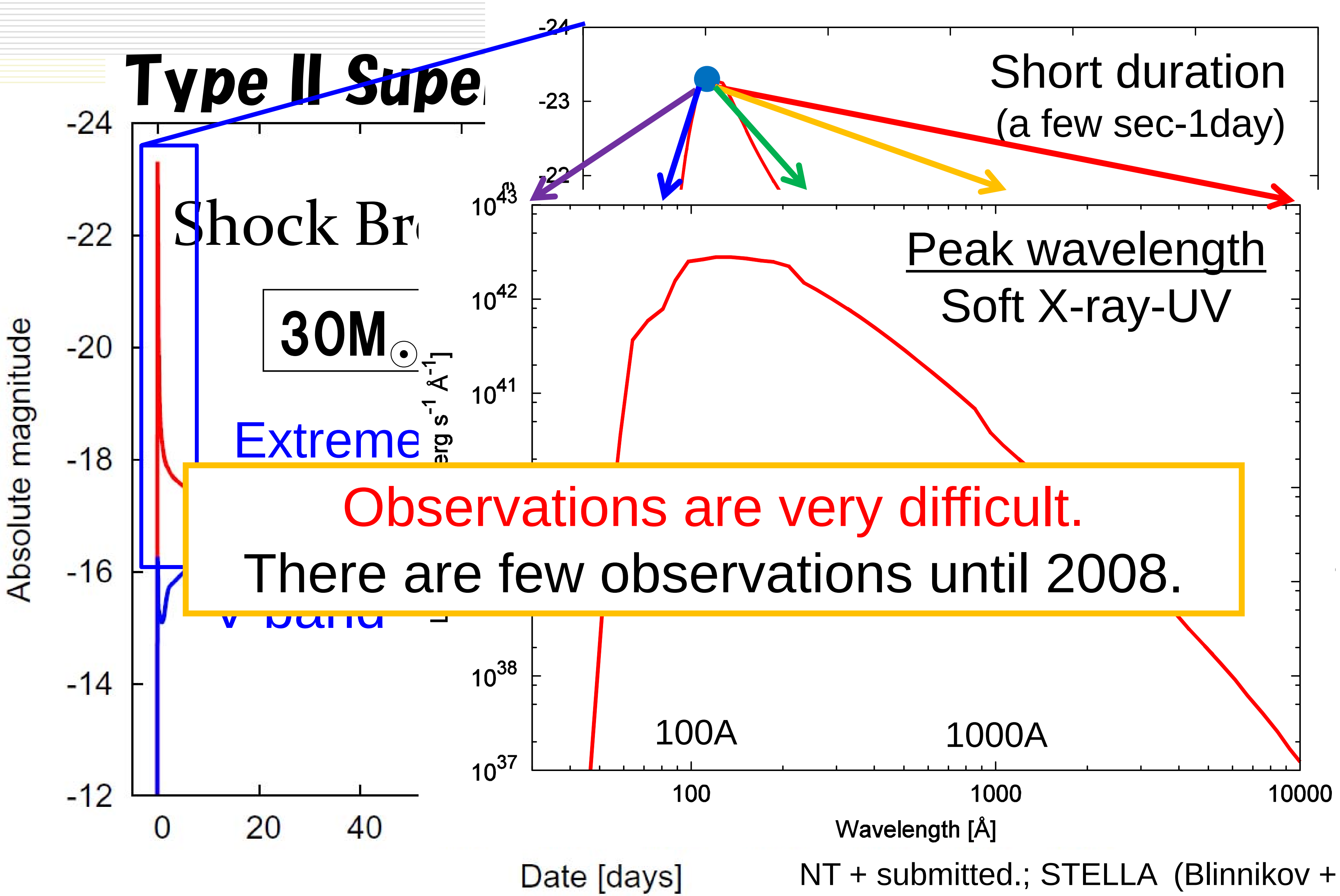
STELLA (Blinnikov + 98)

V-band LCs of Type IIP SNe



Sahu + 06

LCs of Type IIP SNe



Observations are very difficult.

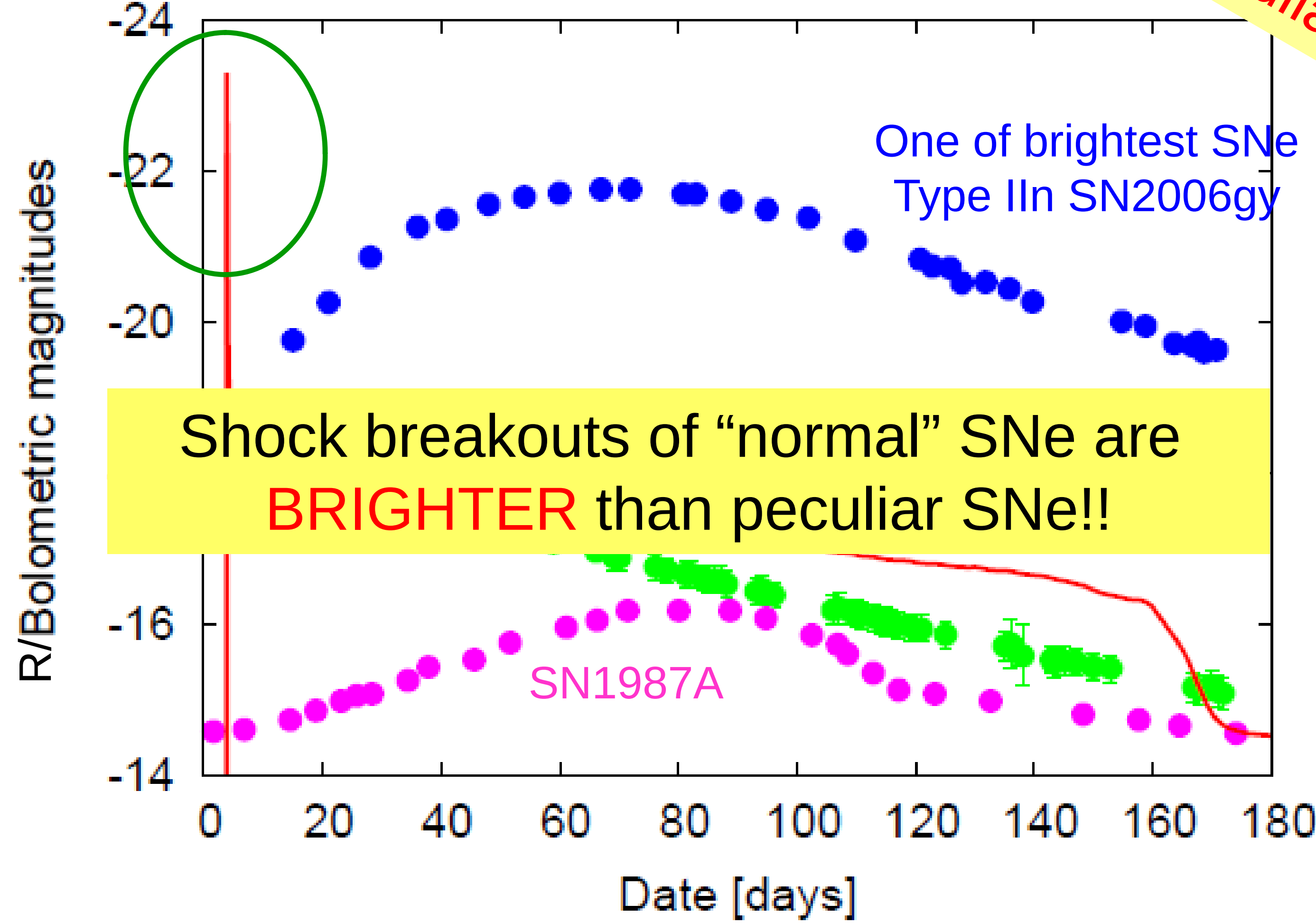
There are few observations until 2008.

NT + submitted.; STELLA (Blinnikov + 98)

Shock breakouts are bright!

This is a “peculiar” SN.

- **SN 2006gy (z=0.02: Smith + 08; Kawaba... NT + 09)**
  - M_R~-22 ($M(^{56}Ni)$~$15M_\odot$ or CSM interaction)



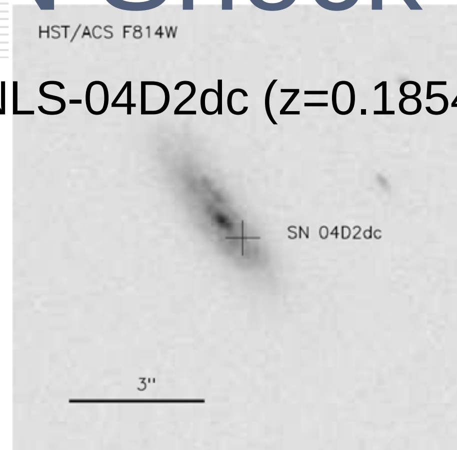
Shock breakouts of “normal” SNe are BRIGHTER than peculiar SNe!!

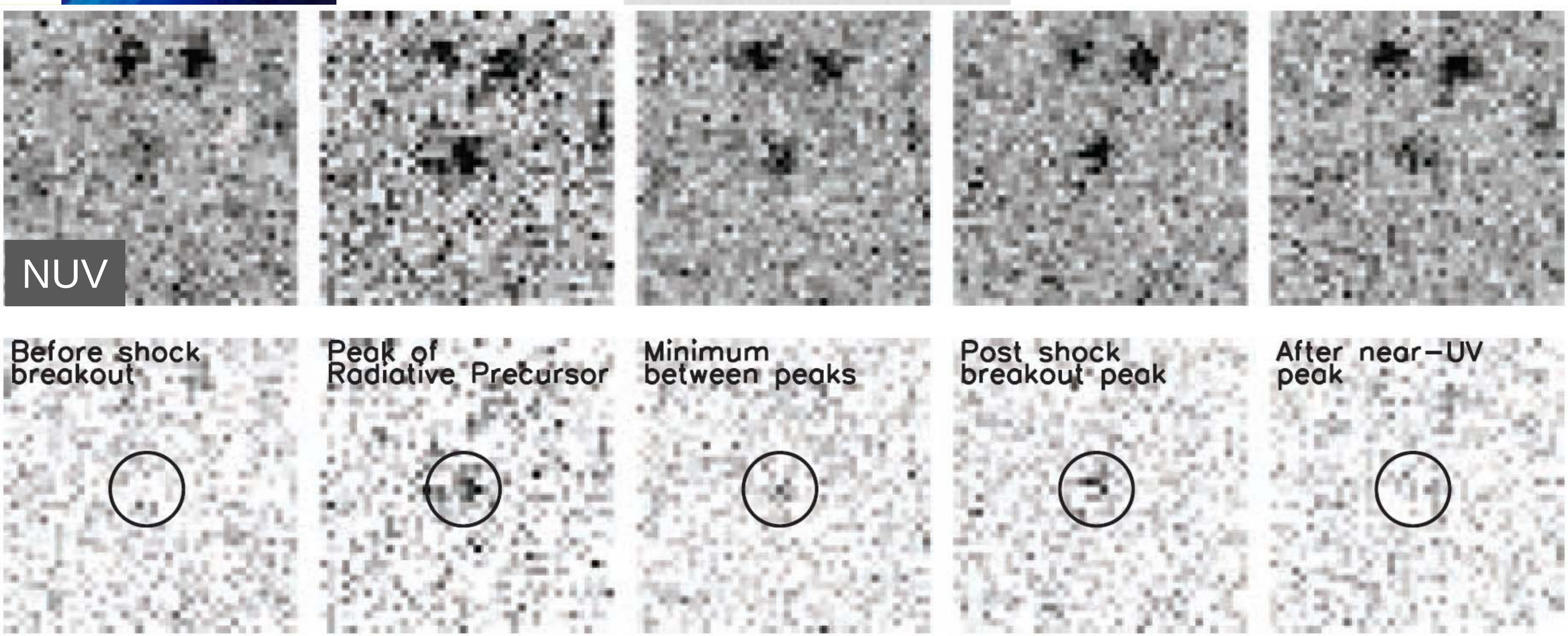
First observations of Type IIP SN Shock breakouts

SNLS SuperNova Legacy Survey

SNLS-04D2dc (z=0.1854)

Schawinski et al. 08
Gezari et al. 08

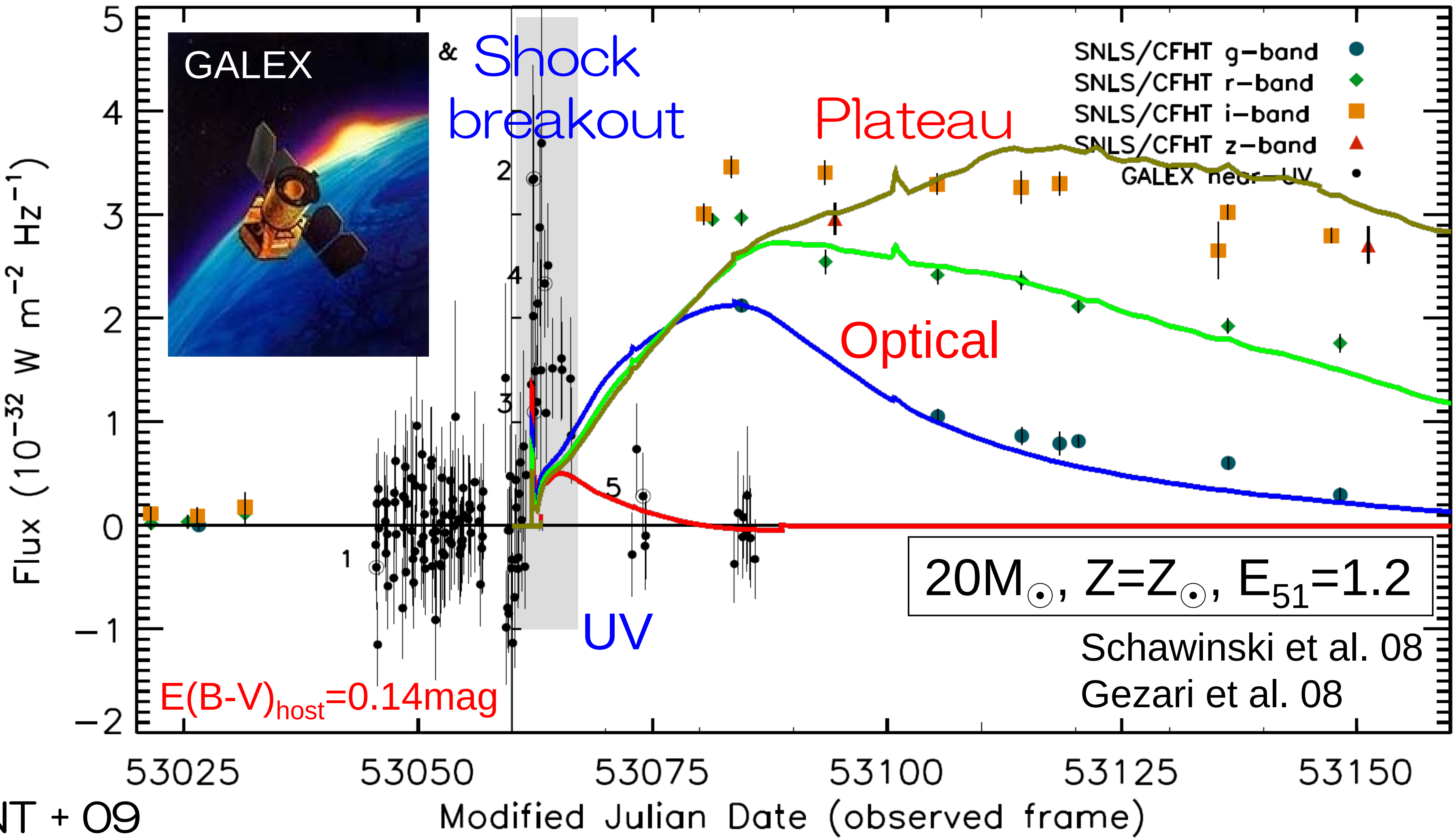




Shock breakouts of Type IIP SNe
—Observations and model—

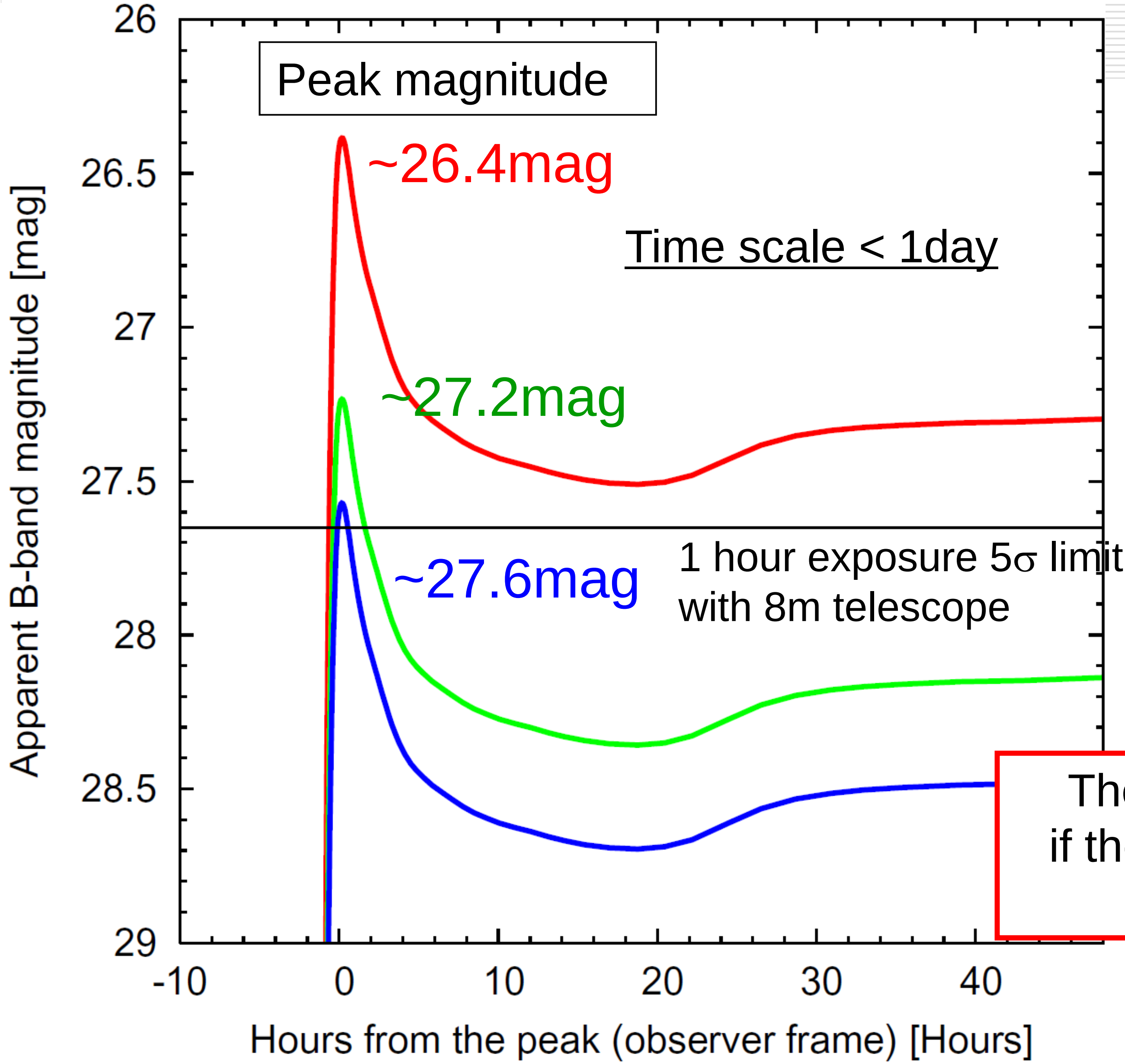
SNLS-04D2dc

SNLS SuperNova Legacy Survey



NT + 09

When the same SN takes place at high z,



SNLS-04D2dc

Redshift z=1

$E(B-V)_{Gal}$=0.02mag.

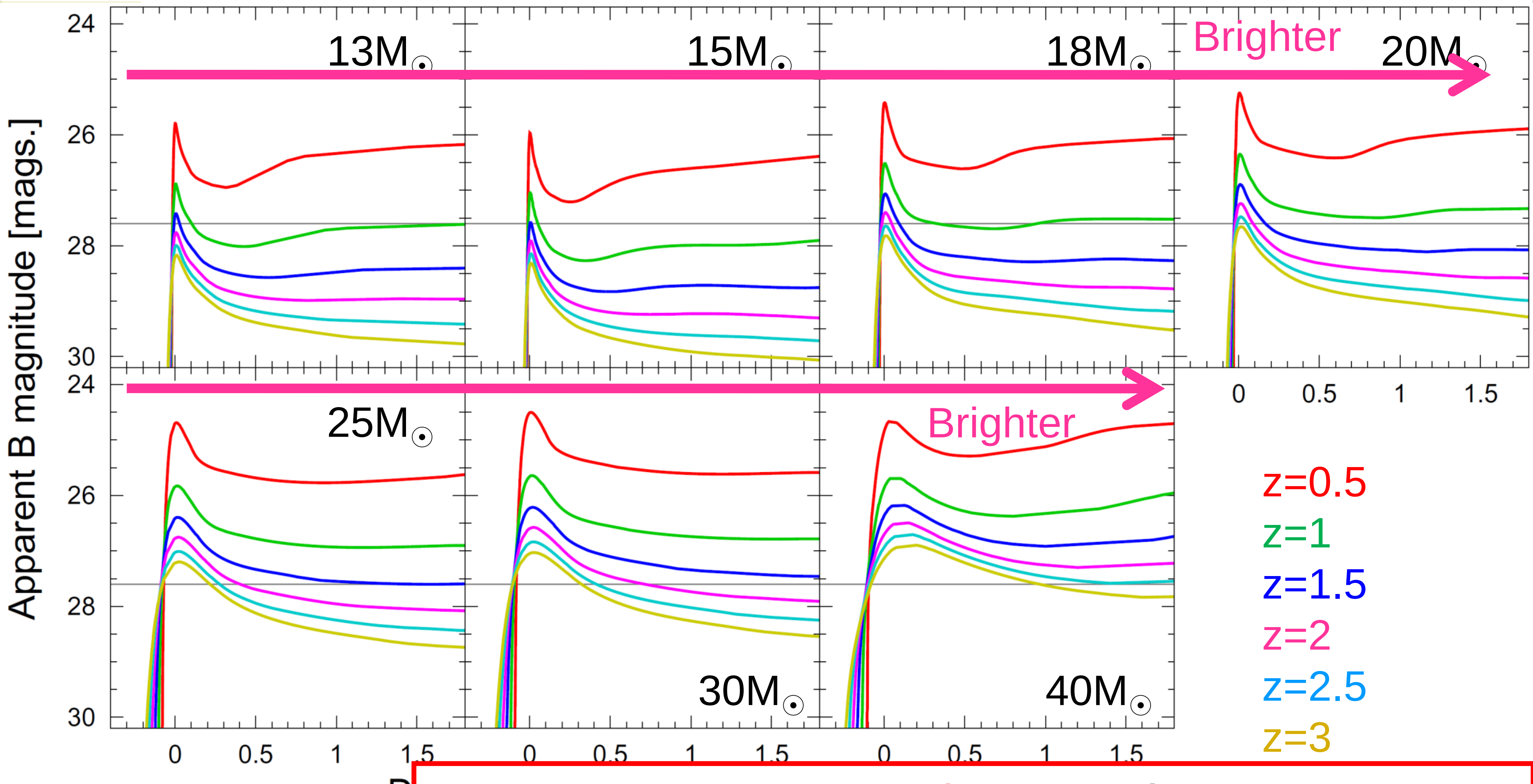
$E(B-V)_{host}$=0

$E(B-V)_{host}$=0.1mag.

$E(B-V)_{host}$=0.14mag.

The SN can be detected, if the extinction of the host galaxy is small.

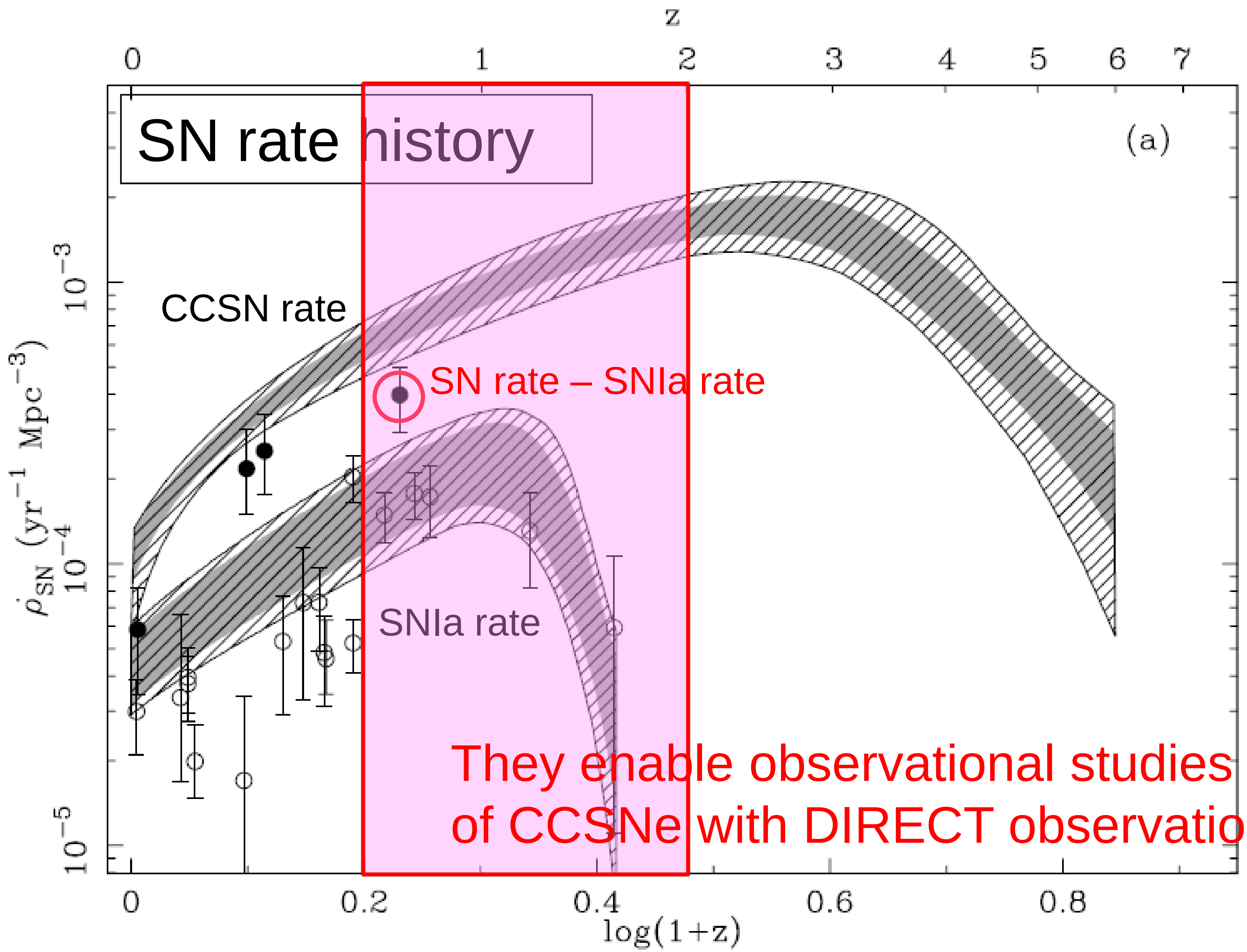
Theoretical predictions -B-band light curves-



More massive stars have apparently more luminous shock breakouts.

NT + submitted

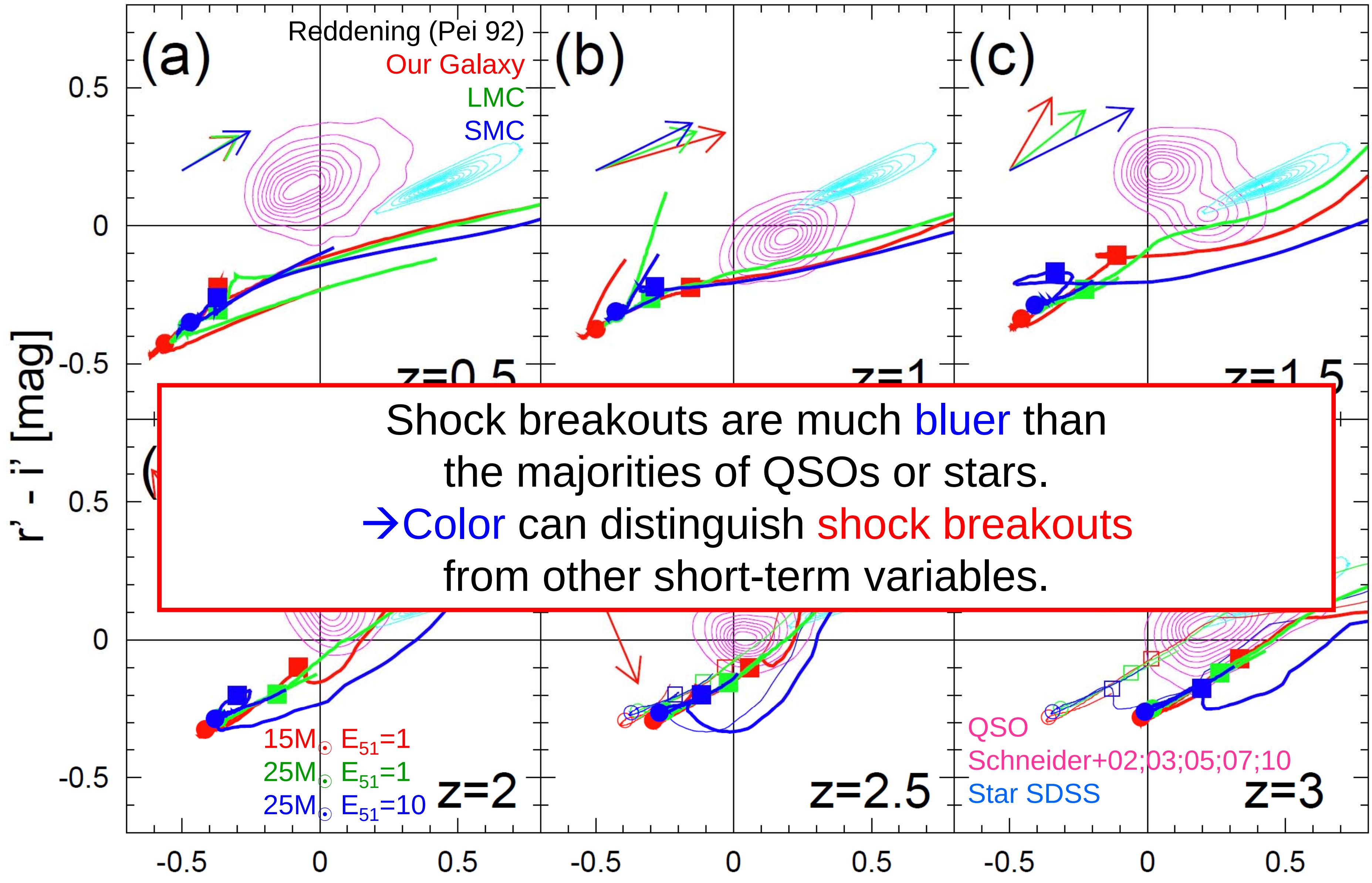
Shock breakouts reveal high-z CCSNe



They enable observational studies of CCSNe with DIRECT observations.

(Hopkins & Beacom 2006)

Identifying shock breakouts by colors



IGM absorption included (Madau95)

Summary of shock breakouts

理論的特徴

- 超新星爆発において最も明るい現象
  →最遠方の重力崩壊型超新星の観測手段となりうる
- 観測されたのは **3** 例のみ。
  可視光の観測 **or S/N** のよい観測は**(**今のところ**)**存在しない
  →**shock breakout** の物理：観測に基づいて検証する必要

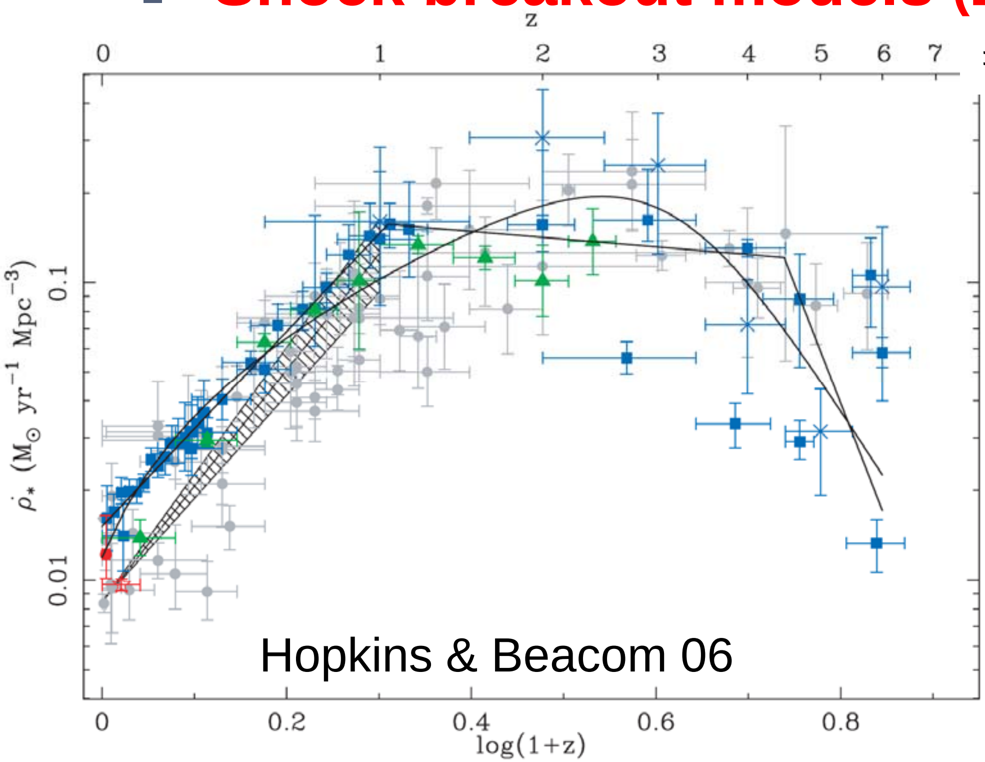
観測的特徴

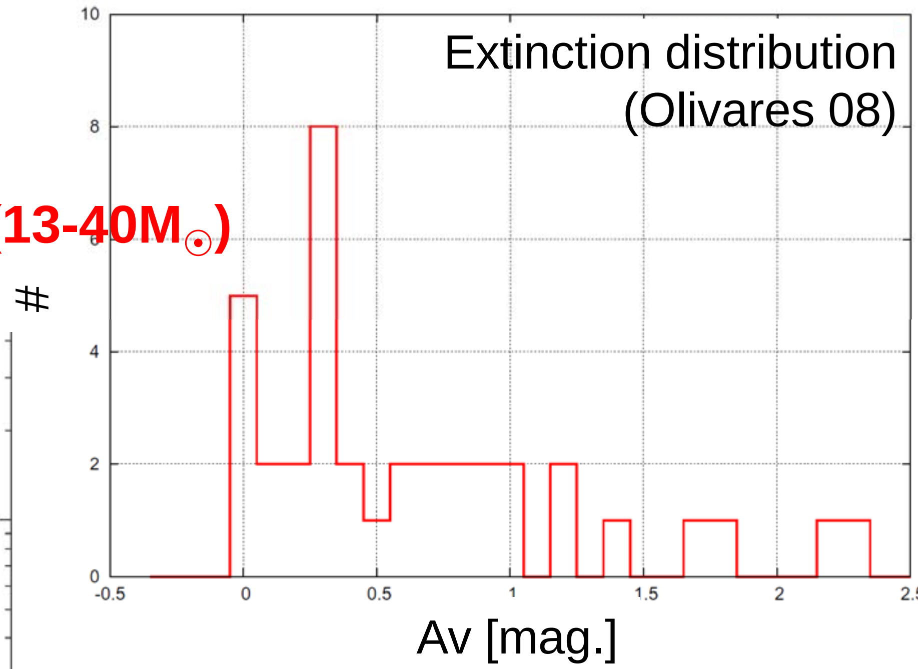
- タイムスケール：数時間**-**一日
- スペクトル：非常に青い **(peak ~100A)**
- 光度曲線と色が**ID**および**SN**の性質の制限に重要
  → 観測間隔の短い**(~hr)**多色観測が必須

KWFCによる観測を用いてShock breakoutの物理を検証・確立

Expected number of detections

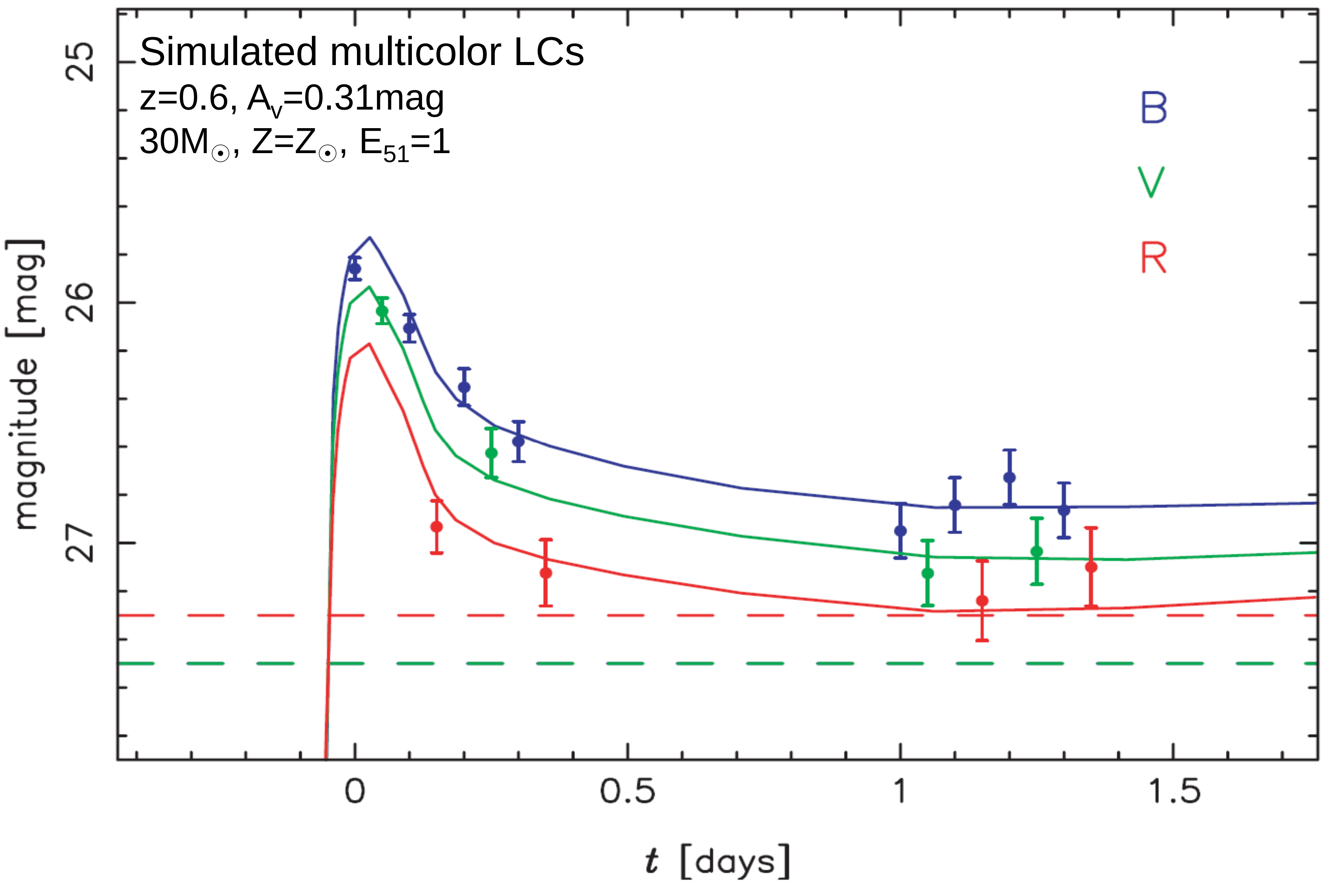
- **Cosmic star formation history (Hopkins & Beacom 2006)**
- **Distribution of host galaxy extinction (Olivares 08)**
- **IGM absorption (Madau 95)**
- **Salpeter's IMF**
- **Shock breakout models (13-40$M_\odot$)**



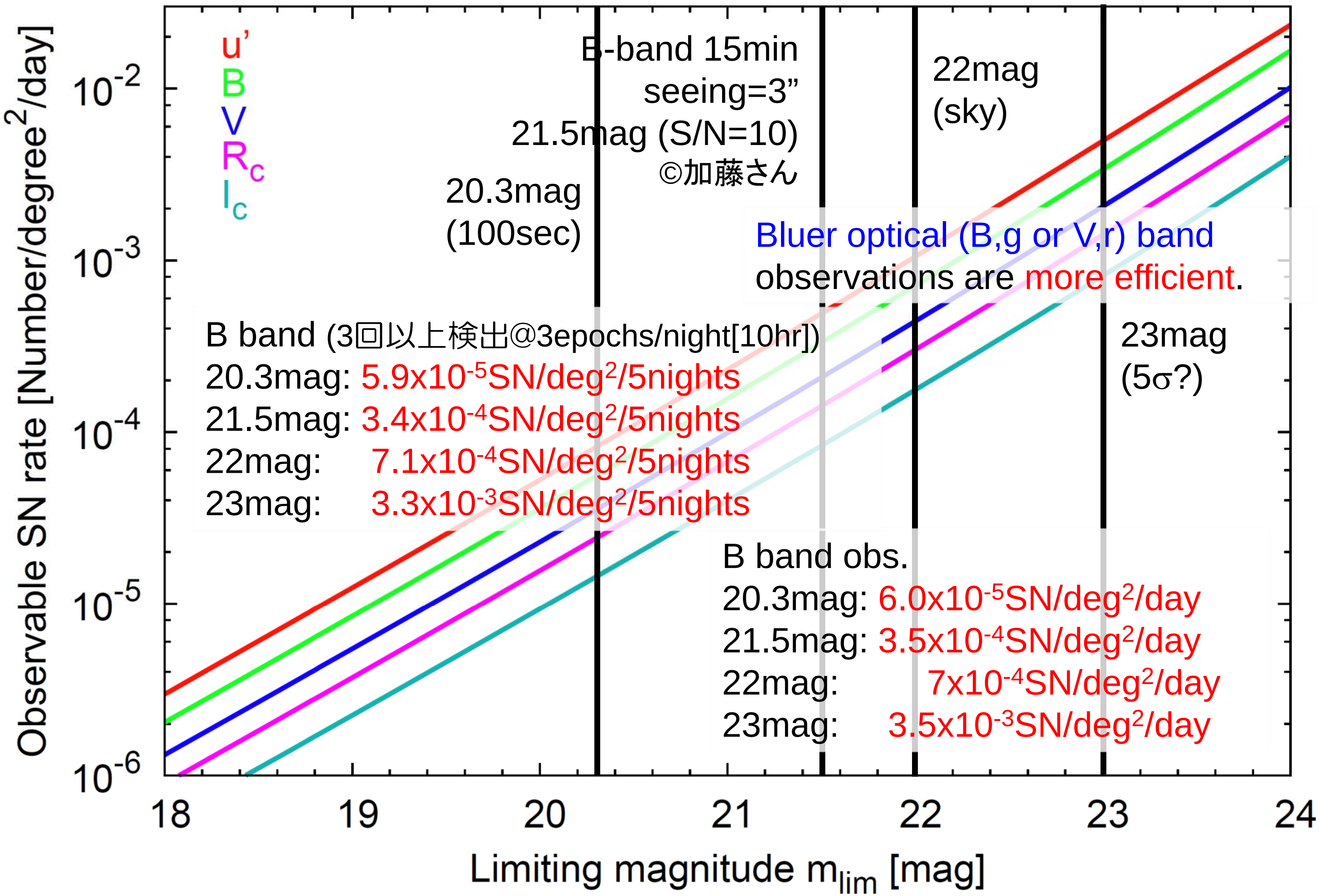


gray: Hopkins (2004)
Hatched region & green: FIR (24 mm)
red: radio (1.4 GHz) & H estimate
blue: UV & UDF

Expected LCs w/ 2days obs.



Observable SN rate

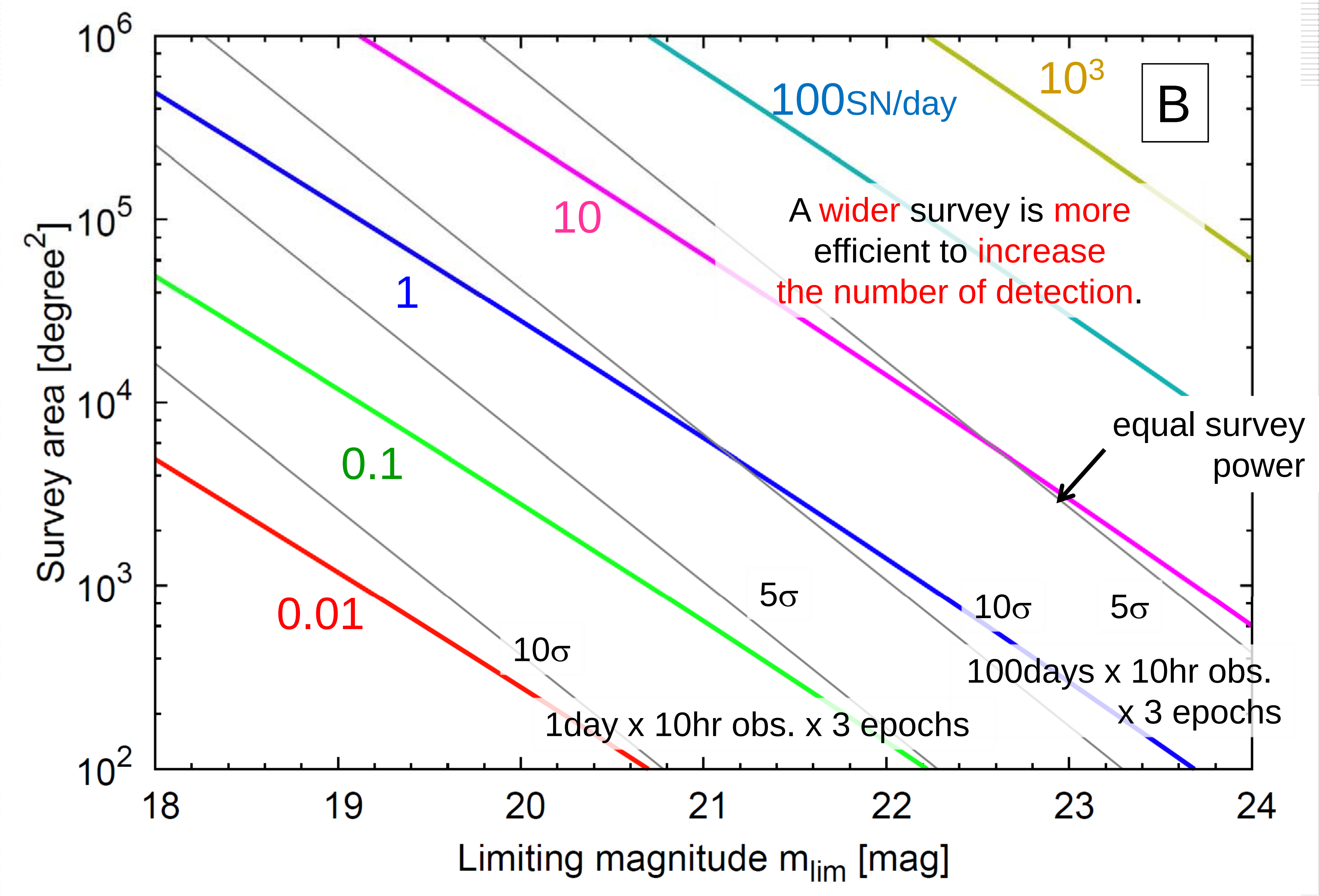


Bluer optical (B,g or V,r) band observations are more efficient.

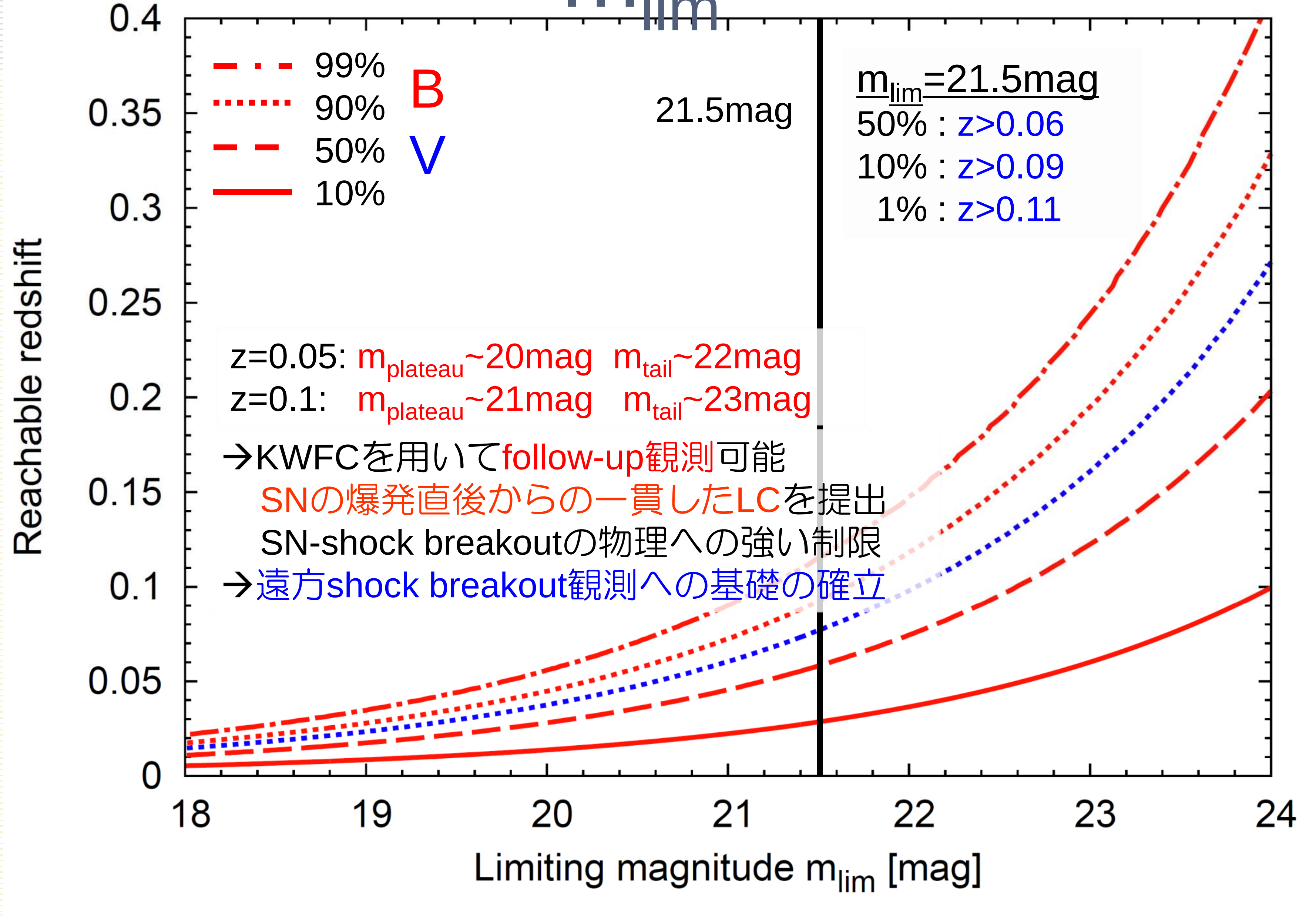
B band (3回以上検出@3epochs/night[10hr])
20.3mag: 5.9×10^{-5} SN/deg^2/5nights
21.5mag: 3.4×10^{-4} SN/deg^2/5nights
22mag: 7.1×10^{-4} SN/deg^2/5nights
23mag: 3.3×10^{-3} SN/deg^2/5nights

B band obs.
20.3mag: 6.0×10^{-5} SN/deg^2/day
21.5mag: 3.5×10^{-4} SN/deg^2/day
22mag: 7×10^{-4} SN/deg^2/day
23mag: 3.5×10^{-3} SN/deg^2/day

Rate($m_{peak}<m_{lim}$) : m_{lim} vs. Survey area



Reachable redshift: z_{max} vs. m_{lim}



Other SN surveys
-KWFC's competitors-

- **KWFC/Kiso observatory**
  - AΩ: 14.7 m^2deg^2 (Diameter: 1.08m FoV: 4deg^2)
- **Palomar Transient Factory (PTF)**
  - AΩ: 35.3 m^2deg^2 (Diameter: 1.2m FoV: 7.8deg^2)
- **Lick Observatory Supernova Search (LOSS)**
  - AΩ: 0.02 m^2deg^2 (Diameter: 0.76m FoV: 45min^2)
- **Catalina Sky Survey (CSS)**
  - AΩ: 12.3 m^2deg^2 (Diameter: 0.7m FoV: 8deg^2)
- **Skymapper**
  - AΩ: 32.6 m^2deg^2 (Diameter: 1.35m FoV: 5.7deg^2)
- **Pan-STARRS PS1**
  - AΩ: 30.5 m^2deg^2 (Diameter: 1.8m FoV: 3deg^2)
- **Nearby Supernova Factory (SNfactory)**
  - AΩ: 11.3 m^2deg^2 (Diameter: 1.2m FoV: 2.5deg^2)

Summary

- 超新星爆発 shock breakout
  - 初観測 SNLS-04D2dc のshock breakout
    多色光度曲線の再現 → 理論モデルを用いた予言
  - 遠方重力崩壊型超新星の新しい観測手段
  - しかし観測例が少なくShock breakoutの物理の理解のためには近傍の詳細な観測が重要
- KWFCを用いたShock breakout survey
  - Observable SN rate: 3.4×10^{-4} SN/deg^2/5nights
  - Redshift: $z>0.06$ (50%) & $z>0.09$ (10%)
  - KWFCを用いてfollow-up観測が可能 @m_{lim}=21.5mag

遠方shock breakout観測への基礎の確立