Time Domain Science with TMT

Masaomi Tanaka
(National Astronomical Observatory of Japan)

Time Domain Science?

- **Supernovae**
- **Gamma-ray bursts**
- **Variable stars**
- **Planet transits**
- **Astrometry**
- **and ...**

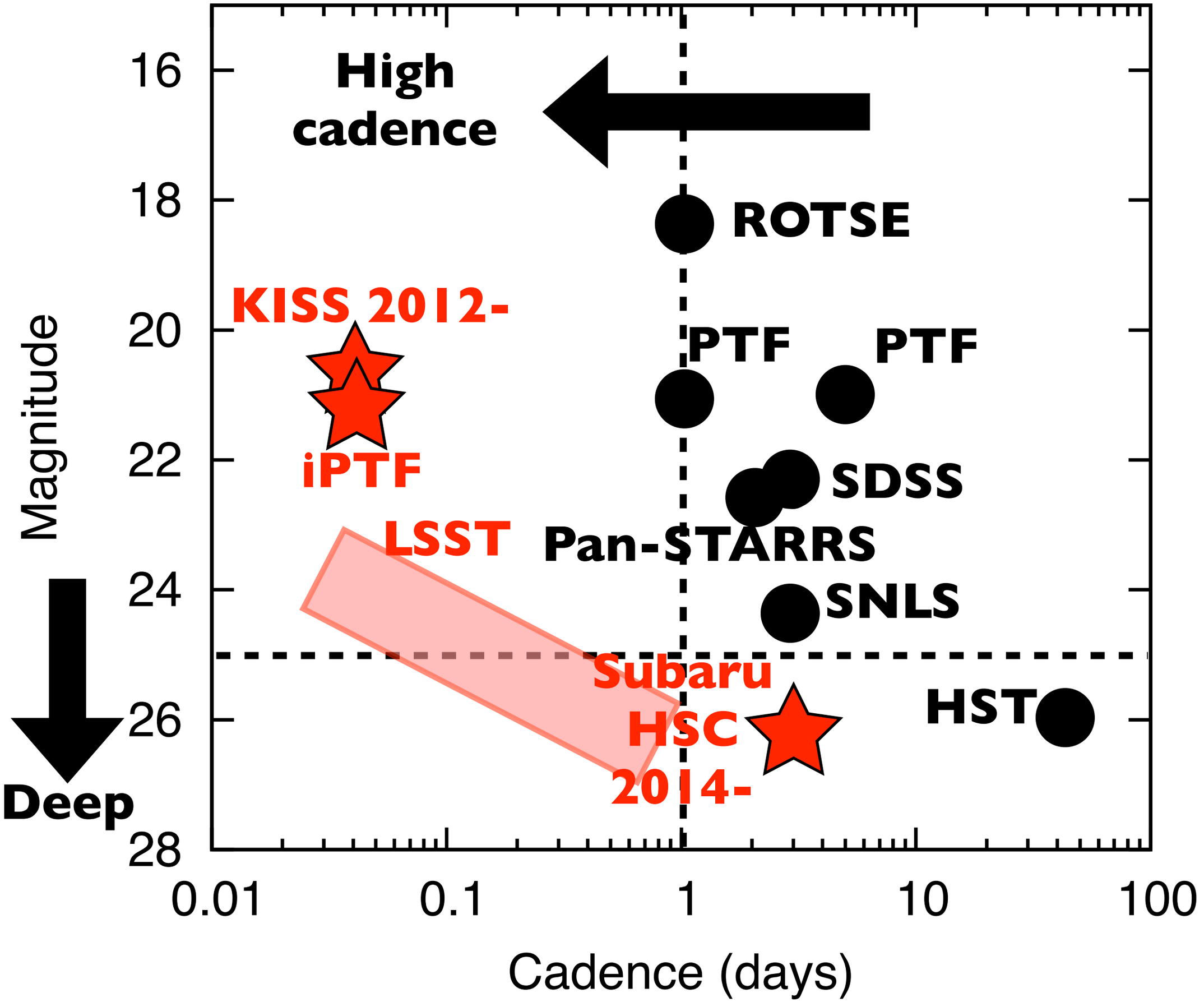
Transient objects

(Xiaofeng Wang's talk for SN cosmology)

Optical Transient Surveys

Survey	Diameter (m)	FOV (deg^2)	Depth (R mag)	Area/ day(deg^2)
ROTSE-III	0.45	3.42	18.5	450
KISS	1.05	4	21	100
PTF	1.26	7.8	21	1000
Pan-STARRS	1.8	7	21.5	6000
SDSS-II	2.5	1.5	22.6	150
GOODS	2.5 (HST)	0.003	26	0.04
SNLS	3.6	1	24.3	2
Subaru/HSC	8.2	1.75	26.5	3.5
LSST	8.4	9.5	25 -	-

(partly taken from Rau et al. 2009, PASP, 121, 1334)


High cadence
ROTSE
KISS 2012-
PTF
PTF
iPTF
SDSS
LSST
Pan-STARRS
SNLS
Subaru HSC 2014-
HST
Deep
Magnitude
16
18
20
22
24
26
28
0.01
0.1
1
10
100
Cadence (days)

Theoretically expected

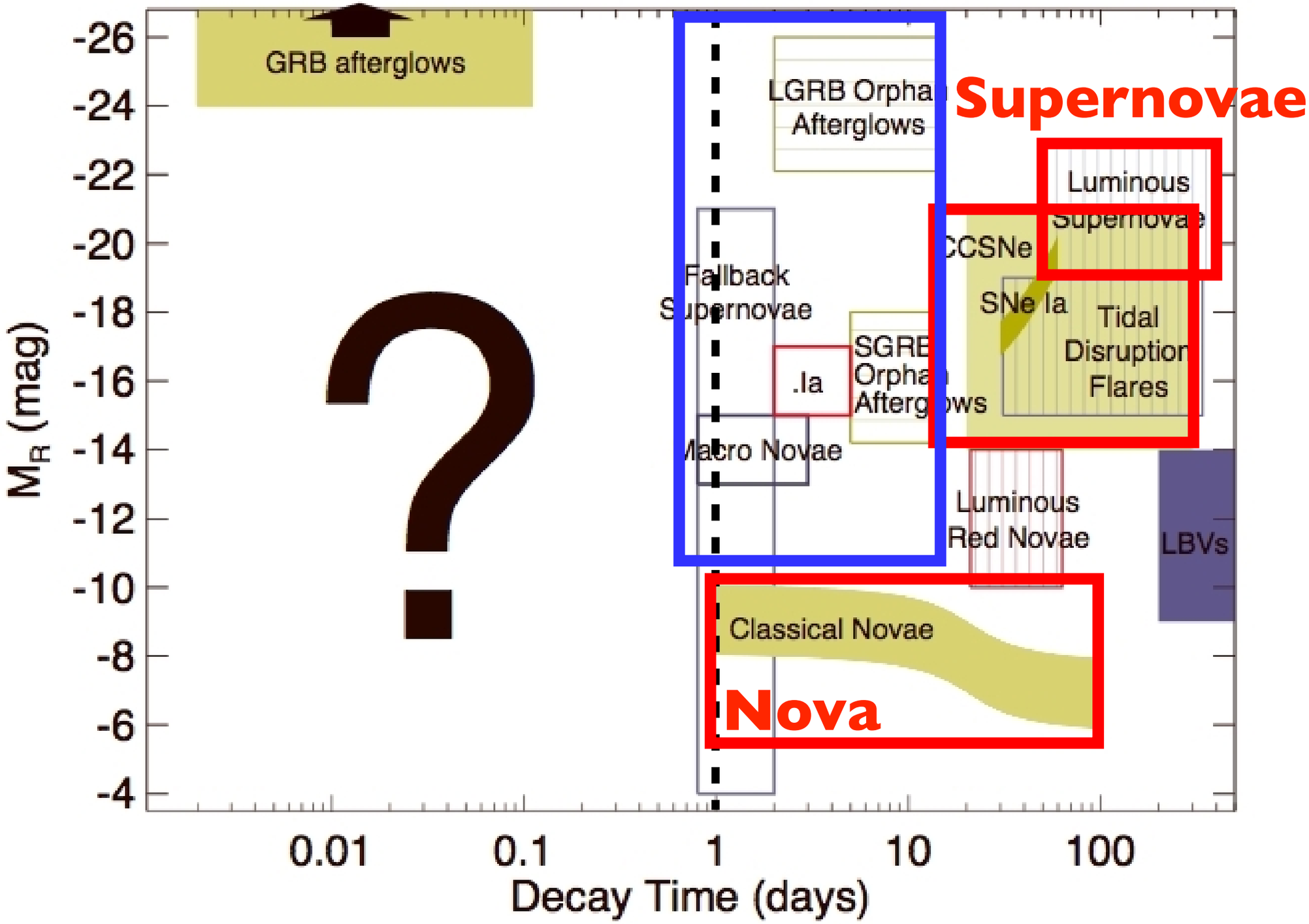
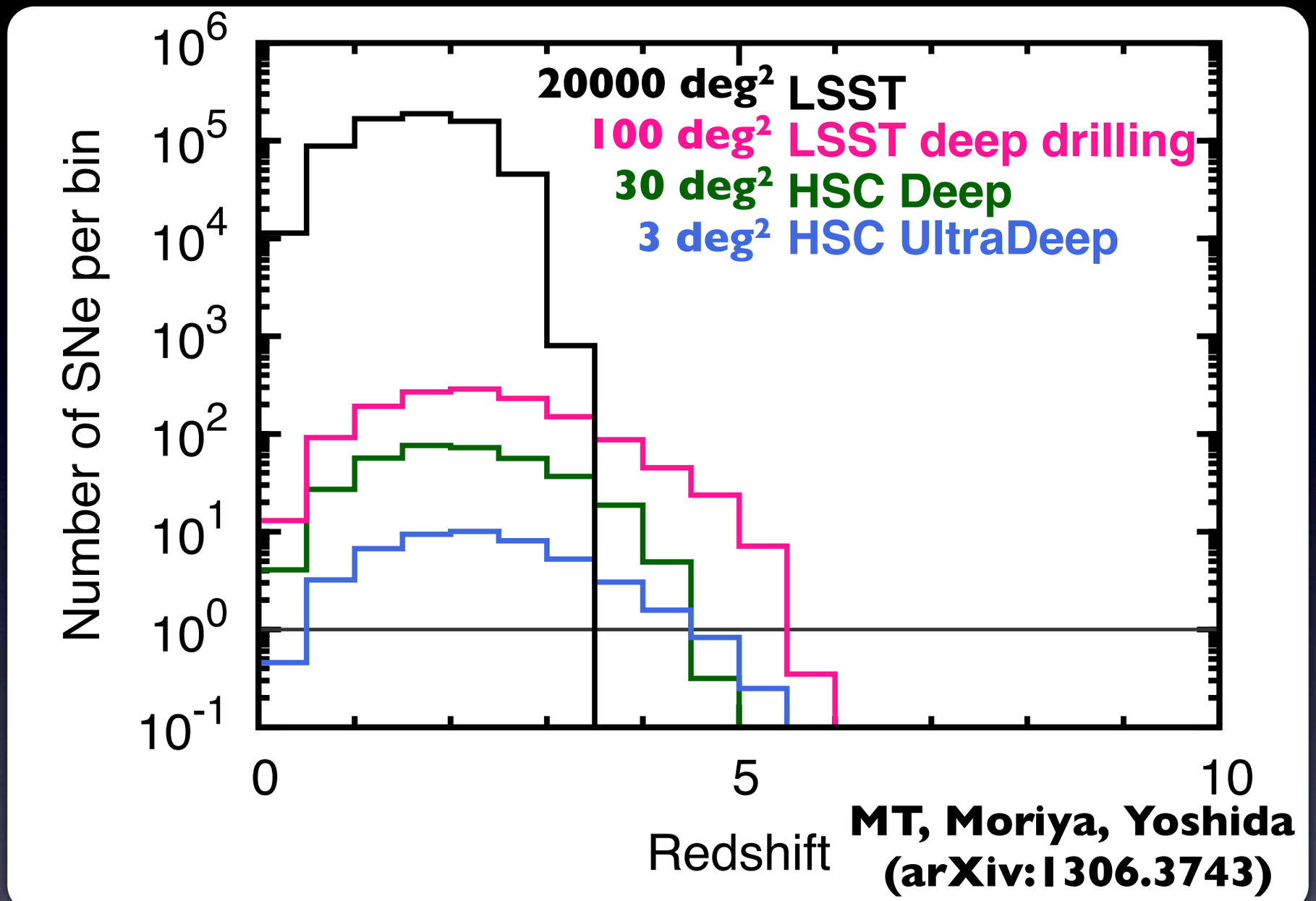


Figure from LSST Science Book
(after PTF collaboration, Rau+09, Kasliwal+,Kulkarni+)

“Superluminous” supernovae at z ~ 6



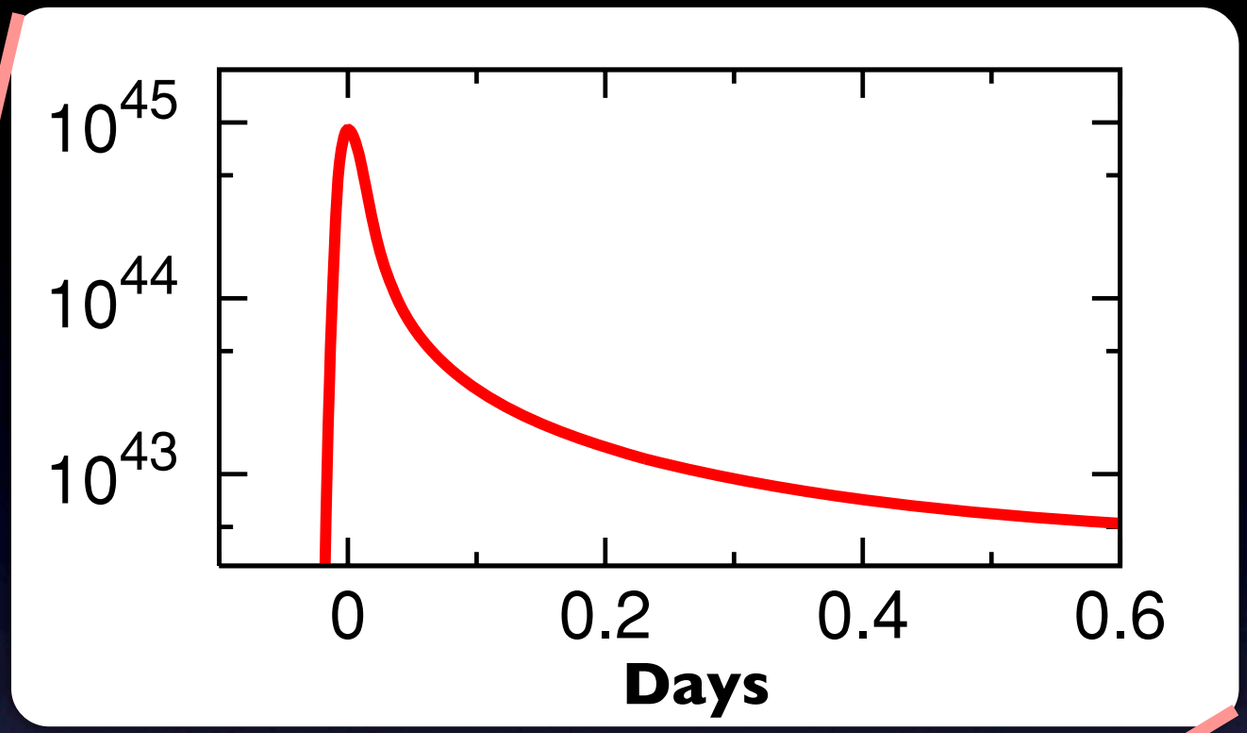
Opt/NIR spectroscopy with TMT

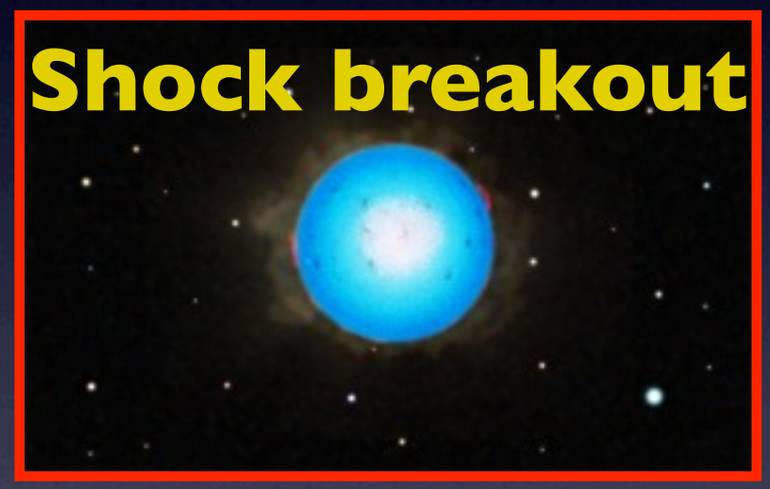
Direct measurement of massive star population (= IMF)

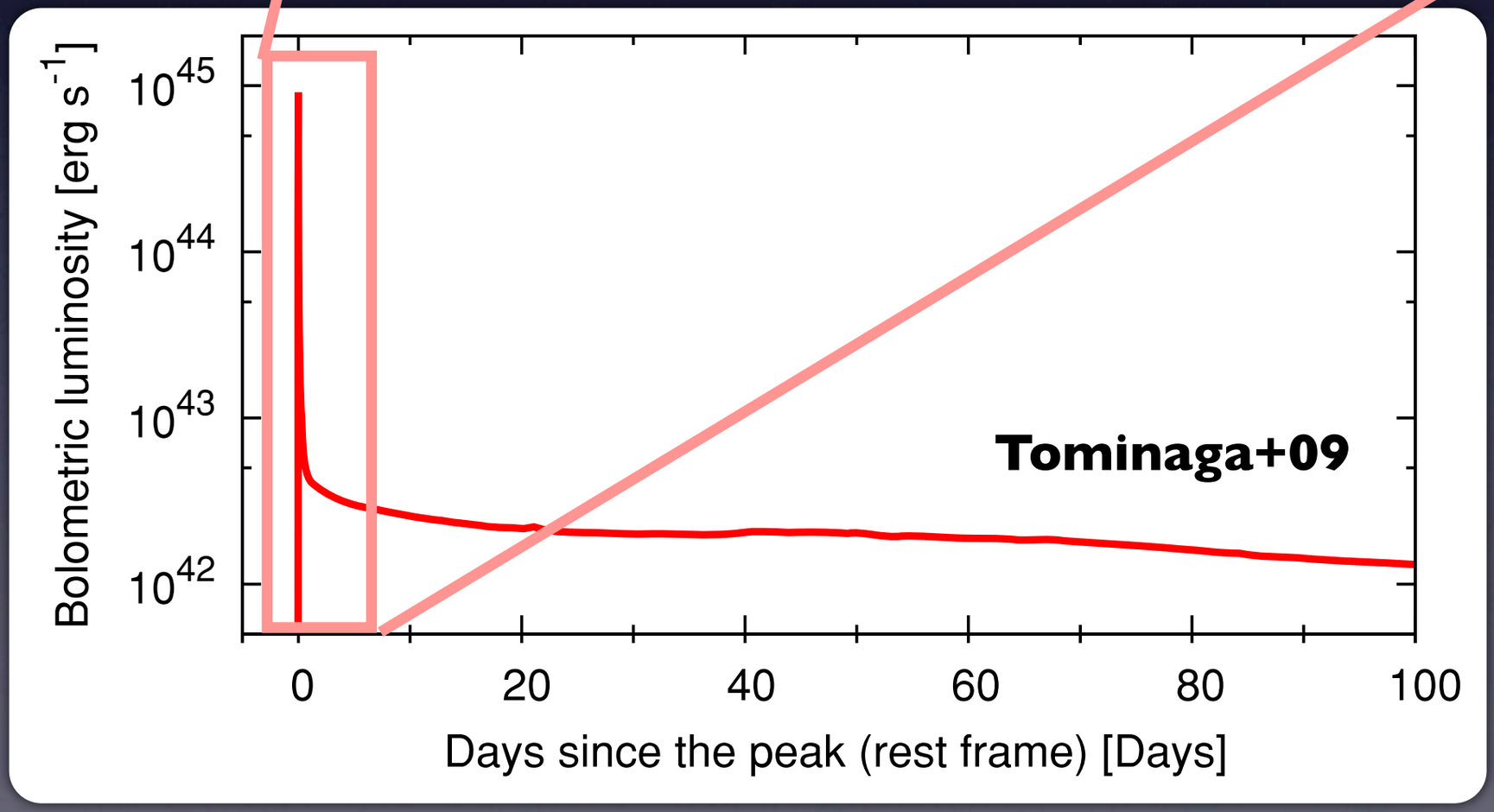
R ~ 500-1000
Opt (i,z): ~26 AB mag
NIR: ~25 AB mag

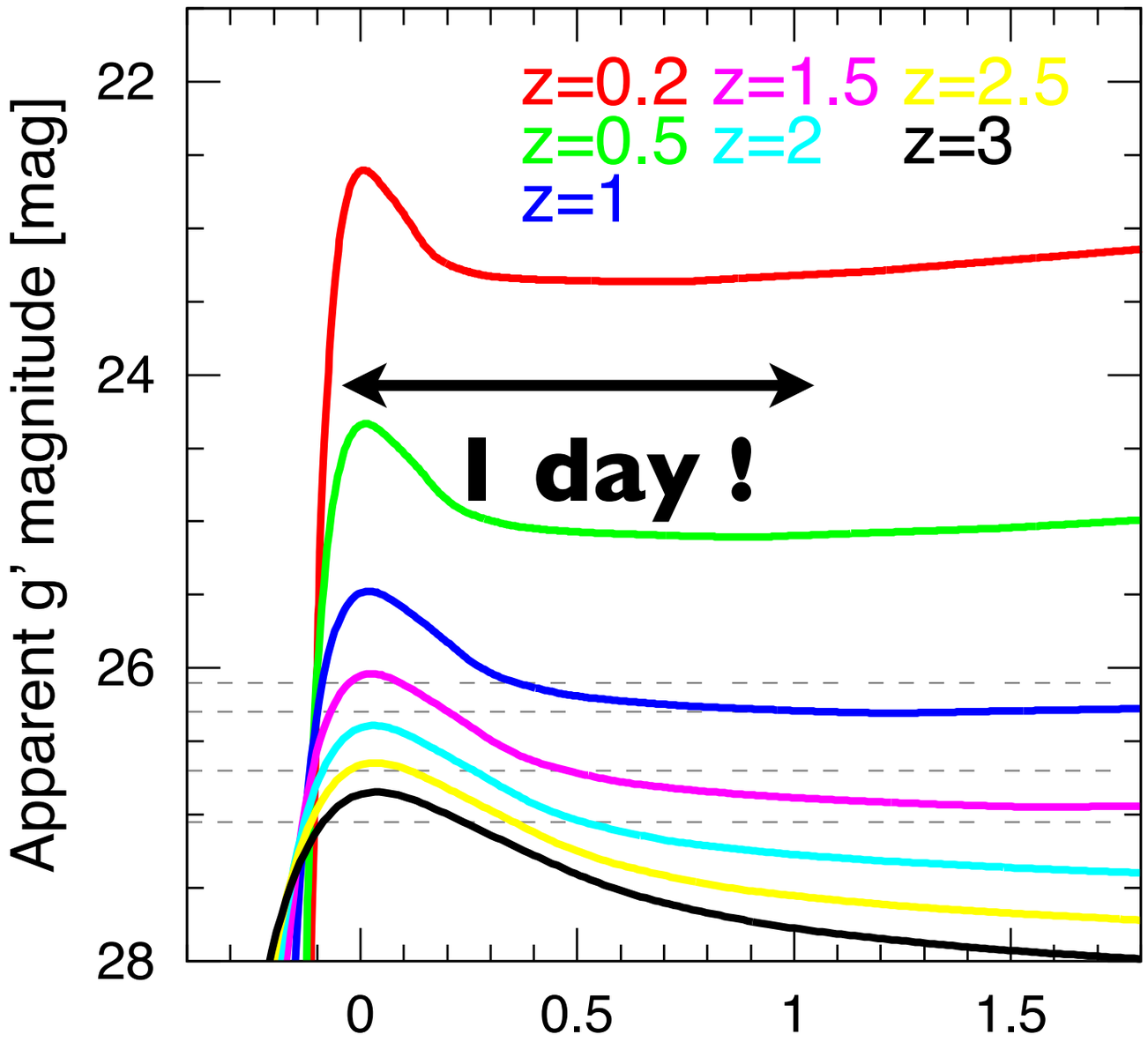
see e.g., Cooke+09, Quimby+11, Gal-Yam+12

The moment of supernova explosion









Tominaga+11

High-cadence 10 deg² survey with 27 mag (g)

Typical supernovae at z~2

R ~ 500-1000
Opt (g): ~27 AB mag

Prompt Optical spectroscopy with TMT

New window to study supernovae (progenitor mass/radius, kinetic energy)

Direct imaging

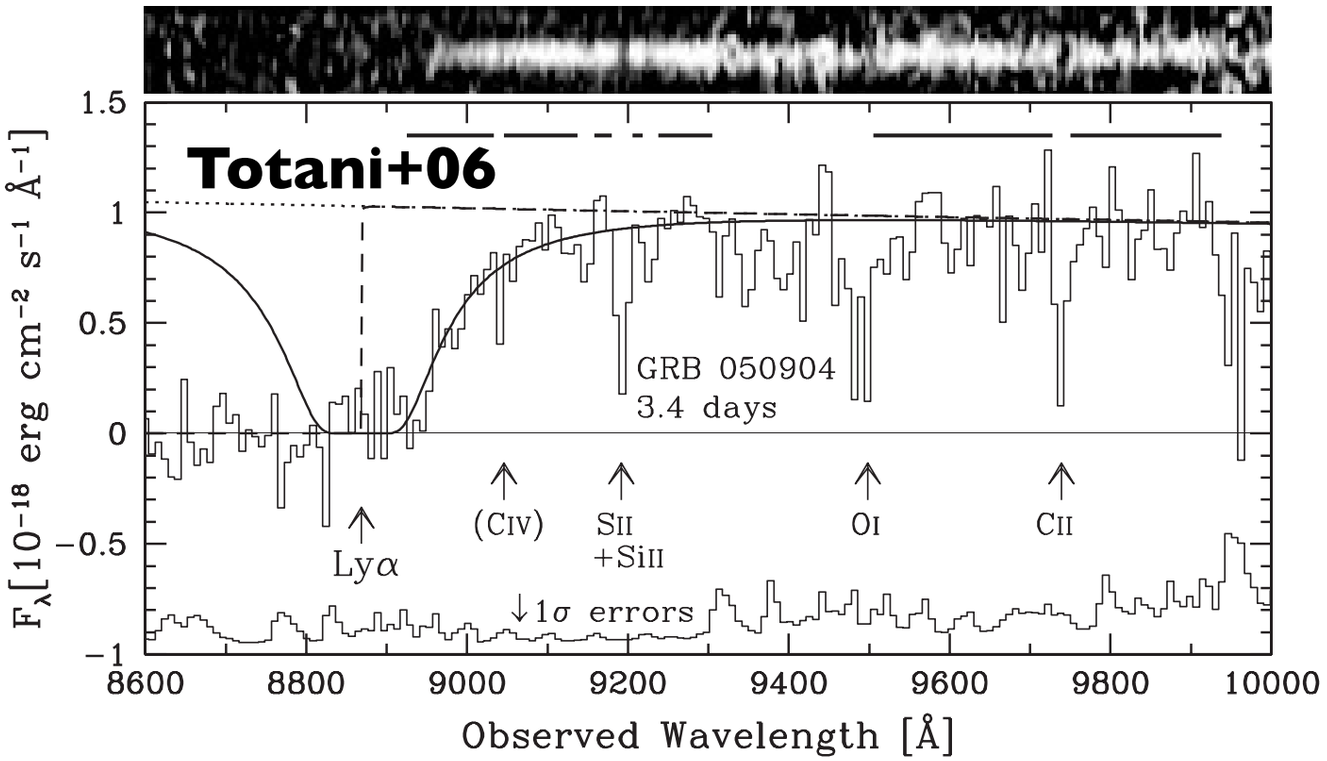
SN 1987A
LMC (50 kpc)

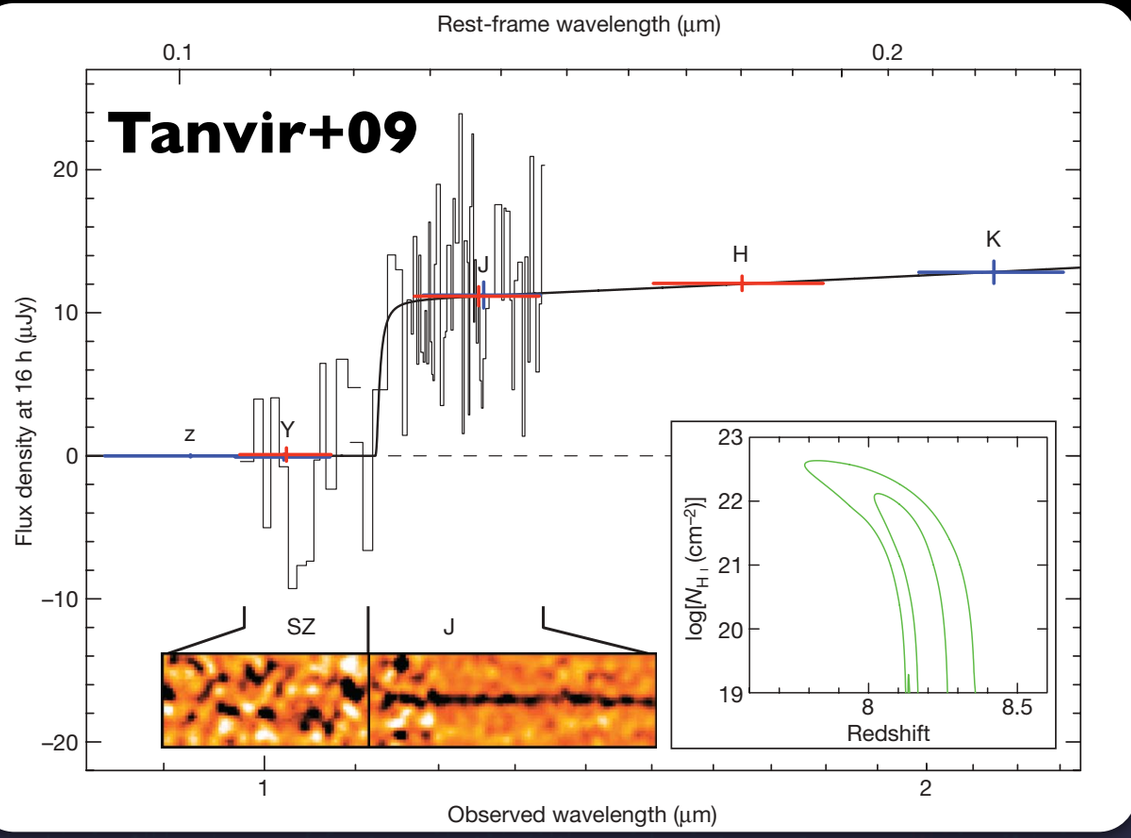
SN 2011dh in M51
(7 Mpc)

10 mas resolution with TMT

First resolved image beyond LMC (multi-D geometry)

Gamma-ray bursts up to z ~ 10





GRB 050904 @ z = 6.3
3.4 days
Subaru/FOCAS (R ~ 1000)

GRB 090423 @ z = 8.2
18 hours
VLT/ISAAC

Prompt NIR spectroscopy with TMT

→ **Reionization history at z ~ 6 - 10**

(Masami Ouchi's talk)

More opportunities with TMT

- Supernovae
  - Multi-D geometry by spectropolarimetry
- Gamma-ray bursts
  - GRB-SN connection at z > 1 (NIR spectroscopy)
  - Chemical abundances (high spectral resolution)
- "Time-resolved" science
  - Variability with ~ msec (high time resolution)

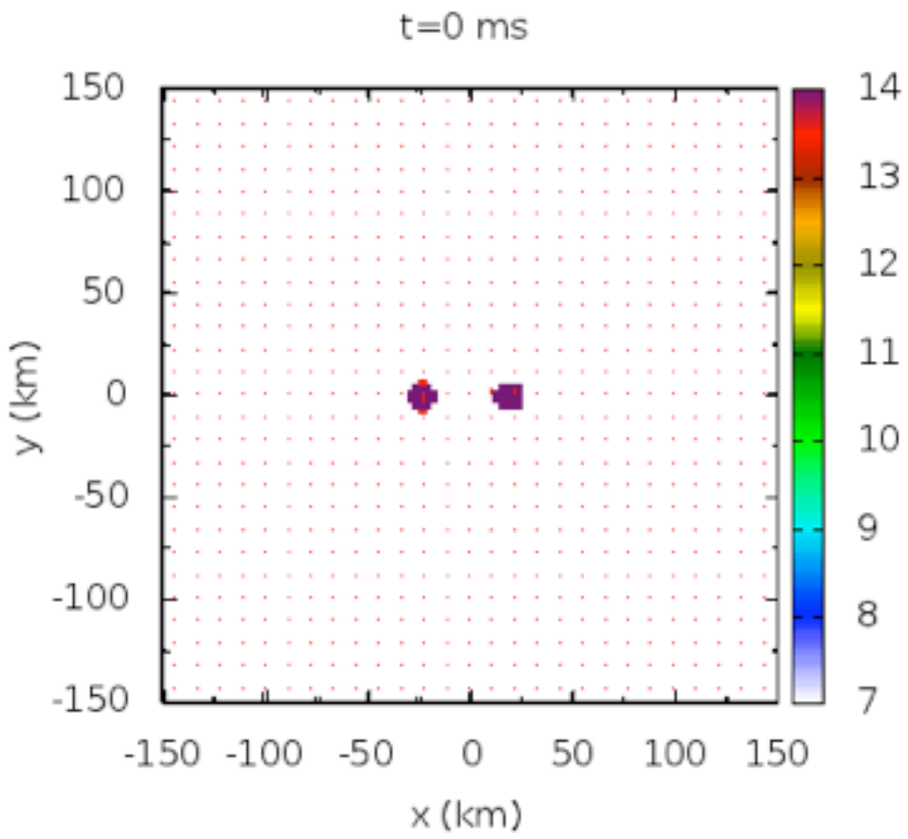
1st gen. instruments
>2nd gen. instruments
(see Warren Skidmore's poster)

New astronomy with gravitational waves

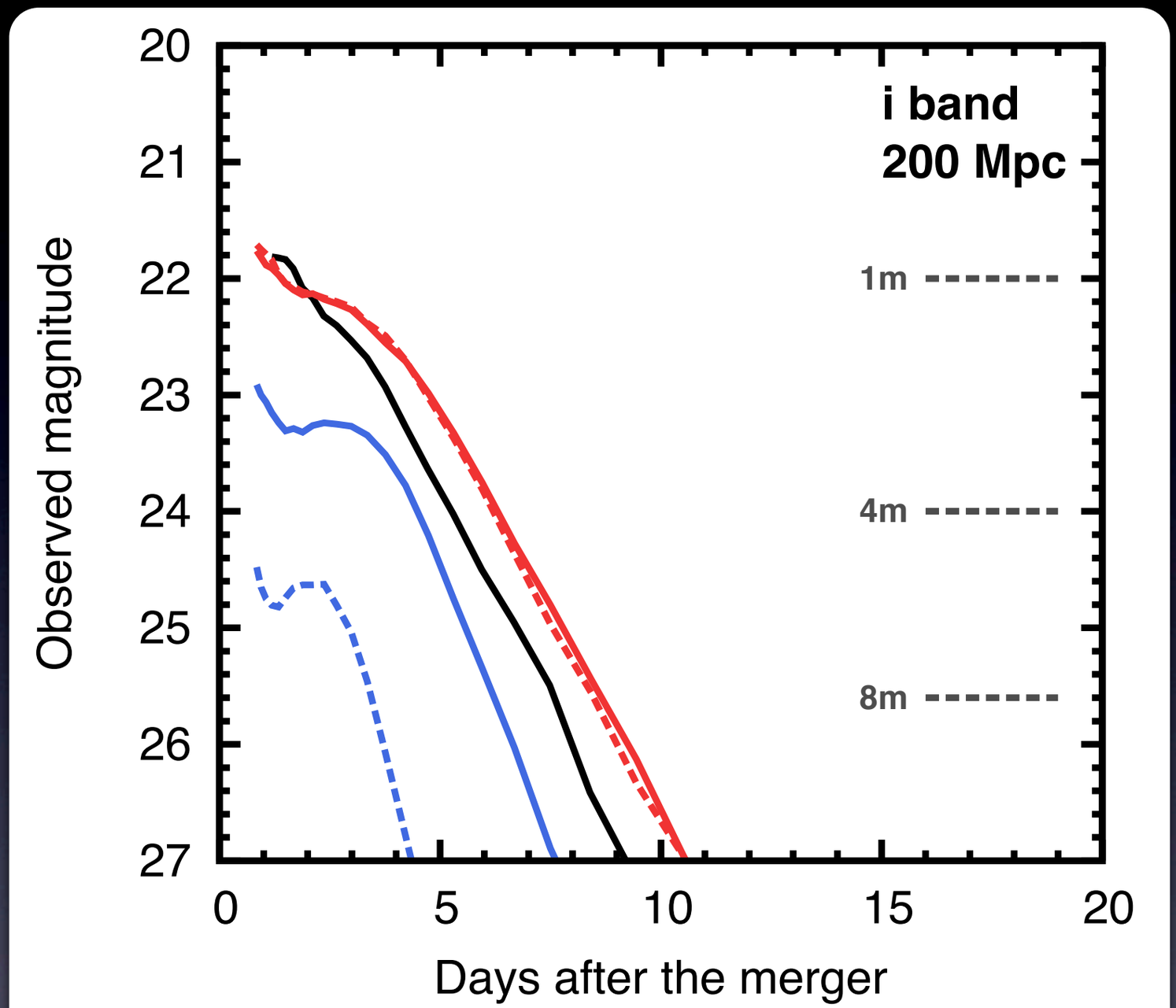
2017 -
- Advanced LIGO (US)
- Advanced VIRGO (Europe)
- KAGRA (Japan)

NS-NS merger with 200 Mpc

Hotokezaka+13



Toward the dawn of GW astronomy



Emission powered by radioactive r-process elements
MT & Hotokezaka (arXiv:1306.3742)

GW detection
~ 100 deg^2 localization

↓

Search with Subaru/LSST

↓

Spectroscopy with TMT

Identification of GW sources

Li & Paczynski 98, Kulkarni 05, Metzger+10, Kaesn+13, Barnes & Kasen 13

Summary: Time Domain Science with TMT

- **Science cases for <u>transients</u>**
  1. **Massive star population (IMF) at z ~ 6**
  2. **The moment of supernova explosion**
  3. **Resolved image of extragalactic supernovae**
  4. **Reionization history with GRBs at z ~ 6 -10**
  5. **Identification of gravitational-wave sources**
- **Hope for TMT**
  - **Sensitivity, spatial resolution, and rapid ToO (<10 min)**
  - **Polarization, high spectral resolution, and high time resolution (>2nd gen. instruments)**