HSCを用いた超新星爆発研究

冨永望 (甲南大)

on behalf of
HSC-transient team
Contents

• Objectives
• Cadence requirements
• Strategy
• Science cases
Objectives

- Type Ia SN
- Core-Collapse SN
- Shock Breakout
- Type II(n)/II(L) LSN
- Ultra-Bright Optical Transient
- GRB Orphan Afterglow
- QSO
- Tidal disruption event (TDE)
Cadence requirements

- $\tau \sim$ day $\rightarrow$ in a night and/or in a month
  - SN shock breakout
  - solar system, [weak lensing (i): $>10$-30min]

- $\tau \sim$ month $\rightarrow$ in a month and in 2-4 months
  - SN Ia, core-collapse SN, GRB orphan afterglow
  - AGN

- $\tau \sim$ 1-several year(s) $\rightarrow$ in 5 years
  - Super Luminous SN
  - AGN
Survey strategy

led by Nishizawa-san, Yasuda-san, Tominaga

• Dynamic scheduling is compatible with transient studies to balance completeness and maintain cadence in the multi bands.

• Satisfactions of cadence requirements have small disadvantage in completeness and dead time. (preliminary)
  – Wide: daily/monthly schedule for WL, shock breakout, SS, AGN
  – Deep/UD: 1 intensive year for SNe Ia, CCSNe & continuous obs. over 5 years for SLSNe
Transient finding

• **Catalog finding**
  – make a photometric catalog for a reference image
  – compare it with a new catalog to find objects with flux variation

• **Image subtraction**
  – find variable objects in bright galaxies
  – a powerful tool commonly used for SNe and low-luminosity AGN
Transient classification
led by Tanaka-san, Urata-san

- Color (evolution) & multicolor light curves
- Photometric/spectroscopic redshift

In Taiwan, we are testing
- support vector machine
- pattern mining
Transient server
led by Tominaga, Yasuda-san, Urata-san, Morokuma-san

HSC

Raw data
(at least half day delay)

HSC onsite server @Hilo 2012/10~

Full reduction @NAOJ, IPMU 2012 end?!
**SN2012ee**

<p>| | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>32</td>
<td>source ID</td>
<td>639410</td>
<td>submit</td>
<td>KSFJ2044-0542 0016295_3</td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>score</td>
<td></td>
<td></td>
<td>[0, 1, 2]</td>
<td></td>
</tr>
</tbody>
</table>

**Template image**

**Current image**

**Subtracted image**

**Previous image**

**Radial profile**

A list of SN candidates is available at ~10-20min after the exposure.

**Minor planet (93951) 2000 WT179**

<p>| | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>37</td>
<td>source ID</td>
<td>639783</td>
<td>submit</td>
<td>KSFJ2215+1311 0016305_5</td>
<td></td>
</tr>
<tr>
<td>37</td>
<td>score</td>
<td></td>
<td></td>
<td>[0, 1, 2]</td>
<td></td>
</tr>
</tbody>
</table>

**Template image**

**Current image**

**Subtracted image**

**Previous image**

**Radial profile**
Follow-up observation

- **Photometry**
  - continuous observation to obtain light curves
  - **NIR** light curves for SNe Ia at $z>1$
  - backup observation of HSC-deep/UD fields when the seeing or weather condition is bad

- **Spectroscopy** (8m-class telescopes needed)
  - within 1 night (SN shock breakout)
  - within 2 weeks (SNe Ia, CCSNe)
  - in the next semester (SLSNe)

Openuse, alert, and collaborations
Science cases
Type la SNe

- SDSS: $0.05 < z < 0.4$
- SNLS: $0.3 < z < 1.0$
- HST: $z > 1.0$
- DES: $0.3 < z < 1.0$
  - $\sim 5000$ SN Ia

SN Ia $@ z > 1$ is still small number.

HSC-UD survey

- $\sim 130$ SN ($\sim 60$ at $z > 1$) for S/N>5
- $\sim 80$ SN ($\sim 20$ at $z > 1$) for S/N>10
  (3 bands detection)
If we can use all S/N>5 sample in addition to UNION2 sample, error on $\Omega_M$ and $w$ will be decreased by a factor of 2.
Type Ia SNe -rate-

• **SN Ia rate density**
  – Most accurate SN Ia rate upto z~1.5
  – constrain delay time distribution

• **Delay time distribution**
  – delay time between star formation and SNe Ia
  – constrain progenitor system
Core-collapse SNe

- Available for free with SNe Ia cadence

<table>
<thead>
<tr>
<th>Survey</th>
<th>Tel.</th>
<th>Redshift</th>
<th># of SNe</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNLS</td>
<td>CFHT</td>
<td>~0.3</td>
<td>120</td>
</tr>
<tr>
<td>GOODS</td>
<td>HST</td>
<td>0.1-1.3</td>
<td>45</td>
</tr>
<tr>
<td>HSC-UD</td>
<td>Subaru</td>
<td>0.2-1.0</td>
<td>~165</td>
</tr>
</tbody>
</table>
Shock breakout

led by Tominaga, Morokuma-san

- **Brightest** phenomenon (normal SNe @z~3)
- >3 g- and >1 r-bands obs. in 1 night
- **1st year science**
- **Discovery channel**
  - only 3 events
  - no opt. obs.

---

### Table:

<table>
<thead>
<tr>
<th>Num. SNe (1st year)</th>
<th>Num. SNe</th>
<th>Redshift 50%</th>
<th>Redshift 10%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wide</td>
<td>19</td>
<td>≥0.5</td>
<td>≥0.9</td>
</tr>
<tr>
<td>Deep</td>
<td>9</td>
<td>≥0.6</td>
<td>≥1.4</td>
</tr>
<tr>
<td>UD</td>
<td>2</td>
<td>≥0.8</td>
<td>≥1.7</td>
</tr>
</tbody>
</table>

---

### Graph:

- z=0.2
- z=1.5
- z=2.5
- z=0.5
- z=2
- z=3

---

Days since bolometric peak (observer frame) [Days]
Super Luminous Supernova

- Rare extremely bright SNe
- CCSN detection @ z~4

Slow follow-up obs.
1-month stacked data

Moriya-san’s talk for detail
Distance ladder in SNe

SN rate history

HSC CCSNe

HSC SN shock breakout

HSC SLSNe

IMF, SFH @ high redshift

GRBs

HSC SNe Ia

Hopkins & Beacom 06 and references therein
Other transients

• **GRB orphan afterglow**
  – off-axis view of GRBs
  – 1 candidate in SDF data
  led by Huang-san & Urata-san

• **Tidal disruption event (TDE)**
  – a BH swallows an orbiting star
  – several events observed so far
  led by Kong-san

• **Variable stars**
  – High proper motion stars
  – RR Lyrae stars
  led by Morokuma-san, Tominaga
Summary

• Many SN science cases are available with HSC-wide/deep/UD.
• Cadence requirements range from day to year (but are flexible and feasible).
• Science cases
  – SNe Ia: cosmology, rate, large sample at $z > 1$
  – CCSNe: rate, large sample at $z > 0.5$
  – Shock breakout: first detection in optical
  – SLSNe: detection at $z \sim 4$
• Distance ladder in SNe upto $z \sim 4$