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

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Outline

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

$<\sim 1$ day
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.
Web interface for intranight transients
Rapidly declining transient

A rapid declining transient

Subaru HSC survey
Optimized for Optical Transients (SHOOT) 14di

Flux [µJy]

+1.8 mag/day

z=0.42

Date [JD - 2456840.5]

AB magnitude [mag]

2 Jul 2014
3 Jul 2014
2015
2 Jul 2014 - 2015
Comparison of rest u-band LCs
Decline rate and color

The most rapid decline was found.
Origins of rapid decline

• Shock breakout at stellar surface (NT+11)

• Cooling envelope (Tsvestkov+12)

• Shock breakout in dense CSM (Moriya+18)
Origins of rapid decline

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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.

25Msun
R = 1200Rsun
E<0.4x10^{51}ergs
Rapidly rising transients
Rapidly rising transients

Tanaka, NT+ 16
Rising time scale

Tanaka, NT+ 16; Drout+14; Gezari+15
Rate of rapidly varying transients

Event rate: \( R = 1/\tau \Omega V_{\text{max}} \)  

\[
\tau V_{\text{max}} = \frac{1}{4\pi} \sum_{\text{field}} \int_{0}^{z_{\text{max}}} \max \left\{ \tau_{\text{tran}}, \frac{\tau_{\text{obs,field}}}{1 + z} \right\} \frac{dV}{dz} dz
\]

1 rapidly declining transient and 5 rapidly rising transients  

\( (|dm/dt| > 1 \text{mag/day}) \)

\( \sim 1 \times 10^{-4} /\text{yr/Mpc}^3 \)  
\( \sim 6 \times 10^{-5} (\tau/1\text{day})^{-1} /\text{yr/Mpc}^3 \)  

NT+19  
Tanaka, NT+16  
c.f. CCSN rate: \((3-7) \times 10^{-4} /\text{yr/Mpc}^3\)

High Cadence Transient Survey (HiTS) with CTIO/DECam (Forster+18)  
26 rising transients (24 transients are rapid \(|dm/dt| > 0.2\text{mag/day}\) )  
Detection efficiency: 28% for low \( M_{\text{dot}} \), 72% for high \( M_{\text{dot}} \)  
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.