

Transient survey and multi-messenger astronomy with Subaru/Hyper Suprime-Cam

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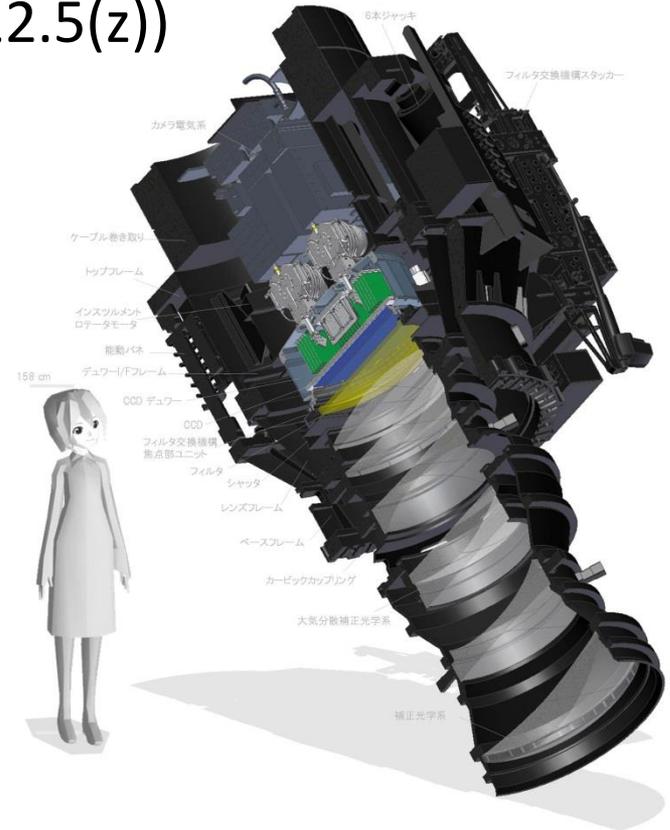
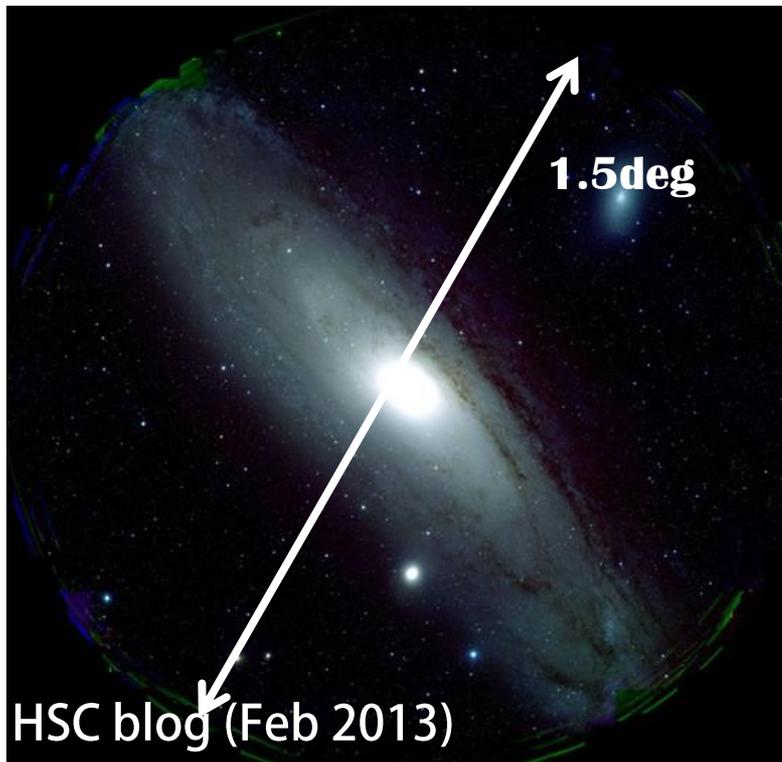
26th Sep 2018
Chile-Japan Academic Forum 2018

Outline

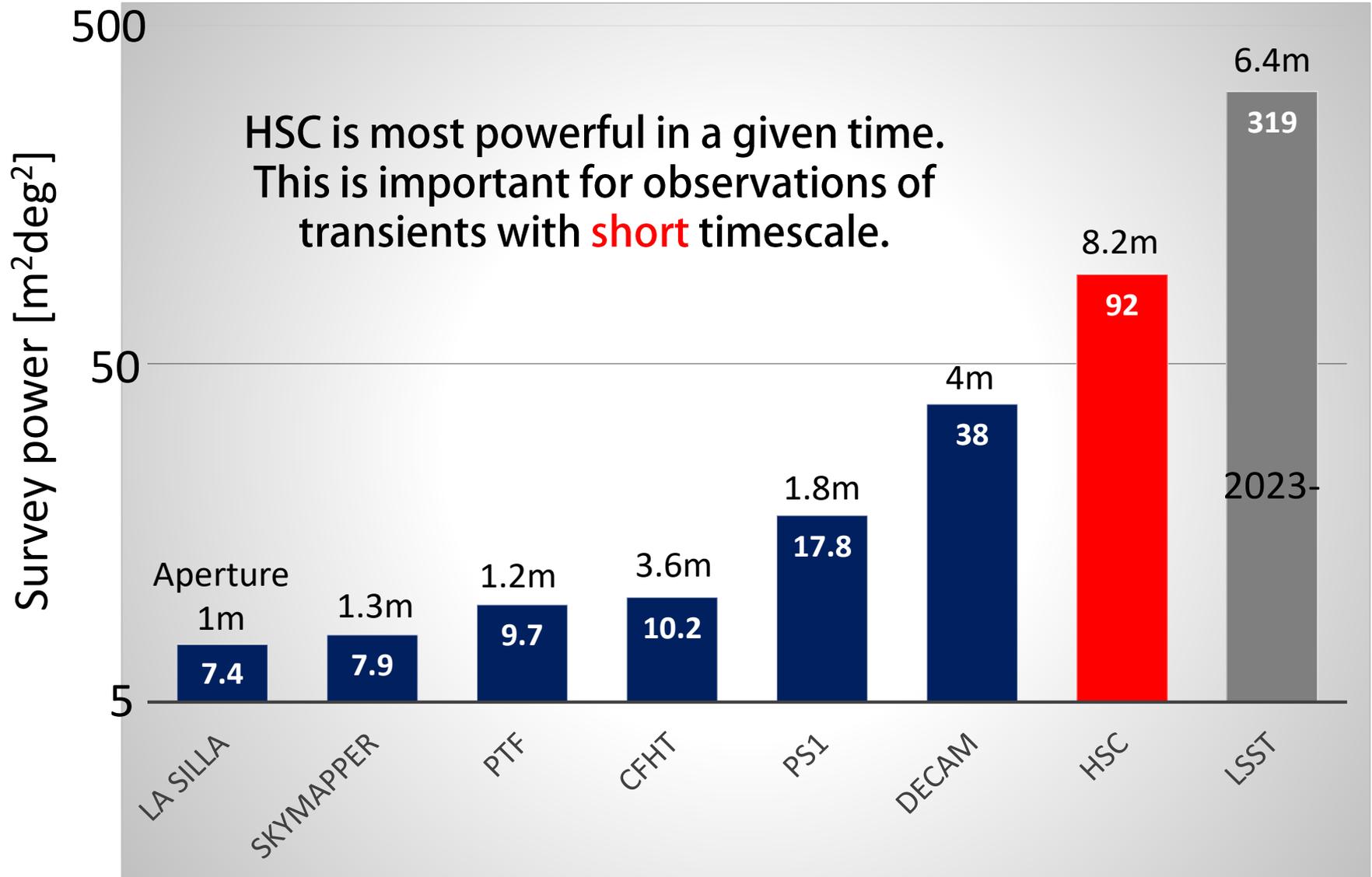
- Subaru/Hyper Suprime-Cam
- Follow-up obs. of gravitational waves
- Follow-up obs. of fast radio bursts

Hyper Suprime Cam on Subaru telescope

- Hyper Suprime-Cam (HSC)
 - Diameter: 8.2m, FoV: **1.77deg²**, ~900M pixels
 - $m_{\text{lim}} (5\sigma)$ w/ 1min: 24.5(i) 23.8(z)
(DECam 1min: 23.3(i), 22.5(z))



Survey power of telescopes/cameras

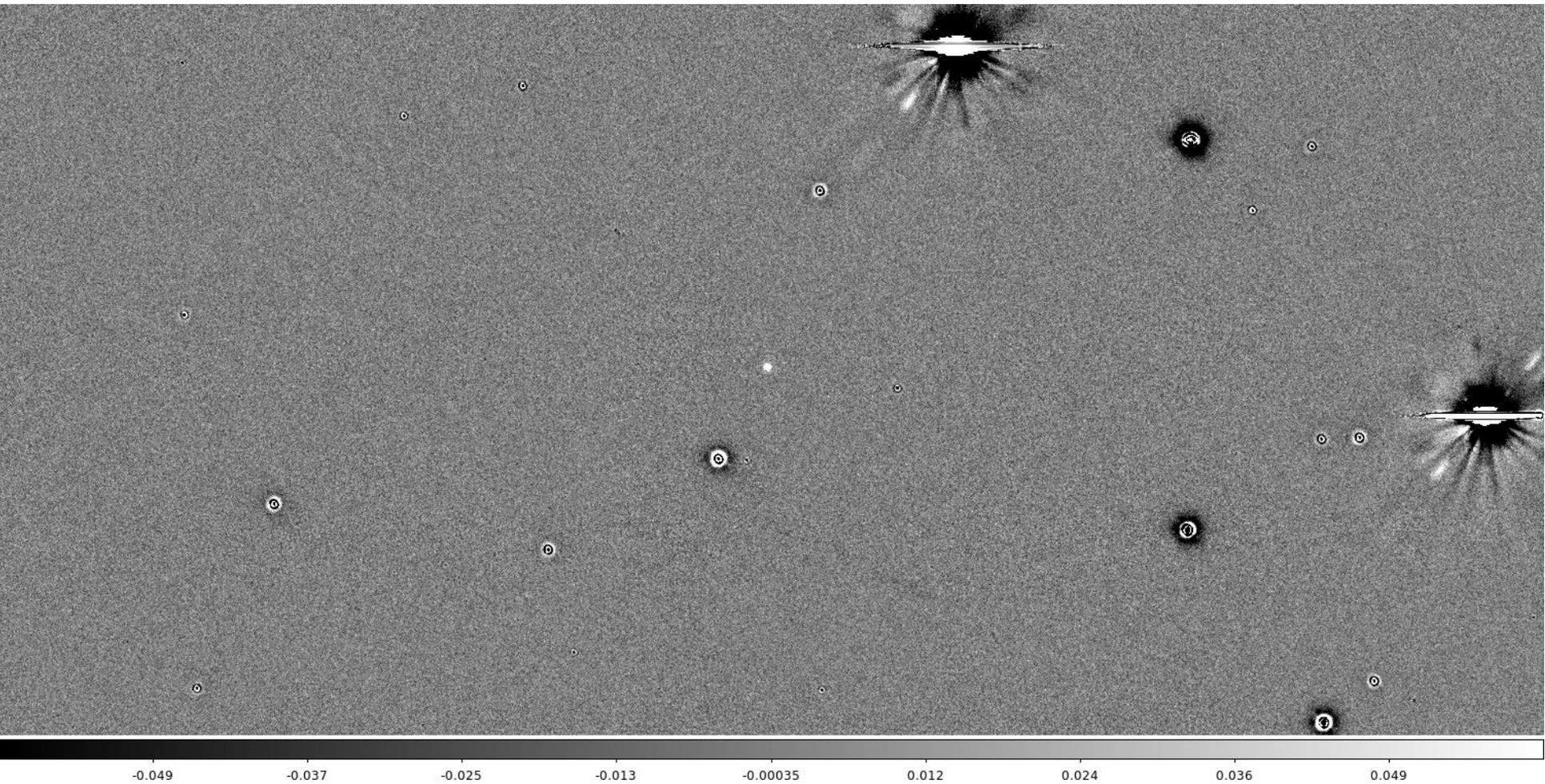


Real-time detection and quick alert

- In order to utilize the capability of Subaru/HSC, we realize **the prompt transient detection** by developing a **real-time data analysis system with machine learning (CNN, AUC boost, and partial AUC)** for real and bogus classification.

How can we discover transients?

-Image subtraction-



-0.049 -0.037 -0.025 -0.013 -0.00035 0.012 0.024 0.036 0.049

Real-time detection and quick alert

- In order to utilize the capability of Subaru/HSC and realize **the prompt detection of transients**, we developed a real-time data analysis system with machine learning (CNN, AUC boost, and partial AUC) for real and bogus classification.
- The analysis can finish within **~30min** (depending on survey strategies). Supernova candidates had been reported immediately after the observations (NT+14ab;15ab).

Supernova candidates discovered with Subaru/Hyper Suprime-Cam *The Astronomer's Telegram*

ATel #6763; *Nozomu Tominaga (Konan U./Kavli IPMU, U. Tokyo), Tomoki Morokuma (U. Tokyo), Masaomi Tanaka (NAOJ), Naoki Yasuda (Kavli IPMU, U. Tokyo), Hisanori Furusawa (NAOJ), Jian Jiang (U. Tokyo), Nobuhiro Okabe (Kavli IPMU, U. Tokyo), Toshifumi Futamase (Tohoku Univ.), Satoshi Miyazaki (NAOJ), Takashi J. Moriya (AIfA, U. Bonn), Junichi Noumaru (NAOJ), Kiaina Schubert (NAOJ), and Tadafumi Takata (NAOJ)*

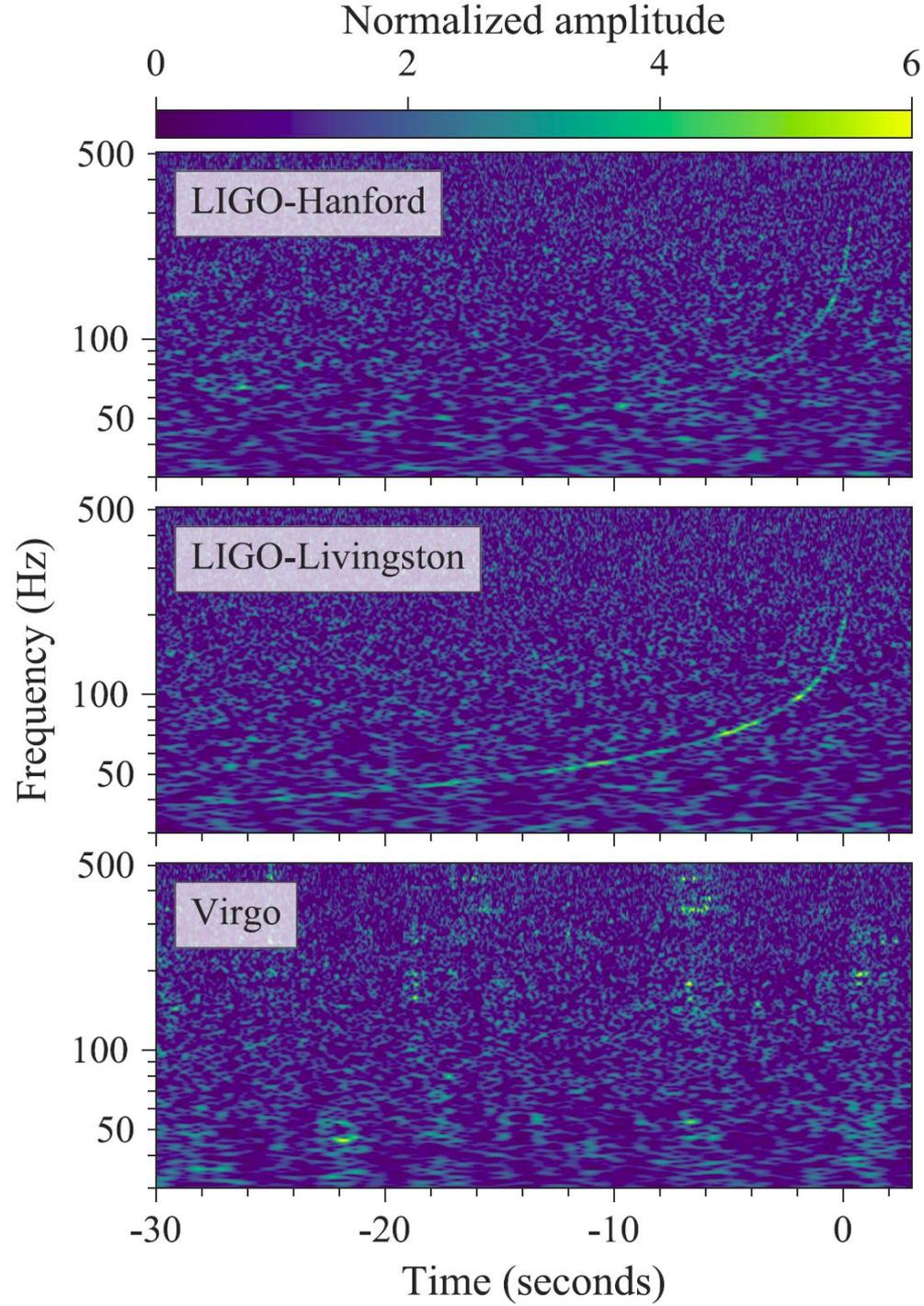
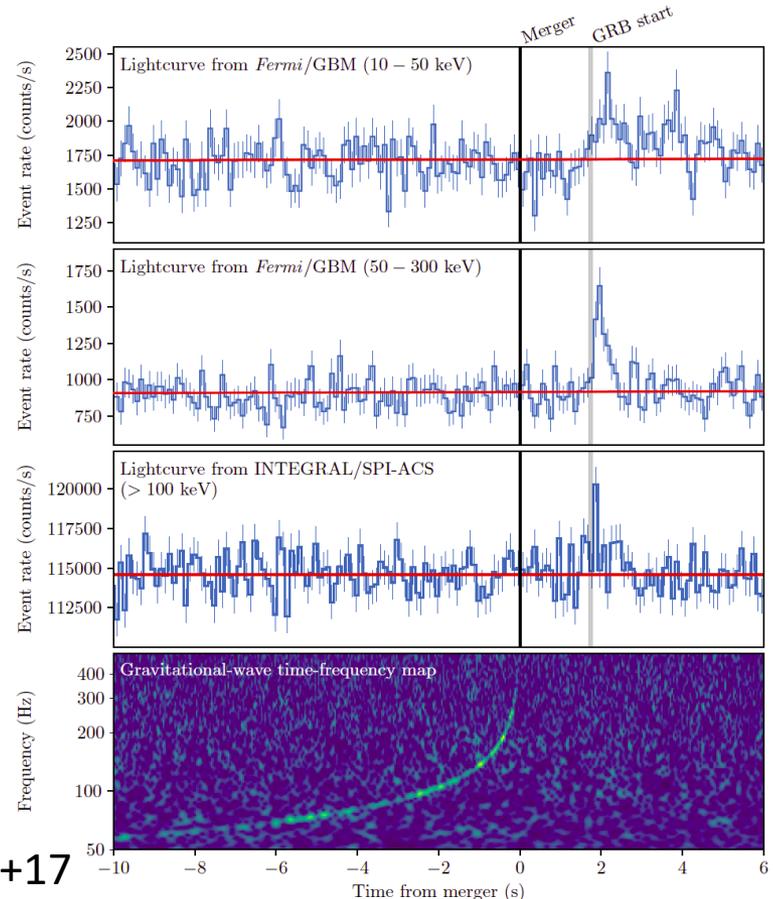
on 27 Nov 2014; 18:03 UT (Obs.: 26 and 27 Nov 2014)

<http://tpweb2.phys.konan-u.ac.jp/~tominaga/HSC-SN/>

Follow-up obs. of
gravitational wave

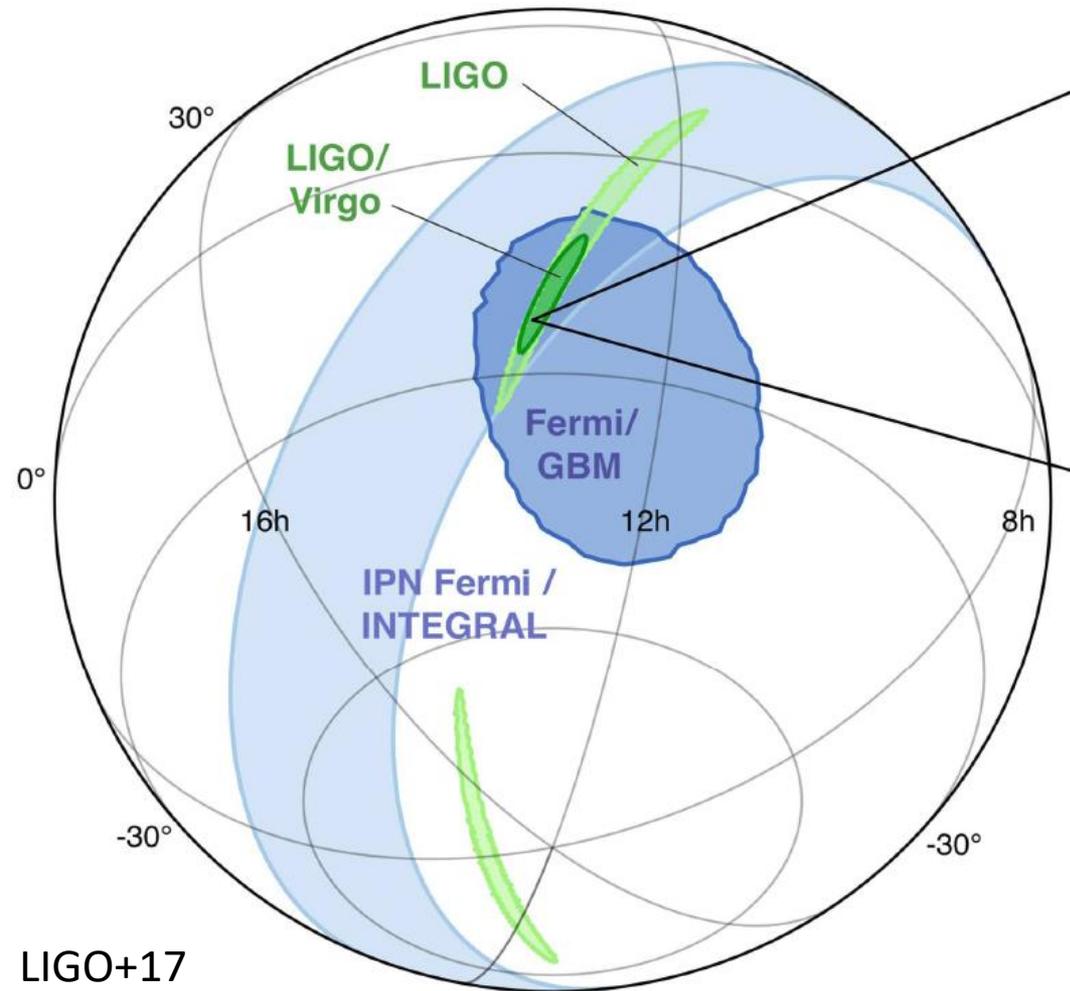
GW170817

The component masses is in the range $1.17\text{--}1.60 M_{\odot}$, with the total mass of the system $2.74^{+0.04}_{-0.01} M_{\odot}$.

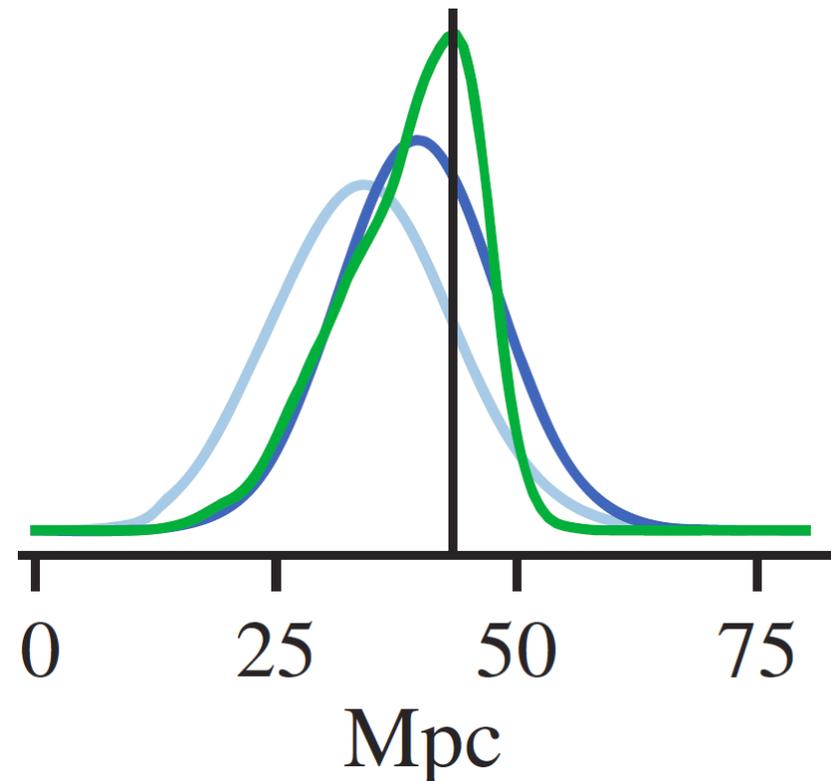


GW170817

Localization with 3 detectors are as narrow as **28deg²** for a 90% credible region. (~1300deg² for GW151226)



Distance is **40⁺⁸₋₁₄Mpc**.

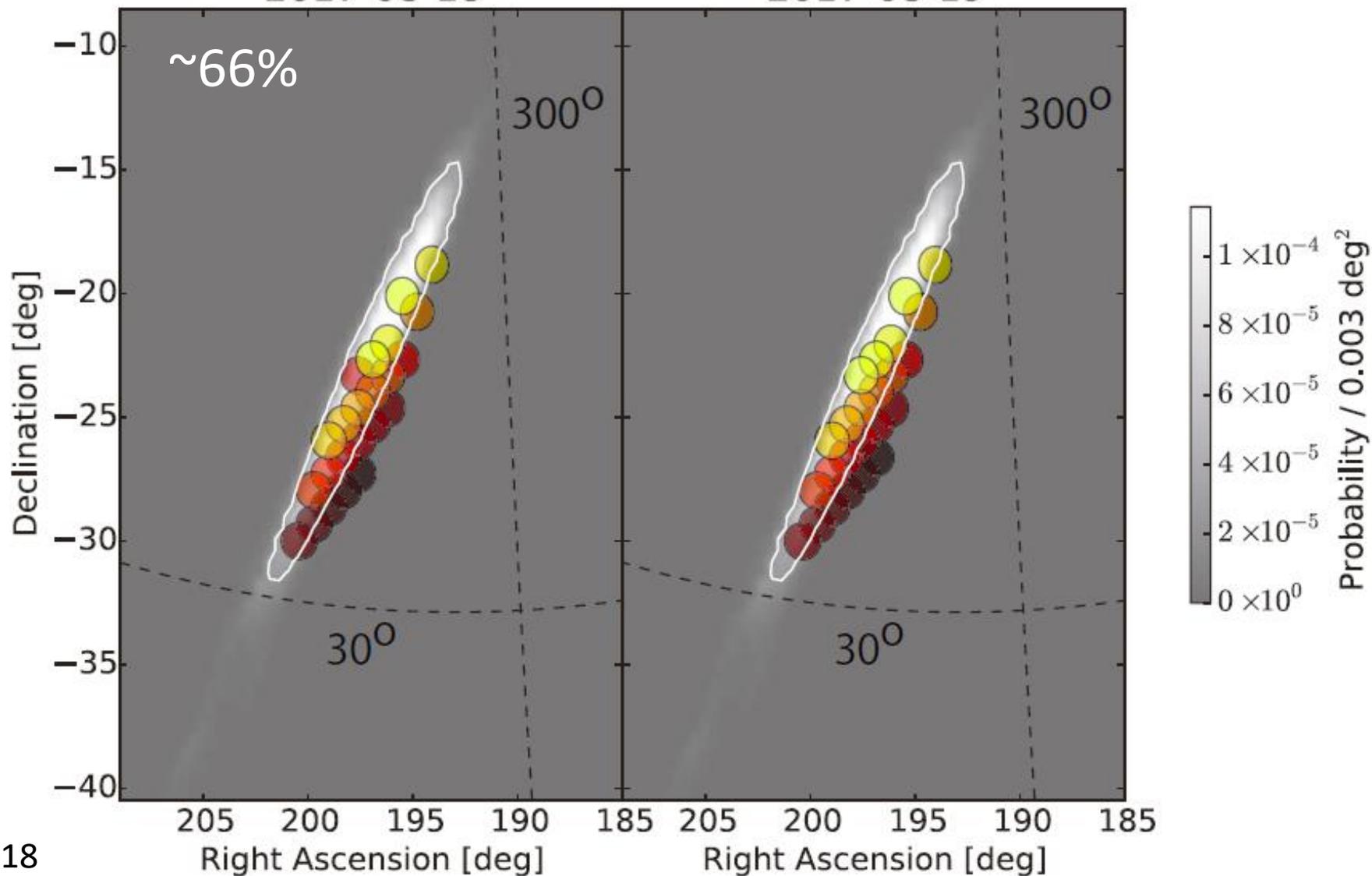


HSC observations

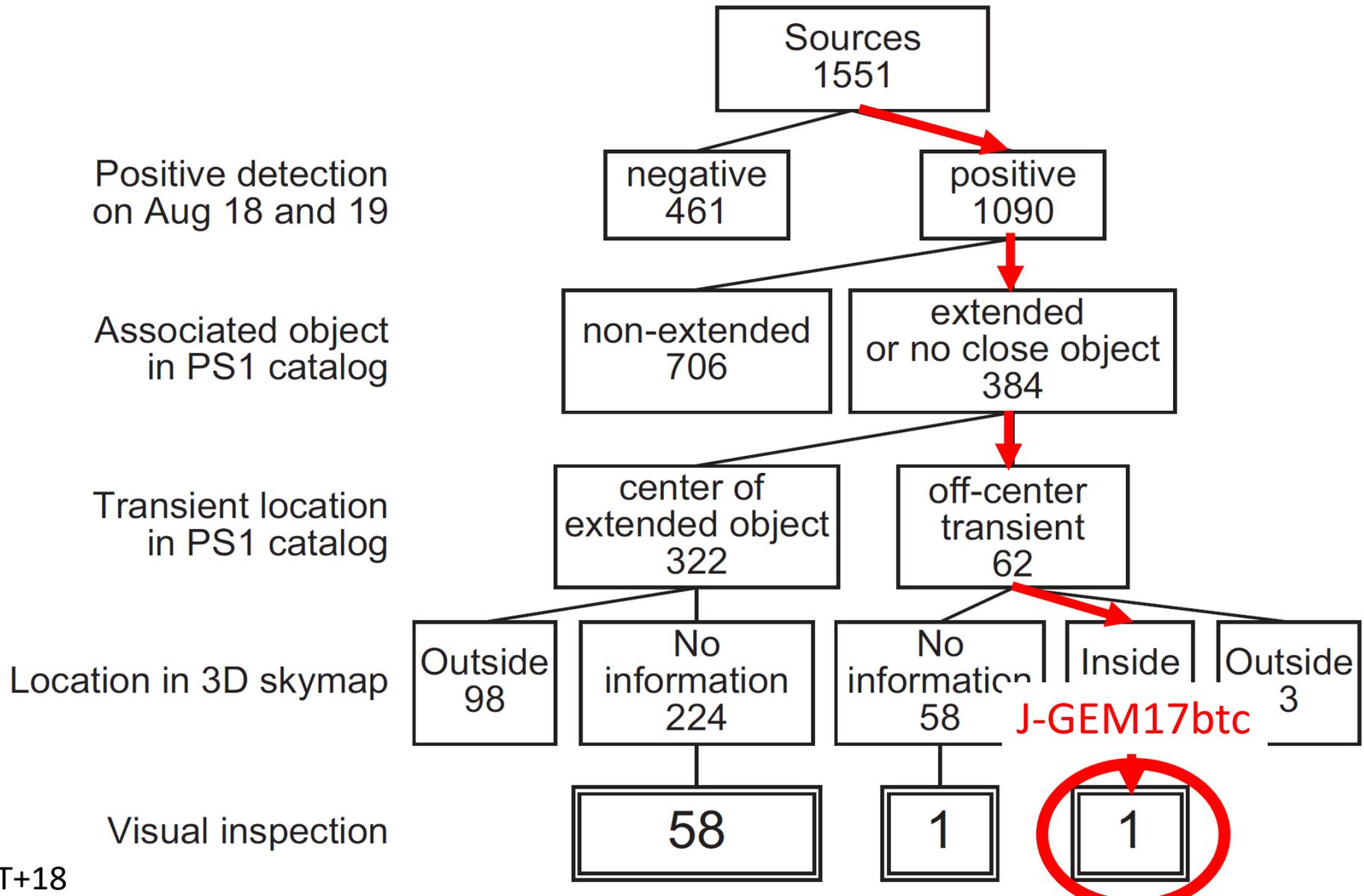
HSC Pointing map for GW170817

2017-08-18

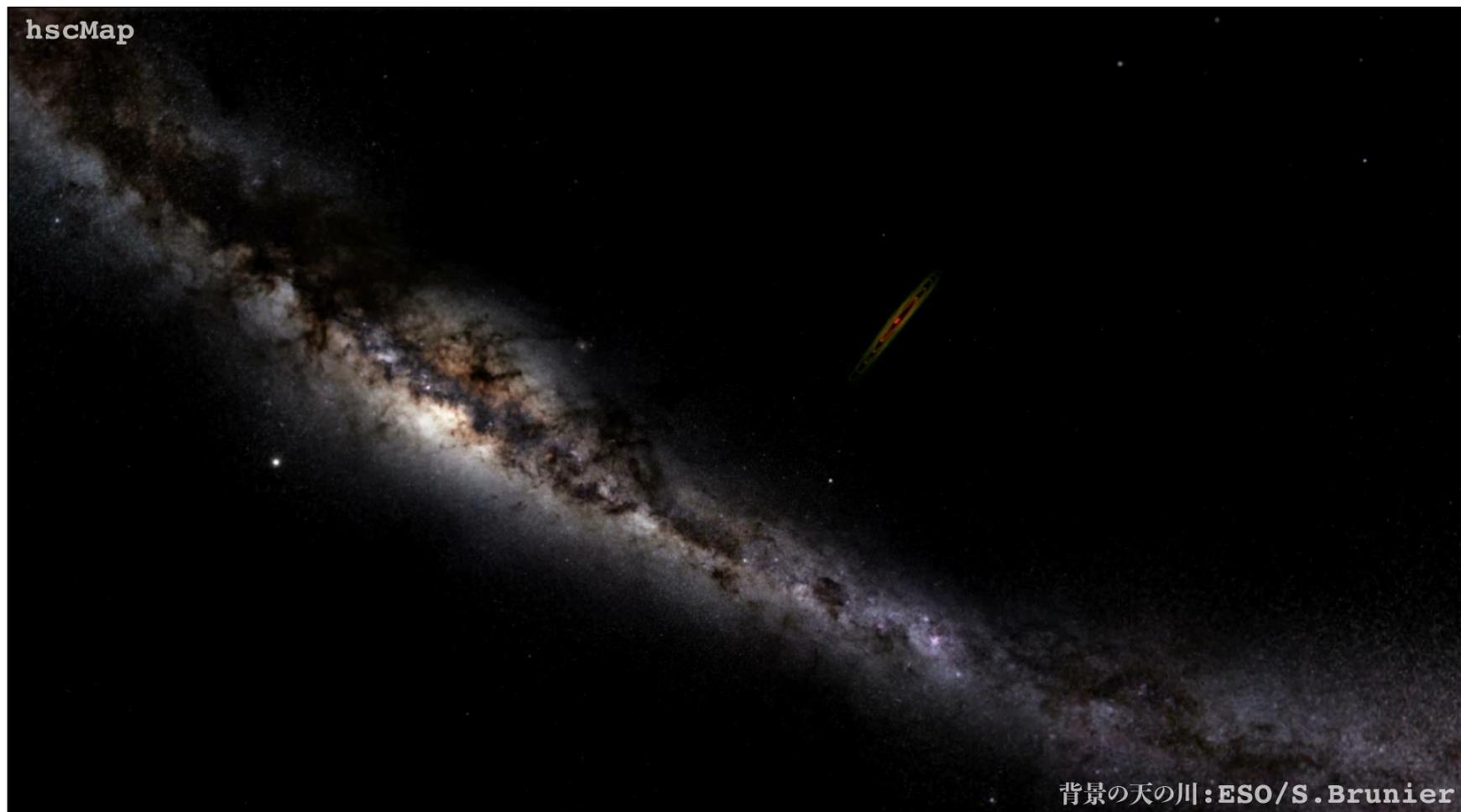
2017-08-19



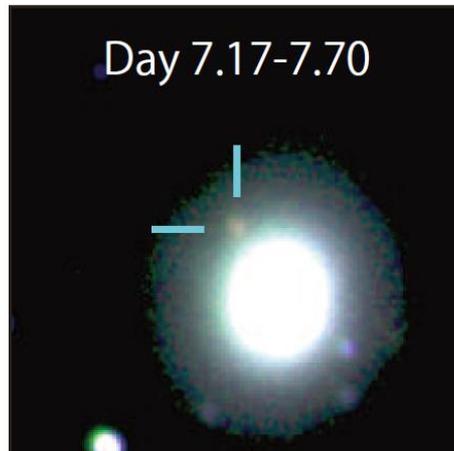
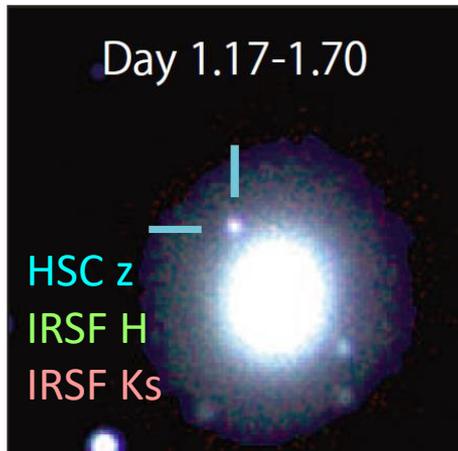
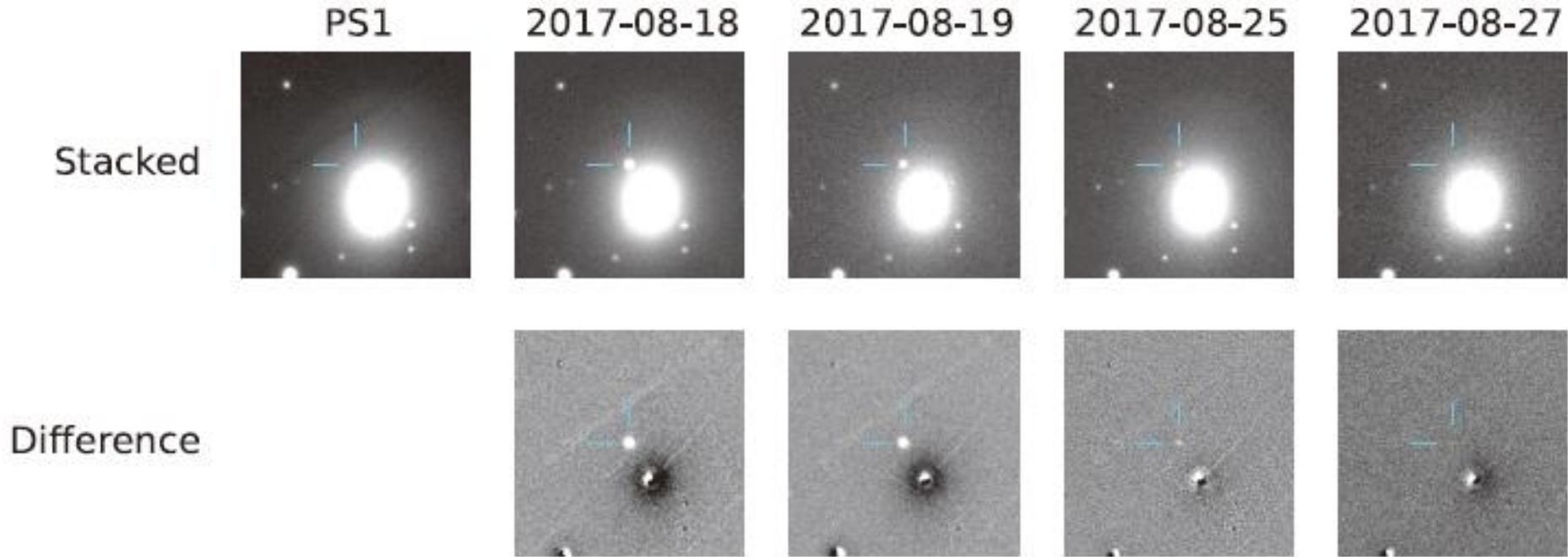
Source screening



Optical follow-u obs. of GW170817



J-GEM17btc (SSS17a)

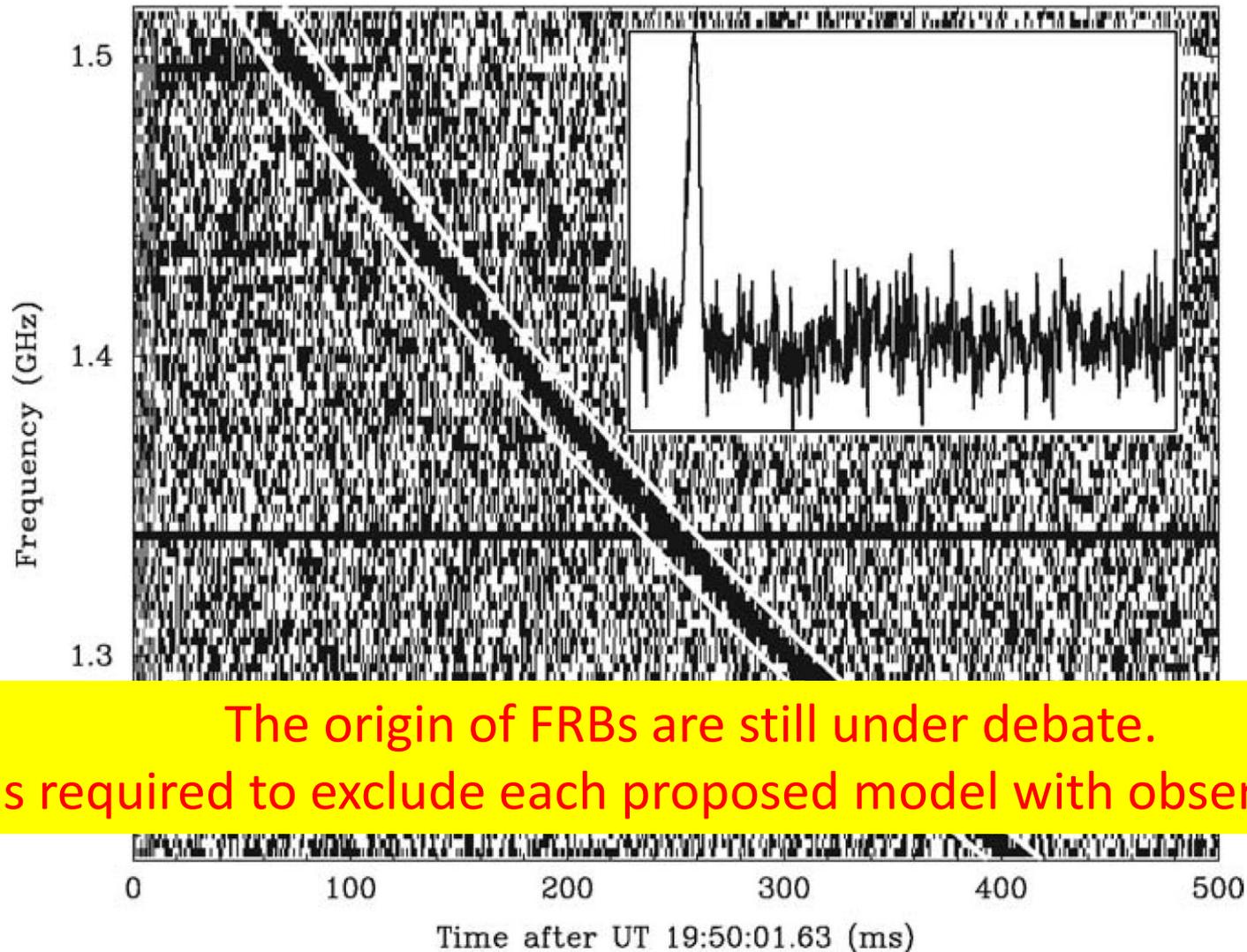


No other plausible
source in the
probable region of
GW170817

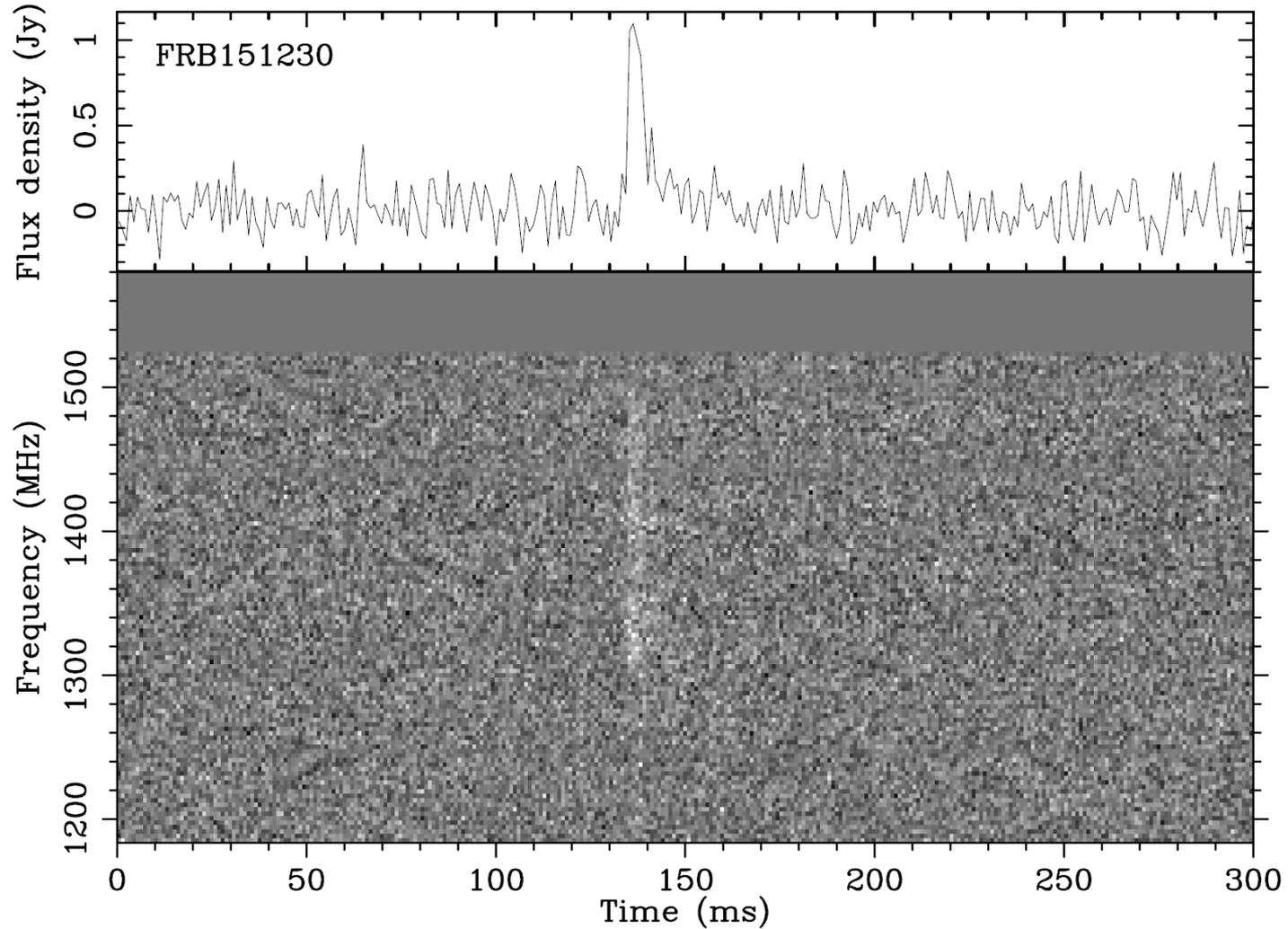
Follow-up obs. of
fast radio bursts

Fast Radio Burst 010724

Bright millisecond radio transients with high dispersion measure



FRB151230 ($z < 0.8$ from DM)

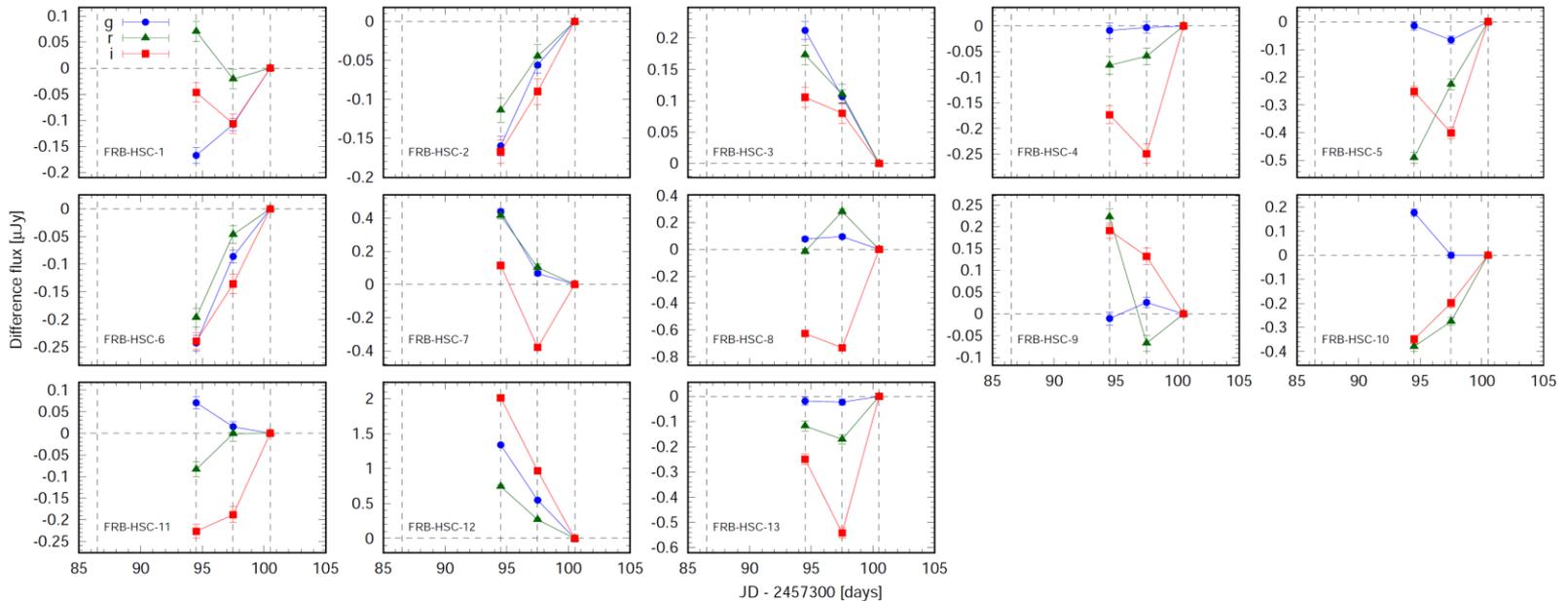
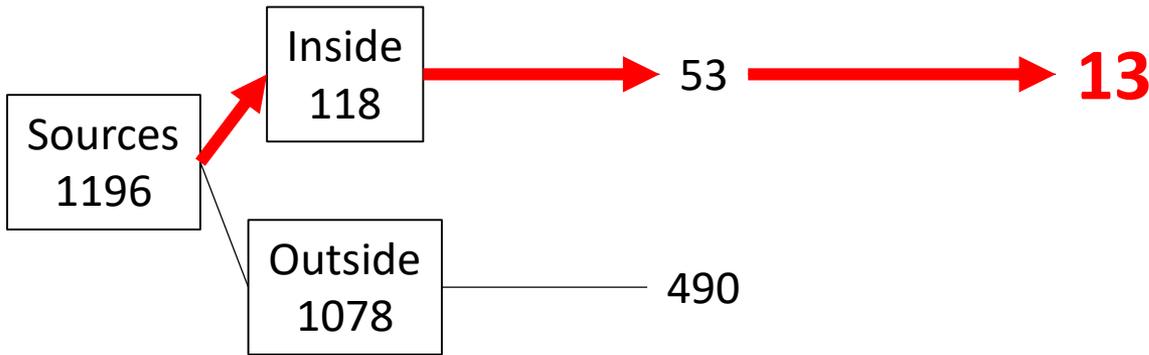


Source screening

Location
($r < 15$ arcmin)

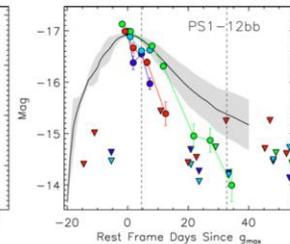
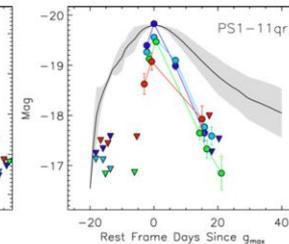
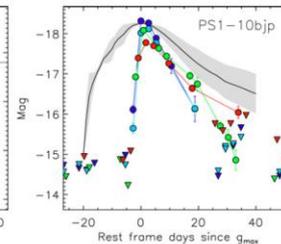
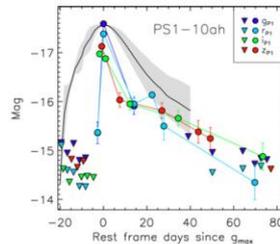
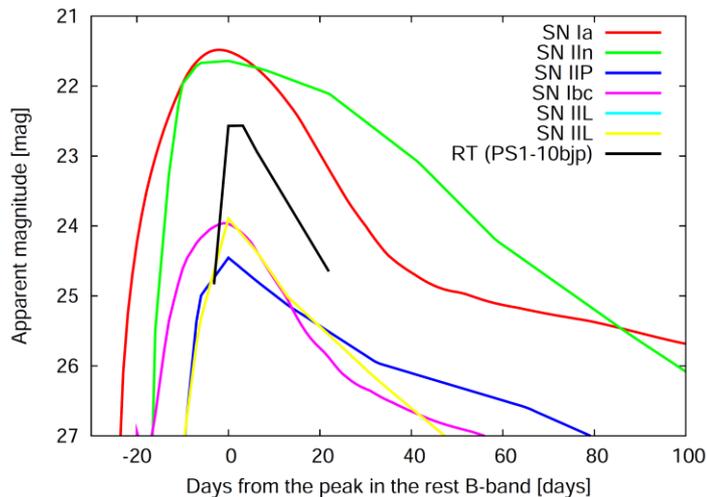
Detection with an
alternative image
subtraction method

Visual
inspection

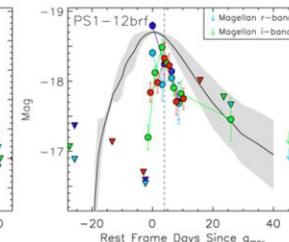
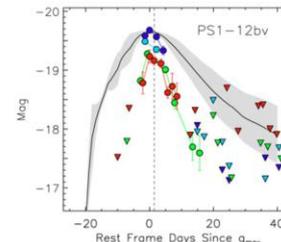


Classification

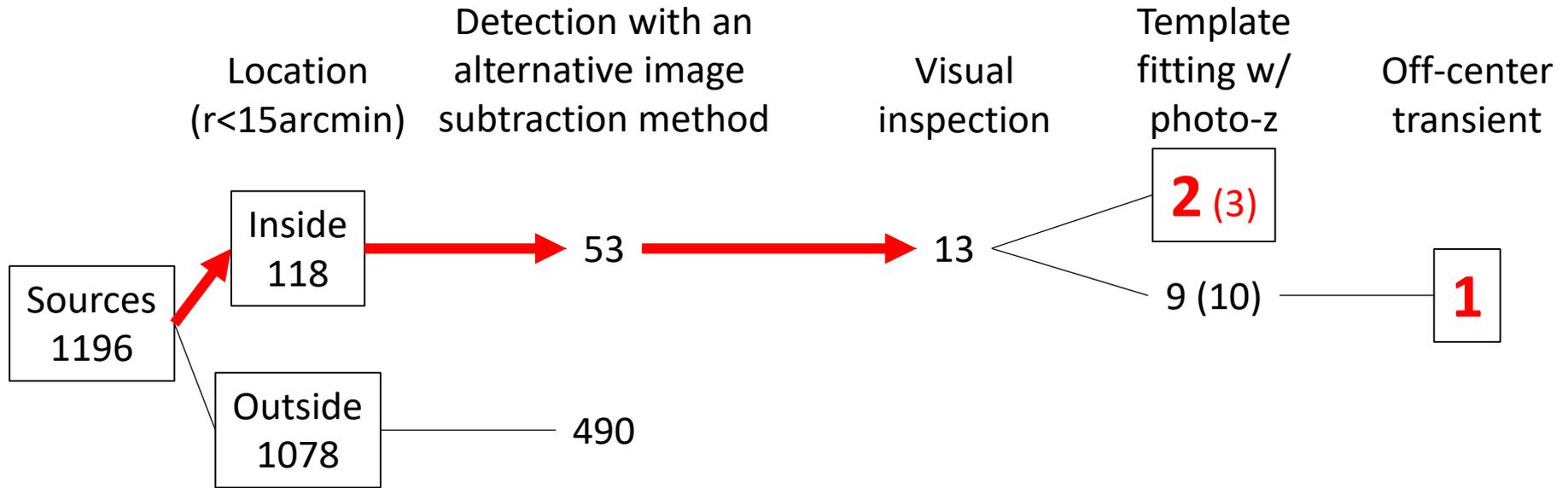
1. Intrinsic radio flux (S/N) and non-detection with other beams \rightarrow **Cand-5** is excluded
2. Photometric redshifts of host galaxies \rightarrow **Cand-6** is excluded.
3. **Difference LC fitting** with SN and rapid transient templates



Hsiao+07
Nugent+02
Drout+14



Source classification



- There are **3** interesting variable candidates.
 - 2 candidates: core-collapse supernovae.
 - 1 candidate: a rapid transient at the faint and rapid end.
- There is **no candidate** reproduced with Type Ia SN.
- The other candidates could be optical variability of AGN.

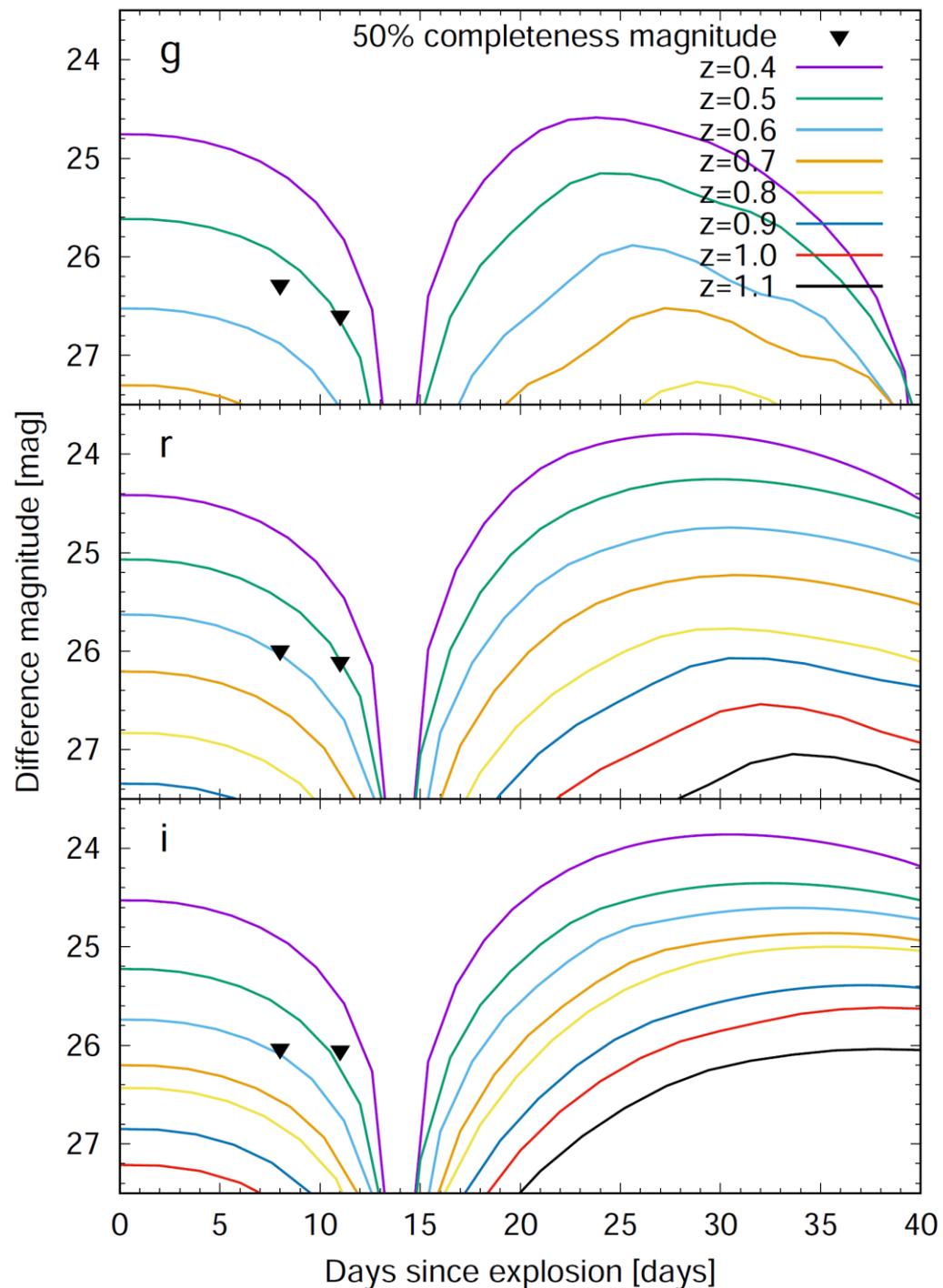
No SN Ia in the field

According to the limiting magnitude, if SN Ia at $z < 0.6$ is associated with FRB151230, SN Ia should be detected in the field.

The association of SNe Ia with $t_{\text{exp}} = 0$ at $z \leq 0.6$ with FRB 151230 is excluded.

There are two requirements for SN Ia and FRB151230 association.

- FRB 151230 is located at $z \sim 0.6-0.8$.
- The DM of the host galaxy of FRB 151230 $< 300 \text{ pc cm}^{-3}$.



Summary

- Subaru/HSC is the world's best imaging instrument for time-domain astronomy.
- **Realtime transient finding pipeline** is available.
- Follow-up observation of GW170817
 - **J-GEM17btc (SSS17a)** is the most-likely and distinguished candidate as the optical counterpart of GW170817.
 - There are no other plausible candidates.
- Follow-up observation of FRB151230
 - **3 interesting candidates** are identified. Among them, 1 candidate can be an RT at the faint and rapid end.
 - Association with SNe Ia and FRB151230 is **partly excluded**.