

SUBARU TELESCOPE 20TH ANNIVERSARY, Time Domain Astronomy session

Nov. 17-22, 2019

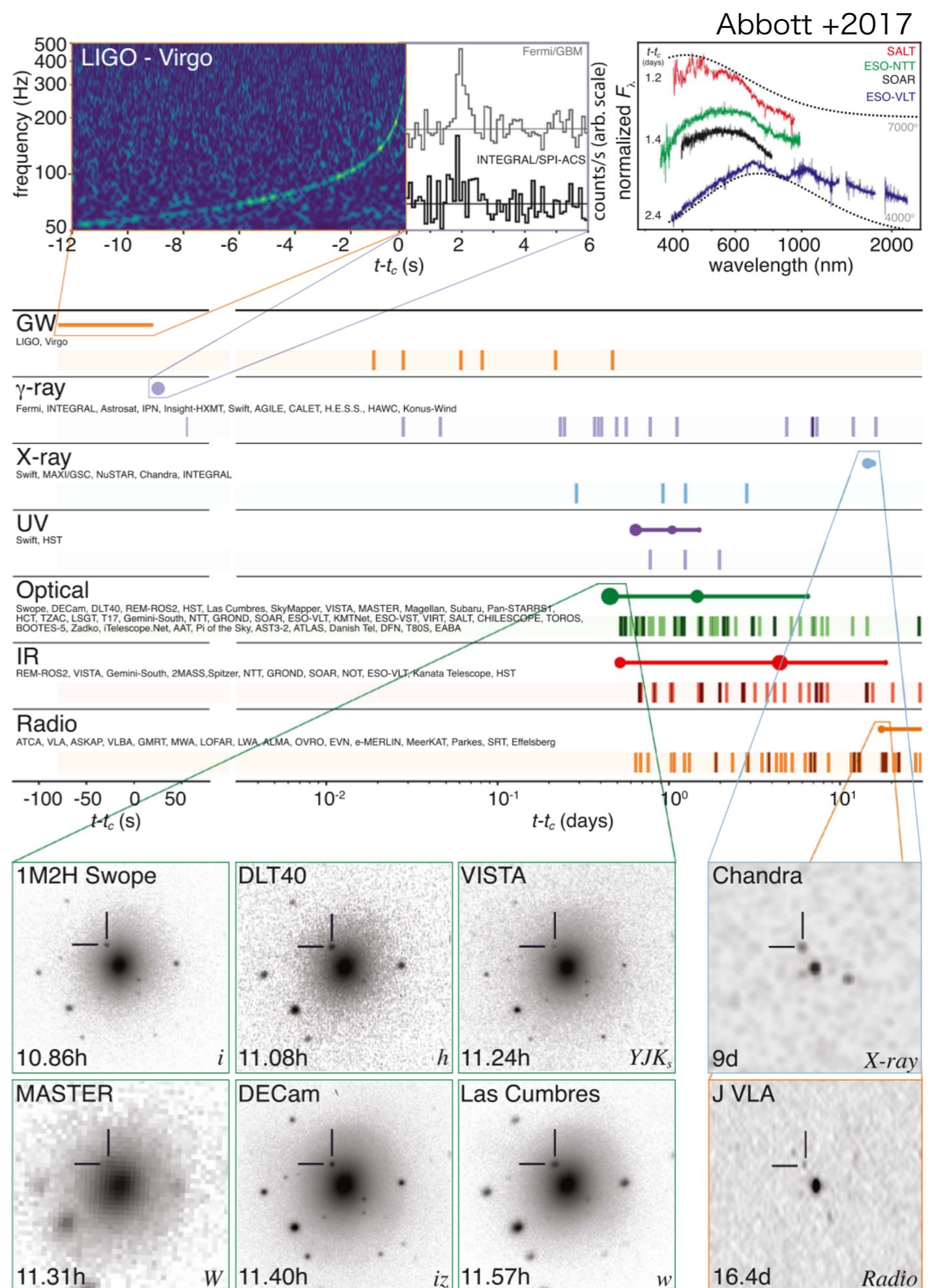
J-GEM Optical and NIR Follow-Up in Gravitational-Wave Third Observing Run

Mahito Sasada (Hiroshima University)

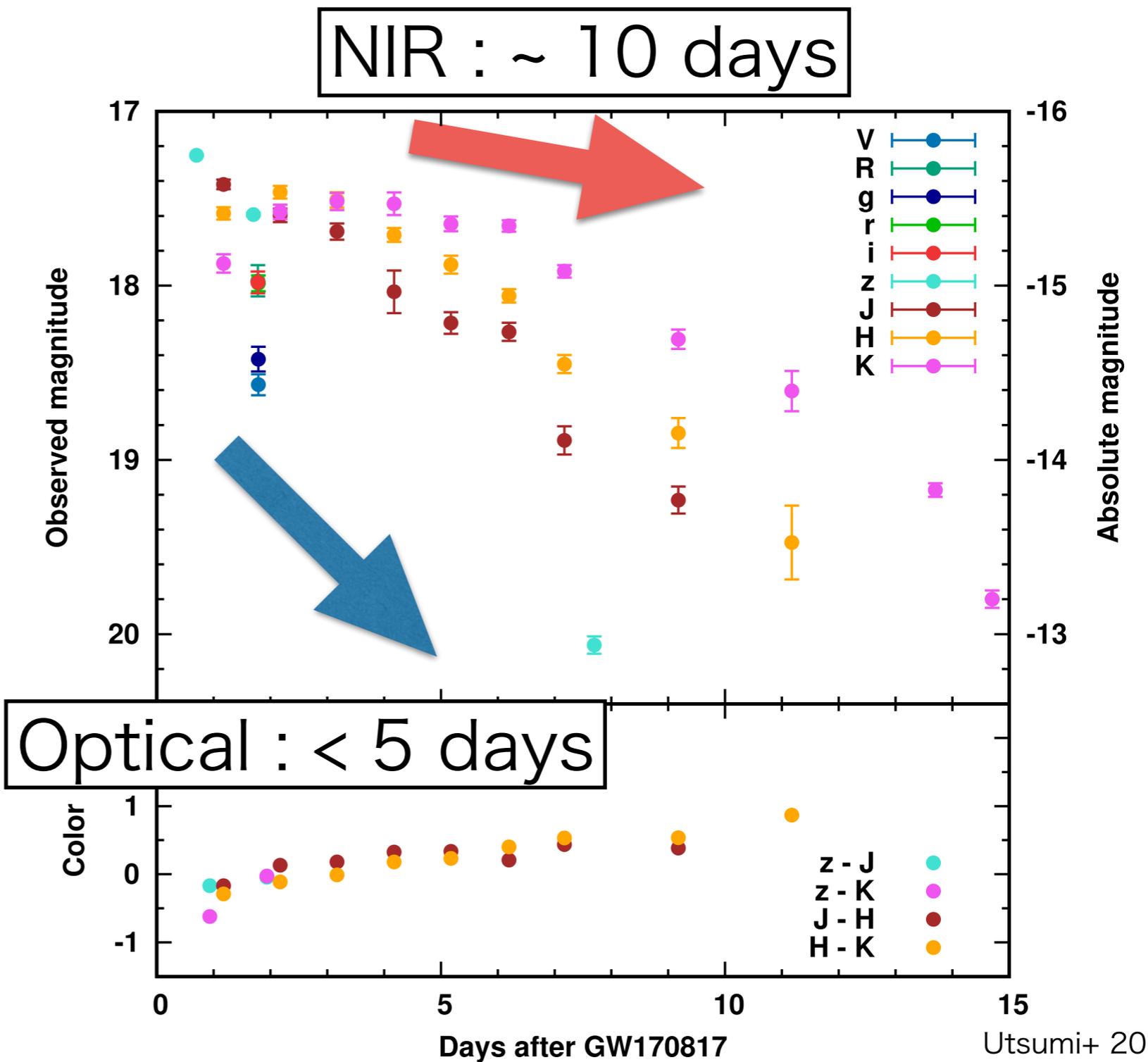
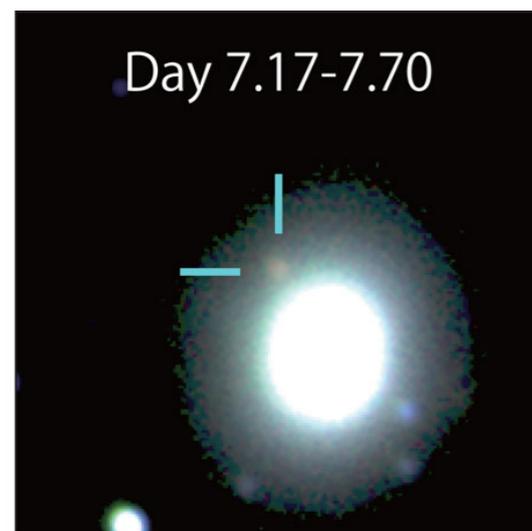
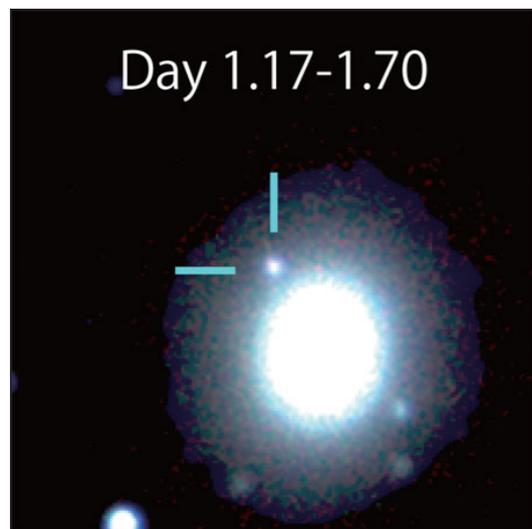
on behalf of J-GEM Team

GW170817

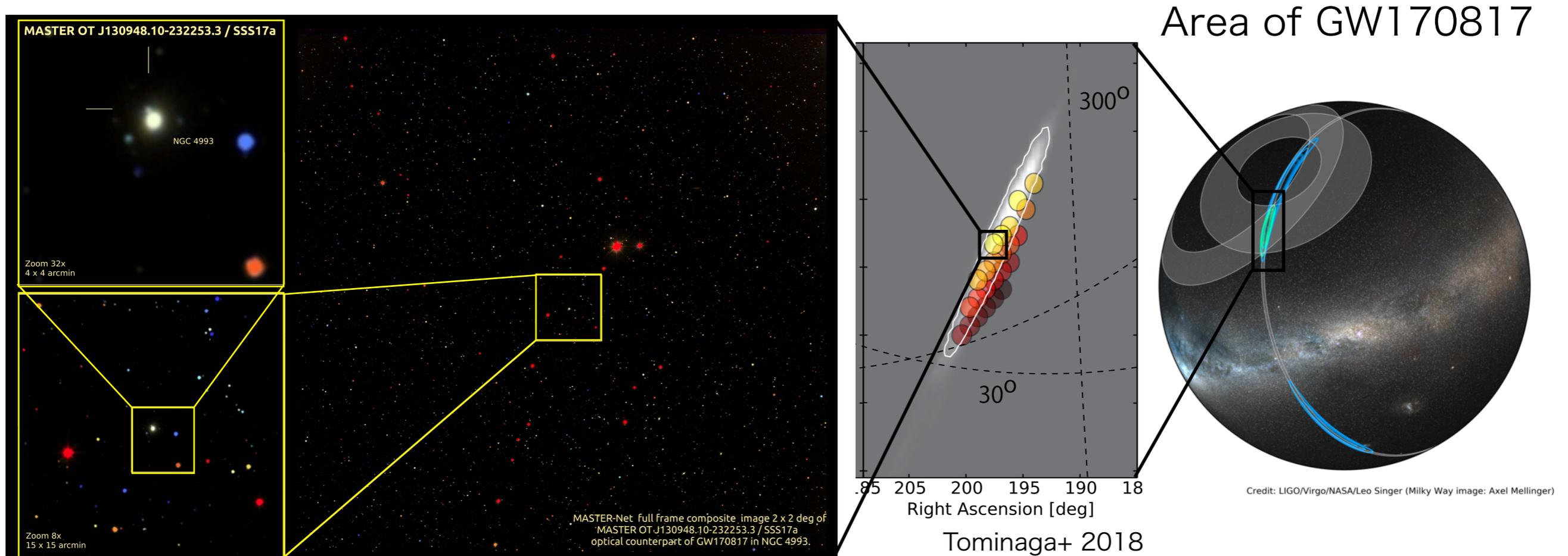
- LIGO/Virgo detected the GW on 17 Aug. 2017.
- GW170817 was identified as the EM counterpart in the entire wavelength.
- Detected in all wavelengths
 - **Gamma-ray**
 - **X-ray**
 - **Optical and NIR**
 - **Radio**
- No Detection in IceCube neutrino.



Light curves in Optical and NIR



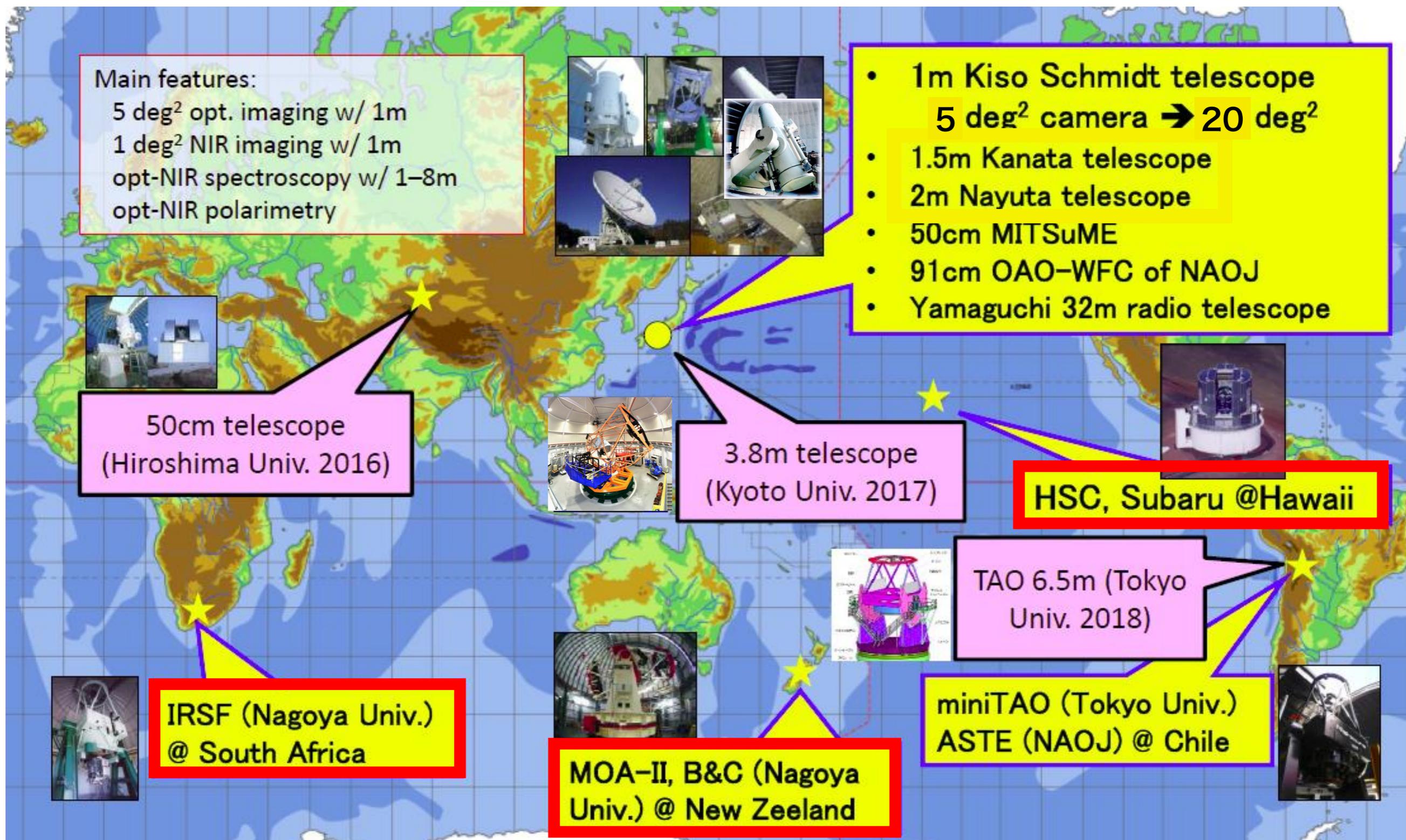
Identification of Optical Counterpart



Lipunov+ 2017

- There are many stars and galaxies within the probable region of GW170817 (28 sq. deg).
- It is not easy to identify an optical transient from the obtained image.

J-GEM (Japanese collaboration for Gravitational-wave Electro-Magnetic follow-up)



Purpose of J-GEM

Purpose

- Multi-messenger observation to reveal the physical background of GW sources
- Identify and observe an optical counterpart of GW source

Requirements

- Survey huge area (> 10 sq. degrees)
- Identify the optical counterpart as soon as possible to understand an early phase of GW event.

Approach

- We do a survey observation for GW possible region by using many Japanese telescopes

Two types of telescope

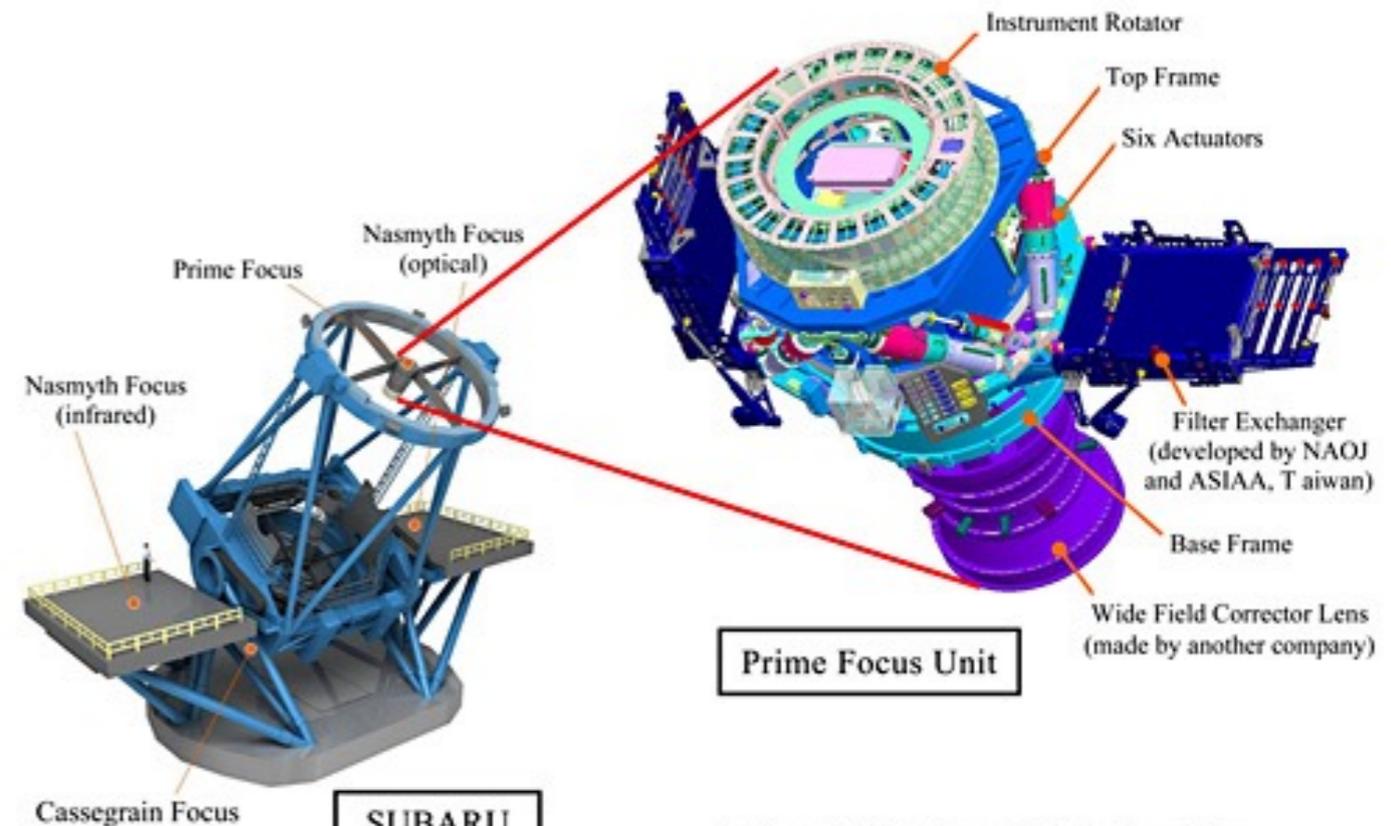
Normal Telescope (FoV < 1 deg²)



- Kanata
- OAO WFC
- B&C
- IRSF
- MITSuME
- SaCRA
- Nayuta
- Akeno/Okayama
- Seimei

Galaxy-targeted survey

Telescope having large FoV (FoV > 1 deg²)

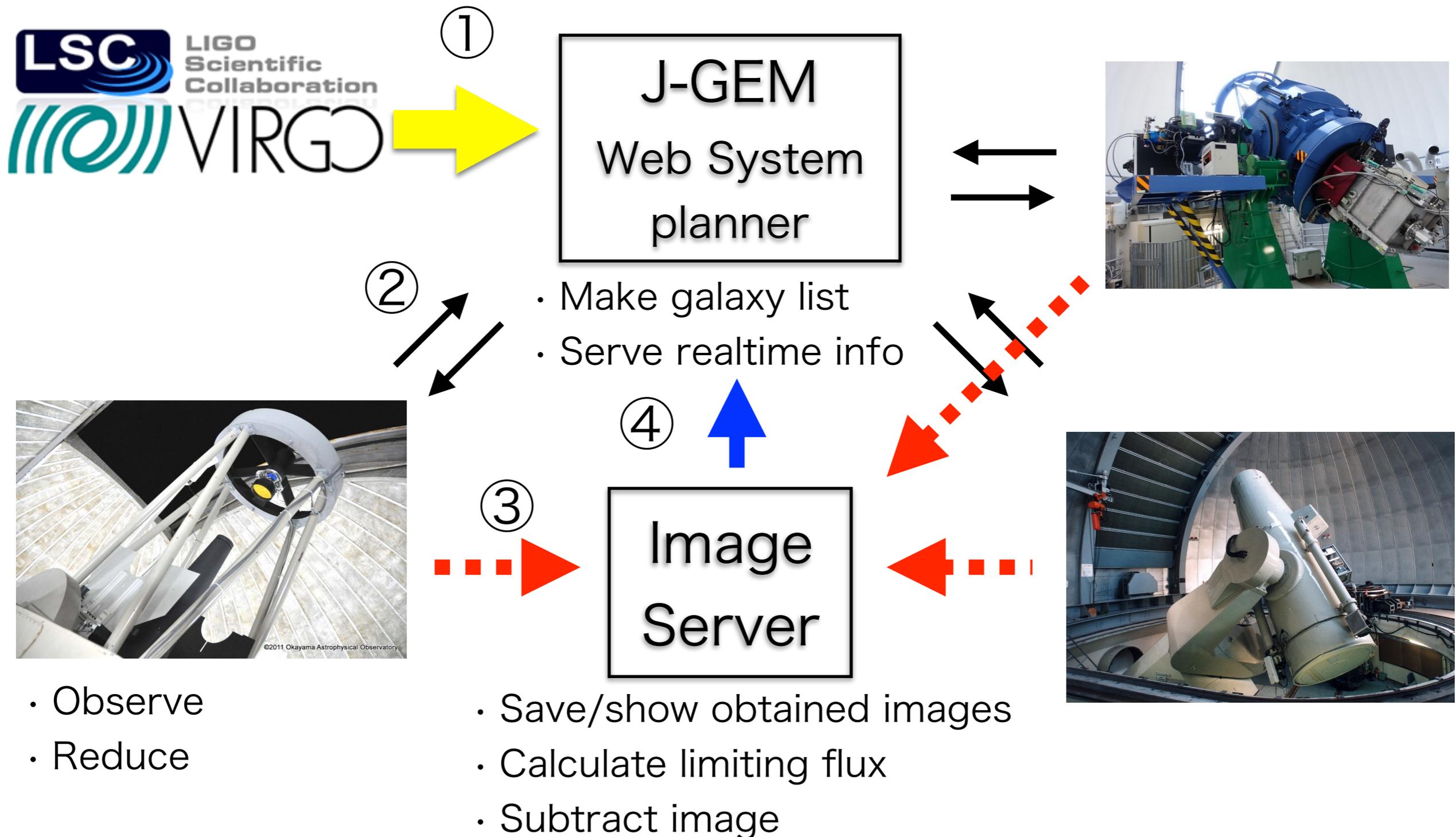


Courtesy of National Astronomical Observatory of Japan

- Subaru
- MOA-II
- Kiso Tomo-e

Wide-field survey

Scheme of Transient Survey



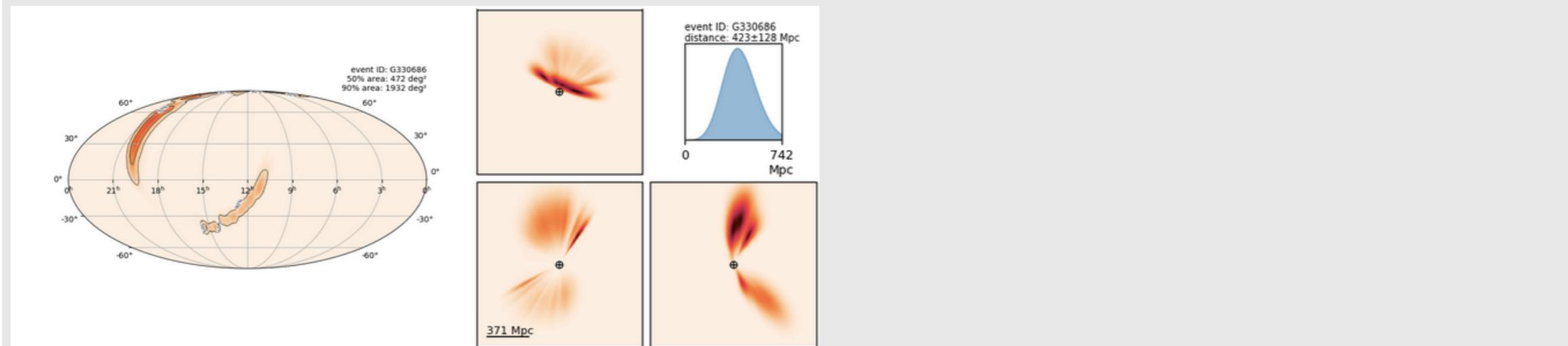
User interface: planner

For normal operation

[Event list](#) | [Candidates](#) | [Observing Log](#) | [Cross Table](#) | [GCN template](#) | [All Observing Log](#) | [Groups](#) | [Depths](#) | [Transients](#) | [Admin](#)
 Need machine readable format like JSON output? Just replace "main.html" with "processor.py" or [click here](#).

Sat, 22 Jun 2019 09:11:47 GMT

candidate : S190426c



galid	eventid	prob	inserted	ra	dec	dist	OptExpected	NirExpected	state	obsids	updated	filter and depth (5 σ AB)
GL232822+852913	S190426c	0.004373	2019-04-27 11:55:01.261810	352.0922	85.4869	354.2081	25.2	22.7	Curated	Kanata-HONIR	2019-04-27 11:31:45.128061	H=15.35,R=27.39,H=13.21,R=25.13
GL001239+854312	S190426c	0.0043644	2019-04-27 11:55:01.261810	3.1639	85.7199	292.5736	24.8	22.3	Curated	Kanata-HONIR	2019-04-28 08:27:10.122503	H=16.87,R=19.15,H=18.14,R=19.46
GL233253+853017	S190426c	0.0039403	2019-04-27 11:55:01.261810	353.222	85.5048	304.0923	24.9	22.4	Curated	Kanata-HONIR	2019-04-27 01:21:28.630183	H=15.35,R=27.39

Galaxy ID

Probability

Galaxy Info

Observational Information

- List candidate galaxies from GLADE catalog.
- Share information to avoid a duplication of observations

User interface: Image Server

Obs. Image

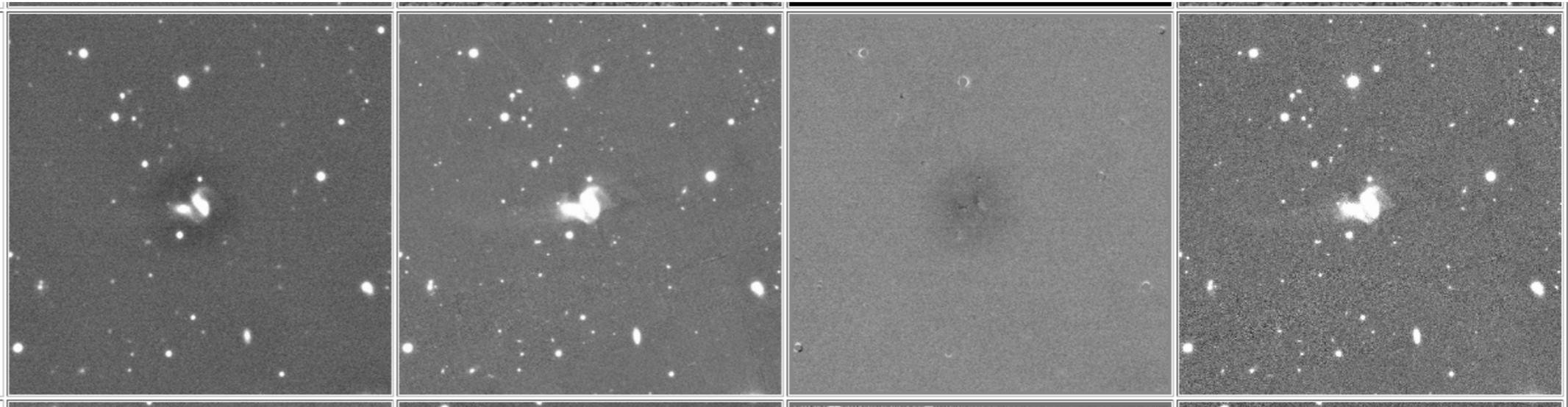
Ref. Image

Sub. Image

Blinking gif

Galaxy GL224423+042110
Telescope Kanata
Filter R
Obs. MJD 58420.60
Uploaded (UTC) 2018/10/30 04:02:59.28
Has Transient —
Report NO
UL >19.74

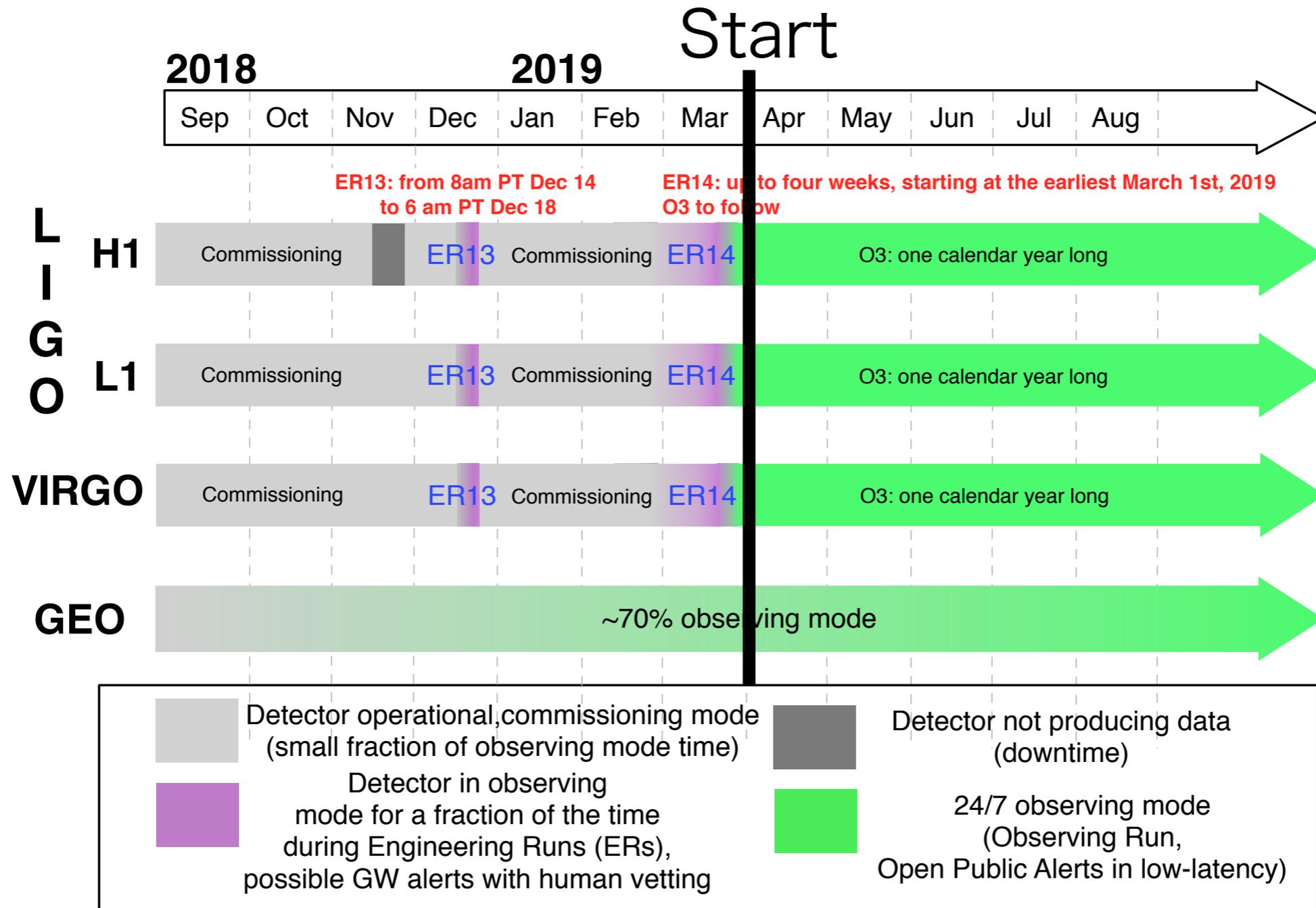
[Image detail & report \(JS9\)](#)



- Show an observing and reference image (PanSTARRS and 2MASS).
- Image subtraction
- Compare between obtained and reference images using subtracted image and blinking gif image.

Third Observing Run (03)

Schedule of O3



O3 has been performed since Apr. 2019. Many GWs have been detected.

All GW alert; 35 events

GraceDB — Gravitational-Wave Candidate Event Database

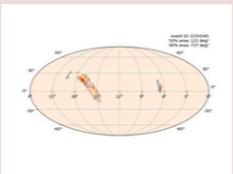
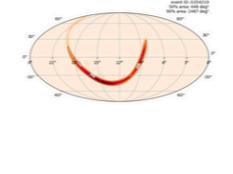
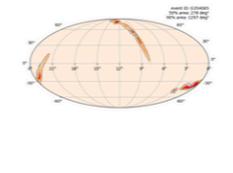
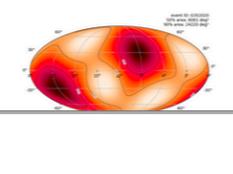
HOME	PUBLIC ALERTS	SEARCH	LATEST	DOCUMENTATION	LOGIN
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LIGO/Virgo O3 Public Alerts

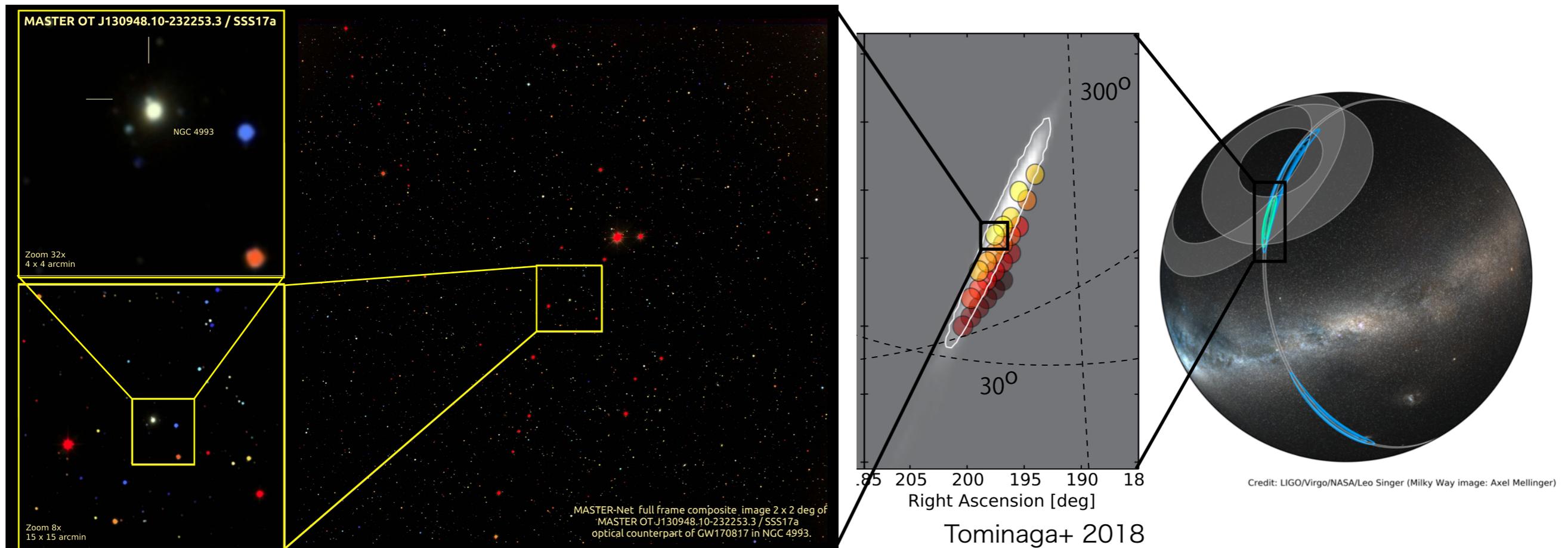
Detection candidates: 35

SORT: EVENT ID (A-Z) ▾



Event ID	Possible Source (Probability)	UTC	GCN	Location	FAR	Comments
S191110af		Nov. 10, 2019 23:06:44 UTC	GCN Circulars Notices VOE	No public skymap image found.	1 per 12.681 years	RETRACTED
S191110x	MassGap (>99%)	Nov. 10, 2019 18:08:42 UTC	GCN Circulars Notices VOE		1 per 1081.7 years	RETRACTED
S191109d	BBH (>99%)	Nov. 9, 2019 01:07:17 UTC	GCN Circulars Notices VOE		1 per 2.062e+05 years	
S191105e	BBH (95%), Terrestrial (5%)	Nov. 5, 2019 14:35:21 UTC	GCN Circulars Notices VOE		1 per 1.3881 years	
S190930t	NSBH (74%), Terrestrial (26%)	Sept. 30, 2019 14:34:07 UTC	GCN Circulars Notices VOE		1 per 2.0536 years	

Localization of GW170817

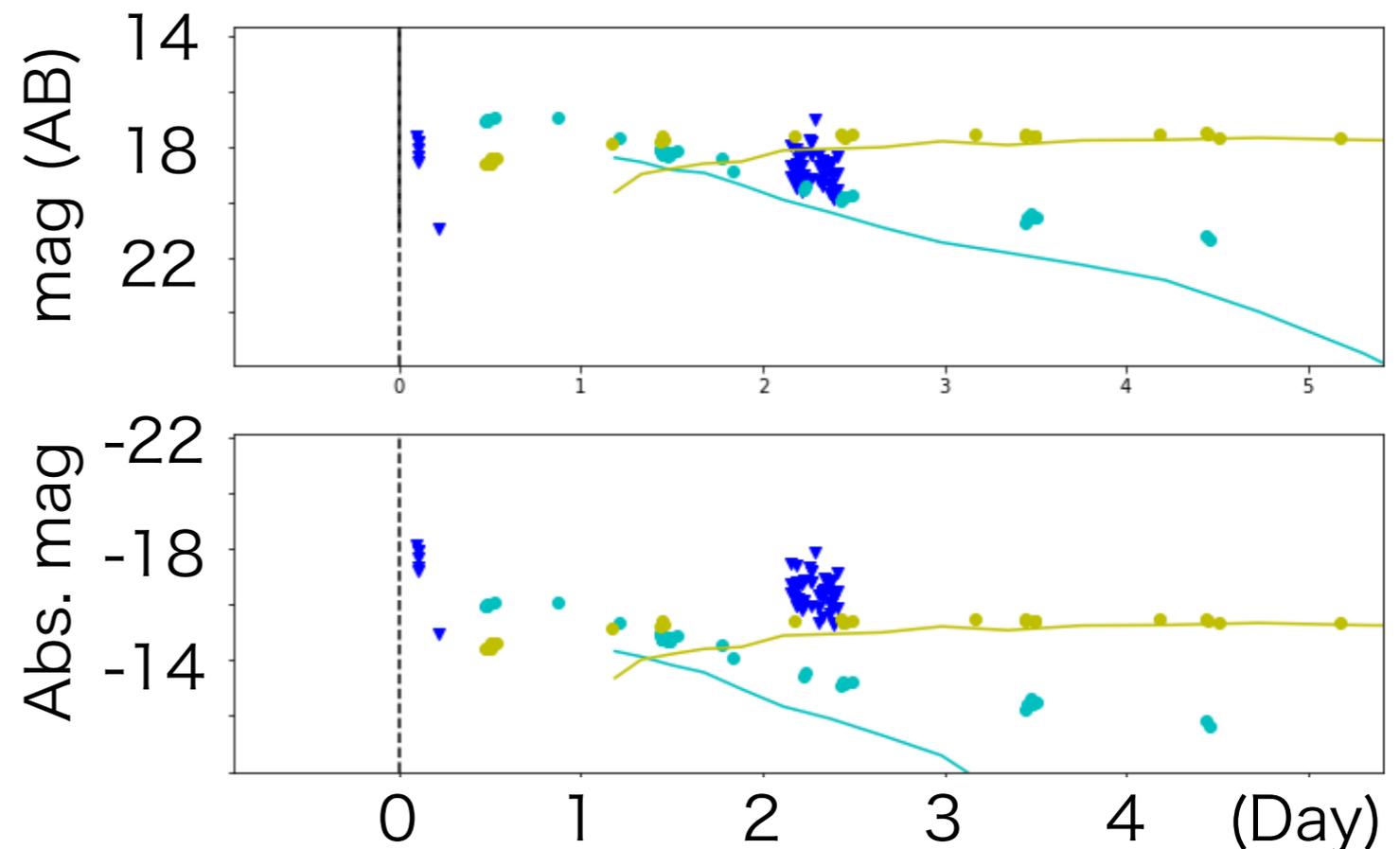
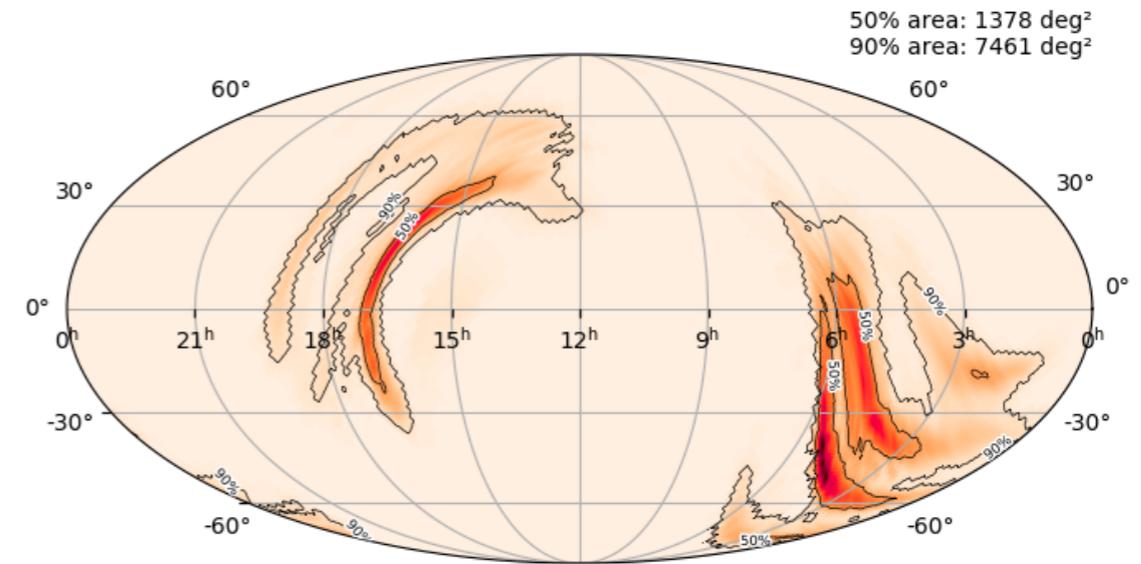


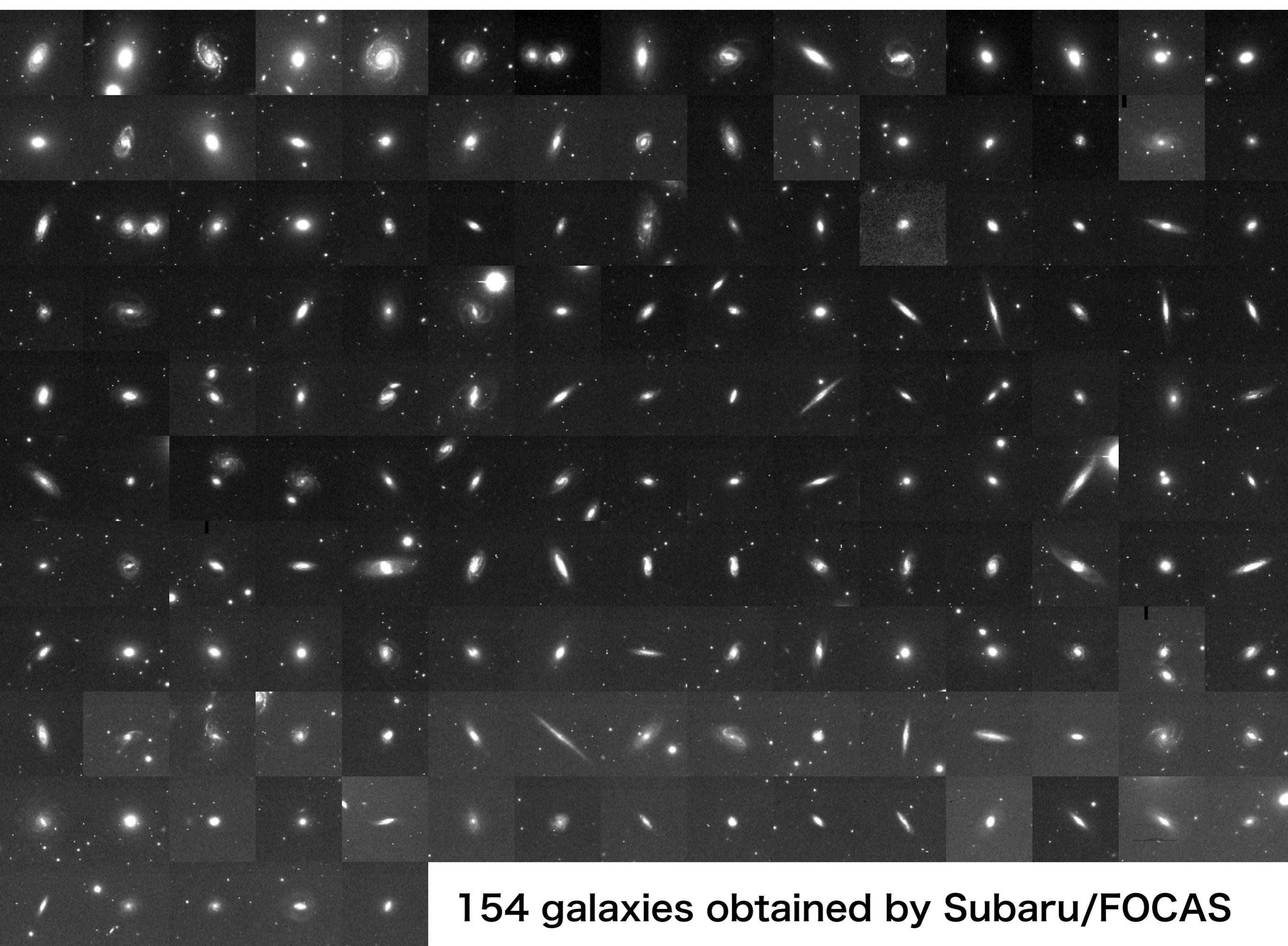
Lipunov+ 2017

- Localization: **28 sq. deg**
- Distance: **40 Mpc**
- Brightest Magnitude: **17~18 mag**

BNS Event: S190425z

- First BNS event
- Distance: 155 ± 45 Mpc
- 90% area: 7461 sq. deg
- Observe 23 galaxies listed in GLADE catalog
- Percentage of coverage: 1.1%
- The ToO observations were performed by Subaru/FOCAS.
- GCN circular; #24192, 24230, 24328



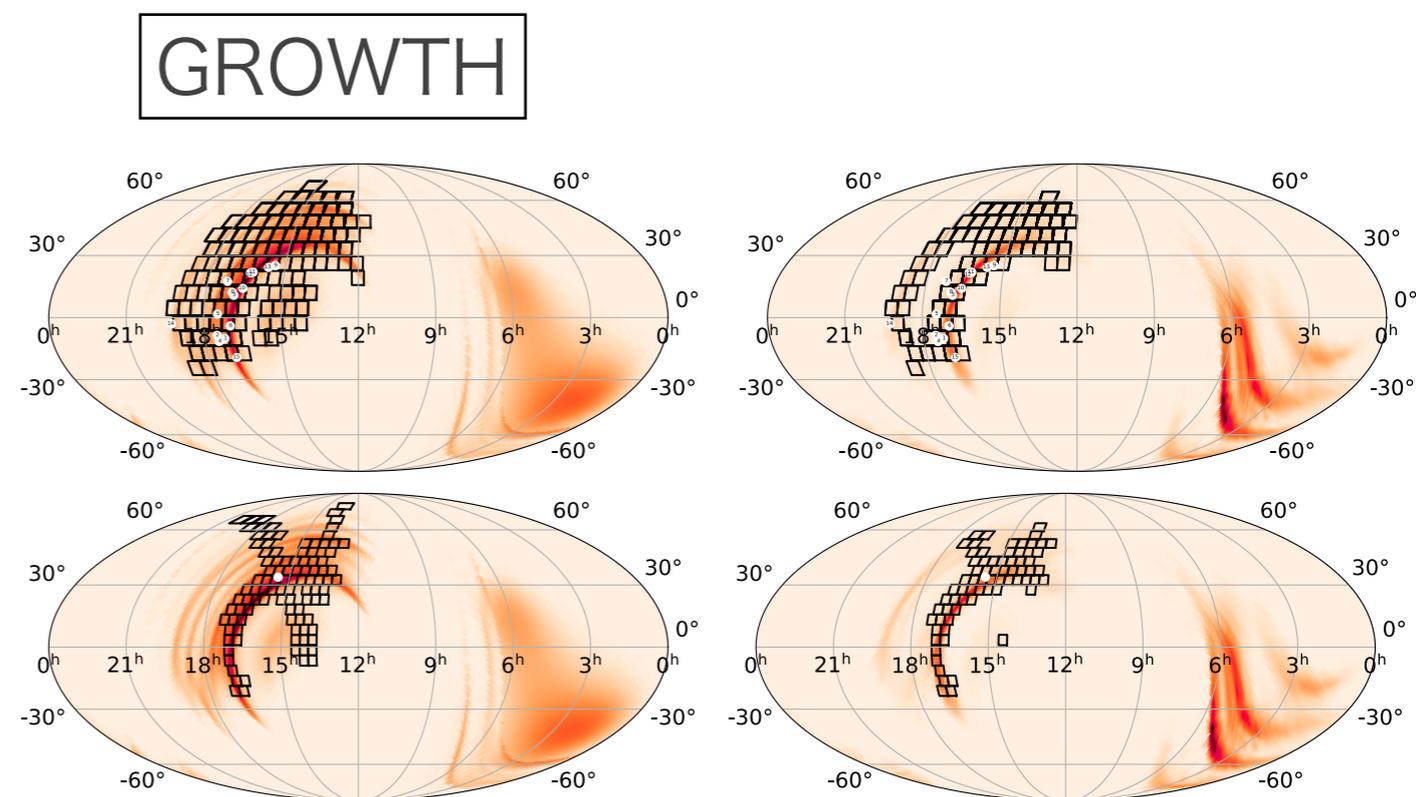


154 galaxies obtained by Subaru/FOCAS

Results of Subaru/FOCAS and Other Group

- Survey 154 galaxies to discover the optical counterpart of the GW event S190425z associated with a host galaxy.
- Limiting magnitude is 23 --- 24 mag for 5-sigma detection
- Other group also tried to identify electromagnetic counterpart.

Did not find any optical counterpart of S190425z



Summary of J-GEM Activity

	Type	Distance (Mpc)	localization (deg ²)	Observation (Gal. number)	Cumulative Prob (%)	GCN
S190408an	BBH	1473±358	387	6	1.2	24064
S190412m	BBH	812±194	156	197	21.2	24113, 24350
S190425z	BNS	155±45	7461	178	1.1	24192, 24230, 24328
S190426c	BNS, NSBH	377±100	1131	106	5.6	24299
S190510g	BNS, Terrestrial	277±92	1166	29	2.9	24464
S190521r	BBH	1136±279	488	113	11.3	24661
S190814bv	NSBH	267±52	23	54	23.2	25377, 25389
S190930t	NSBH	108±38	24220	26	0.4	25920, 25941

Did follow-ups to 17 GW alerts

We have submitted 13 reports for 8 GWs to GCN Circular.

Summary

- Our observational systems both for normal and wide-field FoV telescopes work well.
- Web-base and communication systems:
 1. planner : Share a list of candidate galaxies and observational information.
 2. Image Server : Assemble observed images and subtract from reference.
- We are following up the GW alerts, especially having-NS events.
- We submitted 13 reports of our follow-up to the GCN Circular.

Thank you for your attention