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ToO Patrol (ToP) Project of GWAC

Searching for the optical counterparts of GW
events

Han X. H., Xin L. P., Wang J.,
Wu C., Turpin D., Wei J. Y.,
Leroy N., Antier S., on behalf
of GWAC team and
GRANDMA team

Les Houches May, 2018

3rd SVOM Scientific Workshop — Disentangling the merging universe with SVOM



Outlines

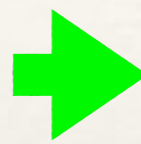
- ❖ GWAC system
- ❖ ToP project of GWAC and ToP activities
- ❖ ToP GW campaign for O3
- ❖ ToP joins in the GRANDMA

GWAC system: hardware

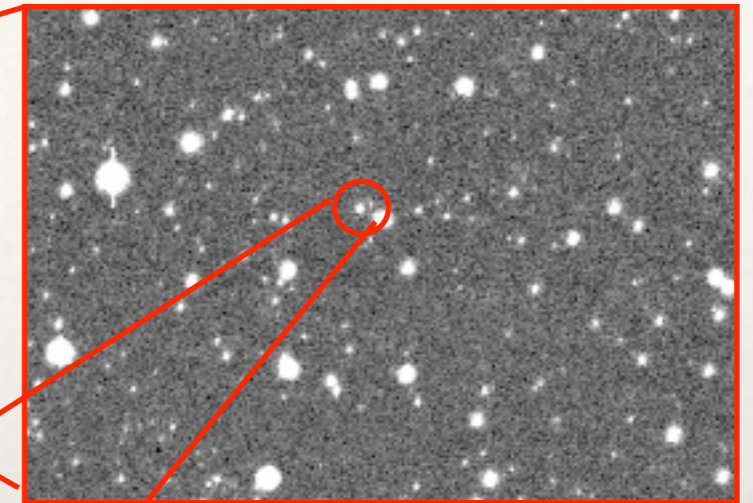
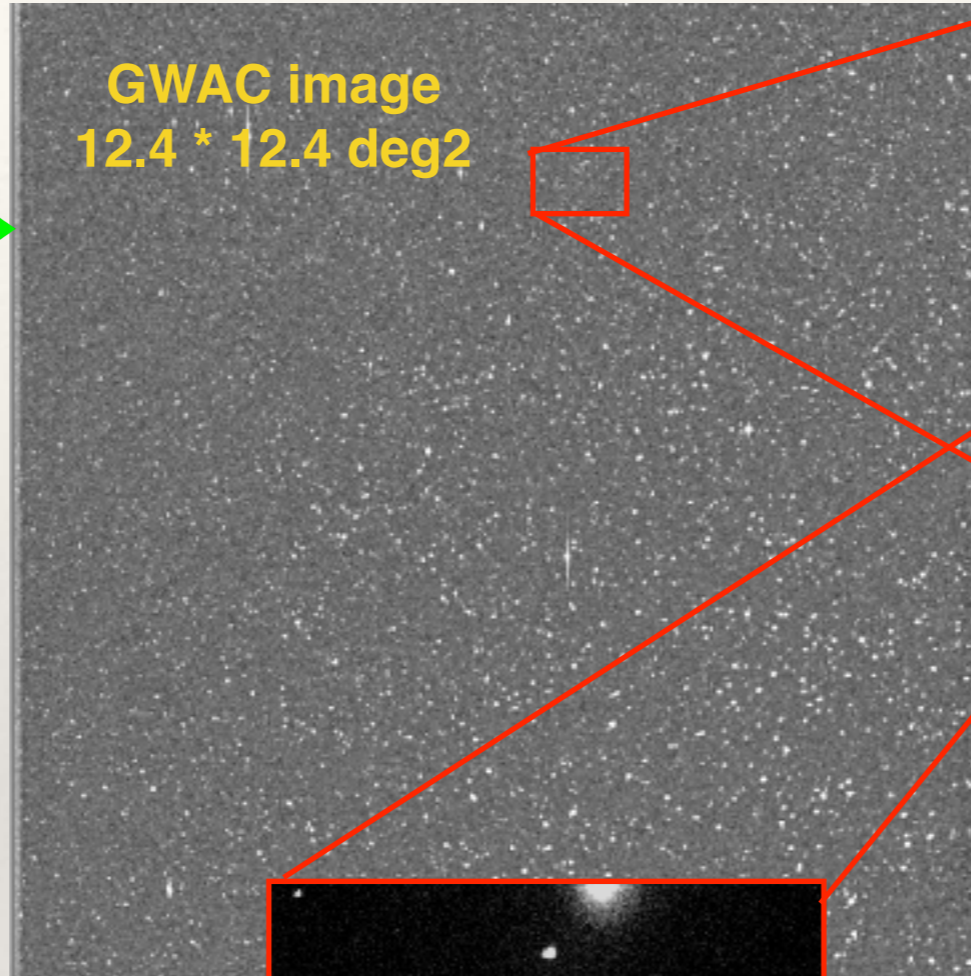


Telescope	Num for O3	Location	Aperture (cm)	FoV	Filter	m_{limt} [Single/Stack]	Obs. mode for ToO
GWAC	3 / 4	Xinglong	18	25°	Clear	16/17	Tiling
F-60A/B	2	Xinglong	60	10' / 18' (2Kx2K)	Clear, BRI	18/19	Gal. target / Point
30cm	1	Xinglong	30	1°	Clear, BRI	16.5/17	Gal. target / Point

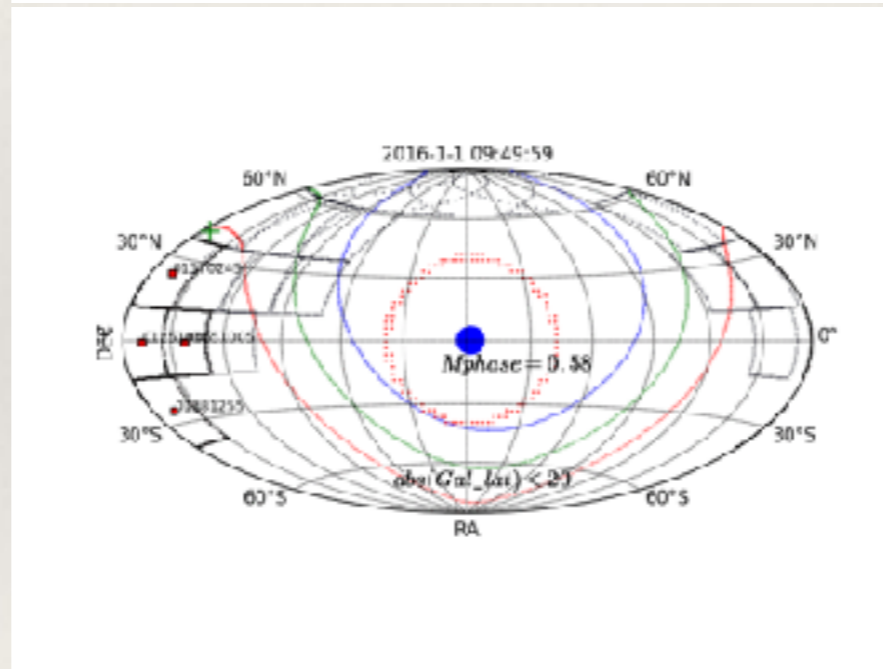
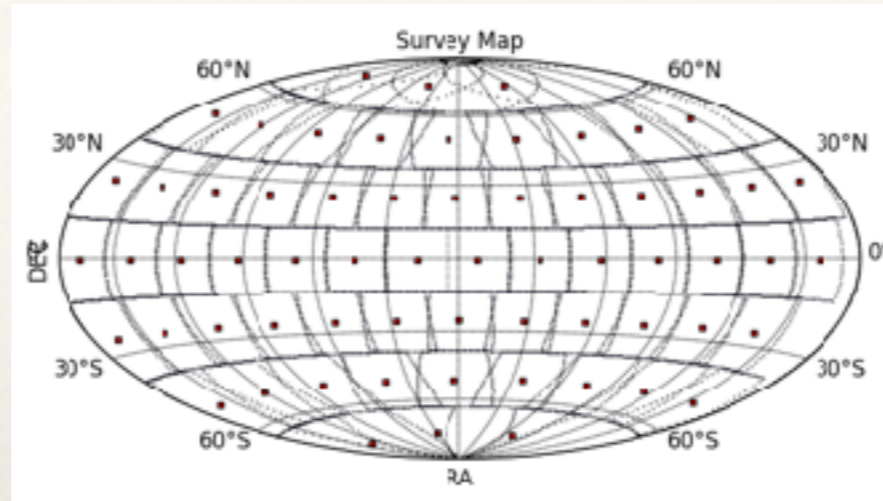
GWAC system: observation strategy



GWAC image
12.4 * 12.4 deg²



GWAC system: observation strategy



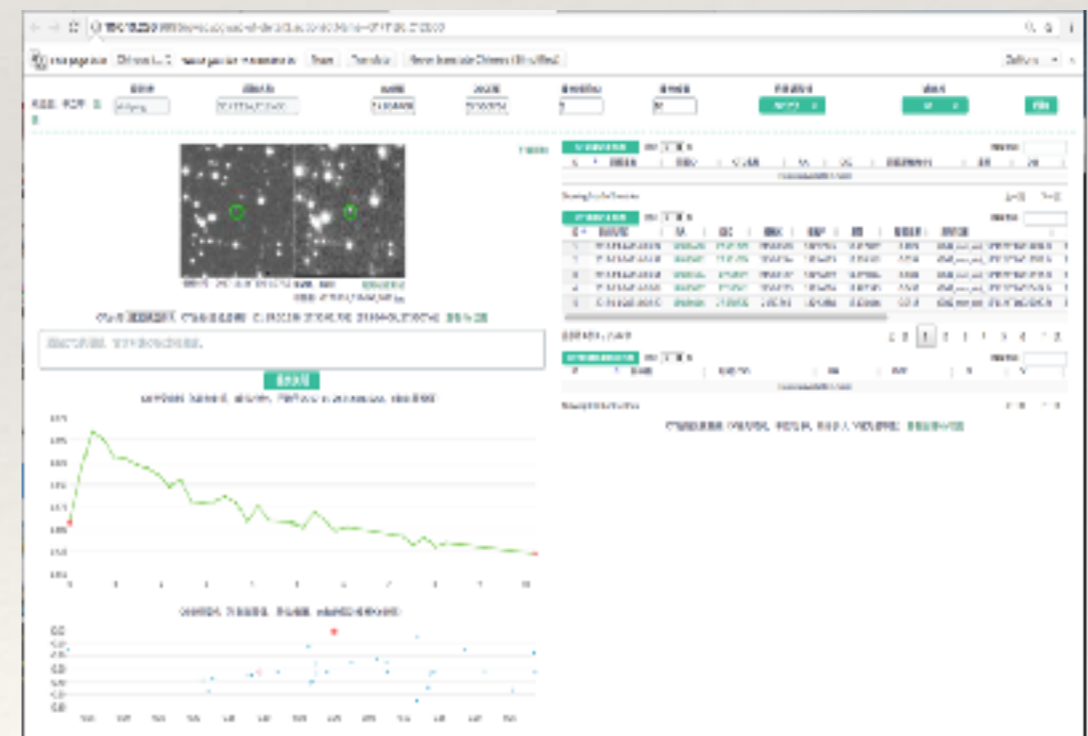
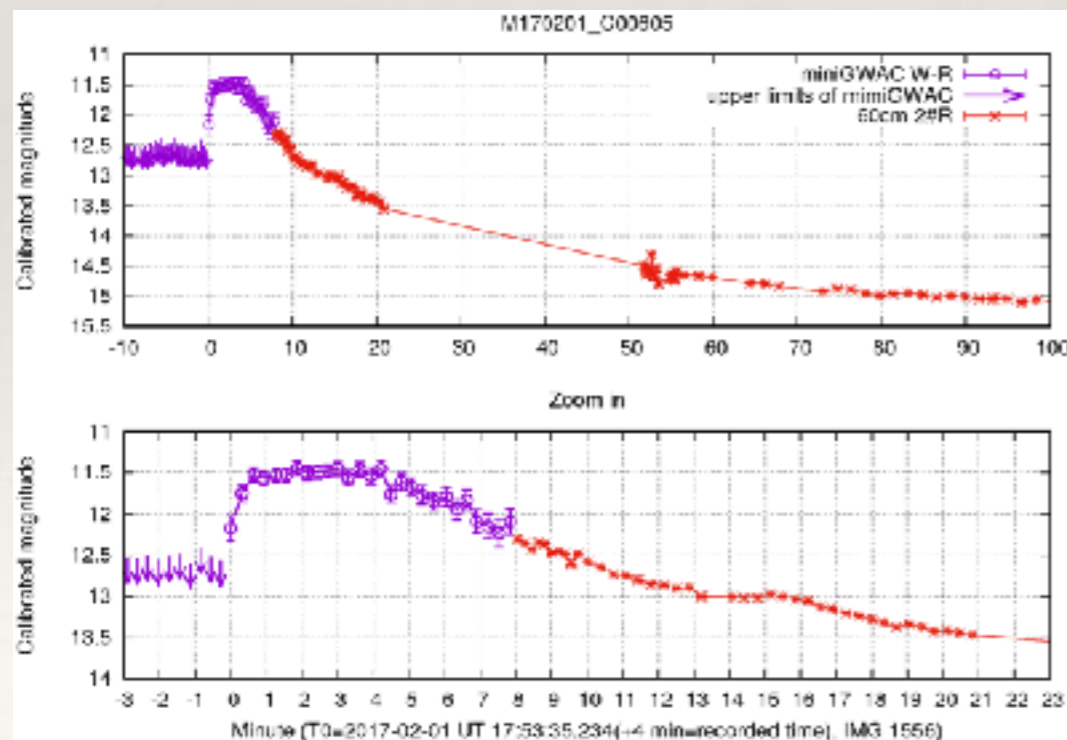
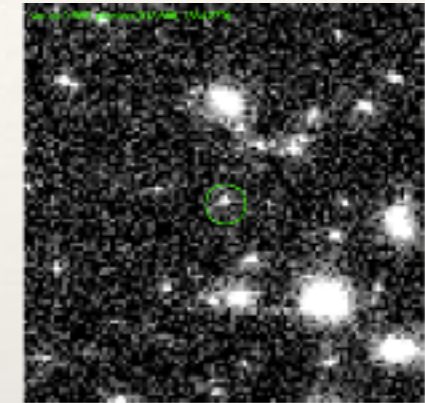
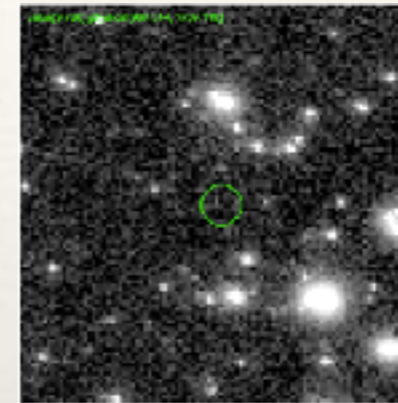
Fixed Grid

Multi-observation mode

- ❖ **Monitor mode (Routine Observation)**
- ❖ Patrol mode
- ❖ Template mode
- ❖ Auto-ToO mode
- ❖ Manual-ToO mode
- ❖ Sync mode
- ❖ Manual mode

GWAC system: software

- ❖ Automatic scheduling and observation
- ❖ Realtime data reduction
- ❖ Powerful user support



ToO Patrol (ToP) project of GWAC

ToO Patrol (ToP) project dedicated for ToO follow-up observations using GWAC system

History:

- ❖ **SVOM and LIGO signed MOU in March, 2015**
- ❖ **GWAC team followed up the GW151226**
- ❖ **We started the ToO project since April 2016 at Les Houches**
- ❖ **1st ToP workshop at Xinglong observatory in May, 2017**
- ❖ **ToP is following up for several types of ToO**



April 2016, Les Houches

ToO Patrol (ToP) project of GWAC



1st Workshop of ToP at Xinglong, May, 2017

ToP activities: GW

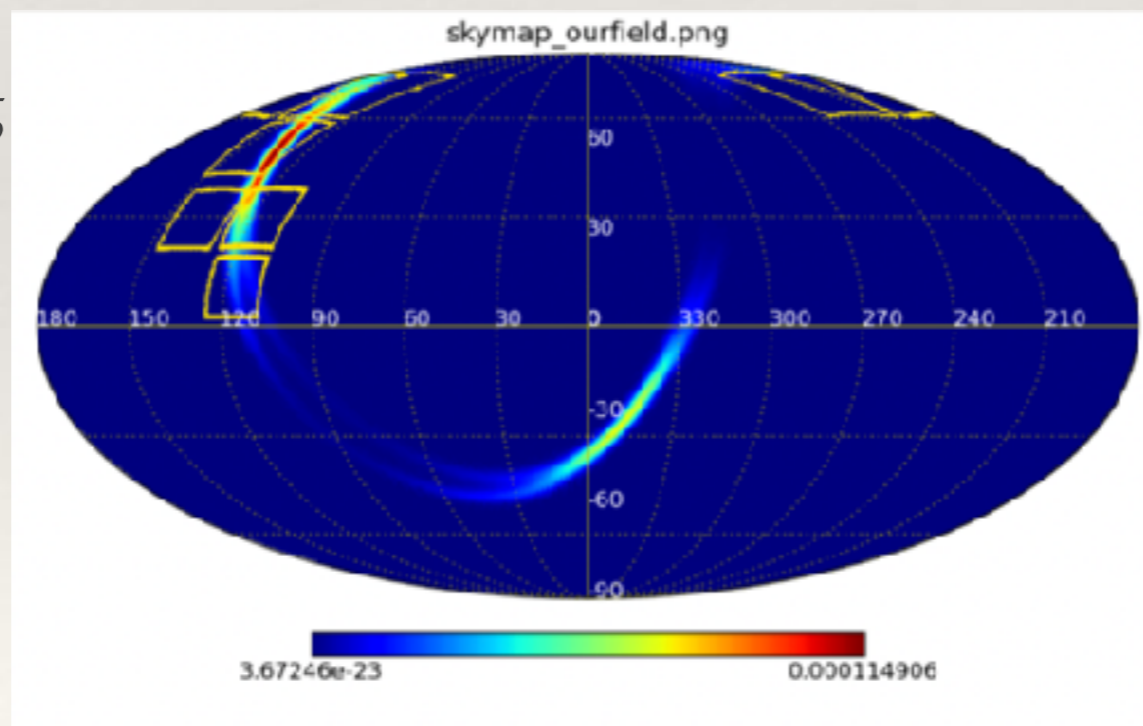
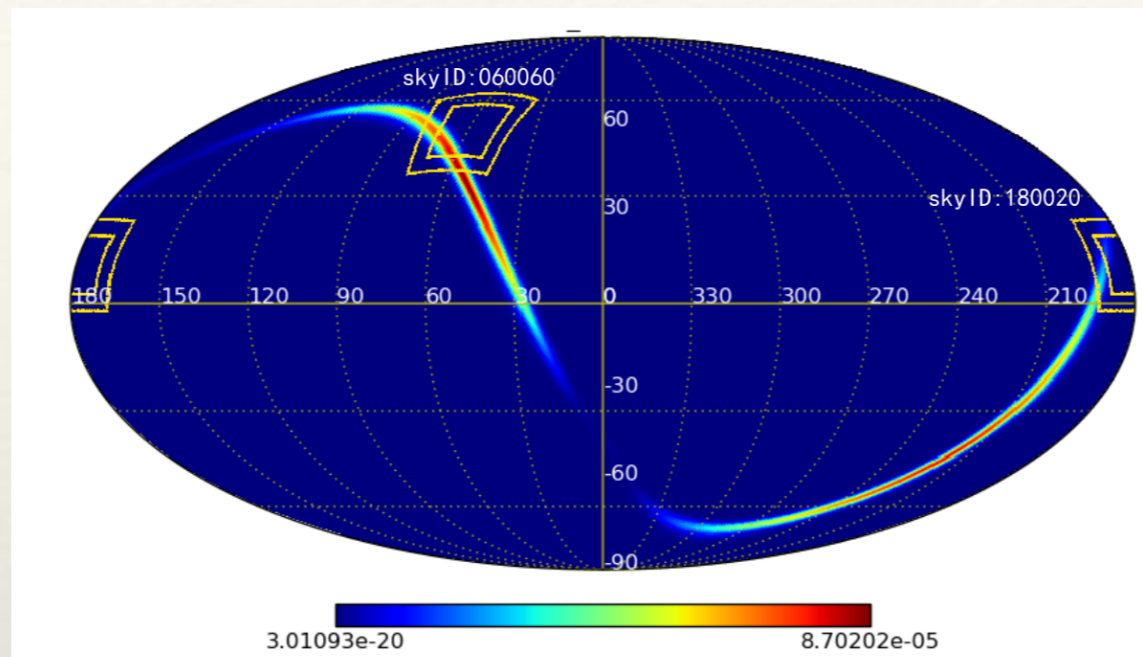
GW follow-ups

During O1 run:

- GW151226

During O2 run:

- GW170104
- 6 other events
- 10 GCN circulars (2 GCN circulars using 2.16m Xinglong and 2.4m GMG)



- **Sky map of GW151226**
- First observation of ToP with Mini-GWAC**
- **Sky map of GW170104**
- Observation started in minutes after the alert (2 hours after T0)**
- Coverage of 84.4% probability**
- Upper limit of 11 mag**

The largest probability coverage for GW170104 in shortest latency for optical band

<http://www.svom.fr/en/#filter=.coulissesarticle.portfolio566load>

ToP activities: Fermi/GBM GRB

Fermi/GBM GRB follow-ups

Since Nov. 2017:


- 10+ events

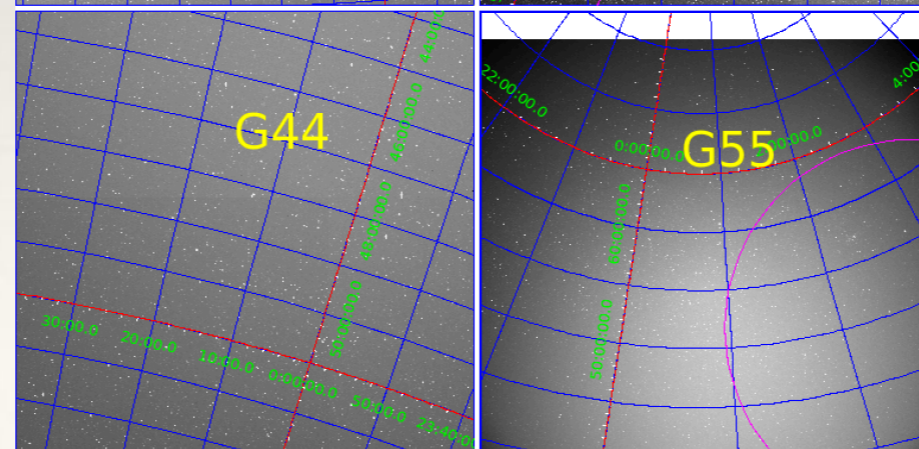
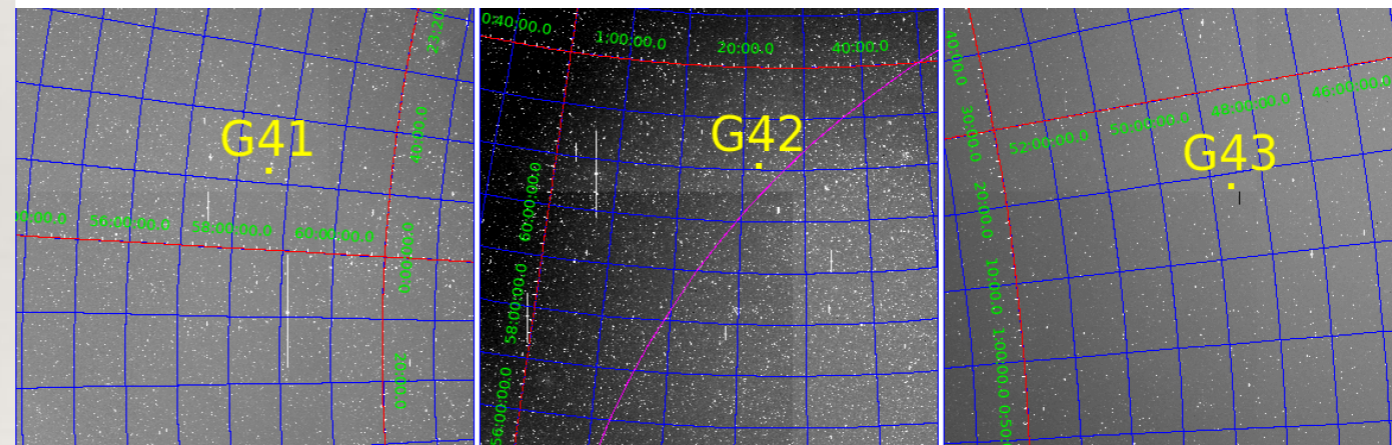


First GBM/GRB trigger (531225917) 2017 Nov. 1

112	Fermi-GBM	3	531239007	2017-11-01T14:23:22.80	GEOLUN	57.970000	46.970000	15.0100	2017-11-01T14:23:36	This is a REAL trigger, Response ASAP.
112	Fermi-GBM	2	531236667	2017-11-01T13:44:22.53	GEOLUN	31.400000	42.670000	13.2800	2017-11-01T13:45:00	This is a REAL trigger, Response ASAP.
112	Fermi-GBM	1	531225917	2017-11-01T10:45:12.67	GEOLUN	38.250000	48.350000	16.2400	2017-11-01T10:45:50	This is a REAL trigger, Response ASAP.

- **Trigger Time (10:45:12.67 UTC)**
- **Alert arrived at 10:45:50 UTC**
- **Grid ID: 01110557 (Pointing RA: 11.11 DEC: 55.75)**
- **Observation command is sent at 10:46:01 UTC**
- **First image is taken at 10:47 UTC (2 minutes after trigger time)**

 Slack API Tester APP 6:46 PM
New Fermi-GBM alert
Trigger ID: 531225917
Trigger Time: 2017-11-01T10:45:12.67
RA: 38.25
DEC: 48.35
POS Error: 16.24
MMA on duty: Xuhui
GWAC scientist on duty:
This alert is currently reachable.
The follow up cmd is sent



Online data process:

824 new sources

Online GRB filter:

2 candidates

Human check:

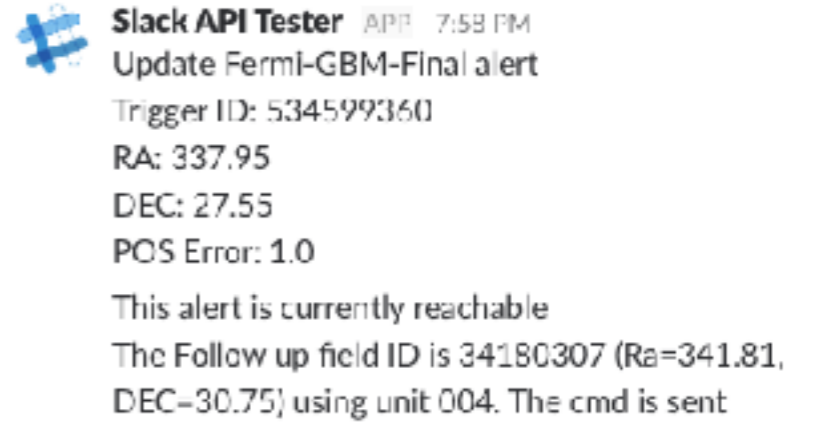
0 new credible source

ToP activities: Fermi/GBM GRB

First real Fermi/GBM GRB trigger (GRB171210A) on 2017 Dec. 10

Trigger File	115	Fermi-GBM	8	534599360	2017-12-10T11:49:15.26	GEOLUN	337.950000	27.550000	1.00000	0.00	2017-12-10T11:58:35	This is a REAL trigger, Response ASAP.
Trigger File	112	Fermi-GBM	8	534599360	2017-12-10T11:49:15.26	GEOLUN	337.770000	27.570000	1.00000	151.70	2017-12-10T11:50:53	This is a REAL trigger, Response ASAP.
Trigger File	112	Fermi-GBM	7	534599360	2017-12-10T11:49:15.26	GEOLUN	338.400000	29.610000	1.22000	82.20	2017-12-10T11:50:41	This is a REAL trigger, Response ASAP.
Trigger File	112	Fermi-GBM	6	534599360	2017-12-10T11:49:15.26	GEOLUN	338.490000	28.600000	1.50000	57.40	2017-12-10T11:49:52	This is a REAL trigger, Response ASAP.

- Trigger Time (11:49:15 UTC)
- Alert arrived at 11:49:52 UTC
- Grid ID: 34180307 (Pointing RA: 341.81 DEC: 30.75)
- Observation command is sent at 11:50:21 UTC
- Taking data since (**1 hour after trigger time (due to CCD failures)**)
- No new source detected
- Real GRB confirmed



Slack API Tester APP 7:58 PM
Update Fermi-GBM-Final alert
Trigger ID: 534599360
RA: 337.95
DEC: 27.55
POS Error: 1.0
This alert is currently reachable
The Follow up field ID is 34180307 (Ra=341.81, DEC=30.75) using unit 004. The cmd is sent

ToP activities: Swift GRB & Neutrino

Swift GRB follow-ups

Since 2017:

- 2 GRBs
- 1 FRB

Since 2018:

- Swift GRB **automatic** follow-up

Neutrino follow-ups

Since 2017:

- 7 events (~30%)



ToO Patrol (ToP) project of GWAC

Instrument & ToO type

Telescope	ToO type	Observation strategy	Status
GWAC	GW	Tiling	●
	Fermi/GBM GRB	Tiling	●
Mini-GWAC	GW	Tiling	●
	Swift GRB	Pointing	●
F-60A/B	GW	Galaxy Targeting	●
	Neutrino	Pointing	●
30cm	GW	Galaxy Targeting	●

● Ready

● No longer use

● Not ready

ToP GW campaign for O3 run

ToP needs to be ready for O3 run

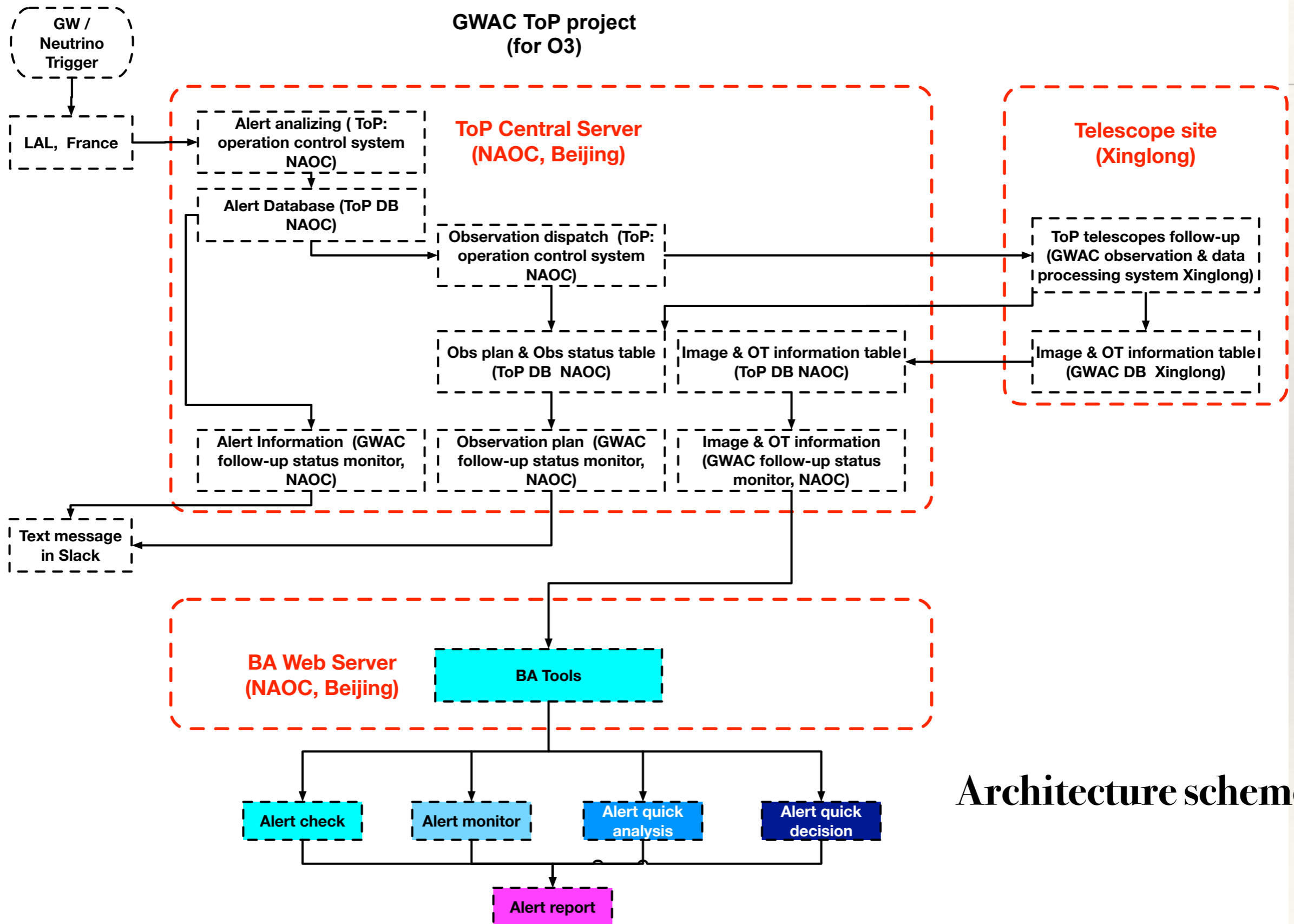
Telescope	ToO type	Observation strategy	Status
GWAC	GW	Tiling	●
	Fermi / GBM GRB	Tiling	●
Mini-GWAC	GW	Tiling	●
F-60A/B	Swift GRB	Pointing	●
	GW	Galaxy Targeting	●
30cm	Neutrino	Pointing	●
	GW	Galaxy Targeting	●

● Ready

● No longer use

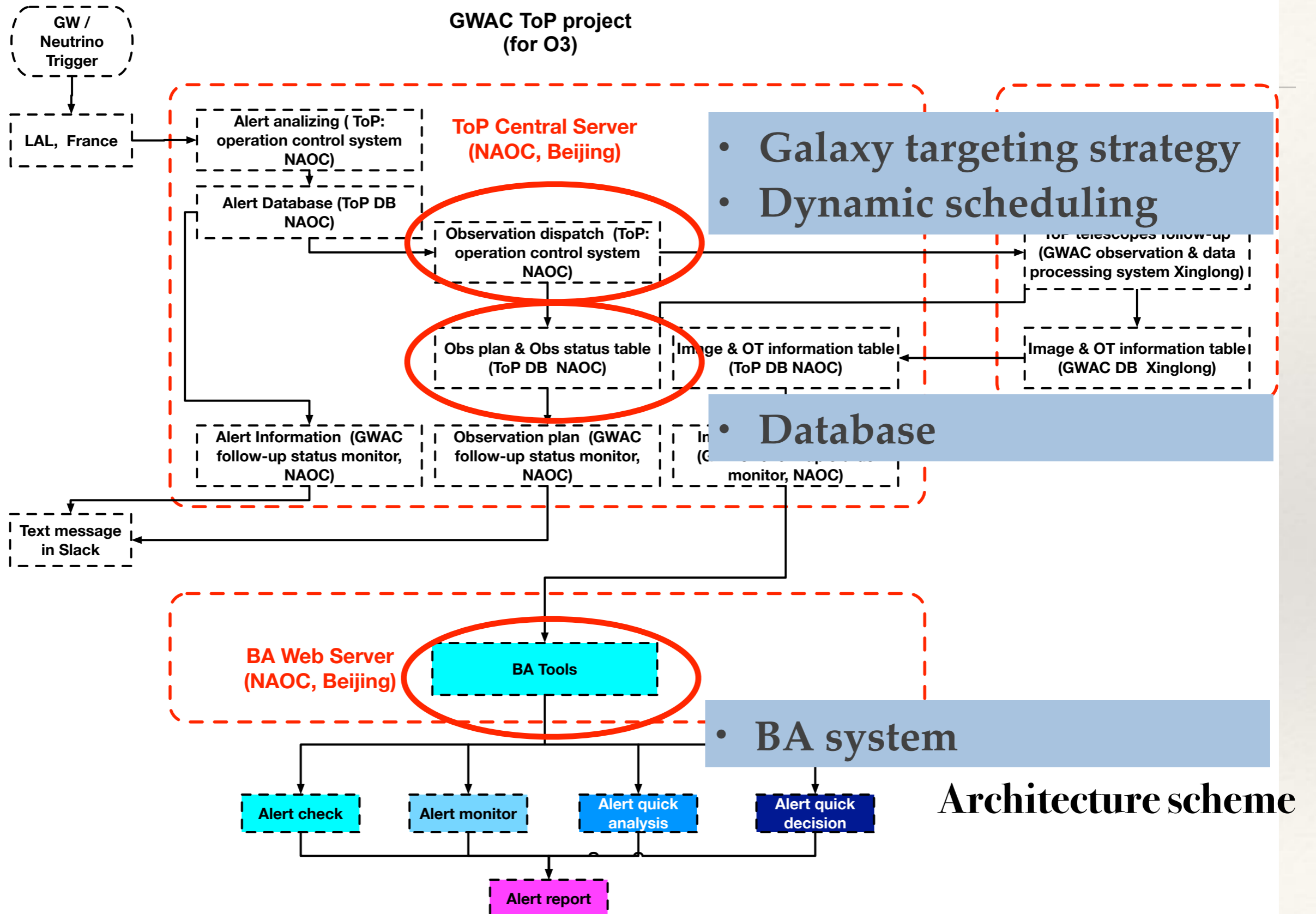
● Not ready

ToP GW campaign for O3 run




Architecture scheme

ToP GW campaign for O3 run



ToP GW campaign for O3 run

Preliminary BA system of ToO Patrol (ToP) project



The BA tool page will allow you to monitor the MM follow-up observations made by the GWAC. Through this web interface the Burst advocate will also have the possibility to send requests to the Observer Assistant (OA) at Xinglong if interesting OT need additional observation with the 30cm and the 60cm.

If you are a GWAC BA for the first time, please consult the BA procedure pages before!

Please sign in or monitor to have access to the BA management tools.

If you have any problem feel free to contact:

Xiujun TORPEL : xtorpe@nao.cas.cn or kahui@nao.cas.cn or liping@nao.cas.cn

Please choose the trigger type you want to monitor!

Gravitational wave Trigger

Gamma-ray Burst Trigger

Neutrino Trigger

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CHINESE ACADEMY OF SCIENCES

Trigger(s) received today : 2018-03-13

last update: 2018-04-08 13:10:05 UTC

Details	Trigger ID	Trig. facility	date [UTC]	RA (J2000) [°]	Dec. (J2000) [°]	POS Error [°]	S/N	P(GRB)	GWAC scientist	BA on duty	GWAC color	Xinglong reader
	534260022	Fermi-GBM	2018-03-13T17:30:30.84	102.17	54.12	4.32	4.60	99%	Liping Xin	L.Samir/D.Nicolae	●	click here [1] or [2] Monitor

List of triggers not reported yet

Details	Trigger ID	Trig. facility	date [UTC]	RA (J2000) [°]	Dec. (J2000) [°]	POS Error [°]	S/N	P(GRB)	GWAC scientist	BA on duty
	534260022	Fermi-GBM	2018-03-13T17:30:30.84	102.17	54.12	4.32	4.60	92%	Liping Xin	T.Damien/D.Nicolae

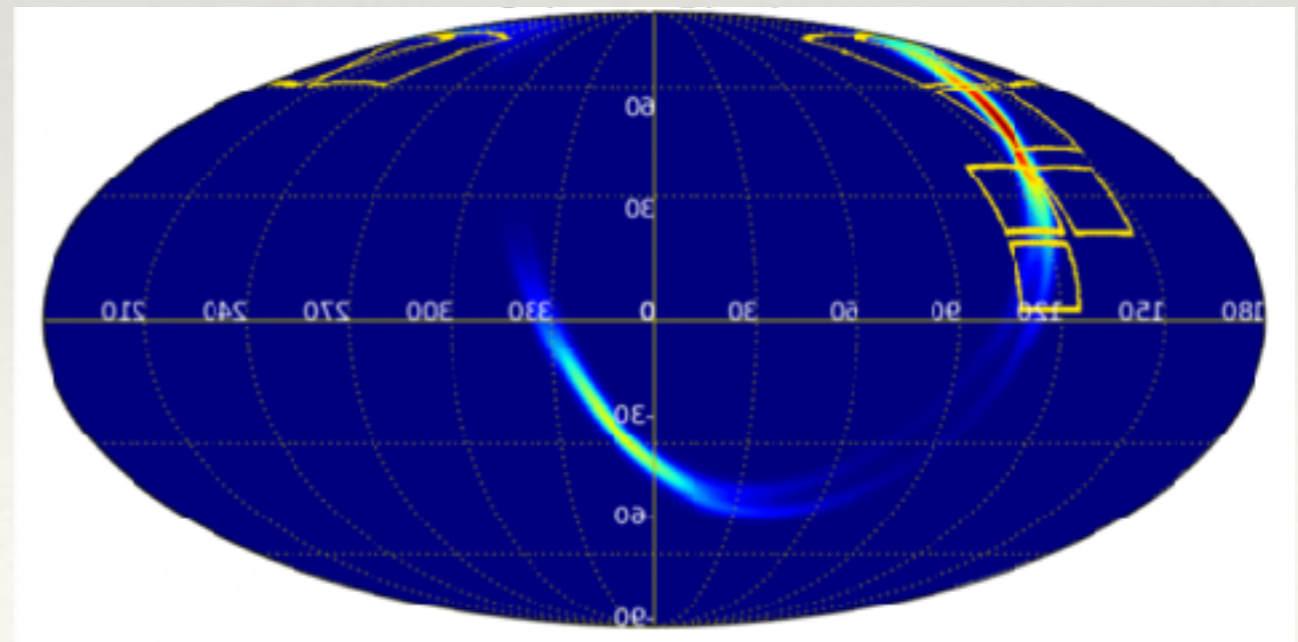
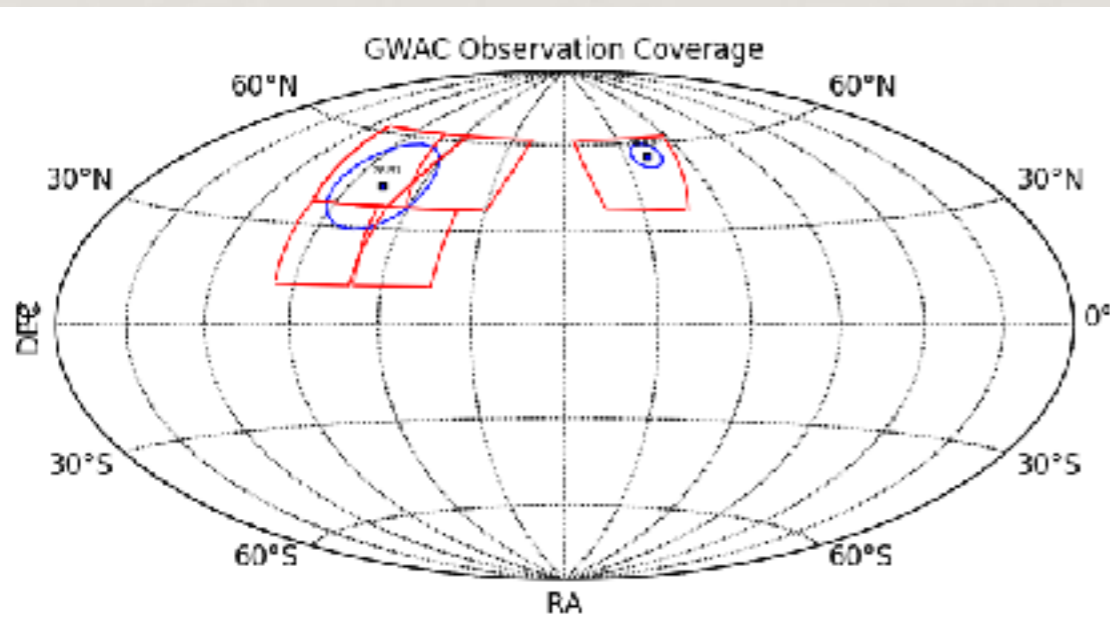
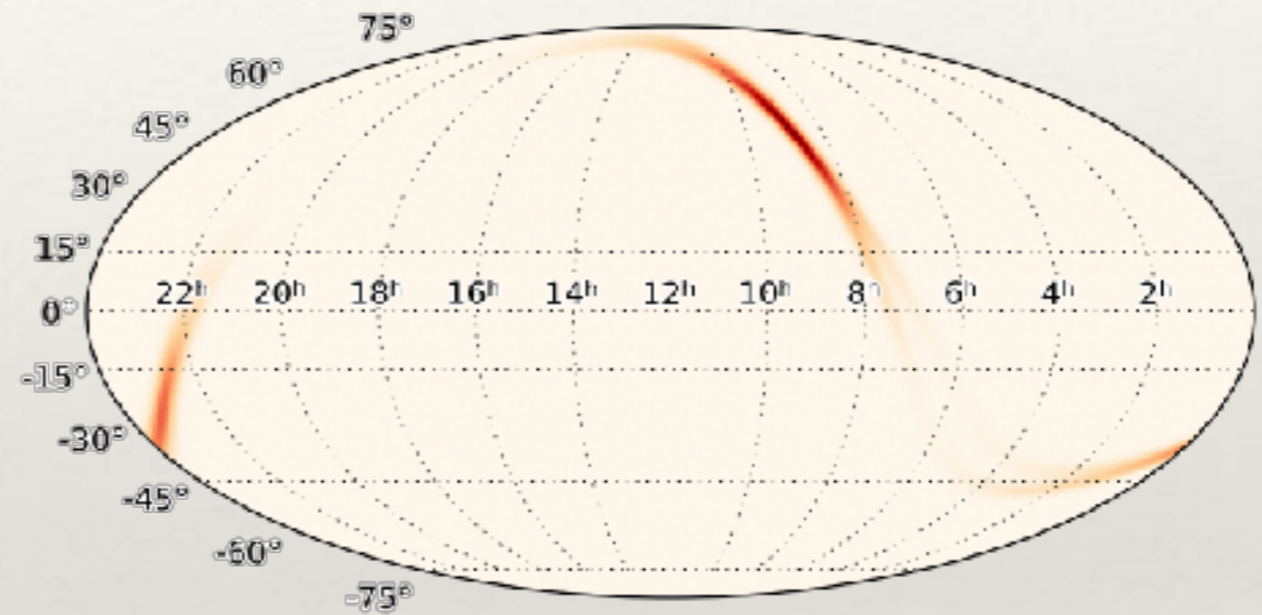
Make a report

The archive of the past GRB triggers received at Xinglong can be found here :

Archive data

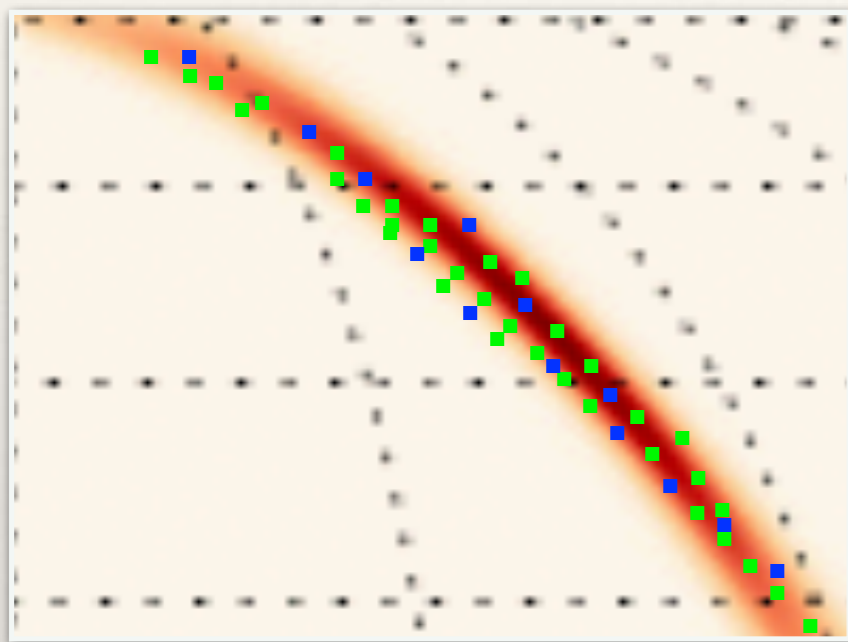
Observing strategy and scheduling of ToP

Tiling strategy using GWAC



Observing strategy and scheduling of ToP

Gal. targeting strategy using F60A/B & 30cm



Gal ID	Ranking
Gal. 1	1
Gal. 2	2
Gal. 3	3
Gal. 4	4
Gal. 5	5
Gal. 6	6
Gal. 7	7
Gal. 8	8
Gal. 9	9
Gal. 10	10
...	...



Galaxy Ranking

based on:

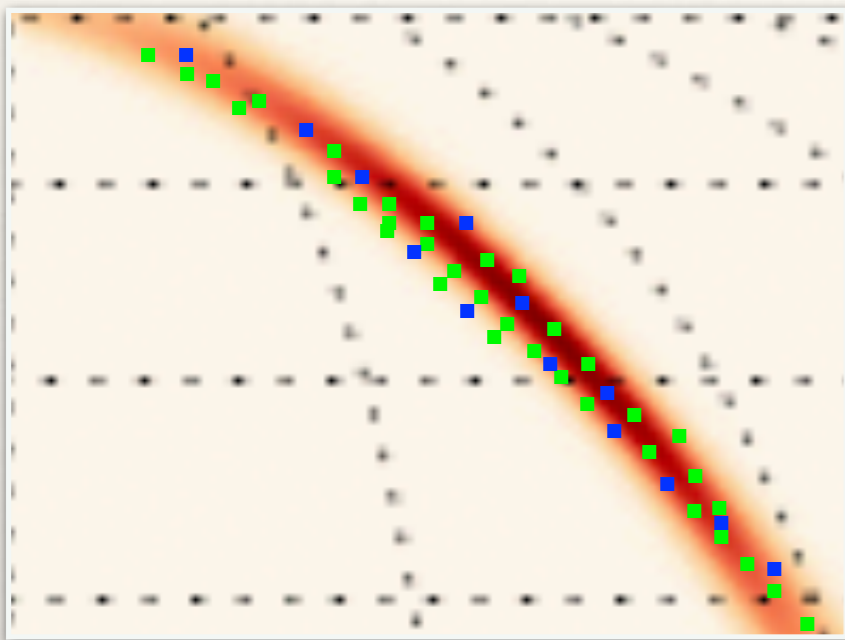
- 3-D sky map of event
- probability of galaxy
- location of telescope
- detection capability of telescope
- weather or other conditions

Gal ID	Ranking
Gal. 11	1
Gal. 12	2
Gal. 13	3
Gal. 14	4
Gal. 15	5
Gal. 16	6
Gal. 17	7
...	...



Observing strategy and scheduling of ToP

Gal. targeting strategy using F60A/B & 30cm



Gal ID	Ranking
Gal. 1	1
Gal. 2	2
Gal. 3	3
Gal. 4	4
Gal. 5	5
Gal. 6	6
Gal. 7	7
Gal. 8	8
Gal. 9	9



~50 * 3 galaxies per night

Galaxy Ranking

based on:

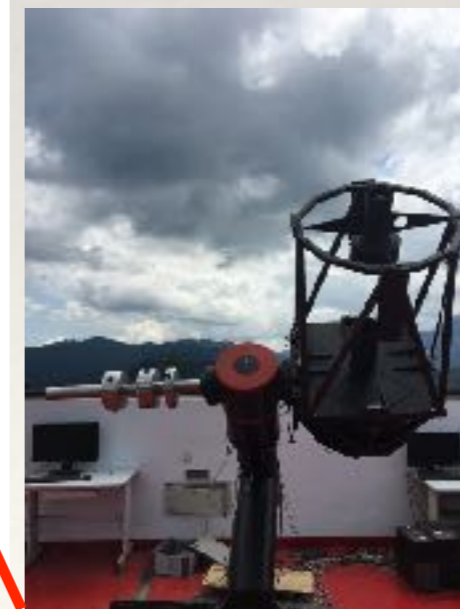
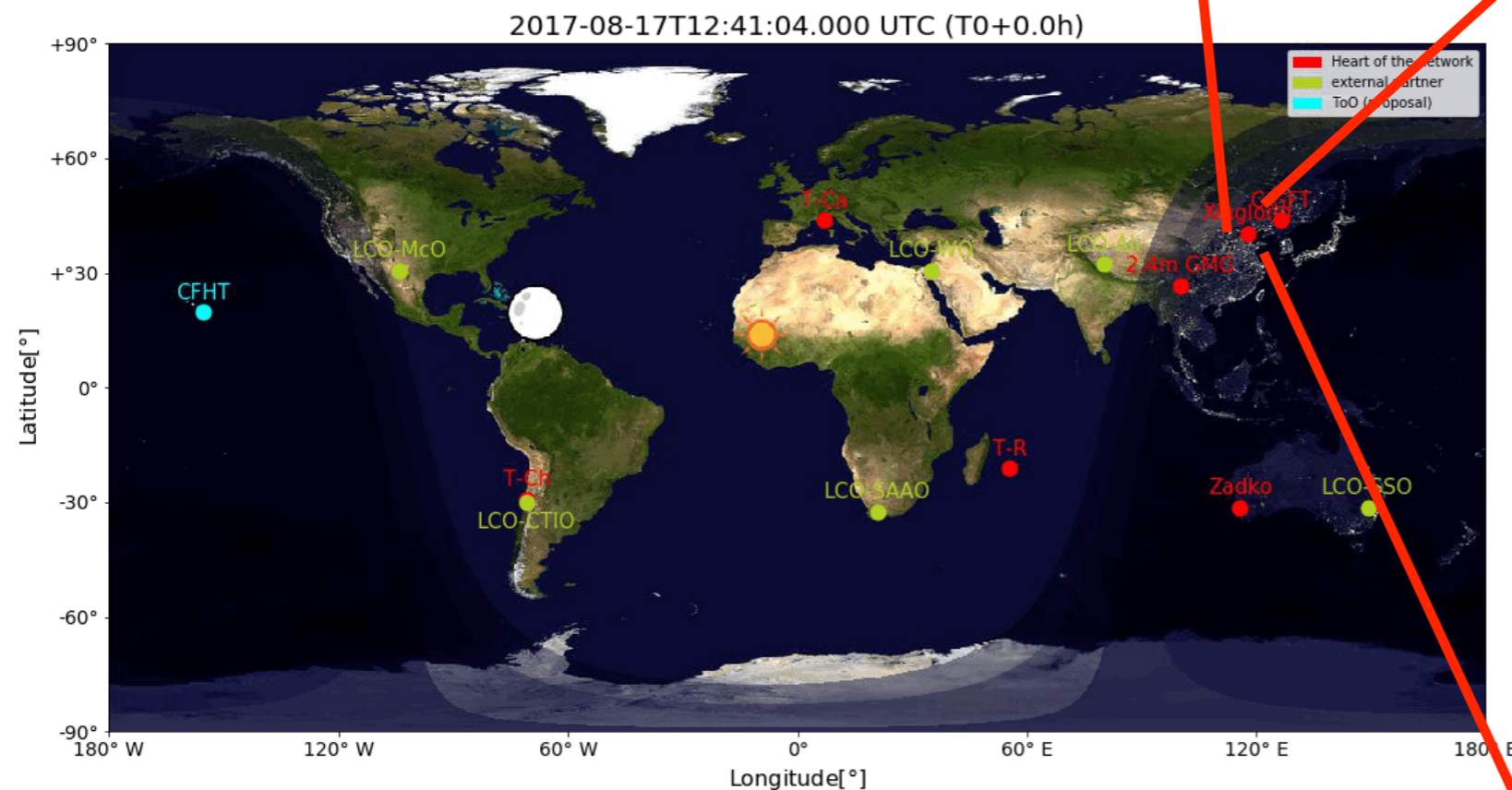
- 3-D sky map of events
- probability of galaxy
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Gal ID	Ranking
Gal. 11	1
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Gal. 15	5
Gal. 16	6
Gal. 17	7
...	...



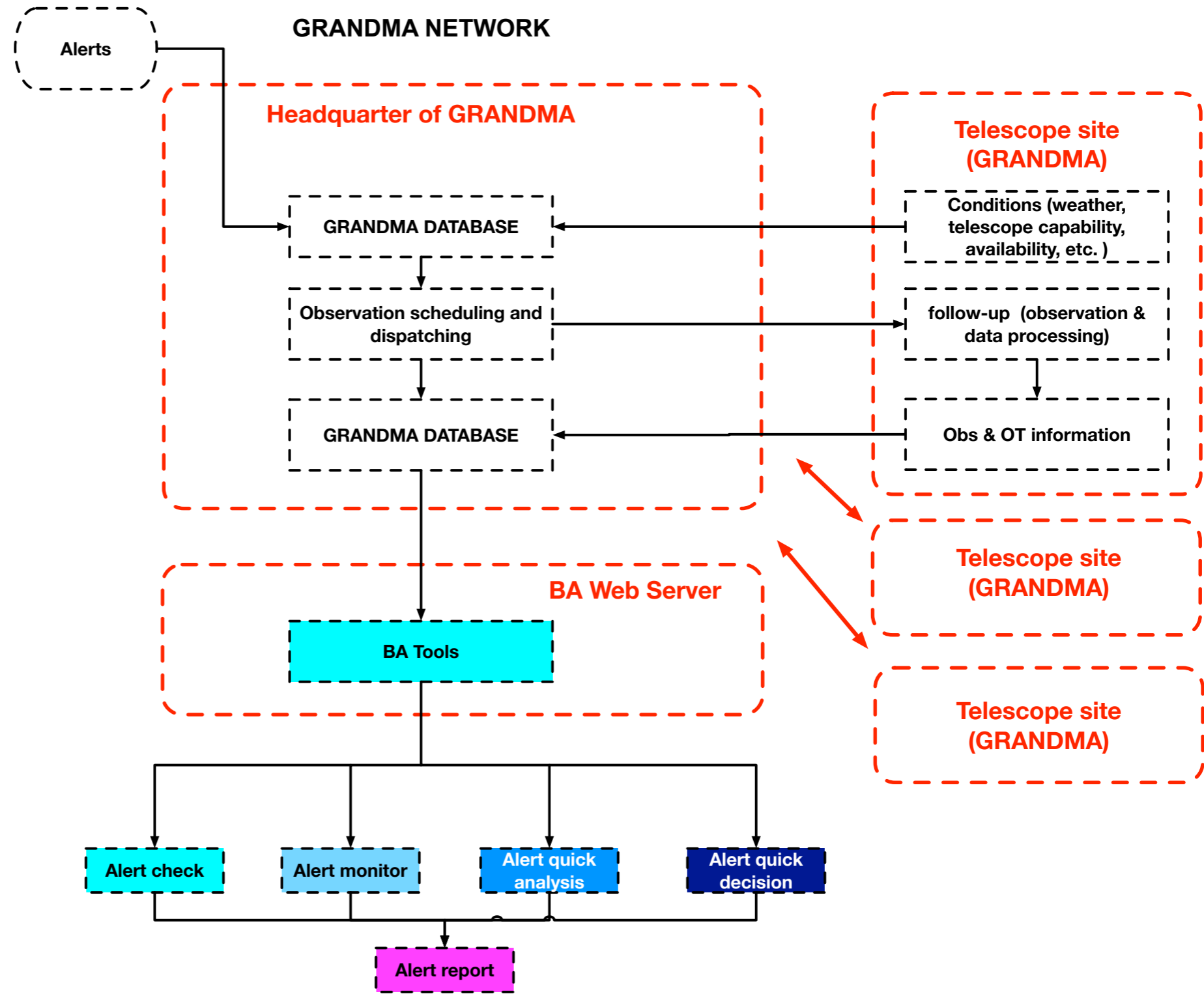
ToP joins in the GRANDMA

GWAC team will join in the hardware and software development of GRANDMA

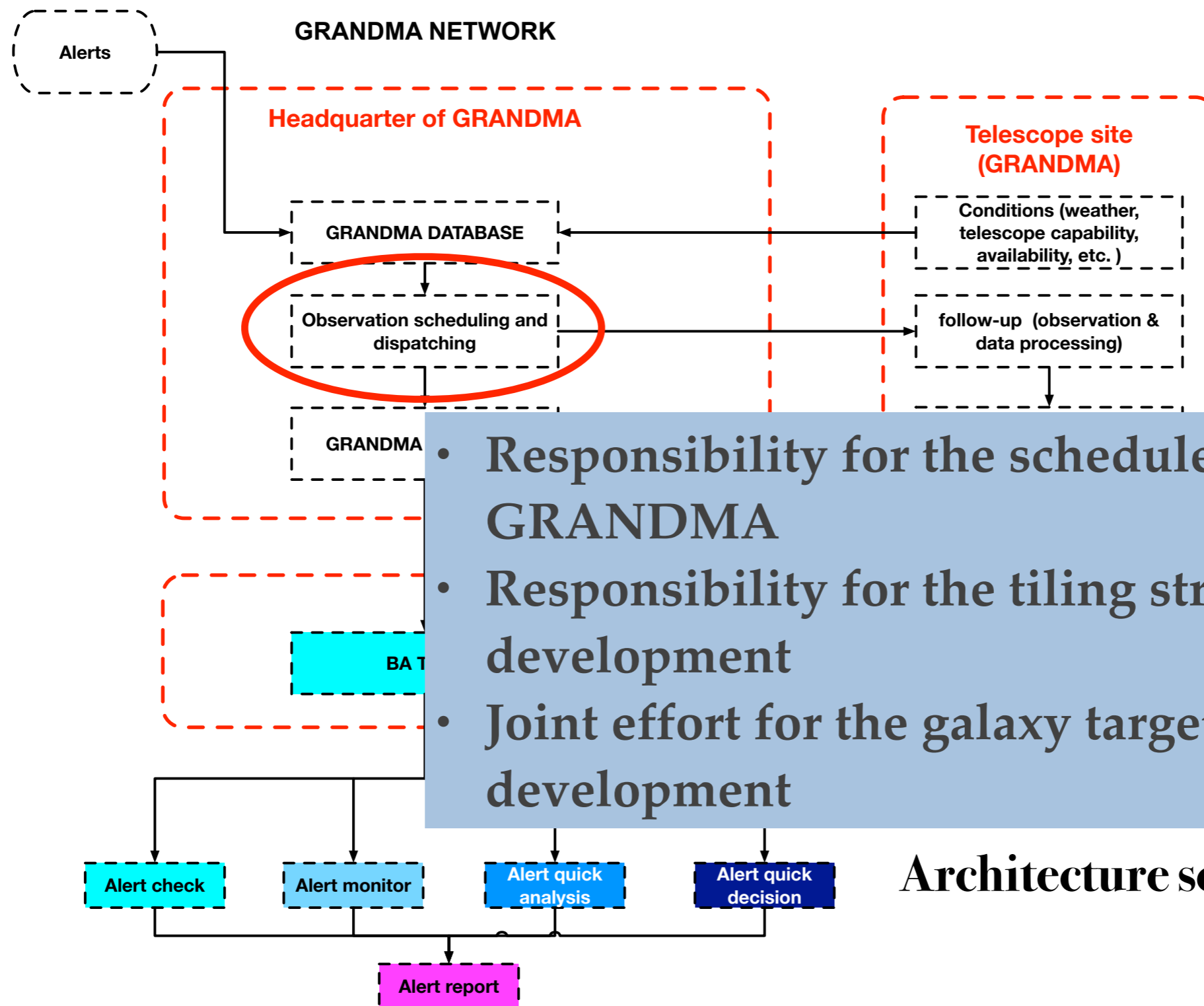


ToP joins in the GRANDMA

“Hub and spoke”
architecture scheme



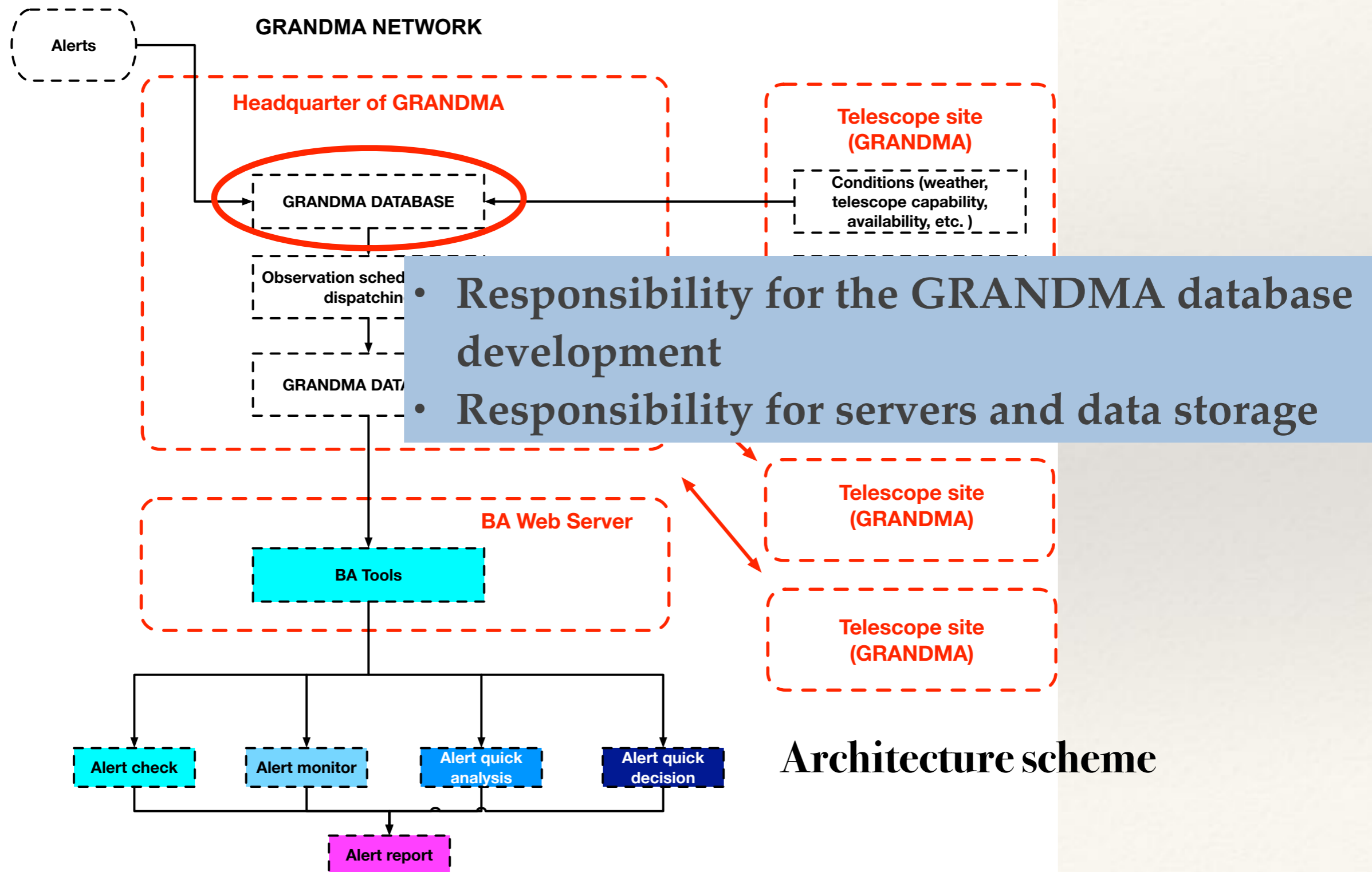
ToP joins in the GRANDMA



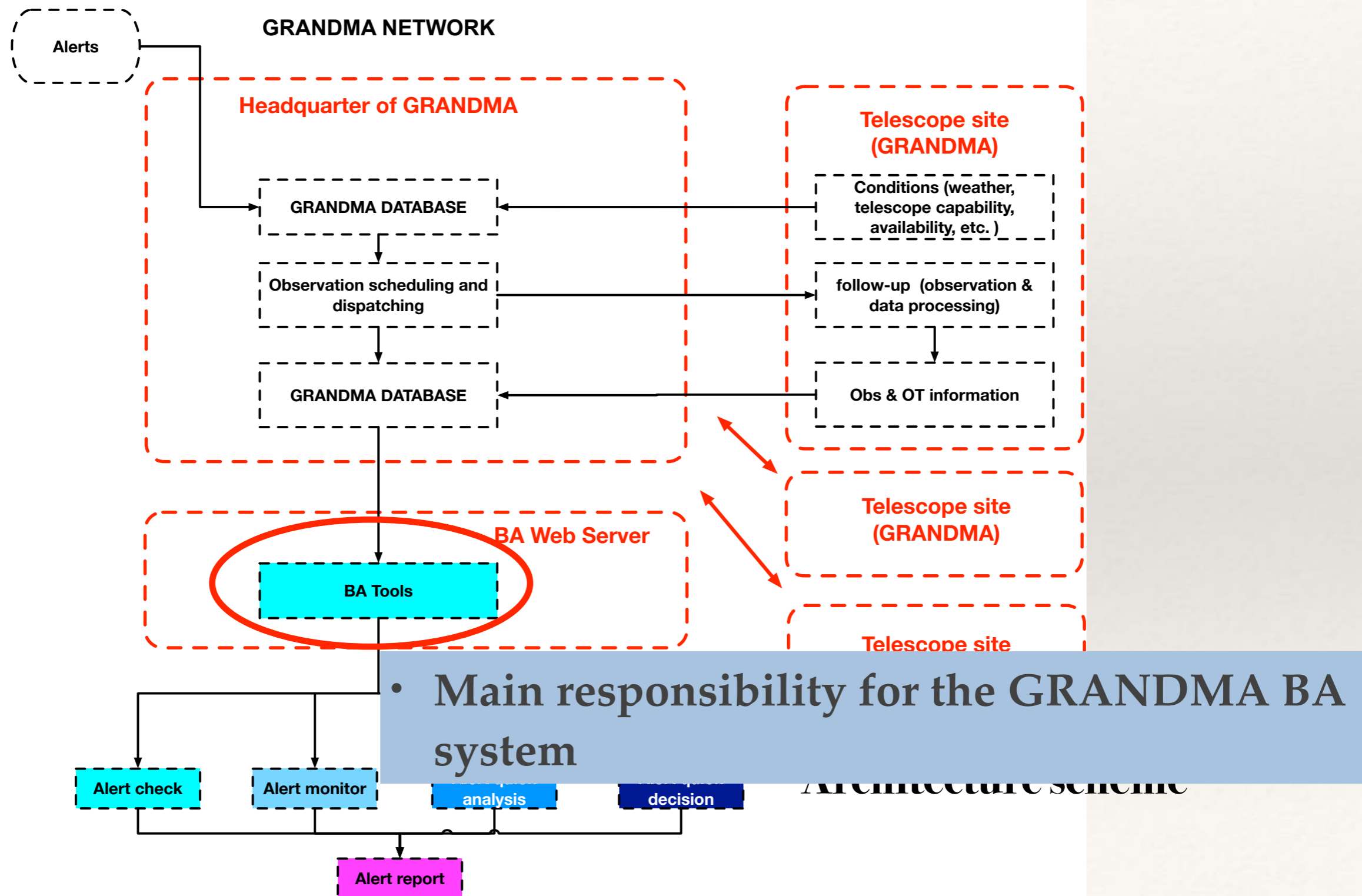
- Responsibility for the scheduler of GRANDMA
- Responsibility for the tiling strategy development
- Joint effort for the galaxy targeting strategy development

Architecture scheme

ToP joins in the GRANDMA



ToP joins in the GRANDMA



Conclusion

- ❖ ToP project of GWAC has been and is doing several types of ToO follow-up observations since 2017
- ❖ ToP with four GWACs, two F-60A / B, one 30cm telescope will be prepared for GW / O3 run
- ❖ ToP will join in the GRANDMA with its telescopes, servers, database, scheduling and BA system

Thank you for your attention!

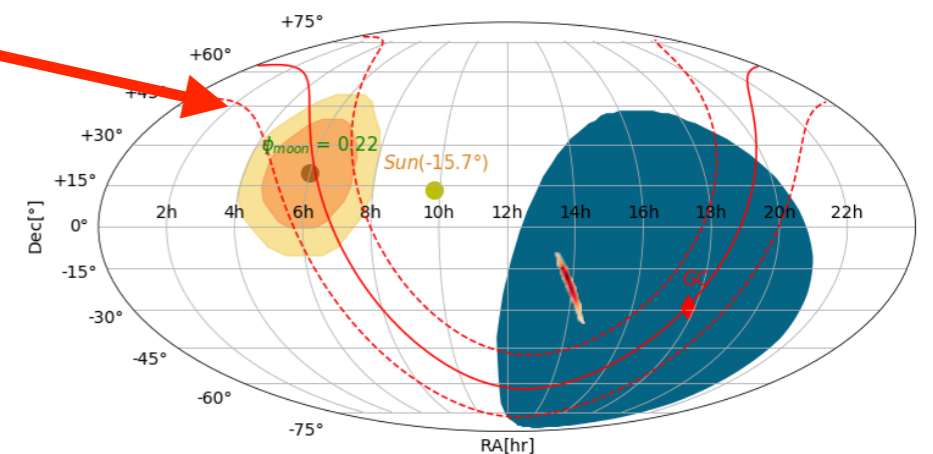
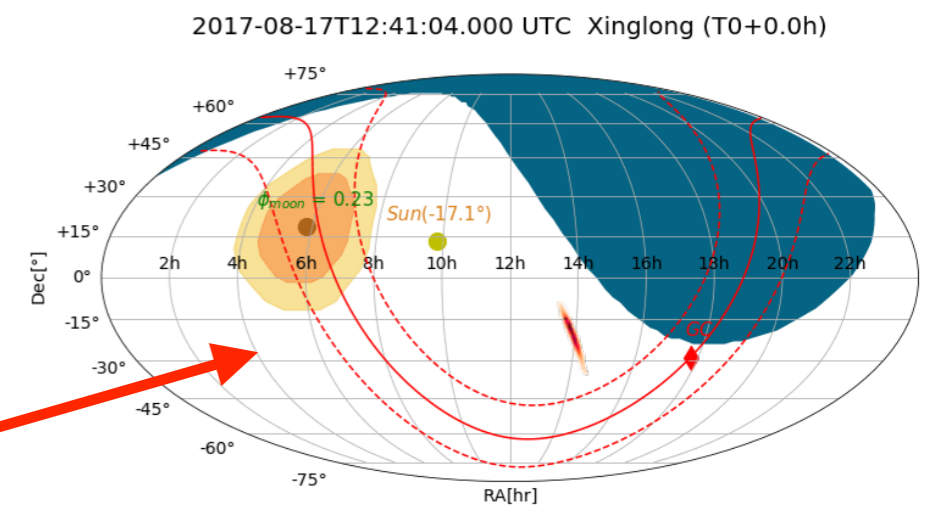
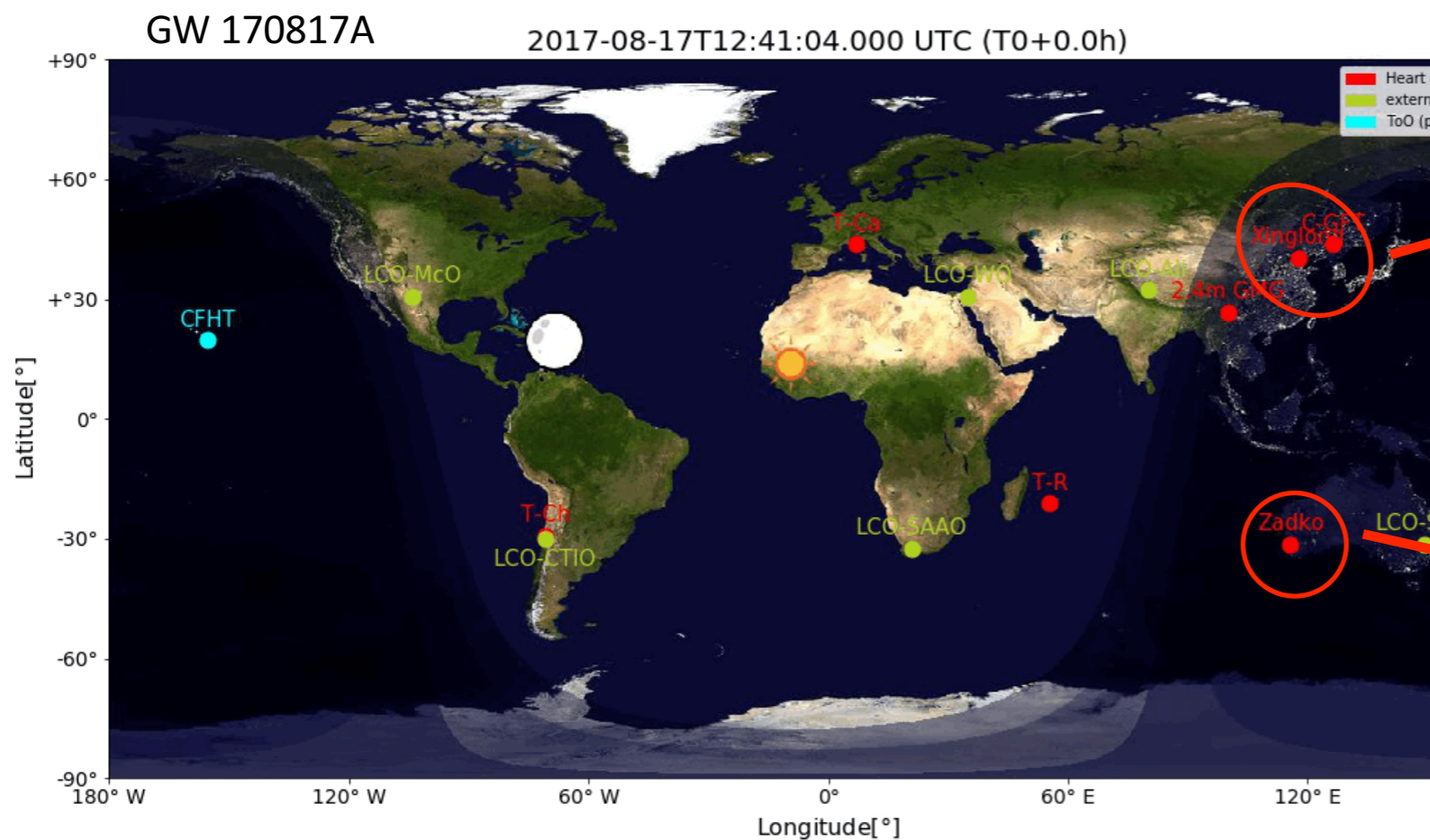


Back-up

Observing strategy and scheduling of GRANDMA

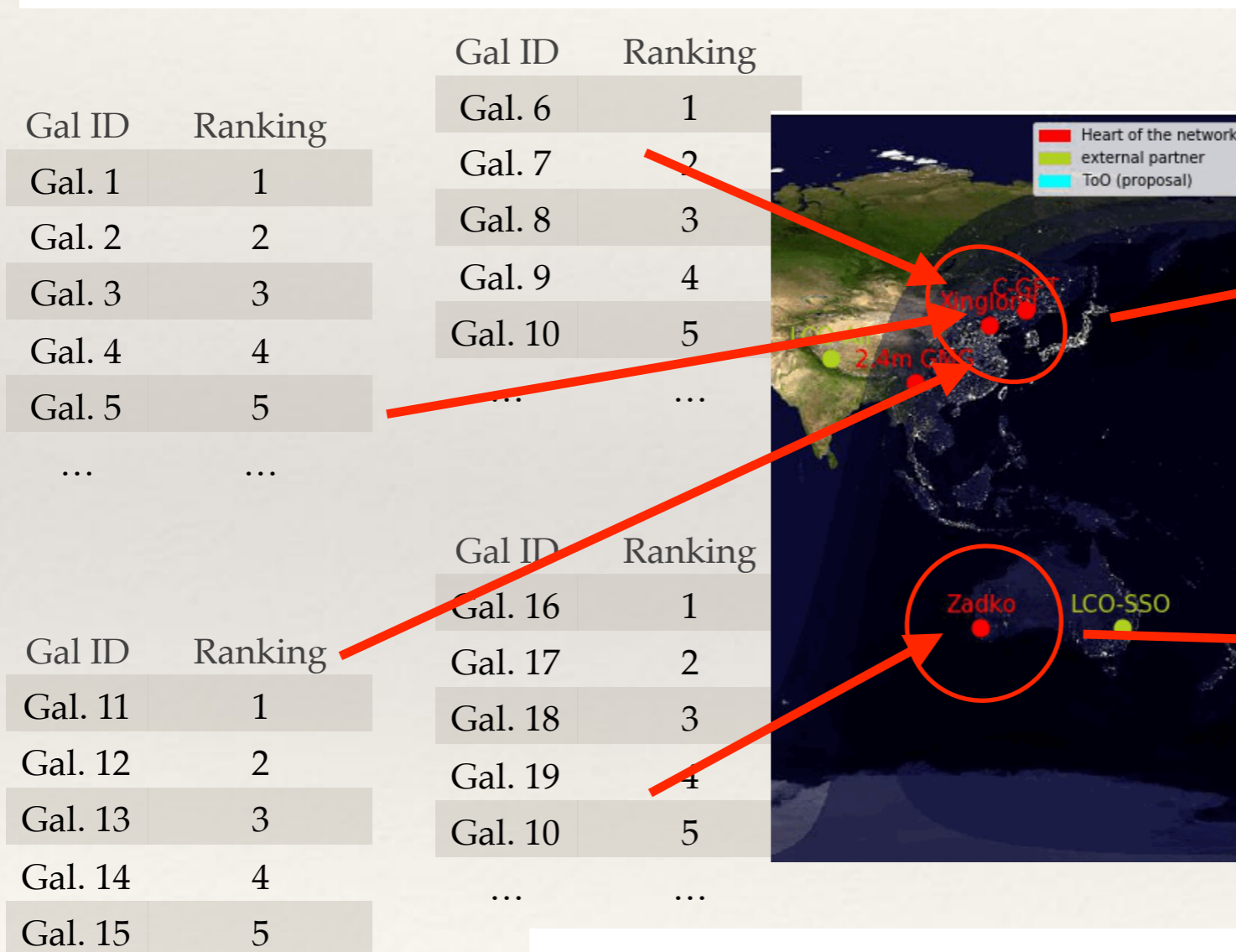
Dynamic Scheduling for GRANDMA network

Complexity of scheduling system

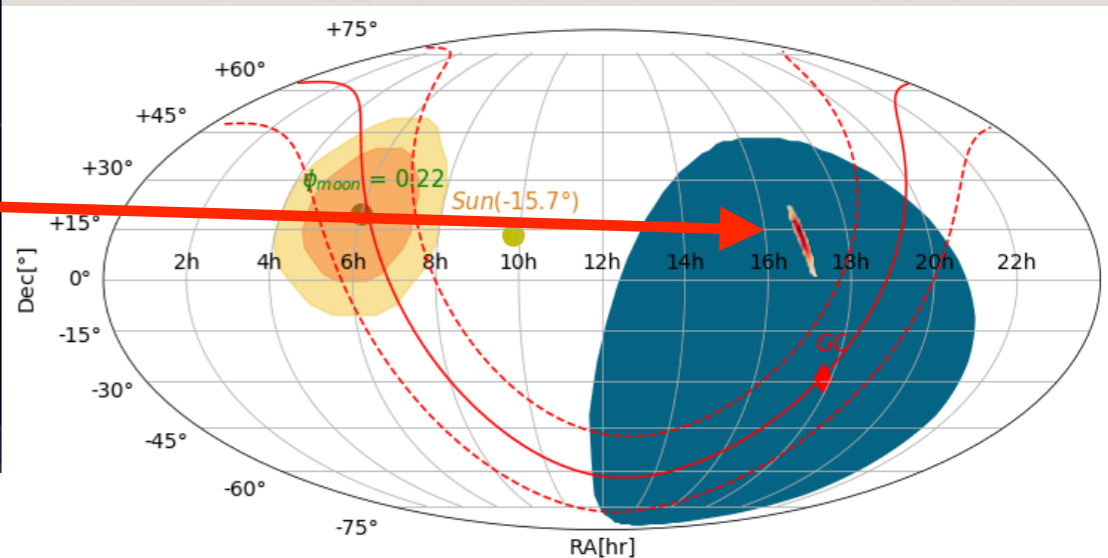
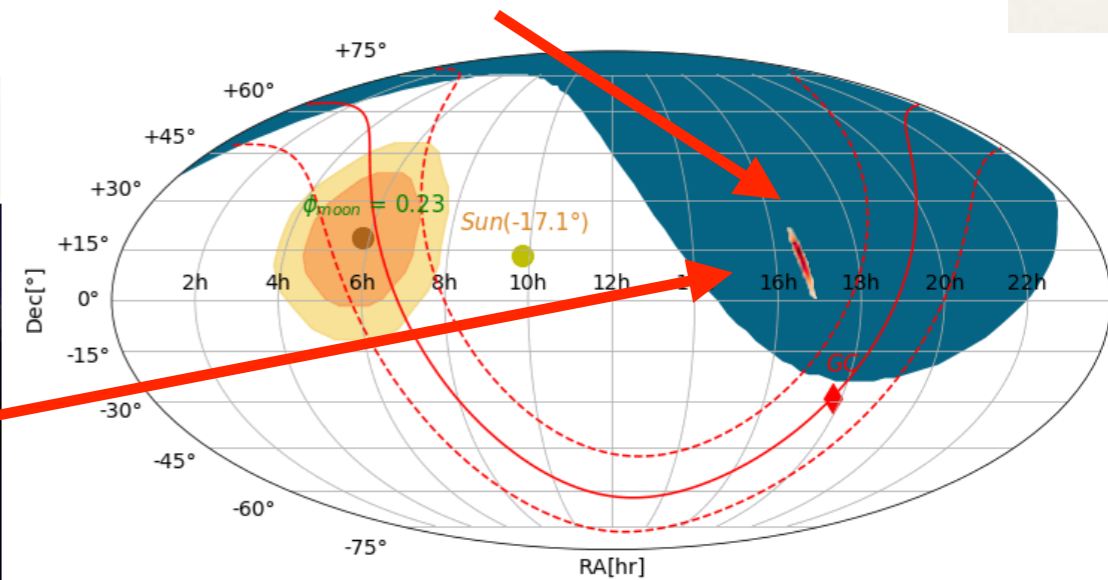


Observing strategy and scheduling of GRANDMA

Scenario one: an event observable at several observatories



~50 * 5 galaxies per night



Observing strategy and scheduling of GRANDMA

Scenario two: an optical counterpart detected by one telescope

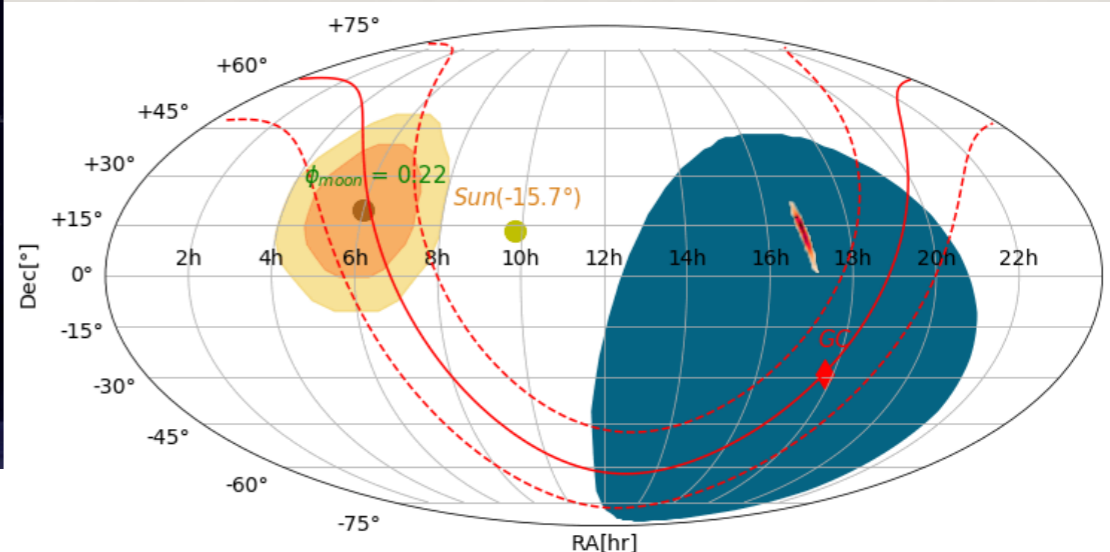
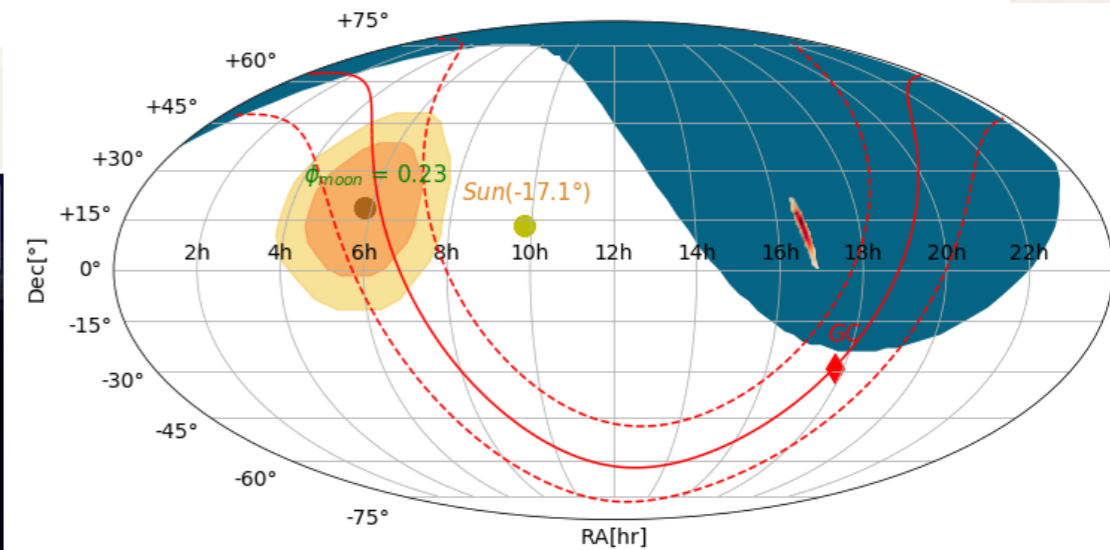
Gal ID	Ranking
Gal. 1	1
Gal. 2	2
Gal. 3	3
Gal. 4	4
Gal. 5	5
...	...

Gal ID	Ranking
Gal. 6	1
Gal. 7	2
Gal. 8	3
Gal. 9	4
Gal. 10	5
...	...



Gal ID	Ranking
Gal. 11	1
Gal. 12	2
Gal. 13	3
Gal. 14	4
Gal. 15	5
...	...

Gal ID	Ranking
Gal. 16	1
Gal. 17	2
Gal. 18	3
Gal. 19	4
Gal. 10	5
...	...

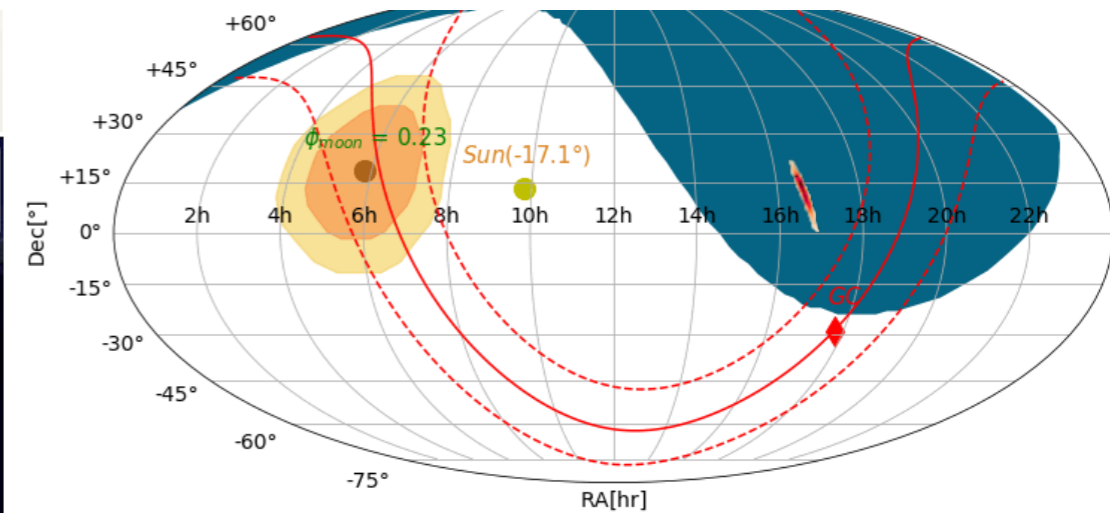


Observing strategy and scheduling of GRANDMA

Scenario two: an optical counterpart detected by one telescope

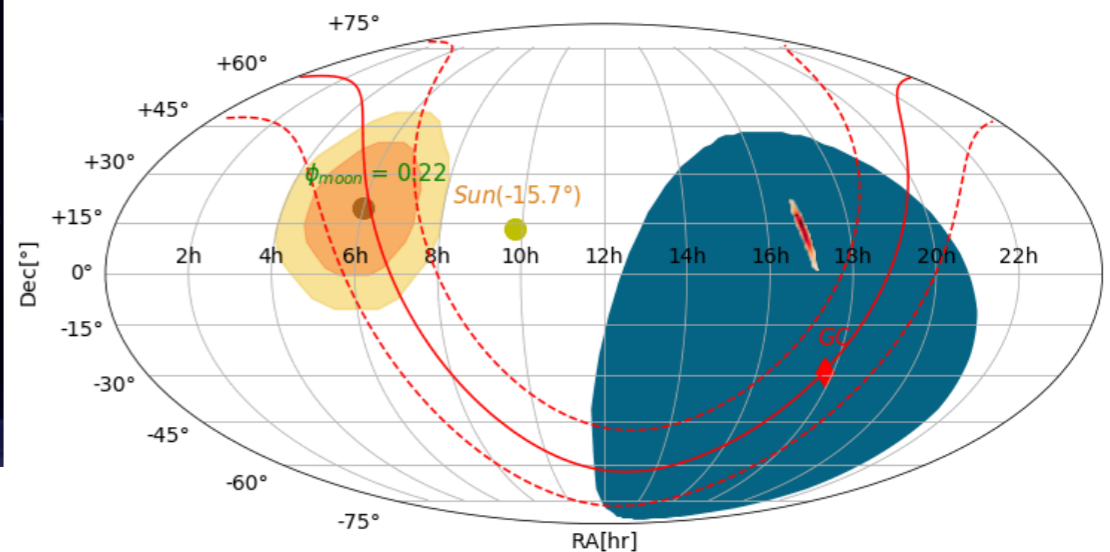
Gal ID	Ranking
Gal. 1	1
Gal. 2	2
Gal. 3	3
Gal. 4	4
Gal. 5	5
...	...

Gal ID	Ranking
Gal. 6	1
Gal. 7	2
Gal. 13	1
Gal. 9	4
Gal. 10	5
...	...



Gal ID	Ranking
Gal. 11	1
Gal. 12	2
Gal. 13	3
Gal. 14	4
Gal. 15	5
...	...

Gal ID	Ranking
Gal. 16	1
Gal. 13	1
Gal. 18	3
Gal. 19	4
Gal. 10	5
...	...



Multi-band confirmation

Observing strategy and scheduling of GRANDMA

Dynamic Scheduling for GRANDMA network

Conditions:

- weathers,
- telescope availability,
- visibility,
- updated skymap,
- observed target list
- optical candidate list
- etc.

