GRANDMA

A network of facilities dedicated to the electromagnetic follow-up of the GW-O3 candidates

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On behalf on the GRANDMA team
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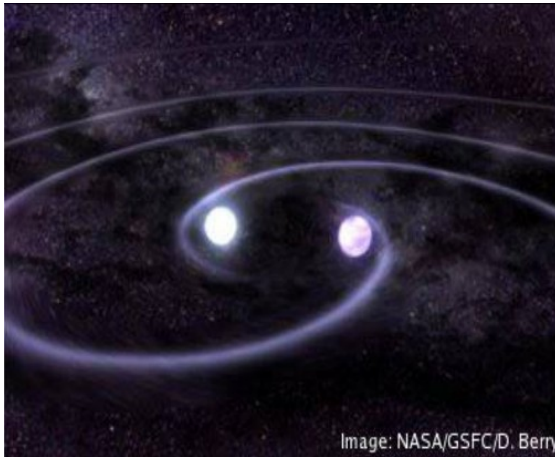
1st workshop French-Mexican LIA ERIDANUS
June 2019

Motivations

Search for electromagnetic counterparts related to GW

Image: NASA/GSFC/D. Berry

Merger : NS-NS

Kilonova
Short GRBs afterglow

Merger : NS-BH

Possible EM counterpart

Other sources

Core collapse supernovae
Binary black hole merger

Motivations

Search for electromagnetic transients related to GW

GRANDMA objectives

- Identify optical counterpart of GW events
- Characterise the counterpart :
    - Perform highly-sampled light curve
    - Measure source redshift and spectral features
- Put upper limits in case of no detection

Outline

I. The electromagnetic (optical) follow-up of GW events

II. The GRANDMA project for O3 follow-up campaign

III. 6 weeks of O3 with GRANDMA

EM follow-up of GW
Problematic 1 : large uncertainty on localisation

Vary from a few tens of square degrees to more than 1000 !
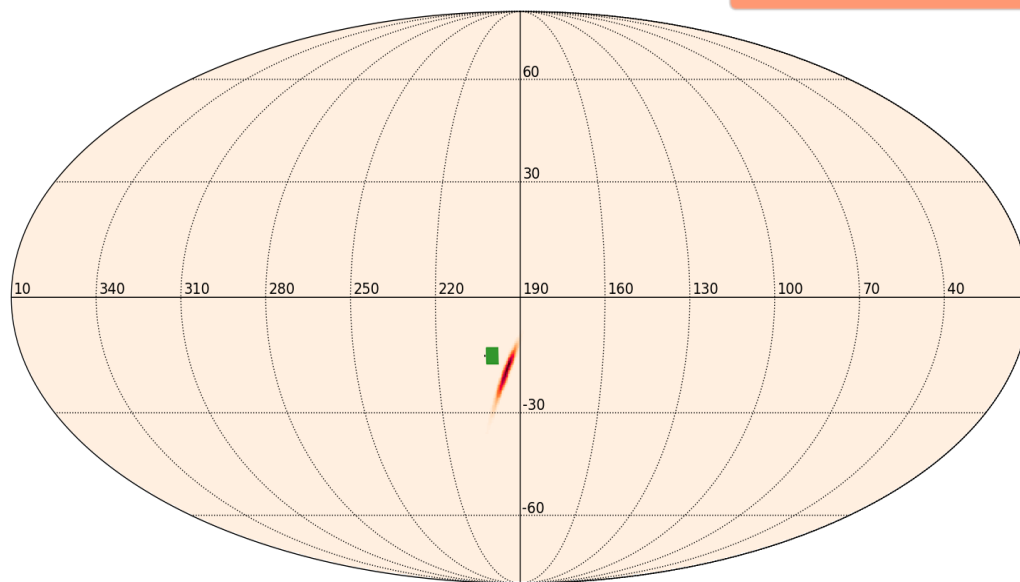

GW170817 BNS
28 deg2
[26-48] Mpc

Tarot Réunion (17.6 deg^2)
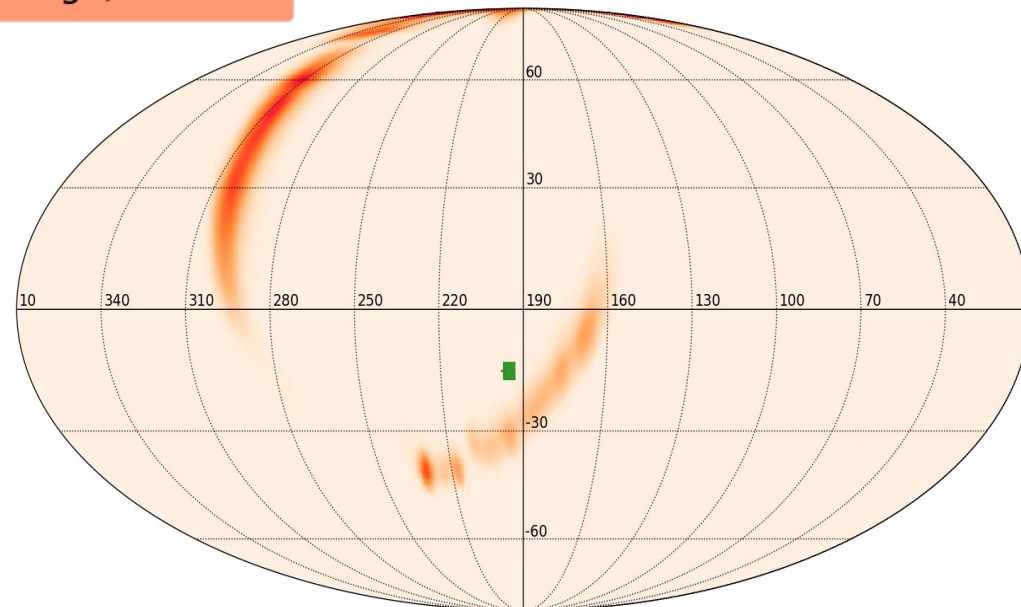Zadko (0.1 deg^2)

S190426c NS-BH
~2000 deg2
[295-551] Mpc

67 galaxies (GLADE)

~50 000 galaxies (GLADE)

HARD to cover the whole GW skymap with typical optical telescope FoVs
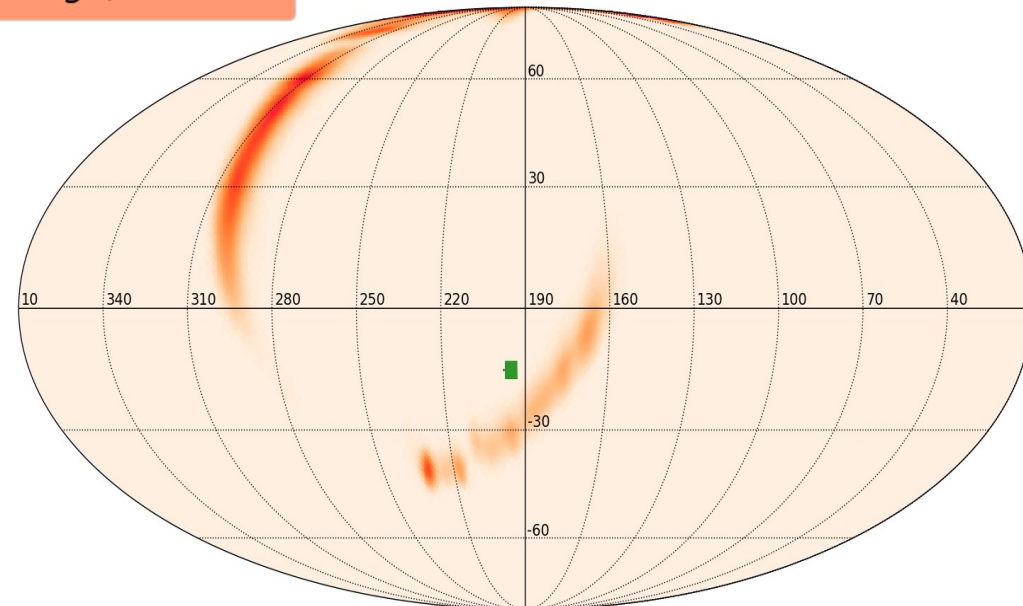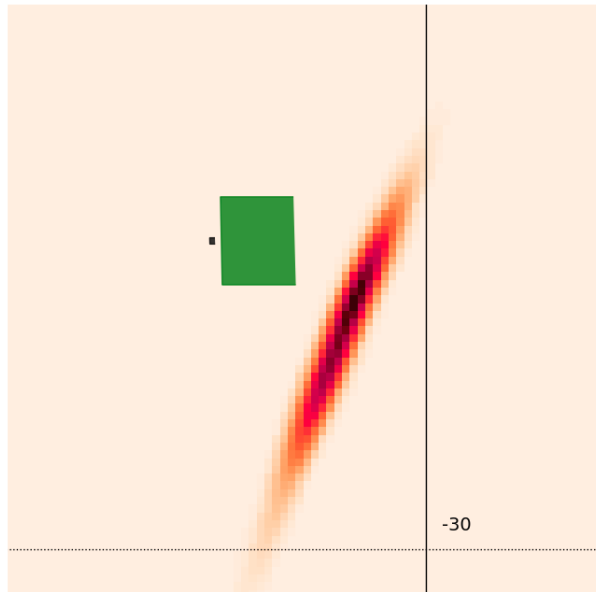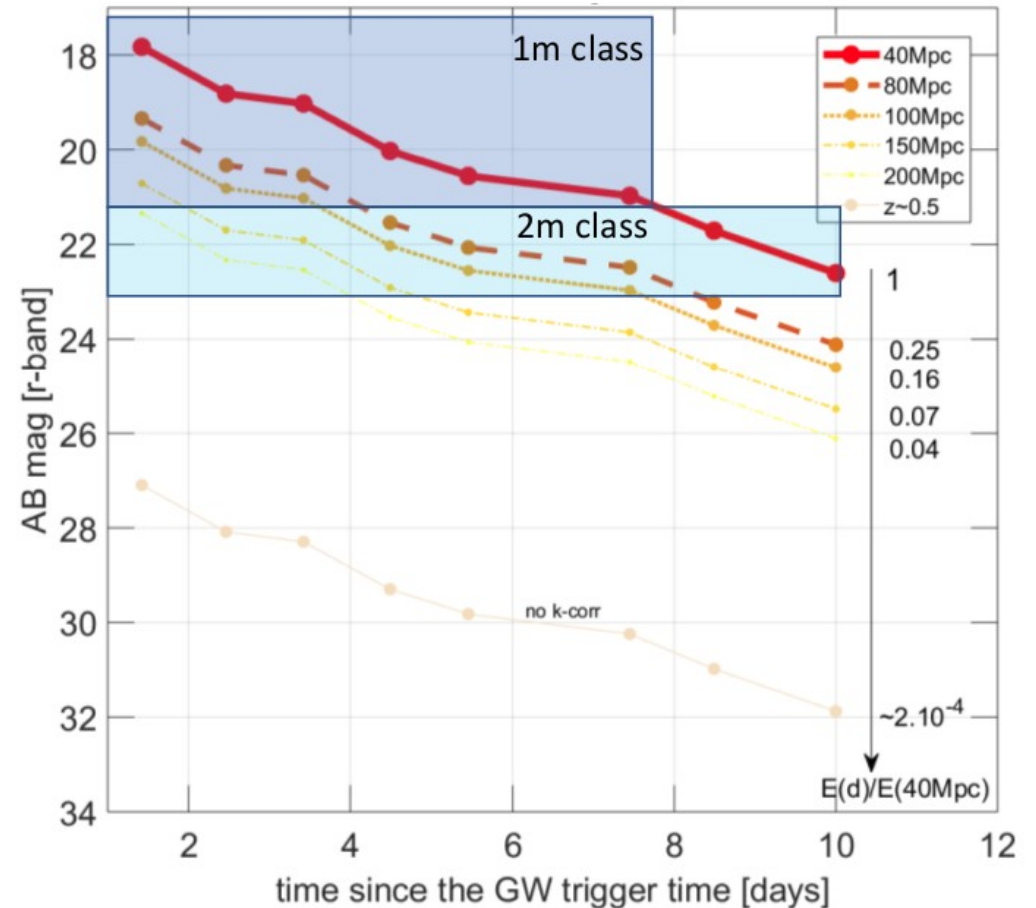
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**HARD to cover the whole GW skymap
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Kilonova GW170817
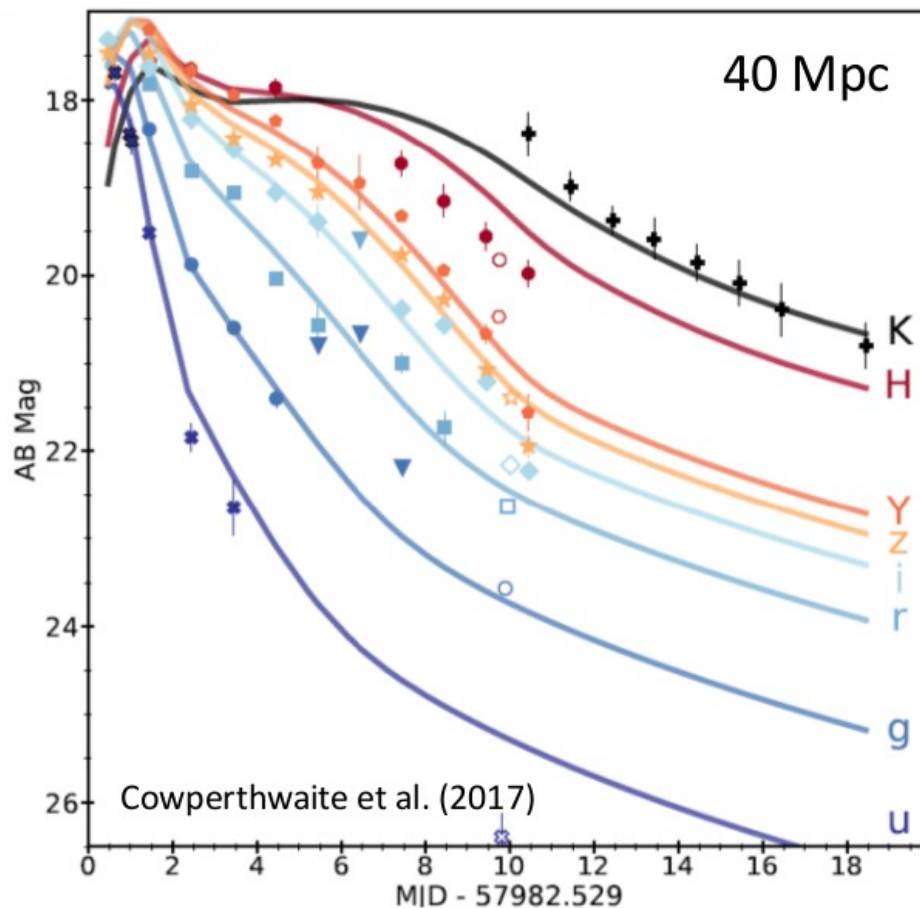
→ **And possibility of Short GRB afterglows**

Sources can be faint, Fast decrease in luminosity
→ require fast response

EM follow-up of GW
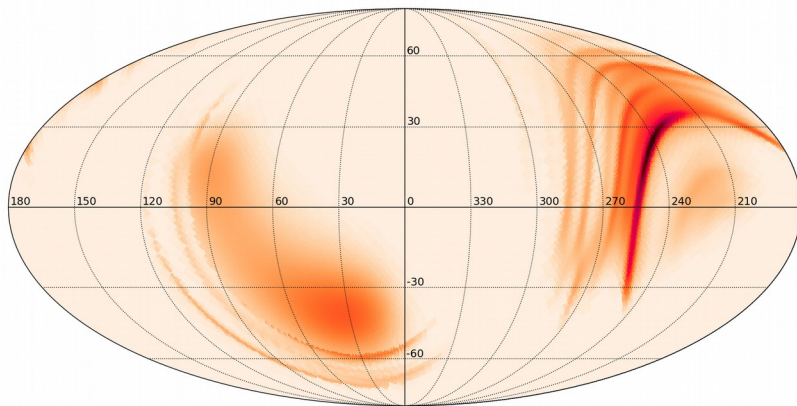# Problematic 3 : identification of candidates

Observation of a large region of the sky

Many unrelated or fake transients

Example of the first BNS of O3 :

Many candidates reported in GCN :

Ia Supernovae
IIb Supernovae
Dwarf star

Use spectroscopy to characterise candidates

The « Four GW commandments » for the astronomers

i.   Have a large FoV
ii. Be Fast
iii. Be deep in photometry
iv. Be efficient in identifying the good EM counterpart

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One telescope alone can usually not perform this task
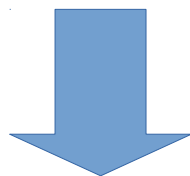
Global network required

Outline

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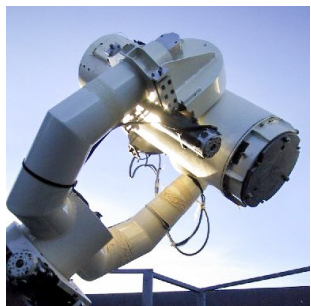
III. 6 weeks of O3 with GRANDMA

GRANDMA

Global Rapid Advanced Network Devoted to the Multi-messenger Addicts

Created 1 year ago by OCA (Nice), LAL (Orsay) and NAOC (Beijing)

PI : S. ANTIER

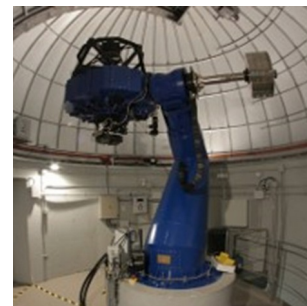(https://grandma.lal.in2p3.fr)

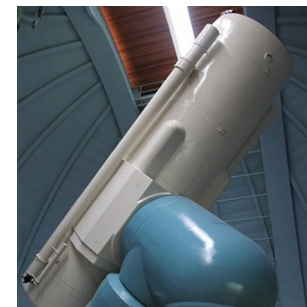Tarot-Calern · Tarot-Chile · Tarot-Réunion · OAJ-T80 · Zadko
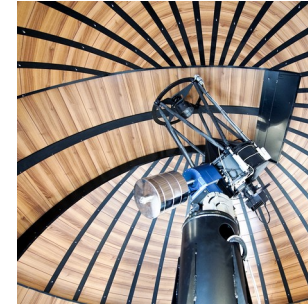
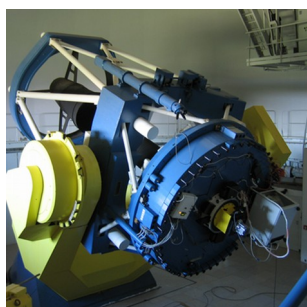Abastunami-T70 · Abastunami-T48 · LesMakes 60 · ShAO-2-m · IRiS

Xinglong-TNT · OSN-T150 · 2.2m CAHA · GMG-2.4 · Xinglong-2.16
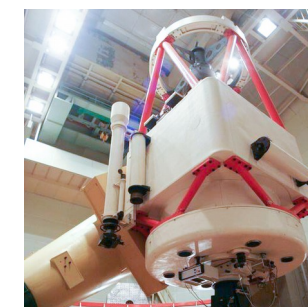
GRANDMA network

- ➢ ~ 20 telescopes in 13 observatories
  both hemispheres + very good longitude coverage
- ➢ ~ 60 people involved

GRANDMA network

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  both hemispheres + very good longitude coverage
- ~ 60 people involved

Continuously integrating new telescopes !

We are also involving the amateur community through the Kilonova
Catcher project with a dedicated database and website.
(https://grandma-kilonovacatcher.lal.in2p3.fr/)
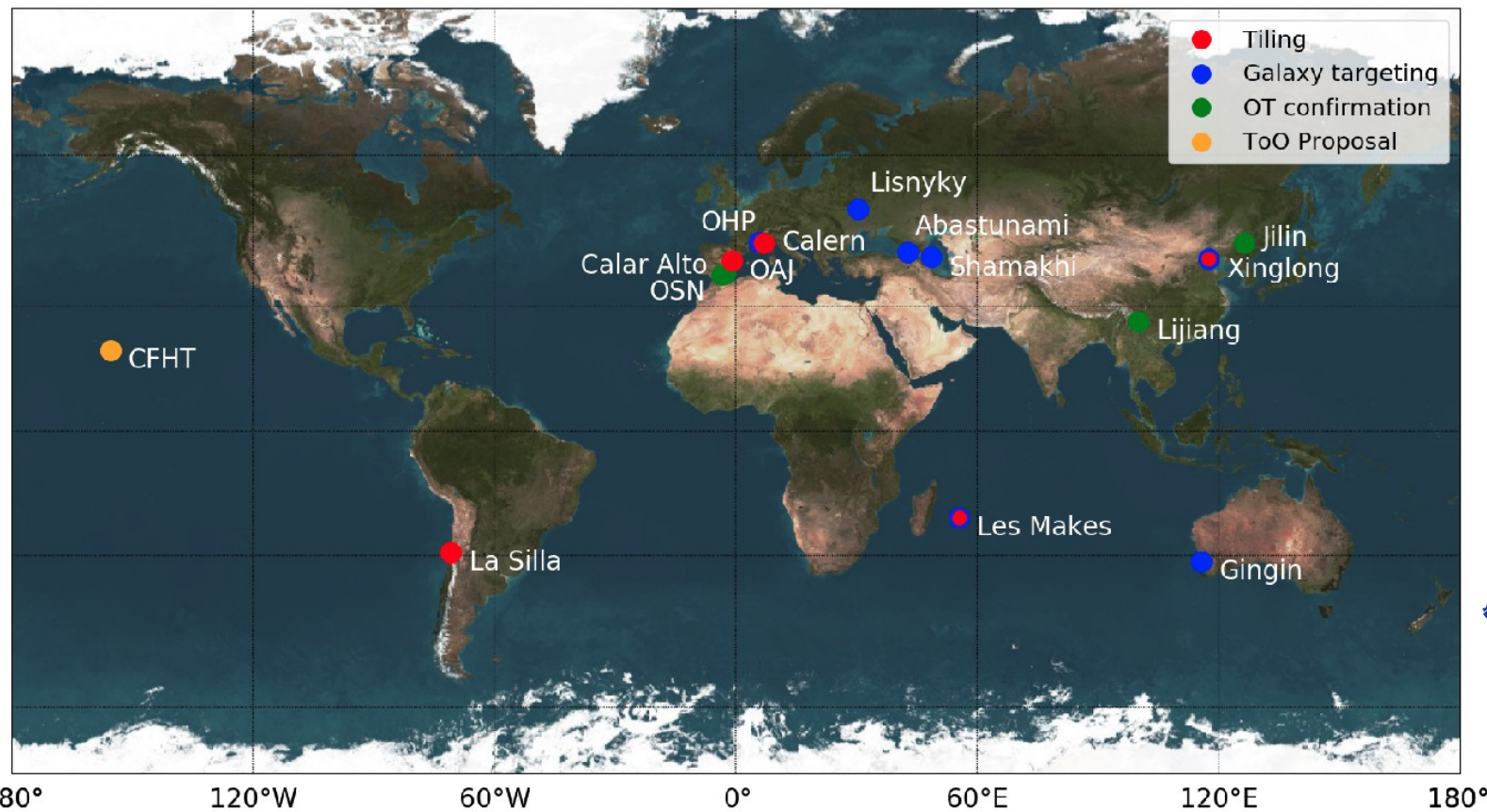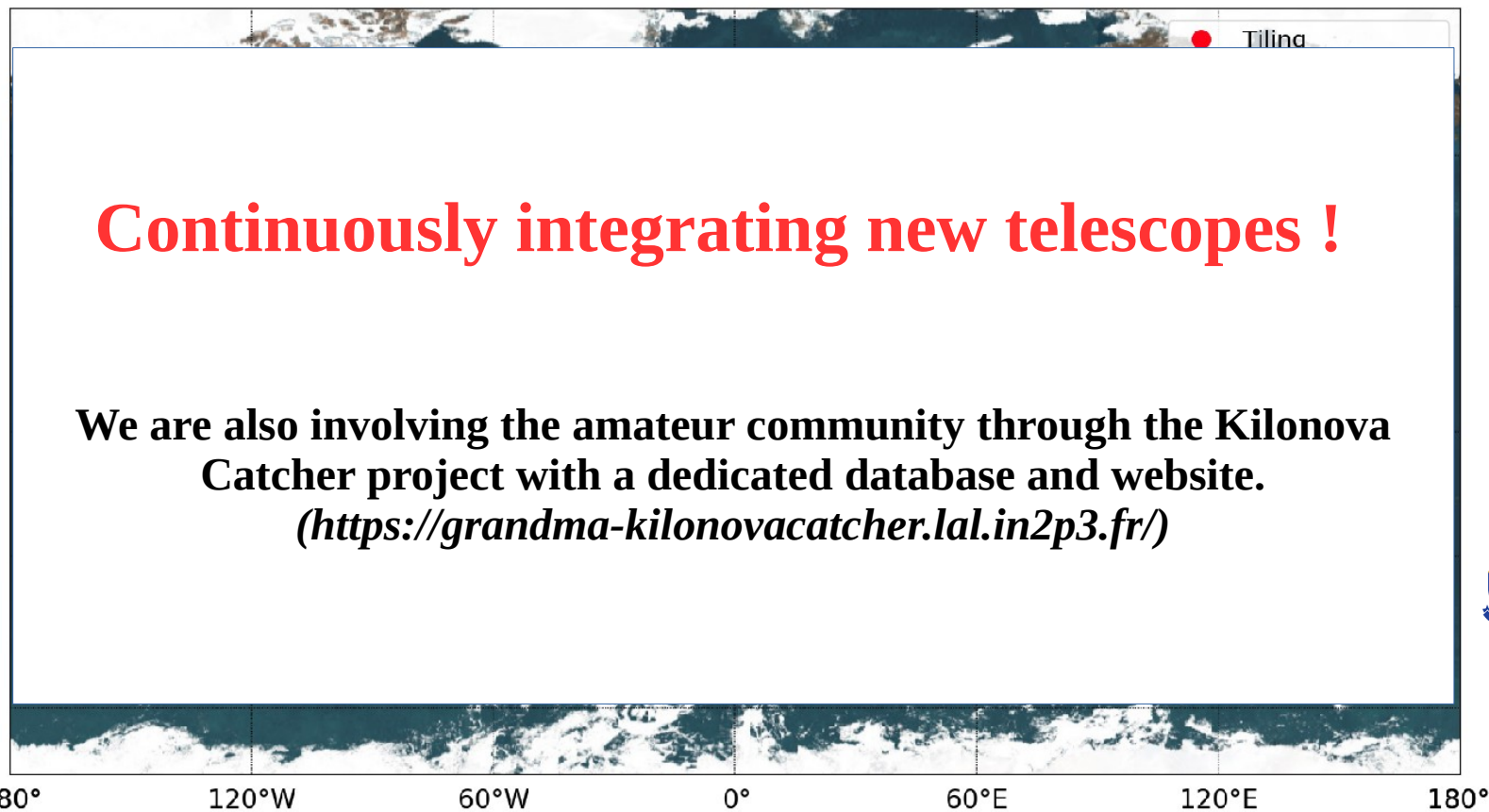
GRANDMA strategy step 1 : Identify counterpart candidates
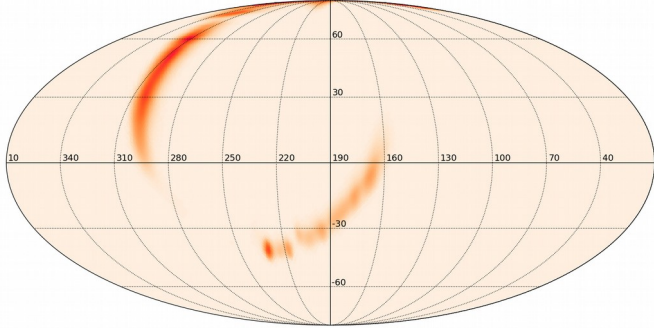
GW alert
skymap

Observation plan
for the whole network

GRANDMA strategy step 1 : Identify counterpart candidates

GW alert
skymap

Observation plan
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Tarot chile

Large FOV telescopes → Tiling
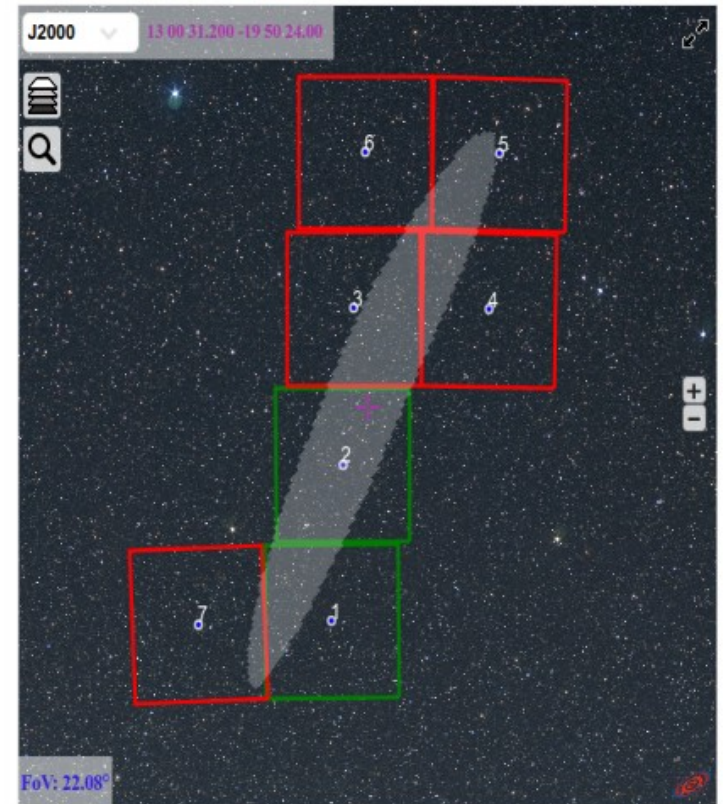
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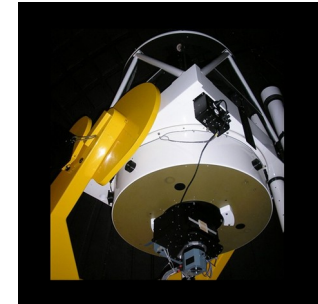
Zadko

Small FOV telescopes → Galaxies targetting
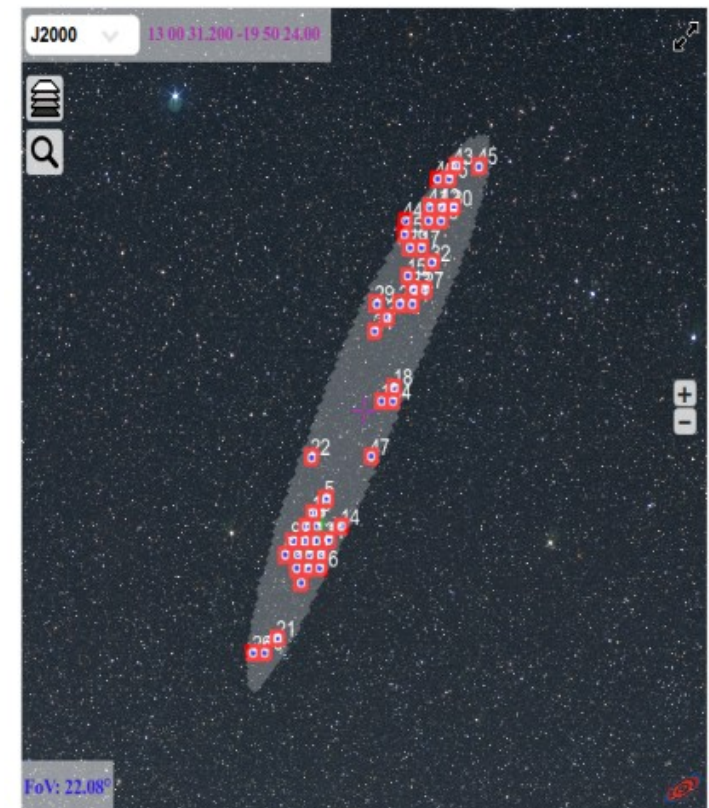
GRANDMA strategy step 1 : Identify counterpart candidates

GW alert
skymap

↓

Observation plan
for the whole network

↓

OT candidates

August 21, 2017
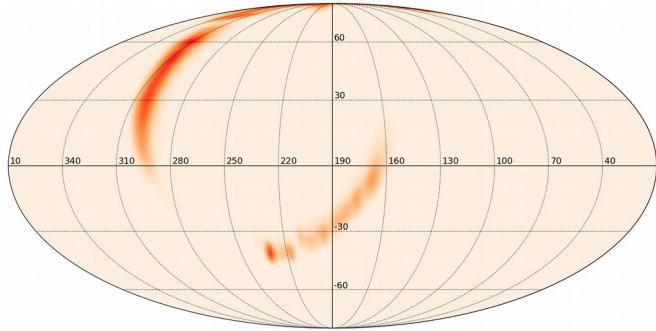
Swope & Magellan Telescopes

GRANDMA strategy step 1 : Identify counterpart candidates

2.2m CAHA
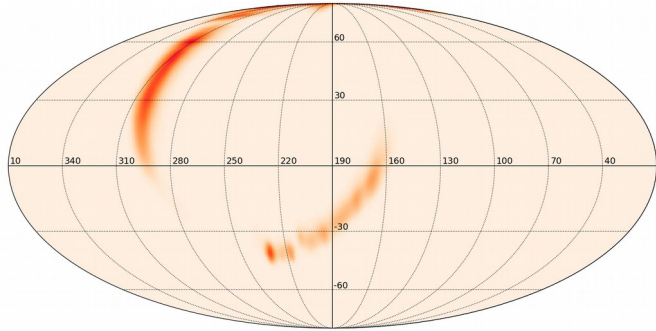
Xinglong-2.16

GMG-2.4

GW alert
skymap

Observation plan
for the whole network

OT candidates

Deep photometry
instrument follow-up
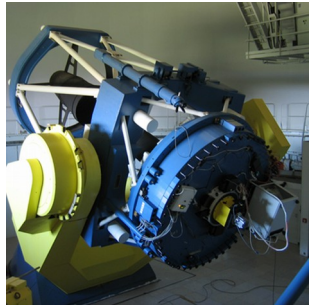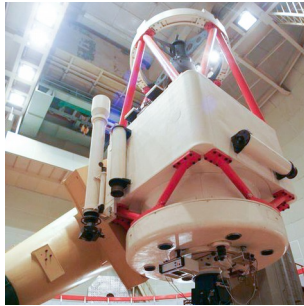
GRANDMA strategy step 1 : Identify counterpart candidates

CAHA

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GW alert
skymap

Observation plan
for the whole network

OT candidates

Deep photometry
instrument follow-up

External
Candidates
(GCN)
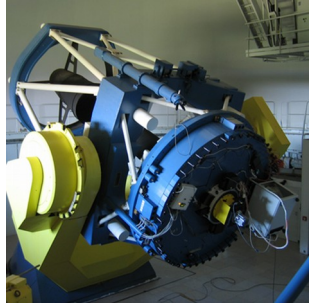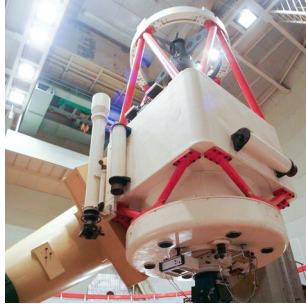
GRANDMA strategy step 1 : Identify counterpart candidates

GW alert skymap

Observation plan for the whole network

OT candidates

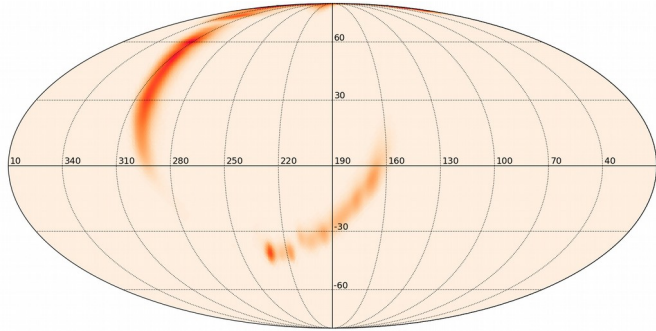External Candidates (GCN)

Deep photometry instrument follow-up
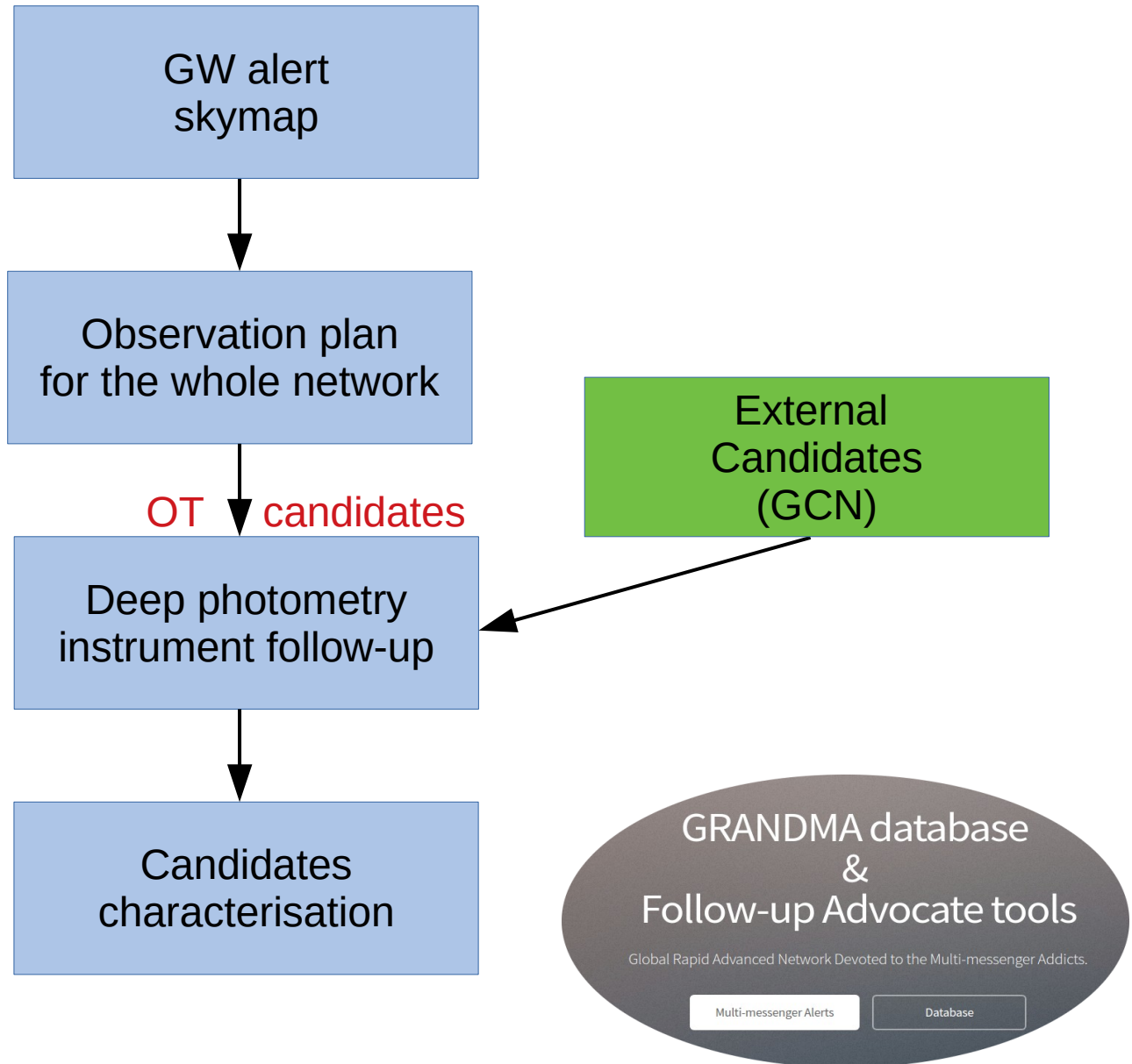
Candidates characterisation

GRANDMA database & Follow-up Advocate tools

Global Rapid Advanced Network Devoted to the Multi-messenger Addicts.

Multi-messenger Alerts | Database

Interesting OT candidates :

Perform additionnal photometry and spectroscopy observations with GRANDMA dedicated telescopes

Reject contaminants
Publicly release our candidates as soon as possible

In case of confirmed EM counterpart

Intensive GRANDMA follow-up over 10 days

Outline

I. The electromagnetic (optical) follow-up of GW events

II. The GRANDMA project for O3 follow-up campaign

III. 6 weeks of O3 with GRANDMA

GRANDMA follow-up since beginning of O3

Results of the GRANDMA follow-up
9/14 alerts followed :

Alert ID BNS NS-BH BBH	~Distance (Mpc)	~Size skymap 90 % (deg²)	cumulative probability observed by tiling	Targeted galaxies	~Delay since preliminary Notice (h)
S190412m	800	150	73 %	-	10
S190421ar	2200	2000	17%	-	20
S190425z	150	10000	3%	119	7
S190426c	400	2000	11%	-	6
S190503bf	400	450	17%	-	4
S190510g	230	1000	44 %	-	21
S190512at	1400	320	34 %		13.8
S190513bm	2000	500	24 %	-	0.7
S190517h	2950	1000	9 %	-	4.2

No interesting candidates found

S190425z : first BNS of O3, GRANDMA network efficiency

The observation started ~7h after the GW trigger time
Observed with 8 telescopes
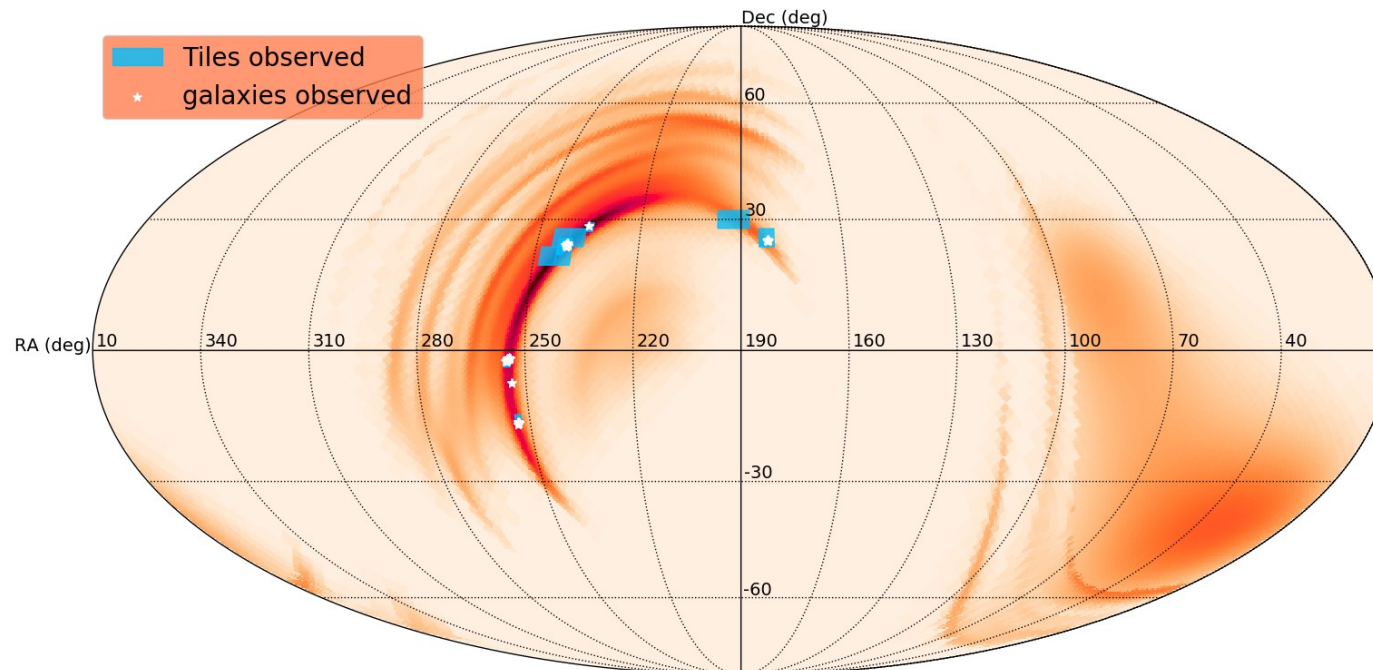
A total of ~170 deg² observed by tiling with overlap (Tarot network)
A total of 119 targeted galaxies (Les Makes-T60, AZT-8 and Abastumani-T70)

Characterisation of candidates :
Swift UVOT candidate with CAHA 2.2m → classified as dwarf star
ZTF candidate with Lijiang 2.4m → classified as type II supernovae

GRANDMA « services »

➢ Automatic treatment of LVC alerts (reception + revision)

➢ Automatic generation of observation plan adapted for each alert and telescopes

➢ Common database to report observations automatically

➢ Web interface to monitor the follow-up

➢ Automatic generation of GCN circulars

➢ **In development :**
  ➢ Improvement of observation strategies

  ➢ Development of a 'common' detection pipeline

Conclusions

➢ Built a world wide network of ~20 telescopes, with wide variety of performances (10' to 16° FoV), rapid response time and spectrographs.

➢ Observation stategy adapted for each alert and telescopes

➢ GRANDMA will be active for the whole O3 run and will follow all GW alerts
  ➢ Rapid skymap scan with wide FOV
  ➢ Galaxies targetting with small FOV
  ➢ Candidates follow-up with up to 2.4m telescopes

Thank you
for your
attention !

Example of the GW170817 kilonova

Tarot Réunion (Tiling)

Tarot Calerne, Tarot Chile (Tiling)

50cm to 1m class (Galaxy targetting)

1m class single frame (Galaxy targetting)

1m class stacking (Galaxy targetting)

2-3m class (OT characterisation)

The kilonova of GW170817 would have been detectable by almost all our instruments from 0.45 to ~10 days after the GW /GRB trigger time

Cowperthwaite et al. (2017)

Example of the GW170817 kilonova

GW170817 Kilonova at larger distances

Courtesy D. Turpin

Just by a distance effect, a GW170817-like kilonova is hard to catch with 1m class telescopes for D>100-150 Mpc (in r-band)

At D = 100Mpc, the KN signature could be still detectable (by 1m tel) within $T-T_{GW} < 2-3$ days

Many galaxies to target with blind or optimised search

GW170104
~2000 deg2
[664-1180] Mpc

GW170817
28 deg2
[26-48] Mpc

**Total of >120 000
galaxies using
GLADE**
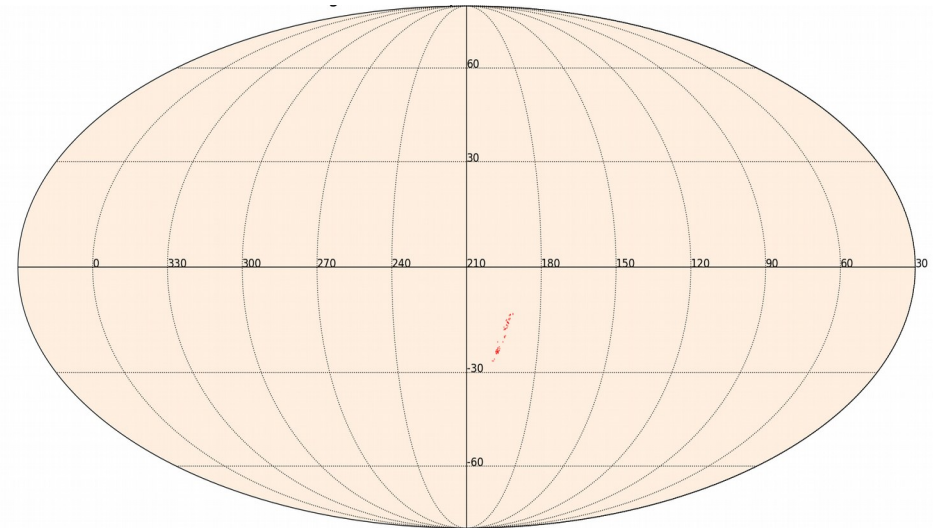
**Total of 67
galaxies using
GLADE**

Example of the GW170817 kilonova

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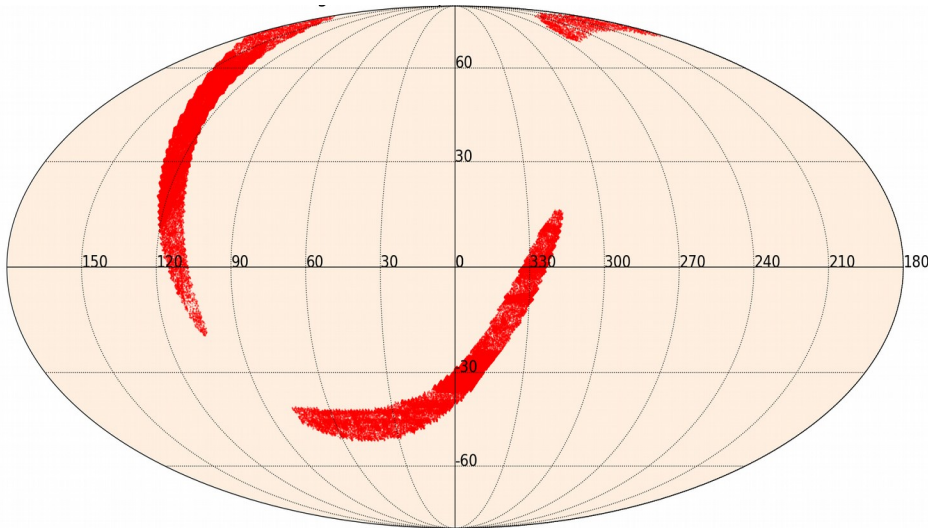At D = 100Mpc, the KN signature could be still detectable (by 1m tel) within $T-T_{GW} < 2-3$ days
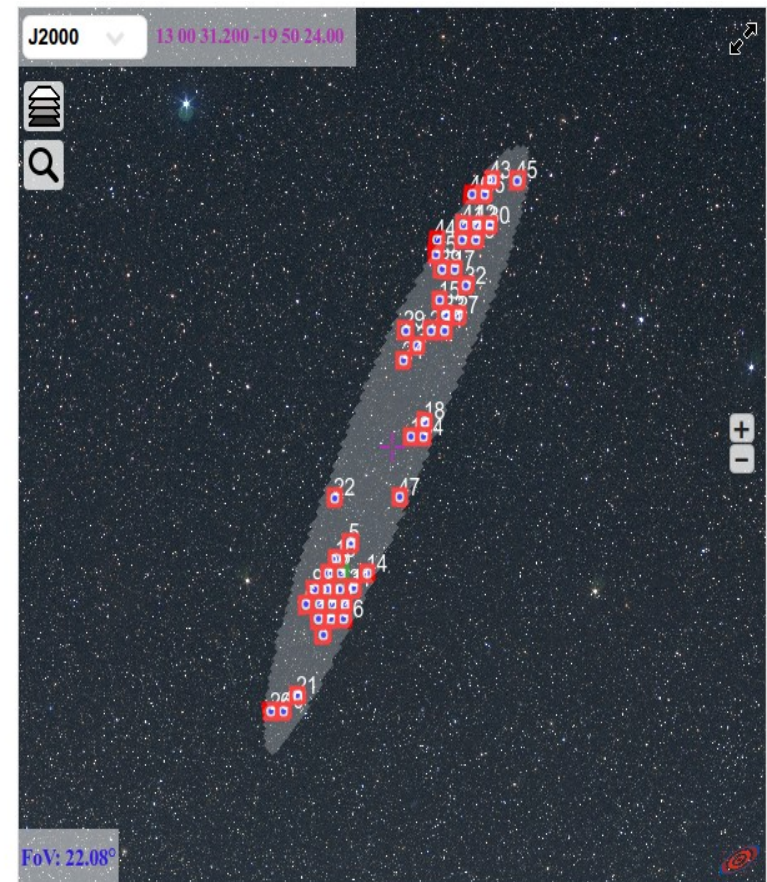
Courtesy D. Turpin

GRANDMA : example of observation plan

➢ **Large FoV telescopes :** tiling, using a predefined tesselation of the sky ordered by probability

➢ **Small FoV telescopes :** galaxy targeting

Tarot-Réunion - 16 deg2
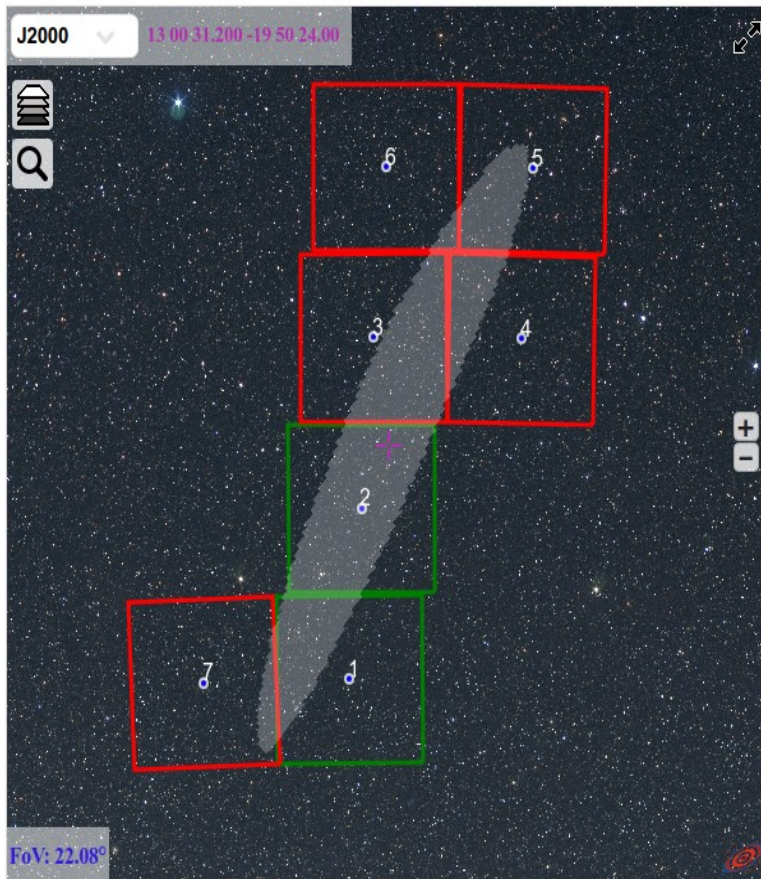
Zadko - 0.15 deg2

GRANDMA telescopes

Telescope	Location	Aperture (m)	FoV	Mag lim (single / stack)	Obs. mode
Tarot-TRE	Réunion	0.18	4°	16/17	Tiling
Tarot-TCA	France	0.25	1.9°	17/18	Tiling
Tarot-TCH	Chili	0.25	1.9°	17/18	Tiling
Abastunami-T48	Georgia	0.48	20'	15/17	Galaxy targeting
OHP-IRiS	France	0.5	24'	18/19	Galaxy targeting
Makes-60	Réunion	0.6	23'	18/19	OT
Abastunami-T70	Georgia	0.70	30'	18/19.5	Galaxy targeting
Lisniky AZT-8	Ukraine	0.70	16'	18/19.5	Galaxy targeting
TNT	China	0.8	12'	19/20	Galaxy targeting
OAJ-T80	Spain	0.8	2°	18/19	Tiling
Zadko	Australia	1	23'	20/22	Galaxy targeting
OHP-T120	France	1.2	13'	20/21	OT
OSN-T120	Spain	1.2	13'	20/21	OT
CAHA-2.2m (phot/**spec**)	Spain	2.2	12' / 16'	22 / 19	OT
GMG-2.4 (phot/**spec**)	China	2.4	10' / 10'	24 / 19	OT
Shamakhi-60cm	Azerbaijan	0.6	17'	18/19	Galaxy targeting
Shamakhi-2m **spectro**	Azerbaija	2	21'	18	OT