

Multi-messenger astronomy with

# GRANDMA telescope network



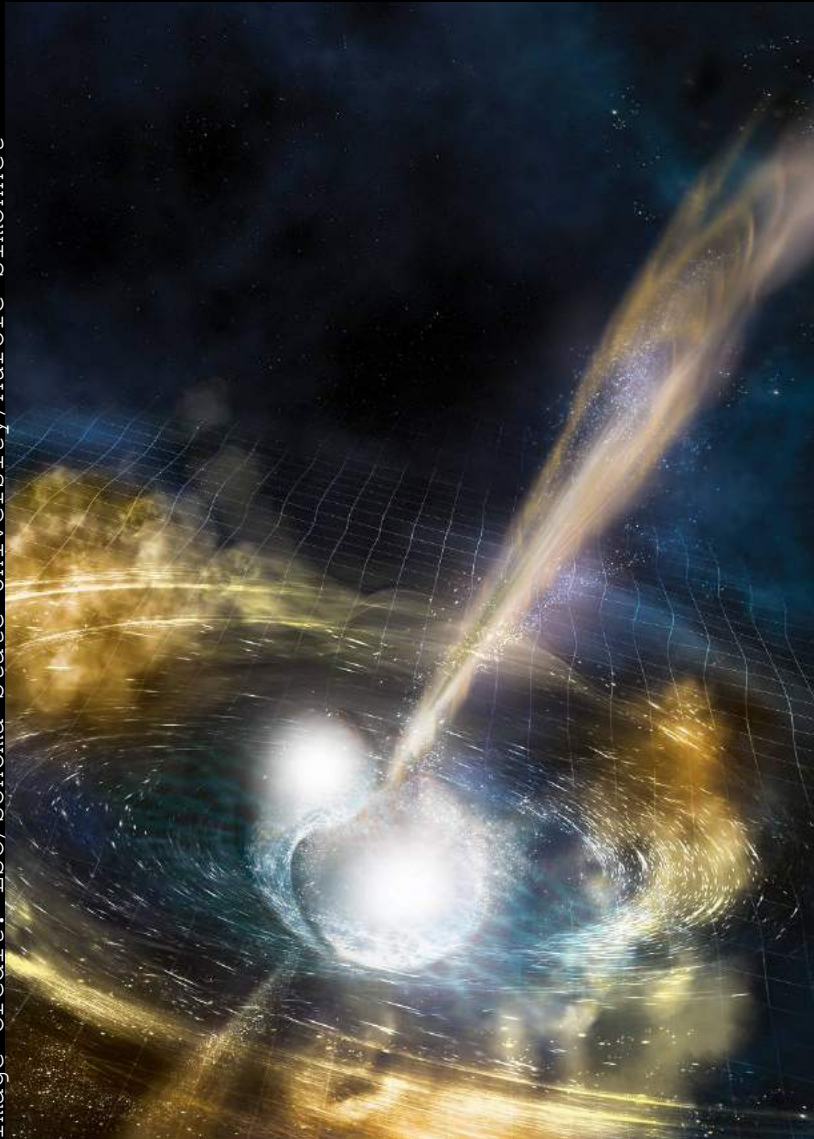
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*Antoine Cailleau*

*SF2A*

[grandma.lal.in2p3.fr](http://grandma.lal.in2p3.fr)

# What is multi-messenger astronomy ?

Image Credit: LSC/Sonoma State University/Aurore Simonnet



**Electromagnetic  
Transients**

**+**

**New messengers**

Gravitational waves

Neutrinos

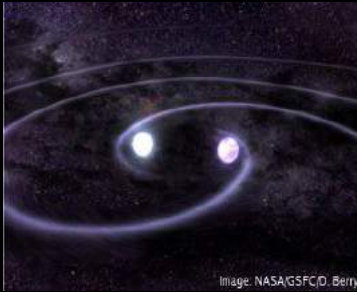
**=**

**Multi-messenger  
astronomy**

# What is multi-messenger astronomy ?

Transient phenomena: shortest times scales (milliseconds to several years)

*To emit GWs, a source must be compact, relativistic and asymmetric*



## **Merger (NS-NS; NS-BH; BH-BH)**

- Short GRBs, Kilonova
- Other cases ? FRB ?

## **Collapse of a single star**

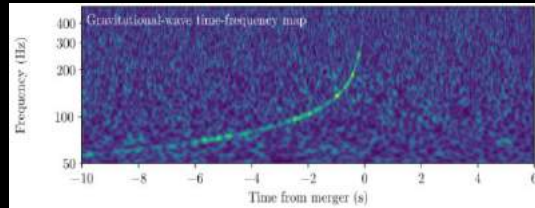
- Type Ib, Ic, II supernovae
- Long GRBs
- Intermediate cases



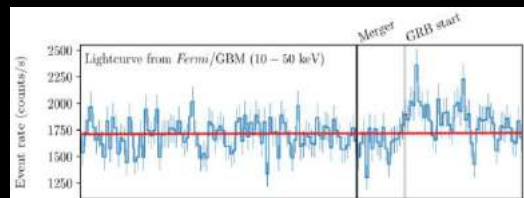
## **Neutron star instabilities**

- Soft Gamma-ray repeaters
- Radio/ Gamma-ray pulsar glitches

# GW170817- a first multi-messenger case



**Gravitational wave**  
Initial system

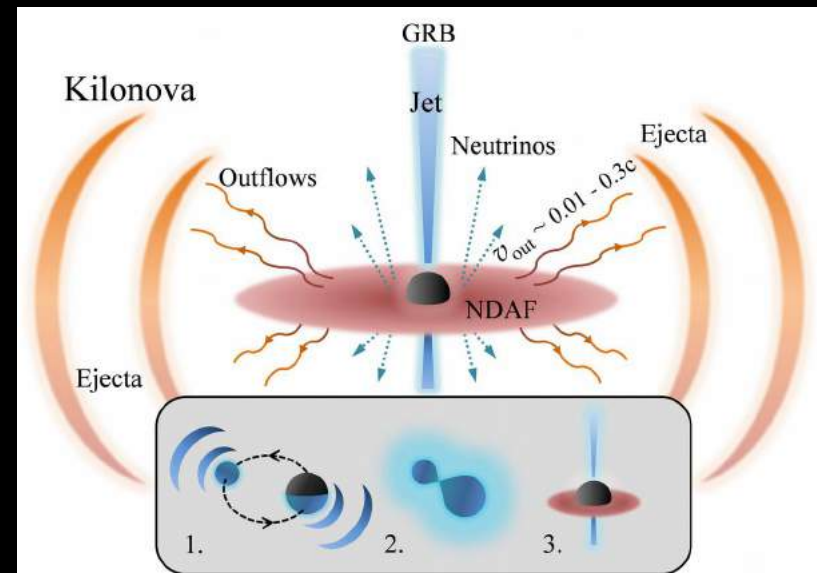
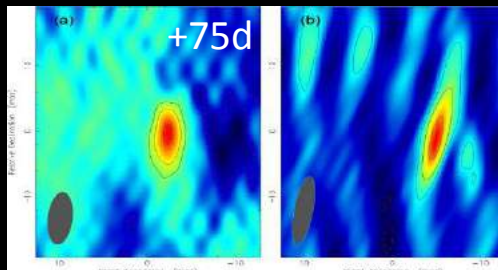


**GRB**  
Jet  
Acceleration mechanisms

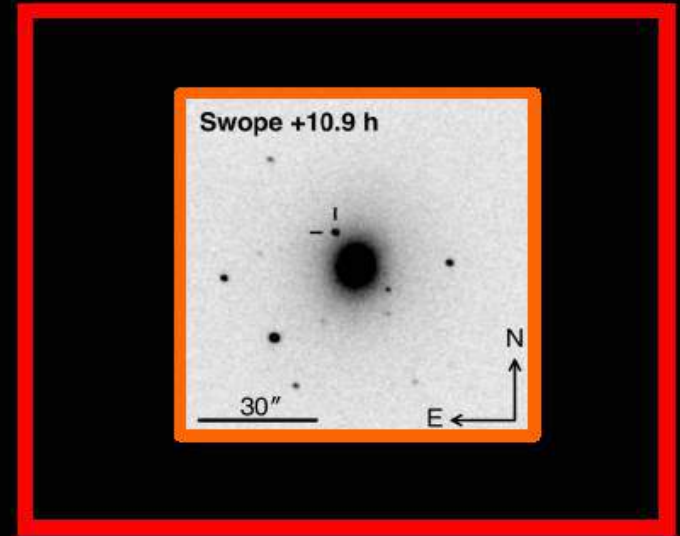
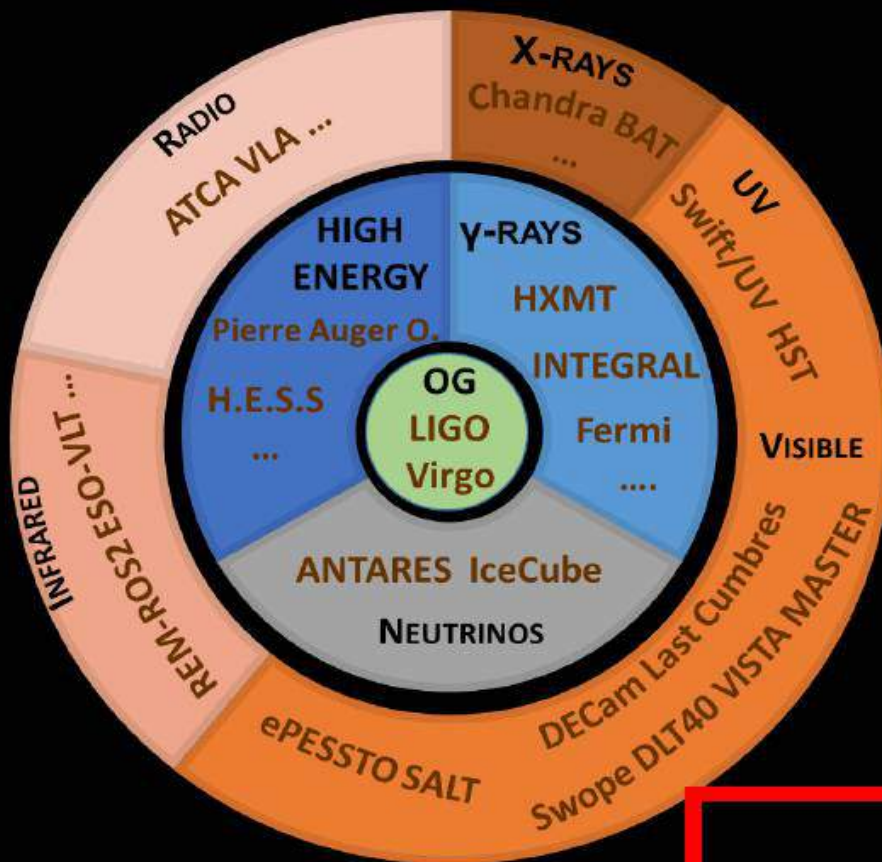


**Kilonova**  
Localization (arcsec)  
Host galaxy  
Redshift

+230d



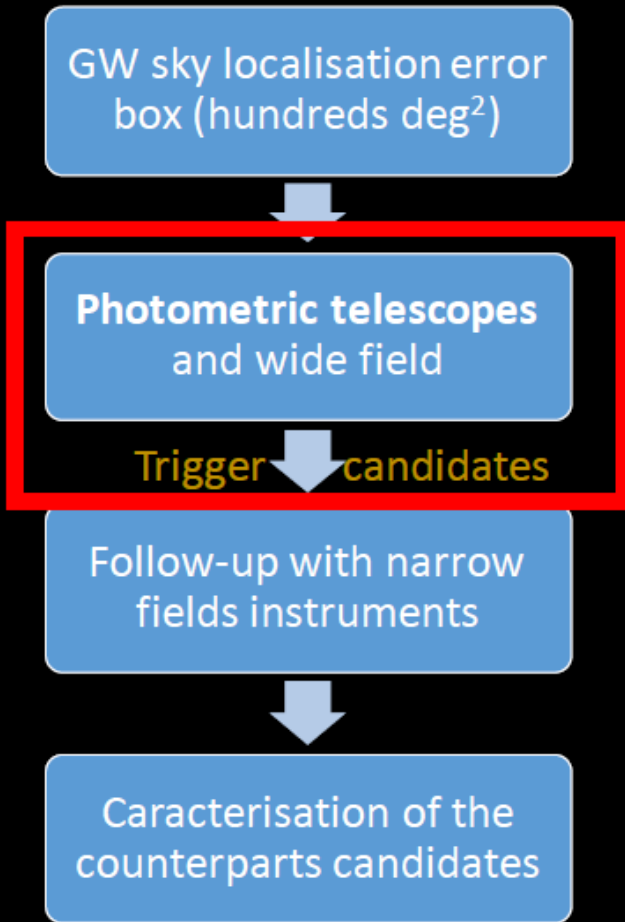
# GW170817- discovery sequence



Your contribution as  
amator

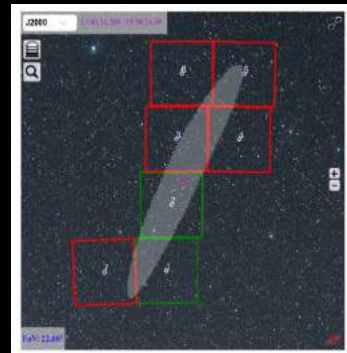


# Identification of the EM/neutrino counterpart



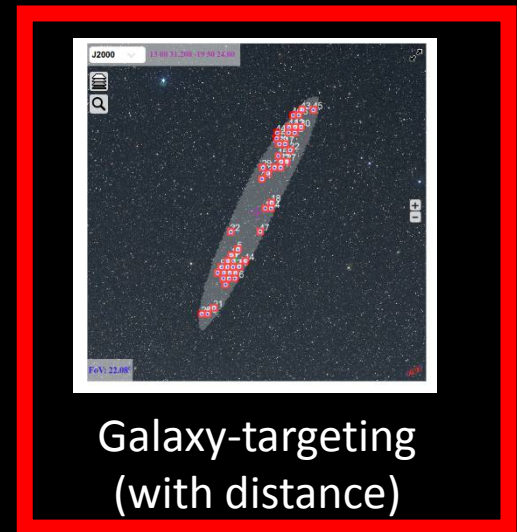
Needs a large astronomical collaboration

Needs specific observational strategies



Tiling strategy

Your contribution as amator !



Galaxy-targeting (with distance)

# LIGO

*Livingston  
Louisiana - USA*



Next observational campaign O3 starts !

# VIRGO

*Santo Stefano a Macerata  
Italy*



# LIGO

*Hanford  
Washington - USA*



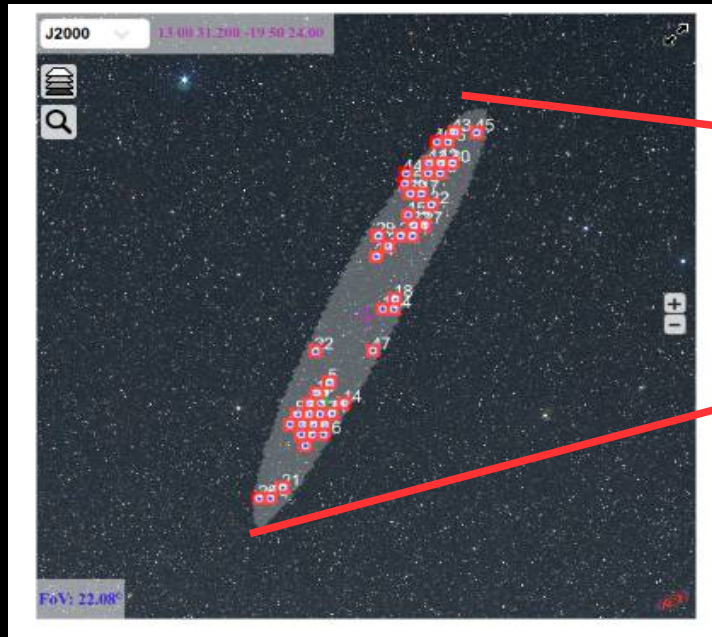
# GRANDMA Network



And your's !

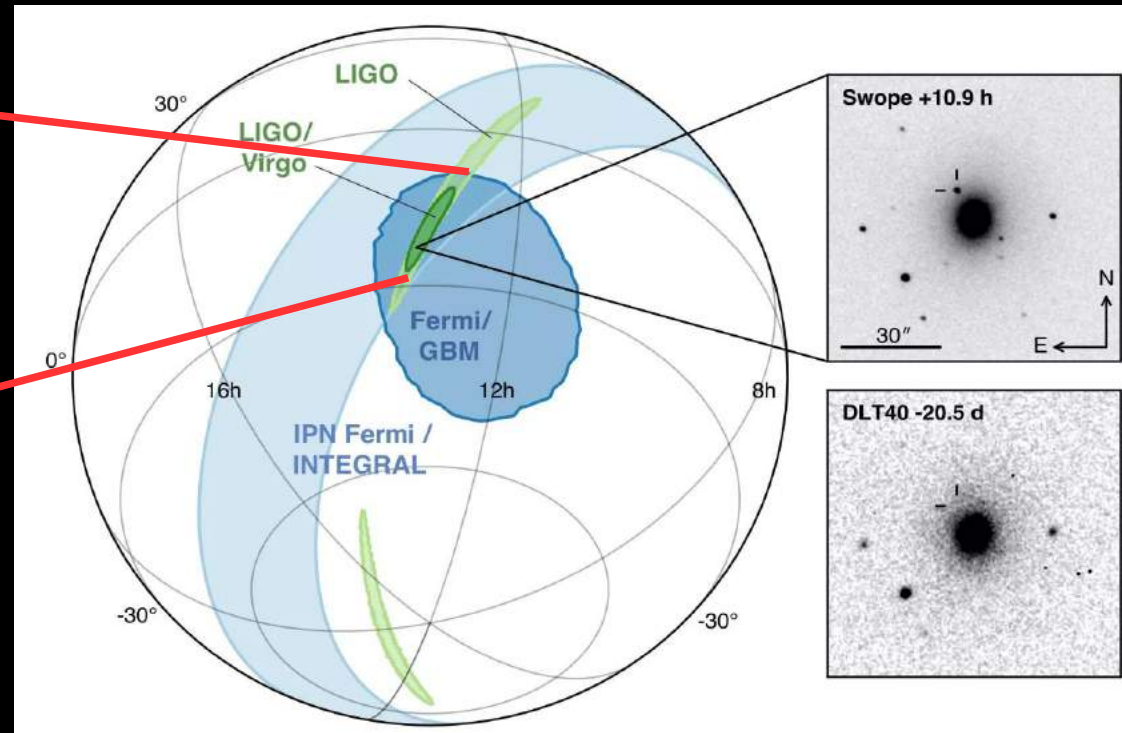


# GRANDMA Citizen Science program



Galaxy targeting

**Your contribution as  
amator !**



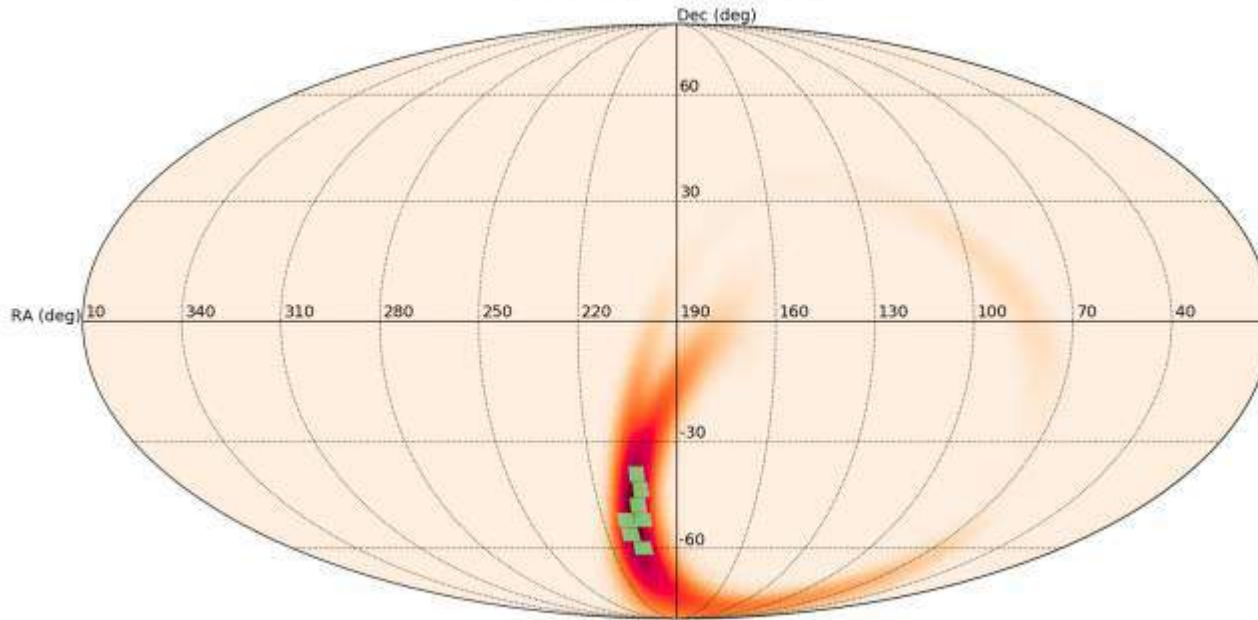
Simple sky acquisition with your scope,

- Simple fit / fits format
- Fit header with simple date (Ra/Dec)
- Put your image quickly on GRANDMA website

If you can do a lot better, do as usual !

# TAROT detection exemple

S190421ar follow-up with Tarot



only 10% of the area covered despite five hours of observation

Time Start (UTC)	Time End (UTC)	RA (deg)	DEC (deg)	Proba (%)
2019-04-22 17:19:22	2019-04-23 01:37:03	205.714	-60.000	2,6
2019-04-22 17:32:30	2019-04-23 01:05:10	204.179	-38.571	2,5
2019-04-22 17:44:37	2019-04-23 01:18:28	203.774	-51.429	2,4
2019-04-22 18:00:09	2019-04-22 20:18:14	204.828	-47.143	2,8
2019-04-22 19:39:33	2019-04-23 00:11:50	210.000	-55.714	2,6
2019-04-22 19:52:45	2019-04-22 22:12:51	203.226	-42.857	2,5
2019-04-22 20:50:10	2019-04-22 22:26:08	210.566	-51.429	2,3

# Amator How to join ?

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## KILONOVA CATCHER

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THE GRANDMA CITIZEN SCIENCE WEBSITE ON GRAVITATIONAL WAVE ASTRONOMY.

SIGN IN

SIGN UP

<https://grandma-kilonovacatcher.lal.in2p3.fr>

or

« Grandma astronomy » on Google ... !

# Amator how to proceed

I DON'T REMEMBER HOW TO PROCEED WHEN A GW ALERT OCCURS

HELP

Don't panic !  
Let me show you  
the most simply  
way !

## LIST OF THE LAST GW EVENTS

elapsed time since the GW alert date

GW alert name / Access to your observation plan

1314d 20h 44m 36s

GW150914

Choose events

YOUR TELESCOPE SETTINGS

## YOUR OBSERVATORY/TELESCOPE SETTING

Name	First name	email	Longitude [°]	Latitude [°]	FoV [°]	Tel. diam. [cm]	F/D	Filter	CCD
Cailleau	Antoine	acracing@hotmail.fr	43.6441	2.0883	0.36	51	4.97	Sloan g'2	Sbig ST8

Verify yours personal  
data,

MODIFY YOUR PERSONAL DATA

CHANGE OR ADD A NEW OBS/TEL

Answer about dark  
correction,

CLOSE

And simply update  
your science image

## YOUR LAST IMAGE

You haven't added images yet with this telescope.



Thanks for your attention !

Mailing list inscriptions :

<https://listserv.in2p3.fr/archives/kilonovacatcher-l.html>

Website :

<https://grandma-kilonovacatcher.lal.in2p3.fr/>

Instant message application Slack :

[https://join.slack.com/t/kilonovacatcher/shared\\_invite](https://join.slack.com/t/kilonovacatcher/shared_invite)