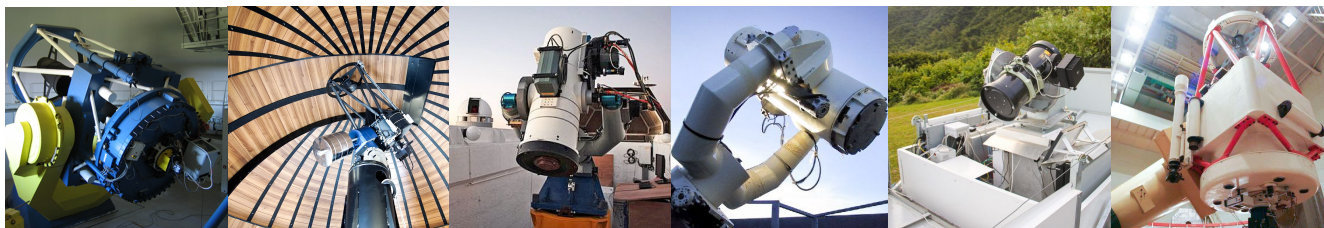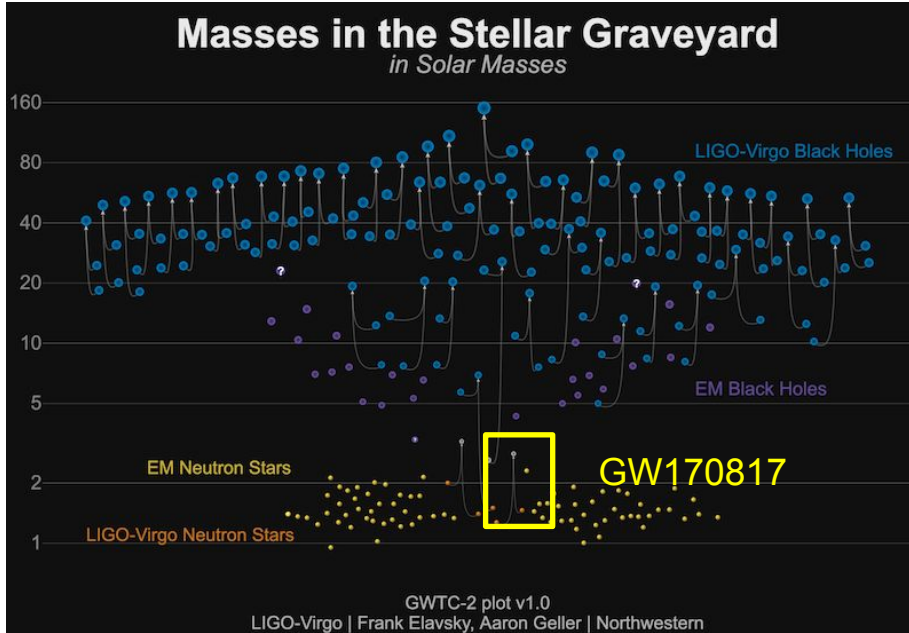# Multi-Messenger Studies with GRANDMA

P-A Duverne - IJClab - Virgo group

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CAT Seminar

Multi-Messenger Astronomy

Masses in the Stellar Graveyard
in Solar Masses

GW170817

Gravitational waves

Initial system
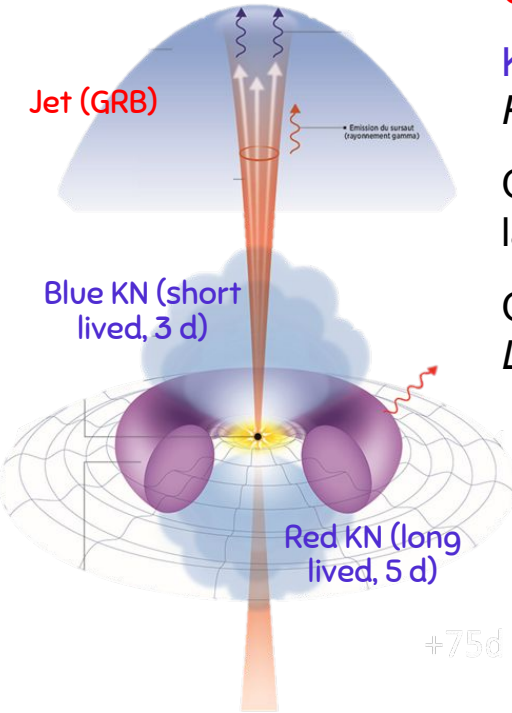*Distance*
Localisation > 10 deg^2

vs

EM counterpart

Ejected matter
Localisation ~ arcmin
Environment

Run O1,O2 and O3 : 50 new compact objects collisions
2 confirmed Binary neutron stars - **1 event with EM counterpart**

EM counterpart to GW events

GRB : Powered by on-axis jet

Kilonova (KN): Optical and NIR transient
*Powered by r-process in neutron rich environment*

Observed properties differed from mass ratio, equation of state of NS, lanthanide fraction, nature of the post-merger

Only one clear confirmed event (AT2017gfo)
Less than 10 candidates found by Tanvir et al., Troja et al.

Jet (GRB)

• Emission du sursaut (rayonnement gamma)

Blue KN (short lived, 3 d)

Red KN (long lived, 5 d)

+75d

Cr: La Recherche/Bruno Bourgeois

AT2017gfo/GW170817 properties
- 40 Mpc
- Localized in NGC4993
- Identified by LVK in 39 deg2
- *~10 Galaxy compatible*
- Absolute 16 mag in K-band mag
- Fading in 0.5 mag per day

Villar et al. 2017
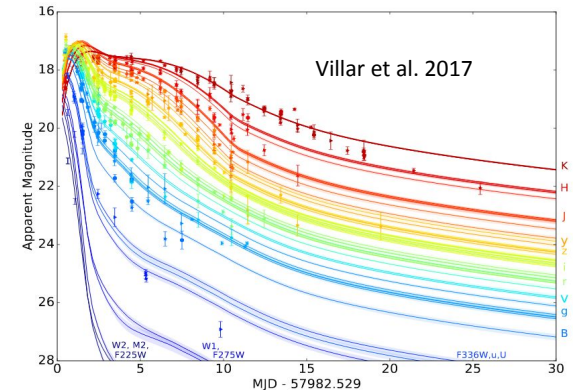
Collecting MM sample of GW events, a real challenge
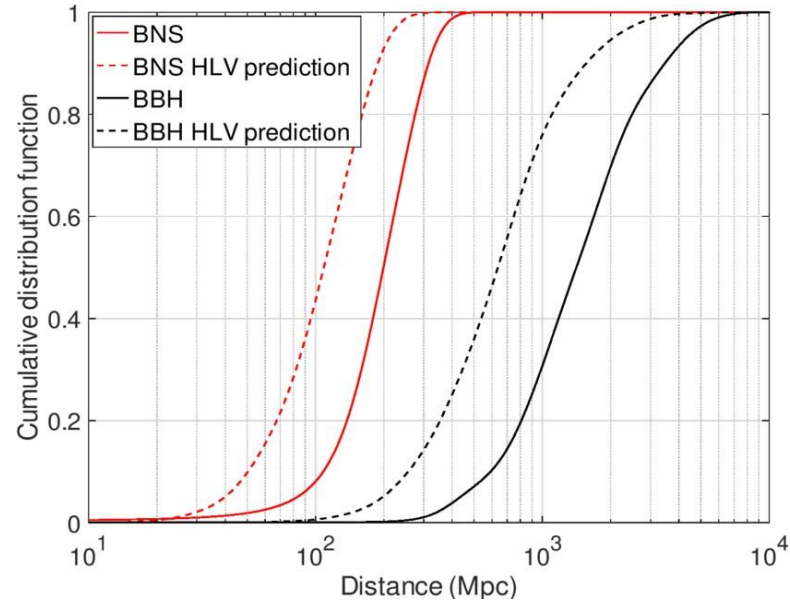
GRANDMA collab., MNRAS, 2020

Predicted rates for BNS and BHNS mergers based on O3 GW constraints:

- **1 (+10 -1)** per year in the 200 Mpc

- **10 (+52 -10)** in the 400 Mpc

GW170817 at 40 Mpc -> 1 event every ~ 12 years

Up to **1 GW alert per day** in O4 (HLV prediction)

KN **peak magnitude > 20.5** mag for a BNS merger within **200 Mpc**

GRB: < 1 GW + GRB per year observable by Fermi

Identify and characterize KNe associated to GW events

Kilonova Challenge	Solution
Short lived	Speed
Faint - Peak at 20.5 mag at 200 Mpc	Deep Observations
Rapid Color Evolution	Observation in g and r (adding i if possible)
Large localisation uncertainties + Many alerts to follow + Well sampled lightcurves	No duplication Coordination of Observations Choosing alerts
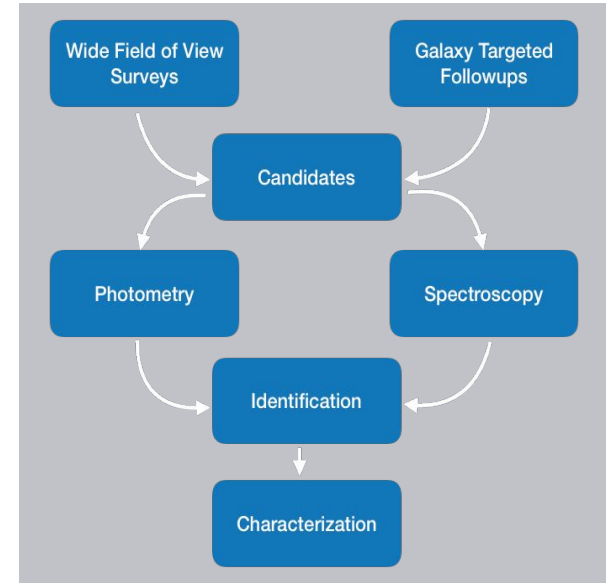
Need a **Network** of **Telescopes** and **People** (EM & GW)

Global **R**apid **A**dvanced **N**etwork **D**evoted to **M**ulti-messenger **A**ddicts

Created in 2018, by LAL – OCA

PI. S. Antier

Already a large Community
29 groups - 14 countries
75 scientists
CNRS/- APC - IAP - IJClab - OCA - IRAP – LAM - IPHC

Wide-fields up to 20 mag, EM candidates ~ 23 mag in photometry, 22 mag in spectroscopy

Upgrades of instruments in sites (ex: Eurovision Transient Facility)

GRANDMA science program

GRANDMA is involved in several science projects :

GW Science program

○ [...]

Neutrino
○ High Energy Neutrino alerts
○ SNEWS alerts – SNe neutrinos

Orphan KNe
○ Alerts by ZTF
○ Prepare the LSST era

GW science program

Observations
Maximal coverage of the GW events
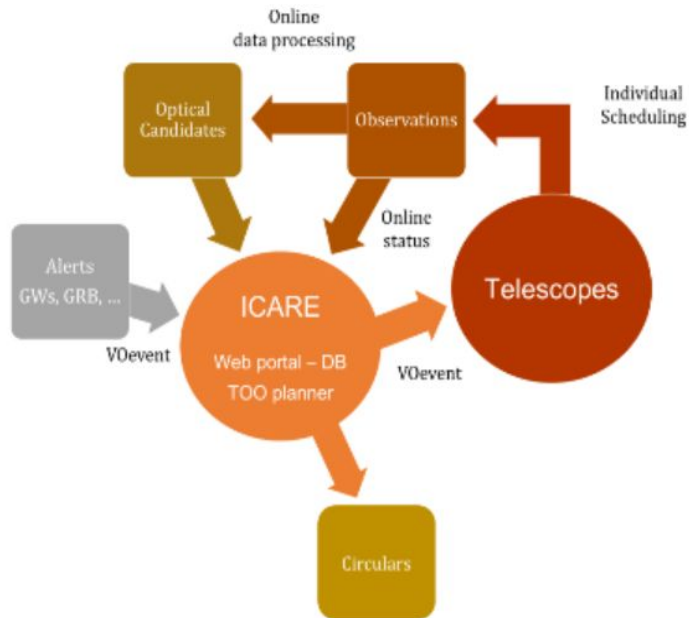Maximal follow-up of events
Early and long term characterization

Kilonovae/GRB modeling
Three KN models
GRB modeling

Binary Neutron star characterization
Ejecta mass
Equation of State of NS
Exotic physics

GRANDMA orchestration

6 FTE a year to run the project

All our tools are public

ICARE *Central database of GRANDMA*
In collab. GROWTH, OzGRAV, gitlab.in2p3.fr/icare/icare

MANGROVE *Galaxie catalogs using stellar mass*
Ducoin et al., 2020, MNRAS, 492, 4768

GWEMOPT : *The observation scheduler*
Coughlin, in collab. GROWTH, github.com/mcoughlin/gwemopt

STDPIPE, GMADET : *Detection of transients*
Karpov, Corre gitlab.in2p3.fr/icare/stdpipe

Astrorapid : *Transient Classifier*
Stachie et al 2020, MNRAS, 497, 1320

MUPHOTEN : *Transient photometric characterisation*
Duverne et al. - in preparation

O3 with GRANDMA

49/56 O3 alerts were followed by GRANDMA
~ 10 alerts followed by other optical groups

15 min for the first observation after the GW trigger
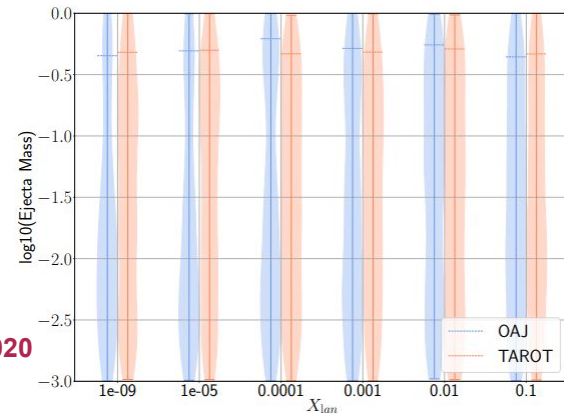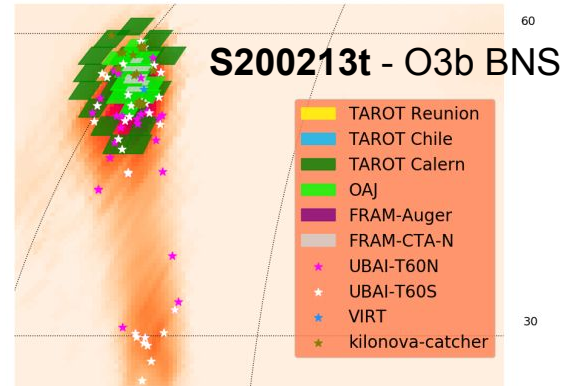*1.5 h delay for 50% of alerts*

~ **200 deg²** covered in each alert at 18 mag
11 alerts covered above 90% c.r

ToO observations with 2-m spectro in China, CFHT
Participation of **amateur astronomers**

No EM GW counterpart found
Upper limits on ejecta properties

O3b and global summary of O3: **GRANDMA Observations of O3 Observational Campaign**, **MNRAS, 2020**
O3a and presentation of the collaboration: **The first six months of O3 with GRANDMA**, **MNRAS, 2020**

S200213t - O3b BNS

TAROT Reunion
TAROT Chile
TAROT Calern
OAJ
FRAM-Auger
FRAM-CTA-N
★ UBAI-T60N
★ UBAI-T60S
★ VIRT
★ kilonova-catcher

My contribution: MUPHOTEN

SN2018cow – A Fast Blue Optical Transient

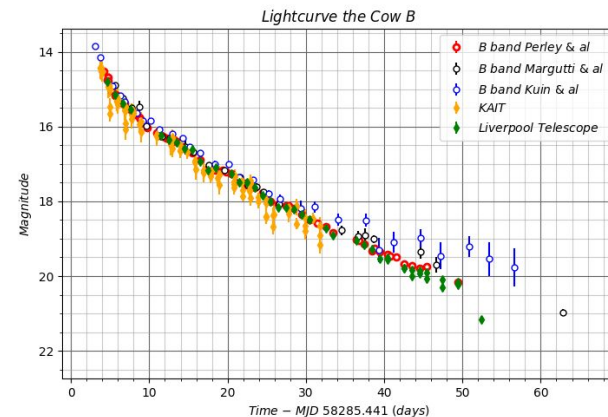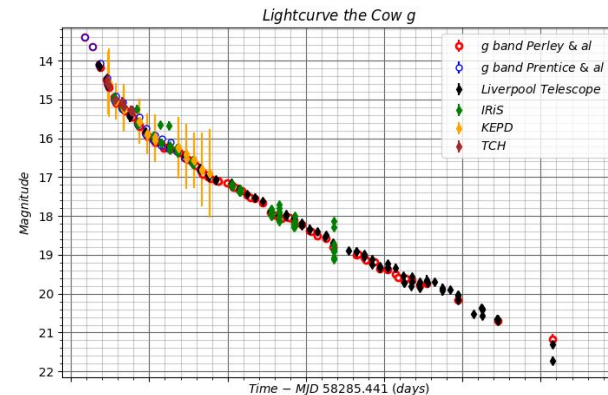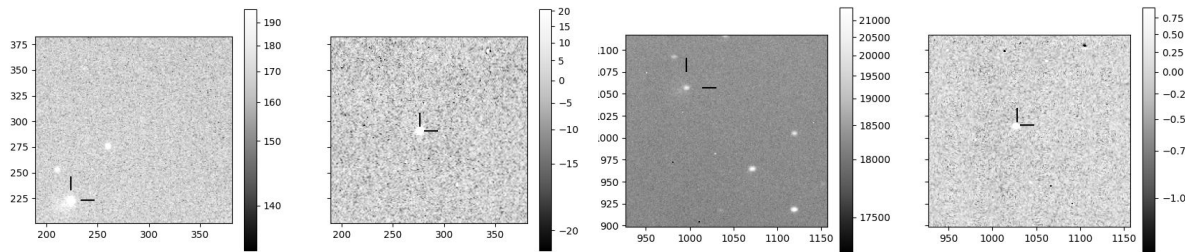Data from GRANDMA telescopes : IRiS, KAIT, TCH

Data from collaborators: KEPD, LT (publicly available data)

Analysis with **M**Ulti-band **PHO**tometry Tool for **TE**lescope **N**etwork

Provides :

- Background Estimation
- Photometry
- Host galaxy Subtraction
- Vetoes for poor quality images

Results consistent with Perley et al., 2018, Margutti et al., Kuin et al. and Prentice et al.

The future MM era is bright !
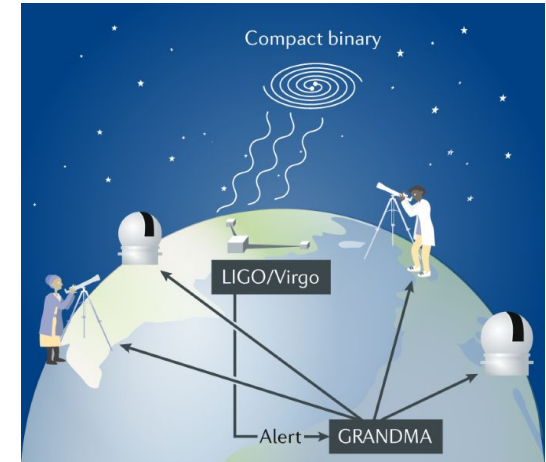

In the PAST

O1-O3 campaign

Astrophysics
Nuclear physics
General Relativity

In the future: O4 and beyond

Kilonova will have a **major role** in Multi-Messenger Astronomy
Observations extremely challenging

We propose **GRANDMA**, as a solution for GW events observations,

as a bond between Physicists and Astrophysicists communities

Come and join us!

Grandma@lal.in2p3.fr
Seminars visible at
GRANDMA-youtube
channel