




KILONOVA CATCHER

Kilonova-cachter, a citizen science program for fast transients

Damien TURPIN (CEA)& Sarah ANTIER (OCA)

Astro-colibri meeting, 2023

courtesy : TAROT Coll. & kilonova-Catcher astronomers

UCLab Irène Joliot-Curie Laboratoire de Physique des 2 Infinis

ARTEMIS

Université de Paris

irap astrophysique & planétologie

cea

APC, CNRS, FRANCE

IAP

Scientific objectives : High phenomena

Compact object coalescences

Core collapse Supernovae

Fast transients (TDE, LBOTs, ...)

KILONOVA CATCHER

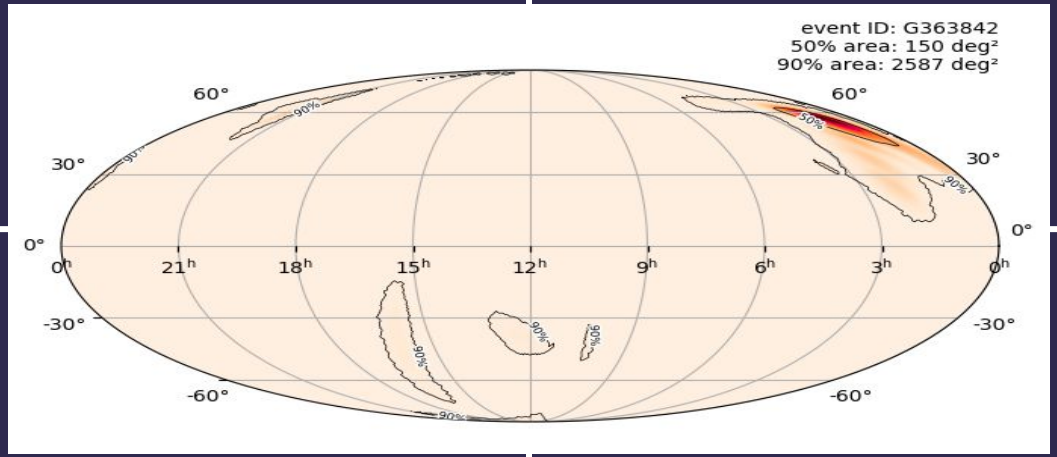
Motivations and birth

3

KILONOVA CATCHER

Gravitational waves science

Astrophysical origin sometimes unclear



large localization regions (> 1000 sq.deg) and partionned in the two celestial hemispheres

Alert at any time (time-domain astronomy, welcome !)

Cosmological distances = large volume of Universe to cover

KILONOVA CATCHER

GW light signatures for compact object collisions

ANATOMY OF A BINARY NEUTRON STAR MERGER

T_0 - 200s

1 THE TWO NEUTRON STARS COME CLOSER TOGETHER

These events are observed in other galaxies («at an extragalactic distance»).

T_0

2 MERGER OF THE TWO NEUTRON STARS

At the merger time, the gravitational -wave signal reaches its maximum intensity. The detection is obtained at this time by the LIGO/Virgo/KAGRA (LVK) detectors.

T_0 + 2s

3 THE GAMMA-RAY BURST

A plasma jet, travelling at the speed of light, is launched. The first electro-magnetic counterparts escape from the heart of the jet as a bright flash of gamma-rays are emitted during 1-2 seconds at maximum. If the jet is oriented towards us, this flash could be detected by gamma-ray satellites.

Being able to detect kilonovæ very early on implies that we are not directly observing towards the gamma-ray burst jet from which the emitted light can be billion times brighter than the kilonova one.

T_0 + 5H / 10H

4 THE KILONOVA RADIATION

A fraction of matter is torn off of the two neutron stars and ejected in the interstellar medium by several processes. These violent matter ejections enhance the rapid capture of surrounding neutrons by lighter atomic nuclei enabling the formation of new radioactive nuclei which are among the heaviest ones in the Universe. They heat up the surrounding plasma which then cools down by radiating away UV to infrared light.

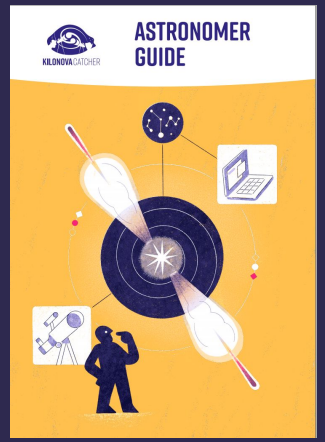
This light, being about 100 to 1000 times more luminous than a nova, is called «kilonova». It finally reveals to us the production sites of the heaviest atoms in the Universe!

A RED KILONOVA ....

A large faction of the matter extracted from the neutron stars is ejected at a tenth of the light speed into a diffuse torus of plasma expanding in equatorial directions. Various heavy elements are then synthesized, such as Gold or Strontium. **Those heavy elements, efficient absorbers of the UV and the blue-ish light, will therefore enable the free escape of the red-ish and infrared light photons.**

... BUT ALSO BLUE

A minor fraction of the neutron star matter can also be expulsed at high velocity (up to ~30% of the light speed) along the polar axis. The nucleosynthesis of heavy elements is then much less efficient than in the red kilonova ejecta. **This ejecta, less opaque to blue-ish photons and heated at several tens of thousands of Kelvin, will mainly radiate light at the UV and blue wavelengths.**



Turpin J. and D. et al., 2022

Scenario based on GW170817 / ATgfo2017

Global Rapid Advanced Telescopes Devoted to Multi-messenger Addicts

GRANDMA

37 telescopes - 26 observatories - ToO time guaranteed - 40 institutes/groups - *PI. S. Antier - Born in 2018*

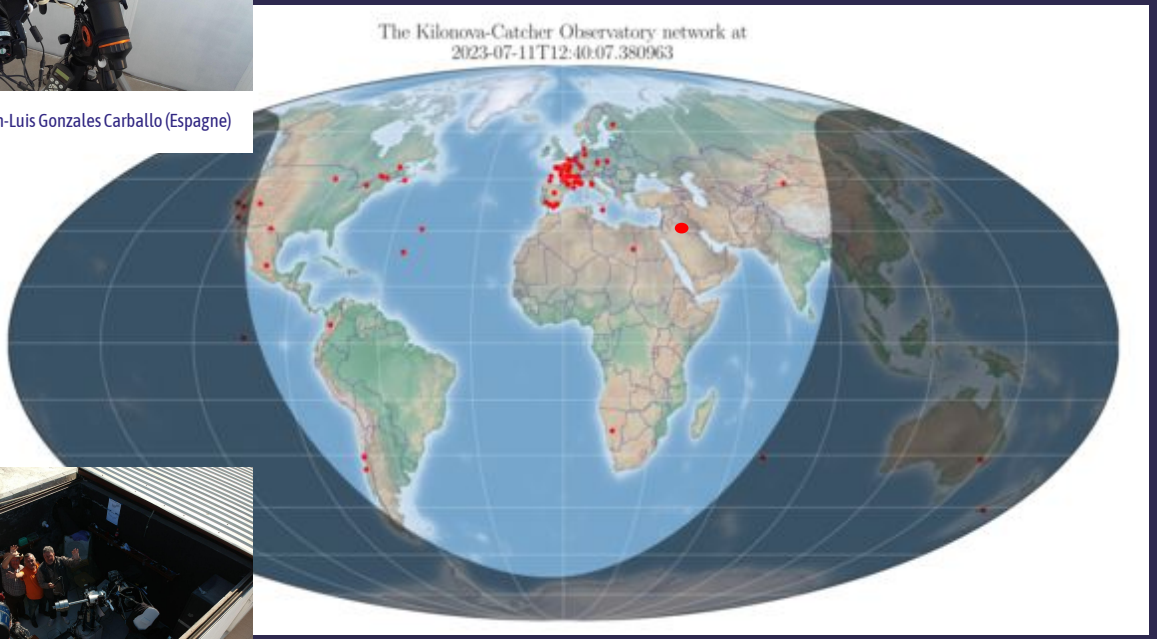
Coordination on multiple axis

- Observations
- Data reduction
- Interpretation

KILONOVA CATCHER

A Citizen science program managed by GRANDMA - Born in 2019

courtesy : Juan-Luis Gonzales Carballo (Espagne)



courtesy : Denis St-Gelais (Mexique)

- GRANDMA is organizing the follow-up and send out alerts via Skyportal
- GRANDMA is taking care of communication, mentoring of the amateurs
- GRANDMA is performing data analysis and scientific exploitation

Scientific programs of GRANDMA and Kilonova-catcher

I. Binary neutron stars - Kilonovae - GW counterparts

GRANDMA Observations of LIGO-Virgo O3 run, MNRAS, 2020, Antier

II. Relativistic jets - Gamma-ray bursts

GRANDMA and HXMT Observations of GRB 221009A, ApJ, 2023, Kann et al.

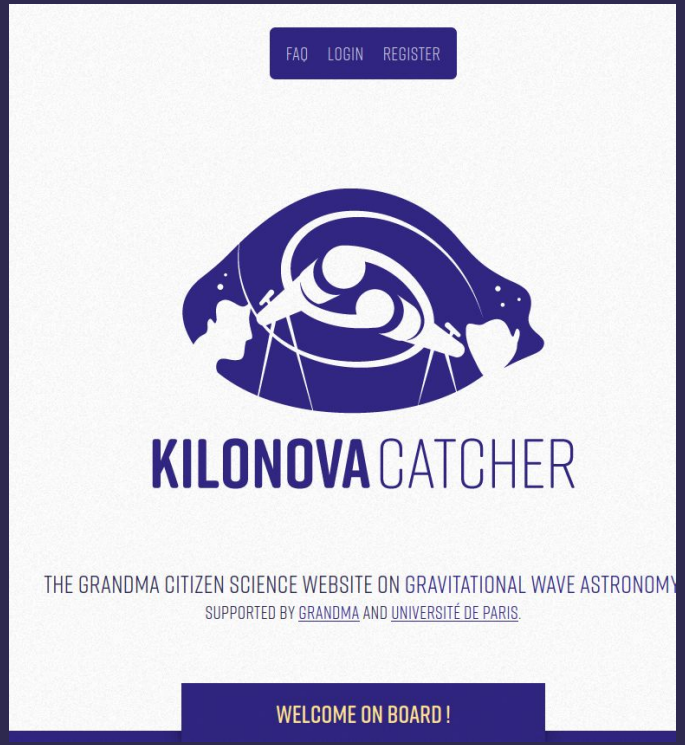
III. Vera-Rubin Fast transients

GRANDMA Observations of ZTF/Fink Transients, 2022, MNRAS, Agayeva

IV. Continuous Training with other opportunistics sources (SNIa, ...) ...

kilonovacatcher.in2p3.fr

by IJCLAB



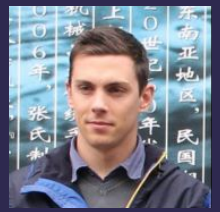
From alerts to publications

9

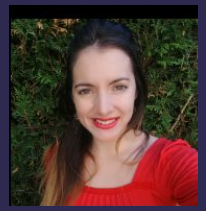
The GRANDMA Kilonova-Catcher - Core team

KILONOVA CATCHER

OUR SCIENTIFIC SUPERVISORS



Damien TURPIN
damien.turpin@cea.fr



Sarah ANTIER
sarah.antier@oca.eu

OUR ASTRONOMER EXPERTS

Alain KLOTZ
alain.klotz@irap.omp.eu

Antoine CAILLEAU
http://astromecca.fr/

OUR PUBLIC RELATION MANAGER

Quentin ANDRE

OUR GRAPHIC DESIGNER

jennifer turpin
motion design / direction artistique

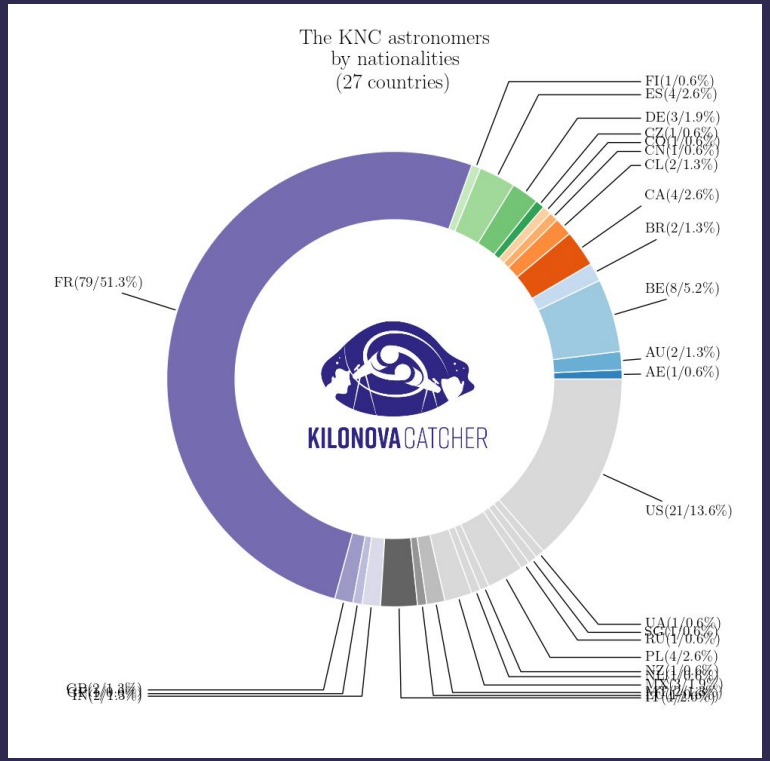
Jennifer TURPIN
web & logo design
https://jenniferturpin.fr/

OUR TECHNICAL SUPPORTS

Antoine PERUS
IT dept. at IJCLab
(Paris, France)

Sébastien GREGOIRE
IT dept. at IJCLab
(Paris, France)

The amateur network



~ 5% provided photometric results

~ 10% can reach 21 mag in r-band

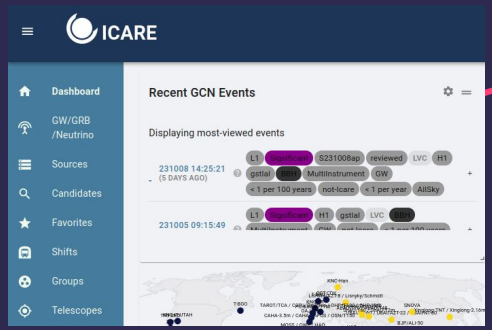
~ 50% provided images once

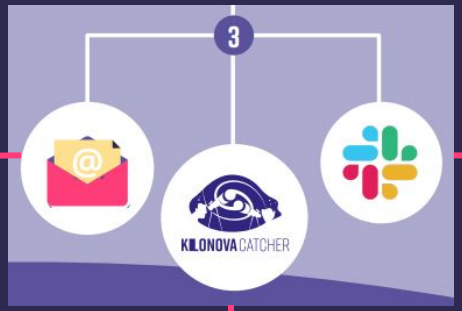
~ 100 accounts

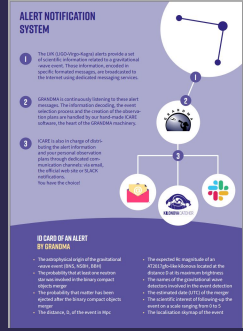
Since 2019, +700 images uploaded and 70% science valid (for 30 alerts)

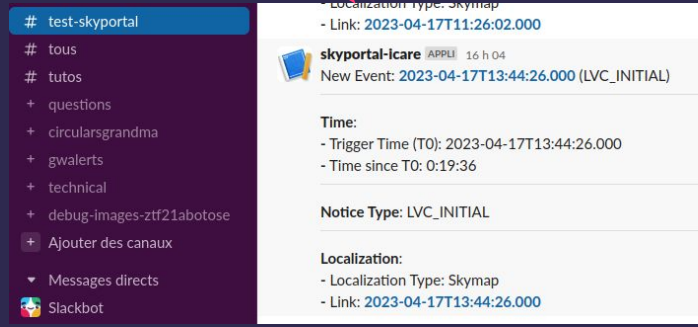
We have provided sloan filters g, r, i, z to 6 amateur astronomers (CNRS MITI science program)

How to get the alert and obs plan info. ?





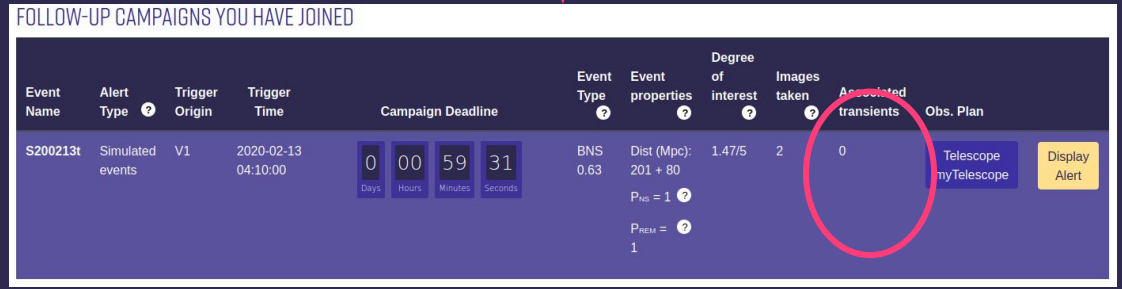




Skyportal for plans
See. T Jegou du Laz talk

GWEMOPT, M4OPT
for optimization for GW

Mangrove for galaxies
selection for GW, Ducoin 2020

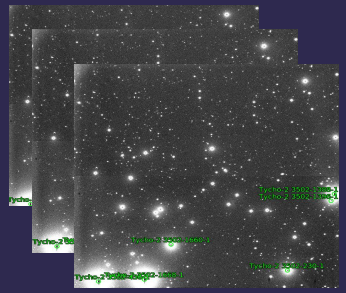


Once data have been taken: Standardisation of the optical image analysis

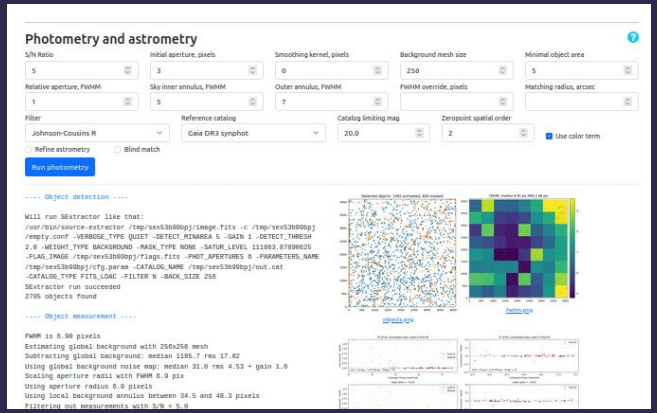
STDPIPE and MUPHOTEN

S. Karpov (FZU)

P. Duverne(APC)



Mask

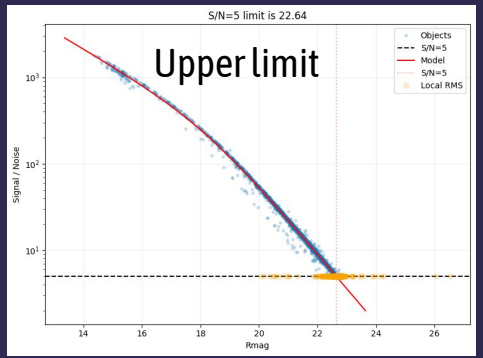


Astrometry / SCAMP
Co-adding images

Can we agree on ?

Sloan filters for time domain
Upper limit definition

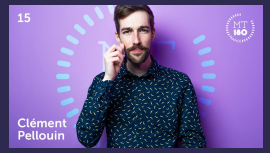
Catalogs
Reference images
Color term ?
Aperture vs Detection



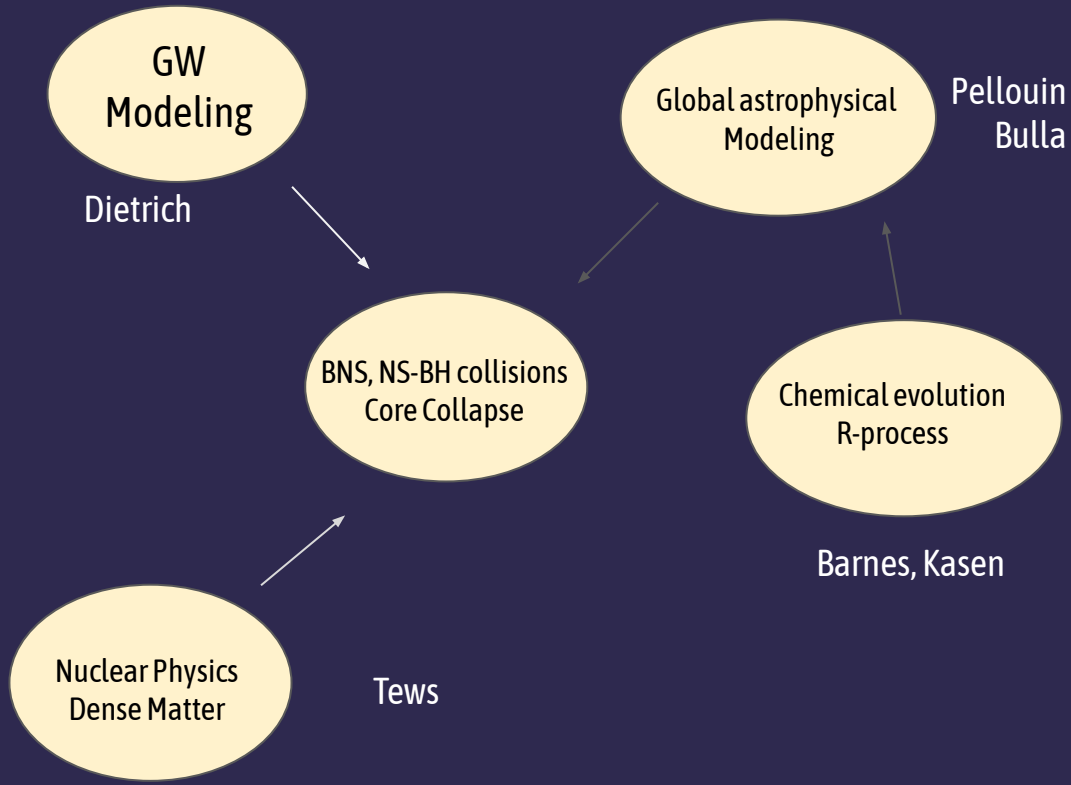
stdpipe.readthedocs.io,
Duverne et al, 2022, PASP

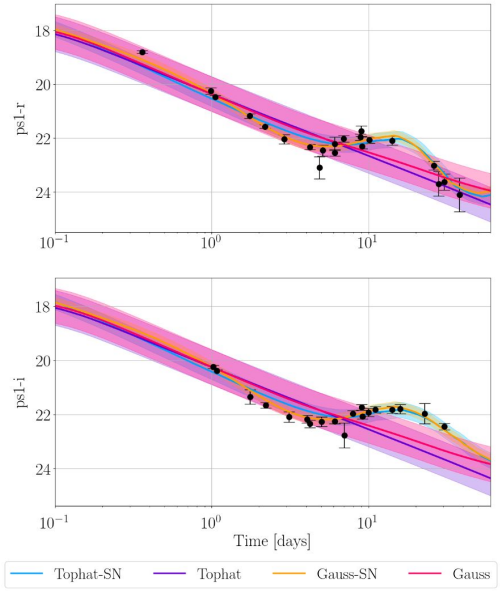
Modelisation : exemple for BNS/NSBH, collapsars

NUCLEAR MULTI-MESSENGER ASTRONOMY (NMMA) / IAP MODEL



P. Pang (Utrecht)





GRB 230812B
Hussenot et al., 2023, submitted MNRAS

Connection with

Connection with

Objective: Fast/Automatic First instants of GRANDMA follow-up
In collab with T. Esposito, A. Perrocheau

Unistellar have about 1000 amateurs potential interested into transients
200 amateurs astronomers contributed to the data

We are connecting Skyportal to Unistellar

Evaluation of the photometry sensitivity of Unistellar Telescopes (on going)
-> Probably 17.5 sensitivity in broadband filter 30 min

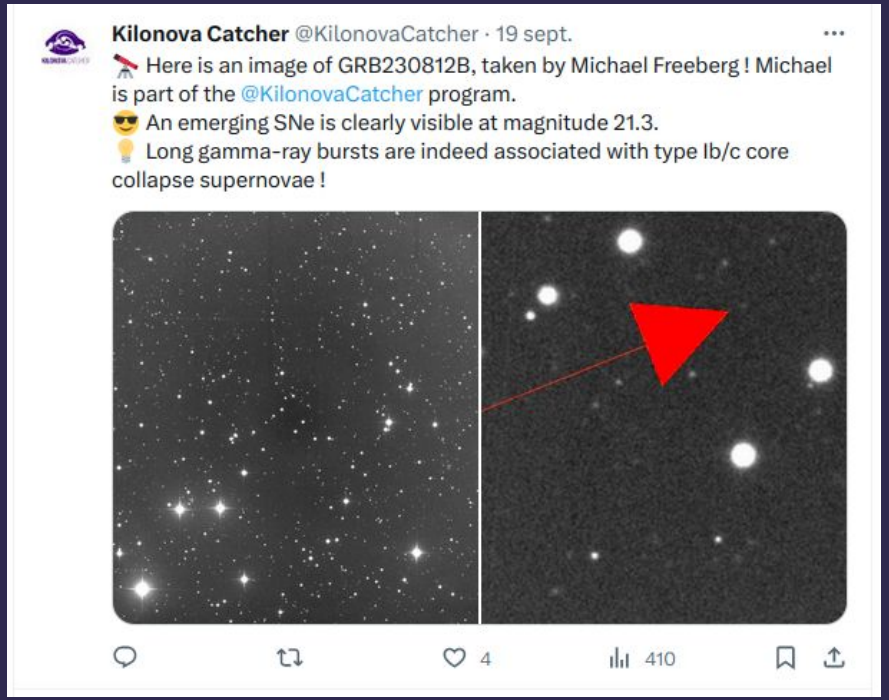
Skyportal is connected to public ZTF and provide complementary data to GRANDMA

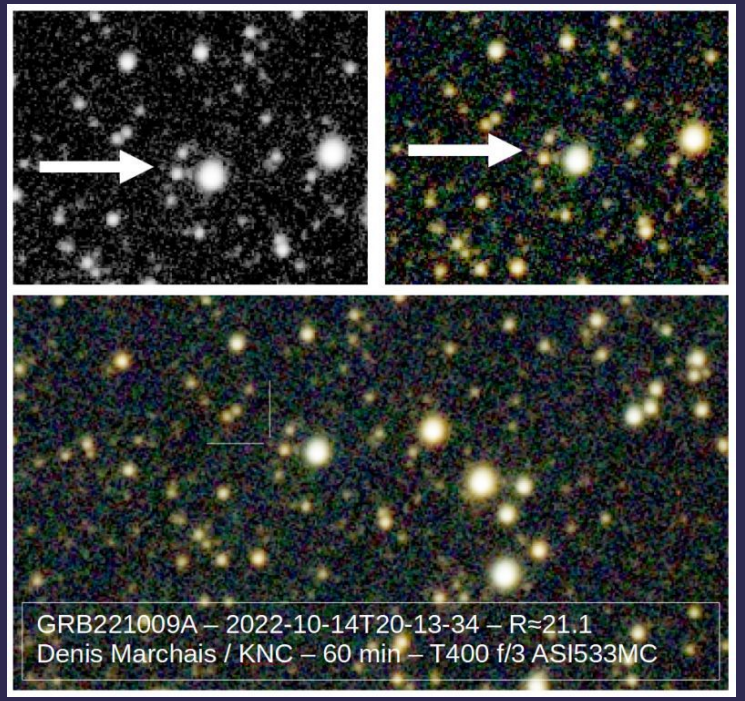
No official partnership

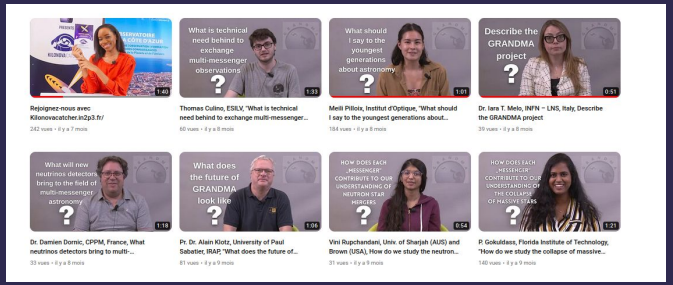
Idea is to redirect the observations from a source to Kilonova-catcher or flag sources in colibri with Data from Kilonova-catcher

A large fraction of our participants use Astro-colibri

Multi-messenger science dissemination







@KilonovaCatcher, twitter X

@grandmacollaboration, youtube with regular telecons

KILONOVA CATCHER

Details of the programs

KILONOVA CATCHER

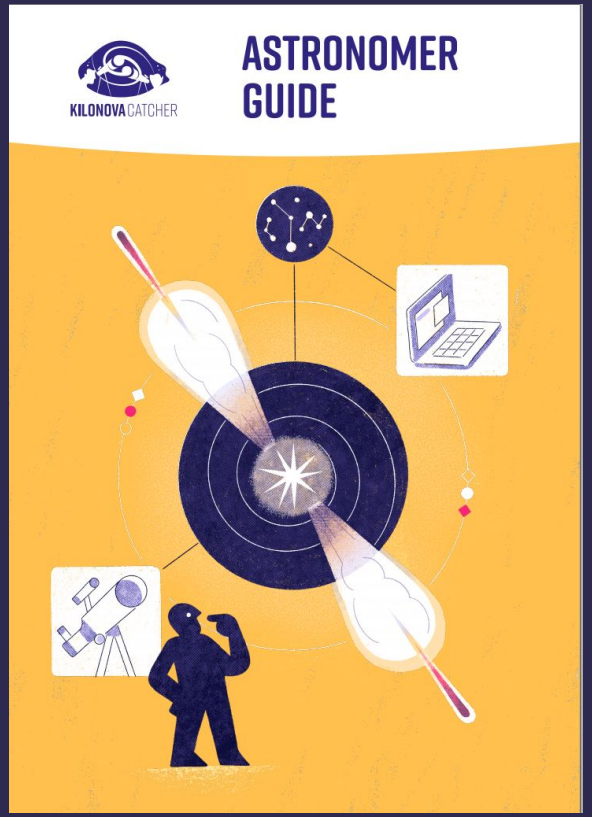
I. *Binary neutron stars - Kilonovae - GW counterparts*

What are the interesting GW sources for us ?

What kind of information GRANDMA is going to send to us ?

How fast should I observe once a GW alert is received ?

How fast should I send my images ?



What are the expected electromagnetic counterparts ?

What should I do to be able to identify a O4 GW/EM counterpart ?

What would be the best strategy for extracting all the necessary information for science ?

KILONOVA CATCHER

I. Binary neutron stars - Kilonovae - GW counterparts

Where to search ?

We use the same code than for the GRANDMA pro telescopes to make your obs. plan!

Observatory and time info

S200213T

GPS 45.50000 E +45.50000 2367.00

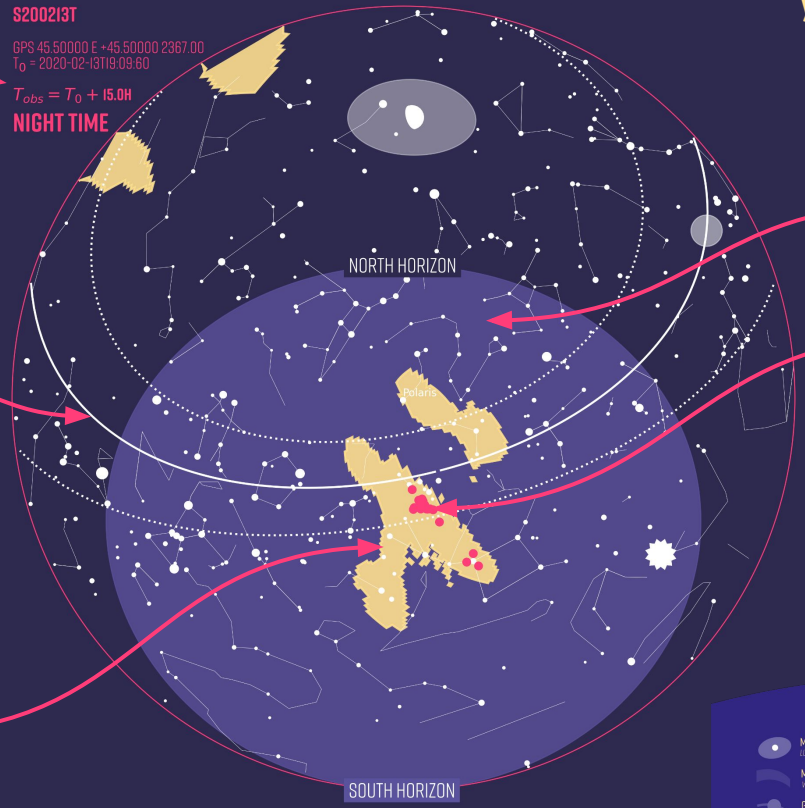
T_0 = 2020-02-13T19:09:60

$T_{obs} = T_0 + 15.0H$

NIGHT TIME

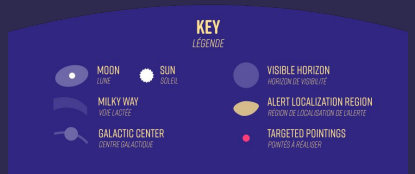
Galactic plane
(now we have a better display of it)

GW 90% localisation area

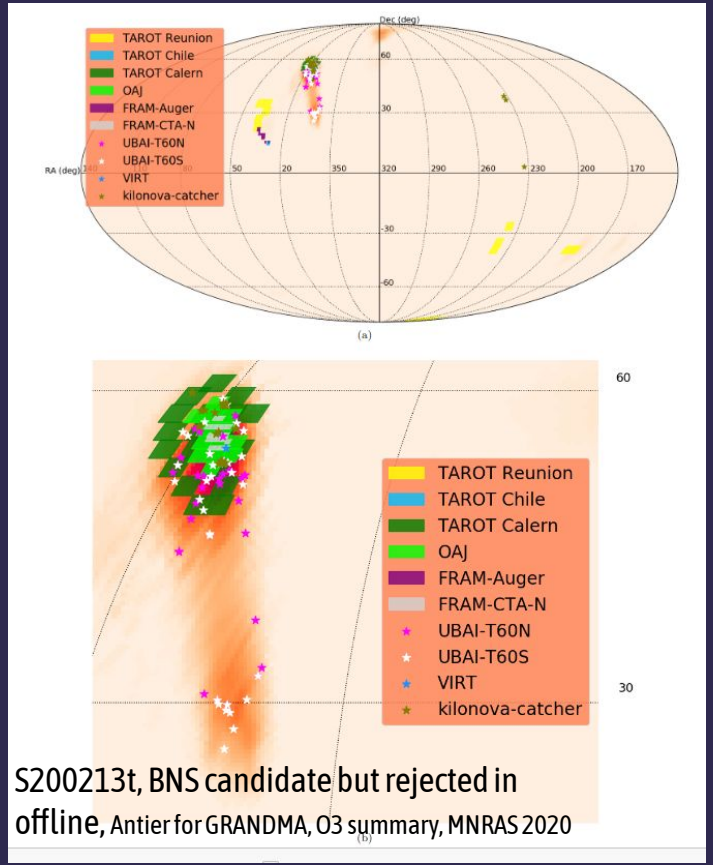


Your visible sky (Elev >30°)

Your telescope pointings



I. Binary neutron stars - Kilonovae - GW counterparts
Follow-up strategies and results



S200213t, BNS candidate but rejected in offline, Antier for GRANDMA, O3 summary, MNRAS 2020

THE OBSERVATION STRATEGY TO ADOPT

1. **Make successive observation sequences with a «blue»** (UBV/ug) **and a «red»** (RI/riz) **filter.** Ex: one 300s exposure with a B filter and one 300s exposure with a Rc filter
2. **Expose as long as it is needed** to detect the kilonova in a given field (the expected apparent magnitude will be communicated to you) at least in the red filter
3. **Observe several sky regions of your observation plan** by order of probability that your images contain the gravitational-wave event
4. **Send your calibrated images** (Dark and Flat correction, astrometrically solved if possible) as soon as possible using the Kilonova-Catcher web application
5. **Think about making revisits** of sky regions you previously observed hours ago or on promising transient sources flagged by GRANDMA

O4 observational camp.

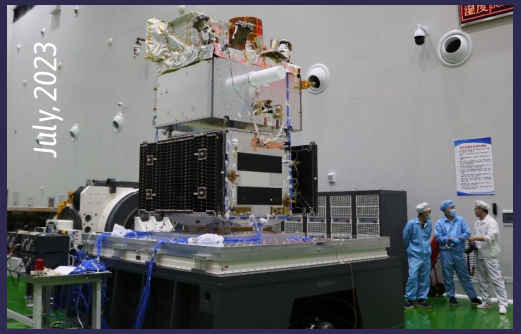
LIGO/Virgo/KAGRA S230627c
About 20 fields with multiple galaxies in the field

and

Follow-up of source counterpart-candidates (e.g GOTO23hn, ...)

No confirmed sources

II. Relativistic jets - Gamma-ray bursts in partnership with



Kilonova-catcher will participate to GRB-SVOM follow-up (based on best effort) for the first hours

- *Find visible counterpart if not provided*
- *Follow-up of bright sources*

Versatile Satellite (Gamma, X-rays, Visible)
Launch Spring 2024
60 GRBs per year

Public alerts *within 30 s*
up to 5 ToOs per day with < 3h delay

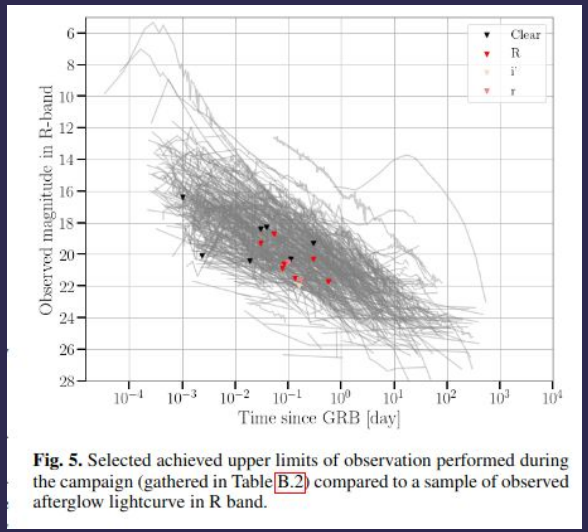


Fig. 5. Selected achieved upper limits of observation performed during the campaign (gathered in Table B.2) compared to a sample of observed afterglow lightcurve in R band.

Tosta e Melo & Ducoin for GRANDMA, A&A, 2023

Ready for O4 campaign, ,8 weeks of GRB follow-up

KILONOVA CATCHER

II. Relativistic jets - Gamma-ray bursts - More science

- GRANDMA and HXMT Observations of GRB 221009A -- the Standard-Luminosity Afterglow of a Hyper-Luminous Gamma-Ray Burst
  A big thank you to : E. Broens, H-B. Eggenstein, M. Freeberg, R. Kneip, A. Lekic, B. Delaveau, E. Durand, S. Leonini, D. Marchais, R. Ménard, F. Romanov, M. Serrau, S. Vanaverbeke, G. Parent, E. Maris, F. Bayard, O. Aguerre and M. Richmond (hope I forgot no one...)

- Ready for O4 II: GRANDMA Observations of Swift-BAT GRBs during Spring 2022 (to be submitted very soon to MNRAS)
  A big thank you to : O. Aguerre-Chariol, E. Broens, M. Freeberg, R. Kneip, D. Marchais, A. Oksanen, A. Popowicz, M. Serrau, J-P Vignes, F. Kugel, A. Klotz

- GRANDMA and partners follow-up of GRB230812B (to be submitted this month)
  A big thank you to : M. Odeh, S. Leonini, M.Serrau, J. Nicolas, M. Freeberg, L. Rousselot

III. Vera-Rubin Fast transients in partnership with

J. Peloton (IJCLAB)

Follow-up of fast transients with GRANDMA (< 20.5 mag in r-band)
e.g orphan GRBs, Kilonova, emerging SN..

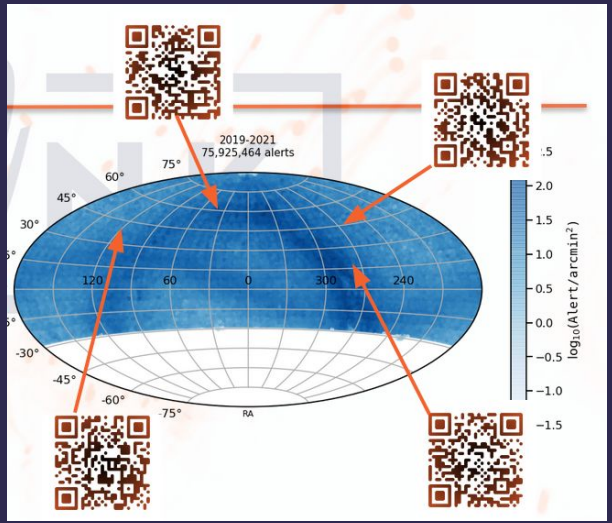
Complementary observations with Vera

Two channels following in Fink : Kilonovae and fast Transients

Open to work with others brokers ;)

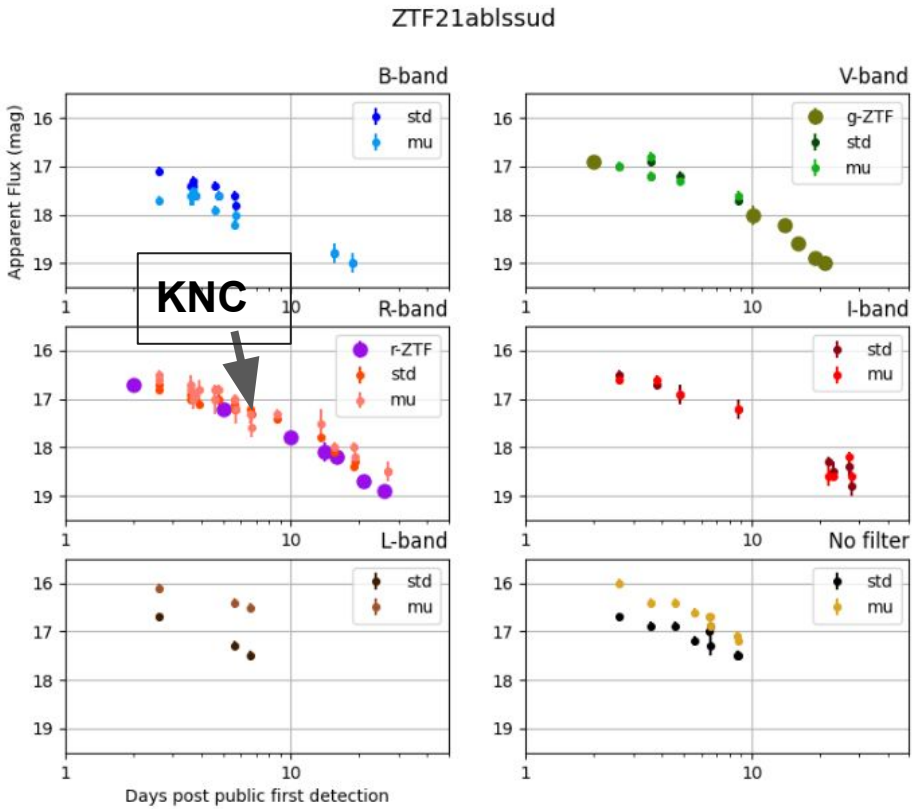
Fink is an alert broker for transient & variable science galactic to extragalactic
Users focus on the science, Fink provides tools

Since 2019: 201 million alerts received of ZTF, 136 million processed https://fink-broker.org



KILONOVA CATCHER

III. Vera-Rubin Fast transients



ZTF21abissud, CV

6 follow-up with amateurs over the kilonova-channel of FINK.

GRANDMA Observations of ZTF/Fink Transients during Summer 2021, Aivazyan, 2021, MNRAS

IV. Training Programs (what is not in the articles)

Motivations : Keep Kilonova-catcher busy

- Help to find new recrues
- Global improvements of practices

(e.g especially on images taken)

- Feedback from amateurs on regular basis
- Construction on A Network
- Confirmation of (risky/–) associations ?

Amateurs participate in their leisure activity, and on different rythme,
Keep cool and stay fun !

Subject
GRB231115A: GRANDMA Observations
Date
2023-11-15T23:22:01Z (5 days ago)
From
Cristina Andrade at UMN <andra104@umn.edu>
Via
Web form

A. Iskandar (XAO), F. Wang (THU/BJP), J. Zhu (BJP), L. Wang, X. Zeng, C. Andrade (UMN), A. de Ugarte Postigo (CNRS/OCA), D. Akl (AUS), E. Broens (KNC), S. Antier (OCA-Artemis), I. Tosta e Melo (UniCT-DFA), P. Hello (IJCLAB), D. Turpin (CEA-Saclay/Irfu), T. Pradier (Unistra/IPHC), M. Coughlin (UMN), S. Karpov (FZU), J. Peloton (IJCLab) report on behalf of the GRANDMA collaboration:

We observed the field of GRB 231115A (Fermi GBM team, GCN 35035) covering the complete INTEGRAL error box (D'Avanzo et al. GCN 35036;Mereghetti et al. GCN 35037) within the GRANDMA collaboration. Imaging with the 0.4m SNOVA telescope did not find any candidate in r-band around 2023-11-15 17:37:53 (e.g 2h after the trigger time) down to an upper limit of 18.9 (5-sigma threshold) or 19.3 (3-sigma threshold) using PS1 catalog as photometric comparison. We also looked carefully at the location of AT 2023xvj (Kumar et al. GCN 35041).

The amateur contribution to GRANDMA, Kilonova Catcher (KNC), made no detection with a 30x180s image using a clear filter on 2023-11-15T20:00 UTC (TGRB + 3.28h). We determine a detection limit of 20 mag in r-band, using PS1 for calibration and color term correction. At 2023-11-15T18:53:25.219, we obtained R>18 from 5x180s exposure. The upper limit is given at 5-sigma averaged over all the images.

These upper limits are consistent with previous reports by MASTER (Lipunov et al. GCN 35046).

GRANDMA is a worldwide telescope network (grandma.ijclab.in2p3.fr) devoted to the observation of transients in the context of multi-messenger astrophysics (Antier et al. 2020 MNRAS 497, 5518). Kilonova-Catcher (KNC) is the citizen science program of GRANDMA (http://kilonovacatcher.in2p3.fr/).

Conclusions

Damien TURPIN (CEA-AIM), PI

- Over the last 4 years: Kilonova-catcher member has been multiplied by 4
- Diversification of the sources observed by the Kilonova-catcher program

GW is the core main program, listening GW triggers !

- Kilonova-catcher amateurs have participated / and co-auteurs to 5 referee publications since 2019 ex. GRANDMA O3 publication, 2020, 70 citations

Data Science exploitation is managed by GRANDMA

- Amateurs can reach 21.0 mag in color (and made progress)
- Amateurs update their instrument to fit professional requirements (e.g sloan filters, CNRS MITI)