KILONOVA CATCHER

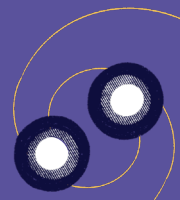
ASTRONOMER GUIDE

ANATOMY OF A BINARY NEUTRON STAR MERGER

T_0 - 200s

1 THE TWO NEUTRON STARS COME CLOSER TOGETHER

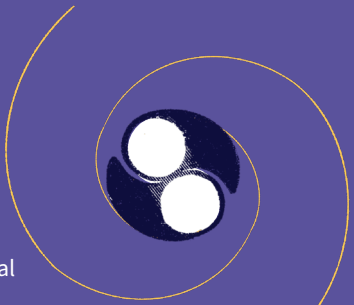
These events are observed in other galaxies («at an extragalactic distance»).



T_0

2 MERGER OF THE TWO NEUTRON STARS

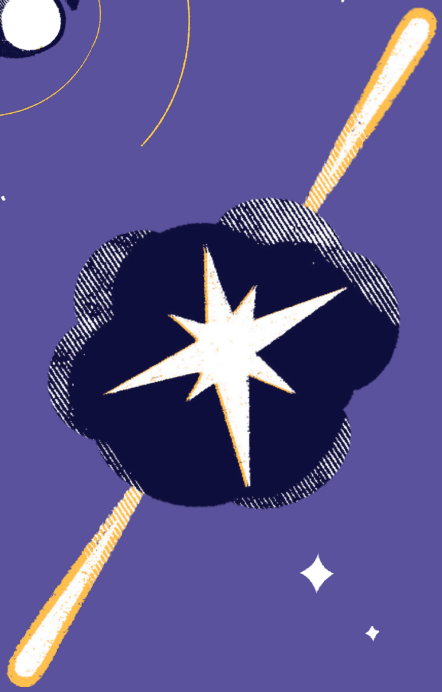
At the merger time, the gravitational -wave signal reaches its maximum intensity. The detection is obtained at this time by the LIGO/Virgo/KAGRA (LVK) detectors.



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.



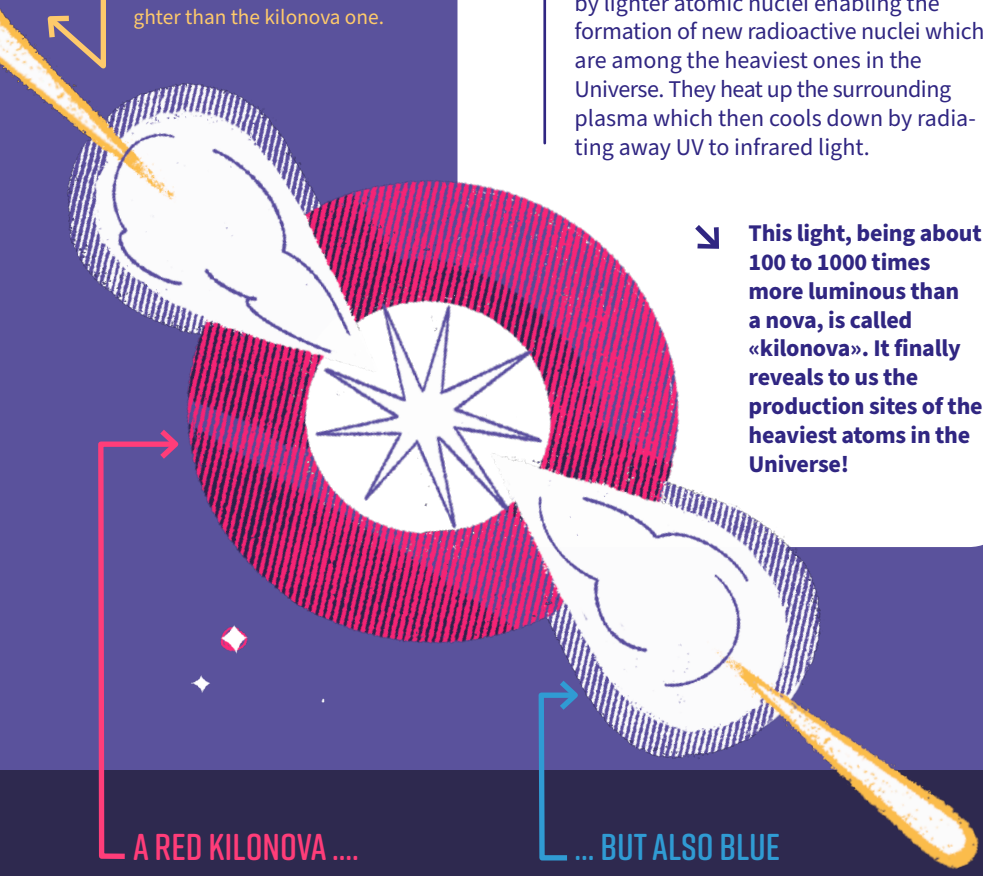
T0 + 5H / 10H

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.

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.

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

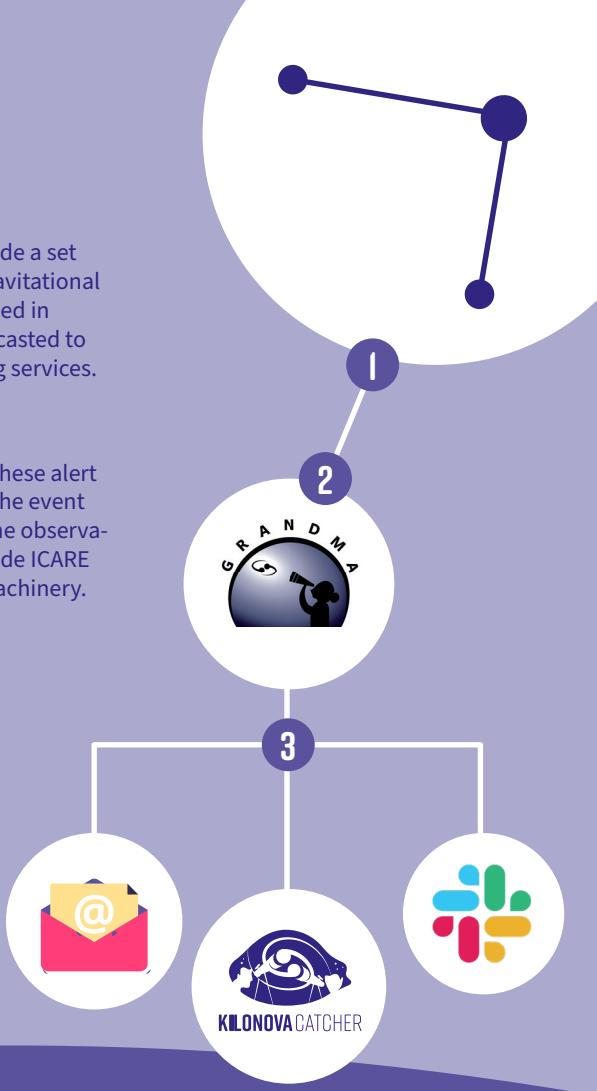
A minor fraction of the neutron star matter can also be expulsed at high velocity (up to ~30% of the light speed) along the polar axis. The nucleosynthesis of heavy elements is then much less efficient than in the red kilonova ejecta. **This ejecta, less opaque to blue-ish photons and heated at several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

ALERT NOTIFICATION SYSTEM

1. The LVK (LIGO-Virgo-Kagra) alerts provide a set of scientific information related to a gravitational -wave event. Those information, encoded in specific formated messages, are broadcasted to the Internet using dedicated messaging services.

2. GRANDMA is continuously listening to these alert messages. The information decoding, the event selection process and the creation of the observation plans are handled by our hand-made ICARE software, the heart of the GRANDMA machinery.

3. ICARE is also in charge of distributing the alert information and your personal observation plans through dedicated communication channels: via email, the official web site or SLACK notifications.
You have the choice!



ID CARD OF AN ALERT BY GRANDMA

- The astrophysical origin of the gravitational -wave event (BNS, NSBH, BBH)
- The probability that at least one neutron star was involved in the binary compact objects merger
- The probability that matter has been ejected after the binary compact objects merger
- The distance, D, of the event in Mpc
- The expected Rc magnitude of an AT2017gfo-like kilonova located at the distance D at its maximum brightness
- The names of the gravitational wave detectors involved in the event detection
- The estimated date (UTC) of the merger
- The scientific interest of following-up the event on a scale ranging from 0 to 5
- The localisation skymap of the event

WHERE AND WHAT TO SEARCH?

A NEEDLE IN THE HAYSTACK.... HOW TO BE RIGHT ON THE MARK ?

GRANDMA provides an observation plan optimised for the identification of the galaxy that would have potentially hosted the gravitational-wave merger event.

This plan is a list of coordinates centered at the position of the most promising host galaxy candidates. It contains the following information:

- The name of the targeted galaxy
- RA and Dec of the image center
- The probability that the observed sky field will contain the gravitational-wave event

If the host galaxy of the merger event is scheduled in your observation plan, you will likely detect the associated kilonova !

HOW TO IDENTIFY A KILONOVA ?

The kilonova light we observe will be likely the combination of the different ejecta components. We need to know their respective signatures !

THE BLUE KILONOVA VISIBLE FROM 1 TO 2 DAYS

It dominates the overall emission during the first hours after quickly fading away in the UBV (ug) filters by >1 mag/day.

THE RED KILONOVA VISIBLE FROM 5 TO 8 DAYS

Initially dominated by the blue component, the red component dominates 1-2 days post merger time. It mainly shines in the Rc, Ic, J, H (riz) filters with a decaying flux of > 0.5 mag/day.

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

HOW TO SEND MY IMAGES ?

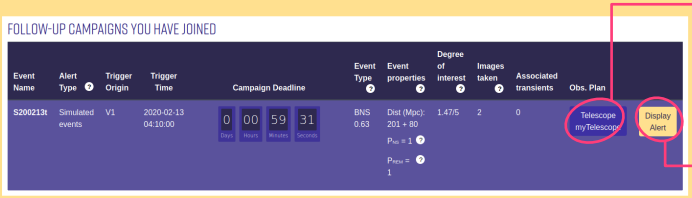
HOW TO BE SURE MY IMAGES ARE COMPLIANT WITH THE GRANDMA SCIENTIFIC REQUIREMENTS ?

1 CONNECT TO YOUR KILONOVA-CATCHER ACCOUNT

Check that you are participating to a follow-up campaign

↘ Note : An observation plan is only generated if the gravitational-wave event is observable at an elevation E > 30° above your local horizon. Contact us if no plan has been generated for your telescope and you think it is an error.

If an observation plan has been generated for one of your telescopes it will appear here.
Click to download it



2 GO THE THE ALERT PAGE

Click here

3 VISUALISE YOUR OBSERVATION PLAN

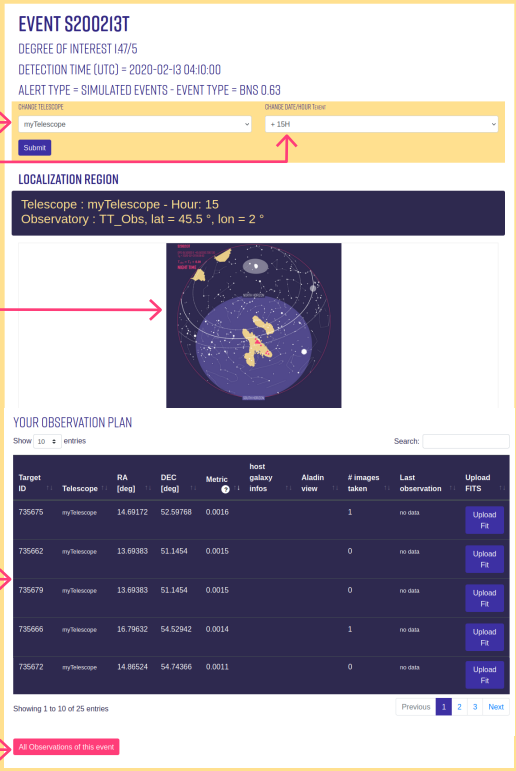
Change your telescope

Modify the date (up to 24 hours after the merger time)

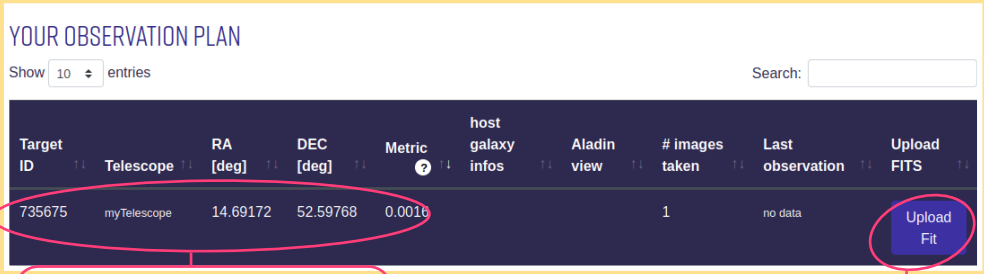
Visualise the localisation region of the alert and your scheduled pointings to be done with your selected telescope.

Visualise the observation plan in a dedicated table at the bottom of the page

To get the list of all the KNC images taken for this event



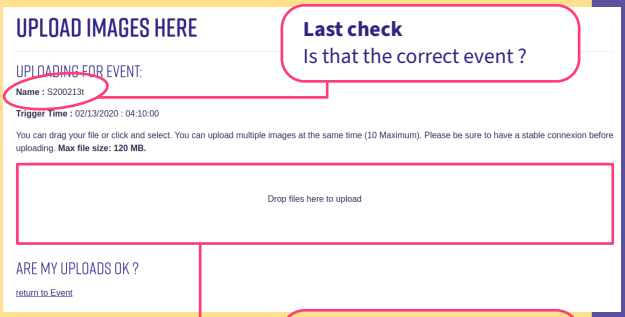
4 CHECK-LIST BEFORE SENDING AN IMAGE



Careful check if the image to be sent is in good agreement with the scheduled observation (telescope, RA, dec)

Click here to send your image associated to this sky region

5 SENDING THE IMAGES



Last check
Is that the correct event ?

Click or drag and drop your images here

SOME BASIC RULES

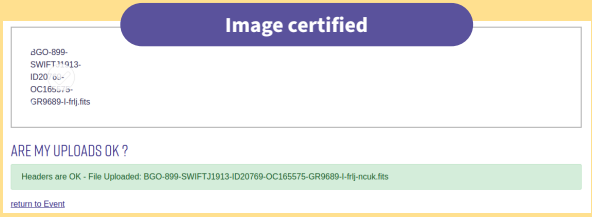
- The format of your image files must be **.fits** or **.fit**.
  We do not accept any other format.
- The header of your fits files must contain at least the following information:
  - → **RA and Dec of the image center**
  - → **Tstart of the observation**
  - → **Tend of the observation**
  - → **filter name**
- The image name must **avoid the following special characters:** '-','+','*','/','\','#', space,'@' and no accent.

6 CHECK IF THE IMAGE IS VALID

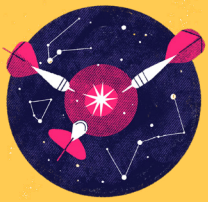
Image not certified

Be careful, some information are missing in the fits file header. **You must complete them by clicking in the provided link.**
If you have not given the required information, GRANDMA will not be able to analyse your images !

Image certified



Great ! Your image will be analysed by the GRANDMA scientists



GOOD WAYS TO BE PREPARED FOR THE OBSERVATIONS

- Always have a notification tool connected and ready to alert you at any time (email, slack, web site.)
- Have a good understanding of the alert information that will be delivered to you so that you can autonomously make the decision to perform a follow-up or not
- Download the observation plan via the Kilonova-Catcher web site or by email
- Check and prepare the coordinate list to be ingested into your telescope poointing software
- Prepare the filters to be used for your observations
- Think about making revisits of sky regions previously observed or on promising targets communicated by GRANDMA

JOIN US

KILONOVACATCHER.IN2P3.FR

Contact us for more information

Damien Turpin damien.turpin@cea.fr

Sarah Antier-Farfar sarah.antier@oca.eu

IJCLab Irène Joliot-Curie Laboratoire de Physique des 2 Infinis

Université de Paris

GRANDMA

irap astrophysique & planétologie

OBSERVATOIRE DE LA CÔTE D'AZUR UNIVERSITÉ CÔTE D'AZUR

cea irfu

cnrs

PNHE Programme national hautes énergies