How to catch a Kilonova

for amateur astronomers

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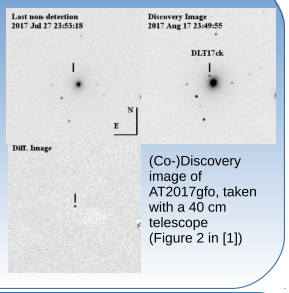
What is a “Kilonova” ?

“Kilonova” = a sequence of gamma-ray, visible light, X-ray and radio emissions, following a Binary Neutron Stars (BNS) or a neutron star - black hole (NSBH) merger [2] [3]

- The first (and to date *only*) such event (AT2017gfo) was observed following the first gravitational wave detection of a BNS merger (GW170817) [5][6]
- LIGO & Virgo Gravitational Wave Observatories are again trying to detect more such events, and astronomers worldwide try hard to catch the “kilonova” counterpart.



(Co-)Discovery image of AT2017gfo, taken with a 40 cm telescope (Figure 2 in [1])

Step 0: Manage your expectations :-)

Judging from GW170817/AT2017gfo, kilonovae are challenging but reachable by ambitious amateurs: *relatively rare* (perhaps 1 event per year), *faint* (18...20+ mag), *hard to identify* (uncertainty of predicted location: 10s ...1000s of deg² !), but ***scientifically extremely interesting***. *You could be the first amateur to help discover one!*

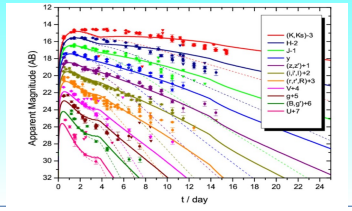
Step 1: Prepare yourself

The gravitational wave community has not yet fully embraced amateurs as partners, and most of their documentation is tuned towards professional astronomers. The learning curve can be a bit steep at first. Alerts of neutron star mergers are now (since April 2019) public, but you need to understand how to digest those alerts first:

1) A **must read**: LIGO/Virgo Public Alerts User Guide : https://emfollow.docs.ligo.org/userguide/index.html
2) Register with the KilonovaCatcher Project & mailing list: https://grandma-kilonovacatcher.lal.in2p3.fr/
3) Kilonovae *fade fast* in optical light. You need to be prepared to respond *fast* (the first (say) 48 hours are decisive)!

Step 2: Join the hunt and listen for alerts

- Initial trigger for observations is likely to come from Gravitational Wave detectors
- Those public alerts are published and followed up on NASA’s **GCN “Gamma-ray Coordinates Network”** (*not* (!) via ATELs)
- GCN offers human generated and machine generated messages (“Circulars” and “Notices”)
- Subscribe to GCN notifications [7] and/or have a computer script listen to machine readable GCN notices to alert you when needed



Light curves of AT2017gfo from [4]

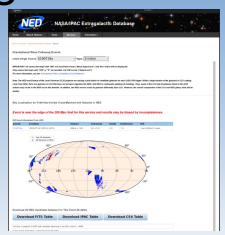
(note the offsets for readability)

Step 3: Action!!! Respond to alerts & observe

Following a GCN alert for a BNS or (less likely) a Neutron Star Black Hole (NSBH) merger:

- decide whether it's an interesting one (est. distance, false alarm probability, alert’s skymap shape)
- Identify potential host galaxies that are consistent with the 3D-skymap (direction **and** distance) and prioritze the list (or get a ready-made list from sources like NED [8] or KilonovaCatcher [9])
- begin taking images of potential host galaxies with limiting mag at least (say) 17, better 18+mag, depending on the estimated distance. Use *unfiltered images for max. depth until a counterpart is discovered*, then switch to filtered observations if possible.

Simultaneously: *keep watching GCN for updated information (updated skymaps, candidate optical counterparts, retractions of alerts...)*



See [8] for a web-service offered by NED to catalog candidate host galaxies for a given GW alert

Step 4: Share your data (and do it fast!)

Speed is crucial! Recommendation: pass your calibrated images to the professionals for automatic comparison to reference images to rapidly identify a kilonova transient (and avoid false alerts by NEOs, CVs, SNs, ...)

==> again, see the KilonovaCatcher Citizen Science project by the GRANDMA collaboration [9]

References:

[1] Valenti, S., David, Sand, J., et al. 2017, ApJL, 848, L24
[2] B.D. Metzger, G. Martínez-Pinedo, S. Darbha, et al,2010, MNRAS,406,4
[3] B.D. Metzger, E. Berger, 2012, ApJ, 746,1
[4] Yu, Yun-Wei et al. ApJ. 861 (2018) no.2, 114
[5] I. Arcavi, G. Hosseinzadeh, D. A. Howell, et al ,2017, Nature, 551
[6] LIGO Scientific Collaboration and Virgo Collaboration, Fermi Gamma-ray Burst Monitor, and INTEGRAL ,20177, ApJL, 848,L1
[7] https://gcn.gsfc.nasa.gov/
[8] https://ned.ipac.caltech.edu/gwf/events
[9] https://grandma-kilonovacatcher.lal.in2p3.fr/