

# A REVOLUTION IN OUR KNOWLEDGE OF THE EARLY UNIVERSE, FUNDAMENTAL PHYSICS AND TRANSIENT ASTROPHYSICS...



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+ access to optical telescopes

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+ LOFAR







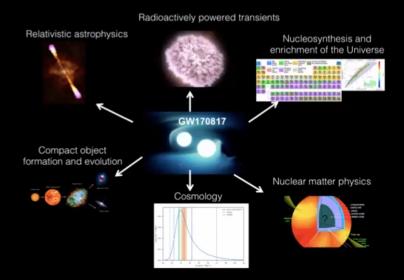




Ghirlanda et al. 2019, Science



A relativistic energetic and narrowly-collimated jet successfully emerged from neutron star merger GW170817!



Kilonova/GW - EOS constraints

Kilonova/GW - Nucleosynsthesis

GRBs - BNS/NSBH merger up to high z

Relativistic jet properties

Jet-less/jet GRBs

- Large increase of detection rate
  - population of BNS/NSBH/BBH
  - o detections along the cosmic history
- Better parameter estimation
- Higher chance to detect other sources and counterparts: core-collapse SN, new-born neutron stars, magnetars, FRBs, neutrinos

**GRB/stable NS remnant** 

**Link to Star Formation History** 

**Emission mechanism** 

Cosmology

### Multi-messenger synergies



- Easy access follow-up of large error box
- Characteristation of the potential counterpart with spectroscopy (nature, redshift...)

### X-ray telescopes: Swift, INTEGRAL, SVOM, ATHENA...

- Very clean sky
- Provide transient triggers (GRB, AGN, Novae...)
- ToO program (not so easy access)

SED TXS 0506+056

MeV GeV

TeV

#### γ-ray telescopes: Fermi-LAT

- All-sky complete monitoring
- Provide transient triggers (GRB, AGN...)

### VHE γ-ray telescopes: HESS, MAGIC, CTA...

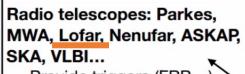
- Most natural common science case
- Follow-up (not easy access)

### VHE γ-ray telescopes: HAWC, LHAASO...

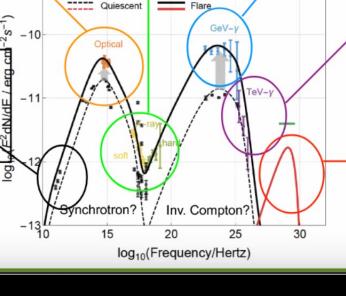
- All-sky monitoring
- Provide triggers

#### Neutrino telescopes: ANTARES, IceCube, KM3NeT, GVD...

- Mutual follow-up
- Confirmation of sources, improve significance



- Provide triggers (FRB...)
- Follow-up
- + link with LIGO/VIRGO
- + SK, SNEWS



D. Dornic Not to scale (Probably) one identified source Neutrinos from the AGN blazar TXS 0506+056 Sept. 22, 2017: 2014-2015: A (orphan) neutrino flare found from the 13 + 5 events excess Alert systems Coordination (Prioritization in between of candidates) Joint analysis Interpretation instruments Prioritization of triggers required Viewing angle Sky-localization A difficult parametrization ET+CE ET+2CE Simple 1-zone models are not working properly  $N_{\text{det}}(\Delta\Omega < 100 \text{ deg}^2)$ More sophisticated multi-zone models on the  $V_{det}(\Delta\Omega < 1000 \text{ deg}^2)$ 428484 market to satisfy the energetic problem: interaction with external field (Sikora 2016), jet-cloud interaction (Liu 2018), formation of a compact core (Gao 2019).. Distance Too large numbers of ⇒ Simultaneous X-ray data are extremely triggers well localized to important for the modeling, even more mportant than the very high energy be followed-up Connection to multi-messengers Binary neutron star inspirals could last for O(hours-days) in future detectors, and are M. Branchesi well-modeled by Post-Newtonian expansions "Early warning" for astronomers is realistic, given how long these signals could last (Gao et al, 2018) (Cerruti et al, 2018) We propose an alternative to matched filtering that could provide early warnings to D. Dornic astronomers, with excellent sky resolution

A. Miller

### There is a need for

Preparation

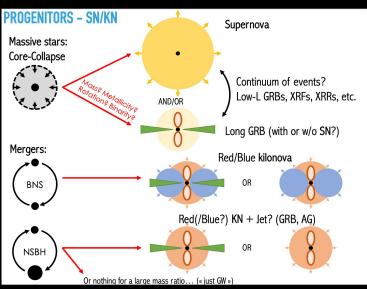
Coordination

High quality data set (multi-wavelength + multi-messenger)

Exchange within instruments

Exchange between communities

## Joint efforts?



#### BNS MERGERS: GW+EM

- GW/bright SGRB: current limitation = GW horizon (wait for 05? ET?)
- Other counterparts: best case = kilonova (less anisotropic)

Searching the KN remains very difficult (a weak transient on a week timescale in a large error box)

Some expected improvments:

- more interferometers in the GW network: better localization
- LSTT (large fov + deep limit mag. cadence?)

Needs dedicated follow-up instruments (an example: GRANDMA)

- Afterglow: very difficult without an accurate localization with the KN
- Rare MM-detections can be complemented by other (EM-only) channels: SGRB+AG; SGRB+AG+KN; orphan KN?; orphan AG?

F. Daigne

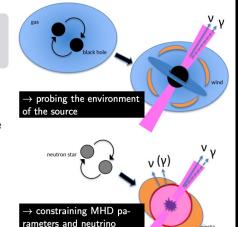
#### Binary mergers

Phys. Rev. D 93, 044019Phys. Rev. D 93, 123015

Mergers of compact objects (Neutron Stars -NS-, Black Holes -BH-) are established gravitational wave (GW) emitters.

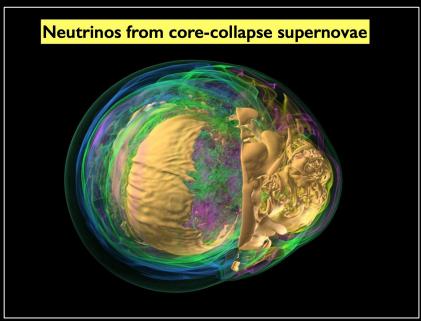
- BNS (NS+NS) or NSBH (NS+BH): may produce short Gamma-Ray Bursts with neutrino production
- BBH (BH+BH): neutrinos may be produced in the accretion disks of the BHs

Spectrum	$E^{-\gamma}$ often considered in searches
	and MeV/GeV emission?
Shape	isotropic (not realistic at high energy)
	or presence of directional jet?
Timing	GW170817 + GRB170817A observation
	GW170817 + GRB170817A observation hints to prompt signal for BNS



transport mechanisms

#### M. Lamoureux



D. Dornic

### Joint efforts?

- Search for "non-obvious" joint observations
- Extraction of physical constraints in multi-messenger analyses (observation + non-observation)
- Computing ressources for joint analyses
- Coordination for follow ups (shifts, MoU, data sharing,...)
- Definition of prioritization for follow ups