Search for neutrino counterparts of gravitational-wave events with ANTARES

ICRC 2019, Madison
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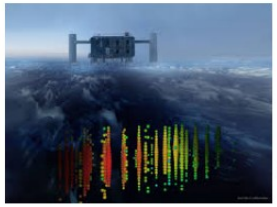
On behalf of the ANTARES collaboration

The ANTARES neutrino telescope in the multi-messenger context

Multi-messenger approach:
Look for neutrinos in coincidence in space and time with signals detected by other observatories.

- Background reduction
- Increase of discovery potential
- Full sky search

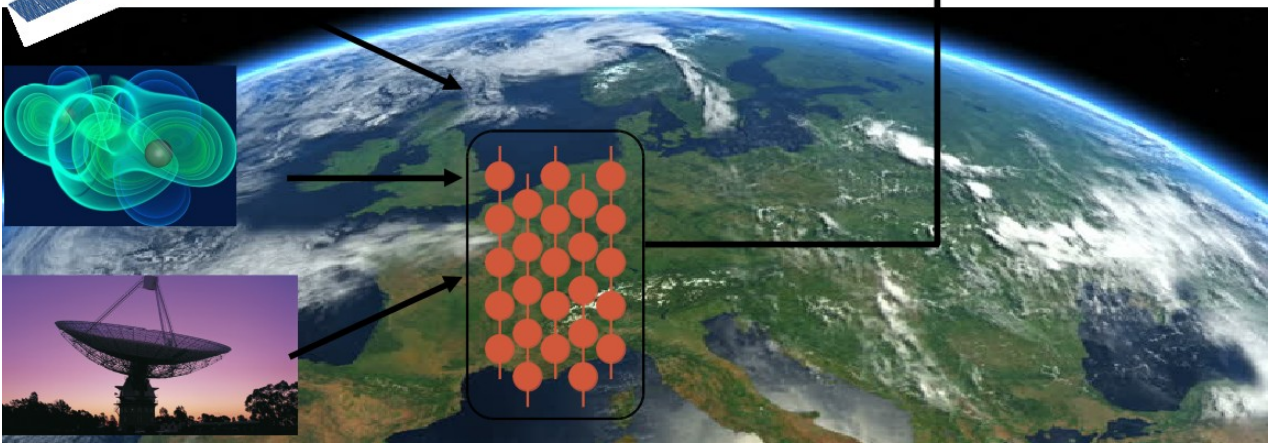


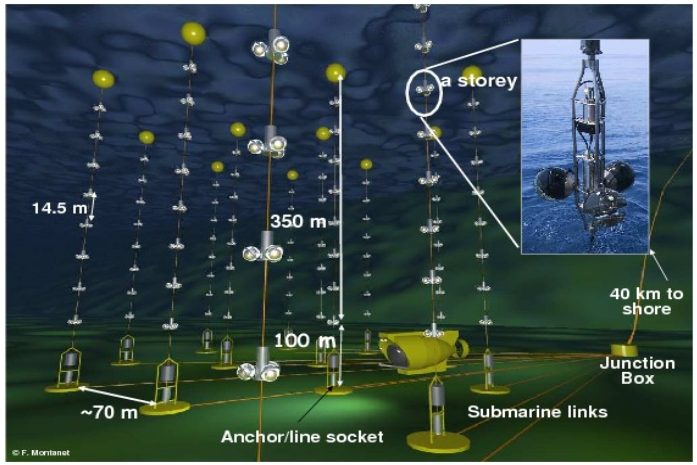
D.Dornic et al.
- Poster: PS1-100
- Talk: NU9e

Real time

Offline: Refined

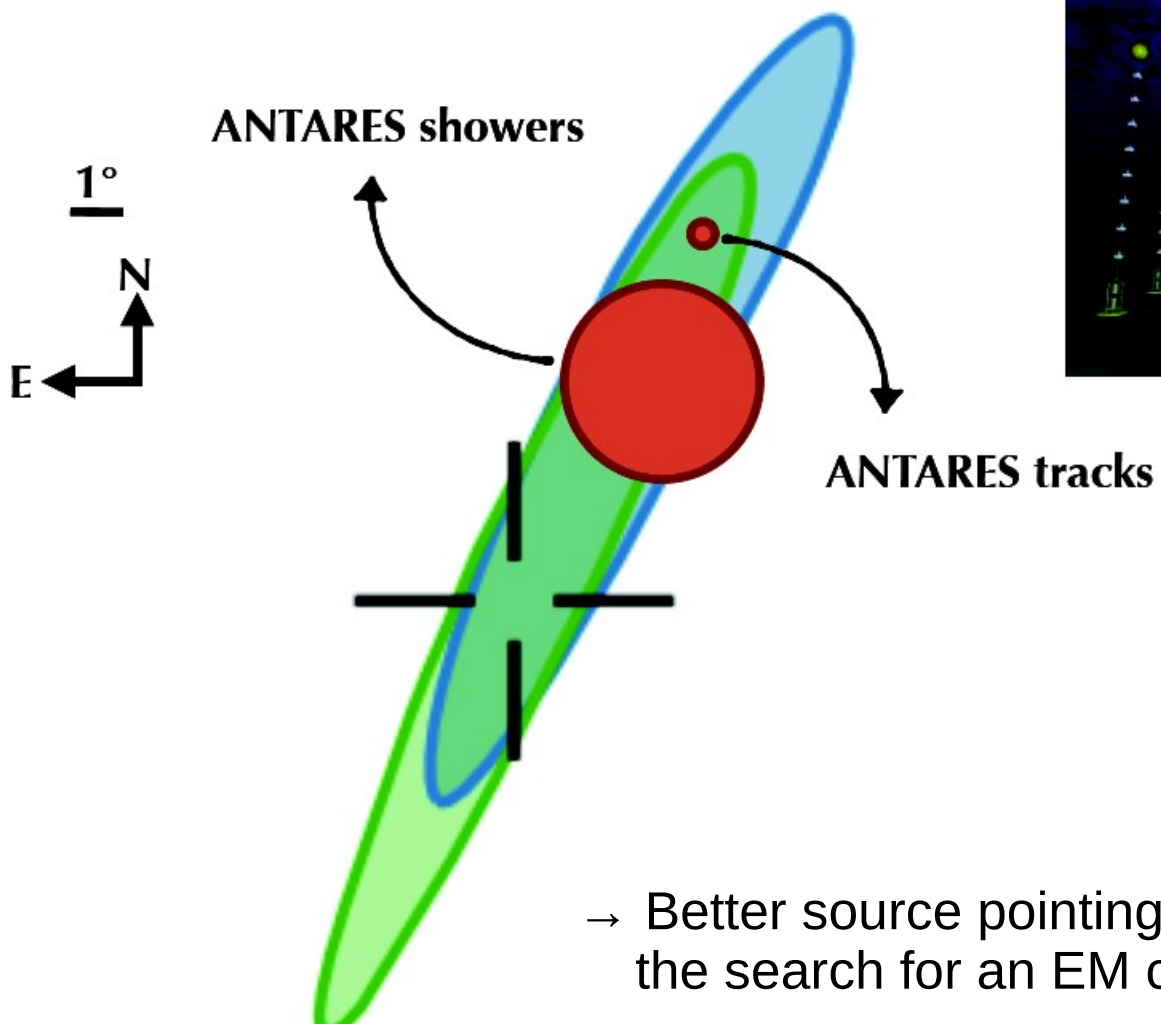
Time dependent searches





- Typical signal: High-energy muon neutrino-induced upgoing tracks in the detector

Where can neutrinos help?



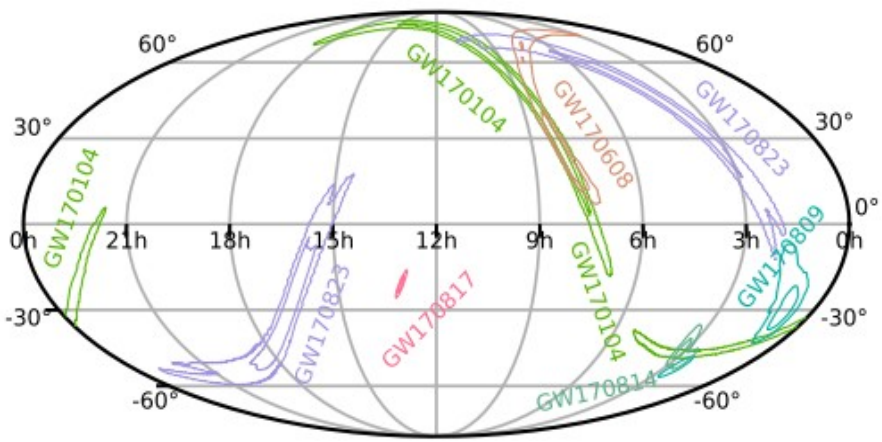
angular resolution:
<deg (tracks)
~deg (showers)

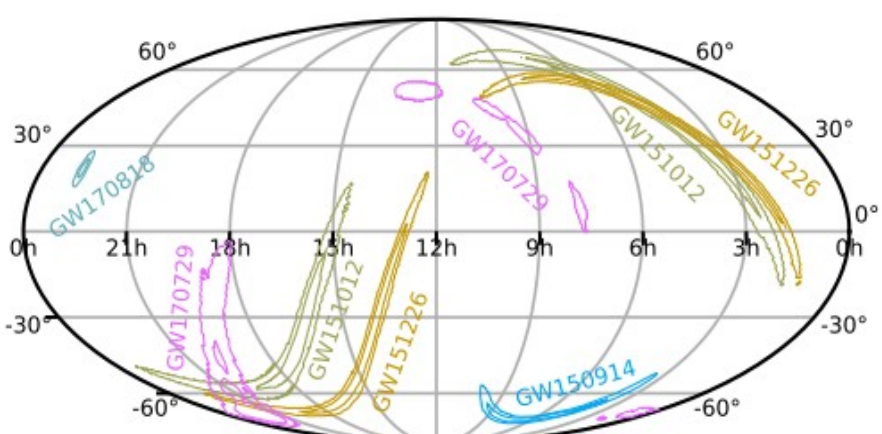
field-of-view:
> 2π sr

→ Better source pointing helps for the search for an EM counterpart

State of the art of GW astronomy:

Cataloged GW events from O1+O2:





- 11 BBH events:
  5 followed by ANTARES + **6 NEW here**
- 1 BNS event
  - With Multi-Messenger observation
  - Joint search ANTARES+IC+Auger

Since the beginning of O3:
- 18 (?) BBH candidates
- 3 (?) BNS candidates
- 1st (?) NSBH candidate:

Preliminary results here

(and counting...)

Neutrino search in coincidence with GWs: Method and samples

- Search during +/-500 s around the merger
- Search below (upgoing events) & above (downgoing) the horizon
- Selection: 1 event passing the cuts found inside the GW 90% localization error box in the time window → 3σ detection
- Optimization and background estimation done on data
- Only muon neutrinos for the moments: all flavor coming
- Six new O2 GW events (BBHs) considered:

- GW170608
- GW170729
- GW170809
- GW170814
- GW170818
- GW170823

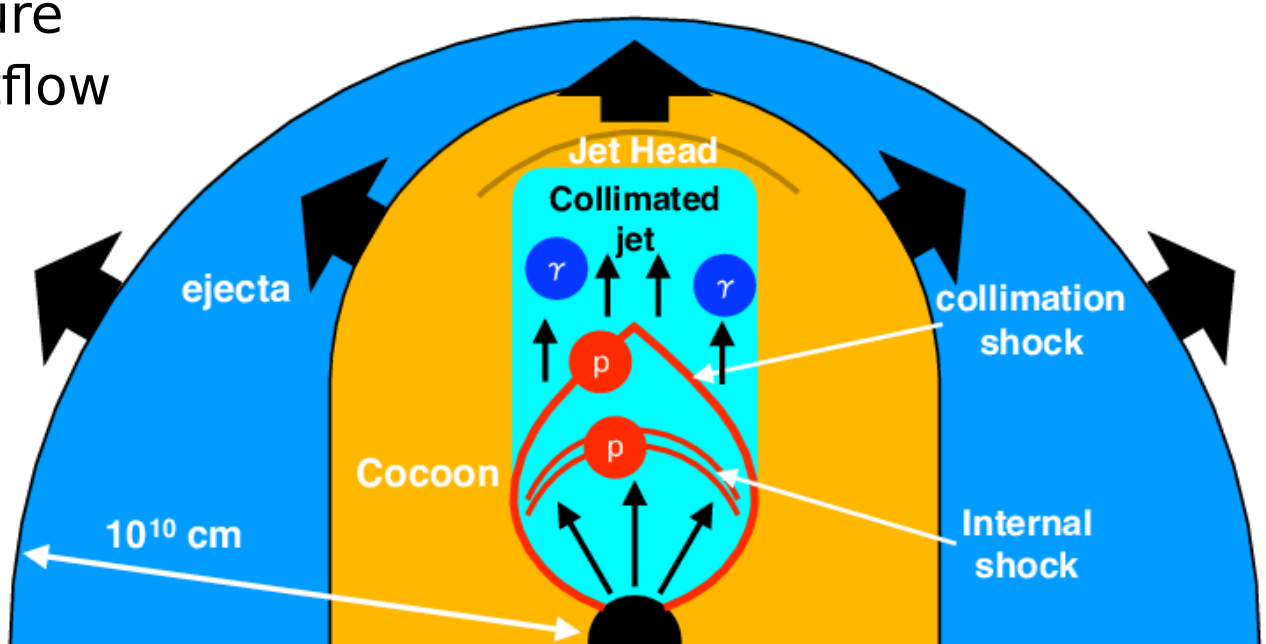
+ 1st NSBH candidate from O3 (S190426c)

Offline follow-up of BNS-NSBH events (candidates from O3 + GW170817)

Neutrino emission from BNS/NSBH events

Expected if:
- **ejection process with hadronic component**
- **cosmic-ray acceleration related to magnetar**

- Confirm hadronic content of ejecta
- Constrain the structure of the relativistic outflow



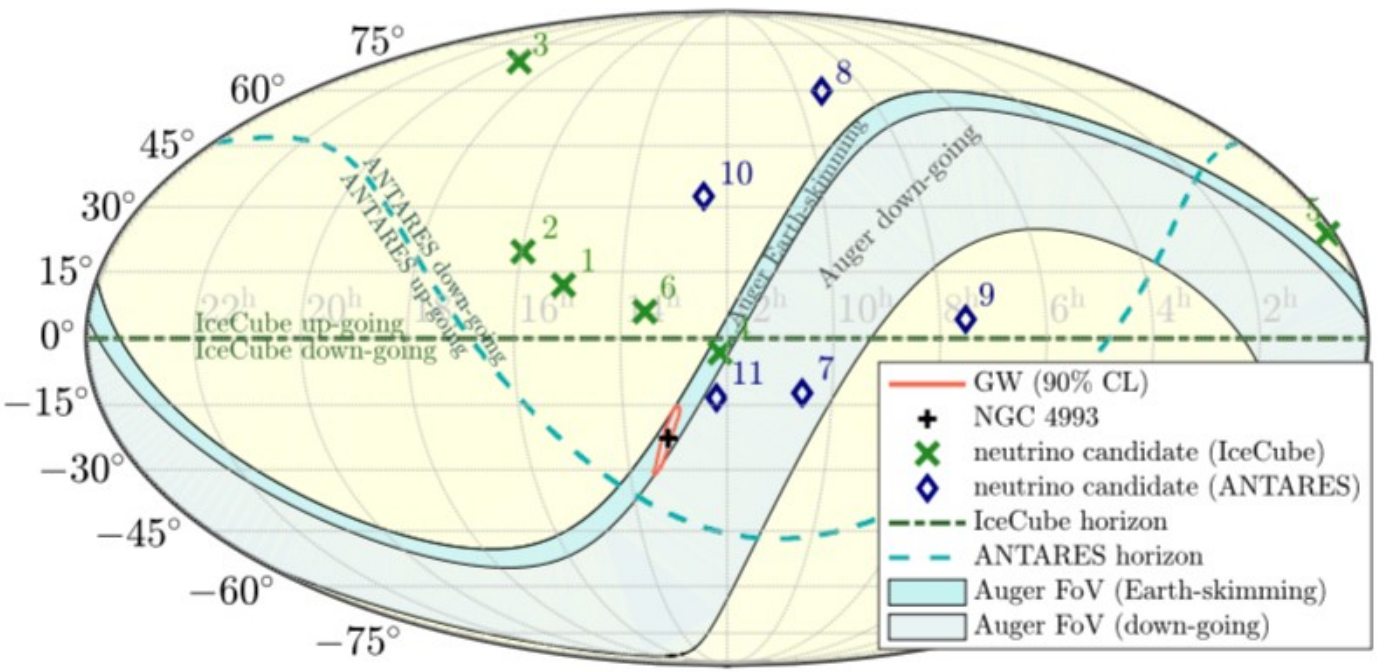
Joint follow-up of GW170817: ANT-IC-Auger

ANTARES:

Search over ±500 s and +14 days

Track + shower events (all flavors)

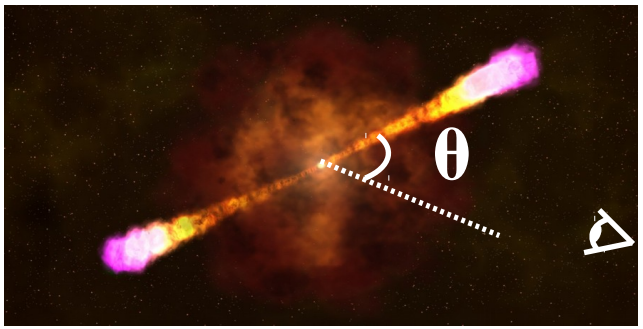
Over ±500 s around the merger:



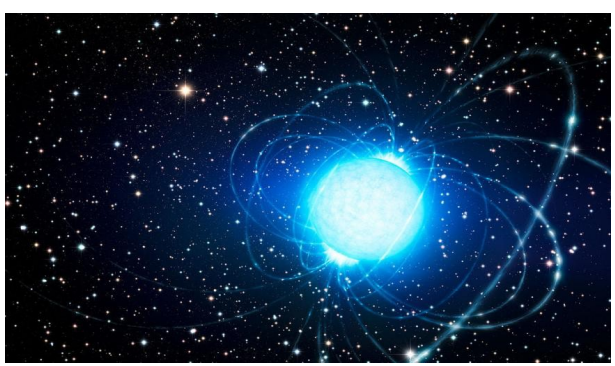
Albert et al., ApJL, 850, 2 (2017)

No counterpart over +14 days either

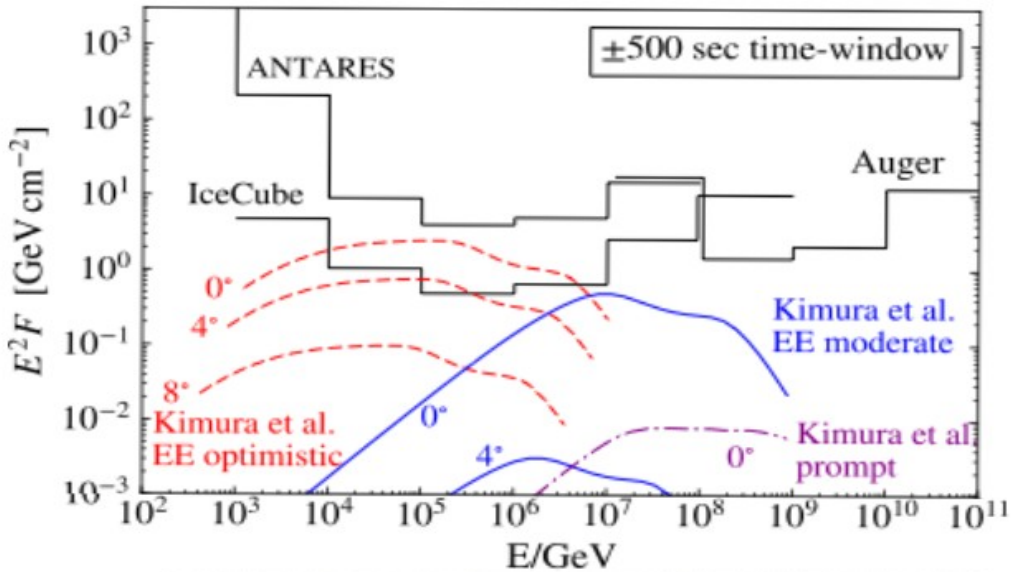
Constraints on the source: GW170817

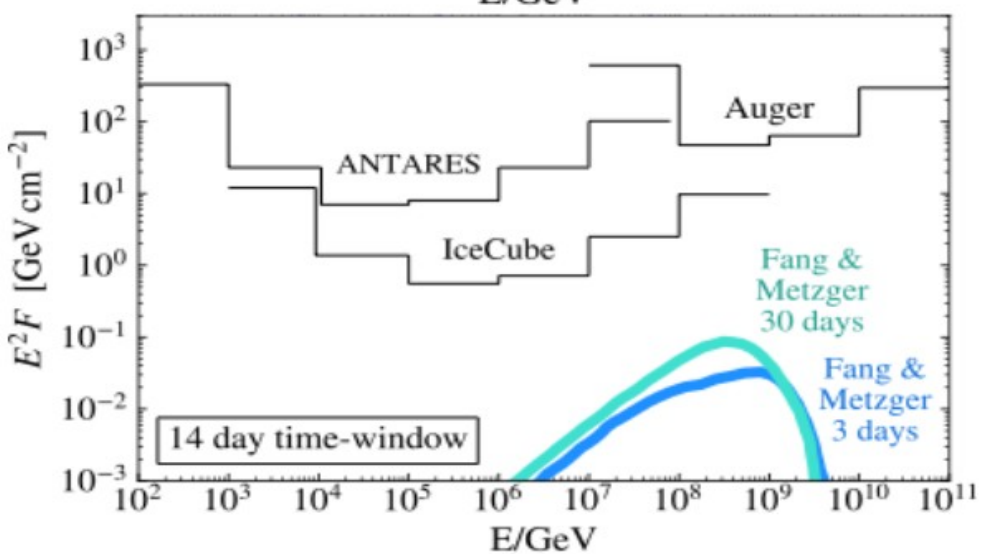


Neutrino emission related to the prompt/extended high-energy emission (**Kimura et al., 2017**)

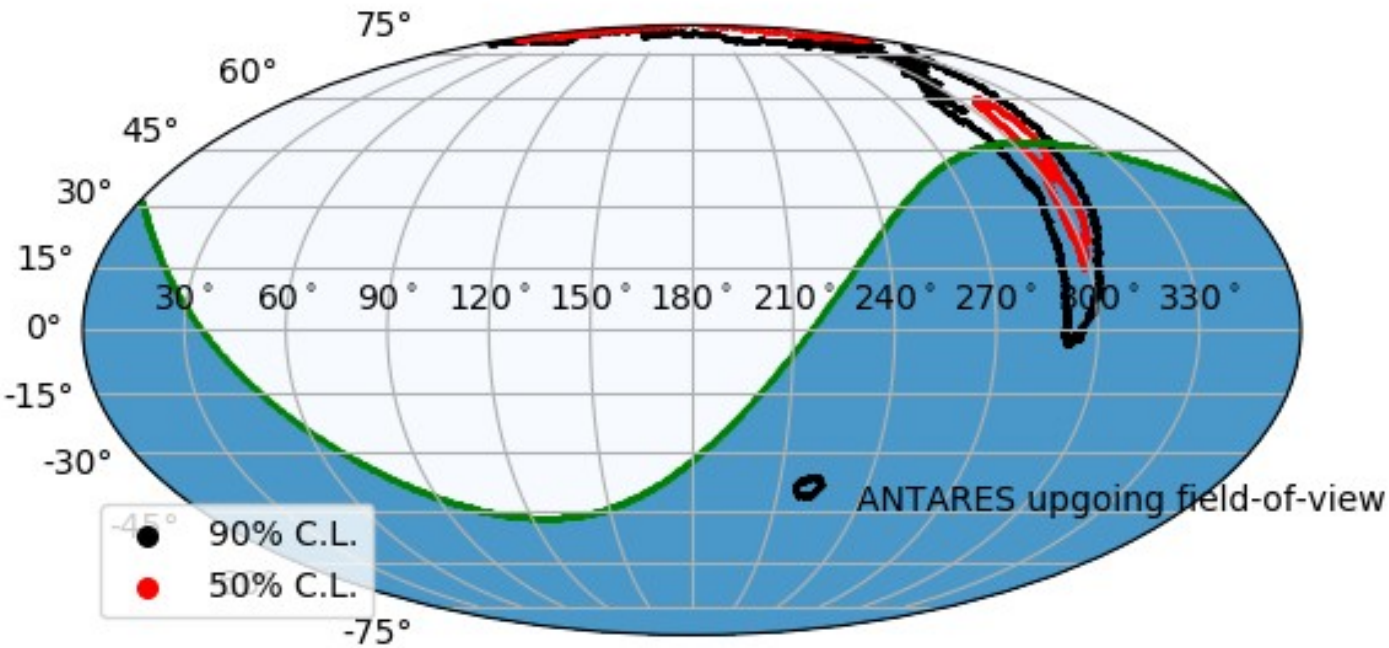


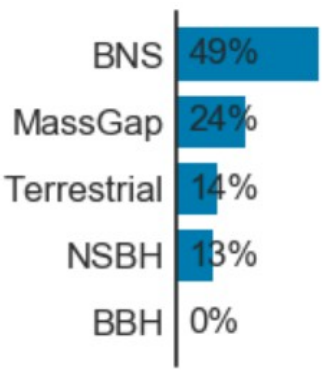
Fang & Metzger 2017:
Magnetar + ejected material from the coalescence:
↳HE cosmic ray acceleration
↳HE neutrino production





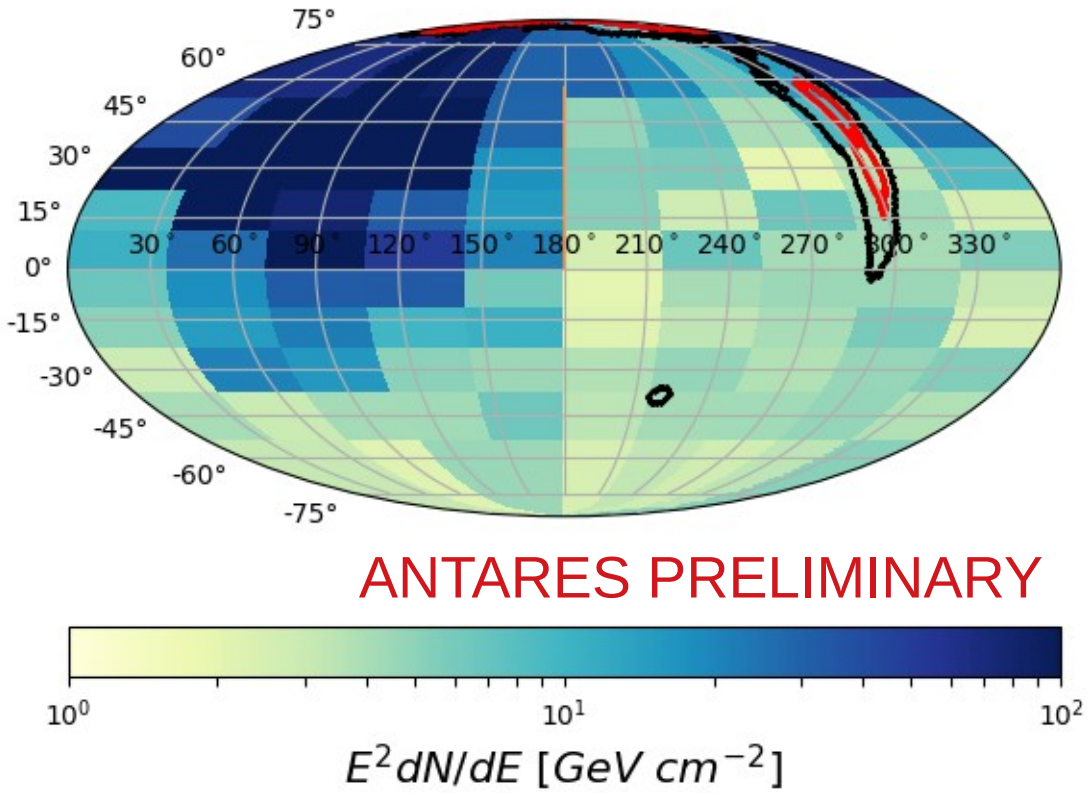
1st NS-BH candidate of O3: S190426c



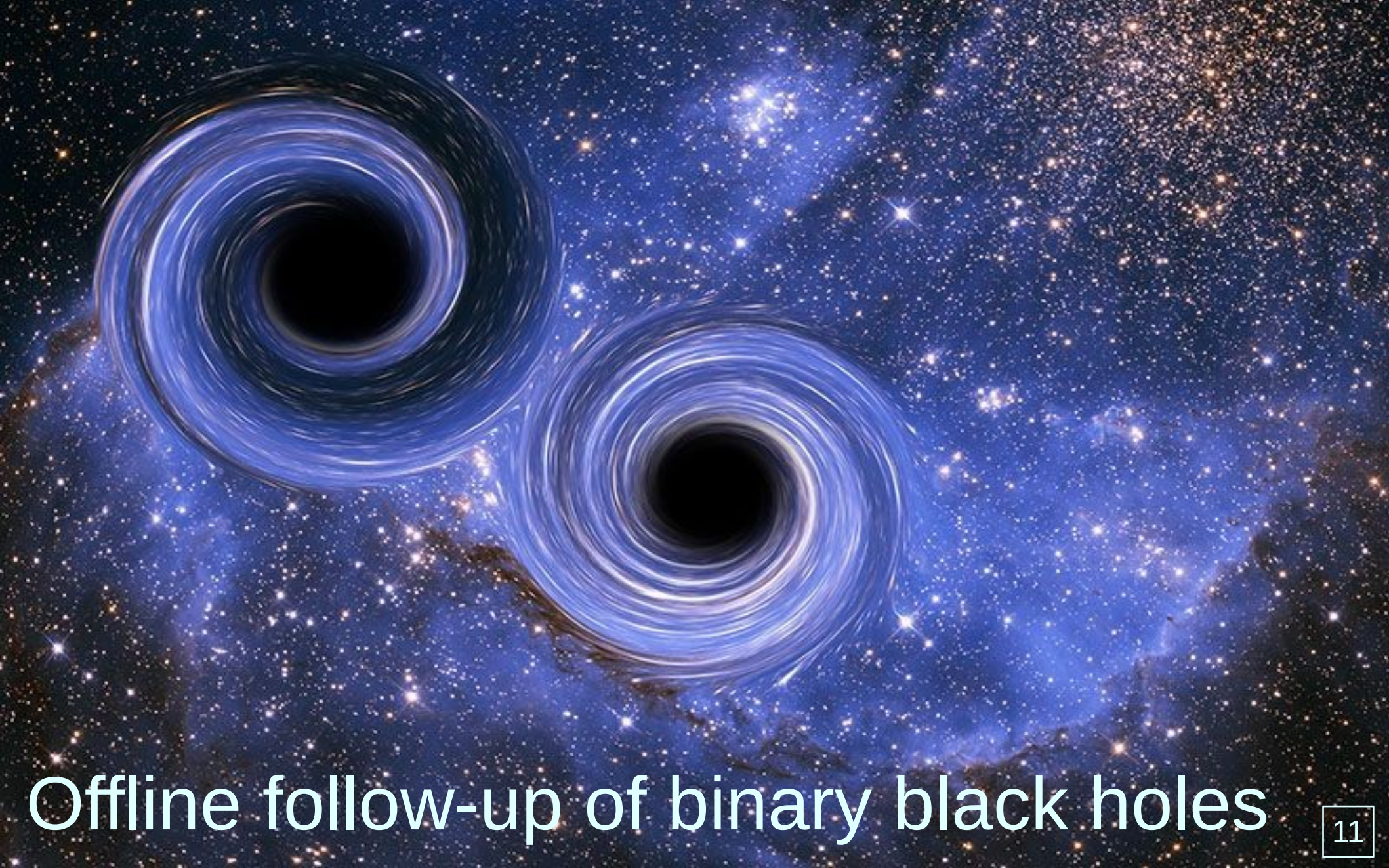


- ANTARES visibility, 90% error box: 55% downgoing, 45% upgoing
- Distance: 377+/-100 Mpc
- Relative probabilities (GCN 24411): NSBH 12/3 : MassGap 5/3 : BNS 3/3

S190426c: ANTARES preliminary result



No matching neutrino found in ANTARES data with S190426c



Offline follow-up of binary black holes

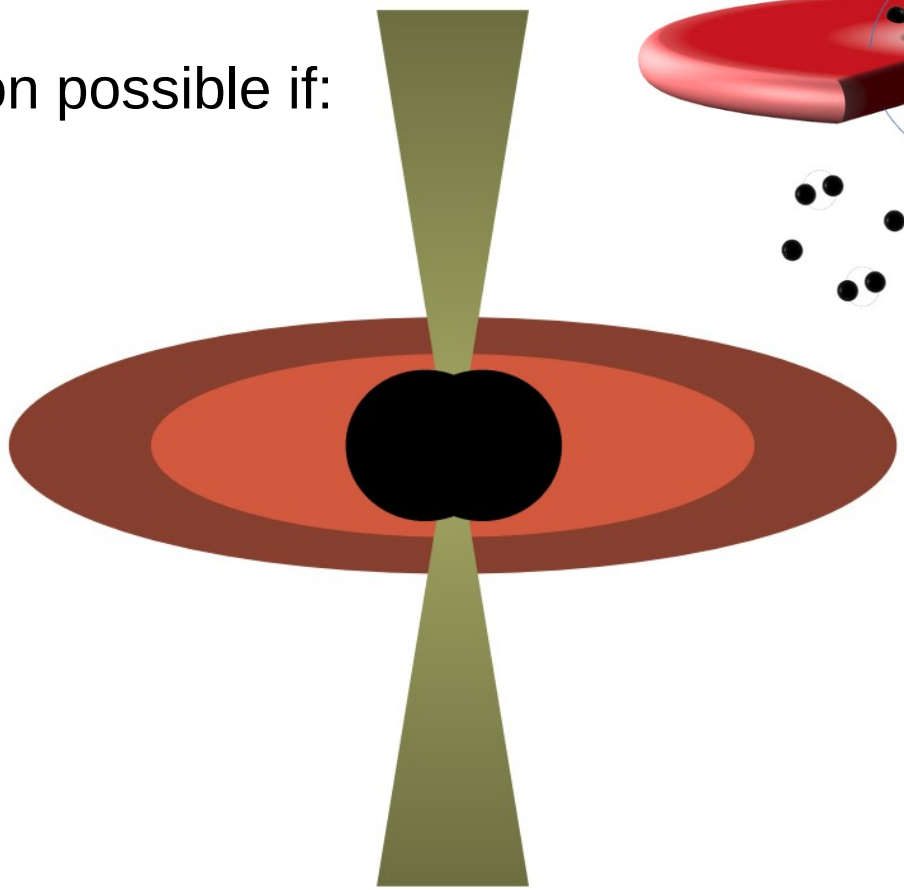
Neutrino and EM emission from BBHs ?

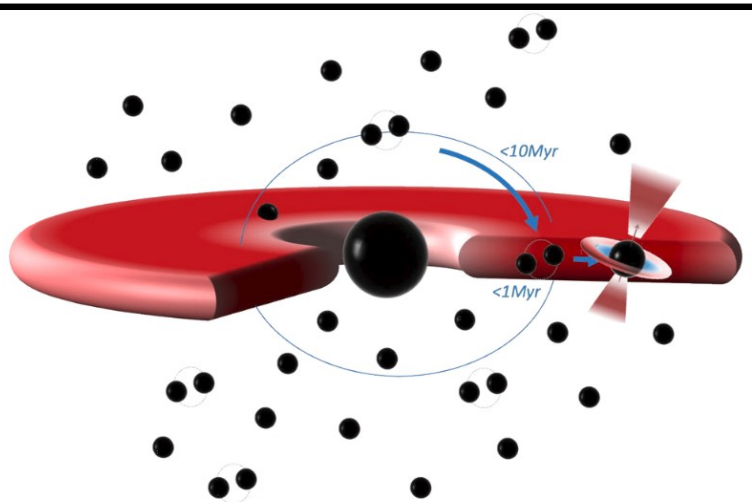
General understanding:
No EM or neutrino emission expected
But...
EM and neutrino emission possible if:

- Hadronic environment
- Strong magnetic field

↓

- Accretion disk
- Relativistic jet
- Mergers in AGNs

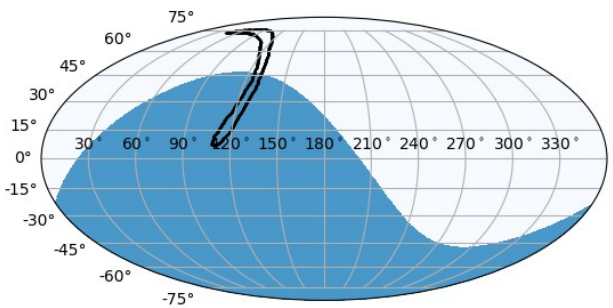




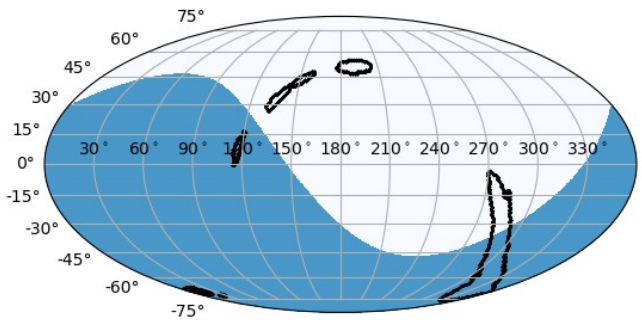
Perna et al., 2016
Kotera & Silk, 2017
I.Bartos et.al, APJ, 2017

Localization of the events of the search:

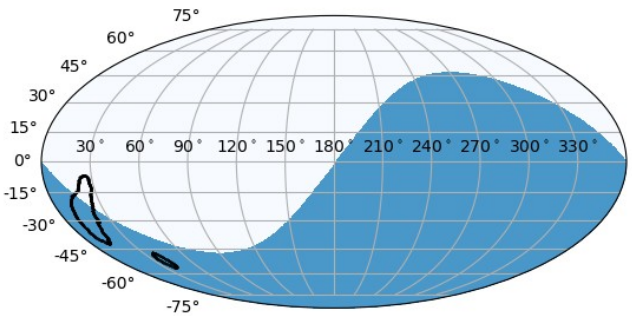
GW170608



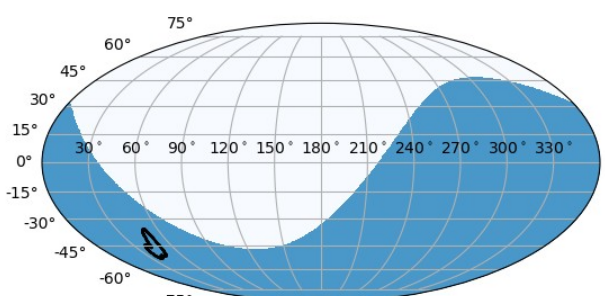
GW170729



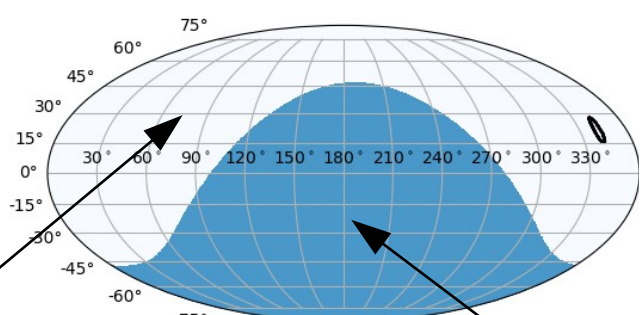
GW170809



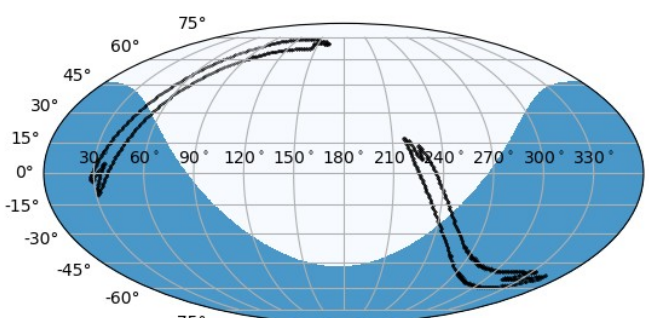
GW170814



GW170818



GW170823

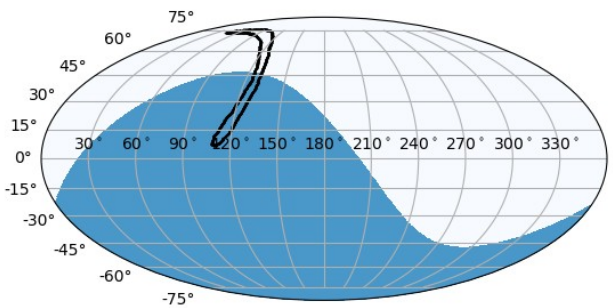


above the horizon

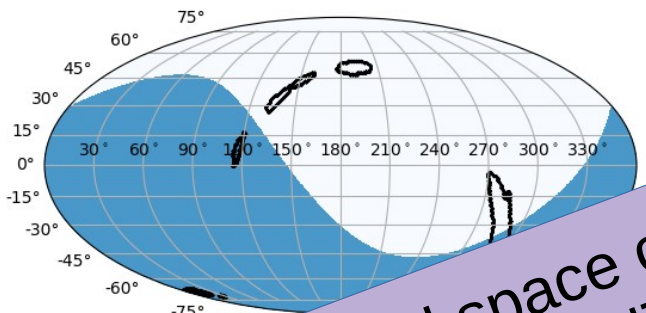
below the horizon

Results of the ANTARES search:

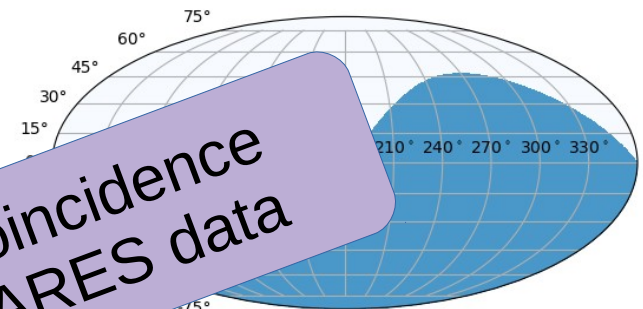
GW170608



GW170729

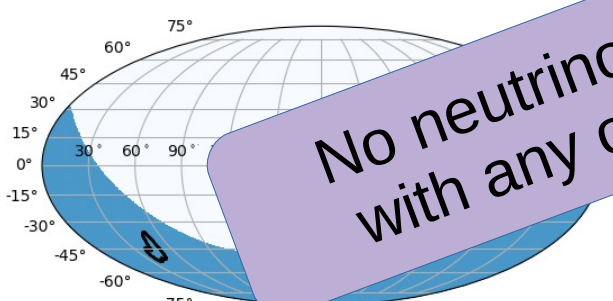


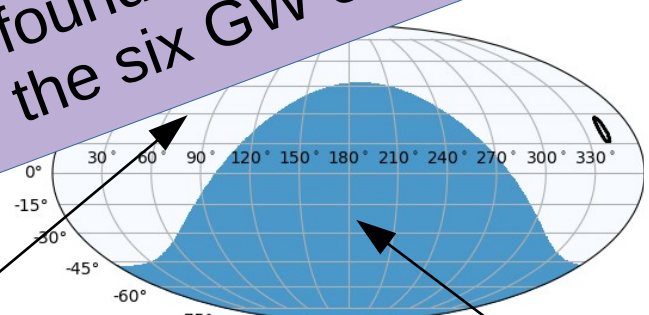
GW170809



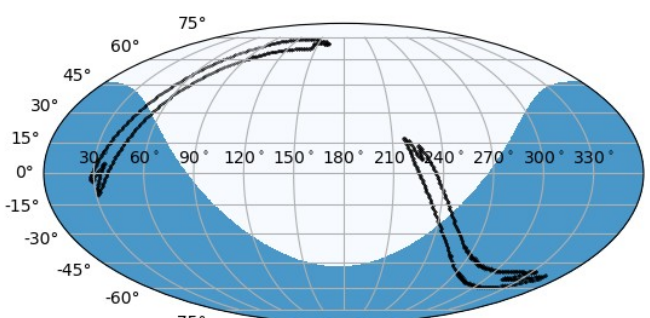
No neutrino found in time and space coincidence with any of the six GW events in ANTARES data

GW170814





GW170823

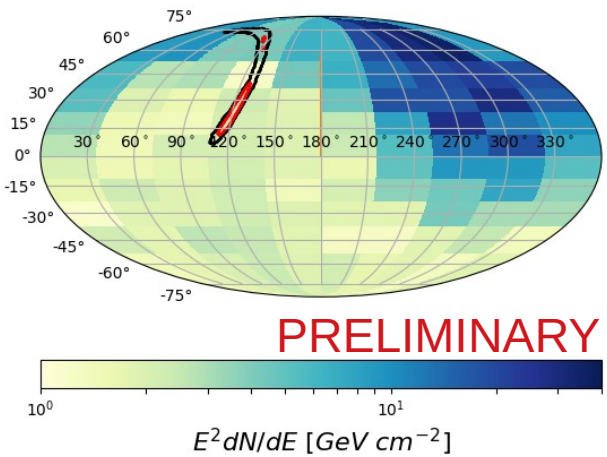


above the horizon

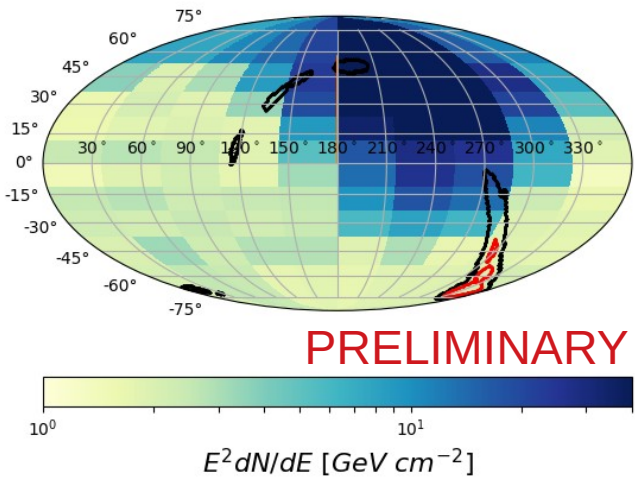
below the horizon

ANTARES constraints on the neutrino fluence

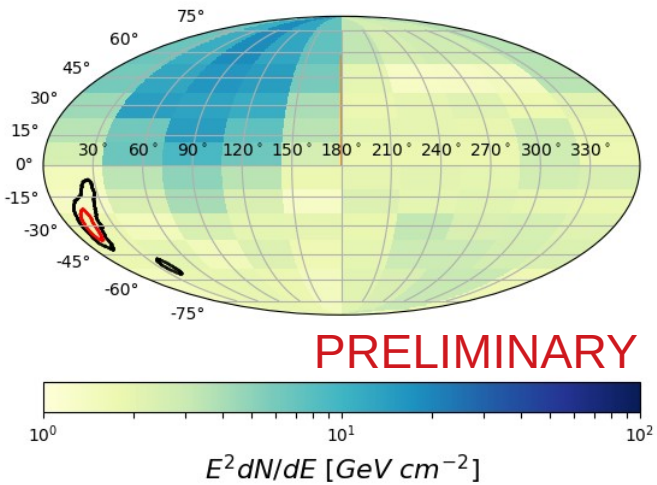
GW170608



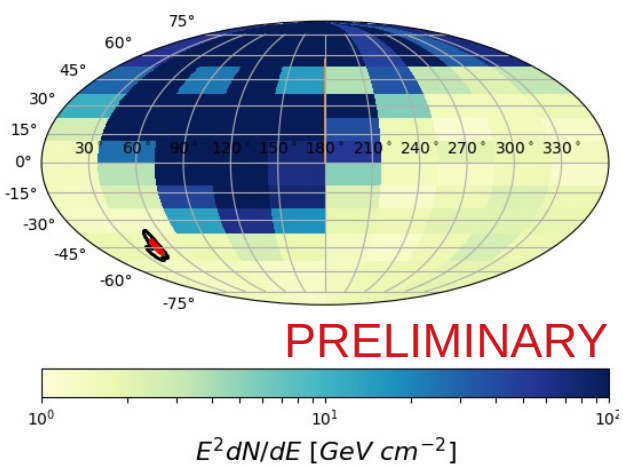
GW170729



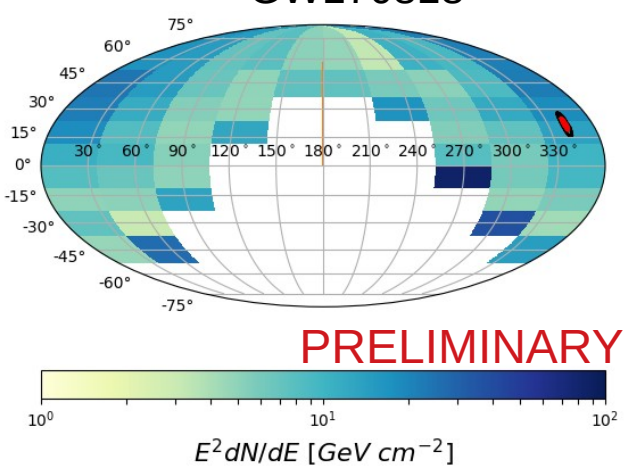
GW170809



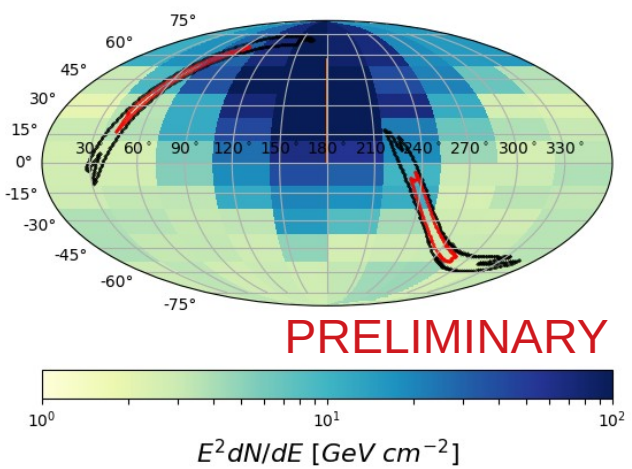
GW170814



GW170818

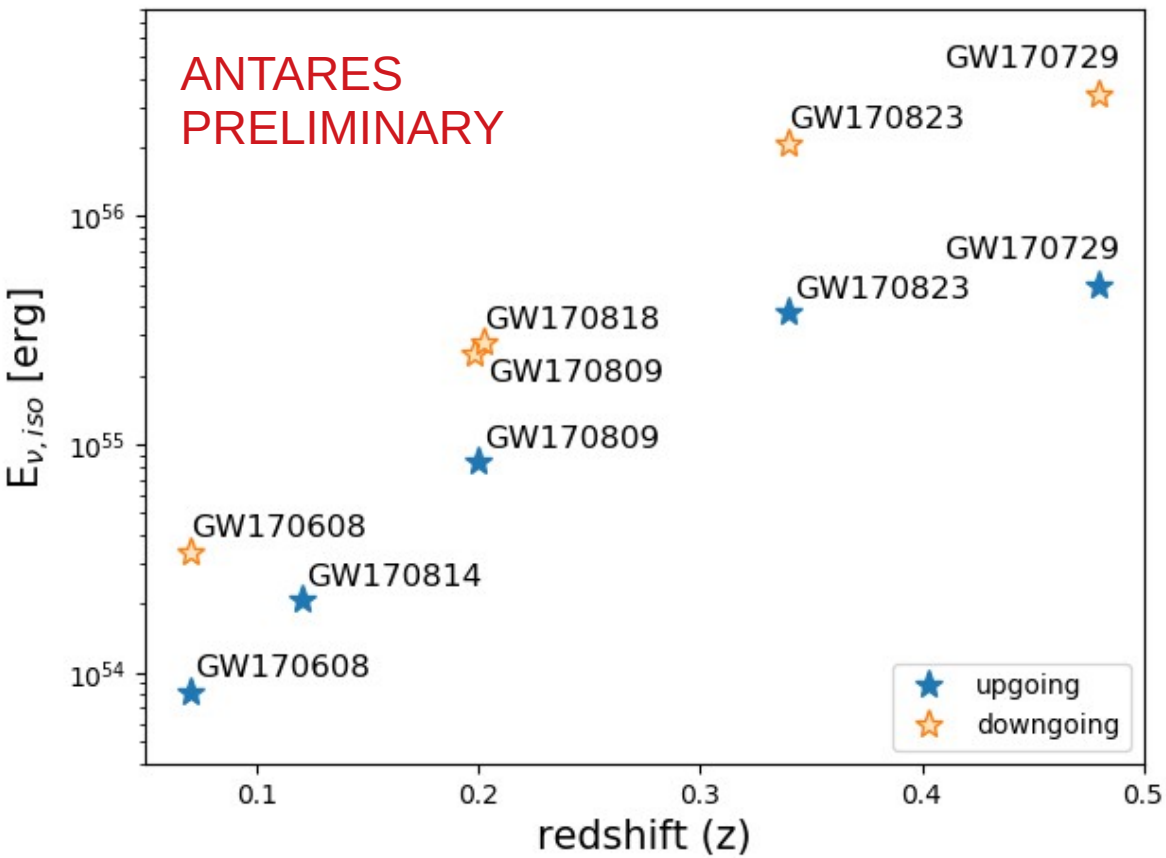


GW170823



ANTARES constraints on $E_{\nu iso}$ from BBHs

- Energy range : [100 GeV, 100 PeV]
- Redshift : from mean of the Ldist distribution
- Average upper limit (up/down) used



CONCLUSIONS AND OUTLOOK

- All GW O2 events have been followed with the ANTARES telescope: no neutrino in correlation with GW emission was found:
  → Constrains on the neutrino fluence and isotropic energy
- Preliminary results for 1st NSBH candidate: no coincident neutrino
- Multi-messenger approach allows for all-sky search and background reduction with an increase of discovery potential
- Same approach can be used for localized transient sources (GRBs, FRBs), also above the horizon!

Coming soon…

- From muon neutrinos to all flavor search for O2 BBH events
- Stacking analysis of all BBH events will come after the end of O3
- Interesting O3 events (BNS, NSBH) will be followed using the approach presented here

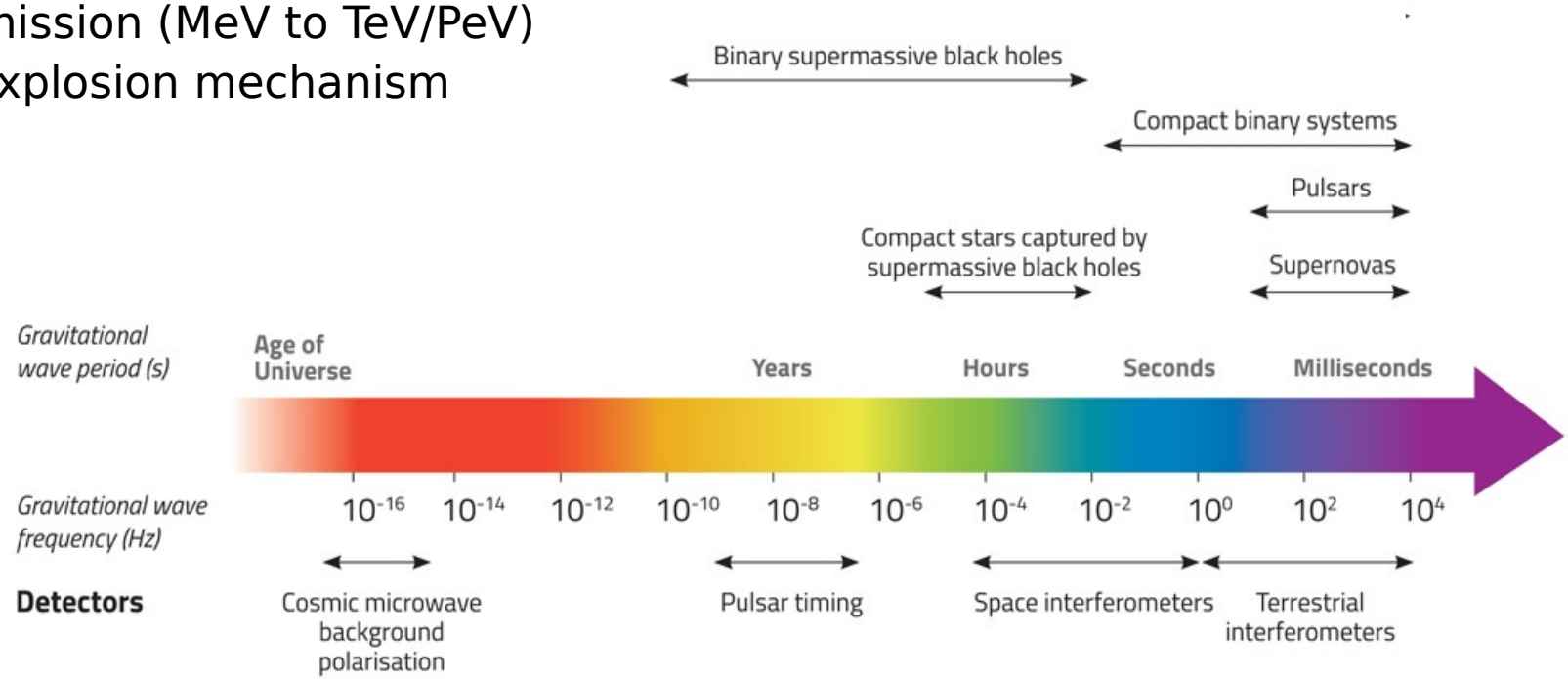
Thanks for your attention

Stay tuned...

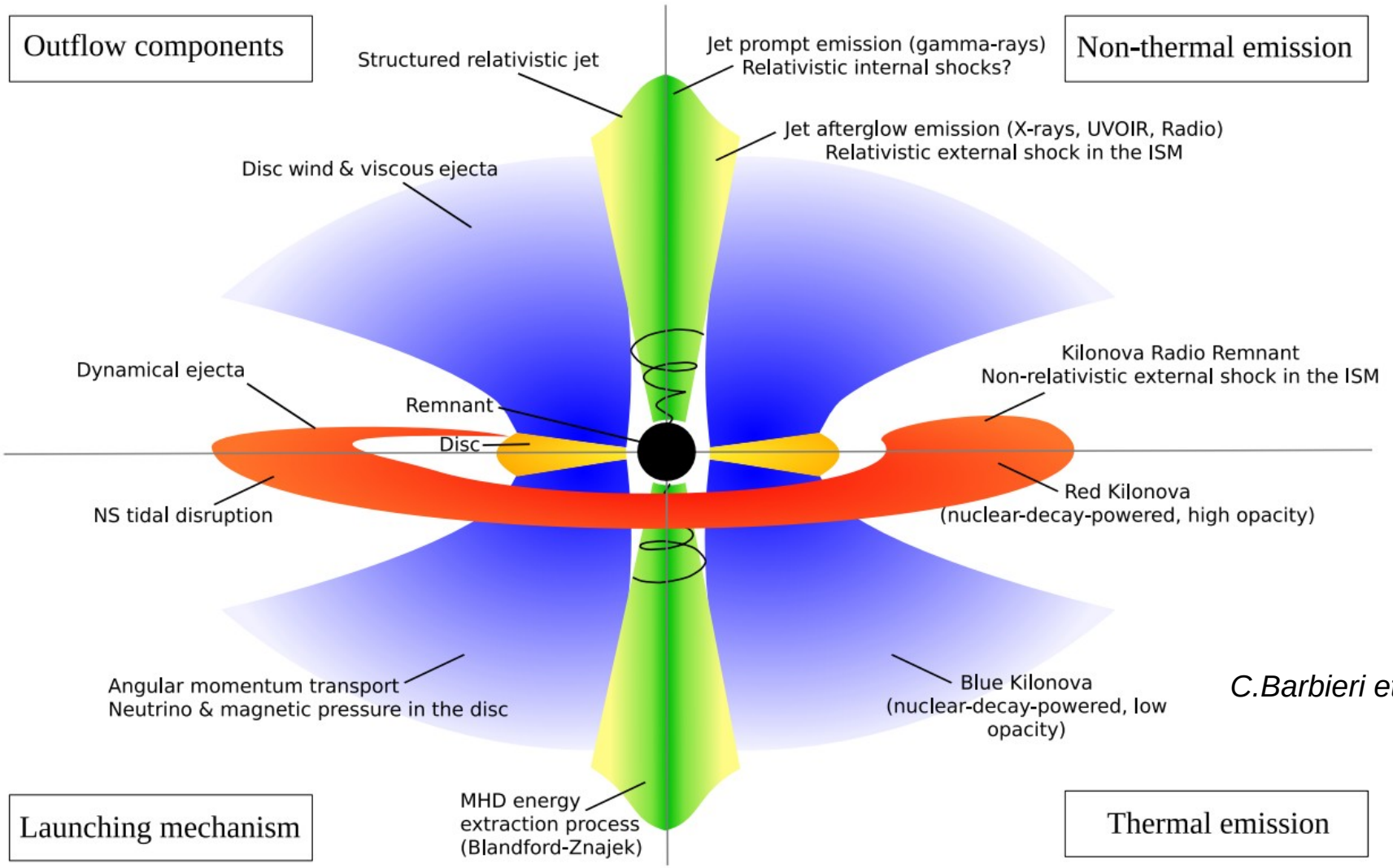
Multi-messenger astronomy is the way!
(and it never sleeps)

Different types of GW sources:

- **Compact binary mergers:**
  (BBH, BNS, NSBH)
  - Test particle acceleration
  - Reveal ejecta structure (GRB physics)
- **Core-Collapse Supernova:**
  - Neutrino emission (MeV to TeV/PeV)
  - Constrain explosion mechanism
- **Pulsars**
- **Primordial**
- **...**



What we learnt from GW170817:



C.Barbieri et al. (2019)