Searches for electromagnetic counterparts of multi-messenger transients with INTEGRAL

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LIGO/Virgo 2015- August 2017: 5 binary black holes
Electromagnetic follow-up challenges

The alerts are promptly distributed to observers from radio to gamma-ray, who made the agreements with LIGO/Virgo collaboration.

LIGO/Virgo - INTEGRAL MoU was lead by the project scientist, ISDC, and institutes from the entire INTEGRAL collaboration.
INTEGRAL

Features all-sky sensitivity > 100 keV (no Earth shadow), but almost no resolution for weak events from some directions.

Broad energy range (3 keV - 8 MeV) in FoV (~800 deg$^2$).

In 300 s
INTEGRAL observations of GW150914

$10^{-6}$ - ratio of energy in 75-2000 keV to GW energy

A milestone observation, also establishing an example of INTEGRAL observations, SPI-ACS in this case.
LVT151012

The most distant GW event so far

The GW localization required **synergy of all INTEGRAL instruments**, all-sky and pointed

Also allowed us to provide an update and review of the INTEGRAL sensitivities

Similar limits were obtained for GW170104, GW170814
GW151226

The only event so far missed due to the perigee passage (85% duty cycle)
GW170817+GRB170817A

Binary Neutron Star merger, discovered by Fermi/GBM and LIGO, was independently detected by INTEGRAL/SPI-ACS (in a very good with Fermi characterization)

Despite soft GRB spectrum and only moderately favorable orientation, INTEGRAL achieved confident detection of 4.6 SNR
Joint localization

By comparing time of burst arrival to INTEGRAL localization can be improved. Such localizations, **promptly available in the future, will aid the follow-up**

LIGO/Virgo observation alone allows to measure distance to the GW source of 40 Mpc, exceptional for a short GRB with measured distance, and well within LIGO BNS horizon.
A GRB at 40 Mpc could have produced bright hard X-ray/gamma-ray afterglow and gamma-ray lines of the kilonova from 3 keV to 8 MeV.
Summary

INTEGRAL follow-up 5 out of 6 reported events, as expected with 85% duty cycle. Combination of the high duty cycle and high sensitivity is unique and allowed it to contribute to the historic detection of GRB170817A

Detection of a GRB from an off-axis merger implies much more frequent GRB-BNS associations, which might happen regularly in the next LIGO-Virgo run (from late 2018)

Multimessenger observations open possibilities for studying processes in energetic events involving compact objects, implications that go beyond BNS mergers. This will improve with more detections in O3.

Early joint GRB-GW detection teaches to be prepared for unexpectedly optimistic scenario!

Neutrino follow-ups remain very promising and tentative MM detections might soon reach the level of solid evidence.
Backup
GW170814 first joint LIGO+Virgo detection

Precise localization allowed accurate follow-up with IBIS, JEM-X, and SPI

This case is not expected to be very frequent, but it’s vital for exploring the complete localization, (INTEGRAL work in progress)
GW170104

Again, no detection and quite suitable orientation for an upper limit

Many events in the future will follow these examples, it’s time for catalog studies
GBM channels vs SPI-ACS
INTEGRAL pointed follow-up

A GRB at 40 Mpc could have produced bright hard X-ray afterglow

Kilonova is powered by radioactive decays, which could produce gamma-ray lines, visible by SPI