# Searches for electromagnetic counterparts of multi-messenger transients with INTEGRAL

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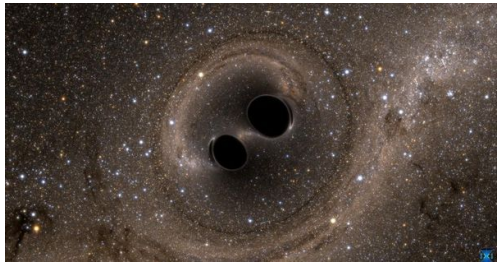
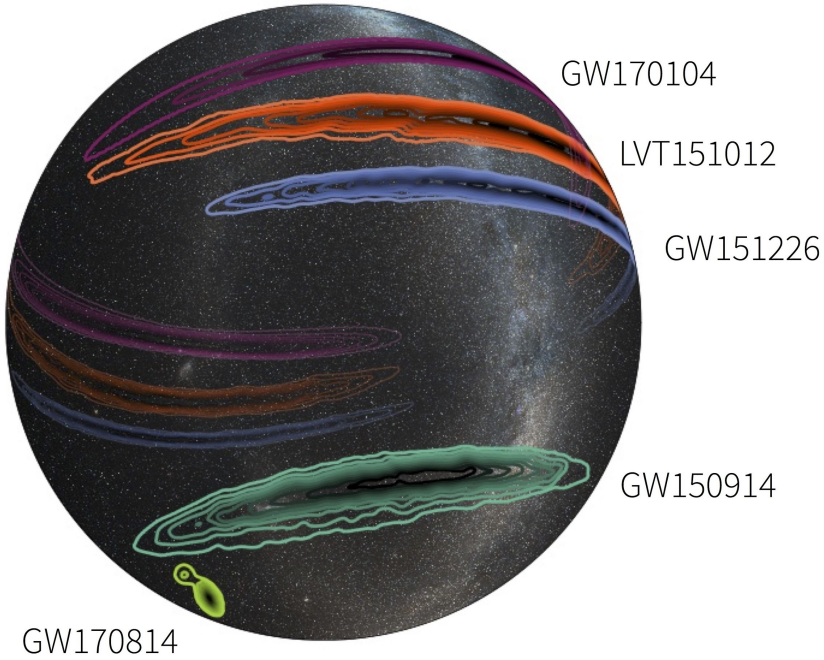
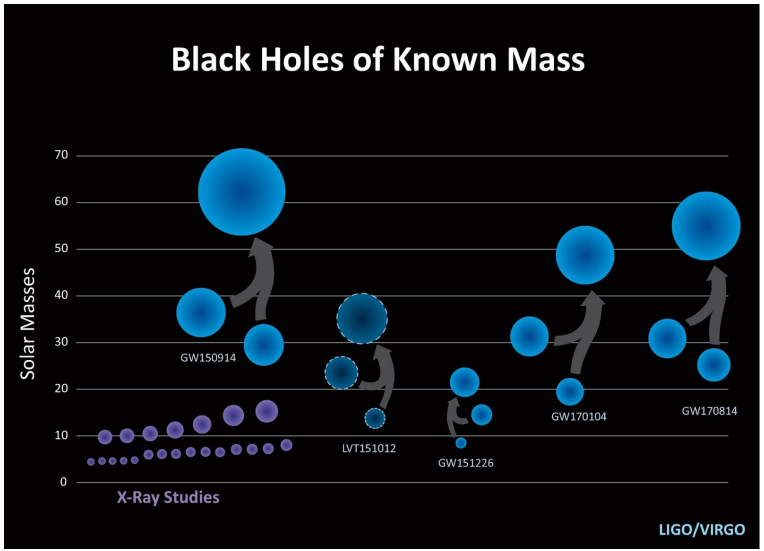
on behalf of the INTEGRAL MM collaboration

Fermi symposium 2017, Garmisch-Partenkirchen

# LIGO/Virgo 2015- August 2017: 5 binary black holes



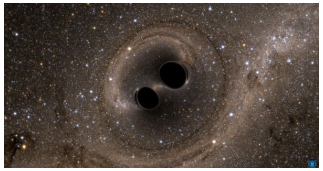


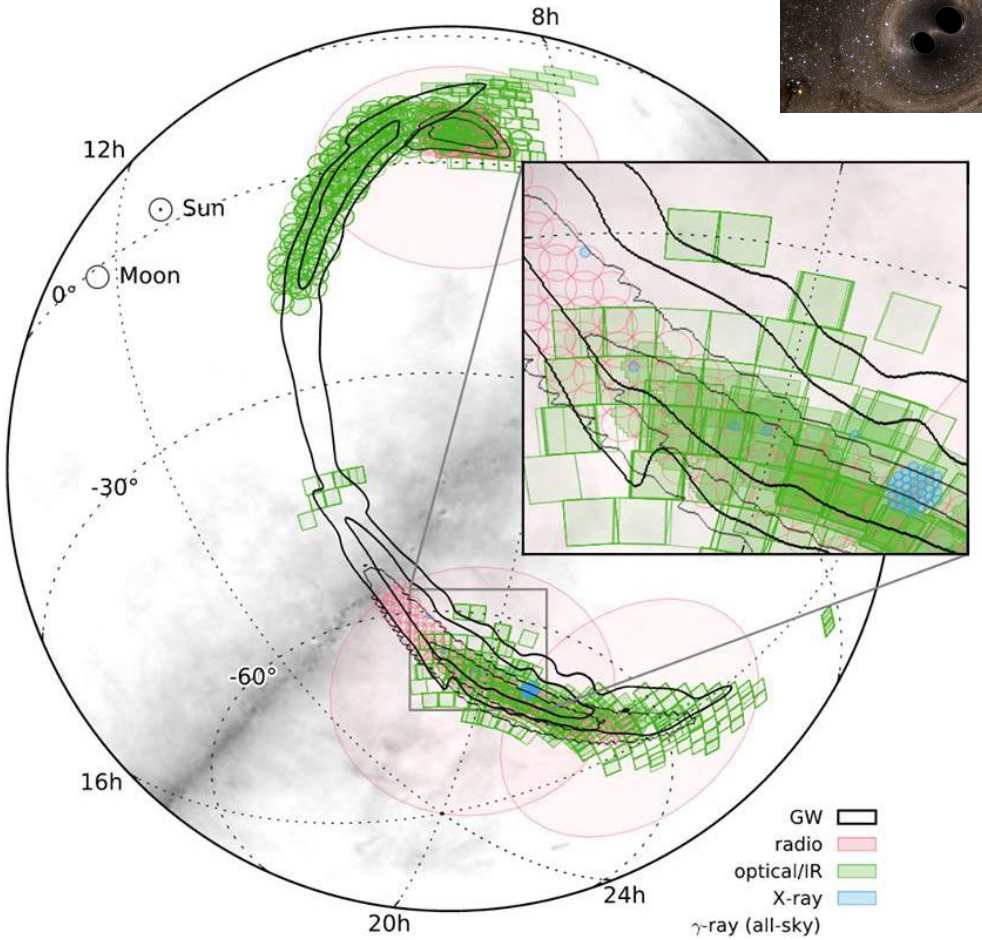



# Electromagnetic follow-up challenges

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



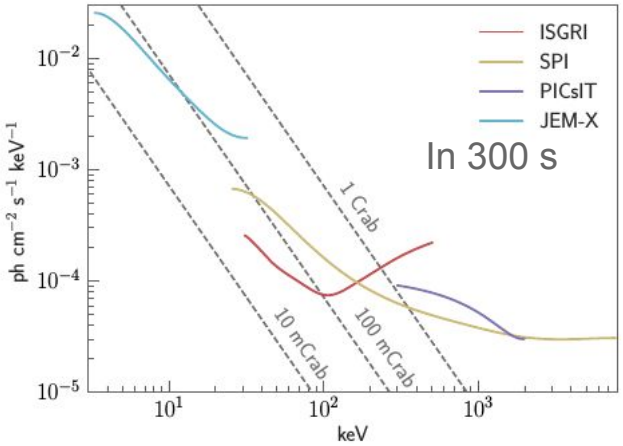


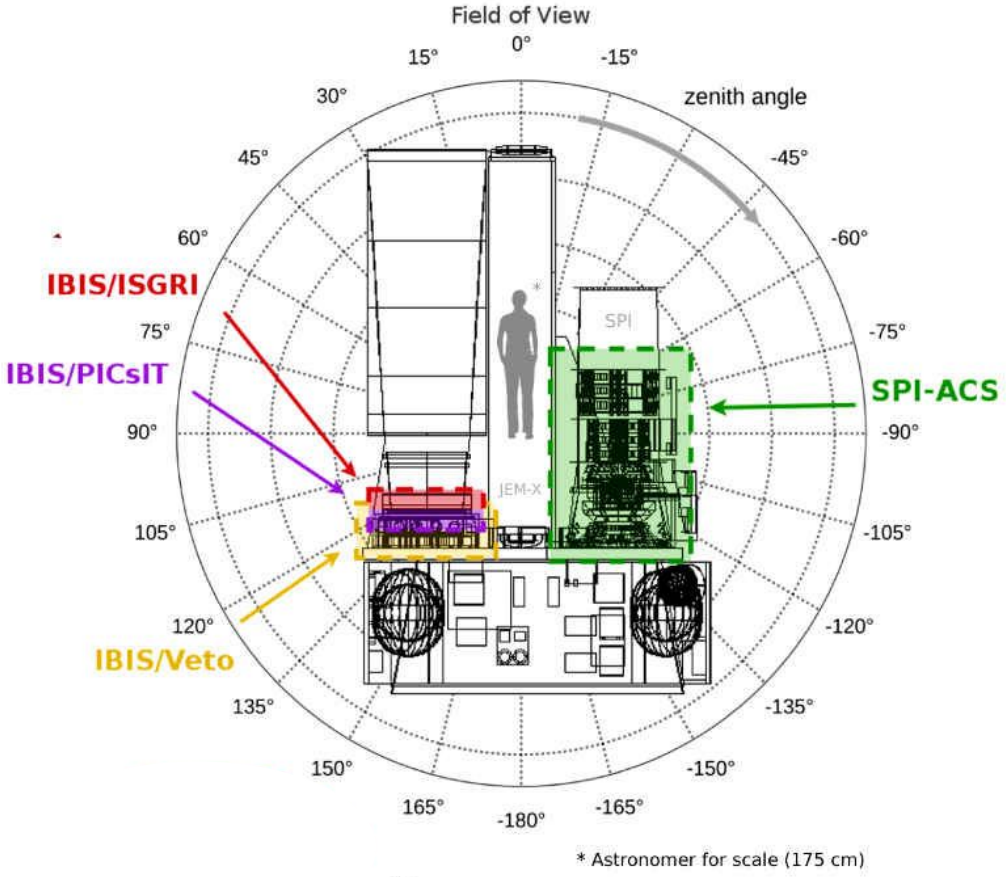

Follow-up of GW150914

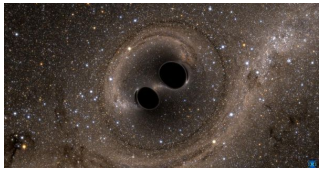
# INTEGRAL

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$^2$).

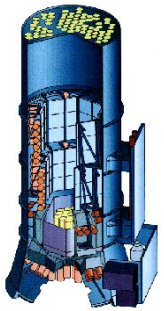


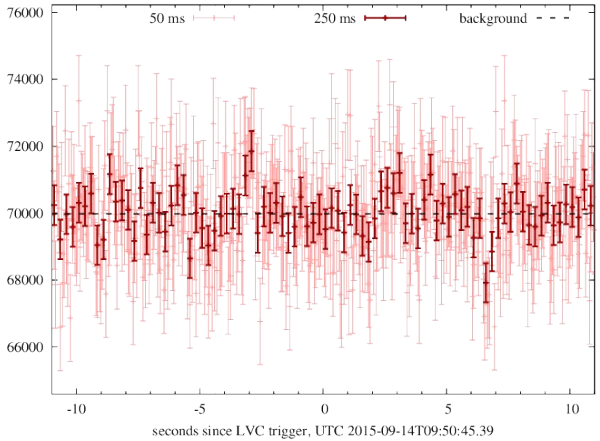



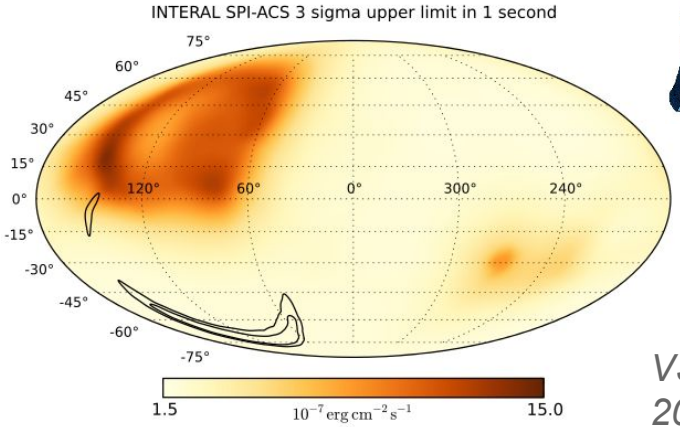


# INTEGRAL observations of GW150914

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





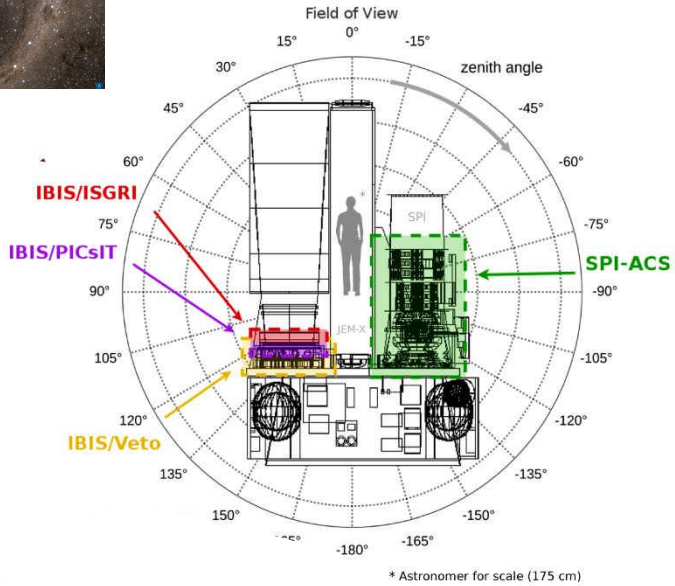

*VS 2016c*

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

# LVT151012

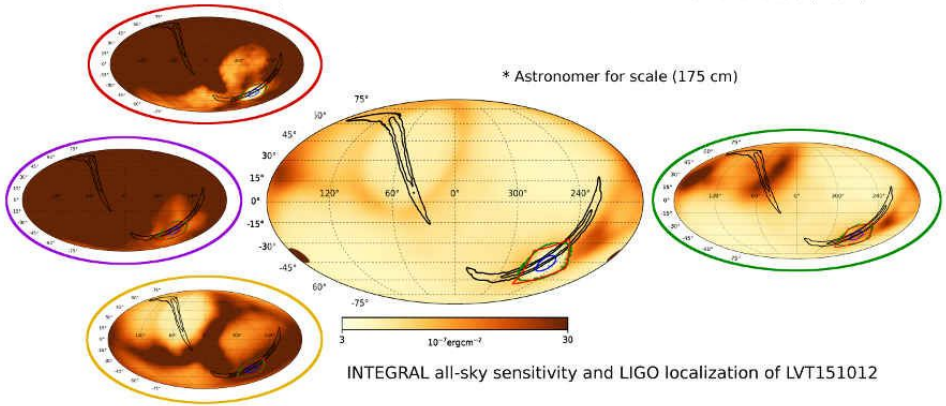
The most distant GW event so far

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

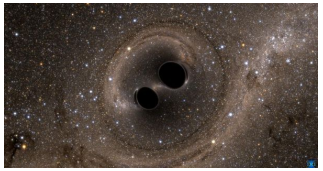



Also allowed us to provide an update and review of the INTEGRAL sensitivities

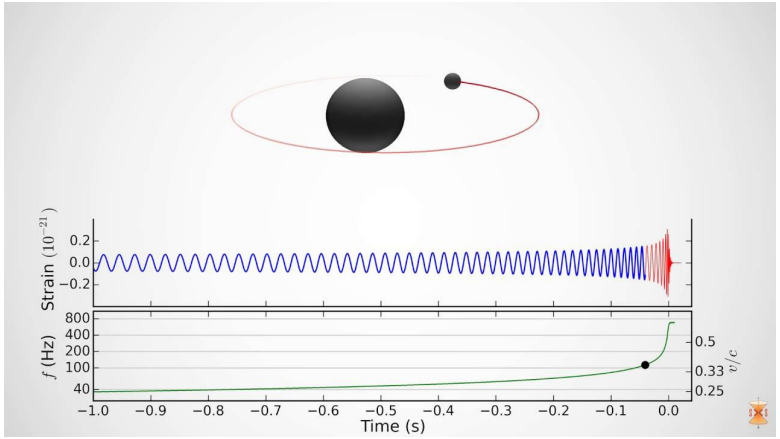
Similar limits were obtained for GW170104, GW170814

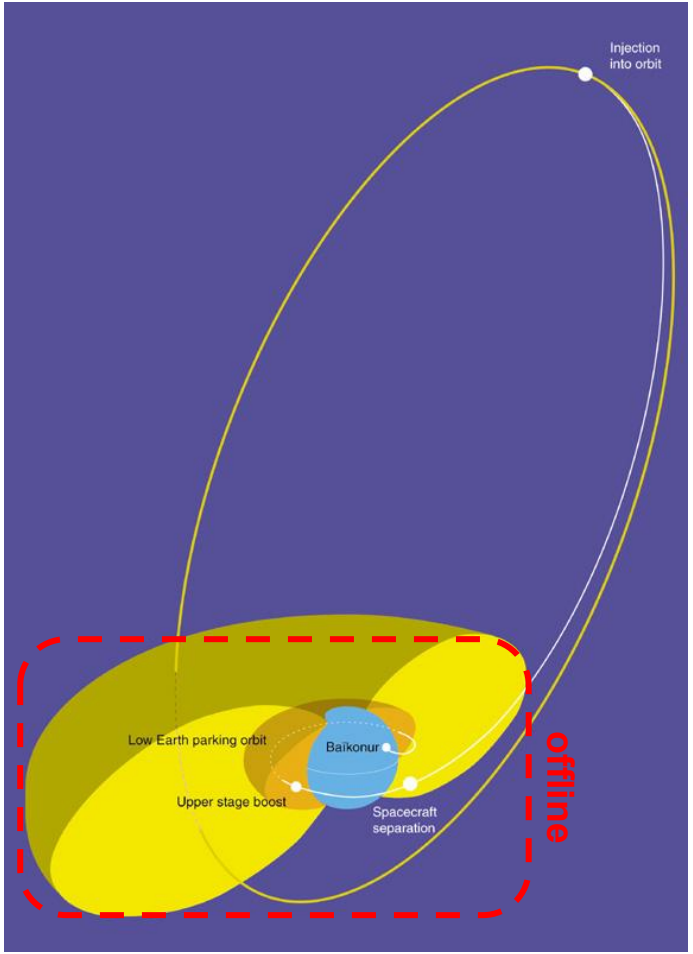


# GW151226



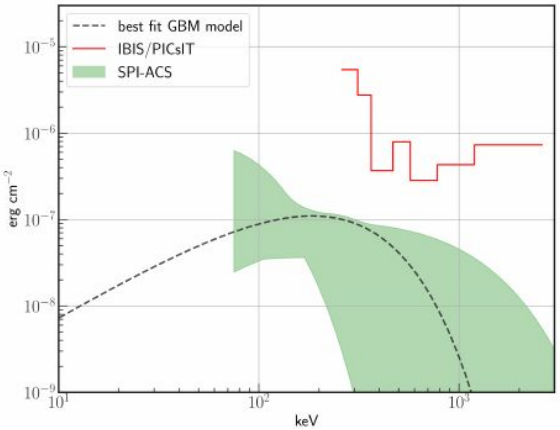
**The only event so far missed** due to the perigee passage (85% duty cycle)



# GW170817+GRB170817A

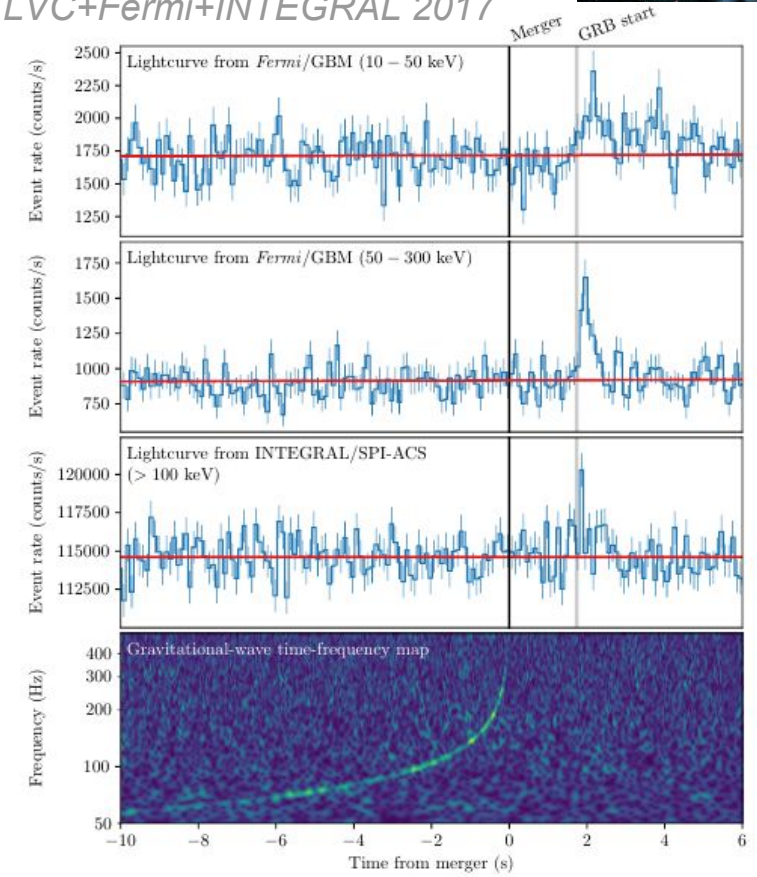
**Binary Neutron Star merger**, discovered by Fermi/GBM and LIGO, was independently detected by INTEGRAL/SPI-ACS (in a very good with Fermi characterization)




*INTEGRAL 2017*

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

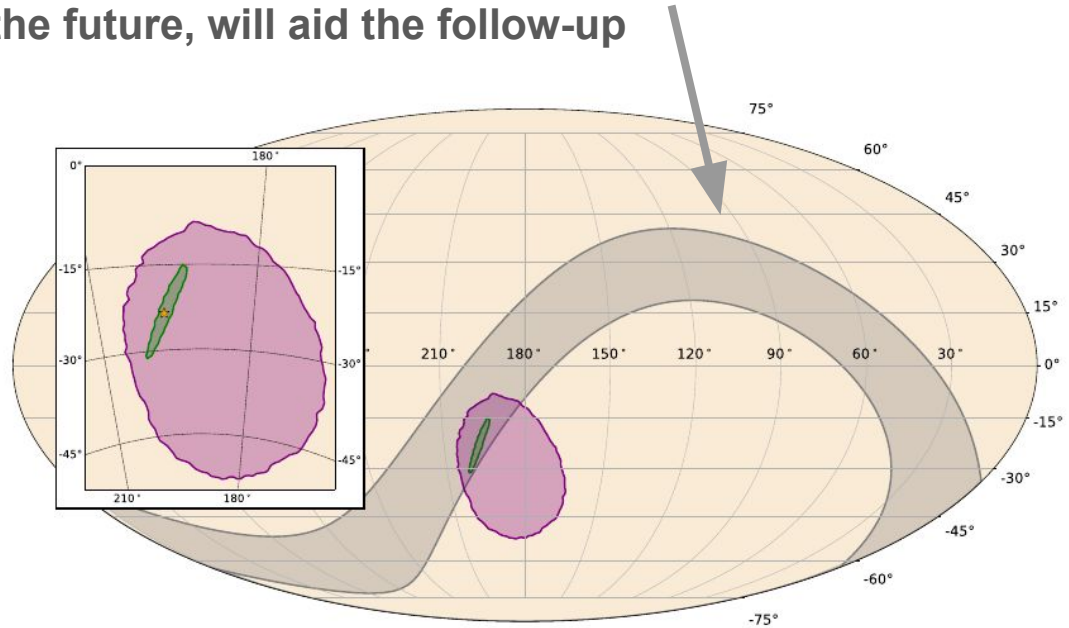
*LVC+Fermi+INTEGRAL 2017*



# 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**

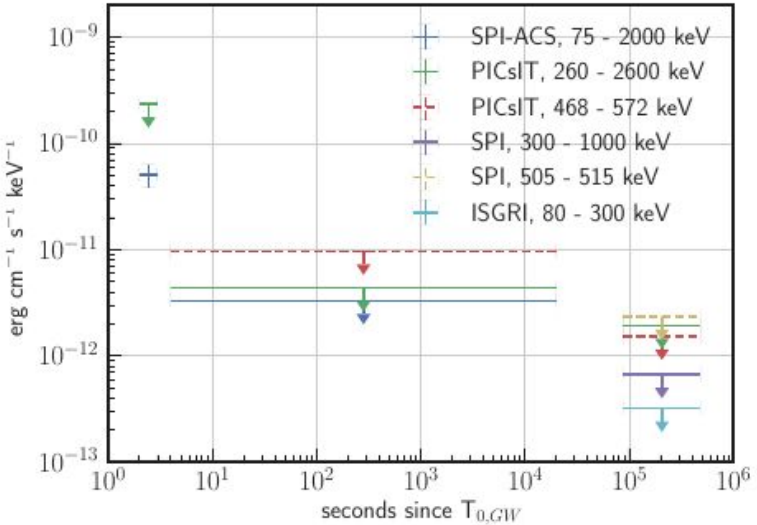
LIGO/Virgo observation alone allows to measure distance to the GW source of **40 Mpc**, exceptional for a short GRB with measured distance, and well within LIGO BNS horizon

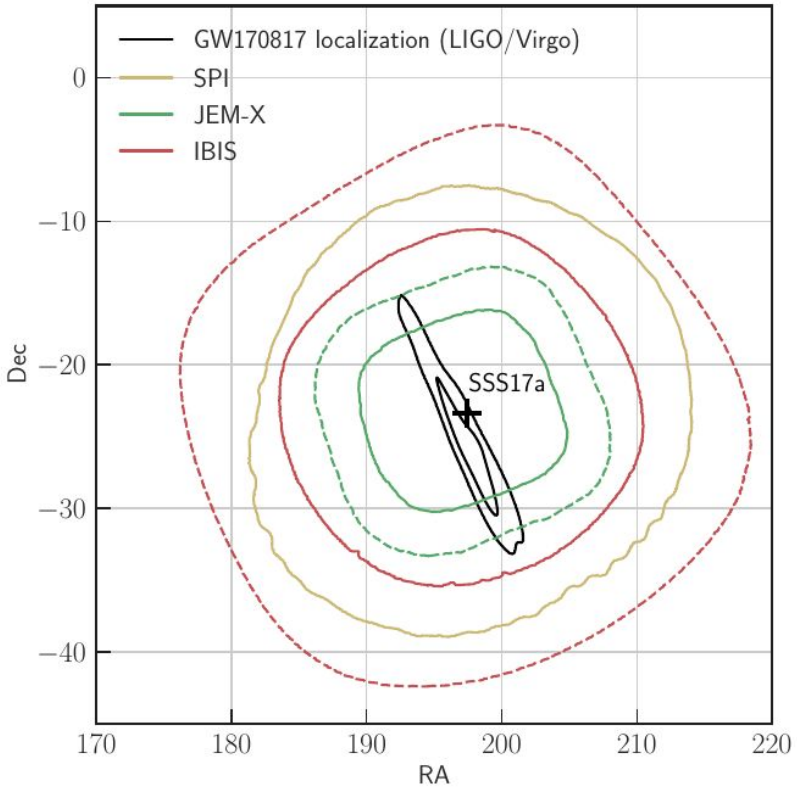



*Svinkin 2017* *LVC+Fermi+INTEGRAL 2017*

# INTEGRAL pointed follow-up

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.**




*VS 2017*

# 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**

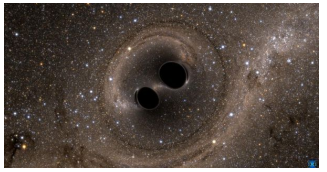
Detection of a GRB from an off-axis merger implies much more frequent GRB-BNS associations, which **might happen regularly in the next LIGO-Virgo run (from late 2018)**

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**!

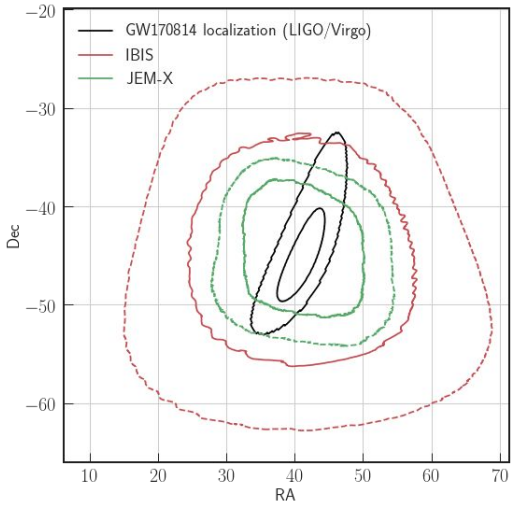
**Neutrino follow-ups** remain very promising and tentative MM detections might soon reach the level of solid evidence

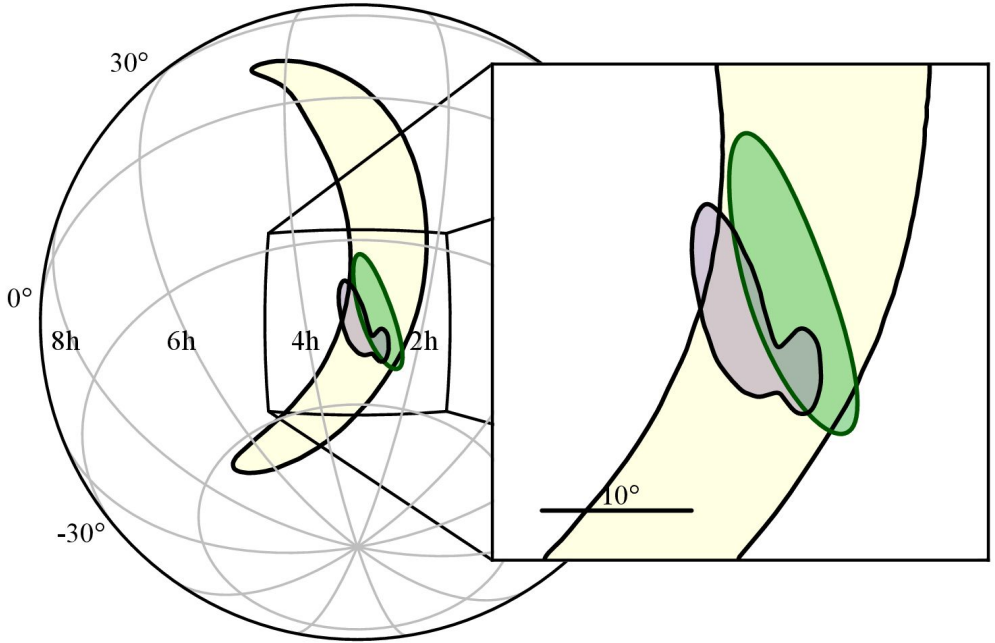
# Backup



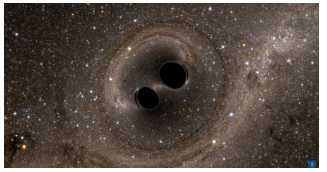
# GW170814 first joint LIGO+Virgo detection

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



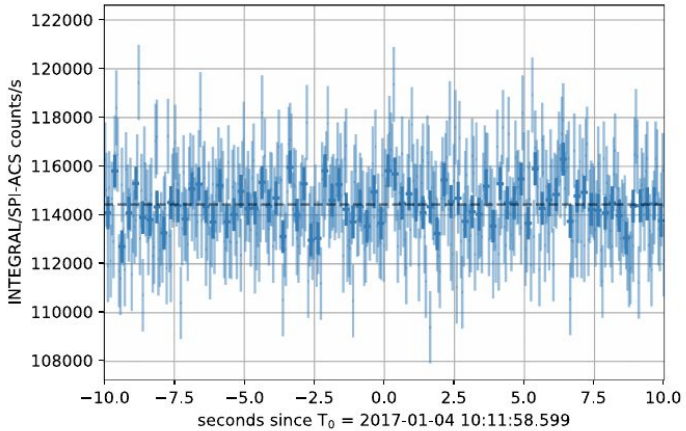



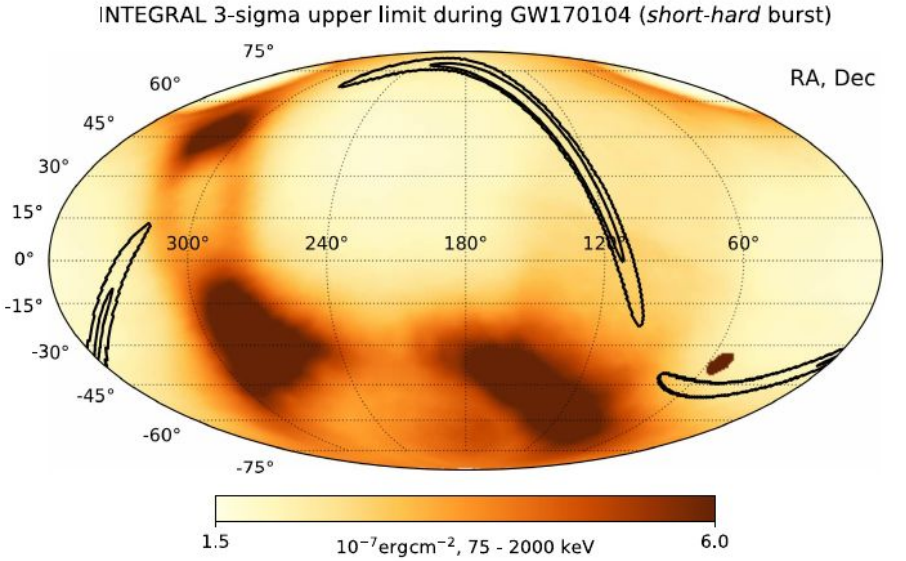

This case is not expected to be very frequent, but it's vital for exploring the complete localization, (INTEGRAL work in progress)



# GW170104

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

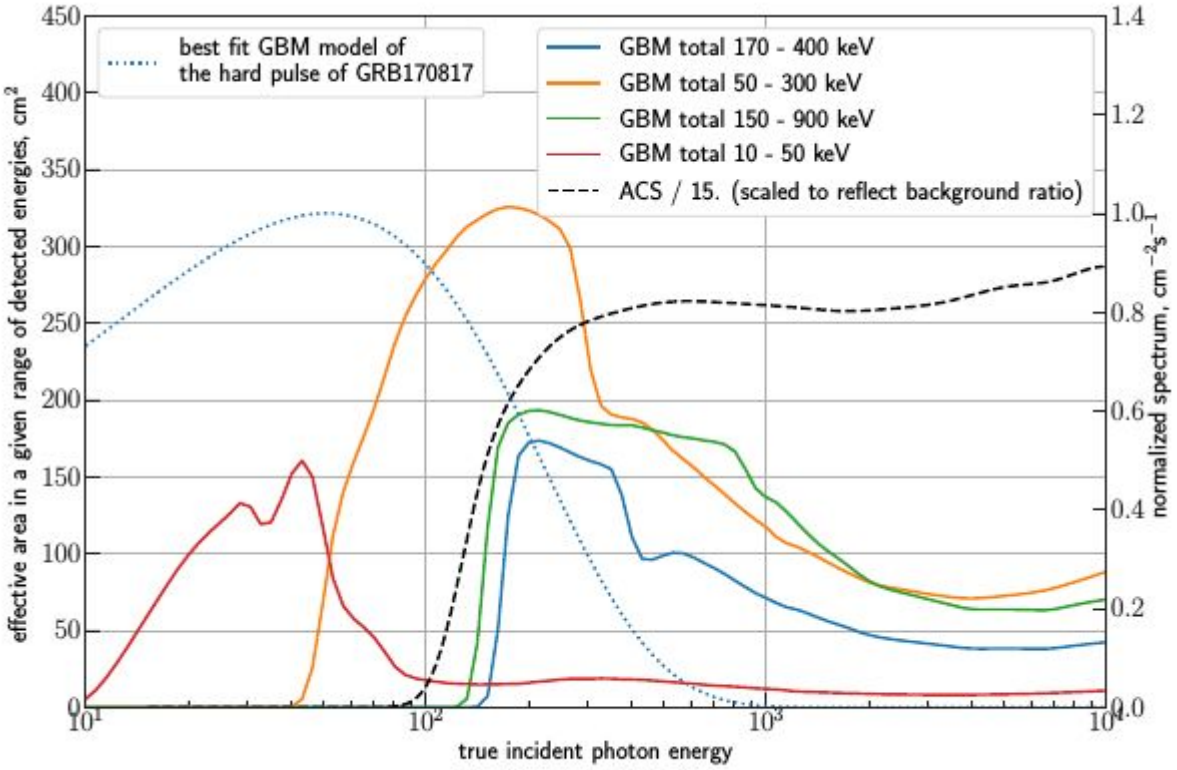



*VS 2017*

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