INTEGRAL follow-up of the gravitational wave events

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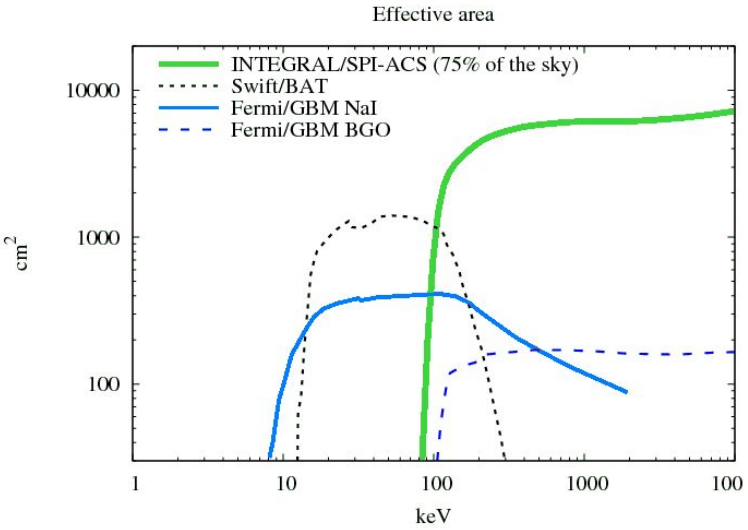
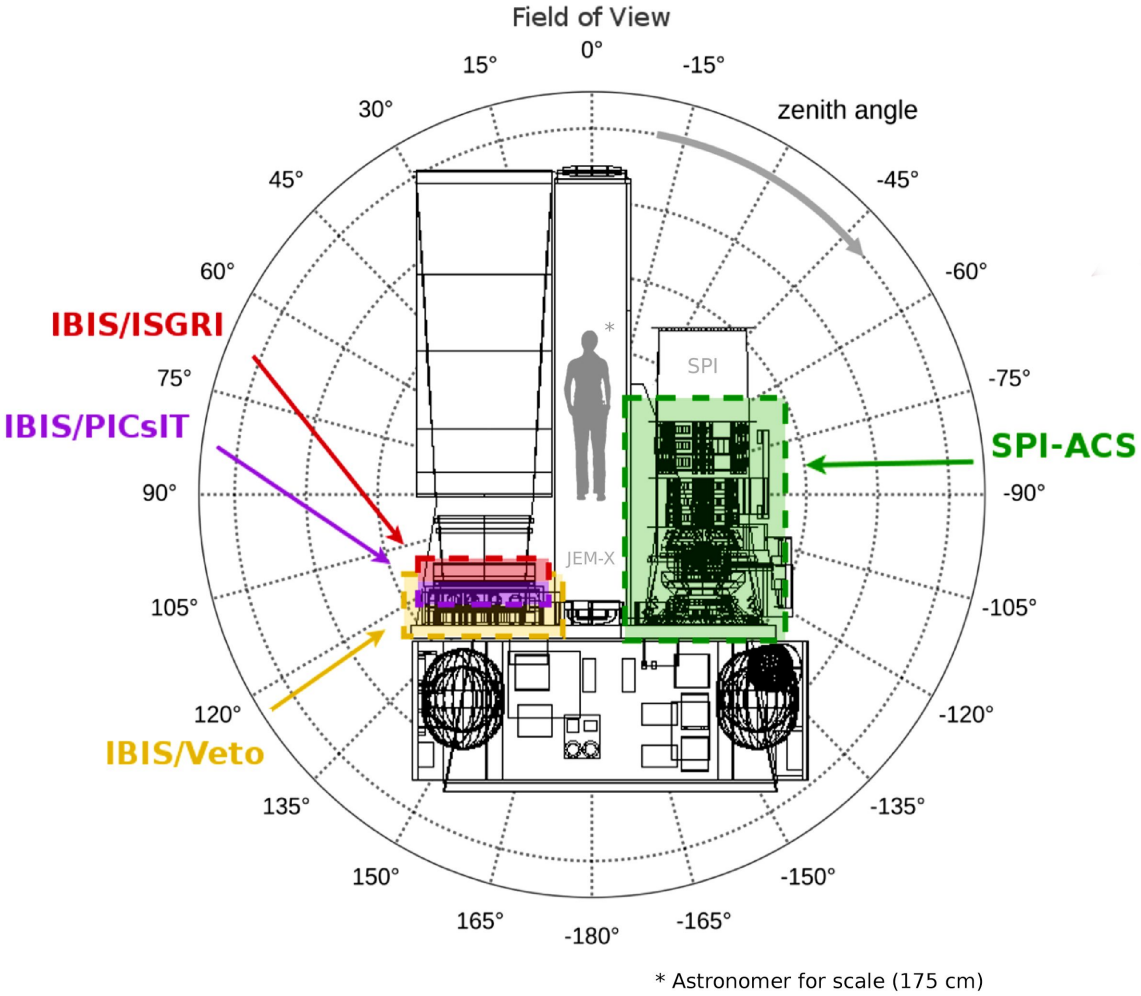
X-ray Universe 2017
Roma

Substantial fraction of the **INTEGRAL** mass is detectors

>~100 keV - gamma rays are stopped by substantial mass: they typically reach active medium: principal detectors or active shields





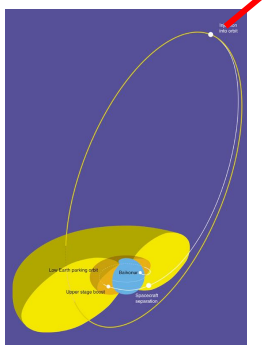
* Astronomer for scale (175 cm)

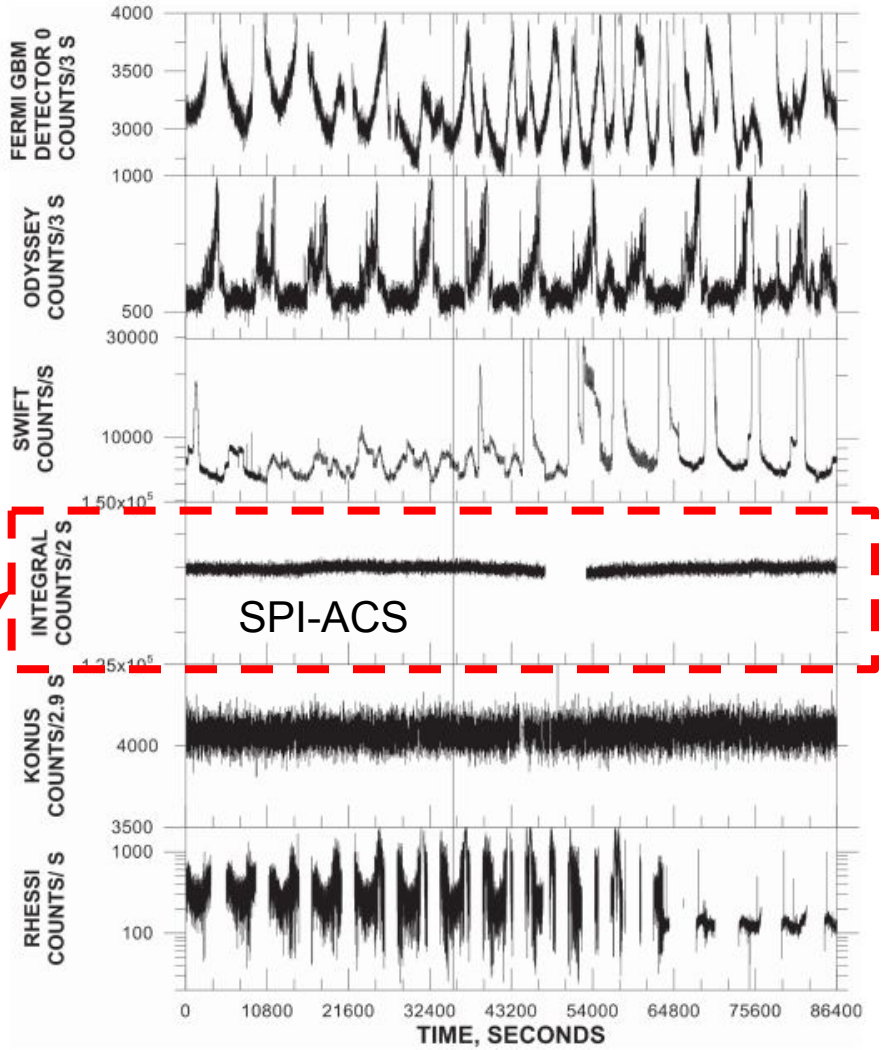
Orbit and background

Owing to its very elongated orbit, INTEGRAL features typically very **stable background** on scale of 2 days.

Enhanced high particle flux provides a mild disadvantage.

And no Earth shadow!



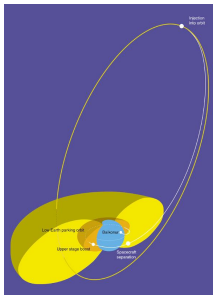


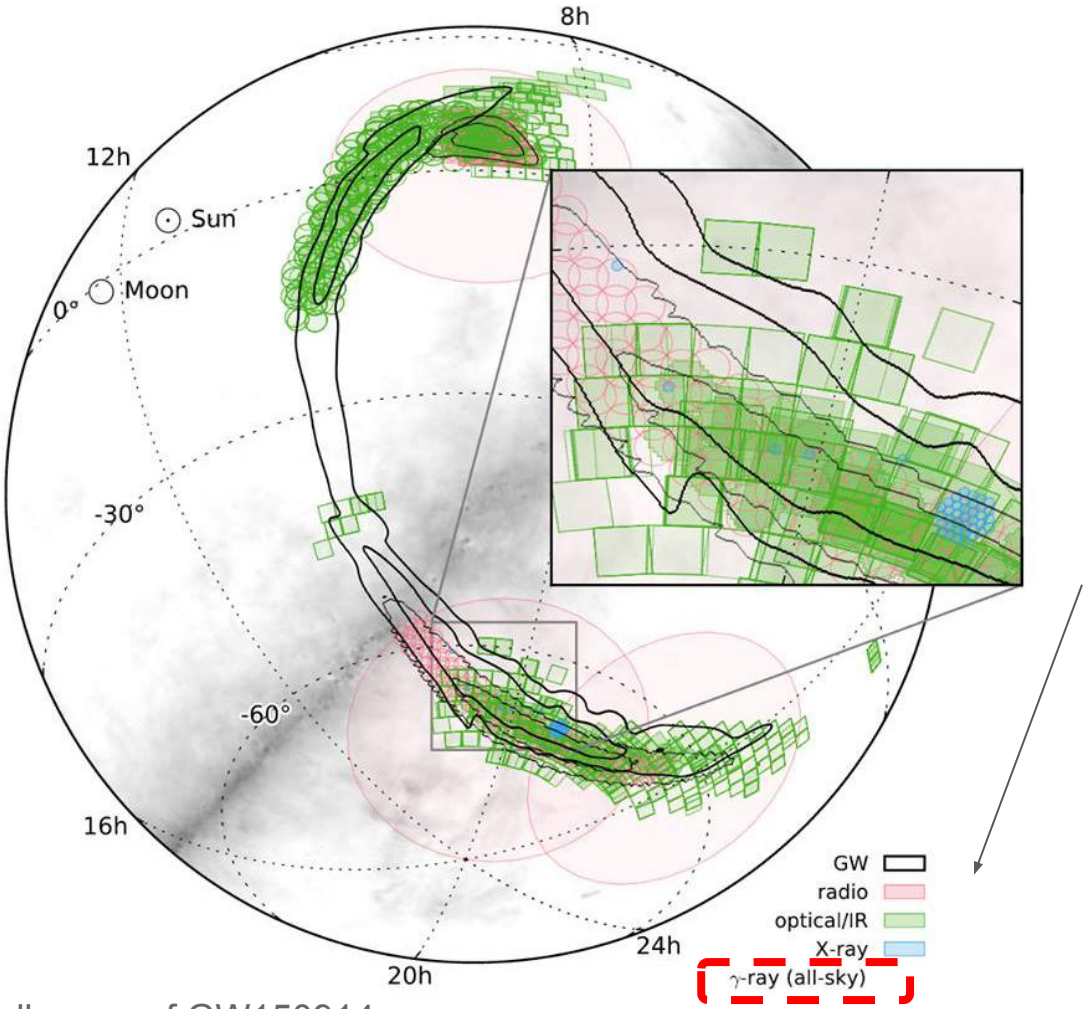
Hurley et al 2016

Electromagnetic Follow-up of GW

GW events localizations are very extended

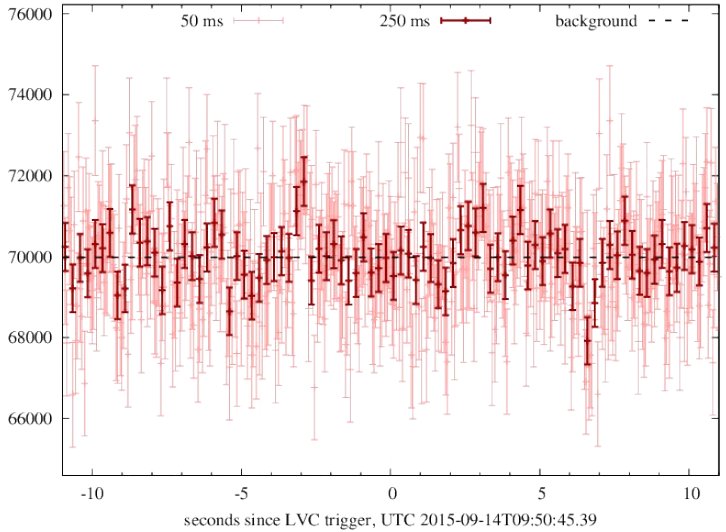
Only **INTEGRAL**, and Konus-Wind (albeit with lower sensitivity and resolution) have true instantaneous all-sky coverage

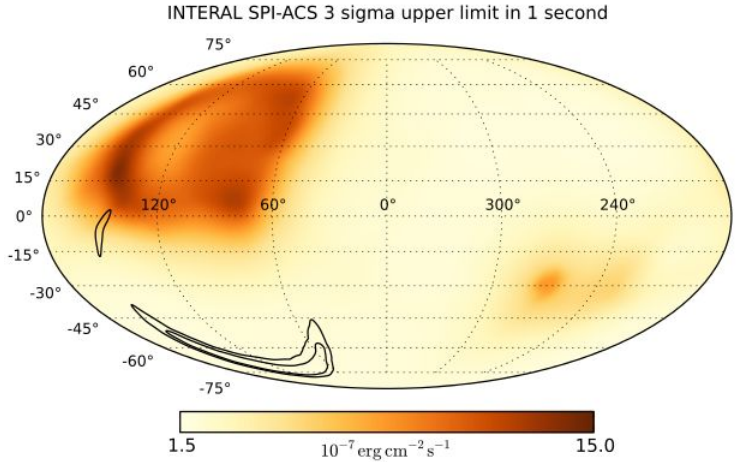




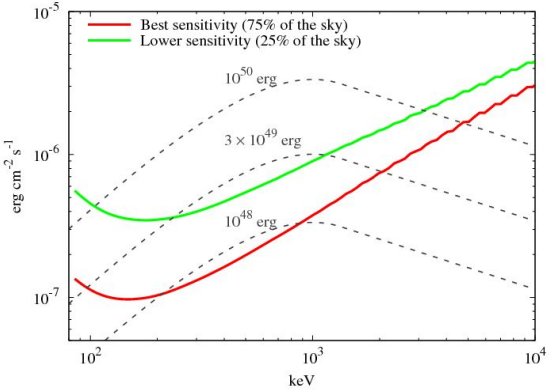
Follow-up of GW150914

Fist Binary BH merger GW150914: upper limit



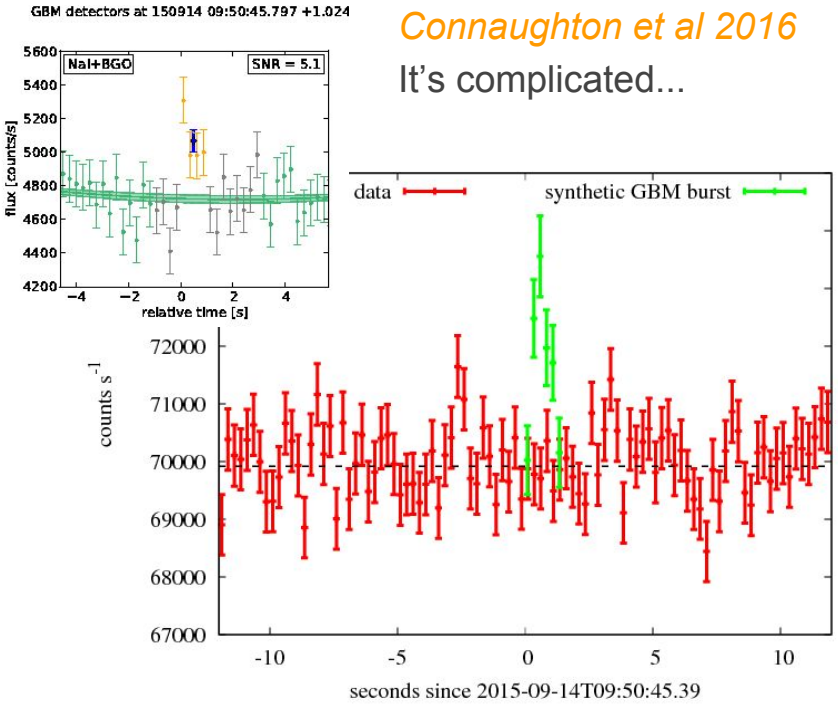


10^{-6} - ratio of energy in 75-2000 keV in 1 second to GW



The region was in a **very favorable orientation** for SPI-ACS!
Favorable background conditions too.

Fermi/GBM candidate 2.9 sigma



Connaughton et al 2016

It's complicated...

Some spectra, soft and weak, could be marginally compatible with SPI-ACS and GBM data, but **the probability is likely low**

But, given that the the excess in Fermi/GBM is limited to high energy, soft spectrum implies no detection.

Greiner et al 2016

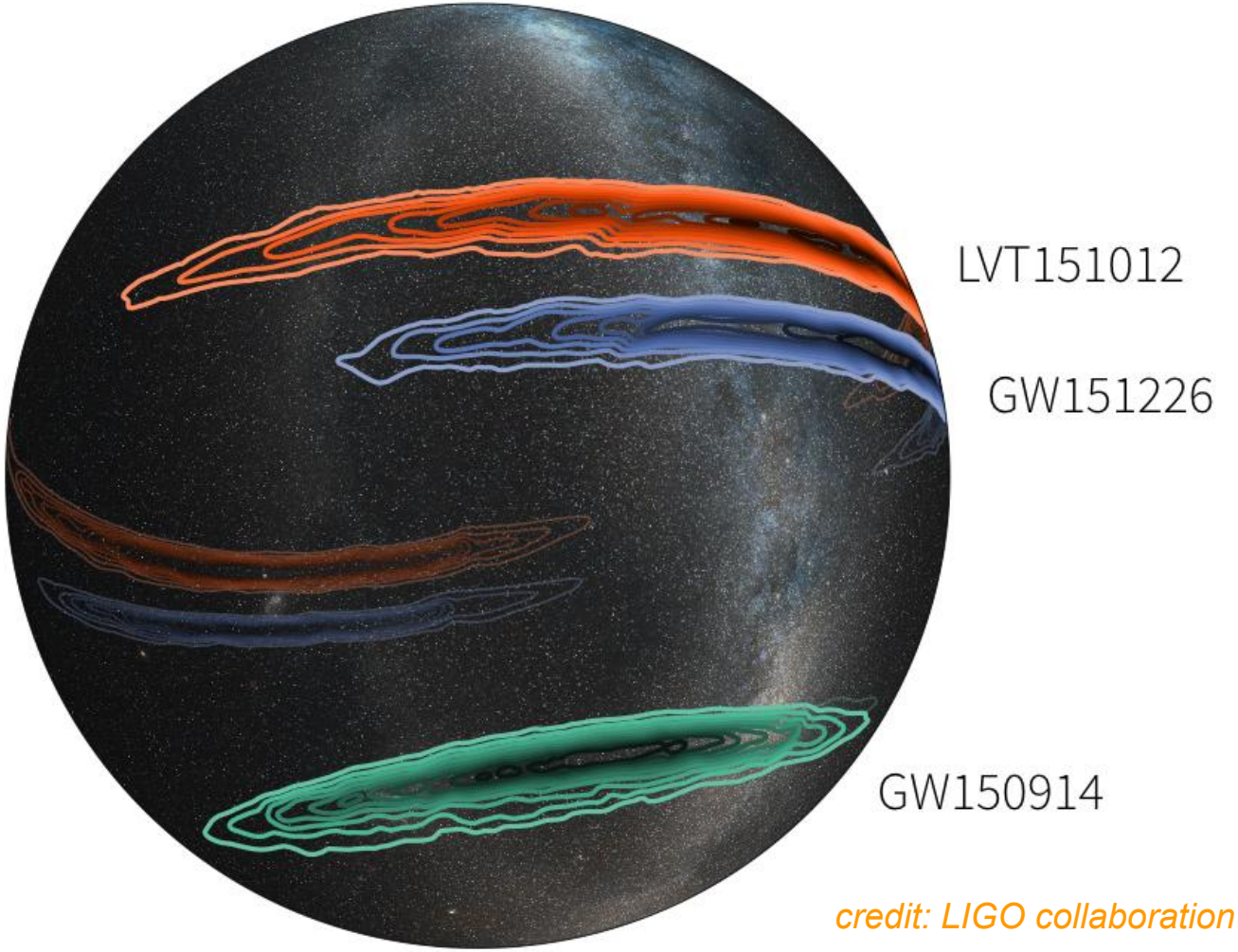
Fully taking into account statistical and systematic uncertainties in the GBM parameter estimation is required, **parameter space is very complicated!**

Rescaling real GRB with a moderately hard spectrum assuming **best fit fluence of GBM-GW150914,** results in **15 sigma** detection: **good margin**!

The collaboration is still ongoing, very useful for future observations!

LIGO O1

September 2015
to January 2016

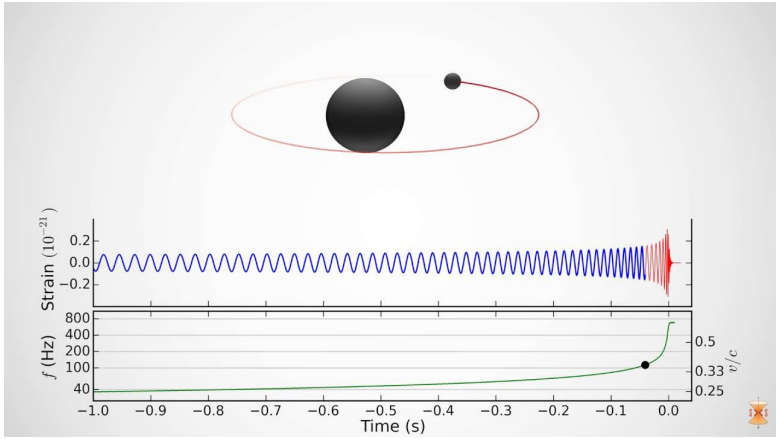


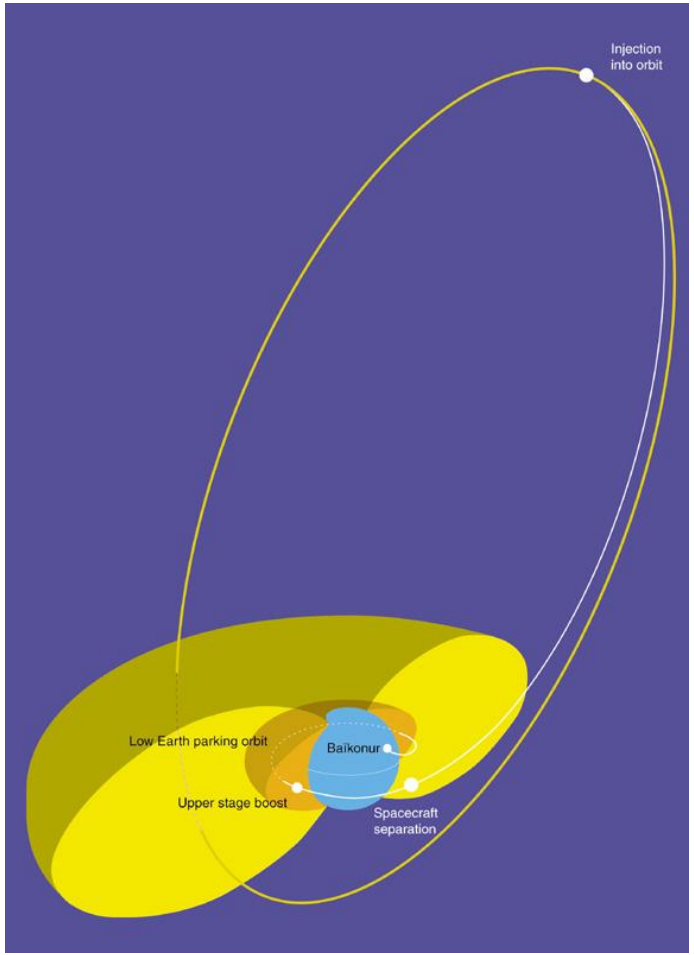
credit: LIGO collaboration

GW151226?

No data for hours around the event

With current orbit, duty cycle 85%...



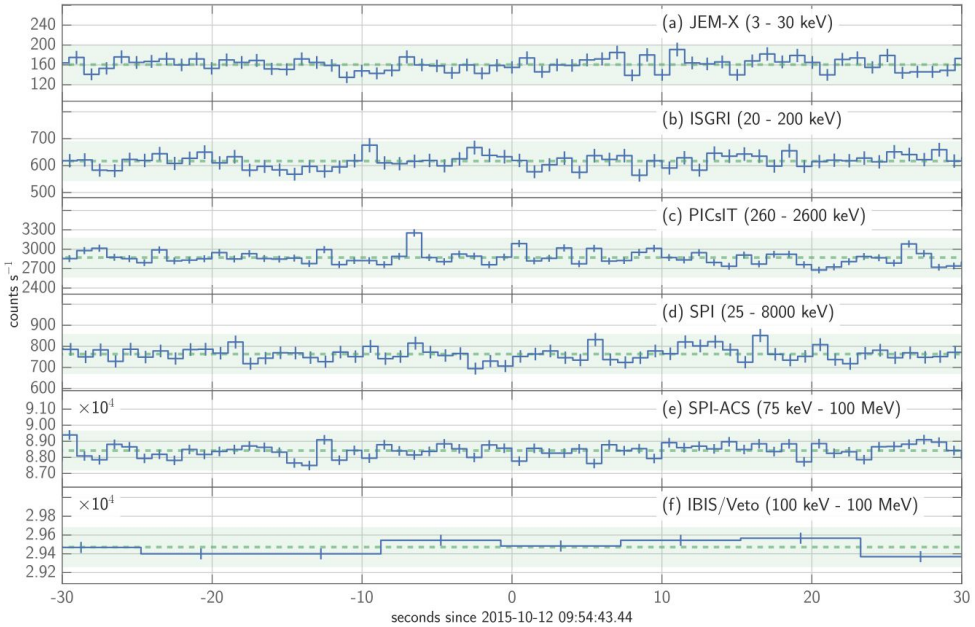


Compare e.g. to about 50% of Fermi/GBM

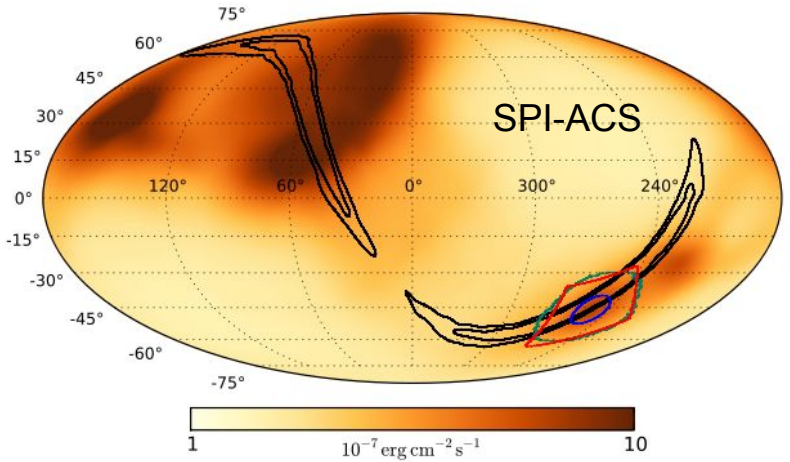
LVT151012: SNR of 9.6, FAP of 2%

VS17

Rare lucky case: peak of the localization is in the FoV

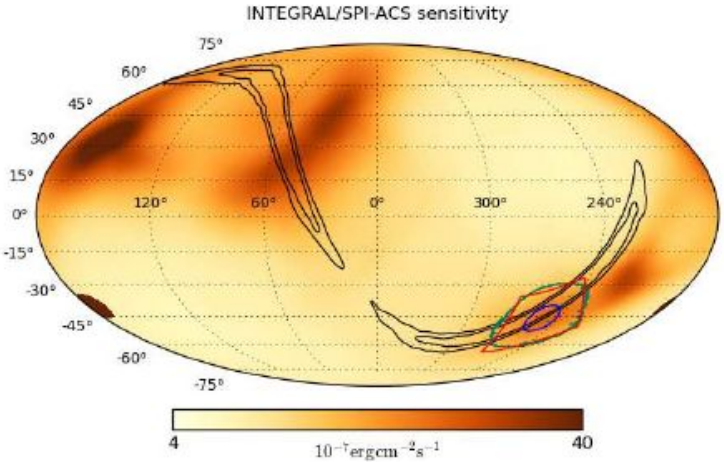


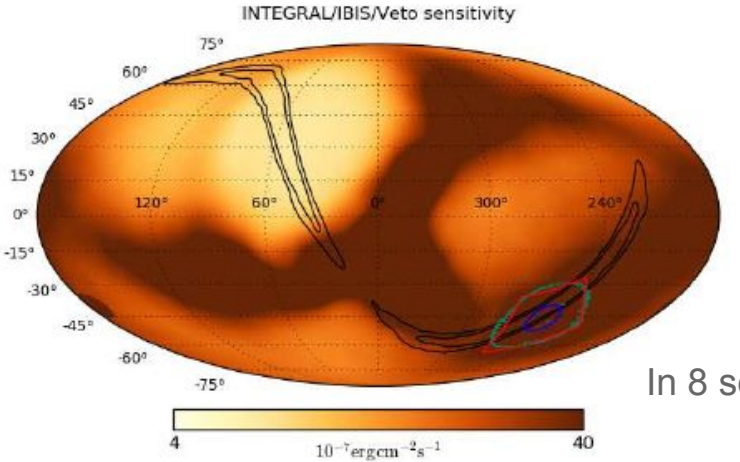
1 second, α=-0.5, E_{peak}=600 keV

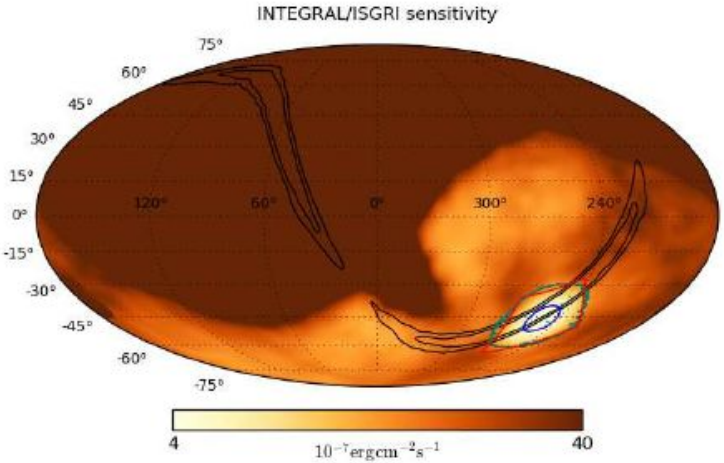


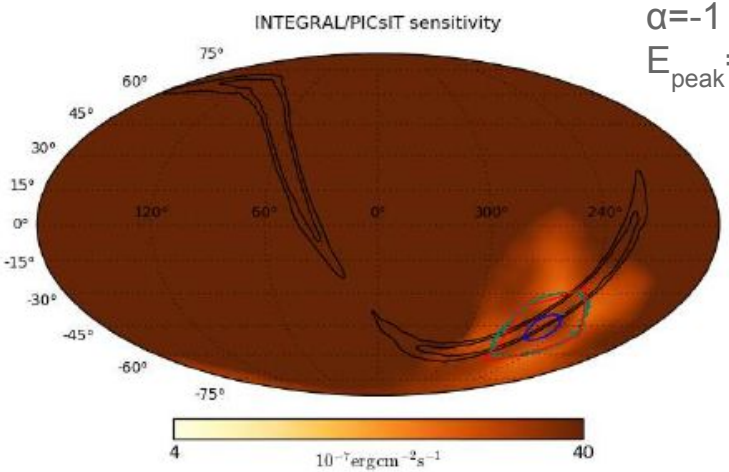
Depending on the true source location, spectrum, and duration, the best limit may come from SPI-ACS, IBIS/Veto, ISGRI, PICsIT, SPI, or JEM-X.

LVT151012: complicated case: all-sky









In 8 seconds

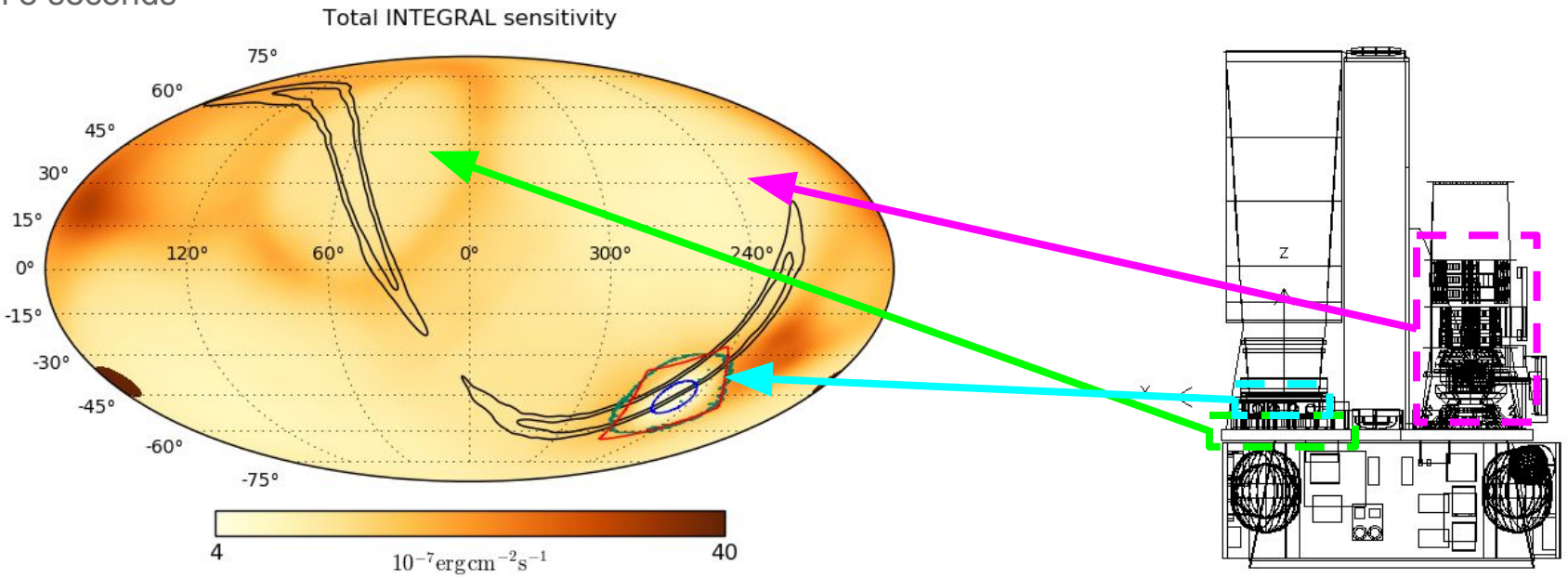
α=-1

E_{peak}=300 keV

Relative contribution of PICsIT and ISGRI reverses for very hard bursts

LVT151012: complicated case: all-sky

In 8 seconds

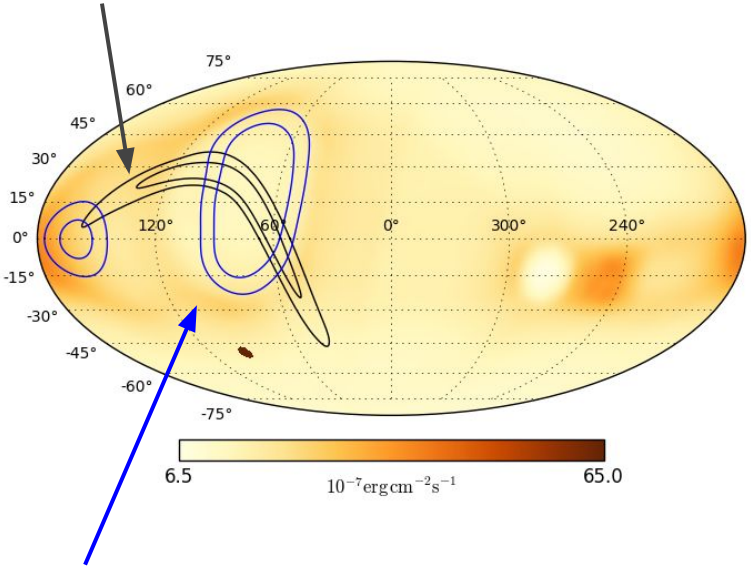


Total sensitivity is within 30% from the best in 95% of the sky, SPI-ACS only - in 75%

All-sky localization

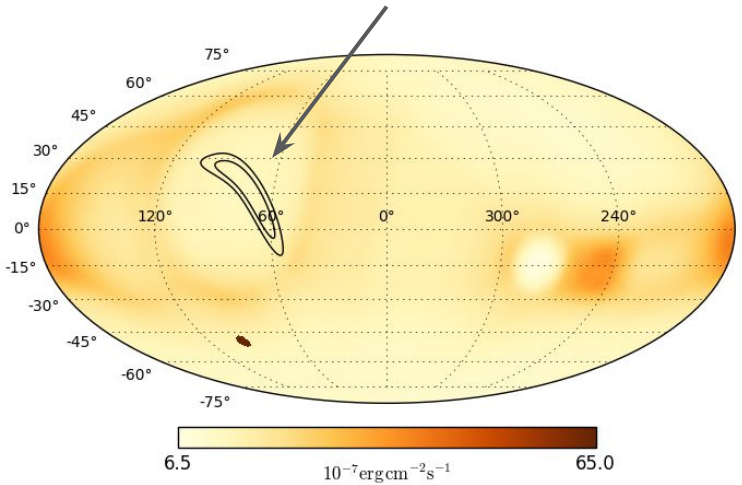
synthetic NS merger event at 200 Mpc

LIGO localization



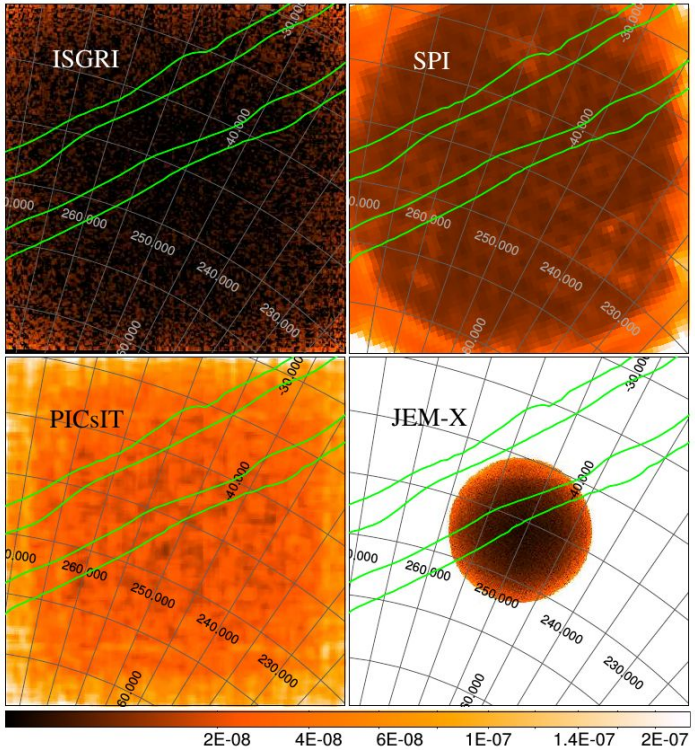
INTEGRAL localization

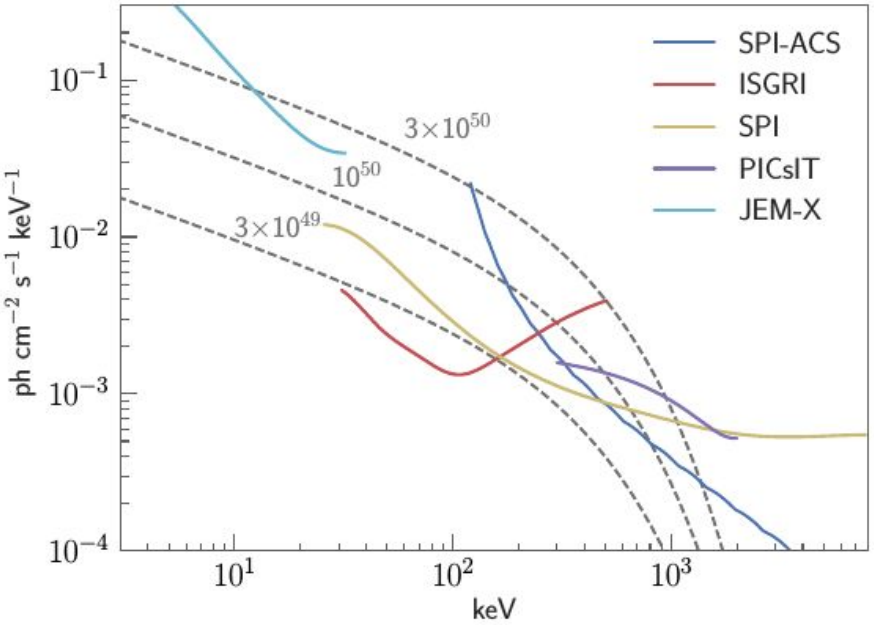
INTEGRAL + LIGO localization



INTEGRAL FoV observations of LVT151012

demonstrate that observations with INTEGRAL pointing instruments can provide tight upper limit, allow us to provide an **up-to-date review of INTEGRAL sensitivity, after 15 years in orbit**.





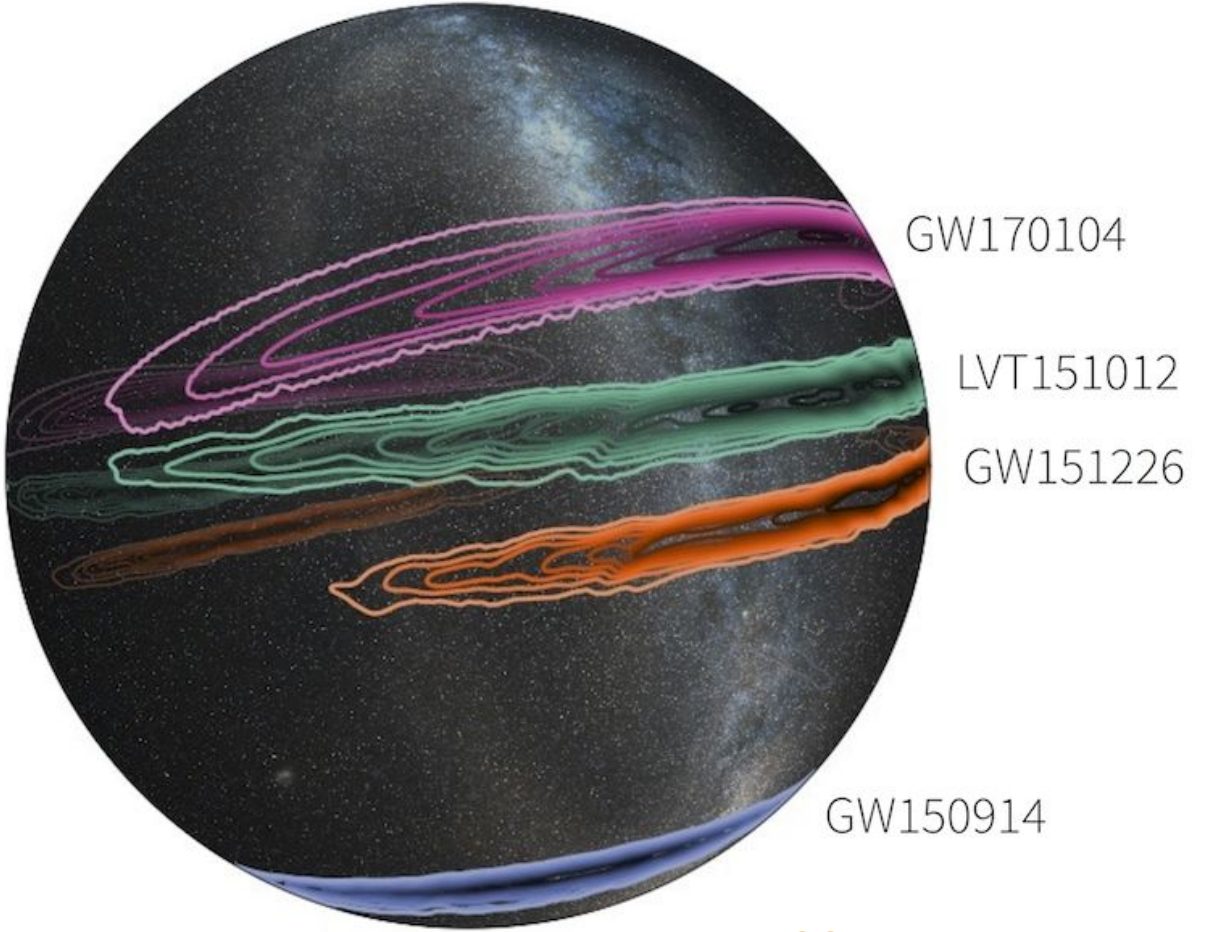
LIGO O2

Ongoing since December 2016

GW 170104, another binary BH merger reported on June 1.

In total **6 possible events** were identified as of April 23

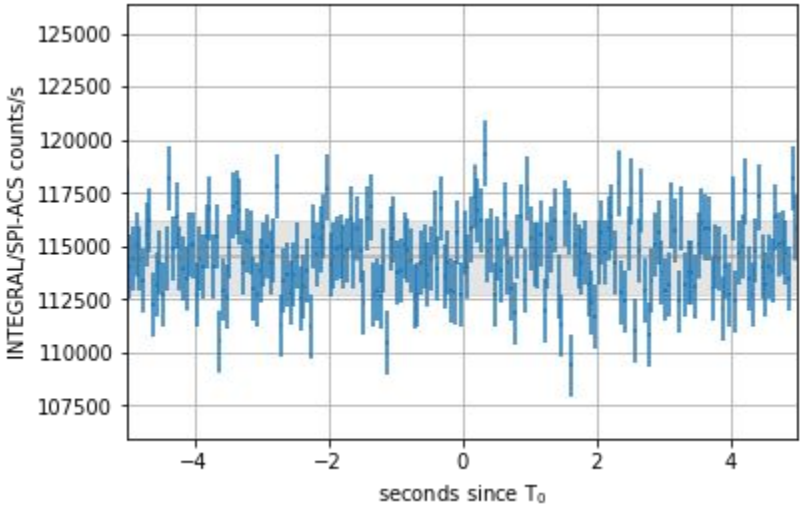
http://www.ligo.org/news.php for public updates!

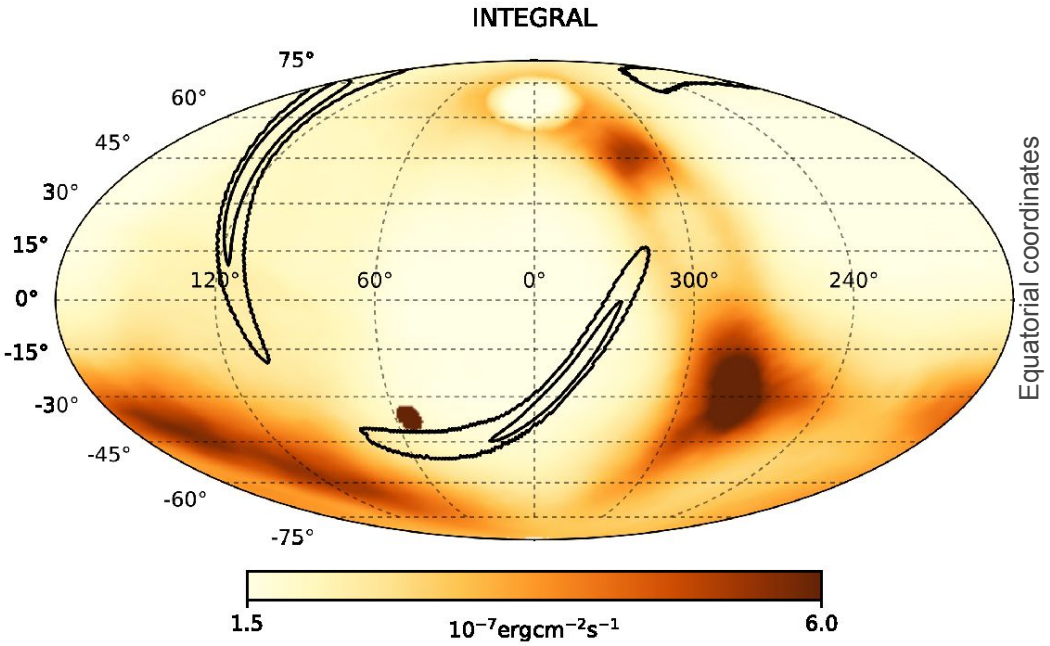


credit: LIGO collaboration

INTEGRAL upper limit on counterpart of GW170104

Down to 1.6 x 10^{-7} erg cm^{-2} for a 1 s duration, 4.5 x 10^{-7} erg cm^{-2} or 10 s, and 5 x 10^{-8} erg cm^{-2} for 0.1 s.





No significant excess is detected.

1 second, α=-0.5, E_{peak}=600 keV

Good but not perfect orientation

VS et al in preparation

Conclusions and outlook

- INTEGRAL features exceptionally **truly all-sky sensitivity**, **very stable background**, and **unprecedented effective area above 100 keV**, making it particularly suited for transient follow-up searches.
- Multimessenger transient follow-up revealed **importance of collaboration and intercalibration** between GRB detectors: INTEGRAL/SPI-ACS, Fermi/GBM, Konus-Wind, AstroSAT, AGILE, POLAR, CALET/CGBM, etc…
- The case of LVT151012 required **extensive review of of all-sky and field-of-view sensitivity of INTEGRAL after 15 years in orbit**.

- At this point **3+1 binary blackhole mergers were reported by LIGO and no group claimed a secure EM counterpart**.
- **INTEGRAL has observed full localization regions for 2+1 LIGO events,** the searches are ongoing as LIGO continues to deliver exciting follow-up opportunities, looking forward to binary NS merger!