INTEGRAL upper limits on γ-ray emission to GW150914

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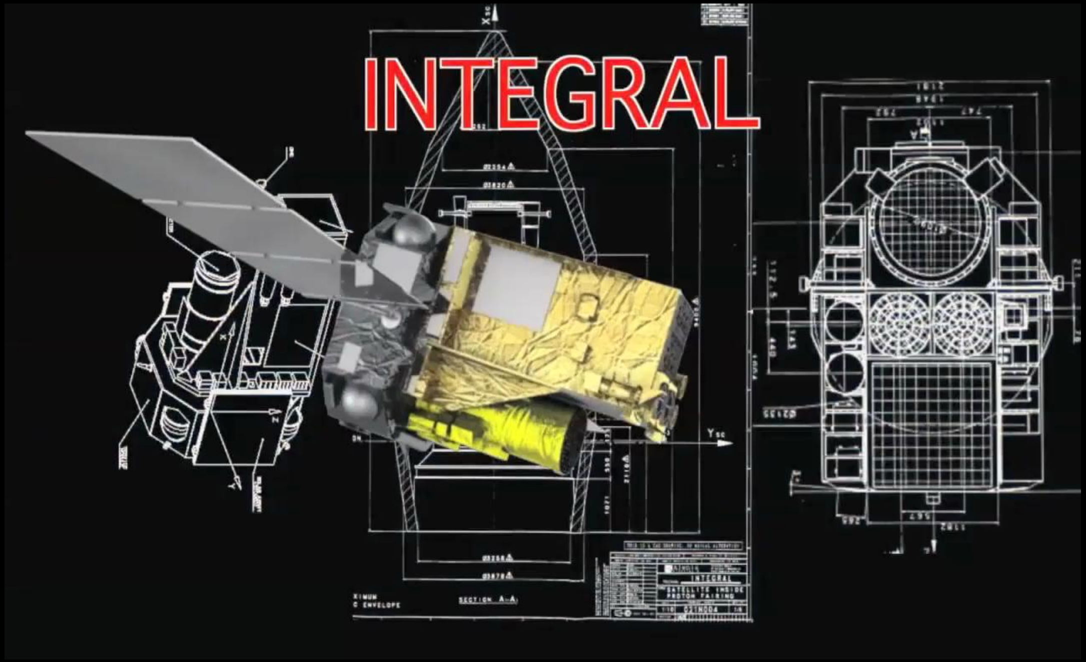
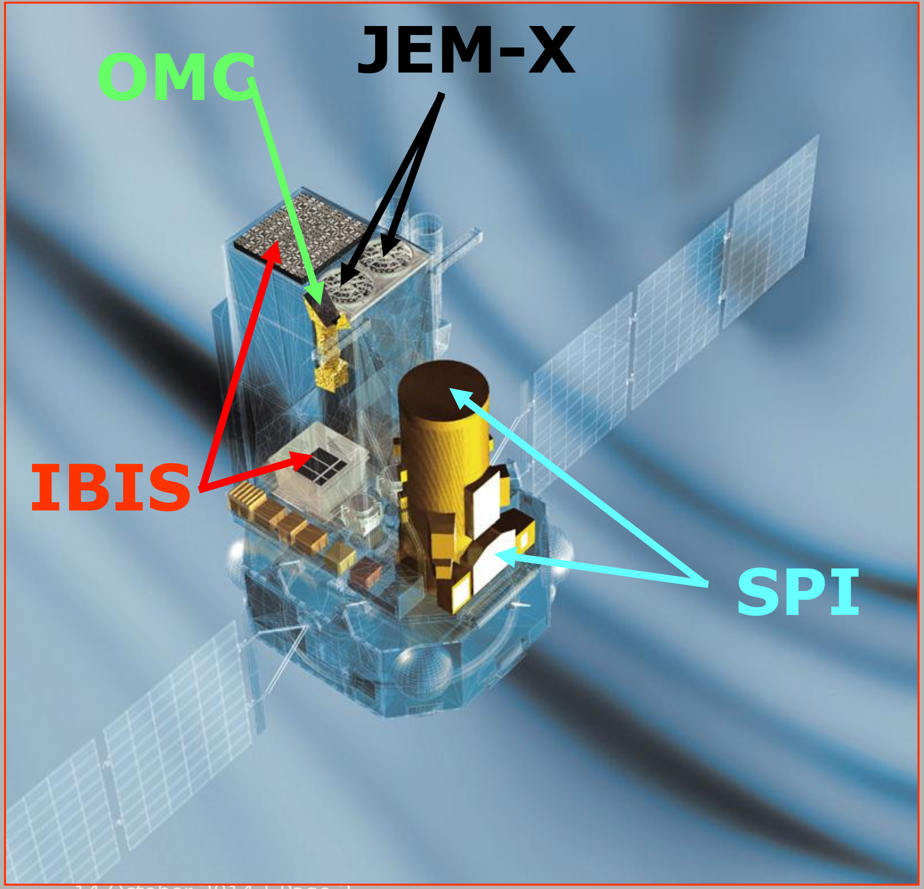
on behalf of the
INTEGRAL GW Team
Ligo-Virgo MoU 5/4/2014



INAF after GW150914, Monte Mario, 11 aprile, 2016

➢ INTErnational Gamma-Ray Astrophysics Laboratory

- ESA's 2nd gamma-ray mission after COS-B (1975)
- Launched 17 October 2002
- Highly elliptical orbit (~72 hrs); 58 hrs of continuous science, now a bit less



➢ **4 instruments:**

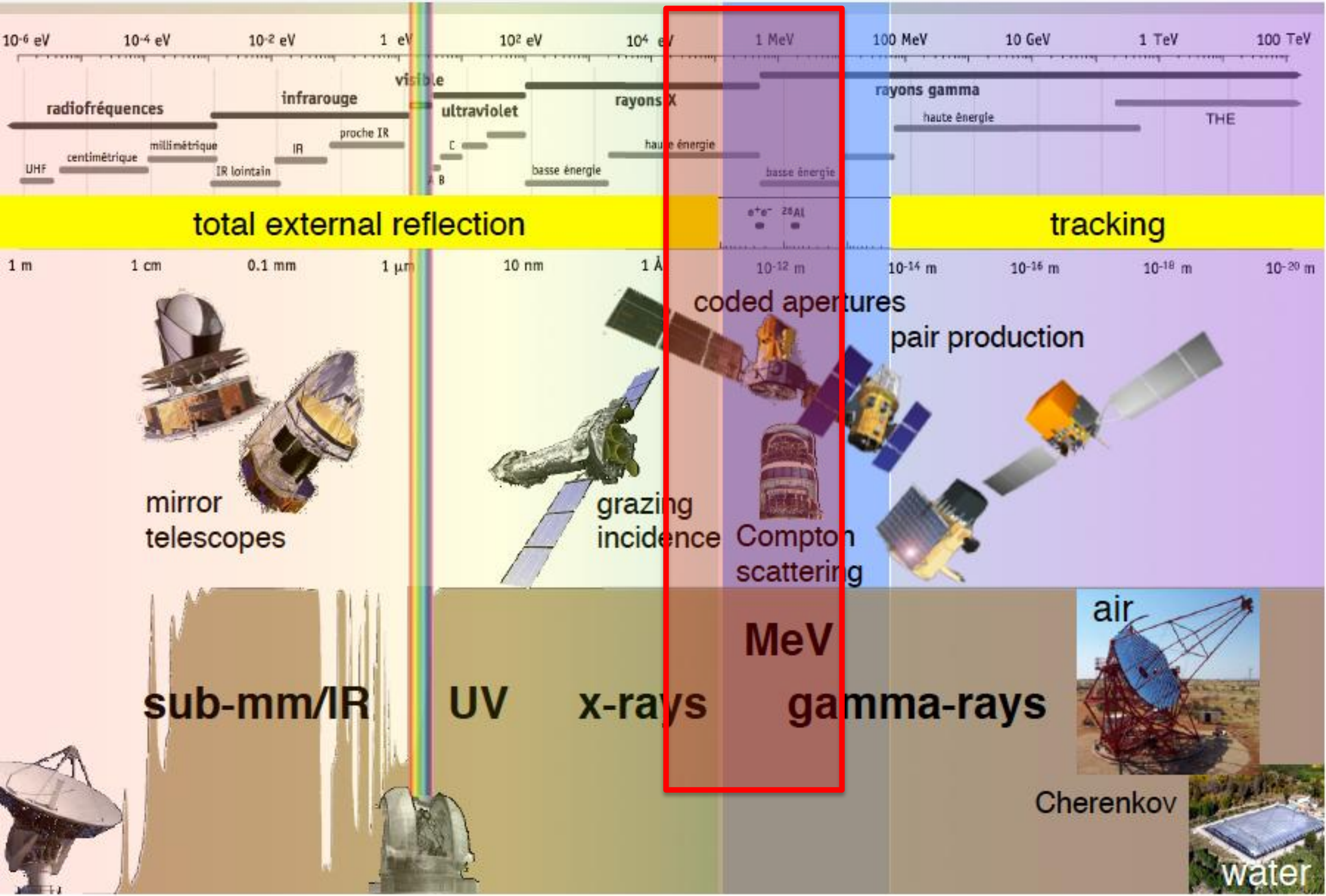
- **<u>IBIS</u> (ISGRI/PICsIT):** 15 keV-10 MeV
  hard X-ray/γ-ray imaging
  [angular resolution: 12']
- **<u>SPI</u>:** 20 keV-8 MeV
  hard X-ray/γ-ray spectroscopy
  [ΔE = 3 keV @ 1.7 MeV]
- **<u>JEM-X</u>:** X-ray monitor (3-35 keV)
- **<u>OMC</u>:** Optical monitor (V-band)

➢ ***All operating simultaneously***

- IBIS, SPI, JEM-X: coded masks: FOV
- Low fluxes, high background ➔
  long exposure times (hrs – weeks)
  [typically 10x XMM-Newton]

Electromagnetic Astronomy

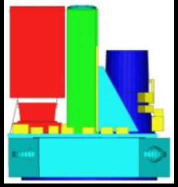
INTEGRAL 3keV – 10 MeV



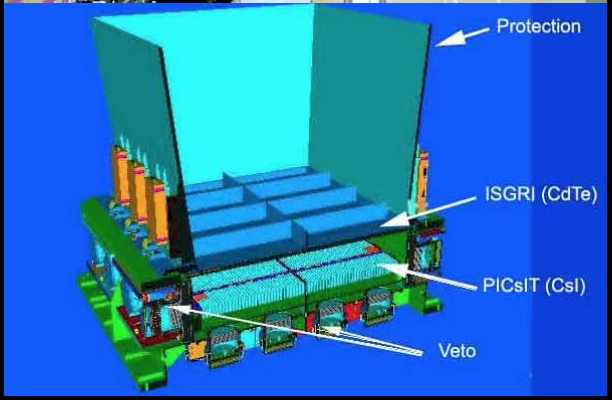
The SPI/ACS detectors view ~4π solid angle of the sky.
E>75 keV, Tres=50ms
Effective area: up to 1m^2

The IBIS detectors ISGRI and PICsIT have max sensitivity to directions normal to SPI/ACS factor of 5 at least

The sensitivity to a gamma-ray transient depends on sky position and its evaluation must take into account the payload and satellite masses distribution



Outside the IBIS FOV (~30x30 deg^2) the ISGRI and PICsIT detectors also view ~4π in the ~0.25-2.6 MeV band.
PICsIT: T_res=15.6ms
Effective area up to ~900cm^2



INTEGRAL e’ simile a BeppoSAX per la ricerca di controparti di GRB

INTEGRAL UL on ©-ray emission from GW150914

- ✓ The Real-time IBAS GRB trigger system has not been triggered by the GW event. Off-line analysys has then been performed.

- ✓ INTEGRAL has observed the whole sky in the range from 50KeV - 10MeV before and after the reported gravitational wave event GW150914 discovered by the LIGO/Virgo collaboration

- ✓ Using the omni-directional view of the INTEGRAL/SPI-ACS and the IBIS-PICSIT we have obtained tight upper limits on the:

  hard X-ray/γ-ray prompt emission

- ✓ The INTEGRAL data strongly constrain the fraction of energy emitted in the high energy electromagnetic component from the full *high-probability sky region* of LIGO/Virgo trigger

INTEGRAL UL on γ-ray emission from GW150914

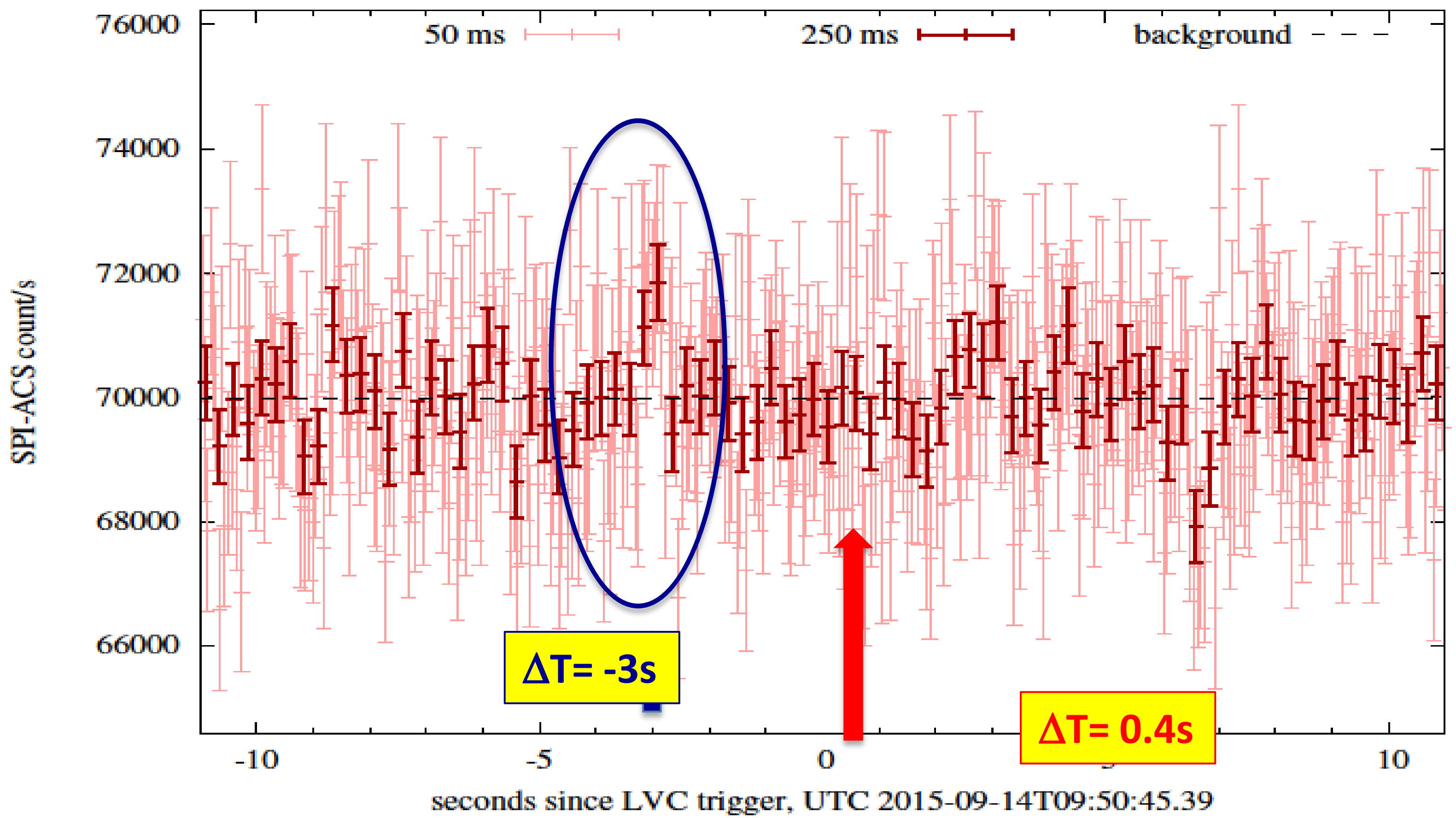
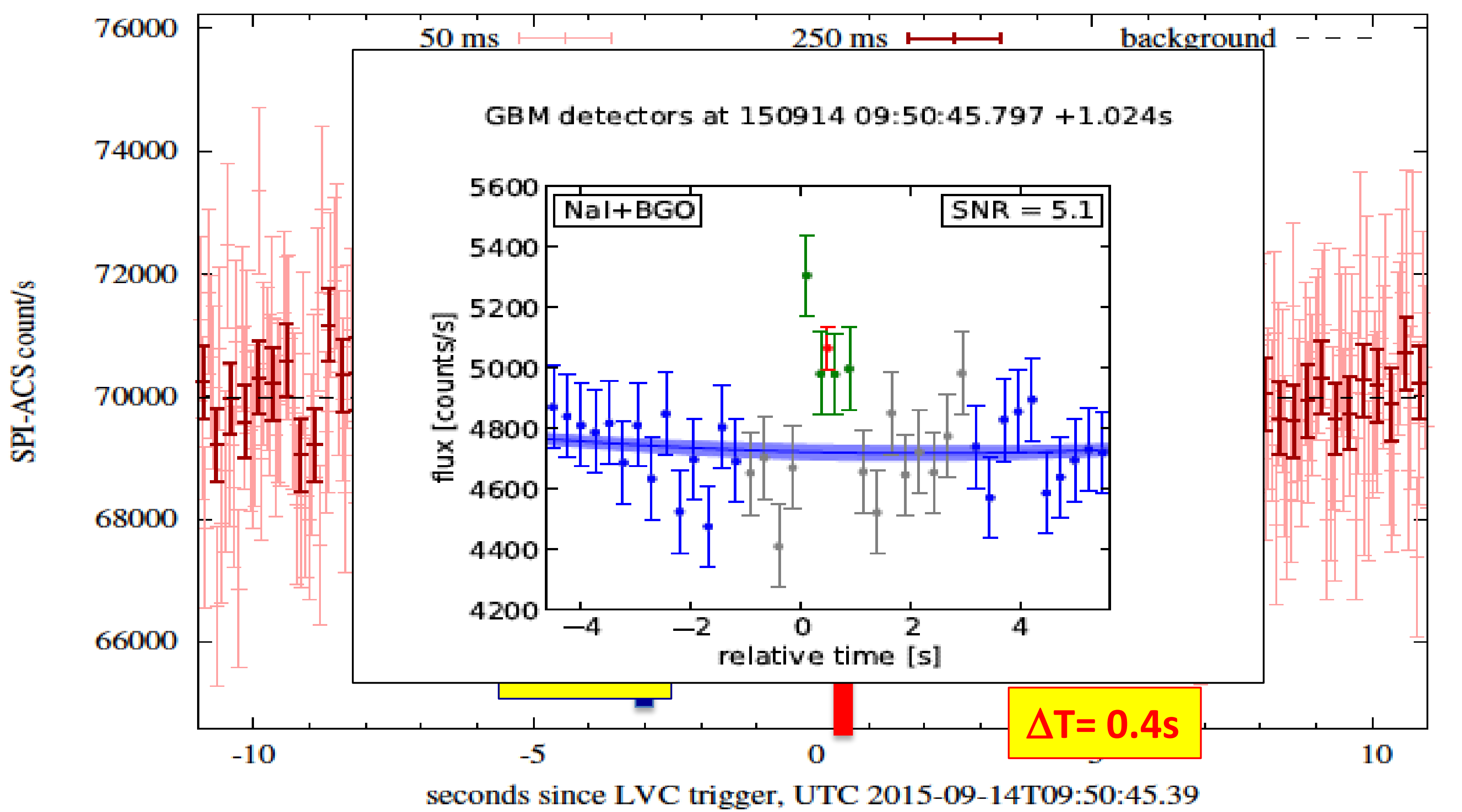


Fig. 1.— INTEGRAL/SPI-ACS lightcurve in ±10 s around GW150914 trigger time. Light red symbols represent the measurements at the natural instrument time resolution of 50 ms; dark red points are rebinned to 250 ms. The dashed black curve is the background level estimated from a long-term average.

http://arxiv.org/abs/1602.04180

INTEGRAL UL on γ-ray emission from GW150914



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INTEGRAL UL on γ-ray emission from GW150914

arxiv1602.04180, arxiv1602.08492

- Our upper limits on the hard X-ray **fluence at the time of the event** range from $F = 2 \times 10^{-8}$ erg cm^{-2} to $F = 10^{-8}$ erg cm^{-2} - 75 keV-2MeV energy range for typical spectral models.

- Our results constrain the ratio of the energy promptly released in γ-rays in the direction of the observer to the gravitational wave energy

$$\boxed{E_g/E_{GW} < 10^{-6}}$$

What are the implications of this energetic constraint?

INTEGRAL UL on γ-ray emission from GW150914

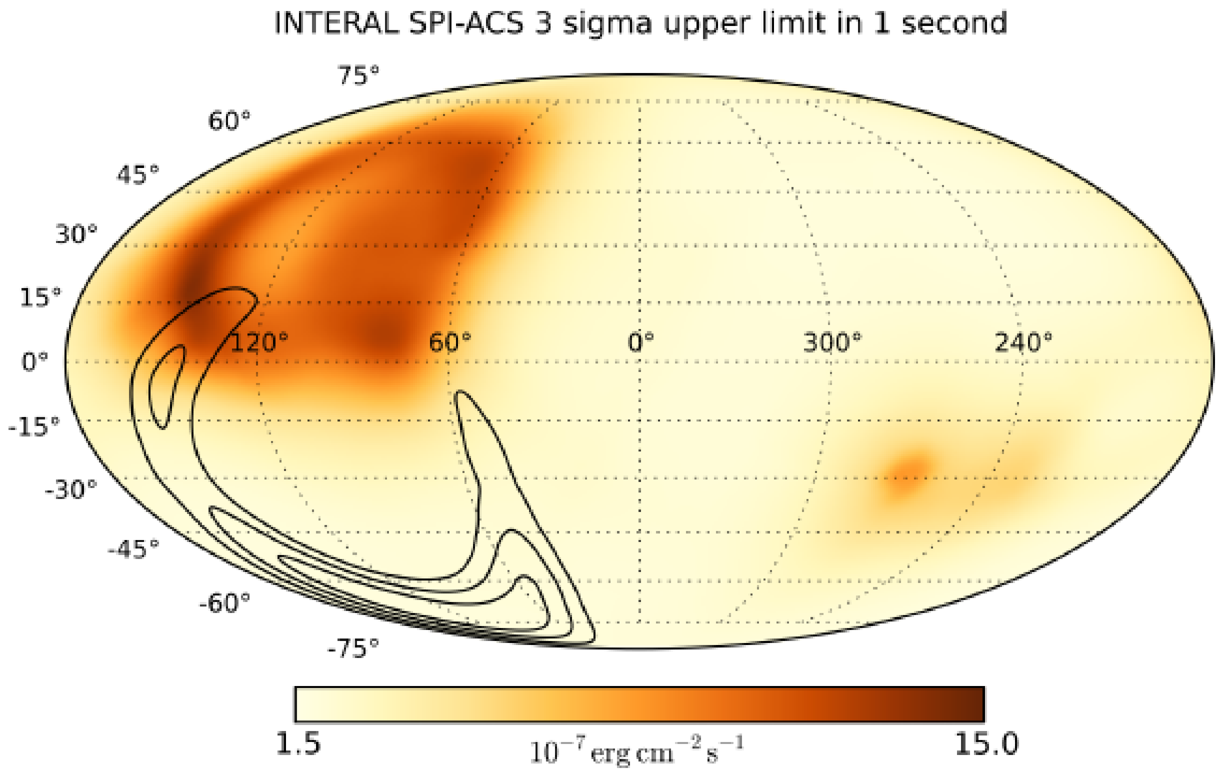


Fig. 2.— INTEGRAL/SPI-ACS 3 sigma upper limit in 1 second for a characteristic short hard GRB spectrum: Band model with parameters $\alpha = -0.5$, $\beta = -2.5$, $E_{peak} = 1000$ keV. In black contours regions (68%, 90%, and 99.8%) we show the high-probability GW150914 trigger localization (LIGO/Virgo scientific collaboration 2016).

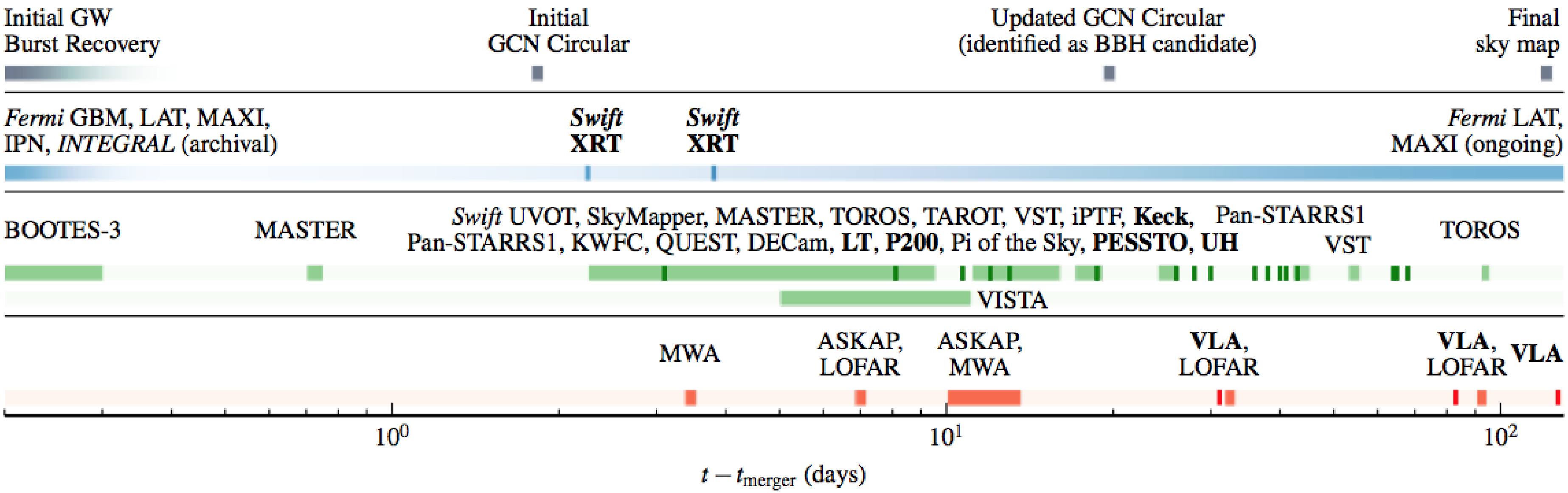
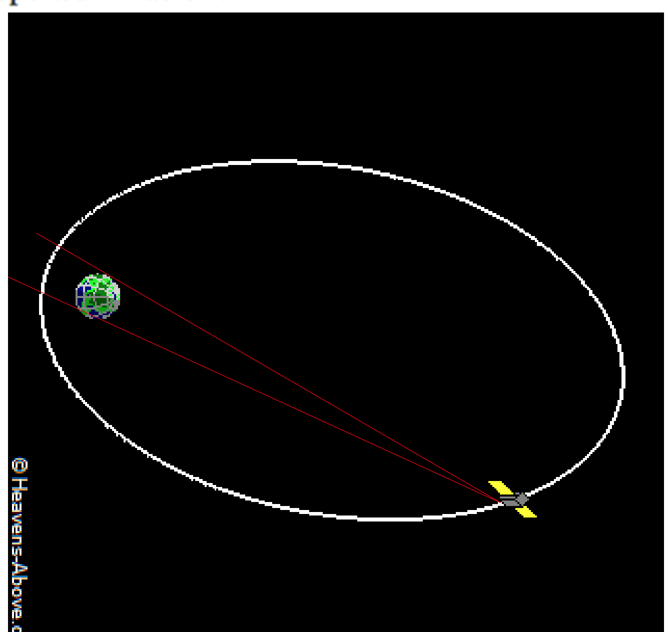


Figure 1. Timeline of observations of GW150914, separated by band and relative to the time of the GW trigger. The top row shows GW information releases. The bottom four rows show high-energy, optical, near-infrared, and radio observations respectively. Optical spectroscopy and narrow-field radio observations are indicated with darker tick marks and boldface text. More detailed information on the timeline of observations is reported in Table 2.

arxiv1602.08492



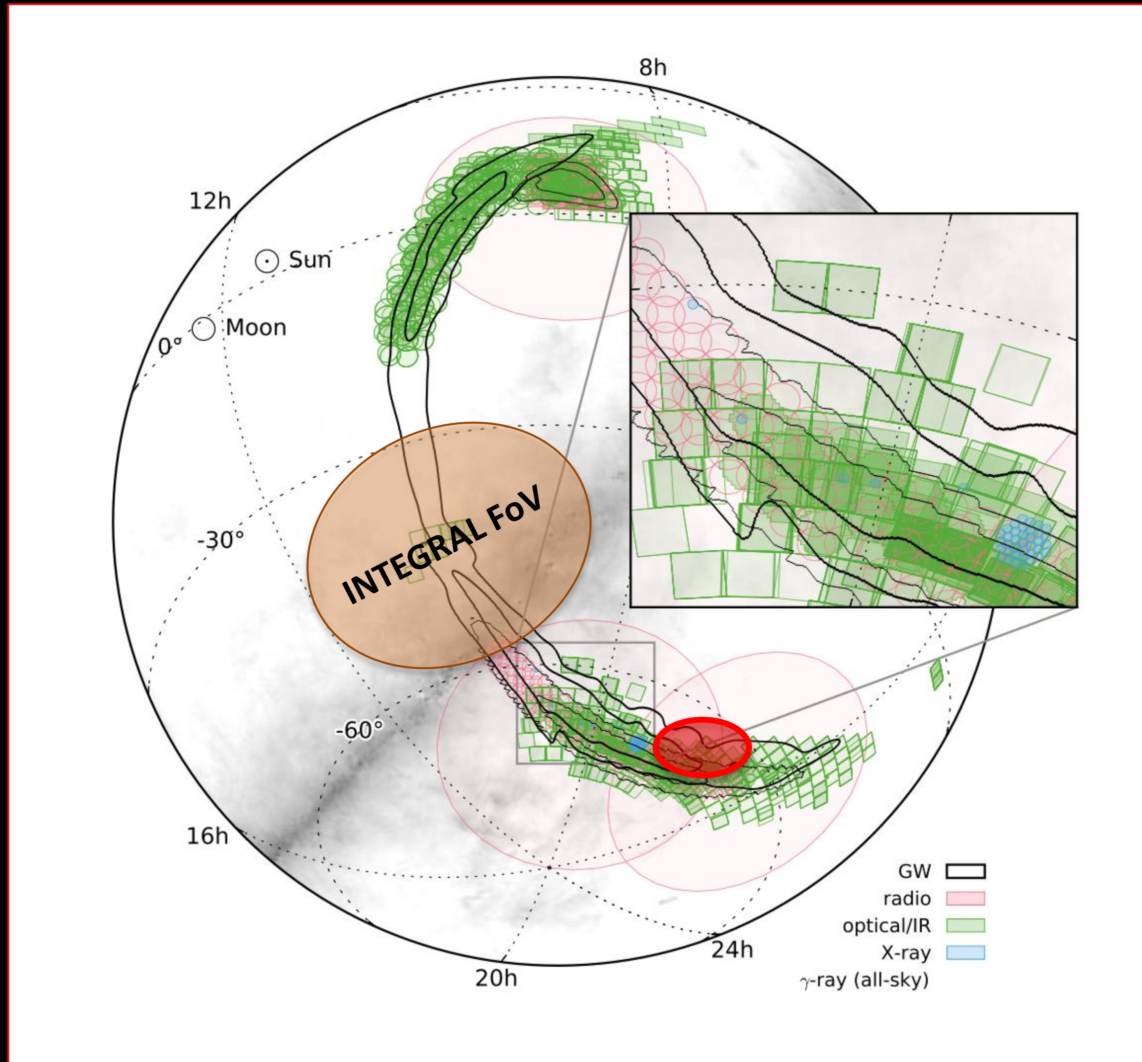
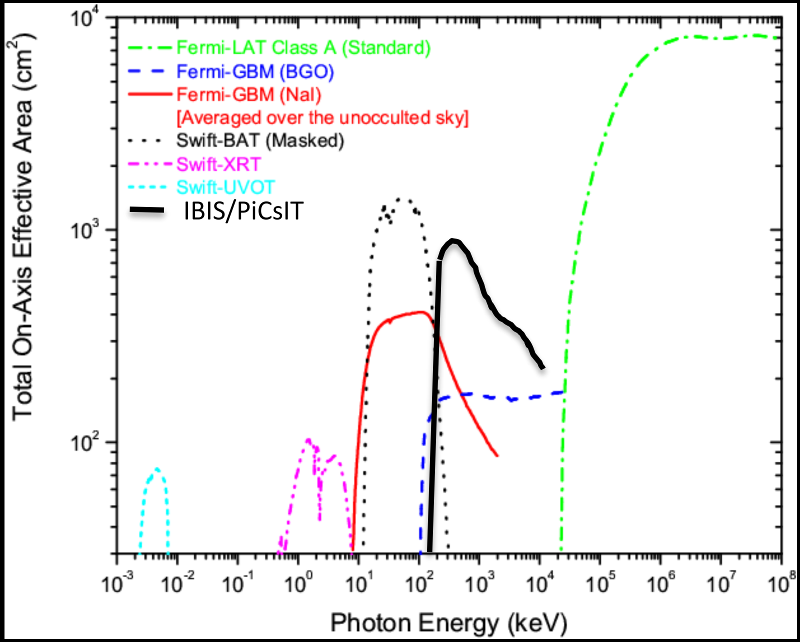


Figure 3. Footprints of observations in comparison with the 50% and 90% credible levels of the initially distributed GW localization maps. Radio fields are shaded red, optical/infrared fields are green, and XRT fields are blue circles. The all-sky *Fermi* GBM, LAT, *INTEGRAL* SPI-ACS, and MAXI observations are not shown. Where fields overlap, the shading is darker. The initial cWB localization is shown as thin black contour lines and the refined LIB localization as thick black lines. The inset highlights the *Swift* observations consisting of a hexagonal grid and a selection of the *a posteriori* most highly ranked galaxies. The Schlegel et al. (1998) reddening map is shown in the background to represent the Galactic plane. The projection is the same as in Fig. 2.

INTEGRAL vs Fermi/GBM

	SPI/ACS	PICsIT	GBM	GBM
Detector	BGO	CsI	BGO	NaI
Energy range	>75 keV	0.2-2.6 MeV **CM: 0.3-10MeV**	0.15-30 MeV	8-1000 keV
Effective area	Up to ~1m^2	Up to ~900cm^2	Up to ~400cm^2	Up to ~150 cm^2
Time resolution	50ms	15.6ms	5μs	????



Conclusions

- The SPI/ACS and GBM have quite different energy coverage and effective area
- Assuming the Fermi/GBM spectral model, INTEGRAL would have detected a signal of significance in the range 5-15 sigma. The higher value is for the southern (most probable) direction
- More events expected! And IBIS could also enter the game
- IBIS can play an important role for extended sky coverage and deeper (factor ~5) sensitivity in localized regions, using both ISGRI and PICsIT detectors

CONCLUSIONS

- INTEGRAL operation mode has been changed to IMMEDIATELY follow-up the NEXT GW trigger

- The INTEGRAL has observed the whole sky in the range from 50KeV-10MeV and constrained the energy emitted in the high energy electromagnetic component from the full *high-probability sky region* of LIGO/Virgo trigger to:

$$E_g/E_{GW} < 10^{-6}$$

✓ The INTEGRAL, BATSE, BeppoSAX, SWIFT may have already observed signatures from GW annihilation phenomena, without recognising them! → Dark GRB (Swift), BATSE-BeppoSAX GRB, Long GRB, INTEGRAL Time-lagged GRB ?!?

To detect the counterparts all we need is:

INTEGRAL extended (ESA-ASI) and INAF support

Thanks for your attention!