INTEGRAL:
detection capabilities, reaction & policies

Erik Kuulkers
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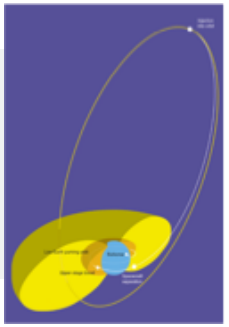
INTEGRAL
Project Scientist

integral

→ SEEKING OUT THE EXTREMES OF THE UNIVERSE

ESA, C. Carreau

Introduction



- **INTE**rnational **G**amma-**R**ay **A**strophysics **L**aboratory
- Launched 17 October 2002
- Highly elliptical orbit (~64 hrs); ~52 hrs of continuous science

- Mission operations currently funded until 31 December 2018

- Indicative approval of mission operations until 31 December 2019; 31 December 2020 expected to be done during March SPC meeting

- To be done in October 2018 (2-year cycle):
  - Confirmation of funding extension period 2019-2020
  - Approval of extending operations period 2021-2022

- Re-entry in 2029

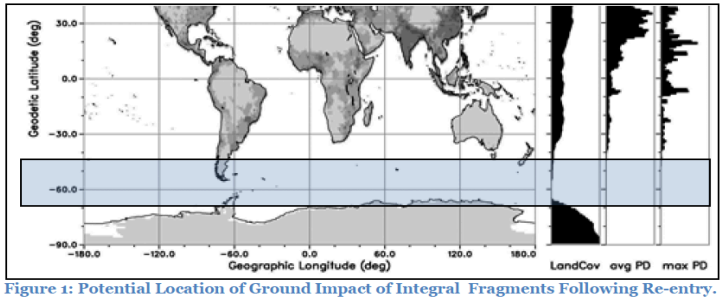
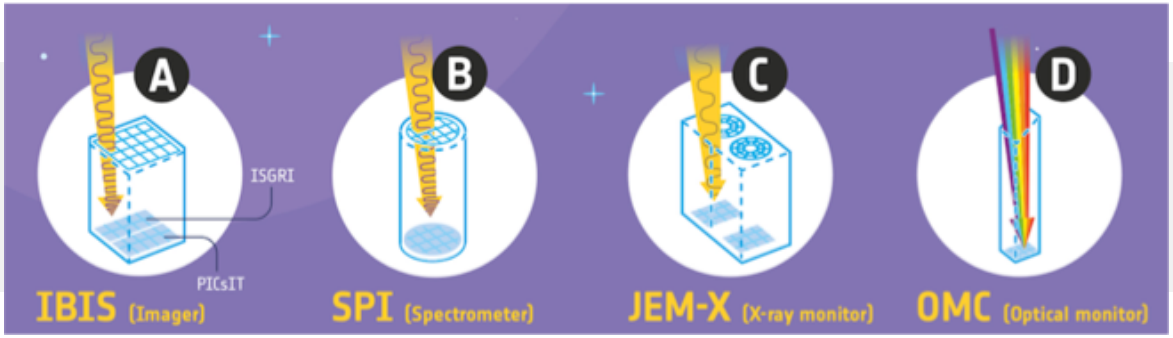
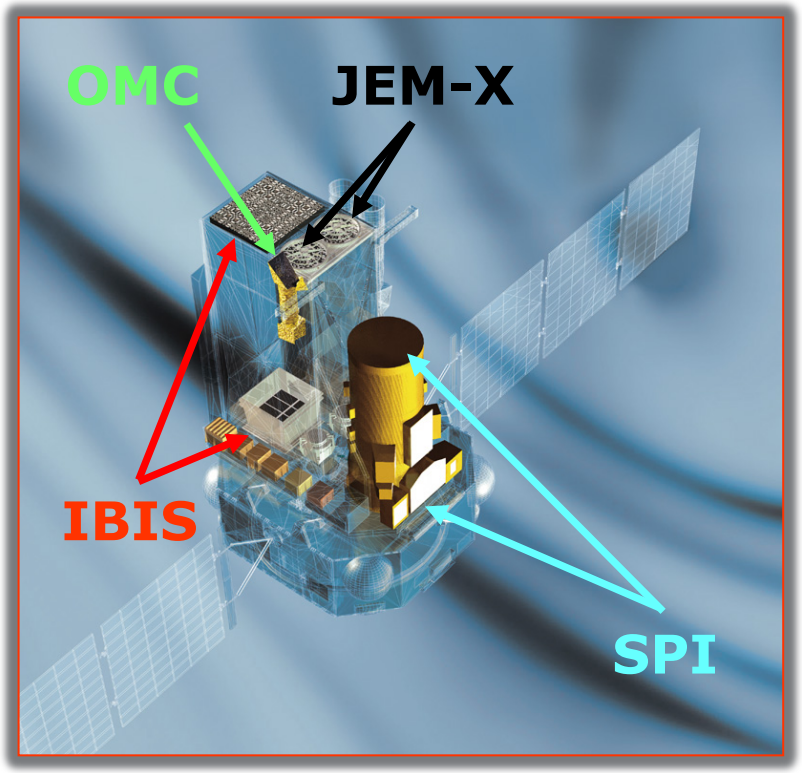


Figure 1: Potential Location of Ground Impact of Integral Fragments Following Re-entry.

Introduction



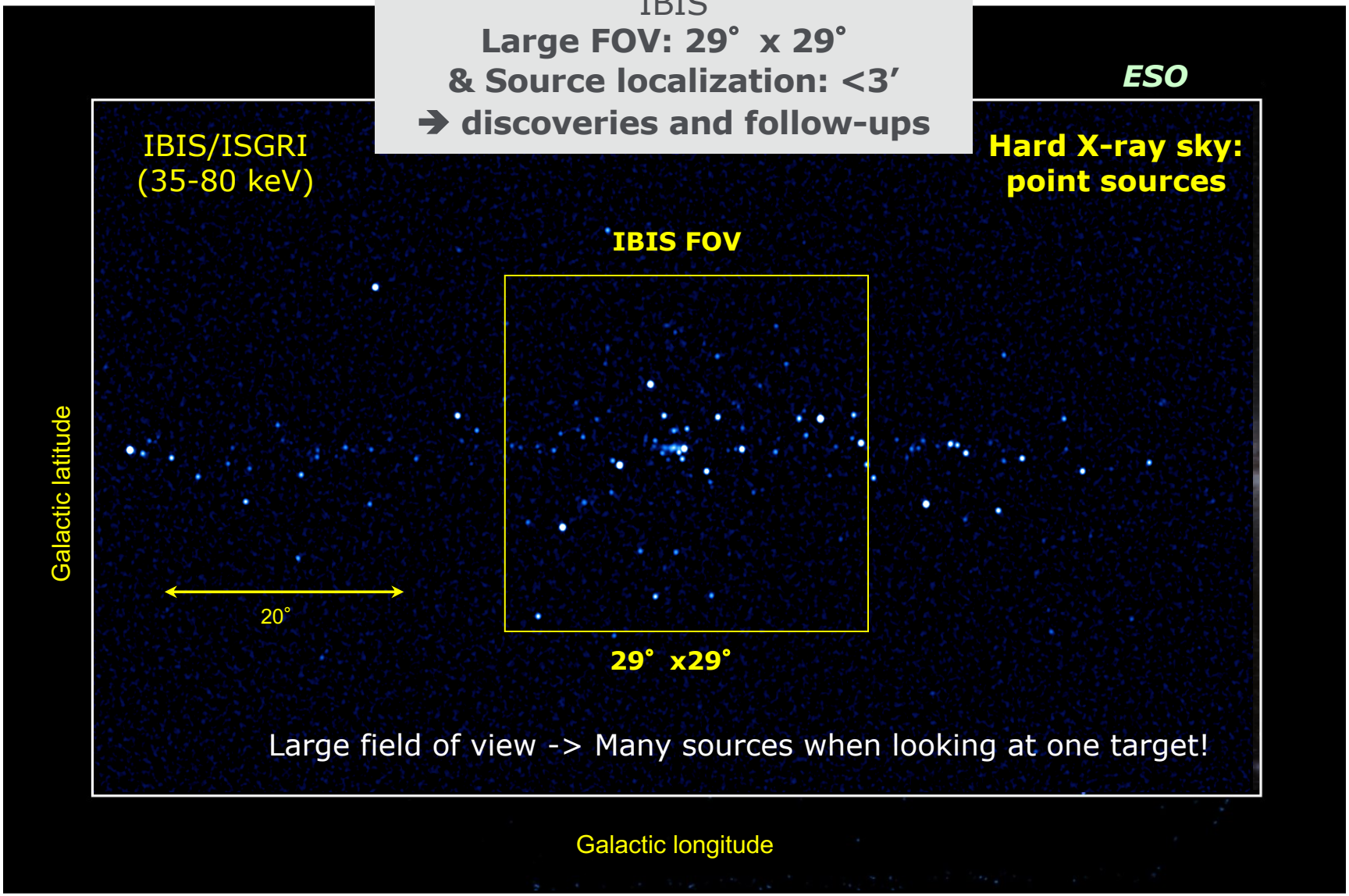


- **4 instruments:**
  - **IBIS**: imaging
  - **SPI**: spectroscopy
  - **JEM-X**: X-ray monitor
  - **OMC**: optical monitor

- ***All operating simultaneously***
  - IBIS, SPI, JEM-X: large FOV (up to 900 square degrees)

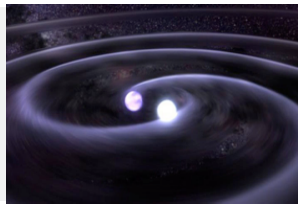
Key science capabilities

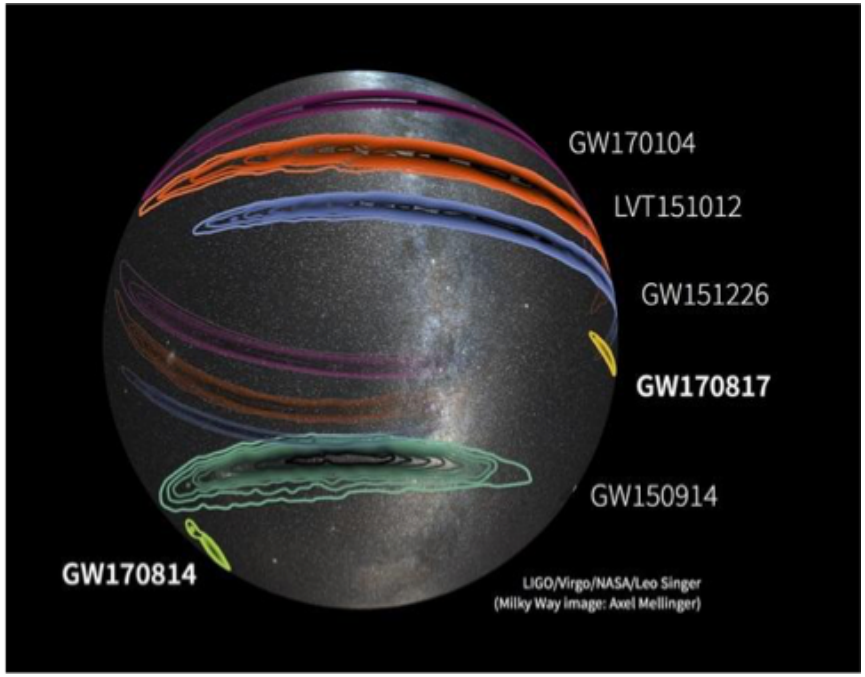
IBIS
Large FOV: 29° x 29°
& Source localization: <3’
➔ discoveries and follow-ups

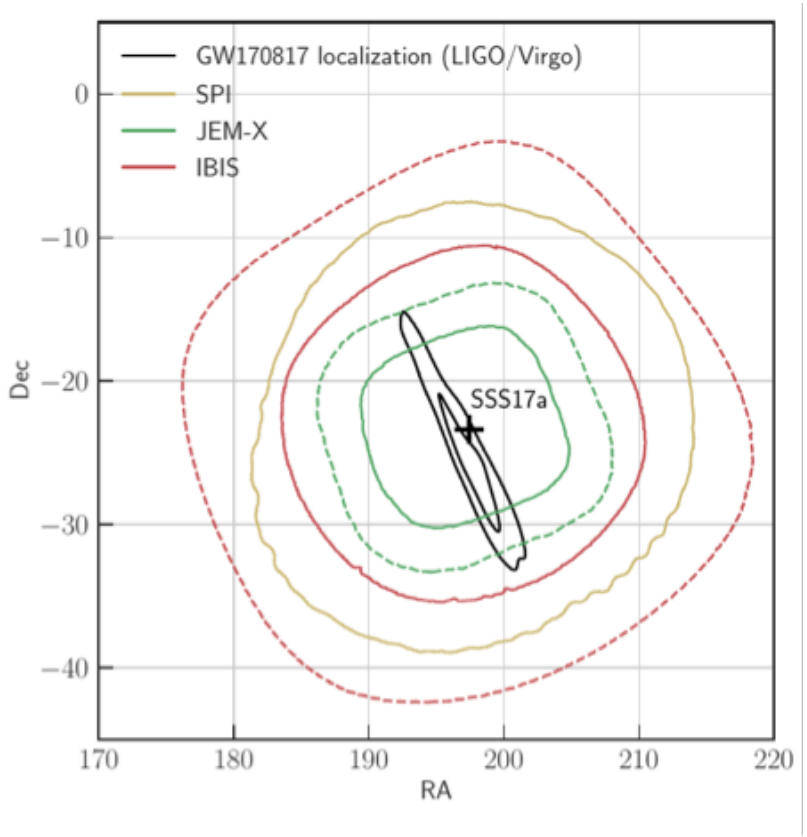


GW events

- (a)LIGO + (a)Virgo: typically ~ 10°x 10°
- INTEGRAL: wide, comparable FOV ~ 10°x 10° (fully coded)

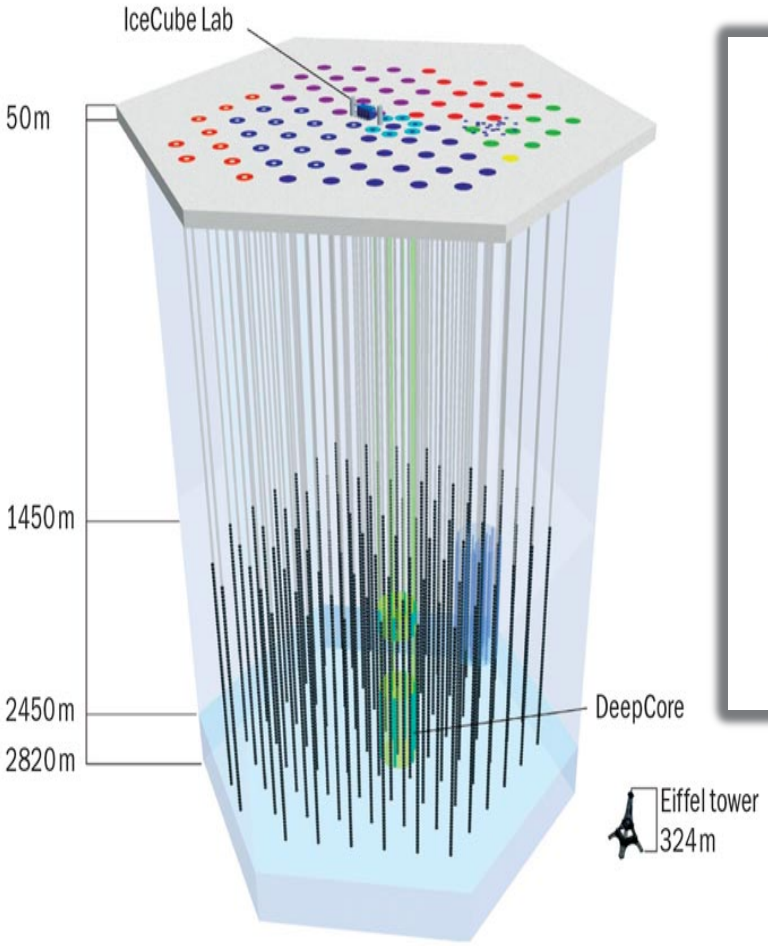


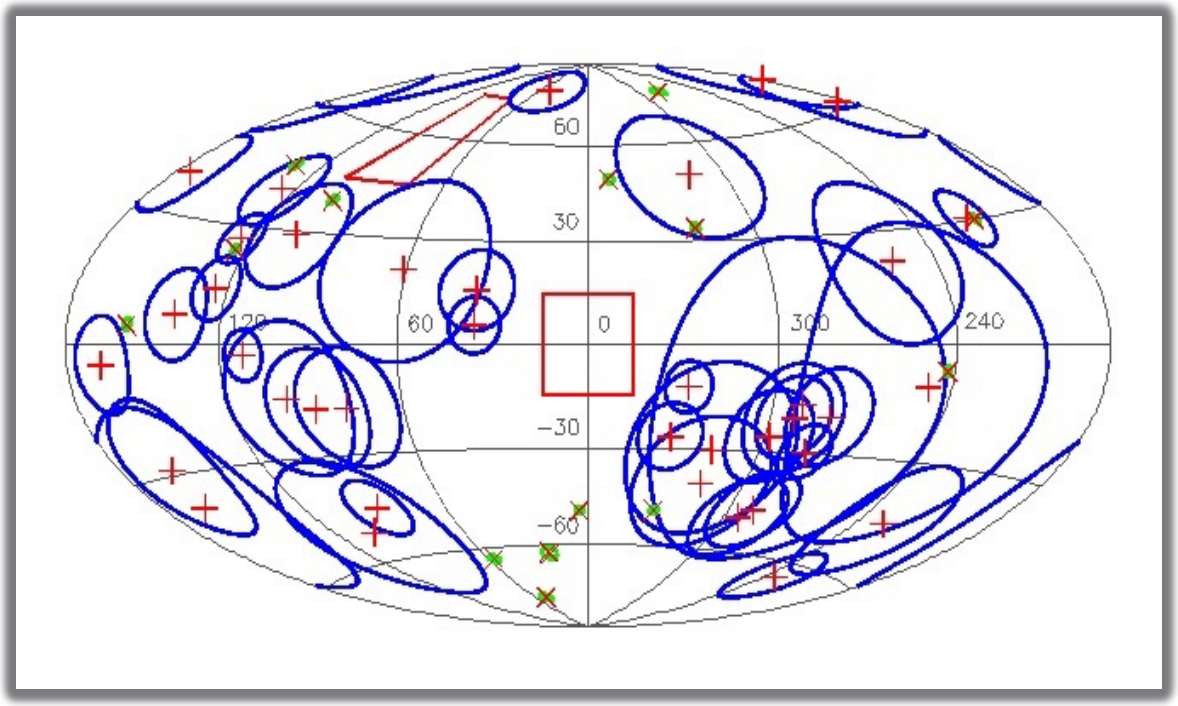




Neutrino events

@ Ultra High Energy, search for:
- places of HE Cosmic Ray acceleration (GRBs?,AGN?)
- Dark Matter decay



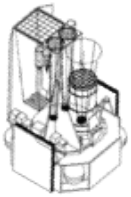


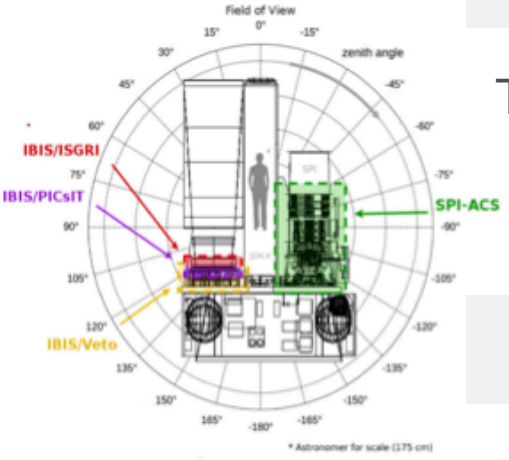
IceCube high-energy e-neutrino events (blue) and muon events (green crosses)
54 events in 2010−2014

4π of the sky: expect the unexpected

Shields of SPI & IBIS

- **SPI/ACS:**
  >75 keV, 50 ms - Effective area: ~1 m^2
- **IBIS/Veto**
  ~0.25-2.6 MeV, 15.6 ms - Effective area: ~900 cm^2





Thanks to the Anti-Coincidence Shields (ACS) of SPI & IBIS it will ***immediately*** detect high-energy photons from *any* event at ***any direction on the sky***

- **Omni-directional view!**

- γ-ray burst (GRB) detections by INTEGRAL so far, on average:
  - ~200 per year in the ACS of SPI ← data & alerts public
  - ~5 per year in Field of View of IBIS & SPI ← alerts public (IBAS)

GW170817 / GRB170817A

Fermi

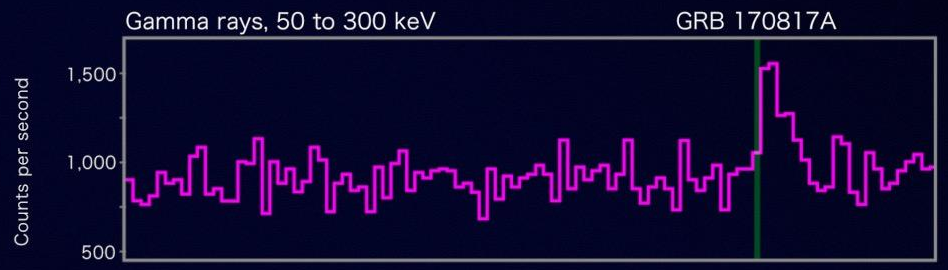
Reported 16 seconds after detection

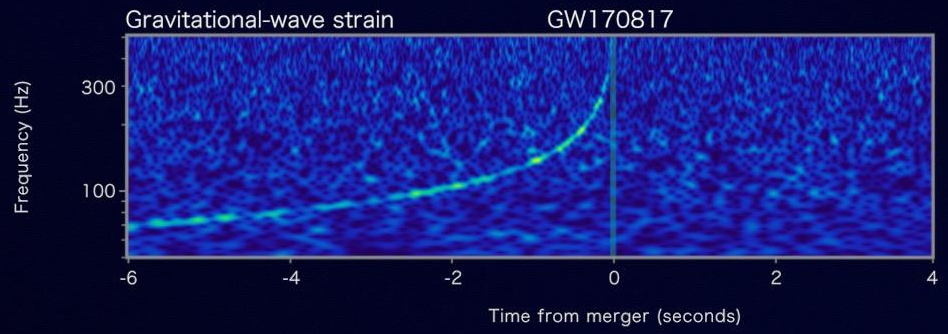
LIGO-Virgo

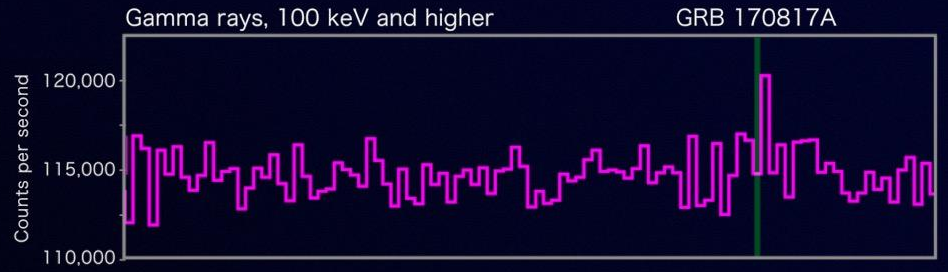
Reported 27 minutes after detection

INTEGRAL

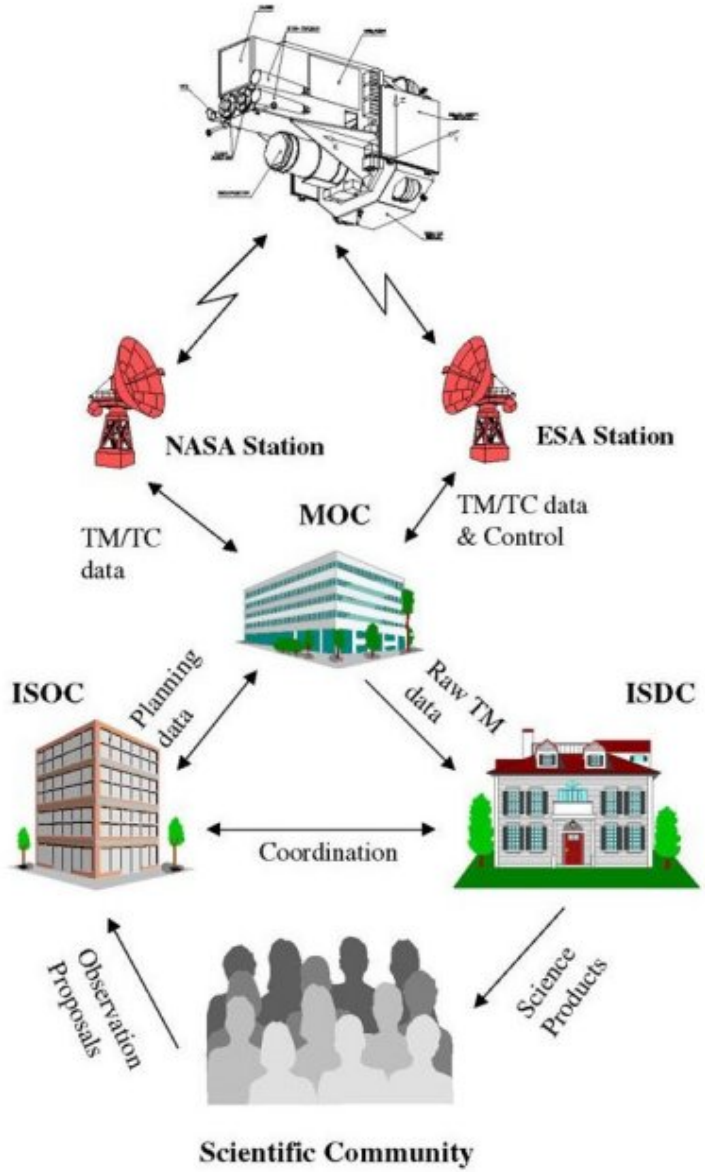
Reported 66 minutes after detection







INTEGRAL – Ground Segment



@ISDC (INTEGRAL Science Data Centre):

- ➢ Automatic: IBAS & SPI-ACS GRB alerts
- ➢ Near-real time data available within few hrs
- Manual: Quick-look analysis for transient events
- ➢ Consolidated data available weeks

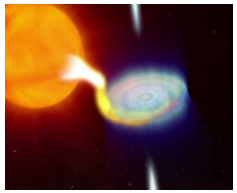
→ "raw" data & data products (images, light curves) into archive

ISOC & MOC: working hours

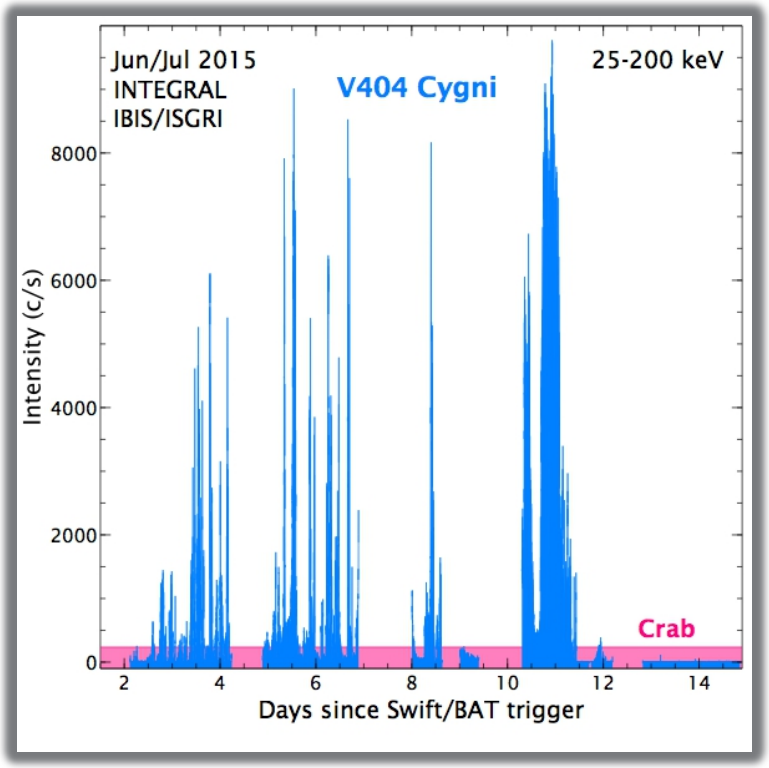
ISDC: generally 24/7

Case-by-case basis: make data products available to public to increase data usage

Encouraging use of data products: example

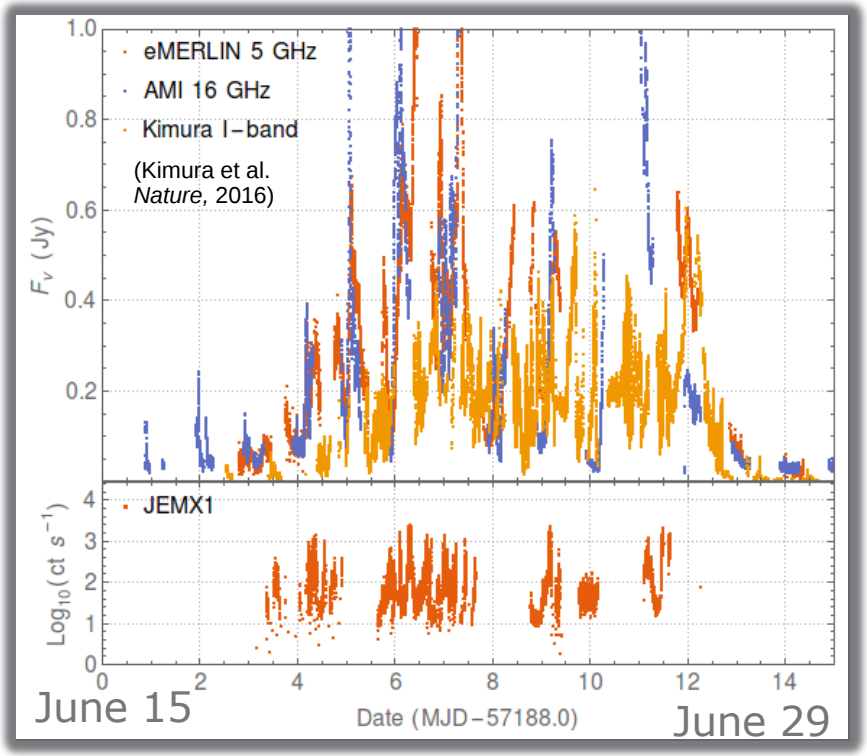


~50 times brighter than
Crab in hard X-rays



- INTEGRAL ToO: ~2 Msec (~17 days)
- Most of the data public immediately
  + ready-to-go data products @ ISDC

Multi-λ: ~19 orders of magnitude from
150 Mhz to 10 TeV



Currently 29 papers using INTEGRAL
data on V404 Cyg

INTEGRAL observatory – Calls for proposals

Spring – call for proposals → for observations year after (1-year proprietary)

AO16: 5 March - 13 April 2018; observations: 2019

- Normal, regular observing proposals (can be fixed time)
- ToO proposals (including GRB data rights)

→ TAC accepts typically ~15-20 ToO proposals for total ~10-15 Msec with approved observing strategies (especially important for proposals asking for same target)

[Long-term planning: out of 21 Msec per year ~2 Msec reserved for ToOs]

Not possible:

1) 'Nearby' SN:

- D ≤ 60 kpc (incl. Magellanic Clouds) for cc-SN (II, Ib, Ic)
- D ≤ 1 Mpc (incl. M31) for thermonuclear SN (Ia)

→ will be observed as per observation strategy laid out in documentation

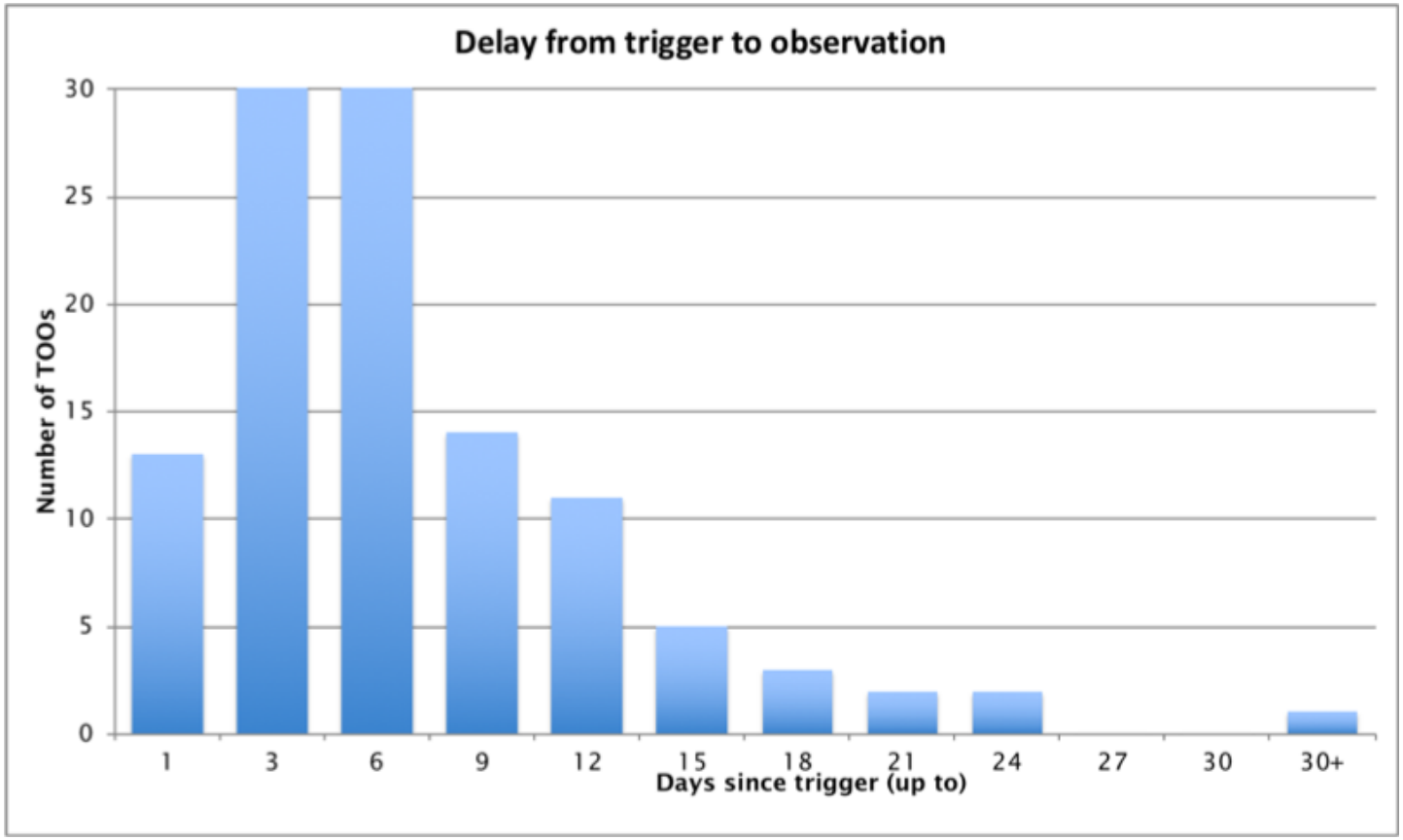
2) Events captured within MoU's / LoI's

➢ Project Scientist keeps flexibility for *unique* events, *not* covered by accepted TAC proposal (i.e., so-called DDT time) ➔ out-of-TAC proposal

Most of the time: data public!

INTEGRAL – ToO capabilities

- Typically: Observer alerts SOC → SOC analyses ToO → if OK alert PS → PS decides → if accepted, alert MOC; SOC makes new schedule → MOC approves timeline + commands to satellite + slewing→ ToO starts at agreed time



- Record time between ToO trigger & start of observation: 4.7 hours

(GW170817: 17 hrs, due to perigee passage & agreed change in timeline)

INTEGRAL – MoU's / LOI's – 'New Astronomies'

- The INTEGRAL Project signed a Memorandum of Understanding (MoU) with LIGO/Virgo consortium to participate to the EM follow-up campaign of **GW signals** until 1 June 2017 (extended up to 25 Aug 2017)
- Also MoU signed with IceCube collaboration on 25 October 2016 to receive from the IceCube collaboration the private **very-high energy neutrino** multiplet alerts and to establish a close collaboration in general
- A LoI was signed on 29 December 2017 with the deep-sea neutrino telescope ANTARES, to receive their alerts of **neutrino events** and to do targeted follow-up observations with INTEGRAL in collaboration with the ANTARES team. The expected typical rate of these alerts is of order of 3 per month
- A Letter of Intent (LoI) was signed on 29 March 2017 for follow-up of **Fast Radio Bursts (FRBs)** discovered by the SUPERB project (using Parkes radio observatory), in collaboration with the SUPERB team

- INTEGRAL Users Group recommends to repoint INTEGRAL as fast as possible to search for possible gamma-ray counterparts once a candidate position is known with sufficient accuracy (as judged by PS)
  → Observation to be done without disclosing information

INTEGRAL – Searches for prompt emission

Currently:

- INTEGRAL activities to follow-up GW/neutrino/FRB triggers are carried out within special INTEGRAL Project team: Project Scientist, ISDC, IBAS team, instrument teams + various scientists/experts

- In case an event coincides with a GRB (IBAS or SPI/ACS), respective PIs notified and GRB data rights transferred to INTEGRAL Project

- Data over a 2-day long window centred on trigger time are analysed for new transient sources on timescales from sec to hours

In practice: data available within hours; analysis done at ISDC by Volodymyr Savchenko using dedicated scripts → single-point failure!

- Additional follow-up observations on case-by-case basis based on input from ISDC: Project Scientist decides go/no-go

Early 2018: optimize activities (many events / no single-point-failures):
Setting requirements on software systems (web-based), hardware infrastructure, team organization (e.g., event advocates), procedures on operations, observing strategies, decision flow charts, etc.

Summary of aims for 2017-2018 and 2019-2020

➢ Strong focus on:

The ToO capabilities of INTEGRAL in the broadest sense:

- The "New multi-messenger astronomies":
  - LIGO-Virgo detection of GW events, on high-energy neutrino events and FRBs, as well as INTEGRAL follow-up observations
- Reserved ~2 Msec of the time on ToOs for other transients:
  - Novae, Supernovae, outbursts of Black Holes in XRBs and AGNs: Micro-quasars, Blazars and Quasars (seen out to z=3.6)

+ Legacy programs in areas for which INTEGRAL was designed:

- (Galactic) nucleosynthesis; synergy with NuSTAR, Swift, XMM-Newton
- Continued monitoring of the Galactic Center, e+/e- annihilation emission and precise study of its asymmetric structure.
- Study of polarization at γ-ray energies (100 – 3000 keV) - of relativistic jets of black holes in XRBs and AGNs, and sources like Crab, etc.

Conclusions

- After >15 years of operations: we have a reasonably well working environment, with limited resources

- But: new events/science challenges the established work flow!
  → if you want to join the bandwagon: need to be adaptable/dynamic

- Multi-messenger / wavelength (astro)physics
  → need a way to (promptly) communicate!
[on both observation planning and science level]

- Don't forget PR