INTEGRAL: detection capabilities, reaction & policies

Erik Kuulkers - INTEGRAL Project Scientist

integral → SEEKING OUT THE EXTREMES OF THE UNIVERSE
**Introduction**

- **INTEGRAL** National Gamma-Ray Astrophysics Laboratory
  - 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
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

IBIS/ISGRI
(35-80 keV)

IBIS FOV

Hard X-ray sky:
point sources

Large field of view → Many sources when looking at one target!
GW events

- (a)LIGO + (a)Virgo: typically $\sim 10^\circ \times 10^\circ$
- INTEGRAL: wide, comparable FOV $\sim 10^\circ \times 10^\circ$ (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

- **SPI/ACS:**
  > 75 keV, 50 ms - Effective area: ~1 m²

- **IBIS/Veto**
  ~0.25-2.6 MeV, 15.6 ms - Effective area: ~900 cm²

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

Graphs and charts showing detections and data analysis for GW170817/GRB170817A.
@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-\(\lambda\): \(~19\) 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)
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