The Integral Mission

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40th Saas-Fee Course

Les Diablerets

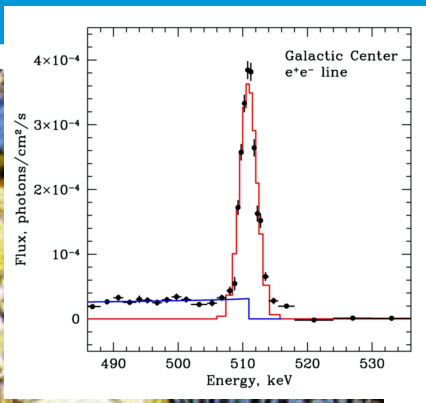
18 March 2010

Talk overview

- Why do we do Gamma-ray astronomy?
- Integral the Mission
  - History
  - Instrument overview
  - Coded Mask imaging
  - Ground Segment
  - AO process and timeline for AO-8
  - Proposal types and data rights
- Science with Integral
- The future

Why a Gamma-Ray Observatory?

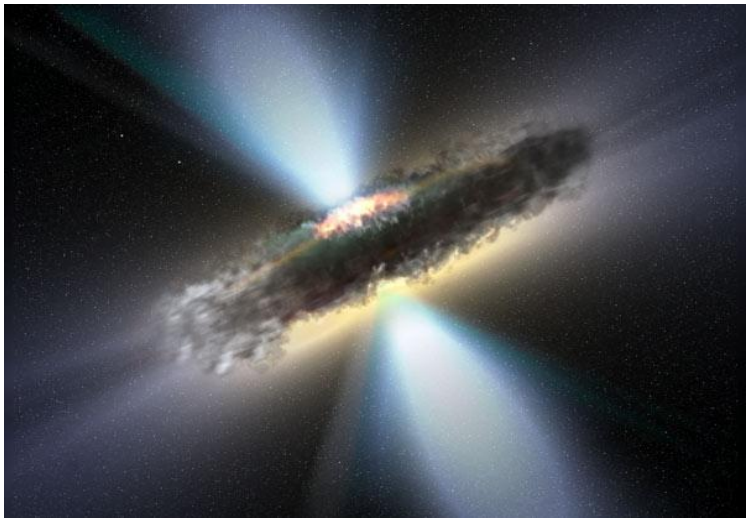
Beyond X-rays: new sources; HE processes; accretion physics; cosmic HE background; GRBs; …

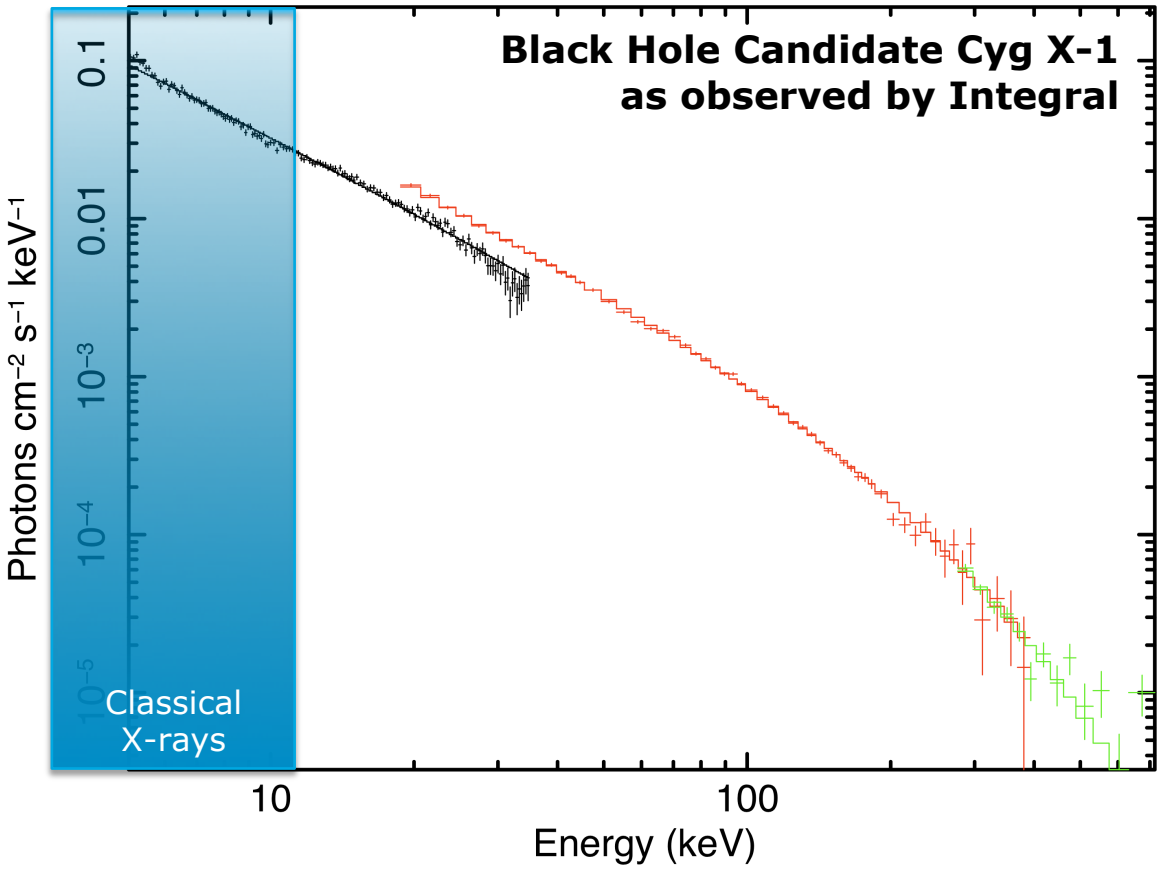


Element formation; radioactivity; Nova & SN activity; ISM; CR interactions

Seeing more of the universe

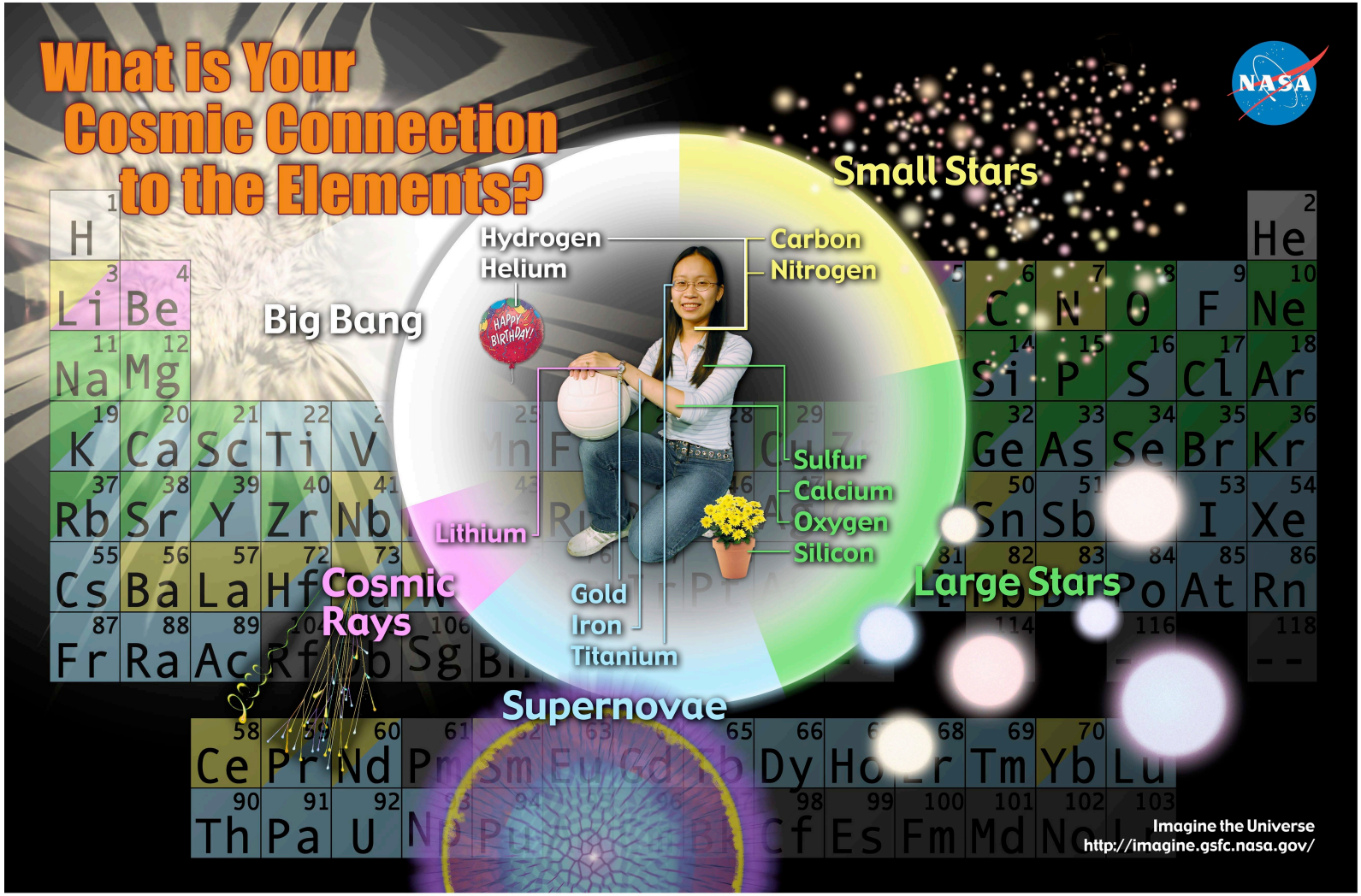
- Observing at higher energies in broad band is essential to understand certain sources.
- Different physical mechanisms can be studied.
- Heavily enshrouded sources become visible in hard X-rays
  ➔ hidden sources found.





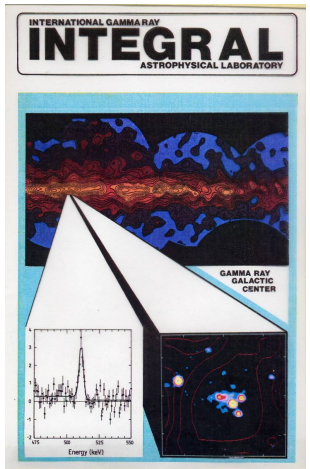
Understanding our origins

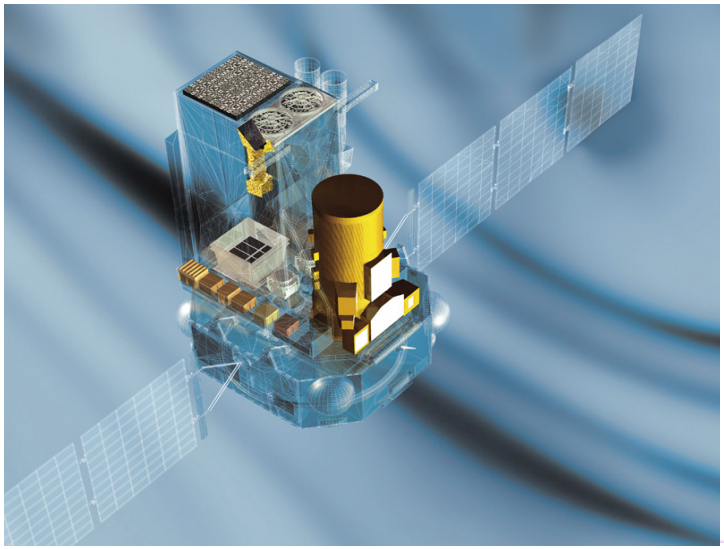
- Observing gamma-ray lines tells us about nucleo-synthesis, the creation of the elements in our universe.

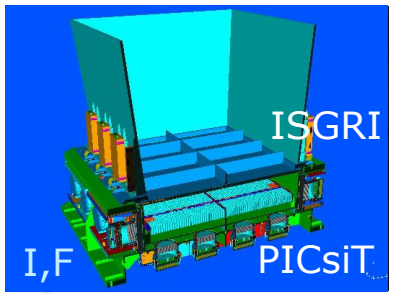


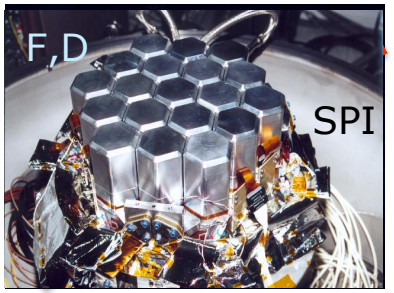
Some Integral history

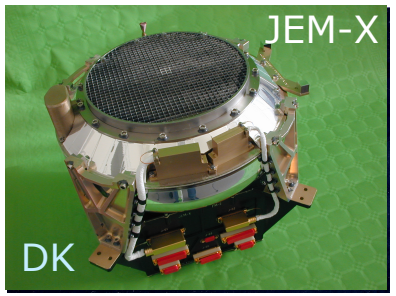
- **Fall 1989:** Mission proposed to ESA by European and US scientists.
- **1991:** Endorsed for Phase A study.
- **June 1993:** Selected as medium-size mission with 4 instruments.
- **Shortly afterwards:** US and UK withdraw support for main instruments!
  ➔ **Complete re-organisation of effort.**
- **May 1995:** Selection of instruments with new organisation.
- **1996:** Ground Segment built up. ISDC installed in Versoix. ISOC set up at ESTEC.
- **… years of development and testing …**

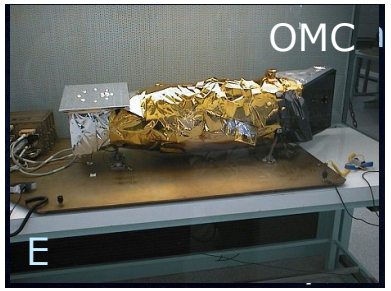






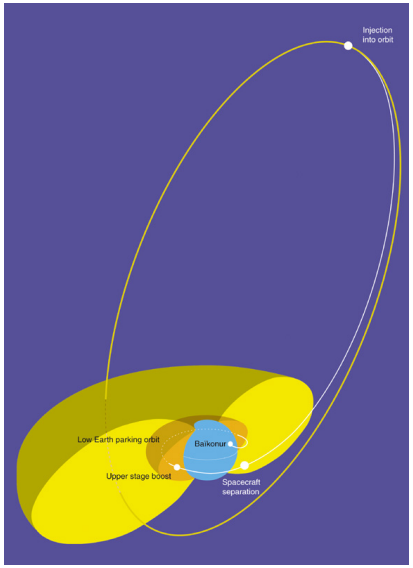


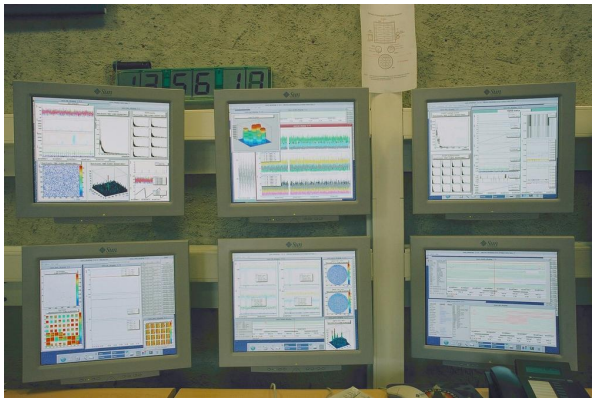




17 October 2002 – LAUNCH!

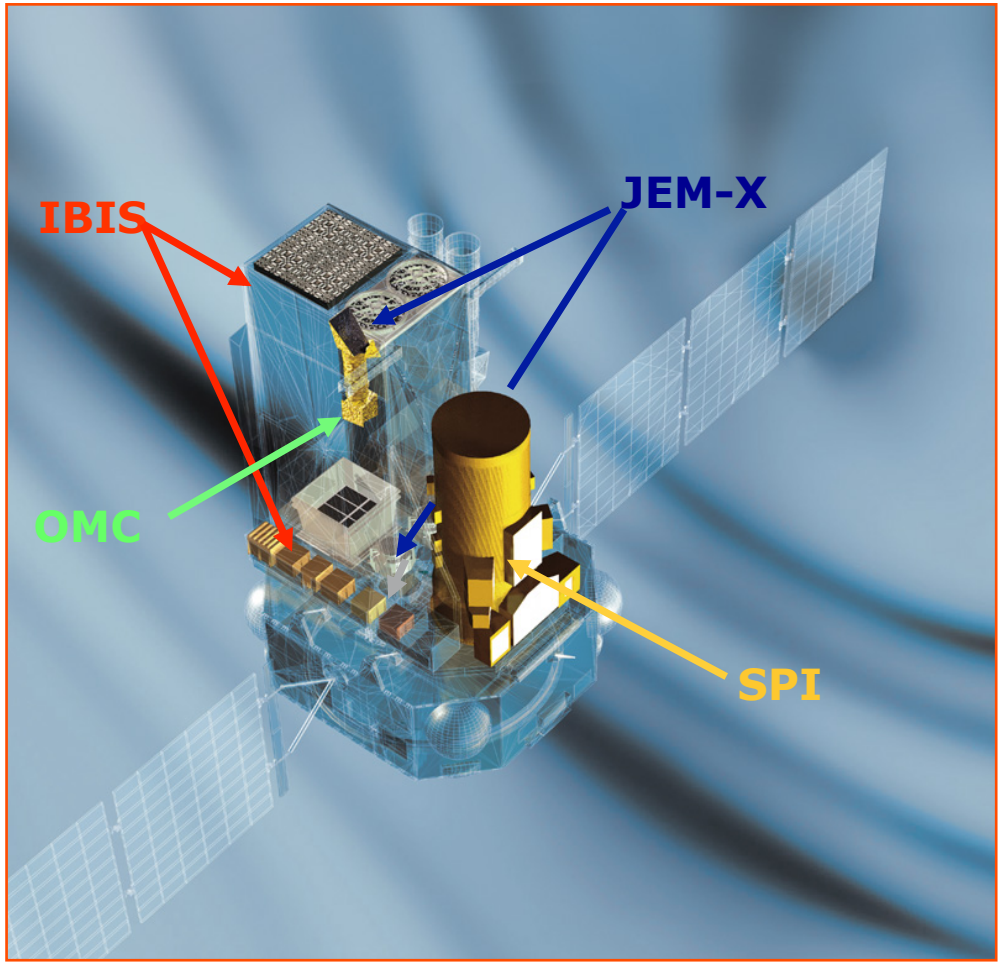
- Picture-perfect launch with Proton rocket from Baikonur.
- Eccentric 3-day orbit to stay largely out of radiation belts and to allow long observations.
- Spacecraft and instruments working fine from start.
- Full ground segment working from day 1.

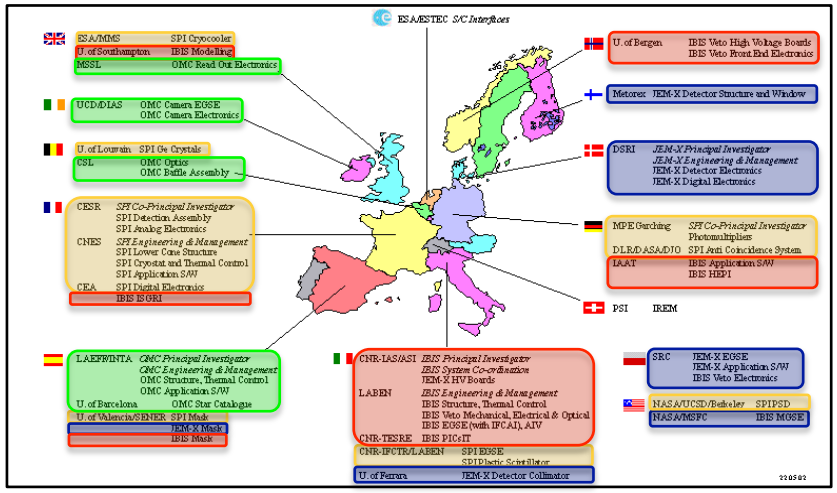




Integral in flight

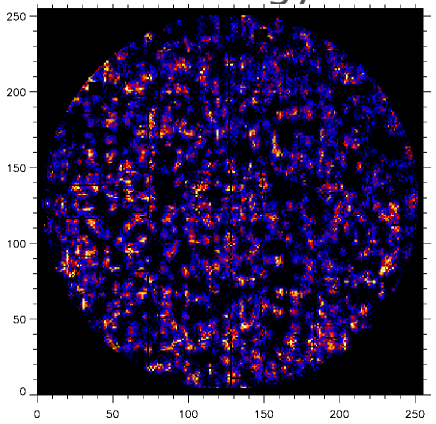
- **IBIS**: accurate point source imaging. 9°×9° FCFOV. 15 keV – 10 MeV.
- **SPI**: fine spectroscopy of narrow lines & diffuse emission. 16° FCFOV. 20 keV to 8 MeV.
- **JEM-X**: X-ray monitor. 5° FOV. 3-35 keV.
- **OMC**: V-band optical monitor. 5°×5° FOV.



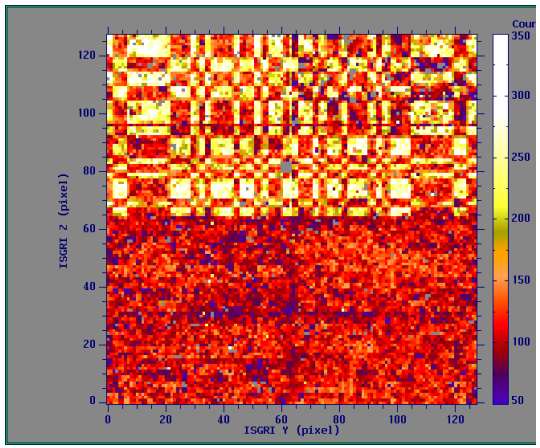


‘Seeing’ with Coded Masks

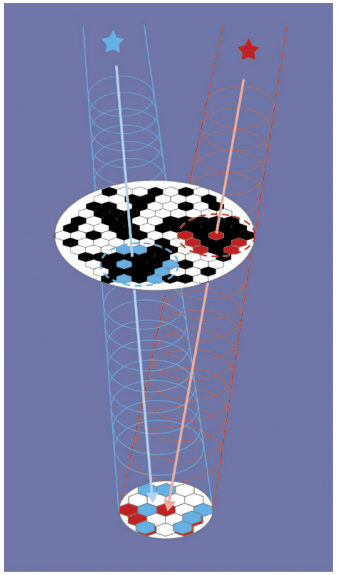
- Photons above ~15 keV cannot yet be focused. Other imaging techniques (Compton scattering, tracks) require even higher energies.
  ➔ “Coded Masks” for Integral high energy instruments
- Drawbacks:
  - ☹ Fills detector plane for a point source ⇒ entangled sources!
  - ☹ Background relevant in whole detector!
- Advantage:
  - ☺ Wide fields of view and very good angular resolution.
  - ☺ Best energy resolution.

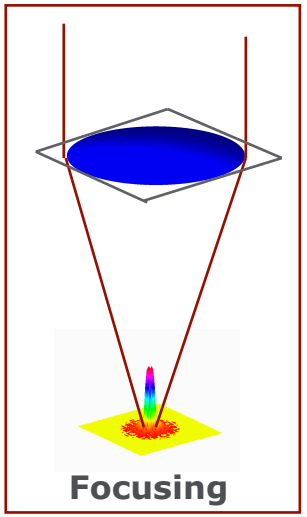


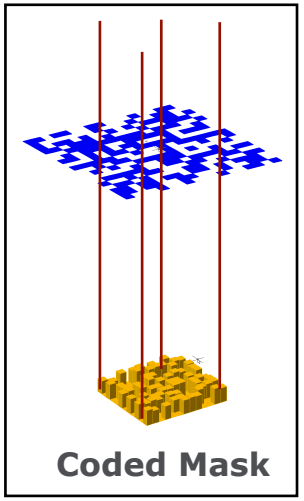
JEM-X off-axis shadowgram



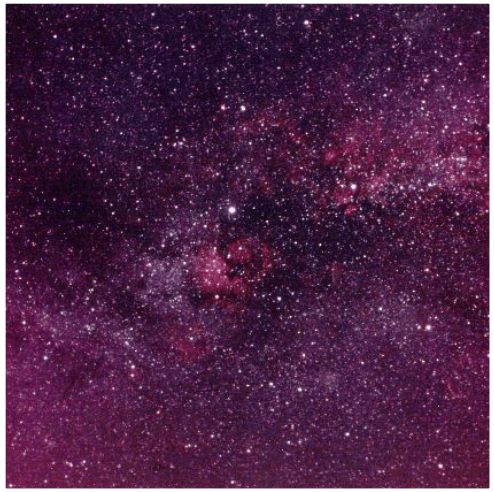
IBIS off-axis shadowgram


SPI mask
& detector



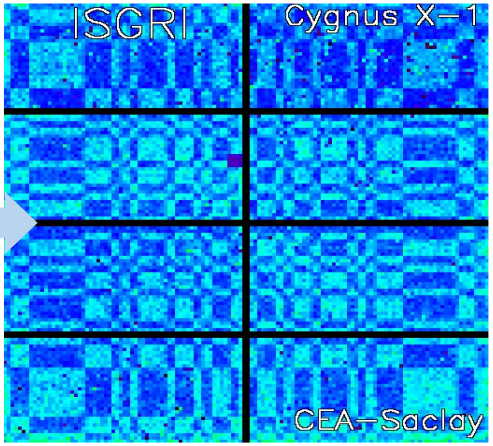


Coded Mask Image Reconstruction

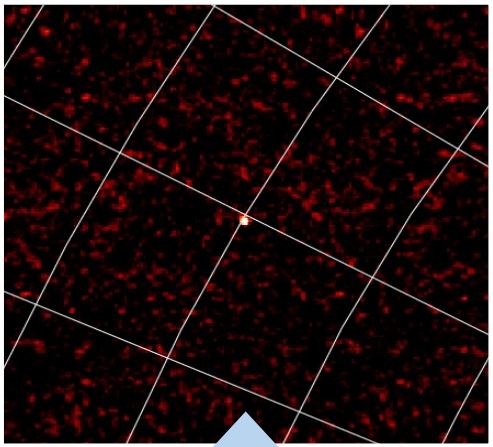


Observation

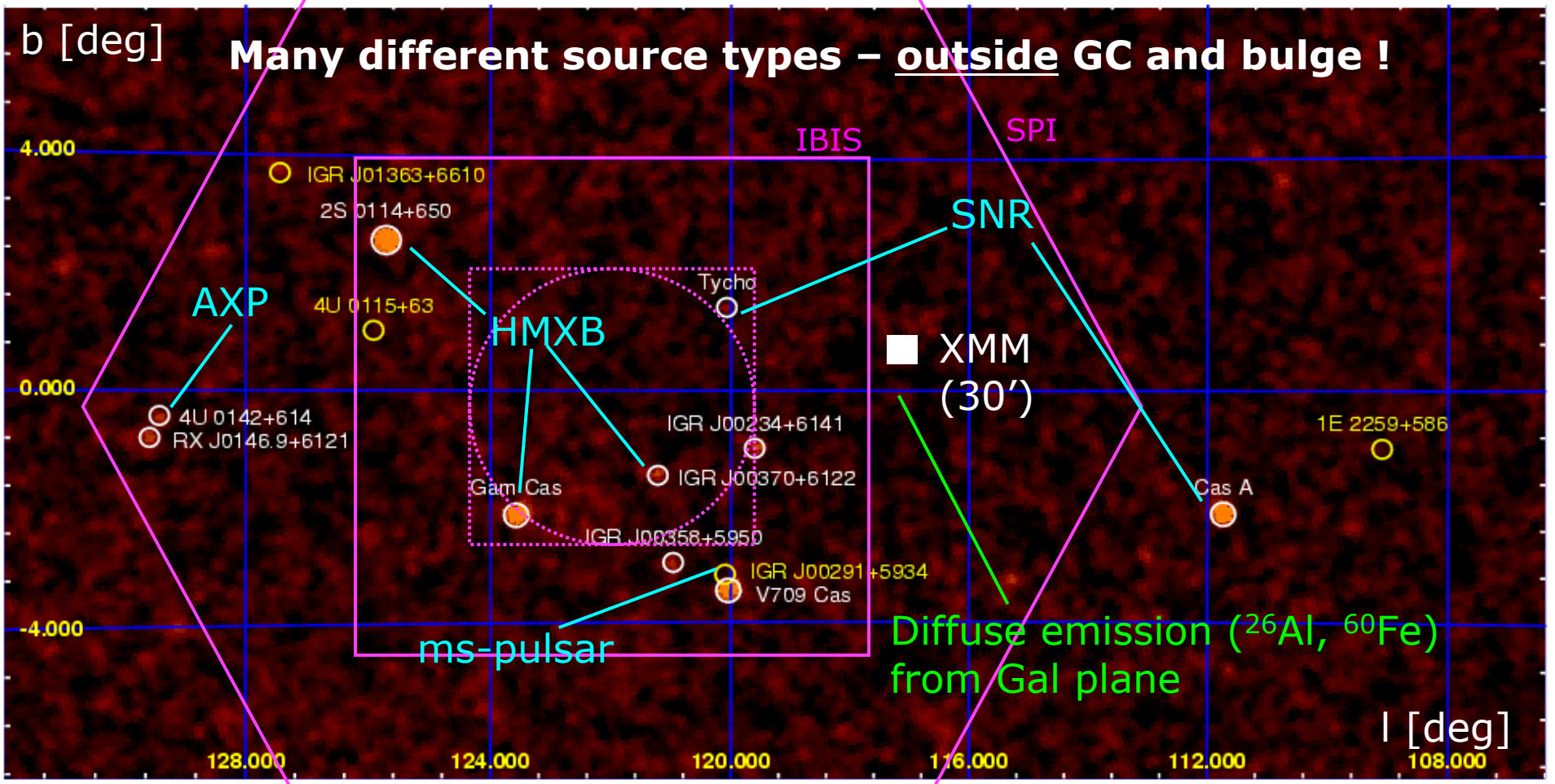
Transmission



Decoding

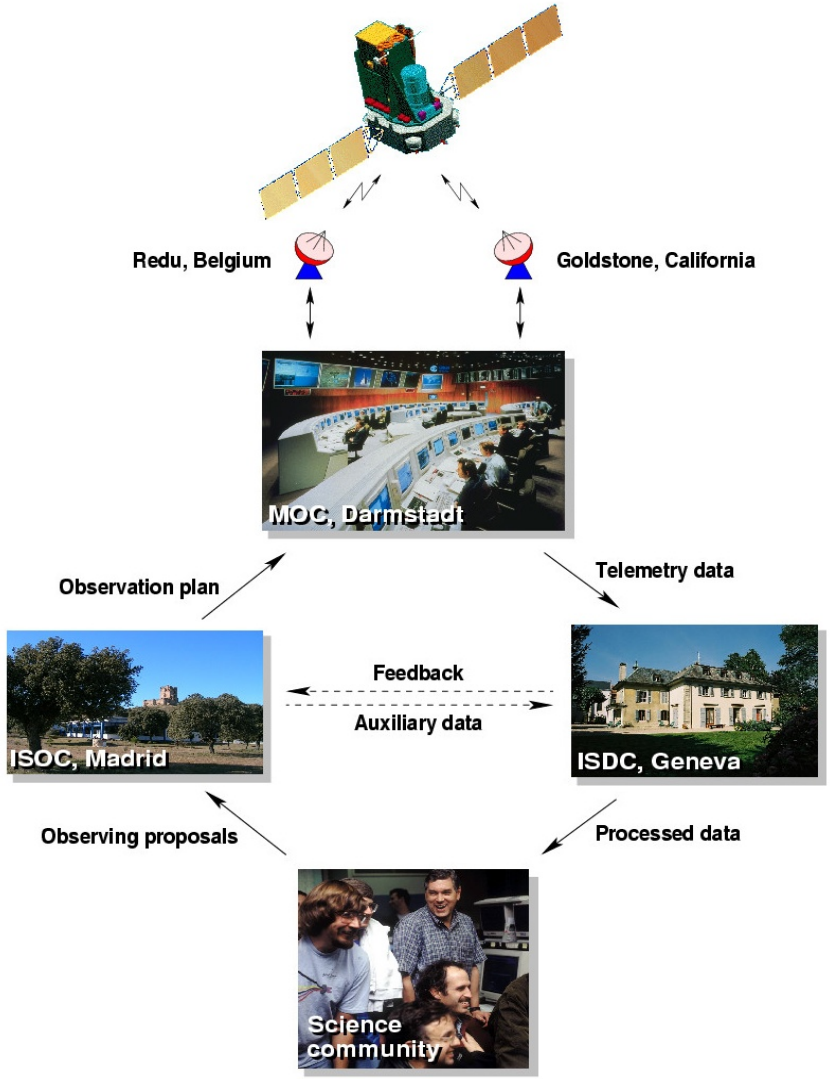


A wide-angle view of the sky



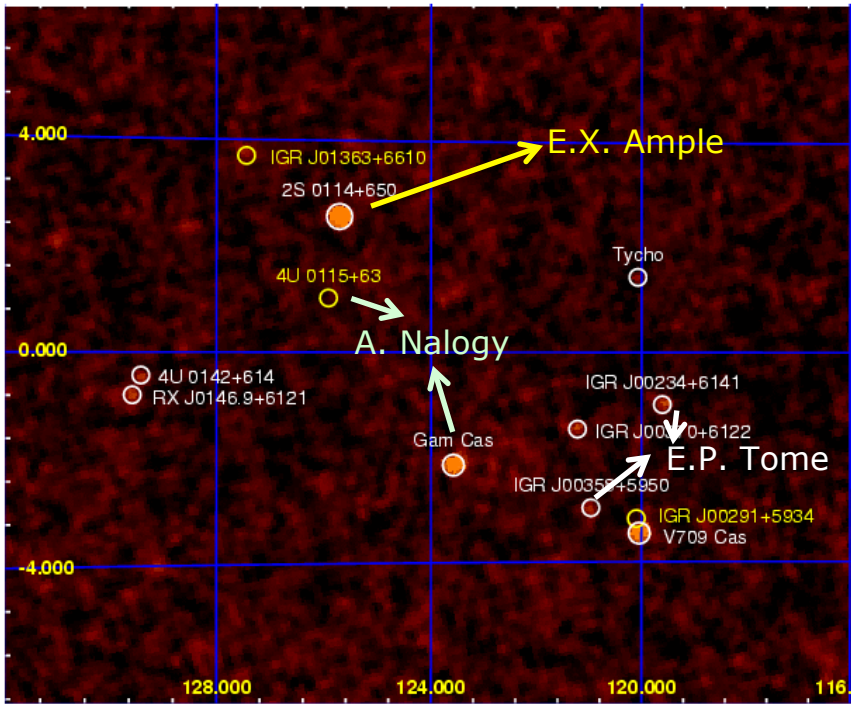
Integral Ground Segment

- Three centres to manage satellite
- **ISOC** organizes calls for proposals, manages proposals from scientific community and creates observation plan (long- and short-term).
- **MOC** controls satellite according to planning, receives telemetry via ground stations and monitors satellite & instrument health.
- **ISDC** receives telemetry, processes the data, monitors instruments, does quick-look analysis and distributes data to users.
- In addition, the four instrument teams continue to be tightly involved for instrument monitoring, calibration & software development.



Sharing time

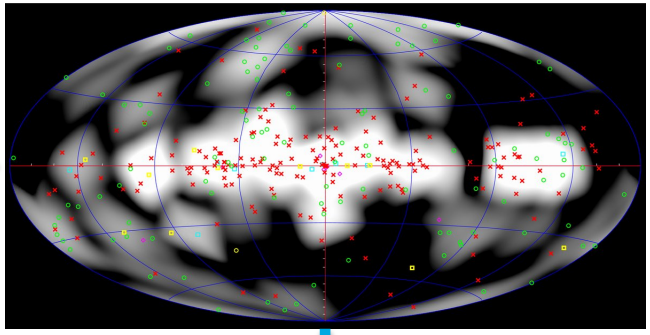
- At the beginning a fraction of the Integral time was reserved for the instrument teams. Since 2009 all data are open to the scientific community.
- As compensation for the launcher, the Russian community has a guaranteed return of 25% of the Integral time.
- Successful observing proposals have data rights for 1 year, afterwards all data become public. Some observations are immediately public.
- In AO-4 (2006/2007) **Key Programmes** were introduced: large observing programmes where secondary sources could be attributed to **data right proposals**.
- Since AO-7 (Oct 2009 – Dec 2010) **all normal (non ToO) observing proposals** are being shared in this way. PIs of observing proposals have data rights to specific sources in field, others are open for proposals.



Two-stage proposal submission per AO

Observing proposal

Approved observing programme



Documentation, exposure maps, …

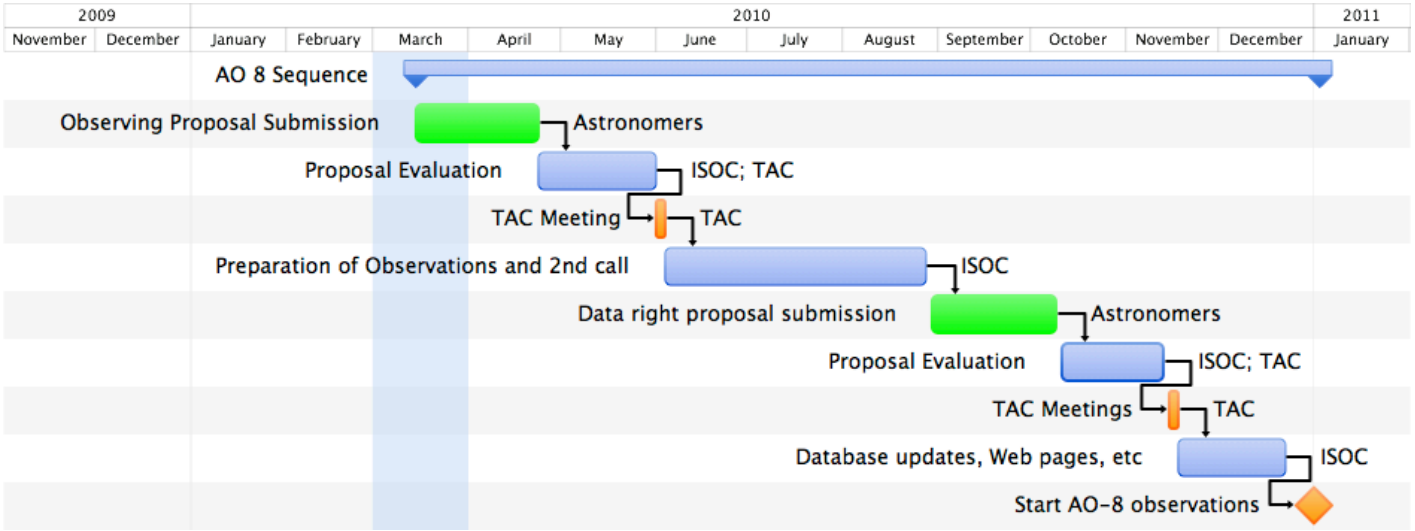
Data right proposal

Approved data rights

SOURCE NAME	RA (degrees)	DEC (degrees)	PI	PROP ID	OPEN TIME PROPOSALS SUBSCRIBED TO
North Ecliptic Pole	---	---	Ajello	0730101	0720022
IGR J16318-4848	247.9667	-48.8083	Barragan	0730023	0720047
1E 1740.7-2942	265.9785	-29.7452	Bazzano	0730011	0720047
H 1517+656	229.4483	65.4233	Beckmann	0730013	0720022
IGR J21247+5058	321.1642	50.9733	Beckmann	0730014	0720026 0720030
NGC 2110	88.0475	-7.4561	Beckmann	0730097	0720009
RBS 0076	8.3933	-19.3594	Bianchin	0730057	0720003
1ES 0033+595	8.9692	59.8347	Bianchin	0730057	0720030
PKS 0118-272	20.1319	-27.0235	Bianchin	0730057	0720003
PKS 0516-621	79.1872	-62.1182	Bianchin	0730057	0720017
PKS 0700-661	105.1303	-66.1791	Bianchin	0730057	0720017
PKS 0727-11	112.5796	-11.6869	Bianchin	0730057	0720028
GB6 J1239+0443	189.8865	4.7181	Bianchin	0730057	0720003 0720006
OP 313	197.6192	32.3456	Bianchin	0730057	0720003
PKS 1329-049	203.0186	-5.1620	Bianchin	0730057	0720003 0720006

AO-8 sequence of events

- **15 March 2010:** Call for observing proposals
- **23 April 2010:** Deadline for observing proposal submission
- **1-3 June 2010:** TAC Meeting observing proposals
- **30 August 2010:** Call for data right proposals
- **8 October 2010:** Deadline for data right proposals
- **mid Nov 2010:** TAC (virtual) meetings on data right proposals
- **1 January 2011:** Start of AO-8 observations

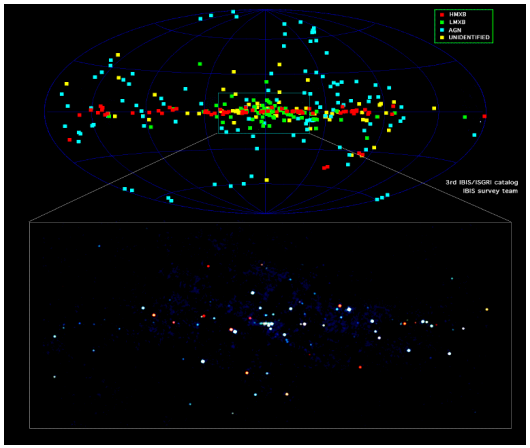


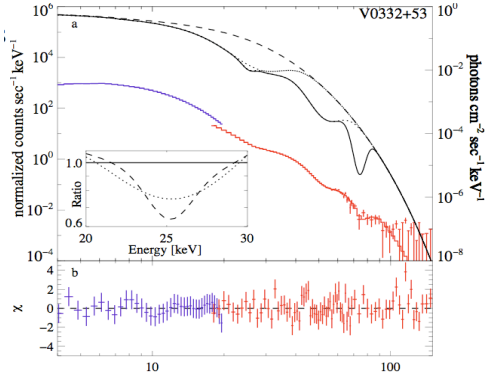
Proposal types and data rights

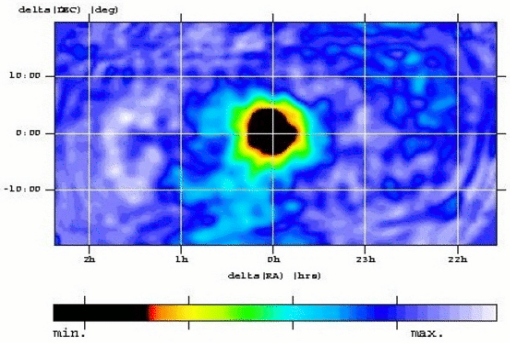
- **Normal proposals & key programmes (stage 1)**:
  - Define region to be observed and observing strategy.
  - Main data rights reserved for PI & CoIs for 1 year.
  - Secondary sources can be shared by data right proposals.
- **Targets of Opportunity (ToO) proposals submitted in AO call (stage 1):**
  - Define trigger conditions, region(s) and observing strategy.
  - All data rights reserved for PI & CoIs for 1 year.
- **GRB in FOV (stage 1):**
  - No dedicated follow-up observations, data right assignment only.

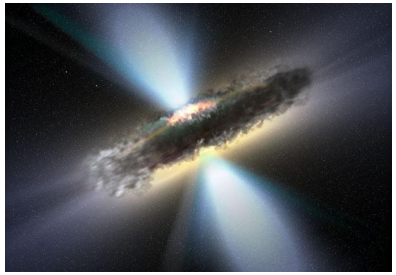
- **Data right proposals (stage 2):**
  - Define sources and accepted programmes to share.
  - Specific data rights reserved for PI & CoIs for 1 year.

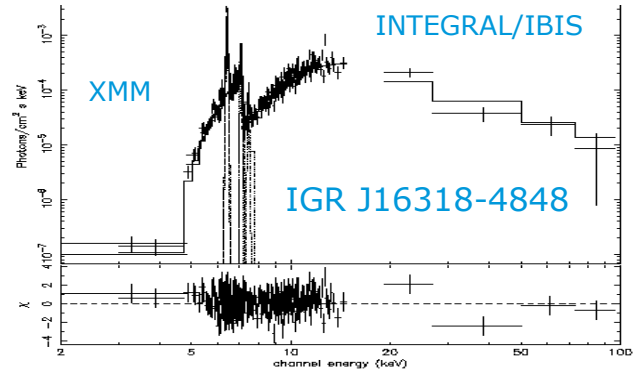
Science with Integral

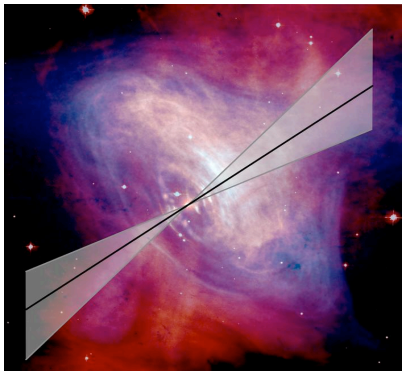


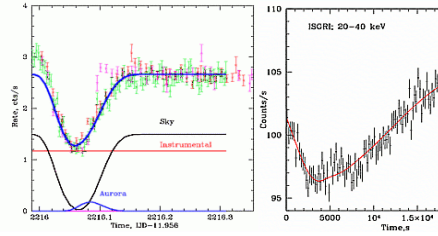


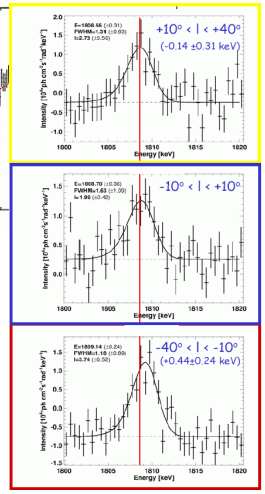


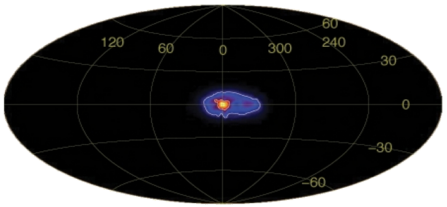


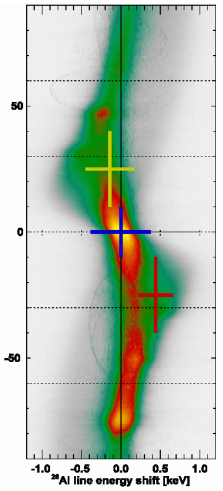






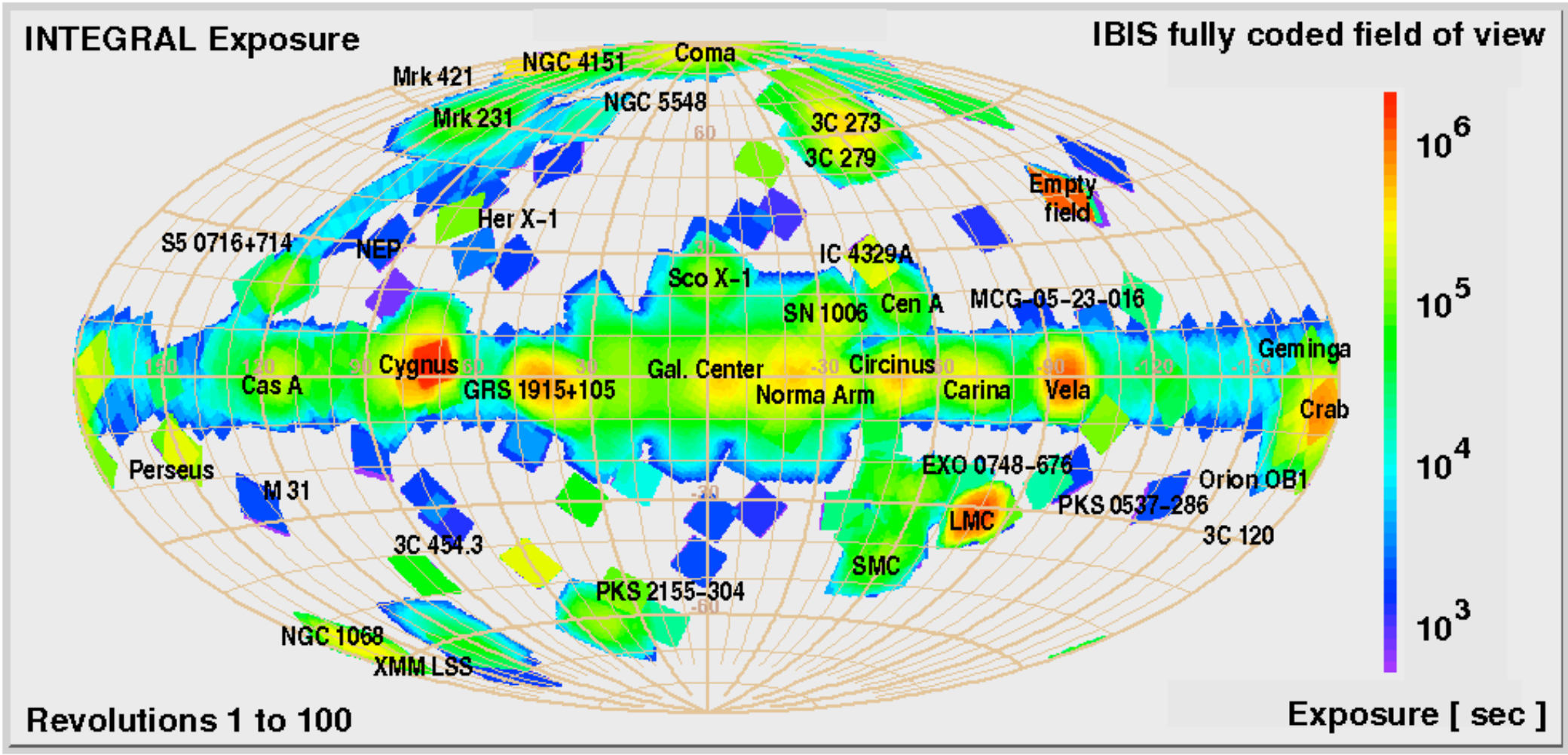






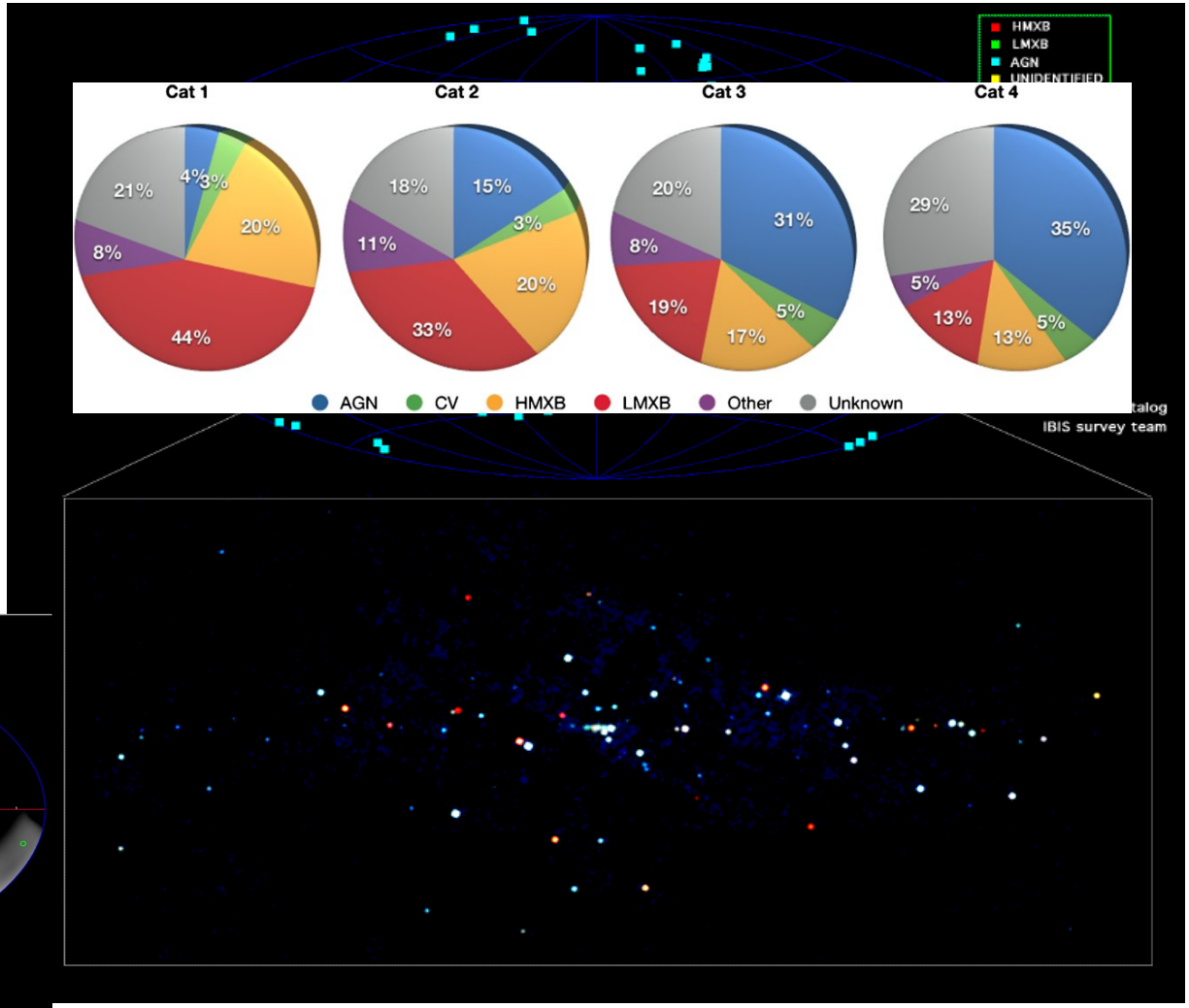
- Very wide range of scientific topics, e.g., massive stars, galactic compact objects, diffuse emission in the galaxy (nucleosynthesis), AGN, cosmic background, …
- Selected science presented later.

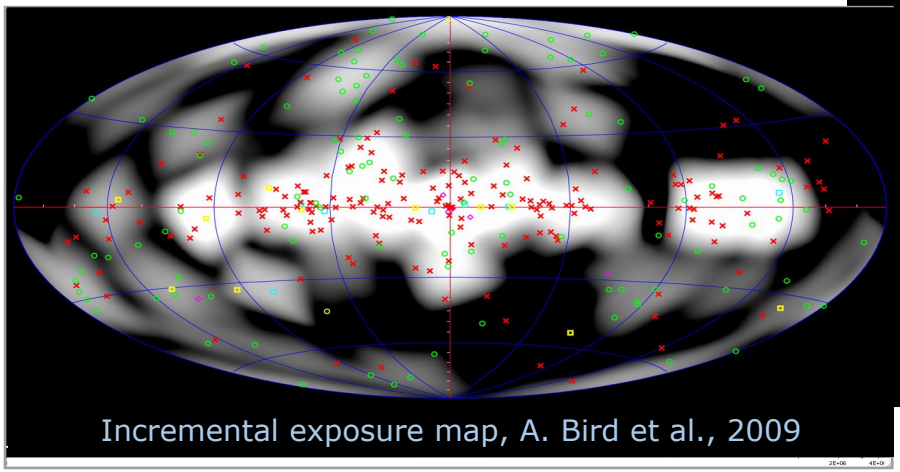
Covering the sky



IBIS-ISGRI all-sky survey

- 4th ISGRI catalogue:
  723 sources, >300 more than in 3rd version.
- ~30% not yet identified: AGN? LMXB?
- AGN share increasing strongly, related to sky coverage.

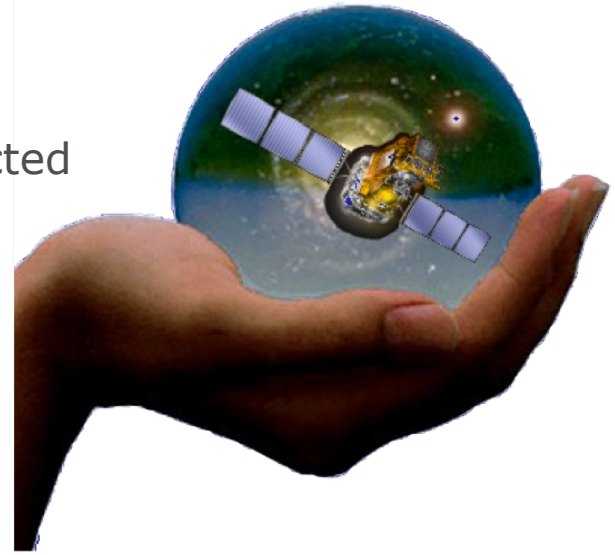




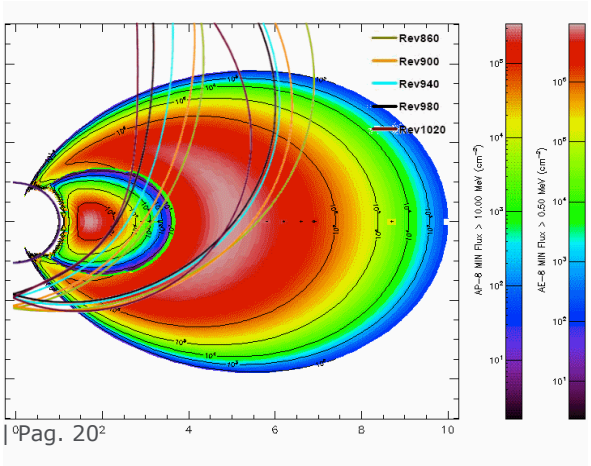
Incremental exposure map, A. Bird et al., 2009

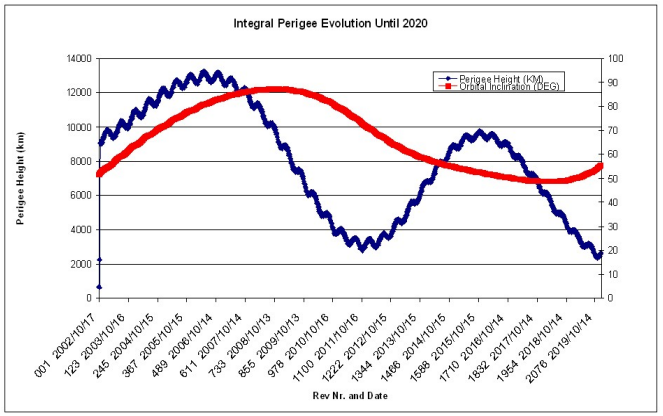
The future

- Spacecraft, instruments and ground segment are all operating very well. Consumables for >15 years operations.
- Perigee altitude dropping quickly: ~6000 km end 2009. Predicted minimum ~3000 km in 2011 ➔ Passing through proton belts.

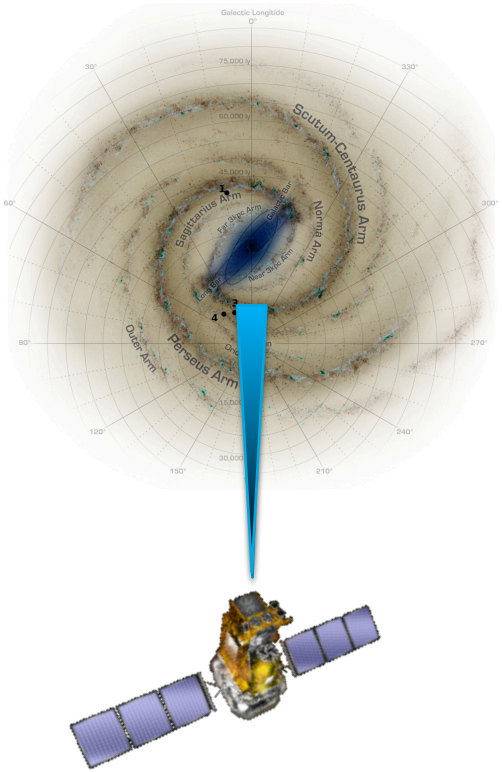


- Approved rolling 4-year mission extension up to end 2012, but need confirmation for 2011/12.
- Further extensions will need to be very well justified.
- Extension request is being prepared, MEOR on 1 July.
- SPC decision on confirmation 2011/2012 and further extension to be taken in November.





Bonus Track: Galactic Bulge - The Movie



Kuulkers, 2009