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Ideas to promote INTEGRAL

Guidelines (after discussion)

- Show what would be missed by discontinuing INTEGRAL
- Increase usage and awareness
- Find new/outstanding science goals which can be achieved only during extension in 2023-2025
- Investigate possible unorthodox operating modes

Multi-messenger synergies

- LIGO/Virgo will probably resume at the end of 2022, so nearly no overlap with the current extension (EK, contact directly LIGO !)
- FRB – GRB connection is promising and SPI-ACS made detection, besides IBIS serendipitous result
- Some GRB are giant magnetar flares
- Neutrinos seem to be poorly associated to EM phenomena
- LSST stream of alerts can be filtered to isolate possible blue transients, possibly unusual early supernovae or

INTEGRAL as essential monitor

- The disappearance of INTEGRAL would make us blind to several high energy Astrophysics phenomena that are relevant for other key operating missions:
  - Accreting millisecond pulsars – key target for NiCER, fundamental physics associated to the neutron star EoS, alternative targets for supra-nuclear density matter to merging neutron star binaries
  - Any transient source in the "milli-crab Universe". This is presently a unique domain for INTEGRAL due to the lack of sensitivity or proper observational strategies of other missions.

INTEGRAL as unique sensitive monitor

- Any transient source in the "milli-crab Universe". This is presently a unique domain for INTEGRAL due to the lack of sensitivity or proper observational strategies of other missions.
    - SVOM (50% sky): to be launched in 2022, will observe roughly only 50 % of the sky at once and point mostly away from the Galactic plane where most transient are located but the high background hampers the optimal detection of GRBs (core science targets of SVOM).
    - Einstein Probe: 60° FoV at 0.5-5 keV. Lobster eye telescope very sensitive but will lack the capability of understanding transients in the local universe due to low on-axis effective area for characterization: only few cm^2.
    - HXMT (50% sky, difficult on crowded regions and faint sources): sources at millicrab, included AMXPs are out of reach because <<100-300 mCrab (sensitivity limit of HXMT)

Abandon AO, data rights, TOOs?

- Abandoning AOs could significantly reduce costs through planning simplification
- Limit the number and type of TOOs to outstanding events defined by PS and solicited by community on a casa-by-case way?
- Make all data public immediately ! It seems that this is anyway the road that most agencies would like to take for the coming future. Public data is perceived as a positive boost of the science exploitation of an astronomy dedicated observatory-like mission.
- INTEGRAL could become our relatively low-cost sentinel of the X- and Gamma-ray sky. Pointing to best known locations for variable/transient sources as much as possible, with a pointing plan defined a priori by the IUG (for example).

Increasing visibility with scientific alerts

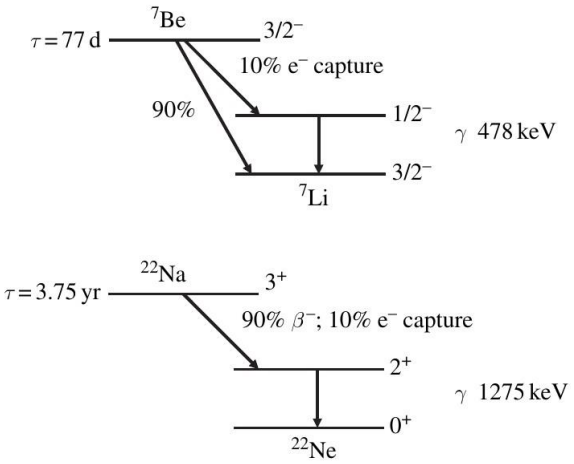
- Increase rate real-time alerts:
  - IBAS/SPI-ACS alerts (recently investigated with Swift/GUANO team)
  - IBAS/ISGRI weak and weaker events: distribute and advertise
- Distribute QLA alerts:
  - new possible sources on ScW, mosaic image time scales in automatic fashion
  - Counterparts of all kinds of sources, LSST etc
- Continue to guarantee and facilitate IPN localizations

Quality outreach: the living INTEGRAL sky

- If data were all public !!
- With moderate development effort:
  - We can expose ISDC quick-look results every few hours with near real time sky map.
  - We can link a recipe to make image with the ODA.
  - We could (with additional effort and after ISGRI calibration) expose the historic light curve of relevant sources detected in images, as well as links to produce spectra.
  - *We need to federate computer resources with other partners*; UNIGE cannot provide it all.

An outstanding science target (LD)

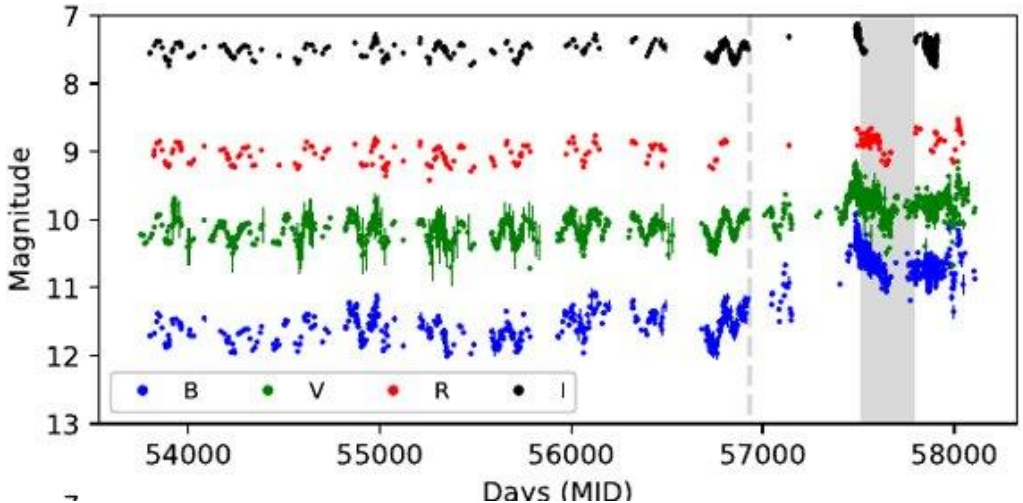
- A bright galactic Nova is likely to give a clear signal of positron annihilation and nuclear lines
- Lorenzo Ducci proposes to follow T Coronae Borealis a recurrent nova (RN) with 80 years recurrence time. It is the nearest RN (800+/-30 pc, GAIA).
- 511 keV signal is expected to happen ~1 week before the optical outburst and be visible at the nova distance
- Nuclear lines 22Na and 7Be produce the strongest mono-energetic gamma-ray lines. They can last for long time and give important constraints on nucleosynthesis and nova models: detectabe at the source distance



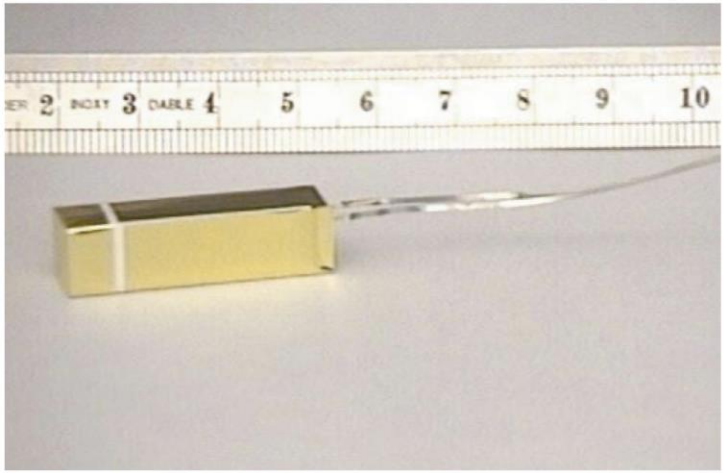
Status of T CrB

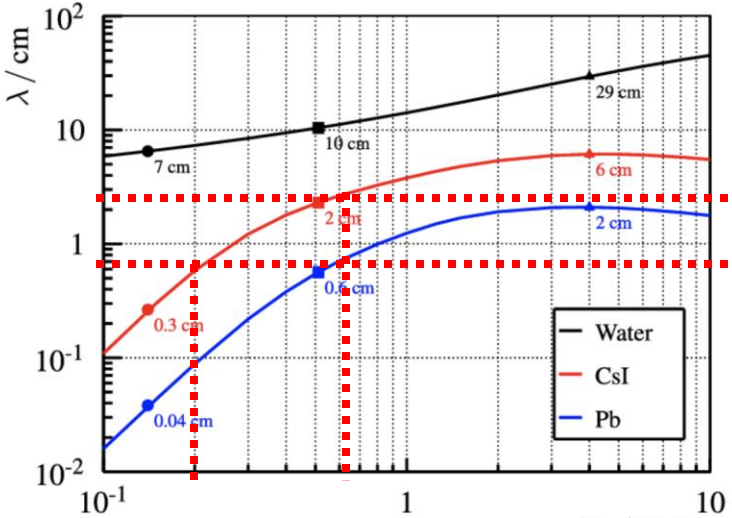
- Since 2015 T CrB entered in the so-called ``super active'' state:
  - Munari et al. (2016) reported an optical brightening that started in early 2014, particularly evident in the B band
  - Luna et al. (2018 A&A 619, 61, 2019 ApJ 880 94, 2020 ApJL 902 14) reported a strong X-ray variability, indicating a sudden increase in the rate at which the material reaches the boundary layer and change in its structure.
    Radio observations also indicate that T CrB entered in the super active state (Linford et al. 2019 ApJ 884, 8).
- super active state corresponds to a transient accretion high state which is expected to trigger eruptions in recurrent novae and were observed (in optical) eight years before the two past nova eruptions.
- a new explosion It is expected in 2026 +/- 3 (Luna et al. 2020, Linford et al. 2019, Munari et al. 2016) or even earlier (mid-2023, Schaefer 2019 AAS Meeting 61, 122.07).

Status of T CrB



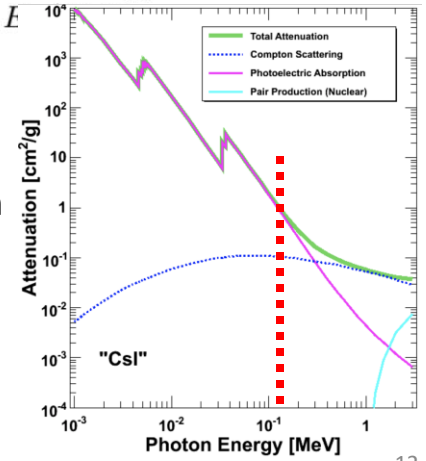
PICSIT as GRB polarimeter





NO

- PICSIT detector has layout sensitive in XY but not Z suitable for GRB polarimetry. It has dimensions similar to POLAR2 (to be launched in 2024+ by the Chinese Space Agency). Most of the GRBs that will be accessible to POLAR-2 will also be accessed by PICSIT.
- PICSIT pixels are 8.5x8.5x30 mm CsI. Gamma-rays with energies above 200 keV interact mostly through Compton scattering in CsI. They typically scatter into neighbouring pixels with ~100 % efficiency.
- The detector becomes partially transparent roughly above 1 MeV, where the mean free path of photons becomes larger than pixel length.
- PICSIT has 2856 cm2 active area, larger than POLAR-2 (comparable effecitve area if 50% efficient).
- INTEGRAL would potentially be a better Compton telescope than anything else !

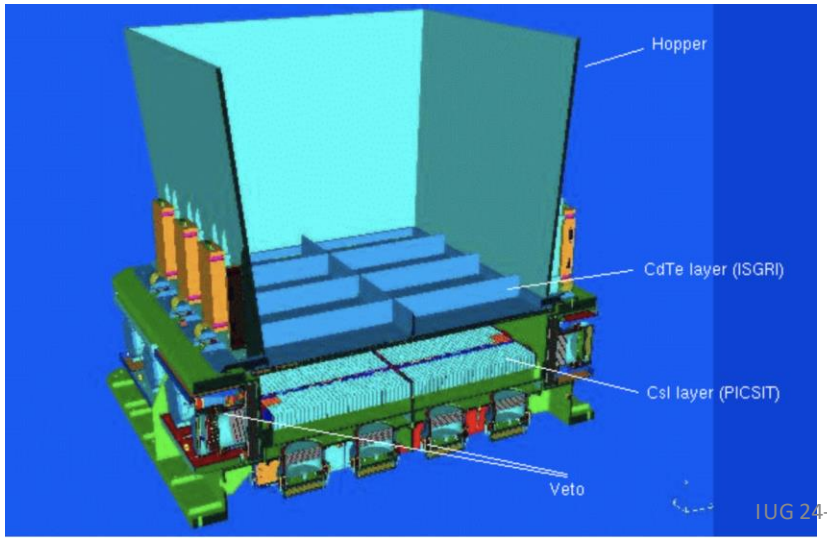


PICSIT as GRB polarimeter

Use PICSIT as a wide field-of-view GRB polarimeter in the energy range >200 keV:

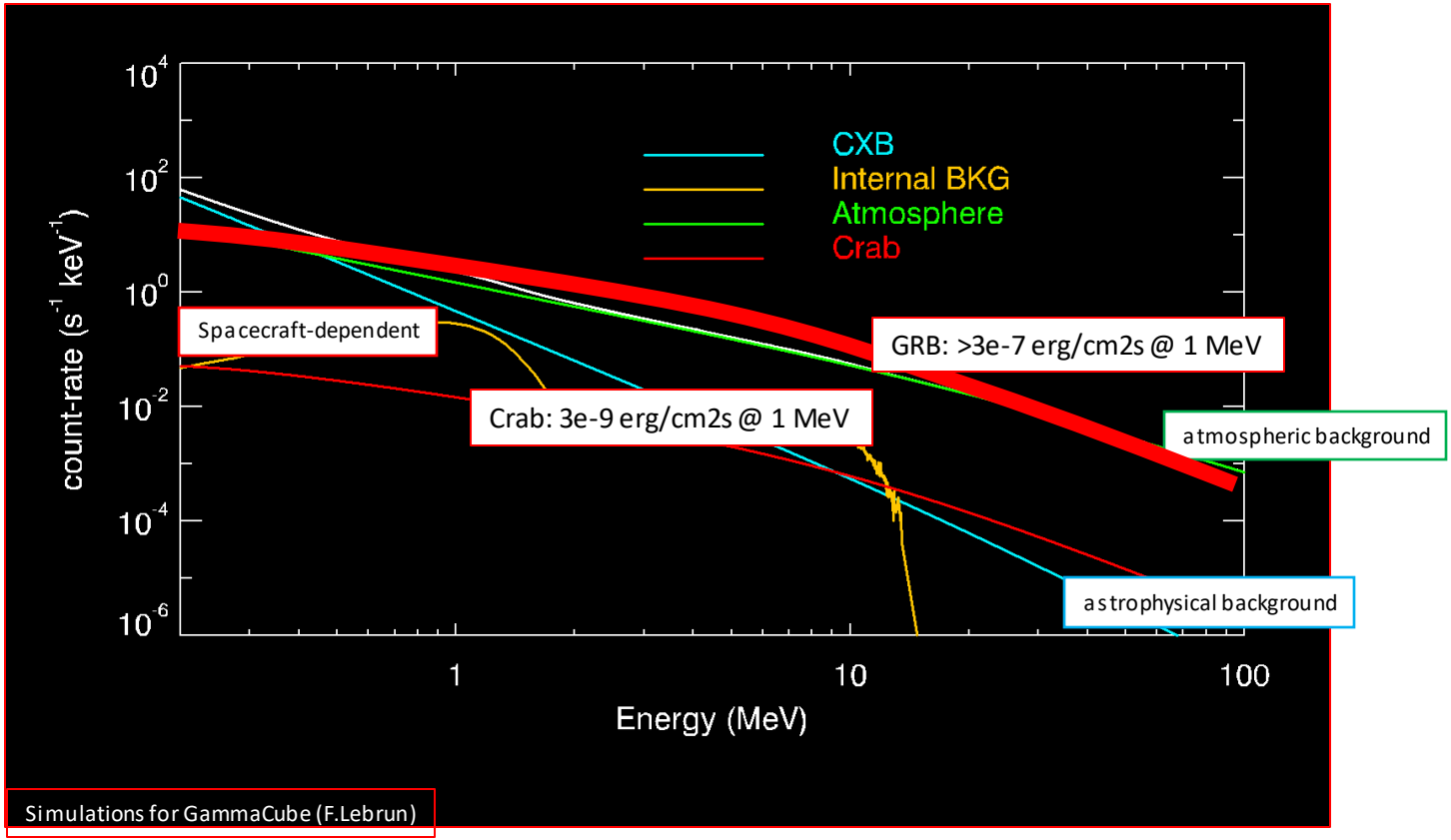
NO

- Disregards the coded mask to increase angular acceptance
- Use ISGRI as an additional veto along with both the BGO to isolate only gamma events Compton scattering in PICSIT. ISGRI pixels are 2 mm thick, photons with energies >200 keV pass unhindered.
- Read out full information on event-by event basis in PICSIT (not histograms per pointing)
- Compton scattering events are “multiple pixel” events. Full information is needed: timing and amplitude, positions and signal of triggered pixels



- Need to find telemetry.
- Can we reduce CR spurious tracks with a modification of on-board S/W (cut in event delta time) ?
- Need to study method feasibility (maybe on slew data?)

Background considerations (modelling is needed)



Pietro's comments

- Carlo you overlooked the fact that we already transmit all the PICSIT/ISGRI Compton data since day zero. They have been used extensively for the polarization studies (Philippe may comment more in dates this point) Crab, Cygnus, GRBs and other strong sources…
- *For this purpose, it would become essential, at least in our preliminary view, to download the event-by-event telemetry of PiCSIT.*
  This is a different story and it is impossible for all the data. We would need 3 times the TLM allocated to all the instruments. During design, we have requested ESA several times to increase the TLM rate to download the all the PICSIT data photon-by-photon. It was never accepted, despite the long fight, with the argument that the increase TLM rate would have had an additional cost (10Meu, if I properly remember !). Finally we have implemented the Spectral-imaging, Spectral-timing and Compton packets to transmit the images and other data in the only possible way. IBIS Compton mode transmits single pixel triggered and multiple as well in different packets. The VETO gating system is optimized also for Compton photon detection. Furthermore, IBIS has a very complicated data management onboard, with CPU (ESA imposed!) that is 95-98% occupied. It gives priority to the above mentioned data, without damaging the PPM information from ISGRI.
- *How this can be achieved I do not know, as I do not remember how much is required. A mitigation of the telemetry problem could be achieved by changing the onboard S/W to disregard most CR tracks with a cut on the delta time between events.*
  Sorry, it is impossible. The PICSIT CR tracks are managed onboard by the HEPI and DPU after the VETO, and they are recorded as images without extra TLM occupation. Otherwise we would have had simply increased the PICSIT threshold. This is why the sensitivity of PICSIT is reduced up to 350 KeV were the track disappear. This has been all assessed during the commissioning and tested in orbit with ALL the TLM al located to PICSIT, if I am not wrong the 23 November 2002. There is a paper from Malaguti with a GRB spectrum analyzed in PPM. All the data have been analyzed to look for TLM optimisation.
- *All this requires a feasibility study, maybe on slew data, and a preliminary assessment on our ability to change TM assignmen ts and onboard S/W. Thus some qualified manpower to be found.*
  The above question has been already analyzed and it is useless, and impossible, to change at this stage the IASW. Giovanni La Rosa, copied, made a full study long ago when ESA asked, again, innovative (impossible) solutions several years ago. He can send you the relevan t document if you like. Also, apart the GRB in PPM that are available in Compton mode, the sensitivity of PISCIT in PPM is lower that SPI and INTEGRAL is optimized as an Observatory with IBIS and SPI optimized in different areas to give the maximum synergy and best sensitivity overall. We can alway improve, if possible, though with realistic actions.

ACS as super BATSE?

NO

- Reading out each module rather than the collective signal from all modules.
- With this it would be possible to reconstruct the direction of GRBs with ACS alone, and improve backg It's straightforward to argue that this would be the largest GRB detector….. and in the nearest future nobody plans to launch something as big as that, so it's a good case, given the multi-messenger context
- Would it work, at least in principle or it is not possible to get the individual segment signal out "by design"?

Andreas' comments

- unfortunately the capabilities of ACS for reconstruction of the incoming direction are quite poor.
- In my paper on INTEGRAL Spectrometer SPI's GRB detection capabilities (A&A 411, L299 2003) I described in section 3.1 "ACS detection capabilities" the readout the individual ratemeter values HK data of each FEE: "The measurement time of the individual FEE ratemeter can be adjusted between 0.1 and 2 s. An integration time of 1.048 s has been selected for the mission.
- All 91 FEEs are read out successively in groups of 8 FEEs every 8 s. The readout of all 91 ratemeter values thus needs 96 s.
- This shows you that there are some minor possibilities for quite long GRBs - which I think was used up to now in only 1 or 2 cases.