ALERTS FROM HIGH-ENERGY OBSERVATORIES (FROM SPACE)

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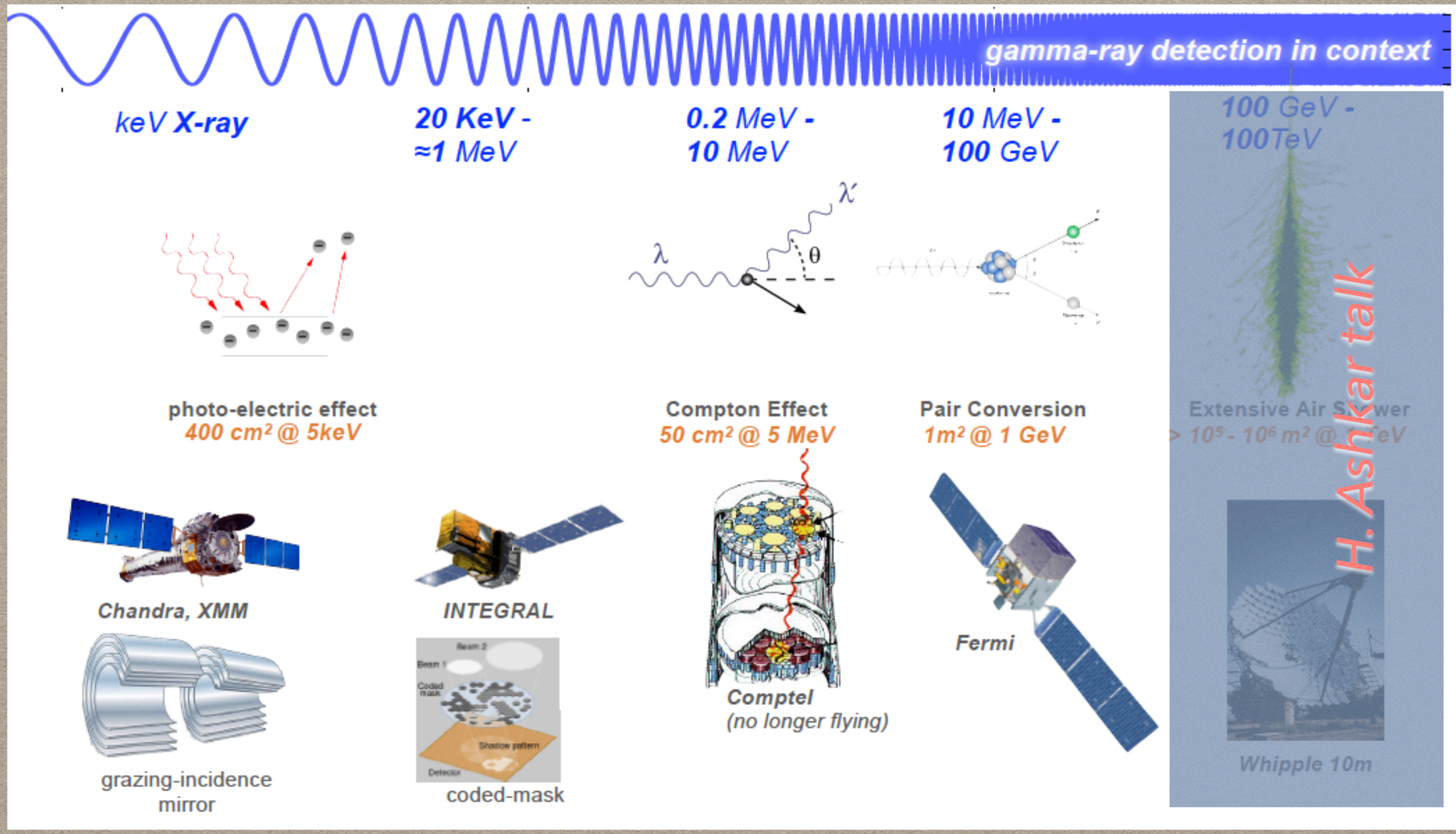
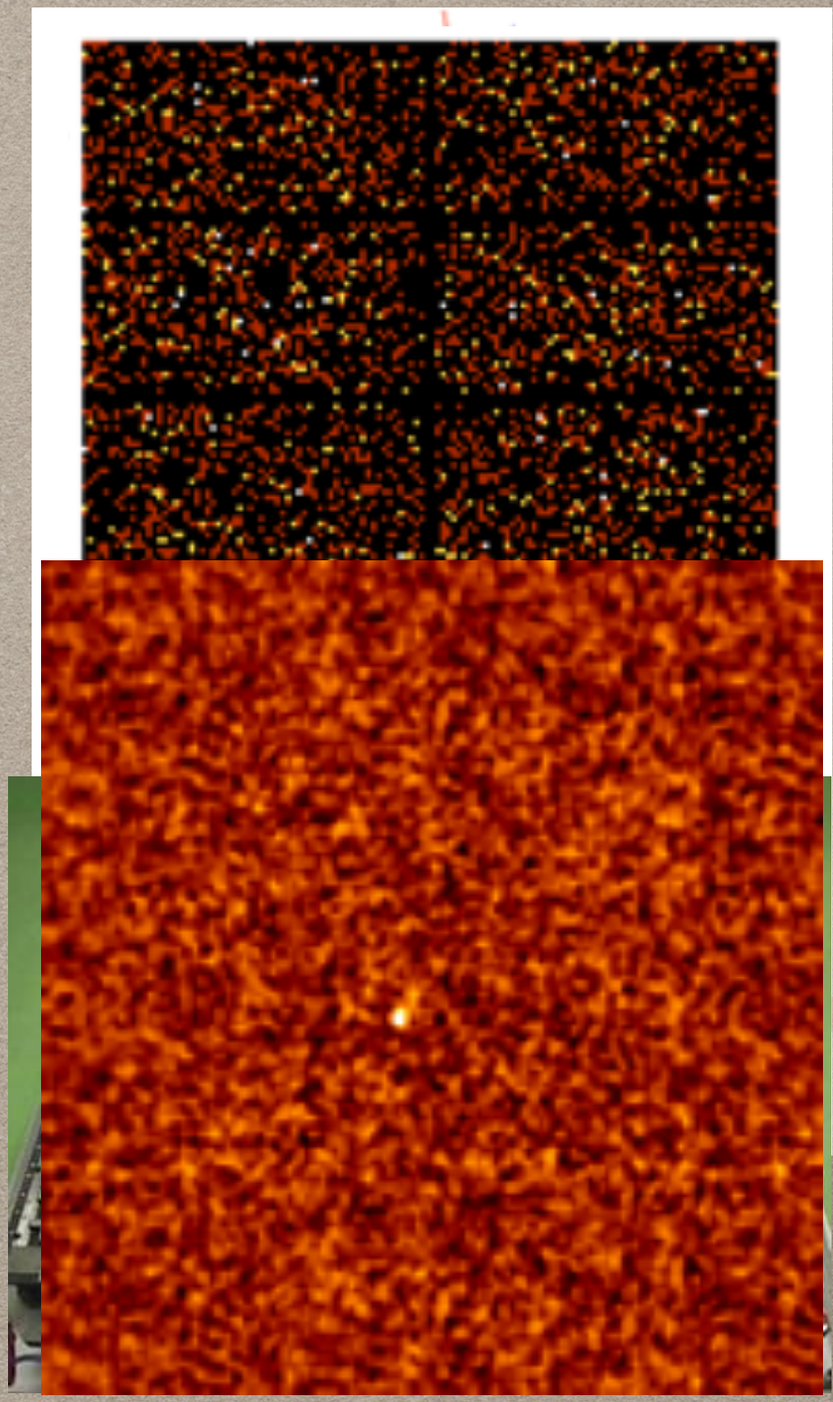
THE CONTEXT

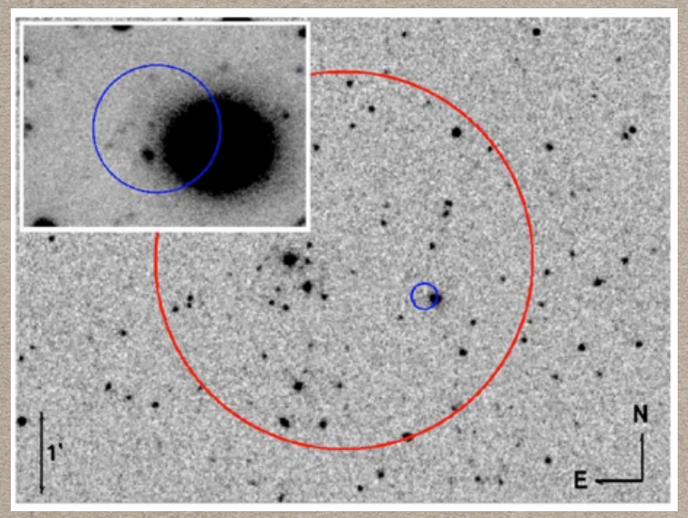

gamma-ray detection in context
keV X-ray
20 KeV - ≈1 MeV
0.2 MeV - 10 MeV
10 MeV - 100 GeV
100 GeV - 100TeV
photo-electric effect
400 cm² @ 5keV
Compton Effect
50 cm² @ 5 MeV
Pair Conversion
1m² @ 1 GeV
Extensive Air Shower
> 10⁵ - 10⁶ m² @ TeV
Chandra, XMM
INTEGRAL
Comptel
(no longer flying)
Fermi
Whipple 10m
grazing-incidence mirror
coded-mask
H. Ashkar talk

WIDE FIELD HARD X-RAY IMAGING

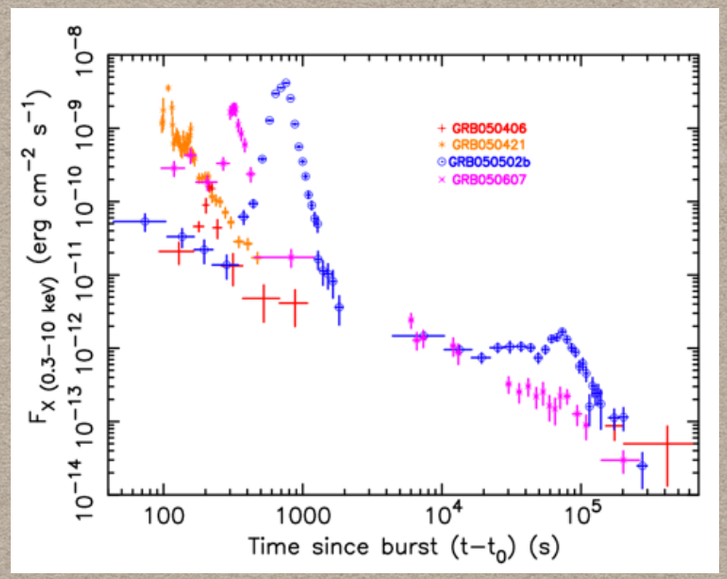
- Above 10 keV it is very difficult to perform direct imaging with mirrors (the maximum energy is proportional to the focal length)
- Coded mask (indirect) imaging is a solution (**INTEGRAL/IBIS** and SPI, BeppoSAX/WFC, **Swift/BAT**, GRANAT/SIGMA, etc.) often coupled to pixellated CdTe detectors
- Each pixel records background and possibly source(s) photons
- Image deconvolution techniques are required to reconstruct the sky
- Wide field of view → all-sky monitoring of the transient sky, optimal for Gamma-Ray Burst searches (BAT on board Swift or IBIS on board INTEGRAL)
- State of the art PSF ~ 12 arc min @ 100 keV
- It is difficult to image diffuse sources, and its sensitivity limited (mCrab) due to the high background
- Can be used up to a few MeV (SPI on board INTEGRAL)



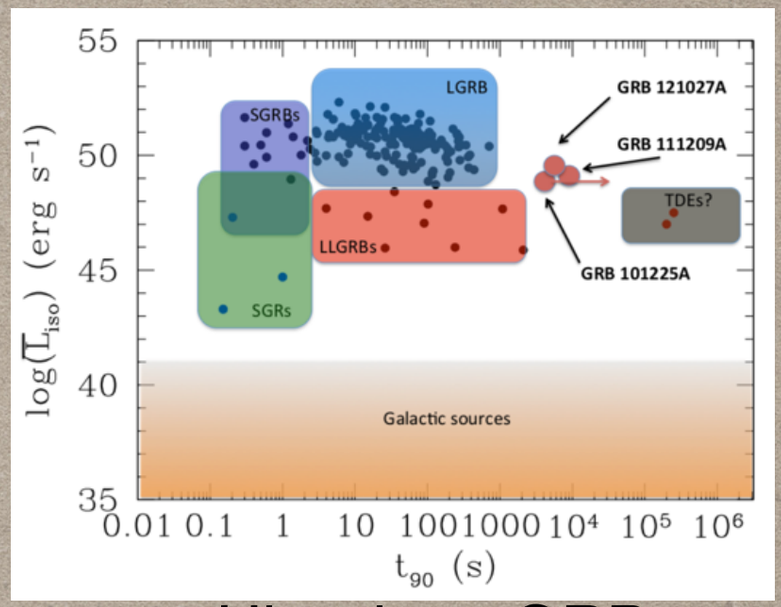
SWIFT RESULTS



Localization of SGRBs

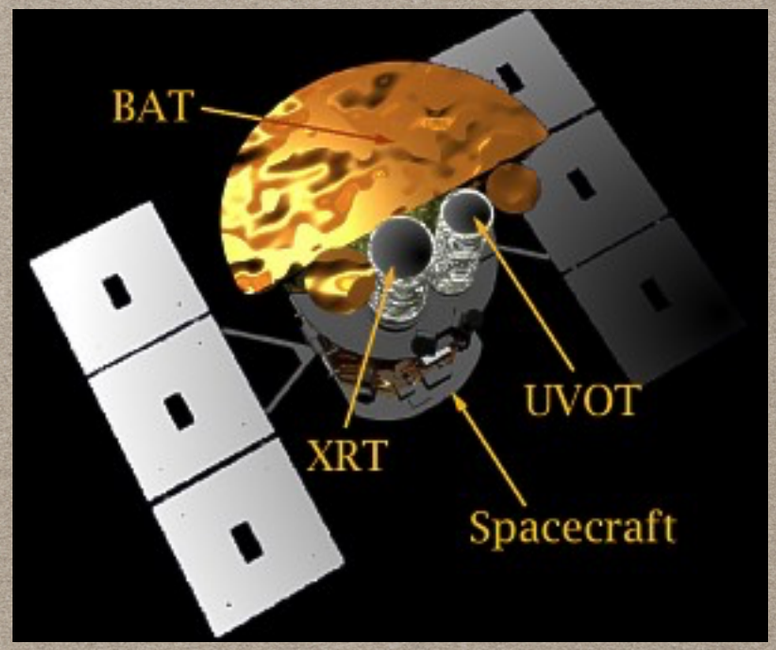


The light curve zoo

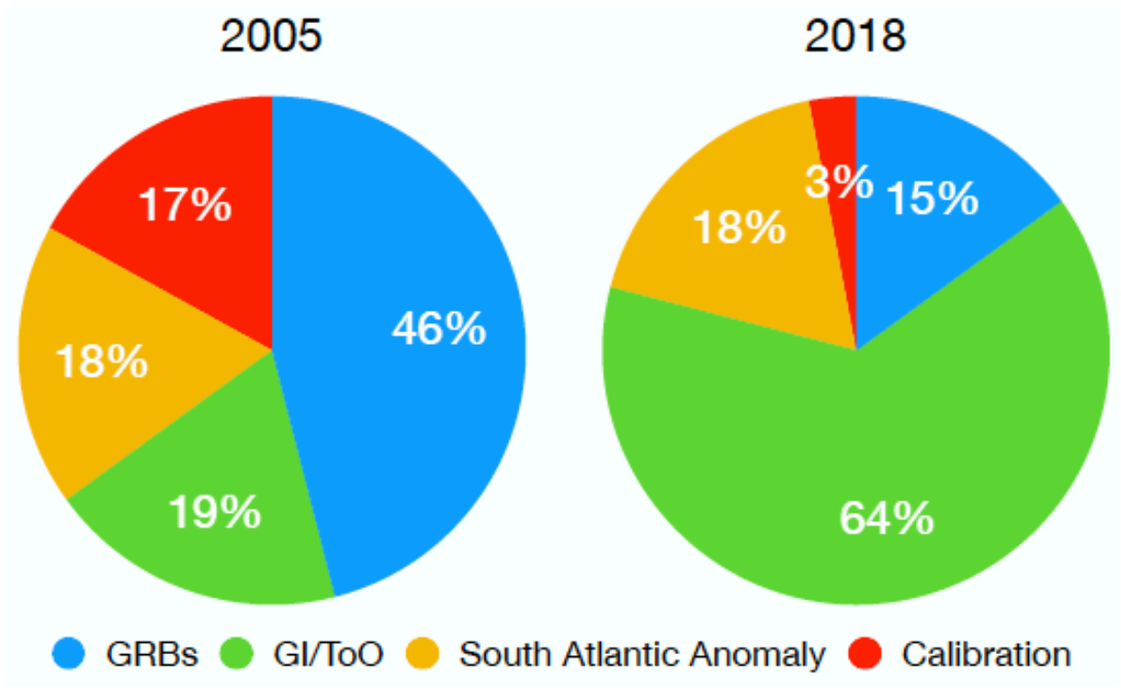


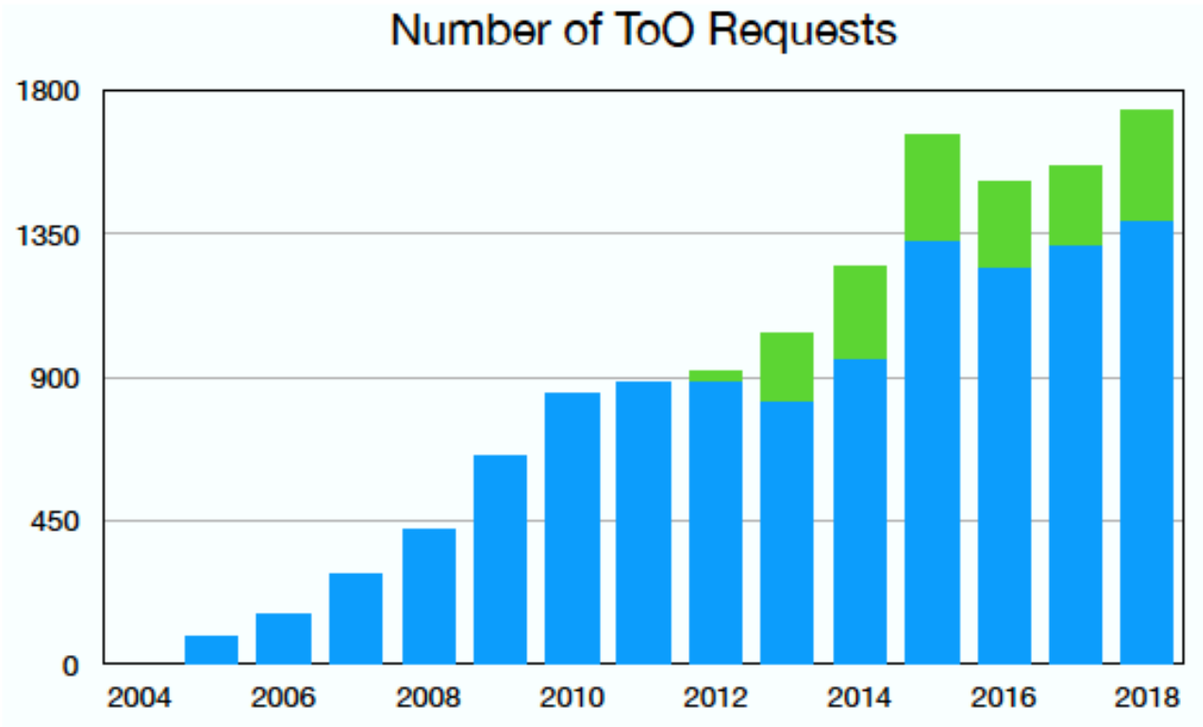
Ultra-long GRBs

- *Many, many other results, e.g. high-z GRBs, long GRBs without SN, low-z with SN*
- *Swift has observed over 1000 GRBs and is still finding exceptional objects*



SWIFT EVOLUTION
(COURTESY P. O'BRIEN)



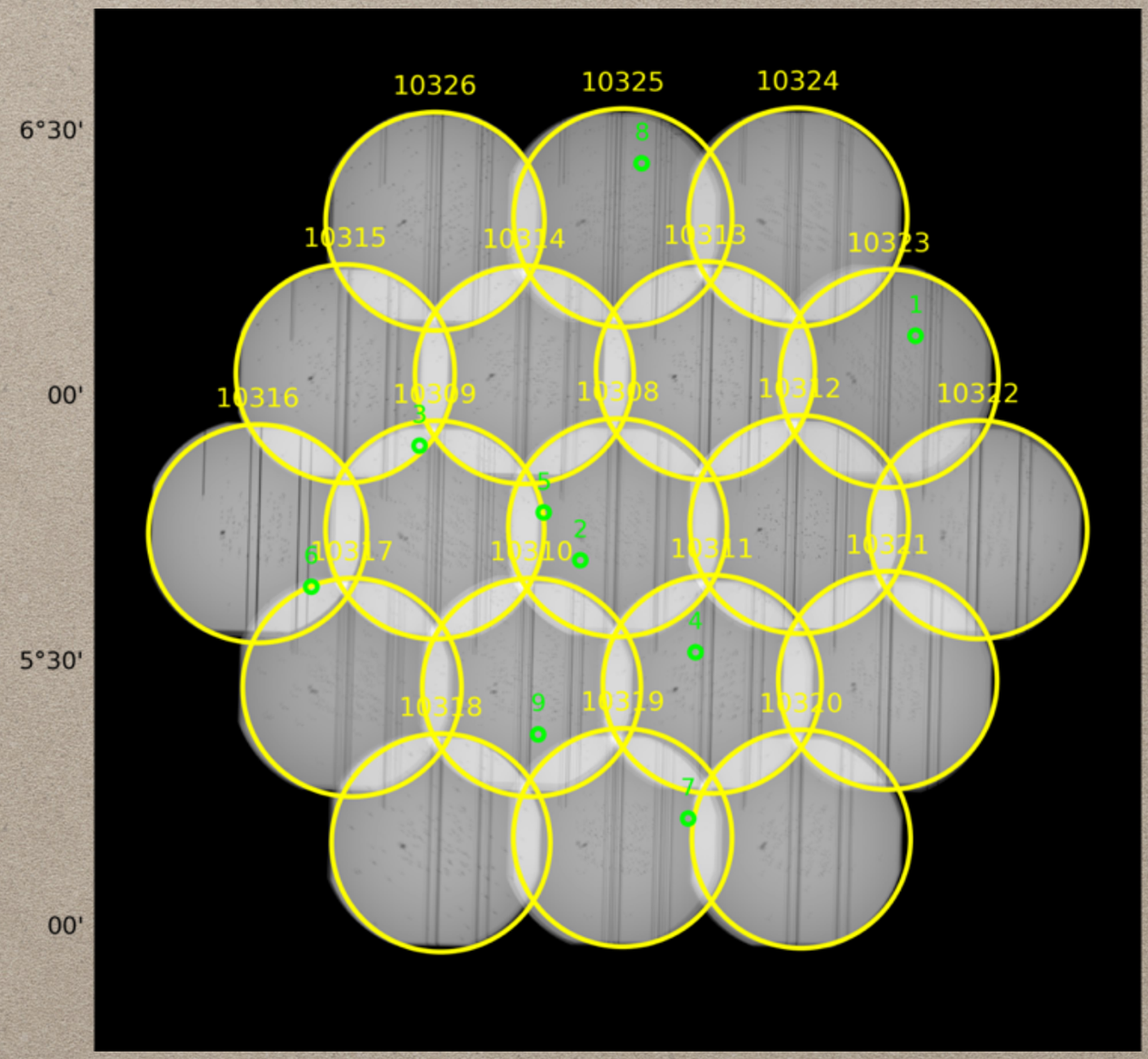


Early on: all GRBs followed until too faint
Now: GRBs followed usually for only for 1-3 days
Much more time now spent on GI/TOOs

Ever increasing no. of TOO requests
(NuStar coordinated in green)

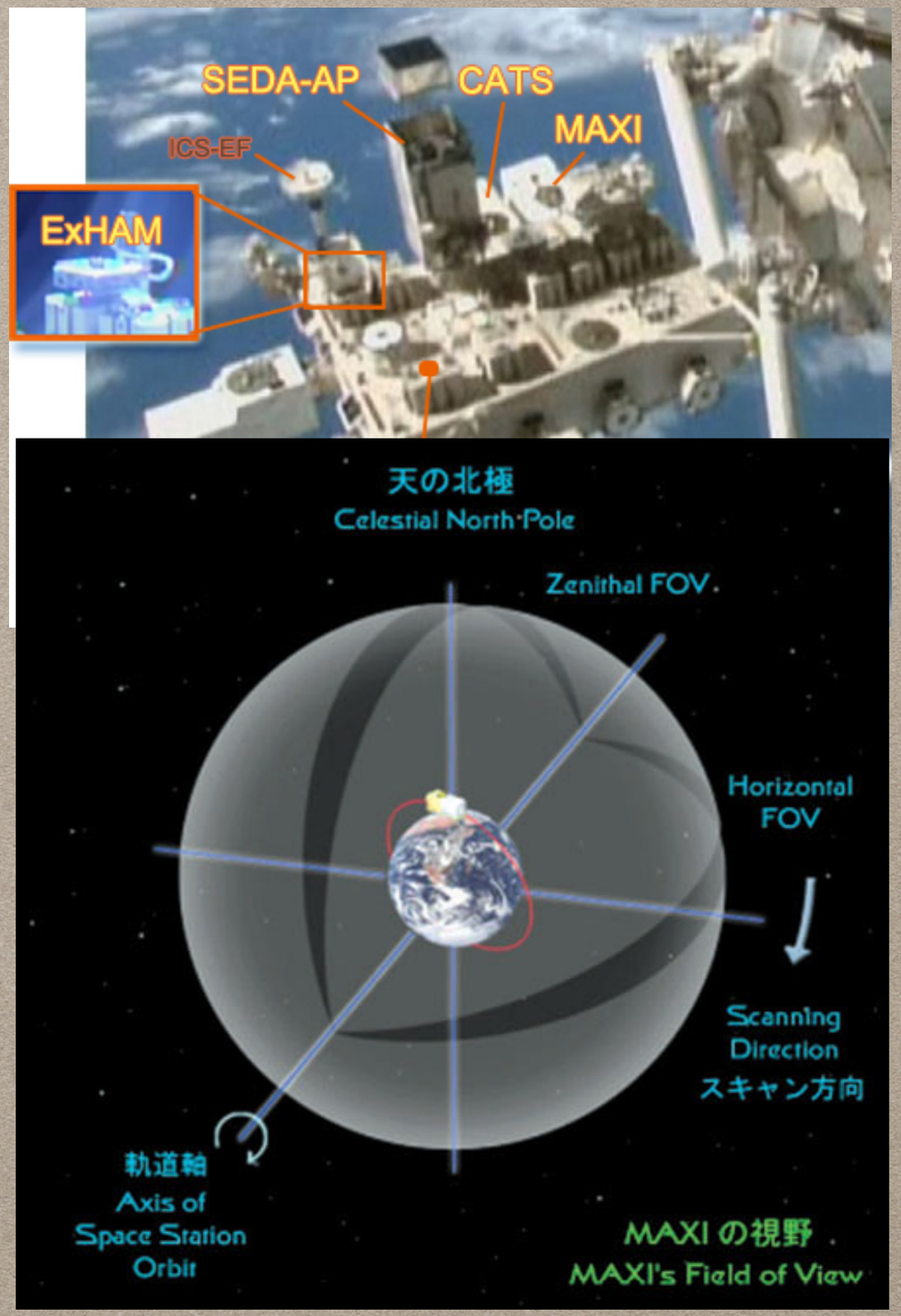
SWIFT & MULTI-MESSENGER ALERTS (COURTESY P. O'BRIEN)

- Alerts with large error regions are no simple to handle -> Tiling
- An example of a neutrino alert tiling is shown
- about ~1.7° diameter



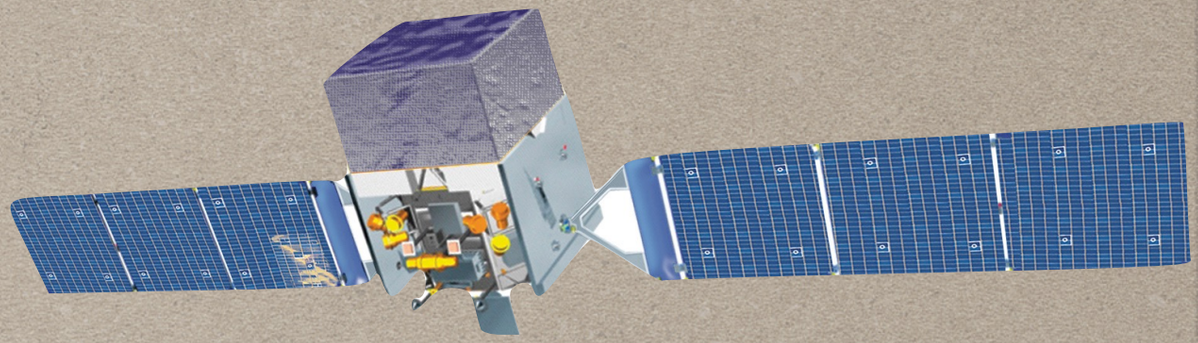
MAXI ON BOARD THE ISS

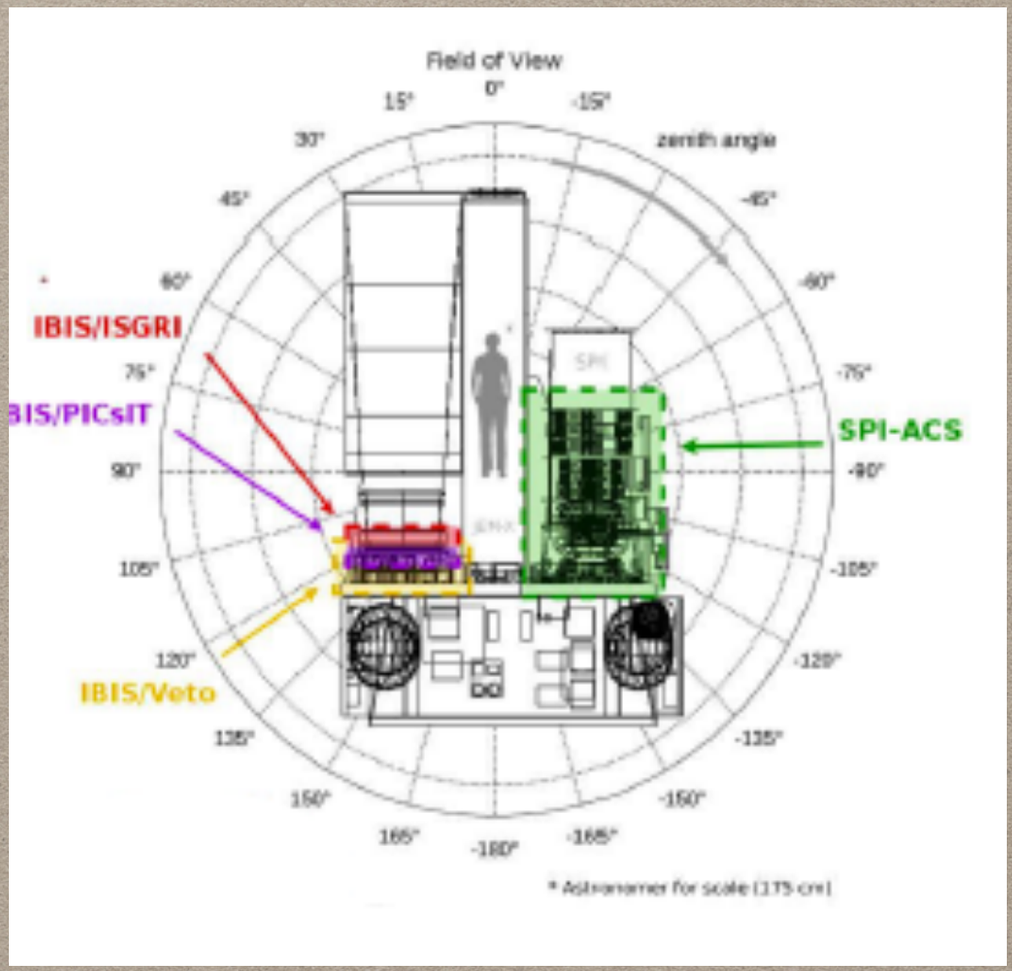
- Japanese experiment on the ISS since almost 10 years
- Working in the 0.5-30 keV energy range; sky scanning slit cameras; ~10 mCrab sensitivity
- MAXI monitors the X-ray variability once every 96 minutes for more than 1,000 X-ray sources covering the entire sky on time scales from a day to a few months
- Routinely discovers new sources, mainly transient XRB



FERMI & SPI/ACS

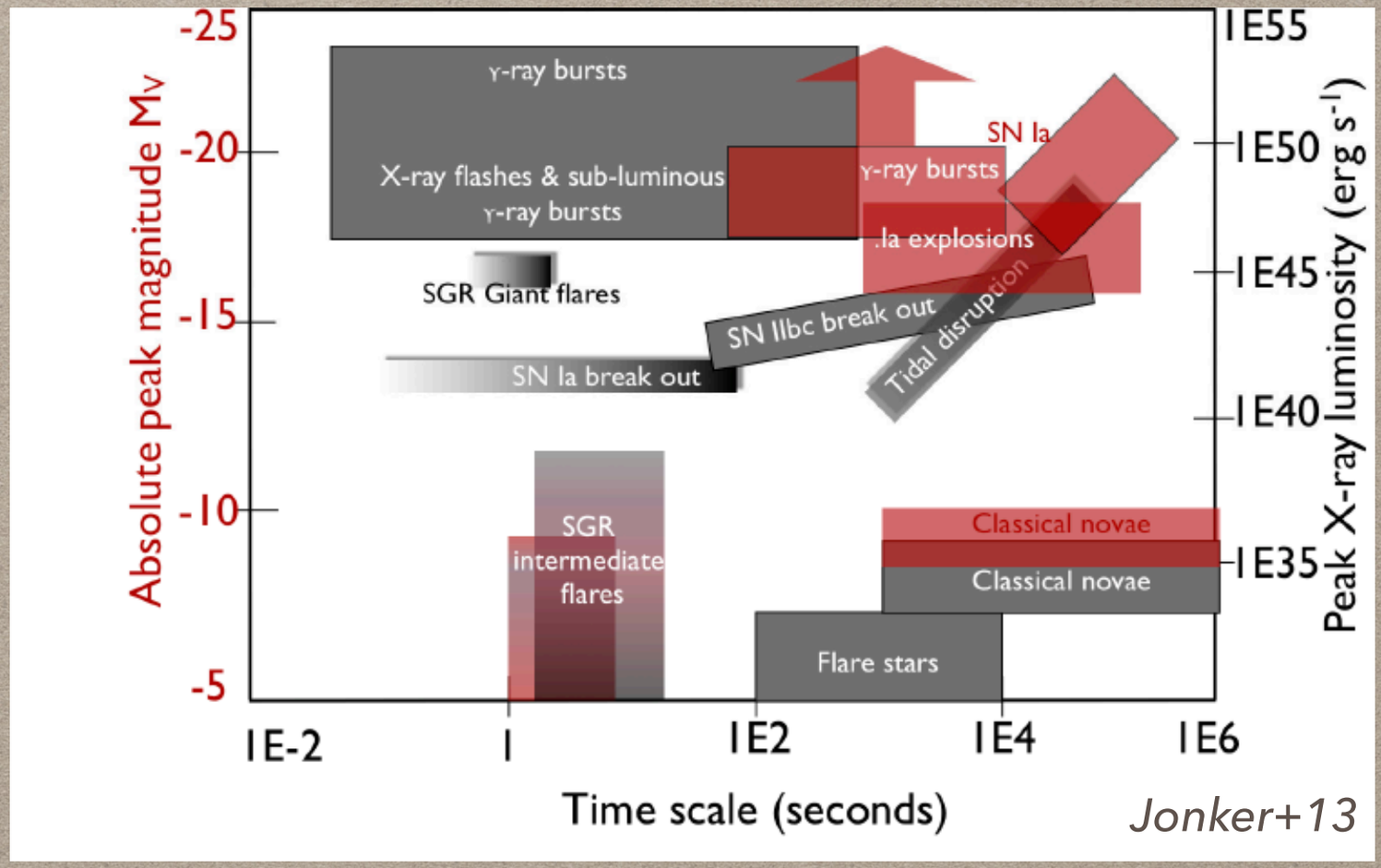
- Fermi provides ~10° (GBM) localizations, but « suffers » from Earth occultation and SAA passages. Operates in the 25 keV-20 MeV range
  - Carries the LAT (GeV) that will autonomously look for triggers of the GBM in its data
- SPI/ACS is the largest gamma-ray detector in space, its on a 2.5 days orbit far from the Earth, but provides only light curves above ~100 keV with very rough localisation capabilities
- They both triggered on the gamma-ray counterpart of GW 170817



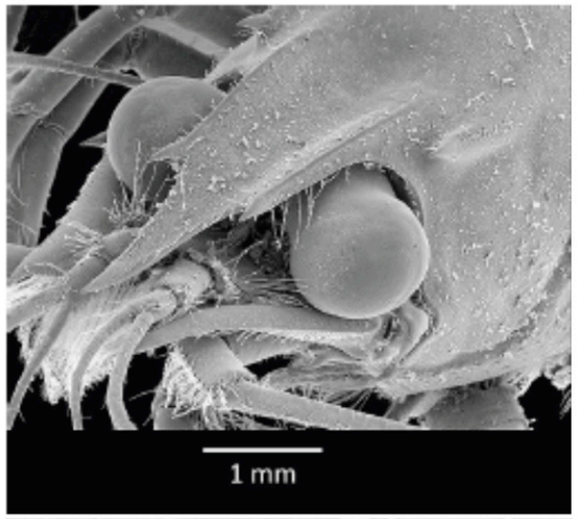


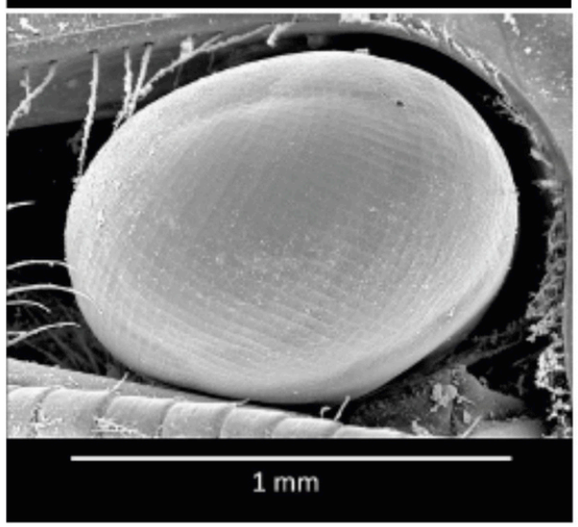
THE FUTURE: WIDE FIELD X-RAY IMAGING

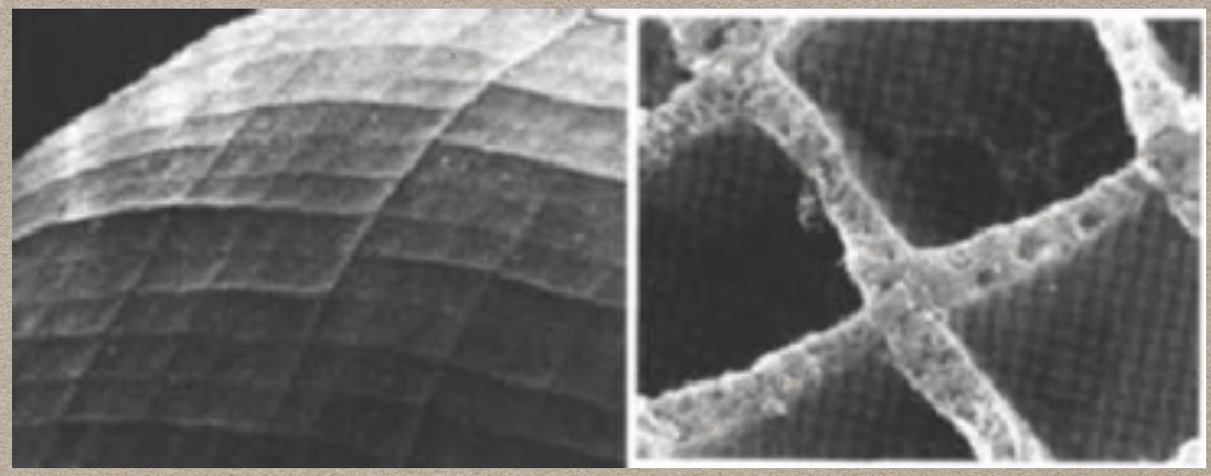
- Time Domain Astronomy (the systematic study of the variable sky) is becoming a hot topic in X-ray astronomy
- Several future projects (Einstein Probe (CAS), THESEUS (ESA), TAP (NASA), High-z Gundam (JAXA)) will make use of « Lobster Eye » optics in order to survey the variable X-ray sky



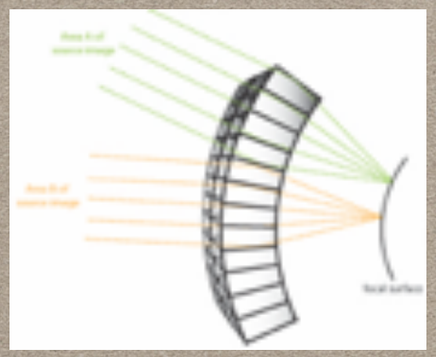
X-RAY ASTRONOMY FUTURE (W-FOV)

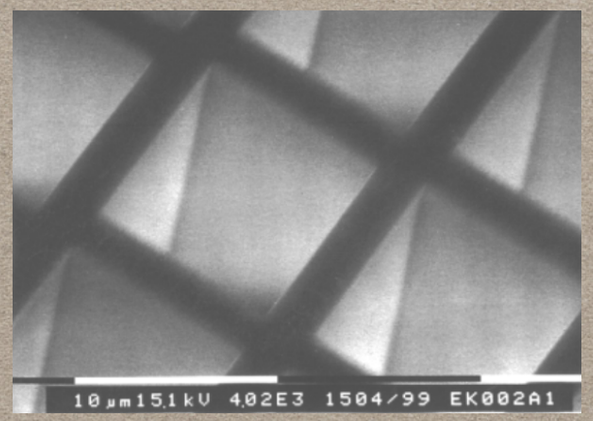






Lobsters and other kind of decapods are a rare example in Nature where the vision is obtained by reflection and not by refraction. This kind of vision is adapted for low-background wide vision (like the dark deep sea). Can be adapted to X-rays (Angel 1979).

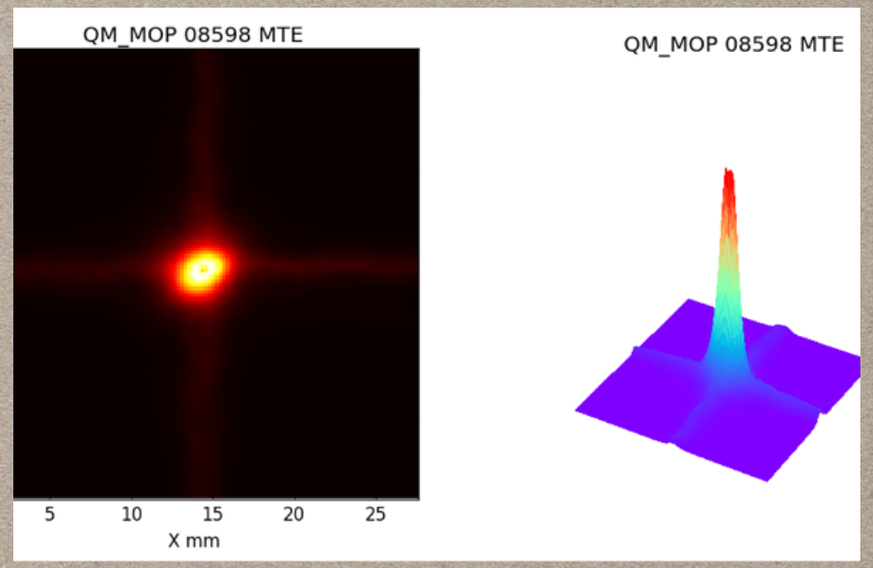


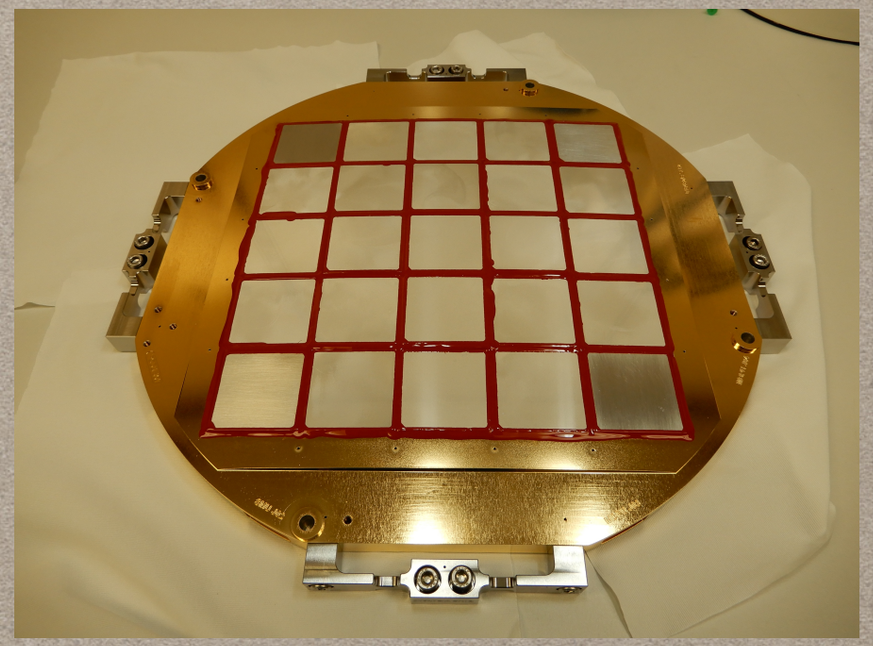


40 microns pitch lead glass plates produced by Photons

LOBSTER EYE OPTICS

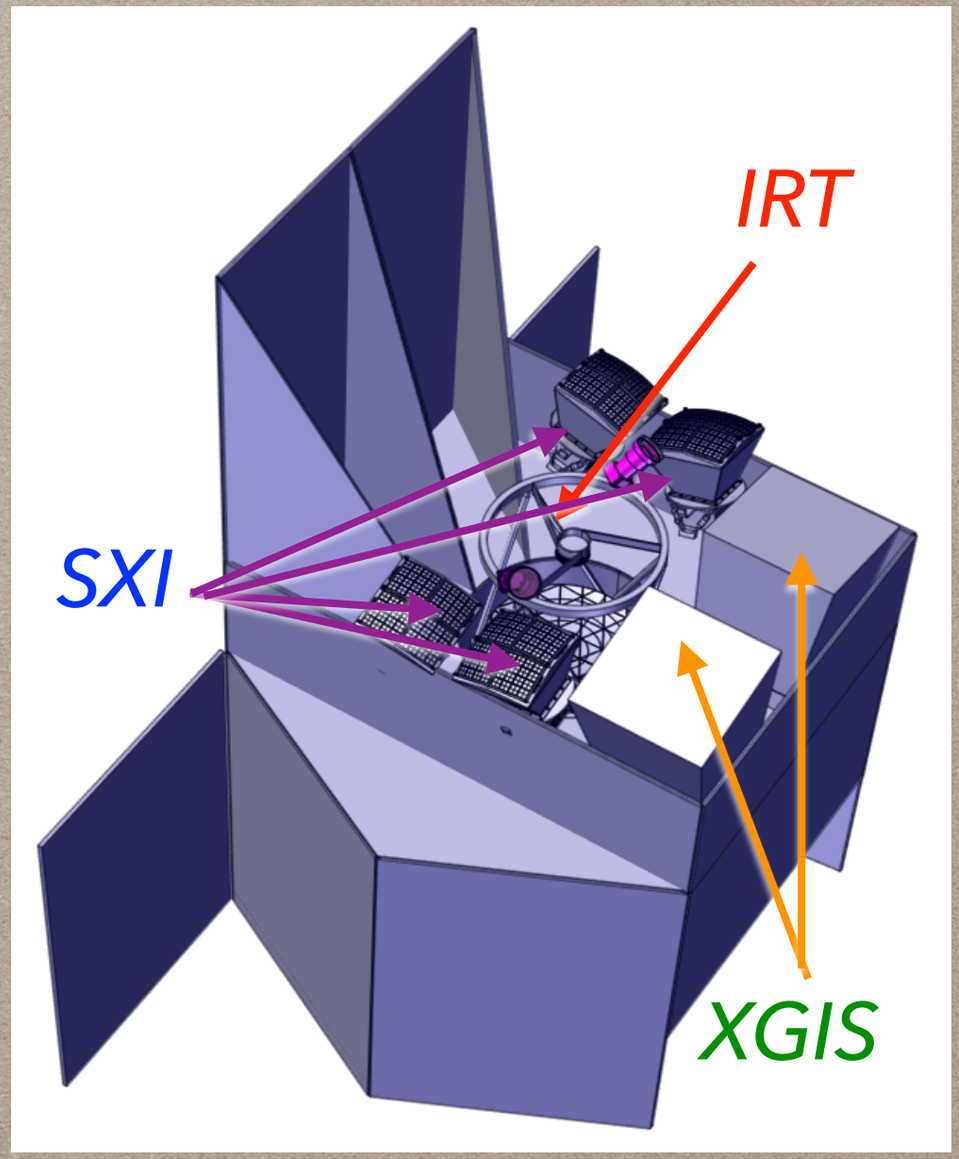
- Lobster Eyes are very light (few kg vs. several tens of kg for traditional X-ray optics)
- Hence they are adapted for small missions like SVOM (total mass 1000 kg) or SMILE and Einstein Probe (small mission developed jointly by ESA and CAS)
- They have a peculiar PSF (The one of MXT is shown, small FOV version, to be flown on SVOM)
- 50% of the flux in the central peak 22% in each arm, the rest in a diffuse patch
- But micropore optics in general can be used also in a Wolter-I approximation (single peaked PSF, small FOV) as foreseen for the next major X-ray observatory ATHENA (bases on Si)





THESEUS: TRANSIENT HIGH ENERGY SKY AND EARLY UNIVERSE SURVEYOR

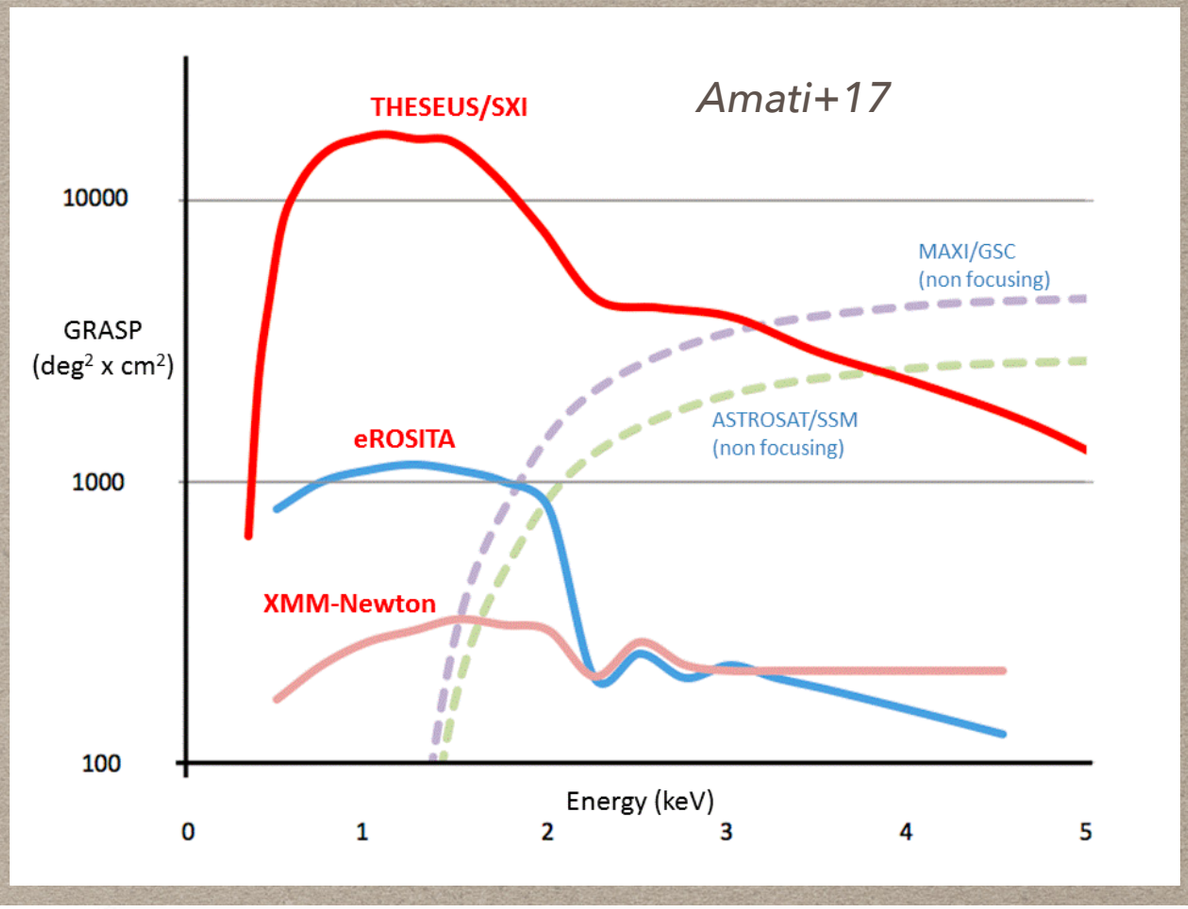
- ESA M5 mission candidate (**launch 2032**). Currently in phase A (ends 2021). LEO with 6° inclination and ~600 km altitude.
- Dedicated to deep Universe astrophysics and cosmology, and transient (multi-messenger) sky
- Carries a wide FOV X-ray telescope (SXI, 4 units, 0.3-6 keV, ~1 arc min accuracy), a coded mask system (XGIS, 2 units, 2 keV-10 MeV), a NIR telescope (IRT, 0.7-1.8 μ). **French lead.**
- 1 sr FOV for the X-ray monitor -> several hundreds GRBs detected per year, and hundreds of other X-ray transients (TDEs, AGNs, magnetars, binaries, stellar flares,...)

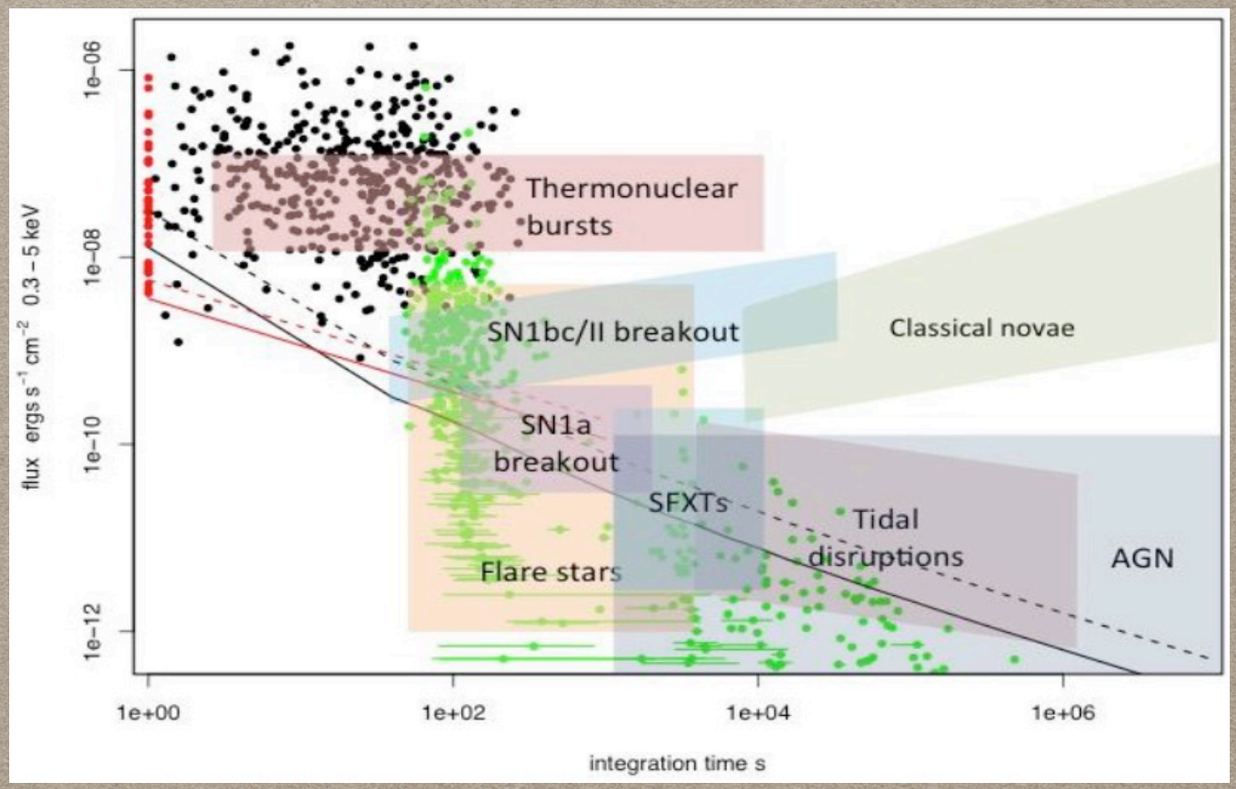


https://www.isdc.unige.ch/theseus/
https://indico.in2p3.fr/event/19356/

SXI GRASP

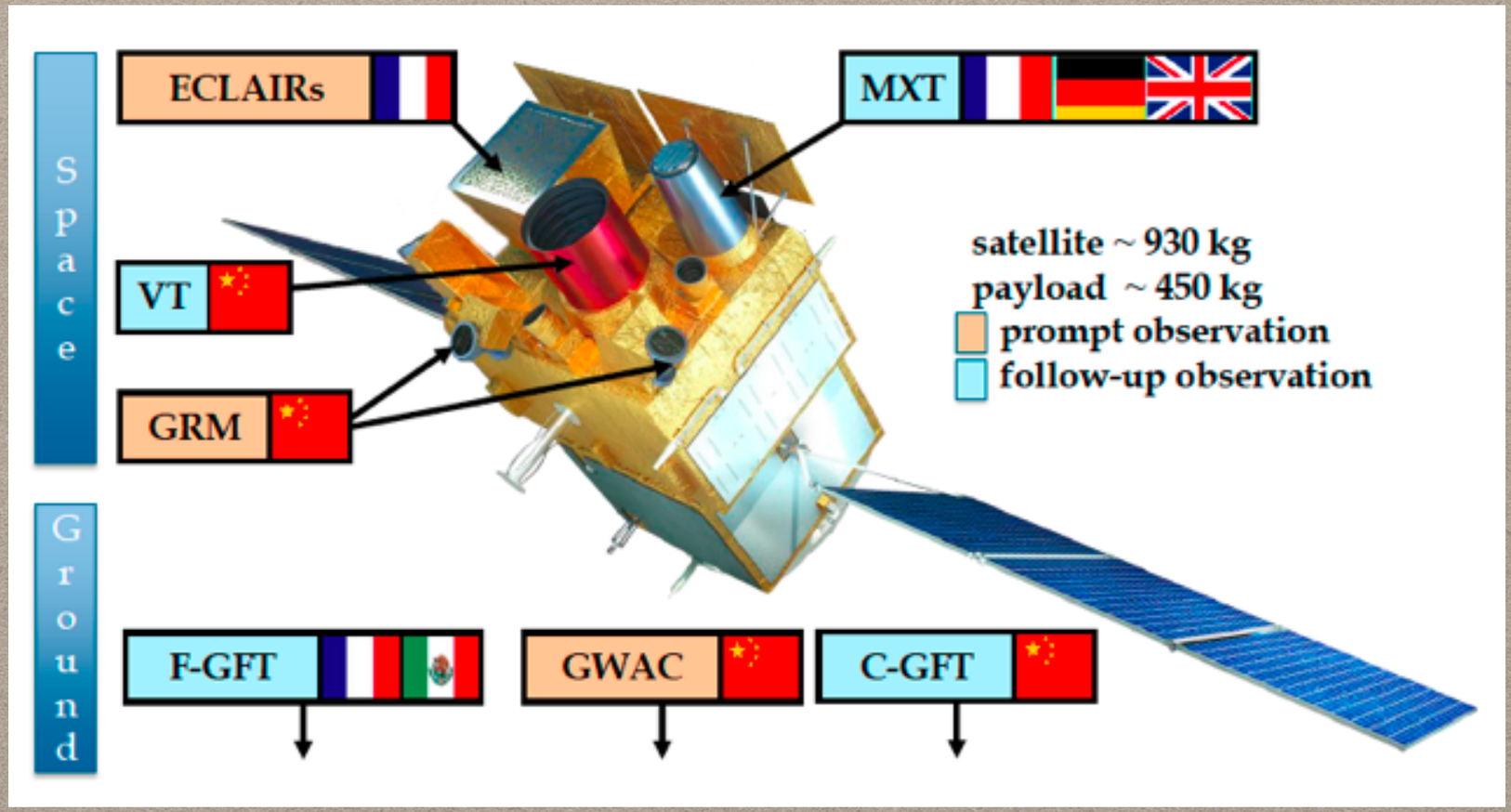
- The Grasp is the product of the effective area of an X-ray telescope and the covered sky area
- Despite the fact that « Lobster Eye » optics do not provide a high effective area, their large field of view makes them the best suited telescopes for hunting new X-ray transients with un-precedented sensitivity
- Difficulty: requires large detectors (~half of the optics surface). Challenging thermal setup.
- Similar project being developed by China: Einstein Probe (~2025)





THE NEAR FUTURE: SVOM
(SEE N. DAGONEAU TALK)

- Sino-French Collaboration, to be launched by 2021
- Will carry multi-wavelength payload
- Dedicated ground follow-up telescope
- Optimized pointing strategy (anti-solar) to enhance red shift determination
- Wide field (2sr) monitoring of the X-ray sky starting at 4 keV



CONCLUSIONS

- In the X/gamma-ray domain here are several currently working facilities (renewed generally on a 2 years depending on results **and** funding) that are able to
  - monitor large fraction of the sky (Swift/BAT, Fermi, INTEGRAL, MAXI, …)
  - follow-up rapidly any kind of alert (**Swift/XRT**, Chandra, XMM, …)
- Well localized alerts from other wavelength can be followed from space and ground based telescopes (optical, radio, VHE) can be fed with relatively well (~arc min or less) localized (public!) alerts from space
- These facilities will be available for still for several years, and SVOM will join soon
- In addition in the 2030s ATHENA will replace XMM (for follow-up from space), and possibly THESEUS, TAP or Einstein Probe will provide a sensitive wide field X-ray monitoring of the sky increasing the possibility of synergies among the different observatories