Science Drivers for Small Missions in High-Energy Astrophysics

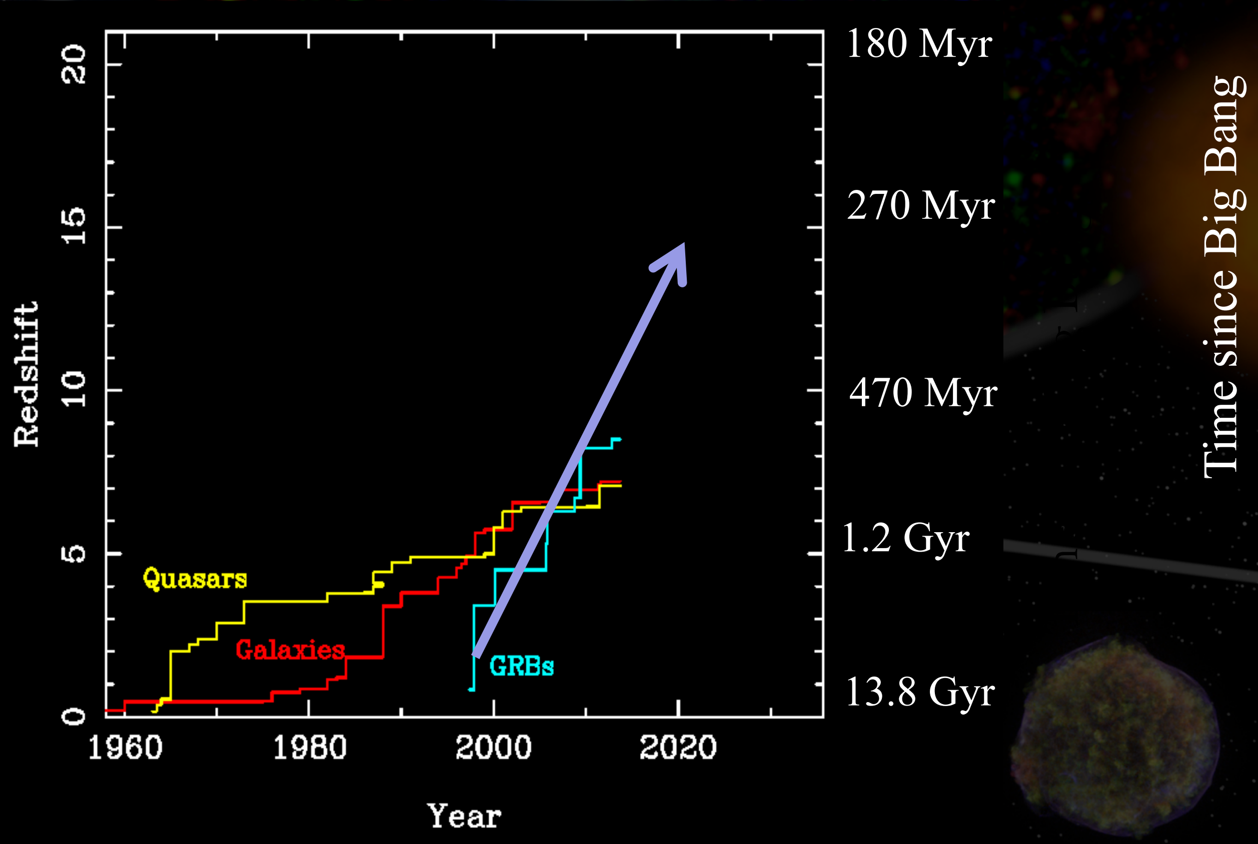
Luigi Piro
IAPS/INAF

Summary

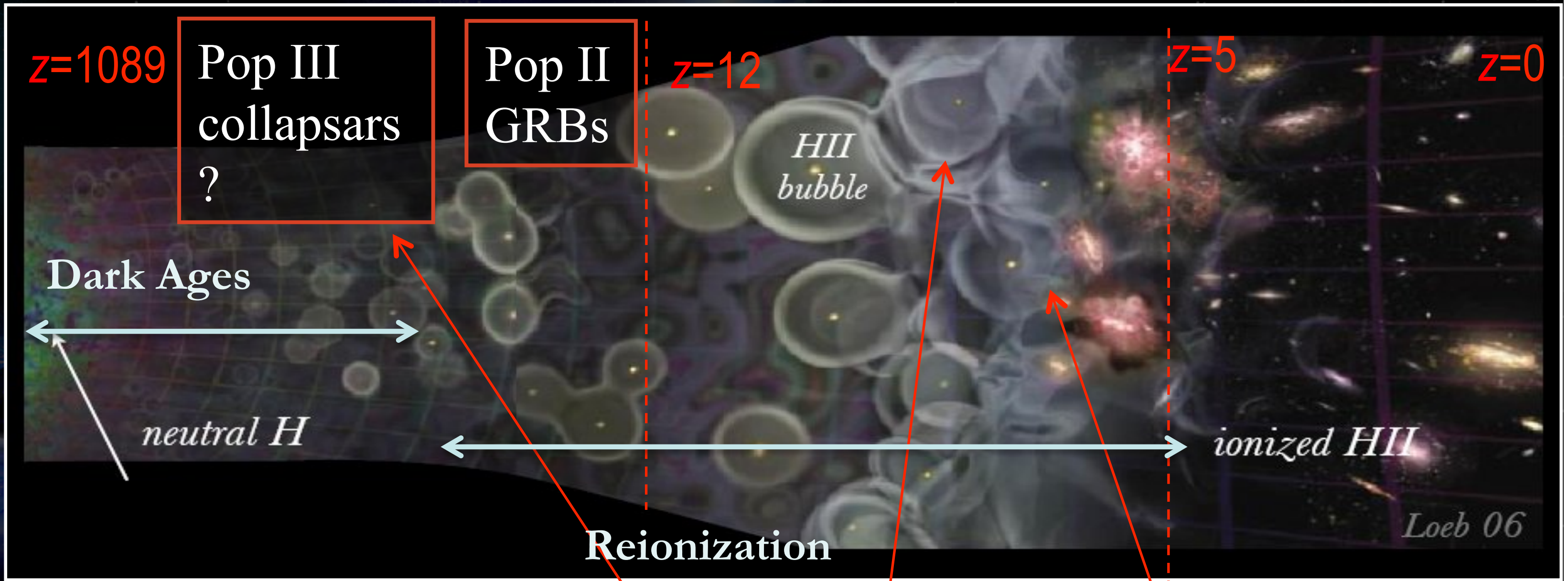
- Small missions: either focussed science case or serve as pathfinders and sentinels
- Topical science cases:
- GRB as beacons at high-z
- Wide field X-ray sky monitoring and survey
- Polarimetry

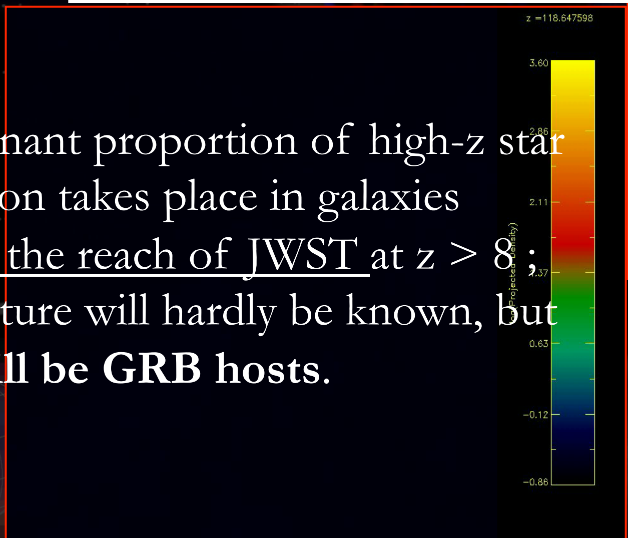
Why GRBs

- Uniquely luminous transient sources at cosmological distances.
- Powerful probes of the universe, beacons into the Dark ages
- Laboratories for matter and radiation under extreme conditions.



The first stars, the first BH, the first metals



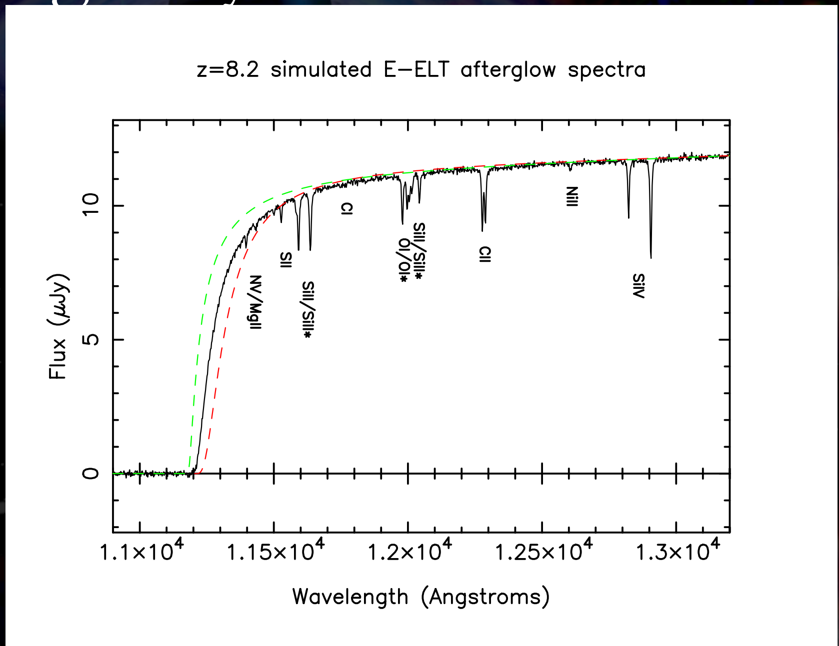


- A dominant proportion of high-z star formation takes place in galaxies beyond the reach of JWST at z > 8 ; their nature will hardly be known, but **they will be GRB hosts**.

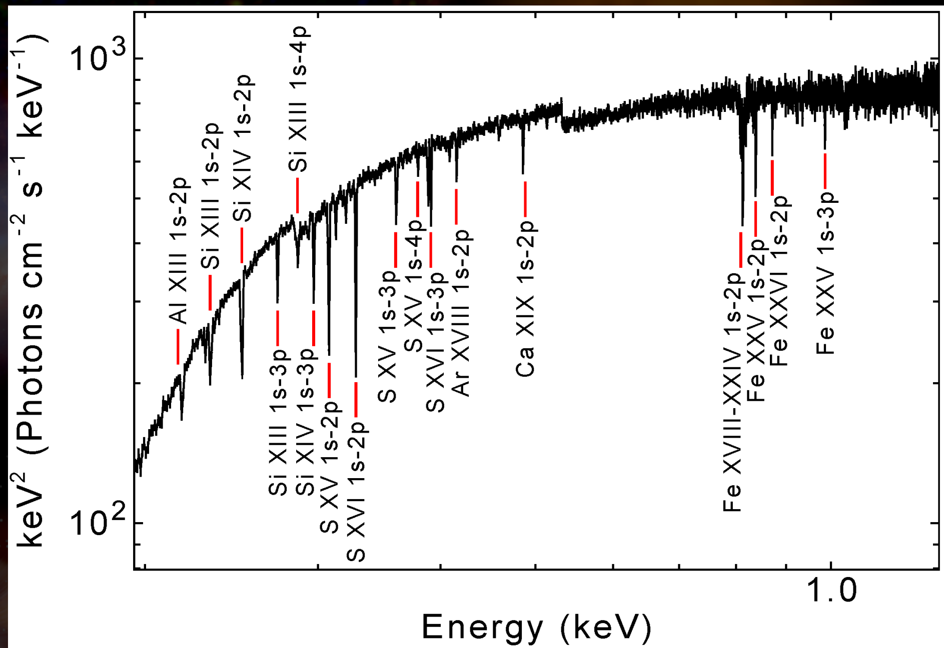
- There will likely be no direct detections of population III sources; **pop III collapsars predicted to produce GRB-like events**.

Follow-up of high-z GRB with large facilities

- Optical/IR abs. spectroscopy of the host galaxy
- X-ray spectroscopy of the progenitor environment

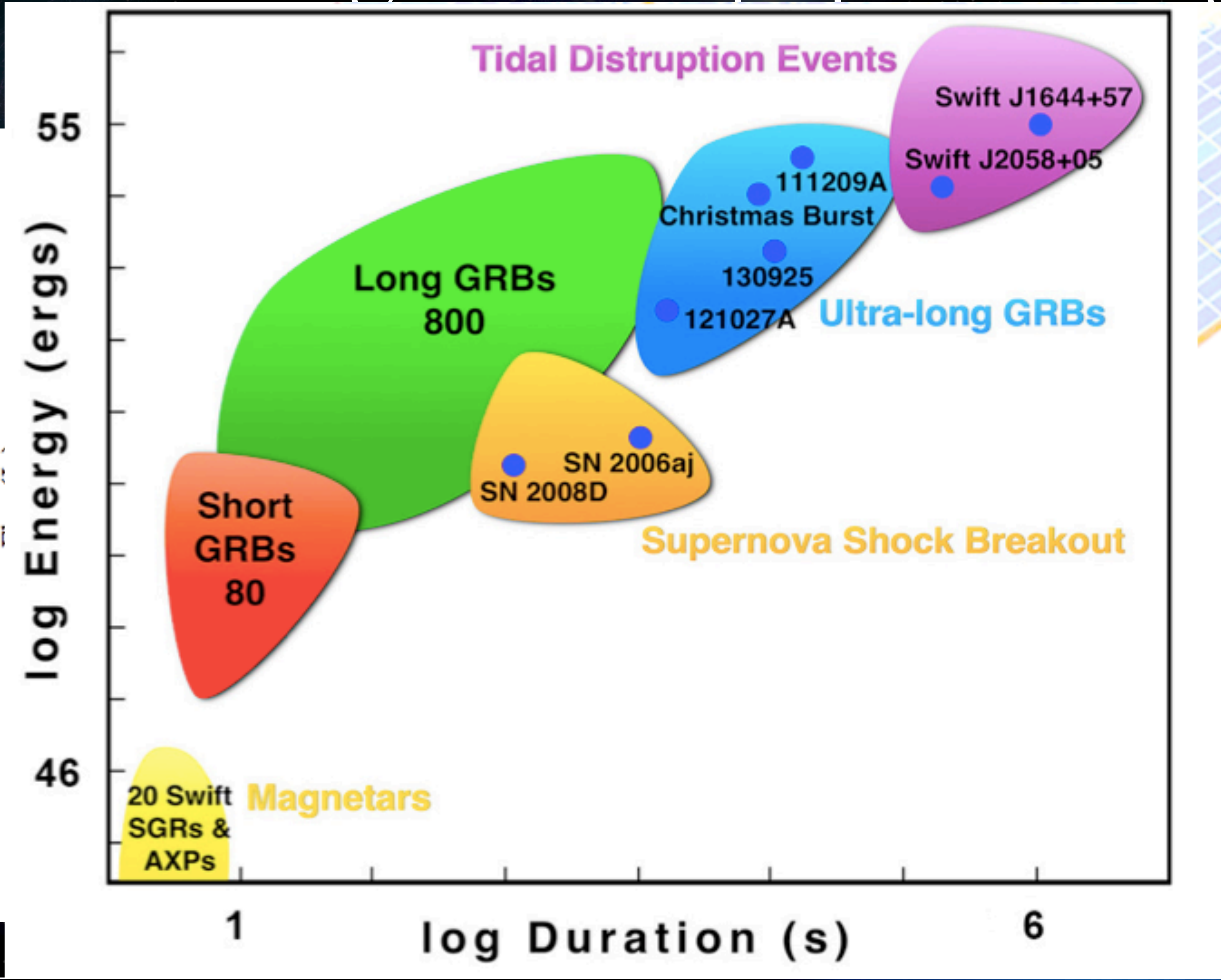


30+ m class ELTs



ESA L2 X-ray Observatory

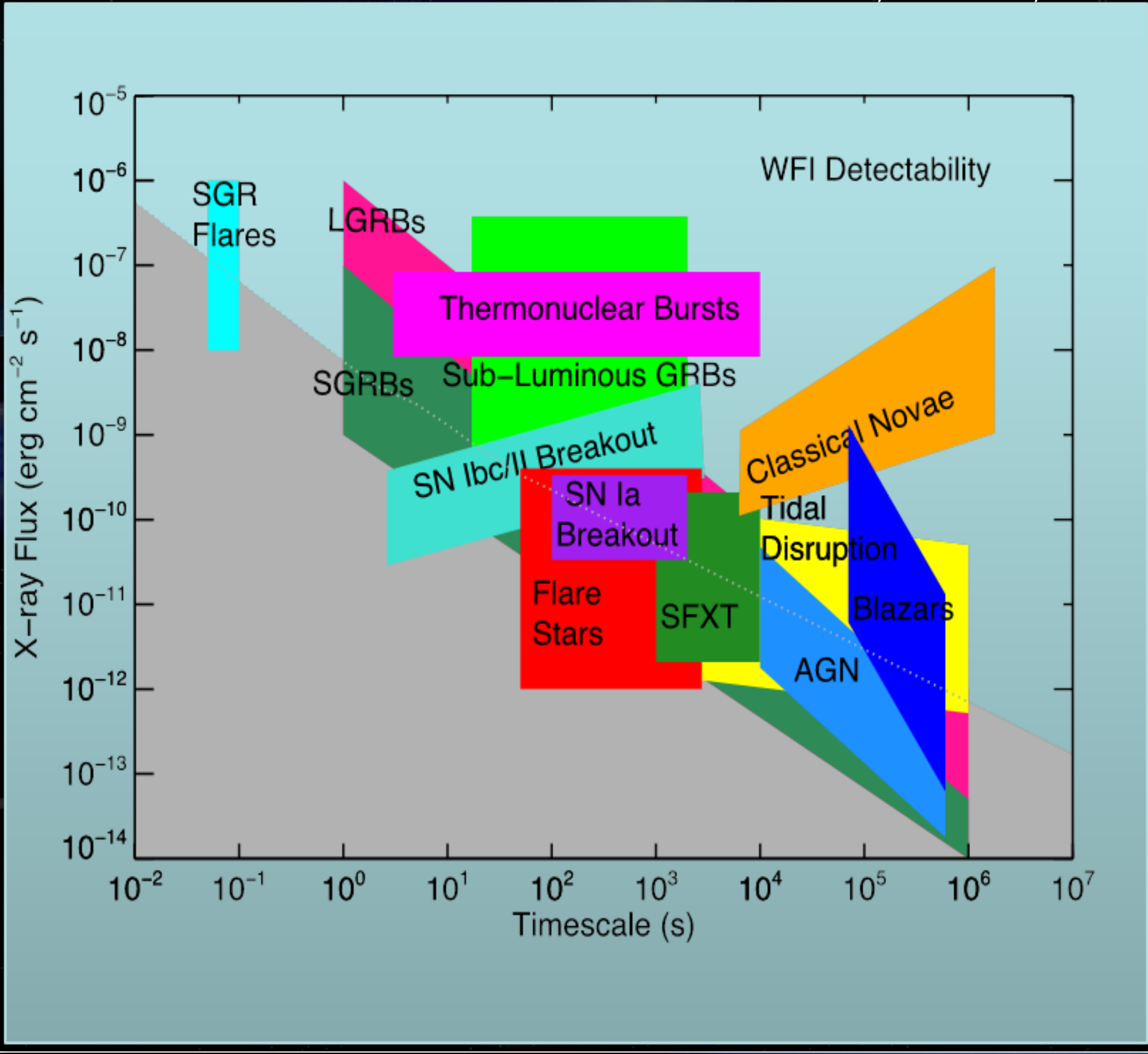
Ultralong GRB: a popIII analogue?



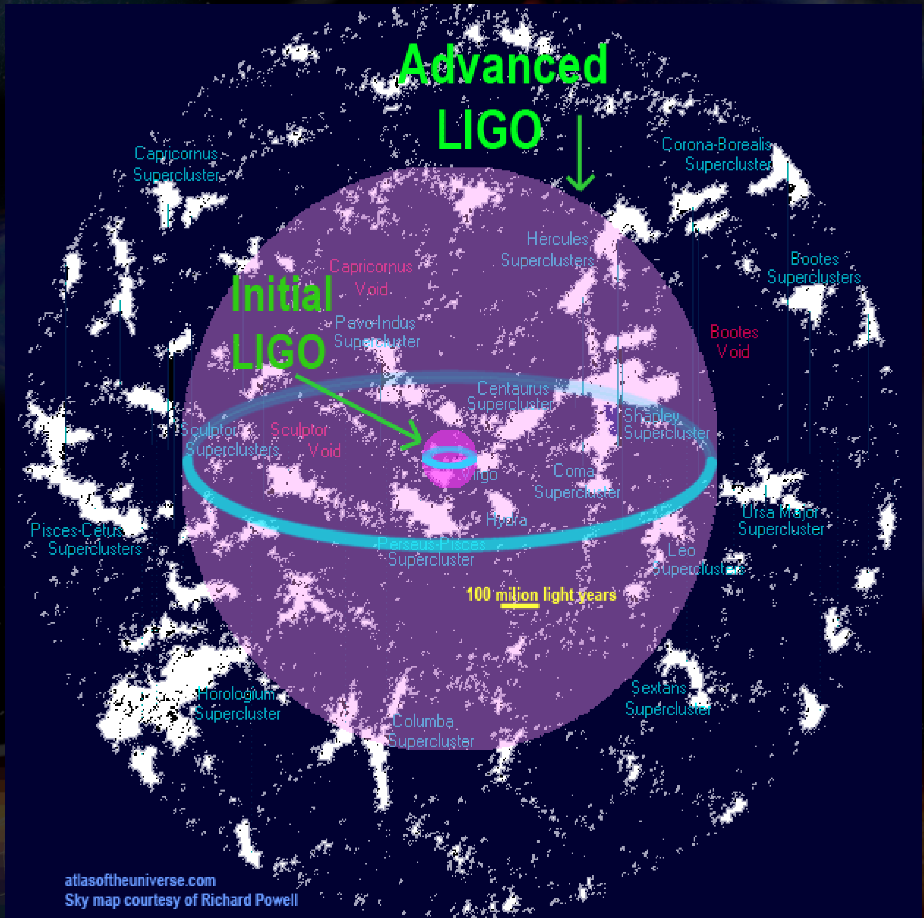
Science requirements for (high-z) GRBs

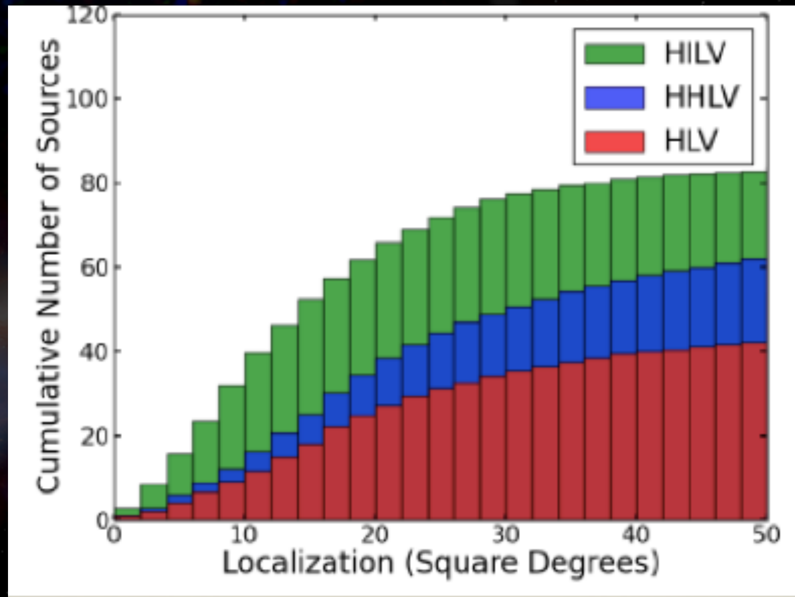
- About ~ 50/yr at z>7
- FoV >~ 1 sr (about 15 in 3 yrs)
- Mixed popII, II.5 and III, with popIII dominating at z>10
- To catch popIII collapsar (long and faint) requires a X-ray sensitivity of ~10^{-12}-10^{-11} (0.1-1mCrab) in 1000-10.000 s (enabled by focussing techniques as Lobster-eye optics)

The transient X-ray sky

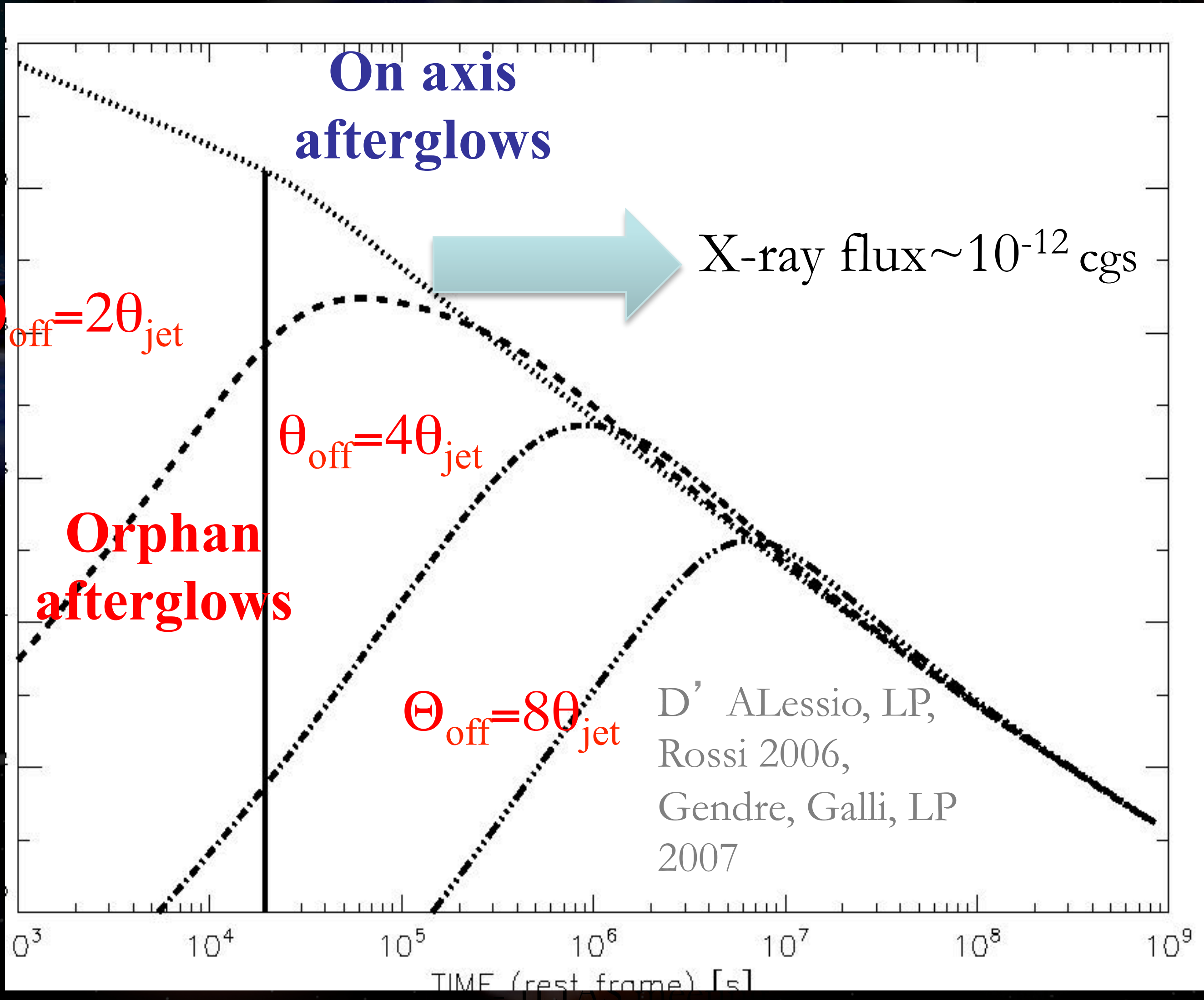


EM counterparts to GW

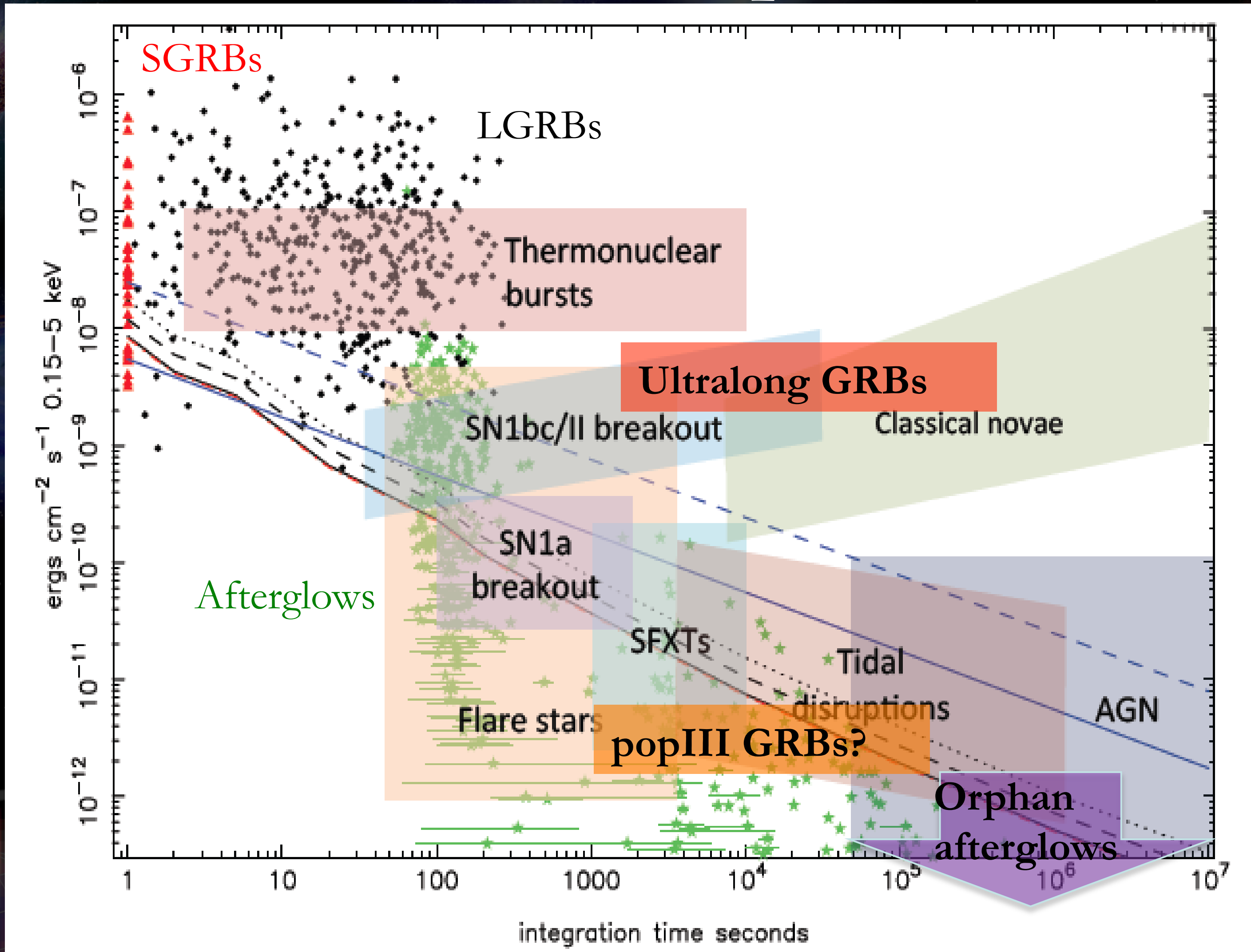




Finding off-axis jetted mergers/GRBs

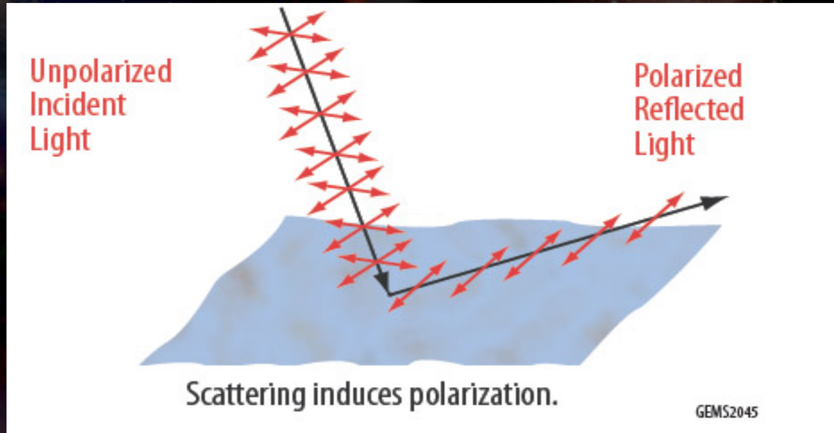


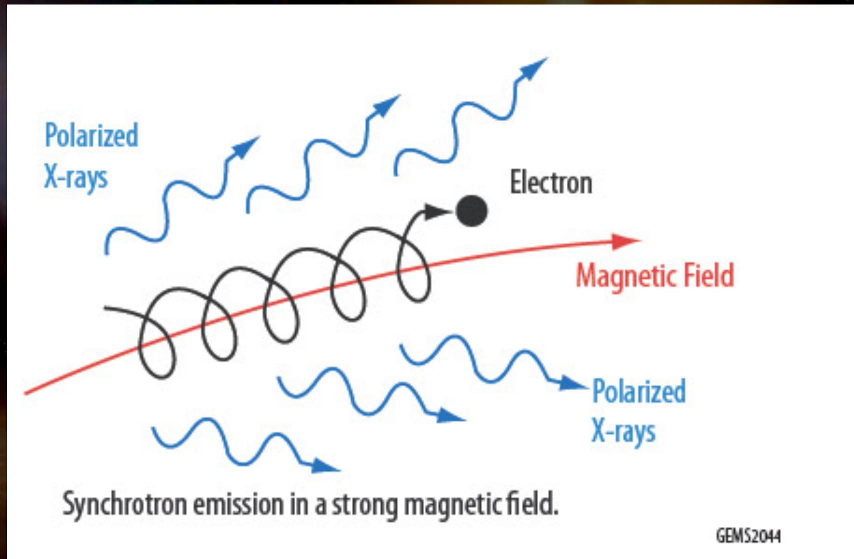
Sensitivity Requirements

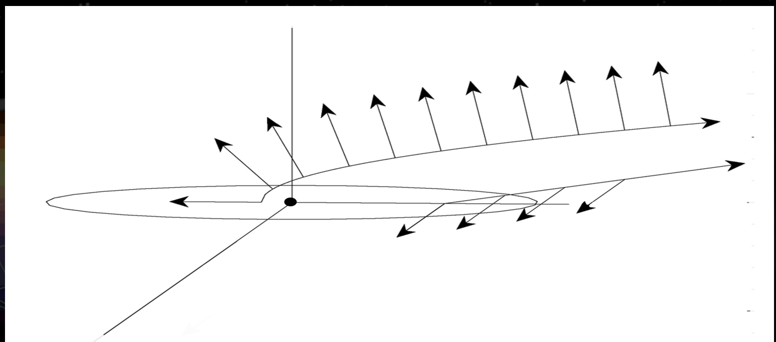


The fourth dimension: Polarimetry

- Polarimetry probes physics of photon emission and propagation
- Polarization measurements allow us to study:
  - ✓ Scattering geometry
  - ✓ Magnetic fields
  - ✓ Strong gravity







Observational status (I)

- Insofar only Crab in X-rays (OSO 8), other results from hard X-rays (Integral, GRB GAP)
- Crab Nebula:
  - X-rays from nebula 19.2%±1.0% ; (Weisskopf et al. 1978)
  - γ -rays (INTEGRAL IBIS&SPI): (46 ±10) % (Forot et al. 2008)
  - High-energy electrons responsible for the γ -rays polarized photons are produced in a highly ordered structure close to the pulsar while X-rays sample larger region (thus lower fraction)
- Cyg X-1: a polarized jet component dominating >300keV (INTEGRAL)
- GRBs: polarization in the prompt: nature of the relativistic jet. INTEGRAL GRB 041219A 96%+-40% (Kalemci et al 2007), Ikarus GAP (Yonetoku et al 2013): GRB110301A 70%±22%, GRB110721A:84(+16,-28)%

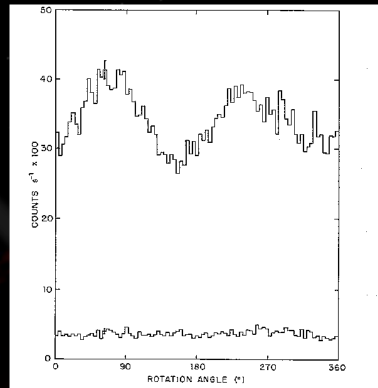
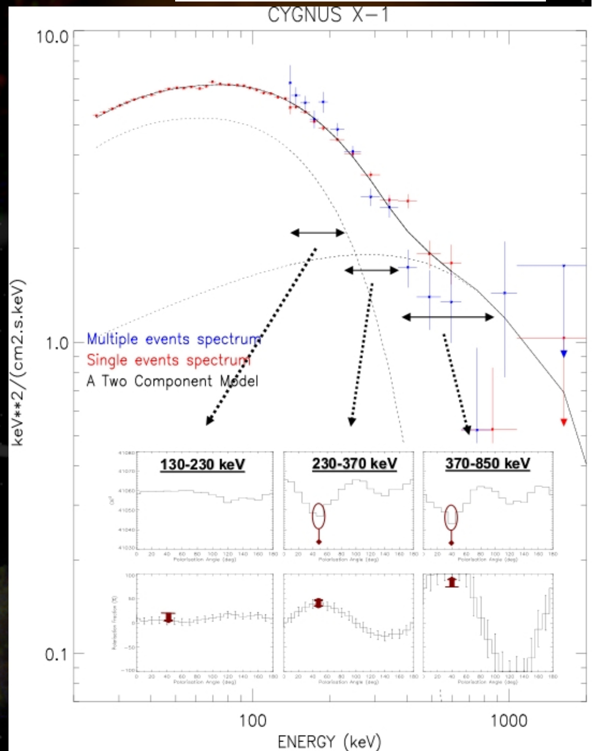


FIG. 2.—Average modulation curves obtained with both detectors at 2.6 keV during (*upper curve*) observations of the Crab Nebula and during (*lower curve*) observations of the Earth-occulted instrumental background.



Observational status (II)

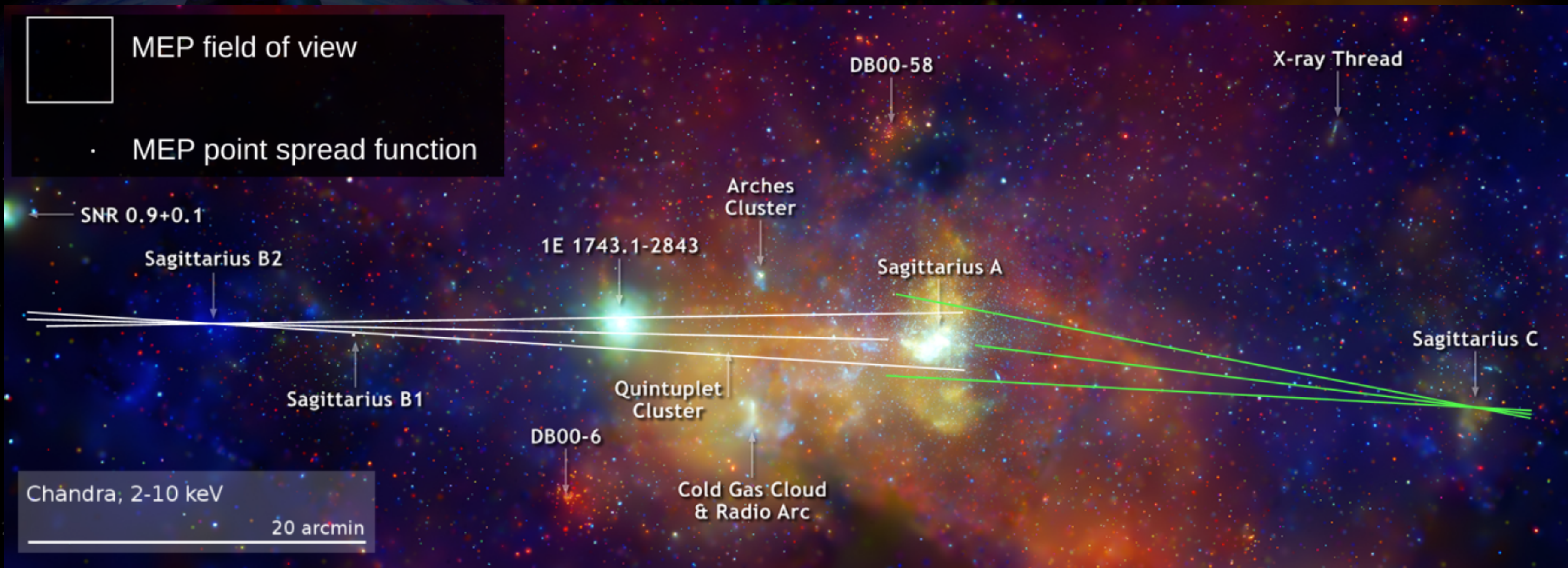
- Quantum gravity theories predict Lorentz Invariance Violation (LIV):
- Velocity and phase (pol. Angle) dispersion (Mpl=Planck scale=2.4 10^{18} GeV)
- From Crab:
- X-rays: $\xi < 10^{-4}$
- Gamma-rays $\xi < 10^{-9}$
- From GRBs $\xi < 10^{-15}$

$$\omega_{\pm} = |p|\sqrt{1 \pm \frac{2\xi k}{M_{Pl}}} \approx |k|(1 \pm \frac{\xi k}{M_{Pl}})$$

$$\Delta\theta(p) = \frac{\omega_+(k) - \omega_-(k)}{2} d \approx \xi \frac{k^2 d}{2M_{Pl}}$$

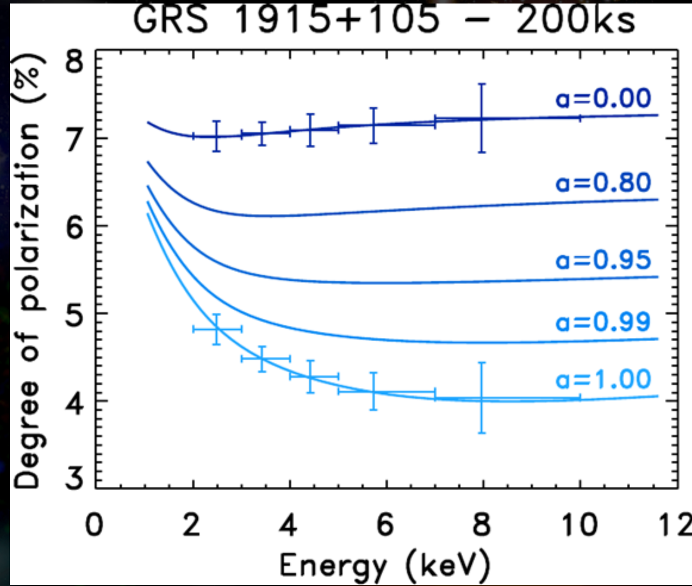
X-Ray Polarimetry: key drivers

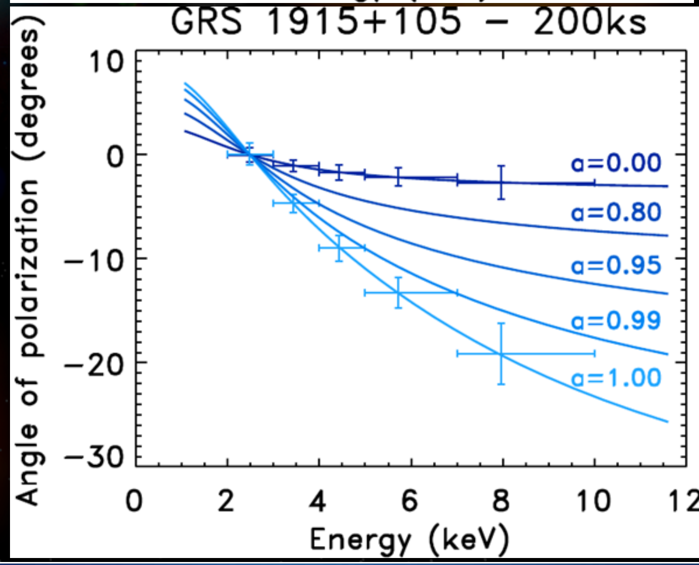
- **Astrophysical measurements** (radiation processes, source geometry)



X-Ray Polarimetry: key drivers

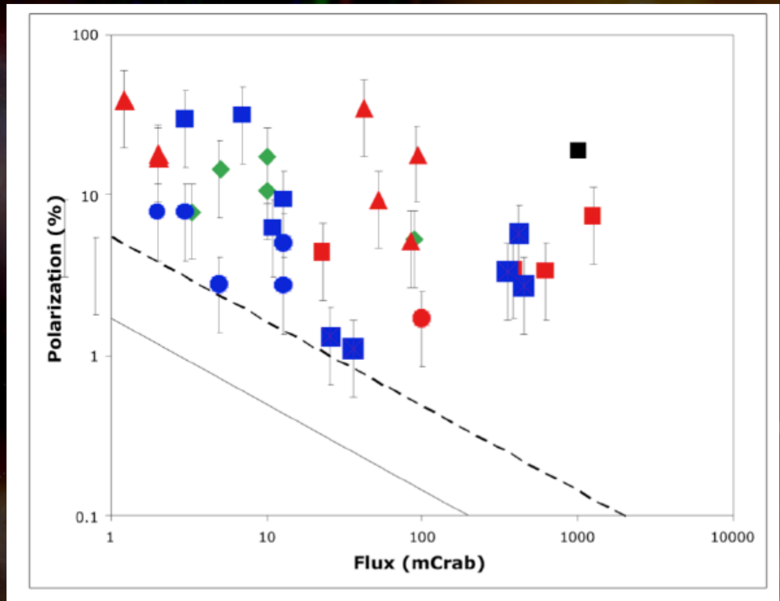
- **Strong Gravity:** Effects of General and Special Relativity on X-ray polarization in BH & NS. Measure of BH spin
- Quantum Electro Dynamics : Vacuum Polarization & Birefringence in strong magnetic fields. Measure of B field in magnetar





Science requirements

- Spectral resolved polarization for bright galactic sources and (~1% for a flux > 10 mCrab with ~10^5 s and enable measurements ~ few % on brightest AGNs



Conclusions

- High-z GRBs and popIII GRBs require large FOV and high sensitivity monitor (e.g. Lobster eye)
- EM counterparts of GW drives a similar requirement for the Wide Field X-ray Monitoring
- Add to the era of Large monitor/surveys (DES, LSST, PTF, LoFAR) the X-ray view
- Physics of GRB and LIV: gamma-ray polarimetry of the Prompt emission
- Physics of compact sources and GR: high sensitivity (photoel. Effect) X-ray polarimetry with optics