X-ray investigation of the Universe in the context of ESA Cosmic Vision

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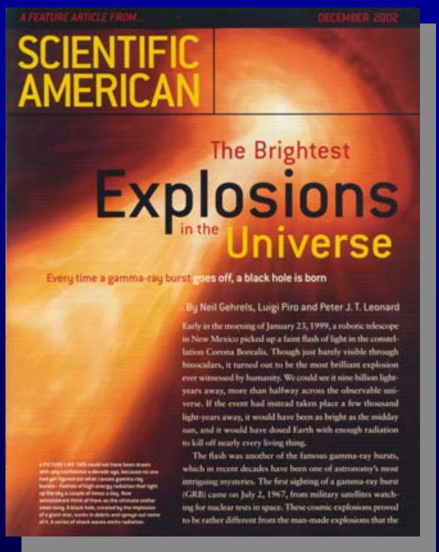
Summary

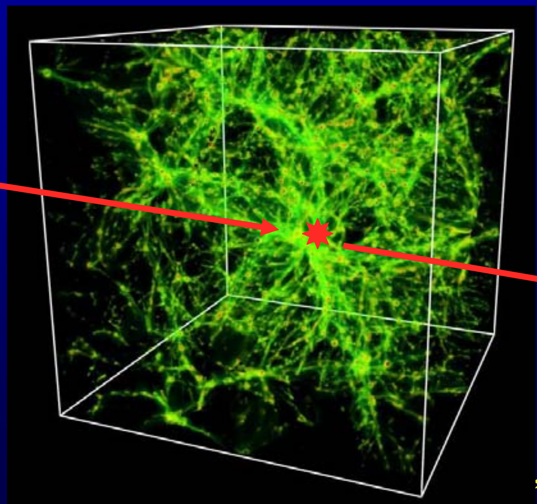
- ESA Cosmic Vision 2015-2025
- Science themes: the X-ray vision
- Small/mid size: ESTREMO/WFXRT
- Cornerstone, Large Observatory: XEUS

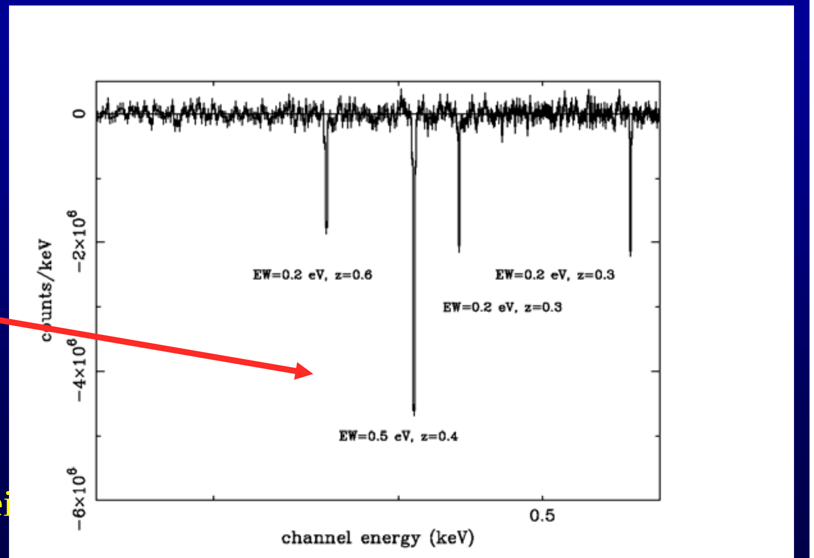
ESA CV themes by X-ray missions

- 3.What are the fundamental physical laws of the Universe?
  - 3.3 Matter under extreme conditions
- 4. How did the Universe originate and what is it made of?
  - 4.1 The early Universe
  - 4.2 The Universe taking shape
  - 4.3 The evolving violent Universe

ESTREMO/WFXRT
Extreme phySics in Transient and Evolving cosMos







Mission goals

- The mission is based on innovative instrumental and observational approaches, out of and complementary to the mainstream of observatories of progressively increasing area:
- **Observing with fast reaction transient sources, like GRB, at their brightest levels, thus allowing high resolution spectroscopy.**
- **Observing and surveying through a X-ray telescope with a wide field of view and with high sensitivity extended sources, like cluster and WHIM**
- These instrumental and operational capabilities are synergically providing the key to address ESA CV themes 3 and 4

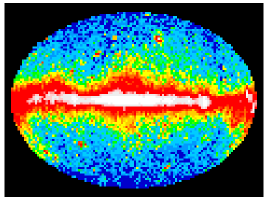
The violent Universe

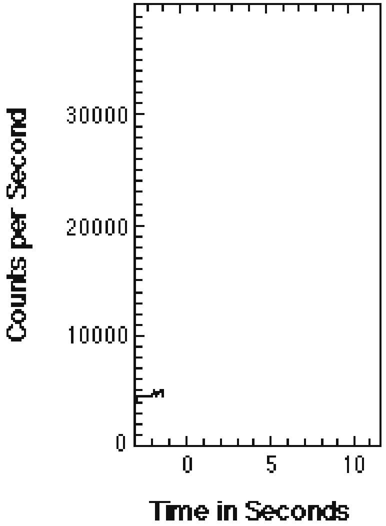
- Goal: study objects under extreme conditions, in terms of gravity, density and temperature (Gamma-Ray Bursts, Neutron Stars, Black Holes). Examine the accretion process of matter falling into black holes in X-rays, and look for clues to the processes at work in gamma-ray bursts.
- The key asset of **ESTREMO/WFXRT** in this regard is the capability **to observe the most extreme objects of the Universe during their bursting phases**. The large flux achieved in this phase allows unprecedented measurements **with high resolution spectroscopy**.

The Early Universe and its evolution to present ages

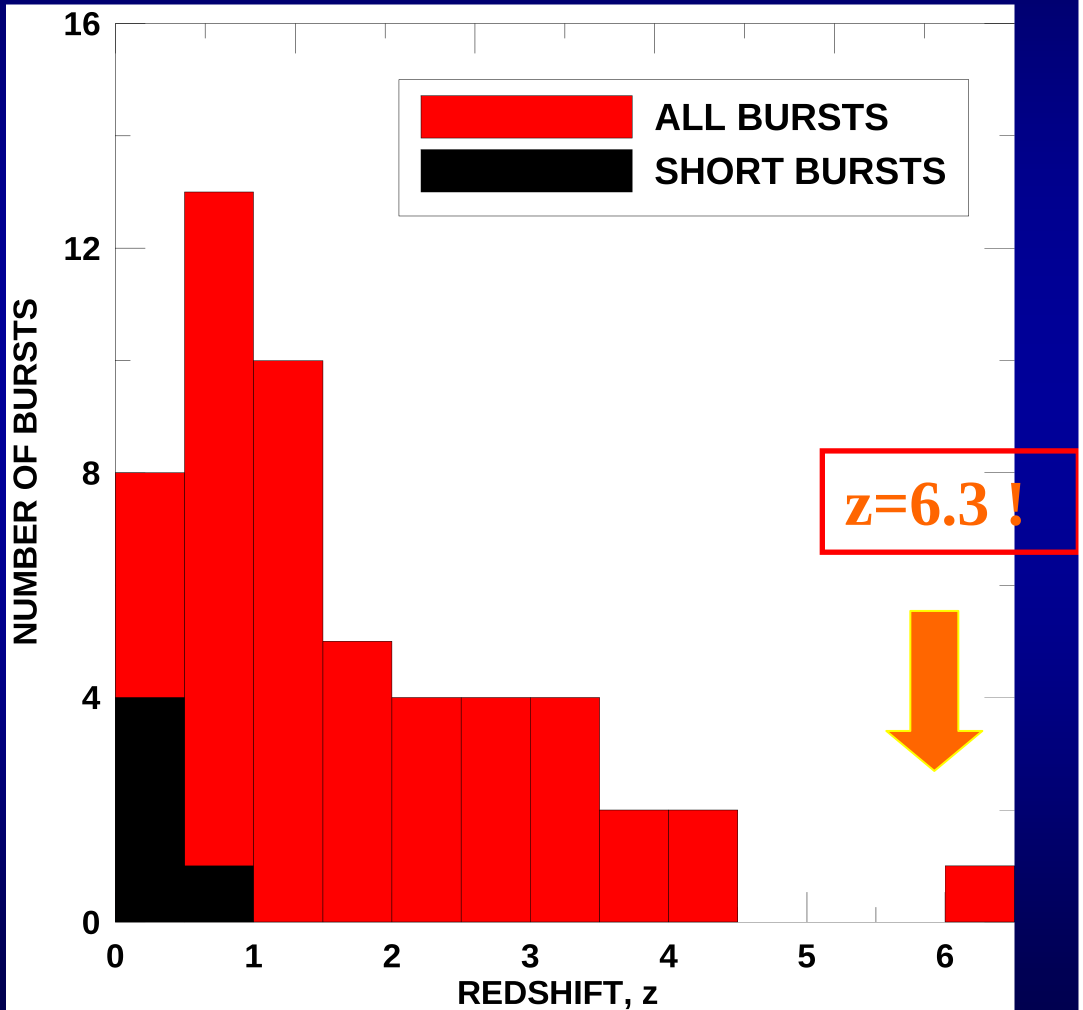
- **ESTREMO/WFXRT** will use two different cosmological probes (Gamma-Ray Burts) to large scale structures (Clusters of Galaxies and the cosmic network) to address this challenging goal by observing:
- The X-ray cosmic web, filaments (WHIM: Warm Hot Intragalactic Medium) of gas accreting onto **Dark Matter** structures.
- Outskirts of clusters (where most of the yet unobserved cluster mass is residing)
- Cluster surveys to constrain **Dark Energy**.
- Gamma-Ray Bursts as beacons to
  - **pinpoint the formation of first population of luminous sources ignited in the dark Universe (z>7)**
  - **measuring the cosmic history of metals in star forming regions**
  - **probing the WHIM properties through high resolution absorption studies.**
  - **Derive the luminosity-redshift relation of GRB as clues to the nature of the Dark Energy**

GRB: The brightest and most distant sources





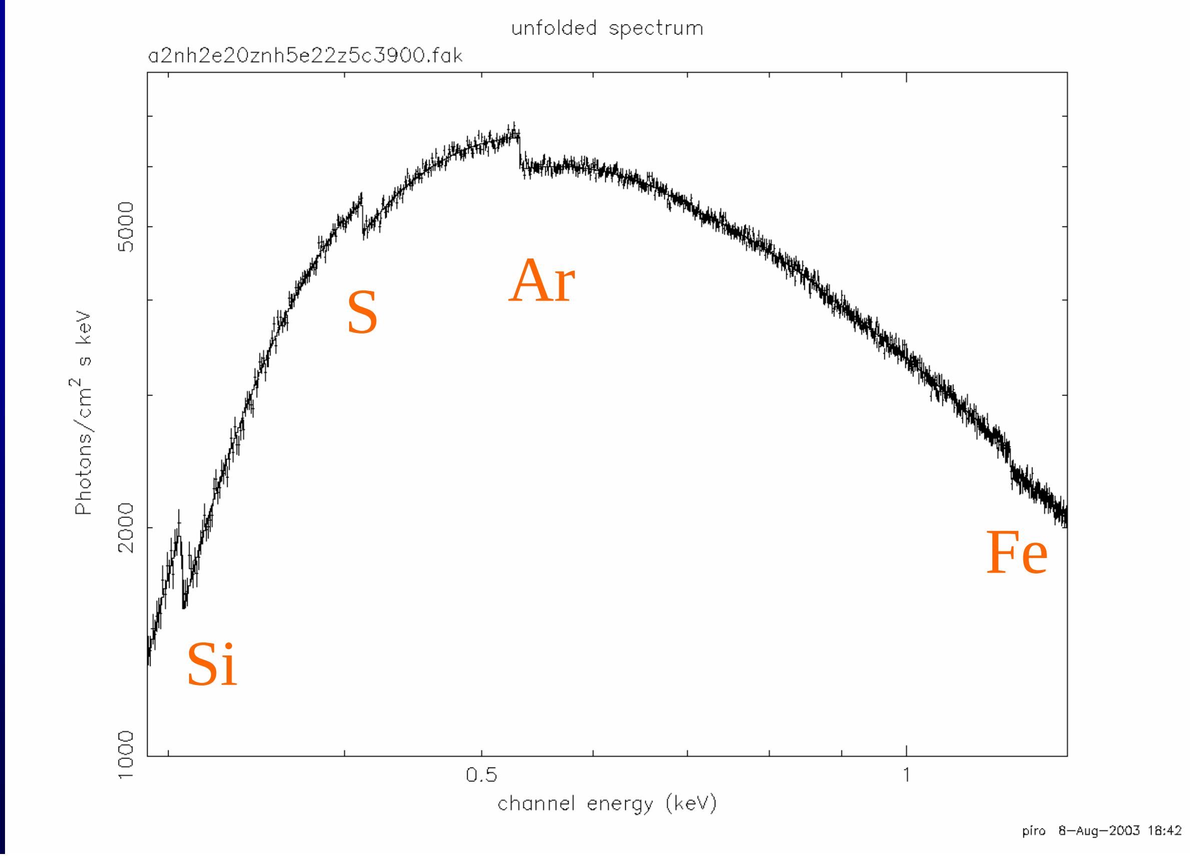
Observing a mid-bright GRB afterglow with a fast (min.) pointing with 2000 cm^2 telescope yields 10^6 X-ray photons, and 10^3 cts in 1 eV resolution bin



GRB: Tomography of the Universe I

- Map the metal evolution vs z

Simulation of X-ray edges produced by metals (Si, S, Ar, Fe) by a medium with column density NH=5 10^{22} cm^{-2} and solar-like abundances in the host galaxy of a bright GRB at z=5., as observed ESTREMO/WFXRT (1min to 60 ksec)



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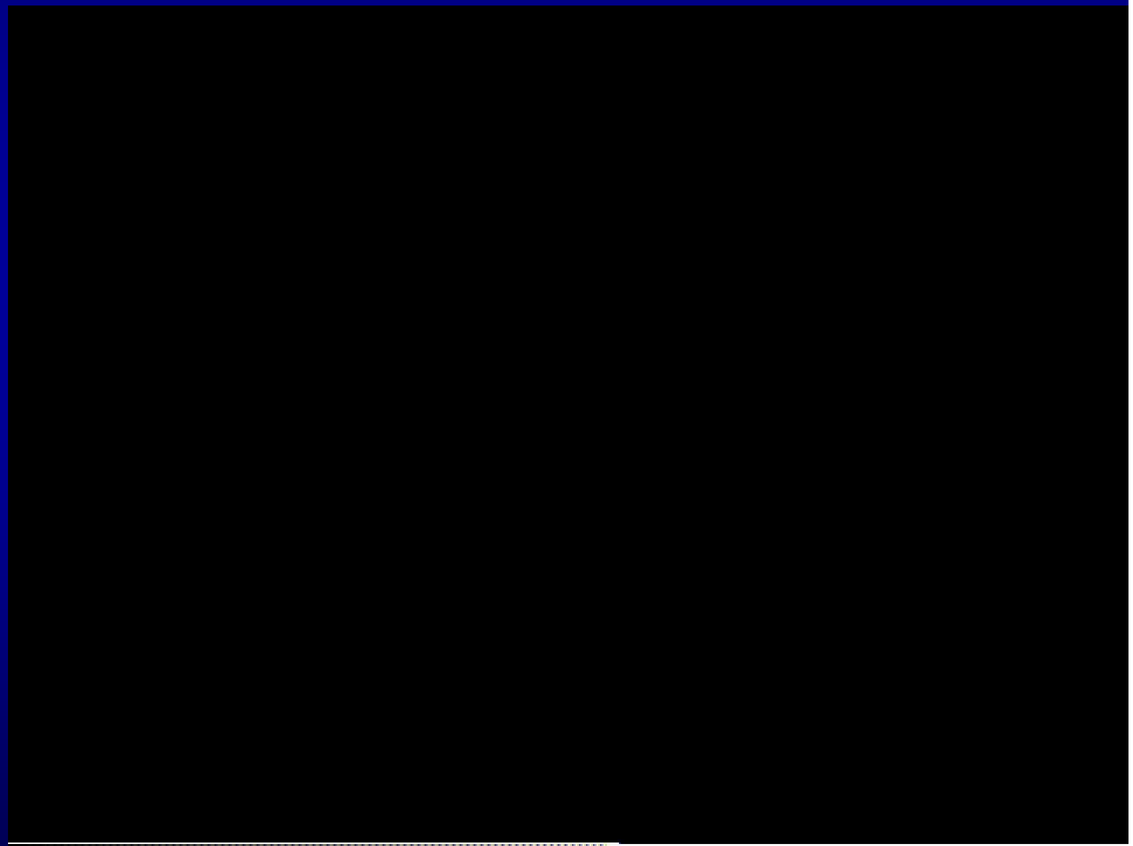
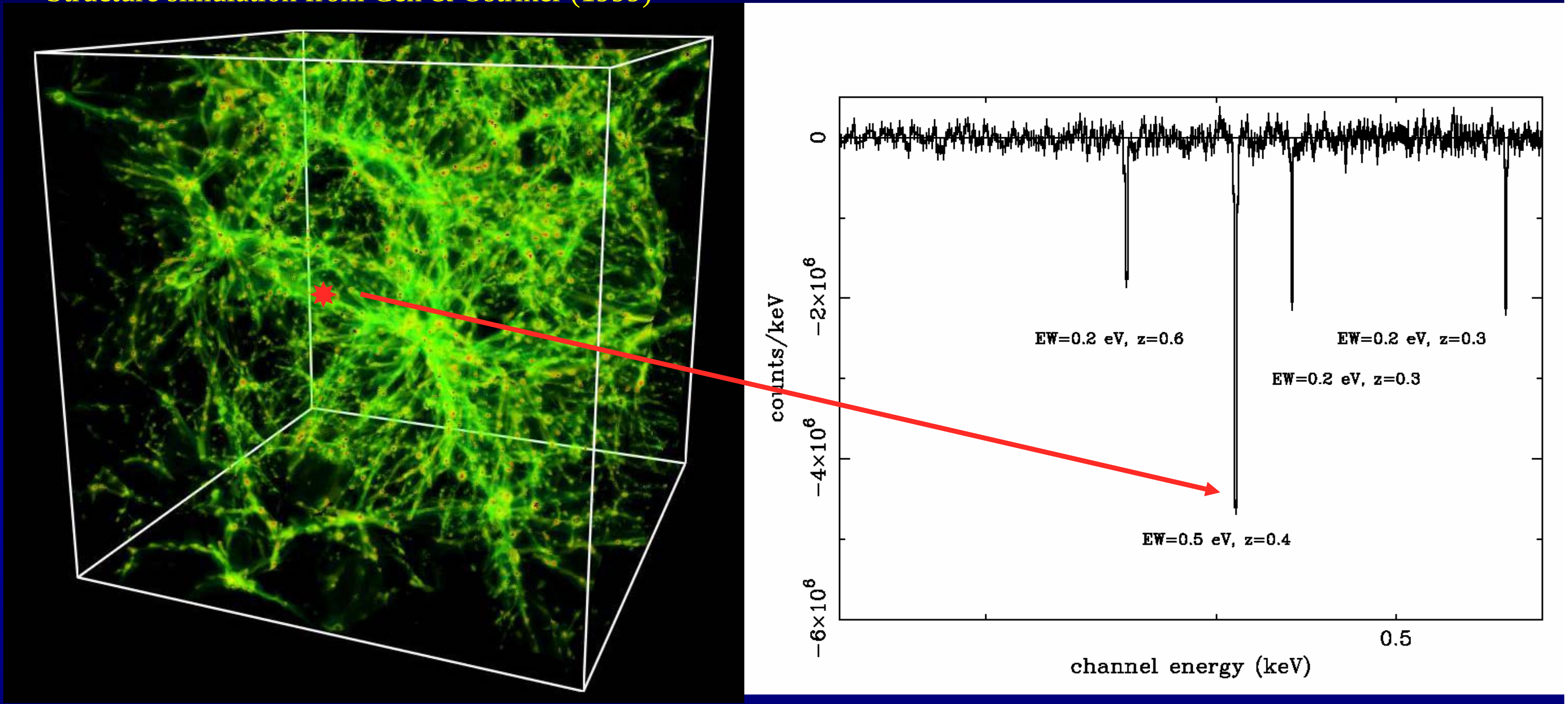
Tomography of the Universe II: the Cosmic Web

- At z~0 the baryon in stellar systems, neutral Hydrogen, X-ray emitting gas in cluster of galaxies is one order of magnitude less than the predictions
- From models most of the baryons in the loca (z<1-2) Universe in hot or warm filamentary structures heated by the gravitational pull of DM



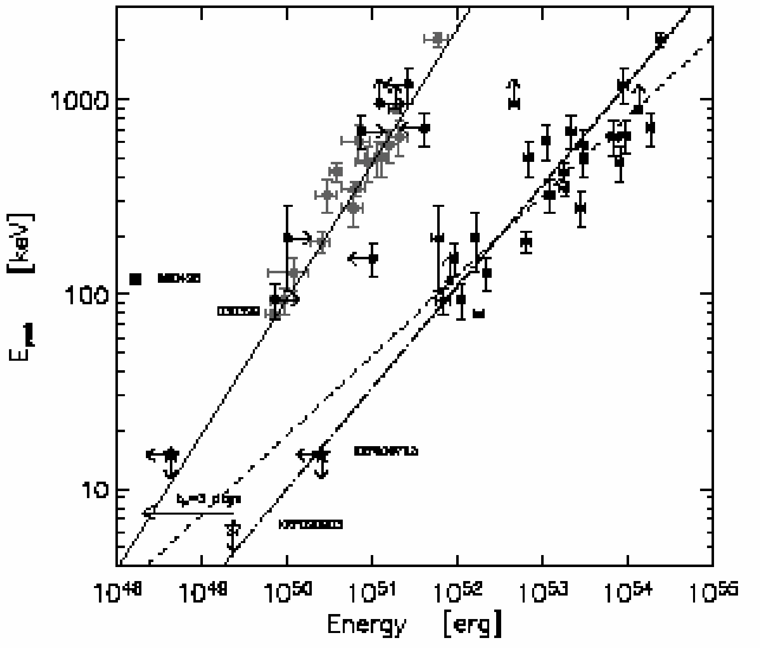
Dark matter & WHIM: X-ray forest

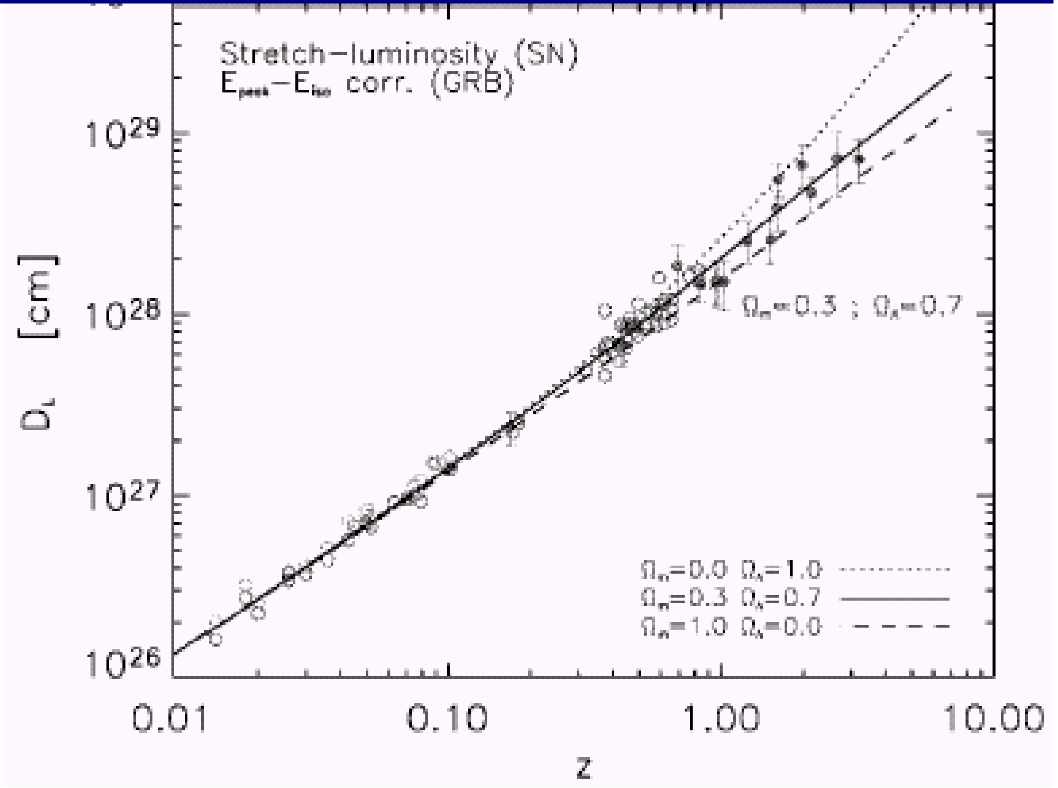
Structure simulation from Cen & Ostriker (1999)



Simulations of WHIM absorption features from OVII as expected from filaments (at different z, with EW=0.2-0.5 eV from Hellsten et al 98) in the l.o.s. toward a GRB with Fluence=4 10^{-6} as observed with ESTREMO/WFXRT (in 60 ksec). About 10% of GRB (10 events per year per 3sr).

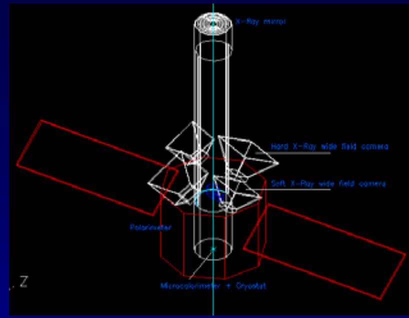
GRB as standard candles: new rulers to measure the Universe





- Ghirlanda et al 2004, Amati et al 2002

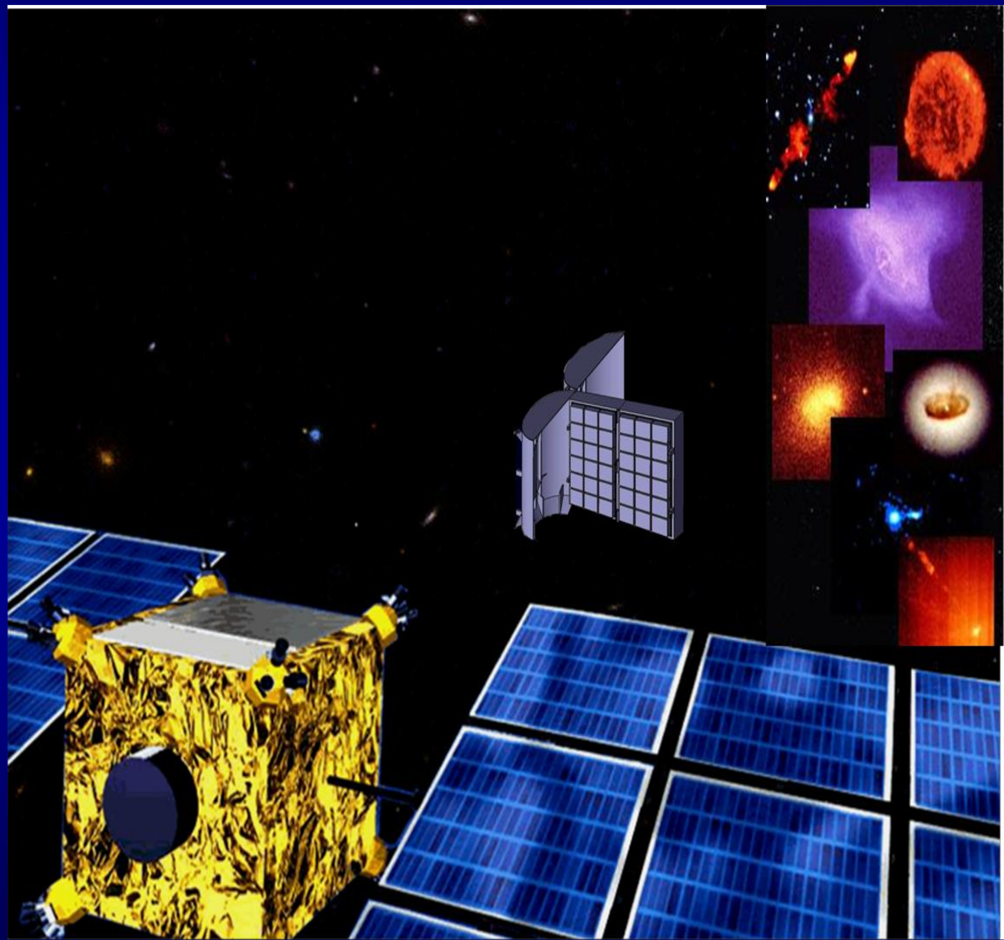
Mission profile



- **Wide field monitor in the X/hard-X range to localize transients**
- **Fast (min) autonomous follow-up observations with X-ray telescope (2000 cm^2) with**
- **High resolution X-ray spectroscopy (0.1-8 keV range, 2eV resolution below 2 keV with TES microcalorimeters)**
- **Wide field (1°) for imaging with 10” resolution (CCD) for extended faint structures and cluster survey**
- **Low background: 600 km equatorial orbit**

XEUS: X-ray Evolving Universe Spectroscopy

- Under study by ESA and JAXA
- Large Observatory

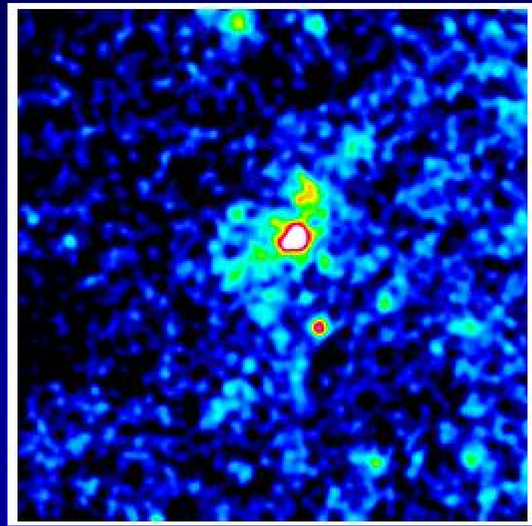


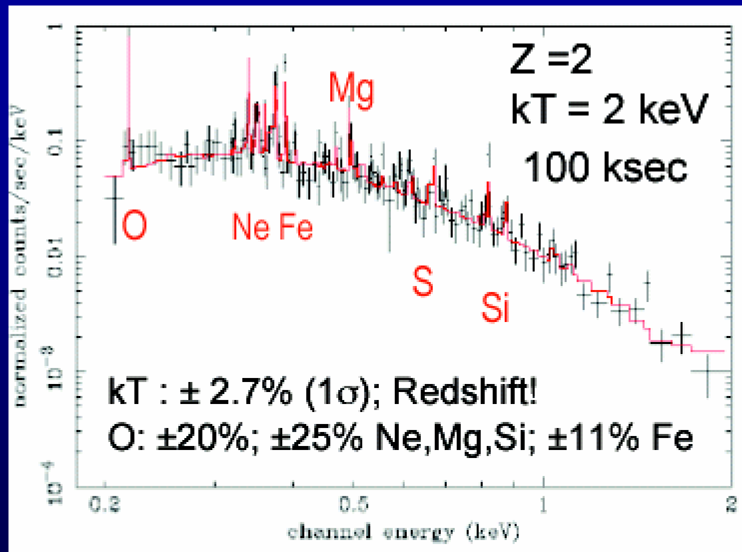
Scientific objectives

- Study of the largest structures in the Universe - clusters and groups of galaxies, their formation and evolution in the Early Universe.
- Study of the coeval growth of galaxies and their supermassive black holes
- Study of gravity in the strong field limit and matter under extreme conditions

Evolution of large scale structures

- Formation of first galaxy groups (expected to emerge at z about 2): $L=10^{43}$ erg s^{-1}
- Trace the evolution (incl. Abundances) to present massive clusters

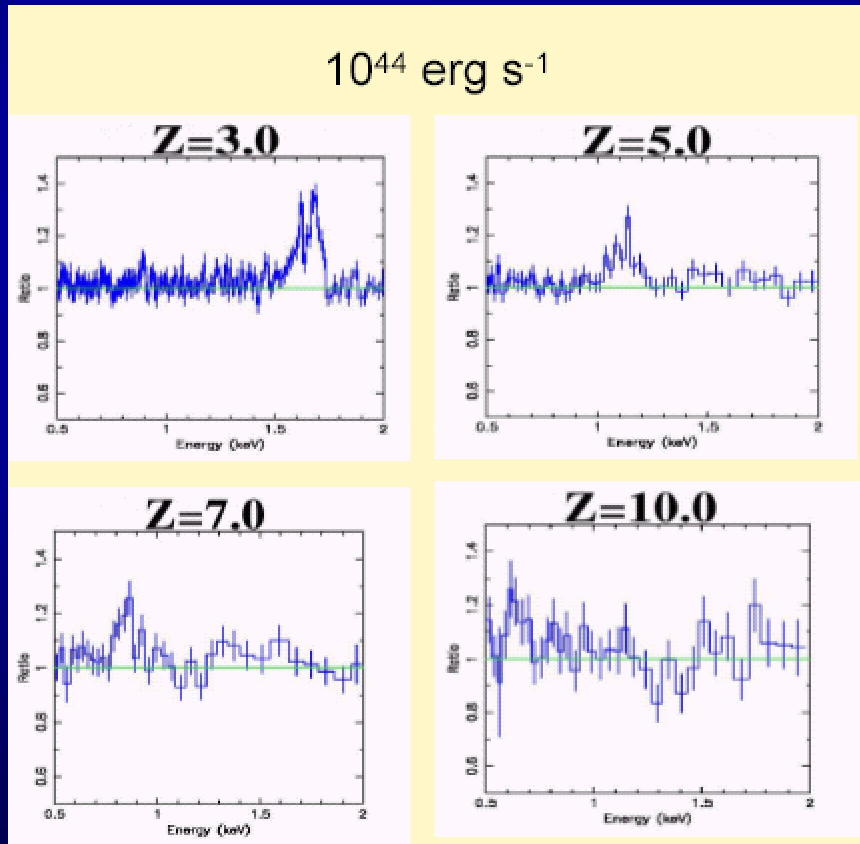




Coheval growth of Super Massive Black Holes

- Present theories indicate that first stars were very massive (100 Msun) and soon formed a stellar mass black holes very likely in GRB explosions. Supermassive black holes then grew in cataclysmic feeding events. Likely 10^6 Msun, $Lx=10^{43}$ erg s^{-1} around z=10
- co-ex-istence and co-evolution of stars and central black holes early in the universe

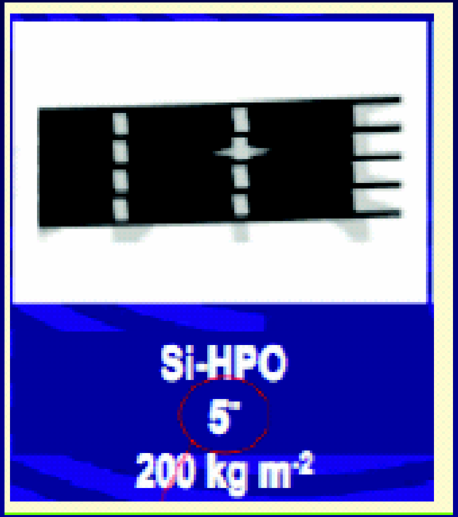
Fe line



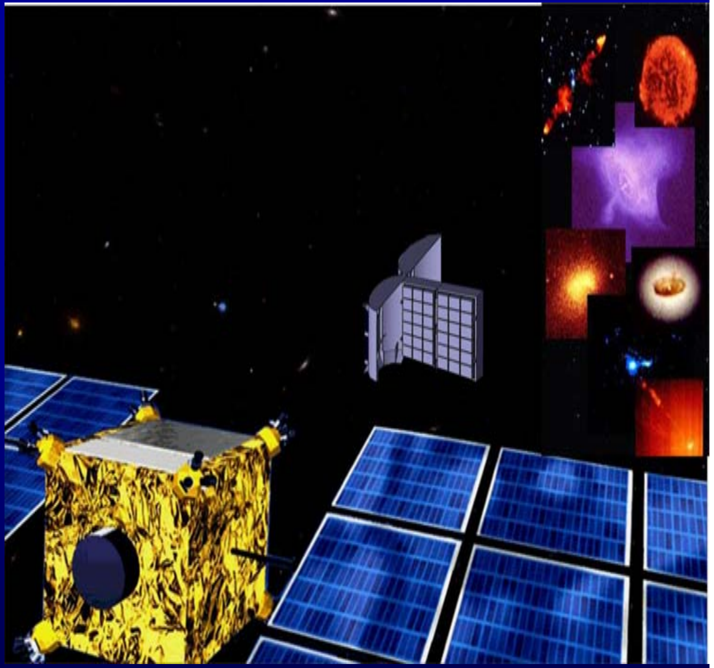
Scientific requirements

- Science Requirements are set by these very demanding objectives (drivers):
- To measure the spectra of objects at flux levels close to 5 10^{-18} erg cm^{-2} s^{-1}.
- A spatial resolution at better than 5" HEW (*2" goal*) is required in order to avoid source confusion at these faint levels.
- An energy resolution of 2 eV @ 1keV
- FOV=7' (WFI), 0.5' (Cryo.Spectrometer, *1.7' goal*)
- Bandpass: 0.1-10 keV *(40 keV goal)*
- *High Timing resolution: 100usec (goal)*
- *Polarimetric capability (goal): 2% in 10ksec*

Payload



- Mirrors: high resolution, large effective area (5m^2 @1 keV, 1m^2 @ 6 keV) with f=35-50 m
- Focal plane core instruments:
  - WFI (imaging active pixel)
  - Narrow Field Cryo spectrometer (TES / STJ)
- Additional:
  - 2nd NFCryoSpec, Hard X-ray Camera,
  - High Time Res.
  - Polarimeter

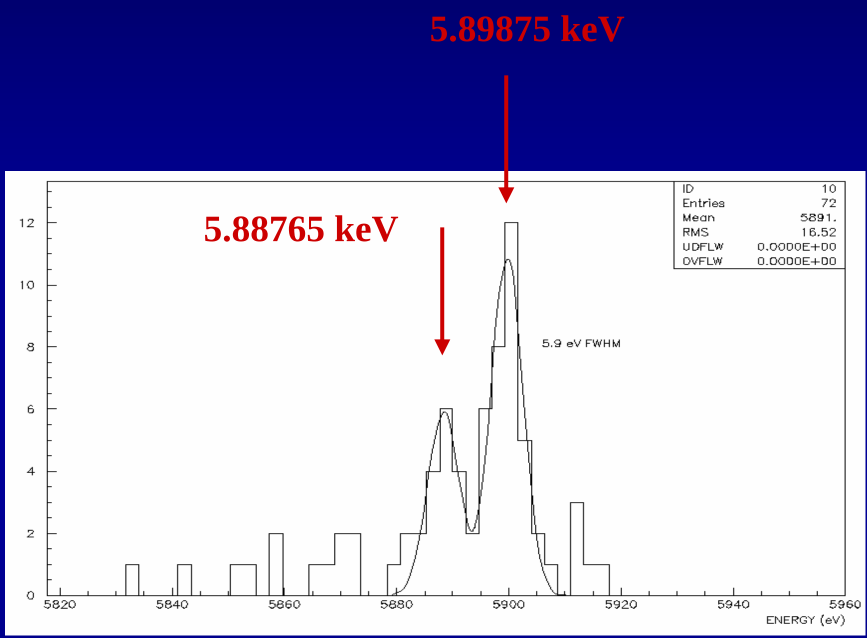


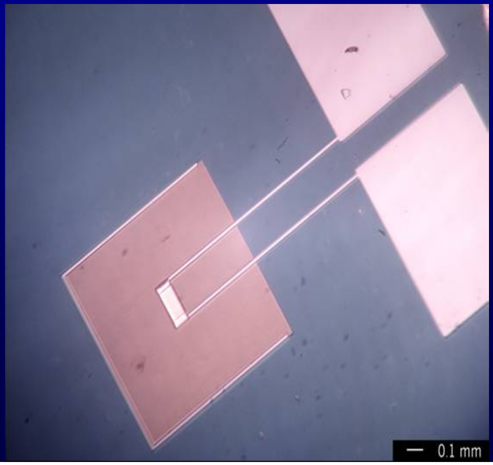
Technology

- Mirrors: New ESA light-weight Si (200kg m^{-2} , 10 times lighter than XMM)
- WFI: Silicon active pixels (MPE)
- NFCryoSpec: Transition Edge Sensor (NL/I/UK/G/Fin/S/Sw/J)
- HXC: J
- HTRS: F
- XPOL: I

TES development in the European context

- SRON: 3.9 eV @ 6 keV
- Italy (led by INAF-IASF-Rome, INFN-Genova,): 5.9 eV @ 6 keV
- EURECA consortium





Summary

- Both missions characterized by hot, unique yet complementary science (wide field+bright transients during their explosive phases vs faint sources)
- Some of the key hardware is similar (cryogenic TES)
- Technological implementation: fast autonomous slewing vs formation flight
- Small/mid size, 2016 launch time frame: ESTREMO/WFXRT
- Cornerstone, Large Observatory, post 2020: XEUS