# ESTREMO/WFXRT: Extreme phySics in the TRansient and Evolving COsmos

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## ABSTRACT

We present a mission designed to address two main themes of the ESA Cosmic Vision Programme: the Evolution of the Universe and its Violent phenomena. ESTREMO/WFXRT is based on innovative instrumental and observational approaches, out of the mainstream of observatories of progressively increasing area, i.e.: 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 Warm Hot Intragalactic Medium (WHIM). ESTREMO/WFXRT will rely on two cosmological probes: GRB and large scale X-ray structures. This will allow measurements of the dark energy, of the missing baryon mass in the local universe, thought to be mostly residing in outskirts of clusters and in hot filaments (WHIM) accreting onto dark matter structures, the detection of first objects in the dark Universe, the history of metal formation. The key asset of ESTREMO/WFXRT with regard to the study of Violent Universe 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 mission is based on a wide field X-ray/hard X-ray monitor, covering >1/4 of the sky, to localize transients; fast (min) autonomous follow-up with X-ray telescope (2000 cm$^2$) equipped with high resolution spectroscopy transition edge (TES) microcalorimeters (2eV resolution below 2 keV) and with a wide field (1°) for imaging with 10" resolution (CCD) extended faint structures and for cluster surveys. A low background is achieved by a 600 km equatorial orbit. The performances of the mission on GRB and their use as cosmological beacons are presented and discussed..

**Keywords:** X-ray instruments, Cosmology, Gamma-Ray Bursts, Clusters of galaxies

## 1. INTRODUCTION.

The exploration of the Universe through the X-ray window is giving access to a wealth of phenomena from the most extreme manifestations of physical laws in compact sources to a privileged view of the large scale cosmological structures. X-ray observations of the Universe have thus the capability to address fundamental questions of mankind, such as those posed in the context of the ESA Cosmic Vision 2015-2025, i.e.:

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1. How did the Universe originate and what is it made of?

 1.1 The early Universe

 1.2 The Universe taking shape

 1.3 The evolving violent Universe

2. What are the fundamental physical laws of the Universe?

 2.1 Matter under extreme conditions

In the following we will briefly describe the scientific context embedded in those questions and relevant to our proposed approach, with a preliminary mission profile and instrument definition. The science case related to observing and surveying the sky with the Wide Field X-Ray Telescope is described in more detail in [1]

## 2. THE SCIENTIFIC CONTEXT

### 2.1 X-ray Cosmology

The formation of cosmic structures is one of the most important topics in current research. Theoretical models based on hydrodynamical numerical simulations (e.g. [2]) predict that the majority of baryons in the local Universe resides in large scale structures, the so-called **Warm Hot Intergalactic Medium (hereafter WHIM).** Since baryons make up only 5% of the total mass/energy of the Universe the evolution of large scale structure is mostly determined by **Dark Matter**, which constitutes 25% of the total mass/energy of the Universe. Baryons that fall in the Dark Matter potential wells are heated up to X-ray emitting temperature $10^5$-$10^7$ K. Thus X-ray observations play a fundamental role in characterizing the formation and evolution of large scale structure, more specifically they:

1) provide detailed information on the state of the plasma trapped in the deep potential wells of clusters and groups;

2) allow the study of baryons organized in WHIM filamentary structures, with typical sizes of a few tens of Mpc, that has so far proved almost inaccessible to direct observation;

3) enable us to statistically trace the mass distribution on very large scales independently from galaxies and star formation within them.

The bulk of the kinetic energy of the gas falling in the potential well of clusters and groups is converted into thermal energy, the efficiency of this process will depend on the thermal history of the accreting gas, in this context pre-heating of the gas by AGN or supernovae may play an important role. Thus the study of X-ray emission from the WHIM and cluster outskirts would also provide important clues on the connection with galaxy formation processes. Moreover spectroscopic measures of metal abundances would provide unique information on the star formation history in different environments.

Analyses of presently available X-ray spectra obtained with Chandra and XMM satellites provided only tentative evidence of WHIM detection so far (e.g. [3,4], Kaastra 2003). Therefore, detecting WHIM, measuring its abundance and characterizing its physical stage represent a very important issue in astrophysics and cosmology today.

The other larger piece of the puzzle is constituted, by 70%, of the elusive **dark energy**, whose most prominent signature is the acceleration of the Universe taking place around z=1, as shown by the Hubble diagram of supernovae. Understanding cosmic acceleration and the nature of dark energy is one of the most important goals in physics and astronomy today, and these results must be checked by a variety of precise cosmological tests over a wide range of astrophysical objects with small statistical and systematic errors. As described below, we will study the prospects of using two different class of sources to address this theme.

Our observational window on the Universe extends in distance up to z=6.6, the redshift of the most distant object discovered so far (a quasar), and then recovers at z=1000, the epoch of primordial fluctuations measured by BOOMERANG and WMAP. The formation of the first objects, stars, and protogalaxies, should have taken place at epochs corresponding to z=10-30, certainly beyond z=6. These first gravitationally bound proto-systems are the result of the evolution of the primordial fluctuations observed at z=1000, this evolution depending on cosmological models and dark-matter properties. The big observational gap in between these epochs is then particularly serious. **Discover and study the first "light" from primordial gravitationally bounded object in the Universe at z=10-30** is thus a primary goal of Cosmology and Astrophysics. Far Infrared and X-rays are the only two windows in which these studies can be attempted, with the X-ray revealing the most energetic part of the phenomenon.

**Finally, the study of the history of metal enrichment in the Universe from early epoch to the local Universe**. This is a key information needed for the hierarchical model of the formation and evolution of small to large scale structures of the Universe. In particular X-ray "light" emitted from distant sources will be selectively absorbed at specific frequencies by metals along the line of sight, thus allowing to build up a "map" of metal abundances and hence star formation rate as function of the redshift. This observation complements the measurements of metals in emission lines underlined above for WHIM and cluster of galaxies.

### 2.2 The violent Universe and the transient phenomena

Gamma-Ray Bursts

***Gamma-Ray Bursts*** are the brightest and most distant sources in the Universe. The radiation intensity of GRB's is so high that they can be detectable out to much larger distances than those of the most luminous quasars or galaxies observed so far. The average redshift distribution of GRBs peaks at z=2.8 with 3 GRBs (out of 50) at z>4 and one at z=6.3. Many of unknown optically dark GRB can be at higher redshift. About 10 % of GRB observed have an afterglow X-ray fluence (integrated from 60 sec to 60.000 after the main pulse) greater than 4 $10^{-6}$ erg $cm^{-2}$, and 2% of the events a factor 5 times brighter. In comparison, a primordial super-massive Black Hole ($10^6$ $M_\odot$) at z=10 accreting at 10% of the Eddington limit would have a X-ray flux of about 2 $10^{-18}$ erg $cm^{-2}$ $s^{-1}$, while a $10^{41}$ erg/s galaxy would have a flux of 5 $10^{-20}$ erg $cm^{-2}$ $s^{-1}$. Even for an integration time of $10^6$ sec, the corresponding fluences would still be $10^{6-8}$ times lower than compared to GRB afterglow. In addition, Gamma-ray Burst (specifically the so called long-burst) are now unquestionably associated with explosions of massive stars taking place in star formation regions. A large fraction of GRB afterglows shows evidence of intrinsic absorption, of the order of $10^{22}$ $cm^{-2}$, i.e. typical of what expected for a star-forming region.

**X-Ray Flashes (XRF)** and X-Ray Rich (XRR) are two classes of GRBs discovered by BeppoSAX [5] . Their light curves and spectra are very similar to that of classical long Gamma-ray Burst (GRB). The difference is that the spectrum of XRR and XRF is much softer than GRB, with a peak energy of about few tens of keV, against hundred of keV for GRB. After near 10 years from their discovery the origin of XRR and XRF is still debated, and a deeper investigation is required. It should be noted that SWIFT is not best suited to study such events, having a low energy threshold of about 15 keV. Several models have been proposed to explain the origin of XRF and XRR. In the High redshift scenario XRF and GRB have the same intrinsic properties and their spectral diversities are ascribed to their different distance. Considering that some redshift of a few XRF have been measured, with an average value of 1.7 [6] this scenario cannot apply to the whole population. However, some of dark (i.e. without optical afterglow) XRF can be events lying at z>5 because of the extinction produced by the Lyman-alpha forest. In the framework of the off-axis scenario XRF would be normal GRB seen off-axis. This scenario is broadly consistent with the data [6]. If so, a large population of soft and more numerous events is expected to exist.

Compact objects and matter in extreme conditions

Fine X-ray spectroscopy is of key importance in the study of **Neutron Stars** (NS). The measurement of the gravitational redshift in observations of X-ray bursts, through detection of redshifted lines can lead to determination of the NS mass-radius relationship, hence constraining the **equation of state of the dense nuclear matter** [7]. In this context, newly discovered, important class of thermonuclear bursts are the “superbursts”, i.e. very long (~ hours) events due to unstable burning of carbon and/or other products of the hydrogen/helium burning occurring on the NS surface. Despite these events are ~1000 times more energetic than normal type I bursts, only a few of them are known. It is very important to study their frequency and characteristics as a function of accretion rate. Iron lines have been found in the spectrum of a superburst by 4U1820-30 [8].

Flaring behaviour of compact sources at time scales of hours to min is today a rather established, but poorly studied phenomenon. Strong events have been found in BH systems, like rapid flux variability of V4641 SGR [9], giant outbursts of Cyg X-1 [10] and bright flares from XTE J1650-500 [11]. These are probably not related to disk instability but can be interpreted in many ways, as violent activity of the inner accretion disk (e.g. feeding of material into jets), fluctuations of direct wind accretion, presence of thick, possibly clumpy absorbers or outflows. High resolution spectroscopy of these bright transient events is therefore a tool for important diagnostics.

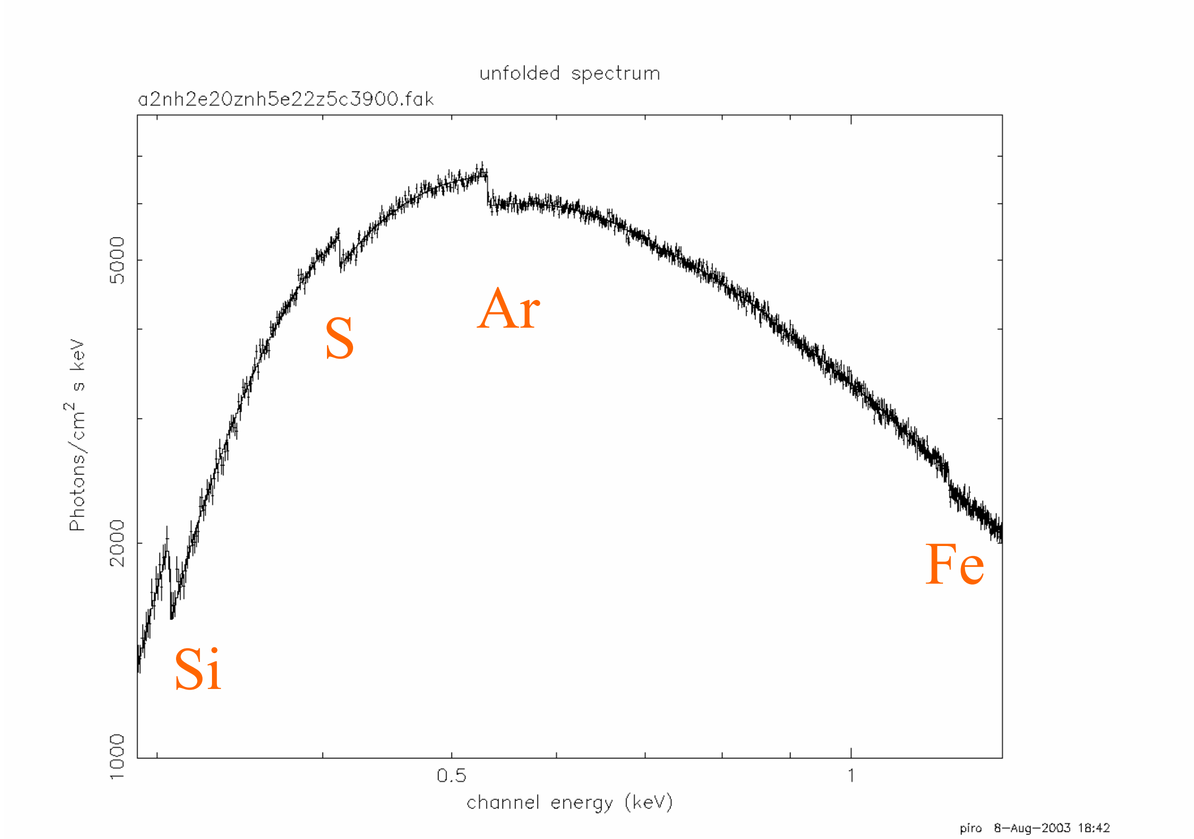


Fig. 1. Simulation of X-ray edges produced by metals (Si, S, Ar, Fe) by a medium- bright burst (integrated flux from 1 min to 60 ksec = 4 $10^{-6}$ erg $cm^{-2}$) with column density NH=5 1022 cm-2 and solar-like abundances in the host galaxy of a GRB at z=5., as observed ESTREMO/WFXRT (1min to 60 ksec)

## 3. SCIENCE GOALS AND MISSION PROFILE

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 (minute time scale) transient sources, like GRB, at their brightest levels, thus allowing efficient high resolution (goal: DeltaE=1 eV) spectroscopy.

• Observing and surveying extended sources (Clusters of galaxies and WHIM filaments) by exploiting the 'flat' spatial resolution (10" HPD within 30' radius) of a high sensitivity wide-field (1°) X-ray telescope.

### 3.1 X-ray cosmology

ESTREMO/WFXRT will use two different cosmological probes, namely Gamma-Ray Burts and large scale structures (Clusters of Galaxies and WHIM) 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 with metal absorption and edges

–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

In the current framework of WHIM mission-concepts, three alternative observational approaches have been considered: 1) spectroscopy of WHIM absorption features against a bright background source, in particular GRB afterglows with microcalorimeter detectors on 2) spectroscopy of WHIM emission features with an array of microcalorimeters 3) mapping of WHIM emission with a low background Wide Field Detector (at CCD-like spectral resolutions). Clearly a mission able to exploit simultaneously all three observational strategies would allow a major step forward.

For instance: spectroscopic measurements of WHIM on the line of sight to GRBs would allow to observe enough filaments (>500) to determine $\Omega_B$. with a precision of 2-3%. Follow up observations in emission of WHIM filaments detected in absorption would allow us not only to image the structure and so to derive its physical size, but also to estimate its density through line ratio diagnostics permitted by the high resolution spectrometers.

The Wide Field instrument will also be used to survey large areas of the sky (>10,000 sq. degrees) with a high sensitivity, reaching flux limits of the order $10^{-14}$ erg cm$^{-2}$ s$^{-1}$ will detect galaxy clusters out redshift 1-1.5. This will lead to the discovery of over 50,000 groups/clusters (of which 1,000 with mass $>10^{14}$ $M_{sun}$) which will be employed to: 1) trace the large scale structure and combined with the large optical-infrared surveys currently planned or under way (CFHT-LS, VST, VISTA) , systematically study the role of the environment in the evolution of galaxies out $z\sim1.5$ (as an example consider the 2 sq. deg. COSMOS); 2) study the evolution of the LSS and with this (3) measure the w parameter of the Dark Energy equation of state with a precision better than 10%.

An alternative approach to measure Dark Energy that is currently under investigation employs GRBs as standard candles much in the same way as supernovae.

At the same time the large FOV and high sensitivity of the Wide Field Imager can also be employed to study low surface brightness regions such as the outer regions of galaxy clusters. Adopting dedicated observing techniques it would be possible to measure the cluster emission out to the viral radius for the first time, thereby studying the assembling process of the largest structures to have decoupled from the Hubble flow. This study will be complemented by spectroscopic observations of the WHIM in emission in the vicinity of galaxy clusters thereby allowing us to follow the formation process of clusters from a very early phase.

In this paper we focus in particular on the spectroscopy capability of the mission.

For what concerns the use of GRB as bright cosmological beacons we present in Tab. 1 the typical fluences and number of burst expected. The main point to be underlined is that with ESTREMO/WFXRT, by observing the burst afterglow with a typical reaction time of a minute, will yield some millions of counts in the total spectrum, and typically thousand of counts in 1 eV bin below 1 keV. Tab. 2 shows that, as far as the total fluence is only concerned, a typical observation lasting about 50-60 ksec would suffice. In passing we point out that we have derived similar results by considering the typical afterglow light curve observed by SWIFT.

A significant fraction of GRB show intrinsic (i.e. in situ) absorption, of the order of few $10^{22}$ cm$^{-2}$[12,13]. By exploiting the large area of ESTREMO/WFXRT, its fast reaction capability and the spectral resolution, it will be possible to measure metal edges in a large sample of GRB ( Fig. 1) This will allow to achieve two major results. First, a direct measure of the redshift, including events in the dark region of the Universe ($z=7$-$20$). Second, the evolution of metal abundances as function of redshift.

Tab. 1 WHIM absorption lines towards GRB afterglows

| logFx @11hrs | P(NGRB with F>Fx)[1] | Number of GRB per yr for FOV=3sr | Fx@60s (erg/cm2/s) | Fluence(t>60s) (erg/cm2) | Counts NFI-TES (0.1-10 keV) | Cts/eV @0.5 keV | EWmin (5σ) (eV) @0.5 keV |
|---|---|---|---|---|---|---|---|
| -12.25 | 42% | 30-100 | $2.4\ 10^{-9}$ | $4\ 10^{-7}$ | $2\ 10^{5}$ | 500 | 0.3 |
| -11.4 | 8% | 10-20 | $1.7\ 10^{-8}$ | $3\ 10^{-6}$ | $2\ 10^{6}$ | 4000 | 0.1 |
| -11.0 | 3% | 3-8 | $3.4\ 10^{-8}$ | $7\ 10^{-6}$ | $5\ 10^{6}$ | 8000 | 0.07 |

Notes : Adopting a power decay law with a slope -1.3; [1]fraction of GRB with an afterglow flux larger than Fx in the sample of BeppoSAX GRB [14]

Tab. 2 Fraction of the total fluence of the afterglow of a GRB in the interval t0=60 s and t, for a decay power law with slope –1.3

| t(s) | % |
|---|---|
| 600 | 50 |
| 6000 | 75 |
| 60.000 | 94 |

For what concern the detection of WHIM, we expect to detect several hundreds of filaments in OVII in a 2 year period. We present in Fig. 2 a simulation of the absorption lines by ESTREMO/WFXRT towards the line of sight to a GRB produced by filaments at different redshift.

The use of GRB as probes to WHIM carries a number of advantages with respect to bright blazars. GRBs are more distant, thus they can probe more filaments and potentially trace the evolution of the WHIM from z=1 to 0. Second, their afterglow fade away with time. Thus it can be possible to carry out deep follow up observations in emission towards the direction where strong absorption lines produced by WHIM filaments have been detected.

The capability of ESTREMO/WFXRT for what regards the emission spectroscopy of WHIM is summarized in Fig. 3 following [15]. As shown in the figure, the line can be well detected even with an extraction region of 3'. This allows to select the region where the filament is most prominent, thus optimizing the signal to noise ratio. The main background component is the thermal local foreground emission [16].

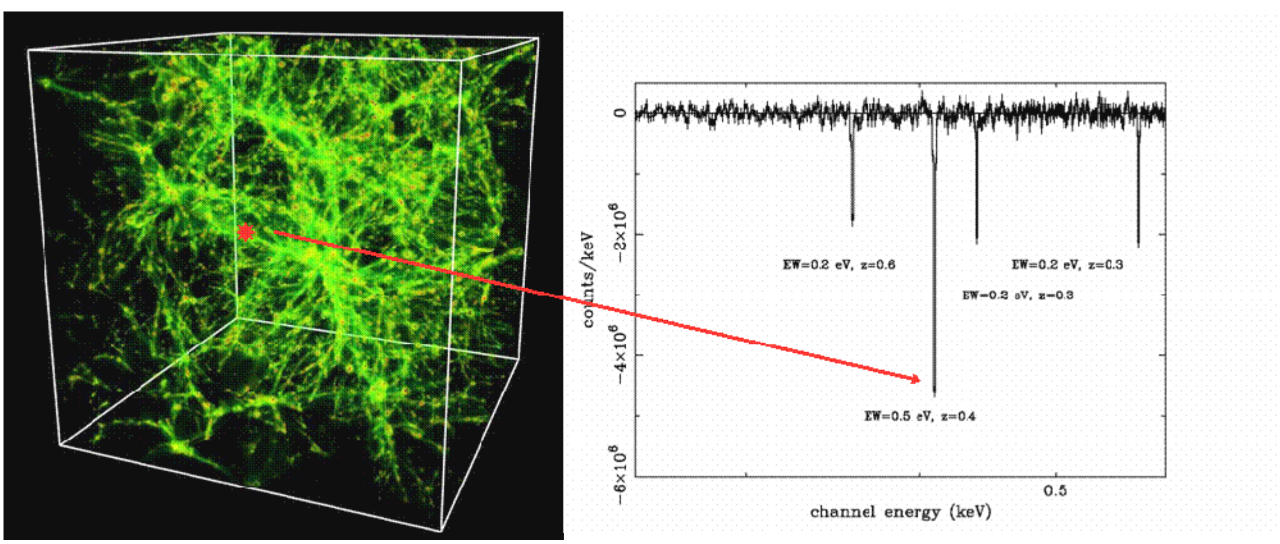


Fig. 2. Simulations of WHIM absorption features from OVII as expected from filaments (at different z, with EW=0.2-0.5 eV in the l.o.s. toward a GRB with Fluence=4 $10^{-6}$ as observed with ESTREMO/WFXRT (in 60 ksec). About 10-20 GRBs per year per 3sr with a similar or larger fluence are expected.

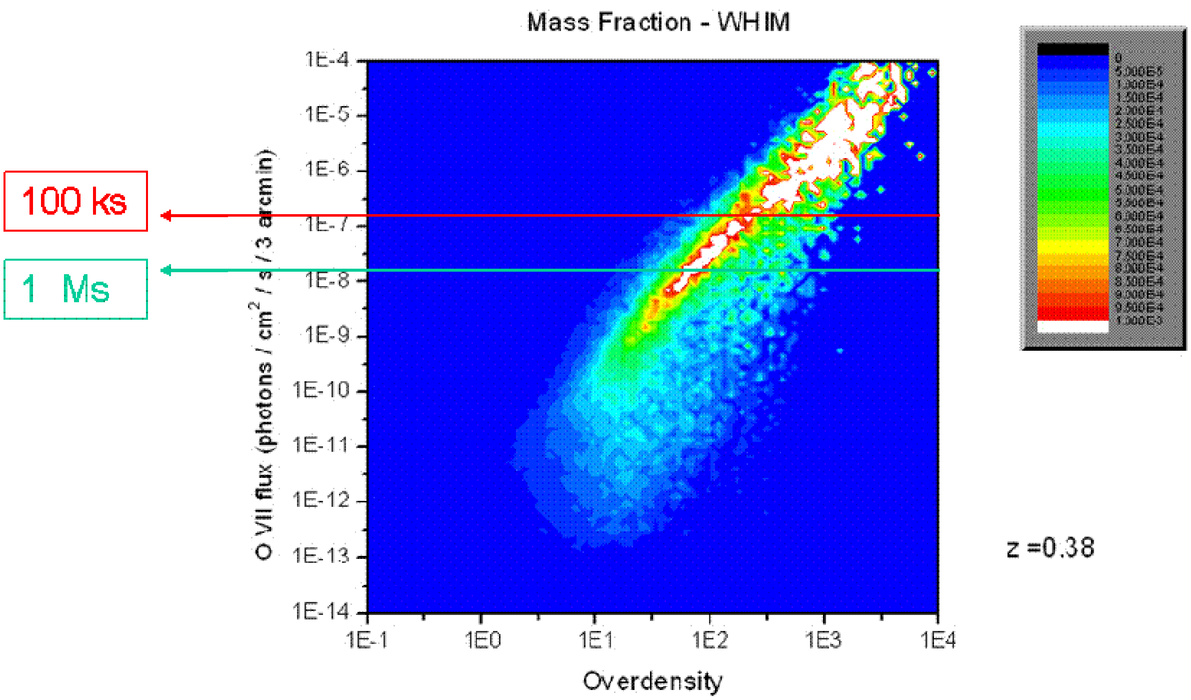


Fig. 3 OVII line intensity from a WHIM integrated in a 3' circle. 70% (50%) of the mass of WHIM produces OVII line detectable by ESTREMO/WFXRT in 1 Msec (100 ksec) observation.

### 3.2 The violent Universe and the transient phenomena

Gamma-Ray Burst, X-Ray Flashes and X-Ray Rich

In addition to the cosmological use of the GRB (evolution of the metals, dark matter and dark energy, WHIM,…), ESTREMO/WFXRT could provide important observations of the XRF and XRR.

To clarify the nature of XRF (off axis GRB's, low energetic events,…) a large energy band covering also low energies, and a rapid follow-up are important. If we look to the 2000-2003 Hete II burst sample, which is not biased against XRR and XRF [17], we find that XRR and XRF represent about the 60% of the population and the numbers of the three classes of burst are roughly equal. If the rate is 1000 GRB per year in all the sky, then we expect to observe a large number of XRR/XRF per year with a wide X-ray monitor such us that planned for ESTREMO, characterized by a large energy band extending to low energies (few keV).

Compact objects and matter in extreme conditions

Rapid response to X-ray transient events and capability of high resolution spectroscopy are the key to probe the extreme relativistic regime of the inner regions in BH accretion disks and physical conditions at the neutron star surface, e.g. by detection of gravitationally redshifted line features in superbursts. In such a way the phenomena currently observed sporadically will be upgraded to real classes allowing to more detailed and well constrained models.

## 4. MISSION AND PAYLOAD CONFIGURATION

- Wide field monitor in the X/hard-X range to localize transients (>1/4 of the sky)
- 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

### 4.1 Narrow Field Instrument configuration

We are studying two optional configurations for the Narrow Field Instruments.

- A single telescope with the two detectors (TES and CCD) sharing the focal plane.
- Two telescopes, one devoted to the TES, the other to the CCD

A single telescope configuration is based on a X-ray mirror with a polynomial profile, that assures a wide field (1 degree) of view with a rather constant point spread function along the field. This is described in more detail in [1]. Focal length is 4 m. The effective area on axis is about 2000 cm$^2$ at 1 keV, reducing to 60% at 30' off axis. The focal plane assembly is with the TES lying in the optical axis but below the optimal focal plane (i.e. defocused) and the CCD lying in the focal plane. The CCD mosaic has a hole in the center with a footprint area corresponding to the TES. This configuration thus assumes that the single telescope has a spatial resolution tailored to the CCD (15"). The TES requirement is 1', thus allowing it to be placed (defocused) below the CCD. The distance between the TES detector head and the external entrance window is between 4 and 6 cm. For a focal lenght of 4 meter, and optics diameter of 70 cm, it is derived that the spot has a diameter of 1mm (corresponding to 0.9') at about 10 cm below the focal plane. A detailed analysis is being carried out with ray tracing adopting first a polynomial optics profile is under way.

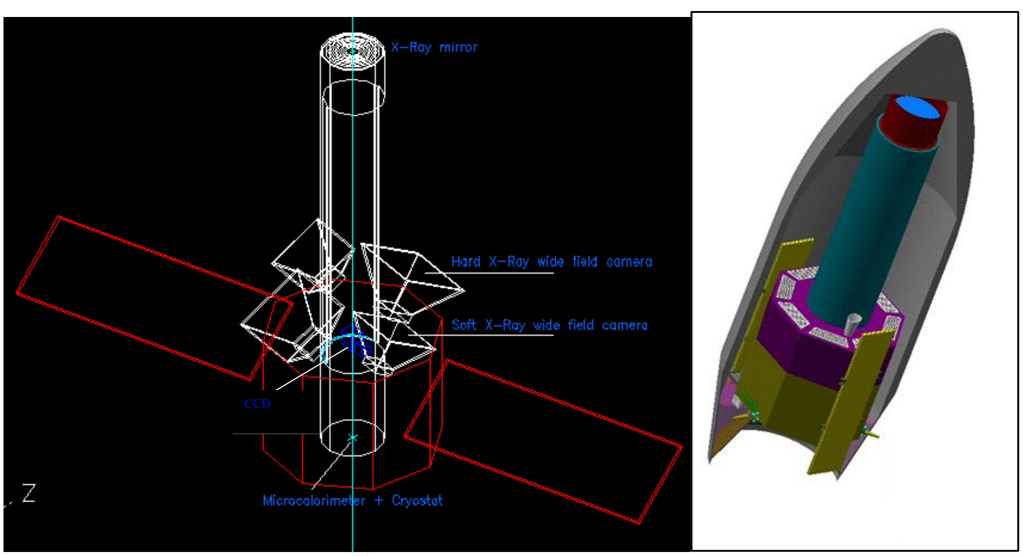


Fig. 4 Payload layout for a single telescope configuration (f/l=4 m) and 4 WFI (left panel). On the right panel the accommodation in the VEGA shroud with a configuration with 8 WFI.

For a twin telescope configuration the focal lengths should be slightly reduced to fit in the VEGA launcher shroud,. For the WFXRT we are studying the configuration starting from Panoramix parameters (Tab. 3).

Tab. 3 Parameter for WFXRT for the twin telescope configuration

| | |
|---|---|
| Optics configuration | Polynomial |
| Number of mirror | 50 |
| Outer radius | 350 mm |
| Inner radius | 105 mm |
| Optics height | 280 mm |
| Focal length | 3.5 m |
| HEW from 0 to 30' off ax | 10 arcsec |
| Mirror thickness max | 1 mm |
| Mirror support material | SiC |
| Weight (mirror+tube) | 196 kg (mirror:138 kg, tube= 58 kg) |
| Reflecting surface material | Ir+C overcoating |
| On-axis effective area | 1200 $cm^2$ at 1.5 keV<br>140 $cm^2$ at 6 keV |
| Off (30')/on axis eff.area | 65% @1 keV |

For the TES telescope we first note that the shallower requirement on the angular resolution allows a much lighter weight. This can be achieved e.g by replicated optics with a thickness about 1/8 of e.g JET-X, or by plastic (e.g. Suzaku-like) foils. For a focal length of 3.5 meters, compatible with allocation in the VEGA shroud in a twin telescope configuration, an area of about 1500 cm2 can be achieved with a total weight less than 70 kg.

We point out that this first assessment gives a conservative estimation of the mass and length of the telescope, thus it gives the maximum momentum of inertia of this configuration. The maximum diameter of the mirror corresponds to a focal length of 3.5 meter and is dictated by the allocation. A shorter focal length will allow a larger diameter.

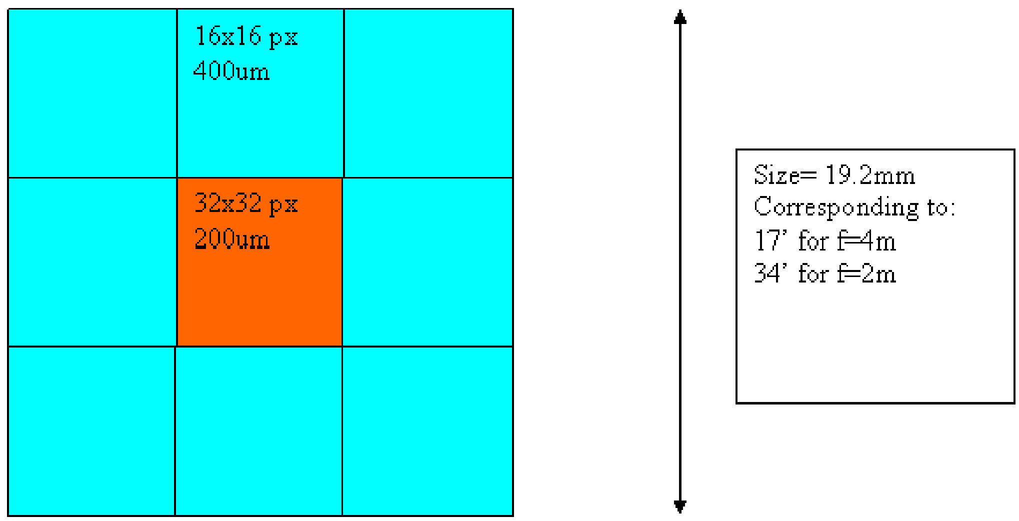

Fig. 5 TES configuration

TES

The bandwidth lower limit: 0.1 keV (this is mostly depending on filters) with an extension at 7-8 keV For the energy resolution the most stringent requirement is from WHIM is absorption, 2 eV below 1 keV (1 eV goal).

From WHIM in emission the FOV requirement is about 15'x 15'. Pushing the angular resolution below 1' is not a main science driver, taking into account the number of counts for extended sources. The minimum size of the field of view of the TES is to be.at least 4', i.e. greater than the (quadratic) sum of the location accuracies of the WFI and pointing after slew.

The main constraint on the pixel size is derived from the maximum count rate before pile up and degradation of the energy resolution. No significant degradation in energy resolution is expected below about 300 cts/s/pixel. Note that the count rate level can be increased by implementing smaller (faster) pixels. Accepting a small (TBD) degradation of the resolution, about 1000 cts/s/pixel should be stand. Considering a source of about 1 Crab, giving about 10.000 cts/s, implies that the optics PSF should be oversampled with at least 10 pixels. For a focal length of 4 meters, the plate scale =1.16 mm/arcmin. Thus, assuming a HEW of 1 arcmin, this requires a maximum pixel size s=0.4 mm. For a focal lenght of 2 meters, this requires a maximum pixel size of 0.2mm.

In Fig. 5 a possible configuration based on a mosaic of TES chips. It is based on a central chip with 1000 pixels with a pixel size of 0.2mm. Note that the field of view of this central part corresponds to 5.5'x5.5' (for a focal length of 4 m) with a large oversampling of a 1' optics point spread function. The small pixel size in the center part will also allow to improve the spectral resolution. To increase the total field of view, the central chip is surrounded by chips with 256 twice larger pixels.

CCD

A preliminary configuration for the X-ray camera for WFXRT is made of an array of nine CCDs arranged in an inverted pyramid that matches the focal surface of the mirrors. Each device is a 600 x 600 pixel front side illuminated frame store with pixel size 40 μm corresponding to 2.4 arcsec in the focal plane. Energy resolution provided by the CCDs is $\Delta E/E \leq 10\%$ at 1.5 keV

### 4.2 Wide Field Instrument configuration

The main requirement is to maximize the number of bright GRB (needed for WHIM studies in absorption), that drives the field of view (FOV) to at least 3 sr (about ¼ of sky). Bandpass is 2-200 keV, with the main driver being the low energy extension needed to catch XRF and galactic transients. Requirement on position accuracy is 2-3 arcmin resolution, with coded mask technique. The minimum exposed area is driven by the requirement on position accuracy and number of bright GRBs. In the 20-200 keV range, requiring a 15 σ significance in 10 s integration time, in order to localize the source with at least 3' accuracy and start to slew this corresponds to a 5σ sensitivity in

1 s of $3.8 \times 10^{-7}$ erg/cm2/s or 3.5 ph/cm2/s or 10 Crab. This goal can be easily achieved with a small area (about 200 $cm^2$). Note that the reducing the FOV is not an advantage, as expected given that in 20-200 keV the CXB is not the main component of the BKG and that we are selecting very bright sources. In this case therefore the number of units is driven by other design requirements. This is not the case of the 2-20 keV range, where the diffuse CXB can be, depending on the field of view of each unit, a substantial component of the total background.. Based on GRB X-ray logN-logS BeppoSAX, 70% of GRBs have a 2-10 keV fluence > $10^{-7}$ erg/cm2/s. Requiring 10 $\sigma$ significance of 2-20 keV time integrated counts , in order to perform spectral continuum analysis, this corresponds to a required 2-20 keV 5$\sigma$ sensitivity in 1 s of ~$2.2 \times 10^{-8}$ erg/cm2/s or ~1.8 ph/cm2/s or ~500 mCrab. About 150-200 GRB per year in a 3sr are expected to be detected. For a configuration based on 4 units (each with a FOV of 0.75 sr) the minimum effective area would be 135 $cm^2$ . Increasing the area to about 400 $cm^2$ will allow sensitive spectral analysis. Different detector technologies are under consideration, in particular CdZnTe, Si strip detectors (SAGILE-like) and the evolution to Si-drift.

Finally, the option of a small omnidirectional spectrometer is being considered for two reasons. It can allow to measure the GRB spectrum (Epeak) upto 1 MeV. It can provide the GRB temporal trigger, thus allowing to optimize the WFI in the lower (X-ray) energy range.

## 5. SPACECRAFT AND LAUNCHER

- Time to to slew to 60 degrees: 60 sec (goal), 180 sec (requirement)
- 3-axis stabilized, smart pointing
- Post facto attititude reconstruction: <10”
- Rotating solar panels
- Orbit: LEO preferred for lower bkg and payload mass,
- P/L mass: 750 kg
- P/L power: 1000 W
- downlink in S and X bands upto 512 kbps and 210Mbps respectively during the passage
- VEGA launcher (upto 2200 kg)

At present we are aiming to fit the whole mission within a launch with VEGA. For background requirements, the goal is a LEO equatorial orbit. For an equatorial orbit of 600 km the total mass is 2200 kg. Assuming that 40% (conservative) is for the payload and 60% devoted to spacecraft, the cap for the payload is 880 kg. Present estimation of the payload mass, including 20% contingency, is 750 kg. A more detailed study is being carried out with Alcatel Alenia Space (Turin), based on model payload and mass distribution. Preliminary results confirm the compatibility of the mass and dimension with VEGA (Fig. 4). In addition, the analysis of momentum of inertia of the satellite demonstrates that the requirement on the fast slewing can be achieved with standard reaction wheels.

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