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SIXE (SPANISH ITALIAN X-RAY EXPERIMENT): A SUMMARY OF THE PHASE-A STUDY

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ABSTRACT. In this paper we present a summary of the SIXE (Spanish Italian X-ray Experiment) for which we successfully finished the Phase-A study under financial support of the Spanish PNIE (Plan Nacional de Investigación Espacial).

1. Foreword

The ultimate goal of the MINISAT program is the development and construction of a series of medium size and versatile platforms, which could be able to be used in different missions without the need of substantial changes in their structure.

After the construction of the first spacecraft of this series, the MINISAT-01, the Spanish National Plan for Space Research (PNIE) made a call for proposals to choose a new payload for the next mission. In response to this announcement of opportunities ten new proposals were submitted, of which five were selected in order to study their feasibility. SIXE is just one of these last five proposals.

SIXE (Spanish Italian X-ray Experiment) is the final result of a cooperative effort between Spanish Institutions - the *Institut d'Estudis Espacials de Catalunya (IEEC)*, the *Instituto Nacional de Técnica Aeroespacial (INTA)* - and the Italian Institution - *Istituto di Astrofisica Spaziale (IAS), CNR.*

SIXE has been designed to meet the following set of criteria:

a) The goal of the experiment is basically scientific. Our aim is to provide, for the first time, to Spanish astronomical community with a reliable X-ray observatory, able to study frontier topics and capable to perform high-quality and competitive science.

b) According to the selection criteria of the call for proposals mentioned above, the technical requirements of the experiment are fully compatible with the MINISAT-01 platform and only a few changes are required with respect to the initial design of the spacecraft. Major changes have been, thus, completely discarted.

c) According to the spirit of a mission based on a small spacecraft, the experiment has been designed to fulfill the scientific goals in a short time and with a small economic budget.

d) A major fraction of the design and building processes can be achieved in Spain and Italy.

The result of the present study is that not only the experiment is feasible from the technological point of view, within the requirements imposed by the MINISAT platform, but also that the foreseeable results can be qualified as being of the maximum scientific interest.

2. Executive Summary

During the last years, X-ray Astronomy has experienced a large development and has significantly contributed to a better understanding of our Universe. Nevertheless, and besides the success of X-ray Astronomy, there exist still today large areas where we lack a profound knowledge of the detailed physical mechanisms responsible for the emission of X-rays. These areas of course require new methods of research and, consequently, new instruments. One of these areas is, for sure, the study of the temporal variability of X-ray sources, especially those which radiate in the region of high energy, namely the $3 \leq E(keV) \leq 50$ band.

This band is especially interesting because some of the most interesting X-ray sources emit a sizeable fraction of their energy in this spectral region, besides being variable sources. The underlying physical mechanism powering most of these sources is, roughly speaking, accretion onto a compact object (white dwarfs, neutron stars or black holes). Moreover, most of the information we can retrieve from these systems is done via the detailed analysis of their variability (QPOs, pulsations, bursts,...) and of their spectral features. To this point, it is important to remark that the variability on time scales of the order of a millisecond and even less can provide us with valuable information about the behavior of matter in the surface of a neutron star or close to the horizon of a black hole. Accordingly, SIXE has been designed as an effective tool able to follow such kind of temporal variability as well as simultaneously perform medium resolution spectral analysis.

Moreover, **one of the purposes of SIXE consists in eliminating one of the major drawbacks of major missions, as it is the impossibility of devoting a large fraction of the observing time to continuous monitoring of a single source, since most of these facilities have a significant observing pressure and, besides, some times there are conflicts between the different experiments on board**. Nonetheless there are several astronomical problems that can be only solved through a continuous monitoring of the sources or, at least, through long observing runs. Such large observing times can only be achieved through a small mission, as it is the case of a minisatellite, in which apparently major drawbacks, such as its small size and cost, can be transformed into advantages. As an example, RXTE on average provides only 50 Ks of effective observing time to any source. SIXE could provide almost 200 times more coverage. Obviously, this can only be done if a small number of sources is selected in a very careful way. To be precise, **SIXE could provide the unique possibility of observing phenomena with time scales within the range 10^{-4} to 10^{7} seconds, something totally unprecedented.**

In the next paragraphs we mention just a few examples of which kind of science can be done with SIXE, through some simulations. The reader will find a thorough description of scientific goals in Giovannelli et al. (1999a,b), and in the references therein. The most important topics on which SIXE could cast some light are the following:

1) Analysis of the time variability on time scales of a few tenths of millisecond of galactic sources in several evolutionary stages. This could provide valuable information about the behavior of matter in the neighborhood of the surface of a neutron star or the neighborhood of the event horizon of a black hole.

2) Very recently it has been discovered that some of the X-ray pulsars which have an accretion disk around them present phases during which the spin velocity increases followed by a sudden change to a phase in which the pulsar brakes down. Until now it has been completely impossible to resolve the transition with high temporal accuracy. SIXE could do that in a few cases.

3) The current theories predict that in some clusters of galaxies we should observe an excess of non-thermal emission, which could provide information about the inter galactic magnetic field. Provided its large integration times, SIXE could measure this effect.

The detector to be used in a mission like SIXE is naturally chosen from the above mentioned scientific issues, namely the conditions of stability and sensibility to high energy photons. The only detectors that can simultaneously accomplish both requirements are the class of multiwire gas proportional counters. Regarding the need to achieve a high time resolution during long runs (of the order of a tenth of a millisecond during a few years) the best solution is to use an on board GPS receiver. It is important to remark that thanks to the modifications introduced during this phase, SIXE has a large effective area in the high energy region, comparable to that of more complex missions, which converts SIXE in a highly competitive instrument when studying phenomena which show variability. In the enclosed table the general characteristics of the detector are shown. The total mass is of 103.1 kg and the required power is of 58.5 W (in these figures the optical camera has been included).

The proposed configuration has four X-ray detectors with an effective area of about 500 cm^2 each one. The optical axis is parallel to the plane of the solar panels. Therefore, we discard a solution with fully revolving solar panels. This condition stems from the inherent costs which are unavoidable with a reasonable budget, and implies that SIXE will not be able, generally speaking, to deal with targets of opportunity. However, SIXE will have a small freedom to temporarily suspend the planned program in order to observe serendipitous phenomena of high scientific interest.

In order to deal with the variability of faint sources or to detect small fluctuations in the X-ray flux, it is of the maximum importance to determine in real time and with the highest accuracy the internal noise of the detectors. This point is so important to us that we have decided to devote two detectors to measure the internal noise. For this reason, the detectors have been placed into two banks with an offset angle of 3.5^o. This procedure allows the instrument to point simultaneously to the source and to the background. In order to maintain a sustained equivalence between both pairs of detectors, the banks will be regularly switched. Nevertheless the ultimate configuration could be changed during phase B if new arguments relevant to our decision appear.

Under no circumstances major changes in the MINISAT-01 platform are required and only small modifications are planned. SIXE has been designed, according to the call of proposals, to be fully compliant with the basic characteristics of the MINISAT program and it is only necessary to minutely exhaust the already attainable possibilities, mainly in attitude control, since we require a precision of 0.15^o.

Keeping in mind the ultimate challenge of improving the scientific output of SIXE without increasing too much its cost, we have considered the possibility of substituting the optical sensor of the instrument (but not that of the platform) by an optical camera, which could work simultaneously as a sensor and as an optical monitor with two or more photometric filters. **Such a solution, which is technically feasible, will make of SIXE a leading and unique multifrequency instrument**. The feasibility study has been performed by the LAEFF and will be presented in a near future. Therefore, in this document only a summary of such study is presented.

The mission has been conceived for a minimum duration of 3 years. The selected orbit should be circular and with a height between 550 and 600 km. The preferred inclination is between 20^o and 25^o. These values have been derived from a compromise between the need of minimizing the background radiation, the situation of the Maspalomas ground station, which has been selected as the primary ground station, and the coverage of the appropriate sky areas during adequate observing times, according with the spirit of the mission. The advantage of these orbits is that they are accessible to small launchers and that are very similar to the orbit selected for the MINISAT-01 spacecraft, thus leading to an optimal use of the actual ground station structure.

SIXE will observe very bright sources and, therefore, a large amount of data will be generated. The number of daily contacts between Maspalomas and the spacecraft will be of the order of 6 with a total amount of time of roughly 50 minutes (the reader will find more precise data in table 5.7 of the Phase-A report, not completely reproduced in this paper). Therefore, it seems adequate to have an additional ground station. The Italian partners of SIXE have requested and obtained the use of the Malindi ground station for such a purpose. Should this secondary ground station be available the total amount of contact time would be of more than 100 daily minutes and the number of useful contacts would be doubled. There are alternative solutions, in the case that ASI will decide to not participate to this experiment. In the worst of the cases, SIXE could appeal to its ability of on board processing or, even, the observations could be limited to slightly dimmer sources without being these a major disadvantage.

The total budget is estimated to be 4.019 KECUS. In this estimate we include the costs of design, development, checking and quality control of the instrument, its integration and qualification, the implementation of the ground and user segment, the operational phase and the management costs from the design phase to the operational phase.

It is important to point out here that SIXE is an instrument designed to be completely functional from the very beginning and that it is a highly qualified instrument able to do high quality science. In other words, with such an instrument the Spanish astronomical community will own a leading instrument in the field of high energy astronomy. Besides, thanks to a reasonable number of contacts with different Spanish companies, we can assure that the Spanish industrial sector can develop most parts of the instrument. Of course, Italian industries as well can develop most of the experiment.

3. Technical description

The Spanish Italian X-ray Experiment (SIXE) was presented in response to the call for ideas for the Spanish satellite MINISAT-02. According to the guidelines of this call for ideas, the design of SIXE must be compatible with the performance of MINISAT, without introducing essential changes in the platform with respect to MINISAT-01. The compatibility of the experiment with a minisatellite platform imposes restrictions on the mass, power and dimensions of the payload, that prevent high-resolution imaging or spectroscopic studies. High-resolution timing of the X-ray flux from celestial sources is a natural field of application of a minisatellite payload devoted to the hard X-ray band. Keeping these constraints in mind, we present here the scientific requirements deduced from the scientific objectives of the mission, the implications on the type of X-ray detector to be selected, and the detector's conceptual design.

3.1. Scientific requirements

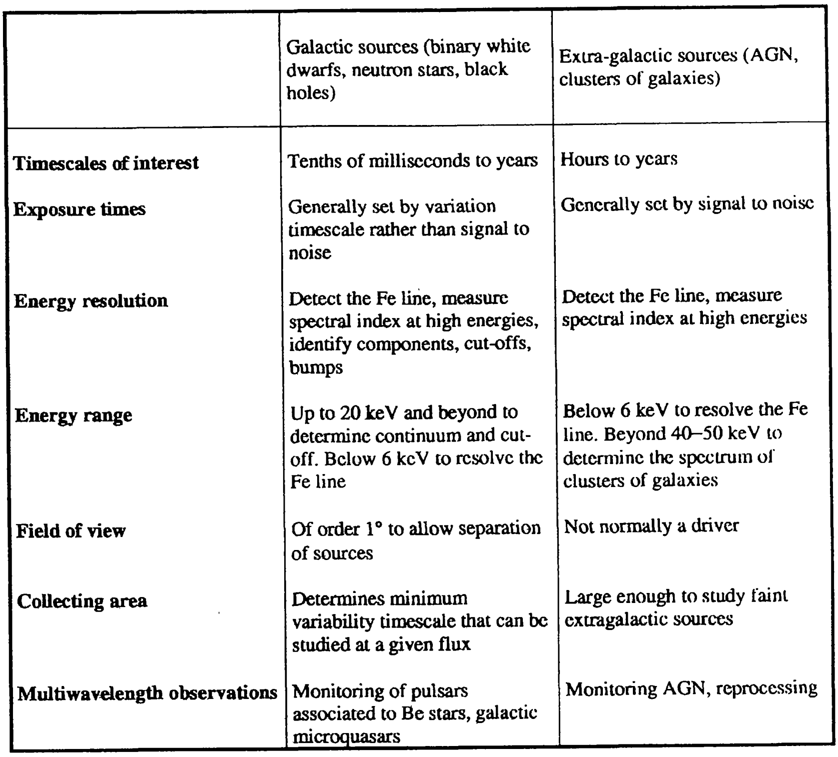
SIXE will be focused mostly on sources related with accreting compact objects, both of stellar size (X-ray binaries, cataclismic variables, black hole candidates, etc) and of galactic size (AGN, Seyfert galaxies, etc). These sources are mostly variable in nature, but all of them share some characteristics which demand special features of the instruments used in their study. Common emission mechanisms are in action in these objects, where the energy input is usually dominated by the conversion of kinetic energy of fast accreting material into hard X-rays via processes such as bremsstrahlung radiation of fast electrons, inverse Compton upscattering of softer radiation, direct Comptonization and reflection of initial X-rays. Besides, previous missions have shown that the most valuable information about these sources is gained through the study of their rich variability signatures.

The fulfillment of the scientific objectives of SIXE demands a series of scientific requirements on the mission (payload, mission analysis, platform, ground segment). We analyze here the requirements on the energy range to study, timing resolution and accuracy, clock and detector stability, sensitivity, field of view of the detector and spectral resolution. In Figure 1 (Table 1), a comparison of the constraints set by different observational requirements in some areas of X-ray astronomy is given.

To summarize, the requirements on SIXE can be quantified as follows:

Energy range: 3-50 keV

Low end: observation of the Fe line, observation of non-magnetic systems at low mass accretion rates. High end: observation of clusters of galaxies, cut-off in the spectrum of pulsars, presence and properties of the Compton bump in AGN's.



	Galactic sources (binary white dwarfs, neutron stars, black holes)	Extra-galactic sources (AGN, clusters of galaxies)
Timescales of interest	Tenths of milliseconds to years	Hours to years
Exposure times	Generally set by variation timescale rather than signal to noise	Generally set by signal to noise
Energy resolution	Detect the Fe line, measure spectral index at high energies, identify components, cut-offs, bumps	Detect the Fe line, measure spectral index at high energies
Energy range	Up to 20 keV and beyond to determine continuum and cut-off. Below 6 keV to resolve the Fe line	Below 6 keV to resolve the Fe line. Beyond 40–50 keV to determine the spectrum of clusters of galaxies
Field of view	Of order 1° to allow separation of sources	Not normally a driver
Collecting area	Determines minimum variability timescale that can be studied at a given flux	Large enough to study faint extragalactic sources
Multiwavelength observations	Monitoring of pulsars associated to Be stars, galactic microquasars	Monitoring AGN, reprocessing

Fig. 1. Table 1: Comparison of requirements in two areas of X-ray astronomy.

Timing resolution and accuracy: $< 100\mu s$

Dynamic time scale of neutron stars, non-radial oscillations of neutron stars, periods of the innermost stable orbits inside accretion disks around black holes.

Detector stability: $10^{-4} - 10^{7}$ s

Long-term observations: Emission from magnetic and non-magnetic systems, pulsars associated to Be stars, non-pulsating X-ray sources.

Sensitivity: $\sim 10^{-11}$ **erg** $cm^{-2}s^{-1}$ **(2-10 keV),** $\leq 10^{-6}$ **photon** $cm^{-2}s^{-1}keV^{-1}$ **(50 keV)**

Observation of Active Galactic Nuclei, and clusters of galaxies.

Field of view: $1^o \times 1^o$

Avoid confusion of sources (there are $\sim$ 300 sources separated by more than 1°.

Energy resolution: $\sim$ 1 keV at 6.7 keV, $\leq$ 2 keV at $E > 20$ keV

Detection of the Fe line at $\sim$ 6.7 keV, measurement of the spectral index at $E > 20$ keV.

The timing accuracy and detector stability requirements impose the additional restriction that the detector clock must be stable on long periods ($\frac{10 \mu s}{100}$ days $\approx 10^{-12}$), which can only be attained with **periodic calibrations** of the on-board clock. For a calibration rate of $0.1 s^{-1}$, a **clock stability** better than 10^{-6} is required. Detector stability is needed to do accurately a long term monitoring of flux variations of AGNs and galactic sources down to small amplitude changes (**response stability**), and to follow the long term variability of spectral features: line shifts, spectral index variations, etc (**spectral calibration stability**).

The required sensitivity can only be achieved in a minisatellite payload with a combination of a **large sensitive area** (within the dimensions imposed by the platform and, specially, by the launcher system), and accurate **background reduction techniques**.

For an adequate timing study of the X-ray sources, it is necessary to determine the **background in real time**. Because the background can be assumed to change smoothly with time, integration times of order 100 s for the background determination will be in order.

3.2. Detector class

Several types of X-ray detectors have been considered for the SIXE instrument (proportional counters, solid-state, scintillators, microcalorimeters). As general rule, X-ray detectors needing focusing artifacts cannot be considered for a minisatellite. Furthermore, optical focusing of hard X-rays has not been achieved up to now, and the first astronomical mission that plans to focus X-rays above 10 keV (NGXO) is a high cost project (about 2 orders of magnitude more expensive than SIXE). Also, given the requirement of a large sensitive area of the detector, high-resolution microcalorimeters are ruled out as an alternative.

Solid-state detectors suffer from the same drawback as microcalorimeters (low sensitive area) and, in addition, they cannot give a long term stability due to the susceptibility of these devices to performance degradation from radiation induced damage.

Proportional counters have been extensively used in previous and present X-ray astronomical missions, showing a good performance and stability. They can provide good timing accuracy, long-term stability, good energy resolution and high quantum efficiency up to 50-70 KeV (e.g. Ubertini 1987).

Scintillators are usually an alternative to proportional counters when the high end of the energy range goes much beyond 50 keV. Conversely, they do not give better performance than proportional counters below 20 keV. Furthermore, the complexity of design is larger, and the need of including photomultiplier tubes can make them marginally compatible with a minisatellite mission.

Consequently, the preferred option to implement SIXE will be the use of proportional counters. The wide experience of the astronomical community with this kind of detectors (including the experience of some members of the proposed consortium in the design and development of ballon-borne and space-borne proportional counters) will allow also to minimize the technical risks. This is an important point, because the purpose of SIXE is not to do a technological demonstration, but to perform a scientific experiment.

3.3. Experiment conceptual design

As a consequence of the considerations given in the previous section, a proportional counter approach has been selected for SIXE. The characteristics of the proportional counter have been chosen so that they fulfill the scientific requirements summarized in Par. 4.1.

The SIXE instrument will consist of four identical gas filled multicell proportional counters, collimated and mounted on two banks with their view axis slightly off, so that two of the proportional counters receive incoming photons from the X-ray source, while the other two are looking to the blank sky. In this way, **background determination in real time** will be achieved. This background monitoring philosophy will avoid the systematic errors in background determination which affect other missions, limiting their sensitivity and their ability to measure small amplitude variations in flux from the cosmic X-ray sources. The **field of view** of $\sim 1^o \times 1^o$ will be provided by a mechanical collimator on top of each one of the proportional counter windows.

The **energy range** of the instrument will be defined by the quantum efficiency of the detection gas mixture and the transmission curve of the window. A thin plastic window with appropriate grid for structural reliability can provide a large transmission of X-rays above 3 keV, with a rapidly decreasing transmission fraction for lower energies. A gas mixture based on an inert gas (for instance Xe) at high pressure will give a good detection efficiency up to 50-70 keV. Addition of a small fraction of Ar will improve the mobility of ions and, thus, the timing capabilities of the proportional counter. An organic polymer (like isobutane) can be used as a quenching gas.

The **energy resolution** achievable with such a proportional counter is within the scientific requirements. At high energies (above 35 keV) the spectral resolution can be improved with the use of the escape gate technique.

Timing resolution and accuracy of the order of $20\mu s$ can be achieved with state-of-the-art proportional counters, but the actual figures will depend appreciably on the design of the front-end electronics.

2002MmSAI..73..402G

Commercially available TCXO give a **clock stability** compliant with the scientific requirements, provided that a procedure for periodic calibrations of the on-board clock is adopted. **Periodic calibrations** of the clock can be obtained with the aid of a GPS receiver on board the minisatellite.

Background reduction will be achieved by application of **anticoincidence techniques**. In order to be able to perform anticoincidence studies, each proportional counter will be of the multicell type. Two types of anticoincidence events are envisaged, those due to wall penetration by high-energy particles will excite the lateral cells of the proportional counter, while the energetic particles entering the detector volume through the window, as well as gamma rays, will excite more than one detection cell. In both cases, the event will be flagged as a probable background event.

4. The proposed experiment for the MINISAT-02

The global experiment consists of:

i) 4 identical modules of X-ray multiwire proportional counters: $\sim$ 800 cm^2, high pressure xenon filled, berillium window, honeycomb mechanical collimator, electronic box;

ii) an optical monitor of the class of OMC-INTEGRAL (Gimenez, 1999) in order to perform also simultaneously optical two-colour photometry of the X-ray targets.

The configuration has been chosen for a PEGASUS envelope. Figure 2 shows: the sketch of the payload inside the Pegasus (upper left panel), SIXE with its four modules and the optical monitor OMC-type in the center (upper right panel), configuration of SIXE and OMC pointing axes (lower left panel: the offset of SIXE detectors has been exaggerated for clarity), distribution of SIXE (FWHM) and OMC FOV's and SIXE visible regions (lower right panel).

5. Calculated performance of the detector

Table 1, in Par. 2 summarizes the main parameters of the performance of the detector, estimated from its design.

5.1. Sensitivity

Continuum and line sensitivity of SIXE have been calculated by using the detector efficiency and a model of background. Such a model has been constructed from RXTE and GINGA background measurements, normalized to take into account the differences in FOV, energy, external area and detector volume. Three components of the background have been considered (aperture background, cosmic rays and trapped protons, and activated background) and their contribution has been normalized accordingly. Figure 5 shows the line and continuum 3σ-sensitivity in 10^5 s, together with the spectra of MCG-6-30-15 (dot-dashed line) and Coma cluster (dashed line).

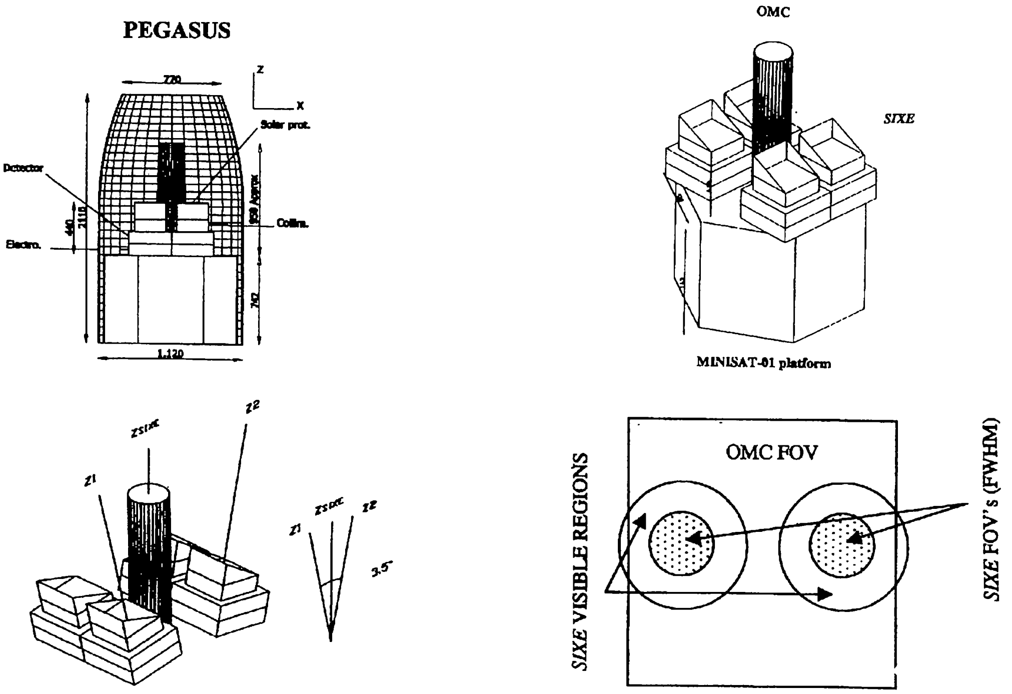


Fig. 2. The sketch of the payload inside the Pegasus (upper left panel), SIXE with its four modules and the optical monitor OMC-type in the center (upper right panel), configuration of SIXE and OMC pointing axes (lower left panel: the offset of SIXE detectors has been exaggerated for clarity), distribution of SIXE (FWHM) and OMC FOV's and SIXE visible regions (lower right panel).

Energy range	3-50 keV
On-source sensitive area	$\cong$1000 cm^2
Off-source sensitive area	$\cong$1000 cm^2
Integrated detection efficiency	82% (3-50 keV), 72% (3-70 keV)
Continuum sensitivity (at 50 keV)	3×10^{-6} ph·cm^{-2}·s^{-1}·keV^{-1} (3σ, 10^5 s)
Line sensitivity (6.7 keV, narrow line 1 keV)	10^{-5} ph·cm^{-2}·s^{-1} (3σ, 10^5 s)
Saturation rate	~50,000 c/s
FOV	~1° circular (FWHM)
Collimator transparency	88%
Temporal resolution	1 μs
Timing accuracy	better than 2 μs (absolute)
Spectral resolution (FWHM)	~5% (E>35 keV), ~$46/\sqrt{E}$ % (E<35 keV)
Dead time	16-20 μs
Residual instrumental background	63 c/s

Fig. 3. Table 2: Estimated performance of the detector.

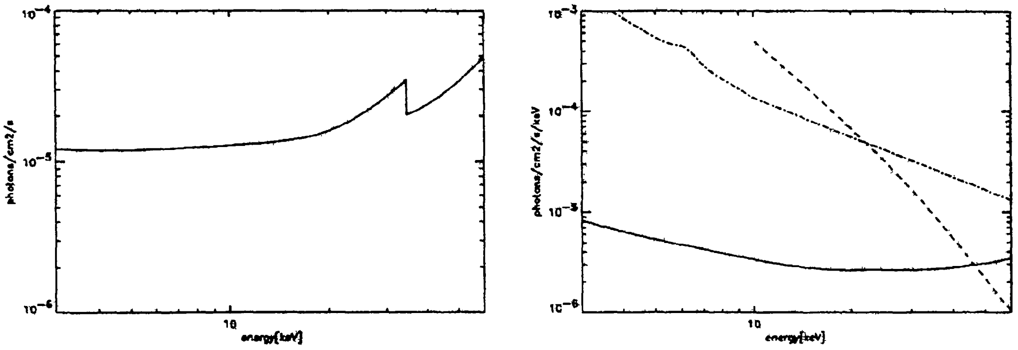


Fig. 4. 3σ sensitivity of SIXE in 10^5 s, assuming the effective area of 2 modules ($\sim 1000\ cm^2$). Left panel: narrow line sensitivity; right panel: continuum sensitivity (solid line), the continuum flux of MCG-6-30-15 (dot-dashed line) and Coma cluster (dashed line)

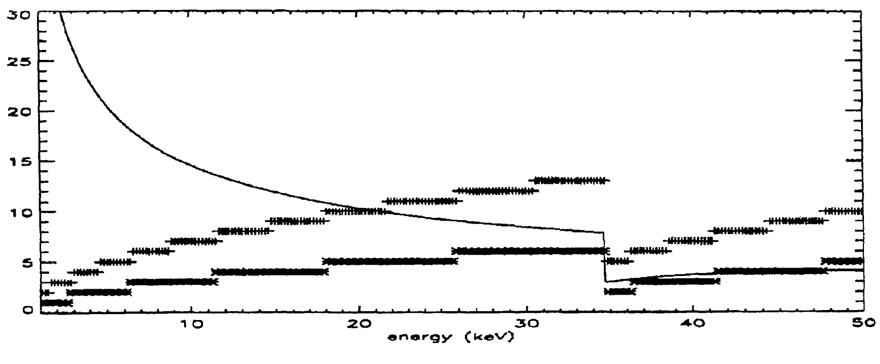


Fig. 5. Spectral resolution of the detector in percent (solid line), and the ratio of the size of the energy bins given by the PHA to the energy resolution at the center of the bin, for 128 (*) and 256 (+) energy levels.

5.2. Spectral resolution

Figure 6 shows the spectral resolution of the detector modules, as function of the X-ray photon energy, together with the size of the energy bins resulting from the number of PHA channels for 128 and 256 energy levels. Both numbers of channels are adequate to take advantage of the spectral capabilities of the detector gas mixture. The spectral resolution has been crudely estimates from the experience gained with the POKER detectors (Bazzano et al., 1983).

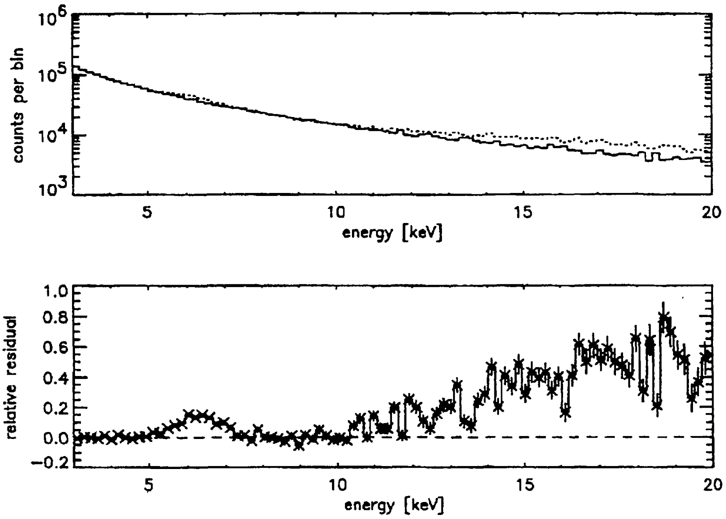


Fig. 6. Top panel: comparison of simulations of SIXE observations of a pure power-law (solid line) and a power-law plus reflected component (dashed line) spectra for MCG-6-30-15.. Bottom panel: residuals of the power-law substracted spectra of MCG-6-30-15 clearly showing the iron and Compton bump components. Error bars are indicated. Observation time is 10 days.

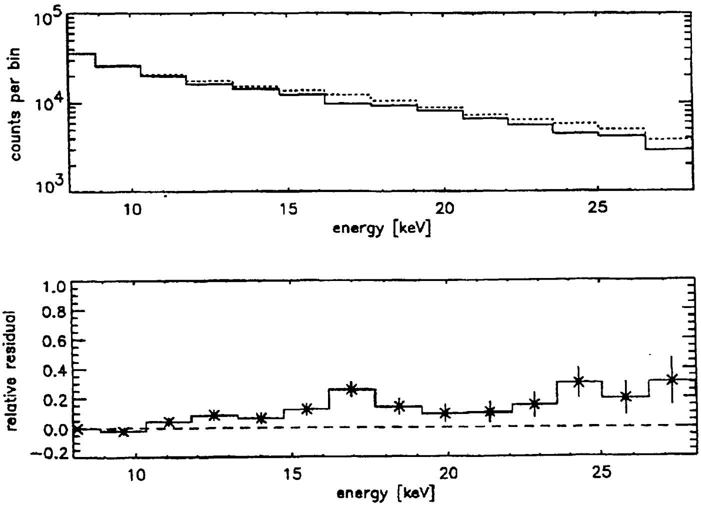


Fig. 7. Top panel: comparison of simulations of SIXE observations of two spectral states of MCG-6-30-15. Bottom panel: residuals of the spectra observed for the two states indicating a change in the Compton bump component. Error bars are indicated. Observation time is 2 days.

5.3. Simulated observations

Several simulations of observations of X-ray sources have been performed using the characteristics of the SIXE detector and the background expected at SIXE's orbit. Two scientific cases have been selected in order to check the consistency of the performance estimated from the detector design with that needed to achieve the scientific objectives of the mission.

5.3.1. Seyfert 1 galaxies

The X-ray spectrum of typical Seyfert 1 galaxies is known to be the combination of three main components: a power-law continuum extending to low energies, a hard bump which appears at $E = 10$ KeV, and the characteristic iron line located at $E = 6.4$ KeV. The standard model used to explain these properties assume that the power-law component is the primordial emission of the galaxy, while the other two (iron line and Compton bump) would be produced by the reflection of the power-law continuum by surrounding material. The only way to finally accept or reject the standard picture will be through the study of the variability of the reflected components. With this purpose, some observations have been carried out by the RXTE (Lee et al., 1998). However, the longer observation time available for SIXE will be necessary to finally shed light into the problem.

One of the best candidate to perform such observations is the nearby galaxy MCG-6-30-15. Based on the average spectrum of this galaxy and the typical variability measured up to now for the reflected components, we have simulated observations with SIXE of two typical spectral states in order to determine its capability to monitor this object (Figures 7 and 8). It has been found that with an observation time of 5 hours it will be possible to clearly identify both the Compton bump and the iron line in the spectrum. Longer observation times (2 days) will allow to determine in which spectral state is the galaxy (Figure 7). These results combined with the exposure times offered by SIXE mean that it will be possible for the first time to obtain a complete sampling of the spectral variability of a Seyfert 1 in scales in the range 2 days-months.

5.3.2. Clusters of galaxies

A non-thermal hard X-ray emission excess is predicted in galaxy clusters associated to a radio halo due to the Compton scattering of the Cosmic Microwave Background photons by relativistic electrons. If present, the excess should appear at energies $E > 15$ KeV as an additional component with a spectral index greater than 2.34 above the already detected thermal bremsstrahlung emission. Up to now several attempts have been made to observe this excess in Coma cluster ($d = 138$ Mpc) with reported upper limits for the emission in all but one case (Rephaeli et al., 1994). In observations made by Beppo-SAX, a marginal excess of 2×10^{-11} erg cm^{-2} s^{-1} in the range 20-80 KeV was detected (Fusco-Femiano et al., 1999). However, due to the poor significance of the detection, a detailde analysis of the spectral shape of the excess was not possible and hence a confirmation of the model is still not possible.

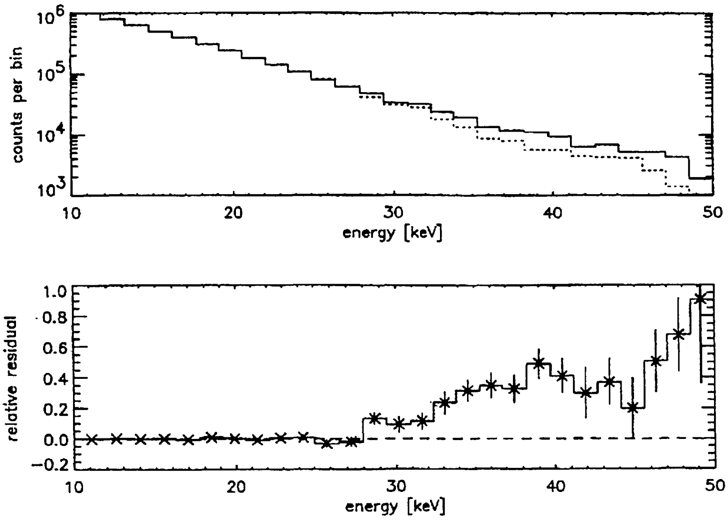
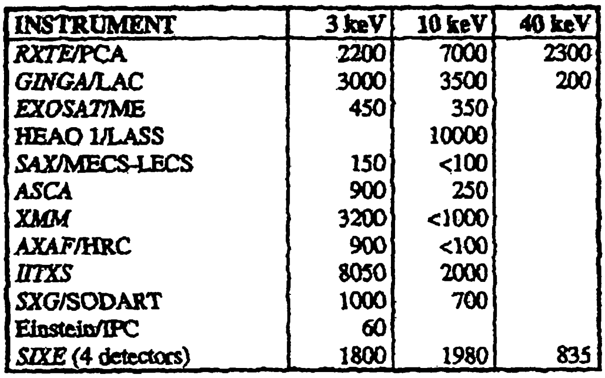


Fig. 8. Top panel: comparison of the simulated X-ray spectrum of the Coma cluster with and without the non-thermal component (solid and dashed lines, respectively). Bottom panel: residuals of the subtraction of the models compared with the error-bars of the observations. The spectra correspond to a 30 days observations.

Due to its good response at high energies, high effective area and long exposure times, SIXE will be particularly suited to confirm or reject the presence of the Compton component in the Coma cluster. Assuming a one-month observation and taking into account the time lost due to eclipses and other effects, the total exposure offered by SIXE would be $1.7 \times 10^9\ s \times cm^2$, to be compared with the $7.3 \times 10^7\ s \times cm^2$ attained by Beppo-SAX, and hence a much higher sensitivity would be possible. We have carried out a simulation of a one-month observation of the cluster with SIXE assuming the already measured fluxes and spectral shape of the thermal component, and adding a non-thermal component with the fluxes measured by Beppo-SAX and the spectral index expected from theory. Figure 8 shows the comparison of the simulated spectra with and without the non-thermal component (solid and dashed lines, respectively). The excess appears clearly above 30 KeV and it can be seen that around 15 significant points of the excess (0.7 KeV resolution) would be obtained that would allow its accurate spectral fitting.

5.3.3. Fast timing of cosmic X-ray sources

As it has been mentioned, millisecond time-scales are naturally present in neutron stars and black holes, since they correspond to the dynamical time-scales near the object. Fast timing of cosmic X-ray sources demands high counting rates in order to obtain statistically significant detections in a reasonable short interval of time. Since the strenght



INSTRUMENT	**3 keV**	**10 keV**	**40 keV**
RXTE/PCA	2200	7000	2300
GINGA/LAC	3000	3500	200
EXOSAT/ME	450	350	
HEAO 1/LASS		10000	
SAX/MECS-LECS	150	<100	
ASCA	900	250	
XMM	3200	<1000	
AXAF/HRC	900	<100	
IITXS	8050	2000	
SXG/SODART	1000	700	
Einstein/IPC	60		
SIXE (4 detectors)	1800	1980	835

Fig. 9. Effective areas of different instruments at 3, 10, and 40 KeV, in cm^2.

of the QPOs increases with the energy, it is necessary to have good sensitivities at high energy, for which reason new missions like AXAF or XMM are useless for studying these phenomena. In Table 4 it is presented a comparison between the effective areas of several missions and that of SIXE, at three different energies.

We have made a simulation of the detection of X-rays from a number of galactic sources, taking into account their spectral properties and the estimated performance of SIXE. The results are shown in Table 5, where it can be seen that the predicted event rate is fairly large and, in most cases, larger than the expected residual background.

6. Conclusions

The phase-A study of SIXE has clearly demonstrated its viability. In spite of its reduced size, weight and cost, SIXE is an important experiment that can provide new results in astrophysics in the study of flux and spectral variability of selected X-ray cosmic sources, thanks to its philosophy of use. Indeed, with few selected targets, representative of homogeneous class of cosmic sources SIXE can obtain the highest performance obtainable with the present and near-future even bigger X-ray experiments. The fundamental characteristic of SIXE: Effective Area x Observing Time is $\sim 10^{10}\ cm^2 \times s$, which is at least one order of magnitude better than those of all the other experiments.

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Source	Counts/s/500 cm^2	Type of source
4U 1728-16 GX9+9	539-564	Low-Mass X-ray Binary (LMXB)
4U 1735-44	318	LMXB
4U 1813-14 GX17+2	1007	LMXB
4U 1837+0.4 Ser X-1	406-504	LMXB
4U 2142+38 Cyg X-2	776-1126	LMXB
4U 1728-33 GX354-0	112	Globular cluster source
4U 1820-30	580-618	Globular cluster source
4U 1642-45 GX340+0	659	Optically unidentified object
4U 1702-36 GX349+2	1146	Optically unidentified object
4U 1744-26 GX3+1	477	Optically unidentified object
4U 1708-20 GX9+1	956	Optically unidentified object
4U 1758-25 GX5-1	1822	
4U 1811-17	490	
4U 1516-56 Cir X-1	30	High-Mass X-ray Binary (HMXB)
4U 1700-37	335	HMXB
4U 1956+35 Cyg X-1	700	HMXB
4U 1656+35 Her X-1	267-346	Intermediate mass
4U 1617-15 Sco X-1	7692-8670	LMXB
4U 1626-67	59	LMXB
4U 1636-53	127-233	LMXB
4U 1659-48 GX339-4	1246	LMXB
4U 1705-44	1560	LMXB

Fig. 10. SIXE's estimated event rate for a set of galactic X-ray sources. The known spectrum of these sources has been taken into account, together with estimated performance of SIXE.

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DISCUSSION

W. ZHANG: When is the expected launch date for SIXE?

C.D. LA PADULA: In Italy it has been not funded yet... The phase-A study has been supported by the Spanish PNIE (Plan Nacional de Investigación Espacial). Spanish community is strongly interested in carrying the mission going on. At the moment we have not a possible date for launching SIXE. However, after receiving the funds, SIXE will fly within three years.