SIXE (Spanish Italian X-ray Experiment): a Payload for the Spanish MINISAT-02 Satellites

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ABSTRACT. SIXE (Spanish Italian X-ray Experiment) is an X-ray payload with geometric area of ~ 3200 cm², formed by four identical gas-filled Multiwire Proportional Counters devoted for a long term spectroscopy of selected X-ray sources in the energy range ~ 3 -60 KeV. The spectral resolution of $\sim 5\%$ for $E > 35$ KeV and $\Delta E/E = 60/E^{1/2}$ for $E < 35$ KeV, the continuum sensitivity (3σ in 10^5 s) of $\sim 3 \cdot 10^{-6}$ ph/cm² · KeV, the line detection sensitivity (3σ in 10^5 s) of $\sim 3.5 \cdot 10^{-6}$ ph/cm² · KeV, the time accuracy of 0.1 ms, the experiment weight of ~ 90 Kg, the full dimensions including the electronic box of $\sim 660 \times 660 \times 400$ mm³, the power budget of ~ 40 W, the telemetry rate of ≤ 100 Kbit/s and on-board memory of ~ 2 Gbytes makes this experiment fully compatible for a minisatellite mission, such as for instance the spanish MINISAT 02. The main scientific goal of SIXE is the study of the short and long term spectral and intensity variabilities of few selected extragalactic and galactic X-ray sources, such as quasars, Seyfert galaxies, high and low mass X-ray binaries, etc. Since the sensitivity and the energy resolution of SIXE are rather good, it is possible to study the behaviour of the eventual Fe lines with respect to the continuum emission. This possibility of SIXE is unique for the present generation of X-ray experiments, since no one is dedicated to long term monitoring of X-ray sources.

1. Introduction

SIXE (Spanish Italian X-ray Experiment) has been already submitted to Spanish PNIE (Plan Nacional de Investigación Espacial) by Drs Franco Giovannelli (IAS: Italian Co-P.I.) and Jordi Isern (IEEC: Spanish Co-P.I.) as answer to a call for proposals for scientific space missions to be flown on board the Spanish MINISAT-02. PNIE, after a scientific selection as well as the technical compatibility with the MINISAT-02 platform, approved the proposal on April 3, 1997 for the phase-A study. SIXE received financial support from the PNIE" in October 1997. Phase A study will end in October 1998.

2. Summary

The project SIXE is based on a new philosophy for the use of a space experiment and permits to join the Italian know-how on the detection of X-ray radiation and the preparation of scientific space payloads with the technological and managerial support of the INTA, as well as the recently born space capabilities developed at IEEC. SIXE is devoted to long-term observations of few selected X-ray sources, representants of homogeneous classes of cosmic sources, in order to study intensity and spectral variabilities of the X-ray emission and the presence of eventual Fe lines with respect to the continuum.

- The time resolution is of the order of ~ 0.1 msec,
- the spectral band of ~ 3 -60 keV of the multiwire proportional chambers (MWPC), with total active surface of ~ 3200 cm² (effective area of order of 2000 cm²; sensitivity ($E > 15$ keV) i.e. 3σ in 100 ks of $\sim 3 \cdot 10^{-6}$ ph/s·cm²,
- a mechanical honeycomb collimator of FWHM $\sim 1^\circ.2$ - 2° ,
- the philosophy of the mission is: long term measurements ($\sim 10^{10}$ cm² s) of selected X-ray sources,
- the possibility of having on board an optical monitor (in two colours: B and V),
- the simplicity, its low cost and the possibility of a fast realization, thanks to the use of updated, very well known (by our group) technologies, assure to SIXE to have a real high degree of interest even in the very competitive world of X-ray astronomy. Indeed, several, among the most famous X-ray astronomers, namely G. Vedrenne (CNES), J. Beall (St. John College) and K. Wood and G. Gursky (NRL) have expressed a favorable opinion on the project SIXE.

We have asked the Scientific Selection Committee of ASI to produce quickly an evaluation of this proposal (phase-B of SIXE) in order to be able to comply with the schedule of the Spanish MINISAT-02 project, which has the dead line, for the phase-A study, at the end of October, 1998.

After that, the final selection of the MINISAT-02 scientific payload will be made. The phase-B should start roughly at the end of 1998 in order to be completed at the end of 1999.

If the phase-A of SIXE will give positive answers (we can assure this, being our study of phase-A, at the moment, almost completed), the possibility that SIXE will be selected as the actual main scientific payload for the MINISAT-02 is very high, since, among other experiments under phase-A, it is the only "big" payload able to constitute the "main payload", especially if associated to the Optical Monitor.

The phases C and D may be concluded in the following 3-4 years and the launch may be programmed for 2002-2003.

3. Scientific Case

The basic idea of SIXE is very simple: we will select a limited number of high energy cosmic sources representatives of homogeneous classes of objects and we will observe them for a long time (the order of one or more months) in order to study in details their behaviour, with the possibility of a high time resolution (up to ~ 0.1 msec).

Since the mean-life time of the mission is of $\sim 2-3$ years, a number of sources not larger than $\sim 15-25$ should be cleverly selected, taking into account not only their nature, but also the constraints of the minisatellite itself.

In the following we will discuss some classes of sources, from which the targets will be selected.

3.1. Hard X-ray Emission from Clusters of Galaxies (CGs)

In the clusters showing an extended radio halo, a non-thermal emission of hard X-rays (HXR), due to Compton diffusion of relativistic electrons in the microwave cosmic background (CMB), is expected. The radio halos in clusters extend in a scale of the order of one Mpc; probably they are associated with the compenetration of clusters-subclusters.

The coordinated detection of radio and HXR radiation directly provide some of the basic properties of the intercluster (IC) magnetic field and cosmic rays electrons.

The importance of these determinations is due to the fact that they are essentially based only on observable quantities, while if only radio measurements are used, it is necessary to make additional theoretical assumptions in order to determine the magnetic field B and the electron density.

Many observations of CGs have been performed in the range 1-10 keV, while only few measurements are available in the harder X-ray region, by which it has been possible to obtain only upper limits to the hard X-ray emission. The detection of HXR emission can provide additional information on the intercluster medium because of a totally different emission mechanism.

The knowledge of the magnetic field properties in CGs is very important for the research on the intercluster plasmas.

Sixe has the necessary requirements for measuring the HXR emission from CGs. Indeed:

- i) its sensitivity is of $\sim 3 \cdot 10^{-6}$ ph/s $\cdot$ cm² for ($E > 15$ keV) i.e. 3 sigma in 100 ksec,
- ii) FOV of ~ 1.2 deg x 1.2 deg (relatively small for the CGs) can prevent the confusion of sources during the measurements,
- iii) the actual possibility of having on board an optical monitor, the same that was studied for the INTEGRAL-ESA mission, with the F.O.V. ~ 2 deg (thanks to the collaboration of the OMC-INTEGRAL group leadered by Dr Alvaro Gimenez (LAEFF-INTA), may provide simultaneous, precious optical information; but, even more

important

iv) its philosophy: long-term measurements of selected objects. In the case of CGs, these long-term measurements may provide independent information on the hard tail of the thermal spectrum.

The present upper limits on the HXR emission are greater than the minimum intensity detectable from a source by SIXE. For instance, for the Coma Cluster, whose radio halo is one of the most studied, the upper limit to the HXR emission given by CGRO-OSSE is $\sim 10^{-6}$ ph/s cm² keV at 50 keV (Rephaeli et al., 1994). Thus, SIXE, with its measurements of duration of the order of a month, will allow to reduce by an order of magnitude this upper limit, with a consequent enhancement of the probability to actually detect the HXR emission from the cluster.

3.2. Active Galactic Nuclei (Extragalactic Quasars) and Galactic Microquasars

There are many extragalactic sources that show HXR emission in the energy range of SIXE (3-60 keV), such as quasars (QSOs), Seyfert Galaxies (SGs), BL Lac-type objects (BLLs) and Radiogalaxies (RGs).

The rapid variability measured on the emission of these sources demonstrates that the nucleus emitting radiation is compact ($\lesssim 10^{15}$ cm) and probably is unique: a black hole of $\sim 10^{-6} - 10^9 M_{\odot}$.

The power-law spectrum fitting the emission of these objects in the range 3-100 keV is the main characteristic of AGNs and has a "canonical" spectral index of ~ 0.7 . However, some measurements show a spectral index rather different, like for instance that of the QSO 3C 273, whose spectral index is ~ 0.5 in the range 2-10 keV and shows variations (Turner et al., 1990).

The law governing such variations is not known because of lack of long-term measurements, that SIXE, on the contrary, can provide.

The problem of the spectral "break" at 10 keV is crucial; over this break, the spectrum flattens. This fact, if confirmed, should give consistency to the idea of the presence of a Compton reflected component in the spectrum, as observed by GINGA.

SIXE, thanks to its technical characteristics and philosophy of measurements, will be able to supply that answer.

Furthermore, having on board SIXE an Optical Monitor, it will be possible to study the analogies among extragalactic high energy sources, by means of observations of few selected objects, such as the Seyfert galaxy NGC 4151 and the quasar 3C 273. Indeed, the main idea is that the engine producing high energy radiation is of the same kind for all the extragalactic emitters, with the only difference in the different mass and in the different mass accretion rate, as already suggested by Giovannelli and Polcaro (1986), and now very popular in the more recent literature. Furthermore, this analogy can be extended until Galactic black hole candidates, with the obvious scale factors for the

masses of the collapsed objects and the mass accretion rates.

Then, taking into account the new discoveries of the so-called Galactic microquasars (GmQSOs), *SIXE* is able to experimentally demonstrate the equivalence existing among Galactic Microquasars and AGNs.

Following the current definition, a GmQSO is a Galactic X-ray binary with radio jets. Then, the list of known GmQSOs contains 8 objects. In addition, there are few more objects that are possible candidates for being included into the list (e.g. Ziolkowski, 1997). The prototype of this class of objects is the great annihilator 1E 1740.7-2942 (Mirabel et al., 1992).

The signatures of an accreting black hole in a binary system are:

i) Flickering: rapid variations of X-ray flux on milliseconds time scale and amplitude of the order or greater than 10%.

ii) Presence of an ultrasoft components ($KT \sim 0.1-0.3$ keV) in the X-ray spectrum.

iii) Presence of a power-law component in the X-ray spectrum, extending to several tens or several hundreds keV. This component is also called the ultra-hard component.

iv) Bimodal behaviour (or state transition). This term refers to the alternation between high soft state (mainly ultrasoft components) and low hard state (dominated by ultrahard components).

v) Absence of the characteristic 2 keV blackbody component at any level of X-ray emission (and in particular, at high X-ray luminosity: $L_x \geq 10^{37}$ erg/s). This component, prominent in the spectra of non-pulsating neutron star sources at high luminosity levels, is believed to originate on the surface of a weakly magnetized neutron star.

vi) Large inner radius of the disk and low colour temperature of the inner edge of the disk, as obtained from multi-colour blackbody fits to the ultrasoft component of the X-ray spectrum.

The results of such fits indicate that the inner radii of disks around black hole candidates are, consistently, by a factor of ~ 4 larger than for the disk around the neutron stars (Tanaka and Lewin, 1995). They indicate also that the inner parts of disks around black hole candidates are cooler than the disks around neutron stars (the fits are made under the assumption that the ultrasoft component originates at the inner region of an accretion disk, while the power-law component is due to up-comptonization of soft photons).

None of the above indicators is, by itself, sufficient to pinpoint a black hole. Counter examples for the properties i-iv) are known: some confirmed neutron star sources display, on some occasions, one or more of these properties. Indicators v) or vi) are sufficient only in principle. In practice, the observer can never be absolutely sure that the missing blackbody component will not appear at the higher level of source activity. Similarly, the fit to the disk spectrum give only rough estimates. In addition, the estimate of the inner radius of the disk depends on the distance to the source, which, usually, is not accurately known. On the other hand, all confirmed black hole candidates

display at least one of the properties ii) and iii) (usually both).

Of course, they satisfy also indicators v) and vi), if the respective information is available.

Then, to summarize: the properties ii), iii), v) and vi), while not conclusive, are certainly useful indicators, suggesting the presence of a black hole. However the conclusive evidence belongs only to the dynamical mass estimate: if the object is compact and has a mass greater than $\sim 2-3 M_{\odot}$, it must be a black hole.

In spite of the many order of magnitude differences in the masses of the involved black holes and in the total energetics of the systems, one may note substantial similarities between two classes of objects.

i) Similarities in the X-ray spectra (Tanaka and Lewin, 1995):

- a) The power-law components have similar slopes.
- b) The intensity of power-law components is highly variable on short time scale.
- c) The slope of the power-law for a given source remains approximately constant in spite of large variations of the source intensity.
- d) The soft component, believed to originate in the inner region of the accretion disk, is usually seen in both types of objects. In the microquasars it is observed an ultrasoft X-ray component, in the AGNs as an "UV bump".

ii) The common disk luminosity - radio luminosity relation:

Falcke and Biermann (1996) found that the same relation between the total luminosity of the disk and the radio luminosity of the central compact source is obeyed by AGs and GmQSOs.

iii) The common disk luminosity-length of the jets relation:

Sams et al. (1996) found empirical correlations between the total luminosity of the disk (optical plus X-ray) and the length of the jets (both radio jets and optical/infrared jets). The same two correlations (one for radio jets, the other for optical jets) were found to hold both for AGNs and GmQSOs.

iv) The common disk luminosity-brightness temperature of the jets relation:

Sams et al. (1996) found empirical correlations between the total luminosity of the disk and the brightness temperature of the jets (both radio jets and optical/infrared jets). Again, the same two correlations (one for radio jets, the other for optical jets) were found to hold both for AGNs and for GmQSOs.

The above similarities suggest that substantial amount of the underlying physics might be the same for AGNs and the GmQSOs. Then, following the current knowledges, it is possible to conclude that:

- 1) Most of the GmQSOs (perhaps almost all of them) seem to contain black holes.
- 2) Two of them (those with superluminal jets), namely GRO J1655-40 (Remillard, 1997; Zhang et al., 1997) and GRS 1915+105 (Morgan et al., 1996; Zhang et al., 1997), possibly contain rapidly rotating Kerr black holes.

The question of possible connection between fast rotation and the highly relativistic nature of the jets remains open.

- 3) There is a substantial similarity between the AGNs and the GmQSOs.
- 4) The investigation of microquasars might be very helpful in understanding AGNs, since they are much easier to observe than AGNs themselves:
 - a) They are typically ~ 100 times brighter than AGNs (as seen from the Earth);
 - b) The corresponding variability time scales are $\sim 10^7$ - 10^8 times shorter than in AGNs.
- 5) The mechanism of the jet acceleration remains still unknown, although the efforts done by many authors (e.g. Li et al., 1997; Kirk, 1997; Ostrowski, 1997).

Therefore SIXE is able to usefully observe selected microquasar candidates, compatibly with its FOV, which exclude observations in crowded fields, in order to provide, instead, precious informations on the non-thermal part of the spectrum, as well on the eventual long and short-term variabilities, both in X-ray and in optical, never measured since today.

3.3. Galactic X-Ray Binaries

The X-ray sky is essentially dominated by X-ray sources lying around the galactic plane; they have luminosities up to $\sim 10^{38}$ erg/s, and most of them are binary systems. The known binary systems before ROSAT were of ~ 100 and all of them emit at least up to ~ 25 keV. They are formed by a compact object and a "normal" star. In these systems the mechanisms of transport of matter are conclusive on the evolutionary studies.

An indicator of these mechanisms is the X-ray emission.

The interactions between the two components of a binary system demonstrate through a wide fan of physical processes along a large part of the electromagnetic spectrum, and in particular in the X-ray range; Furthermore, these processes occur in very different time scales: from fraction of millisecond to months. Then SIXE is able to cover all those time scales.

The galactic sources that SIXE can actually observe in the best way will be therefore selected among the classes of binary systems containing white dwarfs, neutron stars and black holes.

The peculiar aspect of the mission is the long term monitoring of a selected number of sources representatives of homogeneous classes of objects in order to study their spectral and temporal variabilities. Indeed,

- i) the large area of the detectors ($\sim 3200 \text{ cm}^2$),
- ii) the high time resolution: $\sim 0.1 \text{ ms}$,
- iii) the high sensitivity: $\sim 3 \cdot 10^{-6} \text{ ph/s} \cdot \text{cm}^2$,
- iv) the long-term observations: 15-25 sources during 2-3 years,
- v) the presence of the Optical Monitor in two colours (B and V),

allows to explore accurately the temporal variations in very different time scales, correlate the variations in the optical band, coming from the optical component of the system and/or from the more external part of an eventual accretion disk, with X-ray emission originated in the vicinity of the collapsed object.

It is important to remark that, even if SIXE is a small payload, its scientific objectives are extremely exciting and competitive: a study of the variability of X-ray sources across 10 orders of magnitude in time ($\sim 10^6$ - 10^{-4} sec) and, furthermore, correlated with the optical variations makes this project unique, and characterized by exposures (area $\times$ time) extremely high if compared with the present and near future missions, included larger satellites.

In the following we will discuss, for few groups of sources, the main lines of investigation that will be made possible with SIXE.

3.3.1. High Mass X-Ray Binaries

X-ray/Be sources are binary systems containing as collapsed object an X-ray pulsing neutron star. These systems show large variations along practically all the electromagnetic spectrum, and in particular they flare-up in X-ray range periodically, or almost periodically. The UV emission is basically coming from the low-density polar regions and the IR emission is coming from the matter (disk-like) surrounding the optical companion.

The relationship between the IR and X-ray variations is still under discussion, although de Martino et al. (1990 a, b) have shown such a correlation for one particular object: A 0535+26/HDE 245770.

Optical indicators of high energy processes have been found in such system (e.g. Giovannelli and Sabau-Graziati, 1992 and references therein) as well as in A 1118-61/Hen3-640 (e.g. Polcaro et al., 1993; Coe et al., 1994; Villada et al., 1998).

a) Typical Systems: High Eccentricity (A0535+26-like). One of the most studied transient X-ray sources has been A0535+26, pulsing at ~ 104 s and eccentrically orbiting ($P_{orb} \sim 111$ days) around the O9.7 IIIe star HDE 245770 (Flavia's star). For an exhaustive review see Giovannelli and Sabau-Graziati (1992) and the references therein and more recently Burger et al. (1996).

This system has been defined as a typical X-ray/Be system, in which the neutron star accretes matter through stellar wind from the primary optical companion, which does not fill its Roche Lobe.

This system shows outbursts because of the periastron passage effect; indeed, it experiences:

- an X-ray outburst (~ 0.1 - 0.3 Crab) around the periastron passage (normal outburst) of the neutron star in a high eccentric ($e \sim 0.5$) orbit around the massive ($M \sim 20 M_{\odot}$) Be star

if it is in a "quiescent" state, i.e. emission of steady stellar wind;
 - an X-ray outburst (~ 0.5 -1 Crab) close to the periastron passage (anomalous outburst) of the neutron star around the Be star in "active" state, i.e. emission of puffs of material overlapped to the steady stellar wind;- an X-ray outburst (~ 1 -3 Crab) at any orbital phase (casual outburst) when the Be star is expelling a shell (typical formation time of shells: ~ 1000 -2000 days); the periastron passage is still favouring the trigger of the outburst because of gravitational reasons.

At the periastron it is possible the formation of a temporary accretion disk around the neutron star, as demonstrated by Giovannelli and Ziolkowski (1990); this could explain also the sudden increase of X-ray luminosity because of the higher efficiency of the matter-accretion process with the respect to the accretion via stellar wind.

Through the deep study of this system, a better knowledge of the class of the high eccentric X-ray/Be systems (10^3 - 10^4 in the Galaxy) has been reached. They are important from the evolutionary point of view, since they can be originated by a supernova asymmetric explosion in a medium mass (10 - $20M_{\odot}$) binary system, as demonstrated by Giovannelli et al. (1993 a, b; 1994 a; Giovannelli and Sabau-Graziati, 1998).

SIXE could be extremely useful in searching for the interactions between the neutron star and Be star during X-ray quiescence of the system (~ 5 -10 mCrab), thanks to its capability in carrying on measurements simultaneously in X-ray and in optical ranges.

Furthermore, A 0535+26 shows a long-term spin-up phase -that could be studied with SIXE- alternated by short spin-down phases. There are good reasons, both experimental (Giovannelli and Ziolkowski, 1990) and theoretical (Bisnovatyi-Kogan, 1991), to believe that

this pulsar is very close to its equilibrium period.

Thus, the X-ray monitoring of such a system could provide crucial information on the general problem of the equilibrium rotational period of the pulsars in binary systems.

b) Atypical Systems: Low Eccentricity (A1118-61-like ?)

The southern X-ray transient source A1118-61 whose companion is the Be star Hen3-640 has been extensively studied but not at the level of A0535+26. However, our group performed a long term optical monitoring of this system and the results have been discussed in the papers by Villada et al. (1992), Polcaro et al. (1993), Giovannelli et al. (1994b) Coe et al. (1994a,b), and Villada et al. (1998).

In spite of the long monitor, no orbital periodicity has been detected, although an orbital period of ~ 350 days could be expected following the Corbet (1986) relationship between the spin period of the pulsar (405 s) and the orbital period of the system.

A relationship between the H alpha equivalent width (EW) and the orbital period of

X-ray transient sources has been reported by Reig et al. (1997). By using the best fit of that diagram and the average value of the H α -EW (~ 70 Å) of Hen3-640 when A1118-61 is in X-ray quiescence, we could expect for the system an orbital period of ~ 350 days. This orbital period, that should be in agreement with the expected value for X-ray/Be systems, needs an experimental confirmation in different wavelength regions. Indeed, in spite of the long X-ray monitor performed by CGRO-BATSE (Bildsten et al., 1997) and optical monitor performed by our group (1988-1998) (Villada et al., 1998), no such a periodicity has been detected. Only two X-ray outbursts have been detected in 1976 and 1992 (see Coe et al., 1994a,b). During the 1992 outburst, the H α -EW of the Be star reached a value of ~ 107 Å, while its average value is ~ 70 Å.

So a further relationship between the H α -EW and X-ray emission could be probable. This could mean that the X-ray outbursts are produced when the shell around the Be star is swept out, instead of the periastron effects. For this reason, Villada et al. (1998) claim A1118-61/Hen3-640 as an atypical X-ray/Be system. But, if it is true, the orbit should have low eccentricity ($e < 0.3$) and this system could be generated by a symmetric supernova explosion in a medium-mass binary system.

Then, we suggest to follow the monitoring of this system in the optical region, in order to find the orbital period, and to perform X-ray measurements with SIXE, especially when the H α -EW will increase to reach again the value of ~ 100 Å; in this moment an X-ray outburst is expected. In this way we may also definitively demonstrate the strong correlation between the low-energy indicator (H α -EW) of high energy process (X-ray outburst). Similar correlations have been found by our group in the case of A0535+26, where the H γ intensity directly correlates with the X-ray outburst (see Giovannelli and Sabau-Graziati, 1992 and the references therein).

c) Permanent X-ray Sources: Vela X1-like

Gamma-rays up to $7 \cdot 10^{16}$ eV were observed from the X-ray binary systems Cyg X3, Vela X1 and LMC X4. This is a strong indication that protons (or nuclei) experience an acceleration in the vicinity of the accreting pulsar. A burst at energies above 100 TeV has been detected from Cyg X3 (following the onset of a large radio flare by 6.1 days), together with the 12 ms periodicity of the pulsar in the orbital phase window 0.55-0.58 (Gregory et al., 1990).

Following the recent models, the protons, accelerated in the vicinity of the pulsar, are driven by the magnetic field to hit the surface of the companion (Vestrand and Eichler, 1982). In fact, Hillas (1984) has shown that the production of UHE gamma-rays must occur far from the pulsar, otherwise the gamma-rays would be self absorbed by pair creation in its strong magnetic field, and peaked around phase 0.6-0.7.

A test of Vestrand-Eichler's and Hillas' model could be done with conventional spectroscopy, in UV and optical bands, searching for lines produced by the interaction

of accelerated particles onto the surface of the optical companion, modulated with the orbital period.

The best candidate to test this model is the binary system 4U 0900-40/HD 77581 (Vela X1), composed by the 283 s X-ray pulsar and by the B0.5 Ib supergiant, thanks to its brightness ($M_v = 6.8$) and its relative short orbital period ($P_{\text{orb}} = 8.96443 \pm 0.00022$ days (Boynton et al., (1986))). The parameters of this system can be found in the papers by Khruzina and Cherepashchuk (1986) and by Deeter et al., (1987).

The UHE luminosity of Vela X1 was estimated by Protheroe et al. (1984) as $L_\gamma(E > 3 \cdot 10^{15} \text{ eV}) = 2 \cdot 10^{34} \text{ erg/s}$. According to Hillas (1984), this correspond to deposit an energy on the external layers of the B0 star by the energetic particle beam of $\sim 10^{37} - 10^{38} \text{ erg/s}$. Most of this energy should be thermally dissipated in a very hot spot on the surface of the star, by the medium and low energy components of the particle cascades. Only a small fraction of it (namely $= 0.1\%$) is radiated away as high energy gamma-rays and neutrinos.

We expect, therefore, if this mechanism is in action, that the bright spot must emit detectable high excitation lines, modulated with the orbital period and should be more intense around the phase 0.6-0.7, where there is a peak in the gamma-ray emission.

Many observations in all the wavelength regions have been performed on this system, particularly in UV and soft X-ray, as well as in optical. Nevertheless, systematic dedicated observations have never been performed in the hard X-ray range.

However, in Vela X1 the K_α emission line and the absorption window of Fe K-shell at 6.42 keV and 7.24 keV have been detected (Nagase et al., 1986). The equivalent width of the fluorescent line of Fe is relatively wide when the inhomogeneities of the surrounding matter enhance. Then, the structure of the Fe line is correlated with the photoionization of the stellar wind, which is the vehicle of the mass accretion from the B0 supergiant onto the neutron star. However, the formation region of this line is still uncertain, since, also excluding the accretion disk that seems absent in this system, still remain three possible formation regions: the atmosphere of the B0 companion, the stellar wind, and the magnetosphere of the neutron star (e.g. Hatchett and Weaver, 1977; Basko, 1978, 1980; Bai, 1980). The fact that the Fe line has been observed also during the eclipse of Vela X1 (Ohashi et al., 1984; Sato et al., 1986) gives evidence of the contribution of the stellar wind to the reprocessing of Fe line. However, being the atmosphere of the B0 star very extense, it is partially responsible of the Fe line in emission.

Thus, a detailed study of Fe line with respect to the continuum X-ray radiation at different orbital phases will provide precious information on its formation regions, and on the hydrogen column. This kind of problem is of course general for all the binary systems of this class, namely formed by a neutron star and a supergiant as companion.

Since the orbital period is ~ 8.9 days, SIXE could measure Vela X1 system during several orbital periods, with a double result: to observe the eventual orbital modulations

(that must exist) and the history of the spin period (283 s) which shows phases of spin-down during the secular phases of spin-up.

This is a problem of great importance since it is associated with the dynamic behaviour of the internal structure of the neutron star.

3.3.2. Low Mass X-Ray Binary Systems

SIXE can provide information on:

i) long-term evolution (weeks, months) in the colour-colour diagram of Z and atoll sources and the relative study of different temporal variability (QPOs, Red Noise, flares) correlated to different spectral states (van der Klis, 1995). Correlations with eventual variations in the optical band in the emission, mostly coming from the more external layers of the accretion disk.

The high time resolution (~ 0.1 ms) of SIXE and the long term exposures will allow to deeply investigate the Red Noise on a large scale of variability and QPOs along all the range of frequencies associated up to kHz-QPOs, recently discovered in some LMXRBs from the RXTE satellite (e.g. van der Klis et al., 1996).

This is particularly interesting since the time scales of the phenomena occurring at the vicinity of the neutron star are $\lesssim 1$ ms.

The eventual correlations between optical and X-ray emissions may clarify the complex problematic of the radiating processes and further partial reprocessing in optical of the X-ray component (King, Kolb and Burderi, 1996);

ii) the orbital periods of the LMXRBs. Indeed, for most of these systems the orbital periods are not known.

Recently thermal instabilities of the accretion disk have been proposed to explain the transient behaviour of many sources (van Paradijs, 1996). For short orbital periods (< 2 days) the irradiation of the external layers of the disk by means of radiation coming from the compact source seems to have a stabilizing effect. Additive information on orbital periods on the masses of the components of LMXRBs are necessary in order to verify these models.

Long-term monitoring of some of these systems can either provide or improve significantly the precision on the orbital parameters and the evaluation of the masses. In particular, an accurate measurement of the neutron star mass in a LMXRB could clarify the evolutionary scenario in these systems, namely conservative or not and if the Accretion Induced Collapse is a significant process for the formation of neutron stars (e.g. Burderi, King and Wynn, 1996);

iii) systematic research of coherent pulsations in LMXRBs. Indeed, this is a crucial point for the evolutionary scenario of these systems, which assume that they are progenitor of the millisecond radio pulsars (e.g. Bhattacharya and van den Heuvel, 1991).

The recent discover of coherent X-ray pulsation from the X-ray transient source SAX J1808-36 (vand der Klis, 1998) have revealed the missing link between the millisecond radio pulsar and their supposed progenitors, namely the LMXRBs after a search lasted for more than 15 years.

The large effective area and the high temporal resolution of the RXTE satellite have revealed how crucial is to detect these weak pulsations, and SIXE, again, match both these characteristics.

It is likely that we are not in presence of an isolated phenomenon and that at least few LMXRBs (transient or not) are close to millisecond, or even submillisecond X-ray pulsators.

Several scientific results could be acheived from a sistematic study of these kind of variabilities. The kind of phenomena producing such a variabilities seems to originate very close to the neutron star surface (that is placed at few Schwarzschild radii); then their study will allow the comprehension of the physics in strong gravitational fields and test the equation of state of the ultradense matter (Burderi and D'Amico, 1997; Burderi and King 1998).

Moreover, the fast orbital modulation discovered in SAX J1808-36 (Chakrabarty and Morgan 1998) and expected in most LMXB is a powerful diagnostic of the orbital evolution under significant mass transfer.

The combined study of the X-ray and optical light curves (particularly in the case of transient sources) will severely constrain all the models of disk instabilities, recently developed, to explain the transient behavior of an increasing number of galactic sources (King, Kolb, and Burderi, 1996, van Paradijs 1996).

Finally, few signatures of the presence of weak magnetic fields (that seems to determine the coherent pulsed emission) are expected as the onset of the so called propeller regime or the switching on of a radio-pulsar when the accretion rate is sufficiently low (Campana et al., 1998).

From what was discussed above it is clear that a multifrequency study of temporal variability of LMXRBs is of great scientific interest and that, in light of the new results, this allows to address several opened questions of fundamental importance in the physics of accretion onto compact objects.

3.3. Cataclysmic Variables

Cataclysmic Variables (CVs) are binary systems in which the primary component is a white dwarf and the secondary is a late-type Main-Sequence star ($M \lesssim 1 M_{\odot}$). Depending on the magnetic field intensity at the white dwarf, the accretion of matter from the secondary star onto the primary can occur either via an accretion disk or a channelling through the magnetic poles or in an intermediate way. Usually the mass transfer rate is ranging from $\sim 10^{14}$ to 10^{18} g/s (Smak, 19895a, 1985b). CVs in a time-

scale of order between weeks and years flare-up almost periodically, about a few magnitudes in optical wavelengths, the duration of the outbursts being much shorter than the recurrence time. CVs are, in general sense, low mass binary systems, but only few of them were detected as X-ray emitters, essentially because of their lower X-ray luminosities with respect to those of the already mentioned LMXRB, and the sensitivities of the X-ray detectors on board spacecrafts. For this historical reason, the CVs were always considered as a separate class of binary systems.

CVs can be classified following two different criterions:

- i) the outburst properties,
- ii) the accretion behaviour.

The first classification is the historical one, based on the optical observational properties, while the second is more physical and better describe the whole behaviour of the systems. Depending on the magnetic field strength, the accretion structure varies, originating a new more adequate classification of CVs in order to explain the physics of these systems:

a) Non-Magnetic CVs. The intensity of the magnetic field is so low that the matter transferred from the optical companion (the secondary star), via overflowing of its Roche lobe, onto the white dwarf (the primary) forms a rotating gaseous accretion disk around it, because of the conservation of the angular momentum.

b) Polars. The intensity of the magnetic field is so strong that the accretion material flows along the field lines and forms accretion columns at the two magnetic poles of the white dwarf. In terms of a model, polars represent an extreme case of accretion onto a strongly magnetic, synchronously rotating white dwarf;

c) Intermediate Polars. The intensity of the magnetic field is moderately strong (as compared to polars). Consequently:

- i) the magnetic field is too weak to control the flow at large distances from the white dwarf and does not prevent the formation of a disk;
- ii) the magnetic field is still sufficiently strong, however, to control the flow near the white dwarf. As a result, a fraction of the accretion energy is dissipated near the magnetic poles of the white dwarf, like in polars. Nevertheless, the magnetic field of the white dwarf is too weak to enforce synchronous rotation. So, the rotation period is different than the orbital period. Then, the non-synchronous rotation can be used as the defining property of intermediate polars (Warner, 1983).

The most recent exhaustive book on CVs has been published by Warner (1995).

It appears evident that the strong interactions between the two components of the binary systems - the collapsed object and the optical companion - originate a vaste fan of physical processes which manifest themselves in a large part of the electromagnetic spectrum. Therefore, multifrequency observations, possibly simultaneously performed, are crucial in order to understand the physics governing these kind of cosmic sources.

3.3.1. SS Cygni

Following the historical classification of CVs, SS Cygni is a dwarf nova, and in particular the brightest one, its optical magnitude ranging from ~ 12 to ~ 8 during quiescent and outburst phases, respectively. For this reason it is the most observed CV, not only in the optical, where measurements are available since the end of the last century, but also in the other wavelength regions, the system being one of the most interesting laboratory for the study of the physical processes occurring in CVs because of the strong interactions between the two components of the system. Despite the enormous amount of multifrequency experimental data available during a long time, the morphology and the nature of the system are still unsettled questions.

For extensive reviews see the papers by Giovannelli and Martinez-Pais (1991), Giovannelli (1996a), Giovannelli and Sabau-Graziati (1998). For an deep time-resolved optical spectroscopic study in quiescence and in outburst see the papers by Martinez-Pais et al. (1994, 1996), respectively.

Briefly, SS Cyg is a CV suspected to be an IP. Indeed its emissions shows:

- i) two anticorrelated components modeled with a black body at 20-30 eV and a thermal bremsstrahlung at ~ 20 keV in X-ray range;
- ii) modulations with the orbital period (~ 6.6 h) and spin period of the white dwarf (~ 12 min) in UV and optical ranges.

Our main goal is to search for both periodicities in SS Cyg in quiescence along an outburst cycle in the X-ray, optical (medium-high resolution spectroscopy and fast photometry - resolution time up to 0.1 ms -) and IR possibly simultaneously in order to provide data for a diagnostic of the accretion pattern, the determination of plasma physics and energy budget.

3.3.2. TT Ari

TT Ari belongs to the class of nova-like systems. It shows occasionally low optical states where the mass transfer rate is greatly decreased (Hudec et al., 1984).

The EINSTEIN X-ray satellite was the first to identify copious X-ray emission with TT Ari (Cordova et al., 1981), although it appears to have been detected prior to this by HEAO-1 A1 experiment (Robinson, 1996). The EINSTEIN data exhibited variations at ~ 1000 s and modulations of the X-ray flux at a period near both the spectroscopic and photometric periods (Jensen et al., 1983; Schwarzenberg-Czerny, 1987). Quasi Periodic Oscillations (QPOs) at 32, 12 and 9 s were also observed in the EINSTEIN data. Simultaneous optical observations also exhibited oscillations at the first two of these periods. The importance of studying TT Ari lies in its rich multi-period, multi-state behaviour.

The relationship of QPOs to X-ray or optical luminosity in TT Ari are not known.

Of particular importance in any future X-ray observations of TT Ari is a test of the validity of the unexpected result from EINSTEIN that the optical and X-ray flickering is related, but with a delay between the optical and X-ray emission by approximately 1 minute (Jensen et al., 1983).

We have re-analyzed the EINSTEIN data and the optical simultaneously taken from two different observatories, and the delay between the X-ray flickering relative to the optical actually exists. This is not due to X-ray reprocessing, however, since the X-ray variability lags the optical. Instead, it is likely related to the mechanism responsible for heating and/or the cooling timescale of an X-ray emitting disk corona and/or perhaps from a small region close to the white dwarf.

TT Ari is usually found in its high state at $V \sim 10.5$. It drops, around once per decade for several months, into low optical states with $V \sim 12-14$. The X-ray observations, however, show that the level of X-ray fluxes do not closely follow these definitions of optical states. That is, the long-term flux variations in X-rays are not correlated with the optical flux.

The orbital period of the system, from radial velocity measurements is $P_{\text{orb}} = 0.13755114(13)$ days (~ 3.30 hours, Thorstensen et al., 1985). The photometric period ($P_{\text{ph}} = 0.1329$ d ~ 3.19 h) is 3.4% shorter than this (Tremko et al., 1992). The photometric variations do not appear to be strictly periodic and their origin is unclear. A ~ 4 day periodicity found in U band by Semeniuk et al. (1987) suggests the presence of variations at the beat period between the photometric and spectroscopic periods.

This behaviour is similar to the intermediate polar TV Col where the spectroscopic period (5.5 h) is slightly larger than the photometric period (5.2 h) and a variation at the ~ 4 day beat period is observed (Motch, 1981; Augusteijn et al., 1994).

However, TV Col shows stable X-ray variations with a period of 32 min, presumably the white dwarf's rotation period, while it is unclear whether or not a stable variation exists in TT Ari.

The CIV UV resonance line shows variable P-Cygni-like features (Guinan and Sion, 1981). Modulations in the equivalent width of the absorption component of the CIV line are suspected of varying on the spectroscopically determined orbital period (Robinson and Cordova, 1994). This behaviour is similar to other CVs where the origin of the P-Cygni profile is assumed to be a high velocity wind emanating from the accretion disk or close to the white dwarf.

The geometry of this wind as well as its association with the accretion disk and the production of X-rays have yet to be resolved.

Baykal et al. (1995) reported a 100% modulation in the X-ray count rate of the ROSAT data at the orbital period with similar phasing to the CIV variations.

This behaviour has been found in many UV and optical lines, as well as in the continuum emission of SS Cygni, which is suspected to be an intermediate polar (see Giovannelli and Martinez-Pais, 1991; Martinez-Pais et al., 1994; Giovannelli, 1996a and

the references therein).

We found modulations of X-ray emission from TT Ari at 836 s in the data of ROSAT and GINGA, as well as oscillations with a period of ~ 8.3 s. The first period could be the rotation period and the second could be associated with some phenomenon at the surface of the white dwarf. Additional X-ray observations can give the answer to the origin of those modulations.

In order to clarify the physics of TT Ari, we will perform X-ray measurements with RXTE (15th-22nd December, 1988), already approved and scheduled. Since it is also crucial to perform simultaneous optical, we have planned the use of observatories covering longitudes from Canary Islands through Europe, North America and Hawaii, for a total of 222 deg in longitude. Since in December the weather is of moderate quality at the variety of sites we are planning to use, assuming an observing efficiency of 65%, a total on-source time of 40 Ks will allow to complete the coverage by the participant observatories.

However, in order to definitively clarify the whole behaviour of such a system (IP) it is necessary to perform a long-term observation in X-rays, including many orbital periods (order of at least 10) and possibly the coordinated observations in other energy ranges. Only SIXE can be useful for this purpose in X-rays.

3.4. Young Open Clusters (YOCs)

An alternative scenario to that of the SNRs for the production of high energy gamma-rays for the COS B diffuse sources has been proposed by Polcaro et al. (1991).

In this model, the interactions of strong stellar winds (thousands km/s) from peculiar stars (the WR star ST3 in the case of the young open cluster Berkeley 87 (Berk 87) has a wind with a velocity of ~ 5200 km/s) with the dense intercluster medium produce shock waves. The presence of these shock waves is supported by optical spectroscopy and imaging of the cluster Berk 87. The high velocities of the wind particles (~ 1000 - 5200 km/s as reported by Manchanda et al., 1996) coming from the numerous early-type stars seem to provide good conditions for the injection of particles into the system of shock fronts. There, shock waves can accelerate the ambient cosmic ray particles up to the maximum energy of $\sim 10^{16}$ eV (Cesarsky and Montmerle 1983).

The presence of a diffuse X-ray emission from the cluster region, in the 2-6 keV range, measured by the EXOSAT satellite (Warwick et al. 1988), could be explained as due to non-radiative heating of the intercluster medium by shocks. No X-ray emission from point-like sources down to a flux limit of $2 \cdot 10^{-13}$ erg.cm⁻².s⁻¹, in the 0.5-4 keV range, was detected by IPC measurements of the Einstein observatory in a field $1^\circ \times 1^\circ$ centered on the centroid of the COS B gamma-ray source position (Singh et al. 1982). For all these reasons the association of the COS B source 2CG 075+00 with Berk 87 young open cluster was considered virtually certain by Polcaro et al. (1991). They estimated a local enhancement of the energy density of cosmic rays of the order of 100

in the central part of Berk 87, by using the COS B detected gamma-ray flux from 2CG 075+00 ($\sim 1.3 \times 10^{-6}$ ph cm⁻² s⁻¹). The observation of Berk 87 by EGRET-CGRO instrument, in the energy range 20 MeV-30 GeV, has confirmed this identification. EGRET detected a gamma-ray point source (CGRO J 2021+37), practically coincident with Berk 87 cluster. The measured flux from this EGRET point source is $F_{\text{gamma}}(E > 100 \text{ MeV}) = (9.14 \pm 0.94) \times 10^{-7}$ ph cm⁻² s⁻¹ (Giovannelli et al. 1995a; Polcaro et al. 1995), and is consistent with that measured by COS B.

In the second EGRET catalog (Thompson et al., 1995) the source J2021+37 was redefined as 2EG J2019+3719 and 2EG J2026+3610. The source 2EG J2019+3719 is still fully compatible with the Berk 87 young open cluster. The spectrum of 2EG J2019+3719 has a slope $\gamma = 1.9 \pm 0.1$ and the flux is, within the errors, the same as that reported for the "old" source J2021+37, for which the spectral slope had not been given.

With this slope, Berk 87 could emit up to energies of $\sim 10^{16}$ eV as discussed by Giovannelli et al. (1996), and de-excitation lines, such as those of ¹²C* and ¹⁶O*, like in the Orion complex, could be detected. Furthermore, in the TeV region, the emission of Berk 87 could be detected by Wipple-like detectors.

This identification suggests that young open clusters, similar to Berk 87, can form one important class of objects producing relativistic cosmic rays (Manchanda et al. 1996). A recent review on young open clusters as gamma-ray emitters is that by Giovannelli (1996b).

Therefore, we propose to observe with SIXE few YOCs Berk87-like (which are contained in the COS B error boxes and from which gamma-ray emission has been measured by CGRO-EGRET) in order to definitively understand the mechanism of such an emission, which render these YOCs responsible of an appreciable part of the cosmic-ray production, at least until the knee of the cosmic-ray spectrum, as discussed by Giovannelli (1997).

3.5. Pre-Main-Sequence Stars (PMSSs);

The study of PMSSs is of great interest as it provides crucial information on stellar evolution and, particularly, on the role of magnetic fields, angular momenta, accretion of matter and mass loss processes, as well as indirect information on the formation processes of the Sun and Solar system.

With the nowadays knowledge of PMSSs, we can say that they are sites of a variety of extraordinary astrophysical processes, including accretion disks and outflows. The former have been detected by means of observations of molecular lines in cold gas. The best known class of PMSSs is that of the T Tauri Stars (TTs), identified by strong H α line in emission, which is believed to be generated in an extended circumstellar envelope, indicating a continuous mass accretion process. A recent review on TTs is

that by Giovannelli (1996c).

RU Lupi was selected by many groups as a convenient target in order to study the behaviour of TTs. In particular, our group performed a long campaign of coordinated ground- and space-based multifrequency observations -often simultaneous- of RU Lupi in order to obtain a large set of physical parameters to be used in understanding the physics governing the correlated processes occurring in this system.

An extensive review paper on RU Lupi has been published by Giovannelli (1994). Briefly, a model with a protoplanetary accretion disk around a moderately magnetic ($\sim$ hundreds gauss) star seems to be the most promising picture for this source, as deeply discussed in Giovannelli et al. (1995b) and Lamzin et al. (1996). However, a critical point is not yet solved, namely the rotational period of the star. Indeed, the rotational period, wrongly claimed in most of the literature as small as ~ 3.7 days, has been suggested to be ~ 27 days (Giovannelli, 1994) on the basis of such a periodicity in the Flare-Like-Events (FLEs) detected in many wavelength regions (from X-rays to IR). If this rotational period should be confirmed, the relationship between X-ray flux and rotational period should be respected, on the contrary to the case in which the ~ 3.7 days is used.

But this long rotational period could open a problem in the evolution of such a sources and on the magnetic braking, and furthermore in the production mechanism of X-ray emission that was measured only in phase with the 27 days periodicity. This could mean, in other words, that this star shows a detectable X-ray emission (X-ray flare) because of rotational effects, namely a mechanism (with the proper scale factor) similar to that occurring in the X-ray pulsars.

Then, we propose to search for the rotational period with SIXE through the detection of FLEs, as well as in the optical following the classical techniques, and possibly also in the IR, in order to definitively found such a periodicity and then reconsider the evolutionary tracks of PMSs.

3.6. Stellar Flares

The characteristics of SIXE:

- good sensitivity,
- good spectral resolution,
- optimum time resolution,
- its philosophy: long term observations,

will allow a long-term monitor of selected stars among those showing stellar flares. Thus, it will be possible to improve the statistics on stellar flares and then their role in the global energetic balance of the stars, as well as their role in the contamination of the circumstellar medium and interstellar medium. Furthermore, it will be possible to have information on the background radiation and on the nature of flares and bursts from non identified objects.

4. Technical description

4.1. Introduction

The SIXE experiment should be in orbit within 4-5 years, hence it is impossible to think to develop detectors of new conception. SIXE has been born under the sake of simplicity, reliability and low cost, compared to the scientific results that can be obtained.

The phase A study, founded by the Spanish Institutions, is at its conclusion (dead-line 31 October, 1998).

SIXE is constituted by four identical GSPC (Gas Proportional Counters) detectors, with an optimum spectral resolution an sensitivity in the 5-60 keV range. The total area, 3200 cm² makes this experiment competitive with others of this decade; especially for its sensitivity and for the peculiar targets of the mission, that should permit to observe for long time a selected number of sources, in order to solve many problems related to spectral and luminosity variability that cannot be achieved with other experiments already scheduled. Furthermore, the high time resolution (0.1 ms) makes SIXE unique in its class.

Fig. 1. One detection module of SIXE

4.2. The SIXE experiment

One of the four detection modules is shown in Fig. 1. Fig. 2 shows their disposition on the platform, inside the Pegasus envelope.

The main characteristics of SIXE are shown in Table 1. The background we have used for computing its sensitivity is derived from our balloon-borne experiments data, modified accordingly to the parameters of an eccentric orbit, the diffuse cosmic background and with other experimental background data coming from the Japanese

satellite GINGA.

4.2.1. The detector

The detectors for SIXE are basically derived from the IAS's GSPCs that have been flown with success on board on numerous stratospheric balloons. The technology, obviously, will be improved especially with respect to the mechanical structure, the gaskets, the collimators, the gas mixture and its purification, the implementation of an up-to-date electronics, and so on.

Laboratory tests, carried on at IAS, have demonstrated the possibility of using a mixture of Ar and Xe as X-ray detectors (for the photoelectric conversion), and a small percentage of Isobutane acting as quenching gas.

For the windows, in the past we have adopted "sandwich" carbon fiber windows, in which, in the internal side, there is a thin layer of aluminum for electric field continuity. Beryllium is more transparent to soft radiation but mechanically it is fragile and somehow porous if thin films are to be used, in addition, no one supplies Be syntherized films bigger than 5x5 cm.

The almost concluded Phase A will establish the window final design.

Furthermore, using the experience obtained through the balloon detectors (e.g. POKER experiments) we can say, with no doubt, that SIXE detectors can easily sustain a pressure of 2-2.5 bars with any difficulty.

Regarding electronics, we intend to use the "escape gate" technique, already tested in POKER experiments, thus permitting a spectral resolution better than 12% above 30 keV (K edge of Xe).

In Fig. 3 one can see the efficiency curves as a function of energy for a 6 cm deep detector, filled with the Xe, Ar and Isobutane mixture at 2.5 bars, with a $50\mu\text{m}$ Be window, as results from the computations reported in the Phase A study. This doesn't

Fig. 2. SIXE inside the Pegasus envelope.

Fig. 3. Efficiency curve vs energy for a 6 cm deep detector.

Fig. 4. Sensitivity of SIXE for an integration time of 10^5 s.

mean that Be will be adopted definitely.

In Fig. 4 is shown the sensitivity of SIXE for an integration time of 10^5 s (at 3σ) with the formerly described configuration.

In Fig. 5 we have plotted the SIXE sensitivity with respect to other experiments already in orbit or in final realization phase.

In Table 2 we report a compendium of one SIXE detector performance. Table 3 reports the main characteristics of one SIXE module. Note that each module is limited by the encumber characteristics imposed by the Minisat platform.

There will be an anti-coincidence shield, it can be composed by one of the two methods, or both:

- i) internal anodes (lateral and bottom rows of anode wires); simple to obtain,
- ii) external scintillation plastic plates and PMs; we will try to avoid them for simplicity's sake.

The background measurement is of extreme importance, considering we are up to look for sources variability. This can be made or by "rocking" the payload on and off the source, or by off-setting the detectors by just the collimator FOV amount. We have decided for the second solution, since the background measurement is made contemporary to that of the source. One will lose half of the sensitive area, but still have the continuous monitoring of the source behavior.

Let us spend some words about the reliability of the experiment:

We will have four identical detectors, each of them composed of three identical modular parts: the window-collimator, the detector itself and the electronics housing.

Spare parts can be easily replaced if another goes damaged during ground tests. Even

Fig. 5

Let us spend some words about the reliability of the experiment:

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Table 1.

Energy range	$\approx 3\text{-}60\text{ keV}$
Sensitive area	$\approx 3200\text{ cm}^2$
Spectral resolution	$\approx 5\%$ ($E > 35\text{ keV}$) $\Delta E/E = 60/E^{1/2}$ ($E < 35\text{ keV}$)
Field of view	$1.5^\circ \times 1.5^\circ - 2^\circ \times 2^\circ$
Continuum sensitivity 3σ in 10^5 s	$\approx 3 \cdot 10^{-4}\text{ ph}\cdot\text{cm}^{-2}\cdot\text{s}^{-1}\cdot\text{keV}^{-1}$
Line detection sensitivity 3σ in 10^5 s	6.7 keV, narrow line - line width = 1.18 keV
	$\approx 3.5 \cdot 10^{-6}\text{ ph}\cdot\text{cm}^{-2}\cdot\text{s}^{-1}\cdot\text{keV}^{-1}$
Residual instr. BGD	$\approx 4 \cdot 10^{-4}\text{ cts}\cdot\text{cm}^{-2}\cdot\text{s}^{-1}\cdot\text{keV}^{-1}$ (GINGA data)
Timing accuracy	$\leq 0.1\text{ ms}$
Full dimensions (all)	$\leq 660 \times 660 \times 400\text{ mm}$
Experiment weight	$\leq 90\text{ kg}$
Power budget	$\leq 40\text{ Watt}$
Telemetry rate	$\leq 100\text{ kbit/s}$
On-board memory	$\approx 2\text{ Gbytes}$

Table 2.

Gas cell dimensions	$\approx 280 \times 280 \times 20$
Sensitive area	$\approx 800\text{ cm}^2$
Gas mixture	25% Ar, 74% Xe, 1% Isobutane
Filling pressure	$\approx 2 - 3\text{ bar}$
Absorption depth	6 cm
Collimator	Honeycomb structural, $1.5^\circ \times 1.5^\circ - 2^\circ \times 2^\circ$
Collimator shadow	$\approx 15\%$
Detection module dimensions	$\leq 325 \times 325 \times 300\text{ mm}^3$

Table 3.

Energy range	$\approx 5\text{-}60\text{ keV}$
Sensitive area	$\approx 800\text{ cm}^2$
Spectral resolution	$\approx 5\%$ ($E > 35\text{ keV}$) $\Delta E/E = 60/E^{1/2}$ ($E < 35\text{ keV}$)
Field of view	$1.5^\circ \times 1.5^\circ - 2^\circ \times 2^\circ$
Temporal resolution	$\leq 0.1\text{ ms}$
Continuum sensitivity 3σ in 10^5 s	$\approx 6 \cdot 10^{-6}\text{ ph}\cdot\text{cm}^{-2}\cdot\text{s}^{-1}\cdot\text{keV}^{-1}$
Line detection sensitivity 3σ in 10^5 s	6.7 keV, narrow line - line width = 1.18 keV

in the electronics bay, every amplifier or any other component can be easily substituted, this because the electronics bay is sealed with gaskets and kept to 1 bar of CO₂, thus giving the opportunity of opening such a bay and replace the defective component at once. Furthermore, being CO₂ a good dielectric element, corona discharge risk is completely removed. All this is aimed to ensure that SIXE will go into its orbit with everything working properly, and keep doing it for its whole life-time.

4.2.2. On-board electronics

The on-board electronics block diagram is shown in Fig. 6.

Its main parts are: the front-end electronics, the event discrimination and timing, the A/D conversion and data handling, the telecommand decoding and the telemetry stream generation. Let us examine these points in more detail:

- a) The front-end electronics are basically charge amplifiers, and successive voltage amplifier stages, they branch in two directions; in one of them we try to maintain the best rise-time in order to have a good event timing; in the other line we try to keep the best collection of secondary “shower” electrons, in order to have the best spectral resolution. In this block we have several discriminators, with different thresholds, for the determination of valid, escape-gating signals and anti-coincidence events. All related pulses are generated here.
- b) The A/D conversion, made with traditional analog track-and-hold circuits, is done only on valid events, using a logic event validation network, in order to keep the dead time as low as possible.
- c) The data handling circuitry provides to the creation of digital data containing all the information relative to energy and timing, providing as well some flags to indicate single or double good events (i.e. fluorescence electrons), rejected events, etc.

From the platform we receive a very accurate absolute timing pulses (differential GPS receiver timing), that we will use for timing the events. The platform will have enough mass storage in order to keep all data in memory for its download when passing the tracking station(s). Telecommands coming from ground will be decoded on board; they can control the thresholds, the high voltages, etc.

Since on board we will have an Optical Monitor, the telemetry load will be rather high, so we suggest to check the possibility of using, together with the INTA's base of Maspalomas, also the ASI's Malindi base; this will ensure a telemetry coverage almost double as if only one base is used. The INTA's ground segment is already operative, it is the same used for Minisat 01, and probably will be upgraded with new generation, more powerful computers.

The use of Malindi base allows to reduce the orbit inclination of the satellite from 29°.5 to ~15°; with this orbit the cosmic X-ray background is drastically reduced.

The orbit of SIXE has been cleverly studied, avoiding as much as possible Van Allen belts and geo-magnetic anomalies, especially taking into account that during 2002-2004

Fig. 6 . The on-board electronics block diagram.

the Sun will be in its maximum sunspot activity; orbit altitude, excentricity and inclination have been optimized for a very high observation duty-cycle.

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