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The Indian multi-wavelength astronomy satellite

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Abstract. The Indian X-ray Astronomy Experiment (IXAE) is currently in operation on-board the IRS-P3 satellite launched by the PSLV-D3 rocket in 1996 March 21. Based on IXAE observations, several interesting results have been obtained so far, including possible evidence for matter disappearing behind the event horizon of a black hole in the superluminal Galactic X-ray source GRS 1915+105. Encouraged by the success of IXAE, a full-fledged satellite for astronomical observations is currently under consideration. A large area xenon filled proportional counter array (LAXPAC), a soft X-ray telescope (SXT), one X-ray sky monitor (XRM) and an UV/optical telescope (UVT) are being considered for inclusion in the Indian Multi-wavelength Astronomy Satellite (IMAS).

1. Introduction

Since the launch of UHURU, the first X-ray satellite (Giacconi et al., 1971), there has been spectacular progress in the field of X-ray astronomy. In Fig. 1 some major milestones in the developments of X-ray telescopes are shown in juxtaposition with developments in the

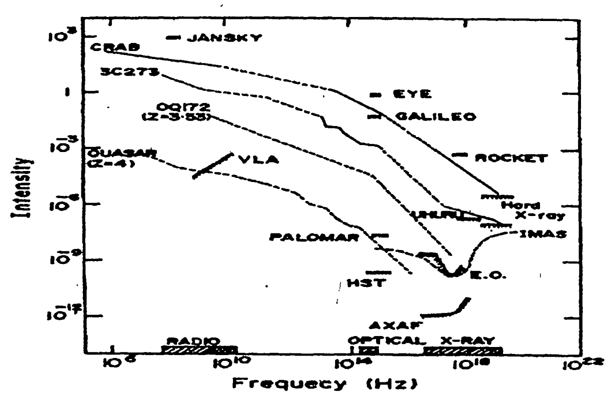

Figure 1. Sensitivity of X-ray telescopes starting from the first rocket flight (ROCKET) to the future AXAF satellite are shown along with those of UHURU (the first X-ray satellite) and Einstein Observatory (EO). For comparison, the improvements in senstivitiy of telescopes used in radio and optical wave-bands are shown. The typical spectra of CRAB and some quasars are also given in the figure.

optical and radio. From the first rocket flight, the improvement in the sensitivity of X-ray telescopes can be traced through UHURU, the Einstein Observatory (the first X-ray satellite to use focusing technique) and AXAF (to be launched in the near future. These improvements can be compared with the similar improvement in radio (from Jansky to VLA) and optical (from naked eye to Galileo to the Hubble Space Telescope). It can be truly said that study of any astrophysical object is incomplete without inputs from X-ray astronomy. X-ray wavelength, however, has a special niche in astrophysical studies because they closely trace high energy phenomena. Any accelerating site reveals itself in the X-ray wave-band since electrons, having a very low mass, are efficient emitters of X-rays. Further, the electrons thermalise and create plasma, whose emission can be studied to get a handle on the nature of the site of the astrophysical phenomena.

In the Indian scenario, opportunities to launch X-ray payloads of reasonable sensitivity were available only recently, after the spectacular success of the Polar Satellite Launch Vehicle (PSLV) series of rockets. The developmental flights of PSLV rockets gave an opportunity to include small sized piggy-back experiments in conjunction with the remote sensing payloads. Keeping in mind the weight, power and other requirements the Indian X-ray Astronomy Experiment (IXAE) was designed, developed and fabricated. Time variability in X-ray pulsars and other Galactic sources can be done using large area proportional counters with a narrow field of view collimator. Tracking of pulse period over a long period of time, measuring the pulse profile variations and obtaining the orbital elements of X-ray binaries and also a study of the time variability of binaries harboring black holes are the main objectives of IXAE.

2. Indian X-ray Astronomy Experiments (IXAE)

The Indian X-ray Astronomy Experiment (IXAE) on board the IRS-P3 satellite was launched on 1966 March 21 by the PSLV-D3 rocket from the Shriharikota range (SHAR), India. The development of IXAE was a joint effort between the Space Physics Group, TIFR, Mumbai and Technical Physics Division, ISAC, Bangalore with ISRO providing the launch, tracking and all other satellite related infra-structural facilities. IXAE includes three Pointed Proportional Counters (PPC) and one X-ray Sky Monitor (XSM). It includes microprocessor based processing electronics for each of the detectors. An optical star tracker based pointing system is used in a closed loop so that the PPCs can be pointed towards a desired X-ray source with a pointing accuracy of $< 0.1°$. The X-ray payloads, however, have to operate in a time-sharing mode with the remote sensing payloads of IRS-P3. The satellite is in an orbit of 830 km altitude and 98° inclination. This orbit skims through the inner radiation belt and hence is very background-prone. Typically the duty cycle of observation is 5-10% for the PPCs and 1-2% for the XSM (see Agrawal et al., 1997 for instrumental details).

3. Results

Several interesting sources like Cyg X-1, GRS 1915+105, 4U 1907+09, Vela X-1, GX 1+4 etc. were observed in the first year of operation of IXAE (Agrawal et al., 1996; Paul et al., 1997; Paul et al., 1998a; Rao et al., 1998). One of the most interesting results obtained using the IXAE data is the detection of several types of bursts from GRS 1915+105 (Paul et al., 1998b). GRS 1915+105 is a X-ray binary with a black hole as one of its components.

Similarities of its properties with quasars, like a radio jet with superluminal motion and correlated X-ray, radio and infrared variabilities, has prompted it to be called a mini-Quasar.

Recent progress in the understanding of accretion onto black holes has indicated a possible way of uniquely identifying black holes in X-ray binaries. It is found that the accretion disks around black holes are cooled by advection in their innermost parts and it has been realized that advection is one of the most fundamental features of the black hole accretion (Chakrabarti, 1996; Abramowicz & Percival, 1997). In the IXAE observations of GRS 1915+105 possible evidence for the direct detection of advection has been obtained. This is based on the detection of regular and persistent X-ray bursts from this source (see Figure 2). The bursts are different in temporal structure and regularity of occurrence from the classical bursts in Low Mass X-ray Binaries (LMXB). The bursts have a slow exponential rise and sharp decay. The sharp decay, which is the most significant difference from the bursts in neutron star sources, and the hardening of the spectrum as the burst progresses, indicate a possibility that we are observing the advection of matter into the black hole horizon (Paul et al., 1998b).

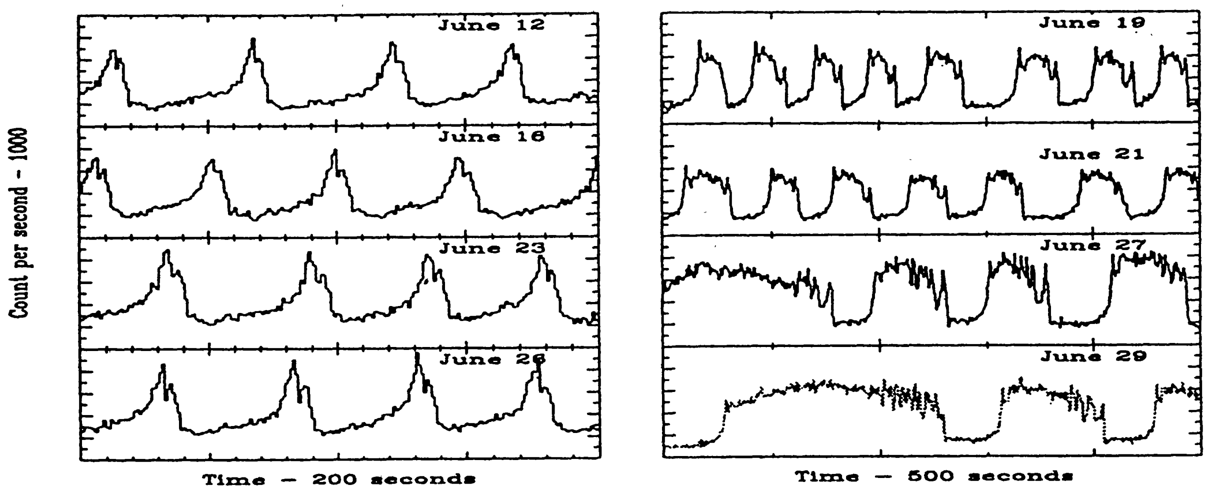

Figure 2. The regular (left panel) and irregular (right panel) bursts observed in GRS 1915+105 with one of the PPCs. Date of each observation is given in the respective panels

4. Indian Multi-wavelength Astronomy Satellite (IMAS)

Working groups with representations from most of the astronomical institutes in India were formed by Chairman, ISRO to examine the possibility of fabricating and launching an astronomical satellite in the near future. After several joint meetings, a consensus has emerged to fabricate a multi-wavelength astronomical satellite. The primary motivation was to make a top-of-the-class astronomical observatory with the best known and available technologies. For a Strawman concept, constraints applicable for a IRS class of satellite was assumed. In the given weight, size and time constraints the following instruments were found suitable for inclusion in IMAS.

The main X-ray instrument will be a Large Area Xenon-filled proportional Array Counter (LAXPAC) with a total area of 6000 cm². These will be high pressure xenon filled proportional counters giving a good energy response (2 – 80 keV) and reasonable energy resolution. A focusing Soft X-ray Telescope (SXT) with conical mirrors but with modest area (200 cm²) and good energy resolution (X-ray CCD) will provide complementary data at low energies. An X-ray Monitor (XRM), which is Proportional counter based, will be very useful to track ~ 100 bright X-ray sources with good sky coverage (~ π str.). Concurrently a wide field of view UV Telescope (UVT) of 50 cm aperture will give very useful information on astrophysical sources. The institutes across India which have taken up responsibility of making some part of the payloads are Tata Institute of Fundamental Research, Mumbai, ISRO Satellite Centre, Bangalore, Indian Institute of Astrophysics, Bangalore, Raman Research Institute, Bangalore, Bhabha Atomic Research centre, Mumbai, IUCAA, Pune and Physical Research Laboratory, Ahmedabad.

The combined sensitivity of the various detectors of IMAS are schematically shown in Figure 1. One of the unique features of IMAS will be the reasonable sensitivity across a large wave-band. The 0.3 to 80 keV X-ray spectral studies are expected to yield significant results in a variety of astrophysical sources like X-ray binaries, active galactic nuclei (AGN), cataclysmic variables etc. An example of a simulated spectrum of a Seyfert 1 galaxy, NGC4151, in an observation of about 50,000 s is shown in Fig. 3. The input spectrum includes a power-law spectrum, its reflection from a cold slab of matter obscuring 35% of the power-law source,

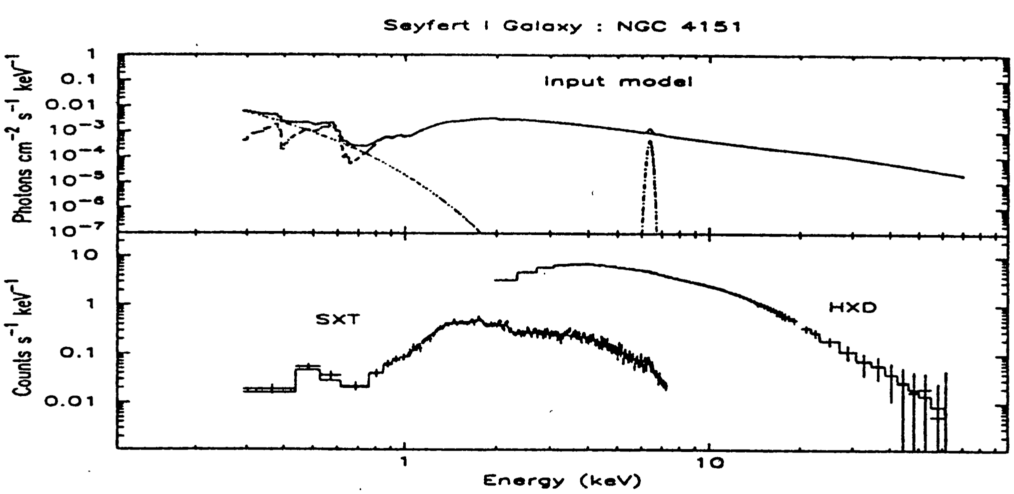

Figure 3. The simulated spectrum of the Seyfert galaxy NGC 4151 (top panel) including several spectral components (see text). The expected counts in the soft X-ray telescope (SXT) and the hard X-ray detectors (HXD) of IMAS are shown in the lower panel. The histogram in the lower panel is the best-fit spectrum obtained by χ^2 minimization which 'recovers' most of the input components

a narrow iron line at 6.4 keV, an ionized absorber and a soft excess represented as a low energy bremsstrahlung of temperature 0.2 keV. The 2 – 10 keV flux is normalized to that obtained from an ASCA observation (Weaver et al., 1994). The simulated spectrum (shown in the top panel of the figure) is folded through the expected response of the detectors and the predicted count spectrum is shown in the bottom panel of the figure. A combined fit to the simulated data shows that all the components are necessarily required to get an acceptable value of χ^2 and without the wide bandwidth of observation some of the components will not be distinguished. Similarly, the simultaneous measurement of UV flux is expected to yield very interesting information on several astrophysical objects like AGNs, CVs, stellar flare etc. In the first year of operation of IMAS an all sky survey is envisaged and this will be the first all sky survey in the UV band.

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