COMMISSION N°48 : HIGH ENERGY ASTROPHYSICS (ASTROPHYSIQUE DES HAUTES ENERGIES)

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I. X-RAY ASTRONOMY

The european X-ray observatory (EXOSAT), which was launched in 1983 and which finished operations in April 1986, has brought a rich harvest of results in the period 1984-1987, surveyed here. The EXOSAT payload consisted of three sets of instruments : two low energy imaging telescopes (LE:E<2 KeV), a medium-energy experiment (ME:E=1-50KeV) and a gas scintillation proportional counter (GSPC:E=2-20KeV). Over most of the energy range covered, EXOSAT was not more sensitive than its predecessor, the american EINSTEIN satellite. But the EINSTEIN satellite is far from having exhausted the treasures of the X-ray sky. And EXOSAT, thanks to its elliptical 90-hour orbit, had the extra advantage of being able to make long, continuous observations of interesting objects, lasting up to 72 hours. Thus, EXOSAT was very well suited for variability studies, and many of its most important findings are in this area. EXOSAT observations sample a wide range of astrophysical sources : X-ray binaries, cataclysmic variables and active stars ; supernova remnants and the interstellar medium ; active galactic nuclei, and clusters of galaxies. Among the highlights, let us mention :

- the detection of quasi-periodic oscillations (QPO) in seven well known X-ray sources, starting with the galactic bulge source GX 5-1, and including Sco X-1, the brightest X-ray source in the sky, Cyg X2 and the Rapid Burster. The majority of the QPO sources are very luminous ($>10^{38}$ erg/sec), and the oscillations are strong (5% rms variation in flux), persistent ($> 10^5$ cycles), and take place at high frequency (5-50 Hz). Other characteristics of the QPO, however, such as their relation to the source intensity or the spectral shape, vary widely from source to source. QPO sources are believed to be binary systems containing a neutron star, and the models proposed generally involve interactions between the accretion disk and the neutron star magnetosphere.

- the mapping out of the X-ray galactic ridge in the 2-6 KeV band. The "ridge" is a disk of radius 10 to 12 Kpsec and a height of a few hundred parsecs ; its total luminosity is 10^{38} erg/sec.

- the detailed observations of active galactic nuclei (AGN), revealing, in some cases, the presence of a soft X-ray component, in the .05-1 KeV range. Long term monitoring of AGN allowed to study their variability on timescales from minutes to years. For NGC 4151, the flux in the 2-10 KeV band can vary by a factor 2 over periods of six months, while the soft component remains constant. A possible interpretation is that the soft component originates in a hot intercloud medium in the narrow-line region, while the hard X-ray flux is emitted by regions surrounding the nucleus. EXOSAT observations indicate that rapid variability, on time scales of the order of an hour, is frequent in AGNs.

The results obtained by EXOSAT have found a useful complement in those obtained by the japanese satellite TENMA, which was launched in 1983. The main instrument on board of TENMA consists of two sets of four Gas Scintillation Proportional Counters, which attain maximum efficiency in the range 1.5-35 KeV, and yield a spectral resolution ~ 9% at 6 KeV. The most interesting results obtained with the TENMA satellite concern the iron line spectroscopy.

Iron lines in emission have been detected in a wide variety of sources, including AGN, clusters of galaxies, SNR and X-ray binaries. TENMA has also taken spectra of the galactic ridge ; the spectra have a characteristic thermal shape, and in most of them the helium-like iron line is present at 6.7KeV, at about the expected intensity for a normal Fe abundance. The temperatures derived from the spectra are in the 5-10 KeV range. It is difficult to explain the galactic ridge as a superposition of small sources ; it seems more likely that the existence of a new, perhaps transient, very hot phase of the interstellar medium has been revealed.

In many sources, the iron K-edge absorption feature at ~ 7.2 KeV has also been measured by TENMA. This is important because, by comparison with the soft X ray photoelectric absorption, it allows to measure the iron abundance. TENMA observations of galactic massive binaries and of a few AGN indicate that their Fe abundance is normal.

II. COSMIC GAMMA RAYS

The analysis of the data of the Cos B satellite has been pursued by various groups ; the activity has been centered on the detailed comparison of the gamma ray data with observations of atomic and molecular hydrogen, taking advantage of the new CO survey of the Columbia group. In September 1985, the Cos B data base has been released ; it is now available for the whole scientific community.

New results have been obtained in gamma ray spectroscopy. Line emission due to the decay of the radioactive isotope ^{26}Al, at 1.809 MeV, has been observed by the gamma ray spectrometers on board of the HEAO 3 and SMM satellites, and confirmed by several balloon experiments. A diffuse ^{26}Al line is expected from the interstellar medium ; novae, Wolf-Rayet stars, and, to a lesser extent, supernovae should contribute to it.

Recent observations by SMM of the electron-positron pair annihilation radiation around 511 KeV suggest the existence of an extended steady source of this radiation, super imposed to the central, highly variable point source which had been discovered earlier. This emission implies the presence of a background of positrons, whose origin is still open to debate. They may be products of the decay of radioactive nuclei, such as ^{44}Ti, or perhaps ^{56}Ni from supernovae, or ^{26}Al from novae and Wolf-Rayet stars ; or they may be accelerated and ejected by pulsars.

Much excitement has been generated in the high energy community these last years over the detection of very high energy (TeV range) and ultra high energy (PeV range) gamma ray emission from X-ray binaries such as Cyg X-3 and Her X-1. At such energies, the observations are made from ground, using the atmospheric Cerenkov technique for TeV gamma rays, and arrays of particle detectors for PeV gamma rays. The fluxes measured for X-ray binaries are always close to the limit of detection of the instruments used, and these observations await for confirmation from more powerful installations.

Two groups have reported detection of muons from Cygnus X-3 with proton decay experiments, but other experiments, obtained upper limits lying below the detections claimed.

III. COSMIC RAYS

Many aspects of the mechanism of particle acceleration by diffusive shock waves have been examined in detail : effect of oblique waves ; of stellar wind terminal shocks ; dynamic effects and damping of cosmic-ray generated waves, etc.

A complete, but approximate, time-independent solution to the problem of cosmic-ray dominated shocks has been developed ; for interstellar conditions, the spectrum predicted is close to a power law of index (-2), and the efficiency of acceleration is ~ 25%.

IV. PROSPECTS FOR THE NEAR FUTURE

In the very near future, much attention will be devoted to observations of high energy radiation from supernova 1987A, and their interpretation. Predictions have been made by many groups for the flux and flux variations expected in the framework of various models : comptonisation of the cobalt decay line radiation, of the radiation from a central pulsar ; radiation associated to newly accelerated particles, etc. The japanese-british large area proportional counter, on board of the japanese Ginga satellite, and the european-soviet payload Roentgen on board of the Qvant module attached to a MIR station, are operational now, and can measure this radiation respectively in the range 0.5-20 KeV and 2-1500 KeV.

In the next year and a half, many hard-X and γ ray experiments (most often american) will be flown by balloons over the southern hemisphere, to measure the continuum and, hopefully, the gamma-ray line emission from SN 1987A. The SMM satellite may also contribute to this search.

In 1988, two satellites will be launched by the Soviet Union, which are devoted to high energy astrophysics : the soviet-french-polish experiment GAMMA 1, for observations of gamma rays of energy >50 MeV, and GRANAT, which will carry soviet and danish X-ray experiments, soviet and french gamma ray-burst experiments, and the french gamma-ray camera SIGMA (30 KeV-2 MeV).

Important advances are also expected for ground gamma ray astronomy in the TeV range, since new and sophisticated detector systems will be put in operation all over the world.

It is only towards the end of the decade that other missions, delayed by the consequences of the Challenger accident, will be launched, such as the german ROSAT soft X-ray satellite, the american Gamma Ray Observatory, the european ULYSSES which carries the most promising cosmic-ray experiments to be flown in the near future...

More details about these and other topics of high energy astrophysics can be found in the proceedings of the following meetings :

X-Ray Astronomy in the EXOSAT era.
(edited by A. Peacock)
Space Science Reviews, N°1-4 (1985)

The physics of accretion onto compact objects.
(edited by K.O. Mason, M.G. Watson and N.E. White)
Springer-Verlag, Lecture Notes in Physics, n°266 (1986)

High Energy Phenomena around Collapsed Stars.
(edited by F. Pacini)
NATO ASI Series, Reidel (1987)

Proceedings of the 19th International Cosmic Ray Conference,
La Jolla, August 1985

Proceedings of the 20th International Cosmic Ray Conference,
Moscow, August 1987.

Gamma-Ray Astronomy
(edited by K. Hurley and G. Vedrenne)
Advances in Space Research, Vol.6 n°4, Pergamon Press (1986).

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