X-RAY-ASTRONOMY

Design and in Orbit Performance of the Position Sensitive Proportional Counter on Board the X-Ray Astronomy Satellite ROSAT

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ABSTRACT

The Position Sensitive Proportional Counter (PSPC) was the prime focal plane instrument on board ROSAT. It was a conventional multi-wire counter, operating in an energy range from 0.1 to 2.4 keV. The counter gas was a mixture of 65%Ar, 20%Xe and 15%CH_4 at a pressure of about 1.5 bar, replenished at a flow rate of 2.5 stcm^{3}min^{-1}. At 1 keV the detector had an energy resolution of $\Delta E/E$ = 0.41 FWHM, a position resolution of 230 µm FWHM and a quantum efficiency of 50%. The background rejection capability of the detector in space environment was 99.85%. Within the first four years of the mission the PSPC has been used for 80% of the observing time. Thereafter the gas supply was nearly exhausted and the PSPC was used only for special observations. The drop of the gas gain of the detector during the whole mission was 10%. After eight years a final observation with the PSPC has been carried out with an extremely reduced gas flow and at the boarder of the radiation belts with a very high particle background. During this observation the detector probably suffered a discharge and within several days an increasing area with 50% gain loss developed. We will report about the detector design, the in orbit performance of the PSPC and some results of the ROSAT mission.

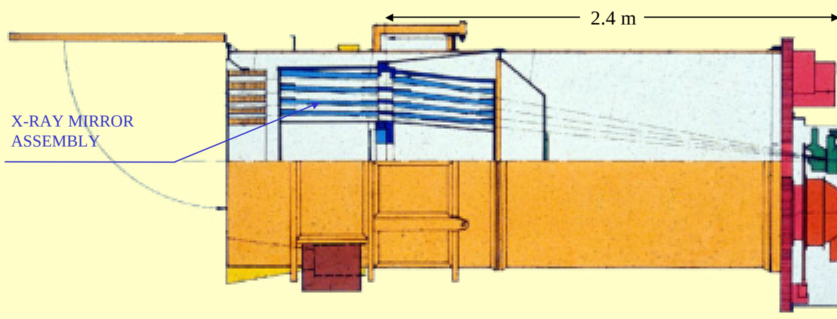


Fig. 1: Schematic cross section of the X-ray telescope of ROSAT

INTRODUCTION

ROSAT (RÖNGEN SATELLIT) [1] is a German X-ray satellite with major contributions from UK (UV-telescope) and USA (HRI-detector and satellite launch). The satellite was launched in 1990 and operated for more than eight years in orbit. The main scientific objective of the ROSAT mission was the performance of the first X-ray all sky survey in the energy band from 0.1 to 2.4 keV with an imaging telescope. After completion of the survey ROSAT was used in pointed mode for detailed observations of selected objects. The main scientific payload of ROSAT was an imaging X-ray telescope with a fourfold nested Wolter type 1 mirror system with a maximum aperture of 83 cm and a focal length of 2.4 m. The focal plane instrumentation [2] carried two different types of X-ray image detectors, which complement one another: two redundant Position Sensitive Proportional Counters (PSPC) with a sensitive area of 8 cm diameter, and one High Resolution Imager (HRI) based on micro channel plates, with a sensitive area of 2.5 cm diameter. The detectors are mounted on a carousel, which allows the positioning of the desired detector in the focus of the mirror system. Except for the HRI, the whole focal plane instrumentation was developed and built in our institute.

Fig. 2a: The wire grid system of the PSPC . The ceramic frames have a size of 20 cm x 20 cm. The detector housing is removed.

Fig. 2b: The completely integrated PSPC. On top of the detector housing is a filter wheel with four positions. One position holds a vacuum door with three calibration sources.

DESIGN AND PERFORMANCE OF THE DETECTOR

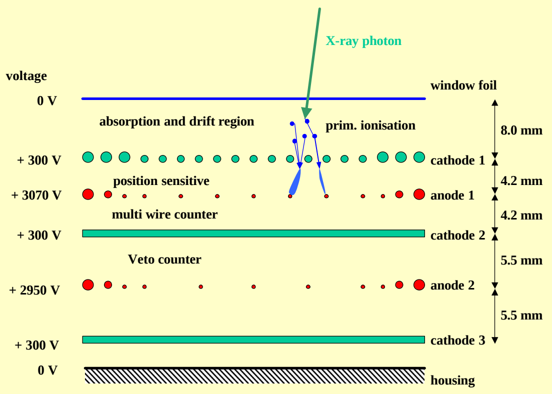


Fig. 3: **Schematic diagram of the grid system**.

WIRE GRID PARAMETERS

Anode grids: 10µm tungsten wires with 1.5mm pitch for anode 1 and 2mm for anode 2. Side wires have increasing diameters. The signal of anode 1 is used as trigger for readout and for the energy measurement of an event.

Cathode grids: 50µm platinum iridium wires with 0.5mm pitch. Cathode1 and cathode 2 are electrically subdivided in strips of 3.5mm width for the position readout of the events by the center of gravity method. Cathode1 and cathode 2 are mounted orthogonal to each other for the readout of both coordinates of the events.

DETECTOR GAS

Composition: 65% Ar, 20% Xe, 15% CH_4; **Purity:** C_nH_m<1 vpm, O_2< 0.5 vpm, H_2O < 1 vpm, Kr < 0.5 vpm, N_2 < 5 vpm; **Gas pressure:** 1466 mbar at 22 °C; **Flow rate:** selectable by telecommand 2.5 – 5 std cm^3 min^{-1}, normal 2.5 std cm^3 min^{-1}; **Regulation:** Gas density regulation. Reference is a sealed volume in the detector housing. **Regulation accuracy:** ± 1mbar.

ANTICOINCIDENCE SYSTEM FOR BACKGROUND REJECTION

By using the signals of anode2 and the outer strips of cathode1 and cathode2 in anticoincidence, a five sided anticoincidence is realized. The experiment electronics checks the signal patterns of cathode1 and cathode2 .

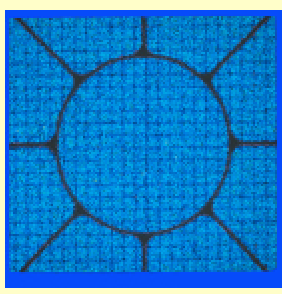


Fig. 4: Flat field illumination with 0.93 keV X-rays; shadow of the window support structure and the 100 µm support wires..

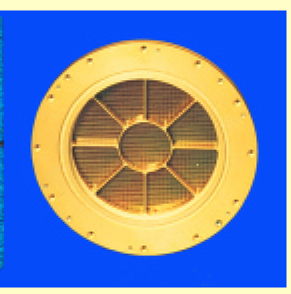


Fig. 5: Detector widow : 1µm polypropylene foil with carbon and lexan coating

AGING EFFECTS DURING 8 YEARS IN ORBIT

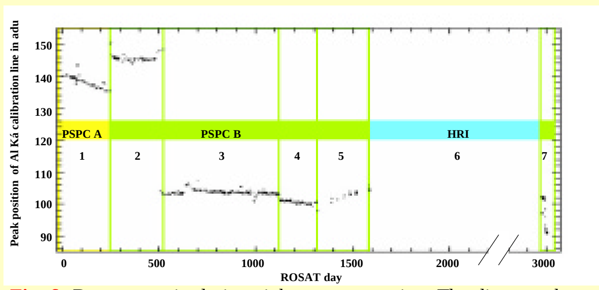


Fig. 6: Detector gain during eight years operation. The diagram shows the peak position in adu channels of the 1.5 keV Al Ka line of the calibration source (Al fluorescence excited by an Fe^{55} source).

Period 1: PSPC A showed a stronger gain decrease compared to PSPC B. PSPC A has been destroyed after 8 month of operation, when the telescope had an accidental short look into the sun.

Period 2: Redundant PSPC B with nominal high voltage setting.

Period 3: Reduced high voltage due to a warm spot with 0.5 cts/s.

Period 4: Same HV setting with reduced gas flow to save gas.

Period 5: Alternating observations between HRI and PSPC with outgassing of the PSPC during HRI observations.

Period 6: Only HRI observations. Gas for PSPC nearly exhausted.

Period 7: PSPC with a factor 20 reduced gas flow.

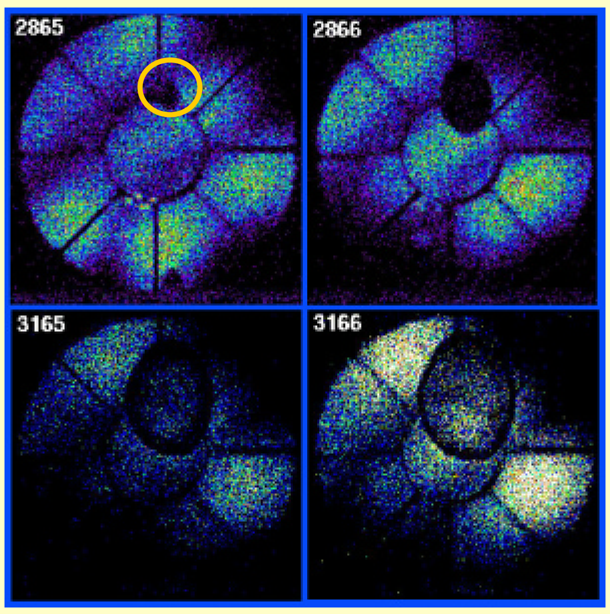
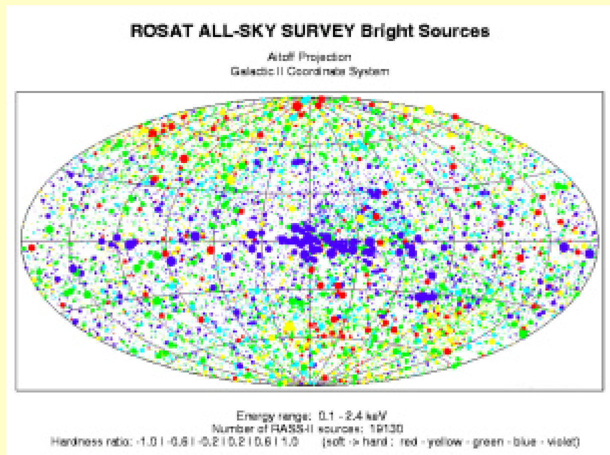


Fig. 7: X-ray images of the 1.5 keV calibration sources during the last days of the ROSAT mission. A hot spot developed in the upper part of the image, probably caused by the extremely reduced gas flow and the high particle flux in the radiation belts. This area increased rapidly [4].

RESULTS OF THE ROSAT MISSION



With more than eight years of active observing time (Jun. 1990-Feb. 1999) ROSAT has been so far the most fruitful X-ray astronomy observatory. The ROSAT mission increased the number of known celestial X-ray sources form several 10^3 over more than 10^5. But ROSAT not only contributed to the number of known X-ray sources. Due to the high background rejection efficiency and the good energy resolution of the PSPC four-colour X-ray images of all types of objects like the near moon, comets, normal stars, binary systems, supernova remnants, galaxies, cluster of galaxies and the most distant quasars could be measured with high contrast. After the sky survey about 10^4 pointed observations has been carried out, which led to more than 4500 scientific publications.

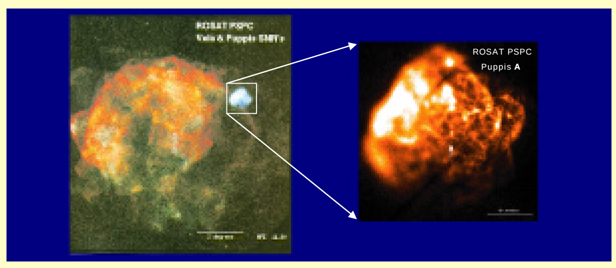


Fig. 8: X-ray images of the supernova remnants Vela and Puppis A.

ACKNOWLEDGEMENTS

The ROSAT project is supported by the Deutsches Zentrum für Luft und Raumfahrt (DLR) .

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[4]Freyberg M. J., priv. communication.

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