THE MIRAX X-RAY TRANSIENT MISSION: RECENT DEVELOPMENTS

João Braga[1], Jorge Mejía[1], Flavio D'Amico[1], Francisco Jablonski[1], Richard Rothschild[2], John Heise[3], Jean in 't Zand[3], Rdiger Staubert[4], Eckhard Kendziorra4[4], Jrn Wilms[5], Ron Remillard[6], Erik Kuulkers[7], and Eduardo Janot-Pacheco[8]

[1]Instituto Nacional de Pesquisas Espaciais (INPE), Av. dos Astronautas 1758, S. J. Campos, SP 12227-010, Brazil
[2]University of California San Diego (UCSD), 9500 Gilman Dr., La Jolla, CA 92093-0424, USA
[3]Space Research Organization Netherlands (SRON), Sorbonnelaan 2 3485 CA Utrecht, The Netherlands
[4]Institut für Astronomie und Astrophysik (IAAT), Sand 1, Tbingen 72076, Germany
[5]University of Warwick, Coventry CV4 7AL, United Kingdom
[6]Massachusetts Institute of Technology (MIT), 70 Vassar St., Cambridge, MA 02139, USA
[7]Integral Science Operations Centre (ISOC), European Space Astronomy Centre (ESAC), Apartado 50727, 28080 Madrid (Villafranca del Castillo), Spain
[8]Instituto de Astronomia, Geofísica e Ciências Atmosféricas (IAG), Universidade de São Paulo (USP), Rua do Matão 1226, Cidade Universitária, São Paulo, SP 05508-900, Brazil

ABSTRACT

The Monitor e Imageador de Raios-X (MIRAX) is a small (∼250 kg) X-ray astronomy satellite mission designed to monitor the central Galactic plane for transient phenomena. With a field-of-view of ∼1000 square degrees and an angular resolution of ∼6 arcmin, MIRAX will provide an unprecedented discovery-space coverage to study X-ray variability in detail, from fast X-ray novae to long-term (∼several months) variable phenomena. MIRAX's instruments will include a soft X-ray (2-18 keV) and two hard X-ray (10-200 keV) coded-aperture imagers, with sensitivities of ∼5 and ∼2.6 mCrab/day, respectively. MIRAX is an approved mission of the Brazilian Space Agency (Agncia Espacial Brasileira - AEB) and is scheduled to be launched in 2011 in a low-altitude (∼550 km) circular equatorial orbit. In this paper we present recent developments in the mission planning and design, as well as Monte Carlo simulations of the instrumental background performed using the GEANT-based MGGPOD package.

1. INTRODUCTION

The "Monitor e Imageador de Raios-X" (MIRAX) is a high-energy astrophysics satellite mission which is part of the Scientific Satellite Program at the National Institute for Space Research (INPE) in Brazil. MIRAX has been selected to be the astrophysics mission within this program and has been approved for development by the Brazilian Space Agency (AEB). Since the Brazilian astronomical community is mostly devoted to the fields of optical and radio astronomy, the development and operation of MIRAX is expected to have a major impact on Brazilian science through the opening of a new observation window for astrophysical research.

The MIRAX project has strong international partnerships. The University of California in San Diego (UCSD) will provide the hard X-ray detectors and participate in the design of the hard X-ray cameras; the Space Research Organization Netherlands (SRON) will provide the soft X-ray imager; the Institut für Astronomie und Astrophysik of the University of Tbingen (IAAT) will provide the on-board computer and participate in software development; and the Massachusetts Institute of Technology (MIT) and the University of Warwick will participate in software development for data acquisition, analysis, storage and distribution.

The main scientific goal of MIRAX is the nearly continuous (9 months per year) , broad-band (2 to 200 keV), high-resolution (∼5-7 arcminutes) monitoring of a specific large region of the sky that is particularly rich of X-ray sources (a 76° x 44° total field centered on the Galactic center and oriented along the Galactic plane). This will not only provide an unprecedented monitoring of the X-ray sky through simultaneous spectral observations of a large number of sources, but will also allow the detection, localization, possible identification, and spectral/temporal study of the entire history of transient phenomena to be carried out in one single mission. With the planned continuous monitoring approach, MIRAX will address key issues in the field of X-ray variability such as black hole state transitions and early evolution, accretion torques on neutron stars (especially through monitoring of X-ray pulsars), relativistic ejections on microquasars and fast X-ray novae. MIRAX will also be able to contribute to Gamma-Ray Burst (GRB) astronomy, since it is expected that $\sim$1 GRB will be detected per month in MIRAX's field-of-view (FOV). MIRAX instruments are expected to be assembled in a dedicated small ($\sim$250 kg) satellite to be launched in a low altitude, equatorial circular orbit around 2011.

2. MIRAX INSTRUMENTS

2.1. The Hard X-Ray Imagers

The HRIs will be built in collaboration with CASS and will operate from 10 to 200 keV. The detector plane will be a 3 x 3 array of state-of-the-art CdZnTe crossed-strip detector modules with 0.5 mm spatial resolution developed at CASS, with a total area of 360 cm^2. Each detector module is a 2 x 2 array of 32 mm x 32 mm x 2mm thick CZT detectors. The detectors will be surrounded by an active plastic scintillator shield and by a passive Pb-Sn-Cu graded shield. A 315 mm $\times$ 275 mm Tungsten coded-mask with 1.3 mm-side square cells (0.5 mm-thick) will be placed 600 mm away from the detector to provide images with 7'30" angular resolution. The basic pattern of the mask will be a 139 x 139 Modified Uniformly Redundant Array (MURA - Gottesman and Fenimore 1989; Braga et al. 2002), which will allow for full shadowgrams to be cast on the position-sensitive detector area and will provide no source ambiguities in the fully-coded field-of-view (FCFOV).

The pointing axes of the two HXIs will be offset by an angle of 29° in order to provide a uniform sensitivity over a 39° FCFOV in one direction; the perpendicular direction will have a 6°12' FCFOV. In such a configuration the FWHM FOV is 58° x 26°. During the observations of central Galactic Plane, the wider direction of the FOV will be aligned with the GP.

2.2. The Soft X-Ray Imager

The SXI, provided by SRON, is the spare flight unit of the Wide Field Cameras (WFCs - Jager et al. 1997) of the BeppoSAX mission (Boella et al. 1997), and will operate from 1.8 to 28 keV. The CXM will have a 5' angular resolution in a 20° $\times$ 20° FWHM FOV. The addition of the WFC to the MIRAX payload will provide soft X-ray spectral coverage which will be extremely important for the study of the several classes of sources in the MIRAX FOV. Furthermore, the excellent perfomance of the WFCs on BeppoSAX brings to MIRAX an instrument that has already been tested and used very successfully in orbit with very little degradation on a time scale of several years.

3. SIMULATIONS AND HXI SENSITIVITY

Simulations of the hard X-ray imager instrumental background in orbit were carried using the MGGPOD Monte Carlo simulation code (Weidenspointner et al., 2004), a user-friendly suite built around the widely used GEANT package. It provides the results of the interactions of the various radiation fields within the instruments and spacecraft materials. With the knowledge of the instrumental background and the diffuse aperture X-ray flux, we performed detailed image simulations of the central Galactic plane as seen by MIRAX, for several instrument configurations and integration times. Preliminary results indicate that MIRAX will be able to detect a variety of systems, both transient and persistent.

The HXI sensitivity can be estimated based on the expected background level in the low-orbit environment, which is about 20 cts/s for a single imager. The Crab nebula plus pulsar photon count rate will be $\sim$108 cts/s. Taken the approximate total contribution of sources in the primary MIRAX FOV (central GP) to be about 1 Crab, the MIRAX sensitivity is expected to better than 2 x 10^{-5} photons cm^{-2} s^{-1} keV^{-1} at 100 keV (5σ) , or $\sim$2.6 mCrab/day in the 10-100 keV range ($\sim$ 40 times better than the Earth Occultation technique of the Burst and Transient Source Experiment on CGRO). The HXIs will have a one-year "survey" sensitivity, considering a conservative systematics limit of 0.1% of background, of about 10^{-11} erg cm^{-2} s^{-1} in the 10–50 keV band. This is $\sim$20 times better than what was achieved by the HEAO 1 A-4 instrument, which carried out the only hard X-ray survey to date (Levine et al., 1984).

In summary, MIRAX will be able to make very unique contributions to the study of energetic transient phenomena in astrophysics by virtue of its observing strategy, which departs significantly from traditional pointed programs and scanning monitors. MIRAX will detect, localize, identify and study unpredictable phenomena which last on the timescales of minutes to days, which would otherwise be missed by traditional observing strategies. In addition, MIRAX will be able to study longer-lived phenomena in exquisite detail from 2-200 keV.

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