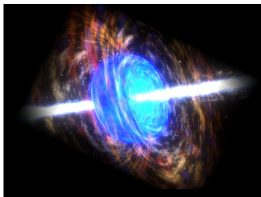
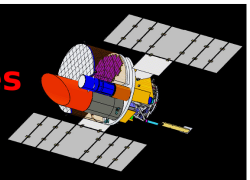


EXIST: Surveying the birth and evolution of Black Holes

ProtoEXIST1



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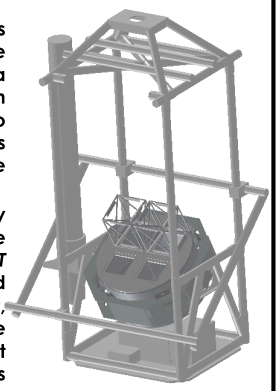
Introduction

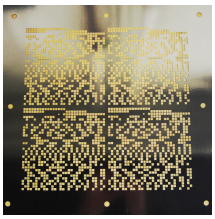
ProtoEXIST1 is the first in a series of balloon-borne experiments for the development of the High Energy Telescope (HET) on the Energetic X-ray Imaging Survey Telescope (EXIST). EXIST is a next-generation wide-field hard X-ray survey mission with onboard X-ray/Optical/IR imaging/spectroscopy capability to explore the birth and evolution of black holes on all scales (see 217.03 and 435.04). The HET is a coded-aperture telescope employing a large-area CdZnTe detector (4.5m^2).

The feasibility of the construction and operation of a large array of tiled, finely pixellated CZT imaging detectors, as will be required for the EXIST HET, is the primary goal of the *ProtoEXIST* program. The *ProtoEXIST1* payload consists of two coded aperture telescopes, each with a 256 cm^2 CZT detector, a 10x10 deg field of view and an angular resolution of ~10' (the pressure tank is designed to accommodate 4 independent telescopes for the future). The first flight out Ft. Sumner, NM is scheduled for the spring of 2009.



Coded Mask and Shield

A coded-aperture telescope employs shadowgram imaging modulated by a coded mask. The mask patterns on both *ProtoEXIST1* telescopes are 2x2 cycles of 32x32 pixel Uniformly Redundant Arrays (URA) of 4.8mm pixel elements, for an image oversampling factor of ~2. They are made of 10 stacked 41x41 cm sheets of 0.3mm Tungsten (99.9%), each precision-etched with the URA pattern, for a total thickness of 3mm, which effectively modulates photons of up to ~300 keV.

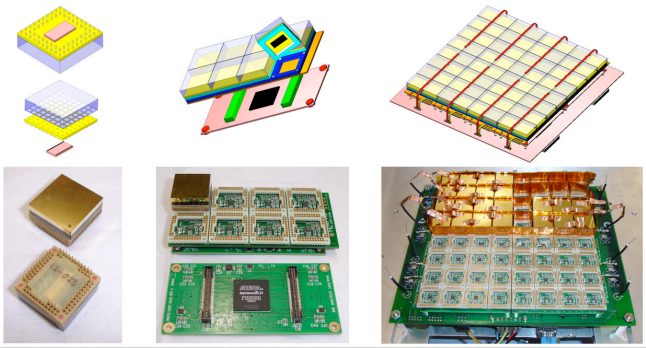


Both telescopes feature passive side shielding based on the graded Z-shield used for *Swift*-BAT and composed of layers of Pb/Ta/Sn/Cu. For the first flight, one telescope will employ passive rear shielding, while the other will utilize a 2cm thick CsI anti-coincidence shield. This will provide a comparison of efficiencies in vetoing rear gamma-ray and particle-induced background events.

CZT Detector Plane Configuration

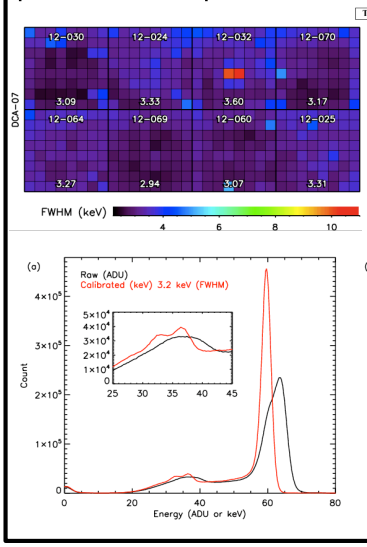
The construction of a large CZT detector plane is achieved through the modularization scheme depicted below. Each CZT crystal (2x2x0.5 cm^3) is bonded to a RadNet ASIC with 64 channels through an interposer board, forming a Detector Crystal Unit (DCU). DCUs are then packed into a 2x4 Detector Crystal Array (DCA, 32cm^2). Finally, a 2x4 array of DCAs and the motherboard constitute the full Detector Module (DM, 256 cm^2) of a *ProtoEXIST1* telescope. For the *ProtoEXIST1* phase of the development program, we employ 2.5mm pitch Redlen CZT crystals (64 pixels/crystal), and the 0.5cm thickness covers the range 20–600 keV. The figure below right shows the DM initially populated with 22 DCUs, separated by 0.4mm gaps between crystals for efficient packaging. RF side shields are employed in order to minimize RF interference between neighbouring DCUs.

(a) Detector Crystal Unit: DCU, 4 cm^2 (b) Detector Crystal Array: DCA, 32 cm^2 (c) Detector Module: DM, 256 cm^2



Detector Performance

Each detector is read out utilizing the Caltech RadNet ASIC, which enables the simultaneous readout of multiple pixel pulse profiles and allows for the reconstruction of energy, position, and the X-ray interaction depth in the CZT. Reconstruction of these quantities also makes possible the measurement of polarization for Compton scattered events.

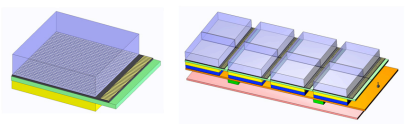


Displayed in the top-left panel is the resolution map from a single DCA on the detector plane, which shows an average energy resolution of 3.1 keV (FWHM) at 59 keV. For the top-right figure, an ^{241}Am source was shined through a 3 mm thick Pb mask with the word "EXIST" etched into it, in order to demonstrate the imaging capability of the tiled DCA array. The left panel shows the summed pulse height histogram of raw (black) and calibrated (red) data.

Future Work

In order to demonstrate the CZT detector technology required for the EXIST HET (0.6cm pixel pitch, 4.5m^2 total area), *ProtoEXIST2* will employ the DB-ASIC for NuSTAR with 1024 channels. In this configuration (2x2 cm^2, 0.6 mm pixel pitch) CZT detectors will be read out through a 1:1 interposer board coupled to a DCA controller board. The DCU and DCA modules for *ProtoEXIST2* are illustrated in the figure to the immediate right. In *ProtoEXIST3* the DB-ASIC will be superseded by the EX-ASIC (a 20μW/pixel version of the DB-ASIC) and the gaps required for the DB-ASIC readout channels will be removed to enable gapless tiling. For *ProtoEXIST2* and 3 we will make use of all 4 independent telescope modules available in the *ProtoEXIST* pressure vessel, in order to test multiple 256 cm^2 detector configurations in a near-space environment.

(a) *ProtoEXIST2* DCU (b) *ProtoEXIST2* DCA



This work supported by NASA grant NNGC06WC12G