EPIC

European (X-Ray) Photon Imaging Camera

a Proposal submitted to the European Space Agency
for the **XMM Cornerstone Mission**

Principal Investigator: Giovanni F. Bignami

Istituto di Fisica Cosmica e Tecnologie Relative del CNR
Via Bassini,15
20133 MILANO ITALY
Tel.2-2367587 FAX 2-2362946 TELEX 313839 MUACNR

Co-Investigators

Ist. Fisica Cosmica T.R./CNR, Milano	G. Boella, G. Bonelli, L. Chiappetti, G. Villa
Ist.Tec. St. Rad. Extr./CNR, Bologna	G. Di Cocco, M. Trifoglio
Ist. Astrof. Spaziale/CNR, Frascati	P.Ubertini
Ist.Fisica Cosmica A.I./CNR, Palermo	G. Manzo, L. Scarsi
Osservatorio Astronomico, Palermo	G.Peres, S. Sciortino
Serv.d'Astrophysique/CEA, Saclay	M. Arnaud, C. Cesarsky, L. Koch-Miramond J. Paul, R. Rothenflug, L. Vigroux
Inst.d'Astrophysique Spatiale, Orsay	E. Falgarone, B. Foing, A. Gabriel
Cent. Etud.Spat. Rayon., Toulouse	J.L. Atteia, P. Mandrou
Physics Dept.,University, Leicester	D.Lumb, K.Pounds, J. Pye, M. Turner, R.Warwick, A. Wells
School of Phys. Univ., Birmingham	C. Goodall, G. Skinner, P. Willmore
MPI für Physisk and Astrophysik:	
-MPE, Garching	W.Pietsch, P. Predehl, C. Reppin, L.Strüder, J.Trümper
-Heisenberg Inst., München	G. Lutz
Astronom.Inst. der Univ., Tübingen	E. Kendziorra,R.Staubert

Associate Scientists:

G. Setti (ESO, Garching), G.C. Perola (IOA,Roma),
J.P.Lasota (DARC,Meudon),R. Rocchia(CFR/CEA, Gif-sur Yvette)
P.Biermann (MPIfR ,Bonn), G.Morfill (MPE,Garching)
S.Murray, D. Schwartz (CfA, Cambridge,MA)

Part 1: Scientific/Technical Plan

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EXECUTIVE SUMMARY

The EPIC (European Photon Imaging Camera) is proposed as an instrument devoted to performing imaging and spectroscopy of the X-ray sky with the ESA XMM mission. Conceived as a "cornerstone" of the Agency's "Horizon 2000" strategic plan, XMM is due to fly in the 1998 time frame as an astronomical facility characterized by an X-ray focussing optics of unprecedented throughput in the domain ~0.1 to 10 Kev and of adequate spatial resolution. The need for an imaging/spectroscopy focal plane instrument as the central part of the XMM mission was recognized early, and has been well studied by the Agency and the astronomical community, as documented in the Mission Science Report (ESA SP 1097), and in the Instrument Working Group Report (ESA SP 1092). From such work, a CCD-based detector emerged as the optimum choice. Indeed, there is now worldwide agreement that the usage of such detectors for future X-ray astronomy holds great promise because of the capability of coupling imaging, based on single photon counting, with the energy resolution typical of silicon solid state detectors.

Our proposing collaboration includes Institutes (from 3 European Countries) which are at the forefront of the instrumental development of CCDs for X-ray astronomy. For the XMM/EPIC program we have chosen to maintain, through the EOB phase, a parallel development of two basic detector types: the frame-transfer, based on the "standard" European TV format, and the more novel "pn-CCD", large-pixel device, which holds great promise from both the time resolution and high-energy efficiency viewpoint. We have, however, taken great care to ensure that, whatever type of CCD is finally chosen, the camera head interfaces, both electrical and mechanical/thermal, be identical, so that no complication arise from the possible use of different chips and front-end electronics.

Very briefly, the European Photon Imaging Camera proposed here shall consist of three separate Focal Plane Cameras at the focus of the three XMM telescopes. They will be mounted on three stand-off structures, and each CCD detector will be cooled by identical radiators, supported by the same structure. Both a preliminary design of the structure and of the radiators are included in the proposal. The data from the camera heads will undergo significant on-board preprocessing to meet the challenge of not losing science while funnelling the hundreds of thousands of 12-bit pixels per chip per second into the extremely tight telemetry budget available.

The projected performance of the EPIC, given in detail in the body of the proposal, confirms in toto the correctness of the suggestion of the Mission Science Report, namely that a CCD array offers the right combination of spatial resolution, wide bandwidth of energy response and good resolving power at the sensitivity levels required by the mission throughput.

The first part of our proposal will address in detail the type of science that the EPIC will be able to produce, in conjunction with the XMM optics. It will be clearly seen that the ambitious objectives set forth for XMM in the Mission Science Report, and indeed in the Horizon 2000 "strategic" view, are well met by our instrument. This conclusion is reached keeping in mind the foreseeable situation in the astrophysics of the late nineties, with the availability of data from ROSAT, JET-X, SAX and AXAF. Clearly, we must capitalize on the low-energy survey of ROSAT and on the experience gained with a similar CCD camera on the smaller throughtput JET-X, where several of the proposing Institutes are involved. We considered of particular relevance those objectives emphasizing the complementary nature of the higher-throughput XMM to the higher-resolution AXAF. These include, for example, cosmological objectives devoted to solving the long-standing puzzle of the X-ray celestial background. This will require the compilation of extensive number-flux distributions for different object categories, and the possible use of a direct fluctuation measurement. The ample energy grasp coupled to an adequate spectral resolution will allow a study of unprecedented amplitude and completeness on the physics of many individual sources, both extragalactic and galactic. In fact, given the very low detectable source fluxes obtainable with the EPIC (about $2x10^{-15} ergs\ cm^{-2}\ sec^{-1}$ at few keV), it may not be inopportune to urge the Agency that every effort be made for reaching an optics quality capable of generating minimal source confusion in our images, as shown by the striking improvement of going from 30" to 15" HEW spatial resolution. For brighter sources, such as those associated with degenerate stars in our Galaxy, time-resolved spectroscopy will be the ultimate tool, possibly applicable also to objects in the Local

Group. Given the importance of source variability studies in general, as emphasized by the successful EXOSAT results, the EPIC will exploit the long-duration XMM orbit for uninterrupted monitoring of important X-ray objects. The instrument imaging capabilities, on the other hand, will be exploited for the study of diffuse sources, such as clusters of galaxies and SNR's or localized galactic emissions on larger scales. Moreover, we expect a large harvest of "serendipitous" science, given the XMM field of view of ~ 30′ x 30′. This will be in the form of rich statistics of X-ray emission (and spectra) from stars of various spectral types, from "field" galaxies (a particularly new topic), and no doubt from new celestial populations.

In the long run, our Collaboration is very much aware of the problems that will arise in trying to relate our X-ray astronomy data to, e.g., optical data, given that many of the extragalactic (and stellar) sources near our sensitivity limit will have magnitudes in the 24-26 range, i.e. difficult both for ground-based and ST observations. Certainly, close collaboration with the XMM Optical Monitor, and in general with multiwavelength data banks will need to be actively pursued.

Our proposal contains a large body of technical work, carried out both in the limited time available since the AO issue as well as before, and it is hoped that the reader will share the confidence that the proposing team has both in the realistic feasibility of our instrument and in its compliance with the XMM interface requirements. Development areas for the SV phase are clearly identified: as mentioned, these include the choice of CCD-type (and associated electronics) between the two currently developed in parallel in England (U. of Leicester + EEV) and France (SAp/CEA Saclay + Thompson) on one side and in Germany (MPE Garching + MBB) on the other. Another important technical/organizational challenge has been identified in the whole calibration program, both before and after the integration with the spacecraft optics. For this topic in particular, we count, if selected, on a fruitful collaboration with ESA and the XMM Telescope Scientist.

A close collaboration with the Agency, needed of course throughout the project, will be particularly relevant also in the area of the data analysis software development and its integration in the mission Observatory. Although this is due to come into being later in the project, we are acutely aware of the importance of providing the world-wide observers' community with a series of user-friendly tools to allow for, under the Agency's auspices, the best possible exploitation of the mission science.

Our instrument is proposed by a large collaboration of thirteen Institutes in four European countries (see Cover Page for a complete list). While we clearly consider national boundaries not important, especially in post-1992 Europe, we felt the importance of an efficient organization of such a large body of scientists (and of related industries). As requested by the Agency, a management scheme was studied, and is submitted, which sees the Principal Investigator as the official contact point with the XMM project within ESA. However, such a scheme foresees the possibility of responsibility delegation at the engineering level, and includes a Project Manager and his Project Group, an ad-hoc Product Assurance expert, as well as a clear-cut sub-system development structure. Coupled to this structure, devoted to internal interfaces but also to contacts with Industries and the Agency, we have also established ad hoc Working Groups. These are designed to tackle such tasks as "Calibration", "AIV", "Data Analysis", "Scientific Objectives and Operations",etc.. Especially during the SV phase, but also afterwards, we expect such groups to feed inputs derived from the expertise of the whole Collaboration into the managerial structure. Of course, such groups can be of limited duration and be created as the needs of our instrument (and of the XMM project) evolve.

As for the funding problem, all four national agencies (ASI, CNES, SERC, and BMFT) have been alerted and are aware of the needs of this proposal. Naturally, they differ in their endorsement procedures and timescales; however, a good contact has been maintained throughout the proposal preparation phase, and they all appear, without exception, receptive of the importance of an instrument like the one proposed here in the context of an ESA cornerstone, as witnessed by the enclosed letters.

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Two significant publications

G.Bonelli, G.Conti, E.Mattaini, O.Citterio "Characterization of the mandrels used to produce replicated prototype mirrors for the italian X-ray satellite SAX" Proc. SPIE conference N.830, S.Diego, Ago 1987

O.Citterio, G.Bonelli, G.Conti. E.Mattaini. E.Santambrogio, B.Sacco, E.Lanzara, H.Brauninger, W.Burkert "Optics for the X-ray imaging concentrators on board the italian X-ray astronomy satellite SAX", Applied Optics, 27, 1470, 1988.

Patrizia A. Caraveo, (key person, Project Group). Born in 1954. Italian degree of Laurea (cum laude) in Physics, University of Milano, 1977. Since 1982, staff scientist at IFC/CNR, Milano. Member of the COSPAR Commission E4 in Galactic and Extragalactic Astronomy. P.A. Caraveo has been involved in the analysis and interpretation of COS-B gamma-ray data and Einstein/EXOSAT x-ray data with special emphasis to X-ray and optical studies of unidentified gamma-ray sources. Approximately 100 scientific publications.
Involvment in EPIC: Documentation Manager with the project Group. Observing Program and Science Data Analysis.

Two significant publications

Caraveo, P.A., Bignami, G.F., Mitrofanov, I. and Vacanti, G. 'Search for Linear Polarization in Gamma-ray Sources: possible Evidence for the Vela Pulsar', 1988, Ap. J. 327, 203.

Caraveo, P.A., Bignami, G.F., and Goldwurm, A. 'A new 60 millisecond X-ray Pulsar and its Massive Early-type Companion', 1989 Ap.J. 338, in press.

Lucio Chiappetti,(Co-I, Project Group), Born in 1955. Italian degree of Laurea in Physics, University of Milano, 1979. Since 1982, staff scientist at IFC/CNR, Milano. Previous research activities: In 1979 and 1980-81 analysis of IUE data of counterparts of X-ray sources. In 1979-80 and 1981-82, at MSSL, analysis of Ariel-5 data. Until Jan 1985 on leave of absence at Exosat Observatory, ESOC Darmstadt as Duty Scientist (main responsability: LE CMA calibrations and analysis s/w, setup of the Exosat result database). Activities at IFC: coordination of the IUE and Exosat analysis software packages, participation to the ZEBRA gamma-ray experiment, extensive participation to the SAX project (ground segment definition, scientific data centre and data analysis definition, on-board data management). Scientific interests: Galactic and extragalactic accretion-driven X-ray sources
Involvement in EPIC: System Scientist within the project group. HS s/w definition, data analysis, flight operations.

Two significant publications

Chiappetti et al.,
The system AM Her = 4U1814+50, Sp.Sci.Rev. 27,3 (1980)

Chiappetti, L.
Exosat Observers Guide Vol III (The Final Observation Tape Handbook) Rev. 2 (1984): sections 3.7.1 (LE Calibration data) and 8.1 (Data analysis techniques - LE analysis)

Bianca Garilli (Key person). Born in 1959. Italian degree of Laurea in Physics, University of Milano, 1983. Since 1985, staff scientist at IFC/CNR, Milano. Previous scientific activities: development of EXOSAT analysis software package, spectral and variability analysis of X-ray data (from EXOSAT and Einstein) on AGNs and BL Lac objects. Optical observations and analisys of clusters of galaxies, including X-ray selected ones.
Involvment in EPIC: Software for data analysis and calibrations.