FAR–ULTRAVIOLET BACKGROUND STUDIES WITH THE PAN–AMERICAN ASTROPHYSICS EXPLORER (PAX)

C. Martin
Columbia University
Departments of Physics and Astronomy
New York, NY 10022 USA

J. Steiner
Instituto de Pesquisas Espaciais
Sao Jose dos Campos, Brazil

ABSTRACT. We describe a proposed far-ultraviolet (FUV) photometric and spectroscopic survey covering the 1300–2000 Å band with a sensitivity comparable to that of the Palomar Sky Survey. Among the numerous scientific objectives of this mission, many have direct bearing on the nature of the FUV background.

1. PAN–AMERICAN ASTROPHYSICS EXPLORER

We are proposing to perform an FUV photometric and spectroscopic survey that covers the 1300–2000 Å band with a sensitivity comparable to that of the Palomar Sky Survey. This investigation will proceed in three phases: an all-sky survey in two bands to 18^m, deep surveys of selected targets of interest in the same bands to 21^m–22^m, and a spectroscopic survey of 2% of the sky to 18^m with a resolution of 3–20 Å. This mission, a *Pan-American Astrophysics Explorer* (*PAX*), can be performed by a Small-Explorer-class satellite. The mission promises to increase by a factor of 100–1000 the numbers of known quasars, active galaxies, white dwarfs, cataclysmic variables, and evolved stars. Low-to-moderate resolution spectra will be obtained for more than 50,000 objects, including thousands of quasi-stellar objects (QSOs) and Seyfert galaxies, thousands of post–main-sequence stars, and ten thousand galaxies to a redshift of 0.2.

The FUV background will be studied by *PAX* in two ways: by direct all-sky photometric mapping of the background in two bands with high-sensitivity and angular resolution; and by detection and characterization of "point sources" such as galaxies and QSOs, which may contribute significantly to the background at low and/or high redshifts.

A single 33 cm triple-reflection telescope with a 4.8° diameter field of view with a 15″ system resolution will perform both the photometric and spectroscopic surveys. At the focus, a 60 mm microchannel plate detector with a solar-blind UV-sensitive photocathode will provide 25 μm spatial resolution. Rotatable objective prisms provide 3–20 Å point-source resolution for the spectroscopic survey. The instrument's electronics package provides detector-pulse amplification and triggering; analog-to-digital conversion; event centroid calculation; bright star recognition and compression; and telemetry formatting, storage, and retrieval using a 64 Mbyte solid-state mass-storage system.

S. Bowyer and C. Leinert (eds.), The Galactic and Extragalactic Background Radiation, 456–458.

2. FUV BACKGROUND STUDIES

2.1. The Interstellar Radiation Field

The *PAX* surveys will make an accurate measurement of the local interstellar radiation field (ISRF), including stars to 18^m. We will use A0 stars to map out the galactic early-star and dust distribution in considerable detail: $E(B-V)$ will be determined with an accuracy of $\pm 2^m$, with a three-dimensional resolution of <50 pc and to a distance of >5 kpc. With this information, it will be possible to interpret the low-galactic-latitude UV background and determine the ISRF at points far from the solar neighborhood. For example, significant dust may be present at high-scale heights (1–2 kpc above the disk), and the amplitude of the backscattered light will depend in part on the average ISRF over several kiloparsecs.

2.2. Reflection from Interstellar Cirrus and the Origin of the UV Background Offset

We will obtain an all-sky photometric map of the background with a 15″ resolution, enabling us to make a comprehensive study of the dust reflection component and its relationship to the *IRAS* cirrus and optical and UV extinction. Optical observations of IR cirrus have discovered structure as fine as 30″ (Guthathakurta and Tyson 1989). The *PAX* photometric survey will produce a complete map of the reflection from high-latitude dust. The all-sky survey will be sensitive to features of 200 $(\Omega/1\ \mathrm{arcmin}^2)^{-1/2}$ ph $\mathrm{cm}^{-1}\ \mathrm{s}^{-1}\ \mathrm{sr}^{-1}\ \mathrm{Å}^{-1}$ on angular scales of Ω. The deep survey will be sensitive (at 3σ) to fluctuations of 5 $(\Omega/1\ \mathrm{arcmin}^2)^{-1/2}$% in the minimum background level of 300 ph $\mathrm{cm}^{-1}\ \mathrm{s}^{-1}\ \mathrm{sr}^{-1}\ \mathrm{Å}^{-1}$ or extinction fluctuations of $\Delta A_V < 0.005^m$. We will use the UV galaxy number count survey to determine the average UV extinction in all high-latitude fields. Direct comparisons of scattering and extinction will yield the albedo and scattering phase function of the dust responsible for the majority of the FUV background and will confirm or refute the hypothesis that the UV background offset is produced by dust without H I gas (Martin, Hurwitz, and Bowyer 1989).

2.3. Galaxy UV Luminosity Density

The integrated light from normal spiral galaxies makes an important contribution to the FUV background. The *PAX* mission should detect several million galaxies, in and out of clusters, out to a redshift of 0.2 in the all-sky survey and to 0.5 in the deep survey. With such a complete sample, it will be possible to determine the recent evolutionary history of galaxies in clusters and in the field in a band that is very sensitive to the star formation rate. Thus, we will obtain an unbiased measurement of the total-galaxy UV luminosity density and its contribution to the FUV background.

2.4. Power Spectrum of Integrated Galaxy Background Fluctuations

We will be able to repeat on a large scale the measurement performed by Shectman (1974) in the optical and Martin and Bowyer (1989) in the FUV of the spatial fluctuations due to the integrated light from clustered galaxies. Significant improvements will be made by increasing the sensitivity and angular range of the measurement by two orders of magnitude. The small-scale fluctuations are most sensitive to the recent evolution of the UV luminosity and star formation rate of galaxies in rich clusters. Fluctuations on scales smaller than 30″ will be dominated by clusters at $z > 0.3$. At the same time, the variance in the small-scale fluctuations measured over large angular separation will probe structures on 300 Mpc scales.

2.5. The Ionizing Background at Low and High Redshifts

Whereas the background at $z = 0$ is unlikely to include a large contribution from active galactic nuclei (AGN), the ionizing background at high redshift may be dominated by them. The effectiveness of QSOs ionizing the IGM is determined by their extreme ultraviolet (EUV) luminosity function and the uniformity of their distribution in space. The *PAX* mission will make a major contribution to the study of QSOs by providing an enormous, homogeneous, magnitude-limited, minimally-biased, *all-sky* photometric sample of QSOs. Moreover, the mission will provide a very large (4000) catalog of QSOs with redshifts, luminosities, and low-resolution spectral properties. The observations will be performed in the spectral band most sensitive to the accretion disk luminosity, with the greatest diagnostic power for disk properties, at the peak of the optical-UV energy distribution, and with the fewest contaminating background sources and associated biases. It is only with such a sample that the fundamental problems of the QSO luminosity density, evolution, spatial distribution, and relationship to lower-luminosity AGN can be attacked.

Recently, two lines of evidence suggest that major contributors to the ionizing background at high redshift remain unidentified (Shapiro and Giroux 1987; Bajtlik, Duncan, and Ostriker 1988). The discovery of the high-redshift QSO HS1700+6416 ($z = 2.72$), observable to a rest wavelength of ~300 Å (Reimers et al. 1989, in preparation), indicates that there is hope for discovering lines of sight through the intergalactic medium that permit the observation of the ionizing flux of high-redshift sources. High-redshift QSOs with FUV continua attenuated by the cumulative effect of Lyman continuum absorbers will be identified based on their UV and optical colors alone. At the same time, we will determine the luminosity function of QSOs with the large EUV excess that HS1700+6416 appears to have. Discovery of IGM holes, necessary for the observation of any objects at high redshift, will provide candidate objects for the He II Gunn-Peterson test, which will provide another important measurement of ionizing background at high redshifts. These lines of sight will be obvious areas for deep searches with the *PAX* deep survey and the Hubble Space Telescope for any hitherto undiscovered sources of ionization at high redshift.

REFERENCES

Bajtlik, S., Duncan, R. C., and Ostriker, J. P. 1988, *Ap. J.*, **327**, 570.
Reimers, D., et al. 1989, in preparation.
Guhathakurta, P. and Tyson, J. A. 1989, preprint.
Martin, C. and Bowyer, S. 1989, *Ap. J.*, **338**, 667.
Martin, C., Hurwitz, M., and Bowyer, S. 1989, submitted.
Reimers, D., et al. 1989, *Astr. Ap.*, **218**, 71.
Shapiro, P. R. and Giroux, M. L. 1987, *Ap. J. (Letters)*, **321**, L107.
Schectman, P. 1974, *Ap. J.*, **183**, 233.