THE EXTREME ULTRAVIOLET EXPLORER MISSION

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ABSTRACT. The *Extreme Ultraviolet Explorer* mission is described. For the first six months, an all-sky survey will be carried out covering 90 to 750 Å, or essentially the entire extreme ultraviolet (EUV) bandpass. This EUV survey will be made in four bands, or colors: λλ 90–150 Å, 170–250 Å, 400–600 Å, and 550–750 Å. A portion of the sky which is free from the normally intense 304 Å geocoronal helium background will be surveyed at greater sensitivity; the wavelength coverage of this band is from 90 to 400 Å. Following the sky survey portion of the mission, spectroscopy of individual sources will be carried out. Three spectrometers employing novel variable line-space gratings will provide spectra with ~1 Å resolution over the band from 70 to 760 Å. This spectroscopy will be carried out by guest observers chosen by NASA in a manner roughly analogous to the *International Ultraviolet Explorer* (*IUE*) guest observer program.

1. Introduction

The *Extreme Ultraviolet Explorer* (*EUVE*) mission is the culmination of some 25 years of effort at the University of California at Berkeley to develop the field of extreme ultraviolet (EUV) astronomy (defined here as astronomy from roughly 100 to 1000 Å). A primary goal of the *EUVE* mission will be to carry out an all-sky survey over the entire EUV band. This survey will be conducted in four subbands, or colors. It was originally expected that this would be the first survey in this band, but in the passage of time the British Wide Field Camera, which was flown as part of the *ROSAT* mission, has carried out a sky survey at the shortest EUV wavelengths. While it is certain that the majority of EUV sources will be observed at these shorter wavelengths, it is clear that the sky should be mapped over the entire EUV band at least once. In addition, our experience with X-ray astronomy, where at least five surveys of roughly equal sensitivity were conducted, has shown that multiple surveys bring out new and unexpected results.

The *EUVE* mission will also carry out a deeper survey over a limited portion of the sky along the ecliptic. These data will provide insights into the types of sources which would be discovered in a more sensitive all-sky survey. Specifically, would fainter sources be similar in character to the sources observed at higher intensities, or would an entirely new class of sources be evident?

Finally, *EUVE* will carry out spectroscopy of the brighter sources discovered in the survey phase of the mission. This spectroscopy will be carried out exclusively by guest observers, similar in manner to the *IUE* guest observer program.

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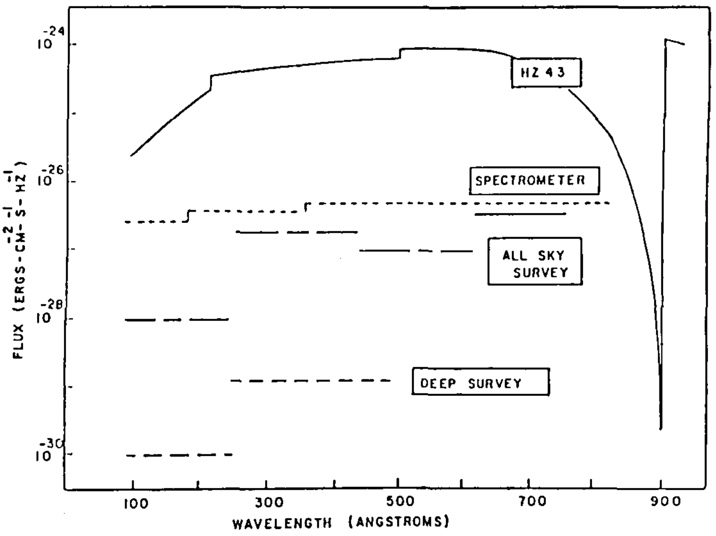

FIGURE 1 — The overall sensitivity of the *EUVE* instruments when combined with the anticipated sky integration times in the survey phase. The dotted line that is marked "spectrometer" shows the sensitivity for a continuum source and one day's integration time.

In Figure 1 we show the sensitivity of the instrumentation on the *EUVE* satellite. For comparison we show the spectrum of the hot white dwarf HZ43, the most intense EUV source now known. The all-sky/all-band surveys will be capable of detecting sources roughly one-hundredth as intense as HZ43. The deep survey is much more sensitive but covers only part of the EUV band and only a part of the celestial sphere. The sensitivity of the spectrometer depends on the integration time and the character of the source; we show in Figure 1 the sensitivity for a continuum source and one day's integration.

2. The EUVE Instrumentation

The mirror designs for *EUVE* are shown in Figure 2. The complement of mirrors used for the all-sky survey consists of two Wolter-Schwarzschild Type I mirrors used to carry out the short-wavelength bands of the survey and one Wolter-Schwarzschild Type II mirror for the longer wavelength bandpasses. The large graze angles in this design (Finley *et al.* 1988) prevent the (presumably more numerous) shorter wavelength sources from registering in the long-wavelength band and compromising this part of the survey. A standard Wolter-Schwarzschild Type II mirror is the collector for the three spectrometers and the deep survey instrument. The bandpass separation for the sky survey is provided by thin (300–3000 Å thick) organic and metallic filters working in combination with the characteristics of the mirrors.

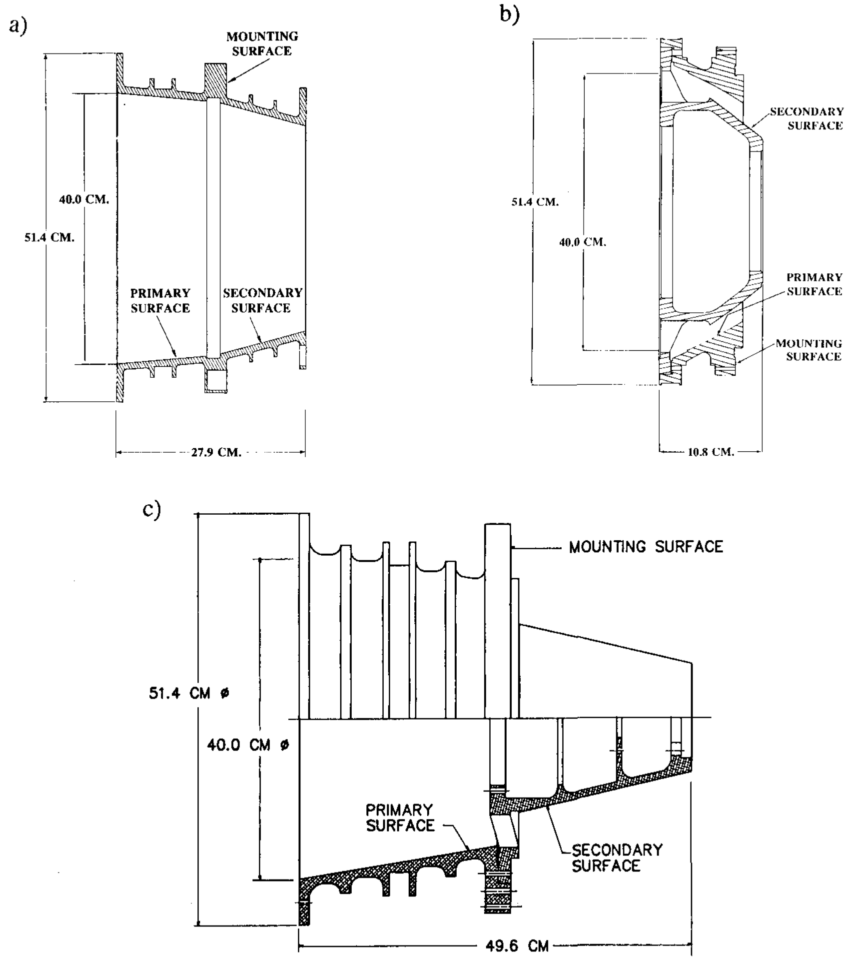

FIGURE 2 — Cross-sectional schematic diagrams of the three types of mirrors employed.

The detectors employed are photon-counting multichannel plate intensifiers with wedge-and-strip encoding. This type of detector was invented in our laboratory by Dr. Michael Lampton and co-workers (Martin *et al.* 1981) and was extensively improved and space-qualified by Dr. Oswald Siegmund and co-workers (Siegmund *et al.* 1986). The detectors in *EUVE* provide 1500 × 1500 rms resolution elements, are linear to better than 0.5%, and possess a variety of additional attributes (they are stable, rugged, and solar-blind; they have graceful degradation with high counting rate, as well as other attributes).

The spectrometer is an entirely new design invented at Berkeley (Hettrick and Bowyer 1983). This spectrometer uses variable line-space gratings, which provides a substantial number of advantages for spectroscopy with grazing incidence optics. First, it is highly efficient in that it requires a minimum number of grazing incidence reflections. Second, the image plane is nearly normal to the direction of the principal ray. Finally, it is readily

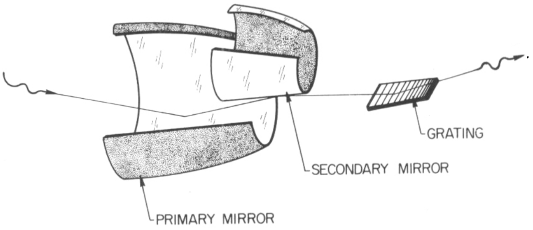

FIGURE 3 — A schematic illustration of the concept of the variable line-space grazing incidence spectrometer.

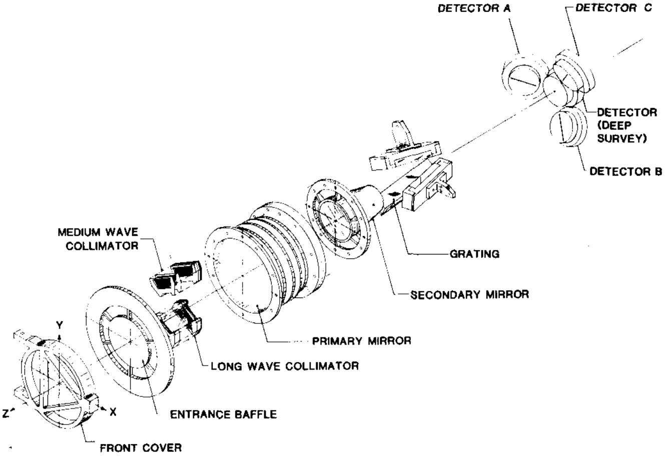

FIGURE 4 — An exploded schematic of the spectrometer on *EUVE*.

adaptable to grazing incidence optics and provides the opportunity for optimizing parameters such as compactness, plate scale, and resolution. The concept of this spectrometer is illustrated in Figure 3.

This concept has been implemented in the *EUVE* deep survey/spectrometer assembly (Martin *et al.* 1985). This assembly is shown in Figure 4. Three spectrometers are employed so that the gratings will be reasonably on-blaze over the wavelength range from 70 to 760 Å. The characteristics of the gratings used in these spectrometers are listed in Table 1.

TABLE 1. Grating characteristics

	Short	Medium	Long
Bandpass	70–190	140–380	280–760
Line density (mm^{-1})	1675–3550	830–1750	415–875
Average plate scale (Å mm^{-1})	2.4	4.8	9.6
Blaze angle	3°	3°	3°
Coating	Rhodium	Platinum	Platinum
Filters	Lexan/B	Al/C and Lexan/B	Al and Al/C

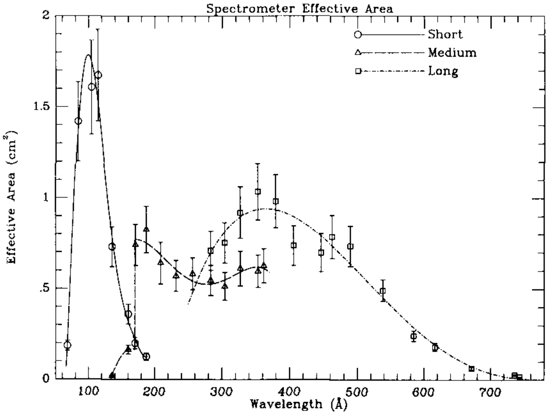

FIGURE 5 — Effective area versus wavelength for three bandpasses.

Figure 5 shows a plot of effective area versus wavelength for the three spectrometer bandpasses. The data points are calibration measurements, and curves are model fits. To determine the instrument effective areas during calibration, the aperture of each spectrometer channel was illuminated with a grid of monochromatic pencil beams. Throughputs were measured by comparing instrument counts with incident beam intensities. The effective areas were then derived by multiplying the measured throughputs by the geometric area of each spectrometer channel.

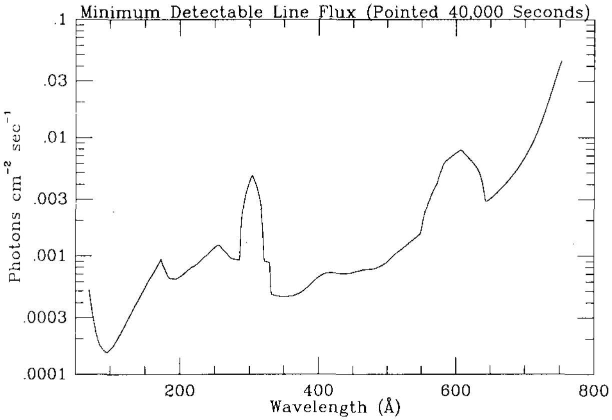

FIGURE 6 — Minimum detectable line flux in a simulated 40,000 second observation.

Figure 6 is a plot of the minimum detectable flux (MDF) for lines for a 3 σ detection in a simulated 40,000 second observation with the spectrometer. The MDF as a function of wavelength is produced by folding the projected instrument response together with expected background rates from diffuse airglow and detector noise. The MDF is then a threshold spectrum which source emissions must exceed to be detected. This calibrated sensitivity of the instrument, in source flux units, can then be compared directly with model source spectra.

The MDF for continuum sources for the spectrometer depends strongly on how the data are binned during processing. This is because the noise level decreases approximately as the square root of the number of bins. Figure 7 shows this function for 1 and 10 Å bins.

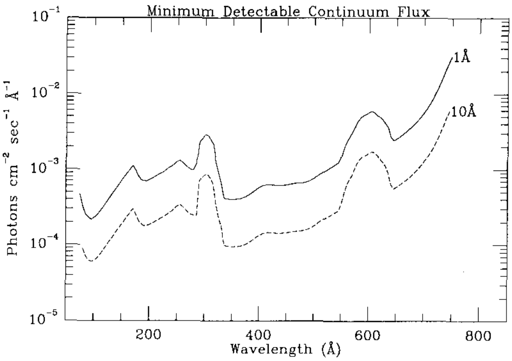

FIGURE 7 — Minimum detectable flux for continuum sources in 1 and 10 Å bins.

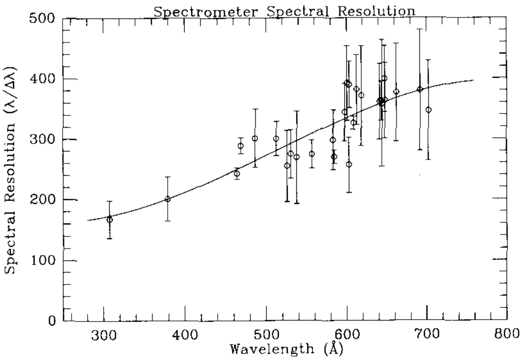

FIGURE 8 — Spectrometer spectral resolution as a function of wavelength.

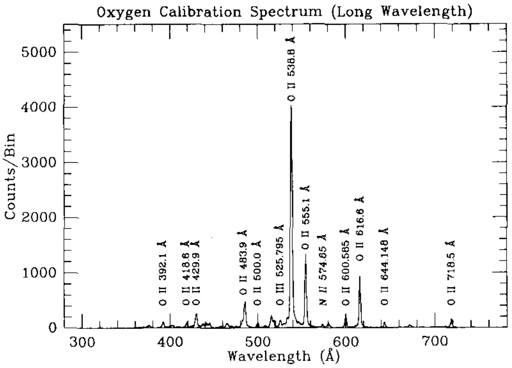

FIGURE 9 — Oxygen calibration source spectrum.

The spectral resolution and the positions of several wavelengths on the spectrometer detectors were measured using collimated beams of EUV light. Various calibration sources were used to produce complete spectra of magnesium, aluminum, argon, oxygen, and neon in the range 104–743 Å. Figure 8 shows the spectral resolution as a function of wavelength as derived from calibration data. The solid line is the best fit to the data. An example of a source spectrum taken during calibration is shown in Figure 9. In-flight calibrations of the *EUVE* spectrometers will be carried out on a regular basis during the course of the mission.

3. The NASA EUVE Guest Observer Program

NASA will conduct a Guest Observer program using the instruments on *EUVE* in a manner rather similar to the *IUE* Guest Observer program. The schedule for this program as of June 1991 is:

September	15	1991	NASA Research Announcement release
December	12	1991	*EUVE* launch date
January	15	1992	Pointed phase proposals due
February		1992	*EUVE* sky survey begins
May		1992	NASA announces Allocation Awards
Summer		1992	Pointed spectroscopic observations begin

In the event that the launch date is revised, the relative offsets for the proposal due date and the awards announcements will be preserved.

Personnel at the Center for EUV Astrophysics will support scientists who have been chosen by NASA as guest observers during the pointed phase of the mission. Typical spectroscopic observations are expected to be 40,000 seconds in duration, observed with a 30% duty cycle, so approximately 150 guest observations per year are anticipated. The expected lifetime of the mission is at least 3.5 years, three of which would be devoted to pointed observations.

The *EUVE* Guest Observer support team at the Center for EUV Astrophysics will provide to NASA a facilities manual, or handbook, describing the instrumentation available for pointed observations. The document includes instrument performance data and sample technical feasibility calculations for proposers. This handbook will be available to respondents to the NASA Research Announcement. The team at Berkeley will provide assistance to proposers in order to clarify information contained in the handbook during the proposal preparation process.

The EUVE Guest Observer support team will monitor the acquisition of guest observer target data. This entails assisting operations in the scheduling of approved pointed observations and assisting in monitoring the quality of the incoming data. The data will then be provided to guest observers, and the *EUVE* Guest Observer support team will assist visiting scientists with data reductions. Guest observers will be encouraged to visit Berkeley at least once to gain familiarity with the data reduction programs being provided by the *EUVE* Guest Observer Center, who will write, document, and distribute the analysis software.

An analysis package for pointed observation data is being written to provide guest observers with routines which take advantage of the extensive design and calibration data available for the *EUVE* instrumentation. Scientists will be able to process data through reduction routines and, in the longer term, some instrument modeling packages will be provided. Guest observers will have access to data in a variety of forms: FITS tables, photon event files, and FITS images. The software modules are being written within the Image Reduction and Analysis Facility (IRAF), public domain software distributed by the National Optical Astronomical Observatories.

The motivation for supporting the spectrometer analysis software within the IRAF is to provide a set of packages that can be ported to the guest observers' home institutions for further use. The IRAF is one of the primary software environments available to astronomers for analyzing a variety of scientific data and for processing data. Facilities to be offered to visiting guest observers will be Unix workstations connected to the local network at the Center for EUV Astrophysics.

EUVE data become available in the public domain after a one year proprietary period. Information on the data will be accessible through the Astrophysics Data System. Tables containing instrument throughput information are available also through the Astrophysics Data System.

4. Acknowledgments

The development of the *Extreme Ultraviolet Explorer* has been a cooperative effort involving a substantial number of people at NASA and UCB. We especially acknowledge the contributions of Roger F. Malina as the Instrument Principal Investigator, and of Michael Lampton, Oswald Siegmund, Herman Marshall, John Vallerga, David Finley, and Peter Vedder in the development of the instruments. This work has been supported by NASA contracts NAS5–29298 and NAS5–30180, which are administered by the Space Sciences Laboratory of the University of California at Berkeley.

5. References

Finley, D. S., Jelinsky, P., Bowyer, S., and Malina, R. F. (1988) Design of the Extreme Ultraviolet Explorer long-wavelength grazing incidence telescope optics, Appl. Opt., 27, 1476.

Hettrick, M. C. and Bowyer, S. (1983) Variable line-space gratings: new designs for use in grazing incidence spectrometers, Appl. Opt., 22, 3921.

Martin, C., Jelinsky, P., Lampton, M., Malina, R. F., and Anger, H. O. (1981) Wedge-and-strip anodes for centroid-finding position-sensitive photon and particle detectors, Rev. Sci. Instrum., 52, 1967.

Martin, C., Mrowka, S., Bowyer, S., and Malina, R. F. (1985) The Extreme Ultraviolet Explorer spectrometer: performance characteristics based on development of the collimator, variable line-space gratings, telescope and detectors, Proc. SPIE, 597, 284.

Siegmund, O. H. W., Lampton, M., Bixler, J., Chakrabarti, S., Vallerga, J., Bowyer, S., and Malina, R. F. (1986) Wedge-and-strip image readout systems for photon-counting detectors in space astronomy, J. Opt. Soc. Am.-A, 3, 2139–2145.