EURD: An Extreme Ultraviolet Spectrograph to Probe the Hot Interstellar Medium

C. Morales[1], J. Trapero[1,2], J.F. Gómez[1], S. Bowyer[3], J. Edelstein[3], and M. Lampton[3]

[1] Laboratorio de Astrofísica Espacial y Física Fundamental, INTA, Apdo. Correos 50727, 28080 Madrid, Spain
[2] Instituto de Astrofísica de Andalucía, CSIC, Apdo. Correos 3004, 18080 Granada, Spain
[3] Space Sciences Laboratory, University of California, Berkeley, CA 94720–7304, USA

Abstract. The EURD instrument has been designed to measure diffuse emission in the extreme ultraviolet (350–1100 Å). This new design provides an unprecedented 4–5 Å spectral resolution and 200 photons/sec/cm^2/sr sensitivity after only 100 hours of observations. One of the goals of this project is to search for spectral lines of highly ionized species from the high temperature component ($10^5 - 10^6$ K) of the interstellar medium that fills the Local Bubble. It is expected that EURD will detect lines due to a thermalized hot component of the interstellar medium, and it will also provide critical diagnostics of the physical properties of this gas. With EURD data we could also detect a spectral line due to the decay of massive neutrinos as well as study oxygen lines from the upper atmosphere airglow. EURD is on board the Spanish MINISAT–01 satellite.

1 Overview

EURD[1] (Espectrógrafo Ultravioleta extremo para la observación de la Radiación Difusa, i.e., Extreme Ultraviolet Spectrograph for the Observation of Diffuse Radiation) is an instrument composed of two spectrographs specially designed to detect diffuse line emission in the 350 – 1100 Å band. It is on board the first mission of the Spanish satellite MINISAT, launched on April 21, 1997. EURD is a joint project of CEA (U.C. Berkeley, USA) and INTA (Spain). A summary of the key instrument parameters are given in Table 1.

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[1] Based on the development and utilization of the Espectrógrafo Ultravioleta de Radiación Difusa, a collaboration of the Spanish Instituto Nacional de Técnica Aeroespacial and the Center for EUV Astrophysics, University of California, Berkeley.

Table 1. Key Instrument Parameters

Bandpass	350-800 Å (long wave spectrometer) 500-1100Å (short wave spectrometer)
Field of View	25.6° × 8.4°
Filters	Open, Opaque, 1000 Å Al, MgF_2
Slit	0.15 × 60 mm
Grating	8 cm diameter 17.6 cm focal length holographically ruled 2460 lines mm^{-1}
Grating substrate	Electroless nickel on aluminum
Grating figure	Ellipse of rotation Semi-major axis 242.87 mm, parallel to ruling Semi-minor axis 176.17 mm
Grating overcoating	Silicon carbide (long wave spectrometer) Boron carbide (short wave spectrometer)
Detector	Low-noise microchannel plate with anticoincidence guard
Detector photocathode	Chemical treatment (long wave spectrometer) MgF_2 (short wave spectrometer)
Size (each spectrograph)	40 × 40 × 13 cm
Weight (each spectrograph)	10 kg

2 Scientific Goals

2.1 Hot Phase of the ISM

There is growing evidence that the Sun is embedded in ionized, hot ($\sim 10^6$ K) gas. Whether this hot gas is a pervasive component of the interstellar medium, or is a local characteristic around the sun (a local bubble) is still a matter of discussion.

A major unknown is the temperature of this hot gas. Estimates range from 10^6 K (e.g., Bowyer, Field, & Mack 1968; Davidsen et al. 1972; McCammon et al. 1983) to 4×10^4 K (Breitschwerdt & Schmutzler 1995). To solve the current undetermination of the temperature of the hot ISM, we need to obtain spectral line data, since the lines from this hot phase will be strongly dependent upon the temperature and thermal history of this material (Breitschwerdt & Schmutzler 1995).

If the detected soft X-ray background (Bowyer, Field, & Mack 1968) is due to emission of hot gas, line emission from highly ionized atoms will be especially intense at extreme ultraviolet wavelengths. EURD, with its high sensitivity and high spectral resolution could give us first, a conclusive proof for the presence of hot gas. Second, we hope to obtain a reliable estimate of the temperature of this hot gas, and therefore provide information about its origin, and present structure and dynamics. Even the absence of lines in

EURD data will pose important constraints on our current models of the interstellar medium. An estimate of the lines produced by a steady–state collisionally ionized plasma at 10^6 K within EURD detectability can be seen in Fig. 1.

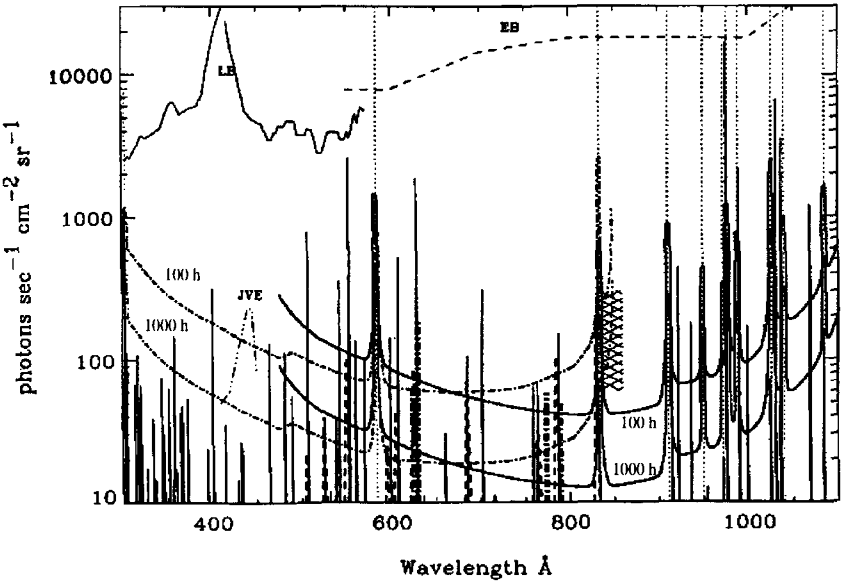

Fig. 1. EURD minimum measurable flux and existing upper limits to the diffuse EUV background. The solid vertical lines are the expected ISM emission from a steady–state collisionally ionized plasma. The dashed vertical lines are the intensities from the delayed recombination model of Breitschwerdt & Schmutzler (1994). The rectangle near 840 Å is the range of the emission signature by decaying neutrinos predicted by Sciama (1994). The dotted vertical lines show the expected nighttime airglow. The dash–dot curves are the flux limits for both short wavelength and long wavelength spectrographs, 100 and 1000 hours of observation. The solid curves are the upper limits of Labov & Bowyer (1991), labeled LB, Edelstein & Bowyer (1997), labeled EB, and Jelinsky et al. (1995), labeled JVE.

2.2 Decay of Massive Neutrinos

Some recent theories suggest that part of the dark matter in the Universe consists of massive neutrinos. Their mass and lifetime are constrained by astrophysical arguments to $\sim 29\,\mathrm{eV/c^2}$ and 10^{24} sec, respectively (Sciama 1990a,b). Their decay would produce a monochromatic photon at $\sim 850\,\mathrm{Å}$, thus within the EURD spectral range. The detection of these neutrinos would solve several outstanding issues, like the ionization observed in the ISM, and the classical dark matter problems: the flat rotation curves of galaxies and the flatness (and future) of the Universe.

2.3 Upper Atmosphere Nightglow

The spectrum of the upper atmosphere nightglow that will be observed by EURD, should contain several O I and O II lines. These oxygen lines have all been detected in laboratory, but only one (O II at 834 Å) has been observed in the atmosphere (Bowyer et al. 1981, Chakrabarti et al. 1984). The opportunity of having simultaneous measurements of all these lines will allow the study of the thermospheric atomic oxygen, and of solar and magnetospheric events that may leave signatures in the O II plasma around the Earth.

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