Measuring EUV Line Emission from the Hot Interstellar Medium

Simon Labov, Christopher Martin, and Stuart Bowyer

Space Sciences Laboratory, University of California, Berkeley

ABSTRACT

In the local interstellar medium, the presence of hot gas (log T ~ 5 to 6) has been inferred from measurements of oxygen VI absorption in the ultraviolet, and from diffuse emission in the extreme ultraviolet (EUV) and soft X-ray regions. Here we describe a spectrometer that is very sensitive to gas in this temperature range. The spectrometer uses an array of plane-ruled gratings at grazing incidence in the extreme off plane mount. A set of Kirkpatrick-Baez mirrors focuses the conically diffracted light on to one of two microchannel plate detectors. The field of view of the instrument is 0.2° by 12°. The predicted sensitivity ranges from 50 to 200 ph/(cm^2 sec str) with a resolving power ($\lambda/\Delta\lambda$) of 15 to 50 over the 50 to 700Å wavelength band. The instrument is currently under construction for a sounding rocket flight.

As indicated by soft X-ray and EUV emission, EUV stellar observations and far ultraviolet absorption line studies, much of the space within 100 parsecs of the sun contains hot tenuous gas. We describe here a new instrument to explore this phase of the interstellar medium by observing diffuse line emission in the EUV.

In the past, a variety of techniques have been used to measure diffuse emission at wavelengths below 1200Å. These measurements are summarized in Figure 1. Soft X-ray measurements show emission lines from highly ionized species (*Inoue et al.*, 1979). The gas scintillation proportional counter produced

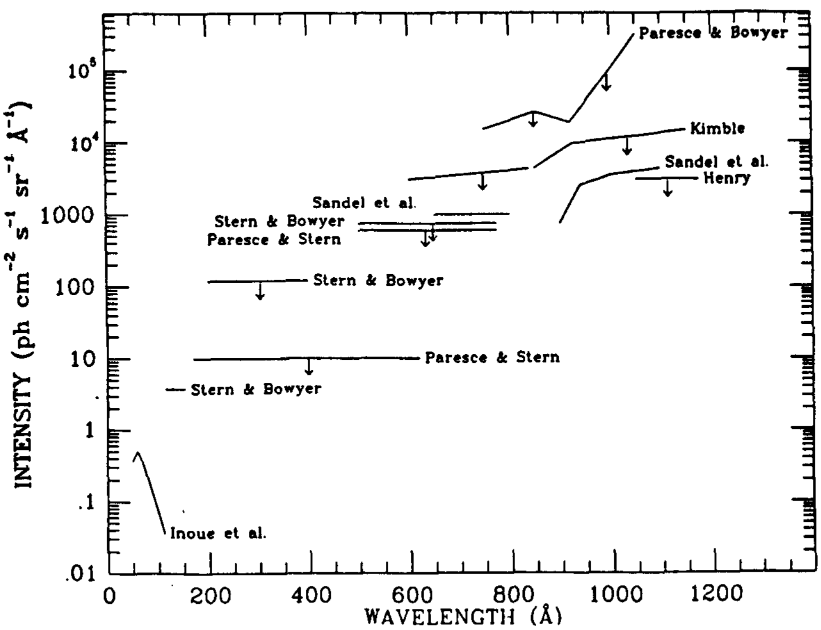

Figure 1. Existing measurements of diffuse radiation between 50 and 1200Å.

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low resolution spectra at higher energies, but only photometric measurements at lower energies. In the EUV, diffuse emission was first detected by a Berkeley sounding rocket instrument (*Cash, Malina and Stern*, 1976), and later confirmed with the Berkeley Apollo Soyuz Test Project EUV telescope (*Stern and Bowyer*, 1979). These results are shown in Figure 1, along with further reductions of the same data with additional assumptions by *Paresce and Stern* (1981). The Voyager spectrometer results (*Sandel, Shemansky, and Broadfoot*, 1979) are shown near 750Å and above the Lyman limit at 912Å out to the far ultraviolet. Also shown in this range are the measurements made by *Kimble* (1983), using an airglow spectrometer flown on a rotating satellite. Kimble used the "up looking" data to derive upper limits. A sounding rocket spectrometer (*Paresce and Bowyer*, 1976) and a sounding rocket photometer (*Henry*, 1973) also produced upper limits in this region.

Notice that only upper limits to the diffuse radiation exist between 130 and 700Å. Furthermore, no spectral measurements of the diffuse flux have been made between 50 and 700Å. Conventional spectrometers cannot observe line emission in this region lack the high sensitivity and spectral resolution necessary to observe line emission in this region. To surmount the problem, we are developing a novel type of spectrometer that operates between 50 and 700Å with high sensitivity and moderate resolution. The purpose of the instrument is to detect line emission from a hot coronal component of the ISM.

Figure 2 shows the light path through the optical system. Diffuse radiation enters the instrument through a wire grid collimator that restricts the field of view to 0.2° by 12° (not shown). The light is then diffracted by an array of objective gratings at grazing incidence in the extreme off plane mount. The gratings are mechanically ruled with high line density at the appropriate blaze angle to improve efficiency. The diffracted light is focused by a Kirkpatrick-Baez array of mirrors orthogonal to the gratings. To construct these mirrors

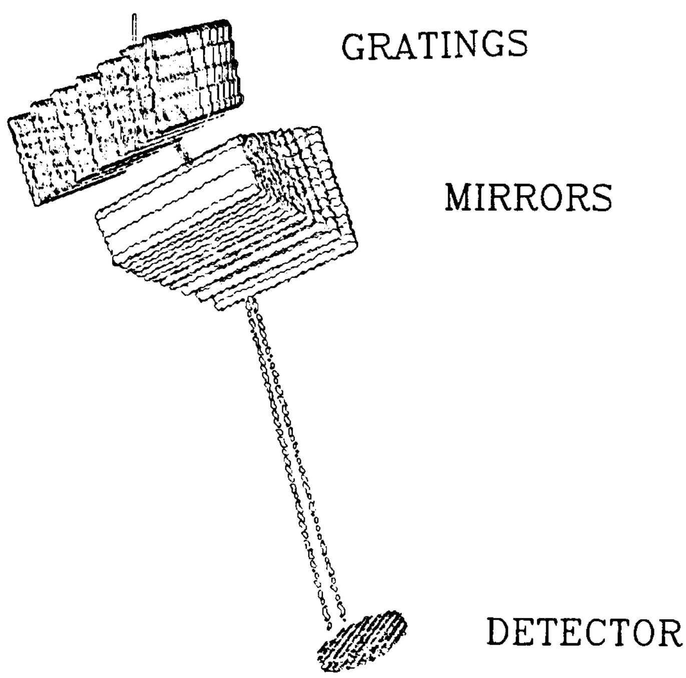

Figure 2. The optical configuration of the EUV diffuse background spectrometer.

we heat float glass, a naturally smooth and flat substate, and allowed it to settle on a properly shaped steal mandrel. Using this technique we will inexpensively fabricate mirrors with adequate resolution.

Notice that each grating is tilted at a slightly different angle with respect to the axis of the system. This simulates a second Kirkpatrick-Baez array, focusing in the non-spectral direction (i.e., along the 12° field of view). As shown by numerical ray tracing shows that the gratings produce spatial resolution of 1.2° even though they are flat, rather than parabolic. This focusing will help insure that no point sources are contaminating the diffuse spectra. In addition, it allows a large geometric area to be concentrated on a reasonably sized detector.

Once the light has been focused, it passes through thin filters and is imaged by one of two microchannel plate type detectors. The filters reduce scattered light and also isolate the detectors from any residual pressure or particle contamination. The detectors use wedge and strip type anodes (*Martin et al.*, 1981) to achieve high resolution imaging in two dimensions with low background noise. A cesium iodide photocathode (*Martin and Bowyer* 1982) deposited on the front microchannel plate gives it high photon counting quantum efficiency.

Many features contribute to the instruments high sensitivity. It uses most of the geometric area available within the diameter of a Black Brant type sounding rocket. It subtends a large solid angle and has only two optical elements, both at grazing incidence. High grating efficiency is obtained by blazing the gratings and mounting them off plane, and the detectors have high quantum efficiency and add little background noise. The system shown in Figure 2 is actually only one of four systems employed in the spectrometer to cover the bandpass from 50 to 700Å with resolving power ranging from 15 near 150Å to 50 near 550Å. The four systems are arranged in two pairs, with each pair focusing on one detector. The two pairs are set side by side in a square configuration.

One way to examine the usefulness of this instrument is to show how well it can constrain a model. Figure 3 shows such results for an isothermal model in which all the absorbing material is between the instrument and the emitting material. The dark line at the bottom of this emission measure vs. temperature plot indicates the minimum emission measure necessary to detect two lines during a 400 second rocket flight. The lines considered are all resolvable from each other and from any nearby airglow, geocoronal or interplanetary lines. Also shown are the constraints on this model from the broad band detection with the Apollo-Soyuz telescope as analyzed by *Paresce and Stern* (1981), the constraints implied by the upper limits of *Kimble* (1983), and by a tentative detection of several emission lines in the far ultraviolet by *Feldman, Brune, and Henry* (1981) as analyzed by *Paresce, Monsignori Fossi, and Landini* (1983). By exploring new parameter space, this instrument will vastly improve the constraints on any model of this hot phase of the ISM.

The sensitivity of the instrument can be described by the minimum detectable line flux. For a 400 second sounding rocket flight, this varies from 50 to 200 photons/(cm^2 sec str) across the bandpass, and is shown by the dark line in Figure 4. Also plotted in Figure 4 is a range of predicted line intensities from a hot coronal medium. To make these predictions we used two isothermal models, the "slab absorption" type described above, and a model in which the absorbing material is interspersed with the emitting material. The steady state plasma codes of *Stern, Wang, and Bowyer* (1978) and *Raymond and Smith* (1977), were applied to these models with the constraints imposed by the broad

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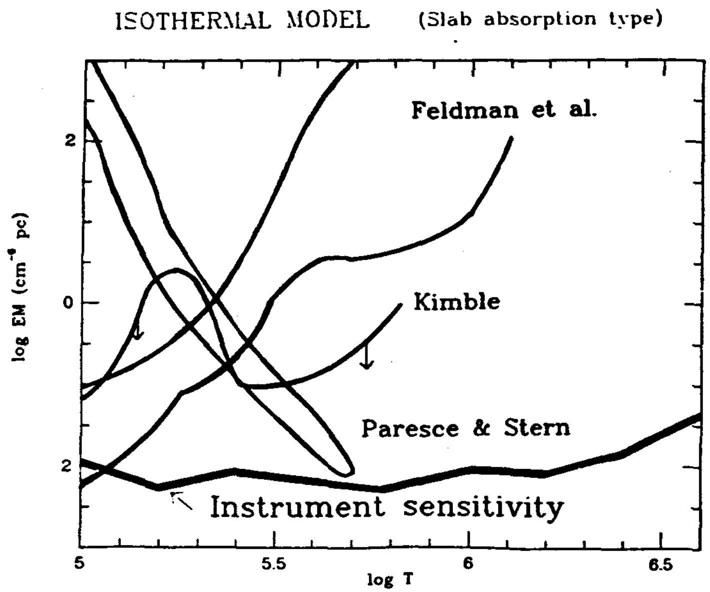

Figure 3. The constraints imposed on an isothermal model by previous observations is shown with the minimum emission measure necessary to detect two emission lines.

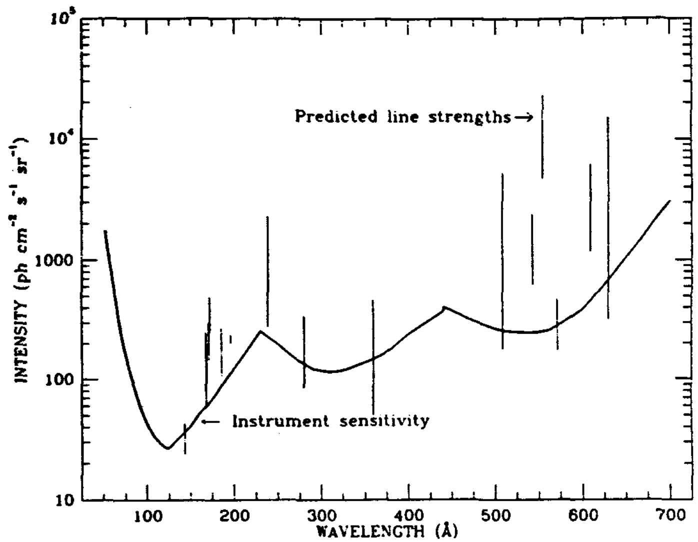

Figure 4. The minimum detectable line flux and a range of predicted line strengths.

band measurements. The large range in strengths reflects the different models and parameters used. After the initial rocket flight, the spectrometer will be suitable for flight in a type container attached to the Space Shuttle With the longer exposures allowed on Shuttle, different regions of the sky can be examined to determine the spatial distribution of the emitting material.

To summarize, we have designed a new type of spectrometer that will be capable of making make the first spectral measurements of the diffuse emission between 50 and 700Å. It will be 1 to 2 orders of magnitude more sensitive to diffuse line emission than any of the current broad band measurements. Attached to the Shuttle in a GAS type container, it will also be able to explore the spatial distribution of the emission with even higher sensitivity. We expect that this instrument will aid our understanding of the hot coronal component of the interstellar medium.

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