

# GRADES: A New Instrument for Spectroscopy of the Local Hot Gas

M. Hurwitz<sup>1</sup>, C. McKee<sup>1</sup>, J. Edelman<sup>1</sup>, J. Vallergera<sup>1</sup>, P. Jelinsky<sup>1</sup>,  
M. Freyberg<sup>2</sup>, and D. Breitschwerdt<sup>2</sup>

<sup>1</sup> Space Sciences Laboratory, University of California, Berkeley, California 94720-7450, U.S.A.

<sup>2</sup> Max-Planck-Institut für extraterrestrische Physik, D-85740 Garching, Germany

**Abstract.** Competing models for the origin of the local component of the diffuse X-ray background span more than an order of magnitude in temperature. We propose to test these models with a new instrument, the GRating Array Diffuse EUV Spectrometer (*GRADES*), which is sensitive to diffuse emission in the 90 - 260 Å bandpass, and offers a peak spectral resolution of about  $\lambda/127$ .

## 1 Introduction

Million-degree gas is often referred to as “X-ray gas”. This misnomer belies the uncomfortable reality that extrapolation of X-ray observational limits to the total plasma luminosity is critically dependent on the details of cooling processes that are not well understood. In collisional ionization equilibrium (CIE) near  $10^6$  K, the total plasma luminosity divided by the luminosity at wavelengths below 100 Å is a factor of 5. Million-degree gas is extreme ultraviolet or “EUV gas.” Even after foreground absorption from the local cloud at about  $2 \times 10^{18} \text{ cm}^{-2}$  (Vallergera et al. 1993), the most energetically favorable band to study a CIE plasma at  $10^6$  K is near 200 Å. The band contains strong emission lines from various ionization stages of iron; if the gas is in CIE, their ratios determine the temperature independent of abundance uncertainties. The strength of the Fe lines relative to those of low-depletion elements can determine the relative CIE abundances. If underionized nonequilibrium prevails (as in conduction [Slavin 1989]), the EUV may carry a higher fraction of the radiated power; line ratios can distinguish underionized emission from the CIE case. Because the absolute strength of the collisionally excited EUV emission lines depend sensitively on the electron temperature, uncharacteristically low values (e.g. overionized nonequilibrium) dramatically alter the EUV spectrum (Breitschwerdt and Schmutzler 1994). For reference: with a mean emission measure of  $0.0038 \text{ cm}^{-6} \text{ pc}$  (Snowden et al. 1997), and a temperature of  $10^6$  K, the strongest CIE emission line is expected to have a flux of about  $120 \text{ photons cm}^{-2} \text{ s}^{-1} \text{ sr}^{-1}$  (hereafter Line Units or LU).

Observational limits have been set at the 1000 LU and 500 LU level (Labov and Bowyer 1991 and Smith et al. 1996, resp.). A deep spectrum taken with *EUVE*, the Extreme Ultraviolet Explorer (Bowyer 1995), suggests

that the emission measure near  $10^6$  K may be a factor of about four below the value from Snowden et al. (Jelinsky et al. 1993). This result, however, relies on subtraction of a very large background signal. Also using *EUVE*, Vallerga et al. find a few marginally significant detections in directions where the 1/4 keV emission is bright. Spectrographs for diffuse emission between 350 and 1100 Å have recently been developed (Bowyer et al. 1997). Observations have not begun (as of 1 June 1997). If the foreground neutral absorption is near or above  $2 \times 10^{18} \text{ cm}^{-2}$ , the brightest CIE plasma emission features in the 350 – 912 Å band will fall below the instrument sensitivity.

## 2 The Proposed *GRADES* Instrument

Consider first a single slit plus cylindrical diffraction grating placed at grazing incidence with respect to the central ray (hereafter “channel”). Baffles restrict the field of view (FOV) to a cone about  $10^\circ$  in diameter. Diffuse sky glow within the FOV will strike the grating and be focused within the plane of dispersion onto a planar photon-counting microchannel plate detector. We vary the spacing of the grooves to provide aberration control and flatten the focal surface (Harada et al. 1991). *GRADES* comprises 16 spectrograph channels, illustrated within the payload envelope of the Spartan Lite (a potential spacecraft carrier) in Figure 1. The off-axis channels are identical to the central one save for a rotation about an axis passing through the detector surface. Outside the entrance slit, each off-axis channel carries a small pick-off mirror to coalign the FOV with that of the central channel within the dispersion plane. Perpendicular to that plane, the FOV is about  $20^\circ$ . *GRADES* provides no angular resolution within its FOV. The integrated flux from point sources is far below the expected diffuse flux in this band. The continuum from the brightest white dwarf in the sky (HZ 43) is comparable to the detector background. The well known flare star AU Mic in outburst (Katsova et al. 1996) produces lines corresponding to  $< 0.5$  LU in diffuse flux when observed with *GRADES*. We summarize the top-level parameters in Table 1.

Without filters, scattering of bright emission lines of geocoronal and interplanetary origin (especially Lyman  $\alpha$ , with a typical flux of 3500 Rayleighs [Chakrabarti et al. 1984]) would exceed the detector background. Page limits do not permit a full discussion of our rationale for filter material selection. The filter for 210 – 260 Å will be 1500 Å thick Aluminum; for 90 – 150 Å, the filter will be 1000 Å thick Lexan plus 300 Å of Boron. Intermediate wavelengths will be spanned by both materials, each covering half of the detector area. We show the system resolution and  $2\sigma$  sensitivity curve for an integration time of 26,000 seconds (1 day at 30% observing efficiency) in Figure 2.

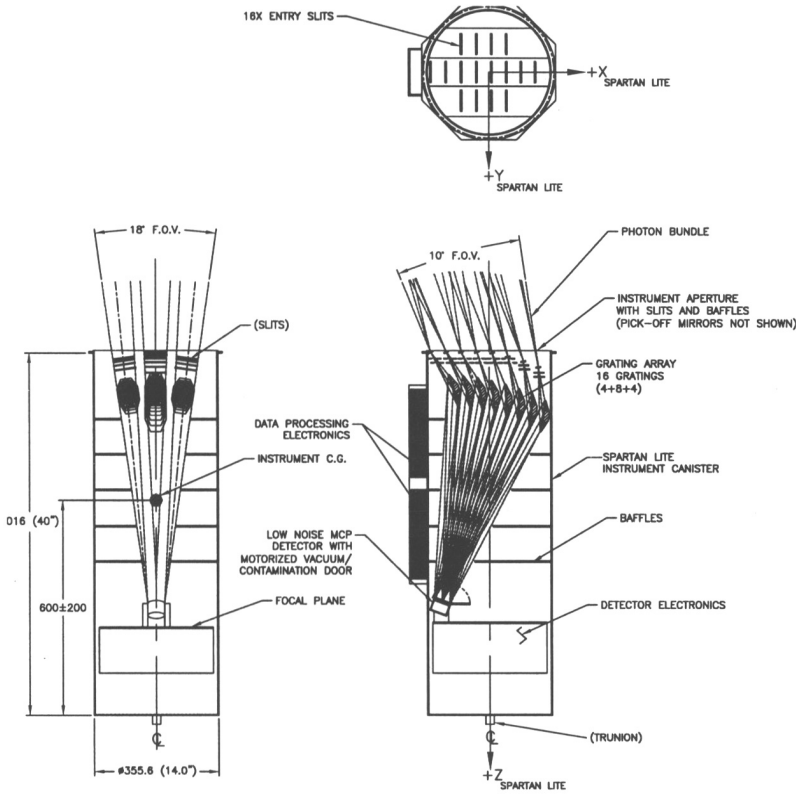


Fig. 1. Full 16-channel *GRADES* illustrated in Spartan Lite envelope.

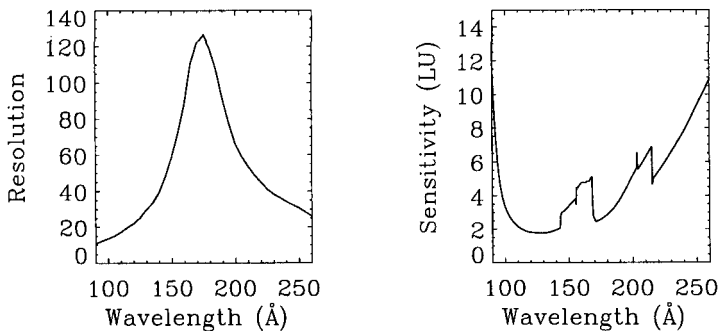


Fig. 2. *GRADES* spectral resolution  $\lambda/\delta\lambda$  (76% energy width) and  $2\sigma$  sensitivity to emission lines (LU) for 1 day in low earth orbit at 30% observing efficiency. Discontinuities are associated with changes in instrument throughput caused by filter support bars or filter transmission edges.

Table 1. Top-Level GRADES Parameters

Entrance slits	$0.013 \times 6$ cm
Grating graze, blaze angle	$14^\circ, 2.6^\circ$
Groove density	$1330 - 1800$ mm <sup>-1</sup>
Grating dimensions, $R_{curve}$	$9 \times 6$ cm, 96 cm
Coatings, Photocathode	Rhodium, NaBr
Detector area, resolution	$5.5 \times 6$ cm, 400 $\times$ 400 resels
Filters	1000 Å Lex. + 300 Å Boron, 1500 Å Alum.
Field of View, Bandpass	$10 \times 20^\circ, 90 - 260$ Å
Spectral Resolution (76% EW)	$11 - 127 (\lambda / \delta\lambda)$
$A_{eff} \times \Omega$	$2.5 \times 10^{-4} - 1.6 \times 10^{-3}$ cm <sup>2</sup> ster
2 $\sigma$ Min. Detectable Line Flux	1.8 - 12 LU in 26,000 sec

### 3 Conclusions

Despite the importance of spectral diagnostics in the  $\sim 200$  Å band, observations of the local diffuse plasma at these wavelengths are extraordinarily scant. A new instrument *GRADES*, optimized for spectroscopy of the diffuse emission from 90 - 260 Å, will permit the first true emission line diagnostics. Data from *GRADES* will enable us to constrain the plasma temperature, emission measure, gas phase abundance of iron, and two classes of nonequilibrium effects independently.

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