O-B STARS IN THE FUV RANGE FROM EURD ONBOARD MINISAT 01 *

C. Morales[1], J. Trapero[1,2], J.F. Gómez[1], A.Giménez[1,2]
S. Bowyer[3], J. Edelstein[3], M. Lampton[3], E. Korpela[3]

[1] Laboratorio de Astrofísica Espacial y Física Fundamental, INTA
[2] Instituto de Astrofísica de Andalucía, CSIC
[3] Space Sciences Laboratory, University of California, Berkeley

ABSTRACT

The instrument EURD has been designed for high-sensitivity spectroscopy of diffuse radiation in the wavelength range from 350 to 1100 Å with spectral resolution of 5 Å. It is onboard Minisat 01, a Spanish satellite that was succesfully launched on April 21, 1997. After in-orbit test of all the systems of the satellite and the scientific payload, observations with EURD started in June 10. During the measurements (taken in the eclipses of each orbit) several individual stars have been detected longward of 912 Å. Essentially these are hot and bright stars emitting in the FUV part of EURD spectral range, from 912 to 1100 Å. They are carefully removed from the overall integration to avoid contamination in the spectrum of the hot component of the insterstellar medium. As a separate task, we have begun to identify these stars and study their spectra. We show an example of the results obtained and the envisaged possibilities for future research. Moreover, The spectra are compared with atmosphere models by Kurucz and with the few stellar observations made in this wavelength range.

Key words: B stars; emission spectra; far ultraviolet spectroscopy.

1. INTRODUCTION

Minisat 01 was succesfully launched from the Canary Islands by means of a Pegasus XL airborne dedicated vehicle on April 21, 1997. It is the first version of a series of small satellites for multiple applications which carries a scientific payload: two astronomical instruments (EURD and LEGRI), a microgravity experiment (CPLM) and a technology demonstration package (ETRV). The 200 kg spacecraft is in Low Earth Orbit (575 km) with an inclination of 151 degrees and an expected mission lifetime of 2 years. In-orbit acceptance tests were successfully carried out and the scientific instruments are fully operational. The ground stations are located at Maspalomas (Canary Islands) for tracking and telemetry, Torrejón de Ardoz (INTA HQ, Madrid) for the mission Control Center, and Villafranca del Castillo (Madrid) for the Science Operations Center (LAEFF).

EURD (Espectrógrafo Ultravioleta extremo de Radiación Difusa) is providing excellent scientific results, mainly in the study of the upper atmosphere. Here we present the first hints obtained about stellar contributions in the very little explored FUV range between 900 and 1100 Å.

Previous missions to explore this wavelength range include Voyager which contains an ultraviolet spectrometer (UVS) that, though designed to study the upper atmosphere of the outer planets, has also proven to be extremely useful for astronomical sources. The spectral range covered is 525 to 1250 Å with a poor resolution of 18 Å. The Copernicus satellite observed 88 early type stars with a resolution of 0.05 Å but in the spectral range band from 950 to 1350 Å. HUT was incorporated on the Space Shuttle and measured 11 OB stars in the range between 912 and 1840 Å with a spectral resolution of 2-3 Å. EUVE provided 1 to 3 Å spectroscopy in the range from 70 to 760 Å. The Far Ultraviolet Spectroscopic Explorer (FUSE), nominally the first NASA mid-size explorer (Midex) spacecraft, should be launched by the end of next year and is designed to obtain high-resolution spectroscopic observations in the spectral band between 900 and 1200 Å.

2. EURD AND STELLAR SPECTRA

EURD is a high sensitivity double spectrometer onboard Minisat 01 for the study of the diffuse radiation in the extreme ultraviolet range between 350 and 1100 Å with 5 Å spectral resolution (see Morales et al. (1997) for a description of the scientific objetives of EURD). EURD is a joint project of CEA (University of California at Berkeley, USA) and INTA (Spain). For a detailed technical description of EURD, see Morales et al. (1996) and Bowyer et al. (1997).

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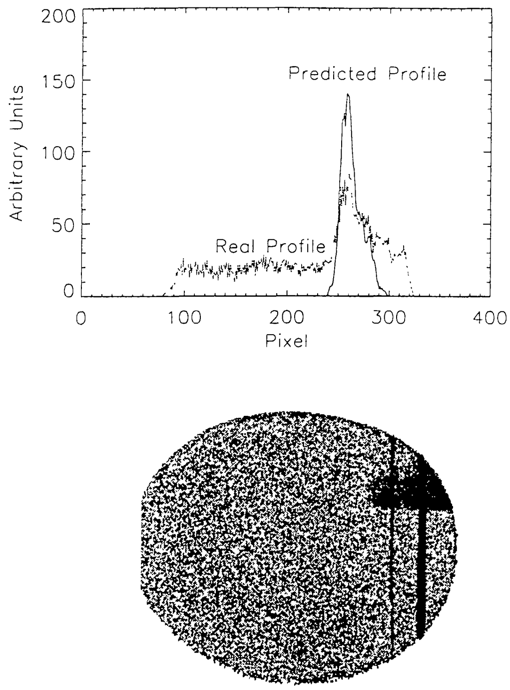

Figure 1. Top: comparison of the spatial profile of the emission of HD 209409 that appears in the detector with the predicted profile using the attitude data, each pixel corresponds to 1'.5. Bottom: corresponding image of the spectrograph. The x-axis is wavelength (550-1100 Å) and the y-axis is spacial dimension (up to 8 deg *long)*

The instrument was switched-on in May 20 and, after a complete internal check-out of all the subsystems, the lids protecting the optics of the two spectrometers (short and long wavelength ranges) were open in May 31, 1997. EURD started routine operations on June 10, always observing in the anti-sun direction, and during the night part of each orbit of Minisat 01.

Observations obtained up to now are being processed and analyzed and already some lines in this difficult wavelength range can be seen coming from the upper atmosphere of the Earth (airglow) and geocoronal emission (see Morales et al. in this volume). In addition, several individual stars have been detected longward of 912 Å. Emission lines from the nearby interstellar medium are not expected until more than 1000 hours of effective integration are achieved.

The stars detected by EURD are essentially hot and bright objects emitting in the FUV part of the EURD spectral range, from 912 to 1100 Å. In Figure 1 (bottom) is a view of spectral images we get with EURD. The bright region in the upper right part of the image is the emission of HD 209409, spread out along the spatial dimension due to Minisat movements during the observation. The bright vertical lines are geocoronal lines, in particular lines of the hidrogen Lyman series to the right and the He 584 line to the left.

3. DATA PROCESSING

The stars need to be carefully removed from the overall integration to avoid contamination of the emission lines produced in the hot component of the interstellar medium. Since the satellite has limited pointing capabilities, some work is needed to identify the stars that appear in the detector. Fortunately, Minisat 01 provides us with attitude data that allows us to reconstruct the pointing and the field of view. Then we compare this data with star catalogues to select those stars with expected FUV emission that should be detected. Using IUE and TD1 spectra, we select the best candidates to produce the observed emision in this spectral range. Using satellite attitude data and the candidates coordinates we produce a predicted profile of the position of the star over the detector.

A real profile taken in the spatial direction of the spectral image (perpendicular to the dispersion axis) will reflect the position of the star over the detector during the observation. The final check is to compare the real profile and the predicted profile for each candidate (Figure 1, top). The star is identified when both profiles coincide. Moreover, the predicted profile allows us to calculate the exact time that EURD has been observing each star in every pixel.

After identifying and extracting the stars, their spectra must be calibrated in intensity and wavelength. The correction for the geometrical distortion of the detector as well as the wavelength and flux calibrations are performed by using the pre-launch parameters determined with the EUV calibration facilities at the Space Sciences Laboratory of the University of California at Berkeley (Bowyer et al. 1997). Spectra of the full moon, which is clearly visible in many images are being used to complement the ground calibrations.

The main sources of background counts were removed using an opaque filter (for intrinsic detector background) and a $MgFl_2$ crystal filter (for internally scattered Lyman alpha airglow emission). The FUV range of the spectrum is dominated by the strong emission of the Lyman series of geocoronal origin. This external contribution was subtracted using a "sky spectrum" obtained from the adjacent region of the detector. It is shown in Figure 2 together with the raw spectrum of HD 209409.

4. HD 209409

As an example of the expected results which will be obtained during the scan of the sky by EURD, we show the FUV spectrum of HD 209409 (31 Aqr or *o* Aqr). This is a B7 IVe star with V = 4.74 and B-V = −0.100 and a well-measured parallax of 8.56 by Hipparcos. The color excess of HD 209409 is taken to be E(B-V) = 0.02 (Zorec and Briot 1991), which leads to a small but significant correction for interstellar reddening.

The spectrum derived from EURD observations, after preliminary calibration and correction for interstellar absorption is shown in Figure 3.

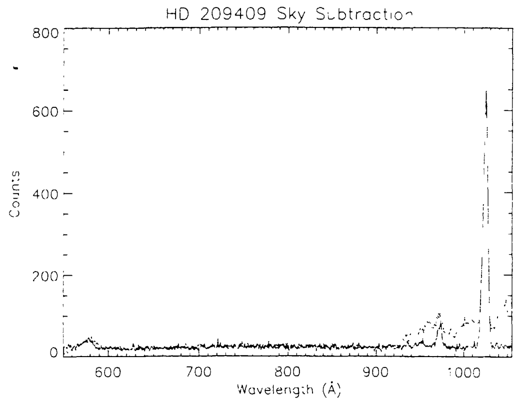

Figure 2. Sky spectrum superposed to the raw spectrum of HD 209409.

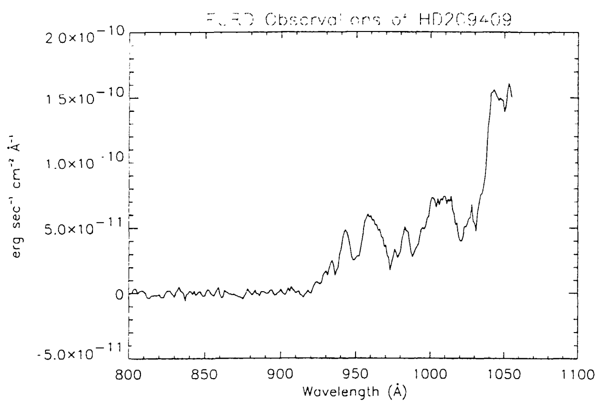

Figure 3. Spectrum of HD 209409 after preliminary calibration and correction for interstellar absorption.

5. COMPARISON WITH KURUCZ MODELS

We have used the grid of theoretical model atmospheres by Kurucz (1991), to compare with the observed spectrum of HD 209409. In order to have a larger spectral range to search for the best fit to the models, the IUE short wavelength spectrum (SWP 34372 L) of HD 209409 has been retrieved from the IUE data archive (ULDA). It is shown in Figure 4, together with EURD observations, and the fitted Kurucz model. Insterstellar extinction was taken into account using the extinction law by Seaton for a color excess E(B-V) = 0.02, which was successfully tested for the IUE range. Kurucz models for a temperature of 14000 K and a $\log g$ of 4.0 adequately reproduce the IUE data for the star. Moreover, the shape of the spectrum in the wavelength range of EURD is also predicted from the fit of the IUE range.

It is clearly seen that an excess of radiation from 912 to 950 Å is present in EURD data regarding Kurucz model. This can not be explained in terms of interstellar extinction since even applying no correction at all the excess would be present. Moreover changing the adopted color excess would seriously affect the fit at the longest wavelengths. It is not yet established wheater this effect is due to the star, or to uncertainties in the preflight calibration. We note that observations with EUVE of the hot star ϵ CMa (Cassinelli et al., 1995) already have shown an excess in the range of 504 to 750 Å, which is important in understanding the ionization of the local interstellar medium. **** HD 209409, though less bright than ϵ CMa (B2 II), indicates the kind of information that can be provided by EURD to understand hot stars.

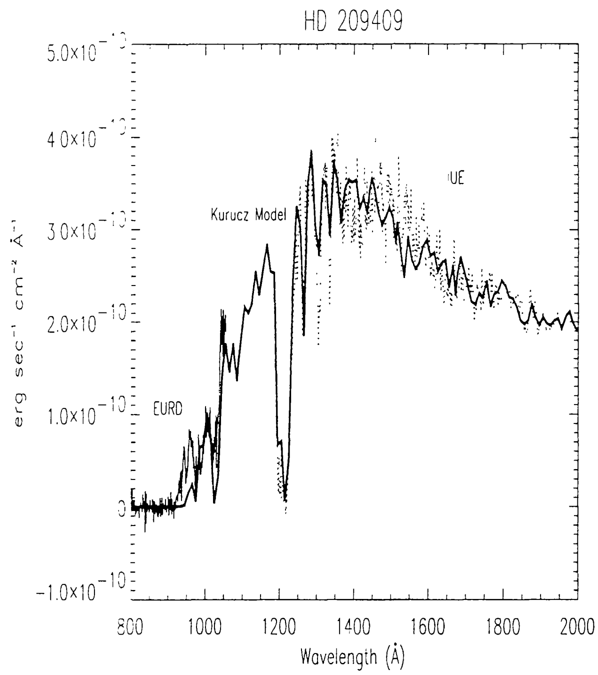

Figure 4. IUE and preliminary EURD spectra of HD 209409 together with the fitted Kurucz model.

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REFERENCES

Bowyer, S., Edelstein, J., Lampton, M., 1997, ApJ, 485, 523

Cassinelli, J.P., Cohen, D.H., MacFarlane, J.J., Drew, J.E., Lynas-Gray, A.E., Hoare, M.G., Vallerga, J.V., Vedder, P.W., Welsh, B.J., Vedder, P.W., 1995, ApJ. 438,932

Morales, C., Bowyer, S., Gómez, J. F., Trapero, J., Ulibarrena, M., Gutiérrez, F., López-Moreno, J.J., Pérez Mercader, J., Lampton, M., Edelstein, J., 1996, in International Conference on Small Satellites: Missions and Technology (INTA:Madrid), 61

Morales, C., Trapero, J., Gómez, J. F., Bowyer, S., Edelstein, J., Lampton, M., 1997, in The Local Bubble and Beyond, D. Breitschwerd & M. Freyberg, eds., in press

Seaton, M. J., 1979, MNRAS 187,73

Zorec, J., Briot, D., 1991, A & A, 245,150