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HOPKINS ULTRAVIOLET BACKGROUND EXPLORER

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ABSTRACT. The Hopkins Ultraviolet Background Explorer (HUBE) is currently the NASA MIDEX Astrophysics Alternate Mission, but HUBE has now also been proposed to NASA as a Small Explorer (SMEX). I show, through simulations, the very high quality of astrophysically important data that can be expected from HUBE, should it be implemented as a Small Explorer.

1. Introduction

In this volume, in a companion paper (Henry 1997a), I discuss the scientific value and interest of the cosmic diffuse ultraviolet background radiation. In the present paper, I describe the capabilities of a specific proposed complement of instruments (an imager, and two spectrometers) for measuring the intensity and distribution of the ultraviolet background radiation. Together, these three instruments form *HUBE, the Hopkins Ultraviolet Background Explorer*, which was selected in April 1996 by NASA as the Astrophysics MIDEX Alternate Mission.

Selection as an Alternate Mission does *not* guarantee construction and launch of the mission; indeed, that result could only occur should the primary mission fail in its definition study. The primary mission, MAP, is under definition by scientists at Goddard Space Flight Center, and in my judgment is almost certain to succeed. This being the case, I have (with the vital help of many people: please see the Acknowledgments below) created a slightly simplified version of HUBE, and submitted it, at lower cost, to NASA: but now as a Small Explorer (SMEX). The result of the SMEX competition is to be announced in 1997 October.

NASA's priorities in selecting missions are based on studies that are carried out by the United States National Academy of Sciences, and by internal NASA study panels. The study that is probably most relevant in judging HUBE's chances in the SMEX competition is the Structure and Evolution of the Universe “roadmap,”

● http://www.srl.caltech.edu/seus/roadmap/,

which was the result of the work of a panel that was chaired by Dr. Roger D. Blandford of the California Institute of Technology. In Fig. 1, I display the SEUS Explorer Program recommendations for the field of ultraviolet astronomy (I have corrected minor errors that appear in the original table). HUBE appears to address most of what is called for in the “Elements" and “Cycles" Campaigns, missing only on the “Dark Matter" Campaign - which is ironic, because in fact (Henry 1997a) implementation of HUBE might well result in the discovery of both the baryonic and non-baryonic dark matter in the Universe!

MISSION	PRIMARY SCIENCE	INSTRUMENT GOALS	SIZE	KEY TECHNOLOGY
"Dark Matter" Campaign: Cosmological Helium Probe	Measure $^3He/^4He$ isotope ratios in Local Universe He Gunn-Peterson effect	Extreme Ultraviolet/Far Ultraviolet (EUV/FUV) spectroscopy	MIDEX	Grating spectrometer
"Elements" Campaign: UV spectroscopic survey	Survey starburst galaxies Study star formation and evolution from z = 0 - 2	900 – 1200 Å 1200 – 2800 Å spectroscopy	MIDEX, SMEX	Channel Plate Detectors Lightweight optics
"Cycles" Campaign: UV diffuse spectral imager	Study hot ISM in our and other galaxies	Spectroscopy 900 – 1200 Å 1200 – 2800 Å	SMEX	Diffuse grating spectrometer
"Cycles" Campaign: UV Imaging Survey	Understand geometry and structure of active galactic nuclei	All sky coverage 900 – 2800 Å	SMEX	Channel plate detectors Normal incidence optics

Fig. 1. The SEUS Explorer Program Ultraviolet Astronomy SMEX/MIDEX recommendations.

A brief description of an earlier version of HUBE is given by Kimble et al. (1990), and Henry (1997b) has demonstrated the suitability of HUBE for meeting our need for an ultraviolet sky survey that would complete humankind's initial survey of the universe. The latter paper also presented HUBE's sensitivity for the detection of point sources; study of point sources therefore will not be discussed in the present paper.

2. The HUBE Instruments

There are three HUBE instruments:

- The Imager, an f/3.5 camera (split photocathode: 1350-1600 Å and 1350-2000 Å), 2.5 degree field-of-view with point source location to 10".

- The Far Ultraviolet Spectrograph (FUVS), an f/2.4 spectrograph (1230-1800 Å) with 5 Å spectral resolution.

- The Extreme Ultraviolet Spectrograph (EUVS), an f/2.4 spectrograph (850-1200 Å) with 3 Å and 17 Å resolution.

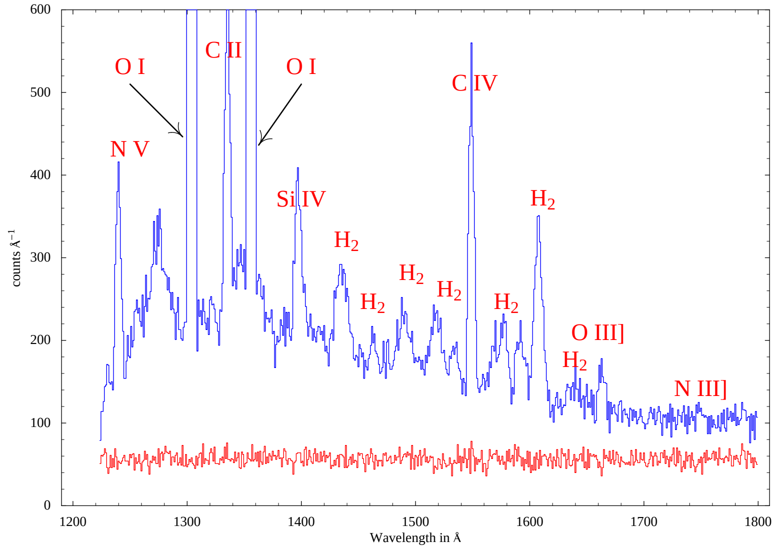

Fig. 2. Simulated HUBE Far Ultraviolet Spectrograph (FUVS) Observation: a 3600-s integration of the diffuse UV background at high galactic latitudes. The lower line (near zero) is the contribution of detector internal background to the observed signal. Molecular hydrogen emission, high-ionization line emission, and continuum are all detected easily. Geocoronal emissions, at O I 1304 and 1356 Å , are easily removed.

All three instruments incorporate photon-counting microchannel plate detectors virtually identical to detectors that are now flying successfully on the Extreme Ultraviolet Explorer (EUVE). High sensitivity for diffuse radiation requires short focal lengths and fast f/ratios. For this reason instruments such as those on the Hubble Space Telescope (HST) are completely insensitive to the UV background, as are instruments on every other mission that is currently scheduled for flight (for example, the Far Ultraviolet Spectroscopic Explorer, FUSE).

3. The Far Ultraviolet Spectrograph (FUVS)

A simulation of the capability of FUVS for analysis of the diffuse ultraviolet background radiation is given in Fig. 2. It is a remarkable coincidence that so many fundamentally different emission mechanisms are seen or predicted to be of roughly comparable intensity! The emission sources are nevertheless separable by virtue of their characteristic spectral signatures and spatial structures. A suitably designed all-sky survey mission will therefore contribute dramatically to our understanding of a broad range of galactic and extragalactic sources.

In particular, Fig. 2 shows the response of the FUVS to a 3600-s exposure to a UV background composed of *a)* 300 photons cm^{-2} s^{-1} sr^{-1} $Å^{-1}$. (hereafter called "photon units") of extragalactic *and/or* dust-scattered continuum radiation; *b)* high-ionization line emission predicted by the model of Paresce et al. (1983) as a "canonical galactic corona" at levels consistent with the line intensities reported by Martin & Bowyer (1990); and *c)* molecular hydrogen fluorescence at a level appropriate to high galactic latitudes according to the model of Jakobsen (1982). All three components are detected at high signal-to-noise, with no difficulty in separating the various contributors to the spectrum.

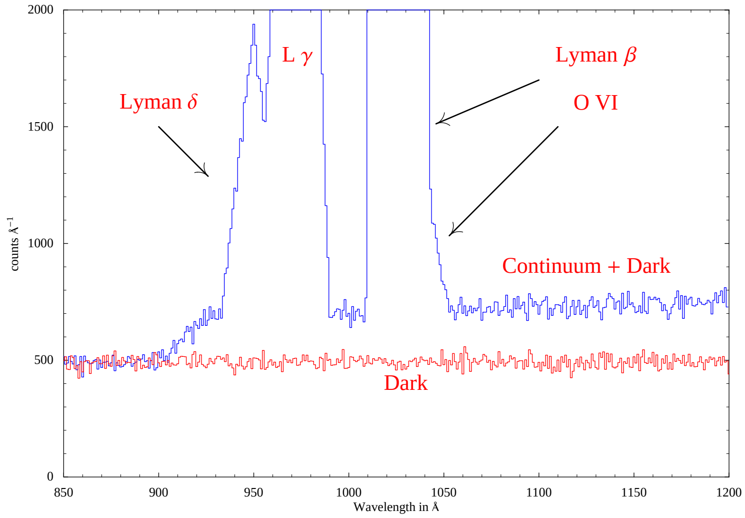

Fig. 3. HUBE simulated EUVS observation of the diffuse background: half of the slit of the HUBE short-wavelength spectrometer EUVS is 17 Å spectral resolution, to allow us to measure the strength of the continuum emission at wavelengths shortward of Lα, and in particular to determine the reality of the sharp, even abrupt decline in the background below Lα that the existing data (Henry 1997a) suggest exists. Here I show the response (3600-s integration) of EUVS to a continuum background of 300 photon units. The O VI emission is blended with terrestrial Lβ at this low resolution. If it should turn out that there is *negligible* continuum below Lα, such simulations suggest that we will be able to set an upper limit as low as 30 photon units. Most of the "dark current" that is shown is actually grating-scattered terrestrial Lα radiation; it is isolated cleanly below 912 Å.

4. The Extreme Ultraviolet Spectrograph (EUVS)

The EUVS operates shortward of the intense geocoronal Lyman alpha line. One major reason for including an EUV spectrograph in the HUBE complement is the desire to test the idea (Henry 1991) that there is a break in the diffuse ultraviolet background spectrum at Lyman alpha. If such a break exists, it would be natural to attribute it to an origin of the longer-wavelength diffuse background in Lyman alpha recombination radiation from an ionized intergalactic medium.

In Fig. 3 I show the response of EUVS to a diffuse continuum background at the same level as that "detected" in the FUVS simulation of Fig. 2; that is, this is what we might expect to see if the continuum background is *not* due to recombination radiation.

But testing speculative cosmological ideas is far from all that EUVS will do: as Fig. 2 shows, FUVS should detect emission lines from C II, C IV, O II, and N III (detectable in longer exposures), and in Fig. 4 I show what we expect of that kind from EUVS, which can detect high excitation lines, such as O VI (1032 Å/1038 Å). The emission from O VI is particularly important because it is produced in gas at about 300,000 K and would represent direct evidence for the predicted hot halo of our galaxy (Spitzer 1956).

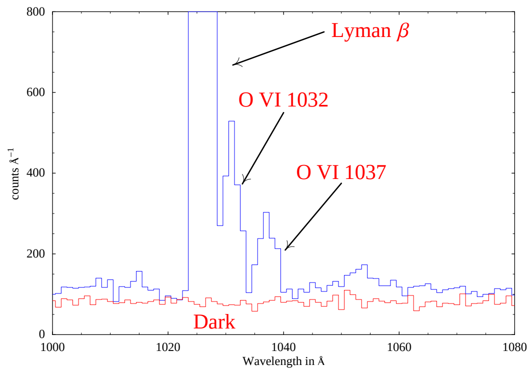

Fig. 4. Simulated HUBE EUVS observation of OVI: Benjamin & Shapiro (1992) calculated the ionization balance of low-density gas cooling from a high temperature in the galactic corona. Their model, normalized to the intensity of C IV reported by Martin & Bowyer (1990), predicts an average flux in O VI of 30,000 photons cm^{-2} s^{-1} sr^{-1} $Å^{-1}$. The figure shows that intensity folded through our short-wavelength spectrometer, EUVS, for a typical observation (3600 s) (only 1/10 that intensity is assumed in Fig. 5). The hot halo of the galaxy is detected with high signal-to-noise. Dixon et al. (1996) reported 4σ detection of such emission; HUBE will map such emission with high signal-to-noise over the entire sky. Note the high reliability of our simulation: our assumed detector noise is the actual background experienced by the detectors on EUVE. (Only the data from the 3 Å portion of the EUVS slit are shown; the diffuse continuum is not easily detectable in this short an exposure at this resolution, but will be simultaneously detected at high signal-to-noise with the 17 Å portion of the slit, as was shown in Figure 3.

5. Summary

The power of the HUBE instruments for increasing our knowledge and understanding of the universe is epitomized by the simulation that appears in Fig. 5, a simulated *one-week* exposure with the Extreme Ultraviolet Spectrograph (EUVS). Only in *this* figure do we suppress the zero level; what the actual limitations, due to systematic effects, will be, will only be apparent on orbit. If such long exposures prove to be possible, we will clearly have data of the very highest quality, giving us new insights into the character of the interstellar medium, and possibly also concerning the nature of the universe itself.

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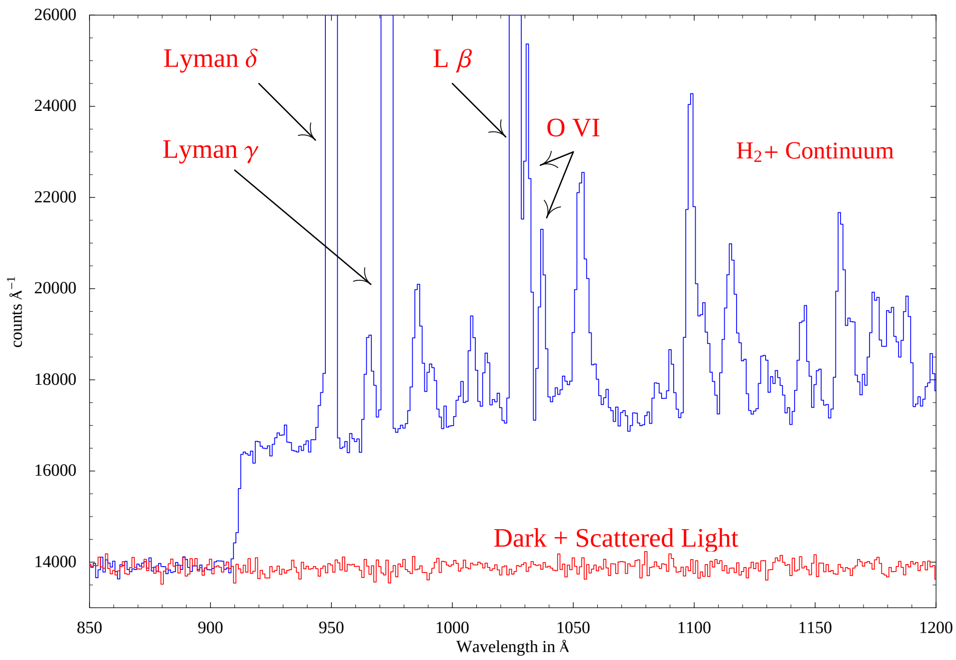

Fig. 5. Simulated HUBE Extreme Ultraviolet Spectrograph (EUVS) observation. In this one-week observation, all of the different components of the diffuse radiation field are visible and cleanly separable. Although our standard exposure time is only 3600 s, we will occasionally make repeat observations of selected regions of interest. Note that this simulation is of data from the central part of the slit, where the spectral resolution is 3 Å; a simulation of the wide part of the dumbbell-shaped slit was shown in Fig. 3.

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