Capabilities of HUBE, the Hopkins Ultraviolet Explorer

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In April 1996, the Hopkins Ultraviolet Background Explorer (HUBE) was selected by NASA as a Medium-class Explorer *Alternate* Mission. (An Alternate Mission undergoes Pre-Phase-A study, and also undergoes Definition Study, should the primary mission not succeed in its own Definition Study phase.) HUBE, as a Medium-class Explorer, will open an important new field of astrophysical research: doing for diffuse UV radiation what IRAS and COBE have already done for the diffuse infrared. Although optimized for the study of the diffuse UV background, HUBE, as the first sensitive survey instrument in the UV, will discover vast numbers of point sources. For example, HUBE will discover all of the quasars that are exploitable by HST and FUSE. Please visit the HUBE homepage, http://msx4.pha.jhu.edu

1. Introduction

HUBE will perform an all-sky survey of the cosmic diffuse ultraviolet background radiation and ultraviolet point sources in the wavelength ranges 850–1200 Å and 1230–2000 Å. Both imaging and spectroscopy will be employed to produce a wealth of significant new information on the following important astrophysical problems:

- the nature of the hot component of the interstellar medium (ISM) and the galactic halo,
- the distribution of molecular hydrogen in the ISM,
- the distribution of interstellar dust and the scattering properties of the interstellar grains,
- the integrated light of galaxies, for study of star formation and galaxy evolution,
- the possibility of radiation from an ionized intergalactic medium, or (more speculatively) from the decay of neutrinos or more exotic particles of non-zero rest mass,
- the location and ultraviolet brightness, of faint stars, galaxies, and quasars, and
- spectra of faint point sources, 912 – 1800 Å.

2. The HUBE Team

HUBE Co-Investigators are: A.F. Davidsen, P.D. Feldman, H. Ford, J. Kruk, J. Murthy, D.A. Neufeld (JHU), L.J. Paxton, K. Peacock (JHU/APL), J. Atkins, E. Hammond (Morgan State U), G. Carranza (Córdoba, Argentina), P.A. Charles (Oxford), M. Clampin (STScI), E. Conway (Sykesville Middle School), P. Jakobsen (ESTEC), R.A. Kimble (GSFC), R.W. O'Connell (UVa), A. Sandage (Carnegie), and C. Vaz (U. Algarve, Portugal).

3. The HUBE Concept

HUBE has been described in a preliminary way by Kimble et al. (1990). An overview of diffuse ultraviolet background radiation is given by Henry (1991), while recent research papers on this subject include Henry (1995), Henry & Murthy (1993, 1994), Murthy & Henry (1995), and Murthy et al. (1993, 1994).

Survey of the State of our Study of the Universe at All Astronomical Wavelengths

Wave-length	Radio	μ-wave	Sub-mm	Infra-red	Visible	**Ultraviolet**	Soft X-ray & EUV	X-Ray	γ-ray
Detailed Study of Point Sources	VLBI	(ground)	SWAS	ISO & SIRTF	HST	HST, FUSE & IUE	Einstein	Einstein & AXAF	GRO
Point Source Sky Survey	(ground)	(ground)	DIRBE	IRAS & WIRE	(ground)		Uhuru & EUVE	Uhuru & HEAO	GRO
Diffuse Background Sky Survey	RAE-A	COBE	DIRBE	IRAS & WIRE	UVISI		Rosat & EUVE	HEAO	GRO

Hube will fill *both* the remaining blanks in our inventory of the Universe

FIGURE 1. HUBE, the Hopkins Ultraviolet Background Explorer, when implemented by NASA will fill the last remaining gaps in humankind's initial survey of our Universe. It will carry out a mapping mission for the diffuse ultraviolet background radiation, as well as a point source survey that will find millions of ultraviolet-emitting objects.

HUBE will operate in two extremely dark regions of the electromagnetic spectrum: shortward of Lyman α, and between the intense geocoronal Lyman α line at 1216 Å and the zodiacal light, which brightens greatly longward of 2000 Å. The sky background in the HUBE band is $\sim$ 100 times fainter than that in the visible, even from space. As a result, the potential for HUBE to detect entirely new classes of objects is very great. HUBE will, for example, be ideal for detecting large, extremely low surface brightness objects, such as Lyman α emitting clouds out to redshifts ~ 0.5.

Three small (two 20 cm aperture, one 8 cm aperture) complementary, co-aligned instruments are employed by HUBE to elucidate the relative contributions of the possible sources listed above. All instruments incorporate photon-counting microchannel plate detectors virtually identical to detectors now flying successfully on EUVE. The three instruments are:

- an $f/3.2$ imager (1350 − 2000 Å and 1350 − 1600 Å), 2.5° field of view, 35″ resolution,
- FUVS, an $f/2$ spectrograph (1230 − 1800 Å) with 5 Å spectral resolution
- EUVS, an $f/5$ spectrograph (850 − 1200 Å) with 3 Å and 17 Å resolution.

The HUBE instruments will be mounted on a near-duplicate of the SWAS spacecraft to be built by Goddard Space Flight Center. The all-sky survey will require, nominally, 217 days of operation, allowing, in a two-year mission, selection of a large number of additional "deep-pointing" targets for intensive examination. HUBE is inexpensive because it is small and simple. High sensitivity for diffuse radiation requires short focal lengths and fast f/ratios. For this reason instruments such as IUE and HST are com-

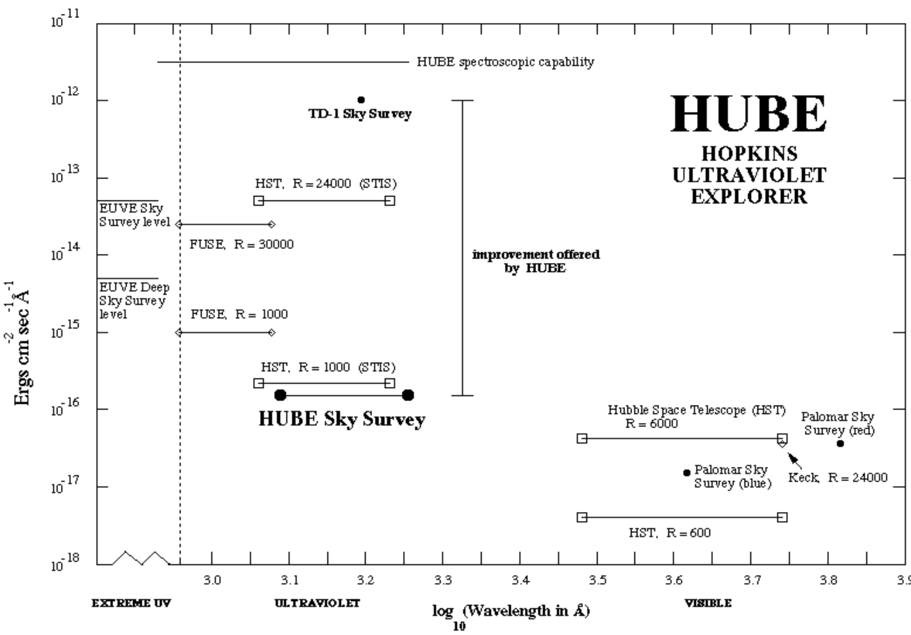

FIGURE 2. In any wavelength band, one wishes to have available a sky survey that is well-matched to the attainable magnitude limits of the most powerful large telescopes in that same wavelength band. For example, in the visible, the Palomar Sky Survey is well-matched to the capabilities of Keck and HST. In marked contrast, the only all-sky survey in the ultraviolet, TD-1, is ludicrously ill-matched to the power of HST-STIS and FUSE. Our figure shows how HUBE will remedy this situation.

pletely insensitive to the UV background. The optics, detectors, pointing, mechanical, and thermal requirements for HUBE pose no significant new technical challenges. The required spacecraft can be provided economically by reproducing the Goddard SWAS design. As a result, the proposed cost for HUBE is exceptionally well-founded.

We particularily emphasize that while HUBE will break new ground scientifically, in all other respects it is extremely conservative. There is no detector development involved; the HUBE detectors are simple adaptations of currently-flying (EUVE) detectors, and these detectors are of a kind with which the Johns Hopkins Applied Physics Laboratory has substantial direct experience. The spacecraft maximizes investment return on the Goddard Space Flight Center development of the SWAS spacecraft. The instruments are simple and straightforward. The weight and power and cost estimates are clear and firm.

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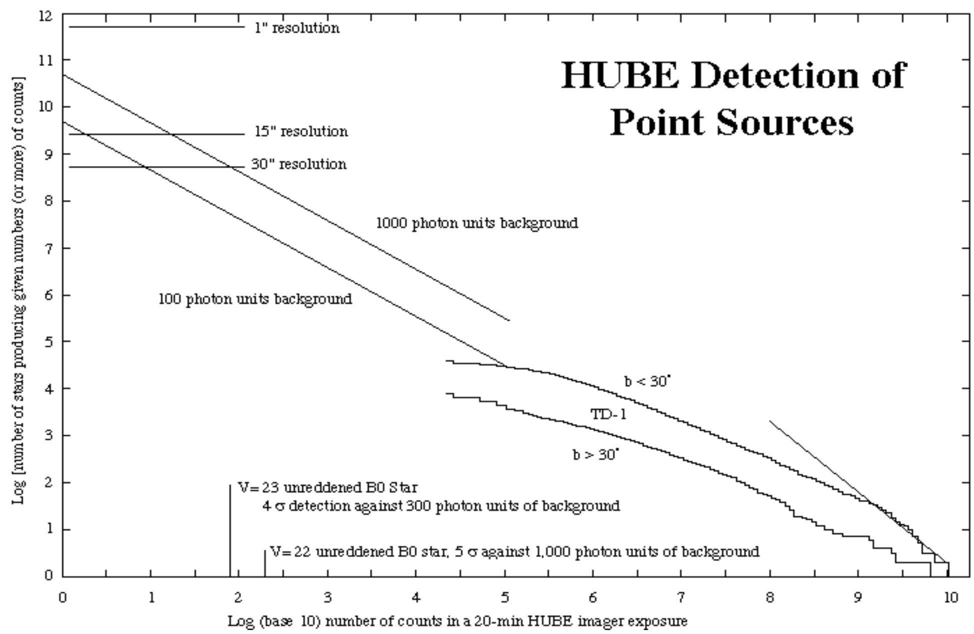

FIGURE 3. Point Sources as Detected by the HUBE Imager: along the bottom scale, the logarithm of the number of counts the HUBE imager will obtain for one star in a 20 minute exposure. The limits for detection of these stars against the cosmic diffuse background are shown as short vertical lines. The vertical axis gives the logarithm of the number of stars that will produce that number of counts (or more); that is, this is a standard log N - log S plot. The actual stars that are plotted are two samples, the TD-1 stars at latitudes higher than $|b| = 30$ degrees (lower curve), and the TD-1 stars at lower latitudes (the upper curve). The short straight line tangent to the bright end of the upper curve is what would be expected for a uniform distribution of equal-brightness stars throughout space. It matches the upper curve for the brightest stars, which are essentially unreddened, but note the immediate, strong, and increasing effects of interstellar reddening for fainter stars. The data plotted go about a factor 10 in brightness fainter than the level to which TD-1 is believed to be complete; this incompleteness is apparent at the faint ends of the two lines. It is interesting to speculate from these data as to how many fainter stars HUBE will detect. Limits on what HUBE might find for fainter stars are provided by existing measurements of the cosmic diffuse background. If one assumes that the measurement or upper limit is due to an unresolved population of faint point objects (eg, white dwarfs or halo stars), one gets the distributions shown by the straight lines labelled “100 [1000] photon units background.” It is clear that the $35''$ spatial resolution of HUBE is adequate to avoid any likely source-confusion problems. UIT and FAUST experience strongly confirms this idea.

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