Diffuse UV Background

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Abstract

We show that *FUSE* is capable of providing unique data on the diffuse ultraviolet background radiation shortward of Lyman α. This is the only way of confirming previous *Voyager* measurements of the diffuse background, which are contaminated with Lyman β because of the poor (28 Å) spectral resolution of *Voyager*. Confirmation of the *Voyager* measurements is important in its own right, but also may be of unique importance to cosmology, as the *Voyager* measurements show a drastically different picture of the diffuse ultraviolet background short of Lyman α, compared with what is seen longward of Lyman α, suggesting the possibility that the general diffuse background longward of Lyman α is at least partially of cosmological origin (intergalactic hydrogen recombination radiation). While we have just, once again, been successful in obtaining *GALEX* observing time longward of Lyman α, *FUSE* provides our only opportunity to test the strengthen our case shortward of Lyman α.

Investigator List

	Investigator	Institution	Country
PI:	Prof. Richard Conn Henry	The Johns Hopkins University	USA
CoI:	Prof. Jayant Murthy	Indian Institute of Astrophysics	India
CoI:	Ms. P Shalima	Indian Institute of Astrophysics	India

Scientific Justification

FUSE has given much information on celestial point sources, but also can measure bright *diffuse* sources: e.g., Shelton et al. (2001) and Welsh et al. (2002) observed OVI emission.

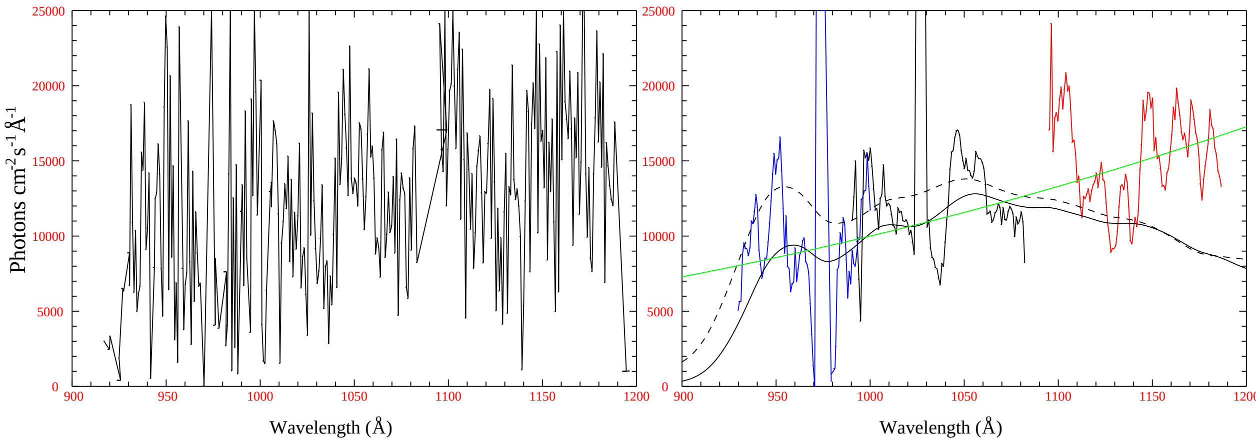

Figure 1: Archival FUSE LWRS spectra of the diffuse background radiation at $l = 297.6, b = +0.3$ show the quality of data we can expect (4154 s observation). Left: 0.9 Å resolution spectra (to bring out the better spectral resolution that should be possible). Right: a running mean of the same data. The dashed line is a 30,000 K Kurucz model; the solid black line is a Kurucz 25,000 K model. The green line is a *power law*—the brightness decreases with the cube of the energy.

Murthy and Sahnow (2004) discovered that *FUSE* can also make useful measurements of diffuse *continuum* sources. In the case of bright regions such as Orion, spectra of spectacular quality have been obtained (Murthy, Sahnow, & Henry 2005).

This proposal is oriented toward cosmology: toward confirmation of the measurements of the diffuse background that we earlier made with *Voyager* (Murthy et al. 1999). Figure 1 suggests the quality of spectra that we will obtain (we propose 15,000 s observations).

The *greatest* scientific interest in the diffuse UV background lies in the existing evidence that exotic sources contribute very substantially to the diffuse UV background at moderate and high Galactic latitudes. The evidence for an exotic origin (perhaps redshifted Lα radiation from the IGM) to the UV background is reviewed in Figure 2. The critical point, of course, is the dramatic abrupt drop in the UV background shortward of 1216 Å, suggestive that a good part of the longward radiation is red-shifted Lα from the IGM.

Figure 3 shows, left, on a *logarithmic* intensity scale, the brightness of the sky at about 1000 Å as reported by Murthy et al. Our map is in galactic coordinates. Note the dramatic

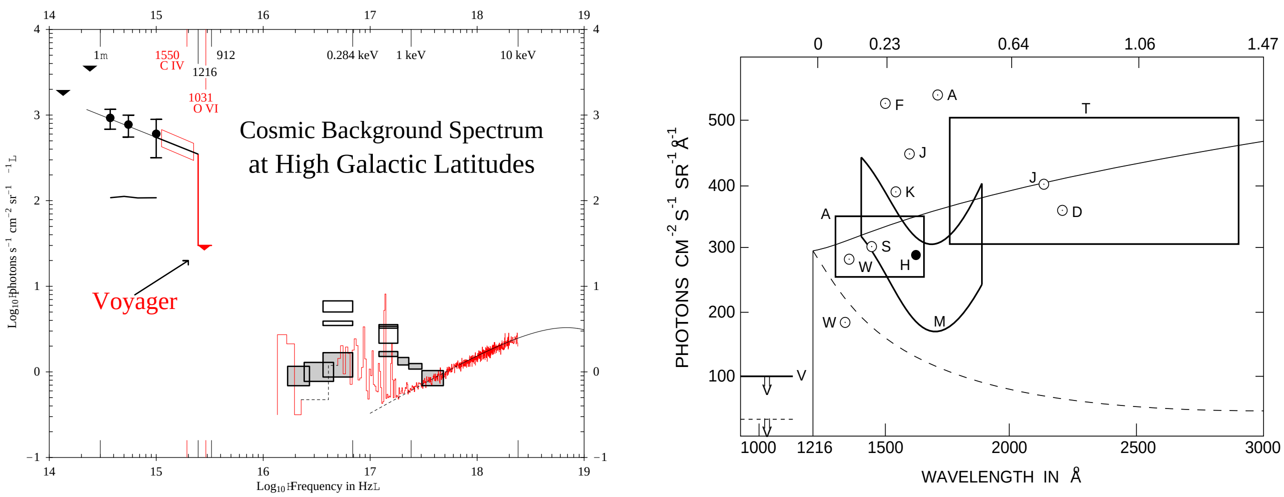

Figure 2: Left: Diffuse background overview. Right: The UV details (Henry & Murthy 1995).

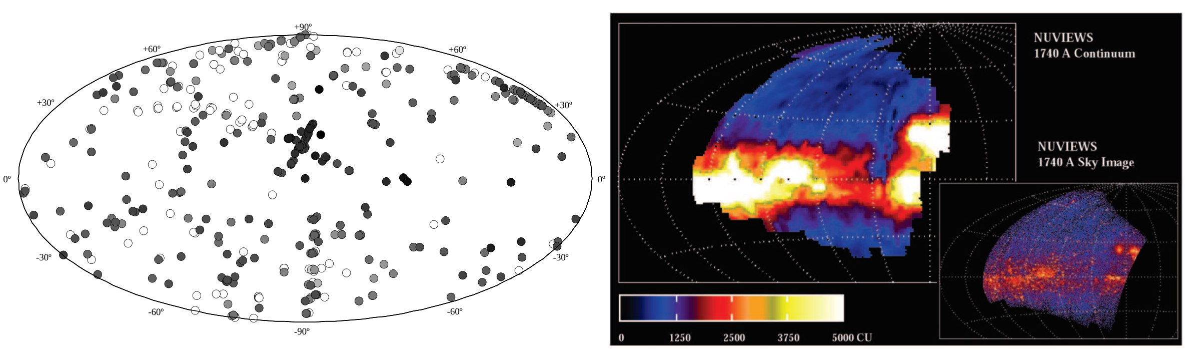

Figure 3: Left: *Voyager* galactic coordinate diffuse sky at ∼ 1000 Å (logarithmic brightness scale). Right: The blue glow is the 1740 Å diffuse UV background of Schiminovich et al. (2001).

difference between our 1000 Å "sparse" map, and the 1740 Å map! The latter may contain a significant contribution from *general* diffuse galactic light; the former certainly does not (but, *what are the bright patches?*). The case that the diffuse UV background at high Galactic latitudes short of 1700 Å (but longward of 1216 Å) is mainly extragalactic is very strong.

Now, what *are* the bright patches in the *Voyager* map of Figure 3? That is the major question that we address in the present proposal. In Figure 4, on the left, we see the excellent fit of a Kurucz 25,000 K stellar model to our *Voyager* spectrum. (The model is also shown smeared to *Voyager* resolution.) Clearly, in this case, we are merely seeing starlight scattered from dust. But, the spectrum in the *right* part of the figure is typical of *most* of the bright patches in our 1000 Å *Voyager* map. The spectrum is exponential or power law, and bears no resemblance to a stellar spectrum!

We expect to elucidate the mystery of the character of the bright patches shortward of

Lα with the observations we propose here. The spectrum we show in Figure 1 was obtained by Murthy and Sahnow from archival *FUSE* observations. The result is tantalizing: the spectrum shows the "power-law rise" of Figure 4's second part (Voyager target "Lam Lib"), *but* we also see structure that is not dissimilar to that in Figure 4's *first* part. There is no *Voyager* observation of this (or *any!*) *FUSE* location.

Clearly, *FUSE* is the only available tool for pursuing this intriguing mystery. How should we go about it? While perfection would be a sky survey, that is clearly not possible. What we propose is to use the existing *Voyager* observations as a *guide*, so that we will *only* observe locations with *FUSE* where we *know* that the observing time will be spent productively. In Table 1 we list the six *FUSE*-accessible *Voyager* targets having fluxes greater than 3000 photons cm^{-2} s^{-1} sr^{-1} Å^{-1} which we know (from experience) is the *FUSE* practical limit. In our observing list we give, for each of these targets, *three* locations : the *Voyager* target itself, plus positions 0.5° north and south of that spot. The *Voyager* slit is 0.8° long, and the *Voyager* spectra are integrations of a patch $0.8° \times 0.1°$. We will thus obtain information on the small-scale structure of the "mystery patches."

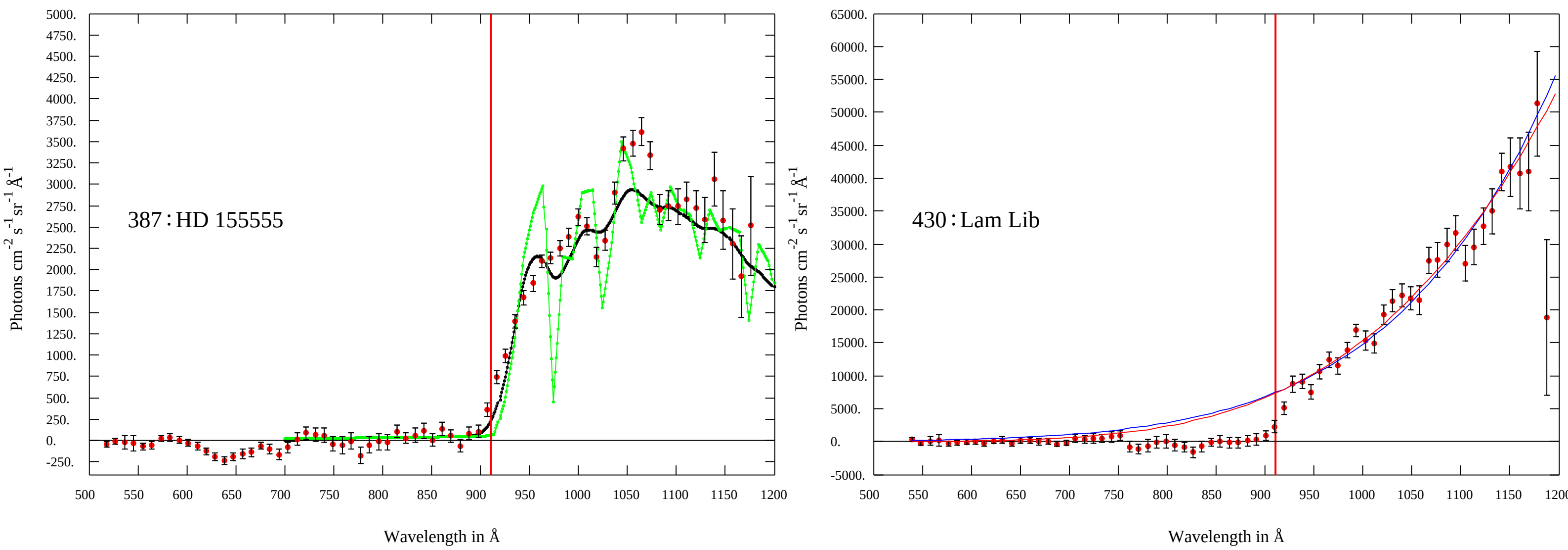

Figure 4: *Voyager* spectra (names: *Voyager* project names) of scattered starlight (left); radiation of uncertain origin (right). The red line marks the Lyman limit, 912 Å, below which no astrophysical signal can be seen.

References:

Henry, R. C., & Murthy, J., 1995, in Extragal. Bkgrd Rad., ed. Calzetti et al., CUP
Murthy, J., Sahnow, D. J., & Henry, R. C., 2005, ApJ, 618, L99
Murthy, J., & Sahnow, D. J., 2004, ApJ, 615, 315
Murthy et al. 1999, ApJ, 522, 904
Shelton, R. et al., 2001, ApJ, 560, 730;
Welsh, B. et al., 2002, A&A, 394, 691
Schiminovich, D., Friedman, P. G., Martin, C., & Morrissey, P. F. 2001, ApJ, 563, L164

Feasibility and Safety Considerations

Murthy & Sahnow (2004) clearly demonstrate the feasibility, as does the actual result which is displayed in Figure 1. As all of our targets are "blank sky" regions, safety is guaranteed. (As a precaution, we checked our proposed targets against the full TD1 catalog, finding no danger.) The low S/N we expect is not a problem, because we expect continuum sources. We propose to observe diffuse targets using the LiF LWRS aperture. Because we are observing diffuse targets, we do not require pointing accuracy better than about $0.1'$ if that. (As there are no point sources in our *FUSE* field, we have simply put placeholders $V = 22$ and a very low arbitrary flux value in the Observing Summary. The surface brightness is from *Voyager*).

Description of the Observations

The flux is that observed by *Voyager* at ~ 1000 Å in photons cm^{-2} s^{-1} sr^{-1} Å^{-1} .

Target	RA	Dec	Number	Flux	Error	n_H	l	b
1	190.1	-64.6	1188-2 (428)	18864 ±	383	0.019	301.7	-1.7
2	194.6	-62.3	932-2 (427)	15499 ±	123	0.025	303.7	0.6
3	216.9	-62.6	338-1 (414)	6338 ±	171	0.016	313.7	-1.7
4	143.5	59.3	37-1 (398)	3578 ±	350	0.007	155.2	43.5
5	135.5	58.1	36-1 (397)	3530 ±	285	0.014	158.3	39.8
6	259.4	-67.0	755-2 (387)	3390 ±	57	0.027	324.9	-16.3

Additional Information

We will use the same technique as described in Murthy & Sahnow (2004) to analyze the data. A brief summary of the approach is given here.

We used the standard CALFUSE pipeline (v2.4) to process the files after adding together all the different exposures in one observation (using the program ttag_combine.c available as part of CALFUSE). For the faint backgrounds that were present in most of S405/505 observations, we used only broad bands to extract the flux; however, for the brightest observations, such as the diffuse background observations we expect here, it was possible to extract a spectrum, albeit at a lower resolution. We found that CALFUSE tended to overestimate the background for these relatively faint extended sources and therefore replaced the background subtraction procedure with an empirical model in which we estimated the background from the flux beside the aperture. In addition, to increase the S/N, we binned the data by a factor of 128 in the spectral direction, yielding 1 Å bins. The resultant spectrum is shown in Figure 1.

Previous FUSE Observing Programs

We were allocated 24000 seconds in Cycle 3 to observe 4 locations near the star α Cru and another calibration star (Eps CMa) to search for dust halos near the star. We have also been allocated 40000 seconds in Cycle 5 to observe 4 locations toward the Coalsack nebula in order to derive the dust grain parameters in the region. Few of these observations have yet been performed. Murthy has analyzed the S405/505 observations for the presence of diffuse radiation—published in ApJ (Murthy & Sahnow 2004; Murthy, Sahnow, & Henry 2005).

Vita

Dick Henry is the author of an *Annual Reviews* article on diffuse ultraviolet background radiation (ARAA **29**, 89, 1991). Dick is also author of a more recent ApJ Letter giving an overview of diffuse background radiation at *all* wavelengths, with an emphasis on ultraviolet *Voyager* results (ApJ **516**, L49, 1999).

The references to the observations in the right part of Figure 2 of the present proposal are given in Dick's paper (with Jayant Murthy) on page 51 of "Extragalactic Background Radiation," ed. Calzettit et al., Cambridge University Press, Space Telescope Science Institute Symposium Series # 7, 1995; this paper also discusses the science in some depth.

Jayant Murthy is a Professor in the Indian Institute of Astrophysics. He has been working on understanding the diffuse UV radiation field for the last 15 years using data from several spacecraft including UVX, MSX, FUSE, Voyager, and IRAS. He is the Principal Scientist on TAUVEX - an Indo-Israeli mission to observe a substantial fraction of the sky in three wavelength bands.

P Shalima is a graduate student at the Indian Institute of Astrophysics. She is working on problems of the diffuse background.

Observing Summary:

Object name	RA	V	Spec	λ_{ref}	FWHM	Aperture	S/N	Special
IntTime	Dec	E(B-V)	Src	$Flux_{\lambda ref}$	$SB_{\lambda ref}$	FluxAcc	Resln	Req
							Channel	
bkgd.01.0	12:40:33.92	22	OTR	1000		LWRS	7.5	
15000 s	-64:34:20.7		EC	1.5e-13	0.88E-17	HIGH	0.9Å	
							LiF1	
bkgd.01.1	12:40:33.92	22	OTR	1000		LWRS	7.5	
15000 s	-64:04:20.7		EC	1.5e-13	0.88E-17	HIGH	0.9Å	
							LiF1	
bkgd.01.2	12:40:33.92	22	OTR	1000		LWRS	7.5	
15000 s	-65:04:20.7		EC	1.5e-13	0.88E-17	HIGH	0.9Å	
							LiF1	
bkgd.02.0	12:58:17.16	22	OTR	1000		LWRS	6.8	
15000 s	-62:16: 5.4		EC	1.5e-13	0.72E-17	HIGH	0.9Å	
							LiF1	
bkgd.02.1	12:58:17.16	22	OTR	1000		LWRS	6.8	
15000 s	-61:46: 5.4		EC	1.5e-13	0.72E-17	HIGH	0.9Å	
							LiF1	
bkgd.02.2	12:58:17.16	22	OTR	1000		LWRS	6.8	
15000 s	-62:46: 5.4		EC	1.5e-13	0.72E-17	HIGH	0.9Å	
							LiF1	
bkgd.03.0	14:27:25.76	22	OTR	1000		LWRS	4.4	
15000 s	-62:37:25.2		EC	1.5e-13	0.30E-17	HIGH	0.9Å	
							LiF1	
bkgd.03.1	14:27:25.76	22	OTR	1000		LWRS	4.4	
15000 s	-62:07:25.2		EC	1.5e-13	0.30E-17	HIGH	0.9Å	
							LiF1	
bkgd.03.2	14:27:25.76	22	OTR	1000		LWRS	4.4	
15000 s	-63:07:25.2		EC	1.5e-13	0.30E-17	HIGH	0.9Å	
							LiF1	
bkgd.04.0	09:34: 7.76	22	OTR	1000		LWRS	3.3	
15000 s	+59:16:50.3		EC	1.5e-13	0.17E-17	HIGH	0.9Å	
							LiF1	
bkgd.04.1	09:34: 7.76	22	OTR	1000		LWRS	3.3	
15000 s	+59:46:50.3		EC	1.5e-13	0.17E-17	HIGH	0.9Å	
							LiF1	
bkgd.04.2	09:34: 7.76	22	OTR	1000		LWRS	3.3	
15000 s	+58:46:50.3		EC	1.5e-13	0.17E-17	HIGH	0.9Å	
							LiF1	
bkgd.05.0	09:01:51.96	22	OTR	1000		LWRS	3.3	
15000 s	+58:06:23.3		EC	1.5e-13	0.16E-17	HIGH	0.9Å	
							LiF1	

Observing Summary:

Object name IntTime	RA Dec	V E(B-V)	Spec Src	λ_{ref} $Flux_{\lambda ref}$	FWHM $SB_{\lambda ref}$	Aperture FluxAcc	S/N Resln Channel	Special Req
bkgd.05.1 15000 s	09:01:51.96 +58:36:23.3	22	OTR EC	1000 1.5e-13	 0.16E-17	LWRS HIGH	3.3 0.9Å LiF1	
bkgd.05.2 15000 s	09:01:51.96 +57:36:23.3	22	OTR EC	1000 1.5e-13	 0.16E-17	LWRS HIGH	3.3 0.9Å LiF1	
bkgd.06.0 15000 s	17:17:31.46 -66:57:25.0	22	OTR EC	1000 1.5e-13	 0.16E-17	LWRS HIGH	3.2 0.9Å LiF1	
bkgd.06.1 15000 s	17:17:31.46 -66:27:25.0	22	OTR EC	1000 1.5e-13	 0.16E-17	LWRS HIGH	3.2 0.9Å LiF1	
bkgd.06.2 15000 s	17:17:31.46 -67:27:25.0	22	OTR EC	1000 1.5e-13	 0.16E-17	LWRS HIGH	3.2 0.9Å LiF1	