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Ultraviolet Background Radiation from Not-So-Dark Matter in the Galactic Halo

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Abstract: Murthy et al. (2025) (hereafter Paper I) have recently reported the discovery of unexpectedly bright diffuse extreme-ultraviolet radiation at high latitudes in both the Northern and Southern Galactic Hemispheres. After correction for extinction by the total interstellar dust in the direction of each observation, the spectra are nearly identical, suggesting that the radiation has a unique source and likely originates in the halo of our galaxy. The observed spectrum extends down to 912 Å, the interstellar hydrogen absorption edge. Radiation even slightly short of that edge would, if ubiquitous, be sufficient to explain the high degree of ionization in our galaxy and throughout the universe. We hypothesize that this newly discovered radiation originates in the slow decay of dark matter. The intensity of the radiation implies that the decay cannot be via the weak interaction, suggesting the existence of a new, even weaker fundamental interaction, consistent with the exceedingly long decay lifetime required.

Keywords: ultraviolet background radiation; dark matter

1. Introduction

The observation of cosmic background radiation over a great range of wavelengths has provided us with many fundamental discoveries in astrophysics (Figure 1) [1]. One of the most difficult spectral regions over which to observe this background radiation is the ultraviolet because of the need for space-based observations and the high opacity of the interstellar medium. The spectral range between the Lyman limit (912 Å) and Lyman alpha (1216 Å, hereafter Ly α) is further complicated because of the brightness of interplanetary Ly α emission, due to solar radiation scattered from interplanetary hydrogen, which is scattered throughout the instrument.

The cosmic ultraviolet background is made up of many sources [2,3]. It is dominated by scattering from interstellar dust at low galactic latitudes, as would be expected from the concentration of both hot stars and interstellar dust in the galactic plane. Contributions from an extragalactic background light (EBL) are important at the galactic poles where the extinction is low, with possible contributions from other galactic components, such as emission lines from hot gas [4], molecular hydrogen fluorescence [5], or two-photon emission [6]. Figure 2 plots the locations (in galactic coordinates) of the hot stars whose ultraviolet light scatters off the interstellar dust, providing the bulk of the diffuse ultraviolet background. Taking into account all the stars in the Hipparcos catalog and fitting them with Kurucz model stellar atmospheres, Henry showed in 2002 [7] that the albedo (a) of the dust grains is small and that there is little or no back-scattered light from these stars

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at high galactic latitudes. These conclusions are insensitive to the value of the Henyey–Greenstein parameter (g), which characterizes the degree to which individual grains are either forward-scattering or backward-scattering, because they are based on averages over the whole sky.

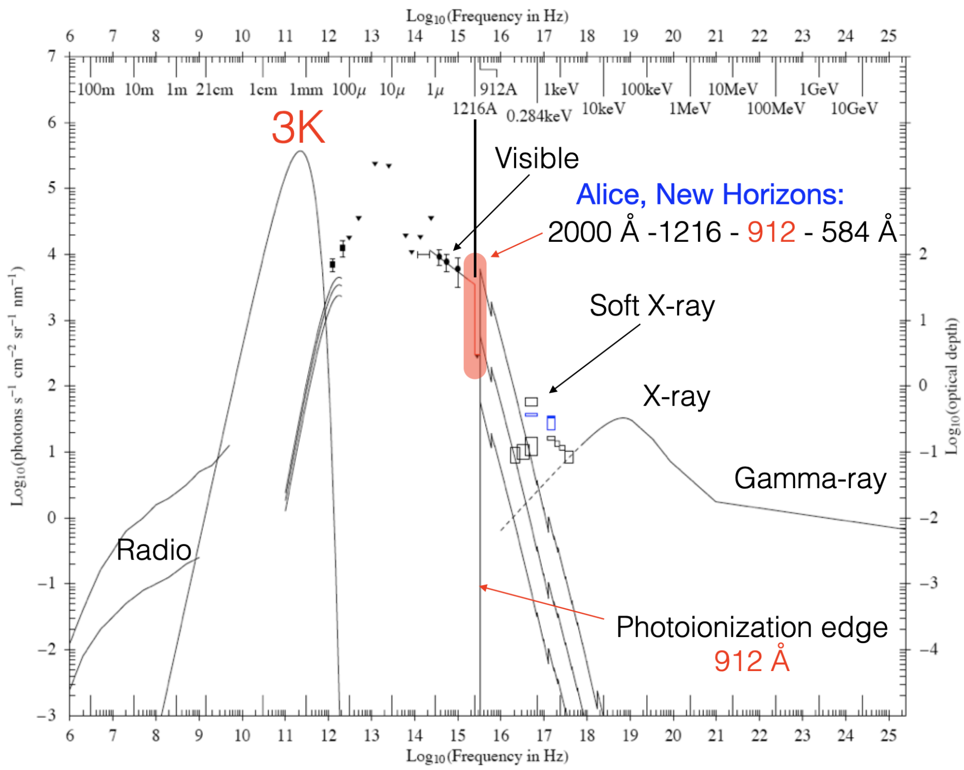

Figure 1. The spectrum of the universe as observed from Earth [1]. This paper deals with the spectral region near 1216 Å (shaded orange and labelled "Alice, New Horizons").

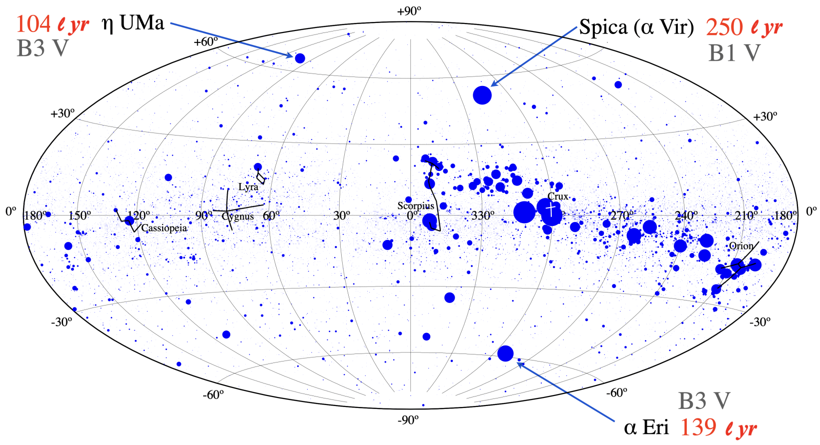

Figure 2. The locations of the hot stars whose dust-scattered light is responsible for most of the diffuse ultraviolet background (from Henry 2002 [7]).

In 2015, Henry et al. [8] used data from the Galaxy Evolution Explorer (GALEX [9]) to map the diffuse ultraviolet background radiation over the range 1300–1700 Å. They found an unexplained excess beyond that which could be attributed to known sources of about 300 photons cm^{-2} s^{-1} sr^{-1} Å^{-1} (hereafter photon units). In particular, comparison with the 100 μm infrared background from the COBE and IRAS satellites ruled out the possibility of explaining the excess in terms of starlight scattered from interstellar dust. Henry et al. [8] also reviewed our limited knowledge of the cosmic diffuse background at ultraviolet wavelengths shortward of Ly α, concluding: "it could be that our 'second component' of the diffuse FUV background persists shortward of the Lyman limit, and is the cause of the reionization of the universe".

2. Observations

In pursuit of that putative 'second component', we teamed up with NASA's New Horizons mission carrying the ALICE ultraviolet spectrometer, which is ideally suited to the study of the cosmic background shortward of Ly α [10]. Our results have been described in detail by Murthy et al. (2025) [11]. The New Horizons observations were taken at a distance of about 57 A.U. from the Sun with the goal of characterizing the background radiation in the optical and ultraviolet bands, far from the atmospheric and interplanetary emission that contaminated earlier observations of the cosmic background. Observations from the Long-Range Reconnaissance Imager (LORRI [12]) have produced conflicting results, with Symons et al. [13] claiming an unexplained excess in the cosmic optical background while Postman et al. [14] reported no excess. This difference may reflect the fact that it is more difficult to correct for foreground sources in the optical band than the ultraviolet.

The Alice spectrograph [10] made simultaneous observations at locations slightly offset from the LORRI pointings and extending from about 600 to 1800 Å. From these observations, Murthy et al. [11] extracted the diffuse background in each location. Alice included two apertures: a narrow "Stem" with a field of view (FOV) of $0.1° \times 4.0°$ and a square "Box" with a FOV of $2.0° \times 2.0°$, which are slightly offset from each other. The Box spectra have a higher signal-to-noise but lower spectral and spatial resolution than those from the Stem. We have averaged the observed background at high latitudes over both apertures in Figure 3. The spectra suggest that the radiation that we are tentatively attributing to dark matter ends very close to the hydrogen ionization edge of 912 Å. If the spectrum does include even a small amount of hydrogen-ionizing radiation, that would easily account for the remarkable reionization history of the universe.

In this work, we are only concerned with the offsets, that is, the remainder after subtraction of the dust-scattered light. These offsets represent the extragalactic background light (EBL) and any isotropic Galactic sources and are, indeed, isotropic (Figure 4). Tabulating contributions from all known sources explains less than half of the signal seen in the New Horizons data (Figure 5).

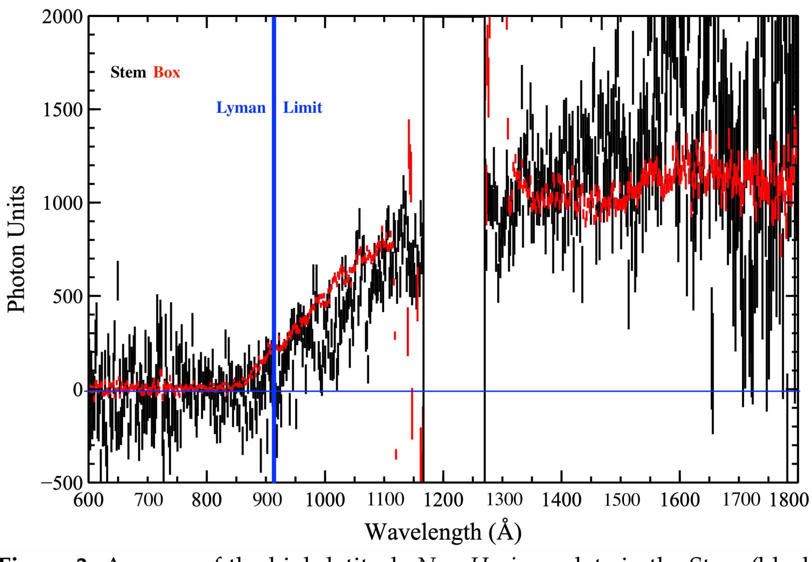

Figure 3. Average of the high-latitude *New Horizons* data in the Stem (black) and Box (red) (from Paper I). The spectral region around 1216 Å is strongly affected by scattered solar Ly α from the interplanetary medium, and the relatively faint cosmic background cannot be reliably extracted here.

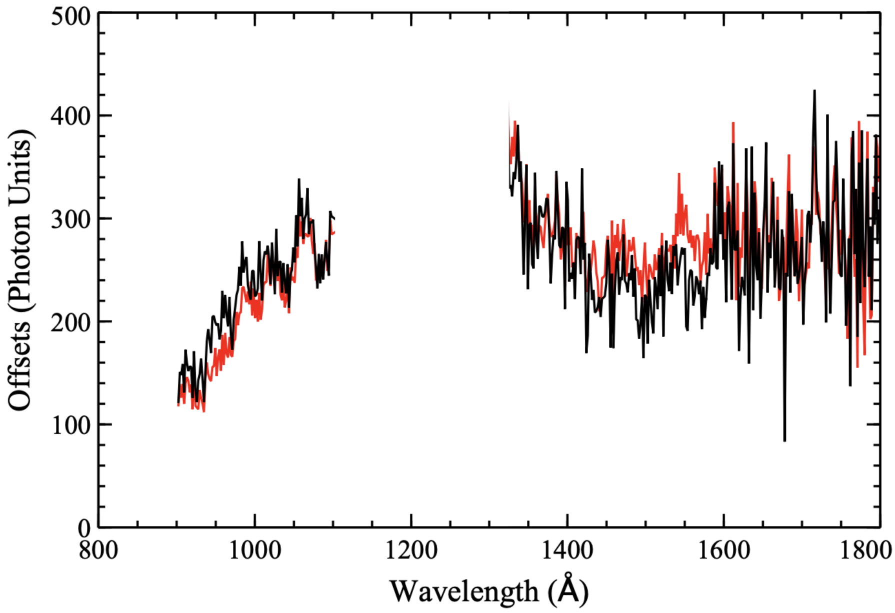

Figure 4. Averages of the spectra show that offsets in both the northern (black) and southern (red) hemispheres are almost identical (from Paper I).

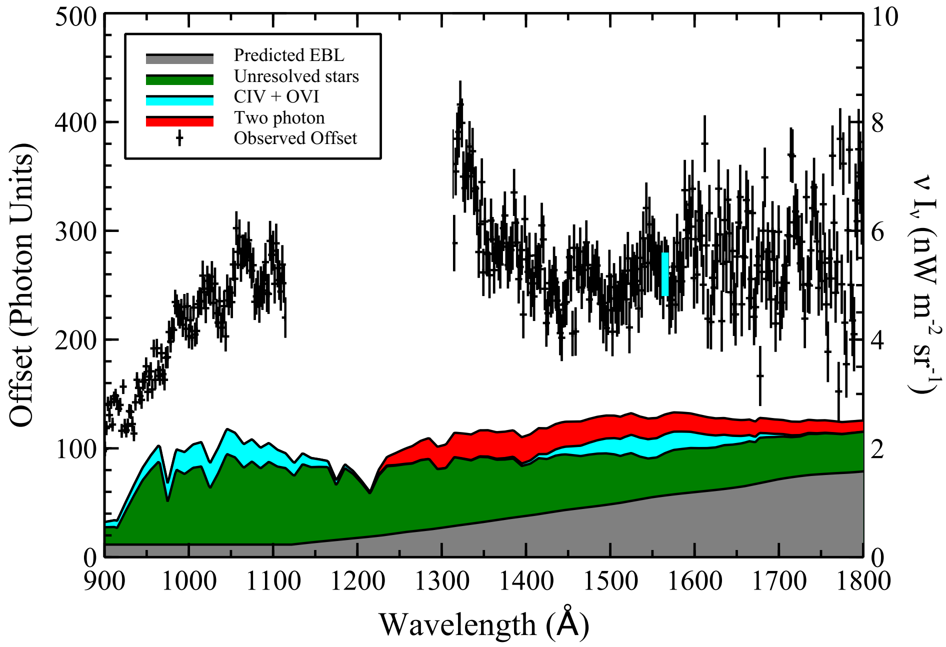

Figure 5. Offsets at high galactic latitudes with possible contributions from known galactic components shown as colored regions at bottom (from Paper I).

3. Galactic Halo

The great majority of all observations of the cosmic ultraviolet background have been made at wavelengths longer than that of Ly α. Figures 2 and 6 below (from our earlier analysis of GALEX data [8]) are helpful for understanding the context of our new discussion of the observational situation in the ultraviolet. The new observations from *New Horizons* (Figure 5) confirm that the extreme ultraviolet background near both galactic poles is unexpectedly bright and spectrally unique. Furthermore, they push this conclusion all the way to the Lyman limit.

It is unlikely that this radiation originates inside the Milky Way, because for each observation, a correction is made for interstellar absorption. The fact that the same spectrum results from this correction process in nearly every direction observed strongly suggests that the radiation originates outside the disk of our galaxy. At the same time, an extragalactic origin is ruled out by tomographic studies correlating GALEX observations with spectroscopic sources in the Sloan Digital Sky Survey out to redshift $z = 2$ [15], and by upper limits on correlations between GALEX data and galaxy clusters at high galactic latitudes in the Planck survey, which imply that only about 3% of the ultraviolet background can be attributed to clusters of galaxies out to redshift $z = 0.3$ [16]. If this ultraviolet background light does not come to us from the galactic disk, or from outside the galaxy, then by process of elimination, we conclude that its source must lie in the galactic halo. Only a small fraction of this radiation can be explained in terms of known sources. The remainder remains a mystery.

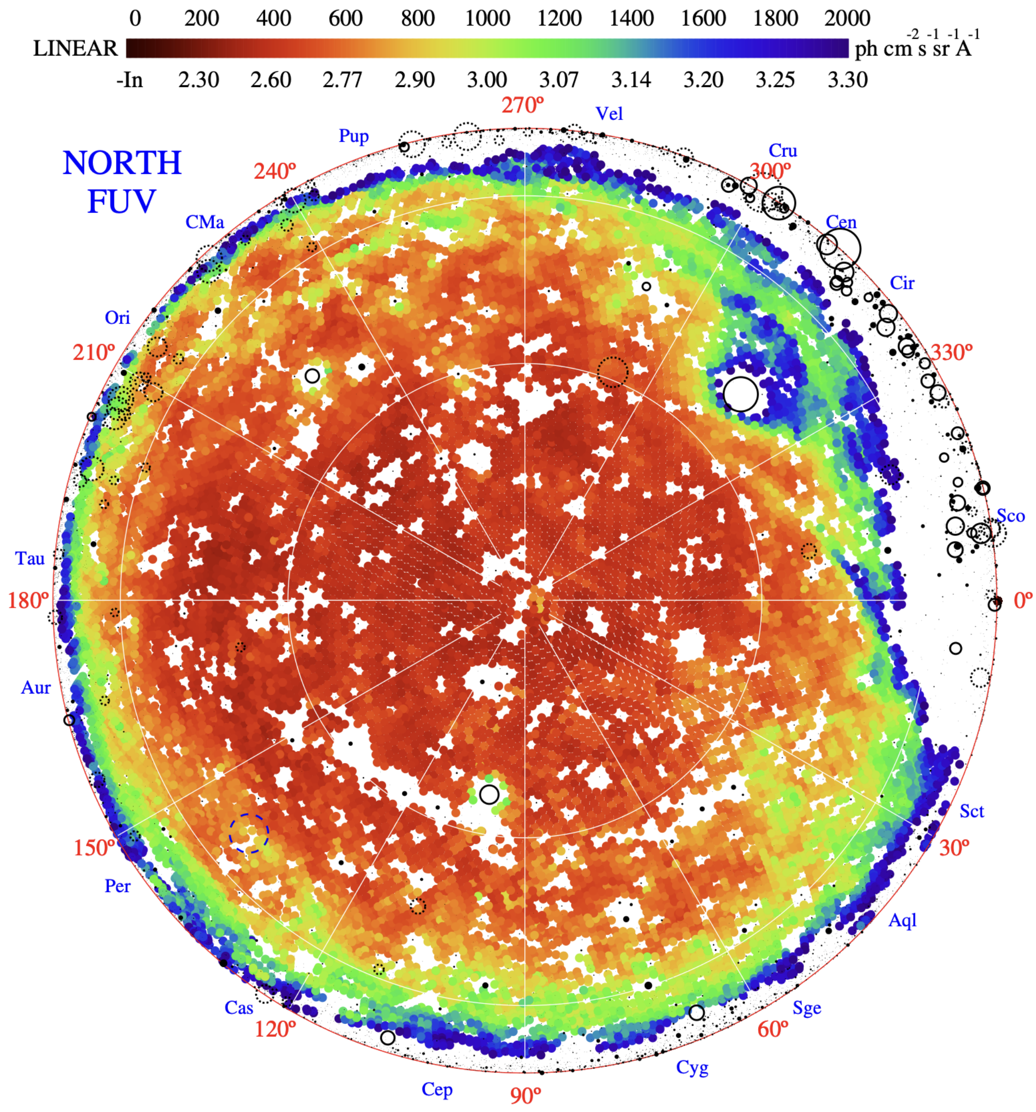

Figure 6. The unexpectedly bright ultraviolet night sky between 1300 and 1700 Å at the highest galactic latitudes from earlier GALEX data [8]. The *New Horizons* observations we report here are equally inexplicable based on known astrophysical sources.

4. Not-So-Dark Matter

Challenged by this mystery, we propose that the radiation originates in the slow decay of dark matter in our galactic halo. If this is so, then the new observations from

New Horizons may be telling us that what is actually mapped in Figure 6 is a uniform distribution of dark matter, mottled at lower latitudes by scattering from interstellar dust. Similar mottling was (barely) detected in the visible by Feltz in 1972 [17].

Similar proposals have been made before, the best known of which was probably the decaying tau-neutrino hypothesis of the early 1990s, widely associated with Dennis Sciama [18] but originally proposed by Adrian Melott, Douglas McKay, and John Ralston in 1988 [19]. Strong lower limits on that particle's decay lifetime were set by Hopkins Ultraviolet Telescope observations of a rich cluster of galaxies [20]. Nevertheless, one can argue for the plausibility of such a mechanism on general grounds, in that the distinct spectrum of the mysterious radiation resembles that which would be expected on the basis of elementary quantum mechanics for massive, electrically neutral particles decaying slowly via two-photon emission (Figure 7, based on Table 1 of Spitzer and Greenstein [21] but shifted 264 Å to shorter wavelengths so as to match the observed spectrum).

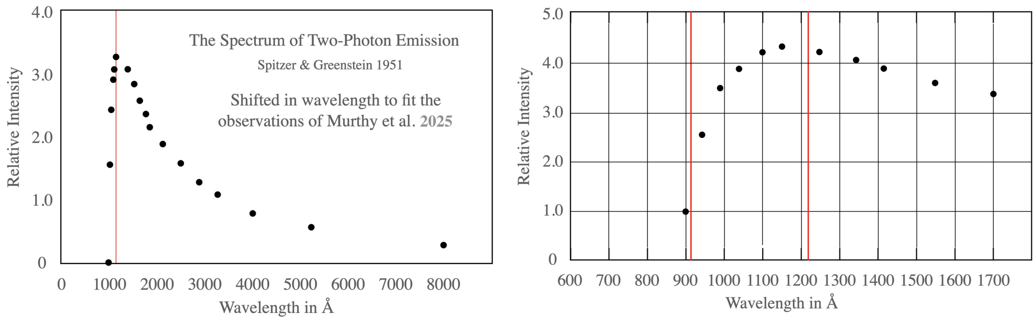

Figure 7. (**Left**) The predicted spectrum of radiation from massive, electrically neutral particles decaying via two-photon emission (adapted from Spitzer and Greenstein [21]). (**Right**) The magnified portion allows for comparison with the observations discussed above and plotted in Figures 3–5.

Other ideas that have been explored in connection with the diffuse ultraviolet background include Hawking radiation from primordial black holes (PBHs) that formed before primordial nucleosynthesis, thus evading upper bounds on the density of ordinary baryonic matter, and bremsstrahlung radiation from the annihilation of axion quark nuggets (AQNs), remnants from the quark-hadron transition in the early universe. PBHs with masses around $\sim 10^{21}$ g would emit in the right waveband, but with a combined intensity that is too low given the inferred density of galactic dark matter [22]. AQNs are more intriguing candidates at present and would also resolve three other mysteries in fundamental physics and cosmology: the strong CP problem in quantum chromodynamics, the origin of matter–antimatter asymmetry, and the similarity in densities of dark and visible matter [23]. Efforts to calculate the intensity of background radiation from these objects in the ultraviolet and other bands are ongoing [24–26].

5. Conclusions

The ALICE spectrometer aboard NASA's planetary *New Horizons* mission may have serendipitously made a momentous discovery in fundamental physics, namely that much of the diffuse cosmic ultraviolet background radiation comes from dark matter that is not so dark after all (Figure 6). This hypothesis can be tested by making additional measurements at other locations and galactic latitudes, including latitudes where we expect that radiation from dark matter is unlikely to dominate the observed spectrum.

The ALICE instrument currently provides the only means to conduct these tests. Fortunately, New Horizons is in good condition and capable of making many more ALICE observations in the years to come. Long observations would be particularly valuable, so that the resulting high-resolution (narrow-slit) spectrum has lower noise compared with what is seen in our Figure 3. This would test our hypothesis that dark matter decay may be responsible for the high state of ionization of hydrogen in the universe. The mechanism by which the universe was reionized is not yet fully understood; early results from the James Webb Space Telescope quantifying the role of early dwarf galaxies are intriguing but still preliminary [27].

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