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MARINER 6 MEASUREMENTS OF THE LYMAN-ALPHA SKY BACKGROUND

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ABSTRACT

The *Mariner 6* ultraviolet spectrometer measured the Lα sky background while in interplanetary flight, and it was found that the most intense region was concentrated not along the galactic equator nor in H II regions, but in Ophiuchus where the measured intensity is 4.9×10^{-4} ergs cm^{-2} sec^{-1} sterad^{-1}.

Lyman-alpha radiation that is observed from a spacecraft in interplanetary flight may originate in the Galaxy, in the solar system, or at the interface of these two systems. Münch (1962) has examined the problem of Lα scattering and absorption in the interstellar medium and finds that the mean free path of a Lα photon before it is absorbed by dust in an H I region is 50 pc. He further points out that while the flux beyond the Lyman limit from OB stars is the major source of Lα radiation in the Galaxy, the mean mutual distance of these early-type stars exceeds the annihilation mean free path of the scattered Lα photon. He suggests that the diffuse galactic Lα radiation may not be uniform, but may be more intense near nearby B-type stars and in the large extended H II region excited by γ Vel and ζ Pup. The problem of the origin, scattering, and absorption of Lα radiation in the interstellar medium has also been treated by Kaplan and Pikel'ner (1963), Kurt and Germogenova (1967), and Aller and Liller (1968). Tinsley (1969) has also suggested that there may be sources of Lα along the galactic equator associated with gaseous nebulae.

The first measurements of the Lα sky background from a spacecraft well beyond the geocorona were made by Kurt (1965) with a photon counter on *Zond 1*. Subsequent measurements on *Venera 2* and *Venera 3* (Kurt 1967) and *Venera 4* (Kurt and Dostovalov 1968) showed an apparent enhancement of the Lα emission along the plane of the Milky Way. One of the models offered by Kurt and Syunyaev (1967) to explain these observations involves the scattering of solar Lα photons by interplanetary hydrogen atoms that have been concentrated in the plane of the Galaxy by the interaction of the solar wind and the galactic magnetic field.

Observations of the Lα sky background were made with a simple ultraviolet photometer on *Mariner 5* during the flight to and beyond Venus in 1967. These observations were interpreted (Barth 1970) as showing that (1) the Lα radiation varied in intensity across the sky with symmetry that appeared to fit galactic coordinates and not ecliptic; (2) there was an apparent increase in the Lα intensity in crossing the galactic plane in the Vela-Carina region.

The *Mariner 6* observations of the Lα sky background were made with a scanning spectrometer of 250 mm focal length through a telescope of 250 mm focal length. The spectral resolution was 10 Å, and the field of view of the telescope $0\overset{\circ}{.}23 \times 2\overset{\circ}{.}3$. The spectral region 1100–4300 Å was scanned every 3 seconds, with the Lα line appearing in the second and third orders.

In 1969 on August 12, 13 and 14, when the spacecraft was 8 million km past Mars, ultraviolet spectrometer measurements were carried out to verify and extend the ultraviolet observations of *Mariner 5* and *Venera 2*, *3*, and *4* with the advantage of additional spectral resolution. The regions of the sky that were scanned during 10.5 hours of observing time were limited only by the location of the Sun and the operating characteristics of the spacecraft. These regions, which are outlined on the galactic star chart in Figure 2, fall into several groups: those along the galactic plane in Puppis, Vela, Carina, Crux, and Norma; those approximately perpendicular to the galactic equator in Hercules, Lyra, Cygnus, and Pegasus; and two regions in the southern galactic hemisphere.

In all of the observations, except where an ultraviolet star was in the field of view, the only discernible spectral feature was the Lα line at 1216 Å. Approximately 340 individual spectral scans from the Hercules region were summed to give the spectral data between 1185 and 1250 Å which is displayed in Figure 1. During each spectral scan individual measurements were made every 2.2 Å. The spectral line identified as Lα lies at 1216 ± 2 Å as determined by comparison with the Lα line observed in the observations of Mars (Barth *et al.* 1969). The observed spectral line has the instrumental line shape of 10 Å within the 2.2 Å sampling interval of the instrument.

In order to determine intensity of the Lα radiation from the various regions of the sky, the spectral data were summed in groups that varied from 100 to 1200 individual spectra, and an integration under the Lα line was carried out. The average intensities for some

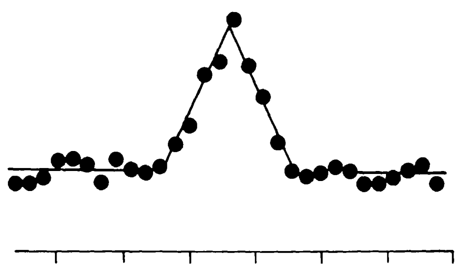

FIG. 1.—Spectral measurements of Lα sky brightness. The spectrometer resolution is 10 Å, and the spectrum is sampled every 2.2 Å. This spectrum is the average of 340 individual observations taken during 17 minutes of observing time.

twelve regions are given in Figure 2 in units of 10^{-4} ergs cm^{-2} sec^{-1} sterad^{-1}. The path of the *Mariner 5* observations is also shown in this figure. The observational results may be summarized as follows:

1. The north-south asymmetry in the Hercules-Cygnus-Pegasus region that was measured with the *Mariner 5* photometer is repeated in the spectrometer observations of *Mariner 6;* the intensity in the northern galactic hemisphere is 4.9×10^{-4} ergs cm^{-2} sec^{-1} sterad^{-1}, and in the southern hemisphere 3.7×10^{-4} ergs cm^{-2} sec^{-1} sterad^{-1}.

2. The spectrometer measurements in the plane of the Galaxy do not show an enhanced emission, in contrast to the suggestion from the *Mariner 5* data that the Vela region showed an increase in Lα intensity; in fact, the spectrometer measurements of *Mariner 6* give an intensity of 3.5×10^{-4} ergs cm^{-2} sec^{-1} sterad^{-1}, one of the lowest intensities measured.

3. Contrary to the suggestion of Münch (1962), the H II region excited by γ Vel and ζ Pup is not a region of enhanced Lα intensity.

The statistical uncertainty associated with this preliminary reduction of the spectrometer data is less than 10 percent for each value reported here. The absolute error is dependent on the laboratory calibration and the environment associated with the instrument during ground handling and interplanetary flight subsequent to the calibration. Based on Lα experiments flown on other spacecraft by the same experimental group, the absolute error is estimated to be less than 50 percent.

Recent calculations of the intensity of galactic Lα intensities have given estimates for the contribution from late-type stars (Biermann 1969) and from early-type stars (Adams 1970) that are much less than the earlier estimates by Münch (1962). These new esti-

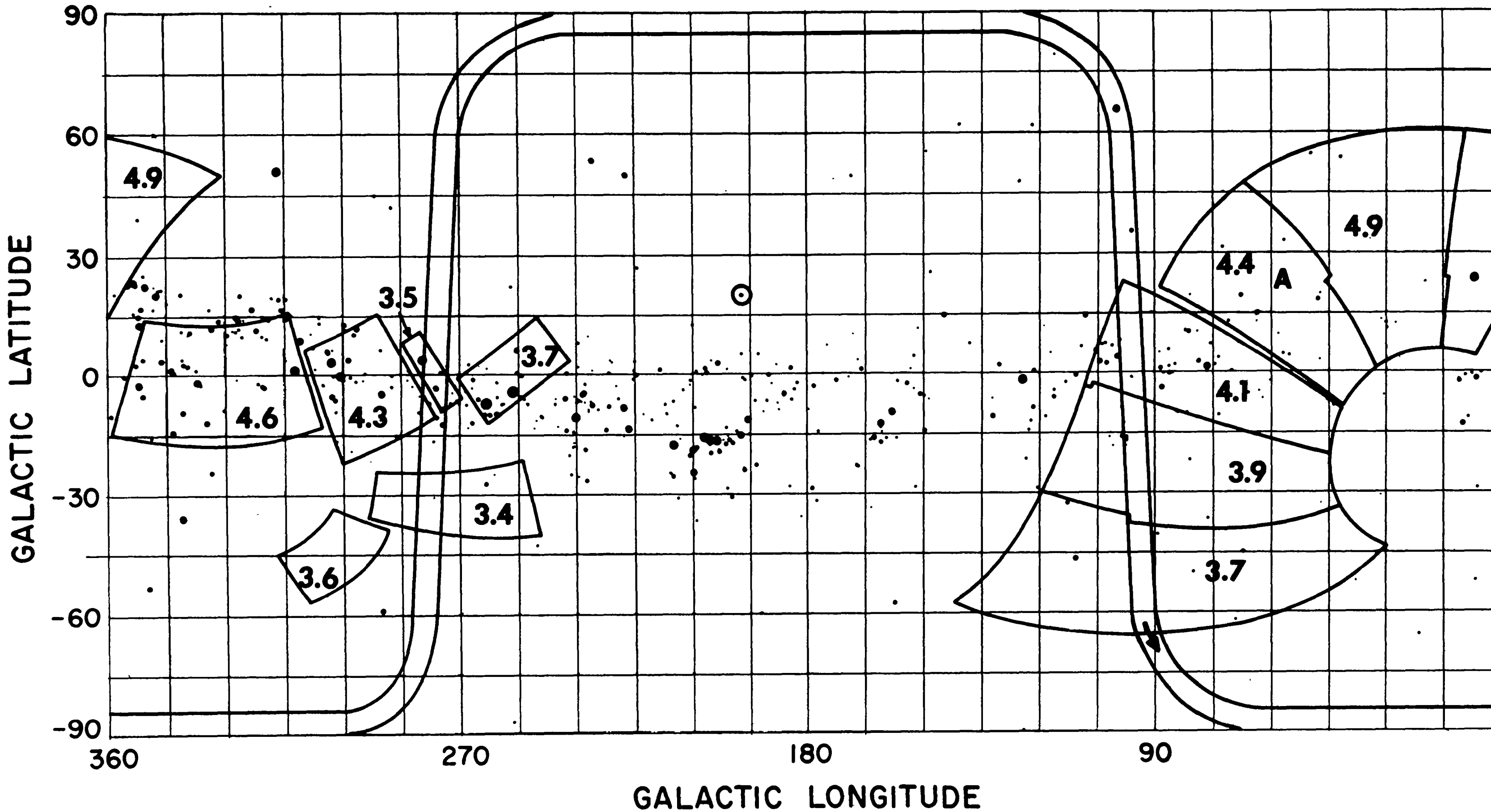

FIG. 2.—Intensity of Lα sky background in units of 10^{-4} ergs cm^{-2} sec^{-1} sterad^{-1} for twelve regions of the sky. Galactic star chart depicts stars according to their ultraviolet magnitude. Position of the Sun at the time of the *Mariner 6* observations is indicated at $b^{\rm II} = 20°$, $l^{\rm II} = 198°$. Position of solar apex is indicated by the symbol A. Observational track of the *Mariner 5* measurements is also shown.

mates are many orders of magnitude less than the *Mariner 6* measurements for the late-type stars and more than one order of magnitude less for the early-type stars. However, the early-type stars are at distances from the solar system that are greater than 50 pc, the annihilation mean free path calculated by Münch (1962). Thus, theoretical calculations and observational evidence tends not to favor the Galaxy as the source of the Lα sky background.

Blum and Fahr (1969) have developed a model in which interstellar hydrogen enters the solar system because of the relative motion of the Sun with respect to the interstellar medium. Once in the interplanetary medium, the atomic hydrogen is ionized by the solar wind and ultraviolet radiation. In this model, the Lα sky background originates from solar Lα photons that have been scattered by the interstellar hydrogen in the solar system. An intensity of 2.3×10^{-2} ergs cm^{-2} sec^{-1} sterad^{-1} is calculated by using an interstellar hydrogen density of 1 atom cm^{-3} and the rates of solar-wind and ultraviolet ionization used by Blum and Fahr. The *Mariner 6* observations show that the region of the most intense Lα emission is not in the direction of motion of the Sun with respect to the nearby stars (the solar apex) as suggested by Blum and Fahr, but nearby in Ophiuchus with an intensity of 4.9×10^{-4} ergs cm^{-2} sec^{-1} sterad^{-1}. Since the distribution of atomic hydrogen in the solar system is sensitive to the ionization rates used in the calculations, these quantities should be carefully evaluated before attempting to bring the observations and calculations into agreement. Once this is done, however, the measured intensity of the Lα sky background may be used to infer the density of the interstellar atomic hydrogen located just outside the solar system, if the Blum and Fahr model is assumed to be the appropriate one.

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