REVISED INTERSTELLAR NEUTRAL HELIUM/HYDROGEN
DENSITY RATIOS AND THE INTERSTELLAR
UV-RADIATION FIELD

P. W. BLUM and H. J. FAHR
Institut für Astrophysik und Extraterrestrische Forschung der Universität Bonn, Bonn, F.R.G.

(Received 30 April, 1975)

Abstract. The data deduced from the UV-spectroscope on the Copernicus satellite strongly suggest that the most important ionization source in interstellar space near the solar system is a UV radiation field originating from B-stars. Adopting this hypothesis, we have used the ionization state of several elements in the interstellar medium observed by Copernicus to determine the required radiation field. From this, the degree of ionization of elements that could not be observed by Copernicus is estimated.

It is shown that this interpretation of the Copernicus data can be made consistent with neutral interstellar hydrogen densities inferred from extraterrestrial Lx observations and with electron densities deduced from pulsar dispersion measures. Furthermore, it is shown that the ratio of neutral interstellar helium to neutral interstellar hydrogen is likely to be 2 to 3 times as large as the cosmic abundance ratio of these elements. The possibility that this ratio is about 10 times as large, meaning equal interstellar neutral hydrogen and helium densities near the solar system, cannot be ruled out. It would, however, require an interstellar radiation temperature near 9000 K. A comparison of the intensity of the interplanetary back scattered He 584 Å and the H 1216 Å radiation would lead to a direct determination of this ratio provided the solar radiation at these lines is known.

1. Introduction

The distribution and intensity of the interplanetary 584 Å radiation scattered from neutral helium within the solar system has been a subject of several theoretical and observational investigations (Fahr and Lay, 1973; Weller and Meier, 1974). Generally this distribution depends on the intensity of the solar He 584 Å line and the density distribution of interplanetary neutral helium. Neutral helium densities within interplanetary space are proportional to the neutral helium density no(He) outside the heliosphere (transheliospheric). They also depend upon the parameters of the interstellar wind such as velocity and temperature (Blum et al., 1975). In all previous investigations and computations of the expected interplanetary helium resonance radiation it was assumed that the transheliospheric helium density is determined by its cosmic abundance relative to hydrogen. This means that the neutral helium number density no(He) would be about 10% of the neutral hydrogen number density no(H). The neutral hydrogen density near the solar system has been deduced from the analysis of interplanetary Lx radiation.

The analyses of the OGO III, IV, V, VI Lx data facilitate the deduction of some important parameters of the transheliospheric neutral interstellar hydrogen gas. The methods of these deductions are reviewed by Fahr (1974). In principal four unknown parameters are involved in the theoretical interpretation of the extraterrestrial Lx
isophotes, namely the density, the temperature, the relative velocity of the trans-heliospheric hydrogen gas, and the intensities of the galactic background radiation. An independent determination of each individual parameter is not possible. At present every theoretical explanation of the extraterrestrial Lyman-α data has to adopt two of these parameters in order to determine the other two.

This is the reason why different authors favor different values of the interstellar parameters. Thomas and Krassa (1972), Bertaux and Blamont (1972), and Blum (1972) favor a density $n_o(H)$ of the trans-heliospheric neutral hydrogen of between 0.02–0.03 cm$^{-3}$, whereas Wallis (1973) and Fahr and Lay (1973) give support for a trans-heliospheric H-density of $n_o=0.1–0.2$ cm$^{-3}$. This latter value is in better agreement with the $n_o$ values indicated by the column density measurements made over longer distances by 21-cm radio methods or determinations of equivalent widths of stellar Lyα absorption lines.

Up to now none of the $n_o(H)$ values mentioned above can be ruled out. However, the fact that recent measurements of the extraterrestrial Lyman-α background radiation made by Mariner IX far from the Earth’s hydrogen geocorona point out minimum intensities of the order of 130 rayleighs (Bohlin, 1973), whereas OGO V had indicated minimum intensities of 250 rayleighs, gives strong support for the possibility that the OGO V intensities contain large terrestrial contributions from the hydrogen geocorona. If 150 rayleighs of the OGO V intensities are ascribed to terrestrial origin (Thomas and Krassa, 1974) this would mean that only 100–300 rayleighs (minimum to maximum) can be taken as due to the extraterrestrial component. This would reduce $n_o(H)$ to about two-thirds of each of the values mentioned above. Thus $n_o(H)$ in any case is likely to be smaller than 0.08 cm$^{-3}$.

On the basis of these data it had been expected from cosmic abundance ratios that the neutral helium number density $n_o(He)$ near the solar system would be in the range of 0.003–0.02 atom cm$^{-3}$. However, this paper will show that an increase of these densities by up to an order of magnitude is likely since the cosmic density ratios refer to total densities – i.e., neutral and ionized densities combined – whereas the ionization ratios of the various interstellar elements may differ appreciably. For the interplanetary scatter of the solar helium resonance radiation only the neutral helium density is of importance, and not the total helium density.

2. Ionization Equilibrium of Hydrogen and Helium in the Local Interstellar Gas

A. DISCUSSION OF IONIZATION SOURCES

We shall assume that the present state of the near interstellar medium is determined by an ionization equilibrium. The other possibility would be that the ionization state of the interstellar matter in the vicinity of the solar system is determined by a gradual recombination process still in progress. The initial ionization would have been produced by a radiation pulse due to a supernova explosion less than $10^6$ years ago. As the recombination times in interstellar space are of the order of $10^4$ to $10^5$ years,