THE $^4He/^1H$ RATIOS IN THE CHEMICAL COMPOSITIONS OF SOLAR FLARE PARTICLES AND THE PRIMORDIAL SOLAR NEBULA

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ABSTRACT

Except for the proton component, it is well known that the chemical abundances of solar flare particles are similar to those of galactic cosmic rays at their sources. In order to infer the $^4He/^1H$ ratio in the solar atmosphere, this ratio as observed in the interstellar gases has been taken into account in addition to those which have been obtained of galactic cosmic rays and the stars classified as the early types. Since it is clear that the most of these ratios ever deduced for both of the sun and solar flare particles are lower than those for the interstellar gases, this ratio thus obtained seems to suggest that hydrogens are relatively overabundant in the chemical abundances of the sun and the primordial solar nebula as compared to those of the interstellar gases being currently observed.

1. Introduction

As well known, the relative abundance of the helium atoms in the sun has never been exactly determined spectroscopically because the temperature of the solar photosphere is too low for these atoms to be excited(1). Using the observed data on the chemical composition of solar flare particles and the solar chromosphere, the ratio of heliums to hydrogens in number, being denoted as $^4He/^1H$ in this paper, has thus been estimated so far. This ratio, however, gives a value about equal to 0.0625, which is not coincident with those which have been estimated as 0.091 - 0.11 from the spectroscopic observations of the early type stars. Even now, it can, therefore, be said that the ratio $^4He/^1H$ for the sun has not been determined as yet. For this reason, many people still use the values as estimated for these stars in investigating some problems on solar physics, though they do not seem to be confident of their usage of those values for this ratio.

Recently, the spectroscopic data on the ratio $^4He/^1H$ have been accumulated from the investigations on the chemical compositions of the interstellar gases and the planetary nebulae(2). In this paper, this ratio in the sun will be reexamined by taking into account these data.

2. The Relative Abundance of Helium Atoms in the Solar Atmosphere and Solar Flare Particles

It is thought that the chemical composition of solar flare particles may give us an important clue to understand the acceleration mechanism of these particles in solar flares. This composition has, therefore, been repeatedly observed by means of balloons, rockets and satellites since the late 1950's. At present, it is known that this composition tends to become systematically overabundant for the heavy nuclei with the increase of their charge numbers(3, 4). It has, however, been shown that the relative abundance of hydrogen atoms is somehow variable, but the ratio $^{4}He/^{1}H$ is given to be 0.063 $\pm$ 0.015 (1).

Since it is known that the ratio of helium to the medium nuclei (C,N,O) in number is almost constant from one observation to another, the variability on the ratio $^{4}He/^{1}H$ seems to have been caused by that of the hydrogen atoms in solar flare particle events. However, it should be noted that this ratio as given above is much less than that which is currently applied to the study of the solar interiour and atmosphere. Furthermore, this ratio is not coincident with those which have been determined from the spectroscopic observations on the interstellar gases and the planetary nebulae(2). Really speaking, the former is also much less than the latters.

In order to compare these ratios from each other, they are shown in Fig. 1 as a function of the logarythmic value

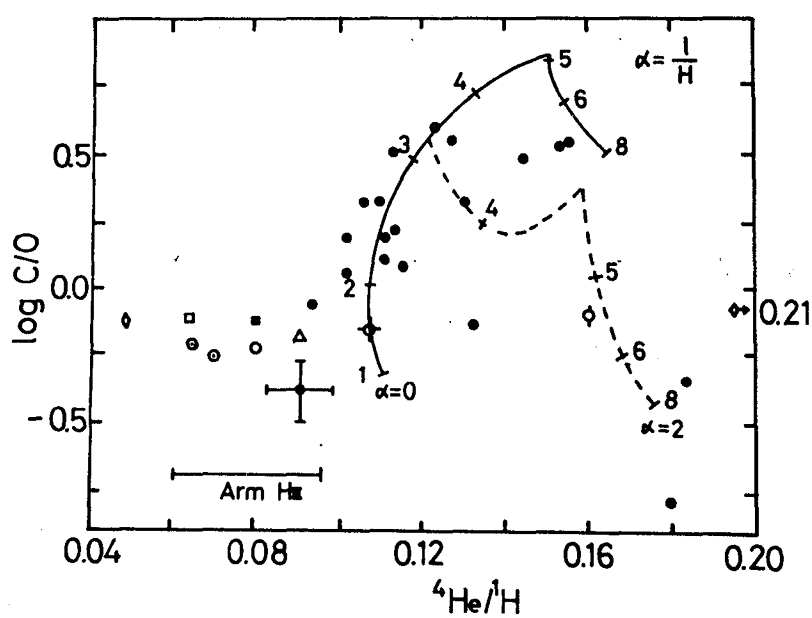

Fig. 1 Relation between the ratios C/O and $^{4}He/^{1}H$ for the interstellar gases, the solar atmosphere, solar flare particles and galactic cosmic rays(see text for the detail).

of the ratio C/O(2). In this figure, black circles(1) show the spectroscopic data on the interstellar gases and the planetary nebulae. White circles with and without dot inside (5, 6), black squares(7) and triangle(8) all indicate the data from the spectroscopic observations on the solar atmosphere by different authors. Two diamonds have been obtained from the chemical composition of galactic cosmic rays(9). The left-end one indicates the value for the high-energy galactic cosmic rays, which is still less than that for solar flare particles which is indicated by white square.

It is clear from Fig. 1 that the ratio C/O remains almost constant for all the values of the solar atmosphere and solar flare particles, whereas the ratio $^{4}He/^{1}H$ widely ranges from 0.06 to 0.095. In this figure, there are two curves for the relation between the ratios of C/O and $^{4}He/^{1}H$ which are given as a function of the stellar masses. Black and dashed curves, respectively, correspond to different values of the mixing length, l, in the convective layers of the stars of different masses, where H denotes the scale height of these layers. The numbers on these curves give the masses of the stars in the unit of the solar mass.

Since the ratio $^{4}He/^{1}H$ for the sun is highly deviated from these two curves, the relative abundance of hydrogen atoms may be overabundant to the sun as compared with other sunlike stars. If this is to be the case, the accretion of hydrogen gases may have happened very effectively during the early phase of the formation of the primordial solar nebula. Thus the excess of hydrogens seems to have resulted in the relative abundances of the present solar atmosphere.

3. Conclusion

The $^{4}He/^{1}H$ ratios in the chemical compositions of solar flare particles and the solar photosphere have been shown to be always less than those which are observed on the interstellar gases and the planetary nebulae. This tendency is also found on the chemical composition of the primordial solar nebula. These results suggest that the primordial solar nebula might have already been overabundant of hydrogen atoms in the initial stage of its evolution.

It is noted that this overabundance of hydrogen atoms in the chemical composition of the present solar atmosphere seems favorable to fix the case for the missing solar neutrinos, which is now thought as the one of the most difficult problems in astrophysical research(10).

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