THE SOURCE COMPOSITION OF GALACTIC COSMIC RAYS AS POSSIBLY ORIGINATED FROM THE DUST IN THE CIRCUMSTELLAR AND INTERSTELLAR SPACE

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ABSTRACT. The chemical composition of galactic cosmic rays in their sources is similar to that of interstellar clouds or grains which are relatively enriched in refractory and siderophile elements as compared with the chemical composition of the solar atmosphere. Taking into account this fact, it is shown that the cosmic ray source matter can be identified as the dust or grains observed in the envelopes of red supergiant stars or the matter originally ejected from supernova explosions.

Key words: Galactic cosmic rays, Cosmic ray source matter

1. INTRODUCTION

At present, it is thought that the cosmic ray source matter is mainly supplied from gases ejected from supernova explosions (e.g., Oda et al., 1988). However, we not known even now on how the chemical composition of this matter is formed by using the matter ejected from supernovae. As have been shown by many people, both refractory and siderophile elements are enriched by a few times more in the chemical composition of this matter as compared with that of the solar atmosphere, which is now thought of as the standard for the chemical composition of the local galactic matter (Sakurai, 1989). Since the first ionization potentials for the most of these elements are relatively lower than those of volatile elements as C, N, O, He, Ne and others, it has been pointed out that the most elements contained in the cosmic ray source matter may be only partially ionized before and during their acceleration somewhere in the interstellar space. In fact, the ionization states of the elements play some important role in the efficiency of their

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acceleration as pointed out by Cassé and Goret (1978) for the first time.

After ejected in association with supernova explosions, the matter embedded in the expanding outer envelopes of parent stars begins to cool down. While drifting in the nearby space surrounding suprenovae, this matter further cools down into lower temperature state. Therefore, it seems possible that, after cooled down into a state as low as 1000K in temperature, the matter initially ejected from supernova explosions becomes the source matter of galactic cosmic rays. In this paper, we will examine if this possibility is valid and acceptable, and then discuss that the chemical composition of the cosmic ray source matter is formed in association with the condensation process of the elements in such environments as seen in the circumstellar gases of red supergiant stars or in the gases ejected from supernova explosions.

2. THE SOURCE COMPOSITION OF GALACTIC COSMIC RAYS

Both refractory and siderophile elements are relatively enriched in the chemical composition of the cosmic ray source matter as compared with that of the solar atmosphere. In this case, these two compositions are normalized by the Si abundances in them. It is noted that the condensation temperature for each of these elements is usually higher than 1000K, though being dependent on the ambient temperature (Wasson, 1985). This means that, as compared with volatile elements, they are relatively easily condensed into dusts or grains in the process of their formation while gases containing those elements are being cooled down in the interstellar space.

It thus seems that the condensation process as related to the formation of dusts or grains plays an important role in making the observed chemical composition of the cosmic ray source matter. By examining the possible contribution of this process, we have obtained such a relation of the relative enrichment of various elements to their condensation temperatures as shown in Fig. 1. It follows from this figure that, for the source composition of galactic cosmic rays, both refractory and siderophile elements are mostly enriched by a few times more in comparison with the chemical composition of the solar atmosphere (Sakurai, 1989). Following the procedure as ever made by many people, these two compositions are normalized by the abundances of the element Si in them. All volatile elements with the condensation temperature less than 500K are well underabundant in the chemical composition of the cosmic ray source matter as compared with that of the solar atmosphere. These

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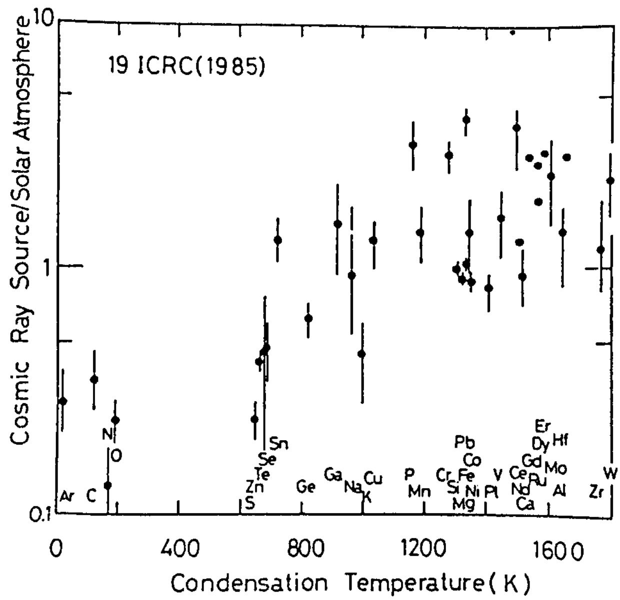

Fig. 1 The abundance ratios of the elements of the chemical composition of the cosmic ray source matter to that of the solar atmosphere as a function of the elemental condensation temperatures, normalized by the element Si.

results suggest that the elements with the condensation temperature higher than about 1000K are relatively enhanced in the cosmic ray source matter by some process as the condensation of gases into dusts or grains in the interstellar space.

3. A POSSIBLE PROCESS AS RELATED TO THE FORMATION OF COSMIC RAY SOURCE MATTER

As shown in Fig. 1, the chemical composition of the cosmic ray source matter is similar to that of dusts or grains in the circumstellar gases and in the dense giant gas clouds in the interstellar space. Furthermore, these dusts or grains there seem to have been formed as the result of the efficient condensation of non-volatile elements associated with the cooling of these gases. Therefore, the chemical composition of dusts or grains thus formed may be nearly the same as that of carbonaceous chondrites classified as C2 (or CM). As well known, both refractory and siderophile elements are generally more enriched in these chondrites as compared with that of Cl chondrites (Wasson, 1985).

The results summarized above suggest that the cosmic ray source matter is formed through the condensation process of gases which takes place in the circumstellar gases or in gases ejected from supernova explosions. Since this process works efficiently within those gases with temperature less than about 1000K, the cosmic ray source matter must have passed through such a low temperature state when it is formed somewhere in the interstellar space. The most probable places for this condensation to occur seem to be identified as the deep inside of the circumstellar gases of red supergiant stars or of the low-temperature dense gases surrounding supernova remnants.

4. CONCLUDING REMARKS

Even now,we have not found as yet any real mechanism for cosmic rays to be accelerated from the matter enriched by refractory and siderophile elements in the galactic space.

According to our scenario (Sakurai, 1990), the cosmic ray source matter in a low-temperature state would become heated and ionized partially by shock waves associated with stellar winds and/or supernova explosions. The elements, being partially ionized, would be accelerated to cosmic ray energy due to their interaction with shock waves just mentioned.

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