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COSMOGENIC ^{26}Al IN DEEP-SEA STONY SPHERULES

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Size dependence of averaged cosmogenic ^{26}Al activity in deep-sea stony spherules were estimated considering the effects of orbital evolutions by the Poynting-Robertson effect in the interplanetary space and the atmospheric entry. It is found that the contribution of the dust particles with high eccentricity in interplanetary motion can be ignored practically because such particles would have so high atmospheric entry velocities that they would disappear in the upper atmosphere besides the probabilities of capturing by the earth are low. To examine the results by measurering ^{26}Al activities in the spherules, we expect, the Poyinting-Robertson effect can be verified.

Radionuclides ^{26}Al is produced in the interplanetary dust particles through irradiation of the solar cosmic rays. The amounts of such nuclide production would have been determined by the motion of the dust particles and the spatial intensity of the solar cosmic rays. The Poynting-Robertson effect which has been thought to be decisive for the motion of the interplanetary dust particles has been not yet proved observationally and also experimentally. In reality, the interplanetary dust particles have various origins and are experienced complex processes of evolution. For example, comets scatter the dust near the sun which are thought to be main source of the dust around the earth's orbit. And the collisional process of the dust particles is also important. Then, it is not so clear whether the dust particles which have been affected mainly the Poynting-Robertson effect only are present or not. We think that the deep-sea spherules are the candidates of that,which would be proved by measuring the long-lived cosmogenic radionuclides in them.

In the following calculations, changes of the orbital elements a (semimajor axis) and e (eccentricity) of the paticle on an elliptical orbit according to the Poynting-Robertson effect[1] are taken into account. The energy spectrum of the solar cosmic rays, cross sections of ^{26}Al producing reactions, and p/α ratio were to be followed Lal and Venkatavaradan[2]. And the spatial distribution of the solar cosmic ray intensity is to be inversely proportional to r (heliocentric distance). The starting point was set to $a = 2.8$ AU which is the average heliocentric distance of asteroids. The results would be not so differed in the case of the more distant starting points due to the character of the spatial distribution of the solar cosmic ray intensity.

Fig. 1 shows ^{26}Al cumulation with time in the particle of 100μm in diameter moving from $a = 2.8$ AU to $a = 1.0$ AU according to the Poynting-Robertson effect with each initial eccentricity e_0. In the case of $e_0 < 0.3$, ^{26}Al production is almost equal to that in the case of circular orbit. In the case of higher eccentricity, however, ^{26}Al production decreases.

A particle having low eccentricity will be trapped by the earth when the semimajor axis a is nearly equal to 1 AU Hence, we expect for ^{26}Al production in such particle the value of the top point of the curve drawn in Fig. 1. But in the case of high eccentricity, a particle would cross the earth's orbit even when it's semimajor axis had not yet approached 1 AU. So we must calculate the probability for the particle to be captured by the earth in each stage of orbital evolution to estimate the average nuclide production, and the atmospheric entry velocity in each case to take the effect of the atmospheric entry into account.

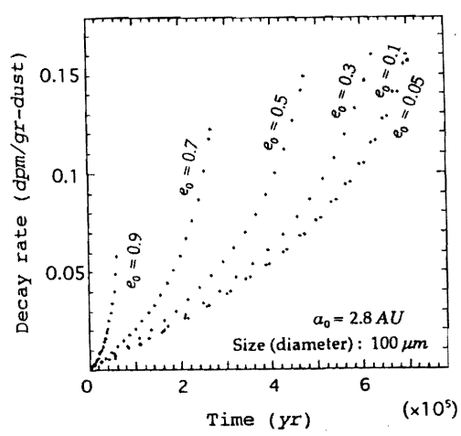

Fig. 1. ^{26}Al cumulation with time in the particle moved from $a = 2.8$ AU to $a = 1.0$ AU according to the Poynting-Robertson effect with each initial eccentricity.

Fig. 2 shows the expected atmospheric entry velocity of particles in the case of the initial eccentricity $e_0 = 0.1$, 0.3, 0.5, 0.7 and 0.9 with 0.1 $rad.$ of the inclination of the orbial

plane. In the low eccentricity case, the particle captrue probability is high and the entry velocity is low. In the high eccentricity case, particularly $e_0 > 0.7$, the particle would rarely be captured by the earth and if captured, the entry velocity would be very high. By performing the atmospheric entry calculations[3][4], we can see that the process make the final sizes of particles be very small regardless of the initial sizes when the entry velocity is high. Fig. 3 shows the average ^{26}Al production in each entry velocity. In the high eccentricity cases, ^{26}Al productions are fairly low as compared with the low eccentricity cases, however, which would not make serious influences on the whole average of ^{26}Al. Moreover, the atmospheric entry process would further weaken the influences because of their high entry velocities.

Similar calculations were performed in various sizes, then atmospheric entry processes were calculated in each, and finally summed up the results to get the final size dependences of ^{26}Al productions. In this calculation, size distribution of the particles was to be of $dn \propto s^{-4}ds$ at the starting point in the interplanetary motion which agrees with the terrestrial observation and the experiments carried out on space crafts[5]. Actually, interplanetary dust particles would be the mixed ones of various eccentricities, so we must average various cases of the initial eccentricity e_0. In Fig. 4, the circles represent the average ^{26}Al productions of after-atmospheric entry of the cases of every 0.05 steps of e_0 below 0.5, and the crosses represent that of below 0.75. Fine dotted line represents the case of the circular orbit ($e_0 = 0.0$) of pre-atmospheric entry. That these two results of after-atmospheric entry are almost the same though there is some difference in pre-atmospheric ones, means that the cases of e_0 above 0.5 merely do contribute to the final results.

The influence of variation of the inclination of the orbital plane is not considered here, however high inclination cases do not contribute to the after-atmospheric entry results by the atmospheric filteration. It can be said that if the cases of various orbital elements are taken into account, the final size dependence of ^{26}Al productions does not differ seriously from the case of the circular orbit ($e_0 = 0.0$) of pre-atmospheric entry, which is easier to calculate.

References
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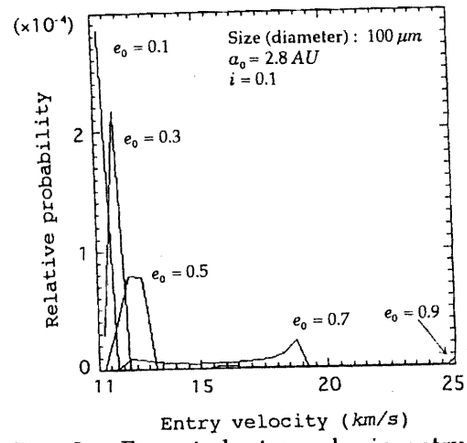

Fig. 2. Expected atmospheric entry velocity of particles in the case of the initial eccentricity e_0 = 0.1, 0.3, 0.5, 0.7 and 0.9.

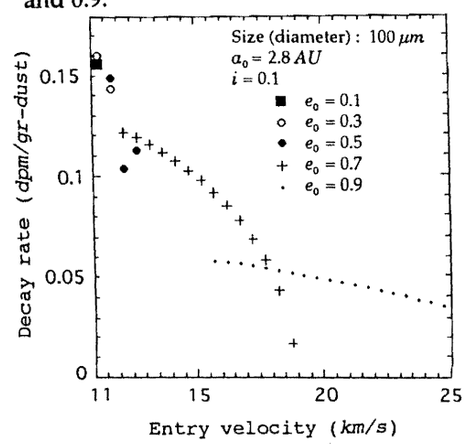

Fig. 3. Average ^{26}Al production in each entry velocity corresponding to Fig. 2.

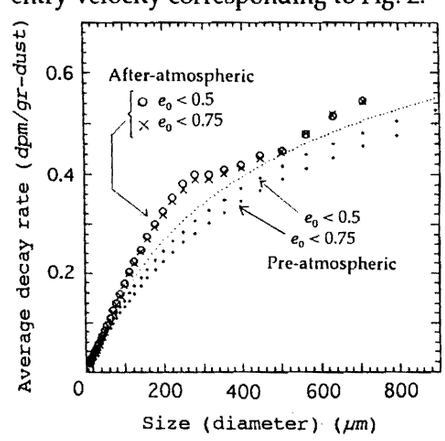

Fig. 4. ^{26}Al production of the average of each case of every 0.05 steps of e_0 below 0.5 and below 0.75. Fine dotted line represents the case of the circular orbit (e_0 = 0.0) of pre-atmospheric entry.