Uniform Injection of ^{54}Cr into Solar Nebula and Temporal Change of Isotopic Ratio in Meteorites. Taishi Nakamoto[1] and Akira Takeishi[1], [1]*Department of Earth and Planetary Sciences, Tokyo Institute of Technology, Meguro, Tokyo 152-8551, Japan.*

Temporal change of ^{54}Cr isotopic ratio in meteorites:

Chromium has four stable isotopes whose mass numbers are 50, 52, 53, and 54. The ratio of ^{54}Cr to the major isotope ^{52}Cr in various meteorites including chondrites, differentiated meteorites, and iron meteorites shows variations (anomalies). The degree of anomalies is of the order of 10^{-4}.

Sugiura and Fujiya [1] estimated formation ages of each meteorite parent body and found that ages of meteorite parent bodies and the degree of ^{54}Cr isotope ratio anomaly in the meteorites have a good correlation. They thought that this relation is caused by an increase of material carrying ^{54}Cr included in meteorites. Based on this interpretation, they carried out numerical simulations, in which small dust particles carrying ^{54}Cr are injected into the solar nebula at a certain time and diffuse in the nebula, and showed that the correlation between the meteorite parent body age and the isotopic anomaly can be reproduced by this small grain injection model.

Model improvement:

Although the Sugiura and Fujiya model [1] is interesting and attractive, we think some points should be reconsidered. First, they assumed that small dust particles from a supernova arrive at a narrow area on the disk the distance from the central star is R and the width is 5 AU. Here, R is one of the model parameters of their model. However, the injection to such a narrow area seems unrealistic. Numerical simulations of molecular cloud core collapses due to a supernova shock wave [2] suggest a more uniform injection of dust particles into the solar nebula. Secondly, they supposed that the solar nebula is static. This assumption should also be reconsidered because the evolutional time scale of the solar nebula is not much different from parent body formation time scales.

Thus, in this study, we examine the concentration of ^{54}Cr carrying dust particles in the solar nebula as a function of time with a uniform injection model. Also, the solar nebula dynamical evolution is taken into consideration.

Results:

Using our uniform injection model, we obtained a result that the concentration of ^{54}Cr carrying grains in the meteorite parent body formation region increases as the time. This result can be understood as follows (see Fig. 1). First, in general, the surface density of the solar nebula at the time of t, $\Sigma(r, t)$, decreases with r, where $\Sigma(r, t) = \int \rho(r, z, t) dz$ and $\rho(r, z, t)$ is the density, and the cylindrical coordinates (r, φ, z) are employed. Let us write the mass of ^{54}Cr carrying small grains injected to the disk per unit area as Σ_{54}. We suppose that the material is injected uniformly, so Σ_{54} is independent of r and φ. After the injection, the concentration of ^{54}Cr carrying small grains per unit disk area, which is denoted as $C_{54}(r, t)$, is given as $C_{54}(r, t) = \Sigma_{54}/\Sigma(r, t)$. Then, we find that $C_{54}(r, t)$ increases with r, in general. Since the meteorite parent body formation region is rather close to the Sun, e.g., 2 - 4 AU, the concentration in that region is initially rather low. On the other hand, diffusive motion of small grains in the solar nebula is caused by turbulence, and the mass flux due to the diffusion is usually in proportion to the gradient of the concentration. This means that the distribution of concentration becomes flattened with time. Thus, the concentration in the meteorite parent body formation region increases as the time.

According to our numerical simulations, the quantitative relation between the ^{54}Cr anomalies and the parent body ages obtained by Sugiura and Fujiya [1] can be reproduced when the turbulent diffusivity parameter α, which is a model parameter representing the strength of turbulence in the disk, is of the order of 10^{-3} - 10^{-2}. This value is consistent with the one estimated by studies on the magneto-hydrodynamics behaviors of the solar nebula [3].

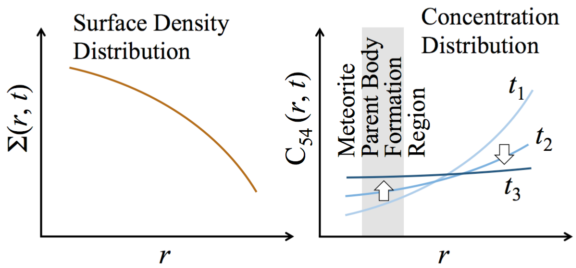

Fig 1. Schematic distributions of the surface density $\Sigma(r, t)$ and the ^{54}Cr concentration $C_{54}(r, t)$. The surface density decreases with r, in general, so the concentration increases with r. Since the mass flux caused by diffusion is proportional to the gradient of the concentration, the distribution of the concentration becomes flattened as the time. Thus, the concentration in the meteorite parent body formation region increases with time.

References:

[1] Sugiura, N. and Fujiya, W. (2014), *Meteorit. Planet. Sci.* 49, 772 - 787. [2] Vanhala, H. A. T. and Boss, A. P. (2002) *Astrophysical J.* 575, 1144 - 1150. [3] e.g., Fromang, S. (2010) *Astronomy & Astrophysics* 514, L5. Flock, M. *et al.* (2012) *Astrophysical J.* 744, 144.