# 54Cr Isotopic Anomalies in Asteroids Caused by Injection and Diffusion in Solar Nebula

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Temporal change of $^{54}Cr$ isotopic ratio in meteorites:
Chromium has four stable isotopes: their 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). Sugiura and Fujiya (2014) estimated formation ages of each meteorite parent body and found that ages of meteorite parent bodies and the degree of $^{54}Cr$ isotopic anomalies in the meteorites are in a good correlation. They thought that this relation is caused by an increase of $^{54}Cr$-rich particles contained in meteorites. Based on this interpretation, they carried out numerical simulations, in which small $^{54}Cr$-rich dust particles are injected into the solar nebula at a certain time and diffuse in the nebula, and showed that the correlation can be reproduced by the small grain injection model.
Injection Model Revisited:
Although the Sugiura and Fujiya model is interesting and attractive, we think some points should be reconsidered. First, they assumed that small dust particles from a supernova arrive only at a narrow ring area on the disk at a certain distance from the central star. However, the injection to such a narrow ring seems unrealistic. Secondly, they supposed that the solar nebula is static. The solar nebula evolves in the time scale not much different from the time scale of parent body formation. Thus, we examine the concentration of $^{54}Cr$-rich dust particles in the solar nebula as a function of time with a uniform injection model. The solar nebula dynamical evolution is also taken into consideration.
Results:
We obtained results that the concentration of $^{54}Cr$-rich grains in the meteorite parent body formation region increases as the time. The surface density of the solar nebula decreases with radial distance, and we suppose that the material is injected uniformly, then after the injection, the concentration of $^{54}Cr$-rich small grains per unit disk area becomes an increasing function of the radial distance. 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 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 in proportion to the gradient of the concentration. So, the distribution of concentration approaches a flat one with time. Thus, the concentration in the meteorite parent body formation region increases with time.
According to our numerical simulations, the quantitative relation between the $^{54}Cr$ anomalies and the parent body ages obtained by Sugiura and Fujiya (2014) can be reproduced when the turbulent diffusivity parameter $a$, which is a model parameter representing the strength of turbulence in the disk, is of the order of $10^{-3}$ - $10^{-2}$.

Keywords: Isotopic Anomaly, Solar Nebula, 54Cr, Meteorite Parent Body Formation, Injection

 