Proto-stellar cosmic rays and extinct radioactivities in meteorites

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Calcium-aluminium-rich inclusions (CAIs) and chondrules of chondritic meteorites may originate with the melting of dustballs launched by magnetically driven bi-polar outflow from the inner edge of the solar nebula (Shu *et al.*, 1996). Bombardment by proto-stellar cosmic-rays may produce in the precursors of CAIs and chondrules radio-nuclides that are difficult to obtain with other mechanisms. Reasonable scalings from the observed hard X-rays for the cosmic-ray protons released by flares in young stellar objects (Shu *et al.*, 1997) yield the correct amounts of Ca-41, Mn-53, and excess La-138 (Shen *et al.*, 1998) inferred for the early solar system. However, reactions induced by protons and alpha particles under-produce Al-26 by a factor of ~20 (Lee *et al.*, 1998). The missing Al-26 may be made in transformation involving He-3 accelerated in impulsive flares. The main target is Mg-24 that should be abundant in the precursors. The mechanism allows a simple explanation for the very different Al isotope ratios inferred for normal CAIs, CAIs with fractionated and un-identified nuclear (FUN) anomalies, and chondrules. In this model, the later resetting of K isotopes is required to remove the over-produced Ca-41 (Srinivasan *et al.* 1996) from analogous He-3 reactions. Also, the Ni-60 anomaly in eucrites thought to be from Fe-60 (Shukolyukov and Lugmair, 1993) is re-interpreted as the result of early bombardment of iron in the Ni-poor crust of differentiated asteroid via Fe-57(alpha, n)Ni-60.

References

Lee, T., Shu, F.H., Shang, H., Glassgold, A.E. and Rehm, R.E. (1998) *Astrophys. J.*, submitted.

Shen, J.J., Ho, C.J. and Lee, T. (1998) *Science*, submitted.

Shu, F.H., Shang, H., Glassgold, A.E. and Lee, T. (1997) *Science*, **277**, 1475.

Shu, F.H., Shang, H. and Lee, T. (1996) *Science*, **271**, 1545.

Shulkolykov, A. and Lugmair, G. (1993) *Earth Planet. Sci. Lett.*, **119**, 159.

Srinivasan, G., Sahijpal, S., Ulyanov, A.A. and Goswami, J.N. (1996) *Geochim. Cosmochim. Acta*, **60**, 1823.