Astrophysics Seminars

Formation criterion and process of extremely metal-poor stars: the role of first supernovae

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Metal-poor stars are living fossils with records of the metal enrichment in the early Universe. They are classified primarily into C-enhanced metal-poor (CEMP) stars and C-normal metal-poor (CNMP) stars according to their carbon abundances. Recently, the new classification of CEMP stars is presented. Their carbon and iron abundances show lower limits of A_cr(C) ~ 6 and [Fe/H]_cr ~ -5, respectively. This suggests the critical elemental abundances above which thermal emission cooling of carbon and silicate grains operates to induce the fragmentation of their parent gas clouds, and low-mass stars are likely to be formed. Since the dust cooling rate depends on the condensation efficiency of metal and grain size distribution with a given metallicity, we estimate them from the observed lower-limits of carbon and iron abundances. Then, we derive the critical condition of the formation of EMP stars. The different classes of CEMP stars are well-explained as the difference of main grain species for their formation.

We also present results of numerical simulations of the metal-enrichment process and EMP star formation. From their small metal content, they are considered to acquire heavy elements from a single or several supernovae (SNe) of first-generation (Pop III) stars. We simulate the feedback effects of photoionization and SNe with a range of masses of Pop III stars and hosting minihalos (MHs). For pair-instability supernovae (PISNe) with large explosion energy ~30x10^{51} erg, the ejected gas reaches to the neighboring halos, i.e., external enrichment (EE) takes place in all relevant mass range of MHs. Yet, the metals cannot penetrate into the central part of halos, and the resulting metallicity is [Fe/H] < -5. This is consistent with no observational sign of PISNe among EMP stars. For core-collapse supernovae (CCSNe) with normal explosion energy ~1x10^{51} erg, the ejected gas falls back into minihalos and internal enrichment (IE) occurs. The metallicities in the recollapsing region are -5 < [Fe/H] < -3 in most cases. We can conclude that IE by CCSNe can explain the metallicity range and elemental abundance ratios of EMP stars.

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