

Dust Formation in Stellar Winds of Very Massive Population III Stars

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The discoveries of a huge amount of dust grains at high redshift ($z > 5$) have posed the fundamental problem on the origin of dust in the early universe. In such an early epoch, core-collapse supernovae (SNe) are considered to be dominant sources of dust, while asymptotic giant branch stars could be also possible dust sources. What mass range of stars can contribute to the dust budget in the early universe strongly depends on the initial mass function (IMF) of the stars. Numerical simulations show that the IMF of the first stars (so-called Population III stars) would be weighted towards much higher mass than those in the present universe. In particular, Population III stars exceeding $\sim 200 M_{\text{sun}}$ are suggested to undergo intense mass loss at the red supergiant (RSG) phase and to eject the outer envelope that is enriched with CNO elements via the rotationally induced chemical mixing and/or the dredge-up. Thus, it is an important issue to explore whether such metal-enriched stellar winds are possible formation sites of dust in the early universe.

In this talk, we investigate the formation of dust grains in a mass-loss wind at the RSG phase of a very massive Population III stars with the zero-age main sequence mass of $500 M_{\text{sun}}$. We show that, for a derived mass-loss rate of $3 \times 10^{-3} M_{\text{sun}}/\text{yr}$, C grains form around 10 times radius of the central stars, with the lognormal-like size distribution. The average grain radius is sensitive to the assumed wind velocity v_w , but the condensation efficiency of dust is unity for the range of $v_w = 1-100 \text{ km/s}$. This allows us to estimate the total mass of C grains produced during the RSG phase to be $1.7 M_{\text{sun}}$. The advantage of this formation channel for dust formation is that newly formed C grains are injected into the interstellar medium without being destroyed by the shock wave of the SN because the central star finally collapses into a black hole. From the relatively high dust yield and dust-to-gas mass ratio (8.2×10^{-3}), we conclude that very massive Population III stars could be efficient sources of dust in the early universe, if they had formed. We also briefly discuss the observational signatures of these C grains.