P1 - Dust production rate in the early universe

The universe is a dynamic and wild wonderland, composed of exotic objects. There in space, we find chemical compounds in their solid form, which are called cosmic dust. They form large dust and gas clouds, or nebulae, which absorb, scatter and re-emit radiation from distant galaxies and stars; thereby shaping our knowledge of astronomy. These dust particles are the building blocks of planets, and also the source of hydrocarbons; the unit of life on earth.

To trace the origin of cosmic dust and its evolution through space and time have keenly interested scientists with various expertise over the past couple of decades. However, despite significant advancements in our understanding, we are yet to identify all the possible astrophysical events and objects that can account for the total amount of dust that is present in galaxies, both locally as well as in the early universe. The high-z galaxies in the early universe provide an unique laboratory to study dust production, given that the rate of dust formation is strongly constrained by the young age of those galaxies. In other words, we are to identify objects or processes that is capable to produce dust fast enough to quantify the large masses of dust present in those early galaxies.

Supernovae, resulting from the explosive ends of massive stars, are known as one of the key agents of rapid dust synthesis. Smaller, yet more abundant, AGB stars are also known to form a lot of dust in galaxies. In addition, dust formation is also well known in Luminous Blue Variable (LBV) stars, Wolf–Rayet stars, red supergiant stars, in novae, and arguably also in the winds blown off the accretion disks surrounding the supermassive blackholes. In addition, of course the dust that is produced in such stellar environments, grow in mass and size through accretion in the interstellar clouds. The rate of production when balanced to the rate of depletion or destruction of these grains either by star formation or by interstellar shocks, we obtain the net-dust that is present at a given time.

There has been a previous attempt to quantify the total dust in the high-redshift ($z = 6.4$) quasar J1148+5251, which provided the upper limits on the dust masses and their rates of formation. However, in the last decade we have substantially improved our understanding of, (a) the overall dust formation rates in supernovae, categorized by its types; how shocks and interaction with surrounding medium can play significant roles (b) the revised Initial Mass Function (IMF; that is the stellar mass probability) (c) the dust formation dynamics and rates in Active Galactic Nuclei (AGN) (d) the percentage of dust destruction by shocks as a function of dust type and size of grains (e) the star formation rate in the early galaxies, and (f) the evolution of binary stars.

Based on the above, there is an imminent requirement to revise our model of the dust formation history of the early universe, that will indeed take us a step closer to disentangling the mystery of the origin of cosmic dust in space. This project therefore will review the rates and weights of all the source and sink mechanisms of cosmic dust in the early galaxies, thereby summarizing its history of evolution. Most excitingly, with the soon-to-be launch of the high resolution James Webb Space Telescope, which is perfectly suited to look at the early universe, this project will be providing a perfect balance between the theoretical models and observational findings.