P2 - Determining dust temperatures in and out of equilibrium

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.

These solid compounds are synthesized in space through a series of physical and chemical processes. Interestingly, the necessary physical conditions required for the nucleation of atoms and molecules in their gas phase are often only found in extreme astrophysical environments characterized by shocks, turbulences and strong radiations; for example in the winds of the massive stars, or the stellar remnants resulting from supernova explosions. Owing to the rapid evolving nature of these environments, the processes leading up to the formation of cosmic dust are understood to be away from chemical equilibrium.

The temperature of the dust grains are defined by their mineralogical properties that determines their rate of absorption and emission, based on their sizes and shapes. In case of newly synthesized dust in the hot gas, the temperature is controlled by the collisional exchange of energy with the gas or with other grains, and the radiative energy balance through emission and absorption of photons. Theoretically speaking, temperature is an equilibrium concept, only applicable when thermal equilibrium is attained. Also it is the key physical quantity that characterizes the spectra of any solid object.

So here is this physics problem, where we have to determine when and how thermal equilibrium is met in the newly forming solid compounds (of various chemical compositions and sizes) from a gas that is not in chemical equilibrium, by balancing the rates of energy exchange. By providing a model to solve this issue, in this project we will make an accurate estimation of the temperature distribution of newly synthesized dust grains, given various physical condition. This tool is highly required to analyze or predict any observation in the infrared wavelengths, where dust is often the key contributor. The results will be applied to supernova ejecta, where the date of dust formation and its composition still remains a topic of major debate.