Commentary on Three-dimensional Dust Monte-Carlo Radiative Transfer Models

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Cosmic dust plays an important role in producing and processing of the interstellar radiation. Dust grains absorb starlight, converting into infrared thermal radiation. This radiative transfer process is very complicated. To study properties of the stellar and interstellar medium by using multi-band observation data, numerical models need to be constructed to simulate the complicated radiative transfer process. Comparing the simulation results with the observation data, we can invert the input parameters of the numerical models, so as to recover the astrophysical and chemical properties associated with the input parameters.

The three-dimensional (3D) distribution of dust requires the use of 3D radiative transfer models, to simulate radiative transfer more realistically. Monte-Carlo method is applicable to any 3D dust density distribution. Instead of solving radiative transfer equations directly, it uses probability distribution functions for random sampling. Monte-Carlo method propagates a large number of photons in a 3D grid to obtain the statistical results.

For simulating different physical environments, we introduce six 3D dust Monte-Carlo radiative transfer models, which are HO-CHUNK, Hyperion, 3D Mocassin, SKIRT, STOKES and RADMC-3D. These codes are open source codes developed based on the Monte-Carlo method. HO-CHUNK, 3D Mocassin, SKIRT and STOKES are used to simulate the protostar, photo-ionization environment, disk galaxies and active galactic nucleus respectively. Hyperion and RADMC-3D are general-purpose codes that can be used to simulate any 3D geometry. All of them calculate the dust local thermal equilibrium (LTE) emission, while HO-CHUNK and SKIRT can simultaneously calculate the non-LTE emission from very small grains and polycyclic aromatic hydrocarbon. All of the codes calculate the scattering of dust grains except HO-CHUNK. To improve the computing performance, all of them have been parallelized except STOKES.

Basic input parameters of all the codes are: 3D distribution of the dust, physical and chemical properties of the dust, 3D distribution of the radiation sources, physical and chemical properties of the sources, and parameters control the simulation process and outputs. General simulation performance of these codes have been summarized into a table, to help researchers finding appropriate code which is more suitable for their research objectives.