Usage Report for Fiscal Year 2016

Project Title:

Radiative Transfer Simulation for Massive Star Formation

Name:
Yichen Zhang

Laboratory at RIKEN:
Star and Planet Formation Laboratory

Massive stars impact many areas of astrophysics, yet how they form is still poorly understood. The key question is whether they form in a similar way as low-mass stars. It is observationally challenging, because compared with the low-mass stars, forming massive stars are more embedded inside their parent gas cores, therefore the light from the protostar has always been reprocessed by the core before it can reach the observer (radiative transfer, hereafter RT). Only through RT simulation we can derive the true properties of the protostar and the surrounding cores from the observation, and constrain the theories. The current project is specifically focused on the continuum RT in which the radiation is being reprocessed by the dust in the core. This process determines the appearance of embedded young massive stars in wide-band observations from near-infrared to mm wavelengths. The thermal equilibrium from the absorption and emission of continuum radiation by the dust grains determines the temperature of the dust grains (and gas temperature through gas-dust coupling), which can significantly affect the chemical composition and evolution in such cores.

The project is using a Monte-Carlo algorithm to simulate the RT of dust continuum emission for a large number of models covering wide ranges of initial, environmental conditions suitable for massive star formation and different evolutionary stages, calculating the temperature profiles of the cores and the continuum emission at infrared wavelengths. The project utilizing the RIKEN Supercomputer system started end of November, 2016. Currently, jobs have been run for totally 432 models, which has covered the whole designed parameter space. The results include: 1) temperature structures of the cores surrounding the massive protostars for all of these 432 models, which allow us to investigate the evolution of the temperature structures in the massive star forming cores and effects of different initial and environmental conditions; 2) the total fluxes at different wavelengths from near-IR to mm wavelengths (i.e. spectral energy distribution, SEDs) are generated for these models, forming an SED model grid which can be used to fit the observed SED to efficiently estimate the properties of the massive protostars and their surrounding structures from infrared continuum observations with various telescopes, and allow statistical studies of massive star formation. These results are being analyzed and publication is under preparation. The fitting tool based on the SED model grid has been constructed and now is being tested using observations of exemplary sources.

The future plan includes: 1) expand the model grid to cover the parameter space with finer intervals, which will be performed soon using rest of the time available in this fiscal year. This will improve the accuracy and efficiency of the SED model fitting tool we are constructing. 2) Simulate the images at different wavelengths for these models, which means, instead of a total flux at a given wavelength, we will obtain the information of the spatial distribution of the emission. This will help to break the degeneracy of the SED fitting and provide stronger constraint on theoretical models when compared with real observations. To obtain images, larger number of photon-packets in the simulation is needed to reduce the Monte-Carlo noises, and therefore require more time to complete for the whole model grid. We will continue to apply for the computing time in the next fiscal year. 3) Although the current model grid covers different evolutionary stages of massive star formation, from birth of protostars to the parent core being finally dispersed by the feedback from the (proto)stars, the time step is not fine enough to follow the chemical evolution inside the cores. We therefore plan to run models with much finer time steps for certain fiducial initial/environmental conditions to calculate the change of the temperature and densities in the core which can be further coupled with chemical modeling to predict the chemical evolution inside the cores.