Usage Report for Fiscal Year 2019

Project Title:

Radiative Transfer Simulation for Massive Star Formation

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1. Background and purpose of the project, relationship of the project with other projects

Massive stars impact many areas of astrophysics, yet how they form is still not well understood. The key question is whether they form in a similar way as low-mass stars. It is observationally challenging, because compared with low-mass protostars, massive protostars are more embedded inside their parent gas cores, therefore the light from the protostars have always been reprocessed by the cores before they can reach the observer (the process called 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 dust continuum RT in which the radiation is being reprocessed by the dust in the core. This process determines the appearance of embedded young massive protostars 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.

2. Specific usage status of the system and calculation method

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 various infrared wavelengths. The final goal of the project is to achieve a model grid with both spectral information (spectral energy distributions, SEDs, i.e. total fluxes at different wavelengths from near-IR to mm wavelengths) and also images (i.e. flux spatial distributions in each wavelengths). The SED model grid and image model grid can be used to fit the observed SED or images separately or simultaneously to estimate the properties of the massive protostars and their surrounding structures.

3. Result

In the previous years, we have finished the SED model grid, which contains 432 physical models and 8640 SED. We also have developed the fitting tool to fit the observed SEDs with the model grid. The model grid and fitting tool have been open to the community (https://doi.org/10.5281/zenodo.1288282), including several version updates. This model grid is now being used to fit the real observations. We are testing whether there need to be improvements in the setting-up of the physical models. Since the next level calculation, which is to obtain the image model grid, will take much longer time than SED-only calculations, we hope to test the SED model grid first before starting carrying out the image calculations. Therefore, we have not yet started the next level simulations

4. Conclusion

Now, we are intensively comparing the current model calculation results with observations without running new models on the supercomputer. The models can successfully reproduce the observed SEDs towards many massive protostars in our observational sample.

5. Schedule and prospect for the future

The future plan includes: 1) Simulate multi-wavelength images and achieve the image model grid. 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 plan to first test the SED model grid by comparison to observations before carrying out new simulations for images. But we expect to start (and possibly finish) the image calculation and obtain the image model grid. After testing the fitting with image information, we will add this new feature to the online model. 2) We will start to further expand the model grid to cover even wider parameter space, especially extending to the low-mass star formation regime. This will be helpful to test whether a same model across low and high-mass star formation can explain wide range of IR observations of large sample of sources. More models will also be added to make the parameter space interval much finer to improve the accuracy and efficiency of the SED fitting tool.

6. If no job was executed, specify the reason.

In FY19, we have not yet started the next level simulations, which is to obtain the image model grid. We hope to test the SED model grid first before starting carrying out the image calculations, which will take much more times than the SED-only calculations. We expect to start the image calculation and obtain the image model grid by FY20.