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Numerical Modeling of Star Formation and Stellar Feedback in the Multiphase Interstellar Medium

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The gas in the interstellar medium (ISM) is multiphase, spanning a wide range of density, temperature, and ionization state. Most star formation in galaxies occurs in giant molecular clouds (GMCs), which are supported against gravity by turbulence and magnetic fields. Newly formed massive stars inject huge amount of energy and momentum into natal molecular clouds and the surrounding ISM in the form of ultraviolet (UV) radiation, stellar winds, and supernovae. This “stellar feedback” plays several important roles in the evolution of the ISM and next-generation star formation, such as dispersal of GMCs, turbulence driving, launching of galactic outflows, chemical enrichment of the ISM. Numerical simulations are an indispensable tool for modeling the complex interplay between gravity, turbulence, magnetic fields, stellar feedback, and the resulting multiphase ISM structure and star formation.

Recently, we developed a model for the ISM photochemistry coupled with UV radiative transfer that can be used to study star-forming ISM in a wide range of environments.[1] Based on the chemical network detailed in [2], we model time-dependent abundances of hydrogen and steady-state abundances of carbon- and oxygen-containing species, and include all essential heating and cooling processes required to capture the multiphase ISM structure. We follow the propagation of UV radiation from young massive stars using a ray tracing technique[3] to explicitly model (1) photoionization of neutral hydrogen by Lyman continuum photons, (2) photodissociation of molecules by Lyman-Werner photons, and (3) the grain photoelectric effect by far-UV photons.

We integrated our module into the TIGRESS (Three-phase Interstellar Medium in Galaxies Resolving Evolution with Star Formation and Supernova Feedback) numerical framework[4] implemented in the Athena code[5], in which star formation and stellar feedback cycle in the multiphase ISM is self-consistently determined. We also perform high-resolution simulations focusing on the evolution of individual, isolated GMCs in which early feedback (UV radiation and stellar winds) plays an essential role in regulating cloud lifecycle and efficiency of star formation.[6]

This talk will give an overview of our numerical approach for modeling star formation and stellar feedback in the multiphase ISM. The highlights of our recent studies that aim to explain how star formation is regulated on scales of galaxy disks and GMCs, and the role of stellar feedback will be presented. Finally, our results will be compared with various observational constraints.

References

[1] J.-G. Kim et al., 2022 ApJ submitted
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[4] C.-G. Kim & E. C. Ostriker 2017, ApJ, 846, 133
[5] Stone et al., 2008, ApJS, 178, 137
[6] J.-G. Kim et al. 2021, ApJ, 846, 133

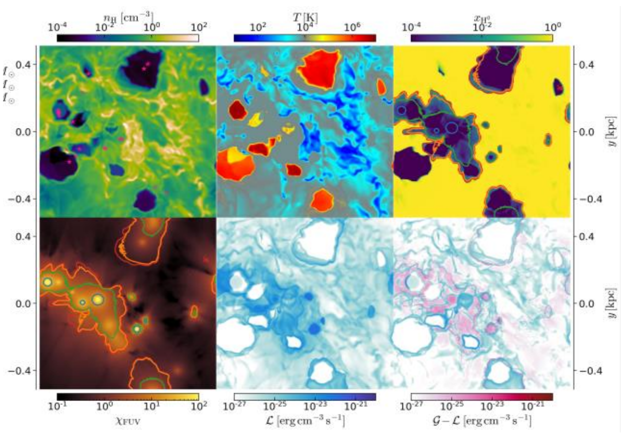

Fig 1. Example snapshot of TIGRESS simulations for the solar neighborhood model. Clockwise from top-left: density, temperature, H neutral fraction, net cooling rate, cooling rate, and mean intensity of FUV radiation at the disk midplane. In the top left panel, positions of young star cluster clusters are shown as circles.

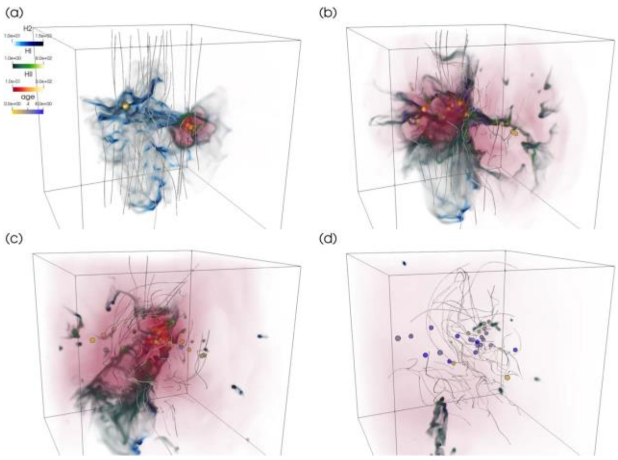

Fig 2. Volume rendering of star-forming giant molecular clouds with UV radiation feedback, at 1, 3, 5, 8 Myr after the first star formation. Blue/green/red colors indicate molecular/neutral atomic/ionized gas. Lines show magnetic fields.