Can Thermal Instability Grow behind a Shock Wave in HI and Molecular Clouds?

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Thermal instability is an important physical process to determine the structure in the interstellar medium. It is widely known that low and mid-temperature parts of the interstellar medium (ISM) is consist of warm and cold neutral medium (WNM and CNM) [1]. Field, Goldsmith & Habing (1969) calculated the thermal equilibrium state. They showed that there are three physical states under the pressure equilibrium: two stable states of CNM and WNM and one unstable state [2].

The thermal instability is considered to be the origin of the tiny scale structures which have been detected HI gas [3] and molecular cloud [4] [5]. Many authors have studied the dynamical condensation (fragmentation) process of the ISM driven by thermal instability in the shocked layer of WNM. Koyama & Inutsuka (2002) show that tiny clumps of CNM are formed as a result of thermal instability in the layer compressed by shock propagation [6] . Recently, Inoue & Inutsuka (2008, 2012) studied the analogous process, including the effect of the magnetic field, and showed the generation of sheetlike HI clouds and molecular cloud [7] [8] .

While the thermal instability in the condensation process of WNM to CNM have been studied intensively, its role in CNM and the molecular clouds has not yet been examined. Because the interstellar clouds are known to be always turbulent with supersonic velocity dispersion [9] [10], detailed study of the effect of thermal instability in the shocked cloud must be explored.

Using 1D hydrodynamics simulations with the effects of detailed cooling, heating and chemical processes, we examine thermal stability of shocked gas in HI and molecular clouds. We also estimate the e-folding time of the thermal instability to obtain the degree of perturbation grow in shocked gas. We find that both HI clouds and molecular clouds can be thermally unstable in the cooling layer behind the shock wave. Seed density perturbations in HI cloud can grow exp(5)~150 times larger than the initial state, while perturbations in molecular cloud can grow roughly exp(1)~2.7 for high Mach number shock. These results suggest that, in order to discuss fine structures in the clouds, the isothermal approximation may not adequate in CNM and molecular cloud.

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