論文内容の要旨

Giant Molecular Cloud Formation at the Interface of Colliding Supershells in the Large Magellanic Cloud

(大マゼラン雲におけるシェル衝突面での巨大分子雲形成)

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Abstract

Abstract

Giant molecular clouds (GMCs) are the principle site of the stellar cluster formation. Understanding the formation and the evolution of the GMCs are quite important to get a general understanding of the evolution of galaxies from the Local Group to the most distant Universe. Recent theoretical works of the GMC formation have argued that the filamentary GMCs formed at the stagnation point of the converging flows that are driven by supersonic turbulence and/or interstellar shocks. Compared to the observational works of the evolution of the GMCs, however, there is almost no observational work targeted on the kinematics of the GMC formation. Case studies that can prove theoretical predicts are now aspired.

Large Magellanic Cloud (LMC) is the nearest external galaxy (distance $\sim$ 50 kpc) and is relatively face-on to us (inclination $\sim 35°$). It has a large population of super-bubbles and supergiant shells (SGSs) in its gaseous disk. Star-forming regions N48 and N49 are located at the high column density H I ridge between two kpc-scale SGSs, LMC 4 and LMC 5. Young massive GMCs ($> 10^6$ $M_{\odot}$), which is considered to be formed by the collision of two SGSs, are identified without any signs of massive cluster formation. The GMCs in the N48 and N49 is the one of the best target to investigate the GMC formation process via large-scale colliding flows driven by the SGSs. In this thesis, high-resolution observation of the atomic Hydrogen (H I) gas is performed towards the H I ridge, and the GMC formation process at the colliding area of the two SGSs are studied from the analysis of the large-scale kinematics of the H I gas.

Before analyzing the H I gas, the detailed structure of the GMCs are investigated by the ASTE and Mopra observation. With 7 pc spatical resolution of ASTE, it is revealed that the GMCs consists of a lot of envelope-less dense molecular clumps of $\sim$ 10 pc diameter within a characteristic separation of $\sim$ 40 pc. The N48 region is located in the high column density H I envelope at the interface of the two SGSs and the star formation is relatively evolved, whereas the N49 region is associated with LMC 5 alone and the star formation is quiet. The clumps in the N48 region typically show higher $n(H_2)$ ($\sim 2 \times 10^3$ cm^{-3}) and $T_{\rm kin}$ ($\sim$ 100 K) than the N49 clumps. The N48 clumps are more evolved than the N49 clumps but still in the early phase of cluster formation.

New H I 21 cm line observation is performed toward the ridge using Australia Telescope Compact Array (ATCA) with 1.5 km baseline configurations. The obtained data

is combined with the archival shorter baseline data (Mao et al.), and the archival single dish data of Parkes telescope. Achieved beam size is 24.75″ by 20.48″, which corresponds to spatial resolution of $\sim$ 6 pc in the LMC, which is comparable to the ASTE resolution, and is quite high for the 21 cm line observation in the external galaxy. With this high-resolution observation, it is newly revealed that the structure of H I gas is highly filamentary, and the molecular clumps are distributed along the filamentary H I. From the channel maps of the new H I data, the identification of the filamentary features are performed by chaining the H I cores that are identified by the dendrogram. In total 39 filamentary features are identified, which implies that the H I gas structure of the ridge mainly consists of the composition of the filamentary features. Typical width of the filamentary features is $\sim$ 21 (8–49) [pc], and the typical line mass is $\sim$ 90 (20–190) [$M_\odot$/pc]. Since the molecular clumps are found in the most prominent filamentary feature, the evolution of the filamentary features might lead to the formation of the molecular clumps.

The H I position velocity diagram perpendicular to the ridge show that the axisymmetric, ellipse-like distribution at the colliding area of the shells (N48 region), and the molecular clouds are found at their central part. This is one suggestive evidence that the large-scale kinematics of H I gas around the GMCs are now gravitationally evolving. The characteristic separation and the typical mass of the N48 clumps ($\sim$ 40 pc, $\sim 2\times10^4$ $M_\odot$) can be explained by the Jeans length and the Jeans mass with theoretically predicted densities of shell-shocked atomic medium ($\sim$ 30–120 cm^{-3}). The mass of the GMCs and the molecular clumps can be doubled by the accretion of the H I envelope within 10^7 years. These suggests that the H I envelope of the GMCs are gravitationally bound, and the accretion of the H I is now non-negligible, even in the size scale of the molecular clumps.

Proposed formation scenarios of the GMCs in the N48 and N49 regions can be suggested as follows both in a large-scale and a high-resolution scale. At first in the large-scale, the expansion and the collision of the two SGSs aggregate and compress the diffuse medium into the high column density ridge. Secondly, the clumpy GMCs are formed via the instability induced by the shocks of the shells and their collision. And currently the H I gas surrounding the GMCs is getting to gravitationally bound to the GMCs and accretes onto them until the stellar cluster formation starts. On the other hand in the high-resolution scale, the structure of the H I gas is getting highly filamentary during its evolution. The molecular clumps are formed along the evolved filamentary H I gas. The H I gas around the molecular clumps are also getting to bound to the clumps, and the H I accretion onto the clumps are now non-negligible. These agree well with the theoretical predicts insisting that several times shocks are required to form GMCs, and newly suggest that the GMCs formation involves filamentary nature of the atomic medium and the gravitationally bound H I envelopes around the formed GMCs.