Formation, evolution, and survival of massive star clusters
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Formation of the twin galactic starburst regions NGC 6357 and NGC 6334

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Abstract. New CO J=1–0 observations with NANTEN and NANTEN2 reveal that extensive collisions between two molecular clouds at relative velocity of 15 km s^{-1} triggered the O star formation in the Galactic mini-starbursts NGC 6357 and NGC 6334. Correlated/anti-correlated gas distributions and intermediate velocity features between the two clouds lend support for the cloud-cloud collision scenario. The timescale of the collision and high-mass star formation is as short as less than 0.5 Myrs, suggesting rapid O star formation.

Keywords. ISM: clouds — ISM: molecules — ISM: kinematics and dynamics — stars: formation

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High-mass star formation is one of the top-priority issues in astrophysics. We have now growing evidence for O star formation triggered by supersonically colliding clouds in massive star clusters and young single O stars (e.g., Furukawa *et al.* 2009; Ohama *et al.* 2010; Torii *et al.* 2011, 2015; Fukui *et al.* 2014, 2015a,b). This suggests collisions play a substantial role in O star formation.

NGC 6357 and NGC 6334 are outstanding twin young HII regions with O stars extensively distributed across ∼100 pc at distance 1700 pc (Figure 1a). These large HII regions are rich in molecular gas and are thus reasonable targets to study the mechanism of O star formation. Most recently, based on new NANTEN and NANTEN2 CO J=1–0 observations, we discovered in NGC 6357 and NGC 6334 two molecular clouds are colliding with each other at a relative velocity of ∼15 km s^{-1} to trigger O star formation.

The results are summarized in Figure 1. The red-shifted cloud (hereafter the red cloud) has strong CO emission and are elongated along the Galactic plane over 100 pc, showing a good coincidence with NGC 6357 and NGC 6334 and their O-star clusters depicted by crosses (Figure 1b). On the other hand, the blue-shifted cloud (hereafter the blue cloud) is weak in CO, but shows an elongated distribution similar to the red cloud (Figure 1c). The blue cloud toward NGC 6357 shows a good coincidence with the red cloud above 0.8° and nested distributions with the red cloud below 0.8° (black dashed lines). The blue cloud in NGC 6334 also shows a good correlation with the red cloud especially toward the clusters (white dashed lines). These correlated and anti-correlated distributions between the two velocity clouds are usually seen in cloud-cloud collision as predicted in numerical studies (Habe & Ohta 1992; Takahira *et al.* 2014). In addition, in the longitude-velocity diagram in Figure 1d the two clouds are connected by intermediate velocity bridging features, which are similar to that seen in RCW 38 (Fukui *et al.* 2015b). Synthesis observations by Haworth *et al.* (2015) indicate that these "bridging features" are unique characteristics to cloud-cloud collision.

The collisions in NGC 6357 and NGC 6334 are occurring between the two filamentary clouds across ∼100 pc, along the Galactic arms. The timescale of the collision can be estimated as a crossing time to be ∼0.5 My. The results demonstrate that cloud-cloud collision has a potential to cause extensive O star formation on a Galactic scale. Further

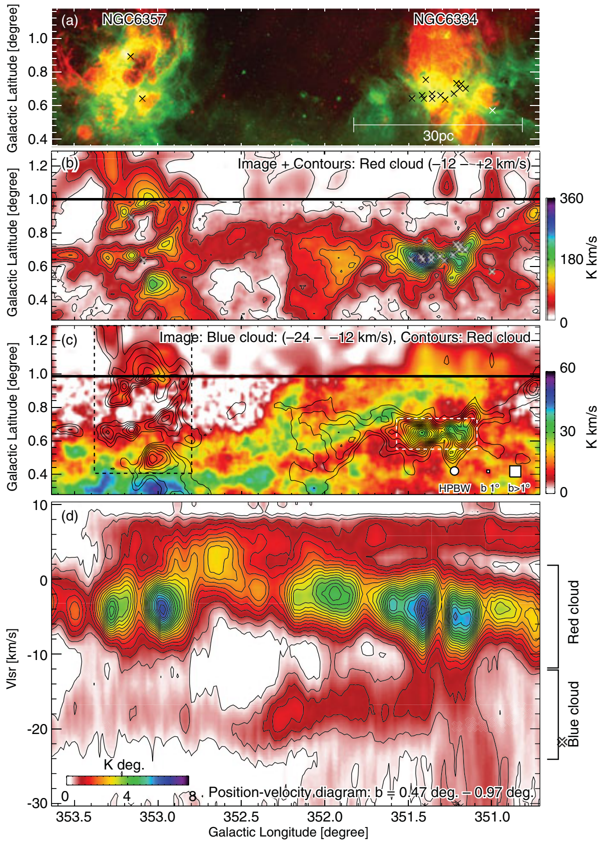

Figure 1. (a) A composite image of NGC 6357 and NGC 6334, where red and green indicate Hα (Parker *et al.* 2005) and Spitzer 8 μm (Benjamin *et al.* 2003), respectively. (b) The red cloud toward the same region in (a). (c) The contour map of the red cloud is superimposed on the image of the blue cloud. The dashes lines indicate the region where correlations of the gas distributions between the two clouds are seen. (d) Longitude-velocity diagram of the two clouds. In panels (a)–(c) crosses indicate the clusters.

molecular studies which cover several 100-pc scales along the arms will be extremely important in order to better understand the role of cloud-cloud collisions in galactic activity.

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