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Super-star-cluster forming clouds in the young starburst galaxy NGC 5253

R. E. Miura[1], D. Espada[1,2], K. Nakanishi[1,2], A. Hirota[1,3], and H. Sugai[4]

[1] National Astronomical Observatory of Japan, National Institutes of Natural Sciences, 2-21-1 Osawa, Mitaka, Tokyo 181-8588, Japan, e-mail: rie.miura@nao.ac.jp
[2] Department of Astronomical Science, The Graduate University for Advanced Studies (Sokendai), 2-21-1 Osawa, Mitaka, Tokyo 181-0015, Japan
[3] Joint ALMA Observatory, Alonso de Cordova 3107, Vitacura, Santiago de Chile
[4] Kavli Institute for the Physics and Mathematics of the Universe, Todai Institutes for Advanced Study, The University of Tokyo, 5-1-5 Kashiwanoha, Kashiwa, Japan

Abstract. We present high spatial resolution (0.″2, or 3 pc) CO(2–1), H30α, and 230 GHz continuum data towards the nearest (young) starburst dwarf galaxy, NGC 5253, taken with ALMA. Among the 120 molecular clouds we identified, we found a compact cloud with a notably large velocity width (hereafter HVCC). The peak location of the HVCC is consistent with the H30α and continuum emission peaks, as well as with two young super-star-clusters (SSCs) which are the main source of the starburst in the central region. The main characteristics of the HVCC are: (i) its large velocity gradient ($\sigma \sim 10 \mathrm{kms}^{-1}$), and (ii) its extended emission along the Hα bipolar outflow. We interpret that the large velocity gradient is partly due to rotation and conclude that the HVCC is a compact SSC-forming cloud where outflows are being ejected at multiple directions.

1. Introduction

The nearest (D = 3.15 Mpc; Freedman et al. 2001) young nuclear starburst galaxy, NGC 5253, is arguably one of the best laboratories for understanding the star-formation process at the very early stage of a starburst (Martín-Hernández et al. 2005; Caldwell & Phillips 1989). NGC 5253 is a compact blue dwarf galaxy, hosting several young clusters (Calzetti et al. 2015). It is expected that such recent star formation has been activated in the last tens of Myr after a gradual decrease of star formation (McQuinn et al. 2010). In the nucleus starburst region there is a deeply embedded radio compact (1–2 pc size) HII region excited by 4700 O stars (Turner et al. 2000). It is powered by two massive ($\sim 10^5 M_\odot$) and young (~1 Myr) super stellar clusters (SSCs) separated by 0.″3 or ~ 5 pc (Alonso-Herrero et al. 2004; Calzetti et al. 2015), which are named as SSC-5 and 11. The bipolar outflow ejected from these central SSCs is observed in Hα (Westmoquette et al. 2013). SSC-11 is the predominant site of star formation and deeply obscured by dust (Bendo et al. 2017).

We have obtained high resolution and high sensitivity Band 6 data towards NGC 5253 with the ALMA telescope, and we present here the CO(2–1), H30α, and 230 GHz continuum data towards the central SSCs.

2. Results

We have identified 120 molecular clouds in NGC 5253 using the package CPROPS

(Rosolowsky & Leroy 2006). The molecular properties are characterized by a typical radius of 3.8 pc and a velocity width of 2.2 kms^{-1} (Miura et al. 2017). Among them, we found a compact and massive molecular cloud with a relatively large velocity width (Hereafter HVCC; R = 4.2 pc, σ_v = 9.3 kms^{-1}, $M_{\rm lum}$ = $9.8 \times 10^4\, M_\odot$). Its properties are unique compared with the other clouds in the galaxy, and rather similar to the clouds in the Galactic Center (Oka et al. 2001). The CO(2–1), H30α and 230 GHz continuum emission peak at the same position, and coincide with SSC-11. Extended structures are seen in CO(2–1) emission along the direction of the Hα bipolar outflow (Fig.1) as well as in H30α. Notably, the CO position-velocity diagram of HVCC shows that there is a velocity gradient in the direction perpendicular to the Hα outflow, and the profile towards SSC-11 has a double peak shape.

3. Discussion and conclusion

We discuss three possible causes for such a large velocity width: (1) expansion by supernovae (SN) explosions, (2) molecular gas outflow, and (3) disk rotation.

1) SN explosion: We estimated a kinetic energy $E_{\rm kin}$ = $8.4 \times 10^{49} \alpha$ erg for HVCC, where $\alpha = 1$ if velocity dispersion is only in the line-of-sight, or α = 3 in the isotropic case. The derived kinetic energy is 1–2 dex smaller than the energy released from a typical supernova explosion (10^{51}–10^{52} erg). In addition, the estimated ages of the central SSCs are quite young (~ 1 Myr-old), and in such time scales these events are rare. Therefore it is unlikely that the origin of the large velocity width is originated via SN.

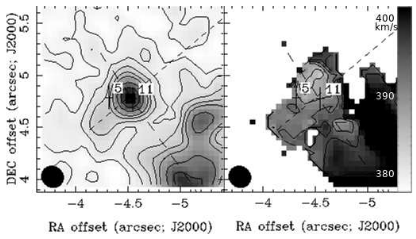

Fig. 1. The CO(2–1) integrated intensity map (left), and intensity-weighted velocity field (right) of the HVCC region. The short- and long-dashed lines indicate the direction of the Hα bipolar outflow and the direction with largest velocity gradient, respectively. The coordinates are shown as offsets from α = 13$^{\rm h}$39$^{\rm m}$56$^{\rm s}$.32, δ = −31°38′29″.15. The locations of the two central SSCs, SSC-11 and SSC-5, are marked with crosses.

2) Outflow: We assume that the outflow is also ejected from HVCC along the line of sight. The estimated outflow mass rate is $\dot{M}_{\rm out}$ = $0.1\, M_\odot\, {\rm yr}^{-1}$ in a timescale of 1 Myr, the age of SSC-11. SSC-11 ($M_{\rm ssc}$ = $2.6 \times 10^5\, M_\odot$) can be interpreted as a small scale analog of the well-known starburst NGC 253 ($M_{\rm ssc}$ = $1.4 \times 10^7\, M_\odot$), where the estimated outflow mass rate is ~ 1/50 of that in NGC 253 ($\dot{M}_{\rm out}$ = $3 - 9\, M_\odot\, {\rm yr}^{-1}$; Bolatto et al. 2013). As for the CO extended emission along the Hα bipolar outflow direction can be interpreted as outflows launched from HVCC, which appears on the sky plane. If so, this suggests that the outflows are ejected in the multiple directions.

3) Rotation: Interpreting the velocity gradient as rotation, the dynamical mass ($M_{\rm dyn}$ = $V_{\rm rot}^2 r/G$) is calculated to be ~ $4{\times}10^5\, M_\odot$, which is comparable to the sum of the molecular mass of HVCC and the stellar mass of SSC-11. We argue that HVCC might be supported by rotation.

We conclude that the relatively large velocity width of HVCC is consistent with rotation and it is a compact SSC-forming cloud with outflows along multiple directions and launched from the SSC.

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