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EMISSION LINE VELOCITY FIELD OF THE MAGELLANIC IRREGULAR GALAXY NGC 4449

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ABSTRACT

The imaging spectroscopic observations of the Magellanic irregular galaxy NGC 4449 were made to show the detailed kinematic structure of the galaxy. Many filamentary structures and Several bubble-like structures are recognized in a 3D data cube of Hα emission line. Velocity field shows the kpc-scale mosaic structure and counter-rotation of ionized gas.

Key Words : irregular galaxies, internal motion

I. INTRODUCTION

NGC 4449 is a nearby (at distance of 5.4 Mpc) Magellanic irregular galaxy which has many H II regions and a huge H I envelope. The galaxy shows violent star formation activities, and it has been the target of numerous observations. We performed imaging spectroscopic observations of the galaxy. We obtained tridimensional data cube of Hα emission line to show detailed kinematic structure and then to investigate the star formation mechanism of NGC 4449.

II. OBSERVATIONS

The imaging spectroscopic observations were made on 1992 April 25–28 with the 188-cm reflector equipped with a Cassegrain spectrograph in the Spectronebulagraph (SNG) mode (Kosugi et al. 1995) at Okayama Astrophysical Observatory. SNG, a slit-scanning type 3D-spectroscopic system, controlled the telescope and the long-slit spectrograph and automatically scanned the image of the object. The resulting scanned area was $56'' \times 270''$ during four nights. The spatial sampling along the slit is $1.46''$ pix^{-1} and the interval of the step of the scan is $1.8''$ which is the same width of the slit. The seeing during the observation was 2–3″. Position angle of the slit was set at 19° to cover the most of H II regions in the galaxy, while the optical major axis of the galaxy is 45°. A 1800 grooves mm^{-1} grating blazed at 5000 Å was used to obtain spectra having a dispersion of 0.40 Å mm^{-1}. In the wavelength coverage from 6545 Å to 6750 Å, Hα, [N II], and [S II] were included, but only Hα velocities were measured.

The data reduction was made using IRAF and SNGRED software package developed by two of us (G. K. and M. Y.) . We also measured OH sky lines at 6577.28 Å and obtained the slight systematic error to correct the wavelength of Hα.

III. RESULTS

Many filamentary structures have been newly recognized in intensity map of each velocity range. Several bubble-like structures are also recognized in slices of 3D-data cube. They are rings or half-rings in the spectra and in the intensity maps. Sizes and velocity differences of these structures are comparable to superbubbles found in many star bust galaxies. But few spherical shell are discerned in 3D space.

Hα velocity field shows the kpc-scale mosaic structure of blueshift and redshift components with slow global rotational motion. Rotational motion is consistent with previous works. There is no systematic difference between the [O III] velocities of H II regions measured by an echell spectrograph (Hartmann et al. 1986) and Hα velocities measured by us.

The kpc-scale mosaic structure is the first kpc-scale kinematic structure recognized in irregular galaxies. The nearly face-on orientation, slow rotation, strong Hα emission and the weak stellar continuum of the galaxy help us to detect these structure. While it is unable to determine the direction of the motion (upward or downward flow to the disk) from our data, the kpc-scale mosaic structure probably reflects an mechanism of an interaction between the disk and the halo of the galaxy.

Diffuse emission lines show large velocity dispersion, or large turbulent motion of diffuse gas in the galaxy.

IV. DISCUSSION

(a) Counterrotation and the Origin of Star Burst

Our Velocity field confirms counterrotation between ionized gas and the H I halo which was first recognized by van Woerden et al.(1974). Velocity field of ionized gas in the galaxy shows slow rotation which shows redshift motion at the North-East end of bar, while velocity field of the huge H I halo shows blueshift motion at the North-East direction of the galaxy.

NGC 4449 is one of counterrotating galaxies compiled by Galleta (1995). He showed that counterrotation appears in all morphological types, from ellipticals to spirals or irregulars. NGC 4449 is an unique object among the four irregulars of his compilation, because other three are interacting/merging galaxies. The origin of counterrotation in interacting/merging galaxies can be attributed to its interaction. These systems will evolve to a final structure resembling counterrotating elliptical galaxies. Non-interacting spiral galaxies with massive cold counterrotating stellar disk are another type of counterrotating galaxies which need other formation mechanism, because strong interaction and merging heat the disk. Secondary infall of diffuse gas can form massive cold counterrotating disk. The counterrotating H I halo of NGC 4449 might be infalling to form a cold counterrotating disk.

Accretion from the counterrotating gaseous halo may be the origin of large turbulent velocity and star burst activity in NGC 4449. In the interface between the inner ionized gas disk and the outer H I halo, counterrotating gas will lose their angular momentum effectively and fall toward the inner region of the galaxy and trigger the burst of star formation.

There are other possibilities that observed counterrotation is apparent one. Warped outer disk shows opposite velocity gradient when it is observed from viewing direction between the rotational axis of the inner disk and that of the outer halo, as in the case of IC 10 (Cohen 1979). Warped inner gas disk in barred galaxies also shows apparent counterrotation as in the case of NGC 2217 (Bettoni et al. 1990). The observations of stellar velocity field is necessary to solve the ambiguity.

(b) Kpc-Scale Mosaic Structure

The largest cloud complexes in galaxies contain 10^7 solar mass or more of atomic and molecular gas. They are identified by H I 21-cm emission and by the clustering of giant molecular clouds. Size of these cloud complexes, several hundred pc, are comparable to those of bright H II regions, indicating that they are a characteristic scale of galactic star formation process. The kpc-scale mosaic structure in our Hα velocity field seems to correspond to the kinematical structure of the cloud complexes.

The Jeans and Parker instabilities are considered as formation mechanism of the cloud complexes (Elmegreen 1987, Matsumoto et al. 1990). These two instabilities are different in symmetry respect to the disk plane. The mirror symmetry is dominant in the Jeans instability, while the glide reflection symmetry is dominant in the Parker instability (Horiuchi et al. 1988). Our results prefer the glide reflection symmetry.

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