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Effect of the bar pattern speed on the molecular gas dynamics in galaxy NGC 7479
（NGC 7479 における分子ガスの運動に及ぼす棒状構造のパターン速度の影響）

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Summary

In this thesis, we report the results of a study of the molecular gas dynamics, the molecular gas distribution, and the star formation in the bar of the nearby barred spiral galaxy NGC 7479, focusing on the effect of the bar pattern speed. It is important to determine the bar pattern speed to understand the structure and evolution of galaxies. However, it is difficult to measure the bar pattern speed in galaxies because the galactic bar structure is formed as a pattern of stars and interstellar gas. Several studies of observations and simulations have suggested that star formation activity is generally suppressed in the bar compared to the spiral arm and other structures.

In order to determine the bar pattern speed of NGC 7479, we performed ^{12}CO(J=1-0) observations with the Atacama Compact Array of Atacama Large Millimeter/submillimeter Array. The Position-Velocity (P-V) diagram along the major axis of the bar shows that there are gas components in the bar region that rotate with the rigid-like rotation of the bar. Furthermore, we found an offset of the velocity from the rigid-rotation of the bar that is an effect of the inward motion of the gas along the bar. In addition, there is a large velocity gradient of ±200 km s^{-1} from the systemic velocity in a region within a radius of 3 kpc. This feature suggests that the central region of NGC 7479 has fast rotating gas such as a ring structure. On the other hand, the P-V diagrams along the minor axis of the bar show that there are large velocity jumps of nearly 100 km s^{-1} in the bar region due to the shock along the bar. We investigated the variation of star formation efficiency in NGC 7479 and found that star formation efficiency in the bar is comparable to that in the arms. By assuming that the radial gas velocity approaches 0 km s^{-1} at the corotation radius, we extended the Kuno-method, which was proposed by Kuno et al. (2000), to eliminate the effect of inward motion around the corotation radius and determined the bar pattern speed. The bar pattern speed of NGC 7479 obtained by the extended Kuno-method is 18 km s^{-1} kpc^{-1} ≤ Ω_{bar} ≤ 24 km s^{-1} kpc^{-1} and it means that NGC 7479 is a fast-bar galaxy.

Furthermore, we investigated the molecular gas dynamics and the molecular gas distribution in NGC 7479 by using smoothed particle hydrodynamical (SPH) simulations based on the results of the observation. We performed six different simulations with the bar pattern speed Ω_{bar} = 12 km s^{-1} kpc^{-1}, 18 km s^{-1} kpc^{-1}, and 24 km s^{-1} kpc^{-1} and sound speed cs = 10 km s^{-1} and 15 km s^{-1}. Finally, by comparing the results of observation

and simulations, we determined that Ω_{bar} = 18 km s^{-1} kpc^{-1} is the parameter that best reproduces the gas distribution and gas dynamics. The result is consistent with the bar pattern speed derived by Kuno-method.

The results of our SPH simulations of the gas show that the offset of velocity in the P-V diagram along the bar is caused by the inward motion in the bar region. Considering the inward motion of the bar, when either the major axis of the bar or the major axis of the offset ridge is aligned with the line of node of the galaxy, the bar pattern speed can be determined directly using the Kuno-method by observing the bar with a spatial resolution sufficient to resolve the offset ridge of the bar.

From the results of simulations of the gas, we found that the strengths of the shock and shear of the gas in the bar increases as the bar pattern speed becomes slower. These changes in gas dynamics can be due to the different relative velocity between the bar pattern speed and the rotational velocity of the galactic disk. Furthermore, we found that the gas in the bar of a slow-bar galaxy is present in orbits along the offset ridge, which is a region of strong shear, whereas the gas in the bar of a fast-bar galaxy is also present in orbits in the low shear region that is outside the offset ridge. These results suggest that the growth of gravitational instability in the bar of a slow-bar galaxy is prevented by the strong velocity shear and it is related to suppression of star formation in the bar region. On the other hand, in the case of a fast-bar, these dynamical effects on the molecular gas are smaller, and thus the star formation efficiency is not reduced even in the bar region.