論文内容の要旨

論文題目：The Resolved Kennicutt-Schmidt Law in Nearby Galaxies
（近傍銀河における構造と星形成則）

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We study the spatially resolved Kennicutt-Schmidt law (K-S law) using our new CO(J=1-0) data from the CARMA and NOBEYAMA Nearby-galaxies (CANON) CO survey. The data of 10 galaxies resolved their galactic disks at a high resolution, enabling the comparisons of the K-S law between galactic structures (e.g. spiral arms, bar) in individual galaxies and among the galaxies. In order to estimate star formation rates (SFRs) and molecular gas density accurately, new approaches to estimate them are adopted. For example, we subtract the diffuse ionized gas (DIG) component whose emission does not originate from recently-formed young massive stars, in Hα and 24 m images. To estimate the amount of molecular gas, we combine the CO(J=1-0) data from the Combined Array for Research in Millimeter-wave Astronomy (CARMA) and Nobeyama 45m single-dish telescope (NRO45) (i.e. we filled the missing information in interferometer observations with single-dish observations). Our new CO(J=1-0) data have a high image fidelity at a high spatial resolution (< 4") and cover roughly the entire disks.

We discuss the K-S law on a 500 pc scale which is the size of the environment around giant molecular clouds (GMCs) possibly regulating star formation . The K-S plot, SFR (Σ_{SFR}), star formation efficiency (SFE = Σ_{SFR}/Σ_{H2},where Σ_{H2} is the molecular gas surface density) and the SFE described in unit of a physical timescale (i.e., $SFE_{tphy} = \Sigma_{SFR}/\Sigma_{H2}{}^{N}$, where N is the index of the K-S law) are discussed. We also discuss the star formation mechanism that is indicated by the K-S law index.

First, we discuss star formation mechanism and the comparison to previous study from all our 10 galaxies:

1) The most striking result is the super-linear slope of the K-S law (N = 1.29 and 1.75 — the two indies correspond to the analysis with and without the DIG emission: Figure 1). The index of the K-S law is often used to differentiate the mechanisms for star formation. For example, N = 1 corresponds to a constant star formation timescale. N = 1.5 is derived from a simple self-gravitational instabilities. And N = 2 can represent the cloud-cloud collision as a trigger of star formation. Our result, N = 1.75, is between the models of self-gravitational instabilities and cloud-cloud collision.

2) The most recent study (Bigiel et al., 2008) obtained N = 1, as opposed to the results from earlier studies, and is becoming the standard of the K-S law index. We argue that this discrepancy is caused by the difference of the adopted molecular gas tracers. The high excitation transition line of CO(J=2-1) used by Bigiel et al. [2008] more likely traces the dense gas rather than the bulk gas. We conclude that the CO(J=1-0) line is the best tracer to study the relation between SFR and the bulk molecular gas.

3) The CO(J=1-0) line trace the total amount of molecular hydrogen, even though there is a assumption of conversion factor. The correlation between Σ_{SFR} and Σ_{H2} estimated CO(J=1-0) looks to reflect star formation mechanism from amount of molecular gas. On the other hand, high excited CO lines (CO(J=2-1) and CO(J=3-2)) and HCN line trace dense molecular gas

which is directly relating to star formation. We conclude that the correlation between SFR and gas surface density unit area traced by CO(J=1-0) line is the best way to study the relation between SFR and the bulk molecular gas.

4) The correlation of the K-S law is dominated by the varaiety of SFE obtained within a galaxy on 500 pc scale of our study. We find the scatter of the correlation of the K-S law is dominated by SFE variation among galaxies on kpc scale (> 1 kpc), and within a galaxy on sub-kpc scale (several hundred pc). The scatter of the correlation of the K-S law within a galaxy can be caused by the spatial offsets between GMCs and star-forming regions.

Next, we compare star formation activities (SFAs: SFR, SFE and SFE_{tphy}) between galactic structures and among galaxies. The difference among structure is large even within a galaxy. This difference, however, becomes less obvious if we analyze the data of all galaxies at the same time. They remains a possible difference between the nuclei and the rest of the structures.

1) Both Σ_{SFR} and SFEs exhibit a variety among each structure of each galaxy. As the trend from all galaxies, the mean of Σ_{SFR} is highest in the nucleus and lowest in the "other region". Exceptionally, in NGC 3521, the highest mean Σ_{SFR} is seen in the bar. As same as Σ_{SFR}, the mean SFE is also highest in the nucleus and lowest in the "other region". As exceptions, the highest mean SFE is appeared in the spiral arms in NGC 4254 and 4736, while the lowest mean SFE is seen in the bar in NGC 4303.

2) Some galaxies show the difference of SFE_{tphy} obtained in each galaxy. Six out of the 10 galaxies display little difference of SFE_{tphy} among structures, but the rest of four galaxies, NGC 4254, 4303, 4321 and 5194, show a large variation in SFE_{tphy}.

3) Both Σ_{SFR} and SFEs vary from structure to structure when they are obtained from all galaxies. However, SFE_{tphy} of each structure is comparable. This suggests star formation mechanism and activities would be little different among structures from all galaxies.

4) The index obtained in each structure at the same of all galaxies indicate that basically stars can form with free-fall time of local molecular gas regardless of structures. The index of K-S law is considered to trace star formation mechanism of given area. We obtain different but close value of the K-S law index in each structure. As another mechanism in the disk region, star formation can be regulated by some trigger mechanism. While in the nucleus, we find a possibility to bear stars in dense cores with constant efficiency, since the K-S law slope has a range between N = 1–1.5. We may detect dense molecular gas having stars at higher Σ_{H2}, even in CO(J=1-0) line.

We also compare SFAs among galaxies. SFAs vary from galaxy to galaxy.

1) We compared SFAs among galaxies. SFRs, SFEs and SFE_{tphy} from all galaxies varied in each galaxy, and showed the highest value in NGC 4736 which has the post-starburst nucleus. Moreover slopes of the K-S law were clearly different depending on galaxies. It indicates that star formation property is different in each galaxy.

2) We obtained variety of the different slopes (i.e. N) from 1.5 to 3.8 among galaxies. This could reflect individuality of SFAs and mechanism of star formation from galaxy to galaxy.

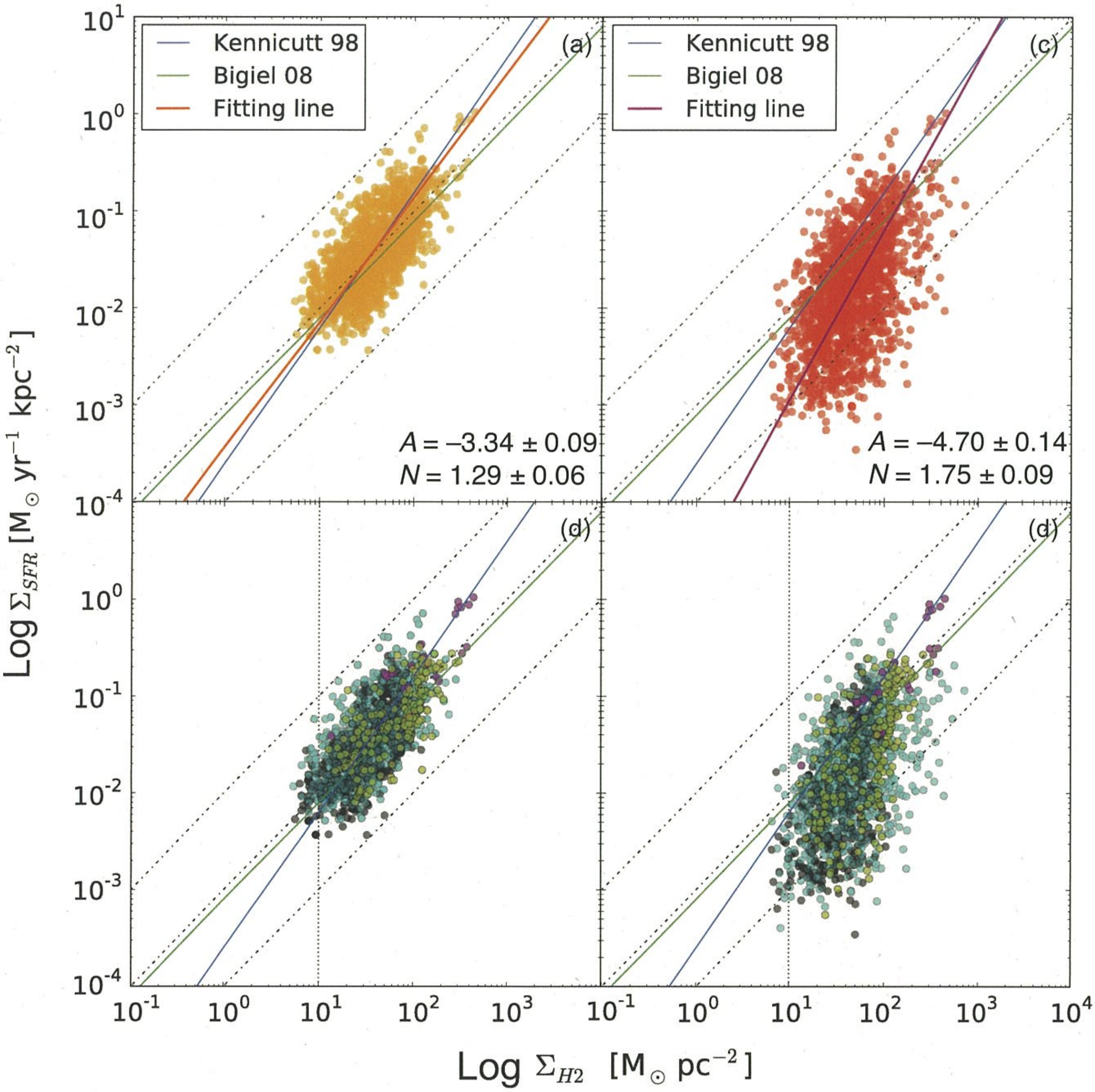

Figure 1. The K-S plots (a), (b) with and (c), (d) without DIG emission. In, (b), (d) we separated galactic structures (the nuclei, spiral arms, bar and "other region") with different colors, i.e. pink, cyan, yellow and black, respectively. Dot-dashed lines are SFEs of 10^{-8}, 10^{-9} and 10^{-10} yr^{-1} from the top to bottom.