The Effect of Galaxy Interactions on Molecular Gas Properties

Pan et al. 2018　ArXiv ID : 1810.10162

ABSTRACT

Galaxy interactions are often accompanied by an enhanced star formation rate (SFR). Since molecular gas is essential for star formation, it is vital to establish whether, and by how much, galaxy interactions affect the molecular gas properties. We investigate the effect of interactions on global molecular gas properties by studying a sample of 58 galaxies in pairs and 154 control galaxies. Molecular gas properties are determined from observations with the JCMT, PMO, CSO telescopes, and supplemented with data from the xCOLD GASS and JINGLE surveys at ^{12}CO(1–0) and ^{12}CO(2–1). The SFR, gas mass (M_{H_2}), and gas fraction (f_{gas}) are all enhanced in galaxies in pairs by ~ 2.5 times compared to the controls matched in redshift, mass, and effective radius, while the enhancement of star formation efficiency (SFE $\equiv$ SFR/M_{H_2}) is less than a factor of 2. We also find that the enhancements in SFR, M_{H_2} and f_{gas} increase with decreasing pair separation and are larger in systems with smaller stellar mass ratio. Conversely, the SFE is only enhanced in close pairs (separation < 20 kpc) and equal-mass systems; therefore most galaxies in pairs lie in the same parameter space on the SFR-M_{H_2} plane as controls. This is the first time that the dependence of molecular gas properties on merger configurations is probed statistically with a relatively large sample and with a carefully-selected control sample for individual galaxies. We conclude that galaxy interactions do modify the molecular gas properties, although the strength of the effect is merger configuration dependent.

銀河相互作用における分子ガスの性質の変化を調べた
⇒相互作用銀河の星形成活動の理解につながる
特に銀河間距離と質量比によってどう変わるのか
根拠のあるα_{CO}(金属量依存性 Accurso+2017)と注意深く選び出したコントロールサンプルによる大きなサンプル(58)での初めての研究

データ
分子雲観測(右)
星質量、星形成率はMPA-JHU
金属量もMPA-JHUのO3N2

Table 1. Summary of the observations.

	galaxies in pairs				pool of controls
project	PI programs	JINGLE	JINGLE Pilot	xCOLD GASS	xCOLD GASS
number	21	5	2+2+1	27	154
telescope	JCMT	JCMT	JCMT/PMO/CSO	IRAM	IRAM
tracer	^{12}CO(2-1)	^{12}CO(2-1)	^{12}CO(2-1)/(1-0)/(2-1)	^{12}CO(1-0)	^{12}CO(1-0)
beam size	22″	22″	22″/52″/30″	22″	22″

相互作用の有無での違い
sSFRとMH2、fgasについては相互作用銀河でエンハンス
SFEは大きな変化なし

ΔMH2、Δfgas、ΔSFEはΔSFRが上がると上昇
相関はΔMH2、Δfgasの方がΔSFEより強い

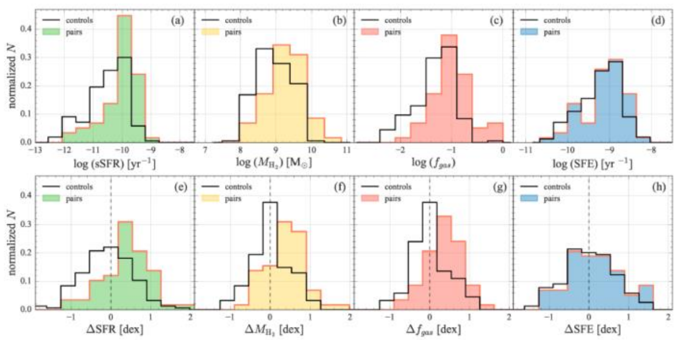

Figure 4. Histograms showing the distribution of physical quantities sSFR, M_{H_2}, f_{gas}, and SFE in upper row, and the offset of these properties with respect to the control sample in the lower row. The galaxies in pairs and controls are plotted as filled and open histograms, respectively. The vertical dashed lines in the lower panels indicate zero enhancement. The enhancements of SFR, M_{H_2} and f_{gas} are observed statistically significant for both raw and offset quantities (Table 3). The strength of SFE offset is not as large as that of other properties, and a Kolmogorov-Smirnov test suggests that the difference is not significant.

相互作用の性質による違い
<距離>
銀河間距離が近いとエンハンスが強くなる。ΔSFEについては最も小さい距離binのみ
<質量比>
major mergerだとエンハンスが強い。ΔSFEは等質量ペアのみ。

⇒分子ガスのエンハンスの物理的起源は不明
一つの可能性としては相互作用によってHII → HI → H2が促進される
(Kaneko+2017,Moreno+2018)
SFEについては銀河全体でみるとなまされている？

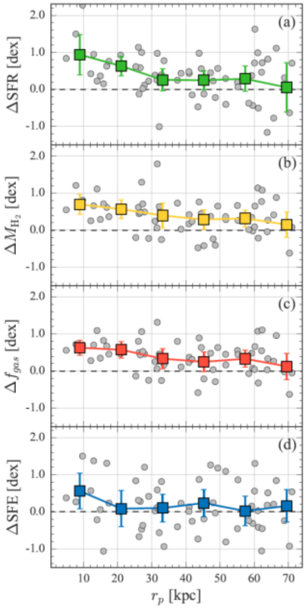

Figure 8. Offset properties as a function of projected galaxy separation for our sample. Gray circles denote individual galaxies. Mean values per r_p are indicated with colored squares. Error bars are obtained by calculating the sample standard deviation and dividing by $\sqrt{N}$, where N is the number of galaxies at each r_p bin. The horizontal lines indicate no enhancement. ΔSFR, ΔM_{H_2}, and Δf_{gas} all increase with decreasing pair separation over the range from $\sim$ 70 to 10 kpc. However, any SFE enhancement is only significant at the smallest pair separations.

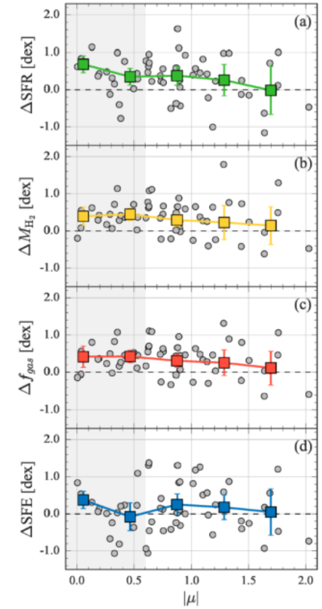

Figure 9. Offset properties as a function of the absolute value of stellar mass ratio $|\mu|$ of the galaxies in pairs. The major merger regime ($|\mu| < 0.6$) is highlighted in gray. The individual galaxies in pairs are shown with gray circles and the means are in colored symbols. ΔSFR, ΔM_{H_2}, and Δf_{gas} exhibit a trend with mass ratio of the two galaxies in a pair. We find no apparent dependence between the mass ratio and ΔSFE. Any SFE enhancement is only significant in the equal-mass pairs ($|\mu| \approx 0$).

SFR-MH2 relation
今回のペア銀河とhigh-z (U)LIRGはSFEが一桁程度違う
両者の間には近傍(U)LIRG
high-z (U)LIRGについてはgas reservoirのみでなく、SFEも上昇 (今回のペア銀河はガスのみ)

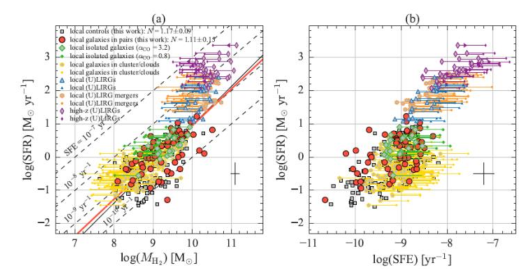

Figure 11. SFR plotted as a function of mass (a) and star formation efficiency (b) of molecular gas. Our galaxies in pairs and the pool of controls are shown as red circles and gray squares, respectively. Red and black solid lines give the best-fitting linear relation for our galaxies in pairs and controls, respectively. The values of the best-fitting power law index are given in the plot. Literature data have been included for comparison. The local normal isolated galaxies (green diamonds) and (U)LIRGs (blue triangles) are taken from Gao & Solomon (2004). Galaxies in the Virgo cluster and nearby clouds are taken from the Herschel Reference Survey (HSR, yellow pentagons; Boselli et al. 2010). Orange hexagons show local (U)LIRG mergers from Gao & Solomon (1999). Purple thin diamonds show high-z (U)LIRGs from Combes et al. (2013). Due to the lack of metallicity and M_* measurements to calculate the physically-motivated α_{CO}, we apply two α_{CO}, 3.2 (large symbols) and 0.8 (small symbols), for all galaxies compiled from literature (see text for details). The two symbols of a given galaxy are connected with a horizontal line, indicating the most plausible range of M_{H_2} for the galaxy. In the cases where the line is not detected, the upper limits of L_{CO} and M_{H_2} are computed at 3σ. These galaxies are indicated by a horizontal arrow (all of them are high-z (U)LIRGs). The SFRs of the local isolated galaxies and local and high-z (U)LIRGs are calculated using L_{IR} calibrated by Kennicutt (1998b). The SFRs of the HSR galaxies are determined by the mean values of different SFR estimates using Hα, 24μm, FUV, and radio (Boselli et al. 2015). The figure shows that the gap between our galaxies and high-z (U)LIRGs on the SFR-M_{H_2} plane (the bimodal star formation mode) can be bridged by local (U)LIRGs. Moreover, the high SFR of high-z (U)LIRGs is not only due to an enhancement of molecular gas reservoir, but also the SFE of the molecular gas.

今後
銀河を空間分解して、星形成と分子ガスプロパティを見たい
MaNGA銀河のALMA観測