Resolving the Rise and Fall of Star Formation in Galaxies
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Revealing the Relation between Star Formation Activity of Jellyfish Galaxies and Ram Pressure Stripping

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Abstract. Jellyfish galaxies are starburst galaxies with ram-pressure-stripped tails and blue star-forming knots. These galaxies show a snapshot of star formation enhancement triggered by ram pressure stripping (RPS), being important targets for studying the RPS-induced star formation in gas-rich galaxies. Here we investigate the star formation activity of five jellyfish galaxies in massive clusters, using Gemini GMOS/IFU observations. From the Hα-derived star formation rates (SFRs), we find that our sample shows higher SFR excess to the star formation main sequence than the jellyfish galaxies in low-mass clusters. From the compiled sample of jellyfish galaxies in low-mass to high-mass host clusters, we suggest that the star formation activity of jellyfish galaxies has positive correlations with host cluster mass and degree of RPS. These relationships imply that higher ram pressure environments tend to trigger stronger starbursts in jellyfish galaxies in the early stage of RPS.

Keywords. Galaxy evolution; Galaxy environments; Ram pressure stripping; Starburst galaxy; Jellyfish galaxy; Integral Field Spectroscopy

1. Introduction

Ram pressure stripping (RPS; Gunn & Gott 1972) is the gas stripping mechanism related with the interaction between gas and intracluster medium (ICM). This process is one of the main drivers of galaxy evolution in dense environments. In the long-term view, RPS quenches the star formation activity by transforming gas-rich galaxies into gas-deficient galaxies. However, RPS enhances the star formation activity of galaxies within a few hundred Myrs since the first infall to the cluster center (Bekki & Couch 2003). For instance, some ram-pressure-stripped galaxies show star-forming regions in their disks and tails, exhibiting "jellyfish-like" morphology (Ebeling et al. 2014). Thus, these jellyfish galaxies are ideal laboratories for studying the relationship between star formation activity and RPS.

Integral-field spectroscopy (IFS) has been widely used to investigate the star formation activity of jellyfish galaxies. The GAs Stripping Phenomena in Galaxies with MUSE (GASP; Poggianti et al. 2017) is one of the most successful IFS survey observing jellyfish galaxies at low redshift ($\langle z \rangle \sim 0.05$), demonstrating the star formation enhancement of the GASP jellyfish galaxies compared to the non-RPS control sample (Vulcani et al. 2018). However, previous IFS studies have been limited to jellyfish galaxies in relatively low-mass clusters, which are likely to show mild RPS effects on galaxies. In contrast,

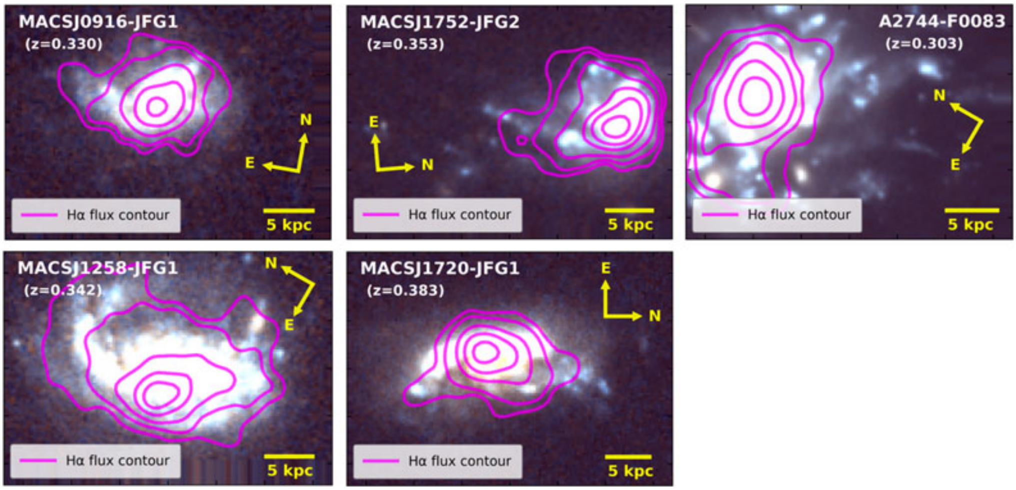

Figure 1. The Hubble Space Telescope (HST) optical images of the five jellyfish galaxies in this study. The Hα flux distributions observed by the Gemini GMOS/IFU are overlaid with magenta lines.

massive clusters at intermediate redshift are expected to exert much more extreme RPS to galaxies due to high ICM density and dynamical instability (McPartland et al. 2016). Thus, jellyfish samples in massive clusters can be helpful to reveal the relation between the RPS-driven star formation activity and their host cluster properties.

In this study, we investigate the relation of star formation rates (SFRs) of jellyfish galaxies with their host cluster velocity dispersion ($\sigma_{v,\rm cl}$) and ram pressure ($P_{\rm ram}$). We compile the Hα-derived star formation rates (SFRs) of jellyfish galaxies in clusters with a wide range of cluster velocity dispersion from 500 km s^{-1} to 1500 km s^{-1}. For the jellyfish sample in massive clusters, we use the Gemini GMOS/IFU data of five jellyfish galaxies represented in Figure 1 (Lee et al. 2022a). These GMOS/IFU observations can provide a great opportunity to understand how strong RPS in massive clusters affect the star formation activity in jellyfish galaxies.

2. Data and Methods

We obtained the GMOS/IFU data of five jellyfish galaxies in the MAssive Cluster Survey (MACS; Ebeling et al. 2001) and Hubble Frontier Fields (HFF; Lotz et al. 2017) clusters at $z > 0.3$ with four Gemini science programs since 2019 March (27.4 hours in total, PI: J. H. Lee). We derived SFRs from the extinction-corrected Hα luminosity adopting the dust extinction laws in Cardelli et al. (1989) and the initial mass function in Chabrier (2003), which are consistent with the methods for SFR estimation in the GASP studies. Along with our GMOS/IFU results, we also collected the Hα-derived SFRs of jellyfish galaxies in the GASP clusters (Gullieuszik et al. 2020), A901/2 multicluster (Roman-Oliveira et al. 2019), and A1758N cluster (Ebeling & Kalita 2019). The MACS and HFF clusters show higher cluster velocity dispersions ($\sigma_{v,\rm cl} \gtrsim 1000$ km s^{-1}) than the GASP clusters ($\langle\sigma_{v,\rm cl}\rangle = 730$ km s^{-1}) and A901/2 ($\langle\sigma_{v,\rm cl}\rangle = 800$ km s^{-1}), implying that the five jellyfish galaxies in this study are subject to stronger RPS than those in low-mass clusters. The ram pressure exerted on individual galaxies ($P_{\rm ram} \sim \rho_{\rm ICM}\Delta v^2$) was calculated using the scaling relation between the cluster velocity dispersion and ICM density, as suggested in Gullieuszik et al. (2020). Lee et al. (2022a) described more detailed information about data and methods.

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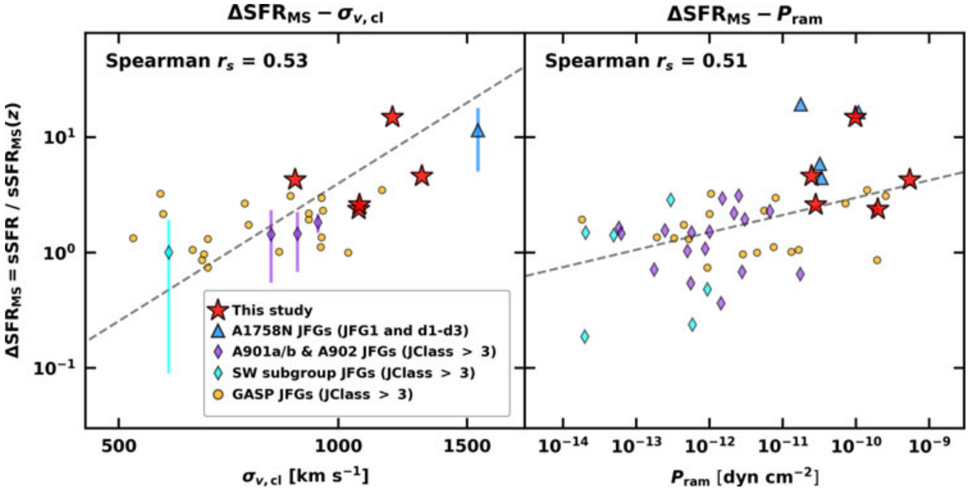

Figure 2. SFR excess to the star formation main sequence (ΔSFR_{MS}) of jellyfish galaxies as functions of host cluster velocity dispersion (left) and ram pressure (right). Gray dashed lines denote the results of linear fitting for the relations.

3. Results and Discussions

Figure 2 illustrates the main results of this study (Lee et al. 2022b). We estimate the SFR excess (ΔSFR_{MS}) relative to the star formation main sequence at the redshift of each host cluster (Speagle et al. 2014) as an indicator of RPS-induced star formation activity in jellyfish galaxies. We plot the SFR excess as functions of host cluster velocity dispersion (*left*) and ram pressure on each galaxy (*right*). We select the jellyfish galaxies with clear RPS signatures, using a visual classification index (JClass > 3) used in Poggianti et al. (2017).

This figure shows that the SFR excess of jellyfish galaxies positively correlates with cluster velocity dispersion and ram pressure. This implies that the star formation activity of jellyfish galaxies is more enhanced as they are in more massive clusters and undergo stronger RPS. In massive clusters, an increase of ram pressure due to dense ICM and cluster dynamics (e.g., cluster collisions or mergers) can lead to efficient gas compression and intense starburst in gas-rich galaxies (Owers et al. 2012; Roediger et al. 2014). Recently, Roberts et al. (2022) also found a positive correlation between host halo mass and SFR excess of ram-pressure-stripped galaxies in the Coma cluster and the SDSS groups/clusters. We suggest that these correlations show the short-term triggering effect of RPS on the star formation activity of jellyfish galaxies. In the future, more IFS studies of jellyfish samples in various environments would be helpful to strengthen the trends between the star formation activity and RPS.

Supplementary material

To view supplementary material for this article, please visit https://doi.org/10.1017/S1743921323000303.

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