Variation of the Mid-infrared versus Hα Luminosity Correlation with Increasing Redshift for Galaxies in the Local Universe

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Abstract

The correlation between mid-infrared (MIR) and Hα luminosity (hereafter referred to as the MIR versus Hα correlation) has been investigated for years, and these approximate linear correlations have been applied to many studies to derive the ongoing star formation rate (SFR) for galaxies near and far. We present and analyze the correlations between rest-frame 12 and 22 μm and Hα luminosities for a large sample of star-forming galaxies with redshift ranging from 0.03 to 0.15 selected in the cross-matched SDSS DR7 and ALLWISE survey. For the galaxies located in a relatively narrow redshift bin (Δz ∼ 0.01), we find that the fitting slope of the MIR versus Hα correlation is always less than 1, and less than the slope derived for all the star-forming galaxies covering a broad redshift range (0.03 < z < 0.15). Additionally, the fitting intercept increases with redshift. We check the influence on the [L[MIR]] versus [L[Ha]] correlation from K- and aperture correction, the variation of either star formation history or morphology, and find their influence is not large enough to account for the inconsistency of the MIR versus Hα correlation individually. We also find that there is possible evolution for the SFR versus M* (stellar mass) correlation within the redshift coverage from 0.03 to 0.15. Finally, we warn that an unwanted error might be brought in if the MIR versus Hα correlation derived from the sample covering a large redshift interval has been applied, and indicate an explicit study is needed to establish an accurate, redshift-independent MIR versus Hα correlation.

Key words: galaxies: starburst – infrared: galaxies – stars: formation

1. Introduction

Mid-infrared (MIR) emissions are crucial for quantifying extragalactic star formation activities. For star-forming galaxies, the majority of the MIR output arises from the dust re-radiation of ultraviolet (UV) photons emitted by young massive stars, whose life-scale is significantly less than that of less massive stars. Alternatively, the MIR continuum is also characterized by some broad emission features (Gillett et al. 1973; Willner et al. 1977), which have been found to be associated with polycyclic aromatic hydrocarbons (PAHs; Léger & Puget 1984; Puget & Léger 1989). The correlations between MIR and other ongoing star formation tracers have been established in past studies (e.g., Calzetti et al. 2005, 2007; Wu et al. 2005; Kennicutt et al. 2007, 2009; Zhu et al. 2008; Wen et al. 2014; Zhu & Wu 2015) after the successful launch of space-based infrared telescopes such as Infrared Space Observatory (Kessler et al. 1996), Spitzer Space Telescope (Werner et al. 2004), and Wide-field Infrared Survey Explorer (WISE; Wright et al. 2010). One of these conventional star formation tracers is Hα luminosity (or other ionized hydrogen emission lines). For star-forming galaxies, the Hα emission originates from H II regions around the young massive stars. Because the extreme-ultraviolet (EUV) photons whose energies of larger than 13.6 eV are required to ionize the surrounding neutral gas, the Hα emission only emerges close to the stars with ages of less than 10 Myr and masses greater than 17 $M_\odot$ (Kennicutt 1998; Kennicutt & Evans 2012; Watson et al. 2016). The tight correlation between MIR versus Hα luminosity (hereafter as MIR versus Hα correlation), which is almost linear, suggests that MIR emission might also be a good tracer of ongoing star formation.

However, even though PAH emission has been adopted to calibrate ongoing star formation rate (SFR; e.g., Roussel et al. 2001; Flores et al. 2004; Wu et al. 2005; Zhu et al. 2008; Wen et al. 2014), a correlation between the emissions of PAHs and cold dust has also been discovered and studied (Haas et al. 2002; Boselli et al. 2004; Bendo et al. 2006, 2008; Lu & Helou 2008; Zhu & Wu 2015). Even for the MIR continuum, some studies (e.g., Calapa et al. 2014; Lu et al. 2014; Jones et al. 2015) have suggested that apart from being related to ongoing star formation, there is still residual MIR emission associated with photodissociation regions or much cooler regions excited by interstellar radiation fields (ISRFs) created by evolved stars. It is worth noting that the existence of MIR emission heated by ISRF would add an extra component to the global MIR output. Unless this extra cold MIR component keeps constant for all the galaxies in a designated sample, the derived slope of the MIR versus Hα correlation should not be linear anymore. But a constant cold MIR component is unrealistic. In fact, the cold MIR component is dominated by the emission associated with low-mass to moderate-mass stars, which means the cold MIR emission is unfixed from galaxy to galaxy. Alternatively, previous investigations have revealed that the MIR versus Hα correlation (or other ionized hydrogen emission lines) is almost linear not only for isolated H II regions in nearby galaxies belonging to SINGS (Spitzer Infrared Nearby Galaxies Survey;...
Kennicutt et al. 2003, but also for the star-forming galaxies with redshift \( z = 0.25 \) (Zhu et al. 2008; Wen et al. 2014).

One of the possible explanations for this contradiction is the existence of evolution for MIR versus H\(_{\alpha}\) correlation. If so, the MIR versus H\(_{\alpha}\) correlation derived based on a large sample of galaxies covering a wide redshift range is actually a joint effect of the intrinsic MIR versus H\(_{\alpha}\) correlation and evolution. In order to explore this supposition and make the result more clearly, we will study the MIR versus H\(_{\alpha}\) correlation for a large sample, particularly in three isolated redshift bins using SDSS (Sloan Digital Sky Survey; York et al. 2000) and WISE data. The structure of the paper is as follows. We describe the construction of our sample and the data reduction in Section 2. The major results on correlation analysis are presented in Section 3. Some discussions and a summary of this work are given in Sections 4 and 5. Throughout this paper, we adopt a LCDM cosmology with \( \Omega_{m} = 0.3, \Omega_{\Lambda} = 0.7, \) and \( H_{0} = 70 \) km s\(^{-1}\) Mpc\(^{-1}\).

2. Sample and Data Reduction

The data used in this work were from the combined WISE and SDSS survey: the WISE data provide IR photometry in four different bands and the SDSS data provide optical spectra, which enables us to derive the intrinsic H\(_{\alpha}\) luminosity to trace ongoing star formation.

First, we downloaded a set of catalogs\(^4\) and merged them together. The data included in these catalogs was processed by Max-Planck-Institute for Astrophysics (MPA) and Johns Hopkins University (JHU). This spectral sample consists of 927,552 sources, and about two-thirds of them belong to the main galaxy sample (Strauss et al. 2002), with \( r\)-band Petrosian magnitudes brighter than 17.77 mag and \( r\)-band Petrosian half-light surface brightnesses brighter than 24.5 mag arcsec\(^{-2}\). In addition to the fluxes of emission lines, some derived parameters were also provided in the MPA-JHU catalogs, such as spectral redshift, stellar mass, gaseous metallicity, etc.

We uploaded the merged SDSS catalog to the IRSA (NASA/IPAC Infrared Science archive) website\(^5\) to cross-match with the ALLWISE Source catalog, which contains accurate positions and four-band photometry whose center wavelength is 3.4 \( \mu\)m (W1), 4.6 \( \mu\)m (W2), 12 \( \mu\)m (W3), and 22 \( \mu\)m (W4), for over 747 million IR objects. The matching radius was 3\(''\), and 902,173 of the SDSS input sources had available WISE photometry (at least one band of photometry has a signal-to-noise ratio (S/N) > 5), corresponding to a completeness of 97.2%. When checking the data, we found that some of the sources have abnormal photometric errors in the W1 band. The left panel of Figure 1 presents a dependence of W1 photometry flux uncertainty (in units of magnitude) on W1 magnitude for all the sources after cross-matching (902,173). The magnitude is from the instrumental profile-fit photometry that will be adopted in this work. Parts of the sources with W1 magnitudes ranging from 13 to 15 have apparent abnormal photometric errors. However, these sources show normal photometric errors in W2 (middle panel of Figure 1), or in the two longer wavelength bands if they were detected there. We have attempted to account for this issue on the IRSA webpage and in the published papers for the WISE survey and data, but have not found any helpful explanations.

Only the diagram of W1 photometric error against R.A., illustrated in the two right panels of Figure 1, seems to provide an answer: the photometry or the calibration in W1 band might have had some problems in special regions. In order to avoid introducing extra errors, we edited our sample by getting rid of the sources with R.A. greater than 235\(\degree\) in the spring sky and sources with R.A. greater than 45\(\degree\) in the fall sky. A total of 123,144 sources were eliminated, and 779,029 sources were remained. Since we adopted the instrumental profile-fit magnitudes to derive the 12 and 22 \( \mu\)m luminosities, a photometric S/N criterion of 5 was applied for high S/N sources in both the W3 and W4 bands.

\(^4\) http://www.mpa-garching.mpg.de/SDSS/DR7/

\(^5\) http://irsa.ipac.caltech.edu/
After doing that, we are left with 78,699 sources, which correspond to 10.1% of the input sample. The significant decrement in the sample size is due to the fact that the sensitivity of $W4$ is far lower than those in the three other bands. Therefore, the photometry in $W4$ is definitely much shallower. The IR spectrum of NGC 3351, which had been included in the sample of SINGS, was adopted to perform K-corrections in the 12 and 22 $\mu$m bands to get the rest-frame $W3(12\mu m)$ and $W4(22\mu m)$ luminosities, represented by $L[W3]$ and $L[W4]$, respectively. An explicit description of the K-correction is in Section 4.1. Hereafter, the luminosity and stellar mass for galaxies are in units of $L_\odot$ and $M_\odot$ (solar luminosity and mass). Furthermore, the broadband luminosity, such as $L[r]$ and $L[W1]$ ($r$ and $W1$ band luminosities), refers to the luminosities multiplied by the corresponding frequency. For instance, the $L[W3]$ is actually $\nu L[W3]$.

2.1. Star-forming Galaxies Selection

The star-forming galaxies are selected on the basis of the optical spectral classifications of galaxies, which were performed by adopting the traditional BPT diagnostic diagram: [N II]/H$\alpha$ versus [O III]/H$\beta$ (Baldwin et al. 1981; Veilleux & Osterbrock 1987). We excluded the aborption line galaxies according to the measured equivalent width of H$\alpha$ line emission (EW[H$\alpha$]) after stellar absorption correction. Alternatively, the galaxies with S/N of EW[H$\alpha$] lower than 5 were also excluded. Then, to be more precise, only the sources whose S/Ns for all four emission lines were greater than 5 were adopted. The red dotted curve in panel (a) of Figure 2 (top left panel) was introduced by Kauffmann et al. (2003c), to distinguish the star-forming galaxies and those whose optical outputs had been contaminated by the emission related to central nuclei. We also plotted a red dashed curve in this panel, which was proposed by Kewley et al. (2001) and usually utilized to select genuine narrow-line active galactic nuclei (AGNs). In this study, no optical-selected narrow-line AGNs or even composite galaxies (Wu et al. 1998; Kewley et al. 2006) were included, even though their output from the optical to the IR might be dominated by ongoing star-formation as well. Hence, only star-forming galaxies were adopted for the following study, with a total of 34,798 candidates. The redshift distribution for these star-forming galaxies is demonstrated in panel (b) of Figure 2 (top right panel). Since we will use the difference between the $r$-band model and fiber magnitude to perform the fiber coverage correction, we set a lower redshift limit of 0.03 (represented by the red vertical lines in panel (b) of Figure 2). At redshift 0.03, $1''$ is ~0.6 kpc. Hence, the smallest coverage by the 3$''$ SDSS fiber is an aperture with a diameter of about 1.8 kpc. After doing that, 1969 nearby galaxies were excluded, and the amount of star-forming galaxies in the sample decreases to 32,829. In order to obtain the rest-frame $r$-band model magnitude, the K-correction was conducted with the help of the code supplied by Blanton (version tag v4_1_4). The method and the spectral energy distributions (SEDs) used by this code are described by Blanton et al. (2003) and Blanton & Roweis (2007). Additionally, we also obtained the rest-frame luminosity in the $W1$ band, derived from the linear interpolation between the...
obse...ed $W1$ and $W2$ fluxes. The rest-frame $W1$ luminosity indicates star contents that are much cooler than those dominating the host’s output in the rest-frame $r$-band. Panels (c) and (d) of Figure 2 present the variation of the rest-frame $r$ and $W1$ band luminosities with redshift. The ranges of these two luminosities are dependent on increasing redshift. In Section 4.3 we discuss the influence from this bias on the main conclusions derived in this work.

2.2. $H\alpha$ Luminosity

The optical $H\alpha$ emission lines suffer dust extinctions from both the Milky Way and the host galaxy. Because all the line fluxes provided in MPA-JHU catalogs were corrected for foreground (Galactic) reddening, we only needed to correct the intrinsic extinction for the galaxies in our sample. The intrinsic extinction correction was performed based on the color excess $E(B - V)$, which was acquired from the Balmer decrement $F_{H\alpha}/F_{H\beta}$ (Calzetti 2001).

Alternatively, the optical spectra of SDSS were taken with $3''$ diameter fibers, thus the measured $H\alpha$ emission fluxes only originated from the central regions, which means a corresponding aperture correction is needed. Conventionally, the method provided by Hopkins et al. (2003, hereafter H03; see their Equation (A2)) was adopted to obtain the $H\alpha$ luminosity for a whole galaxy:

$$L[H\alpha] = 4\pi D_L^2 S_{H\alpha} 10^{-0.4(r_{\text{model}} - r_{\text{fiber}})}.$$

Here, $D_L$ is the luminosity distance, $S_{H\alpha}$ is the flux of $H\alpha$ emission, and $r_{\text{model}}$ and $r_{\text{fiber}}$ are the $r$-band model and fiber magnitudes, respectively.

This aperture correction approach relies on an assumption: the distribution of the $H\alpha$ emission is the same as the distribution of the continuum; alternatively, for the intrinsic extinction correction, we also assumed that the extinction level covered by the SDSS fiber is universal for the whole galaxy. With the help of the Calar Alto Legacy Integral Field Area (CALIFA) survey, Duarte Puertas et al. (2017; hereafter DP17) estimated the $H\alpha$ emission after aperture and extinction correction for more than 200,000 SDSS star-forming galaxies. The CALIFA is an integral field spectrographs (IFS) survey for more than 600 nearby galaxies. The CALIFA observations were employed by DP17 to establish a growth curve, the variation of emission line flux as the fiber coverage increases, which made it possible to perform accurate aperture and extinction correction for SDSS galaxies empirically. Panel (a) of Figure 3 (left) shows the comparison between $L[H\alpha]$ ($H\alpha$ luminosity after aperture and extinction correction) estimated with H03 method ($L[H\alpha](H03)$) and derived by DP17 ($L[H\alpha](DP17)$). Panel (b) of Figure 3 (right) presents the variation of the luminosity ratio $L[H\alpha](H03)/L[H\alpha](DP17)$ with $L[H\alpha](H03)$. The red solid lines in both panels represent the mean value (1.128) of the $L(H\alpha)$ ratio, and the red dashed lines on either side of the solid lines represent the 50% offsets ($L[H\alpha](H03)/L[H\alpha](DP17) = 1.5$ or 0.666). To some extent, the $L[H\alpha]$ derived from these two different approaches can match each other roughly for most of the star-forming galaxies except some outliers; and the $L[H\alpha]$ ratio does not show apparent variation as the $L[H\alpha](H03)$ increases. We excluded the sources outside the 50% offsets, which led the amount of the star-forming galaxies to 32,235, which is referred to as the final sample.

2.3. Redshift Slices

The redshift of the star-forming galaxies in our sample ranges from 0.03 to 0.15, covering a comoving radial distance of 500 Mpc, corresponding to a timescale of ~1.5 Gyr, or approximate one-ninth of the age of universe. It is reasonable to suspect that the evolution will disturb the calibration for the MIR versus $H\alpha$ correlation. Alternatively, for galaxies with identical intrinsic size, the distinction between distances indicates different aperture corrections, and the correction decreases with increasing redshift. Panel (a) of Figure 4 shows the difference in dependence on spectral redshift between the $r$-band model and fiber magnitudes. All the star-forming galaxies belonging to the final sample are presented as gray dots, and the black contours indicate their distributions.

In order to make the MIR versus $H\alpha$ correlation more clear and explicit in the following section, we focused on the star-forming galaxies inside three discrete redshift bins: 0.04 < $z$ < 0.05 (blue), 0.09 < $z$ < 0.10 (green), 0.14 < $z$ < 0.15 (red), each with a thickness of ~40 Mpc. The adoption of this bin size ($\Delta z \sim 0.1$) is not physical. We only intend for the redshift coverage in each bin to be narrow and contain enough sources for our study. Alternatively, we hope the expression of the bin size is as simple as possible. The comoving radial distance is almost 125 Mpc and 620 Mpc at $z = 0.03$ and 0.15, respectively. Thus, the percentage for each bin is ~8% when considering a 40 Mpc bin size and 500 Mpc coverage for all the galaxies in the final sample. There are 2712, 2396, and 957 star-forming galaxies in each redshift bin, as shown in Figure 4. Panel (a) of Figure 4 presents the galaxies inside these three bins using blue, green, and red color schemes.

Figure 3. Panel (a) shows the comparison between $L[H\alpha](H03)$ and $L[H\alpha](DP17)$. Panel (b) presents the variation of the luminosity ratio with $L[H\alpha](H03)$. The red solid lines in both panels represent the mean value (1.128) of the $L(H\alpha)$ ratio; the red dashed lines on either side of the solid lines represent the 50% offset ($L[H\alpha](H03)/L[H\alpha](DP17) = 1.5$ or 0.666).
respectively. In the other panels of Figure 4, we plotted the distributions of $L[\text{H}\alpha]$ (panel b), $L[\text{W}3]$ (panel c), $L[\text{W}4]$ (panel d). We will discuss the possible selection bias in Section 4.3.

### 3. Result: $L[\text{H}\alpha]$ versus $L$(MIR)

Figure 5 shows the correlations between rest-frame $W3$ ($12 \mu m$) and $W4$ ($22 \mu m$) luminosities and three different $H\alpha$ luminosities: $L[\text{H}\alpha]$ ($\text{H}03$) refers to the $\text{H}\alpha$ luminosity after the intrinsic extinction and aperture correction, where the aperture correction has been conducted using the approach proposed by Hopkins et al. (2003); $L[\text{H}\alpha]$ ($\text{DP17}$) refers to the $\text{H}\alpha$ luminosity after the intrinsic extinction and aperture correction provided by Duarte Puertas et al. (2017); $L[\text{H}\alpha]$ ($\text{H03}$) refers to the absorbed $\text{H}\alpha$ luminosity after the aperture correction using the approach by Hopkins et al. (2003); and the subscript “abs” indicates this $\text{H}\alpha$ luminosity is actually the difference between $L[\text{H}\alpha]$ ($\text{H03}$) and $\text{H}03$ luminosity performing intrinsic extinction correction. The gray dots represent all the star-forming galaxies in the final sample, and three colored contours donate the distributions for the galaxies belonging to the three redshift bin: $0.04 < z < 0.05$ (blue), $0.09 < z < 0.10$ (green), $0.14 < z < 0.15$ (red). Using the linear regression, we obtain the best nonlinear fits for the galaxies in the final sample (the gray solid line in each panel of Figure 5) and in each redshift bin. We adopt the IDL function, called robust_linefit, pro to carry out the linear regression. The purpose of this code is to do outlier-resistant two-variable linear regression. As a bisector fitting, the bisector of the “$Y$ versus $X$” is first determined. Then the distance perpendicular to this bisecting line is used in calculating weights, which is better when the uncertainties in $X$ and $Y$ are comparable. The fitting parameters are listed in Table 1. In order to be more clear, we also label the slope and intercept for each fitting in every panel of Figure 5 as $y = a(x) + b$, with corresponding color. The black solid lines in panels (a1), (a2), (b1), and (b2) represent the correlations derived by Wen et al. (2014): $y = 1.061x + 0.670$ for $W3$; $y = 1.088x + 0.524$ for $W4$.

From Figure 5, we see that the linear regression for the final sample is very close to the corresponding fitting result proposed by Wen et al. (2014). But the sample size is different, particularly for $W3$, since no extra limitation, such as the S/N of $W4$, was considered in Wen et al. (2014). Much more galaxies were employed to conduct the linear regression in Wen et al. (2014) than in this study.

In addition, there are two main results that can be seen in Figure 5. First, either in Wen et al. (2014) or for the final sample in this study, the derived slopes of linear regression are close to or greater than 1. But for the linear regression for the galaxies in the three redshift bins, the fitted slopes are always less than 1.

The second main result is that the intercepts derived for the galaxies in the three redshift bins are always larger than those...
derived by Wen et al. (2014) or for all the galaxies in the final sample. Moreover, intercept value increases with redshift. This tendency is hard to observe in regression results, because of the diversity of the fitting slope, which makes an accurate comparison almost unfeasible. In order to make it more clear, we calculate the intercept by fixing the slope at 1 (value c in Table 1). When the sample’s redshift has been restricted to some special discrete intervals, the increasing value of c looks like stairs climbed step-by-step. Actually, this second main result can be treated as the reason for the first main result, because the increasing of the fitting intercept with redshift will result in a much steeper slope for the whole sample. The intercept is actually the logarithmic mean value of the MIR-to-Hα ratio. Figure 6 shows the MIR-to-Hα ratio as a function of $L[H\alpha]$. The horizontal gray line in each panel is the mean value of the ratio for all the star-forming galaxies (gray dots) in the final sample. We see that these derived ratios increase from lower-redshift bins to higher-redshift bins gradually for a designated $L[H\alpha]$, particularly when $L[W4]$ is involved.

As we know, the $L(H\alpha)$ versus $L(MIR)$ correlation has come into wide use, especially for estimating current SFR with measured MIR luminosity. However, our study seems to show that the fitting result from the galaxy sample covering a large redshift range is actually inappropriate as a standard. Before presenting an affirmative conclusion, we should confirm that these main results that we have obtained are galaxies’ intrinsic properties.

4. Analysis and Discussion

It is indispensable to uncover the reasons for the inconsistency of the $L(H\alpha)$ versus $L(MIR)$ correlation. As we demonstrated in Section 2, the MIR luminosities have been corrected for their non-zero redshift, and the Hα luminosities have been corrected for the coverage by SDSS fibers and extinction. Hence, the influence from these corrections should be checked first.

4.1. The Effect from K-correction

The K-correction for luminosities in the W3 and W4 bands in this work is performed by utilizing the IRS spectrum of NGC 3351. NGC 3351 belongs to SINGS, which is a multiband survey for 75 galaxies in the local universe with distances of less than 25 Mpc. NGC 3351 is a spiral galaxy with a distance of 9.3 Mpc and $M_K$ of $-20.4$ (Kennicutt et al. 2003). The nuclear type of this galaxy was classified as a starburst (SB) by Kennicutt et al. (2003). Nevertheless, not all the galaxies in our final sample have MIR properties similar to NGC 3351, especially the less massive ones. In order to evaluate the influence from K-correction on the MIR versus Hα correlation, with the help of transmission curves provided by Wright et al. (2010) we estimate the ratio between the integrated fluxes for all the SINGS galaxies whose nuclear types are classified as H II or SB: the numerator is the observed flux increasing with redshift at a designated wavelength and the denominator is the rest-frame flux. The included galaxies are as follows: NGC 0925, NGC 1377, NGC 1512, NGC 1705, NGC 2403, NGC 2798, NGC 2915, NGC 2976, NGC 3049, NGC 3184, NGC 4536, NGC 4559, NGC 6946, NGC 7793, IC 4710, Mrk33, and NGC 3351. These H II/SB galaxies all have available IRS low-resolution spectra. There are high and low observation modes for IRS, with spectral resolutions of R600 and R50–100, respectively. For high-resolution spectroscopy,
Figure 6. Variation of MIR-to-H$\alpha$ ratio as a function of increasing $L[\text{H} \alpha]$. The gray dots represent all the star-forming galaxies, and the mean value of their MIR-to-H$\alpha$ ratio is represented by a horizontal gray line in each panel. The three colored contours are the distributions for the galaxies belonging to the three redshift bins, as in Figure 5.

Table 1

| $y$ | $x$ | Sample | $a$ | $b$ | $s$ | $c$ | $r$ |
|-----|-----|--------|-----|-----|-----|-----|-----|
| $L[\text{W3}]$ | $L[\text{H} \alpha(\text{H03})]$ | FS | 0.779 ± 0.008 | 1.057 ± 0.003 | 0.134 | 1.254 ± 0.149 | 0.894 |
| $L[\text{W3}]$ | $L[\text{H} \alpha(\text{H03})]$ | z1 | 1.675 ± 0.035 | 0.939 ± 0.012 | 0.149 | 1.188 ± 0.175 | 0.728 |
| $L[\text{W3}]$ | $L[\text{H} \alpha(\text{H03})]$ | z2 | 2.086 ± 0.036 | 0.907 ± 0.012 | 0.107 | 1.298 ± 0.128 | 0.740 |
| $L[\text{W3}]$ | $L[\text{H} \alpha(\text{H03})]$ | z3 | 2.058 ± 0.061 | 0.915 ± 0.021 | 0.103 | 1.310 ± 0.123 | 0.730 |
| $L[\text{W4}]$ | $L[\text{H} \alpha(\text{H03})]$ | FS | 0.688 ± 0.008 | 1.083 ± 0.003 | 0.133 | 1.385 ± 0.147 | 0.899 |
| $L[\text{W4}]$ | $L[\text{H} \alpha(\text{H03})]$ | z1 | 2.023 ± 0.030 | 0.909 ± 0.011 | 0.128 | 1.304 ± 0.152 | 0.783 |
| $L[\text{W4}]$ | $L[\text{H} \alpha(\text{H03})]$ | z2 | 2.296 ± 0.036 | 0.896 ± 0.012 | 0.107 | 1.425 ± 0.130 | 0.724 |
| $L[\text{W4}]$ | $L[\text{H} \alpha(\text{H03})]$ | z3 | 2.678 ± 0.063 | 0.862 ± 0.021 | 0.107 | 1.471 ± 0.132 | 0.665 |
| $L[\text{W3}]$ | $L[\text{H} \alpha(\text{DP17})]$ | FS | 0.870 ± 0.007 | 1.042 ± 0.003 | 0.133 | 1.216 ± 0.148 | 0.895 |
| $L[\text{W3}]$ | $L[\text{H} \alpha(\text{DP17})]$ | z1 | 2.017 ± 0.033 | 0.892 ± 0.012 | 0.147 | 1.146 ± 0.179 | 0.743 |
| $L[\text{W3}]$ | $L[\text{H} \alpha(\text{DP17})]$ | z2 | 2.319 ± 0.033 | 0.876 ± 0.011 | 0.102 | 1.261 ± 0.126 | 0.765 |
| $L[\text{W3}]$ | $L[\text{H} \alpha(\text{DP17})]$ | z3 | 2.186 ± 0.057 | 0.897 ± 0.019 | 0.098 | 1.277 ± 0.120 | 0.756 |
| $L[\text{W4}]$ | $L[\text{H} \alpha(\text{DP17})]$ | FS | 0.792 ± 0.008 | 1.066 ± 0.003 | 0.138 | 1.347 ± 0.153 | 0.890 |
| $L[\text{W4}]$ | $L[\text{H} \alpha(\text{DP17})]$ | z1 | 2.375 ± 0.029 | 0.861 ± 0.010 | 0.129 | 1.262 ± 0.160 | 0.780 |
| $L[\text{W4}]$ | $L[\text{H} \alpha(\text{DP17})]$ | z2 | 2.541 ± 0.035 | 0.863 ± 0.012 | 0.108 | 1.388 ± 0.135 | 0.726 |
| $L[\text{W4}]$ | $L[\text{H} \alpha(\text{DP17})]$ | z3 | 2.843 ± 0.064 | 0.840 ± 0.021 | 0.110 | 1.438 ± 0.139 | 0.648 |
| $L[\text{W3}]$ | $L[\text{H} \alpha(\text{H03} \text{abs})]$ | FS | 2.215 ± 0.006 | 0.914 ± 0.002 | 0.134 | 1.518 ± 0.162 | 0.893 |
| $L[\text{W3}]$ | $L[\text{H} \alpha(\text{H03} \text{abs})]$ | z1 | 3.483 ± 0.025 | 0.740 ± 0.009 | 0.139 | 1.494 ± 0.201 | 0.785 |
| $L[\text{W3}]$ | $L[\text{H} \alpha(\text{H03} \text{abs})]$ | z2 | 3.780 ± 0.026 | 0.727 ± 0.009 | 0.098 | 1.552 ± 0.146 | 0.788 |
| $L[\text{W3}]$ | $L[\text{H} \alpha(\text{H03} \text{abs})]$ | z3 | 3.982 ± 0.041 | 0.715 ± 0.014 | 0.091 | 1.560 ± 0.140 | 0.774 |
| $L[\text{W4}]$ | $L[\text{H} \alpha(\text{H03} \text{abs})]$ | FS | 2.201 ± 0.008 | 0.931 ± 0.003 | 0.158 | 1.650 ± 0.189 | 0.855 |
| $L[\text{W4}]$ | $L[\text{H} \alpha(\text{H03} \text{abs})]$ | z1 | 3.785 ± 0.025 | 0.715 ± 0.009 | 0.139 | 1.610 ± 0.209 | 0.760 |
| $L[\text{W4}]$ | $L[\text{H} \alpha(\text{H03} \text{abs})]$ | z2 | 3.988 ± 0.031 | 0.717 ± 0.011 | 0.117 | 1.679 ± 0.176 | 0.674 |
| $L[\text{W4}]$ | $L[\text{H} \alpha(\text{H03} \text{abs})]$ | z3 | 4.477 ± 0.056 | 0.675 ± 0.019 | 0.126 | 1.721 ± 0.193 | 0.556 |

Note. Column (1): names of MIR luminosities. Column (2): names of H$\alpha$ luminosities. $L[\text{H} \alpha(\text{H03})]$ and $L[\text{H} \alpha(\text{DP17})]$ represent the H$\alpha$ luminosity estimated with the approach provided by Hopkins et al. (2003) and Duarte Paetras et al. (2017), respectively, the $L[\text{H} \alpha(\text{H03} \text{abs})]$ is the absorbed H$\alpha$ luminosity, the aperture correction is conducted with the approach provided by Hopkins et al. (2003). Column (3): sample used for correlation analysis. “FS” represents the final sample covering redshifts from 0.03 to 0.15; “z1,” “z2,” and “z3” represent three redshift bins: 0.04 < z < 0.05, 0.09 < z < 0.10, 0.14 < z < 0.15. Columns (4)–(5): the coefficients $a$ and $b$ of the linear regression: $\log_{10}(y) = a + b \log_{10}(x)$. Column (6): the standard deviation $s$ of the fitting residuals. Column (7): the intercept $c$ of the fitting when the slope has been fixed to 1: $\log_{10}(y) = c + \log_{10}(x)$. Column (8): the coefficient $r$ of the Spearman Rank-order correlation analysis.

The wavelength coverage is 10–19 $\mu$m (short-high is shortened as SH) and 19–37 $\mu$m (long-high: LH). For low-resolution spectroscopy, the wavelength coverage is 5–14 $\mu$m (short-low: SL) and 14–38 $\mu$m (long-low: LL). Since the wavelength coverage of WISE W3 filter starts from ~7.5 $\mu$m, which is shorter than the blue boundary of the high-resolution
spectroscopy, for these H II/SB galaxies, we adopt their low-resolution IRS spectroscopy as the templates. In practice, we first downloaded the needed low-resolution spectra from the IRS A website, then matched the SL and LL spectra for each H II/SB galaxy. The coincident range between SL and LL spectra is from 14.2666 to 14.7366 μm, which was used to derive a shifting coefficient for matching.

Figure 7 (left for W3; right for W4) shows the dependences of the flux ratios on increasing redshift for each H II/SB galaxy. The green line in each panel represents NGC 3351. The red and blue lines represent the galaxy with the highest or lowest flux ratio: NGC 0925 (red) and IC 4710 (blue) on the left; NGC 2403 (red) and IC 1377 (blue) on the right.

4.2. The Effect from Aperture Correction

As we have pointed out above, the optical spectra of SDSS were taken with 3'' diameter fibers, which led to only information from the central parts of the nearby galaxies being obtained with SDSS spectra. Hopkins et al. (2003) proposed multiplying a coefficient, the difference between the r-band model and fiber magnitudes, to undertake the aperture correction. In fact, this method is on the basis of the assumption that the distribution of the Hα emission is identical in the distribution of the r-band continuum, which is dominated by stellar content. In addition, the intrinsic extinction is also derived using the SDSS spectra, which enables us to bring in another assumption: the magnitude of extinction in the region enclosed by the SDSS fiber is the same as the extinction for the whole galaxy. Although the IFU spectra from the CALIFA survey were utilized by DP17 to assist with undertaking aperture correction, the principle assumption is still unchanged.

In terms of current data, there is a shortage of absolute tracers to calibrate ongoing star formation. This deficiency makes it almost impossible to conduct systematic investigations to evaluate the effect of aperture correction on the inconsistency of MIR versus Hα correlation. Therefore, in this work we have to adopt the galaxies located in some narrow MIR luminosity bins to compare L[Hα(H03)] at different redshifts. Due to the variation of the luminosity coverage, there is almost no matching between the redshift bins 1 (z: 0.04 0.15) and 3 (z: 0.14 0.15) in both L[W3] and L[W4] (see Figure 4). Therefore, redshift bin 2 (z: 0.09 0.10) is utilized as an intermediary to compare with bins 1 and 3. For both L[W3] and L[W4], we define some special luminosity bins, and the selection of luminosity bins is on the basis of the coincidence of L[W3] or L[W4] for neighboring redshift bins. The comparisons are illustrated in Figure 8 (L[W3] bins) and Figure 9 (L[W4] bins), and blue, green and red represent galaxies belonging to redshift bins 1, 2, and 3. The two black decimals in the to-left corner in each panel provide the range for L[W3] or L[W4] in logarithm, and the width of the luminosity bin is always 0.1 in logarithm; the two colored integers represent the sample sizes, and the two decimals represent the median value for corresponding distributions. We should take the note that the distributions in Figures 8 and 9 have been normalized with 100 as the peak.

For most of the star-forming galaxies in the nearby universe, the distribution of their H II regions in disks is not as extended as the stars traced by the optical continuum, such as r-band luminosity. From panel (a) of Figure 4, it is easy to see that the degree of the aperture correction decreases with redshift. Hence, for the galaxies with identical intrinsic size, if there is an overestimation for aperture correction, it will be more severe for the low-redshift ones. Provided the intercept distinction shown in Section 3 is due to aperture correction, it is reasonable to anticipate that the L[Hα(H03)] for lower-redshift galaxies would be greater than that for higher-redshift ones. However, as shown in Figures 8 and 9, not all of the lower-redshift samples have relatively greater L[Hα(H03)]. As illustrated in Figure 8, only the distributions in panels (b2), (a3), and (b3) follow the exception: greater L[Hα(H03)] for lower redshift. In panels (a1), (b1), and (a2), the higher-redshift samples have greater L[Hα(H03)], which is the opposite of our previous exception. For galaxies with similar L[W4] (Figure 9), only the comparisons shown in the upper three panels (between redshift bins 1 and 2) follow the trend as expected; but for the samples of redshifts bin 2 and 3 (three lower panels), the higher-redshift samples always have larger L[Hα(H03)].

Unfortunately, current data do not enable us to quantify the effects from aperture correction. In order to solve this problem, extra studies with Hα imaging or IFU observations are required and are scheduled for the future. However, at least the inconsistencies of the MIR versus Hα correlation can be explained using more than inaccurate aperture correction estimates.

4.3. Intrinsic Distinction

The analysis above indicates that the inaccuracy or error from the K- and aperture corrections cannot solely account for the results we have obtained. Therefore, some intrinsic properties, such as the star formation history and morphology, should be considered account for the inconsistency of the L(Hα) versus L(MIR) correlation.
Figure 8. Distributions (normalized with 100 as the peak) of $L([\text{H} \alpha])$ for star-forming galaxies in a special $L([W4])$ bin, selected from three redshift bins: $0.04 < z < 0.05$ (blue filled), $0.09 < z < 0.10$ (green with diagonal lines), $0.14 < z < 0.15$ (red blank). The two black numbers in each panel present the ranges of the $L([W3])$ in logarithm. Below the black numbers are two integers to represent the sample sizes for the distributions with the same colors, and two decimals to represent the median value for the corresponding distributions.

### Table 2

| $y$ | $x$ | Sample | $a$ | $b$ | $s$ | $c$ | $r$ | Keel |
|-----|-----|--------|-----|-----|-----|-----|-----|------|
| $L([W3])$ | $L([\text{H} \alpha(H03)])$ | FS | $0.132 \pm 0.008$ | $1.140 \pm 0.003$ | $0.145$ | $1.295 \pm 0.161$ | $0.894$ | IC 4710 |
| $L([W3])$ | $L([\text{H} \alpha(H03)])$ | $z1$ | $1.676 \pm 0.035$ | $0.939 \pm 0.012$ | $0.149$ | $1.189 \pm 0.175$ | $0.728$ | IC 4710 |
| $L([W3])$ | $L([\text{H} \alpha(H03)])$ | $z2$ | $2.158 \pm 0.036$ | $0.906 \pm 0.012$ | $0.107$ | $1.360 \pm 0.129$ | $0.740$ | IC 4710 |
| $L([W3])$ | $L([\text{H} \alpha(H03)])$ | $z3$ | $2.169 \pm 0.061$ | $0.914 \pm 0.021$ | $0.103$ | $1.408 \pm 0.124$ | $0.729$ | IC 4710 |
| $L([W3])$ | $L([\text{H} \alpha(H03)])$ | FS | $0.938 \pm 0.007$ | $1.034 \pm 0.003$ | $0.131$ | $1.218 \pm 0.147$ | $0.894$ | NGC 0925 |
| $L([W3])$ | $L([\text{H} \alpha(H03)])$ | $z1$ | $1.649 \pm 0.035$ | $0.940 \pm 0.012$ | $0.149$ | $1.166 \pm 0.175$ | $0.728$ | NGC 0925 |
| $L([W3])$ | $L([\text{H} \alpha(H03)])$ | $z2$ | $2.043 \pm 0.036$ | $0.908 \pm 0.012$ | $0.107$ | $1.262 \pm 0.128$ | $0.741$ | NGC 0925 |
| $L([W3])$ | $L([\text{H} \alpha(H03)])$ | $z3$ | $1.996 \pm 0.061$ | $0.916 \pm 0.021$ | $0.103$ | $1.257 \pm 0.123$ | $0.730$ | NGC 0925 |
| $L([W4])$ | $L([\text{H} \alpha(H03)])$ | FS | $0.193 \pm 0.008$ | $1.152 \pm 0.003$ | $0.142$ | $1.460 \pm 0.158$ | $0.898$ | NGC 1377 |
| $L([W4])$ | $L([\text{H} \alpha(H03)])$ | $z1$ | $2.054 \pm 0.030$ | $0.909 \pm 0.011$ | $0.128$ | $1.335 \pm 0.152$ | $0.783$ | NGC 1377 |
| $L([W4])$ | $L([\text{H} \alpha(H03)])$ | $z2$ | $2.381 \pm 0.036$ | $0.896 \pm 0.012$ | $0.107$ | $1.509 \pm 0.130$ | $0.724$ | NGC 1377 |
| $L([W4])$ | $L([\text{H} \alpha(H03)])$ | $z3$ | $2.798 \pm 0.063$ | $0.862 \pm 0.021$ | $0.107$ | $1.590 \pm 0.132$ | $0.665$ | NGC 1377 |
| $L([W4])$ | $L([\text{H} \alpha(H03)])$ | FS | $1.273 \pm 0.007$ | $1.006 \pm 0.002$ | $0.123$ | $1.329 \pm 0.139$ | $0.899$ | NGC 2403 |
| $L([W4])$ | $L([\text{H} \alpha(H03)])$ | $z1$ | $2.010 \pm 0.030$ | $0.909 \pm 0.011$ | $0.128$ | $1.291 \pm 0.152$ | $0.783$ | NGC 2403 |
| $L([W4])$ | $L([\text{H} \alpha(H03)])$ | $z2$ | $2.237 \pm 0.036$ | $0.896 \pm 0.012$ | $0.107$ | $1.366 \pm 0.130$ | $0.724$ | NGC 2403 |
| $L([W4])$ | $L([\text{H} \alpha(H03)])$ | $z3$ | $2.568 \pm 0.063$ | $0.862 \pm 0.021$ | $0.107$ | $1.360 \pm 0.132$ | $0.665$ | NGC 2403 |

**Note.** The definitions of columns (1)–(8) are the same as those in Table 1. Column (9): the SINGS galaxy whose IR SED is utilized as a template for performing $K$-correction.

Figure 10 presents the distributions of $r$-band absolute magnitude $(M_r)$, stellar mass $(M^*)$, luminosity-to-stellar mass ratio at rest-frame 22 µm $(L([W4])/M^*)$, rest-frame $g$–$r$ color, and observed R90/R50 ($g$ and $r$ bands) for the star-forming galaxies in the three redshift bins. The distributions have also been normalized with 100 as the peak, using blue, green, and red to represent the galaxies belonging to redshift bins 1, 2, and 3, respectively. The decimals in each panel show the median values for the corresponding distribution, just as in Figures 8 and 9. $M_r$ is estimated from the model photometry, and the approach for carrying out $K$-correction has been provided by Blanton et al. (2003) and Blanton & Roweis (2007). $M^*$ is provided by MPA-JHU, which estimated the stellar mass by SED fitting for all the star-forming galaxies belonging to SDSS DR7. We adopt $L([W4])/M^*$ as the tracer of specific star formation rate (SSFR), by assuming $L([W4])$ is dominated by ongoing star formation. $D_4(4000)$ (the 4000 Å break strength) is employed to represent star formation history. The break at rest-frame 4000 Å is the strongest discontinuity in the optical spectrum of a galaxy, owing to the accumulation of a large number of spectral lines in a narrow wavelength region (Balogh et al. 1999). Alternatively, one of the advantages of $D_4(4000)$ is that it is insensitive to dust extinction. The correlation between star formation history and $D_4(4000)$ was established by Kauffmann et al. (2003a, 2003b): galaxies dominated by older stellar populations have greater $D_4(4000)$ than those dominated...
by younger stellar populations; and $D_n(4000) = 1.4$ is generally adopted to distinguish early- ($>1.4$) and late- ($<1.4$) type galaxies. R90 (R50) is the radius containing 90% (50%) flux in g-band or r-band petrosian photometry. The ratio of R90-to-R50 (R90/R50) is generally referred to as the concentration index, and serves as an indicator of the morphology. Strateva et al. (2001) proposed R90/R50 = 2.6 (r-band) as the boundary to distinguish early- ($>2.6$) and late-type ($<2.6$) type galaxies. However, it should be noted that the R90/R50 used here is not rest-frame, since we could not derive the rest-frame r-band R90/R50. The central wavelength of the SDSS r-band varies from approximately 5700 to 5200 Å when the redshift increases from 0.05 to 0.15, and the corresponding wavelength in the g-band is 4460 to 4075 Å.

Figure 10 shows that the galaxies in the higher-redshift bins tend to be luminous and hold more stellar contents. Combining the distributions illustrated in Figure 2, it is evident that there is a selection bias: more luminous and more massive galaxies are easy to detect as redshift increases. In addition, Figure 10 also shows that the galaxies in the higher-redshift bins have smaller R90/R50 in both the g and r bands. A smaller R90/R50 indicates more late-type morphology for disk galaxies. However, there is no significant difference in the distribution of $D_n(4000)$, which seems to indicate a homogeneity in the star formation history. One of the reasons for the conflict demonstrated by R90/R50 and $D_n(4000)$ is the different covering regions for galaxies: $D_n(4000)$ is derived from the SDSS spectrum, which suggests only the region covered by the 3" fiber has a contribution to $D_n(4000)$; while an advantage for R90/R50 is that it is not limited to the aperture covered by SDSS fibers. Thus, the conflict is probably from the difference in stellar population. Alternatively, another probable explanation is that $D_n(4000)$ is more sensitive to the existence of an old stellar population, while R90/R50 is more sensitive to the
morphology, and the existence and fraction of a stellar bulge (Kauffmann et al. 2003a, 2003b). However, a more delicate investigation is needed to remove this degeneracy. Then, just like in Section 4.2, we compare the galaxies with similar $L_{W3}$ and $L_{W4}$ in Figures 11 and 12, respectively. We only use the MIR bins of $9.5 < \log L_{W3} < 9.6$ (redshift bin 1 (blue) and 2 (green)) or $10.0 < \log L_{W3} < 10.1$ (redshift bin 2 (green) and 3 (red)) for comparison. The decimals in each panel show the median values for the corresponding distribution with the same color.

Figure 11. From left to right: normalized distribution of $M_r$, $M^*$, $L_{W3}/M^*$, $D_n(4000)$ and $R90/R50$ ($r$ band) for star-forming galaxies in a special $L_{W3}$ bin (upper panels: $9.5 < \log L_{W3} < 9.6$; lower panels: $10.0 < \log L_{W3} < 10.1$), selected from three redshift bins: $0.04 < z < 0.05$ (blue filled), $0.09 < z < 0.10$ (green with diagonal lines), $0.14 < z < 0.15$ (red blank). The decimals in each panel show the median values for the corresponding distribution with the same color.

Figure 12. Same as Figure 11, but for the distributions for star-forming galaxies in a special $L_{W4}$ bin (upper panels: $9.5 < \log L_{W4} < 9.6$; lower panels: $10.0 < \log L_{W4} < 10.1$).

For nearby star-forming galaxies, the MIR continuum and the PAH features consist of two distinct components connected to both the hot and cold dust emission. The hot dust emission is heated by young massive stars, and is correlated with ongoing star formation. The cool dust is generally considered to be heated by relatively weak radiation field, such as that created by medium-sized stars, and this it is correlated with $M^*$ (stellar mass).

There is a tight correlation between SFR versus $M^*$ for star-forming galaxies; this is called the main sequence. The galaxies...
located in the main sequence are generally called main-sequence galaxies (Noeske et al. 2007). The SFR versus $M^*$ correlation has been argued to evolve with redshift: a higher SFR-to-$M^*$ ratio (SSFR) would be expected when redshift increases (Elbaz et al. 2007; Noeske et al. 2007; Whitaker et al. 2014). After the launch of the Herschel Space Observatory (Pilbratt et al. 2010), more investigations have verified this tendency again and put the redshift frontier at $z = 2 \sim 4$ (Elbaz et al. 2011; Burgarella et al. 2013). However, these previous investigations generally used observations covering a significant redshift range. For instance, the redshift in Whitaker et al. (2012) spanned as far as $z = 2.5$, and the redshift bin was 0.5. Therefore, in these studies, the galaxies selected from SDSS have often been categorized as a homogeneous, non-evolving sample. However, even though there is a upper limit ($z \sim 0.2$) for the galaxies in the SDSS main galaxy sample, this sample still covers a wide distance range. According to the cosmology adopted in this work with $\Omega_m = 0.3$, $\Omega_b = 0.7$, and $H_0 = 70$ km s$^{-1}$ Mpc$^{-1}$, the age of the universe is 13.46 Gyr. Considering the redshift of the farthest sources in the main galaxy sample is approximately 0.2, the lookback time is 2.43 Gyr, or 18% of the age of the universe. The upper boundaries of the three redshift bins in this work are 0.05, 0.10, 0.15 respectively, indicating lookback times of 0.67, 1.30, 1.89 Gyr, or a percentage of the age of the universe of 5%, 10%, 14%, respectively. Therefore, it is a reasonable hypothesis that non-negligible evolution exists for the galaxies in the main galaxy sample.

Figure 13 shows variations of $L[W3]$ and $L[W4]$ with $L[W1]$ and $M^*$, and the fitting parameters are listed in Table 3. $L[W1]$ is the rest-frame $W1$ luminosity, which is usually treated as a tracer of the stellar content for star-forming galaxies (Zhu et al. 2010; Wen et al. 2013). An acknowledged advantage of $W1$ luminosity is the less intrinsic extinction relative to the optical photometries. Figure 13 presents an obvious increase of the fitting intercept, particularly for the correlations with $M^*$. Both the luminosities and $M^*$ in Figure 13 have been derived using SDSS or WISE photometries, so no aperture correction has occurred.

Theoretically, MIR emission consists of hot and cold components for normal galaxies without hosting AGN, and their $L[MIR]$ (rest-frame $L[W3]$ or $L[W4]$ in this study) could simply be expressed as:

$$L[MIR] = (a \times \text{SFR}) + (b \times M^*),$$

(2)

where $a$ ($b$) represent the corresponding coefficient. $(a \times \text{SFR})$ represents the fraction of hot dust components, while $(b \times M^*)$ represents the fraction of cold dust components. For the galaxies with almost the same stellar mass, Figure 13 shows that higher-redshift galaxies have greater $L[W3]$ and $L[W4]$, which suggests a larger fraction of hot dust components $(a \times \text{SFR})$, or a higher SFR-to-$M^*$ ratio. This increasing fraction of hot dust components as redshift is an indication of the evolving MIR versus $H\alpha$ correlation.
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5. Summary

In order to explore why the slope of the $L[MIR]$ versus $L[H\alpha]$ correlation is almost always linear, and why the intercept of the correlation is always small enough for both isolated H II regions and star-forming galaxies, we use bisection fitting to present and analyze the correlations between MIR and H$\alpha$ luminosities for a large sample of galaxies selected from the cross-matched SDSS DR7 and ALLWISE survey. The galaxies in three individual redshift bins ($0.04 < z < 0.05$, $0.09 < z < 0.10$, $0.14 < z < 0.15$) are adopted for comparison. The adoption of this bin size ($\Delta z \sim 0.1$, ~40 Mpc) is artificial in order to include enough galaxies within a narrow bin size. The main results described in this paper can be summarized as follows:

1. For all the selected star-forming galaxies in the final sample, the slopes of the MIR versus $H\alpha$ correlations are approximately equal to 1. For the galaxies in each redshift bin, the corresponding slope is always less than 1 and less than the slope derived for all the selected star-forming galaxies within redshift $0.03 \sim 0.15$. For the galaxies in the three discrete redshift bins, the fitting intercept increases with redshift.

2. We adopt the published IRS spectra of SINGS H II or SB galaxies to test the effects of $K$-correction on the inconsistency of the MIR versus $H\alpha$ correlation, and find the effects of $K$-correction are not significant, or are negligible.

3. Inaccurate aperture correction is a possible reason for the inconsistency. Thus, the effects of aperture correction could partly be responsible for the conclusion; unfortunately, we fail to quantify its influence using only current data.

4. We find that there are intrinsic distinctions between the star formation history and morphology for galaxies belonging to different redshift bins, even though the distinctions are slight. Alternatively, the redshift coverage from 0.3 to 0.15 for the galaxies in this study corresponds to a timescale of approximately one-tenth of the age of universe, and there is still possible evolution for the main sequence (SFR versus $M'$ correlation); galaxies with higher redshift have a larger fraction of hot dust components.

This study finds that the intrinsic slope of the MIR versus $H\alpha$ correlation is less than 1. Even though previous studies pointed out that the slope of the MIR versus $H\alpha$ correlation was almost equal to or even greater than 1, we find this linear correlation to be a probable combination of intrinsic slope and possible evolution, as well as inaccurate aperture correction. We previously would estimate the ongoing SFR for galaxies based on the equation calibrated from MIR versus $H\alpha$ correlation. But that approach is likely to cause undesired errors if the MIR versus $H\alpha$ correlation has been derived from a sample covering a wide redshift interval. Unfortunately, we could not quantify the magnitude of the error only using current data. Therefore, there is a pressing need for an explicit study to establish an accurate and redshift-independent MIR versus $H\alpha$ correlation, particularly to eliminate the effect from aperture correction. This would necessarily require $H\alpha$ imaging or at least IFU observations.

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| $y$ | $x$ | Sample | $a$ | $b$ | $s$ | $c$ | $r$ |
|-----|-----|--------|-----|-----|-----|-----|-----|
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| $L[W3]$ | $L[W1]$ | FS | $-1.135 \pm 0.006$ | $1.131 \pm 0.002$ | $0.092$ | $0.111 \pm 0.107$ | $0.944$ |
| $L[W3]$ | $L[W1]$ | z1 | $-0.848 \pm 0.027$ | $1.099 \pm 0.009$ | $0.093$ | $0.053 \pm 0.105$ | $0.887$ |
| $L[W3]$ | $L[W1]$ | z2 | $-0.452 \pm 0.035$ | $1.060 \pm 0.011$ | $0.084$ | $0.123 \pm 0.094$ | $0.836$ |
| $L[W3]$ | $L[W1]$ | z3 | $0.259 \pm 0.060$ | $0.993 \pm 0.019$ | $0.089$ | $0.192 \pm 0.102$ | $0.792$ |
| $L[W4]$ | $L[W1]$ | FS | $-1.133 \pm 0.011$ | $1.144 \pm 0.003$ | $0.163$ | $0.241 \pm 0.182$ | $0.839$ |
| $L[W4]$ | $L[W1]$ | z1 | $-0.146 \pm 0.048$ | $1.034 \pm 0.016$ | $0.162$ | $0.168 \pm 0.181$ | $0.669$ |
| $L[W4]$ | $L[W1]$ | z2 | $0.190 \pm 0.062$ | $1.005 \pm 0.020$ | $0.147$ | $0.249 \pm 0.170$ | $0.507$ |
| $L[W4]$ | $L[W1]$ | z3 | $1.040 \pm 0.105$ | $0.929 \pm 0.033$ | $0.155$ | $0.352 \pm 0.186$ | $0.378$ |
| $L[W3]$ | $M'$ | FS | $-0.663 \pm 0.012$ | $0.995 \pm 0.004$ | $0.200$ | $-0.706 \pm 0.228$ | $0.747$ |
| $L[W3]$ | $M'$ | z1 | $1.704 \pm 0.033$ | $0.745 \pm 0.010$ | $0.157$ | $-0.842 \pm 0.220$ | $0.722$ |
| $L[W3]$ | $M'$ | z2 | $2.417 \pm 0.038$ | $0.702 \pm 0.012$ | $0.133$ | $-0.684 \pm 0.195$ | $0.617$ |
| $L[W3]$ | $M'$ | z3 | $3.378 \pm 0.057$ | $0.632 \pm 0.017$ | $0.133$ | $-0.517 \pm 0.217$ | $0.546$ |
| $L[W4]$ | $M'$ | FS | $-0.647 \pm 0.015$ | $1.006 \pm 0.005$ | $0.251$ | $-0.576 \pm 0.290$ | $0.615$ |
| $L[W4]$ | $M'$ | z1 | $1.854 \pm 0.043$ | $0.741 \pm 0.014$ | $0.207$ | $-0.727 \pm 0.286$ | $0.521$ |
| $L[W4]$ | $M'$ | z2 | $1.794 \pm 0.054$ | $0.773 \pm 0.017$ | $0.186$ | $-0.558 \pm 0.258$ | $0.332$ |
| $L[W4]$ | $M'$ | z3 | $0.803 \pm 0.101$ | $0.889 \pm 0.031$ | $0.234$ | $-0.357 \pm 0.296$ | $0.144$ |

Note. The columns are the same as in Table 1. The $L[W1]$ and $M'$ in column (2) is rest-frame $W1$ luminosity and stellar mass.
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