論文の内容の要旨

A study of star-forming galaxies at $2.1 < z < 2.5$ selected by broad-band flux excesses

（広帯域フィルターのフラックス超過を用いた赤方偏移 2.1–2.5 の星形成銀河の研究）

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To understand galaxy formation and evolution is one of the biggest goals of modern astronomy. In this context, thousands of observations have been conducted to investigate properties of star-forming galaxies. Most star-forming galaxies exhibit prominent emission lines in their spectra, such as Lyα, Hα, and [OIII]. Hence the emission lines have been used to detect the star-forming galaxies and derive their properties. Emission line fluxes have been usually measured from spectroscopic or narrow-band imaging data. However, such observations require long observation time to construct large samples which are necessary to investigate statistical properties of the galaxies.

In this thesis, we establish a method to derive the emission line fluxes from broad-band photometry using a multi-band photometric catalog of the Fourstar Galaxy Evolution Survey (ZFOURGE). The wide wavelength coverage (0.3–8 μm) of the ZFOURGE and its deep near-infrared broad/medium-band imaging data allow us to accurately estimate properties of the galaxies by SED fitting. When performing the SED fitting, it is important to consider effects of the emission lines, which boost fluxes in the broad-band filters. Unless these effects are taken into account, the SED fitting overestimates continuum levels resulting in overestimated stellar masses. Hence we use spectral templates in which the emission lines are included. We find that the stellar masses can be overestimated by nearly 1 dex in some cases without the emission line templates.

We define "flux excess" as a difference between an observed flux and a continuum flux derived from the SED fitting, and select Hα emitters and [OIII] emitters at $2.1 < z < 2.5$ based on the flux excesses in the $K_{\rm s}$-band and $H_{\rm s}/H_{\rm l}$-band, respectively. When comparing the Hα fluxes derived from the flux excesses with those derived from narrow-band color excesses, long-slit spectroscopy and integral-field spectroscopy, we find 73%, 67% and 62% of the Hα emitters have consistent fluxes within a factor of 2 in

both methods, respectively. Scatters around the one-to-one relations are similar in any pairs among the four derivation methods. Therefore we conclude that there is no significant error introduced by using the flux excess.

We investigate properties of both the Hα and [OIII] emitters selected by the flux excesses. Almost all our Hα emitters are classified as star-forming galaxies by the UVJ diagram, which indicates that our method works properly to select the star-forming galaxies.

First we find a correlation between star formation rates (SFRs) and the amounts of dust attenuation to Hα. This suggests that more luminous Hα emitters are more obscured by the dust.

Next we compare our Hα luminosity function with that obtained by a narrow-band imaging survey named the High-z Emission Line Survey (HiZELS). Our luminosity function exhibits an excess compared to the result of the HiZELS in the bright-end, while both luminosity functions are in good agreement in the faint-end. We show that most of the difference between the luminosity functions can be explained by a combination of extended Hα profiles and the correlation between the Hα luminosity and the amount of dust attenuation. According to our simulation with structural parameters in a literature, the fixed 2" aperture of the HiZELS might have missed at most $\sim 40\%$ of Hα fluxes of galaxies in the bright-end. In addition, its luminosity function has been derived assuming the attenuation of 1 mag to Hα for all the galaxies, which are insufficient for the most luminous Hα emitters. Despite the excess, we obtain a consistent cosmic star formation rate density with previous studies as the contributions of the most luminous Hα emitters to the total SFR in the universe are insignificant due to their small numbers.

The star formation main sequence (SFMS) of our Hα emitters agrees well with those of previous studies at $\log M/M_{\odot} > 9$. On the other hand, there are many low-mass galaxies much above an extrapolation of the SFMS. Such low-mass galaxies with large specific star formation rates (sSFRs) have also large Hα/UV luminosity ratios, which suggests that they might have undergone short-period starbursts within past 10 Myr. In addition, they are also selected as the [OIII] emitters with extremely high ($\gtrsim 1000$ Å) equivalent widths. This makes their large sSFRs more reliable because the [OIII] equivalent width is an independent proxy of the sSFR.

We find that strong [OIII] emitters are characterized by large sSFRs, large [OIII]λ5007/Hβ ratios, and small amounts of the dust attenuation as expected from previous studies. Given that the Hα emitters represent diverse populations of the star-forming galaxies, the [OIII] emitters are expected to be a sub-population of the Hα emitters. When comparing these two populations, we find that more than 70% of the [OIII] emitters are also selected as the Hα emitters, while $\sim 55\%$ of the Hα emitters are also selected as the [OIII] emitters. This result is qualitatively consistent with our expectation. However, there are uncertainties in the fractions due to different sensitivities of our selection to both emission lines.

In conclusion, the combination of our flux excess method and deep imaging data of the ZFOURGE has enabled us to discover the star-forming galaxies with extreme properties, which are important populations to better understand galaxy evolution. For example, Hα luminosities of the galaxies in the bright-end of the Hα luminosity function correspond to SFRs of a few 100 $M_{\odot}\mathrm{yr}^{-1}$. In addition, we find large AGN fraction in the bright-end. Therefore it is important to investigate the most luminous galaxies to better understand what triggers the very active star formation activities and how the AGNs are connected with them. Our method is an efficient way to detect such very rare objects.

On the other hand, the low-mass galaxies with large sSFRs are also very important populations, which are expected to be undergoing rapid stellar mass assembly. We might obtain a clue to understand the downsizing of galaxies by investigating typical stellar masses of such populations at different redshifts. In addition, since supernova feedbacks have been thought to play an important role in star formation histories of low-mass galaxies, investigating the bursty galaxies may put a constraint on the feedback models. Moreover, they are also interesting targets to understand ionizing photon escapes at this redshift because their properties are similar to those of the local galaxies with large escape fractions.similar to local galaxies with large escape fractions.