Star Formation in the Central Kiloparsec of Nearby Active Galaxies

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Star Formation in the Central Kiloparsec of Nearby Active Galaxies

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Abstract. We investigate star formation (SF) activity in the central kpc of a sample of nearby Active Galactic Nuclei (AGNs). AGN activities are expected to either trigger SF via accreting ISM to the central regions of the host galaxies or quench the SF via the energy feedback of the AGNs. To study the AGN-SF relation we select 113 nearby galaxies that host 8 GHz central radio sources. We use 8 GHz radio emission to represent the AGN activity and 8 micron dust emission in the central kpc regions of these galaxies to estimate the SF rate (SFR). The SFR is found to be correlated with the stellar mass for stellar mass greater than $10^{10}$ solar mass and looks scattered for stellar mass less than $10^{10}$ solar mass. There is no correlation between the specific SFR (SSFR) and the AGN activity for all sources. However, if we exclude the sources with the central stellar mass greater than $10^{10}$ solar mass, we find that the 8 GHz radio emission is well correlated with the SSFR. These results suggest that the AGN activity is significant in triggering SF activity only for small galaxies. Besides, we also select about 20 nearby AGN galaxies to investigate the radial variation of their surface specific star formation rate.

1. Introduction
Active galactic nuclei (AGNs) are believed to be powered by accretion onto central supermassive black holes in their host galaxies. The properties of molecular gas near an AGN can be significantly influenced by the AGN. AGN activities are expected to either trigger star formation (SF) via accreting ISM to the central regions of the host galaxies or quench the SF via the energy feedback of the AGNs. Measuring the star formation rate (SFR) of the host galaxy is thus important for studying the co-evolution of AGN and their hosts. In this paper, we select more than one hundred nearby galaxies that host 8 GHz central radio sources to study the AGN-SF relation. Besides, we also select about 20 nearby AGN galaxies to investigate the radial variation of their SFRs.

2. Methods
We select our sources from the AGN lists of [1], [2], [3], and [4]. There are total 113 nearby active galaxies in our sample. We obtained the 8 GHz fluxes of these source from the VLA archive at https://archive.nrao.edu/archive/archiveimage.html. We obtained the 3.6, 4.5, 8 and 24 μm IR images of these sources from the Spitzer archive. We use the 3.6 and 8 μm images to estimate the stellar mass and SFR respectively. The stellar mass and the SFR are calculated using the formulae of [5] and [6]. We use the 8 GHz fluxes to represent the strengths of the host AGNs. In studying the radial variation of the SFRs of nearby AGN galaxies, the positions of
Figure 1. Comparison of the SFR within 1 kpc estimated by the Spitzer 8μm dust intensity with the SFR obtained from the SDSS DR4.

the nuclei are identified using the 8 GHz images or with fitting the bulge centers of the 3.6 μm images. The physical scales are estimated using the parameters determined in the bulge fitting of the 3.6 μm images.

3. RESULTS

We compare the SDSS SFR catalog with the SFR that was estimated by Spitzer 8μm dust intensity. As can be seen in Figure 1, the SFRs estimated by emission line intensities and those estimated by the 8 μm dust intensities are linearly correlated, indicating that the 8 μm emission is also a good star formation tracer. However, we note that the SFR from the SDSS DR4 is estimated using the averaged magnitude within 3 arc second, and the SFR derived from the 8 μm dust is estimated within the central 1 kpc radius.

To study the activity of AGN, we select 8 GHz emission as our AGN activity tracer. We select the active galaxies with a compact point source from the VLA archive images to avoid contamination from the free-free emission associated with the ionized gas surrounding hot young stars.

The relation of SSFR, stellar mass surface density and 8 GHz luminosity for the central 1 kpc radius region of 113 nearby active galaxies is shown in Figure 2 and Figure 3. These AGNs have been classified into different types according to their line widths. In Figure 2, we find that the 8 GHz luminosity and the SSFR are uncorrelated. Even for Seyfert 2 galaxies, which are believed to have significant star formation activity, the correlation coefficient $r$ between the SSFR and the 8 GHz luminosity is only 0.22 with a probability $p = 77.33\%$. In other words, the SSFR has no strong correlation with AGN activity for all nuclei types. But we note that the Seyfert 1 and other active galaxies have higher radio powers than Seyfert 2 have.

On the other hand, Figure 3 shows a strong correlation between the stellar mass surface density and the 8 GHz luminosity. The correlation coefficient $r$ is 0.41 with a probability
Figure 2. Relation between the 8 GHz luminosity and the SSFR surface density. Red circles are Seyfert 1.0-1.5 galaxies, green circles are Seyfert 1.8-2.0 galaxies and black circles are other active nucleus types.

$p = 99.68\%$ for Seyfert 1. This result indicates that the central radio powers of AGNs are correlated with the central stellar mass. This indicates that the AGN activity is related to the central mass or concentration of the host galaxy.

We note that the 8 GHz emission might be contaminated by free-free emission from star formation. To check whether 8 GHz do represent the activity of AGN, we compare the 8 GHz fluxes with the X-ray flux derived from XMM for our AGN sources. The result is shown in Figure 4. The correlation coefficient between the 8 GHz and the soft X-ray (0.5-2.0 keV) fluxes is $r = 0.32$ with a probability $p = 99.61\%$ for 82 AGN galaxies. However, we note that there is no correlation for Seyfert 2 galaxies; the probability of Seyfert 2 is only $p = 11.84\%$. This suggests that the 8 GHz luminosity do represent the activity of the AGN, at least for Seyfert 1 galaxies.

To further investigate the effects caused by different environmental properties within the central regions of the active galaxies, we compare the SSFR for different types of galaxies, including both active and normal galaxies. The normal galaxies are selected from [7] and [5]. Figure 5 shows a strong correlation between the stellar mass and SFR for both active and normal galaxies within the central 1 kpc radius. Most of the active galaxies seem to locate at relatively higher SFR regions.

However, as shown in Figure 6, most of nearby galaxies, including normal and active galaxies actually have similar SSFR, $\sim 10^{-9.5} - 10^{-10.5}$ except for elliptical type galaxies. In other words, the high SFRs of the active galaxies are actually caused by their high surface stellar density instead of having enhanced SFRs triggered by AGN activity. Different SSFRs are mainly related to different morphologies of host galaxies instead of AGN activities.

The SSFR is in fact the ratio between the current SFR to the accumulated old SF and cannot represent the current star formation efficiency (SFE). In order to obtain the current SFE, we
Figure 3. Correlation between the SSFR surface density and the stellar mass density within 1 kpc radius. Symbols are the same as in Figure 2. The correlation coefficient $r = 0.41$ with a probability $p = 99.68\%$ for Seyfert 1 (red circles).

Figure 4. Comparison between the 8 GHz luminosity and x-ray luminosity (0.5–2.0 keV). Symbols are the same as in Figure 2.
Figure 5. Relation between stellar mass surface density and star formation rate surface density within 1 kpc. Red color means elliptical-like, green means spiral-like and black means irregular or unclassified galaxies. Crosses represent 133 active galaxies and circles are 155 normal galaxies.

Figure 6. Relation between stellar mass surface density and specific star formation rate surface density within 1 kpc. Symbols are the same as in Figure 5.
need to have the molecular mass instead of stellar mass. We therefore try to obtain molecular gas to estimate the SFE (SFR/M_{\text{gas}}) for several normal and active galaxies. We have searched sources from the BIMA-SONG project, which have performed CO(1–0) observations for several active and normal galaxies. We are able to select 11 normal and 6 active galaxies with CO(1–0) observations in our sample. Although we have only a small sample, we find that the fractions of the gas to stellar mass surface density around the active galaxies are usually higher than that in the normal ones. However, the SFEs in the central regions of the active and normal galaxies are almost the same. The AGNs usually have larger central stellar masses as we have shown; therefore, they also have more gas abundance. In other words, the high SFR around AGN is actually caused by a large gas abundance instead of a high SFE.

Besides, we find that the radio powers of the AGNs seem to be related to the existence of some inner structures in the optical images of these AGNs. These structures locate within the central regions of the host galaxies. In fact, the radio power shows a strong correlation with SSFR only for AGNs with the inner structures. This suggests that the AGN activity might also be related to the central environments of the host galaxy.

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References
[1] Condon, J. J., Huang, Z.-P., Yin, Q. F., Thuan, T. X., 1991, Astrophys. J., 378, 65
[2] Ho, L. C., Ulvestad, J. S., 2001, Astrophys. J. Supp., 133, 77
[3] Spinelli, P. F., Storchi-Bergmann, T., Brandt, C. H., Calzetti, D., 2006, Astrophys. J. Supp., 166, 498
[4] Melendez, M., Kraemer, S. B., Schmitt, H. R., 2010, MNRAS, 406, 493
[5] Wu, H., Cao, C., Hao, C.-N., Liu, F.-S., Wang, J.-L., Xia, X.-Y., Deng, Z.-G., & Young, C. K.-S. 2005, Astrophys. J. Lett., 632, L79
[6] Zhu, Y.-N., Wu, H., Li, H.-N., & Cao, C. 2010, Research in Astronomy and Astrophysics, 10, 329
[7] Tully, R. B., 1988, Science, 242, 310