The challenges in observational studies of galaxy-AGN coevolutions

Observations of direct connections between galaxy star formation and supermassive black (SMBH) accretion are very challenging. In particular, the vastly different physical sizes and time scales of galaxy star formation and SMBH accretion often produce severe selection bias if we focus only on the galaxies hosting SMBHs that are currently “on.” Another challenge in the search of the direct connection between galaxy and AGN is that rapidly growing systems are often enshrouded by dust. Therefore, a substantial population SMBHs might be growing in an obscured phase that can be missed. To explore the connection between galaxy and AGN, these effects must be treated carefully.

Revealing the correlation between the SFR and the BHAR in star-forming galaxies with Chandra

Studies of the typical star formation rates in AGN host galaxies have shown that while there is strong SFR-BHAR correlation in high luminosity AGN (Rosario et al., 2012), at lower luminosity AGN the connection appears to be relatively weak or absent. This difference between the high- and low-luminosity AGN may be attributed to the different time scales of star formation and AGN accretion (Hickox et al. 2014). Since AGN accretion rates vary in time scale much shorter than that of star formation, the average BHAR for star-forming galaxies might be a better indicator to study the connection between SFR and accretion.

We select 1,785 star-forming galaxies selected using Herschel SPIRE 250 μm filter (Alberts et al. 2013) in Bootes (0.25<z<0.8). The redshift measurements are from AGN and Galaxy Evolution Survey (spectroscopic) and Spitzer Deep Wide Field Survey (photometric). In this sample, there are 140 X-ray or mid-IR selected AGNs for which we can measure their accretion rates directly. For the SF galaxies without individually detected AGNs, we measured the average LX using an X-ray stacking analysis. We find that the average black hole accretion rate (BHAR) is strongly correlated with SFR in SF galaxies, which support a scenario in which galaxy and SMBH grow from a common gas reservoir that can obscure the central SMBH during the luminous quasar phase.

AGNs hosted by galaxies with stronger SF show signs of nuclear obscuration

To explore the effect of the star-forming gas and dust to the observed AGN properties, we use X-ray stacking analysis to study the average X-ray spectra for IR-bright and IR-taint galaxies, we find that for IR-bright galaxies, the average X-ray spectrum shows signs of Fe-K emission, which is an indicator of AGN obscuration.

The connection between SF and obscuration in mid-IR selected quasars

Far-IR emission in obscured and un-obscured Quasars

There is increasing evidence for the connection between SFR and BHAR in the starburst galaxies and powerful AGNs consistent with a scenario in which AGN and galaxies have gone through a dust-envisioned phase, where the gas-rich major merger drives both active starburst and luminous AGN activity (i.e. quasar) (e.g. Sanders 1988, Hopkins 2008). In this phase, the rich dust and gas in the host galaxy might also be responsible for the obscuration observed in some luminous AGN. However, results current X-ray selected AGN samples do not support this scenario (e.g. Rovilos et al. 2012, Merloni et al. 2014).

To investigate the heavily obscured quasar population, we study an IR-selected quasar sample at 0.7<z<1.6 in Bootes (Hickox et al. 2007) to test whether the obscuration in bright AGN is related to star formation. We separated our sample into obscured AGN and unobscured AGN using a optical/mid-IR color selection criteria (Hickox et al. 2007). We measured the far-IR detection fraction for obscured and un-obscured AGN separately, and found that obscured AGN have a higher far-IR detection fraction and stronger SF luminosity.

Conclusion

In these works, we attempted to addresses one of the most important unresolved issue in current studies of galaxy evolution, the origin of the tight relationship between the SMBH mass and the host galaxy mass. We have found that the average BHAR and SFR are strongly correlated in SF galaxies. This is likely due to a common gas reservoir which fuels both active SF and BH accretion, and is supported by current X-ray surveys. This suggests that in addition to a parsec-scale torus, the presence of large-scale star-forming dust might also play obscure the nuclear structure. This work is supported by a Fellowship from the William H. Neukom 1964 Institute for Computational Science.