Low luminosity AGNs in the local universe

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Abstract. Galaxies are known to contain black holes (e.g. Ferrarese & Merritt 2000), whose mass correlates with the mass of their bulge. A fraction of them also has an Active Galactic Nucleus (AGN), showing excess emission thought to be due to accretion of mass by the supermassive black hole at the center of the galaxy. It is thought that AGNs play a very important role during the formation of galaxies by creating large outflows that stop star formation in the galaxy (see e.g. Kormendy & Ho 2013). The aim is to detect the fraction of Low Luminosity Active Galactic Nucleus (LLAGN) in the nearby Universe. At present, they are typically found using optical spectroscopy (e.g. Kauffmann, Heckman et al. 2003), who discuss the influence of the AGN on the host galaxy and vice versa. However, optical spectra are seriously affected by extinction in these generally very dusty objects, and therefore can only give us partial information about the AGN. I used a newly-found method, and apply it to the S4G sample, a large, complete, sample of nearby galaxies, which I am studying in detail with a large collaboration, to detect the fraction of low luminosity AGNs, and to better understand the relation between AGNs and their host galaxy which is thought to be crucial for their formation.

1. Introduction
Galaxies are the basic building blocks of the Universe, and understanding their formation and evolution is crucial to many areas of current astrophysical research. Nearby galaxies contain the ‘fossil record’ of the evolution of galaxies and provide a wealth of detail to extensively test the current models of galaxy formation and evolution. A galaxy’s structure is linked to both its mass and evolutionary history. Probing galactic structure requires understanding the distribution of stars among galaxies of all types luminosities across full range of environments. Understanding this history is to obtain census of stellar structure in galaxies in the local volume.

Galaxies are known to contain black holes (e.g. Ferrarese & Merritt 2000), whose mass correlates with the mass of their bulge. The tight correlation between nuclear black hole and bulge mass (e.g., Magorrian et al. 1998; Tremaine et al. 2002) implies the processes are intimately connected. These black holes are located in the nuclei of almost all galaxies. Interestingly, their mass scales with the mass of their surrounding spheroids. This fundamental connection shows that the super massive black hole and its host system must have formed in concert. A small fraction of galaxies also has a very bright nucleus called as an Active Galactic Nucleus (AGN), showing excess emission thought to be due to accretion of mass by the super massive black hole at the center of the galaxy. It is thought that AGNs play a very important role during the formation of galaxies by creating large outflows that stop star formation in the galaxy (see e.g. Kormendy & Ho 2013). The complex central regions of active and inactive galaxies are thus an ideal laboratory for study of the evolution and formation of galaxies.

Here we propose to study the presence of Low Luminosity Active Galactic Nucleus (LLAGN). At present, they are typically found using optical spectroscopy (e.g. Kauffmann, Heckman et al. 2003),
who discuss the influence of the AGN on the host galaxy and vice versa. However, optical spectra are seriously affected by extinction in these generally very dusty objects, and therefore can only give us partial information about the AGN. Here we propose to use a newly-found method, and apply it to a large, complete, sample of nearby galaxies, which we are studying in detail with a large collaboration, to detect the fraction of low luminosity AGNs, and to better understand the relation between AGNs and their host galaxy.

2. Samples
In this study we took the Spitzer Survey of Stellar Structures in Galaxies (S4G; Sheth et al. 2010) sample of more than 2500 galaxies, for which deep [3.6] and [4.5] micron images have been reduced and archived deep [3.6] and [4.5] micron images in collaboration with the DAGAL EU RTN network (http://www.dagalnetwork.eu/), and S4G Extension sample of more than 300 galaxies (http://sha.ipac.caltech.edu/applications/Spitzer/SHA/) both taken with the Spitzer Space Telescope.

The S4G is a volume, magnitude, and size-limited survey of more than 2500 nearby galaxies using the IRAC Infrared Array Camera (Fazio et al. 2004) with deep imaging at 3.6 and 4.5 μm on board the Spitzer Space Telescope which one of the Spitzer Legacy Program of late type galaxies (Figure 1).

![Figure 1. The 2,352 S4G galaxies are represented as overlays in red on the all-sky ISSA (IRAS Sky Survey Atlas) image above (http://irsa.ipac.caltech.edu/data/SPITZER/S4G/).](image)

This survey contains over 2300 galaxies within 40 Mpc (v < 3000 km/s), away from galactic plane (|b| < 30°), with corrected for internal extinction B band Vega magnitude brighter than 15.5 and B-band diameter larger than 1 arcmin with distances determined from HI radial velocities. Since S4G selection based on radial velocities from HI, it lacks early-type galaxies. This has been corrected for in the S4G Extension, a sample containing 465 galaxies. We also include them in this study.

3. Method
We used a newly-found method, to discover LLAGNs. The method is based on the work of Stern et al. (2005), who show that these objects fill a particular area in the Spitzer-IRAC [3.6]-[4.5] vs. [5.8]-[8.0] color-color diagram. We determined the central colors for all these galaxies, and detected LLAGNs by just studying the central [3.6]-[4.5] color, as has been shown by Van Der Wolk et al. (2011), and reference therein (Figure 2).
Van der Wolk (2011), working with Peletier and Barthel in Groningen, showed that for nearby galaxies the [3.6]-[4.5] colour by itself is also able to isolate LLAGNs. AGNs contain a hot core, which causes [3.6]-[4.5] to be larger than 0.4 (Vega system). Other emission in the center of galaxies, such as stars or PAH-dust emission never reach such red [3.6]-[4.5] color. The [3.6] micron images are almost unaffected by extinction by dust, and can be used to obtain accurate estimates of the stellar mass in these galaxies (e.g. Meidt et al. 2014). Also, the [3.6]-[4.5] color is a useful indicator of the fraction of AGB stars in these galaxies (Peletier et al. 2012).

We show that Spitzer Space Telescope is a powerful tool for studying AGN demographics. We investigate nature of galactic nuclei with a strong near infrared [3.6]-[4.5] color excess which provides a robust technique for identifying AGNs. We used this color criteria method which is one of the best way of distinguishing AGNs from normal galaxies and an efficient way of finding LLAGNs in a large sample. We measured the central colors of galaxies and detected AGNs with using near infrared excess. The nearby active galactic nuclei show infrared excess in comparison to normal nuclei which are dominated by stellar and star formation emission. This gives rise to the interpretation that this excess is related to supermassive black hole accretion.

Figure 2. Spitzer colour-colour diagram. SAURON Sa sample nuclei are plotted in red and nearby active galaxy nuclei in black. For M 87 we also indicate the colours of the large-scale jet knots A/B indicates as M87 jet, the stellar emission at the same radius as the jet (M87gal) and the stellar-subtracted jet emission (M87jet,ns). Black bodies at various temperatures are plotted with a black line. Power-law models $F_\nu \propto \nu^\alpha$ at various spectral indices -1 ≤ α ≤ 3 are plotted with a green line (Van der Wolk thesis, 2011).
4. Analyses and Results

We measured the central colors of galaxies and detected AGNs with using near infrared excess. The nearby active galactic nuclei show infrared excess in comparison to normal nuclei which are dominated by stellar and star formation emission.

Color-color diagram of the galaxies in S4G sample is shown in Figure 3. In the diagram, Aperture 3 is versus Aperture 30. Aperture 3 shows the central color of the galaxy and Aperture 30 shows approximately the color of the whole galaxy, which is not affected by the central color.

Galaxies in both samples whose [3.6]-[4.5] colors ≥ 0.1 mag are represented by the yellow area. These galaxies show redder central colors indicating (Stern et al. 2005) that most of the galaxies in yellow area have an active galactic nucleus.

![Figure 3. Central [3.6]-[4.5] color- outer [3.6]-[4.5] color for the S4G sample.](image)

Once the AGN candidates have been detected, the next step is to understand what kinds of object this method gives. The first thing to do is to see whether these objects have radio and x-ray continuum counterparts, expected for AGNs. I searched galaxies whose [3.6]-[4.5] colors ≥ 0.1 magnitudes as defined by AGN in VLA FIRST and NVSS surveys for radio detections and CHANDRA and XMM Newton surveys for X-ray detections (Figure 4 and 5).

![Figure 4. Number of AGNs detected in VLA FIRST, NVSS, CHANDRA and XMM Newton surveys.](image)
Figure 5. AGNs survey detections is given by percentages.

AGNs survey detections show in Figure 5 is given by percentages: %24 X-ray surveys, %33 radio surveys, %43 non-detected AGNs. These percentages represent the radio and X-ray measurements of AGNs in both samples.

5. Future Works
I will find the fraction of LLAGNs in both samples and represent relations of AGN fractions with galaxy mass, morphological type and environment, in order to understand the occurance of AGN.

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