Hyper Massive Black Holes in nearby evolved galaxies

Romero-Cruz, F. J.[1], Torres-Papaqui, J. P.[1], Ortega-Minakata, R.[1], Morales, A.[1] & Lopez-Cruz, O.[2]

fromero@astro.ugto.mx, papaqui@astro.ugto.mx, rene@astro.ugto.mx, amorales@astro.ugto.mx & omarlx@inaoep.mx

[1] Departamento de Astronomía, Universidad de Guanajuato, México. [2] Departamento de Astrofísica, INAOE, México.

Introduction

We consider that BHs in the center of evolved galaxies have accreted all the available gas around them and so the nuclear activity of the galaxy has diminished considerably.
Usually we can classify the galaxies depending on their activity type according to the classical diagnostic diagrams (Baldwin et al. 1981, Veilleux et al. 1987) which require all the emission lines in their spectra (see figure 1), the absence of some of them (or all) might be a consequence of their low activity and so those galaxies can be considered as very evolved.

An additional criteria based on the Infrared signature of the galaxy has been suggested to classify the type of activity (Coziol et al. 2015). We use this new diagnostic diagram to show that galaxies without the necessary emission lines in their spectra are indeed AGN.

Samples

Almost a million spectra from the SDSS DR7 (Abazajian et al. 2007) analyzed with the Starlight Code (Cid-Fernandes et al. 2005).

We consider two subsets: Sample A, the galaxies that can not be classified with the classical diagrams (about 16,000) and sample B, the others (more than 900,000).
From these samples we considered only those with $\sigma > 250$ km/s which would correspond to an estimated BH mass of the order of $10^9 M_\odot$ (Gültekin et al. 2009, McConnell et al. 2013). After this filter our samples reduced drastically to 1,790 and 69,000 respectively.

Methodology

We performed a statistical analysis comparing the basic physical properties of both samples, then we use the diagnostic diagram proposed by Coziol et al. (2015) based on IR data from the WISE survey. For sample B we already know the type of activity because of the BPT diagram, with the IR color diagram we confirm such classification.

Besides, we separated the sample also in morphology (Torres-Papaqui et al. 2011) and observed that Early type galaxies consistently are in the AGN region of the IR diagram (see figures in the results section).
We made the same analysis with sample A and observed that they are too in the AGN region, this confirms our assumption that the absence of emission lines in galaxies is a characteristic of low star forming and evolved galaxies.

References

Abazajian, K. et al. 2009, ApJS, 182, 543
Baldwin, J., Phillips, M. & Terlevich, R. 1981, PASP, 93, 5
Cid Fernandes, R. et al. 2005, MNRAS, 358, 363
Coziol, R., Torres-Papaqui, J. P. et al. 2015, AJ, 149, 192
Gültekin, K. et al. 2009, ApJ, 698, 198
López-Cruz, O. et al. 2001 RMxAC, 11, 183
López-Cruz, O. Anorve, C. et al. 2014 ApJL, 795, L31
McConnell, N. et al. 2013, ApJ, 764, 184
Torres-Papaqui, J. P. et al. 2011, Revista Acta Universitaria, 21, 82
Villeux, S. et al. 1987, ApJS, 63, 295.

Partial results

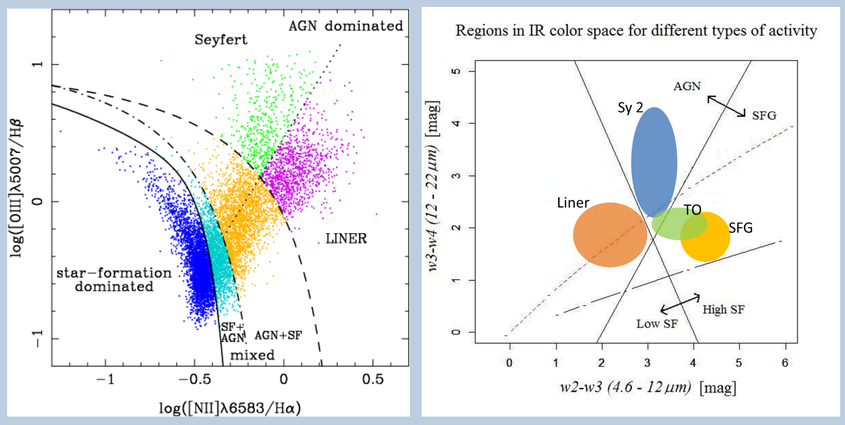

Figure 1: Left panel, BPT diagram. The emission lines necessary to construct it are shown in the axis (Taken from Torres-Papaqui et al. 2011). Right panel, the IR color diagram proposed by Coziol et al. (2015), this is a schematic representation for the different regions occupied by the different types of activity. 3 of the 4 bands of the WISE survey are used in its construction.

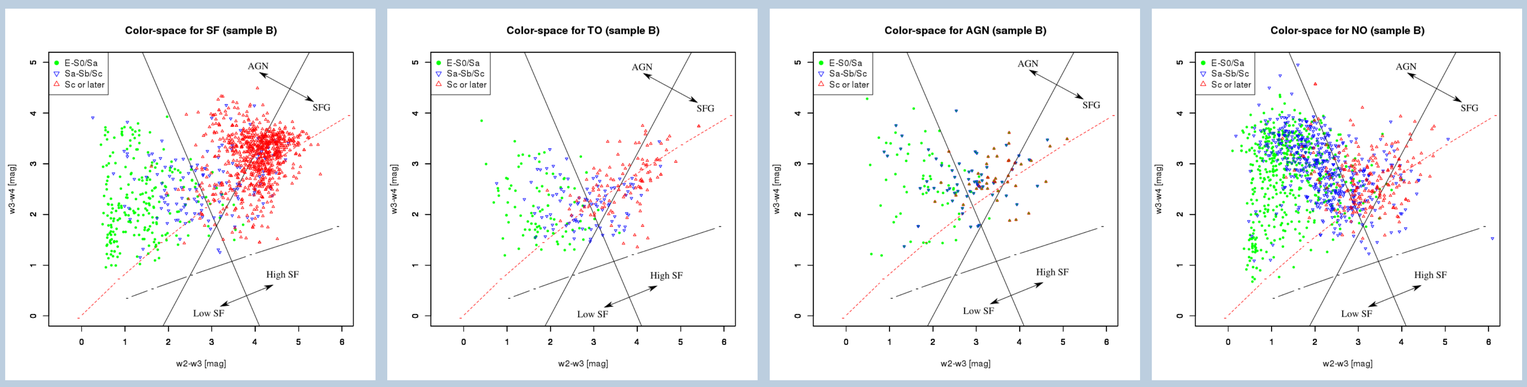

Figure 2: IR color diagram for galaxies (sample B) classified according to different classes (SF, TO, AGN and NO in the BPT diagram) and separated by morphological type. In all cases Early type galaxies show a trend to lie in the AGN-Low SF region of the diagram, even the ones classified as NO in the BPT (NO comes from the fact that at least one of the emission lines necessary in the BPT is missing).

We observe that in sample B Early type galaxies lie in the AGN-Low SF regions of the IR color diagrams independently of their BPT classification. The physical reasons of this behavior are yet to be fully explained but the observational evidence here is remarkable.

For sample A, the left panel of figure 3 shows the Star Forming History as calculated by the Starlight Code, we observe that the maximum of the star formation rate occurs approximately 10 Gyr ago and decreases in present time, which is consistent with our initial idea of evolved galaxies. It is important to emphasize that the WISE IR data have a photometric quality index in each band based on S/N and for band w4 ($22\mu m$) most of the data have only upper limits in their measurements (snr<2) so we conservatively excluded them. This reduced considerably our sample but still we could observe some important details.
In the right panel of figure 3 we can see that some elements of our final sample (WISE data objects with snr ≥ 10) lie in the AGN-Low SF region which is again consistent with our hypothesis of evolved galaxies. Incidentally, the object marked as Holm 15A corresponds to a galaxy which according to López-Cruz et al. (2014) hosts a hyper-massive BH ($M_{BH} \geq 10^9 M_\odot$).

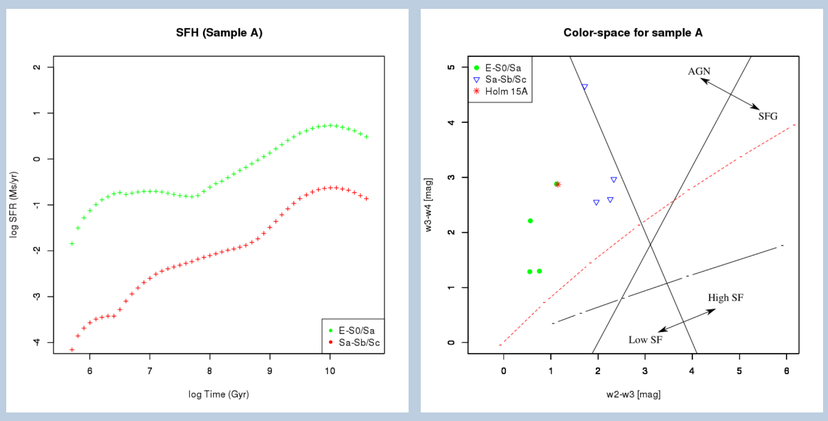

Figure 3: Left panel. Star formation history for sample A, calculated using the Starlight Code. Right panel, IR color diagram for a subsample of sample A using WISE information with high photometric quality, we observe that the galaxies lie in the AGN-Low SF regions in agreement with the initial hypothesis.

Conclusion

The IR color diagram is useful to classify galaxies which do not show the main emission lines in their spectra. The idea that this characteristic is present in evolved galaxies that also host very massive BHs is consistent with the results shown.
In our sample A we found that the median for σ is 279 km/s which according to the $M - \sigma$ scale relation would correspond to Black holes with an estimated mass of $\sim 10^{9.22} M_\odot$. The predominant morphology type is Early.

For the next stage in our study we will use Integrated Field Spectroscopy techniques (CALIFA and SAMI surveys) and photometric analysis (López-Cruz et al. 2001).