

**PhD name: Alberto Traina**  
**PhD Cycle: 36**  
**Tutor: Carlotta Gruppioni**

**RESEARCH PROJECT: Tracing SMBH accretion density and star formation rate density through cosmic time: the ALMA view from the survey A3COSMOS**

Active Galactic Nuclei (AGN) are among the most studied, but not yet fully understood, astrophysical objects. The activity from an AGN is known to be triggered and powered by accretion onto the supermassive black hole (SMBH) at the center of the host galaxy. The properties of SMBH are not independent from the surrounding environment, as suggested by the tight correlations between SMBH mass and a number of host properties (see, e.g., Magorrian+1998, Ferrarese+2002). In addition, the evolution of galaxies (Thomas+2010) and AGN (Ueda+2003) seems to follow a similar scenario (i.e., the downsizing). On the one hand, massive galaxies formed earlier and faster than their lower mass counterparts; on the other hand, in the same way, more powerful AGN, coupled with more massive BH, grew up at earlier times. Another important aspect of such AGN-galaxy “co-evolution” is the co-existence of both AGN-driven and galaxy-driven emission within individual sources. Indeed, an additional non-stellar component from an AGN may be needed to reproduce the observed broad-band spectral energy distribution (SED), as well as to explain the integrated properties of the host. In this perspective, the study of the accretion of material onto the SMBH, as well as their growth with cosmic time is crucial. To this purpose, tracing the BH accretion rate density (BHARD) and compare its evolution with redshift with the star formation rate density (SFRD) can provide insightful clues in understanding the interplay between SMBH and galaxy growth through cosmic time.

Most of the galaxies contributing to the SFRD, especially at high redshift, are in the so-called phase of obscured accretion (Vignali+2014), meaning that part of both the SF and AGN emission is enshrouded in the galaxy dust and gas. Although X-rays are poorly affected by obscuration, the compact ISM of high- $z$  galaxies can hide an important fraction of the AGN emission making the X-ray instruments blind to the emitted radiation. On the other side of the spectrum, IR and mm bands are less affected by the torus and host obscuration, thus allowing to observe AGN and to constrain their properties up to much higher redshift than X-ray studies, in an unbiased way.

In this context, a powerful tool to investigate the evolution of galaxies (and AGN) is the analysis of large samples of sources, using their observed photometry to reconstruct the SED. A multi-wavelength survey of star-forming galaxies spanning a wide redshift range of the observed galaxies is well suited for these studies.

Our project mainly focuses on the reconstruction of the SFRD and BHARD using the A3COSMOS survey (Liu+2019). In particular, one of the most important goals is to measure the contribution to the total SFRD from galaxies hosting an AGN.

The A3COSMOS survey comprises star-forming galaxies followed-up with ALMA in the COSMOS field. It is not properly an homogeneous survey, since it combines public archival ALMA data taken over different areas, depths, and at various (sub)-mm bands., observed by ALMA. Up to now, the survey contains about 1200 galaxies and covers 622.8 sq. arcmin by summing together the pointings.

During this year, we have first re-analyzed the SEDs of all galaxies reported in the in the A3COSMOS “robust” catalogue (containing the main galaxy properties, e.g., stellar mass, SFR, dust luminosity) using the CIGALE (Boquien+2019) code for SED fitting and we have compared our results with those obtained by Liu+ using MAGPHYS (da Cunha+2008), probing the reliability of our measurement of the physical properties and testing the uncertainties due to the considered code. In a second step, starting from the A3COSMOS photometry table, we have built a new catalogue using data from the COSMOS2020, the superdeblended, the SPLASH and the UV DR4 catalogues. We performed the SED fitting for this catalogue using the new fluxes from the above catalogues and compared the results with the previous ones, finding a good agreement and increasing the number of analyzed sources. Finally, in order to find the AGN in the sample, we added the AGN component to the SED templates and performed a further SED fitting. For each source we measured the AGN fraction (i.e., the ratio between the AGN luminosity and the total IR luminosity) in the 5-40  $\mu\text{m}$  band to select the sources containing an AGN. This, allowed us to derive the bolometric correction and, thus, the bolometric AGN luminosity needed to estimate the BHARD estimate. After the construction of a preliminary version of the IR luminosity function, we are currently building up a more general and flexible routine to calculate the luminosity function as a mosaic of several independent ALMA pointings, instead of treating A3COSMOS as a “classical” flux-limited survey.

## **WORKSHOPS, CONFERENCES & MEETINGS**

16 December 2020, Bologna, Italy (online, Google Meet). Christmas lecture: "Gaia: Early Data Release3, mission status, and science highlights from the second data release"

17 June 2021, Bologna, Italy (online, Google Meet). Spring lecture: "What's the universe made of? A strong gravitational lensing perspective"

28 June - 2 July 2021, online (Zoom): "Observing the millimeter Universe with the NIKA2 camera"

30 June 2021, Bologna, Italy (online, Google Meet). Talk presented at the Weekly PhD Seminar: "Tracing SMBH accretion density and star formation rate density through cosmic time: the A3COSMOS view"

Seminars of the following series (2020/2021): Astrophysics Talk; Joint Astrophysical Colloquium; IRA online coffee talk; Virtual AstroPizza; QUID ULTRA colloquium; FAME (Friday AGN Meeting)

Internal online meetings: Weekly group meeting; Dusty coffee

## **PhD SCHOOLS**

12-23 July 2021, online (Zoom): "International Summer School on the Interstellar Medium of Galaxies, from the Epoch of Reionization to the Milky Way"

## **INTERNAL COURSES**

30 November - 2 December 2020, Bologna, Italy (online, Zoom) - "The Interstellar Medium"

19 - 23 April 2021, Bologna, Italy (online, Zoom) - "Gamma Ray Bursts: from observations to physical properties"

5 - 14 May 2021, Bologna, Italy ( in presence and online, via Zoom) - "Writing, talking and presenting Science"

## **ISA LECTURES**

19 January 2021, online (Zoom): "Extreme events: how to describe and predict them using mathematical theories (Sandro Vaienti)"

26 January 2021, online (Zoom): "RNA: Biological Functions and Therapeutic Potential (Marco Marcia)"

## **ACQUIRED EXPERTISES**

X-ray data reduction; SED-fitting techniques (CIGALE); python programming; statistical methods for galaxy and AGN evolution (LF, SFRD, BHARD); use of the ex-IASF cluster

## **PUBLICATIONS**

1) - Title: "Compton-Thick AGN in the NuSTAR era VII. A joint NuSTAR, Chandra and XMM-Newton analysis of two nearby, heavily obscured sources"  
(arXiv:2109.00572, accepted for publication on ApJ)

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