PhD Cycle XXXVI

Project Title: *Physical and geometrical properties of the obscuring torus in AGN through X-rays and SED fitting*

Candidate: Dhrubojyoti Sengupta

Supervisor: Prof. Cristian Vignali

Co-Supervisors: Dr. Stefano Marchesi
Prof. Francesca Pozzi

RESEARCH PROJECT[1]

Scientific Background: Most of the Cosmic X-ray Background (CXB) radiation from 1 keV to 100 keV is the result of AGN emission (eg., Gilli et al 2007). Contribution of unobscured AGN to the CXB is almost completely resolved into point-like sources at E<10 keV, while the detection of obscured AGN, which are responsible for a significant fraction ($\sim 40\%$ at the peak) of the CXB emission, is found to be challenging. On the observational side, the Compton-Thick (CT, i.e. those with column density $>10^{24}$ cm^{-2}) AGN fraction (10-20$\%$, Comastri 2004; Ricci et al. 2015) in the local universe is much lower than expected from CXB population synthesis models (20-50$\%$, Gilli et al. 2007; Ueda et al. 2014; Ananna et al. 2019). Therefore, to fill the gap between observations and model predictions, a complete census of obscured AGN is needed at different wavelengths.

Aim of the project: It is commonly accepted that the nuclear obscuration in an AGN-galaxy (at least at low redshift) is caused by the circum-nuclear material of molecular and dusty clouds called "torus", but its geometrical, physical, and chemical properties are far from being accurately known. On that path, I will test the contemporary AGN unification models and the geometry of torus with the latest modeling techniques, to provide an exhaustive picture of obscuration in AGN.

Scientific Study: I am carrying out a comprehensive and systematic analysis of seven obscured AGN candidates in the local Universe ($z < 0.05$) using a twofold approach: firstly, an X-ray spectral analysis of local Seyfert 2 galaxies will be carried out using sensitive E<10 keV observations with Chandra and XMM-Newton, coupled with NuSTAR data at E>10 keV, to examine the properties (i.e., obscuration, covering factor) of the torus from an X-ray point of view over the required broad ($\sim 0.5-50$ keV) energy range. This is being done by using the most up-to-date *MyTorus* (Murphy and Yaqoob 2009; Yaqoob 2012), *borus02* (Baloković et al. 2018) and *UxCLUMPY* (Buchner et al. 2019) models, which allow for a proper geometrical characterization of the obscuring material in the smooth/clumpy configurations. Secondly, the analysis of AGN spectral energy distributions (SED) will be carried out using multi-component models (galaxy, AGN; e.g., Berta et al. 2013). The goal is to infer the torus geometry with its host galaxy properties in the mid-IR, taking into account all of the physical processes and components of AGN. Finally, I will produce a self-consistent multi-wavelength analysis, i.e. a joint analysis combining the mid-IR SED-derived view of the obscuring medium with the X-ray perspective, using X-CIGALE (Yang et al. 2020) and following the approach outlined by Buchner et al. 2019 and Esparza-Arredondo et al. 2020.

Progress Report: I am analysing the X-ray spectra of these seven obscured AGN from the Swift-BAT 100 month volume-limited sample: *MCG-02-12-017, NGC 2788A, NGC 4180, 2MASX J20145928+2523010, ESO 406-G 004, NGC 1106, ESO 138-G 001.* Based on their soft X-ray and BAT spectral fits, these are the last seven CT-AGN candidates from the sample having archival NuSTAR data that have not been published yet. I have currently finished analysing: **MCG-02-12-017** (XMM-Newton and NuSTAR), **NGC 4180** (Chandra and NuSTAR) and **NGC 2788A** (Swift-XRT and NuSTAR) in the soft and hard X-ray bands. Based on the data quality and model fitting, we can classify the objects and their obscuring medium by computing the main spectral parameters like column densities and covering factors along with the soft X-ray emission from the host galaxy. Both **NGC 4180** and **NGC 2788A** fit into the CT-AGN scenario with 'uniform' torus, because their line of sight (los) column density, $N_{H,Z} > 10^{24}$ cm^{-2}, is consistent with the 'global average' column density ($N_{H,S}$) at the 3σ confidence level. They also have equivalent width (EW) > 1 keV for $Fe_{K\alpha}$ line, which indicates strong CT absorption. In case of **MCG-02-12-017**, its $N_{H,Z} \sim 10^{23}$ cm^{-2} is 10 times smaller than $N_{H,S}$, suggesting a 'patchy' torus scenario, where the obscuring material is distributed in dense clouds rather than forming a uniform structure. Overall, this will be an interesting target for follow-up observations with XMM-Newton and NuSTAR to monitor long-term los column density variability and confirm or reject the patchy torus case. Along with these results, the sources show moderate to large covering factors ($\sim 0.67-0.91$), and a luminosity $L_{2-50keV} = (0.5-9.6) \times 10^{42}$ erg/s, which is in agreement with these source being low redshift Seyfert 2 galaxies. In the following months, I will proceed in completing the X-ray spectral analysis of the remaining four sources. The sample of seven sources with X-ray spectral analysis will be the subject of the first paper. Thereafter, I will proceed with SED-fitting techniques and combine it to the X-ray analysis to get a complete picture of these obscured AGN sources, which will be the subject of next publication.

[1] I would like to bring into notice that I arrived in Bologna at the last week of January, and finally get to start my research work from mid-February, 2021.

Workshops, Conferences and Meetings

- August 17-19, 24-26 and 30-September 1, 2021, Chandra X-ray Center (USA), by Zoom and YouTube
  Workshop: Chandra Data Science: Novel Methods in Computing and Statistics for X-ray Astronomy
- September 1-3, 2021, Niels Bohr Institutet (Denmark), by Zoom and YouTube
  Conference: Young Astronomers on Galactic Nuclei (YAGN 21)

PhD Schools

- Not Yet

Internal Schools

- November 30-December 2, 2020, Bologna, Italy, Virtual
  Title: The Interstellar Medium
- April 19-23, 2021, Bologna, Italy, Virtual
  Title: Gamma Ray Bursts: from observations to physical properties
- May 5-14, 2021, Bologna, Italy, Virtual and in-person
  Title: Writing, talking and presenting Science

Seminars

- January 13-July 7, 2021, Bologna, Italy, Virtual
  Name: Weekly PhD Seminar (WPS)
  Title of My Talk: Who is Hiding the AGNs? (June 23, 2021)
- November 10 2020 - present, Bologna, Italy, Virtual
  Name: INAF-OAS
- November 16 2020 - present, Bologna, Italy, Virtual
  Name: INAF-IRA
- February 2 2021 - present, Bologna, Italy, Virtual
  Name: FAME

ISA Lectures

- July 6, 2021, Bologna, Italy, Virtual
  Title of Talk: How positive pedagogy can address mental health and well being of students?
  Lecturer: Dr. Priyank Shukla, Ulster University, UK
- September 28, 2021, Bologna, Italy, Virtual
  Title of Talk: "How the Brain Controls Pain"
  Lecturer: Dr. Mary Heinricher, Oregon Health and Science University, USA

Research Abroad

- Not Yet

Scientific Proposals

- Not Yet

Publication

- "*X-ray Analysis of 7 CT-AGN candidates from a 100 month volume limited sample of Swift-BAT selected sources*" - Sengupta et al. 2021 (In Preparation)