2nd year Ph.D. report - Lorenzo Ferrari Barusso

Ph.D. supervisor: prof. Flavio Gatti.

Research activity:

During this year my research work was part of the Athena project. Athena (Advanced Telescope for High Energy Astrophysics) is an ESA project to investigate the universe in the X-ray band. Measurements will examine the baryonic matter evolution in large scale structures, warm-hot intergalactic medium, as well as in energetic compact objects like Black holes, Gamma ray burst. In order to better comprehend our Universe.

Because most of the baryonic component of the Universe is locked up in hot gas at temperatures of around a million degrees, and because of the extreme energetics of the processes close to the event horizon of black holes, understanding the Hot and Energetic Universe requires space-based observations in the X-ray band. Specifically, the theme calls for spatially-resolved X-ray spectroscopy and deep wide-field X-ray spectral imaging with performance greatly exceeding that offered by current observatories like XMM-Newton and Chandra.

ATHENA consists of an X-ray telescope with a fixed 12 m focal length. The telescope focuses X-ray photons onto two instruments, the innovative X-ray Integral Field Unit (X-IFU), based on cryogenic detectors; and the Wide Field Imager (WFI), a Silicon-based DEpleted P-channel Field Effect Transistors (DEPFET) detector. These two instruments combine the high spectral resolution of X-IFU and the high spatial resolution of WFI to provide the scientific goals, with a measurement spectrum from 0.5 to 10 KeV.

X-IFU is based on 50 mK cooled Transition Edge Sensors (TES), films working around the metal-superconductor transition. These can deliver the necessary energy resolution, while providing exceptional efficiency compared to the dispersive spectrometers flown on the current generation of X-ray observatories. The TES technology has already demonstrated the required spectral resolution (2 eV FWHM) but needs to be developed further to provide this over a large field of view (5' diameter).

My research work is focused on X-IFU, in particular the anticoincidence detector, that is one of the core parts of the instrument. Its scope is the reduction of the signal background of about 2 orders of magnitude. Without it, it shouldn't be possible to disentangle signals from background on the X-ray main detectors. It will be positioned beside the detector just 1 mm apart.

During this year I've managed to carry on the analysis started last year. The study on the fabrication processes and issues of the demonstration model are concluded. This was a crucial step to define the physics and the performances of the device as the functioning is based on the materials film growth. Several detectors have been made and tested and we're now comparing results with the mathematical model of the detector. This to confirm the thermal behavior, for the transient characterization I'm developing a new sample that will be studied in the following year. All of this to reach the TRL5 (Technology Readiness Level) and fulfil Space missions requests. At this step is fundamental to establish all the procedures and have complete control over the physics of the detector. Regarding this, other than all the fabrication processes, I have started the mechanical tests over the structure of the detector. This is a fundamental step over the trade off on the final shape of the detector. The study has been carried on over two different hexagonal shape. One detector with a single monolithical absorber and one with four freestanding independent absorbers. I was able to fabricate the samples thanks to the study made last year on the Silicon deep etching Bosch process, so we have performed vibrational tests simulating the vibration during a rocket launch for a space mission. The study was focused on the resonance modes and the crystalline stability over a 2kHz range at 2G excitation. Both geometries passed the qualifying tests, showing a vibrations amplification factor of approximately 1000. From this basis now new prototypes much more similar to the final detector will be fabricated and tested.

Papers:

- G. Addamo et al. [LSPE collaboration] “The large scale polarization explorer (LSPE) for CMB measurements: performance forecast” JCAP08(2021)008 DOI: https://doi.org/10.1088/1475-7516/2021/08/008 (2021)

- M. Fedkevych, M. Biasotti, M. De Gerone, L. Ferrari Barusso et al. “Direct Search for Low Energy Nuclear Isomeric Transition of Th-229m With TES Detector” IEEE Transactions on Applied Superconductivity. DOI: https://doi.org/10.1109/TASC.2021.3063328 (2021)

- B. Siri, E. Celasco, L. Ferrari Barusso et al. “Impact of Annealing on TC and Structure of Titanium Thin Films” IEEE Transactions on Applied Superconductivity. DOI: https://doi.org/10.1109/TASC.2021.3071997 (2021)

Conferences:

In November I participated to the ASC20 conference:

- Applied Superconductivity Conference ASC20 (https://ascinc.org/)

With the following contribution, in the form of a talk: L. Ferrari Barusso “**Development status of the Cryogenic AntiCoincidence detector for ATHENA X-IFU**”- Wk2EOr2B-03.