X-IFU Filters: Soap Bubbles to Block Undesired Photons

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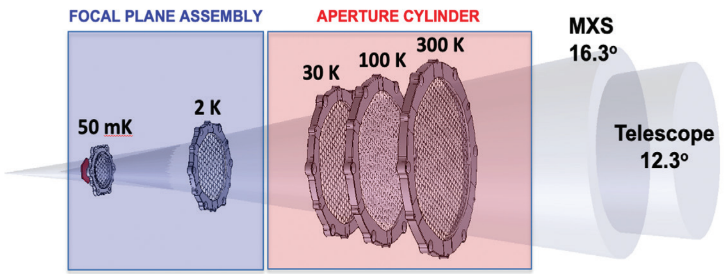

Schematic configuration of the X-IFU thermal filters. The filters operate at different temperatures between 50 mK and 300 K, are located at distances from the focal plane between 15 and 355 mm, and have diameters in the range ~30-130 mm, driven by the aperture cone of the modulated x-ray sources (MXS). Each honeycomb metal mesh has a nominal open area of ~ 98%.

The X-ray Integral Field Unit (X-IFU), an array of X-ray microcalorimeters that will operate at the focal plane of the *Athena* telescope, detects individual X-ray photons by measuring the temperature rise produced by the absorbed energy. In order to accurately measure the energy and arrival time of each detected photon, the X-IFU pixels have sub-millimetric size (low heat capacity), operate at temperatures below 100 mK (low thermodynamic noise), and use very sensitive resistive thermometers based on superconductors operated in the transition between normal metal and superconducting behaviours.

The X-IFU is sensitive also to lower energy photons (UV/Vis/IR) which, though not detected as single events, deposit energy on the absorber increasing the noise. The Photon Shot Noise (PSN), i.e. the fluctuation of energy deposited by low energy photons due to their discrete nature and random statistical fluctuation of arrival times, can cause a significant deterioration of the intrinsic energy resolution.

The main role of the filters that will be mounted in front of the X-IFU detector is, indeed, to reduce the PSN caused by photons emitted by warm surfaces of the instrument and spacecraft (mainly IR), or by astrophysical sources bright in the UV/Vis range of the electromagnetic spectrum. In particular, the X-IFU will have two sets of filters: the first one named "Thermal Filters (THFs)" (responsibility of UNIPA and INAF-OAPA, Palermo, Italy) will be mounted inside the cryostat, and the second one named "Optical Blocking Filters (OBFs)" (responsibility of UNIGE, Geneva, Switzerland) will be mounted on a filter wheel, being optionally selectable for specific science cases. The figure shows a schematic configuration of the THFs stack consisting of five filters, two mounted on the focal plane assembly and three on the aperture cylinder of the cryostat. In the preliminary design, both the THFs and the OBFs consist of a very thin plastic film (50-150 nm thick, slightly more than a soap bubble) coated with a layer of pure aluminium (30-70 nm thick) supported by a honeycomb metal mesh which provides mechanical strength and attenuation in the radio frequency band.

The filters are key elements for the proper operation of the X-IFU, however, though very thin and made of light elements, they cannot be fully transparent to X-rays and thus they define the detector low-energy response (E < 1 keV, down to 200 eV). The greatest challenge in the design of these elements is thus to maximize the X-ray transparency, still provide the required attenuation of the UV/Vis/IR photons, and being strong enough to survive the vibro-acoustic loads during the launch of *Athena*.

Representative breadboards of the THFs and OBFs will be manufactured and tested before April 2022 to support the demonstration of the X-IFU technology readiness, necessary to pass the critical milestone of the Athena mission adoption by ESA. In addition, considering the long timeframe of the *Athena* mission development (launch expected in the early 30s), new filter technologies beside the baseline are being currently investigated to try to further improve the X-IFU detector efficiency, and open new perspectives for future missions beyond *Athena*.