# Development status of Filter Wheel for WFI instrument of ATHENA

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ATHENA is the future X-ray telescope to observe hot and energetic Universe. It has been selected by European Space Agency (ESA) as a second large mission with a launch foreseen in 2031. Polish engineers and researchers were invited to participate in the design and construction of subsystems for both ATHENA instruments. In this paper, we present the procedure and results of acoustic tests of Filter Wheel Assembly (FWA) designed in Poland for Wide Field Imager (WFI). WFI is one of the ATHENA's detector which requires large area thin optical filters of the size never used before in space. The goal of acoustic tests was to check if such optical filters placed on FWA will survive acoustic loads generated during the mission launch. The test's results were very successful, proving that 170x170 mm, a few hundred nm thin optical filters will not be destroyed by acoustic waved in normal pressure conditions, therefore closing WFI in vacuum is not required.

## 1 Introduction

ATHENA is the ESA second large mission (Nandra et al., 2013), which currently succesfully passed Mishion Formulation Review, on the end of phase A. The telescope will consist of a single large-aperture X-ray mirror, utilizing a novel technology (Sillicone Pore Optics) developed in Europe. In case of such a large mirror, the focal plane is located 12m from the mirror ensuring 5 arcsec HEW (Half Energy Width) on-axis angular resolution (Willingale et al., 2013). The focal plane will contain two instruments. One is the Wide Field Imager (WFI) providing sensitive wide field imaging and spectroscopy and high count-rate capability (Rau et al., 2013; Meidinger et al., 2017, 2019). The other one is the X-ray Integral Field Unit (X-IFU) delivering spatially resolved high-resolution X-ray spectroscopy over a limited field of view (Barret et al., 2013, 2016, 2018; Pajot et al., 2018).

ATHENA undertakes three key scientific objectives: i) determine when large-scale hot gas formed in the Universe and how it was trapped in Galaxy Clusters (Barret et al., 2019) ii) determine physical processes responsible for the black hole

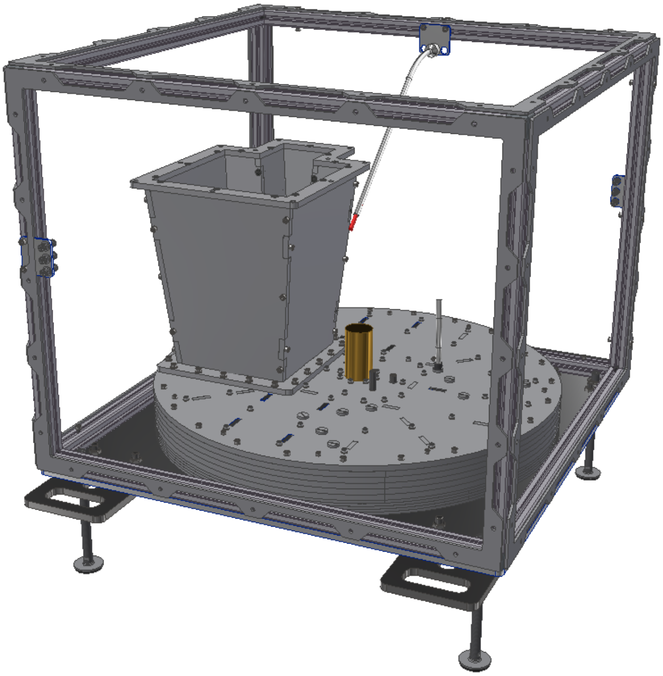

Fig. 1: Model of WFI FWA for Acoustic Tests campaign. On the left side of instrument the stray-light baffle is clearly visible.

growth, and trace energetic and transient phenomena to the earliest cosmic epochs (Barret & Cappi, 2019), iii) explore high energy phenomena in all astrophysical contexts, including those yet to be discovered. Aside from these topics, the outstanding capabilities of Athena as an observatory are expected to make a profound impact in all fields of Astrophysics (Rau et al., 2016), from understanding the structure and energetics of stellar winds and their interplay with atmospheres and magnetospheres of planets, or exploring the behaviour of matter under extreme conditions of density and magnetic fields in stellar binaries and neutron stars (Majczyna et al., 2020), to probing the physics of the enrichment and heating of our Galaxy's Inter-stellar Medium by supernova explosions. This will take a full advantage of ATHENA's synergies with the set of multi-wavelength astronomical facilities then in exploitation (e.g. LOFAR, SKA, ALMA, JWST, ELT, LSST, CTA, to name but a few).

In this paper we present Acoustic Test Campaign results of testing the WFI instrument Acoustic Development Model (A-DM), as shown in Fig. 1. During the tests, optical blocking filters designed in University of Palermo (UNIPA) (Barbera et al., 2018) were mounted on Filter Wheel Assembly (FWA) (Rataj et al., 2016), designed in Poland for WFI detector. Tests have been performed in laboratories of University of Science and Technology (AGH) in Cracow, Poland (Fig. 2). Preparation for tests and the tests themselves took place in cooperation with scietiests and engineers from UNIPA, Max Planck Institute and ESA.


Fig. 2: Left: Assembly process of WFI filter wheel A-DM in Clean Room. Right: Reverberation chamber in AGH LAT (Laboratory of Technical Acoustics), where tests were performed.

## 2 Optical blocking filters for WFI Filter Wheel Assembly

WFI is large area detector with expected field of view $40' \times 40'$, based on a large array of depleted field effect transistors (DEPFET). WFI will provide imagining in the 0.2-15 keV band simultaneuosly with spectrally and time resolved photon counting. The detector is designed to consist of: large detector array (LDA) with $1024 \times 1024$ pixels, and smaller fast detector (FD) with $64 \times 64$ pisels and high count rate to observe very bright point sources. Both detector arrays are based on silicon abosrbers providing high quantum efficiency up to 15 keV.

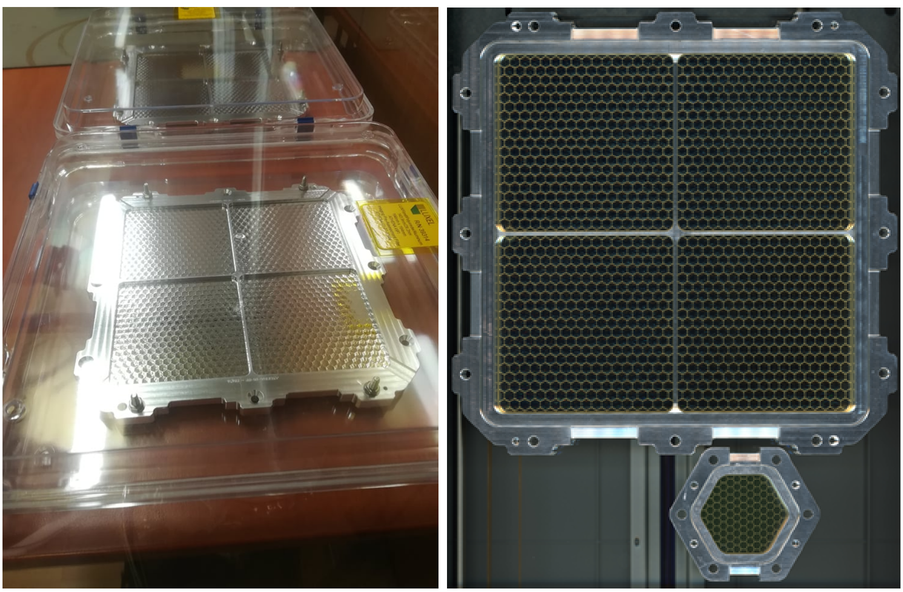

Fig. 3: Optical filters delivered by Marco Barbera from University of Palermo.

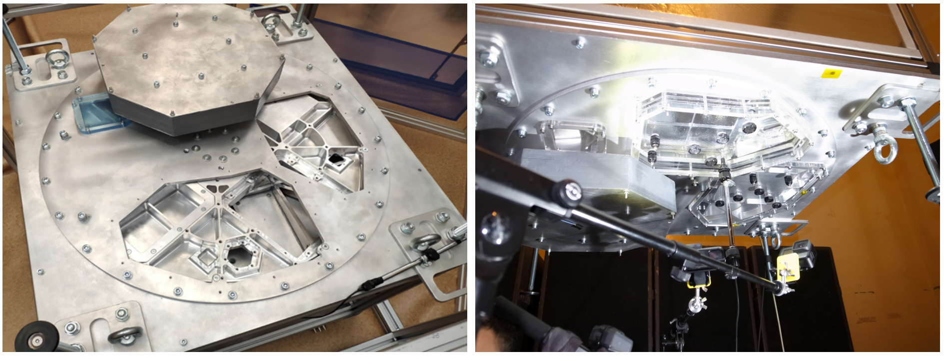

Fig. 4: Left: Acoustic development model (A-DM) of WFI with dummy detector seen on the top of filter wheel. Right: FWA with optical filter mounted in the acoustic chamber.

Optical blocking filters (OBF) are needed to protect detector form UV/Opt photons, since optically generated photo-electrons may degrade the spectral resolution by introducing a signal offset. The use of OBF in front of detector will allow the observation of X-ray sources that present a UV/Opt bright conterparts. The filters designed by Barbera et al. (2018) are very innovative in the sence that they are very thin $< 200$ nm, and very large in size up to $170 \times 170$ mm$^2$ for LDA, and $25 \times 25$ mm$^2$ for FD. Knowing that filters have to survive acoustic and vibration loads during launch, the use of a reinforcing structure to mechanically support the thin aluminized polyimide film has been investigated. Currently the mesh design is tested, but for the purpose of our tests, the shape of honeycomb is adopted, as presented in Fig. 3.

Such filters will be mounted on the FWA developed by Space Research Center (SRC) (Rataj et al., 2016) in Poland. FWA will allow to use filters in seven different positions including close and open position. It will also allow to calibrate WFI detector. The acoustic development model (A-DM) of FWA was build at SRC in Warsaw, and it is presented at the left panel of Fig. 4. The aim of the A-DM is to check whether the proposed technical solutions enable filters to survive the launch phase, during which strong acoustic loads may occur. Tested device mass is approximately 120 kg.

## 3 WFI filter acoustic noise tests

The main goal of the tests was to check if large area thin filters will survive acoustic noise during the launch of ARIANE 6 rocket, which will be used to place ATHENA on the orbit. Tests have been performed in two campaigns. First part is dedicated to *dummy* tests with dummy filter, in which several design variants were tested in order to choose the optimal configuration for further tests. Second part: *main* tests were conducted with target filters specimen in optimal WFI FWA design configuration.

The main outcome of the *dummy* tests was to provide sound pressure level (SPL) on the tested filters and displacements/accelerations of the filter wheel, in order to select optimal design configuration for *main* tests. Results were used for estimating the real load levels on the filters by UNIPA and AGH teams. *Dummy* tests were

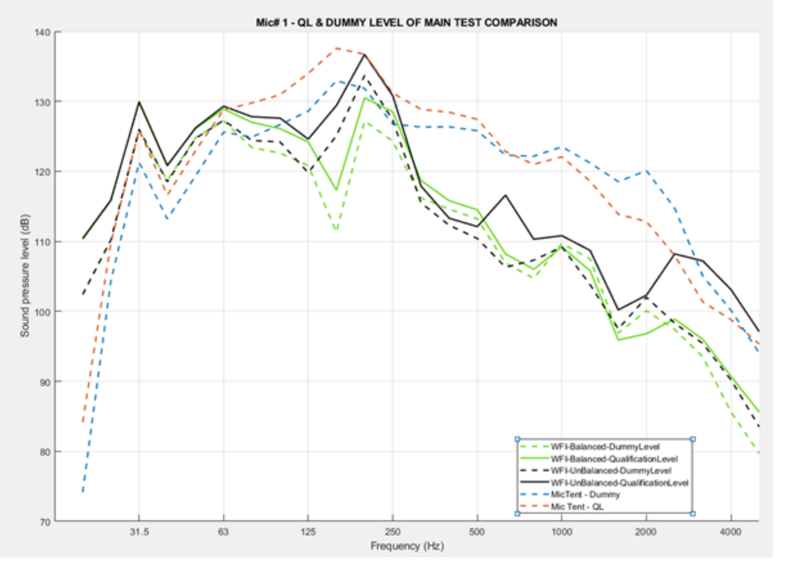


Fig. 5: Example of measurements of accoustic loads in *dummy* and *main* tests for different filter wheel configurations: balanced and unbalanced. Qualification level (QL) for ARIANE racket is also ploted by red dashed line.

named after dummy filter – filter specimen built with thick foil. The main purpose of this test was to check the influence of design variables on SPL on WFI filters area. The main goal of *dummy* test is to find optimal design solutions for *main* test. The criterion for the selections were: i) minimum overall SPL with the assumptions of most conservative microphone positions, ii) minimum acceleration on the FWA frame, iii) the minimum peak differential pressure.

The WFI Main Filter acoustic noise tests were performed in AGH two weeks after *dummy* tests. The purpose of these tests was to check the WFI filters strength under qualification level (QL) (for ARIANE racket) of acoustic load excitation generated in the acoustic chamber.

## 4 Results and conclusion

The results of the measurement of acoustic loads *dummy* and *main* tests are given in Fig. 5. During the *dummy* test optimal configuration of DM was found as an input to *main* tests. Furthermore, the data on the behavior of the structure during changes of its elements have been collected, which are of key importance for the investigation of propagation of acoustic waves in the instruments.

Results of *main* tests clearly shown that filters can survive both in balanced and unbalanced configuration of the FWA, which is beneficial for further design development of WFI. The unbalanced configuration presented much worse sound pressure levels compared to balanced. It was not observed during *dummy* test campaign. The impact of filters thickness is visible above 1500Hz. During last stage of tests the acoustic load were increased until filters have been damaged, which allowed to measure limit acoustic load, up to which filters are safe.

The acoustic test results ensured us, that the FWA mechanical design is correct to prevent thin, large area optical filters to survive during the ATHENA launch. This means that we do not have to close WFI detector in the vacuum, which is very costly operation and requires the complete change of the instrument design. Currently FWA is redesigned to be fully ready for the next test, which will be the vibration test held in the Max Planck Institute, Munich, Germany.

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