X-IFU Aperture Cylinder and FPA Filters

Marco Barbera\textsuperscript{1,2}, A. Collura\textsuperscript{2}, F. Gatti\textsuperscript{3}, U. Lo Cicero\textsuperscript{2}, C. Macculi\textsuperscript{4}, T. Mineo\textsuperscript{5}, L. Piro\textsuperscript{4}, L. Sciortino\textsuperscript{1}, S. Sciortino\textsuperscript{2}, S. Varisco\textsuperscript{2}, ..... 

1 - UNIPA/Dipartimento di Fisica e Chimica, Palermo, Italy
2 - INAF/Osservatorio Astronomico di Palermo G.S. Vaiana, Palermo, Italy
3 - UNIGE/Dipartimento di Fisica, Genova, Italy
4 - INAF/Istituto di Astrofisica e Planetologia Spaziale, Roma, Italy
5 - INAF/Istituto di Astrofisica Spaziale e Fisica Cosmica, Palermo, Italy

and the ATHENA Italian Consortium
OUTLINE

• Quick intro on X-IFU Aperture Cylinder and FPA Filters

• Assessment Phase 0-A1 On-going Activities

• Assessment Phase A1-A2 Activity Planning
Filters in the X-IFU Functional Block
Why X-IFU needs Filters

1) Radiation Heat Load
   The cryostat provides a cooling power of approx 1 µW at the cold stage to dissipate conduction heat load and detector bias power. The IR radiation from the cryostat thermal and structural shields provides an additional heat load.

   **Radiation Heat Load < 1 % of Conduction Heat Load and Bias Power**

2) Photon Shot Noise
   The micro-calorimeters are also sensitive to photons at lower energies than X-rays. Although the detector does not trigger on individual low energy photons, the statistical fluctuation of the absorbed energy during the detection time interval, can introduce a degradation of the energy resolution of the detector (photon shot noise).

   **Photon Shot Noise < 0.2 eV FWHM**

3) EMI (up to 10 GHz)
   Cryostat shields should also operate as Faraday cages to protect the detector from EMI coming from the read-out electronics and spacecraft environment (telemetry).

   **Attenuation level TBD**
Baseline Design

The baseline design adopted in the ATHENA proposal, based on the IXO-XMS study, consists of 5 identical filters with a total of 2800 Å of polyimide and 2100 Å of aluminum with integrated Polyimide support meshes 10 µm thick (93% open area) on the two outer and larger diameter filters.
ASTRO-H 5 filters: Polyimide 4600 Å + Al 4000 Å total, Si mesh on three filters

X-IFU – Baseline 5 filters: Polyimide 2800 Å + Al 2100 Å total, mesh 93% on the two outer filters

The low energy response of the X-IFU is essentially defined by the AC and FPA filters
**Ongoing activities: Design Optimization**

A more efficient design, currently under investigation, consists of 5 identical filters with a total of 2250 Å of polyimide and 1000 Å of aluminum. The two outer and larger diameter filters are supported by an Al lithographic mesh 2 μm thick with > 93% open area.
On-going Activities: Simulations

IR transmission

Radiative power onto the detector array
Thermal modeling of the filters inside the cryostat (COMSOL multiphysics)

Ray tracing (mesh imaging, filter tilt angle)
On-going Activities: Material Investigations

Thin foil (Polyimide, Si$_3$N$_4$)

Si$_3$N$_4$ membranes
Mesh open area 85%,
Filter diameter 100 mm, thickness 650 Å
[Courtesy of HS foils, Finland]

Si$_3$N$_4$ membranes
500 Å thick can also be built with
diameter up to 20 mm mesh-less, or larger than 50 mm with mesh.
[Courtesy of LUXEL, USA]
Mesh for the larger diameter filters (Al, Si, Polyimide)

**Lithographic Si**
- **Support mesh:** 200 µm thick, 3.2 mm pitch
- **Fine mesh:** 8 µm thick, 200 µm pitch
- **Mesh Open Area:** 93%

![Lithographic Si](image1)

[Mc Cammon et al., JLTP (2008) 151, 715–720]

**Lithographic Al**
- **Fine Mesh:** 8 µm bar width, 1.4 µm thick, 200 µm pitch
- **Mesh Open Area:** 92.4% (Optical Measurement)

![Lithographic Al](image2)

[Courtesy of LUXEL]
On-going Activities: Test samples procurement

1. 45nm Polyimide / 20nm Al film, supported by Al lithographic mesh, with ID > 50mm.
   - Mesh to have nominal 92% transmission (Optical Measurement)
   - Mesh Pitch = 200 microns
   - Calculated Mesh Bar Width = 8 microns
   - Mesh Bar Thickness = 1.4 microns

2. 45nm Polyimide / 20nm Al film, meshless, with ID < 50mm.

Witness filters (taken from same lots as Item 1 and 2) mounted on ring frames with ID < 10 mm for Synchrotron X-ray transmission measurements and IR transmission measurements.

Witness filters (taken from same lots as Item 1 and 2 on) mounted on solid frames for X-Ray Photoelectron Spectroscopy and Atomic Force Microscopy.
Assessment Phase 0-A1 Activity Planning

Main Activities

Performance simulations
- Thermal modeling to derive temperature profile on each filter at equilibrium.
- IR transmission, Radiative load onto detector and NEP
- EM attenuation (Al foil and mesh)

Material investigation
- Thin foil (Polyimide, Si$_3$N$_4$, ...)
- Mesh type (Al, Si, Polyimide, ...)

Samples procurement

Preliminary tests
- X-ray transmission - XANES and EXAFS vs. T
- Aluminum oxidation (EXAFS and XPS)
- IR transmission vs. T
- EM shielding (< 10 GHz) at T=300 K and T < 1.2 K (TBV)

Required Inputs

Thermal/Mechanical IF (Cryostat, Aperture Cylinder)
Required EM attenuation in X-band
**Main Activities**

- Filters and Frames preliminary design
- Inspection, handling and storage procedures (procurement/construction of shipment boxes, storage cabinet, handling tools, ...)
- **Filters procurement** (1 set representative of the current flight design + witness samples)
- **Test measurements**
  - Environmental: cooling, vibration, ageing (e.g. atomic oxygen, micro-meteoroids, TBC)
  - Vis/IR transmission, XPS, AFM, ...
  - X-ray transmission
- DM filters and frame design
- DM filters procurement (2 sets + witness samples)
- Visual Inspection
- Shipment for integration in the DM
- Test measurements on back-up filters and witness samples

**Required Inputs**

- Thermal/mechanical IF
- EM attenuation in X band
- Vibrational load

**Technology Development**

- Q1-2016
- Q4-2016
- Q1-2017
- Q3-2017

**DM Development**

- TBC
- Not covered in present budget
Lithographic Aluminum fine mesh

Example of previously built lithographic Al Mesh by LUXEL:

Mesh Bar Width = 1.5 µm
Mesh Pitch = 24 µm
Mesh Bar Thickness = 0.306 µm
Open Area = 88%

Proposed Al Mesh:

Mesh Bar Width = 10 µm
Mesh Pitch = 600 µm
Mesh Bar Thickness = 2 µm
Open Area = 95%

Model predicts the proposed mesh raises the burst strength of 50 nm polyimide by > 2X