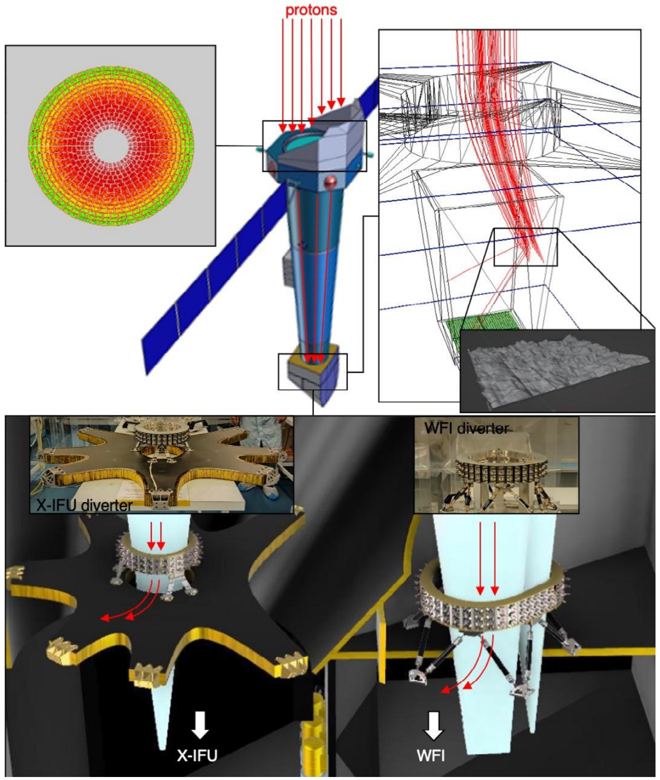
A magnetic broom for sweeping protons off the *Athena* focal plane

Valentina Fioretti

Osservatorio di astrofisica e scienza dello spazio di Bologna - INAF, Italy



Simulated proton distribution at the mirror exit (top-left). Simulated proton deflection of the WFI diverter (top-right) with an example surface roughness model for secondary proton scattering evaluation. Design of the novel X-IFU and WFI proton magnetic diverters (bottom). Credits: ESA, Masaryk University, LK Engineering and Frentech Aerospace.

Low-energy charged particles can emulate the grazing angle reflection of X-ray photons by scattering on the mirror surface into the focal plane. The resulting increased non-X-ray background can have a serious impact on the performance and efficiency of an observatory like *Athena*.

The shielding solution adopted in past X-ray missions to avoid the collimation of trapped electrons is the use of magnetic diverters. These devices are composed of a set of permanent magnets that together deflect protons and electrons outside the field of view of the instruments. What came as a surprise after the launch of XMM-*Newton* is that low-energy protons (< hundreds of keV) populating the interplanetary space can also scatter towards the focal plane, causing hits in the detectors that are difficult to be distinguished from real X-ray photons without large losses in observation efficiency.

The ESA-funded AREMBES and EXACRAD projects, led by INAF, provided a pioneering study of the in-orbit low-energy particle environment and the physical processes behind the proton scattering, building blocks of the simulation of the proton scattering at the *Athena* mirror and the residual background at instrument level. The result is that the minimization of the proton focusing effect is indeed mandatory for *Athena*, posing a new technological challenge on the path to fulfilling the mission science objectives. Due to the heavier particle mass, a magnetic diverter for protons requires in fact a 40 times higher magnetic field strength to achieve the same deflection than for electrons!

An ESA Technology Demonstrator Activity (TDA) to design the *Athena* charged particle diverter kicked off in 2018, driven by requirements for maximizing deflection efficiency, minimizing the residual magnetic field at instrument level, and minimizing total mass. While previous electron diverters were placed at the rear mirror aperture in the spider shadow, the novel technology of the *Athena* magnetic diverter creates a semi-monodirectional deflection for both protons and electrons with the use of modified Halbach arrays at the detector side. The design foresees a circular array of 30 magnets at 80 cm on top of the X-IFU and a pear shape array of 36 magnets at 60 cm on top of the WFI to enclose both the Large Detector Array and the Fast Detector. The total system mass, including a 20% margin, is 46.2 kg. The diverter manufacturing was successfully completed and environmental tests are currently being performed.

The field measurements implemented in the trajectory simulation show compliance with the deflection requirements (100% below 66 keV for X-IFU and 76 keV for WFI), but simulations also predict a potential secondary scattering of the deflected protons on the diverter walls and on focal plane assembly surfaces (e.g. baffles). To minimize this scattering, additional saw-shaped structures and vanes will be applied to exposed surfaces. In the meantime, proton scattering measurements on representative surface samples are being performed to ensure scientific performance.