Enabling soft gamma-ray focusing with Laue lenses

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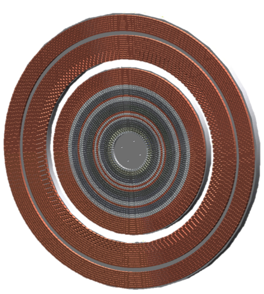
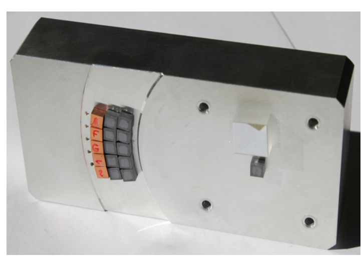
Sensitive observations in the sub-MeV domain have the potential to achieve several high-priority goals in astrophysics, including determining the origin and evolution of Type Ia supernovae, understanding the physics of exploding massive stars (Type II supernovae), constraining the origin of Galactic positrons, determining the role of novae in nucleosynthesis, and probing the regions near black holes where jets are formed. A sensitivity leap of two orders of magnitude is required in the soft gamma-ray domain to address these questions. Observations in this domain are hampered by intense instrumental background in detectors, which limits the sensitivity of current telescopes. Building bigger detectors is a costly solution as sensitivity only (roughly) scales with the square root of the detector surface. A Laue lens telescope allows the decoupling of the collecting area from the sensitive area, dramatically increasing the signal-to-noise ratio and hence the sensitivity [1].

A Laue lens is based on Bragg diffraction within a large number of crystals (in transmission geometry) arranged so that they all diffract towards a common point. The concept works from ~80 keV to ~1 MeV, being limited by absorption at the low end, and decreasing reflectivity at the high end. Bent silicon crystals are promising for energies up to the positron annihilation line (0.511 MeV), including Ni-56 lines at 0.158, 0.269 and 0.480 MeV, perhaps even allowing a two-reflection Wolter I geometry that would enable true imaging at ~30" angular resolution [2]. At higher energies, pure metal mosaic crystals (e.g. Cu, Ag, Pd, Rh) are the most efficient, reaching ~20% reflectivity [3]. In this case, the lens is a single reflection concentrator, which still has huge advantages for point sources with known positions (<1', e.g. supernovae, novae, AGN). Laue lenses are chromatic by nature, which makes them best suited for observations of emission lines [4]. However, broad band coverage with moderate effective area is possible as well. Typical focal lengths range from 5 m to 30 m, which can be realized using a deployable mast (e.g. NuSTAR [5]). An ideal focal plane instrument is a Compton camera, which takes full advantage of the imaging capabilities of the lens and allows efficient background (e.g. Nuclear Compton Telescope [6]).





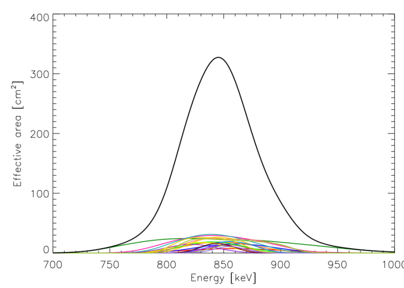


Figure 1: *Left:* Drawing of a full Laue lens (diameter: 1 m). *Middle:* Prototype made of 3 sections of concentric rings using 5x5 mm^2 copper and silicon crystals [7]. The rays arrive from the back of the aluminum substrate, go through it before being diffracted by the crystals. *Right:* Effective area of a Laue lens designed to observe the 847 keV line from Type Ia SNe. Each color curve represents the contribution of one crystal ring. In this case, 32 concentric rings were used with a focal length 30m. The ratio of effective area to focal spot area is about 140.

References:

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