Observing Bright Sources with the Athena-WFI

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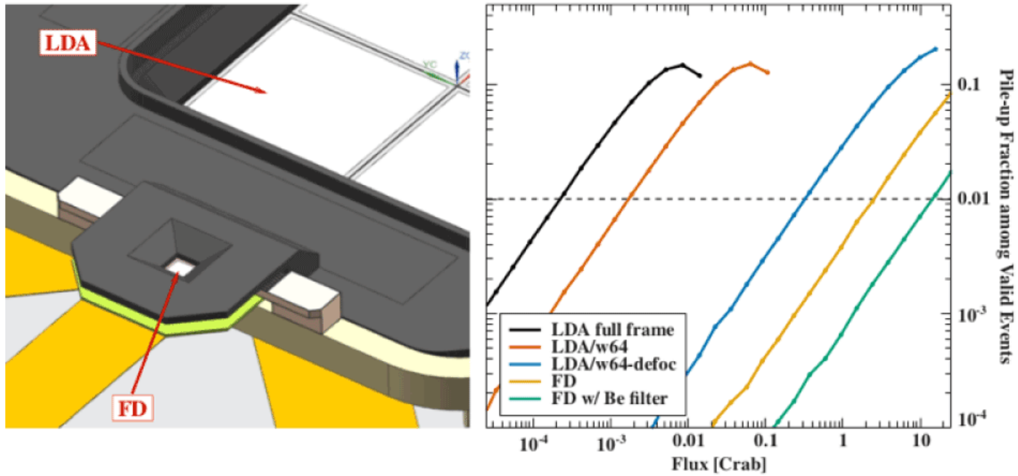
Most X-ray binaries are transient with week to months long, bright outbursts. Their observations allow us to study how accretion flows change with mass accretion rate, a physical question interesting for both Galactic and extragalactic accreting objects (timescales for accretion scale with mass, the relevant timescales in AGN are too long to observe the switch on and switch off of an accretion flow in the lifetime of a single astronomer).

At their peak such outbursts can exceed the brightness of the Crab pulsar, i.e., Athena's instruments will have to cope with rates above 100000 counts per second (even the Crab reaches a brightness of more than 2 Crab during the peak of its 33ms pulse).



Left: Schematic drawing of the Fast Detector (FD) next to the Large Detector Array (LDA). Right: Fraction of events influenced by pile-up for a Crab-like X-ray source for different detector configurations (w64: 64-row window mode). Usable spectra are obtained for less than 1% pile-up (dashed line). Credit: WFI Team

At high count rates, nonlinear effects can distort our measurements. For the Wide Field Imager (WFI), the important processes are "pattern pile-up", "energy pile-up", and "intraframe splits". As a photon interacts with the detector, the number of electrons in the charge cloud created by the incident photon is proportional to its energy. The charge cloud is collected in a readout anode. The readout operates in a "rolling shutter" mode: pixels in one detector row are read out, while all other rows continue to collect X-rays. If more than one photon hits a single pixel between two readouts, the individual photons' energy cannot be recovered. The deposited charge is interpreted as that of a single photon with a higher energy ("energy pile-up"). Secondly, as the charge cloud size is comparable to the pixel size, charge from a single photon can be deposited in adjacent pixels. Such "split events" are recombined during data processing. As the charge pattern of two photons hitting adjacent pixels during one readout cycle can not be distinguished from a split event, the measured charge is again erroneously assigned to a single, higher energy photon ("pattern pile-up" or "grade migration"). Finally, a photon hitting the pixel while it is read out will also distort the energy reconstruction as a "intra frame split".

The severity of all types of pile-up events is count rate dependent. For observations of bright sources, it is therefore mandatory to achieve readout frequencies that are significantly higher than the expected count rate. The frame rate of the WFI Large Detector Array (LDA) limits it to fluxes of ~0.1mCrab. Reading out only part of the WFI in a window mode allows to reach a maximum source flux of ~1mCrab. To observe brighter sources, the WFI will have a Fast Detector (FD) which is mounted beside the LDA. Mounted 3.5cm offset from the focal plane, the point source image is defocused and read out in two halves simultaneously at a frame time of 80 mus. In combination, these effects allow the FD to observe sources up to 2Crab, keeping the 1% pile-up limit. An additional Be filter is currently under study which would allow even sources above 40 Crab to be observed pile-up free. This filter would remove photons below 2keV without affecting the diagnostically important iron band.