Time distribution in the *Athena*/WFI

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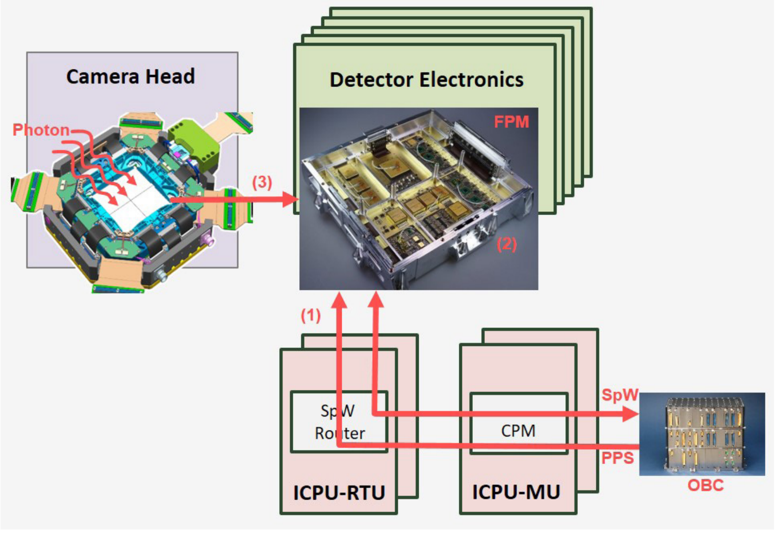

WFI Architecture showing the three main contributors to the timing distribution: (1) Time delays and jitter between the onboard computer (OBC) and camera detector electronics (DE), (2) Internal delays in the DE, and (3) Delay between the photon capture and the time stamping in the DE. The OBC photo is from Herschel Planck (source ESA). Photo credits: WFI DE FPM, J. Reiffers (MPE).

A former classmate, when finishing his physics degree, told me that he had no idea what "time" was. He knew that it was a negative sign in a tensor. Luckily, as a "slow-moving creatures like engineers", I have not to deal with these definitions (*cited from "A first course in general relativity", Bernard F. Schutz*). Yes, this nugget is about time. But, which "time"? Let's say for simplicity, the "time" that "engineers" use.

The time distribution problem within the *Athena* spacecraft appears simple. Ground operations (Earth) synchronize its time with the *Athena* onboard computer, and the WFI instrument synchronizes its own time with that of the onboard computer. The WFI needs a synchronized time with the onboard computer for housekeeping (e.g., time stamps of temperature measurements in the filter wheel) and for science operations. Housekeeping time constraints are low. We will focus here on the scientific observations.

In brief, the WFI instrument is composed of a DEPFET detector, instrument electronics to control the detector, and additional electronics units to communicate with the spacecraft onboard computer. The science requirement for the absolute knowledge error (AKE) of the WFI timestamp relative to the onboard computer clock is <5μs (3σ). This performance is needed to, e.g., enable sufficiently accurate cross-correlation of WFI observations with those obtained with other observatories. A good example here are the observations of pulsars, i.e., rapidly rotating magnetized neutron stars.

The three main contributors to the *Athena* timing distribution are: (1) Time delays and jitter between the onboard computer and Detector Electronics (DE), (2) Internal delays in the DE, and (3) Delay between the photon capture and the time stamping in the DE. The first contributor is the most critical and two solving methods are identified. The first method uses only the timecode of the SpaceWire (SpW) communication network, and the second method uses a combination of pulse-per-second (PPS) signal and SpW network.

The SpW network standard has been established relatively recently and a few missions such as ESA's Solar Orbiter use it exclusively for time distribution. In theory SpW can achieve a <5μs AKE, but its inherent non deterministic nature, the usage of a SpW router and the need to use the same physical channel for science data transmission make it challenging to achieve the necessary accuracy in a realistic operational scenario.

MPE has heritage using the PPS method in other space missions but what is novel for the WFI is the combination of SpW and PPS signal to overcome the challenges posed by clock oscillator's drift. In the WFI, the clock oscillator's drift is corrected via software for each PPS pulse. Applying this method reduces the time delay to a value of the order of nanoseconds, more than satisfying the demanding requirement of <5 μs.