TES-based microcalorimeter for future X-ray astronomy missions

Software development for instrument calibration

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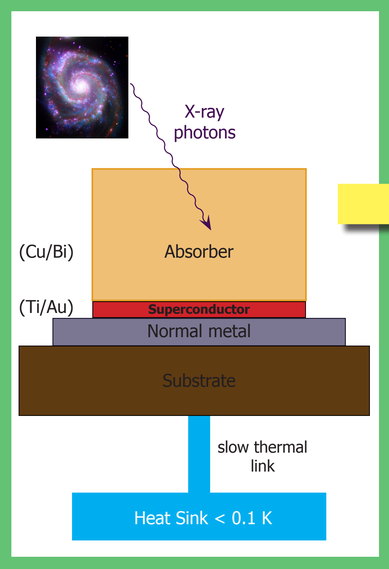
The XMS (X-ray Microcalorimeter Spectrometer) is an instrument prototype with imaging capability in X-rays and high-spectral resolution. This instrument is a microcalorimeter based on transition edge sensors (TES). As part of the Spanish contribution to the advancement of the XMS, we present the work carried out by the X-ray astronomy group at the Instituto de Física de Cantabria in collaboration with The Netherlands Institute for Space Research. Our main task involves the development and testing of software for this prototype with the purpose of instrument calibration, X-ray pulse detection and energy resolution calculations.

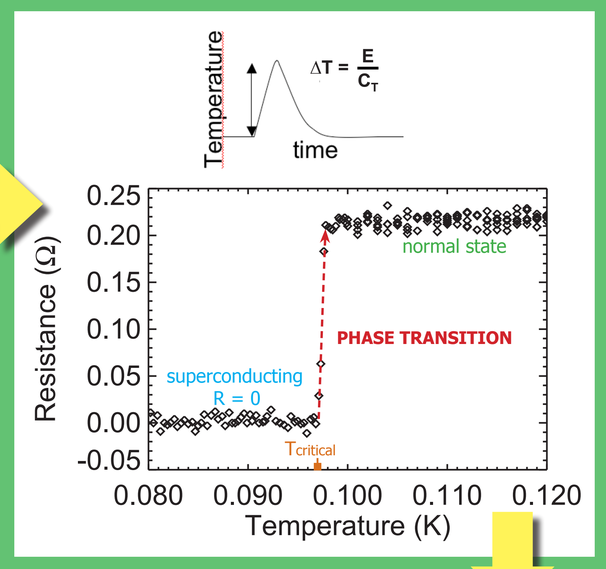
The Instrument

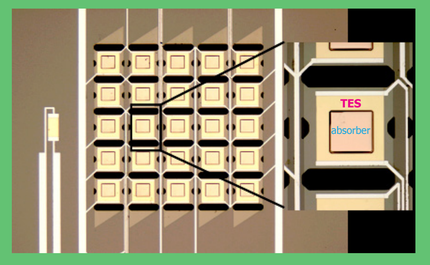
The **XMS microcalorimeter** can gauge the energy of absorbed radiation by converting it into heat. The energy of an incoming X-ray photon can be determined by measuring the rise in temperature of the absorber. This temperature increase is directly proportional to the energy of the photon.

A **Transition Edge Sensor (TES)** is used because it acts as an incredibly sensitive "thermometer" due to the abrupt phase transition from the superconducting state to the normal state, where the resistance changes from 0 to a finite value within a temperature range of very few mK. The TES is cooled to <100 mK and biased in its transition.

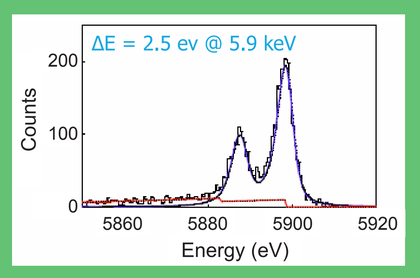
The TES is coupled to a super-conducting quantum interference device (SQUID) in order to read out the signal (ie. pulses in current).

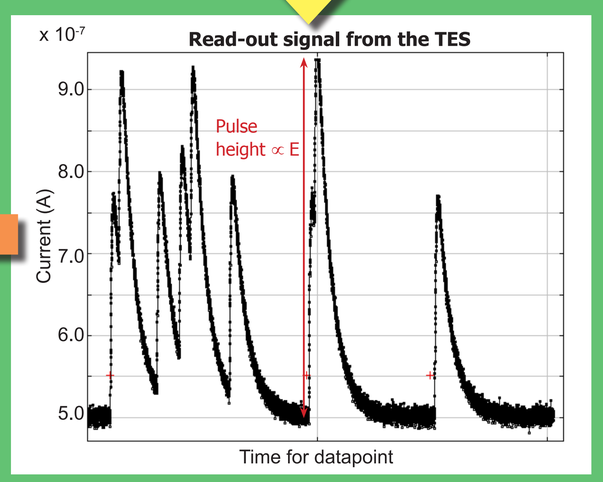






5x5 pixel array with Ti/Au TES of 150x150 μm²

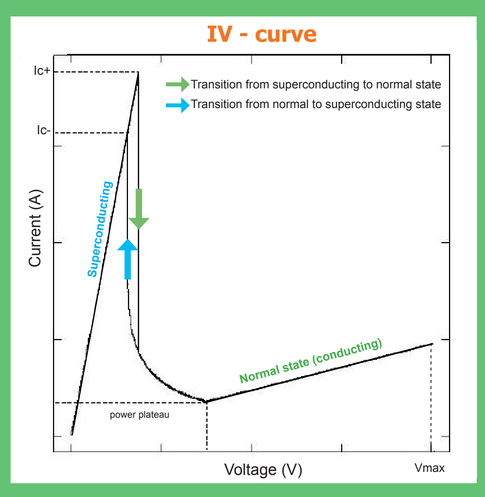


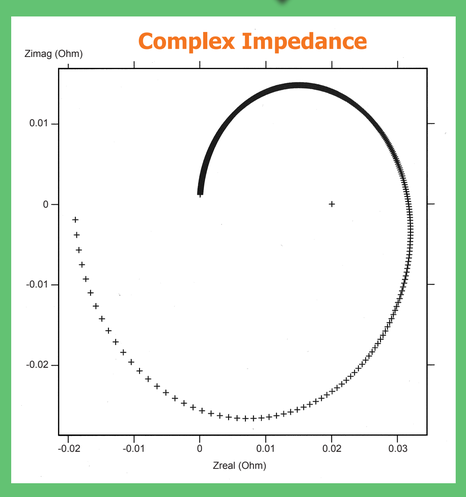


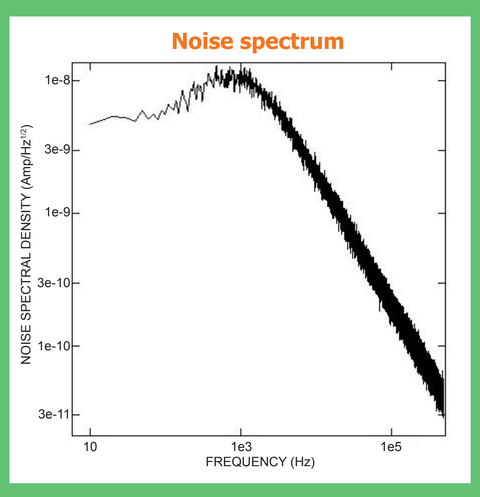
The Software

Consists of a series of processing chains developed to carry out the **detection of pulses** and to **characterize** & **calibrate** the instrument, more specifically aiming to:

- Calculate the **energy resolution** of the instrument by analyzing the pulses resulting from X-ray photons hitting the detector.
- Obtain characteristics of the **IV-curve** (current vs. voltage).
- Calculate the **complex impedance** of the TES.
- Analyze the **noise spectrum** of the TES.

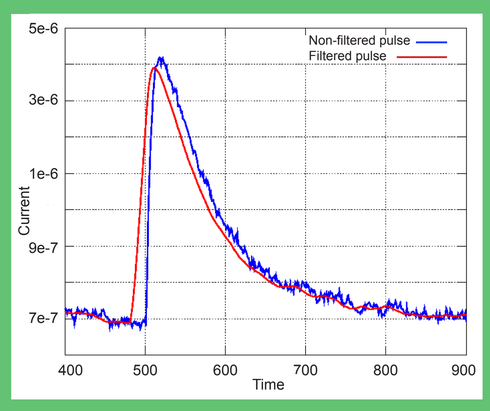


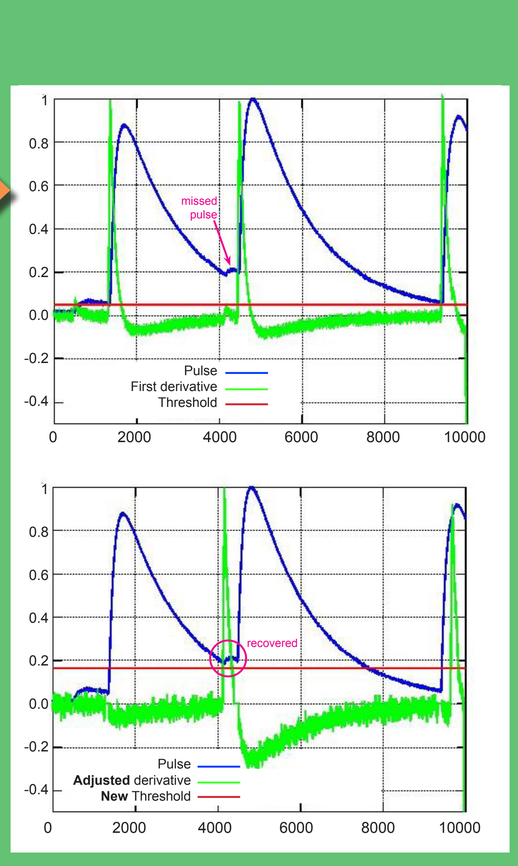




Pulse Detection

- The input data consists of values of current I(t) vs. time (t).
- The data is **low-pass filtered** (using a box-car function) to eliminate noise.
- Using the **1st derivative** of the filtered data provides a much more sensitive way to handle pulses that are piled-up.
- An initial threshold value is set to look for single pulses.
- An **adjusted 1st derivative** and a new threshold level are used to search for secondary pulses.
- Finally, the pulse detection task calculates the initial & end times of ALL pulses in an event.





Science with the XMS

The XMS instrument, because of its excellent spectral resolution (2.5-3 eV at 6 keV) has the **potential to carry out breakthrough science** in the field of astrophysics. Those contributions as described in past proposed space missions (IXO/ATHENA) with this instrument as payload would further our understanding of:

- **Cosmic Feedback processes** involving the energy outflow from supermassive black holes and of the surrounding hot medium in galaxy bulges, groups and clusters.
- **Missing baryons & the detecting WHIM lines** both in emission, and in absorption against a bright background source.
- **Cluster physics & evolution.**
- **Chemical evolution through cosmic** time by measuring the abundances of all elements from C to Zn in the hot intracluster medium of clusters.
- **Map the abundance patterns of Supernova Remnants.**
- Reveal the physical **nature of gas and dust in the diffuse interstellar medium** of our Galaxy, via absorption features imprinted on the X-ray spectrum.
- **Interactions of space plasmas** and magnetic fields by giving us deeper insights into the complex workings of planetary magnetospheres and exospheres.

References

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