SISWICH INSTRUMENT SPECTRAL CALIBRATION OPTIMIZATION: SISCO

E. J. Marchesini[1], A. Sharma[1,2], R. Campana[1], S. Srivastava[1], E. Borciani[1], G. Dilillo[3], G. Della Casa[3], F. Ceraudo[3], Y. Evangelista[3], P. Calabretto[1], E. Virgilli[1], C. Labanti[1]

[1]INAF-OAS, via Piero Gobetti 101, Bologna, 40129, Italy
[2] Dipartimento di Fisica e Astronomia, Uni. Padova, via F. Marzolo 8, Padova, 35131, Italy
[3]INAF-IAPS, via del Fosso del Cavaliere 100, Rome, I-00133, Italy

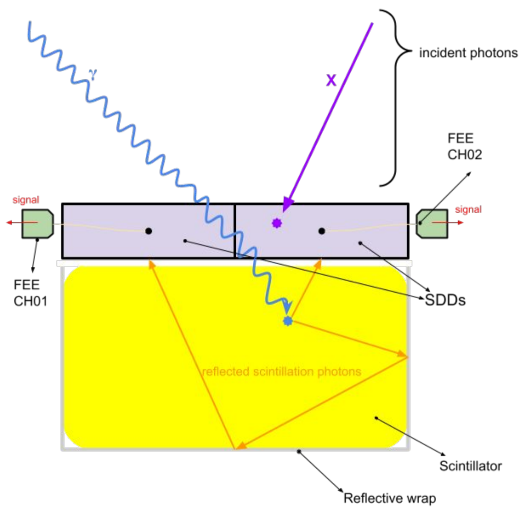


Figure 1: A diagram detailing the double-detection mechanism of a typical siswich detector.

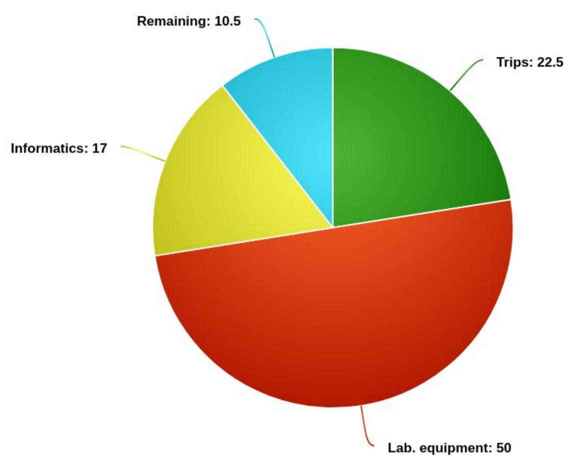
Current and future space telescopes, such as HERMES, THESEUS, and ALBATROS, implement a new radiation detector technology **that is able to detect both X-rays and γ-rays (2 keV up to 20 MeV), unprecedented in astrophysics.** This instrument concept is called **"Siswich": Silicon-Scintillator Sandwich.** Thus, a new spectroscopic calibration standard must be developed for this technology, including an accurate statistical analysis of the influence any calibration errors or uncertainties may have on the resulting scientific data. The interest in this broadband technology impacts on open questions in the field of gravitational waves, on the identification of new γ-ray sources, on the physical process behind GRB prompt emission, and on the study of high-energy AGNs, particularly blazars.

While most astronomical detectors work with only one detection principle, the **siswich detectors exploit two**: the SDD as a direct X-ray photon detector, and the scintillator as an indirect gamma-ray detector (see Fig. 1). This "double detection"' mechanism yields a broad sensitivity energy range from 2 keV to 2 MeV (with can be extended up to 20 MeV, depending on the architecture). **The SISCO mini-grant project aims at developing a standard calibration procedure for siswich detectors, and at analysing the impact the calibration model of choice has on the scientific data output.**

A new data-reduction and calibration pipeline was already created, called **MESCAL** (her**MES** **CAL**ibration pipeline), and is already published in the literature [1]. See also related poster for more details. In this poster, we present the ongoing work that expands on the initial scope of the MESCAL pipeline, focusing on analyzing the changes in non-linearity of the scintillator and its dependence on temperature, as well as measuring the relative flux in the mid-region between the SDD and scintillator sensitivity curves to create a compound sensitivity function.

SISCO, step by step

90% of the SISCO budget has already been executed



Avg. time between buying and receiving items ~5 months

The main steps in the ongoing SISCO tests are:

1. Test equipment setup
2. Data acquisition @ room temperature
3. Data acquisition @ thermal chamber
4. Data analysis

1. Test equipment

We set an HERMES-like detector [2] at our laboratories @ OAS-INAF Bologna. The original proposal included the testing of a THESEUS [3] prototype, but this prototype is still being used for testing by the THESEUS collaboration.

The TE setup consists of several power supplies, a pulser to simulate input photons with electric pulses, and a Digilent Analog Discovery device that works as both an oscilloscope and digitizer. The board has been put into a safety isolated box. Several plastic pieces were designed ad-hoc and 3D printed to hold the GAGG:Ce crystals in place (see Fig. 2).

With the setup in place, we proceeded to test the functionality and performance of the instrument.

Several impulses were acquired with a variety of ASIC configurations (threshold, shaper/stretcher, OR acquisition mode). Ad-hoc software was built to analyse the data.

The instrument proved to be still functioning properly, at least for 10 channels, with linearity being consistent at 98% between 2 and ~40 keV, which is in line with expectations.

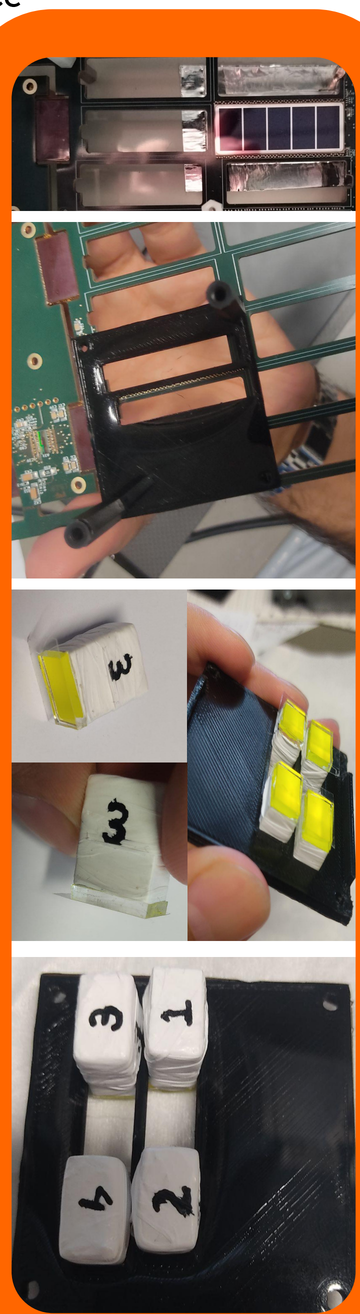


Figure 2:

The HERMES-like detector setup. First, the board was set into a protective box for safety *(first panel)*. An ad-hoc plastic holder was designed and printed to hold the scintillators in place *(second panel)*. Then, the GAGG:Ce scintillator crystals were cleaned, wrapped up with reflective paper, covered with teflon for isolation, and stuck in place with the holder and a pad of adhesive silicon, to flatten out imperfections and help the overall optical contact of the crystal with the SDD *(third panel)*. Finally, the four crystals were numbered for reference *(fourth panel)*.

2. Data acquisition @ room temperature

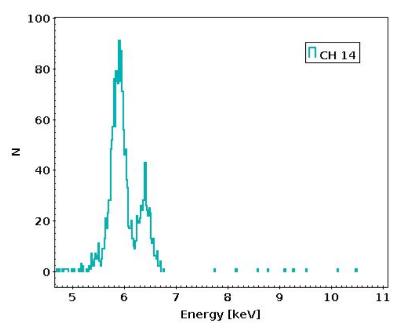


Figure 3: Fe55 spectrum acquired for SISCO.

We acquired a spectrum of the Fe55 source, in order to find the Mn Kα and Kβ lines, located at 5.89 and 6.49 keV, respectively. The resulting resolution is good enough to distinguish clearly both emission lines (Fig. 3).

We also acquired spectra of Am241, Ba133 and Cs237, which will be used for calibration later on.

3. Data acquisition @ thermal chamber

The plan for the following tests consists of:

1. Acquiring another set of Fe55, Am241, Ba133, Cs237 and Na22 spectra with more statistics to avoid adding uncertainty to the data analysis.
2. Acquiring the same set of data under a thermal cycle ranging from 20°C to -20°C, in steps of 10°C.

4. Data analysis

We aim at two different analyses, to be done with the same set of data, which will be the main component of a peer-reviewed publication::

1. Building a compound sensitivity function of the siswich detector, focusing on the range between ~30 and 100 keV. We plan on measuring the relative number of photons detected by each channel per bin of energy, and then find via regression models which function can best describe the output of the detector. This function will be useful when accounting for mixed events in the calibrated output data.
2. We will build a light yield curve for our GAGG:Ce scintillators, which will be compared to the one published in [4]. We will also compare the results obtained at different temperatures. Since the scintillators used in SISCO are the same that have been used in [4], we will test whether there is an effect on the light output due to aging, and/or due to changes in temperature.

CONCLUSIONS

IMPROVED CALIBRATION FOR SISWICH DETECTORS

ONGOING TESTS ON MIXED EVENTS AND GAGG:CE LIGHT OUTPUT

REFERENCES:
[1] Dilillo et al. 2024, A&C 46, 100797
[2] Fiore et al. 2020, SPIE 11444, 1R
[3] Amati et al. 2022, SPIE 12181, 26
[4] Campana et al. 2023, NIMPA 1056, 168587

Contact us:
ezequiel.marchesini@inaf.it

THE MINI-GRANT WAS ESSENTIAL, GIVING US POSTDOCS A CAREER-CHANGING CHANCE TO LEAD OUR OWN PROJECTS. WE FULLY SUPPORT THIS SCHEME FOR EXPANDING ACADEMIC HORIZONS!

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