Sensor Testing for DarkNESS

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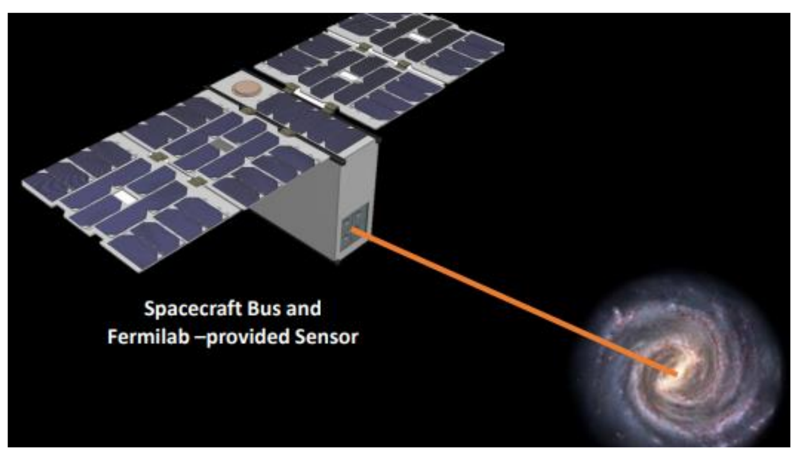
DarkNESS

DarkNESS is a mission with the objective of making X-Ray observations of the Milky Way's galactic center. It will use CCDs to search for a 3.5 keV signal that may be a signature of dark matter decay.



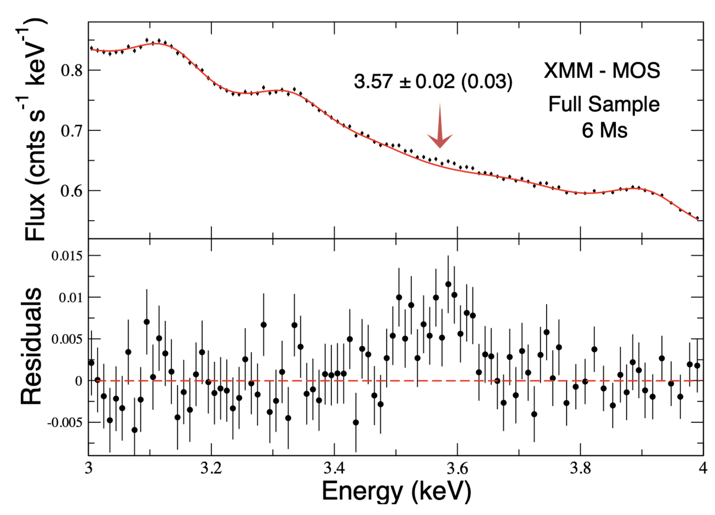


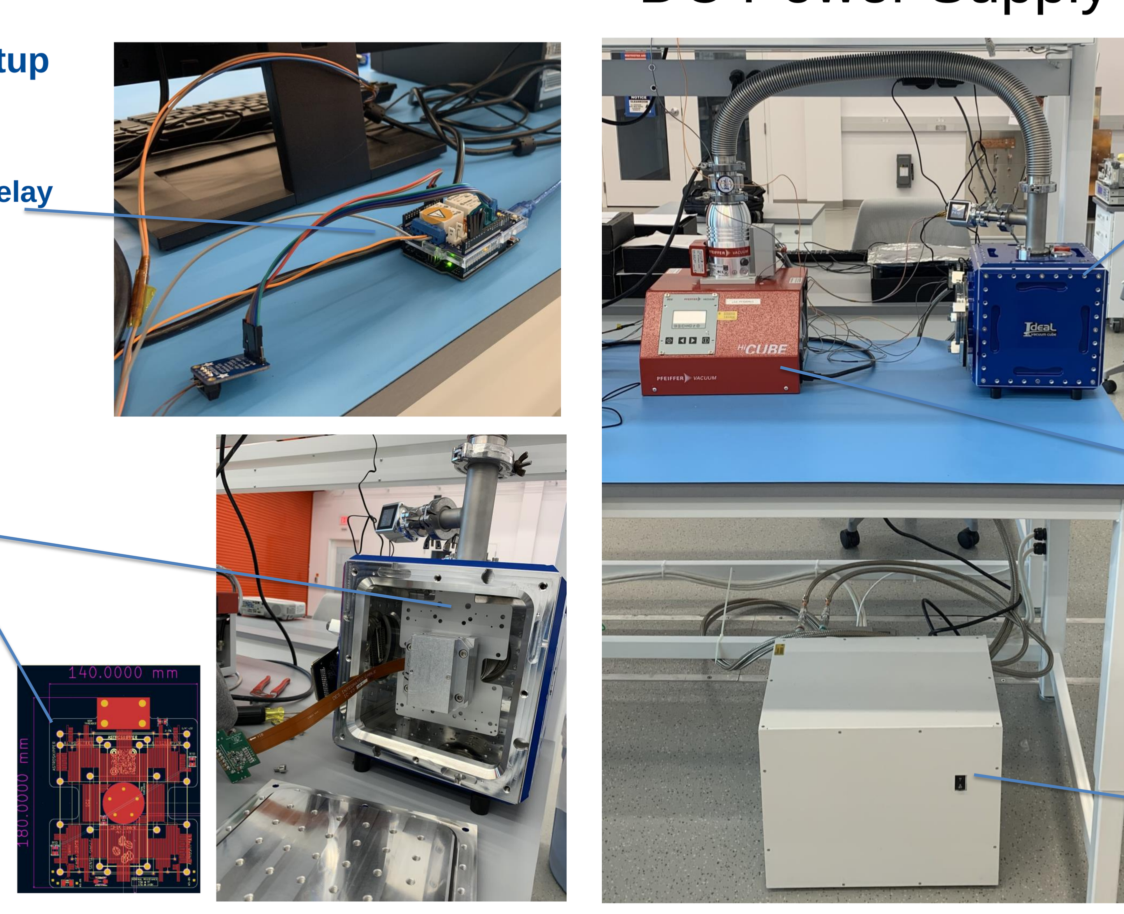
Fig. 1 DarkNESS satellite (left), keV signal (right)

Goal

Build a sensor test station using the following components:

- Vacuum Chamber
- Integrated Heater PCB
- Space LTA (Low Threshold Acquisition Electronic)
- Temperature Controller
- High Vacuum Pump
- Pressure Sensor
- Cryo Cooler
- Charge-Coupled Device (CCD)
- Temperature Sensor
- DC Power Supply

Fig. 2 Lab setup



Temperature Controller Theory

- Pulse Width Modulation (PWM) is a way to control analog systems using a digital output. Using a digital device, a sine wave can be created switching a signal between off and on.
- A Proportional, Integral, Derivative (PID) is a closed-loop control scheme that uses the error between the current output and the desired setpoint to compute a desired output.

$$u(t) = K_p e(t) + K_i \int_0^t e(t)dt + K_d \frac{d}{dt} e(t)$$

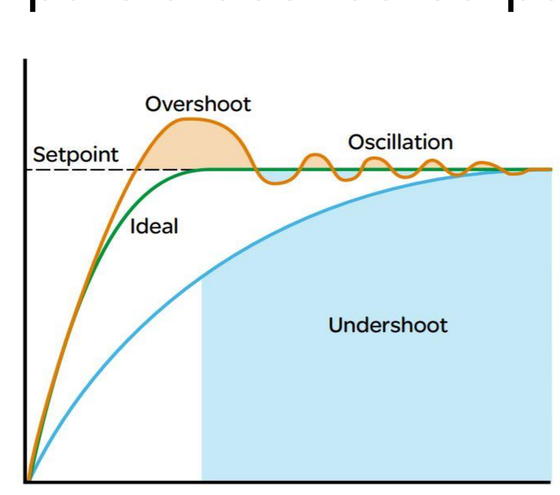


Fig. 3 Ideal control using PID (theory)
(https://www.eurotherm.com/auto-tuning-pid-control-in-a-plc/)

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Implementation and Results

The PID controller was applied using an Arduino UNO for processing and Arduino 4 Relay Shield to control the actuator, which has a 50W heater. C++ was used for programming the Arduino and the digital PID was implemented through this formula:

$$\text{Heater Power} = P(T - T_s) + I \int_{t-5}^{t} (T - T_s)dt + D(T - T_s)\frac{d}{dt}$$

Fig. 4 (left) shows the performance of the controller. After setting -80℃ as setpoint the temperature stabilizes, oscillates then keeps steady. The right plot shows the monitoring of the pressure when vacuum pump is turned on.

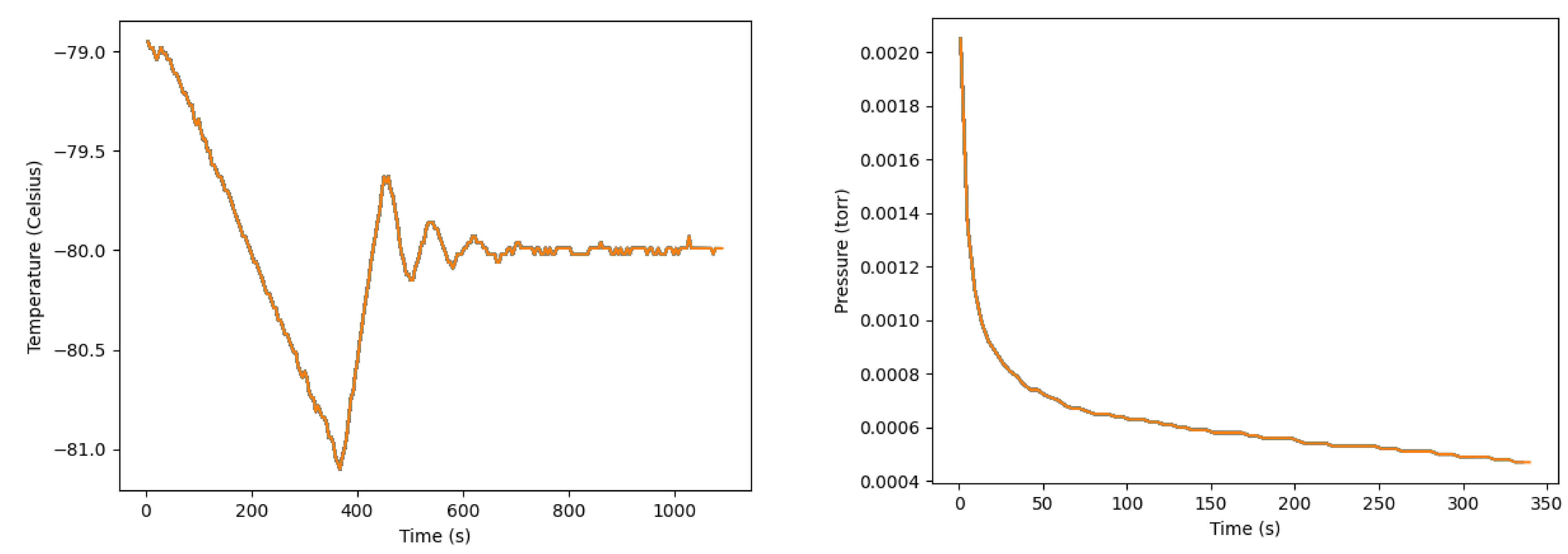

Fig. 4 Real-time Temperature (left), Real time Pressure (right)

The system maintains a steady temperature with the heater being fed 30 V DC. The size, cost and performance of the controller makes it an ideal solution for DarkNESS. It performed within the requirements and an image was taken using the station as shown (Fig. 5). Here cosmic rays are observed.

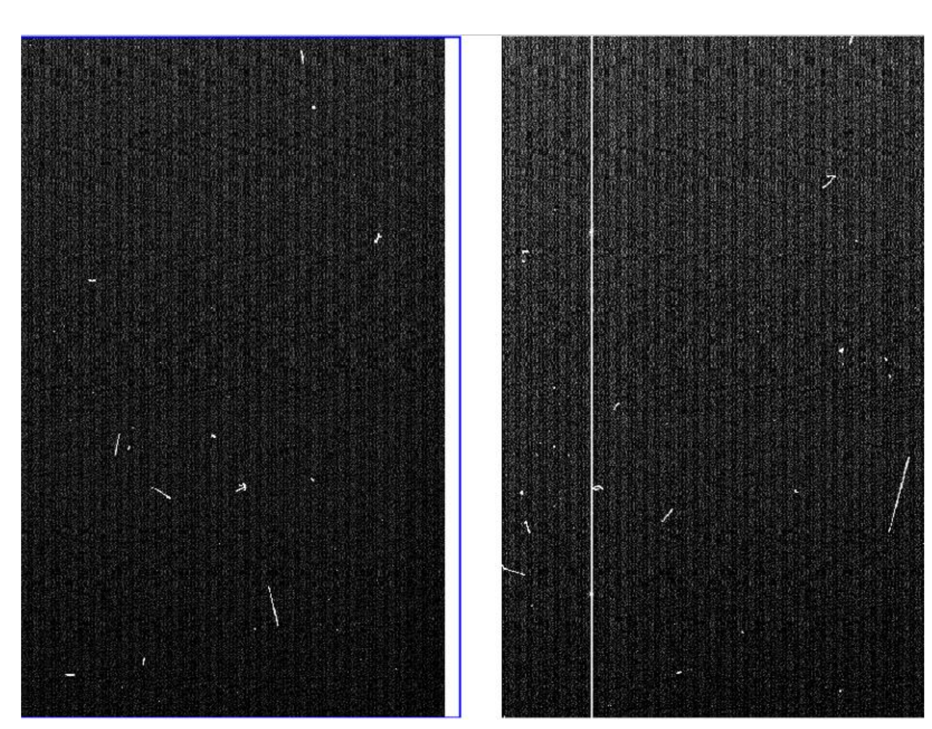

Fig. 5 Cosmic Rays inside vacuum cube

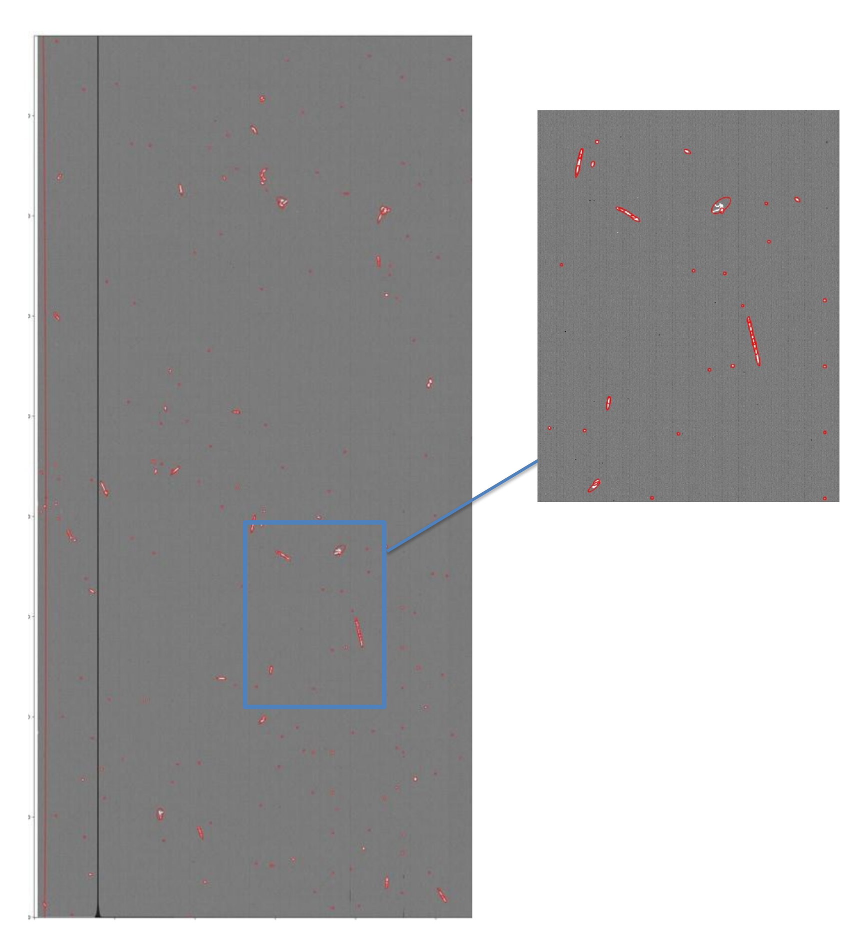

Fig. 6 Particles identified by jupyter code

Conclusions/ What's Next?

- A PID temperature controller was successfully implemented as well as a python script for real-time monitoring.
- An autotuning method needs to be applied optimize the PID parameters for any system.
- Temperature controller is yet to be tested when using the Space Multi-CCD module package.

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