Excellence Cluster Origins
Technical University of Munich

ComPol - A Compton polarimeter in a Nanosat

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Scientific motivation

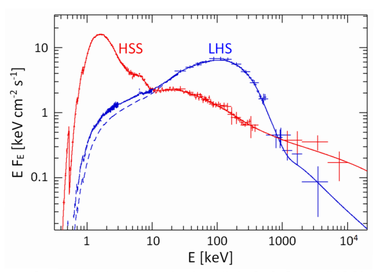
What will be observed?

Hard X-rays from the black hole binary system Cygnus X-1 in two measurement modes.

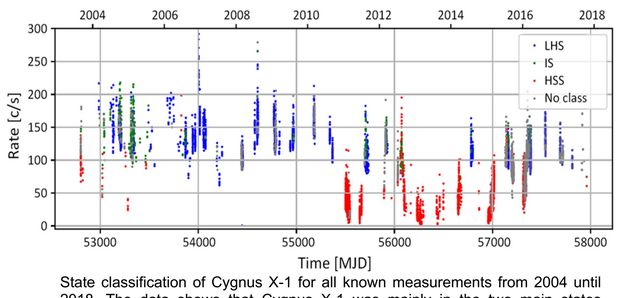
Spectroscopy
(20 keV – 2 MeV)

Open questions:
- Geometrical difference between the main states?
- What causes state transitions?

Approach: *new!*
- Continuous observation



Cygnus X-1 spectra in the High Soft State (HSS) and the Low Hard State (LHS)
Paredes, Josep M. et al. "Gamma Rays from Compact Binary Systems." AIP Conference Proceedings (2008)



State classification of Cygnus X-1 for all known measurements from 2004 until 2018. The data shows that Cygnus X-1 was mainly in the two main states LHS/HSS (blue/red), and sometimes in an intermediate state (green) or it could not be classified
F. Cangemi et al., "High energy spectral study of the black hole Cygnus X-1 with INTEGRAL", SF2A, 2018

Polarimetry
(20 keV – 300 keV)

Open questions:
- How is the geometrical structure?
- X-ray production mechanism?

Approach: *new!*
- Explore hardly studied energy range

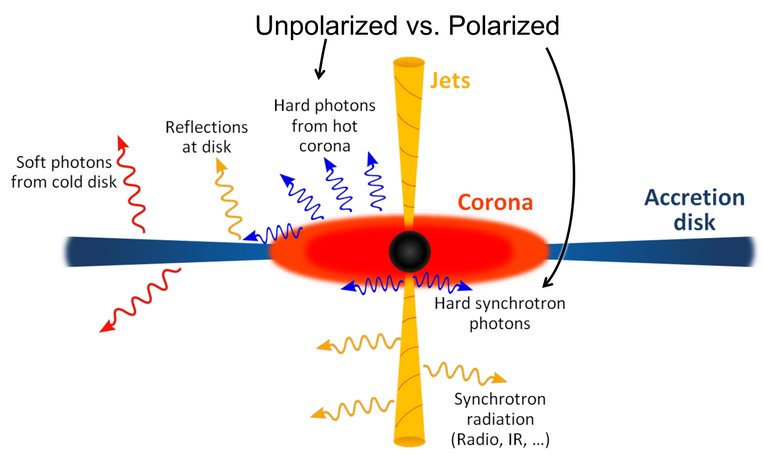
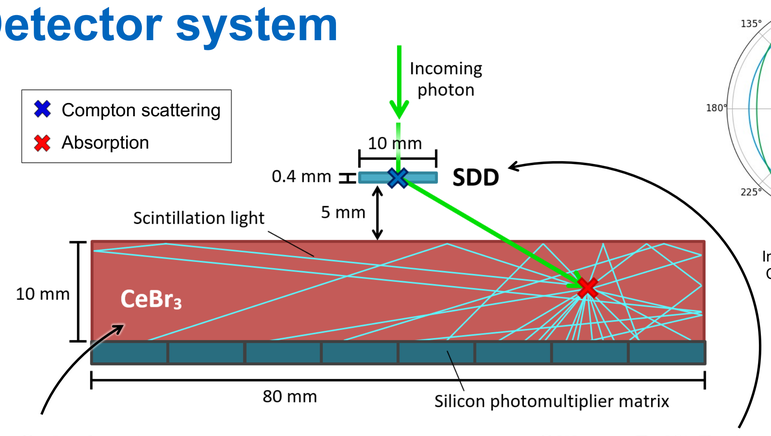
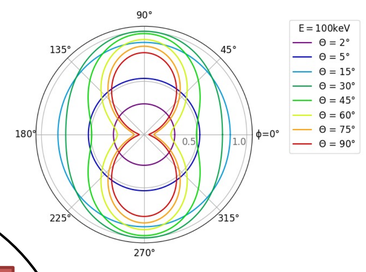


Illustration of the geometry and the possible X-ray emission mechanisms of Cygnus X-1.

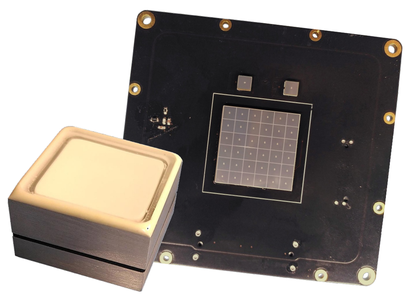
Detector system





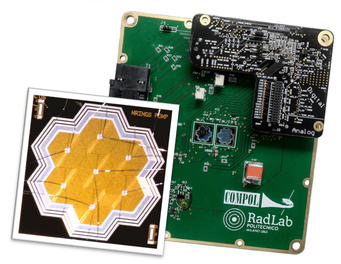
Incoherent Scattering Cross section (barn)

Calorimeter
- Scintillating crystal: $CeBr_3$
- Silicon photomultiplier matrix on the backside



ISS Prototype Calorimeter

Silicon Drift Detector
- Developed for KATRIN/TRISTAN (Neutrino mass experiment)
- Excellent energy resolution (300 eV @ 20 keV)

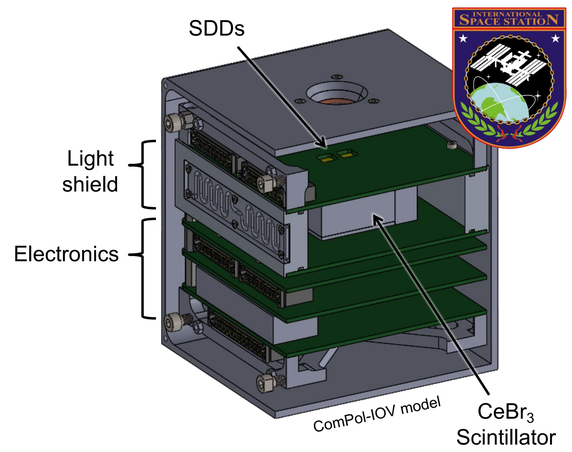


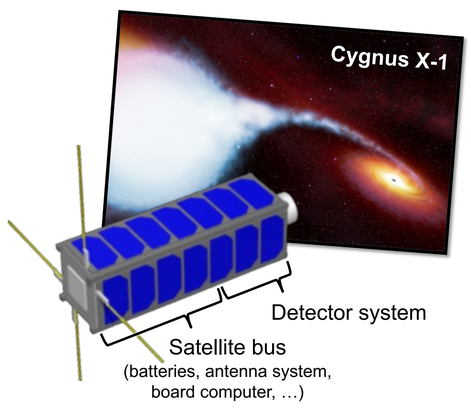
ISS Prototype SDD

Project schedule

In-Orbit Verification
- Mounted on the outside of the ISS
- Mission duration: > 6 months
- Launch date: summer 2024
- Mission goals:
  - Demonstrate functionality
  - Long term operation in LEO
  - Evaluate data acquisition routines
  - Background studies

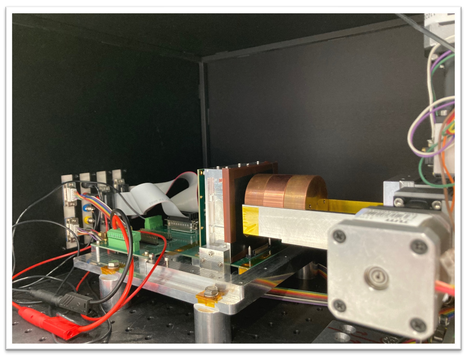
Nanosatellite mission
- 3 Unit CubeSat (10x10x34 cm^3)
- Mission duration: > 12 months
- Launch date: > 2024
- Mission goals:
  - Continuous, long-term pointing at Cygnus X-1
  - Spectroscopy
  - Polarimetry





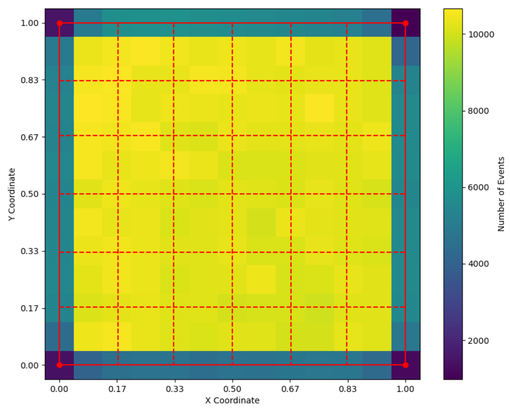
Position calibration

Measurement
- Calorimeter imaging in a 13x13 grid
- Using an ^{241}Am (60keV) source
- Utilize a copper collimator with a 1mm aperture
- Record coordinate data with light distributions for training a neural net



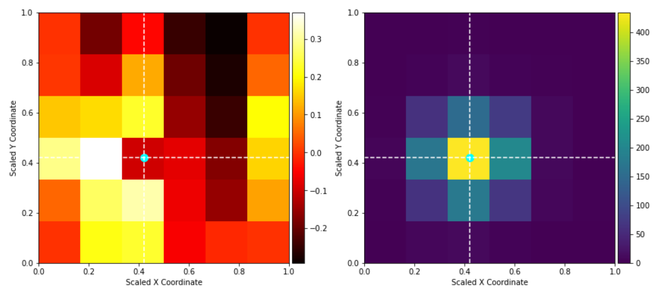
Experimental Setup for Calibration

Motivation
- Reconstruct event positions with high precision
- Assess the distribution of the azimuthal angle for detailed analysis
- Compute the degree of polarization to determine emission mechanism of Cygnus X-1



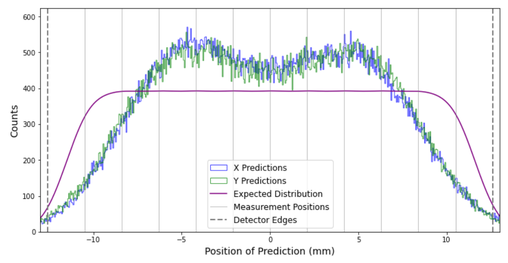
Number of taken Events per Coordinate

First results
- Multilayer Perceptron with three hidden layers
- Achieved position resolution of 3.6 mm
- Enhanced predictive accuracy at the center (2.5 mm)

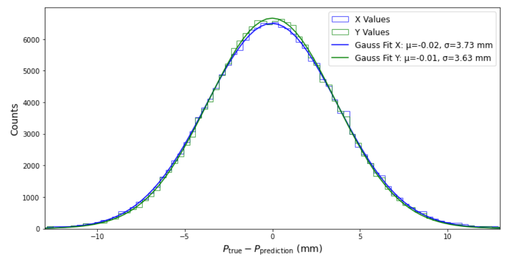


Averaged Input Values for specific Coordinate

Model Predictions for specific Coordinate



Model Predictions and expected Distribution from Measurement



Difference of Model Predictions and True Values

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