Soft X-ray polarimeter-spectrometer SOLPEX

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Motivation

Reliable detection of X-ray polarisation provides unique, yet unexplored tool of studying non-isotropic distribution of particles in the solar corona

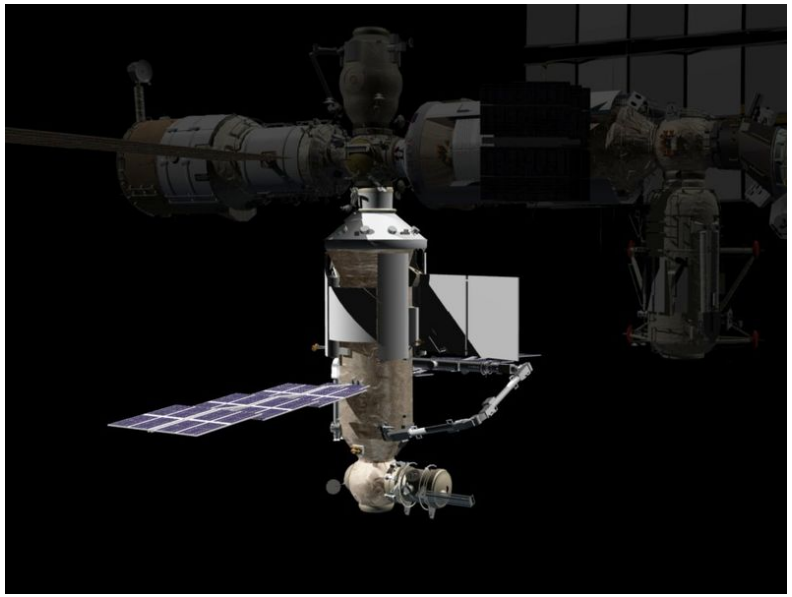
Ubiquitous presence of collimated non-thermal electron beams during flare impulsive phase is indispensable in order to explain observed patterns of hard X-ray flare emission

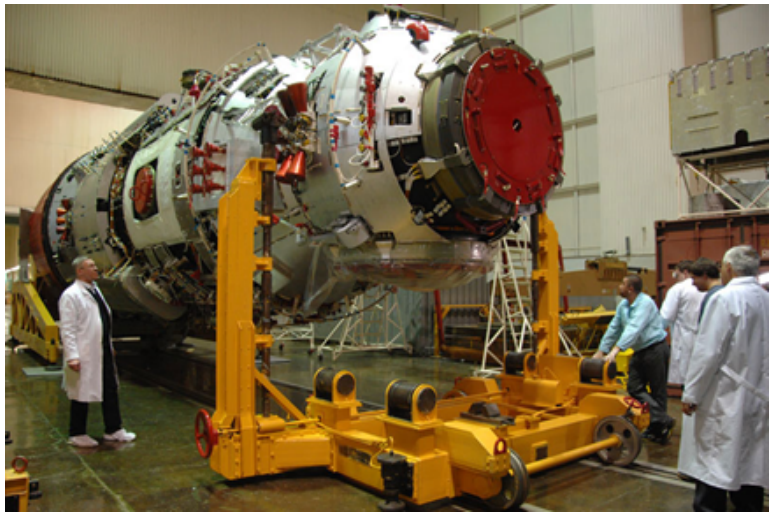
The X-ray polarization measurements have unique potential to constrain processes leading to the electron beaming and define the orientation of magnetic field loops with respect to line of sight

ISS Nauka module

Nauka (Russian: Нау́ка; lit. Science), also known as the Multipurpose Laboratory Module (MLM) or FGB-2, (Russian: Многофункциональный лабораторный модуль, or МЛМ), is the major Russian laboratory module which will take the place of Pirs.

SUN-pointing platform will be attached to NAUKA





MLM Nauka module arrives to RKK Energia's KIS test facility in Korolev on Dec. 14, 2012.
Credit: RKK Energia

Is ISS a good observing platform?

Easy access to ISS, instrument mounting by cosmonauts

Possibility of using large instruments

No substantial limitation on power

Large volumes of data storage on „popular” media

Possibility of „repairs” and memory module transport to the ground

Rough Pointing- few arcmin due to ISS motions

Spacecraft day/night shifts (16 nights/24h)

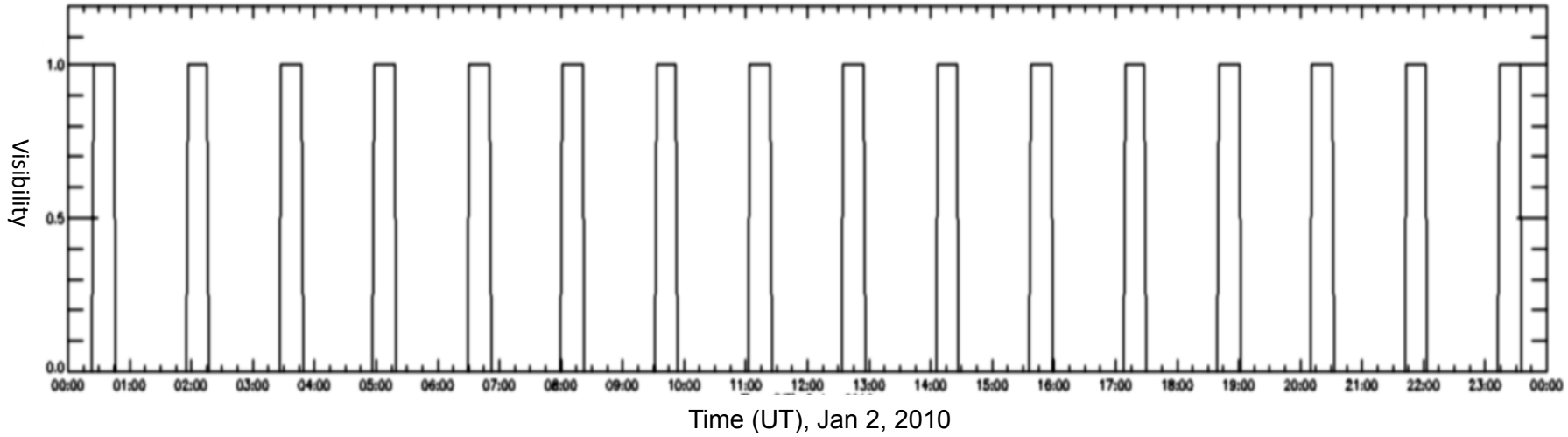
Vignetting by various ISS structures: only ~10 min of uninterrupted measurements per orbit possible

Sun visibility from Nauka

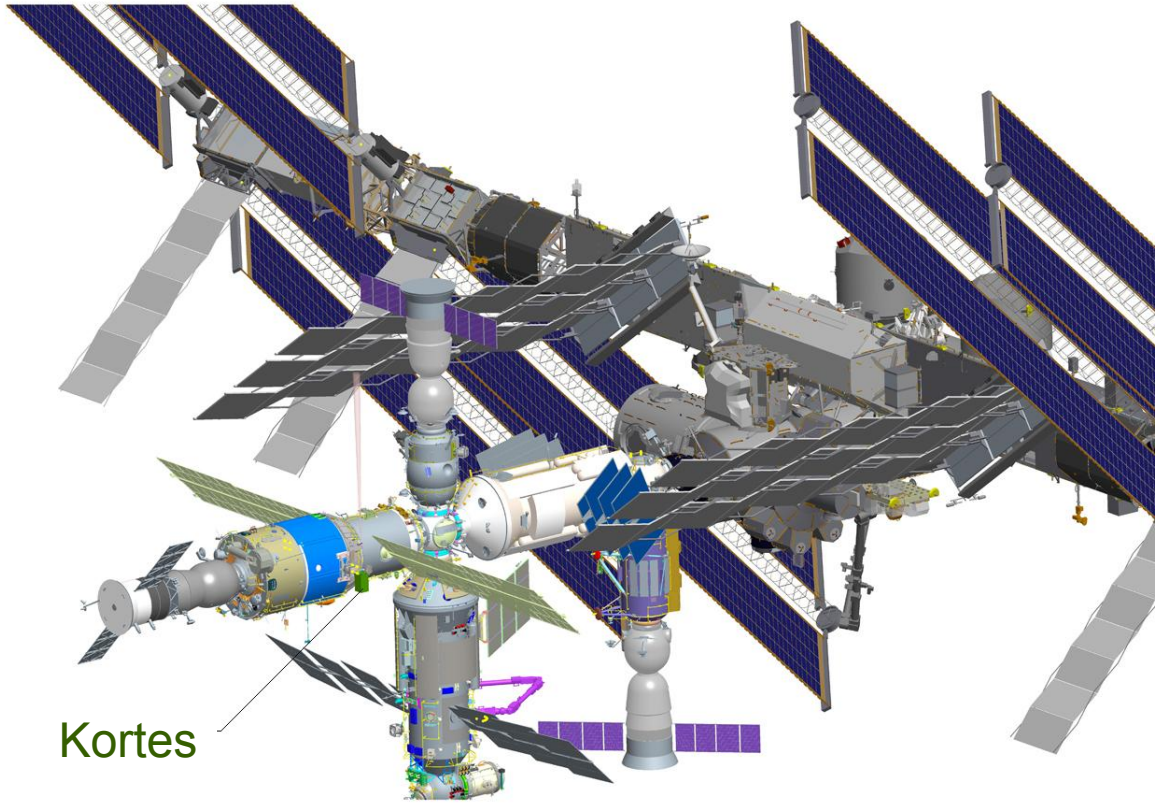
The ISS orbits the Earth at 51.6° to the Equator, following the direction of the Earth's rotation from west to east.

The Earth itself is tilted at 23.4° to the plane of its orbit around the sun (sun vector)

The ISS's altitude varies between 320 to 410 km, and it takes 92 minutes to circle the Earth.



SUN-pointing platform - Kortes



Kortes

Block of detectors – vacuum space outside the ISS on 2D-platform

Block of electronics – inside the ISS

Block of FIAN detectors:

- 2 telescopes – 171 and 304 Å (some other channel for technology & science testing)
- 2 spectroheliographs 180-210 Å & 280-330 Å
- X-ray spectropolarimeter SolPEX (0.5-15 keV)

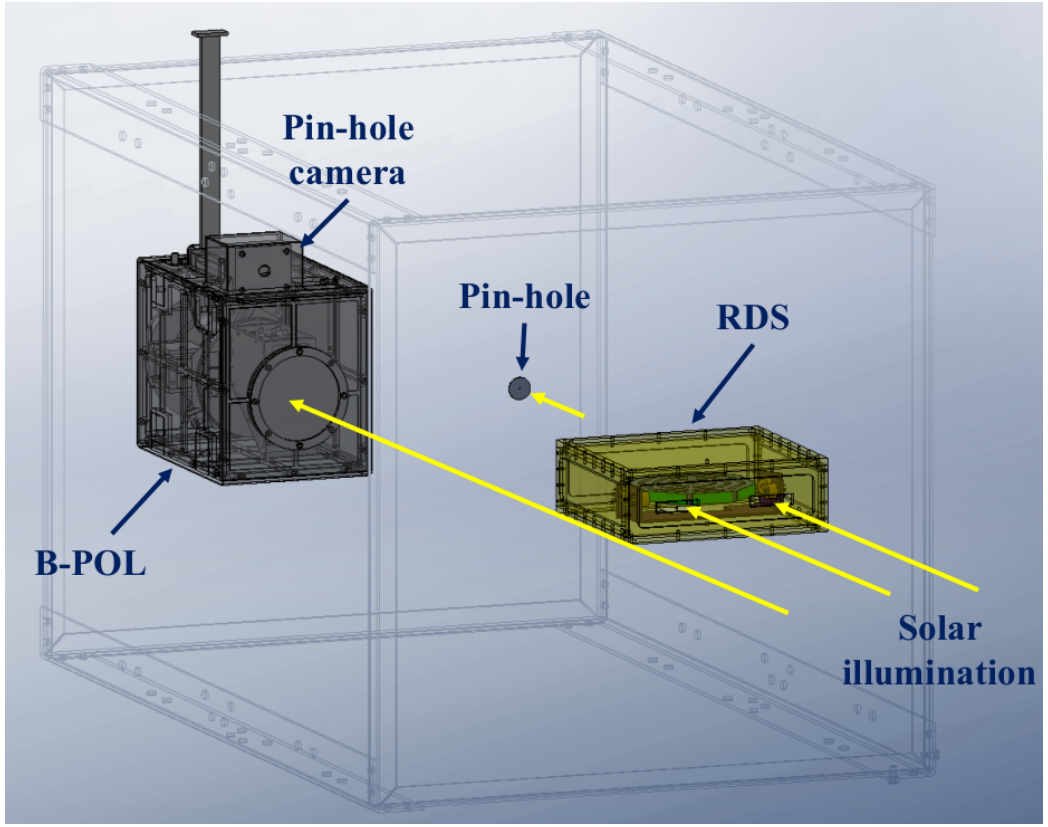
SolPEX objectives

Measurements of polarization in soft X-ray continuum emission and possibly in selected emission lines (1-2% detection limit) (B-POL)

Measurements of X-ray spectra evolution with very high time resolution (0.1 s) rotating drum spectrometer (RDS) - idea proposed by Stefan Płocieniak

Imaging the soft X-ray Sun with moderate spatial (~20arcsec) and high time resolution (0.1 s) pin-hole imager (PHI)

General view



Design: Jarek Bąkała SRC PAS, Solar Physics Div.

Pin-hole imager

Rotating, **bent-crystal Bragg spectropolarimeter** with capillary 2D collimator

Rotating drum, flat crystal**, multiple band Bragg-crystal spectrometer**

6D Hexapod precision (arcsec) pointing device

Front-end open-space electronics

Pin-hole imager

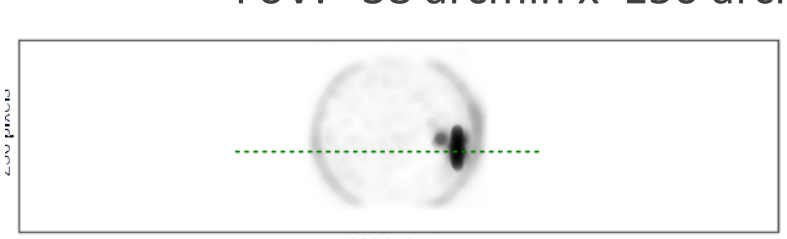
Focal length ~60cm

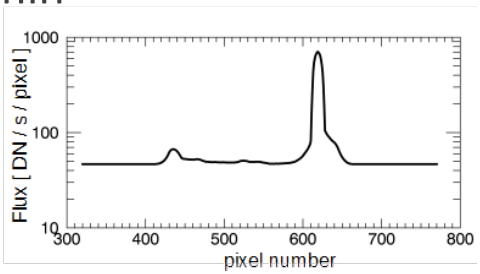
Spatial resolution:

- 0.5 mm hole ~2 arcmin (AR)
  - 20 x 20 pixel area
- 0.1 mm hole ~30 arcsec (flare)
  - 4 x 4 pixel area

Solar diameter: 200 x 200 pixels

FoV: 38 arcmin x 150 arcmin





Energy range: 1-10 keV, dE: ~1 KeV

Primary role: localize sources (AR & flares) on the disk in the instrument coordinate system

Secondary: detect active phenomena on the disk, analyse individual lightcurves for separate AR

Easy concept: pin-hole (adjusted diameter open down to 0.1 mm, can be changed depending on the activity), CCD detector (256 x 1024 pixels 26 µ)

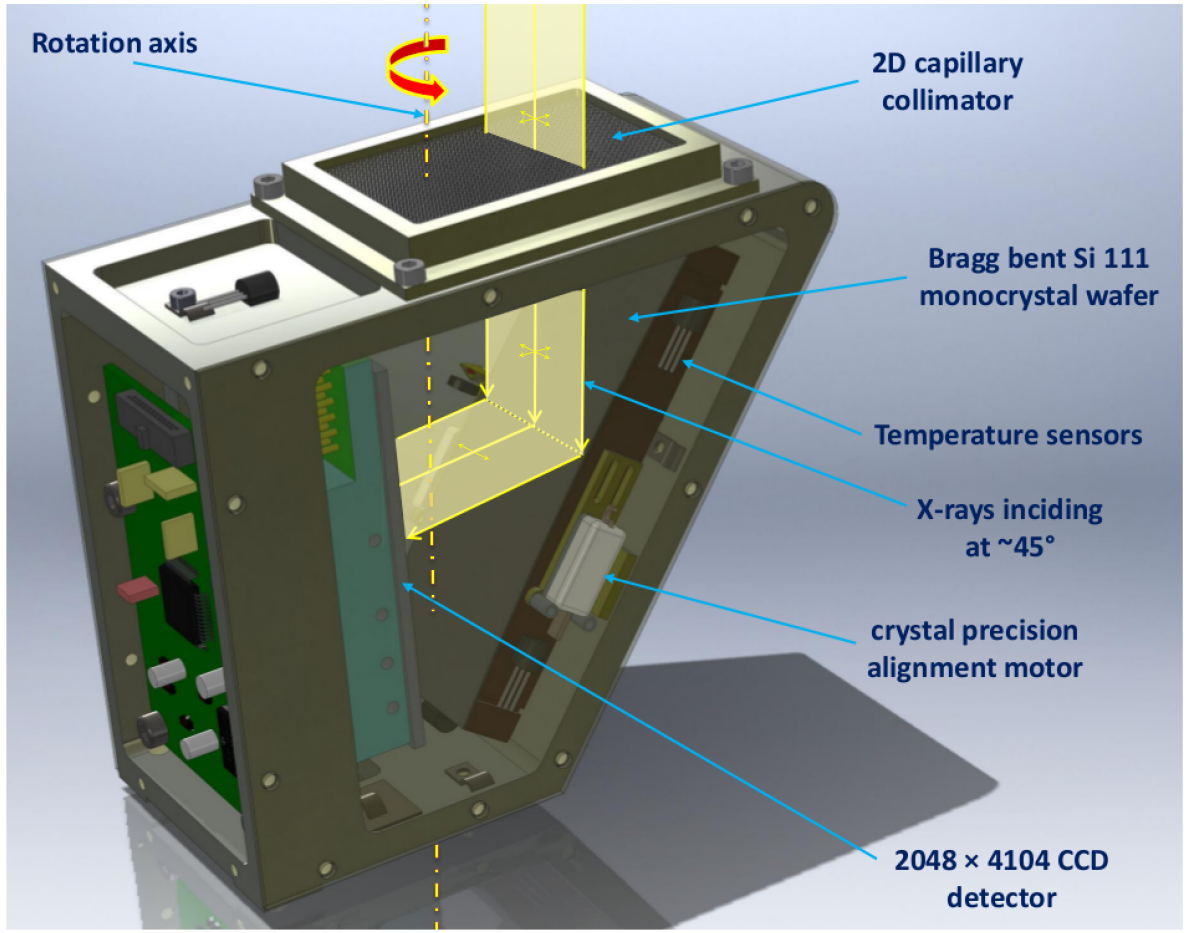
Image readout: each ~0.2 s

Will provide positions [x,y] of more prominent individual sources (resolution ~1.5 arcmin).

Limited spectroscopy, similar to RHESSI at lower energy range (Fe XXV and Fe/Ni line groups distinguishable)

Purpose: **Locate the X-ray source on the Sun**

Rotating polarimeter unit



Si 111 bent crystal at the Brewster angle ~45°

CCD detector (1024x256 pixels)

Rotating at 1 rev./s

Pointed using pin-hole image

Spectro-Polarimeter monocrystal wafer: cylindrical Si 111

2d=6.271 Å

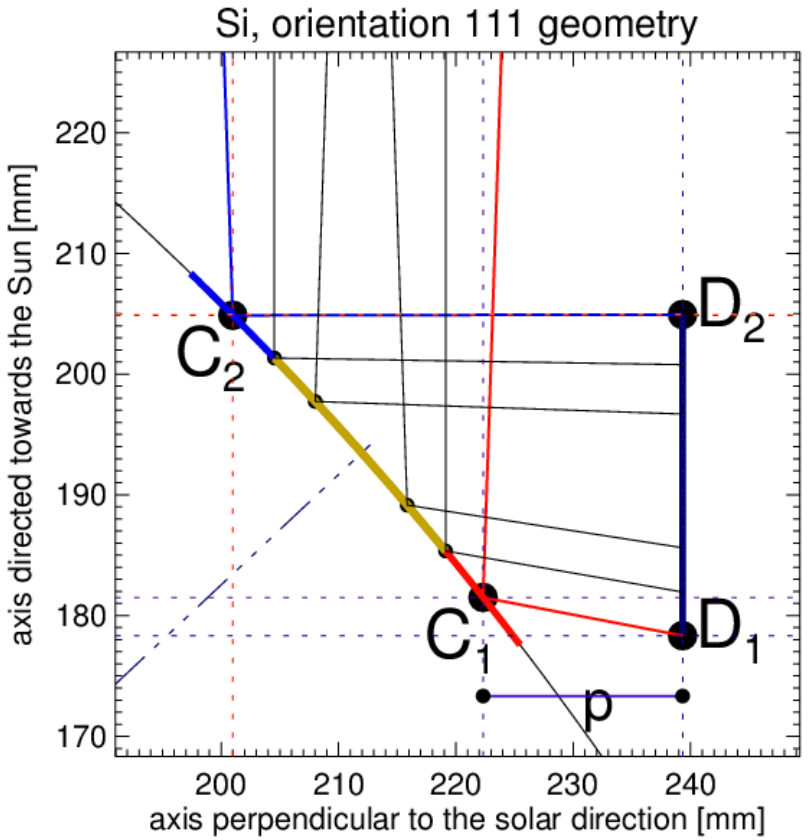
Spectral range:
3.940 - 4.505 Å

Radius of curvature:
180.0 mm

Crystal length & width:
38.2 & 10 mm

Calculated ideal

FWHM & Resolution:
4.4 arcsec ~ 0.0005 Å
< line thermal wdths

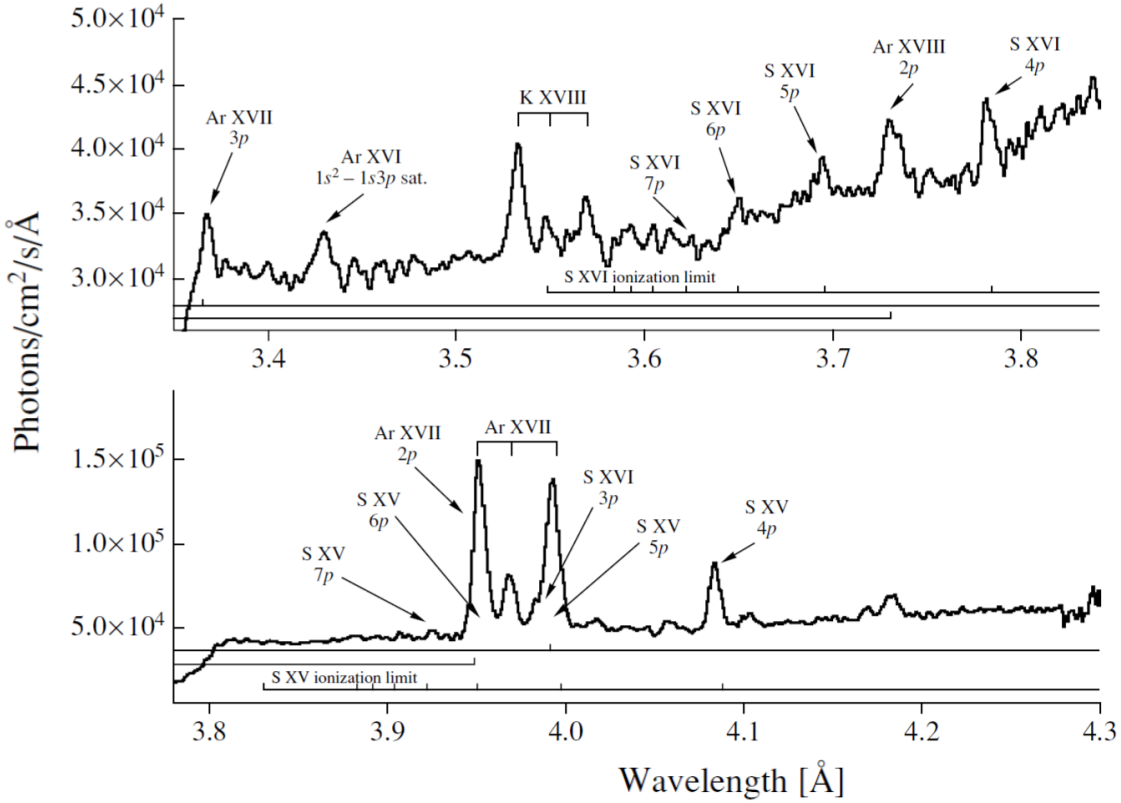


courtesy Żaneta Szoforz

Why this selection?

Continuum and line emission should be prominent for a wide range of physical conditions on the Sun i.e. AR and/or flares

Clean spectral range in the vicinity of the lines, allowing for separate measurements for the continuum and line rotationally modulated pattern

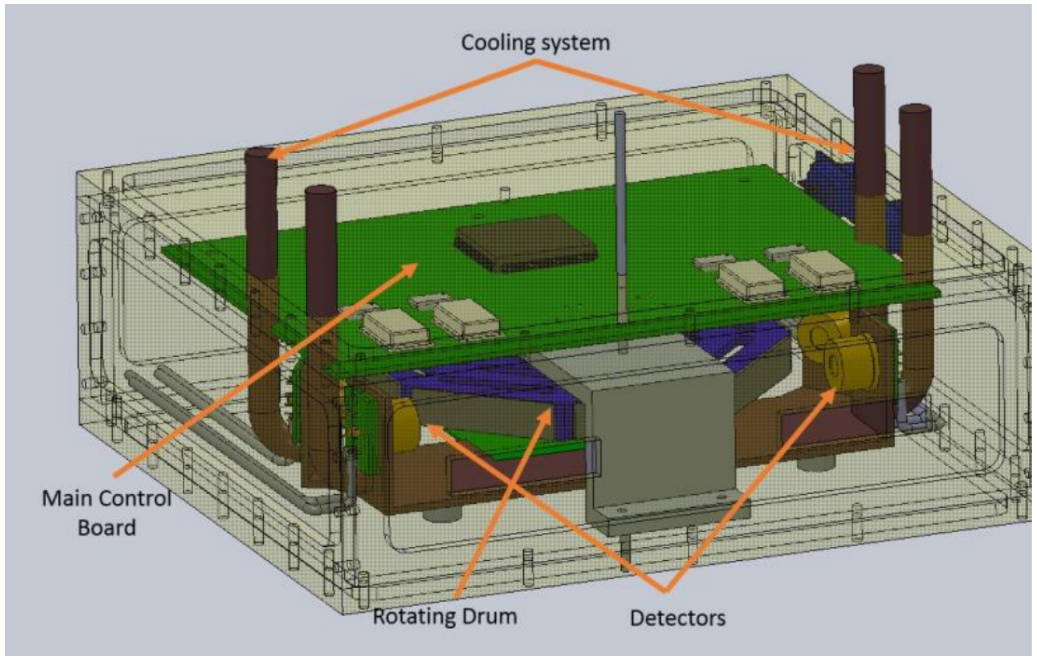


Sylwester et al. (2005)

Average solar flare spectra, obtained by the RESIK instrument

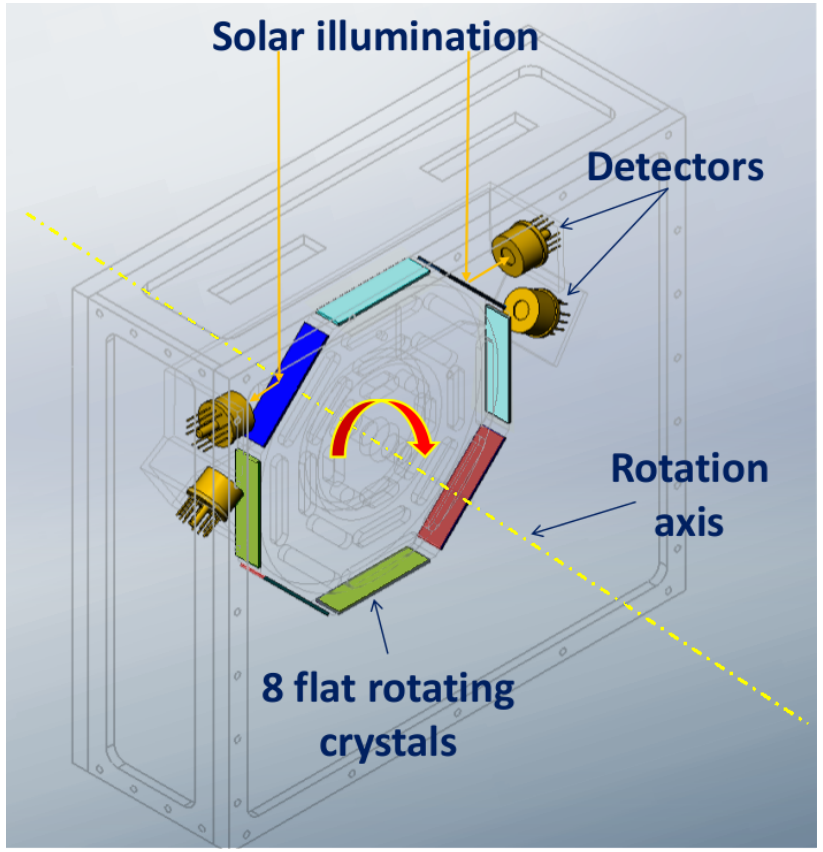
A very high time resolution (0.1s) spectroscopy for flares

New concept: Stefan Płocieniak SRC PAS



Fast rotating drum equipped with 4 pairs of identical crystals in the Dopplerometer orientation Bragg-illuminate the ”standard” SDD detectors’

Rotating Drum Flat spectrometer unit



Thanks to the rotation photons are being „reflected" from the crystal.

By monitoring the photon arrival time, accurate „intercept" angle can be estimated & converted to wavelength

Histogram spectrum will be revealed with sufficient amount of detections

Fast rotating (10 rev/s) drum with a set of 8 crystals (4 pairs of identical flat monocrystals in Dopplerometer configuration)

4 large area ~0.25cm2 PIN detectors

Summary

Placing the instrument onboard ISS provides a unique opportunity for testing new measurement ideas

Very short design time is an obstacle, but many components are already at hand & tested at SRC PAS SPD

Detailed ground calibration & alignment & testing (innovative) procedures are necessary

New measurement techniques can be tested and interesting flare physics can possibly be revealed