Bragg soft X-rays spectrometers: our future missions

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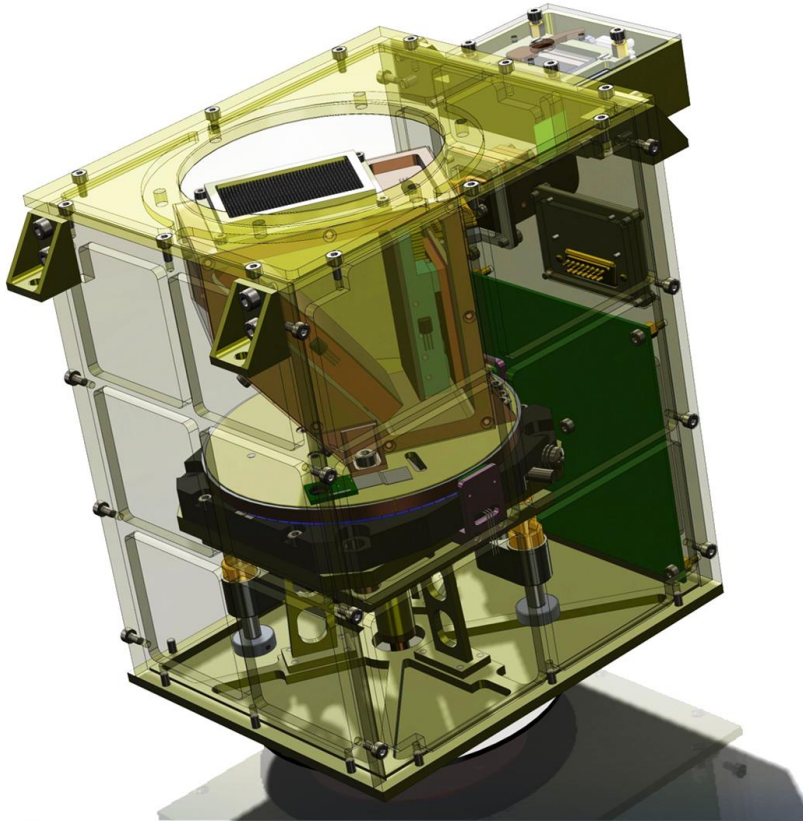
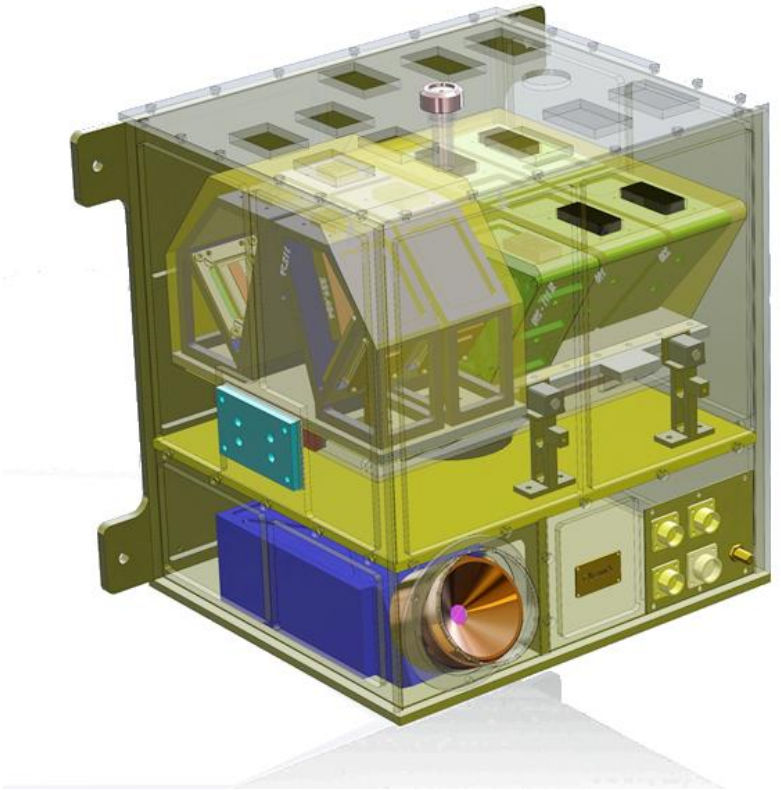
Solar spectroscopy and polarimetry experiments

SOLPEX



CHEMIX



Motivation

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

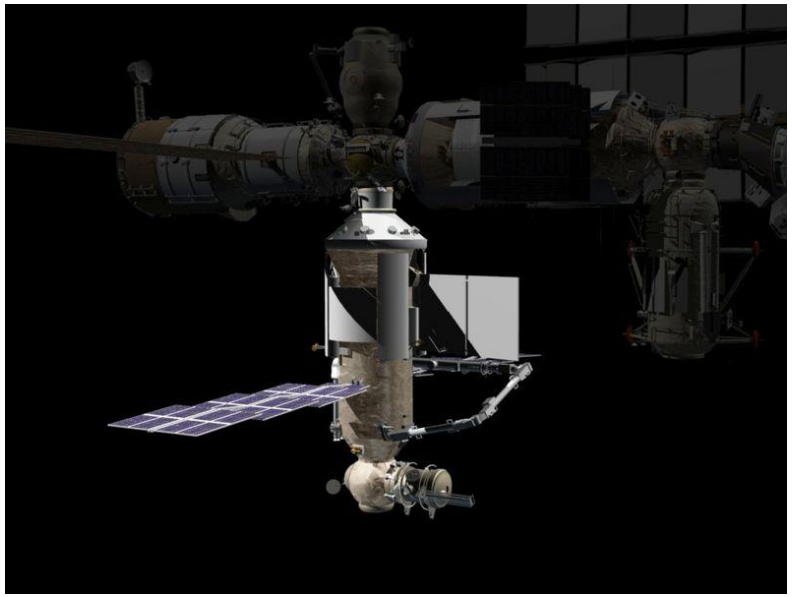
Ubiquitous presence of collimated non-thermal electron beams during flare impulsive phase is indispensable in order to explain observed patterns of hard X-ray flare emission

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

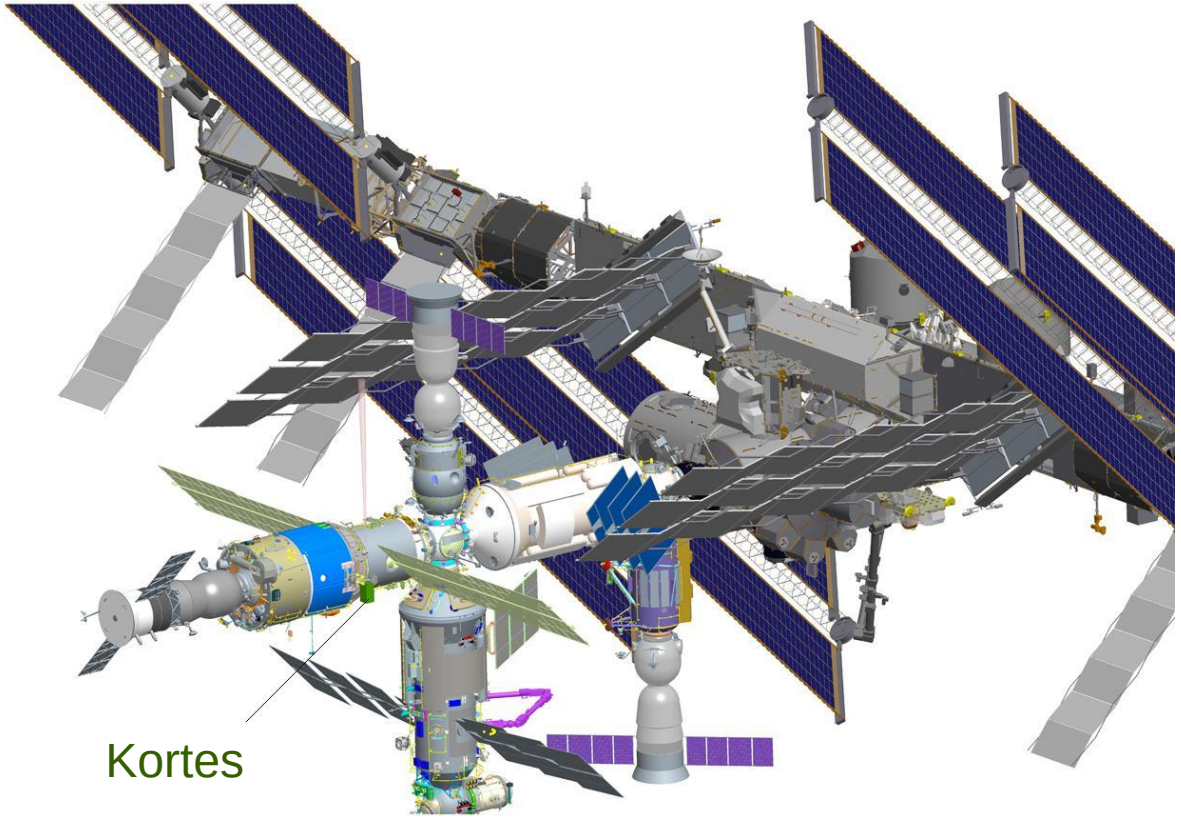
SUN-pointing platform - Kortes

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)



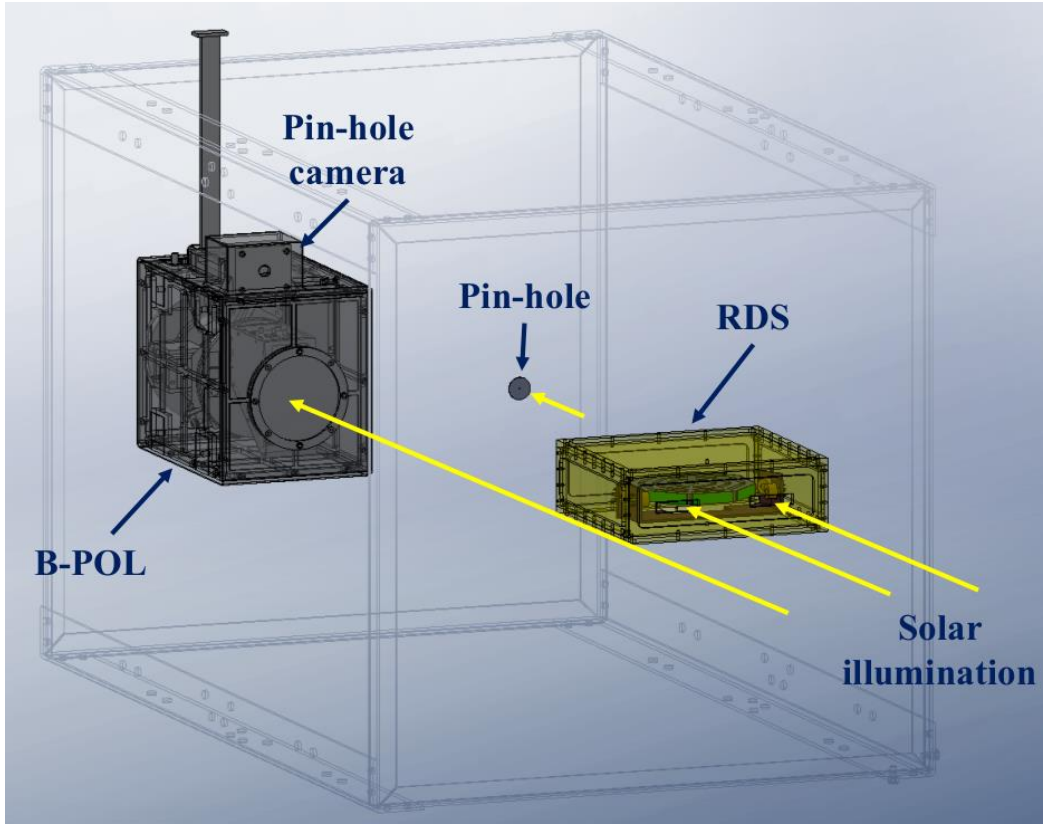
SolPEX objectives

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 and precision (arcsec) pointing device

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

Front-end open-space electronics

Pin-hole imager

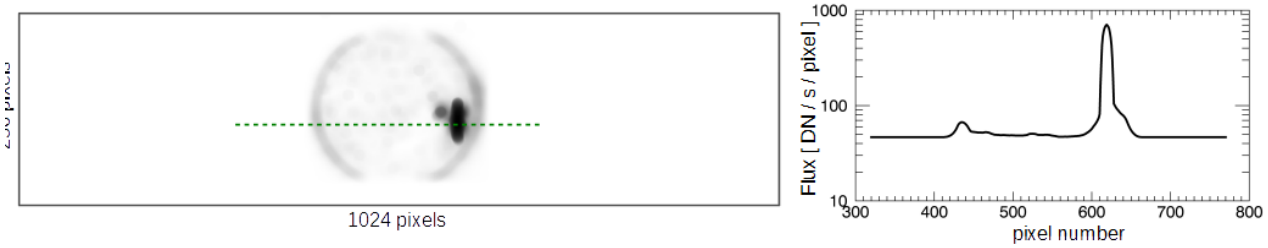
Focal length ~60cm

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)

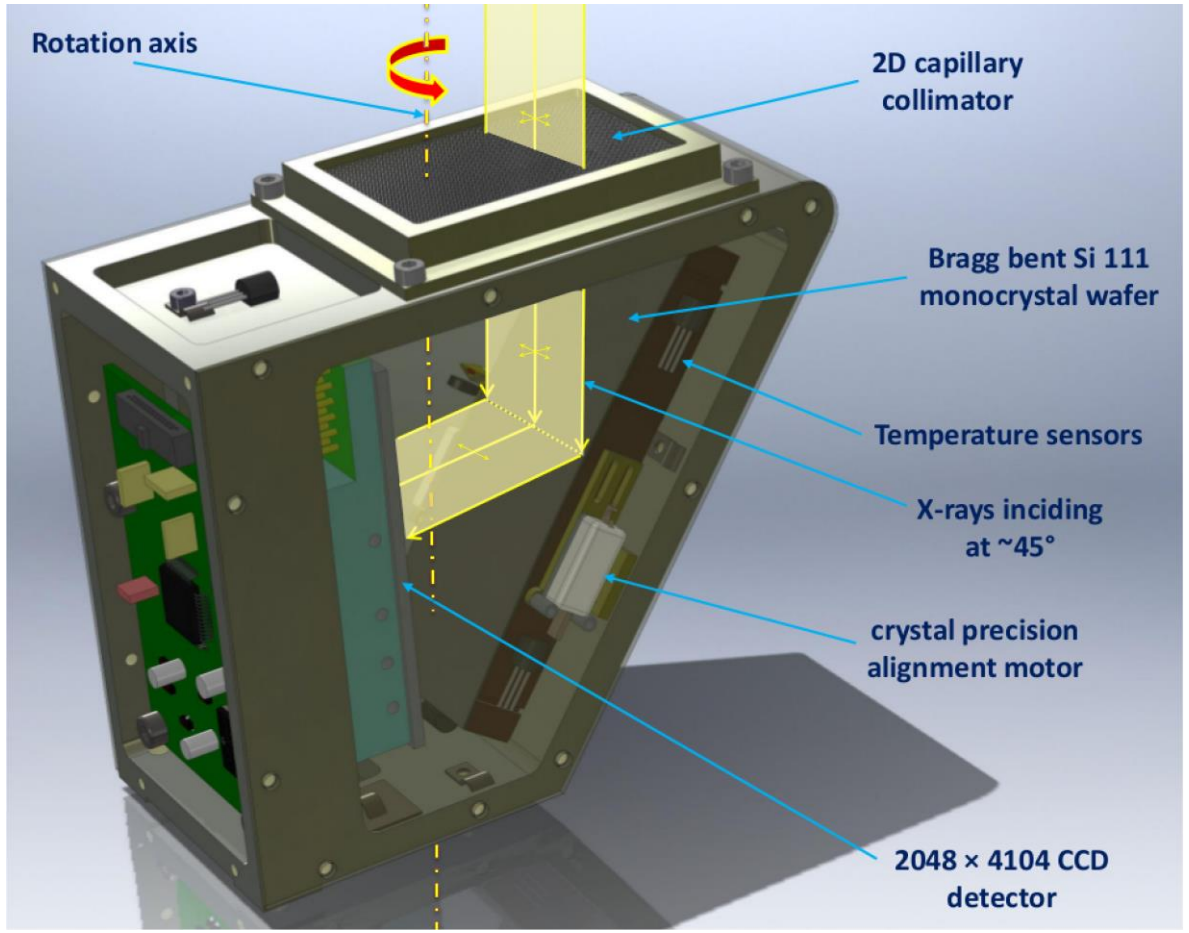
Image readout: each ~0.2 s

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

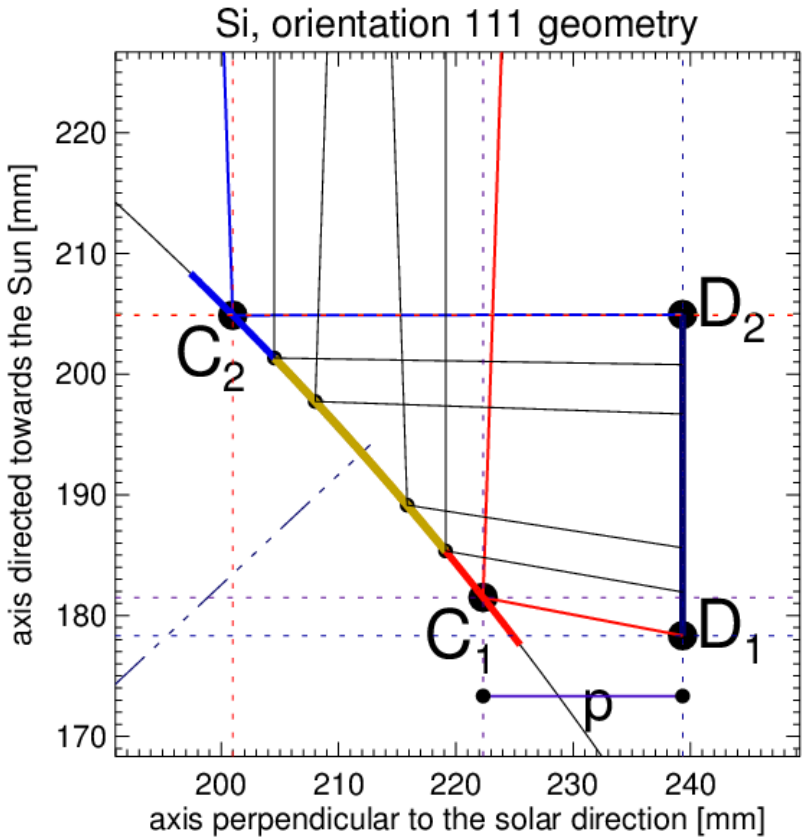
Spectral range:
3.940 - 4.505 Å

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

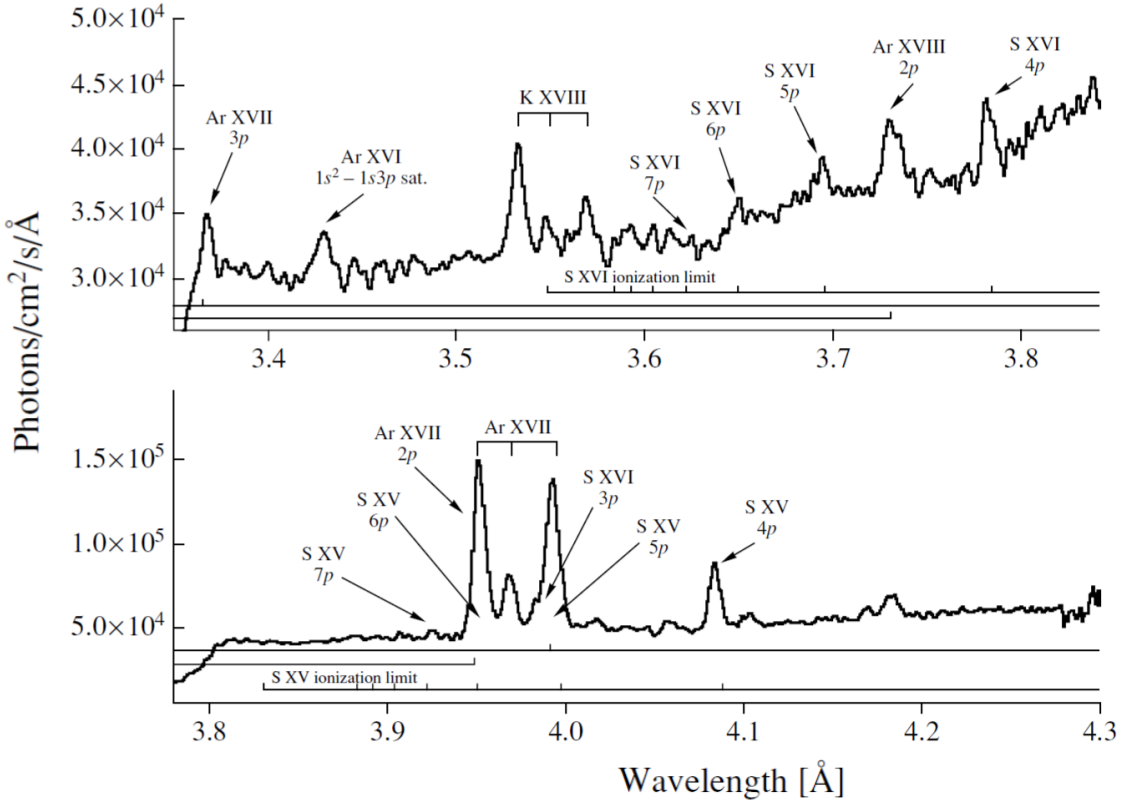


courtesy Żaneta Szoforz

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

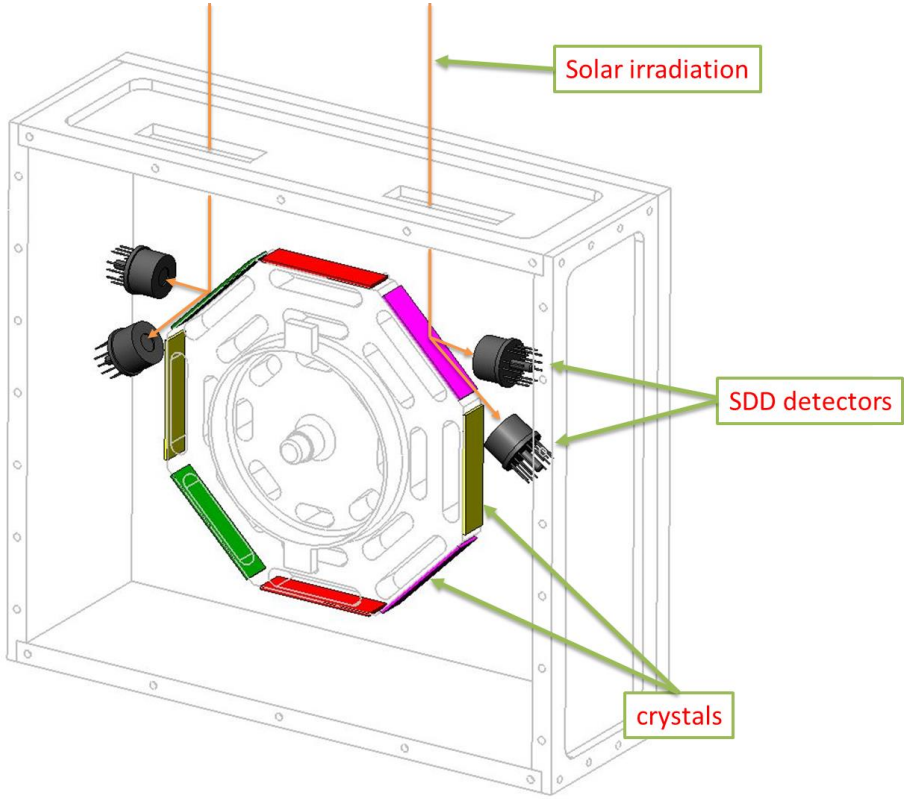


Sylwester et al. (2005)

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



Rotating Drum Flat spectrometer unit

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

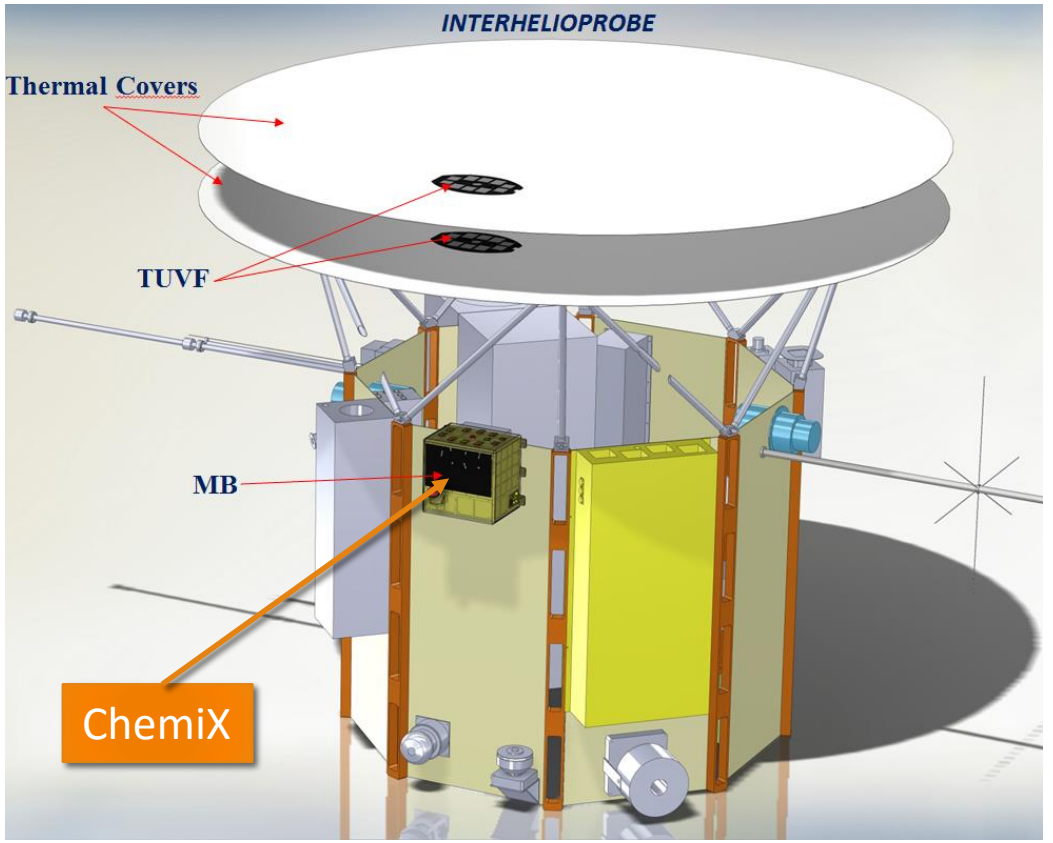
By monitoring the photon arrival time, accurate „intercept" angle can be estimated & converted to wavelength

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 ~0.25cm^2 PIN detectors

Solar X-ray Spectra from 0.3 A.U.: The CHEMIX Bragg spectrometer on Interhelioprobe



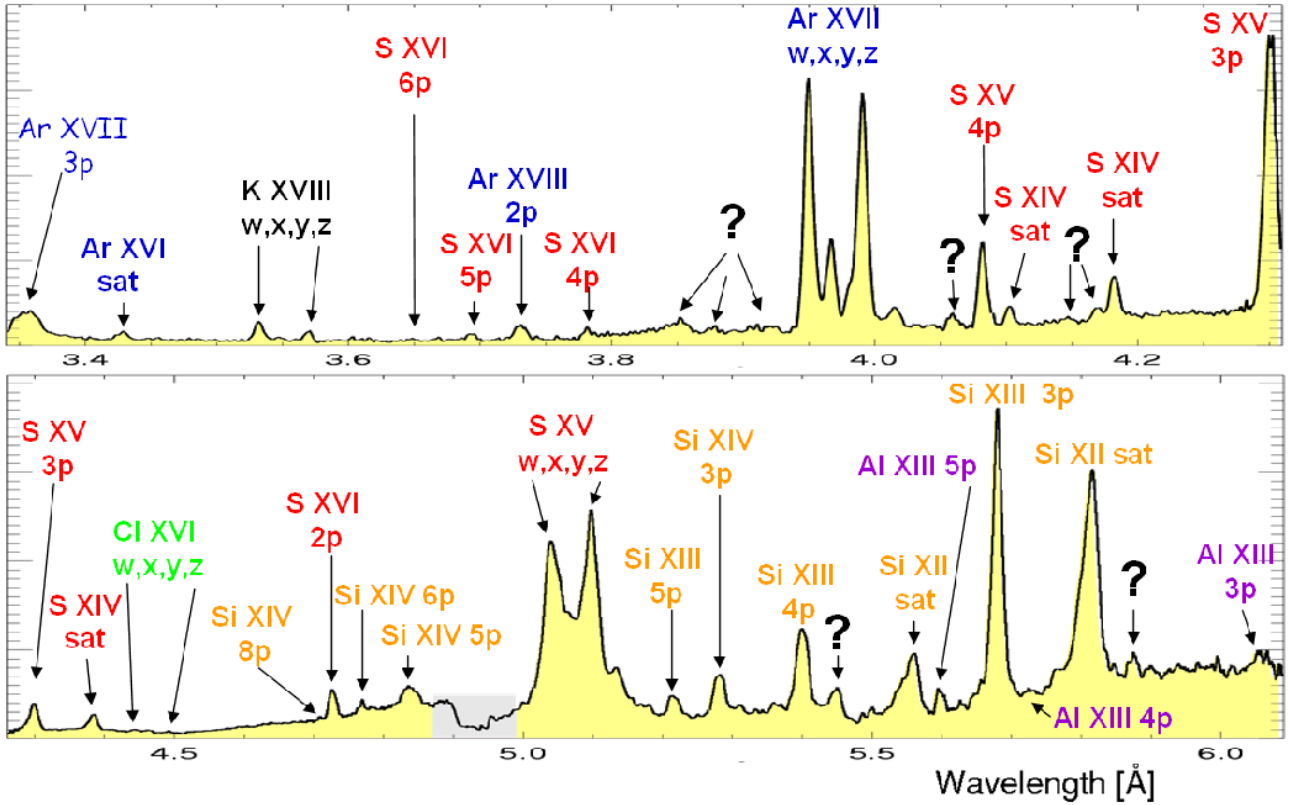
Motivation

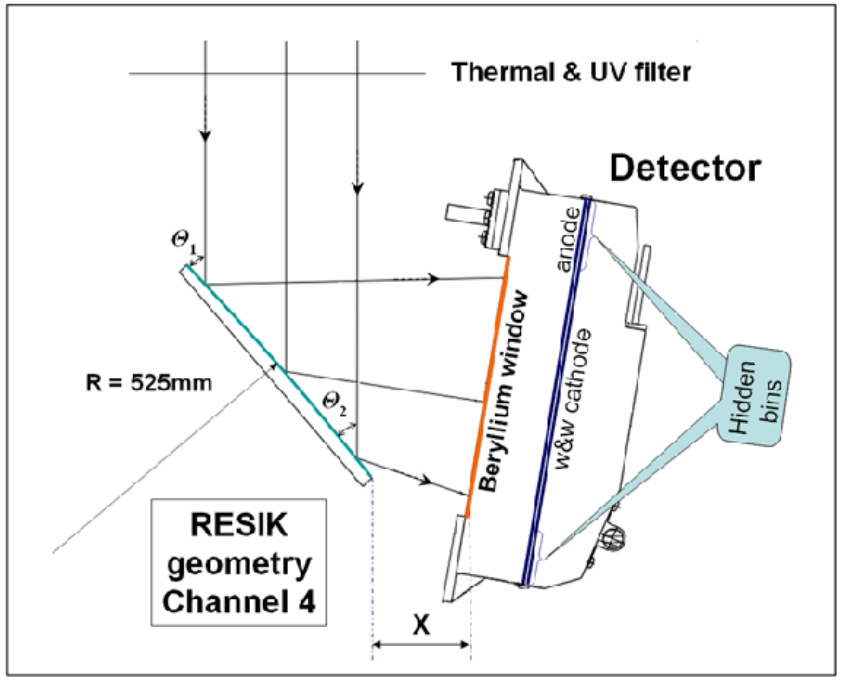
- **Spectra are formed** in optically thin multi-million K plasmas; every formed photon escapes the source region (coronal part of active region or flare)
- Prominent **continuum** formed in f-f, f-b, and two-photon processes
  - f-f bremsstrahlung (emitted by electrons passing protons)
  - f-b depends on plasma composition; important are more abundant elements (softer X-ray range)
  - Two-photon emission is weak ~100 × less important
- **Lines** seen in emission arise as a consequence of presence of heavier elements in trace quantities
  - Line intensities are proportional to abundance of elements
  - In the range 1.5 – 9Å, lines from Mg, Al, Si, S, Cl, Ar, K, Ca, Fe & Ni are seen in the spectra

X-ray spectrometers Requirements for Abundance Studies

- Good spectral resolution, allowing lines of particular elements to be distinguished
- Good sensitivity allowing to see lines of low abundance elements like Cl and K
- Reliable continuum level can be measured – this allows for absolute abundance determinations (relative to hydrogen)
  - Previously difficult to accomplish as the observed background usually contaminated by crystal fluorescence
  - Early Bragg spectroscopy: Intercosmos, P78, Hinotori, XRP on SMM, BCS on Yohkoh – always contaminated

Bent crystal Bragg reflections + position-sensitive detectors allow instantaneous record of spectra

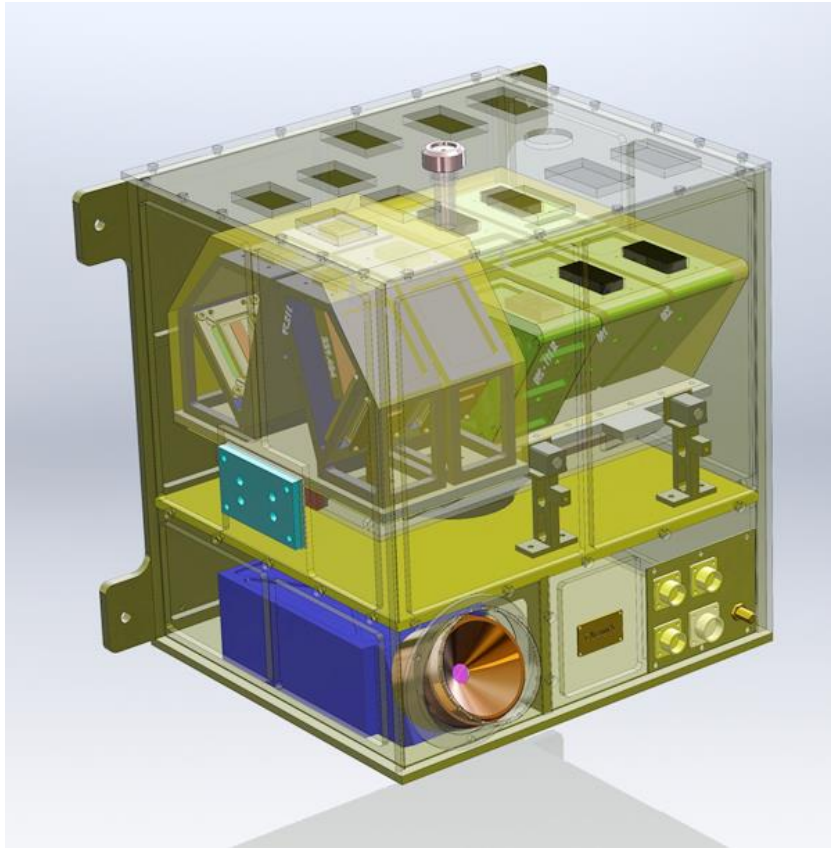




RESIK (2002-2003)

Subsystems of ChemiX

- Particle detector (provides „own" instrument safety)
  - Issue flag to switch-OFF entire instrument or selected blocks in case of emergency (SEP, CME front passages)
  - Takes „standard" measurements of particle spectra
- (Very) soft pin-hole CCD X-ray imager ~ 1 arcmin resolution
  - Detect S/C pointing based on the limb-brightening ring - provides detailed pointing (few arcsec accuracy)
  - Localize AR important in X-rays & follow their (separate) lightcurves
  - Identify flares within individual AR → provide target data to the pointing platform
- Internal Target pointing platform carrying all crystals & CCDs
  - Within second lock the spectrometer on target
- Spectral atlas spectrometer
  - Takes spectra in the range 1.5-9 Å regularly within selected FOV on the disk. DGI depends on the intensity- statistically defined threshold 10 000 counts over the spectrum
  - Provides spectral line & continuum intensities with unprecedented accuracy (2 × RESIK at perihelion)
- Dopplerometer (X-ray Tachometer)
  - Looks toward „differential" spectral line positions at the very high spectral resolution
  - Provides selected spectral line shapes at several points over the line profile



Instrument philosophy

- Take measurements of soft X-ray spectra at the highest rate possible (every ~0.5 s)
- Store the results into a large instrument internal data bank (256 GB)
- Beam-down essential characteristics of measurements (lightcurves in selected spectral ranges), source coordinates
- Downlink (when possible) „interesting” portions of data from the onboard memory

Summary

Spectrometer-palarimeter B-POL will provide a measurments of the linear polarymetry both of the soft X-ray continuum and emission lines.

New Bragg bent crystal spectrometers ADS and ChemiX for determination of elemental abundances from X-ray line spectra

Multi-temperature analysis of elemental abundances, will be used, allowing for model-independent precise determinations of absolute coronal plasma abundances

Improved element abundance estimates will allow better understanding of FIP effect

Spectra will improve plasma energy budget estimates through DEM and plasma motions

Thank you