



ChemiX's present status

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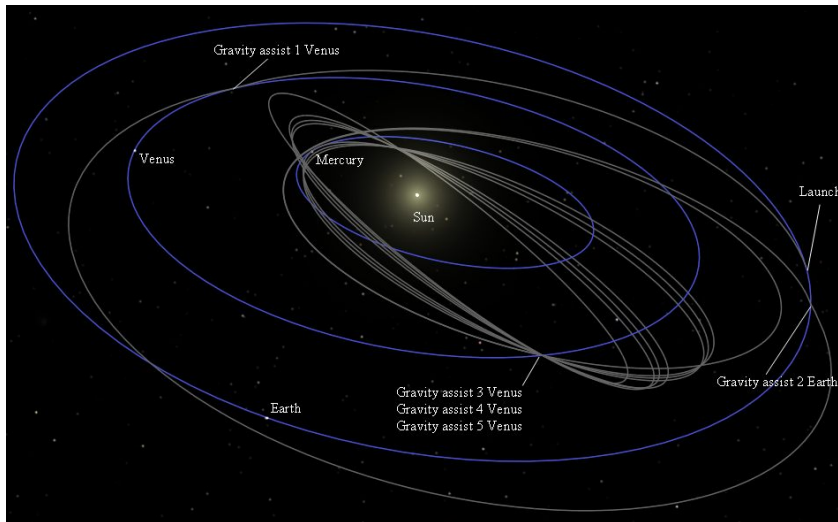
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Interhelioprobe (IHP) mission

Solar observations from inner heliosphere



- High-resolution observations of the solar atmosphere
- In-situ measurements of heliosphere near Sun
- Out-of-ecliptic observations
- Observations of Sun invisible side

perihelion **60-70 R_{\odot}**
 aphelion 250-260 R_{\odot}
 inclination to ecliptic up to **30°**

18 instruments:
 10 remote sensing
 8 in situ observations

Joint IZMIRAN & IKI project
 Funded by the Russian Federal Space Agency (ROSKOSMOS)
 Spacecraft is designed and constructed at Lavochkin Scientific Association
 (It will be also Flight Operation Center)

The two IHP missions are planned to be launched in **2025** and **2026**



ChemiX: X-ray Bragg spectrometer

10 spectral channels

4 1.5 Å to 8.8 Å

6 Fe (~ 1.85 Å), Ca (~ 3.2 Å) and Ar (~ 3.9 Å)

The main scientific goal of ChemiX is the determination of **elemental composition** of hot solar coronal plasma structures

Additionally we will study:

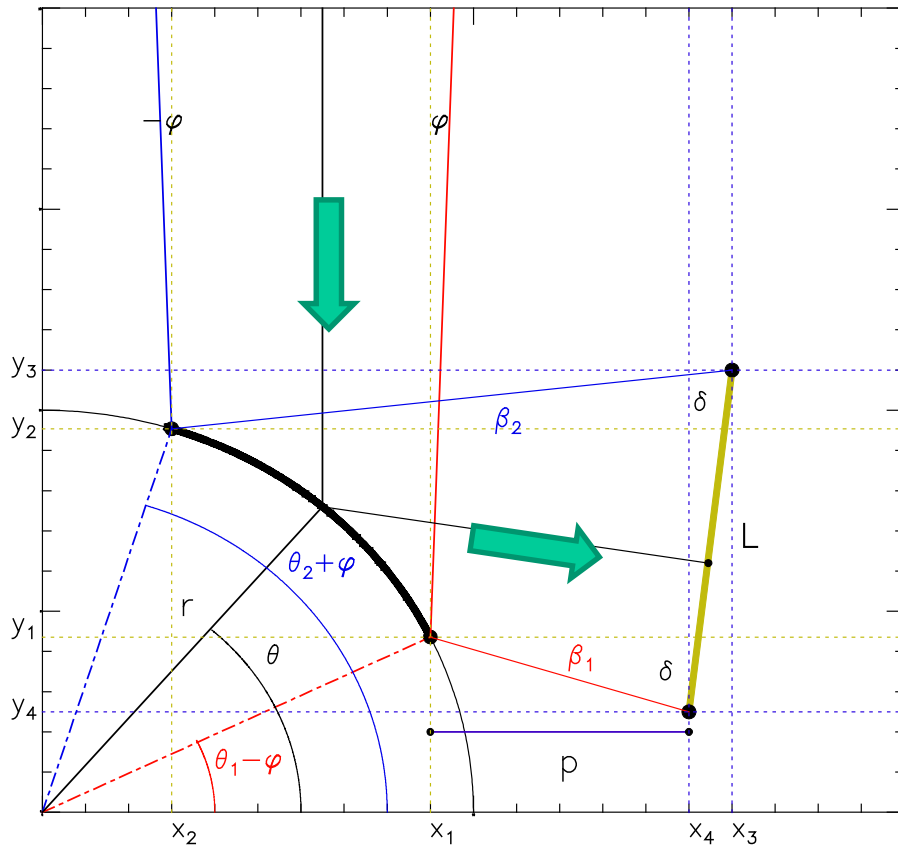
- Thermal (ion temperature) and turbulent line widths
- Multi-temperature structure of the thermal plasma (DEM-diagnostics)
- the movement of the plasma along and perpendicular to the line of sight
- the energy distribution of electrons in the 2 - 10 keV range

Chemix will consist of:

- Spectrometer
- Dopplerometer
- Particle detector monitor
- Pin-hole CCD X-ray imager with ~ 1 arcmin spatial resolution
- Micro-positioning platform system carrying all crystals & CCDs
- Thermal and ultraviolet filter (TUVF) boards

X-ray Bragg spectrometer

$$2d \sin\Theta = n\lambda$$



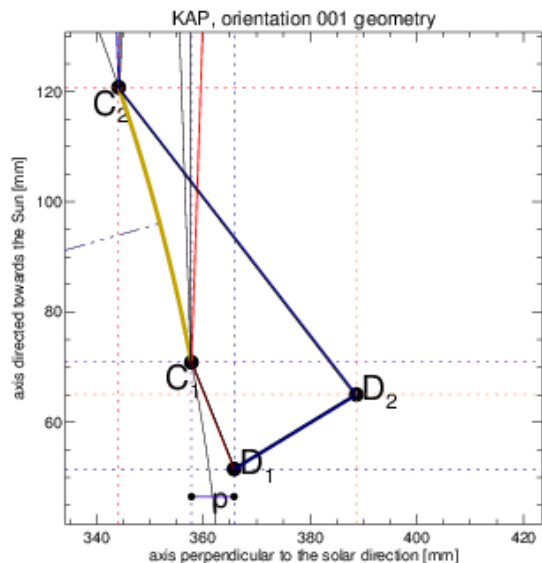
Input data

- crystal $2d$ spacing,
- detector size L ,
- the minimal distance between the crystal and the detector p ,
- desired wavelength range λ_1, λ_2 (Θ_1, Θ_2)

Results

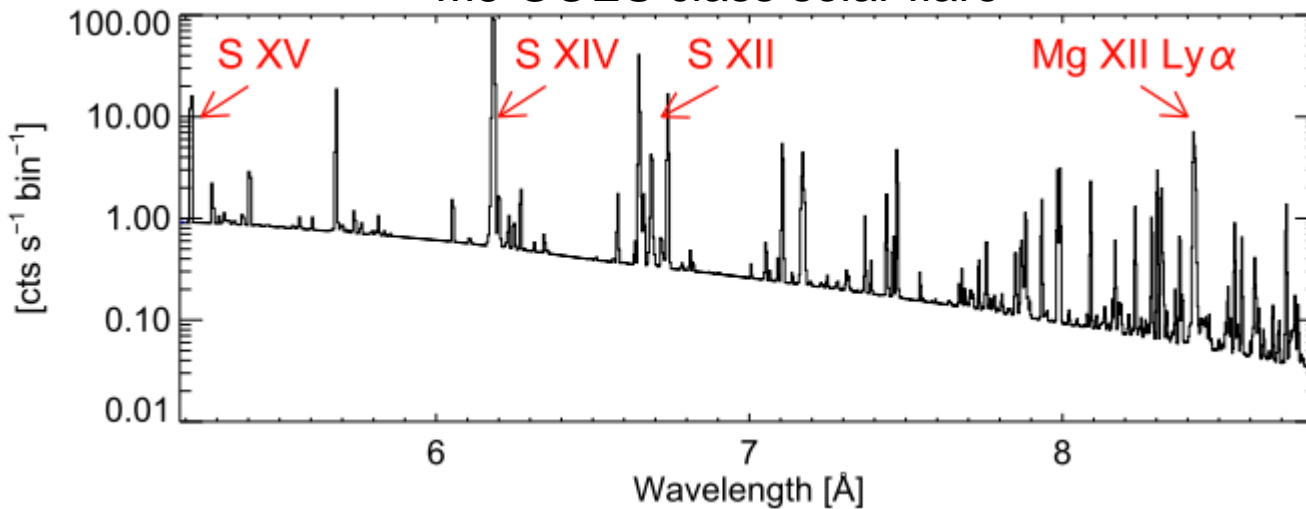
- crystal radius and length
- detector orientation and position
- optimal geometry of the crystal-detector system

X-ray Bragg spectrometer



KAP 001 $2d = 26.64 \text{ \AA}$

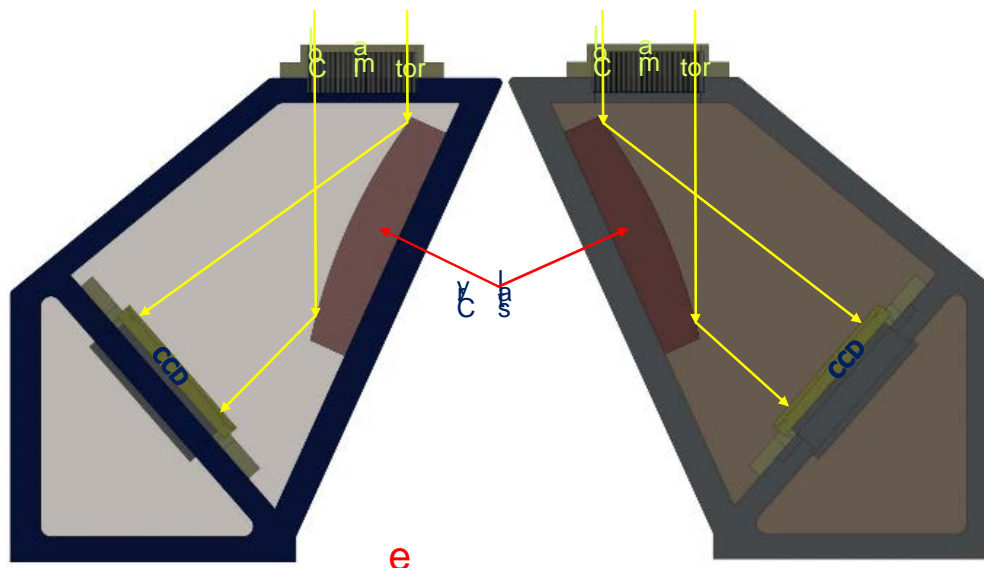
M5 GOES class solar flare



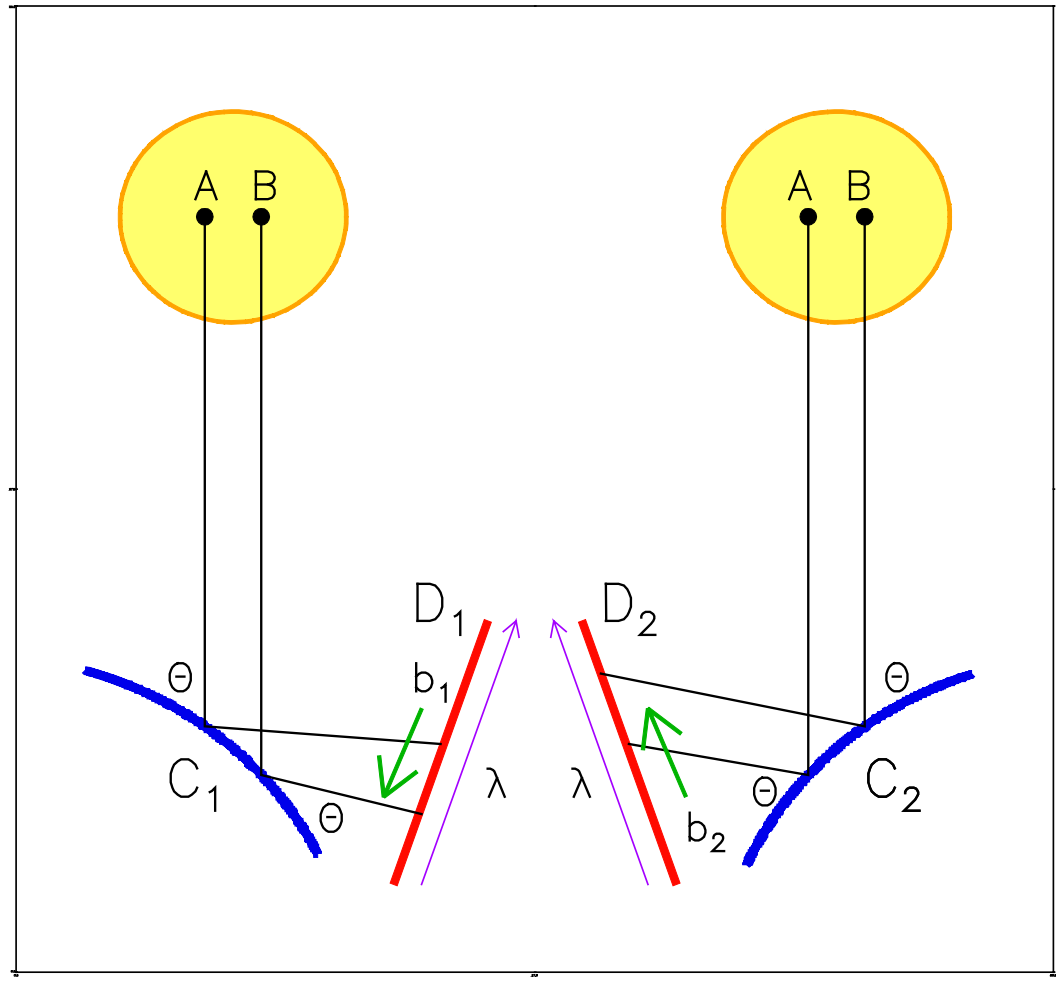
$T_e = 18.7 \text{ MK}$
 $EM = 5.6 \cdot 10^{49} \text{ cm}^{-3}$

Spectrometer Channels

Channel # (crystals' number)	Crystal	Diffracting plane	2d [Å] (at 20° C)	Wavelength Range [Å]	Average spectral resolution [mÅ/pix]	Curvature radius [mm]	Crystal length [mm]	Crystal width [mm]
1 (1)	Si	111	6.271	1.500 – 2.713	1.41	176.000	46.5	10.0
2 (1)	Quartz	10_10	8.514	2.700 – 4.304	1.82	166.729	44.8	10.0
3 (1)	KDP	011	10.185	4.290 – 5.228	0.98	410.425	53.5	10.0
4 (1)	KAP	001	26.64	5.200 – 8.800	4.2	364.731	61.7	10.0



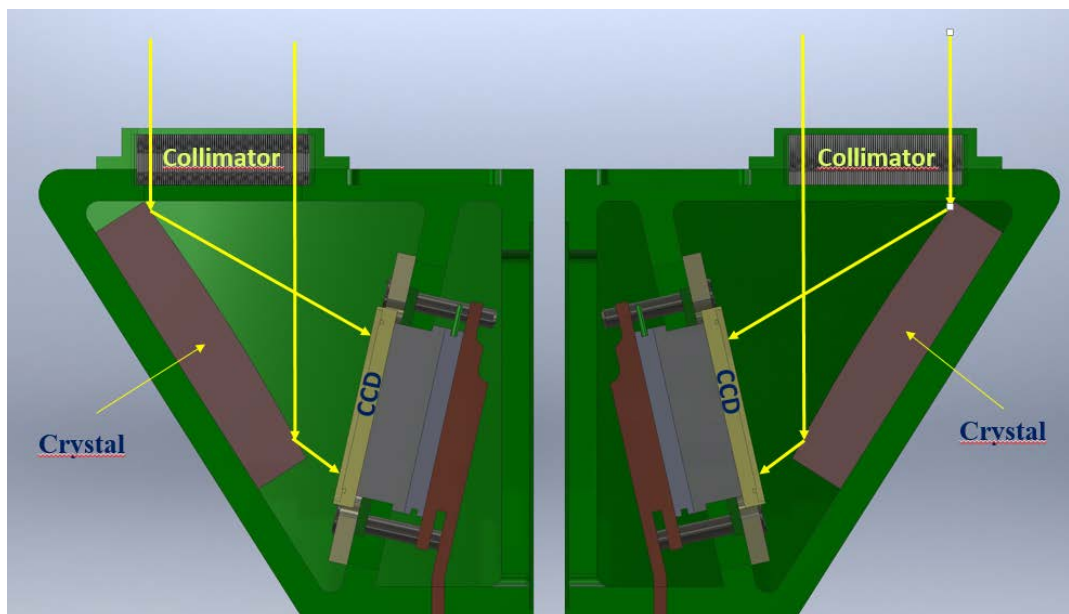
The principle of the ChemiX dopplerometer

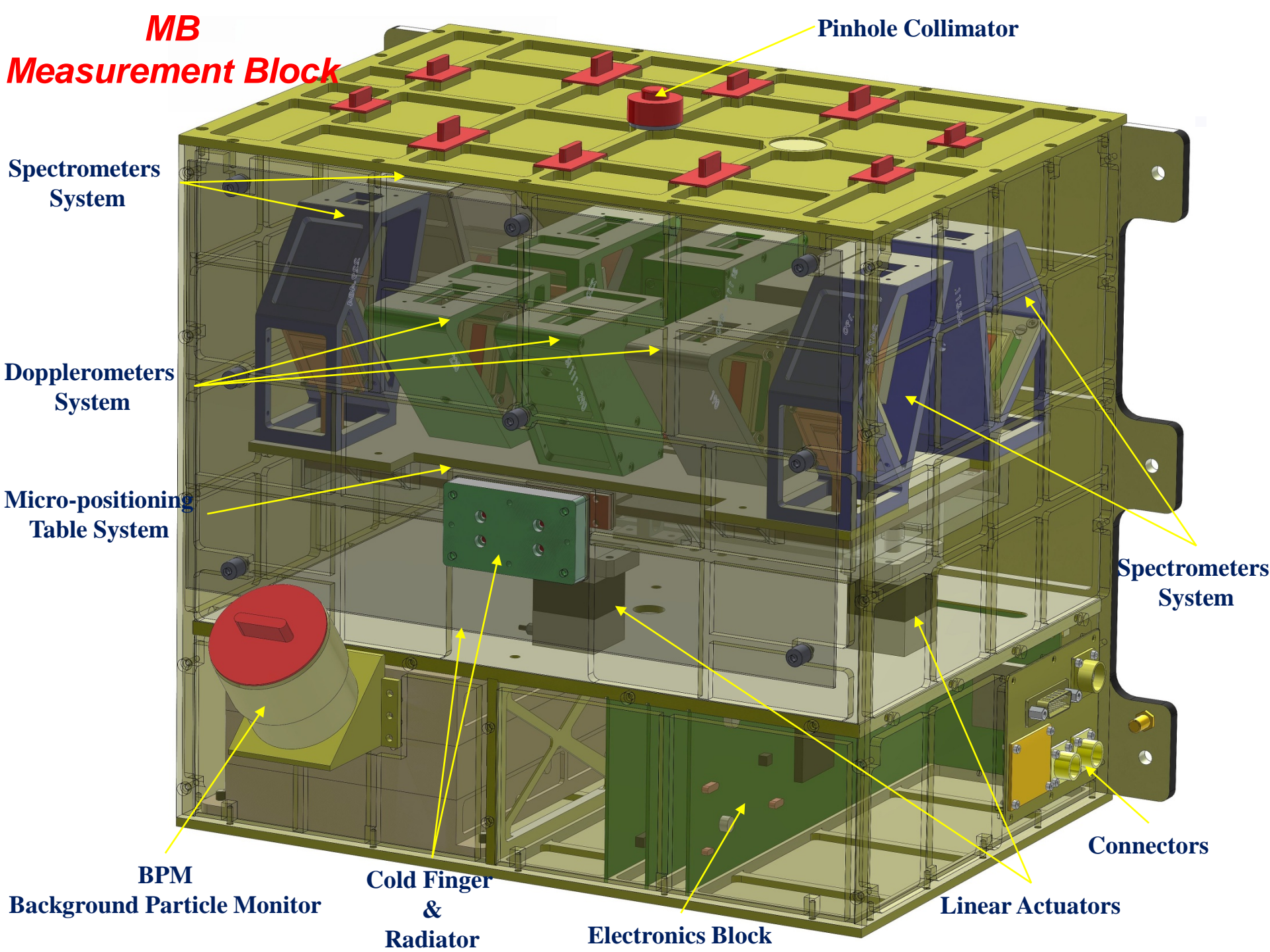


The ability to distinguish surface proper motions and Doppler shifts due to LOS motions during flare X-ray emission.

Dopplerometer Channels

Channel # (crystals' number)	Crystal	Diffracting plane	2d [Å] (at 20° C)	Wavelength Range [Å]	Average spectral resolution [mÅ/pix]	Curvature radius [mm]	Crystal length [mm]	Crystal width [mm]
5, 6 (2)	LiF	022	2.848	1.835 - 1.949	0.12	650.00	46.1	10.0
7, 8 (2)	Si	111	6.271	3.150 - 3.324	0.11	2500.0	58.2	10.0
9,10 (2)	Si	111	6.271	3.900 – 4.080	0.19	1000.0	47.0	10.0







The Background Particle Monitor (BPM)

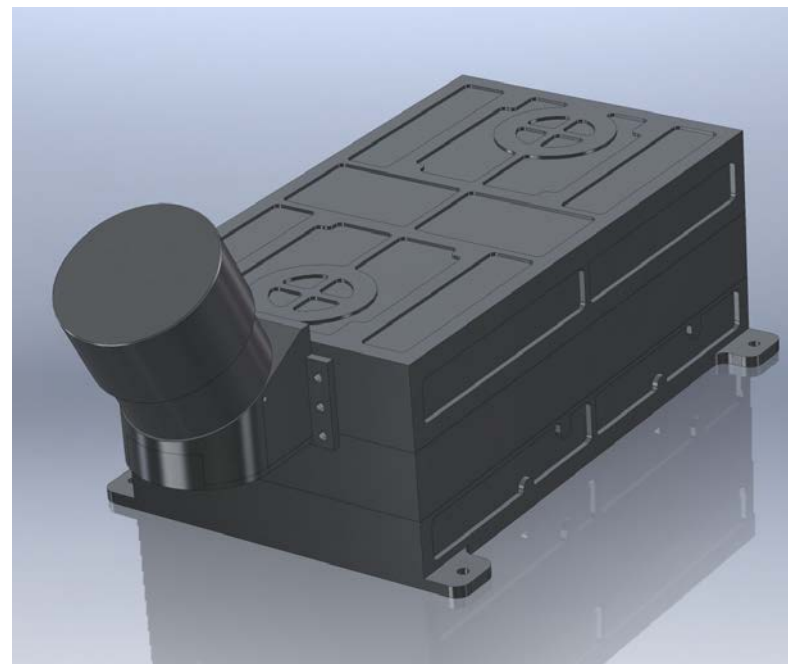
Safety

For exceptionally high levels of particle flux detected by the BPM a dedicated flag will be used to switch off the ChemiX instrument or some of its sensitive subsystems to prevent their damage.

Science

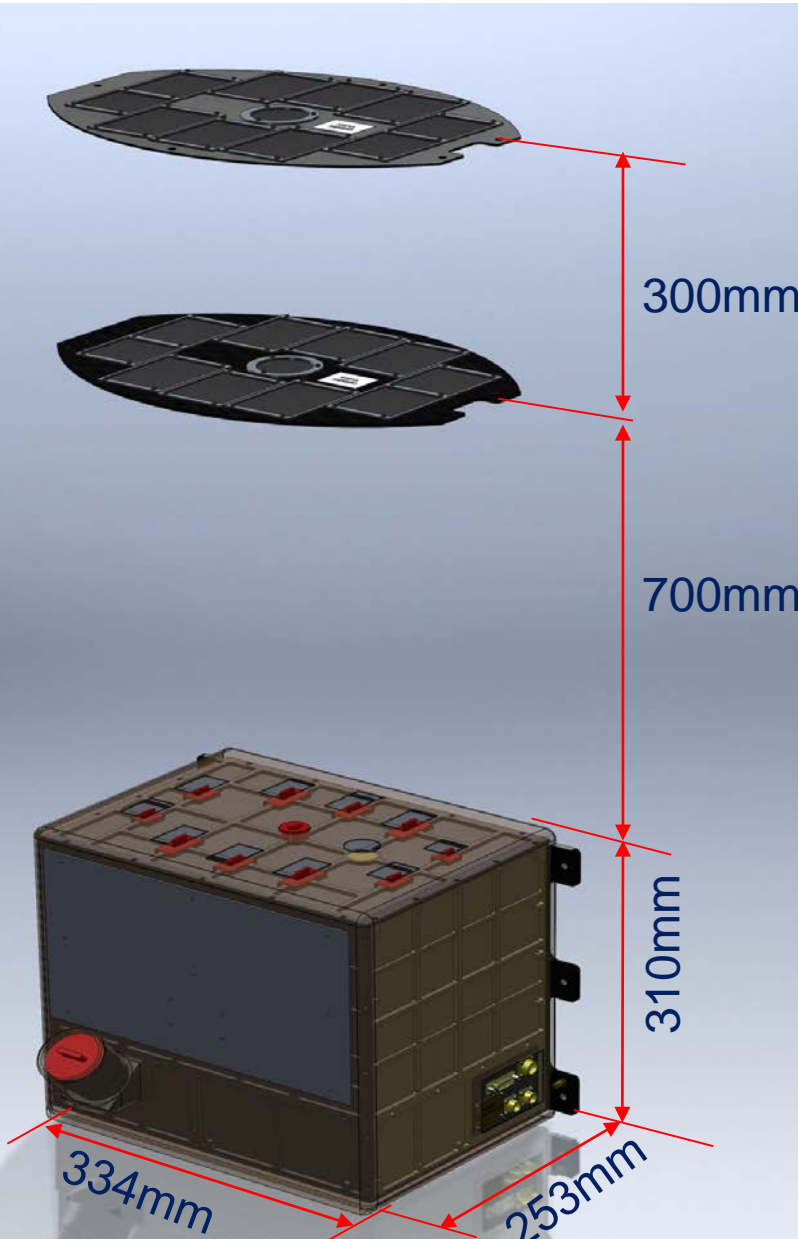
With independent power supply it can measure spectra of intense energetic particle events (electrons, protons, and light nuclei up to nuclei of oxygen).

Under development at the **Institute of Radio Astronomy, NASU** at Kharkiv, Ukraine



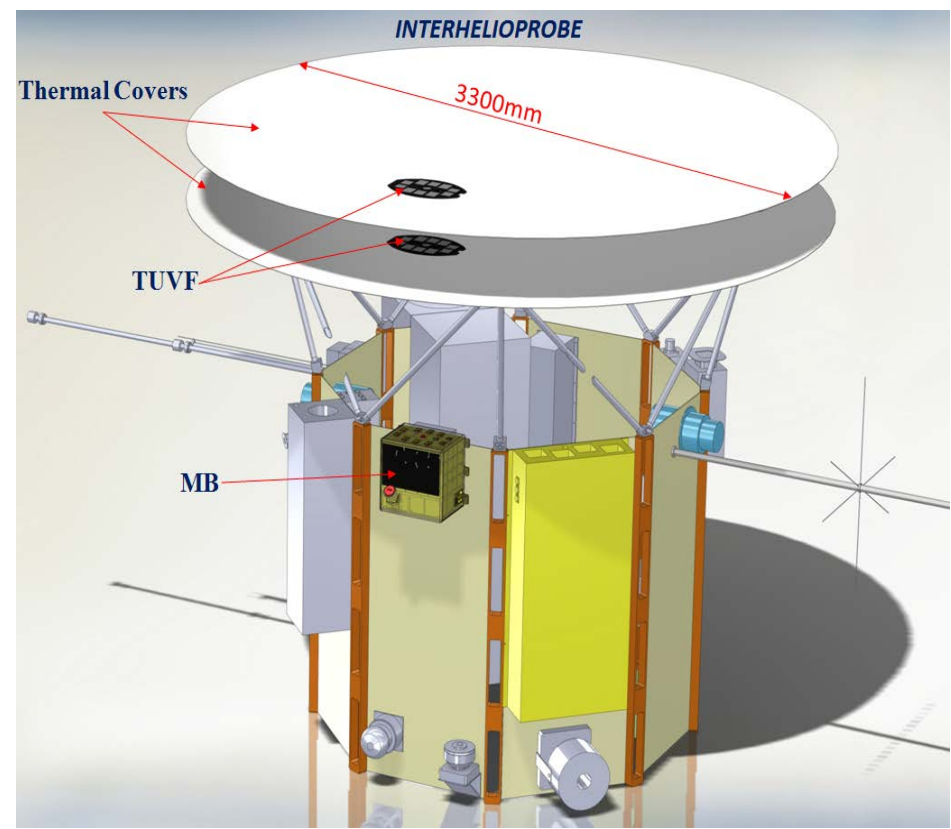
No	Particle sort	Energy range, MeV
1	Electrons - e	0.06 — 2.4
2	Protons - p	1.2 — 14
3	Deuterons - d	1.6 — 18 (0.8 – 9 MeV /nucleon)
4	Alpha-particles	5 — 52 (1.3 — 13 MeV/nucleon)

Thermal and ultraviolet filters (TUVF)



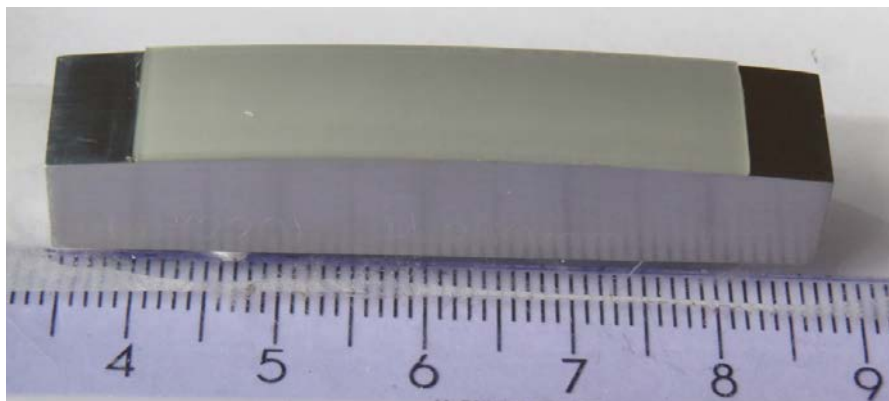
Two filter boards will be mounted on the spacecraft's thermal screen. Taking into account high temperature existing here ($\sim 400\text{ }^{\circ}\text{C}$) we use:

- carbon-carbon composite as thermal shield
- graphite foil as UV filters.



Prototype convex LiF(220)

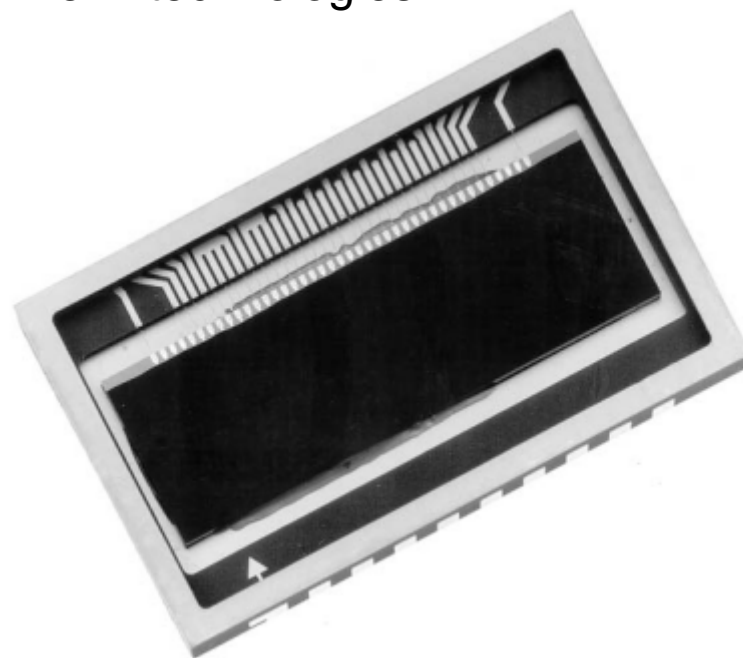
supplied by Saint-Gobain



LiF(220) $2d = 2.848 \text{ \AA}$

- Orientation $\pm 5'$
- Sized 43 mm x 10 mm
- Cylindrical convex curvature along 43 mm at radius 250 mm $\pm 1\%$
- Aluminum holder supplied by Saint-Gobain

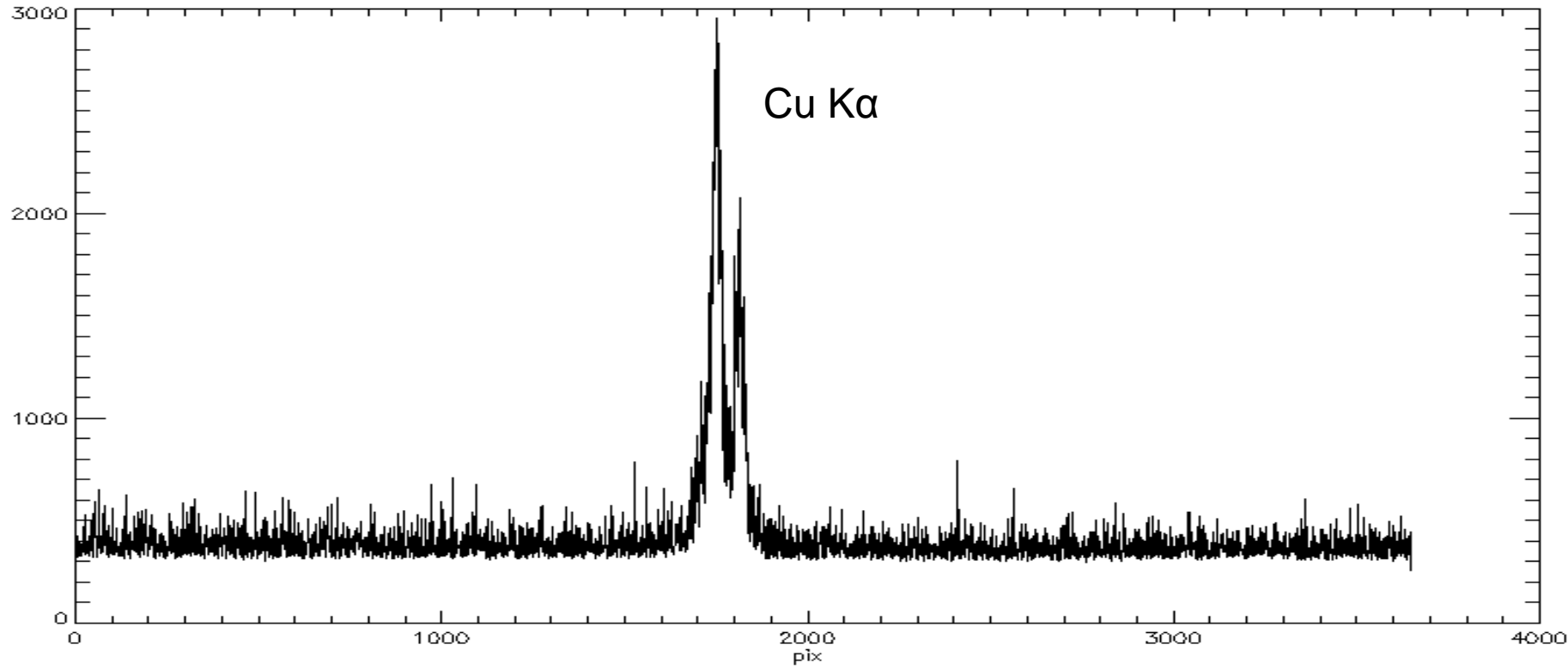
CCD42-10 Back Illuminated
High Performance AIMO CCD Sensor
e2v technologies



- 2048 by 512 Pixel Format
- $13.5 \mu\text{m}$ Square Pixels
- Image Area 27.6 x 6.9 mm

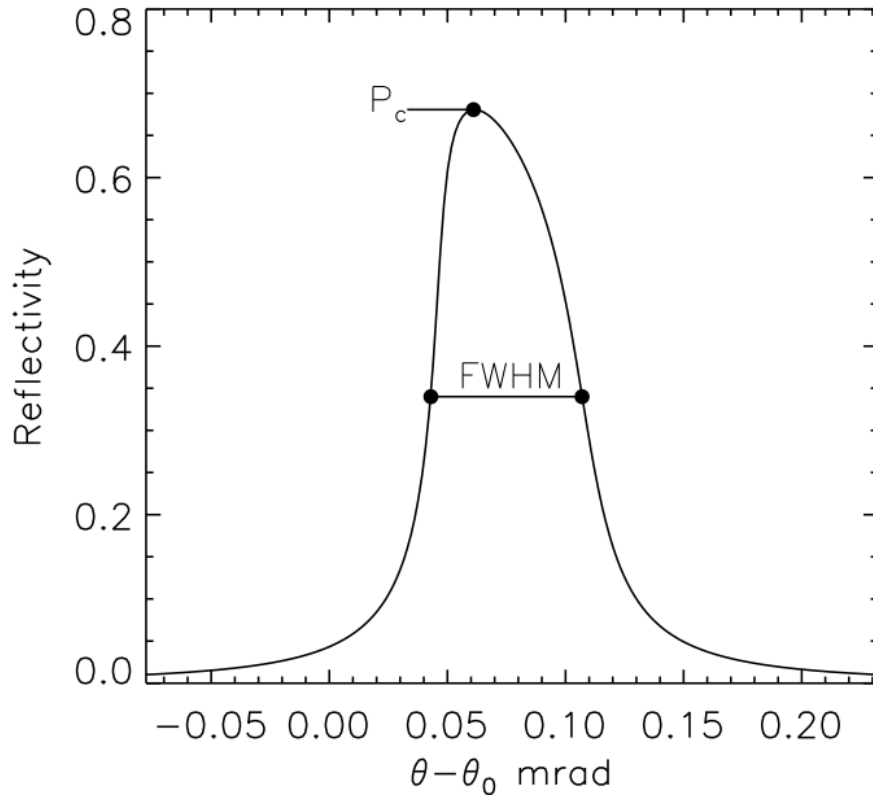


The laboratory tests of the bent crystals



Example of Cu K α line measurements with convex (R=250 mm) LiF (220) crystal

$$R_c(\theta) = \int R(\theta) d\theta$$

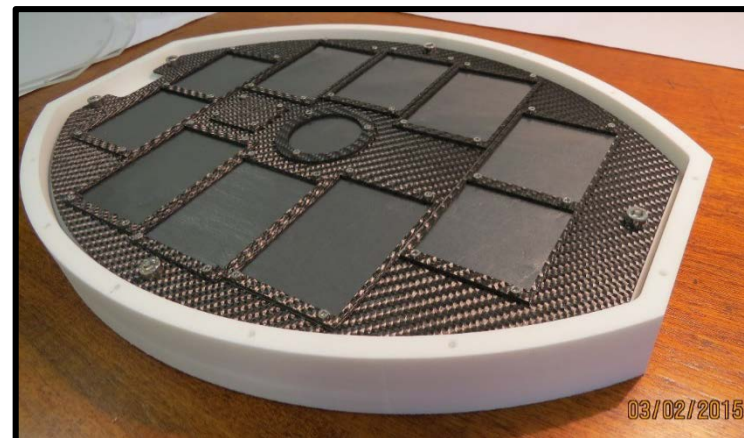
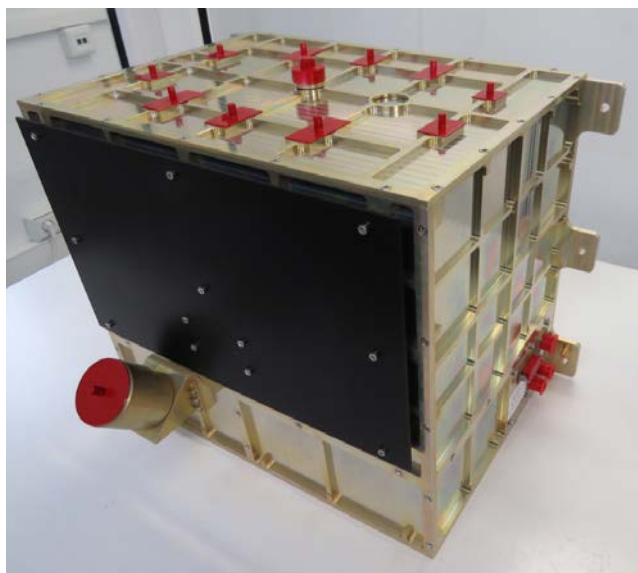


XOP (X-ray Oriented Programs)

(with XCRYSTAL_BENT application)

Conclusions & Summary

- “Phase B” (concept study & initial operations) funded by Polish Science Centre (NCN) coming to the end
- 10 spectral channels were defined
- part of crystals and detectors were purchased, initial tests are in progress
- two engineering models (MB + TUVF) were sent to Russia with the technical documentation



we are (almost) **ready to build** the technological model of the ChemiX
but
Interhelioprobe launch is moved **after 2025**



Thank you