ChemiX – the soft X-ray Bragg spectrometer under development for the Interhelioprobe Mission.

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and the


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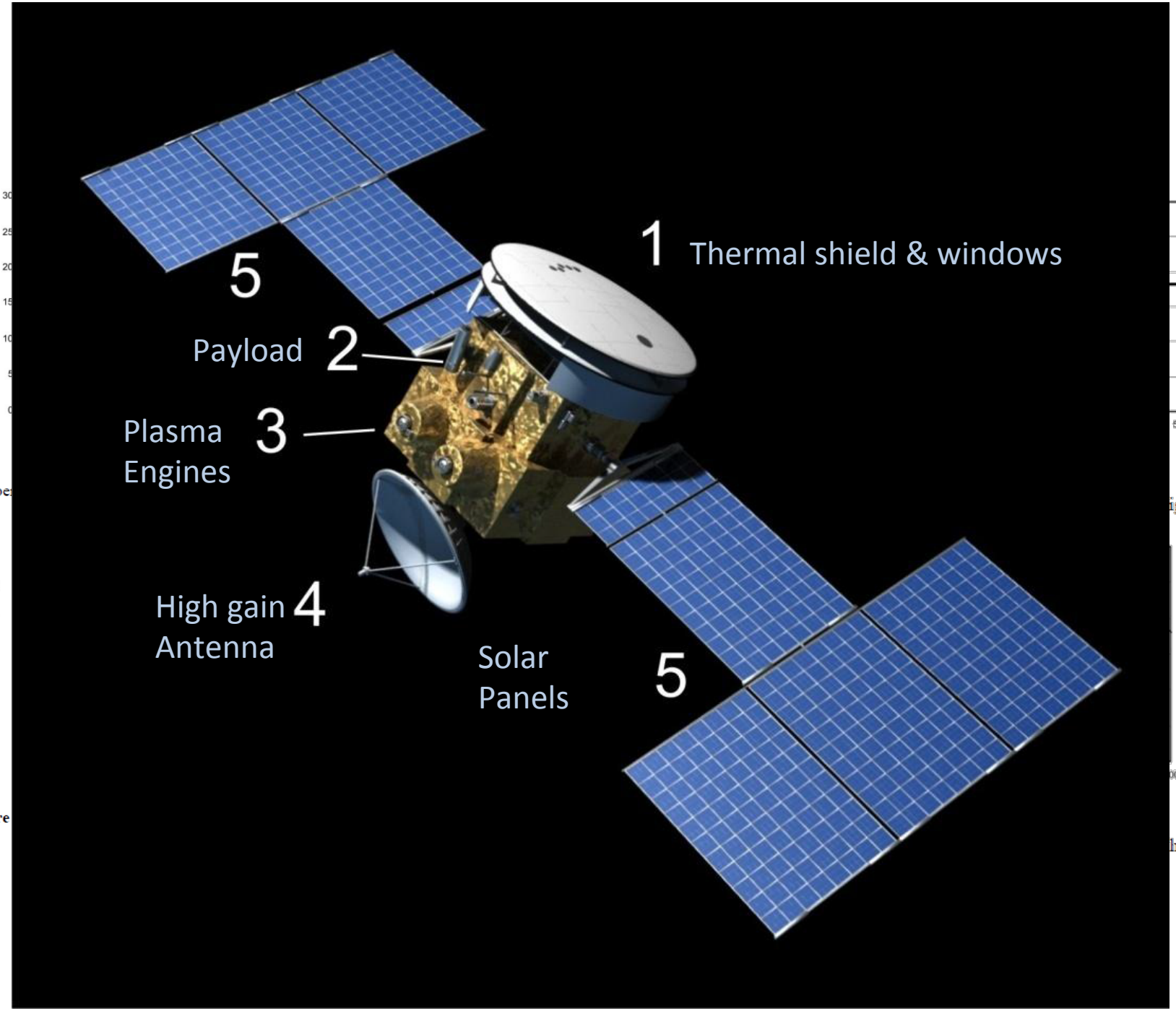
Why we designed & build **ChemiX** (**Chem**ical composition **i**n **X**-rays)

- Continue important observations of spectra in the **softer X-ray range** (SMM FCS, BCS, RESIK) T>2 MK
- **Isolate** spectra from **individual targets** on the Sun
- Construct **fluorescence-free** spectrometer
- **Improve on signal/noise** (several x better than RESIK)- allow reliable continuum flux determination
- Preserve **1 s cadence**
- Determine turbulent widths and line Doppler shifts
- **Determine coronal abundances** to the **accuracy equivalent/better** as the photospheric ones

I. Mission Summary

Funding	The Russian Federal Space Agency (Roscosmos)
Principal Investigators	L.M. Zeleny (IKI), V.D. Kuznetsov (IZMIRAN)
Spacecraft design	The Lavochkin Association, Russia
Number of Spacecraft	2
Spacecraft	3-axis stabilized platform, circle-shaped shield with windows, ≈3.7×4.5×3.7 m^3
Orientation	Sun-pointing
Launcher	"Soyuz-2/1b" rocket with "Fregat" rocket stage
Cosmodrome	Baikonur, Republic of Kazakhstan
Launch date	2020 (№1), 2021 (№2)
Orbit	Venus resonance orbits with multiple gravity assists. Perihelion: 60-70 Rs. Aphelion: 250-260 Rs. Inclination: up to 30° to the ecliptic.
Mission active operation time	5 years
Total mass of scientific payload	160 kg
Number of scientific instruments	19
Flight Operation Center	The Lavochkin Association, Russia
Science Operation Center	IKI, Moscow, Russia
Ground stations	"Medvezgyi Ozera" (70-m antenna), Moscow Region, Russia "Ussuriysk" (70-m antenna), Russia
Scientific traffic	Up to 1 GB/day
General Concept	- Multi-wavelength solar observations at short distances from the Sun (up to 60R_S) - Out-of-ecliptic solar observations (up to 30°) and observations of the Sun's opposite side - In situ measurements in the inner heliosphere (and) out of the ecliptic plane



Inclination, degree

Perihelion, R_S

Figure 4. Depe

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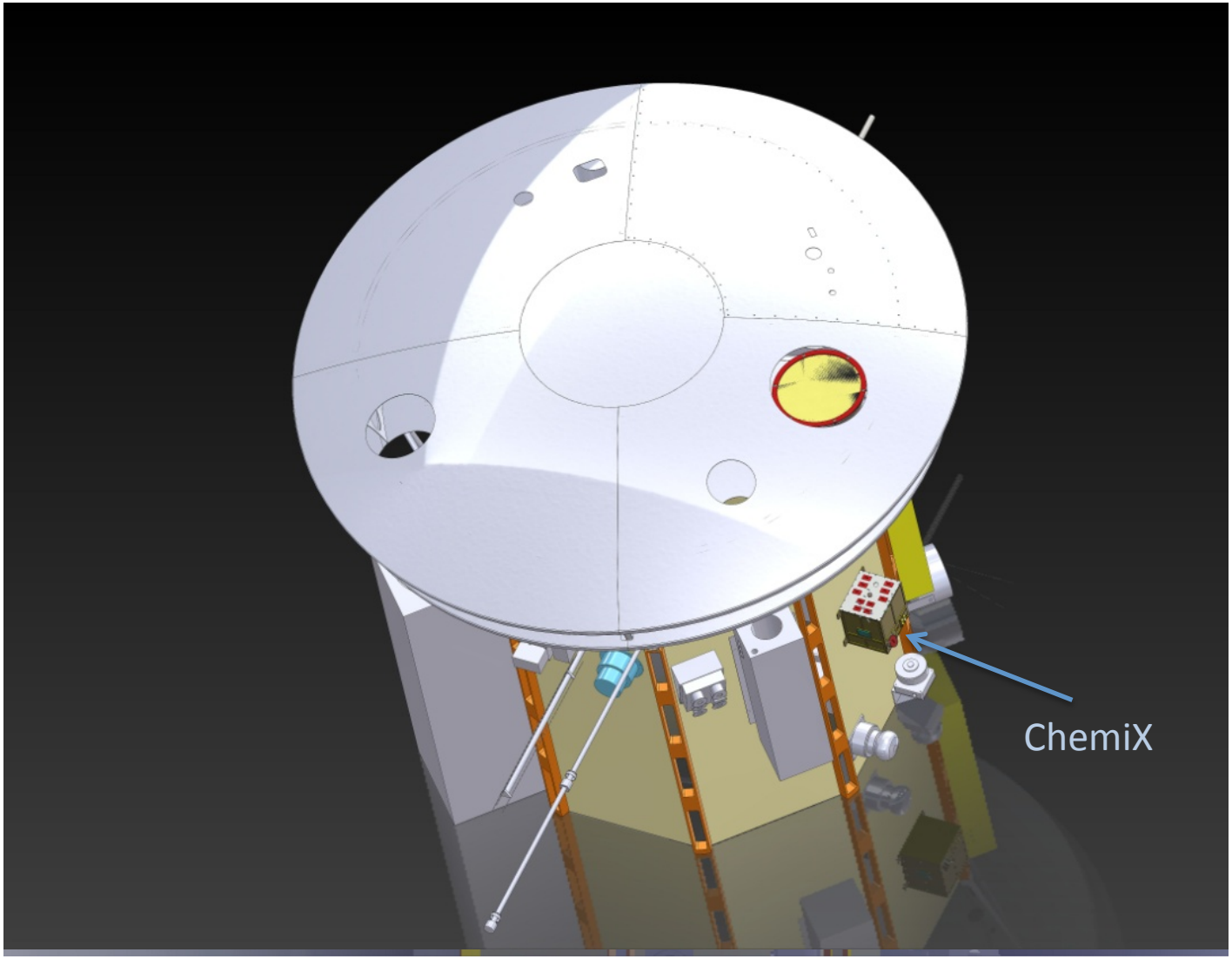
Figure

hick red lines

ChemiX on IHP



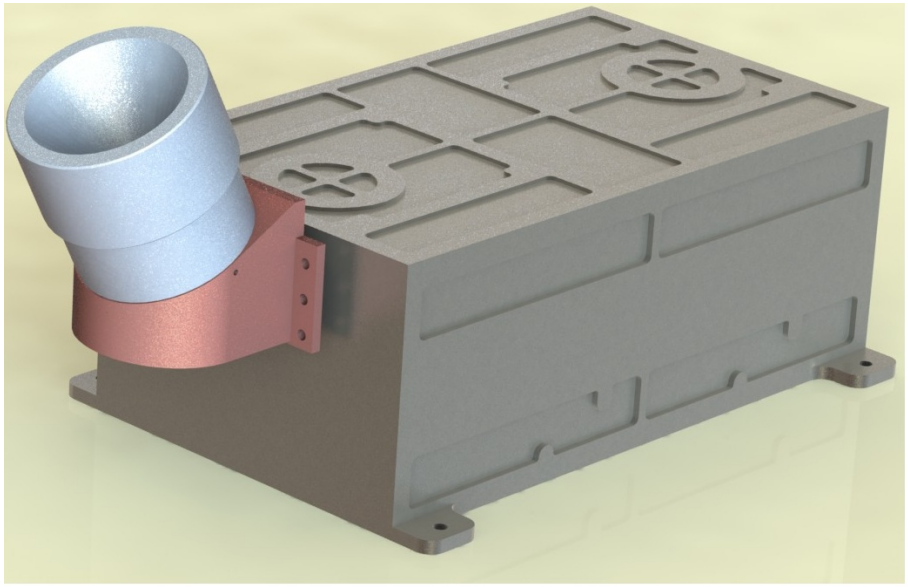
- Large entrance window
- 11 CCD's
- Unit to detect particles

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 otherwise
- **(Very) soft pin-hole CCD X-ray imager ~ 1 arcmin resolution**
  - Detect pointing based on the limb-brightening ring - provides detailed pointing (few arcsec accuracy)
  - Localize ARs important in X-rays & follow their (separate) lightcurves
  - Identify flares within individual AR →provide target data to the pointed table
- **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 say 10 000 counts in the spectrum
  - Provides spectral line & continuum intensities with unprecedented accuracy (2 x RESIK at perihelion)
- **Dopplerometer**
  - Looks toward „differential" spectral line positions at the very high spectral resolution
  - Provides selected spectral line shapes at several points over the line profile

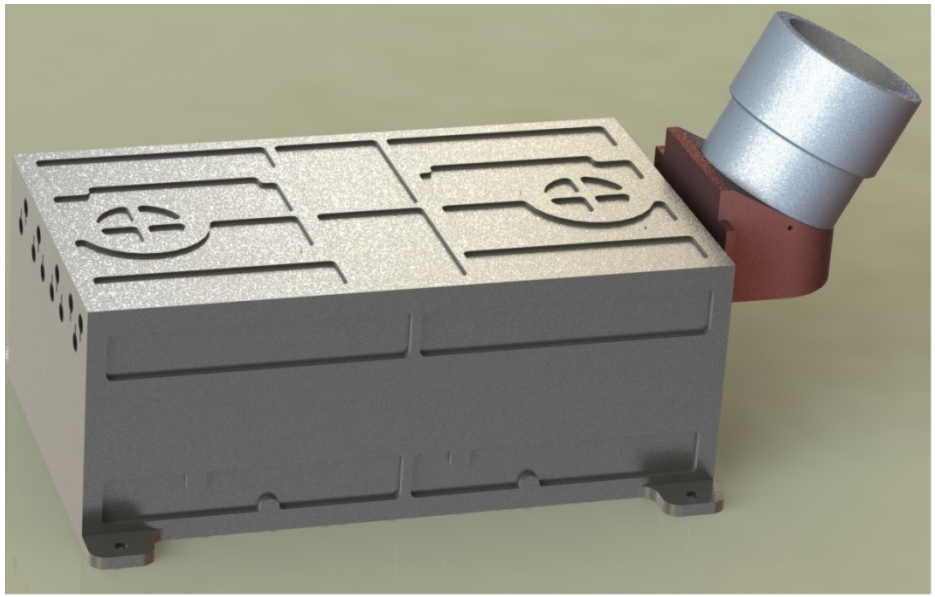
All spectra are being taken instantaneously at all wavelengths

Background energy particle detector of ChemiX instrument Kharkiv National University Group (dr. Dudnik)

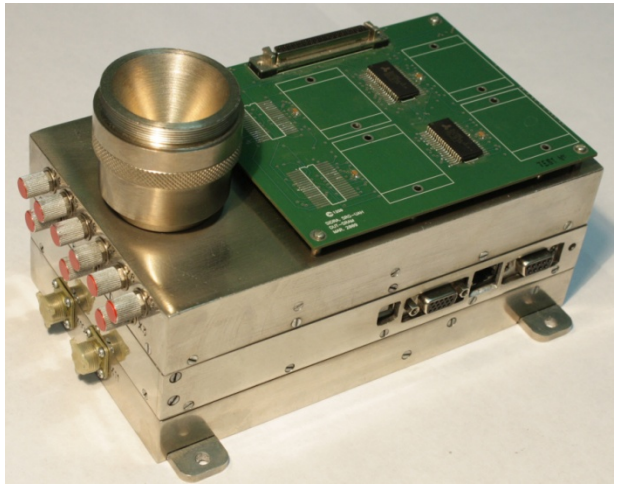


Energy ranges of registered particles

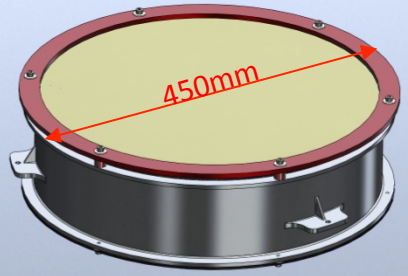
№	Particle sort	Energy range, MeV
1	Electrons - e	0.06 — 2.4
2	Protons - p	1.2 — 14
3	Deuterons - d	1.6 — 18 (0.8 – 9 MeV /nucleon)
4	Alpha-particles	5 — 52 (1.3 — 13 MeV/nucleon)



Past inspected version of the breadboard model



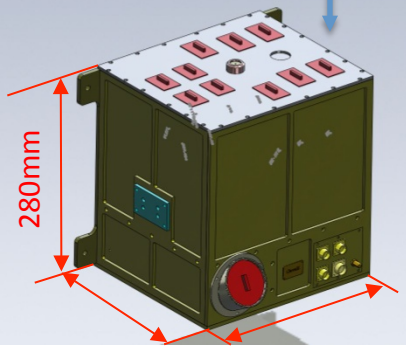
TUVF



~2m

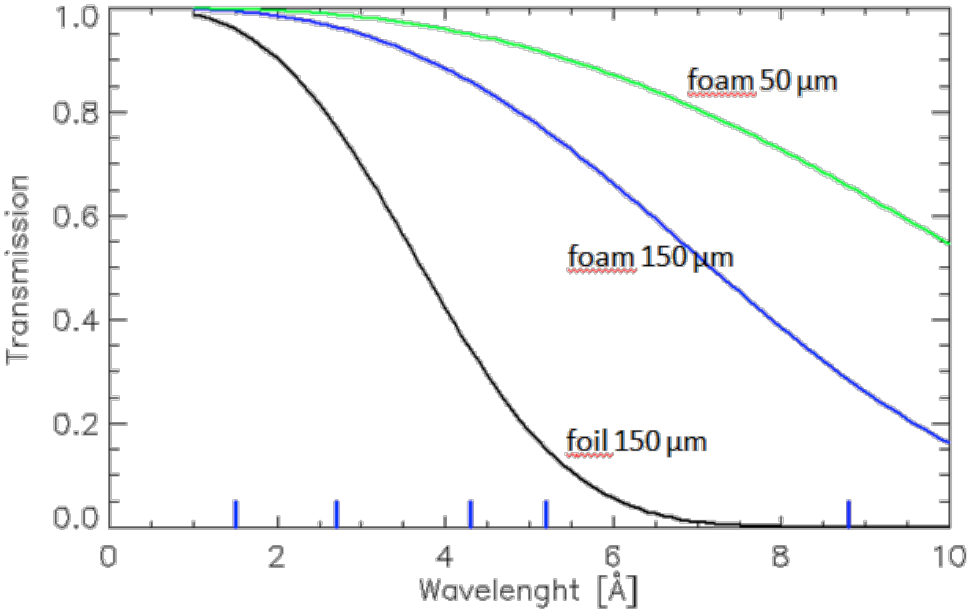
Weight:
TUVF - 1.5 kg
MB - 4.5 kg

MB

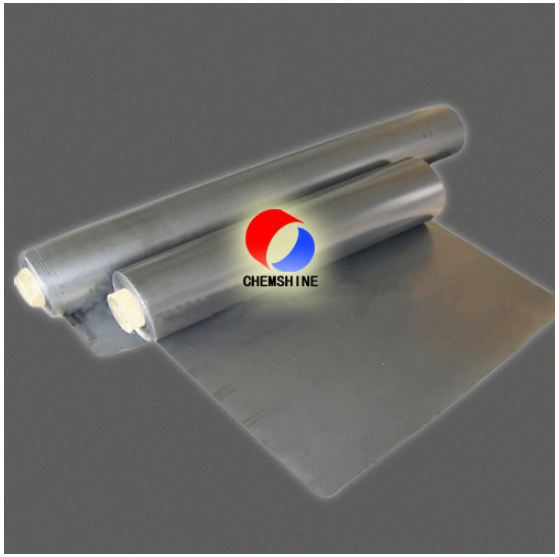


http://www.chemshine.com/EproductShow.aspx?id=8

Entrance window – graphite foil/foam

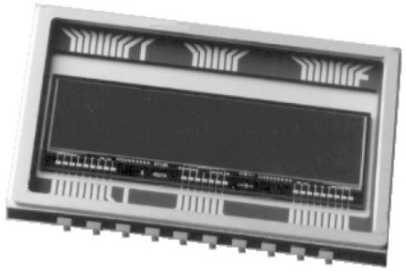


Technical Graphite foil can work at -200 ÷ 650℃ air condition, -200 ÷ 3000℃ vacuum or inert environment.



Detectors & crystals

CCD30-11 Back Illuminated Deep Depletion Full Frame Scientific CCD Sensor



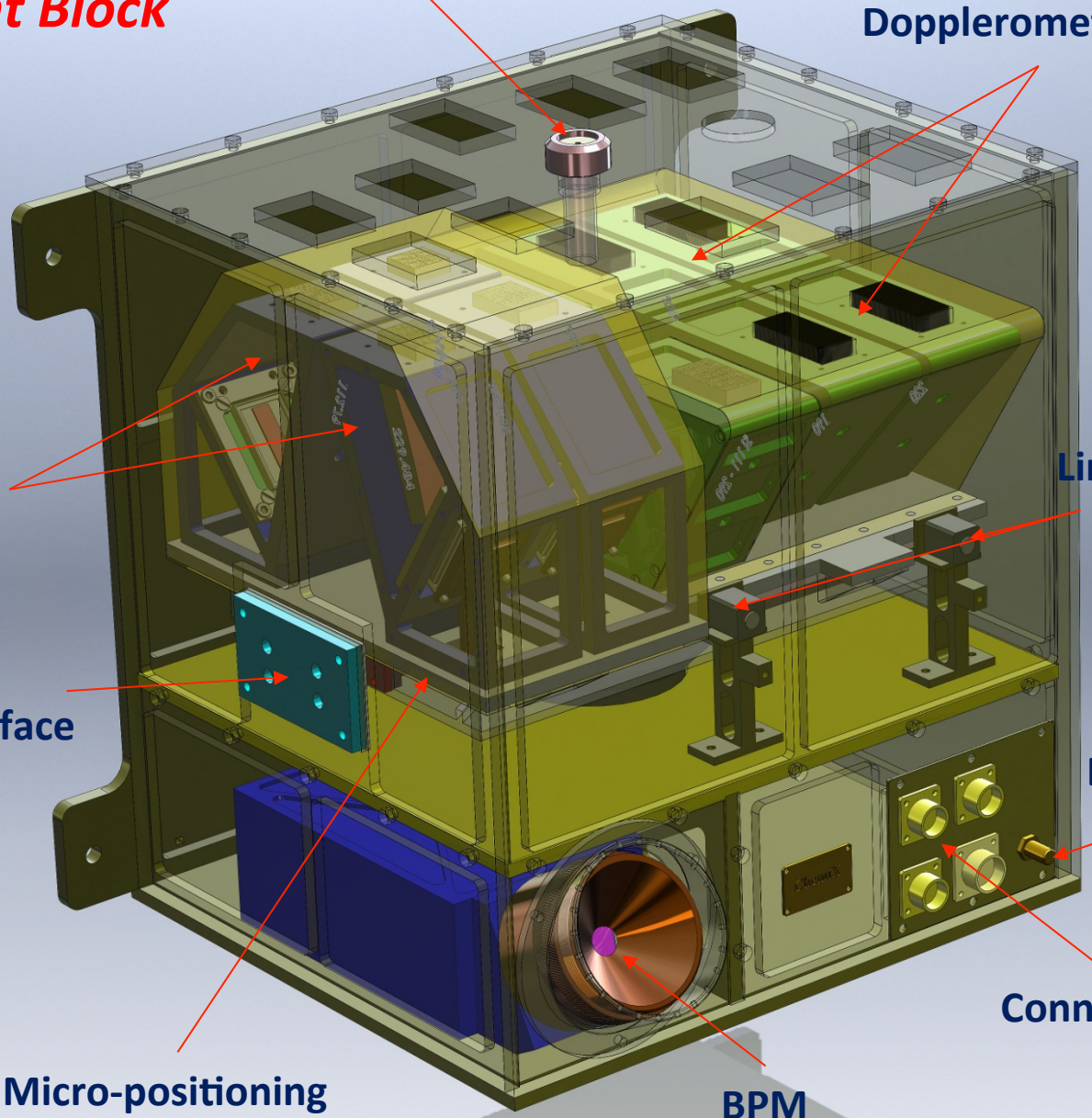
11 identical units

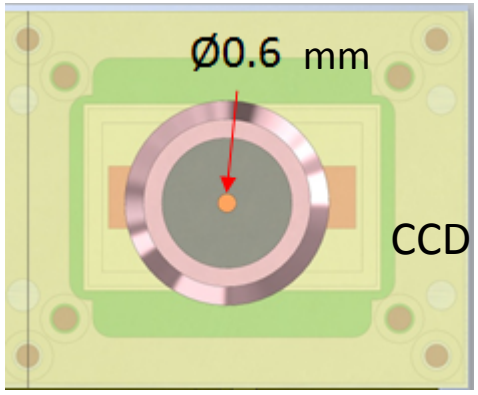
- E2V
- 1024 x 256 pixels
- Image area 26.6 x 6.7 mm
- Pixel size 26 x26 µm

No	crystal	orientation	2d	wavelenght range [Å]	average spectral resolution [mÅ/pix]	curvature radius [mm]	total desired crystal lenght [mm]
Spectrometer							
1	Si	111	6.271	1.500 - 2.713	1.46	113.844	41.3
2	Quartz	10-10	8.514	2.700 - 4.304	1.95	112.789	41.2
3	ADP	101	10.648	4.290 - 5.228	1.46	247.454	51.6
	KDP	011	10.185	4.290 - 5.228	1.43	229.484	49.9
4	KAP	001	26.64	5.200 - 8.800	4.73	204.909	52.95
Dopplerometer							
1	LiF	022	2.848	1.770 - 1.943	0.30	220.000	43.0
2	Si	111	6.271	3.000 - 3.378	0.70	290.000	50.5
3	Si	111	6.271	3.700 - 4.201	0.78	190.000	42.8

- Detectors - large enough to have sensitivity similar to RESIK on LEO
- Crystals made of materials **not contributing to fluorescence** within the measurement region

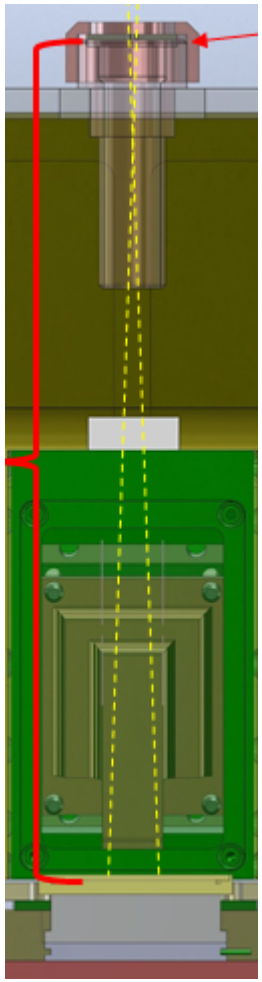
MB
Measurement Block





(SphinX D2)

Pin-hole imager will observe also limb-brightening E ~0.5 keV



Main functionalities:

Locate the solar disk within the orientation frame of S/C

Follow the brightness evolution of individual pixels/AR/Flares & **detect flares**

Provide coordinates of the target(s) to the pointing system of crystal-detector units (within IDPU)

one pixel = 38 arcsec

At perihelium Sun diameter = 177 pixels (see the corona up to 5 – 7 solar radii above limb)

At aphelium Sun diameter = 42 pix (early in the mission)

At 1 a.u. Sun diameter = 54 pix

Diffraction smearing at the CCD distance

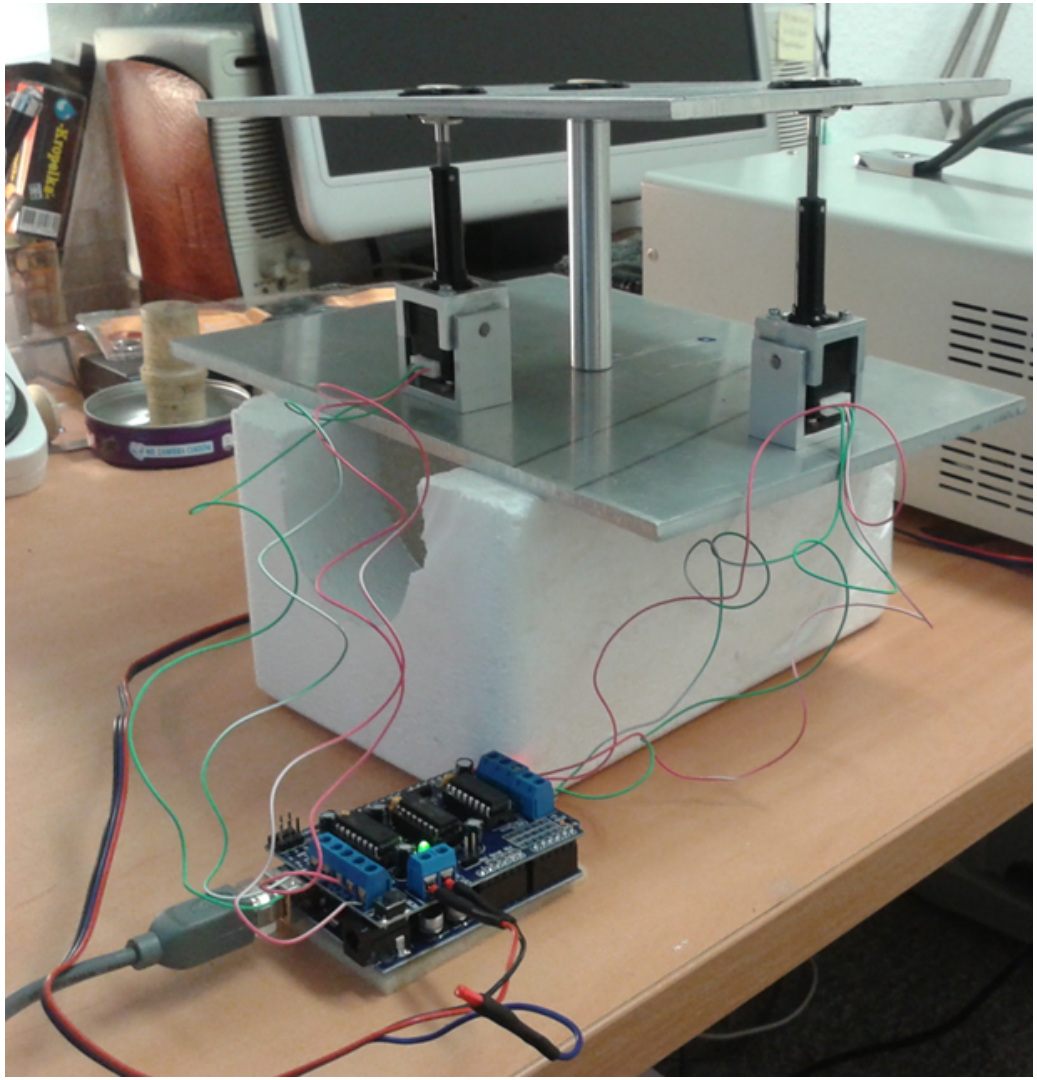
for 5 A = ~ 8.3 um = 0.4 pixel

for 10 A =~ 11.8 um = 0.5 pixel

for 20 A =~ 16.7 um = 0,6

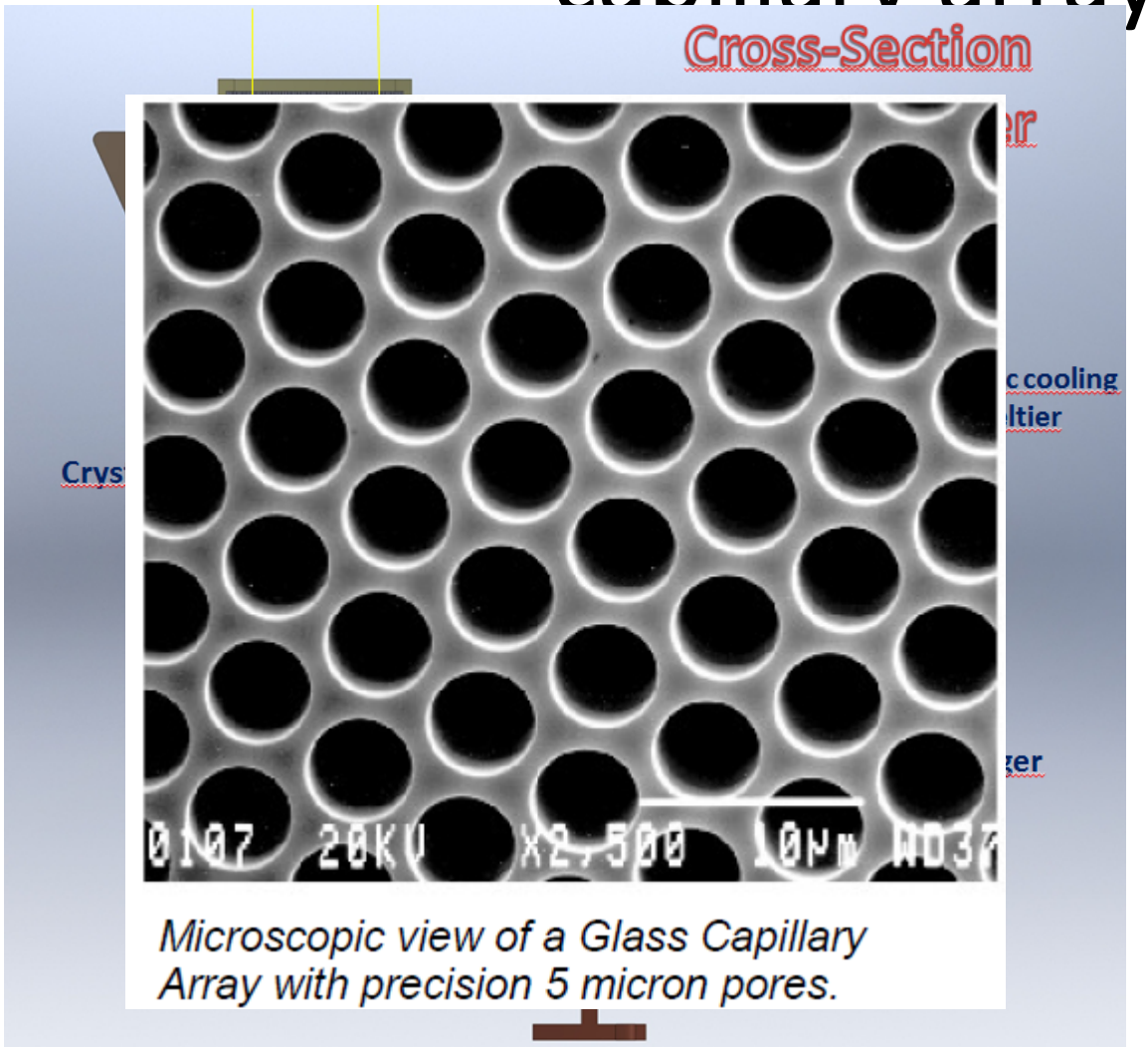
good for deconvolution & point source location (flares)

Pointed platform- provides fast (<1s) repointing within the area of 3° x 3°



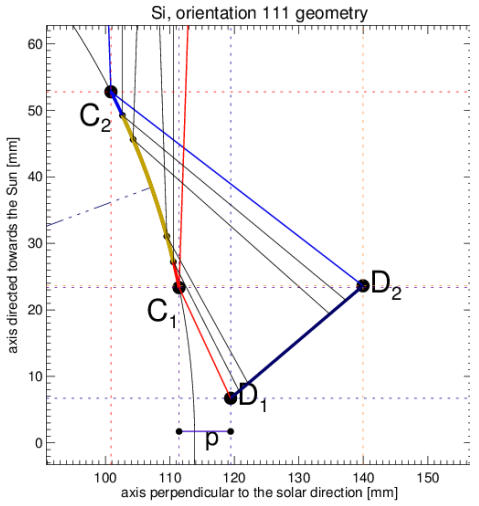
- Very lightweight & fast
- Takes known coordinates of the source from on-board controller
- Movie of the action available
- Larger off-sets possible
- Will be locked for launch

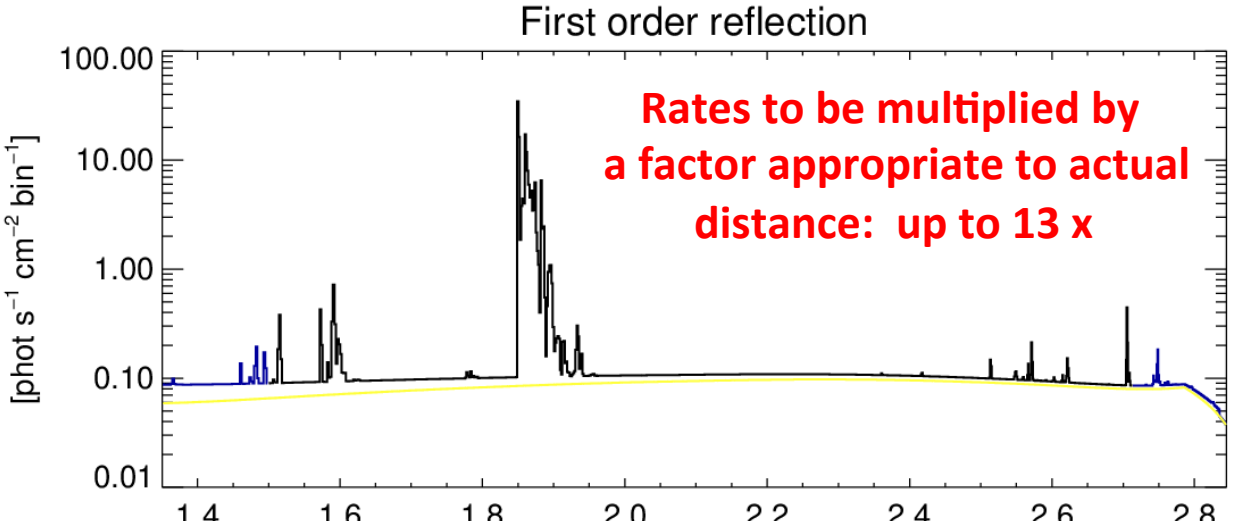
2D collimation with spectrometer capillary arrays

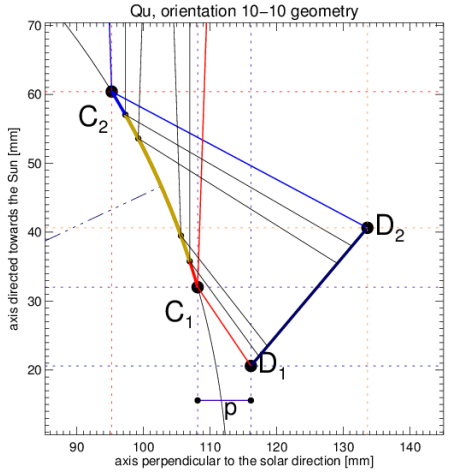


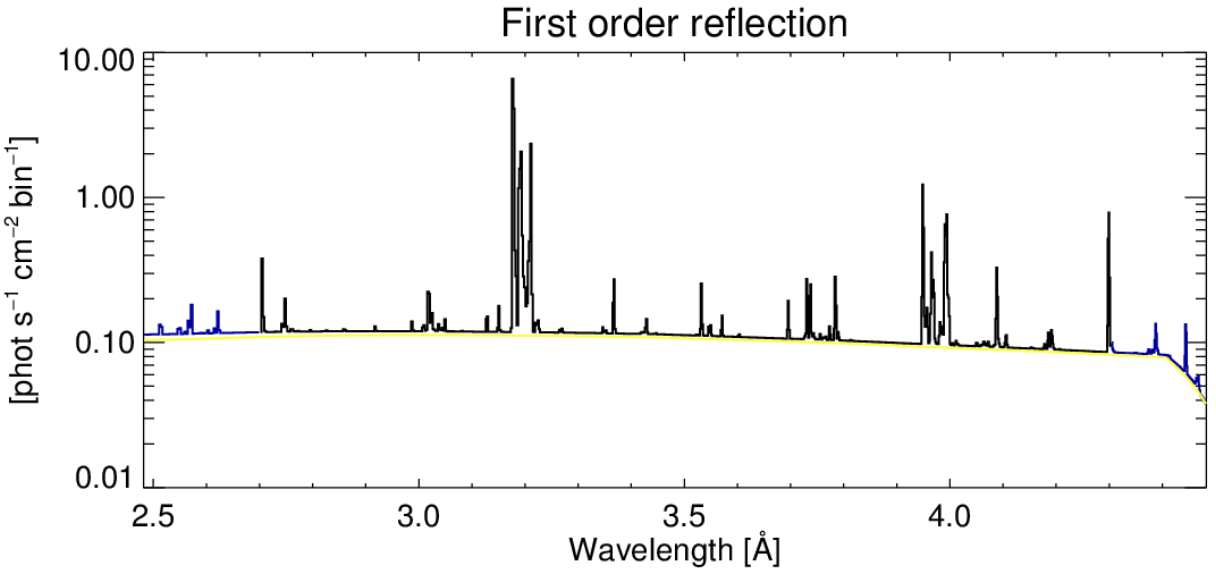
- Motivation: limit the FOV to a single AR
- Prevent spectral overlapping from multiple sources
- Allow to study variability of line profiles

Crystal geometry & Synthetic spectra for 1st order reflection **M5.5 flare 1a.u.**









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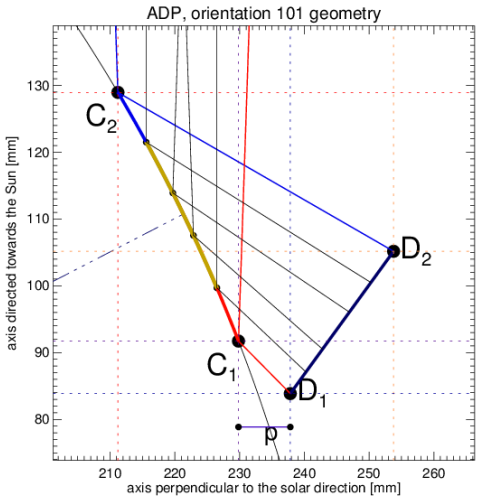
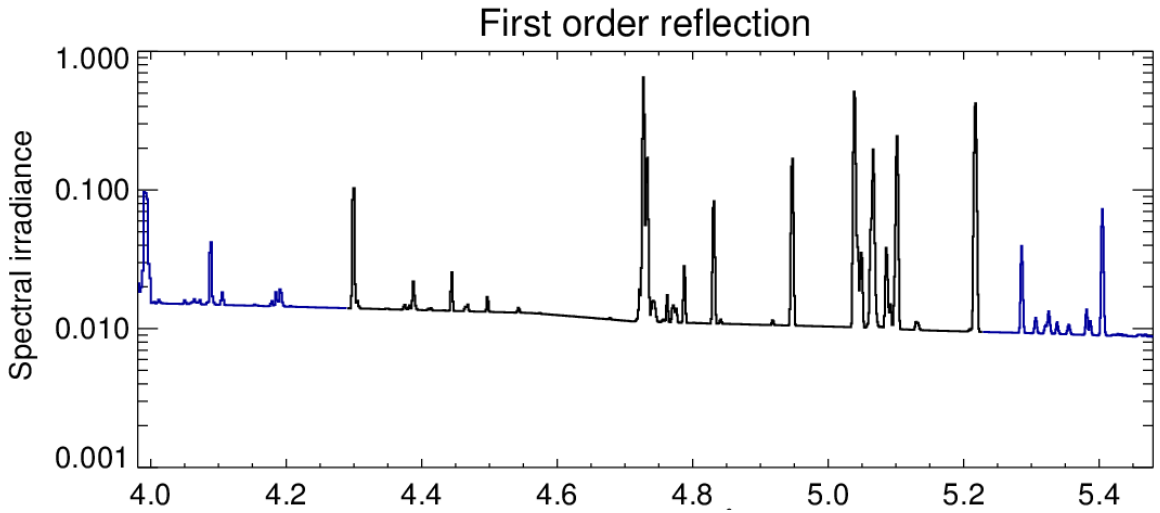
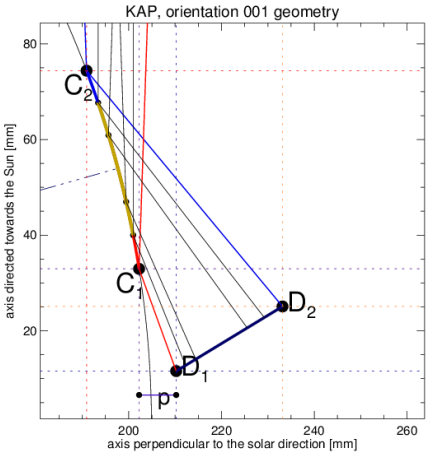
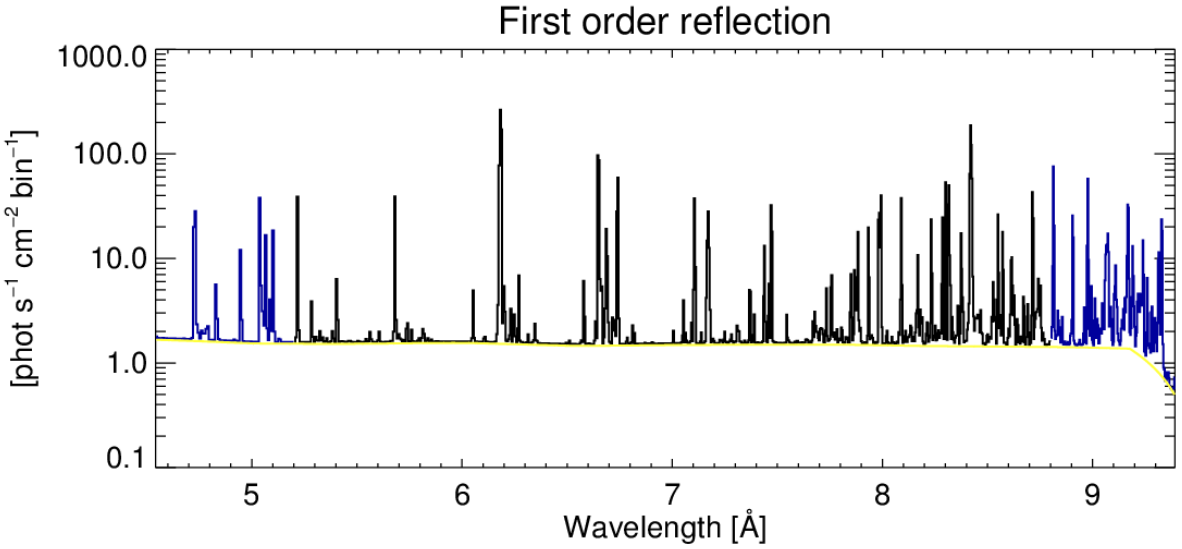
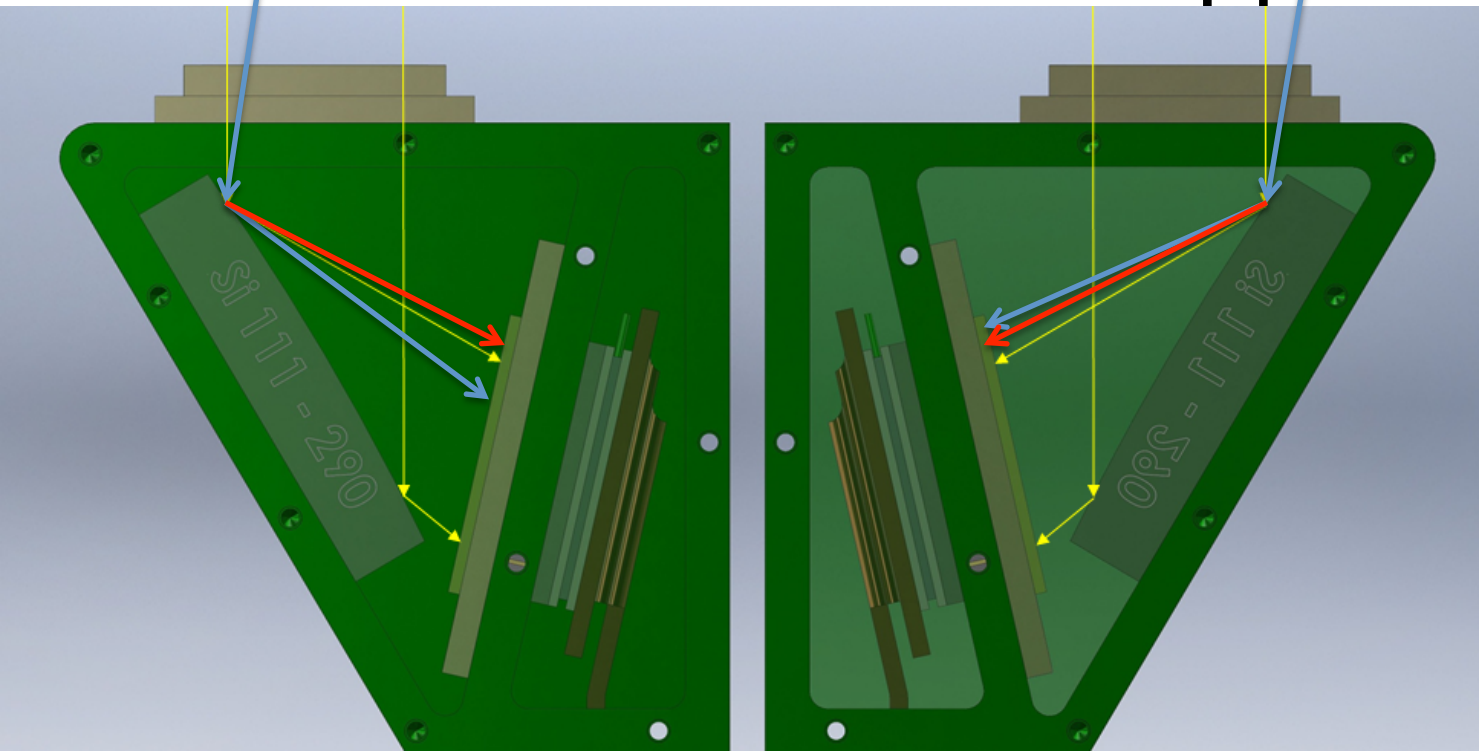








3 double sections of Dopplerometer



Lines selected:

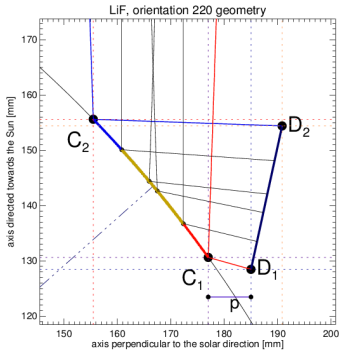
Fe XXV T ~20 MK
Hot flare

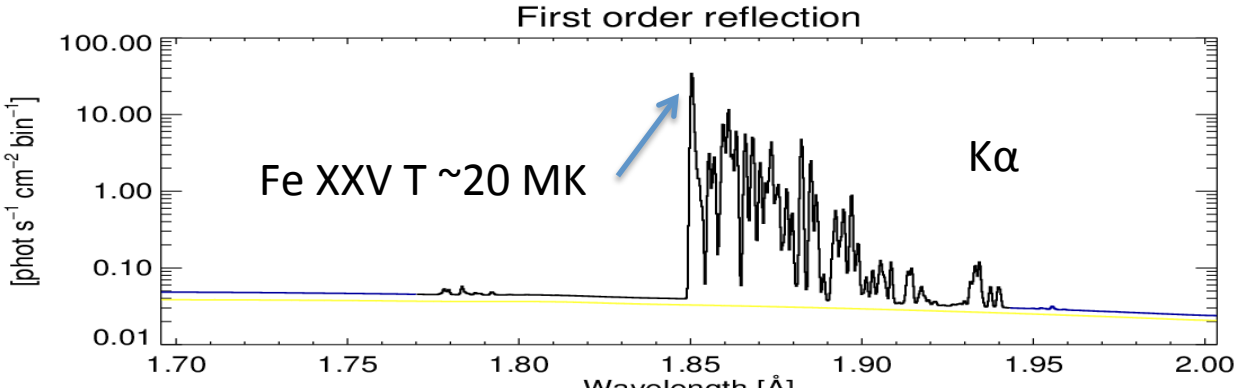
Ca XIX T ~10 MK
Evaporated material

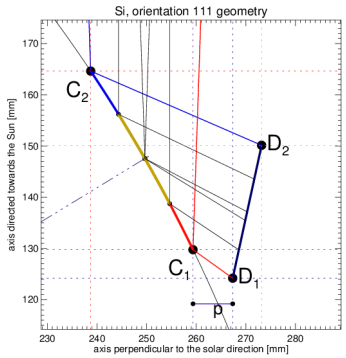
Ar XVII T ~4-5 MK
AR plasmas

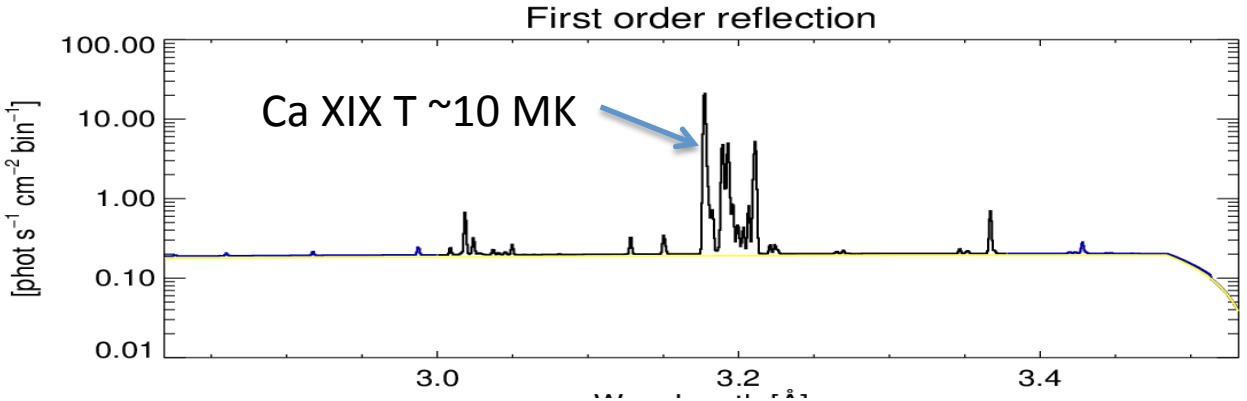
- Dispersion senses opposite
- Identical crystals and detectors
- This system allows to disentangle between transwersal and radial motions

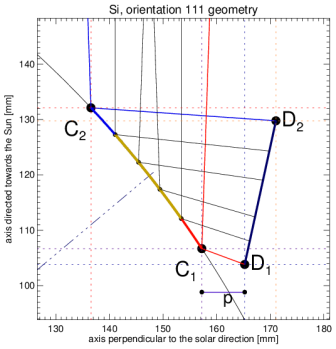
Wavelength ranges for Dopplerometer

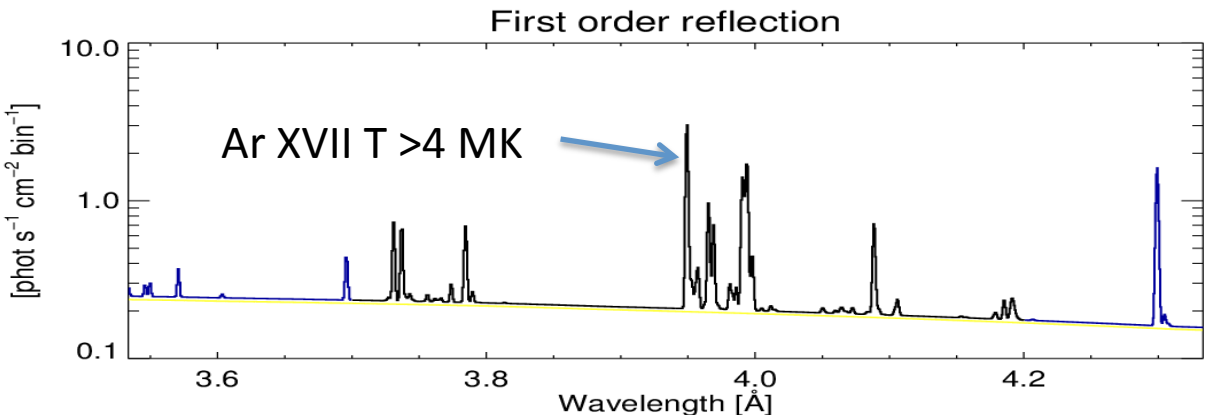




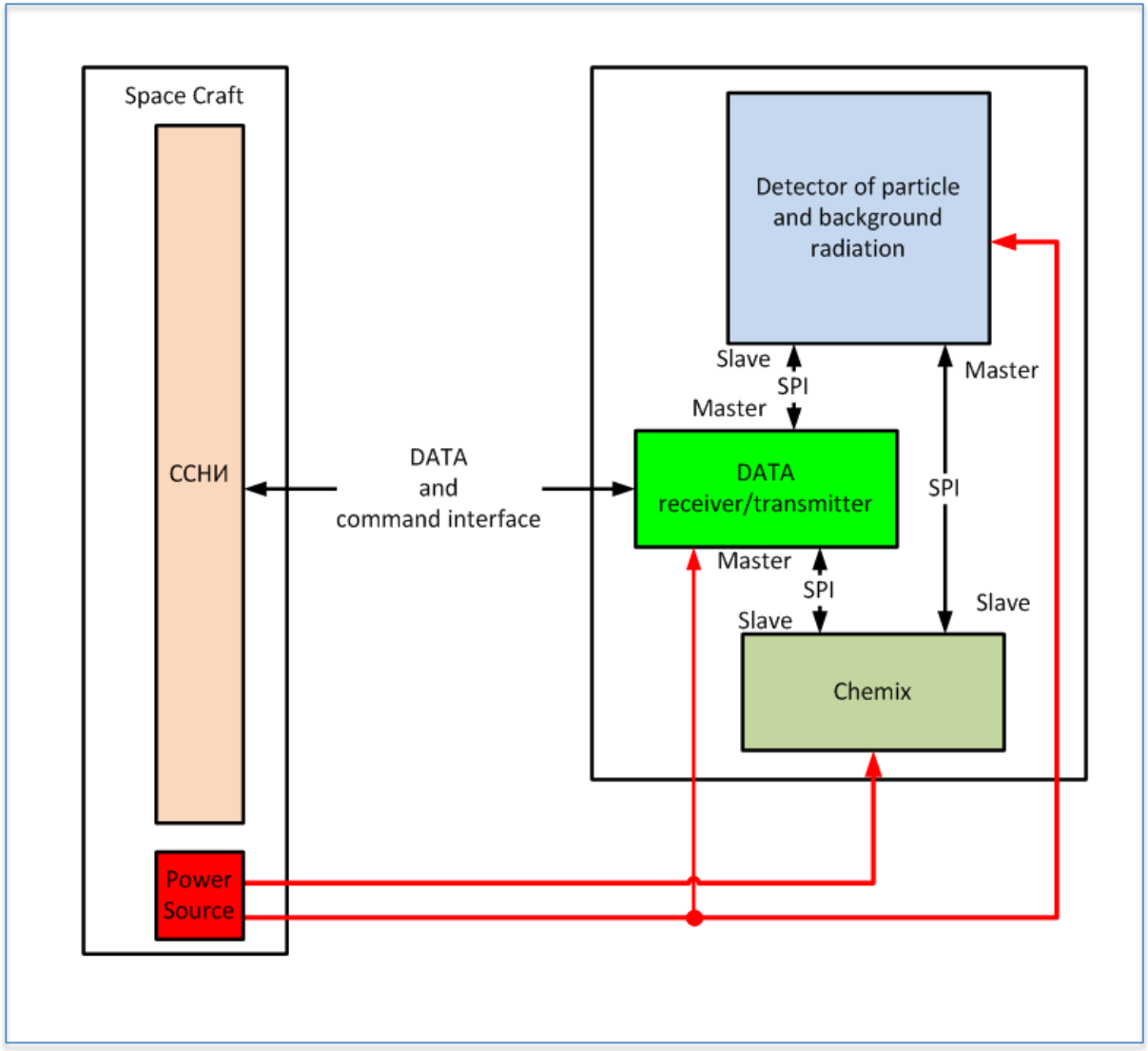








Electronics & logic



Particle monitor outcomes as the first defense for the instrument health. **Always on**, except really dangerous particle intrusions detected internally by the IDPU. Delayed S/C commanded reset brings spectrometer to life.

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

Collaborations possible

- Crystals
  - Testing radiai of curvature & reflecting properties
  - BESSY II is envisaged
- Simulations of non-classical flaring scenarios
  - Non- Maxwellian (kappa plasmas)
  - Transient ionisation plasmas
  - Abundance differentiation processes
- Instrument end-to-end testing