SOLAR X-RAY SPECTRA FROM 0.3 A.U.
THE CHEMIX BRAGG SPECTROMETER ON THE INTERHELIOPROBE

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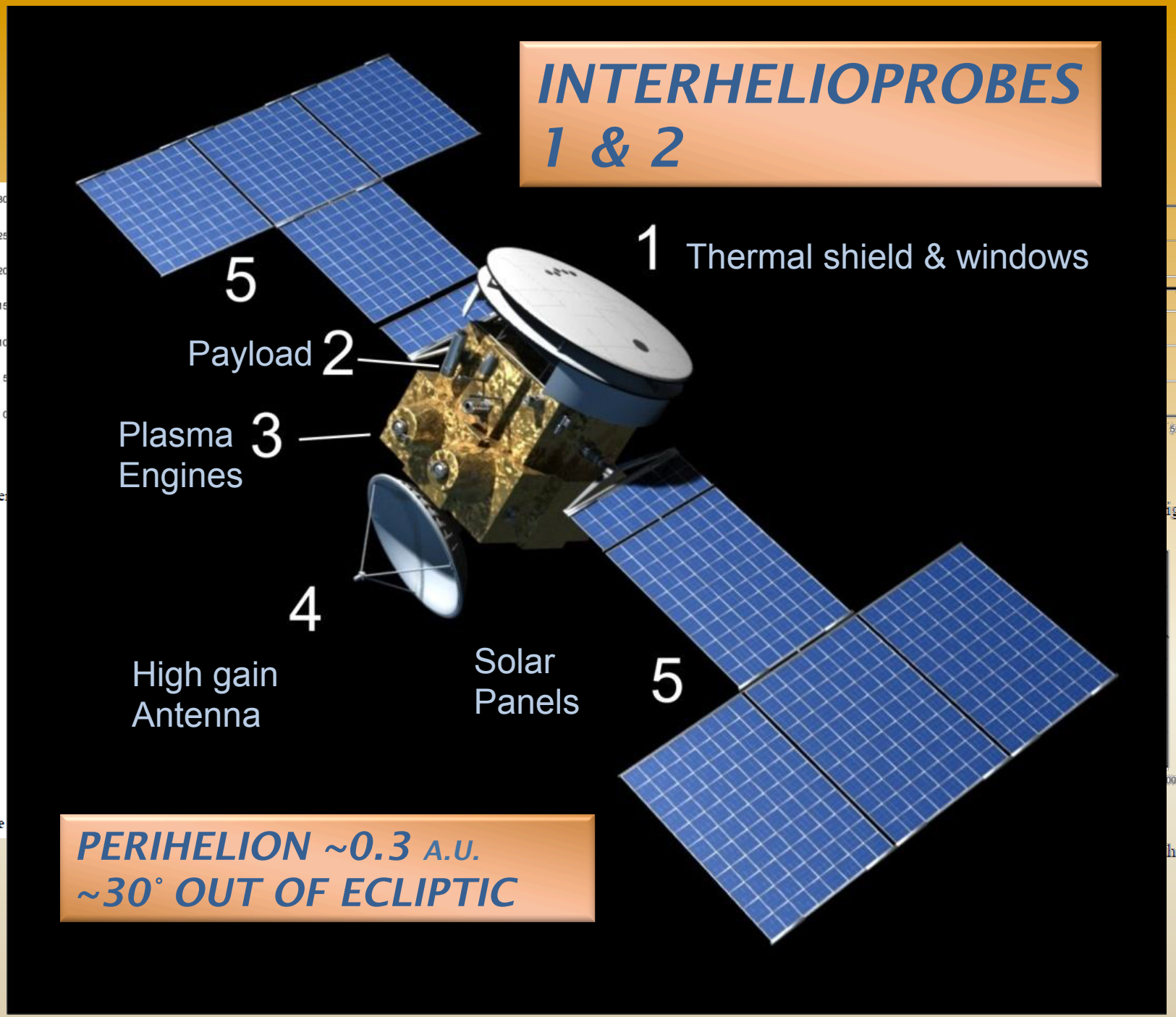

INTERHELIOPROBES
1 & 2
1 Thermal shield & windows
2 Payload
3 Plasma Engines
4 High gain Antenna
5 Solar Panels
5
PERIHELION ~0.3 A.U.
~30° OUT OF ECLIPTIC

What solar soft X-ray spectroscopy offers us

- **Spectra** are formed in optically thin multi-million K plasmas; every photon emitted escapes from the source region (active region or flare coronal plasma).
- **Prominent continuum** mostly **f-f** and **f-b**

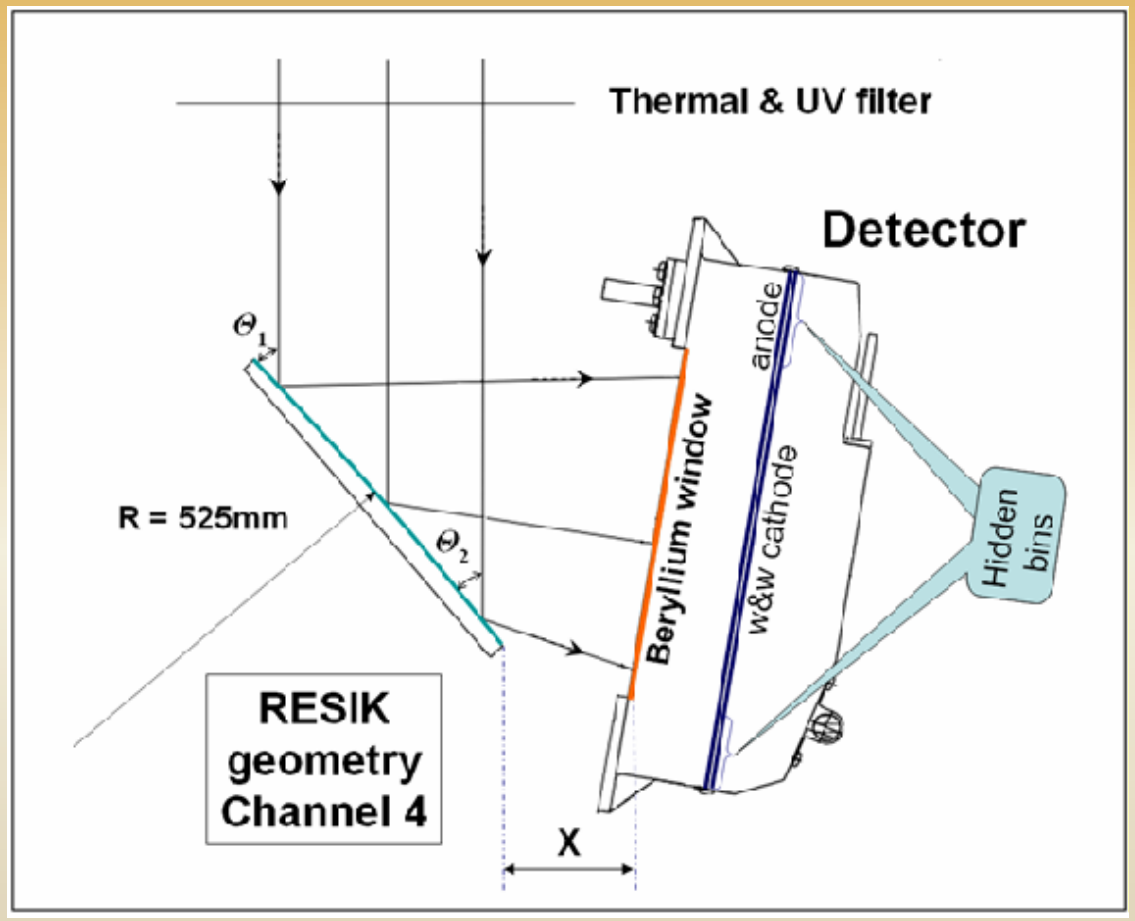
  - f-f or **bremsstrahlung** (emitted by electrons passing protons)

  - **f-b** depends on plasma composition; abundant elements most important emitters.
- **Emission lines** due to transitions in highly ionized heavier elements:
  - Line intensities proportional to element abundances.
  - Lines due to ions of Mg, Al, Si, S, Cl,Ar, K, Ca, Fe & Ni feature in the range 1.5 – 9Å.

X-ray spectrometers: Requirements for Abundance Studies

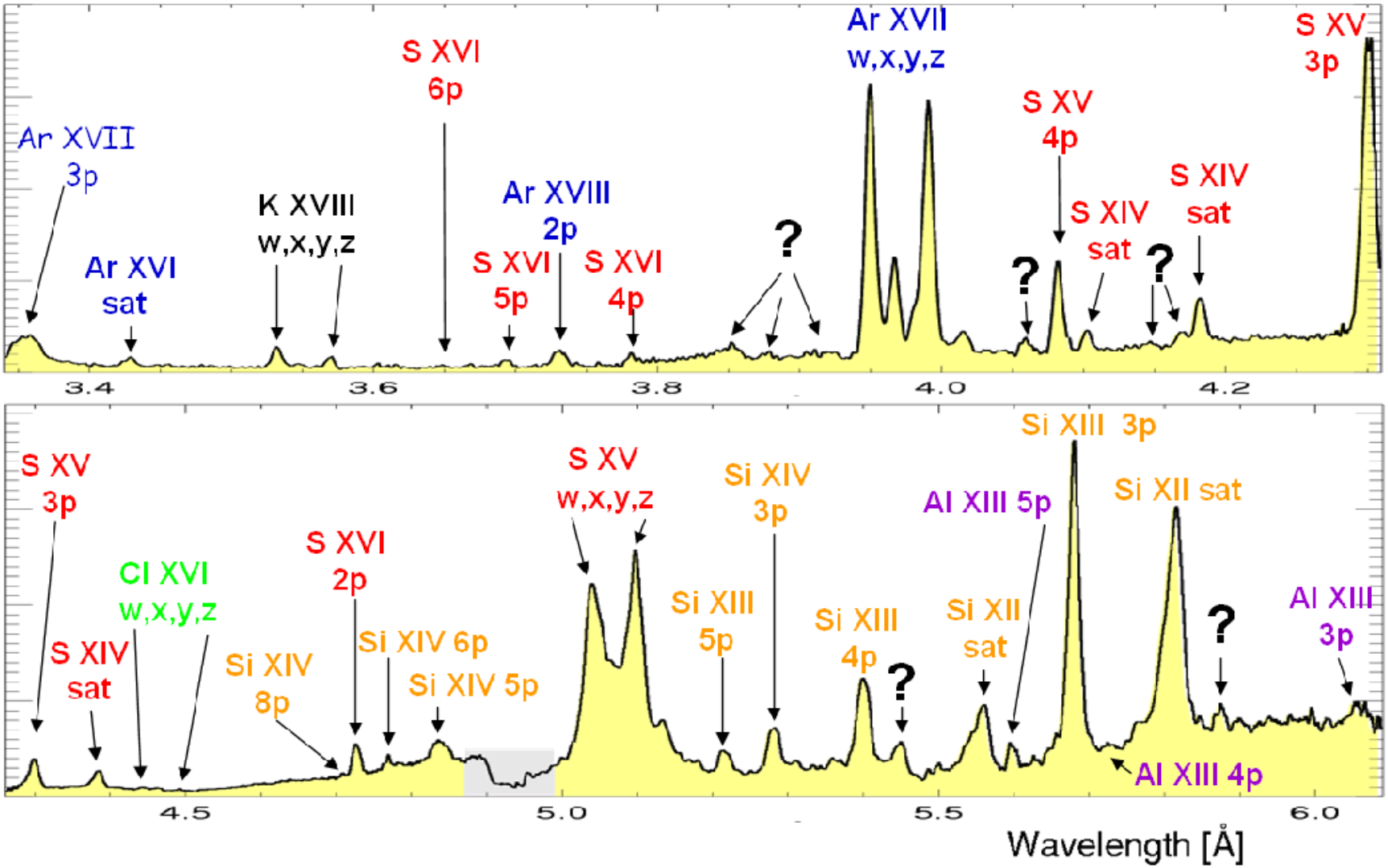
- **Good spectral resolution** allowing lines of particular elements to be distinguished.
- **Good sensitivity** allowing lines of low-abundance elements like Cl and K to be seen.
- **Reliable continuum** level can be measured – this allows for **absolute** abundance determinations (relative to hydrogen)
  - 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



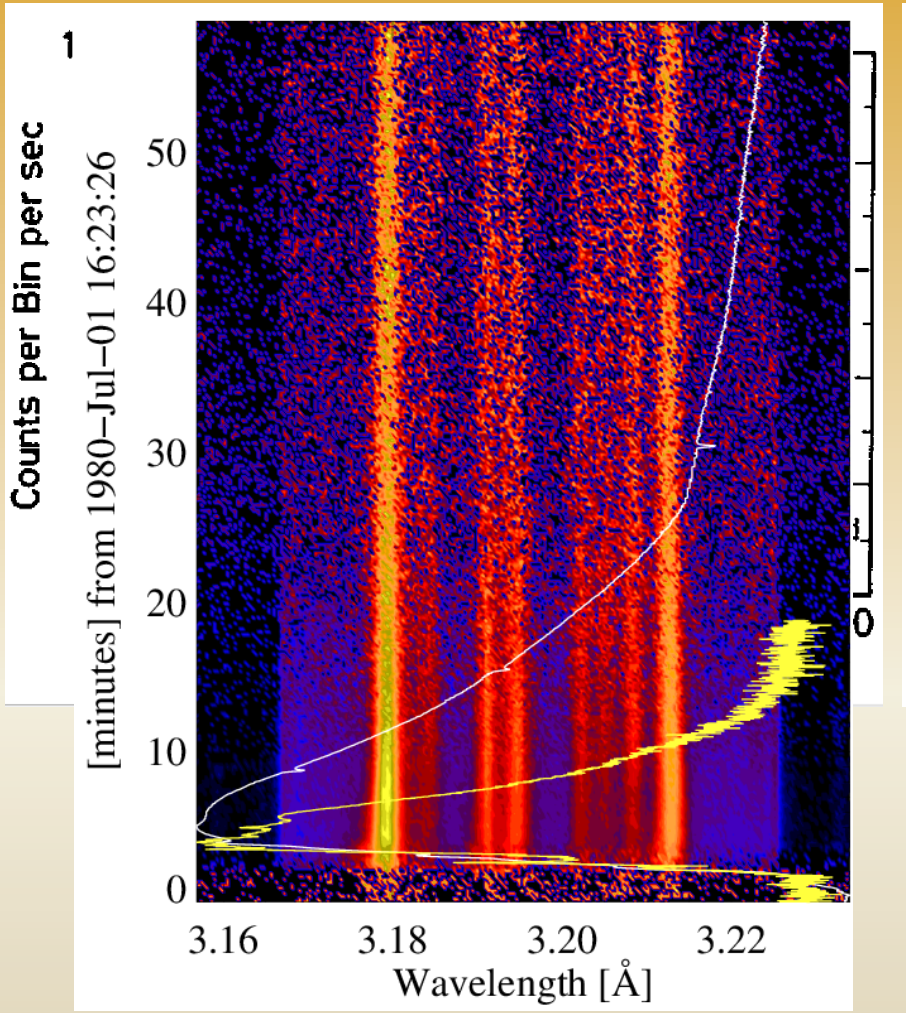
- Used on SMM BCS (1980, 84-89)
- Yohkoh BCS (1991-2001)
- RESIK (2002-2003)

RESIK Spectra: T-range 3-30 MK
the best calibrated spectrometer

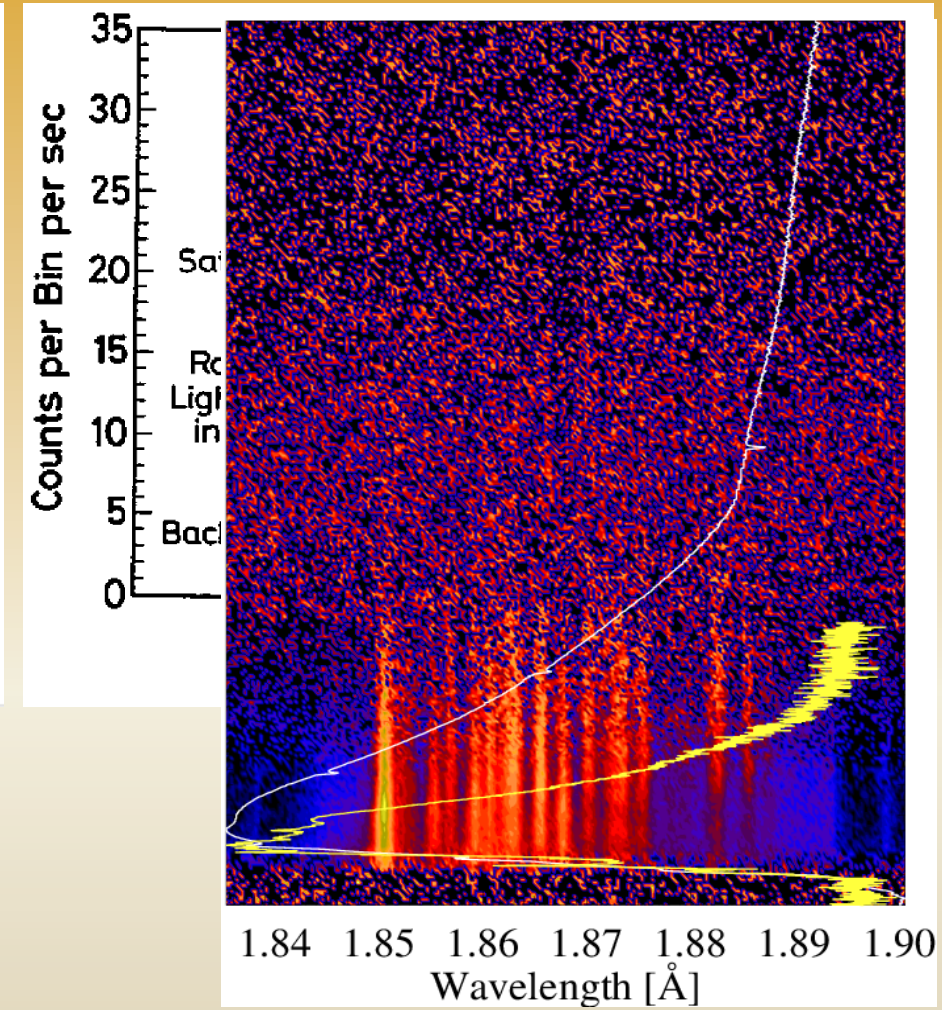


SMM BCS Spectra: T = 10-40 MK

the best spectral & time resolution ever recorded

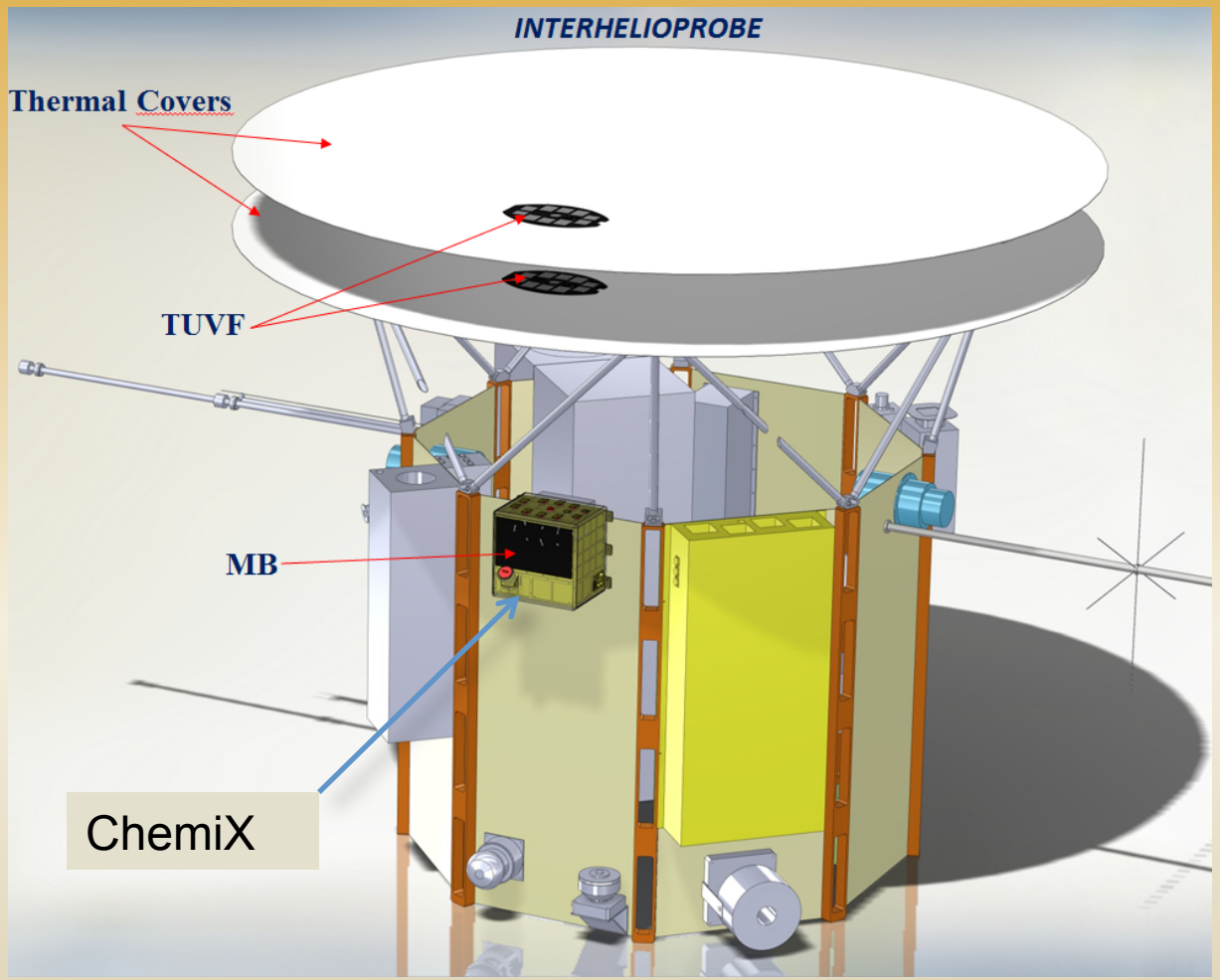


Ca XIX + sats.



Fe XXV + sats.

ChemiX on InterHelioProbe will take spectra from 0.3 a.u.



Large entrance window (11 sections)

Unit to detect particles

10 crystals & 11 CCDs

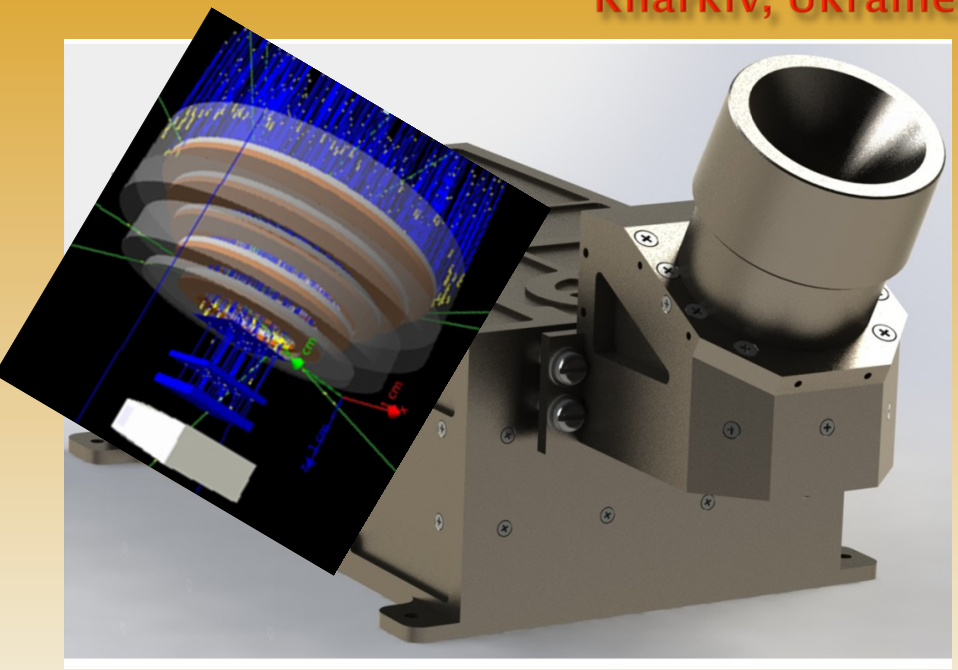
Pin-hole soft X-ray imager 0.5-10 keV

Subsystems of ChemiX

- **Particle detector (provides instrument safety)**
  - Will issue switch-OFF flag to instrument in case of emergency
  - Will measure particle spectra
- **(Very) soft pin-hole CCD X-ray imager ~ 1 arcmin resolution**
  - Detect S/C pointing to few arcsec accuracy
  - Localize an X-ray AR & record its light curves
  - Identify flares within individual AR and provide data to pointing platform
- **Internal Target pointing platform carrying all crystals & CCDs**
  - Will lock the spectrometer on target in < 1s.
- **Spectral atlas spectrometer**
  - Will record spectra in 1.5 - 9 Å range regularly within selected FOV - variable DGI to maintain constant (10 000) total counts in spectrum
  - Line & continuum intensities will have unprecedented accuracy (2 x RESIK at perihelion)
- **Dopplerometer (X-ray Tachometer)**
  - Disentangle spatial and spectral displacements of spectral lines.
  - Provides detailed spectral line shapes.

Background energy particle detector

Institute of Radio Astronomy National Academy of Sciences of Ukraine, Kharkiv, Ukraine (Dr. O. Dudnik)



Energy ranges of registered particles. 65 channels

№	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)

Time resolution 1 or 10 s, 3.4 kB/s

Objectives:

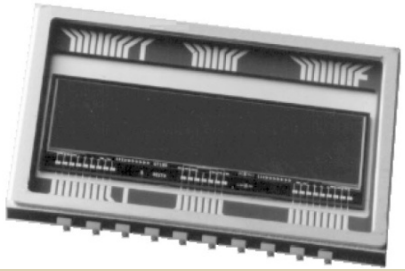
1.Will monitor solar high energy charged particle fluxes and interplanetary cosmic rays;
2. Issue flags to switch off ChemiX sensitive subsystems in case of high particle flux levels;
3. Provide input to estimate background count rates of ChemiX CCDs.

10 ChemiX crystals & Detectors

Crystal	Diffracting plane	$2d$ [Å]	Wavelength Range [Å]	Av. spectral resolution [mÅ per pixel]	Curvature radius [mm]	Crystal length [mm]	Crystal width [mm]	Number of crystals
Spectrometer channels								
Si	111	6.271	1.500–2.713	1.41	176.000	46.5	10.0	1
Quartz	$10\bar{1}0$	8.514	2.700–4.304	1.82	166.729	44.8	10.0	1
KDP	011	10.185	4.290–5.228	0.98	410.425	53.5	10.0	1
KAP	001	26.64	5.200–8.800	4.2	364.731	61.7	10.0	1
Dopplerometer channels								
LiF	022	2.848	1.835–1.949	0.12	650.0	46.1	10.0	2
Si	111	6.271	3.150–3.324	0.11	2500.0	58.2	10.0	2
Si	111	6.271	3.900–4.080	0.19	1000.0	47.0	10.0	2

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

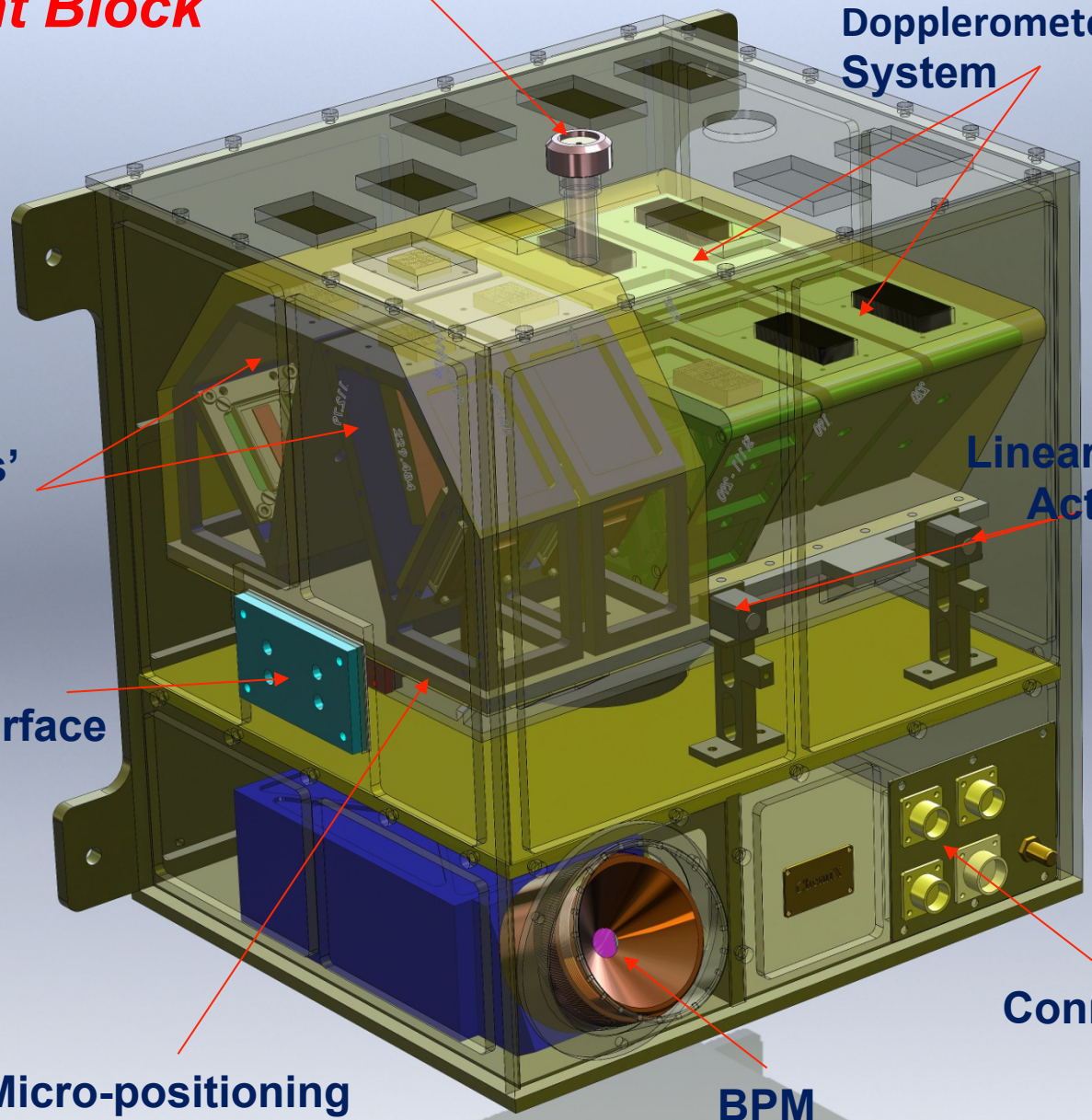
e2v, 1024 x 256 pixels, 26 x26 µm



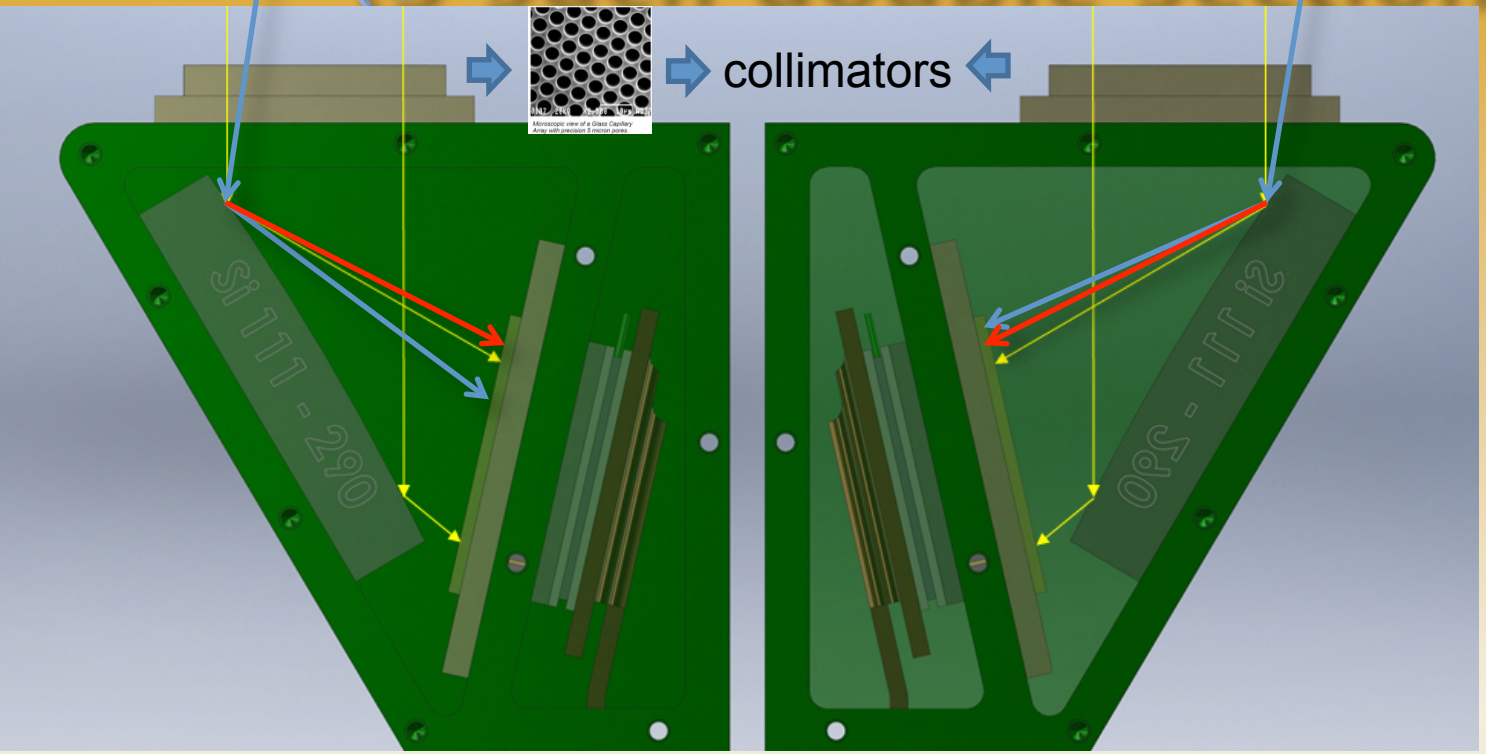
Detectors - large enough to have sensitivity similar to RESIK (in LEO)

Fluorescence from crystal material negligible for each spectral range

MB
Measurement Block



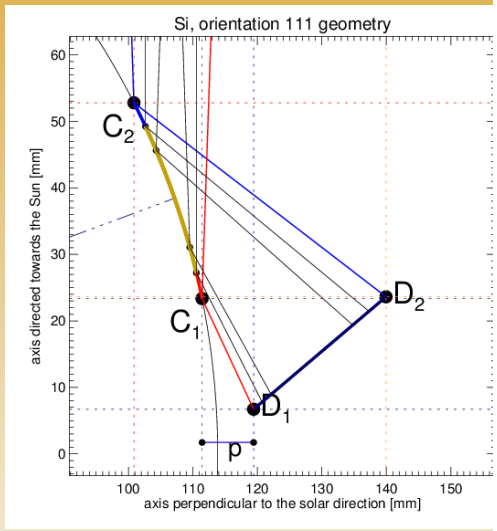
The concept of Dopplerometer (3 such double sections)

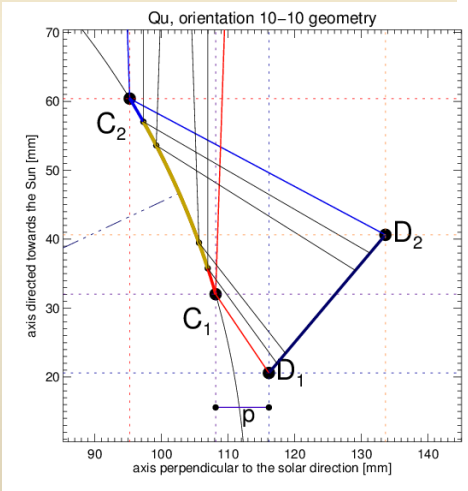


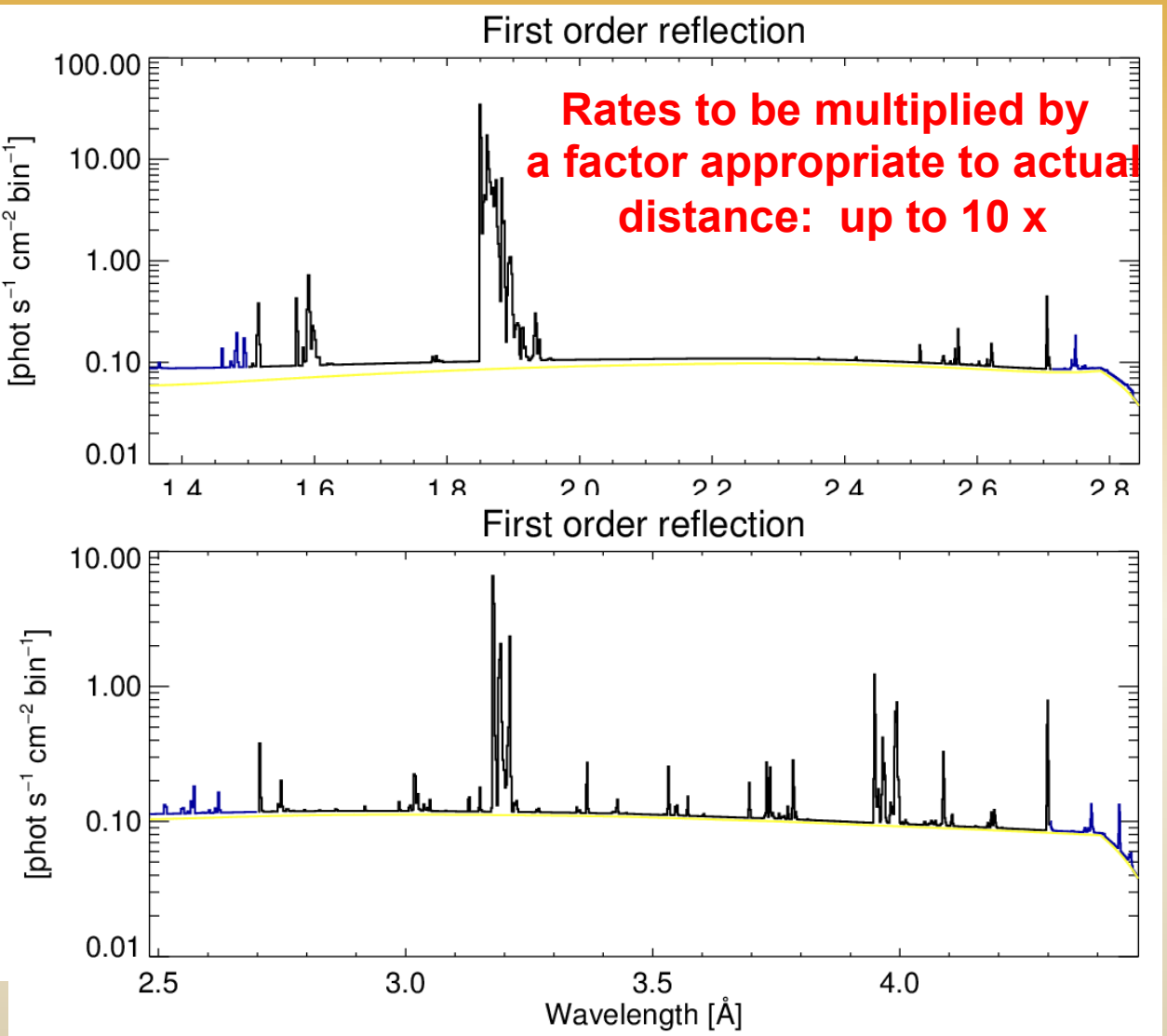
Line ranges selected:
Fe XXV
T ~20 MK
Hot flare
Ca XIX
T ~10 MK
Evaporated material
Ar XVII
T ~4-5 MK
AR plasmas

- Identical crystals and detectors but dispersion directions will be opposite.
- System allows plasma spatial motions (along dispersion) to be distinguished from radial motions

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







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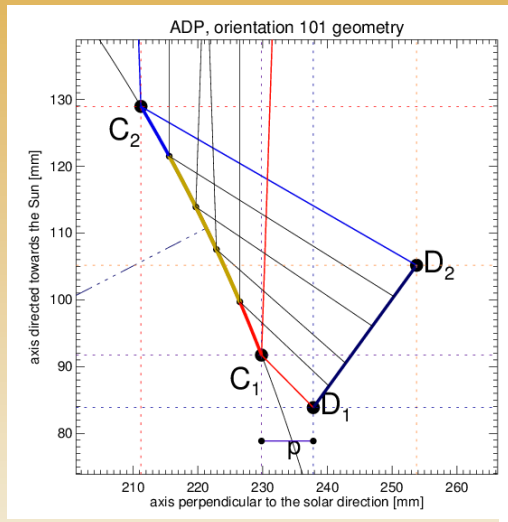
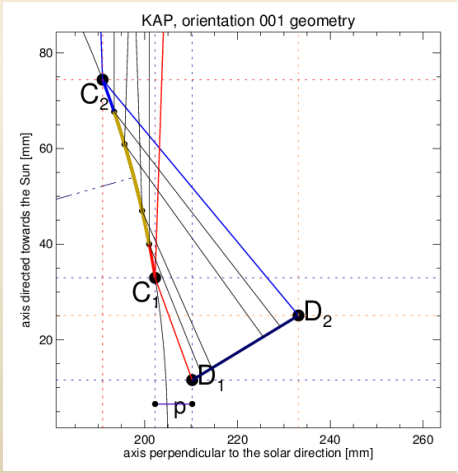
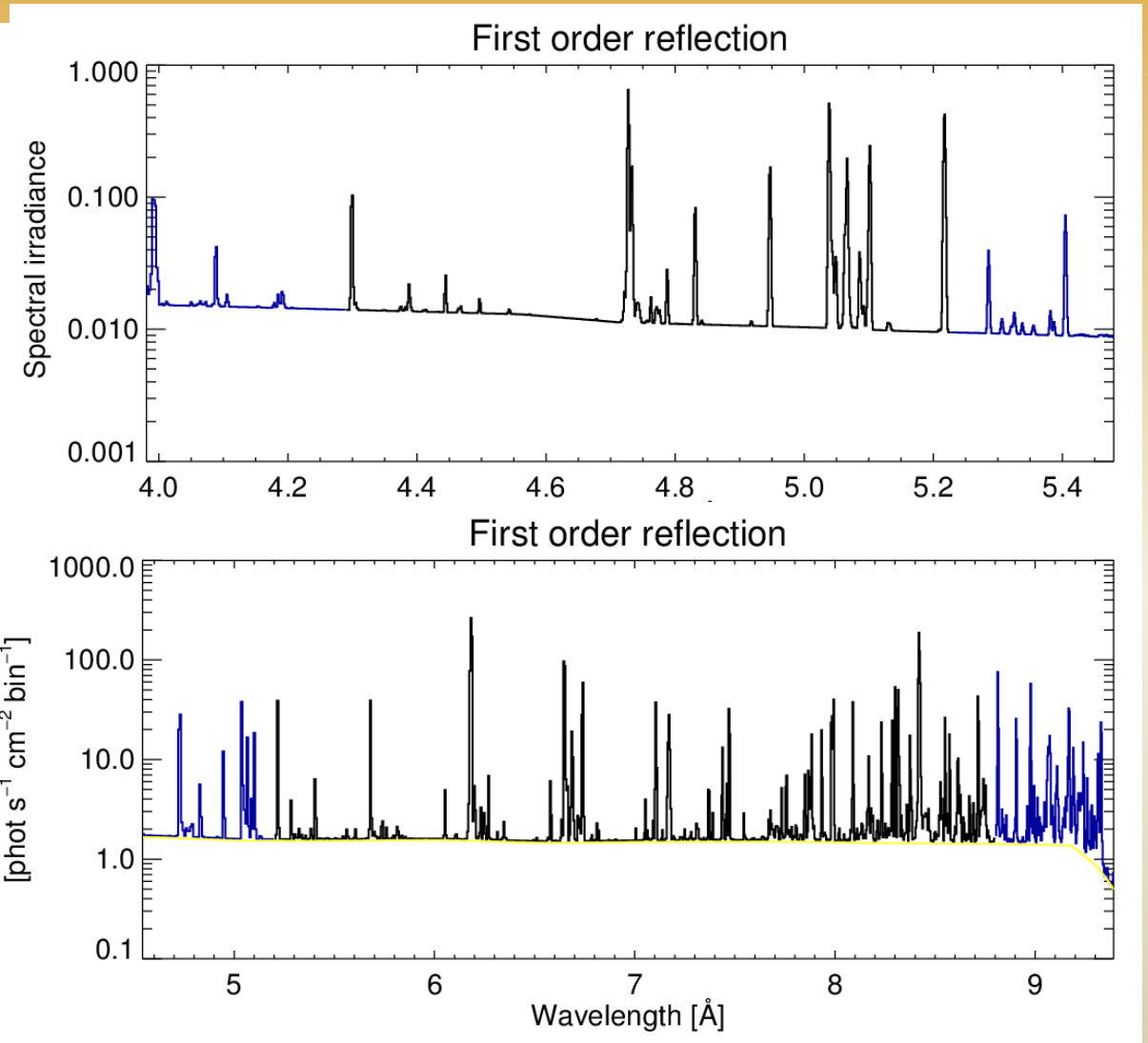
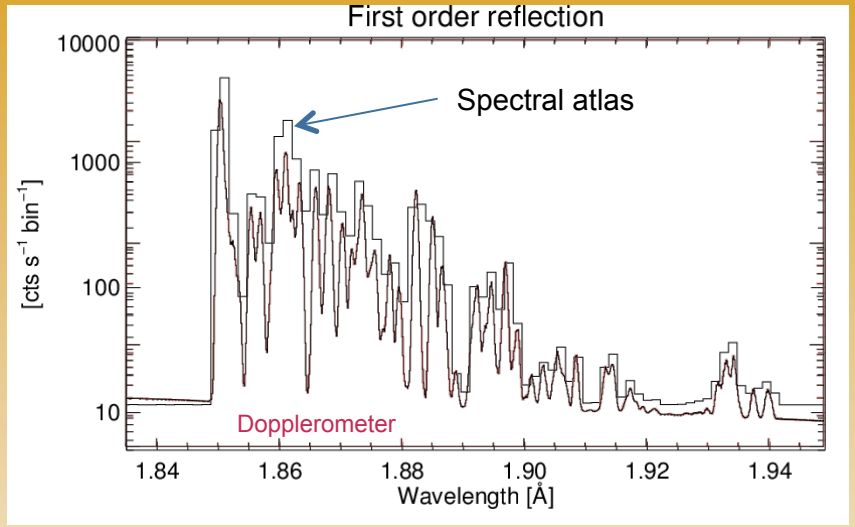
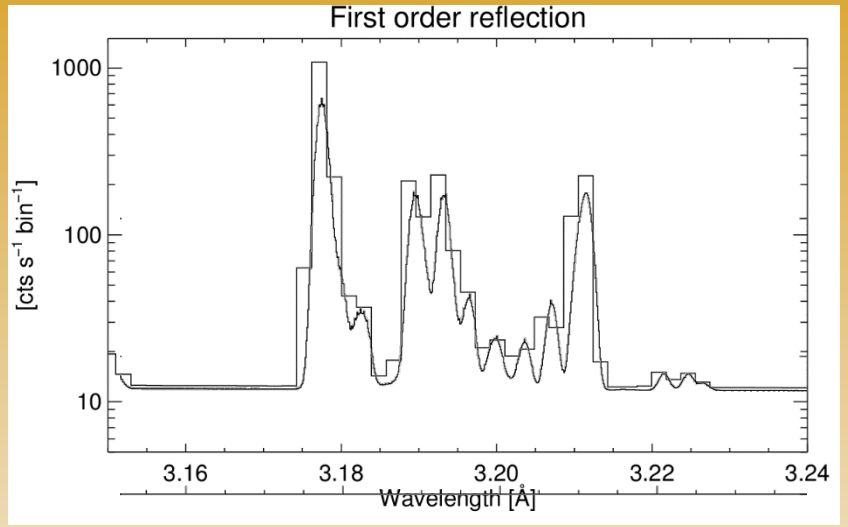


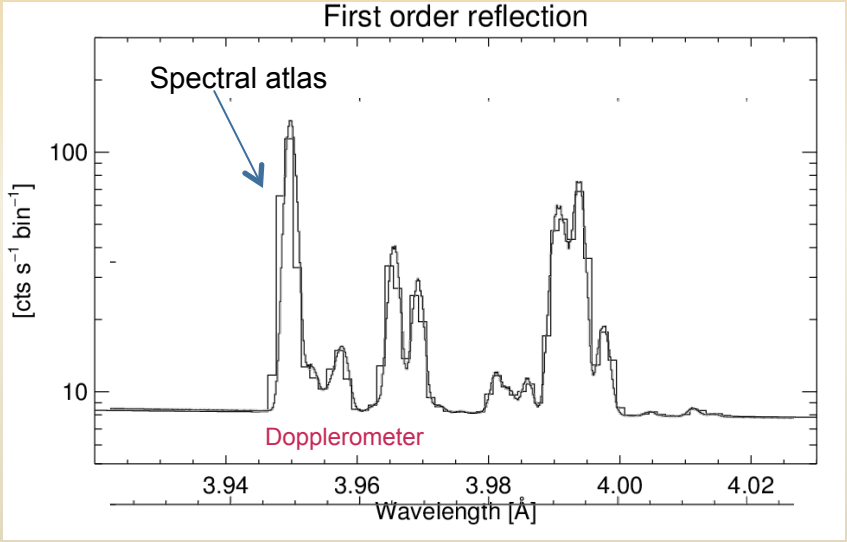


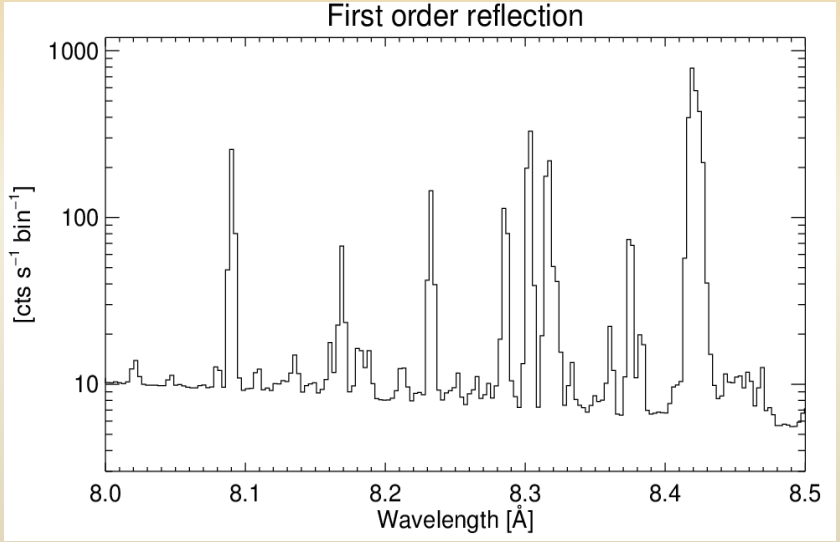


Selected spectral ranges of interest
M5.5 flare 0.3 a.u. 10s integration









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 (light curves in selected spectral ranges) and source coordinates
- Downlink (when possible) “interesting” portions of data from the onboard memory

Conclusions

- New (only) Bragg bent crystal spectrometer **ChemiX** to determine element abundances from X-ray line spectra under construction by international team.
- Instrument to be placed on two Russian interplanetary missions – **Interhelioprobe**.
- Multi-temperature analysis of spectra (recall the talk on RESIK abundance determination)
- Spectra will improve **plasma energy budget estimates** through DEM and plasma motions