SolpeX: the soft X-ray flare polarimeter for ISS

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Motivation

- 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 (vide RHESSI results)
- No systematic, accurate measurements of the solar soft X-ray polarization have been performed yet
- Reliable measurements are available from laboratory (EBIT)

Importance of polarisation detection

- Quasistationary ions colliding with unidirectional electrons generally emit line radiation that is both anisotropic and polarized.
- The intensity of a specific line from a beam-excited ion depends on the observation angle relative to the axis defined by the electron beam and on whether or not the emission is analyzed with a polarization-sensitive instrument.
- New information can be inferred on the electron beam chracteristics generally believed to be responible for flare non-thermal impulsive phase emission

Previous X-ray polarisation detections (through Compton scattering)

- Intercosmos (Tindo i in. 1970, 1972a, 1972b, 1976),
- OSO-7 (Nakada i in. 1974),
- STS-3 (Tramiel i in. 1984)
- CORONAS-F (Zhitnik i in. 2006)
- RHESSI (McConnell i in. 2003, Boggs i in. 2006, Suarez-Garcia i in. 2006)

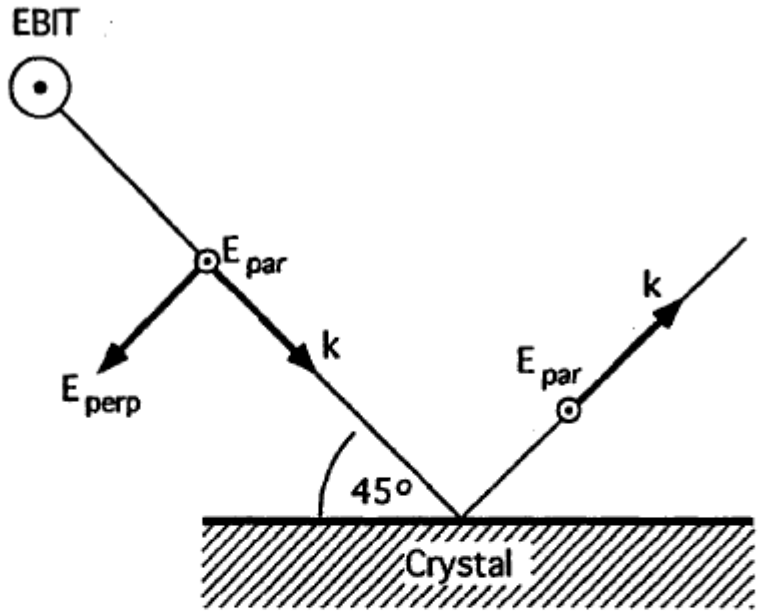
SolpeX (Solar Polarimeter in X-rays)

Science & measurements:

- Detect polarisation of solar soft X-ray emission at ~3 keV during impulsive flares
- Determine azimuth & directivity of the non-thermal electron beam
- Record transient soft X-ray spectra in the spectral range ~ 3 keV ($\lambda / \Delta \lambda \sim 40000$)
- Record context impulsive phase X-ray spectra using novel flat crystal drum spectrometer

Principle of polarisation detection

- Brag… be used to de… t
- Verif…



PHYSICAL … JUNE 1996

emission

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Dep…

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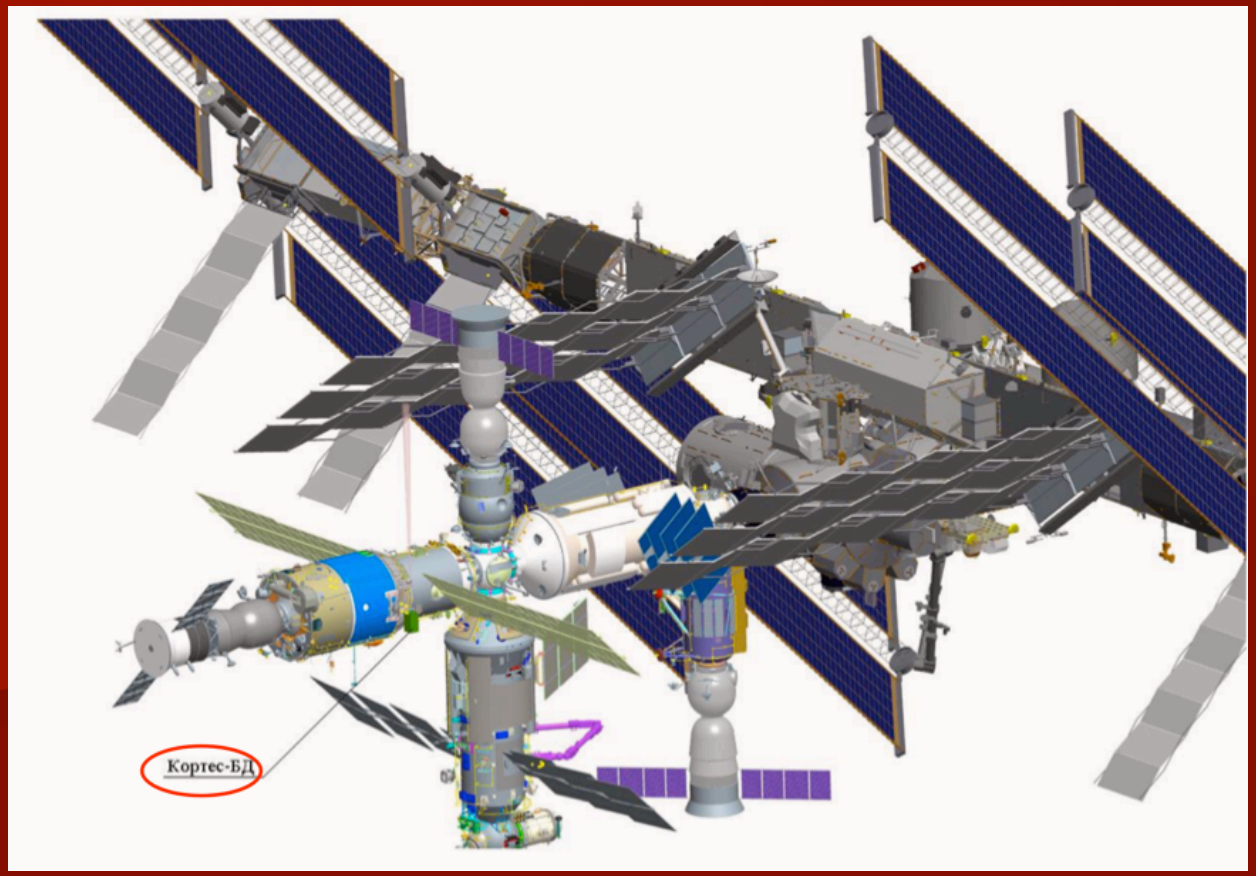
Figure 5: Schematic diagram of the reflection of linearly polarized x rays off a crystal surface at a Bragg angle of 45°. The electron beam is in the direction out of the page as indicated at the EBIT position. The plane of dispersion of the crystal is perpendicular to the beam direction. Only the parallel polarization state is reflected; the polarization state perpendicular to is completely absorbed by the crystal.

Instrument „location" will be ISS Russian new module „Nauka"



Pros:

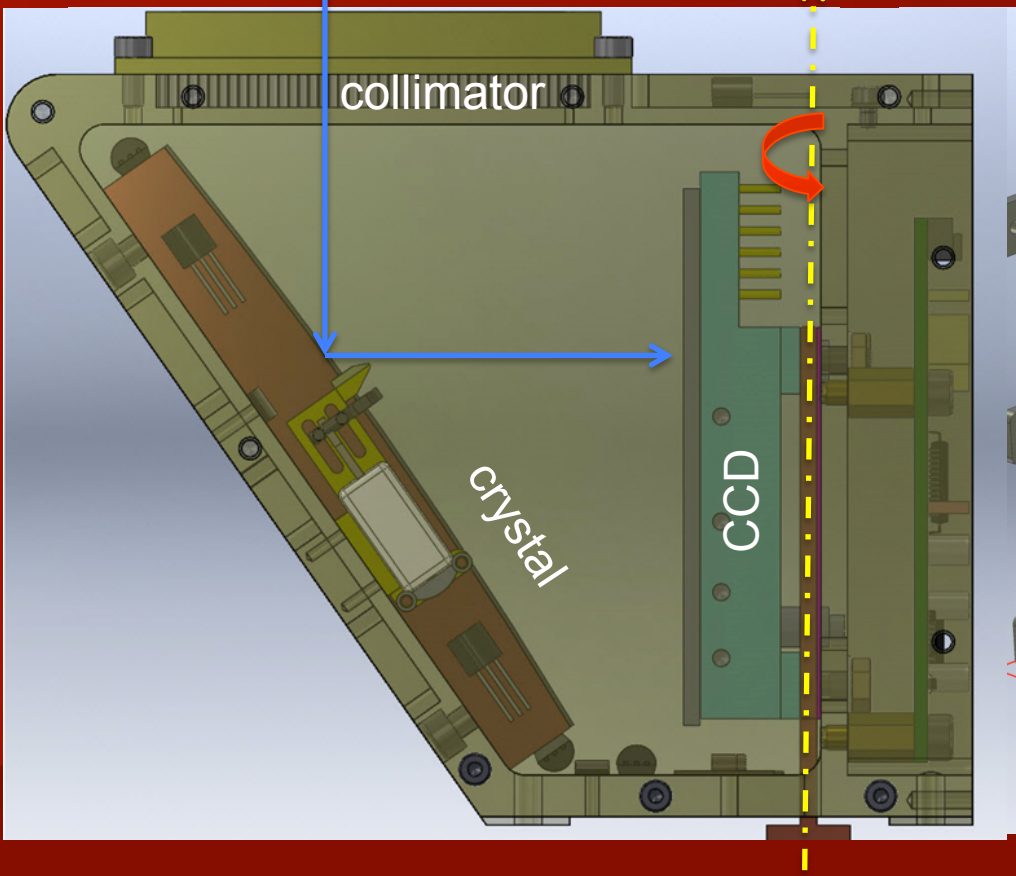
- "Easy" delivery
- Unlimited telemetry
- Large inertia
- Larger size & mass of instruments possible

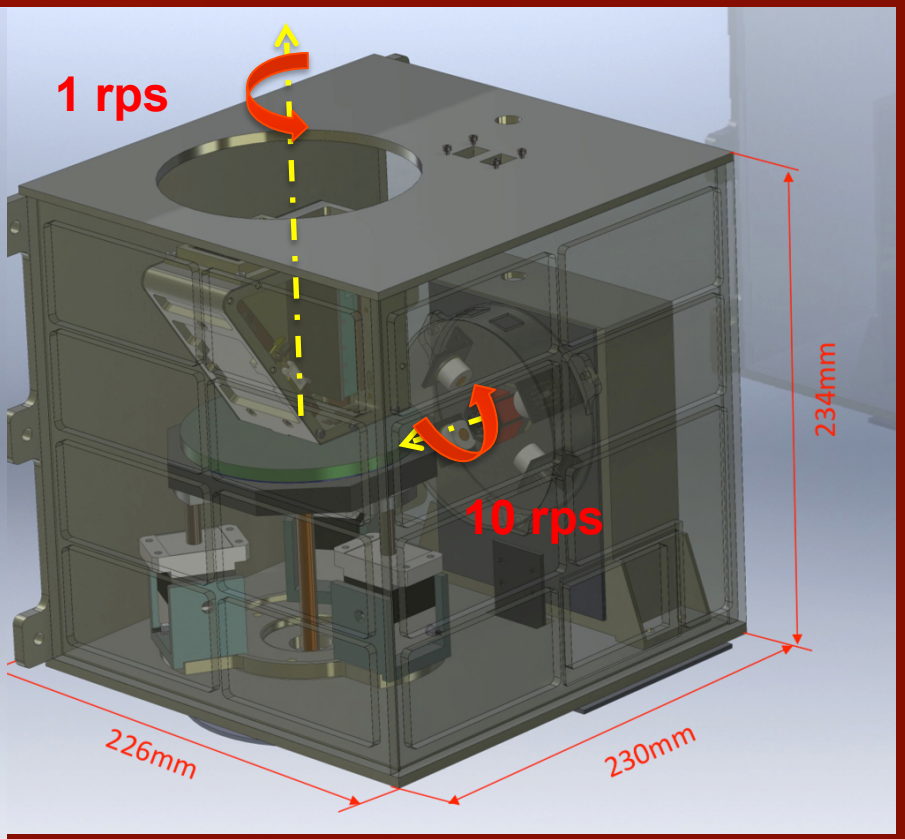
Cons:

- Only 10-12 min of solar pointing/orbit ~ 2h/day
- Rough pointing

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

Instrument concept

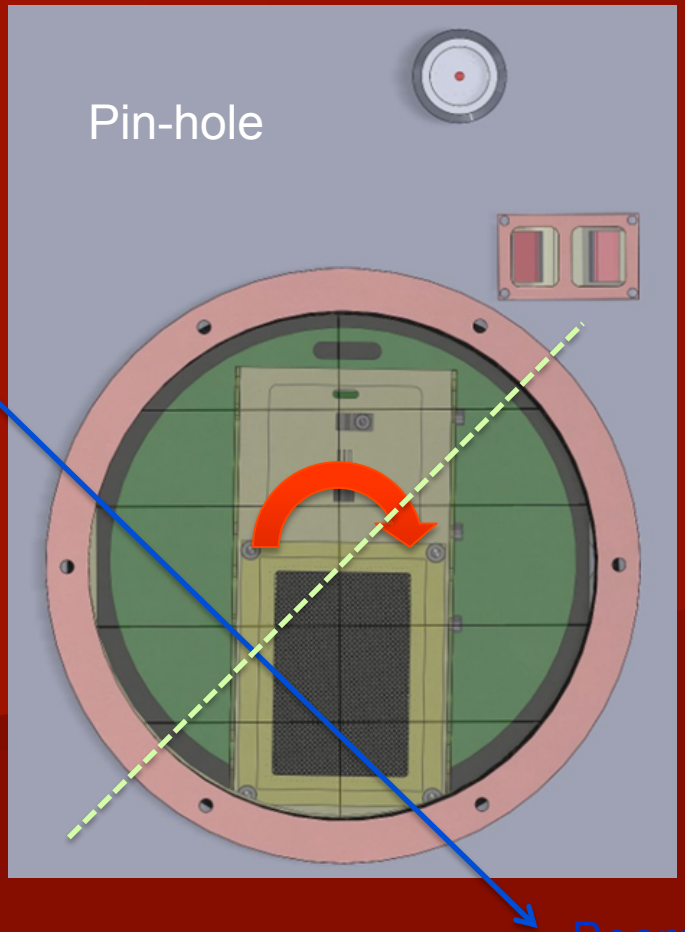




Inside Cortez Russian module

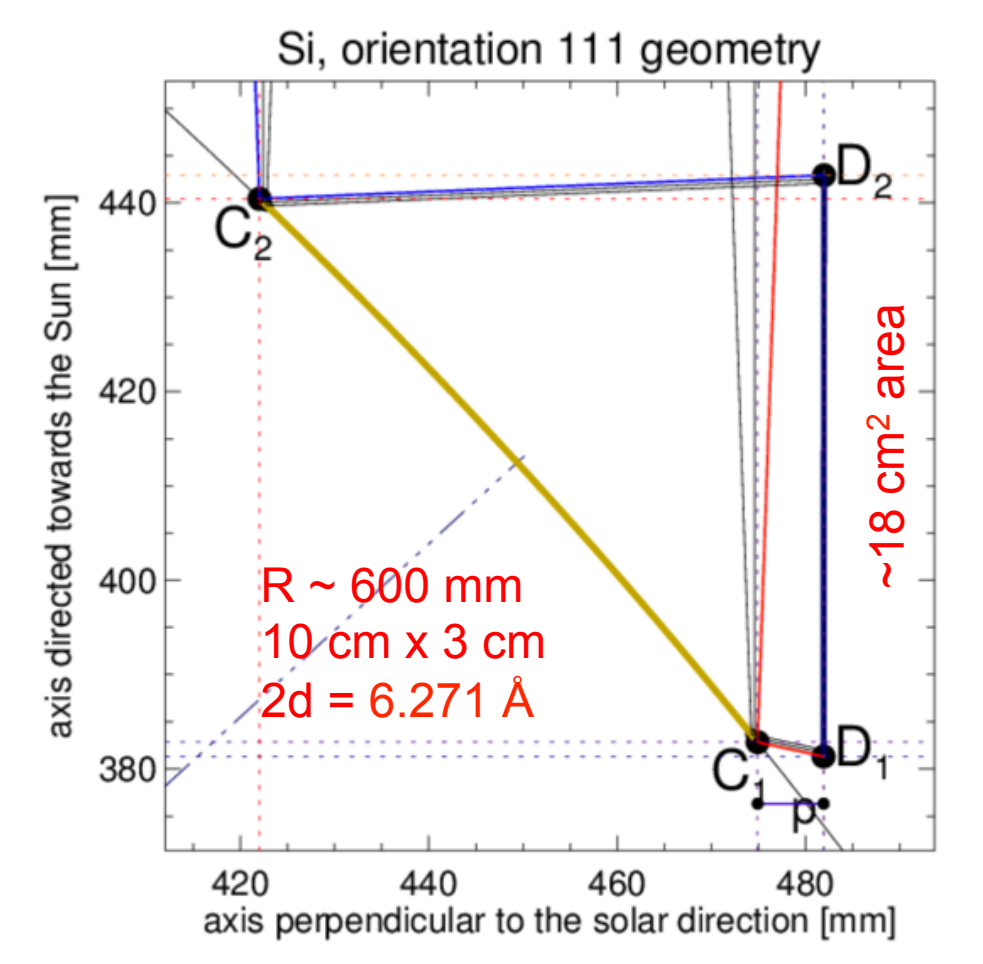
mass: 10 kg, power 30 W, data rate 1Gb/24h

Rotating crystal & detector as seen from the Sun



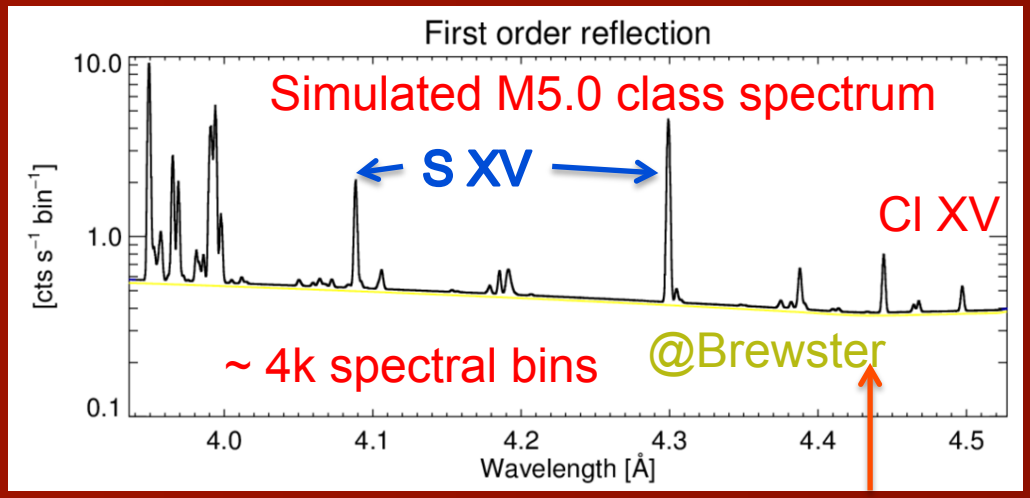
- rotation modulation absent for unpolarized emission (thermal isotropic source)
- If anisotropic beam is a source of soft X-rays, the maximum signal in the continuum is observed when dispersion direction is perpendicular to the beam
- Context Cortez EUV images (304, 193) and pin-hole images (with limb brightening and AR location) will allow to coalign with the solar reference coordinate system

Crystal- detector geometry

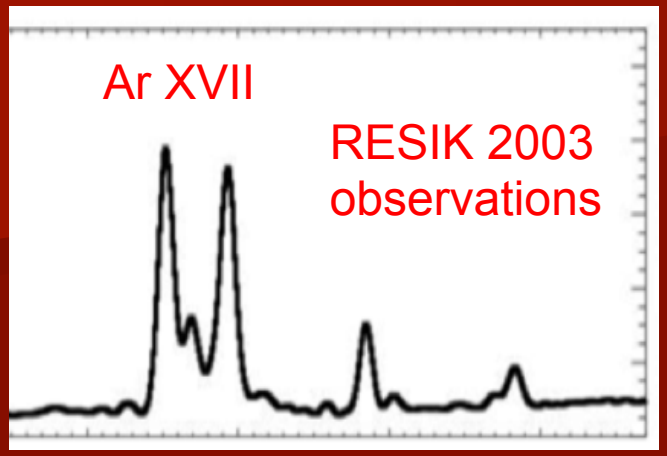


- Bent monocrystal wafer of large area 3 x 10 cm, of cylindrical form
- 4k x 2k CCD (e2v CCD261-84, 0.3mm thick) detector records spectra at all wavelengths instantaneously

Why the spectral range 3.9 - 4.5 Å?

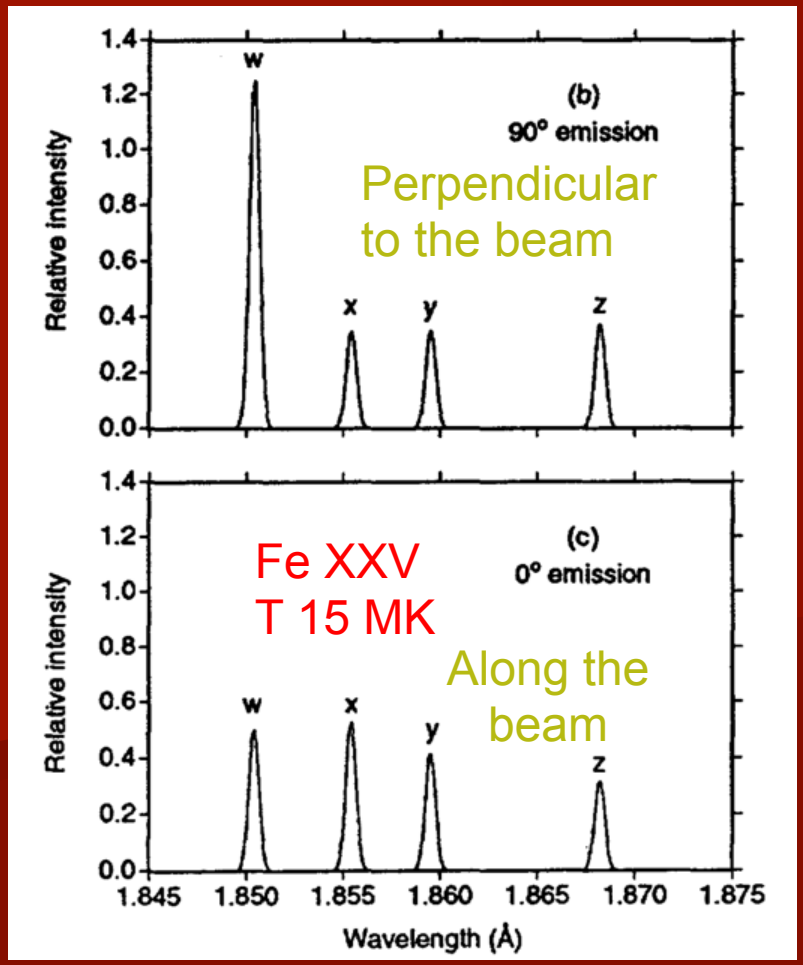


- 0.0001 Å/pixel → tens of points over line profiles (thermal + turbulent)
- Well understood processes of continuum formation
- Thermal (free-free, free bound & non-thermal)
- E ~ 3 keV (thermal/non-thermal boundary)



- Always seen for activity levels > B5
- Clean continuum next to strong lines
- Ar XVII triplet well studied in the lab.
- Cl XVI triplet also seen resolved
- Reach dielectronic satellite line diagnostics available

From Triplet line ratios *w,x,y* & *z*



- A possibility to determine the inclination of the beam towards direction to the "observer"

"Linear X-Ray Line Polarization Effects on Spectral Measurements Using an Electron Beam Ion Trap" Peter Beiersdorfer, 1998

Predicted He-like lines' polarisation

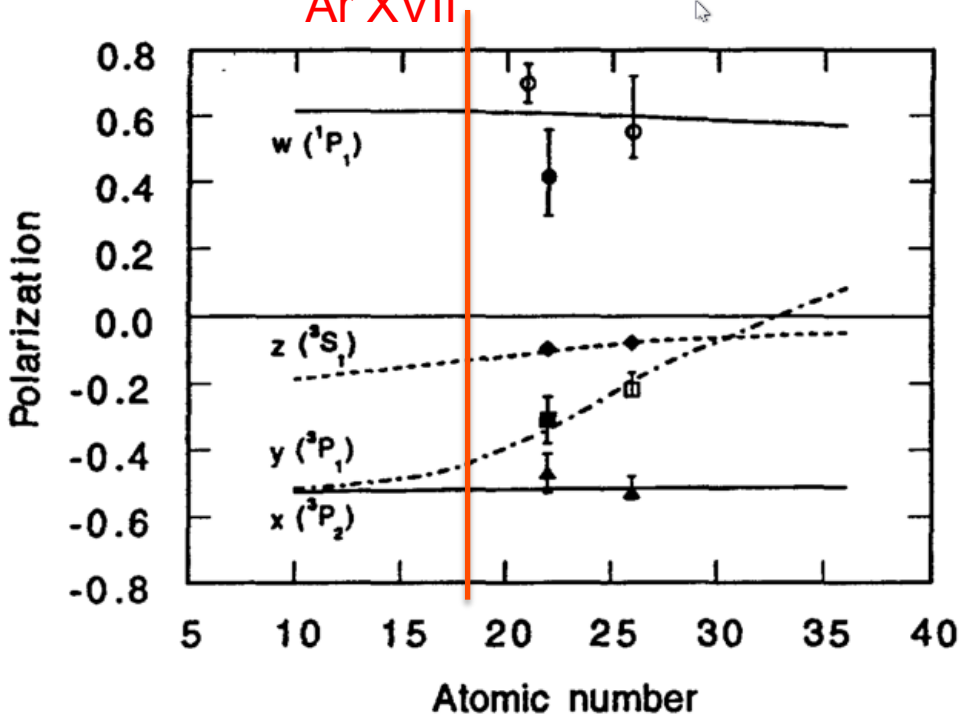


Figure 7: Predicted polarizations of the four 2 → 1 transitions w, x, y, and z in the heliumlike ions Ne^{8+} through Kr^{34+}. The

Measurement strategy

- Follow lightcurves of individual active regions (from pin-hole camera imaging)
- Detect flare (onboard algorithm)
- Lock 2D fine collimator (3 x3 armin) i.e. polarimeter rotation axis on the flare
- If no-flare is in progress- axis points to the brightest AR
- Record spectra, instantaneously in all wavelengths, at several phases of the rotation

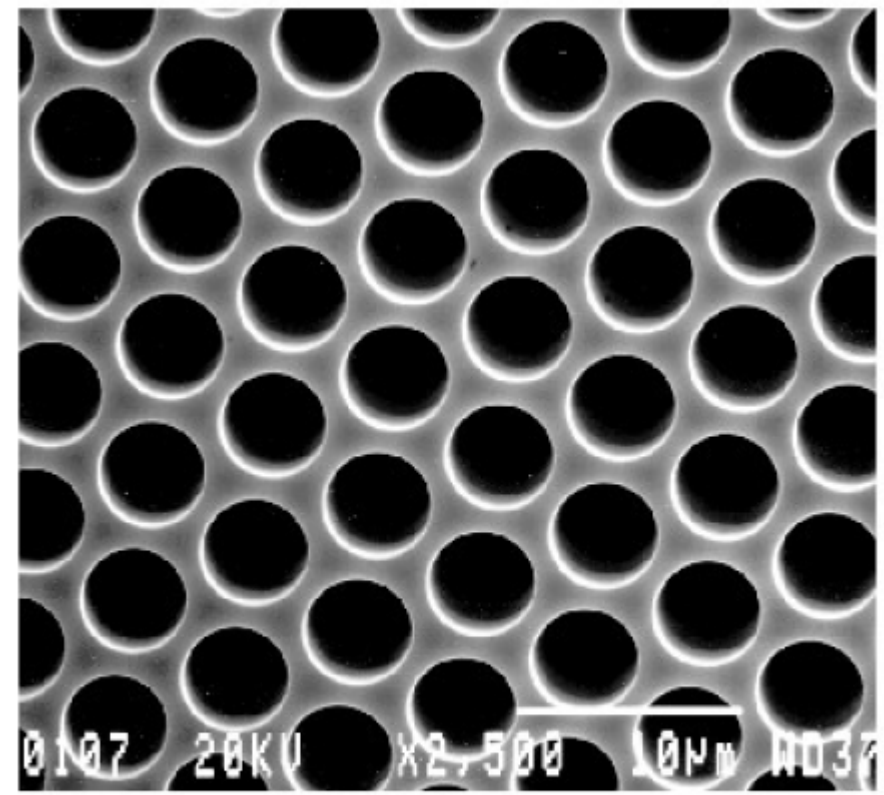
Polarimeter unit constantly rotates (at 1 rps)

Flat "context" spectrometer also revolves at the constant speed (at 10 rps)

Polarisation Detection accuracy

- M5 flare, single rotation. Overall count rate in the selected part of the spectrum ~2000 cts/ rotation → 200 counts/readout phase
  - (overall) few percent
  - Spectral line (100 cts/rotation)→ 30%
  - Continuum 4.226-4.233 Å (25 cts/rotation)→ 50%
- Provided the Beam is interacting for 10s
  - (overall) 2 percent
  - Spectral line (100 cts/rotation)→ 10%
  - Continuum → 20 %

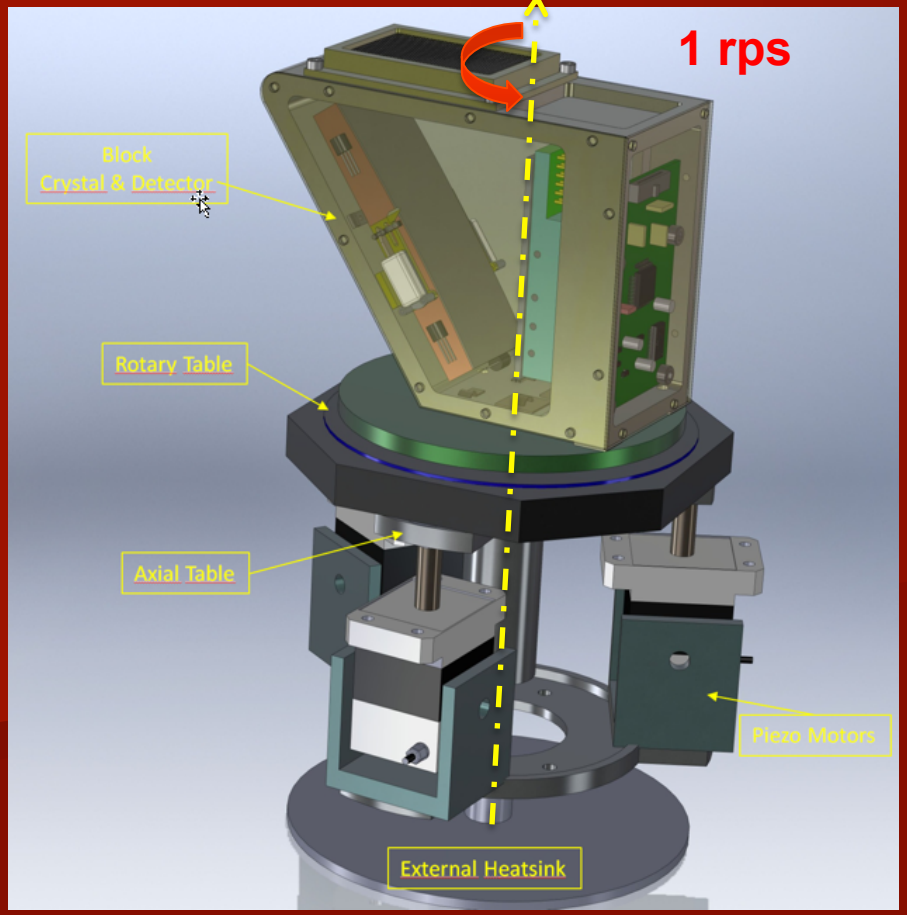
2D collimation using capillary arrays



Microscopic view of a Glass Capillary Array with precision 5 micron pores.

- Aim: limit the FOV to a single flare or AR
- ~3 arcmin FWHM
- Prevent spectral overlapping from multiple sources
- Increases S/N
- Allow to study variability of line profiles

Challenges



- How to remove heat from CCD? (must be cooled below -20°C→ rotating external radiator mounted to the rotating table
- How to power rotating electronics?
- How to transfer data from the rotating CCD?
- How to control rotating unit functions?
- How to eliminate rotation jitter

Status of the project

- "Phase B" concept study & initial operations funded by Polish science funding agency (NCN)
- Selection of crystals done and geometry of the polarimeter established
- Initial tests of a large (3 cm x 6 cm) 300 micron thick CCD performed in X-rays on our X-ray test chamber
- Three-leg precise pointing unit developed & tested
- Pin-hole imager characteristics (0.1 mm aperture; 1024 x 256 CCD) selected
- X-ray filters defined, purchase is in progress
- Delivery of the engineering unit to Russia expected in one year time frafron now

Conclusions

- SolpeX – is the first X-ray solar polarimeter based on bent crystal Bragg reflection concept
- Expected high sensitivity of detection of the line and continuum polarisation
- Context X-ray spectra will be observed using flat monocrystals fixed to the rotating drum (photon flux limited time resolution <1s)
- Studies of line profiles, multithermal character of the "thermal" source possible thanks to very high dispersion.
- Absolute elemental composition will be determined for Ar, S & Cl

Thank you
& keep fingers crossed

Selection of optimum spectral