PRESENT STATUS OF RESEARCH AT THE WROCLAW SOLAR PHYSICS DIVISION OF SPACE RESEARCH CENTRE PAS

Janusz Sylwester

Outline

- History & heritage
- Main contributions to solar physics
- Present team, science interests and collaborations
- Experiments we are working on
- Awards
- Possible collaborations

The past: political opportunities and Founders

- Intercosmos (1967) – no launch payments

Kapustin Yar
Sounding rockets
7 launches

1970
1971
1977
~~1979~~
1980
1981
1983
1984

Plesetsk
Orbital
missions
launches

1994
Coronas-I

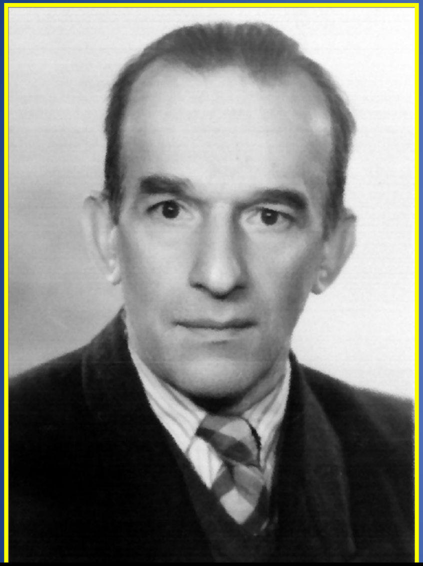
1995
Interball-Tail

2001
Coronas-F

2009
Coronas-Photon

The past: Founders

- The Professors:



Jan Mergentaler
(1901-1995, Lwów-Wroclaw)
in 1951 became interested in Solar Physics – organizer of Wroclaw heliophysical Centre, 1956 – solar monograph

Stefan Piotrowski (1910–85), supported the development of Wroclaw group remotely, as Head of Astronomical Division, PAS, Warsaw, where the group was initially assigned

Prof. Jerzy Jakimiec – overlooked from the beginning (30 years) the scientific aspects of the program

Dr. Zbigniew Kordylewski – was (and is) responsible for the hardware development over more than 35 years

Prof. Antoni Opolski took charge of the developing Laboratory in 70-ties

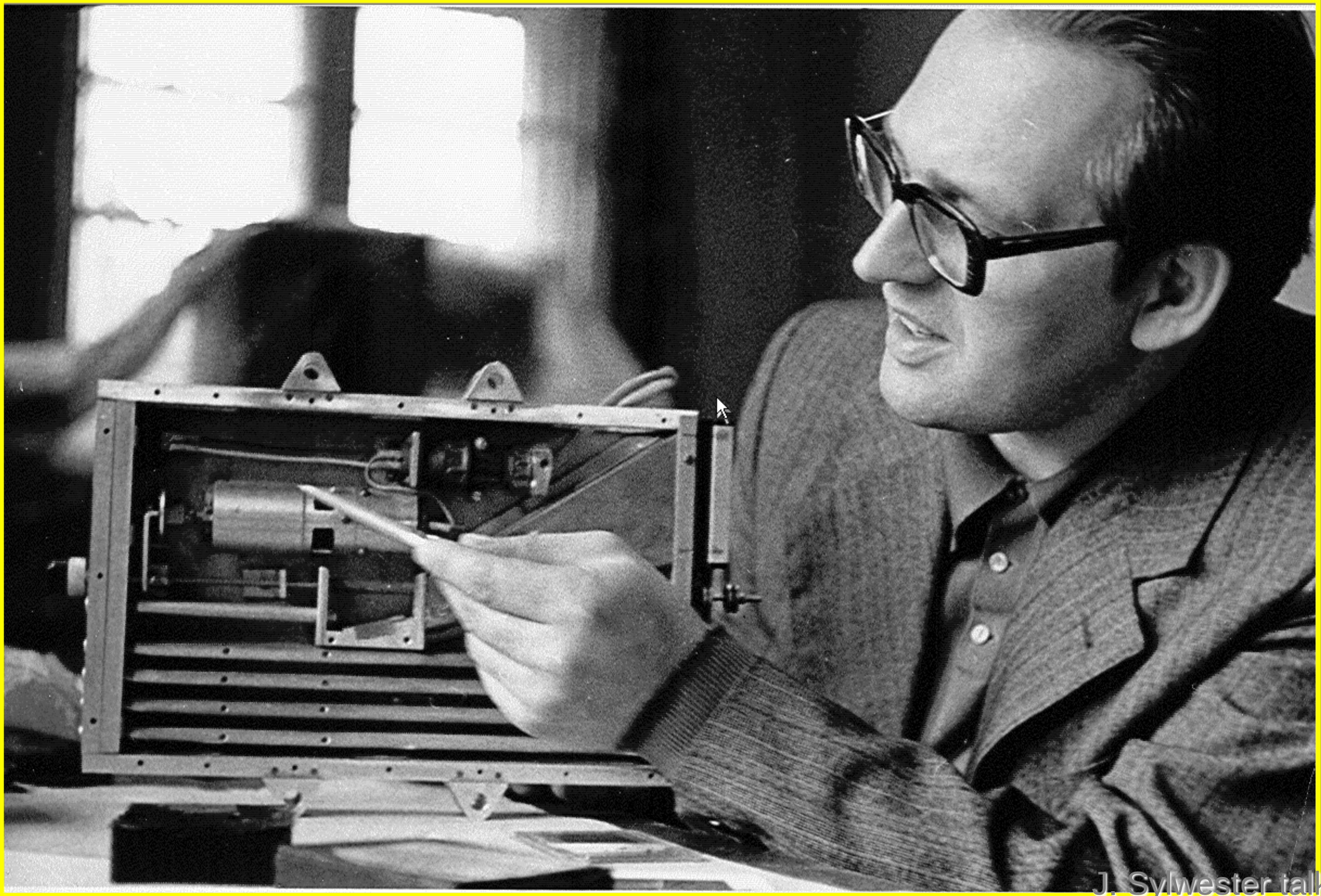
Prof. Stanislaw Grzedzielski and Prof. Zbigniew Klos, as Directors of Space Research Centre, of which the Solar Physics Division is now a part looked with an interest to the group development

First Polish (and INTERCOSMOS) space experiment 28 November 1970

At Kapustin Yar, early morning h = ~500 km, 10 min in space *(around 05:32 UT)*

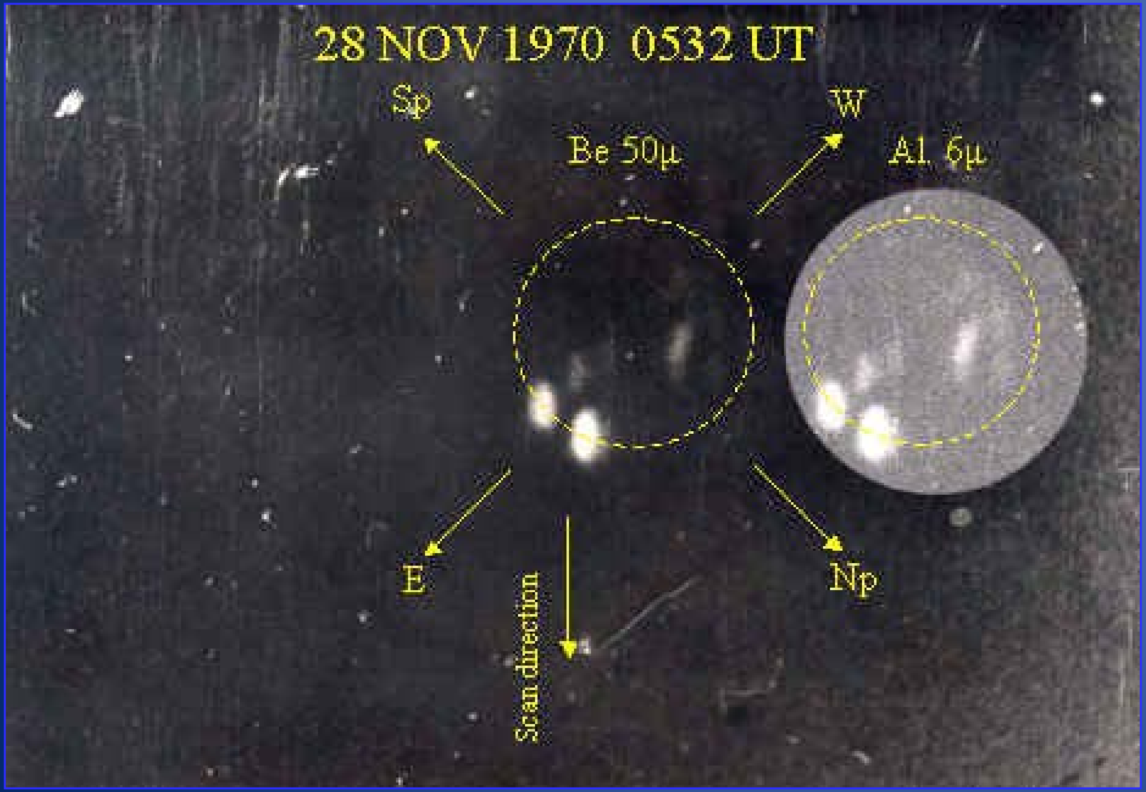
Dr. Zbigniew Kordylewski

in 1971, presenting Polish part of Vertical-1 payload, after recovery



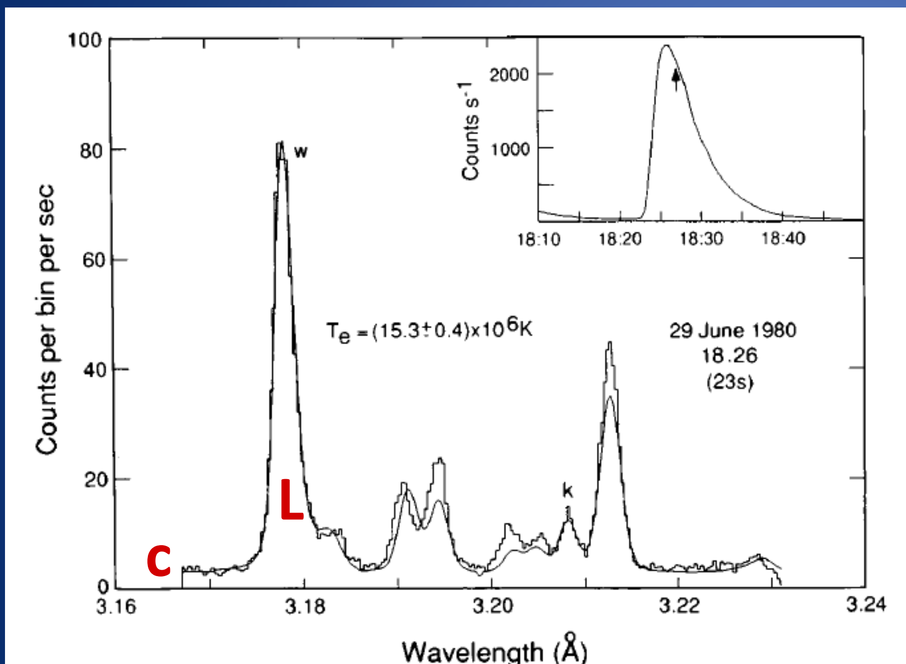
J. Sylwester talk at XXXII Assembly of the PAS 21st September 2005, Wroclaw

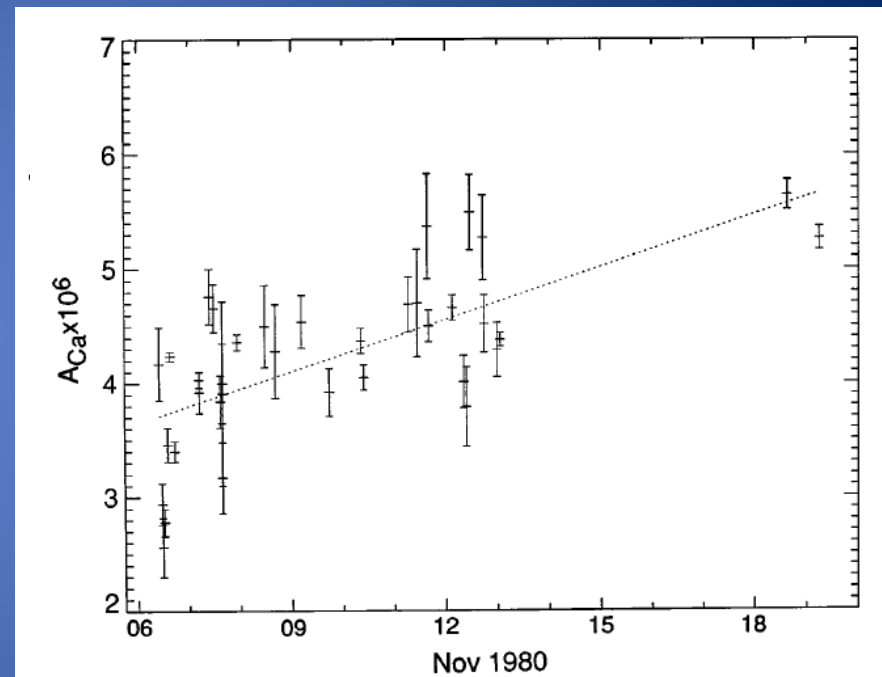
First Polish (and INTERCOSMOS) space experiment 28 November 1970



The Be 50 μm and Al 6 μm filter images represent emissions from the hotter and cooler plasma. The ''filetr ratio'' technique allowed to determine the temperature structure within individual active regions. The spatial resolution in the images is rather low (1 arcmin), typical for pin-hole technique

Spectroscopic evidence of changing abundance in flares (since 1984)





L/c is sensitive to elemental abundance

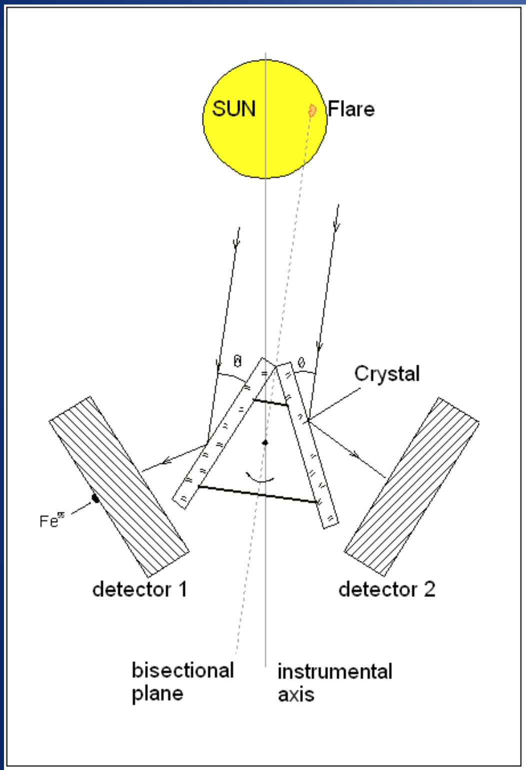
L ~A_{El} ; c ~ hydrogen and helium

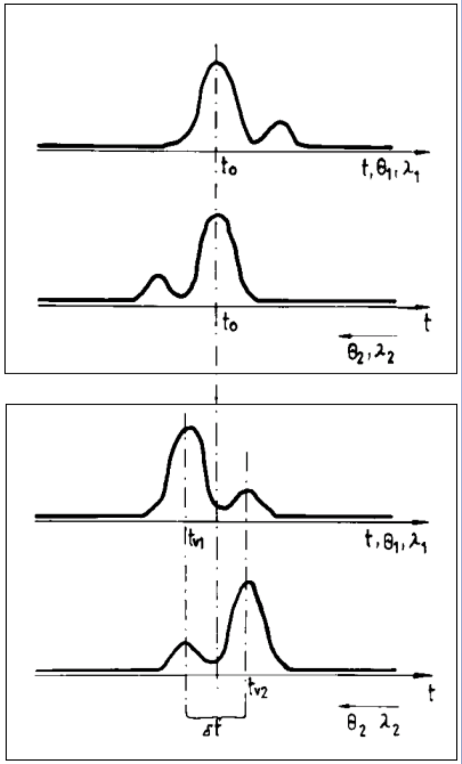
Sylwester et al., 1984, Nature, 310, 665

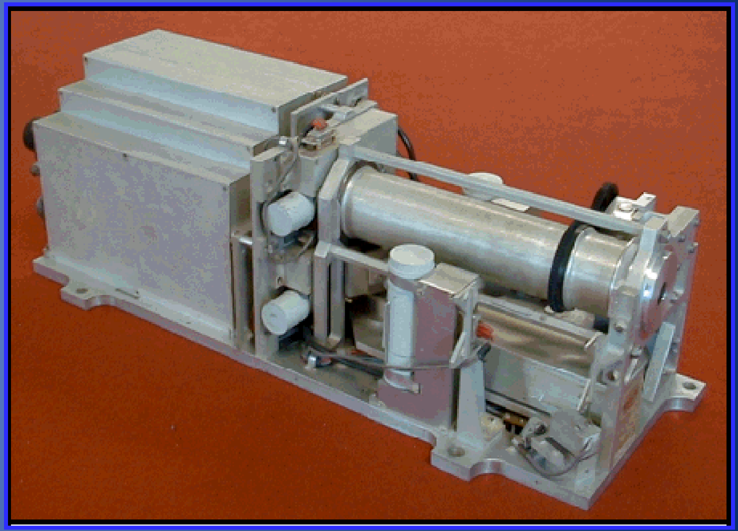
Sylwester et al., 1998, ApJ 501, 397

New experience - new designs

- X-ray Dopplerometer (~1980): absolute measurements of line shifts



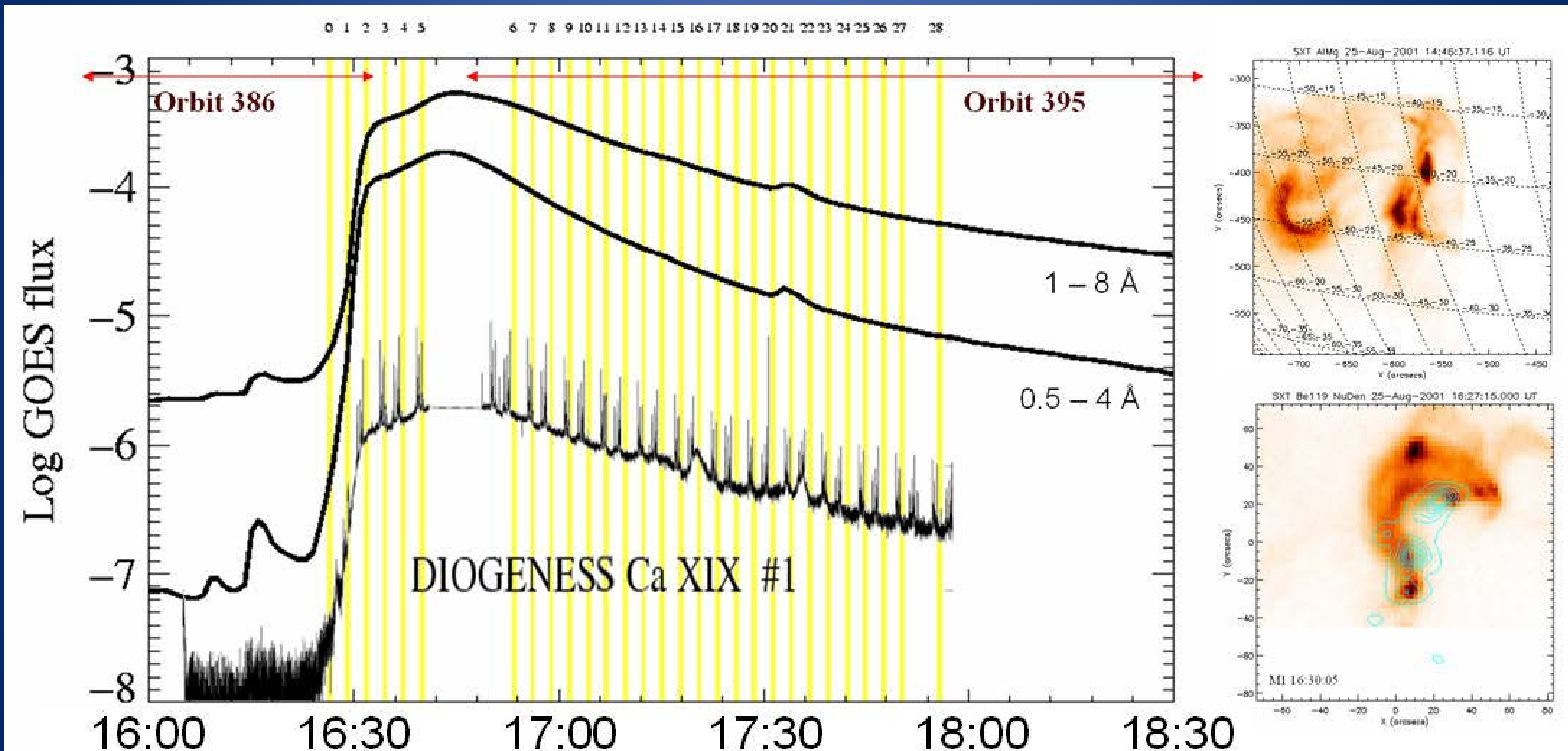




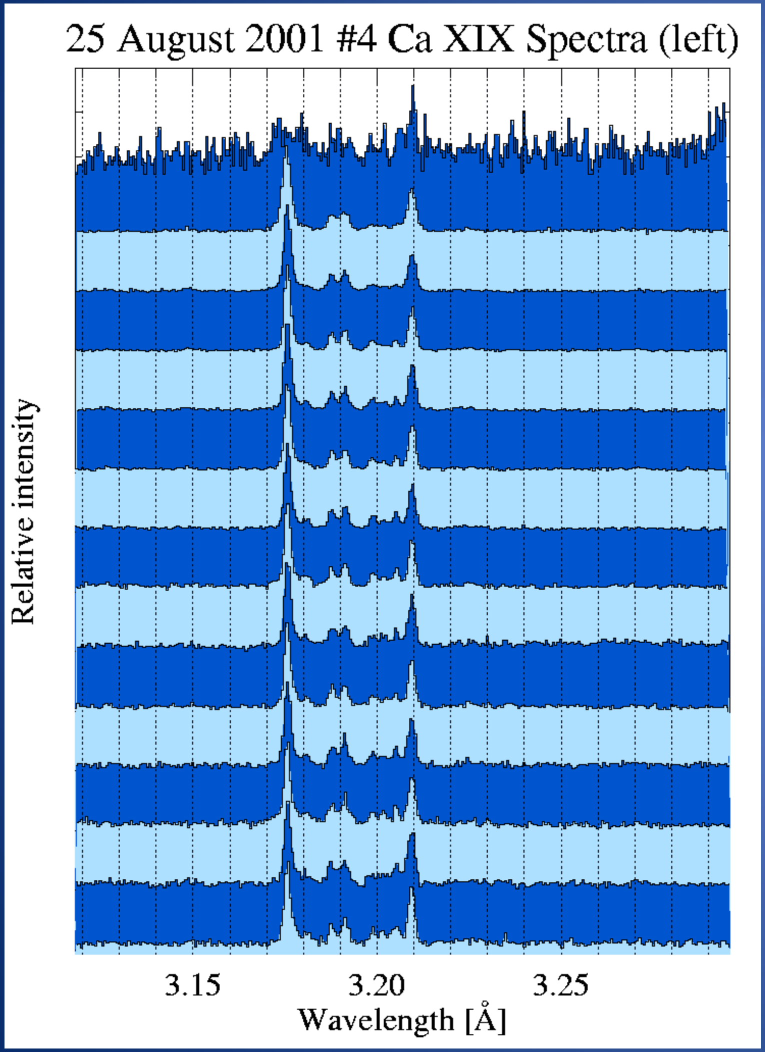
RDR – Rocket Dopplerometer flown aboard Vertical-11 sounding rocket
Made in one year, launched in 1983

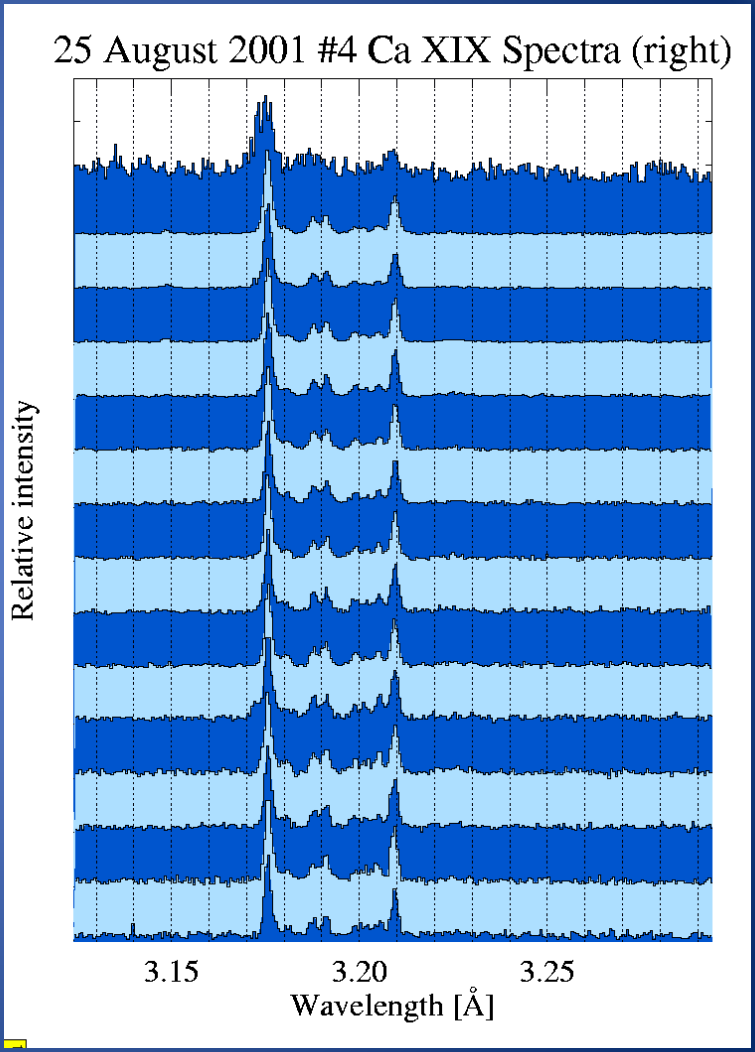
Satellite dopplerometer results CORONAS-F.

25 Aug 2001 3B/X5.3

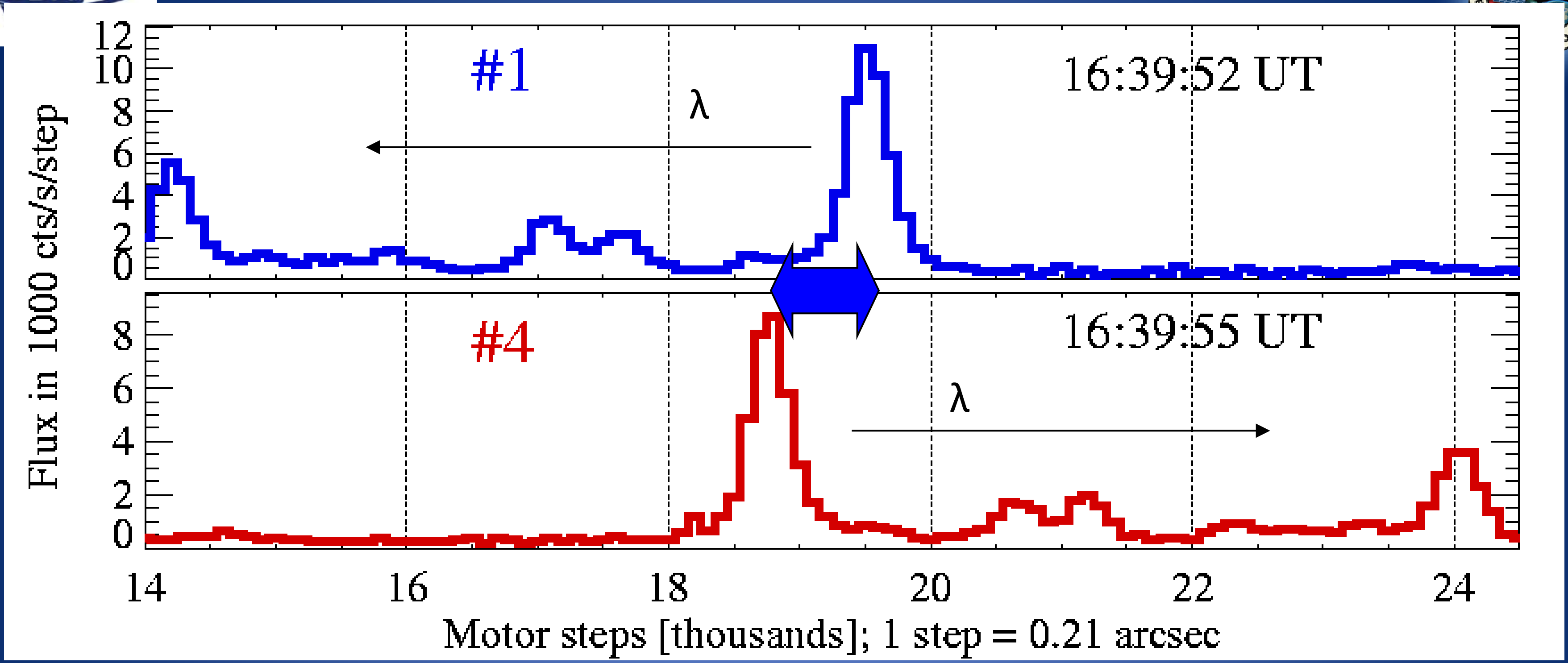


Ti e Sequence of left & right scans



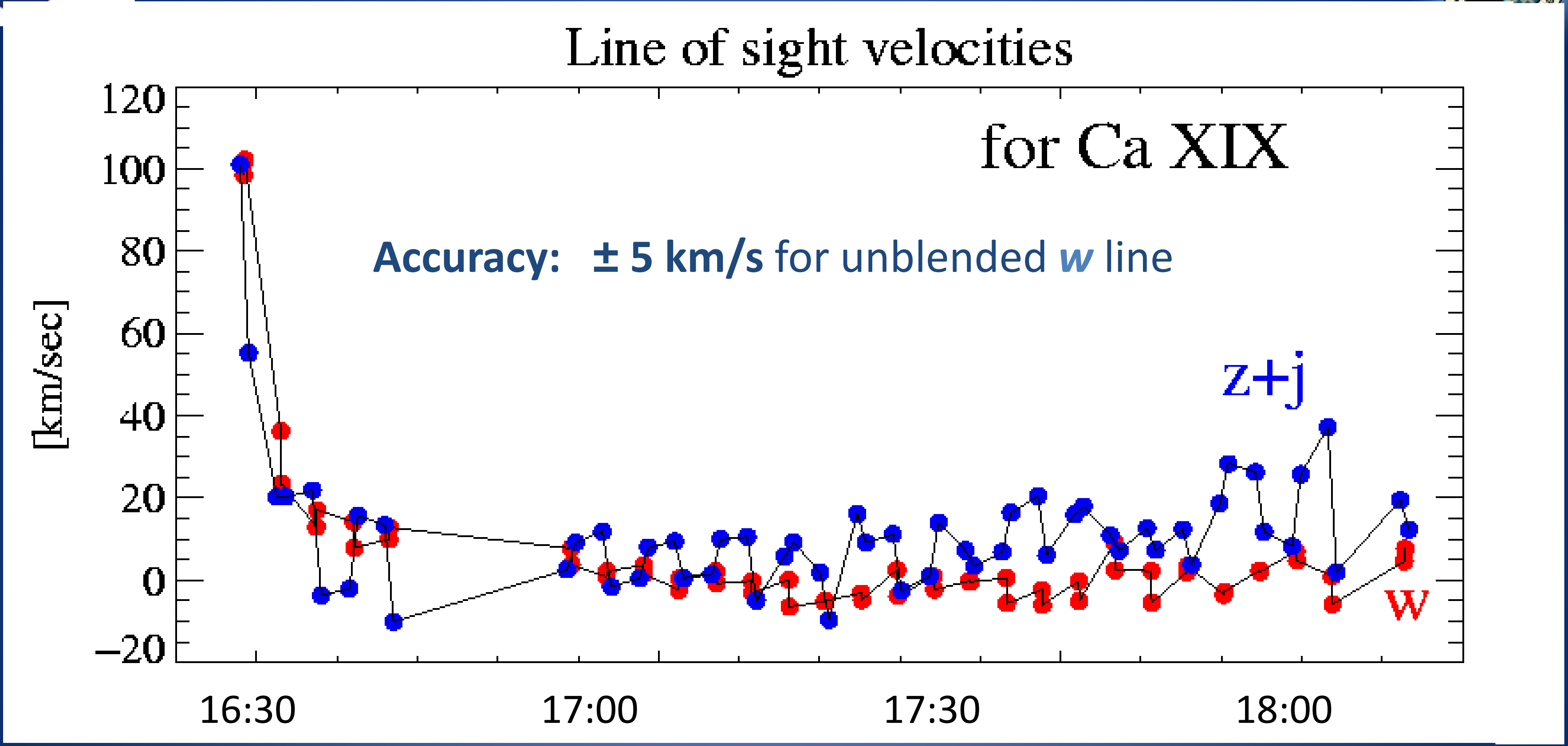


X-ray Dopplerometer results



Spectra recorded nearly simultaneously in Channels #1 and #4 of Diogeness during the maximum phase of X5.3 flare on 25 Aug. 2001. The scanning in both channels is made in the opposite wavelength sense. Thus the intercombination and forbidden lines comprising the Ca XIX triplet are seen on the opposite sides of the presented range (recorded 20 s apart in time).

Velocities: entire spectra shifted

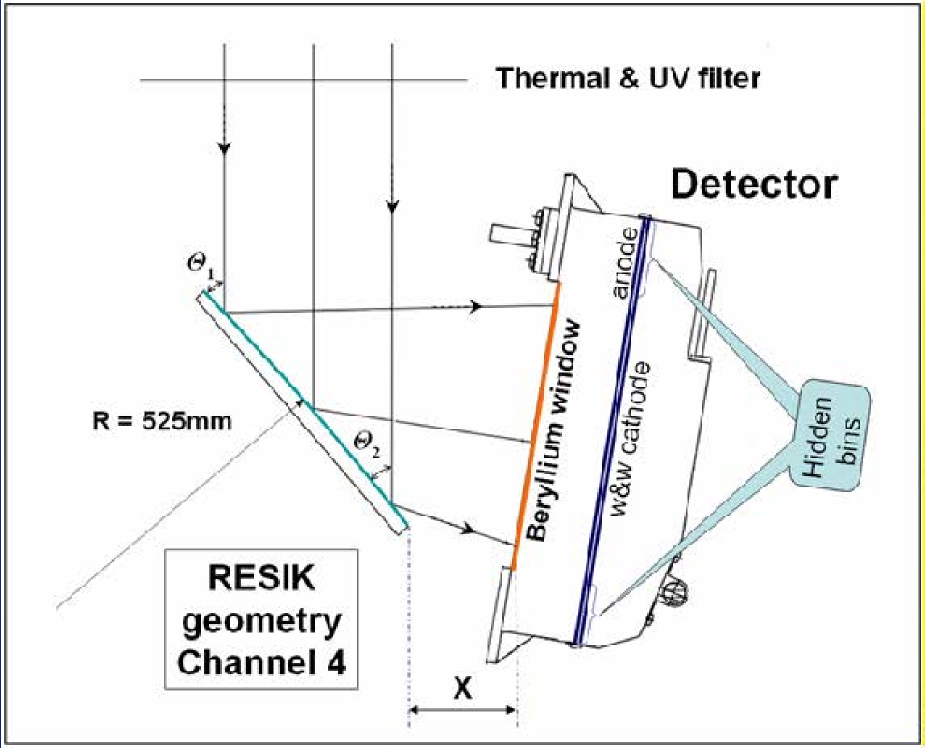


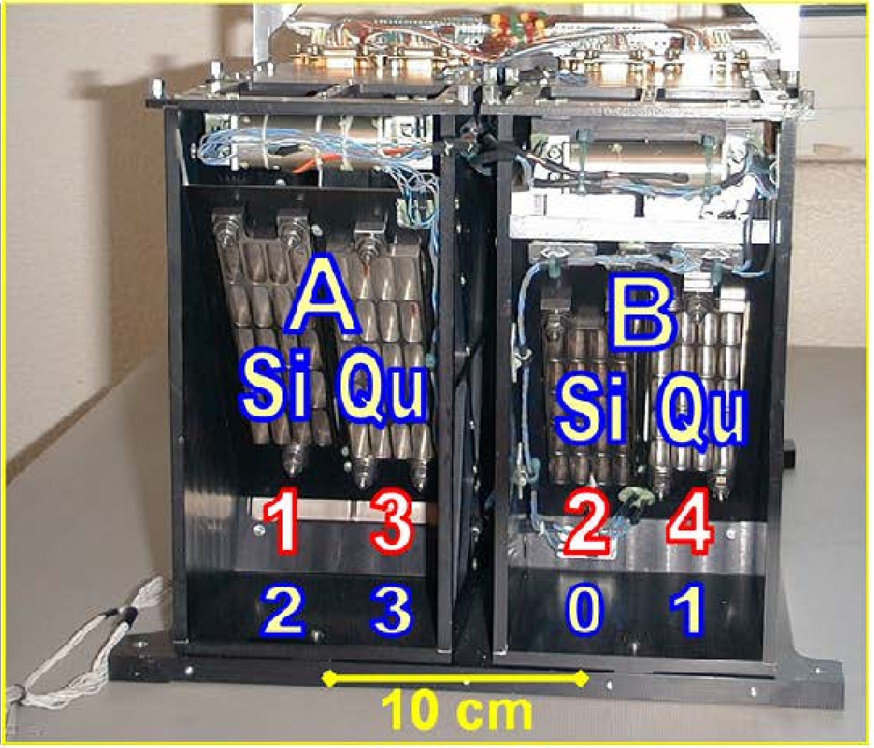
Velocities as determined for the resonance (*w*) and forbidden lines (*z*) of the Ca XIX triplet. The forbidden line is blended with a strong dielectronic satellite line (*j*) which might account for slightly different pattern of behaviour later in the flare decay.

Bragg spectrometer: $k\lambda = 2d\ sin\Theta$

Рентгеновский Спектрометр с Изогнутыми Кристаллами

Measures spectra in range: 0.335 nm – 0.610 nm, instantly in all λ



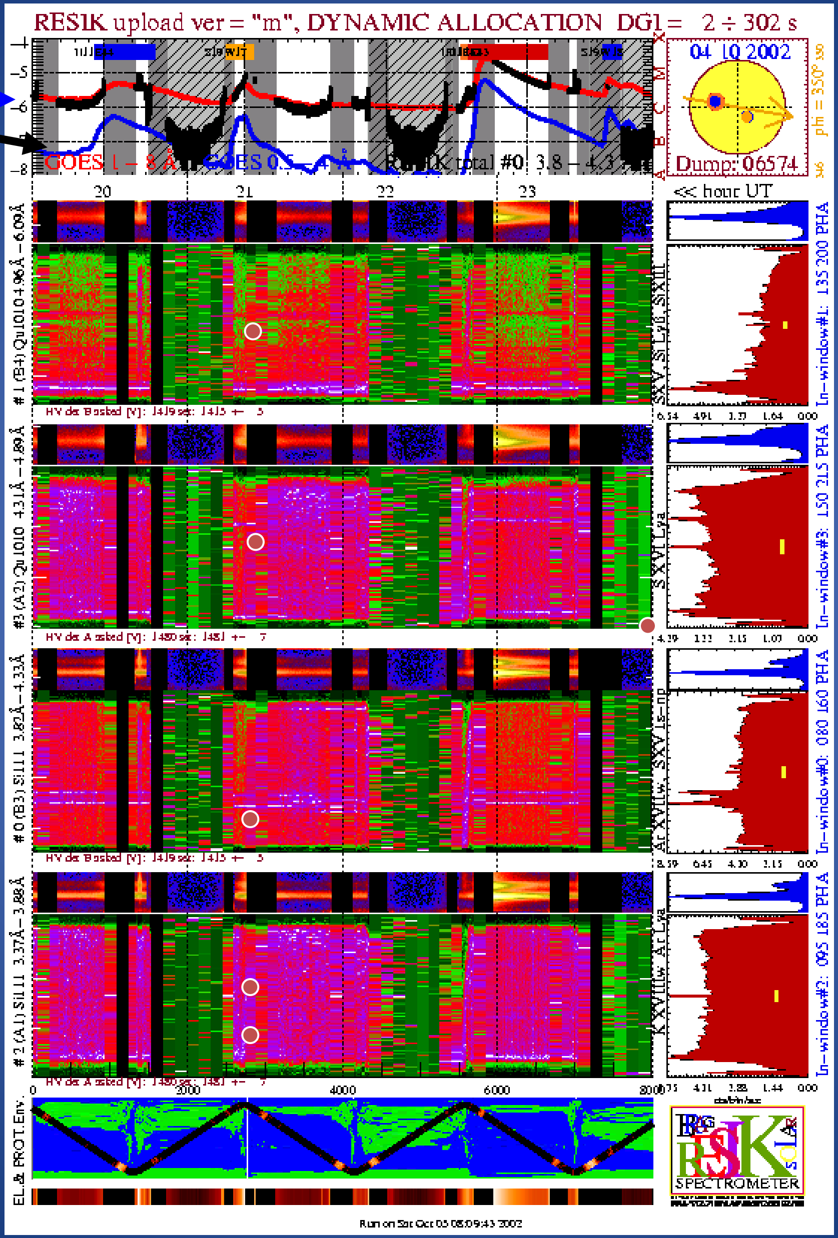


What we see - page from Catalogue (2000 pages)

fluxes

S/C nights

Spectra normalized to maximum in each channel 4.96 - 6.09



4.31 - 4.89 Å

Black - HV off

3.82 - 4.33 Å

3.37 - 3.88 Å

Orbit & particles
'electrons PHA'

Flare positions & dispersion plane

PHA spectrum #4 4

PHA spectrum #3 3

ADS = 112 - 165

PHA spectrum #2 2

ADS = 80 - 165

PHA spectrum #1 1

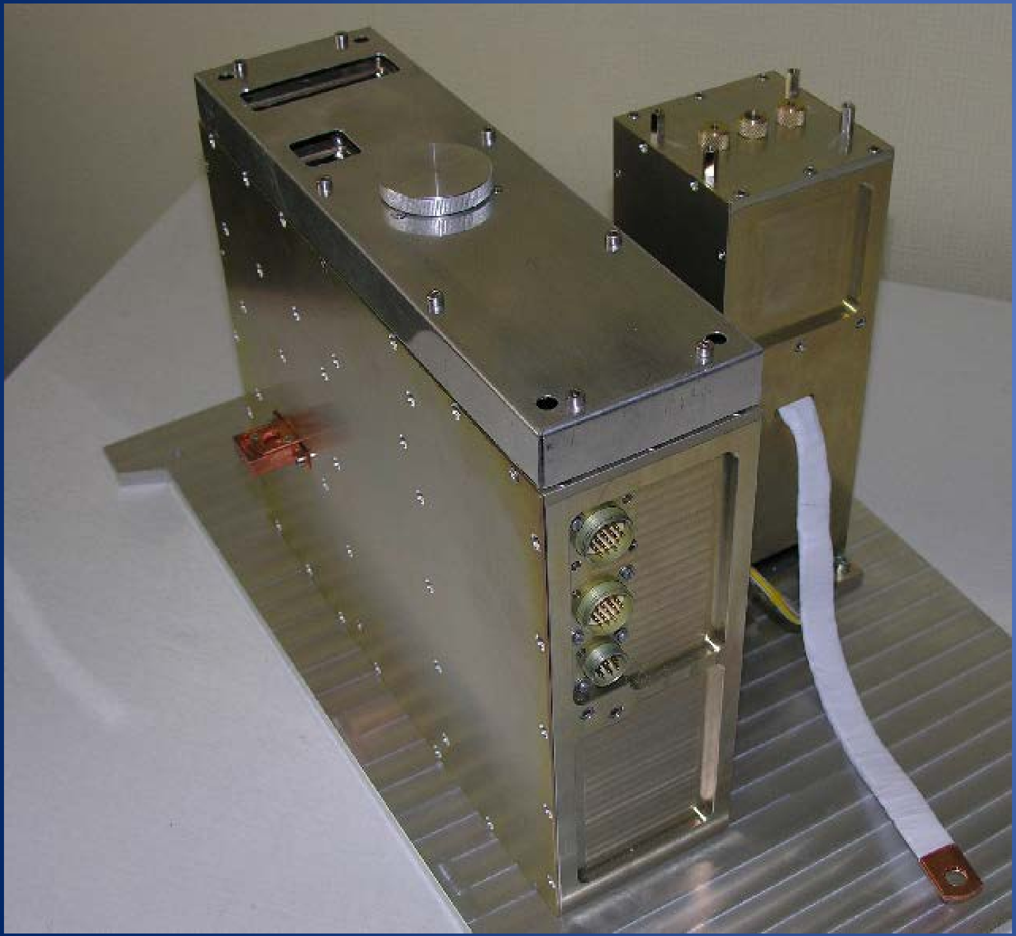
ADS = 80 - 165

engineering

for publication

SphinX

Polish concept, design & manufacture



Measures the X-ray emission of the Sun

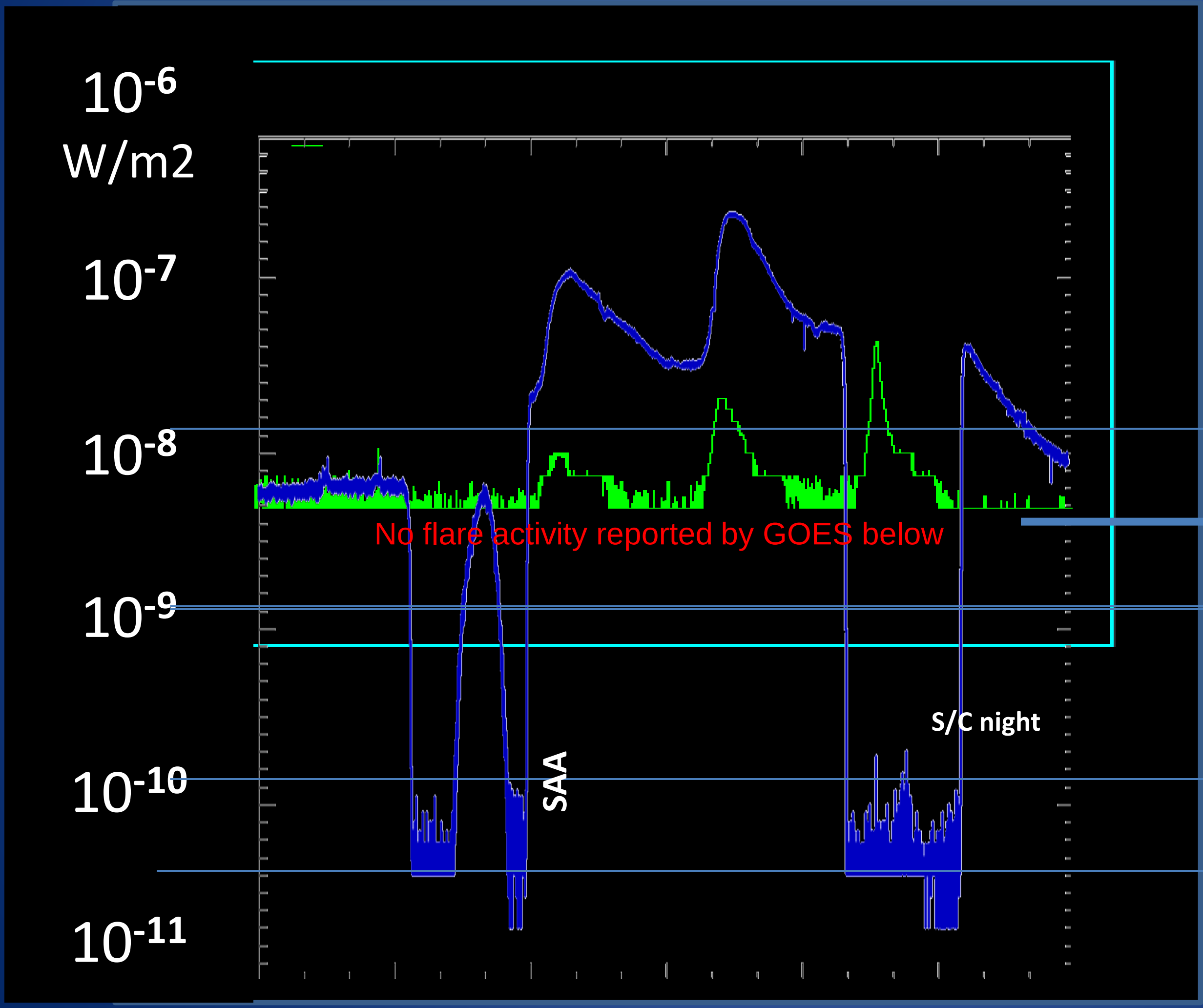
in the 85 – 15 keV band

withwith *unprecedented*

- Time resolution ~0.00001 s
- Sensitivity 100 x better than *GOES* (NOAA) XRM – the standard for 30+years
- Energy resolution 3x RHESSI (NASA)

Aimed to see Non-AR level of emission

GOES X class range → to be extended down



C = 10^{-6} W/m^2

B = 10^{-7} W/m^2

A = 10^{-8} W/m^2

S = 10^{-9} W/m^2

Q = 10^{-10} W/m^2

SphinX detection threshold

Main contributions to solar physics dodac referencje!

- Discovery of Ca abundance between flares (SMM spectra, 1984)
- First determinations of absolute the Ar abundances in the Sun (RESIK, 2010)
- Detection of X-ray Doppler-shifted lines from multi-million K plasmas (Diogeness, 2003)
- Study of Si, S, Ar & K abundances in flares (RESIK, 2013)
- Determination of non-active –X-ray solar luminosity (SphinX, 2010)
- Introduction of new X-ray flare classes (sphinX, 2010)
- Recovery of DEM pattern for flares (2015, next talk)

SPD SRC Awards

- PAS – RAS International Award 2011
  - IZMIRAN
  - FIAN
  - SRC PAS
- PAS-NANU International Award 2014,

  Radioastronomical Institut NANU
  DrS. O. W. Dudnik
  Mgr. E. W. Kurbatov

  SRC PAS

  Janusz Sylwester
  Dr. Szymon Gburek
  Dr. inż. Mirosław Kowaliński
  Mgr. inż. Piotr Podgórski

Present team, science interests and collaborations

- The SPD Team now, one of 5 SRC Divisions. In charge Dr. Mirek Kowaliński
  - 8 scientists, 4 PhD students, 7 engineers, physicist
  - Cleanroom, cooled vacuum chambers, X-ray sources & optics, various support equipment
- Data reduction & interpretation in progress
  - RESIK & Diogeness Spectra
  - RESIK particle signal
  - SMM BCS old spectra
- Science interests
  - AR and flare Plasma diagnostics (T, EM, DEM), spectral synthesis
  - Abundance determinations (next talk)
  - Particle background
  - SXR & HXR imaging
- Main collaborating people
  - Kenneth Phillips (X-ray spectroscopy)
  - Oleksyi Dudnik (Particles in magnetosphere)
  - Elena Dzifcakova (Non-Maxwellian plaslmas), ISSI collaboration

Experiments we are working on

- STIX on Solar Orbiter (phases C, D), ESA
- PROBA-3, ESA
- Interhelioprobe 1 & 2 (Roskosmos)
- SolpeX for ISS (FIAN)
- CubIXSS with USA
- SphinX-NG – looking for the opportunities… possibly Ukraine Dr. Kowalinski will describe this nano-satellite in details

STIX: The Spectrometer Telescope for Imaging X-rays (fixed)

ESA: Solar Orbiter, 2018

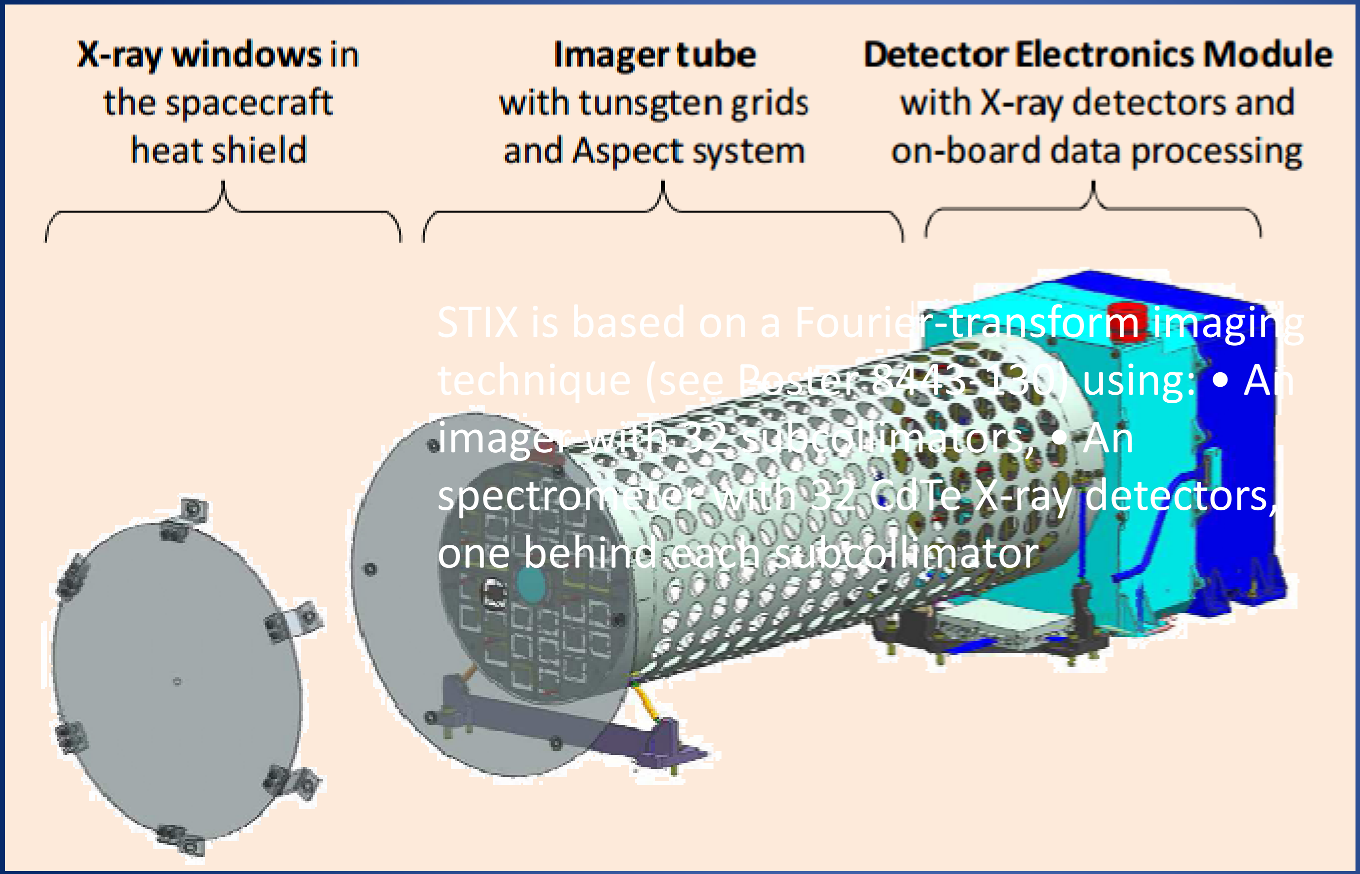
http://sci.esa.int/solar-orbiter/51217-instruments/

- Understanding the acceleration of electrons at the Sun and their transport into interplanetary space
- Determining the magnetic connection of the Solar Orbiter back to the Sun

Polish involvement: 30%, second after Switzerland, IDPU, EGSE, Data simulator, interface to spacecraft (talk of Dr. Kowaliński)

STIX - cd

STIX provides imaging spectroscopy of solar X-ray emissions with unprecedented spatial resolution and sensitivity near perihelion.



Energy range: 4-150 keV
Effective area: 6 cm^2
Field of view: 2°
Finest angular resolution: 7 arcsec
Image position accuracy: 4 arcsec
Energy resolution (FWHM):

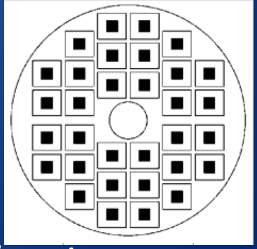
- 1 keV at 6 keV
- 15 keV at 150 keV

Time resolution (stat limited): ≥ 0.1 s

SYSTEM PARAMETERS

Mass: 5 kg
Power: 4 W
Volume: $76 \times 22 \times 22$ cm^3
Temperature:

- Feedthrough: +270°C
- Spacecraft: +50°C
- CdTe Detectors: –20°C

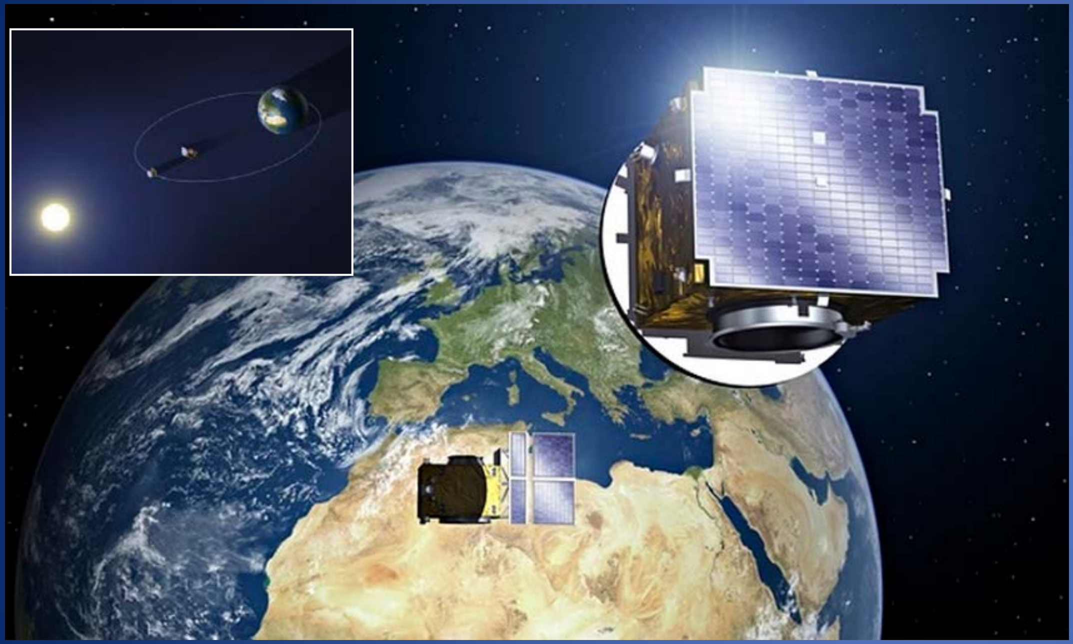


STIX is based on a Fourier-transform imaging technique using:

- An imager with 32 subcollimators,
- An spectrometer with 32 CdTe X-ray detectors, one behind each subcollimator

Proba-3 ESA, 2018 (fixed)

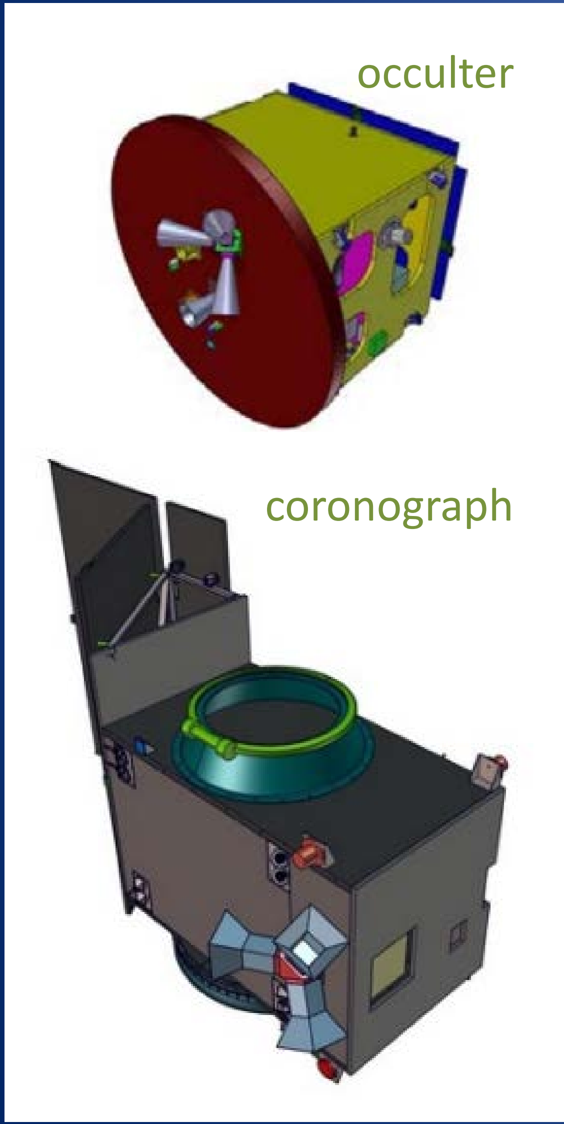
http://www.esa.int/Our_Activities/Space_Engineering_Technology/Proba_Missions/About_Proba-3



Proba-3 is ESA's – and the world's – first precision formation flying mission. A pair of satellites will fly together maintaining a fixed configuration as a 'large rigid structure' in space to prove formation flying technologies.

The paired satellites will together form a 150-m long solar coronagraph to study the Sun's faint corona closer to the solar rim than has ever before been achieved.

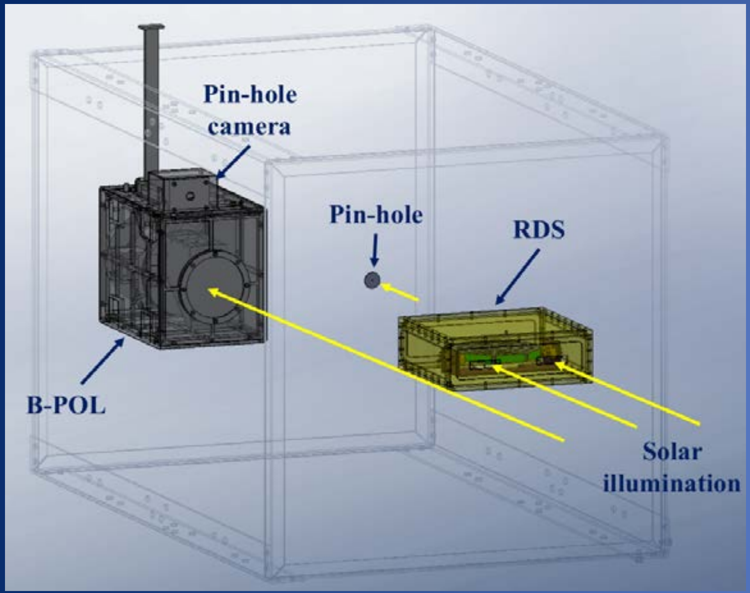
Proba-3 cd

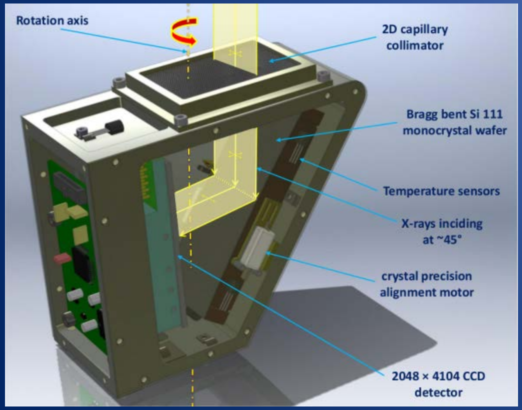


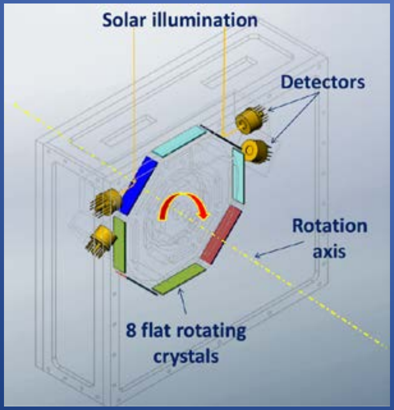
- Poland shares ~30% of the mission cost hardware through contracts with ESA (Warsaw)
- Science groups are located in Wroclaw SPD-SRC PAS (3 people) and University Astronomical Institute (3 people)

Coronagraph spacecraft 340 kg;
Occulter spacecraft 200 kg
High Earth orbit, 19.7 hours orbital period, 60 530 km apogee, 600 km perigee

SolpeX for ISS, to be placed on new NAUKA Russian module ~2018

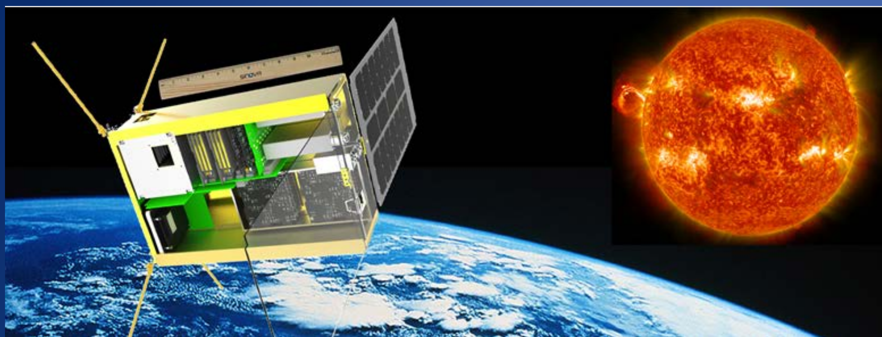




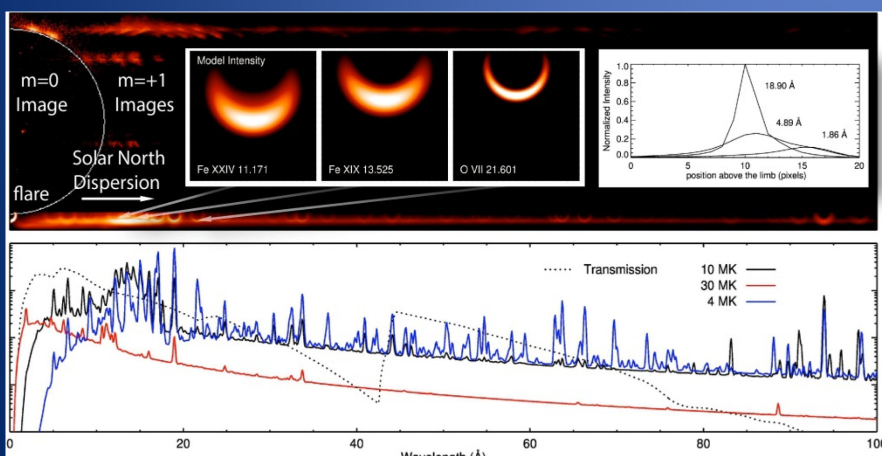


- A part of KORTES under construction at FIAN
- First Bragg solar polarimeter
- New concept of fast-rotating drum flat crystal spectrometer
  - Pin-hole imager- will provide location of the source on the disk
  - ISS offers a chance to test these concepts

CubIXSS 6U nanosatellite collaboration with SwRI, LASP & GSFC



60 cm x 20 cm x 10 cm, 8 kg, 20 W, -
SASS (0.5-100 keV), MOXSI (0.12-10 keV)

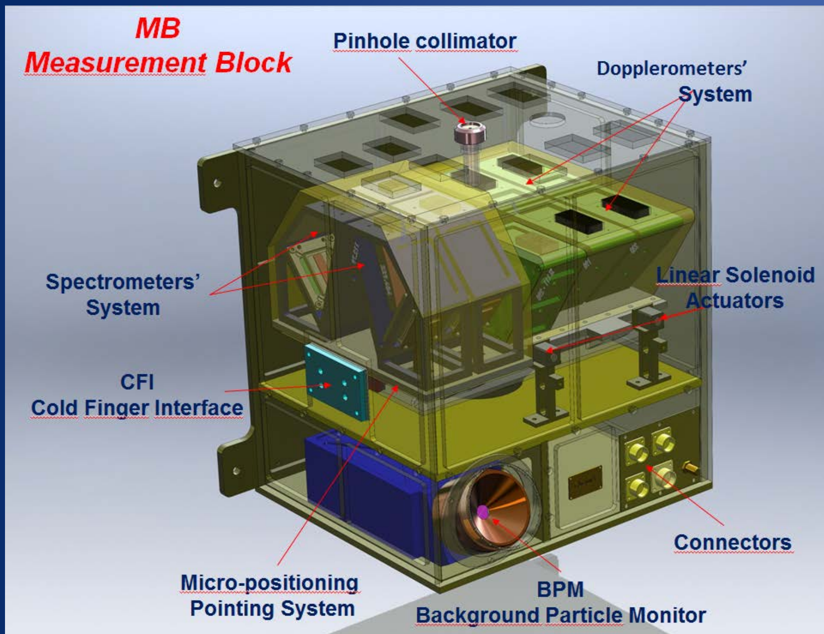


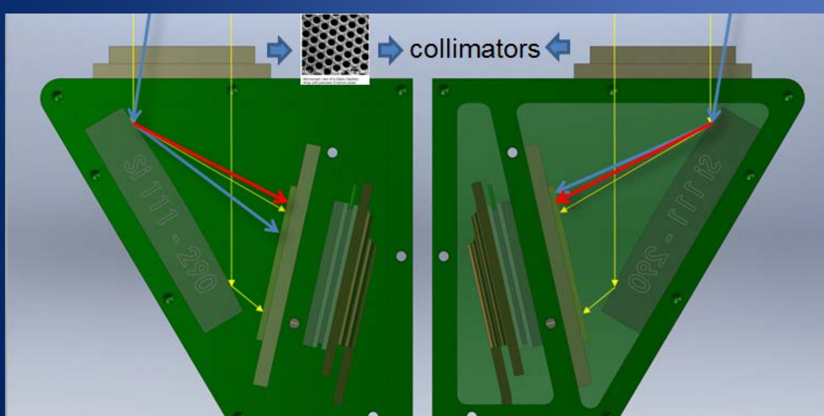
revolutionary X-ray observations of the high temperature corona. These observations will allow us to address fundamental questions related to the physics of magnetic reconnection and particle acceleration, the heating of the solar corona, and the coupling of the Sun's radiative output to the Earth's upper atmosphere. With CubIXSS we will:

- *Quantify the evolution of thermal and non-thermal emission during solar flares;*
- *Constrain theories of coronal heating by measuring the distribution of high temperature plasma in the non-flaring corona;*
- *Understand the flow of mass and energy into the corona by determining the composition of the solar upper atmosphere for both quiescent and impulsively heated loops; and*
- *Measure the solar irradiance and its variability at soft X-ray wavelengths and model its impact on the Earth's ionosphere and thermosphere.*

ChemiX on Interhelioprobe 1 & 2
Chemical composition in X-rays

Dr. Oleksiy Dudnik presentation





NATURAL HISTORY MUSEUM

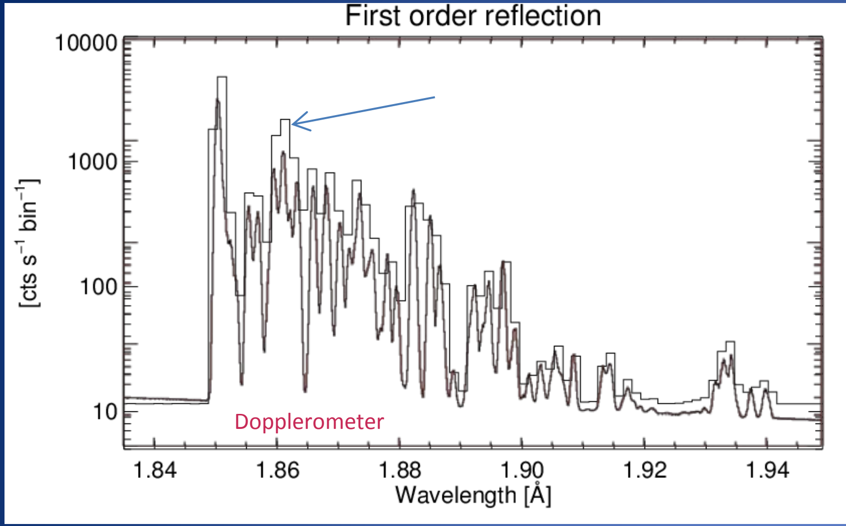
Determination of

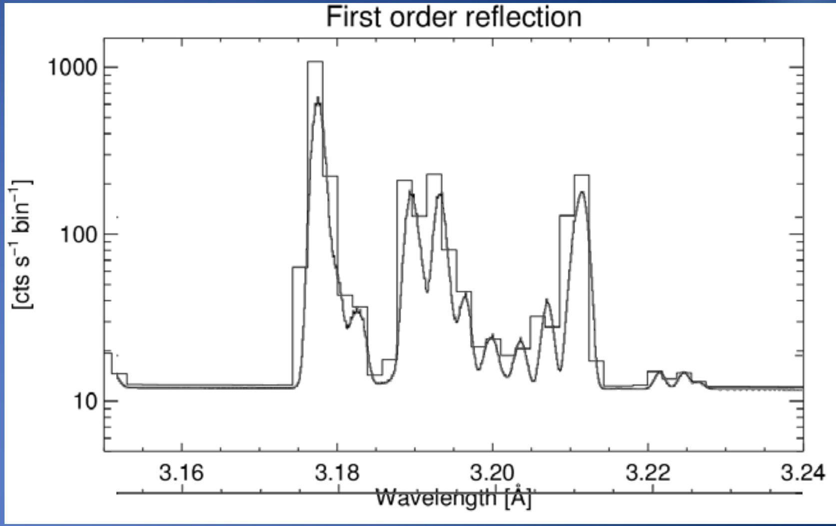
Mg, Al, Si, S, Cl, Ar, K, Ca, Fe & Ni

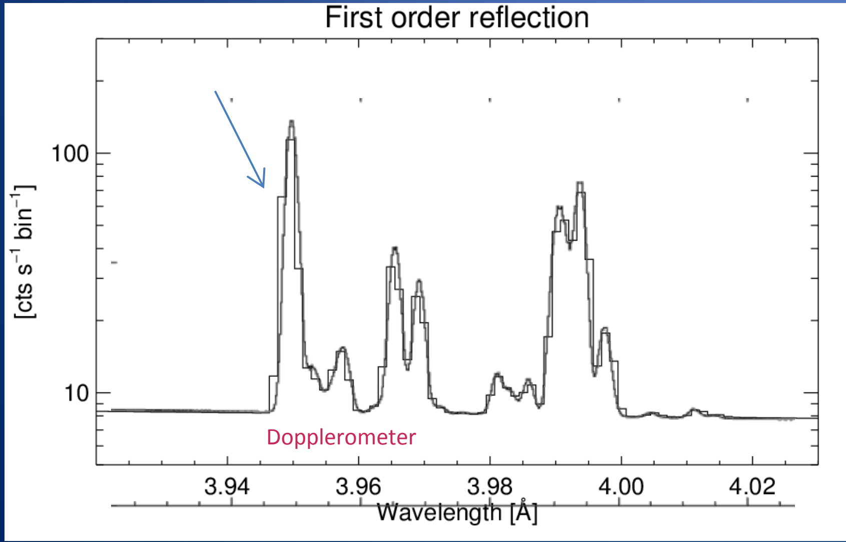
coronal abundances

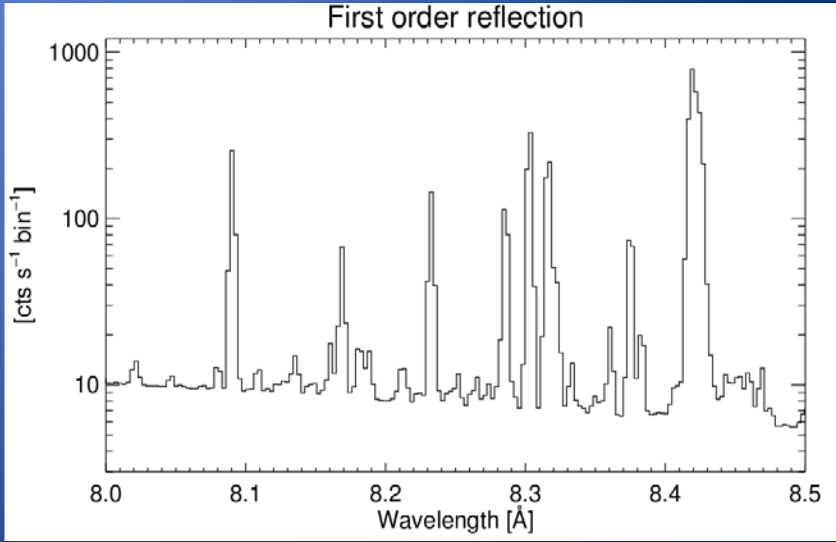
- Studies of DEM plasma distribution in AR & Flares
- Detection of Non-Maxwellian plasmas
- Spectra of particle environment, e, p, He-O

ChemiX spectra









We are looking for collaborations

THANK YOU !