

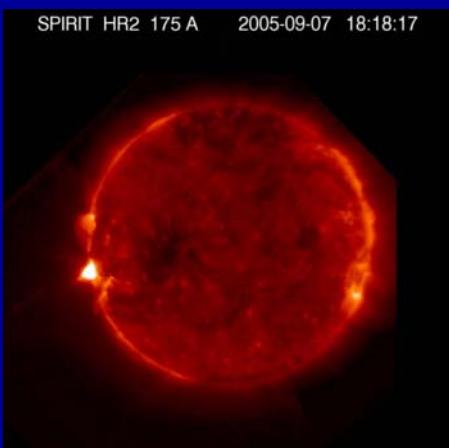
Coronas-F observations of the Sun and Extreme Solar Events

**V.D.Kuznetsov
and CORONAS-F Team**

**Solar Extreme Events:
Fundamental Science and Applied Aspects
(SEE-2005)**

**International Symposium
Nor Amberd, Armenia**

26-30 September 2005

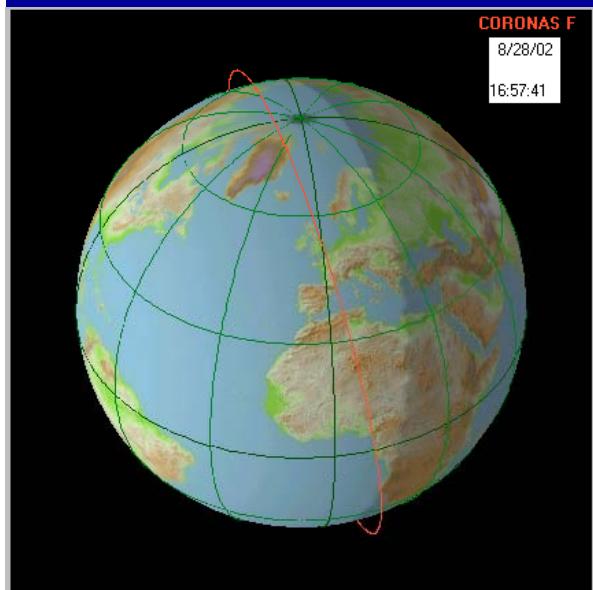


CORONAS-F Satellite

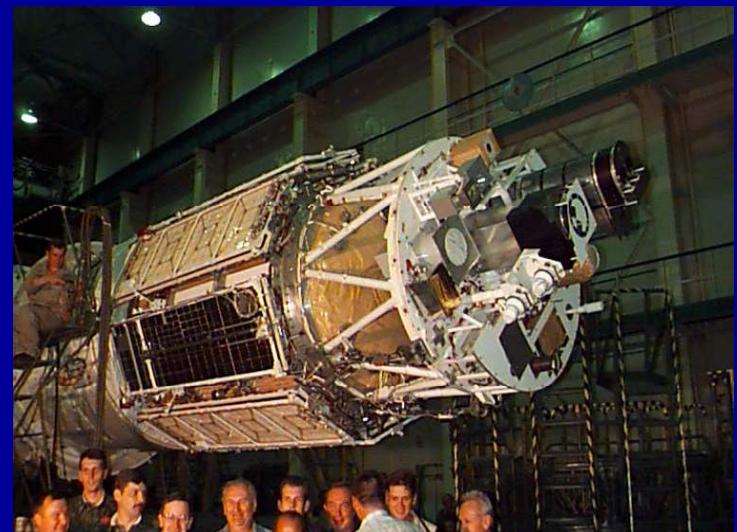
- Launched July 31, 2001

Orbital data:

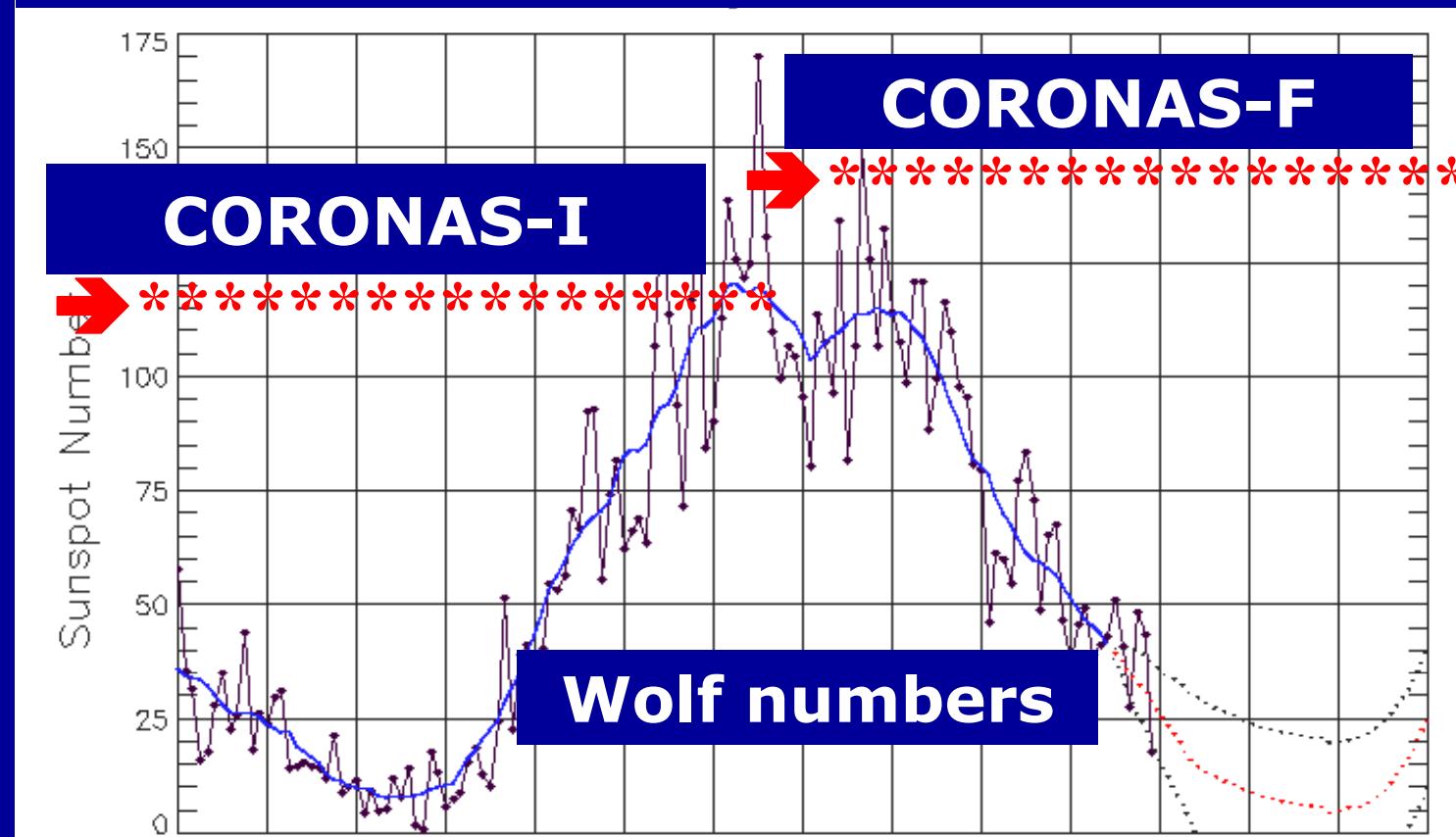
- altitude of the circular orbit
~ 500 km
- orbital period ~ 95 min
- inclination ~ 83°



Sun
synchronous
orbit of about
20 days in
recurrent
intervals



Observations of the Sun during 23th current solar cycle by CORONAS satellites

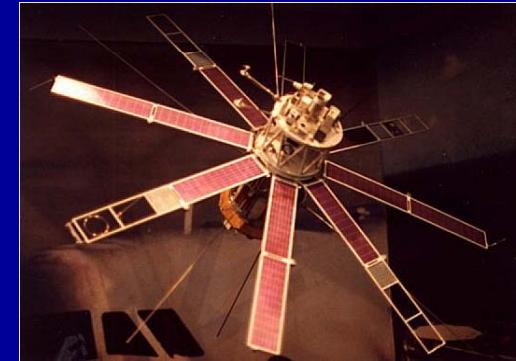


1996 1998 2000 2002 2004 2006 годы



CORONAS-F Instruments

- 1. Multi-channel Photometer (DIFOS)**
- 2. Solar X-ray Telescope (SRT-K)**
- 3. X-ray Spectroheliograph (RES-K)**
- 4. Spectrometer (DIOGENESS)**
- 5. X-ray Spectrometer (RESIK)**
- 6. Solar X-Ray Spectropolarimeter (SPR-N)**
- 7. Flare Spectrometer (IRIS)**
- 8. Gamma Spectrometer (HELIKON)**
- 9. X-ray Spectrometer (RPS)**
- 10. Time-Amplitude Spectrometer (AVS)**
- 11. Solar UV Radiometer (SUFR-sp-k)**
- 12. Solar UV Spectrophotometer (VUSS-L)**
- Solar Cosmic Rays Complex (SCR):**
 - 13. MCL - Cosmic Ray Monitor**
 - 14. SCI-3 - Spectrometer of the Energy and Ion Chemical Composition**
 - 15. SONG - Solar Neutrons and γ -rays Spectrometer**
- 16. Data Build-up System (SSNI)**

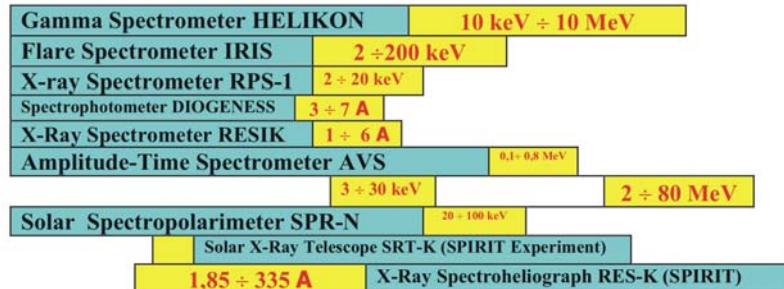


Measuring channels of the CORONAS-F instruments

Helioseismology

350-1500 nm Spectrophotometer DIFOS

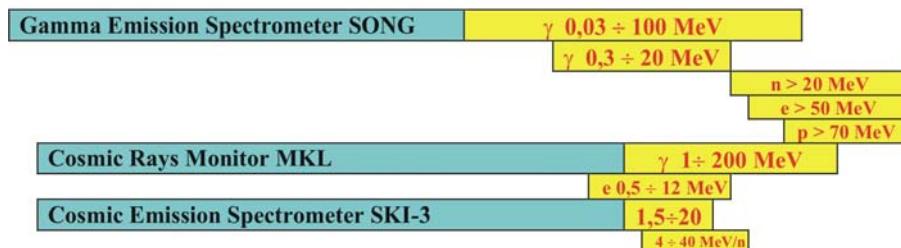
Solar Flares and Imaging of the Sun



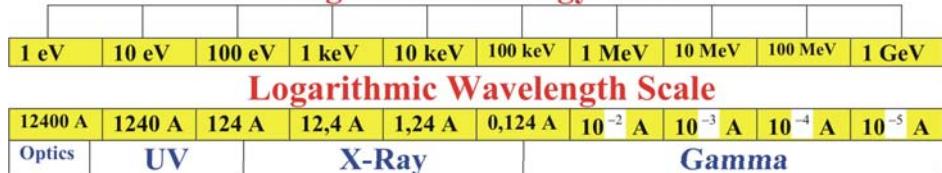
Ultra Violet Emission of the Sun

10 ÷ 1300 Å	Solar UV Radiometer SUFR-Sp-K
	Solar UV Spectrophotometer VUSS-L

Solar Cosmic Rays



Logarithmic Energy Scale



Integral covering of the energy and wavelength scale



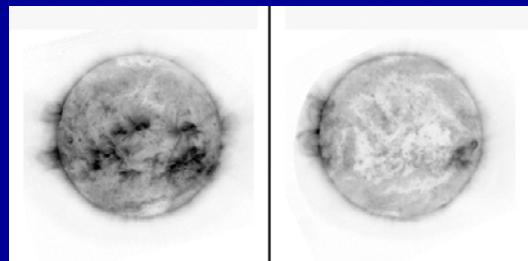
CORONAS-F Instruments



SPIRIT Experiment

Asymmetry of Solar activity on 15 October-29 November 2003

2003-10-15 13:38:12



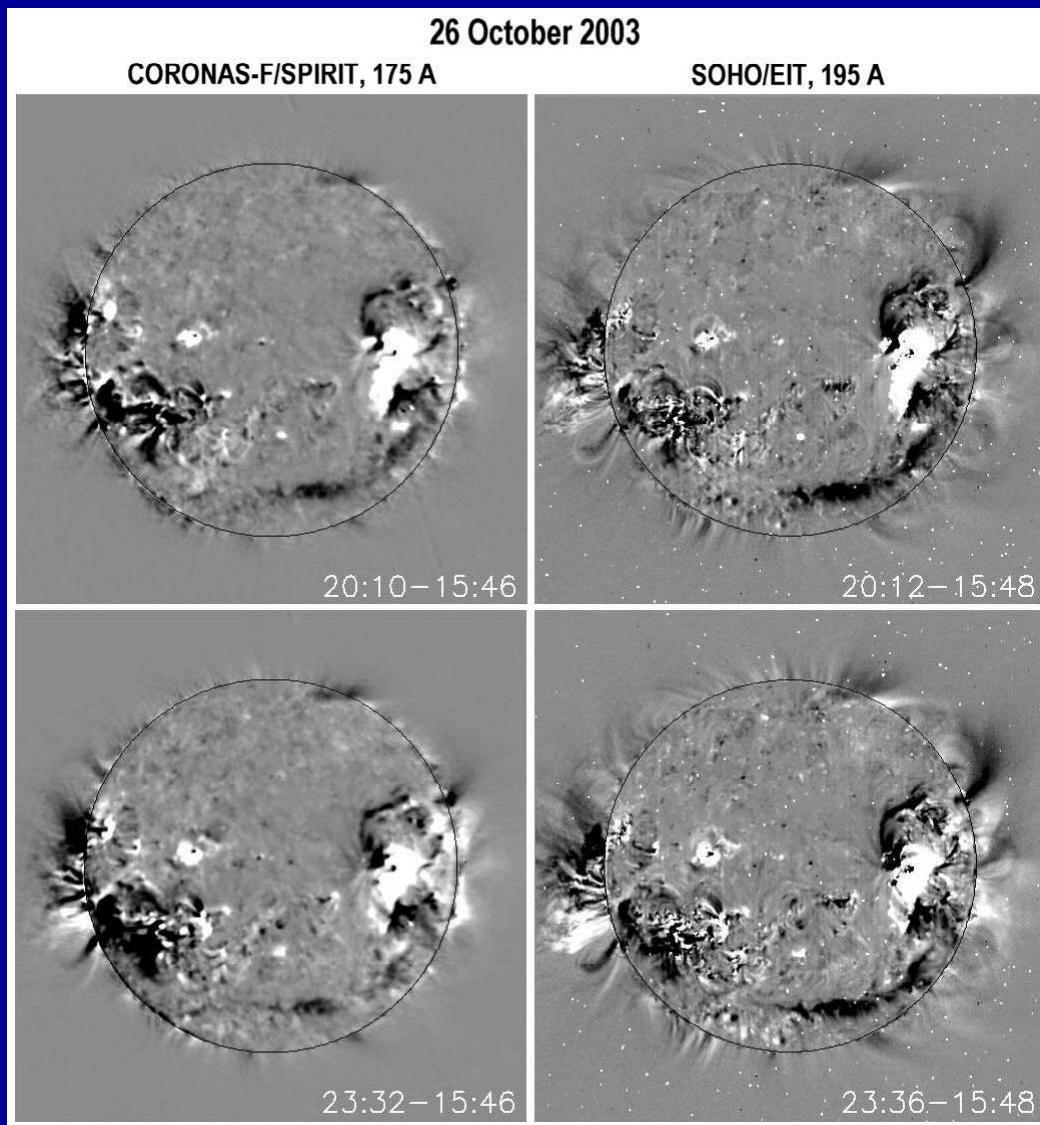
SPIRIT: HR2 175 A



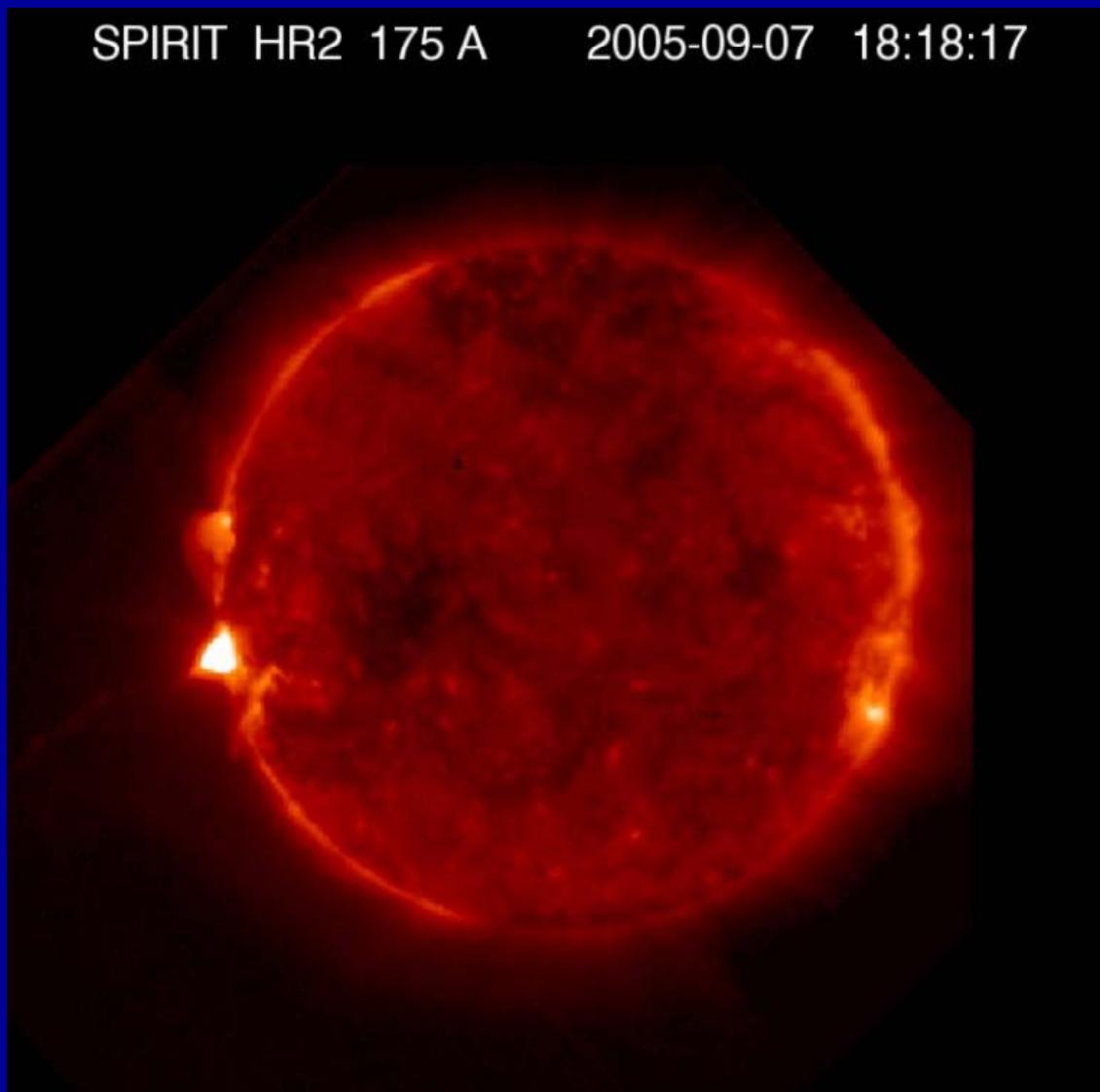
HR2_175_new.avi

SPIRIT Experiment

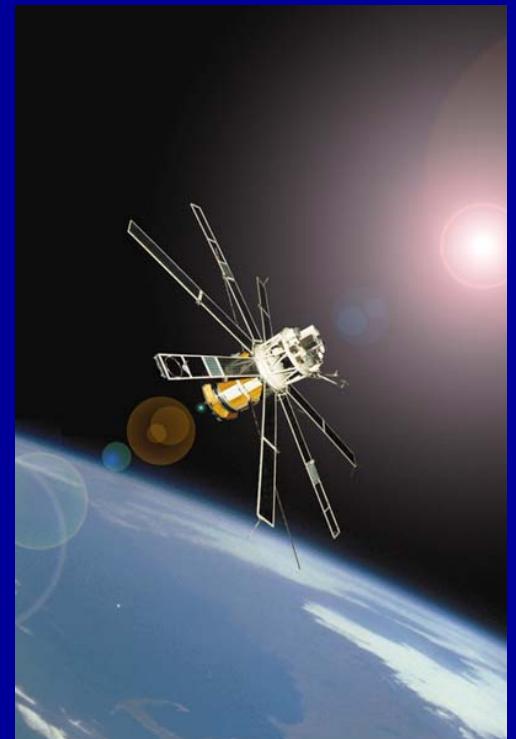
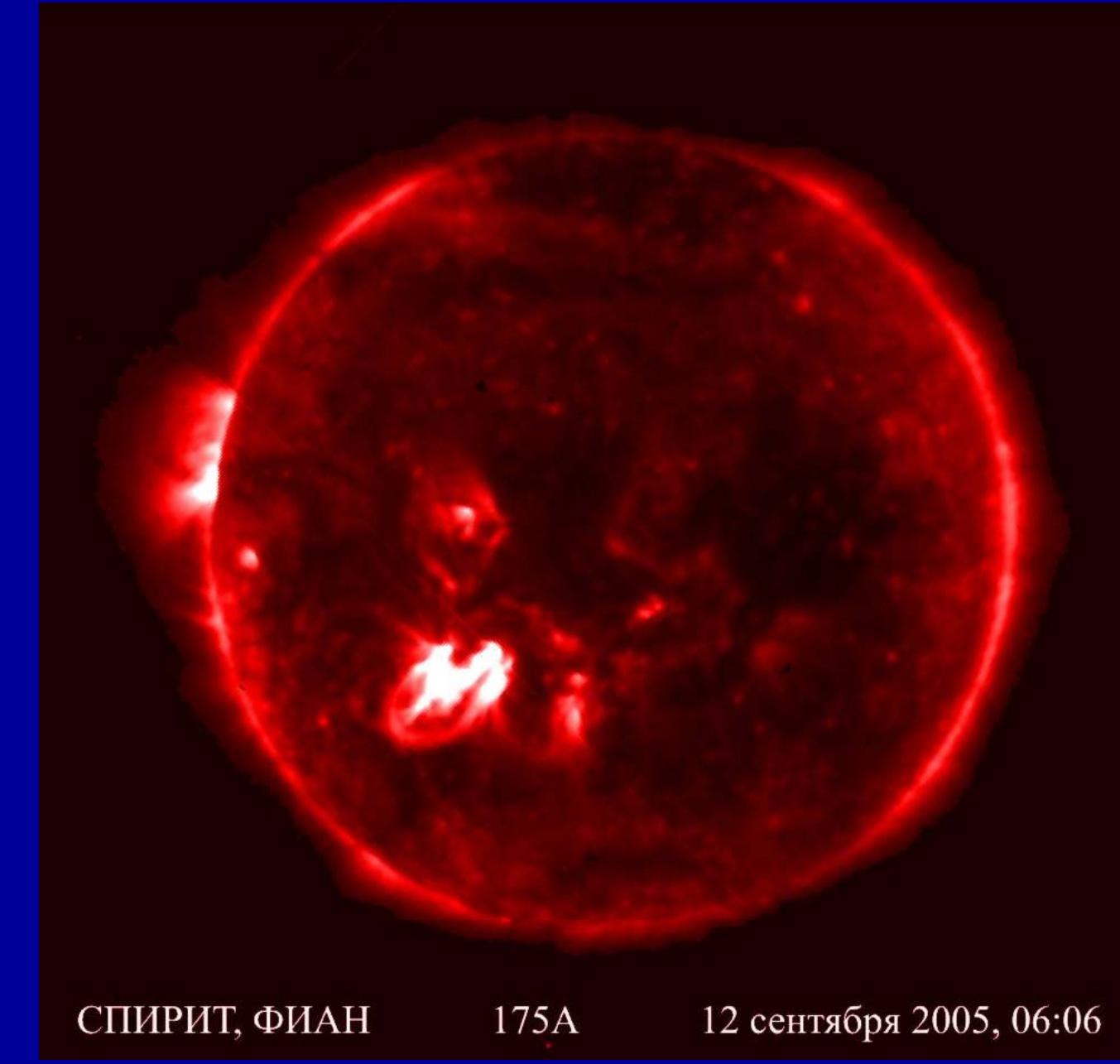
Powerful solar flares and ejections on 26 October 2003



Extreme Solar Event on 7 September 2005 (Solar Flare X17.1)



12 September 2005, AR10808



СПИРИТ, ФИАН

175A

12 сентября 2005, 06:06

September 2005

Flares in AR10808

8 Sept - X5.4/2B

9 Sept - X1.1/2F, M6.2/1F, X3.2/ and X6.2/2B

10 Sept - X1.1/ и X2.1

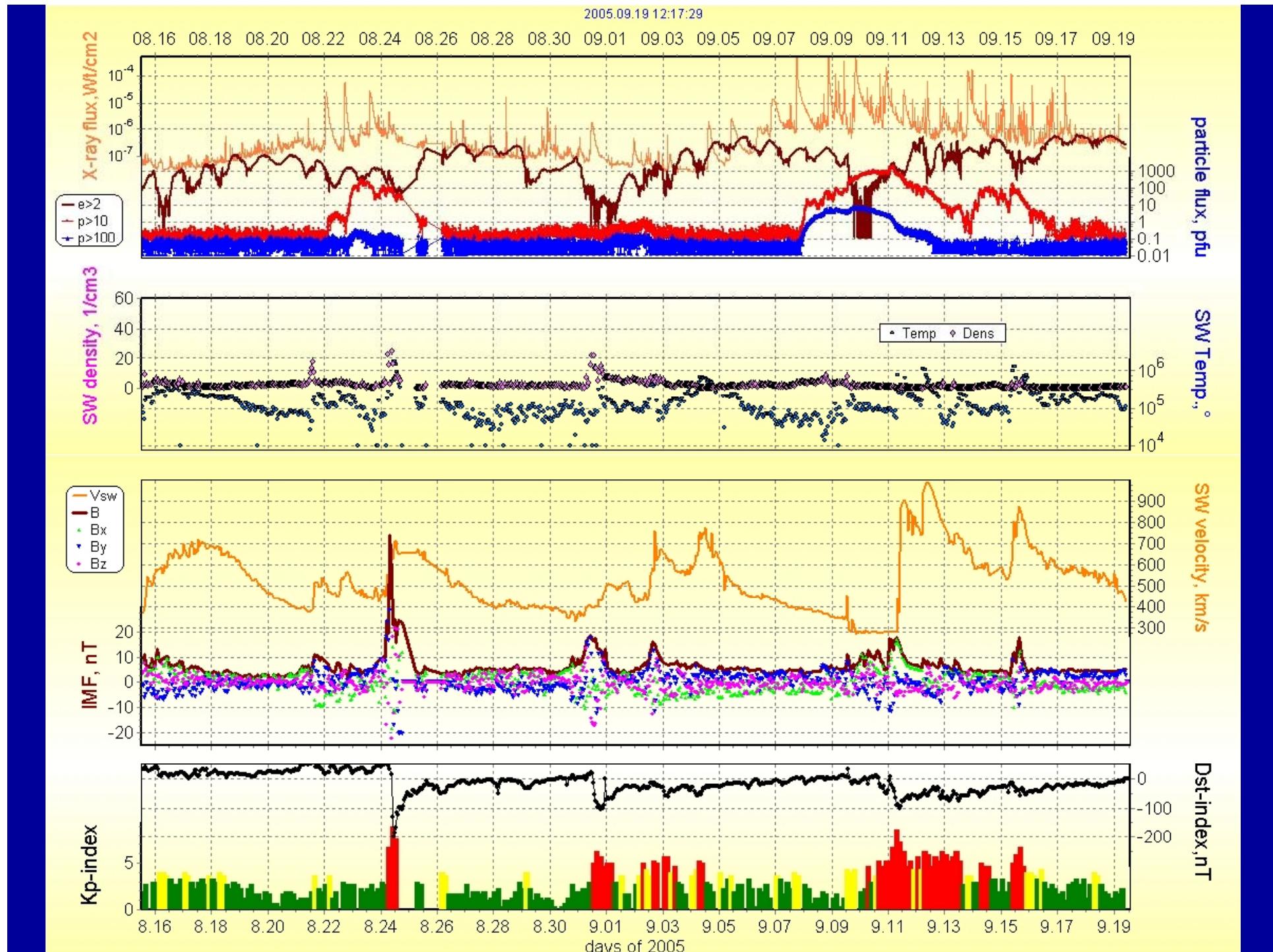
12 Sept - M6.2/2F

13 Sept - X1.5/2B и X1.7/1B

15 Sept - X1.1/2N

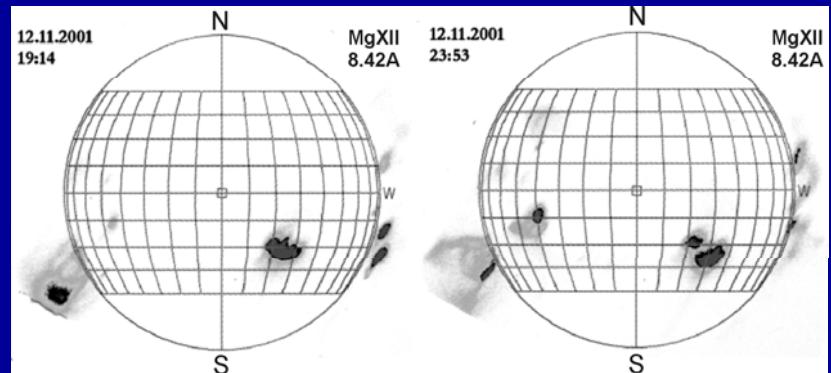
17 Sept - M9.8/

A lot of middle class flares

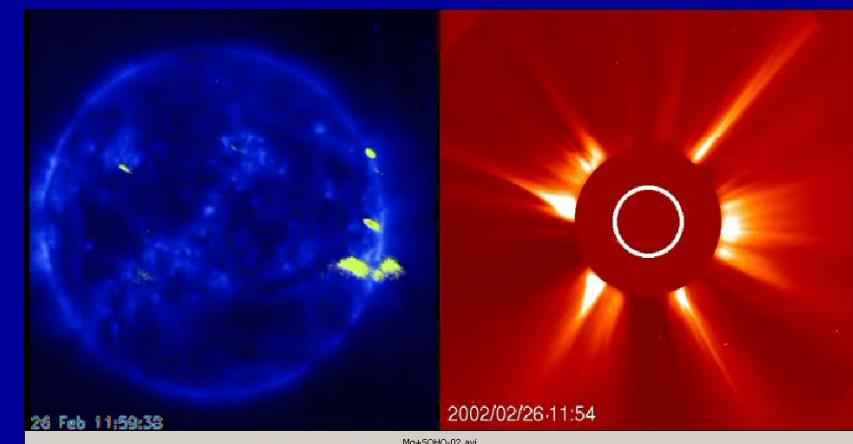
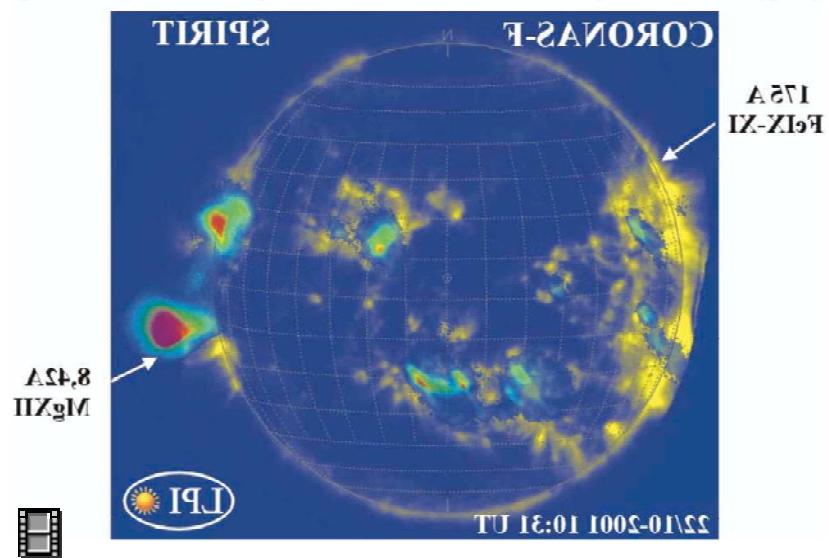


SPIRIT Experiment Observations in MgXII (8,42 Å)

Hot flare plasma in the corona
(up to 20 mill. degr.)

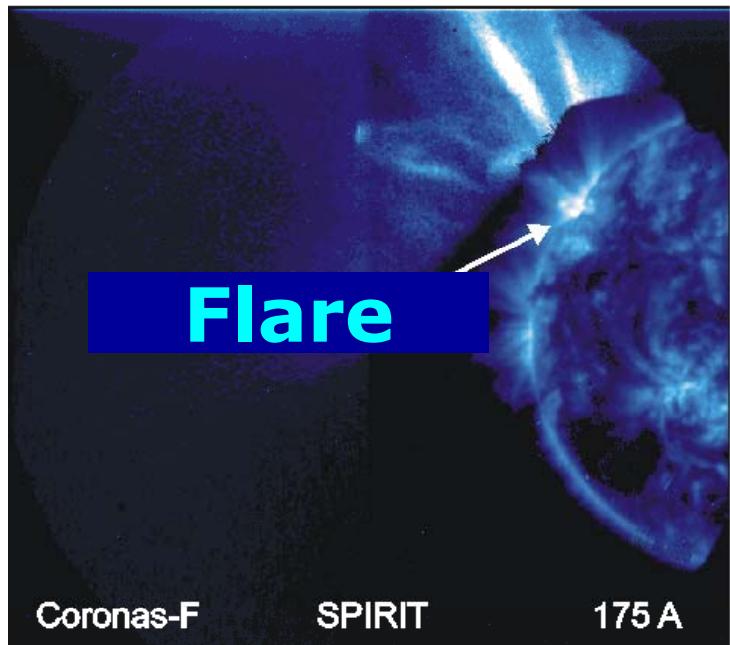


Superposition of two Sun images in 10 MK band
(MgXII 8.42 Å) and in 1.6 MK band (FeIX-XI, 175 Å)



CORONAS-F SPIRIT &
SOHO/LASCO

08/12-01 07:24:25 UT

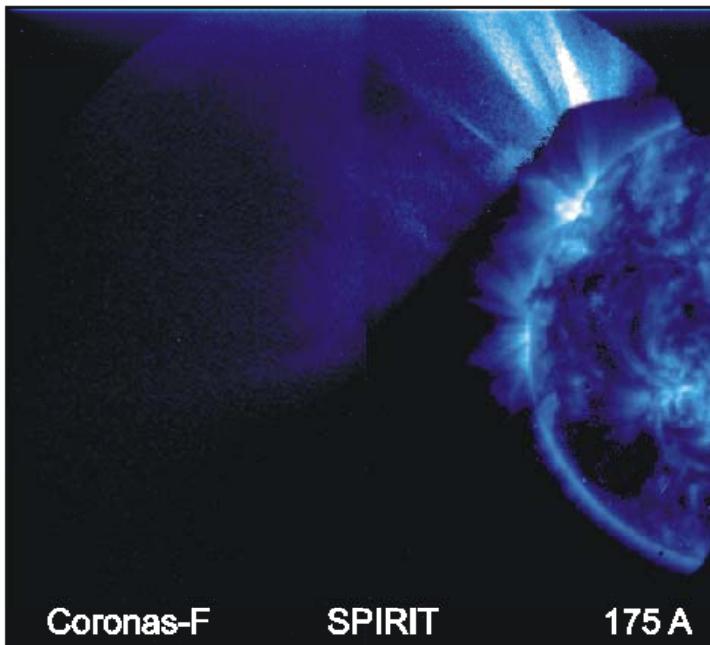


Coronas-F

SPIRIT

175 Å

08/12-01 09:03:25 UT



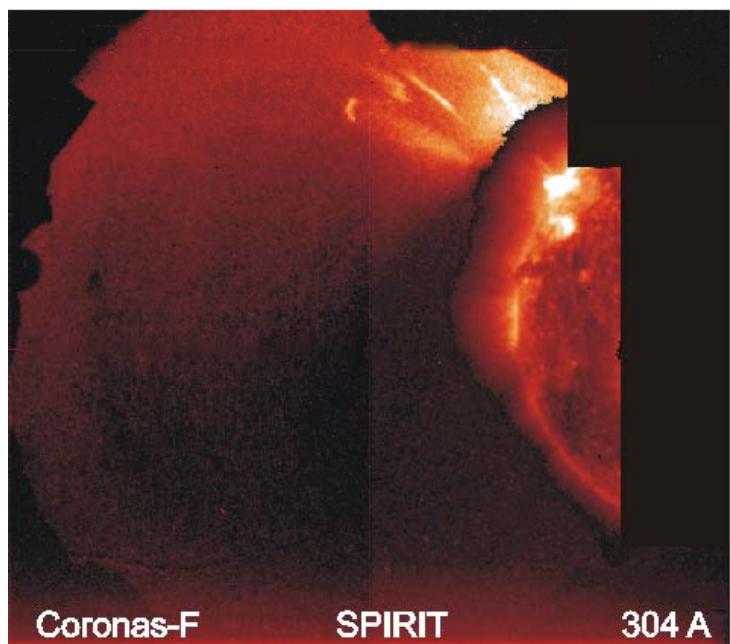
Coronas-F

SPIRIT

175 Å

**SPIRIT
Coronograph**

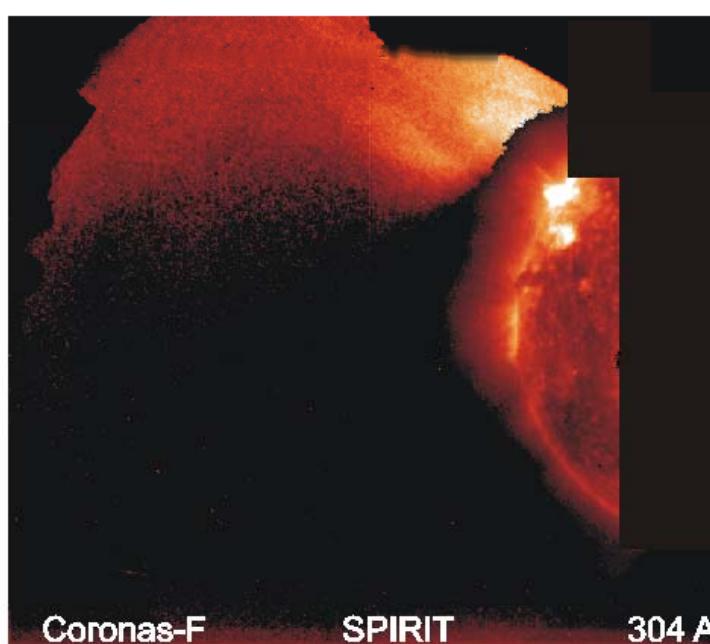
X-ray corona



Coronas-F

SPIRIT

304 Å

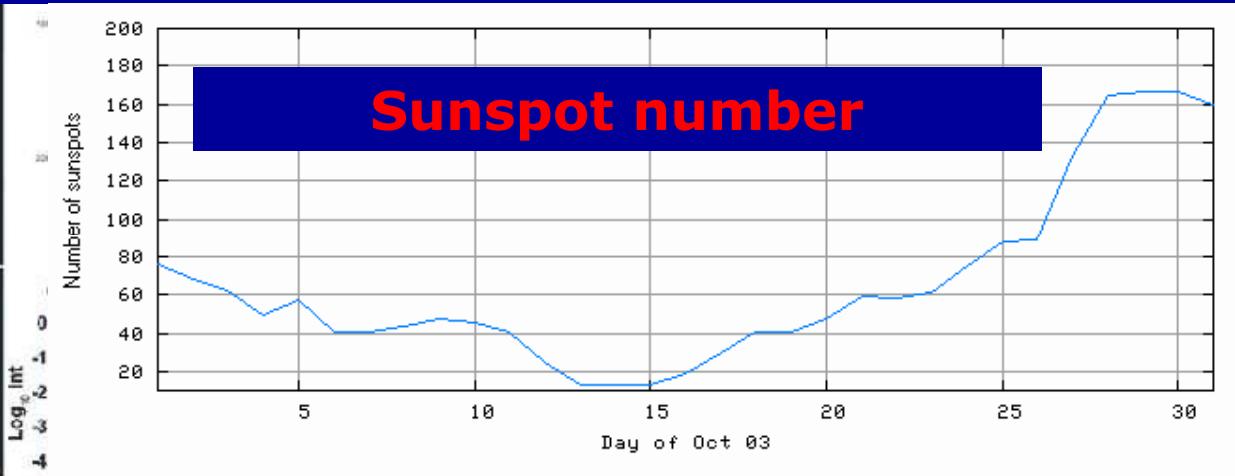
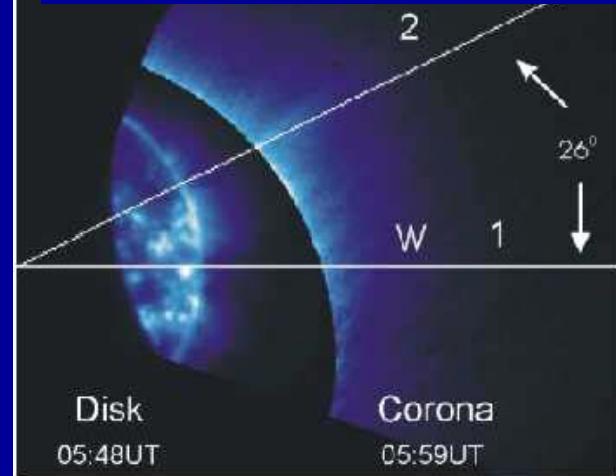


Coronas-F

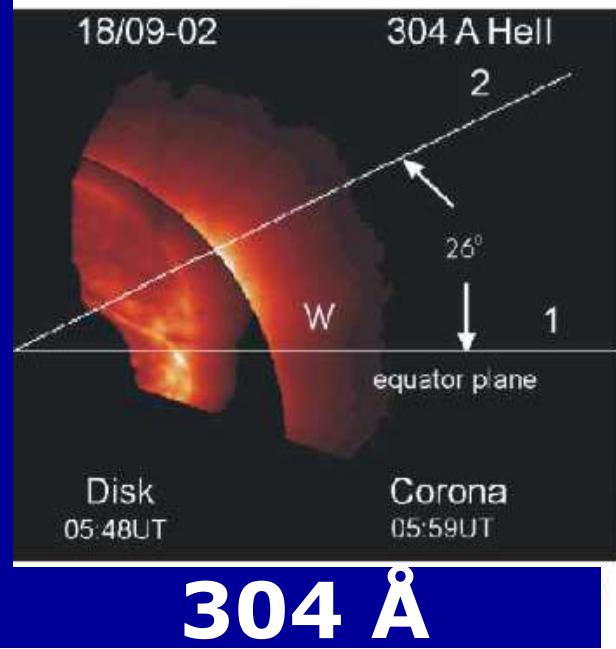
SPIRIT

304 Å

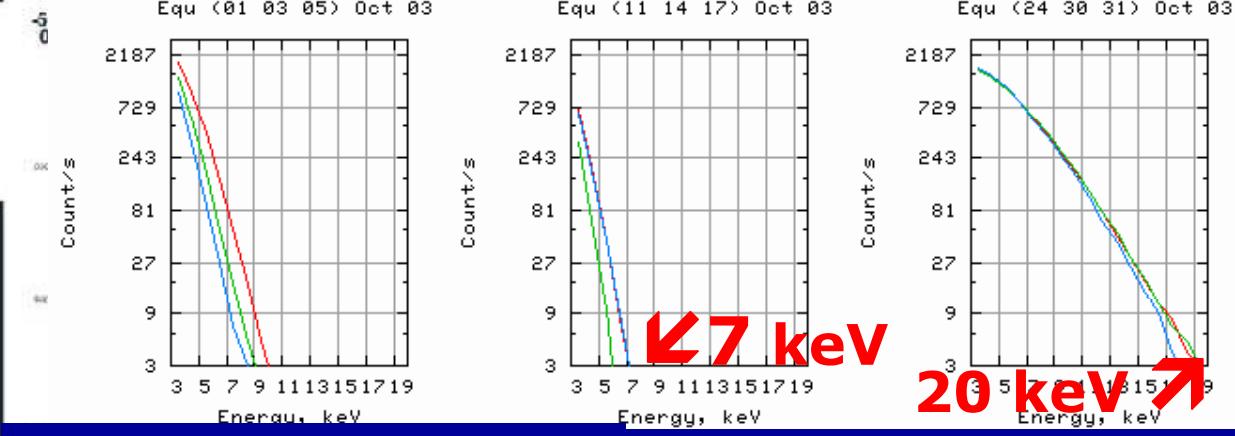
Magnetic heating of the corona



175 Å

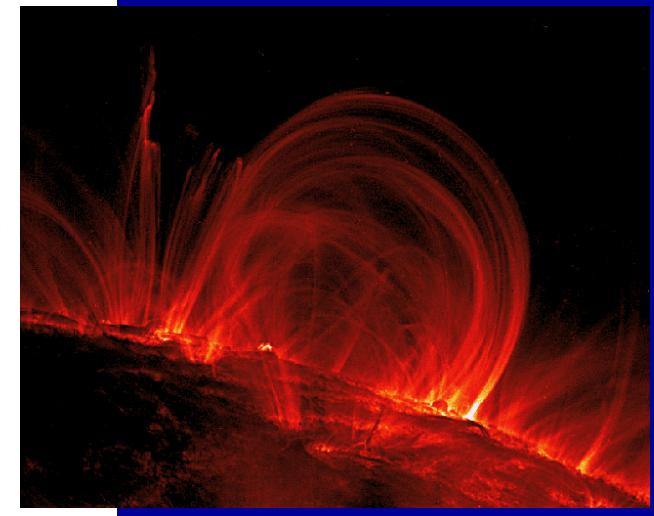
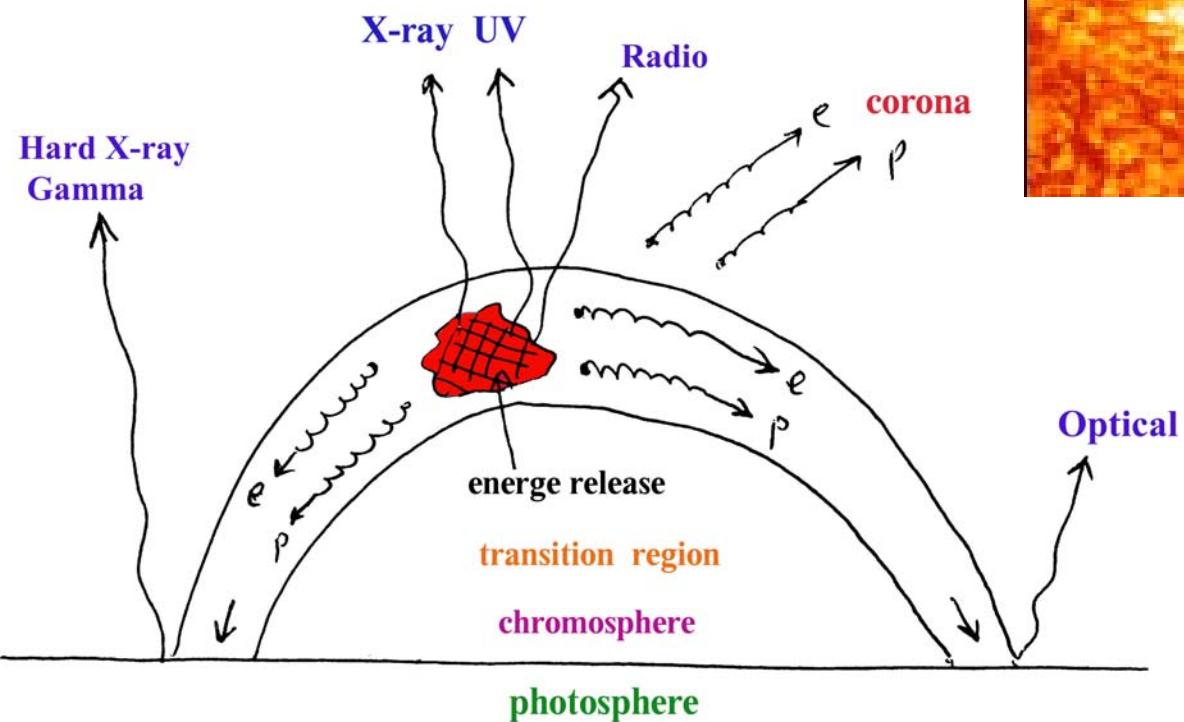


304 Å

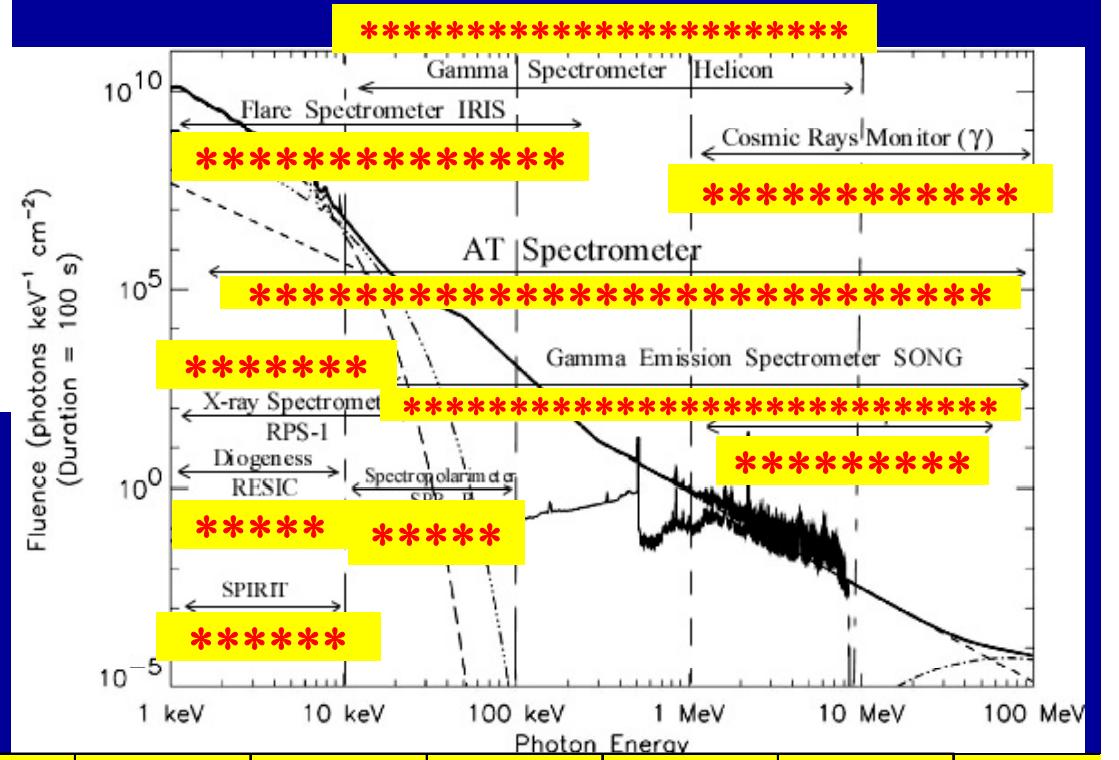
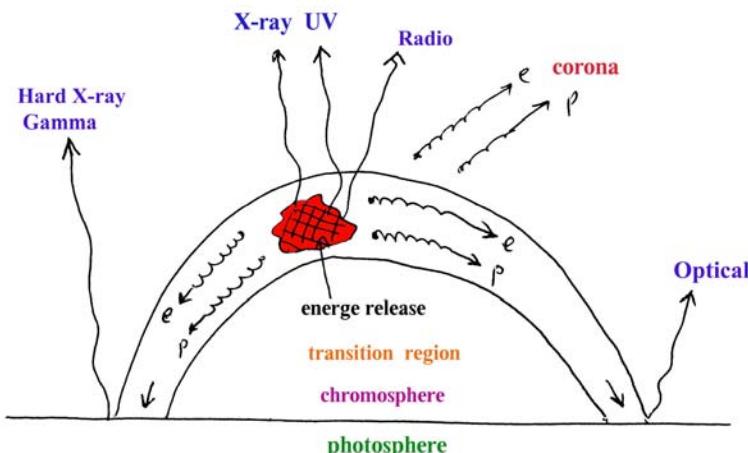


X-Ray corona

Solar Flares

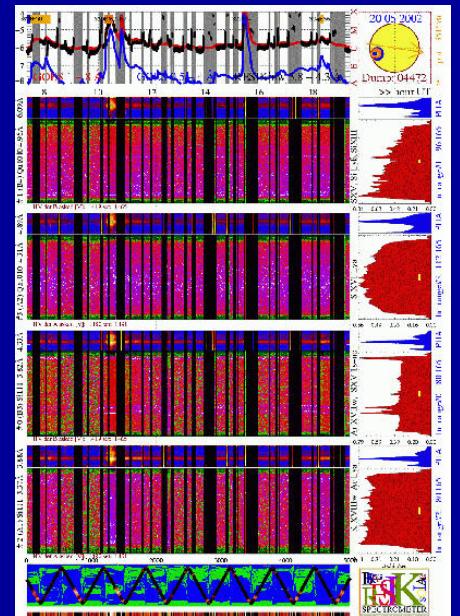
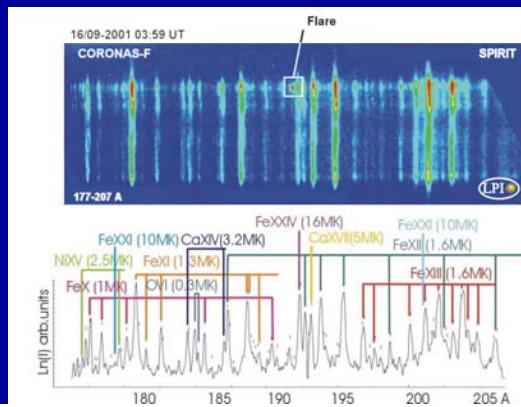
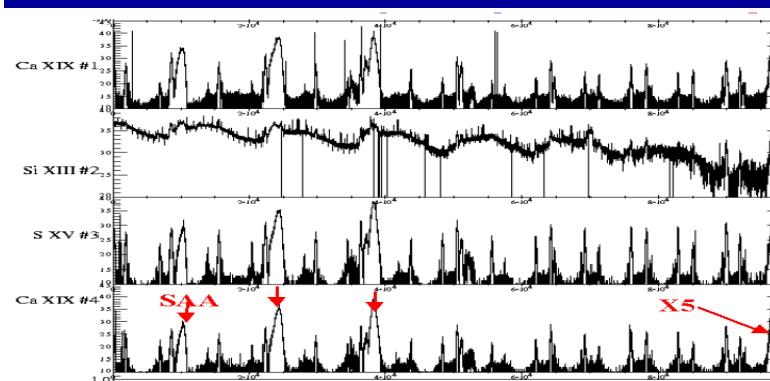
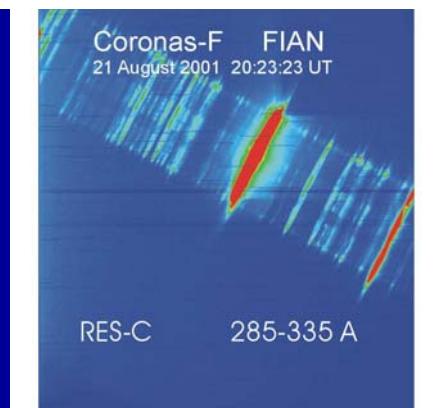
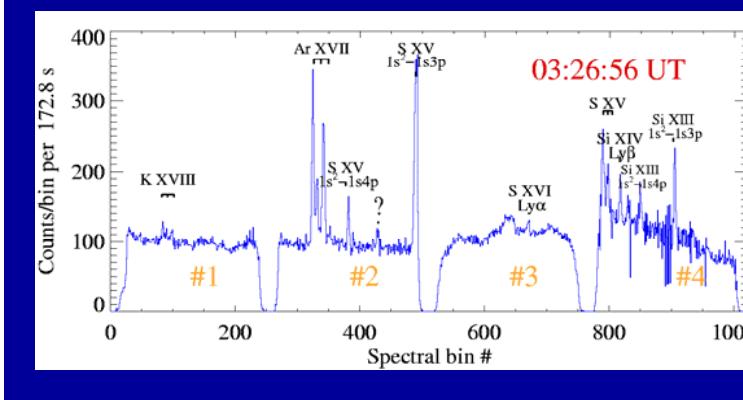
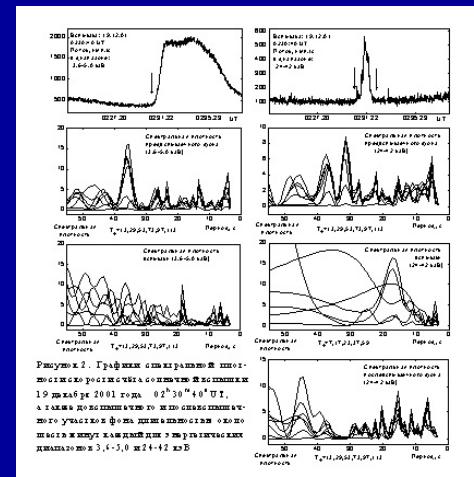
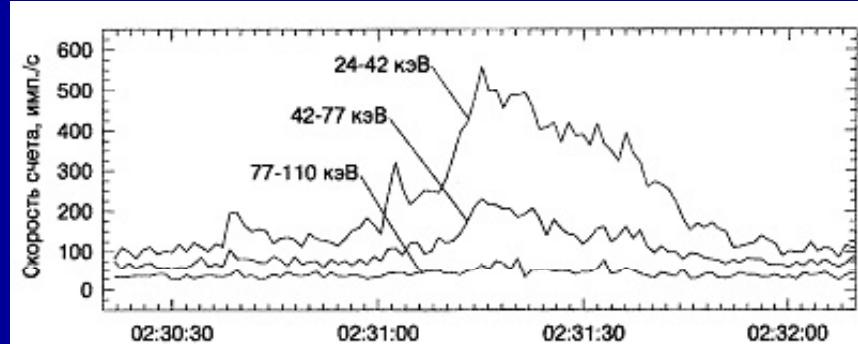
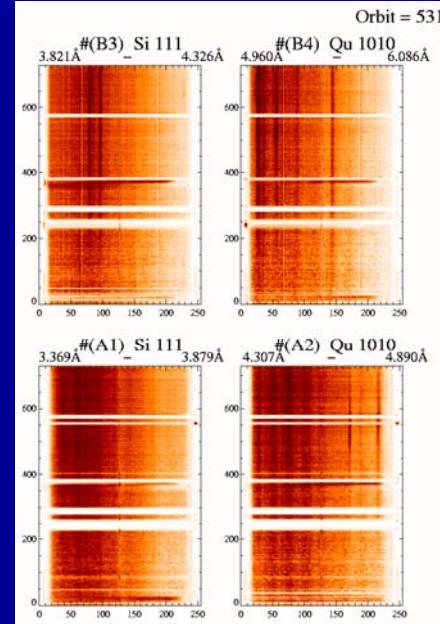


CORONAS-F Energy Range and Composite Flare Spectrum



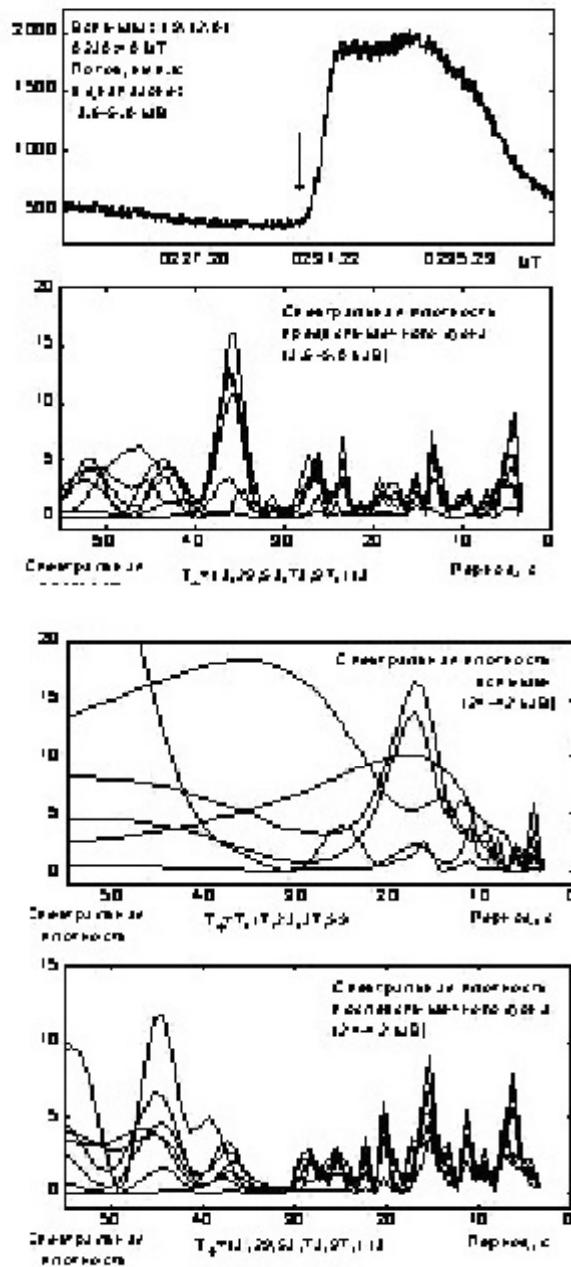
1 eV	10 eV	100 eV	1 keV	10 keV	100 keV	1 MeV	10 MeV	100 MeV
12400 Å	1240 Å	124 Å	12,4 Å	1,24 Å	0,124 Å	10^{-2} Å	10^{-3} Å	10^{-4} Å
Optics	UV	X-Ray			Gamma			

CORONAS-F Solar Flares



Flare Spectrometer IRIS

Temporal Profile of X-Ray Emission (3÷40 кэВ)



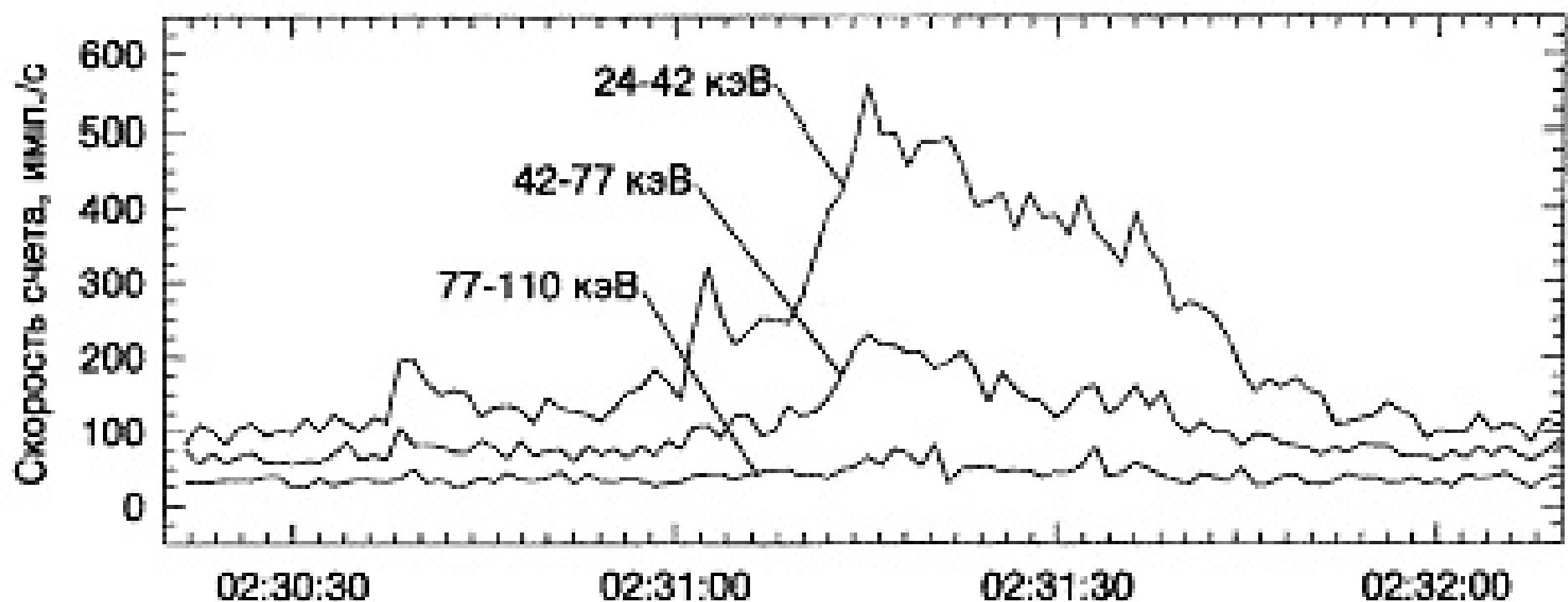
Pre-Flare Phase
 $T = 35$ sec

Flare Phase
 $T = 18$ sec

Post-Flare Phase
 $T = 5$ и 15 sec

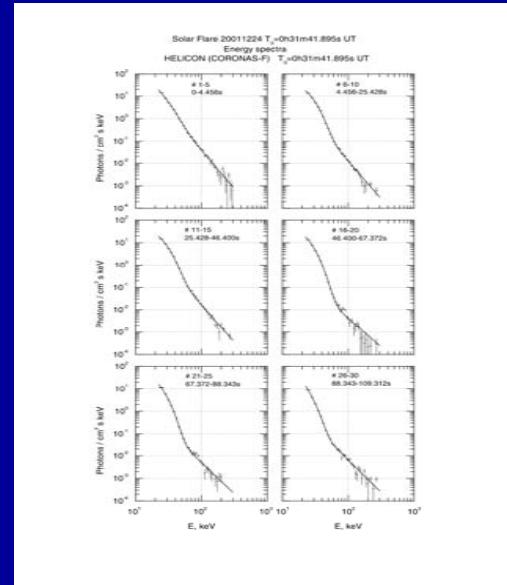
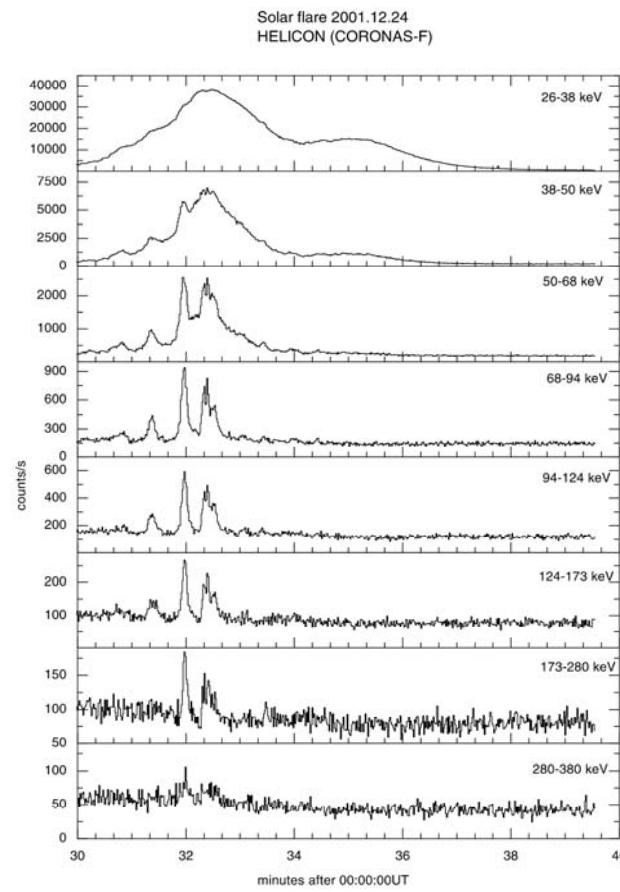
Flare Spectrometer IRIS

Impulsive Phase of the Flare (energy release)

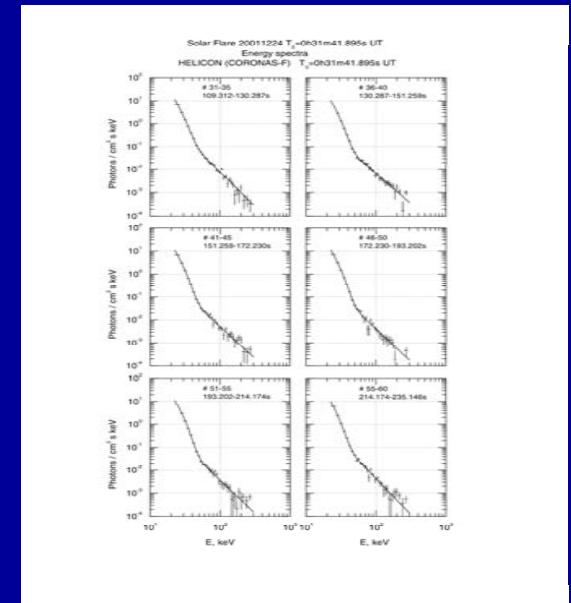


Gamma- Spectrometer HELICON

Impulsive Phase of the Flare



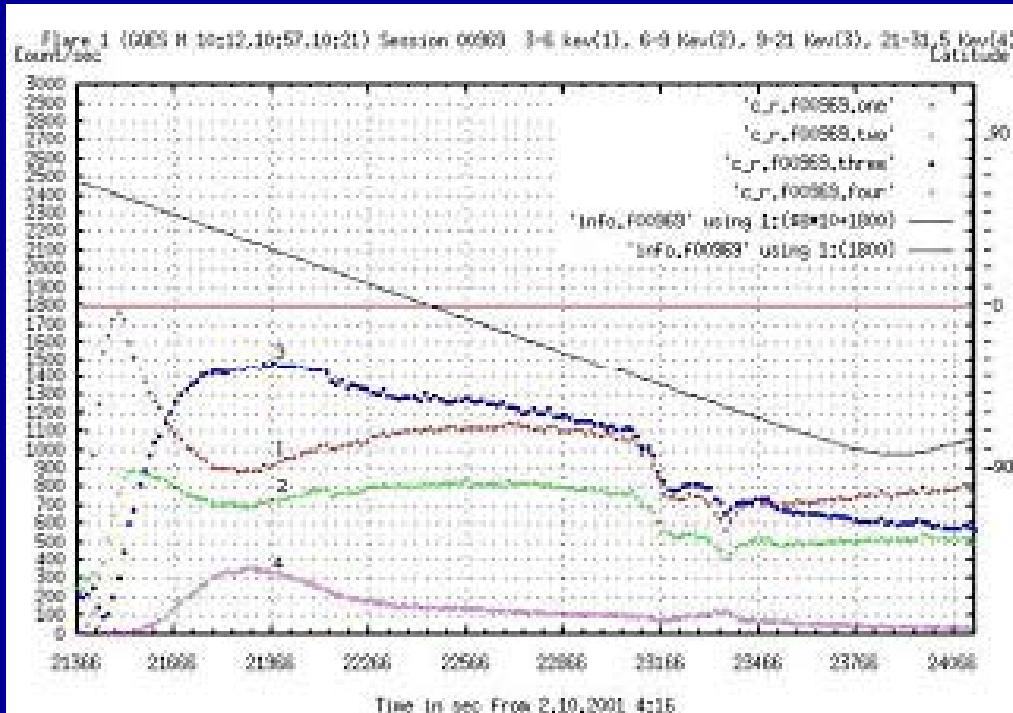
0 -109 сек



109 – 235 сек

Emission time profile in eight energy channels and energy spectra for the major flare of December 24, 2001 (0 h 31 m 41.895 s UT) obtained in different phases of the event.

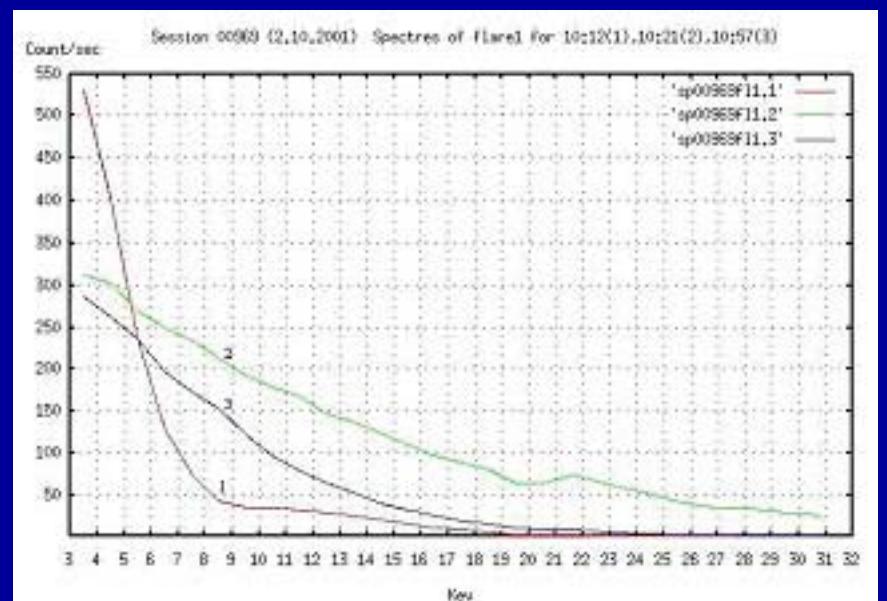
CORONAS-F X-ray Spectrometer RPS-1



Time profiles of
class M flare
(3-30 keV)

Spectra of the class M flare emission

- 1 – the onset of the flare
- 2 - the maximum of the flare
- 3 – the end of the flare

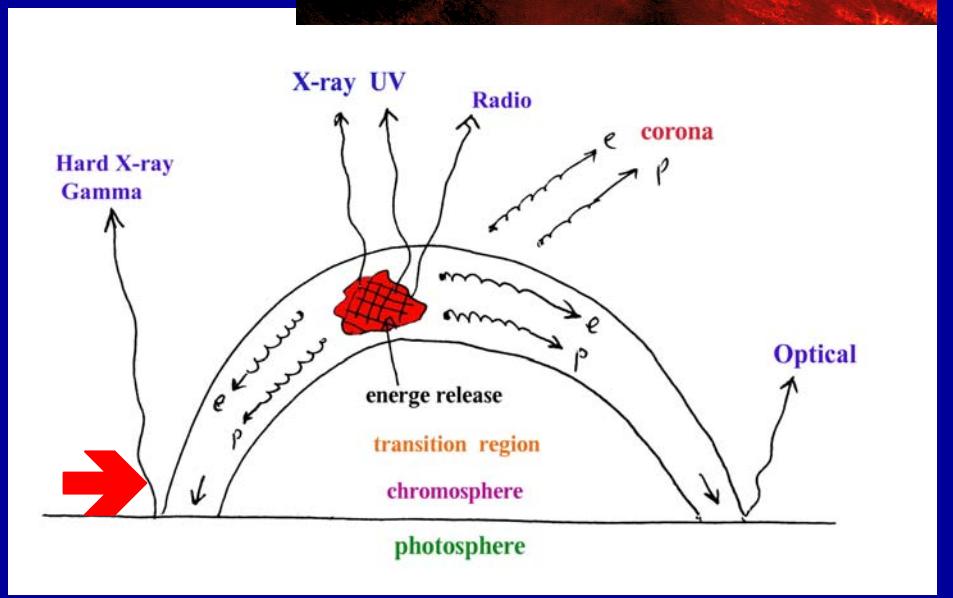
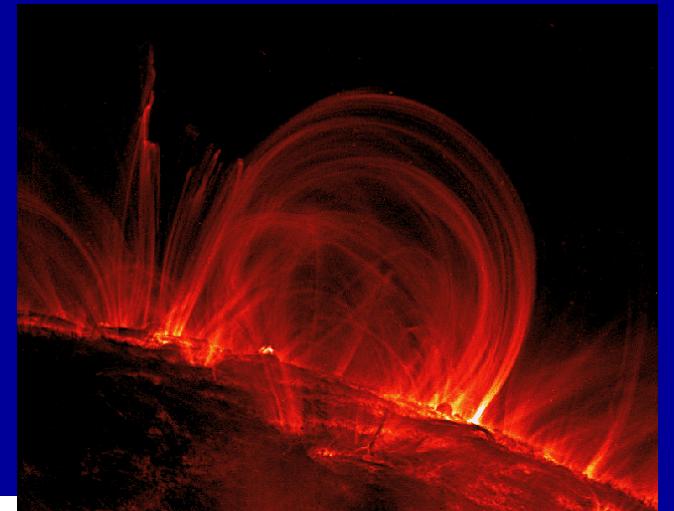
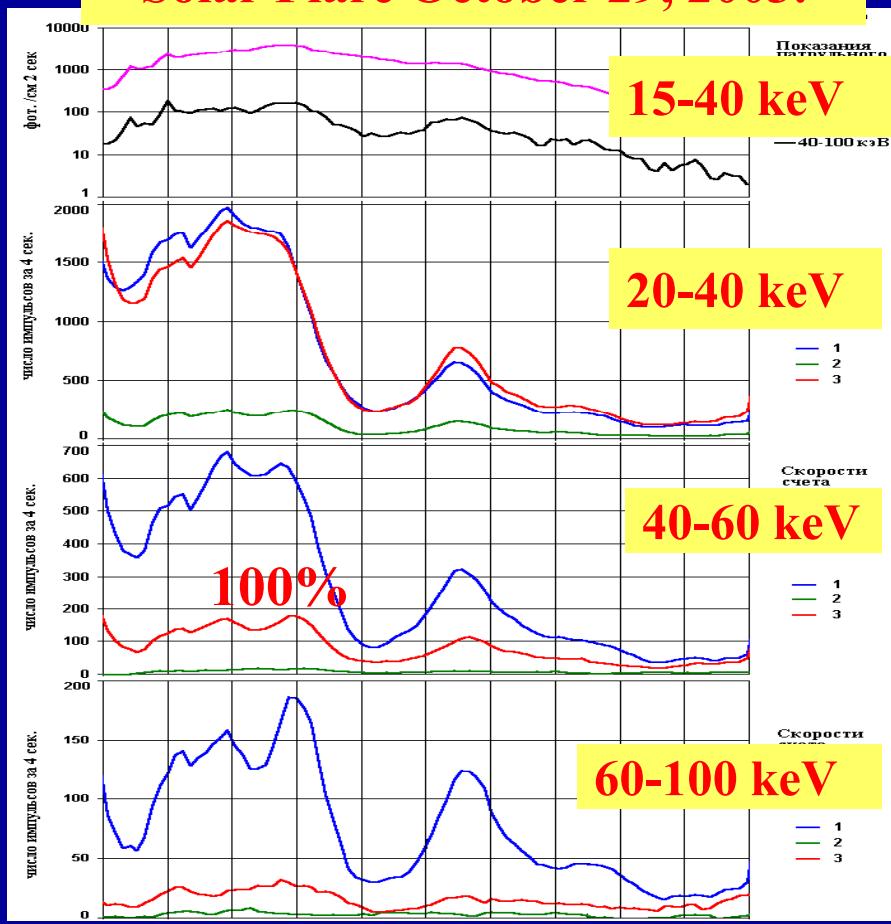




Spectropolarimeter SPR-N

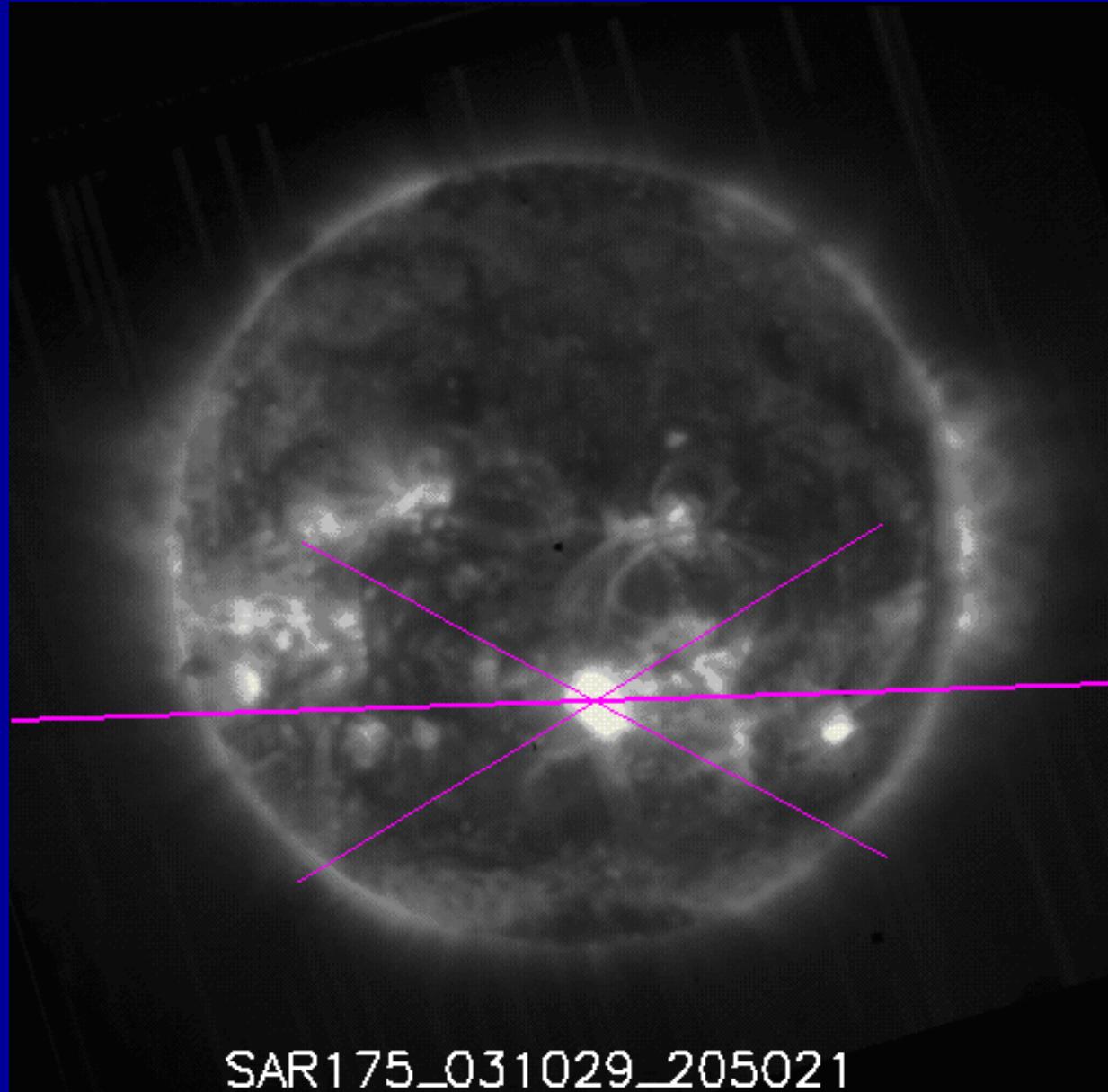
Solar Hard X-Ray Polarization

Solar Flare October 29, 2003.



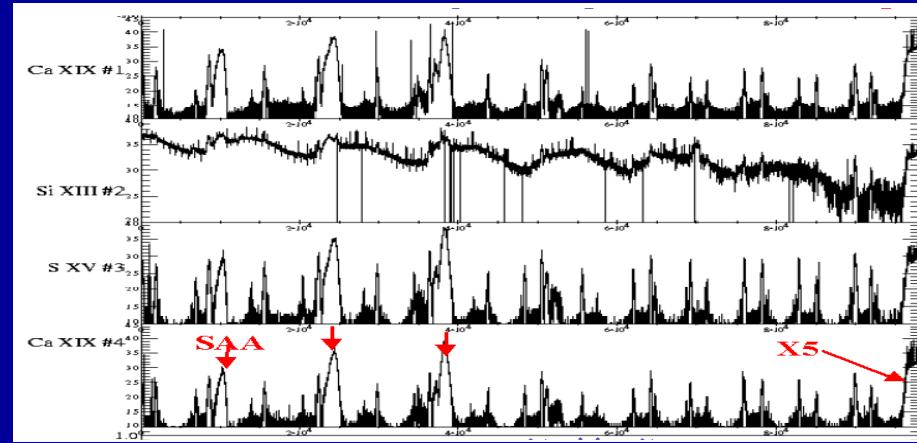
CORONAS-F Solar X-Ray Spectropolarimeter

A Position of the Polarization Plane During the Solar Flare October 29, 2003.

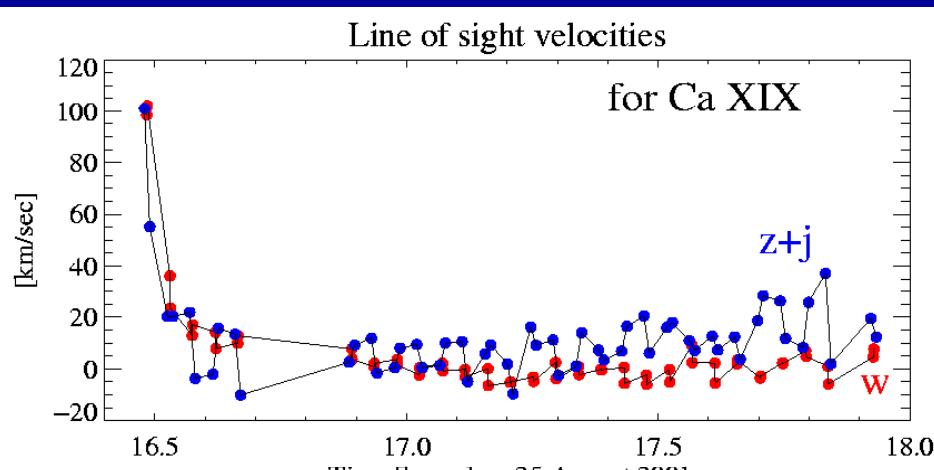


SAR175_031029_205021

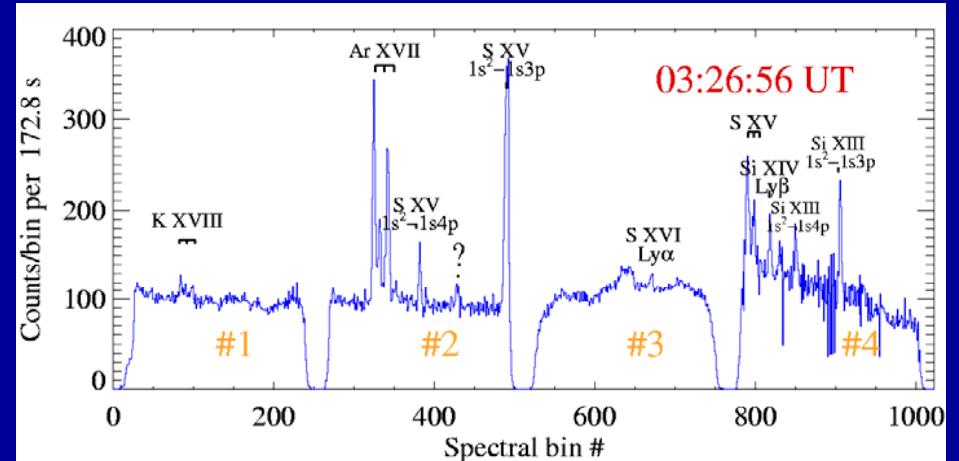
CORONAS-F Spectrometer DIOGENESS and X-ray Spectrometer RESIK



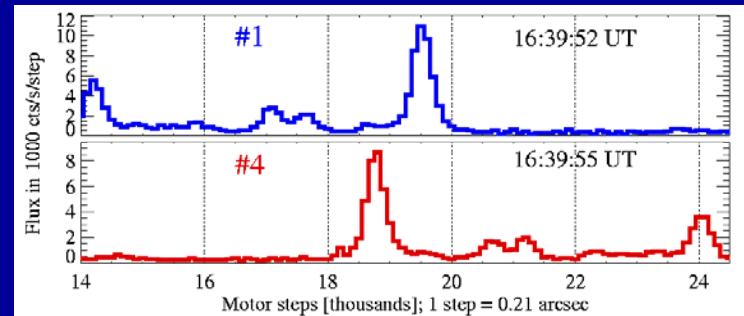
Very intense X5 flare on 25 August 2001 (3÷7Å)



First absolute determinations of the Doppler shifts for X-ray lines formed in hot multimillion degrees solar flare plasmas – detection of fast plasma motions during early phase of 25 August 2001 X5.3 flare

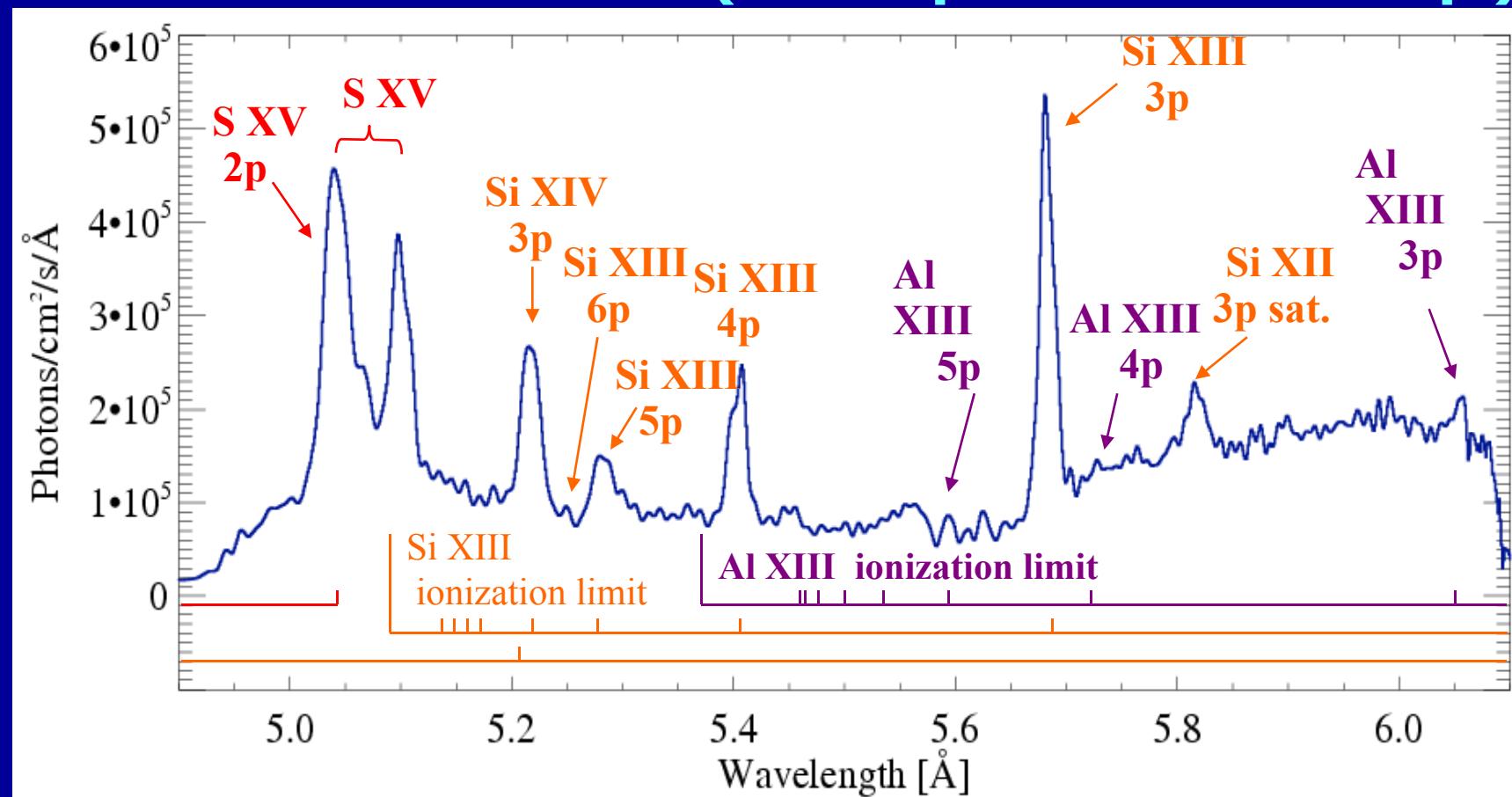


Spectra in the four RESIK channels obtained near the peak of the X1.5 class flare on April 21, 2002.



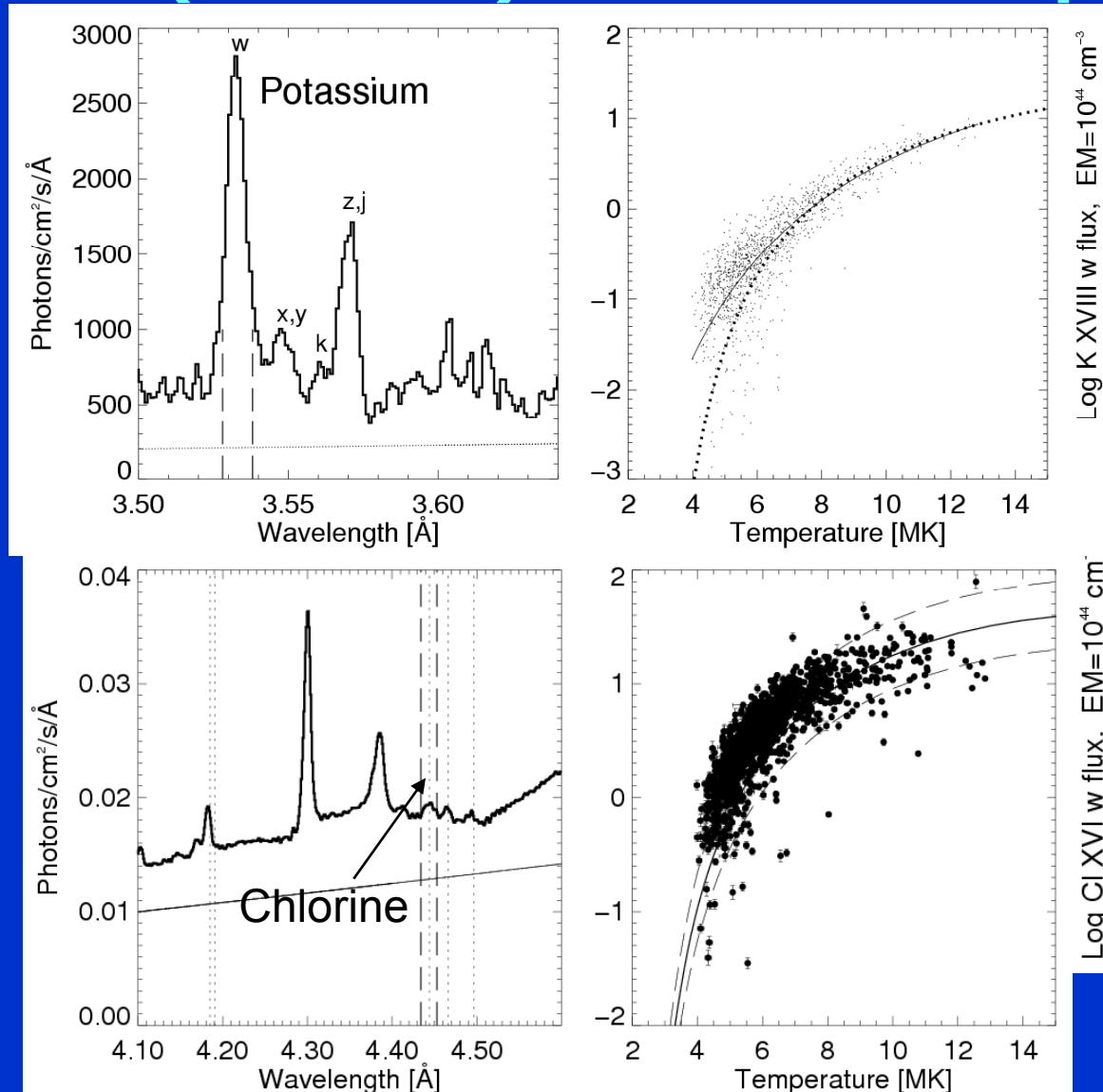
X-Ray Spectrometer RESIK

The S XV triplet and the lines of H-like ions (Si XIV and Al XIII) corresponding to the transitions from $n = 3$ to ionization limit ($1s - np$ and $1s^2 - 1snp$)



X-Ray Spectrometer RESIK

Absolute content of elements K (Potassium) and CL (Chlorine) in solar atmosphere



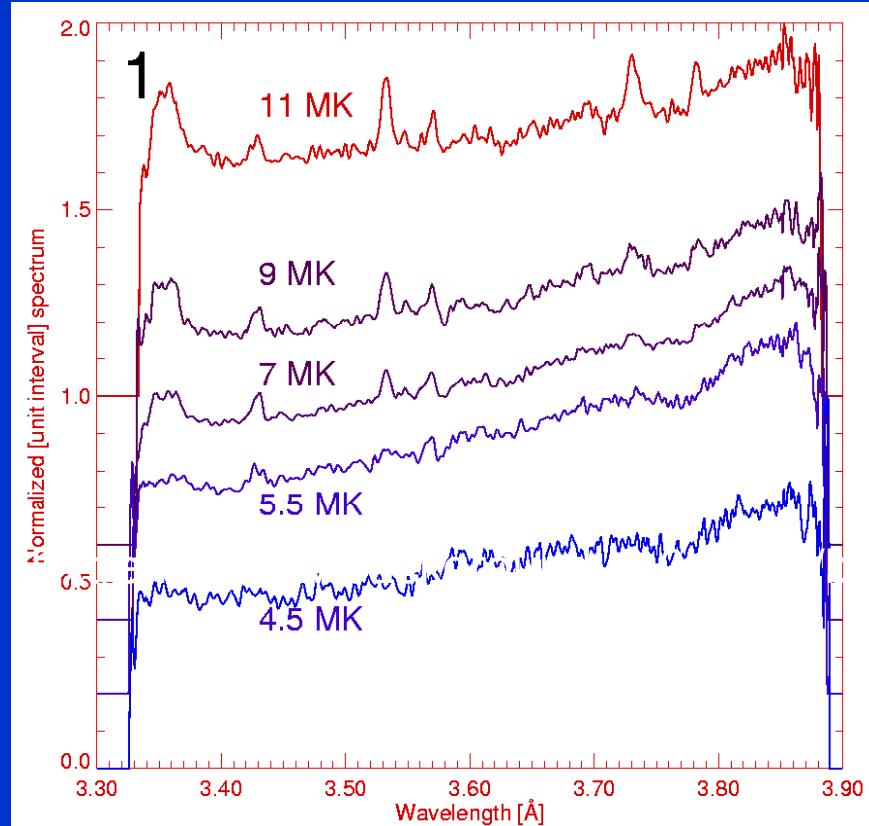
$$A_K = 6 \cdot 10^{-7}$$

$$A_{Cl} = 7.7 \cdot 10^{-7}$$

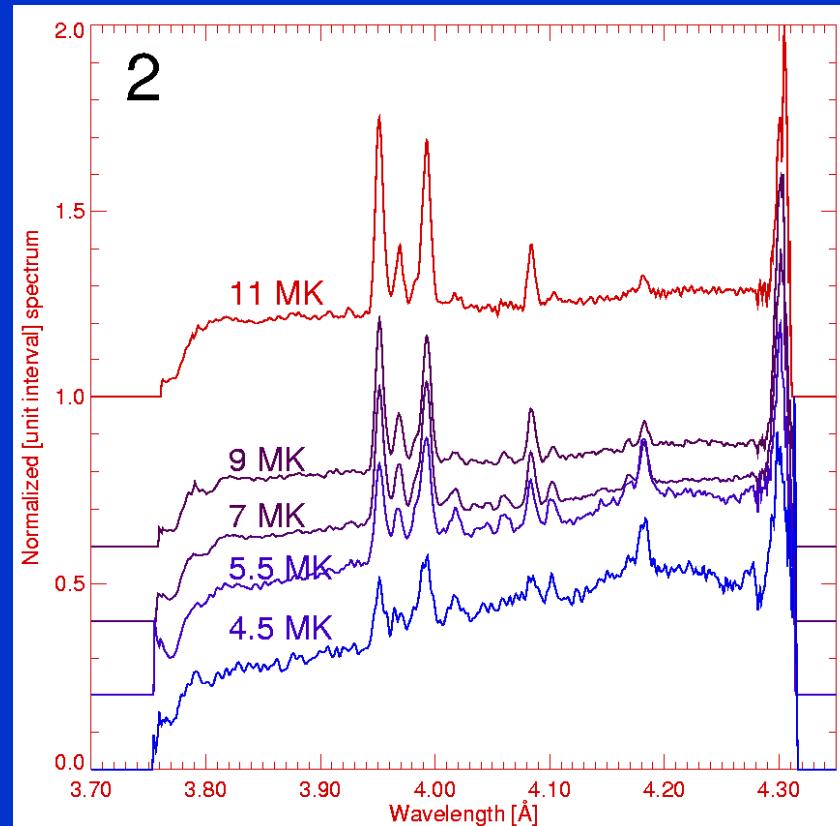
X-Ray Spectrometer RESIK

Dependence of the spectra from the temperature of solar plasma

K (Potassium)

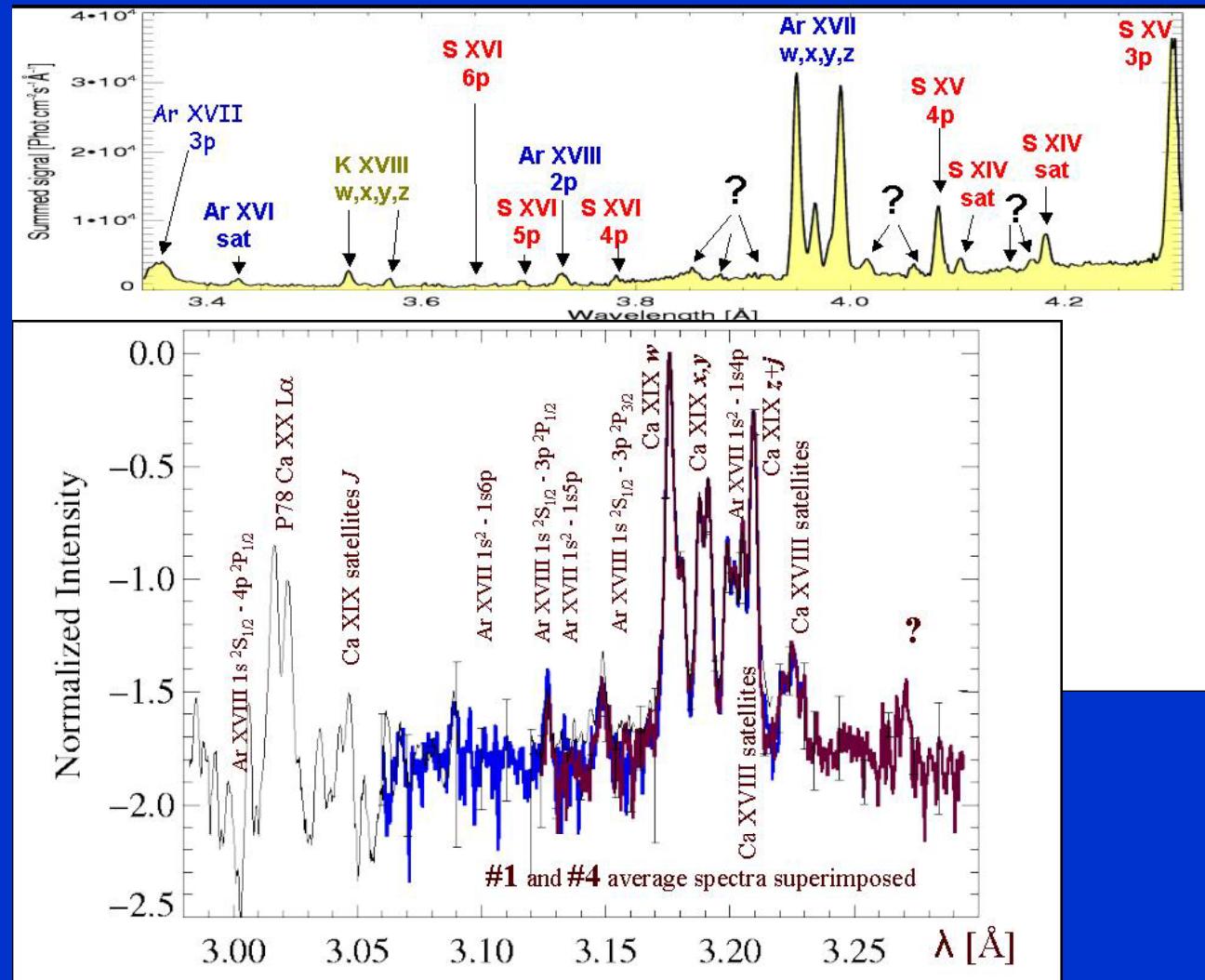


Ar (Argon)

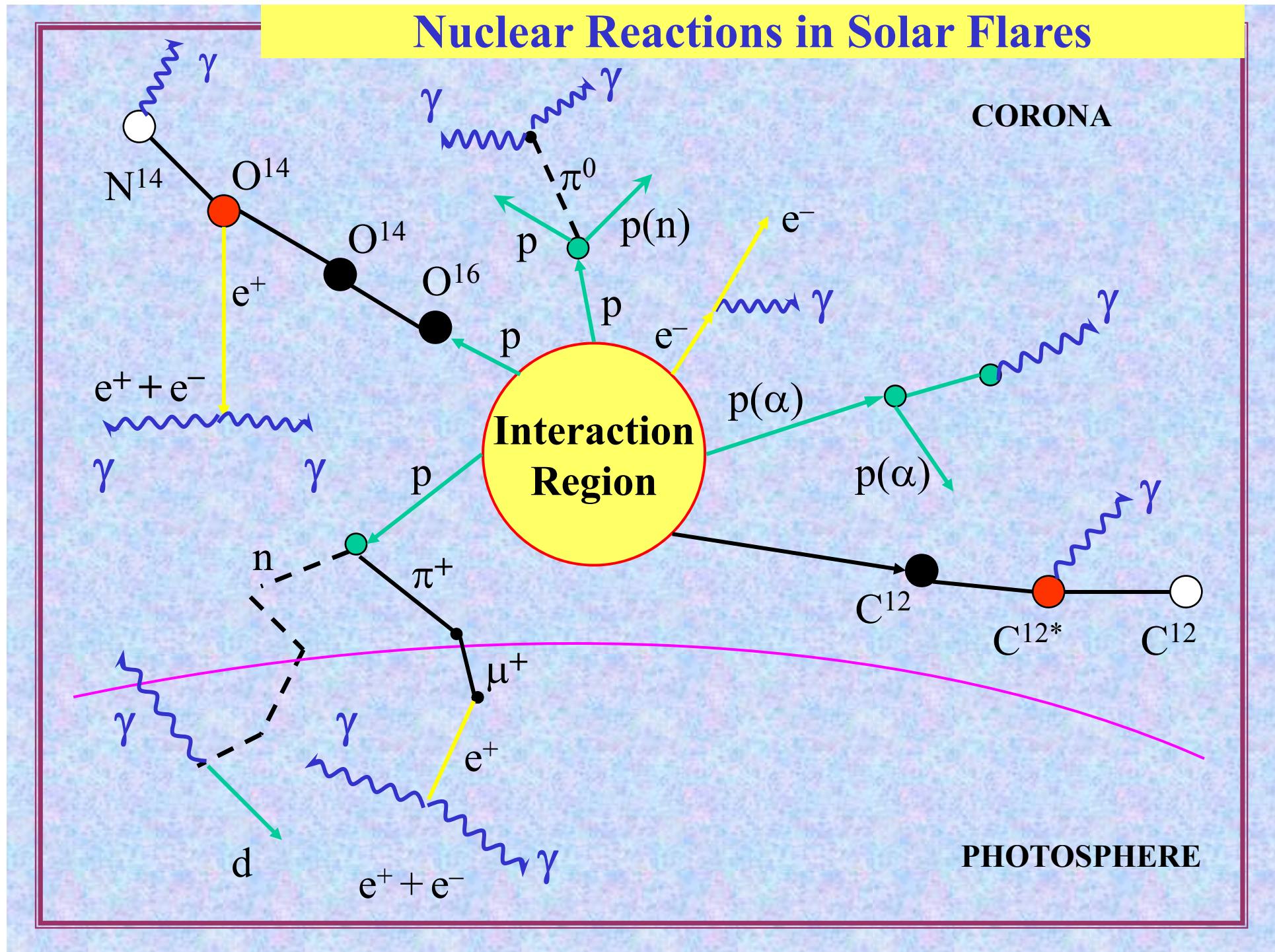


Spectrophotometer DIOGENESS X-Ray Spectrometer RESIK

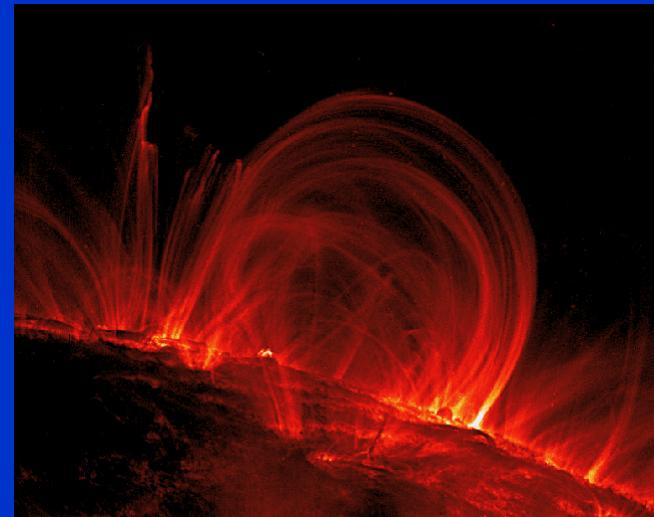
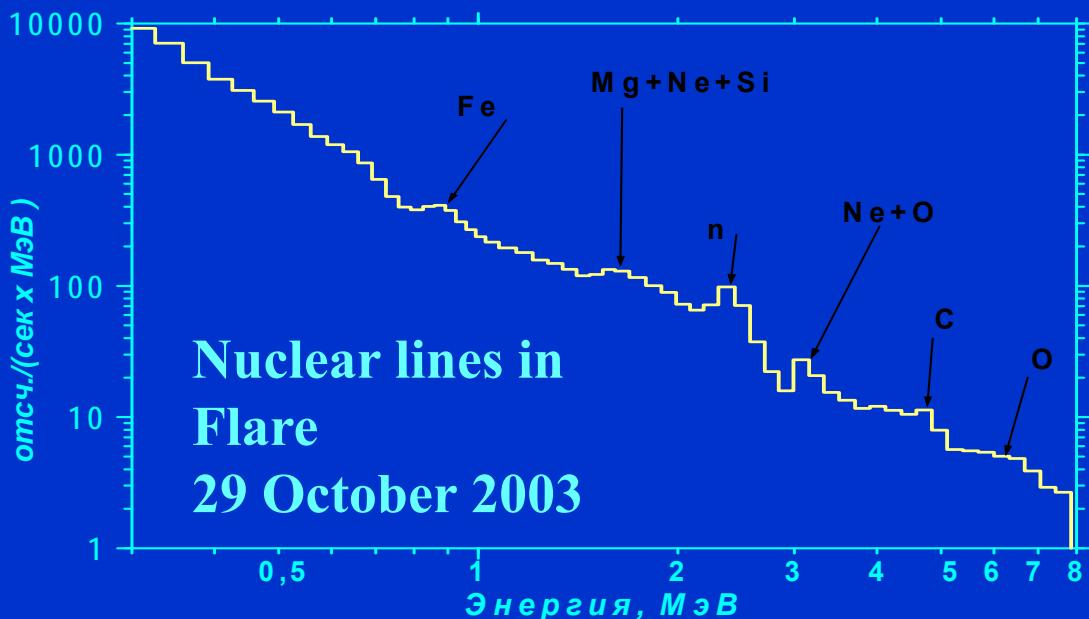
Spectral Atlases (http://www.cbk.pan.wroc.pl/resik_catalogue.htm).



Nuclear Reactions in Solar Flares



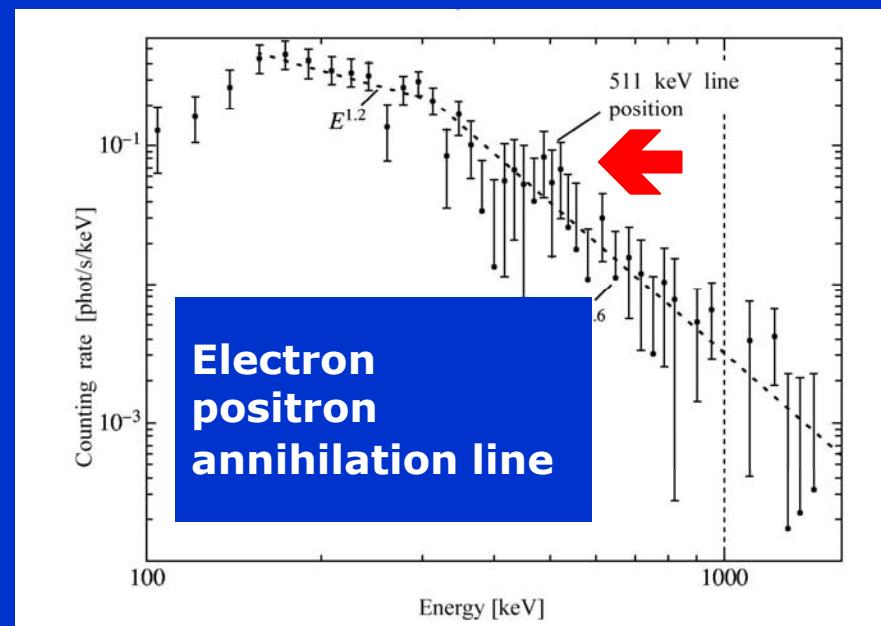
Amplitude-Time Spectrometer Nuclear Processes in Solar Flares



Five complexes of nuclear spectral lines

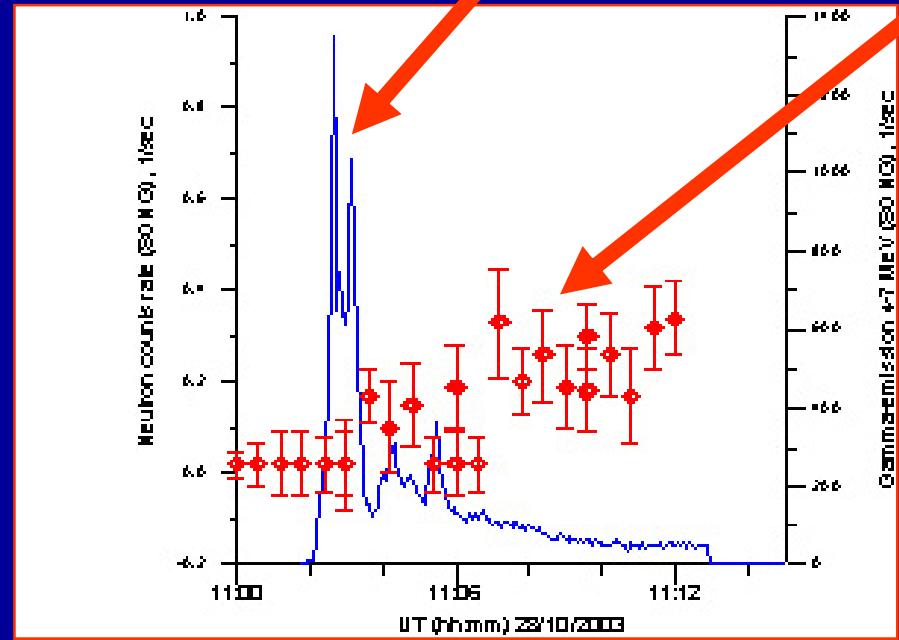
^{56}Fe , $^{24}\text{Mg} + ^{20}\text{Ne} + ^{28}\text{Si}$,
 $^{20}\text{Ne} + ^{16}\text{O}$, ^{12}C , ^{16}O .

Caption neutron line in energy range 2,14-2,64 MeV.



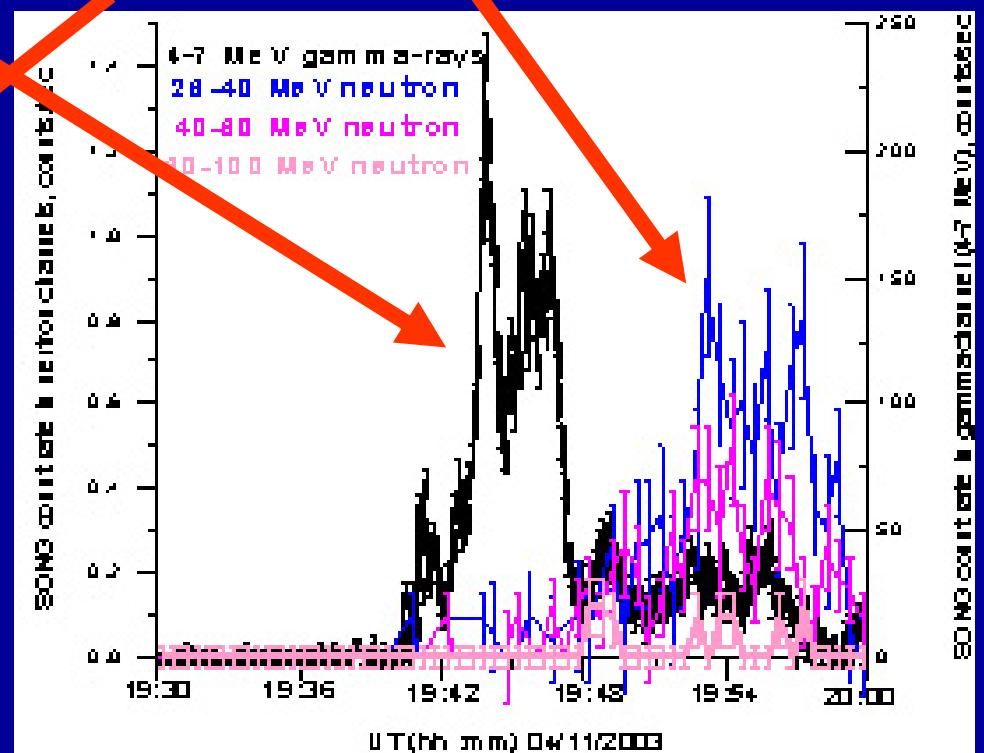
Solar Neutrons and γ -rays Spectrometer SONG

Gamma emission
 $E = 4\text{-}7 \text{ MeV}$



Flare on 28 October 2003

Neutrons
 $200 - 400 \text{ MeV}$

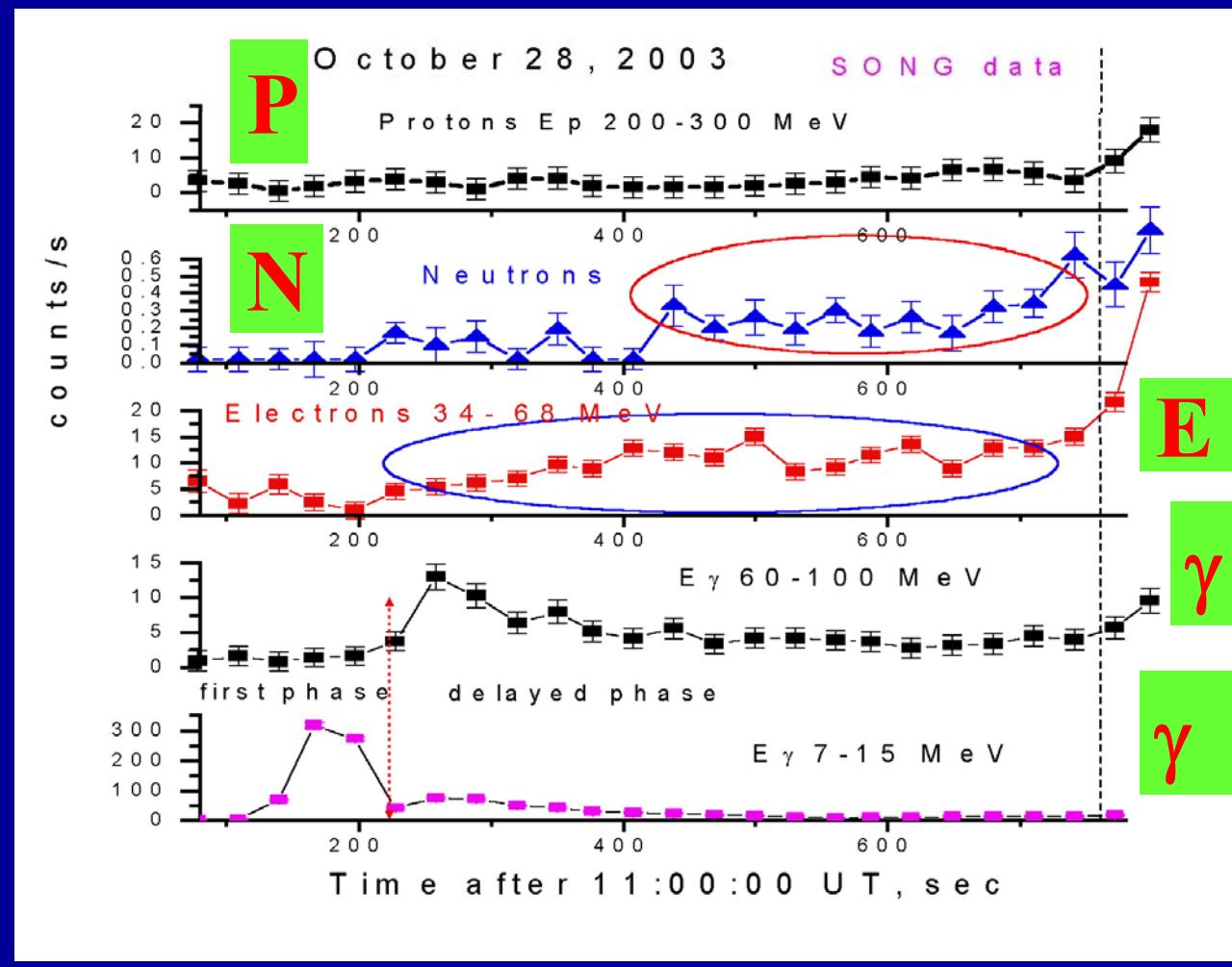


Flare on 4 November 2003

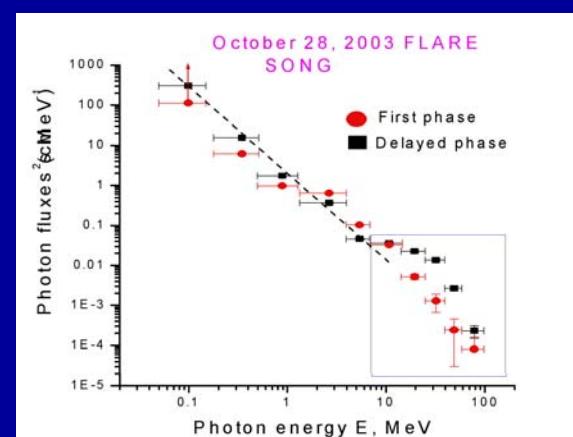
Solar Cosmic Rays

Two Phases of Acceleration. Pion Decay.

SONG Spectrometer

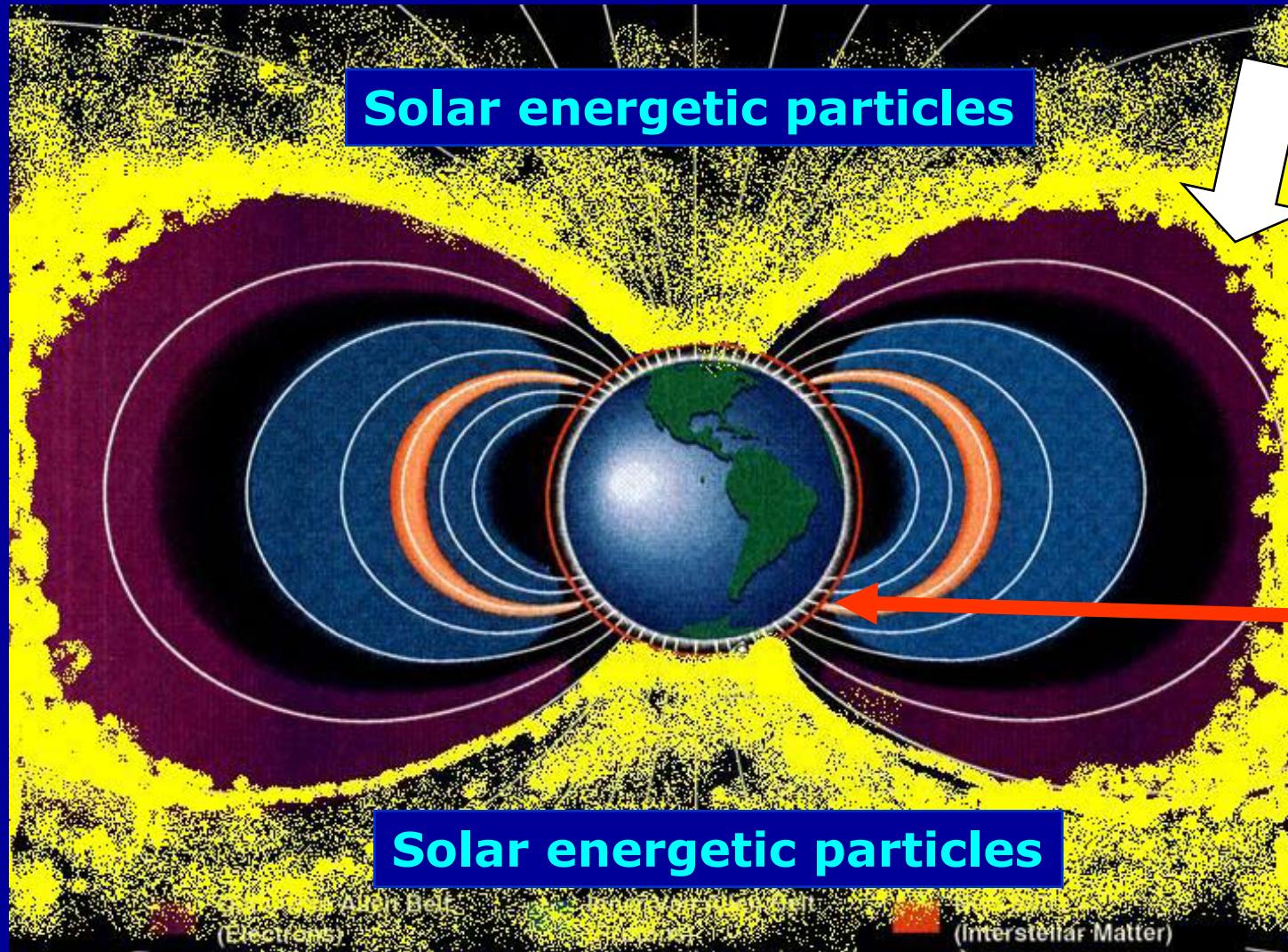


Gamma Rays
Spectra



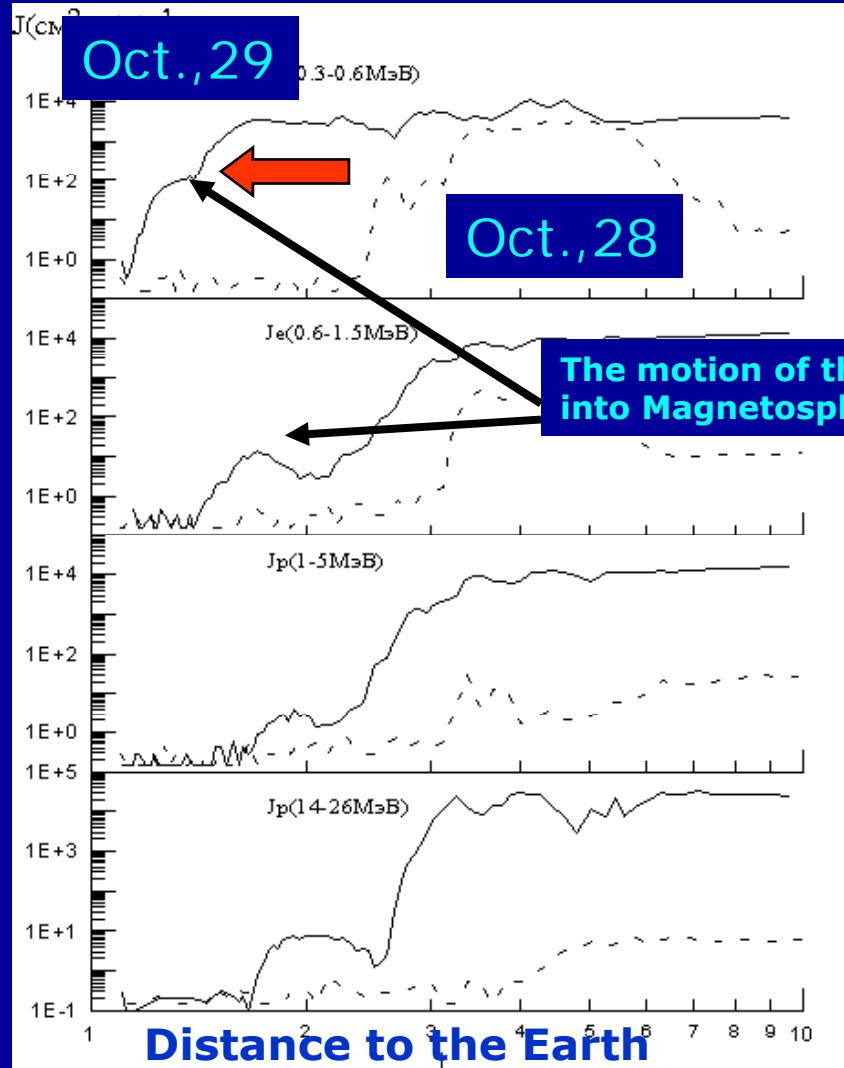
Solar Cosmic Rays

Solar Energetic Particle Penetration into Magnetosphere

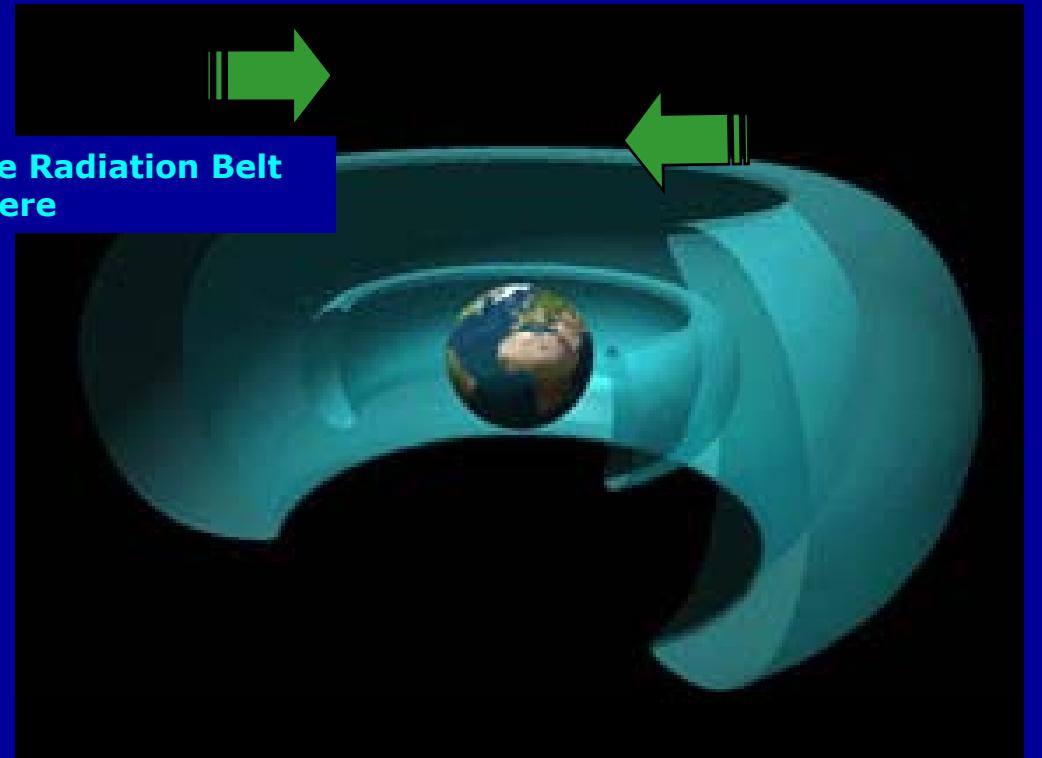


Solar Cosmic Rays

Radiation environment in near Earth Space



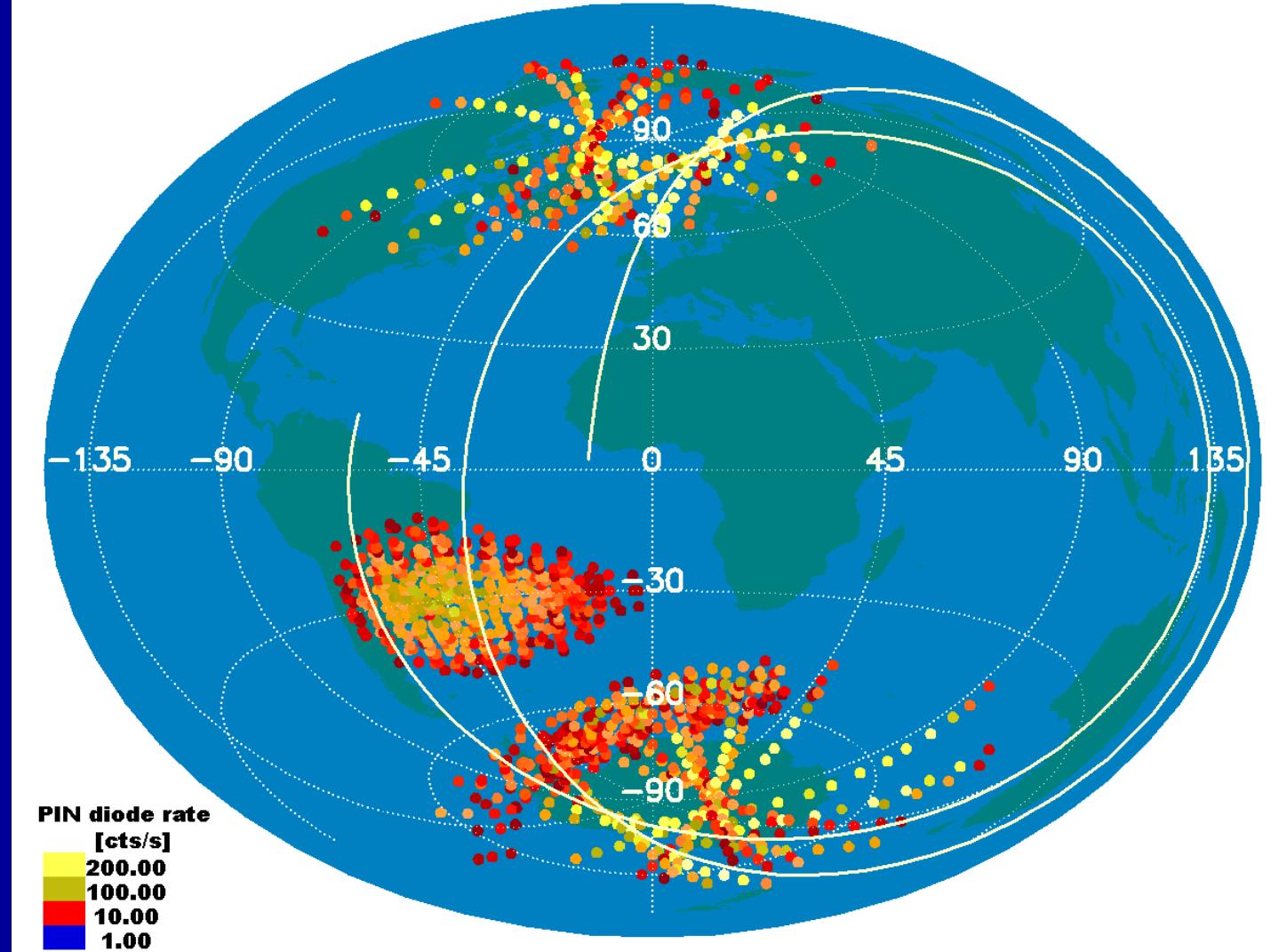
Electron Radiation Belts



X-Ray Spectrometer RESIK

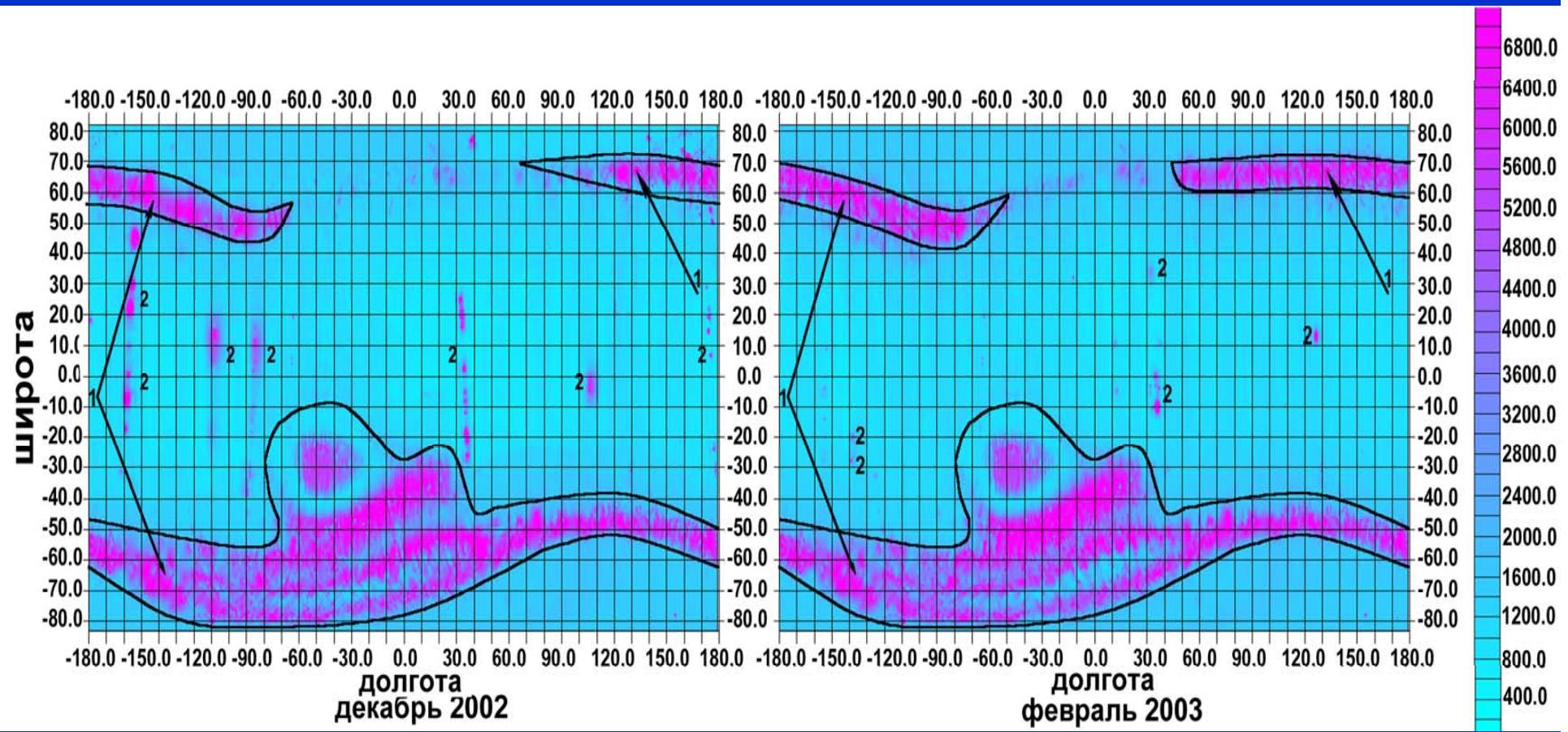
The map of the background radiation distribution (protons E > 1.5 Mev)

2002/04/01 - 2002/05/01



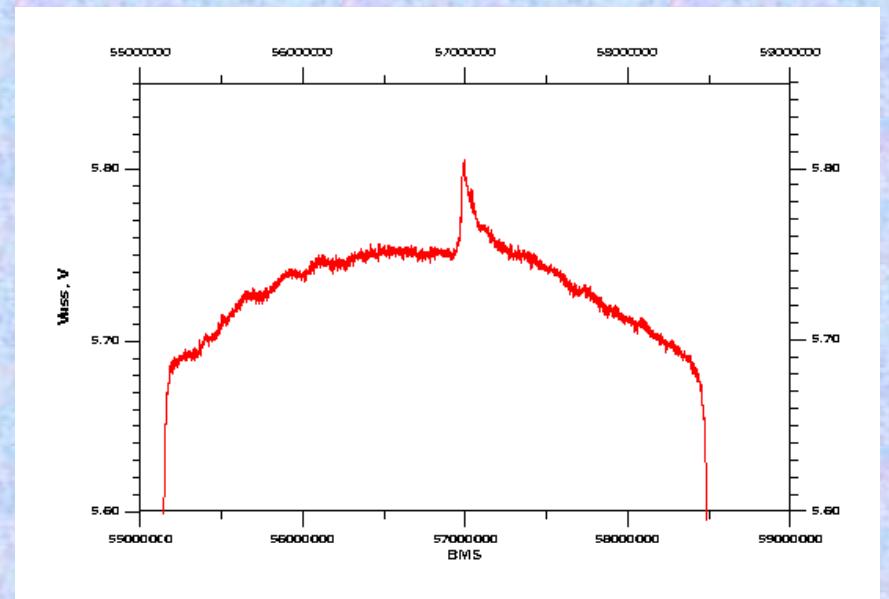
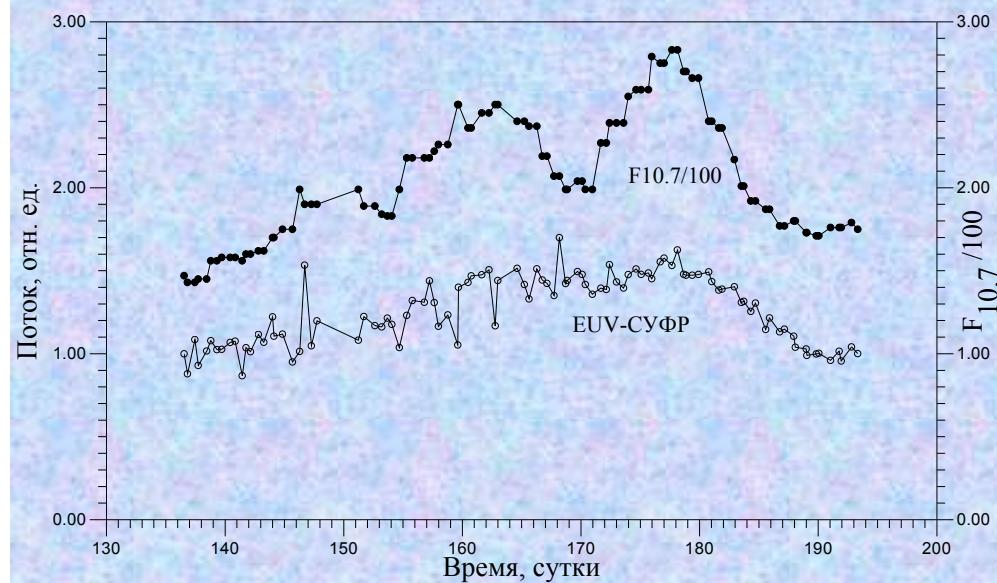
Amplitude-Time Spectrometer (0.1÷11 MeV)

The maps of quasi-stationary precipitations of energetic particles from the magnetosphere into ionosphere



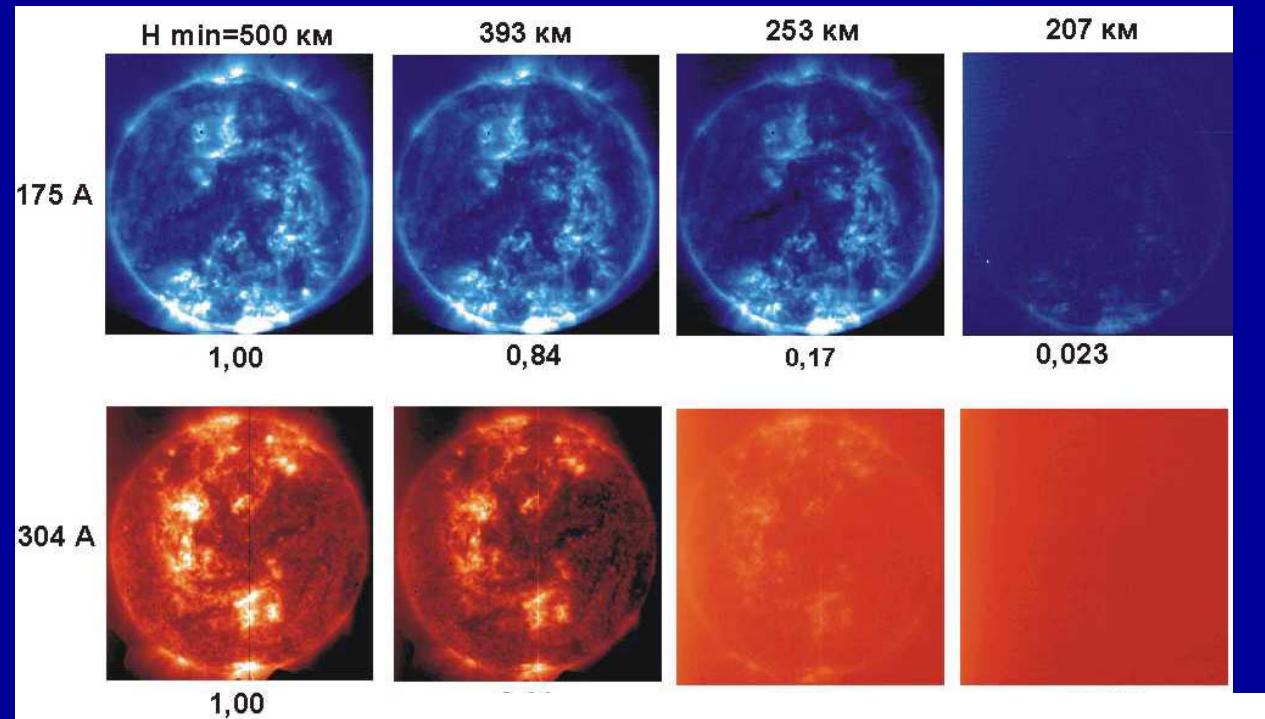
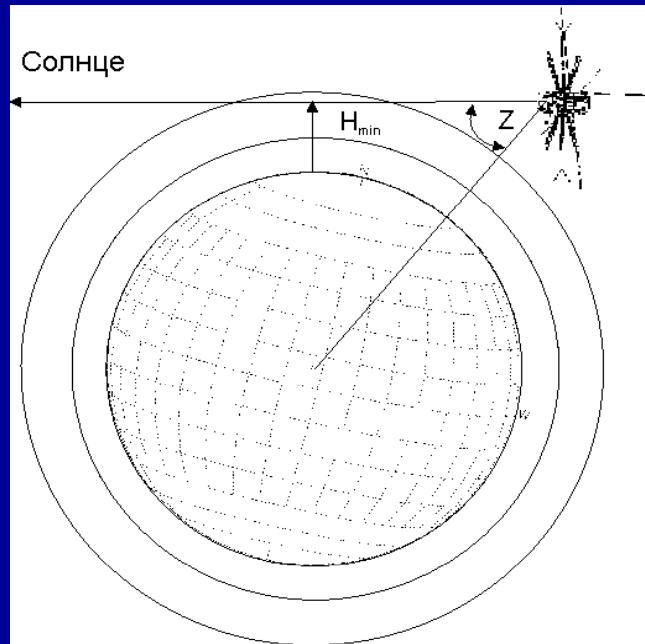
Solar UV Radiometer (SUFR-sp-k) (10÷1300 Å) Solar UV Spectrophotometer (VUSS-L) (1200 Å)

Solar Flare 21.01.2003

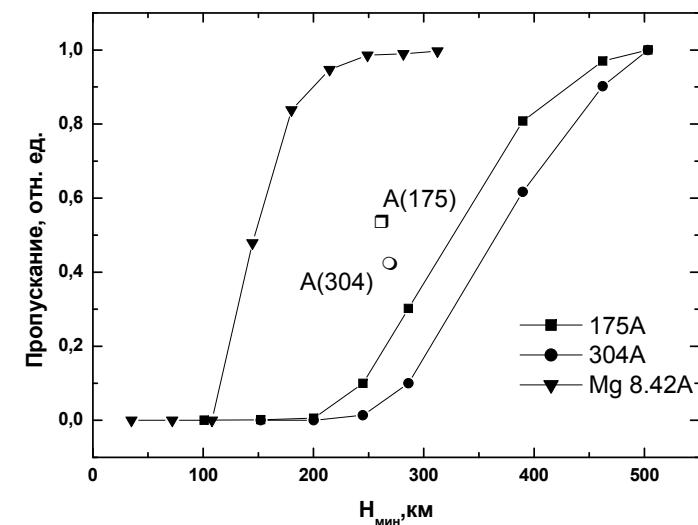


UV/Radio Flux Correlation

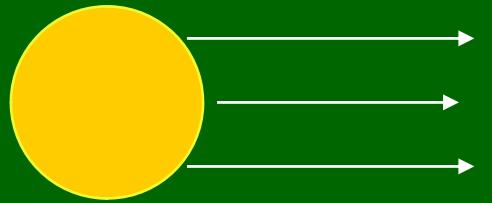
Solar Terrestrial Relations



**X-Ray transparency
of the Earth
atmosphere**



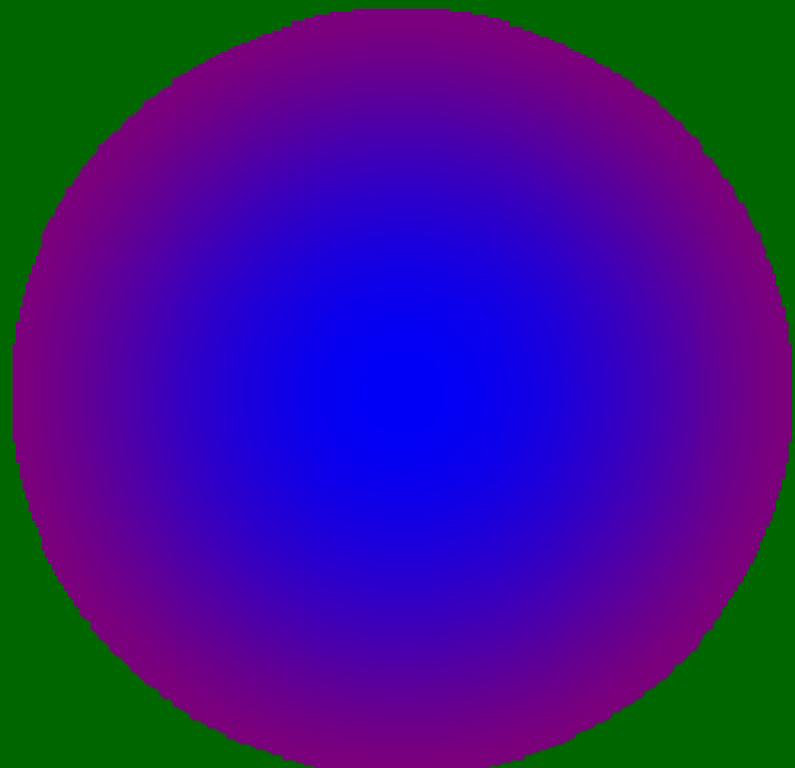
Spectrophotomer DIFOS Global Oscillations of the Sun



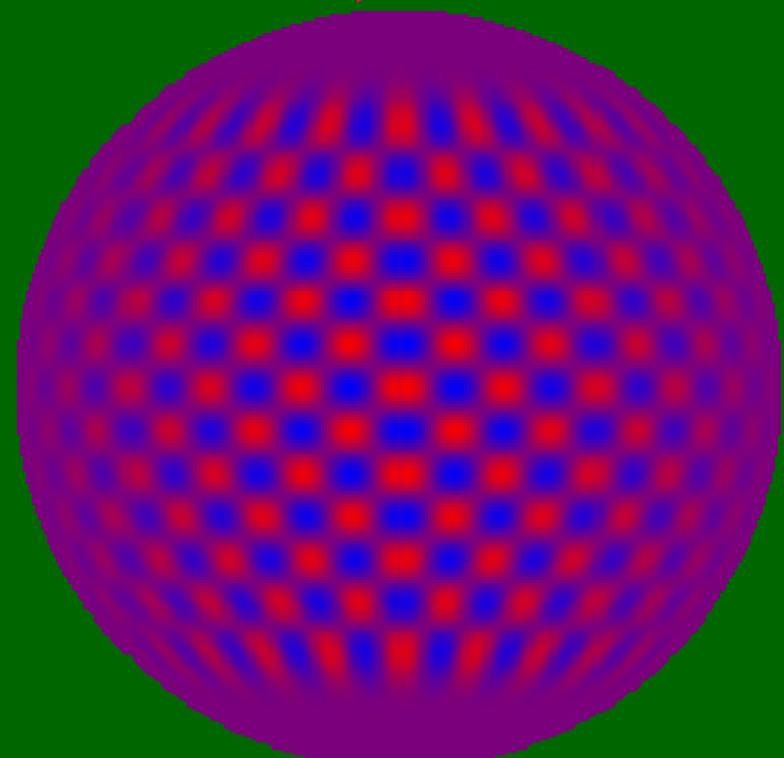
$\lambda = 400 \div 1600 \text{ nm}$



$l = 1, m = 1$

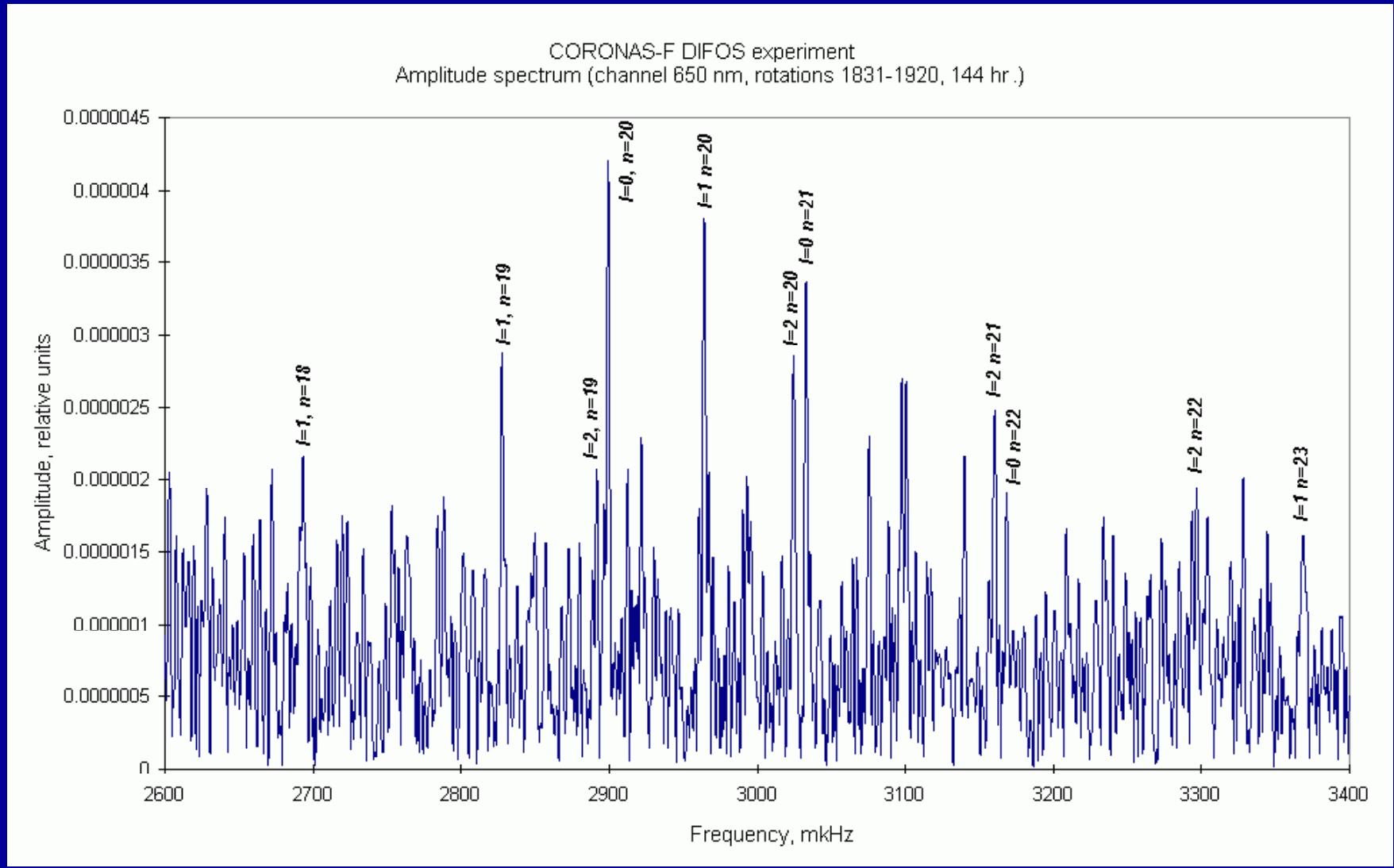


$l = 36, m = 24$

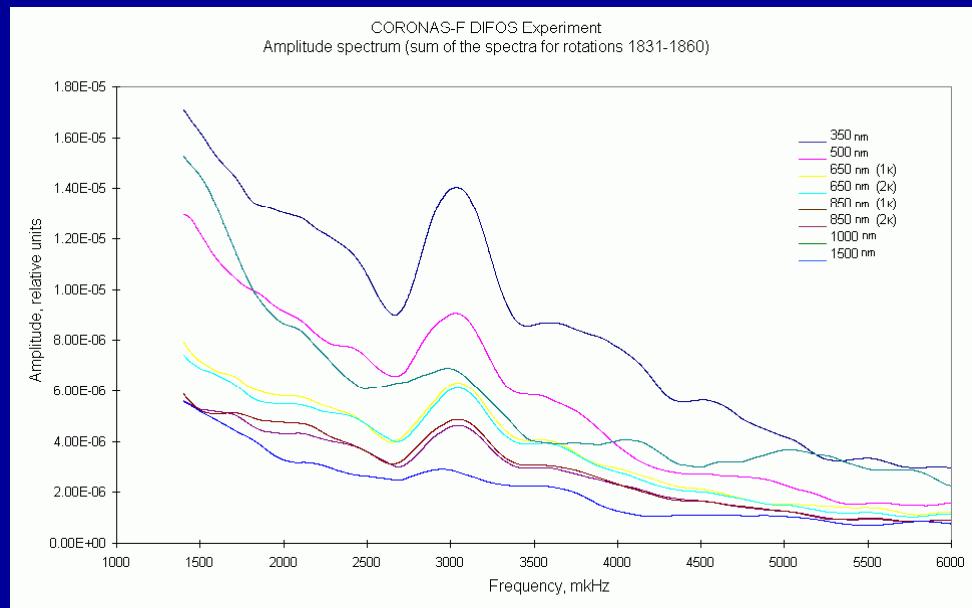


DIFOS Experiment

Amplitude spectrum of p-modes (400-1600 nm)

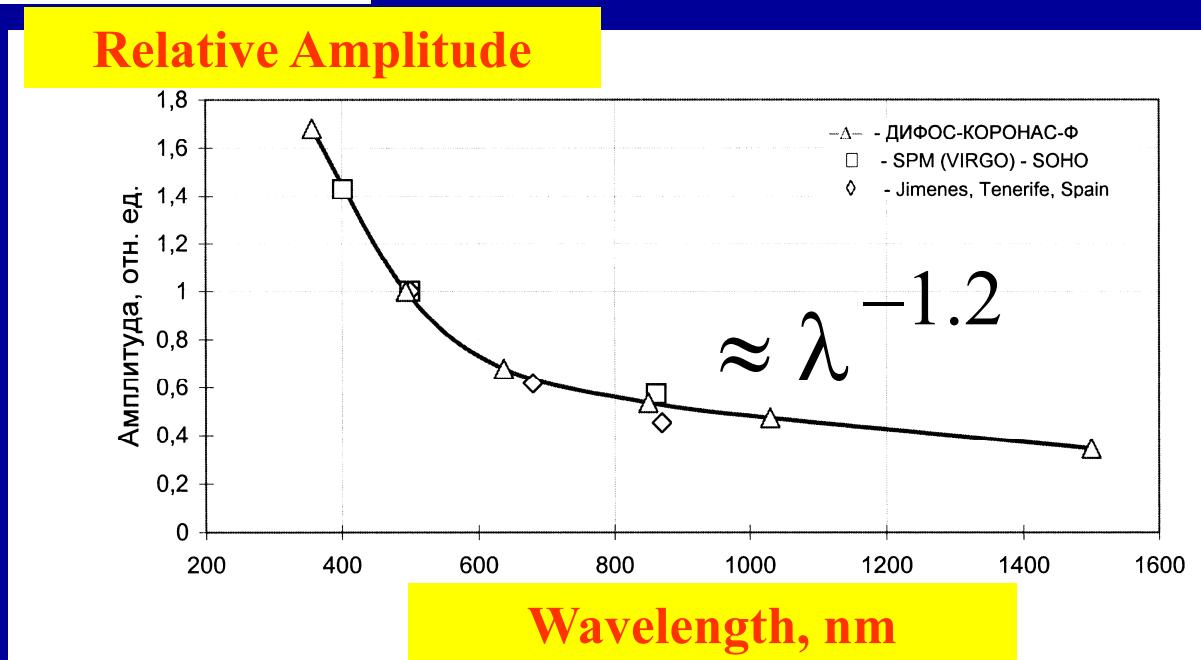


DIFOS Experiment

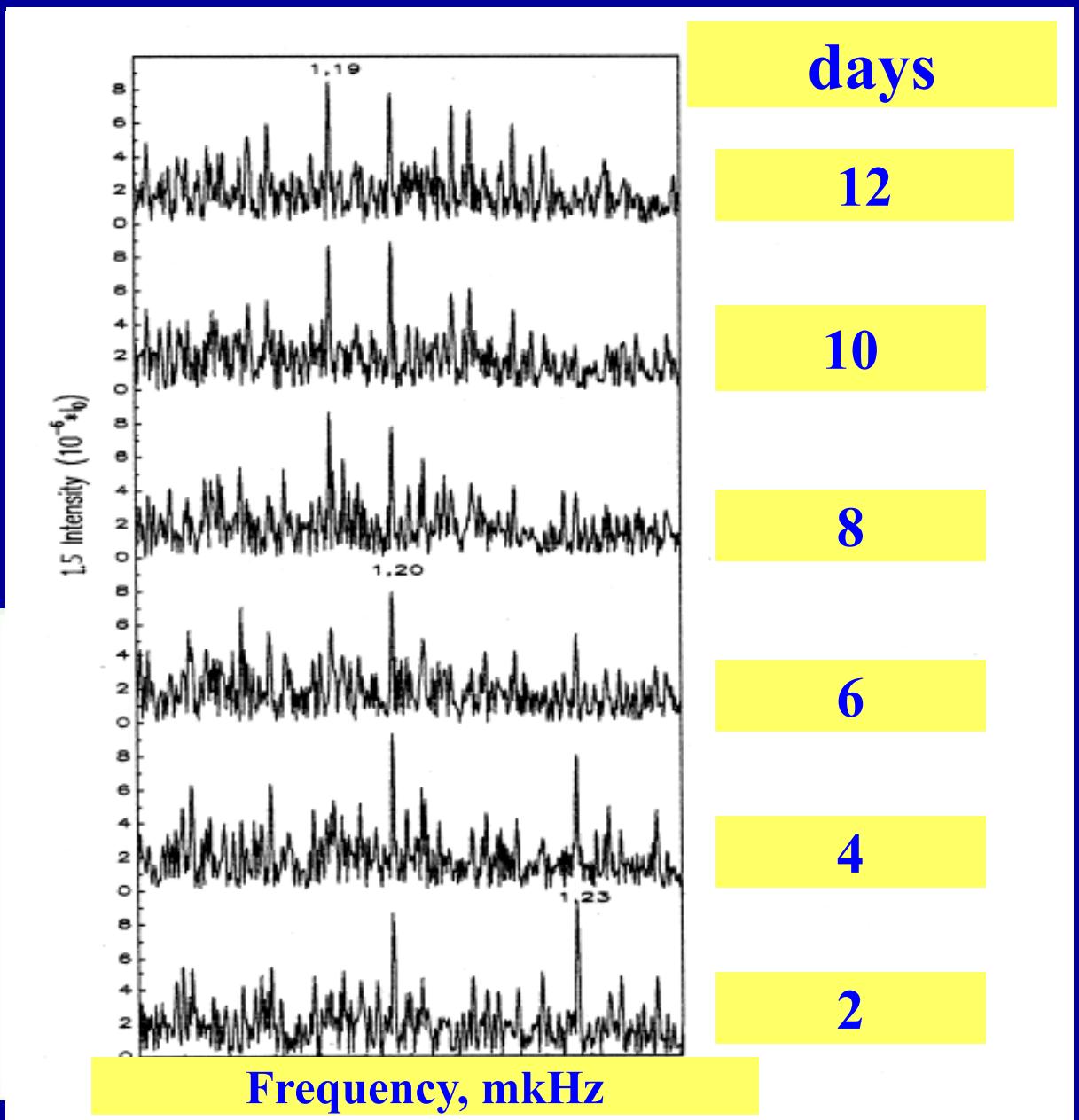
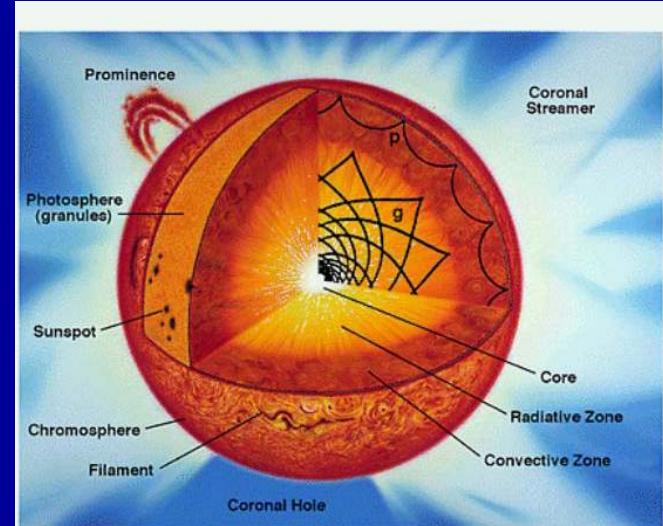
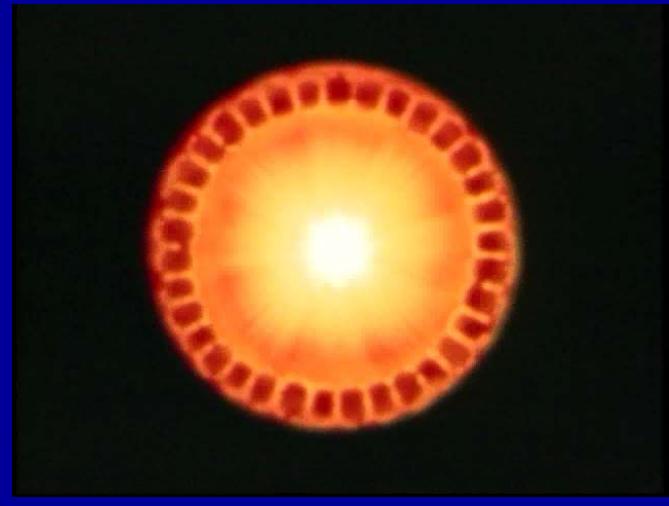


Amplitude of global oscillations in different spectral channels

Amplitude of global oscillations versus wavelength of observations

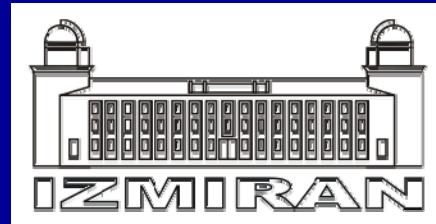


P-mod Dynamics of Global Oscillations of the Sun





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