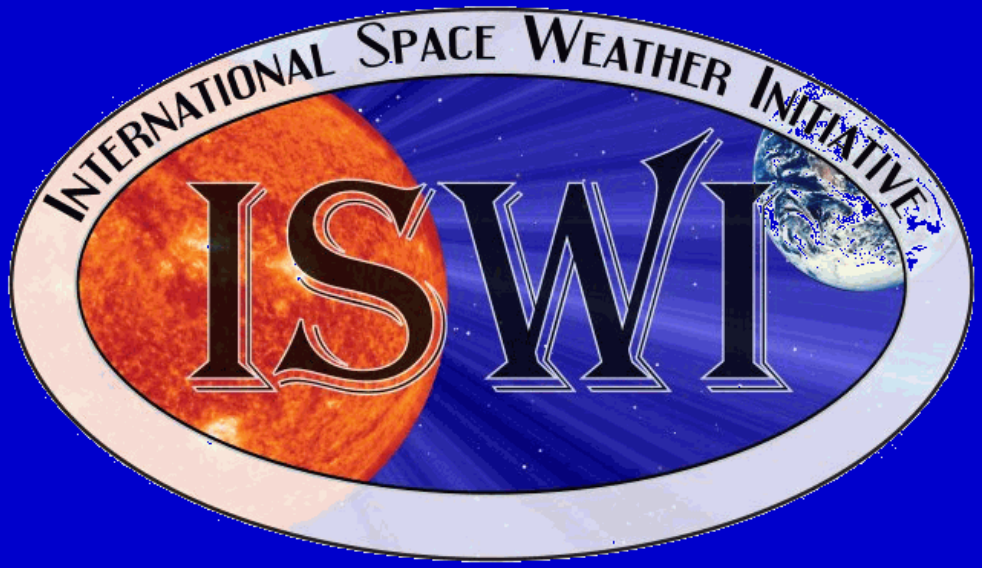
International Space Weather Initiative (ISWI) in Slovakia and Related ISWI Activities



I. Dorotovič, National ISWI Coordinator

Slovak Central Observatory P. O. Box 42
SK-94701 Hurbanovo, Slovak Republic
ivan.dorotovic@suh.sk

Solar and space weather research in Slovakia :

Astronomical Institute, Slovak Academy of Sciences - AISAS, Tatranská Lomnica, Department of Solar Physics: (www.astro.sk)

- coronal station at Lomnický Štít for systematic observation of coronal emission lines and prominences,
- investigation of solar activity cycles, structure and dynamics of the solar atmosphere, solar flare activity research, rotation of the solar corona,
- observation of the corona during total solar eclipses.

Institute of Experimental Physics, Slovak Academy of Sciences - IEPSAS, Košice , Department of Space Research: (space.saske.sk)

- Neutron Monitor at Lomnický Štít, cosmic radiation research,
- participation in various space programs: Active, CORONAS-F, Interball (Russian satellites); satellite TC2 (energetic neutral atom measurements), Venus Express magnetometer; future missions: BepiColombo (ESA), RadioAstron (Russia), project JEM-EUSO.

Centre of Space Research: Space Weather Influences

AI SAS, T. Lomnica (main institution) + IEP SAS and P.J. Šafárik University, both in Košice (participating institutions).

Geophysical Institute, Slovak Academy of Sciences, Bratislava (gpi.savba.sk/)
and **Geomagnetic Observatory** (GPI SAS) Hurbanovo (www.geomag.sk)

- solar-terrestrial connections and Earth's magnetosphere and climate
- solar proton events and geomagnetic activity
- forecats of geomagnetic activity based on space weather phenomena (flares, CMEs, SPEs) using artificial neural networks.

Faculty of Mathematics, Physics and Informatics, Comenius University, Bratislava → Division of Astronomy and Astrophysics : (www.daa.fmph.uniba.sk/department)

- solar flare and active region research, solar EUV and SXR spectroscopy;

→ Division of Physics of the Earth: (www.earthphysics.sk/)

- Earth's magnetic field
- interaction of different materials with cosmic rays
- upper atmosphere response to the solar proton events.

BMP (BIOMET), Bratislava (www.biopocasie.sk)

- medical-meteorological forecast = numerical information of the health risk level.for meteosensitive persons.
- new product (2010): individual bio-meteorological forecast which characterizes better symptoms of weather influence on individuals.

Slovak Central Observatory, Hurbanovo (Department of Solar Physics) (www.suh.sk)

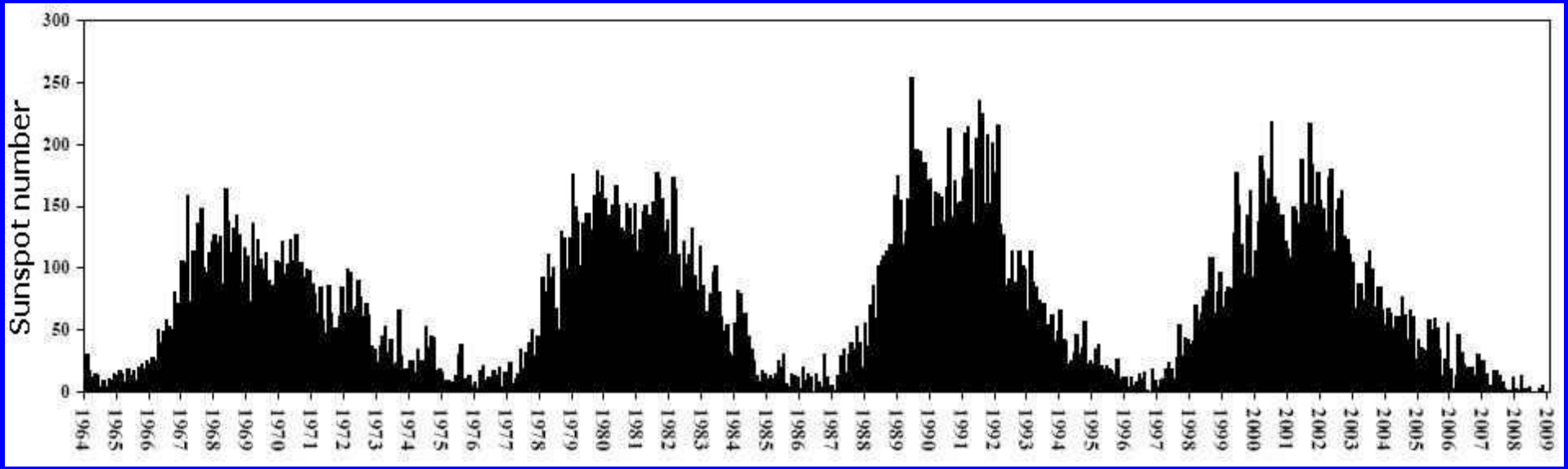
- observation of sunspots, flares, and prominences,
- investigation of solar activity cycles,
- fine structures and oscillations in the solar atmosphere,
- space weather research,CME statistics in the solar cycle 23, cosmic radiation
- observation of the corona during total solar eclipses.

Rimavská Sobota Astronomical Observatory (http://www.astrors.sk/)

• observational program:

- photographic observations of the solar photosphere (full disc and the sunspot details) and prominences.

Basic daily patrol observations of sunspots are currently carried out in a **network of 18 observatories and individual observers**.
National centre for sunspot observations
-Astronomical Observatory and Planetarium Prešov.



Sunspot numbers observed in Slovakia (1964 – 2008, 44 years with 106 971 individual observations.

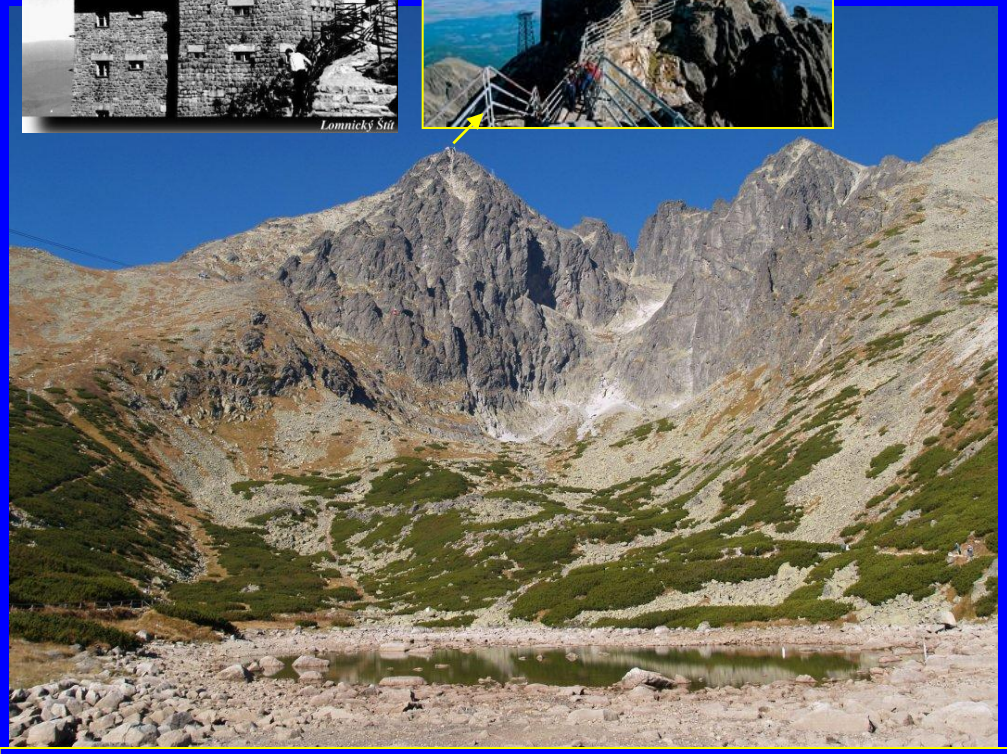
-Solar observations are performed also by members of **Slovak Union of Amateur astronomers - SUAA**

Astronomical Institute, Slovak Academy of Sciences, Tatranská Lomnica

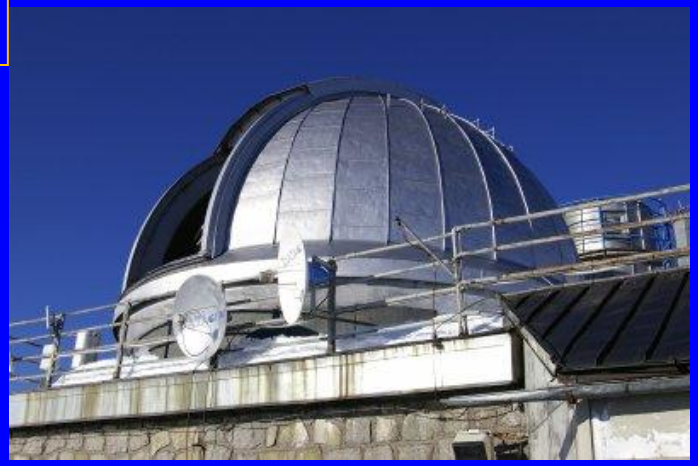
Lomnický Štít Observatory :

AI SAS

http://www.astro.sk/l3.php?p3=lso



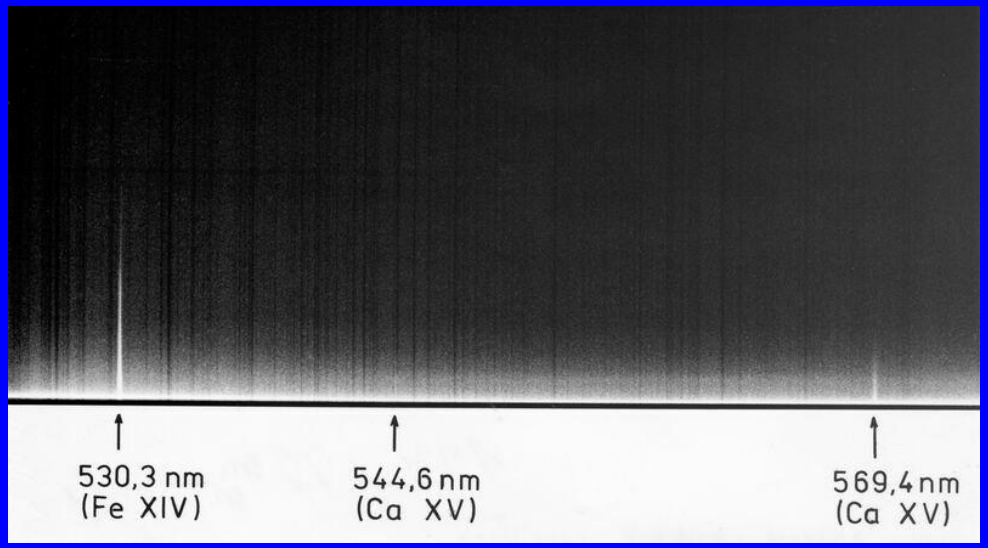
Coronal station on the Lomnicky peak was constructed in the years 1957-1962.



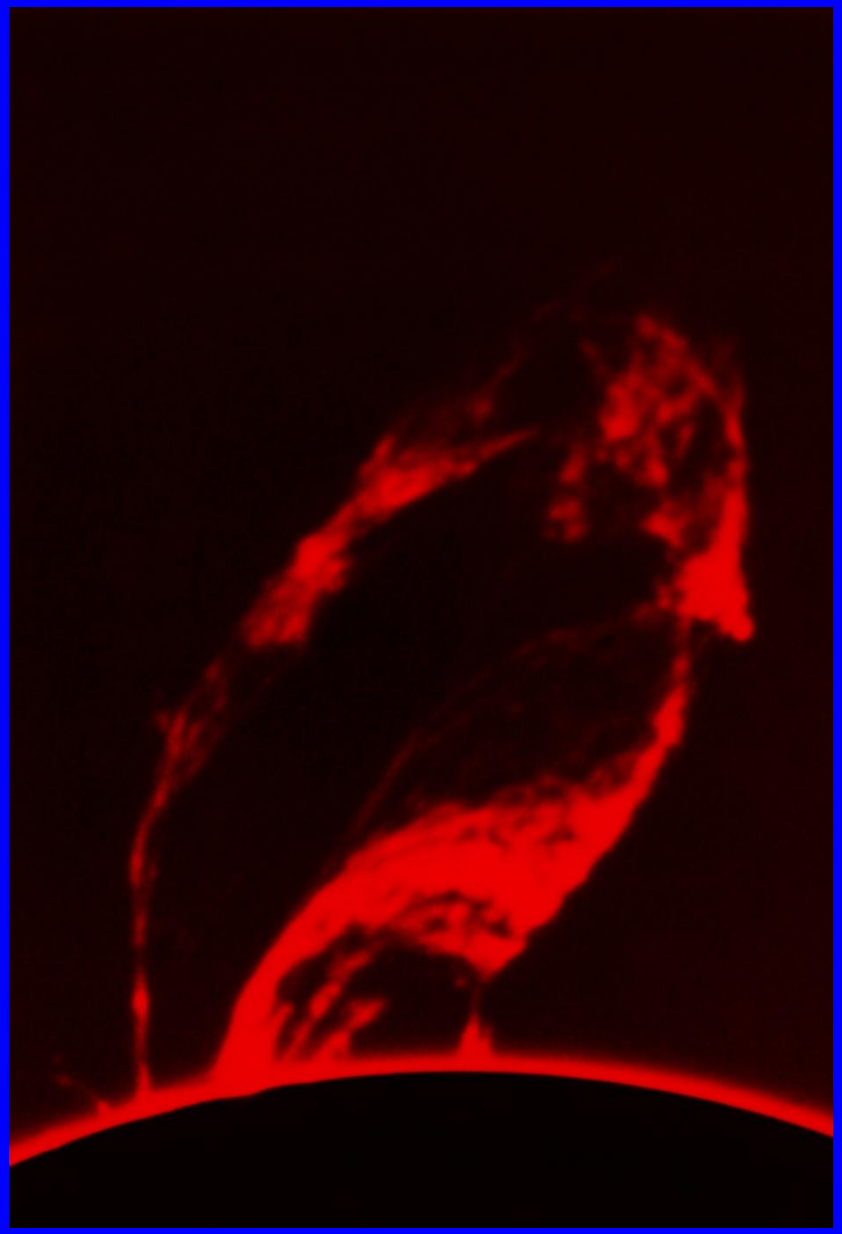
Dome of the observatory

Two identical coronagraphs (D/f = 20 cm/4m) at the Lomnický Štít Observatory for the green coronal line intensity measurements (installed in 1964) and prominence patrol observations (installed in 1970).

Post-focal equipment of the coronagraphs



Spectrum of the solar corona



Prominence patrol image

Stará Lesná Observatory

http://www.astro.sk/l3.php?p3=slo

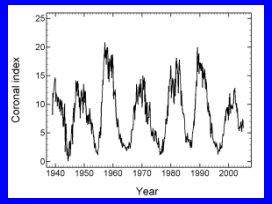
50cm horizontal spectrograph (f=35 m) for spectral observation of the solar surface, and a small 10cm refractor for drawing of sunspots.

Buildings of Horizontal Solar Telescope

Assistant Pavol Bendík drawings sunspots (in another dome of the SLO)

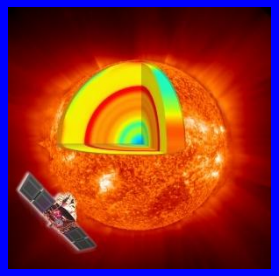
Research activities of the Solar physics department:

- Spectropolarimetry of prominences and coronal loops of active regions with a 20 cm coronagraph and spectrpolarimeter COMP-S (at Lomnický Štít coronal station, 2634 m above sea level) – test observations



- Main target: long-term variation of the green corona, time-latitude distribution of the corona brightness, global circulations, magnetic fields, solar cycles
- Prominences in H-alpha 0.5 nm filter: time-latitudinal observations, CME's onset, magnetic fields

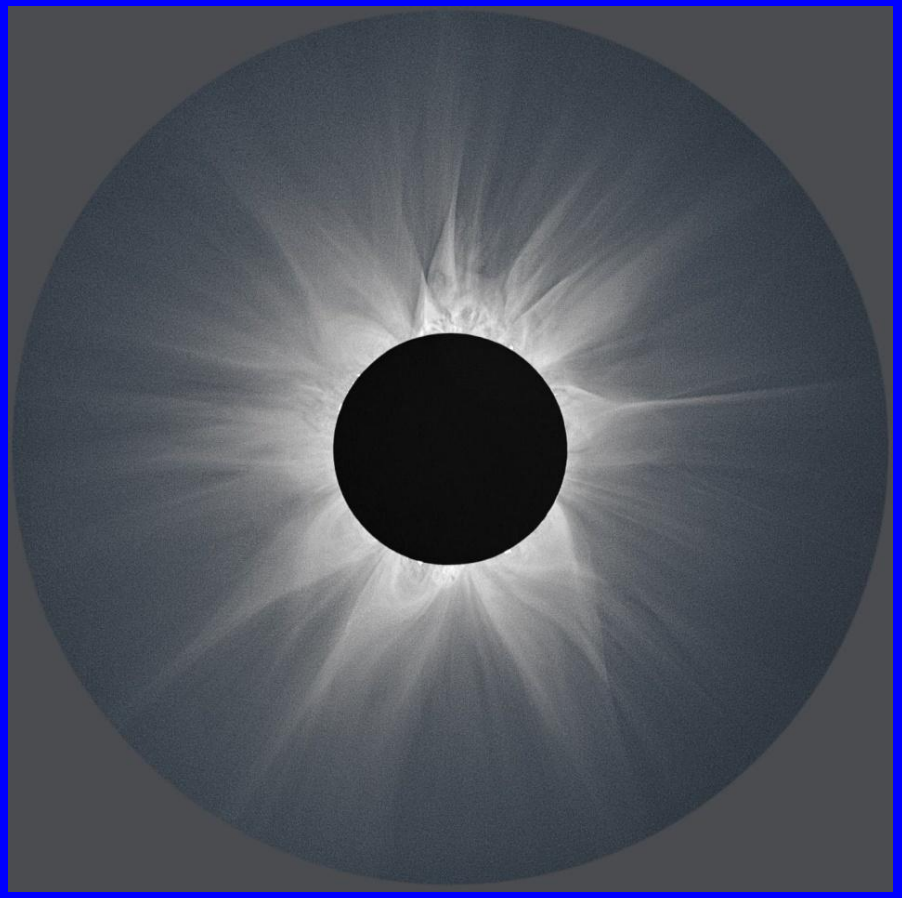
- Eclipse observation of the solar corona



- Investigation of the solar chromosphere, transition region and corona using satellites (SoHO, TRACE, Hinode) and ground-based telescopes (DOT, SST, VTT)
- Dynamics and energy transport in the upper solar atmosphere – observational verification of different heating mechanisms

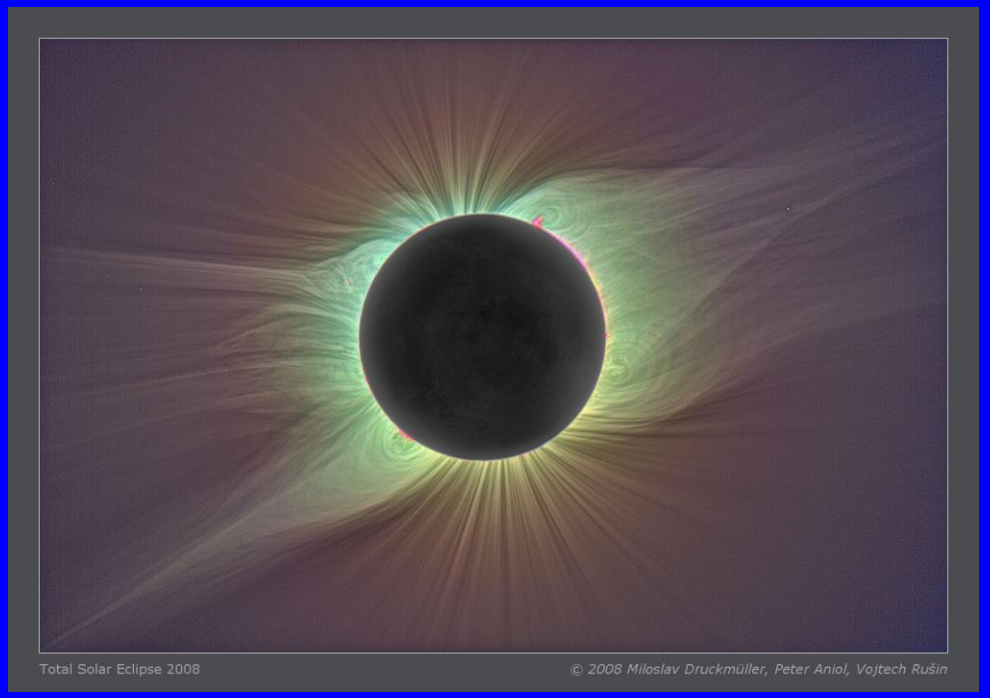
Solar corona

Solar cycle maximum

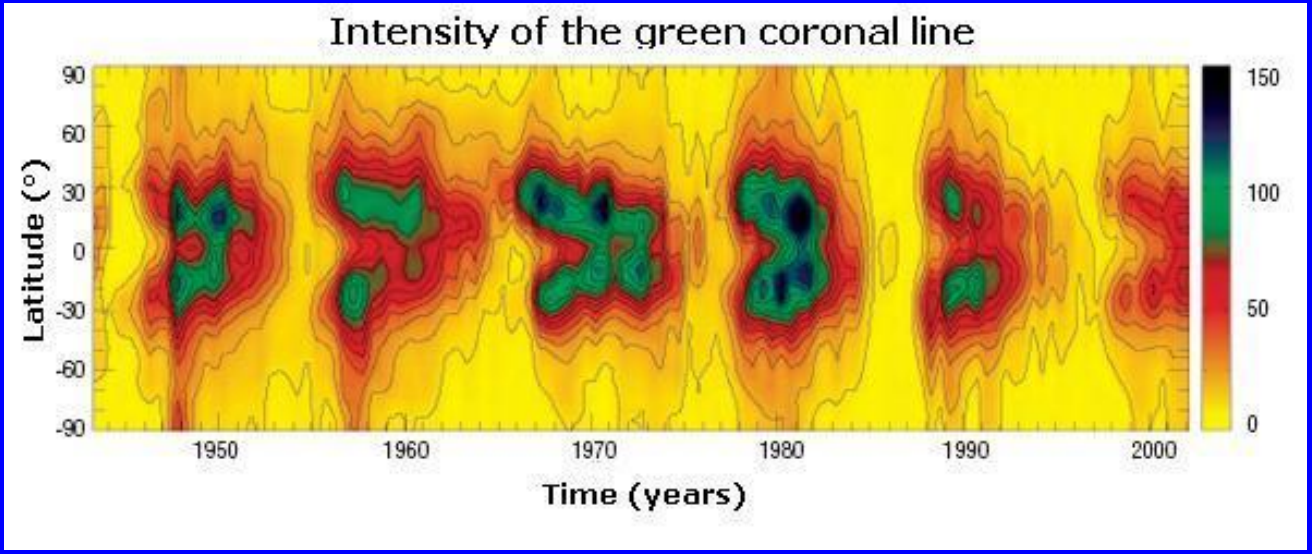


Composition of 5 images of solar corona taken with different exposures on 16 February 1980, Jawala gera in India, 20 cm telescope, F = 300 cm (image courtesy – V. Rušin Al SAS Tatranská Lomnica; processed by M. Druckmüller).

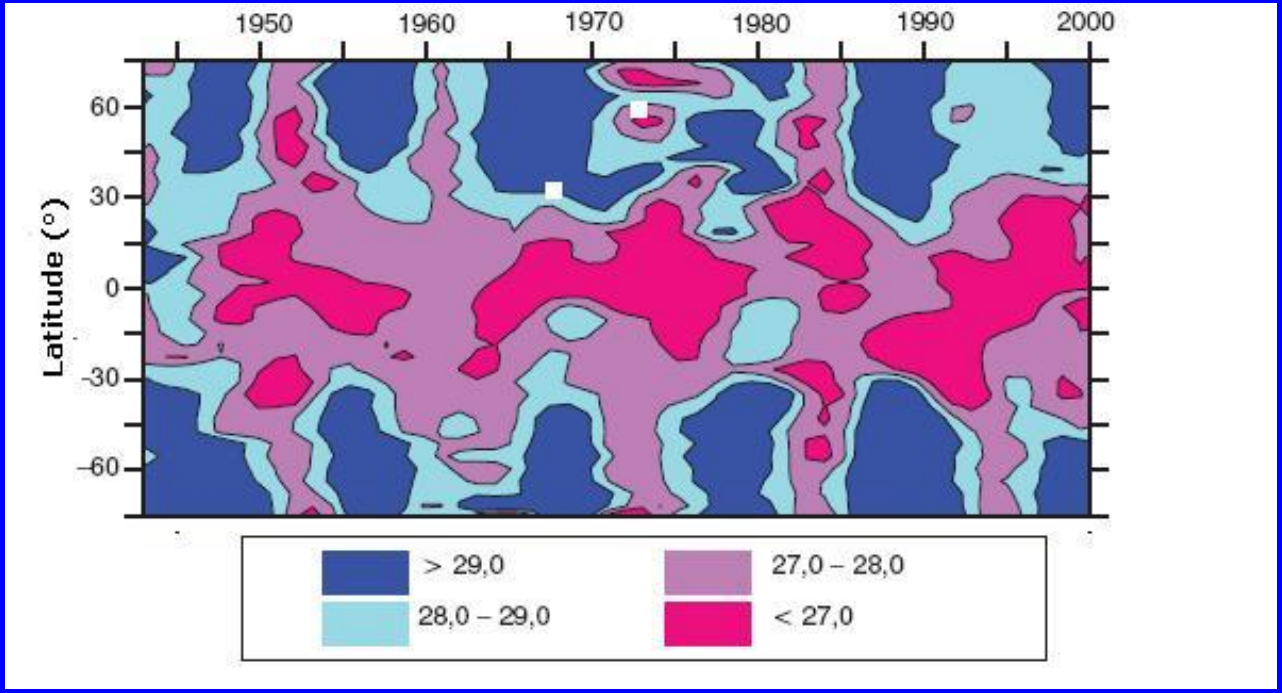
Solar cycle minimum



Solar corona, 1 August 2008, Altai, Russia (image courtesy – M. Druckmüller, P. Aniol, V. Rušin).



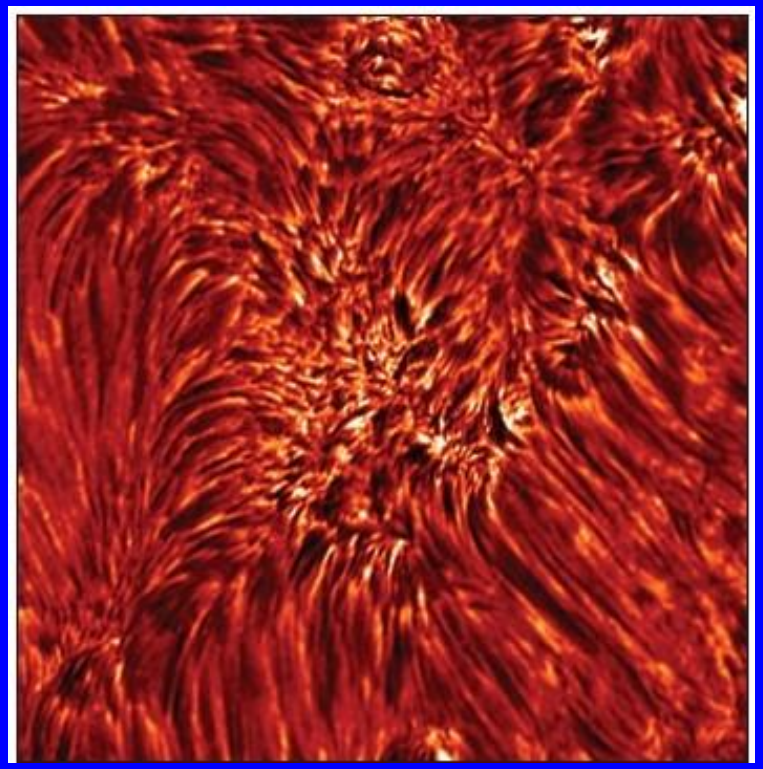
... in the solar cycles 18 – 23 (first half of the cycle 23).

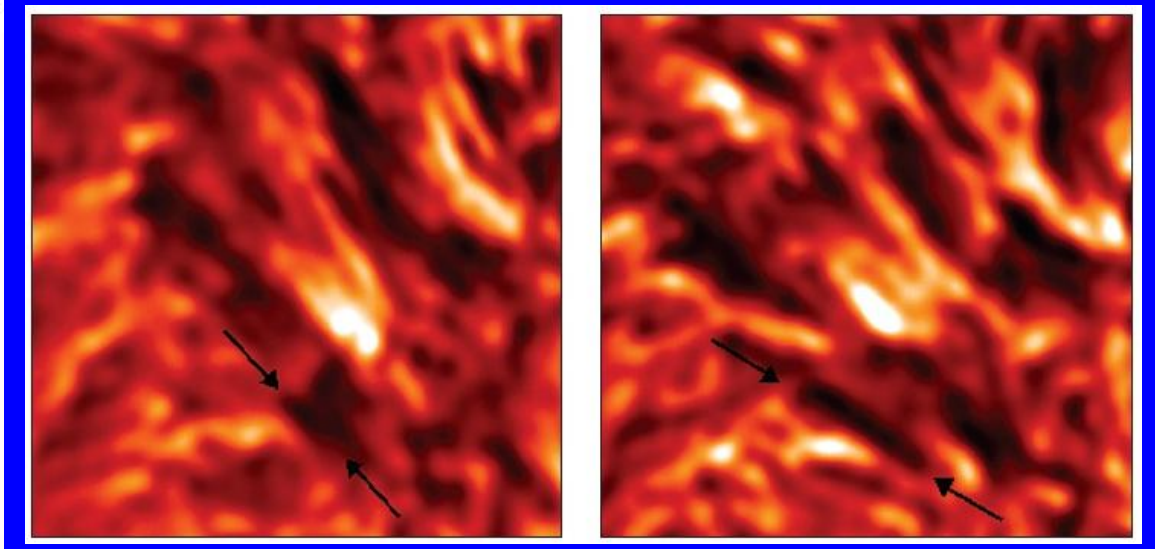


Cyclic variations in the differential rotation of the solar corona

Solar photosphere, chromosphere & Solar activity

- Hemispheric Sunspot Numbers Rn and Rs from 1945 till 2004: Catalogue and N-S asymmetry analysis
- Influence of the 5-min oscillations on the solar photospheric layers
- Periodicities in Irradiance and in other Solar Activity Indices During Cycle 23
- SOHO/CDS observations of waves above the network
- Quasi-biennial oscillations in the N-S asymmetry of solar activity
- Towards the understanding of coronal hole occurrence during the Schwabe cycle





Evolution of a dynamic fibril feature in 2.8 minutes (Dutch Open Telescope – DOT).

Institute of Experimental Physics, Department of Space Research, Košice

http://space.saske.sk

IEP SAS

CR measurements in High Tatras since 1958.
Contribution of Czechoslovak physicists to IGY (International Geophysical Year).
IEP SAS is running cosmic ray Neutron Monitor (**NM**) measurements at Lomnický Štít.

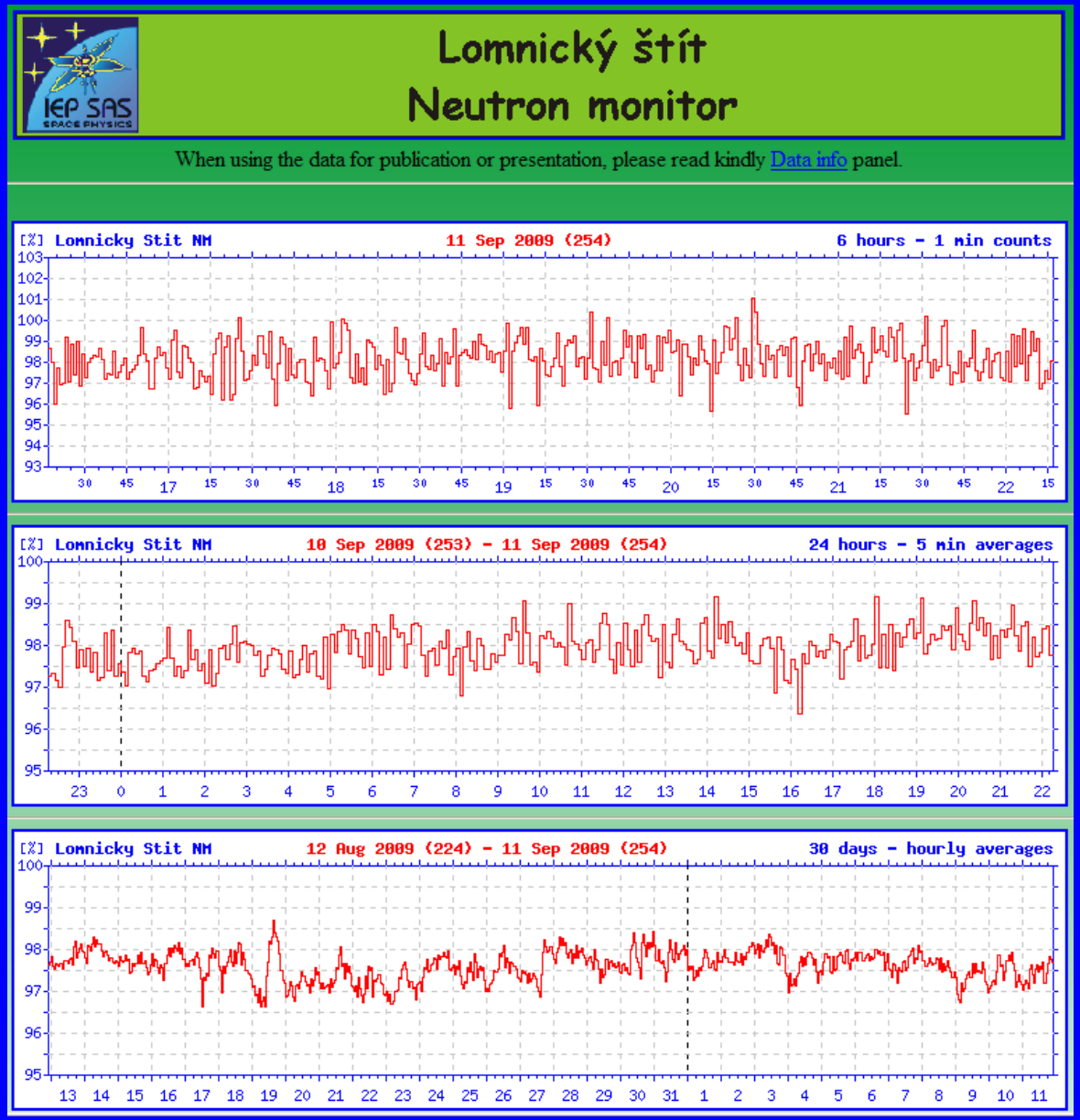
Today at Lomnický Štít – neutron monitor with high statistical accurracy (1.6. 10^6 /hour).

Current status of cosmic ray measurements:

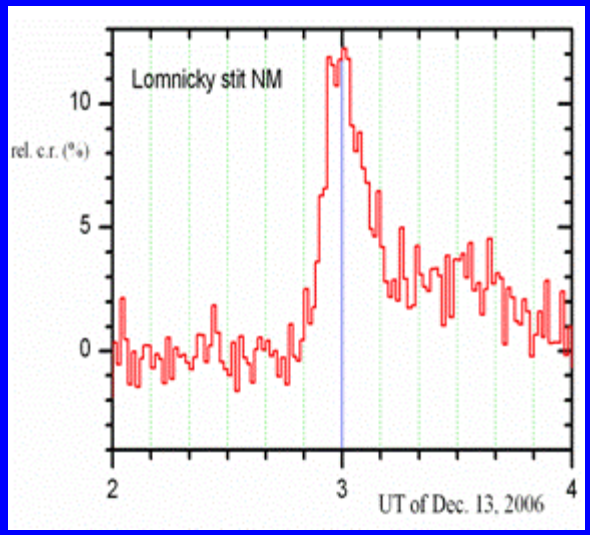
8NM64 neutron monitor (NM) measures continuously cosmic rays at Lomnický Štít with high statistical acurracy (average count rate ~440 s^{-1}). This allows ***to detect small variations of primary cosmic rays on the ground***.

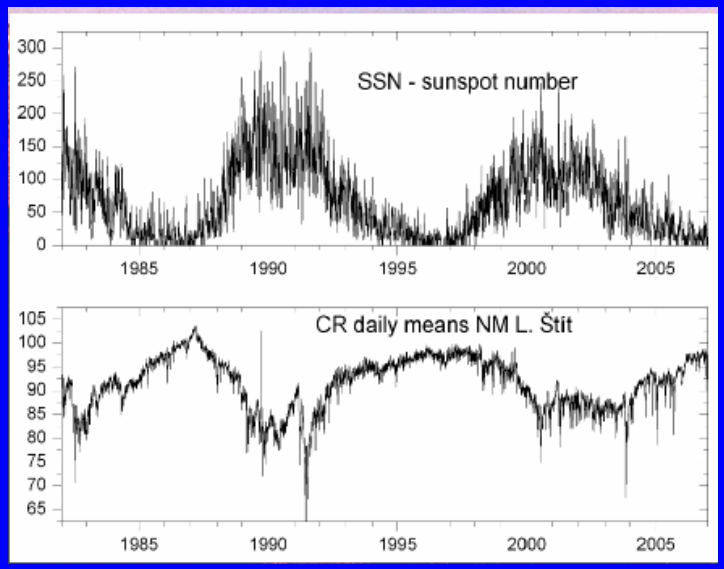
Cosmis rays: useful tool to study solar flares, CME's, solar cycle variability, space weather effects, etc.

Data available in real time:
http://neutronmonitor.ta3.sk/

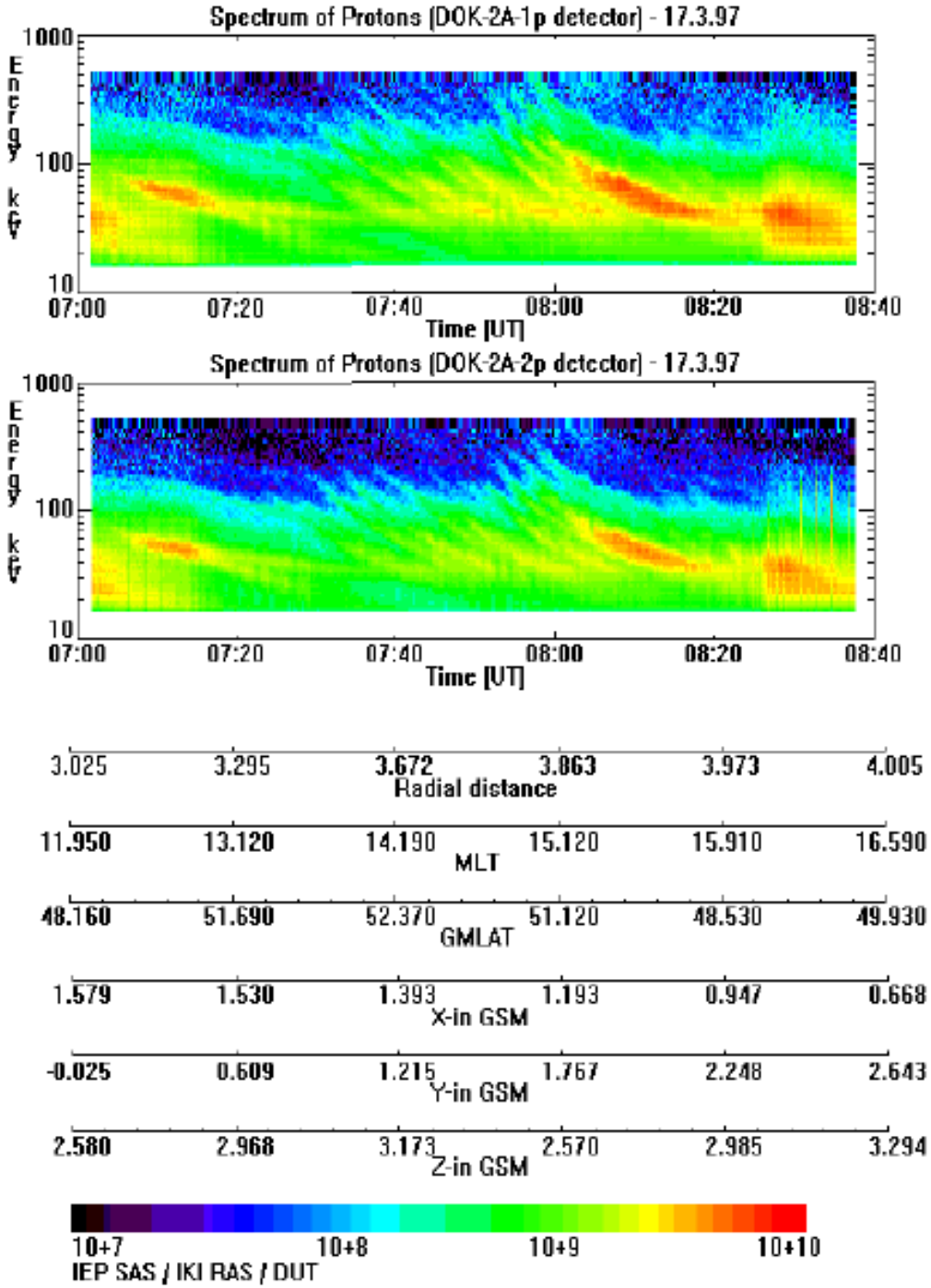


Recent GLE 70: acceleration to >4 GV indicated byLomnický Štít NM with 1min resolution.





The institute participates also in several satellite measurements of energetic particles (hardware, scientific collaboration) - http://space.saske.sk/projects/?lang=1

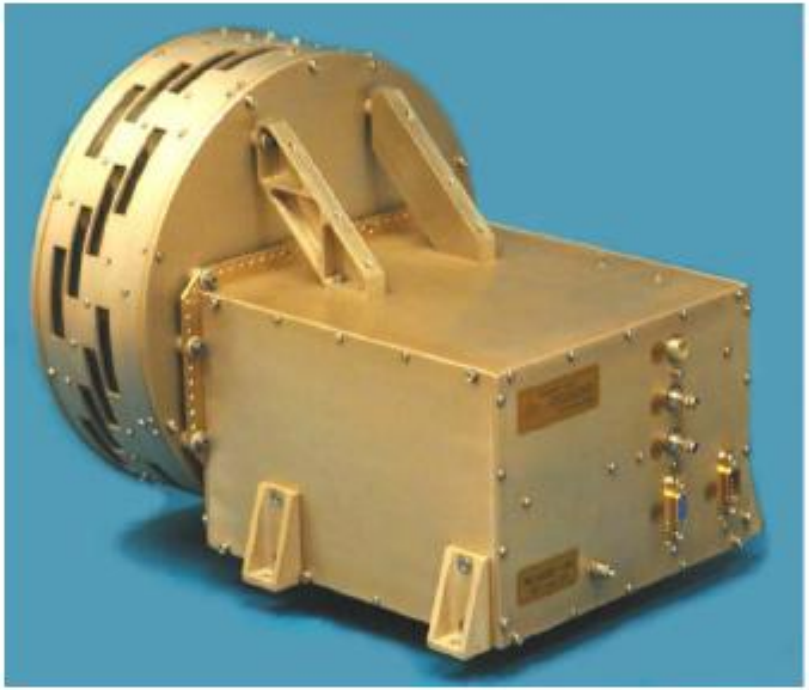


Detailed energy spectra – observation of dispersive effects of ions in outer magnetosphere on day side by DOK-2 on Interball-2.

$J(E)*E^3$, J(E) is differ. intensity of particles ($\#/cm^2.s.ster.keV$), E is kinetic energy in keV.

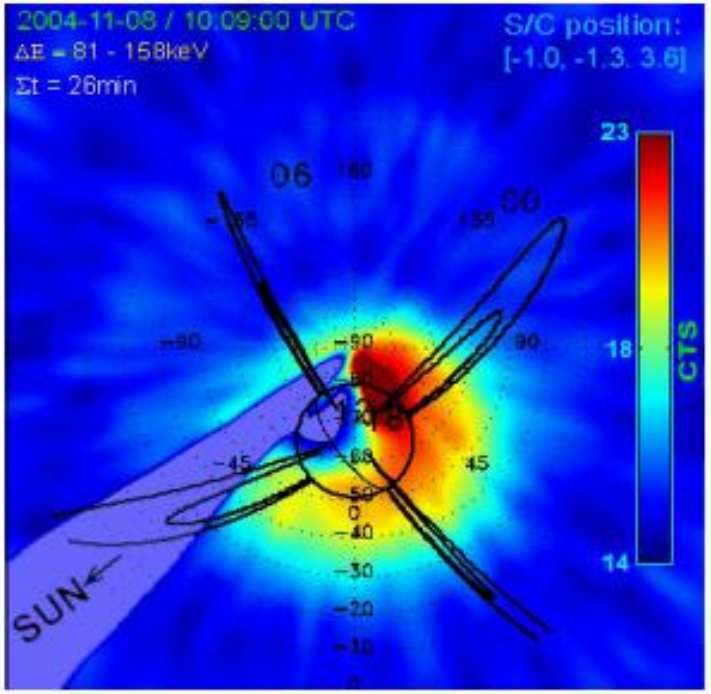
Contribution to data analysis by dr. M. Slivka, CSc.

These effects – identification of particle injection on the night side of magnetosphere during substorms. Curves – estimates of timing and site of the injection.



Detection of high energy neutral atoms on European-Chinese satellite Double Star TC2 is done by instrument NUADU (cooperation with STIL, Maynooth, Ireland). Significant part of NUADU was developed at DSP IEP SAS in Košice.

3D „remote sensing" of energetic particle flux – charge exchange in geocorona of Earth.



Distribution of energetic neutral atoms observed by NUADU during geomagnetic storm on November 8, 2004.

Decice developed in DSP mainly by

ing. J. Baláž, PhD.

Geophysical Institute, Bratislava

http://gpi.savba.sk/

GPI SAS

- solar-terrestrial connections and Earth's magnetosphere and climate
- solar proton events and geomagnetic activity
- forecats of geomagnetic activity based on space weather phenomena (flares, CMEs, SPEs) using artificial neural networks.

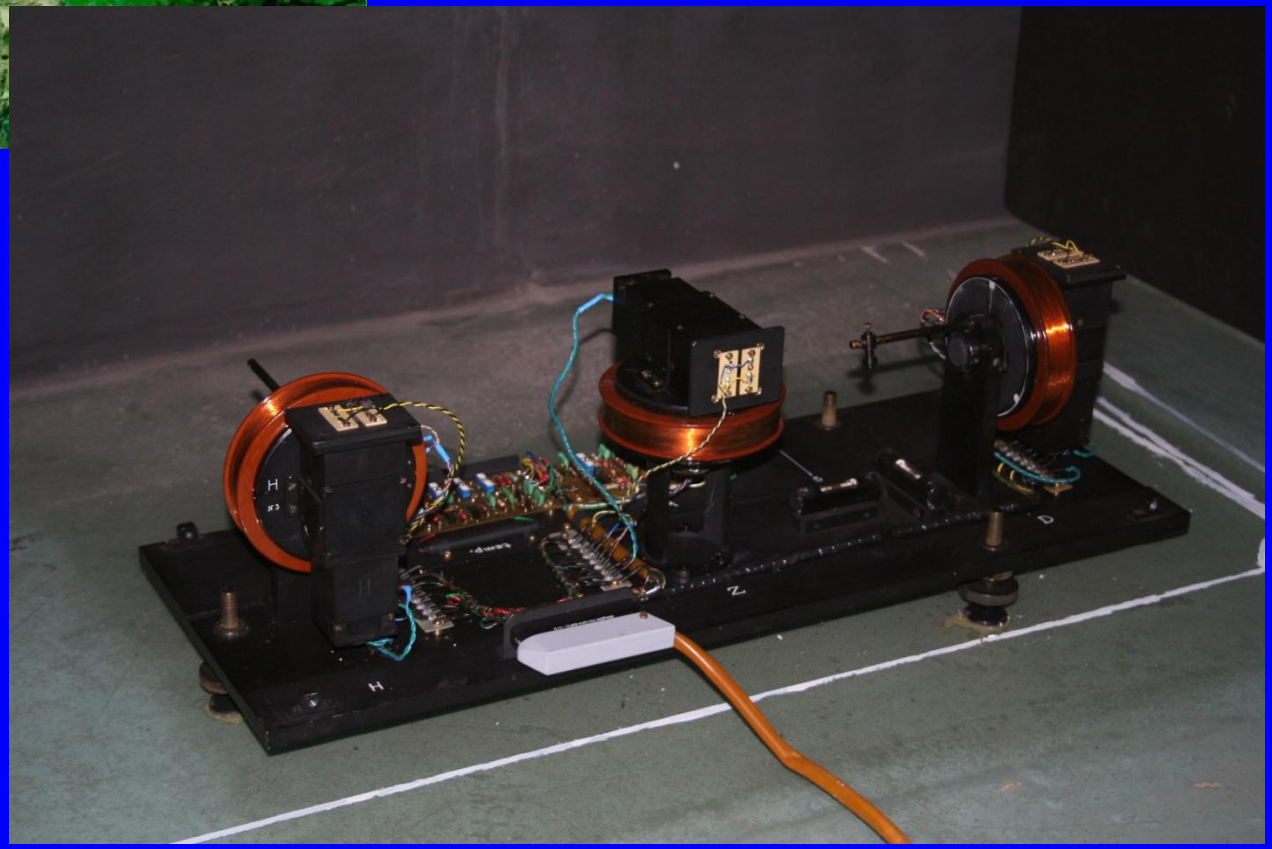
Geomagnetic observatory, Hurbanovo

http://www.geomag.sk

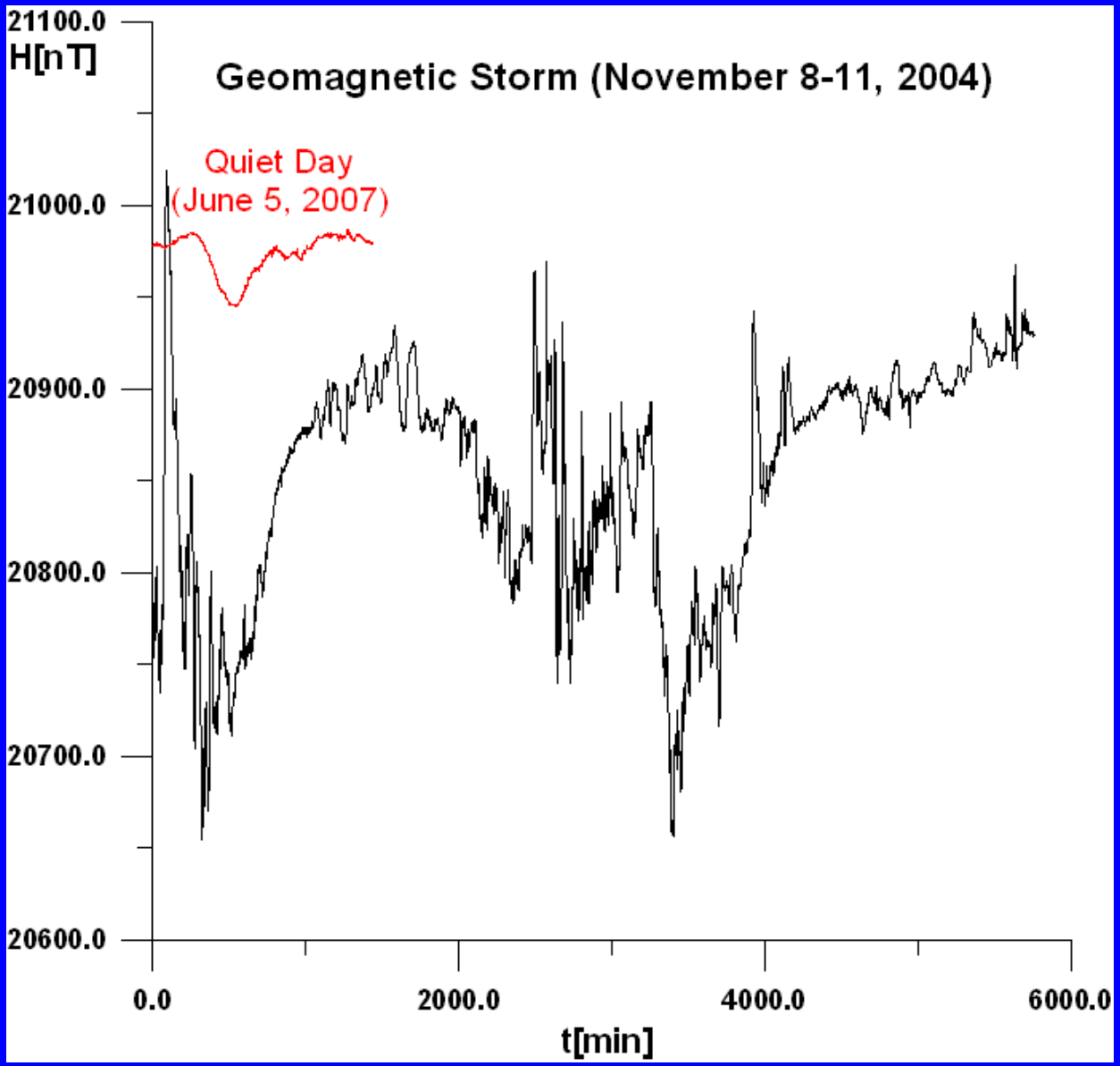
The absolute house of the Hurbanovo Geomagnetic Observatory, where absolute measurements of the geomagnetic field are performed two times a week.

Pillar No. 3 in the absolute house. All Hurbanovo's geomagnetic field values are referred to this place.

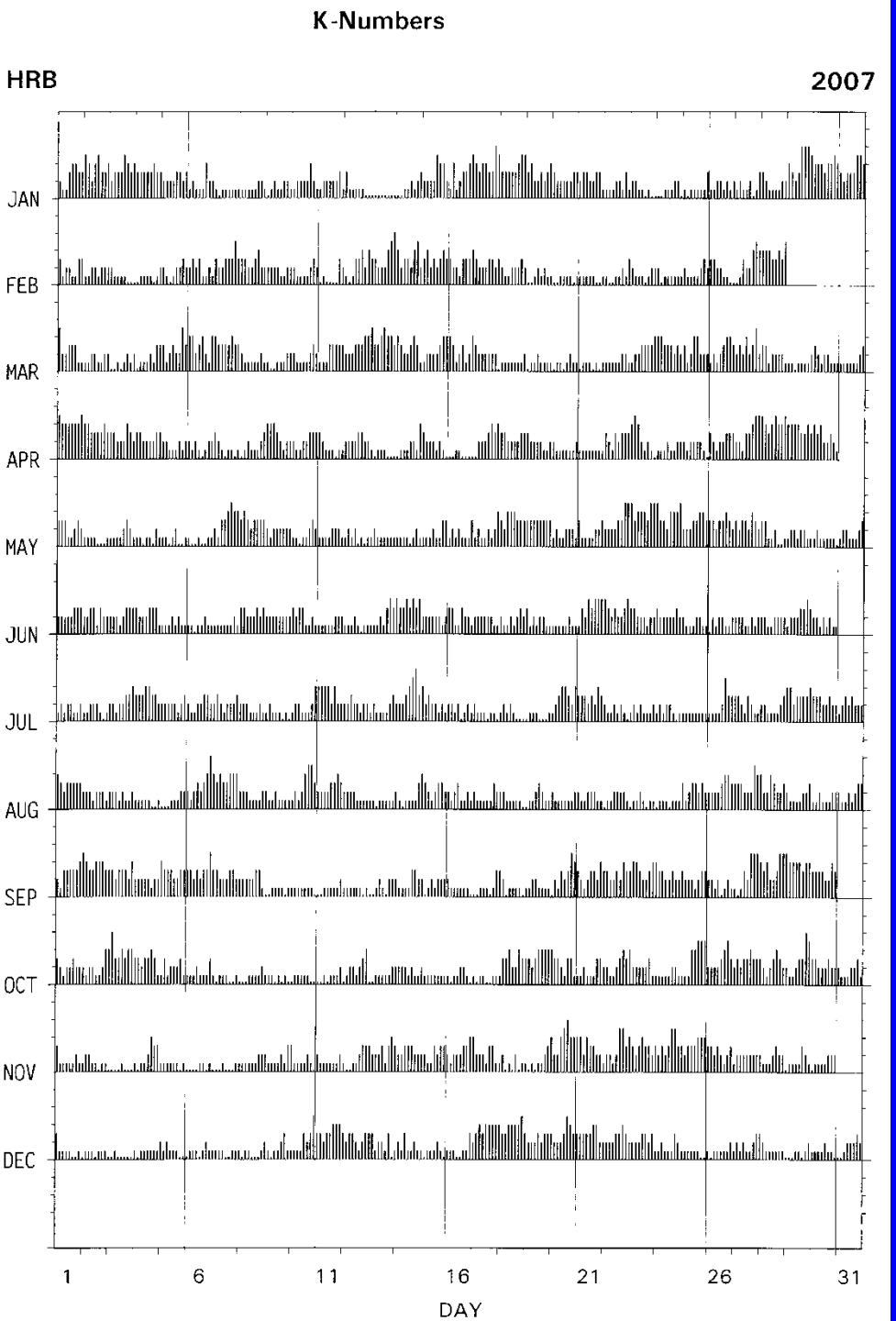
The variation house of the Hurbanovo Geomagnetic Observatory. Registrations of the geomagnetic field are running here.



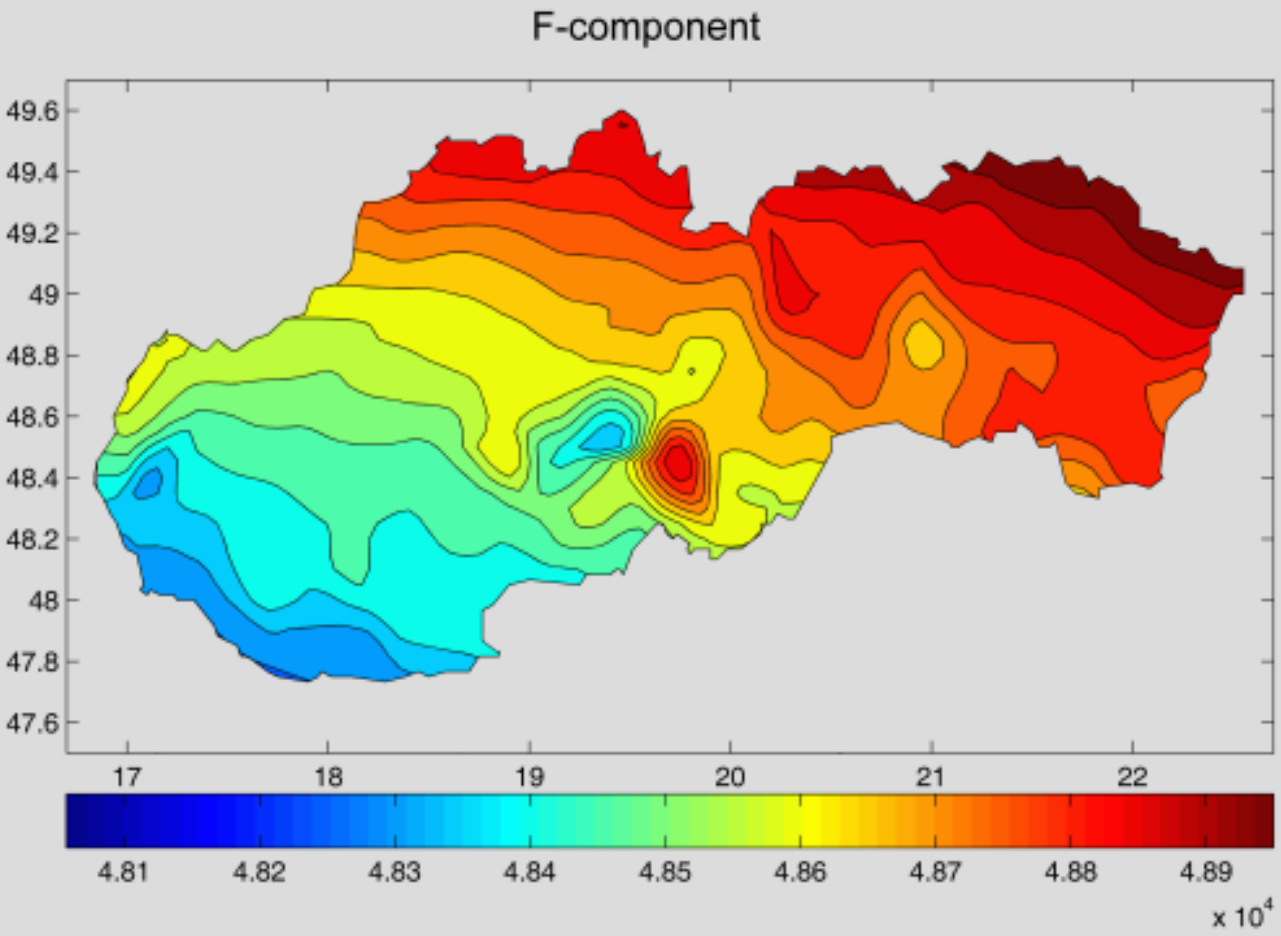
Three sensors of the variation station at the Hurbanovo Geomagnetic Observatory. The data registered by it are sent to the INTERMAGNET data base every day.



The geomagnetic storm recorded by Hurbanovo Geomagnetic Observatory on November 8-11, 2004. The record of a magnetogram from a quiet period (June 5, 2007) was added to the picture for comparison.

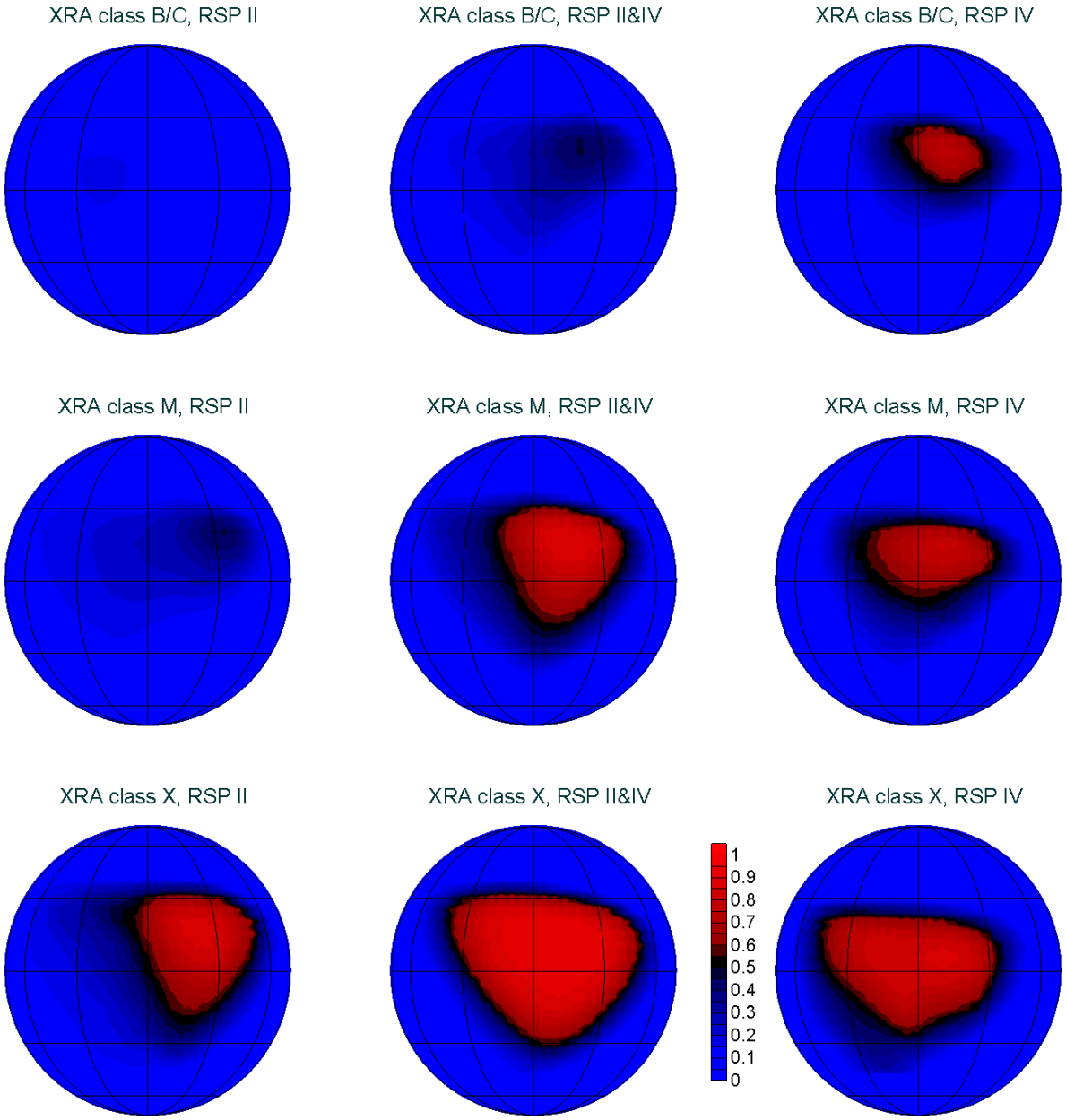


Hurbanovo Geomagnetic Observatory asseses the geomagnetic activity level. For each 3-hour interval a value of so-called K index is assigned.



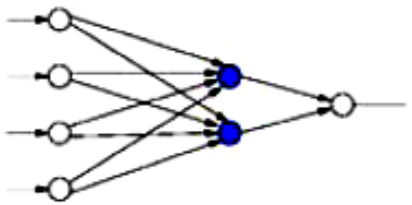
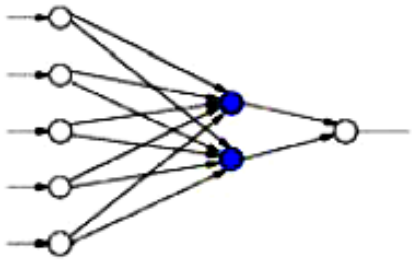
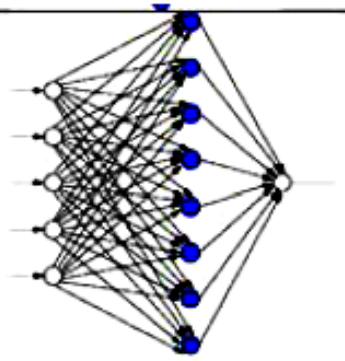
Map of isolines of the total field (F) on the territory of Slovakia for the 2007.5 epoch. The values assigned to isolines are given in nanoteslas. The spacing between adjacent contours is 50 nT.

Space weather modelling using artificial neural networks:

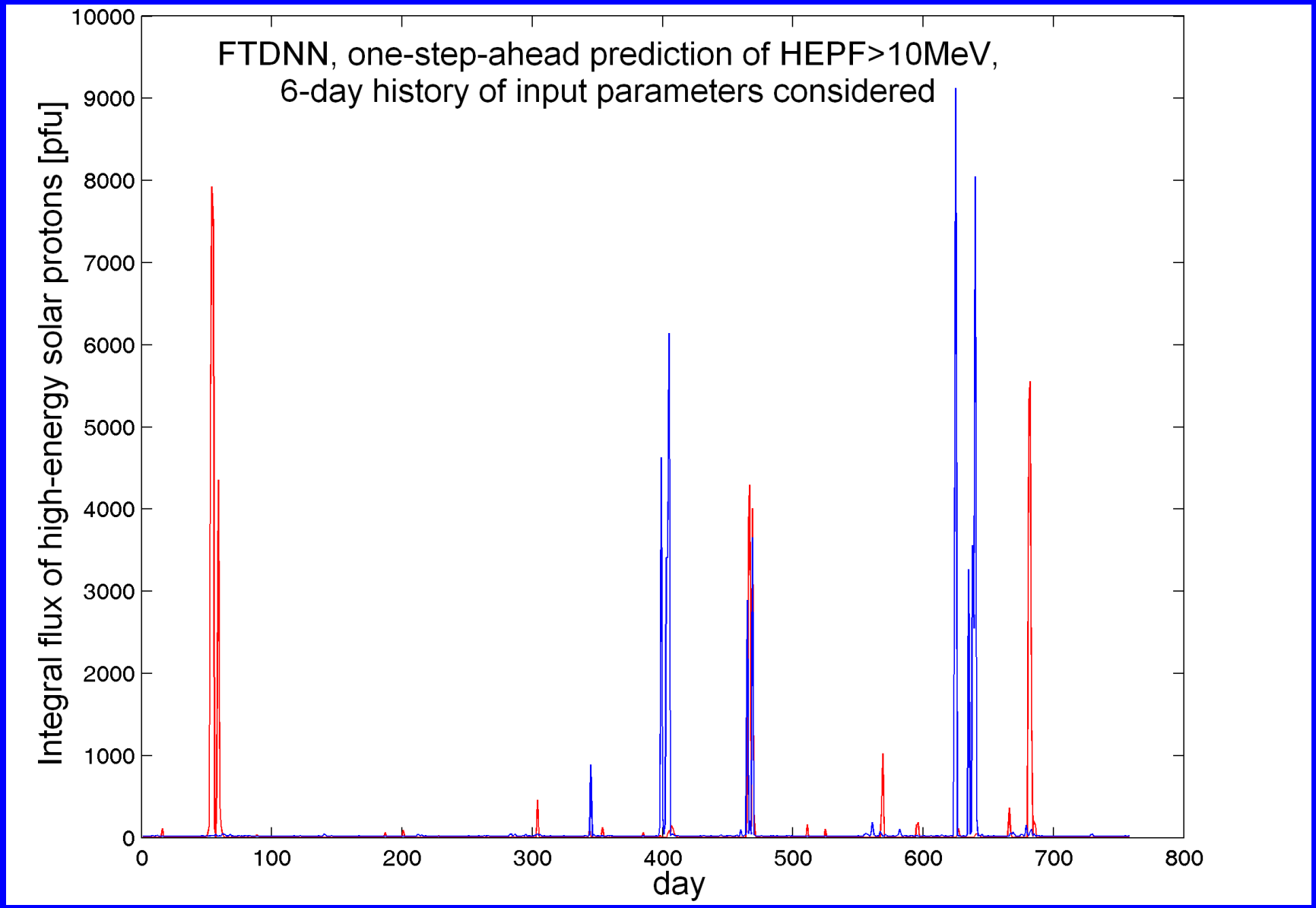


Regions on the solar disc where the geoeffective XRA events occur.

Some geomagnetic response vs. no geomagnetic response

Neural network scheme (Model input parameters)		Observed responses	Forecast responses	False alarms
λ φ RSP II/IV XRA_Class		23	8 (35%)	2
		93	48 (52%)	41
λ φ RSP II/IV XRA_Class Δlog(F)		23	10 (43%)	1
		93	50 (54%)	45
λ φ RSP II/IV XRA_Class Δlog(Φ)		23	11 (48%)	1
		93	51 (55%)	50

Prediction of SEP events:
blue curve – observation, red curve – prediction



Comenius University, Faculty of Mathematics, Physics and Informatics, Bratislava

Division of Astronomy and astrophysics :

http://www.daa.fmph.uniba.sk/department)

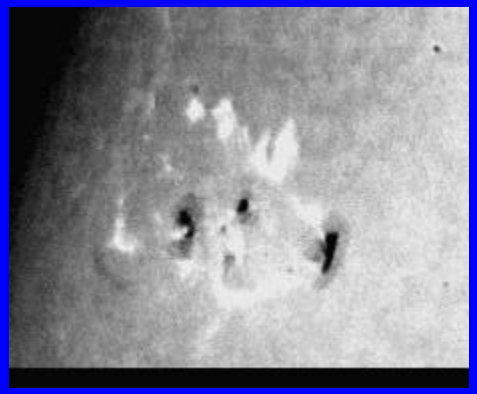
FMPI

- **Astronomical and Geophysical Observatory Modra**

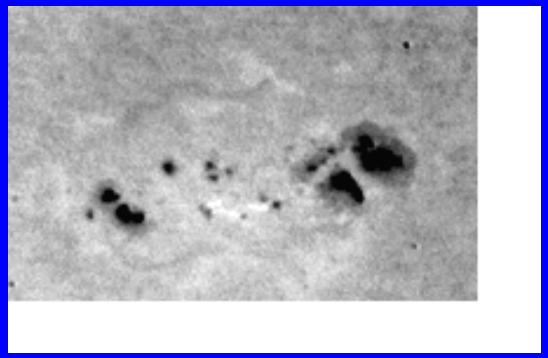
AGO Modra observatory

- solar flare and active region research and solar EUV and SXR spectroscopy,
- diagnostics of non-thermal distribution of electron in the corona

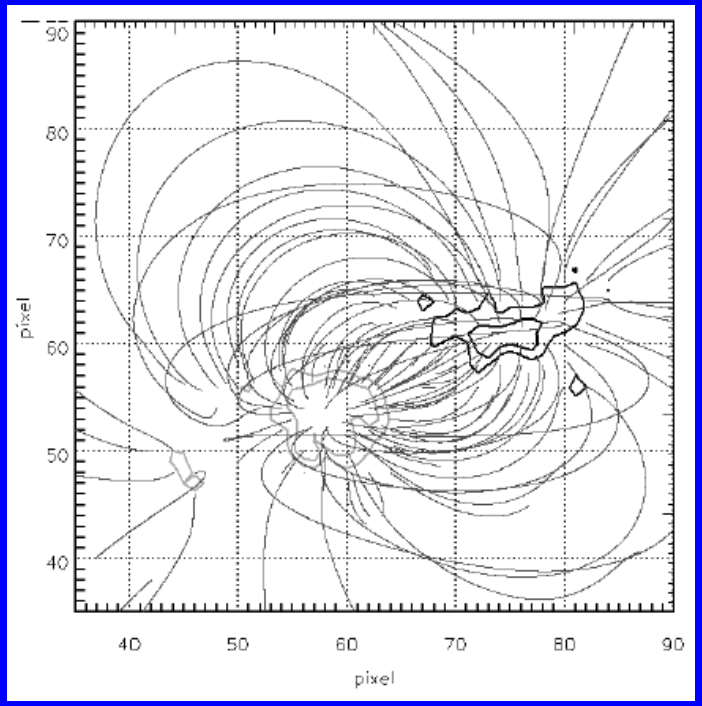
Images of AR 8636 July 7th, 1999



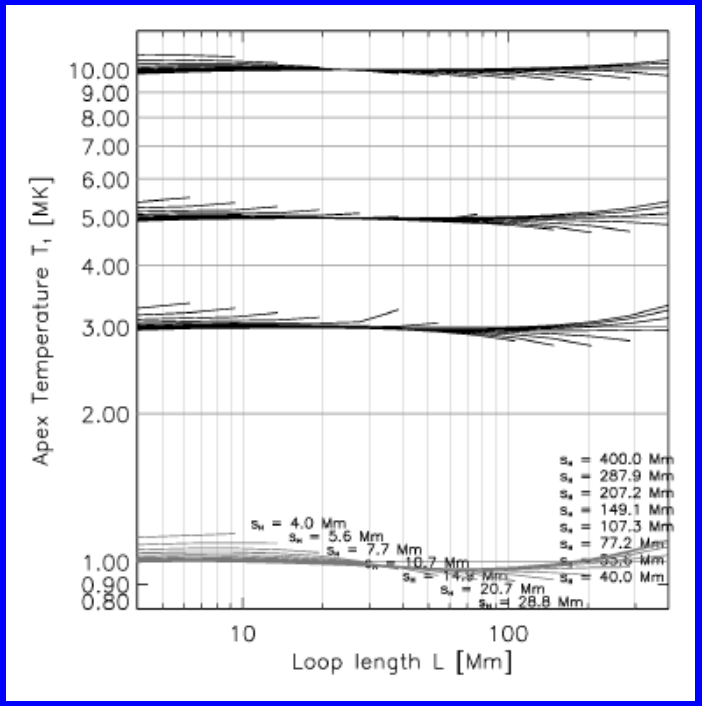
Evolution of the solar flare



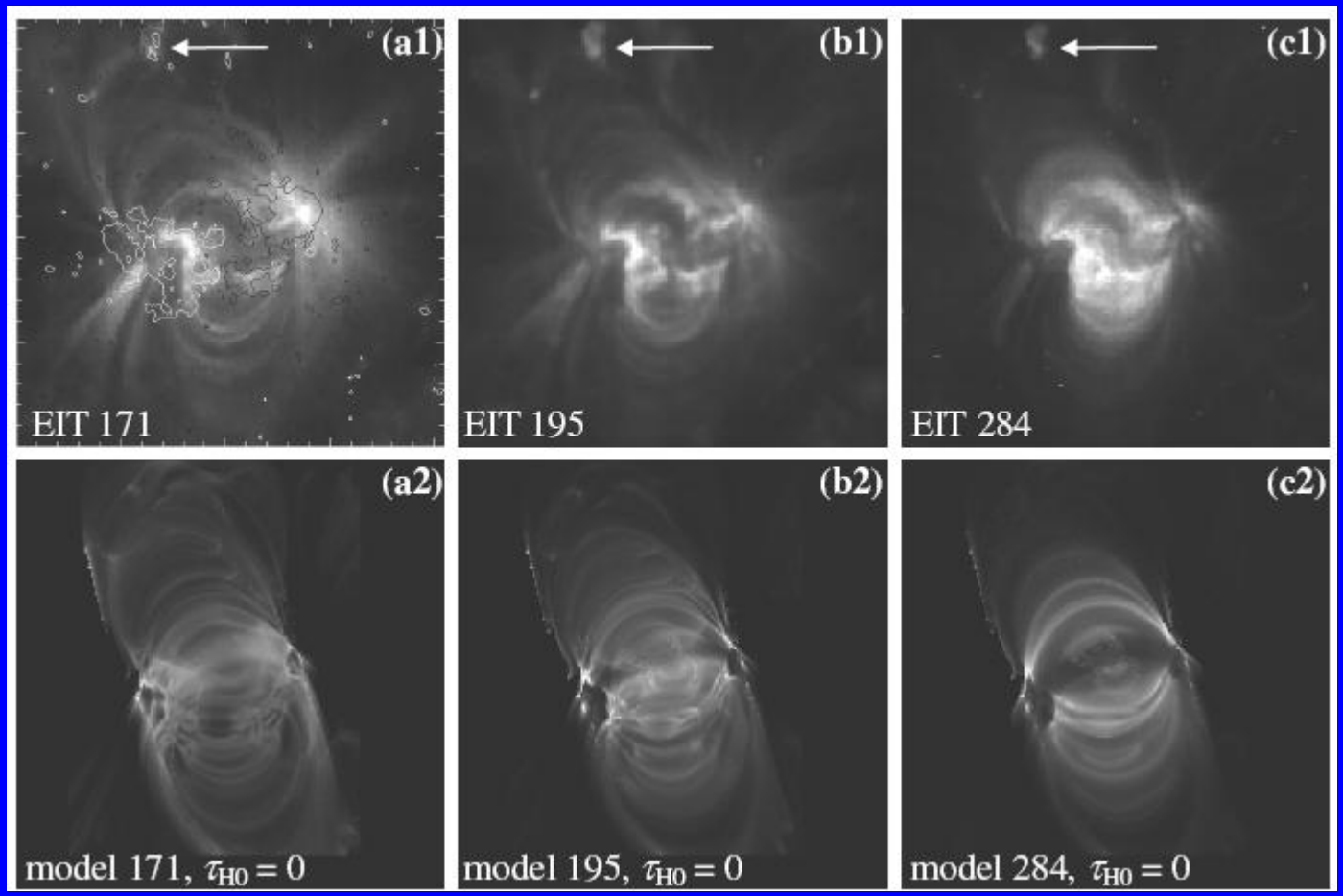
Evolution of huge filament



Magnetic field lines extrapolated by Fourier transform

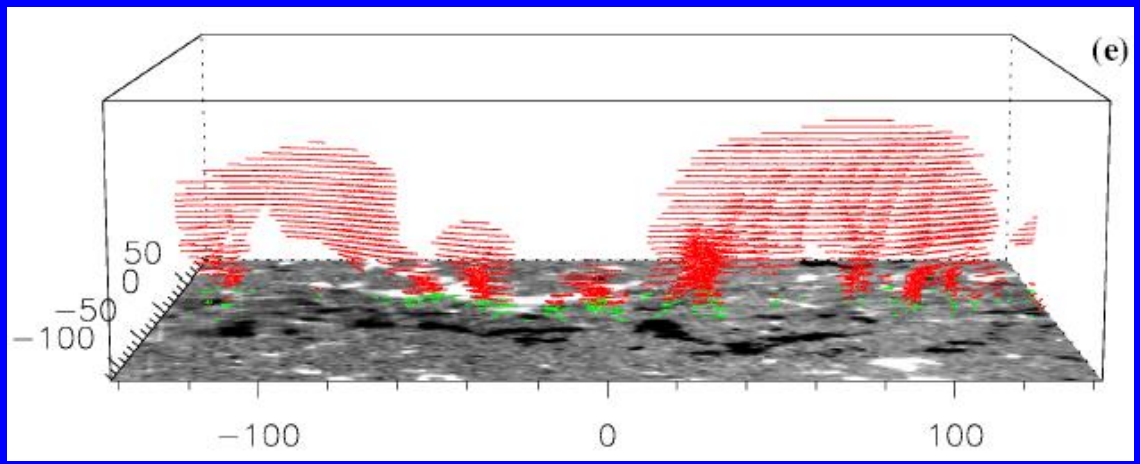


Scaling laws for coronal loops



Filament model

Observations of an active region performed by SOHO/EIT (a1,b1,c1) versus hydrostatic emission models (a2,b2,c2).



Division of Physics of the Earth:

http://www.earthphysics.sk/

- Astronomical and Geophysical Observatory Modra

- Earth's magnetic field
  → magnetohydrodynamics
  → physics of ionosphere and magnetosphere

- interaction of different materials with cosmic rays
- upper atmosphere response to the solar proton events.

BMP (BIOMET), Bratislava
http://www.biopocasie.sk

- **medical-meteorological forecast** = numerical information of the health risk level.for meteosensitive persons.
- new product (2010): **individual bio-meteorological forecast** characterizes better symptoms of weather influence on individuals. It is based on input parameters as region of Slovakia, where a person lives and the illness type he suffers from. The additional input criteria there are: sex, age, category body weight and blood pressure.

- Another study: **UV-index in Bratislava,** in collaboration with Slovak Hydrometeorological Institiute.

Slovak Central Observatory, Hurbanovo

http://www.suh.sk

SCO

Historical building of the Observatory →

- the observatory was founded in 1871

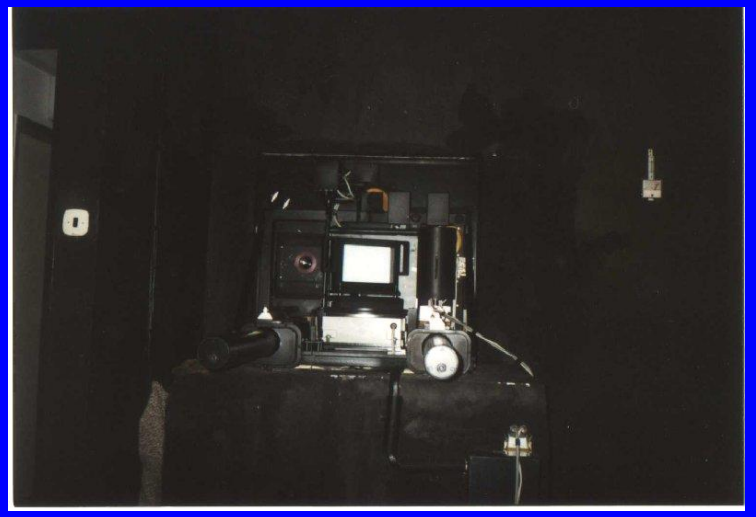
Department of Solar Physics

Building of the Solar Department

Coude refractor with D/f of 15/225 cm.

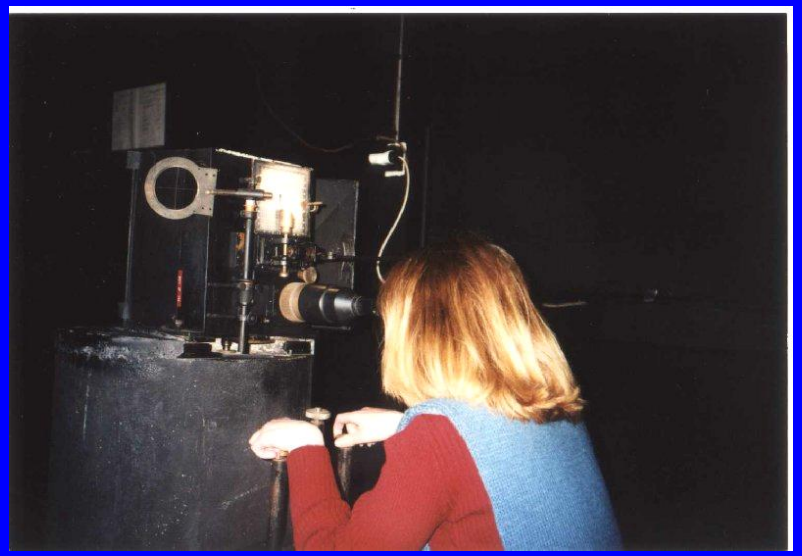
Coelostat (60 cm mirrors)

The colimator (left) and the objective of the spectrograph (right)



Grating of the spectrograph

Observing room of the horizontal solar telescope with spectrograph



Spectrohelioscope, flare patrol

Coronagraph, prominence patrol
D/primary focus/ effective focus
of 9/125/375 cm

SOLAR RESEARCH

Astronomical observations and research are oriented mainly to the field of solar physics (sunspots, solar flares, prominences, total solar eclipses). In south Slovakia there are usually nearly 300 days per year when the Sun can be observed.

OBSERVATIONS:

- Daily drawings of the **sunspots** - Coude refractor with D/f of 15/225 cm.
- Patrol observations of the chromospheric **flares** - spectrohelioscope with D/f of 10/500 cm.
- Patrol observations of **prominences** (Lyot coronagraph with D/primary focus/ effective focus of 9/125/375 cm).
- **Spectroscopic** observations using Horizontal solar telescope with spectrograph (HSTS) with parameters D/f of 50/3500 cm; spectrograph: grating with 632 graves/mm, focal length of the collimator is 96.6 cm, focal length of the camera is 96.4 cm.
- Observation of total solar **eclipses**.

Daily observations of the Sun are sent online to SIDC on a daily basis, to SONNE Network in Germany on a monthly basis, and to the national coordinators (Prešov – Slovak Republic, Valašské Meziříčí – Czech Republic).

Solar Activity and Earth's Magnetic Field

(data according to observations of the Scientific Observational Dept.
of the **Slovak Central Observatory - SCO Hurbanovo**)
47°52,372' N and 18°11,368' E

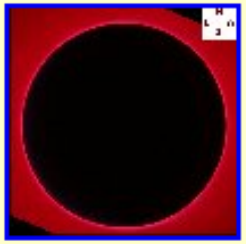
slovensky

SEPTEMBER 2009

H-alpha Coronograph, Heyde Dome
H-alpha filter - FWHM 0.6 nm

Coudé Refractor, Historical Building of the SCO
D/f: 150/2250 mm

Image archive

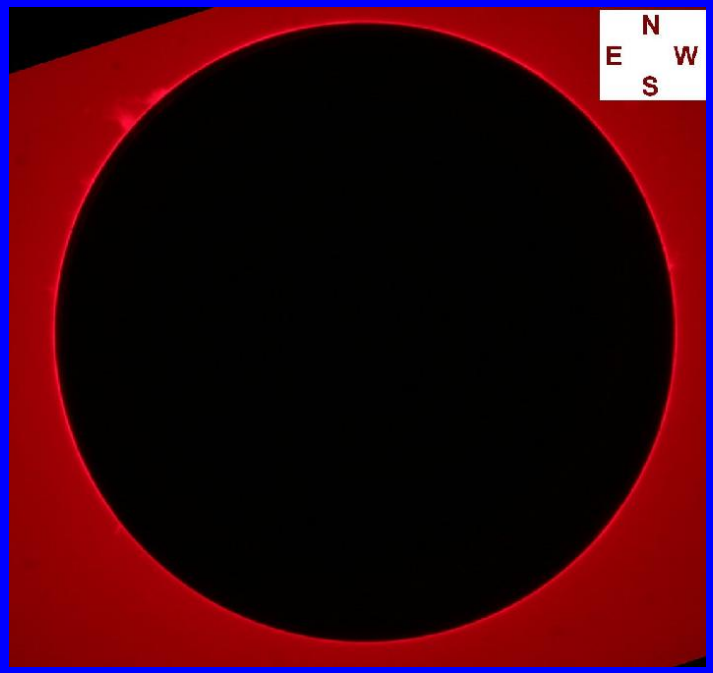


09-09-2009, 08:19 UT

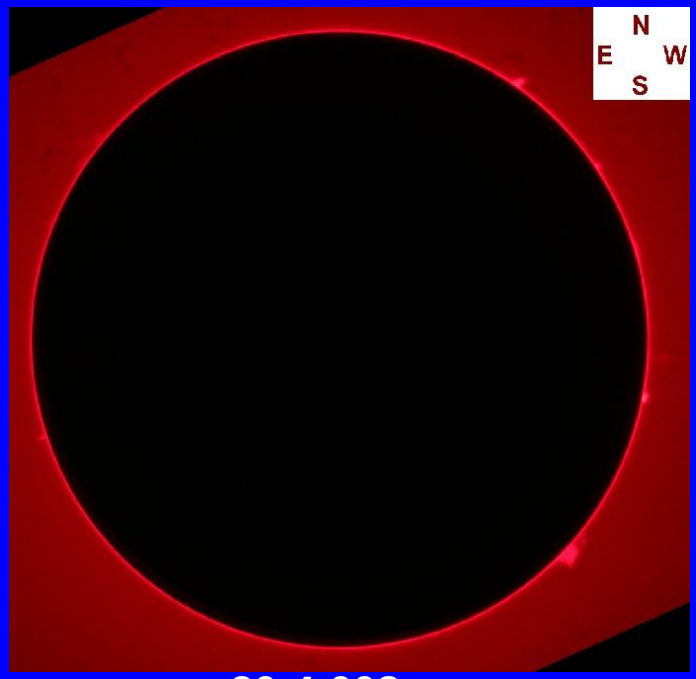
Sunspot drawing archive

Deň Day	1	2	3	4	5	6	7	8	9	10	11
R	12	0	0	▲	0	0	0	0	0	0	0
O	4	4	4	▲	3	5	5	5	4	3	2
MPZ	np	np	np	np	np	np	np	np	np	np	np

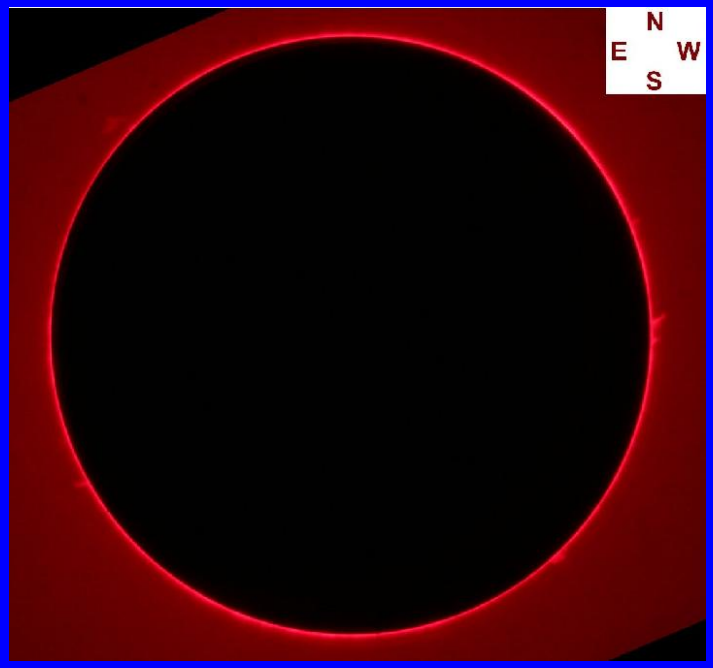
http://www.suh.sk/index.php?option=com_content&view=article&id=140&Itemid=108



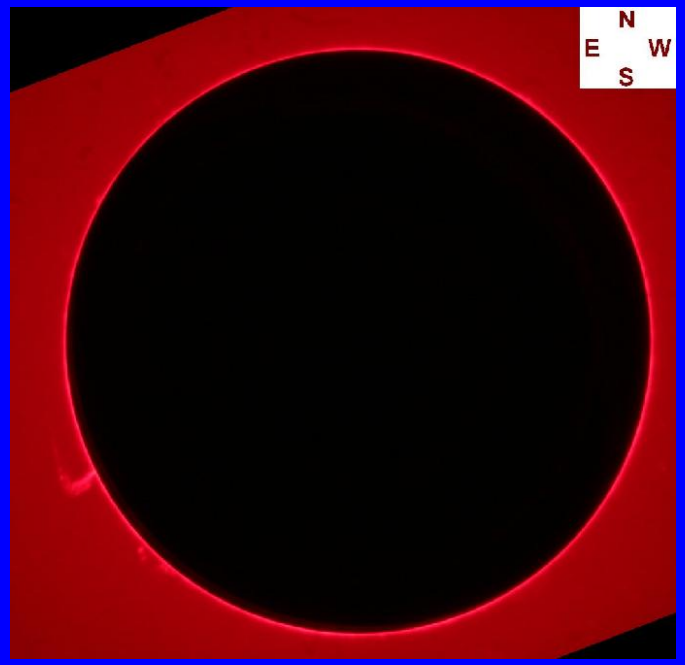
19-2-2008



30-4-008



9-3-2008



15-5-2008

RESEARCH PROJECTS:

- **Eclipse expeditions - experiments:**

- structure, photometry, and polarization of the white-light corona
- structure of the green corona
- colour of the solar corona
- infrared corona
- fast changes in the structure of the corona
- air temperature measurement during the total solar eclipse

- **Fine structure of the solar photosphere**

- evolution and horizontal motions of fine structure features near a solar pore

- **North-south asymmetry of the solar activity**

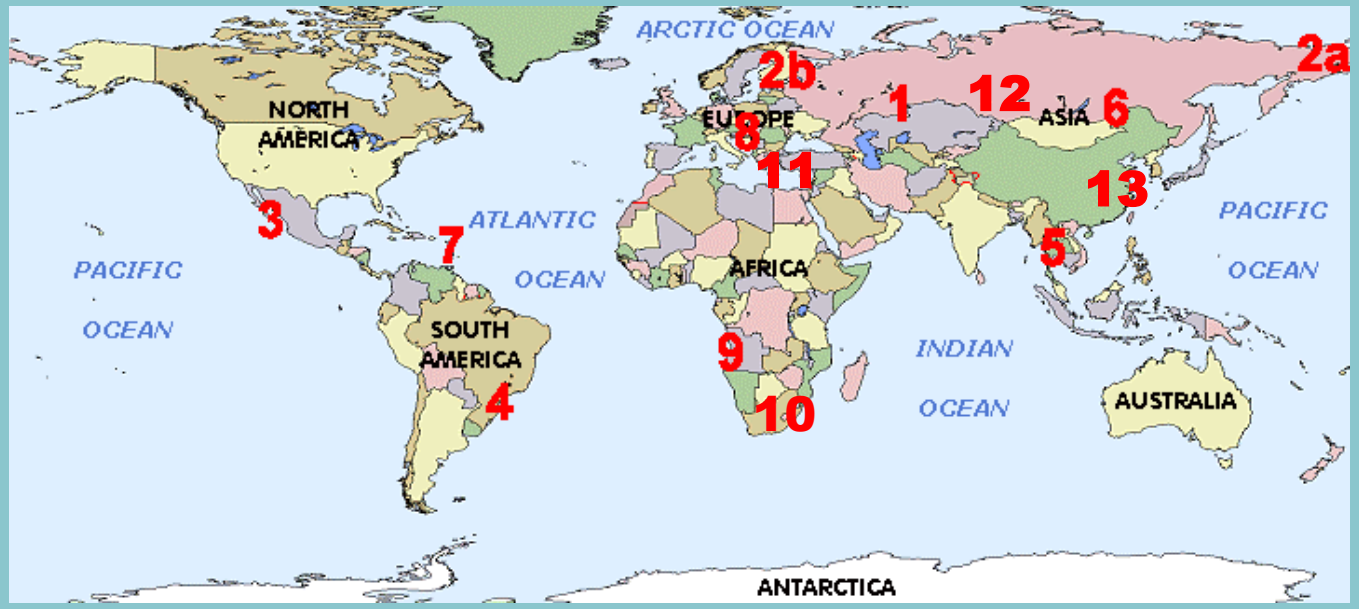
- Analysis of Ca II K3 spectroheliograms from the Astronomical Observatory of the University of Coimbra (Observatório Astronómico da Universidade de Coimbra – OAUC, Portugal) – in collaboration with the AI SAS in T. Lomnica

- **Space weather; Sun - Earth connections**

- relation of the solar activity, interplanetary conditions and the geomagnetic activity (sunspots, UV-index, CMEs, solar wind, Forbush Decreases, Dst-index)
- participation in the ESA project "SEISOP - Space Environment Information System for Operations" – in collaboration with UNINOVA-CA3, FCT UNL, Caparica, Portugal

- **Modified Coronal Index** calculated from the EUV satellite measurements (SOHO/CELIAS, TIMED, SORCE)

Eclipse expeditions of the Observatory Hurbanovo



1 – 19 June 1936, Krasnyj Borek, Russia
2 – 20 July 1990, a - Chukotka, Russia, b – Ilomantsi, Finland
3 – 11 July 1991, La Paz, Mexico
4 – 3 November 1994, Criciuma, Brazil
5 – 24 October 1995, Nakhon Sawan, Thailand
6 – 9 March 1997, Chita - Pervomajskij, Siberia, Russia
7 – 26 February 1998, Guadeloupe, France
8 – 11 August 1999, Velem-Tihany-Kiskunmajsa, Hungary
9 – 21 June 2001, Sumbe, Angola
10 – 4 December 2002, Messina, South Africa
11 – 29 March 2006, Side, Turkey
12 – 1 August 2008, Novosibirsk, Russia
13 – 22 July 2009, Tianhuangping, Anji, China

Polarization of the white-light corona

Photos: I. Dorotovič

Baily‘s beads

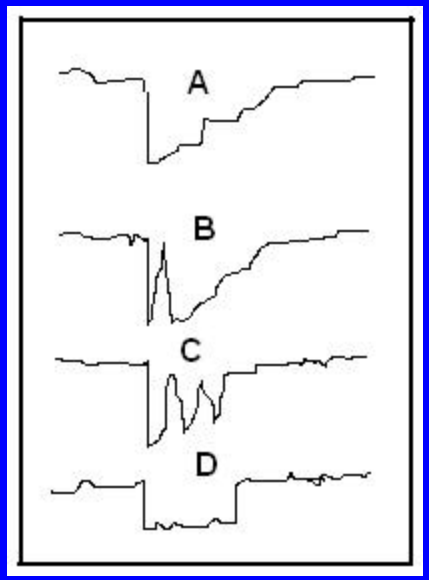
White-light corona

Photo: T. Pintér

22 July 2009, Tianhuangping, Anji, China

Characteristics of Forbush decreases in solar cycle 23:

37 FD events with a decrease > 2%,
4 types of FDs identified according to recovery phases

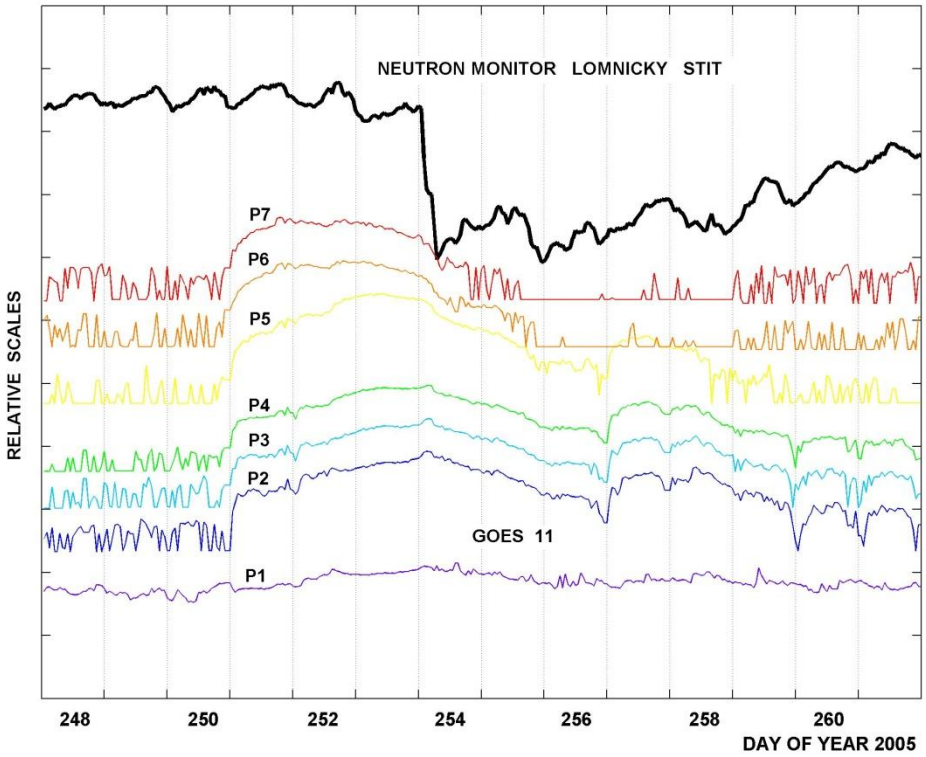


A - 20 events

B - 13 events

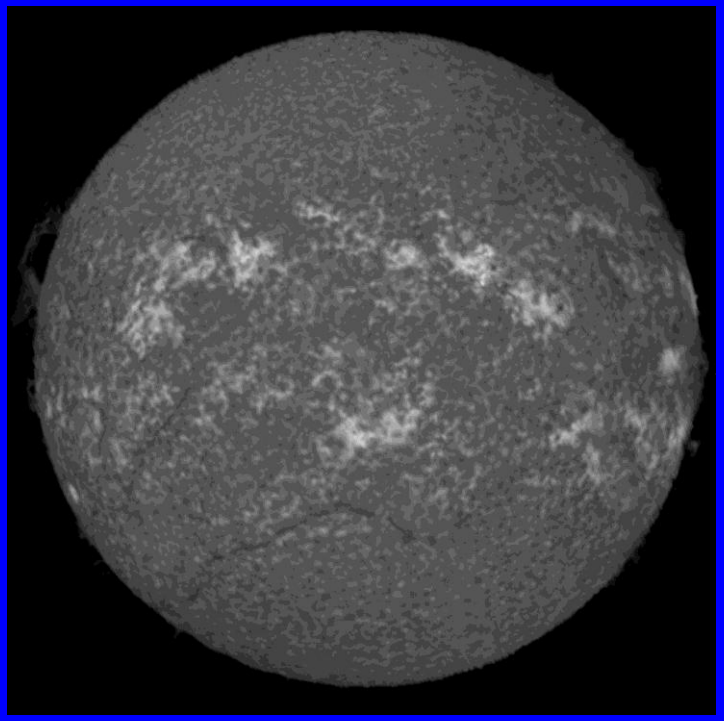
C - 3 events

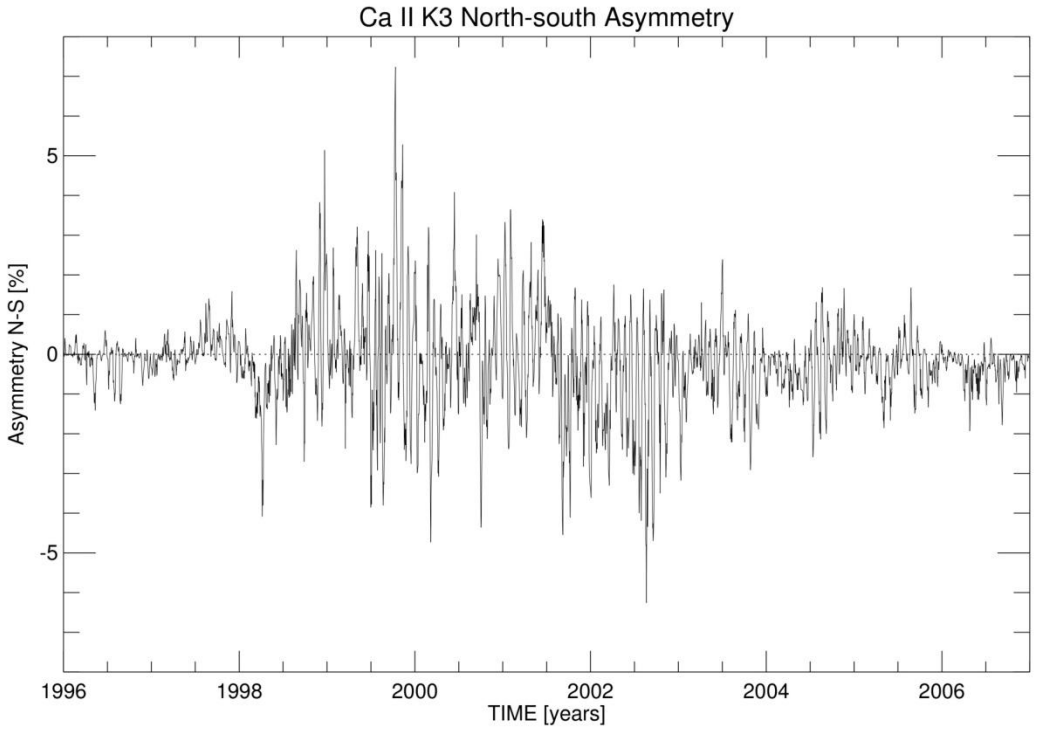
D - 1 event



Evolution of cosmic radiation and proton counts in individual channels P1-P7 (GOES 11) in 2005, DOYs 248-261.

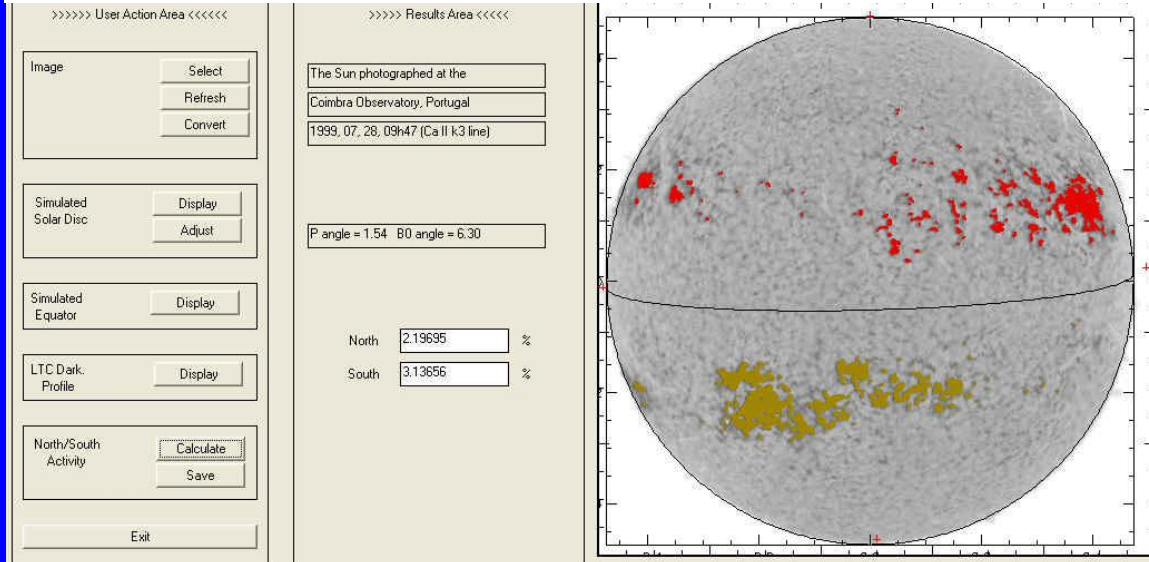
North-south asymmetry of the solar activity / CA II K3 plages:





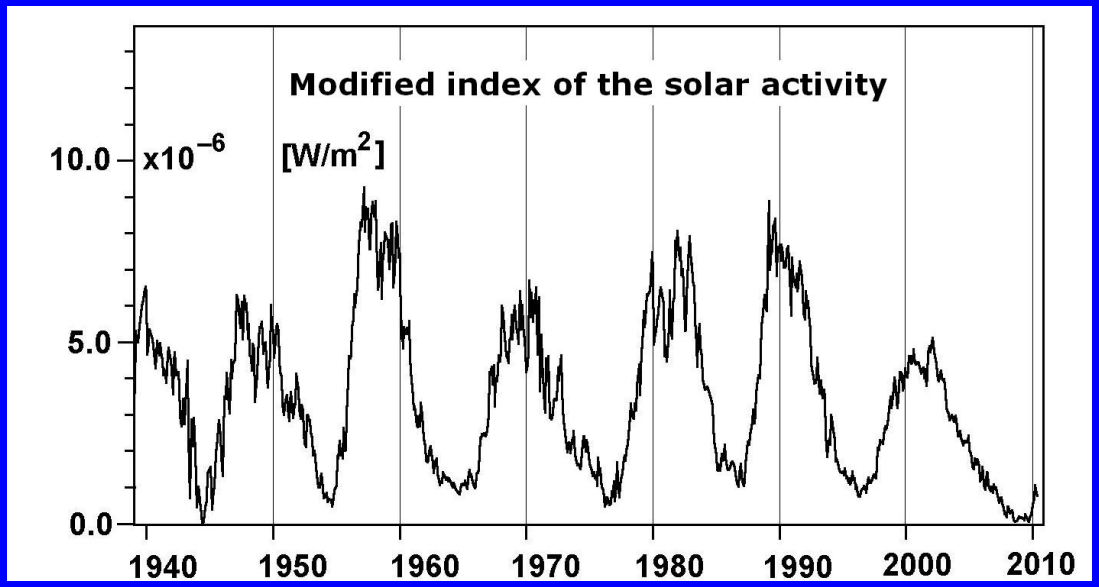
OAUC spectroheliogram

27-04-2002

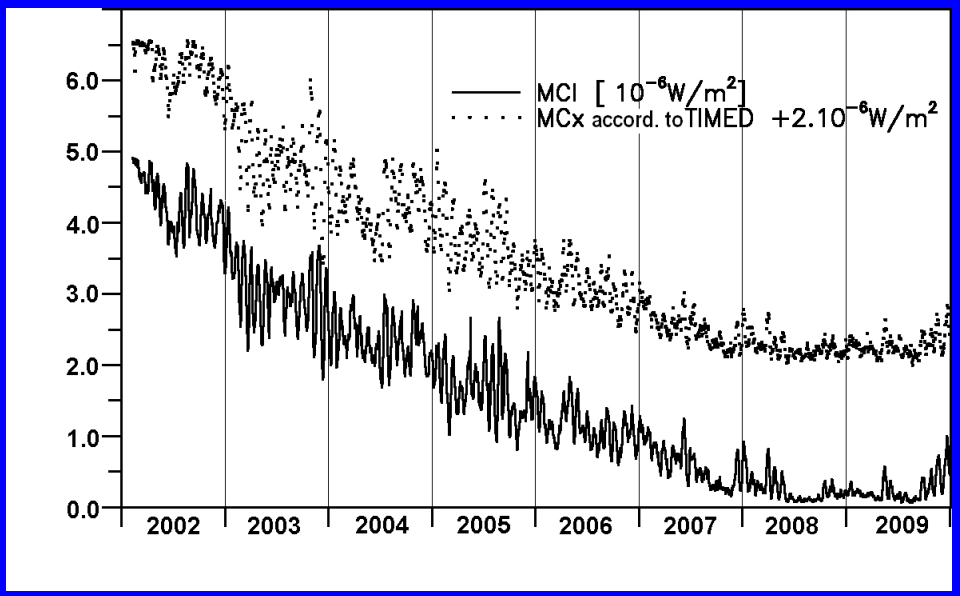


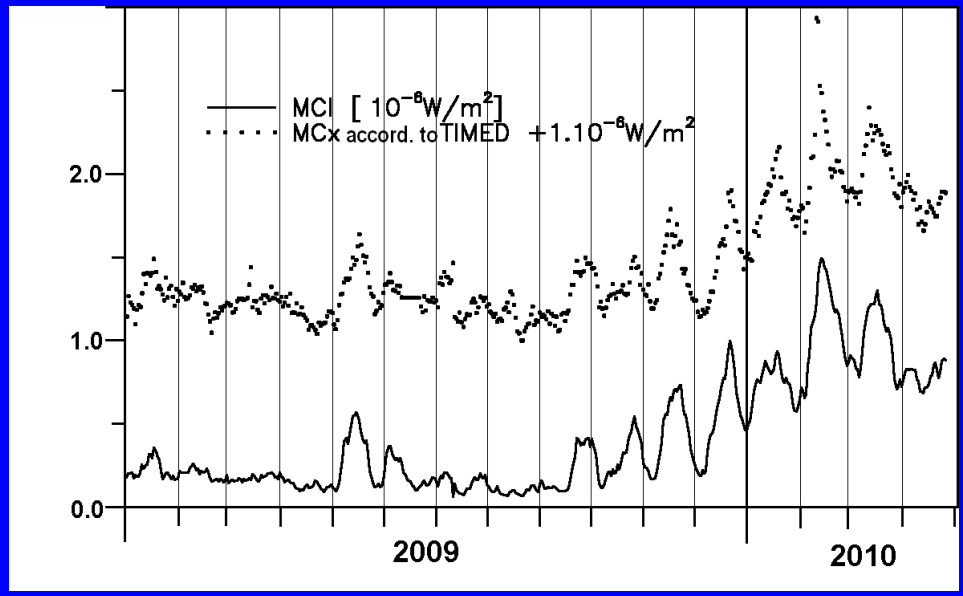
Software tool to determine the area of CA II K3 plages

Modified Coronal Index (MCI) of Solar Activity:



Evolution of the solar activity represented by the monthly means of the MCI.

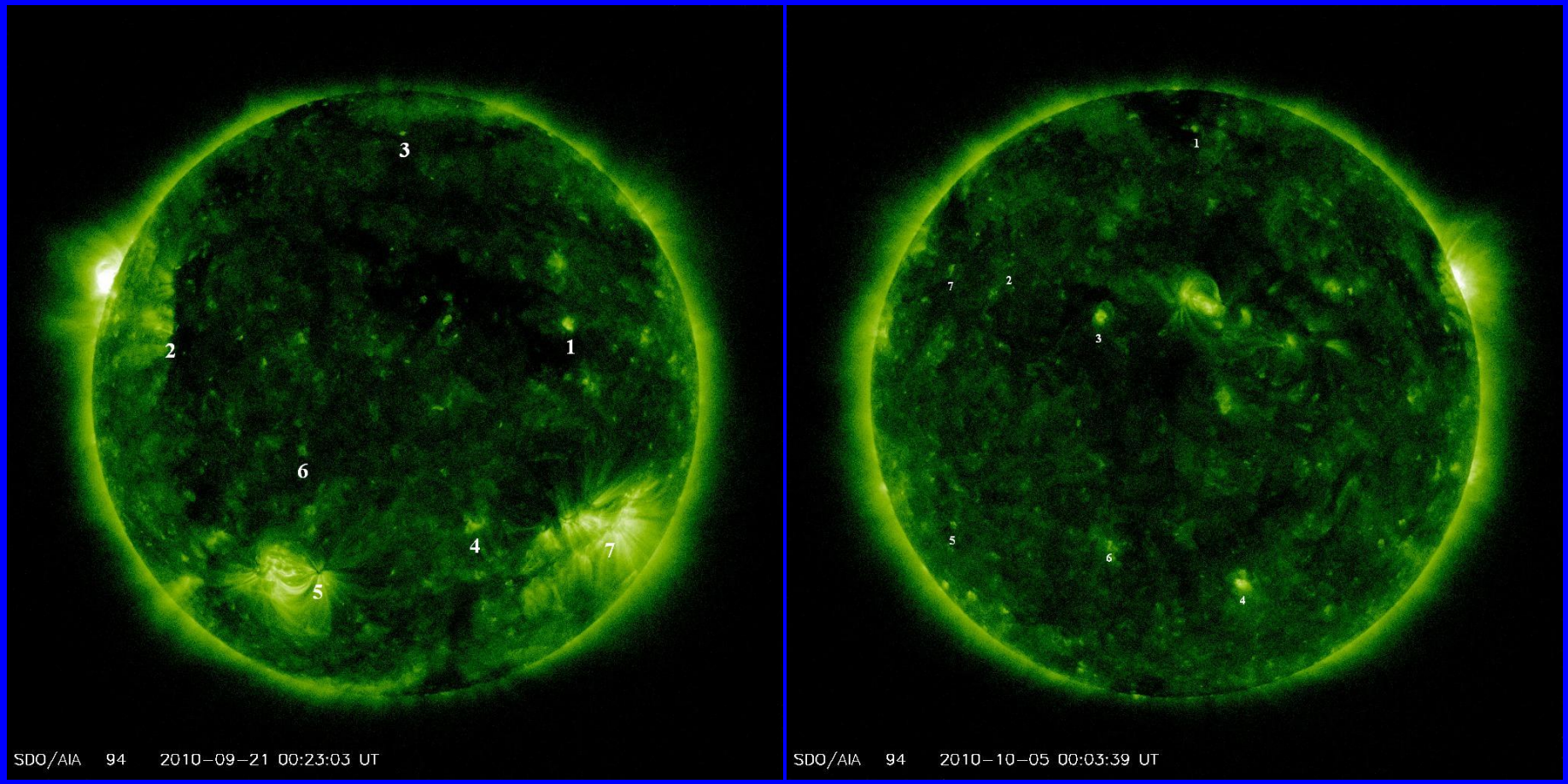




Evolution of daily values of MCI and approximated values using measurements of the TIMED satellite.

Differential rotation of the solar corona and proper motion of coronal bright points (CBPs):

- SDO images, AIA 094, used for this purpose



- calculation of angular speed of rotation for selected CBPs

Rimavská Sobota Astronomical Observatory - observational activities

- the observatory was founded in 1975

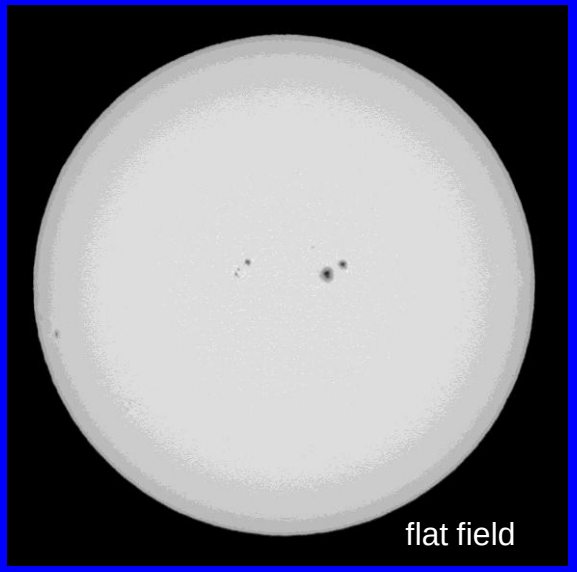
-photographic observations of the solar photosphere (full disc and the sunspot details) and prominences.

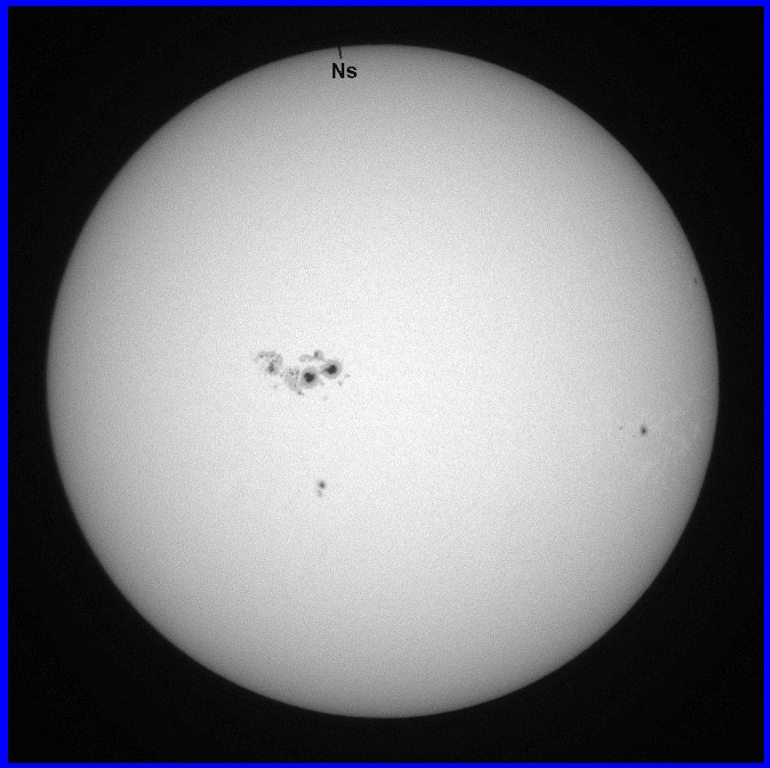
There are more than 6900 drawings of the solar photosphere (Coude refractor 150/2250, magnification 56x, projection, the diameter of the drawing: 25 cm).

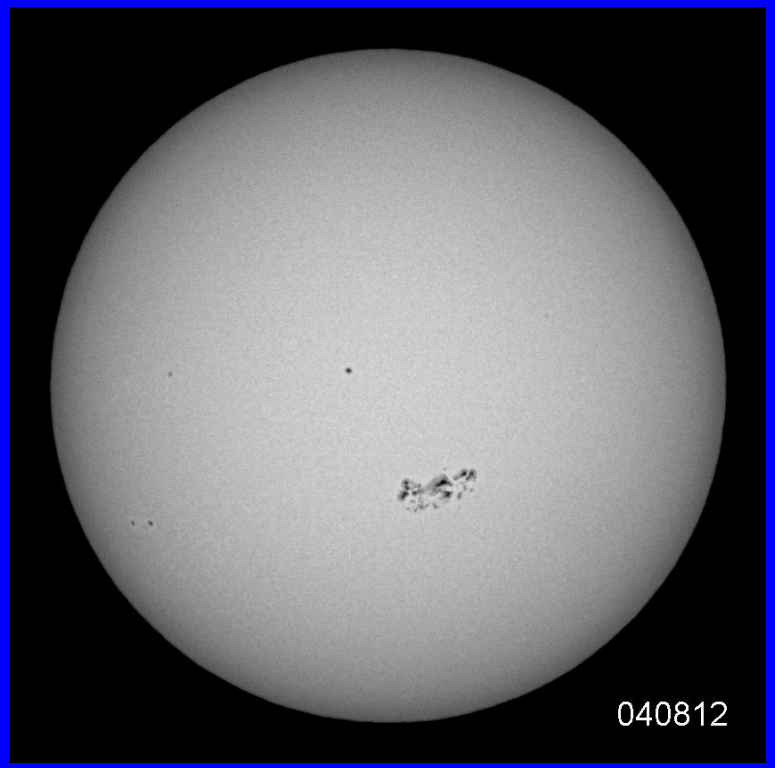
Since 2003 the details of sunspots and prominences are observed using a CCD camera SHT 1.3 (donated by the company SoftHard Technology).

Full disc

- Sonnar 4/300 + TK2, f_{ef} = 600 mm
- δ = 1,52´´
- Baader Astrosolar sheet (visual)
- field of view 0,66 x 0,82°
- resolution 2,3”/px
- exp. time ~ 10 ms

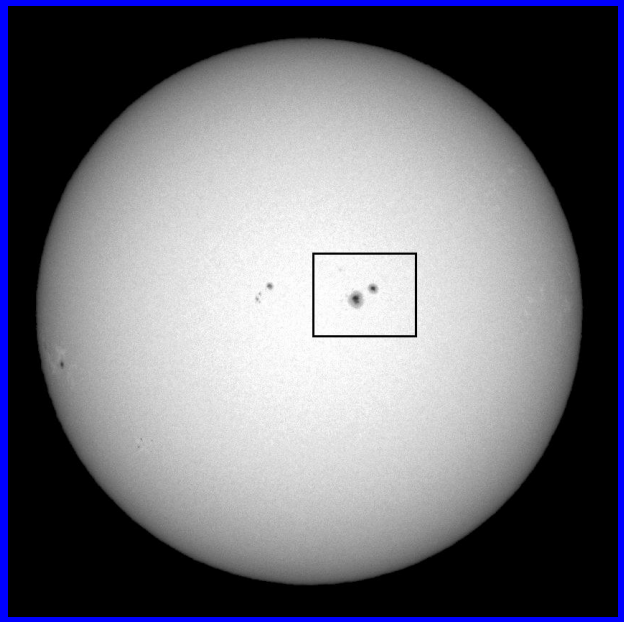


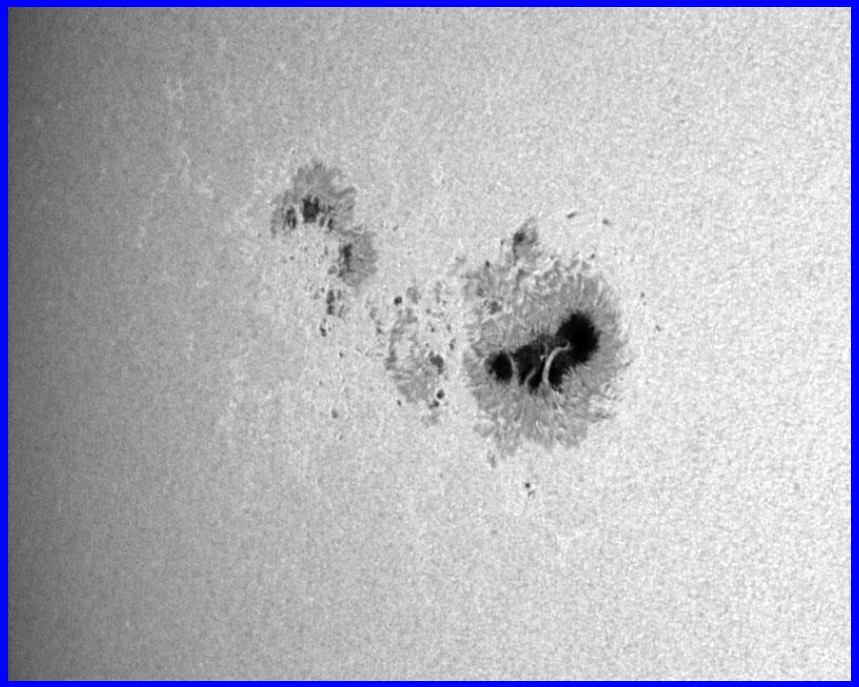


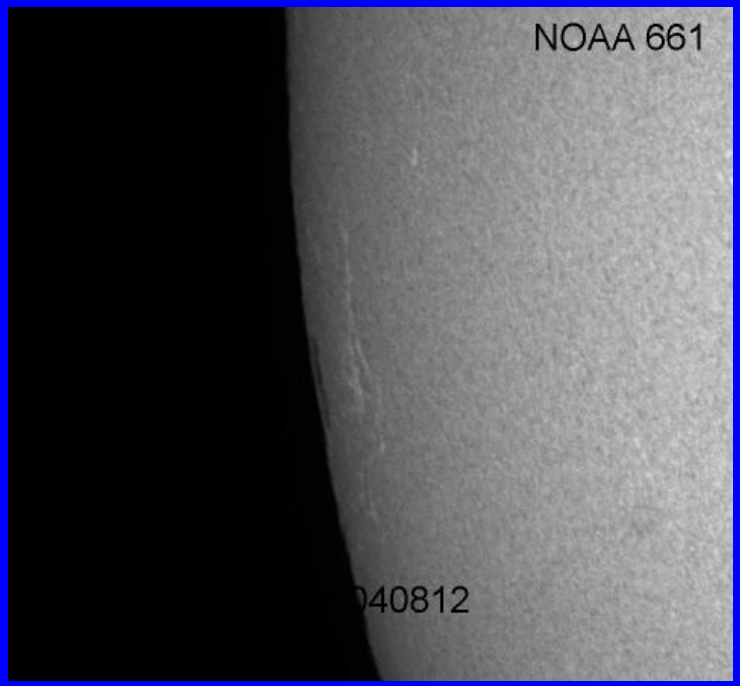


Details

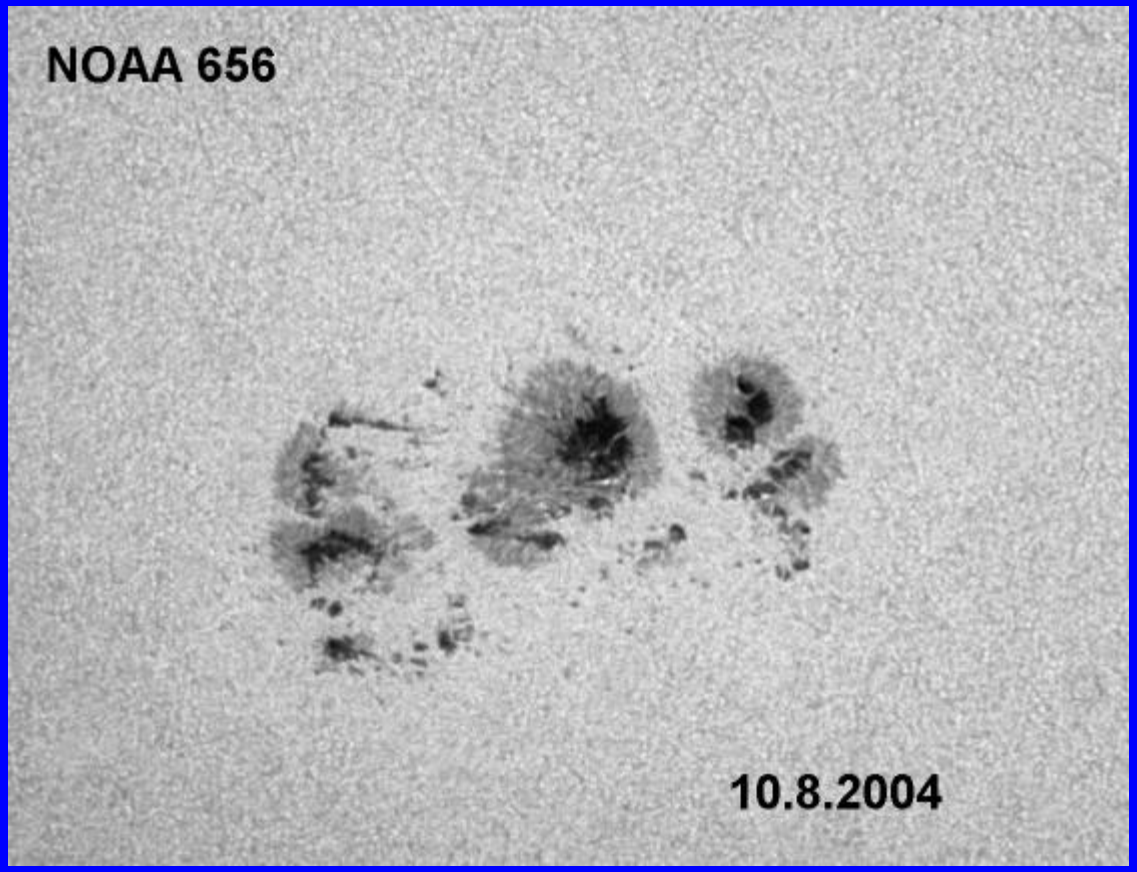
- 160/2450 + 2x Barlow
- f_{ef} = 4900 mm
- δ = 0,7´´
- Baader Astrosolar sheet (photo)
- objective dethermal orange filter
- field of view 4,8´x 6,0´
- resolution 0,28´´/px
- exp. time ~ 3 ms





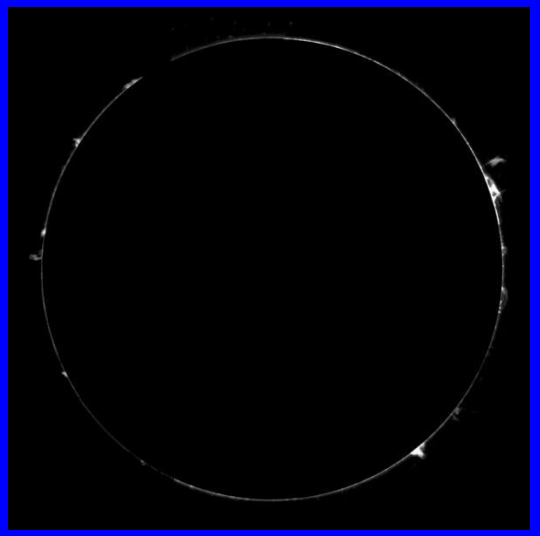


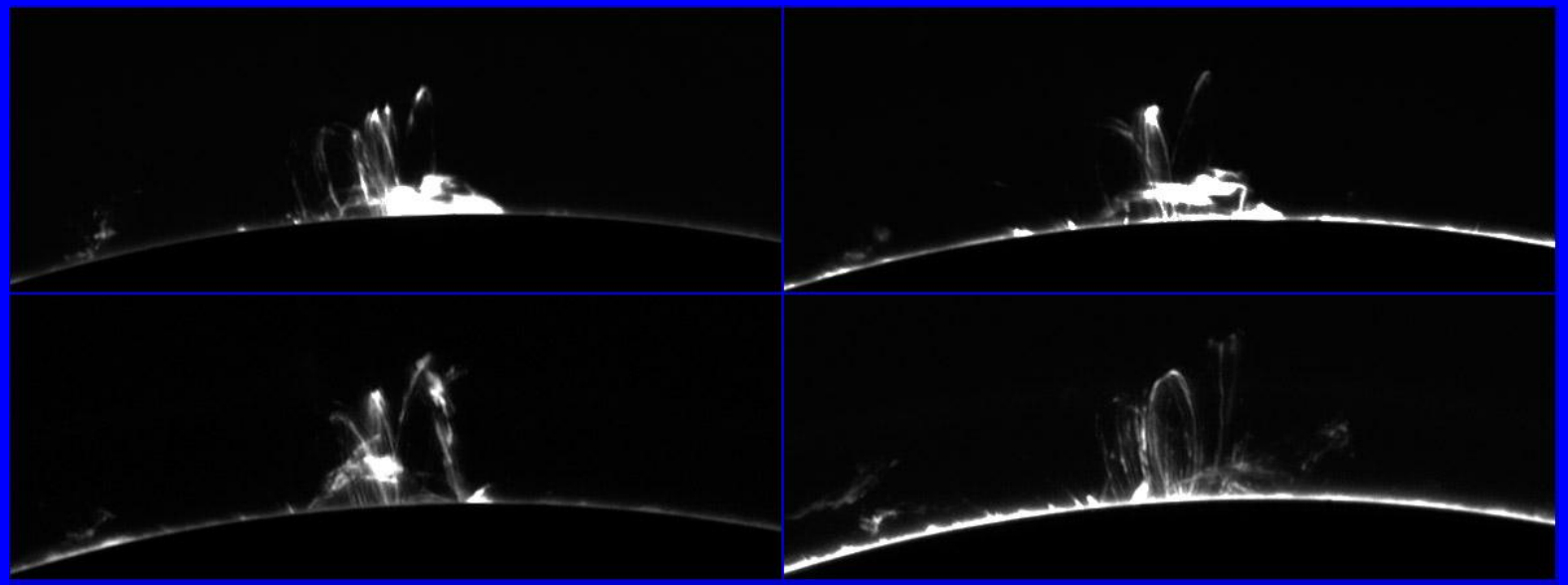
Details - animations



Prominences

- 110/1200 (Gajdušek,Otavský, Kozelský)
- f_{ef} = 1800 mm
- δ = 0,1´´
- Baader Hα filter (656,3 nm), bandwidth 0,4 nm
- field of view 13´x 16´
- resolution 0,8”/px
- exp. time ~ 13 ms
- all disc = composition 9 x 40°





Eruptive prominences PA 275, July 27,2005, 09:39-12:24 UT

Prominences - animations

SID (Sudden Ionospheric Disturbances) monitoring in Slovakia:

- registration of solar flares: **J. Karlovský** (Hlohovec) a **R. Slošiar** (Bojnice) constructed their own **SID monitors**, which are installed in Bojnice and in the Observatories Hlohovec, Hurbanovo, and Partizánske. J. Karlovský constructed also one SuperSID monitor.

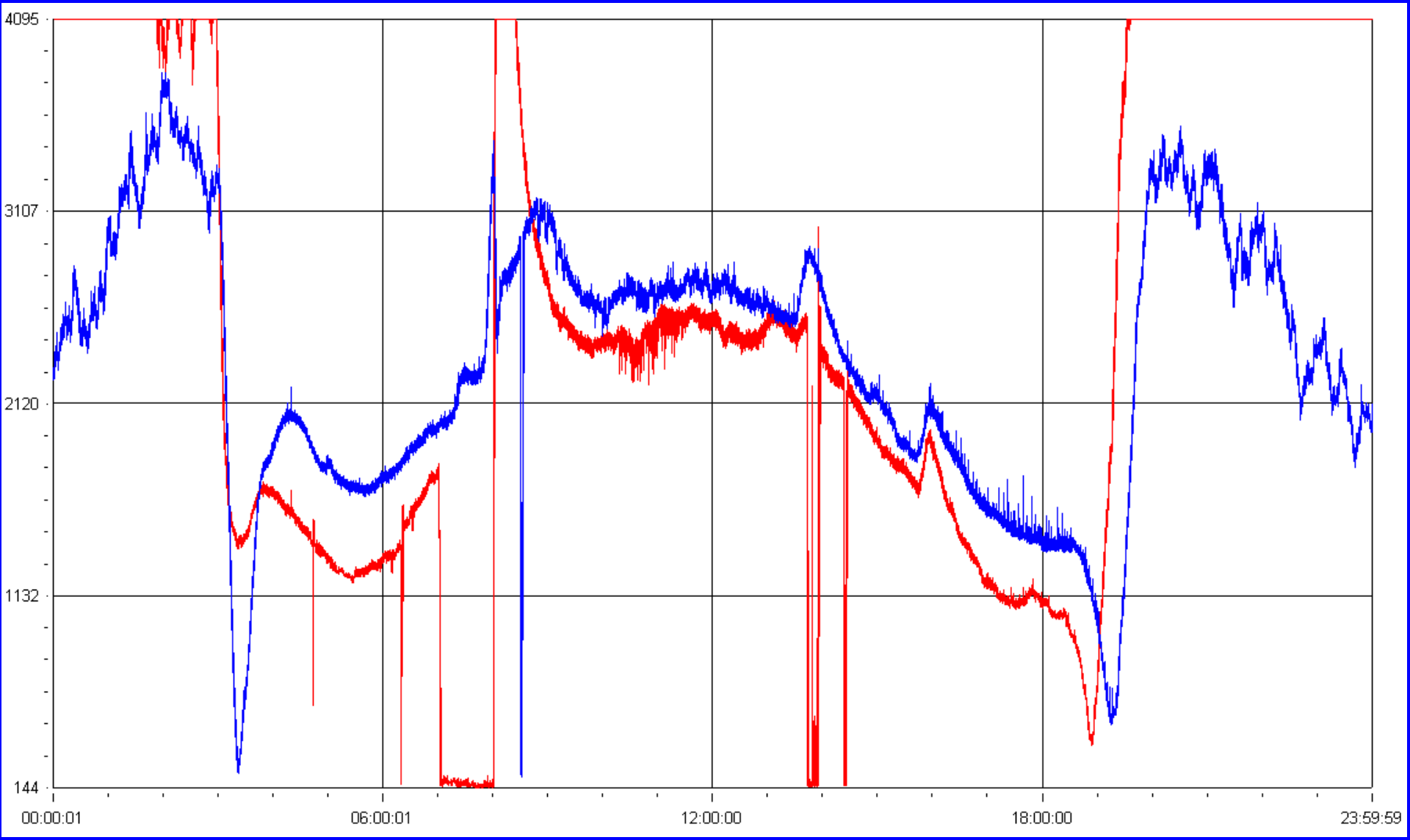
SID monitoring – real-time data:

- Bojnice
  http://195.160.182.241/page/rudy/
- Hlohovec
  http://karlovsky.info/sid/temphtml.htm
- Hurbanovo
  http://www.suh.sk/skypipedata.htm
- Partizánske
  http://195.160.182.241/page/

In the SCO Hurbanovo are also installed other **SID monitors** and one **SuperSID monitor** (this one in the frame of the ISWI program , http://www.iswi-secretariat.org/) – real-time data will be available soon. Another **SuperSID** monitor is being installed in the Astronomical Observatory in Rimavská Sobota

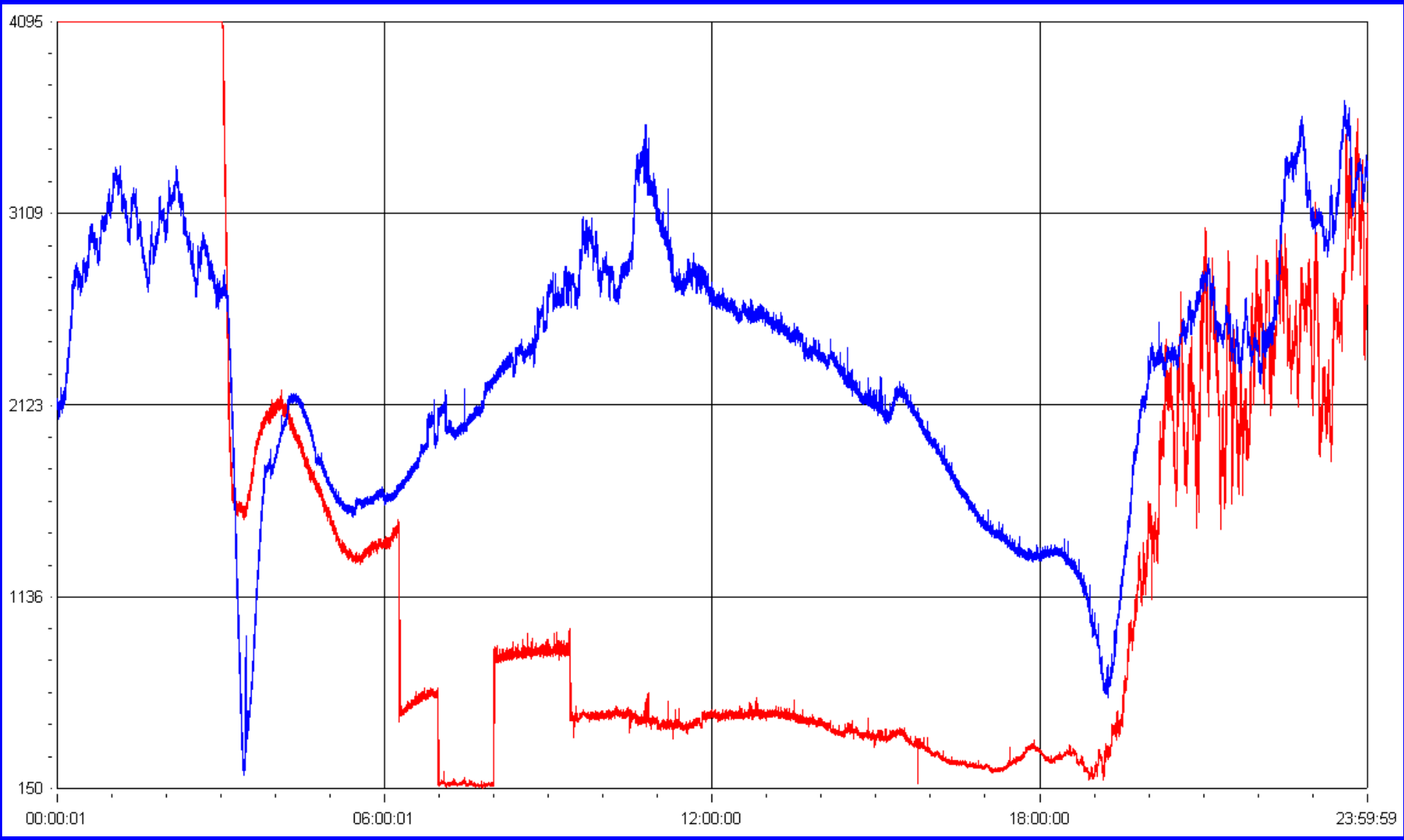
In the near future will be installed in the SCO Hurbanovo one radio spectrometer **E-CALLISTO**.

SID Monitor – Slovak Central Observatory, Hurbanovo, http://www.suh.sk/skypipedata.htm



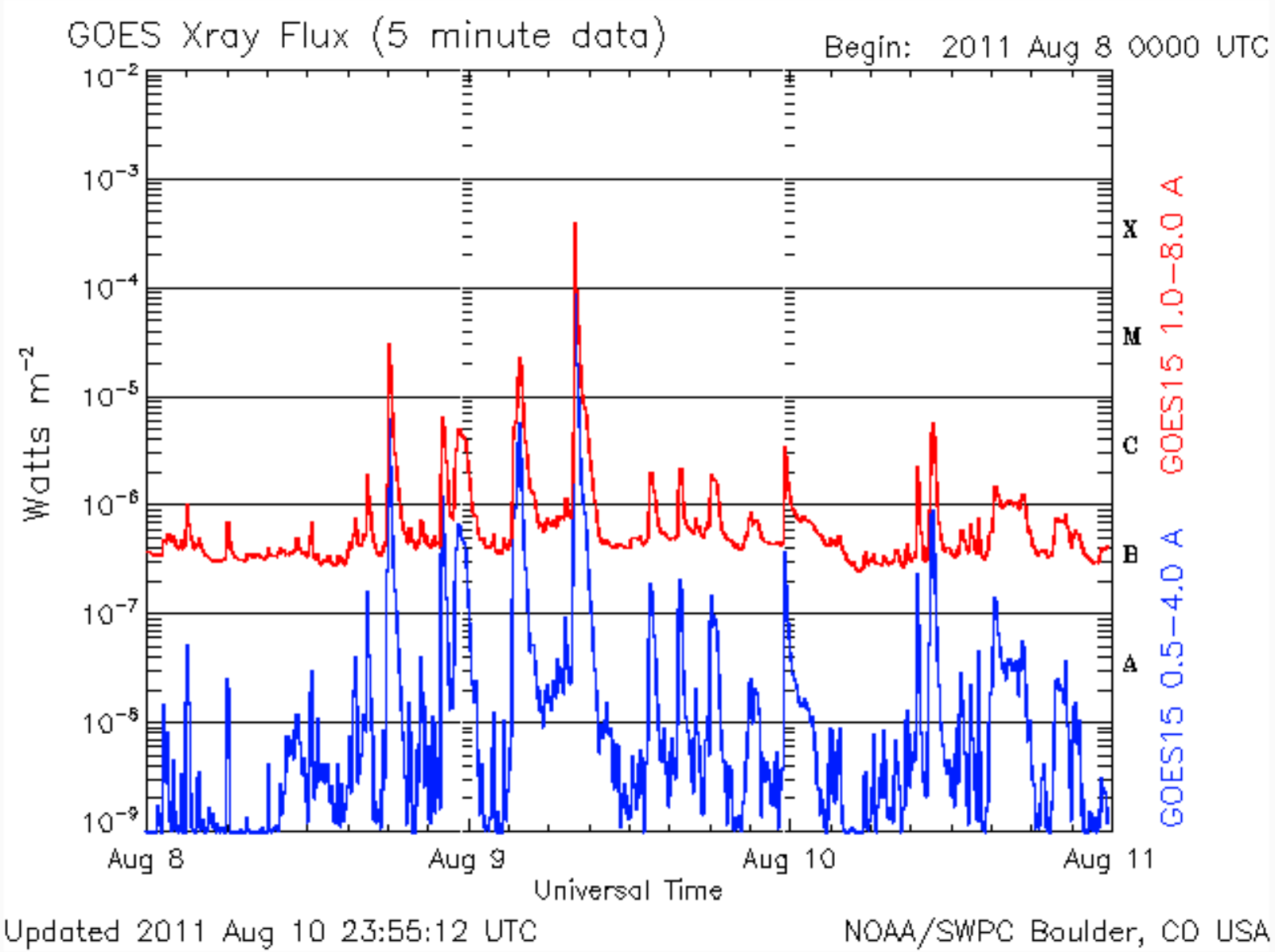
Time [UT}

9 August 2011



Time [UT}

10 August 2011


GOES Xray Flux (5 minute data)
Begin: 2011 Aug 8 0000 UTC
Watts m-2
10-2
10-3
10-4
10-5
10-6
10-7
10-8
10-9
X
M
C
B
A
GOES15 1.0-8.0 A
GOES15 0.5-4.0 A
Aug 8
Aug 9
Aug 10
Aug 11
Universal Time
Updated 2011 Aug 10 23:55:12 UTC
NOAA/SWPC Boulder, CO USA

Educational activities and public outreach:

Education and popularization of astronomy:

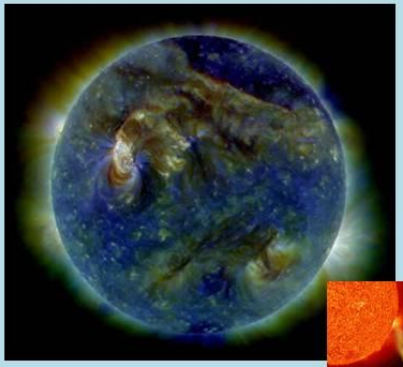
- most of the National ISWI committee members have also teaching activities.
- SCO in Hurbanovo organizes a two-years course of astronomy at high-school level including lectures on solar physics a space weather.

- Astronomical observatories and planetaria in Slovakia perform guided tours, training of amateur astronomers and students, organize public astronomical events, summer programs, lectures and competitions, publish brochures, posters and other astronomical material for visitors, etc..
- AI SAS in Tatranská Lomnica organizes guided tours, Open House days , etc.

2011 ISWI Summer School in Space Science

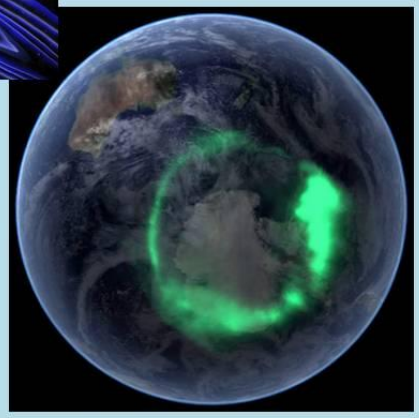
21 – 27 August 2011, Tatranská Lomnica, Slovakia

- **Organiser:** International Space Weather Initiative
- **Co-organisers:** Centre of Space Research: Space Weather Influences, Tatranská Lomnica
  Slovak Central Observatory, Hurbanovo



- **School directors:** N. Gopalswamy (Nat.Gopalswamy@nasa.gov) and I. Dorotovič (ivan.dorotovic@suh.sk)
- **Local Organising Committee:**

I. Dorotovič (chair of the LOC), E. Hodálová, SCO, Hurbanovo · J. Koza, A. Kučera, AI of SAS, Tatranská Lomnica · K. Kudela, R. Langer, IEP of SAS, Košice · M. Lorenc, T. Pintér, SCO, Hurbanovo · F. Valach – GPI of SAS, Geomagnetic Obs., Hurbanovo



- **Invited lecturers:**

Ch. Amory-Mazaudier, M. Bárta, M. Danielides, J. M. Davila, I. Dorotovič, J. Dudík, W. Dziembowski, R. Erdélyi, N. Gopalswamy, A. Hanslmeier, P. Heinzel, R. Huth, F. Jansen, F. Kamalabadi, J. Koza, A. Kučera, K. Kudela, J. Laštovička, E. D. Lopez, D. Maia, D. Odstrčil, D. Pérez-Suárez, R. A. Ribeiro, M. Sobotka, F. Valach

Website: http://stara.suh.sk/id/iswi/ISWI_School2011.htm

Slovak ISWI webpage: http://stara.suh.sk/id/iswi/iswi_SK-en.htm

International ISWI webpage: http://www.iswi-secretariat.org/