Research Interests

Observational and research experience

As an undergraduated I elaborated a dissertation entitled "Five-minute Oscillation in the Solar Photosphere" for state examination (Dorotovič, 1987). It was based on investigation of spectroscopic material obtained using horizontal solar telescope with spectrograph (HSTS) of the Slovak Central Observatory in Hurbanovo, Slovakia. Plasma motions were evaluated from Doppler shifts of the spectral line of neutral iron FeI 628 nm.

After joining the Slovak Central Observatory in Hurbanovo, I participate in following observational activities:

- **spectroscopic observations** - 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.
- daily drawings of sunspots - Coude refractor D/f of 15/225 cm.
- observation of total solar eclipses:
  - I observed the eclipses in 1998, 1999, 2009, and 2017 (experiments – structure of the infrared corona, flash spectrum, images of the white-light corona).
  - I co-operated in processing of results of the eclipse on 3 November, 1994.
- patrol observations of prominences – Lyot coronagraph D/primary focus/effective focus of 9/125/375 cm.

In the PhD Thesis „Cycle of the Solar Activity in the Corona" (Dorotovič, 1998) periodicities of various indices characterizing activity in the solar corona are investigated and results compared with periodicities of the photospheric activity and the geomagnetic activity. Some results of the thesis were published in English as well: Dorotovič (1996), Dorotovič et al. (1997a, 1997b).

Scientific advisor in past projects

"SPACE ENVIRONMENT INFORMATION SYSTEM FOR MISSION CONTROL PURPOSE – SEIS"

The **SEIS** project was presented as a poster in the:

– 17th National Meeting on Solar Physics, Tatranská Lomnica in Slovakia, 24-28 May 2004,–

– IAU Symposium No. 223: "Multi-Wavelength Investigations of Solar Activity", St. Petersburg, 14-19 June, 2004 (Dorotovič et al., 2004).

„COSIS – COIMBRA OBSERVATORY: SOLAR INFORMATION SYSTEM"

The **COSIS** project was presented as a poster in the:

- 18th National Solar Physics Meeting, 22 – 26 May, 2006, Modra, Slovakia (in Slovak),
- XVI ENAA, 21-22 July, 2006, Espinho, Portugal,
- 26th General Assembly of the IAU, Joint Discussion 8, 17-18 August 2006, Prague, Czech Republic, JD08,
- Coimbra Solar Physics Meting 2006: *The Physics of Chromospheric Plasmas*, 9 – 13 October, 2006, University of Coimbra, Portugal (Dorotovic et al., 2007b).

„SOLAR ARRAY DEGRADATION: A MONITORING AND PREDICITVE TOOL"

The radiation environment encountered in space by satellites is extremely variable and depends mainly on the satellite position and space weather status. Satellites have usually solar arrays in their power subsystem. They are a critical component of a satellite and their lifetime limits the mission's total duration. Therefore an important problem to address is the solar array performance over time. Contributed talk

presenting the software tool for monitoring and predicting the solar array performance degradation, denoted Solar Array Monitor (SAM), which was developed by the UNINOVA/CA3 research group in the frame of the European Space Agency (ESA) project, "Fuzzy Logic for Mission Control Purposes" - Case 3 AO/1-3874/01/D/HK, was accepted by the OC of the 5th international conference on optimization (Optimization2004), which was be held at the Faculty of Science, University of Lisbon from the 25th of July to the 28th of July 2004.

Research activities

„CYCLES OF THE SOLAR ACTIVITY IN THE PHOTOSPHERE, CHROMOSPHERE, AND THE CORONA"

The amount of the solar activity on the Sun is not constant, and is closely related to the number of sunspots that are visible. Variations of different indices of solar activity exhibit cyclic behaviour (11-/22-year cycle).

I have close cooperation with Dr. Rybák from the Astronomical Institute of the Slovak Academy of Sciences, Tatranská Lomnica, Slovakia. Recently we:

- investigated the temporal variability of the coronal green line index in the period of 1947 – 1998 (Rybák and Dorotovič, 2002),
- analysed a relationship between the green coronal intensities and the photospheric magnetic flux; we revealed a solar cycle dependence of this relation (Dorotovič and Rybák, 2003).

Recently some impulses of solar activity - transitory enhancements of the activity apart from the cycle maximum - have been observed (e.g. october/november 2003). An overview of this activity was published in (Pastorek et al., 2005) and (Dorotovič and Vörös, 2005), prepared in colaboration with my collegues (Dr. Pastorek, Dr. Lukáč, Slovak Central Observatory – SCO, Hurbanovo; Dr. Vörös, Space Research Institute, Graz, Austria, Geophysical Institute, Hurbanovo, Slovak Republic) and based mainly on the observations in SCO and Observatório Astronómico de Universidade Coimbra (OAUC), presented (during the 17th National Meeting on Solar Physics which will be held from 24th May to 28th May in Tatranská Lomnica in Slovakia).

North-south (N-S) asymmetry of the solar activity has been revealed in many indices of the activity. Patrice Journoud studied this asymmetry using the ionized calcium (Ca II K_3) line spectro-heliograms obtained in the OAUC. Results of this investigation were presented in (Dorotovič et al. 2007a). Later we calculated using this software tool the N-S asymmetry of the bright Ca II K_3 area for the period 1996-2006. The results of cross-correlations with the sunspot activity and the green corona intensities have been presented during the 20th Slovak National Solar Physics Meeting (Dorotovič et al., 2009).

„FINE STRUCTURES IN THE SOLAR PHOTOSPHERE"

High resolution study of photometric characteristic and structure of features in the solar photosphere has already attracted a lot of observational and teoretical interest. Overview of historical observations and new results obtained in the field is published e.g. in the reviews by Sobotka (1997, 1999); properties of fine structures in sunspots are described e.g. by Sobotka et al. (1993, 1994, 1997a, 1997b, 1999).

In April 2000 I have started my cooperation with Dr. M. Sobotka in this field. During a short-term fellowship at the IAC, La Laguna, Tenerife, Spain, I acquinted myself with basic restoration and alignment processing of raw images taken at the Swedish Vacuum Solar Telescope (SVST) on La Palma. Then images acquired on 5 June 1993 were restored and aligned as a first step. Detailed information on the observational material as well as the results of the analysis of fine structures in the leading sunspot of this group is presented in Sobotka et al., 1997a. Investigation of temporal evolution of fine structures in and around the pore (which was in the field-of-view of the SVST as well) was the subject of our further common research during my next short-term stays at the Astronomical Institute, Ondřejov, Czech Republic. A paper Dorotovič et al. (2002) with results of this investigation has been already published in the Astronomy and Astrophysics. Currently, Patrice Journoud is investigating plasma flows around a solar pore using this images.

I would like to continue this research (penumbral extensions and their relation to the umbral dots) by processing and investigating further La Palma Obs. series of high-resolution observations of features in the solar photosphere.

SPACE WEATHER:

„ SOLAR WIND – EARTH'S MAGNETOSPHERE COUPLING; SOLAR RADIATION, CORONAL MASS EHECTIONS – CMEs"

It is know for many years that there exists strong solar wind – Earth's magnetosphere coupling. Space weather could cause manifold problems in the technological systems (spacecrafts, airplanes, ground-based technological systems) and in the human beeing. Therefore it is necessary to monitor and predict the space weather effects and improve the space weather services. There is general need to predict also the geomagnetic activity as accurately as possible. Deterministic models (e.g. nonlinear prediction filters, neural networks) which use only the time series of Ey and some other solar wind parameters can predict the time evolution of geomagnetic indices with relatively high accuracy and can account for ~70-90% of the observed geomagnetic variance. Recent studies have already posed the question about the influence of small-scale solar wind turbulence on the efficiency of solar wind – magnetosphere coupling. A consideration of turbulence characteristics in prediction schemes could increase the accuracy of predictors. First results of the study of this topic (I. Dorotovič, Z. Vörös [Space Research Institute, Graz, Austria and Geophysical Institute, Hurbanovo, Slovak Republic]: Examining the role of turbulence in the solar wind - magnetosphere interaction processes) were presented in (Dorotovič and Vörös, 2004). Wider statistical study of intermittency parameters (skewness and kurtosis) during selected coupling events in the period of 1996-2002 was presented in (Dorotovič and Vörös, 2005) .

Cross-correlation between variations of solar radiation and sunspot and CME activity respectively, in the 23rd solar cycle was studied in (Lorenc et al., 2008).

„SOLAR ACTIVITY, EARTH'S CLIMATE AND FOREST GROWTH"

It is generally known that the Sun is the main driver of the space weather (SW). An increasing number of studies indicates that variations in solar activity (SA) and SW have had a significant influence on Earth's climate. Obviously, the amount and intensity of sunlight impacts on tree growth, in addition to rainfall, humidity, soil nutrients etc. The most important aspect of the solar variability is the 11 year cycle, and also 22 year magnetic cycle, observed in sunspot number variations. Examinations of tree rings seem to indicate that tree growth is affected in these cycles - there is evidence that the thickness of tree ring depends on the level of the solar activity. In the frame of this activity correlation study between the solar activity and cork oak production as measured on selected trees in Coruche, Portugal by Dr. P. Surový from the University of Évora has been carried out. The results obtained show a slight increase of this production in 1997 which is one year after the minimum of the SA (Surový, 2008). We investigated also impact of solar activity on the growth of pine trees (*Pinus cembra*: 1610 – 1970; *Pinus pinaster*: 1910 – 1989). The width of the annual rings was smaller in the years of maximum SA; furthermore, in the case of *Pinus pinaster* it was found that it is the latewood growth that it is affected while the earlywood growth is not affected, as a corollary the percent of late wood also shows a significative negative correlation with SA (Surový et al., 2010).

Dorotovič and Trigo (2010) found certain influence of solar activity on modes of tropospheric circulation variability represented by North Atlantic Oscillation (NAO) index and Arctic Oscillation (AO) meteorological indicies, respectively. It was found some stratification of the NAO index with solar activity, i.e. that the shape of probability distribution functions (PDFs) of these indicies is slightly different during individual solar cycle phases.

„FORBUSH DECREASES AND GROUND LEVEL ENHANCEMENTS OF THE COSMIC RADIATION "

Space weather events during strong Forbush Decreases (FDs) in January 2005 were analysed using both the satellite and ground-based data (Dorotovič et al. 2008a, 2008b). In the paper (Dorotovič et al., 2009) we identified several additional events in the period between 1995 and 2007. We found that the majority of FDs studied is accompanied by an abrupt count increase in the proton channel P1 and by a simultaneous decrease in the channel P7 (GOES). Rybanský et al. (2010) identified four types of FDs according to their recovery phase to the original level. Firoz et al. (2011) studied relationship of ground level enhancements (GLEs) with several solar, interplanetary and geophysical parameters.

Mobility project Slovakia – Portugal 2015 (SK-PT-2015-0004)

Title: Evolution of Solar Activity over a Solar Cycle – from Statistics to Physics
Acronym: ESASOC
Period: 1 January 2016 – 31 December 2017
Partners: *Slovakia*: Slovak Central Observatory, Hurbanovo and Astronomical Institute SAS, Tatranská Lomnica; *Portugal*: Geophysical and Astronomical Observatory of the University of Coimbra (Observatório Geofísico e Astronómico da Universidade de Coimbra – OGAUC), Coimbra and Computational Intelligence Research Group of the Institute of Developing New Technologies – CTS/UNINOVA-CA3, Caparica

In this project we investigated the evolution of solar features over the 24th solar cycle using the high spatial and temporal resolution observations using the instruments Helioseismic and Magnetic Imager (HMI) and Atmospheric Imaging Assembly (AIA) onboard the Solar Dynamics Observatory (SDO) and using the spectrograms (Ca K1 and K3, H-alpha) taken by the Geophysical and Astronomical Observatory in Coimbra (Portugal). The main aim was to obtain knowledge about the distribution of solar features on the solar disc over a solar cycle (north-south asymmetry) and about characteristics of differential rotation of the Sun. A better understanding of solar activity (SA) processes will contribute to improve knowledge about solar cycles evolution, space weather forecasting models and ultimately designing better early warning systems that could help taking pre-eruptive measures to avoid damages caused by solar storms. To enable the proposed studies and fulfill the objectives software tools for detection, identification and automatic tracking of various solar phenomena (sunspots, plages, coronal bright points) has been already developed. It is based on the Gradient Path Labelling method (Dorotovič et al., 2018) and a mathematical morphology method (Barata et al., 2018), respectively. The first software tool can be used for calculation of angular rotational speed (**differential rotation**) of coronal bright points (CBPs) and other solar features, and the second one for the calclulation of the **north-south asymmetry of the solar activity**. The software tools will require further extensions and improvements to fully answer the proposed objectives.

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