PROPOSAL FOR OBSERVING PROGRAM 2007
for the Dutch Open Telescope (DOT) combined with RHESSI/SoHO/TRACE observations

Title of the program:	Physical mechanisms driving solar microflares and supergranular network dynamics – relevance for coronal heating and mass supply

Principal Investigator:	Ján Rybák
Affiliation:	Astronomical Institute, Slovak Academy of Sciences, SK-05960 Tatranská Lomnica, Slovakia
Email address:	choc@astro.sk
Co–Investigators:	Astrid Veronig[1], Peter Gömöry[2], Sigrid Stoiser[1]
Affiliation(s):	1 – Institute for Physics/IGAM, University of Graz Universitaetsplatz 5, A-8010 Graz, Austria 2 – Astronomical Institute, Slovak Academy of Sciences, SK-05960 Tatranská Lomnica, Slovakia
Email addresses:	asv@igam.uni-graz.at, gomory@astro.sk, sis@igam.uni-graz.at

Type of the program: DOT chromospheric and photospheric high-cadence imaging

Targets: active regions or at least magnetic flux concentrations near the disk center, chromospheric network near the disk center.

Cooperating instruments: Reuven Ramaty High Energy Solar Spectroscopic Imager satellite (RHESSI); Transition Region and Coronal Explorer satellite (TRACE); Solar and Heliospheric Observatory satellite (SoHO): Coronal Diagnostic Spectrometer (CDS), Michelson Doppler Imager (MDI), Extreme-ultraviolet Imaging Telescope (EIT); Kanzelhöhe Solar Observatory (KSO): Hα telescope. Hinode X-Ray Telescope (XRT) and EUV Imaging Spectrometer (EIS) instruments time will be applied for once the DOT time will be allocated.

Scientific objectives:

This proposal merges together attempts to observe two kinds of solar structures – solar microflares and supergranular network – which are planned to be investigated to address common open questions of their drivers and their impact on the coronal heating and dynamics.

Microflares are small-scale dynamic events potentially important for the heating of the solar corona as well as for the mass supply to the corona and the solar wind. At present, mainly two types of models are invoked to understand the heating of the corona: a) AC (alternate current) models in which the energy is transported by (various) types of waves in a magnetized plasma from the convection zone to the corona where they dissipate their energy; b) DC (direct current) models in which magnetic free energy is accumulated in the corona by (slow) footpoint motions, and explosively released via magnetic reconnection in numerous small-scale flare events, so-called microflares or nanoflares. Intrinsically, due to their small sizes and fast dynamics, the analysis of microflares demands high spatial resolution observations combined with good temporal cadence. Our objective is to analyse the dynamics and plasma evolution during microflares by studying the chromospheric response to electron beam and/or conductive heating (flare footpoints: RHESSI hard X-rays, DOT Hα and Ca II H) together with the transition region and coronal response (flare loops: RHESSI and Hinode XRT soft X-rays, post-flare loops: TRACE EUV) in imaging data combined with X-ray spectral analysis (RHESSI soft and hard X-rays). These observations will allow us to draw inferences on the plasma temperature and emission measure evolution as well as on the importance and energetics of accelerated electrons in microflares. The RHESSI instrument has an unprecedented spectral resolution of 1 keV as well as unprecedented sensitivity in the range 3–20 keV, where the transition between thermal and non-thermal emissions is supposed to take place, which makes it a highly valuable instrument for the analysis of microflares (cf. the RHESSI microflare studies by Benz & Grigis 2002, Solar Phys. 210, 431; Krucker et al. 2002, Solar Phys. 210, 225; Liu et al. 2004, ApJ 604, 442; Qiu et al. 2004, ApJ 612, 530). In addition, we also plan to use CDS spectroscopy in order to study mass motions related to the chromospheric evaporation process. The comparison of these observational data with theoretical predictions in the frame of electron-beam-driven and conductively driven chromospheric evaporation for individual microflares can help us to better understand: a) whether non-thermal electrons are present in microflares which hints at magnetic reconnection as the underlying physical process, b) how much plasma is brought into the corona by microflares, c) which process (electron beams or heat conduction from the hot coronal microflare plasma) dominates the mass transport, d) how much energy is deposited during microflares which is available for the heating of the corona.

Similar studies have been applied to regular, i.e. larger flares (Veronig & Brown 2004, ApJ 603, L117; Veronig et al. 2005, ApJ 621, 482) as well as to microflares (Stoiser 2004, diploma thesis, Univ. Graz). It turned out that large uncertainties in the obtained parameters are introduced by the limited spatial resolution of X-ray instruments which most probably give upper limits to the flare source sizes, whereas the high-resolution observations from TRACE hint at very fine thread-like flare structures. However, due to the temperature coverage ($\lesssim 2$ MK; the 195 Å channel, however, may also have substantial contributions from Fe XXIV at ~ 20 MK) the coronal TRACE observations are generally restricted to the post-flare phase and do not allow direct insight into the important impulsive flare phase. In this respect DOT offers the great possibility to study the chromospheric flare response with very high spatial resolution (as high as $0.2''$) at two different heights of the chromosphere using the Hα and Ca II H lines. Combined with good temporal resolution this will provide us with better insight into the source sizes related to the impulsive phase as well as the source evolution and complexity.

Supergranular network is clearly related to the heating of the corona as well. On the other hand its close relation to the underlying layers is obvious today. Photospheric and chromospheric layers are planned to be investigated in order to identify the most probable physical mechanisms responsible for the energy transfer and dynamics of the solar corona above the chromospheric network. Our previous results derived from data of the SOHO JOP 78[1] indicate the presence of downward propagating waves in/above the chromospheric network and led to the assumption that reconnection of the magnetic field lines should be the dominant mechanism to heat the solar corona above the particular chromospheric network (Gömöry at al. 2006, A&A 448, 1169). In contrast, findings of other authors (e.g. Marsh et al. A&A 404, L37 (2003)) show evidence of propagating intensity oscillations spreading out from the photosphere to the corona and therefore prefer alternative heating mechanism of the corona, i.e. dissipation of magneto-hydrodynamic waves which originate from the solar convective zone. To clarify these findings a new joint observing program (JOP 171) of the SOHO instruments (CDS, EIT, MDI) and the TRACE satellite was proposed. First runs of the JOP 171 were already performed but only with very limited support of the photospheric measurements. As the drivers of all proposed heating mechanisms are localized in the photosphere, additional information are necessary to data of the JOP 171 for better identification of the heating mechanism. We expect that time series of the speckle-reconstructed DOT filtergrams taken simultaneously with the CDS spectra will provide an excellent material to study the properties of the mentioned drivers.

[1] Details at: `http://sohowww.nascom.nasa.gov/soc/JOPs/jop078/jop078.html`

Planned analysis:

Microflares: we plan to use the high-resolution images acquired by the DOT in the center of the Hα and Ca II H spectral lines in a high time cadence mode in order to study the chromospheric signature of microflares in terms of geometry/topology, source sizes, and evolution. These data shall be combined with observations from RHESSI, Hinode XRT, SoHO/EIT-MDI-CDS, TRACE and KSO. RHESSI and KSO data will be available in the desired mode. As regards the TRACE and SoHO/EIT-MDI-CDS observations, we will propose a JOP campaign and ask for allocating the observing time in case that DOT observing time for the planned project is allocated.

The RHESSI instrument will be used to study the high energy-component of the microflares: evolution of the integrated full-Sun soft and hard X-ray fluxes (thermal-nonthermal behaviour); imaging of the soft X-ray flare loop and, if possible, also of the hard X-ray footpoints (which depends on the count statistics which is intrinsically low in microflares); X-ray spectroscopy in the range 3–20 keV to study the thermal flare plasma and the energetics and importance of accelerated electrons.

Hinode XRT SXR images will be used to study flare loops in terms of connectivity and source sizes.

TRACE 195 Å EUV images will be used to study post-flare loops in terms of connectivity and source sizes. The delay between the impulsive phase and the appearance of the post-flare loop in the TRACE 195 Å (Fe XII) channel together with the flare peak temperatures inferred from RHESSI spectroscopy also allows us to get insight into the cooling of the flare plasma.

High resolution longitudinal photospheric magnetograms from the MDI/SoHO instrument studied in combination with the chromospheric and coronal flare emission (DOT, RHESSI, TRACE, Hinode XRT) will allow us to get insight into the magnetic topology and connectivity of the microflares.

CDS spectroscopy will be applied in order to study mass motions related to chromospheric evaporation in microflares.

Supergranular network: the CDS spectroscopy, although of low spectral resolution, provides a perfect temperature coverage of the line emission from chromosphere up to the corona. Therefore, the CDS data are planned to be used for the study of waves in the upper solar atmosphere and for the determination of direction of the wave propagation. To do that we will apply cross-correlation technique (Gömöry at al. 2004, ESA SP-575, 400) and wavelet analysis on the intensities and the Doppler shifts of the selected CDS spectral lines.

The main argument to try to acquire DOT data is that the filtergrams taken in the G-band and red and blue continuum should enable us to analyze footpoints of the magnetic field concentrations. (Complementary SOHO/MDI magnetograms will be also used for the study of the evolution of the photospheric magnetic fields.) These magnetic elements, visible as the photospheric bright points concentrated in the network, are considered to be the prime candidate for drivers of the coronal heating mechanisms (Muller at al. 1994, A&A 283, 232). Moreover, time series of the DOT filtergrams taken in the Ba II 4554 Å, Hα and Ca II H spectral lines will provide additional information about the behaviour of waves in the upper solar photosphere and chromosphere, and will therefore allow a better identification of the coronal heating mechanism.

TRACE measurements will be used mainly for searching for the transition region and coronal responses of the propagating/standing waves.

The spatial co-alignment of the data taken by different instruments will be primarily performed in the following way:

- CDS → EIT: using CDS rasters taken in the He I 584 Å line and EIT filtergrams taken in the He II 304 Å line
- EIT → TRACE: using EIT and TRACE data taken in 195 Å channel
- TRACE → DOT: using TRACE data taken in 1600 Å channel and the DOT filtergrams taken in the Ca II H line (or using white light images if some significant pores will be available in the field-of-view of both instruments)

Time allocation request:

Number of days needed: 14 – 28 (2x14) days
Preferred times: none
Impossible times:

10 Sep 2007	–	11 Nov 2007	MDI 60 Day Continuous Contact Period
12 Feb 2007	–	13 Mar 2007	SoHO Keyhole
17 May 2007	–	06 Jun 2007	SoHO Keyhole
11 Aug 2007	–	10 Sep 2007	SoHO Keyhole
14 Nov 2007	–	03 Dec 2007	SoHO Keyhole

We note that we can perform our study also using MDI full-disk images, i.e. also during the listed time of MDI 60 Day Continuous Contact Period in case that the remaining periods are in conflict with other observations (although, of course, high-resolution MDI maps are preferred).

Observing procedures and requirements:

DOT:

As the main goal we plan to observe with the highest possible time cadence in the Ca II H and Hα spectral lines – cadence of 10 s for speckled images. For further context information on photospheric layers and magnetic flux concentrations (as well as for co-alignment between the various instruments) continuum and G-band images are planned to be acquired, for which a lower time cadence than in Hα and Ca II would suffice.

The support of cooperating instruments (i.e. TRACE, SoHO/CDS-EIT-MDI) will be requested only when our DOT observing time will be allocated. The same procedure will be applied for the Hinode instruments, in particular for XRT and EIS.

RHESSI:

RHESSI observes the Sun in soft and hard X-rays (as well as γ-rays) with a full-Sun field of view. Interruptions of the observations are due to the spacecraft day/night cycle (1 RHESSI orbit $\sim$97 min) and passages over the South Atlantic Anomaly. The maximum spatial resolution is $2.3''$ and the highest time resolution is 2 s depending on count statistics. For microflares the spatial resolution is usually restricted to $7''$ and the time resolution in imaging and spectroscopy to $\gtrsim$20 s. The temporal resolution for the flux evolution in X-rays may be as good as 2 s also for microflares. Microflare studies with RHESSI require that there is no attenuator in the detectors field of view (A0 state) in order to ensure highest sensitivity at low X-ray energies. The A0 state is the default RHESSI observing mode during times of low solar activity which is expected to be the case during the phase of solar cycle minimum in 2007.

CDS, EIT, MDI:

The observing sequences of the CDS, EIT and MDI instruments on-board SoHO are planned in the same mode as described in the proposal of the JOP 171 observing program which is available at `http://sohowww.nascom.nasa.gov/soc/JOPs/jop171`.

TRACE:

We are interested to acquire high resolution EUV images (0.5″) in the Fe XII 195 Å spectral channel with high temporal cadence (5–10 s). A set of white light and UV 1600 Å continuum images shall be acquired as context information as well as for co-alignment purposes.

KSO Hα:

The Kanzelhöhe Solar Observatory (KSO) takes regularly Hα full-disk images (2.2″/pixel) with a cadence of 5 s. These images will be used as further context observations with a much extended field as compared to the DOT Hα.

Additional information:

We apply for the external usage of the DOT in a service mode in which the DOT team operates the telescope. No personal assistance of the proposers is planned on La Palma. The planned JOP campaign shall be run from the proposers' home institutions.

In year 2006 two separated campaigns led by P. Gömöry and A. Veronig were merged together by the DOT TAC to share the common time period. This policy was found to be optimal during the campaign performance in July 2006 when the targets were selected according the current activity conditions around the disk center of the Sun. Based on this experience we apply for the DOT time with a joint proposal.

Some very promising data were obtained during the DOT 2006 campaign. Data were briefly analyzed and the list of priority was prepared listing 4 different data sets. Data are currently under detailed analysis. Details of the performed campaign and a brief summary of the acquired data sets are available at `http://www.astro.sk/~choc/open/06_dot/06_dot.html`. This re-application for the DOT time is mostly motivated in order to acquire more data sets, and better co-spatiality of the CDS data with the microflare occurrence and magnetic field concentrations located in the network.