PROPOSAL FOR OBSERVING PROGRAM 2006
for the Dutch Open Telescope (DOT)
combined with RHESSI/SoHO/TRACE observations

Title of the program:	High-resolution study of solar microflares and their relevance for coronal heating and mass supply
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Type of the program: DOT Hα and Ca II H high-cadence imaging

Targets: Active Regions or at least magnetic flux concentrations 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

Scientific objective: 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 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 nonthermal 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 nonthermal 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 $\sim$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.

Planned analysis:

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, SoHO/EIT-MDI-CDS, TRACE and KSO. RHESSI and KSO data will 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.

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) 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. The CDS spectroscopy, although of low spectral resolution, provides

a perfect temperature coverage of the line emission from the chromosphere to the corona.

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 the 1600 Å channel and the DOT filtergrams taken in the Ca II H line (or, alternatively, using white light images)
- DOT, TRACE → RHESSI: using observations of microflare loop and footpoint structures

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Time allocation request:

Number of days needed: 7 – 10 days
Preferred times: none
Impossible times:

22 Mar 2006	–	21 May 2006	MDI 60 Day Continuous Contact Period
21 Feb 2006	–	22 Mar 2006	SoHO Keyhole
26 May 2006	–	15 Jun 2006	SoHO Keyhole
20 Aug 2006	–	20 Sep 2006	SoHO Keyhole
23 Nov 2006	–	12 Dec 2006	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. A cadence of 10 s for speckled images and 1 s for non-speckled images would be desirable. 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.

We apply for the external usage of the DOT in a service mode in which the DOT team operates the telescope. The support of cooperating instruments (i.e. TRACE, SoHO/CDS-EIT-MDI) will be requested only when our DOT observing time will be allocated.

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 2006.

CDS, EIT, MDI:

The observing sequences of the CDS, EIT and MDI instruments onboard 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.