1a) Project Title: Solar magnetism with the Dutch Open Telescope

1b) Acronym: none

1c) Principal investigator: R.J. Rutten

2) Summary

The Dutch Open Telescope (DOT) on La Palma has become one of the best telescopes worldwide for high-resolution imaging of the sun. It is being equipped with an elaborate and thoroughly tested multi-wavelength speckle imaging system that turns it into a superb tomographic mapper of the time-dependent magnetic topology of the solar atmosphere at intrinsically different heights. This proposal exploits this outstanding capability to study the magnetic coupling between photosphere and corona and the dynamics and evolution of solar active regions, addressing basic issues of solar magnetism that are astrophysical in nature but also bear on the complex relationship between solar activity and the terrestrial climate.

3) Classification: magnetohydrodynamics; stars: activity; Sun: activity, atmosphere, chromosphere, corona, faculae, filaments, flares, magnetic fields; solar-terrestrial relations.

4) Composition of the research team

name	title	speciality	employer	period
R.J. Rutten	Dr.	solar physics	UU (permanent staff)	until 2007 (nominal)
R.H. Hammerschlag	Dr. Ir.	optics/mechanics	UU (permanent staff)	until 2009 (nominal)
P. Sütterlin	Dr.	solar physics	UU (EC–TMR)	until 30-04-2002
F.C.M. Bettonvil	Ir.	optics/mechanics	ASTRON (NWO–GB/E)	until 30-09-2002
J.M. Krijger	Drs.	astrophysics	UU (NWO–GB/E)	until 30-09-2002
vacancy (PhD student)	Drs.	(astro-)physics/ICT	UU	01-05-2001 – 30-04-2006
vacancy (engineer)	Ir.	optics/mechanics	this proposal	01-10-2002 – 30-09-2005
vacancy (PhD student)	Drs.	(astro-)physics	this proposal	01-01-2002 – 31-12-2005
vacancy (PhD student)	Drs.	(astro-)physics	this proposal	01-01-2002 – 31-12-2005

All at 100% of their time except teaching obligations (concentrated in the winter months when the La Palma observing conditions are less favourable). Graduate student supervision is by R.J. Rutten. The formal promotor for J.M. Krijger is Prof. J.M.E. Kuijpers who recently moved from Utrecht to Nijmegen. The director of the Sterrekundig Instituut Utrecht, Prof. A. Achterberg, is prepared to be formal promotor for other PhD students.

5) Research school: Nederlandse Onderzoekschool voor Astronomie (NOVA).

6a) Description of the proposed research

Introduction. The Dutch Open Telescope[1] (DOT) has become an outstanding success[2]. With its simple initial imaging system the DOT has proven to be one of the sharpest solar telescopes worldwide. With its new speckle imaging system the DOT will superbly fit an important science niche consisting of large-field long-duration multi-wavelength imaging *consistently* at high angular resolution. This proposal asks for the minimum manpower to exploit this science capability the coming years. We first describe the science content, then add detail on the DOT and its new imaging system.

DOT science. With the multi-wavelength imaging the DOT becomes a *tomographic mapper* of the topology and evolution of solar magnetic field structure and dynamics in the deep photosphere (G-band and continuum filters), the middle photosphere (tuned Ba II filter), the low chromosphere (Ca II K filter), and the high chromosphere (tuned Hα filter). The consistent speckle registration delivers tomographic mapping sequences at 0.2 arcsec resolution whenever the seeing is reasonable — frequently the case on La Palma during many consecutive hours. A general description of the science background to such high-resolution solar tomography is given in a DOT review for climatologists by Rutten et al. (2001b). It also summarizes the line formation particulars that make the G band, Ca II K and Hα top choice diagnostics. The Ba II filter capability is shown in Sütterlin et al. (2001).

Achieving high angular resolution over long duration in tomographic diagnostics is a principal quest of solar astrophysics. The solar magnetic field breaks through the solar surface in a hierarchy of kilo-Gauss elements ranging from sunspots down to the slender fluxtubes that appear as tiny network bright points at high resolution. These magnetic elements are organised in intricate, continuously evolving patterns that constitute solar activity, control the structure and dynamics of the solar corona and the solar wind, and affect the extended heliosphere including the near-earth environment as well as the terrestrial climate. Their role gives threefold motivation to study solar magnetism: *(i)* – the astronomical context of stellar activity (the sun as "Stone of Rosetta star"); *(ii)* – astrophysical magnetohydrodynamics, with the sun a relatively close-by "cosmic laboratory"; *(iii)* – the solar modulation of the human environment through "space weather".

The field patterning and its evolution at the solar surface are dictated by the subsurface dynamo and convective flows but in turn they dictate the structure, dynamics, and heating of the outer atmosphere. This switch in field role occurs in the optically observable photosphere–chromosphere regime, so that ground-based imaging permits charting the magnetic "footpoint" topology and dynamics. They can be traced up to the chromosphere through imaging in Ca II K and Hα, and higher up in the corona with space-based EUV imaging (SOHO and TRACE, see footnotes on page 6).

High-resolution image sequences using the tomographic DOT diagnostics are useful and desirable to virtually *every* solar physics program addressing issues in which magnetic topology plays a role. Such issues range in spatial scale from tiny network fluxtubes (G-band bright points) to sunspots, prominences, and extended active regions, in temporal scale from high-frequency oscillations to active-region evolution, in dynamical behaviour from stable (but oscillating) sunspots to flares, erupting prominences, and coronal mass ejections, in pattern topology from ephemeral field emergence and network field dispersal to the structure and evolution of active regions and the anchor constraints to filaments/prominences and flare build-up. The two PhD research topics described below are the first choice from all that may be done with the DOT. Other issues may be addressed by others using DOT data in collaborations which we welcome.

A. The magnetic coupling between photosphere and corona. The solar surface is not only an important "surface" in the sense that it is the layer where the solar energy that is generated deeply inside leaves our star, in the form of photons and abruptly killing off the convection that transports it subsurface, but also in being the "beta-flip" layer where the dominance of the gas pressure deeper down changes into dominance of magnetic pressure higher up. The dynamics of the photosphere with

[1] DOT: `http://dot.astro.uu.nl`. The DOT website links to the DOT database containing image sequences and speckle-restored movies resulting from G-band, Ca II K and Hα optics tests. In addition, the website provides preprints, descriptions of DOT science, historical background, and DOT photographs. It attracts roughly 100 visits/day; its movies have been copied by *The Astronomy Picture of the Day* and other outreach sites.

[2] Perhaps also astounding, since the principle of the open telescope and tower as high-resolution strategy was already formulated by Zwaan and Hammerschlag in the early 1970's. Its realization took very long but has ultimately delivered a relatively cheap but highly competitive facility at the forefront of current-day solar physics. Such a delayed success may seem astounding, but the basic principles of optics and mechanics that deliver first-class telescopes do not become obsolete while electronics and computing evolve drastically. The success of the open concept now inspires much larger solar-telescope projects abroad (GREGOR and ATST, see footnotes on page 5 *ff*).

its granulation and turbulent wave excitation is hydrodynamically controlled outside active regions (with NLTE radiation loss a major driver); in contrast, the coronal topology and dynamics are completely governed by MHD processes set by the coronal magnetism. However, the coronal fields are rooted in the photosphere (no magnetic monopoles) and their changes are dictated by photospheric foot point motions: there is *magnetic coupling* between the regimes. It is likely that MHD disturbances excited in the low atmosphere contribute substantially to coronal heating and the generation of the solar wind.

At photospheric levels the basic building block of solar magnetism is the "magnetic fluxtube", a concept originating from Zwaan, developed by Spruit (1977), and now an astrophysical paradigm pertinent also to accretion disks and other objects. Even the DOT is not sharp enough to fully resolve these in the photosphere, but at the DOT resolution they can at least be identified and tracked with time (in the form of G-band bright points that brighten because the CH molecules that produce the dark lines in this band dissociate in the low density caused by the high magnetic pressure in the tube, see Rutten et al. 2001c). At coronal levels, the basic building block is the "coronal loop", also extensively studied at Utrecht (*e.g.,* Kuin and Martens 1982, Martens and Kuin 1982, van den Oord et al. 1997, Fletcher and Martens 1998) and now spectacularly imaged in TRACE 171 Å movies (Schrijver et al. 1999). The connection between photospheric tubes and coronal loops is enigmatic. The fluxtube paradigm prescribes field expansion into magnetic canopies that spread field homogeneously throughout the atmosphere already in the upper chromosphere. Coronal loops delineate slender field configurations at specific temperature that become visible through density contrasts. In between, observations in Hα and EUV lines indicate a plethora of low-lying finely-scaled structures with rapid large-amplitude dynamical changes.

We expect that high-resolution tomography with the DOT, in particular using Hα imaging to define the actual canopy structure, can be the missing link to fill the gap between tubes and loops. The Hα line is about the only groundbased diagnostic that permits mapping canopies. Quantitative interpretation of Hα filtergrams is notoriously difficult because the line mixes Dopplershifts with brightness modulation and is awkwardly sensitive to NLTE population mechanisms mixing both density and temperature variations (because its lower level is so very detached from the hydrogen ground state); in addition, it shows both optically thick and optically thin structures. These mixtures give high-resolution Hα movies their dramatic appearance and rich information content but also make such movies hard to interpret. We believe, however, that combining our extensive radiative transfer expertise with the diagnostic capabilities of DOT two-channel speckle reconstruction in sufficient Hα filtergram spacings will enable us to translate such movies through numerical line formation modelling into quantitative maps of the chromospheric topology. Combining these with concurrent G-band fluxtube mapping and TRACE loop mapping should then bring insight in the photosphere–corona coupling. We plan to start such studies for the relatively straightforward configurations of magnetic network and stable bipolar active regions, and tackle more complex and dynamical configurations when our Hα interpretation capability increases.

Interest in the electrodynamical coupling between the low and high solar atmosphere transcends solar physics because this coupling figures also in the coupling of solar activity, via the solar wind and more incidental excess particle losses as in coronal mass ejections, to the earth environment and terrestrial climate. Solar-terrestrial relationships and "space weather" are now a hot topic, especially in the US. The tube-loop coupling that we propose to study is a necessary step in understanding why (or predict where or when) whole loop systems can become unstable and eject large clumps of coronal matter.

B. Dynamics and evolution of active regions. Active regions are an obviously urgent topic for high-resolution DOT science since solar activity peaks now and declines the coming years. Major issues regarding short time-scale dynamics are the nature of umbral dots (photospheric), umbral flashes (chromospheric), and running penumbral waves (up into the transition region). Umbral dots seem to portray umbral convection, a key phenomenon to understand sunspot stability and breakup. Umbral flashes are undoubtedly magneto-acoustic waves that propagate upwards and steepen into shocks; detailed observation combined with numerical simulation should permit settling the wave excitation mechanism and the atmospheric response. Doing so is important because the umbral atmosphere is the closest thing to radial stratification on the sun, making chromospheric umbral oscillations a stepping stone to more complex MHD geometry. Penumbral waves get much attention at present because they are seen to propagate to large height in SOHO and TRACE UV diagnostics (*e.g.,* Brynildsen et al. 1999), but their nature, properties and cause in the photospheric domain where they are excited are yet unclear.

On longer time scales the assembly, evolution, and decay of sunspots are still poorly understood. The questions are simple: how do spots originate, how do they build up, how do they break up, how do they disappear? Sunspots are studied for centuries already but even these basic questions remain unanswered.

Observationally, the state of the art prior to consistent image restoration was reached in the SVST image sequences analysed by Strous (1994). Obtaining speckle-restored long-duration sequences with the DOT will bring large improvement because the buildup and decay of spots goes through assembly and shedding of tiny fluxtubes that can only be seen and tracked at resolution better than 0.5 arcsec (in the G band, cf. Title and Berger 1996, Strous and Zwaan 1999). With the DOT we expect to spot all the sunspot building blocks, and so observe the flux emergence, accretion and dispersal directly.

Both the fast oscillatory dynamics and the slow evolutionary dynamics of sunspots represent thesis-size topics. The emphasis will be set by the data sequences that we obtain. Ideally, the first part of the proposed thesis effort addresses oscillatory dynamics, followed by a shift to longer time scales when more sequences are available. This sunspot research will gain from the likely addition of Dopplergrams and the possible addition of magnetograms using the Ba II 4554 Å Irkutsk filter (below).

Dutch Open Telescope. The DOT is an innovative telescope which achieves high angular resolution through combining openness (avoiding internal seeing not through telescope evacuation but through wind flushing of the mirror and telescope interior) with an open support tower (avoiding the excitation of local turbulence by wind blocking) and an excellent site on La Palma where the trade winds are often sufficiently strong for telescope flushing and to keep the ground-heated boundary layer of turbulent convection all day below the 15 m DOT tower height.

The DOT demonstrated soon after its first light (autumn 1997) with a simple video camera that the open-telescope concept can successfully replace the vacuum solution to internal seeing that has been used sofar in high-resolution solar telescopes. This breakthrough success of the open principle is now being copied in the major new solar telescope projects abroad (GREGOR and ATST, see footnotes on page 5 *ff*). At home, it led to funding from various sources (Utrecht University, NWO-GB/E, NWO-NOVA, EC-TMR) to implement secondary optics and data acquisition systems to bring the DOT science capabilities at the forefront in optical solar physics, and to demonstrate these capabilities. The program goals were:

- installation of multi-channel optics to feed solar images at different wavelengths simultaneously to different CCD cameras in order to realize "tomographic" imaging of the deep photosphere (G band around 4305 Å), low chromosphere (Ca II K at 3933 Å) and high chromosphere (Hα at 6563 Å, rapidly tunable);
- implementation of image restoration techniques;
- initiation of high-resolution observing of the topology and dynamics of solar magnetism.

Part of the funding for this program (exploitation) expires coming autumn, the remainder (temporal positions) next year. A high-level international visitation is scheduled for March 29–30 (convener Prof. A. Achterberg, director Sterrekundig Instituut Utrecht) to appraise the science potential of the DOT towards the end of this "science capability demonstration period". We used it to develop and build a new DOT imaging system that meets the above goals and is presently being installed after extensive on-telescope component tests which included initial science observations. Since the present proposal aims to exploit the new imaging system we describe it in some detail.

Speckle restoration. With the hiring of postdoc P. Sütterlin (on EC-TMR funding) DOT image restoration through the speckle masking technique (key papers: Weigelt 1977; von der Lühe 1985, 1993; de Boer 1995) was quickly started and found successful even with the simple analog video camera used sofar with digitisation at only 8 bits. Test runs with this initial system, mostly part of international multi-telescope observing campaigns, produced outstanding movies (DOT website) which forcefully demonstrate that the combination of the open principle, the excellent DOT optics, the unsurpassed mechanical stiffness of the DOT (which maintains pointing with 0.1 arcsec stability even when buffeted by strong winds), the good La Palma seeing, and the speckle restoration together produce diffraction-limited resolution (0.2 arcsec in the violet given the 45 cm aperture) over extended durations, up to multiple hours. This success inspired the ambitious plan to equip the DOT with five digital 10-bit large-field cameras that run synchronously in speckle mode and dump speckle bursts on a storage system large enough to permit continuous observing during many hours. This system is now realized thanks to large effort of the Instrumentele Groep Fysica at Utrecht and is being installed on the telescope. Details are given in Sütterlin et al. (2001); first images are shown on the DOT website.

The new imaging system makes the DOT the first solar telescope using speckle registration *routinely*, up to 400 Gbyte of speckle bursts per observing session. At continuous DOT operation the resulting data glut would much exceed what we can possibly handle, so that only selected sequences can be fully processed initially — but neither do we have manpower for continuous rather than campaignwise telescope operation. A companion effort to the present proposal (for which funding will be sought from the EC) aims to parallelise the speckle code, in principle feasible since the many different isoplanatic patches in the field are treated independently. The advent of cheap processor clusters should then make rapid turnaround of the speckle processing realistic, and make more continuous DOT operation desirable.

Multi-wavelength imaging. We have added two cameras to the three needed to achieve the tomographic imaging specified above. The fourth registers images in a wide continuum passband next to Hα for two-channel restoration following Keller and von der Lühe (1992) because the Hα bandwidth (tunable Lyot filter) is too narrow for direct speckle reconstruction of the multiple profile samplings needed to disentangle Dopplershift and brightness modulation within the time limit set by solar dynamics. The fifth channel will be used for continuum near the G band or with another tunable Lyot filter capable of making high-resolution Dopplergrams (and possibly magnetograms) in the Ba II 4554 Å line. It comes from Irkutsk and was tested at the SVST with the DOT camera and speckle system; the very promising results are described in Sütterlin et al. (2001) and are shown on the DOT website.

It was a large design challenge to adapt the fast DOT primary $f/D = 4.4$ ratio to the 0.07 arcsec/px image scale required to fully sample the 0.2 arcsec diffraction limit simultaneously at these different wavelengths in the cramped space available at the DOT top besides the incoming beam, with as additional constraint that light loss in beam dividers and other optics must be minimised since even solar imaging is photon-starved at high resolution in narrow bands with speckle-freezing exposure times. Extensive optics tests were made at the telescope; the spectacular G-band, Ca II K and Hα movies that resulted from these are available on the DOT website. The tests give large confidence that the solutions now being installed (G-band channel complete, Ca II K to follow soon, Hα and possibly Ba II in summer) do not spoil the superb DOT image quality at any wavelength.

Initial observations. The DOT movies obtained sofar used the simple initial video camera and were mostly taken for test purposes but are nevertheless of superior quality. The DOT team has an open data policy — a logical choice when so short on manpower. Hence, umbral fine structure is studied from DOT G-band sunspot movies by M. Sobotka at Ondrejov, penumbral fine structure in the G band by V. Martínez Pillet at La Laguna, running penumbral waves in Ca II K by L. Rouppe van der Voort (PhD student from Utrecht) at Stockholm, Hα prominence topology by J. Kuijpers at Nijmegen, active region morphology by D. Herdiwijaya and G. Admiranto at Bandung, and Ca II K umbral flashes and G-band bright points at Utrecht itself by students and ourselves (Rutten, Sütterlin, Krijger). Various papers are underway, also on the Ba II filter test (with its Irkutsk builders V. Skomorovsky and G. Domyshev). These analyses represent initial expertise buildup for the much more comprehensive data sets that the DOT will generate with the new imaging system, especially when in concert with (E)UV imaging by TRACE (below). We have also developed pertinent expertise in TRACE data reduction and interpretation (Krijger).

International context. The DOT large-field high-resolution imaging capability is complementary to the upcoming high-resolution facilities elsewhere (NSST[3], GREGOR[4], THEMIS[5], ATST[6]) because these aim at combining large aperture (1–4 m) with adaptive optics which will in particular advance Stokes vector

[3]NSST: `http://www.astro.su.se/groups/solar`, New Swedish Solar Telescope, upgrade of the former SVST (Swedish Vacuum Solar Telescope) on La Palma, from 48 cm to 96 cm diameter objective lens. The NSST is presently being installed and is likely to become the first solar telescope using adaptive optics to reach 0.1 arcsec resolution routinely (be it over a small field). The NSST and the DOT are highly complementary and will often be used in tandem – the control rooms are adjacent: the DOT is operated from the SVST/NSST building thanks to splendid hospitality from the Swedish team (of the Royal Swedish Academy of Sciences). In exchange, Hammerschlag has assisted in the NSST turret design and construction.

[4]GREGOR: `http://www.kis.uni-freiburg.de/GREGOR`, upgrade of the present German Gregory Coudé Telescope on Tenerife to 1.5 m aperture with a new feed telescope that follows the DOT example of being domeless — it will be weather-protected by a copy of the DOT clamshell foldaway canopy. This telescope will be particularly suited to high-resolution full-Stokes spectropolarimetry including the important infrared (where Zeeman splitting wins from Doppler broadening). Status: largely funded, operational mid-decade.

[5]THEMIS: `http://www.obs-nice.fr/themis`, major French-Italian facility on Tenerife, helium-filled telescope with 90 cm aperture. The very complex optical system limits the angular resolution severely; an adaptive optics program is being started to overcome this handicap. If this succeeds the strength of this telescope will be in high-precision many-line Stokes polarimetry in the visible.

[6]ATST: `http://www.sunspot.noao.edu/ATST`, Advanced Technology Solar Telescope, a national US project led by the National Solar Observatory to build a next-generation solar telescope of 4 m aperture, in line with the McKee-Taylor decadal survey report. It will be an open telescope. The initial funding proposal (NSF) is being prepared and extensive site testing (possibly including La Palma) is starting up. The timeline projects operation by the end of the decade. The emphasis will be on Stokes vector spectropolarimetry in the visible and infrared.

spectropolarimetry to subarcsecond resolution — but achieve full restoration to the diffraction limit only for the central isoplanatic patch. Speckle reconstruction recovers the full field (hundreds of isoplanatic patches!) but does not easily permit spectrometry and becomes less effective at larger aperture. Thus, large-field speckle imaging at the DOT and adaptive-optics polarimetry elsewhere (NSST, GREGOR) will enhance each other. DOT-like speckle imaging is also pursued at BBSO[7] which is complementary with respect to time zone. The DOT large-field tomographic imaging capability is also highly complementary to ultraviolet imaging of the solar corona from space (SOHO[8], TRACE[9]).

These complementarities imply that most DOT observing and targeting will be scheduled as part of international multi-telescope (both ground- and spacebased) campaigns — as has been the case for DOT observing sofar and is often the case nowadays at other solar observatories. Various such campaigns were (and will be) run by the ESMN[10] network led by the PI of this proposal. It addresses solar magnetometry in European context and includes partners involved in NSST, GREGOR, THEMIS and SOHO. A renewal TMR proposal for 2002–2006 will be submitted to Brussels later this spring, again with the present PI as coordinator. In addition, an INTAS proposal has been submitted for collaboration with the Irkutsk builders of the Ba II filter, and a NATO CRG grant currently supports DOT-oriented collaboration with colleagues at Kiev (both also with the PI as coordinator).

6b) Personnel

PhD students versus postdocs. In this proposal we ask for PhD students to tackle the above research rather than for postdocs for three reasons. Firstly, the European solar physics postdoc supply is presently being drained by the US where ambitious solar physics and space weather programs including NASA's "Living with a Star" create large demand. In contrast, Utrecht maintains delivery of high-quality astrophysics graduates (a problem in the US) and DOT projects also cater to adventurous physics graduates. Secondly, we hope to apply successfully for another EC-TMR grant and so be able to appoint a (non-Dutch) postdoc successor to P. Sütterlin (with the realization of parallel speckle processing as specific task). Finally, we are confident (also on past experience) that solar physics PhD's from Utrecht will easily obtain postdoc positions elsewhere as next step in a solar physics career.

DOT engineer. The proposal also asks for a high-level technician in the role now filled by Bettonvil. It must be emphasised that like any telescope the DOT is a complex system combining mechanics, optics, remote control, data acquisition, and data processing. The DOT team must necessarily include a second engineer next to Hammerschlag to get this whole system working, to keep it working, and to get useful data.

At present, DOT observing requires the presence of both DOT engineers during critical maneuvers, one at the telescope and one in the control room in the Swedish building. The risks of serious damage to the telescope and dome forbid operation by others so far. Adding remote controls and fail-safe measures is high on the priority list after the completion of the new imaging system. Our goal is that the DOT can be operated by science observers (including foreign colleagues) with only one DOT engineer on site.

Other technology items on the DOT priority list are:

- experiments with polarimetry using the Ba II filter, including tests of linear polarization diagnostics (Ba II 4554 Å is the most sensitive one of all lines in this "second" optical spectrum);

[7] BBSO: `http://www.bbso.njit.edu`, Big Bear Solar Observatory, originally of Caltech but now operated by the New Jersey Institute of Technology. Big Bear is the best existing solar-telescope site in the US and shares the La Palma property of offering good seeing over extended durations. Dome seeing spoiled the BBSO image quality considerably in the past but this problem has recently been recognised and is now largely solved. Joint BBSO–DOT campaigns are foreseen to increase high-resolution image sequence durations exploiting the seven hour longitude difference.

[8] SOHO: `http://sohowww.estec.esa.nl`, Solar and Heliospheric Observatory, first cornerstone of the ESA science programme and the flagship of current solar physics. In addition to UV imagers and spectrographs, SOHO contains the visible-light coronograph LASCO and Michelson interferometer MDI which provide context in the form of outer-corona and CME movies (LASCO) and photospheric Dopplergrams and magnetograms (MDI), the latter at up to 1 arcsec resolution.

[9] TRACE: `http://vestige.lmsal.com/TRACE`, Transition Region and Coronal Explorer, NASA SMEX satellite which provides solar image sequences at UV and EUV wavelengths and 1 arcsec resolution since April 1998. In particular, the Fe IX/Fe X doublet at 171 Å which samples 1 million K gas in the corona yields spectacular movies of the shape and dynamics of finely structured coronal loops.

[10] ESMN: `http://www.astro.uu.nl/~rutten/tmr`, European Solar Magnetometry Network, a TMR network of eight solar physics groups in Europe which integrates the use of the five solar telescopes at the Canary Islands with SOHO and with numerical modelling, with emphasis on the development of magnetometry techniques through expertise sharing. It was instrumental in bringing speckle restoration to the DOT in the form of postdoc P. Sütterlin. The ESMN has recently been judged "excellent" in its mid-term review by Brussels.

– improvement of the DOT pointing control, including replacement of the custom-built interface with easier-to-maintain standard encoding hardware (which became available in the meantime);
– automation of the daily sun acquisition in the sky (at present, the sun must be "found" manually every morning with a difficult and risky procedure on the DOT platform itself);
– improvement of the internal telescope seeing through micro-climate control, including registration and analysis of the thermal budget;
– installation of alternative wide-band Hα optics for off-limb prominence observations;
– realization of "zoom" optics permitting flexible choice in trade-off between angular resolution and field size, in particular for Hα (a large field is sometimes desirable for Hα to locate and track the other footpoint of low-lying loops observed as Hα mottles);

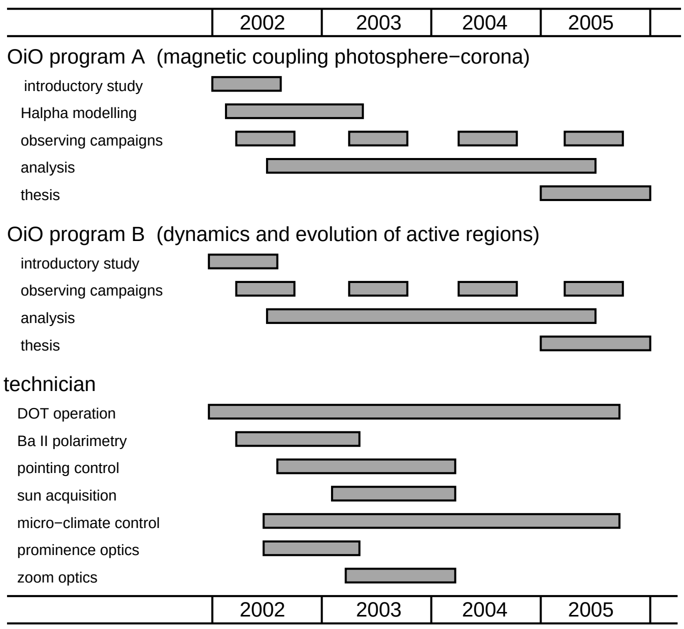
7) Work programme

The chart below specifies the work schedule. The observing campaigns will mostly take place in the spring-to-autumn period with better seeing prospects at La Palma. Their timing is entered only schematically since it will vary with DOT and international campaign planning.

Initial overlap with the DOT OIO, AIO and postdoc at the start of 2002 serves for expertise transfer (speckle processing, TRACE data reduction) to the OiO's. Observing campaigns are also entered in their final year for comparable expertise transfer at the end of the funding period. Their results will be published in major astronomy journals; their PhD theses will largely consist of such publications.

The OiO for project A will initially spend much time on Hα modelling, with initial codes coming from specialist colleagues abroad (the THEMIS group in Meudon, the IAC group in La Laguna, P. Heinzel in Ondrejov).

Project B includes numerical simulation of sunspot oscillations but these are more likely to be contributed by colleagues in Oslo in ESMN collaboration with the OiO (contributing the observations) than to be performed by the OiO.



8a) Expected use of instrumentation

The amount requested for investments (100 kf) in the budget on page 11 is a minimum specified in the table below. It covers only the cost of the two proposed PhD research programs.

A major budget item consists of the DLT tapes on which speckle data is stored during observation to the cost of 1 kf per observing day. The tapes become reusable after the speckle processing, but since the latter is very much slower than the observing (at least until parallel processing becomes effective) a large tape buffer is needed. The item "tapes" below represents a one-year (25 observing sessions) tape buffer for each of the two proposed science programs. Additional tapes for other programs will be applied for elsewhere; external users will be told to bring their own.

The two fast computers are not the ones to be used by the OiO's for their data analysis (the latter are entered under OiO's on page 11) but exclusively for their speckle processing of their observations — which will fill these computers to full capacity.

IDL is the computer language used throughout solar physics for data analysis. It is highly flexible but quite expensive. The DOT team has a relatively cheap "academic group" license of which the budget item covers the part needed for the two projects.

The final item concerns optics needed to enable two-channel speckle processing for the Hα channel (addition of wide-band continuum registration near Hα to evaluate the atmospheric point spread function for deconvolution of the narrow-band data).

Item	goal	cost
DLT tapes program A	speckle data buffer	kf 25
DLT tapes program B	speckle data buffer	kf 25
fast computer program A	speckle processing	kf 15
fast computer program B	speckle processing	kf 15
partial IDL license (A+B)	data analysis	kf 5
hardware program A	Hα optics	kf 15

8b) Required observing facilities

Trips to La Palma for observing with the DOT are an obvious necessity of the proposed porgram. They are budgetted at 1 kf for travel and f 75/day staying cost. These costs correspond to the extensive experience gained over the past years using the cheapest housing available off the mountain summit rather than the Roque de los Muchachos Observatory Residencia. It requires a car but so would the Residencia–telescope commute. For the OiO's the requested amount (under c) on page 11) amounts to four three-week observing campaigns yearly, for the engineer to six three-weeks trips per year.

No costs are projected for the use of other Canary Island telescopes in multi-telescope campaigns. These will normally be operated by colleagues, most likely in ESMN context. Co-observing with BBSO to extend sequence duration is planned. Co-observing with TRACE will be particularly important initially; after 2004 co-observing with the Japanese Solar-B mission will become important, especially with the US-built instruments. These space telescopes are scheduled flexibly with much emphasis to co-observing according to program merit by teams at Lockheed-Martin (Palo Alto) and HAO (Boulder) with close ties to Utrecht including an extensive collaboration record.

9) Literature

Five "most important" publications of the PI on DOT science topics (the first four are available from the ADS server at http://adsabs.harvard.edu/abstract_service.html; the fifth (a proceedings volume) is presently being scanned by ADS):

– Lites et al. (1999)
– Hoekzema et al. (1998)
– Hoekzema et al. (1997)
– Bruls et al. (1995)
– Rutten and Schrijver (1994)

Five selected publications of the DOT team concerning the DOT (the first three are in press, with preprints available at http://dot.astro.uu.nl):

– Sütterlin et al. (2001)
– Rutten et al. (2001a)
– Rutten et al. (2001b)

– Hammerschlag and Bettonvil (1998)
– Hammerschlag (1981)

References

Bruls, J. H. M. J., Solanki, S. K., Rutten, R. J., and Carlsson, M.: 1995, "Infrared lines as probes of solar magnetic features. VIII. Mg I 12 μm diagnostics of sunspots", *Astron. Astrophys.* **293**, 225–239

Brynildsen, N., Kjeldseth-Moe, O., Maltby, P., and Wilhelm, K.: 1999, "Nonlinear Sunspot Transition Region Oscillations in NOAA 8378", *Astrophys. J. Lett.* **517**, L159–L162

de Boer, C. R.: 1995, "Empirical speckle transfer function measurements from partial eclipse observations of the Sun.", *Astron. Astrophys. Suppl.* **114**, 387+

Fletcher, L. and Martens, P. C. H.: 1998, "A Model for Hard X-Ray Emission from the Top of Flaring Loops", *Astrophys. J.* **505**, 418–431

Hammerschlag, R. H.: 1981, "Construction outlines of the Utrecht Open Solar Telescope", in R. B. Dunn (Ed.), *Solar Instrumentation: What's Next?*, Proc. Sacramento Peak National Observatory Conference, Sunspot, New Mexico, 547–582

Hammerschlag, R. H. and Bettonvil, F. C. M.: 1998, "The Dutch Open Telescope at the Roque de los Muchachos Observatory", *New Astronomy Reviews* **42**, 485–488

Hoekzema, N. M., Rutten, R. J., Brandt, P. N., and Shine, R. A.: 1998, "Small-scale topology of solar atmosphere dynamics I. Wave sources and wave diffraction", *Astron. Astrophys.* **329**, 276–290

Hoekzema, N. M., Rutten, R. J., and Cook, J. W.: 1997, "Ultraviolet Jets and Bright Points in the Solar Chromosphere. II. Statistical Correlations", *Astrophys. J.* **474**, 518–528

Keller, C. U. and von der Lühe, O.: 1992, "Solar speckle polarimetry", *Astron. Astrophys.* **261**, 321–328

Kuin, N. P. M. and Martens, P. C. H.: 1982, "On the thermal stability of hot coronal loops - The coupling between chromosphere and corona", *Astron. Astrophys.* **108**, L1–L4

Lites, B. W., Rutten, R. J., and Berger, T. E.: 1999, "Dynamics of the Solar Chromosphere. II. Ca II H2v and K2v Grains versus Internetwork Fields", *Astrophys. J.* **517**, 1013–1033

Martens, P. C. H. and Kuin, N. P. M.: 1982, "On cool coronal loops", *Astron. Astrophys.* **112**, 366–368

Rutten, R. J., Hammerschlag, R. H., Sütterlin, P., and Bettonvil, F. C. M.: 2001a, "Proxy magnetometry with the Dutch Open Telescope", in M. Sigwarth (Ed.), *Advanced Solar Polarimetry – Theory, Observation, and Instrumentation*, Procs. 20th NSO/SP Summer Workshop, Astron. Soc. Pacific Conf. Series, in press, preprint: http://dot.astro.uu.nl

Rutten, R. J., Hammerschlag, R. H., Sütterlin, P., Bettonvil, F. C. M., and van der Zalm, E. B. J.: 2001b, "Solar magnetometry with the Dutch Open Telescope", in A. Wilson (Ed.), *The Solar Cycle and Terrestrial Climate*, Procs. Euroconference Tenerife, ESA Special Publication SP-463, Estec, Noordwijk, in press, preprint: http://dot.astro.uu.nl

Rutten, R. J., Kiselman, D., Rouppe van der Voort, L., and Plez, B.: 2001c, "Proxy magnetometry of the photosphere: why are G-band bright points so bright?", in M. Sigwarth (Ed.), *Advanced Solar Polarimetry – Theory, Observation, and Instrumentation*, Procs. 20th NSO/SP Summer Workshop, Astron. Soc. Pacific Conf. Series, in press, preprint: http://www.astro.uu.nl/∼rutten

Rutten, R. J. and Schrijver, C. J. (Eds.): 1994, *Solar Surface Magnetism*, NATO ASI Series C 433, Kluwer, Dordrecht

Schrijver, C. J., Title, A. M., Berger, T. E., Fletcher, L., Hurlburt, N. E., Nightingale, R. W., Shine, R. A., Tarbell, T. D., Wolfson, J., Golub, L., Bookbinder, J. A., Deluca, E. E., McMullen, R. A., Warren, H. P., Kankelborg, C. C., Handy, B. N., and de Pontieu, B.: 1999, "A new view of the solar outer atmosphere by the Transition Region and Coronal Explorer", *Solar Phys.* **187**, 261–302

Spruit, H. C.: 1977, *Magnetic flux tubes and transport of heat in the convection zone of the Sun*, PhD thesis, Utrecht University

Strous, L. H.: 1994, *Dynamics in Solar Active Regions: Patterns in Magnetic-Flux Emergence*, PhD thesis, Utrecht University

Strous, L. H. and Zwaan, C.: 1999, "Phenomena in an Emerging Active Region. II: Properties of the Dynamic Small-Scale Structure", *Astrophys. J.* **527**, 435–444

Sütterlin, P., Hammerschlag, R. H., Bettonvil, F. C. M., Rutten, R. J., Skomorovsky, V. I., and Domyshev, G. N.: 2001, "A Multi-Channel Speckle Imaging System for the DOT", in M. Sigwarth (Ed.), *Advanced Solar Polarimetry – Theory, Observation, and Instrumentation*, Procs. 20th NSO/SP Summer Workshop, Astron. Soc. Pacific Conf. Series, in press, preprint: http://dot.astro.uu.nl

Title, A. M. and Berger, T. E.: 1996, "Double-Gaussian Models of Bright Points or Why Bright Points Are Usually Dark", *Astrophys. J.* **463**, 797+

van den Oord, G. H. J., Schrijver, C. J., Camphens, M., Mewe, R., and Kaastra, J. S.: 1997, "EUV spectroscopy of cool stars. III. Interpretation of EUVE spectra in terms of quasi-static loops.", *Astron. Astrophys.* **326**, 1090–1102

von der Luhe, O.: 1985, "The Speckle Masking Transfer Function", *Astron. Astrophys.* **150**, 229–231

von der Lühe, O.: 1993, "Speckle imaging of solar small scale structure I. Methods", *Astron. Astrophys.* **268**, 374–390

Weigelt, G. P.: 1977, "Modified astronomical speckle interferometry: "Speckle masking"", *Opt. Comm.* **21**, 55–59

10) Requested budget

SAMENVATTING AANGEVRAAGDE SUBSIDIE

OiO's

a) aanstelling	2 fte × kf 228	= kf 456
b) persoonsgebonden reisbudget	2 fte × kf 7,35	= kf 14,7
c) waarneemreizen	2 fte × kf 40	= kf 80
d) projectgebonden apparatuur/software	2 fte × kf 10	= kf 20
Subtotaal OiO's		= kf 570,7

Overig (technisch personeel)

a) aanstelling	1 fte × 3 jaar × kf 90	= kf 270
b) waarneemreizen	1 fte × 3 jaar × kf 15	= kf 45
Subtotaal Overig		= kf 315

Investeringen	= kf 100

TOTAAL AANVRAAG

Totale kosten OiO's + Overig	= kf 885,7
Totaal gevraagde subsidie voor investeringen	= kf 100

Suggestions for referees

The directors of the other solar observatories/institutes working towards diffraction-limited optical solar physics are:

– Prof. Oskar von der Lühe
  Director
  Kiepenheuer Institut für Sonnenphysik
  Schöneckstrasse 6
  D–79104 Freiburg
  Duitsland
  email: ovdluhe@kis.uni-freiburg.de

– Prof. Göran Scharmer
  Director Research Station for Astrophysics
  The Royal Swedish Academy of Sciences
  Stockholm Observatory
  S-13336 Saltsjöbaden
  Sweden
  email: scharmer@astro.su.se

– Dr. Steven E. Keil
  Director National Solar Observatory
  NSO/Sacramento Peak
  P.O. Box 62
  Sunspott, NM 88349–0062
  USA
  email: skeil@sunspot.noao.edu

– Prof. Philip H. Goode
  Direcor Big Bear Solar Observatory
  Department of Physics and Mathematics
  New Jersey Institute of Technology
  University Heights
  Newark NJ 07102
  USA
  email: pgoode@tesla.njit.edu