DOT Science Support 2009-2011

A Proposal for NOVA-3 Science Support Funding

Principal Investigator: C.U.Keller (Utrecht University)
Co-Applicants: A.Voegler, R.J.Rutten, R.H.Hammerschlag, F.C.M.Bettonvil (Utrecht University)

Executive Summary

The Dutch Open Telescope (DOT) on La Palma, Canary Islands, built and operated with support from NOVA (529kEuro since 1999), UU (~900kEuro since 1999), STW (~350kEuro for construction and 670 kEuro for technical exploitation), and NWO (429kEuro), has been in regular science operations since 2004. The DOT is a fundamental part of the solar observing system, providing relatively large field-of-view image sequences of exceptional quality simultaneously at several wavelengths and serving as a testbed for the open-telescope approach that now all new, large-aperture solar telescope designs rely on. While the Japanese-US-UK Hinode satellite was expected to surpass the DOT in its science niche, a failure in Hinode's narrow-band tunable filter has led the DOT to remain the premier source for high-resolution images in the hydrogen Halpha line. This line has recently garnered renewed attention from the solar physics community due to the much better understanding of how images in this line can be used to extract information about the solar magnetic field.

As of the end of 2007, Utrecht University has stopped its financial contributions. Thanks to external funding sources (EU, STW) and careful budgeting, it has been possible to secure sufficient funding for keeping the DOT open for technical tests during 2008 and 2009, but there are not enough funds to provide continued science observations during this time. We therefore request support for 1 year of junior support staff in 2009 (50.9kEuro) and a guarantee for funding for the junior support staff and some science operations costs in 2010 (74.0kEuro) and 2011 (75.1kEuro) if the EU FP7 Opticon proposal is successful (or an equally large outside contribution can be secured) to continue the highly successful DOT science exploitation.

Introduction and Main Science Goals of DOT

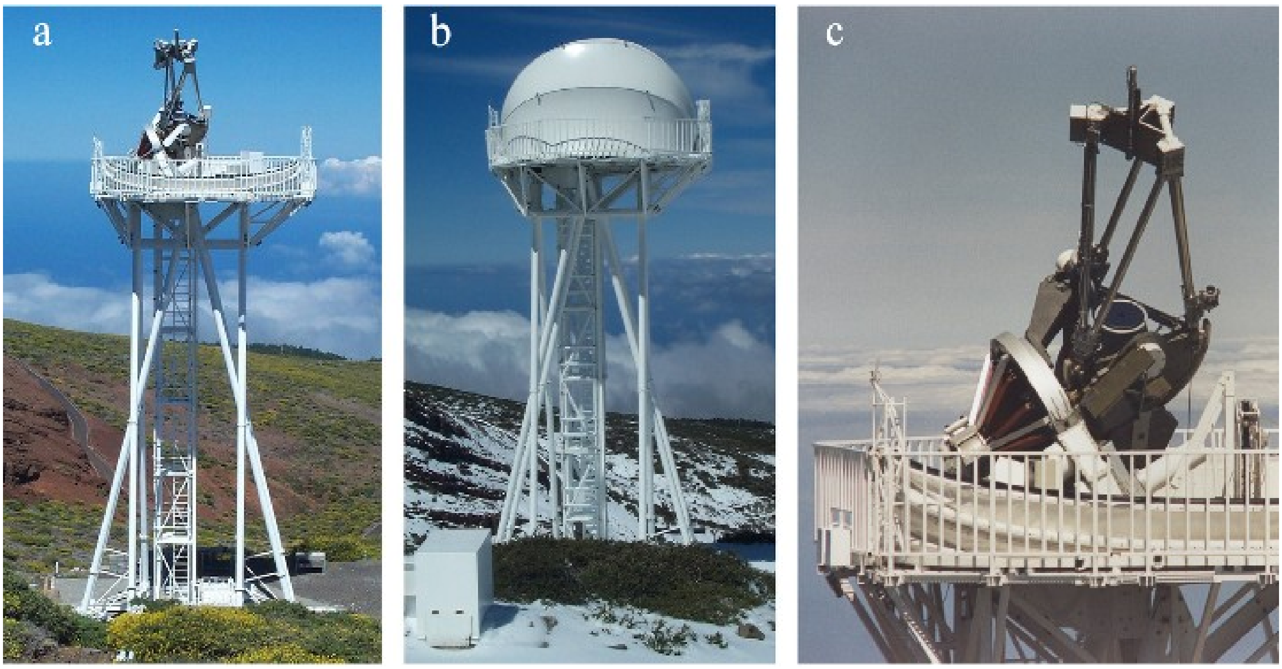

Fig. 1: The existing DOT with 45-cm primary mirror at 2350 m altitude on La Palma. **(a)** The DOT in operation. The 15-m tower and the telescope are sufficiently transparent to not disturb the wind which maintains temperature homogeneity in and around the telescope. At sufficient wind strength (7 km/h can be enough depending on the wind direction) the larger temperature fluctuations occurring near ground level do not reach the telescope. The special tower geometry keeps the platform parallel to the ground even under strong wind loads. The clam-shell canopy is opened completely for observations. **(b)** When not in operation the telescope is protected by closing the folding canopy. It is made of strong tensioned polyester cloth with an outer PVDF coating on which snow and ice do not stick. The canopy can be opened and closed within a few minutes in winds up to 100 km/h. When closed it can withstand much stronger winds, and has already survived storms of 200 km/h. **(c)** The telescope close-up. The primary mirror and the optical beam to the primary focus are fully open to wind. The DOT was the first telescope showing that such an open air path can permit diffraction-limited resolution. Note that the primary mirror is located well above the declination axis of the equatorial mount. It sticks out high above the platform into full wind flushing.

DOT Overview

During the late 1990s the Dutch Open Telescope (DOT, Fig. 1 and http://dot.astro.uu.nl) was the pioneering demonstrator of the open-telescope technology now pursued in the German GREGOR (1.5-m aperture) project and in the 1.6-m new telescope being installed at Big Bear Solar Observatory, and it was inspirational to the national US ATST (4-m aperture) project and the recently initiated project for a European Solar Telescope (EST) of 3-5 m aperture, which is now supported by an EU FP7 Design Study grant with substantial Dutch involvement.

These projects all capitalize on the advents in wavefront restoration through adaptive optics (AO) and numerical image processing which now enable meter-class image sharpness, far beyond the best Fried-parameter values at any solar observing site, and so require telescope technology beyond the 1-m evacuated-telescope technology limit realized by the Swedish 1-m Solar Telescope (SST) on La Palma.

In the meantime the 45-cm DOT became an outstanding supplier of solar-atmosphere image sequences sampling the photosphere and chromosphere simultaneously at up to 0.2 arcsec resolution. All DOT data are publicly available for analysis; the DOT database resides at ftp://dotdb.phys.uu.nl and has a user-friendly graphical interface at http://dotdb.phys.uu.nl/DOT, which for every day with worthwhile data serves a thumbnail pictorial index.

The DOT performs so well thanks to the combination of (i) its wind-swept oceanic mountain site at the Observatorio del Roque de los Muchachos on the Canary Island La Palma, (ii) minimum obstruction to the wind by the very open tower, the very open telescope, and the fully-folding canopy, (iii) effective wind-flushing of the open telescope, (iv) short-exposure speckle imaging, and (v) the consistent application of speckle restoration in an on-site processor farm.

The DOT design and construction are characterized by rigorous adherence to its open principle and large emphasis on mechanical stability. The open tower, fold-away canopy, and equatorial telescope mount are highly transparent to the fairly laminar Northern trade winds that bring the best seeing at the Roque de los Muchachos. They don't spoil the seeing; in addition, the wind flushes the telescope interior faster than internal turbulence can develop. The remaining higher-layer wavefront aberrations are corrected through speckle processing. Its advantages are that it restores the full field of observation in equal measure and that it delivers rather good results already at relatively poor seeing. It requires a large amount of post-processing but this has been remedied with the parallel DOT Speckle Processor in a nearby building. The complete system delivers 0.2 arcsec diffraction-limited image quality whenever the seeing is reasonable, already at Fried-parameter values of order 6-10 cm. At La Palma such seeing sometimes occurs during multiple hours.

During the past years the DOT has been equipped with an elaborate multi-wavelength imaging system harboring six identical speckle cameras that register wide-band continua in the blue and red, the G band at 4305 A, Ca II H with an interference filter that can be tuned per speckle burst through the blue line wing, and narrow-band Halpha using a 250 mA FWHM Lyot filter that can also be tuned per speckle burst. Two-channel speckle reconstruction following Keller & von der Luehe (1992), 2 channel speckle permits the registration of multi-wavelength Halpha movies at 20-30 s cadence or single-wavelength Halpha movies at much faster cadence.

During the past years the DOT was usually manned from early spring until late autumn with R.H. Hammerschlag taking care of the telescope operation and P. Suetterlin in control of all observing and speckle processing. A typical two-week campaign delivers on average 5-6 days with good data. Thanks to the parallel processing the data now become available soon after the campaign.

More detail is given in Rutten et al. (2004) and in the other DOT papers from the past years (over 20 in refereed journals detailing science results, and over 20 in conference proceedings that are reviews or address solar telescope design issues). They are available at http://dot.astro.uu.nl, as are all periodic DOT reports to NOVA.

Solar Magnetism

Magnetism lies at the root of most solar and heliospheric physics. The intricate structure of the solar magnetic field, the 11-year activity (sunspot) cycle and the influence of the field on the heliosphere represent major quests of (astro-)physics which bear directly on the human environment. The sun's magnetic field is generated by enigmatic dynamo processes in the solar interior, is organised into the highly complex patterns of solar activity observed in the solar photosphere, dominates the structure of the outer solar atmosphere (chromosphere, transition region, corona), regulates the solar wind, and affects the whole extended heliosphere.

In terms of pure science, solar magnetism provides the Rosetta stone of cosmic magnetism, not only in other stars but also in accretion disks, cataclysmic variables, galactic dynamics, active galactic nuclei and other cosmic objects in which MHD and plasma processes control the structure and energy partitioning. The sun is close enough to study these processes in observable detail.

Terrestrial plasma confinement machines do not reach the scales, densities and temperatures exhibited in the solar atmosphere. Solar physics complements plasma instability studies in fusion research, the sun representing a non-terrestrial plasma physics laboratory.

Space weather (the solar influence on the near-earth environment and the Earth's climate) is set by solar magnetism. Solar activity modulation affects satellite orbits, influences jet stream patterns and contributes to the causes of minor, possibly major, ice ages.

Solar surface magnetism is the key for advances in these research areas. At the surface, the magnetic field wins from the gas pressure: the plasma beta parameter (ratio of gas to magnetic pressure) flips from large to small across unity, so that the field role switches from being dominated by gas motions to dominating gas motions. At the solar surface, the field displays patterning imposed by the subsurface dynamo and convective flows while, at the same time, it controls flows and wave motions to the outer atmosphere. This flip in domination makes it desirable to observe the magnetic field patterning simultaneously in the photosphere and the overlying chromosphere. The DOT is specifically suited to such solar surface magnetometry with high spatial (angular) resolution.

The solar atmosphere changes dramatically between different regimes and presents drastically different scenes to the terrestrial observer at different wavelengths. The solar photosphere, defined as the layer where the bulk of the electromagnetic radiation escapes as visible light (a dramatic transition from near-equilibrium photon enclosure, killing off the subsurface convection into the shallow pancake pattern called granulation) is also the layer where magnetic fields take over from gas dynamics in dictating the structuring and in supplying the key processes, and it is also the outermost layer where the sun may be regarded as spherical in zero-order approximation. The chromosphere is magnetically split into network and internetwork in quiet regions and is very finely structured above active regions. The transition to the corona consists of tiny fibrils with much variation in length, inclination, and ordering. The closed-field parts of the corona outside coronal holes are made up of bundles of very thin coronal loops. Yet unidentified processes supply energy to the gas in these loops, reaching a balance against cooling by X-ray photon losses at temperatures of 1-2 million K.

The loops are magnetically anchored in yet unknown fashion to the strong-field flux tubes that break out of the photosphere and respond dynamically on a wide variety of timescales to the footpoint forcing. These magnetic connections between very disparate regimes, from gas dynamics via magnetohydrodynamics to plasma physics and from LTE radiation enclosure to X-ray photon drain, require simultaneous study of structures, processes and radiation in the photosphere, chromosphere, transition region and corona.

High-Resolution Proxy Magnetometry

With its speckle data-acquisition system, the DOT became the first solar telescope to regularly provide long-duration (multiple hours) image sequences at consistent 0.2 arcsec angular resolution. The multi-wavelength synchronous speckle system made the DOT a high-resolution mapper of the magnetic topology and its dynamics over a sizable field (90x70 arcsec) in tomographic fashion, simultaneously for the photosphere (G band), low chromosphere (Ca II H), and high chromosphere (tuned Halpha).

Solar surface magnetism consists of a remarkable hierarchy of discrete strong-field structures. The basic entity is the *flux tube*, a key concept of MHD astrophysics. Solar flux tubes have tiny cross-sections (0.2 arcsec) but they became observable with Canary-Island seeing quality, particularly in the Fraunhofer G-band around 4305 A in which they show up as tiny bright points. Recent results from ab-initio magnetoconvecton modeling have crowned may years of effort in numerical MHD simulations by showing in detail how this comes about (Keller et al. 2004, Carlsson et al. 2004).

The low chromosphere sampled by Ca II H or K shows clusters of bright grains outlining the magnetic network and greyish internetwork features marking acoustic oscillation interference patterns. The high chromosphere sampled by Halpha portrays the intricate structure of the magnetic canopies expanding from the network in the form of fine fibrils. These regimes cannot yet be modeled realistically in numerical MHD simulations, but efforts to do so are underway, also at Utrecht.

The Balmer Halpha line comes from the most abundant element but is much less strong than Ca II

H & K in the spatially averaged solar spectrum because its lower-level population has very low weight in the Boltzmann population partitioning over the hydrogen energy levels. Nevertheless, its high excitation energy causes this line to respond to gas at high temperature and also to cool gas when it is shocked (through time-dependent ionization/recombination balancing, a recent finding in the Utrecht thesis of J. Leenaarts), so that it maps low-lying fibrils in the high chromosphere when these are sufficiently dense.

DOT Science

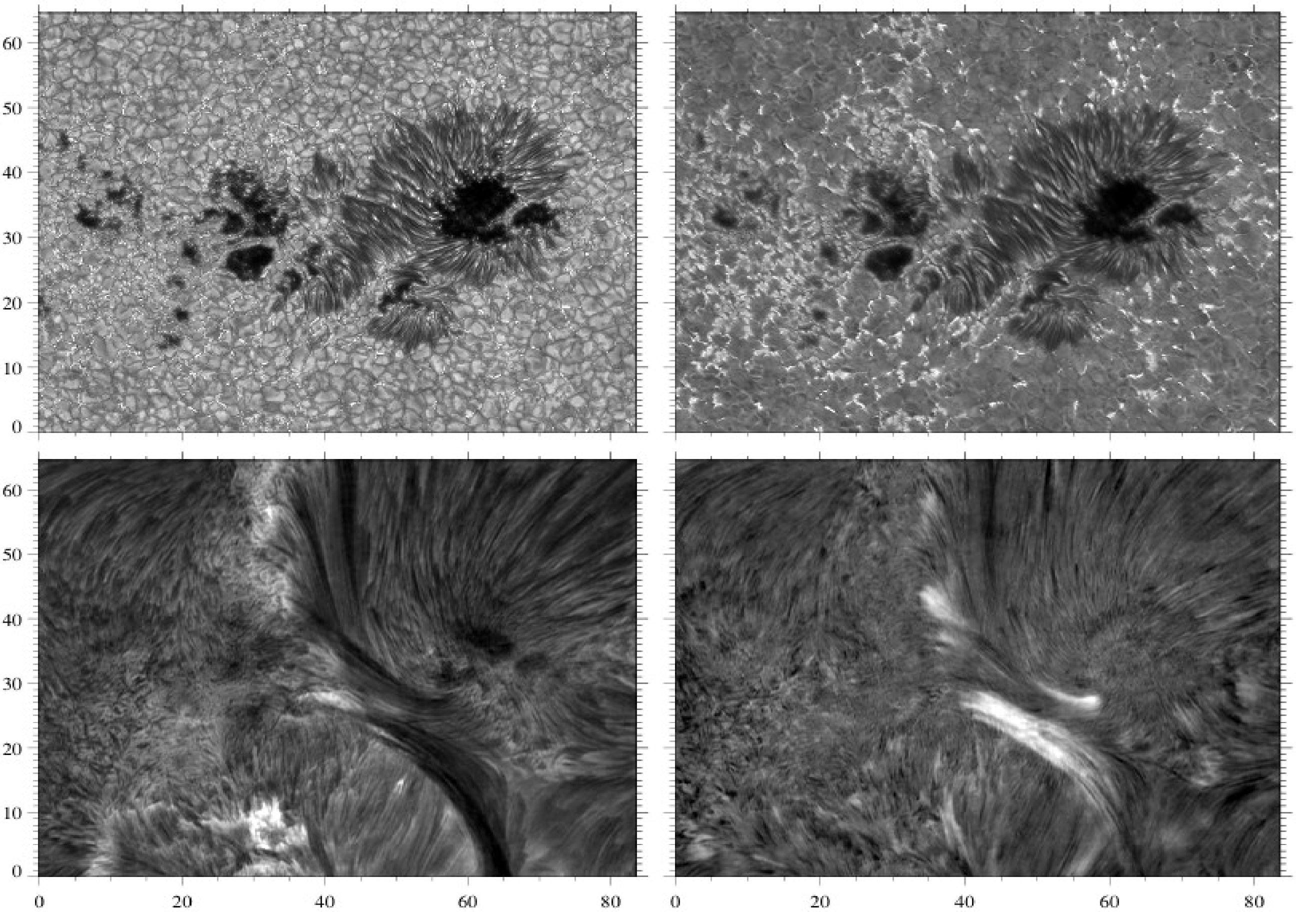

Fig.2: Example of DOT tomography. Co-spatial and synchronous speckle-reconstructed images of solar active region AR10786. Upper-left: G band. Upper-right: outer Ca II H wing. Lower-left: Halpha line-center intensity. Lower-right: Halpha inner-wing Dopplergram, with bright denoting redshift (downward motion). Axis scales in arcsec (1 arcsec corresponds to 725 km on the sun). The G band is the principal diagnostic to chart tiny magnetic elements in intergranular lanes. The Ca II H wing shows them higher up where they appear brighter but less sharp. Halpha line-center displays the magnetic topology of loops connecting the active region to nearby plage and network, overlaid by dark arch filaments. The Halpha Dopplergram shows flows in the latter and a ring-like running penumbral wave spreading outward around the spot. This figure is only a single-moment snapshot; the dynamics in the scene is displayed on a corresponding movie provided on the DOT website. The Halpha Doppler movie in particular demonstrates vividly that dynamical phenomena as running penumbral waves require such sustained-quality time sequences.

The paradigm of stellar activity is that stellar coronae and chromospheres are heated magnetically, but it remains an open question how this comes about. Since the fields are anchored in the dense gas at the solar surface, the dynamics of flux tubes, pores and spots lie at the root of outer-atmosphere heating.

A recent important breakthrough in modeling the topology of solar magnetic fields in and above active regions is the success of Non-Linear Force-Free Field (NLFFF) extrapolation from photospheric magnetograms such as the ones that are presently provided by the SOHO mission and will be provided at better resolution and cadence from 2009 with the SDO mission. This modeling suffers from the fact that the fields are not force-free in the lower atmosphere, but it is now clear that when it is combined with the apparent (but magnetically unsigned) topology displayed by the chromospheric fibrils observed in Halpha, the reliability of the modeling increases to the extent that even the amount of free energy in the field configuration can be estimated (see Bobra et al. 2008). In brief, magnetogram collection from space plus earth-based Halpha fibril observation plus NLFFF modeling is likely to be the path towards realistic field topology estimation including the likelihood of eruption, and so to become the basis for space weather forecasting. This finding lends large motivation to continue DOT observations in the coming years, during which the DOT capability for Halpha mosaic imaging of complete active regions at sub-arcsecond resolution remains virtually unique (see DOT status below).

In addition, by combining high-resolution surface imaging and magnetometry with ultraviolet spectrometry and coronal imaging from space, one may correlate and trace surface motions and corresponding chromospheric dynamics in magnetic structures tomographically, all the way out into the optically-thin plasma regime. Magnetic wave studies of this type are a major component of current solar physics.

Other DOT science goals consist of studying the emergence and decay patterns of solar magnetic fields, the photospheric-chromospheric dynamic connection in non-magnetic regions, the fine structure of plage and sunspots, and the fine structure of prominences.

Current DOT Status

During the past years the operation of the DOT including the salaries of P. Suetterlin and F.C.M. Bettonvil was funded primarily by the Department of Physics and Astronomy, with a sizable contribution from NOVA and smaller contributions from other sources. The Department, presently undergoing a painful reorganization to face an overall deficit, has agreed to the continuation of the DOT on outside funding as a facility that remains available for technological purposes (testbed for the future European Solar Telescope FP7 Design Study grant (2008-2011) and the STW enclosure development grant (-2010), and in principle remains available for observing as well. The DOT account still has reserves form previous years that will be spent during the coming years and are counted as income below, henceforth called UU budget.

A major motivation to continue DOT observing the coming years, while solar activity picks up in Cycle 24, is its role as potential supplier of Halpha imaging. Four years ago, at the negotiation of the past contract, the expectation was that after the launch of the Japanese Solar-B mission, now called Hinode, in the autumn of 2006 the DOT role would be taken over by its SOT telescope, which is much like the DOT in aperture (50-cm), corresponding resolution (0.2-0.3 in the visible), and tomographic imaging capabilitie including the G band, Ca II H and tuned Halpha - much like the DOT but not interrupted by bad weather, poor seeing, or nights outside the orbital eclipse season. Thus, the prospect was that DOT science would be taken over by Hinode.

Unfortunately, this is not the case because Hinode's Halpha imaging suffers from malfunction of the narrow-band tunable filter in Hinode. It cannot register images in Halha with rapid full-profile sampling, and interleaved regsitration of photospheric Dopplergrams and magnetograms using another line is fully out of the question. The upshot is that, although Hinode's mission is driven by the quest to map magnetic fields from the photosphere to the corona, the chromospheric interface is lacking: Hinode charts only the photosphere in visible light, the corona at EUV and X-ray wavelengths, but lacks a chromospheric diagnostic (except for off-limb observation with a wide-band Ca II H filter).

This Hinode malfunction implies that the DOT's Lyot filter for Halpha maintains its present status of being the best Halpha-movie producer including profile sampling worldwide. In addition, if the planned DOT-team effort to repair the Lyot filter for the Ba II 4554 line (at Irkutsk where it was built, in April) succeeds, the DOT will add the capability of taking same-resolution Dopplergrams and magnetograms synchronously and cospatially with its Halpha imaging. It will then, during good seeing, have the capability that was the major driver to launch Hinode.

Outline of science support activities

Here we request funding for a junior support staff member plus some additional operations budget. The tasks of the junior support staff member are (1) observing support, (2) speckle software operation and maintenance, (3) data archiving, and (4) training & support of new telescope users. These activities are outlined below in more detail.

Observing support

The DOT is open for external users. Observing days are distributed among Utrecht users, Spanish time (20%), CCI-ITP time (5%) and external users. Allocation takes place through a peer review process by scientific merit. The emphasis in DOT scheduling has been on partnership in multi-telescope campaigns, since these have become the major and most productive observing mode in solar physics. Typically, wide-field DOT speckle tomography is combined with SST adaptive-optics observing, infrared spectropolarimetry with the other European telescopes on Tenerife, and space observation (SOHO, TRACE, Hinode, RHESSI, and others in future).

Until the end of 2007 observations were done mostly in service mode with Pit Suetterlin being the principal observer. From January 2008 onwards Suetterlin is not part of the DOT staff anymore, although he remains on site as SST support astronomer, thereby keeping his expertise on site. Observations will be carried out by guest observers, but a scientific support staff member, assisting scheduled DOT guest observers and taking care of data quality control is essential to maximize the scientific output of the DOT.

Observing campaigns normally last for 2 weeks for each successful application, which is considered as a minimum to give the observer a reasonable chance of good seeing conditions. During the observing campaign the scientific support staff member will take care of the speckle processing (see also next session), such that the observer can take the fully reduced and processed data home at the end of the campaign.

Speckle software operations and maintenance

The Speckle Masking is the method of choice for restoring DOT solar observations. This sets the DOT apart from the atmospheric restoration programs elsewhere, which rely on adaptive optics. It uses the fact that short-exposure images freeze the atmospheric distortions while still showing signal at high spatial frequencies, although with statistically disturbed phases. Speckle reconstruction through the Speckle Masking technique is a well-established technique also in solar physics but never applied on a scale comparable to what the DOT employs. All data are treated in this way, and the resolution is approaching the diffraction limit (0.2 arcseconds) already from Fried parameters of 7 cm (good but not perfect) and uniform over the full field. This happens not infrequently during multiple hours, resulting in the famous hour-long DOT-movies.

To process the data without delay, the DOT Speckle Processor (DSP) became operational in early 2005, being a 70-processor cluster capable of keeping up with the processing of the average daily harvest of speckle data. Until that moment, a 6 camera two-hour run needed at least one month of wall-clock time - a ratio of 350 between observing- and processing time - which created an enormous backlog in image processing. An innovative and new development for the DSP was direct cooling with water of all CPUs, memory controllers, voltage regulators and storage of the heat in order not to disturb astronomical observations. This passive water system and a small active water system for the auxiliary electronics give both their heat to a 5000 l water tank where the heat is stored. Release through a radiator is done only during the early morning and late afternoon, after sunrise and before sunset. The DSP was built with financial support from NWO and SOZOU. The DSP still runs the initial code, which is based on IDL, and which needs to be ported to C++. Work on this has been done by Alfred the Wijn but never implemented and adapted to the current software version. Porting to C++ speeds up the speckle processing to truly overnight processing, permitting 8-hours run on an every day basis in high-speed cadence, maximizing science output. Both Suetterlin and de Wijn have agreed to lend their expertise to this effort.

Data archiving

The DOT follows an 'open' data policy, meaning that the processed observations are made available on the web. This is of great importance for the scientific community in many respects: theoreticians looking for observational prove (or disprove) of their models and/or ideas have an easy way of finding the needed observations, observers planning a specialized program can check whether similar observations have already been done and then decide to take the available material for further investigations, thus freeing valuable observation time at the observing facilities.

The processed data is stored on a high-volume data server installed in Utrecht, which contains all high-resolution movies of the sun collected since the autumn of 1999.

Recently the DOT database was upgraded with a user-friendly graphical interface showing for every day with worthwhile data a thumbnail pictorial index of what was collected. A search engine helps in finding data and can search according to target, observing mode, time of observation, cadence, solar disk location and average seeing quality, and links as well to the pertinent Mees active region maps.

Further development of the database, maintenance and quality control are typical tasks for the scientific support staff member. The database will also be integrated into the Virtual Solar Observatory, which integrates the DOT data with virtually all other sources of regular solar observations.

Training & support new users

The DOT runs a successful 'hands on telescope' DOT education program, led by Rob Rutten, which brings students (Utrecht and now also the Stockholm and Oslo, but basically open to a wider community) to La Palma gaining experience in solar instrumentation, telescopes and solar physics, on-site teaching included. From 2008 onwards the program will continue. The junior support staff member will assist at the telescope and with the data reduction and handle the local organization.

Management plan, timeline, list of milestones and deliverables

Management Plan

Since 1/1/2008 Christoph Keller has the overall responsibility for the DOT, and he will also have the overall responsibility for the proposed effort. Felix Bettonvil, who spends 80% of his time on European Solar Telescope Design Study tasks (paid by EU grant) and 20% on DOT-related tasks (paid by STW) will be in charge of day-to-day activities and telescope management. Rob Rutten will continue to coordinate the observing program.

Timeline

Certain tasks occur every year. The DOT observing season runs from April to November. In the winter months, technical work is done including research related to the STW project 'Completely open foldable tent construction, still closable in strong wind' that aims at collecting data of the foldable dome construction in many different weather situations, including heavy storms.

The deadline for observing proposals is January 31 of the corresponding year, after which proposals are peer-reviewed by scientific merit.

In the summer the junior support staff will assist in the data collection, reduction, and processing. Observers will be assisted to make them familiar with the instrument and provide help during the observations. The data will be reduced during the night after the observations and will be ready for scientific analysis the following day.

In the September/October time frame, schools for students will take place at the telescope and will need support from the junior support staff.

In the winter the junior support member will work on speckle software and data archiving.

Milestones and Associated Deliverables

6/2008: Job anouncement
9/2008: Shortlist
12/2008: Signed ontract for junior support staff
1/2009: Official start of junior support staff position
12/2009: Operational C++ speckle code
12/2010: Complete integration of all DOT data into the Virtual Solar Observatory

Requested NOVA Funding and Contributions from other Resources

We request support from NOVA to provide for 1 year of junior support staff in 2009 (50.9kEuro) and a guarantee for funding for the junior support staff and some science operations costs in 2010 (74.0kEuro) and 2011 (75.1kEuro) if the EU FP7 Opticon proposal is successful (or an equally large outside contribution can be secured) to continue the highly successful DOT science exploitation.

In late 2007 a budget plan to continue DOT operations during 2008 and 2009 was approved by UU, which enables the continuation at minimum costs. The aim was to keep the DOT fully functional and to continue observations, data reduction and provision of access via the DOT data server. From 2008 on, observations will not be carried out anymore in *service mode* (as has been done on a regular basis until the end 2007) during most of the time, but will be performed by the guest astronomers and/or external observers. The budget includes the costs of travel and subsistence for an external observer. DOT data remain open to stimulate international collaborations. Access to the DOT experts Bettonvil and Suetterlin remains available although both are now being paid from other resources that comes along with its own obligations.

The budgets from 2009 to 2011 look as follows:

EXPENSES

	2009	2010	2011	TOTAL
Fixed operations costs	61.3	62.5	63.8	187.6
Observation related operations costs	21.0	21.4	21.8	64.2
Junior support staff member	50.9	51.9	53.0	155.8
TOTAL	133.2	135.8	138.6	407.6

INCOME

	2009	2010	2011	TOTAL
UU fixed costs operations budget	49.0	15.0	-	64.0
UU observation costs operations budget	21.0	-	-	21.0
STW operations contribution	12.3	12.5	12.8	37.6
OPTICON FP7 Access program	-	34.3	50.7	85.0
NOVA3 junior staff member	**50.9**	**51.9**	**53.0**	**155.8**
NOVA3 additional operations budget	**-**	**22.1**	**22.1**	**44.2**
TOTAL	133.2	135.8	138.6	407.6

NOVA3 request

	2009	2010	2011	TOTAL
	50.9	**74.0**	**75.1**	**200.0**

The fixed costs for keeping the DOT open and the additional costs for observations for 2009 are based on the following cost breakdown:

DOT exploitation budget for 2009

	Fixed costs	Costs for observations
Computer investments	-	-
Instrument development	-	-
Office costs	3.2	0.5
Maintenance costs	2.0	-
Travel costs technical	9.2	-
Travel costs observational	-	14.4
Subsistence costs	12.5	6.1
Local transport	3.4	-
Transport Utrecht – La Palma	-	-
Contribution CCI/ insurances	17.3	-
Workshop consumables	7.4	-
Consumables	6.3	-
TOTAL	**61.3**	**21.0**

Notes: Computer investments: Upgrades of the installation or new computer equipment is not included in the budget.
Instrument development: Development and realization of new instrumentation for the DOT is not included. If new ideas or

new scientific insights emerge, funding should come from external sources, for instance SOZOU.
Office costs: Includes telephone, office consumables, storage media. It is based on costs over recent years.
Maintenance costs: Costs for general maintenance on the installation, cleaning and small repairs. The budget is set to minimum with investments in spares and unforeseen expenditures largely reduced, but ensures keeping the telescope in a safe condition and in good working order.
Travel costs technical: Costs for travel for maintenance, cleaning, calibration, service, system management.
Travel costs observational: Travel costs for operation of the telescope at normal DOT use. Included in the budget are costs for an external observer/guest astronomer, carrying out the observations and data processing.
Subsistence costs: All subsistence costs divided in technical and observational personnel on La Palma, in accordance with the minimum travel needs.
Local transport: Fixed costs for cars (maintenance, ITV tests, taxes, insurances).
Transport Utrecht – La Palma: In the case of new instrumentation costs for international cargo from Utrecht to La Palma has to be paid from the external resources, which fund the instrument development.
Contribution CCI: Annual costs for the CCI common services, observatory contributions, installation insurances and contribution to the IAC Research School.
Workshop consumables: Running costs for mechanical workshop. Sharpening of workshop tools, clamping parts, maintenance machinery.
Consumables: Costs for water and electricity of telescope and DOT Speckle Processor.

For 2010 and 2011 the budget is assumed to be the same with an inflation correction of 2%.

Location(s) where Activities will be Carried Out

Roque de los Muchachos, La Palma, Canary Islands.

References

Bobra, M.G., van Ballegooijen, A.A., DeLuca, E.E. 2008, ApJ, 672, 1209 -1220

Carlsson, M., Stein, R.F., Nordlund, A., Scharmer, G.B. 2004, ApJL, 610, L137-L140

Keller, C.U., von der Luehe, O. 1992, A&A 261, 321

Keller, C.U., Schuessler, M., Voegler, A., Zakharov, V. 2004, ApJL, 607, L59L62

Rutten, R.J., Hammerschlag, R.H., Bettonvil, F.C.M., Suetterlin, P., de Wijn, A.G. 2004, A&A, 413, 1183-1189