European Science Foundation
Standing Committee for Physical and Engineering Sciences (PESC)

ESF PESC EXPLORATORY WORKSHOP

New Generation Large Aperture Solar Telescopes:

Science Drivers, Observational Strategies And Perspectives

Monte Porzio Catone, Italy, 9 - 12 April 2006

Scientific Report by:

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Executive Summary

The workshop was convened by Dr. Gianna Cauzzi (INAF-Arcetri, Italy), Dr. Ilaria Ermolli (INAF-Roma, Italy) and Prof. Francesco Berrilli (Univ. di Roma-Tor Vergata, Italy), and organized in the conference centre "Villa Mondragone" of the University of Roma-Tor Vergata, a striking and historically significant Villa Tuscolana in the town of Monte Porzio Catone. For a group of astronomers, it was particularly exciting to convene in the spaces where Pope Gregorius XIII signed, in 1482, the reform of the calendar that bears his name.

A dedicated web site has been set up with information about the meeting:

http://www.fisica.uniroma2.it/~solare/ESF

The workshop has been mainly supported by the European Science Foundation (EW05-153), with additional generous contributions from the Istituto Nazionale di Astrofisica (INAF) and the Universita' di Roma-Tor Vergata. All local arrangements were provided for all participants, while long-distance travel was covered on personal research funds. Most of the participants arrived on the evening of April 9; the official sessions opened on the morning of April 10.

The meeting had a total attendance of 30 participants, comprising a number of experts in the field of high-resolution solar physics. In particular, all the directors of the currently operating European ground-based solar telescopes were present, as well as representatives of the US-led Advanced Technology Solar Telescope (ATST) project. Included in the number were the ESF PESC representative, Prof. Ian Butterworth, and the EC (Directorate of Research) representative, Dr. Elena Righi-Steele.

The structure of the workshop was organized around reviews (of 30-40 minutes) on topical issues, followed by one or two shorter contributions and extensive discussions. While only about half of the participants provided a 'formal' talk, all of the attendants actively contributed to the discussions, and such a format was much appreciated.

The main goal of the workshop was to assess the situation of ground-based solar physics in Europe, in an era where large aperture solar telescopes (with diameters of several meters) are becoming technically feasible but require a high level of coordination and collaboration in order to pool together the necessary resources. The meeting opened with a series of talks stressing the scientific case for large telescopes, detailing the necessity of maintaining a high polarimetric sensitivity while reaching spatial resolution of the order of few tens of km across the solar surface, and an adequate temporal resolution to follow the evolution of such structures. The breadth and complexity of the issues discussed clearly evidenced the relevant expertise, both theoretical and observational, of European scientists, and how they will substantially benefit from access to a large solar telescope.

The subsequent contributions reviewed the status of future solar infrastructures (both ground- and space-based) with a relevant European participation and that are nearing completion or are in an advanced design stage. Most relevant have then been the extensive discussions, held during the second and third day, on how to best capitalise on the large scientific and technical knowledge that European scientists gained in such enterprises. Particular attention has been given to the issue of increasing European networking and collaboration in order to gain further visibility in the astrophysics field. The presentations on the third day of the EC FP7 and of the ESFRI and ASTRONET efforts, bore directly onto these issues.

Scientific Content

In recent decades, solar physics has experienced a radical transformation, turning from a more phenomenological discipline to a hard physical science, whose focus is the study of the generation and dissipation of the magnetic fields that permeate the solar structure. The forces behind this change have been the vastly increased sophistication of numerical simulations and radical improvements in observational capabilities. It has thus become increasingly clear that the basic interactions between the magnetic fields and the plasma in the solar atmosphere occur at spatial scales that are out of reach of the current solar telescopes, i.e. on the order of few tens of km on the solar surface. Additionally, in order to perform true physical measurements of the conditions of the magnetised solar plasma, it is necessary to extract information from the solar spectrum with great accuracy. The increased light-gathering power of larger apertures will be crucial for instruments that slice the solar flux into ever finer spatial, spectral, and temporal bins while attempting to make observations with a precision of 10^{-3} or better. Therefore, a significant improvement in our diagnostic ability calls for larger aperture telescopes for solar research.

The Exploratory Workshop brought together experts from across Europe to discuss the innovative research that will be made possible with the advent of such large-aperture solar telescopes, and the best strategies to capitalize on the notable European expertise in the techniques of high-resolution solar imaging, precision measurement of magnetic fields and their interpretation, magneto-hydrodynamical simulations etc. In the next few years, several infrastructures with a significant European component will start taking data that will increase the accumulated knowledge in these and other areas. A crucial goal of the workshop was to discuss the European scale networking and collaboration that can produce strategic added value to these developments in high-resolution solar physics research.

The meeting was structured in 3 parts, as described in the following. Discussions often carried on long after the allotted times, and through subsequent contributions.

The science case: polarimetry frontiers and plasma diagnostics

The Sun is a laboratory for plasma physics like no other. All manner of physical processes are constantly at play at a multitude of scales throughout the solar atmosphere. In order to understand what is taking place in the observed structures, solar physics must devise techniques to decipher the radiation coming from the Sun. Further, as our technological capabilities progress, we can explore ever smaller scales and finer details, studying new regimes and revealing new physical processes at play. Thus, this session discussed the techniques and the required capabilities that would be needed to explore these new regimes. From the theory of polarized radiation, one can define the type of observations that would be needed to properly deduce the distribution of the magnetic field on the small scales in the solar photosphere. The requirements laid out included the simultaneous observation of *multiple* magnetically sensitive lines, with a high spatial and spectral sensitivity, and a polarimetric sensitivity that would ideally reach 10^{-5}. Such stringent scientific requirements will need to be carefully evaluated when designing dedicated instruments that might have to compromise, for example, the spatial resolution in order to gain in polarimetric accuracy. However, there is no reason to think that the parallel increases in polarimetric accuracy and inversion techniques that has taken place over the past several decades will not continue into the future. For example, larger telescopes will allow the simultaneous high quality observations of the Hanle and Zeeman effect in solar spectral lines, an approach that almost certainly will provide new insights into the conditions in the solar atmosphere. The discussion touched on how far one can

trust the interpretation of unresolved processes on a theoretical basis alone. It was clear that it will be necessary to try to resolve the finest possible scales in solar atmosphere in order to have a complete understanding of the physics taking place. Obviously then, future infrastructures will have to provide for the possibility to approach the outstanding questions from many different directions, taking full advantage of the flexibility inherent in a ground-based telescope.

Another significant advance in solar physics over the past decade has been the development of magneto-hydrodynamical numerical simulations, that have reached a high degree of realism, especially for what concerns the lower solar atmosphere. Progress has been recently obtained towards more comprehensive models including the chromospheric layers, that well reproduce some of the observational evidences, such as the simultaneous presence of hot and cold features, much spatially structured. An extremely useful indication from the simulations is that small scales are critical in determining the physics at work; a best compromise with what is realistically reachable with observations seems to be a spatial resolution of 30 km on the solar surface. Still, words of caution were spoken about utilising the simulations as the 'truth', especially for what concerns the presence and distribution of (small scale) magnetic fields, that for now do not appear self-consistently in the calculations but are prescribed a priori. It was remarked how high resolution observations, i.e. powerful telescopes, have and will still drive the simulations, rather than the other way around. Finally, in this session there were also several presentations on the advances in understanding the physics of the corona from ground-based observations. The clear goal is to measure and interpret the magnetic field in the coronal plasma. This would allow a complete picture of the magnetic field topology from its emergence from the convective region out into the tenuous corona where the solar wind and heliosphere originate. Coronal observations of the magnetic field are extremely difficult due to the relatively low photon flux and the very low magnetic field strengths (0.001 T). Notwithstanding these obstacles, several exciting advances have been made in recent years and the first direct measurements of the magnetic field strength have been obtained. While European efforts in ground-based coronography have been limited in the past, the consensus was that this is an exciting scientific challenge and that European scientists will increase their role in this area in the coming decade.

Near term and future infrastructures

The second day of the workshop concentrated on reviewing the status of various solar infrastructures, both ground- and space-based, that are nearing completion or are in an advanced design stage. Because of the range of temperatures and processes occurring on the Sun, it is imperative to observe multiple wavelengths and spatial scales. This requires a suite of complementary instrumentation and coordinated approach to the development of new infrastructures. It was underlined that while space-based instruments have particular advantages in terms of wavelength range, temporal coverage, and the absence of atmospheric turbulence, ground-based observatories will always have the advantage of having larger apertures, more flexibility, and almost unlimited data fluxes. The importance of larger apertures was also emphasized because of the need for ever finer spatial, spectral, and temporal sampling of the incoming flux. It is curious to note that, for a given spectral class of star, the number of photons per resolving element is independent on distance - at milliarcsecond resolutions the Sun truly becomes a star!

There was an extended discussion on how to best operate and optimise the European solar telescopes in the Canary Islands. The existing infrastructures, mostly operated by single national bodies, are coming under increasing funding pressure. A more efficient approach

would identify the essential infrastructures that need be maintained and seek to coordinate national resources in support of those structures under a joint management scheme. Such an approach would presumably lead to a European body that would have as its role the coordination of high-resolution, ground-based solar physics at the European level. It was agreed that such an institute would lead to a more effective and more cohesive solar physics community in Europe. No existing European organization, for example JOSO or EAS/SPS is in a position to play this role, and the consensus was that a new consortium should be formed to this end.

The next year will see the arrival of the first data from telescopes such as Solar-B and GREGOR, that will provide an evolution of the current capabilities. These will certainly provide new insights, but already it is clear that these are intermediate steps in the capabilities required for a detailed understanding of the Sun. Infrastructures further into the future were also presented. These included space missions (Solar Orbiter) and ground-based radio facilities (FASR, ALMA, LOFAR). The Advanced Technology Solar Telescope (ATST) was presented by Steve Keil, the project PI. Since the capabilities of the proposed telescope were already well known to the community, this talk highlighted the organizational and funding issues involved in the construction of a large telescope. The US National Science Foundation is looking for international partners to collaborate in the construction (projected cost 160 M$) and operation (projected annual expenses 12 M$, including instrumental development) of the telescope.

Thus the pressing need for a large aperture solar telescope, both to address new scientific questions as well as to complement other infrastructures under development, was made clear. The ensuing discussion focused on how the European community could best obtain access to such a facility, whether through a participation in the ATST or through an independent or complementary project. The advantages and the risks inherent in the various hypotheses were discussed. The level of European participation in the construction and operation of ATST, whether at a 50% or 30% level, were also discussed, as well as the ramifications in other areas of the different levels of contributions.

Networking and collaborations – building a European dimension

This session saw the presentations of Dr. Righi-Steele about the opportunities offered by the upcoming Framework Programme 7 of the EC, whose first calls for proposals will appear by the end of 2006. Much of the topics described were relevant to the possible actions discussed in the above section and in general during the whole Workshop.

FP7 will extend for a longer period than previous instances (2007-2013), and much more accent will be put into achieving international cooperation. For what concerns existing research infrastructures, the main objective will be to optimise their use, development, and integration, focusing on the ‘Integrated Initiative’ instrument (I3), that has proven very effective in FP6. In particular, for the FP7 calls it will be necessary that a proposal contain all three activities (networking, joint research, transnational access), while in FP6 it was possible to have only two. New infrastructures will instead be able to gain support from the EC either accessing funds for design and development studies (‘bottom-up’ approach, as in FP6), or through support for actual construction (‘top-down’ approach). The latter is envisioned in two phases: the preparatory phase, in which construction plans are finalised, legal entities are set up, management aspects are considered etc., and the actual construction phase. It is foreseen that Europe can participate with these instruments in international projects, as long as they have a clear added value for European science. The level of financial participation of the EC will be

decided on a 'case-by-case' basis, but it was made clear that the major financial burden for the realisation of new research infrastructure will be shouldered by the national entities involved.

Directly related to the issue of new research infrastructures is the roadmap currently in the making by ESFRI (European Strategy Forum on Research Infrastructures). ESFRI has been set-up by the EC as an unofficial link among national research ministries, with the goal of assisting the development of research policies, and act as an incubator for new infrastructure projects. The Research Infrastructure roadmap will be a crucial instrument, as it will identify the new RI that more correspond to European needs, and represent a tool for decision makers, providing focus for long-term budgetary planning. Most of the working groups involved, and in particular the one for astrophysics, have already issued preliminary reports; following a phase of validation by ESFRI, the release of the first ESFRI Roadmap is expected for October 2006. While any project can in principle stem out of national agreements, roadmap notwithstanding, it is understood that support from Europe to new RI will be granted only if they appear in the roadmap. Inclusion of new projects will be re-evaluated roughly every two years.

Finally, Dr. Fontana from INAF briefly described ASTRONET, an ERA-Net financed by the European Commission FP6 under the initiative 'Integrating and Strengthening the European Research Area (ERA)' (http://www.astronet-eu.org). The main goal of ASTRONET is to pursue the establishment of a comprehensive long-term planning for the development of European astronomy. Following the preparation of a Science Vision for the scientific development of European astronomy over this time frame, ASTRONET will propose an Infrastructure Roadmap of European astronomy and establish the funding and organizational routes to fulfil the plan.

The discussion focussed on how to best reconcile the needs of the European solar community involved in high resolution studies – identified in the previous discussions - with the opportunities and initiatives just presented. It was agreed that the community must provide a relevant input to the Science Vision in ASTRONET, keeping in mind the complementarity with similar efforts already undertaken (for example ESA's Cosmic Vision); a European entity able to operate in a highly cohesive way was deemed most necessary also for this task. At the end of the meeting, a draft resolution was agreed upon, in which the participants expressed their commitment to establish a European organism charged with defining and coordinating continent-wide efforts to ensure access of European solar astronomers to leading infrastructures.

General assessment and future developments

The workshop has successfully brought together a representative fraction of the European solar physics community involved in high resolution studies. The participants strongly stressed the need for European solar physicists to gain significant access to large scale, leading observing facilities, in order to best exploit their excellent capital of scientific and technical know-how in this field, acknowledged world-wide. During the meeting it was also clearly recognised that the community needs to push networking and cooperation across Europe in a more aggressive way, in order to reach the 'critical mass' that will allow it to work more effectively towards this goal. A resolution defining such commitment (included in this report as "Villa Mondragone Resolution") has been signed by the European participants to the workshop, and distributed to the relevant national communities and funding agencies. The resolution states the intent of creating a European organism charged with defining and coordinating continent-wide efforts to ensure access of European solar astronomers to leading infrastructures. A meeting of representatives of all the interested countries has been already scheduled for mid-June. During the meeting this task will be analysed in more detail, with particular emphasis on the possibilities offered by the upcoming FP7 of the European Commission, and the organisation of the European participation to the ATST.

Villa Mondragone Resolution

Recognizing,

that the European solar physics community, in order to maintain its forefront position in research, needs access to the best observing facilities in the world, and that coordination of European activities will best support this access,

we, the *Undersigned*, resolve as follows.

- An organisation shall be established at the European level with the task to define and to co-ordinate the effort necessary to ensure access of European solar astronomers to, and promote creation of, worldwide leading ground based observing facilities.

Also recognizing

that the Advanced Technology Solar Telescope (ATST) will establish leadership in ground based solar research in the next decade,

that the input of European solar physicists has had a major influence on the design of ATST and will have a decisive impact on its capabilities and success,

we resolve as follows.

- The *Undersigned* shall seek national and European funding for a viable and active partnership in the design, construction and operation of the ATST.
- The *Undersigned* shall develop their own facilities to move in step with the evolving needs of the solar physics community, in terms of research, training of young scientists, and public outreach, during the construction and operation phases of ATST.
- The *Undersigned* shall facilitate the access of the ATST solar community to their own facilities as a recognized contribution to the overall ATST effort.

Villa Mondragone, 12. April 2006

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FINAL PROGRAMME

Sunday 9 April 2006

Afternoon	*Arrival*
19:00-22:00	*Welcome Dinner at Villa Vecchia*

Monday 10 April 2006

09:00-09:15	**Welcome address: Convenors, Univ. Tor Vergata and INAF Representatives**
09:15-09:30	**Presentation of the European Science Foundation (ESF)** **Ian Butterworth** (Standing Committee for Physical and Engineering Sciences)
	Session 1: 'The Science Case: Polarimetry Frontiers' Moderator: **J.C. del Toro Iniesta**
09:30-10:00	New polarimetric diagnostics in solar physics, **E. Landi degl'Innocenti**
10:00-10:20	Spectropolarimetry at "low" spatial resolution with a 4-meter solar telescope, **A. Lopez Ariste**
10:20-11:00	**Discussion**
11:00-11:30	*Coffee break*
11:30-12:10	Why polarimetry beyond the present capabilities? **M. Collados Vera**
12:10:12:30	The physics is in the small scales, **J. Sanchez Almeida**
12:30-13:00	**Discussion**
13:00-14:30	*Lunch*
	Session 2: 'The Science Case: Plasma Diagnostics' Moderator: **G. Cauzzi**
14:30-15:10	The role of high resolution simulations in planning, calibrating and interpreting observations, **M. Carlsson**
15:10-15:30	Pushing the spatial and temporal resolution in current observations **L. Rouppe van der Voort**
15:30-16:30	**Discussion**
16:30-17:00	*Tea break*
17:00-17:40	New Directions in Solar Outer Atmospheric Diagnostics, **S. Solanki**
17:40-18:00	Coronal magnetometry with a large-aperture telescope **R. Casini**
18:00-18:30	**Discussion: innovative science questions**

Tuesday 11 April 2006

Session 3: 'The Current Path: Near Term Infrastructures'

Moderator: **F. Berrilli**

08:30-08:50	Summary of science issues, **J.C. del Toro Iniesta**
08:50-09:30	High resolution observations from the ground, **G. Scharmer**
09:30-10:15	**Discussion**
10:15-10:45	*Coffee break*
10:45-11:05	The Sunrise project, **A. Gandorfer**
11:05-11:25	Solar-B: connecting the photosphere to the corona, **S. Matthews**
11:25-11:45	The GREGOR Telescope, **M. Sigwarth**
11:45-12:30	**Discussion: A vision for European Facilities 2006-14**
12:30-14:00	*Lunch*

Session 4: 'The Road Ahead: Future Infrastructures'

Moderator: **T. Rimmele**

14:00-14:20	Solar Orbiter, **E. Antonucci**
14:20-14:40	The future of solar radio-telescopes, **N. Vilmer**
14:40-15:20	The Advanced Technology Solar Telescope, **S. Keil**
15:20-16:00	**Discussion**
16:00-16:30	*Tea break*
16:30-17:10	Future Instrumental Directions, **C. Keller**
17:10-17:50	Future Telescopes Needs / Operational Considerations, **O. von der Luhe**
17:50-18:30	**Discussion: outstanding technological issues and observational strategies**

Wednesday 12 April 2006

Session 5: 'Networking and Collaborations – Building a European Dimension'

Moderator: **P. Palle**

09:20-10:30	**Discussion**
10:30-11:00	*Coffee break*
11:00-11:15	Possibilities and instruments in FP7, **E. Righi Steele**
11:15-11:30	Roadmaps for astrophysics: the ESFRI initiative, **E. Righi Steele**
11:30-11:45	Roadmaps for astrophysics: the ASTRONET initiative, **A. Fontana**
11:45-12:45	**Round Table Discussion:** • Future efforts • Interaction with broader communities • Define follow-up groups • Meeting report
12:45-13:00	**Closing remarks**
13:00-14:30	*Lunch & Departure*

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Gender:

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Age brackets:

30-35: 3

35-40: 3

40-45: 5

45-50: 10

50-55: 2

55-60: 2

60-65: 4

Country of Research Institution:

Belgium: 1

Czech Republic: 1

France: 1

Germany: 5

Italy: 5

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Norway: 2

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