PREFACE

The International Conference *Optical Turbulence - Astronomy meets Meteorology* was held at the Nymphes Bay, Alghero, Sardinia, Italy on the 15-18 September 2008. The present volume contains the texts related to most of the invited talks, standard talks and poster presented at the Conference. An on-line version of this Conference Proceedings, including figures in color, can be found at the sites: *http* : *//forot.arcetri.astro.it/otam*08 and *http* : *//www.eso.org/otam*08. A Conference report can be found on *The Messanger* - ESO Newsletter - December 2008, N. 134, pag. 53.

Motivations

Optical turbulence (OT) is one of the main causes limiting the spatial resolution attainable in ground-based visible and infrared astronomical observatories. It is certainly one of the principal obstacles to be overcome in achieving the performances potentially accessible by the overwelming facilities planned for the next generation ground-based astronomy, the Extremely Large Telescopes (ELTs). The success of these facilities strongly depend on our ability to:
1. Characterise optical turbulence at astronomical sites from a qualitative as well as quantitative point of view,
2. Improve our knowledge of the mechanisms that produce and develop optical turbulence,
3. Predict 3D maps of optical turbulence to optimise flexible-scheduling of scientific programs and instruments,
4. Correct wavefront perturbations produced by the atmospheric turbulence.
Many of the most challenging scientific programmes to be carried out with ground-based telescopes and aiming to enhance our understanding of Universe requires excellent turbulent conditions to be successful. The competitiveness of ground-based astronomy with respect to the space-based astronomy is strictly related to our ability to identify and predict temporal windows of favourable atmosphere conditions in the most accurate way. New and sophisticated Adaptive Optics (AO) techniques, assisted by either

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natural or laser guide stars (such as Multi-Conjugate AO (MCAO), Ground-Layer AO (GLAO) and Laser Tomographic AO (LTAO)), are conceived to optimise perturbed wavefronts corrections on different fields of view but, to optimise their efficiency, they will also require a detailed knowledge of the vertical distribution of the OT (and not simply integrated values). The new generation of AO requires a detailed understanding of the connections between the turbulence spectrum and the shape of the point-spread function (PSF) over the entire field of view. Some specific topics such as the precise nature and role played by the spatial coherence outer scale in the high angular resolution (HAR) techniques and the turbulence spectrum features in non-Kolmogorov regimes, are still active research topics at the frontiers of the theory in this field.

From the meteorological side, Operational Numerical Weather Prediction (NWP) systems at medium and mesoscale range might play an important role for the ground-based astronomy over the next few decades. 4D-Var Assimilation Data* employing satellites measurements have greatly improved the quality of the medium range weather forecasts recently. A new challenge for the meteorology appeared on the horizon: the Mesoscale Data Assimilation. This consists of a network of surface stations and an assimilation system with a resolution of a few kilometers. Such a system is mandatory to improve the ability of mesoscale models in reconstructing the unresolved physical parameters (such as the OT) evolving at spatial and temporal scales smaller than the resolution of the General Circulation Model† and to improve the accuracy of meteorological weather forecast models that extend over limited surface areas. How this can be set up in remote regions of the Earth, such as those that are typically of interest to astronomers, is an important question. This International conference was aimed to all these topics. The original intention of the Conference was to attempt to link the two communities of astronomers and meteorologists. This step is fundamental to guaranteeing the success of dedicated systems conceived for the prediction of the optical turbulence (seeing and related integrated astroclimatic parameters such as isoplanatic angle, wavefront

*In meteorology, Assimilation Data is the procedure that provides the distribution in space and time of the status of a set of variables supposed to describe the atmosphere in a given volume. The accuracy of this description depends on the nature and density of observations (radio-soundings, satellites, etc.) and it is fundamental for better descriptions of the initialization of a model.

†General Circulation Model (GCM) are models that extend over the whole Earth and are used for weather forecasting.

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coherence time, etc.) above astronomical sites to be done with mesoscale atmospheric models. The reason is simple. We need to apply an investigation tool developed in meteorology (atmospheric models) to do science (the characterisation of optical turbulence) in the astronomical field.

Conference Results

The Conference started with a general introduction by two Emeritus Professors. Jacques Beckers introduced the topic of optical turbulence in high angular resolution techniques, and Rene Racine provided a personal and provocative vision of the problem of the turbulence characterisation in astronomy. Subsequent sessions were dedicated to the characterisation of turbulence from measurements. The number and type of optical instruments to measure the vertical distribution (vertical profilers) has suddenly increased in recent years and many of them are conceived to monitor dedicated regions of the troposphere. Among the most interesting results it is worth to highlight the proliferation of vertical profilers dedicated to measuring and characterising the OT with high vertical resolution near the surface. From a typical resolution of the order of 1 km (typical of Generalized Scidar (GS)) we have moved on to resolving thinner vertical slabs of up to a few tens of meters. Concepts on which the instruments are based and/or results obtained in first site-testing campaigns have been presented for the solar and lunar scintillometers called SHABAR (SHAdow Band and Ranger), respectively from Beckers and Paul Hickson, the SLODAR (SLOpe Detection and Ranging) by Richard Wilson and Tim Butterley; HVR-GS (High Vertical resolution Generalised Scidar) and LOLAS (Low LAyer SCIDAR), were presented by Elena Masciadri and Remy Avila, representing two different ways of improving the resolution of a GS near the surface. A version of the SODAR (SOnic Detection and Ranging) at high vertical resolution called SNODAR (Surface layer Non-Doppler Acoustic Radar) by Colin Bonner and even a vertical profiler based on the measurements of the wavefront angle-of-arrival statistic (Julien Borgnino) were also discussed. Most of these instruments have been employed in these last years to characterise the first kilometer above several astronomical sites (Mt. Graham, Mauna Kea, Paranal, Cerro Tololo) providing fundamental results for the optimisation of many of the GLAO systems that are under feasibility study for the existing facilities. On the topic of the surveys we highlight the conclusion of the analysis of the extended site-testing campaigns made by the TMT group

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on a set of pre-selected sites in the world (Matthias Schoeck) and the presentation of the preliminary results of a cross-correlation analysis between many different optical instruments performed at Paranal in December 2007 as part of the FP6 ELT Design Study (Sarazin). Once more, the spatial coherence outer scale was confirmed to be a key astroclimatic parameter for the astronomical sites (Aziz Ziad). On the meteorological side, a very comprehensive description of a couple of European mesoscale atmospheric models, such as Meso-Nh (Non-hydrostatic Meso-scale atmospheric model) and AROME (Applications of Research to Operations at Mesoscale) (Christine Lac) was presented as well as the American Weather Research and Forecasting model (WRF) (Jordan Powers). Beside, it is worth to highlight the description (Pierre Brousseau) of the status of art of the Data Assimilation systems employed for mesoscale models. As explained previously, the performances of such models strongly depend on our ability to set the initial conditions in the most possible detailed way (that is on the Assimilation Data). Concerning the dynamic and optical turbulence simulations, considerable progress has been made in the last ten years. A key role in this section has been played by the activities of ForOT (Masciadri). ForOT aims to continue the path undertaken by several years ago by Masciadri that led to many relevant results in this discipline and, in particular, to prove that a mesoscale model can reconstruct the optical turbulence above an astronomical site with an accuracy that is not worse than that achievable with measurements. Among the activities of this group, the interesting first simulations of the C_N^2 ever done above Antarctica with good reliability of the model done in statistical terms (Franck Lascaux) are highlighted. Main goal for this research group is to be a reference and a support for observatories in developing turbulence prediction systems above astronomical sites. It is worth noting the creation of the Mauna Kea Weather Center where astronomers hired meteorologists to make an operational forecasting system of the atmosphere above the Mauna Kea summit (Steven Businger). The general impression has been that this research field is gaining interest among the astronomers and this, once more, supports the thesis that it is time to boost actions to support benchmark site-testing campaigns expressly conceived to validate the atmospheric model above astronomical sites as proposed by the ForOT group. There were several contributions aimed at the study the correlation between OT and the meteorological parameters that frequently provide valuable inputs on the OT characteristics. On the front of the Adaptive Optics and Interferometry, we report a few among the most significative results concerning the implications for the turbulence

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constraints. In the field of MCAO, a detailed investigation on the limits of the Taylor hypothesis validity would provide useful insights on ways to improve the sensitivity of the MCAO with natural guide stars (Roberto Ragazzoni). For GLAO systems, if the vertical structure of the turbulence decays sufficiently sharply above an astronomical sites, GLAO systems in the visible can be applied over an extremely large field of view (Olivier Lai). We also discovered that new wavefront sensors concepts, such as the Differentiation Wavefront Sensor, reported on by Eric Gendron, might be used to characterize the turbulence in more efficient way than a Shack Hartmann. An exhustive overview (Peter Wizinovich) depicted the main turbulence constraints dependings on the typology of astronomy (Galactic, extragalactic and solar ones) and the typology of observational techniques. The final session was dedicated to science operations. The studies related to OT do have a direct impact on the implementation of the science operation models that make extensive use of queue schedulino or service observing. Several 8-10 m class telescopes currently implement one of the two approaches:

1. Application of a single administered queue mode observing system (as for ESO)

2. Application of a partner queue mode observing system (as for the Large Binocular Telescope, LBT).

It is evident that the selection of the strategy is widely influenced by organisational issues (the single European agency in the former case, a consortium of a few institutes in the latter) and for this reason the absolute efficiency of a telescope is not the only criterion in selecting a given strategy. However, it is certainly useful to quantify these efficiencies so as to be aware of what might be lost or gained through alternative solutions. On this topic Fernando Comeron noted that, currently at the VLT, a sizeable fraction of observations ($\sim$20%) have to be repeated because conditions strayed outside constraints during the execution; this is an important, hidden source of inefficiency. It is therefore obvious that a tool for the prediction of the state of the atmosphere would defineitely be a major step towards increasing the efficiency of the service mode at the VLT. Thus, it appears evident that the goal of the OT prediction on the time scale of a few hours in advance remains an important objective for observatory operations. The closing discussion session evinced the success of this first step towards a productive collaboration between astronomers and meteorologists. The most evident feature of such a constructive interaction was the decision, promoted by the Principal Investigator (PI) of the E-ELT (Roberto Gilmozzi) to prepare a detailed document outlining the main steps necessary to prepare an

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efficient site-testing campaign, benchmark test expressly conceived for the validation of mesoscale atmospheric models for applications to the astronomy. We are all confident that this document will represent the first step on a path that this conference has definitively and unequivocally traced.

The Local Organizing Committee, the Scientific Programme Committee deserve thanks in supporting such a productive meeting, with an exciting programme of talks and poster presentations.

E. Masciadri & M. Sarazin — Alghero, Italy
(Editors of the International Conference OTAM08) — 15 September 2008

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