Session XII

Observing Facilities

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Bus laden with symposium participants struggles up the winding road to nearly the top of Bakırlıtepe.

Robert Wing easily scales the last 100 m to the summit.

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VARIABILITY STUDIES WITH INTERNATIONAL NETWORKS

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Abstract. Variable stars can be monitored through observing campaigns which coordinate multi-site telescopes at various longitudes. A new practice is now being developed, involving devoted networks of robotic telescopes. We will review these two technologies and will emphasize the NORT (Network of Oriental Robotic Telescopes) project, which we are promoting in Middle Eastern countries.

1. Introduction

For over a decade, coordinated international campaigns have taken place from sites with good longitude and latitude coverage and/or with various instruments working at complementary wavelengths. The aim is to monitor variable stars as continuously as possible to reduce the aliasing problems bound to observations at a single site.

The final goal is to study and to understand the pulsational behavior of the variables, given that the pulsation on the star's surface probes its interior structure and composition in the framework of asteroseismology.

2. Advantages of Campaigns

Coordinated campaigns with existing telescopes give better tools to solve scientific problems by allowing one (*a*) to compare individual observational technologies such as CCD cameras, (*b*) to compare data reduction procedures, (*c*) to develop methods for filling gaps in data (*e.g.* Horne & Baliunas 1986; Serre et al. 1992) due to local bad weather conditions, and (*d*) to develop period-finding techniques such as Fourier analysis or least squares of brightness residuals (LSR), adapted to the observed objects with single and

R.F. Wing (ed.), The Carbon Star Phenomenon, 499-506.

multiple periods or in more complex situations such as variable periods, flares, semi-regularity, and so on.

Multi-site campaigns also lead to a better international organization of science, since they are based on cooperative programs among many experts in various scientific and technical fields: theoreticians, observers, engineers. They are also valuable for the training of young observers, PhD students and young research associates, who follow the scientific evolution of the project from program definition to the interpretation of the results, thereby enabling them to choose their own speciality.

Some campaigns give access to multi-wavelength techniques. They are dedicated to various wavelength regions by using space telescopes (*e.g.* IUE, ROSAT, HST), as well as many existing small- and medium-sized ground-based telescopes around the world.

In a word, they produce better science.

3. Drawbacks of Campaigns

The main drawbacks of multi-site campaigns can be summarized as follows:

Many nights are lost to clouds as some existing telescopes are not located at the best sites in the world.

The costs are significant due to overhead and associated expenses such as travel and accommodation costs for observers going to faraway observatories, and for equipment maintenance or replacement. Also there are considerable handling requirements to mount and dismount instrumentation, to transport equipment to distant observatories, and to adapt it to various existing telescopes. In fact, these costs and handling are so high that they seriously restrict the number of campaigns that can be carried out per year. As examples, we cite the WET (*Whole Earth Telescope*) campaigns (Sullivan 1995) with white dwarfs as prime targets, and the δ Scuti STEPHI (*Stellar Photometry International project*) network campaigns (Belmonte et al. 1994). These and other campaigns are run only once or twice per year or even once in two years for about a one week duration. In consequence, only one or a few stars are monitored during a campaign, and the stars analysed are necessarily short-period variables such as white dwarfs, δ Scuti stars, RoAp stars, post-novae, cataclysmic variables, etc., having periods of some seconds to a few hours or days.

Some technical inconveniences could be added if the scientific organization is badly coordinated, as for example when data from different sites are reduced by different techniques, or obtained by not sufficiently similar instruments at different sites, or even at the same site in long-term monitoring programs, as emphasized by Young (1994).

Problems associated with coordinated observing campaigns are reviewed for example by Sterken (1988) and Breger (1992, 1994).

4. Observational Status of Variability in Red Giants

As the coordinated international campaigns operate one or two times a year for about a week at a time, they are not well adapted to the slowly varying red giants. So, it is not surprising that this subject does not appear in the literature on cool stars. Even variables such as Miras can appear "unfavorable for long-term projects" as stressed by Szabados (1994). However, it is encouraging that a first step was recently taken for the solar-type stars with the presentation of a new project, the SONG (*Stellar Oscillations Network Group*) (see the Madison Meeting of the AAS, 9-13 June, 1996).

Roughly speaking, what do we know about red-giant variability?

Red giants have long periods of about one year. Superimposed on the dominant long period there may also be shorter periods, of say a month to a few months. Moreover, they can show rapid or slow period changes, a critical behavior around phase 0.7–0.8 in the case of Miras, and flares and very rapid variations over a day or less (for example, see a review by Querci, 1986). This knowledge was mainly obtained by single ground-based sites dedicated to long-term monitoring programs. Let us cite (*a*) the pioneering photographic observations made by Campbell, Cannon, Hetzler, Merrill, Payne, etc., (*b*) the contributions to visual photometry made by associations of amateur astronomers such as AAVSO, AFOEV, GEOS, BAN, etc., and (*c*) the photoelectric photometry by Gow, Lockwood, Wing, etc.

Nowadays, the AAVSO includes red giants in its photoelectric photometry survey (*e.g.* Percy et al. 1994), and other societies also make a contribution to the observation of cool stars (see GEOS Circulars, IBVS, etc.). Photographic monitoring by Latvian astronomers led to the discovery of light-curve anomalies. In 1982, red giants were targets in the ESO–LTPV project (Sterken 1994): international teams collaborated for more than a decade (see Jorissen 1994 for results on Barium and S stars).

For the past 10 years, automatic photometric telescopes (APT) have operated on Mt. Hopkins for long-term monitoring of semi-regular variables (Baliunas et al. 1987; Cristian et al. 1995).

More recently, MERLIN, the Multi Element Radio-Linked Interferometer, mapped out H_2O emission in the inner circumstellar envelopes of Miras, SR variables, and red supergiants, giving information about mass loss (Yates & Cohen 1994), and it has also observed OH/IR stars (Migenes et al. 1995). A radio survey could be organized in cooperation with optical networks.

It appears evident that we need a world-wide coordinated monitoring of long-period and semi-regular variables which will permit the detection

of important unknown features in their light curves and, consequently, will lay the observational foundation for red-giant asteroseismology.

5. An International Network: The Network of Oriental Robotic Telescopes (NORT)

Global networks of automated telescopes (GNAT) have been proposed by Budding (1993, 1995), Crawford (1992, 1993, 1995), Querci & Querci (1992), Querci et al. (1993, 1995a,b), and Querci (1995). Here we would like to describe the philosophy of the NORT project, which is a network of 1.3-m diameter automated telescopes for photometric and spectrographic studies, to be installed in desert sites from Morocco to China.

5.1. FRAMEWORK OF THE PROJECT

The NORT will deal with variable stars (mainly red giants), planetary nebulae, and post-novae, to stimulate asteroseismology of long-term variables. As various characteristic times of variation have to be considered, we need a continuous follow-up of some typical stars. This constraint can only be satisfied through using the "best" sites, *i.e.* semi-desert countries, around the world. Some such countries are along the Tropic of Cancer from Morocco to the Chinese deserts, with the further advantage that the longitude interval they cover is complementary to that covered by the U.S.A. where robotic telescopes already exist. It is to be stressed that these countries had great astronomers in the past, but nowadays few of them perform research in astrophysics. However, their universities, their sites (high mountains in semi-desert climate) and their wishes for development can allow them to make progress in astrophysics.

In the NORT project, we propose (*a*) to collaborate in education in astronomy and astrophysics, (*b*) to help in the development of laboratories by giving advice for building well-equipped 60-cm telescopes for student training, and (*c*) to offer engineer and technician training in the French observatories such as Haute-Provence Observatory (OHP), Midi-Pyrénées Observatory (OMP), etc., to collaborate in setting up the network and for making the scientific choice of objects to be observed.

There will be a direct transmission of all the observations collected each day to all universities that are members of the network, via the Internet (or ARABSAT, METEOSAT, ...). The whole network will be fully robotized. Data reduction and interpretation could be made in common by sharing scientific and technical results.

This network is supported by:

- INSU/CNRS (Institut National des Sciences de l'Univers),
- OHP and OMP Observatories in France,
- UN–Space Affairs Division,

and several of the developing countries.

5.2. WHY SITES IN THESE COUNTRIES ?

The oriental countries are suitable because:

- they have high mountains (3000 to 4000 m) in semi-desert areas (north-tropical latitude from 15° to 35°), and consequently a large annual number of nights with a clear sky and low telluric absorption,
- they are in a longitude interval (about 10° West to 110° East) complementary to that of some automated stations already devoted to variable star research, including the Hawaii volcano, Arizona mountains, Chilean cordillera, Etna volcano, and South African desert.

5.3. HOW TO SELECT GOOD SITES FOR OBSERVATIONS?

By using 14-year archives of METEOSAT data and the METEOSAT and NOAA on-line data from the Dax Observatory Science Club, we discovered a set of meteorologically very good sites from Morocco to the Takla Makan and Gobi deserts in China. The final site selection will be made from local astronomical tests such as seeing measurements. It ought to give a list of sites not subjected to the same airstreams. Also, the local access facilities will presumably be a non-negligible factor in the selection.

A minimum number of 9 to 12 stations should be able to follow the variable stars each night, without interruption, throughout the year.

5.4. PROPOSED OBSERVATIONAL TECHNIQUES

We propose the following basis for a decade of collaboration on variable stars:

- First, by photometry, which measures the stellar flux variation itself at several wavelengths and helps to disentangle the evolution and the internal structure of the stars,
- Later, by spectroscopy, which in its low-resolution modes gives the stellar abundances, and in its high-resolution modes is able to give the physical parameters of the stars and their dynamical behavior, and
- Finally, by interferometry at visible frequencies, to obtain diameter variations or the shapes of stars, a detailed description of their external layers, and the eventual discovery of planets.

5.5. PRESENT STATUS OF THE PROJECT

5.5.1. *Training and Scientific Aspects*

A French Committee within CNRS was created in October 1994. Its mission is to take care of the educational problems and the supervising of PhD theses in cooperation. It has eight members, among them two professors in

Astrophysics, two astrophysicist specialists in equipment, two theoretician astrophysicists, and two engineers in electronics and computer science.

The technical training courses have begun at OHP. PhD theses are in progress in France on variable stars of various spectral types.

5.5.2. *Technical Aspects*

Several 60-cm diameter telescopes dedicated to student use, built by a private company in collaboration with the OHP and OMP observatories, are already at work. The mechanical structure calculations for 1.0-m and 1.3-m diameter telescopes are underway at OMP observatory in Toulouse, as well as the optical drawings of their focal-plane instrumentation.

5.5.3. *International Relationships*

We had this idea of a Network of Oriental Robotic Telescopes some years ago. We told our Moroccan colleagues about it and one of us (F.Q.) visited some oriental countries.

During the "First International Conference on Space and Astronomy," held in Amman, Hachemite Kingdom of Jordan, in September 1994, an international committee was created to promote the project. Its members represent the following countries (by longitude): Morocco, France, Libya, Egypt, Lebanon, Iraq, Jordan, and Yemen. Contacts are in progress with the following countries (by longitude): Mauretania, Algeria, Tunisia, Syria, Iran, Saudi Arabia, Bahrain, Pakistan, India, Malaysia, Indonesia, and Brunei. Contacts still have to be developed with Kuwait, Qatar, United Arab Emirates, Oman, Tadjikistan, Uzbekistan, and China.

At the General Assembly of the International Astronomical Union (IAU) held in The Hague (Holland) in August 1994, the Arabic astronomers had a meeting about the NORT. Contacts have been developed (or are to be developed) with the following organizations: IAU, ALECSO, TWNSO, IFSTAD, UNESCO, AUPELF, IMA, etc.

6. Concluding Remarks

We should like to conclude by noting the realistic fact that long-term monitoring of variable stars through global automated dedicated networks leads to a "new field of astronomy – astroeconomics," according to Budding (1995) and Crawford (1995). Today, this fact is still more opportune with respect to the multi-site campaigns and some space missions.

If the project succeeds, as we hope, it should allow several oriental countries from Machreq to Maghrib to make a rapid jump into contemporary astrophysics.

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Discussion

Mattei: Will there be a database created with NORT observations, and will this database be accessible by the astronomical community?

Querci, F.: Yes. However, we have not yet decided where the database will be located.

Gustafsson: Could you give a typical price for one of these units in the NORT?

Querci: At this time we cannot, because not all the elements are manufactured and fully tested at l'Observatoire de Haute-Provence. We can give the price of the equipped telescopes (60-cm and 1.3-m), i.e. the mechanics, optics, electronics, and driving computer. The prototypes for the meteorological station, i.e. the photometer, the spectrographs, and the data transmission system, are respectively undergoing tests, under construction, and in development.

Bakker: Besides astroeconomics, there might also be astropolitics. Most of the countries you've selected are politically unstable. Did you consider that maybe the telescopes are destroyed every two years?

Querci: If astronomy is part of the country's society, they are proud of it. Battling parties may agree that astronomy should be above their struggle. Therefore the telescopes will not be destroyed.