VIII. FUTURE DIRECTIONS

GROUND BASED AND SPACE FUTURE PROSPECTS IN SOLAR INTERFEROMETRY APPLIED TO THE PHOTOSPHERE.

J.P. ROZELOT
Observatoire de la Côte d'Azur
Avenue Copernic 06130 Grasse France

ABSTRACT. This paper sets about a brief review of the current knowledge of ground based interferometry, and then, using the relevant information from this up-to-date technique, its tentative application to the study of solar granular structures. As a matter of fact, most of the fundamental processes in the photosphere take place on very small spatial scales and understanding the formation of the solar granulation, pores as well as tiny photospheric faculae, requires insight into the magnetic network where the thermal instabilities are initiated. The study of fine scale structures, typically of about 15 milliarcsec (11 km) by interferometry, i.e. to a resolution not accessible through classical optical telescopes, is certainly the key to open the door to new scenarios in solar physics. By the way, similar phenomena are likely to be accountered in other type of stars. Particular attention is paid to the role of imaging reconstruction at very high angular resolution. Some of the thus achievable solar programmes are listed, mainly with solar granulation. The new type of instrumentation involved should be in the 90's commissioned. At last, it is pointed out that solar interferometry could be also performed in space, as earlier suggested by J.L. DAME and C. AIME to ESA, for the study of flares, prominences or coronal loops, which are closely linked to the photosphere, and for the 2000's horizon. Some problems inherent to this whole prospect (ground and space) are listed, and discussion is welcomed for determining adequate programmes, and also to highlight promising directions for future investigations.

1. INTRODUCTION

After Michelson's pioneering work of the 20's at Mount Wilson, in the States , interferometry did not make great strides ahead, mainly due to big technical difficulties inherent to this kind of experiment. However, around the 60's, in the visible field, Hanbury-Brown developed the so-called intensity interferometry, the flux performances of which have considerably limited the application field. Thus, the revival of the interferometric technique is essentially due to the painstaking work of A. Labeyrie, which can be roughly divided into four steps:

* the discovery at Mount Palomar Observatory of *speckle interferometry*, with single telescope disclosed of images disturbed by the atmospheric turbulence;

* the initial *fringe observations* using two *small telescopes* of 26 cm in aperture, at the Nice Observatory in 1974. This was followed a few years later, in 1977, by the world premiere measurement using such an interferometer of Capella's angular diameter;

* the first *fringe observations* between *two large telescopes* 1.5 m. in aperture, spaced 13 m. apart. Steps are currently taken to improve its observing efficiency and high resolution astrophysical information will be obtained soon;

J. O. Stenflo (ed.), Solar Photosphere: Structure, Convection, and Magnetic Fields, 463–467.

* The design, studies and construction of a *prototype of an array* of several telescopes, in order to provide a powerful tool for reconstructing images.

Interferometry may be still at teething stage, but its potentials have been well demonstrated by recent measurements using existing facilities, not only in France, but also in the States and in Australia (see for instance Labeyrie, 1988; Davis & Tango, 1985; Shao et al., 1987). The present trend clearly points towards aperture synthesis systems including a large number of subapertures. Moreover, the V.L.T. will be dedicated in an interfero- metric mode in the 1995. With a baseline of about 104 m. between the centres of the most extreme telescopes, resolutions up to approximately 45 milliarcsec at 20 microns wavelength and 0.75 milliarcsec in the blue could be reached.

However despite an intensive work in stellar interferometry, both theoretical and observational, nothing or scarcely anything, has been achieved with solar interferometers. I wish to be clear here: by solar interferometer, I mean a complete instrument with several distinct apertures and a focal laboratory, intended for observations of the Sun. This definition excludes the great amount of theoretical work on solar interferometry carried out by a lot of people, and also solar speckle interferometry practised through a single aperture. With such a concept, a recent proposal was made by Damé (1987), consisting of a "true" interferometer, to be commissioned on the Space Station, and mainly devoted to the ultraviolet field.

Thus, my question remains: why does no such instrument, adaptated to the solar case, using two or more telescopes, as yet exist on ground?

III. WHAT IS AN INTERFEROMETER?

Such an instrument is composed of at least two, usually track-movable telescopes, of high mechanical stability, that makes up a North-South baseline. With additional telescopes, it is possible to make up an array, either on the same line, or on a separate one. In this latter case, a-Y or a cross-like pattern can be built, allowing the closure phase. Figure 1 shows what such a device can be like. On the ground, the baseline can be very long (up to 600 m. for stellar interferometers) giving the interfringe angular value (lambda/B). In the focal laboratory, close to the middle of the baseline, the beam recombining optical device lies on a movable carriage. Its displacements are computer-controlled and correct for part the optical path drift induced by the diurnal rotation.

On the image plane, the field is diaphragmed by means of a slit and the light is dispersed by a grating that lets to observe fringes be simultaneously observed over several spectral channels. Then the fringes patterns are recorded on a camera.

For space, it is necessary to have very rigid mechanical structures, and compact configurations in order to avoid pointing and tracking problems. Recently, Damé (1988) suggested a fixed combination of four 20 cm-telescopes fixed on a 2 m. baseline. This gives complete u-v coverage (no phase closure) with imaging allowed when rotating the interferometer through 180°.

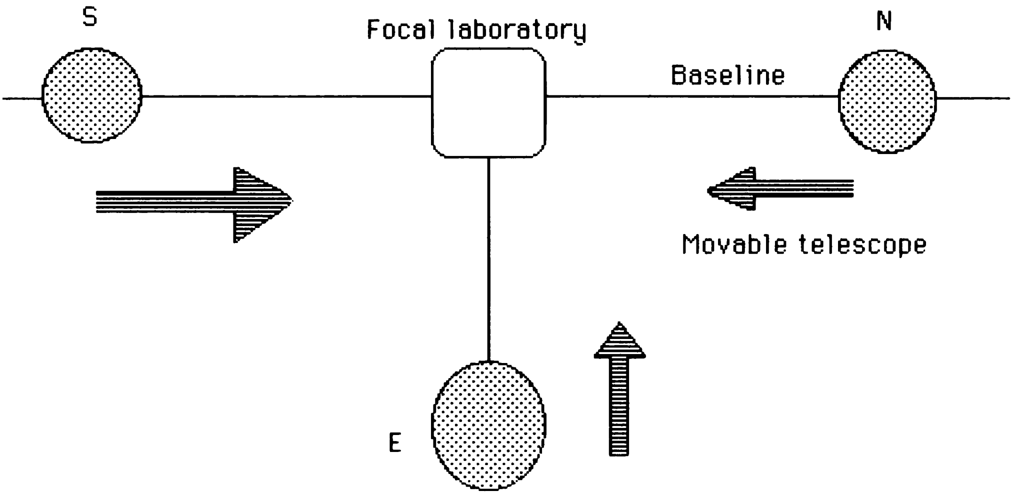

Figure 1. Schematic view of an interferometer.

IV. THE DELAY LINES

With independently mounted telescopes, the entrance pupils are not coplanar as the telescopes points off the zenith. To maintain the geometrical scaling of the lateral pupil geometry, the exit pupil at the combining optics has to be adjusted (Figure 2). This is made by delay lines, which is one of the two possible solutions (the other one being the use of moving telescopes to ensure equal path length for both beams). Such a prototype of delay lines is currently under construction by Aerospatiale, in France, for the so-called "I3T", a small stellar interferometer, and those delay lines will be put into operation at the "Observatoire de la Côte d'Azur" before late 1989.

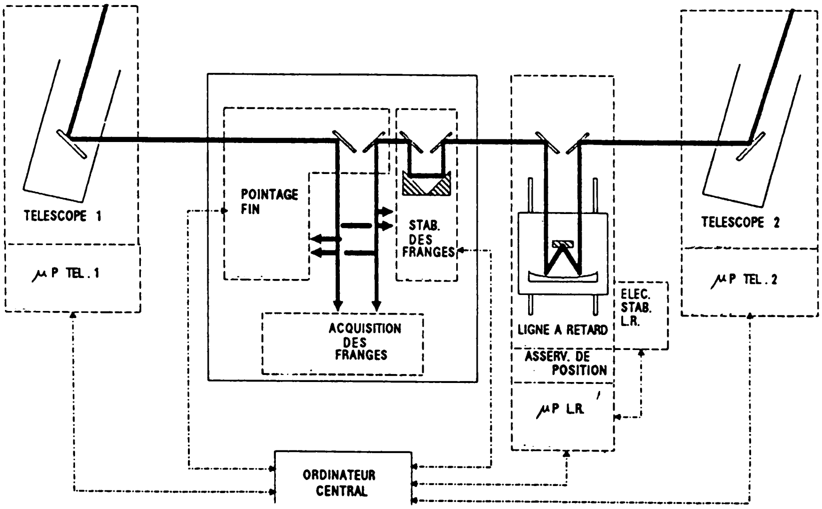

Figure 2. Principle of the delay lines (after Koehler).

It is proposed that the optical elements which have to be translated during the observation be mounted on a track-movable carriage. The conception of this device is given in Figure 2 (Koehler, 1989). The useful course is about 3 m., with about 50 microns positioning accuracy and approximatively 2 mm/s uniform velocity.

This stage require a smooth motion and a very high mechanical stability. Figure 3 give an example of the so-called "oeil de chat", an optical piece that is movable for path length compensation.

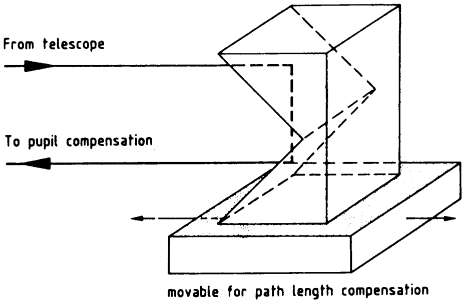

Figure 3. Schematics of the so-called "oeil de chat", movable prisms.

V. A BRIEF LIST OF CONTRAINTS

Among the numerous problems which must be solved to achieved a solar interferometer, it can be listed (more details can be found in Damé (1988):

* a very high *pointing system*, to be sure to look at the same features on the Sun, since the observed object is resolved; on the ground, this must be achieved with a greater difficulty than in space, because of the atmospheric turbulence;

* a very fine accuracy *tracking system*, that means a fraction of the Airy disk or about lambda/10 or lambda/20 (depending on the wavelength under consideration);

* a good *stabilization* of the whole system, with no vibrations, to access small fields on the Sun;

* a good *spectral resolution* on lines profiles: high spatial resolution requires analysis of the fringes by a high dipersion spectrograph (about one Å);

* a good *coverage of the u-v* plane;

* a good *detector*, since there is plenty of flux on the Sun, the S/N ratio must be very high;

* a fast *monitoring system*, since the temporal evolution of the structures implies fast electronics (for instance individual measurements every 10 ms).

VI. SOME PROGRAMMES

A solar interferometer, with telescopes of the class 20 to 30 cm diameter can reach a resolution of 15 ms of arc (11 km), or better.

That means that a lot of work can be achieved with such high resolutions. A number of questions still now without a satisfactory answer, and a number of to-day unsuspected questions is still motivating.

It is a commonplace to say that the Sun's atmosphere is highly structured. This is mainly due to the magnetic fields, which strongly interact with the convective motions. But we scarcely know how the fine magnetic elements are associated or linked with bright spots, fibril structures or feet of the loops. As a matter of fact, most of the fundamental processes in the photosphere take place on very small spatial scales and understanding the formation of the solar granulation, pores as well as tiny photospheric faculae, requires insight into the magnetic network where the thermal instabilities are initiated. The study of fine scale structures, typically of about 15 milliarcsec (11 km) by interferometry, a resolution which is not accessible through classical optical telescopes, is certainly the key to open the door for new scenarios in solar physics.

High angular resolution is also of importance to access problems of line diagnostics, loop constitutions, coronal heating, dynamic of flares, filaments and prominences. At last, interferometry will help understand such fundamentally crucial problems, as the nature of granulation, the physics of spicules and the flow of material that goes from the photosphere to the chromosphere and up to the corona.

By the way, similar phenomena are likely to be encountered in other types of stars.

VI. CONCLUSION

Solar interferometers can be defined as instruments of the "second generation", instruments of the first one being coronagraphs, polarimeters... These new instruments, such as heliometers or heliosismology-meters imply ground-based networks or space networks, and in both cases require efficient international cooperation.

The way is quite clear, now, to build such instruments, and I hope that solar physicists will share my faith in these future views.

VIII. REFERENCES

Damé L.: 1987, First IFSUUS meeting on Physics and Astrophysics in the Space station ERA, Venice: "Solar interferometry from the space station",

Damé L.: 1988, Solar Ultraviolet Network, Proposal submitted to the NASA.

Davis J, Tango W.J.: 1985, Proc. Astr. Soc. Australia, "High angular Stellar interferometry", 6, 34-39.

Koehler, B.:1989, Rapport Aeropsatiale.

Labeyrie, A.:1987, "Multiple aperture Interferometry", in Interferometric imaging in astronomy, Oracle, Arizona, USA, p. 97.

Shao M., Colavita M., Staelin D.H., Johnston K.J., Simon R.S., Hughes J.A., Hershey J.L.: 1987, The Astronomical Journal, 93, 1280-1287.