

AERODYNAMIC AND THERMAL PROBLEMS AROUND AND INSIDE A DOME AND TELESCOPE

Jean RÖSCH  
Observatoires du Pic-du-Midi et de Toulouse

ABSTRACT: Much effort has been spent at Pic-du-Midi, with increasingly large telescopes, to reduce the instrumental causes of image deterioration and take best advantage of local atmospheric conditions. With the new 2-meter reflector, specifically intended for high resolution imaging, the concept has been, ideally, to separate three air-masses: outside, inside the tube, and inside the dome. As a first step, no parallel plate of required size and quality being available, the tube is open to the outer air, but a connection between tube and dome aims at preventing the dome-air flowing across the light-beam. Results and expectations are presented.

INTRODUCTION

Since the first demonstration by Bernard Lyot, in the early forties, of the excellent local conditions on the top of Pic-du-Midi, many efforts have been made there to reduce instrumental and other effects (e.g. dome seeing) which degrade image resolution. These effects need to be reduced to the point where the angular resolution attained really does benefit from the best site conditions. Of course, the constraints become more and more severe as larger instruments become available with improved resolution capability, but progressing from 23 to 38cm, then to 60, and next to 106cm, we have gained not only in resolution but also in experience; for our next step, we are faced with the problems concerning the 2-meter reflector (T2M) which has been sponsored and built there by INAG. I would like to report on what we have already learned from this instrument, since it could be useful for others, and what we expect to do and to obtain in the near future. I must emphasise here the very hard and comprehensive work performed by the "2m-Telescope Team" under the leadership of G. Coupinot.

I shall deal only with the aerodynamic and thermal problems, and not with the mechanical or optical problems since limitations in these areas should not arise for an instrument of this size. Neither shall I speak of site-testing or "microsite"-testing, i.e. choice of the best

place within the area already chosen as the "site" of the observatory.

#### OUTLINE OF THE PROBLEM

Image deterioration induced by the dome has long been a concern for astronomers. Lyot had imagined, in 1943, a 150cm fork-mounted telescope protected by an outer shell, also fork-shaped, which, for cost and other reasons, was never built. Otherwise, the situation is that air masses at different temperatures are likely to be mixed with one another, thus producing local fluctuations of refractive index.

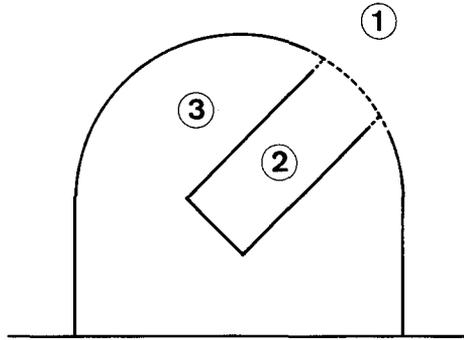


Figure 1 - (1) Atmosphere, (2) Tube, (3) Dome.

As shown in Fig. 1, three volumes play a role in the phenomenon: (1) the atmosphere outside the dome, (2) the interior of the tube, (3) the interior of the dome. To avoid temperature fluctuations, one can either enclose the tube (solid walls, mirror at the lower end, upper end open) with air taken from the atmosphere outside (Couder, 1953; Gillingham, 1978) or separate the three volumes from one another (dashed lines in Fig. 1). The second solution was adopted for the solar turret-dome (couple tourelle) at Pic-du-Midi (Rösch, 1962), and proved to be quite rewarding; in that case, the refractor objective separated volumes (1) and (2), and one just needed a soft gasket between the tube and the dome to separate (3) from (1) and (2), thus preventing the warmer air from flowing outwards from the dome across the light beam. An equivalent example is the Solar Tower at Sacramento Peak, (Dunn, 1964) which has the refinement that volume (2) is evacuated; filling with helium could be an alternative solution (Rösch, 1955, 1965).

A "closed dome" system was also chosen for the T2M. However, a high-quality parallel plate is required and it has not been possible, up to now, to obtain a guarantee from the manufacturers of a sufficient index homogeneity over the size needed. Therefore, the present scheme is only the first step towards the ideal solution since volume (3) will be isolated but volume (2), remaining open to volume (1), will have to be maintained at the same temperature.

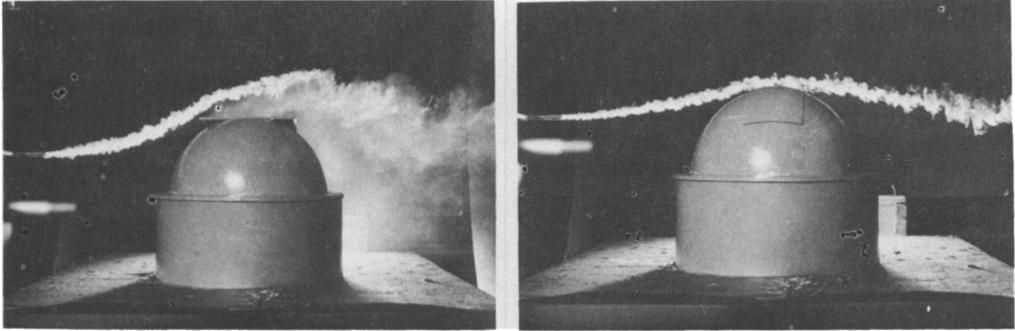


Fig. 2 - Turbulence around domes.

#### EFFECTS AROUND THE DOME

We first consider the aerodynamic effects around the dome in volume (1). Fig. 2 shows wind-tunnel tests on two types of domes both spherical, but one (left) with the classical two doors moving apart horizontally for observation, and the other (right) with a unique shutter rolling backwards (in French: *cimier*), a system now in use for a number of large telescopes. Clearly, the first system creates a much more turbulent situation in front of the aperture, which cannot but create serious index inhomogeneities (Rösch, 1964; Ponov and Shcheglov, 1976). It may be noted that observers at the Canada-France-Hawaii Telescope have found a definite improvement of the resolution when windscreens are in place to shield the dome aperture below the optical beam. The type of dome used for the Pic-du-Midi 2m Telescope has its opening reduced to a minimum and it would be almost equivalent to a full sphere once this opening receives a parallel plate to separate volumes (1) and (2), (the parallel plate need not be carried by the tube of the telescope).

#### THE DOME FOR THE 2m TELESCOPE

The principle of the design of this dome, which has been given years ago (Rösch, 1943), is demonstrated in Fig. 3. A spherical dome is cut by a plane inclined to the horizontal at about  $45^{\circ}$ , and the part thus separated (termed in French, *calotte*, a cap) is able to rotate on its base. A circular aperture is provided near its edge; the center of this aperture as seen from the center of the sphere, may occur, by rotation of the cap, at any desired zenith distance; rotation of the whole dome on its horizontal base allows pointing in any azimuth direction. Fig. 4 is a view of the dome on its tower; the circular opening has a diameter of about 2.2 meters. A PDP 11 computer controls the rotations of the dome and cap so as to maintain the center of the aperture within a few centimeters from the optical axis.

The dome is built of a steel frame covered with "sandwich" flat

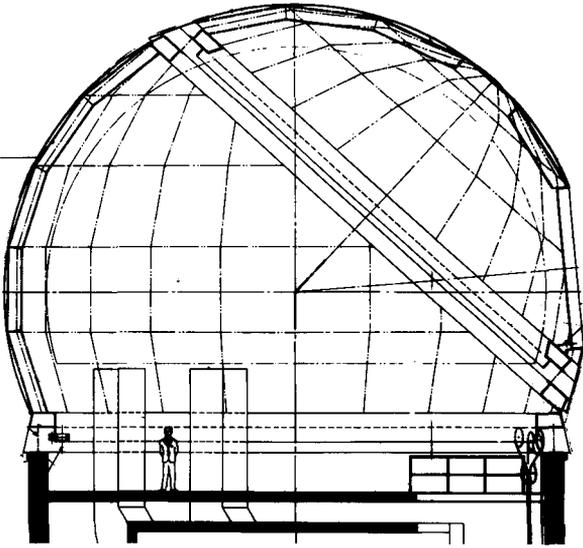


Figure 3. Principle of the "cap-dome"

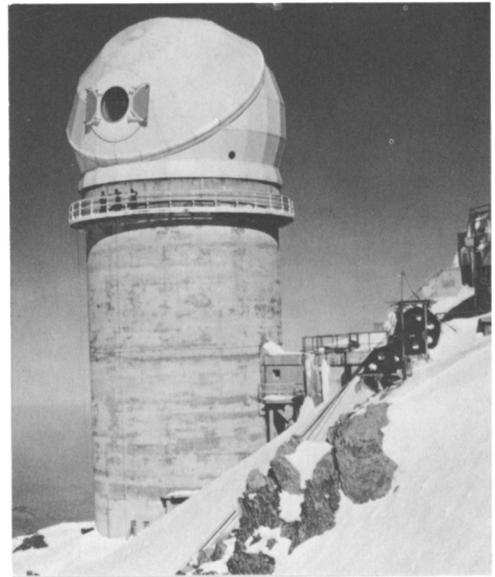


Figure 4.  
The 2-meter Telescope

panels of insulating synthetic material between two steel sheets, without any metallic part conducting heat (or cold!) from outside to inside. The tube of the telescope is structurally of the Serrurier type, but surrounded with insulating panels. Insulation is to be provided also on the back of the mirror casing. Having done this, the main problem is then the connection between the tube and dome.

## THE TUBE-DOME CONNECTION

The straightforward solution of using a soft bellows to connect the front rim of the tube with the rim of the circular aperture of the cap has been rapidly discarded for several mechanical, operational and financial reasons. An alternative idea is that if air exchanges between volumes (3) and (1) are damped through convenient channels, the flow could be reduced to an acceptable level. It led to the design represented in Fig. 5.

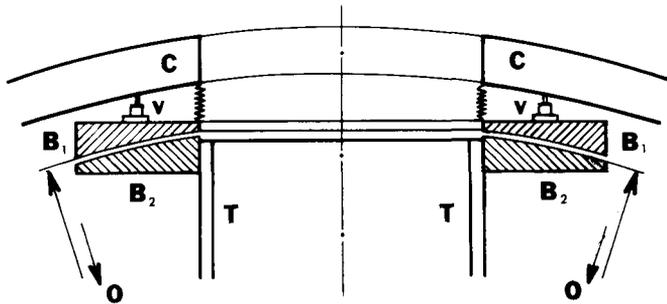


Fig. 5 - The tube-dome connection (principle)

It consists essentially of two ring-shaped baffles  $B_1$  and  $B_2$  made of light synthetic material.  $B_2$  is carried by the upper end of the tube  $T$ ; its outer face is spherical, centered on the instrumental center  $O$ .  $B_1$  is supported by the cap through three adjustable screw-jacks, and its inner face is also a portion of a sphere having  $O$  as its center. The three screw-jacks are locally controlled by proximity sensors in order to maintain the gap between the baffles as small as possible: the ultimate expectation is of the order of millimeters. Since the inner sphere rotates around the center of the instrument, and the outer one is concentric, tube and dome can move freely and independently, an enormous advantage from the operational point of view.

## RESULTS AND EXPECTATIONS

The first pictures were obtained in September 1980 though various teething troubles with the instrument and dome were encountered. Nevertheless, the experience was instructive. The tube-dome connection was not yet operative, so that a gap of 10cm or more existed between the edge of the tube and the observing aperture, and consequently there could be a strong draught between volume (3) and volume (1). However, meteorological conditions in that season were such that blowing external air into the dome by means of powerful fans could lower the temperature inside to  $9^{\circ}\text{C}$ , while it was  $6^{\circ}\text{C}$  outside. Then, image-tube exposures of the order of seconds produced pictures of globular clusters with angle resolution down to about  $0.5''$ .

Since that time, a number of drawbacks in the mechanics and electronics have been corrected, and progress has been made in solving the thermal problems. Ducts and fans have been installed to fill the tube, before observation, with air taken from outside; in other words, to try to equalise the temperatures in volumes (1) and (2); this has proved efficient and star images approaching  $0''4$  have been obtained in spite of the fact that the gap between baffles  $B_1$  and  $B_2$  still amounts to some centimeters. Steps for the future are: (a) refrigeration of the air of volume (1), dome closed, to the temperature predicted for the next night; and (b) control of the gap to less than one centimeter.

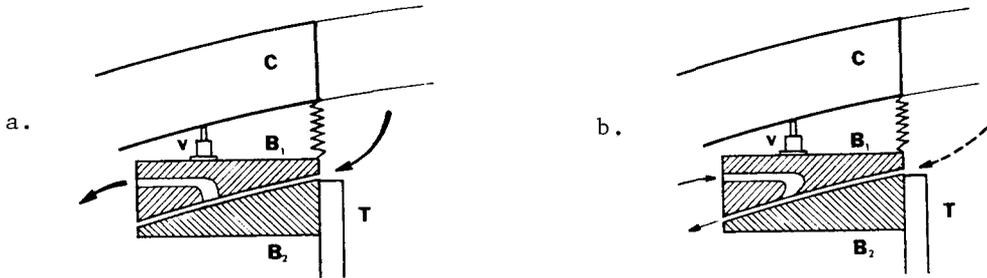


Fig. 6 - Present (a) and projected (b) design of tube-dome connection

Another possible way for improvement appeared during the tests. It had been planned to suck the outer air by a powerful fan through the gap by a circular groove in baffle  $B_1$  (Fig. 6a); as could be foreseen, the effect on the stellar images proved to be catastrophic. The suggestion now is to change the profile of the groove, reduce the flow to a small fraction of what it is now, and reverse its direction (Fig. 6b); it is expected that most of the air extracted from volume (3) by the fan will return to it as indicated by the arrow, and would oppose any free escape from volume (3) to volume (1) and (2) between the baffles; the depression caused by the returning flow at the inner edge of the groove will just cause a very gentle aspiration of outer air, which should be reduced to almost zero by practical adjustment.

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