

Technical Report No. 15

IR THERMOGRAPH STUDY OF CTIO TELESCOPES

Preliminary Report

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## Summary

From 26-29 December 1983, at the invitation of CTIO, I examined the four largest telescopes at CTIO and the general mountain environment at CTIO with a 8-12  $\mu\text{m}$  infrared thermograph. The purpose of this examination was to locate possible sources of seeing associated with equipment, telescope, building, and outside environment. We identify, after a preliminary examination of the videotapes, the following potential sources of seeing: (a) the oil bearings of the 4 meter telescope and the associated heating of the horseshoe, (b) the cassegrain cage of the 4 meter, (c) some heating from structures around the walls of the 4 meter dome, (d) the walls of the buildings of the smaller telescopes (both inside and outside), (e) the electronics inside the domes of the smaller telescopes, and (f) the concrete surfacing on the mountain top. Suggestions are made as to how to reduce these sources of seeing and as to further tests to be made.

## Equipment

I used an Inframetrics Model 525 Thermograph which covers the 8-12  $\mu\text{m}$  spectral range with a scanned HgCdTe liquid nitrogen cooled detector. The field of view is  $14^\circ \times 18^\circ$  but is occasionally reduced to as little as  $3.5 \times 4.5^\circ$  with the electronic zoom adjustment. The image is delivered in standard US RS330 compatible television format (525 horizontal lines/frame at 30/60 Hz frame/field rate) and was originally recorded on a VHS portable tape recorder. The resulting VHS tapes were copied to Betamax format for CTIO use. The VHS tapes were taken back to the USA and are available for CTIO use when needed. The equipment was identical to that used at the MMT in 1980. The results of the MMT experiments are described in MMT Technical Report No. 10 (TR10).

## Summary of Data

Almost all observations are recorded on videotape with voice track explaining the observing parameters. The videotapes contain occasional isotherm images as well as video line extraction and (x,y) plots of T vs position along the line. The first two tapes (12-20-83A and 12-26-83A) contain at the beginning a demonstration of the camera and its isotherm and line scan features.

Table I below summarizes the 6 video tapes with data.

Table I

<u>Date</u>	<u>Tape I</u>	<u>Content</u>
20/21 Dec 83	12-20-83A	Survey of KPNO 4 meter telescope made to check out equipment and for comparison with CTIO 4 meter telescope.
26/27 Dec 83	12-26-83A	Evening and night survey of CTIO 4 <sup>m</sup> telescope and outside area.

27 Dec 83	12-27-83A	Daytime examination of CTIO 4 <sup>m</sup> telescope, Cassegrain cage, CTIO surrounding from 4 <sup>m</sup> catwalk.
27 Dec 83	12-27-83B	Daytime examination of 1.5 <sup>m</sup> telescope.
27/28 Dec 83	12-27-83C	Evening and nighttime examination of concrete surface on CTIO mountain.
28 Dec 83	12-28-83A	Nighttime views of CTIO surrounding and of other open domes from 4 <sup>m</sup> catwalk, examination of 36", 40", and 60" telescopes, examination of 4 <sup>m</sup> prime focus cage while inhabited.

#### 4<sup>m</sup> Dome Interior

The hottest components in the 4<sup>m</sup> dome are both the oil pads and the electronics in the Cassegrain Cage. Photos 1 and 2 show images of the oilpads supporting the big horseshoe. The oil itself is hot, heating the surrounding support structure as well as the horseshoe itself. Immediately surrounding the pad the  $\Delta T$  equals 3-10<sup>o</sup> C. The same is the case for the support in the back. I estimate a total conductive heat dissipation to the air from these pads and their immediate surroundings to be  $\approx 200$  watts (=  $10 \times \text{Area} \times \Delta T = 10 \times 2 \times 10$  where Area is in m<sup>2</sup> and  $\Delta T$  in <sup>o</sup>C.). The horseshoe and telescope soaks up this heat and retains it for a long time. Photo 3, for example, shows the area on the horseshoe edge which was supported  $\approx 1$  hour before. It retains the heat for many hours (10-15 hours). Also I suspect that the entire horseshoe and telescope may gradually heat up as the result of this oil heating. Photo 4 shows, for example, the inside of the horseshoe which is  $\sim 1^{\circ}$  warmer than the rest. The horseshoe and telescope should be examined carefully with direct thermal sensors to estimate the amount of heating by the oil. The obvious solution appears to be refrigeration of the oil to give at delivery to the pads an ambient temperature.

Photos 5, 6, and 7 show images of some of the worst offending components in the cassegrain cage, while surveying it during daytime on December 27. The amount of heating in the cassegrain cage depends, of course, on the equipment and power supplies in use. The box with electronics shown in Photo 5 is 20<sup>o</sup>C warmer than the surrounding, emitting about 100 watts. Photo 6 shows a power supply and Photo 7 another one viewed from outside the cassegrain cage. In total I estimate 300-1000 watt dissipation right underneath the telescope. This estimate is uncertain because only part of the electronics is visible. A measurement of the electrical power consumption in the cage should give a good estimate. The solution here is to enclose the cassegrain cage with a good insulation and to draw the warm air away from the cage. Also outside the cassegrain cage is there offending electronics on the telescope, like the  $\Delta T \approx 10^{\circ}\text{C}$  encoder box shown in Photo 8. Again those components should be enclosed and connected with the same air removal system. Note again that during these tests not all equipment was turned on so that there may be other offending

components which were not detected.

The prime focus cage was close to ambient temperature except when occupied on the night of December 28 when the passenger compartment showed a  $\sim 1^{\circ}\text{C}$  temperature excess resulting in  $\sim 50$  watts dissipation in the middle of the lightpath. This may be a problem. I do not know what the electronics of, for example, the IR secondaries dissipate.

The floor of the 4 meter building was  $4-5^{\circ}\text{C}$  cooler than the air. Photo 9 shows a photograph of the cooling coils which are well visible by their localized cooling effects. The general philosophy appears to be that undercooling is good. It, however, generates undoubtedly a microclimate near the floor with  $\Delta T$  values like  $\sim 5^{\circ}\text{C}$ , but one hopes that these don't penetrate upwards into the lightpath. But what about the air which is cooled this way at the upper level where the control room is? It is at the same height as the primary optics and may cause problems.

I looked elsewhere in the dome for thermal effects. Although further away from the lightpath, thermal disturbances/heat generated anywhere in the dome may eventually be forced out through the slit in the dome into the lightpath, thus causing seeing effects. The floor in front of the aluminizing chamber appeared hot during the inspection of December 28, although it did not appear so earlier (December 26). So things appear to change. While it was hot, its  $\Delta T \approx 1-2^{\circ}\text{C}$  causing a conductive heatflow of  $\approx 250$  watts. Photo 10 shows it. The walls near the cable trays (just underneath the inside dome catwalk) were about  $1.5^{\circ}$  warmer causing 2000 watts dissipation because of its large area (see Photo 11). The situation on top of the dome is somewhat confusing. The cloth disk used for flatfielding and the heavy metal structure appeared to have a  $2^{\circ}$  temperature excess as compared to the telescope tube near the mirror covers. On the other hand, the flatfielding disk (Photo 12) has a very small thermal mass so it should represent the local air temperature. Could it be that the air temperature while the dome is open is indeed  $2^{\circ}\text{C}$  higher in top of the dome as compared to the area near the mirror covers, which is in turn  $5^{\circ}$  warmer than the cooled floor?

#### Outside of Domes

I examined at night the exterior of the various domes. The top of the smaller domes as viewed from the 4<sup>m</sup> catwalk are cooled by radiation cooling (Photo 14) by a few degrees on a wind calm night. On December 28 all domes were opened towards the direction of the camera on the 4<sup>m</sup> catwalk so one could see the interior. The interior of the 40 inch was exceptionally warm ( $\Delta T \approx 5^{\circ}$  with outside), but the other domes were within a few degrees. All buildings with the  $\text{TiO}_2$  sunscreen showed a very hot exterior below it with typical  $\Delta T = 5^{\circ}\text{C}$  above the air (measured with thermometer) at sunrise. This may be residual heat from previous solar heating or it may be generated inside. Anyway, it causes  $\sim 5000$  watt heating which may be a problem. The 4<sup>m</sup> building (Photo 13) did not have this problem. Only the heavy metal structural beams and the concrete support pillars had substantial excess temperature. Their area is far below that of the concrete parking lots which are probably much bigger trouble makers.

## Surface Area

Photo 15 shows the 36 inch dome and the surrounding concrete pathways and road. The concrete is very warm as compared to the sandy areas inbetween. Photo 16 shows the concrete walkways in the central area. This photo was taken at midnight long after the sun had set. In the day and night of 27/28 December, I made a number of measurements to determine the characteristics of these walkways, roads, and parking lots. Results: (a) time constant for shadows to disappear  $\approx$  3-4 minutes (e<sup>-</sup>time), (b) thermal difference of concrete to air drops from  $\approx$  7°C just after sunset to  $\approx$  3.5°C at sunrise (e<sup>-</sup>time  $\approx$  15 hours), (c) thermal difference of air with sand is  $\approx$  2°C at sunset, (d) thermal difference of air with gravel is  $\approx$  1°C at sunset, falling to -0.5°C at sunrise, and (e) thermal difference with air of a rock outcropping is similar to that of concrete.

So the concrete gives a very warm environment for the telescopes. I estimate that the 1500 m<sup>2</sup> surrounding the 4<sup>m</sup> and the area between the 4<sup>m</sup> and 1.5<sup>m</sup> telescopes causes 130 kW convective heat dissipation just after sunset, dropping to 60 kW at sunrise. This is major and may especially affect the seeing at the 1.5<sup>m</sup> telescope which is closest to the ground. At the height of the 4<sup>m</sup> telescope the thermal ground effects may have disappeared, but that should be confirmed by further microthermal measurements.

Photos 17 and 18 show the concrete areas near the 4<sup>m</sup> and 1.5<sup>m</sup> telescopes which were measured.

## Sky Monitoring

As was done at the MMT0 tests (TR10) I tested the thermograph as a sky monitor to detect the presence of cirrus and other clouds on dark nights both at CTIO and KPNO. The thermograph indeed turned out to be a sensitive detector of light cloud cover, showing the presence of very thin cirrus clouds when experienced astronomers at CTIO and KPNO could not detect any visually on a dark night.

## Comparison with KPNO 4 meter telescope

The KPNO and CTIO 4 meter telescopes are identical, their enclosures are somewhat different, and their environment is quite different. Many of the features seen at the CTIO telescope are therefore present at the KPNO telescope, specifically (a) the oil pad heating, (b) the cassegrain cage problems, and (c) the cooled floors (both cooling systems were in use). The prime focus cage at KPNO was not occupied, so I cannot comment on it. The KPNO 4<sup>m</sup> suffers from some heat sources which were absent or less serious at CTIO. These are: (a) the area underneath the telescope is 1.5°C hotter than the general environment. With an area of  $\sim$  33 m<sup>2</sup> it causes 500 Watts convective cooling, (b) the visitor area windows are 1°C warmer, with an area of  $\sim$  25 m<sup>2</sup> it causes 250 W convective heat input, and (c) the area around the Coude focus at the end of the polar axis is  $\sim$  5°C hotter. This Coude area may be a major source of seeing. It could be closed off at the small telescope support ring area.