28. SUPER SEEING FROM THE AUSTRALIAN ANTARCTIC TERRITORY?

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ABSTRACT

Seeing, the degradation of resolution due to the earth's atmosphere, is a crucial factor in determining the performance of ground-based telescopes. This degradation is predominantly the result of thermal inhomogeneity of the air, to which a substantial contribution arises from the diurnal cycle of solar heating. In most of Antarctica the diurnal variation in temperature is negligible throughout winter, so good seeing can be expected on this account. Above the highest point of the Antarctic plateau the predominant air flow is a slow settling from the stratosphere which should promote extraordinarily uniform optical quality. Unfortunately, the lower boundary layer in which a strong inverse temperature gradient develops, especially in winter, is likely often to degrade what might otherwise be unprecedented seeing. Critical tests are needed to measure this degradation and determine whether it can be circumvented by mounting a telescope on a higher pier than usual.

28.1 THE IMPORTANCE TO ASTRONOMY OF GOOD SEEING

For astronomy at wavelengths from the near-infrared (IR) up to a few mm, it is clear that high Antarctic sites, with their very dry cold atmosphere, offer the potential of enormous gains in sensitivity. Another important attraction at a very high altitude Antarctic site may be better angular resolution, i.e. better seeing, than from anywhere else on the Earth's surface. Seeing is a measure of the distortion suffered by an initially plane wavefront propagating through the earth's atmosphere. The distortions of most significance are due to refractive index inhomogeneity on a scale from about 1 cm up to a few metres and the refractive index variations are predominantly due to air temperature variations.

For telescopes larger than about 20 cm diameter for the visible and about 1 m for the near-IR, the image resolution at even the best sites currently in use is always degraded to some extent by seeing; in the visible, these sites yield images with a median full width half maximum about 0.6 arsec. For many critical astronomical observations, the figure of merit in deciding the sensitivity of a telescope is its collecting area divided by the area into which it concentrates a star image. So the inverse of the seeing diameter is generally as significant a measure of performance as the diameter of a telescope's mirror. For some observations, high angular resolution is crucial to obtaining the desired scientific result; in these cases good seeing is the most critical requirement of all.

28.2 FACTORS AFFECTING SEEING IN ANTARCTICA

At most observatory sites, diurnal temperature variation is a major cause of seeing degradation, both in the free atmosphere and, especially for large instruments, in the immediate vicinity of the telescope. In Antarctica, at least during the dark months, systematic diurnal variation in temperature is negligible, so seeing will not suffer on this account. The Antarctic atmospheric circulation pattern centres on the highest point of the plateau, where the predominant airflow is a slow settling to feed the very consistent downward-flowing surface winds. This should promote extraordinarily stable and uniform optical quality in the upper atmosphere above this highest point (Dome A). The thinness of the air above Dome A (which is at an altitude equivalent in pressure to above 5000 m) will also contribute to good seeing.

There have been few measurements of seeing reported from high altitude Antarctic sites – just some visual observations from the South Pole, which is at about 2800 m (Harvey 1989, 1991). These have not been remarkably good but most have been in daytime (i.e. summer) and have been made from small telescopes a few metres at most above the snow. Near-ground effects can dominate seeing degradation at many observing sites - hence the elevation of telescopes on piers and towers - but this is especially likely in Antarctica. There the ground cools well below the bulk air temperature, setting up a strong inverse air temperature gradient in the lower several to many tens of metres. In winter, the gradient can reach 0.1°C/m or more. Stirring of this boundary layer leads to large air temperature variations near the surface from hour to hour and, presumably, to significant thermal inhomogeneity which must degrade seeing.

28.3 MEASUREMENT OF ANTARCTICA'S SEEING POTENTIAL

Crucial uncertainties which must be resolved before we will know whether 'super seeing' is economically attainable from Antarctica are the quality of seeing from above the boundary layer and the height to which a telescope must be raised to avoid significant seeing degradation by this layer. Part of the program of the US Center for Astrophysical Research in Antarctica (CARA) is to measure seeing at the South Pole more quantitatively than in the past. It is important (a) that this program be extended to include measurements which will resolve the uncertainties just mentioned and (b) that, as soon as appropriate techniques for doing this are proved at the Pole, the same measurements be made at higher altitude sites. Initial moves have been made towards setting up a collaboration to this end, involving CARA, a few Australian institutions, and a group at the University of Nice, who have relevant experience in site testing for seeing (e.g. Vemin and Azouit 1990) as well as experience in building optical instruments for operation at the South Pole (for solar seismology). Encouraging contact has also been made with Soviet astronomers, which should lead to seeing tests being made at the Soviet Antarctic station, Vostok, currently the highest, manned, inland base.

28.4 INSTRUMENTATION TO CAPITALISE ON SUPER ANTARCTIC SEEING

In the wavelength range from 2.27 to 2.45 μm, which is free of atmospheric emission lines, the thermal radiance from the atmosphere is very steeply dependent on temperature, such that Antarctic sites offer about one hundred fold reduction compared with sites at O°C. Because of these and other factors (Burton et al. 1992) there is enormous potential for Antarctic telescopes working in this wavelength range. At 2.4 μm, the diffraction limited resolution (the Airy disc radius) of a 3 metre diameter telescope is 0.2 arsec. So with a telescope of this size or larger, seeing which frequently allowed close to diffraction-limited performance would further enhance the near-IR sensitivity gain and deliver very high resolution indeed. As argued above, there are good reasons to think such seeing will be attainable at a very high Antarctic site but it may be necessary to mount the telescope higher above the terrain than is usual on mountain-top sites.

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