Design and Test of an Instrument for Measuring Microthermal Seeing on Magdalena Ridge

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Background  Magdalena Ridge is the site of an ambitious multi-element imaging interferometer under construction by New Mexico Tech and Cambridge University. The Magdalena Ridge Observatory Interferometer (MROI) is located west of Socorro in the Magdalena Mountains at an altitude of 10,500 ft. We have designed and built an instrument for performing microthermal measurements of ground-level seeing at the MROI site. High-speed thermocouple pairs are used to take temperature measurements. The rapid temperature measurements are directly related to the local turbulence which in turn is responsible for the ground-level astronomical seeing.

Theory  Variations in the refractive index of the atmosphere affect astronomical seeing. The refractive index of the atmosphere changes with temperature fluctuations in the air. By measuring temperature fluctuations, it is possible to derive the refractive index and thus the contribution to astronomical seeing from the air at the point of measurement.

Following the work of Pant et al. (1999), the full width at half maximum atmospheric seeing is

\[ E_{\text{fwhm}} = 5.25 \times 10^{-3} \left( \int_0^H C_{N}^2(dh) dh \right)^{1/3} \]  

where \( C_{N}^2(dh) \) is the refractive index coefficient. The temperature structure coefficient, \( C_{TC}^2(dh) \), is used to find \( C_{N}^2 \) at temperature, \( T \), and pressure, \( P \):

\[ C_{TC}^2(h) = \left( 8.01 \times 10^{-8} \frac{T_0}{T(h)} \right)^2 C_{N}^2(h) \]  

Our instrument measures the temperature structure function, \( D_T(h) \), associated with \( C_{TC}^2(h) \) via

\[ D_T(h) = C_{TC}^2(h) |F|^2 \]  

This is performed by taking the average of the temperature difference between two points squared, at height, \( k \), and separated a distance, \( \Delta r \):

\[ D_T(k, \Delta r) = \left\langle (T(k) - T(k + \Delta r))^2 \right\rangle \]  

Results  Preliminary results are given in Figure 5. Shown are log plots of the temperature structure coefficient, \( C_{TC}^2(h) \), for each height above the ground and the ratio of \( C_{TC}^2(h) \) for consecutive levels. The values are computed on a 1 minute basis. The voltages are converted to temperature and the difference between sensors at each height is found. Baselines are subtracted separately in each 1 minute sequence to produce a zero-mean time series for all intervals. The RMS of the zero-mean time series is what is used to make the plots.

The System Works  The difference in temperature is often less for sensor pairs at higher altitudes than for sensor pairs at lower altitudes. This is the behavior we expect of ground-level turbulence. Also notice how it is quite easy to distinguish daytime from nighttime. During the daytime, the fluctuations in temperature are much greater than they are during the nighttime.

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