OBSERVATIONS OF SEEING AT 0.5 AND 12.4 μm

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January 6, 1993

Abstract. A variety of observations have been made of solar features (sunspots, faculae, the limb) using both array and single element scanning techniques. The telescope was the 1.6 m McMath-Pierce on Kitt Peak. Array data were acquired with a 58x62 pixel Si:Ga detector at 4.8, 7.8, 12.4, and 18 μm, while a CCD camera recorded the same image position at 0.5 μm. In a separate experiment, a nutating mirror device was used to generate a raster scan of solar disk areas, the output being fed to a Si PIN diode (0.5 μm filter) and a As:Si diode (12.4 μm filter). The scanner data yield simultaneous images at the two wavelengths and was essentially a repeat of the 1970 Turon-Léna experiment with updated equipment. Examples of images at the various wavelengths are given in the poster. Analysis of the data is incomplete at this time. We can report that the effects of seeing were encountered at all wavelengths, including 18μm, even though conditions were deemed good at times (for example, penumbral filaments were resolved in sunspots). We have thus been unable to verify, as yet, the conditions reported by Bester et al, in which exceptional seeing is realized in the infrared.

Key words: Seeing, Infrared, Solar

1. Introduction

Bester et al (1992) have proposed the intriguing possibility that at times of 'good seeing' the atmosphere behaves not in accord with Kolmogorov turbulence but rather in agreement with a random walk model. The Kolmogorov picture leads to an image resolution θ which depends on wavelength λ given by

$$\theta = \theta_v \left(\frac{\lambda_v}{\lambda}\right)^{\frac{1}{5}}$$

while in the case of random walk

$$\theta = \theta_v \left(\frac{\lambda_v}{\lambda}\right)$$

The value of θ_v, the resolution at visible wavelengths, assumes the effects of diffraction and telescope aberrations are negligible. In our case diffraction is significant at 12.4μm, about 4 arc-sec, and there are optical aberrations in the visible. But if we ignore these effects as constant, the Kolmogorov formula yields a factor of 2 improvement in resolution in going from 0.5μm to 12.4μm whereas the random walk condition leads to a factor of 25, a tremendous gain (see also Coulman and Vernin 1991; McKechnie 1991). The question is: under realistic conditions can the random walk atmosphere be realized?

We have obtained the first pictures of the solar surface in mid-infrared wavelengths. The detector is a cryogenically cooled 58x62 Si:Ga. At our poster session

J.G. Robertson and W.J. Tango (eds.), Very High Angular Resolution Imaging, 299–301.

we show these observations as a video of a quiet region near disk center, as well as of two sunspot areas. All images show the effects of atmospheric seeing.

Dan Gezari, who has considerable experience on stellar observations with this camera at the NASA Infrared Telescope Facility on Mauna Kea, had not previously encountered seeing effects in the mid-infrared. Indeed, many of our single-frame images appear to be diffraction limited. But run as a movie the IR images clearly distort and move about. Are we suffering from bad seeing? Judging from the resolution achieved on sunspot structures and past results in solar observing, the seeing would be deemed good; perhaps not the equal of Mauna Kea, but certainly not 'bad'. Another factor peculiar to solar observations is mirror seeing: the heating of the reflectivity layer in the presence of solar flux. This is especially true for non-vacuum telescopes with low coefficient of expansion mirrors. To what extent mirror seeing affects the present material is unknown.

In another experiment we obtained simultaneous images at $0.5\mu m$ and $12.4\mu m$ using simple diodes and a raster scan. Seeing was not as good as with the array device, and the images appear dominated by something akin to telescope shake. Because the sun looks different at the two wavelengths, with more fine structure at $12.4\mu m$, the IR pictures are more detailed than in the visible leading one to surmise better seeing in the IR. But this may or may not be the case.

2. The Observations

2.1. Array data

During the interval 22 to 29 September 1992, the NASA 5-18μm camera was set up on the main image of the McMath-Pierce Telescope for continuum imaging of solar disk features. See Gezari et al (1992) for technical details of the camera. Telescope image scale is 2.39 arc-sec/mm. Internal to the camera is a 2:1 demagnification, leading to 0.335 arc-sec per 70 micron pixel. Field of view for the 58x62 element Si:Ga array is then 19.4x20.8 arc-sec. Filters inside the camera dewar provide spectral transmission windows at 4.8, 7.8, 12.4, and $18.1\mu m$, with bandwidths of $\delta\lambda/\lambda = 0.1$. Because the telescope is f/54 and the camera acceptance f/35, background is higher than optimum, about 20% at $12.4\mu m$, but this was not a problem.

TABLE I

Observational sequences (movies). Cadence is the rep rate, No. is the number of frames, and Contrast is intensity difference between extremes displayed.

Region	Wavelength (μm)	Exp. (sec)	Cadence (sec)	No.	Contrast (%)
Quiet Sun	12.4	3	20	85	1
Small spots	4.8	0.03	15	85	10
Big spot	4.8	0.1	15	85	20

To avoid saturation and achieve adequate S/N, 0.03 sec exposures are co-added to achieve the effective exposure time. This is bracketed by a dark field, taken off the solar disk, and a flat field, acquired by moving the image slowly in a quiet area at roughly the same limb distance as the region of interest.

Seeing was fair to good. We can expect the best solar seeing on Kitt Peak in summer about 45 to 90 minutes after sunrise (6.5 > airmass > 3.0). For the mid-infrared one must then compromise between deterioration of seeing and diminishing background from watervapor emission within the spectral windows. Our observations began at an airmass of about 1.8. With hindsight perhaps we should have begun earlier.

Within the displayed intensity range, given by the contrast, these are thermal pictures where temperature is a linear function of brightness. Concerning seeing, notice that for the 'small spot' series the exposure time has the minimum value of 0.03 sec. Despite this short interval, image distortion is evident from frame to frame. Overall random shifts might be due to visible light limb guider error, but not image distortion. The same comments apply to the 12.4μm 'quiet sun' movie.

2.2. Scanner data

A rocking mirror device (Livingston 1968) caused 166 arc-sec of the solar disk to be swept past a 0.5 arc-sec square hole at 2.5 sec/cycle in the RA direction. Coincidentally, the telescope was driven in DEC at 0.2 arc-sec/sec to create a rectilinear raster scan. A beam splitter behind the aperture delivered dissected light to PIN and the As:Si diodes. These 0.5μm and 12.4μm simultaneous signals were recorded with the general purpose program MULTI. The setup is identical to that of Turon and Léna (1970) except for much improved IR detectivity. Deduction of the wavelength dependence of seeing should be straight forward from limb scans. Unfortunately, the data in hand (8 May 1992) suffers from telescope wind shake and the seeing was not very good. We plan to repeat the experiment next summer.

3. Conclusions

Reports from the stellar observers to the contrary, we have demonstrated that even at 18μm seeing is not negligible. At least this is true in the daytime with a 1.6 m telescope under fair to good conditions. We have not yet been able to measure wavelength dependence with really good seeing, and thus have failed to adequately test the Bester et al hypothesis that the atmosphere can depart substantially from the Kolmogorov turbulence model.

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