Rev. Mexicana Astron. Astrof., **8**, 3-6 (1983)

INFRARED OBSERVATIONS OF THE THERMAL EMISSION FROM THE CORONA

A. Mampaso and C. Sánchez-Magro

Instituto de Astrofísica de Canarias
Universidad de La Laguna
España

and

M.J. Selby and A.D. MacGregor

Astronomy Group, Blackett Laboratory
Imperial College
London

Received 1982 October 14

RESUMEN

Durante el verano de 1978 observamos la Corona F en el cercano infrarrojo a 2.2μm y 3.5μm tratando de medir la localizada emisión térmica predicha por Peterson (1963) y otros. No detectamos esta emisión aún cuando nuestros errores experimentales están muy por debajo de los valores previamente reportados. Creemos que si existen picos de emisión térmica alrededor del Sol, son mucho más débiles o tienen forma diferente a los previamente encontrados.

Este resultado demandará, en caso de ser confirmado, una revisión de la dinámica y estado físico del polvo circunsolar.

ABSTRACT

During the summer of 1978 the F Corona was observed from the ground in the near infrared at 2.2μm and 3.5μm in an attempt to measure the localized thermal emission from dust predicted by Peterson (1963) and several other workers. We failed to detect this emission even though our experimental errors were well below previously quoted emission values. If thermal emission peaks around the sun exist, we believe they are either much weaker or have different shapes compared to previous ones found. This result, if confirmed, will require a revision of the dynamics and physics of circumsolar dust.

Key words: SUN – CORONA

I. INTRODUCTION

Peterson (1963) predicted the existence of infrared emission peaks around the sun as a consequence of the creation of dust-free zones. These are formed by the accumulation of dust as it spirals in toward the sun; at a given solar radius the grain temperature becomes sufficiently high for evaporation to take place. Dust free zones, occuring at several differing solar radii can be explained as changes in chemical composition of the dust. A study of these emission peaks should help to determine the nature and size of the dust grains.

Apart from the dust emission the near IR continuum from the solar corona can be explained by Thomson scattering of free electrons. These electrons could be discontinuously packed in the solar wind in relation to the solar activity. Dust emission or electron scattering should be clearly indicated by color and polarization measurements.

The detection of a peak at 3.9 $R_\odot$ in the near infrared at 2.2μm during the solar eclipse of 1966 was reported by Peterson (1967). In the following year Peterson (1969) and Mac Queen (1968) found emission peaks at 3.4 $R_\odot$, 3.9 $R_\odot$, 8.7 $R_\odot$ and 9.2 $R_\odot$, with the 3.9 $R_\odot$ peak dominant. Their observations were taken from the ground and balloon and clearly showed the 3.9 $R_\odot$ peak at 2.2μm and 3.5μm in almost identical position, although the relative intensities for the two experiments differed by a factor of two. The equivalent widths of the peaks were of the order of 8 arc minutes.

Since these initial experiments there have been several reports of additional work. Kaiser (1970), Koutchmy and Magnant (1973), Mukay *et al.* (1974) and Mukay and Yamamoto (1979) have tried to construct suitable dust models but found it difficult to explain the shape of the observed peaks, as did Kaiser (1970), Calbert and Beard (1972) and Roser and Staude (1978). It was also difficult to find a unique model which could explain why peaks are not observed in the visible (Mac Queen 1968; Beard 1979; Mukay and Yamamoto 1979).

There have been several attempts to confirm the earlier observations. Saito, Poland, and Munro (1977) failed to find emission maxima from Skylab but did see 50% coronal emission changes over two days which could be explained by Thomson scattering by electrons. Earlier, Calbert and Beard (1972) suggested that scattering from electron streams could account for the observed emission peaks. This was later justified by Mac Queen and Poland (1977) who found variations of 10^{-8} $B_{\odot}$ in the radiance of a fixed coronal position with a persistence time of months which would be more than sufficient to explain the peak intensities. Similarly, Bohlin (1971) found coronal changes in the visible larger than 10^{-9} $B_{\odot}$. Adney (1973) reported an emission maxima at 2.2μm appearing at 4.3 $R_{\odot}$ with a different shape to the earlier Peterson and Mac Queen observations. Blavers *et al.* (1980) from radial velocity measurements in the F corona found their results to be consistent with an emission peak at 4 $R_{\odot}$. Lena *et al.* (1974) report the detection of an emission peak at 10μm. On the other hand, Ney (1980) failed to find the 4 $R_{\odot}$ peak at 3.5μm during the solar eclipses of 1979 and 1980.

As indicated in the above review, the position, color shape and even existence of circumsolar emission peaks is far from clear, which lead us to attempt further observations at 2.2μm and 3.5μm out of the eclipse from a good infrared ground based site.

II. OBSERVATIONS

Observations were made between June and September 1978 at Izaña, Tenerife (altitude 2.300 m) using a 25 cm. aperture telescope with an occulting screen 12 meters above the ground. The InSb detector together with the beam stops and filters were cooled to 77 K and placed at the F/4 Newtonian focus of the telescope. To reduce light scattering within the instrument, all mirrors were gold coated and the entrance pupil of the telescope was restricted to a slit 22 cm X 3 cm. and well baffled. The corona was scanned using the earth's motion with the telescope aperture slit set transverse to this, so that we could reach 2 $R_{\odot}$ from the solar center with the telescope system, the sky image on the detector was chopped at 15 Hz. This was achieved by oscillating the primary mirror of the telescope, to give a peak amplitude of 2.5 arc minutes. The sky aperture was also 2.5 arc minutes which is less than the halfwidth of the Peterson and MacQueen peak. The sky and coronal backgrounds and possible peak emissions will appear to a first approximation as differentiated signals. α Lyr and the magnitudes given by Johnson (1966) were used as calibration.

During clear days over the observing period, over one hundred scans between 2 $R_{\odot}$ and 10 $R_{\odot}$ were recorded. Roughly 60% were taken at 3.5μm, 35% at 2.2μm and the rest at 1.2μm, 1.65μm and 5.0μm. The measurements

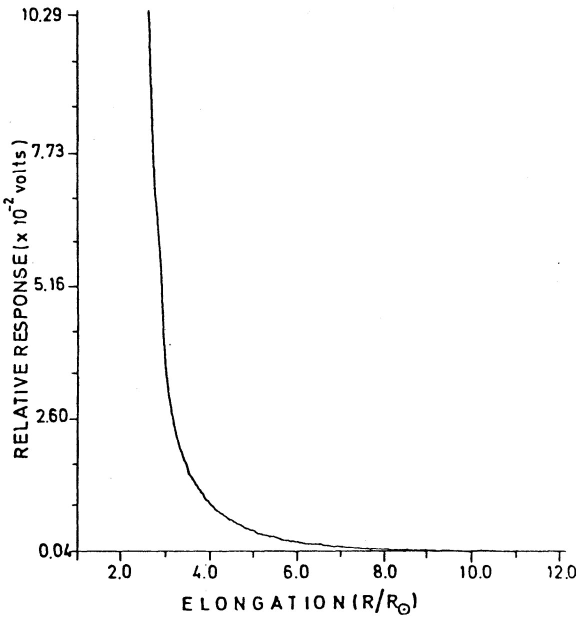

Fig. 1. This figure shows the measured signal using chopping detection techniques at 3.5μm, when the sun and the corona pass through the fixed solid beam of the instrument. The chopping amplitude is 2.5 arc min and the frequency 15 Hz. The collecting area was 66 cm^2. The data was collected on a clear day, (August, 6th., 1978.)

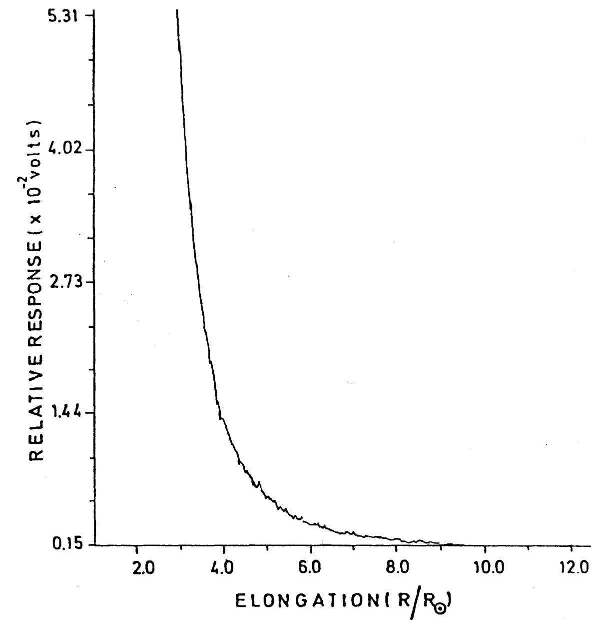

Fig. 2. Mean observed signal similar to the one in Figure 1, but obtained as the mean value of seven scans for a dusty day, (August, 24th., 1978).

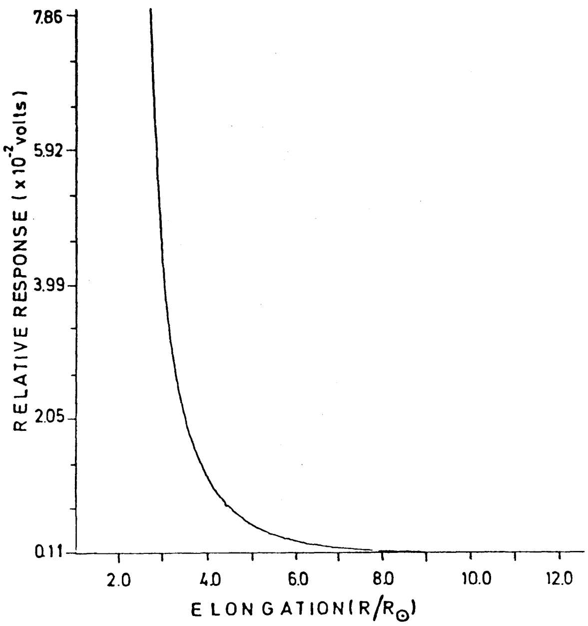

Fig. 3. Means signal obtained when calculating the mean of seven scans for a clear day, (September, 6th., 1978). The total observing time was two hours.

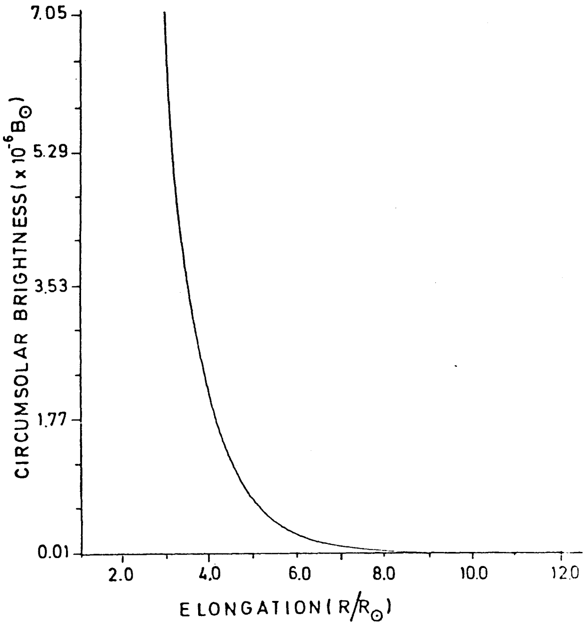

Fig. 4. Circumsolar radiance obtained by deconvolving the data on Figure 1, with the instrumental profile.

were in general very noisy at 5.0μm, and not very interesting at 1.2μm and 1.65μm where electron scattering is likely to be dominant. In addition the atmospheric scattering is considerably larger at the shorter wavelengths. Of all these scans, about 20 were done during excellent atmospheric conditions, mainly at 3.5μm, which appeared to be the best wavelength for these ground based observations.

Figure 1 shows a scan at 3.5μm on a day with very good atmospheric transparency. On days with dust in suspension in a south wind over the site, the signal was noisier (see Figure 2), and sometimes structure appeared which changed in time. We assumed this was consistent with the forward scattering properties of atmospheric dust over the site.

In an attempt to detect coronal peaks we added all the scans at the same wavelength for good days and the result proved negative after adding more than forty scans at 3.5μm. To check the possibility that temporal changes in coronal electron streams could have smeared out the peaks we added scans done on the same day during two hours of observation (see Figure 3), and again peaks were not observed. The same procedure of adding scans was performed for dusty days when it was evident there was a substantial increase in the scattered background. No stable structure over two hours of integrated observation was even observed. We concluded it would be difficult to see how atmospheric dust present during our observations could erroneously give the coronal peak shapes of Peterson and MacQueen. To measure the circumsolar sky luminance we deconvolved our scans with the instrumental profile. Figure 4 shows the result for one scan at 3.5μm.

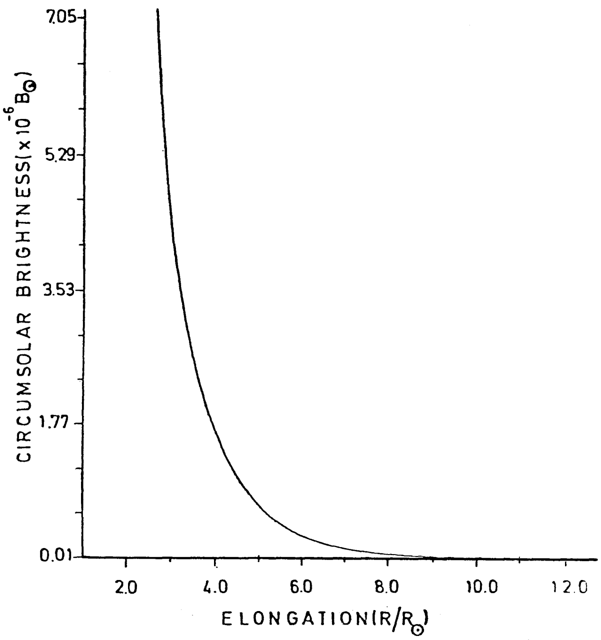

Fig. 5. The Peterson maxima are added to the radiance obtained for a clear day. The peaks are virtually invisible.

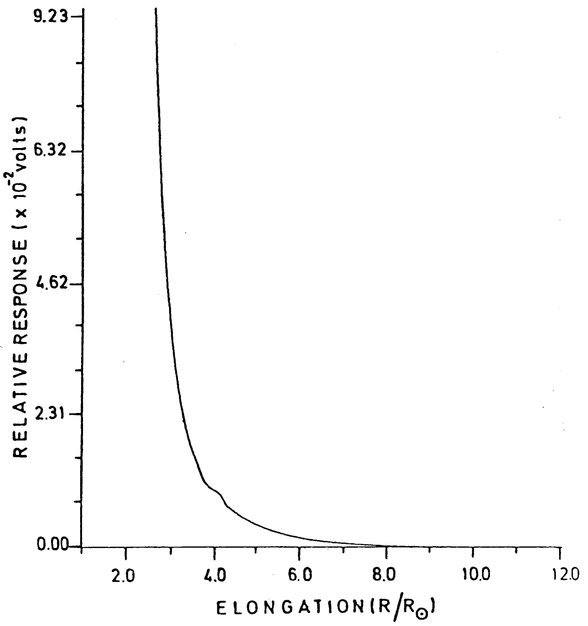

Fig. 6. Convolution of the data on Figure 5, with the instrumental profile. The Peterson peaks are now prominent, indicating the advantage of the chopping technique.

III. DISCUSSION

We superimposed the Peterson peak data at 4 $R_\odot$ (suitably corrected for atmospheric extintion) to a deconvolved scan produced over one good observing day at 3.5μm. The result is shown in Figure 5, where the peak structure is hardly evident. However, after this curve is convolved with our instrumental profile, which is what we would record in our scans, the peak is easily detected (see Figure 6). This clearly demonstrates the advantages of using the sky chopping technique.

We estimate we would have detected peak structure similar to that of Peterson with peak intensities reduced by almost one order of magnitude. We conclude that such peaks did not exist during our observing period. If, however, comparable infrared emission peaks emerge intermittently due to scattering from electron condensations, then we feel confident our ground-based system can monitor them at 3.5μm and possibly detect them at 2.2μm.

REFERENCES

Adney, K.J. 1973, *NASA Report*, UMSS-ARF-73-284.
Beard, D.B. 1979, private communication.
Blavers, W.I., Eitter, J.J., Carr, P.H., and Cook, B.C. 1980, *Ap. J.*, **238**, 349.
Bohlin, J.D. 1971, *Solar Phys.*, **18**, 450.
Calbert, R. and Beard, D.B. 1972, *Ap. J.*, **176**, 497.
Johnson, H.L. 1966, *Ann. Rev. Astr. and Ap.*, **4**, 193.
Kaiser, C.F. 1970, *Ap. J.*, **159**, 77.
Koutchmy, S. and Magnant, F. 1973, *Ap. J.*, **186**, 671.
Lena, P., Viala, Y., Hall, D., and Soufflot, A. 1974, *Astr. and Ap.*, **37**, 81.
MacQueen, R.M. 1968, *Ap. J.*, **154**, 1059.
MacQueen, R.M. and Poland, A.J. 1977, *Solar Phys.*, **55**, 143.
Mukay, T., Yamamoto, T., Hasegawa, H., Fujiwara, A., and Koike, C. 1974, *Pub. Astr. Soc. Japan*, **26**, 445.
Mukay, T. and Yamamoto, T. 1979, *Pub. Astr. Soc. Japan*, **31**, 585.
Ney, E. 1980, private communication.
Peterson, A.W. 1963, *Ap. J.*, **138**, 1218.
Peterson, A.W. 1967, *Ap. J., (Letters)*, **148**, L37.
Peterson, A.W. 1969, *Ap. J.*, **155**, 1009.
Roser, S. and Staude, H.J. 1978, *Astr. and Ap.*, **67**, 381.
Saito, K., Poland, A.I., and Munro, R.H. 1977, *Solar Phys.*, **55**, 121.

A. Mampaso and C. Sánchez-Magro: Instituto de Astrofísica de Canarias, (C.S.L.C.), Universidad de La Laguna, Tenerife, España.
A.D. MacGregor and M.J. Selby: Astronomy Group, Blackett Laboratory, Imperial College, London SW7 2BZ, Great Britain.