Solar Flares at 10μ with a Warm Bolometer

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Abstract: These notes assess the feasibility of flare observations at 10μ with a room-temperature bolometer array from Glasgow. The idea is to take a trial look at the Sun with the Santa Barbara bolometer array at the focal plane of one of the group's Dobsonian telescopes.

1 Introduction

The far infrared (here taken to be 5-30μ) is almost unknown in research on solar flares. Early work in France [Lena1970], [Koutchmy and Peyturaux1970] established the basic parameters for solar observations in this spectral range. [Turon and Léna1970] and [Hudson1975] showed that active-region plage (really, faculae, since 10μ forms close to the photosphere) could readily be detected. This made it highly likely that flares also could be detected.

In the far IR, a broad-band observation will show flare continuum. This should be dominated by free-free radiation (bremsstrahlung on neutral hydrogen), with free electrons coming from ionized metals (in quiet times) or possbly from transient hydrogen ionization (in flare conditions). In either case the radiation forms deep in the atmosphere. The free-free continuum has a well-defined and narrow contribution function [Lindsey and Heasley1981] and thus should be an excellent and relatively model-independent guide to the structure of the deep atmosphere during a solar flare. Recently [Melo *et al.*2006] reported first flare observations at these wavelengths.

The early observations were made with sensitive bolometers, used as point detectors at the focal planes of 1.5 m telescopes (Kitt Peak and Mt. Lemmon) at mountain sites in a dry country (Arizona). These notes consider what one can do with better technology, specifically with warm bolometer arrays. The development of array detectors is a major step forward already, since these make it possible to do differential photometry without chopping.

2 Signal-to-noise for a warm bolometer array

We assume a bolometer array with 28μ pixels and an NEP (Noise Equivalent Power) of 10^{-8} W/Hz$^{1/2}$ in each pixel. This would be the signal level equal to the thermal noise for a one-second data integration. For the quiet Sun we can estimate the SNR via

$$SNR = S_\lambda \Delta\lambda A \epsilon \Omega_{pix}/\Omega_\odot \sim 1.7$$

assuming a 19-inch aperture, 2 m focal length, a dirty mirror (area A = 0.18 m^2) and poor sky transparency giving $\epsilon \sim$0.1, and a solar spectral irradiance $S_\lambda \sim 0.3$ mW/m^{2}nm over a 1-μ bandpass at 10μ. I think this is consistent with

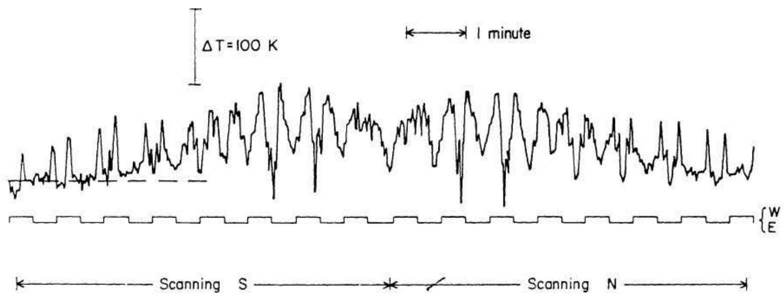

Figure 1: Strip-chart recordings of 20μ photometry of a solar active region made with the Mt. Lemmon 60-inch telescope through one layer of "Black Polymulch" (like bin-bag black poly). The successive lines of the scan show repeatable features identifed with faculae (if bright) or sunspots (if dark).

the SNR one can see in Fig. 1 (from Hudson, 1975). Those observations were made with a He-cooled bolometer and a 60-inch telescope. The thermal load on the detector would be about 0.3 W. Is this OK? A related question would be, can we gain SNR by slightly cooling the detector?

Is Glasgow really dry enough to permit 10-μ astronomical observations, i.e. how sure are we that ϵ is really as big as 0.1? [Taylor and Yates1957] give some basic information about IR propagation in humid places. They find about 50% transmission for the 10-μ band under awful conditions: 40.5° F, 48% relative humidity, 52 mm precipitable H_2O, across a 24 mile path length at sea level (the path actually traversed the Chesapeake Bay). Presumably this means that one can do IR astronomy, at least solar observations, from Glasgow as well.

3 How to proceed

The easiest way to check the SNR empirically is with one of the Astro group's large Dobsonian telescopes, in order to increase the SNR. Probably setting up to do a drift scan would be easiest. If the interface permitted, recording full images at 1-Hz cadence would be idea, and would generate about 100 MB per transit. Our recommendation would be to be careful with the black poly. Armstrong & Low (1973) claim that it has a cutoff wavelength of 2.8 μ, but this must depend on the thickness and the manufacturer. Probably it would be wisest to cover the aperture with two or even three layers to be careful. Somewhere in the University there will be a blackbody source that one could use to calibrate the chosen bin bag.

The estimated SNR of 2 may be a slight underestimate. The 10 μ window is actually fairly wide, the diffraction limit of the telescope is larger than the pixel size, and atmospheric transmission is likely to be more than 50%, and one might get a better NEP by a small amount of cooling. We definitely want to check empirically to see what aperture would be needed for any real observations.

References

[Armstrong and Low1973] Armstrong, K.R., Low, F.J.: 1973, New techniques for far-infrared filters. *Applied Optics* **12**, 2009 – 2009.

[Hudson1975] Hudson, H.S.: 1975, The solar-flare infrared continuum - Observational techniques and upper limits. *Solar Phys* **45**, 78 – 78. doi:10.1007/BF00152217.

[Koutchmy and Peyturaux1970] Koutchmy, S., Peyturaux, R.: 1970, Study of the Solar Continuum in the Intermediate Infra-Red Spectral Range 3.5-24.4 4u. *A&A* **5**, 470.

[Lena1970] Lena, P.: 1970, Continuum Infrared Radiation of the Solar Photosphere. *A&A* **4**, 202.

[Lindsey and Heasley1981] Lindsey, C., Heasley, J.N.: 1981, Far-infrared continuum observations of solar faculae. *ApJ* **247**, 353 – 353. doi:10.1086/159043.

[Melo *et al.*2006] Melo, A.M., Kaufmann, P., Kudaka, A.S., Raulin, J.P., Marcon, R., Marun, A., Pereyra, P., Levato, H.: 2006, A New Setup for Ground-based Measurements of Solar Activity at 10 μm. *PASP* **118**, 1563 – 1563. doi:10.1086/509267.

[Taylor and Yates1957] Taylor, J.H., Yates, H.W.: 1957, Atmospheric transmission in the infrared. *Journal of the Optical Society of America (1917-1983)* **47**, 223.

[Turon and Léna1970] Turon, P.J., Léna, P.J.: 1970, High resolution solar images at 10 microns: Sunspot details and photometry. *Solar Phys* **14**, 124 – 124. doi:10.1007/BF00240164.