NEAR-INFRARED CCD OBSERVATIONS OF UMBRAL DOTS

MALCOLM W. EWELL, JR.

Big Bear Solar Observatory, California Institute of Technology, Pasadena, CA 91125, U.S.A.

(Received 27 June, 1991; in revised form 16 August, 1991)

Abstract. Umbral fine structures have been observed at 8500 Å using a new CCD detector. Four frames with diffraction-limited seeing were obtained. Between 68 and 91 umbral dots with a brightness contrast greater than 2% were found in each frame, although no dots were found in the darkest part of the umbra. The intrinsic flux of the umbral dots varies widely, indicating that their intrinsic brightness does as well. The mean dot lifetime is estimated as 15 min, although some dots were observed to live more than 2 h. Some of the umbral dots are flowing into the umbra at speeds up to 0.5 km s⁻¹. These dots have higher than average contrast and are associated with penumbral grains.

1. Introduction

The study of umbral dots is important because they potentially hold clues to the magnetic structure and energy transport mechanism in sunspot umbrae. Several theoretical explanations have been put forth for umbral dots, including: penetrative convection (Choudhuri, 1986; Parker, 1979), nonlinear oscillatory convection (Knobloch and Weiss, 1984), and non-thermal heating (Kitai, 1986). The penetrative convection model currently seems to be the most promising (Garcia de la Rosa, 1987a), but the matter is by no means closed.

This work was motivated by the availability of a new CCD camera. This type of detector is ideally suited for the observation of umbral dots because of its large dynamic range and linearity. The near-infrared wavelength range was chosen for lower contrast and better seeing. A single exposure in the near infrared can detect the weakest umbral structures while not over-exposing the photosphere, and the relative brightness and contrast of various features can be easily measured. These observations are the first of umbral fine structures ever reported at this wavelength.

2. Observations

The active region BBSO 2180 was observed with the 65 cm vacuum reflector at Big Bear Solar Observatory on 21 July, 1990. The region was at 16° E, 30° S in heliocentric coordinates. The detector used was a 1024 × 1024, 12-bit Virtual Phase CCD, made by Texas Instruments, Japan, mounted in Orbiting Solar Laboratory brassboard camera No. 3, built for NASA by the Lockheed Palo Alto Research Laboratory. The data was taken through a 400 Å wide infrared filter, centered at 8550 Å. The quantum efficiency of the CCD is falling in this wavelength range, so the effective center wavelength of the observations is somewhat shorter that 8550 Å. The frames were exposed so that the photosphere approximately half filled the wells, giving exposure times of either 78 or
98 ms. The image scale was 0.16" per pixel, chosen to critically sample at the 0.35" diffraction limit of the telescope.

More than 300 frames were taken, spaced approximately every 30 s between 16:34 UT and 19:39 UT. The best frames were selected by eye based on the amount of detail visible in the granulation and the penumbral fine structure. This procedure identified 4 frames that showed structure at the diffraction limit. These four frames are reproduced as Figure 1. The frames were fortuitously evenly spaced, being separated by 27, 25, and 33 min.

Fig. 1. The four data frames used for most of the analysis.