Preliminary Report: 1980 Eclipse Coronal Oscillations Experiment

Jay M. Pasachoff

Hopkins Observatory, Williams College, Williamstown, Massachusetts 01267, *U.S.A.*
and
Institute for Astronomy, University of Hawaii Honolulu, Hawaii 96822, *U.S.A.*

and

Donald A. Landman

Institute for Astronomy, University of Hawaii Honolulu, Hawaii 96822, *U.S.A.*

(Received July 18, 1980, revised August 18, 1980 and September 29, 1980)

Abstract

We searched for short period (1 second) brightness oscillations in coronal loops during the 1980 total solar eclipse using cooled photomultipliers and digital microprocessor data handling and recording. The experiment was designed to test the prediction of such oscillations based on a theory of coronal heating through surface Alfven waves. A second experiment using a silicon vidicon spectrometer observed ultraviolet and infrared spectra of the corona to measure temperature from the Doppler broadening of strong ultraviolet lines and density from the relative abundances of the forbidden iron-thirteen lines. Data reduction is under way.

We successfully conducted a series of observations at the total solar eclipse of the Sun at Hyderabad, India, on 16 February 1980. One of the two major experiments was a search for short-period oscillations in coronal loops to test a new theory of coronal heating. The experiment was especially timely in view of recent evidence from Orbiting Solar Observatory 8, with confirming evidence dealing with other stars than the Sun from the International Ultraviolet Explorer and High-Energy Observatory 2 (Einstein Observatory), that the acoustic-wave-theory of coronal heating has to be discarded. The current status of coronal heating methods has been reviewed by Zirker (1980) and Linsky (1980).

In a second experiment, we took infrared and ultraviolet spectra of the corona. The infrared observations, of the forbidden iron-thirteen lines, were designed to investigate coronal density. The experiment was an improved version of earlier work by the Williams College group (Pasachoff and Muzyka 1976) based on theoretical work by Landman and others. The ultraviolet observations, to compare the coronal and photospheric spectra with high accuracy in the ultraviolet region between 3900 and 4000 A, was designed to investigate coronal intensity, using theoretical calculations by Cram (1976).

The expedition was supported by research and equipment grants from the U.S. National Science Foundation and the National Geographic Society. The Williams/Hawaii group was part of a larger expedition of twelve United States observatories and universities that was sent by the National Science Foundation to observe the eclipse from the Japal-Rangapur Observatory of the Osmania University, Hyderabad.

The Williams College/University of Hawaii group searched for oscillations of about 1-second in duration in coronal loops. NASA's Skylab missions had revealed that the corona is probably entirely composed of such loops, which are held together by the solar magnetic field.

The eclipse took place at the maximum of the solar activity cycle. Coronal loops are most frequently present at this phase. This particular cycle is one of the highest on record, and perhaps the second highest since sunspots were discovered by Galileo in 1610, and thus particularly favorable for finding suitable regions for study.

The exact mechanism by which the high temperature of the corona is provided is a source of much debate among solar astronomers. It had generally been accepted since the 1940's that some sort of mechanical energy is being transferred from the convection zone below the visible surface of the Sun up to the corona, where it is dissipated. But theoretical work over the years has not been able to provide satisfactory mechanisms that transfer enough energy to provide the observed heating. The recent solar observations from OSO-8 found too little energy being transferred upward by a significant factor. The Einstein Observatory observations show that acoustic waves could not be the heating mechanism for all stars, and thus imply that a new heating mechanism may operate in the Sun as well. Many solar physicists are beginning to look at mechanical ways of transfering energy.

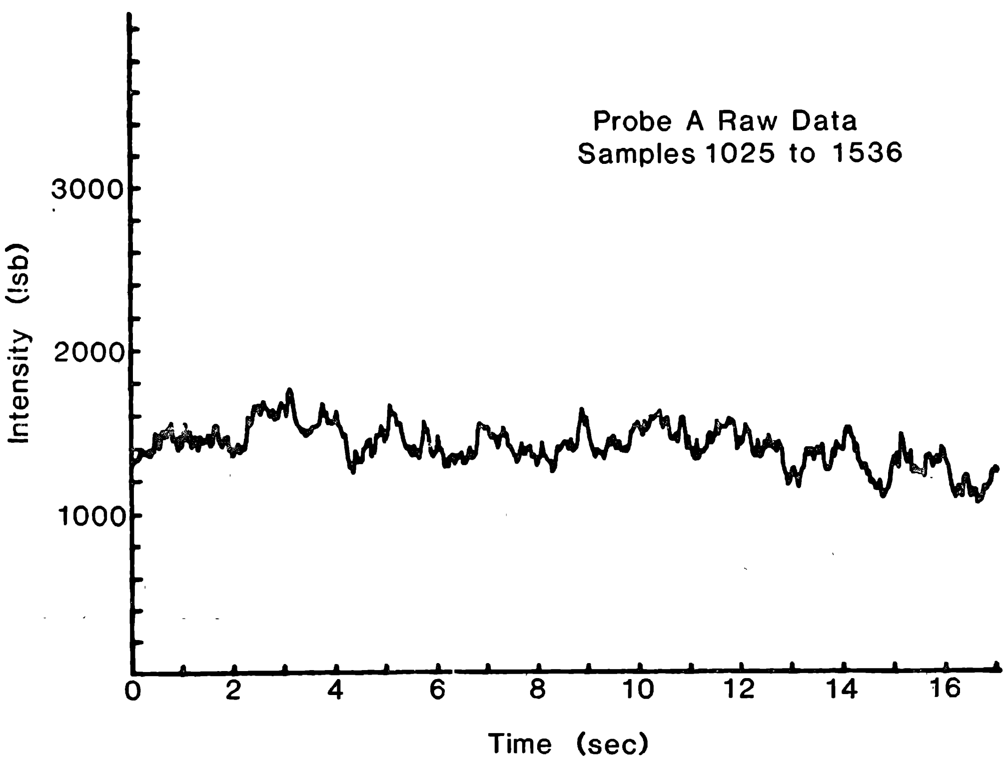

Fig. 1: The raw oscillation data from an 8-second period (a 256-bit string collected at 30 Hz). We had two independent photomultiplier systems, and the microprocessor sampled first one and then the other.

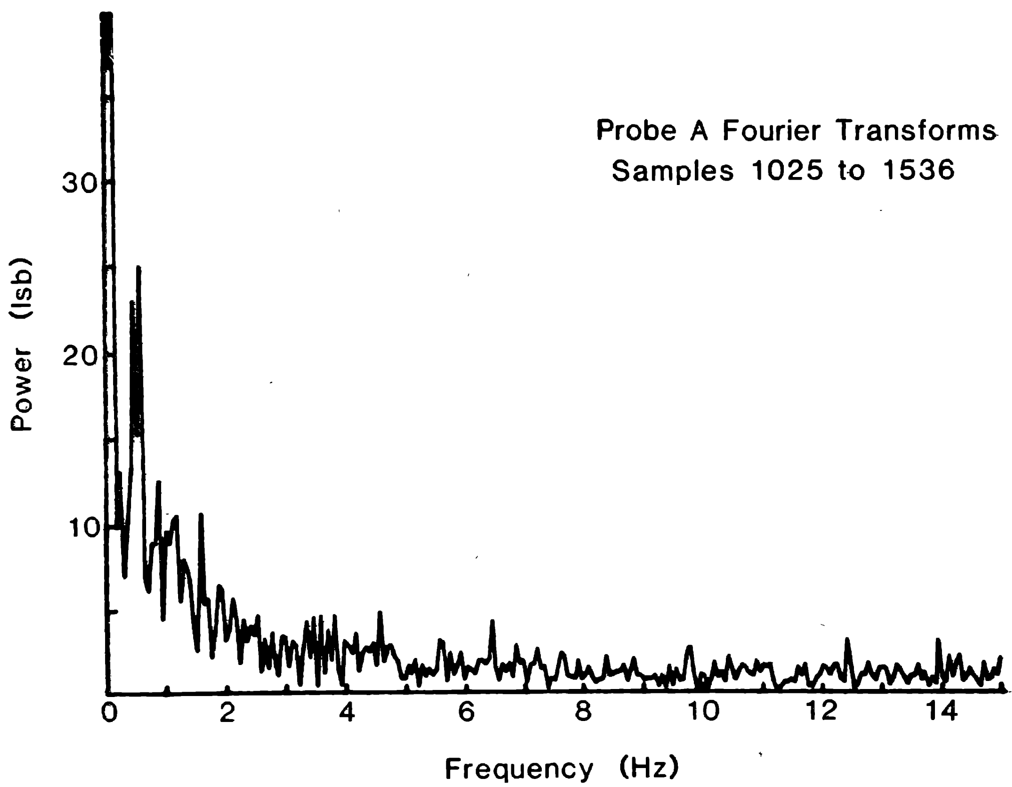

Fig. 2: The Fourier transform of the data shown in Figure 1. The vertical scale is in "least significant bits (lsb)" of digital data. There is a suggestion of enhanced power at approximately 0.5 Hz, detailed analysis is now under way. We are now carrying out such Fourier transforms for various intervals of time with computers at both Tektronix and at Williams College.

New theoretical work by James Ionson at the University of Maryland, now at NASA's Goddard Space Flight Center, has indicated a mechanism for this energy transfer—surface Alfven waves—that had not been previously considered. Ionson's work began in collaboration with Donat Wentzel at the University of Maryland. Ionson's theory (1980) predicts that the coronal loops should fluctuate in brightness by a few per cent with a period of only 1 second, a prediction that we investigated. The solar corona has not previously been studied with such high precision in time and in space. Other lines of solar research, such as those of J. Hollweg (1980a, 1980b), also indicate the possibility of such short-period oscillations.

The Williams/Hawaii group used photomultipliers to observe radiation in the coronal green line from regions of coronal loops a few seconds across, and recorded the data in digital form using microcomputers. One of the major problems involved in these observations was the accurate pointing of the telescope during the brief period of total eclipse. The expedition tackled this problem with the aid of fiber optics, which were inserted into the focal plane of the telescope to take the bits of coronal radiation for analysis. This left the rest of the image of the corona to be recorded on videotape and simultaneously displayed on a television screen. The television screen allowed real-time feedback so that we could adjust the pointing of the telescope. In the middle of the eclipse, for example, one of the fiber optics probes was relocated to a stronger region of the corona than its original placement.

The second experiment used an electronic imaging device, the Tektronix Rapid Scanning silicon vidicon spectrometer, to study the spectrum of the solar corona in order to provide independent determinations of its temperature and density. In the first part of the eclipse, spectra were taken in the ultraviolet region of the spectrum that includes the strongest spectral lines from the solar photosphere. The fact that these lines are broadened and so blurred by the Doppler effect is one of the primary signs that the corona has so high a temperature, but only accurate comparison of the coronal and photospheric spectra can give a temperature value rather than a lower limit. All previous determinations had been made on film, which is inherently less accurate for such a comparison. A photoelectric experiment that had been arranged by an Australian group for the 1974 eclipse in Australia had been clouded out, but the theoretical studies made on that occasion (Cram 1976) will be of use now.

A second set of observations with the silicon vidicon spectrometer were in the infrared part of the spectrum, and recorded the relative intensities of a pair of lines formed by twelve-times ionized iron in the corona. The ratio of intensities of these two lines is a sensitive indicator of the density at the positions in the corona under observation.

The data are now in computers at Williams College and at Tektronix. Figure 1 shows a scan of the oscillation data from an 8 second period toward the beginning of the eclipse. Figure 2 shows a Fourier transform of the data shown in Figure 1. The eclipse has been divided into shorter records of various lengths to increase the chance for finding transient oscillations and to minimize the effect of tracking problems. There is a suggestion of enhanced power at about 0.5 Hz. These are preliminary scans, work is continuing in producing scans and in studying them.

J. Phil Schierer of Tektronix, Inc., was experiment coordinator of the expedition, and designed the equipment that we used. Bruce Miller of Tektronix, Inc, designed the digital electronics for the experiment. Two Williams College undergraduates, Richard Boyce and Eric Pilger, also participated in the expedition.

The expedition was supported in part by N.S.F. Research Grant AST-7922104 and Equipment Grant CDP-7922926, in addition to logistic and travel support supplied by the National Science Foundation through the National Center for Atmospheric Research. It also received support from the National Geographic Society. We thank especially Ronald R. La Count of the National Science Foundation, Eugene Prantner and colleagues of the National Center for Atmospheric Research, and the Director and staff of the Osmania University of Hyderabad for their assistance.

References

Cram, L. 1976, *Solar Physics* **48,** 2.

Ionson, J. 1980, private communication.

Hollweg, J. 1980a, preprint.

Hollweg, J. 1980b, private communication.

Linsky, J. L. 1981, *A. Rev., Astr. Astrophys.* in press.

Pasachoff, J.M. and Muzyka, D.F. 1976, *Vistas in Astronomy*, **19,** 341.

Zirker, J. 1980, 1981 *Science Year, The World Book Science Annual* (*Chicago: Field Enterprises Educational Corporation*).