Research Note

SECIS: THE SOLAR ECLIPSE CORONAL IMAGING SYSTEM

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ABSTRACT. The Solar Eclipse Coronal Imaging System (SECIS) is an instrument designed to search for short-period modulations in the solar corona seen either during a total eclipse or with a coronagraph. The CCD cameras used in SECIS have the capability of imaging a selected portion of the corona at a rate of 50 frames per second, with the intensities in each pixel digitised in 12-bit levels. The data are captured and stored on a modified PC. It will thus be possible to search for fast changes or short-period wave motions in the corona that will have important implications for the coronal heating mechanism. Tests have been carried out during the 1998 total solar eclipse visible in Guadeloupe (French West Indies) and with the Evans Solar Facility coronagraph at the National Solar Observatory, Sacramento Peak, with scientifically useful results obtained from the latter.

1. INTRODUCTION

The problem of exactly why the solar coronal temperature is so high (~ 10⁶ K) remains unknown despite more than 50 years of theoretical and observational work (Phillips 1995). It is known that magnetic fields are involved, so that somehow magnetic energy is converted to thermal energy. Currently, the debate centres on whether the energy to heat the corona derives from dissipation of magnetohydrodynamic (MHD) waves (e.g. Hollweg 1981) or from numerous small-scale magnetic reconnections (‘nanoflares’, Parker 1988). There are theoretical arguments and observational evidence for both mechanisms.

Wave-heating or nanoflare-heating might result in short-term variability of coronal structures, for example white-light or X-ray loops. This has been searched for with coronographs observing in the Fe XIV ‘green’ line (at 530.3 nm, emitted at a temperature of ~ 2 x 10⁶ K.). Wood et al. (1998) observed significant variations in compact loop structures with timescales of about 30 minutes in data from the LASCO C1 mirror coronagraph on board the SOHO spacecraft. Also, Stenborg et al. (1998) have used a new ground-based German–Argentinian MICA coronagraph to look for variability in both the green and ‘red’ lines (the latter at 637.5 nm being due to the cooler Fe X ion): MICA is capable of imaging the corona every minute.

However, theoretical studies of MHD wave heating show that only very high frequencies (~ 0.5 Hz) are implicated for significant heating of coronal loops (Porter, Klimchuk & Sturrock 1994). Intensity modulations with such high frequencies are beyond the observational capabilities of either spacecraft or ground-based coronagraphs or spacecraft X-ray instruments such as the Soft X-ray Telescope on the Japanese YOHKOH spacecraft. Hence there is a need for instrumentation that can image at much higher frequencies.

Fast intensity modulations were first searched for during the total solar eclipse of February 1980, when Pasachoff & Landman (1984) found some evidence of periodicity, with enhanced power in the 0.5–2 Hz frequency range when observing in the green line. Their result was confirmed in more refined observations in the June 1983 eclipse (Pasachoff & Ladd 1987). Portions of the corona on opposite limbs were examined in these observations. Earth atmospheric effects were removed by taking the intensity ratio of the green-line intensity to that in a neighbouring 10-nm-wide portion of continuum. Figure 1 (from Pasachoff & Ladd 1987) shows the Fourier spectrum of this ratio for part of the data set. The excess power in the 0.5–2 Hz frequency range is about 1% of the total.

In more recent eclipses, Pasachoff et al. (1995) used imaging techniques to search for modulations in coronal loops in partly cloudy conditions during the 1994 November 3 eclipse. They again found excess power at a frequency of ~ 1 Hz. A modified experiment by this same group during the 1995 October 24 Indian eclipse with CCD imaging was used, with an
image rate of 5 frames a second, on some coronal loops, though a fault in the optical system produced ambiguous results. Possible short-period oscillations have also been detected by Singh et al. (1997), who observed the continuum at \( \sim 550 \) nm, and by Rusin \\& Minarovic (1994), who observed the red and green lines.

Searches with the Evans Solar Facility coronagraph at the National Solar Observatory, Sacramento Peak for green-line modulations in both intensity and velocity have been made by Koutchmy, Zugda \\& Locans (1983). These observations were made using repeated spectral scans across the green line. Evidence for periodicity with periods of 43 s, 80 s, and 300 s was found.

In summary, there is some evidence from these observations for short-period wave motions in the corona that may be important for understanding coronal heating.

Apart from wave motions, white-light observations made with a very large optical telescope, the CFHT instrument, during the 1991 eclipse visible from the Mauna Kea observatory (Vial et al. 1992; Koutchmy et al. 1994) show the presence of a moving white-light cloud or "plasmoid" with dimensions of 3 to 4 arcsec. The motion was complex, with the plasmoid apparently being heated up, splitting into two components, and finally merging with the ambient corona after about 4 minutes. If such plasmoids are common, they, rather than MHD waves (or perhaps in addition to them), may be important for heating the corona.

2. SECIS EXPERIMENT SUMMARY

In collaboration with a number of research groups, we have developed an instrument called the Solar Eclipse Coronal Imaging System (SECIS). The purpose of the SECIS instrument is to look for short-period oscillations or fast changes in the green-line corona. It will be able to image small, moving features such as the plasmoids seen by Vial et al. (1992). The 1999 eclipse will offer a rare opportunity of observing a total eclipse whose path crosses easily accessible regions, including south-western UK and other highly populated areas of Europe with good infrastructure and availability of resources. The SECIS instrument will also complement the SOHO and Yohkoh spacecraft which are currently observing the Sun.

Figure 2 shows the set-up for observing the 1999 eclipse. A tracking heliostat mirror will reflect sunlight into a Schmidt-Cassegrain reflecting telescope, mounted horizontally on an optical bench attached to a trestle-like table. Light from the eclipsed Sun will pass from the telescope to a beam splitter. The direct beam will pass to a green-line interference filter in front of one of the CCD cameras, and the reflected beam will pass to a broad-band filter (bandpass 10 nm) in front of a second CCD camera, the purpose of which is to monitor sky brightness (i.e. act as a "control" channel). The two cameras will operate at 50 frames s\(^{-1}\), forming a \(0.5^\circ \times 0.5^\circ\) image of a portion of the corona which will be pre-selected by inspection of SOHO and Yohkoh images taken shortly before the eclipse. The spatial resolution will be \(3.5^\prime \times 3.5^\prime\) arc. The data from each camera will be captured by a specially adapted PC having an extremely fast frame-grabbing capability and will be stored on large-capacity hard disks for further off-line analysis. A small monitor will record data from either channel during selected time intervals, thus enabling alignment to be checked.

Our procedure is thus similar in principle to Paschoff et al. (1995). Intensity fluctuations including periodic modulations can be examined in specific coronal structures with very high spatial and temporal resolution.

3. SECIS TESTING

Initial tests of SECIS were carried out at the total solar eclipse of February 28, 1999 in Guadeloupe (French West Indies) and also during a one month run at the Evans Solar Facility, Sacramento Peak, New Mexico.

In Guadeloupe, the weather was cloudy for much of the two days available before the eclipse, so testing on the sun before the eclipse was extremely limited. Only on the evening before the day of totality did we actually record solar images on our computer. On the day of the eclipse, the weather quickly improved and by the time of totality the sky was almost cloudless. Most unfortunately we lost electric power from...
the portable generator just 2 or 3 minutes before totality, and although power was soon restored, the interval for rebooting the computer was too short. Most of our fellow-observers suffered much the same fate as we did. It seems likely that the computer crashes were related to spikes on the power supply arising from overusage.

We did record a sequence of partial eclipse images shortly after totality, simply to see whether we could retrieve these data after shutting the equipment. This turned out to be successful, and these images were stored.

The observing run at the Evans Solar Facility (ESF), National Solar Observatory, Sacramento Peak was more successful. The 40-cm diameter ESP coronograph allows an artificial eclipse to be made inside the telescope. This blocks the light from the Sun’s disk, allowing the faint coronal light from the Sun’s atmosphere to be observed. The observations presented here were obtained on 5 September 1998, during an excellent coronal day, on an active region visible above the north western limb.

Figure 3 shows a section of data taken at the ESF and gives some idea of the spatial resolution and dynamic range available with SECIS. The leftmost panel was produced by summing 1000 × 15 msec frames taken in the light of the Fe XIV coronal green line, while the middle and right panels provide corresponding images at almost the same dates from the Yohkoh and TRACE missions. The raw SECIS frames were first corrected for electronic detector dark offset and also for pixel-to-pixel response differences. The dark current correction was made by taking several frames in zero illumination directly before and after the observations and then subtracting them from the data. Flat-fields were obtained by placing a diffuser in the optical path and then taking exposures of a uniformly illuminated surface on the inside of the dome. The flat-fielding also removed any possible radial effects produced within the optical set-up. In each case, the familiar loop-like structure of an active region is evident, while there is some indication that a small amount of quiet, diffuse corona may be visible in the SECIS image. Taking into account the different dates on which the observations were taken, coupled with the fact that the temperatures probed by each instrument are different, there is a remarkable similarity.

In order to detect any periodicities in the green line signal, the data were analysed using Fourier techniques. A preliminary Fourier analysis for two representative regions (labeled ‘Region A’ and ‘Region B’) is presented in Figure 4. Within region ‘Region A’, there is clearly enhanced power in the 0.0–4.0 Hz region, possibly indicating that waves are an important heating mechanism in the active regions.

4. AUGUST 11th 1999 – ECLIPSE SITE AND PREPARATIONS

We intend to observe the 1999 August 11 eclipse from the Bulgarian Black Sea Coast. The site will most likely be a meteorological station at Sabla, about 60 km north of Varna, and almost exactly on the centre line of the eclipse path which at this point is about 120 km wide. The time of mid-eclipse at this location will be 11:11 U.T. According to this, for the month of August, the number of clear days there is 17.6 (out of 31), and the mean diurnal temperature is 22.1°C. This information agrees with Espenak & Anderson (1997) who give the probability of seeing the eclipse as 63% for this location.

5. WORLD WIDE WEB SITES

The following WWW sites are useful for providing further information about SECIS and the 1999 eclipse:

  The official UK eclipse site. The SECIS instrument, together with the Wroclaw heliostat and initial results from Sacramento Peak, is described under “Eclipse Science”/“What the Scientists are doing” in this site.
  This site, due to Dr Fred Espenak, gives eclipse prediction information, including maps of the eclipse path and likely meteorological conditions.
AR8322 in FeXIV (5303 Å)

Fig. 4. Initial Fourier results from Sacramento Peak data showing enhanced power in the 0.0–0.4 Hz frequency range for Region A.

Acknowledgements

PTG is grateful to the Department of Education for Northern Ireland and the Rutherford Appleton Laboratory for financial support. This work was supported by PPARC and the Leverhulme Trust.

References