Recent Observations of the Solar Corona with a New Ground-Based Coronagraph in Argentina (MICA)

G. Stenborg [1], R. Schwenn [1], N. Srivastava [1], B. Inhester [1], B. Podlipnik [1], M. Rovira [2] and C. Francile [3]

[1] *Max-Planck-Institut für Aeronomie, Max-Planck-Str. 2, (37191) Katlenburg-Lindau, Germany*
[2] *Instituto de Astronomía y Física del Espacio, C.C.67 - Suc.28, (1428) Buenos Aires, Argentina*
[3] *Observatorio Astronómico Félix Aguilar, Benavidez 8175 Oeste, (5413) Chimbas, San Juan, Argentina*

Abstract. As part of the new German-Argentinian Solar-Observatory in El Leoncito, San Juan, Argentina, a new ground-based solar telescope (MICA: Mirror Coronagraph for Argentina) began to operate in August 1997. MICA is an advanced mirror coronagraph, its design being an almost exact copy of the LASCO-C1 instrument. Since its installation, it has been imaging the inner solar corona (1.05 to 2.0 solar radii) in two spectral ranges, corresponding to the emission lines of the Fe XIV and Fe X ions. The instrument can image the corona as fast as every minute. Thus, it is ideally suited to study fast processes in the inner corona. In this way it is a good complement for the LASCO-C1 instrument. We present a brief review of the characteristics of the instrument, and some recent observations.

INTRODUCTION

A low beta plasma is a good tracer of the lines of force of the magnetic field. However, the resistivity of the plasma, specially at fine scales, plays an important role and has to be taken into account. So the analysis of quasi-stationary coronal structures (specially the small-scale structures) gives an important insight of the solar magnetic field and solar activity. The fundamental problem faced in the study of coronal transients is to understand their origin and accelerating processes in the lower part of the corona. Systematic observations of the evolution of structures in the inner corona with both high temporal and spatial resolution is therefore necessary for the study of mass motions and instabilities in all parts of the corona.

Due to limitations caused by scattered light in the Earth's atmosphere, emission line features could be very well seen only during eclipses. There was an observational gap between close-to-limb early coronagraphic (both ground and space based) observations and what we know from eclipses. The externally occulted coronagraphs used so far in space missions suffered from vignetting at the inner edge of the occulter and did not allow useful observations inside about 2 solar radii. This problem was finally overcome with the use of internally occulted coronagraphs. The residual instrumental stray-light and scattered light in the terrestrial atmosphere is reduced considerably by the use of mirror optics instead of lenses, as pointed out in the 60's by (3). LASCO-C1 aboard SOHO (1) and a prior prototype (2) were the first internally occulted coronagraphs designed with reflective optics. Following this line, MICA incorporates all the advantages of internally occulting and mirror design such as compactness, low level of instrumental scattered light and optical achromacy, to name the most important ones.

As part of a bilateral science program between Argentina and Germany, a new internally occulted mirror coronagraph (MICA) was installed in the Prof. Ulrico Sesco Observing Station of OAFA at El Leoncito (69.3 W, 31.8 S), San Juan, Argentina, at an altitude of 2400 m, 50 km eastwards from the Argentinean "Cordillera de los Andes". The participating institutions are: Instituto de Astronomía y Física del Espacio (IAFE) and Observatorio Astronómico "Félix Aguilar" (OAFA), San Juan University, on the Argentinian side and Max-Planck-Institut für Aeronomie (MPAe) and Max-Planck-Institut für Extraterrestrische Physik (MPE) on the German side.

THE INSTRUMENT

The MICA system is almost identical to the LASCO-C1 instrument as described by (1). It is designed to produce filtergrams of the emisson line corona in several wavelengths. A temperature-controlled set of narrowband interference filters is used to observe the structures in the emission corona. The hot structures ($\sim$1.8 MK) are revealed by observing the emission of the well-known green coronal line with a 0.9 Å wide filter at 5303 Å (emissions of a forbidden transition of Fe XIV ions). Cooler structures ($\sim$1.0 MK) are observed by imaging the emission of the red coronal line with a similar filter at 6374 Å (i.e. emissions of Fe X ions). The instrumental straylight, the scattered light in the terrestrial atmosphere and the continuum coronal signal (Thompson scattering of the photospheric light by free electrons in the corona) have to be removed in order to detect the faint emission line corona. Therefore, the subtraction of reference images taken in the nearby continuum of the green and red coronal lines is performed with the help of two wide filters ($\sim$9 A FWHM) at 5260 Å and 6340 Å respectively.

MICA's field-of-view ranges from 1.05 to 2.0 solar radii. The detector is a 1280x1024 pixels, Peltier cooled CCD array with 12-bit AD conversion, the pixel width being 16 microns. The pixel width is equivalent to 3.7 arc-sec, resulting in a spatial resolution of $\sim$ 8 arc-sec. Since MICA is not constrained by telemetry, the temporal resolution is extremely high as compared to LASCO-C1. Typical exposure times for on-line images are 40 sec, while 15 sec are necessary for the off-line images. The time gap between images is not greater than 10 seconds, mainly due to instrumental procedures as filter changing, uploading of commands to the CCD controller when necessary, and CCD readout time.

Auxiliary Instruments

For the automatic operation of MICA, the system has a set of auxiliary devices i) to detect the actual weather conditions in the site, ii) to control the temperature of the filters and canister of the telescope, iii) to keep automatic tracking of the Sun, iv) to control the camera operation and filters mechanism, etc.

Two auxiliary devices especially developed, the sky and sun testers, are mounted close to MICA in order to continuously register the sky (aureola) and solar disk brightness, respectively. These values are used by the control software of the telescope to automatically decide whether the conditions are good for starting (continuing, stopping) coronal observations.

The whole system is operated by a computer and controlled by a specifically-designed program. The telescope can then be operated manually by a user sitting in the control room or automatically. In the latter case the observation routine is programed in advance. All the controlling system the operator uses while operating the telescope manually are accessible and programmable for the automatic operation. A synoptic default program is actually running taking green line images as long as the weather conditions allow.

OBSERVATIONS

Some Comments on Image Processing

Raw images taken by MICA do not show much coronal signal. It becomes visible after subtracting a nearby continuum image as already mentioned. Rapid chopping of the central wavelength between the coronal line and continuum is important in order to avoid the changes in sky brightness. Besides, before proceeding with the subtraction the images have to be corrected by the electronic detector dark offset (a constant added to the output even for zero input light), instrumental gain transfer function (response of any individual pixel), etc. The former is made by taking dark frames once a day unless changes in the temperature of the CCD are detected, and the latter by means of flat-fields. These are taken every 20 minutes in average for all of the filters used in the observation routine, since they are also used for calibration in intensity relative to the Sun's surface brightness. The flat-fielding procedure also removes the effect of a radial neutral density filter built into the optics. A diffusor placed in the door lid allows to take the flat-fields by just taking images with the door closed. Finally the subtracted image is rotated so that the heliographic north always points up.

The images are processed in real-time by a second computer at the site. Every time a new sequence of images is stored in the control computer, the second one begins to process them, allowing to monitor the activity in the solar corona with just a delay of a few minutes.

Some Recent Observations

In Figure 1 both a typical processed green line image as obtained by MICA and by LASCO-C1 are shown. Note the internal edge of MICA's field-of-view (1.05 solar radii) and LASCO-C1 (1.10 solar radii). Thus this capability of MICA allows tracking the coronal features at lower altitudes compared to LASCO-C1.

In Figure 2 we present an example of the red emission coronal line (east limb) as observed on 26 November, 1997 at three different times, in order to show the high temporal resolution of MICA. In addition by comparing figures 1 (left) and 2 which have been taken 10 minutes apart, we can point out that the structures in green and red emission look different although they have origin in the same active region. In Figure 3 a sequence of three green line images is presented, showing the complete MICA's field-of-view. This sequence also demonstrates the capability of MICA to take coronal images at a very high cadence compared to LASCO-C1.

DISCUSSION

Since August 1997 a new, small, ground-based light mirror coronagraph (MICA) is providing valuable data of the emission corona in two spectral ranges. Although mainly limited by the brightness and temporal variability of the sky, recent observations made by MICA present a very detailed view of transient phenomena in both temporal and spatial scale. It has been shown that by using tools of image treatment and background correction the instrument is able to detect the coronal emission of the Fe XIV and Fe X ions (green and red coronal lines) out to 1.6 solar radii.

In upcoming papers by using the high temporal resolution of the observations we will try to narrow down the uncertainty in the study of coronal transients and the conditions that trigger them. In the future we will also exploit in addition the high sensitivity of the instrument to the incoming radiation in order to study the temporal evolution of the atmosphere's transparency.

ACKNOWLEDGMENTS

This study is based on data obtained in the framework of the German-Argentinian HASTA/MICA Project at OAFA (El Leoncito, San Juan, Argentina), in a collaborative effort by IAFE, OAFA, MPAe and MPE.

REFERENCES

1. G. E. Brueckner and R. A. Howard and M. J. Koomen and C. M. Korendyke and D. J. Michels and J. D. Moses and D. G. Socker and K. P. Dere and P. L. Lamy and A. Llebaria and M. V. Bout and R. Schwenn and G. M. Simnett and D. K. Bedford and C. J. Eyles, *Solar Phys.* **162**, 357-402 (1995).
2. A. Epple and R. Schwenn, *Proc. of the 15th National Solar Observatory/Sacramento Peak Summer Workshop*, 233-238 (1995)
3. G. Newkirk and D. Bohlin , *Appl. Opt.* **2**, 131-140 (1963)
4. Schwenn and B. Inhester and S. P. Plunkett and A. Epple and B. Podlipnik and D. K. Bedford and C. J. Eyles and G. M. Simnett and S. J. Tappin and M. V. Bout and P. L. Lamy and A. Llebaria and G. E. Brueckner and K. P. Dere and R. A. Howard and M. J. Koomen and C. M. Korendyke and D. J. Michels and J. D. Moses and N. E. Moulton and S. E. Paswaters and D. G. Socker and O. C. St. Cyr and D. Wang, *Solar Phys.* **175**, 667-684 (1997)

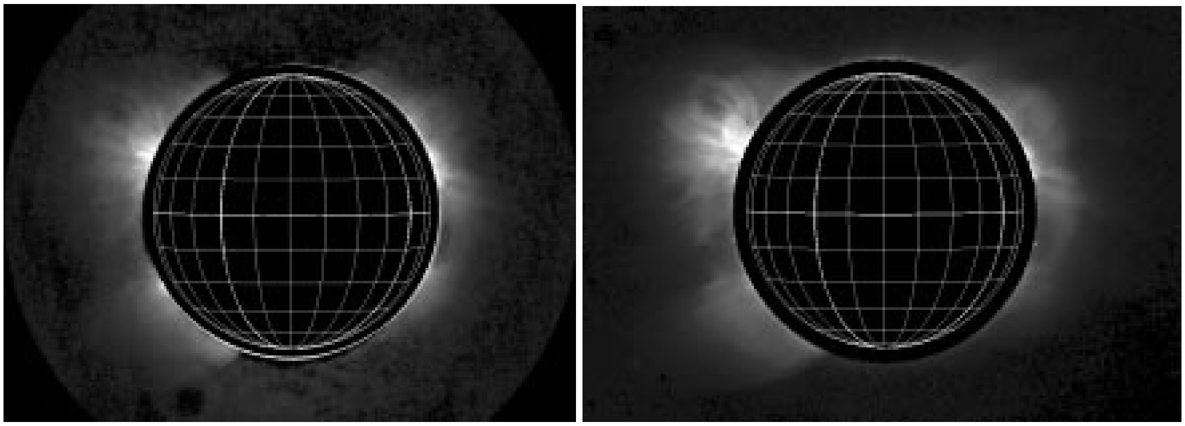

FIGURE 1. Near simultaneous observations in Fe XIV emission by MICA (left) and LASCO-C1 (right) on 26 November, 1997 at 12:15:10 UT and 12:24:14 UT respectively.

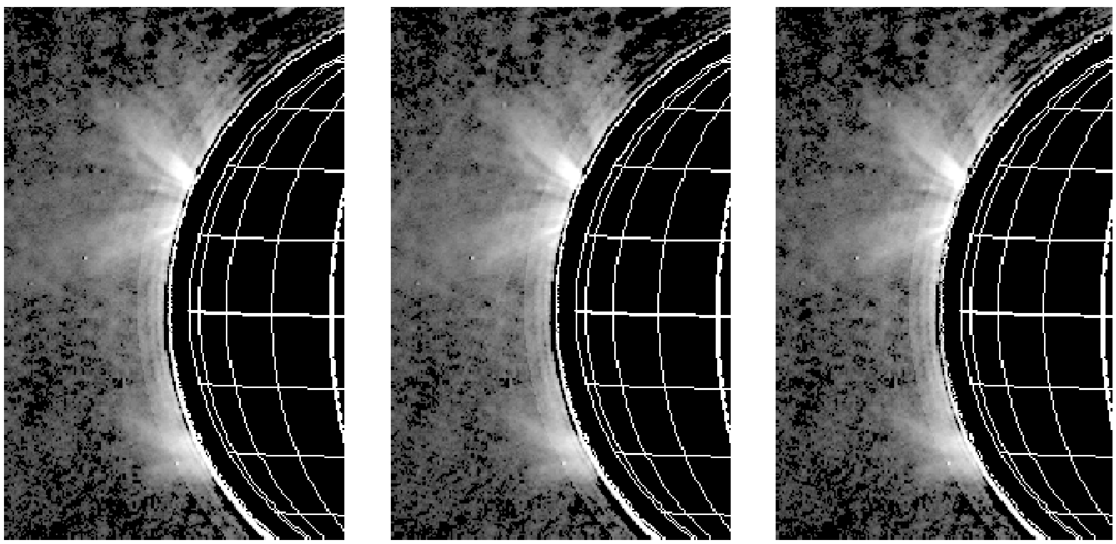

FIGURE 2. Time-lapse images of Fe X emission line as observed by MICA on 26 November, 1997 at 12:19:23 UT, 12:20:11 UT and 12:20:59 UT respectively, the exposure time being 40 seconds.

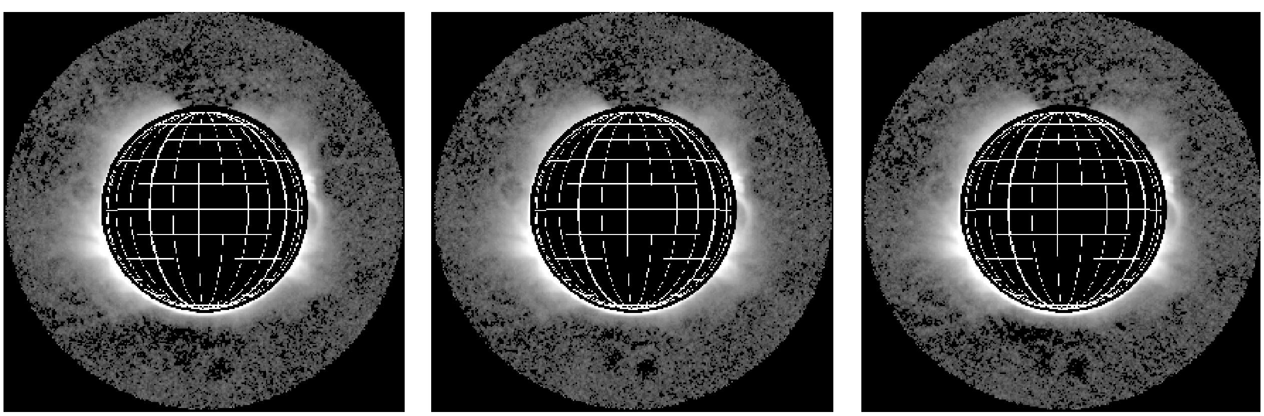

FIGURE 3. Time-lapse images of Fe XIV emission line as observed by MICA on 29 May, 1998 at 13:39:06 UT, 13:40:15 UT and 13:41:24 UT respectively, the exposure time being 60 seconds.