EARLY RESULTS FROM TECONET
Science return from the JOSO Working Group 7 project

F. Clette, J.-R. Gabryl

Royal Observatory of Belgium, B-1180 Brussels, Belgium

ABSTRACT

In 1998, the “Eclipse 99” Working Group of JOSO (Joint Organization for Solar Observations) introduced the project of coordinated coronal observations across Europe, at the occasion of the August 11, 1999 total solar eclipse (TSE). This network, called TECONet (Trans-European Coronal Observing Network), finally involved 28 amateur or professional teams, distributed along the totality band from France to India. All teams conducted polarimetric imaging of the electron corona, with similar spatial coverage and resolution. We present here a first evaluation of the collected data and also, sample results extracted from this fairly homogeneous data set. We finally outline how this rather unique coordination will allow the quantitative determination of electron density distributions and the dynamical study of global-scale evolutions in the solar corona.

Key words: Sun: corona; solar eclipses; organizations.

1. INTRODUCTION: basic concepts and preparation

The Trans-European Coronal Observing Network (TECONet) was initiated in 1998 by the “Eclipse 99” Working Group of JOSO (Clette 1999). This project is based on the combination of several key concepts:

- Broadband polarimetry of the K-corona: combined with an absolute photometric calibration, the image sets can thus lead to the quantitative determination of electron densities.
- Basic instrumental requirements: all instruments must satisfy a set of specifications, which ensures a good homogeneity of the data collected at different sites. Simple photographic equipment can be used, so that amateur astronomers or professional observers with limited resources can participate.
- Coordinated observations by multiple stations distributed along the totality band: the long time intervals between images made at different longitudes makes it possible to monitor the coronal evolution and to carry out dynamical studies of transients. The network also offers better chances to collect a substantial set of images (weather).
- Participation on a voluntary basis: as no funding was available, all participating teams used their own equipment and cared for the construction of a rotating filter mount.

The constitution of the network effectively started in the fall of 1998, about one year before the eclipse. A call for participants was issued, and was later followed by a selection of the candidates, in order to only involve experienced observers (familiarity with astronomical imaging and photography, former experience of solar or eclipse photography by preference).

In order to help the participants to develop their instrumentation, a definition of the necessary equipment was given, together with two reference designs for the rotating polarizing filter mount. These designs were based on proven devices used by expeditions of the Royal Observatory of Belgium (ROB) to previous eclipses. Standard observing procedures were also defined: camera and polarization filter alignment techniques and the critical “totality” observing sequence. The procedures included step exposures of the photosphere during the partial phases, that will allow converting the images to absolute intensities.

Over several months, a lot of time was dedicated to the follow-up work. We checked the conformity of the assembled equipment to the common specifications and we supervised the development work of the different teams (technical advice). In a final stage that started about two months before the TSE (June 98), non-standard components were sent to many of the participants: namely, pre-calibrated film rolls and sheet polarizers. 50 rolls of Kodak Tmax 400 black & white film from a single batch were pre-exposed in the laboratory, using a reference step-density scale (5 exposures). This pre-calibration will allow the compensation of variations in the effective response curve of the films due to the inevitable inaccuracies of the subsequent chemical development process (processing time and temperature). This calibration, together with the photospheric exposure sequences mentionned above, forms the base for accurate determinations of intensities and electron densities. Still,

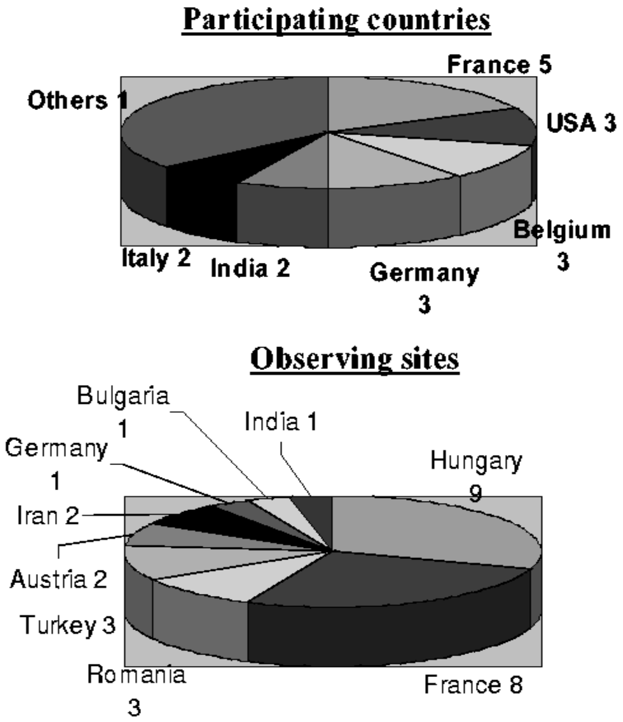

Figure 1. Distribution of participating countries (top) and of the eclipse observing sites (bottom).

those important steps are often overlooked in coronal imaging experiments. Pieces of linear polarizing film (Edmund Scientific TechSpec cat# D45,204), pre-cut to requested sizes, were also provided. These items were shipped to all photographic stations, thanks to funding from the ROB.

Furthermore, a proposal was also introduced for joint SOHO/TECONet observations, involving mainly the LASCO and EIT imagers.

2. THE NETWORK AT ECLIPSE TIME: a first evaluation of the network output

At the time of the TSE, 28 stations took part in the coordinated observations. They were set up by amateur (17 teams) and professional observers (11 teams) of 16 different nationalities (Fig. 1 top). As several groups organized several observing sites, polarimetric instruments were set up on 30 different observing sites, with notable concentrations in Hungary and France (Fig. 1 bottom).

By mid-September 1999, most of the photographic films had been collected and developed at the ROB, and most of the observing logs and reports, which will allow the proper processing of those data, had been received. Figure 2 provides a first statistics of the results returned by all stations. Figure 3 summarizes the geographical distribution of TECONet stations, and a detailed list of participants is given in Table 1.

Twelve stations were clouded out, mainly because of

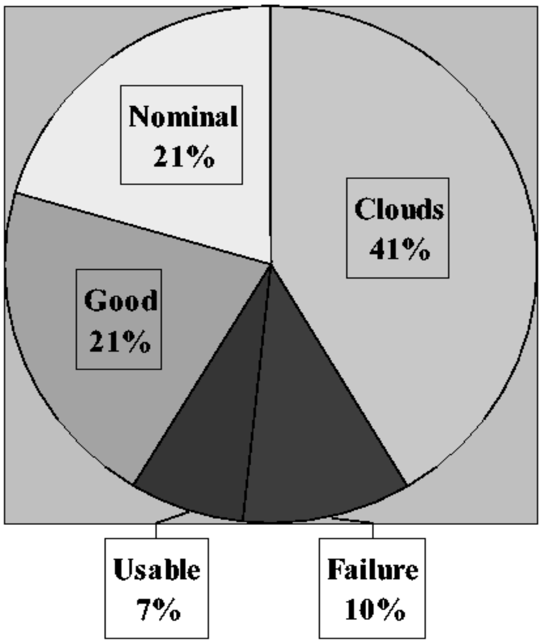

Figure 2. Chart of the TECONet's data return, based on station counts.

the unfavorable weather prevailing over Western Europe. Among them, the only station in India was also unable to observe the eclipse because of the bad weather (rain season). Three additional teams did not bring back data for technical reasons (instrument failure during totality, manipulations errors due to a lack of experience). It is interesting to note that the lower success rate of amateurs astronomers, as compared with professional teams, is only due the weather circumstances. Indeed, the amateurs were more concentrated in the West, where the clouds were more abundant, while professional astronomers avoided that unfavorable region.

On the other hand, out of the 29 stations checked so far, 14 stations produced useful data. About half of those data sets can be rated as excellent (good photometric quality, complete image set). Despite of the 50% overall success rate, the successful observations are evenly distributed along the totality band. This well balanced geographical distribution ensures a uniform temporal coverage over a 1 h 40 min duration, between 10:25 and 12:05 UT.

3. SAMPLE RESULTS

All photographic films have been developed using the same standard development procedure. In a subsequent step, the films must be scanned to convert them in numerical form in view of further processing. Four stations used CCD cameras and will take care of the proper pre-processing of the digital images. This work is now in progress, but the full analysis process will probably take several months.

In central Romania, the Belgian team set up by the

Table 1. Full list of TECONet participants

Team	Country	Observing site	Result
Photographic observations			
J. Ballevre	France	Vouzier, France	clear sky, perfect sequence
J. Draeger	Germany	Hungary	manipulation errors, some image defects
EAGB	Belgium	Rimnicu-Vilcea, Romania	clear sky, perfect sequence
M. Gigolashvili	Georgia	Elazig, Turkey	clear sky, good images, tracking problem
A. Lindquist	Sweden	Albena, Bulgaria	clear sky, good sequence, coronal decentred
T. Mirtorabi	Iran	Tiran, Iran	clear sky, good sequence
A. Ozguc	Turkey	Elazig, Turkey	clear sky, perfect sequence
J. Sykora, P. Bendik	Slovakia	2 sites, Hungary	clear sky, some incorrect exposure settings, dust specks
G. Szecsenyi-Nagy	Hungary	3 sites, Hungary	clear sky, good sequences
D. Trowbridge	USA	Pacs, Hungary	thin clouds, some good sequences, tracking problem
CCD observations			
EAGB	Belgium	Rimnicu-Vilcea, Romania	clear sky, successful observations (120 images)
J. Pasachoff	USA	Rimnicu-Vilcea, Romania	clear sky, successful observations (small FOV)
I. Rodriguez-Hidalgo	Spain	Kastamonu, Turkey	clear sky, successful observations but centering problems
L. Van Driel	France	Szombathely, Hungary	clear sky, no polarisation
No observations			
R. Bareford	USA	Annelles, France	photo, cloudy, tracking problem
P. Corelli	Italy	Salzburg, Austria	photo, clouded out
C. Cox	Ireland	Reims, France	photo, clouded out
A. Desai	India	Isfahan, Iran	photo, equipment failure during totality
EAGB	Belgium	Alsace, France	CCD + photo, clouded out
GFOES- A. Philippe	France	Alsace, France	photo, clouded out
GFOES- P. Gredin	France	Oeuilly, Aisne, France	photo, clouded out
F. Heinicke	Germany	Stuttgart, Germany	photo, clouded out
V. Kinet	Belgium	Alsace, France	photo, cloudy, strong transparency degradation
L. Korosi	Romania	Timisoara, Romania	photo, clouded out
S. Rosoni	Italy	Vorau, Austria	photo, clouded out
I. Ross	Canada	Csopak, Balaton, Hungary	photo, thin high clouds, severe smearing due to vibrations
F. Rouviere	France	Alsace, France	photo, clouded out
D. Sarkar	India	Virandiyara Village, India	photo, clouded out
D. Staps	Germany	Munich, Germany	photo, clouded out

ROB successfully observed the corona using a CCD system. This experiment is based on video CCD camera (740×580 pixels) with 8-bit digitization, placed a the focus of a 200 mm, f/2.8 telelens. A motorized rotating filter is placed in front of the optics, and an optoelectronic sensor triggers exposures at 15° angular steps. This system collected 120 images in 90 seconds: 5 exposure levels, and 2×12 angles in each polarization sequence. These images were corrected for the dark current, for the flatfield and for non-linearities in the response. They were then co-registered and intensity-rescaled before being composited. The full image set, which includes the whole intensity range between the limb and the sky background at about 3 $R_\odot$, was then processed to extract the Stokes parameters of linear polarization. We used a procedure that was already applied to several previous TSEs (Gabryl et al. 1998, Clette et al. 1994). The results shown here are preliminary, as several corrections to the raw images must still be refined (detector blemishes, optical artifacts, intensity scale)

Figure 5 shows a greyscale image of the total intensity. Figure 4 provides contour plots of the polarized brightness and of the degree of polarization. Note first the numerous prominences visible at the limb. Overall, the coronal intensity distribution is fairly symmetrical, as expected for a period of high solar activity. A lower brightness is present between position angle (PA) 170° and PA 230°, apparently marking the position of the South pole of the global heliospheric magnetic field. Some strongly non-radial streamers emerge from the North polar region (PA 30° and 320°). A comparison with LASCO C2 images shows that these structures extend further out with the same inclination. The deviation, away from bright loop structures around PA 55°, thus occurs entirely below 2 $R_\odot$. The polarization reaches a maximum of 45% in the broad streamer at PA 165°. At its base, this prominent high-latitude streamer features a bright prominence imbedded in a very dark cavity. A narrow radial strip at PA 325° is marked by a remarkably low polarization, as well as a low brightness. It seems to correspond to a narrow fan of open field lines, which seems to be overlying a long filament channel belonging to the "polar crown". Overall, the measured polarizations are a bit low for a period of strong solar activity. This might indicate that most features seen above the limb were emerging from the front or far sides of the Sun. This would also explain why long streamers extending beyond 3 or 4 $R_\odot$ were notably absent from this corona. At this stage however, it is still difficult to tell if such a geometry was responsible for a steeper radial intensity gradient in the corona or if there was an unusually bright sky background. The absolute intensity calibration included in the TECONet observations should help us to conclude on this issue.

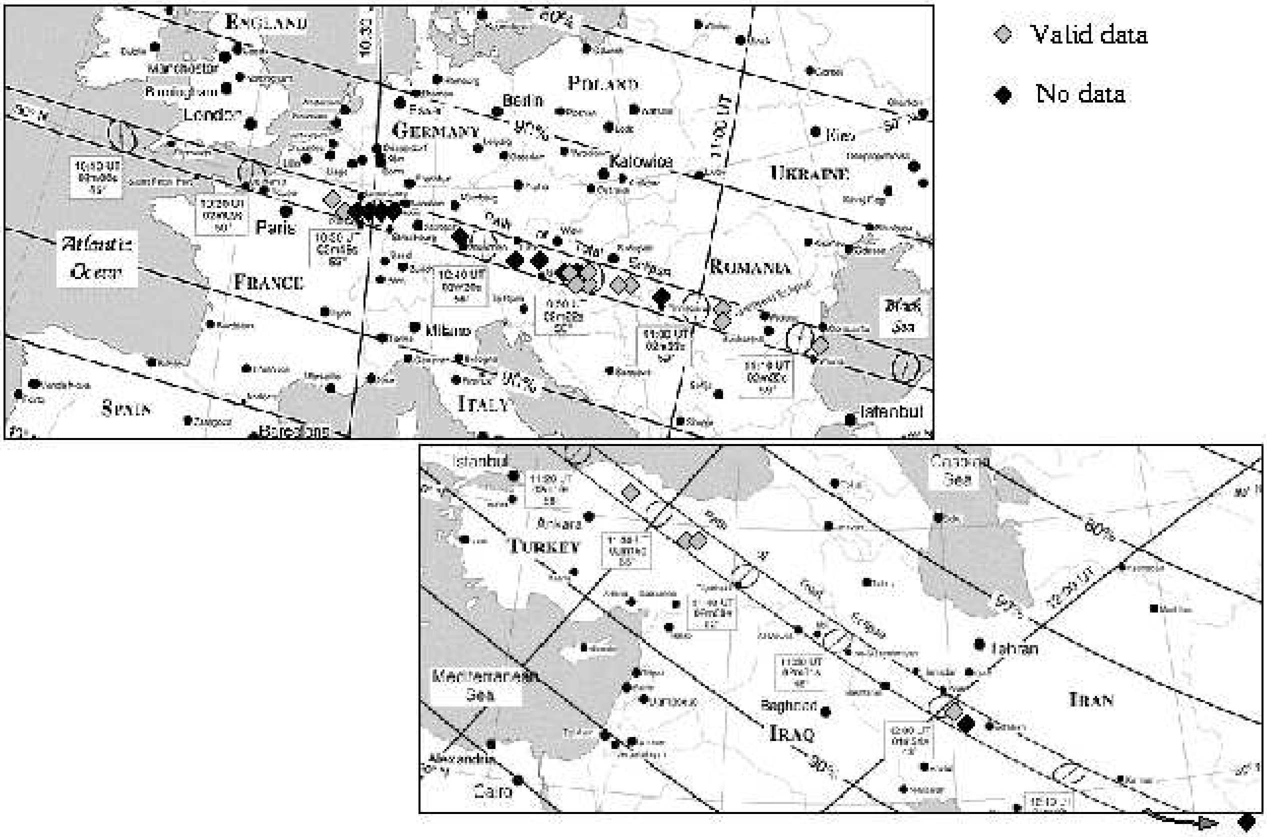

Figure 3. Geographical distribution of the observing stations. White and black diamonds indicate whether useful data were obtained or not. Note the "gap" in Eastern France and across Germany, due to the very cloudy weather.

4. UPCOMING TASKS: data analysis

The first task will consist in digitizing all the negatives produced by TECONet. All numerical images (photo and CCD) will then be submitted to a global analysis, in four successive steps:

1. Pre-processing: cosmetic corrections (blemishes, flatfield, vignetting) and response linearisation.
2. Computation of polarized brightness maps for each station (different procedures will have to be developed to accommodate some differences in the executed sequences)
3. Multi-station intercomparisons: intensity cross-calibration, coronal evolution
4. Determination of electron density distributions (global and local) and of density variations.

As noted already during the TECONet development phase, an analysis team must be constituted to share this extensive work. Steps #1 and #2 involve the largest amount of work, and are the ones that require wider support. The final steps are more attractive, as they deliver the scientific results, but are less demanding. JOSO could provide logistic support by finding or attracting collaborators, and also by supporting information exchanges (mail, data shipment) and grant requests (official letters). Clearly, all the efforts invested in the development of TECONet and the successful acquisition of this unique data set would be meaningless if they do not lead to scientific results. So, after the climax of the eclipse itself, the analysis effort is thus as important as the previous phases. All volunteers wanting to contribute to this endeavor are welcome to join the TECONet community.

5. CONCLUSIONS

The coordination of this project relied almost entirely on one of the authors (F. Clette). For several months, it thus represented a heavy, though manageable, workload . At this stage in the project, it is clear that the experience and the personal relations established over that period represent an investment for the future, as they provide the base for any future coordinated project of this kind. On the other hand, an enhanced workforce is obviously needed to carry out and complete the analysis tasks in a reasonable time.

Due to the bad weather in Western Europe, the success rate (station count), proved to be a bit lower than expected. Still, the primary goals have been achieved: namely, overcoming the bad weather and

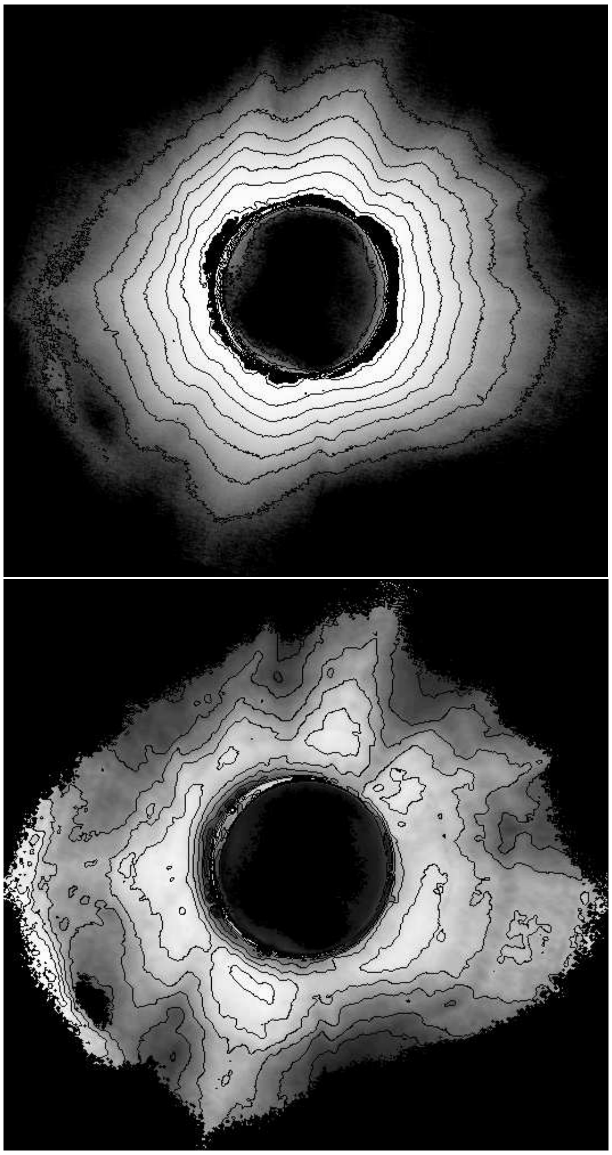

Figure 4. Contour maps of the polarized brightness (top) and of the degree of polarization (bottom) derived from the ROB CCD image set. Contours are separated by a factor of 2 in intensity (relative scale), and by 5% in polarization,respectively. The degree of polarization reaches a maximum of 45% in the broad streamer at PA 165°. The enhanced polarisation on the East side of the field of view comes from a faint optical ghost reflection, and must still be corrected.

breaking the "2-min barrier" of the totality observed from a single site.

After the eclipse, we also realized two other contributions from this network. The project helped to introduce the JOSO to the world, beyond the European context and the professional circles. Indeed, TECONet was presented on different important eclipse-related Web sites: the JOSO pages themselves, but also the IAU Eclipse pages (J.M. Pasachoff), and Fred Espenak's NASA "Eclipse" pages. This attracted the attention of the media in Europe and the USA, and lead to several interviews and to articles in newspapers and magazines.

Finally, this joint observing project, organized in an international context, proved to be a unique experience for all participants, in particular for amateur astronomers. The observations were often prepared and discussed collectively in amateur associations, and thus involved the participation or interest of many more people than the observers themselves. As a matter of fact, many of them already volunteered to take part in a future eclipse observing network.

Now that it is available, this original multi-site polarimetric image set will certainly give rise to an additional interest from the solar physics community. We thus hope that the TECONet project will attract new collaborators wanting to contribute to the analysis phase that is just beginning now but already looks promising.

ACKNOWLEDGMENTS

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REFERENCES

Clette, F. 1999, in "Solar Magnetic Fields and Oscillations", 3^{rd} ASPE, eds. B. Schmieder, A. Hofmann, and J. Staude, ASP Conf. Ser., in press

Clette, F., Cugnon, P., Gabryl, J.-R. 1994, in "Solar coronal structures", Proc. of IAU Coll. 144, eds. V. Rusin, P. Heinzel and J.-C. Vial, 535

Gabryl, J.-R., Cugnon, P., Clette, F. 1998, Contr. Astron. Obs. Skalnate Pleso, Vol. 28, No. 3, 216-223

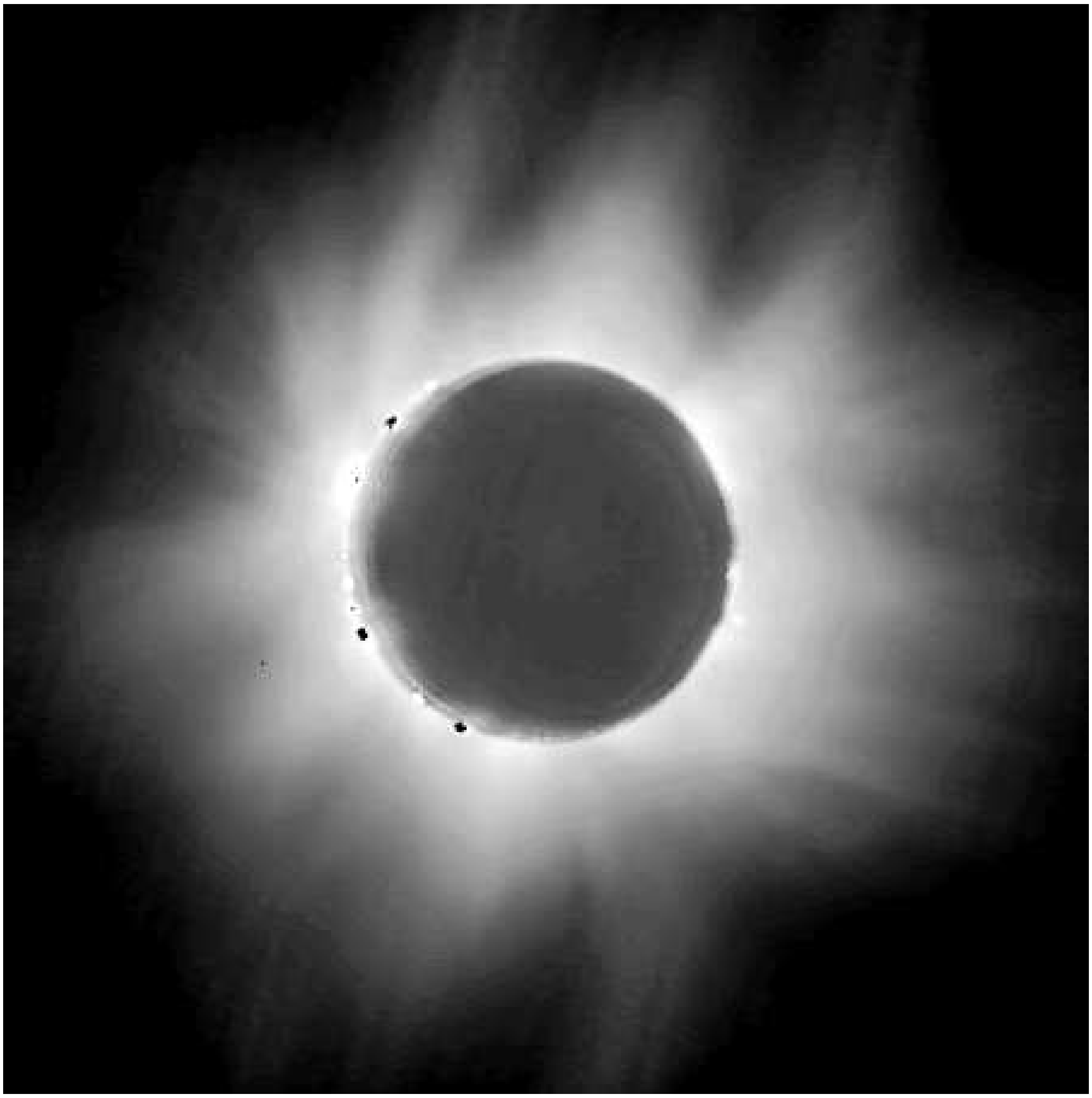

Figure 5. Synthetic map of the total intensity (logarithmic scaling) obtained by merging all polarimetric sequences (120 images) acquired by the CCD experiment that was set up by the ROB in central Romania. Several prominences recorded at the limb appear as dark blobs on this greyscale image, due to a thresholding effect (artifact of the presentation). In this composite image, the lunar limb is blurred because of the lunar motion during the image sequence.