ASTRONOMY AND SPACE SCIENCE
eds. M.K. Tsvetkov, L.G. Filipov, M.S. Dimitrijević, L.Č. Popović,
Heron Press Ltd, Sofia 2007

First Results from Coronagraph Observations at the NAO–Rozhen

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Abstract.

A new Lyot type coronagraph for prominence observations was assembled in June 2005 at the National Astronomical Observatory – Rozhen, Bulgaria. A short description and parameters of the instrument, as well as other solar facilities are presented. The preliminary results from quiescent and active prominences are presented and discussed. The observing program related to science objectives of the solar section of the Institute of astronomy, Bulgarian Academy of Sciences is considered.

1 Introduction

The first steps to starting of solar observations of Solar Division in the Institute of Astronomy, Bulgarian Academy of Sciences (BAN) was made in 1994 when a Solar tower with 8-m dome (Figure 1 left) was built in the territory of the National Astronomical Observatory (NAO) Rozhen at 1750 m above sea-level. There is a parallactic mounting in the solar tower that allows assembling

Figure 1. The Solar tower in NAO – Rozhen (**left**) and first instrument - solar refractor (**right**)

of at least two basic solar instruments: a coronagraph and a solar refractor (Figure 1 right). Initially 13-cm solar refractor was assembled in the Solar tower for white-light observations of the solar photosphere and the activity events at a photospheric level. A coronagraph, analog of Small Coronagraph in Astronomical institute of Wroclaw Universiry, Poland was planned to be elaborate.

2 A New Coronagraph in Solar Tower at NAO – Rozhen

During a long-standing joint collaboration between the Institute of Astronomy, BAN and Astronomical institute of Wroclaw University, Poland detail investigations of the construction of the polish Small Coronagraph were made. On the base of these investigations, as well as of the useful advices of Prof. B. Rompolt one of the authors of this paper (N. Petrov) in 2001 and 2002 calculated the optical system and mechanical construction of the 15-cm Lyot-coronagraph with H_α filter (1.8 Å). The scheme of the coronagraph is given by Figure 2 where are shown the essential optical details of the instrument.

The objective O1 made by Carl Zeisse, Jena, the most critical component of the instrument, consists of a lens corrected for spherical aberration. Its diameter is 150 mm with 2250 mm focal length F1. The occulting cone shaped diaphragm (artificial Moon) D is placed in the focal plane of the main objective. The shape of the occulting diaphragm, as well as its well-polished duralumin surface allows avoiding the light and heat to the sides. A hollow stem in the field lens O2 that confirms the role of a radiator supports the occulting diaphragm. In view of the different visible diameters of the Sun in different months of the year a set of 6 different occulting diaphragms was made.

The field lens O2 with diameter of 72 mm and a focal length F2 of 220 mm is located approximately 20 mm (f1) behind the edge of the occulting diaphragm, very close to the focal plane of the main objective O1. The ratio between F2 and

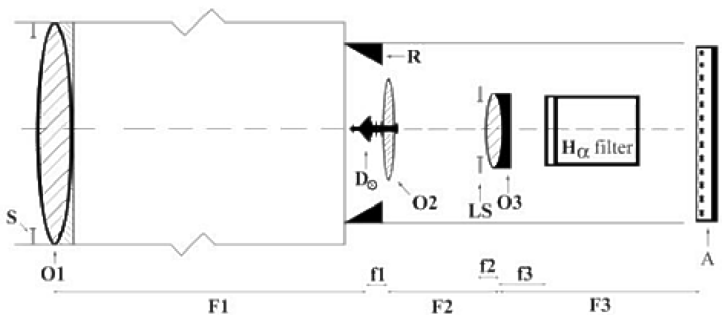

Figure 2. An optical scheme of the coronagraph.

F1 is F2/F1 = 1/10. The field lens uniforms alight of the field of view falling on the objective O3. If the field lens were in the focal plane, any dust on the lens would be sharply focused at the eyepiece or camera. The field lens O2 images the entrance aperture S of the objective O1 on an iris diaphragm LS called Lyot Stop. The opening of the iris diaphragm is adjusted to be somewhat smaller than the image of the brilliant ring of light diffracted from the edge of the entrance aperture S and intercepts it, avoiding another possible source of scattered light. The diffraction from the edge of the iris diaphragm LS is insignificant since the very intense light from the solar disk is almost completely retained by the occulting diaphragm D.

Close behind the iris diaphragm LS the objective O3 is located that forms an image of the occulting diaphragm D and corona surrounding it in the camera A. The objective O3 is interchangeable and has diameter of 45 mm and focal length of 150 mm. Next to the objective O3 is located a birefringent H filter with 1.8 Å band-pass in the hydrogen H_α line. The filter is heated to an operating temperature of $40°$C by an electronic thermostatic control with oversupply 17.2 V.

The resulting solar image can be recorded by a photographic, digital or CCD camera. The coronagraph in NAO – Rozhen is equipped with digital camera Canon EOS 350D (8 Mpxs) with digital matrix size 22.2×14.8 mm. In registration regime, at maximal camera resolution, obtained images have size of 456×2304 pxs. Therefore, one pixel corresponds to size of 6.4×6.4 μm.

Theoretical coronagraph resolution is $1''.1$. It necessary more long observations and additional investigations to estimate the real coronagraph resolution because it, as at another telescopes, strong depends on atmospheric conditions in the region of observation. The statistical data from the observations with telescopes in NAO–Rozhen show that the mean resolution for night observations is about of $2''$. The basic parameters of the coronagraph are summarized in Table (1).

The coronagraph was built in the workshop of the Institute of astronomy during 2003-2004. In the beginning of May 2005, it was assembled in the Solar

Table 1. Basic parameters of the coronagraph

Parameter	**Value**
Diameter of the main objective O1	150 mm
Focal length of the main objective O1	2250 mm
Effective focal length of the coronagraph optical system	4500 mm
Field of view	$15'$
Theoretical resolution limit	$1''.1$
Band-pass of the H filter	1.8 Å
Mean diameter of the solar disk in the focal plane of the main objective O1	≈ 21 mm
Total weight of the coronagraph	62 kg
Altitude above sea-level	1750 m

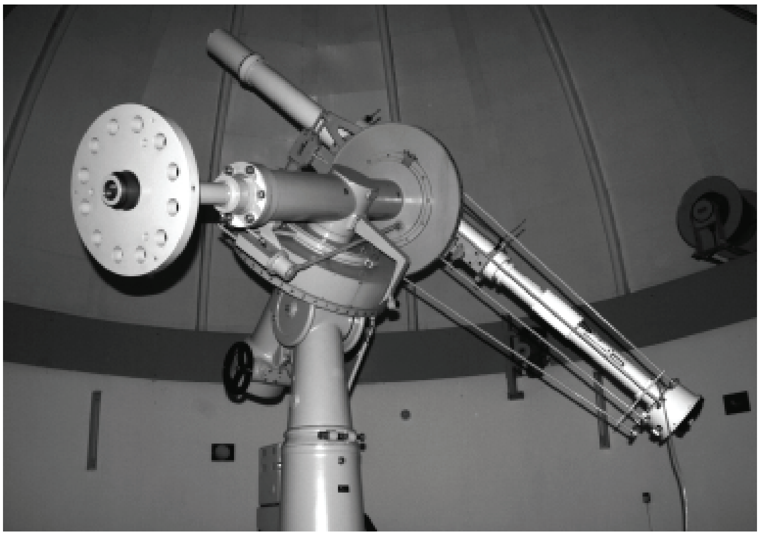

Figure 3. The new coronagraph of the Institute of astronomy assembled in Solar tower at NAO – Rozhen.

tower (Figure 3) in NAO – Rozhen. The initial rough adjustments connected mainly with the focusing of the coronagraph were made using black-white films KODAK P3200. The first successful image of a solar prominence was obtained on July 13, 2005 using digital camera Canon EOS 300D. In August 2005 the coronagraph was equipped with digital camera Canon EOS 350D. Technical parameters of the digital camera allow obtaining long series of qualitative images with high resolution. During several months, from August to October 2005 the fine adjustments of the optical of the coronagraph system were performed. In the second half of October, the prominence images with high quality and resolution were obtained.

The basic goal of the coronagraph in NAO – Rozhen is observations of solar prominences and low solar corona until two solar radii.

3 First Observation of Solar Prominences

From mid-October to the end of 2005, many observations of solar prominences were made. Long series of H_α filtergrams for selected prominences at the solar limb were obtained. The registered prominences were mainly quiescent ones but there were several cases of an activation of quiescent prominences and one case of a surge prominence.

In Figure 4 are represented several remarkable quiescent prominences (QPs) observed with the coronagraph in NAO – Rozhen. Figures 4 a and b represent

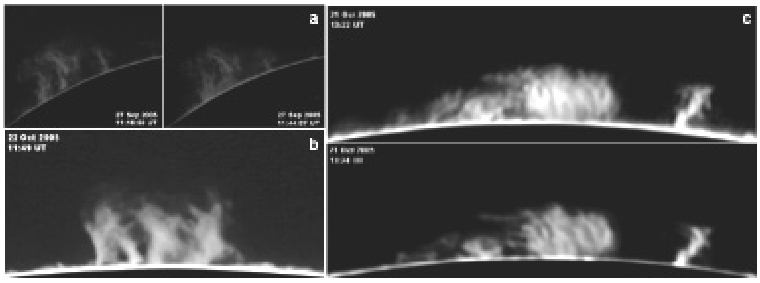

Figure 4. Quiescent prominences observed on 27 September 2005 (a), 22 October 2005 (b) and 21 October 2005 (c) by the coronagraph in NAO – Rozhen.

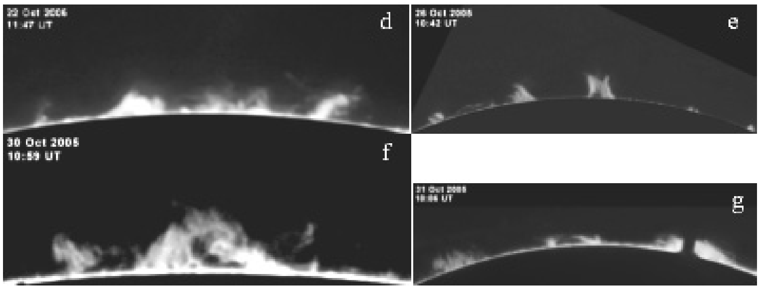

Figure 5. Quiescent prominences observed on 22 October 2005 (d), 26 October 2005 (e), 30 October 2005 (f) and 31 October 2005 (g) by the coronagraph in NAO – Rozhen.

two QPs of 27 September 2005 and 21 October 2005 with different medium-scale structures in two moments of their evolution. Figures 4 c and Figure 5 f show two comparatively high QPs of 22 and 30 October 2005 with typical medium-scale structures. In Figure 5 d, e and g are shown three cases (22, 26 and 31 October 2005) of frequently occurred observational situations when several QPs are near located at the solar limb.

Figure 6 represents a QP (05 November 2005) in 4 moments of its evolution. The QP is almost in side-on position at the limb and separate elements of prominence body are distinct visible. Figure 7 represents a sample of images of a QP of 11 November 2005 tracing QP evolution during the observation. The QP body is at small angle to the limb plane so that the arches of prominence medium-scale structure are well visible. The internal prominence structure was undergone of slow variations during the observation. Figure 8 shows a very interesting case of QP activation (15 November 2005) connected with a process of reconnection of the magnetic field in the prominence configuration. The sample of QP images well traces the reconnection process leading to change of the prominence medium-scale structure and prominence view as a whole. The magnetic field reconnection took place between 09:20 UT and 10:11 UT.

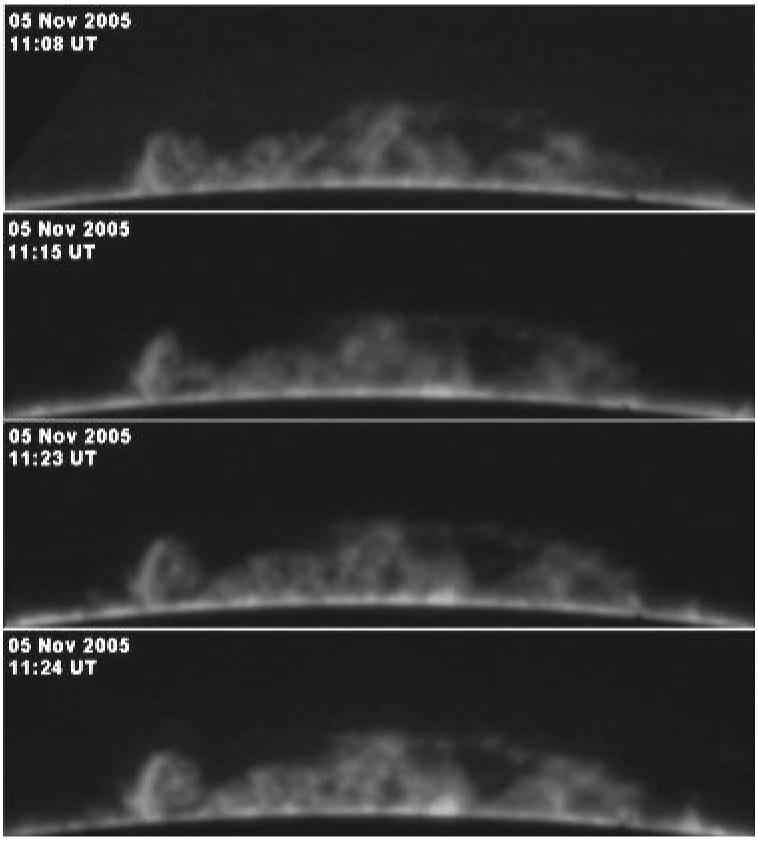

Figure 6. A sample of four H-alpha filtergrams of quiescent prominence observed on 05 November 2005 by the coronagraph in NAO – Rozhen.

4 Observing Program of the Coronagraph

The first results from prominence observations and obtained images with high quality and resolution encourage us to realize observational program in H_α line that will carry out in the following basic directions:

- fine structure and dynamics of quiescent prominences;
- dynamics and internal structure evolution of eruptive prominences;
- dynamics of active prominences (surge and spray);
- monitoring of solar prominences.

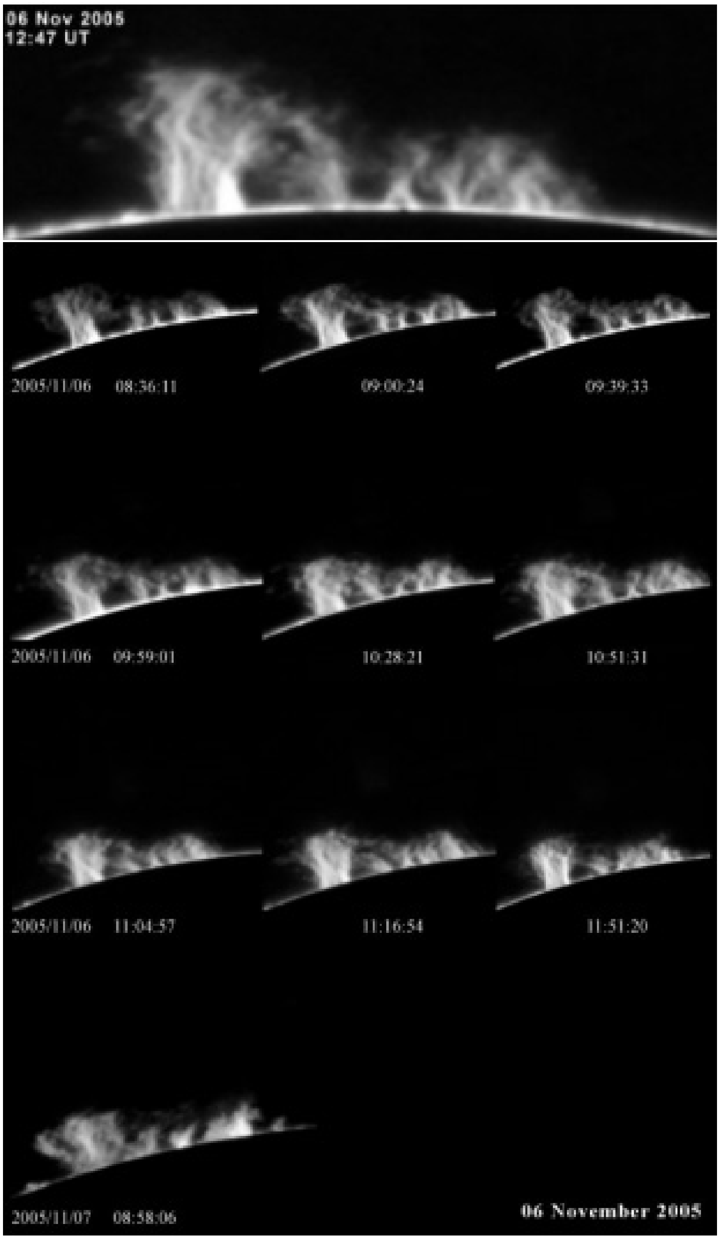

Figure 7. A sample of H-alpha filtergrams of quiescent prominence observed on 06 November 2005 by the coronagraph in NAO – Rozhen. Top: Detail view of the medium- and fine-scale internal structure of the prominence.

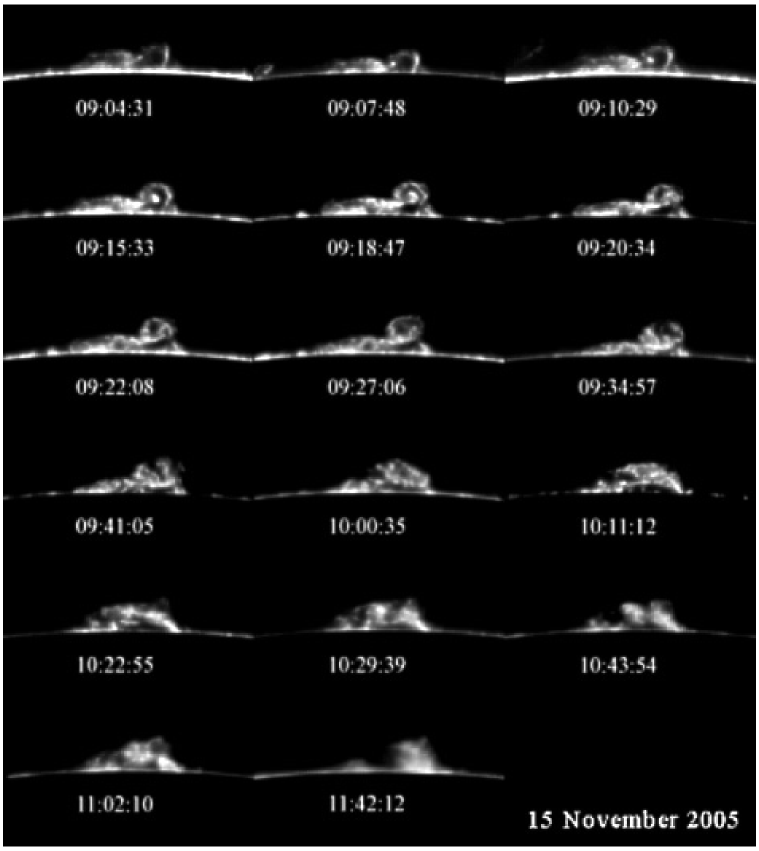

Figure 8. A sample of H-alpha filtergrams showing the quiescent prominence activation observed on 15 November 2005 by the coronagraph in NAO – Rozhen.

The equipment of the coronagraph and the building are not fully completed. In future, the coronagraph will be equipped with spectrograph that will allow registering of the line-of-sight velocity from fine internal structure of quiescent and eruptive prominences. On the base of such observations, we could investigate the dynamics of the fine-scale internal structure of the prominences and prominence oscillations.

In the near future one is coming a detail investigation of the influence of the atmospheric conditions at NAO–Rozhen on the quality of coronagraph observations, as well as an exact determination of the real resolution of the coronagraph.

Using digital camera for image registering we obtain images directly in file format. That makes easy the creation of the archive of our observational data. A system of archiving of the solar images is developed.

Acknowledgments

The authors are grateful to CNSys Computers & Networking, Sofia and OPTICOELECTRON GROUP, Panagyurishte for financial support of the coronagraph building. The coronograph realization was particularly supported by National Scientific Foundation under Grants F1510/2005 and D0-406/2005. The authors are grateful to constructors I. Parov, V. Marinkov and I. Pamukchiev from the workshop of the Institute of astronomy, for the building and mounting of the coronagraph.