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Interactive multi-instrumental database of solar activity observations

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Abstract. The project of creating a center of access to solar activity data on the basis of domestic ground-based observations is presented. The center uses a complex of automated systems for recognition of solar activity objects. The observational data are based on the continuous synoptic observations at the Kislovodsk Mountain Astronomical Station (KMAS) of the Central Astronomical Observatory of the Russian Academy of Sciences. The KMAS data we are considering are images of the solar photosphere, chromosphere, corona, and observations of the magnetic fields on the Sun. The creation of the system will allow users to find the data on individual events as well as to conduct statistical studies of a large number of events using an interactive database interface. The concept behind the operation of our computer vision system is that the data will be analyzed almost in real time as soon as they arrive to the KMAS operations center and undergo basic processing. This will allow the system to issue space weather alerts in due time as well as to create images and videos for quick viewing and to archive the solar activity data. The complex and a unique data processing pipeline consisting of hardware and control software that has been created at the KMAS is described. We build software modules that detect, track, and analyze numerous phenomena in real data streams, including flares, filaments, sunspots, active regions, coronal holes, coronal mass ejections (CMEs), coronal oscillations, and jets. Detections of CMEs and filaments are made based on the continuous data from the Solar Patrol Optical Telescopes (SPOT).

Keywords: Sun: activity, chromosphere, magnetic fields; virtual observatory tools

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1 Introduction

The KMAS has a long history of the synoptic observations of the Sun using a wide range of instruments (Fig. 1): the white light measurements, on the basis of which the observatory has been obtaining long series of sunspot parameters since 1954; the coronograph measurements in the lines 5303 Å and 6374 Å; the chromospheric images in the cores of the Ca II K and H_α lines to determine the geometric characteristics of plages and filaments (prominences). Since 2014, daily observations of the magnetic field on the full disk of the Sun have been continuously carried out using the STOP magnetograph (Tlatov et al. 2015). In addition, the solar patrol optical telescopes (SPOT) (Berezin et al. 2023) are used to make minute-by-minute measurements of the Ca II K and H_α line profiles with a resolution of 40 000 on the full disk of the Sun, which allows detailed diagnostics of the chromospheric parameters with a spatial resolution of about $1''.5$. The observations in the radio band at wavelengths of 3.2 and 4.9 cm and the measurements of the Earth's magnetic field are also carried out in continuous mode.

Some of the most relevant data are published on the observatory website.[1] The objects (spots, filaments, etc.) are detected on the images of the Sun by computer vision methods under the control of operators, and their contours are daily plotted on the three-dimensional interactive map "Observe The Sun"[2] presented on the Internet. There is also an API[3] for querying the contours of all the objects featured on the "Observe The Sun" map.

However, for a number of technical reasons, maintaining and developing "Observe The Sun" is becoming more and more challenging each year. Therefore, there is a need to develop an alternative data presentation system. Another major challenge is to organise the open access to the huge amount of spectral and spectropolarimetric data from the SPOT and STOP instruments.

2 Description of the database

Over the entire period of the SPOT (since 2011 in the Ca II K line and since 2015 in the H_α line) and STOP (since 2014) observations, we have accumulated a large amount of low-level data: optical spectra from all over the solar disc. These are on the order of $7 \cdot 10^{11}$ complete spectral line profiles. The total volume of the dataset

[1] http://en.solarstation.ru/
[2] https://observethesun.com/
[3] https://github.com/observethesun/helio

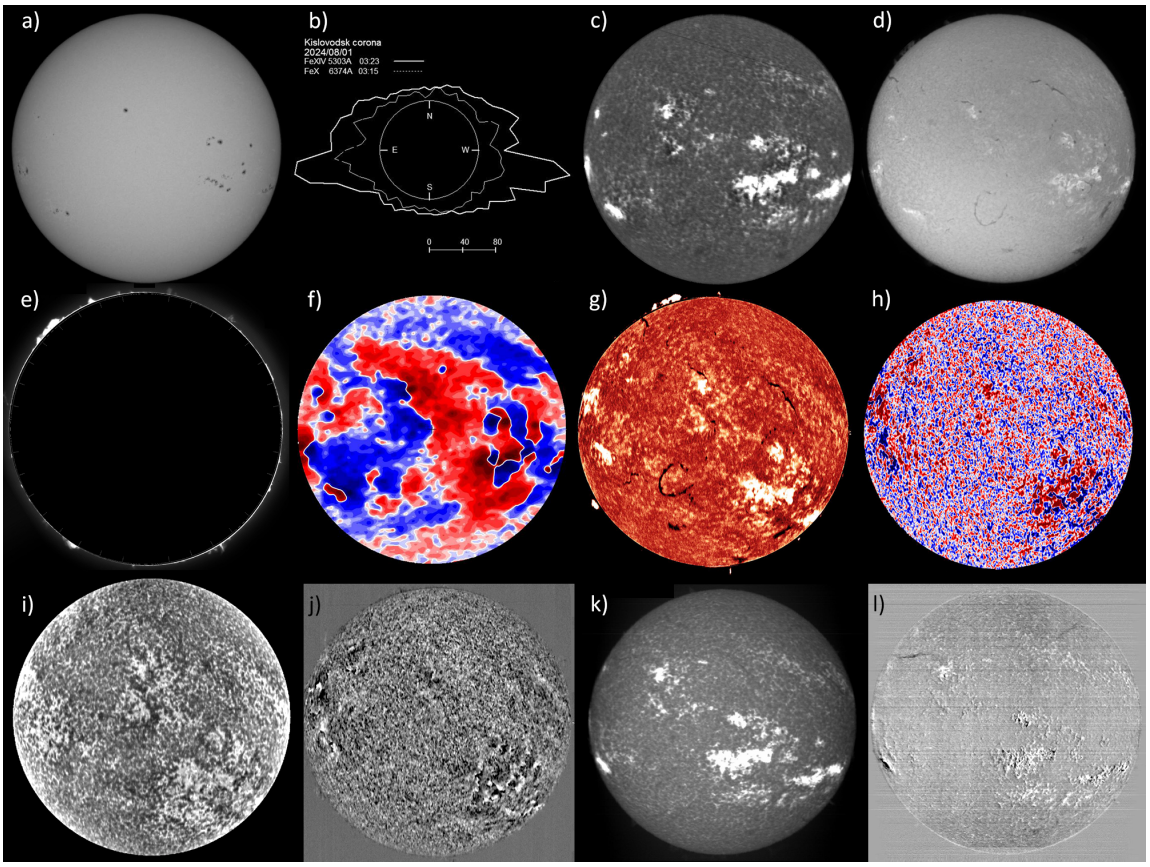

Fig. 1. The main types of the observations at the KMAS: (a) photosphere in white light; (b) coronal intensity in the lines 5303 Å and 6374 Å; (c) intensity in the core of the Ca II K line; filter measurements of the intensity in the H_α line core on the solar disc (d) and in the prominences (e); (f) line-of-sight component of the magnetic field; H_α line core image (g), H_α Doppler velocities (h), H_α line width (i), and the intensity difference in the wings of the H_α line (j) from the SPOT H_α observations; Ca II K core intensity (k) and the intensity difference in the wings of the Ca II K line (l) from the SPOT Ca II K observations.

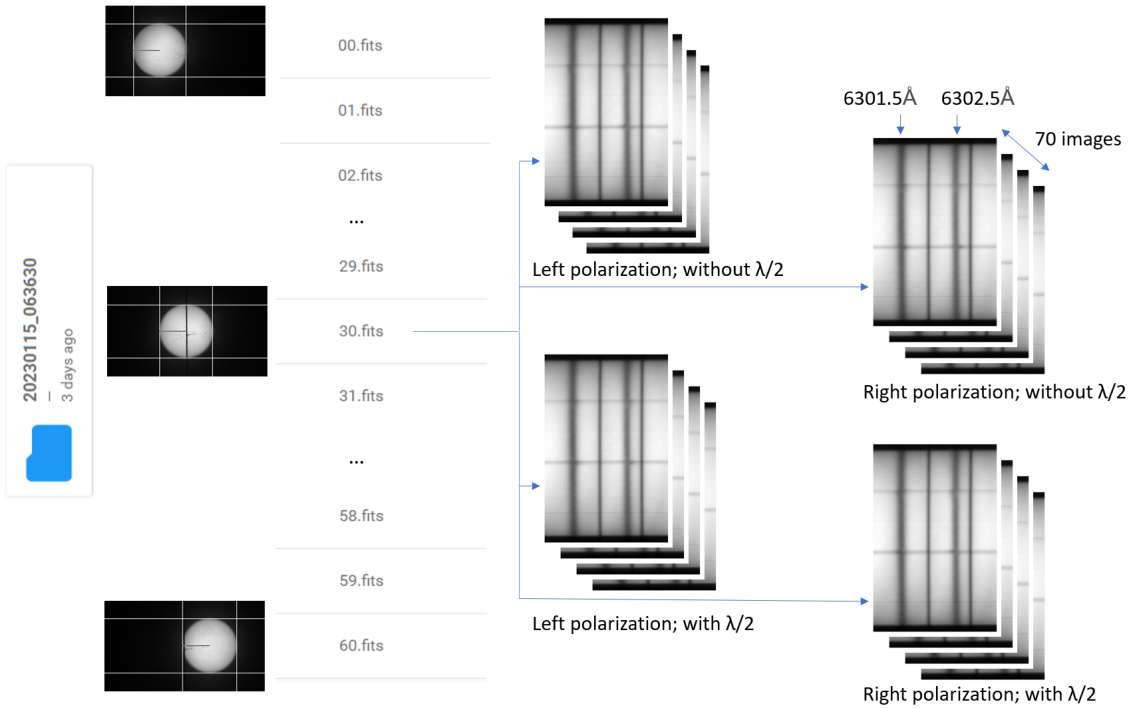

Fig. 2. Structure of the STOP magnetograph data: different polarization components of the spectra near the Fe I 6301.5 Å and 6302.5 Å magnetosensitive lines; measurements with a $\lambda/2$ plate are used to eliminate instrumental polarization.

is about 160 TB. We have organised the open access[4] to these data in cooperation with Kalmyk State University.

The data server runs on two Intel® Xeon® Silver 4214R processors and has a total disc space of 320 TB. The data are presented as level 0 and level 1 data. Level 0 are the frames of the spectra, numbered in the order in which the image of the Sun passes through the spectrograph slit. A more detailed description of the SPOT spectra can be found in Berezin et al. (2023). The STOP magnetograph data are presented in a similar way, except that at each position of the Sun's image on the spectrograph slit, spectra of four different types of light are recorded: with the left circular polarization, with the right circular polarization, and the same but with a half-wave phase plate placed in front of the instrument (Fig. 2).

Level 1 is our version of spectral data processing presented in FITS and JPG format. In the case of STOP, these are daily maps of the line-of-sight component

[4] http://solar-data.ru:8080/

of the magnetic field on the full disc of the Sun. The SPOT data are presented as multilayer images containing the intensity in the line core, Doppler shifts and spectral line width (according to the single-component chromospheric model), the intensity difference in the blue and red wings of the line, the continuum image, and 3 layers containing technical information.

3 Conclusion

The creation of a multispectral database of solar activity is a priority national task. We have presented our variant of some elements of its implementation. The open access to the lowest-level data, in our opinion, is an important element for the development of the observing and data processing methods. National databases of active regions, flares, CMEs, etc. should be created on the basis of low-level data. It is necessary to create data application models and software for users of different experience.

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References

Berezin I.A, Tlatov A.G., Pevtsov A.A., 2023, Astrophysical Journal, 950, p. 100

Tlatov A.G., Dormidontov D.V., Kirpichev R.V., et al., 2015, Geomagnetism and Aeronomy, 55, p. 969