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Measurements of strong magnetic fields in umbra of sunspots: Crimea vs Mt. Wilson

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The comparative analysis for 1324 measurements of the corresponding sunspot magnetic fields with $B > 2.5$ kG (according to Crimean data) obtained at Crimean and Mt. Wilson observatories from 2010 to 2017 has been carried out. It has been shown that the difference between measurements can exceed 1 kG in some cases. The averaged values of the magnetic field are equal to 2759 G (Crimea) and 2196 G (Mt. Wilson). The maximum sunspot magnetic field measured at Mt. Wilson does not reach 2.7 kG while according to Crimean data it can exceed 4.0 kG. The correlation coefficient between measurements of magnetic fields in different observatories does not exceed 0.22. The probable reasons of significant discrepancies are discussed.

Keywords: Sun: sunspot magnetic fields

1 Introduction

Sunspots are the largest magnetic flux concentrations in the solar photosphere. The magnetic energy density inside sunspots is higher than the kinetic energy density, resulting in a partial suppression of the convection. Larger umbrae are darker and show a higher magnetic field strength.

Visual (photographic) measurements of sunspot magnetic fields using the Zeeman effect have continued until the present time at Crimean Astrophysical Observatory (CrAO) and Mount Wilson Observatory (MWO). Maximum distance between sigma components of simple triplets is measured in the profile of the line. Then the measured size is transferred into intensity of a magnetic field.

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The longest series of observations of sunspot magnetic fields exist at MWO (Hale et al., 1919; Livingston, 2006). The MWO archive of drawings of umbrae, penumbra, and other magnetic structures began in 1917. A majority of these drawings has been digitized (scanned), and their images are available online (ftp://howard.astro.ucla.edu/pub/obs/drawings). In a typical year, there are about 330 clear days at MWO.

Visual measurements have been carried out since 1955 at CrAO (Severny, Stepanov, 1956; Stepanov, Petrova, 1958). The observations have been carried out in the line FeI 6302 Å since 1957. The data are presented in a kind of sketch of the solar disk with all sunspot groups and their temporary numbers. The drawings have been digitized (scanned) for data beginning from 1984, and their images are available online http://solar.craocrimea.ru/eng/ sunspots_mf.htm#archive. There are about 220 clear days at CrAO in a typical year.

Lozitska et al. (2015) compared measurements of sunspot magnetic fields during 2010–2012. However, sunspots with strong and weak magnetic fields were not separated. Besides, Lozitska et al. (2015) compared the full number of measurements of the sunspot magnetic field strengths at Mt. Wilson and Crimea but not measurements of corresponding sunspots.

The aim of this paper is to provide a comparison between the visual measurements at MWO and CrAO for corresponding sunspots with strong (> 2.5 kG according to CrAO measurements) magnetic fields.

2 Observations and data processing

The daily observations at MWO are performed at the 150-foot (45.7 m) Solar Tower (ST, http://obs.astro.ucla.edu/150_tele.html). Solar images are constructed using a coelostat and a lens, and have a diameter of about 42 cm. When taking a measurement, the observer marks the boundary of the solar disk, and draws the position and configuration of sunspots. Magnetic field measurements are then carried out by measuring the splitting of the Zeeman components. The intensity of the magnetic field at the center of the sunspot was measured visually using the iron spectral line FeI 5250 Å line with Landé factor 3.0. An image of the sunspot to be measured passes through a polarization analyzer placed in front of the slit of the 75-foot (22.9 m) spectrograph. The analyzer alternately transmits left and right circularly polarized light in narrow strips along the slit. The micrometer is placed at the focus of the spectrograph and, by tilt of the glass plate, shifts the wavelength position of the image of one strip until the two oppositely polarized Zeeman sigma components in adjacent strips coincide. The amount of shift corresponds to the field strength. With this setup, sunspot field strengths can be obtained at the accuracy of hundreds gauss. The measured value of the magnetic field is then denoted on the drawing of the respective sunspot umbra (Fig. 1).

Visual measurements of sunspot magnetic fields have been carried out at Tower Solar Telescope (TST-2) in the CrAO from 1955. The 60-cm coelostat, 45-cm spherical primary mirror (f/27), one flat and two convex secondary mirrors provide f/27, f/46 and f/78 Cassegrain foci (12, 21 and 30 m) on the entrance slit of a spectrograph. There are also an echelle-grating, Universal Spectrophotometer with a scanning system and a CCD camera. Solar images have diameters from 8 to 30 cm. Observations

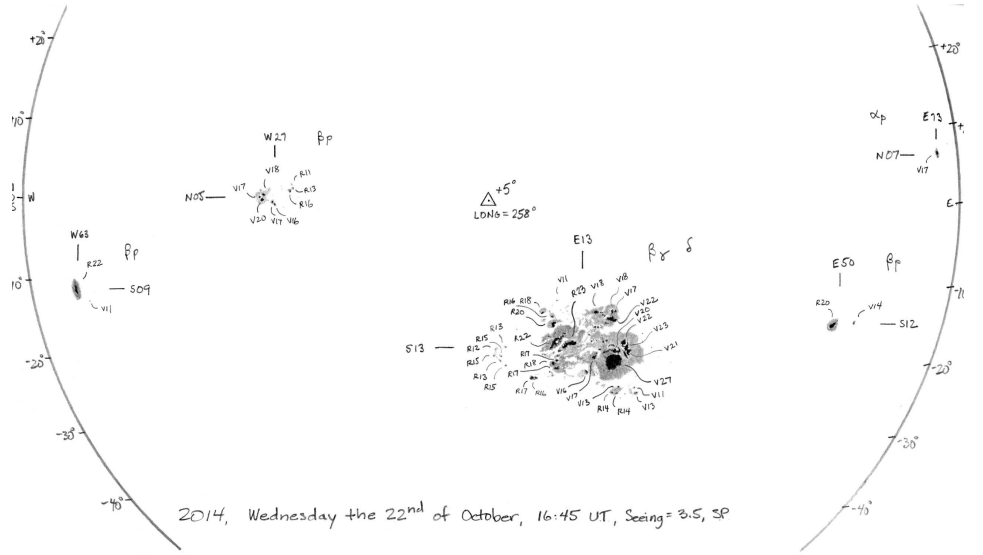


Figure 1 A sample daily drawing of sunspots measured at MWO on October 22, 2014. On the drawing, West is at the left.

have been carried out in the spectral line FeI 6302 Å with Landé factor 2.5 since 1957. Then the measured distance is transferred in intensity of a magnetic field using the special table and then denoted on the drawing of the respective sunspot umbra. The procedure of daily observations at TST-2 and ST (MWO) is similar. The sunspot field strengths can be obtained at the accuracy of one hundred gauss. Note that the sunspot penumbras as distinguished from MWO are not drawn at CrAO. Besides, the daily drawings consist of two pictures of different scales (Fig. 2).

In order to compare the sunspot magnetic fields from CrAO and MWO we selected magnetic field values greater than 2.5 kG according to CrAO measurements from 31 July 2010 to 01 October 2017. After that we selected corresponding sunspot magnetic fields measured in MWO. As a result, we found 1324 corresponding sunspots (see Table 1 at http://solar.craocrimea.ru/eng/observations.htm). The typical time difference between measurements was about 10 hours. It should be emphasized that according to the CrAO data we found about 134 sunspots with the magnetic fields greater than 3 kG. The strongest magnetic fields were measured on 22 May 2016 in NOAA 12546 (4.1 kG) and on 3 September 2017 in NOAA 12674 (4.6 kG). In turn, the magnetic fields measured at MWO do not exceed 2.7 kG. The diagrams of magnetic field measurements for corresponding sunspots are presented in Fig. 3. The average value of CrAO measurements is 2759 G, while the average value of MWO measurements is 2196 G. Thus, the difference between measurements exceeds 500 G. Besides, the correlation coefficient between MWO and CrAO measurements turned out to be about 0.22. These results suggest that MWO data cannot be used for sunspots with strong magnetic fields.

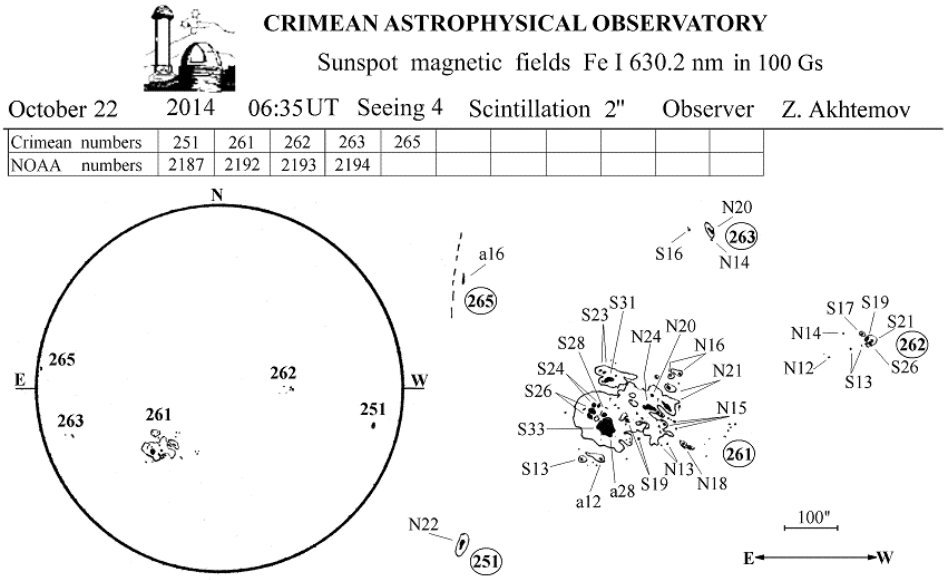


Figure 2 A sample daily drawing of sunspots measured at CrAO on October 22, 2014.

3 Discussion and conclusions

In spite of significant progress in the sunspot magnetic field measurements, the visual method based on the measurements of the Zeeman splitting gives the most reliable results. In fact, visual measurements of magnetic field strengths in sunspot umbra provide data on magnetic field strength modulus directly, i.e., irrespective of any solar atmosphere model assumptions. In addition, results of measurements are not affected by the signal saturation for strong magnetic fields, low light level, instrumental polarization etc. Unlike magnetographic measurements, these data do not need various calibration curves for different sunspots and other features of the Sun.

Taking into account the above-mentioned and the similarity of methods of measurements we have compared results of strong magnetic fields of sunspots measured at CrAO and MWO. Although the difference between the formation heights of lines 6302 Å and 5250 Å is less than 30 km and the time of measurements of corresponding sunspots does not exceed 15 hours, the results of measurements of strong magnetic fields at CrAO and MWO turned out to be quite different.

It seems to us that this discrepancy can be caused by the small thickness of the tip plate used at MWO, and, because of that, the visual measurements of strong magnetic fields become impossible (A. Pevtsov, private communication). Also some problems can be caused by the calibration of measurements at CrAO and MWO (Livingston et al., 2006; Lozitska et al., 2015). We hope to consider these questions in future.

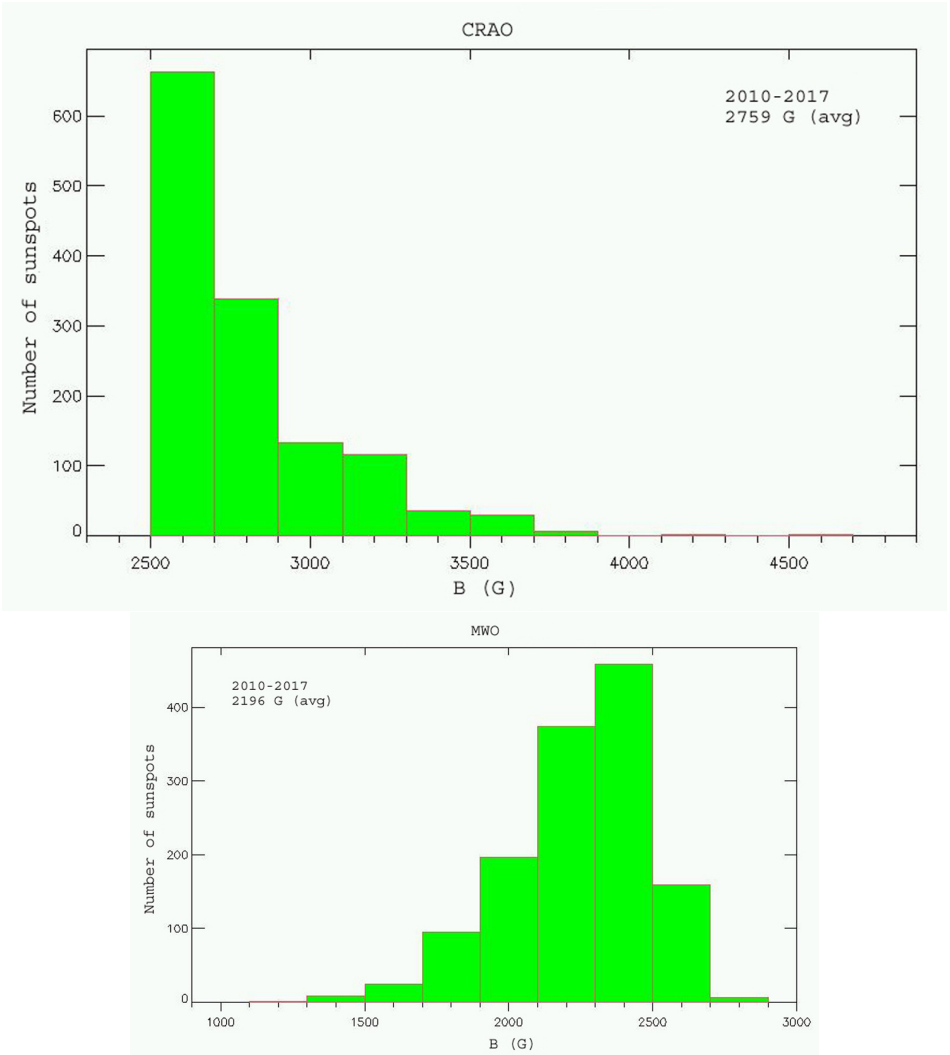


Figure 3 Comparison of corresponding sunspot magnetic field measurements at CrAO and MWO in eight intervals of the magnetic field.

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References

Hale, G.E., Ellerman, F., Nicholson, S.B., Joy, A.H., 1919, Astrophys. J., 49, 153.
Livingston, W., Harvey, J.W., Malanushenko, O.V., Webster, L., 2006, Solar Phys. 239, 41.
Lozitska, N.I., Lozitsky, V.G., Andryeyeva, O.A., Akhtemov, Z.S., Malashchuk, V.M., Perebeynos, V.A., Stepanyan, N.N., Shtertser, N.I., 2015, Adv. Space Res., 55, 897.
Severny, A.B., Stepanov, V.E., 1956, Izv. Krim. Astrofiz. Obs., 16, 3.
Stepanov, V.E., Petrova, N.N., 1958, Izv. Krim. Astrofiz. Obs., 18, 66.