Short paper

AR 12536: An unusual bipolar sunspot group

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Observations of a highly tilted bipolar sunspot group from 2016 April and May are presented together with confirmation of the bipolar nature of the group based on magnetograms from the Solar Dynamics Observatory.

Introduction

During 2016 April and May a highly tilted bipolar sunspot group was observed – quite unusual given that most bipolar groups have the line between the leader and follower sunspots tilted by only a few degrees with respect to the solar equator. Here the observations of this group are described, the confirmation of the bipolar nature of the group is made using magnetograms from the Solar Dynamics Observatory and measurements of the tilt are given. Also the calculation of the tilt and length of the group are provided.

Warning: never look at the Sun with the naked eye or with any optical instrument unless you are familiar with safe solar observing methods.

Observations

Regular white light observations are made using an 80mm refractor on an equatorial mount and the projection method. A projection box is attached to the eyepiece holder so as to form, with a suitable eyepiece, an image of the whole of the solar disk of 6-in (15cm) diameter at the far end of the projection box. Following east-west alignment of a prepared blank disk sheet, sunspots are drawn for subsequent analysis that includes the number of groups, the sunspot number, group classification and group heliographic location. The calculation of the latter is eased considerably using the author's *HelioViewer* software tool.[1] Occasional white light images of interesting sunspot groups are taken with a 105mm ETX telescope, Baader N3.8 solar film and an Imaging Source DMK camera.

Appearance

NOAA Active Region[2] 12536 was initially seen on 2016 April 26 as a small single sunspot at a heliographic latitude of 14°N and longitude 118°, close to the eastern limb during solar rotation 2176. On the following day two small sunspots had developed towards the south of the penumbral spot. One of these developed further into a small penumbral sunspot of similar size to the northern penumbral spot. Thus AR 12536 had the appearance of a bipolar D group (bipolar with leader and follower sunspots both having penumbra) which was highly tilted with respect to the solar equator (*i.e.* the line between the leader and follower being at an angle of much more than the usual few degrees).

By April 30, the northern penumbral sunspot increased in size towards the direction of the southern penumbral spot. The total area was 150 millionths of the Sun's visible hemisphere (MSH).[3] On May 01, with AR 12536 just past the solar central meridian, the northern penumbral sunspot had reduced in size to be more like the southern penumbral spot. In addition several pores were seen within the group, as shown in Figure 1.

By the following day the leading southern sunspot had become more asymmetrical and the northern follower had reduced in size.

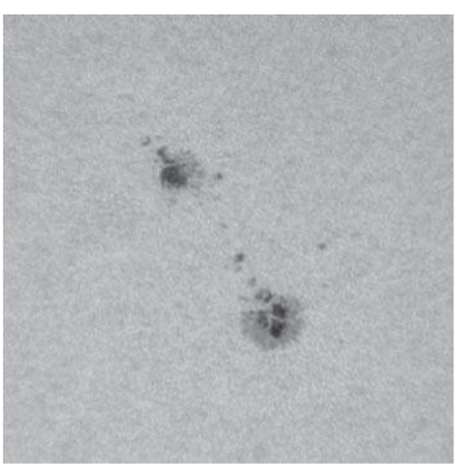

Figure 1. AR 12536 on 2016 May 01, 14:35 UT. Solar rotation axis vertical, north towards the top and east towards the left. *Peter Meadows.*

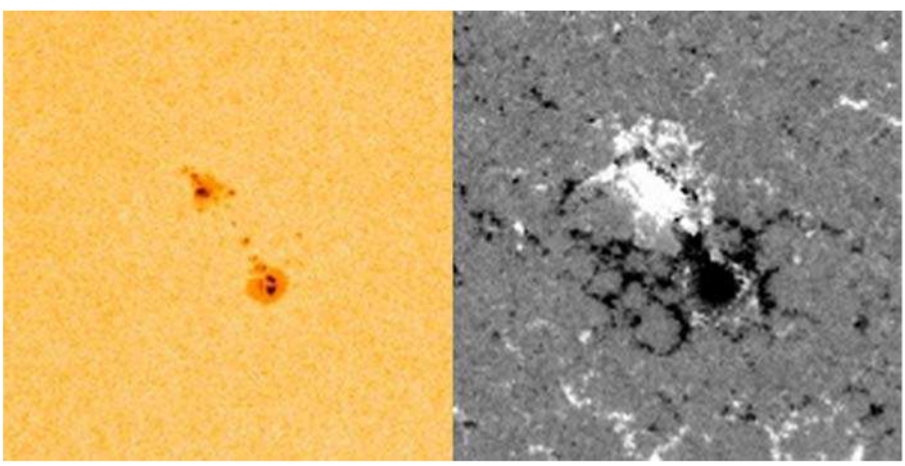

Figure 2. SDO HMI continuum *(left)* and magnetogram *(right)* images of AR 12536 on 2016 May 01, 12:00 UT. Solar rotation axis vertical, north towards the top and east towards the left. *NASA/SDO.*

Table 1. Average tilt measurements of AR 12536

	Tilt angle (α)	*Separation (β)*
Disk drawings	+54±5°	4.4±0.8°
HMI continuum	+54±3°	4.7±0.8°
HMI magnetogram	+54±3°	4.5±0.8°

The number of pores had also reduced. On subsequent days the group continued to decay such that on May 04 it was of type C (bipolar with one main spot with penumbra) with an area of 60 MSH, but still highly tilted. When last seen on May 05 just a single A type sunspot (unipolar without any penumbra) was present (no observations were made on May 06 and 07 when the group would have been close to the western limb). AR 12536 was not seen on the next solar rotation (2177) or indeed during the previous rotation (2175).

SDO magnetogram

Although AR 12536 had the appearance of a bipolar group, type D or C, throughout most of its passage across the solar disk, confirmation of being bipolar can only be shown by examining the magnetic polarity of the leader and follower sunspots (they should be of opposite polarity). This is possible using the Solar Dynamics Observatory (SDO) Helioseismic and Magnetic Imager (HMI) images.[4] Figure 2 shows the HMI continuum and magnetogram images from 2016 May 01, where the image orientation is such that the solar rotation axis is vertical, north towards the top and east towards the left. The magnetogram clearly shows a difference in magnetic polarity at the position of the leader and follower sunspots, as indicated by the white (positive polarity) and black regions (negative). Magnetograms from other dates during the passage of AR 12536 show a similar separation in magnetic polarity thus confirming that this group is indeed of a bipolar type.

Tilt measurements

The tilt of the leading and following sunspots with respect to the solar equator of a bipolar sunspot group, α, is given by:[5]

$$\tan(\alpha) = \tan \frac{\Delta\varphi}{\alpha} \sin(\Delta\lambda)$$

where $\Delta\varphi$ is the difference in latitude of the leading and following sunspots and $\Delta\lambda$ is the difference in longitude. The angle is positive when the leader is closer to the equator than the follower, as was the case for AR 12536.

An associated parameter is the separation of the leading and following sunspots along the photosphere on a great circle, β:

$$\cos(\beta) = \sin(\varphi_L)\sin(\varphi_F) + \cos(\varphi_L)\cos(\varphi_F)\cos(\Delta\lambda)$$

where φ_L and φ_F are the latitude of the leading and following sunspots respectively.

The measurement of the tilt angle and the separation of leader and follower sunspots has been calculated using disk drawings from every day between 2016 April 27 and May 05 inclusive (9 observations),[6] and the HMI continuum and magnetogram images[7] for the same time period as the disk drawings. HMI images at both 00:00 and 12:00 UT were used. The *HelioViewer* software was used to manually determine the latitude & longitude of the leader and follower sunspots in the case of the disk drawings and HMI continuum images, and the centre of the northern and southern polarity regions in the case of the HMI magnetogram images. In all cases the central meridian distance was less than 60° which avoided any foreshortening errors.

Table 1 gives the average tilt and separation angles – the tilt angle is the same from the disk drawings and the HMI images: 54°, while there is only a small variation in separation angle at almost 5°.

Discussion

Extensive studies on tilt angles of bipolar groups have been performed by professional solar astronomers.[5,8–12] Large numbers of bipolar sunspot groups, with a separation β of >3° (to avoid including unipolar groups), indicate a mean tilt angle of approximately +5°, but with an approximately Gaussian distribution with a full-width half maximum of about 40°. The tails of the tilt distribution include bipolar groups with tilt angles of +90° and −90°. There is also a slight latitude dependency in the mean tilt, known a Joy's Law, where the mean tilt increases with heliographic latitude, from approximately +2° at the equator to +10° at a latitude of 30°. Tilt angles and Joy's Law have been used to distinguish between different models to understand the magnetic properties of the Sun.[13]

Conclusion

Regular white light observations using a modest 80mm refractor and the projection method identified that bipolar group AR 12536 had an unusual but not unique tilt of +54°.

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