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Automatic Algorithm for Tracking Bipolar Magnetic Regions

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Abstract. Properties of bipolar magnetic regions (BMRs), particularly, the tilt angle play critical roles in generating the observed polar magnetic field and its reversal. Hence, a long-term study of BMR over its lifetime is crucial not only to understand the solar dynamo but also to identify the origin of the properties of BMR. In our work, we have developed an automatic algorithm to detect and track the BMRs from the line-of-sight (LOS) magnetograms of Michelson Doppler Imager (MDI) for the period of Solar Cycle 23 over its lifetime/disk passage. Here, we present the details of our algorithm and the features of BMR, particularly the tilt angle, magnetic field strength and lifetime.

Keywords. Sun: activity, Sun: magnetic fields, (Sun:) sunspots, Sun: photosphere

1. Introduction

BMRs are observed to be tilted with respect to the equator. The tilt angles are found to increase with latitude which is known as Joy's Law (Hale et al. 1919). The tilt of the BMR is vital in Babcock–Leighton mechanism, which generates the poloidal magnetic field of the Sun (Babcock 1961; Leighton 1964; Mordvinov et al. 2022). The scatter around this Joy's law produces variations in the solar cycle (Karak 2020; Karak & Miesch 2017, 2018; Lemerle & Charbonneau 2017). Stenflo & Kosovichev (2012) identified BMRs from the LOS magnetograms of MDI and found no systematic dependence between the tilt and magnetic flux of the BMR. Nevertheless, in a similar work, Jha et al. (2020) observed that for the BMRs with maximum magnetic field value greater than 2 kG, tilt decreases for increasing flux indicating tilt quenching. In the mentioned studies, every detected region is considered as a separate BMR which might affect the statistics since different BMRs will have different weightage. Here, we have tracked the identified BMRs for their lifetime or throughout their disk passage to study their properties.

2. Data and Tracking Algorithm

We use the LOS magnetogram data from MDI (Scherrer et al. 1995) and then employ a fully automatic algorithm to identify and track the BMRs. As a first step for the tracking algorithm, we identify BMRs following the method used in Jha et al. (2020), which is based on the technique explained in Stenflo & Kosovichev (2012). Our tracking algorithm is based on the idea of sunspot tracking described in Jha et al. (2021) with the needed modification in the case of BMRs.

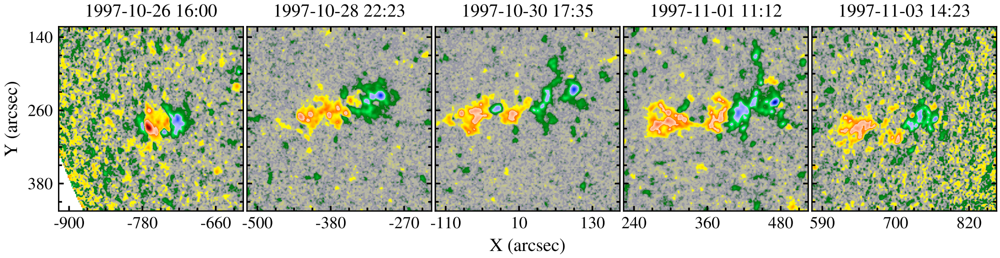

Figure 1. Snapshots of a BMR at different stage of tracking.

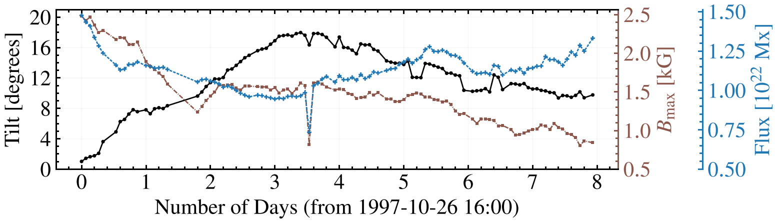

Figure 2. Evolutions of BMR tilt, flux and $B_{\max}$ over its lifetime.

3. Results and Conclusion

In Figure 1, we have shown one representative example of a BMR tracking algorithm. Although our algorithm has tracked this BMR from 26/10/1997 16:00:29 to 03/11/1997 14:23:44, we have demonstrated only a few intermediate tracking steps.

The analysis was done for the period of solar cycle 23. During this period, 3550 BMRs where identified and tracked. Figure 2 shows the evolution of a BMR (NOAA 8099) tracked from 26/10/1997 16:00 to 03/11/1997 14:23. Here, we observe systematic decrease of the $B_{\max}$ over the course of the BMRs lifetime, but the tilt is found to increase till the fourth 4^{th} day and decrease thereafter. On studying averaged evolution of tilt over all the tracked BMRs lifetime, we find that tilt increases in the initial three days and later it remains unchanged. Whereas, $B_{\max}$ is found to systematically increases over the lifetime of the BMR until 6^{th}day. Detailed description of algorithm and results can be viewed at https://youtu.be/zkc7whYhfhM and will be published in a forthcoming article (Sreedevi et al. under preparation).

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