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Study of Sunspots using AutoTAB to identify the theory of their formation

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One of the intriguing mechanisms of the Sun is the formation of sunspots or, more generally, the bipolar magnetic regions (BMRs), which are observed as regions of concentrated magnetic fields of opposite polarity on the photosphere. These BMRs are tilted with respect to the equatorial line, which statistically increases with latitude. The thin flux tube model, employing the rise of magnetically buoyant flux loops and their twist by Coriolis force, is a popular paradigm for explaining the formation of tilted BMRs. In our study, we assess the validity of this model by analyzing the tracked BMR data obtained through the Automatic Tracking Algorithm for BMRs (AutoTAB)[1]. We find that the polarity separation of BMRs increases over their lifetime, supporting the assumption of a rising flux tube from the convection zone[2]. Moreover, we observe an increasing trend of the tilt with the flux of the BMR. Furthermore, we observe Joy's law dependence for emerging BMRs from their first detection, indicating that at least a portion of the tilt observed in BMRs can be attributed to the Coriolis force.

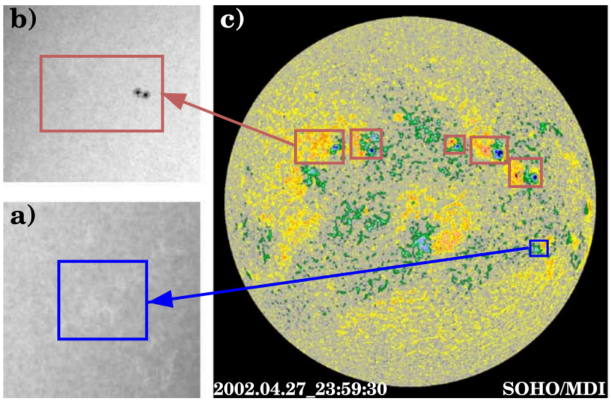

Figure 1. The line-of-sight magnetic field on the surface of the Sun obtained from a representative magnetogram. The rectangles mark the bipolar magnetic regions detected by our code[3]. Panels (b) and (c) show their corresponding white-light images, in which we can see the sunspot in panel (a). For panel (b), the sunspot is not seen because the magnetic field of that region is weak, which does not produce enough intensity contrast in white light.

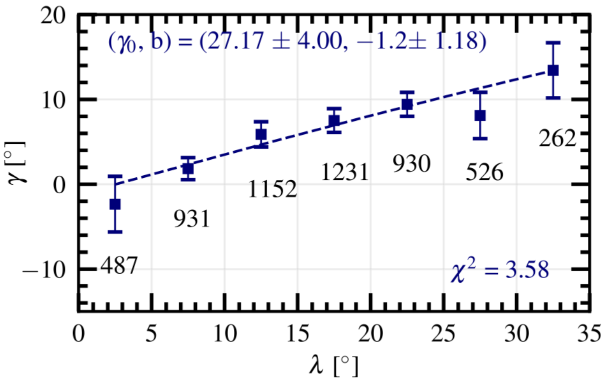

Figure 2. Tilt vs latitude of the BMRs. We observe Joy's law dependence of tilt at the first detection of the BMR emerging between 45° east–west. (Gaussian) Mean tilt in each 5° latitude bin as a function of the latitude. Blue-dashed lines represent Joy's law fit. Numbers appearing below the points mark the total number of BMRs in the associated bins.

References

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