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Observed Joy's law during the emergence of bipolar sunspots unveils their origin

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The solar convection zone is characterized by the birth of the concentrated magnetic field regions known as Bipolar Magnetic Regions (BMRs), which are tilted with respect to the equatorial line. The thin flux tube model, employing the rising of magnetically buoyant flux loops tilted by the Coriolis force, is a popular paradigm to explain the formation of the tilted BMRs. In this study, we assess the validity of the thin-flux tube model by analyzing the tracked BMR data obtained through the Automatic Tracking Algorithm for BMRs (AutoTAB). Our observations reveal that the tracked BMRs exhibit the expected collective behaviors, and the polarity separations of BMRs increase over their lifetimes, supporting the assumption of the rising omega-shaped flux tubes from the CZ. Furthermore, we observe an increasing trend of the mean tilt with the flux of the BMR, suggesting that rising flux tubes associated with lower flux regions are primarily influenced by the drag force and the Coriolis force, while in higher flux regions, magnetic buoyancy dominates. Importantly, we observe Joy's law dependence for emerging BMRs from their early emergence, indicating the tilts in the BMRs are formed below the photosphere, the tilts observed in BMRs can be attributed to the Coriolis force and helical convection. Thus all these results support the thin-flux tube model.

References

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