Algebraic quantification of an active region contribution to the solar cycle

A quick, precise, and generalized method to determine an active region's contribution to polar field at cycle minimum

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1. Active regions in solar cycle development

- Polar field precursor for solar cycles
- Polar field evolution in Babcock-Leighton dynamos
  - Active regions (ARs) with initial axial dipole
  - Surface flux transport (SFT) processes
  - Contribution to the final dipole

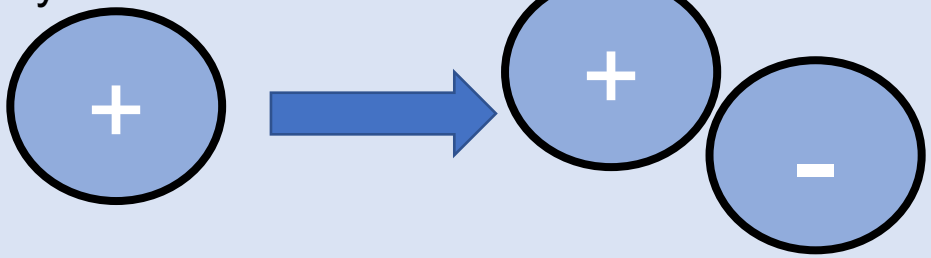
1. Active regions in solar cycle development

- Methods to predict AR contribution
  - SFT numerical simulations
  - Algebraic method $\frac{D_f}{D_i} = A \exp\left(\frac{-\lambda^2}{2\lambda_R^2}\right)$ (Jiang et al. 2014, Petrovay et al. 2020)
- Restrictions on current methods
  - Bipolar regions vs. realistic regions (Iijima et al. 2019, Jiang et al. 2019, Yeates 2020)

    ARs with asymmetric polarities, ARs with complex configurations

2. Generalizing algebraic method

Petrovay et al. 2020



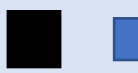
Contribution of a unipolar region

Contribution of a bipolar region

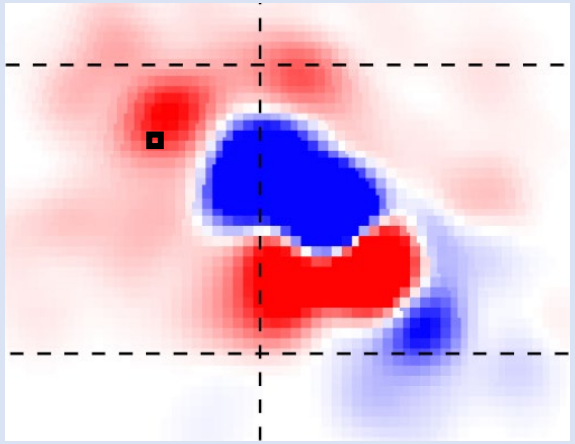
$$\frac{D_f}{D_i} = A \exp\left(\frac{-\lambda^2}{2\lambda_R^2}\right)$$

Algebraic method for bipolar regions

Size → 0



Contribution of a unipolar flux point



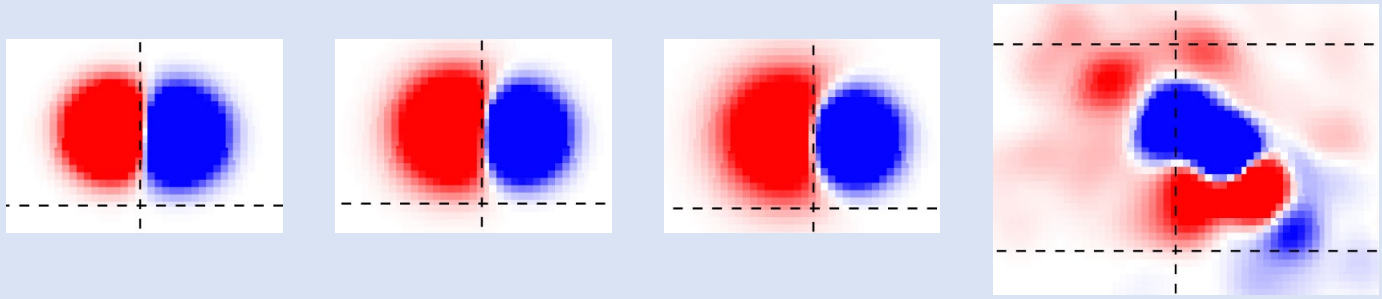
Integration over the AR

Generalized algebraic method

Observed ARs as linear addition of the unipolar points

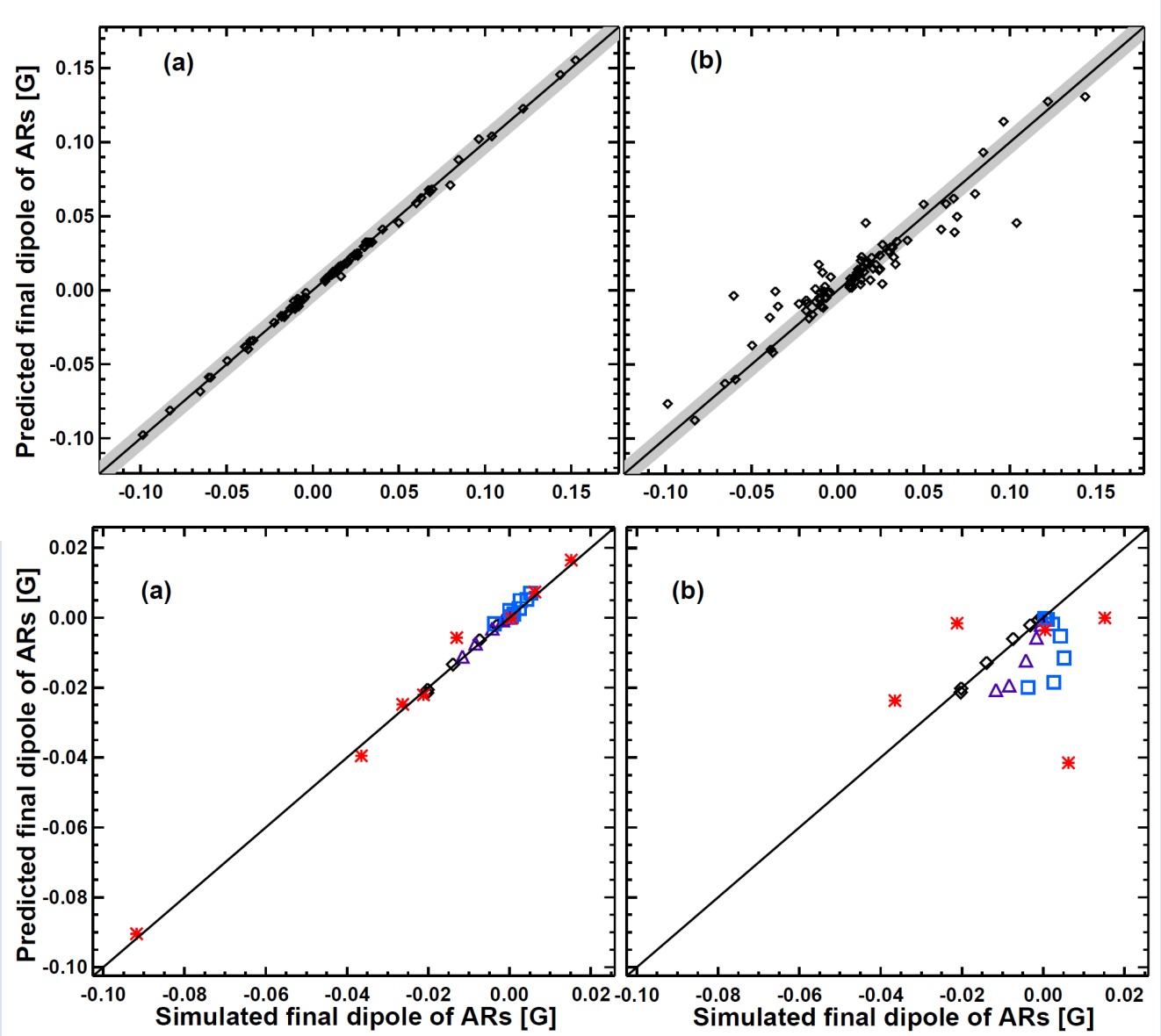
3. Evaluation with SFT simulations

- Compare SFT simulations with algebraic method for ARs
- Two types of ARs considered
  - Observed ARs during Carrington rotations 2145-2159
  - Artificially created ARs with bipolar, asymmetric bipolar and complex configurations



Different types of created ARs

3. Evaluation with SFT simulations



Up: evaluation by observed ARs
Down: evaluation by artificial ARs

Left: comparison of the **generalized algebraic method** with SFT simulations
Right: comparison of the **algebraic method for bipolar regions** with SFT simulations

4. Discussion and conclusion

■Advantages of the generalized method

- More precise than previous method based on bipolar regions
- More efficient than SFT simulations

■Expected usage

- Prediction of ARs contribution to solar cycle
- Not a complete replacement of SFT simulations

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