Minimum Energy Method for Resolving the Azimuthal Ambiguity in Hinode/SOT Vector Magnetogram Data

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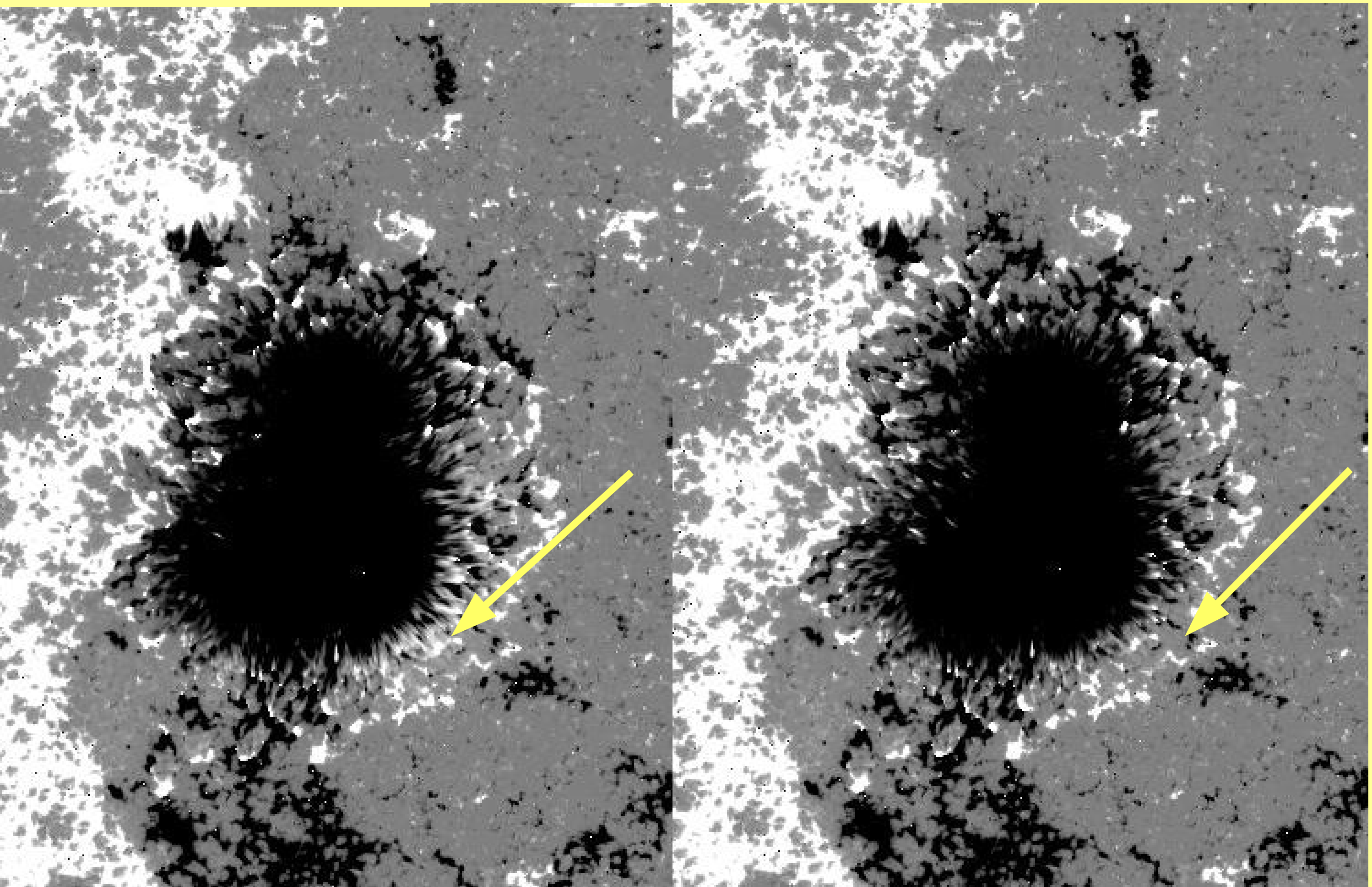
- A fast, Fortran code for solving the 180°azimuthal-angle ambiguity.
- Based on the "minimum-energy" approach, best-performing in numerous objective model-based tests.
- Available at: www.cora.nwra.com/AMBIG/

- **GOAL: automated algorithm with high “*performance value*”** (courtesy C. Henney):
  - *Accurate enough for science goals, fast enough for large data sets*
    - Stable for conditions of interest (e.g. Quiet areas, complex groups)
    - Fast relative to inversion time,
      (define Time= InversionTime / AmbigTime)
    - Is the algorithm automatic?
      If yes, (set Auto= 1, otherwise Auto= ∞)
    - **Merit = (% accuracy * Stability + Time) / Auto**

- **Assume an inversion procedure:**
  - **I, Q, U, V spectra → B_{los}, B_{trans}, φ (or |B|, φ, γ) at a single height**
    - e.g., MERLIN or MEKSY Milne-Eddington technique assuming linear source function
    - RMO (“Integral”), JLS (“derivative”), etc methods also acceptable, but best to account for magneto-optical effects.
  - No procedure (yet) solves the ambiguity as part of the inversion.

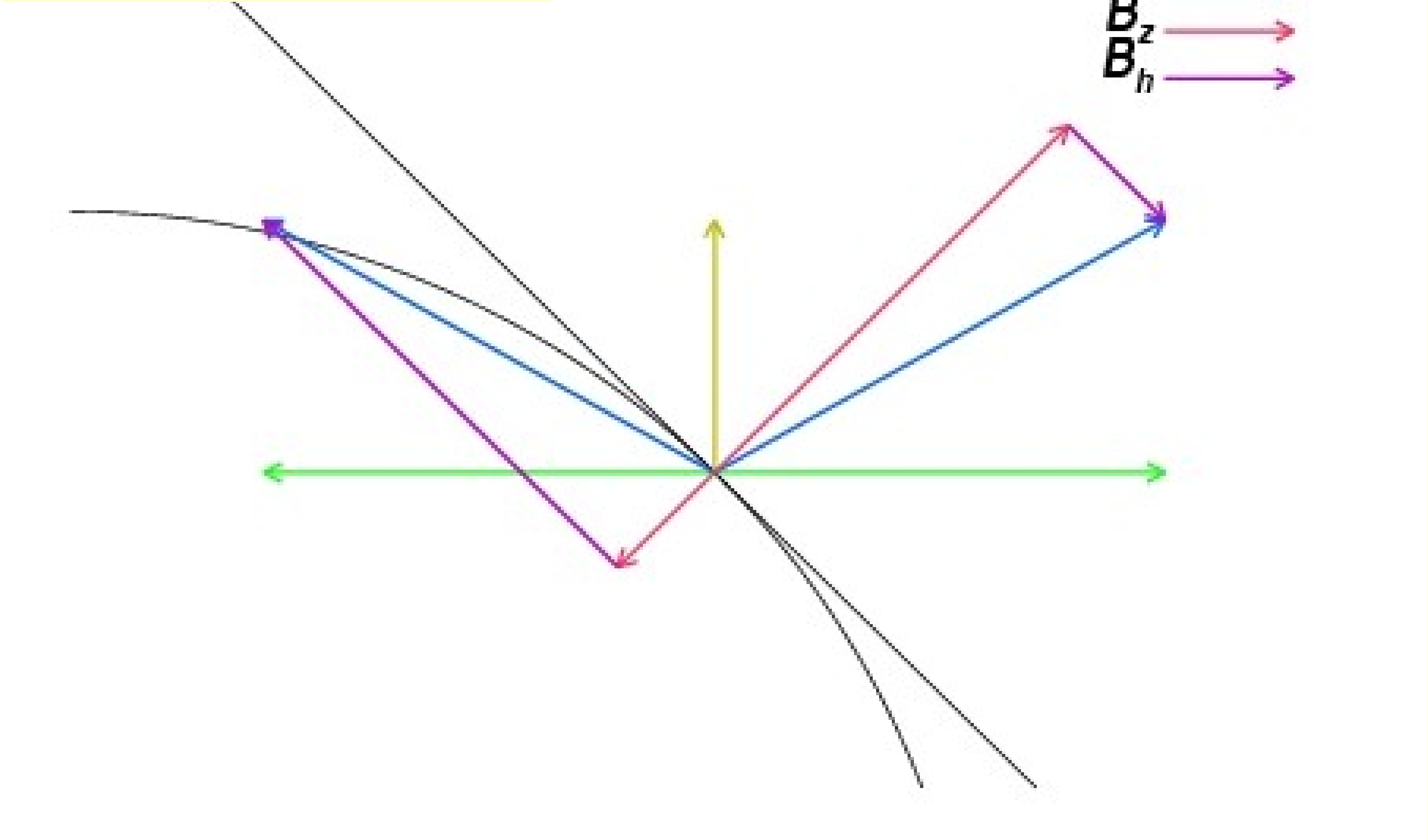


Far left: $B_{\parallel}$ of “Japan sunspot” at S10 W11 (μ=0.98), some false positive penumbral areas due to projection.

Left: Bz, radial field.

B_{trans} direction must be chosen at each point

Bt is ambiguous; direction choice influences **B**, and radial component **Bz**, true magnetic neutral (“inversion”) line, *etc*.



NWRA's Automated Ambiguity Resolution

- **Loosely based on the Minimum-Energy Approach:**
  - Minimize the functional $E = \sum \left(\left| J_z \right| + \nabla \cdot \vec{B} \right)$
- **J_z requires derivatives in the horizontal, heliographic plane**
  - J_z employed rather than some approximation to J, to increase speed and reduce need for additional derivatives.
- **div(B) requires derivatives in the *vertical* as well as horizontal direction.**
  - The derivatives for $\partial B_z / \partial z$ are computed from a potential field using the observed unambiguous line-of-sight field as the boundary.
  - Tests showed derivatives from the potential field were adequate if combined with a robust optimization
- **Now in Fortran**
  - Accepts generic FITS, all Hinode L2 FITS, and formatted-array input
  - 512^2 magnetogram takes $\approx$ 10 minutes

NWRA's Automated Ambiguity Resolution, cont'd.

- Global Optimization: Simulated Annealing is used to minimize the functional in strong-field areas.
  - Cooling schedule can be modified to best suit pipeline or targeted science.
- Weak-field areas solved by acute-angle to nearest-neighbor.
  - Propagate "correct" solution to areas dominated by noise.

Why "Minimum Energy" approach?

- **Best-Performing automated algorithm when tested against a variety of modeled observational challenges:**
  - highly-mixed potential/non-potential,
  - off-disk-center constant twist
  - off-disk-center constant twist with added photon noise
  - effects of spatial resolution
- **Repeatable, objective.**

See Metcalf et al 2006;
Leka et al 2009 (in preparation)

Summary:

- Now available: a fast, Fortran code for solving the 180°azimuthal-angle ambiguity.
- Based on the “minimum-energy” approach, best-performing in numerous objective model-based tests.
- ***All cases presented here ran in less than 10 minutes.***
- Thus***, “Merit” is high.***

- Available for use on L2 Hinode SOT/SP (and other ***B*** data) from: www.cora.nwra.com/AMBIG/
- Note: still an “α-version”, please try to make it fail so that we can fix it.