Stereoscopic disambiguation of solar vector magnetic fields using observations from SO/PHI and SDO/HMI

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The solar vector magnetic field $\vec{B}$ inferred from spectropolarimetric observations has:

$$\vec{B} = \overrightarrow{B_{los}} + \boldsymbol{\zeta}\left|\overrightarrow{B_{tr}}\right|\hat{t}$$

- ✓ determinate amplitude and sign of the line-of-sight (LoS) component $\overrightarrow{B_{los}}$,
- ✓ determinate amplitude $\left|\overrightarrow{B_{tr}}\right|$ and direction $\hat{t}$ of the transverse component,
- • but indeterminate orientation $\boldsymbol{\zeta = \pm 1}$ of the transverse component.

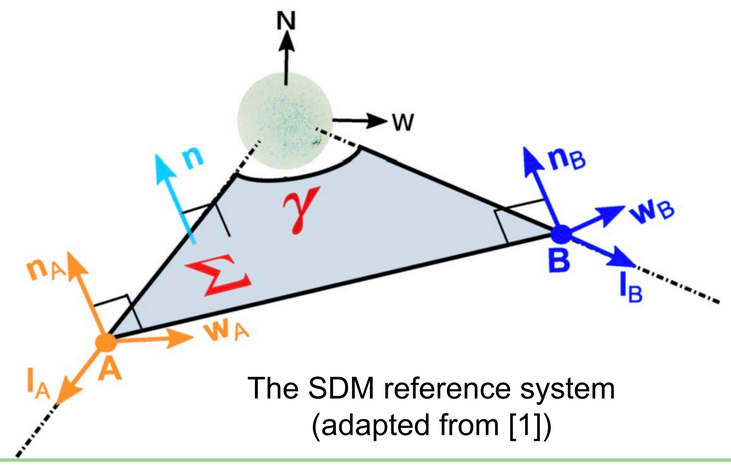
Resolving the ambiguity in the orientation of $\overrightarrow{B_{tr}}$ is equivalent to fix the parity of $\boldsymbol{\zeta}$ in each pixel of the detector image plane.

Stereoscopic Disambiguation Method (SDM)

- Stereoscopic observations by two detectors at different viewpoints with a separation angle γ.
- Specific SDM reference system with magnetic vectors reprojected on it (B_{los}, B_w, B_n).
- $B_n^{\mathrm{A}} = B_n^{B}$ by construction → used for image destretching after the image co-registration.
- $\boldsymbol{\zeta}$ is given by two geometrically equivalent SDM equations:

$$\boldsymbol{\zeta} = \frac{B_{\mathrm{los}}^{\mathrm{A}} \sin\gamma}{B_{\mathrm{w}}^{\mathrm{A}} \cos\gamma - B_{\mathrm{w}}^{\mathrm{B}}} \quad \text{and} \quad \boldsymbol{\zeta} = \frac{B_{\mathrm{los}}^{\mathrm{B}} - B_{\mathrm{los}}^{\mathrm{A}} \cos\gamma}{B_{\mathrm{w}}^{\mathrm{A}} \sin\gamma}$$

The SDM was developed in [1], and first applied to the SO/PHI observations in [2].



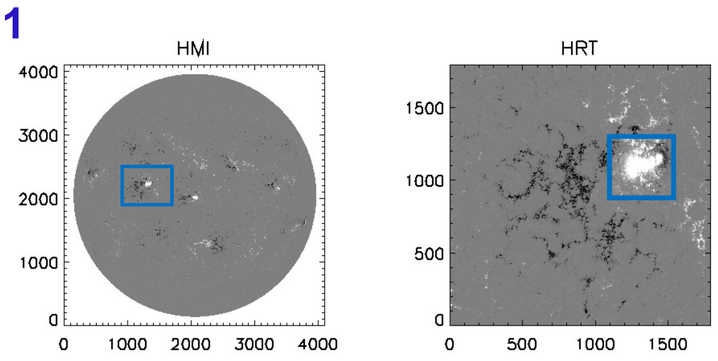
The SDM reference system (adapted from [1])

Application of the SDM on SO/PHI-HRT and SDO/HMI magnetograms

- We applied the SDM to SO/PHI-HRT and SDO/HMI data: use one of these two magnetograms to disambiguate the other one.
- HMI data: 720s ambiguous vector magnetogram ('hmi_ME_720s_fd10' data series)
- In each pixel, the SDM equation with a higher level of reliability is chosen.

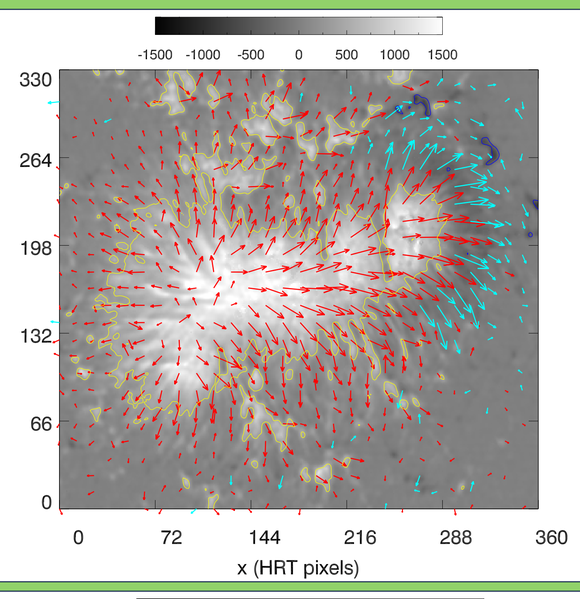
Observations of SDO/HMI and SO/PHI-HRT | **Disambiguated HRT magnetogram** | **Disambiguated HMI magnetogram**

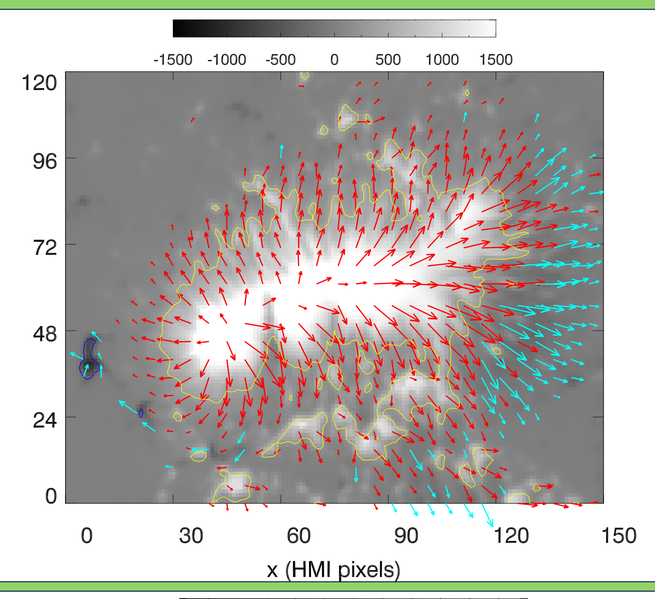
Case 1



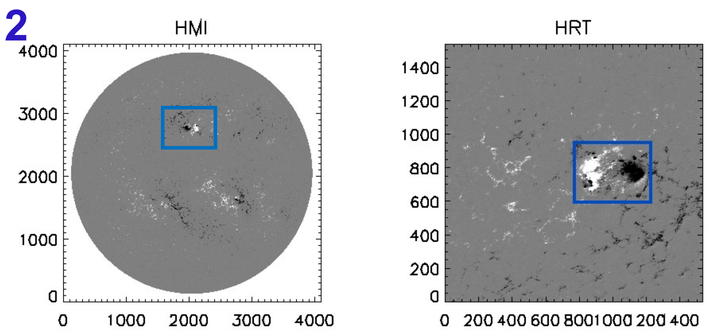
October 15, 2023. SO at 0.34 AU with $\gamma = -60°$

- Solar Orbiter was on the Sun-L5 line.
- A successful disambiguation case for typical PMI observations, onboard Vigil mission, which will be launched to the L5 point in 2031.



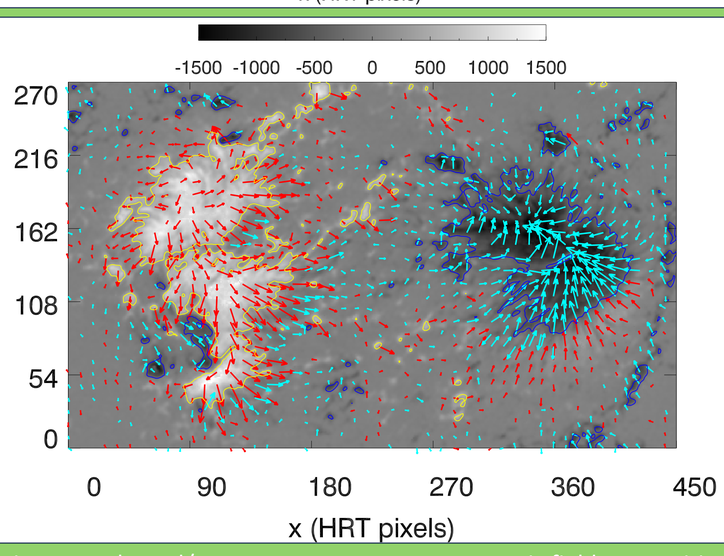


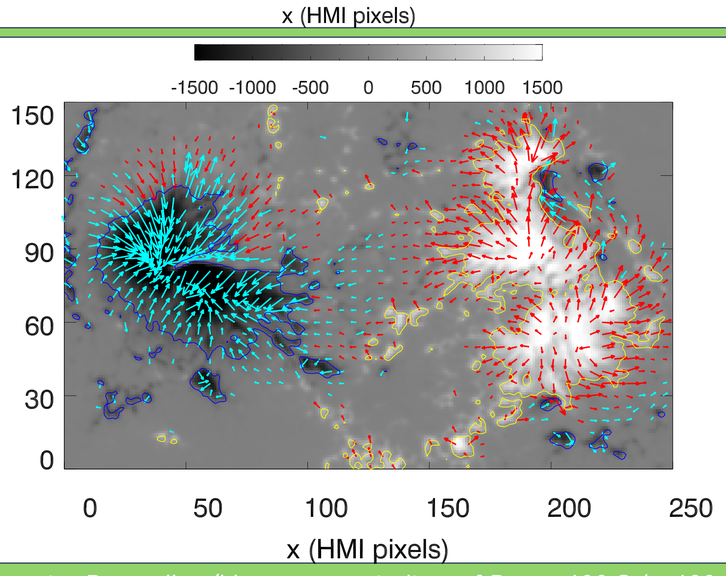
Case 2



October 30, 2023. SO at 0.55 AU with $\gamma = -22°$

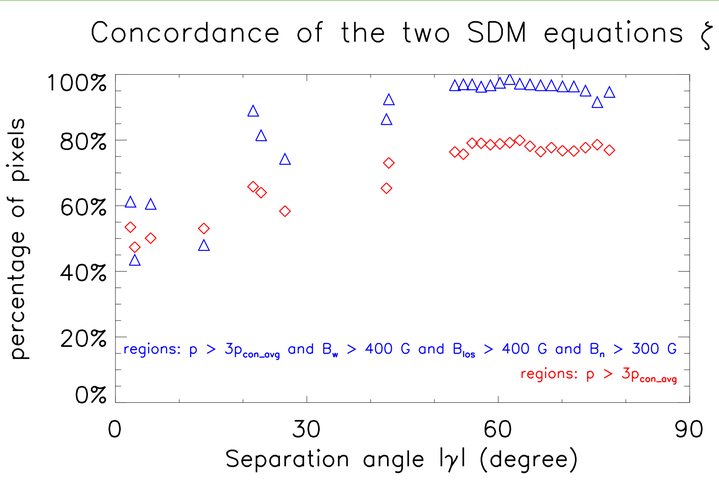
- The SDM gives expected results in most areas.
- Suspicious results in localized areas. The relatively small separation angle is not very ideal for the SDM (see below).





B_{los} in greyscale; red/cyan arrows: transverse magnetic fields on positive/negative B_{los}; yellow/blue contours: isolines of $B_{los} = 400$ G / -400 G

SDM diagnostic: concordance of two SDM equations

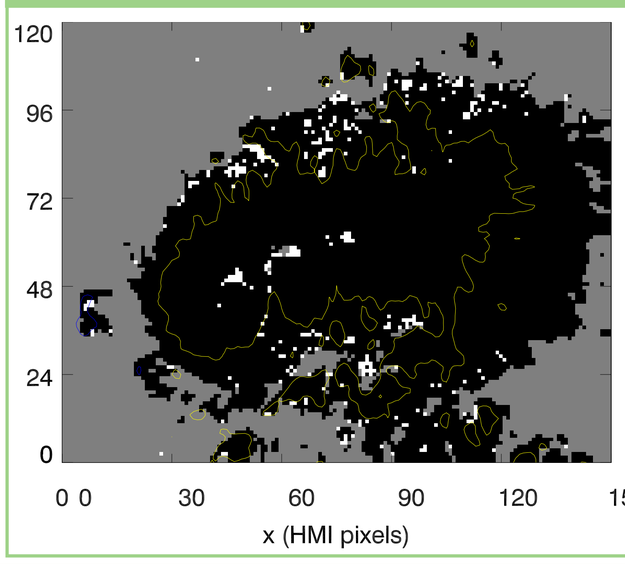


p: total polarization degree
p_{con_avg}: mean value of total polarization degree in the continuum

Concordance rate of the two SDM equations for 25 cases with different γ.

- $|\gamma| > 40°$: high concordance → reliable SDM results.
- $|\gamma| < 20°$: low concordance → not reliable SDM results.
- Strong B_{los}, B_w, B_n yield high concordance.

Comparison with single-view disambiguation method



- Comparison between the SDM and Metcalf's ME0 method[3] for the HMI magnetogram in the case 1 above.
- ME0 HMI data: 'hmi.B_720s'.

The SDM and ME0 method provide $\overrightarrow{B_{tr}}$ with:

- *same orientation in black regions.*
- *opposite orientation in white regions.*
- *grey regions: not considered ($\left|\overrightarrow{B_{tr}}\right| < 300$ G).*

Concordance on 97% of pixels

Conclusions

- The SDM successfully disambiguates vector magnetograms in strong field areas.
- SDM results are relatively more reliable when the separation angle between two detectors is larger.
- The SDM gives the same disambiguation results as the ME0 method in most analyzed areas.

References: [1] Valori et al., Sol.Phys., 297 (2022) [2] Valori et al., A&A, 677 (2023) [3] Metcalf et al., Sol.Phys., 237 (2006)