

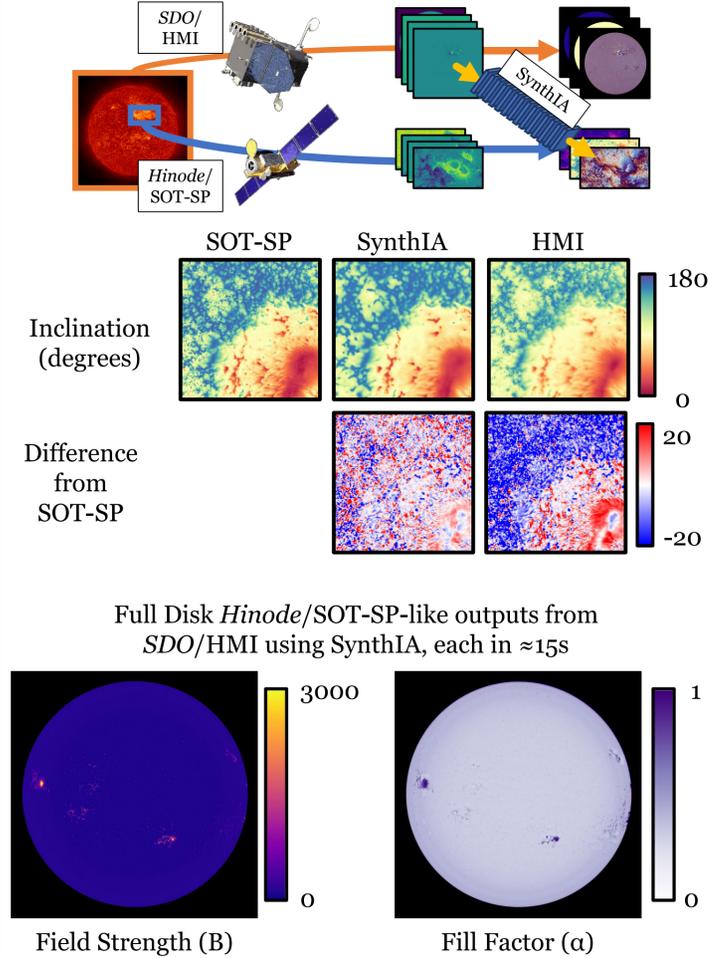
Aiming Hinode in the Right Direction: How Pointing Could Change Your Science

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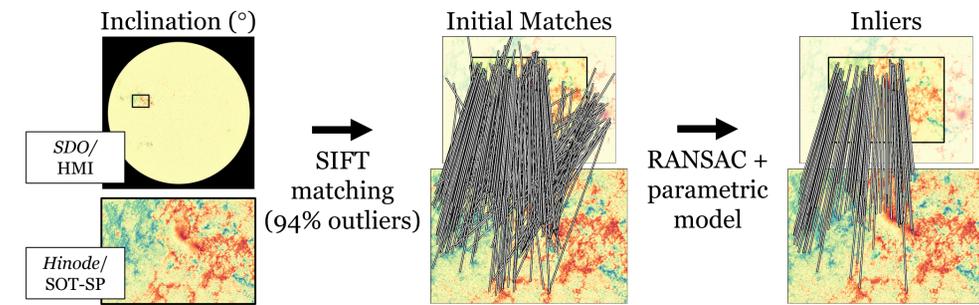
Motivation

Goal: accurate pixel-to-pixel alignment of *Hinode*/SOT-SP and *SDO*/HMI for virtual instruments or intercomparison.



Method and Setup

Goal: fit parametric model between coordinates to correspondences. **Challenge:** outliers

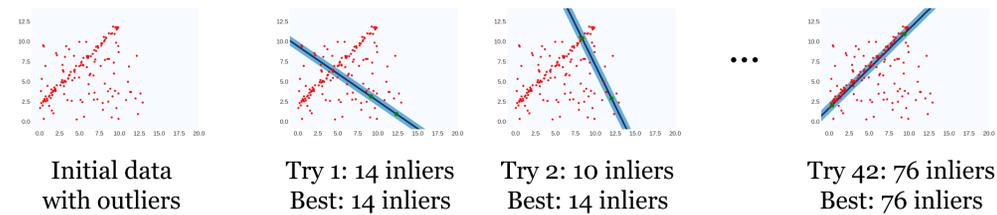


Key to Success: Random Sample Consensus (RANSAC), Fischler and Bolles, 1981

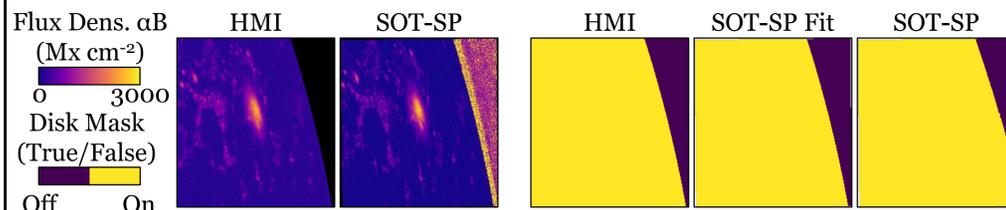
$$f([x, y]) = R(\theta, c_x, c_y) \begin{bmatrix} s_x & 0 \\ 0 & s_y \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} t_x \\ t_y \end{bmatrix}$$

Scale: s_x, s_y ; pointing: t_x, t_y, θ
Can assume s_x, s_y are fixed or free

Least Squares: $\sum_i \|f([x_i, y_i], \mathbf{m}) - [x'_i, y'_i]\|^2$ RANSAC: $\sum_i \|f([x_i, y_i], \mathbf{m}) - [x'_i, y'_i]\| < \epsilon$



Result: Given transformation, can warp *anything*: data, coordinates, disk masks, etc.



Data and Correspondence

12K *Hinode*/SOT-SP Level 2 Scans (2011 – 2021)

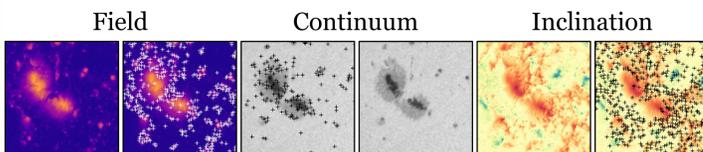
- Criteria: near-square aspect, near-continuous, non-polar
- Accounted for: non-uniform slit motion, time

50K *SDO*/HMI hmi.ME_720s fd10 etc. Scans

- Criteria: contemporaneous with the *Hinode*/SOT-SP Scan

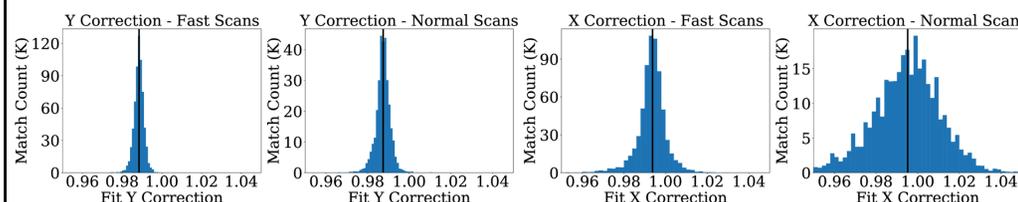
Key to Success:

- Scale Invariant Feature Transform (SIFT), Lowe et al. 2004 to automatically find and match features
- Standard in computer vision; robust, but has outliers
- Accounting for SOT-SP's scanning slit in standard recipe



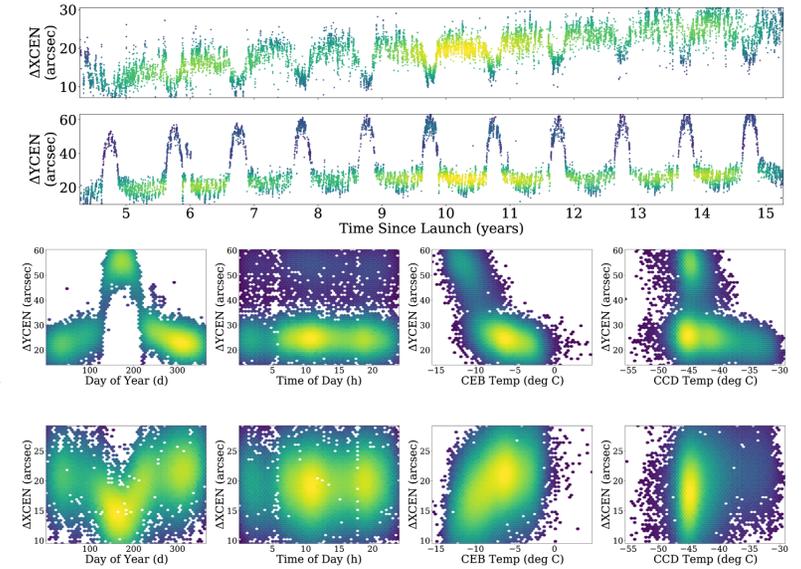
Scale

Estimated scale **smaller** than pipeline (X: 99.4%; Y: $\sim 98.5\%$) and matches Level 1 values. Smaller value better explains correspondences and aligns. Fit scale doesn't correlate with time of day/year/mission or location.



Pointing Updates

Pointing correction has secular and cyclic trends and strong bias

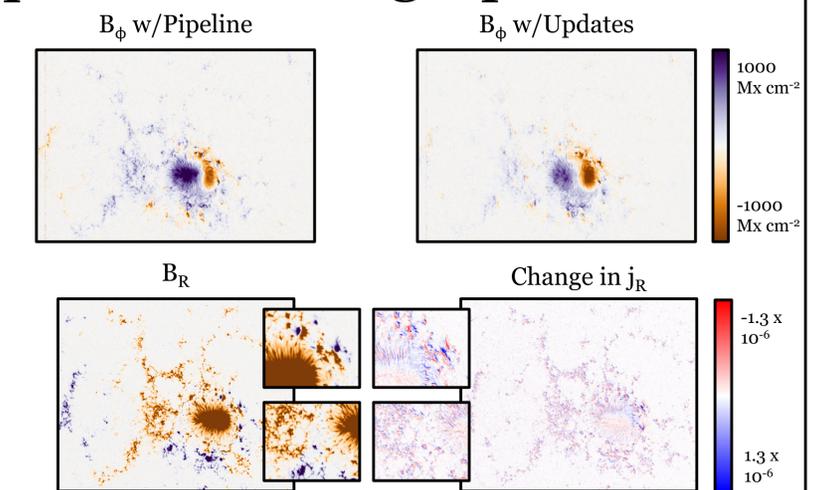


Pointing strongly depends on time of year and temperature

Pointing update predictable and was likely much smaller at launch time

Impact of Pointing Updates

Some pointing is just wrong, and field changes considerably



Pointing updates change spatial structure of radial current density

Pointing updates lead to location-dependent re-scaling of radial current density

