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Improved reconstruction of solar magnetic fields from imaging spectropolarimetry through spatio-temporal regularisation

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Determination of solar magnetic fields with a spatial resolution set by the diffraction limit of a telescope is difficult because the time required to measure the Stokes vector with sufficient signal-to-noise ratio is long compared to the solar evolution timescale. This difficulty becomes greater with increasing telescope size as the photon flux per diffraction-limited resolution element remains constant but the evolution timescale decreases linearly with the diffraction-limited resolution.

The magnetic field vector tends to evolve more slowly than the temperature, velocity, or microturbulence. We exploit this by adding spatio-temporal regularisation terms for the magnetic field to the linear least-squares fitting used in the weak-field approximation, as well as to the Levenberg-Marquardt algorithm used in inversions. The other model parameters can be allowed to change in time and space with far less restrictive constraints. Our results show that the noise in the reconstructed magnetic field vector is greatly reduced by spatio-temporal regularisation, while all other model parameters can capture the faster variability of the atmosphere imprinted in the line profiles.

These methods are fundamentally important for the interpretation of data from the new generation of 4-m telescopes like DKIST and the planned EST, where solar evolution time will be critically low.

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