Constraining the magnetic vector in the quiet solar photosphere

The 1.5 m solar telescope GREGOR at the *Observatorio del Teide*, Tenerife

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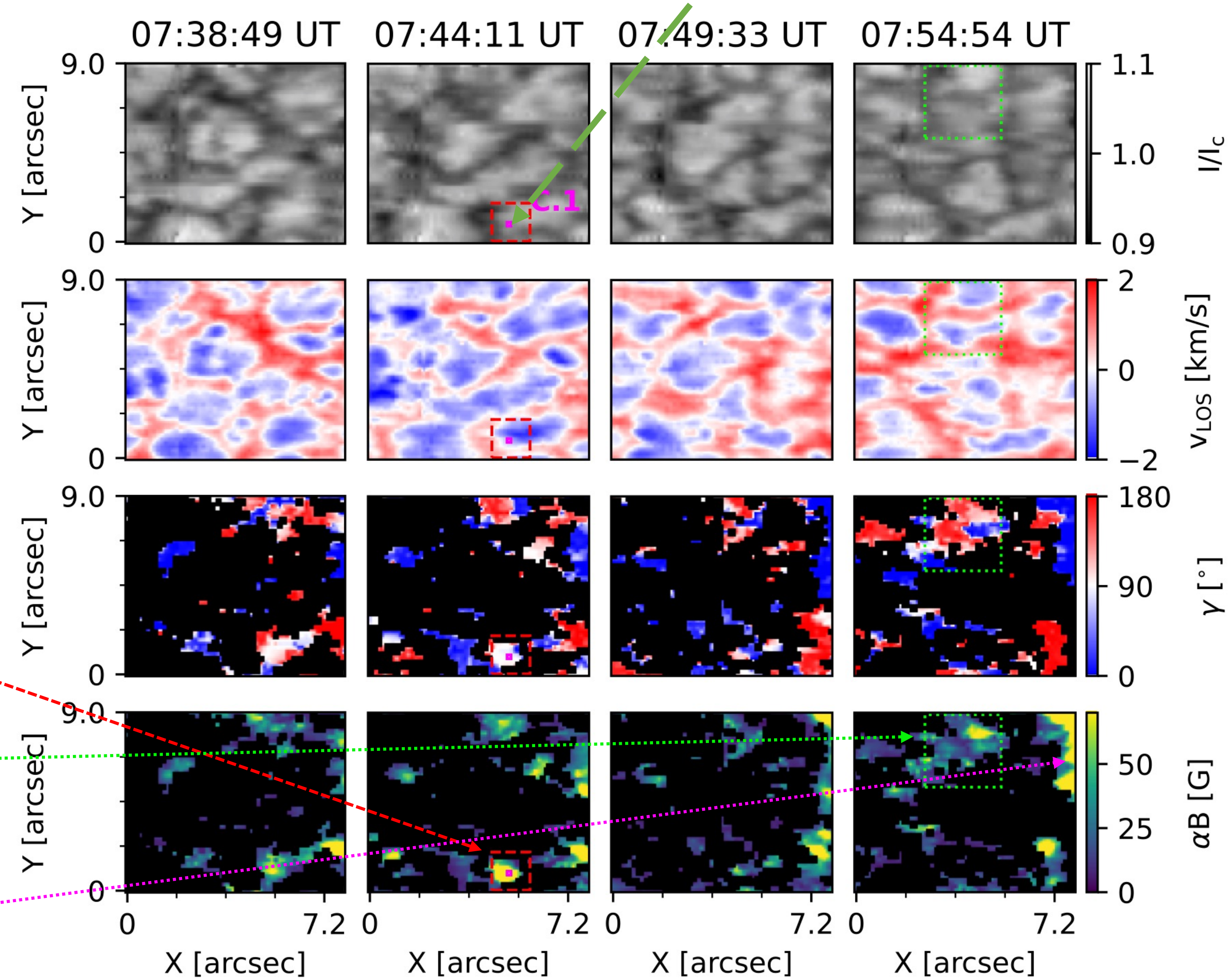
Dynamic small-scale magnetism

We use the Stokes inversions based on response functions (SIR) inversion code to infer properties of the atmosphere from full-Stokes observations taken by the **GRIS-IFU** at **GREGOR** in May 2019 with the 1564.9 nm line.

This region of interest contains at least three small-scale features:

1. A short-lived linear polarization feature
2. A complex, weak magnetic structure with mixed polarities and transverse fields
3. A longitudinal kilo-Gauss magnetic element

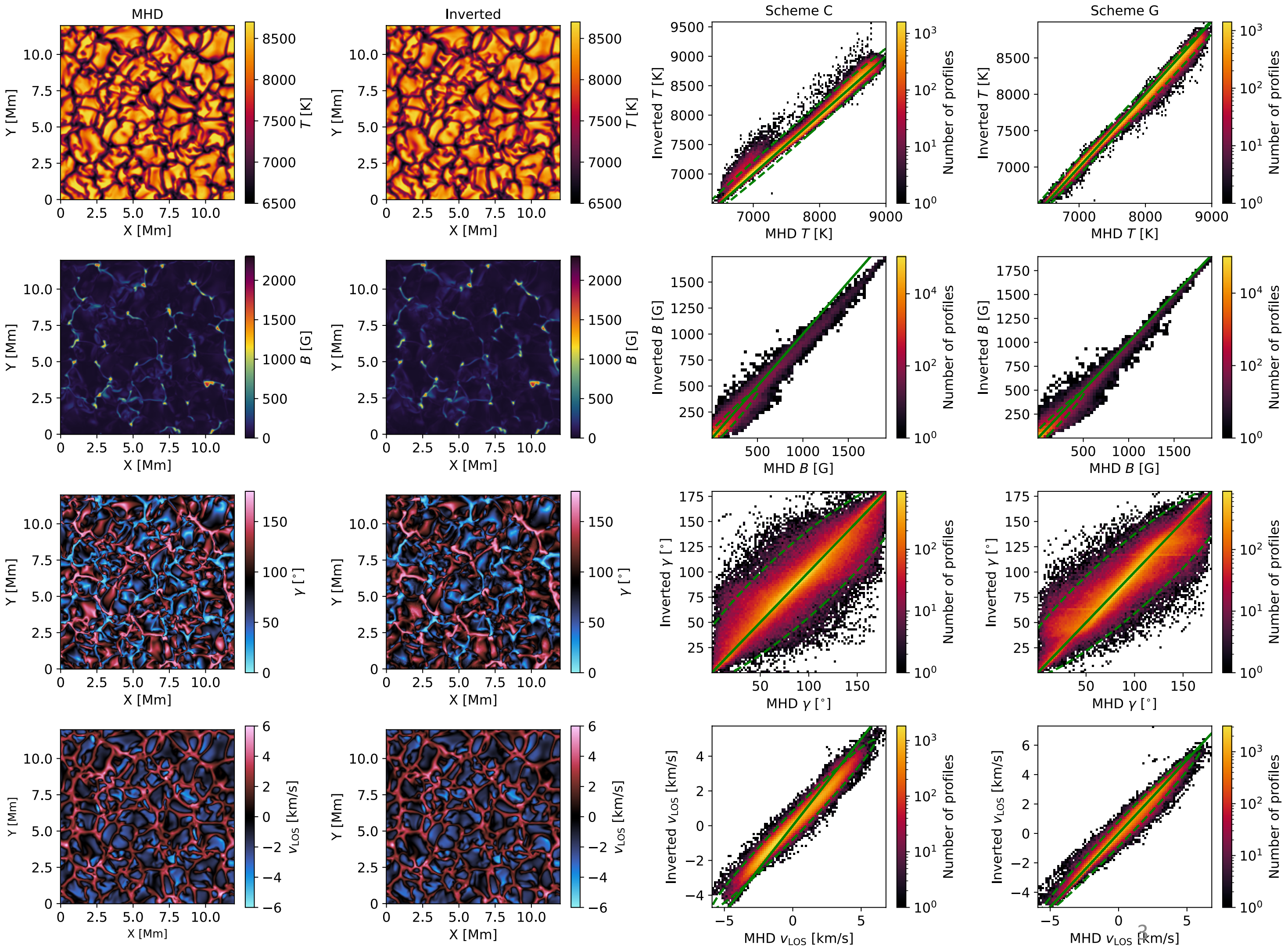
This profile is shown on the last page!



SIR: B. Ruiz Cobo and J. C. del Toro Iniesta, “Inversion of Stokes Profiles,”, vol. 398, p. 375,Oct. 1992

How well can the inversion recover the MHD values statistically?

MURaM: A. Vogler, S. Shelyag, M. Schussler, F. Cattaneo, T. Emonet, and T. Linde, vol. 429, pp. 335–351, Jan. 2005



Using SIR, we produce synthetic spectra from MURaM outputs and invert to test how well we can retrieve information.

Scheme C: every parameter is constant in depth (except T)

Scheme G: we allow linear gradients in B, γ, and v_{LOS}

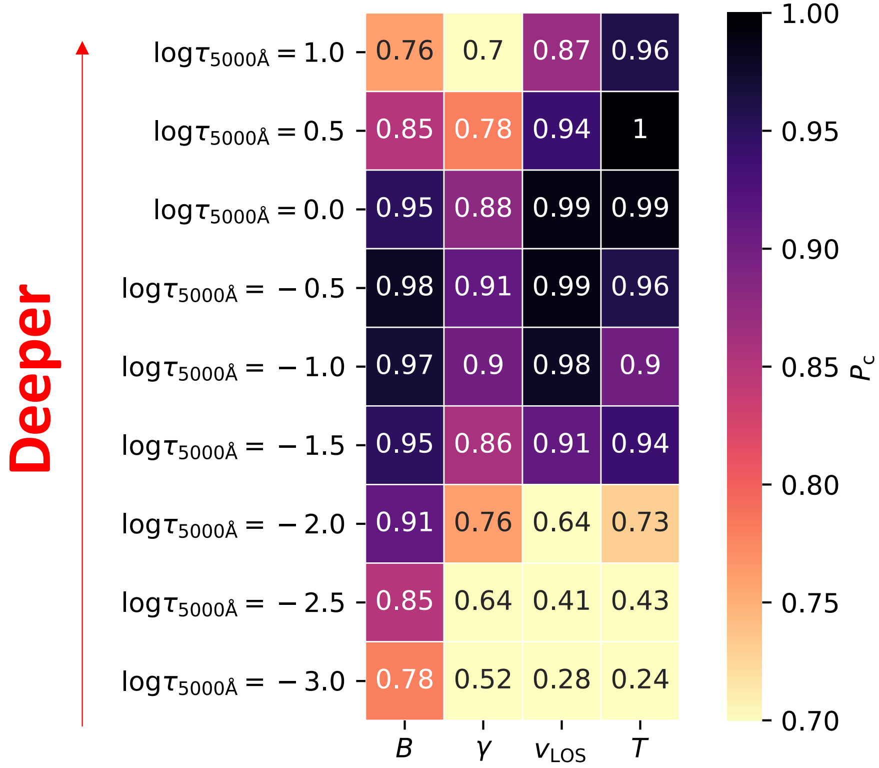
Scheme G lowers the χ^2 statistically particularly in intergranular lanes

To which optical depths are the atmospheric parameters responsive?

We correlate the MHD and Scheme G inverted values at incremental optical depths. Figure on the right shows the Pearson correlations, P_c.

- Temperature, T, is responsive very deep in the atmosphere in the continuum ($\log \tau_{5000Å} = 0.5$), but shallower in the spectral line
- Line of sight velocity, v_{LOS}, is responsive very deep, and over a narrow range of optical depths than T
- Modulus of magnetic field strength, B, is responsive to a large range of optical depths (peaks at $\log \tau_{5000Å} = -0.5$)
- Inclination angle of the magnetic vector, γ, peaks at the same depth as B but is the lowest correlated parameter

These results reflect the response functions very closely (of course!)



Instrumental degradation to GREGOR resolutions

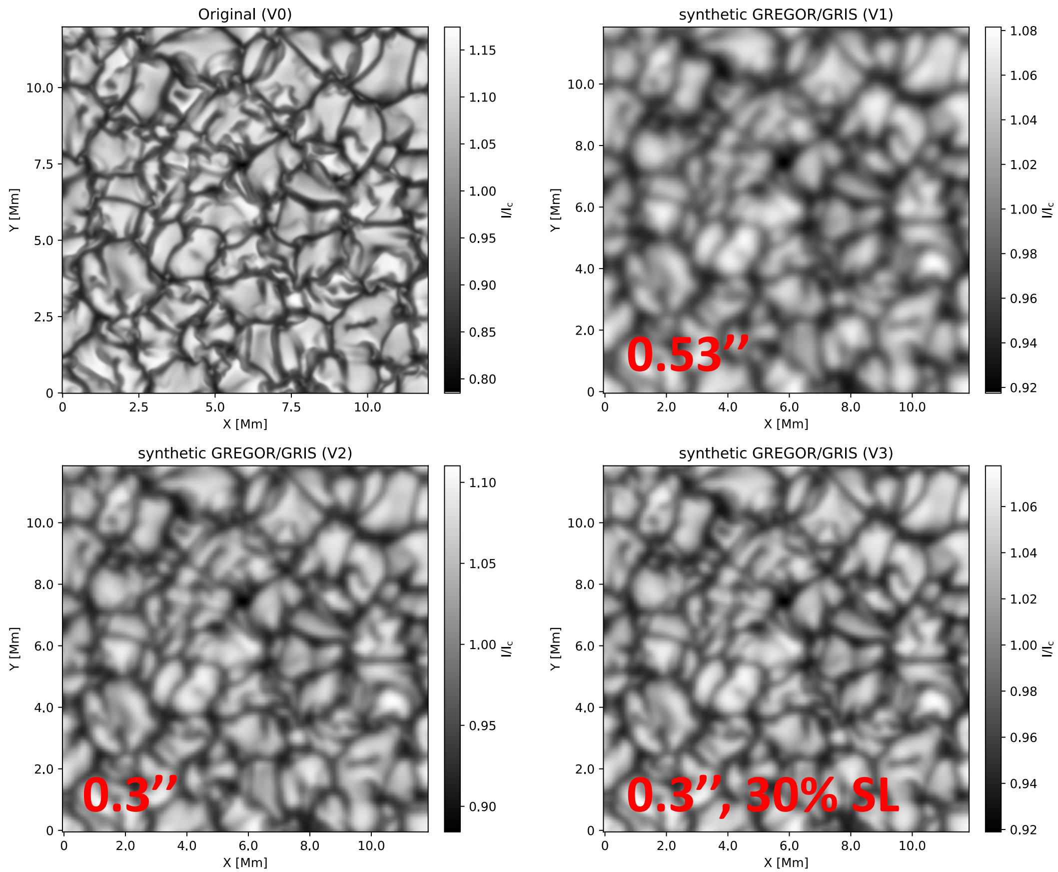
We convolve the synthetic spectra spatially to reduce the continuum intensity contrast to that achieved by GREGOR (peak value of 3.1% for 6 May 2019)

Stray light further degrades the contrast

Upper and lower estimates on our effective spatial resolution: 0.3'' – 0.53''

We resample to 100 km, degrade spectrally, and add noise at 8×10^{-4} and 3×10^{-4} I_c

We consider the impact of varying spatial resolution, stray light and S/N



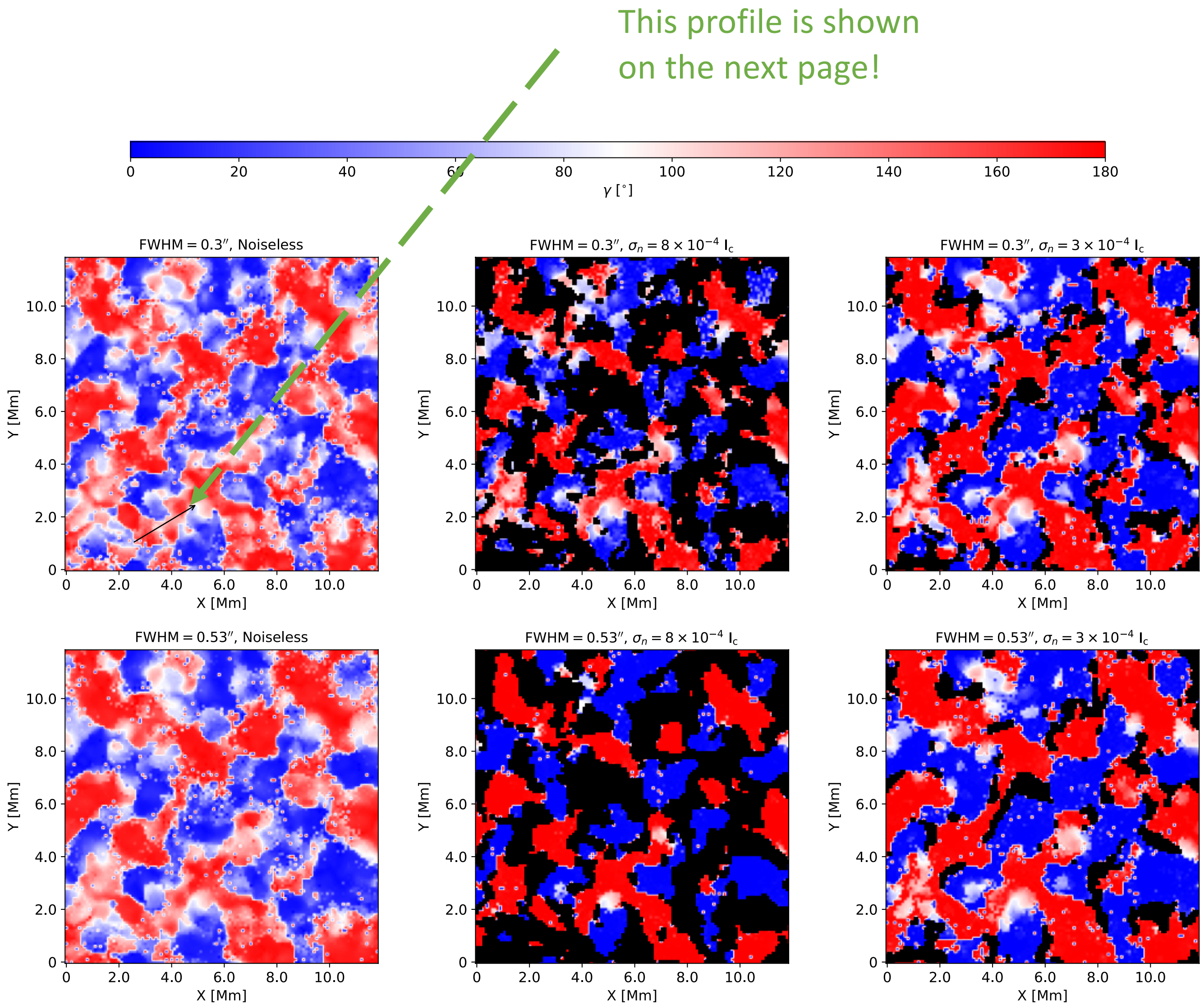
Impact of S/N & spatial resolution

Reduced spatial resolution and low S/N have a similar impact:

1. The amplitudes of the polarized Stokes vectors are reduced
2. Because linear polarization signals are typically weaker, this has a huge impact on the retrieval of magnetic field inclinations

Observing at high resolution, with good seeing conditions and a high S/N is **essential**.

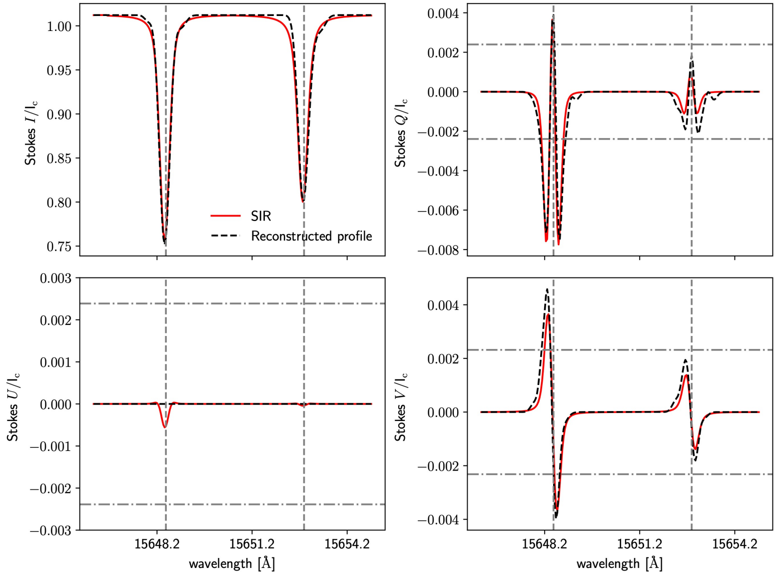
Unpolarized stray light impacts only on *T*.



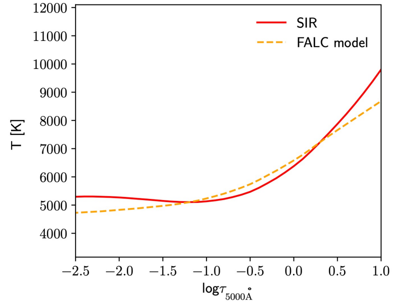
GRIS-IFU

This profile has enough information to constrain γ

$\alpha B = 146$ G



B [G]	193
αB [G]	146
γ [°]	85
ϕ [°]	89
v_{LOS} [km/s]	-0.8

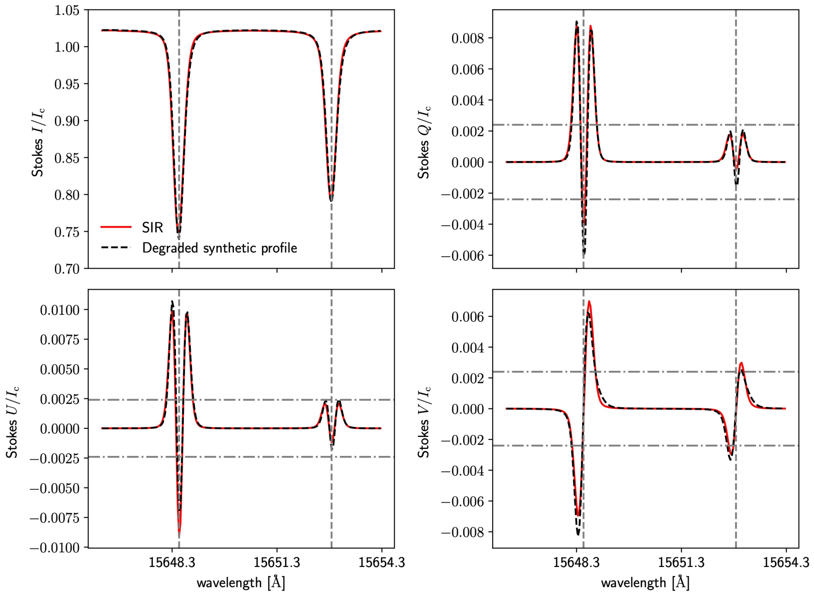


MURaM

This profile has enough information to constrain γ and Φ (without disambiguation)

$\alpha B = 143$ G

Very similar magnetic flux density between observations and degraded simulations!



B [G]	337
αB [G]	143
γ [°]	97
ϕ [°]	25
v_{LOS} [km/s]	-0.3