The Hα line as a probe of chromospheric magnetic fields

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The Hα line is a cornerstone diagnostic for probing the solar chromosphere, but its potential for magnetic field inference via spectropolarimetry remains underutilized. One contributing factor is that previous studies—based on simplified 1D radiative transfer (RT) models—suggested a dominant photospheric origin for the Hα Stokes V signal, casting doubt on its chromospheric sensitivity. Moreover, until now, no polarimetric studies have employed full 3D RT modeling to reassess this interpretation in a more realistic atmospheric context. In this work, we present the first comprehensive 3D RT polarimetric synthesis of the Hα Stokes profiles under the field-free approximation, using a state-of-the-art 3D rMHD model of the solar atmosphere. For context and comparison, we also synthesize the Ca II 8542 Å and Fe I 6173 Å lines. Line-of-sight (LOS) magnetic fields are inferred from the Hα and Ca II 8542 Å lines using the weak-field approximation, while Milne-Eddington inversion is employed for the Fe I 6173 Å line. Our results show that the core of the Hα line forms significantly higher in the chromosphere—approximately 500 km above the Ca II 8542 Å line—with peak magnetic sensitivity at $\log \tau_{500} = -5.7$, compared to $\log \tau_{500} = -5.1$ for Ca II 8542 Å line. These findings are consistent with recent observational evidence (Mathur et al. 2023, 2024) confirming that Hα line core probes magnetic fields at higher atmospheric layers than the Ca II IR triplet lines. This study supports the argument that spectropolarimetric observations of the Hα line provide complementary insights into magnetic field stratification at greater chromospheric heights, particularly when recorded simultaneously with widely used diagnostics such as the Ca II 8542 Å line.