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PRD vs. CRD CaII K Stokes profiles from solar plage

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1. Introduction

The CaII H & K resonance lines are strongly affected by partial frequency redistribution (PRD) of line photons. Observations of their full Stokes vector profiles $\vec{I} = (I, Q, U, V)^{\mathrm{T}}$ are now becoming feasible and quantification of the PRD effects for $\vec{I}$ in the presence of a magnetic field is needed.

Zeeman splitting and PRD together produce complicated line profiles, the theoretical formulation of which is still incomplete. Our approach to compute PRD Stokes vector profiles is based on an *intuitive* extension of the formulation for the complete redistribution (CRD) case (Rees et al. 1989) with *frequency-dependent* PRD line source functions, which are obtained from the solution of the multi-level non-LTE scalar radiative transfer (field-free approximation) and statistical equilibrium equations by means of the Hubený & Lites (1995) PRD version of MULTI (Carlsson 1986). The computed PRD line source functions and opacities are used to formally solve for the emergent Stokes vector for a given magnetic field configuration by means of the Stokes Profile Synthesis Routines (SPSR) of Murphy & Rees (1990), based on the diagonal element lambda operator (DELO) method (Rees et al. 1989).

2. FALC-FALC tube: different vertical lines of sight

The CaII K-line formation in solar plage is exemplary for the PRD–CRD Stokes profile differences. A thin flux tube model, consisting of a FALC (Fontenla et al. 1992) tube atmosphere with a magnetic field strength $B_0 = 1500\,\mathrm{G}$ and a magnetic filling factor $\alpha = 0.01$ at standard optical depth unity embedded in a FALC surrounding atmosphere, sampled on vertical rays at increasing distance from tube center, serves to demonstrate the line profile differences for the various rays. The tube boundary height increases with distance from tube center and causes the line formation region (at a certain wavelength) to shift from the magnetic atmosphere into the non-magnetic surroundings.

The behavior as a function of distance to the tube center is very similar for PRD and CRD profiles, so that the application of PRD does not provide addi-

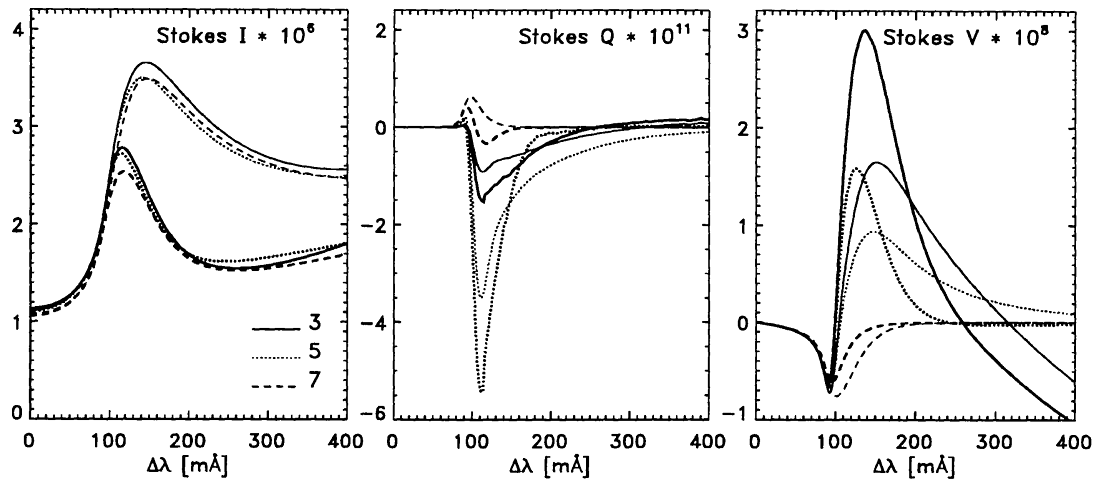

Figure 1. CRD (thin curves) and PRD (thick curves) K-line Stokes I, Q and V profiles for rays 3, 5 and 7 of the FALC-FALC tube model

tional diagnostic tools. The Q^{PRD} and V^{PRD} peak values are somewhat larger than the CRD peak values and especially between the K_1 and K_2 wavelengths Q^{PRD} approaches faster to zero than Q^{CRD}. The profile changes as function of distance to tube center are best understood from Stokes V, which mirrors the behavior of the I profile in close agreement with the weak field approximation. Close to tube center (ray 3) a large part of the line is formed within the magnetic part of the atmosphere, producing a small negative V-peak between K_3 and K_2, and a larger positive V peak (due to stronger field in deeper atmosphere) between K_2 and K_1; V turns negative again beyond K_1. With increasing distance from tube center the tube boundary height increases and more of the line is formed below the tube boundary, reducing and eventually eliminating the positive V-peak, so that on rays far from tube center only the small negative V-peak due to the small canopy field remains.

Stokes Q behaves similarly and the point at which the peaks in Q and V disappear is only slightly dependent on the use of PRD or CRD for the photon scattering. The strength of these peaks in spatially unresolved V-profiles provides a (complicated) measure for the magnetic filling factor, the analysis of which not necessarily requires PRD.

References

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