On the Invariance of PCA Quick-Look Polarization Analysis to Different Magnetic Activity Samples

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Abstract.

We find a quasi-invariance in the highest ranked Stokes eigenprofiles to different magnetic compositions of the active region used to define them. For the intensity one requires significant rotations of the basis in the PCA eigenspace to obtain eigenprofiles which represent the derivatives of the zeroth order eigenprofile and which allow one to estimate velocity and vector magnetic field parameters. The derived velocities and magnetic splittings show increased deviations from those given by a direct profile inversion. For the Stokes net-polarization profiles we find that the highest ranked eigenprofiles are essentially invariant. The only changes in the resulting vector fields are solely due to changes in the shape of the zeroth order intensity, i.e. in the mean thermodynamic state, and are negligible.

In a previous Principle Component Analysis (PCA) of the line profiles of the FeI $\lambda 630.15$ & $\lambda 630.25$ nm lines for a solar active region (Skumanich & López Ariste 2002, hereafter SLA02), it was shown that one can consider the expansion of any Stokes parameter at any point $x$ by its principle components, i.e. eigenprofiles of its covariance matrix (which we label 'harmonics'), as a perturbation series expansion. Thus, in the case of the intensity $I(x, \lambda)$, SLA02 write $I_0(x, \lambda) = c_0(x)f_0^I(\lambda)$ for the leading or zeroth order term in the expansion, where the fundamental (harmonic) eigenprofile is $f_0^I(\lambda)$ and $c_0(x)$ is its coefficient, and show that the first 'overtone' eigenprofile, $f_1^I(\lambda)$, is directly proportional to the first derivative of the fundamental, i.e. to $\partial I_0(x, \lambda)/\partial \lambda$. Thus the coefficient of $f_1^I(\lambda)$ was interpreted as the line-of-sight (LOS) velocity perturbation, $v_{\text{los}}$, to the leading order term. However in the case of the second overtone, $f_2^I(\lambda)$, a 'demixing', i.e. a rotation in the $(f_2^I(\lambda), f_3^I(\lambda))$ space by an angle $\theta_2$, was found to be necessary to obtain a second overtone $f_2^I(\lambda, \theta_2)$ that was proportional to the second derivative, $\partial^2 I_0(x, \lambda)/\partial \lambda^2$, and whose coefficient was interpreted as the Zeeman splitting or broadening perturbation, $Z^2 \equiv (B^2 + B_{\text{los}}^2)$. Here $B, B_{\text{los}}$ are the field strength and LOS component respectively.

In the case of the net-polarization parameters ($Q, U, V$) the fundamental eigenprofile $f_0^V$ proved to be proportional to $\partial I_0(x, \lambda)/\partial \lambda$ while $f_L^U$, which is identical for $L = Q$ or $U$, was proportional to $\partial^2 I_0(x, \lambda)/\partial \lambda^2$. Using the weak

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