Converging Flows in the Penumbra of a δ-Sunspot

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Abstract. Flows are observed in the penumbra of a δ-configuration sunspot which appear to converge upon the line separating locally positive and negative polarity magnetic field. These flows persist for many hours. Observations of this region with the Advanced Stokes Polarimeter indicate a convex vector field geometry with magnetic lines of force arching upwards from positive polarity, then downwards to negative polarity. Upward flows from opposite ends of an individual magnetic line of force would rapidly load mass at the apex of the arch, but there is no observational evidence of the dynamics that such a loading would require. We perform analyses of the observed Stokes spectral profiles of the region of converging flows in order to extract information about unresolved structure of the magnetic field and associated flows. Fits to the observed profiles with Milne-Eddington atmospheres having two magnetic components (plus an unmagnetized component) within each spatial resolution element suggest strongly that, as in penumbrae of simple sunspots, the field geometry in the convergence zone is “fluted”. However, unlike simple sunspots which have only an outward-directed Evershed flow in the more horizontal components, the two-component analysis reveals oppositely-directed flows in the components. We interpret these observations as indicative of an interleaved system of field lines in the vicinity of the polarity reversal, whereby the convergent streams are able to slip by one another and return downward into the solar interior. We also perform an analysis of one-component fits allowing for full variation of the thermodynamics and vector field along the line-of-sight. This analysis supports the notion of a return flux carrying these flows, which likely have the same physical origin as the Evershed effect in ordinary sunspots.

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