The Paradox of Filamented Coronal Hole Flow but Uniform High Speed Wind

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Plumes and rays in coronal holes are nearly radially aligned density striations that follow the ambient magnetic field. They have long been known, but have gained new interest with growing awareness that coronal hole flow is inherently filamentary. In retrospect, filamentary flow should have been no surprise. This is because $\beta \ll 1$ in coronal holes inside $\sim 10\ R_\odot$, allowing the flow to be filamentary down to the smallest scale of photospheric magnetic activity. While the magnetic field itself is locally smooth across any height above ca. 50,000 km, SOHO/MDI has shown that the photospheric magnetic field is a complex array of rapidly evolving small bipoles that are constantly emerging, evolving, and cancelling. The resulting activity is manifested in microflares, concentrated in the magnetic network, that produce impulsive injections at the footpoints of coronal field lines. The uneven distribution of this activity in space and time is the source of coronal hole filamentation. What is surprising is that the radial flow speed also exhibits filamentary structure. It is not well described as smooth, spherically symmetric, diverging flow, but instead ranges from 300 to over 1000 km/s at 5.5 $R_\odot$ among field-aligned filaments like those seen in plumes and rays [Feldman et al., JGR, Dec. 1997]. This is completely unlike the constant high speed solar wind reported beyond 0.3 AU. Consequently, plumes and filamentary structure must be strongly mixed, and the mixing must be far along by 0.3 AU to be consistent with Helios observations. The paradox is what causes the mixing? Existing models of coronal heating and solar wind acceleration hardly address this issue. One possibility we are investigating is the MHD Kelvin-Helmholtz instability, to which the shear between plumes and interplume corona is expected to become unstable at 5-10 $R_\odot$. This instability can be simulated and followed far into the nonlinear regime and may lead to Alfvénic fluctuations like those seen at 1 AU.