Using Type III Radio Bursts to Probe the Sun's Plasma Density Profile

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Recently we developed and applied a new technique to extract the power-law index of the Sun's electron number density profile $n_e(r)$ directly from the time-varying frequency of type III coronal radio bursts, with frequencies in the range 40 – 400 MHz measured near Potsdam and Moscow. Unexpectedly we found that coronal type III bursts often are almost linear in $1/f - t$ dynamic spectra and, assuming a constant electron beam speed, several events had power-law indices $\beta \approx 2$ for $n_e(r) = A\,(r - R_1)^{-\beta}$, where r is the radial distance and R_1 is an arbitrary offset. At first sight this result appears inconsistent with the well-known Baumbach-Allen and Saito et al. models for r in the range 1.05 R_S to 4 R_S, where the Sun's photosphere is at $r = R_S$. However, we were able to reconcile the radio and coronagraph data with a wind-like model $n_e = A\,(r - R_S)^{-2}$, with a simple physical explanation in terms of conservation of electrons flowing with constant speed from localized sources relatively near the photosphere. This paper analyses 37 well-defined coronal type III radio bursts, finding β in the range 0.4 to ∞, with mean and median values of 2.4 and 1.0, respectively. A strong tendency is found for bursts from the same group to have similar power-law indices, thereby favouring the hypothesis that they are produced in the same source region. The typical density profiles are thus more gently sloping than expected from the existing empirical coronal models. Indices lower and higher than 2 also occur, the former plausibly due to non-radial curved magnetic field lines. Smaller power-law indices could result from the effects of non-conical geometry of the plasma flow tubes, deceleration of coronal plasma, and/or the curvature of the magnetic field lines. However, magnetic curvature effects are not strong to explain such low indices if β were truly ≥ 6, as for the previous models, but may be able to reduce true values of $\beta \approx 2$ to apparent values close to 1. Independent data from spectroscopic measurements and quasilinear simulations will be discussed.

Keywords: type III solar radio bursts; corona; density profile; electron beams; radio emission, solar radio telescopes.