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Gyrosynchrotron Emission from Stellar Coronae

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Abstract. We analyze quiescent radio spectra of main-sequence cool stars in terms of a simple gyrosynchrotron model. We find that the underlying (assumed) power-law electron distribution is often very hard, with power-law indices (in $\mathrm{d}N/\mathrm{d}E \propto E^{-\delta}$) mostly around $\delta \approx$2–3.5.

Late-type active stars are notorious emitters of steady synchrotron emission ascribed to accelerated MeV electrons in closed magnetic loops (White, Kundu, & Jackson 1989). The Sun produces such electron populations during flares only, revealing power-law density distributions in energy where $\mathrm{d}N/\mathrm{d}E \propto E^{-\delta}$, with $\delta \approx$ 3–5. We have analyzed three- and four-point VLA radio spectra (1.4–14 GHz) of several nonflaring K/M dwarf stars. The model of White et al. (1989) has been applied to fit the spectra. In summary, this model is based on a dipolar (or "monopolar") magnetic field buried under the stellar surface, with a characteristic scale length, a base density of nonthermal electrons, a base magnetic field strength, and the index δ of the (assumed) power-law electron distribution. Two expansion laws for the densities are available. The measured flux determines the number of required loops. Since the fitting problem is somewhat underdetermined, we searched all solutions in the gridded parameter space that acceptably fit (in the χ^2 sense) the spectra. The δ parameter was the best constrained of all, often found between $2.0 \leq \delta \leq 3.5$ (Table 1 for dipole fields).

Table 1. Power-law indices δ for our star sample (dipole model)

star	δ	star	δ	star	δ
UV Cet/1	2.00–2.90	YY Gem/2	2.00–2.20	Gl867B	2.00–5.00
UV Cet/2	2.30–3.40	YY Gem/3	2.50–3.40	Gl355	2.00–5.00
UV Cet/3	2.00–3.10	Castor	2.00–4.00	GJ9638	2.00–5.00
UV Cet/4	2.00–3.20	Gl494	2.00–5.00	KZ And	2.00–5.00
UV Cet/5	2.00–3.00	Gl644	3.00–4.50	Gl171.2A	2.00–2.80
EQ Peg B	2.00–5.00	Gl719	2.00–5.00		
YY Gem/1	2.00–4.60	Gl799	2.10–2.70		

The hardness of our electron distributions typically exceeds that of nonthermal solar flare electron distributions. Impulsive solar flares show a soft-hard-soft spectral signature in the photon power-law index Γ, with a peak of typically

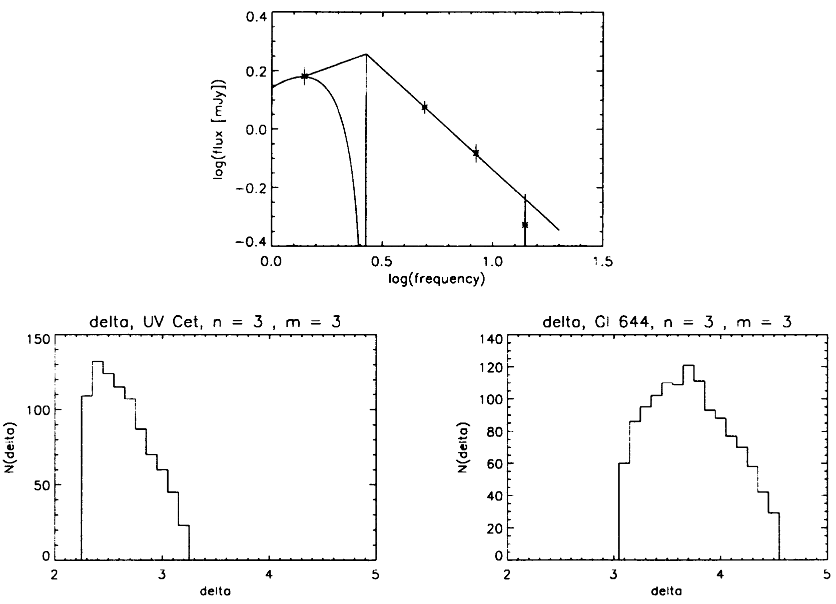

Figure 1. *Top:* Spectral fit to a 4-point spectrum (UV Cet). The curved solid line refers to optically thick radiation that disappears around 2.6 GHz. The power-law fit at higher frequencies is based on optically thin emission. *Bottom:* Number of solutions in parameter space for given δ (examples). Left: UV Cet. Right: Gl 644.

$\Gamma > 3$ lasting only for a short time (e.g., Dennis 1988). In the thick-target approximation, $\delta = \Gamma + 1$, resulting in δ larger than 4. On the other hand, long-lasting gradual flares are microwave-rich compared to their hard X-ray output; they show a soft-hard-harder development, typically reaching Γ = 3–4 at the flux peak and converging to Γ = 1.9–3 (from a sample presented by Cliver et al. 1986). This implies δ = 2.9–4. The stellar observations may suggest that nonthermal radio emission in stars stems from processes similar to large solar flares.

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