VLA OBSERVATIONS OF QUIESCENT AND FLARE MICROWAVE EMISSION FROM LATE-TYPE STARS: A UNIQUE PROBE OF CORONAL MAGNETIC FIELDS

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The high sensitivity and angular resolving power of the VLA permits observations for the first time of the steady (quiescent) microwave emission from stellar coronae as well as detailed studies of stellar flares. Gary and Linsky (1981) first detected steady 6 cm emission from χ^1 Ori (GO V) and UV Cet (M5.6e V), and Topka and Marsh (1982) subsequently detected quiescent emission from both components of EQ Peg (dM3.5e + dM4.5e).

Listed in Table 1 is a summary of sources detected in our program. χ^1 Ori was detected for two hours as a steady 1.1 mJy source at 6 cm on 1980 October 2, not detected during the previous hour of observation or on 1981 August 22, and then detected again as a 0.3 mJy source on 1981 October 16. Accordingly, the source is variable, but probably not on time scales that we associate with flaring. UV Cet was always a bright source when observed on each of four occasions, and its flux was always variable. Another dMe star system Wolf 630AB (dM4e + dM4e) also is a variable microwave source and, like the other detected systems, is a strong X-ray source. The dMe binary system YY Gem (dMle + dMle) is a variable 6 cm source with a flux that appears to depend on photometric phase.

The importance of these detections is that the flux levels are far larger than computed on the basis of thermal bremsstrahlung emission from the hot coronal plasma that produces the observed *Einstein* X-ray fluxes. Included in Table 1 are predicted values of the 6 cm flux, computed assuming optically thin bremsstrahlung emission in a 10^7 K corona consistent with the measured soft X-ray flux (cf. Gary and Linsky 1981). Since the 6 cm fluxes of the sources that have been detected all are considerably in excess of the predicted values and there is evidence for circular polarization in three of the sources,

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J. O. Stenflo (ed.), Solar and Magnetic Fields: Origins and Coronal Effects, 387–390.

Table 1. VLA detections

Source	Date	Time UT	6 cm Flux (mJy) (±3 σ or 3σ upper limit)	Fractional circular polarization	Predicted bremsstrahlung flux (mJy)
χ^1 Ori (G0 V)	2 Oct 80	1500-1555	<0.5	---	0.14
		1555-1606	0.8±0.8[1]		
		1606-1613	1.2±0.8		
		1616-1625	1.4±0.7	0±0.3	
		1625-1635	1.3±0.4		
		1655-1751	1.0±0.3		
	3 Oct 80	0756-1119	<1.8	---	
	22 Aug 81	1344-1934	<0.3	---	
	16 Oct 81	1050-1252	0.3±0.2	0	
UV Cet (M5.6 eV)	3 Oct 80	0358-0550	1.0-1.7±0.3[2]	0.5±0.3 RH	0.02
	19 Jun 81	1625-1717	1.7-2.3±0.4[2]	0.3±0.2 RH	
	22 Aug 81	0715-1345	1.5-2.2±0.5[2]	0.5±0.4 RH	
	22 Aug 81	0715-1345	<10.0[3]	---	
	16 Oct 81	0420-1040	1.5-4.0±0.5[4]	0.3±0.1 RH	
YY Gem (dM1e + dM1e)	20 Jun 81	1925-2142	<0.2	---	0.007
	22 Aug 81	1942-2004	1.8±0.3		
		2007-2034	1.6±0.3		
		2037-2104	1.5±0.3	~0.1 LH	
		2107-2134	1.1±0.3		
		2137-2204	0.9±0.3		
	23 Aug 81	1340-1401	1.4±0.3		
		1404-1431	1.3±0.3	0	
		1434-1501	1.3±0.3		
	26 Sep 81	1249-1343	0.4±0.2		
	27 Sep 81	1255-1339	0.4±0.2	0	
	28 Sep 81	1248-1338	0.5±0.2		
Wolf-630 AB (dM4e + dM4e)	22 Aug 81	2241-2400	0.5±0.2	0	0.20
	23 Aug 81	0000-0300	<0.2	---	
	27 Sep 81	0027-0045	1.4±0.3		
	28 Sep 81	0028-0041	1.5±0.3	~0.3 LH	
	29 Sep 81	0021-0039	1.2±0.2		

[1] 2 cm
[2] Variable flux.
[3] 20 cm
[4] Some flaring.

https://doi.org/10.1017/S0074180900030035 Published online by Cambridge University Press

we believe that the observations can be explained by gyroresonance emission from thermal electrons trapped in coronal magnetic fields. This is the emission process thought responsible for microwave emission from magnetic flux tubes above sunspots (e.g. Pallavicini et al. 1981). Model calculations by Gary and Linsky (1981) indicate that for modest photospheric magnetic fields (1000-2000 gauss) and coronal temperatures (5-10 × 10^6 K), gyroresonance emission is optically thick and the source radius is larger than the photospheric radius for several harmonics of the gyroresonance frequency. They found that the observed 6 cm flux from χ^1 Ori could be explained by coronal fields of

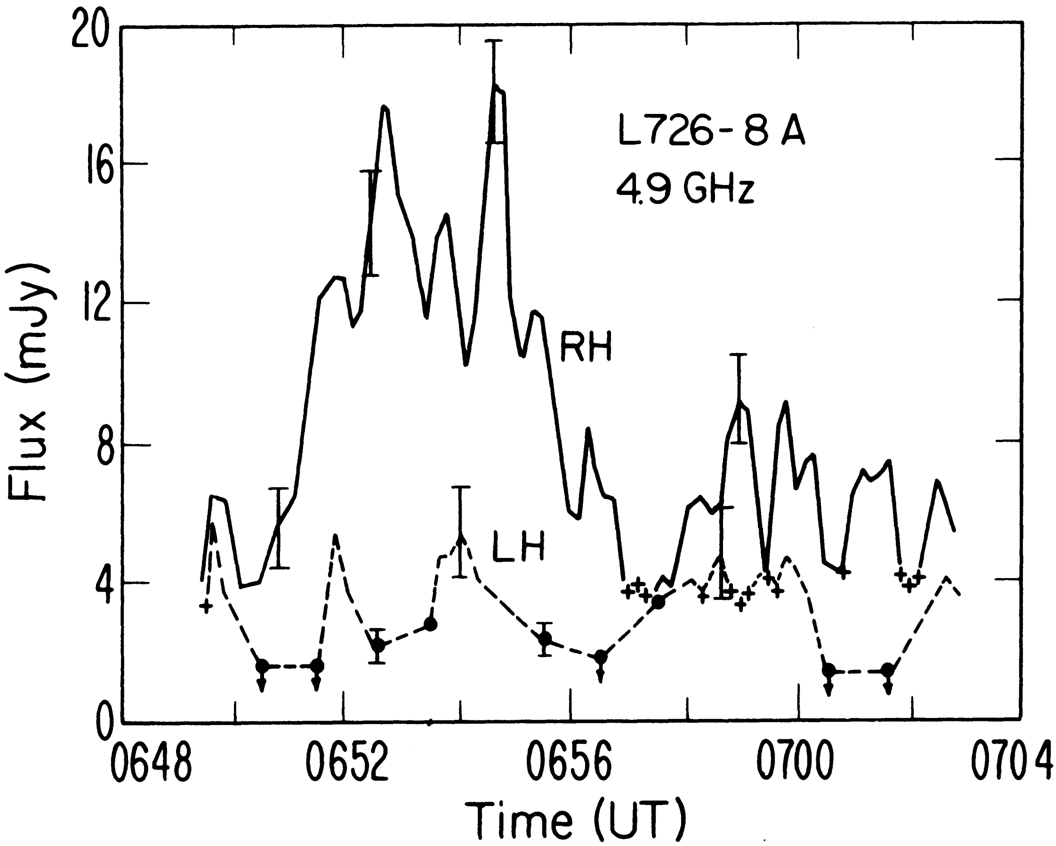

Fig. 1. 6 cm (4.9 GHz) flux of L726-8A in right-hand (RH) and left-hand (LH) circular polarization taken from VLA maps of 10 s integration time. Error bars indicate the typical 1σ rms noise level. For maps on which no source was visible, the 3σ noise level has been plotted as a '+'. In the LH flux curve, fluxes denoted by dots were taken from 1 minute integrated maps. Dots with arrows denote upper limits. From Gary et al. (1982).

at least 300 gauss and perhaps larger (if the emission is at a low harmonic). This technique provides a new and perhaps unique method for measuring coronal magnetic fields in late-type stars.

During our observing program we detected an unusual microwave flare from L726-8A (dM5.5e), whose companion is the prototype flare star UV Ceti (Gary, Linsky and Dulk 1982). The 6 cm flare had a peak flux of 10 mJy, and was almost entirely right hand circularly polarized. Furthermore, the flare exhibited a quasi-periodic variation in flux with a period of about a minute as illustrated in Fig. 1. The variability may be produced by oscillations of Alfvén or slow mode MHD waves in a magnetic loop of length L ~ 0.2 $R_{\odot}$, or perhaps by maser action. Either explanation requires large coronal magnetic fields and the observed period may turn out to be a means of measuring such fields.

This work is supported by NASA grants NSG-7287, NAGW-91, NGL-06-003-057, and NSG-9287 to the University of Colorado.

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DISCUSSION

BENZ: **Why do you know that the radio emission of stellar coronae and flares is gyrosynchrotron and not a plasma emission process?**

LINSKY: **We have no definitive proof as yet concerning the emission mechanisms, but there is some important evidence. We believe that the emission process for the quiescent corona is gyroresonance emission as a consequence of the high percentage of circular polarization, $\approx 10^7$ K brightness temperatures, and analogy with microwave emission above sunspots. The flare emission process is less certain, but for stellar flares the brightness temperatures appear to be $\geq 10^{10}$ K, suggesting a coherent process.**