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DETECTION OF QUIESCENT EXTREME-ULTRAVIOLET EMISSION FROM THE VERY LOW MASS DWARF VAN BIESBROECK 8: EVIDENCE FOR A TURBULENT FIELD DYNAMO

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ABSTRACT

We report the detection of quiescent EUV emission from the very low mass dwarf VB 8 by the *Extreme Ultraviolet Explorer* (*EUVE*) in the Lexan/B band (65–190 Å). We interpret this emission in terms of a hot coronal plasma and combine this information with previous X-ray detections to estimate the quiescent plasma temperature and emission measure. The combined observations made by *Einstein*, *ROSAT*, and *EUVE* between 1979 and 1994 are consistent with a quiescent coronal plasma temperature of (2–6) × 10^6 degrees and indicate the same emission measure to within a factor of about 2. The nonflaring corona of VB 8 then appears relatively constant over timescales of more than 10 yr. Our results are consistent with the picture of a turbulently driven or distributive dynamo for VB 8, rather than with a large-scale field dynamo which appears to dominate the solar corona. Evidence from X-ray and optical data concerning the long-term coronal variability of the more active stars of higher mass also points toward the idea that active late-type stars in general are dominated by a turbulent dynamo.

Subject headings: MHD — stars: coronae — stars: individual (van Biesbroeck 8) — stars: low-mass, brown dwarfs — turbulence — ultraviolet: stars

1. INTRODUCTION

Surveys of the sky at X-ray wavelengths suggest that emission, characteristic of hot, multimillion-degree collisionally excited plasmas, is an ubiquitous feature of main-sequence stars with convective envelopes, i.e., stars with spectral types mid-F through M (e.g., see reviews by Rosner, Golub, & Vaiana 1985 and Pallavicini 1989). This hot plasma is believed to be confined by closed magnetic loop structures similar to those observed in EUV and X-ray images of the solar corona. The magnetic loops are then thought to be generated in the form of flux tubes by a magnetic dynamo operating near the boundary between the convective envelope and radiative core. A nice overview of this classical dynamo scenario is presented by De Luca & Gilman (1991).

Canonical stellar evolution theory predicts that main-sequence stars with masses of approximately 0.3 $M_\odot$ and lower are "fully convective," i.e., the temperature gradient throughout these stars is sufficiently high that they are adiabatically unstable, and they do not possess radiative cores (e.g., Dorman, Nelson, & Chau 1989, and earlier references therein). If this is indeed the case, then the nature of the outer atmospheres of these stars becomes a matter of special astrophysical interest because conventional thinking suggests that the cyclic large-scale "shell" field dynamo, such as that which dominates solar magnetic activity, should not work (e.g., Rosner 1980). Do these stars support hot, X-ray–emitting coronae, and if so, how?

The first part of this question was perhaps answered in the early 1980s when Johnson (1981) reported the detection of the very low mass star VB 8 (Van Biesbroeck 1961) by the *Einstein* high-resolution imager (HRI). VB 8 (distance = 6.4 pc) has a spectral type M7e V (Dahn, Leibert, & Harrington 1986) and a mass of $M/M_\odot \sim 0.08$, based on the photometry compilation of Leggett (1992) and the mass-luminosity relation of Henry & McCarthy (1993). This places VB 8 well below the theoretical fully convective mass limit and near the hydrogen-burning limit. Subsequently, more extensive X-ray surveys of emission of M dwarfs with *Einstein* and *ROSAT* (e.g., Barbera et al. 1993 and Fleming et al. 1993, respectively) have confirmed unequivocally that the late M dwarfs do indeed sustain hot, X-ray emitting coronae. Interestingly, these surveys differ in their conclusions as to whether or not there exists a drop in X-ray luminosity as the fully convective limit is reached. Barbera et al. (1993) present evidence supporting such a drop in X-ray luminosity, whereas Fleming et al. (1993) argue that the ratio of X-ray to bolometric luminosity, $L_X/L_{\rm bol}$, is not correlated with M_v for M_v above and below the values corresponding to the fully convective limit. The matter now appears to have been settled in favor of the latter, following the Fleming, Schmitt, & Giampapa (1995) *ROSAT* study of all K and M dwarfs within 7 pc of the Sun.

VB 8 has also been detected by *EXOSAT* (Johnson 1987; Tagliaferri, Doyle, & Giommi 1990) and *ROSAT* (Fleming

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TABLE 1

EUV AND X-RAY OBSERVATIONS OF VB 8

Instrument	Year	Count Rate (count ks^{-1})	L_X, L_{EUV}[a] (ergs s^{-1})	Reference
EUVE DS Lexan/B..........	1994	1.98 ± 0.16[b]	7.44×10^{26}	This paper
ROSAT PSPC................	1991	31 ± 3[c]	8.3×10^{26}	Fleming et al. (1993)
EXOSAT LE1 3000LX......	1985	3.4 ± 0.3[d]	1.8×10^{28}	Johnson (1987); Tagliaferri et al. (1990)
Einstein HRI..................	1979	5.8 ± 1.7	2.6×10^{27}	Johnson (1981)

[a] EUV and X-ray luminosities are from the same references as the count rates, except for *Einstein: EUVE* L_{EUV} corresponds to the Lex/B 65–190 Å bandpass and $\log T = 6.5$; *ROSAT* L_X (0.1–2.4 keV) corresponds to quiescence and a two-component model with temperatures $\log T = 6.0$ and 6.95; *EXOSAT* L_X (0.05–2 keV) corresponds to flare and an average conversion for $\log T \sim 6.6$–7.3; *Einstein* L_X was calculated here for assumed $\log T = 6.5$ and 10% bandpass (~0.12–3.7 keV).

[b] Stochastic variability with flare corresponding to an energy of $\sim 5 \times 10^{31}$ ergs.

[c] Flared during observation; count rate corresponds to quiescence (Fleming et al. 1993).

[d] Large flare occurred during observation; count rate corresponds to average value during flare (Tagliaferri et al. 1990).

et al. 1993), and now by *EUVE*. VB 8 flared during both the *EXOSAT* and *ROSAT* observations, and Tagliaferri et al. (1990) established that essentially all of the photons detected by *EXOSAT* originated during the flare; the quiescent emission was not detected. These flares are very strong indications that the corona of VB 8 is heated by magnetic processes; the consequences are discussed more fully by Tagliaferri et al. (1990). Interestingly, Johnson (1987) derived a very cool temperature for the nonflaring corona, 6.4×10^5 K. This is cooler than any temperature found for other M dwarfs or, indeed, other late-type stars, using X-ray data (e.g., Schmitt et al. 1990), and suggests that the corona of VB 8 might be fundamentally different to the coronae of higher mass stars with radiative cores. The EUV and X-ray observations of VB 8 are summarized in Table 1.

It is through observations of nearby very low mass stars, such as VB 8, that we might gain further understanding of how the magnetic field generation and coronal heating in these stars work. Ideally, one would like to observe them at high spectral resolution in the EUV and X-ray range, such

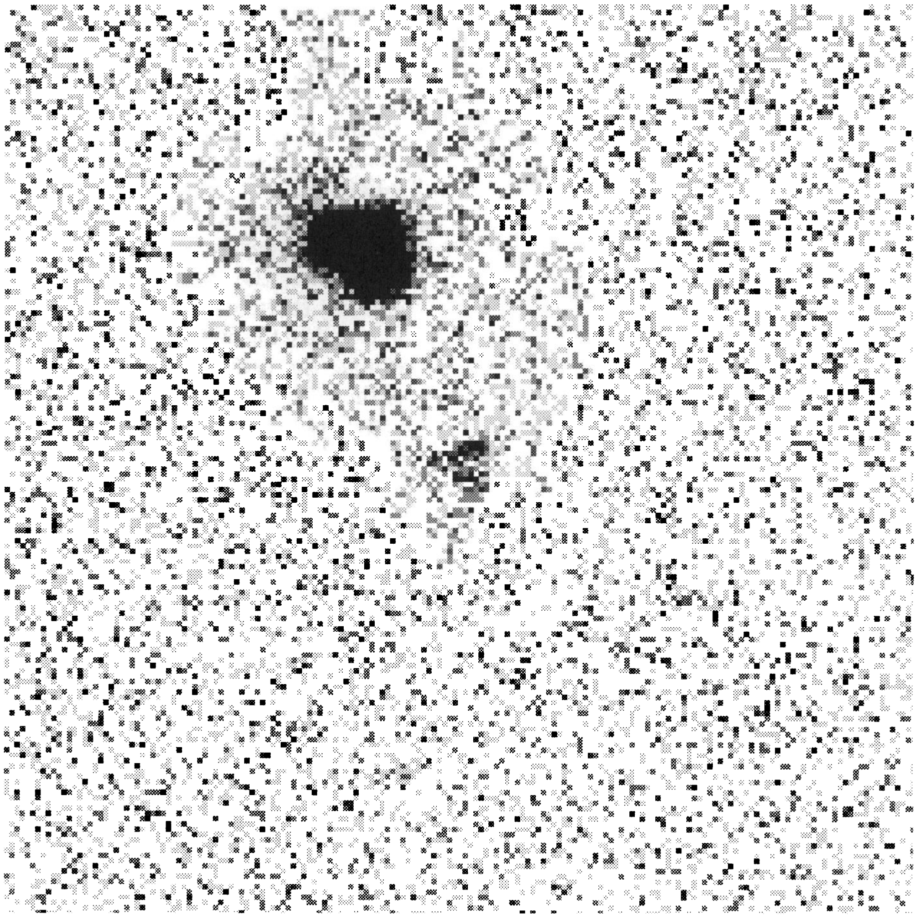

FIG. 1.—Central portion of the *EUVE* Deep Survey (DS) image showing the detection of VB 8 in the Lexan/B filter. VB 8 lies in the center; the bright source toward the top and slightly left of center is the dMe flare star binary Wolf 630 (GJ 644 AB), which appears saturated at the contrast level of this image. Note the characteristic trilobed structure of the DS point-spread function just discernible in the VB 8 image.

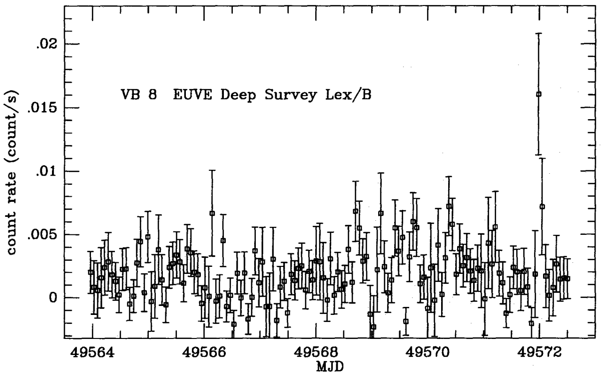

FIG. 2.—DS light curve of VB 8. Each time bin corresponds to one *EUVE* orbit, or about 5540 s of elapsed time and between ∼500 and ∼2000 s of exposure time.

that the details of the coronal temperature distribution and density can be derived through a detailed analysis of spectral lines. Unfortunately, the very low mass stars like VB 8 are more than an order of magnitude too faint in the EUV and X-rays to be observed with the *EUVE* spectrometers or with *ASCA*. However, the nearest very low mass stars are within the reach of broadband EUV and X-ray instruments. Such observations are therefore extremely important because they offer the only opportunity of studying the coronae of low-mass stars at the present time.

In this paper, we discuss the detection of VB 8 in the *EUVE* Deep Survey (DS) Lexan/B filter. Using the observed count rate, combined with the count rates from the earlier *Einstein* and *EXOSAT* and, more recently, *ROSAT* observations, we provide new constraints for the coronal temperature structure and variability. The results are discussed in the context of the operation of magnetic dynamos in very low mass, fully convective stars. Finally, we review briefly some evidence supporting the idea of the dominance of a turbulent dynamo, rather than a solar-like large-scale field dynamo, throughout the range of very active late-type stars.

2. OBSERVATIONS

The *EUVE* DS instrument shares a telescope with the three EUV spectrometers. On-boresight photons not intercepted by one of the three symmetrically oriented spectrometer reflection gratings impinge upon the DS Lexan/B filter. This filter has a 10% transmission bandpass of 65–190 Å and an effective area which peaks at about 28 cm^2. The *EUVE* instrumentation is described in more detail by Welsh et al. (1990) and by Bowyer & Malina (1991).

Our original *EUVE* observation with the Deep Survey (DS) and Deep Survey Spectrometer telescope (DSS) was aimed at the dMe binary Gl 644, otherwise known as Wolf 630, and so VB 8 was observed as a serendipitous counterpart. The observation spanned the period 1994 July 30 23:08 to 1994 August 8 23:59 with an effective exposure time of about 200 ks. VB 8 is easily visible as a source in the resulting DS detector photon image, with a count rate of 1.98 ± 0.16 count ks^{-1} and is imaged close enough to the telescope boresight so as not to suffer from the gradual broadening that characterizes the point-spread function at large distances from boresight. The DS photon image of VB 8 and Wolf 630 is illustrated in Figure 1.

The DS data reduction followed the procedures described in Drake, Laming, & Widing (1995). We constructed a light curve from the photon event list using the IRAF/PROS XTIMING package. The background was determined from a region adjacent to VB 8 and was sufficiently large so as to minimize Poisson errors. By experimenting with different time bins we found the smallest time bin which yielded a reasonable number of source counts. Our final light curve uses contiguous time bins of 5540 s, which corresponds to the average *EUVE* orbital period (the effective exposure times vary between ∼500 and 2000 s) and is illustrated in Figure 2. The light curve exhibits some structure suggestive of stellar variability which is not consistent with a constant source count rate. However, it is clear that we have detected the *quiescent* EUV coronal emission from VB 8. Around MJD 49572 a flarelike brightening occurred, corresponding to an increase from the quiescent count rate of slightly less than order of magnitude. The flare decay timescale was roughly one *EUVE* orbit, or about 1–2 hr; the corresponding flare energy for an assumed flare temperature of 10^7 K was $\sim 5 \times 10^{31}$ ergs.

3. BROADBAND FILTER ANALYSIS

3.1. *Overview of the Method*

While a broadband filter on its own carries no spectral information, by combining information for different filters it is, in principle, possible to gain information regarding the plasma temperature and emission measure. This is not a new approach; see, for example, a discussion of a similar method applied to *EXOSAT* broadband observations presented by Pallavicini et al. (1988).

For a given plasma radiative loss model, an observed broadband count rate corresponds to a plasma emission measure, EM, for any given *isothermal* plasma temperature, T. Each filter count rate, then, when combined with a plasma radiative loss model, defines a locus in the emission measure–temperature plane. In the case of a truly isothermal plasma, the intersection of two different loci corresponding to two different filter count rates in the EM-T plane yields the plasma EM and T. In the case of stellar coronae, the plasma is not isothermal, and the individual loci then represent the *upper limit* to the plasma EM at any given T. Given sufficient observations in a number of different bandpasses, it is, in principle, possible to invert the system of equations describing the EM-T loci for each of the different filters to yield the continuous emission measure distribution as a function of temperature EM-(T). In practice, the EUV and X-ray wavelength range is not sufficiently well sampled by the combination of broadband instruments on missions launched to date to make this feasible. Also, we note that, when combining nonsimultaneous observations with different instruments, this type of analysis implicitly assumes that the source is effectively constant (i.e., the variability of the source is relatively small). We argue that this is the case for all but the *EXOSAT* observation of VB 8 below.

We have used the observed VB 8 count rates from the different satellites listed in Table 1 to calculate EM-T loci using the optically thin plasma radiative loss model of Landini & Monsignori-Fossi (1990), modified to include more complete and modern atomic data (Monsignori-Fossi 1993) calculated for the "cosmic" composition of Allen (1973). The exact plasma composition is not very important

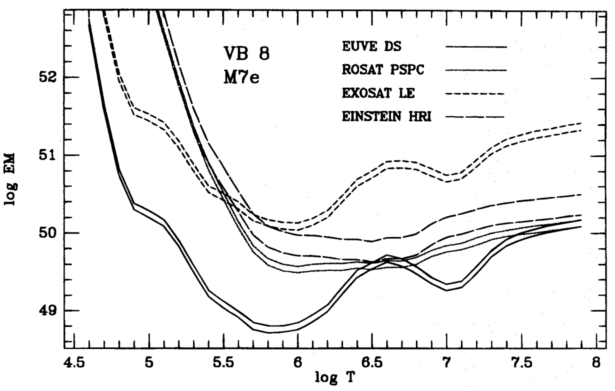

FIG. 3.—Logarithmic EM-T loci for each of the observations listed in Table 1 (see text). Each locus is represented by two curves corresponding to the uncertainties in the measured count rates.

for the analysis, as long as there are not extreme deviations from the solar or "cosmic" mixtures present in the corona of VB 8. Global metallicity differences with respect to the Allen (1973) abundances are simply reflected in a commensurately different EM, since most of the flux up to temperatures of 30×10^6 K or so is in the form of spectral lines. The resulting loci are illustrated in logarithmic form in Figure 3. Interstellar medium absorption by H and He was corrected for using a neutral hydrogen column density of $N_{\rm H} = 1.5 \times 10^{18}$, based on interpolation in the data compiled by Fruscione et al. (1994). We emphasize that the precise value of $N_{\rm H}$ is not important for this analysis. There are two features of Figure 3 of special interest which we discuss below.

3.2. *Coronal Temperature*

The formal isothermal temperature solution based on the *EUVE*, *EXOSAT*, and *Einstein* HRI loci is $\log T = 6.6$. Solutions cooler than $\log T \sim 6.5$ are excluded by our *EUVE* observations.[11] If we allow slightly more pessimistic uncertainties than pure counting statistics, such as some small variability of the quiescent coronal emission between the different observations, a second solution $\log T \sim 7.8$ is possible.

We consider the prospects for significant plasma at temperatures of $\log T \sim 7.8$ in the corona of VB 8 to be poor, but difficult to rule out with empirical certainty at this time. At these temperatures, Fe is stripped down to the H-like and He-like charge states, and only bremsstrahlung would be observed in the *EUVE* Lexan/B bandpass. Such temperatures should be discerned by the *ROSAT* PSPC pulse height spectra, however. Fleming et al. (1993) fitted a two-temperature model to the energy distribution of VB 8 (though this corresponds to a partly flaring state) and Proxima Centauri observed by the PSPC and obtained much cooler temperatures of 10^6 and 9×10^6 K. This result is confirmed by Giampapa et al. (1996). Our isothermal solution of 4×10^6 K is essentially the geometric mean of these. We also note that this temperature is in good agreement with the temperatures determined for M dwarfs from *Einstein* IPC observations by Schmitt et al. (1990).

As mentioned above, the coronae of late-type stars have *continuous* rather than isothermal temperature distributions, and the interpretation of Figure 3 is not quite so straightforward as the isothermal case implies. However, more careful consideration of the temperature sensitivities of the different instruments supports the general picture. For example, it is clear that the *Einstein* and *ROSAT* observations require significant material at temperatures $T \geq 10^6$ K, otherwise their observed count rates cannot be produced without significantly overpredicting the observed *EUVE* DS count rate. A relatively flat EM distribution between 10^6 K and 10^8 K would overpredict the *EUVE* count rate, and we know from Figure 2 that this corresponds to quiescence. The only plausible EM distribution which reproduces all the observed count rates is then one which peaks at $T \sim 2$–6×10^6 K. We note that qualitatively similar EM distributions have been observed for the intermediate activity dwarfs ϵ Eri and ξ Boo A, based on detailed line analyses of *EUVE* spectra (Laming, Drake, & Widing 1996a, 1996b; Drake, Laming, & Widing 1996).

3.3. *Variability*

The responses of the *EXOSAT* and *EUVE* telescope and Lexan filter combinations are very similar; indeed, it is clear from Figure 3 that the two curves have very similar shapes. The difference between them, then, represents a change only in the source EM. Hence, the separation of the *EXOSAT* and *EUVE* loci is simply a reflection of the large flare which occurred during the former observation. A similar argument can be applied to the comparison between the *Einstein* HRI and *ROSAT* PSPC loci. The near coincidence of the loci indicates that the source EM was the same to within a factor of about 2 during the two observations and corresponds to quiescence (Fleming et al. 1993; Johnson 1987). If we now fold in the *EUVE* Lexan/B information, our conclusions above regarding the coronal temperature imply that the source EM during this observation was also very similar to that during the X-ray observations. The source is either essentially constant to within about a factor of 2, or else three of the observations taken between 1979 and 1994 fortuitously coincided with times when VB 8 was at the same activity level. We strongly favor the former explanation.

4. DISCUSSION: EVIDENCE FOR A TURBULENT DYNAMO

The two main conclusions of this work are (1) the predominant emission measure in the corona of VB 8 lies at temperatures between $T \sim 2 \times 10^6$ and 6×10^6 K, and (2) this *quiescent* coronal emission appears to be relatively constant over timescales of more than 10 yr. How does a (supposedly) "fully convective" star such as VB 8 maintain a dynamo to sustain this type of coronal activity? Other stars of very late spectral type also exhibit flares; e.g., the M8e V star VB 10 (Herbig 1956; Linsky et al. 1995) and the M8e V star LHS 2397a (Bessell 1991). These observations of

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[11] By combining the *EXOSAT* and *Einstein* observations of VB 8, Johnson (1987) derived an isothermal plasma temperature of $T = 6.4 \times 10^5$ K, which he noted was exceptionally cool. Indeed, to our knowledge such a cool *dominant* temperature has not been found for any other stellar corona to date. However, this temperature is somewhat misleading since it appears that it was derived from a combination of the *EXOSAT flare* count rate and the *Einstein* count rate, which presumably corresponds to quiescence (see text). Indeed, the *EXOSAT quiescent* count rate is not quoted in the text of Johnson (1987), and, moreover, Tagliaferri et al. (1990) assert that the photons detected during this observation are all from the flare period. Our *EXOSAT* and *Einstein* EM-T loci in Figure 3 formally recover the Johnson (1987) isothermal plasma "temperature," which provides a good consistency check between the two analyses. These intersect at $\log T = 5.7$. The temperature derived in this way is meaningless, of course, since the two observations refer to entirely different plasmas: one the flaring corona and the other the quiescent corona.

flares provide strong evidence that magnetic activity is a common phenomenon in the very low mass stars, right down to the hydrogen-burning limit.

If the solar dynamo is indeed located in a thin layer near the boundary between the convective envelope and radiative core, as current theory suggests (e.g., see De Luca & Gilman 1991 for a recent review), then it would seem difficult to stretch the solar $\alpha\omega$ dynamo analogy to the M dwarfs which are probably fully convective (we say "probably" here because it might be possible that a small radiative core can be sustained by the influence of magnetic fields; see, e.g., the discussion in Cox, Shaviv, & Hodson 1981). However, melodramatic analogies to the solar case are perhaps misleading. For example, the need to place the solar dynamo at the interface of the radiative core and convective envelope was observationally confirmed by the apparent absence of differential rotation within the convection zone (see, e.g., De Luca & Gilman 1991): no such observations exist for M dwarfs. Indeed, the dynamo theory applied with varying degrees of success to the Sun has not yet been applied with a similar degree of rigor to the very low mass stars. Moreover, the need for a large-scale, solar-like magnetic field is not yet an observational requirement for M dwarfs as it is for the Sun. The observation of cycles analogous to the solar cycle would change this view.

Recently, Weiss (1993) and Durney, De Young, & Roxburgh (1993; see also the discussion by Rosner et al. 1995, and Rosner 1980) have suggested that small-scale magnetic fields can be generated in the solar convection zone by a turbulently driven dynamo. This "turbulent field" does not require rotation, although the generation rate increases with increasing rotation. Interestingly, the total energy stored in the turbulent field could be higher than that in the large-scale field. These papers also discuss the possibility that low-mass stars, which under conventional dynamo theory are probably unable to generate a large-scale field due to the absence of the radiative core, should only have turbulent fields. The turbulent field theory (or the "distributive" dynamo of Rosner 1980) is also particularly appealing since it might explain two important observational clues: (1) the apparent lack of a change in coronal heating efficiency going from stars which have radiative cores to the fully convective M dwarfs mentioned in § 1, and discussed by Fleming et al. (1993) and Fleming et al. (1995); and (2) an absence of long-term stellar cyclic X-ray variability by more than a factor of ~2 in *all* of the Hyades late-type dwarfs (including those with radiative cores) uncovered in the study of *Einstein* and *ROSAT* observations by Stern, Schmitt, & Kahabka (1995; see also Schmitt, Fleming, & Giampapa 1995).

The Hyades dwarfs of the Stern et al. (1995) study *do* posess radiative cores and, based on the solar analogy, are presumably capable of generating solar-like large-scale fields. Stern et al. also pointed to the evidence from long-term Ca II emission core monitoring presented by Baliunas et al. (1994) and references therein, which shows that smooth solar-like cyclic variability is not generally observed in young (less than 1 Gyr) active dwarfs (see also the review by Saar & Baliunas 1992). On shorter timescales, Mathioudakis et al. (1995) have also seen no differences in EUV luminosity more than a factor of 2 in a sample of active stars when comparing *EUVE* survey fluxes to those derived from the *ROSAT* Wide Field Camera survey performed 2 yr earlier. Further support for the turbulently driven dynamo comes from the very recent *ROSAT* study of M dwarfs by Giampapa et al. (1995), the modeling of which suggests that the coronal geometry for low-mass dwarfs is dominated by relative compact loop configurations, and that the emission contribution of structures with large-scale dipolar or quadrapolar geometry is negligible.

The *ROSAT*, *EUVE*, and Ca II observations could all be explained if turbulent magnetic activity dominated over any large-scale field activity at the rotation rates typical of active dwarfs. Stern et al. also pointed out that the most active M dwarfs should not exhibit cyclic activity.

A "saturation" limit in stellar activity marked by a maximum in X-ray surface flux is observed in the very rapidly rotating stars such as the young Pleiades dK stars and the very active RS CVn systems (see, e.g., the discussion of Sciortino 1993). Can activity saturation explain the lack of long-term variability in the active stars? While this activity saturation is not yet well understood, it cannot in itself explain why the active stars do not appear to show much long-term variability because stars such as the Hyades dwarfs of Stern et al. (1995) are not at the saturation limit. The lack of substantial long-term variability must set in at activity levels below the saturation level, or, in evolutionary terms, it must persist well beyond the point at which a young, rapidly rotating star spins down to below its saturated state.

The picture which emerges from the above discussion is one in which the very low mass, fully convective stars do not have radiative cores, and the large-scale field dynamo does not operate. The magnetic activity on these stars is generated by a turbulently driven dynamo process such as that discussed by Durney et al. (1993) and by Weiss (1993). More massive stars with radiative cores generate solar-like large-scale magnetic fields through the operation of an $\alpha\omega$ type shell dynamo. However, they also generate small-scale magnetic fields through the operation of a turbulently driven dynamo. In stars with radiative cores which have relatively high rotation rates, such as the fairly young Hyades dwarfs discussed by Stern et al. (1995), the turbulent dynamo dominates, and well-defined activity cycles are not observed. As stars evolve and spin down from young, rapid rotators, their magnetic activity changes from a regime in which the turbulent dynamo dominates to one characterized by a solar-like large-scale field shell dynamo. This scenario is essentially the same as that predicted in the earlier discussion of Weiss (1993).

It might be possible that large-scale field dynamos do operate in the lowest mass, "fully convective" stars, but that the turbulently driven dynamo dominates, as we suspect is the case in the active stars with radiative cores. One observational test of this picture might be to determine whether or not the very slow rotators among the lowest mass, "fully convective" stars exhibit stellar cycles or not; a positive result would provide a challenge for modern dynamo theory. Such a test would require long-term monitoring of the chromospheric or coronal emission of these faint stars, which is not an easy task. Alternatively, in the case of the more massive stars with radiative cores, one might expect the activity in the outer atmospheres of stars dominated by a turbulently driven, or distributive, dynamo to have different functional dependencies on the various stellar parameters to the activity of stars dominated by a large-scale field shell dynamo. In this regard, the growing body of data on chromospheric and coronal emission from late-type stars perhaps warrants detailed reexamination to look for changes in outer atmosphere activity in regimes which might be expected to be dominated by solar-like and by turbulently driven, or distributive, dynamos. One possible example can be found in the recent results of Hempelmann et al. (1995), whose analysis of the rotation-activity relation based on *ROSAT* all-sky survey data shows evidence for a qualitative change in behavior near Rossby number values $\mathrm{Ro} \sim 1$: for $\mathrm{Ro} > 1$, coronal activity appears to drop more rapidly with increasing Rossby number than for $\mathrm{Ro} < 1$ (see also Walter 1982 and Vilhu 1984).

5. SUMMARY

We have shown that the dynamo processes which must be at work in VB 8 sustain an active, relatively constant corona with a temperature of several million degrees. This coronal temperature is typical of M dwarfs with higher masses and radiative cores. These results provide evidence that a turbulent dynamo such as that discussed by Durney et al. (1993) and Weiss (1993), or a similar dynamo mechanism, rather than a solar-like large-scale field shell dynamo, dominates the magnetic activity of fully convective M dwarfs. The implication then, is that this dynamo also dominates the young active stars with radiative cores, such as the Hyades dwarfs discussed by Stern et al. (1995). As these stars spin down with age, their magnetic activity changes from a regime dominated by the turbulent field dynamo to one characterized by solar-like large-scale field shell dynamos which give rise to activity cycles. This scenario provides a qualitative picture of the evolution of magnetic activity with stellar age which supports the behavior predicted earlier by Weiss (1993).

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