CORONAL STRUCTURE IN YOUNG FAST ROTATORS

D. García-Alvarez\textsuperscript{1}, J.J. Drake\textsuperscript{1}, V. Kashyap\textsuperscript{1}, L. Lin\textsuperscript{1}, and B. Ball\textsuperscript{1}

\textsuperscript{1} Harvard-Smithsonian CfA, 60 Garden Street, Cambridge, MA 02138

ABSTRACT

We present an analysis of high resolution Chandra spectra of three fast-rotating (P_{\text{orb}} \leq 12 \text{ hr}) late-type dwarfs with similar ages \sim 30 \text{ Myr}. We have determined the temperature structure and chemical composition of the emitting plasma in their coronae as analyse how rotation rate and spectral type can affect their coronal properties.

Key words: stars; fast rotators; coronae; abundances.

1. INTRODUCTION

The last four years—the beginning of the Chandra and XMM-Newton era— have seen early hints of abundance anomalies fleshed out into an interesting array of diverse abundance patterns in which active stars appear to show signs not only of low FIP element depletion, but also of high FIP element enhancements (e.g.; Drake 2003, and earlier references therein). These patterns of coronal abundance anomalies are telling us something about the dynamical structure and heating of coronal plasma; the challenge is to learn to read these patterns. The aim of the work we present is to analyse how rotation rate and spectral type affect the stellar coronal properties.

2. THE TARGETS AND THE DATA ANALYSIS

Our sample contains three fast-rotating (P_{\text{orb}} \leq 12 \text{ hr}) late-type dwarfs with similar ages \sim 30 \text{ Myr}. Their physical parameters and spectra are shown in Table 1 and Fig. 1 respectively. AB Dor, Speedy Mic and RST 137B were relatively quiescent, showing no large flare events, excepting the moderate event on AB Dor midway through the observations. Pipeline-processed photon event lists were reduced using CIAO 3.2, and were analyzed using the IDL-based PINTofALE\textsuperscript{1} software (Kashyap & Drake 2000). The analysis we have performed consisted of line identification and fitting, reconstruction of the plasma emission measure distribution including allowance for blending of the diagnostic lines used, and finally, determination of the element abundances. Spectral line fluxes were measured by fitting modified Lorentzian functions. We use the “line-free” continuum spectral regions 2.4-3.4, 5.3-6.3 and 20.4-21.4 Å which serve as both temperature constrain and to provide an absolute normalisation for the DEM.

3. THERMAL STRUCTURE AND ABUNDANCES

In order to obtain the differential emission measure (DEM) we have performed a Markov-Chain Monte-Carlo analysis using a Metropolis algorithm (MCMC) on the set of supplied line flux ratios (O, Ne, Mg, Si, Fe 17,

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|c|c|c|}
\hline
Star & Sp.Tp. & B-V & P_{\text{rot}} & \sin i & ObsID & Exp \\
\hline
AB Dor & K0V & 0.80 & 12hr & 93 & 16 & 60 \\
Speedy Mic & K3V & 0.94 & 9hr & 132 & 3491 & 70 \\
RST137B & M0V & 1.60 & 9hr & 50 & 16 & 60 \\
\hline
\end{tabular}
\caption{Summary of Stellar Parameters.}
\end{table}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{Figure1.png}
\caption{Chandra X-ray HETG-ACIS-S spectra. The strongest lines are identified.}
\end{figure}

\footnote{Available from http://hea-www.harvard.edu/PINTofALE}
2. CONCLUSIONS

AB Dor, Speedy Mic and RST 137B represent young (~30 Myr) rapidly rotating (P_{orb} ≤ 12 hr) with spectral type ranging from K0 V to M V. As such, a comparison between their coronal properties provides an illuminating glimpse of any fundamental underlying differences in their magnetic dynamos and activity. Based on an analysis of high resolution Chandra X-ray spectra of these stars we draw the following conclusions.

1. The temperature structures of both AB Dor and Speedy Mic are fairly similar, showing a peak at log \( T[K] \approx 7.0 \). RST 137B shows a flatter DEM which also peaks at log \( T[K] \approx 7.0 \). AB Dor and Speedy Mic show more evidence of emitting plasma at log \( T[K] > 6.3 \). The slope for the DEM, between log \( T[K] = 6.2 \) and log \( T[K] = 7.0 \), seems to be shallower as the rotational rate and spectral type increase.

2. Studies have shown that photospheric abundances for AB Dor and its ‘close’ companion RST 137B can be assumed as solar-like. Based on this, we observe that all three stars show evidence for an inverse-FIP effect showing depletion of the low FIP elements (<10 eV) relative to photospheric values. The fastest rotator of our sample, RST 137B, shows depletion in all the elements relative to those of AB Dor and Speedy Mic. Depletion in the low FIP elements only is observed in Speedy Mic.

3. Speedy Mic and RST 137B show much lower Fe abundances compare with AB Dor, than those of Si and Mg – elements that both have very similar FIP to Fe. This effect could be showing a mass dependency for the chemical fractionation (such as gravitational settling of the heavier Fe ions).

ACKNOWLEDGMENTS

DGA and WB were supported by Chandra grants GO1-2006X and GO1-2012X. LL was supported by NASA AISRP contract NAG5-9322. JJD and VK were supported by NASA contract NAS8-39073 to the Chandra.

REFERENCES

Drake, J. J. 2003, Advances in Space Research, 32, 945
—. 2000, Bulletin of the Astronomical Society of India, 28, 475