BASIC PARAMETERS DETERMINING X-RAY EMISSION LEVEL IN STARS OF SPECTRAL TYPE LATER THAN F5

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This is a merely exploratory search for estimating the importance of those stellar parameters which we believe to be relevant to the X-ray emission from stars possessing outer convective envelopes.

Belvedere et al.(1981,1982) have shown that a mechanism which converts magnetic into thermal energy is plausible for explaining the X-ray emission level in late type main sequence and giant stars. One of the main conclusions of their work is that the average surface X-ray flux F_x depends on the square of the average surface magnetic field strength B. The surface magnetic activity, in stars possessing outer convective envelopes, is likely due to the interaction of rotation with convection which produces both differential rotation (Belvedere et al. 1980a) and dynamo action by the α-effect (Belvedere et al. 1980b). Therefore we would expect that the level of magnetic field intensity depends on star's rotation Ω and the depth of the convection zone(c.z.) D, because both parameters are very important in determining the strength of the interaction.

In order to estimate the dependence of B on Ω and D, we assume that the amplitude of B is limited by buoyancy, thus comparing the rise time of a flux tube at the bottom of the c.z. with the amplification time of the dynamo process (Durney and Robinson 1982). This leads to the following expression:

$$B \propto \rho_b^{1/2} \Omega H_b^{5/2} R_b^{-3/2} \quad (1)$$

where ρ_b, H_b and R_b are respectively the density, the pressure scale height and the radial distance from the star's center at the bottom of the c.z. Assuming the c.z. adiabatically stratified, both ρ_b and H_b can be expressed in terms of fractional depth $d=D/R_S$ ($R_S \equiv$ stellar radius) of the c.z. We thus obtain from expression (1), neglecting the very slowly varying factor $(R_b D/R_S)^{1/4}$:

$$B \propto d^3\Omega \qquad \text{and} \qquad F_x \propto d^6\Omega^2 \quad (2)$$

In the following figure we plot the X-ray surface flux $\log F_x$ of 41 stars observed by Pallavicini et al.(1981), Stern et al.(1981) and Walter (1981) vs. their rotational velocities $v_e = \Omega R_S \simeq v \sin i$ (see Uesugi and Fukuda, 1982, for Stern's stars). The straight lines show the behavior of the theoretical relationship (2) calibrated with the Sun, taking the flux

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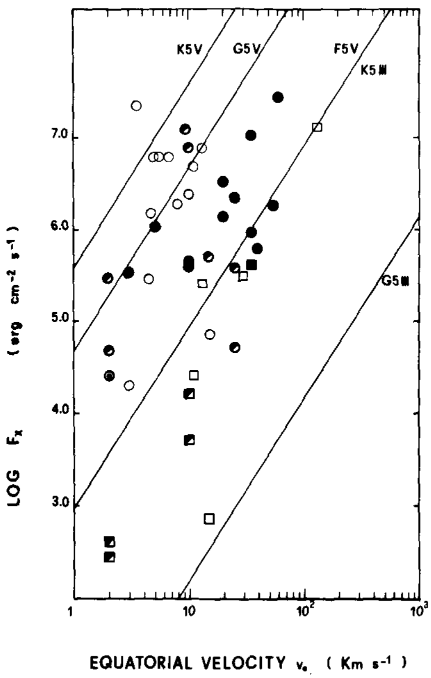
level of $\log F_{xo}=4.7$,for different spectral type and luminosity class stars.

Besides the uncertainties due to v sin i,here assumed as v_e,and the observed F_x values,if we take into account that the rotational velocities of K stars are probably overestimated (Catalano,private communication), we see that the positions of most stars in the Figure can be accounted for in the framework of the present discussion.



In the figure,circles and squares represent respectively luminosity class V and III stars. Filled,empty and half filled symbols represent respectively F,G and K spectral type stars.

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DISCUSSION

Haisch: Comparing time-averaged surface He II fluxes is really the only sensible kind of comparison you can make between theory and observation. The problem is that I do not know what that means physically. We know that the X-ray flux is highly structured and originates from only a small fraction of the stellar surface. So I do not know what it means physically to compare the surface-averaged heating with the average X-ray emission.

Zuccarello: All of these calculations have been made in the framework of dynamo theory. We suppose that the magnetic field intensity depends on the interaction between rotation and convection. So we have used this data to make a comparison between theory and observation. I do not know if it is possible at the moment to make any other such comparison.

Kodaira: I have a comment concerning the small radius involved in the flare. I have shown that this may be up to 10^{19} and this is only a few percent of the stellar surface. This is the size of the white-light flare but may be the Hα-emitting region can be smaller than that. The ratio of the size of the white-light kernel to the total volume involved in the flare is of the order 100. If we take that same ratio here a very large volume may be involved, extending to a global instability. So I am not so sure that only a small fraction of the stellar surface may be involved in a stellar flare.

Rosner: I would like to make a comment here. This paper was mostly concerned with quiescent activity and not flaring. So I think that Dr. Haisch's comment was appropriate i.e. that solar X-rays arise in relatively compact active regions.

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