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ENERGY LOSSES BY STELLAR ACTIVITY PHENOMENA

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ABSTRACT For active late-type dwarfs, the total energy losses including both chromospheric and coronal radiation as well as the energy losses caused by stellar flares reach $3\cdot10^{-3}$ L_{bol}. To maintain such high energetic losses requires a high efficiency of the dynamo action in the convection zone. Mass loss by active late-type stars can probably approach the rate of 10^{-11} $M_{\odot}$/yr if we take into account the large-scale structure of their coronae and transient events. The phase of activity can continue for up to 1% of the lifetime of these stars on the main sequence due to braking by such a stellar wind.

ENERGY LOSSES IN OUTER ATMOSPHERES

Solar cycle is a result of the coupling between the middle-scale and large-scale magnetic fields. The energy losses of active regions relating to the middle-scale magnetic fields are determined by thei X-ray radiation. The behavior of the L_x/L_{bol} ratio versus colour index B-V shown in Fig.1 (where values of the L_x/L_{bol} for the red dwarfs are taken from Pallavicini et.al, 1990; Katsova & Tsikoudi 1992) exhibits the saturation effect similar to that found earlier by Vilhu & Walter 1987. It means that practically the whole volume of the inner corona ($r<1.5R_*$) is occupied by hot coronal loops.

The strong spottedness and the winds of active late-type stars manifest theirselfs also at the far-IR (Katsova & Tsikoudi 1992; Mullan et.al,1992).

For active red dwarfs, the power expending during flares is close to the X-ray luminosity and can reach it, so that $L_x/L_{bol} \approx L_{fl}/L_{bol} \approx 10^{-3}$ (Gershberg & Shakhovskaya 1983).

Energy losses in the chromospheric lines of the dG and early dKe stars exceed as a rule the coronal energy losses due to emission features on the middle and small scale like flocculae and boundaries of chromospheric networks. For the later active stars, coronal energy losses begin to dominate.

THE LARGE-SCALE CORONAL STRUCTURES AND STELLAR WIND

In the presence of the large-scale magnetic fields structures like coronal holes and streamers form, and the rate of mass loss by late-type dwarfs can reach 1-2·10^{-11} $M_\odot$ /yr; that is a factor 10-100 greater than in the solar case (Badalyan & Livshits 1992). We are estimated wind energy losses at the level of its formation (Fig.2).

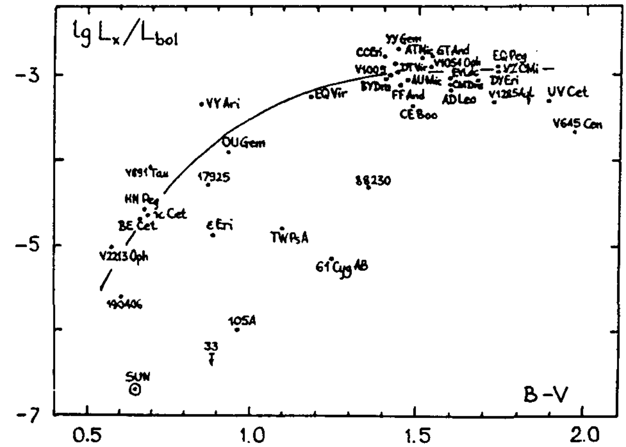

Figure 1

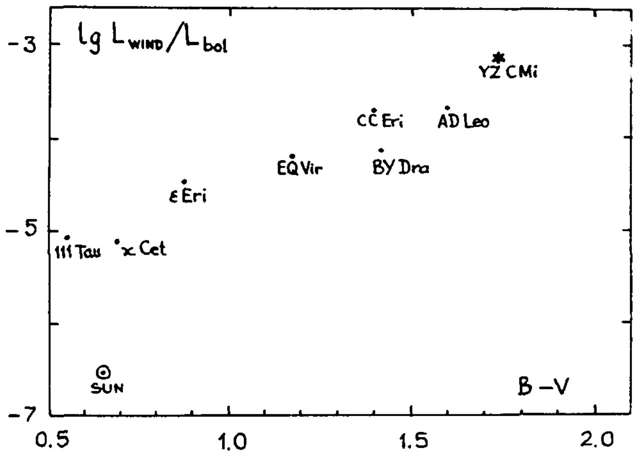

Figure 2

Thus, the stellar activity cycle is arranged in such a manner that an active late-type dwarfs lose on the different space scales up to 3·10^{-3} L_{bol} due to both stationary and nonstationary processes (see Table).

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TABLE The energy losses as regards to the bolometric luminosity for stars of different spectral types) L_{act}/L_{bol}:

spectral type	dG2	dK5	dM4e
chromophere	$2\cdot10^{-5}$	$6\cdot10^{-5}$	$2\cdot10^{-4}$; 10^{-3} (flares)
corona	$2\cdot10^{-7}$	$3\cdot10^{-4}$	10^{-3}
wind	$5\cdot10^{-8}$	$3\cdot10^{-5}$	$3\cdot10^{-4}$; $8\cdot10^{-4}$(transient)

SOME PROBLEMES WITH THEORY

i - How is it possible to provide such a high ratio of $L_{act}/L_{bol} \approx 3\cdot10^{-3}$? It needs to create not only middle-scale magnetic field, but also the large-scale structures, i.e. connection between toroidal and poloidal components of the field. The dynamo mechanism has to be extremely intensive. The energy of the mean magnetic field of the convective zone can be estimated after Vainstein et al(1980)

$$E_{MF} = 4\pi R^3 \omega_0 (B_\varphi B_r \ /4\pi)$$

where $\omega_0 = v_{rot}/R_*$ is angular velocity of the rotating star. For $B_\varphi = 1000$ G and $B_r = 10^{-3} B_\varphi$ we obtain $E_{MF} = 10^{30}$ erg/s and lg $E_{MF}/L_{bol} = -3.6$ for the Sun. This value lies close to the boundaries of the dynamo possibility.

ii - Mass loss of about 10^{-11} $M_\odot$/yr exists apparently in active late-type dwarfs in the form of a quasi-stationary wind as well as non-stationary events like transients. This restricts the time scale of the existence of activity as well as the redistribution of the angular momentum and braking due to a magnetic stellar wind can be estimated as

$$\tau = 0.6(R_*/r_A)^2 \cdot M \cdot dM/dt^{-1}.$$

For the radius of the Alfven sphere $r_A = 10R_*$ and $M_* = 0.5M_\odot$ this becomes $3\cdot10^8$ years. This is 2 order of magnitude less than the lifetime on the main sequence for the dK5 stars which is $40\cdot10^9$ years.

Therefore, the energetic losses during the phase of stellar activity of the late-type dwarfs have to be taken into account when dynamo theory and structure of the convective zone are considered.

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