EVIDENCE FOR STELLAR CHROMOSPHERES IN GLOBULAR CLUSTERS

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ABSTRACT. We suggest that the conspicuous gaps frequently seen in the color-magnitude diagrams of globular clusters are caused by a sudden increase in chromospheric activity shortly after stars evolve away from the main sequence.

Color-magnitude diagrams (CMDs) of globular clusters which include large numbers of randomly-selected stars belonging to the sub-giant branch (SGB) nearly always display conspicuous gaps at some point on the SGB (see, e.g., Alcaino and Liller 1980, 1984; Buonanno et al. 1984; Harris and Canterna 1980). The exact point where the gap occurs on the SGB seems to be weakly correlated with the metallicity of the cluster; a better correlation exists between gap location and Kukarkin's K index, a measure of the ratio of red to blue stars in the horizontal branch.

Standard stellar evolution theory does not predict a sudden change in the rate of evolution (Iben, private communication; Armandroff and Demarque 1984), and attempts to produce these gaps by hypothesizing discontinuities in the chemical composition of the stellar interior or changes in atmospheric structure have not been entirely successful (Armandroff and Demarque 1984).

In looking for a probable cause, it occurred to us that the gaps come just in that region of the CMD where chromospheric activity is always found, although it must be remembered that the metal-to-hydrogen ratio in globular clusters is one or two orders of magnitude smaller than in solar-type stars. For example, in NGC 288 there is a clearly defined gap at $M_V = +3.1 \pm 0.2$ and $B-V = 0.71 \pm 0.03$. (Buonanno et al. 1984), corresponding to M(Bol) = +2.8 and T(eff) = 5100^0 K. (VandenBerg 1983). A star with these characteristics almost definitely will possess a well-developed chromosphere (Linsky 1980).

The usual spectral manifestations of chromospheric

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activity are emission lines seen in the deep cores of saturated absorption lines, especially those of Ca II, Mg II, and H-alpha. Indeed, these emission lines normally play an important role in the radiative cooling of chromospheres (Linsky 1980). However, in the cooler regions of the chromosphere and especially in low-metallicity stars, the situation is radically changed, and another cooling mechanism dominates, namely H^- emission (Athay 1976; Osterbrock 1961).

We suggest, then, that the SGB gaps in globular clusters arise owing to a sudden increase in the amount of chromospheric activity shortly after a star evolves away from the main sequence. Given a sufficiently extended and optically thick chromosphere, the H^- emission would affect the total emergent flux of the star causing it to appear slightly more luminous and cooler as is observed.

Because of its greater importance in the near-infrared, H^- emission should be more evident in globular cluster CMDs using a B-I color index instead of B-V, and indeed this is exactly what is found. In the V, B-I CMD for M4 (NGC 6121), the start of the SGB appears totally detached from the main sequence lying some 0.6 magnitudes to the right of the turnoff (Alcaino and Liller 1984).

What is needed now, of course, is a careful quantitative study of the expected conditions in the chromospheres of low-metallicity stars, including possible reasons for the sudden increase in nonradiative heating necessary to create a chromosphere.

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