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What Happens to the Gas in Globular Clusters?

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Abstract. Observations of globular clusters show that they contain much too little gas or dust, compared to what should be present due to the mass-losing stars in the cluster. Many authors have been intrigued by the fate of the gas in globular clusters. They have suggested various mechanisms by which the gas could escape from the cluster, such as stellar UV radiation, cluster winds driven by X-ray bursters, novae, or flare-stars, relativistic winds from millisecond pulsars, condensation into stars, accretion processes drawing upon a central gas reservoir, continuous sweeping of the cluster gas by the gaseous medium of the Galactic halo...

Recent results also show that globular cluster stars show many abundance anomalies. Accretion of interstellar gas by the cluster stars has been suggested as a plausible mechanism to explain these anomalies. It is also a major ingredient of the EASE scenario linking halo field stars to globular clusters, which we have recently developed to explain strong r-and s-elements correlations in halo field dwarf stars.

We have explored the mechanisms of gas and dust accretion onto main sequence stars in globular clusters.

1. Fate of the gas in globular clusters

Many attempts have been made to detect intracluster gas or dust in globular clusters. Apart from a few exceptions, most of them explained by other effects (such as foreground contamination), there has been so far little success at finding positive measurements (Roberts 1988). However, as recently pointed out by Knapp al. (1996) escape velocities have often been overestimated so that the clusters observed were in fact too weakly bound to be able to retain their gas anyway. Knapp et al. (1996) have searched for the presence of ionized gas in six clusters, which they selected because of their high escape velocities. They did not detect any gas, but they point out that if the gas flows out of the cluster via a wind rather than accumulating in the cluster center in the form of a reservoir, the remaining amount of gas in the cluster would be below their detection limits.

On the other hand, there is now strong observational and theoretical evidence that stars reaching the asymptotic giant branch lose a large amount of mass. The apparent discrepancy between the predicted amount of gas in globular clusters and observations has led to a number of papers on possible mechanisms responsible for gas removal in globular clusters (Scott and Rose 1975, Faulkner and Freeman 1977, VandenBerg and Faulkner 1977, VandenBerg 1978, Scott and Durisen 1978, Faulkner 1984, Faulkner and Coleman 1984, Smith 1996). These mechanisms include stellar UV radiation, cluster winds driven by X-ray bursters, novae, or flare-stars, relativistic winds from millisecond pulsars, condensation into stars, accretion processes drawing upon a central gas reservoir, continuous sweeping of the cluster gas by the gaseous medium of the Galactic halo...

Stellar ejecta in globular clusters with shallow potential wells can leave the cluster via a smooth wind-like outflow. Faulkner and Freeman (1977) and VandenBerg and Faulkner (1977) find steady-state time-independent flow solutions in clusters of $10^5 M_\odot$. However, they show that in globular clusters with deep enough potential wells, the gas can accumulate into the cluster, forming a central reservoir with a radius comparable to the globular cluster core radius. Faulkner and Coleman (1984) show that a small number of low-velocity low-mass stars in the cluster center can in this case accrete enough matter to form $10 M_\odot$ black holes. All those studies looked at what happens in present-day globular clusters. Smith (1996) addressed the question to see if such winds might have been possible within young globular clusters, during epochs of much higher stellar mass-loss rates. He shows that many globular clusters have high enough escape velocities to retain at least some of the stellar ejecta. A substantial amount of intracluster material could have been acquired when the turn-off mass was about $5M_\odot$. In less tightly bound clusters, the stellar ejecta is lost from the cluster either stochastically or through a continuous wind. It has been suggested by a number of authors that if indeed the gas and dust ejected by the cluster's intermediate-mass stars can in some cases be retained in the cluster, this gas could be accreted by other cluster stars, producing anomalies in the surface chemical abundances.

2. Accretion processes onto globular cluster stars

We have examined in detail three possible accretion mechanisms in globular clusters. These mechanisms are the accretion from a central reservoir of gas, from a wind, and during close encounters between a mass-losing AGB star and a main sequence star.

Smith (1996) has shown that accretion from a wind is much less efficient than accretion from a central reservoir. The main reason for this result is that the accretion rate is proportional to the gas density, which is in the first case several orders of magnitude lower than in the second case.

We have recently examined the accretion during close encounters, taking into account the probability of such encounters during the life of a main sequence star in a cluster. We find that the total accretion is, on average, very small (Ledent 2000). Of course, some stars could accrete a large amount of gas if their orbit keeps them close to mass-losing AGB stars for a long time.

However, accretion from a central reservoir of gas is a much more promissing mechanism to "absorb" the gas ejected by stars in globular clusters. Our preliminary results show that, in some cases, a large fraction of the ejected gas could be re-accreted by the other cluster stars (Thoul et al. 2000). This could explain some abundance anomalies observed in globular clusters. It also supports the EASE scenario, developed to explain some strange abundance correlations between s-process elements and α-elements in halo field stars (Jehin et al. 1999).

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