KINEMATICS OF THE LMC CH-STARS

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ABSTRACT. Velocities have been measured for 74 CH stars in the direction of the Large Magellanic Cloud (LMC). These have been used to study the kinematics of the oldest stellar population. Velocities of these objects appear to reflect two distinct subgroups - one associated with the old globular cluster population and a second with the LMC disk.

1. Introduction

To investigate how the LMC formed, it is useful to study the kinematics of its oldest members. Although globular clusters are bright objects and thus easily studied, only about a dozen very old clusters are known. In the Galaxy, kinematic studies of CH stars (Hartwick & Cowley 1985) have shown that these stars belong to the halo population. Carbon stars are relatively bright and easily recognized on low-dispersion plates. Thus, they were selected as test probes for a study of the properties of any LMC halo.

2. Observations

CH-star candidates were identified on CTIO Curtis Schmidt thin-prism plates. Moderate dispersion (~3A) resolution spectroscopy was then obtained using the CTIO 4-m spectrograph both to confirm that the candidates were CH stars and to measure their velocities. The present study is based on 74 CH-star velocities, determined using cross-correlation techniques with respect to velocity standards in both the Galaxy and the LMC.

3. Velocity distribution and implications for the structure of the LMC

The CH-star velocity distribution shows a distinct asymmetry with an extended, low-velocity tail. In Fig. 1b the velocity distribution of LMC CH-stars is compared to that of H I gas (Fig. 1a), where only H I velocities (Rohlfs *et al.* 1984) near the kinematic line-of-nodes and beyond 2° from the rotation centre are plotted. Note that, while the CH-star velocity peak falls near the H I mean

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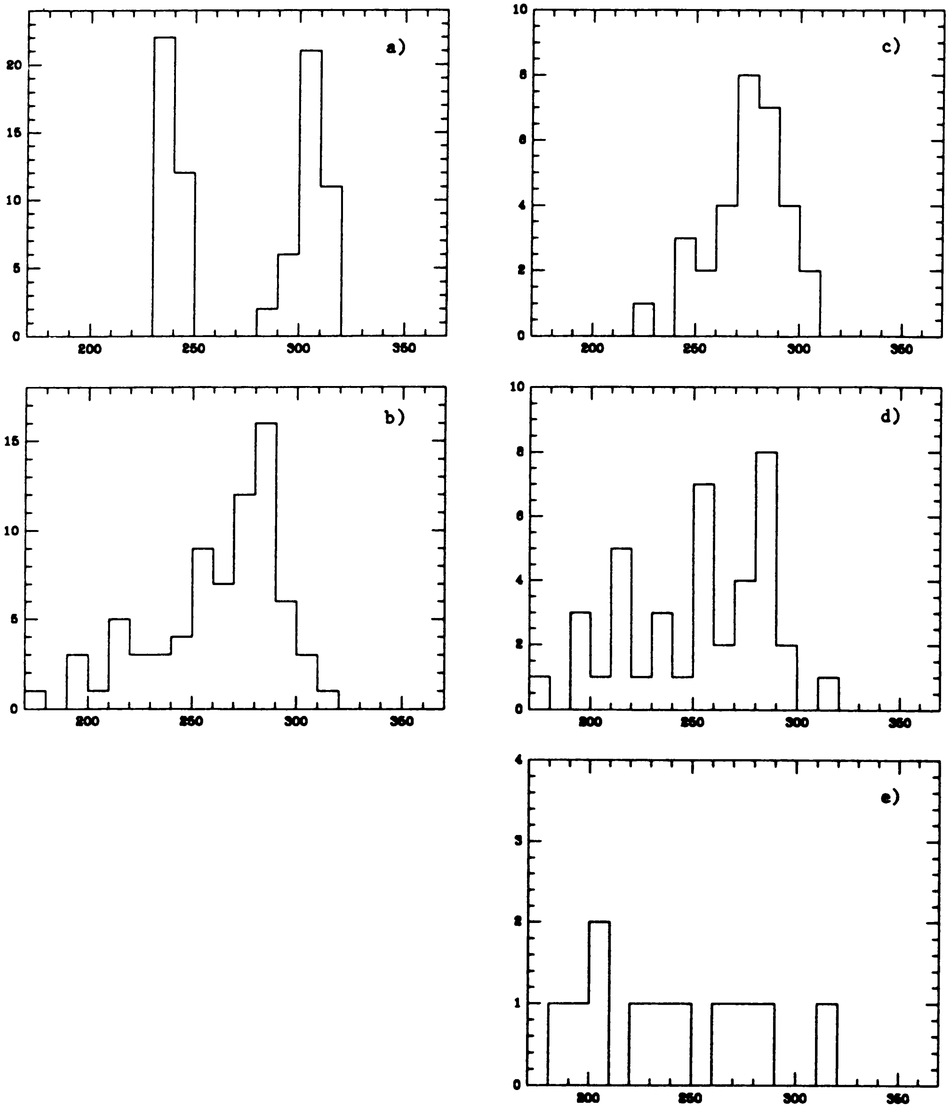

Figure 1. Frequency versus heliocentric velocity for various LMC components (a) HI near the kinematic line of nodes; (b) 74 LMC CH stars - note the asymmetry; (c) CH stars with ω > 5 deg. (see text for explanation) (d) CH stars with ω < 4.7 deg. (e) 11 class VII (oldest) LMC globular clusters including NGC 1841 and Reticulum. Note that the ordinate scales are not the same in all histograms.

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(V_{hel}~270 km s^{-1} or V_G=45 km s^{-1}, assuming V_{LSR}=250 km s^{-1}), the mean velocity of the distribution is considerably lower. The offset in systemic velocity for our whole CH-star sample is even more apparent in results from kinematic modelling, where one formally solves for the rotational velocity, V_{max}, the position angle of the lines of nodes, θ_o, and the systemic velocity, V_{sys} (see Table 1). All solutions have been made using two values of the LMC transferse velocity towards position angle 110°: V_{trans}=0 and 275 km s^{-1}. The velocity offset with respect to hydrogen gas was also seen in the oldest (classes V-VII) clusters (Ford 1970, Freeman *et al.* 1983 - FIO), although the relatively small number of old clusters makes it more difficult to define. (Also see Fig. 4, Hartwick & Cowley 1988). FIO cluster velocities were used in the present models, except for NGC 1841 whose velocity is the mean of recent determinations by Storm and Carney (1990) and Schommer *et al.* (1990). The same sources were also used to add a mean velocity for the Reticulum cluster. Table 1 gives solutions for the class-VII clusters.

Table 1. Kinematic modelling results[a]

Sample	V_{trans} km sec^{-1}	n	V_{max} km sec^{-1}	θ_o deg	V^b_{sys} km sec^{-1}	σ km sec^{-1}	V_{max}/σ
HI	0	74	72±5	-7±7	50±1	5±0.5	15
	275	74	91±8	-23±6	50±1	5±0.5	18
CH stars, all	0	74	51±10	22±12	28±4	24±2	2.1
	275	74	63±10	-16±10	26±4	24±2	2.6
CH stars, $\varpi > 5$	0	31	47±13	-21±24	41±7	10±1	4.9
	275	31	96±15	-42±10	38±7	9±1	10
CH stars, $\varpi < 4.7$	0	39	48±15	32±19	26±5	21±3	2.3
	275	39	54±14	-3.5±18	26±5	21±3	2.5
Class-VII Clusters	0	11	81±26	45±19	28±8	25±6	3.3
	275	11	90±38	8±17	28±10	31±7	2.9

[a]Solutions of equation 1 of Hartwick and Cowley (1988); i = 27 deg assumed

[b]V_{sys} is systemic velocity with respect to the Galaxy, assuming V_{LSR} = 250 km sec^{-1}

The most plausible explanation for the velocity asymmetry in Fig. 1b is that we are seeing a superposition of at least two distinct kinematical subgroups. A number of experiments were carried out in an attempt to separate the two subgroups. The results of dividing the sample according to distance from the kinematical center, (ϖ, measured in the plane of the LMC) are shown in Fig. 1c and Fig. 1d and in Table 1. For those stars with ϖ>5°, there is a relatively symmetrical distribution centred near the systemic LMC velocity (VG~41 km s^{-1}), with a relatively small (negative) value of θ_o and a small velocity dispersion, σ. For CH stars lying within ϖ <4.7°, the distribution and kinematical properties are similar to the class-VII clusters, i.e. low systemic velocity (V_G~ 28 km s^{-1}), high θ_o, and relatively high σ. The distribution of velocities for class-VII clusters is shown in Fig. 1e, and can be compared with Fig. 1d.

While it would be unreasonable to expect such an arbitrary cut through the data to produce a clean decomposition, the indication is that CH stars do indeed consist of two distinct dynamical entities: an LMC disk population and an "old cluster-like" population with mean velocity ~20 km s^{-1} lower than the LMC itself. This "halo" population appears to be rotating, in agreement with FIO's conclusions. The data, as they stand, do not allow us to deduce the origin of this low-velocity subgroup. However, two possibilities are that we might be seeing stars and clusters orbiting the centre of mass of the combined LMC-SMC system or the effects of a violent, early tidal encounter between the Galaxy and the LMC.

4. Conclusions

The goal of our investigation was to study the LMC halo population using CH stars as probes. The asymmetrical velocity distribution exhibited by these stars suggests that they trace at least two distinct dynamical entities. Subdivision of our sample according to distance from the kinematical centre and subsequent modelling leads to the conclusion that the two dynamical groups are: 1) a LMC disk population, and 2) what appears to be an old-cluster population. It remains to be seen whether the two subgroups can be separated on the basis of intrinsic stellar properties such as colour or metallicity. Until then, our preliminary conclusion is that the LMC halo is not like that in the Galaxy - rather it forms a relatively rapidly rotating subsystem with systemic velocity ~20 km s^{-1} lower than the LMC itself. A study of the projected distribution of a pure sample of the old-cluster population might eventually shed some light on the origin of this velocity offset.

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