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Variable Stars in the MACHO Bulge Database

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1. Microlensing Databases: The Way of the Future

The MACHO Project has been monitoring large fields in the direction of the Galactic bulge, the LMC and SMC for over 6 years. The nightly observations of this microlensing survey provide very large databases for astronomers (see **http://wwwmacho.mcmaster.ca/**).

The MACHO database contains ~5 Terabytes of data as of mid-1998. For comparison, the HST Archive contains about ~2 Tb, and the Sloan Digital Sky Survey will reach ~10 Tb. Our database can be used to attack a variety of astrophysical problems, and has produced results relevant to microlensing, galactic structure, and stellar evolution. Of particular importance are the large numbers of variable stars (tens of thousands) found as byproducts of the microlensing search [1]. In years to come, the microlensing databases will play a dominant rôle in variable star science. Important science can still be done with limited resources, even in places with no access to large telescopes (all you need is computer!).

2. Galactic Structure Using The MACHO Bulge Database

The structure of the inner Milky Way is complex, not only because of reddening, but also because of population gradients (Figure 1). We have used different distance indicators present in the MACHO bulge database to trace the main components present in these fields: the Milky Way bulge, disk and inner halo, and the Sgr dwarf.

The density distribution of these components is probed as follows:

- The bulge is studied using clump giants [2], semiregular and long period variables [3], and δ Sct [4] variable stars. These tracers clearly show a barred distribution (Figure 2), with the near side of the bar located at positive longitudes, confirming the results of previous studies [6].
- The inner disk is studied using short period contact binaries. The distribution of these binary stars is consistent with an exponential disk density distribution, showing no cutoff or hole in the inner regions.

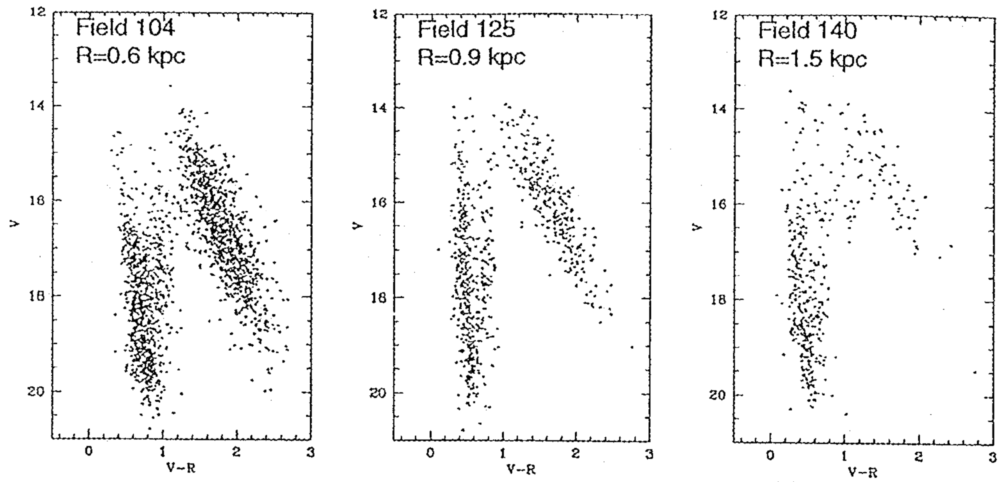

Figure 1. Color-magnitude diagram of variable stars in 3 fields at different distances from the Galactic center. The total number of variables stars in the inner fields is 10× that of the outer fields. Even though the inner field is more reddened in the mean, a gradient in populations is clearly seen.

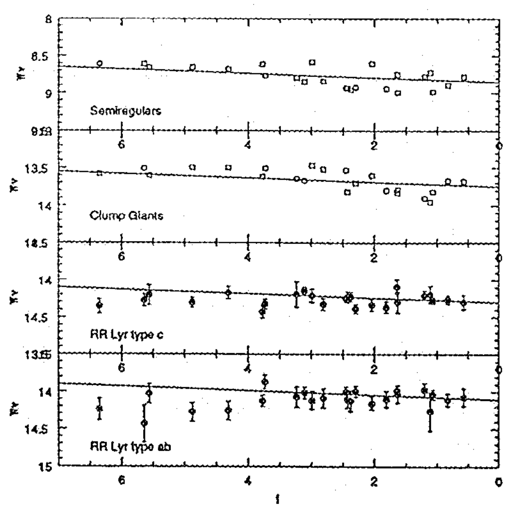

Figure 2. Mean magnitudes of RRab and RRc compared with clump giants and semiregular variables for the 24 inner MACHO bulge fields as a function of Galactic longitude. The solid line shows the fit to the bar from Stanek et al. (1996) [6]. The RR Lyrae stars do not follow the barred distribution seen in the clump giants and other tracers.

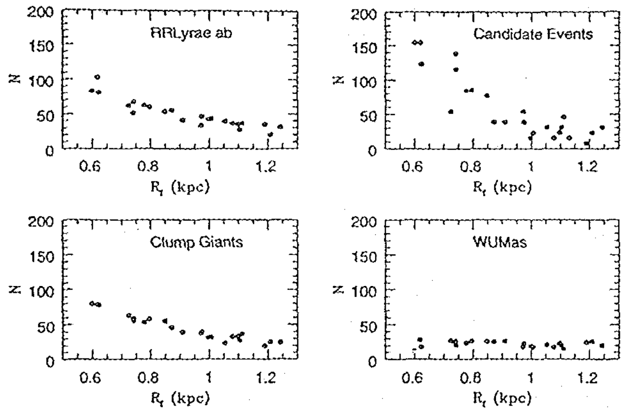

Figure 3. Number counts of different tracers as function of distance from the Galactic center (for $R_o = 8$ kpc, and $b/a = 0.7$). The counts have been arbitrarily normalized. The bulge tracers (clump giants), and the inner halo tracers (RR Lyrae) are very concentrated, while the disk tracers (WUMa stars) show a flat distribution. The candidate microlensing events are more concentrated than any of the known stellar populations.

- The inner halo is studied using RR Lyrae variable stars [2],[5]. The RR Lyrae with $0.4 < R < 1.3$ kpc show a density law that is well fit by the extension of the metal-poor halo present in the outer regions of the Milky Way. In particular, there is no cutoff or core seen in the RR Lyrae distribution, the power law continues to the innermost fields.
- RR Lyrae, Semiregular and Long Period variables of the Sgr dwarf are used to measure the distance and 3-D structure of this galaxy [3],[7].

3. Implications for Microlensing

The MACHO Collaboration has detected nearly 300 candidate microlensing events in the fields towards the Galactic bulge. The interpretation of these events strongly depends on the structure of the inner Galaxy. Fortunately, the large number ($N \sim 42000$) of variable stars found in these fields [1] can be used to study the Milky Way inner structure.

Since the bulge, disk, and halo components have different kinematics in these inner fields [8], microlensing events in these components would have different distributions of observed parameters.

Figure 3 shows the radial distribution of the candidate microlensing events compared with tracers of the bulge (clump giants), disk (WUMa stars), and halo (RR Lyrae). These candidate events are much more concentrated than any other known stellar population, consistent with their microlensing interpretation, and ruling out a new kind of variable star.

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