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THE EDGE OF THE GALACTIC DISK[1]

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ABSTRACT

As part of a stellar population sampling program, a series of photometric probes at various field sizes and depths have been obtained in a low-extinction window in the Galactic anticenter direction. Such data set strong constraints on the radial structure of the disk. At the forefront of this "drilling" program, very deep CCD frames probe the most external parts of the disk. Over the whole effective magnitude range (18–25), all contributions in the statistics which should be expected from old disk stars beyond 6 kpc vanish, although such stars dominate by far at distances less than 5 kpc. This is the signature of a sharp cutoff in the star density: the edge of the Galactic disk between 5.5 and 6 kpc. As a consequence, the Galactic radius does not exceed 14 kpc (assuming $R_{\odot} = 8.5$). Colors of elliptical galaxies measured in the field rule out the risk of being misled by undetected extinction.

Subject headings: Galaxy: stellar content — Galaxy: structure

1. INTRODUCTION

Efforts to sample star distributions in the Galactic plane should face both the problem of overcrowding and the complex structure of the absorbing layer. For these reasons the outer part of our own Galactic disk is very poorly known. The radial scale length of the density decrease is controversial and we have nearly no indication what happens at the end.

Two previous papers (Mohan et al. 1988; Robin, Crézé, & Mohan 1992) present the first results of a stellar population sampling program, including a series of photometric probes at various field sizes and depths in a low-extinction window in the Galactic anticenter direction. Wide-field photometry in *UBV* in the magnitude range 12–17 is shown to interpret unambiguously in terms of extinction and stellar density. The interpretation partially uses the model developed by Robin & Crézé (1986) and Bienaymé, Robin, & Crézé (1987). The model ingredients which play a role in the present anticenter investigation are the density law of the Galactic disk (radially exponential) and the luminosity function from Wielen, Jahreiss, & Krüger (1983). Strong constraints are set on the radial structure of the disk: the Galactic disk scale length is 2.5 kpc. Based on this scale length and assuming no dramatic change in the luminosity function one can predict what should normally happen at faintest magnitudes: the V, $B-V$ distribution of stars from this investigation is given in Figure 1*a* and the V counts are plotted in Figure 2 (*dashed line*).

2. DEEP OBSERVATIONS TOWARD THE ANTICENTER

Deep CCD observations in the *BV* bands have been obtained at the 3.6 m CFH Telescope in a low-extinction window at low latitude in the direction of the Galactic anticenter. A detailed description of observational and data analysis aspects is given elsewhere (Robin et al. 1992). Observations cover four neighboring fields adding up to 29 arcmin^2. Field characteristics are given in Table 1. The detection limit is about magnitude 28 in V, while the completeness limit corresponding to a photometric accuracy better than 0.1 is 25 in V and 22.5–24 in B depending on the frame. The resulting V, $B-V$ distribution is plotted in Figure 1*b* down to $V = 23$. B data are lacking beyond this limit. Differential star counts down to $V = 25$ are plotted on Figure 2 together with the associated 1 σ error bars.

3. INTERPRETATION

The faint star count predictions deviate strongly from the observations at the faint end, and there is a clear excess of blue stars in the lower left part of Figure 1*a*. The bulk of disk contributors in this magnitude range is made of disk dwarfs beyond 5.5 kpc (in Fig. 1*a* stars closer than 5.5 kpc are plotted as full circles while more distant stars are crosses).

All disagreements in the V, $B-V$ diagram vanish if the stellar Galactic disk ends abruptly at 5.5 kpc as also shown in the V star counts in Figure 2 (*solid line*). Other explanations could come from the extinction along the line of sight, the scale length used in the model or the luminosity function. We show below that none of these hypotheses resists investigation.

Interpretation of the cutoff seen in the V, $B-V$ diagram in terms of absorbing cloud would need a total extinction $A_V = 2.4$ over the line of sight, including a cloud of $A_V = 1.2$ at 5.5 kpc that is about 300 pc from the Galactic plane. The extinction measured from the *UBV* diagrams and H I column density gives a total extinction to 4 kpc of $A_V = 1.2$. The colors of four elliptical galaxies measured in the fields give an estimate of the total extinction inside the Galaxy of 1.4, incompatible with the existence of a deeply absorbing cloud at 5.5 kpc. This is also in agreement with the fact that the fields are inside Special Area 23 selected by Kapteyn as a low-extinction window.

Density distributions with scale lengths larger than the adopted 2.5 kpc would impose a still closer cutoff (at 3.5 kpc from us if $h = 3.5$ kpc) while shorter scale lengths are hardly compatible with the observations of bright stars in the same region (Mohan et al. 1988).

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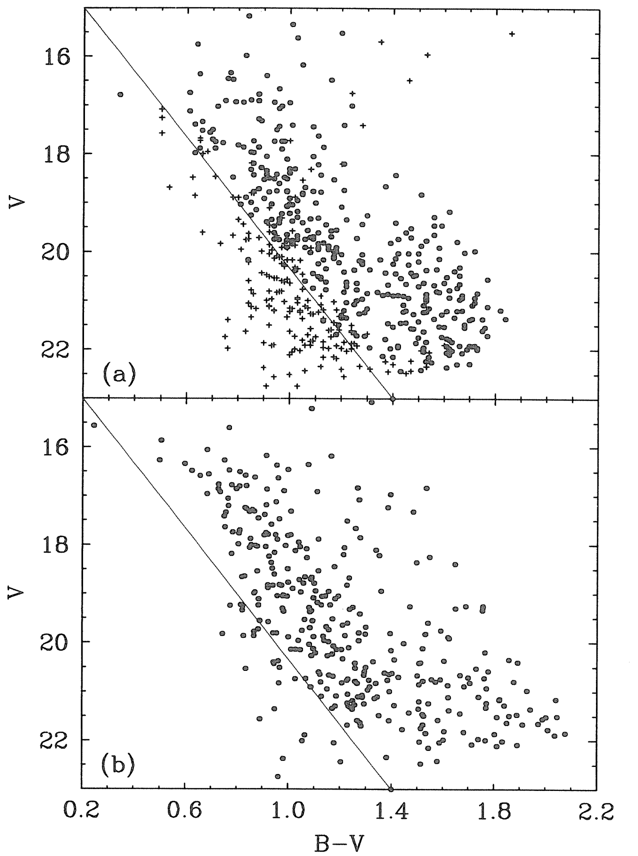

FIG. 1.—(V, $B-V$) diagram of anticenter stars. (*a*) Model predicted distribution. Dots are stars closer than 5.5 kpc while crosses are stars beyond 5.5 kpc. (*b*) Observed distribution. The solid line is a guide to identify the zone where most stars are beyond 5.5 kpc.

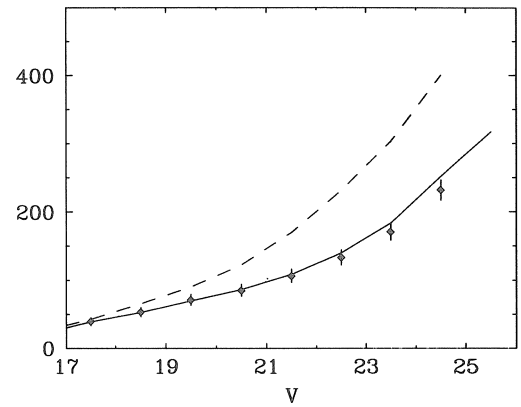

FIG. 2.—V star counts to magnitude 25 in the anticenter direction. *Diamonds:* Observed counts with 1 σ error bars (Poisson noise only). *Dashed line:* Predicted counts assuming no cutoff in the radial distribution of stars. *Solid line:* Predicted counts assuming a cutoff at 5.5 kpc from the Sun.

4. DISCUSSION

Stars that should be expected to appear in the sample to $V = 23$ at distances larger than 5.5 kpc are common dwarfs of absolute visual magnitudes between 3 and 7, a part of the luminosity function which is well known from the study of the solar neighborhood. Moreover, these stars appear at brighter V magnitudes when they are closer. Changing their luminosity function would lead to strong disagreements with Schmidt plate data of Mohan et al. at magnitudes 12–16 and with the CCD data at magnitudes 17–21. Rather than invoking a sudden change of the luminosity function of stars of magnitudes 3–7 at 5.5 kpc from us, the data are better interpreted as a sharp cutoff of the density distribution for all stars at this distance. This observation is indicative of the end of the star formation process, possibly related to the external Lindblad resonance.

Most external disk galaxies show a radial truncation. These cutoffs seem to arise within 1 kpc or less (van der Kruit 1988).

TABLE 1

FIELD COORDINATES AND AREA

Field	R.A. (1950)	Decl. (1950)	l	b	Area (arcmin^2)
1.........	$5^h53^m06^s.5$	+30°39′43″	179°.70	2°.88	6.7
2.........	5 52 45.4	+30 40 52	179.64	2.83	6.5
3.........	5 52 54.7	+30 36 13	179.73	2.82	7.7
4.........	5 52 46.4	+30 38 24	179.68	2.81	6.6

From a sample of seven edge-on galaxies this drop has been found between 3.4 and 5.3 times the old disk scale length (van der Kruit & Searle 1981, 1982). When reanalyzing the sample of Wevers, van der Kruit, & Allen (1986) of 20 face-on spirals, van der Kruit (1988) showed that the mean ratio between R_{max} and scale length h is 4.5 ± 1.0 for 16 galaxies and larger than 6.0 for the remaining four spirals. However, the Barteldrees & Dettmar (1990) sample gives a mean ratio of 2.8 ± 1. It should be noted that the scale lengths of external spirals may be uncertain by a factor of 2 (Knappen & van der Kruit 1991).

In our Galaxy star counts in the anticenter (Robin et al. 1992) give a radial scale length of 2.5 ± 0.3 kpc. Together with the presently determined cutoff it implies a ratio R_{max}/h of 5.6 ± 0.6 if $R_\odot = 8.5$ kpc or 5.2 ± 0.6 if $R_\odot = 7.5$ kpc, in agreement with the observed ratio in external galaxies.

Indications for a cutoff in the disk distribution has already been found in other data. From the *IRAS* Point Source Catalog, Habing (1988) found a cutoff at distances between 1 and 2.5 kpc. However, Habing stressed that this very short cutoff distance depends strongly on the assumed disk scale length (4.5 kpc), which, on the other hand, is inconsistent with our wide field star count results. Habing did not test any model with a shorter scale length for the old disk components. In the view of the present result, the combination of short scale and larger distance cutoff should be tested against *IRAS* data.

The edge of the disk was also determined in the gaseous component of the Galaxy at larger distances. Wouterloot et al. (1990) got a sharp decline of the CO cloud density between 18 and 20 kpc, a signature that star formation stops at about this distance. However, these distances being derived from kinematics are subject to errors due to perturbations of the velocity field. H II regions observed by Fich, Blitz, & Stark (1989) also end at galactocentric distances of about 15 kpc.

Our determination of the radial extent of the old disk does not conflict with the possibly larger extent of young stars or star-forming regions if an evolutionary scenario like the one of Larson (1976) (where the star formation propagates from the center of the Galaxy to the outer part) is realistic. In this case one expects to find only recent star formation in the outer part of the Galaxy and no old disk stars.

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