Gaia 1 cannot be a Thick Disk Galactic cluster

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Gaia 1 was discovered by (Koposov et al. 2017) as a stellar over-density in the Gaia satellite first data release and originally classified as a satellite of the Milky Way. Following medium- and high-resolution spectroscopic investigations by (Simpson et al. 2017) , (Mucciarelli et al. 2017), and (Koch et al. 2017) revealed that Gaia 1 is, more conservatively, an intermediate-age Galactic cluster, previously overlooked because of its proximity to the bright star Sirius. In spite of all these works, Gaia 1 properties are far from being settled, and worrisome discrepancies exist among the various studies. The age ranges from 3 to 6 Gyr, which is well within the domain of Milky Way (MW) old open clusters. Metallicity is found to go from [Fe/H]=0 to [Fe/H]=-0.6 (virtually a factor of 10 difference), which represents almost the entire range of metallicity for MW old open clusters. Because of the well-known age metallicity degeneracy, the isochrone fit works fine in both extremes. It is particularly difficult to understand the reasons for such huge differences, and we look forward for a prompt solution of this puzzle, which makes any spectroscopic inference weak at present.

Meanwhile there is an issue which has not been tackled properly by these studies, and which I want to discuss in this note. If the metallicity is -0.6 and the age 6 Gyr (Koch et al. 2017), Gaia 1 would bear a remarkable similarity with Whiting 1 (Carraro et al. 2007). What, however, makes Whiting 1 not an open cluster is its position in the Galactic halo, as amply discussed in (Carraro et al. 2007). In the case of Gaia 1 (Koch et al. 2017) conclude that Gaia 1 is a thick disk cluster because of its actual location, almost 1 kpc above the *formal* (b=0^o) Galactic plane. They also derived the Galactic orbit of the cluster and found contradicting results. On one side, the eccentricity (e= 0.12) is found be compatible with thin disk stars, but the maximum height above the plane, Zmax =1 kpc is according to them too high for the thin disk and more compatible with the thick disk. If true, Gaia 1 would be the first open cluster ever associated with the thick disk, which is well known to be devoid of such clusters. The orbit integration is done for a perfectly flat and time independent disk potential - and run for 10 Gyr ! - while the disk of the Milky Way is known to exhibit a significant warp and a significant flare (Momany et al. 2006), which are prominent also in the direction of Gaia 1 (Carraro et al. 2007). This is illustrated in Figure 1, where thin disk old open clusters' locations from (Carraro et al. 2007) are confronted with the warped and flared Galactic disk (Momany et al. 2006). Not surprisingly, Gaia 1 (the filled square) falls nicely in the distribution of such objects and is located less than half a kpc from the *real* Galactic disk. This results rules out its association with the Galactic thick disk, and lend additional support to the nature of Gaia 1 as yet another thin disk old open cluster (Mucciarelli et al. 2017).

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- Gaia_1 == newly identified STAR CLUSTER from Gaia DR1 sources
- property == large discrepancy: age 3 -- 6 Gyr; [Fe/H] ~ -0.6 – 0
- nature == thick disk cluster ? – rare! → accretion origion?

** Galactic disk warp & flare ** ➔ "thin disk" population

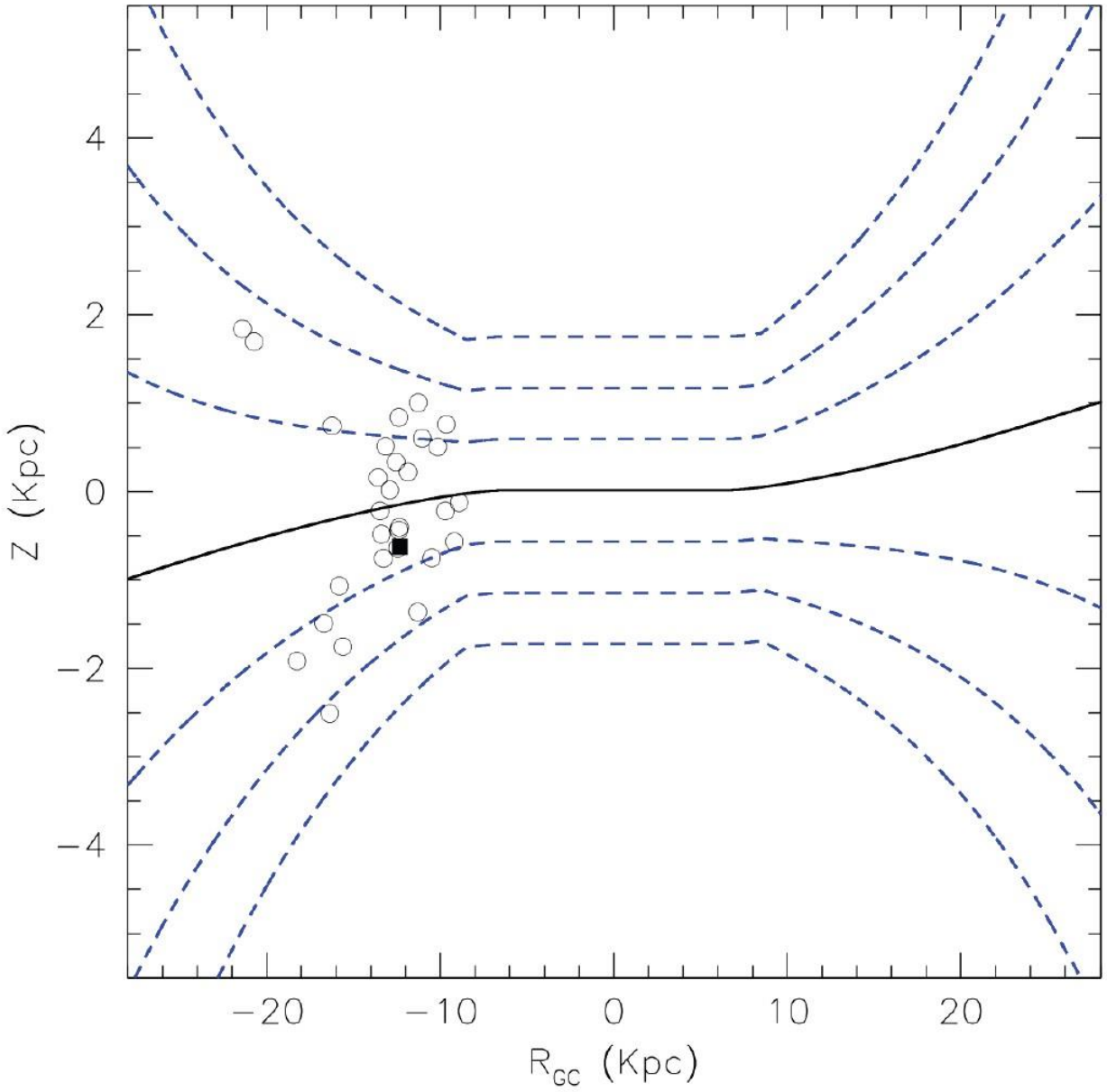


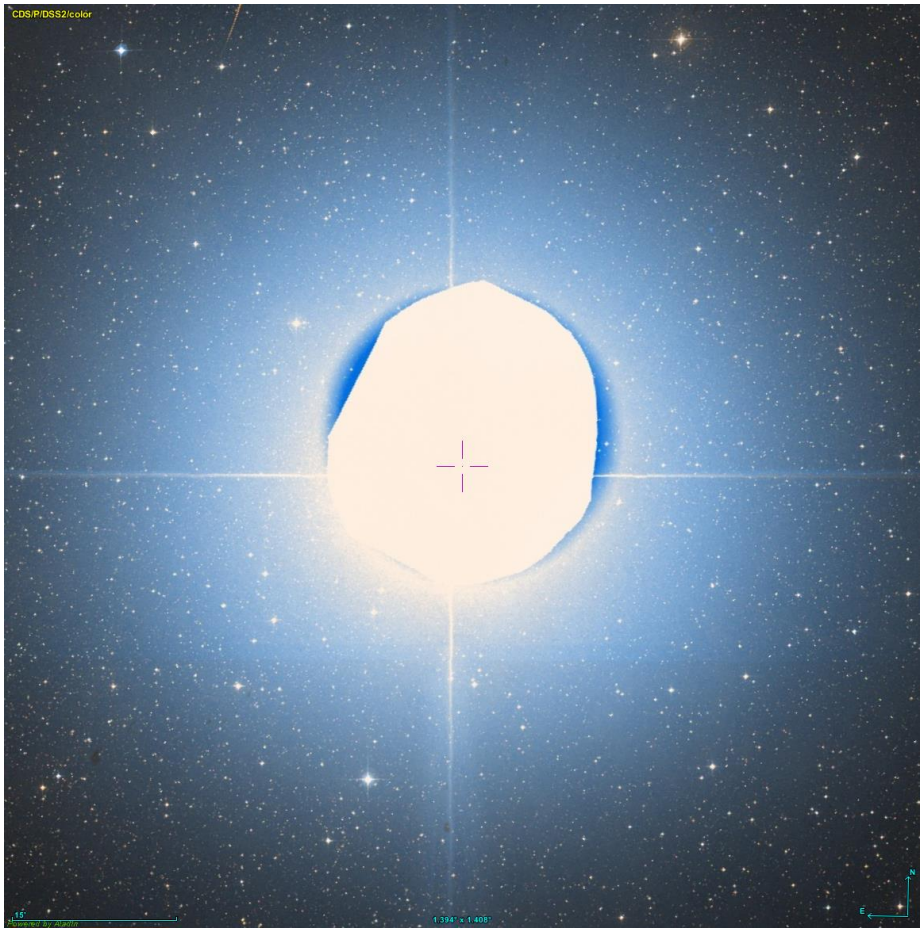
Figure 1. A cut in the YZ plane of the warped and flared Galaxy. The thick line marks the mean warped stellar disk whereas the blue dashed lines trace the density at 1, 2 and 3 the scale-height of the disk. The filled square marks the location of Gaia 1. With open circles anti-center old open clusters from (Carraro et al. 2007) are shown.

Sirius 天狼星

双星

A：大犬座α，A0型，-1.45mag；

B：白矮星，~7mag



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Gaia 1 and 2. A pair of new Galactic star clusters

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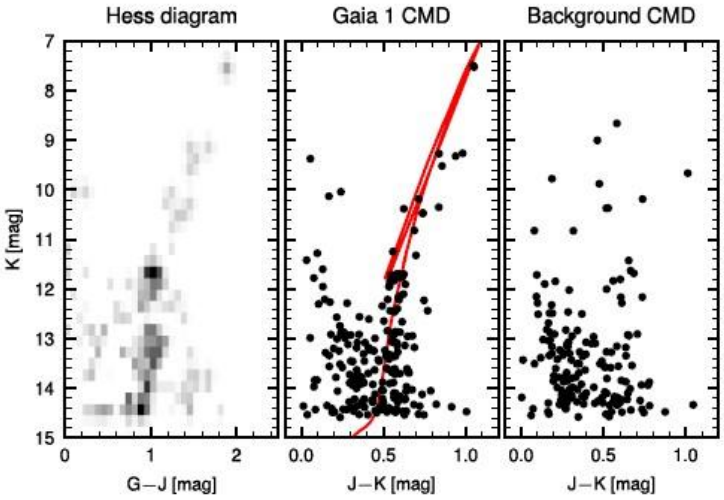

Figure 4. Left-hand panel:the background-subtracted and extinction-corrected 2MASS-*Gaia* Hess diagram of the central 0.°1 of *Gaia* 1 (area within the annulus with inner and outer radii of 0.°3 and 1° has been used for background); Middle panel: the 2MASS $J - K_s$, K_s CMD of *Gaia* 1 obtained using sources within 0.°1 from *Gaia* 1 centre. The PARSEC isochrone with the age of 6.3 Gyr and [Fe/H] $= -0.7$ at the distance modulus of $m - M = 13.3$ is overplotted in red. Right-hand panel: the CMD of the background field offset by 0.°5 from *Gaia* 1 and with the same area as used for the middle panel.

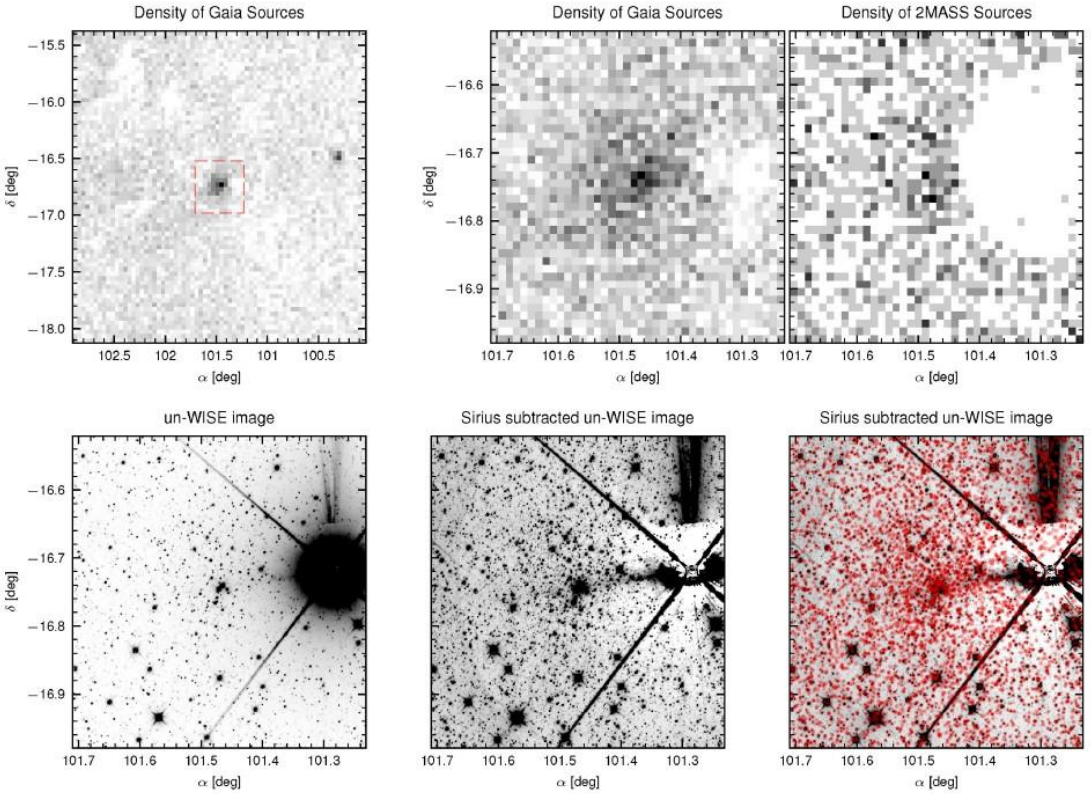

Figure 3. Distribution of sources around *Gaia* 1. Top left: the density of all *Gaia* sources with $G < 20$ within ~ 3 degrees of *Gaia* 1. The overdensity on the right edge of the panel is Berkeley 25, an old open cluster. The red box indicates the size of the region shown on other panels of the figure. Top middle: the density of *Gaia* sources with $G < 20$ in the $\sim$30 arcmin $\times$ 30 arcmin field of view around *Gaia* 1. Top right: the density of the 2MASS sources in the same field of view. Bottom left: the 30 arcmin $\times$ 30 arcmin image from the *WISE* survey showing *Gaia* 1. Bottom middle: the same image with the PSF of Sirius-subtracted. Bottom right: the same image with *Gaia* source positions overplotted in red.

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Astronomy & Astrophysics

Detailed chemical abundance analysis of the thick disk star cluster Gaia 1⋆,⋆⋆

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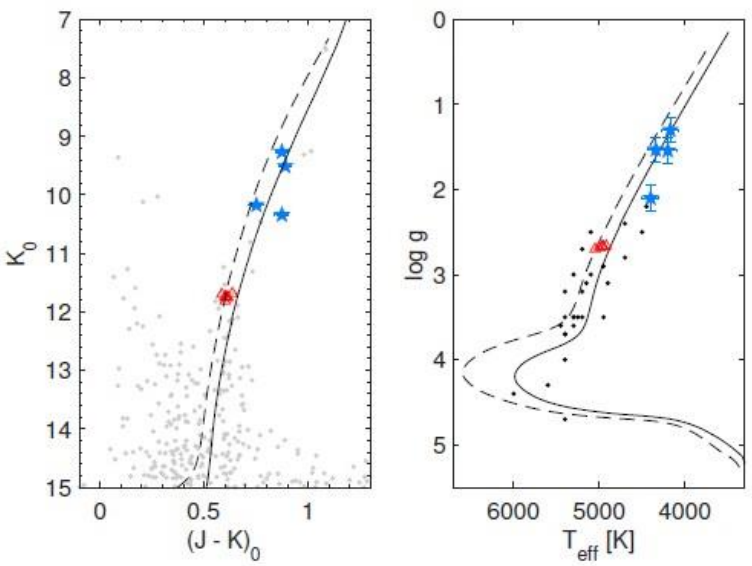


Fig. 1. *Left panel*: color magnitude diagram from 2MASS of stars within ∼2 half-light radii of Gaia 1 (gray points). *Right panel*: Hertzsprung-Russell diagram, constructed from our best spectroscopic stellar parameters. Our targets are highlighted in blue, red triangles are the He-clump targets of Mucciarelli et al. (2017), and the sample of Simpson et al. (2017) is shown in black. Each panel also displays Dartmouth isochrones (Dotter et al. 2008) using an age (6.3 Gyr) and metallicity (−0.7 dex), as suggested by Koposov et al. (2017, dashed line), and one with 12 Gyr and −0.65 dex (solid line).

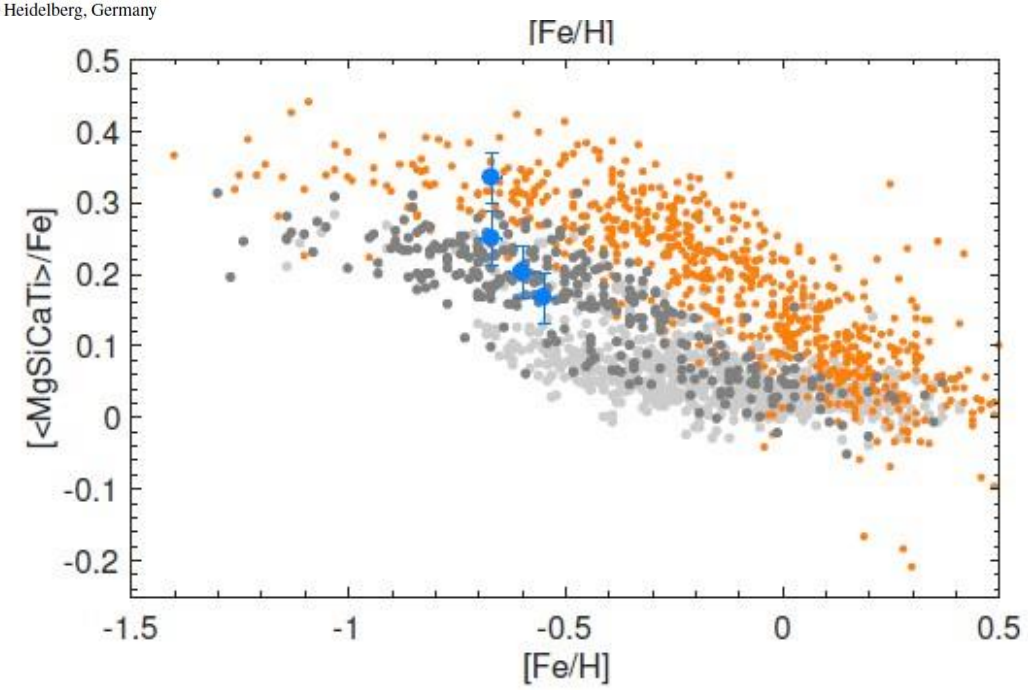
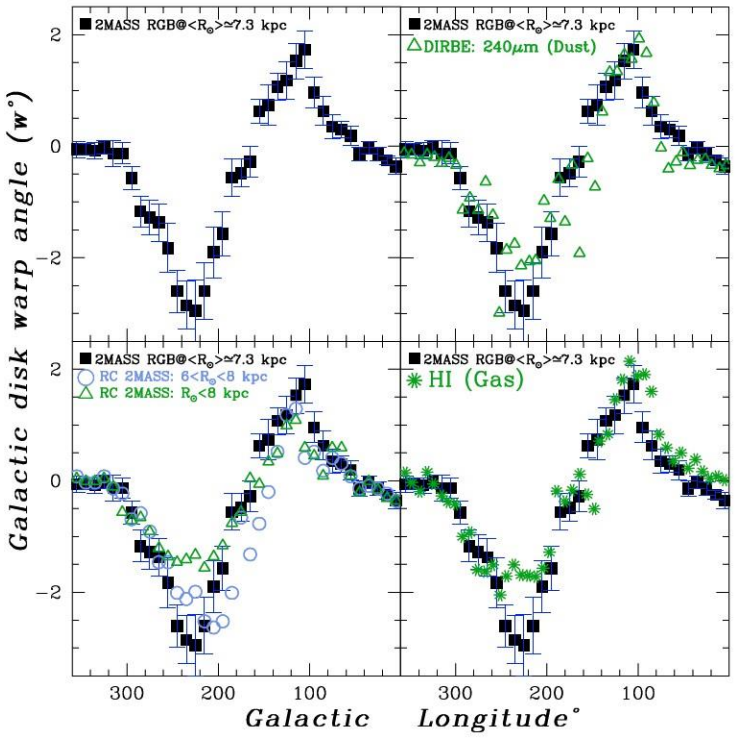


Fig. 4. Abundance ratios of the α-elements. Our stars are shown as blue symbols. Orange dots denote bulge stars from Gonzalez et al. (2011), Bensby et al. (2013), Johnson et al. (2014), while disk stars are depicted as gray points (Reddy et al. 2003, 2006; Bensby et al. 2014). Here, we specifically distinguish between thin (light gray) and thick disk stars (dark gray). The bottom panel shows the straight average of the Mg, Si, Ca, and Ti abundances as a proxy for α-enhancement. In all panels, the axis have been truncated to highlight the abundance region of our targets.



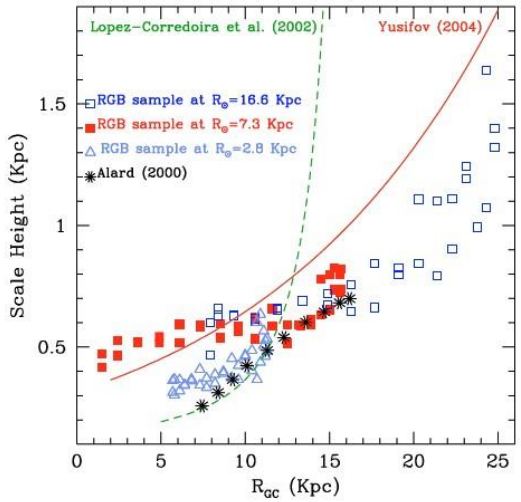


Fig. 14. Variation of the scale-height (derived from the $R_{\odot}$ = 2.8, 7.3 and 16.6 kpc RGB samples) as a function of Galactocentric distances. We also show a comparison of our results with two models and data-points from Alard (2000).

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Astronomy & Astrophysics

Outer structure of the Galactic warp and flare: explaining the Canis Major over-density⋆

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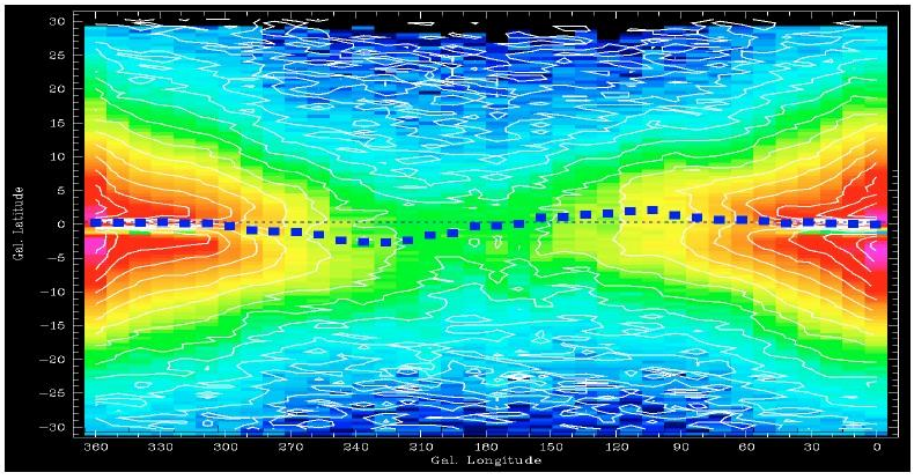

Fig. 9. The upper left panel displays the stellar warp as derived from red giants at $R_{\odot} \simeq 7.3$ kpc. In the lower left panel we compare the derived warp with those based on two RC samples between: (i) $6 \leq R_{\odot} \leq 8$, and (ii) $0 \leq R_{\odot} \leq 8$ kpc. The upper right panel over-plots the dust warp as derived from DIRBE at 240 μm data, whereas the lower right panel over-plots the Galactic warp as derived from neutral H I gas (also from Freudenreich et al. 1994). The lower panel shows the density maps and contours of the $R_{\odot} \simeq 7.3$ RGB sample. One can trace by eye the warp signature (a colored version is more appropriate). Over-plotted is also the location of the mean mid-plane warped disk as a function of longitude.