Interstellar extinction in the Galactic Center and its impact on the study of AGB stars

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ABSTRACT

We present here a high resolution interstellar extinction map of the central 280 × 200 pc of the Galactic Center (GC). We derive this from the *Spitzer*/IRAC GC point source catalog of Ramírez et al. (2008), consisting of ∼1 million sources, the majority of which are red giants and AGB stars. We derive new extinction values by using the [3.6]−[5.8] colour-magnitude diagram together with the newest isochrones of Marigo et al. (2008). We find extinction values up to $A_V \sim$ 90 mag. We also present a study of the Long Period Variables (LPVs) in the GC. We discuss the locus of LPVs in the *Spitzer*/IRAC colour-magnitude diagrams as well as their period-magnitude relations.

Subject headings: Galaxy: stellar content — infrared: stars — infrared: ISM — ISM: dust, extinction

1. Introduction

The variable star content of the inner bulge is of great interest both as a population and as a distance indicator. Long-period, large-amplitude variables situated on the Asymptotic Giant Branch (AGB), comprised of Miras and OH/IR stars, are the easiest objects to detect due to their high luminosities. During recent years, the inner region of our Galaxy has been extensively searched for OH/IR stars (see e.g. Wood et al. 1998, Vanhollebeke et al. 2006). However the analysis of Mira variables has been restricted to low extinction windows far

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from the Galactic Center (such as NGC6522). Glass et al. (2001) surveyed a $24 \times 24\,\mathrm{arcmin}^2$ area centered on the Galactic Center (GC) with a variability study spanning 4 years of observations. The majority of sources are Mira Variables and OH/IR stars with periods ranging from 150 d to about 800 d.

In most parts of the inner Bulge, the study of the stellar population is hampered by its high interstellar absorption (Frogel et al. 1999; Schultheis et al. 1999); studies in the infrared are therefore crucial. Studies in the near-IR using 2MASS or DENIS data resulted in extinction maps with a typical resolution of several arcmin (see e.g. Marshall et al. 2006, Schultheis et al. 1999). However, these maps are limited to the sensitivity of near-IR surveys which gives an upper limit of $A_V < 25$.

We present here a high resolution interstellar extinction map using IRAC data and isochrone fitting of the red giant stars. We further discuss the nature of the known Long-Period Variables (LPVs) in the Galactic Center region.

2. The data set

2.1. The Spitzer IRAC Point source catalog of the Galactic Center

The central $2.0^\circ \times 1.4^\circ$ of the GC were mapped with Spitzer/IRAC between 3.6 and 8.0 μm (Stolovy et al. 2006 and Stolovy et al. 2008, in preparation). Ramírez et al. (2008) performed point-source extraction on the IRAC data and published a confusion-limited catalog of point sources that included photometry from 2MASS as well as IRAC. The IRAC magnitudes are referred to as [3.6], [4.5], [5.8] and [8.0]. The average confusion limits are 12.4, 12.1, 11.7 and 11.2 magnitudes, however they can vary by 2 or 3 magnitudes within the survey. The whole Galactic Center catalog (see Ramírez et al. 2008 for more details, here referred to as the GALCEN catalog) consists in total of about one million sources. Most of the sources show characteristics of being red giants and AGB stars, however there are several hundreds of extremely red objects which may be massive YSOs.

2.2. Long Period Variables

Glass et al. (2001) surveyed an area of 24×24 arcmin^2 centered on the Galactic Center and have found about 400 periodic variables with Mira-like amplitudes and an average period of 427 d. They detected also 64 known OH/IR stars. We refer to this catalog as the Glass-LPV catalog. Compared to the well-explored Sgr I Baade's window of low extinction which lies at l = -1.37^0 and b = -2.63^0, their GC field contains more than ten times the number of variables per arcmin^2. Note that the average period in the SgrI field is 333 days. Due to the limiting sensitivity of their survey, small amplitude variables such as semiregular variables were not considered in their study.

3. Interstellar extinction

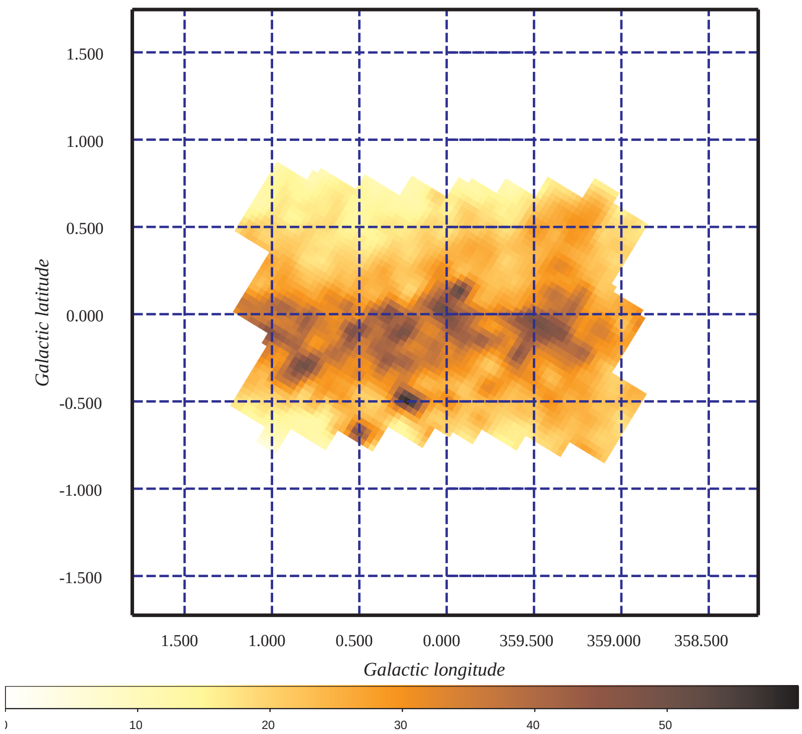

Fig. 1.— Interstellar extinction map of the central 280 × 200 pc of the Galactic Center, with a spatial resolution of 2′. We derived the extinction from the [3.6]−[5.8] colour-magnitude diagram of point sources in the Ramírez et al. (2008) GC catalog, compared to Marigo et al. (2008) isochrones. The colour bar is in units of A_V.

Interstellar extinction remains a serious obstacle for the interpretation of the stellar populations in the Galactic Center region. Several studies have been undertaken to probe the extinction in this region (e.g. Schultheis et al. 1999, Marshall et al. 2006). Ganesh et al. (2008) map the extinction towards the inner bulge with a spatial resolution of 2′, by combining GLIMPSE-II (which maps the inner galaxy with Spitzer/IRAC but does not cover the region in Fig. 1) and 2MASS data and by making use of the latest isochrones for evolved stars (Marigo et al. 2008). Extinction values for $A_V > 20$ are derived using the

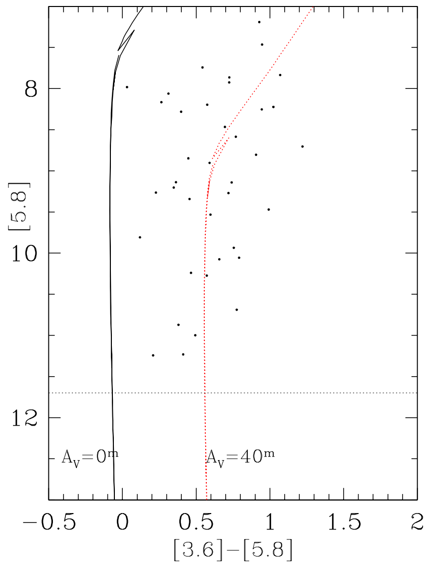

Fig. 2.— [5.8] vs. [3.6]-[5.8] colour-magnitude diagram towards a region of high extinction (see text) in the GALCEN survey. An isochrone of 40 mag extinction is displayed. The horizontal dotted line indicates the approximate confusion limit. The size of the field is 2′.

[3.6]-[5.8] colour, while for $A_V < 20$ 2MASS J and K data are used. With the large number of filter combinations at their disposal (three from 2MASS and four from GLIMPSE-II) they have looked at several colour combinations for the colour magnitude diagrams (CMD). They have chosen the [5.8] vs. [3.6]−[5.8] colour magnitude diagram as the dispersion is small. Also the $A_{[3.6]} - A_{[5.8]}$ colour excess is sensitive to variations in the interstellar extinction (see e.g. Indebetouw et al. 2005).

This pair of filters has the advantage of simultaneous observations, and [3.6]−[5.8] also has better completeness (more stars detected through high extinction) compared to $J - K_s$. In addition, metallicity effects are neglible in [3.6]−[5.8] in contrast to $J - K_s$ where the RGB/AGB branch of a metal-rich stellar population shifts to redder $J - K_s$ colours.

We have used the technique of Ganesh et al. (2008), described above, to derive a similar extinction map for the GC. We have used the GALCEN catalog of Ramírez et al. (2008), and chosen stars with $[3.6] < 12.5$ and $[5.8] < 12.0$.

Figure 2 shows a CMD towards a region of high extinction ($A_V = 40\,\mathrm{mag}$) in the GALCEN survey. Despite this high extinction we get sufficient sources to determine the extinction reliably. The highest A_V values we can detect are about $A_V \sim 90^m$ which are associated with infrared dark clouds.

4. LPVs in the *Spitzer* colour-magnitude diagrams

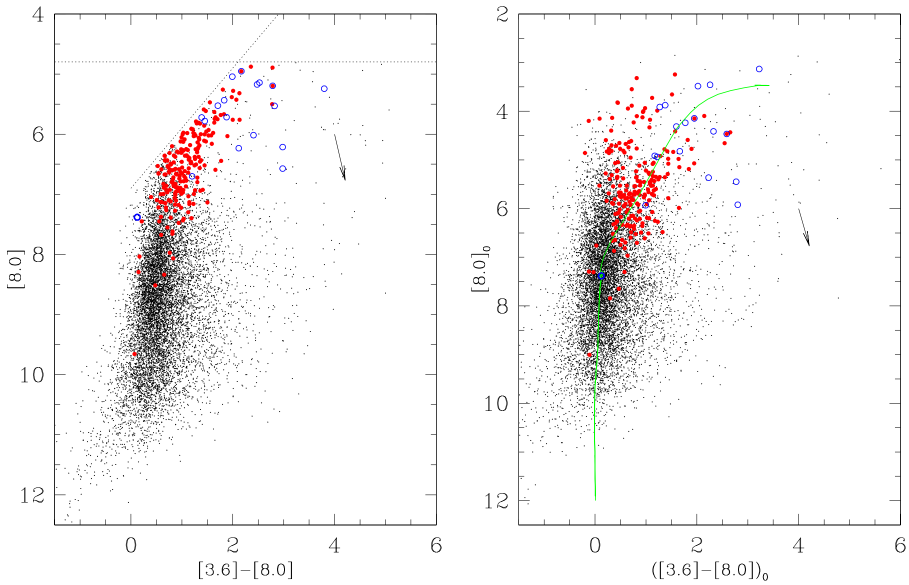

Fig. 3.— *Left panel:* [8.0] vs. [3.6]-[8.0] colour-magnitude diagram of the Glass et al. (2001) field, superimposed with the known LPVs (red filled circles) and OH/IR stars (blue open circles). The extinction vector of A_V=20 is indicated. The dotted horizontal line indicates the saturation limit at [8.0] while the dotted diagonal line shows the saturation limit at [3.6]. *Right panel*: Same diagram but dereddened (see text). Superimposed is the isochrone (Marigo et al. 2008) for 10 Gyr and Z=0.02 put at a distance of 8 kpc.

Figure 3 (left panel) shows the [3.6]-[8.0] vs [8.0] diagram for the Glass et al. (2001) field. On the right panel of Fig. 3 the dereddened [3.6]-[8.0] vs [8.0] diagram shows clearly the locus of the known AGB stars which are above the RGB tip ($[8]_0 \sim 7.3$ at a distance of 8 kpc). We used the extinction map as discussed in Sect. 3 for dereddening. The dereddened CMD fits well the superimposed isochrone of Marigo et al. (2008). This agreement makes us confident of the derived extinction values. The AGB variables show a large scatter in this diagram due to strong variability (we only have single-epoch measurements) and infrared excess related to heavy mass-loss.

5. The Period-magnitude relation

AGB variable stars in the Galactic bulge follow in the near-IR a well-defined period-magnitude relation. Glass et al. (2001) showed that the mean K magnitude for the Glass-

LPVs, measured over a complete cycle, follows a logP vs. K relation. The dispersion, however, is large due to extinction.

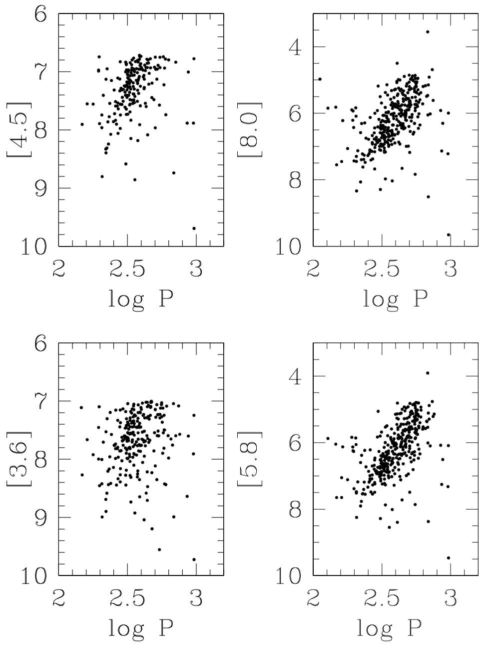

Fig. 4.— IRAC magnitude vs. log P for Glass-LPVs identified in the survey of Glass et al. (2001), where P is the period.

Figure 4 shows the [IRAC] magnitude vs. log period relation for the Glass-LPVs. The IRAC bands are not corrected for extinction. The dispersion is much smaller compared to K as the IRAC bands are less sensitive to variation in extinction. Even within the IRAC bands, the dispersion decreases to longer wavelengths as the effects of extinction decrease.

In contrast to the light curves obtained by Glass et al. (2001) we have only single epoch measurements in the IRAC bands. Part of the observed scatter in Fig. 4 is thus related to the variability of the LPVs. The K amplitude distribution of the Glass-LPVs peaks around 0.8 mag, going up to 1.5 mag for the OH/IR stars. The calculated and observed properties of Miras and OH/IR stars from ISO data (Marengo et al. 2006) suggest a similar range in variability at IRAC wavelengths.

6. Summary

We present a high resolution interstellar extinction map, derived from the *Spitzer* IRAC catalog of point sources in the Galactic Center (Ramírez et al. 2008). We used the

RGB/AGB population together with the newest isochrones (Marigo et al. 2008). Compared to previous near-IR extinction maps, all regions of high A_V can be resolved. The maximum value is $A_V \sim 90$ mag. With this extinction map, we study Long-Period Variables in the GC of Glass et al. (2001) in the *Spitzer* bands. They follow a well-defined period-magnitude relation in the IRAC bands. Part of the observed scatter in this relation is due to intrinsic variability of the Glass-LPVs, as we have only single-epoch observations.

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