New insights into the dust lanes of the Galactic bar

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ABSTRACT

Trails of dust inside galactic bars are easily observable in external galaxies. However, information on the dust lanes of the Milky Way is harder to obtain due to our position within the Galactic disc. By comparing the distribution of dust and gas in the central regions of the Galaxy, we aim to obtain new insights into the properties of the offset dust lanes leading the bar's major axis in the Milky Way.

On one hand, the molecular emission of the dust lanes is extracted from the observed CO $l-b-V$ distribution according to the interpretation of a dynamical model. On the other hand, a three dimensional extinction map of the Galactic central region constructed using near-infrared observations from 2MASS is used as a tracer of the dust itself and clearly reveals dust lanes in its face-on projection. Comparison of the position of both independent detections of the dust lanes is performed in the (l, b) plane.

In both the gas and dust distributions, the dust lanes are found to be out of the Galactic plane, appearing at positive latitudes for $l < 0°$ and at negative latitudes for $l > 0°$. However, the amplitude of the tilt is more pronounced for the molecular gas than for the dust resulting in the dust lying closer to the Galactic plane, on average, than the molecular gas.

This type of study may be generalised to other stellar observations - work is currently underway to perform similar 3D studies of the ISM in the Galactic plane using the GLIMPSE point source catalogue.

Subject headings: Galaxy: structure — Galaxy: center — ISM: kinematics and dynamics — ISM: dust, extinction

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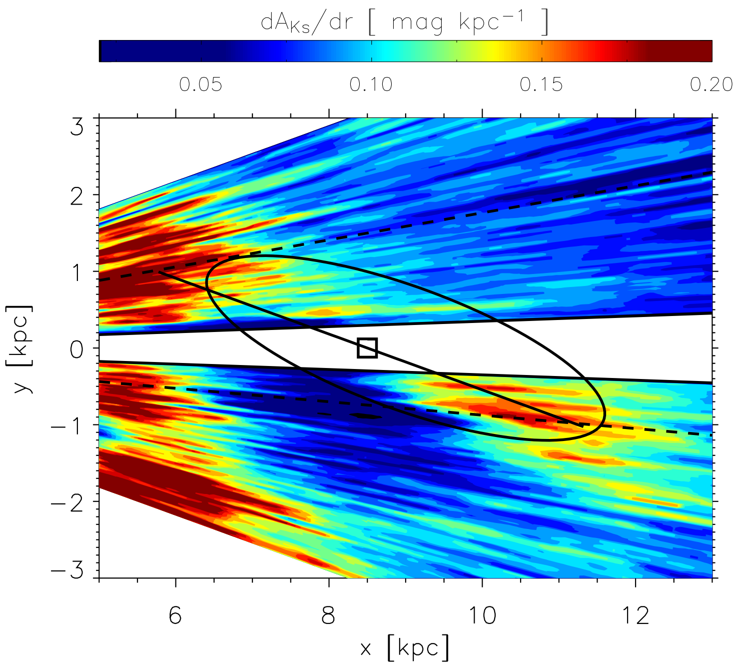

Fig. 1.— Dust extinction of the Galactic centre (Marshall et al. 2006).

1. Introduction

Barred galaxies are ubiquitous in the Universe. Many of these are observed to have dust lanes - trails of gas and dust, seen in extinction, leading the bar's major axis. Our position in our Galaxy does not give us a clear view of the inner regions. Photometric studies are hampered by the high source confusion and severe interstellar extinction whereas gas kinematic studies are rendered difficult due to line of sight crowding of the gas emission lines.

We combine the results from gas dynamics and stellar reddening studies in order to provide a description of the dust lanes leading the bar's major axis. We find that both the dust and the gas components of the dust lanes are tilted with respect to the $b = 0°$ plane. Furthermore, they are offset from one another which may be an effect of the large scale magnetic field or which may be indicating changing dust properties in the dust lanes of the Milky Way bar.

2. Dust lanes - NIR extinction

We use a three dimensional extinction map (Marshall et al. 2006) to isolate the extinction of the bar's dust lanes. This map uses a Galactic model (Robin et al. 2003) to extract the three dimensional reddening information contained in the Two Micron All Sky Survey (Skrutski et al. 2006). The uncertainty in the distance to extinction features ~ 0.5 kpc.

The dust lanes, detected by their near infrared extinction, as seen from the North Galactic Pole, are displayed in Fig. 1. The quantity plotted is differential extinction, assumed to be proportional to the density of big dust grains. Gray indicates no data, the square represents the centre of the Galaxy, at an assumed distance of 8.5 kpc from the Sun (itself at the origin, outside the figure). The ellipse is chosen, by inspection, to include as much of the dust lane extinction while avoiding unrelated dust. The straight line indicates the orientation of the stellar bar in the Galactic model (20°) and the dashed lines show the end of the dust lanes as seen in CO emission. The elongated structure seen in extinction, running along the modelled stellar bar, is due to the dust lanes. Its thickness along the line of sight is increased due to the distance uncertainty in the extinction map.

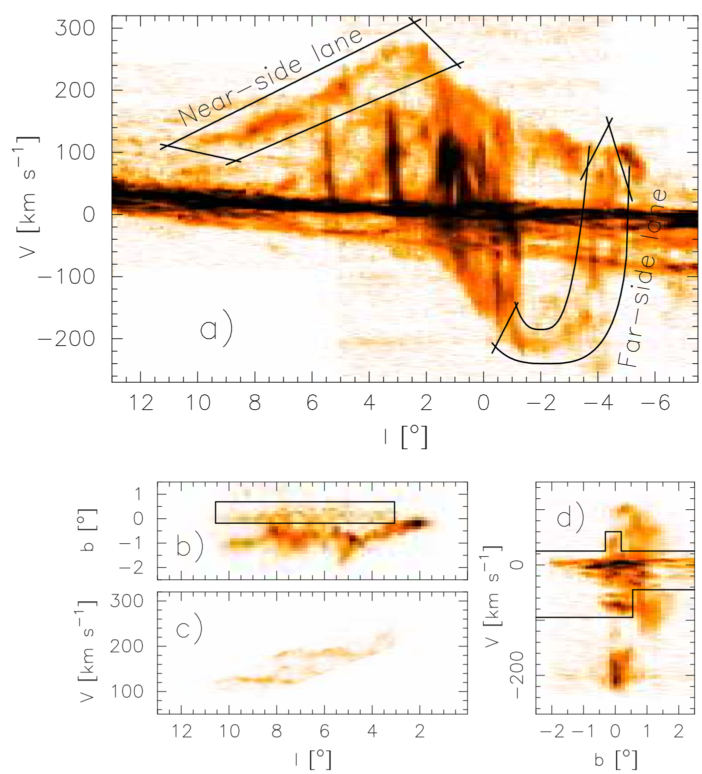

Fig. 2.— Selection of the dust lanes from ^{12}CO observations (Dame et al. 2001). See text for further details.

3. Dust lanes - CO emission

Figure 2 shows the observed (Dame et al. 2001) $l-V$ distribution of ^{12} CO towards the Galactic centre. Overlaid contours highlight elements of the dust lane selection. The different subfigures illustrate the selection of the emission arising from the dust lanes : (a) Emission from the dust lanes (dark contours) was isolated by using a dynamical model (Fux 1999). However, some of this selected emission may not originate from the dust lanes (see b-d, below). (b) The highlighted emission is unrelated to the near-side lane (see c, below) (c) Two features have nearly constant velocity emission. These contrast with the global $l-V$ inclination of the near-side lane. (d) Unrelated emission to the far side lane selection include spiral arms and the 3-kpc arm.

4. Results and discussion

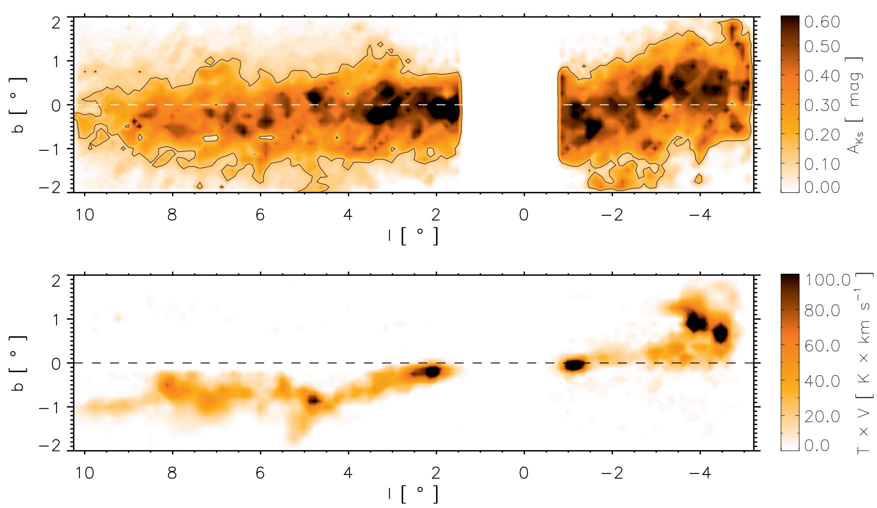

Fig. 3.— Dust lanes, projected on to the $(l,\, b)$ plane, as seen by their dust extinction (top) and ^{12}CO emission (bottom).

Figure 3 displays the total extinction of matter within the ellipse of Fig. 1, as well as the ^{12}CO emission as selected in Fig. 2. Both the dust and gas display a large scale tilt with the near-side dust lane ($l > 0°$) lies below the $b = 0°$ plane, and the far-side dust lane ($l < 0°$) lies above the $b = 0°$ plane.

Figure 4 shows the intensity weighted mean plane of both the dust and the gas. The dust seems to lie, on average, at lower $|b|$. Dust - CO separations have been observed in external galaxies, for example in a spiral arm of M83 (Lord et al. 1991). However, the interpretations

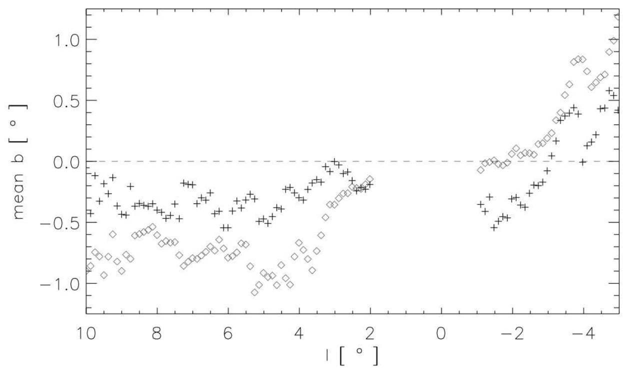

Fig. 4.— Intensity weighted mean plane of the dust (crosses) and CO (diamonds) of the Galactic dust lanes.

cannot be easily ported to galactic bars where the gas and dust enter a shearing shock.

We therefore suggest two different scenarios, as the observed offset can be interpreted as a vertical displacement in z, or as a horizontal offset on a common but tilted plane:

Vertical offset:

The dust and gas hit the shock and are driven to lower $|z|$, either due to the interaction with the bar's shock or by the effect of the Galactic potential on the co-moving gas and dust.. At the shock front, the big grains are shattered into smaller grains which protect the CO molecules by increasing the UV extinction. Downstream, and therefore at lower z, coagulation reduces the abundance of the small grains and the CO is then disassociated by UV photons and/or is frozen onto dust grains.

Horizontal offset:

In this scenario, both the dust and gas are coplanar on a tilted plane. If the large scale magnetic field is strong enough, it will only be weakly affected by the bar's shearing shock. As a result, molecular clouds decouple from the regular magnetic field and the dust is carried further downstream than the molecular gas. This mechanism has recently been invoked to explain a similar dust - CO offset in NGC 1097 (Beck et al. 2005).

5. Conclusion

In order to differentiate between possible scenarios used to explain this dust-CO offset, further observations and modelling are required. Nevertheless, we have detected the dust lanes by their CO emission and their NIR dust extinction. This reinforces the dynamical model (Fux 1999), as well as the use of the Galactic model (Robin et al. 2003) to construct three dimensional extinction maps (Marshall et al. 2006). Work is planned to adapt the extinction technique to use the GLIMPSE point source catalogue, which will enable deeper, higher resolution extinction maps.

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