A TINNY GALACTIC DUST CLOUD PROJECTED ONTO NGC 3269?

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ABSTRACT

We report on new observations obtained with the Magellan Clay telescope of a tiny dust patch in the Sa galaxy NGC 3269, in the Antlia galaxy cluster. It has already been suspected to be a projected Galactic foreground cloud. In this case, a size of about 4" and a maximum absorption of ~1 mag in the B band would make it unique so far. We present further evidence for its Galactic nature from imaging under excellent seeing conditions (0.3–0.6). This dust cloud could be the first optically identified counterpart of a new type of molecular cloud recently discovered by Heithausen.

Key words: dust, extinction — ISM: clouds

1. INTRODUCTION

In the course of studying the globular cluster systems NGC 3258 and NGC 3268 in the Antlia Cluster, we noted a tiny dust patch in the neighboring galaxy NGC 3269 (Dirsch et al. 2003) with a diameter of about 4", barely visible on images found in the literature.

This is striking, since NGC 3269 is a grand-design Sa spiral without signs of star formation or small-scale substructure. Moreover, the galaxy seems to be devoid of H i (Barnes & Webster [2001] quote from their Australia Telescope Compact Array (ATCA) observations an upper limit of about 109 M⊙). We estimated the absorption in Washington C and Kron-Cousins R filters and found a reddening law less gray than the standard one (He et al. 1995). The average absorption in R is about 0.3 mag, comparable to the average foreground absorption in the line of sight. At the distance of NGC 3269, this patch would be a large dust cloud with a diameter of about 500 pc. Besides the fact that the existence of a singular dust complex of this dimension is strange by itself, it should be accompanied by star formation and should have many cores with very high line-of-sight absorption, causing the average R-value to be larger, i.e., to tend toward gray absorption. If the dust cloud were located inside the galaxy with some stellar light in front of it, these effects would be even more pronounced. These reasonings gave rise to the conjecture that this cloud could be a Galactic cloud in the foreground, projected onto NGC 3269. The low Galactic latitude of NGC 3269 (−19°) supports this interpretation. To our knowledge this would be the first detection of an isolated Galactic dust cloud of this angular size (at 100 pc distance, 4" = 400 AU). A larger dust complex in this region is not obvious. In the catalog of Galactic dust clouds by Dutra & Bica (2002), the entry nearest to NGC 3269 is the IR-excess cloud IREC 403 (Désert et al. 1988), whose center is 78' away. IRAS maps show 100 μm emission about 5' north of NGC 3269 and about 10' to the southwest. NGC 3269 itself is projected toward a local minimum of emission.

An accidental projection of a Galactic dust cloud onto a galaxy may by itself be of no great interest. However, Heithausen (2004) reported the discovery of tiny molecular clumps with densities indicating a high overpressure with respect to the ambient interstellar medium (ISM) and sizes resembling that of our dust patch. Their properties suggest that they may be an abundant structural feature of the ISM. Our dust patch might be the first optical identification of this kind of molecular cloud. Therefore, one would like to have further support for or counter-evidence against this hypothesis. The seeing on our Washington images was about 1", and measurements on scales of the order of the seeing may be unreliable. In this contribution, we report new observations under extremely good seeing to call further attention to this apparently rare phenomenon.

2. OBSERVATIONS

During an observing run at the 6.5 m Magellan Clay telescope at Las Campanas Observatories, Chile, we took advantage of a period of excellent seeing and imaged NGC 3269 in the Harris filters B and R with MagIC. The observing date was 2004 January 31. The CCD has a pixel scale of 0.069 pixel−1, providing a field of view of 2.36 × 2.36. The total exposure time in B was 1800 s and was 1200 s in R. The frames were bias-subtracted and flat-field corrected using the IRAF1 script magic_tools.2 The seeing on the B image was 0.35, and on the R image it was 0.76. Figure 1 shows the dust patch in the southwestern part in NGC 3269 in the B band. In this image, the sky has been subtracted. Further substructure is visible. The shape is not spherical, and the points of highest absorption are located somewhat off-center. The galaxy exhibits a very smooth stellar light distribution, which is distorted only by our dust cloud and two extremely small dust cloudlets (0.5') nearby (marked in Fig. 1). The inset shows NGC 3269 on a larger scale in Washington C (see Dirsch et al. [2003] for details). Clearly visible are extended arclike structures indicating previous or ongoing tidal interactions. These events might also have been responsible for a gas removal out of NGC 3269.

3. REDEENING

The dust patch is not projected onto a homogeneously bright surface, which would ease measuring the absorption. There is a gradient in surface brightness in the east-west direction. The gradient is smallest in the north-south direction, and we therefore chose to place a slit across the patch in this direction. The slit has a length of 210 pixels and a width of 30 pixels (corresponding to 145.2 × 20.0). We take the average along the width. Figure 2 displays the result.

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1 IRAF is distributed by the National Optical Astronomy Observatory, which is operated by the Association of Universities for Research in Astronomy, Inc., under cooperative agreement with the National Science Foundation.

2 See http://www.lco.cl/lco/magellan/instruments/MAGIC/iraf减_reductions.html.
The top left panel of Figure 2 shows the $B$ profile on a linear scale after sky subtraction. To measure the relative absorption, we adopt a background level of 70. The top right panel shows the same for the $R$ image (note that the scale is now different). We adopt 220 as the local background value. The bottom panels show the relative absorption in $B$ and $R$.

With these values we calculate the average absorption ratio $A_B/A_g$ and the $R$-value $A_B/(A_B - A_R)$, which are shown in Figure 3 (left and right, respectively). For $A_B/A_g$ the uncertainty in dividing two small numbers is evident in Figure 3 (left). This is less obvious in Figure 3 (right) because here the boundary of the dust patch is relatively sharp. The worse seeing in $R$ lets the $R$ absorption reach zero less rapidly than the $B$ absorption. We consider only the “plateau” in the pixel interval 520–570. In this region $A_B/A_R=2.00 \pm 0.28$, where the uncertainty is the standard deviation. The uncertainty of this average value is difficult to formalize because the intensities are not independent, but they should be much smaller than 0.25 mag. Our Harris filters match Johnson $B$ and Cousins $R$. A standard reddening law in these filters is given by He et al. (1995). The standard value of $A_B/A_R$ is 1.65, very similar to that given by Rieke & Lebofsky (1985) for the Johnson system. Given that we average over small structure, which also makes the derived $A_B/A_R$ value grayer, the real value for $A_B/A_R$ will be higher (not lower!) by an unknown amount.

Figure 3 (right) displays $R=A_B/[(E(B-R)]$, and we measure an average of $1.6 \pm 0.25$, again in the pixel interval 520–570. The standard value according to He et al. (1995) is 2.5, compared to 2.3 in the Johnson system (Rieke & Lebofsky 1985).

The statistical uncertainty alone would be small enough to conclude that the reddening law is indeed less gray than the standard reddening law. The systematic uncertainty is dominated by the adoption of a sky value. The sky values, measured in the outer regions of the frames, are 176 in the $B$ frame and 1160 in the $R$ frame. The relative accuracy of the sky determination for the $R$ frame is below 1%, and for the $B$ frame it is about 1%. Adopting 1% for both bands translates into uncertainties of an absolute level of $\pm 10$ units in the $R$ band and $\pm 2$ units in the $B$ band. Error propagation gives an uncertainty of 0.05 in both $A_B$ and $A_R$, leading to a value of about 0.1 for $A_B/A_R$ and $A_B/[(E(B-R)]$.

Another factor is the local background. However, as can be seen from the scatter in the top panels of Figure 2, no uncertainty is larger than the uncertainty caused by the sky value. For simplicity we have assumed that the galaxy’s brightness is constant along the slit, although the background is slightly fainter in the northern part, which is best visible for the $R$ frame in Figure 2. Thus, we underestimate the absorption by a tiny amount. Since the gradients in $B$ and $R$ are correlated, the reddening value is only differentially affected. Also, the nonstandard photometry is a second-order effect because of our differential approach. The systematic uncertainty is thus smaller than the statistical one.

4. DISCUSSION

The above uncertainties support the claim that the reddening has a somewhat stronger wavelength dependence than the standard reddening law, in contrast to the expectation of a grayer reddening law if the dust patch were located in NGC 3269. A stronger wavelength dependence points to a smaller grain size than in any “standard” extinction case. In Bok globules one finds $R_V$ values as high as 6.5 (Strafella et al. 2001), compared to the standard value of 3.1. This indicates that our cloud probably is not simply a distant Bok globule (which then would be located in the Galactic halo).
On the other hand, although H i has not been detected in NGC 3269, the current upper limits of the H i column density reported by Barnes & Webster (2001) still do not rule out a considerable H i content of the dust patch and its nature as a large complex in NGC 3269. They give their 1 σ sensitivity as $4.3 \times 10^{18} N_{\text{H}i} \text{ cm}^{-2}$. Adopting a 5 σ detection limit of $2 \times 10^{19} N_{\text{H}i} \text{ cm}^{-2}$ in an $87' \times 73'$ beam, the corresponding upper limit for the dust patch, normalizing to area, is $10^{22} N_{\text{H}i} \text{ cm}^{-2}$. We adopt for the ratio of $V$ absorption to total neutral hydrogen column density $A_V/N_{\text{H}i} = 5.3 \times 10^{-22} \text{ cm}^{-2}$ (Bohlin et al. 1978; Weingartner & Draine 2001). With this value, the expected column density is $4 \times 10^{20} N_{\text{H}i} \text{ cm}^{-2}$, which is below the detection limit anyway.

To our knowledge this is the first detection of an isolated dust cloud of this tiny angular size. The smallest globules in the surveys of Clemens & Barvainis (1988) and Bourke et al. (1995) have diameters of about 30″. Larger projected dust structures have been seen before, for example, against Maffei 1 (Buta & McCull 2003). Our case could be a rare coincidence. On the other hand, structures of this size are extremely difficult to see, and the projection onto an extended background source is practically the only way to detect such objects. This is probably hopeless with spiral galaxies with a lot of internal dust. Early-type galaxies at low Galactic latitudes are, on the other hand, not the most favored objects in galaxy studies, so tiny clouds may systematically be overlooked.

Our findings might gain interest in the context of studies of small molecular clouds. Heithausen (2004) recently presented interferometric observations of “small-area molecular structures” (Heithausen 2002). He could resolve some tiny molecular clouds with properties suggesting that this kind of molecular structure is a common feature of the ISM. The angular sizes resemble that of our dust patch, which, if in the Galaxy, is expected to also be associated with molecular gas. It is therefore possible that our cloud is an optical counterpart to the molecular clumpuscules of Heithausen. According to him, “it is unknown what creates or maintains these structures.”

To get an idea of the mass associated with the absorption at a fictitious distance, we adopt for the ratio of $V$ absorption to total neutral hydrogen column density $A_V/N_{\text{H}i} = 5.3 \times 10^{-22} \text{ cm}^{-2}$ (Bohlin et al. 1978; Weingartner & Draine 2001). This holds for the diffuse ISM, but the normalization should not drastically differ from that in dense clouds (Weingartner & Draine 2001). Thus, the total number of hydrogen atoms is
$N_{\text{tot}} = (1.9 \times 10^{21}) r^2 \alpha^2 \pi A_f$, $r$ being the distance and $\alpha$ the angular radius. The mean $R$ absorption within our slit is 0.2, a value that we also use for the $V$ absorption. An adopted distance of 100 pc and a radius of 2000 AU then suggest a mass of $\approx 10^{-5} M_{\odot}$. Given the nature of this estimate and the unknown distance, this mass is not too different from the masses of the molecular clumps given by Heithausen. The corresponding density is very high, about $0.5 \times 10^6$ cm$^{-3}$. Heithausen (2002) noted that CO molecules in these clouds are not likely to survive the interstellar radiation field unless there is sufficient shielding. Our dust cloud could provide the necessary shielding. If the cloud is in the Galactic disk, its distance can be as large as 1000 pc. Its radius would then be 2000 AU, still significantly smaller than typical Bok globules (e.g., Strafella et al. 2001).

The tiny clumpuscules indicated in Figure 1, if associated with the larger cloud, would have diameters of the order 50 AU at 100 pc distance. They are too small for reliable absorption measurements.

Whatever the nature of our dust structure may be, it would be interesting to search for more examples. Another candidate may be hosted by NGC 3923; this is hardly visible on images found in the NASA/IPAC Extragalactic Database, but features prominently in recent Hubble Space Telescope images (Th. Puzia 2004, private communication).

A related issue is perhaps the recent detection of small-scale H i clouds (Braun & Kanekar 2005) in the local ISM with extremely low column densities. The connection of this new atomic feature to molecular or dust structures is unknown. However, it shows that there are more small-scale phenomena in the ISM than previously thought.

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