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A Census of Dust Absorption at the Galactic Centre

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Abstract. The Galactic Centre offers a uniquely valuable line of sight for studies of the nature of dust in the ISM, but the long-held assumption that the line of sight samples only the diffuse ISM has been subverted by ground-based and ISO observations demonstrating the presence of absorption bands due to solid-phase volatile ices in the field. Spatial variability of the observed features suggests a patchy distribution of even the foreground diffuse-medium absorption. To map this clumpy distribution and to produce an inventory of the dust components, we are carrying out a narrow-band imaging survey over a field which extends from the Galactic Centre to beyond the circumnuclear ring, using both IRCAM3 and Michelle on UKIRT to cover the 3 μm water ice, 3.3 μm PAH, 3.4 μm hydrocarbon and 9.7 μm silicate absorption features. This paper presents the rationale for this programme and reports on progress with analysis of the survey data.

1 Introduction

Through detailed infrared spectroscopy, we know much about the nature of the materials present in hydrocarbon dust grains in the diffuse ISM. The 3.4 μm absorption band, first seen in the diffuse ISM along the line of sight to the Galactic Centre (GC) (e.g. Willner et al. 1979, Butchart et al. 1986), has been thoroughly analyzed, and substructure within the band is identified with short-chained aliphatic hydrocarbons. ISO detections of the corresponding weak deformation modes at 6.85 and 7.25 μm (Chiar et al. 2000) have considerably narrowed the range of possible hydrocarbon materials (Pendleton & Allamandola 2002).

The relationship of the diffuse-ISM hydrocarbons to other grain components is poorly known, although there is a correlation between the 3.4 μm band and the silicate feature over a range of extinctions (Pendleton et al. 1994, Sandford et al. 1995). Spectropolarimetry suggests that these materials cannot be physically associated with any form of aligned grains which are responsible for the visual and near-IR polarization of starlight (Adamson et al. 1999), and they cannot be associated with organic refractory mantles (i.e. a result of processing of ices - Chiar et al. 1998). The observations tend to favour models invoking small grains over those requiring carbonaceous mantles on large grains, though the key spectropolarimetry results will remain controversial until observations of organic and silicate polarization spectra can be obtained in exactly the same line of sight.

In dark clouds, the 3.4 μm band is replaced by absorption at 3.47 μm (Allamandola et al. 1992), which is known to be associated with ices rather than the silicates (Brooke et al. 1996, Brooke et al. 1999, Chiar

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et al. 1996), indicating a major change in the nature of the hydrocarbon-bearing grains. Absorption due to polycyclic aromatic hydrocarbons (PAHs) has been suggested on the basis of a 3.25 μm absorption band seen in some dark cloud sources (Brooke et al. 1999, Sellgren et al. 1994). While seen in sources with deep ice absorption, correlations suggest that these materials are in fact more closely related to refractory grains such as silicates (Brooke et al. 1999). In fact, dense-cloud and diffuse-cloud PAHs may be different in nature: the dense-cloud feature at 3.25 μm peaks at a shorter wavelength, indicating a lower temperature and/or different composition, than the feature observed toward GCS3 in the Galactic Centre (which peaks at 3.28 μm - Chiar et al. 2000).

2 Rationale

Our CGS4 spectroscopy of dust grains in the Galactic Centre (Chiar et al. 2002) permitted complete deconvolution of the complex of ice and dust absorption features along this line of sight. Fig. 1 shows the deconvolved hydrocarbon absorption feature in the 3.2-3.7 μm region, comprising the 3.4 μm aliphatic hydrocarbon band and a broad (FWHM 0.15 μm) absorption centered around 3.3 μm. Previous work, which has relied on fitting a local continuum across the sharp 3.4 μm band in what is a very difficult part of the telluric spectrum, has inadvertently removed this broad feature. The band is indicative of aromatic hydrocarbons, although it is too broad for absorption arising in PAHs embedded in solid grain material.

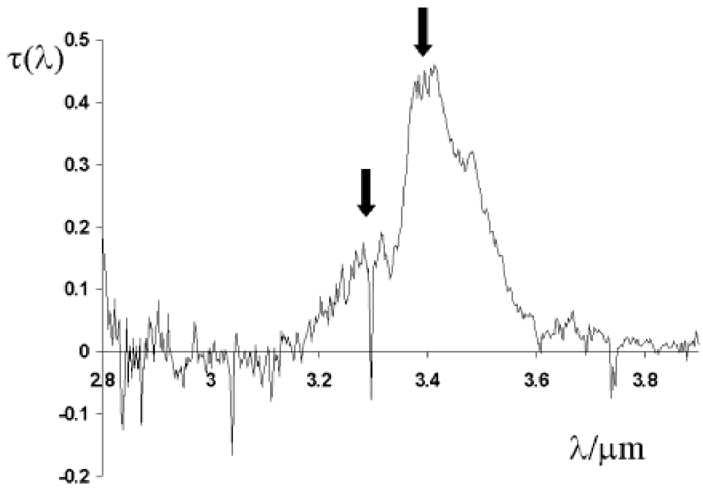

Fig. 1 Spectrum of hydrocarbon absorption in the Galactic Centre, deconvolved from the ice band (Chiar et al. 2002). Sharp negative lines are ratioing and atmospheric artifacts; arrows indicate the main 3.4 μm band and the $\sim$3.3 μm "PAH" absorption. Subfeatures near 3.5 μm are also associated with aliphatics.

The strength of the ice band varies dramatically across the Galactic Centre field. This may be due to additional ice absorption in the circumnuclear molecular ring (IRS8 and IRS19 are both situated in or behind the ring, and these two sources have strong ice bands relative to the 3.4 μm feature; see the map of this region in Chiar et al. - this volume). Our spectroscopy shows that the 3.4 μm band also varies across the field, raising the possibility that it arises in diffuse clouds which are detectably patchy, on very small transverse scales. The aim of the current programme is to determine the variability of hydrocarbon and ice absorption across the entire Galactic Centre, and so (i) to determine the scale size of the absorbing regions and (ii) further define the relationship between the aliphatic and aromatic hydrocarbon components.

3 Observations

We have carried out a 3 and 10 μm survey of the central 2 arcminutes of the Galactic Centre, in narrow-band filters which sample all the key NIR dust features. The field of view includes the circumnuclear ring, and JHK imaging data already exist with which to constrain the extinction and short-wavelength wing of the ice absorption (Blum et al. 1996). Observations were obtained with the UKIRT facility imagers IRCAM3 and Michelle, in the summer of 2001 and 2002 respectively.

3.1 3 μm photometry

IRCAM3 mosaics were obtained using the 3.1, 3.3, 3.4, 3.6 and 4.0 μm narrow-band filter sets. A mosaic in the broad L' filter was also obtianed. Fig. 2 shows a selection of images, and the filter bandpasses used.

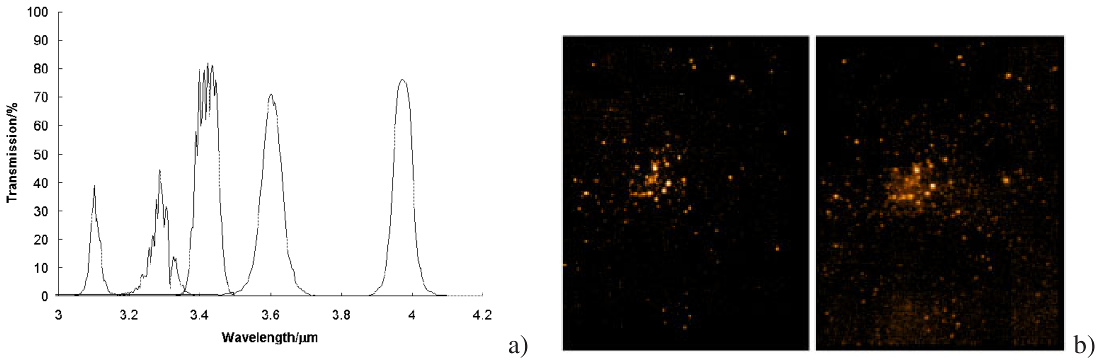

Fig. 2 a) The IRCAM3 filter set after convolution with atmospheric transmission; b) IRCAM3 mosaics in the 3.1 & 3.3 μm filters. North is at the right, East is at the top.

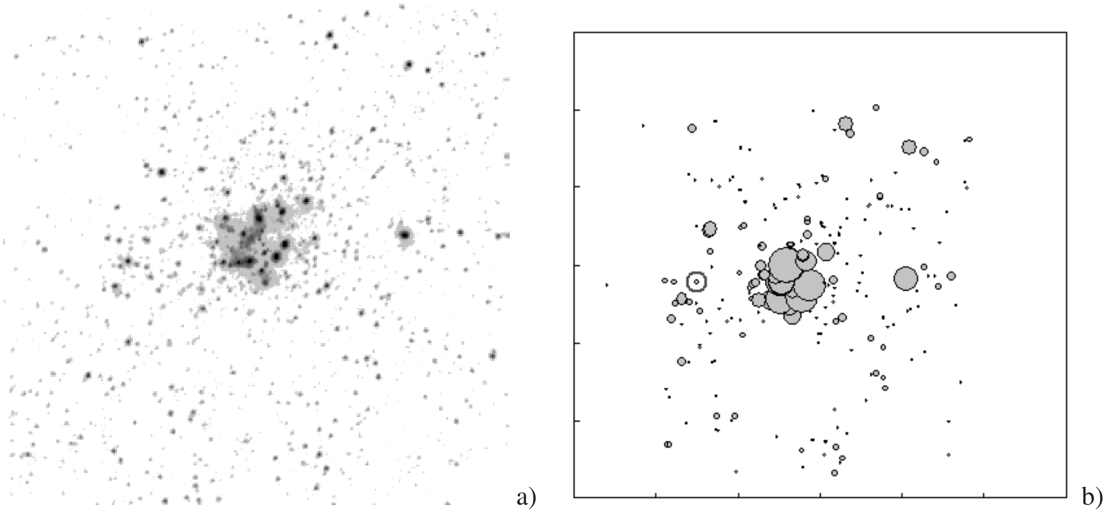

Fig. 3 a) L' continuum mosaic; b) Derived catalogue. Orientation is as in Fig. 2.

The L' mosaic image provides a deep L-band catalogue of the nuclear region, containing approximately 270 sources. Most of these are also detected in all the narrow-band filters. The basic catalogue is the deepest available wide-field L-band list of which we are aware in this region; only 10 of these sources have L-band photometry in the Blum et al. catalogue (Fig. 4), which covers a similar area of sky. By comparison, the existing near-infrared data required to provide additional model constraints is more extensive: 96 of these sources are detected in J H and K by Blum et al. Work is in progress on deeper JHK imaging data over the same field, taken with UFTI on UKIRT. This will permit constraints to be placed on extinction and thus remove an apparent degeneracy between the depth of the ice band and the degree of extinction.

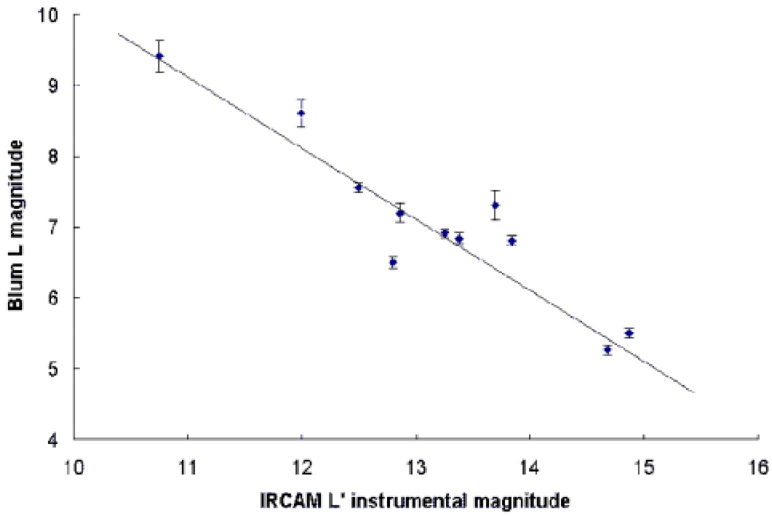

Fig. 4 Photometry within the overlap between our work and Blum et al. L band catalogue. Instrumental magnitudes from IRCAM3 are negative.

3.2 10 μm photometry

Michelle imaging in filter bandpasses in the 7.9, 9.7, 11.6 and 12.5 μm filters was carried out in summer of 2002. A small chop was used (of order three arcseconds) to chop out as much as possible of the extended structure which pervades the Galactic Centre. The imaging is most sensitive in the 7.9 μm filter, where more than 20 sources are detected within the immediate environs of the Galactic nucleus. The majority of these sources are associated with stellar objects also detected in the L-band catalogue. These data will provide a measure of the silicate absorption complementing the hydrocarbon and ice measurements, for comparison with the data on organic and volatile components from the 3 μm survey.

4 Modelling

Modelling of the data consists of iterative fitting of a model spectrum of a hot stellar source, subjected to both continuum extinction and the combined effect of the silicate, ice and hydrocarbon absorptions, folded through the known bandpasses of the filters used. Since the images contain sources for which these features have already been observed spectroscopically, the scaling factors between observed counts and feature depths are self-calibrating. Initial results suggest that with the continuum extinction fixed by JHK photometry, reliable ice-band optical depths can be extracted, but to isolate the three main components of the hydrocarbon band from one another will be difficult. Clearly, silicate depths will be available only for a small subset of the sources detected in the L-band survey, but the detection of stellar sources in the silicate filters at this distance is a major challenge.

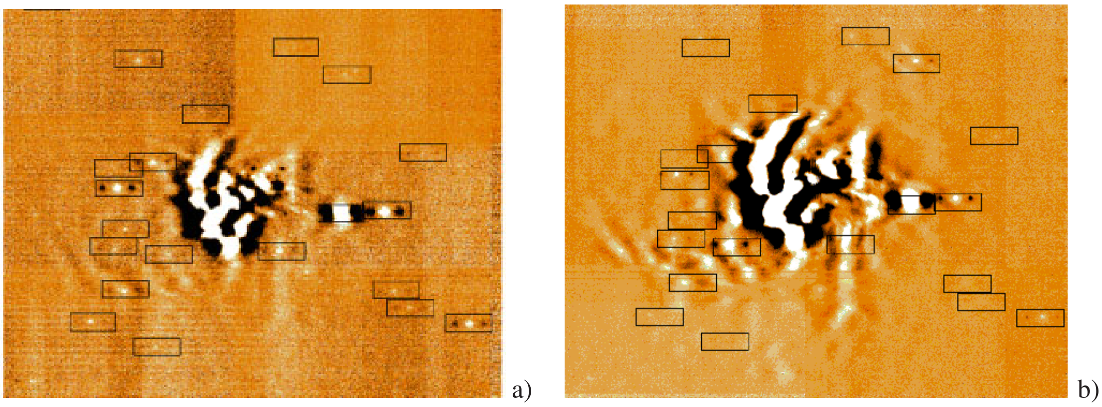

Fig. 5 a) 7.9 μm image; b) 11.6 μm image. As for the IRCAM3 frames, North is to the right, East is to the top. Each detected source (the best detections are shown in boxes) shows the chop/nod signature, with positive beam in the centre and two negative beams on either side.

5 Summary

Observations with the UKIRT facililty imager IRCAM3 have produced both an L-band catalogue, and narrow-band images over the central two arcminutes of the Galactic Centre. The catalogue is the deepest available over such a wide area in this region: some 270 sources are detected in the broad L' filter, an order of magnitude more than are present in the previous deepest list (Blum et al.). Narrow-band detections in filters distributed across the three-micron window are available for most of the detected sources. The fluxes are being fitted to produce a catalogue of the variation of key volatile and refractory dust components as a function of position within the Galactic Centre. Work is in progress on complementary JHK imaging, which supplements the JHK catalogue of Blum et al., and permits the continuum extinction to be constrained. Finally, we have recently obtained Michelle observations over a similar field, detecting more than 20 faint point sources exterior to the central cluster, most of which are probably stellar in nature.

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References

Adamson,A.J., Whittet,D.C.B., Chrysostomou,A.C., Hough,J.H., Aitken,D.K., Wright,G.S., Roche,P.F. 1999, ApJ, 512, 224
Allamandola, L.J., Sandford,S.A., Tielens,A.G.G.M., Herbst,T.M. 1992, ApJ, 399, 134
Blum,R.D., Sellgren,K., Depoy,D.L. 1996, ApJ, 470,864
Brooke,T.Y., Sellgren,K., Smith,R.G. 1996, ApJ, 459, 209
Brooke,T.Y., Sellgren,K., Geballe,T.R. 1999, ApJ, 517, 883
Butchart,I., McFadzean,A.D., Whittet,D.C.B., Geballe,T.R. & Greenberg,J.M. 1986, A&A, 154, L5
Chiar,J.E., Adamson,A.J., Whittet,D.C.B. 1996, ApJ, 472, 665
Chiar,J.E., Pendleton,Y.J., Geballe,T.R., Tielens,A.G.G.M. 1998, ApJ, 507, 281
Chiar,J.E., Tielens,A.G.G.M., Whittet,D.C.B., Schutte,W.A., Boogert,A.C.A., Lutz,D., van Dishoeck,E.F., Bernstein,M.P. 2002, ApJ, 537, 749
Chiar,J.E., Adamson,A.J., Pendleton,Y.J., Whittet,D.C.B., Caldwell,D.A., Gibb,E.L. 2002, ApJ, 570, 198
Pendleton,Y.J. & Allamandola ,L.J. 2002, ApJS, 138, 75
Pendleton,Y.J., Sandford,S.A., Allamandola,L.J., Tielens,A.G.G.M., Sellgren,K. 1994, ApJ, 437, 683
Sandford,S.A., Pendleton,Y.J., Allamandola,L.J. 1995, ApJ, 440, 697
Sellgren,K., Smith,R.G., Brooke,T.Y. 1994, ApJ, 433, 179
Willner, S.P., Russell,R.W., Puetter,R.C., Soifer,B.T. & Harvey,P.M. ApJ, 229, L65