Sub-Arcsecond Resolution Mid-IR Imaging of The Starburst NGC 520

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Abstract

We present sub-arcsecond resolution mid-infrared images of the nearby starburst NGC 520 in four narrow filters (7.9, 9.7 , 11.6 and 12.5 μm). These data, together with matched-resolution VLA data at four frequencies and Brγ data, have enabled us to calculate, in a self-consistent way, the properties of the starburst. This model agrees with our estimate of extinction from the 9.7 μm silicate absorption feature, which we have also used to produce a map of the column density of the obscuring material.

1 Introduction

We have commenced a programme of using mid-infrared (Mid-IR) observations to study the interstellar medium, in particular the dust component, in a sample of nearby infra-red bright starburst/AGN galaxies. In this poster we present our data for NGC 520 (Arp 157), a merging system[1] at a distance of ≈ 30 Mpc ($1'' = 145$ pc).

As there is no evidence for an AGN in this system, we can attribute its entire IR luminosity, $L_{IR} = 8.9 \times 10^{10} L_\odot$, to embedded star formation. The high extinction present in this system is clear from comparison of R-band ($\lambda_c = 0.6\,\mu$m, figure 1) and K-band ($\lambda_c = 2.2\,\mu$m, figure 2) images.

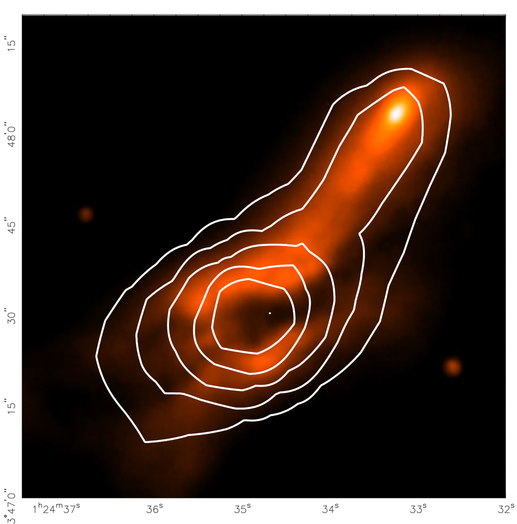

Figure 1. NGC 520: R-band (colour, from [2]) and ISOCAM 15 μm (contoured at 0.2 mJy arcsecs$^{-2} \times 0.5''$)

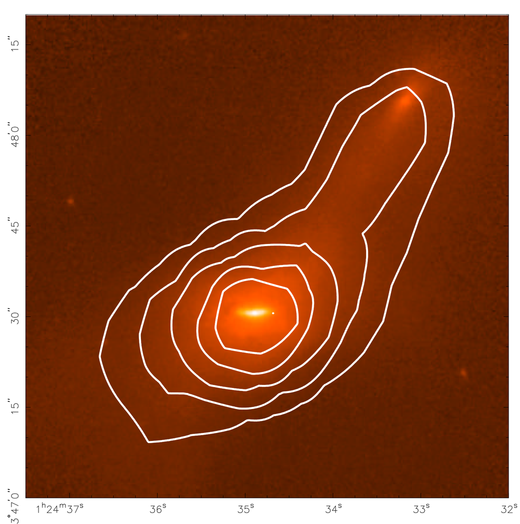

Figure 2. NGC 520: K-band (colour, from [3]) and ISOCAM 15 μm (contoured at 0.2 mJy arcsecs$^{-2} \times 0.5''$)

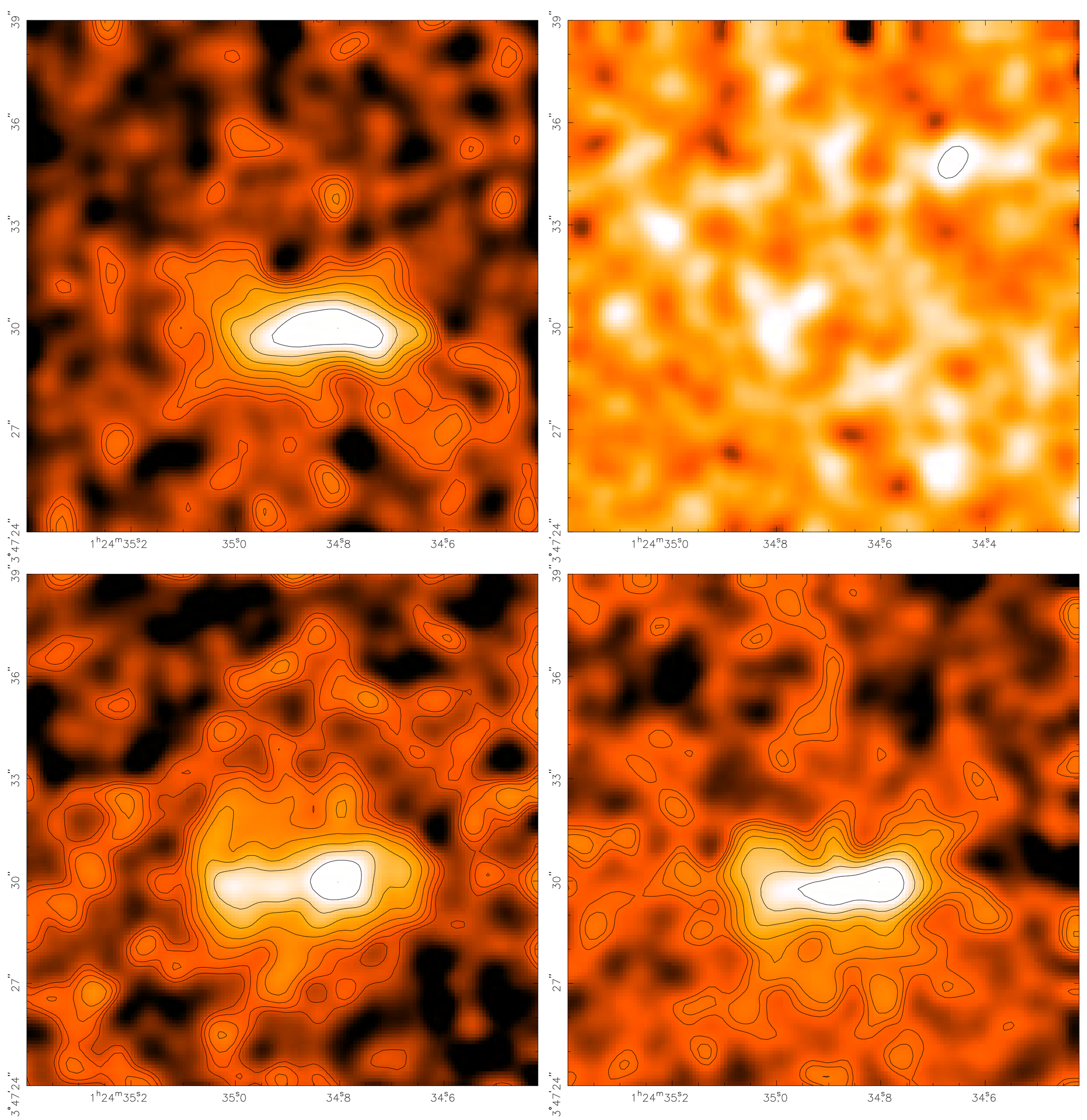

Figure 3. Michelle observations of NGC 520. Top row, left: 7.9 μm; right: 9.7 μm; Bottom row, left: 11.6 μm; right: 12.5 μm (contours are at 90, 10, 22 and 55 mJy arcsecs$^{-2} \times 0.75''$ respectively).

2 The Case for Mid-Infrared Observations

The Mid-IR is increasingly being seen as the key to understanding the phenomena of Luminous IR galaxies in the local universe as well as intense star-formation at medium and high redshift. The reasons for this are:

- Much smaller extinction compared to optical wavelengths ($A_{0.5\mu m}/A_{7.7\mu m} \approx 50$).
- Possibility of diffraction-limited seeing from the ground on 8-meter class telescope, giving resolution of $0''\!.4$.
- A number of emission/absorption features which could be used to determine the intensity & spectrum of the heating source as well as the extinction along the line of sight.

The Mid-IR spectrum of NGC 520 in the 6-15 μm range is shown in figure 5. It displays the three components often seen in the mid-infrared:

- The Unidentified Infrared Bands (UIB) centered at 3.3, 7.7, 11.3 and 12.7 μm. These are attributed to transiently heated Polycyclic Aromatic Hydrocarbons (PAH) molecules with ≈ 100 atoms.
- The continuum is attributed to Very Small Grains (VSG), again transiently heated by single UV photons. These must be sufficiently small to reach high temperatures when heated by single photons, yet big enough not to have sharp emission features.
- The deep silicate absorption at 9.7 μm (see figure 6).

The intensity of UIB is an accurate tracer of UV radiation field, while their ratios can tell us a lot about the environment of PAH molecules. For example, the 3.3 μm UIB is the highest in energy, and is therefore emitted by the smallest PAHs and/or the PAHs exposed to the hardest UV field. Comparison to lower energy UIBs could therefore constrain PAH size distribution or the hardness of the UV field.

3 Observations

Observations were carried out with the MICHELLE instrument on UKIRT on the nights of 26thJuly (filters at 7.9, 9.7 and 11.6 μm) and 27thJuly (12.5 μm filter) in photometric conditions. Background subtraction was performed with the standard technique of chopping of the secondary and nodding of the primary mirrors, both with a throw of 19.76 arcsecs. Our field of view was 70″x 50″.

3.1 Supporting observations

We have produced VLA radio maps of this source at matched resolution at four frequencies (figure 4). We also used an archival ISOCAM Circular Variable Filter (CVF) spectrum (figure 5).

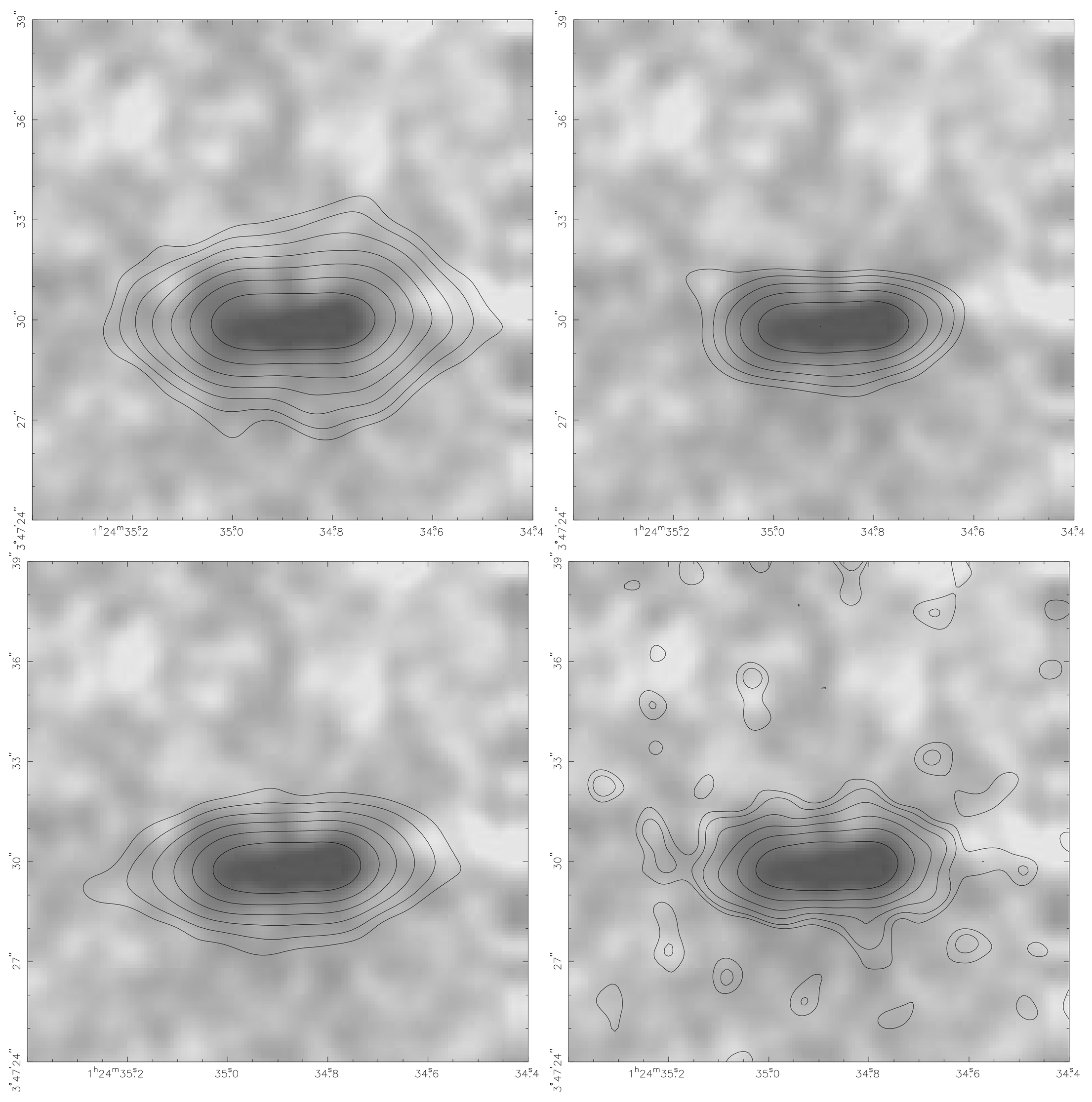

Figure 4. VLA observations of NGC 520 (contours) overlaid on 12.5 μm image (colour) , top row: 1.4 and 4.9 GHz; bottom row: 8.5 and 15 GHz. Contours are at 21, 3.2, 4.4 and 7.4 mJy beam$^{-1} \times 0.5''$ respectively.

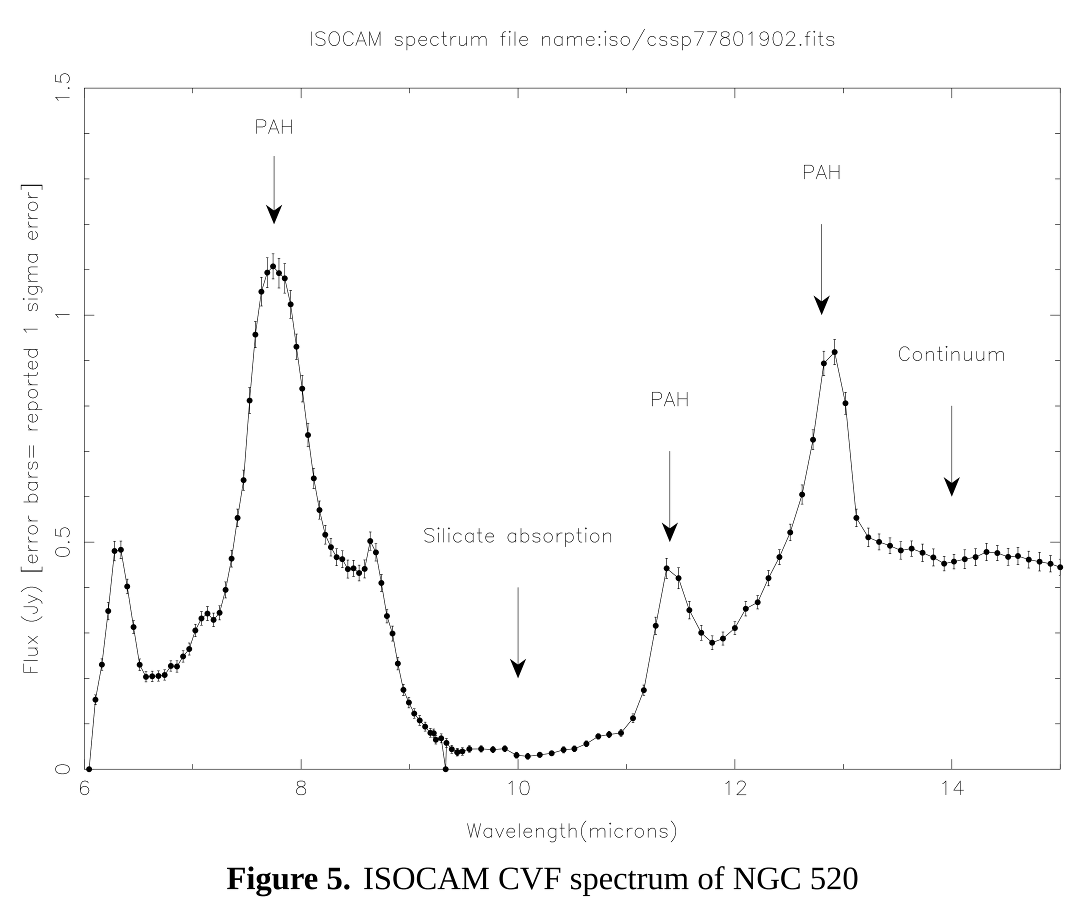

Figure 5. ISOCAM CVF spectrum of NGC 520

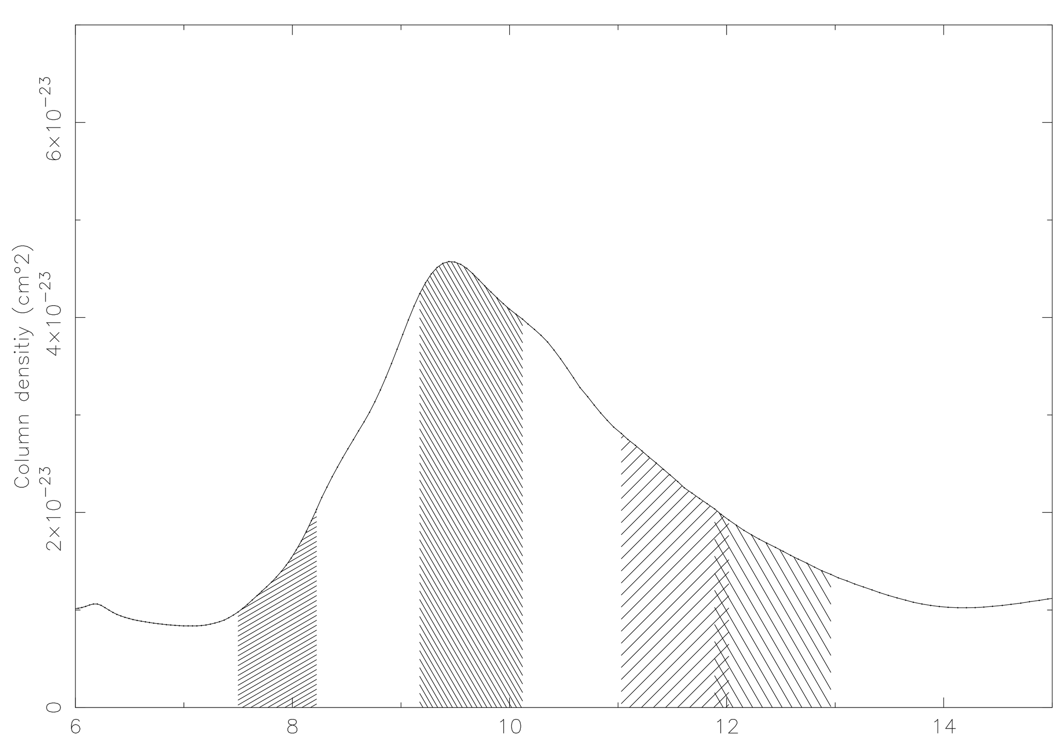

Figure 6. Interstellar extinction curve from [4] overlaid with the pass bands of our filters

4 Discussion

Good quality data at a large number of wavelengths has allowed to draw detailed conclusions about the starburst in NGC 520:

- Radio free-free emission indicates UV photon density of $N_0 = 8.1 \times 10^{53}\,\mathrm{s}^{-1}$. This can be reconciled with estimate by Kotilainen et al [3], which is $N_0 = 2.6 \times 10^{53}\,\mathrm{s}^{-1}$, by revising their K-band extinction estimate to $A_K = 3$.
- Using IRAS data, and the Radio-FIR correlation, we estimate the total energy release in the nuclear starburst in NGC 520 to be $6.7 \times 10^{10} L_\odot$. Mid-IR data indicate around $7 \times 10^8 L_\odot$, or 1% of the total luminosity, is emitted in the 7.7 μm UIB.
- The luminosity and N_0 estimates indicates an age of 5.2 Myr and starburst mass of $1.0 \times 10^8 M_\odot$ (assuming an instantaneous burst of star-formation). This can be compared to the mass of cold molecular material $= 4.3 \times 10^9 M_\odot$.
- Using detailed stellar population models[5] we used the above parameters to estimate the supernova rate to be $\nu_{SN} \approx 0.1\,\mathrm{yr}^{-1}$. This is close to the value inferred from synchrotron radio emission component, using the method of Condon 1992[6], $\nu_{SN} \approx 0.15\,\mathrm{yr}^{-1}$.
- We find that the relative variations in our Mid-IR data — that is, the colour maps — are consistent with a constant source spectrum which suffers absorption by a varying column density of intervening material. The inferred map of the line-of-sight gas column density is shown in figure 8. The average column density over the starburst disk is $6 \times 10^{22}\,\mathrm{Hcm}^{-2}$ which corresponds to $A_K = 4$, a value close to that indicated by Brγ data.

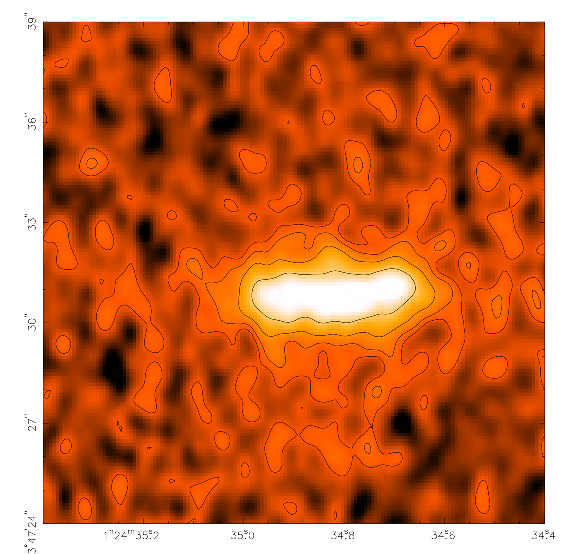

Figure 7. Map of Brγ emission, from [3] (overlaid with own contours at peak$\times 0.5''$)

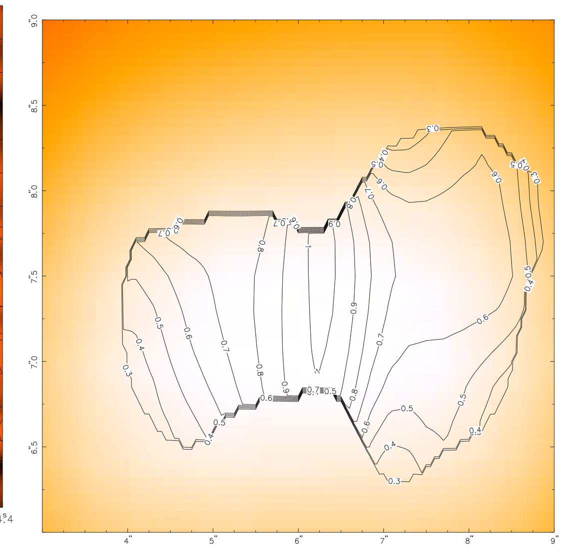

Figure 8. Gas column density $\times 10^{23}\,\mathrm{Hcm}^{-2}$, estimated from the 9.7 μm absorption feature (different scale to previous figures)

5 Conclusions

- We have presented new Mid-IR and Radio data which further constrain the properties of the starburst in NGC 520 and indicate it is more deeply embedded then previously thought ($A_K \approx 3.5$).
- We show that Mid-IR emission accurately and efficiently traces intense star formation.
- We demonstrate that Mid-IR imaging in several filters around the 9.7 μm absorption feature can be used to make meaningful maps of the column density of the obscuring material.

We believe that with a larger number of number of narrow-band filters (around six) it should be possible to accurately dis-entangle the mid-infrared UIB and continuum and the effects of extinction. These data should be sufficient on their own to constrain UV radiation field, heating source spectrum *and* extinction along the line of sight in deeply embedded starbursts, all at the high angular resolution possible from the ground.

Acknowledgements

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References

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