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Dust in spiral disks: opacity profiles from FIR emission and counts of distant galaxies

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Abstract.

Dust emission in the far-infrared (FIR) characterizes the temperature and quantity of interstellar dust in a spiral disk. The three Spitzer/MIPS bands are well suited to measuring the gradient in temperature and the total optical depth in the disk of a spiral galaxy. Another way to estimate the quantity of dust in a spiral disk is the "Synthetic Field Method" (SFM, González et al. (1998)), which uses the number of distant field galaxies seen through the disk of the nearby spiral. The optical depth estimated from this method can be compared to the values derived from the FIR emission. Since the two techniques depend on different assumptions regarding the dust geometry and emissivity, this comparison between the optical depth profiles can potentially shed light on the structure and quantity of the ISM in spiral disks, especially any colder components. The dust responsible for the opacity from distant galaxy counts appears to be predominantly cold ($T \leq 20$ K.). The differences between the radial absorption profiles can be explained by spiral arms in the SFM measurements. Taken over the same aperture, galaxy counts show higher extinction values than the FIR derived ones. The implications for dust geometry can hopefully be explored with a more rigorous estimate of dust mass from the FIR fluxes.

1. Introduction

The dust content of spiral disks can be measured from Far-Infrared (FIR) or sub-mm emission, reddening or by dust absorption of a known background source. The emission depends on the temperature and mass of the dust in the spiral disk. The number of distant galaxies depends on the average optical depth and hence cloud cover. By comparing these two measurements, we hope to probe the ISM geometry in spiral disks.

The number of distant galaxies seen through the disk of a galaxy in an HST image needs to be calibrated for crowding and confusion with the "Synthetic Field Method" (SFM, Figure 1). The FIR emission is measured from Spitzer/MIPS data taken for the SINGS project (Kennicutt et al. 2003). The emission can be translated into an optical depth with an estimate for the emissivity and the temperature similar to Alton et al. (1998). First we compare the

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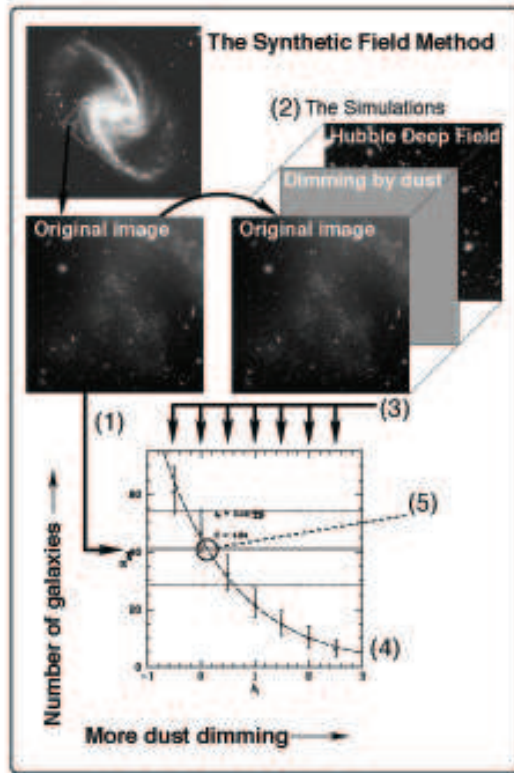


Figure 1. A schematic of the “Synthetic Field Method” (González et al. 1998; Holwerda 2005). First a WFPC2 field is retrieved from the Hubble Space Telescope archive and redrizzled. The SFM steps are:

1. The number of distant galaxies in the original science field are counted.
2. The “synthetic fields” are made by combining a dimmed Hubble Deep Field with the science field.
3. The numbers of synthetic galaxies are counted in the synthetic fields.
4. $A = -2.5 \text{ Log}_{10}(N/N_0)$ it fitted to the number of synthetic galaxies (N) as a function of the applied dimming (A).
5. From the intersection between the number galaxies in the science field and the fit, the average dimming in the image is found.

radial profiles from the MIPS images to the SFM profiles from Holwerda et al. (2005) for 10 galaxies common to both samples. In addition, the WFPC2 field-of-view is used as an aperture on the MIPS images and the opacity measures for that section of the disk are compared directly.

2. Radial Profiles

Figure 2 shows a typical profile. The FIR profiles are fitted with two thermal components ($T = 50 \text{ K}$ and $T < 30 \text{ K}$). The SFM profile is determined from the section of the disk covered by the WFPC2. In the case of NGC 2841, the bump at $150''$ in the SFM profile appears due to the spiral arm. Figure 3 shows the FIR and SFM values from the radial profiles. The SFM values are higher for the outer disk while some of the inner disk show higher FIR derived opacities. This could be explained by the difference in field-of-view over which these radial profiles were measured.

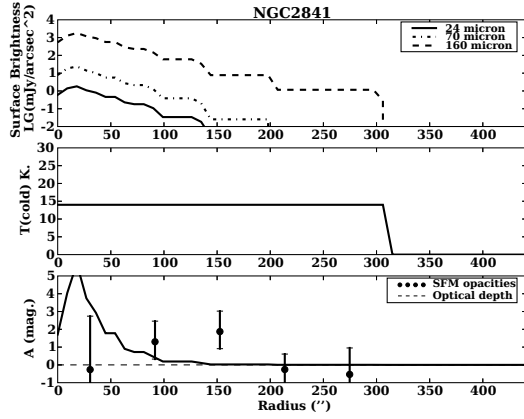


Figure 2. The radial profiles of NGC2841. The MIPS profiles (top), the derived cold dust temperature profile (middle) and inferred opacity profile (bottom). The points are the opacity measurements from the counts of distant galaxies in HST data.

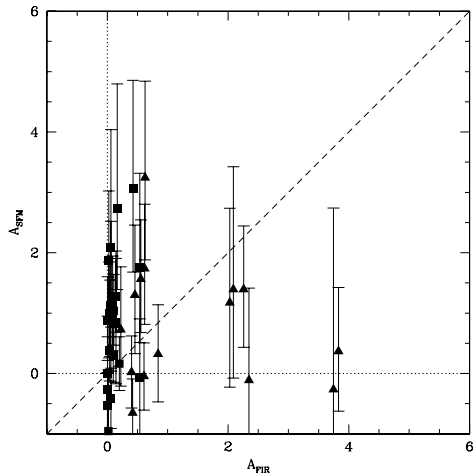


Figure 3. The absorption estimates from emission (A_{FIR}) and counts of distant galaxies (A_{SFM}) for 10 galaxies in our sample. The squares are for the outer radii ($R > 0.5 R_{25}$) and the triangles for the inner parts of the disk ($R < 0.5 R_{25}$).

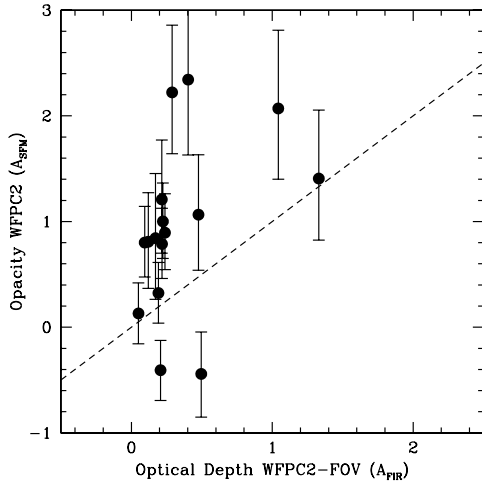


Figure 4. The absorption estimates from emission (A_{FIR}) and counts of distant galaxies (A_{SFM}) for the section of the disks covered by the WFC2. Negative values from the counts of galaxies may very well be due to cosmic variance in those numbers, which is reflected in their uncertainties.

3. WFC2 Apertures

To remedy the above problem with the radial profiles, the opacity and FIR flux within the WFC2 FOV can also be compared. Figure 4 shows the ratio of FIR derived opacity and the one based on counts of galaxies. The majority of the SFM opacities is still greater than the FIR ones, indicating a high filling factor for the cloud volume. The implication could be that (a) the average cloud size is very small, or (b) the clouds are predominantly oblate in the plane.

4. Conclusions

1. The dust found by the SFM is predominantly cold ($T < 20 K$).
2. The higher SFM radial profile in the outer disk most likely due to spiral arms.
3. Compared over the same aperture, SFM values remain higher than the FIR ones.

Future work comparing FIR emission and galaxy counts should include an improved estimate of the dust mass from FIR, since a 2 temperature component fit is too simplistic.

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References

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| <p>Alton et al.: 1998, ApJ 507, L125 González et al.: 1998, ApJ 506, 152</p> | <p>Holwerda, B. W.: 2005, <i>Ph.D. thesis</i>, Kapteyn Astronomical Institute Holwerda et al.: 2005, AJ 129, 1396 Kennicutt et al.: 2003, PASP 115, 928</p> |
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