The Spitzer Space Telescope and DIRBE Studies of the Near Infrared Background

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• The Diffuse Infrared Background Experiment (DIRBE) was one of three instruments on the Cosmic Background Explorer (COBE) satellite that was launched in 1989
DIRBE Beam Size

0.7°
• DIRBE imaged the sky in 10 IR bands from 1.25 microns to 240 microns with a 0.7 degree beam.
But there are multiple foregrounds hindering our detection of this background comprised of light from stars and interstellar dust in our own galaxy and dust in our solar system (S shape in the images on the right).

### TABLE 2

<table>
<thead>
<tr>
<th>Component</th>
<th>2.2 $\mu$m $(\text{kJy sr}^{-1})$</th>
<th>3.5 $\mu$m $(\text{kJy sr}^{-1})$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>137.5 $\pm$ 0.3</td>
<td>105.3 $\pm$ 0.3</td>
</tr>
<tr>
<td>Zodi</td>
<td>101.8 $\pm$ 3.8</td>
<td>80.4 $\pm$ 3.3</td>
</tr>
<tr>
<td>ISM</td>
<td>…</td>
<td>1.1 $\pm$ 0.2</td>
</tr>
<tr>
<td>Stars, $m &lt; 9$ mag</td>
<td>7.4 $\pm$ 2.2</td>
<td>5.3 $\pm$ 1.8</td>
</tr>
<tr>
<td>Stars, $m &gt; 9$ mag</td>
<td>11.9 $\pm$ 0.6</td>
<td>5.7 $\pm$ 0.3</td>
</tr>
<tr>
<td>CIRB</td>
<td>16.4 $\pm$ 4.4</td>
<td>12.8 $\pm$ 3.8</td>
</tr>
</tbody>
</table>
The Cosmic Infrared Background (CIRB)

- The Zodiacal Light is the biggest foreground contributor but that is removed with modeling and will improve with better models over time.
- Unresolved foreground stars are the next big contaminant to the DRIBE images due to the very large (0.7 degrees) beam.
- This is where the higher resolution and large area mapping capabilities of Spitzer stand to make the biggest contribution.

Gorjian, Wright & Chary 2000
• ....aren’t there a large number of deep and large surveys done by *Spitzer* (SDWFS, SWIRE, COSMOS, …)? Why don’t you use those?

• Yes! But all of them saturate on bright (m < 9 ) stars which make up more than half of the stellar contribution to the DIRBE measurements.

• What about WISE and AKARI?

• WISE and AKARI have the same saturation issues and does not go as deep.

• Our data though was taken in *Spitzer’s* High Dynamic Range mode which prevents saturation up to magnitude 3.6\( \mu \text{m} = 8 \)

• Then we used *Spitzer’s* subarray mode to individually measure stars as bright 4.5 mag.

• So for these 24 square degrees we have measured sources ranging from 4.5\(^{th}\) to 19\(^{th}\) magnitude. A huge dynamic range!

• Finally we have had an extensive effort to cross calibrate *Spitzer* to DIRBE
Regions covered in this effort:
Six 2 degree x 2 degree regions
• Unresolved foreground stars are the next big contaminant to the DRIBE images due to the very large (0.7 degree) beam
• This is where the higher resolution and large area mapping capabilities of Spitzer stand to make the biggest contribution.
Spitzer’s great sensitivity also offers the opportunity to add up the Integrated Galaxy Light (IGL) to compare to the residual left from the foreground subtraction of the DIRBE data. If there is no unresolved Diffuse Extragalactic Background light (EBL) then the IGL should match the EBL.

The plot compares the integrated galaxy light from deep Spitzer imaging in GOODS (Chary, unpublished) with the DIRBE-estimated EBL at 3.6 microns (solid symbol with error bars; Gorjian et al). The solid line is the contribution to the IGL from galaxies brighter than the corresponding flux density limit. Aperture corrections to the galaxy photometry have been derived based on the morphology of galaxies in higher resolution Hubble images. The horizontal dashed line intercepts the y-axis at a point equal to the IGL if the aperture correction were applied assuming the standard point spread function.
Figure 1: Left panel: The total optical to far-IR EBL measured from a combination of absolute photometry (i.e. HST, DIRBE, IRTS, and FIRAS) and with indirect techniques (GeV/TeV blazar spectra and resolved/stacked galaxy counts) [6].
The Cosmic Infrared Background (CIRB)
Cross Calibration

- To accomplish this task great care has to be taken to cross calibrate Spitzer with DIRBE.
- For this we needed a number of stars that were isolated in the DIRBE beam and re-imaged them with Spitzer.
- Unfortunately all the appropriate DIRBE stars saturated Spitzer.
- Fortunately many of these bright stars were used to establish the Spitzer PRF based on fits to their wings so that they could later be subtracted in searches for faint companions.
Final result (core PRF)

3.6 µm

4.5 µm
Examples of alignment/normalization

- All stars aligned/normalized with special calibration set of Vega.
- Background and normalization are fitted iteratively from radial profiles. Background determined in the external part of the image, normalization within the green circle. Pulldown is also masked to avoid biasing the fit.
Fig. 1. — *WISE* 3.4 μm images of the sample of main sequence stars. The images are all scaled on the same linear stretch. Each image spans ~ 0.7° or ~ 1 DIRBE beam. The colored boxes indicate a 5′ × 5′ IRAC field of view. The blue boxes indicate stars with DIRBE counterparts. These are the stars used in this study. Magenta boxes indicate stars with DIRBE counterparts, but which also have equally bright neighbors well within the DIRBE beam. These stars are outliers in the trends shown in this study, and were thus rejected in the final analysis. Red boxes indicate stars where no DIRBE counterpart was found. These are the fainter stars, apparently below the limiting magnitude of the DIRBE point source catalog.
region 3813 channel 1

slope = 1.0086
The Cosmic Infrared Background (CIRB)
<table>
<thead>
<tr>
<th>Authors</th>
<th>CIRB(kJy sr(^{-1}))(^a)</th>
<th>Zodi-Model(^b)</th>
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<td>Hauser et al. (1998)</td>
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<td>Kelsall et al. (1998)</td>
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<td>12.8±3.8</td>
<td>Wright (1998)</td>
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<tr>
<td>Matsumoto et al. (2005)</td>
<td>16.9±3.5</td>
<td>Kelsall et al. (1998)</td>
</tr>
<tr>
<td>Levenson et al. (2007)</td>
<td>15.6±3.3</td>
<td>Wright (1998)</td>
</tr>
<tr>
<td>Levenson &amp; Wright (2008)</td>
<td>10.8(^{+2.1}_{-1.1})</td>
<td>N.A. (Galaxy Counts)</td>
</tr>
</tbody>
</table>

• Note.—Foreground subtraction intensities were measured in the DIRBE 3.5 \(\mu m\) band while galaxy count intensities were measured in the *Spitzer* 3.6 \(\mu m\) band. These results do not distinguish between these nearly identical bands.

• \(^a\)For comparison, \(\nu I_\nu (\text{nWm}^{-2}\text{sr}^{-1})=(3/\lambda[\mu m])I_\nu [\text{kJy sr}^{-1}]\)

• \(^b\)The Kelsall et al. (1998) zodiacal light model gives a CIRB 4.0 kJy sr\(^{-1}\) higher in the L band.
### Preliminary Results

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A global fit to all 6 regions, with one slope (1.0013) and 6 intercepts:
13.82 (zodi=82.2), 13.66 (zodi=76.0), 14.50 (zodi=79.9),
16.48 (zodi=106.9), 16.23 (zodi=96.8), 15.34 (zodi=92.8) kJy sr\(^{-1}\)

Based on scatter of points \(\sigma = 0.2\) kJy sr\(^{-1}\)
Based on scatter among intercepts \(\sigma = 0.5\) kJy sr\(^{-1}\)
Total scatter in intercepts is 3 kJy sr\(^{-1}\)
Future Work

- Four of our regions are covered by the Sloan Digital Sky Survey and so we will take their star/galaxy identifications to help do a precise IGL measurement.
- Precise error measurement for the stellar contribution
The End