Detailed Site Evaluation of the South Pole in the MWIR Using the SPIREX/ABU Telescope

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INTRODUCTION

- Instrument description
- Background analysis
- Quality of standard photometric observations
- Correcting photometry using off-source background
- Judgement of site quality
Our data analysis program had five goals.

Using L band (3.5 μm) data:

• Determine the long term stability of the (source free) background.
• Determine the quality of photometric data obtained from several standard sources.
• Can observations be photometrically corrected for atmospheric conditions?
  – Can the quality of observations be assessed with a simple observation of off-source background?
  – Are other metrics available for correction?
• Determine the percentage of ‘good’ or ‘correctable’ observing time during the South Pole night.
• Are there any easily observable weather pattern correlates?
The SPIREX/ABU instrument has operated during the South Pole austral winter for two years.

- The instrument has provided deep, wide-field, thermal infrared (2-5 micron) imaging capability for key sources in the southern hemisphere, such as...
  - Magellanic Clouds
  - Galactic Center
  - Active star formation regions
  - Young clusters
  - Mass-losing evolved stars

NGC6334
SPIREX/ABU is a 60 cm telescope with a large, high resolution InSb detector

- 60 cm aperture
- Aladdin 1024 X 1024 InSb first-generation detector
- Located at the ‘darksector’ at the South Pole
- Has a smaller guide instrument located coaxially
13,000 raw images (fields) were collected during the 1999 observing season.

- 110 observing days out of 199 days at site.
- Total exposure time during observing season almost $1.5 \times 10^6$ seconds.
- More than $5 \times 10^5$ seconds in L band observations.
- Analysis concentrated on L band data

**L band observation statistics:**

- 38% of total observing time
- Average of 9 reduced frames /day with 3.5 hours ‘on target’ (collecting data)
- 29% of total time spent observing (8 hour day + maintenance)

<table>
<thead>
<tr>
<th>Wavelengths</th>
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<tbody>
<tr>
<td>Broadband</td>
<td>Narrowband</td>
</tr>
<tr>
<td>L</td>
<td>L'</td>
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<tr>
<td>3.5 µm</td>
<td>3.8 µm</td>
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<tr>
<td>PAH</td>
<td>H₂</td>
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<tr>
<td>3.3 µm</td>
<td>2.4 µm</td>
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The 6,275 images collected at L and L’ wavebands were analyzed to assess observing conditions.

- Off-source background was obtained for all images and collated into a searchable database with other measured parameters and observing log entries.

- Several hundred standard source frames (co-added, analyzed images) were collected as calibration during the season.

- Data was reduced automatically by the RIT SPIREX/ABU Pipeline.

- Skydip data was obtained over a wide range of zenith angles frequently during the observing season.
5200 source-free background frames in L band were analyzed.

- The greatest volume of data over the longest time period was available in L band.

- Source free background was corrected for atmospheric absorption using the model developed.

- Correlation with ~20 measured parameters was examined graphically and through ANOVA statistical measures.

- Blind comparisons made with observer’s log show background strongly dependent on observing conditions.
The combined (terrestrial + sky) background was monitored over the 110 day observing season.
Background was correlated with time of year and ambient temperature.
The background is strongly dependent on ambient temperature

- Off-source background correlated and consistent with direct variation with temperature.
- Other effects (clouds, telescope malfunctions) may be present in these data.
The relationship of off-source background to atmospheric transparency suggests a correction method for photometry

- Higher background on days with ‘poor’ seeing.
- Background originates from airglow of OH radicals and thermal emission from clouds.
- On ‘usable’ days, atmosphere is optically thin. Linear model may be used to correct photometric measurements.
- The ability to correct the data extends the number of useful observing days and increases the quality of the data.
- Further studies are taking place to determine the effect of clouds and airglow on point source images - and whether corrections may be performed to enhance image quality.
- Higher background causes lower signal strength from a distant source.

If the above effect can be modeled, photometry can be corrected for atmospheric conditions (within a restricted range of conditions)
Hundreds of frames of standard sources were captured in L band over the observing season.

- Data from one field used as ‘source’
- Next field (spatially dithered) used as ‘background’
- Normalized flat field obtained earlier in season.
- Simple data reduction performed. No averaging of fields in dithered data acquisition ‘cross’ was performed for this analysis:
  \[
  \text{Reduced data} = \frac{(\text{source} - \text{background})}{\text{flat field}}
  \]
- For five field average, expect data to be statistically better by ~2.

**Results:**

- **Best data** - Std. Dev. of 6.5% (0.07 mag.)
- **Average of all data** - Std. Dev. of 23% (0.22 mag.)
- **Average of all data with correction** - Std. Dev. Of 18% (0.17 mag.)
Standard source photometry is correlated with source-free background from same field.

- Atmosphere begins to affect standard photometry above the (zenith angle) ‘threshold’ of ~1100.
- Scattered data, but roughly linear inverse dependence of photometry on background.
- Suggests that background can be used to correct for moderately poor conditions.
Uncorrected standard source data has large scatter.

- Uncorrected data shows standard deviation of ~25%, lower mean value.
- Data most variable on days with clouds or haze noted in logbook.

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<tr>
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<th>Mean</th>
<th>% Dev</th>
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<tbody>
<tr>
<td>Data BG &lt; 1000</td>
<td>237471.1</td>
<td>6.54</td>
</tr>
<tr>
<td>Data BG &gt; 1000</td>
<td>176758.0</td>
<td>24.49</td>
</tr>
<tr>
<td>Corrected Data (BG &gt; 1000)</td>
<td>234334.1</td>
<td>22.48</td>
</tr>
<tr>
<td>Corrected Data (All)</td>
<td>235510.5</td>
<td>18.1</td>
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The standard source data was corrected using a linear, background dependent model.

- Assume optically thin emitter.
- Data with source-free background > 1000 fit to linear correction term.
- Correction applied to data with BG > 1000.
- Corrected data shows 17.3% scatter, correct mean.
Background (and seeing) was correlated with wind direction

- Lowest background occurs when wind is from 70 - 120 degrees
The wind is from the ‘preferred direction’ about 1/2 the time during the winter.
Is the South Pole a good IR observatory site?

Some Site Statistics

- 52% of the observing season had clear skies (background < 1000 at zenith)
- ~3.5 hours per day ‘on source’ (one man operation)
- Average of 9 frames/day, 23 minutes per frame.
Is the South Pole a good IR observatory site?

Site

Number of fields as a function of background
All L band observations
Is the South Pole a good IR observatory site? (3)

- The clear sky background is fit and measured at \( \sim 1100 \) cps at L band
- More than 62\% of the data was collected at backgrounds less than this value!

**The South Pole Sky was clear > 62\% of the time (1999)**