Is “single component” enough for the thermal dust emission?

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A good foreground estimation is required to get a good CMB detection.
Some estimations of the thermal dust emission

- Planck 2013
  - Planck 2013 results. XI. All-sky model of thermal dust emission, 2014 A&A 571, A11
- Planck 2015
- GNILC
  - Planck intermediate results. XLVIII. Disentangling Galactic dust emission and cosmic infrared background anisotropies, 2016, A&A 596, A109
- Different estimations, but same assumption: single component thermal dust
• Line of sight → We know for sure that the real thermal dust emission is **not** single component.

• Therefore, a meaningful discussion should be:
  – Is “single component” good enough as an approximation?
  – Especially for extrapolation down to ~100 GHz

• Simplification of the discussion
  – Multi dust component?
  – Multi other component?
  – Variation of the parameter as function of frequency?
  – Many other possibilities, but we discuss only
What happens if we don’t answer this question

- **Real case is multi, but assume single?**
  - For a few high freq. bands: still good fit
  - But extrapolation will not be reliable

- **Real case is single, but assume multi?**
  - Can fit even the noise, systematics…
  - Over fitting

- **Therefore, we should have a clear answer to “Is single component good enough”?**
  - If good enough: Fine! we can continue to use the current estimations
  - If not good enough: Multi-frequency experiments will be preferred.
The idea

- Use a local region from two adjacent bands to derive the ratio of dust amplitude between them
  - \( R \): ratio by data. \( R_0 \): ratio by existing dust model.
- Use only the regions with very high cross-correlation coefficients between two adjacent bands to cast limits on the error \( R-R_0 \)
\[ x' = x + \Delta x \]
\[ y' = y + \Delta y \]

Assume:

\[ C(x, y) \approx 1 \]
\[ C(x', y') \approx 1 \]

\[ C(x, \Delta x) = k_x \ll 1 \]
\[ C(y, \Delta y) = k_y \ll 1 \]
\[ C(y, \Delta x) \approx k_x \ll 1 \]
\[ C(x, \Delta y) \approx k_y \ll 1 \]
\[ C(\Delta x, \Delta y) - k_\Delta \ll 1 \]

\[ \beta_x = \sigma_{\Delta x} / \sigma_x \ll 1 \]
\[ \beta_y = \sigma_{\Delta y} / \sigma_y \ll 1 \]

Let \( R \) be the ratio given by linear regression, and \( R_0 \) be the expected ratio, then we have:

\[ R_0 = \frac{S_{xy}}{S_x} \]
\[ R = \frac{S_{x'y'}}{S_{x'}} \]
\[ C(x, y) = \frac{S_{xy}}{\sigma_x \sigma_y} \]

We get:

\[ S_{x'} = S_x(1 + 2k_x \beta_x + \beta_x^2) \]
\[ S_{y'} = S_y(1 + 2k_y \beta_y + \beta_y^2) \]
\[ S_{x'y'} = S_{xy}(1 | k_x \beta_x | k_y \beta_y | \beta_x \beta_y) \]
We get:

\[
1 \approx \frac{1 + k_x \beta_x + k_y \beta_y + \beta_x \beta_y k_\Delta}{\sqrt{(1 + 2k_x \beta_x + \beta_x^2)(1 + 2k_y \beta_y + \beta_y^2)}}
\]

\[
R = \frac{S_{x'y'}}{S_{x'}} \approx \frac{\sigma'_y}{\sigma'_x} = \frac{(1 + 2k_y \beta_y + \beta_y^2)}{(1 + 2k_x \beta_x + \beta_x^2)} R_0
\]

By Taylor expansion, we see that \(1 - R/R_0\) and \(1 - C(x',y')\) are same level small numbers → This is the limitation we need!
Test by simulations
(allow 30% chance correlation between dust/non-dust components)

\[ x' = x + \Delta x \]
\[ y' = y + \Delta y \]
Using $r=10$-deg disc as patches, CC is at least 0.95

Note that the CMB map (SMICA) is excluded in advance.
FIG. 4: Similar to Fig. 3 but use only the $|b| > 30^\circ$ region. There is no essential difference to Fig 3.
FIG. 5: Similar to Fig. 3, but with $5^\circ$ smoothing to the input maps and use only the $|\delta| > 30^\circ$ region. There is no essential difference to Fig 3.
FIG. 6: Similar to Fig. 3, but with 5\(^\circ\) smoothing to the input maps and use the polarization data. Note that there is no polarization data for 545 and 857 GHz.
Is the deviation due to…

- Color correction
- CIB
- Free-free
- Zodiac light
- Systematic + Residual CMB
- Due to the limitation given by “High band-band correlation”:
  - Either unaffected by these issues
  - Or these issues must provide strong correlation to thermal dust
Current conclusion

• “single component” is likely not a good assumption for the thermal dust emission
• Especially for the middle frequencies (~100 GHz)
• Measurement of more frequency bands will be great for a reliable estimation of the thermal dust emission.
Thanks!