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Planck LFI

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LIST OF ABBREVIATIONS

acronym	**Explanation**
CC	Color Correction
DMC	Data Management Component
FPdb	Focal Plane database
HFI	High Frequency Instrument
IT	Information Technology
LFI	Low Frequency Instrument
LOS	Line–of–Sight
RF	Referece Frame
PoV	Point of View
SED	Spectral Energy Distribution
SotA	State of the Art
SSB	Solar System Baricenter
SSO	Solar System Object
TBC	To Be Confirmed
TBD	To Be Defined
TOD	Time Ordered Data
TODs	Plural of TOD
TOI	Time Ordered Information
TODs	Plural of TOI

1 Applicable and Reference Documents

Applicable Documents

[AD-0] A&A, 536, A5 (2011), PLANCK *early results. V. The Low Frequency Instrument Data Processing* Zacchei, A., et al.

[AD-0] A&A, 536, A6 (2011), PLANCK *early results. V. The High Frequency Instrument Data Processing* Planck HFI Core Team: et al.

[RD-0] Journal of Instrumentation, Volume 12, Issue 12, pp. T12010 (2009), *Planck-LFI radiometers' spectral response* Zonca, A.; Franceschet, C.; Battaglia, P.; Villa, F.; Mennella, A.; D'Arcangelo, O.; Silvestri, R.; Bersanelli, M.; Artal, E.; Butler, R. C.; Cuttaia, F.; Davis, R. J.; Galeotta, S.; Hughes, N.; Jukkala, P.; Kilpi, V.-H.; Laaninen, M.; Mandolesi, N.; Maris, M.; Mendes, L.; Sandri, M.; Terenzi, L.; Tuovinen, J.; Varis, J.; Wilkinson, A.

Reference Documents

2 Scope of the document

Scope of this document is to define and collect a common descriptiuon of colour corrections in LFI and HFI in the view of creating a common set of Color Correction tables and sw.

2.1 Limits of Applicability

In the following ν is a frequency, while f is an index to define a frequency channell.

Color Corrections (CC) as defined here does not include the effect of beam frequecy dependencies.

3 Bandpass and color correction

Colore Correction (CC) is a coefficient used to convert broad band photometry of a source with Spectral Energy Distribution $\mathcal{S}(\nu)$ to an equivalent monochromatic photometry at a given reference frequecy $\nu_{\rm ref}$: $\mathcal{S}(\nu_{\rm ref})$ taking in account of the bandpass $\tau(\nu)$. The bandpass represents the relative change of instrumental responsivity at different frequeciens ν for a given frequecy channell f or detector h. The LFI and HFI RIMO defines a standardized way to share bandpass among the two instruments and toward the public.

In the RIMO bandpass are defined

1. for each individual radiometer/bolometer composing a frequecy channell;
2. for each frequecy channell.

In both cases bandpasses are normalized to have unit area in frequency

$$\int d\nu\ \tau(\nu) = 1 \tag{1}$$

Frequency channel bandpasses [1] are the average of the bandpasses of individual radiometer/bolometers so we have

$$\tau_f(\nu) = \sum_{h\in f} w_{f,h}\tau_h(\nu); \tag{2}$$

with the sum carried over all the detectors/bolometers entering the frequency channel.

The weights $w_{f,h}$ must respect two rules

1. $w_{f,h}$ must be the same used to define frequecy channel maps out of individual radiometer/bolometers maps or TOIs;
2. $w_{f,h}$ must be normalized
$$\sum_h w_{f,h} = 1. \tag{3}$$

Color Corrections are so defined as

$$C = N_{\rm CC} \int d\nu\ \tau(\nu)\mathcal{S}(\nu); \tag{4}$$

[1] In the RIMO nomenclature those are bandpasses with suffix `BANDPASS_Ffff` with `fff` a three digits number for the frequecy channell.

with N_{CC} a normalization constant which depends on the SED taken as reference (i.e. the SED for which $C = 1$). In practice the normalization will be something like

$$N_{CC} = \left[\int d\nu \mathcal{S}_{\rm ref}(\nu)\tau(\nu)\right]^{-1} \tag{5}$$

with $\mathcal{S}_{\rm ref}(\nu)$ the reference SED (or some other function of frequency).

3.1 Average of Colour corrections and Color correction of averaged map

It has to be noted that in general the average of individual color corrections is not the colour correction for the averaged bandpass which represents the bandpass for a map averaged over the individual detectors definining a frequency channell, unless the reference SED is flat. Infact, let be to denote with C_h the individual color corrections derived for the set of detectors h forming a given frequency channell. The weighted average of individual color corrections are

$$C'_f = \frac{1}{\sum_{h\in f} w_{f,h}} \sum_{h\in f} w_{f,h} \frac{\int d\nu\ \tau_h(\nu)\mathcal{S}(\nu)}{\int d\nu\ \tau_h(\nu)\mathcal{S}_{\rm ref}(\nu)}$$

on the other hand by integrating over the averaged bandpass $\tau_f(\nu)$

$$C"_f = \frac{\int d\nu\ \tau_f(\nu)\mathcal{S}(\nu)}{\int d\nu\ \tau_f(\nu)\mathcal{S}_{\rm ref}(\nu)}$$

after expanding $\tau_f(\nu)$ through Eq. (2) the condition to have $C"_f = C'_f$ is

$$\frac{\sum_{h\in f} w_{f,h} \int d\nu\ \tau_h(\nu)\mathcal{S}(\nu)}{\sum_{h\in f} w_{f,h} \int d\nu\ \tau_h(\nu)\mathcal{S}_{\rm ref}(\nu)} = \frac{1}{\sum_{h\in f} w_{f,h}} \sum_{h\in f} w_{f,h} \frac{\int d\nu\ \tau_h(\nu)\mathcal{S}(\nu)}{\int d\nu\ \tau_h(\nu)\mathcal{S}_{\rm ref}(\nu)}$$

whose sufficient condition to be sactisfacted is $\mathcal{S}_{\rm ref}(\nu) \equiv$ constant giving

$$\frac{\sum_{h\in f} w_{f,h} \int d\nu\ \tau_h(\nu)\mathcal{S}(\nu)}{\sum_{h\in f} w_{f,h} \int d\nu\ \tau_h(\nu)} = \frac{1}{\sum_{h\in f} w_{f,h}} \sum_{h\in f} w_{f,h} \frac{\int d\nu\ \tau_h(\nu)\mathcal{S}(\nu)}{\int d\nu\ \tau_h(\nu)}$$

which can be sactisfacted if $\int d\nu\ \tau_h(\nu) = 1$ for any h.

3.2 LFI Definition

LFI calibrates data in temperature with respect to the CMB, giving $K_{\rm cmb}$ data out of Voltage differences representing variations of input power.

Consequency the reference spectrum is the CMB spectrum and the color correction is defined as

$$C_{\rm LFI}(\alpha) = \frac{\eta_{{\rm cmb},\Delta T}(\nu_{\rm ref})}{\int d\nu\ \eta_{{\rm cmb},\Delta T}(\nu)\tau(\nu)} \int d\nu\ \tau(\nu)(\mathcal{S}(\nu)/\mathcal{S}(\nu_{\rm ref}))/(\nu/\nu_{\rm ref})^2; \tag{6}$$

which for a power spectrum of spectral index α gives [AD-0]

$$C_{\rm LFI}(\alpha) = \frac{\eta_{{\rm cmb},\Delta T}(\nu_{\rm ref})}{\int d\nu\ \eta_{{\rm cmb},\Delta T}(\nu)\tau(\nu)} \int d\nu\ \tau(\nu)(\nu/\nu_{\rm ref})^{\alpha-2} \tag{7}$$

with

$$\eta_{\mathrm{cmb},\Delta T}(\nu) = e^{h\nu/k_{\mathrm{b}}T_{\mathrm{cmb}}} \left(\frac{h\nu/k_{\mathrm{b}}T_{\mathrm{cmb}}}{e^{h\nu/k_{\mathrm{b}}T_{\mathrm{cmb}}} - 1} \right)^2 \tag{8}$$

The reference frequency is defined as the average frequency over the bandpass

$$\nu_{\mathrm{ref}} = \int d\nu \; \nu \; \tau(\nu). \tag{9}$$

3.3 HFI Definition

HFI normalizes fluxes according to IRAS convention [AD-0] where $\mathcal{S}(\nu)$ is expressed as MJy/Sr at fixed nominal frequency, assuming $\nu\mathcal{S}(\nu)$ as constant. So [AD-0]

$$C_{\mathrm{HFI}} = \frac{\int d\nu \; \mathcal{S}(\nu)/\mathcal{S}(\nu_{\mathrm{ref}})\tau(\nu)}{\int d\nu \; (\nu_{\mathrm{ref}}/\nu)\tau(\nu)} \tag{10}$$

with $C_{\mathrm{HFI}} = 1$ for $\mathcal{S}(\nu) \propto \nu^{-1}$ which for a power spectrum with spectral index α

$$C_{\mathrm{HFI}}(\alpha) = \frac{\int d\nu \; (\nu/\nu_{\mathrm{ref}})^{\alpha}\tau(\nu)}{\int d\nu \; (\nu_{\mathrm{ref}}/\nu)\tau(\nu)} \tag{11}$$

The reference frequecy considered by HFI is the nominal frequency of the given frequency channell, so $\nu_{\mathrm{ref}} = 100$ GHz for the 100 GHz channell, $\nu_{\mathrm{ref}} = 144$ GHz for the 144 GHz channell, and so on.

A Conversion from between Wavenumbers and Frequecy

In RIMO BandPasses are expressed as a function of Wavenumber $\tilde{\nu}$ expressed as cm^{-1} instead of frequency expressed as GHz. Conversion between the two quantities is given by:

$$\frac{\tilde{\nu}}{1\ \mathrm{cm}} = C_{\tilde{\nu},\nu} \frac{\nu}{1\ \mathrm{GHz}}. \tag{12}$$

with $C_{\tilde{\nu},\nu} = (29.9792458\ \mathrm{cm\ GHz})^{-1}$.

It is easy to see that color corrections are left unchanged in case of integration over wavenumbers instead of over frequency. It is sufficient to replace $\nu \to C_{\tilde{\nu},\nu}\tilde{\nu}$, $\nu_{\mathrm{ref}} \to C_{\tilde{\nu},\nu}\tilde{\nu}_{\mathrm{ref}}$, $\nu/\nu_{\mathrm{ref}} \to \tilde{\nu}/\tilde{\nu}_{\mathrm{ref}}$.

Of course to have $\int d\tilde{\nu}\ \tau(\tilde{\nu}) = 1$ we have to put

$$\tau(\tilde{\nu}) = C_{\tilde{\nu},\nu}^{-1} \tau(\tilde{\nu}/C_{\tilde{\nu},\nu}). \tag{13}$$