PACS Photometer Passbands and Colour Correction Factors for Various Source SEDs

T. Müller, K. Okumura, U. Klaas

This document gives an overview of the PACS photometer passbands and the transmissions and absoptions of all involved optical elements. It also provides a summary of the PACS photometer colour corrections. These corrections are needed to convert monochromatic flux densities in the PACS data products, which refer to a constant energy spectrum $\nu F_\nu = \lambda F_\lambda =$ const., to the true object SED flux densities at the PACS photometer reference wavelengths 70.0, 100.0 and 160.0 μm. The corrections factors are provided for a range of black-body temperatures, for different power-laws and for modified black-bodies. Corrections are also provided for a comparison with monochromatic colour-corrected flux densities derived from other infrared space missions with bands at similar wavelengths: at 60.0 μm (for a direct comparison with the corresponding IRAS_60-band or the ISOPHOT P3_60-band & C100_60-band), at 71.42 μm (for a direct comparison with the corresponding Spitzer/MIPS 70 μm band), at 90.0 μm (for a direct comparison with the Akari/FIS Wide-S or the ISOPHOT C100_C90 band), at 105.0 μm (for a direct comparison with the ISOPHOT C100_C105 band), at 140.0 μm (for a direct comparison with the Akari/FIS Wide-L bands), 155.9 μm (for a direct comparison with the corresponding Spitzer/MIPS 160 μm band), and at 170.0 μm (for a direct comparison with the ISOPHOT C200_C160 band). The filter transmission (and reflections) show a slight angle dependence, but the influence is very minor and included to a large part in the current flat field.

Contents

1 Introduction

1.1 Applicable documents

- Filter Angles - Blue Photometer, PACS-ME-TN-072, Issue 2
- Filter Angles - Red Photometer, PACS-ME-TN-077, Issue 2
- PACS Filters and Dichroics Interface Control Document, PACS-ME-ID-004, Issue 1/5
- PACS spatial coordinates cheat-sheet, PICC-ME-TN-027,
- Transmittance of the six branches of PACS PFM, PACS-ME-TR-091

1.2 Notes

All corrections are based on a set of combined filter and detector response curves, as they are available as a calibration file in HIPE: PacsCalPhot Calibration Product `calTree.photometer.filterTransmission (FM, 1); calTree.photometer.absorption (FM, 2)`. The various filters have been measured at cold temperature, except the diochroic which was physically too large for the measurement setup. The dichroic (blue/green channel via reflection, red channel via transmission) has only been measured in the warm. The bolometer absorption was derived from the measured reflection (absorption = 1 - reflection).

The filter transmission (and reflections) show a slight angle dependence. The angle dependencies have been measured for all filters for the relevant ranges, but this influence was not investigated so far (angle-dependent transmission and reflection measurements from early 2008 are available on request from the PACS-ICC). It seems the influence is very minor and included to a large part in the current flat field.

For the angle dependent aspects it is necessary to know the coordinates of each pixel. These values are given in the calibration product "PacsCal_SubarrayArray_FM_2_1.fits" available via HIPE. The coordinates given in this file can be transformed to the U,V detector plane via information given in PACS-ME-TN-072/077.

2 The PACS photometer bands

2.1 The PHOT Filter System: Blue/Green Branch

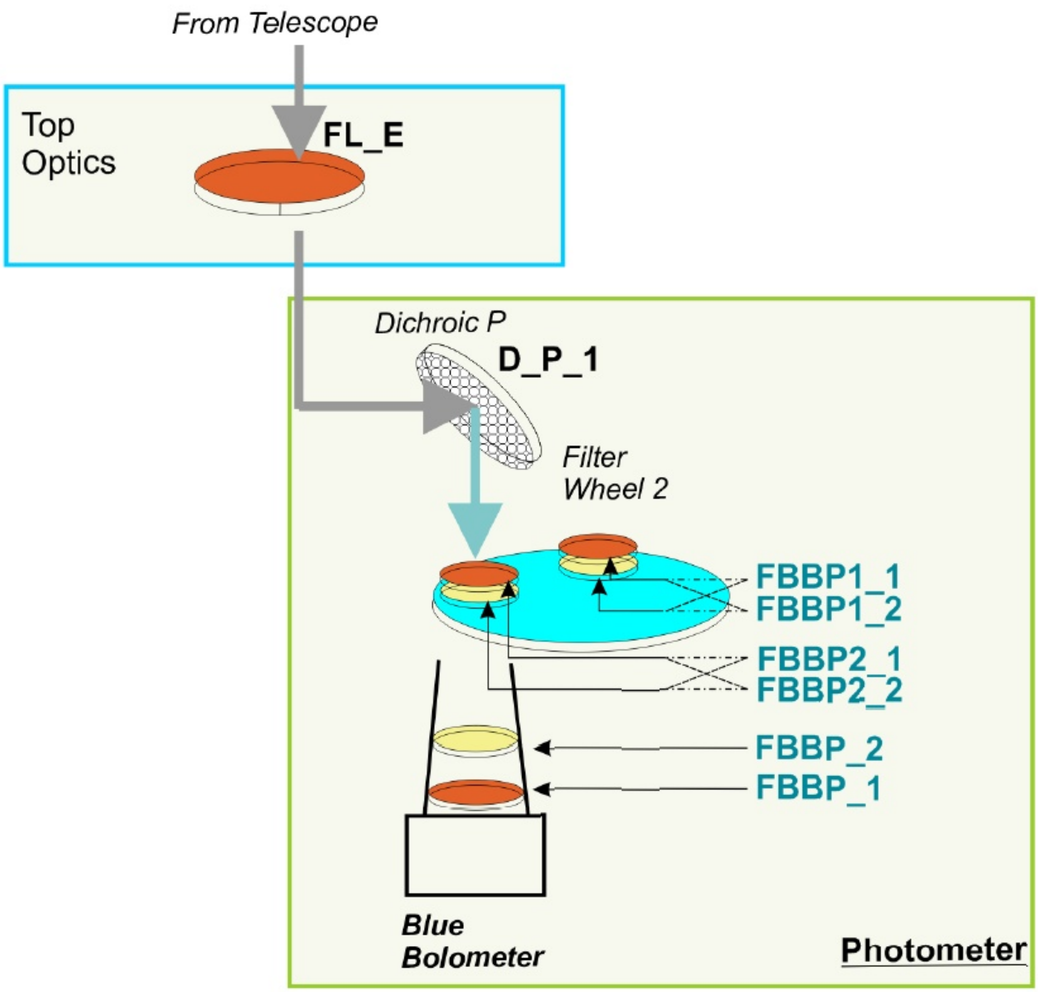

Figure 1: The PACS photometer blue/green filter branch.

The following PACS filters are involved in the blue and green optical paths:

- blue band: FBBP_1, FBBP_2, FBBP2_1, FBBP2_2, D_P_1 (refl.), FL_E
- green band: FBBP_1, FBBP_2, FBBP1_1, FBBP1_2, D_P_1 (refl.), FL_E
- dichroic (DD_P_1) is used in reflection

Each of the 2048 blue pixels sees each filter under a slightly different angle. The following measurements have been performed in the lab to investigate angle-dependent effects:

- FBBP_1 (W922): measured at: 0, 5, 10, 15, 20°; true angles in blue/green: 3.4...17.1;
- FBBP_2 (W931): measured at: 0, 5, 10, 15, 20°; true angles in blue/green: 1.2...11.7;
- FBBP1_1 (B741)/ FBBP2_1 (W932): measured at: 0, 5, 10, 15, 20°; true angles in blue/green: 1.1...12.7;

- FBBP1_2 (B720) / FBBP2_2 (W752): measured at: 0, xx[1], 10, 15, 20°; true angles in blue/green: 1.3...12.6;
- D_P_1 (FS 1557, reflection): measured at: 0, 12.5, 15, 17.5, 20°; true angles in blue/green: 9.4...17.3
- FL_E (W907): measured at: 0, 5, 10, 15, 20, 25°; true angles in blue/green: 13.5...22.5 (chopper at -8°); 3.2...10.1 (chopper at 0°); 6.7...15.6 (chopper at +8°)
  FL-E angles are dependent on chopper position

FILTER	FILTER NUMBER	LOCATION	DESCRIPTION	COMMENTS
F_L_E	W907	TOP OPTICS	LPE 200 cm-1	Cold measurement Res=0,5 cm^{-1}
D_P_1 (REFL)	F1564	BLUE/RED PHOTOMETER OPTICS	REFLECTION AT AN ANGLE OF 12.5°	WARM measurement Res=0,5 cm^{-1}
FBBP_1	W922	BLUE PHOTOMETER	LPE 180 cm-1	Cold measurement Res=0,5 cm^{-1}
FBBP_2	W931	BLUE PHOTOMETER	HPE 70 cm-1	Cold measurement Res=0,5 cm^{-1}
FBBP2_1	W932	FILTER WHEEL 2	LPE 167 cm-1	Cold measurement Res=0,5 cm^{-1}
FBBP2_2	B752	FILTER WHEEL 2	HPE 118 cm-1	Cold measurement Res=0,5 cm^{-1}

Figure 2: The PACS photometer blue filter branch: technical aspects and description of the measurements.

[1]apparently not available

FILTER	FILTER NUMBER	LOCATION	DESCRIPTION	COMMENTS
F_L_E	W907	TOP OPTICS	LPE 200 cm-1	Cold measurement Res=0,5 cm^{-1}
D_P_1 (REFL)	F1564	BLUE/RED PHOTOMETER OPTICS	REFLECTION AT AN ANGLE OF 12.5°	WARM measurement Res=0,5 cm^{-1}
FBBP_1	W922	BLUE PHOTOMETER	LPE 180 cm-1	Cold measurement Res=0,5 cm^{-1}
FBBP_2	W931	BLUE PHOTOMETER	HPE 70 cm-1	Cold measurement Res=0,5 cm^{-1}
FBBP1_1	B741	FILTER WHEEL 2	LPE 118 cm-1	Cold measurement Res=0,5 cm^{-1}
FBBP1_2	B720	FILTER WHEEL 2	HPE 70 cm-1	Cold measurement Res=0,5 cm^{-1}

Figure 3: The PACS photometer green filter branch: technical aspects and description of the measurements.

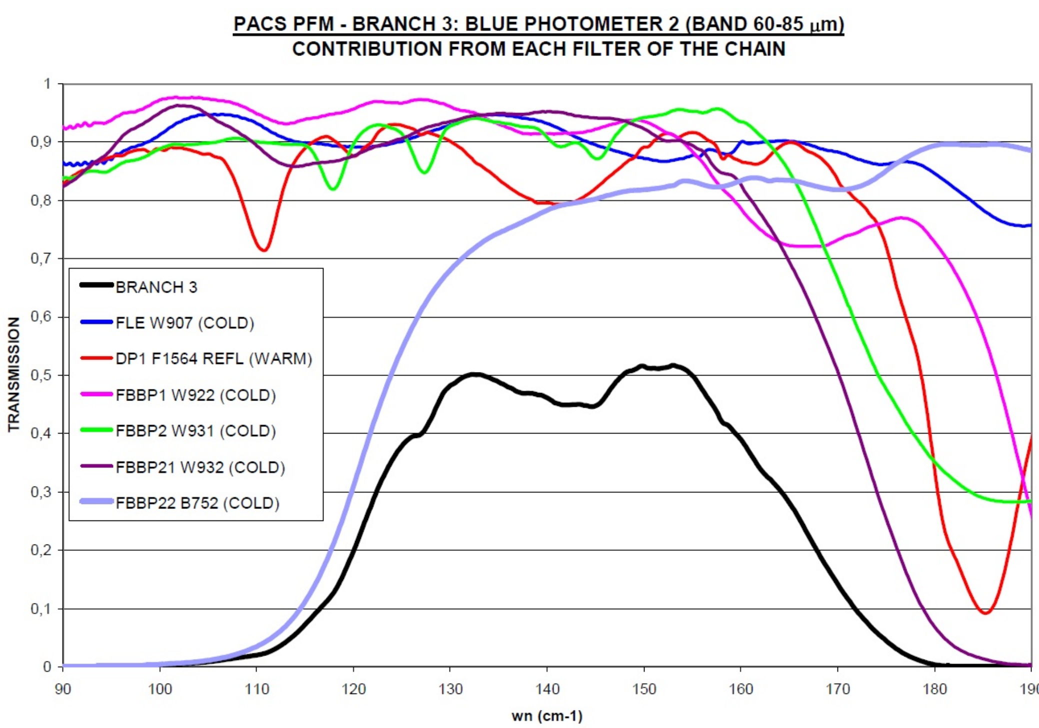

Figure 4: The PACS photometer blue filter branch: measured transmissions. PFM: PACS Flight Model.

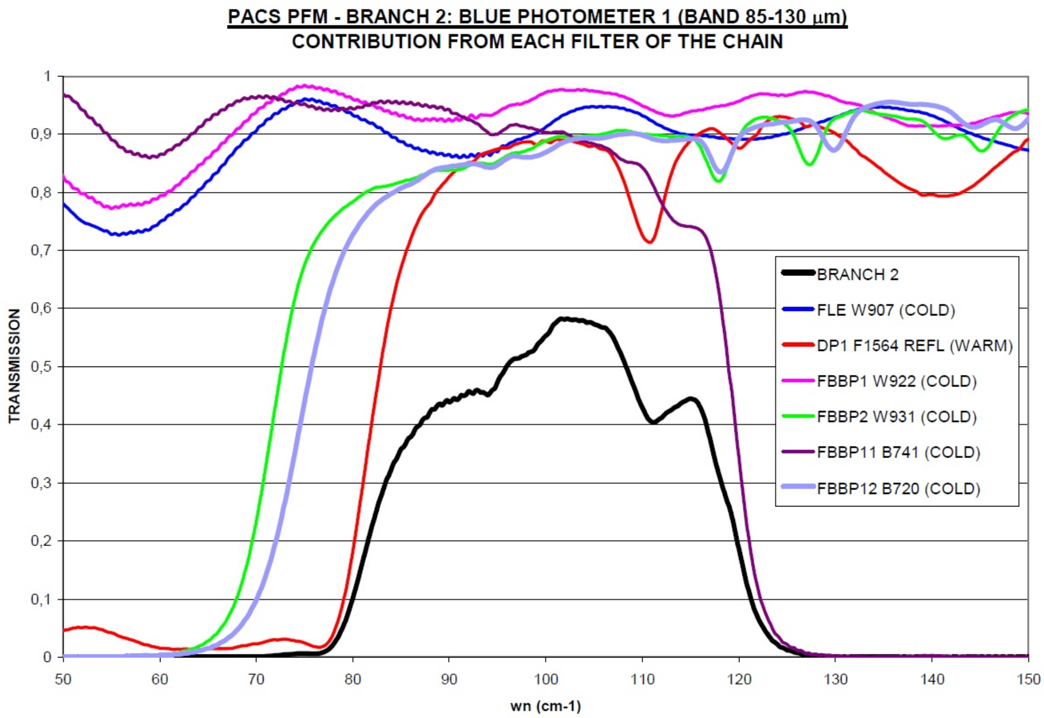

Figure 5: The PACS photometer green filter branch: measured transmissions. PFM: PACS Flight Model.

2.2 The PHOT Filter System: Red Branch

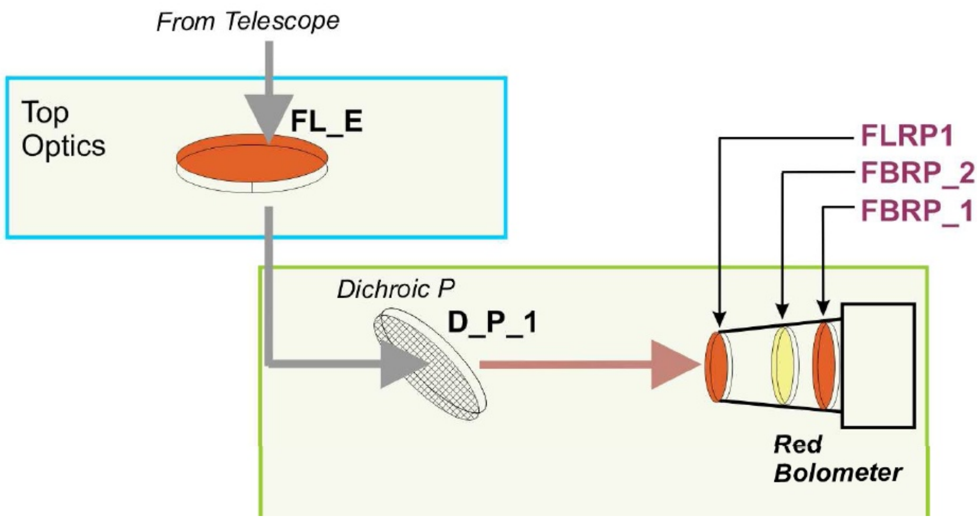

Figure 6: The PACS photometer red filter branch.

The following PACS filters are involved in the red optical path:

- red band:
  FBRP_1, FBRP_2, FLRP1, D_P_1 (transm.),FL_E
- dichroic (D_P_1) is used in transmission

Each of the 512 red pixels sees each filter under a slightly different angle. The following measurements have been performed in the lab to investigate angle-dependent effects:

- FBRP_1 (W925): measured at: 0, 5, 10, 15, 20°; true angles in red: 2.5...13.1;
- FBRP_2 (W930): measured at: 0, 5, 10, 15, 20°; true angles in red: 2.6...9.3;
- FLRP1 (W933): measured at: 0, 5, 10, 15, 20°; true angles in red: 2.5...14.7;
- D_P_1 (FS 1557, transmission):
  measured at: 0, 10, 20, 30°; true angles in red: 6.7...14.1;
- FL_E (W907):
  measured at: 0, 5, 10, 15, 20, 25°; true angles in red: 13.8...22.3 (chopper at -8°); 3.3... 9.8 (chopper at 0°); 6.8...15.3 (chopper at +8°) FL-E angles are dependent on chopper position

FILTER	FILTER NUMBER	LOCATION	DESCRIPTION	COMMENTS
F_L_E	W907	TOP OPTICS	LPE 200 cm-1	Cold measurement Res=0,5 cm^{-1}
D_P_1 (TRANS)	F1564	BLUE/RED PHOTOMETER OPTICS	LPE 77 cm-1	Warm measurement Res=0,5 cm^{-1}
FBRP_1	W925	RED PHOTOMETER	LPE 80 cm-1	Cold measurement Res=0,5 cm^{-1}
FBRP_2	W930	RED PHOTOMETER	HPE 48 cm-1	Cold measurement Res=0,5 cm^{-1}
FLRP1	W933	RED PHOTOMETER	LPE 90 cm-1	Cold measurement Res=0,5 cm^{-1}

Figure 7: The PACS photometer red filter branch: technical aspects and description of the measurements.

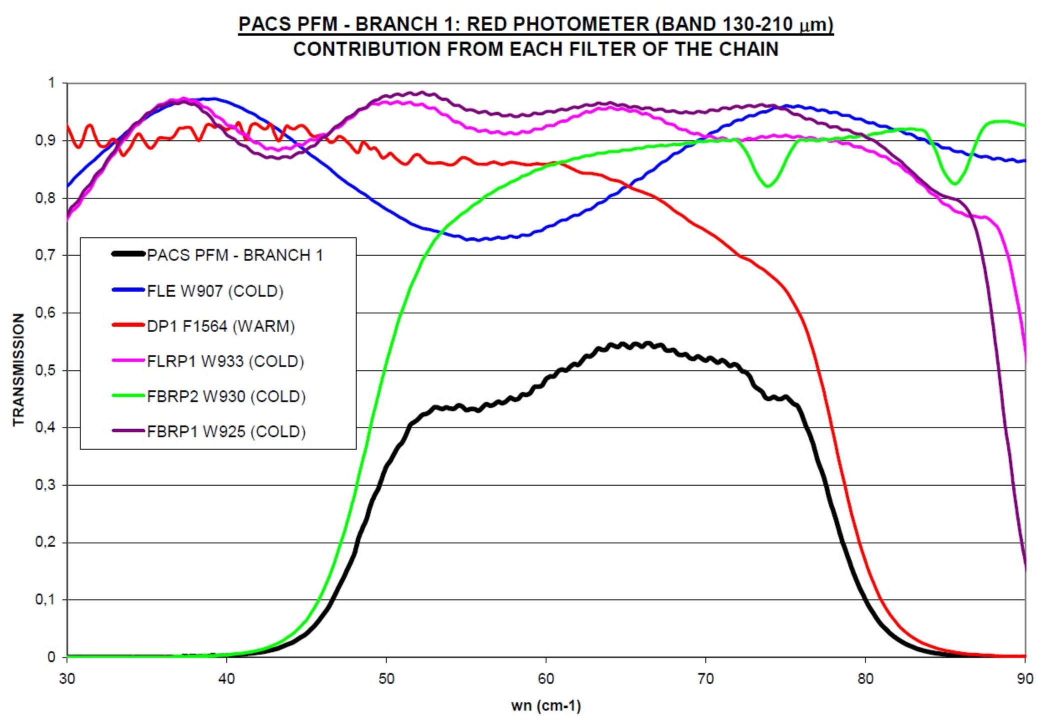

Figure 8: The PACS photometer red filter branch: measured transmissions. PFM: PACS Flight Model.

2.3 The bolometer response

The detector absorptions are based on reflection measurements: $absorption = 1 - reflection$. Light diffusion has not been included, but is generally considered to be irrelevant.

The absorption curves of the blue/green and red bolometers are also given as a calibration product in HIPE: `calTree.photometer.absorption` (FM, 2).

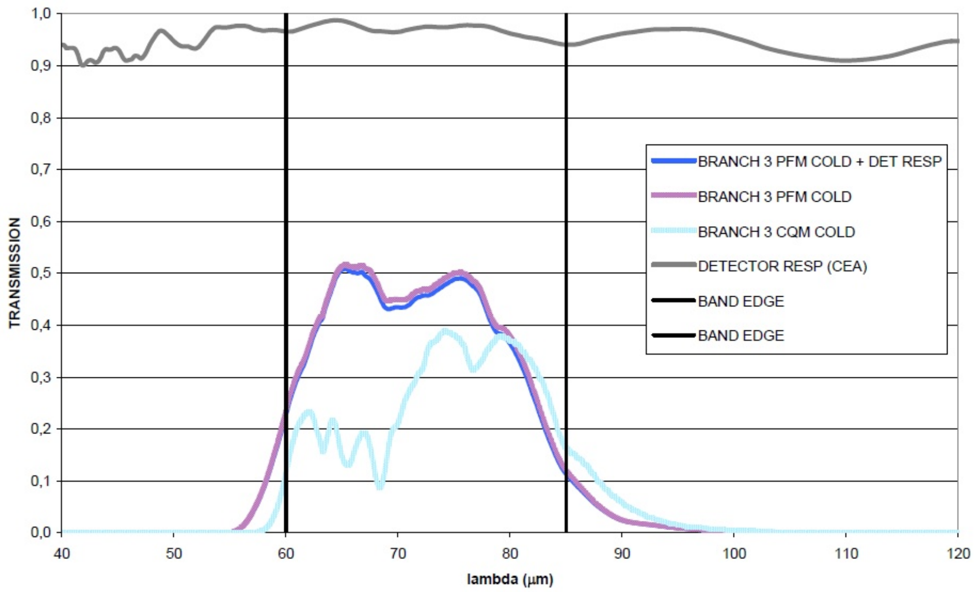

Figure 9: The PACS photometer blue filter and detector branch: measured transmissions and absorption. PFM: PACS Flight Model; CQM: Cryogenic Qualification Model (not relevant for flight data).

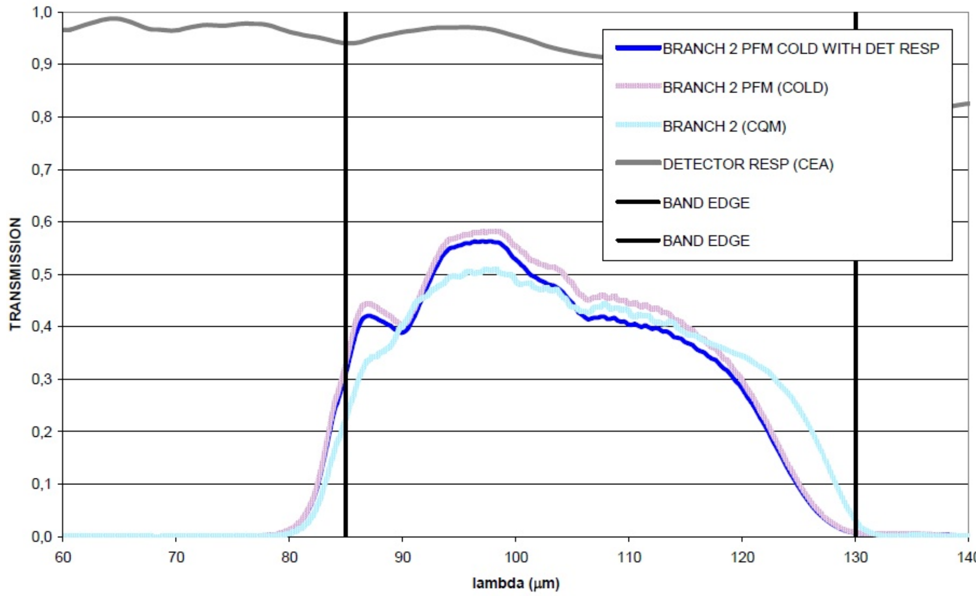

Figure 10: The PACS photometer green filter and detector branch: measured transmissions and absorption. PFM: PACS Flight Model; CQM: Cryogenic Qualification Model (not relevant for flight data).

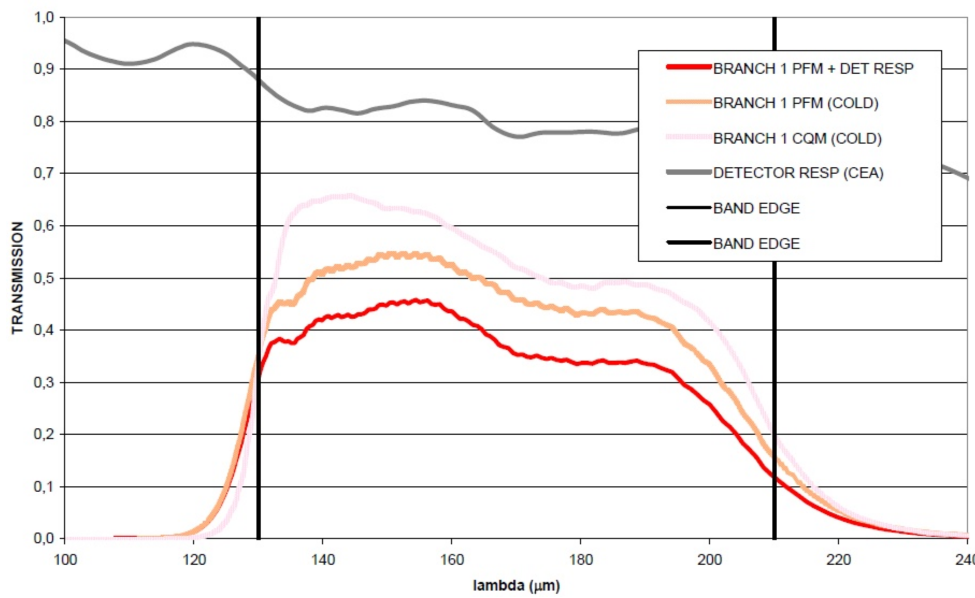

Figure 11: The PACS photometer red filter and detector branch: measured transmissions and absorption. PFM: PACS Flight Model; CQM: Cryogenic Qualification Model (not relevant for flight data).

2.4 Effective spectral response

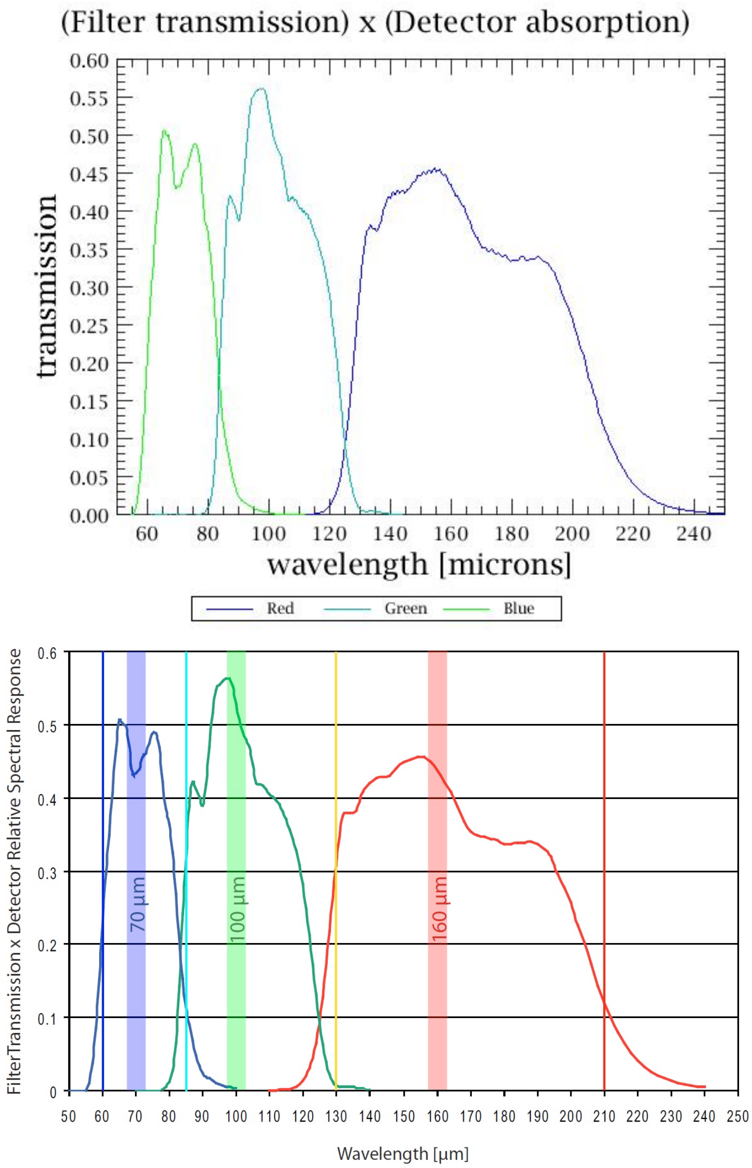

Figure 12: The effective response of the filter/detector chain of the PACS photometer in three bands, based on cold measurements of the filter transmission, warm measurement of dichroic transmission/reflections and cold measurement of detector reflections. Top: based on values given in the HIPE calibration products `photometer.filterTransmission` and `photometer.absorption`; Bottom: Poglitsch et al. 2010, A&A 518L.

2.5 Accessability in HIPE

```
cal = getCalTree().photometer.absorption
---> to show the latest version (FM, 2) of the bolometer absorption
cal = getCalTree().photometer.filterTransmission
---> to show the latest version (FM, 1) of the bolometer
     filter transmission curves (all branch filters combined,
     bolometer absorption not included)

calTree.photometer.absorption           : FM, 2
calTree.photometer.filterTransmission    : FM, 1
```

3 Colour corrections

The PACS photometer standard data products are calibrated in [Jy/pixel] and quoted for the effective wavelengths and an input energy distribution which is constant in the flux per logarithmic frequency interval (flux per octave): flux density with frequency ν goes as $F_\nu \propto \nu^{-1}$ or flux density with wavelength λ goes with $F_\lambda \propto \lambda^{-1}$. If the input spectral energy distriubtion (SED) is not constant in flux per octave, a correction, the "colour correction", must be applied. This correction depends on the shape of the intrinsic SED and on the details of the wavelength repsonse of the system. Below we present the photometric colour corrections "cc" (bold face) for the PACS reference wavelengths (70, 100, 160 μm). They have been determined from the photometer filter transmission curves and bolometer responses (see Section 2.4). The correction factors are usually small, only for sources with temperatures below 20 K they can become quite significant, in particular at 70 μm.

The colour corrections are needed to convert monochromatic flux densities in the PACS data products (calibrated in Jy/pixel), which refer to a constant energy spectrum $\nu\,\mathrm{F}_\nu = \lambda\,\mathrm{F}_\lambda =$ const. to the true object SED flux densities at the PACS photometer reference wavelengths 70.0, 100.0 and 160.0 μm. For this conversion one has to divide the measured and calibrated fluxes by the tabulated values:

$$F_\nu[actual] = F_\nu[quoted]/cc$$

An overview of colour corrections for different types of source SEDs is given in the subsequent sections. Basic correction values are also given in "Poglitsch et al. 2010, A&A 518L, 2P".

The PACS band passes have been measured at cold (operational) temperatures and are accurately known. Nevertheless, large colour correction factors above 1.5 or below 0.5 (mainly for very cold sources) have to be taken with care, and might even dominate the final flux accuracy. Aging effects of the band passes might be important in those cases.

4 Comparision with similar bands from other missions

In addition to the colour correction terms, we provide corrections factors which allow to perform a direct comparison with published monochromatic colour-corrected flux densities derived from other projects. (not with catalogue data which are often given assuming a constant energy spectrum $\nu\,\mathrm{F}_\nu = \lambda\,\mathrm{F}_\lambda =$ const. or a blackbody with 10 000 K temperature!):

- for a comparison of a PACS photometer blue band measurement with monochromatic flux densities derived from IRAS_60-band or the ISOPHOT P3_60-band: use the values at 60.0 μm
- for a comparison of a PACS photometer blue band measurement with monochromatic flux densities derived from Spitzer/MIPS 70 μm band: use the values at 71.42 μm
- for a comparison of a PACS photometer green band measurement with monochromatic flux densities derived from Akari/FIS Wide-S or the ISOPHOT C100_C90 band: use the values at 90.0 μm
- for a comparison of a PACS photometer green band measurement with monochromatic flux densities derived from ISOPHOT C100_C105 band: use the values at 105.0 μm
- for a comparison of a PACS photometer red band measurement with monochromatic flux densities derived from the Akari/FIS Wide-L band: use the values at 140.0 μm
- for a comparison of a PACS photometer red band measurement with monochromatic flux densities derived from Spitzer/MIPS 160 μm band: use the values at 155.9 μm
- for a comparison of a PACS photometer red band measurement with monochromatic flux densities derived from the ISOPHOT C200_C160 band: use the values at 170.0 μm

The corrections (wavelength corrections "lc") have been determined simply from the assumed object SED by going along the SED curve from the PACS key wavelength to the new wavelengths. They have to be applied in the following way:

1. Determine the monochromatic colour-corrected flux density at the PACS reference wavelength: $FD_{cc} = FD/cc$

2. "Transport" the monochromatic colour-corrected flux density at the PACS reference wavelength to a neighbouring wavelengths along the given object SED: $FD_{cc}^{lc} = FD_{cc} \cdot lc$

Example:

Measurements of α Boo (Arcturus, HR 5340, HD 124897, HIP 69673) from OD 220 with OBSIDs 1342188245 & 1342188246, both in blue/red band and OBSIDs 1342188247 & 1342188248, both in green/red band. α Boo has an effective temperature of 4 320 K (SpType K1.5III).

- The measured and aperture corrected fluxes of α Boo are: 15.964 Jy (blue) 7.804 Jy (green), 3.140 Jy (red); details are given in PICC-ME-TN-037)

- Applying the colour correction for a 5000 K blackbody (see Table 1) to obtain monochromatic flux densities at 70.0 μm, 100.0 μm, 160.0 μm:
  FD_{70} = 15.964 / 1.016 = 15.713 Jy; (model flux at 70.0 μm: 15.434 Jy, within 1.8%)
  FD_{100} = 7.804 / 1.033 = 7.555 Jy; (model flux at 100.0 μm: 7.509 Jy, within 0.6%)
  FD_{160} = 3.140 / 1.074 = 2.924 Jy; (model flux at 160.0 μm: 2.891 Jy, within 1.1%)

- Applying additional correction factors to obtain monochromatic flux densities at other wavelengths:
  FD_{60} = 15.713 · 1.356 = 21.307 Jy (model flux at 60.0 μm: 21.039 Jy, within 1.3%)
  $FD_{71.42}$ = 15.713 · 0.962 = 15.116 Jy (model flux at 71.42 μm: 14.823 Jy, within 2.0%)
  FD_{90} = 7.555 · 1.233 = 9.315 Jy (model flux at 90.0 μm: 9.294 Jy, within 0.2%)
  FD_{105} = 7.555 · 0.908 = 6.860 Jy (model flux at 105.0 μm: 6.802 Jy, within 0.8%)
  FD_{140} = 2.924 · 1.304 = 3.813 Jy (model flux at 140.0 μm: 3.794 Jy, within 0.5%)
  $FD_{155.9}$ = 2.924 · 1.053 = 3.079 Jy (model flux at 155.9 μm: 3.048 Jy, within 1.0%)
  FD_{170} = 2.924 · 0.886 = 2.591 Jy (model flux at 170.0 μm: 2.556 Jy, within 1.4%)

The newly derived "off-band" flux densities can now be directly compared to the monochromatic colour-corrected flux densities determined via other instruments or models. It is worth to note here that some of the comparisons are very problematic for extreme SED shapes, e.g., for very cold targets.

4.1 For different blackbody temperatures

Table 1: Photometric colour corrections for a range of different blackbody temperatures from 10 K to 10 000 K (first three columns) and additional correction factors needed to obtain a monochromatic flux density (for the given object SED) at neighbouring key-wavelengths used by other missions.

PACS	blue CC_70	green CC_100	red CC_160	PACS blue band from 70.0 μm to IRAS	MIPS	PACS green band from 100.0 μm to ISOPHOT		PACS red band from 160.0 μm to FIS	MIPS	ISOPHOT
λ_{ref} [μm]	70.0	100.0	160.0	60.0	71.42	90.0	105.0	140.0	155.9	170.0
10 000 K	**1.016**	**1.034**	**1.074**	1.359	0.961	1.234	0.907	1.305	1.053	0.886
5 000 K	**1.016**	**1.033**	**1.074**	1.356	0.962	1.233	0.908	1.304	1.053	0.886
1 000 K	**1.013**	**1.031**	**1.072**	1.337	0.963	1.224	0.910	1.298	1.052	0.888
500 K	**1.011**	**1.029**	**1.068**	1.312	0.965	1.214	0.914	1.289	1.051	0.891
250 K	**1.005**	**1.023**	**1.062**	1.258	0.970	1.192	0.921	1.271	1.048	0.896
100 K	**0.989**	**1.007**	**1.042**	1.081	0.987	1.118	0.946	1.212	1.039	0.913
50 K	**0.982**	**0.985**	**1.010**	0.794	1.023	0.980	0.999	1.105	1.022	0.948
40 K	**0.992**	**0.980**	**0.995**	0.672	1.043	0.911	1.031	1.049	1.012	0.968
30 K	**1.034**	**0.982**	**0.976**	0.507	1.078	0.802	1.088	0.955	0.995	1.005
20 K	**1.224**	**1.036**	**0.963**	0.286	1.153	0.617	1.217	0.781	0.959	1.090
19 K	**1.269**	**1.051**	**0.964**	0.262	1.165	0.591	1.239	0.756	0.953	1.104
18 K	**1.325**	**1.069**	**0.967**	0.237	1.179	0.564	1.264	0.729	0.947	1.121
17 K	**1.396**	**1.093**	**0.972**	0.212	1.194	0.536	1.293	0.699	0.940	1.140
16 K	**1.488**	**1.123**	**0.979**	0.187	1.212	0.505	1.326	0.667	0.932	1.162
15 K	**1.607**	**1.162**	**0.990**	0.162	1.233	0.473	1.364	0.633	0.923	1.187
14 K	**1.768**	**1.213**	**1.005**	0.137	1.257	0.438	1.409	0.596	0.913	1.217
13 K	**1.992**	**1.282**	**1.028**	0.114	1.285	0.401	1.463	0.555	0.901	1.253
12 K	**2.317**	**1.377**	**1.061**	0.091	1.318	0.362	1.529	0.512	0.888	1.296
11 K	**2.816**	**1.512**	**1.110**	0.071	1.359	0.321	1.610	0.464	0.872	1.349
10 K	**3.645**	**1.711**	**1.184**	0.052	1.410	0.277	1.714	0.413	0.853	1.415
9 K	**5.175**	**2.024**	**1.300**	0.035	1.475	0.232	1.849	0.358	0.831	1.501
8 K	**8.497**	**2.554**	**1.491**	0.022	1.559	0.186	2.034	0.300	0.804	1.615
7 K	**17.815**	**3.552**	**1.833**	0.012	1.676	0.140	2.299	0.238	0.771	1.775
6 K	**58.391**	**5.774**	**2.528**	0.005	1.845	0.096	2.706	0.175	0.729	2.013
5 K	**456.837**	**12.259**	**4.278**	0.002	2.110	0.056	3.400	0.114	0.674	2.401

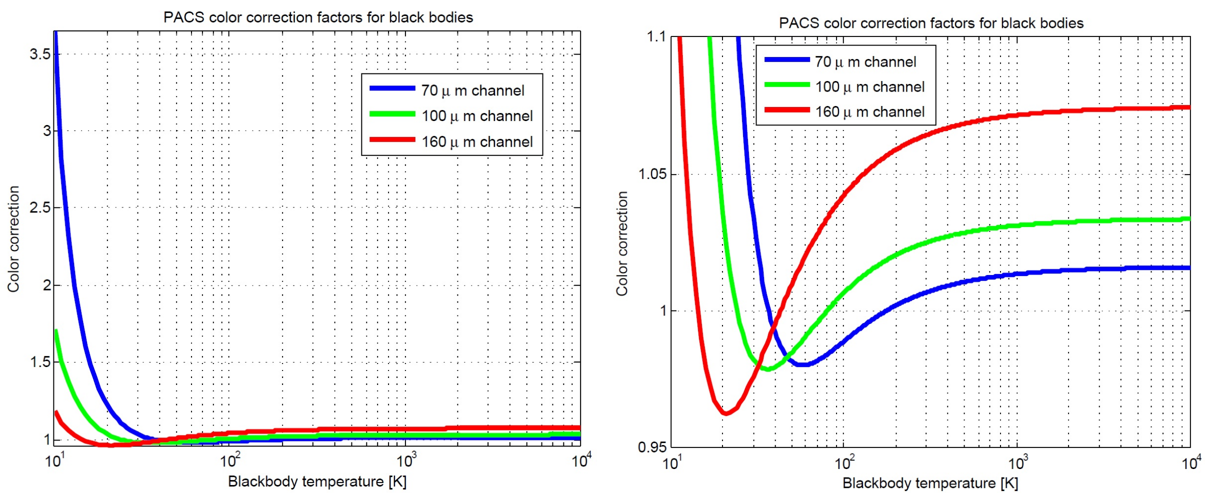

Figure 13: Photometric colour corrections for different black body temperatures in graphical format.

4.2 For different power laws

Table 2: Photometric colour corrections for a range of different power-law spectra ($F_\nu \sim \nu^\beta$) (first three columns) and additional correction factors needed to obtain a monochromatic flux density (for the given object SED) at neighbouring key-wavelengths used by other missions.

PACS	blue CC_70	green CC_100	red CC_160	PACS blue band from 70.0 μm to IRAS		PACS green band from 100.0 μm to ISOPHOT		PACS red band from 160.0 μm to FIS	MIPS	ISOPHOT
				IRAS	MIPS	ISOPHOT		FIS	MIPS	ISOPHOT
λ_{ref} [μm]	70.0	100.0	160.0	60.0	71.42	90.0	105.0	140.0	155.9	170.0
β=-3.0	**1.043**	**1.037**	**1.056**	0.630	1.061	0.729	1.158	0.670	0.925	1.199
β=-2.0	**1.016**	**1.012**	**1.017**	0.735	1.040	0.810	1.103	0.766	0.949	1.129
β=-1.0	**1.000**	**1.000**	**1.000**	0.857	1.020	0.900	1.050	0.875	0.974	1.062
β= 0.0	**0.995**	**1.000**	**1.004**	1.000	1.000	1.000	1.000	1.000	1.000	1.000
β= 1.0	**1.000**	**1.011**	**1.029**	1.167	0.980	1.111	0.952	1.143	1.026	0.941
β= 2.0	**1.016**	**1.034**	**1.075**	1.361	0.961	1.235	0.907	1.306	1.053	0.886
β= 3.0	**1.043**	**1.069**	**1.142**	1.588	0.942	1.372	0.864	1.493	1.081	0.833

4.3 For different modified blackbodies

Table 3: Photometric colour corrections for different modified black-bodies ($F_\nu^{modified} = \nu^\beta B_\nu(T)$) (first three columns) and additional correction factors needed to obtain a monochromatic flux density (for the given object SED) at neighbouring key-wavelengths used by other missions.

PACS	blue CC_70	green CC_100	red CC_160	PACS blue band from 70.0 μm to IRAS	MIPS	PACS green band from 100.0 μm to ISOPHOT		PACS red band from 160.0 μm to FIS	MIPS	ISOPHOT
λ_{ref} [μm]	70.0	100.0	160.0	60.0	71.42	90.0	105.0	140.0	155.9	170.0
$\nu^{-2}B_\nu(10\,K)$	**5.150**	**2.162**	**1.495**	0.038	1.466	0.225	1.890	0.316	0.810	1.597
$\nu^{-2}B_\nu(15\,K)$	**2.013**	**1.356**	**1.126**	0.119	1.282	0.383	1.504	0.485	0.876	1.341
$\nu^{-2}B_\nu(20\,K)$	**1.442**	**1.152**	**1.035**	0.210	1.199	0.499	1.342	0.598	0.911	1.230
$\nu^{-2}B_\nu(30\,K)$	**1.141**	**1.037**	**0.993**	0.372	1.121	0.650	1.199	0.731	0.945	1.134
$\nu^{-2}B_\nu(40\,K)$	**1.058**	**1.008**	**0.987**	0.494	1.085	0.738	1.136	0.803	0.961	1.092
$\nu^{-2}B_\nu(50\,K)$	**1.026**	**0.998**	**0.987**	0.583	1.064	0.794	1.102	0.846	0.970	1.070
$\nu^{-2}B_\nu(75\,K)$	**1.001**	**0.993**	**0.991**	0.721	1.038	0.869	1.061	0.902	0.981	1.043
$\nu^{-2}B_\nu(100\,K)$	**0.996**	**0.993**	**0.994**	0.794	1.027	0.905	1.043	0.928	0.986	1.031
$\nu^{-1}B_\nu(10\,K)$	**4.307**	**1.916**	**1.319**	0.044	1.438	0.250	1.800	0.361	0.831	1.503
$\nu^{-1}B_\nu(15\,K)$	**1.790**	**1.249**	**1.045**	0.139	1.257	0.425	1.432	0.554	0.899	1.262
$\nu^{-1}B_\nu(20\,K)$	**1.322**	**1.086**	**0.988**	0.245	1.175	0.555	1.278	0.683	0.935	1.158
$\nu^{-1}B_\nu(30\,K)$	**1.081**	**1.003**	**0.974**	0.434	1.099	0.722	1.142	0.836	0.970	1.067
$\nu^{-1}B_\nu(40\,K)$	**1.019**	**0.988**	**0.981**	0.576	1.064	0.820	1.082	0.918	0.986	1.028
$\nu^{-1}B_\nu(50\,K)$	**0.998**	**0.986**	**0.988**	0.680	1.043	0.882	1.049	0.967	0.996	1.007
$\nu^{-1}B_\nu(75\,K)$	**0.987**	**0.990**	**1.001**	0.841	1.018	0.966	1.010	1.030	1.007	0.982
$\nu^{-1}B_\nu(100\,K)$	**0.987**	**0.994**	**1.008**	0.927	1.007	1.006	0.993	1.061	1.012	0.970
$\nu^{+1}B_\nu(10\,K)$	**3.116**	**1.541**	**1.083**	0.060	1.382	0.308	1.632	0.472	0.876	1.332
$\nu^{+1}B_\nu(15\,K)$	**1.456**	**1.092**	**0.956**	0.189	1.208	0.525	1.299	0.723	0.947	1.118
$\nu^{+1}B_\nu(20\,K)$	**1.144**	**0.999**	**0.957**	0.334	1.130	0.685	1.159	0.893	0.984	1.026
$\nu^{+1}B_\nu(30\,K)$	**1.000**	**0.973**	**0.997**	0.591	1.057	0.891	1.036	1.092	1.021	0.946
$\nu^{+1}B_\nu(40\,K)$	**0.976**	**0.983**	**1.029**	0.784	1.022	1.013	0.982	1.198	1.039	0.911
$\nu^{+1}B_\nu(50\,K)$	**0.975**	**0.995**	**1.051**	0.926	1.003	1.089	0.952	1.263	1.049	0.892
$\nu^{+1}B_\nu(75\,K)$	**0.989**	**1.018**	**1.082**	1.144	0.979	1.192	0.916	1.346	1.061	0.869
$\nu^{+1}B_\nu(100\,K)$	**1.001**	**1.031**	**1.098**	1.262	0.968	1.242	0.901	1.386	1.066	0.859
$\nu^{+2}B_\nu(10\,K)$	**2.691**	**1.399**	**1.009**	0.070	1.355	0.342	1.555	0.540	0.899	1.253
$\nu^{+2}B_\nu(15\,K)$	**1.333**	**1.038**	**0.943**	0.220	1.185	0.583	1.237	0.827	0.972	1.052
$\nu^{+2}B_\nu(20\,K)$	**1.080**	**0.974**	**0.971**	0.390	1.108	0.761	1.104	1.020	1.010	0.965
$\nu^{+2}B_\nu(30\,K)$	**0.977**	**0.974**	**1.037**	0.689	1.036	0.991	0.987	1.248	1.048	0.890
$\nu^{+2}B_\nu(40\,K)$	**0.970**	**0.997**	**1.083**	0.915	1.002	1.125	0.935	1.370	1.066	0.857
$\nu^{+2}B_\nu(50\,K)$	**0.979**	**1.017**	**1.113**	1.080	0.983	1.210	0.907	1.443	1.076	0.840
$\nu^{+2}B_\nu(75\,K)$	**1.005**	**1.049**	**1.155**	1.335	0.959	1.325	0.873	1.538	1.089	0.818
$\nu^{+2}B_\nu(100\,K)$	**1.023**	**1.067**	**1.175**	1.472	0.949	1.380	0.858	1.584	1.094	0.809

4.4 Other source SEDs

The corrections for main-belt asteroids are 1.00, 1.02 and 1.07 in blue, green and red band. They are based on TPM predictions for Herschel-relevant observing and illumination geometries. The most extreme main-belt asteroid case in our sample is Vesta with its very high albedo. This asteroid requires a correction of 1.03 (instead of 1.02) in green band, no change in the blue and red band.

Note that different solar system objects might require slightly different colour corrections and that simple black body temperatures are not always appropriate.

Table 4: Photometric colour corrections for different atmosphereless solar system objects. The Centaur/TNO temperature range drops from temperatures above 80 K for the inner Centaurs to values of 30 K for the most distant TNOs.

Object	CC_70	CC_100	CC_160
4 Vesta	1.00	1.03	1.07
all other MBAs	1.00	1.02	1.07
nearest Centaurs	0.99	1.00	1.03
most distant TNO	1.15	1.02	0.98
Mars	0.95	1.03	1.05
Uranus	0.98	0.99	1.02
Neptune	0.985	0.99	1.02

Table 5: Photometric colour corrections for other sources (calculations based on specific model SEDs).

Object	CC_70	CC_100	CC_160
HD 161796	1.01	1.05	1.13