IMPERIAL COLLEGE
LONDON

GERB-3 and 4
Ground Calibration

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GERB-3 Re-calibration: March – June 2008 (Original calibration 2002)

GERB-4 Calibration: November 2008 – March 2009

GERB characteristics

WAVEBANDS	Total:	0.32 μm - 100.0 μm	
	Shortwave, SW:	0.32 μm - 4.0 μm	
	Longwave, LW (by subtraction):	4.0 μm - 30.0 μm	
RADIOMETRY		SW	LW
	Absolute Accuracy:	< 1.0 % (2.4%)	< 1.0 %
	Signal/Noise:	1250	400
	Dynamic Range:	0-380 W m^{-2} sr^{-1}	0-90 W m^{-2} sr^{-1}
SPATIAL SAMPLING	44.6 × 39.3 km (NS × EW) at nadir		
TEMPORAL SAMPLING	17 minute SW and LW fluxes		
CYCLE TIME	Full Earth disc, both channels in 5 minutes		
CO-REGISTRATION	Spatial: 3 km wrt SEVIRI at satellite sub-point		
	Temporal: Within 15 min of SEVIRI at each pixel		
INSTRUMENT MASS	25 kg		
POWER	35 W		
DIMENSIONS	476 mm × 275 mm × 345 mm		

One Earth scan (2 minutes 50 seconds)

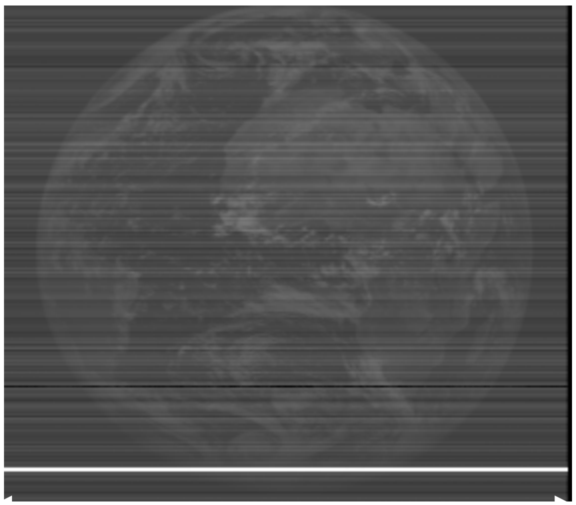
Earth view
V(scene) + offset

minus

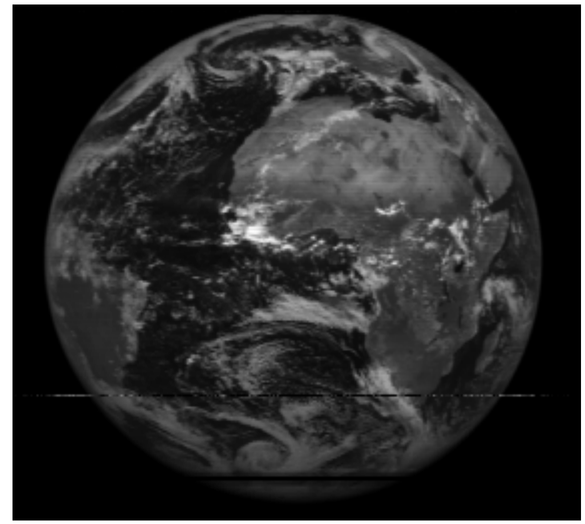
Black body
V(BB) + offset

equals

V(scene) – V(BB)



282 columns



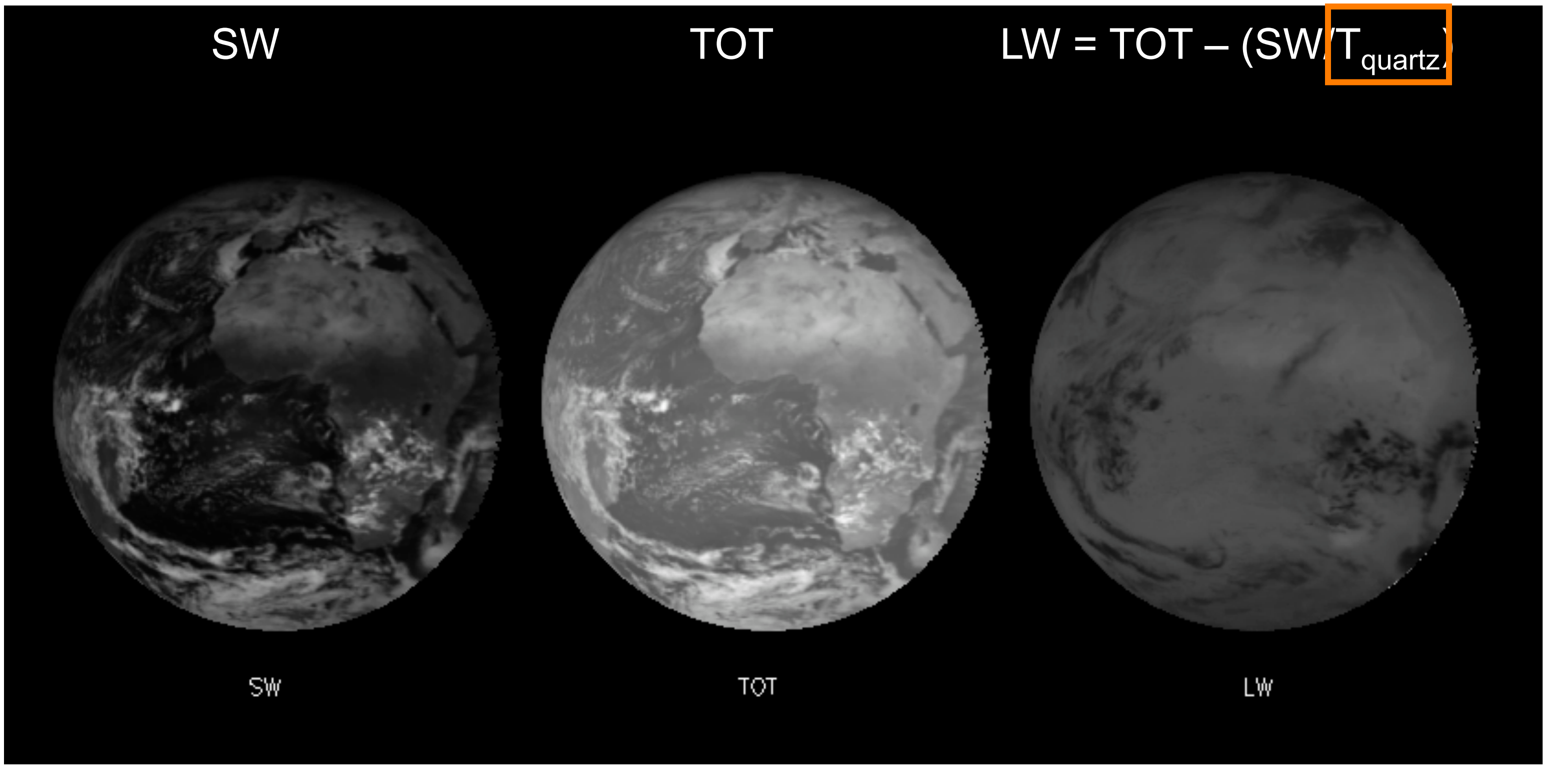
$$\text{Gain (TOT)} = \frac{V(BB) - V(space)}{\text{BB radiance}}$$

$$\text{Gain (SW)} = B \times \text{Gain (TOT)}$$

$$\text{Scene radiance} = \frac{V(Scene) - V(BB)}{\text{Gain}} + \text{BB radiance}$$

Shortwave & Longwave radiances (filtered)

Shortwave and total data re-gridded.
Shortwave then subtracted from total (after accounting for the effect of the quartz filter) to determine the longwave radiance



Level 2 processing 'un-filters' the radiance and derives associated fluxes using additional higher spatial resolution imager data from SEVIRI

- Instrument spectral response (Spot-checks)
- Quartz filter transmission (T)
- Detector Gains (Tot and SW)
- Gain ratio B
- Detector linearity
- IBB calibration
- Detector point spread function

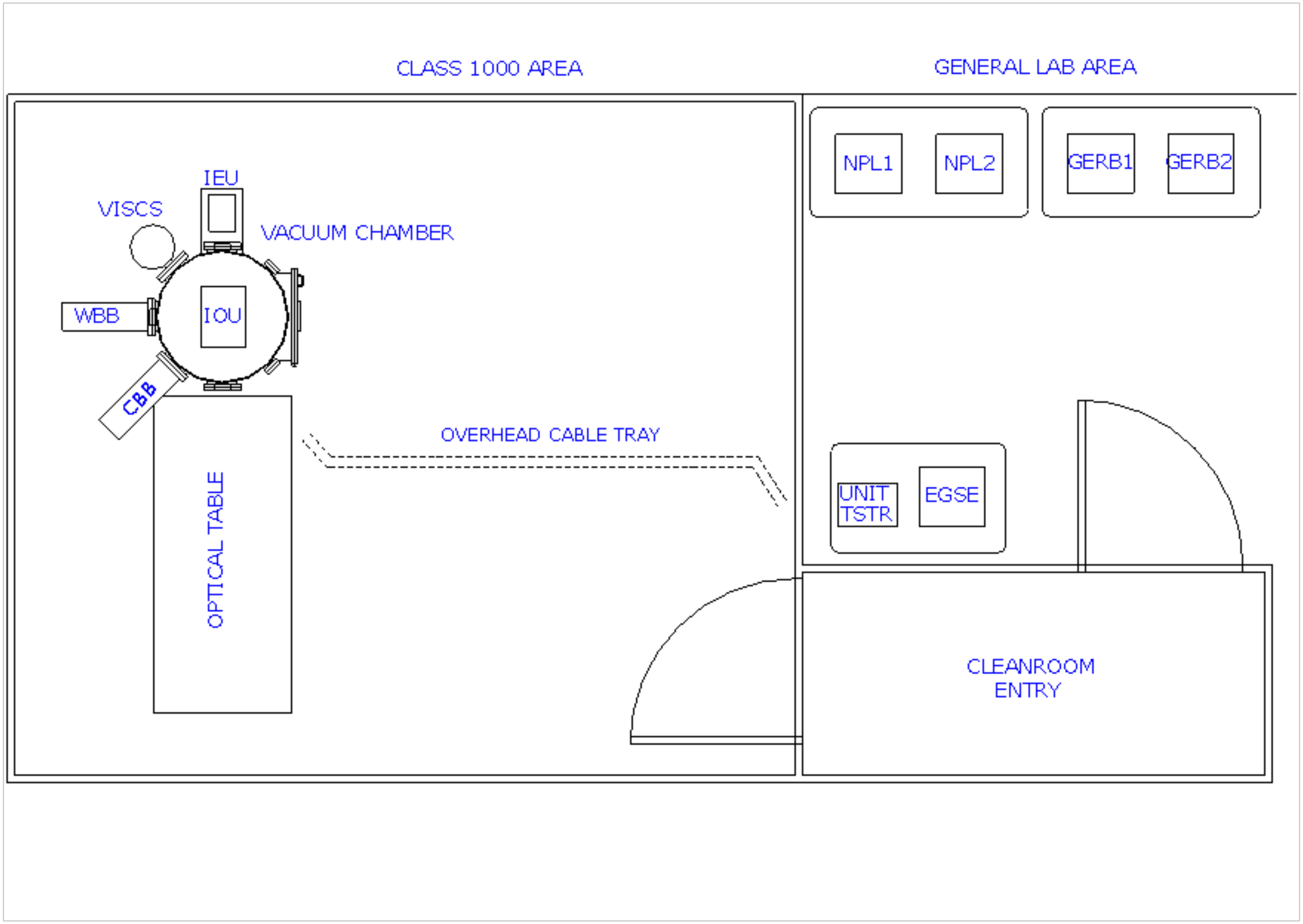
Ground Calibration facility

Earth Observation Characterisation Facility

Clean-room (~60m^3) maintained to better than class G (equivalent - class ISO6, 1000) and controlled to 2% relative humidity and 1°C.

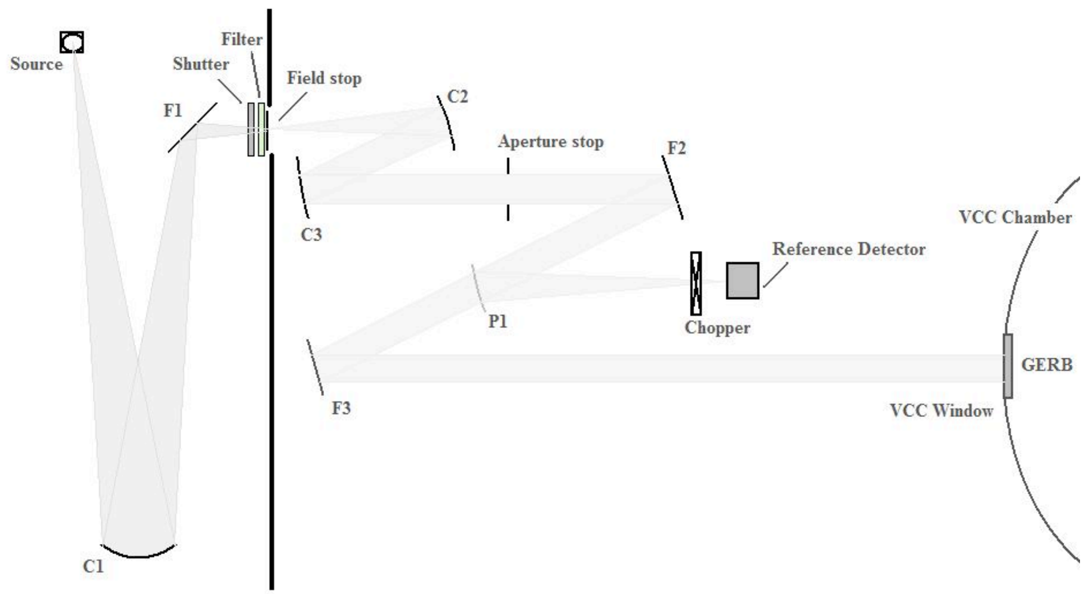
Vacuum Characterisation Chamber

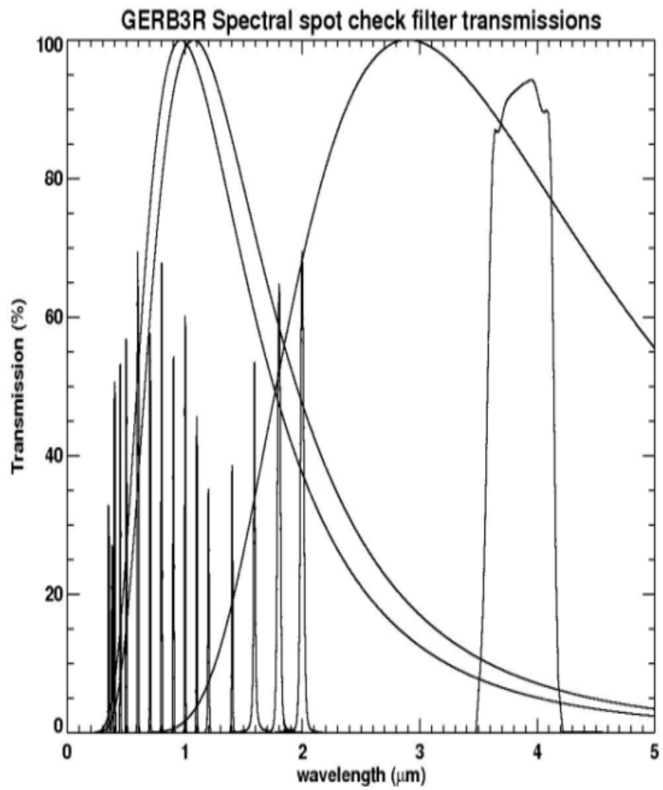
Cryogenically pumped high vacuum chamber capable of 10^{-9} Torr.

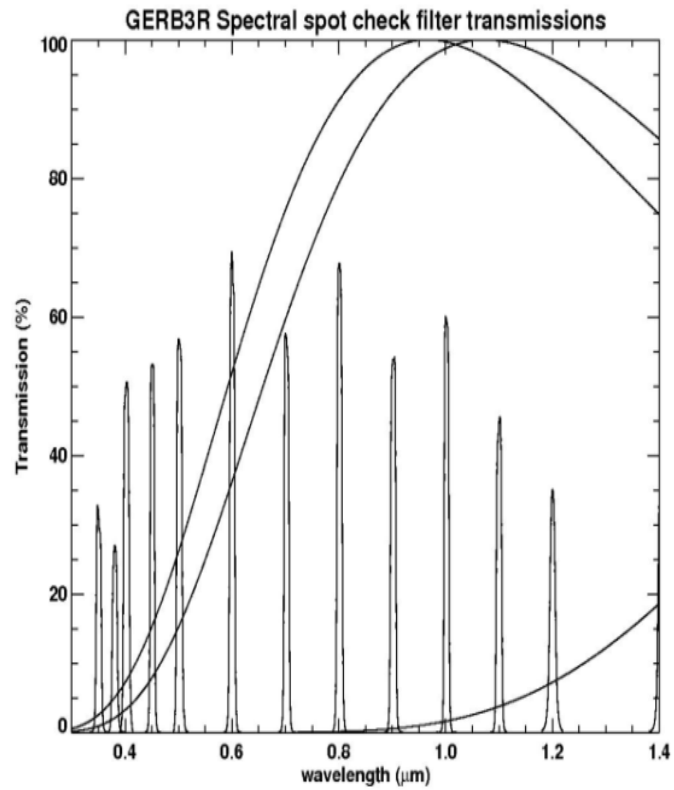


CLASS 1000 AREA
GENERAL LAB AREA
IEU
VISCS
VACUUM CHAMBER
WBB
IOU
CBB
OPTICAL TABLE
OVERHEAD CABLE TRAY
NPL1
NPL2
GERB1
GERB2
UNIT TSTR
EGSE
CLEANROOM ENTRY

Spectral spot check: Optical setup

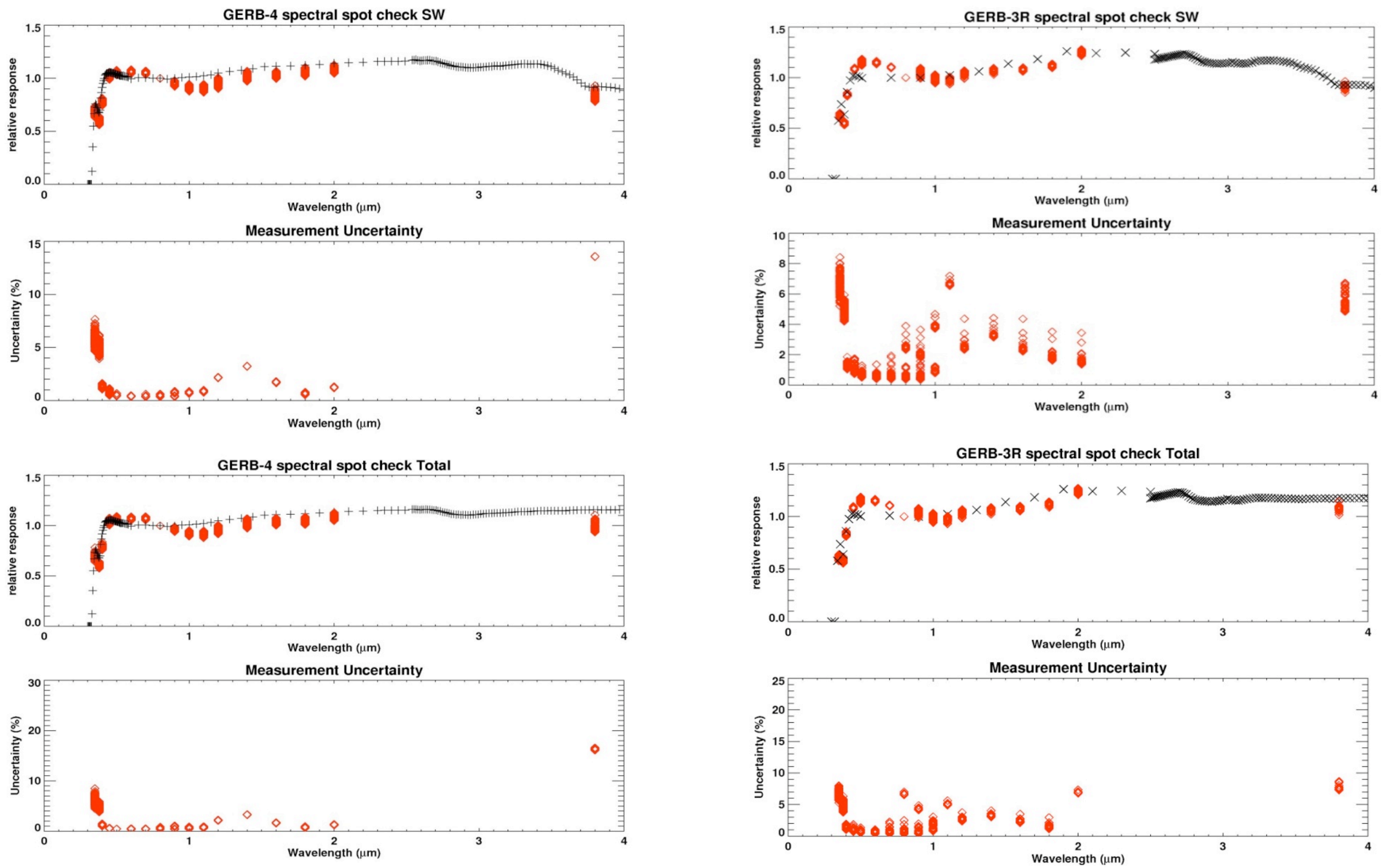




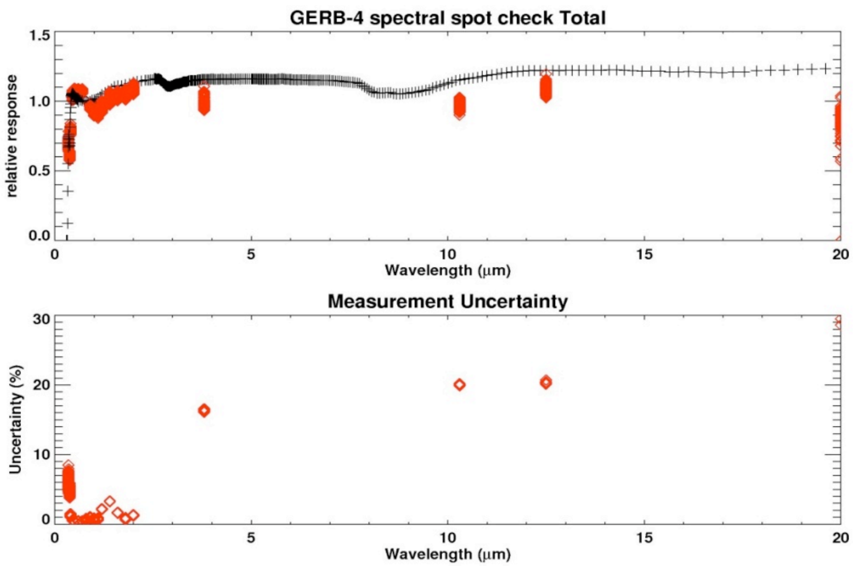


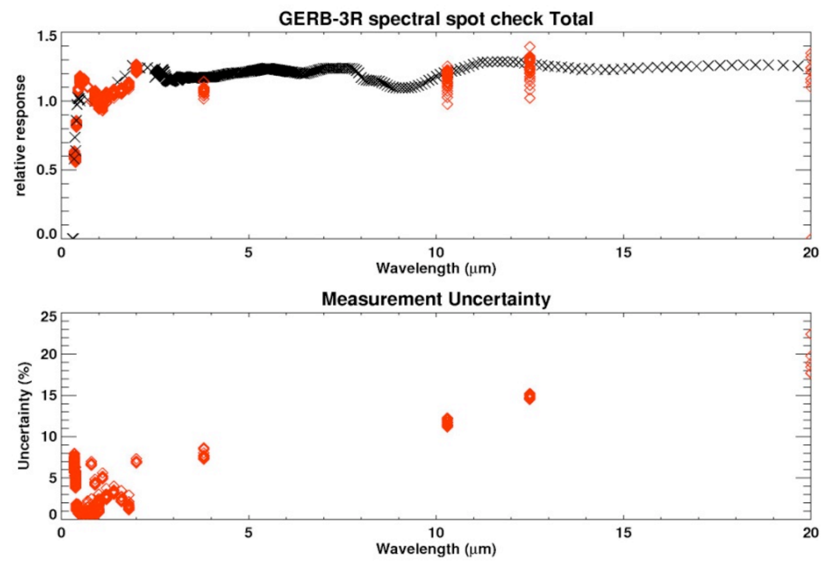
Transmission curves for the spectral filters used in the GERB3r shortwave spectral spot check measurements. Superposed on the filter transmissions are normalized source radiance curves for 1000 K, 2700 K and 3000 K.

Relative spectral response GERB-4 and GERB-3: Normalized to 0.8 μm and Compared to the system level response (mirror/detector combination)



Relative spectral response GERB-4 and GERB-3: Normalized to 0.8 µm and Compared to the system level response (mirror/detector combination)





Individual pixel spectral response functions (system level full range): Red denotes measurements made at Imperial College. Over-plotted in black and crosses is the average response obtained by combination of the GERB unit level, telescope/quartz filter/detector

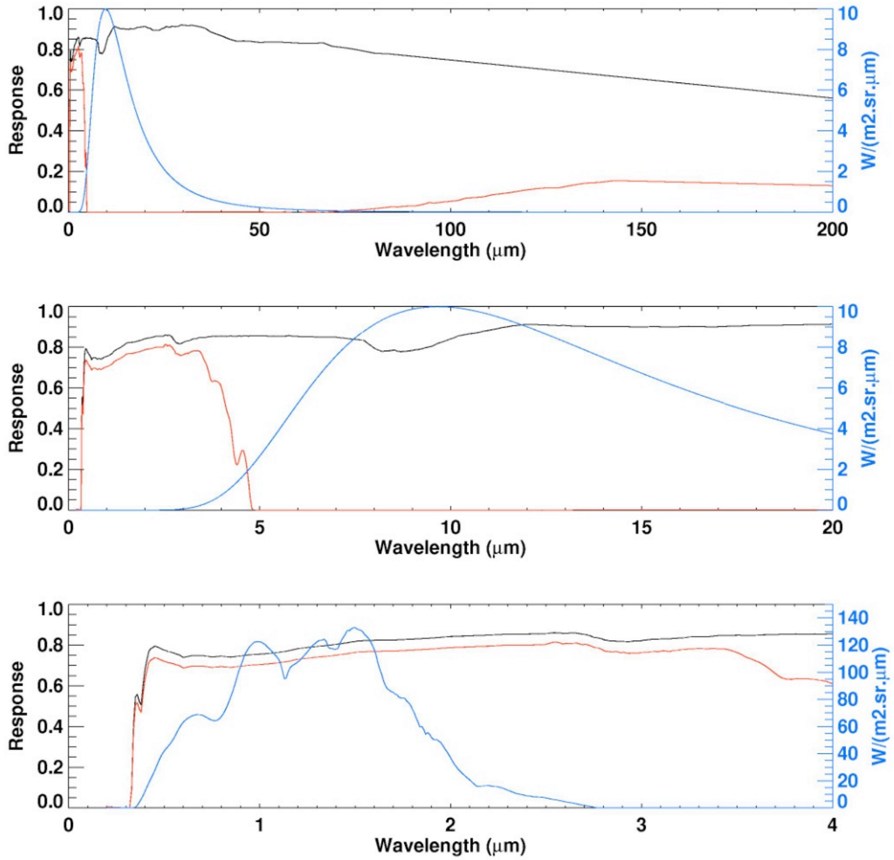
Vacuum calibration chamber (VCC) uses three
sources to characterise the GERB instrument
Performance in two channels

Longwave Gain characterisation:
Cold black body (CBB) maintained at 77 K by liquid nitrogen
Warm black body (WBB) varied between 250 - 340 K

Shortwave Gain and QF transmission characterisation:
Makes use of an NPL visible integrating Sphere
with halogen input lamps
(VISCS)

B: SW and Total gains

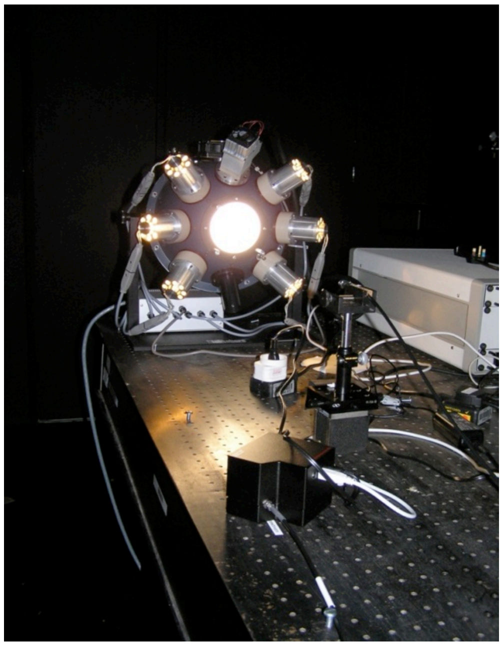
Sources and spectral response used for gain measurements



Black: The total system level spectral response, Red: The shortwave system level response. Blue: The calibration target radiance, upper and middle a black body at 300 K, lower plot the high level VISCS output.

Shortwave Target

NPL TSARS NOW USING 2/6 SOLUX 4700 K LAMPS



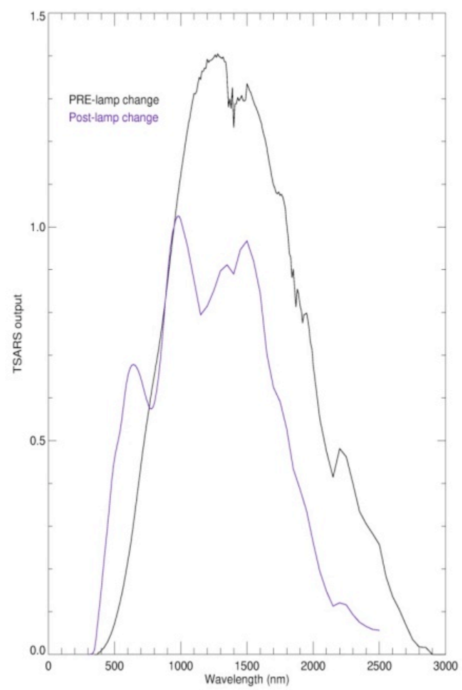
Lamp changes to the Sphere have been made to enhance the shortwave contribution to the integrated signal and give more confidence in the SW gain

Used to determine the **SW gain** and the quartz filter transmission

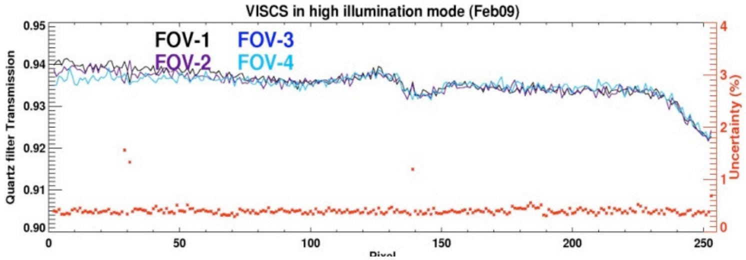
$$G_{sw} = \frac{V_{sw}(sphere\ on) - V_{sw}(sphere\ off)}{L^{f}_{sw}(sphere\ on)}$$

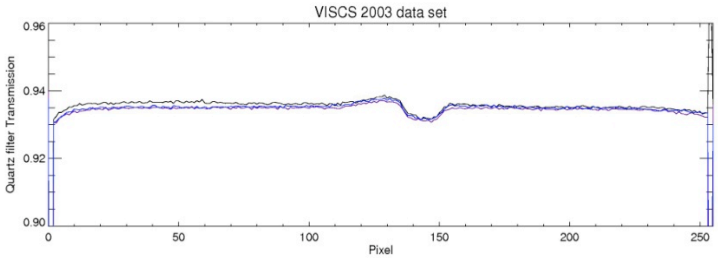
$$T = \frac{\left(V_{sw}(sphere\ on) - V_{sw}(sphere\ off)\right)_{Q-filter\ in}}{\left(V_{sw}(sphere\ on) - V_{sw}(sphere\ off)\right)_{Q-filter\ out}}$$

TSARS Relative spectral output



Quartz filter transmission

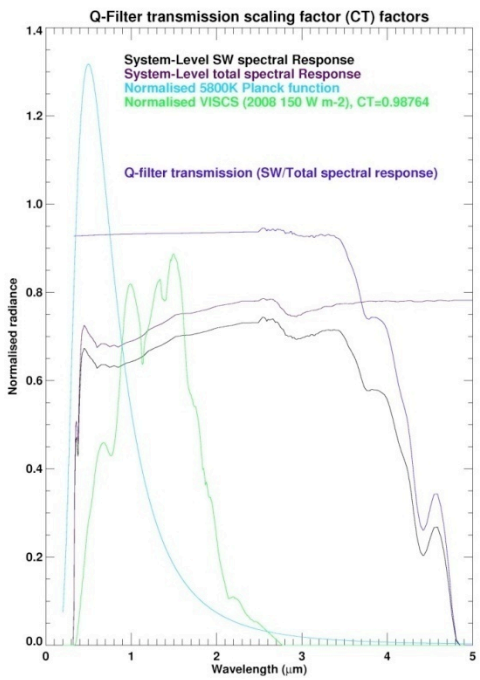




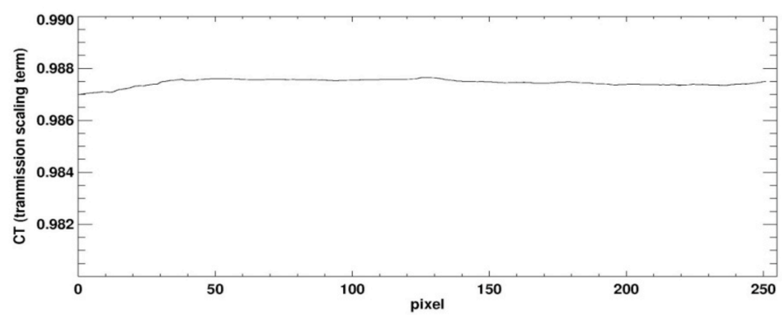
Top GERB-4 Bottom GERB-3

The variation in transmission with pixel
May be due to a thermal residual when the
Background signal is subtracted

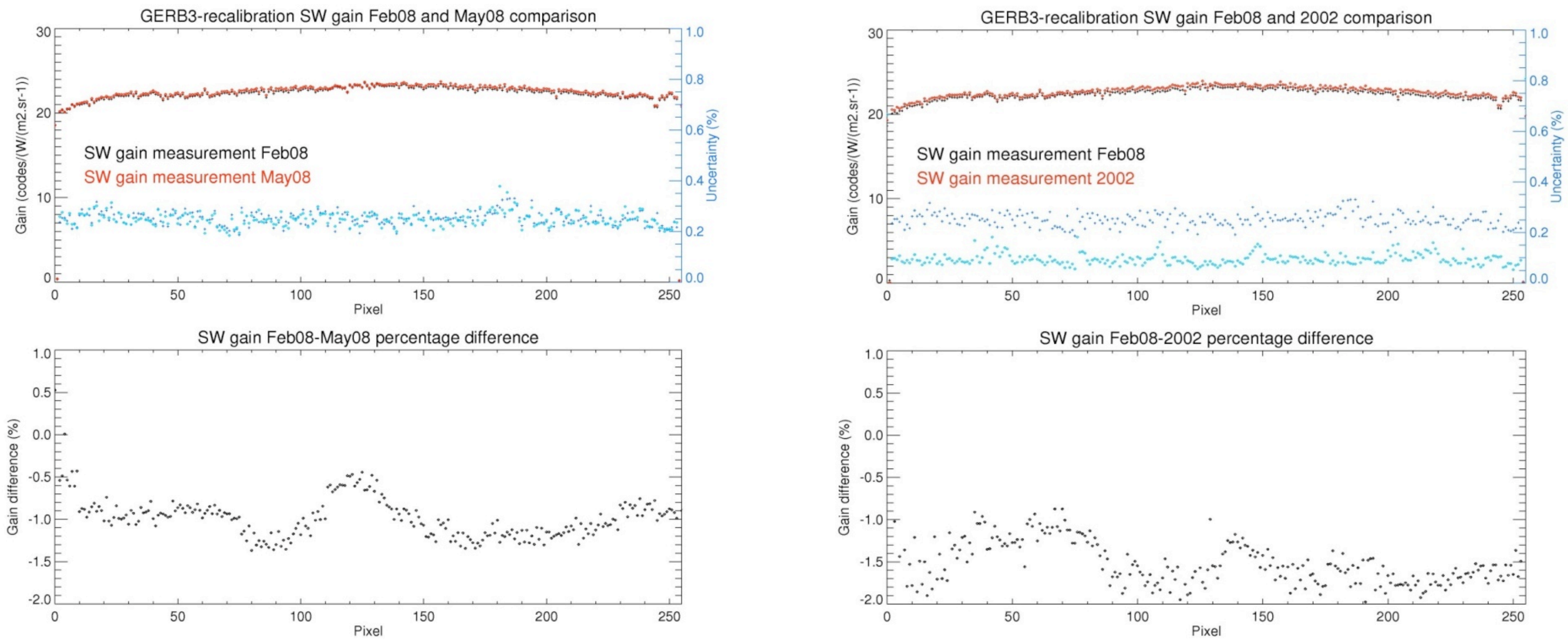
The variation in the central pixels
Are likely due to an optical cross
Talk between filter and windows



These values of T do not include the factor C_T used to scale the spectrally integrated T measured using the VISCS spectral distribution to a value consistent with a solar spectral distribution, show in lower plot.

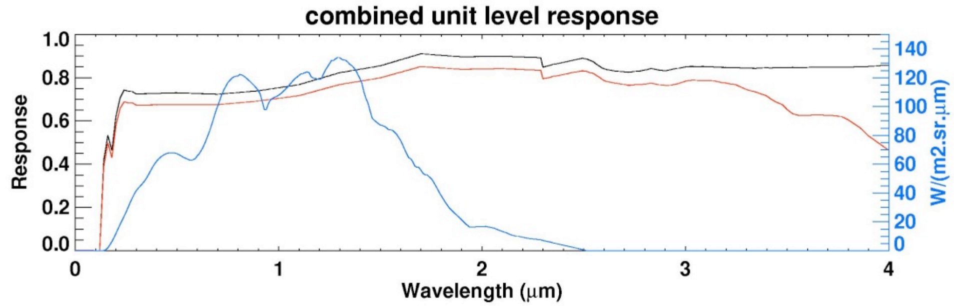


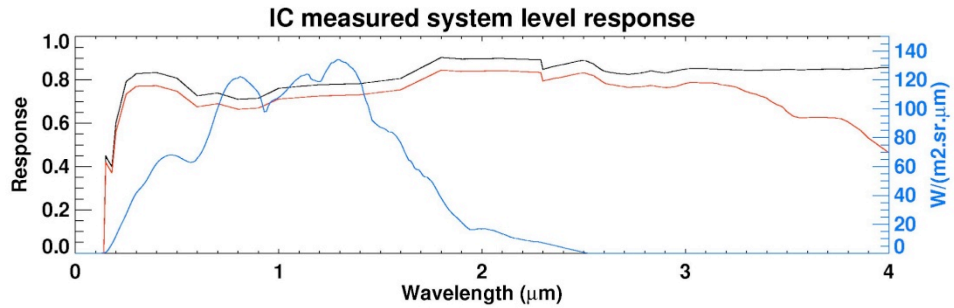
Temporal stability of the GERB-3 SW gain.... GERB or source?

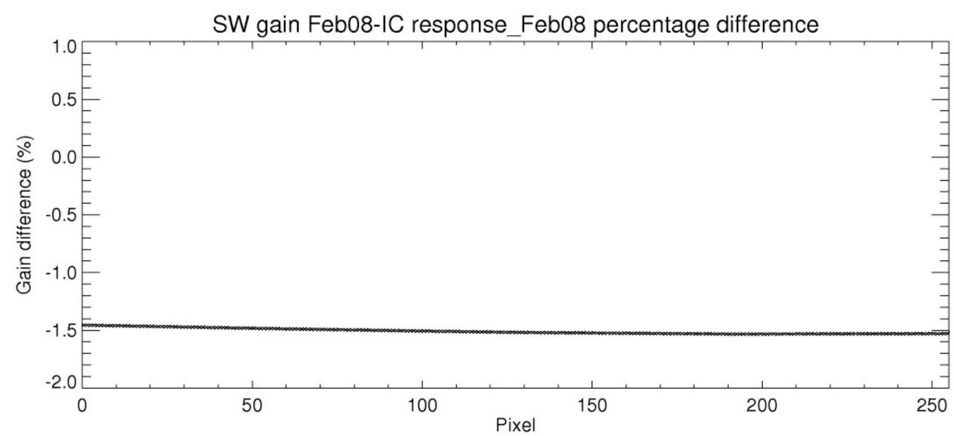


Effects of the chosen Spectral response on the SW gain for GERB-3

Incorporated the Spotcheck Values below 2 µm







Total gain is determined from observations of the warm and cold black bodies

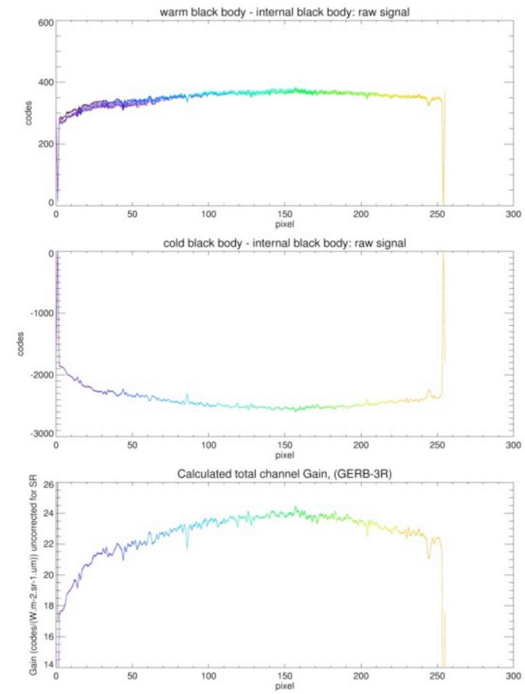
The detected voltage for a given target is given by

$$V_{cbb}^{77K} = G_{tot} \int L_{cbb}^{77K}(\lambda) SR_{tot}(\lambda)\, \delta\lambda + C_{cbb} \qquad V_{wbb}^{T} = G_{tot} \int L_{wbb}^{T}(\lambda) SR_{tot}(\lambda)\, \delta\lambda + C_{wbb}$$

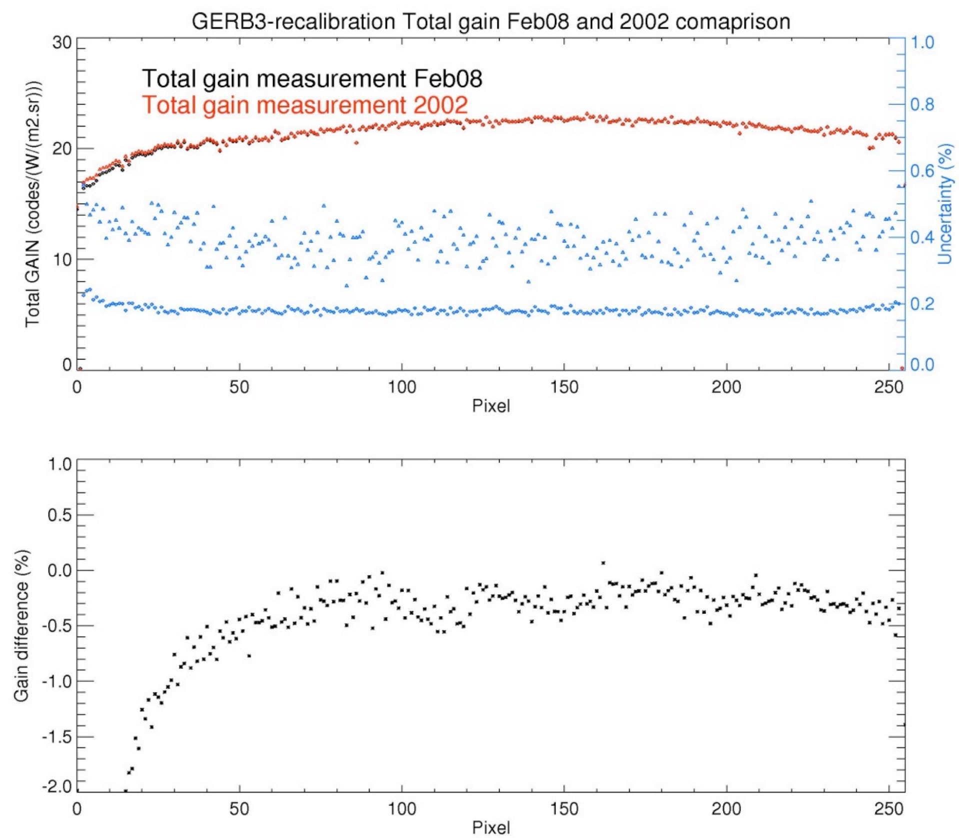
Assuming the off-sets are identical

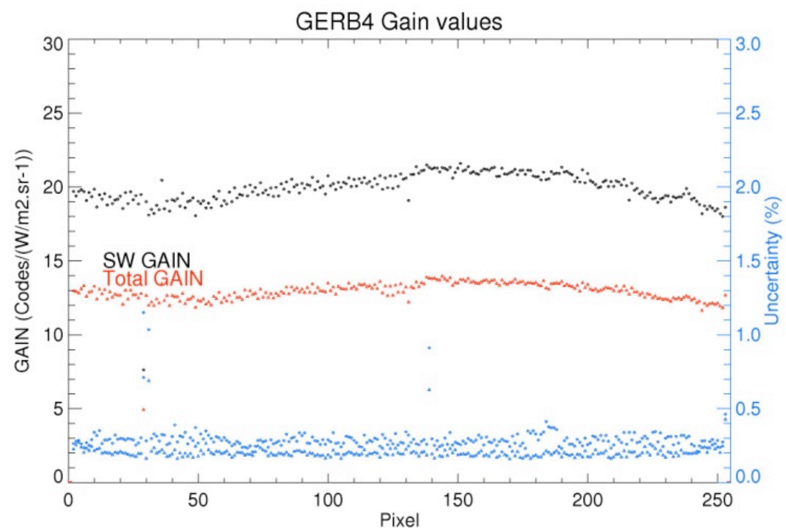
Differencing the two yields

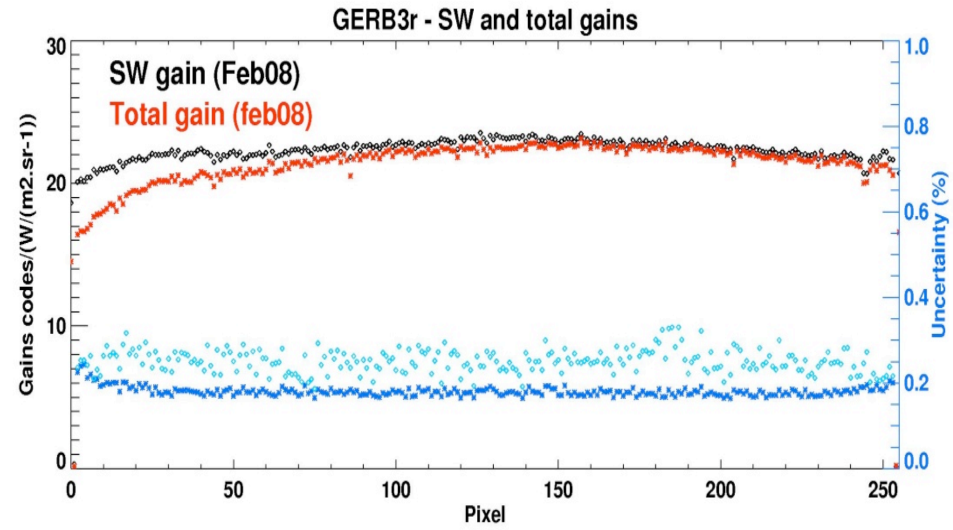
$$V_{wbb}^{T} - V_{cbb}^{77K} = G_{tot}\left\{\int L_{wbb}^{T}(\lambda) SR_{tot}(\lambda)\, \delta\lambda - \int L_{cbb}^{77K}(\lambda) SR_{tot}(\lambda)\, \delta\lambda\right\}$$

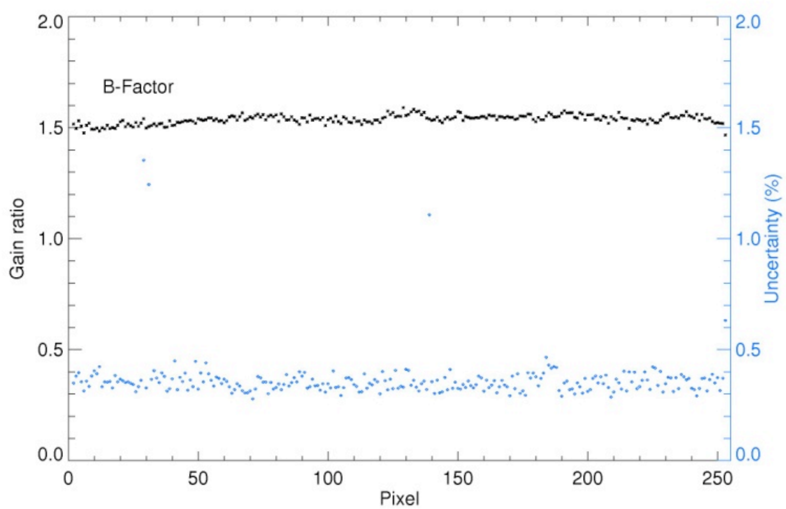


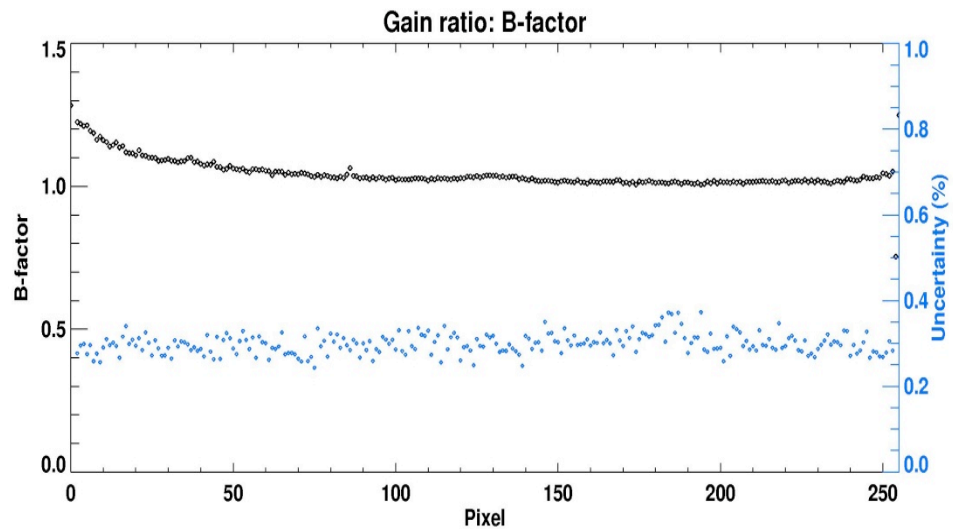
From which the **total gain** can be derived


GERB3-recalibration Total gain Feb08 and 2002 comaprison
Total gain measurement Feb08
Total gain measurement 2002
Total GAIN (codes/(W/(m2.sr)))
Uncertainty (%)
Pixel
Gain difference (%)
Pixel


GERB4 Gain values
SW GAIN
Total GAIN
GAIN (Codes/(W/m2.sr-1))
Uncertainty (%)
Pixel
0
50
100
150
200
250
0
5
10
15
20
25
30
0.0
0.5
1.0
1.5
2.0
2.5
3.0


GERB3r - SW and total gains
SW gain (Feb08)
Total gain (feb08)
Gains codes/(W/(m2.sr-1))
Uncertainty (%)
Pixel
0
50
100
150
200
250
0
10
20
30
0.0
0.2
0.4
0.6
0.8
1.0

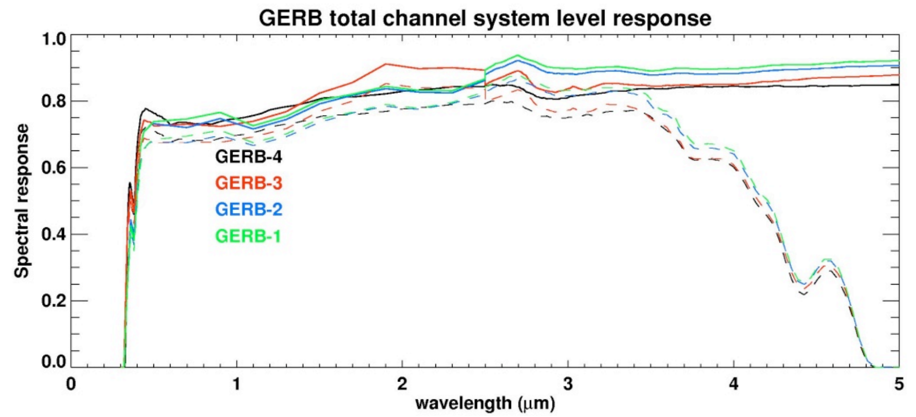

B-Factor
Gain ratio
Uncertainty (%)
Pixel
0
50
100
150
200
250
0.0
0.5
1.0
1.5
2.0
0.0
0.5
1.0
1.5
2.0

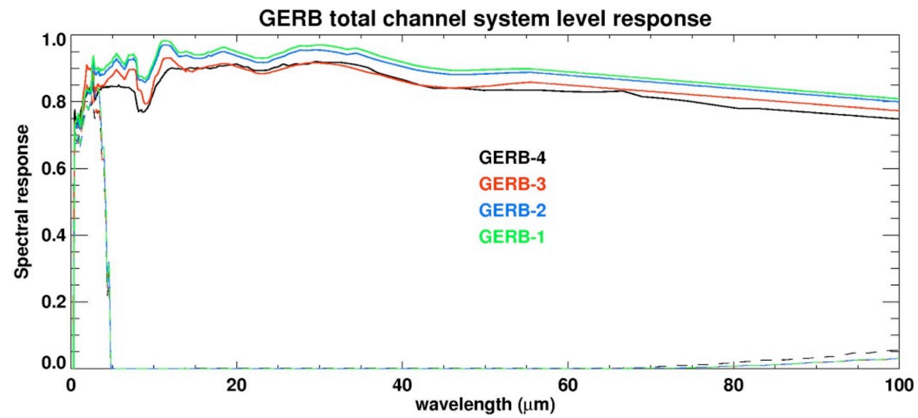

Gain ratio: B-factor
B-factor
Uncertainty (%)
Pixel
0
50
100
150
200
250
0.0
0.5
1.0
1.5
0.0
0.2
0.4
0.6
0.8
1.0

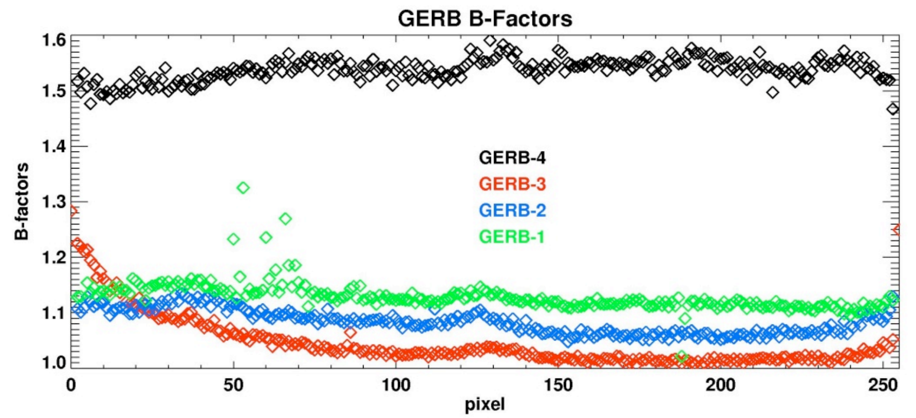
The Spectral response used in the
Analysis of the calibration data is
A combination of the detector response,
Measured by Leicester University and
The telescope mirror response measured
By NPL.

There is no indication, when comparing the
Spectral response of the 4 GERB instruments,
Why there should be a significant drop in the
Long-wave response of GERB-4

This shall be explored further along





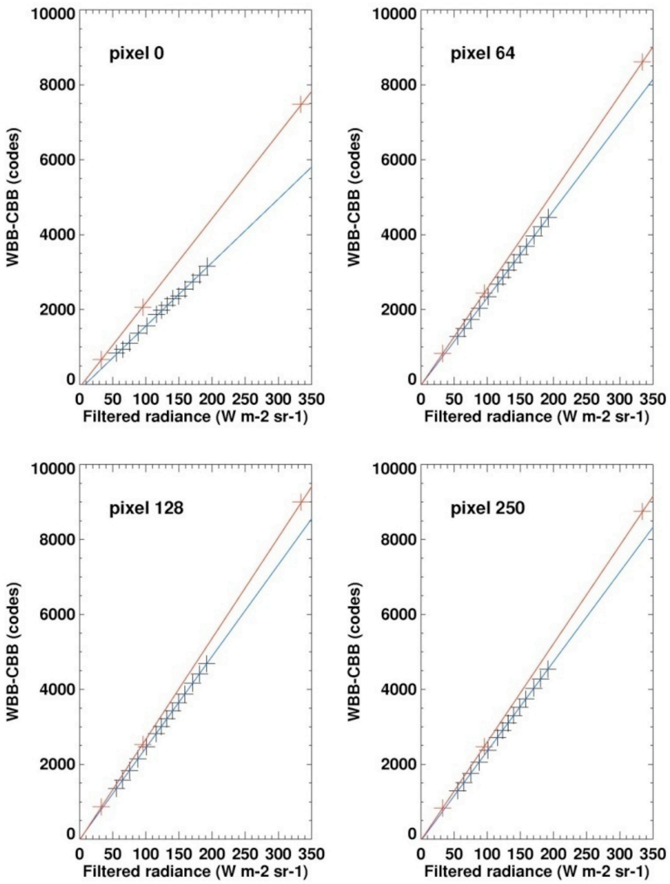


By varying the WBB temperature we can check the detector linearity

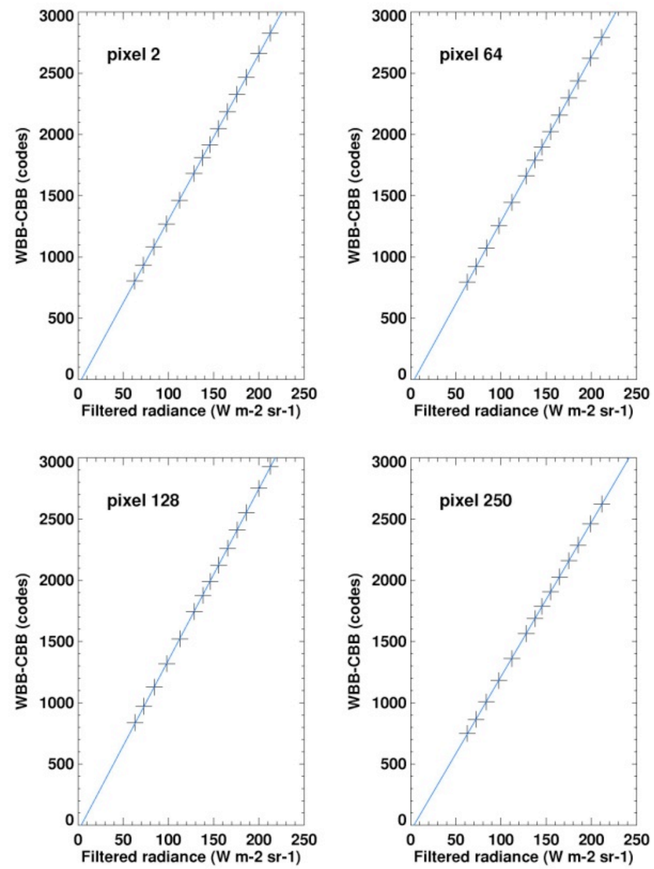
$$V_{wbb}^{T} - V_{cbb}^{77K} = G_{tot}\left\{\int L_{wbb}^{T}(\lambda) SR_{tot}(\lambda)\,\delta\lambda - \int L_{cbb}^{77K}(\lambda) SR_{tot}(\lambda)\,\delta\lambda\right\}$$

We can also derive the gain from the slope of the linearity graph

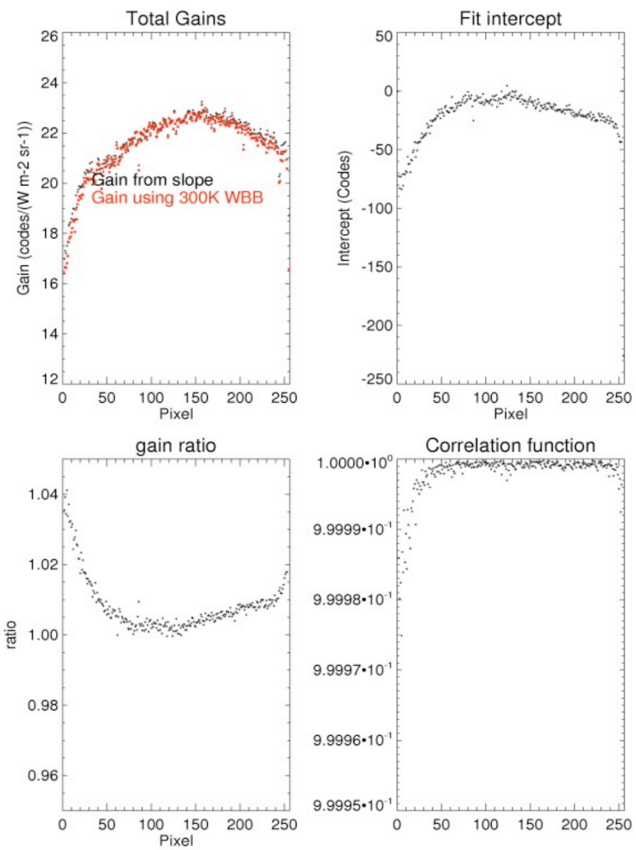
GERB-3



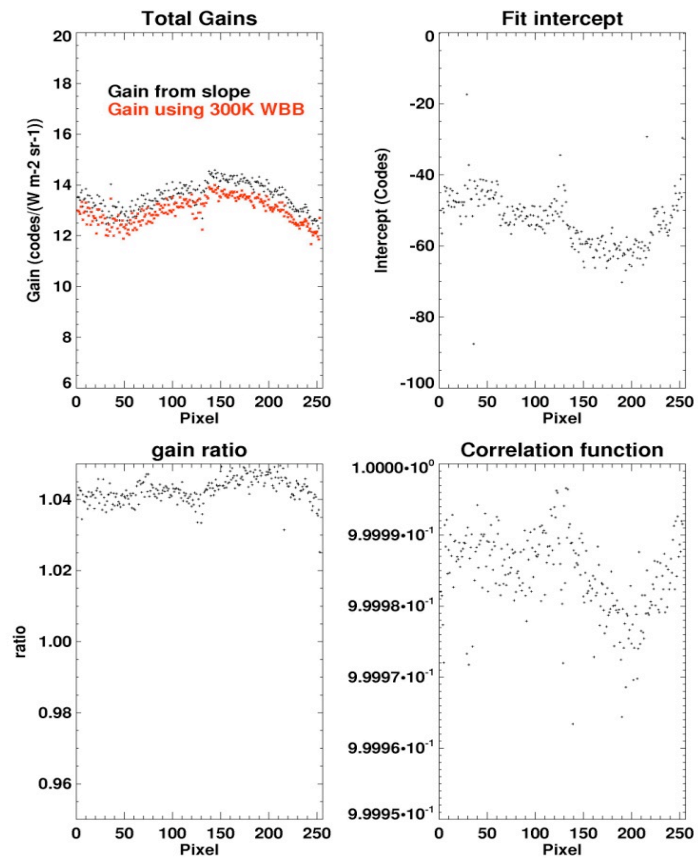
GERB-4



Top left: Black crosses total gain calculated using the slope fitted to the observed voltage difference (WBB – CBB) vs the filtered radiances from the blackbody. Red stars show the total gain derived from a single WBB temperature of 300K. Top right: The intercept of the fitted line. Bottom left: The ratio of the gain derived from the line fit over the gain from 300K WBB. Bottom right: The Correlation function between the fitted straight line fit to the actual data values

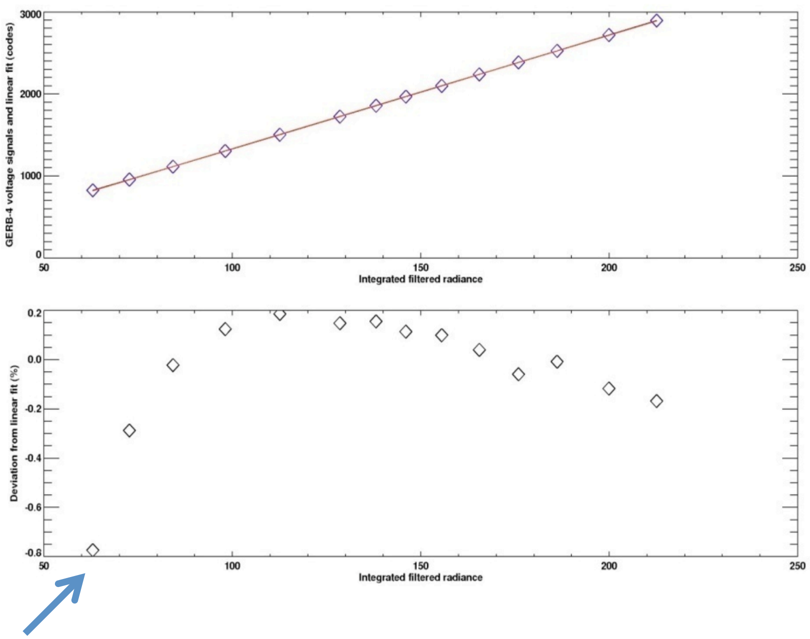


GERB-3



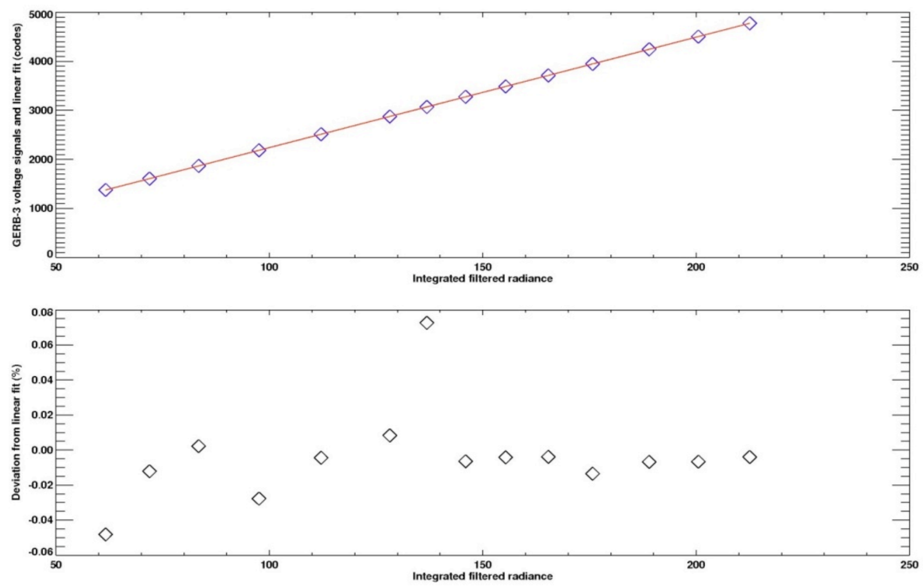
GERB-4

Upper panels: Average (central 100 pixels) voltage reading (wbb-cbb) Vs the black body filtered radiance (wbb-cbb), blue triangles and the linear fit in red. Lower panel shows the percentage deviation of each measurement from the linear fit. The use of a well known spectral response for the GERB-3 instrument results in a significant reduction in deviations from the linear fit for all measurements to within the uncertainty of the voltages and blackbody temperatures.



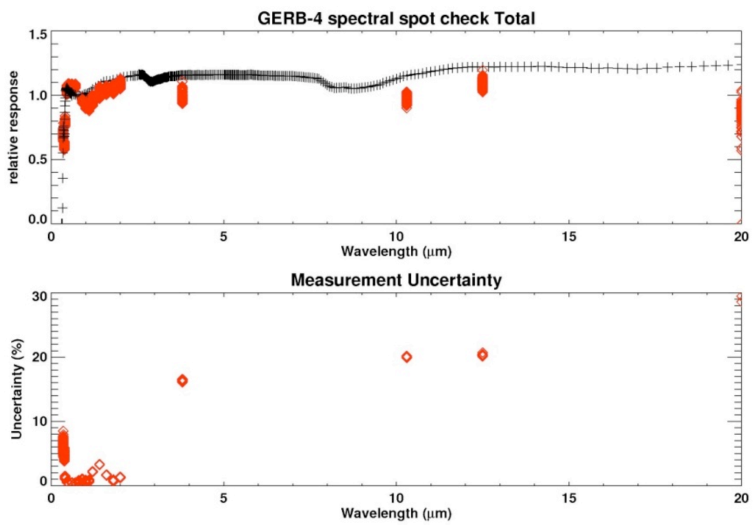
T = 251K
Δ ~ 0.6K

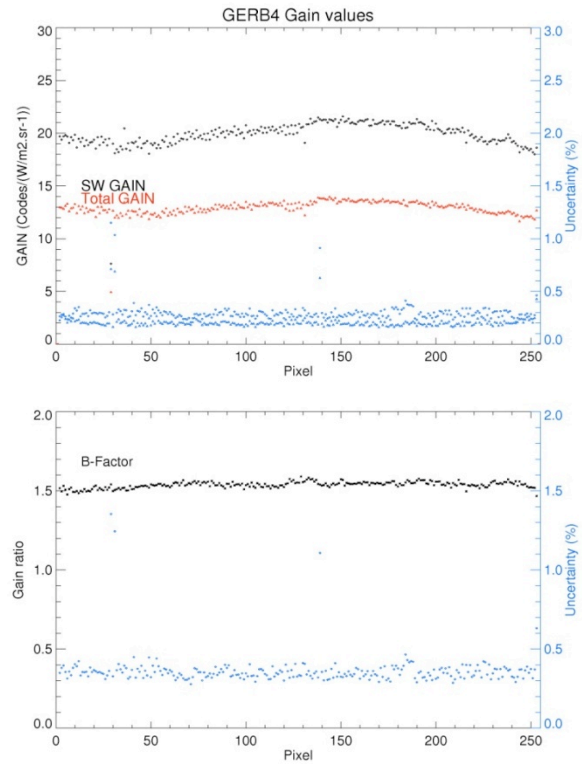
GERB-4

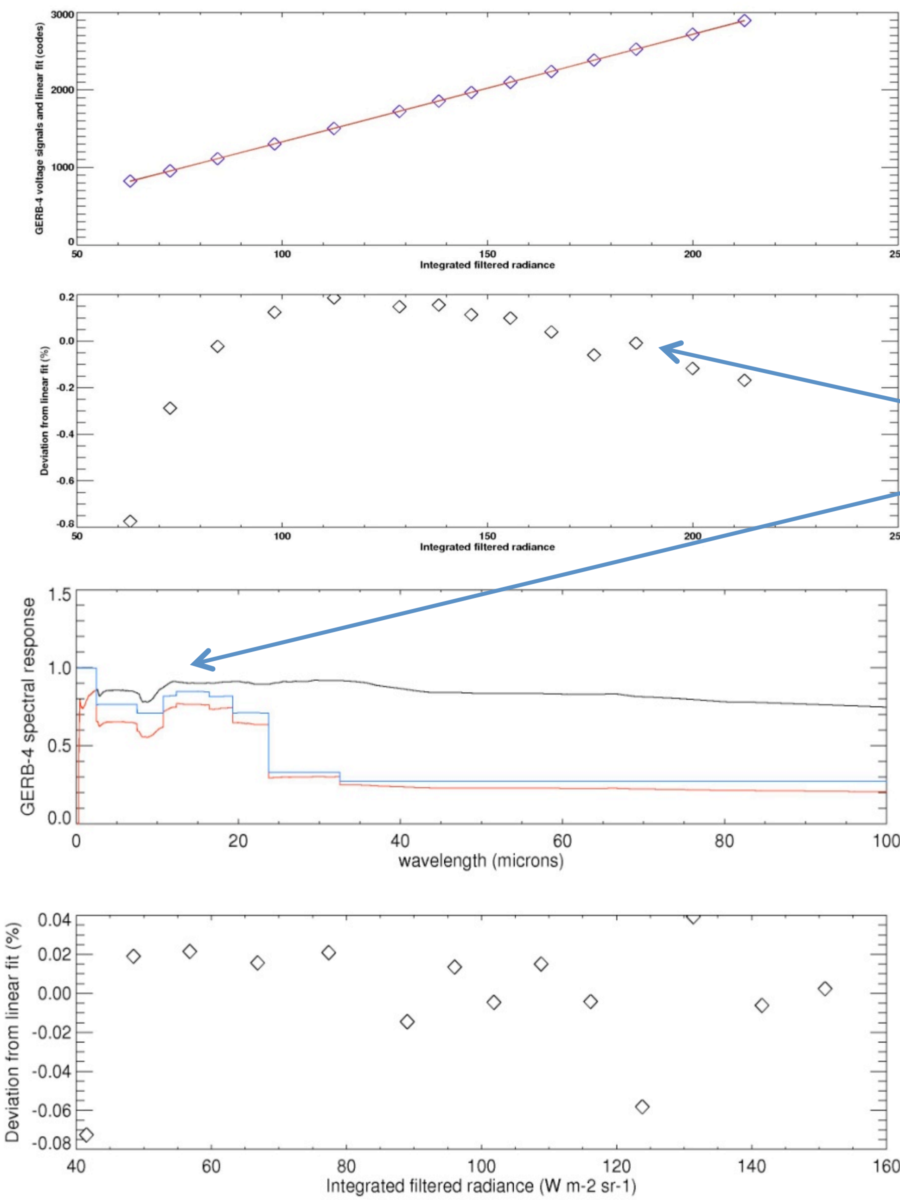


GERB-3

Estimating a corrected spectral response using calibration measurements





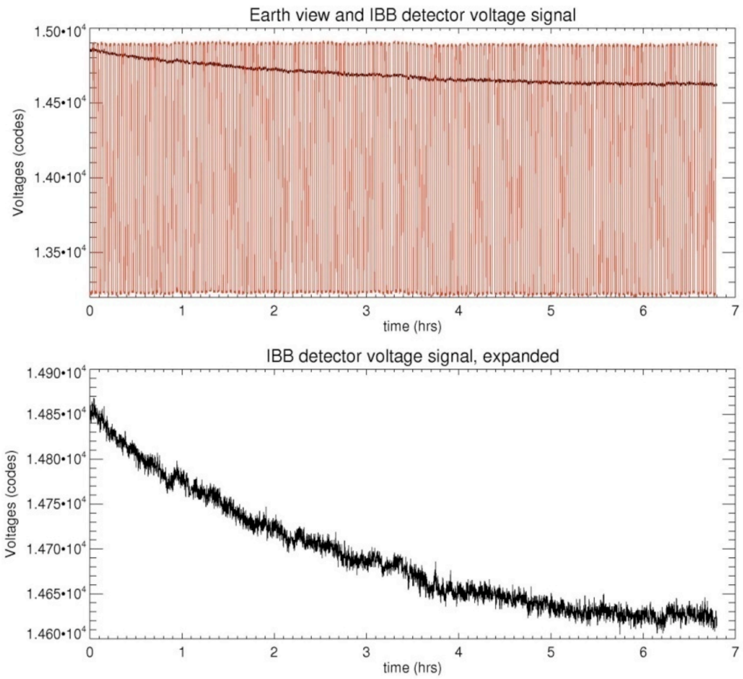


Top panel shows the GERB-4 system level spectral response in black, in blue is the scaling factor used to rescale the spectral response and in red the resultant spectral response. Lower panel shows the deviation from the linear fit of the measured data for GERB-4 using the rescaled spectral response

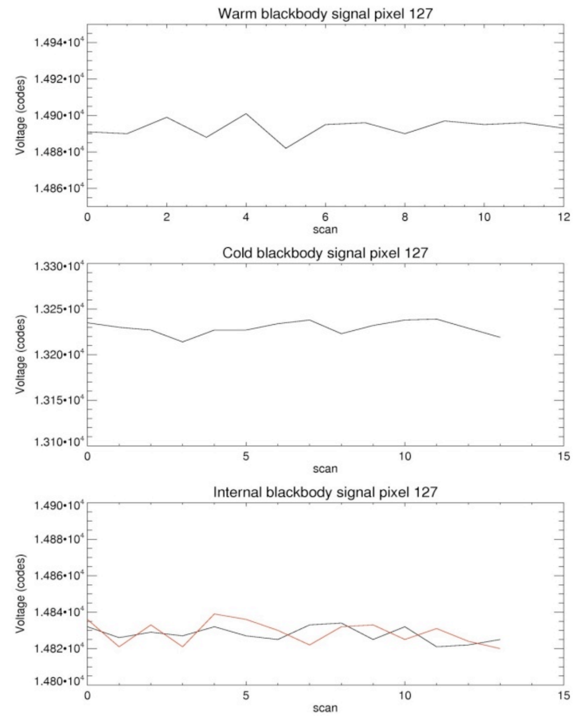
Deviation from the linear fit for the higher warm blackbody temperatures are most sensitive to variations in the SR in the 5 µm – 20 µm spectral region.

Additional filters for the 5 µm – 20 µm spot check measurements would help give confidence in this method of correction

MSG-ICL-GE-RP-0035 Internal Black Body calibration



Top/bottom in black: Pixel 127 IBB voltage readout at height C taken during the IBB cool down period, 302.7 K – 291.2 K. Top red: Pixel 127 Earth view voltage readout alternates between the WBB at 300 K and the CBB at 78 K, these Earth view data are used to derive the detector gain used to calculate the IBB filtered radiances.



Two successive measurement cycles consisting of 48 second dwell times and incorporating approximately 12 data samples. Top: IOU pointing at the WBB. Middle: IOU pointing at CBB. Bottom IBB detector readings during WBB cycle (black) and CBB cycle (red).

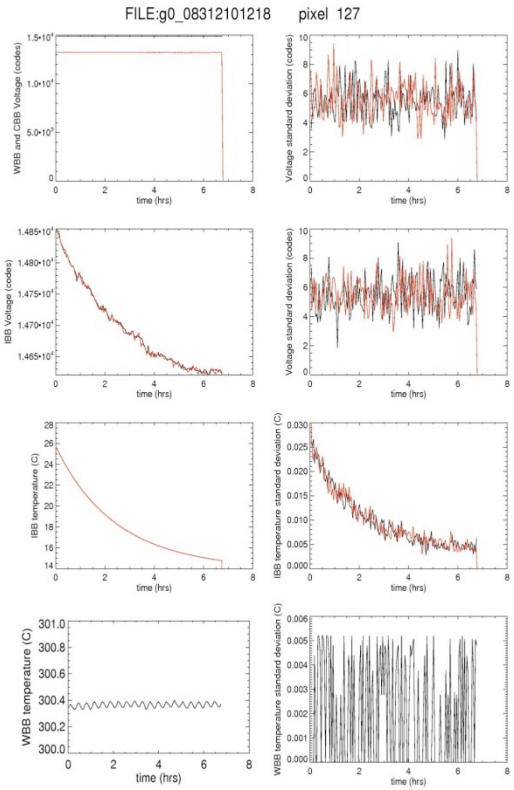
IBB radiances are calculated from calibration measurements thus

$$L_{IBB}^{F} = \frac{V_{IBB} - V_{WBB}}{G} + L_{WBB}^{F}$$

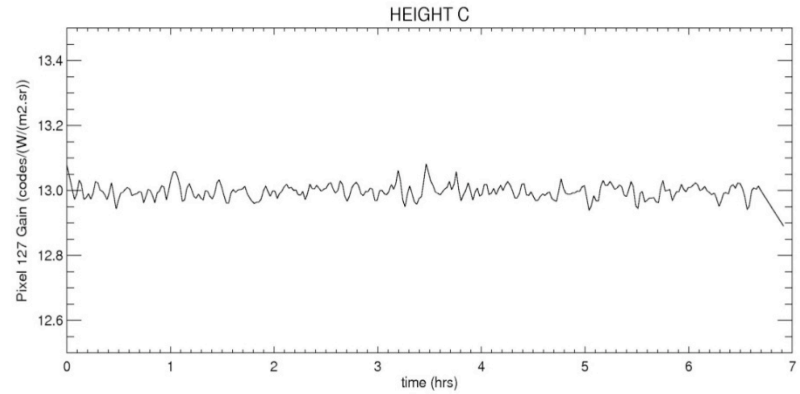
Where the gain, G, of the instrument can be expressed as $G = \frac{V_{WBB} - V_{CBB}}{L_{WBB}^{F} - L_{CBB}^{F}}$

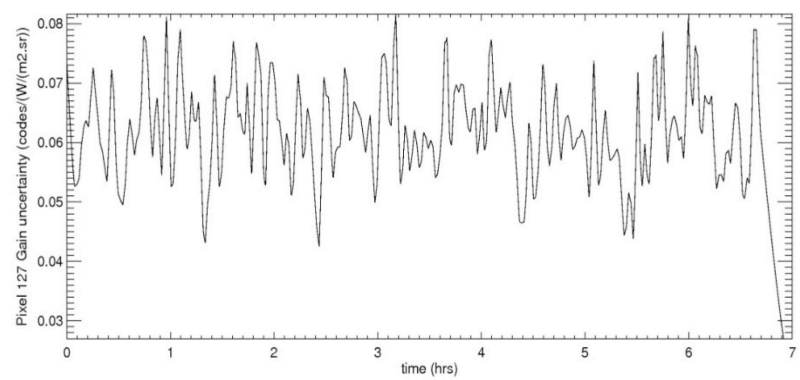
This filtered radiance is then compared to that derived from the integrated Planck function and known black body temperature

$$L_{IBB}^{F} = \int_{0}^{\infty} L_{\lambda} SR_{\lambda} \delta\lambda$$



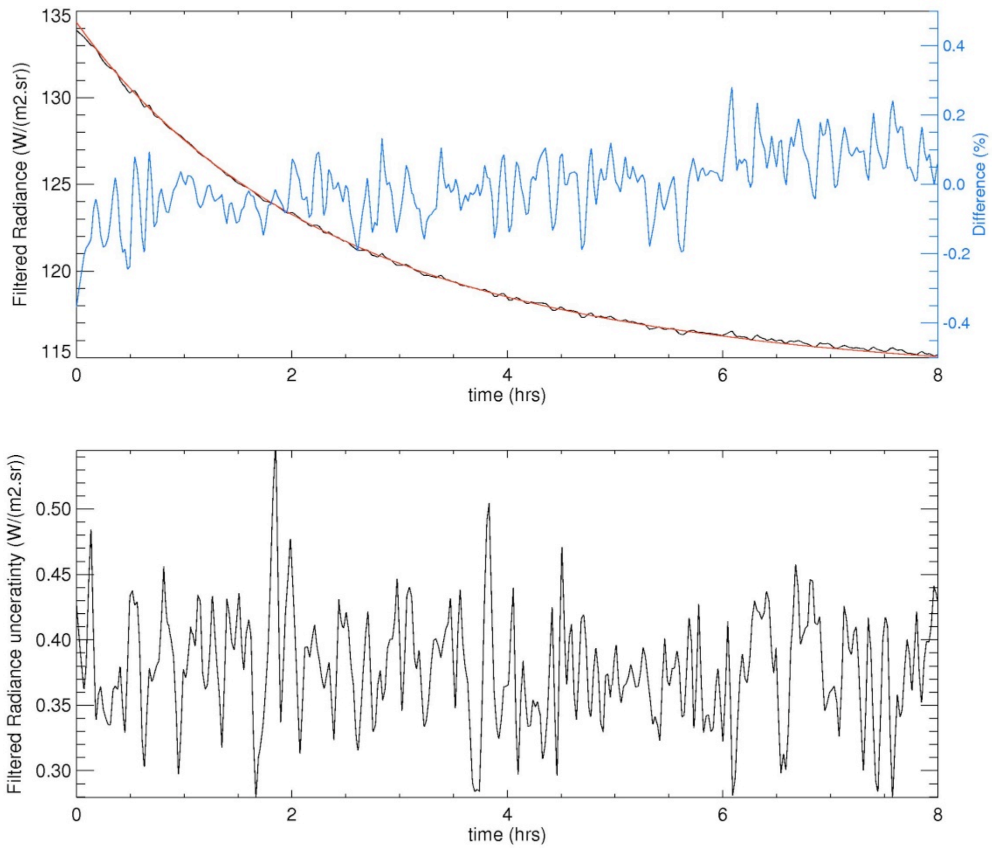
G



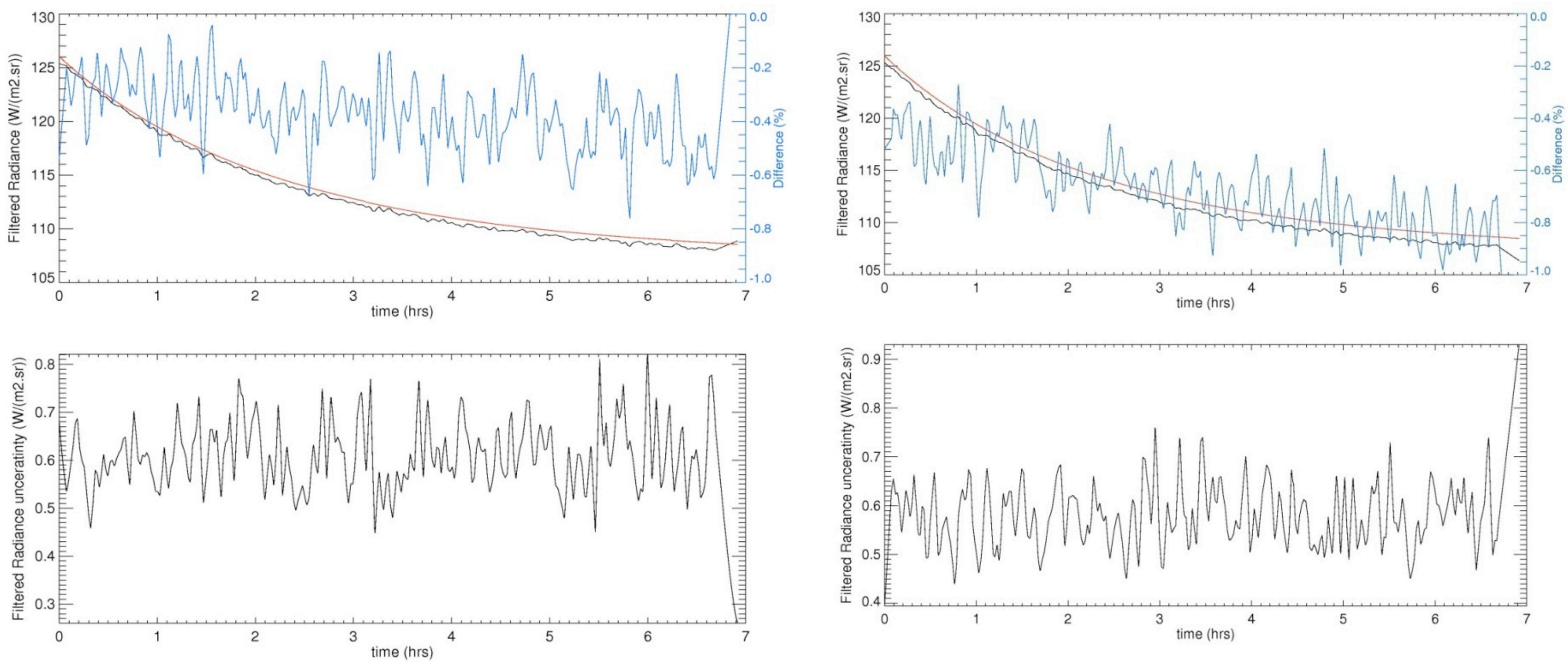


The measured gain, for pixel 127, calculated using the WBB and CBB filtered radiances (derived from the measured temperatures) and the detector voltage measurements. Lower plot shows the measurement uncertainty

GERB-3



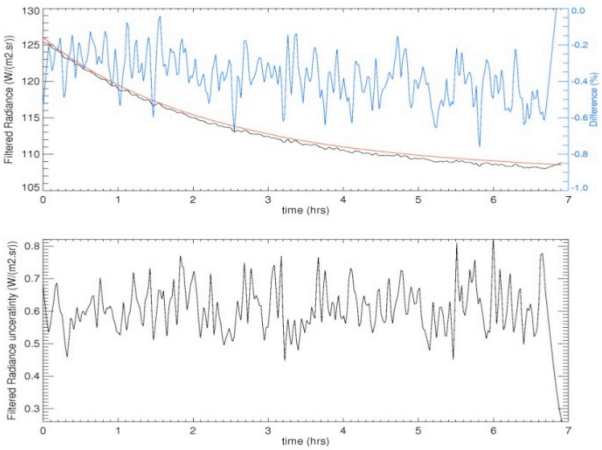
Top, filtered radiance as a function of time for pixels 127. In black is the value derived from voltage readings. In red is the filtered radiance derived using the IBB temperature and the integrated Planck function.



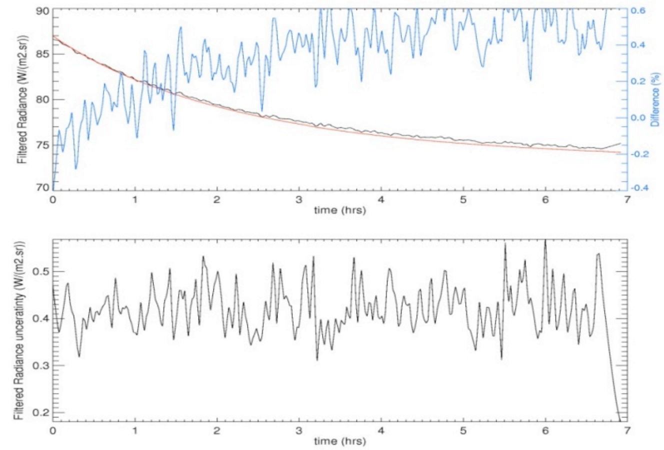
Top, filtered radiance as a function of time for pixels 127 left and 128 right. In black is the value derived from voltage readings. In red is the filtered radiance derived using the IBB temperature and the integrated Planck function.

Manipulated spectral response on IBB radiance measurements

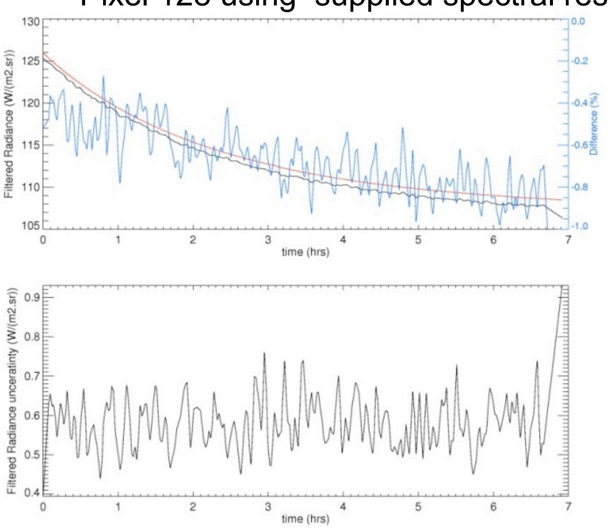
Pixel 127 using supplied spectral response



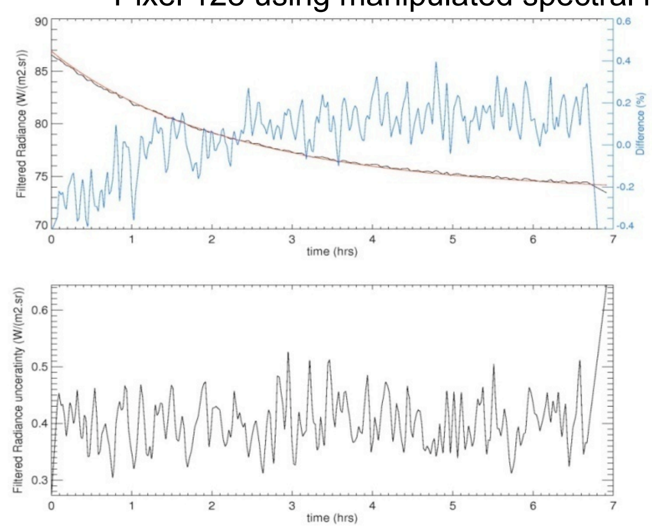
Pixel 127 using manipulated spectral response

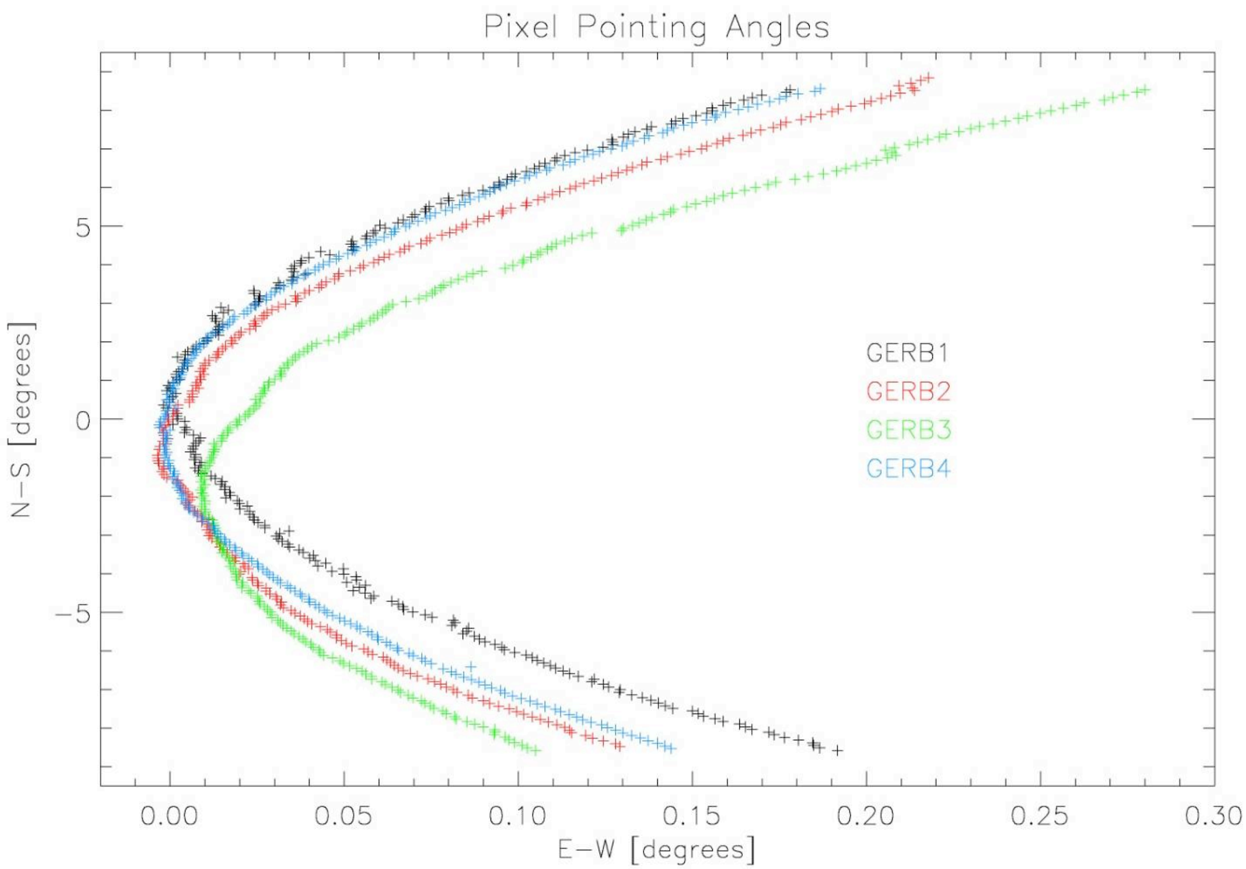


Pixel 128 using supplied spectral response

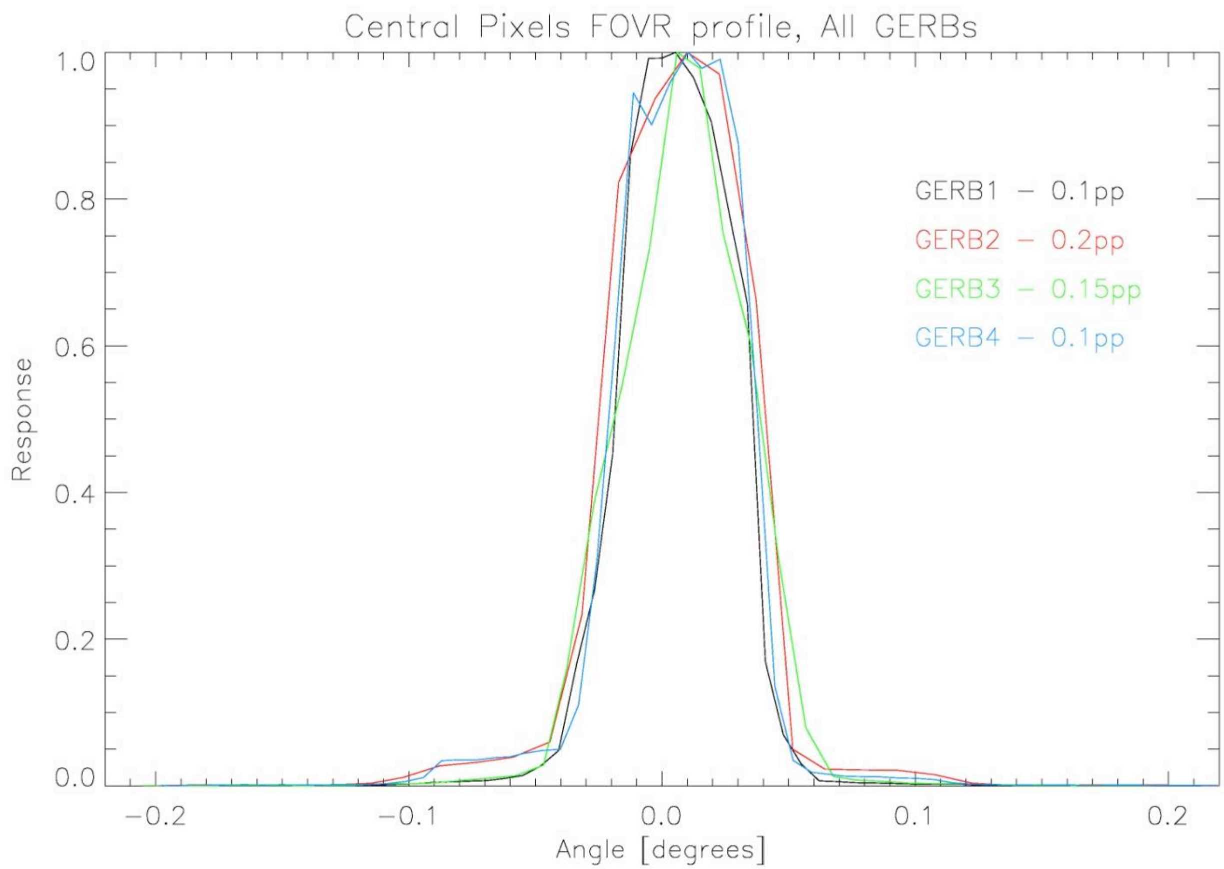


Pixel 128 using manipulated spectral response





Pixel Pointing Angles
N-S [degrees]
E-W [degrees]
5
0
−5
0.00
0.05
0.10
0.15
0.20
0.25
0.30
GERB1
GERB2
GERB3
GERB4



Central Pixels FOVR profile, All GERBs
1.0
0.8
0.6
0.4
0.2
0.0
Response
−0.2
−0.1
0.0
0.1
0.2
Angle [degrees]
GERB1 − 0.1pp
GERB2 − 0.2pp
GERB3 − 0.15pp
GERB4 − 0.1pp

Some concluding remarks

The ground calibration phase for GERB-3 and GERB-4 have been completed successfully:

GERB-3:
shows good temporal stability over a 6 year period the long-wave stability for pixels below 50 are an exception which, like GERB-4, is likely to be a SR issue

GERB-4:
The calibration has highlighted an uncertainty in the knowledge of the spectral response function, particularly the long-wave response.

However it is possible to use the linearity meaurements to obtain a pixel-by-pixel correction for this

Nine reports outline the processing and results of the GERB-3 re-calibration and GERB-4 calibration

MSG-ICL-GE-RP-0027: GERB-3 Re-Calibration: Spectral Response Spot Check

MSG-ICL-GE-RP-0028: GERB-3 Re-Calibration: Radiometric Parameters B, A, T

MSG-ICL-GE-RP-0029: GERB-3 Re-Calibration: Broadband Detector Linearity

MSG-ICL-GE-RP-0030: GERB-3 Re-Calibration: Internal Blackbody Calibration

MSG-ICL-GE-RP-0031: GERB-4 Calibration: Spectral Response Spot Check

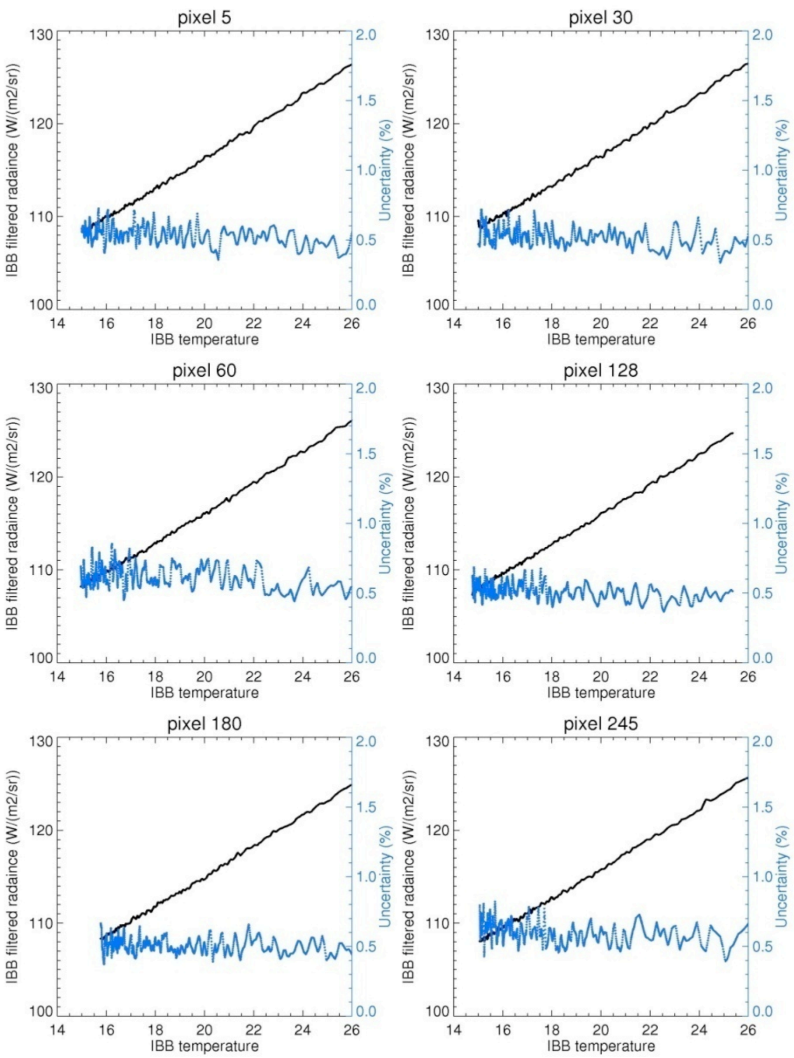
MSG-ICL-GE-RP-0032: GERB-4 Calibration: FOV Response Function Data Processing

MSG-ICL-GE-RP-0033: GERB-4 Calibration: Broadband Detector Linearity

MSG-ICL-GE-RP-0034: GERB-4 Calibration: Radiometric Parameters B, A, T

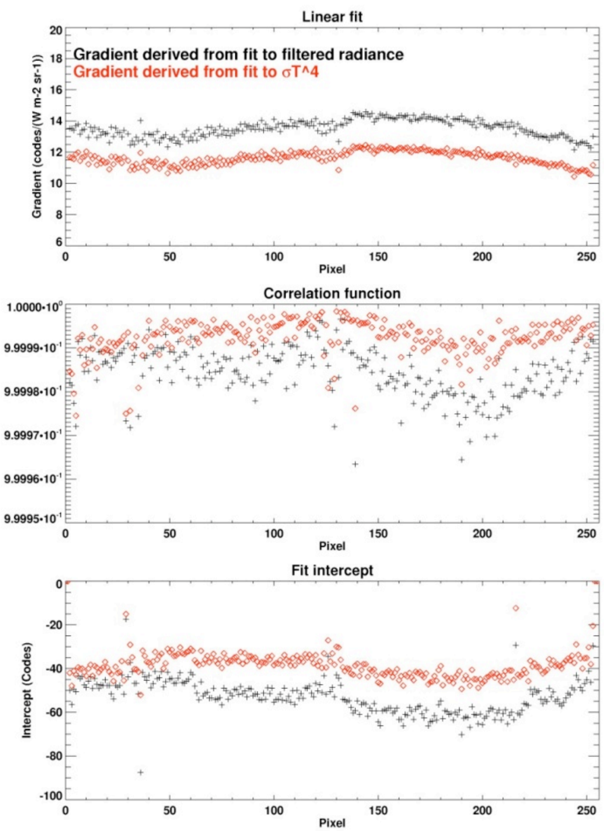
MSG-ICL-GE-RP-0035: GERB-4 Calibration: Internal Blackbody Calibration

Fin



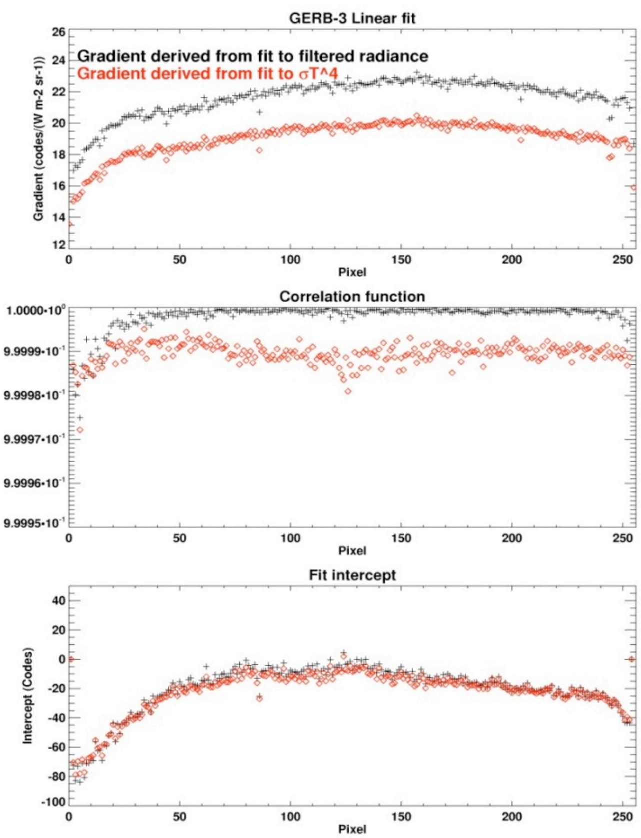
IBB filtered radiance measurements Vs IBB temperature, for selected pixels.

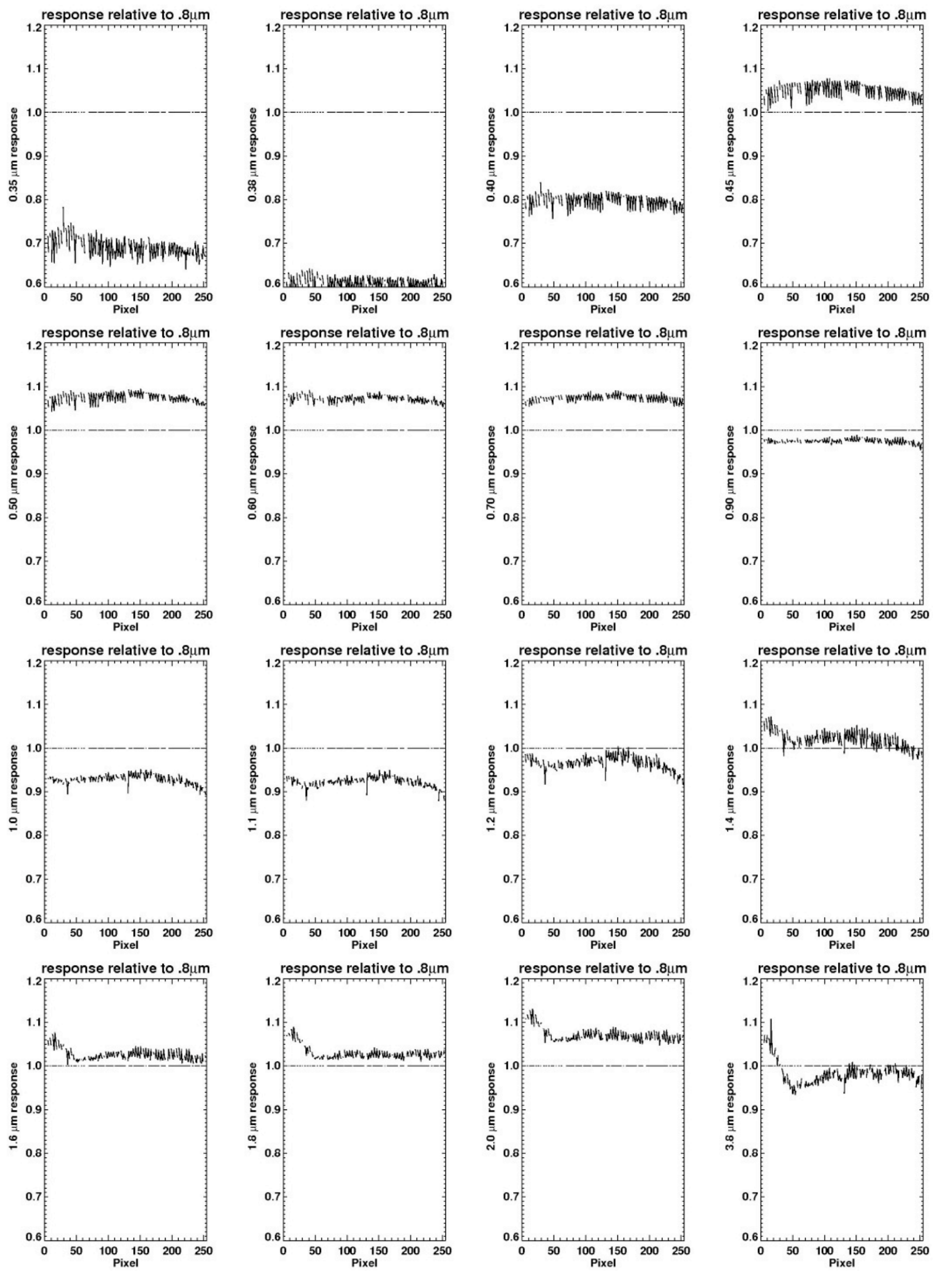
Comparison of fits to σT^4 And filtered radiance



For GERB-4 the filtered radiance
Gives a poorer fit than the power
Law, suggesting that there may be
issues with the spectral response

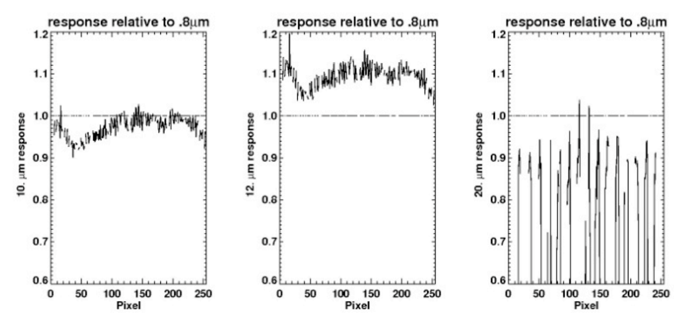
The gains derived from
The slope of the filtered
Radiance fit do not

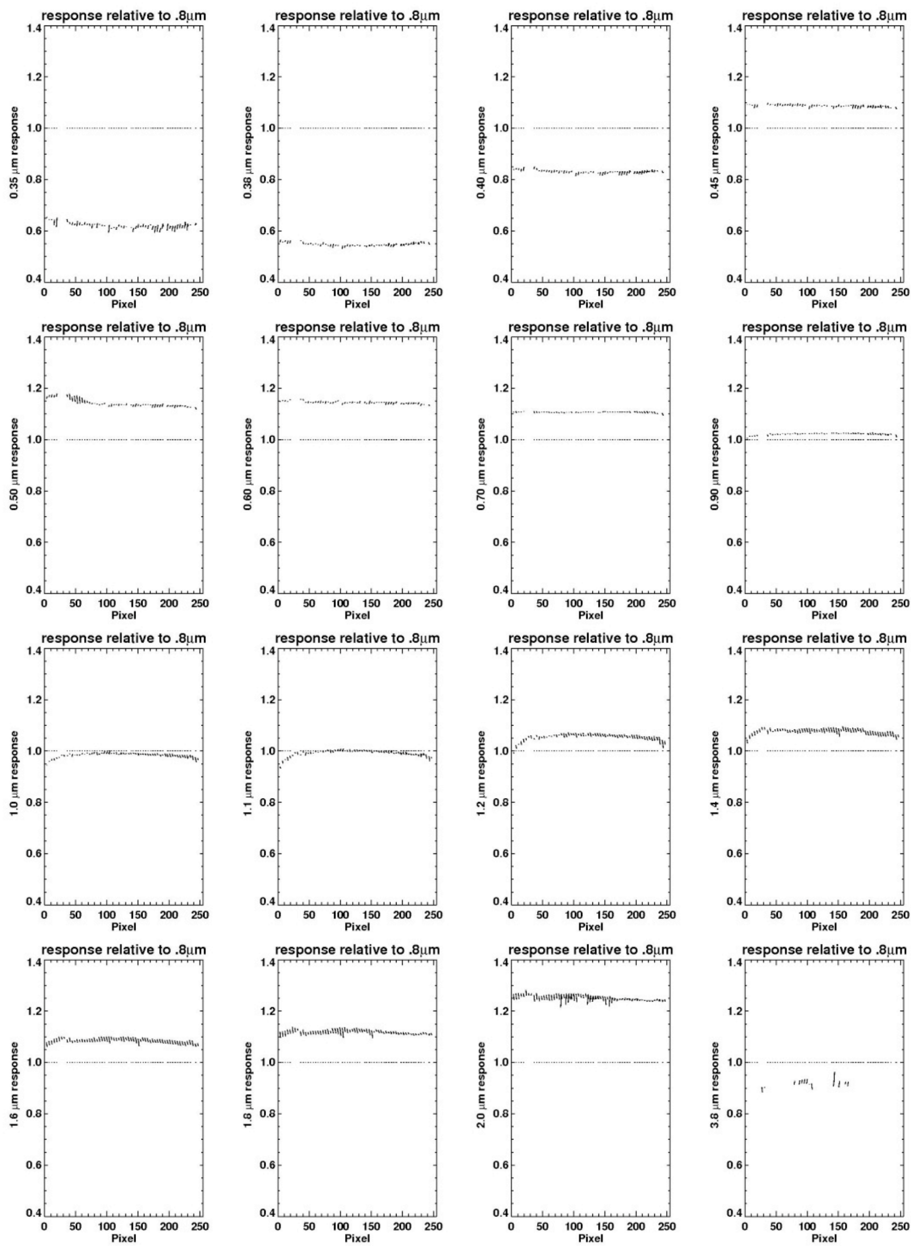




GERB - 4

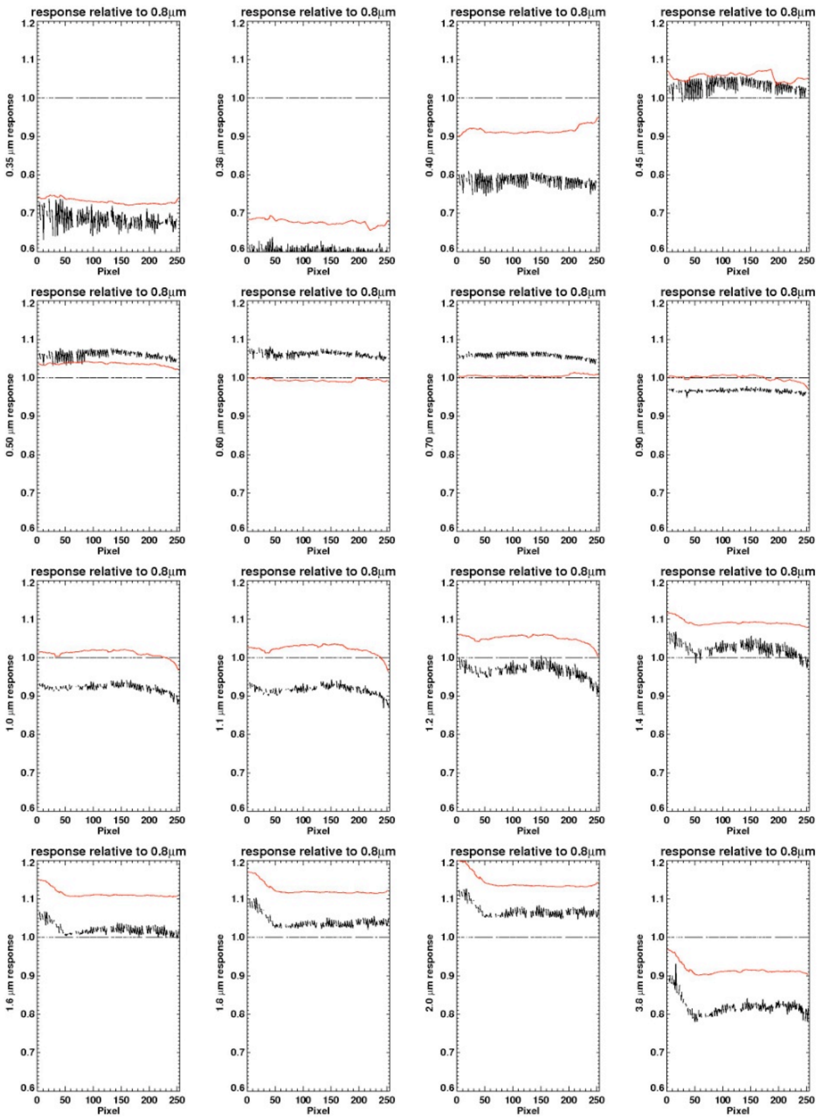
Spectral response relative to 0.8 µm, plotted as a function of pixel





GERB - 3

Spectral response relative to 0.8 µm, plotted as a function of pixel


response relative to 0.8μm
0.35 μm response
0.38 μm response
0.40 μm response
0.45 μm response
0.50 μm response
0.60 μm response
0.70 μm response
0.90 μm response
1.0 μm response
1.1 μm response
1.2 μm response
1.4 μm response
1.6 μm response
1.8 μm response
2.0 μm response
3.8 μm response
Pixel