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LE (CMA) GROUND CALIBRATION SUMMARY REPORT

CONTENTS

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SSD

VERY IMPORTANT NOTE

BEWARE!

The nomenclature used currently at ESOC (also in this document) and that used in the LBT for the two low energy telescopes are not consistent.

ESOC Name	LE1	LE2
LBT Name	LE2	LE1
Experiment #	E1	E2
EDAS Name	L	K
Wall display name	LEIT1	LEIT2
CMA	2R	3
PSD	4R	1R
Grating	1000 l/mm	500 l/mm

BEWARE!

Throughout all this document 8 arcsec pixels are used unless otherwise stated.

Document for which no computer readable source exists any longer

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TABLE OF ABBREVIATIONS

ADC	Analog to Digital Conversion
AT	Acceptance Threshold
ATC	Actual Threshold Channel
CCF	Current Calibration File
CMA	Channel Multiplier Array
EC	Efficiency Correction
FOV	Field of view
FWHM	Full Width Half Maximum
HEW	Half Energy Width (width containing 50% of the counts)
HEW68	" " 68% " ")
HEW90	" " 90% " ")
HT	High Tension
LBT	Long Beam Test
LBTANA	Automatic Analysis Program for LBT data
LE	Low Energy Experiment
LSF	Line Spread Function
X-LSF	LSF along x axis
Y-LSF	" " y "
R-LSF	" " radial axis
T-LSF	" " tangential axis
PET	Position Encoding Threshold
PSF	Point Spread Function
SS	Sum Signal

1. INTRODUCTION

The aim of this document is to describe the information contained in the LE CCFs for what concerns the CMA. The procedures used to derive the values for the CCF, details on the behaviour of the CCF parameters and additional information on parameters not given in the CCF are also supplied.

The knowledge of such information could in fact be of some use when comparing the ground calibration with the in flight ones.

The parts of the LE CCF this document is concerned with are all the "C" data types and the CMA position grid (type A2).

This document is not concerned with the preliminary calibrations of the LE conducted at MSSL and ESTEC (they are described in document SB/81/52/op/ETa by Rod Blissett). The present document refers instead to the four LBTs carried out at the MPI facility in Munich.

The CMA on LE2 (CMA3) was tested during LBT1, 2 and 4; some changes in various settings were made during LBT4 and dealt with in the analysis phase.

The CMA on LE1 during LBT3 was afterwards replaced with CMA2R, which is therefore uncalibrated. Only a limited analysis of LBT3 data was therefore carried out. In the remainder of this document the results given refer to LE2, unless otherwise stated. For the configuration of the LE experiments during and after LBTs, we refer to the document distributed by Piet de Korte, dated 7/12/82 See however the note at the front of the present document.

The analysis of the LBT calibrations is a joint effort of Leiden, Utrecht, MSSL and SSD. Details on how the work was carried out are available in the status and progress reports periodically produced by the various groups. (NB: a systematic collection of all such documents, which does not exist so far, could be of some use in the future). The responsibility of the CMA calibration analysis was divided between Leiden and Utrecht with the participation of LC since July 1982.

The first step of the LBT analysis was an automatic analysis of the Munich Tapes (LBTANA), with the production of five types of files. Types 1 and 2 do not concern the CMA. Type 3 are sum signal histograms, type 4 are bi-dimensional maps (images) and type 5 are summary files containing derived parameters. (Types 4n and 5n are like types 4 and 5, but with the nth version of the linearisation algorithm applied during the analysis).

With a few exceptions noted in the text, all the work done for the CMA CCF made use only of LBTANA output files and not of the LBT raw data.

The software used for handling LBTANA files in ESOC (based on Leiden software and adapted to HP by LC) is described in a write-up kept in file 'SM::LC (on HP3) and is referred to as the SM package.

2.1 CMA Position Grid

This information is contained in data type A2 of the CCF. It is a grid of 61 points chosen to cover the CMA FOV in a uniform way (see Fig 2.1).

The content of the A2 data type is redundant, since the x and y coordinates of the grid points can be calculated by the three parameters (also in the CCF):

(X_0, Y_0) the coordinates of the grid origin

W the grid spacing

The grid origin is the point at the lower left corner of the 9x9 grid of which the 61-point grid is part (ie. point 1 in Fig. 2.1 has coordinates (X_0+W, Y_0+W)).

The grid parameters were chosen to cover the CMA FOV and assume a pixel size equal for both LE1 and LE2. For convenience the pixel size is an integer number of arc seconds. This is the linearised pixel size.

The current pixel size (consistent with the current linearisation software) is 8 arcsec. A change (to be implemented at launch) is due for the pixel size (because of mapping problems during linearisation). The new pixel size will be 4 arcsec. The only change needed for the CCF at that time will be the update of data type A2 (all the other grids remain the same: they still refer to the same points, only the coordinate scale changes).

The values of the grid parameters are given below in Table 2.1. Note that in the CCF all coordinates are in 0.1 pixels.

A subroutine A2CCF (in library LBCCF::LC) is available to generate the full position grid given the values of X_0, Y_0 and W.

The three spare points provided in the CCF outside the 61-point grid are presently still undefined.

Pixel size	8 arcsec*	4 arcsec
X_0	- 460 pixels	- 920 pixels
Y_0	- 460 "	- 920 "
W	115 "	230 "

* = current setting

Table 2.1: Parameters for the CMA position grid

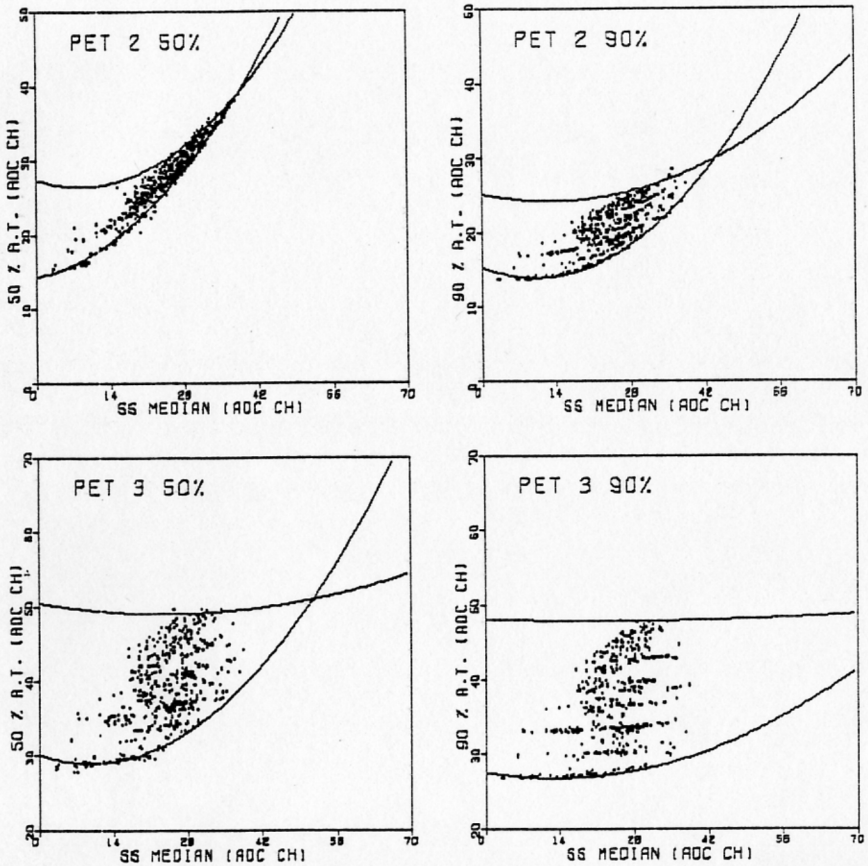

Fig. 2.2.6.1.c

2.3.1 Spatial Resolution: definitions

The spatial resolution analysis made use of LBTANA type 4 files: these are 64x64 or 128x128 maps approximately centered on the LBT source position, with bin sizes appropriate to include the whole extent of the image of the X-ray source.

The Point Spread Function (PSF) as defined here is the result of an integration in ringlets around the centroid of the image. If a cartesian frame (x,y) has its origin in the centroid and if (r, θ) is the corresponding polar frame

$$PSF(r) = \frac{1}{2\pi}\int_0^{2\pi} I(r,\theta)\,d\theta$$

where $I(x,y)=I(r,\theta)$ is the intensity distribution in the image

Since in practice the intensity distribution is a 2d array I_{ij}:

$$PSF_r = \frac{\sum_1^N i \sum_1^N j \; (I_{ij},\; r < r_{ij} < r+\Delta r)}{\sum_1^N i \sum_1^N j \;\; \Delta x\,\Delta y \;\; (r<r_{ij}<r+\Delta r)} = \frac{P_r}{A_r}$$

Operationally this means: for each pixel of the NxN map (which can have a size of $\Delta x \times \Delta y$ true pixels) the distance (r_{ij}) from the centre of the map is computed. The distance will fall into a bin of width Δr, which is incremented by I_{ij}. At the same time also the area of that bin (ie. the number of pixels used in the above sum) is incremented by $\Delta x \quad \Delta y$. At the end the total intensity of every radial bin is normalised to the corresponding area. The value of the PSF in each bin can be attributed to a mean distance $< r >$:

$$< r > = \frac{\sum_1^N i \sum_1^N j \;\; I_{ij}\, r_{ij} \;\; (r < r_{ij} < r+\Delta r)}{\sum_1^N i \sum_1^N j \;\; I_{ij} \;\; (r < r_{ij} < r+\Delta r)} \quad *$$

The errors on the PSF so obtained are:

$$\sigma_{PSF(r)} = \left[\frac{PSF_r}{\sum_1^N i \sum_1^N j \;\; \Delta x\,\Delta y \;\; (r < r_{ij} < r+\Delta r)} \right]^{1/2}$$

*In practice, to weight properly on all map pixels (including the ones with zero content), it is advised to replace $I_{ij}\, r_{ij}$ with $(I_{ij}+1)r_{ij}$.

2.4.1 Hot Spots

This information is contained in data type CG of the CCF.

The relevant analysis was done in ESOC by LC.

In this case the LBT raw data were accessed, since LBTANA does not produce images of the full FOV.

Using a selected list of background runs, images of the full field of view were accumulated and displayed on the Ramtek.

This analysis is not yet terminated, awaiting implementation of linearisation software on HP3.

2.4.2 Miscellaneous

This information is contained in data type CH of the CCF.

At present there is no need to use this space, which is therefore left undefined.

3. CCF Software

The various CCF data types were created into separate disk files by dedicated programs. Those files are then merged into the LE CCF by Glenn Pollard.

The available software comprises: LBT analysis programs, CCF filling programs, programs to display the content of the CCF. Along with the software a number of data files exist: LBT raw data, LBTANA data, work files created by the analysis software, files used as input to the CCF.

About the software we note the following:

No software at all exists in ESOC concerning the CMA efficiency (data type C1).

All the software used for the sum signal analysis (partially mentioned in section 2.2) is available in ESOC and described as the SS Package in a write-up kept in file 'SS::LC (on HP3). The majority of this software will probably be of little use in flight, especially if the SS distribution is radically different from a Pearson distribution. Some routines can however be adapted for future use, as ANALF (computes the median and all other parameters of a SS distribution), THRES (computes the ATC for a SS distribution) and all the count rate dependency package, the 2d-fitting package etc.

The CCF filling routines LC2CF, LCECF, LCFCF could be used to update the CCF if the functional forms built in to describe some dependencies remain unchanged. They require input files containing coefficients. The current input files are:

COEFFS:LC:XX	for data types C2-C5	(LC2CF)
)G277	for data type CE	(LCECF+LCSCA: This data set refers to LBT1-2 data with "old" gain)
COEFn:LC:XX	for data type CF	(LCFCF; use n=1 for nominal CCF).

The following files are also of possible use:

$EOCE:GP:XX	CE data type for "old" gain, LBT1-2	
$EOCF0:GP:XX	CF data type for LE1, PET 0	)
$EOCF2:GP:XX	CF " " " " , PET 2	) currently not used,
$EOCF3:GP:XX	CF " " " " , PET 3	) kept as spare

For future reference all the results of the Pearson fits etc. are kept in the modified summary files.

All the intermediate work files created by the analysis software are also archived on tape.

The software for the PSF/LSF analysis is not implemented in ESOC, but most of it is available on tape. Some pieces of code can be of general use, like all the calculation of PSF and LSF distribution, and the calculation of the parameters (FWHM, HEW etc.) of such distributions.

The two major data sets, ie. the collection of PSF files (all PSF, X-,X-,R-,T-LSFs for all LBT runs) and the summary files with all the derived parameters are kept on tape for future reference.

Raw LBT data and LBTANA data are available in ESOC in a limited amount (ie. not all the data are here). Some software to access them is also available.

The following programs exist to list the content of the CCF (NB. The positiong grids only):

LCLIS to list a number of selected grids in a form suitable to be printed a 132-character line printer. (This program currently accesses only the pre-CCF files which are later merged into the CCF). Sample output is used in Appendix 2.

LCDIS to generate a 32 x 32 Ramtek image (in a disk file), which can contain only the 61-point grid or a derived 32 x 32 grid covering all FOV. (This program can access both the pre-CCF files and the full CCF).

Appendix 1: CMA Ground Calibration Report.

The Pearson Type I Distribution

The standard Pearson type I distribution has the form:

$$y = k \left[1 + \frac{X}{a_1}\right]^{m_1} \left[1 - \frac{X}{a_2}\right]^{m_2} \quad \text{with } \frac{m_1}{a_1} = \frac{m_2}{a_2}$$

Its range is $(-a_1, a_2)$. The peak (or mode which is also the mean) is in the origin $(X = 0)$.

The integral of the Pearson type I distribution can be calculated using the fact that

$$\int_{-a_1}^{x^1} y(x)dx = I_{x_*}(m_1 + 1, m_2 + 1) \qquad \text{where } x_* = \frac{x^1 + a_1}{a_1 + a_2} \quad \text{and}$$

$$I_{x_*}(p,q) = \frac{1}{B(p,q)} B_{x_*}(p,q) = \frac{1}{B(p,q)} \int_0^{x_*} t^{p-1} (1-t)^{q-1} dt$$

$B(p,q)$ is the complete Beta function $B_{x+}(p,q)$ the incomplete Beta function (see Abramowitz and Stegun for details).

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We use a modified Pearson distribution

$$y = K \left[1 + \frac{(X-X_0)}{a_1}\right]^{m_1} \left[1 - \frac{(X-X_0)}{a_2}\right]^{m_2}$$

where K (is the number of counts in the peak of the SS distribution).
- x_0 (is the origin shift and corresponds to the peak channel).
- a_1 (is also related to the peak position and origin shift)
- m_1 (controls the slope of the left part of the curve)
- m_2 (" " " " " right " " " ")

are the five parameters on which the fits were made.

The range of the distribution is (X_0-a_1, a_2+X_0). Note that X_0-a_1 can be less than 0.

The integrals are therefore given by:

$$\int_{x_0-a_1}^{x'} Y(x)dx = I_{x_*}(m_1+1, m_2+1) \text{ where } X_* = \frac{X-X_0+a_1}{a_1+a_2} \quad \text{and}$$

$$\int_a^b y(x)dx = I_{b_*} - I_{a_*}$$

When computing the median we are interested in the median of the distribution above L(0 or X_0-a whichever the greatest).

If $L = X_0-a_1$ the median M is such that

$$\int_{x_0-a_1}^{M} y(x)dx = \frac{1}{2} \int_{x_0-a_1}^{a_2+x_0} y(x)dx \qquad \text{ie. } I_{M_*} = \frac{1}{2} \quad I_{TOT_*}$$

$$\text{where } M_* = \frac{M-X_0+a_1}{a_1+a_2} \qquad TOT_* = \frac{a_2+X_0-X_0+a_1}{a_1+a_2} = 1$$

and since $I_0 = 0$ $\quad I_{TOT_*}(a,b) = I_1(a,b)=1-I_0(b,a)=1$ and $I_{M_*} = \frac{1}{2}$

Since $I_{M_*}(a,b) = 1 - I_{1-M_*}(b,a)$ also $I_{1-M_*}(b,a) = \frac{1}{2}$

Since $B(z,w)=B(w,z)$ we have then $B_{1-M_*}(b,a)=B_{M_*}(a,b)=B_{1-M_*}(a,b)$

which using the definition of B_x implies $1-M_* = M_*$ ie. $M_* = \frac{1}{2}$

From which we get the median $M = X_0 + \frac{a_1}{2} \left(\frac{m_2}{m_1} - 1\right)$

If instead L = 0 the median M is such that

$$\int_0^M y(x)dx = \frac{1}{2} \int_0^{a2+xo} y(x)dx \quad \text{ie. } I_{M_*} - I_{OR_*} = \frac{1}{2} (I_{TOT_*} - I_{OR_*})$$

where $OR_* = \dfrac{a_1 - X_0}{a_1 + a_2}$ which leads to $B_{M_*}(a,b) - \frac{1}{2} B_{OR_*}(a,b) = \frac{1}{2}$ ie.

$$\int_{1-M_*}^{OR_*} t^{a-1} (1-t)^{b-1} \, dt = \frac{1}{2}$$ which can be solved numerically

The efficiency correction for a given ATC T is (see 2.2.4).

If $L = X_a - a_1$ $\quad EC = 1 - I_{T_*}$ $\quad$ with $T_* = \dfrac{T - X_0 + a_1}{a_1 + a_2}$

If $L = 0$ $\quad EC = \dfrac{1 - I_{T_*}}{1 - I_{Z_*}}$ $\quad$ with $Z_* = \dfrac{a_1 - X_0}{a_1 + a_2}$

(NB. if $T_* < 0$ or $T_* < Z$ $\quad EC = 1$)

Since the observed distribution of EC vs SS median looks very regular, even with the large range of values of X_0, a_1, m_1, m_2 present in the data, one can suppose that the EC vs SS median relation is independent on the parameters (X_0, a_1, m_1, m_2).

This is instead NOT the case, as it is proved by some numerical simulations. This means that some hidden relation among the Pearson parameters, although not easily visible, should exist.

Appendix 2: CMA Ground Calibration Report

Sample of the CCF Content

The content of a number of CCF position grids (the whole of them being too voluminous) is presented in the following pages.

For each grid, a description line is added with the following format:

rRhH (PP pp)(PP pp) (PP pp) where

r, h are thee record and half-record of the relevant data type containing thee grid. pp is the value of parameter PP (e.g. energy, sum signal, count rate) to which the grid refers.

The following data is provided:

Data type C1: it is intended to add this as soon as it is available.
- C2: the 1st,2nd,3rd and 5th out of 5 grids.
- C3: as C2.
- C4: the 1st and last of the 5 grids.
- C5: as C4.
- C6: Four grids at different countrates (no energy dependency)
- C7: " " " " " (energy dependency is very mild; see 2.3.2).
- C8: as C7.
- C9: as C7.
- CE: The four grids at zero countrate for the four energies. Moreover Four grids at a fixed energy for 4 selected countrates. All grids appear once for SS median, once for SS HEW.
- CF: Four grids for different some signal medians for acceptance level 50%; the same for 90% level.

NB: All values (grid AND parameters) are in the CCF units (see FOT Handbook).