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RGO/LO Interface Specification

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Introduction

This is an updated summary of previous specifications of input data from RGO to the Lund double star analysis (NDAC/LO/076, 099, 099.1, and 099.2).

Calculation of FOV crossing data

The analysis of IDT data for a given star in a given frame provides an estimate of the parameters β_1 to β_5 defined by the photon count model

$$N_l \sim \beta_1 + \beta_2\left[\cos(p_l + \beta_3) + \beta_4 \cos(2p_l + 2\beta_3) + \beta_5 \sin(2p_l + 2\beta_3)\right] \qquad (1)$$

Here, the reference phases p_l ($l = 1$ to 2560) are defined in such a way that $p = 0$ at frame mid-time ('$l = 1280.5$') and $dp/dt > 0$. The analysis also gives the corresponding information matrix $\mathbf{F}$ ($\mathbf{F}^{-1}$ being the covariance of β). From the OTF calibration we have estimates of what β_4 and β_5 ought to be for a single star; these are denoted $\tilde{\beta}_4$ and $\tilde{\beta}_5$.

The observed β_4 and β_5 values are now 'rectified' so as to correspond to the response of an 'ideal' instrument. The ideal instrument is defined as one yielding $\beta_4 = R$ and $\beta_5 = 0$ for a single star, where R is a predefined value. (R should be chosen close to the actual mean value of β_4.) Rectification is achieved by the transformation:

$$\begin{aligned} \bar{\beta}_4 &= R\,\frac{\tilde{\beta}_4\beta_4 + \tilde{\beta}_5\beta_5}{\tilde{\beta}_4^2 + \tilde{\beta}_5^2} \\ \bar{\beta}_5 &= R\,\frac{\tilde{\beta}_4\beta_5 - \tilde{\beta}_5\beta_4}{\tilde{\beta}_4^2 + \tilde{\beta}_5^2} \end{aligned} \qquad (2)$$

For the calculation of FOV crossing data we also need the (rectified) amplitude and phase of the second harmonic,

$$\beta_2' = \beta_2\sqrt{\bar{\beta}_4^2 + \bar{\beta}_5^2}, \qquad \beta_3' = \beta_3 + \tfrac{1}{2}\mathrm{ATAN2}(-\bar{\beta}_5, \bar{\beta}_4) \qquad (3)$$

The second harmonic phase and (average) amplitude are included because the first harmonic may vanish in some observations (e.g., a binary with $\Delta m = 0$ and projected separation equal to $1/2, 3/2, \ldots$ grid periods). In this case β_3 becomes a random variable and the mean values of β_4 and β_5 (who are defined relative to β_3) become meaningless. The second harmonic usually remains well-defined, and the amplitude and phase obtained through equation (3) are *algebraically* correct as long as $\beta_2 > 0$. Although β_2 may never be strictly zero in practical computation, it may well be that equation (3) is *numerically* unsuitable in some (probably quite rare) cases. *The following alternative method is therefore proposed as a replacement for equation (3),* if permitted by the practical implementation. The β-parameters are in reality determined via the simpler Fourier coefficients b_1 to b_5, defined by the photon count model

$$N_l \sim b_1 + b_2 \cos p_l + b_3 \sin p_l + b_4 \cos 2p_l + b_5 \sin 2p_l \tag{4}$$

The b-coefficients should therefore be available at this processing stage. Obviously only b_4 and b_5 are needed to compute the second harmonic amplitude and phase. First, they are rectified in analogy with equation (2):

$$\begin{aligned} \bar{b}_4 &= R\,\frac{\tilde{\beta}_4 b_4 + \tilde{\beta}_5 b_5}{\tilde{\beta}_4^2 + \tilde{\beta}_5^2} \\ \bar{b}_5 &= R\,\frac{\tilde{\beta}_4 b_5 - \tilde{\beta}_5 b_4}{\tilde{\beta}_4^2 + \tilde{\beta}_5^2} \end{aligned} \tag{5}$$

Then

$$\beta_2' = \sqrt{\bar{b}_4^2 + \bar{b}_5^2}, \qquad \beta_3' = \tfrac{1}{2}\mathtt{ATAN2}(-\bar{b}_5, \bar{b}_4) \tag{6}$$

(This β_3' may differ from equation (3) by $\pm\pi$, but this is of no consequence since it is always $2\beta_3'$ that is used as argument in the trigonometric expressions.)

Now let $k = 1, 2, \ldots, 10$ be the ten successive frames for the transit (FOV crossing) of a given star, and $\mathbf{F}_k$ the corresponding information matrices. The star may be unobserved in some frames; this corresponds to $\mathbf{F}_k = \mathbf{0}$. The total information matrix for the transit is computed as

$$\mathbf{F} = \mathbf{F}_1 + \mathbf{F}_2 + \cdots + \mathbf{F}_{10} \tag{7}$$

and the relative weight of each frame as

$$w_k = [F_{33}]_k / F_{33} \tag{8}$$

The weighted mean values of β_2', β_1, β_2, $\tilde{\beta}_4$ and $\tilde{\beta}_5$ are then:

$$\begin{aligned} \langle \beta_2' \rangle &= \sum_{k=1}^{10} w_k [\beta_2']_k \\ \langle \beta_j \rangle &= \sum_{k=1}^{10} w_k [\beta_j]_k, \qquad j = 1, 2 \\ \langle \tilde{\beta}_j \rangle &= \sum_{k=1}^{10} w_k [\tilde{\beta}_j]_k, \qquad j = 4, 5 \end{aligned} \tag{9}$$

The output per FOV crossing consists of object and timing information; the weight w_k and phases $[\beta_3]_k$, $[\beta_3']_k$ for each of the ten frames; and finally the mean parameters from equation (6) and the total information matrix from equation (4). The value R used in equation (2) is given in the file header record.

The format for the FOV crossing data described below differs from previous specifications mainly on the following points:

- the file label and block header records are defined in accordance with GCID-5;
- the value R is included in the file header record;
- square-root coding is abandoned for $\langle \beta_2' \rangle$, $\langle \beta_1 \rangle$ and $\langle \beta_2 \rangle$; these are instead coded as `INTEGER*4`. The reason for this is that the discretisation error of the previous coding was sometimes comparable to the photon noise.

File format for FOV crossing data

The interface follows the general specifications described in the great-circle reduction programs interface document (GCID–5; Petersen, 10 Nov 1989). The format for the *file label record* is defined in GCID–5, Section 4.4, with

DATAID = 'FOVC'   IDVERS = 4   LRECHD = 32   LREPGR = 0   IXNRGR = 0.

The *block header record* is defined in GCID–5, Section 4.6.

FILE HEADER RECORD FOR FOV CROSSING DATA			
NAME	OFF	LEN	DESCRIPTION
LHEADR	0	4	= 6 Number of words in this header record
FMTBEG	4	4	Observation time of first frame in s since J1988.0
FMTEND	8	4	Observation time of last frame in s since J1988.0
RVALUE	12	4	Value of $R = M_2/M_1$ used for rectification stored as nint($10^6 R$)
IDFOVC	16	4	FOVC file number
NRECBL	20	4	Number of FOVC records in this file

FOV CROSSING DATA RECORD			
NAME	OFF	LEN	DESCRIPTION
IDSTAR	0	4	Star identification number
FMTIME	4	4	Mid-time t of the first frame in the FOVC stored as int(t)
	8	4	Micro-seconds part of the frame mid-time t stored as nint(10^6($t-$int(t)))
WEIGHT(1)	12	2	Weight w_1 of the first frame stored as nint($10^4 w_1$)
BETA3(1)	14	2	First harmonic phase β_3 of the first frame stored as nint($10^4\beta_3/2\pi$)
BETA3P(1)	16	2	Second harmonic phase β_3' of the first frame stored as nint($10^4\beta_3'/2\pi$)
...	...	...	...
WEIGHT(10)	66	2	Weight w_{10} of the 10th frame stored as nint($10^4 w_{10}$)
BETA3(10)	68	2	First harmonic phase β_3 of the 10th frame stored as nint($10^4\beta_3/2\pi$)
BETA3P(10)	70	2	Second harmonic phase β_3' of the 10th frame stored as nint($10^4\beta_3'/2\pi$)
BETA2P	72	4	Mean second harmonic amplitude $\langle\beta_2'\rangle$ stored as nint($10^4\langle\beta_2'\rangle$)
BETA1	76	4	Mean signal parameter $\langle\beta_1\rangle$ stored as nint($10^4\langle\beta_1\rangle$)
BETA2	80	4	Mean signal parameter $\langle\beta_2\rangle$ stored as nint($10^4\langle\beta_2\rangle$)
BETA4	84	2	Mean rectified signal parameter $\langle\tilde\beta_4\rangle$ stored as nint($10^4(1+\langle\tilde\beta_4\rangle\langle\beta_2\rangle/\langle\beta_2'\rangle)$)
BETA5	86	2	Mean rectified signal parameter $\langle\tilde\beta_5\rangle$ stored as nint($10^4(1+\langle\tilde\beta_5\rangle\langle\beta_2\rangle/\langle\beta_2'\rangle)$)
FINF(1,1)	88	4	Matrix element F_{11} stored as nint($10^5\sqrt{F_{11}}$)
FINF(2,2)	92	4	Matrix element F_{22} stored as nint($10^5\sqrt{F_{22}}$)
FINF(3,3)	96	4	Matrix element F_{33} stored as nint($10^4\sqrt{F_{33}}$)
FINF(4,4)	100	4	Matrix element F_{44} stored as nint($10^4\sqrt{F_{44}}$)
FINF(5,5)	104	4	Matrix element F_{55} stored as nint($10^4\sqrt{F_{55}}$)
FINF(1,2)	108	2	F_{12} stored as nint($10^4(1+F_{12}/\sqrt{F_{11}F_{22}})$)
FINF(1,3)	110	2	F_{13} stored as nint($10^4(1+F_{13}/\sqrt{F_{11}F_{33}})$)
FINF(2,3)	112	2	F_{23} stored as nint($10^4(1+F_{23}/\sqrt{F_{22}F_{33}})$)
FINF(1,4)	114	2	F_{14} stored as nint($10^4(1+F_{14}/\sqrt{F_{11}F_{44}})$)
FINF(2,4)	116	2	F_{24} stored as nint($10^4(1+F_{24}/\sqrt{F_{22}F_{44}})$)
FINF(3,4)	118	2	F_{34} stored as nint($10^4(1+F_{34}/\sqrt{F_{33}F_{44}})$)
FINF(1,5)	120	2	F_{15} stored as nint($10^4(1+F_{15}/\sqrt{F_{11}F_{55}})$)
FINF(2,5)	122	2	F_{25} stored as nint($10^4(1+F_{25}/\sqrt{F_{22}F_{55}})$)
FINF(3,5)	124	2	F_{35} stored as nint($10^4(1+F_{35}/\sqrt{F_{33}F_{55}})$)
FINF(4,5)	126	2	F_{45} stored as nint($10^4(1+F_{45}/\sqrt{F_{44}F_{55}})$)

File format for star data

The data type 'STAR' contains the same data as the coordinate file 'COOR', except for the addition of histogram data, a starmapper status word and the position type. In the file header record, the time of the last observation used to update the star catalogue is also added.

The interface follows the general specifications described in the great-circle reduction programs interface document (GCID-5; Petersen, 10 Nov 1989). The format for the *file label record* is defined in GCID-5, Section 4.4, with

`DATAID` = 'STAR' `IDVERS` = 2 `LRECHD` = 18 `LREPGR` = 0 `IXNRGR` = 0.

The *block header record* is defined in GCID-5, Section 4.6.

FILE HEADER RECORD FOR STAR DATA			
NAME	OFF	LEN	DESCRIPTION
LHEADR	0	4	= 4 Number of words in this header record
ICNUMB	4	4	Version number of the star catalogue
ICTYPE	8	4	Type and number of the source catalogue (see GCID-5, Section 6.1)
TLOBS	12	4	Time of the last observation used to update this catalogue (in s since J1988.0)

STAR DATA RECORD			
NAME	OFF	LEN	DESCRIPTION
IDSTAR	0	4	Star identification number
...	...	...	(same as in 'COOR' record)
IFLAGS	47	1	One decimal digit indicating if the star is a variable, or if it is a photometric standard star
NHIST(0)	48	2	Histogram statistics for $\Delta\chi^2$ in bin 0
NHIST(1)	50	2	Histogram statistics for $\Delta\chi^2$ in bin 1
...	...	...	...
NHIST(7)	62	2	Histogram statistics for $\Delta\chi^2$ in bin 7
SMSTAT	64	4	Starmapper status word (see below)
POSTYP	68	4	Position type, i.e., the point in a double or multiple star to which ALPHA, DELTA refer: = 0 for the photocentre or a single star = 1 for the primary (brightest) component = 2 for the secondary component = 3 for the tertiary component, etc = 100 for the geometrical mid-point of a system

The first 12 words in the data record are identical to those in data type 'COOR'. The starmapper status word SMSTAT should give information on the observability of the star on the starmapper and flags derived from such observations. Depending on which rejection criteria are used, it could for instance contain the number of rejected starmapper transits in the first two bytes, and the total number of detected transits in the third and fourth bytes.

The word POSTYP tells us how to interpret the catalogue position for a multiple object. It also makes it possible to have one record for each component of a multiple star, distinguished by POSTYP = 1, 2, ..., even if the components have the same star identification number IDSTAR.