The epoch array shall not contain any *NaN* values, unless referring to the *NaN* padding at the end of the time series. When no measurement is available for a reported epoch, the corresponding array element carries the value *NaN*.

12.6 Variability catalogue

The catalogue of variables is primarily defined by its specific content, e.g. mean magnitude, indicator for flux variability like amplitude or likelihood of variation, variable type, period, phase, etc. The PI is responsible for the exact definition of these parameters, driven by the scientific objective of the programme. Phase 3 requires that these parameters definitions be documented, formally in terms of FITS keywords (TTYPE*i*, TCOMM*i*, TUCD*i,* etc.), and informally in the data release description.

If the catalogue of variables contains a subset of sources published in another Phase 3 source catalogue, then this link should be made explicit using the data link keywords (section 12.3).

Sections 12.4.1 to 12.4.6 apply to the variability catalogue as well.

13. Required, recommended, and optional FITS header keywords per PRODCATG

In order to identify the list of required, recommended, and optional FITS keywords for the characterisation of Phase 3 science data products according to the data product category, please refer to the Table 8 below.

Mandatory keywords consist of the keyword name (a string) and its value. The keyword value is either a string, a number, or a boolean. A number is either a float or an integer.
Whenever the value of a keyword is of type 'string', it cannot be empty (unless specified otherwise, e.g. under certain conditions for REFERENC and TUNIT – see the footnotes to the Table 8). An empty string is defined as a string with zero characters.
For keywords of type 'float' or 'integer', the value shall be within the allowed range as specified in the keyword dictionary (section 5).

Legend:

M	Keyword mandatory.
Meso	Keyword mandatory for ESO files.
Mapp	Keyword mandatory where applicable, refer to the table footnotes for more information.
R	Keyword recommended; it means applicable unless you have a good reason to not use it.
NotAlw	Keyword not allowed: the Phase 3 system will reject the file.
O	It makes sense to provide the value, but it is optional.
N/A	Keyword not applicable, i.e. it is not relevant in the context of the PRODCATG (or it is computed by the Phase 3 system) but it is tolerated, that is it is not checked by our system.

The background of the cell represents the location of the keyword in the FITS file. Example:

M	White background: keyword mandatory in the primary header.
M	Grey background: keyword mandatory in the extension header.

Table 8: Matrix of required, recommended and optional keywords per PRODCATG

	PRODCATG vs SCIENCE.* keyword	IMAGE (single) associated file format	IMAGE (single) MEF format	MEFIMAGE (mosaic) MEF format	IMAGE.FLUXMAP	SPECTRUM	CUBE.IFS	VISIBILITY	SRCTBL	MCATALOG	CATALOGTILE	CATALOG
1	PRODCATG	M	M	M	M	M	M	M	M	M	M	M
2	ASSOCi	Mapp[31]	Mapp[31]	Mapp[31]	Mapp[31]	Mapp[31]	Mapp[31]	Mapp[31]	Mapp[31]	N/A	Mapp[31]	Mapp[31]
3	ASSONi	Mapp[32]	Mapp[32]	Mapp[32]	M[33]	Mapp[32]	M[34]	Mapp[32]	Mapp[32]	N/A	Mapp[32]	Mapp[32]
4	ASSOMi	Mapp[31]	Mapp[31]	Mapp[31]	Mapp[31]	Mapp[31]	Mapp[31]	Mapp[31]	Mapp[31]	N/A	Mapp[31]	Mapp[31]
5	ORIGIN	M	M	M	M	M	M	M	M	M	M	M
6	TELESCOP TELESCi	M	M	M	M	M	M	M	M	M	M	M
7	INSTRUME INSTRi	M	M	M	M	M	M	M	M	M	M	M
8	FILTER FILTERi	M	M	M	M	N/A	N/A	N/A	M	Mapp[35]	Mapp[35]	Mapp[35]
9	OBJECT	M	M	M	M	M	M	M	M	M	M	M
10	RA DEC	M	M	M	M	M	M	M	M	N/A	M	Mapp[36]
11	EQUINOX	Mapp[37]	Mapp[37]	Mapp[37]	Mapp[37]	Mapp[37]	Mapp[37]	Mapp[37]	Mapp[37]	N/A	Mapp[37]	Mapp[37, 36]
12	RADESYS	M	M	M	M	M	M	M	M	N/A	M	Mapp[36]
13	TIMESYS	Mapp[38]	Mapp[38]	Mapp[38]	Mapp[38]	Mapp[38]	Mapp[38]	Mapp[38]	Mapp[38]	Mapp[38]	Mapp[38]	Mapp[38]
14	EXPTIME	M	M	M	M	M	M	M	M	N/A	N/A	N/A
15	TEXPTIME	M	M	M	M	M	M	M	M	N/A	N/A	N/A
16	MJD-OBS	M	M	M	M	M	M	M	M	M	M	M
17	MJD-END	M	M	M	M	M	M	M	M	M	M	M
18	PROG_ID PROGIDi	Meso	Meso	Meso	Meso	Meso	Meso	Meso	Meso	Meso	Meso	Meso
19	OBIDi	Meso	Meso	Meso	Meso	Meso	Meso	Meso	Meso	Meso	Meso	Meso
20	NCOMBINE	Meso	Meso	Meso	Meso	Meso	Meso	Meso	Meso	N/A	N/A	N/A
21	OBSTECH	M	M	M	M	M	M	M	M	Mapp[39]	Mapp[39]	Mapp[39]
22	FLUXCAL	M	M	M	M	M	M	N/A	N/A	N/A	N/A	N/A
23	PROCSOFT	M	M	M	M	M	M	M	M	M	M	M
24	REFERENC	M[40]	M[40]	M[40]	M[40]	M[40]	M[40]	M[40]	M[40]	M[40]	M[40]	M[40]
25	PROVi PROVXTN	Meso	Meso	Meso	Meso	Meso	Meso	Meso	Meso	N/A	Meso	Meso
26	BUNIT	M	M	M	M	NotAlw	M	N/A	N/A	N/A	N/A	N/A
27	GAIN	O	O	O	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
28	DETRON	O	O	O	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
29	EFFRON	O	O	O	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
30	WEIGHT	O	O	O	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
31	CRVALi	M	M	M	M	N/A	M	N/A	N/A	N/A	N/A	N/A

[31] Mandatory for the cases where ancillary files are provided in a non-FITS format.
[32] Mandatory for the cases where ancillary files are provided in association with the scientific data.
[33] The flux map must always be associated with the RMS noise map, or the SNR map, or both.
[34] The IFS 3D cube must always be associated with the white-light image. The white-light image must be delivered using the ASSONi/ASSOCi mechanism.
[35] Applicable to photometric catalogues as well as APEX catalogues.
[36] There can be cases where that keyword does not apply, for instance in the case of target catalogues of spectroscopic surveys, e.g. PESSTO where no appropriate RA/DEC value can be defined to characterise the catalogue as a whole.
[37] If RADESYS='FK5', EQUINOX=2000.0 is mandatory. If RADESYS = 'ICRS', EQUINOX is tolerated and its value needs to be 2000.0.
[38] Must be present if the system used is other than UTC.
[39] Does not apply to catalogues for which no unique value of OBSTECH can be identified.
[40] If a refereed publication is not available at the time of the data release going public, the value can be left to an empty string.

	PRODCATG vs SCIENCE.* keyword	IMAGE (single) associated file format	IMAGE (single) MEF format	MEFIMAGE (mosaic) MEF format	IMAGE.FLUXMAP	SPECTRUM	CUBE.IFS	VISIBILITY	SRCTBL	MCATALOG	CATALOGTILE	CATALOG
32	CRPIXi	M	M	M	M	N/A	M	N/A	N/A	N/A	N/A	N/A
33	CTYPEi	M	M	M	M	N/A	M	N/A	N/A	N/A	N/A	N/A
34	CUNITi	M	M	M	M	N/A	M	N/A	N/A	N/A	N/A	N/A
35	CDi_j	M	M	M	M	NotAlw	M	N/A	N/A	N/A	N/A	N/A
36	CSYERi	R	R	R	R	N/A	R	N/A	N/A	N/A	N/A	N/A
37	CRDERi	R	R	R	R	N/A	R	N/A	N/A	N/A	N/A	N/A
38	PHOTZP	M	M	M	N/A	N/A	N/A	N/A	Mapp[41]	N/A	N/A	N/A
39	PHOTZPER	R	R	R	N/A	N/A	N/A	N/A	R	N/A	N/A	N/A
40	PHOTSYS	M	M	M	N/A	N/A	N/A	N/A	M	M	M	M
41	SPECSYS	N/A	N/A	N/A	N/A	M	M	M	N/A	N/A	N/A	N/A
42	EXT_OBJ	N/A	N/A	N/A	N/A	Mapp[42]	N/A	N/A	N/A	N/A	N/A	N/A
43	CONTNORM	N/A	N/A	N/A	N/A	M	N/A	N/A	N/A	N/A	N/A	N/A
44	TOT_FLUX	N/A	N/A	N/A	N/A	M	N/A	N/A	N/A	N/A	N/A	N/A
45	FLUXERR	N/A	N/A	N/A	M	M[43]	N/A	N/A	N/A	N/A	N/A	N/A
46	WAVELMIN	N/A	N/A	N/A	M	M	M	M	N/A	Mapp[44]	Mapp[44]	Mapp[44]
47	WAVELMAX	N/A	N/A	N/A	M	M	M	M	N/A	Mapp[44]	Mapp[44]	Mapp[44]
48	LAMRMS	N/A	N/A	N/A	N/A	O	N/A	N/A	N/A	N/A	N/A	N/A
49	LAMNLIN	N/A	N/A	N/A	N/A	O	N/A	N/A	N/A	N/A	N/A	N/A
50	SPEC_BIN	N/A	N/A	N/A	N/A	M	NotAlw	N/A	N/A	N/A	N/A	N/A
51	SPEC_ERR	N/A	N/A	N/A	N/A	R	N/A	M	N/A	N/A	N/A	N/A
52	SPEC_SYE	N/A	N/A	N/A	N/A	R	N/A	M	N/A	N/A	N/A	N/A
53	RA_ERR	NotAlw	NotAlw	NotAlw	NotAlw	R	NotAlw	N/A	N/A	N/A	N/A	N/A
54	DEC_ERR	NotAlw	NotAlw	NotAlw	NotAlw	R	NotAlw	N/A	N/A	N/A	N/A	N/A
55	NELEM	N/A	N/A	N/A	N/A	M	N/A	N/A	N/A	N/A	N/A	N/A
56	VOCLASS	N/A	N/A	N/A	N/A	M	N/A	N/A	N/A	N/A	N/A	N/A
57	VOPUB	N/A	N/A	N/A	N/A	M	N/A	N/A	N/A	N/A	N/A	N/A
58	TITLE	N/A	N/A	N/A	N/A	M	N/A	N/A	N/A	N/A	N/A	N/A
59	APERTURE	N/A	N/A	N/A	N/A	M	N/A	N/A	N/A	N/A	N/A	N/A
60	TELAPSE	N/A	N/A	N/A	N/A	M	N/A	N/A	N/A	N/A	N/A	N/A
61	TMID	N/A	N/A	N/A	N/A	M	N/A	N/A	N/A	N/A	N/A	N/A
62	SPEC_VAL	N/A	N/A	N/A	N/A	M	N/A	N/A	N/A	N/A	N/A	N/A
63	SPEC_BW	N/A	N/A	N/A	N/A	M	N/A	N/A	N/A	N/A	N/A	N/A
64	BNOISE	N/A	N/A	N/A	M	N/A	N/A	N/A	N/A	N/A	N/A	Mapp[45]
65	MAPMODE	N/A	N/A	N/A	M	N/A	N/A	N/A	N/A	N/A	N/A	Mapp[45]
66	FEBEi	N/A	N/A	N/A	M	N/A	N/A	N/A	N/A	N/A	N/A	Mapp[45]
67	CONTENT	N/A	N/A	N/A	N/A	N/A	N/A	M	N/A	N/A	N/A	N/A
68	INSMODE	N/A	N/A	N/A	N/A	N/A	N/A	M	N/A	N/A	N/A	N/A
69	BASE_MIN	N/A	N/A	N/A	N/A	N/A	N/A	M	N/A	N/A	N/A	N/A
70	BASE_MAX	N/A	N/A	N/A	N/A	N/A	N/A	M	N/A	N/A	N/A	N/A
71	NUM_CHAN	N/A	N/A	N/A	N/A	N/A	N/A	M	N/A	N/A	N/A	N/A

[41] Mandatory depending on whether fluxes or magnitudes are provided in the source list.
[42] EXT_OBJ is mandatory for externally submitted data products (e.g. spectroscopic public surveys). EXT_OBJ is not applicable to data processed in an unsupervised way, for which the keyword value cannot be assessed and thus the property is not known.
[43] FLUXERR applies to SCIENCE.SPECTRUM with FLUXCAL='ABSOLUTE'. In case of SCIENCE.SPECTRUM with FLUXCAL = 'UNCALIBRATED', the FLUXERR keyword shall be set to -1. The special value -2 is reserved for the case when the flux error cannot be determined.
[44] Applicable to spectroscopic and APEX catalogues. For photometric catalogues, the value is calculated by the Phase 3 system unless the combination (INSTRi, FILTERi) is not unique, in which case please contact Phase 3 operations support staff at https://support.eso.org/ to assess the correct values of the WAVELMIN/MAX keywords, to be added in the headers.
[45] For APEX catalogues only.

	PRODCATG vs SCIENCE.* keyword	IMAGE (single) associated file format	IMAGE (single) MEF format	MEFIMAGE (mosaic) MEF format	IMAGE.FLUXMAP	SPECTRUM	CUBE.IFS	VISIBILITY	SRCTBL	MCATALOG	CATALOGTILE	CATALOG
72	VIS2ERR	N/A	N/A	N/A	N/A	N/A	N/A	M	N/A	N/A	N/A	N/A
73	T3PHIERR	N/A	N/A	N/A	N/A	N/A	N/A	M	N/A	N/A	N/A	N/A
74	STOKES	Please contact Phase 3 operations support staff at https://support.eso.org/ if you intend to submit polarisation data.										
75	HDUCLASS	N/A	M	N/A	N/A	N/A	M	N/A	N/A	N/A	N/A	N/A
76	HDUCLASi	N/A	M	N/A	N/A	N/A	M	N/A	N/A	N/A	N/A	N/A
77	HDUDOC	N/A	M	N/A	N/A	N/A	M	N/A	N/A	N/A	N/A	N/A
78	HDUVERS	N/A	M	N/A	N/A	N/A	M	N/A	N/A	N/A	N/A	N/A
79	SCIDATA	N/A	Mapp[46]	N/A	N/A	N/A	Mapp[46]	N/A	N/A	N/A	N/A	N/A
80	ERRDATA	N/A	Mapp[46]	N/A	N/A	N/A	Mapp[46]	N/A	N/A	N/A	N/A	N/A
81	QUALDATA	N/A	Mapp[46]	N/A	N/A	N/A	Mapp[46]	N/A	N/A	N/A	N/A	N/A
82	CONFDATA	N/A	Mapp[46]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
83	BKGDATA	N/A	Mapp[46]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
84	BKGERR	N/A	Mapp[46]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
85	BKGCONF	N/A	Mapp[46]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
86	ABMAGLIM	M	M	M	NotAlw	N/A	M	N/A	M	Mapp[47]	Mapp[47]	Mapp[47]
87	PIXNOISE	N/A	N/A	N/A	N/A	N/A	M	N/A	N/A	N/A	N/A	N/A
88	MAGLIMi	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Mapp[48]	Mapp[48]	Mapp[48]
89	ABMAGSAT	M	M	M	N/A	N/A	N/A	N/A	M	N/A	N/A	N/A
90	PSF_FWHM	M	M	M	N/A	N/A	N/A	N/A	M	N/A	N/A	N/A
91	ELLIPTIC	M[49]	M[49]	M[49]	N/A	N/A	O	N/A	M[49]	N/A	N/A	N/A
92	SNR	N/A	N/A	N/A	N/A	M	N/A	N/A	N/A	N/A	N/A	N/A
93	SPEC_RES	N/A	N/A	N/A	N/A	M	M	M	N/A	N/A	N/A	N/A
94	SKY_RES	N/A	N/A	N/A	M	N/A	M	N/A	N/A	N/A	N/A	Mapp[45]
95	SKY_RERR	N/A	N/A	N/A	Mapp[50]	N/A	Mapp[50]	N/A	N/A	N/A	N/A	Mapp[50]
96	STREHL	Mapp[51]	Mapp[51]	Mapp[51]	N/A	Mapp[51]	Mapp[51]	N/A	Mapp[51]	N/A	N/A	N/A
97	ARCFILE	Reserved keyword. If present, modified by the Phase 3 system during the archiving process.										
98	CHECKSUM	M M	M M	M M	M M	M M	M M	M M	M M	M M	M M	M
99	DATASUM	M M	M M	M M	M M	M M	M M	M M	M M	M M	M M	M
100	ORIGFILE	Reserved keyword. If present, modified by the Phase 3 system during the archiving process.										
101	P3ORIG	Reserved keyword. If present, modified by the Phase 3 system during the archiving process.										
102	NDIT	Mapp[52]	Mapp[52]	Mapp[52]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
103	NJITTER	Mapp[52]	Mapp[52]	Mapp[52]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
104	NOFFSETS	Mapp[52]	Mapp[52]	Mapp[52]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
105	NUSTEP	Mapp[52]	Mapp[52]	Mapp[52]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
106	FPRAia	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Mapp[53]	M	Mapp[54]

[46] SCIDATA is mandatory for the cases where ancillary extensions are provided in association with the scientific data. ERRDATA / QUALDATA / CONFDATA / BKGDATA / BKGERR / BKGCONF shall be used if the corresponding extension is provided.
[47] For photometric catalogues. And if there is more than one filter, it is not applicable. Use MAGLIMi instead.
[48] For photometric catalogues with more than one filter.
[49] For VIRCAM and OmegaCAM only.
[50] Applicable to the case when SKY_RES is expected to vary within the data collection due to the way it is estimated (see footnote 18).
[51] For AO observations only.
[52] NIR image data products qualify for the keyword if, and only if, all exposures and observations contributing to the given product share the same value for the respective parameter. If, for example, the product has been created from exposures taken with different detector integration time, the keyword DIT should *not* be defined in the FITS header.
[53] Not mandatory in case of complex footprints.
[54] Does not apply to spectroscopic catalogues for which no coverage pattern exists.

	PRODCATG vs SCIENCE.* keyword	IMAGE (single) associated file format	IMAGE (single) MEF format	MEFIMAGE (mosaic) MEF format	IMAGE.FLUXMAP	SPECTRUM	CUBE.IFS	VISIBILITY	SRCTBL	MCATALOG	CATALOGTILE	CATALOG
107	FPDEia	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Mapp[53]	M	Mapp[54]
108	SKYSQDEG	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	M	M	Mapp[54]
109	M_EPOCH	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Mapp[55]	Mapp[55]	Mapp[55]
110	APMATCHD	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Mapp[56]	Mapp[56]	Mapp[56]
111	TXLNKi	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Mapp[57]	Mapp[57,58]	Mapp[57,58]
112	TXRGF	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Mapp[57]	N/A	Mapp[57]
113	TXCTY	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Mapp[57]	N/A	Mapp[57]
114	NOESODAT	Mapp[59]	Mapp[59]	Mapp[59]	Mapp[59]	Mapp[59]	Mapp[59]	Mapp[59]	Mapp[59]	Mapp[59]	Mapp[59]	Mapp[59]
115	TFIELDS	N/A	N/A	N/A	N/A	M	N/A	M	M	M	M	M
116	TTYPEi	N/A	N/A	N/A	N/A	M	N/A	M	M	M	M	M
117	TFORMi	N/A	N/A	N/A	N/A	M	N/A	M	M	M	M	M
118	TCOMMi	N/A	N/A	N/A	N/A	O	N/A	O	O	M	M	M
119	TUNITi	N/A	N/A	N/A	N/A	M[61]	N/A	Mapp[60]	Mapp[60]	M[61]	M[61]	M[61]
120	TUTYPi	N/A	N/A	N/A	N/A	M[62]	N/A	N/A	N/A	N/A	N/A	N/A
121	TUCDi	N/A	N/A	N/A	N/A	M	N/A	O	O	M	M	M
122	TDMINi	N/A	N/A	N/A	N/A	Mapp[63]	N/A	O	O	O	O	O
123	TDMAXi	N/A	N/A	N/A	N/A	Mapp[63]	N/A	O	O	O	O	O
124	TNULLi	N/A	N/A	N/A	N/A	N/A	N/A	O	O	Mapp[64]	Mapp[64]	Mapp[64]
125	EXTNAME	Mapp[65]	Mapp[65]	Mapp[65]	Mapp[65]	Mapp[65]	Mapp[65]	Mapp[65]	Mapp[65]	Mapp[65]	Mapp[65]	Mapp[65]
126	TZEROi									NotAlw	NotAlw	NotAlw
127	TSCALi									NotAlw	NotAlw	NotAlw
128	EXTVER									NotAlw	NotAlw	NotAlw
129	EXTLEVEL									NotAlw	NotAlw	NotAlw

14. Appendix A: Optional ancillary products

Data format PRODCATG = ANCILLARY.*	Description	Usually applied to the following SCIENCE.*
2DSPECTRUM	A 2D spectrum denotes the 2D array with one axis oriented along the dispersion direction (calibrated in wavelength), the other axis being the spatial dimension, normally oriented along the slit. Wavelength calibrated and distortion corrected 2D	SPECTRUM

[55] Applicable to multi-epoch catalogues formatted according to section 12.5.1 only.
[56] For aperture-matched catalogues only.
[57] In case data link is used (see section 12.3).
[58] In case provenance per catalogue record is used (see section 5.2.3).
[59] Applicable to products originating or containing data from a non-ESO facility.
[60] Keyword may be absent for columns representing quantities having no units of measurement, otherwise it must be present.
[61] For quantities having no units of measurement, the value shall be set to an empty string.
[62] In case the UType is not defined in the IVOA document [9] like e.g. for CONTINUUM, the corresponding TUTYPi keyword shall be set to an empty string.
[63] Mandatory for the TTYPE1 array only (start/stop spectral coordinates).
[64] See section 5.18 and section 12.2.6 for applicability.
[65] A specific value is requested in particular cases: 'PHASE3PROVENANCE', 'PHASE3CATALOG', 'PHASE3FILELIST'.