esac

European Space Astronomy Centre
P.O. Box 78
28691 Villanueva de la Ca-ada
Madrid
Spain
T +34 91 8131 100
F +34 91 8131 139
www.esa.int

Solar Orbiter Metis Data Product Description Document

Prepared by	**Roberto Susino**
	INAF - Astrophysical Observatory of Turin
Reference	**Metis-OATO-SPE-021**
Issue/Revision	**2.2**
Date of Issue	**16/11/2022**
Status	**Issued**

APPROVAL

Title Solar Orbiter Metis Data Product Description Document	
Issue Number 2	**Revision Number** 2
Author Roberto Susino	**Date** 16/11/2022
Approved By	**Date of Approval**
Marco Romoli — Digitally signed by MARCO ROMOLI Date: 2022.11.16 17:10:16 CET	16/11/2022

CHANGE LOG

Reason for change	Issue Nr.	Revision Number	Date
First Issue released	1	0	19/06/2019
Updates after new revision of the Metadata Definition for Solar Orbiter Science document (v. 2.4)	1	1	05/09/2019
Changes and corrections after debug of the L0 module of the calibration pipeline	1	2	12/10/2021
Reorganization of document structure	2	0	12/10/2021
Changes and corrections after updates in the processing pipelines required by SOC	2	1	06/10/2022
Minor corrections	2	2	16/11/2022

CHANGE RECORD

Issue Number 2	Revision Number 2		
Reason for change	**Date**	**Page(s)**	**Paragraph(s)**
Removed keyword BLANK from L2 primary headers	16/11/2022	42	4.1.3.1
Fixed wrong date in document footer	16/11/2022	All	N/A

DISTRIBUTION

Name/Organisational Unit	
Daniel Müller	ESA/ESTEC (SCI-SCP) P.O. Box 299 1 (part VI) 2200 AG Noordwijk The Netherlands
Luis Sanchez	ESA/ESAC Camino Bajo del Castillo s/n Urb. Villafranca del Castillo 28692 Villanueva de la Cañada, Madrid Spain
Anik De Groof	ESA/ESAC Camino Bajo del Castillo s/n Urb. Villafranca del Castillo 28692 Villanueva de la Cañada, Madrid Spain
David Williams	ESA/ESAC Camino Bajo del Castillo s/n Urb. Villafranca del Castillo 28692 Villanueva de la Cañada, Madrid Spain
Pedro Osuna Alcalaya	ESA/ESAC Camino Bajo del Castillo s/n Urb. Villafranca del Castillo 28692 Villanueva de la Cañada, Madrid Spain
José Luis Pellón Bailón	ESA/ESOC Robert-Bosch-Str. 5 64293 Darmstadt Germany
Helen Middleton	ESA/ESAC Camino Bajo del Castillo s/n Urb. Villafranca del Castillo 28692 Villanueva de la Cañada, Madrid Spain
Marco Stangalini	ASI – Agenzia Spaziale Italiana Unità Esplorazione e Osservazione dell'Universo Via del Politecnico s.n.c 00133 Roma Italy

Table of contents:

1 INTRODUCTION

1.1 Purpose and Scope

This Data Product Definition Document (DPDD) describes the format and content of the Metis science data. It includes descriptions of the data products and associated metadata, including the data format, content, and generation pipeline. These products will be stored and distributed from the Solar Orbiter Science Archive (SOAR) of the SOC.

The specifications described in this DPDD apply to all Metis science products submitted to ESA's Solar Orbiter SOC for further archival and exploitation. This document only includes descriptions of science products delivered by the Science pipelines run at Altec S.p.A. in Turin (Italy). It does not address the Low-Latency data (see [RD.09]) since it will be described in [RD.05], [RD.06], [RD.07] and [RD.08].

1.2 Applicable Documents

[RD.01] SOL-SGS-TN-0009 Metadata Definition for Solar Orbiter Science
[RD.02] SOL-SGS-ICD-002 Data Producer to Archive ICD (DPAICD)
[RD.03] Metis-ATI-MA-001 Metis Instrument User Manual
[RD.04] Metis-OATO-RPT-017 Metis Ground Calibration Report

1.3 Reference Documents

[RD.05] SOL-SGS-ICD-0004 Solar Orbiter Interface Control Document for Low Latency CDF Files
[RD.06] SOL-SGS-OTH-0002 Dataset Description Document Template for Low Latency CDF Files
[RD.07] SOL-SGS-ICD-0005 Solar Orbiter Interface Control Document for Low Latency FITS Files
[RD.08] SOL-SGS-OTH-0003 Dataset Description Document Template for Low Latency FITS Files
[RD.09] SOL-SGS-TN-0003 Solar Orbiter Low Latency Data: Concept and Implementation
[RD.10] SOL-SGS-PL-0009 Solar Orbiter Archive Plan
[RD.11] SOL-SGS-TN-0017 SOC-Provided Ancillary Data for Solar Orbiter
[RD.12] Metis-OATO-TNO-012 METIS On Board Data Processing Description
[RD.13] Metis-OACT-SPR Scientific Performance Report

1.4 Abbreviations and Acronyms

CCSDS Consultative Committee for Space Data Systems
CR Cosmic Rays
DIT Detector Integration Time
EDDS EGOS Data Dissemination System
FITS Flexible Image Transport System
FS Field Stop
FOV Field Of View
HDU Header Data Unit
HK House Keeping
IDB Instrument Database
IO Internal Occulter
LCVR Liquid-Crystal Variable Retarders
OBSW On Board Software
PCU Photon-Counting Unit

SEP	Solar Energetic Particles
SOAR	Solar Orbiter Archive
SOC	Science Operation Centre
TBC	To Be Confirmed
TBD	To Be Defined
TBW	To Be Written
UV	Ultraviolet
UVD	Ultraviolet Detector
VL	Visible Light
VLD	Visible Light Detector
WCS	World Coordinate System

2 METIS INSTRUMENT DESCRIPTION

Metis is the first solar coronagraph designed for a space mission capable of performing simultaneous imaging of the off-limb solar corona in the visible (broad-band 580-640 nm) and ultraviolet (narrow-band 121.6±10 nm around the H I Lyman-α line) light. Metis is an externally occulted coronagraph, based on an innovative "inverse occultation" optical design, achieved by combining the characteristics of classical Lyot coronagraphs in visible light with those of ultraviolet all-reflective coronagraphs.

The Metis field of view (FOV) is an annulus extending from 1.6° to 2.9° at the edges of the images and up to 3.4° toward the sensor corners. Therefore, Metis can image the solar corona from ~ 1.7 to 3.6 solar radii when Solar Orbiter is at the minimum distance of 0.28 AU (astronomical units) from the Sun, and from ~ 4.2 to 9.0 solar radii when the spacecraft is at 0.7 AU from the Sun.

The Metis telescope consists of the external occultation system, the optical unit, the polarimeter, the visible-light detector (VLD), and the ultraviolet detector (UVD). The polarimeter is equipped with liquid-crystal variable retarders (LCVR) and allows for measurements of the linearly polarized emission of the visible-light corona through the acquisition of images at different polarization angles.

The VLD is a custom-made CMOS-APS sensor with 2048×2048 pixel^2 of 10-μm size, corresponding to a nominal plate scale of ~ 10 arcsec/pixel. The UVD consists of an intensified APS sensor with 1024×1024 pixel^2 of 30-μm equivalent size and a nominal plate scale of 20 arcsec/pixel. It can operate either in analogue or photon-counting mode (PCU), generating, respectively, standard images or lists of detected Lyman-α photons (PCU events).

The on-board data processing pipeline of Metis is capable of executing auxiliary operations, like, e.g., frame averages and statistics (temporal standard deviation), cosmic-ray (CR) and solar-energetic-particle (SEP) removal, light curve computation, image radialization, detector binning and masking, and data compression (see [RD.12] for more details).

Metis can generate different types of scientific data products:

- primary scientific data objects:
  - VL and UV images,
  - PCU events lists,
  - PCU events accumulation matrices and vectors,
- secondary scientific data objects:
  - VL and UV temporal standard-deviation matrices,
  - VL and UV cosmic-ray log matrices,
  - VL light curves,
  - PCU test events lists,
- calibration data objects:
  - PCU offset maps.

They are grouped into three categories: primary data objects, i.e., data generated for science purposes; secondary data objects, i.e., data generated for instrument diagnostics and/or science purposes, as by-products of primary data objects; calibration data objects, i.e., data that may be necessary for the calibration process. They will be described in more detail in Section 3.1.

2.1 Science Objectives

The Metis instrument versatility combined with the characteristics of the Solar Orbiter mission, addresses all the four key scientific questions of Solar Orbiter as summarized in Table 1, by providing unique contributions in investigating the following scientific issues:

- energy deposition and outflows in the expanding corona,
- role of magnetic field lines in channelling the coronal wind,
- coronal fluctuations and their role in the solar wind acceleration,
- coronal mass ejection onset and early propagation,
- eruption of prominences and their propagation in the corona,
- global evolution of the streamer belt,
- acceleration of the solar energetic particles.

Table 1. Key scientific questions of the Solar Orbiter mission addressed by Metis.

Solar Orbiter Top-level Questions	Metis Contribution
What drives the solar wind and where does the coronal magnetic field originate?	Investigation of the region where the solar wind is accelerated to near its asymptotic value
How do solar transients drive heliospheric variability?	Investigation of the region where the first, most dramatic phase of the propagation of coronal mass ejections occurs
How do solar eruptions produce energetic particle radiation that fills the heliosphere?	Identification of the path of shock fronts accelerating particles in the solar corona
How does the solar dynamo work and drive connections between the Sun and the heliosphere?	Study of the overall magnetic configuration by identifying the closed and open magnetic field regions in the corona

2.2 Operational Modes

Metis has six main software operational modes (see [RD.03]) assigned to different tasks (troubleshooting, memory patch, etc.), but the only one able to produce scientific data is the so-called OPS (operational) mode. When in OPS, the instrument is configured to properly start a set of acquisitions belonging to a so-called observation session.

To accomplish the scientific investigations mentioned in Section 2.1, Metis acquisitions will be planned according to different instrument observing studies. Table 2 lists all the possible Metis observing modes, with references to the different type of data products that are generated, typical observation cadences, and expected data volumes. A more complete description of the Metis observing modes can be found in [RD.13].

Table 2. Characteristic of the Metis observing modes.

Mode	Description	Data Products	Typical Cadence	Data Volume [(1)]
WIND	Investigation on the solar wind	4 VL polarized images 1 VL cosmic-ray matrix 1 VL light curve 1 UV image [(2)] 1 UV cosmic-ray matrix	5-30 min	16.14 Mb
MAGTOP	Investigation on the coronal magnetic topology	4 VL polarized images 1 VL cosmic-ray matrix 1 VL light curve 1 UV image [(2)] 1 UV cosmic-ray matrix	5-20 min	26.67 Mb
GLOBAL	Study of the global corona	4 VL polarized images 1 VL cosmic-ray matrix 1 VL light curve 1 UV image [(2)] 1 UV cosmic-ray matrix	5-30 min	Up to 13.73 Mb
LT-CONFIG	Study of the long-term coronal evolution	4 VL polarized images 1 VL cosmic-ray matrix 1 VL light curve 1 UV image [(2)] 1 UV cosmic-ray matrix	20-30 min	5.70 Mb
FLUCTS	Coronal brightness fluctuations	Sequence of VL polarized images	1 s	5.34 Mb
TBF	Coronal brightness fluctuations	Sequence of VL total-brightness images	20 s	5.34 Mb
CMEOBS	Coronal mass ejection observations	4 VL polarized images 1 VL cosmic-ray matrix 1 VL light curve 1 UV image [(2)] 1 UV cosmic-ray matrix	1-5 min	26.67 Mb
COMET	Comet observations	4 VL polarized images 1 VL cosmic-ray matrix 1 VL light curve 1 UV image [(2)] 1 UV cosmic-ray matrix	5-20 min	26.67 Mb
PROBE	Parker Solar Probe joint science	4 VL polarized images 1 VL cosmic-ray matrix 1 VL light curve 1 UV image [(2)] 1 UV cosmic-ray matrix	5-30 min	22.69 Mb

Notes. [(1)] Data volume, comprehensive of detector masking, binning, and compression, for a full set of 4 VL images and 1 UV image. In the case of the FLUCTS and TBF modes, data volume of 1 VL image only. [(2)] Depending on the actual photon count rate, UV images may be replaced by PCU event lists or PCU accumulation matrices, as described in Section 4.

2.3 Calibration

2.3.1 On-ground Calibration

On-ground calibration performed on the instrument, and the relevant results, are described in [RD.04].

2.3.2 In-flight Calibration

In-flight calibration consists of the following operations:

1. adjustment of IO and recentring of the vignetting function,
2. routine acquisition of bias (VL channel) and dark (UV channel) images,
3. radiometric calibration with measurement of calibration star fluxes (both channels),
4. adjustment of boresight parameters with measurement of star positions.

3 DATA GENERATION AND ANALYSIS PROCESS

The Metis science data products are produced by the Metis Instrument Team. The data generation and analysis process are described in this section. The Metis instrument uses the FITS format for its science data products. The format and record structure of each of the science data file types will be described in Sect. 4.

Science data received by the SOC from the Metis team are made available to end users through the Solar Orbiter archive (SOAR) following the policies described in the Archiving Plan [RD.10]. The Metis team will release data in the level-2 (L2) and 3 (L3; later in the mission) of calibration, i.e., calibrated in physical units and ready for scientific analysis; level-0 (L0) and level-1 (L1) data will be not delivered to the SOC initially, but they will be distributed to the scientific community upon request.

3.1 Scientific Measurements

Metis observations consist of images of the coronal emission obtained simultaneously both in the VL (polarized or total brightness) and in the UV H I Lyman-α. Observations will be obtained at high temporal resolution (down to 1 s) and spatial scale (down to about 2000 km in visible light). Different spatial resolutions (through different detector binning) and exposure times will be used depending on the requirements of the specific science goal, corresponding to the specific instrument observing modes listed in Table 2.

As mentioned in Section 2, Metis can generate different data products, for both scientific and instrument diagnostics purposes. They are briefly described in the following sections: more details can be found in [RD.03].

3.1.1 VL Images

The VL detector acquires and delivers frames at constant rate and detector integration time (DIT). For a standard polarized-brightness sequence, each frame is acquired at a different known polarization angle set by the configuration parameters and the number of polarization angles (N_POL) can be chosen to be 3 or 4. For a total-brightness acquisition, each frame is acquired switching the polarization angle (i.e., rotating it by 90°) exactly in the middle of the detector integration time. In both cases, each frame can be corrected by removing cosmic rays and SEP, and several frames given by the NDIT parameter are averaged to increase the signal-to-noise ratio. For a fixed-polarization acquisition, all frames are acquired by keeping the polarization angle at the same fixed value; in this case, neither CR/SEP correction nor frame average can be performed. Finally, the images are compressed (in case, they are radialized, masked, and/or binned) and delivered. This acquisition can be repeated to produce one image at a regular temporal cadence.

3.1.1.1 Stokes Parameters and Polarized Brightness

The sequence of 3 or 4 images acquired at different polarization angles can be combined via demodulation to provide three images of the Stokes parameters I, Q, and U, related to the linear polarization of the coronal visible light. These images are used to calculate the total (B) and polarized (pB) brightness, and the polarization angle (θ), of the visible-light emission of the solar corona, according to the following relationships:

$$B = I, \qquad pB = \sqrt{Q^2 + U^2}, \qquad \text{and} \qquad \theta = \frac{1}{2}\,\text{arctg}\left(\frac{U}{Q}\right).$$

3.1.2 VL Light Curves

The VL channel can also provide a temporal series of 8 mean brightness values computed by averaging the counts detected over 8 sectors defined within the Metis FOV (they are shown in Figure 1). The inner and outer radii defining the sectors can be set using proper configuration parameters. Each light curve is a by-product of a polarized-brightness acquisition obtained with N_POL set equal to 4. During each detector integration, only two of the 8 sectors are considered, depending on the polarization used for the integration, and their mean brightness is computed. A single entry in a light curve is then generated for every set of 4 consecutive polarization acquisitions; in the end, a complete light curve will have

8×NDIT entries. By default, Metis delivers the light curves as low-latency data products (see [RD.09]).

Figure 1. Metis field of view with, highlighted, the 8 sectors used to compute the VL light curves.

3.1.3 UV Images

The UV detector acquires and delivers frames at constant rate and DIT. The frames are averaged in a two-step process: the first is performed in hardware and the second by the software; the number of frames averaged in the two steps are given, respectively, by the NDIT1 and NDIT2 parameters. Between the two average processes, CR/SEP correction can be applied. Eventually, the resulting image is compressed (in case, it is radialized, masked, and/or binned) and delivered. This acquisition can be repeated to produce one image at a regular temporal cadence.

3.1.4 PCU Events Lists

The PCU mode will be used when the rate of the incoming Lyman-α photons will be very low, or in case of a detector reduced efficiency late in the mission. The PCU events lists are generated if the photon count rate is below a parameterized threshold. In this case, the unit will determine the centroid coordinates of the identified events on the sensor and will subsequently deliver a packet containing coordinates pairs and collected photo-charge information.

3.1.5 PCU Accumulation Matrices

These data products are generated by the PCU when the count rate is higher than the parameterized threshold. In this case, the PCU will not generate a list of events, but it will collect those data in a 1024-by-1024-pixel matrix, analogous to a standard UV image. The processing flow for accumulation matrices is the same as that of UV images.

3.1.6 Temporal Standard-deviation Matrices

The detector (either VL or UV) acquires a given number (NDIT) of frames with a given value of the DIT and the on-board processing unit computes the mean and standard deviation of this sequence in each sensor pixel. For the VL, all frames are acquired by keeping the polarization angle at the same fixed value set by the operator via configuration parameters. The purpose of this acquisition is to periodically monitor the detector performance. Eventually, the two images, one with the mean and the other with the standard deviations, are compressed (in case, they are radialized and/or binned) and delivered.

3.1.7 Cosmic-ray and SEP Log Matrices

These data products are generated by the CR/SEP correction algorithm (see [RD.12] for details). They consist in differences between the corrected and the uncorrected images, thus providing information on the location of the pixels affected by CR/SEP hits and the magnitude of the correction applied.

3.2 Data Flow Overview

After the requested telemetry packets are delivered through the EDDS (EGOS Data Dissemination System), they are processed in different ways depending on their type. Housekeeping (HK) telemetry packets are directly converted from SCOS-2000 packets to RAPID files and injected into the local mission database, populating the SCOS archives. This operation is performed via interface with the instrument database (IDB).

The scientific telemetry packets are then processed through a telemetry-to-raw pipeline, that collects all packets belonging to the same data product, checks the completeness of the data product, i.e., if there are missing packets, decodes the packet header (SCOS-2000 and CCSDS), assembles the segment data in each packet, and performs the decompression of the assembled data product (see below).

The decompressed data product is then processed through the scientific pipelines (L0, L1, and L2), that generate the corresponding data FITS files (see Sect. 4) and deliver them to the local mission database. The scientific pipelines perform the scientific calibration of the data, interfacing with an internal calibration database, where calibration and ancillary data are stored, and the local mission database.

The L0, L1, and L2 FITS files are finally transferred to the Solar Orbiter Science Operation Centre (SOC) via GFTS, to be archived into the SOAR.

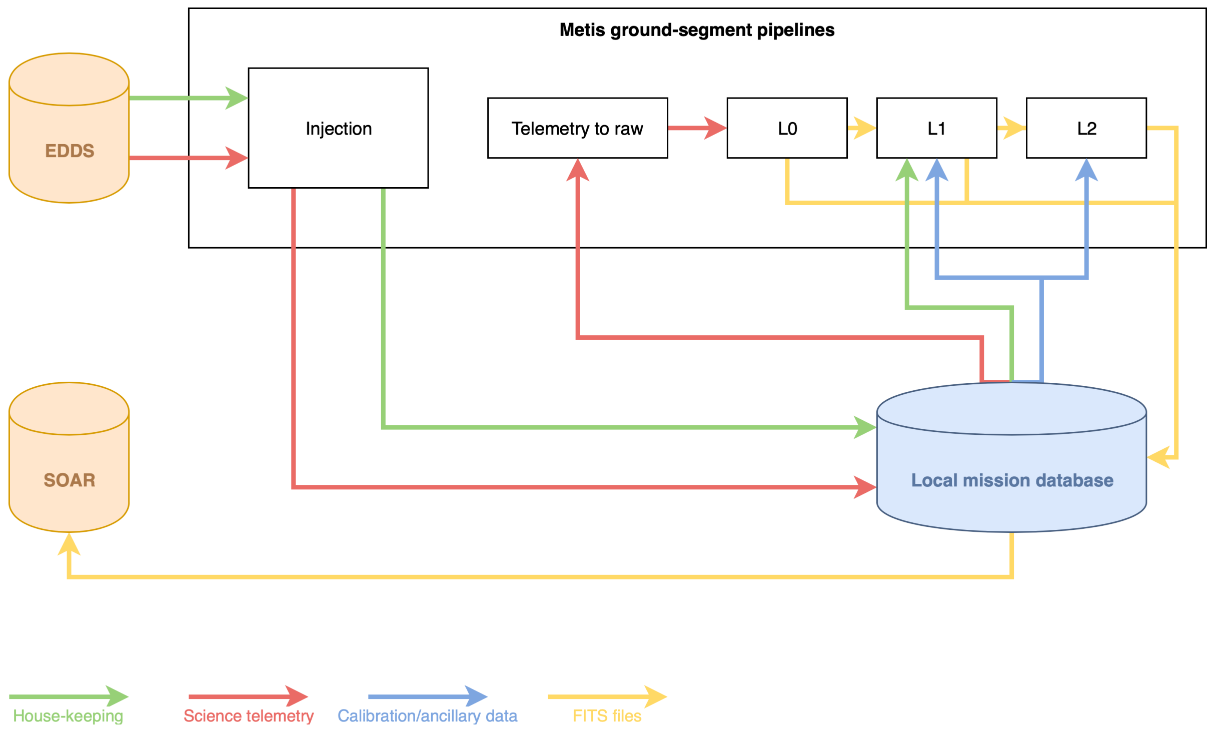

Figure 2. Top-level diagram showing the Metis data product management and processing flow.

3.3 Data Generation

The following sections describe the process used to produce the data products that will be described in detail in Section 4.

3.3.1 L0 - Raw Data

The scientific telemetry packets are grouped to generate the raw data stream. During this operation, a check on the completeness of the data stream is performed. If necessary (i.e., if compression was set during the acquisition), the raw data stream is processed through the decompression algorithm to obtain the uncompressed data. The decompression algorithm also performs a de-radialization of the images (i.e., a transformation from polar to rectangular coordinates) if the radialization was enabled during the acquisition (see [RD.03] for more details on the compression and radialization). Note that the resulting uncompressed images have the nominal detector size of 1024×1024 pixel (for UV data products) and 2048×2048 pixel (for VL data products) even if data were binned by Metis on-board software during their acquisition.

The L0 FITS file is created according to the structure described in Sect. 4.1.1, taking the necessary information from the CCSDS header of the first science telemetry packet, and from the scientific header generated by Metis OBSW during the acquisition and the compression header generated by the compression algorithm implemented in Metis OBSW, both stored at the beginning of the first telemetry packet.

3.3.2 L1 - Engineering Data

Level-1 data are still uncalibrated data (in units of DN). They differ from L0 data because the following operations are performed on the data:

1. images are re-binned to consider the binning commanded during the data acquisition (for instance, VL images that were acquired with a 2×2 binning are re-binned to have the correct size of 1024×1024 pixel),
2. pixel counts are multiplied for the total binning factor (4 for a 2×2 binning or 16 for a 4×4 binning) to consider the fact that Metis OBSW performs the binning operation by averaging (and not summing) the counts in the binned pixels,
3. pixel counts are multiplied for the total number of averaged frames (given by the NDIT parameter for VL data products or by NDIT1×NDIT2 for UV data products) to retrieve the total counts accumulated in each pixel during the full exposure time.

The FITS header also contains all the available orbital and attitude information, and image coordinates are given using the scientific World Coordinate Systems (WCS).

In addition, L1 FITS files include a binary-table extension with a subset of housekeeping (HK) telemetry parameters generated by the instrument and by the spacecraft immediately before and after the scientific acquisition, both raw and in calibrated in physical units, that is useful to perform the processing of the data from Level 1 to Level 2.

The structure of the L1 FITS files is described in Sect. 4.1.2.

3.3.3 *L2 - Science Data*

Level-2 data are calibrated in physical units. Calibration from L1 to L2 includes the following steps:

1. dark-current and bias subtraction,
2. flat-field correction,
3. vignetting correction,
4. radiometric calibration, which includes in turn:
    a. exposure normalisation,
    b. detector efficiency correction,
    c. instrument aperture and pixel solid angle normalisations.

These operations are performed by using the instrument parameters derived from the instrument and spacecraft HK telemetry (e.g., detector temperatures, LCVR voltages, etc.), calibration data (e.g., dark/bias, flat-field images, etc.) obtained during either on-ground or in-flight calibration campaigns, and ancillary files provided by the SOC (e.g., SPICE kernel files; see [RD.11]).

The 3 or 4 images belonging to each polarized-brightness sequence (see Sect. 3.1.1) are processed together applying the Müller demodulation matrix to obtain three images of the Stokes parameters (I, Q, and U) and these are combined, in turn, to obtain the total-brightness (tB), polarized-brightness (pB), and polarization-angle (θ) images (see Sect. 3.1.1.1).

The structure of the L2 FITS files is described in Sect. 4.1.2.3.

3.3.3.1 Known Issues in Data Calibration

A few issues affect the calibration of Metis L2 data.

UVD Anomalies

The UV camera is affected by some anomalies that temporarily alter the instrument radiometric response. For instance, brightenings over the entire or large parts of the detector, lasting from minutes to hours, can be sometimes detected. These anomalies are under active investigation and are not corrected yet in the radiometric calibration.

Optical Misalignments

The optical path of the two instrument channels is not aligned with the corresponding detector centre, therefore the centre of the occulted area generated by Metis IO is not localized at the image centre. This causes a misalignment between the occulted area and the masked area when masking is applied on board during data acquisition, since masking is performed on the detector with respect to its centre (see, e.g., the left panel in Figure 3).
The internal and external radii for masking are chosen so as not to eliminate areas of the FOV in which the data are reliable and can be used for scientific analysis.

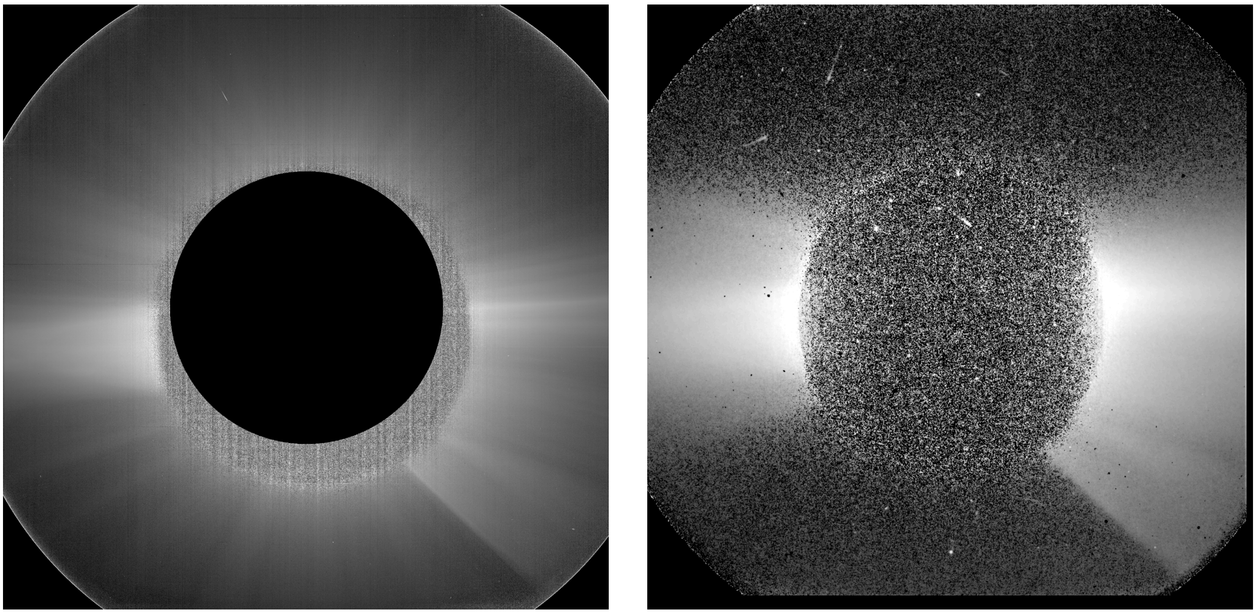

Figure 3. Example Metis L2 images: VL polarized-brightness image with masking applied on board (left) and unmasked UV image (right).

Vignetting Function

The instrument vignetting was measured during the on-ground calibration campaign for the VL channel and has been synthetically adapted to the in-flight occulting configuration that has changed due to launch activity with subsequent IO realignment.
After correction, deviations from the true vignetting function are most evident in the inner FOV, and artifacts also appear at the outer FOV in the form of thin bright arcs at the four image corners (see, e.g., Figure 3, left panel).
Due to the relative misalignment between the VL and UV channels, the vignetting-function matrix must be recentred to be applied to UV data; therefore, two portions at the bottom (South) and right (West) edges of UV images cannot be corrected. These areas are left blank in calibrated images (see Figure 3, right panel).

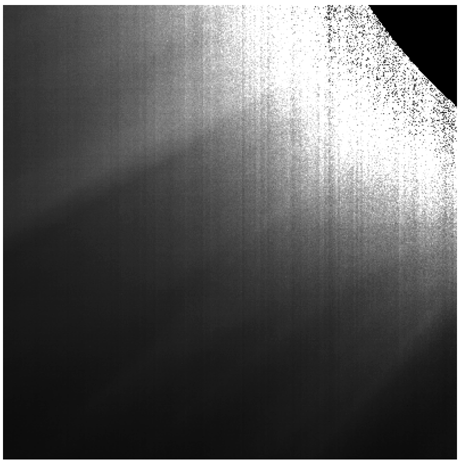

Figure 4. Detail of a Metis VL image showing the characteristic effect of the fixed-pattern noise.

Fixed-pattern Noise

The VL images are affected by a fixed-pattern noise that is due to the detector electronics and appears in L2 data as a variable column pattern (see Figure 4). The present calibration does not correct yet for this source of noise.

Stray-light

Both VL and UV data are not yet corrected for instrument stray light that may affect the images. Stray-light contamination is expected to be larger close to the inner occulted area.

3.3.4 L3 - Higher-level Data

The generation of Metis Level-3 data products is foreseen later in the mission. They will consist of:

- coronal electron-density maps derived from polarized-brightness data,
- coronal outflow velocity maps derived from Doppler-dimming inversion of polarized-brightness and UV data,
- images (in JPEG or PNG format [TBD]) and movies.

3.4 Validation

The following sections describe the process by which the data products are validated.

3.4.1 Instrument Team Validation

The validation and verification of Metis data products is performed by the instrument team after reception and processing of the scientific telemetry. It consists of these main steps:

1. check for telemetry, telecommand, and data errors, discrepancies, and anomalies, such as missing or corrupted telemetry packets, rejected telecommands, discrepancies between planned and used instrument configurations,
2. check of generated data volume and discrepancies with respect to planning,
3. verification of Metis external-door status and spacecraft off-pointing or rolls,
4. verification of image features and possible corruptions through inspection,
5. check of secondary data product (e.g., light curves; only for investigations),
6. check of housekeeping telemetry and image statistics (only for investigations).

3.4.2 SOC Validation

The SOC will check the data types that the Metis team intends to archive. The SOC might also perform spot checks on contents of the files. The exact procedure in which this routine check will take place is still [TBD].

4 DATA PRODUCT DESCRIPTIONS

4.1 Primary Products Formats

Metis science data products are formatted using the FITS standard, in accordance with [RD.01]. This section describes the format and structure for each of the data processing levels and types.

4.1.1 L0 - Raw Data Products

Level-0 data products are organized in FITS files with multiple extensions. The primary HDU (Header Data Unit) contains the primary header that is common to all data types and conforms to the Solar Orbiter standard defined in [RD.01].

The structure of the FITS files is the following:

1. primary HDU: primary header; data only for image data products, i.e., VL and UV images, temporal standard-deviation matrices, CR log matrices, and PCU accumulation matrices,
2. binary-table data extension: only for light curves and PCU event lists [TBD],
3. metadata extension: scientific and compression (if applicable) headers,
4. radialization extension: radialized image (if applicable).

The FITS files follow the filename convention described in [RD.01] with the descriptors listed in APPENDIX B - Data products matrix:

```
solo_L0_[descriptor]_[date/time]_V[version].fits
```

4.1.1.1 Primary Header and Data Unit

Data saved in the primary FITS HDU are 16-bit integer arrays with size of 1024×1024 pixel^2 for UV data products or 2048×2048 pixel^2 for VL data products. The following table describes the structure of the primary FITS header.

Keyword	Value Type	Valid Value(s)	Description
SIMPLE	Boolean	T	Logical keyword specifying whether the file conforms to basic FITS standards
BITPIX	Byte	8 or 16	Number of bits per pixel: 8 for non-image data, 16 for images
NAXIS	Byte	0 or 2	Number of dimensions in the data: 0 for non-image data, 2 for images
NAXIS1	Byte	1024 or 2048	Number of pixels along the 1st axis of images: 1024 for UV data, 2048 for VL data. Not applicable if NAXIS = 0
NAXIS2	Byte	1024 or 2048	Number of pixels along the 2nd axis of images: 1024 for UV data, 2048 for VL data. Not applicable if NAXIS = 0
EXTEND	Boolean	T	FITS file has extensions
FILENAME	String		Name of the FITS file

Keyword	Value Type	Valid Value(s)	Description
FILE_RAW	String		Raw file (reassembled TM packets) the FITS file was derived from
APID	Integer	> 0	APID number of associated TM
OBT_BEG	Float		Start time of data acquisition in on board time units
OBT_END	Float		End time of data acquisition in on board time units
LEVEL	String	'L0'	Data processing level:
ORIGIN	String		Location where the FITS file has been generated
CREATOR	String		Name of the software that produced the FITS file
VERS_SW	String		Version of the software that created the FITS file
VERSION	String	Two-character integer, zero padded	Version number that is the used in the filename
INSTRUME	String	'Metis'	Official instrument acronym
DATAMIN	Integer	$\geq 0, < 2^{14}$	Minimum valid physical value
DATAMAX	Integer	$\geq 0, < 2^{14}$	Maximum valid physical value
BLANK	Integer	0	Data value that is used to mark undefined pixels
COMPRESS	String	'None', 'Lossless', 'Lossy-high quality', 'Lossy-strong', or 'Lossy-extreme'	A cross-instrument description of the data compression quality, referring to the compression applied on board (not necessarily the state of the current file)
COMP_RAT	Float	≥ 1	Compression ratio
CHECKSUM	String		ASCII character string whose value forces the 32-bit 1's complement checksum accumulated over the entire FITS HDU to equal negative 0
DATASUM	String		Character string containing the unsigned integer value of the 32-bit 1's complement checksum of the data records in the HDU
HISTORY	String		History of steps and procedures associated with the processing of the data
COMMENT	String		Comments regarding the FITS file
END			This keyword has no associated value

4.1.1.2 Light-curve Data Extension

The light-curve extension contains a binary table where the light-curve data are stored as 16-bit integer arrays with number of elements equal to the value of the parameter NDIT set for the VL acquisition the light curve belongs to. The table has the following structure:

Column name	Column Type	Description
REL_TIME	Double	[s] Time from the start OBT of the acquisition cadence the light curve belongs to
AVERAGE1	Integer	[DN] Average value in sector 1 (see Figure 1)
AVERAGE2	Integer	[DN] Average value in sector 5
AVERAGE3	Integer	[DN] Average value in sector 2
AVERAGE4	Integer	[DN] Average value in sector 6
AVERAGE5	Integer	[DN] Average value in sector 3

Column name	Column Type	Description
AVERAGE6	Integer	[DN] Average value in sector 7
AVERAGE7	Integer	[DN] Average value in sector 4
AVERAGE8	Integer	[DN] Average value in sector 8

The extension header is a minimal FITS header with the following structure:

Keyword	Value Type	Valid Value(s)	Description
XTENSION	String	'BINTABLE'	Specify that what follows is a binary table
BITPIX	Byte	8	This is always 8 for binary tables
NAXIS	Byte	2	Number of dimensions. This is always 2 for binary tables
NAXIS1	Integer	> 1	Number of bytes in each data row
NAXIS2	Integer	1	Number of data rows
PCOUNT	Byte	0	Number of bytes that follow the table in the supplemental data area called the heap
GCOUNT	Byte	1	Group count. This is always 1 for binary tables
EXTNAME	String	'Light curve'	Name of the extension.
TFIELDS	Integer	9	Number of column fields for each data row
TFORM*i*	String	'[*n*]D' or '[*n*]I' with *n* equal to the acquisition parameter NDIT	Data type for column *i*
TTYPE*i*	String	'REL_TIME' or 'AVERAGE[*n*]' with *n* from 1 to 8	Data name for each column field
END			This keyword has no associated value

4.1.1.3 Metadata Extension

The metadata extension contains a binary table where the Metis scientific header associated with the image, and the compression header (if applicable) are stored. The two headers are saved as ASCII hexadecimal strings in a table with the following structure:

Column name	Column Type	Length	Description	Applicability
SCI_HEADER	String	Twice the byte length of the scientific header	Scientific header	All
CPR_HEADER	String	80 characters (40 bytes)	Compression header	All compressed data

The extension header contains all the parameter values extracted from the two headers. The header structure is described in the following table.

Keyword	Value Type	Valid Value(s)	Description	Applicability
XTENSION	String	'BINTABLE'	Specify that what follows is a binary table	All
BITPIX	Byte	8	This is always 8 for binary tables	All
NAXIS	Byte	2	Number of dimensions. This is always 2 for binary tables	All
NAXIS1	Integer	> 1	Number of bytes in each data row	All
NAXIS2	Integer	1	Number of data rows	All

Keyword	Value Type	Valid Value(s)	Description	Applicability
PCOUNT	Byte	0	Number of bytes that follow the table in the supplemental data area called the heap	All
GCOUNT	Byte	1	Group count. This is always 1 for binary tables	All
EXTNAME	String	'Metis metadata'	Name of the extension.	All
TFIELDS	Integer	1 or 2	Number of column fields for each data row, 1 for non-compressed data, 2 for compressed data	All
TFORM1	String	'[*n*]A'	Data type for 1st column field. *n* is twice the length of the scientific header in bytes	All
TFORM2	String	'80A'	Data type for 2nd column field	All compressed data
TTYPE1	String	'SCI_HEADER'	Data name for each column field	All
TTYPE2	String	'CPR_HEADER'	Data name for each column field	All compressed data
HDR_VERS	String		Version of the scientific header	All
DATATYPE	Integer	0-9	Data object type	All
OBJ_CNT	Integer	≥ 1	Data object counter	All
CONF_ID	Integer	> 0	Acquisition configuration ID	All
SESS_NUM	String		Acquisition session number	All
SEQ_NUM	Integer	≥ 0	Polarization sequence counter	VL images with POL_ID = 1, 2, 3, or 4
N_POL	Integer	1, 2, 3, or 4	Number of polarizations used	VL images with POL_ID = 1, 2, 3, or 4
POL_ID	Integer	0-6	Polarization ID	VL data products except light curves
MEASKIND	Boolean	0 or 1	Measurement kind: 0 = polarized brightness, 1 = total brightness	VL images
FRAMEMOD	Boolean	0 or 1	Frame acquisition mode: 0 = single, 1 = multiple	VL data products except light curves
VLFPFILT	Integer	0, 1, or 2	Fixed polarization pre-filter: 0 = binning, 1 = masking, 2 = no filter	VL images
PRESUM	Boolean	0 or 1	Pre-sum algorithm flag: 0 = disabled, 1 = enabled	UV data products
CR_SEP	Boolean	0 or 1	CR/SEP algorithm flag: 0 = disabled, 1 = enabled	VL/UV images and temporal std-dev. matrices
CME_OBS	Boolean	0 or 1	CME detection algorithm flag: 0 = disabled, 1 = enabled	VL images
SUN_DISK	Boolean	0 or 1	Sun-disk monitor flag: 0 = disabled, 1 = enabled	VL and UV images
SP_NOISE	Boolean	0 or 1	Spatial-noise algorithm flag: 0 = disabled, 1 = enabled	VL and UV images
COMPR	Boolean	0 or 1	Compression flag: 0 = disabled, 1 = enabled	All except light curves and PCU event lists
RADIAL	Boolean	0 or 1	Radialization flag: 0 = disabled, 1 = enabled	All except light curves and PCU event lists
PMPSTAB	Boolean	0 or 1	PMP temperature stability flag: 0 = not stable, 1 = stable	VL data products except light curves

Keyword	Value Type	Valid Value(s)	Description	Applicability
MASKING	Boolean	0 or 1	Masking flag: 0 = disabled, 1 = enabled	All except light curves and PCU event lists
MASKRMIN	Integer	≥ 0, < 1023	[pixel] Min. masking radius	All except light curves and PCU event lists
MASKRMAX	Integer	> 0, ≤ 1023	[pixel] Max. masking radius	All except light curves and PCU event lists
BIN_TYPE	Integer	0, 1, or 2	Uniform binning type	All compressed images
REF_ROWS	Boolean	0 or 1	Reference rows inclusion flag: 0 = not included, 1 = included	VL data products except light curves
R_POL_A	Integer		Reference object with pol. ID 1	Light curves
R_POL_B	Integer		Reference object with pol. ID 2	Light curves
R_POL_C	Integer		Reference object with pol. ID 3	Light curves
R_POL_D	Integer		Reference object with pol. ID 4	Light curves
CME_RMIN	Integer	≥ 0, < 1023	[pixel] Min. radius for CME obs. algo	Light curves
CME_RMAX	Integer	> 1, ≤ 1448	[pixel] Max. radius for CME obs. algo	Light curves
CME_LIMB	Float	≥ 0	Flux threshold for CME on limb	Light curves
CME_HALO	Float	≥ 0	Flux threshold for halo CME	Light curves
FLUX	Float	≥ 0	[DN] Flux threshold for sun-disk monitor	Light curves
DIT	Integer	≥ 1000	[ms] Detector integration time	All
NDIT	Integer	> 0	Number of averaged frames	VL data products
NDIT1	Integer	2^n with $0 \leq n \leq 7$	Number of hardware-averaged frames	UV data products and PCU acc. matrices
NDIT2	Integer	> 0, ≤ 64	Number of averaged frames	UV data products
CADENCE	Integer	≥ 1000	[ms] Acquisition cadence	All
CAD_BEG	String	'[*coarse*]:[*fine*]'	OBT at cadence start	All
CAD_END	String	'[*coarse*]:[*fine*]'	OBT at cadence end	All
CR_SEP_A	Float	≥ 0	CR/SEP algorithm param. A	All except light curves and PCU event lists
CR_SEP_B	Float	≥ 0	CR/SEP algorithm param. B	All except light curves and PCU event lists
SNRMIN	Integer	> 0	[pixel] Min. radius for spatial-noise algo	VL and UV images
SNRMAX	Integer	< 1448	[pixel] Max. radius for spatial-noise algo	VL and UV images
WIDTH	Integer		[pixel] Image width. For non radialized images it is 1024 or 2048.	All except light curves and PCU data products
HEIGHT	Integer		[pixel] Image height. For non radialized images it is 1024 or 2048.	All except light curves and PCU data products
REF_HDR	String		Data product type of reference object	Temporal std-dev. matrices and CR/SEP log matrices
REF_TYPE	Integer	0-9	Header version of reference object	Temporal std-dev. matrices and CR/SEP log matrices
REF_CNT	Integer	≥ 1	Reference object counter	Temporal std-dev. matrices and CR/SEP log matrices
DAC1POL1	Integer	≥ 0	[raw] PMP voltage (DAC1) for pol. ID 0, 1, or 5	VL data products except light curves
DAC2POL1	Integer	≥ 0	[raw] PMP voltage (DAC2) for pol. ID 0, 1, or 5	VL data products except light curves

Keyword	Value Type	Valid Value(s)	Description	Applicability
DAC1POL2	Integer	≥ 0	[raw] PMP voltage (DAC1) for pol. ID 2 or 6	VL data products except light curves
DAC2POL2	Integer	≥ 0	[raw] PMP voltage (DAC2) for pol. ID 2 or 6	VL data products except light curves
DAC1POL3	Integer	≥ 0	[raw] PMP voltage (DAC1) for pol. ID 3	VL data products except light curves
DAC2POL3	Integer	≥ 0	[raw] PMP voltage (DAC2) for pol. ID 3	VL data products except light curves
DAC1POL4	Integer	≥ 0	[raw] PMP voltage (DAC1) for pol. ID 4	VL data products except light curves
DAC2POL4	Integer	≥ 0	[raw] PMP voltage (DAC2) for pol. ID 4	VL data products except light curves
HVU_SCR	Integer	≥ 0	[raw] HVU screen commanded voltage	UV data products
HVU_MCP	Integer	≥ 0	[raw] HVU MCP commanded voltage	UV data products
TSENSOR	Integer	≥ 0	[raw] Sensor temperature	All except light curves and PCU data products
PMPTEMP	Integer	≥ 0	[raw] PMP temperature	VL data products except light curves
NB_IMG	Integer	1, 2, 3, or 4	Number of images in the same data stream	VL and UV images
SN_MEAN1	Integer		[DN] Spatial-noise mean in region 1	VL and UV images
SN_VAR1	Float		Spatial-noise variance in region 1	VL and UV images
SN_MEAN2	Integer		[DN] Spatial-noise mean in region 2	VL and UV images
SN_VAR2	Float		Spatial-noise variance in region 2	VL and UV images
SN_MEAN3	Integer		[DN] Spatial-noise mean in region 3	VL and UV images
SN_VAR3	Float		Spatial-noise variance in region 3	VL and UV images
SN_MEAN4	Integer		[DN] Spatial-noise mean in region 4	VL and UV images
SN_VAR4	Float		Spatial-noise variance in region 4	VL and UV images
SN_MEAN5	Integer		[DN] Spatial-noise mean in region 5	VL and UV images
SN_VAR5	Float		Spatial-noise variance in region 5	VL and UV images
N	Integer	> 0	Number of octets in the data stream	All
M	Integer	> 0	Number of octets contained in the accumulation vector	PCU acc. matrices
X_SIZE	Integer	1024 or 2048		All compressed data
Y_SIZE	Integer	1024 or 2048		All compressed data
Z_SIZE	Integer	0		All compressed data
P_BANDS	Integer	0, 1, 2, or 3	Number of prediction bands	All compressed data
N_BANDS	Integer	≥ 0	Number of bands	All compressed data
ORIG_X	Integer		Original image width pre-binning/pre-masking	All compressed data
ORIG_Y	Integer		Original image height pre-binning/pre-masking	All compressed data
FIRSTROW	Integer	≥ 0	First row	All compressed data
B0_BIN	Integer	0, 1, or 2	Band 0 binning type	All compressed data
B0_DQ	Integer	≥ 0	Band 0 delta quantization	All compressed data
B0_STOP	Integer	≥ 0	Band 0 stop row	All compressed data
B1_BIN	Integer	0, 1, or 2	Band 1 binning type	All compressed data

Keyword	Value Type	Valid Value(s)	Description	Applicability
B1_DQ	Integer	≥ 0	Band 1 delta quantization	All compressed data
B1_STOP	Integer	≥ 0	Band 1 stop row	All compressed data
B2_BIN	Integer	0, 1, or 2	Band 2 binning type	All compressed data
B2_DQ	Integer	≥ 0	Band 2 delta quantization	All compressed data
B2_STOP	Integer	≥ 0	Band 2 stop row	All compressed data
END			This keyword has no associated value	All

4.1.1.4 Radialized Image Extension

For images that were radialized during their acquisition, this extension contains the radialized image with a minimal FITS header. The extension name is ‘Radialized image’.

4.1.2 *L1 - Engineering Data Products*

The L1 pipeline will provide one FITS file for each L0 FITS file, with the following filename convention (see also [RD.01]):

```
solo_L1_[descriptor]_[date/time]_V[version].fits
```

where the list of possible descriptors is given in APPENDIX B - Data products matrix.

The structure of L1 FITS files is the following:

1. primary HDU: primary header; data only for image data products, i.e., VL and UV images, temporal standard-deviation matrices, CR log matrices, and PCU accumulation matrices,
2. binary-table data extension: only for light curves and PCU event lists [TBD],
3. housekeeping extension: binary-table with parameters extracted from housekeeping telemetry,
4. quality-matrix extension.

4.1.2.1 Primary Header and Data Unit

Data saved in the primary FITS HDU are 16-bit or 32-bit integer arrays with size corresponding to the binned sensor size. The following table describes the structure of the primary FITS header.

Keyword	Value Type	Valid Value(s)	Description	Applicability
SIMPLE	Boolean	T	Logical keyword specifying whether the file conforms to basic FITS standards	All
BITPIX	Byte	8, 16, or 32	Number of bits per pixel: 8 for non-image data, 16 or 32 for images	All
NAXIS	Byte	0 or 2	Number of dimensions in the data: 0 for non-image data, 2 for images	All
NAXIS1	Integer		Number of pixels along the 1st axis of images	All except light curves and PCU event lists
NAXIS2	Integer		Number of pixels along the 2nd axis of images	All except light curves and PCU event lists
EXTEND	Boolean	T	FITS file has extensions	All
LONGSTRN	String	'OGIP 1.0'	Specify this keyword in case the FITS header contains strings longer than the 68-character limit	All
FILENAME	String		Name of the FITS file	All
FILE_RAW	String		Raw file (reassembled TM packets) the FITS file was derived from	All
PARENT	String		Name of the parent or input file that got processed to the current one.	All
APID	Integer	> 0	APID number of associated TM	All

Keyword	Value Type	Valid Value(s)	Description	Applicability
DATE	String	Any date	Date and time of FITS file creation, in UTC, in ISO- 8601 format: YYYY-MM-DDTHH:MM:SS.SSS	All
DATE-OBS	String	Any date within mission duration	Must contain the same value as DATE-BEG	All
DATE-BEG	String	Any date within mission duration	Start time of observation, in UTC, in ISO-8601 format	All
DATE-AVG	String	Any date within mission duration	Average time of observation, in UTC, in ISO-8601 format	All
DATE-END	String	Any date within mission duration	End time of observation, in UTC, in ISO-8601 format	All
TIMESYS	String	'UTC'	System used for time keywords	All
TIMRDER	Float	0.0	[s] Estimated random error in time values	All
TIMSYER	Float	0.0	[s] Estimated systematic error in time values	All
OBT_BEG	Float		Start time of data acquisition in on board time units	All
OBT_END	Float		End time of data acquisition in on board time units	All
LEVEL	String	'L1'	Data processing level	All
ORIGIN	String		Location where the FITS file has been generated	All
CREATOR	String		Name of the software that produced the FITS file	All
VERS_SW	String		Version of the software that created the FITS file	All
VERS_CAL	String		Version of the calibration package	All
VERSION	String	Two-character integer, zero padded	Version number that is the used in the filename	All
OBSRVTRY	String	'Solar Orbiter'	Observatory or satellite name, in this case Solar Orbiter.	All
TELESCOP	String	'SOLO/METIS/VLDA'	Telescope that took the measurement	All
INSTRUME	String	'Metis'	Official instrument acronym	All
DETECTOR	String	'UVD' or 'VLD'	Subunit/sensor	All
OBJECT	String	Any string	The use of the keyword OBJECT is still [TBD]	All
OBS_MODE	String	Any string	Observation mode	All
OBS_TYPE	String		Encoded version of OBS_MODE	All
FILTER	String	'UV' or 'VL'	Filter used to acquire this image	All
WAVELNTH	Float	121.6 or 610.0	[nm] Characteristic wavelength of observation	All
WAVEMIN	Float	111.6 or 580.0	[nm] Min. wavelength where response > 0.05 of max.	All
WAVEMAX	Float	131.6 or 640.0	[nm] Max. wavelength where response > 0.05 of max.	All

Keyword	Value Type	Valid Value(s)	Description	Applicability
WAVEBAND	String	‘H I Lyman-alpha 121.6 nm’ or ‘Visible light 580-640 nm’	Bandpass description	All
XPOSURE	Float	≥ 1	[s] Total effective exposure time	All
NSUMEXP	Integer	≥ 1	Number of detector readouts summed together	All
TELAPSE	Float	≥ 1	[s] Elapsed time between beginning and end of observation	All
SOOPNAME	String		Name of the SOOP campaign that the data belong to	All
SOOPTYPE	String		Campaign ID(s) that the data belong to	All
OBS_ID	String		Unique ID of the individual observation	All
TARGET	String	Any string	Type of target from planning	All
BSCALE	Integer	1	Ratio of physical to array value at 0 offset	All
BZERO	Integer	0	Physical value for the array value 0	All
BTYPE	String	‘[UV | VL] image’, ‘PCU [accumulation matrix | event list | test event list]’, ‘[UV | VL] temporal standard deviation’, ‘[UV | VL] cosmic-ray matrix’, or ‘VL light curve’	Science data object type	All
BUNIT	String	‘DN’	Units of physical value, after application of BSCALE and BZERO	All
DATAMIN	Float	≥ 0, < 2^{14}	Minimum valid physical value	All
DATAMAX	Float	≥ 0, < 2^{14}	Maximum valid physical value	All
BLANK	Integer	0	Data value that is used to mark undefined pixels	All
PXBEG1	Integer	≥ 1	First pixel that has been read out in dimension 1	All
PXBEG2	Integer	≥ 1	First pixel that has been read out in dimension 2	All
PXEND1	Integer	≤ NAXIS1	Last pixel that has been read out in dimension 1	All
PXEND2	Integer	≤ NAXIS2	Last pixel that has been read out in dimension 2	All
NBIN1	Integer	1, 2, or 4	Binning factor in the dimension 1	All
NBIN2	Integer	1, 2, or 4	Binning factor in the dimension 2	All
NBIN	Integer		Product of all NBIN values above	All
COMPRESS	String	‘None’, ‘Lossless’, ‘Lossy-high quality’, ‘Lossy-strong’, or ‘Lossy-extreme’	Data compression quality	All
COMP_RAT	Float	≥ 1	Data compression ratio	All
WCSNAME	String	‘Helioprojective- cartesian’	Name of coordinate system	All
CTYPE1	String	‘HPLN-TAN’	Helioprojective longitude (Solar X)	All except light curves and PCU event lists

Keyword	Value Type	Valid Value(s)	Description	Applicability
CTYPE2	String	'HPLT-TAN'	Helioprojective latitude (Solar Y)	All except light curves and PCU event lists
CUNIT1	String	'arcsec'	Units along axis 1	All except light curves and PCU event lists
CUNIT2	String	'arcsec'	Units along axis 2	All except light curves and PCU event lists
PC1_1	Float		WCS coordinate transformation matrix	All except light curves and PCU event lists
PC1_2	Float		WCS coordinate transformation matrix	All except light curves and PCU event lists
PC2_1	Float		WCS coordinate transformation matrix	All except light curves and PCU event lists
PC2_2	Float		WCS coordinate transformation matrix	All except light curves and PCU event lists
CDELT1	Float		[arcsec] Pixel scale along axis 1	All except light curves and PCU event lists
CDELT2	Float		[arcsec] Pixel scale along axis 1	All except light curves and PCU event lists
CROTA	Float		[deg] Rotation angle	All except light curves and PCU event lists
CRVAL1	Float		[arcsec] Value of reference pixel along axis 1	All except light curves and PCU event lists
CRVAL2	Float		[arcsec] Value of reference pixel along axis 2	All except light curves and PCU event lists
CRPIX1	Float	(NAXIS1+1)/2	[pixel] Reference pixel (image centre) location along axis 1	All except light curves and PCU event lists
CRPIX2	Float	(NAXIS2+1)/2	[pixel] Reference pixel (image centre) location along axis 2	All except light curves and PCU event lists
SUNPIX1	Float		[pixel] Sun centre location along axis 1	All
SUNPIX2	Float		[pixel] Sun centre location along axis 2	All
SUN_XCEN	Float		[pixel] Sun centre location along axis 1	All
SUN_YCEN	Float		[pixel] Sun centre location along axis 2	All
IOPIX1	Float		[pixel] Metis boresight (IO centre) location along axis 1	All

Keyword	Value Type	Valid Value(s)	Description	Applicability
IOPIX2	Float		[pixel] Metis boresight (IO centre) location along axis 2	All
IO_XCEN	Float		[pixel] Metis boresight (IO centre) location along axis 1	All
IO_YCEN	Float		[pixel] Metis boresight (IO centre) location along axis 2	All
FSPIX1	Float		[pixel] Metis FS centre location along axis 1	All
FSPIX2	Float		[pixel] Metis FS centre location along axis 1	All
FS_XCEN	Float		[pixel] Metis FS centre location along axis 1	All
FS_YCEN	Float		[pixel] Metis FS centre location along axis 2	All
SCPIX1	Float		[pixel] S/C pointing location along axis 1	All
SCPIX2	Float		[pixel] S/C pointing location along axis 2	All
SC_XCEN	Float		[pixel] S/C pointing location along axis 1	All
SC_YCEN	Float		[pixel] S/C pointing location along axis 2	All
SC_YAW	Float		[arcsec] S/C HPC yaw	All
SC_PITCH	Float		[arcsec] S/C HPC pitch	All
SC_ROLL	Float		[deg] S/C HPC roll angle	All
INN_FOV	Float	1.6	[deg] Inner Metis FOV	All except light curves and PCU event lists
OUT_FOV	Float	3.4	[deg] Outer Meitis FOV	All except light curves and PCU event lists
LONPOLE	Float	180.0	Native longitude of the celestial pole	All
RSUN_ARC	Float		[arcsec] Apparent photospheric solar radius	All
RSUN_REF	Float	695508000.0	[m] Assumed physical solar radius	All
SOLAR_B0	Float		[deg] S/C tilt of solar North pole	All
SOLAR_P0	Float		[deg] S/C celestial North to solar North angle	All
SOLAR_EP	Float		[deg] S/C ecliptic North to solar North angle	All
CAR_ROT	Integer		Carrington rotation number	All
HGLT_OBS	Float		[deg] S/C heliographic latitude (B0 angle)	All
HGLN_OBS	Float		[deg] S/C heliographic longitude	All
CRLT_OBS	Float		[deg] S/C Carrington latitude (B0 angle)	All
CRLN_OBS	Float		[deg] S/C Carrington longitude (L0 angle)	All

Keyword	Value Type	Valid Value(s)	Description	Applicability
DSUN_OBS	Float		[m] S/C distance from Sun	All
DSUN_AU	Float		[AU] S/C distance from Sun	All
AU_REF	Float	149597870691.0	[m] Assumed physical Astronomical Unit	All
HEEX_OBS	Float		[m] S/C Heliocentric Earth Ecliptic X	All
HEEY_OBS	Float		[m] S/C Heliocentric Earth Ecliptic Y	All
HEEZ_OBS	Float		[m] S/C Heliocentric Earth Ecliptic Z	All
HCIX_OBS	Float		[m] S/C Heliocentric Inertial X	All
HCIY_OBS	Float		[m] S/C Heliocentric Inertial Y	All
HCIZ_OBS	Float		[m] S/C Heliocentric Inertial Z	All
HCIX_VOB	Float		[m/s] S/C Heliocentric Inertial X velocity	All
HCIY_VOB	Float		[m/s] S/C Heliocentric Inertial Y velocity	All
HCIZ_VOB	Float		[m/s] S/C Heliocentric Inertial Z velocity	All
HAEX_OBS	Float		[m] S/C Heliocentric Aries Ecliptic X	All
HAEY_OBS	Float		[m] S/C Heliocentric Aries Ecliptic Y	All
HAEZ_OBS	Float		[m] S/C Heliocentric Aries Ecliptic Z	All
HEQX_OBS	Float		[m] S/C Heliocentric Earth Equatorial X	All
HEQY_OBS	Float		[m] S/C Heliocentric Earth Equatorial Y	All
HEQZ_OBS	Float		[m] S/C Heliocentric Earth Equatorial Z	All
GSEX_OBS	Float		[m] S/C Geocentric Solar Ecliptic X	All
GSEY_OBS	Float		[m] S/C Geocentric Solar Ecliptic Y	All
GSEZ_OBS	Float		[m] S/C Geocentric Solar Ecliptic Z	All
OBS_VR	Float		[m/s] Radial velocity of S/C relative to Sun	All
EAR_TDEL	Float		[s] Time (Sun to Earth) – Time (Sun to S/C)	All
SUN_TIME	Float	≥ 0	[s] Time (Sun to S/C)	All
DATE_EAR	String	Any date within mission duration	[UTC] Start time of observation, corrected to Earth	All
DATE_SUN	String	Any date within mission duration	[UTC] Start time of observation, corrected to Sun	All
IDB_VERS	String		Version of the instrument database used for calibration of HK parameters	All
HDR_VERS	String		Version of the scientific header	All
DATATYPE	Integer	0-9	Data object type	All

Keyword	Value Type	Valid Value(s)	Description	Applicability
OBJ_CNT	Integer	≥ 1	Data object counter	All
CONF_ID	Integer	> 0	Acquisition configuration ID	All
SESS_NUM	String		Acquisition session number	All
SEQ_NUM	Integer	≥ 0	Polarization sequence counter	VL images with POL_ID = 1, 2, 3, or 4
N_POL	Integer	1, 2, 3, or 4	Number of polarizations used	VL images with POL_ID = 1, 2, 3, or 4
POL_ID	Integer	0-6	Polarization ID	VL images
MEASKIND	String	'Fixed pol.', 'pB', or 'tB'	Measurement kind	VL images
FRAMEMOD	String	'Single' or 'Multiple'	Frame acquisition mode	VL data products except light curves
VLFPFILT	String	'Binning', 'Masking', 'No filter', or 'Not applicable'	Fixed polarization pre-filter	VL images
PRESUM	String	'Disabled' or 'Enabled'	Pre-sum algorithm flag	UV data products
CR_SEP	String	'Disabled' or 'Enabled'	CR/SEP algorithm flag	VL/UV images and temporal std-dev. matrices
CME_OBS	String	'Disabled' or 'Enabled'	CME detection algorithm flag	VL images
SUN_DISK	String	'Disabled' or 'Enabled'	Sun-disk monitor flag	VL and UV images
SP_NOISE	String	'Disabled' or 'Enabled'	Spatial-noise algorithm flag	VL and UV images
COMPR	String	'Disabled' or 'Enabled'	Compression flag	All except light curves and PCU event lists
RADIAL	String	'Disabled' or 'Enabled'	Radialization flag	All except light curves and PCU event lists
PMPSTAB	String	'Not stable' or 'Stable'	PMP temperature stability flag	VL data products except light curves
MASKING	String	'Disabled' or 'Enabled'	Masking flag	All except light curves and PCU event lists
MASKRMIN	Integer	≥ 0, < 1023	[pixel] Min. masking radius	All except light curves and PCU event lists
MASKRMAX	Integer	> 0, ≤ 1023	[pixel] Max. masking radius	All except light curves and PCU event lists
BIN_TYPE	Integer	0, 1, or 2	Uniform binning type	All compressed images
REF_ROWS	String	'Not included' or 'Included'	Reference rows inclusion flag	VL data products except light curves
R_POL_A	Integer		Reference object with pol. ID 1	Light curves
R_POL_B	Integer		Reference object with pol. ID 2	Light curves

Keyword	Value Type	Valid Value(s)	Description	Applicability
R_POL_C	Integer		Reference object with pol. ID 3	Light curves
R_POL_D	Integer		Reference object with pol. ID 4	Light curves
CME_RMIN	Integer	≥ 0, < 1023	[pixel] Min. radius for CME obs. algo	Light curves
CME_RMAX	Integer	> 1, ≤ 1448	[pixel] Max. radius for CME obs. algo	Light curves
CME_LIMB	Float	≥ 0	Flux threshold for CME on limb	Light curves
CME_HALO	Float	≥ 0	Flux threshold for halo CME	Light curves
FLUX	Float	≥ 0	[DN] Flux threshold for sun-disk monitor	Light curves
DIT	Integer	≥ 1000	[ms] Detector integration time	All
NDIT	Integer	> 0	Number of averaged frames	VL data products
NDIT1	Integer	2^n with $0 \le n \le 7$	Number of hardware-averaged frames	UV data products and PCU acc. matrices
NDIT2	Integer	> 0, ≤ 64	Number of averaged frames	UV data products
CADENCE	Integer	≥ 1000	[ms] Acquisition cadence	All
CAD_BEG	String	'[*coarse*]:[*fine*]'	OBT at cadence start	All
CAD_END	String	'[*coarse*]:[*fine*]'	OBT at cadence end	All
CR_SEP_A	Float	≥ 0	CR/SEP algorithm param. A	All except light curves and PCU event lists
CR_SEP_B	Float	≥ 0	CR/SEP algorithm param. B	All except light curves and PCU event lists
SNRMIN	Integer	> 0	[pixel] Min. radius for spatial-noise algo	VL and UV images
SNRMAX	Integer	< 1448	[pixel] Max. radius for spatial-noise algo	VL and UV images
REF_HDR	String		Data product type of reference object	Temporal std-dev. matrices and CR/SEP log matrices
REF_TYPE	Integer	0-9	Header version of reference object	Temporal std-dev. matrices and CR/SEP log matrices
REF_CNT	Integer	≥ 1	Reference object counter	Temporal std-dev. matrices and CR/SEP log matrices
DAC1POL1	Integer	≥ 0	[raw] PMP voltage (DAC1) for pol. ID 0, 1, or 5	VL data products except light curves
DAC2POL1	Integer	≥ 0	[raw] PMP voltage (DAC2) for pol. ID 0, 1, or 5	VL data products except light curves
DAC1POL2	Integer	≥ 0	[raw] PMP voltage (DAC1) for pol. ID 2 or 6	VL data products except light curves

Keyword	Value Type	Valid Value(s)	Description	Applicability
DAC2POL2	Integer	≥ 0	[raw] PMP voltage (DAC2) for pol. ID 2 or 6	VL data products except light curves
DAC1POL3	Integer	≥ 0	[raw] PMP voltage (DAC1) for pol. ID 3	VL data products except light curves
DAC2POL3	Integer	≥ 0	[raw] PMP voltage (DAC2) for pol. ID 3	VL data products except light curves
DAC1POL4	Integer	≥ 0	[raw] PMP voltage (DAC1) for pol. ID 4	VL data products except light curves
DAC2POL4	Integer	≥ 0	[raw] PMP voltage (DAC2) for pol. ID 4	VL data products except light curves
HVU_SCR	Integer	≥ 0	[raw] HVU screen commanded voltage	UV data products
HVU_MCP	Integer	≥ 0	[raw] HVU MCP commanded voltage	UV data products
HV_SCR_V	Float		[V] HVU Screen + MCP read voltage	UV data products
HV_MCP_V	Float		[V] HVU MCP read voltage	UV data products
HV_MCP_I	Float		[μA] HVU MCP current	UV data products
HV_TEMP	Float		[degC] HVU temperature	UV data products
TSENSOR	Float		[degC] Sensor temperature	All except light curves and PCU data products
PMPTEMP	Float		[degC] PMP temperature	VL data products except light curves
NB_IMG	Integer	1, 2, 3, or 4	Number of images in the same data stream	VL and UV images
SN_MEAN1	Integer		[DN] Spatial-noise mean in region 1	VL and UV images
SN_VAR1	Float		Spatial-noise variance in region 1	VL and UV images
SN_MEAN2	Integer		[DN] Spatial-noise mean in region 2	VL and UV images
SN_VAR2	Float		Spatial-noise variance in region 2	VL and UV images
SN_MEAN3	Integer		[DN] Spatial-noise mean in region 3	VL and UV images
SN_VAR3	Float		Spatial-noise variance in region 3	VL and UV images
SN_MEAN4	Integer		[DN] Spatial-noise mean in region 4	VL and UV images
SN_VAR4	Float		Spatial-noise variance in region 4	VL and UV images
SN_MEAN5	Integer		[DN] Spatial-noise mean in region 5	VL and UV images

Keyword	Value Type	Valid Value(s)	Description	Applicability
SN_VAR5	Float		Spatial-noise variance in region 5	VL and UV images
N	Integer	> 0	Number of octets in the data stream	All
M	Integer	> 0	Number of octets contained in the accumulation vector	PCU acc. matrices
FIRSTROW	Integer	≥ 0	First row	All compressed data
B0_BIN	Integer	0, 1, or 2	Band 0 binning type	All compressed data
B0_DQ	Integer	≥ 0	Band 0 delta quantization	All compressed data
B0_STOP	Integer	≥ 0	Band 0 stop row	All compressed data
B1_BIN	Integer	0, 1, or 2	Band 1 binning type	All compressed data
B1_DQ	Integer	≥ 0	Band 1 delta quantization	All compressed data
B1_STOP	Integer	≥ 0	Band 1 stop row	All compressed data
B2_BIN	Integer	0, 1, or 2	Band 2 binning type	All compressed data
B2_DQ	Integer	≥ 0	Band 2 delta quantization	All compressed data
B2_STOP	Integer	≥ 0	Band 2 stop row	All compressed data
CHECKSUM	String		ASCII character string whose value forces the 32-bit 1's complement checksum accumulated over the entire FITS HDU to equal negative 0	All
DATASUM	String		Character string containing the unsigned integer value of the 32-bit 1's complement checksum of the data records in the HDU	All
INFO_URL	String		DOI instrument paper or URL of information page'	All
COMMENT	String		Comments regarding the FITS file	All
HISTORY	String		History of steps and procedures associated with the processing of the data	All
END			This keyword has no associated value	All

4.1.2.2 Housekeeping Extension

The housekeeping extension contains a binary table where a subset of instrument housekeeping parameters measured during the data acquisition are saved, for reference and/or diagnostic purposes. For each parameter, the table reports the following values (one row per value):

- the last measurement (at time t1) before the start of the acquisition,
- the first measurement (at time t2) after the end of the acquisition,
- the measurement closest to time (t1+t2)/2,
- the minimum, maximum, and average of all measurements between t1 and t2 (only for parameters with calibration in decimal representation).

The table has the following structure:

Column name	Column Type	Description
PAR_NAME	String	Parameter name
GEN_TIME	String	Time of the measurement (generation time of the relevant TM packet). This field if not applicable for the average parameter measurement
RAW_VAL	String	Raw parameter value
ENG_VAL	String	Engineering (i.e., calibrated) parameter value
UNIT	String	Unit, if present
DESCR	String	Description of parameter or measurement

4.1.2.3 Quality Matrix Extension

At L1 level, a quality matrix with same size of the image is created, containing a classification of the quality of each pixel value; the quality is parametrized using an index having the following possible values:

- NaN, for all saturated pixel,
- NaN, for all pixels having a value lower than the average detector bias level,
- 1 for all good pixels, i.e., within the detector linearity range,
- 0 for all remaining pixels.

The quality matrix is saved in an extension of the L2 FITS file whose name is 'Quality matrix'.

4.1.3 L2 - Science Data Products

The L2 pipeline will provide the following data products:

- `solo_L2_metis-uv-image_[date/time]_V[version].fits`
- `solo_L2_metis-vl-image_[date/time]_V[version].fits`
- `solo_L2_metis-vl-pb_[date/time]_V[version].fits`
- `solo_L2_metis-vl-tb_[date/time]_V[version].fits`
- `solo_L2_metis-vl-pol-angle_[date/time]_V[version].fits`
- `solo_L2_metis-vl-stokes_[date/time]_V[version].fits`

The generation of L2 products for temporal standard-deviation matrices and CR/SEP log matrices is foreseen but not implemented yet. Light curves and PCU event lists will not be advanced to level L2.

In general, the structure of L2 FITS files is the following:

1. primary HDU: primary header and data, i.e., UV and VL (fixed polarization, polarized brightness, total brightness, polarization angle, and Stokes *I* parameter) images,
2. Stokes *Q* and *U* parameters extensions (for polarized-brightness sequences),
3. quality matrix extension,
4. error matrix extension.

4.1.3.1 Primary Header and Data Unit

Data saved in the primary FITS HDU are 32-bit floating-point arrays with size corresponding to the binned sensor size. The following table describes the structure of the primary FITS header.

Keyword	Value Type	Valid Value(s)	Description	Applicability
SIMPLE	Boolean	T	Logical keyword specifying whether the file conforms to basic FITS standards	All
BITPIX	Byte	-32	Number of bits per pixel: -32 for floating-point numbers	All
NAXIS	Byte	2	Number of dimensions in the data: 2 for images	All
NAXIS1	Integer		Number of pixels along the 1st axis of images	All
NAXIS2	Integer		Number of pixels along the 2nd axis of images	All
EXTEND	Boolean	T	FITS file has extensions	All
LONGSTRN	String	'OGIP 1.0'	Specify this keyword in case the FITS header contains strings longer than the 68-character limit	All
FILENAME	String		Name of the FITS file	All
FILE_RAW	String		Raw file (reassembled TM packets) the FITS file was derived from	All

Keyword	Value Type	Valid Value(s)	Description	Applicability
PARENT	String		Name of the parent or input file that got processed to the current one.	All
APID	Integer	> 0	APID number of associated TM	All
DATE	String	Any date	Date and time of FITS file creation, in UTC, in ISO- 8601 format: YYYY-MM-DDTHH:MM:SS.SSS	All
DATE-OBS	String	Any date within mission duration	Must contain the same value as DATE-BEG	All
DATE-BEG	String	Any date within mission duration	Start time of observation, in UTC, in ISO-8601 format	All
DATE-AVG	String	Any date within mission duration	Average time of observation, in UTC, in ISO-8601 format	All
DATE-END	String	Any date within mission duration	End time of observation, in UTC, in ISO-8601 format	All
TIMESYS	String	'UTC'	System used for time keywords	All
TIMRDER	Float	0.0	[s] Estimated random error in time values	All
TIMSYER	Float	0.0	[s] Estimated systematic error in time values	All
OBT_BEG	Float		Start time of data acquisition in on board time units	All
OBT_END	Float		End time of data acquisition in on board time units	All
LEVEL	String	'L2'	Data processing level	All
ORIGIN	String		Location where the FITS file has been generated	All
CREATOR	String		Name of the software that produced the FITS file	All
VERS_SW	String		Version of the software that created the FITS file	All
VERS_CAL	String		Version of the calibration package	All
VERSION	String	Two-character integer, zero padded	Version number that is the used in the filename	All
OBSRVTRY	String	'Solar Orbiter'	Observatory or satellite name, in this case Solar Orbiter.	All
TELESCOP	String	'SOLO/METIS/VLDA'	Telescope that took the measurement	All
INSTRUME	String	'Metis'	Official instrument acronym	All
DETECTOR	String	'UVD' or 'VLD'	Subunit/sensor	All
OBJECT	String	Any string	The use of the keyword OBJECT is [TBD]	All
OBS_MODE	String	Any string	Observation mode	All
OBS_TYPE	String		Encoded version of OBS_MODE	All
FILTER	String	'UV' or 'VL'	Filter used to acquire this image	All
WAVELNTH	Float	121.6 or 610.0	[nm] Characteristic wavelength of observation	All

Keyword	Value Type	Valid Value(s)	Description	Applicability
WAVEMIN	Float	111.6 or 580.0	[nm] Min. wavelength where response > 0.05 of max.	All
WAVEMAX	Float	131.6 or 640.0	[nm] Max. wavelength where response > 0.05 of max.	All
WAVEBAND	String	'H I Lyman-alpha 121.6 nm' or 'Visible light 580-640 nm'	Bandpass description	All
XPOSURE	Float	≥ 1	[s] Total effective exposure time	All
NSUMEXP	Integer	≥ 1	Number of detector readouts summed together	All
TELAPSE	Float	≥ 1	[s] Elapsed time between beginning and end of observation	All
SOOPNAME	String		Name of the SOOP campaign that the data belong to	All
SOOPTYPE	String		Campaign ID(s) that the data belong to	All
OBS_ID	String		Unique ID of the individual observation	All
TARGET	String	Any string	Type of target from planning	All
BSCALE	Integer	1	Ratio of physical to array value at 0 offset	All
BZERO	Integer	0	Physical value for the array value 0	All
BTYPE	String	'UV Lyman-alpha intensity', 'VL fixed-polarization intensity', 'VL total brightness', 'VL polarized brightness', 'VL polarization angle', or 'Stokes I'	Science data object type	All
BUNIT	String	'ph/cm2/s/sr' or 'MSB'	Units of physical value, after application of BSCALE and BZERO	All
DATAMIN	Float	$\geq 0, < 2^{14}$	Minimum valid physical value	All
DATAMAX	Float	$\geq 0, < 2^{14}$	Maximum valid physical value	All
PXBEG1	Integer	≥ 1	First pixel that has been read out in dimension 1	All
PXBEG2	Integer	≥ 1	First pixel that has been read out in dimension 2	All
PXEND1	Integer	≤ NAXIS1	Last pixel that has been read out in dimension 1	All
PXEND2	Integer	≤ NAXIS2	Last pixel that has been read out in dimension 2	All
NBIN1	Integer	1, 2, or 4	Binning factor in the dimension 1	All
NBIN2	Integer	1, 2, or 4	Binning factor in the dimension 2	All
NBIN	Integer		Product of all NBIN values above	All
COMPRESS	String	'None', 'Lossless', 'Lossy-high quality', 'Lossy-strong', or 'Lossy-extreme'	Data compression quality	All
COMP_RAT	Float	≥ 1	Data compression ratio	All
WCSNAME	String	'Helioprojective-cartesian'	Name of coordinate system	All
CTYPE1	String	'HPLN-TAN'	Helioprojective longitude (Solar X)	All
CTYPE2	String	'HPLT-TAN'	Helioprojective latitude (Solar Y)	All

Keyword	Value Type	Valid Value(s)	Description	Applicability
CUNIT1	String	'arcsec'	Units along axis 1	All
CUNIT2	String	'arcsec'	Units along axis 2	All
PC1_1	Float		WCS coordinate transformation matrix	All
PC1_2	Float		WCS coordinate transformation matrix	All
PC2_1	Float		WCS coordinate transformation matrix	All
PC2_2	Float		WCS coordinate transformation matrix	All
CDELT1	Float		[arcsec] Pixel scale along axis 1	All
CDELT2	Float		[arcsec] Pixel scale along axis 1	All
CROTA	Float		[deg] Rotation angle	All
CRVAL1	Float		[arcsec] Value of reference pixel along axis 1	All
CRVAL2	Float		[arcsec] Value of reference pixel along axis 2	All
CRPIX1	Float	(NAXIS1+1)/2	[pixel] Reference pixel (image centre) location along axis 1	All
CRPIX2	Float	(NAXIS2+1)/2	[pixel] Reference pixel (image centre) location along axis 2	All
SUNPIX1	Float		[pixel] Sun centre location along axis 1	All
SUNPIX2	Float		[pixel] Sun centre location along axis 2	All
SUN_XCEN	Float		[pixel] Sun centre location along axis 1	All
SUN_YCEN	Float		[pixel] Sun centre location along axis 2	All
IOPIX1	Float		[pixel] Metis boresight (IO centre) location along axis 1	All
IOPIX2	Float		[pixel] Metis boresight (IO centre) location along axis 2	All
IO_XCEN	Float		[pixel] Metis boresight (IO centre) location along axis 1	All
IO_YCEN	Float		[pixel] Metis boresight (IO centre) location along axis 2	All
FSPIX1	Float		[pixel] Metis FS centre location along axis 1	All
FSPIX2	Float		[pixel] Metis FS centre location along axis 1	All
FS_XCEN	Float		[pixel] Metis FS centre location along axis 1	All
FS_YCEN	Float		[pixel] Metis FS centre location along axis 2	All
SCPIX1	Float		[pixel] S/C pointing location along axis 1	All
SCPIX2	Float		[pixel] S/C pointing location along axis 2	All

Keyword	Value Type	Valid Value(s)	Description	Applicability
SC_XCEN	Float		[pixel] S/C pointing location along axis 1	All
SC_YCEN	Float		[pixel] S/C pointing location along axis 2	All
SC_YAW	Float		[arcsec] S/C HPC yaw	All
SC_PITCH	Float		[arcsec] S/C HPC pitch	All
SC_ROLL	Float		[deg] S/C HPC roll angle	All
INN_FOV	Float	1.6	[deg] Inner Metis FOV	All
OUT_FOV	Float	3.4	[deg] Outer Metis FOV	All
LONPOLE	Float	180.0	Native longitude of the celestial pole	All
RSUN_ARC	Float		[arcsec] Apparent photospheric solar radius	All
RSUN_REF	Float	695508000.0	[m] Assumed physical solar radius	All
SOLAR_B0	Float		[deg] S/C tilt of solar North pole	All
SOLAR_P0	Float		[deg] S/C celestial North to solar North angle	All
SOLAR_EP	Float		[deg] S/C ecliptic North to solar North angle	All
CAR_ROT	Integer		Carrington rotation number	All
HGLT_OBS	Float		[deg] S/C heliographic latitude (B0 angle)	All
HGLN_OBS	Float		[deg] S/C heliographic longitude	All
CRLT_OBS	Float		[deg] S/C Carrington latitude (B0 angle)	All
CRLN_OBS	Float		[deg] S/C Carrington longitude (L0 angle)	All
DSUN_OBS	Float		[m] S/C distance from Sun	All
DSUN_AU	Float		[AU] S/C distance from Sun	All
AU_REF	Float	149597870691.0	[m] Assumed physical Astronomical Unit	All
HEEX_OBS	Float		[m] S/C Heliocentric Earth Ecliptic X	All
HEEY_OBS	Float		[m] S/C Heliocentric Earth Ecliptic Y	All
HEEZ_OBS	Float		[m] S/C Heliocentric Earth Ecliptic Z	All
HCIX_OBS	Float		[m] S/C Heliocentric Inertial X	All
HCIY_OBS	Float		[m] S/C Heliocentric Inertial Y	All
HCIZ_OBS	Float		[m] S/C Heliocentric Inertial Z	All
HCIX_VOB	Float		[m/s] S/C Heliocentric Inertial X velocity	All
HCIY_VOB	Float		[m/s] S/C Heliocentric Inertial Y velocity	All
HCIZ_VOB	Float		[m/s] S/C Heliocentric Inertial Z velocity	All
HAEX_OBS	Float		[m] S/C Heliocentric Aries Ecliptic X	All
HAEY_OBS	Float		[m] S/C Heliocentric Aries Ecliptic Y	All
HAEZ_OBS	Float		[m] S/C Heliocentric Aries Ecliptic Z	All
HEQX_OBS	Float		[m] S/C Heliocentric Earth	All

Keyword	Value Type	Valid Value(s)	Description	Applicability
			Equatorial X	
HEQY_OBS	Float		[m] S/C Heliocentric Earth Equatorial Y	All
HEQZ_OBS	Float		[m] S/C Heliocentric Earth Equatorial Z	All
GSEX_OBS	Float		[m] S/C Geocentric Solar Ecliptic X	All
GSEY_OBS	Float		[m] S/C Geocentric Solar Ecliptic Y	All
GSEZ_OBS	Float		[m] S/C Geocentric Solar Ecliptic Z	All
OBS_VR	Float		[m/s] Radial velocity of S/C relative to Sun	All
EAR_TDEL	Float		[s] Time(Sun to Earth) - Time(Sun to S/C)	All
SUN_TIME	Float	≥ 0	[s] Time(Sun to S/C)	All
DATE_EAR	String	Any date within mission duration	[UTC] Start time of observation, corrected to Earth	All
DATE_SUN	String	Any date within mission duration	[UTC] Start time of observation, corrected to Sun	All
IDB_VERS	String		Version of the instrument database used for calibration of HK parameters	All
HDR_VERS	String		Version of the scientific header	All
DATATYPE	Integer	0-9	Data object type	All
OBJ_CNT	Integer	≥ 1	Data object counter	VL and UV images
CONF_ID	Integer	> 0	Acquisition configuration ID	All
SESS_NUM	String		Acquisition session number	All
SEQ_NUM	Integer	≥ 0	Polarization sequence counter	VL images with POL_ID = 1, 2, 3, or 4
N_POL	Integer	1, 2, 3, or 4	Number of polarizations used	VL images with POL_ID = 1, 2, 3, or 4
POL_ID	Integer	0-6	Polarization ID	VL images
POLANGLE	Float	> 0	Polarization angle	VL images
MEASKIND	String	'Fixed pol.', 'pB', or 'tB'	Measurement kind	VL images
FRAMEMOD	String	'Single' or 'Multiple'	Frame acquisition mode	VL data products
VLFPFILT	String	'Binning', 'Masking', 'No filter', or 'Not applicable'	Fixed polarization pre-filter	VL images
PRESUM	String	'Disabled' or 'Enabled'	Pre-sum algorithm flag	UV data products
CR_SEP	String	'Disabled' or 'Enabled'	CR/SEP algorithm flag	VL/UV images and temporal std-dev. matrices
CME_OBS	String	'Disabled' or 'Enabled'	CME detection algorithm flag	VL images
SUN_DISK	String	'Disabled' or 'Enabled'	Sun-disk monitor flag	VL and UV images
SP_NOISE	String	'Disabled' or 'Enabled'	Spatial-noise algorithm flag	VL and UV images
COMPR	String	'Disabled' or 'Enabled'	Compression flag	All

Keyword	Value Type	Valid Value(s)	Description	Applicability
RADIAL	String	'Disabled' or 'Enabled'	Radialization flag	All
PMPSTAB	String	'Not stable' or 'Stable'	PMP temperature stability flag	VL data products except light curves
MASKING	String	'Disabled' or 'Enabled'	Masking flag	All
MASKRMIN	Integer	≥ 0, < 1023	[pixel] Min. masking radius	All
MASKRMAX	Integer	> 0, ≤ 1023	[pixel] Max. masking radius	All
BIN_TYPE	Integer	0, 1, or 2	Uniform binning type	All compressed images
REF_ROWS	String	'Not included' or 'Included'	Reference rows inclusion flag	VL data products
DIT	Integer	≥ 1000	[ms] Detector integration time	All
NDIT	Integer	> 0	Number of averaged frames	VL data products
NDIT1	Integer	2^n with $0 \leq n \leq 7$	Number of hardware-averaged frames	UV data products
NDIT2	Integer	> 0, ≤ 64	Number of averaged frames	UV data products
CADENCE	Integer	≥ 1000	[ms] Acquisition cadence	All
CAD_BEG	String	'[*coarse*]:[*fine*]'	OBT at cadence start	All
CAD_END	String	'[*coarse*]:[*fine*]'	OBT at cadence end	All
CR_SEP_A	Float	≥ 0	CR/SEP algorithm param. A	All
CR_SEP_B	Float	≥ 0	CR/SEP algorithm param. B	All
SNRMIN	Integer	> 0	[pixel] Min. radius for spatial-noise algo	VL and UV images
SNRMAX	Integer	< 1448	[pixel] Max. radius for spatial-noise algo	VL and UV images
REF_HDR	String		Data product type of reference object	Temporal std-dev. matrices and CR/SEP log matrices
REF_TYPE	Integer	0-9	Header version of reference object	Temporal std-dev. matrices and CR/SEP log matrices
REF_CNT	Integer	≥ 1	Reference object counter	Temporal std-dev. matrices and CR/SEP log matrices
DAC1POL1	Integer	≥ 0	[raw] PMP voltage (DAC1) for pol. ID 0, 1, or 5	VL data products
DAC2POL1	Integer	≥ 0	[raw] PMP voltage (DAC2) for pol. ID 0, 1, or 5	VL data products
DAC1POL2	Integer	≥ 0	[raw] PMP voltage (DAC1) for pol. ID 2 or 6	VL data products
DAC2POL2	Integer	≥ 0	[raw] PMP voltage (DAC2) for pol. ID 2 or 6	VL data products
DAC1POL3	Integer	≥ 0	[raw] PMP voltage (DAC1) for pol. ID 3	VL data products
DAC2POL3	Integer	≥ 0	[raw] PMP voltage (DAC2) for pol. ID 3	VL data products

Keyword	Value Type	Valid Value(s)	Description	Applicability
DAC1POL4	Integer	≥ 0	[raw] PMP voltage (DAC1) for pol. ID 4	VL data products
DAC2POL4	Integer	≥ 0	[raw] PMP voltage (DAC2) for pol. ID 4	VL data products
HVU_SCR	Integer	≥ 0	[raw] HVU screen commanded voltage	UV data products
HVU_MCP	Integer	≥ 0	[raw] HVU MCP commanded voltage	UV data products
HV_SCR_V	Float		[V] HVU Screen + MCP read voltage	UV data products
HV_MCP_V	Float		[V] HVU MCP read voltage	UV data products
HV_MCP_I	Float		[μA] HVU MCP current	UV data products
HV_TEMP	Float		[degC] HVU temperature	UV data products
TSENSOR	Float		[degC] Sensor temperature	All
PMPTEMP	Float		[degC] PMP temperature	VL data products
NB_IMG	Integer	1, 2, 3, or 4	Number of images in the same data stream	VL and UV images
SN_MEAN1	Integer		[DN] Spatial-noise mean in region 1	VL and UV images
SN_VAR1	Float		Spatial-noise variance in region 1	VL and UV images
SN_MEAN2	Integer		[DN] Spatial-noise mean in region 2	VL and UV images
SN_VAR2	Float		Spatial-noise variance in region 2	VL and UV images
SN_MEAN3	Integer		[DN] Spatial-noise mean in region 3	VL and UV images
SN_VAR3	Float		Spatial-noise variance in region 3	VL and UV images
SN_MEAN4	Integer		[DN] Spatial-noise mean in region 4	VL and UV images
SN_VAR4	Float		Spatial-noise variance in region 4	VL and UV images
SN_MEAN5	Integer		[DN] Spatial-noise mean in region 5	VL and UV images
SN_VAR5	Float		Spatial-noise variance in region 5	VL and UV images
N	Integer	> 0	Number of octets in the data stream	All
FIRSTROW	Integer	≥ 0	First row	All compressed data
B0_BIN	Integer	0, 1, or 2	Band 0 binning type	All compressed data
B0_DQ	Integer	≥ 0	Band 0 delta quantization	All compressed data
B0_STOP	Integer	≥ 0	Band 0 stop row	All compressed data
B1_BIN	Integer	0, 1, or 2	Band 1 binning type	All compressed data

Keyword	Value Type	Valid Value(s)	Description	Applicability
B1_DQ	Integer	≥ 0	Band 1 delta quantization	All compressed data
B1_STOP	Integer	≥ 0	Band 1 stop row	All compressed data
B2_BIN	Integer	0, 1, or 2	Band 2 binning type	All compressed data
B2_DQ	Integer	≥ 0	Band 2 delta quantization	All compressed data
B2_STOP	Integer	≥ 0	Band 2 stop row	All compressed data
CHECKSUM	String		ASCII character string whose value forces the 32-bit 1's complement checksum accumulated over the entire FITS HDU to equal negative 0	All
DATASUM	String		Character string containing the unsigned integer value of the 32-bit 1's complement checksum of the data records in the HDU	All
INFO_URL	String		DOI instrument paper or URL of information page'	All
COMMENT	String		Comments regarding the FITS file	All
HISTORY	String		History of steps and procedures associated with the processing of the data	All
END			This keyword has no associated value	All

4.1.3.2 Stokes Q and U Extensions

The L2 FITS file containing the Stokes parameters derived from VL polarimetric sequences (FITS descriptor `metis-vl-stokes`) contains two image extensions where the images of parameters Q and U are saved (the image of parameter I is saved in the primary HDU). These extensions have names 'Stokes Q' and 'Stokes U', respectively. All extension headers contain the set of keywords that are mandatory according to the FITS standard for extensions (see the Table below), as well as all the other keywords reported in the primary FITS header.

Keyword	Value Type	Valid Value(s)	Description
XTENSION	String	'IMAGE'	Specify that what follows is an image extension
BITPIX	Byte	-32	Number of bits per pixel: -32 for floating-point numbers
NAXIS	Byte	2	Number of dimensions. This is always 2 for images
NAXIS1	Integer	512, 1024, or 2048	Number of pixels along the 1st axis of images
NAXIS2	Integer	512, 1024, or 2048	Number of pixels along the 2nd axis of images
PCOUNT	Byte	0	Number of bytes that follow the data in the supplemental data area called the heap
GCOUNT	Byte	1	Group count. This is always 1 for images

Keyword	Value Type	Valid Value(s)	Description
EXTNAME	String	'Stokes Q' or 'Stokes U'	Name of the extension.
…			
BTYPE	String	'Stokes Q' or 'Stokes U'	Science data object type
…			

4.1.3.3 Quality and Error Matrix Extensions

L2 FITS files contain two additional image extensions where the quality-index (see Sect. 4.1.2.3) and error matrices pertaining to the data are saved. These extensions have names 'Quality matrix' and 'Error matrix', respectively. Both extension headers contain the set of keywords that are mandatory according to the FITS standard for extensions (see the Table below), as well as the same keywords reported in the primary FITS header.

Keyword	Value Type	Valid Value(s)	Description
XTENSION	String	'IMAGE'	Specify that what follows is an image extension
BITPIX	Byte	-32	Number of bits per pixel: -32 for floating-point numbers
NAXIS	Byte	2	Number of dimensions. This is always 2 for images
NAXIS1	Integer	512, 1024, or 2048	Number of pixels along the 1st axis of images
NAXIS2	Integer	512, 1024, or 2048	Number of pixels along the 2nd axis of images
PCOUNT	Byte	0	Number of bytes that follow the data in the supplemental data area called the heap
GCOUNT	Byte	1	Group count. This is always 1 for images
EXTNAME	String	'Quality matrix or 'Error matrix'	Name of the extension.
…			
BTYPE	String	'Pixel quality' or 'Absolute error'	Science data object type
BUNIT	String	'None', 'ph/cm2/s/sr', or 'MSB'	Units of physical value, after application of BSCALE and BZERO
…			

4.1.4 L3 - Higher-level Data Products

The generation of Metis Level-3 data products is foreseen later in the mission.

L3 data will consist of:

- coronal electron-density maps derived from polarized-brightness data,
- coronal outflow velocity maps derived from Doppler-dimming inversion of polarized-brightness and UV data,
- images (in JPEG or PNG format [TBD]) and movies obtained from time series.

5 APPENDIX A - METIS GROUND-SEGMENT DATA PRODUCT DESCRIPTION

The data format described in this Appendix applies to all the scientific and non-scientific data generated by Metis during the AITV, on-ground calibration, and on-S/C integration campaigns before they are converted into the FITS format.

5.1 Raw TM/TC stream: the .mArc file

5.1.1 *Description*

The .mArc file is a CSV (Comma-Separated Values) text file including one TM/TC CCSDS packet per line. During the AITV, calibration, and on-S/C integration campaigns, every .mArc includes all the TM/TC traffic of the whole test session.

5.1.2 *File format specification (version 1.0)*

If the line begins with a double hash "##", the line is a comment. If the line begins with the string "#!", the line contains an ancillary parameter. All the remaining lines contains either a TM or a TC packet in the format:

```
[Reception Time], [Raw CCSDS packet], [Packet Name], [TM/TC Flag], [Type],
[Subtype]
```

where the fields are specified in Table 3.

Table 3. Description of the .marc file fields (version 1.0).

Field	Description	Format	Fixed length	Mandatory
[Reception Time]	Reception time (UTC) of the packet as logged by the ground segment	String with format: 'YYYY-MM-DDThh:mm:ss.[ms]Z'	Y	Y
[Raw CCSDS packet]	The raw CCSDS packet as received by the ground segment	String in ASCII-HEX representation (two characters per byte)	N	Y
[Packet Name]	The packet name as defined in the Metis IDB	String (8chars)	Y	N
[TM/TC Flag]	Flag indicating if the row includes a TM or a TC packet	String (2 chars). Possible values: 'tm' = telemetry packet 'tc' = telecommand packet	Y	N
[Type]	PUS Type of the packet	String (3 chars)	N	N
[Subtype]	PUS Subtype of the packet	String (3chars)	N	N

Example:

```
2017-03-28T07:58:48.184Z,0C55C641001E1003190E1160A3482CDF141160A34800000
000FC0000000000000000000000,YIT59220,tm,3,25
```

5.2 Decoded TM/TC stream: the .decoded file

5.2.1 *Description*

The .decoded file is a CSV text file listing all the decoded TM/TC CCSDS packets contained in the parent .mArc file, one packet per line. The decoding of the packets is performed using the IDB applicable for the OBSW (On-Board Software) version in use.

5.2.2 *File format specification (version 1.0)*

If the line begins with a double hash "##", the line is a comment. If the line begins with the string "#!", the line contains an ancillary parameter. All the remaining lines contains either a TM or a TC decoded packet. The format of the line is different according if it contains a science packet (TM[21,6]) or a non-science packet.

5.2.2.1 Science data format:

The line contains a TM packet in the format:

```
[Reception Time], [TM/TC Flag], [Type], [Subtype], [OBTime Coarse], [OBTime
Fine], [SSID_Raw], [SSID_Eng], "SCI_DATA_HEADER", [Sci Header raw], "SCI_DATA",
[Sci Data raw]
```

where the fields are specified in Table 4.

Table 4. Description of the .decoded file science fields (version 1.0).

Field	Description	Format	Fixed length
[Reception Time]	Reception time (UTC) of the packet as logged by the ground segment	String with format: 'YYYY-MM-DDThh:mm:ss.[ms]Z'	Y
[TM/TC Flag]	Flag indicating if the row includes a TM or a TC packet	String (2 chars). For science packets it has only one possible value: 'tm' = telemetry packet	Y
[Type]	PUS Type of the packet	String (3 chars)	N
[Subtype]	PUS Subtype of the packet	String (3chars)	N
OBTime (coarse)	The OBT (On Board Time) coarse field of the CCSDS packet header, inclusive of the first bit "OBT Sync Flag"	UINT(32)	Y
OBTime (fine)	The OBT fine field of the CCSDS packet head	UINT(16)	Y
[SSID_raw]	This field reports the Science Structure ID in raw format	String (1 char, see Table 5)	N
[SSID_eng]	This field reports the Science Structure ID label (engineering format) as per IDB definition	String (see Table 5)	N

Field	Description	Format	Fixed length
"SCI_DATA_HEADER"	This string indicates that the following field contains the Scientific data header of the decoded scientific data object. It has to be intended as a one-dimensional vector containing the scientific header as it is transmitted in the first packet of the data object stream. The presence of this string in the line identifies univocally a scientific record	Fixed string	Y
[Sci Header raw]	The scientific data header as it is transmitted in the first packet of the data object stream. It has to be intended as a one-dimensional vector		N
"SCI_DATA"	This string indicates that the following field contains the Scientific data stream of the decoded scientific data object. It has to be intended as a one-dimensional vector containing the scientific stream as it is transmitted in the TM packt(s) The presence of this string in the line identifies univocally a scientific record.	Fixed string	Y
[Sci Data raw]	The scientific data stream as it is transmitted in the packet(s) of the data object, in transmission order. It has to be intended as a one-dimensional vector.		N

Table 5. Possible SSID values and corresponding science data object

Raw SSID	Calibrated SSID	Science Data Object
0	VL_IMAGE	Visible-light images
1	UV_IMAGE	Ultra-violet light images
2	PCU_ACCUMUL	PCU events accumulation matrices and vectors
3	VL_TEMP_MATRIX	Visible-light temporal noise (standard-deviation) matrices
4	UV_TEMP_MATRIX	Ultra-violet light temporal noise (standard-deviation) matrices
5	VL_C_RAY_MAT	Visible-light cosmic rays log matrices
6	UV_C_RAY_MAT	Ultra-violet light cosmic rays log matrices
7	PCU_EVENT_LIST	PCU events lists
8	PCU_TEST	PCU test events lists
9	LIGHT_CURVE	Light curves

5.2.2.2 Non-science packet format:

The line contains a TM packet in the format:

```
[Reception Time], [TM/TC Flag], [Type], [Subtype], [OBTime Coarse], [OBTime
Fine], PARAM_NAME1, VALUE_RAW1, VALUE_ENG1, ...
```

where the fields are specified in Table 6.

Table 6. Description of the .decoded file non-science fields (version 1.0).

Field	Description	Format	Fixed length
Reception Time	Reception time (UTC) of the packet as logged by the ground segment	String with format: 'YYYY-MM-DDThh:mm:ss.[ms]Z'	Y
TM/TC Flag	Flag indicating if the row includes a TM or a TC packet	String (2 chars). Possible values: 'tm' = telemetry packet 'tc' = telecommand packet	Y
Type	PUS Type of the packet	String (3 chars)	N
Subtype	PUS Subtype of the packet	String (3chars)	N
OBTime (coarse)	The OBT coarse field of the CCSDS packet header, inclusive of the first bit "OBT Sync Flag"	UINT(32)	Y
OBTime (fine)	The OBT fine field of the CCSDS packet head	UINT(16)	Y
Reception Time	Reception time (UTC) of the packet as logged by the ground segment	String with format: YYYY-MM-DDThh:mm:ss.[ms]Z	Y

5.2.3 *File format specification (version 2.0)*

5.2.3.1 Science data format:

Each line contains a TM packet in the format:

```
[Reception Time], [TM/TC Flag], [Type], [Subtype], [TimeSync Flag], [OBTime
Coarse], [OBTime Fine], [IDB Packet Name], [SSID_Raw], [SSID_Eng],
"SCI_DATA_HEADER", [Sci Header raw], "SCI_DATA", [Sci Data raw]
```

where the fields are specified in Table 7.

Table 7. Description of the .decoded file science fields (version 2.0).

Field	Description	Format	Fixed length
[Reception Time]	Reception time (UTC) of the packet as logged by the ground segment	String with format: 'YYYY-MM-DDThh:mm:ss.[ms]Z'	Y
[TM/TC Flag]	Flag indicating if the row includes a TM or a TC packet	String (2 chars). For science packets it has only one possible value: 'tm' = telemetry packet	Y
[Type]	PUS Type of the packet	String (3 chars)	N
[Subtype]	PUS Subtype of the packet	String (3 chars)	N
[TimeSync Flag]	This is the first (MSB) bit of the OBT coarse	String (1 char): '0' = OBT synchronised, '1' = OBT not synchronised	Y
OBTime (coarse)	The 31 less significant bits of the OBT coarse field of the CCSDS packet header	UINT(32)	Y
OBTime (fine)	The OBT fine field of the CCSDS packet head	UINT(16)	Y

Field	Description	Format	Fixed length
[IDB Packet Name]	This field displays the packet name as declared in the applicable version of the IDMt	String (8 char)	Y
[SSID_raw]	This field reports the Science Structure ID in raw format	String (1 char; see Table 5)	N
[SSID_eng]	This field reports the Science Structure ID label (engineering format) as per IDB definition	String (see Table 5)	N
"SCI_DATA_HEADER"	This string indicates that the following field contains the Scientific data header of the decoded scientific data object It has to be intended as a one-dimensional vector containing the scientific header as it is transmitted in the first packet of the data object stream. The presence of this string in the line identifies univocally a scientific record	Fixed string	Y
[Sci Header raw]	In this field the scientific data header as it is transmitted in the first packet of the data object stream It has to be intended as a one-dimensional vector		N
"SCI_DATA"	This string indicates that the following field contains the Scientific data stream of the decoded scientific data object. It has to be intended as a one-dimensional vector containing the scientific stream as it is transmitted in the TM packt(s). The presence of this string in the line identifies univocally a scientific record	Fixed string	Y
[Sci Data raw]	The scientific data stream as it is transmitted in the packet(s) of the data object, in transmission order. It has to be intended as an one-dimensional vector		N

5.2.3.2 Non-Science data format

Each line contains a TM packet in the format:

```
[Reception Time], [TM/TC Flag], [Type], [Subtype], [TimeSync Flag], [OBTime
Coarse], [OBTime Fine], PARAM_NAME1, VALUE_RAW1, VALUE_ENG1, PARAM_NAME2,
VALUE_RAW2, VALUE_ENG2, ...
```

5.2.4 *File format specification (version 3.0)*

5.2.4.1 Science data format:

Each line contains a TM packet in the format:

```
[Reception Time], [TM/TC Flag], [Type], [Subtype], [TimeSync Flag], [OBTime
Coarse], [OBTime Fine], [IDB Packet Name], [SSID_Raw], [SSID_Eng],
"SCI_DATA_HEADER", [Sci Header raw], "SCI_DATA", [Sci Data raw]
```

where the fields are specified in Table 8.

Table 8. Description of the .decoded file science fields (version 3.0).

Field	Description	Format	Fixed length
[Reception Time]	Reception time (UTC) of the packet as logged by the ground segment	String with format: 'YYYY-MM-DDThh:mm:ss.[ms]Z'	Y
[TM/TC Flag]	Flag indicating if the row includes a TM or a TC packet	String (2 chars). For science packets it has only one possible value: 'tm' = telemetry packet	Y
[Type]	PUS Type of the packet	String (3 chars)	N
[Subtype]	PUS Subtype of the packet	String (3chars)	N
[TimeSync Flag]	This is the first (MSB) bit of the OBT coarse	String (1 char): '0' = OBT synchronised '1' = OBT not synchronised	Y
OBTime (coarse)	The 31 less significant bits of the OBT coarse field of the CCSDS packet header	UINT(32)	Y
OBTime (fine)	The OBT fine field of the CCSDS packet head	UINT(16)	Y
[IDB Packet Name]	This field displays the packet name as declared in the applicable version of the IDMt	String (8 char)	Y
[SSID_raw]	This field reports the Science Structure ID in raw format	String (1 char; see Table 5)	N
[SSID_eng]	This field reports the Science Structure ID label (engineering format) as per IDB definition	String (see Table 5)	N
"SCI_DATA_HEADER"	This string indicates that the following field contains the Scientific data header of the decoded scientific data object It has to be intended as a one-dimensional vector containing the scientific header as it is transmitted in the first packet of the data object stream. The presence of this string in the line identifies univocally a scientific record	Fixed string	Y
[Sci Header raw]	In this field the scientific data header as it is transmitted in the first packet of the data object stream It has to be intended as a one-dimensional vector		N
"SCI_DATA"	This string indicates that the following field contains the Scientific data stream of the decoded scientific data object. It has to be intended as a one-dimensional vector containing the scientific stream as it is transmitted in the TM packt(s). The presence of this string in the line identifies univocally a scientific record	Fixed string	Y
[Sci Data raw]	The scientific data stream as it is transmitted in the packet(s) of the data object, in transmission order. It has to be intended as an one-dimensional vector		N

5.2.4.2 Non-Science data format

The version 3 of the .decoded file has introduced the a different grouping concept:

- groups of fields associated to the same parameter are delimited by the comma "," character;
- within the group, the fields describing the parameter are separated by the pipe "|" character.

Thus, the .decoded can be considered aa s CSV file and can be imported by using as delimiter character either only the comma or both the comma and the pipe.

Each line contains a TM packet in the format:

```
[Reception Time], [TM/TC Flag], [Type], [Subtype], [TimeSync Flag], [OBTime
Coarse], [OBTime Fine], [IDB Packet Name], PARAM1_IDB_NAME |
PARAM1_IDB_Description | [PARAM1_Eng_Units] | PARAM1_Eng_Value |
PARAM1_Raw_Value , PARAM2_IDB_NAME | PARAM2_IDB_Description | [PARAM2_Eng_Units]
| PARAM2_Eng_Value | PARAM2_Raw_Value, ...
```

Example:

```
2018-11-29T03:56:15.997Z,tm,  3, 25,0,        16,
30162,YIT59201,NIT83001|HK_SID||HK_SID_101|101,NIT0D002|Operational
Mode||SAFE|2,NITG2000|#SPW_Status||268632064|268632064,NIT0A001|SRV_20
Lost||TRUE|1,NIT0E0A0|vlda_temp1| [degC]|23.231645|1474, ...
```

6 APPENDIX B - DATA PRODUCTS MATRIX

Table with a summary of the data products names and descriptions.

Product name	Description	Descriptor	Free field	Level
VL images	Single image acquired by the visible-light channel of Metis	`metis-vl-image`	n/a	0, 1, 2
	Polarized-brightness image obtained from a polarized-brightness sequence	`metis-vl-pb`	n/a	2
	Total-brightness image obtained from either a total-brightness acquisition or a polarized-brightness sequence	`metis-vl-tb`	n/a	2
	Polarization angle obtained from a polarized brightness sequence	`metis-vl-pol-angle`	n/a	2
	Stokes parameters	`metis-vl-stokes`	n/a	2
VL light curve	Temporal series of brightness generated by the visible-light channel of Metis	`metis-vl-light-curve`	n/a	0, 1
VL cosmic-ray and SEP log matrix	Image generated by the CR/SEP correction algorithm on board Metis	`metis-vl-c-ray-mat`	n/a	0, 1
VL temporal standard-deviation matrix	Image consisting in the pixel-by-pixel standard deviation computed from a series of frames acquired by the visible-light channel of Metis	`metis-vl-temp-matrix`	n/a	0, 1
UV image	Single image acquired by the ultraviolet channel of Metis in analogue mode	`metis-uv-image`	n/a	0, 1, 2
PCU accumulation matrix	Image collecting all the Lyman-α photons detected by the ultraviolet channel of Metis in PCU mode	`metis-pcu-accumul`	n/a	[TBD]
PCU event list	Temporal series of Lyman-α photons detected by the ultraviolet channel of Metis in PCU mode	`metis-pcu-event`	n/a	[TBD]
UV cosmic-ray and SEP log matrix	Image generated by the CR/SEP correction algorithm on board Metis	`metis-uv-c-ray-mat`	n/a	0, 1
UV temporal standard-deviation matrix	Image consisting in the pixel-by-pixel standard deviation computed from a series of frames acquired by the ultraviolet channel of Metis	`metis-uv-temp-matrix`	n/a	0, 1

7 SAMPLE FILES

The following Sections report example headers of Metis L2 FITS files for the set of data descriptors listed in Sect. 4.1.3. Only primary headers are entirely reported, while for extension headers only keywords that differ with respect to the primary header are listed.

7.1 Header of metis-uv-image Data

```
SIMPLE  =                    T / file conforms to FITS standard
BITPIX  =                  -32 / number of bits per data pixel
NAXIS   =                    2 / number of data axes
NAXIS1  =                  512 / length of data axis 1
NAXIS2  =                  512 / length of data axis 2
EXTEND  =                    T / FITS file contains extensions
LONGSTRN= 'OGIP 1.0'           / FITS header contains long strings
FILENAME= 'solo_L2_metis-uv-image_20210212T001500_V01.fits' / FITS filename
FILE_RAW= '2021-02-12T00.30.02.846988Z-UV_IMAGE.raw' / filename of raw data
PARENT  = 'solo_L1_metis-uv-image_20210212T001500_V01.fits' / name of the parent
APID    =                 1084 / APID number of associated telemetry
DATE    = '2022-09-30T10:10:33.37' / date and time of FITS file creation
DATE-OBS= '2021-02-12T00:15:00.774' / same as DATE-BEG
DATE-BEG= '2021-02-12T00:15:00.774' / start time of observation
DATE-AVG= '2021-02-12T00:22:30.527' / average time of observation
DATE-END= '2021-02-12T00:30:00.281' / end time of observation
TIMESYS = 'UTC     '           / system used for time keywords
TIMRDER =              0.00000 / [s] estimated random error in time values
TIMSYER =              0.00000 / [s] estimated systematic error in time values
OBT_BEG =    666404048.2064972 / start acquisition time in OBT
OBT_END =    666404947.7114972 / end acquisition time in OBT
LEVEL   = 'L2      '           / data processing level
ORIGIN  = 'Metis EGSE'         / location where the FITS file has been generated
CREATOR = 'metis_l2_prep_uv.pro' / FITS creation software
VERS_SW = '3.1.0-SNAPSHOT | 3.1.2' / version of SW that provided FITS file
VERS_CAL= 'LTP01-03_1.0.0'     / version of the calibration package
VERSION = '01      '           / incremental version number of FITS file
OBSRVTRY= 'Solar Orbiter'      / satellite name
TELESCOP= 'SOLO/Metis/UVD'     / telescope that took the measurement
INSTRUME= 'Metis   '           / instrument name
DETECTOR= 'UVD     '           / subunit/sensor
OBJECT  = 'TBD     '           / the use of the keyword OBJECT is [TBD]
OBS_MODE= 'unknown_obs_mode'   / observation mode
OBS_TYPE= '0000    '           / encoded version of OBS_MODE
FILTER  = 'UV      '           / filter used to acquire this image
WAVELNTH=        121.600000000 / [nm] characteristic wavelength of observation
WAVEMIN =        111.600000000 / [nm] min. bandpass wavelength
WAVEMAX =        131.600000000 / [nm] max. bandpass wavelength
WAVEBAND= 'H I Lyman-alpha'    / bandpass description
XPOSURE =        899.505000000 / [s] total effective exposure time
NSUMEXP =                   15 / number of detector readouts summed together
TELAPSE =              899.505 / [s] elapsed time during observation
SOOPNAME= 'unknown_soop'       / name of the SOOP that the data belong to
SOOPTYPE= '000     '           / campaign ID(s) that the data belong to
OBS_ID  = 'smet_0000_000_000_0000_000' / unique ID of the individual observation
TARGET  = 'TBD     '           / type of target from planning
BSCALE  =                    1 / ratio of physical to array value at 0 offset
BZERO   =                    0 / physical value for the array value 0
BTYPE   = 'UV Lyman-alpha intensity' / science data object type
```

```
BUNIT   = 'ph/cm2/s/sr'        / units of physical value
DATAMIN =   -1.69804011297E+14 / minimum value in data
DATAMAX =    4.47871832188E+12 / maximum value in data
NBIN1   =                    2 / binning factor in the dimension 1
NBIN2   =                    2 / binning factor in the dimension 2
NBIN    =                    4 / product of all NBIN values above
PXBEG1  =                    1 / first pixel read out in dimension 1
PXBEG2  =                    1 / first pixel read out in dimension 2
PXEND1  =                  512 / last pixel read out in dimension 1
PXEND2  =                  512 / last pixel read out in dimension 2
COMPRESS= 'lossless'           / data compression quality
COMP_RAT=    7.395066081780612 / data compression ratio
SN_VAR5 =              0.00000 / spatial-noise variance in region 5
SN_VAR4 =              0.00000 / spatial-noise variance in region 4
SN_VAR3 =              0.00000 / spatial-noise variance in region 3
SN_MEAN1=                    0 / spatial-noise mean in region 1
SN_MEAN2=                    0 / spatial-noise mean in region 2
SN_MEAN3=                    0 / spatial-noise mean in region 3
SN_MEAN4=                    0 / spatial-noise mean in region 4
SN_MEAN5=                    0 / spatial-noise mean in region 5
SN_VAR2 =              0.00000 / spatial-noise variance in region 2
SN_VAR1 =              0.00000 / spatial-noise variance in region 1
SESS_NUM= '104301  '           / acquisition session number
HVU_MCP =        3273.00000000 / [raw] HVU MCP commanded voltage
HV_SCR_V=        5353.71222705 / [V] HVU Screen + MCP read voltage
HV_MCP_V=        813.526316516 / [V] HVU MCP read voltage
HV_MCP_I=        8.08330631256 / [uA] HVU MCP current
HV_TEMP =        9.63264462845 / [degC] HVU temperature
RADIAL  = 'Disabled'           / radialization flag
MASKING = 'Disabled'           / masking flag
COMPR   = 'Enabled '           / compression flag
BIN_TYPE=                    0 / binning type
SP_NOISE= 'Disabled'           / spatial-noise algorithm flag
PRESUM  = 'Disabled'           / presum algorithm flag
CR_SEP  = 'Disabled'           / CR/SEP algorithm flag
CR_SEP_B=              0.00000 / CR/SEP algorithm param. B
HVU_SCR =        2787.00000000 / [raw] HVU Screen commanded voltage
CR_SEP_A=              0.00000 / CR/SEP algorithm param. A
NDIT2   =                   15 / number of averaged frames
SNRMAX  =                    0 / [pixel] max. radius for spatial-noise algo
NDIT1   =                    1 / number of hardware-averaged frames
DIT     =                59967 / [ms] detector integration time
WCSNAME = 'Helioprojective-Cartesian' / name of coordinate system
CTYPE1  = 'HPLN-TAN'           / helioprojective longitude (solar x)
CTYPE2  = 'HPLT-TAN'           / helioprojective latitude (solar y)
CUNIT1  = 'arcsec  '           / units along axis 1
CUNIT2  = 'arcsec  '           / units along axis 2
PC1_1   =       0.999657200181 / WCS coordinate transformation matrix
PC1_2   =     -0.0261817136028 / WCS coordinate transformation matrix
PC2_1   =      0.0261817136028 / WCS coordinate transformation matrix
PC2_2   =       0.999657200181 / WCS coordinate transformation matrix
CDELT1  =        40.8000000000 / [arcsec] pixel scale along axis 1
CDELT2  =        40.8000000000 / [arcsec] pixel scale along axis 2
CROTA   =        1.50027304252 / [deg] rotation angle
CRVAL1  =       -56.0242375111 / [arcsec] value of reference pixel along axis 1
CRVAL2  =        80.9371582313 / [arcsec] value of reference pixel along axis 2
CRPIX1  =              256.500 / [pixel] reference pixel location along axis 1
CRPIX2  =              256.500 / [pixel] reference pixel location along axis 2
```

```
SUN_XCEN=        257.820734287 / [pixel] sun center location along axis 1
SUN_YCEN=        254.480974913 / [pixel] sun center location along axis 2
SUNPIX1 =        257.820734287 / [pixel] sun center location along axis 1
SUNPIX2 =        254.480974913 / [pixel] sun center location along axis 2
IO_XCEN =        257.431372549 / [pixel] Metis IO center location along axis 1
IO_YCEN =        247.553921569 / [pixel] Metis IO center location along axis 2
IOPIX1  =        257.431372549 / [pixel] Metis IO center location along axis 1
IOPIX2  =        247.553921569 / [pixel] Metis IO center location along axis 2
FS_XCEN =              256.500 / [pixel] Metis FS center location along axis 1
FS_YCEN =              256.500 / [pixel] Metis FS center location along axis 2
FSPIX1  =              256.500 / [pixel] Metis FS center location along axis 1
FSPIX2  =              256.500 / [pixel] Metis FS center location along axis 2
SC_XCEN =        257.823529412 / [pixel] S/C pointing location along axis 1
SC_YCEN =        254.465686275 / [pixel] S/C pointing location along axis 2
SCPIX1  =        257.823529412 / [pixel] S/C pointing location along axis 1
SCPIX2  =        254.465686275 / [pixel] S/C pointing location along axis 2
SC_YAW  =       0.130333527706 / [arcsec] S/C HPC yaw
SC_PITCH=      -0.620576849165 / [arcsec] S/C HPC pitch
SC_ROLL =        1.58027313652 / [deg] S/C HPC roll angle
INN_FOV =              1.60000 / [deg] inner Metis FOV
OUT_FOV =              3.40000 / [deg] outer Metis FOV
LONPOLE =              180.000 / [deg] native longitude of the celestial pole
RSUN_ARC=        1937.66965221 / [arcsec] apparent photospheric solar radius
RSUN_REF=        695700000.000 / [m] assumed physical solar radius
SOLAR_B0=        1.21997120784 / [deg] S/C tilt of solar north pole
SOLAR_P0=        21.4785783906 / [deg] S/C celestial north to solar north angle
SOLAR_EP=      -0.924929021896 / [deg] S/C ecliptic north to solar north angle
CAR_ROT =        2241.21611272 / carrington rotation number
HGLT_OBS=        1.21997120784 / [deg] S/C heliographic latitude (B0 angle)
HGLN_OBS=       -164.594435970 / [deg] S/C heliographic longitude
CRLT_OBS=        1.21997120784 / [deg] S/C carrington latitude (B0 angle)
CRLN_OBS=        282.199420535 / [deg] S/C carrington longitude (L0 angle)
DSUN_OBS=        74055036391.9 / [m] S/C distance from sun
DSUN_AU =       0.495027342605 / [AU] S/C distance from sun
AU_REF  =        149597870700. / [m] assumed physical astronomical unit
HEEX_OBS=       -71074969580.8 / [m] S/C heliocentric earth ecliptic x
HEEY_OBS=       -19315866056.4 / [m] S/C heliocentric earth ecliptic y
HEEZ_OBS=       -7706778353.53 / [m] S/C heliocentric earth ecliptic z
HCIX_OBS=       -9416736413.40 / [m] S/C heliocentric inertial x
HCIY_OBS=       -73436962840.8 / [m] S/C heliocentric inertial y
HCIZ_OBS=        1576698780.93 / [m] S/C heliocentric inertial z
HCIX_VOB=        48000.2115811 / [m/s] S/C heliocentric inertial x velocity
HCIY_VOB=       -7199.82134973 / [m/s] S/C heliocentric inertial y velocity
HCIZ_VOB=        1361.01936746 / [m/s] S/C heliocentric inertial z velocity
HAEX_OBS=        68490459284.9 / [m] S/C heliocentric aries ecliptic x
HAEY_OBS=       -27089230216.9 / [m] S/C heliocentric aries ecliptic y
HAEZ_OBS=       -7705777586.11 / [m] S/C heliocentric aries ecliptic z
HEQX_OBS=       -71378026727.1 / [m] S/C heliocentric earth equatorial x
HEQY_OBS=       -19668241825.7 / [m] S/C heliocentric earth equatorial y
HEQZ_OBS=        1576698780.93 / [m] S/C heliocentric earth equatorial z
GSEX_OBS=        218750042707. / [m] S/C geocentric solar ecliptic x
GSEY_OBS=        19315866056.4 / [m] S/C geocentric solar ecliptic y
GSEZ_OBS=       -7707067057.27 / [m] S/C geocentric solar ecliptic z
OBS_VR  =        1065.06719994 / [m/s] radial velocity of S/C relative to sun
EAR_TDEL=        245.570009420 / [s] time(sun to earth) - time(sun to S/C)
SUN_TIME=        247.021012089 / [s] time(sun to S/C)
DATE_EAR= '2021-02-12T00:19:06.34' / [UTC] obs. start time corrected to earth
DATE_SUN= '2021-02-12T00:10:53.75' / [UTC] obs. start time corrected to sun
```

```
DATATYPE=                    1 / data product type
CAD_END = '666404947:43919'    / OBT at cadence end
CONF_ID =                    0 / acquisition configuration ID
MASKRMAX=                  640 / [pixel] max. masking radius
N       =               283588 / number of octects in the data stream
CADENCE =               960000 / [ms] acquisition cadence
OBJ_CNT =                    1 / data object counter
CAD_BEG = '666404048:13533'    / OBT at cadence start
IDB_VERS= '4.0     '           /
HDR_VERS= '4       '           / version of the scientific header
SNRMIN  =                    0 / [pixel] min. radius for spatial-noise algo
TSENSOR =       -26.2271454306 / [degC] UVDA temperature
NB_IMG  =                    1 / number of images in the same data stream
MASKRMIN=                  230 / [pixel] min. masking radius
FIRSTROW=                    0 /
B0_BIN  =                    1 /
B0_DQ   =                    0 /
B0_STOP =                 1024 /
B1_BIN  =                    0 /
B1_DQ   =                    0 /
B1_STOP =                    0 /
B2_BIN  =                    0 /
B2_DQ   =                    0 /
B2_STOP =                    0 /
CHECKSUM= 'C29aD18ZC18aC18W'   / HDU checksum updated 2022-10-05T11:13:05
DATASUM = '76735988'           / data unit checksum updated 2022-10-05T11:13:05
INFO_URL= 'http://metis.oato.inaf.it' / link to more information on the instrume
COMMENT Image was rebinned according to the commanded binning factor.
COMMENT Image values were corrected for the total exposure time.
COMMENT WARNING: UV radiometric calibration is still preliminary.
COMMENT Uncertainty matrix in the FITS extension is preliminary.
COMMENT Rotate CROTA degrees counter-clockwise to have Solar North up.
HISTORY L0 FITS file created on 2022-09-30T06:26:53.430816
HISTORY WCS and solar ephemeris:
HISTORY   SKD version = v107_20210723_001
HISTORY L1 FITS file created on 2022-09-30T10:10:33.37
HISTORY Dark-current correction:
HISTORY   Dark_UVDA_STP144_DIT-59967ms_NDIT1-1_NDIT2-15_z1.fits
HISTORY   extrapolated dark = false
HISTORY   renormalized dark = false
HISTORY Flat-field correction:
HISTORY   FF_UVDA_LYA_20160701_bin=2.fits
HISTORY Vignetting correction:
HISTORY   VF.fits shifted by [-20.2, 49.0] pixel
HISTORY Radiometric calibration:
HISTORY   efficiency corr. map = UV_RC_eff_map_det.fits
HISTORY Update WCS and solar ephemeris:
HISTORY   SKD version = v107_20220927_001
HISTORY L2 FITS file created on 2022-10-05T11:13:04.58
END
```

7.1.1 Quality Matrix Extension

```
XTENSION= 'IMAGE   '           / image extension
BITPIX  =                  -32 / number of bits per data pixel
NAXIS   =                    2 / number of data axes
NAXIS1  =                  512 / length of data axis 1
```

```
NAXIS2  =                  512 / length of data axis 2
PCOUNT  =                    0 / parameter count
GCOUNT  =                    1 / group count
EXTNAME = 'Quality matrix'     / extension name
…
BTYPE   = 'Pixel quality'      / science data object type
BUNIT   = 'None    '           / units of physical value
DATAMIN =              0.00000 / minimum value in data
DATAMAX =              1.00000 / maximum value in data
…
COMMENT Quality matrix values:
COMMENT   NaN = saturated or null L0 pixel counts
COMMENT   0   = unreliable pixel value
COMMENT   1   = good pixel
…
```

7.1.2 Error Matrix Extension

```
XTENSION= 'IMAGE   '           / image extension
BITPIX  =                  -32 / number of bits per data pixel
NAXIS   =                    2 / number of data axes
NAXIS1  =                  512 / length of data axis 1
NAXIS2  =                  512 / length of data axis 2
PCOUNT  =                    0 / parameter count
GCOUNT  =                    1 / group count
EXTNAME = 'Error matrix'       / extension name
…
BTYPE   = 'Absolute error'     / science data object type
BUNIT   = 'ph/cm2/s/sr'        / units of physical value
…
```

7.2 Header of `metis-vl-image` Data

```
SIMPLE  =                    T / file conforms to FITS standard
BITPIX  =                  -32 / number of bits per data pixel
NAXIS   =                    2 / number of data axes
NAXIS1  =                 1024 / length of data axis 1
NAXIS2  =                 1024 / length of data axis 2
EXTEND  =                    T / FITS file contains extensions
LONGSTRN= 'OGIP 1.0'           / FITS header contains long strings
FILENAME= 'solo_L2_metis-vl-image_20210212T001501_V01.fits' / FITS filename
FILE_RAW= '2021-02-12T00.44.27.715211Z-VL_IMAGE.raw' / filename of raw data
PARENT  = 'solo_L1_metis-vl-image_20210212T001501_V01.fits' / name of the parent
APID    =                 1084 / APID number of associated telemetry
DATE    = '2022-09-30T10:08:49.65' / date and time of FITS file creation
DATE-OBS= '2021-02-12T00:15:01.285' / same as DATE-BEG
DATE-BEG= '2021-02-12T00:15:01.285' / start time of observation
DATE-AVG= '2021-02-12T00:29:30.287' / average time of observation
DATE-END= '2021-02-12T00:43:59.288' / end time of observation
TIMESYS = 'UTC     '           / system used for time keywords
TIMRDER =              0.00000 / [s] estimated random error in time values
TIMSYER =              0.00000 / [s] estimated systematic error in time values
OBT_BEG =     666404048.717453 / start acquisition time in OBT
OBT_END =     666405786.717453 / end acquisition time in OBT
LEVEL   = 'L2      '           / data processing level
ORIGIN  = 'Metis EGSE'         / location where the FITS file has been generated
CREATOR = 'metis_l2_prep_vl_generic.pro' / FITS creation software
```

```
VERS_SW = '3.1.0-SNAPSHOT | 3.1.2' / version of SW that provided FITS file
VERS_CAL= 'LTP01-03_1.0.0'     / version of the calibration package
VERSION = '01      '           / incremental version number of FITS file
OBSRVTRY= 'Solar Orbiter'      / satellite name
TELESCOP= 'SOLO/Metis/VLD'     / telescope that took the measurement
INSTRUME= 'Metis   '           / instrument name
DETECTOR= 'VLD     '           / subunit/sensor
OBJECT  = 'TBD     '           / the use of the keyword OBJECT is [TBD]
OBS_MODE= 'METIS_GENERIC'      / observation mode
OBS_TYPE= 'iXmr    '           / encoded version of OBS_MODE
FILTER  = 'VL      '           / filter used to acquire this image
WAVELNTH=        610.000000000 / [nm] characteristic wavelength of observation
WAVEMIN =        580.000000000 / [nm] min. bandpass wavelength
WAVEMAX =        640.000000000 / [nm] max. bandpass wavelength
WAVEBAND= 'Visible light'      / bandpass description
XPOSURE =        450.000000000 / [s] total effective exposure time
NSUMEXP =                   15 / number of detector readouts summed together
TELAPSE =              1738.00 / [s] elapsed time during observation
SOOPNAME= 'unknown_soop'       / name of the SOOP that the data belong to
SOOPTYPE= '000     '           / campaign ID(s) that the data belong to
OBS_ID  = 'SMET_031A_000_000_iXmr_112' / unique ID of the individual observation
TARGET  = 'TBD     '           / type of target from planning
BSCALE  =                    1 / ratio of physical to array value at 0 offset
BZERO   =                    0 / physical value for the array value 0
BTYPE   = 'VL fixed-polarization intensity' / science data object type
BUNIT   = 'MSB     '           / units of physical value
DATAMIN =   -5.48443175330E-07 / minimum value in data
DATAMAX =    2.04315260155E-07 / maximum value in data
NBIN1   =                    2 / binning factor in the dimension 1
NBIN2   =                    2 / binning factor in the dimension 2
NBIN    =                    4 / product of all NBIN values above
PXBEG1  =                    1 / first pixel read out in dimension 1
PXBEG2  =                    1 / first pixel read out in dimension 2
PXEND1  =                 1024 / last pixel read out in dimension 1
PXEND2  =                 1024 / last pixel read out in dimension 2
COMPRESS= 'lossless'           / data compression quality
COMP_RAT=    10.89814583852997 / data compression ratio
SN_VAR5 =              0.00000 / spatial-noise variance in region 1
SN_VAR4 =              0.00000 / spatial-noise variance in region 4
SN_VAR3 =              0.00000 / spatial-noise variance in region 3
SN_MEAN1=                    0 / spatial-noise mean in region 1
SN_MEAN2=                    0 / spatial-noise mean in region 2
SN_MEAN3=                    0 / spatial-noise mean in region 3
SN_MEAN4=                    0 / spatial-noise mean in region 4
SN_MEAN5=                    0 / spatial-noise mean in region 5
SN_VAR2 =              0.00000 / spatial-noise variance in region 2
SN_VAR1 =              0.00000 / spatial-noise variance in region 1
SESS_NUM= '104301  '           / acquisition session number
RADIAL  = 'Disabled'           / radialization flag
MASKING = 'Enabled '           / masking flag
COMPR   = 'Enabled '           / compression flag
N_POL   =                    4 / number of polarizations used
FRAMEMOD= 'Single  '           / frame acquisition mode
SP_NOISE= 'Disabled'           / spatial-noise algorithm flag
SUNDISK = 'Disabled'           / sun-disk monitor flag
CME_OBS = 'Disabled'           / CME detection algorithm flag
MEASKIND= 'pB      '           / measurement kind
CR_SEP  = 'Disabled'           / CR/SEP algorithm flag
```

```
VLFPFILT= 'Not applicable'     / fixed polarization pre-filter
PMPSTAB = 'Stable  '           / PMP temperature stability flag
CR_SEP_B=              0.00000 / CR/SEP algorithm param. B
CR_SEP_A=              0.00000 / CR/SEP algorithm param. A
SNRMAX  =                    0 / [pixel] max. radius for spatial-noise algo
DIT     =                30000 / [ms] detector integration time
NDIT    =                   15 / number of averaged frames
WCSNAME = 'Helioprojective-Cartesian' / name of coordinate system
CTYPE1  = 'HPLN-TAN'           / helioprojective longitude (solar x)
CTYPE2  = 'HPLT-TAN'           / helioprojective latitude (solar y)
CUNIT1  = 'arcsec  '           / units along axis 1
CUNIT2  = 'arcsec  '           / units along axis 2
PC1_1   =       0.999657386506 / WCS coordinate transformation matrix
PC1_2   =     -0.0261745984392 / WCS coordinate transformation matrix
PC2_1   =      0.0261745984392 / WCS coordinate transformation matrix
PC2_2   =       0.999657386506 / WCS coordinate transformation matrix
CDELT1  =        20.2760000000 / [arcsec] pixel scale along axis 1
CDELT2  =        20.2760000000 / [arcsec] pixel scale along axis 2
CROTA   =        1.49986523394 / [deg] rotation angle
CRVAL1  =       -274.377608656 / [arcsec] value of reference pixel along axis 1
CRVAL2  =        573.110285032 / [arcsec] value of reference pixel along axis 2
CRPIX1  =              512.500 / [pixel] reference pixel location along axis 1
CRPIX2  =              512.500 / [pixel] reference pixel location along axis 2
SUN_XCEN=        525.287663820 / [pixel] sun center location along axis 1
SUN_YCEN=        483.890034847 / [pixel] sun center location along axis 2
SUNPIX1 =        525.287663820 / [pixel] sun center location along axis 1
SUNPIX2 =        483.890034847 / [pixel] sun center location along axis 2
IO_XCEN =        524.484612350 / [pixel] Metis IO center location along axis 1
IO_YCEN =        469.986683764 / [pixel] Metis IO center location along axis 2
IOPIX1  =        524.484612350 / [pixel] Metis IO center location along axis 1
IOPIX2  =        469.986683764 / [pixel] Metis IO center location along axis 2
FS_XCEN =              512.500 / [pixel] Metis FS center location along axis 1
FS_YCEN =              512.500 / [pixel] Metis FS center location along axis 2
FSPIX1  =              512.500 / [pixel] Metis FS center location along axis 1
FSPIX2  =              512.500 / [pixel] Metis FS center location along axis 2
SC_XCEN =        525.273722628 / [pixel] S/C pointing location along axis 1
SC_YCEN =        483.894752417 / [pixel] S/C pointing location along axis 2
SCPIX1  =        525.273722628 / [pixel] S/C pointing location along axis 1
SCPIX2  =        483.894752417 / [pixel] S/C pointing location along axis 2
SC_YAW  =      -0.285078456582 / [arcsec] S/C HPC yaw
SC_PITCH=      0.0882218537956 / [arcsec] S/C HPC pitch
SC_ROLL =        1.57986532791 / [deg] S/C HPC roll angle
INN_FOV =              1.60000 / [deg] inner Metis FOV
OUT_FOV =              3.40000 / [deg] outer Metis FOV
LONPOLE =              180.000 / [deg] native longitude of the celestial pole
RSUN_ARC=        1937.65793763 / [arcsec] apparent photospheric solar radius
RSUN_REF=        695700000.000 / [m] assumed physical solar radius
SOLAR_B0=        1.22040590446 / [deg] S/C tilt of solar north pole
SOLAR_P0=        21.4825148678 / [deg] S/C celestial north to solar north angle
SOLAR_EP=      -0.922944058953 / [deg] S/C ecliptic north to solar north angle
CAR_ROT =        2241.21626036 / carrington rotation number
HGLT_OBS=        1.22040590446 / [deg] S/C heliographic latitude (B0 angle)
HGLN_OBS=       -164.583616219 / [deg] S/C heliographic longitude
CRLT_OBS=        1.22040590446 / [deg] S/C carrington latitude (B0 angle)
CRLN_OBS=        282.146271050 / [deg] S/C carrington longitude (L0 angle)
DSUN_OBS=        74055484136.1 / [m] S/C distance from sun
DSUN_AU =       0.495030335590 / [AU] S/C distance from sun
AU_REF  =        149597870700. / [m] assumed physical astronomical unit
```

```
HEEX_OBS=       -71071735019.5 / [m] S/C heliocentric earth ecliptic x
HEEY_OBS=       -19329553859.0 / [m] S/C heliocentric earth ecliptic y
HEEZ_OBS=       -7706591955.06 / [m] S/C heliocentric earth ecliptic z
HCIX_OBS=       -9396587573.70 / [m] S/C heliocentric inertial x
HCIY_OBS=       -73439982923.7 / [m] S/C heliocentric inertial y
HCIZ_OBS=        1577270037.03 / [m] S/C heliocentric inertial z
HCIX_VOB=        48001.5018035 / [m/s] S/C heliocentric inertial x velocity
HCIY_VOB=       -7189.74821859 / [m/s] S/C heliocentric inertial y velocity
HCIZ_VOB=        1360.80305600 / [m/s] S/C heliocentric inertial z velocity
HAEX_OBS=        68498387438.5 / [m] S/C heliocentric aries ecliptic x
HAEY_OBS=       -27070454355.8 / [m] S/C heliocentric aries ecliptic y
HAEZ_OBS=       -7705592121.05 / [m] S/C heliocentric aries ecliptic z
HEQX_OBS=       -71374731300.4 / [m] S/C heliocentric earth equatorial x
HEQY_OBS=       -19681836338.8 / [m] S/C heliocentric earth equatorial y
HEQZ_OBS=        1577270037.03 / [m] S/C heliocentric earth equatorial z
GSEX_OBS=        218746943213. / [m] S/C geocentric solar ecliptic x
GSEY_OBS=        19329553859.0 / [m] S/C geocentric solar ecliptic y
GSEZ_OBS=       -7706880826.87 / [m] S/C geocentric solar ecliptic z
OBS_VR  =        1068.26693314 / [m/s] radial velocity of S/C relative to sun
EAR_TDEL=        245.568966439 / [s] time(sun to earth) - time(sun to S/C)
SUN_TIME=        247.022505603 / [s] time(sun to S/C)
DATE_EAR= '2021-02-12T00:19:06.85' / [UTC] obs. start time corrected to earth
DATE_SUN= '2021-02-12T00:10:54.26' / [UTC] obs. start time corrected to sun
DATATYPE=                    0 / data product type
REF_ROWS= 'Not included'       / reference rows inclusion flag
CAD_END = '666405896:4228'     / OBT at cadence end
POL_ID  =                    1 / polarization ID
POLANGLE=              49.1000 / [deg] polarization angle
DAC2POL3=                 7318 / [raw] DAC2 for pol. ID 3
DAC2POL4=                 6051 / [raw] DAC2 for pol. ID 4
DAC2POL1=                15837 / [raw] DAC2 for pol. ID 0, 1, or 5
CONF_ID =                    0 / acquisition configuration ID
DAC2POL2=                10048 / [raw] DAC2 for pol. ID 2 or 6
DAC1POL1=                15837 / [raw] DAC1 for pol. ID 0, 1, or 5
MASKRMAX=                 1280 / [pixel] max. masking radius
N       =               769728 / number of octects in the data stream
CADENCE =              1830000 / [ms] acquisition cadence
OBJ_CNT =                    1 / data object counter
BIN_TYPE=                    0 / binning type
CAD_BEG = '666404048:47019'    / OBT at cadence start
DAC1POL2=                10048 / [raw] DAC1 for pol. ID 2 or 6
DAC1POL3=                 7318 / [raw] DAC1 for pol. ID 3
IDB_VERS= '4.0     '           /
HDR_VERS= '4       '           / version of the scientific header
DAC1POL4=                 6051 / [raw] DAC1 for pol. ID 4
SNRMIN  =                    0 / [pixel] min. radius for spatial-noise algo
TSENSOR =       -30.1868183994 / [degC] VLDA temperature
PMPTEMP =        29.9586287136 / [degC] PMP temperature
NB_IMG  =                    1 / number of images in the same data stream
MASKRMIN=                  460 / [pixel] min. masking radius
SEQ_NUM =                    1 / polarization sequence counter
FIRSTROW=                    0 /
B0_BIN  =                    1 /
B0_DQ   =                    0 /
B0_STOP =                 2048 /
B1_BIN  =                    0 /
B1_DQ   =                    0 /
B1_STOP =                    0 /
```

```
B2_BIN  =                    0 /
B2_DQ   =                    0 /
B2_STOP =                    0 /
CHECKSUM= 'CA6IF54GCA4GC34G'   / HDU checksum updated 2022-10-05T11:13:12
DATASUM = '2369652384'         / data unit checksum updated 2022-10-05T11:13:12
INFO_URL= 'http://metis.oato.inaf.it' / link to more information on the instrume
COMMENT Image was rebinned according to the commanded binning factor.
COMMENT Image values were corrected for the total exposure time.
COMMENT Uncertainty matrix in the FITS extension is preliminary.
COMMENT Rotate CROTA degrees counter-clockwise to have Solar North up.
HISTORY L0 FITS file created on 2022-09-30T06:27:35.046060
HISTORY WCS and solar ephemeris:
HISTORY   SKD version = v107_20210723_001
HISTORY L1 FITS file created on 2022-09-30T10:08:49.65
HISTORY Bias and dark-current corrections:
HISTORY   solo_CAL_metis-vl-bias_20210224_V01.fits
HISTORY   map_dark_it2_fit_wr.fits
HISTORY Flat-field correction:
HISTORY   flat_vlda_JP_15MHZ_MPS_v1.fits
HISTORY Vignetting correction:
HISTORY   VF.fits shifted by [0.0, 0.0] pixel
HISTORY Radiometric calibration:
HISTORY   cal. factor = 1.38E-15 MSB/DN
HISTORY   1 MSB = 4.67E+20 ph/cm2/s/sr
HISTORY Update WCS and solar ephemeris:
HISTORY   SKD version = v107_20220927_001
HISTORY L2 FITS file created on 2022-10-05T11:13:11.54
END
```

7.2.1 Quality Metrix Extension

```
XTENSION= 'IMAGE   '           / image extension
BITPIX  =                  -32 / number of bits per data pixel
NAXIS   =                    2 / number of data axes
NAXIS1  =                 1024 / length of data axis 1
NAXIS2  =                 1024 / length of data axis 2
PCOUNT  =                    0 / parameter count
GCOUNT  =                    1 / group count
EXTNAME = 'Quality matrix'     / extension name
…
BTYPE   = 'Pixel quality'      / science data object type
BUNIT   = 'None    '           / units of physical value
DATAMIN =              0.00000 / minimum value in data
DATAMAX =              1.00000 / maximum value in data
…
COMMENT Quality matrix values:
COMMENT   NaN = saturated or null L0 pixel counts
COMMENT   0   = unreliable pixel value
COMMENT   1   = good pixel
…
```

7.2.2 Error Matrix Extension

```
XTENSION= 'IMAGE   '           / image extension
BITPIX  =                  -32 / number of bits per data pixel
NAXIS   =                    2 / number of data axes
NAXIS1  =                 1024 / length of data axis 1
NAXIS2  =                 1024 / length of data axis 2
```

```
PCOUNT  =                    0 / parameter count
GCOUNT  =                    1 / group count
EXTNAME = 'Error matrix'       / extension name
…
BTYPE   = 'Absolute error'     / science data object type
BUNIT   = 'MSB     '           / units of physical value
…
```

7.3 Header of metis-vl-pb Data

```
SIMPLE  =                    T / file conforms to FITS standard
BITPIX  =                  -32 / number of bits per data pixel
NAXIS   =                    2 / number of data axes
NAXIS1  =                 1024 / length of data axis 1
NAXIS2  =                 1024 / length of data axis 2
EXTEND  =                    T / FITS file contains extensions
LONGSTRN= 'OGIP 1.0'           / FITS header contains long strings
FILENAME= 'solo_L2_metis-vl-pb_20210212T001501_V01.fits' / FITS filename
FILE_RAW= '2021-02-12T00.45.59.589567Z-VL_IMAGE.raw' / filename of raw data
PARENT  = 'solo_L1_metis-vl-image_20210212T001501_V01.fits, solo_L1_metis-vl-i&'
CONTINUE  'mage_20210212T001531_V01.fits, solo_L1_metis-vl-image_20210212T0016&'
CONTINUE  '02_V01.fits, solo_L1_metis-vl-image_20210212T001632_V01.fits&' /
CONTINUE  '' / name of the parent file
APID    =                 1084 / APID number of associated telemetry
DATE    = '2022-10-05T11:13:22.52' / date and time of FITS file creation
DATE-OBS= '2021-02-12T00:15:01.285' / same as DATE-BEG
DATE-BEG= '2021-02-12T00:15:01.285' / start time of observation
DATE-AVG= '2021-02-12T00:30:16.037' / average time of observation
DATE-END= '2021-02-12T00:45:30.788' / end time of observation
TIMESYS = 'UTC     '           / system used for time keywords
TIMRDER =              0.00000 / [s] estimated random error in time values
TIMSYER =              0.00000 / [s] estimated systematic error in time values
OBT_BEG =      666404048.71745 / start acquisition time in on-board time
OBT_END =      666405878.21745 / end acquisition time in on-board time
LEVEL   = 'L2      '           / data processing level
ORIGIN  = 'Metis EGSE'         / location where the FITS file has been generated
CREATOR = 'metis_l2_prep_vl_polariz.pro' / FITS creation software
VERS_SW = '3.1.0-SNAPSHOT | 3.1.2' / version of SW that provided FITS file
VERS_CAL= 'LTP01-03_1.0.0'     / version of the calibration package
VERSION = '01      '           / incremental version number of FITS file
OBSRVTRY= 'Solar Orbiter'      / satellite name
TELESCOP= 'SOLO/Metis/VLD'     / telescope that took the measurement
INSTRUME= 'Metis   '           / instrument name
DETECTOR= 'VLD     '           / subunit/sensor
OBJECT  = 'TBD     '           / the use of the keyword OBJECT is [TBD]
OBS_MODE= 'METIS_GENERIC'      / observation mode
OBS_TYPE= 'iXmr    '           / encoded version of OBS_MODE
FILTER  = 'VL      '           / filter used to acquire this image
WAVELNTH=        610.000000000 / [nm] characteristic wavelength of observation
WAVEMIN =        580.000000000 / [nm] min. bandpass wavelength
WAVEMAX =        640.000000000 / [nm] max. bandpass wavelength
WAVEBAND= 'Visible light'      / bandpass description
XPOSURE =        450.000000000 / [s] total effective exposure time
NSUMEXP =                   15 / number of detector readouts summed together
TELAPSE =        1829.50000000 / [s] elapsed time between beginning and end of o
SOOPNAME= 'unknown_soop'       / name of the SOOP that the data belong to
SOOPTYPE= '000     '           / campaign ID(s) that the data belong to
OBS_ID  = 'SMET_031A_000_000_iXmr_112' / unique ID of the individual observation
```

```
TARGET  = 'TBD     '           / type of target from planning
BSCALE  =                    1 / ratio of physical to array value at 0 offset
BZERO   =                    0 / physical value for the array value 0
BTYPE   = 'VL polarized brightness' / science data object type
BUNIT   = 'MSB     '           / units of physical value
DATAMIN =       0.00000000000 / minimum value in data
DATAMAX =    1.29263359665E-07 / maximum value in data
NBIN1   =                    2 / binning factor in the dimension 1
NBIN2   =                    2 / binning factor in the dimension 2
NBIN    =                    4 / product of all NBIN values above
PXBEG1  =                    1 / first pixel read out in dimension 1
PXBEG2  =                    1 / first pixel read out in dimension 2
PXEND1  =                 1024 / last pixel read out in dimension 1
PXEND2  =                 1024 / last pixel read out in dimension 2
COMPRESS= 'lossless'           / data compression quality
COMP_RAT=    10.87548293082616 / data compression ratio
SESS_NUM= '104301  '           / acquisition session number
RADIAL  = 'Disabled'           / radialization flag
MASKING = 'Enabled '           / masking flag
COMPR   = 'Enabled '           / compression flag
N_POL   =                    4 / number of polarizations used
FRAMEMOD= 'Single  '           / frame acquisition mode
SP_NOISE= 'Disabled'           / spatial-noise algorithm flag
SUNDISK = 'Disabled'           / sun-disk monitor flag
CME_OBS = 'Disabled'           / CME detection algorithm flag
MEASKIND= 'pB      '           / measurement kind
CR_SEP  = 'Disabled'           / CR/SEP algorithm flag
VLFPFILT= 'Not applicable'     / fixed polarization pre-filter
PMPSTAB = 'Stable  '           / PMP temperature stability flag
CR_SEP_B=              0.00000 / CR/SEP algorithm param. B
CR_SEP_A=              0.00000 / CR/SEP algorithm param. A
DIT     =                30000 / [ms] detector integration time
NDIT    =                   15 / number of averaged frames
WCSNAME = 'Helioprojective-Cartesian' / name of coordinate system
CTYPE1  = 'HPLN-TAN'           / helioprojective longitude (solar x)
CTYPE2  = 'HPLT-TAN'           / helioprojective latitude (solar y)
CUNIT1  = 'arcsec  '           / units along axis 1
CUNIT2  = 'arcsec  '           / units along axis 2
PC1_1   =       0.999657407335 / WCS coordinate transformation matrix
PC1_2   =     -0.0261738029466 / WCS coordinate transformation matrix
PC2_1   =      0.0261738029466 / WCS coordinate transformation matrix
PC2_2   =       0.999657407335 / WCS coordinate transformation matrix
CDELT1  =        20.2760000000 / [arcsec] pixel scale along axis 1
CDELT2  =        20.2760000000 / [arcsec] pixel scale along axis 2
CROTA   =        1.49981963996 / [deg] rotation angle
CRVAL1  =       -273.392433976 / [arcsec] value of reference pixel along axis 1
CRVAL2  =        573.477950982 / [arcsec] value of reference pixel along axis 2
CRPIX1  =              512.500 / [pixel] reference pixel location along axis 1
CRPIX2  =              512.500 / [pixel] reference pixel location along axis 2
SUN_XCEN=        525.238640405 / [pixel] sun center location along axis 1
SUN_YCEN=        483.873189912 / [pixel] sun center location along axis 2
SUNPIX1 =        525.238640405 / [pixel] sun center location along axis 1
SUNPIX2 =        483.873189912 / [pixel] sun center location along axis 2
IO_XCEN =        524.484612350 / [pixel] Metis IO center location along axis 1
IO_YCEN =        469.986683764 / [pixel] Metis IO center location along axis 2
IOPIX1  =        524.484612350 / [pixel] Metis IO center location along axis 1
IOPIX2  =        469.986683764 / [pixel] Metis IO center location along axis 2
FS_XCEN =              512.500 / [pixel] Metis FS center location along axis 1
```

```
FS_YCEN =              512.500 / [pixel] Metis FS center location along axis 2
FSPIX1  =              512.500 / [pixel] Metis FS center location along axis 1
FSPIX2  =              512.500 / [pixel] Metis FS center location along axis 2
SC_XCEN =        525.273722628 / [pixel] S/C pointing location along axis 1
SC_YCEN =        483.894752417 / [pixel] S/C pointing location along axis 2
SCPIX1  =        525.273722628 / [pixel] S/C pointing location along axis 1
SCPIX2  =        483.894752417 / [pixel] S/C pointing location along axis 2
SC_YAW  =       0.699640233261 / [arcsec] S/C HPC yaw
SC_PITCH=       0.455669690934 / [arcsec] S/C HPC pitch
SC_ROLL =        1.57981973393 / [deg] S/C HPC roll angle
INN_FOV =              1.60000 / [deg] inner Metis FOV
OUT_FOV =              3.40000 / [deg] outer Metis FOV
LONPOLE =              180.000 / [deg] native longitude of the celestial pole
RSUN_ARC=        1937.65665873 / [arcsec] apparent photospheric solar radius
RSUN_REF=        695700000.000 / [m] assumed physical solar radius
SOLAR_B0=        1.22045327652 / [deg] S/C tilt of solar north pole
SOLAR_P0=        21.4829438061 / [deg] S/C celestial north to solar north angle
SOLAR_EP=      -0.922727713439 / [deg] S/C ecliptic north to solar north angle
CAR_ROT =        2241.21627645 / carrington rotation number
HGLT_OBS=        1.22045327652 / [deg] S/C heliographic latitude (B0 angle)
HGLN_OBS=       -164.582436976 / [deg] S/C heliographic longitude
CRLT_OBS=        1.22045327652 / [deg] S/C carrington latitude (B0 angle)
CRLN_OBS=        282.140478231 / [deg] S/C carrington longitude (L0 angle)
DSUN_OBS=        74055533017.3 / [m] S/C distance from sun
DSUN_AU =       0.495030662340 / [AU] S/C distance from sun
AU_REF  =        149597870700. / [m] assumed physical astronomical unit
HEEX_OBS=       -71071382408.0 / [m] S/C heliocentric earth ecliptic x
HEEY_OBS=       -19331045679.9 / [m] S/C heliocentric earth ecliptic y
HEEZ_OBS=       -7706571612.52 / [m] S/C heliocentric earth ecliptic z
HCIX_OBS=       -9394391501.77 / [m] S/C heliocentric inertial x
HCIY_OBS=       -73440311829.6 / [m] S/C heliocentric inertial y
HCIZ_OBS=        1577332293.23 / [m] S/C heliocentric inertial z
HCIX_VOB=        48001.6422584 / [m/s] S/C heliocentric inertial x velocity
HCIY_VOB=       -7188.65032564 / [m/s] S/C heliocentric inertial y velocity
HCIZ_VOB=        1360.77947556 / [m/s] S/C heliocentric inertial z velocity
HAEX_OBS=        68499251296.3 / [m] S/C heliocentric aries ecliptic x
HAEY_OBS=       -27068407864.5 / [m] S/C heliocentric aries ecliptic y
HAEZ_OBS=       -7705571880.24 / [m] S/C heliocentric aries ecliptic z
HEQX_OBS=       -71374372054.4 / [m] S/C heliocentric earth equatorial x
HEQY_OBS=       -19683317991.4 / [m] S/C heliocentric earth equatorial y
HEQZ_OBS=        1577332293.23 / [m] S/C heliocentric earth equatorial z
GSEX_OBS=        218746605323. / [m] S/C geocentric solar ecliptic x
GSEY_OBS=        19331045679.9 / [m] S/C geocentric solar ecliptic y
GSEZ_OBS=       -7706860502.61 / [m] S/C geocentric solar ecliptic z
OBS_VR  =        1068.61566762 / [m/s] radial velocity of S/C relative to sun
EAR_TDEL=        245.568852495 / [s] time(sun to earth) - time(sun to S/C)
SUN_TIME=        247.022668653 / [s] time(sun to S/C)
DATE_EAR= '2021-02-12T00:19:06.85' / [UTC] obs. start time corrected to earth
DATE_SUN= '2021-02-12T00:10:54.26' / [UTC] obs. start time corrected to sun
DATATYPE=                    0 / data product type
REF_ROWS= 'Not included'       / reference rows inclusion flag
CAD_END = '666405896:4228'     / OBT at cadence end
DAC2POL3=                 7318 / [raw] DAC2 for pol. ID 3
DAC2POL4=                 6051 / [raw] DAC2 for pol. ID 4
DAC2POL1=                15837 / [raw] DAC2 for pol. ID 0, 1, or 5
CONF_ID =                    0 / acquisition configuration ID
DAC2POL2=                10048 / [raw] DAC2 for pol. ID 2 or 6
DAC1POL1=                15837 / [raw] DAC1 for pol. ID 0, 1, or 5
```

```
MASKRMAX=                 1280 / [pixel] max. masking radius
CADENCE =              1830000 / [ms] acquisition cadence
BIN_TYPE=                    0 / binning type
CAD_BEG = '666404048:47019'    / OBT at cadence start
DAC1POL2=                10048 / [raw] DAC1 for pol. ID 2 or 6
DAC1POL3=                 7318 / [raw] DAC1 for pol. ID 3
IDB_VERS= '4.0     '           /
HDR_VERS= '4       '           / version of the scientific header
DAC1POL4=                 6051 / [raw] DAC1 for pol. ID 4
TSENSOR =       -30.1574346277 / [degC] VLDA temperature
PMPTEMP =        29.9612886856 / [degC] PMP temperature
MASKRMIN=                  460 / [pixel] min. masking radius
SEQ_NUM =                    1 / polarization sequence counter
FIRSTROW=                    0 /
B0_BIN  =                    1 /
B0_DQ   =                    0 /
B0_STOP =                 2048 /
B1_BIN  =                    0 /
B1_DQ   =                    0 /
B1_STOP =                    0 /
B2_BIN  =                    0 /
B2_DQ   =                    0 /
B2_STOP =                    0 /
CHECKSUM= '9CjiEBgi9BgiEBgi'   / HDU checksum updated 2022-10-05T11:13:23
DATASUM = '1211940628'         / data unit checksum updated 2022-10-05T11:13:23
INFO_URL= 'http://metis.oato.inaf.it' / link to more information on the instrume
COMMENT Image was rebinned according to the commanded binning factor.
COMMENT Image values were corrected for the total exposure time.
COMMENT Uncertainty matrix in the FITS extension is preliminary.
COMMENT Rotate CROTA degrees counter-clockwise to have Solar North up.
HISTORY L0 FITS file created on 2022-09-30T06:27:35.722806
HISTORY WCS and solar ephemeris:
HISTORY   SKD version = v107_20210723_001
HISTORY L1 FITS file created on 2022-09-30T10:10:32.35
HISTORY Demodulation performed for angles 49.1, 84.3, 133.2, 181.8 deg
HISTORY Flat-field correction:
HISTORY   flat_vlda_JP_15MHZ_MPS_v1.fits
HISTORY Vignetting correction:
HISTORY   VF.fits shifted by [0.0, 0.0] pixel
HISTORY Radiometric calibration:
HISTORY   cal. factor = 1.38E-15 MSB/DN
HISTORY   1 MSB = 4.67E+20 ph/cm2/s/sr
HISTORY Update WCS and solar ephemeris:
HISTORY   SKD version = v107_20220927_001
HISTORY L2 FITS file created on 2022-10-05T11:13:22.52
END
```

7.3.1 Quality Matrix Extension

See Sect. 7.2.1.

7.3.2 Error Matrix Extension

See Sect. 7.2.2.

7.4 Header of metis-vl-tb Data

```
SIMPLE  =                    T / file conforms to FITS standard
BITPIX  =                  -32 / number of bits per data pixel
NAXIS   =                    2 / number of data axes
NAXIS1  =                 1024 / length of data axis 1
NAXIS2  =                 1024 / length of data axis 2
EXTEND  =                    T / FITS file contains extensions
LONGSTRN= 'OGIP 1.0'           / FITS header contains long strings
FILENAME= 'solo_L2_metis-vl-tb_20210212T001501_V01.fits' / FITS filename
FILE_RAW= '2021-02-12T00.45.59.589567Z-VL_IMAGE.raw' / filename of raw data
PARENT  = 'solo_L1_metis-vl-image_20210212T001501_V01.fits, solo_L1_metis-vl-i&'
CONTINUE  'mage_20210212T001531_V01.fits, solo_L1_metis-vl-image_20210212T0016&'
CONTINUE  '02_V01.fits, solo_L1_metis-vl-image_20210212T001632_V01.fits&' /
CONTINUE  '' / name of the parent file
APID    =                 1084 / APID number of associated telemetry
DATE    = '2022-10-05T11:13:22.52' / date and time of FITS file creation
DATE-OBS= '2021-02-12T00:15:01.285' / same as DATE-BEG
DATE-BEG= '2021-02-12T00:15:01.285' / start time of observation
DATE-AVG= '2021-02-12T00:30:16.037' / average time of observation
DATE-END= '2021-02-12T00:45:30.788' / end time of observation
TIMESYS = 'UTC     '           / system used for time keywords
TIMRDER =              0.00000 / [s] estimated random error in time values
TIMSYER =              0.00000 / [s] estimated systematic error in time values
OBT_BEG =      666404048.71745 / start acquisition time in on-board time
OBT_END =      666405878.21745 / end acquisition time in on-board time
LEVEL   = 'L2      '           / data processing level
ORIGIN  = 'Metis EGSE'         / location where the FITS file has been generated
CREATOR = 'metis_l2_prep_vl_polariz.pro' / FITS creation software
VERS_SW = '3.1.0-SNAPSHOT | 3.1.2' / version of SW that provided FITS file
VERS_CAL= 'LTP01-03_1.0.0'     / version of the calibration package
VERSION = '01      '           / incremental version number of FITS file
OBSRVTRY= 'Solar Orbiter'      / satellite name
TELESCOP= 'SOLO/Metis/VLD'     / telescope that took the measurement
INSTRUME= 'Metis   '           / instrument name
DETECTOR= 'VLD     '           / subunit/sensor
OBJECT  = 'TBD     '           / the use of the keyword OBJECT is [TBD]
OBS_MODE= 'METIS_GENERIC'      / observation mode
OBS_TYPE= 'iXmr    '           / encoded version of OBS_MODE
FILTER  = 'VL      '           / filter used to acquire this image
WAVELNTH=        610.000000000 / [nm] characteristic wavelength of observation
WAVEMIN =        580.000000000 / [nm] min. bandpass wavelength
WAVEMAX =        640.000000000 / [nm] max. bandpass wavelength
WAVEBAND= 'Visible light'      / bandpass description
XPOSURE =        450.000000000 / [s] total effective exposure time
NSUMEXP =                   15 / number of detector readouts summed together
TELAPSE =        1829.50000000 / [s] elapsed time between beginning and end of o
SOOPNAME= 'unknown_soop'       / name of the SOOP that the data belong to
SOOPTYPE= '000     '           / campaign ID(s) that the data belong to
OBS_ID  = 'SMET_031A_000_000_iXmr_112' / unique ID of the individual observation
TARGET  = 'TBD     '           / type of target from planning
BSCALE  =                    1 / ratio of physical to array value at 0 offset
BZERO   =                    0 / physical value for the array value 0
BTYPE   = 'VL total brightness' / science data object type
BUNIT   = 'MSB     '           / units of physical value
DATAMIN =   -1.09968055339E-06 / minimum value in data
DATAMAX =    4.19796628372E-07 / maximum value in data
NBIN1   =                    2 / binning factor in the dimension 1
```

```
NBIN2   =                    2 / binning factor in the dimension 2
NBIN    =                    4 / product of all NBIN values above
PXBEG1  =                    1 / first pixel read out in dimension 1
PXBEG2  =                    1 / first pixel read out in dimension 2
PXEND1  =                 1024 / last pixel read out in dimension 1
PXEND2  =                 1024 / last pixel read out in dimension 2
COMPRESS= 'lossless'           / data compression quality
COMP_RAT=    10.87548293082616 / data compression ratio
SESS_NUM= '104301  '           / acquisition session number
RADIAL  = 'Disabled'           / radialization flag
MASKING = 'Enabled '           / masking flag
COMPR   = 'Enabled '           / compression flag
N_POL   =                    4 / number of polarizations used
FRAMEMOD= 'Single  '           / frame acquisition mode
SP_NOISE= 'Disabled'           / spatial-noise algorithm flag
SUNDISK = 'Disabled'           / sun-disk monitor flag
CME_OBS = 'Disabled'           / CME detection algorithm flag
MEASKIND= 'pB      '           / measurement kind
CR_SEP  = 'Disabled'           / CR/SEP algorithm flag
VLFPFILT= 'Not applicable'     / fixed polarization pre-filter
PMPSTAB = 'Stable  '           / PMP temperature stability flag
CR_SEP_B=              0.00000 / CR/SEP algorithm param. B
CR_SEP_A=              0.00000 / CR/SEP algorithm param. A
DIT     =                30000 / [ms] detector integration time
NDIT    =                   15 / number of averaged frames
WCSNAME = 'Helioprojective-Cartesian' / name of coordinate system
CTYPE1  = 'HPLN-TAN'           / helioprojective longitude (solar x)
CTYPE2  = 'HPLT-TAN'           / helioprojective latitude (solar y)
CUNIT1  = 'arcsec  '           / units along axis 1
CUNIT2  = 'arcsec  '           / units along axis 2
PC1_1   =       0.999657407335 / WCS coordinate transformation matrix
PC1_2   =     -0.0261738029466 / WCS coordinate transformation matrix
PC2_1   =      0.0261738029466 / WCS coordinate transformation matrix
PC2_2   =       0.999657407335 / WCS coordinate transformation matrix
CDELT1  =        20.2760000000 / [arcsec] pixel scale along axis 1
CDELT2  =        20.2760000000 / [arcsec] pixel scale along axis 2
CROTA   =        1.49981963996 / [deg] rotation angle
CRVAL1  =       -273.392433976 / [arcsec] value of reference pixel along axis 1
CRVAL2  =        573.477950982 / [arcsec] value of reference pixel along axis 2
CRPIX1  =              512.500 / [pixel] reference pixel location along axis 1
CRPIX2  =              512.500 / [pixel] reference pixel location along axis 2
SUN_XCEN=        525.238640405 / [pixel] sun center location along axis 1
SUN_YCEN=        483.873189912 / [pixel] sun center location along axis 2
SUNPIX1 =        525.238640405 / [pixel] sun center location along axis 1
SUNPIX2 =        483.873189912 / [pixel] sun center location along axis 2
IO_XCEN =        524.484612350 / [pixel] Metis IO center location along axis 1
IO_YCEN =        469.986683764 / [pixel] Metis IO center location along axis 2
IOPIX1  =        524.484612350 / [pixel] Metis IO center location along axis 1
IOPIX2  =        469.986683764 / [pixel] Metis IO center location along axis 2
FS_XCEN =              512.500 / [pixel] Metis FS center location along axis 1
FS_YCEN =              512.500 / [pixel] Metis FS center location along axis 2
FSPIX1  =              512.500 / [pixel] Metis FS center location along axis 1
FSPIX2  =              512.500 / [pixel] Metis FS center location along axis 2
SC_XCEN =        525.273722628 / [pixel] S/C pointing location along axis 1
SC_YCEN =        483.894752417 / [pixel] S/C pointing location along axis 2
SCPIX1  =        525.273722628 / [pixel] S/C pointing location along axis 1
SCPIX2  =        483.894752417 / [pixel] S/C pointing location along axis 2
SC_YAW  =       0.699640233261 / [arcsec] S/C HPC yaw
```

```
SC_PITCH=       0.455669690934 / [arcsec] S/C HPC pitch
SC_ROLL =        1.57981973393 / [deg] S/C HPC roll angle
INN_FOV =              1.60000 / [deg] inner Metis FOV
OUT_FOV =              3.40000 / [deg] outer Metis FOV
LONPOLE =              180.000 / [deg] native longitude of the celestial pole
RSUN_ARC=        1937.65665873 / [arcsec] apparent photospheric solar radius
RSUN_REF=        695700000.000 / [m] assumed physical solar radius
SOLAR_B0=        1.22045327652 / [deg] S/C tilt of solar north pole
SOLAR_P0=        21.4829438061 / [deg] S/C celestial north to solar north angle
SOLAR_EP=      -0.922727713439 / [deg] S/C ecliptic north to solar north angle
CAR_ROT =        2241.21627645 / carrington rotation number
HGLT_OBS=        1.22045327652 / [deg] S/C heliographic latitude (B0 angle)
HGLN_OBS=       -164.582436976 / [deg] S/C heliographic longitude
CRLT_OBS=        1.22045327652 / [deg] S/C carrington latitude (B0 angle)
CRLN_OBS=        282.140478231 / [deg] S/C carrington longitude (L0 angle)
DSUN_OBS=        74055533017.3 / [m] S/C distance from sun
DSUN_AU =       0.495030662340 / [AU] S/C distance from sun
AU_REF  =        149597870700. / [m] assumed physical astronomical unit
HEEX_OBS=       -71071382408.0 / [m] S/C heliocentric earth ecliptic x
HEEY_OBS=       -19331045679.9 / [m] S/C heliocentric earth ecliptic y
HEEZ_OBS=       -7706571612.52 / [m] S/C heliocentric earth ecliptic z
HCIX_OBS=       -9394391501.77 / [m] S/C heliocentric inertial x
HCIY_OBS=       -73440311829.6 / [m] S/C heliocentric inertial y
HCIZ_OBS=        1577332293.23 / [m] S/C heliocentric inertial z
HCIX_VOB=        48001.6422584 / [m/s] S/C heliocentric inertial x velocity
HCIY_VOB=       -7188.65032564 / [m/s] S/C heliocentric inertial y velocity
HCIZ_VOB=        1360.77947556 / [m/s] S/C heliocentric inertial z velocity
HAEX_OBS=        68499251296.3 / [m] S/C heliocentric aries ecliptic x
HAEY_OBS=       -27068407864.5 / [m] S/C heliocentric aries ecliptic y
HAEZ_OBS=       -7705571880.24 / [m] S/C heliocentric aries ecliptic z
HEQX_OBS=       -71374372054.4 / [m] S/C heliocentric earth equatorial x
HEQY_OBS=       -19683317991.4 / [m] S/C heliocentric earth equatorial y
HEQZ_OBS=        1577332293.23 / [m] S/C heliocentric earth equatorial z
GSEX_OBS=        218746605323. / [m] S/C geocentric solar ecliptic x
GSEY_OBS=        19331045679.9 / [m] S/C geocentric solar ecliptic y
GSEZ_OBS=       -7706860502.61 / [m] S/C geocentric solar ecliptic z
OBS_VR  =        1068.61566762 / [m/s] radial velocity of S/C relative to sun
EAR_TDEL=        245.568852495 / [s] time(sun to earth) - time(sun to S/C)
SUN_TIME=        247.022668653 / [s] time(sun to S/C)
DATE_EAR= '2021-02-12T00:19:06.85' / [UTC] obs. start time corrected to earth
DATE_SUN= '2021-02-12T00:10:54.26' / [UTC] obs. start time corrected to sun
DATATYPE=                    0 / data product type
REF_ROWS= 'Not included'       / reference rows inclusion flag
CAD_END = '666405896:4228'     / OBT at cadence end
DAC2POL3=                 7318 / [raw] DAC2 for pol. ID 3
DAC2POL4=                 6051 / [raw] DAC2 for pol. ID 4
DAC2POL1=                15837 / [raw] DAC2 for pol. ID 0, 1, or 5
CONF_ID =                    0 / acquisition configuration ID
DAC2POL2=                10048 / [raw] DAC2 for pol. ID 2 or 6
DAC1POL1=                15837 / [raw] DAC1 for pol. ID 0, 1, or 5
MASKRMAX=                 1280 / [pixel] max. masking radius
CADENCE =              1830000 / [ms] acquisition cadence
BIN_TYPE=                    0 / binning type
CAD_BEG = '666404048:47019'    / OBT at cadence start
DAC1POL2=                10048 / [raw] DAC1 for pol. ID 2 or 6
DAC1POL3=                 7318 / [raw] DAC1 for pol. ID 3
IDB_VERS= '4.0     '           /
HDR_VERS= '4       '           / version of the scientific header
```

```
DAC1POL4=                 6051 / [raw] DAC1 for pol. ID 4
TSENSOR =       -30.1574346277 / [degC] VLDA temperature
PMPTEMP =        29.9612886856 / [degC] PMP temperature
MASKRMIN=                  460 / [pixel] min. masking radius
SEQ_NUM =                    1 / polarization sequence counter
FIRSTROW=                    0 /
B0_BIN  =                    1 /
B0_DQ   =                    0 /
B0_STOP =                 2048 /
B1_BIN  =                    0 /
B1_DQ   =                    0 /
B1_STOP =                    0 /
B2_BIN  =                    0 /
B2_DQ   =                    0 /
B2_STOP =                    0 /
CHECKSUM= 'PSRJQSQIPSQIPSQI'   / HDU checksum updated 2022-10-05T11:13:23
DATASUM = '1579742797'         / data unit checksum updated 2022-10-05T11:13:23
INFO_URL= 'http://metis.oato.inaf.it' / link to more information on the instrume
COMMENT Image was rebinned according to the commanded binning factor.
COMMENT Image values were corrected for the total exposure time.
COMMENT Uncertainty matrix in the FITS extension is preliminary.
COMMENT Rotate CROTA degrees counter-clockwise to have Solar North up.
HISTORY L0 FITS file created on 2022-09-30T06:27:35.722806
HISTORY WCS and solar ephemeris:
HISTORY   SKD version = v107_20210723_001
HISTORY L1 FITS file created on 2022-09-30T10:10:32.35
HISTORY Bias and dark-current corrections:
HISTORY   solo_CAL_metis-vl-bias_20210224_V01.fits
HISTORY   map_dark_it2_fit_wr.fits
HISTORY Demodulation performed for angles 49.1, 84.3, 133.2, 181.8 deg
HISTORY Flat-field correction:
HISTORY   flat_vlda_JP_15MHZ_MPS_v1.fits
HISTORY Vignetting correction:
HISTORY   VF.fits shifted by [0.0, 0.0] pixel
HISTORY Radiometric calibration:
HISTORY   cal. factor = 1.38E-15 MSB/DN
HISTORY   1 MSB = 4.67E+20 ph/cm2/s/sr
HISTORY Update WCS and solar ephemeris:
HISTORY   SKD version = v107_20220927_001
HISTORY L2 FITS file created on 2022-10-05T11:13:22.52
END
```

7.4.1 Quality Matrix Extension

See Sect. 7.2.1.

7.4.2 Error Matrix Extension

See Sect. 7.2.2.

7.5 Header of `metis-vl-pol-angle` Data

```
SIMPLE  =                    T / file conforms to FITS standard
BITPIX  =                  -32 / number of bits per data pixel
NAXIS   =                    2 / number of data axes
NAXIS1  =                 1024 / length of data axis 1
NAXIS2  =                 1024 / length of data axis 2
EXTEND  =                    T / FITS file contains extensions
```

```
LONGSTRN= 'OGIP 1.0'           / FITS header contains long strings
FILENAME= 'solo_L2_metis-vl-pol-angle_20210212T001501_V01.fits' / FITS filename
FILE_RAW= '2021-02-12T00.45.59.589567Z-VL_IMAGE.raw' / filename of raw data
PARENT  = 'solo_L1_metis-vl-image_20210212T001501_V01.fits, solo_L1_metis-vl-i&'
CONTINUE  'mage_20210212T001531_V01.fits, solo_L1_metis-vl-image_20210212T0016&'
CONTINUE  '02_V01.fits, solo_L1_metis-vl-image_20210212T001632_V01.fits&' /
CONTINUE  '' / name of the parent file
APID    =                 1084 / APID number of associated telemetry
DATE    = '2022-10-05T11:13:22.52' / date and time of FITS file creation
DATE-OBS= '2021-02-12T00:15:01.285' / same as DATE-BEG
DATE-BEG= '2021-02-12T00:15:01.285' / start time of observation
DATE-AVG= '2021-02-12T00:30:16.037' / average time of observation
DATE-END= '2021-02-12T00:45:30.788' / end time of observation
TIMESYS = 'UTC     '           / system used for time keywords
TIMRDER =              0.00000 / [s] estimated random error in time values
TIMSYER =              0.00000 / [s] estimated systematic error in time values
OBT_BEG =      666404048.71745 / start acquisition time in on-board time
OBT_END =      666405878.21745 / end acquisition time in on-board time
LEVEL   = 'L2      '           / data processing level
ORIGIN  = 'Metis EGSE'         / location where the FITS file has been generated
CREATOR = 'metis_l2_prep_vl_polariz.pro' / FITS creation software
VERS_SW = '3.1.0-SNAPSHOT | 3.1.2' / version of SW that provided FITS file
VERS_CAL= 'LTP01-03_1.0.0'     / version of the calibration package
VERSION = '01      '           / incremental version number of FITS file
OBSRVTRY= 'Solar Orbiter'      / satellite name
TELESCOP= 'SOLO/Metis/VLD'     / telescope that took the measurement
INSTRUME= 'Metis   '           / instrument name
DETECTOR= 'VLD     '           / subunit/sensor
OBJECT  = 'TBD     '           / the use of the keyword OBJECT is [TBD]
OBS_MODE= 'METIS_GENERIC'      / observation mode
OBS_TYPE= 'iXmr    '           / encoded version of OBS_MODE
FILTER  = 'VL      '           / filter used to acquire this image
WAVELNTH=        610.000000000 / [nm] characteristic wavelength of observation
WAVEMIN =        580.000000000 / [nm] min. bandpass wavelength
WAVEMAX =        640.000000000 / [nm] max. bandpass wavelength
WAVEBAND= 'Visible light'      / bandpass description
XPOSURE =        450.000000000 / [s] total effective exposure time
NSUMEXP =                   15 / number of detector readouts summed together
TELAPSE =        1829.50000000 / [s] elapsed time between beginning and end of o
SOOPNAME= 'unknown_soop'       / name of the SOOP that the data belong to
SOOPTYPE= '000     '           / campaign ID(s) that the data belong to
OBS_ID  = 'SMET_031A_000_000_iXmr_112' / unique ID of the individual observation
TARGET  = 'TBD     '           / type of target from planning
BSCALE  =                    1 / ratio of physical to array value at 0 offset
BZERO   =                    0 / physical value for the array value 0
BTYPE   = 'VL polarization angle' / science data object type
BUNIT   = 'deg     '           / units of physical value
DATAMIN =       -89.9999901707 / minimum value in data
DATAMAX =        89.9999950584 / maximum value in data
NBIN1   =                    2 / binning factor in the dimension 1
NBIN2   =                    2 / binning factor in the dimension 2
NBIN    =                    4 / product of all NBIN values above
PXBEG1  =                    1 / first pixel read out in dimension 1
PXBEG2  =                    1 / first pixel read out in dimension 2
PXEND1  =                 1024 / last pixel read out in dimension 1
PXEND2  =                 1024 / last pixel read out in dimension 2
COMPRESS= 'lossless'           / data compression quality
COMP_RAT=    10.87548293082616 / data compression ratio
```

```
SESS_NUM= '104301  '           / acquisition session number
RADIAL  = 'Disabled'           / radialization flag
MASKING = 'Enabled '           / masking flag
COMPR   = 'Enabled '           / compression flag
N_POL   =                    4 / number of polarizations used
FRAMEMOD= 'Single  '           / frame acquisition mode
SP_NOISE= 'Disabled'           / spatial-noise algorithm flag
SUNDISK = 'Disabled'           / sun-disk monitor flag
CME_OBS = 'Disabled'           / CME detection algorithm flag
MEASKIND= 'pB      '           / measurement kind
CR_SEP  = 'Disabled'           / CR/SEP algorithm flag
VLFPFILT= 'Not applicable'     / fixed polarization pre-filter
PMPSTAB = 'Stable  '           / PMP temperature stability flag
CR_SEP_B=              0.00000 / CR/SEP algorithm param. B
CR_SEP_A=              0.00000 / CR/SEP algorithm param. A
DIT     =                30000 / [ms] detector integration time
NDIT    =                   15 / number of averaged frames
WCSNAME = 'Helioprojective-Cartesian' / name of coordinate system
CTYPE1  = 'HPLN-TAN'           / helioprojective longitude (solar x)
CTYPE2  = 'HPLT-TAN'           / helioprojective latitude (solar y)
CUNIT1  = 'arcsec  '           / units along axis 1
CUNIT2  = 'arcsec  '           / units along axis 2
PC1_1   =       0.999657407335 / WCS coordinate transformation matrix
PC1_2   =     -0.0261738029466 / WCS coordinate transformation matrix
PC2_1   =      0.0261738029466 / WCS coordinate transformation matrix
PC2_2   =       0.999657407335 / WCS coordinate transformation matrix
CDELT1  =        20.2760000000 / [arcsec] pixel scale along axis 1
CDELT2  =        20.2760000000 / [arcsec] pixel scale along axis 2
CROTA   =        1.49981963996 / [deg] rotation angle
CRVAL1  =       -273.392433976 / [arcsec] value of reference pixel along axis 1
CRVAL2  =        573.477950982 / [arcsec] value of reference pixel along axis 2
CRPIX1  =              512.500 / [pixel] reference pixel location along axis 1
CRPIX2  =              512.500 / [pixel] reference pixel location along axis 2
SUN_XCEN=        525.238640405 / [pixel] sun center location along axis 1
SUN_YCEN=        483.873189912 / [pixel] sun center location along axis 2
SUNPIX1 =        525.238640405 / [pixel] sun center location along axis 1
SUNPIX2 =        483.873189912 / [pixel] sun center location along axis 2
IO_XCEN =        524.484612350 / [pixel] Metis IO center location along axis 1
IO_YCEN =        469.986683764 / [pixel] Metis IO center location along axis 2
IOPIX1  =        524.484612350 / [pixel] Metis IO center location along axis 1
IOPIX2  =        469.986683764 / [pixel] Metis IO center location along axis 2
FS_XCEN =              512.500 / [pixel] Metis FS center location along axis 1
FS_YCEN =              512.500 / [pixel] Metis FS center location along axis 2
FSPIX1  =              512.500 / [pixel] Metis FS center location along axis 1
FSPIX2  =              512.500 / [pixel] Metis FS center location along axis 2
SC_XCEN =        525.273722628 / [pixel] S/C pointing location along axis 1
SC_YCEN =        483.894752417 / [pixel] S/C pointing location along axis 2
SCPIX1  =        525.273722628 / [pixel] S/C pointing location along axis 1
SCPIX2  =        483.894752417 / [pixel] S/C pointing location along axis 2
SC_YAW  =       0.699640233261 / [arcsec] S/C HPC yaw
SC_PITCH=       0.455669690934 / [arcsec] S/C HPC pitch
SC_ROLL =        1.57981973393 / [deg] S/C HPC roll angle
INN_FOV =              1.60000 / [deg] inner Metis FOV
OUT_FOV =              3.40000 / [deg] outer Metis FOV
LONPOLE =              180.000 / [deg] native longitude of the celestial pole
RSUN_ARC=        1937.65665873 / [arcsec] apparent photospheric solar radius
RSUN_REF=        695700000.000 / [m] assumed physical solar radius
SOLAR_B0=        1.22045327652 / [deg] S/C tilt of solar north pole
```

```
SOLAR_P0=        21.4829438061 / [deg] S/C celestial north to solar north angle
SOLAR_EP=      -0.922727713439 / [deg] S/C ecliptic north to solar north angle
CAR_ROT =        2241.21627645 / carrington rotation number
HGLT_OBS=        1.22045327652 / [deg] S/C heliographic latitude (B0 angle)
HGLN_OBS=       -164.582436976 / [deg] S/C heliographic longitude
CRLT_OBS=        1.22045327652 / [deg] S/C carrington latitude (B0 angle)
CRLN_OBS=        282.140478231 / [deg] S/C carrington longitude (L0 angle)
DSUN_OBS=        74055533017.3 / [m] S/C distance from sun
DSUN_AU =       0.495030662340 / [AU] S/C distance from sun
AU_REF  =        149597870700. / [m] assumed physical astronomical unit
HEEX_OBS=       -71071382408.0 / [m] S/C heliocentric earth ecliptic x
HEEY_OBS=       -19331045679.9 / [m] S/C heliocentric earth ecliptic y
HEEZ_OBS=       -7706571612.52 / [m] S/C heliocentric earth ecliptic z
HCIX_OBS=       -9394391501.77 / [m] S/C heliocentric inertial x
HCIY_OBS=       -73440311829.6 / [m] S/C heliocentric inertial y
HCIZ_OBS=        1577332293.23 / [m] S/C heliocentric inertial z
HCIX_VOB=        48001.6422584 / [m/s] S/C heliocentric inertial x velocity
HCIY_VOB=       -7188.65032564 / [m/s] S/C heliocentric inertial y velocity
HCIZ_VOB=        1360.77947556 / [m/s] S/C heliocentric inertial z velocity
HAEX_OBS=        68499251296.3 / [m] S/C heliocentric aries ecliptic x
HAEY_OBS=       -27068407864.5 / [m] S/C heliocentric aries ecliptic y
HAEZ_OBS=       -7705571880.24 / [m] S/C heliocentric aries ecliptic z
HEQX_OBS=       -71374372054.4 / [m] S/C heliocentric earth equatorial x
HEQY_OBS=       -19683317991.4 / [m] S/C heliocentric earth equatorial y
HEQZ_OBS=        1577332293.23 / [m] S/C heliocentric earth equatorial z
GSEX_OBS=        218746605323. / [m] S/C geocentric solar ecliptic x
GSEY_OBS=        19331045679.9 / [m] S/C geocentric solar ecliptic y
GSEZ_OBS=       -7706860502.61 / [m] S/C geocentric solar ecliptic z
OBS_VR  =        1068.61566762 / [m/s] radial velocity of S/C relative to sun
EAR_TDEL=        245.568852495 / [s] time(sun to earth) - time(sun to S/C)
SUN_TIME=        247.022668653 / [s] time(sun to S/C)
DATE_EAR= '2021-02-12T00:19:06.85' / [UTC] obs. start time corrected to earth
DATE_SUN= '2021-02-12T00:10:54.26' / [UTC] obs. start time corrected to sun
DATATYPE=                    0 / data product type
REF_ROWS= 'Not included'       / reference rows inclusion flag
CAD_END = '666405896:4228'     / OBT at cadence end
DAC2POL3=                 7318 / [raw] DAC2 for pol. ID 3
DAC2POL4=                 6051 / [raw] DAC2 for pol. ID 4
DAC2POL1=                15837 / [raw] DAC2 for pol. ID 0, 1, or 5
CONF_ID =                    0 / acquisition configuration ID
DAC2POL2=                10048 / [raw] DAC2 for pol. ID 2 or 6
DAC1POL1=                15837 / [raw] DAC1 for pol. ID 0, 1, or 5
MASKRMAX=                 1280 / [pixel] max. masking radius
CADENCE =              1830000 / [ms] acquisition cadence
BIN_TYPE=                    0 / binning type
CAD_BEG = '666404048:47019'    / OBT at cadence start
DAC1POL2=                10048 / [raw] DAC1 for pol. ID 2 or 6
DAC1POL3=                 7318 / [raw] DAC1 for pol. ID 3
IDB_VERS= '4.0     '           /
HDR_VERS= '4       '           / version of the scientific header
DAC1POL4=                 6051 / [raw] DAC1 for pol. ID 4
TSENSOR =       -30.1574346277 / [degC] VLDA temperature
PMPTEMP =        29.9612886856 / [degC] PMP temperature
MASKRMIN=                  460 / [pixel] min. masking radius
SEQ_NUM =                    1 / polarization sequence counter
FIRSTROW=                    0 /
B0_BIN  =                    1 /
B0_DQ   =                    0 /
```

```
B0_STOP =                 2048 /
B1_BIN  =                    0 /
B1_DQ   =                    0 /
B1_STOP =                    0 /
B2_BIN  =                    0 /
B2_DQ   =                    0 /
B2_STOP =                    0 /
CHECKSUM= '2NHD4KEA2KEA2KEA'   / HDU checksum updated 2022-10-05T11:13:23
DATASUM = '3784440688'         / data unit checksum updated 2022-10-05T11:13:23
INFO_URL= 'http://metis.oato.inaf.it' / link to more information on the instrume
COMMENT Image was rebinned according to the commanded binning factor.
COMMENT Image values were corrected for the total exposure time.
COMMENT Uncertainty matrix in the FITS extension is preliminary.
COMMENT Rotate CROTA degrees counter-clockwise to have Solar North up.
HISTORY L0 FITS file created on 2022-09-30T06:27:35.722806
HISTORY WCS and solar ephemeris:
HISTORY   SKD version = v107_20210723_001
HISTORY L1 FITS file created on 2022-09-30T10:10:32.35
HISTORY Demodulation performed for angles 49.1, 84.3, 133.2, 181.8 deg
HISTORY Flat-field correction:
HISTORY   flat_vlda_JP_15MHZ_MPS_v1.fits
HISTORY Vignetting correction:
HISTORY   VF.fits shifted by [0.0, 0.0] pixel
HISTORY Radiometric calibration:
HISTORY   cal. factor = 1.38E-15 MSB/DN
HISTORY   1 MSB = 4.67E+20 ph/cm2/s/sr
HISTORY Update WCS and solar ephemeris:
HISTORY   SKD version = v107_20220927_001
HISTORY L2 FITS file created on 2022-10-05T11:13:22.52
END
```

7.5.1 *Quality Matrix Extension*

See Sect. 7.2.1.

7.5.2 *Error Matrix Extension*

See Sect. 7.2.2.

7.6 Header of `metis-vl-stokes` Data

```
SIMPLE  =                    T / file conforms to FITS standard
BITPIX  =                  -32 / number of bits per data pixel
NAXIS   =                    2 / number of data axes
NAXIS1  =                 1024 / length of data axis 1
NAXIS2  =                 1024 / length of data axis 2
EXTEND  =                    T / FITS file contains extensions
LONGSTRN= 'OGIP 1.0'           / FITS header contains long strings
FILENAME= 'solo_L2_metis-vl-stokes_20210212T001501_V01.fits' / FITS filename
FILE_RAW= '2021-02-12T00.45.59.589567Z-VL_IMAGE.raw' / filename of raw data
PARENT  = 'solo_L1_metis-vl-image_20210212T001501_V01.fits, solo_L1_metis-vl-i&'
CONTINUE  'mage_20210212T001531_V01.fits, solo_L1_metis-vl-image_20210212T0016&'
CONTINUE  '02_V01.fits, solo_L1_metis-vl-image_20210212T001632_V01.fits&' /
CONTINUE  '' / name of the parent file
APID    =                 1084 / APID number of associated telemetry
DATE    = '2022-10-05T11:13:22.52' / date and time of FITS file creation
DATE-OBS= '2021-02-12T00:15:01.285' / same as DATE-BEG
DATE-BEG= '2021-02-12T00:15:01.285' / start time of observation
```

```
DATE-AVG= '2021-02-12T00:30:16.037' / average time of observation
DATE-END= '2021-02-12T00:45:30.788' / end time of observation
TIMESYS = 'UTC     '           / system used for time keywords
TIMRDER =              0.00000 / [s] estimated random error in time values
TIMSYER =              0.00000 / [s] estimated systematic error in time values
OBT_BEG =      666404048.71745 / start acquisition time in on-board time
OBT_END =      666405878.21745 / end acquisition time in on-board time
LEVEL   = 'L2      '           / data processing level
ORIGIN  = 'Metis EGSE'         / location where the FITS file has been generated
CREATOR = 'metis_l2_prep_vl_polariz.pro' / FITS creation software
VERS_SW = '3.1.0-SNAPSHOT | 3.1.2' / version of SW that provided FITS file
VERS_CAL= 'LTP01-03_1.0.0'     / version of the calibration package
VERSION = '01      '           / incremental version number of FITS file
OBSRVTRY= 'Solar Orbiter'      / satellite name
TELESCOP= 'SOLO/Metis/VLD'     / telescope that took the measurement
INSTRUME= 'Metis   '           / instrument name
DETECTOR= 'VLD     '           / subunit/sensor
OBJECT  = 'TBD     '           / the use of the keyword OBJECT is [TBD]
OBS_MODE= 'METIS_GENERIC'      / observation mode
OBS_TYPE= 'iXmr    '           / encoded version of OBS_MODE
FILTER  = 'VL      '           / filter used to acquire this image
WAVELNTH=        610.000000000 / [nm] characteristic wavelength of observation
WAVEMIN =        580.000000000 / [nm] min. bandpass wavelength
WAVEMAX =        640.000000000 / [nm] max. bandpass wavelength
WAVEBAND= 'Visible light'      / bandpass description
XPOSURE =        450.000000000 / [s] total effective exposure time
NSUMEXP =                   15 / number of detector readouts summed together
TELAPSE =        1829.50000000 / [s] elapsed time between beginning and end of o
SOOPNAME= 'unknown_soop'       / name of the SOOP that the data belong to
SOOPTYPE= '000     '           / campaign ID(s) that the data belong to
OBS_ID  = 'SMET_031A_000_000_iXmr_112' / unique ID of the individual observation
TARGET  = 'TBD     '           / type of target from planning
BSCALE  =                    1 / ratio of physical to array value at 0 offset
BZERO   =                    0 / physical value for the array value 0
BTYPE   = 'Stokes I'           / science data object type
BUNIT   = 'MSB     '           / units of physical value
DATAMIN =   -1.09968055339E-06 / minimum value in data
DATAMAX =    4.19796628372E-07 / maximum value in data
NBIN1   =                    2 / binning factor in the dimension 1
NBIN2   =                    2 / binning factor in the dimension 2
NBIN    =                    4 / product of all NBIN values above
PXBEG1  =                    1 / first pixel read out in dimension 1
PXBEG2  =                    1 / first pixel read out in dimension 2
PXEND1  =                 1024 / last pixel read out in dimension 1
PXEND2  =                 1024 / last pixel read out in dimension 2
COMPRESS= 'lossless'           / data compression quality
COMP_RAT=    10.87548293082616 / data compression ratio
SESS_NUM= '104301  '           / acquisition session number
RADIAL  = 'Disabled'           / radialization flag
MASKING = 'Enabled '           / masking flag
COMPR   = 'Enabled '           / compression flag
N_POL   =                    4 / number of polarizations used
FRAMEMOD= 'Single  '           / frame acquisition mode
SP_NOISE= 'Disabled'           / spatial-noise algorithm flag
SUNDISK = 'Disabled'           / sun-disk monitor flag
CME_OBS = 'Disabled'           / CME detection algorithm flag
MEASKIND= 'pB      '           / measurement kind
CR_SEP  = 'Disabled'           / CR/SEP algorithm flag
```

```
VLFPFILT= 'Not applicable'     / fixed polarization pre-filter
PMPSTAB = 'Stable  '           / PMP temperature stability flag
CR_SEP_B=              0.00000 / CR/SEP algorithm param. B
CR_SEP_A=              0.00000 / CR/SEP algorithm param. A
DIT     =                30000 / [ms] detector integration time
NDIT    =                   15 / number of averaged frames
WCSNAME = 'Helioprojective-Cartesian' / name of coordinate system
CTYPE1  = 'HPLN-TAN'           / helioprojective longitude (solar x)
CTYPE2  = 'HPLT-TAN'           / helioprojective latitude (solar y)
CUNIT1  = 'arcsec  '           / units along axis 1
CUNIT2  = 'arcsec  '           / units along axis 2
PC1_1   =       0.999657407335 / WCS coordinate transformation matrix
PC1_2   =     -0.0261738029466 / WCS coordinate transformation matrix
PC2_1   =      0.0261738029466 / WCS coordinate transformation matrix
PC2_2   =       0.999657407335 / WCS coordinate transformation matrix
CDELT1  =        20.2760000000 / [arcsec] pixel scale along axis 1
CDELT2  =        20.2760000000 / [arcsec] pixel scale along axis 2
CROTA   =        1.49981963996 / [deg] rotation angle
CRVAL1  =       -273.392433976 / [arcsec] value of reference pixel along axis 1
CRVAL2  =        573.477950982 / [arcsec] value of reference pixel along axis 2
CRPIX1  =              512.500 / [pixel] reference pixel location along axis 1
CRPIX2  =              512.500 / [pixel] reference pixel location along axis 2
SUN_XCEN=        525.238640405 / [pixel] sun center location along axis 1
SUN_YCEN=        483.873189912 / [pixel] sun center location along axis 2
SUNPIX1 =        525.238640405 / [pixel] sun center location along axis 1
SUNPIX2 =        483.873189912 / [pixel] sun center location along axis 2
IO_XCEN =        524.484612350 / [pixel] Metis IO center location along axis 1
IO_YCEN =        469.986683764 / [pixel] Metis IO center location along axis 2
IOPIX1  =        524.484612350 / [pixel] Metis IO center location along axis 1
IOPIX2  =        469.986683764 / [pixel] Metis IO center location along axis 2
FS_XCEN =              512.500 / [pixel] Metis FS center location along axis 1
FS_YCEN =              512.500 / [pixel] Metis FS center location along axis 2
FSPIX1  =              512.500 / [pixel] Metis FS center location along axis 1
FSPIX2  =              512.500 / [pixel] Metis FS center location along axis 2
SC_XCEN =        525.273722628 / [pixel] S/C pointing location along axis 1
SC_YCEN =        483.894752417 / [pixel] S/C pointing location along axis 2
SCPIX1  =        525.273722628 / [pixel] S/C pointing location along axis 1
SCPIX2  =        483.894752417 / [pixel] S/C pointing location along axis 2
SC_YAW  =       0.699640233261 / [arcsec] S/C HPC yaw
SC_PITCH=       0.455669690934 / [arcsec] S/C HPC pitch
SC_ROLL =        1.57981973393 / [deg] S/C HPC roll angle
INN_FOV =              1.60000 / [deg] inner Metis FOV
OUT_FOV =              3.40000 / [deg] outer Metis FOV
LONPOLE =              180.000 / [deg] native longitude of the celestial pole
RSUN_ARC=        1937.65665873 / [arcsec] apparent photospheric solar radius
RSUN_REF=        695700000.000 / [m] assumed physical solar radius
SOLAR_B0=        1.22045327652 / [deg] S/C tilt of solar north pole
SOLAR_P0=        21.4829438061 / [deg] S/C celestial north to solar north angle
SOLAR_EP=      -0.922727713439 / [deg] S/C ecliptic north to solar north angle
CAR_ROT =        2241.21627645 / carrington rotation number
HGLT_OBS=        1.22045327652 / [deg] S/C heliographic latitude (B0 angle)
HGLN_OBS=       -164.582436976 / [deg] S/C heliographic longitude
CRLT_OBS=        1.22045327652 / [deg] S/C carrington latitude (B0 angle)
CRLN_OBS=        282.140478231 / [deg] S/C carrington longitude (L0 angle)
DSUN_OBS=        74055533017.3 / [m] S/C distance from sun
DSUN_AU =       0.495030662340 / [AU] S/C distance from sun
AU_REF  =        149597870700. / [m] assumed physical astronomical unit
HEEX_OBS=       -71071382408.0 / [m] S/C heliocentric earth ecliptic x
```

```
HEEY_OBS=       -19331045679.9 / [m] S/C heliocentric earth ecliptic y
HEEZ_OBS=       -7706571612.52 / [m] S/C heliocentric earth ecliptic z
HCIX_OBS=       -9394391501.77 / [m] S/C heliocentric inertial x
HCIY_OBS=       -73440311829.6 / [m] S/C heliocentric inertial y
HCIZ_OBS=        1577332293.23 / [m] S/C heliocentric inertial z
HCIX_VOB=        48001.6422584 / [m/s] S/C heliocentric inertial x velocity
HCIY_VOB=       -7188.65032564 / [m/s] S/C heliocentric inertial y velocity
HCIZ_VOB=        1360.77947556 / [m/s] S/C heliocentric inertial z velocity
HAEX_OBS=        68499251296.3 / [m] S/C heliocentric aries ecliptic x
HAEY_OBS=       -27068407864.5 / [m] S/C heliocentric aries ecliptic y
HAEZ_OBS=       -7705571880.24 / [m] S/C heliocentric aries ecliptic z
HEQX_OBS=       -71374372054.4 / [m] S/C heliocentric earth equatorial x
HEQY_OBS=       -19683317991.4 / [m] S/C heliocentric earth equatorial y
HEQZ_OBS=        1577332293.23 / [m] S/C heliocentric earth equatorial z
GSEX_OBS=        218746605323. / [m] S/C geocentric solar ecliptic x
GSEY_OBS=        19331045679.9 / [m] S/C geocentric solar ecliptic y
GSEZ_OBS=       -7706860502.61 / [m] S/C geocentric solar ecliptic z
OBS_VR  =        1068.61566762 / [m/s] radial velocity of S/C relative to sun
EAR_TDEL=        245.568852495 / [s] time(sun to earth) - time(sun to S/C)
SUN_TIME=        247.022668653 / [s] time(sun to S/C)
DATE_EAR= '2021-02-12T00:19:06.85' / [UTC] obs. start time corrected to earth
DATE_SUN= '2021-02-12T00:10:54.26' / [UTC] obs. start time corrected to sun
DATATYPE=                    0 / data product type
REF_ROWS= 'Not included'       / reference rows inclusion flag
CAD_END = '666405896:4228'     / OBT at cadence end
DAC2POL3=                 7318 / [raw] DAC2 for pol. ID 3
DAC2POL4=                 6051 / [raw] DAC2 for pol. ID 4
DAC2POL1=                15837 / [raw] DAC2 for pol. ID 0, 1, or 5
CONF_ID =                    0 / acquisition configuration ID
DAC2POL2=                10048 / [raw] DAC2 for pol. ID 2 or 6
DAC1POL1=                15837 / [raw] DAC1 for pol. ID 0, 1, or 5
MASKRMAX=                 1280 / [pixel] max. masking radius
CADENCE =              1830000 / [ms] acquisition cadence
BIN_TYPE=                    0 / binning type
CAD_BEG = '666404048:47019'    / OBT at cadence start
DAC1POL2=                10048 / [raw] DAC1 for pol. ID 2 or 6
DAC1POL3=                 7318 / [raw] DAC1 for pol. ID 3
IDB_VERS= '4.0     '           /
HDR_VERS= '4       '           / version of the scientific header
DAC1POL4=                 6051 / [raw] DAC1 for pol. ID 4
TSENSOR =       -30.1574346277 / [degC] VLDA temperature
PMPTEMP =        29.9612886856 / [degC] PMP temperature
MASKRMIN=                  460 / [pixel] min. masking radius
SEQ_NUM =                    1 / polarization sequence counter
FIRSTROW=                    0 /
B0_BIN  =                    1 /
B0_DQ   =                    0 /
B0_STOP =                 2048 /
B1_BIN  =                    0 /
B1_DQ   =                    0 /
B1_STOP =                    0 /
B2_BIN  =                    0 /
B2_DQ   =                    0 /
B2_STOP =                    0 /
CHECKSUM= 'YgZaYZXVYdXZYZXZ'   / HDU checksum updated 2022-10-05T11:13:24
DATASUM = '1579742797'         / data unit checksum updated 2022-10-05T11:13:24
INFO_URL= 'http://metis.oato.inaf.it' / link to more information on the instrume
COMMENT Image was rebinned according to the commanded binning factor.
```

```
COMMENT Image values were corrected for the total exposure time.
COMMENT Uncertainty matrix in the FITS extension is preliminary.
COMMENT Rotate CROTA degrees counter-clockwise to have Solar North up.
HISTORY L0 FITS file created on 2022-09-30T06:27:35.722806
HISTORY WCS and solar ephemeris:
HISTORY   SKD version = v107_20210723_001
HISTORY L1 FITS file created on 2022-09-30T10:10:32.35
HISTORY Bias and dark-current corrections:
HISTORY   solo_CAL_metis-vl-bias_20210224_V01.fits
HISTORY   map_dark_it2_fit_wr.fits
HISTORY Demodulation performed for angles 49.1, 84.3, 133.2, 181.8 deg
HISTORY Flat-field correction:
HISTORY   flat_vlda_JP_15MHZ_MPS_v1.fits
HISTORY Vignetting correction:
HISTORY   VF.fits shifted by [0.0, 0.0] pixel
HISTORY Radiometric calibration:
HISTORY   cal. factor = 1.38E-15 MSB/DN
HISTORY   1 MSB = 4.67E+20 ph/cm2/s/sr
HISTORY Update WCS and solar ephemeris:
HISTORY   SKD version = v107_20220927_001
HISTORY L2 FITS file created on 2022-10-05T11:13:22.52
END
```

7.6.1 Stokes Q Extension

```
XTENSION= 'IMAGE   '           / image extension
BITPIX  =                  -32 / number of bits per data pixel
NAXIS   =                    2 / number of data axes
NAXIS1  =                 1024 / length of data axis 1
NAXIS2  =                 1024 / length of data axis 2
PCOUNT  =                    0 / parameter count
GCOUNT  =                    1 / group count
EXTNAME = 'Stokes Q'           / extension name
…
BTYPE   = 'Stokes Q'           / science data object type
BUNIT   = 'MSB     '           / units of physical value
…
```

7.6.2 Stokes U Extension

```
XTENSION= 'IMAGE   '           / image extension
BITPIX  =                  -32 / number of bits per data pixel
NAXIS   =                    2 / number of data axes
NAXIS1  =                 1024 / length of data axis 1
NAXIS2  =                 1024 / length of data axis 2
PCOUNT  =                    0 / parameter count
GCOUNT  =                    1 / group count
EXTNAME = 'Stokes U'           / extension name
…
BTYPE   = 'Stokes U'           / science data object type
BUNIT   = 'MSB     '           / units of physical value
…
```

7.6.3 Quality Matrix Extension

See Sect. 7.2.1.

7.6.4 Error Matrix Extension

See Sect. 7.2.2.

END OF DOCUMENT