Chandrayaan – 2 Mission

Chandrayaan-2 Large Area Soft x-ray Spectrometer (CLASS)

PDS Archive Software Interface Specification

Version 1.4
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CLASS DATA PROCESSING TEAM
SPACE ASTRONOMY GROUP
U R RAO SATELLITE CENTRE
INDIAN SPACE RESEARCH ORGANIZATION
BANGALORE - 560017

Prepared by

Vaishali S.
CLASS team, SAG, URSC

Reviewed and Approved By

Dr. Shyama Narendranath K.C.
Co-Principal Investigator , CLASS payload
SAG, URSC

Document Control and Data Sheet

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Document Change History

Version No.	Date	A / M / D *	Description
V 0.1	Jul 2020	A	Initial version
V 1.0	14th Aug 2020	A	Updated. Provided to peer review committee
V 1.1	06th Nov 2020	M	Updated after peer review comments
V 1.2	12th Nov 2020	M	Updated after peer review comments
V 1.3	11th Nov 2021 15th Nov 2021 30th Dec 2021	M	Updated with changes related to revision of earlier processed datasets
V 1.4	31st Mar 2023	M	Updated. Level 2 removed and Level 3 renamed as Level 2

* - A : Addition; M : Modification; D : Deletion

Table of Contents

1 Introduction

1.1 Purpose

The purpose of this Software Interface Specification (SIS) document is to provide detailed description of the formats and contents of Chandrayaan-2 Large Area Soft x-ray Spectrometer (CLASS) Planetary Data System (PDS) data archive. This document includes description of the data products and associated metadata, data products generation software and archive format.

1.2 Scope

This document gives an overview of the CLASS instrument flown on Chandrayaan – 2 mission of ISRO and the data flow from spacecraft to ground and until the insertion of data products to ISRO Science Data Archive (ISDA). It gives details of various levels of data products of CLASS, naming conventions and formats. Examples of the data products are also provided. The specifications in this document apply to all data products of CLASS submitted for archival to the ISDA, for all the mission phases of the Chandrayaan-2 Orbiter mission.

1.3 SIS Content Overview

Section 2 describes the Chandrayaan – 2 mission. Section 3 explains the CLASS instrument. Section 4 gives an overview of data organization and data flow. Section 5 describes data archive generation, validation and delivery. Section 6 describes the archive structure. Section 7 describes the file formats used in the archive.

1.4 Audience

This document is intended for general use by data analysts both within and outside CLASS project.

1.5 Applicable Documents

1) *Chandrayaan-2 Large Area Soft X-ray Spectrometer*, V. Radhakrishna, A. Tyagi, S.Narendranath, Koushal Vadodariya, Reena Yadav, Brajpal Singh, G. Balaji, Neeraj Satya,Akash Shetty, H. N. Suresha Kumar, Kumar, S. Vaishali, Netra S. Pillai, S. Tadepalli, Venkata Raghavendra, P. Sreekumar, Anil Agarwal, N. Valarmathi, Current Science, Vol. 118, No. 2, 25 January 2020
2) *Chandrayaan-2 Large Area Soft X-ray Spectrometer (CLASS): Calibration, In-flight performance and first results*, Netra S Pillai, S. Narendranath, K. Vadodariya, Srikar S Tadepalli, Radhakrishna V, Anurag Tyagi, Reena Yadav, Brajpal Singh, Vaishali Sharan, P.S.Athiray, P. Sreekumar, K. Sankarasubramanian, Megha Bhatt, Amit Basu Sarbadhikari, N.P.S.Mithun, Santosh Vadawale, 2021, Icarus, https://doi.org/10.1016/j.icarus.2021.114436

3) CLASS Data User Manual V1.1
4) Chandrayaan-2 PDS4 Data Archive Conventions
5) Planetary Data System Standards Reference, version 1.11.0, October 1, 2018.
6) Data Provider's Handbook, Archiving Guide to the PDS4 Data Standards, version 1.11.0, October 1, 2018.
7) PDS4 Data Dictionary Document, Abridged, version 1.11.0.0, September 23, 2018.
8) PDS4 Information Model Specification, version 1.11.0.0, September 23, 2018.

1.6 Acronyms and Abbreviations

Acronym / Abbreviation	Description
CLASS	Chandrayaan – 2 Large Area Soft x-ray Spectrometer
DP	Data Processing
FITS	Flexible Image Transport System
GTI	Good Time Interval
HK	House Keeping
IDL	Interactive Data Language (a programming language)
ISDA	ISRO Science Data Archive
ISITE	ISRO Satellite Integration and Test Establishment
ISRO	Indian Space Research Organisation
ISSDC	Indian Space Science Data Centre
PDS	Planetary Data System
POC	Payload Operations Centre
PRL	Physical Research Laboratory, Ahmedabad
SAG	Space Astronomy Group
SCD	Swept Charge Device
SPICE	Spacecraft, Planet, Instrument, C-matrix, and Events (NAIF data format). Standard for representing ancillary data
URSC	U R Rao Satellite Centre, Bangalore
UTC	Universal Time Coordinate
XRF	X-ray Flourescence
XSM	Solar X-ray Monitor
Xspec	An X-ray spectral fitting package

1.7 Glossary

Term	Definition
Archive	A place in which public records or historical documents are preserved; also the material preserved – often used in plural. The term may be capitalized when referring to all of PDS holdings – the PDS Archive.
Basic Product	The simplest product in PDS4; one or more data objects (and their description objects), which constitute (typically) a single observation, document, etc. The only PDS4 products that are not basic products are collection and bundle products.
Bundle Product	A list of related collections. For example, a bundle could list a collection of raw data obtained by an instrument during its mission lifetime, a collection of the calibration products associated with the instrument, and a collection of all documentation relevant to the first two collections.
Class	The set of attributes (including a name and identifier) which describes an item defined in the PDS Information Model. A class is generic – a template from which individual items may be constructed.
Collection Product	A list of closely related basic products of a single type (e.g. observational data, browse, documents, etc.). A collection is itself a product (because it is simply a list, with its label), but it is not a basic product.
Data Object	A generic term for an object that is described by a description object. Data objects include both digital and non - digital objects.
Description Object	An object that describes another object. As appropriate, it will have structural and descriptive components. In PDS4 a ‘description object’ is a digital object – a string of bits with a predefined structure.
Digital Object	An object which consists of real electronically stored (digital) data.
Identifier	A unique character string by which a product, object, or other entity may be identified and located. Identifiers can be global, in which case they are unique across all of PDS (and its federation partners). A local identifier must be

	unique within a label.
Label	The aggregation of one or more description objects such that the aggregation describes a single PDS product. In the PDS4 implementation, labels are constructed using XML.
Logical Identifier (LID)	An identifier which identifies the set of all versions of a product
Versioned Logical Identifier (LIDVID)	The concatenation of a logical identifier with a version identifier, providing a unique identifier for each version of product.
Manifest	A list of contents
Metadata	Data about data – for example, a 'description object' contains information (metadata) about an 'object'.
Non-Digital Object	An object which does not consist of digital data. Non-digital objects include both physical objects like instruments, spacecraft, and planets, and non-physical objects like missions, and institutions. Non-digital objects are labeled in PDS in order to define a unique identifier (LID) by which they may be referenced across the system.
Object	A single instance of a class defined in the PDS Information Model.
PDS Information Model	The set of rules governing the structure and content of PDS metadata. While the Information Model (IM) has been implemented in XML for PDS4, the model itself is implementation independent.
Product	One or more tagged objects (digital, non-digital, or both) grouped together and having a single PDS-unique identifier. In the PDS4 implementation, the descriptions are combined into a single XML label. Although it may be possible to locate individual objects within PDS (and to find specific bit strings within digital objects), PDS4 defines 'products' to be the smallest granular unit of addressable data within its complete holdings.
Tagged Object	An entity categorized by the PDS Information Model, and described by a PDS label.
Registry	A data base that provides services for sharing content and metadata.

Repository	A place, room, or container where something is deposited or stored (often for safety)
XML	eXtensible Markup Language.
XML schema	The definition of an XML document, specifying required and optional XML elements, their order, and parent-child relationships.

2 Mission Overview

Chandrayaan-2, the second Indian mission to the Moon was launched on 22nd July 2019 with Orbiter, Lander and Rover configuration. The mission is a highly complex mission, which represents a significant technological leap compared to the previous missions of ISRO. It comprised an Orbiter, Lander and Rover to explore the unexplored high latitude in southern hemisphere of the Moon. The mission is designed to expand the lunar scientific knowledge through detailed study of topography, seismography, mineral identification and distribution, surface chemical composition, thermo-physical characteristics of top soil and composition of the tenuous lunar atmosphere, leading to a new understanding of the origin and evolution of the Moon.

After the injection of Chandrayaan-2, a series of maneuvers were carried out to raise its orbit and on August 14, 2019, following Trans Lunar Insertion (TLI) maneuver, the spacecraft escaped from orbiting the Earth and followed a path that took it to the vicinity of the Moon. On August 20, 2019, Chandrayaan-2 was successfully inserted into lunar orbit.

While orbiting the Moon in a 100 km lunar polar orbit, on September 02, 2019, Vikram Lander was separated from the Orbiter in preparation for landing. Subsequently, two de-orbit maneuvers were performed on Vikram Lander so as to change its orbit and begin circling the Moon in a 100 km x 35 km orbit. Vikram Lander descent was as planned and normal performance was observed up to an altitude of 2.1 km. Subsequently communication from lander to the ground stations was lost.

The Orbiter, placed in a 100 km x 100 km polar orbit around the Moon, will enrich our understanding of lunar origin and evolution, using its eight state-of-the-art scientific instruments. The Orbiter camera is providing the highest resolution (0.3 m) images ever which will be immensely useful to the global scientific community. The precise launch and mission management has ensured a long life of almost seven years instead of the planned one year.

2.1 Mission Objectives

Expanding the technologies inherited from Chandrayaan-1 spacecraft and

1. 'Develop &Demonstrate' newer technologies that will be useful for future planetary missions.
2. To design, realize and deploy a Lunar Lander-Rover capable of soft landing on a specified lunar site and deploy a Rover to carry out in-situ compositional analysis.
3. To carry payloads in the Orbiter-Craft that will enhance the scientific objectives of Chandrayaan-1 with improved resolution.

2.2 Payload Objectives

CLASS is an X ray spectrometer with the primary objective to map the abundances of the major rock forming elements on the lunar surface. Being sensitive to charged particles as well, a secondary objective is to study the particle dynamics in the geotail during Moon's passage once a month.

3 Instrument Overview

CLASS is an X-ray spectrometer operating in the energy range of 0.5 to 20 keV. Solar X-rays trigger X-ray fluorescence from the surface of the Moon that is measured by CLASS. CLASS operates on the sunlit side of the lunar orbit and has an instantaneous ground foot print of 12.5 km. Solar spectrum is simultaneously measured by the Solar X-ray Monitor which is critical for deriving elemental abundances.

Parameter	Value
Energy range	0.5 – 20 keV
Instantaneous ground foot print	12.5 km x 12.5 km
X ray detector	Swept Charge Device
Geometric area	64 cm^2

Table 1 CLASS instrument specifications

3.1 Instrument Design

CLASS consists of 16 swept charge device (SCDs) X-ray detectors that provide a geometric area of 64 cm^2. Two layers of Al filters block visible light. Copper collimators define the field of view and a ground footprint of 12.5 km x 12.5 km on the lunar surface from an altitude of 100 km. An Al door protected the SCDs from radiation damage enroute to the Moon. The door housed 16 Fe-55 radioactive isotopes for onboard calibration. After the calibration phase, the door was opened and locked. The instrument is described in detail in Radhakrishna et al, 2020.

4 Data Overview

This section provides a high level description of CLASS data products under the PDS4 Information Model (IM) and also the flow of the data from the spacecraft to the ground and further processing at ground upto delivery to PDS archive.

The Chandrayaan-2 CLASS PDS Archive confirms with version 1.11.0.0 of the PDS4 IM.

4.1 CLASS data levels

Raw data from CLASS instrument onboard Chandrayaan-2 is subjected to various levels of processing in a pipeline mode resulting in four levels of data as described below

4.1.1 Level 0 data

This consists of raw data collected from the payload, ancillary data (SPICE kernels) and housekeeping data.

4.1.2 Level 1 data

This consists of the combined spectrum from available SCDs and response matrix, with time in UTC and tagged to lunar co-ordinates.

Every L0 data will be processed to produce L1 data.

4.1.3 Level 2 data

This is a derived, higher level data product consisting of elemental maps (wt %) tagged to lunar co-ordinates.

L2 data products will be generated only when sufficient data is available, at least once in a year.

4.2 Data Processing Levels

PDS4 standard defines various levels of data products - Telemetry, Raw, Partially Processed, Calibrated and Derived. CLASS data levels, as described in the earlier section, can be classified as Raw, Calibrated and Derived based on the various levels of processing carried out. The following table shows the mapping between the PDS4, ISRO and CODMAC levels of data processing.

PDS4 level	PDS4 level description	ISRO level / Chandrayaan-2 CLASS level	CODMAC level
Raw	Original data from an instrument. If compression, reformatting, packetization or other translation has been applied to facilitate data transmission or storage, those processes will be reversed so that the archived data are in a PDS approved archive format.	0	2
Calibrated	Data converted to physical units, which makes values independent of the instrument.	1	3
Derived	Results that have been distilled from one or more calibrated data products (for example, maps, gravity or magnetic fields, or ring particle size distributions). Supplementary data, such as calibration tables or tables of viewing geometry, used to interpret observational data should also be classified as 'derived' data if not easily matched to one of the other three categories.	2 / 3	4+

Table 2 Comparison between different data standards

4.3 CLASS PDS4 Data Products

A PDS product consists of one or more digital and/or non-digital objects, and an accompanying PDS label file. PDS labels provide identification and description information for labeled objects. The PDS label defines a Logical Identifier (LID) by which any PDS labeled product is referenced throughout the system. In PDS4, labels are XML formatted ASCII files.

The calibrated (Level 1) and derived (Level 2) data products of CLASS are provided to the PDS Archive. The following table gives an overview of CLASS data products in PDS Archive. Detailed description are given in the following sub-sections.

PDS4 level	CLASS data level	Description	Data Format	Visualisation Tools / Software
Calibrated	L1	Combined spectrum (8 seconds) from available SCDs (with UTC and lunar coordinates)	FITS	Fits viewer; XSPEC for analysis
		PDS4 label file	XML	Text editor
		Response matrix (RMF file)	FITS	Fits viewer
		PDS4 label file	XML	Text editor
Derived	L2	Elemental abundance (wt%) map	TIFF	Open source tool QGIS (https://www.qgis.org/en/site/) Web based tool LROC Quickview (https://quickmap.lroc.asu.edu/)
		PDS4 label file	XML	Text editor

Table 3 CLASS PDS4 data products

4.3.1 Calibrated data products

For a given duration of observation, the Level 0 data is processed and time tagged event data for every SCD is written out as 8 seconds spectrum files (events binned for 8 seconds). There can be one to many no. of 8s spectrum files for every SCD. Next, for every 8s time interval, the spectrum files for all SCDs are added to generate the Level 1 calibrated data. So for a given duration of observation, there will be one to many no. of combined 8s spectrum files with each file corresponding to available SCDs.

Each of the Level 1 file (combined 8s spectrum) has an accompanying PDS4 label file in XML format. These files are organised as year – month – daywise files in the PDS archive.

4.3.2 Derived data products

The lunar elemental maps at 150 km (along track) and 12.5 km (across track) are provided for the elements Sodium (Na), Magnesium (Mg), Aluminium (Al), Silicon (Si) and Iron (Fe).

This will be a data product generated once in a year when sufficient data is available.

4.4 Data Flow

Raw data from the CLASS payload onboard Chandrayaan-2 Orbiter is received at ISSDC, Bangalore and Level 0 data products are generated at ISSDC which are sent to the CLASS POC at SAG, URSC. At the POC, further levels of data products are generated, which comply with the PDS4 standard. These data products are sent to ISSDC for archival (PDS) and dissemination.

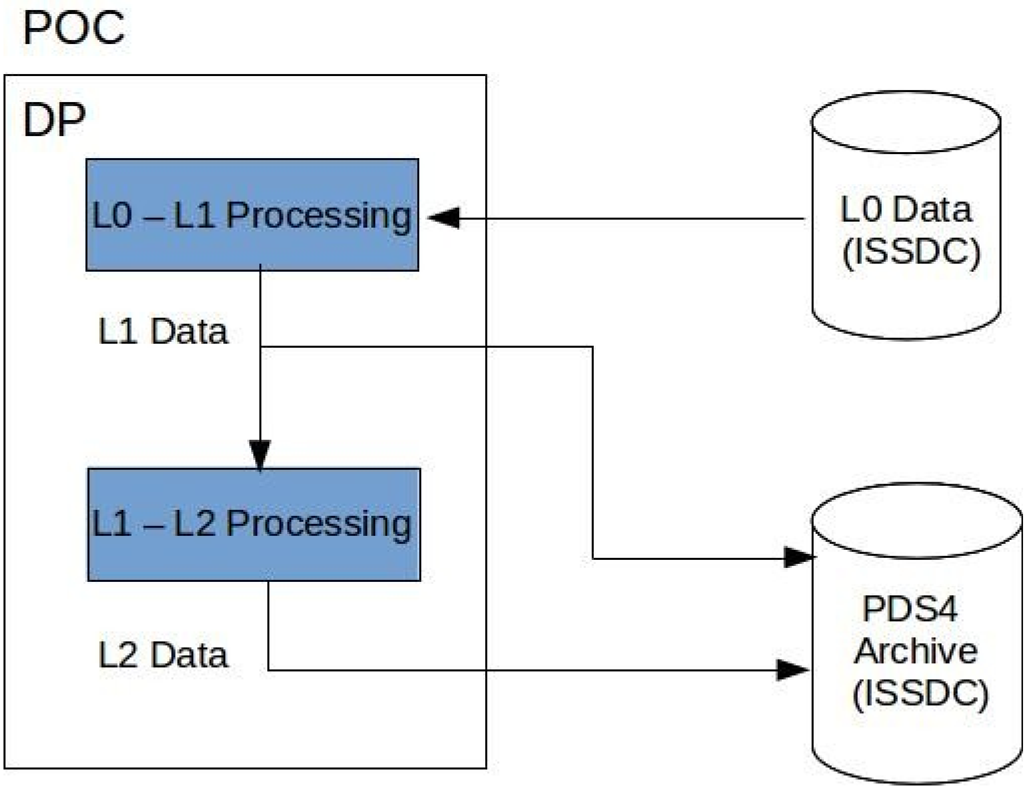


Figure 1 CLASS Data Flow

5 Archive Generation

CLASS archive products are produced by CLASS Data Processing Team at CLASS POC, SAG, URSC, ISRO in cooperation with ISDA, ISSDC. Archived data are made available to users based on the release schedule mentioned in Table 4.

5.1 Data Processing and Production Software

CLASS Level 0 data products from ISSDC are received at the CLASS POC. Every Level 0 data is run through the Level 0 to Level 1 automated data pipeline to produce Level 1 (calibrated) data products. Level 1 data with XRF signals are processed to produce Level 2 (derived) data products.

5.2 Data Validation

CLASS data products generated at CLASS POC are validated by the CLASS team and then subjected to PDS peer review. A science review committee, comprised of external reviewers in the field, will look at CLASS data products and validate its completeness and usability. This review will also verify the data processing pipeline software to ensure that the appropriate methods are adopted in the processing of the data. A technical committee will carry out the validation of the complete archive to ensure compliance to PDS4 standard. This review will be overseen by ISDA.

A sample data archive bundle will be provided to the review committee. The data provider (CLASS team) will address any comments provided by the review commitee, make the appropriate changes and generate the complete archive bundle for peer review. Only after the successful completion of the peer review the data will be ready for public release.

5.3 Data Transfer Methods and Delivery Schedule

CLASS POC at SAG, URSC is responsible for delivering CLASS data archive to ISDA for long term archival. The archive bundle will be transferred electronically from CLASS POC to ISSDC which hosts ISDA.

Following table shows the data release plan for CLASS data

Release	Data Collection Period	Lock-in period	Data Release to public	Data Products	Release Plan
Version 1	12 Sep 2019 to 31 Dec 2019	9 months	30 Nov 2020	Calibrated data (L1)	Subsequent data releases will be done every three (3) months.
		1 year	31 Dec 2020	Derived data (L2)	Subsequent data releases will be done every three (3) months.

Table 4 CLASS data release plan

5.4 Backups and duplicates

The ISDA is responsible for maintaining at least three copies of its science archives and for delivering one copy of the data to the ISSDC for archive. As archives are released, ISSDC generate at least three copies on appropriate physical media for long-term storage.

6 Archive Organization and File Naming Conventions

This section describes the basic organisation of CLASS bundle and the naming conventions used.

6.1 Namespace Registration

PDS4 archive standard is adopted for Chandrayaan-2 mission. ISRO is a member of International Planetary Data Alliance (IPDA). First step towards initiating archive activities for any space agency is to register namespace via IPDA. ISRO had submitted namespace registration request to IPDA, which has been accepted. The namespace will be used as root to the archive of ISRO's upcoming and future planetary missions. For Chandrayaan-2 mission following namespace will be used which is shown in Table 5.

Namespace ID	Logical Identifier prefix	Authority	Steward	Steward ID	Provider / Contact Point
sda	urn:isro:isda	ISRO Science Data Archive	ISRO	isda	Ajay Kumar Prashar T P Srinivasan B.N. Ramakrishna

Table 5 ISDA namespace

6.2 Logical Identifiers

Every product in a PDS archive has a unique Logical Identifier (LID). It also has a Version Identifier (VID) that allows different versions of the product to be referenced uniquely. These are often used together as a LIDVID. When a product is revised, its LID remains the same but its VID is incremented. A LIDVID is guaranteed to be unique across the whole PDS system. If a particular version of a product is desired, LIDVID should be used else only LID should be used.

All LIDs consist of a series of colon-separated segments. VID is separated from LID by double colons.

Chandrayaan-2 archive LIDs are formed based on the following convention :
Namespace:<bundle_id>_<sub-bundle_id>.<instrument_id>:<collection_id>:<product_id>::<version_id>

For eg.
urn:isro:isda:ch2_cho.cla:data:ch2_cla_l1_20200108t231337734_20200108t231345734

Following table shows the values used for LID formation for Chandrayaan-2 CLASS data archive

Namespace	Bundle ID	Sub-bundle ID	Instrument ID	Collection ID	Product ID
urn:isro:isda	ch2	cho	cla	calibration data document	Unique for every product

Table 6 LID for Chandrayaan-2 mission

6.3 Mission Archive Structure at Bundle Level

At mission level, Chandrayaan-2 data archive is organised as a mission bundle. At the next level, data is organised at instrument level. Figure 2 shows the Chandrayaan-2 mission level archive organization.

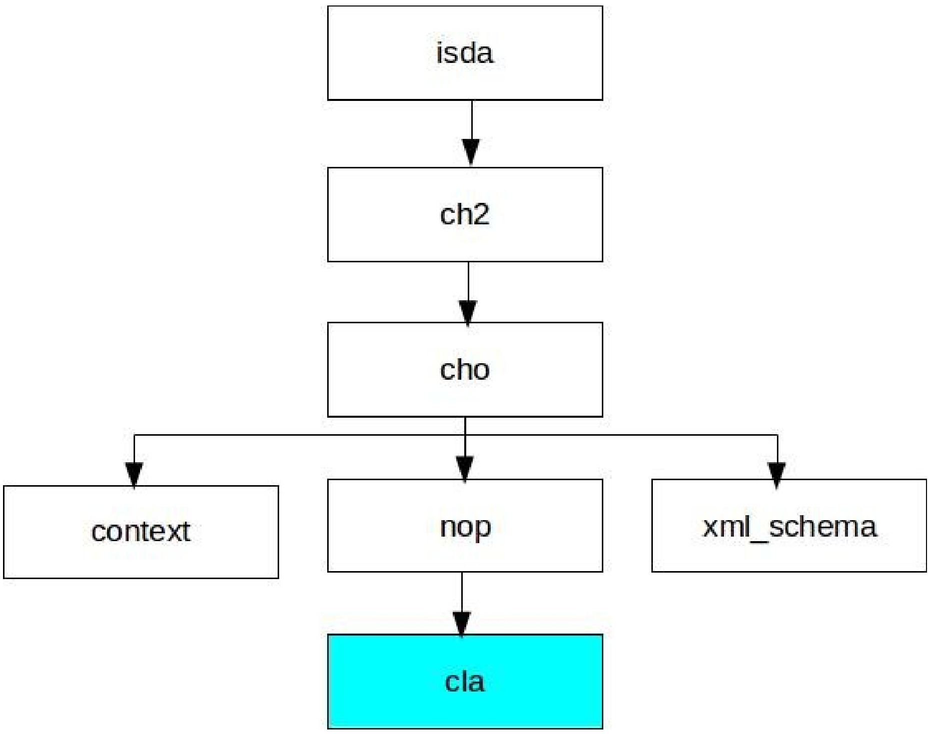


Figure 2 Chandrayaan-2 Mission Archive Organisation

6.4 CLASS Bundle

The highest level of organization for a PDS archive is the bundle. A bundle is a set of one or more related collections which may be of different types. CLASS data is organized as a single bundle as shown in Table 7.

Bundle Logical Identifier	PDS4 Processing Level	Description
urn:isro:isda:ch2_cho.cla	Calibrated, Derived	CLASS bundle contains collections for calibration data, science data and documents

Table 7 CLASS Bundle

6.5 CLASS Collection

A collection is a set of one or more related basic products which are all of the same type. CLASS bundle contains the following collections as shown in Table 8.

Directory	Collection LID	Description
calibration	urn:isro:isda:ch2_cho.cla:calibration	Contains calibration files
data	urn:isro:isda:ch2_cho.cla:data	Contains calibrated and derived data products
document	urn:isro:isda:ch2_cho.cla:document	Contains documents
miscellaneous	urn:isro:isda:ch2_cho.cla:miscellaneous	Contains software codes required for analysis

Table 8 Collections in CLASS bundle

6.5.1 ‘calibration’ collection

The ‘calibration’ collection contains CLASS calibration files namely a RMF file and an ARF file. A background file is also provided. All these files are in FITS format and sample formats (header keywords) are provided in Appendix D (for ARF file) and Appendix E (for RMF file). These files are required to perform analysis of calibrated data. Each file in this collection has an accompanying PDS4 label file in XML format.

6.5.2 ‘data’ collection

The ‘data’ collection contains directories as indicated in Figure 3. Calibrated and derived data are archived separately. Calibrated data products are combined spectrum files in FITS format accompanied by metadata file – PDS4 label – in XML format.

Derived data products are elemental maps in GEOTIFF format accompanied by metadata file – PDS4 label – in XML format. The file naming conventions are explained in section 6.6 and file formats are explained in Appendix B and Appendix F. Appendix G explains the visualisation of the data products using 'PDS4 Viewer' software.

6.5.3 'document' collection

The 'document' collection contains this document (SIS) along with a user manual. Both the files are in PDF format and have a corresponding PDS4 label file in XML format.

6.5.4 'miscellaneous' collection

The 'miscellaneous' collection contains a zip file of the software codes required for analysis, along with a PDS4 label file in XML format.

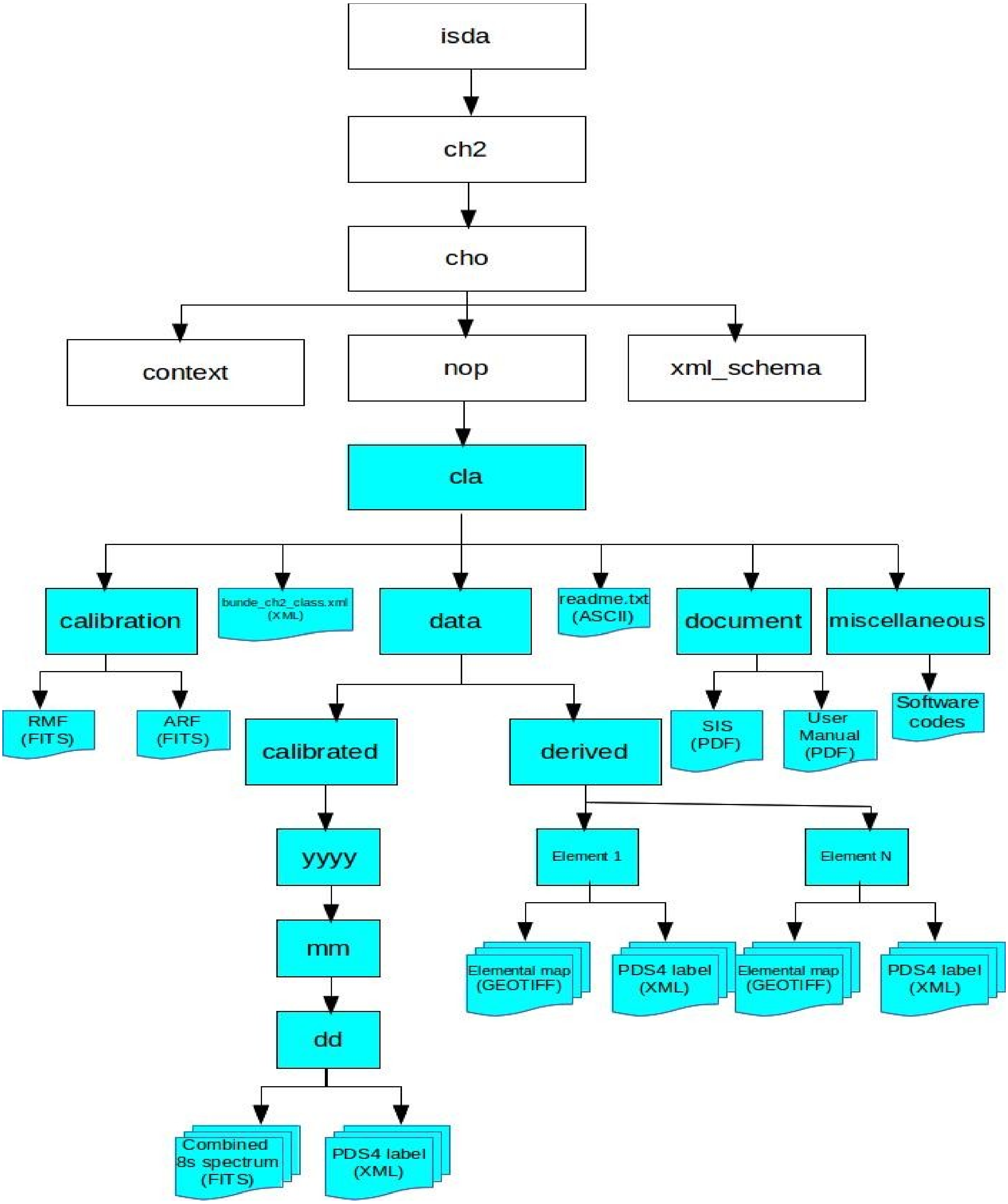


Figure 3 CLASS bundle organisation

6.6 File Naming Conventions & Formats

The file naming convention for CLASS calibrated data is as follows :

ch2_cla_l1_<start_time>_<end_time>.fits

where
start_time – start time of the data in the file in UTC (YYYYMMDDThhmmssmse)
end_time - end time of the data in the file in UTC (YYYYMMDDThhmmssmse)

eg. ch2_cla_l1_20200108T231337734_20200108T231345734.fits

The file naming convention for PDS4 label of CLASS calibrated data is as follows :

ch2_cla_l1_<start_time>_<end_time>.xml

where
start_time – start time of the data in the file in UTC (YYYYMMDDThhmmssmse)
end_time - end time of the data in the file in UTC (YYYYMMDDThhmmssmse)

eg. ch2_cla_l1_20200108T231337734_20200108T231345734.xml

The file naming convention for CLASS derived data is as follows :

ch2_cla_l2_map_<element>_<version>.tif

where
element – element name in 2 characters
version – version number in 2 characters

eg. ch2_cla_l2_map_al_v1.tif

The file naming convention for PS4 label of CLASS derived data is as follows :

ch2_cla_l2_map_<element>_<version>.xml

where
element – element name in 2 characters
version – version number in 2 characters

eg. ch2_cla_l2_map_al_v1.xml

7 Archive Product Formats

This section provides details on the formats of each of the products in the CLASS archive.

7.1 Data File Formats

CLASS data (calibration files, calibrated data files) are provided in FITS format. Data is represented as FITS binary tables. FITS binary table files consist of a Primary Header containing keywords and an extension containing header and data. Fits viewer (HEASARC) tool can be used to view FITS files.

An example FITS header for CLASS calibrated data is given in Appendix B.

Details of the keywords in the header of CLASS calibrated data is given in Appendix C.

Elemental maps are in GEOTIFF format with Latitude, Longitude and abundance in weight %.

7.2 Document Product Formats

Documents in CLASS archive are provided in PDF.

7.3 PDS Labels

PDS4 labels accompanying every data file or document are written in XML format and conform to XML and PDS4 formats. An example label for a data file is given in Appendix F.

Appendix A Support staff and cognizant persons

Team	Contact Person	Contact Number	Email ID
Operations @ ISSDC IDSN Bylalu, Bengaluru	Sreenatha R.	080-2809-4416/17/18 (SCC), 2809-4419 (MOX), 2202-9173/74 (ISSDC-IDSN)	sreenath@istrac.gov.in
Data Processing and PDS4 @ SAG, URSC, Bengaluru	Vaishali S	080-61456259	vaishali@ursc.gov.in
Science	Netra S. Pillai	080-61456259	netra@ursc.gov.in

Appendix B FITS header of calibrated data

```
SIMPLE  =                    T / Written by IDL:  Fri Oct 29 19:31:03 2021
BITPIX  =                    8 /
NAXIS   =                    0 /
EXTEND  =                    T / File contains extensions
DATE    = 'Fri Oct 29 19:31:03 2021' / file creation date
END

XTENSION= 'BINTABLE'           / Written by IDL:  Fri Oct 29 19:31:03 2021
BITPIX  =                    8 /
NAXIS   =                    2 / Binary table
NAXIS1  =                    6 / Number of bytes per row
NAXIS2  =                 2048 / Number of rows
PCOUNT  =                    0 / Random parameter count
GCOUNT  =                    1 / Group count
TFIELDS =                    2 / Number of columns
TFORM1  = '1I      '           / Integer*2 (short integer)
TFORM2  = '1E      '           / Real*4 (floating point)
TTYPE1  = 'CHANNEL '           / PHA channel
TTYPE2  = 'COUNTS  '           / Counts per channel
TUNIT2  = 'count   '           / Physical unit of field
EXTNAME = 'SPECTRUM'           / Name of binary table extension
HDUCLASS= 'OGIP    '           / format conforms to OGIP standard
HDUCLAS1= 'SPECTRUM'           / PHA dataset (OGIP memo OGIP-92-007)
HDUVERS1= '1.1.0   '           / Obsolete - included for backwards compatibility
HDUVERS = '1.1.0   '           / Version of format (OGIP memo OGIP-92-007a)
HDUCLAS2= 'TOTAL   '           / Maybe TOTAL, NET or BKG Spectrum
HDUCLAS3= 'COUNT   '           / PHA data stored as Counts (not count/s)
TLMIN1  =                    0 / Lowest legal channel number
TLMAX1  =                 2047 / Highest legal channel number
TELESCOP= 'CHANDRAYAAN-2'      / mission/satellite name
INSTRUME= 'CLASS   '           / instrument/detector name
FILTER  = 'none    '           / filter in use
EXPOSURE=        8.00000000000 / exposure (in seconds)
AREASCAL=              1.00000 / area scaling factor
BACKFILE= 'NONE    '           / associated background filename
BACKSCAL=              1.00000 / background file scaling factor
CORRFILE= 'NONE    '           / associated correction filename
CORRSCAL=              1.00000 / correction file scaling factor
RESPFILE= '        '           / associated redistrib matrix filename
ANCRFILE= '        '           / associated ancillary response filename
PHAVERSN= '1992a   '           / obsolete
DETCHANS=                 2048 / total number possible channels
CHANTYPE= 'PHA     '           / channel type (PHA, PI etc)
POISSERR=                    T / Poissonian errors to be assumed
STAT_ERR=                    0 / no statistical error specified
SYS_ERR =                    0 / no systematic error specified
GROUPING=                    0 / no grouping of the data has been defined
QUALITY =                    0 / no data quality information specified
EQUINOX =              2000.00 / Equinox of Celestial coord system
DATE    = 'Fri Oct 29 19:31:03 2021' / file creation date
PROGRAM = 'CLASS_add_scds.pro' / Program that created the file
```

```
SW_VERSN=              2.00000 / L0-L1 processing software version
IPFILE  = 'CLA01D18CHO0090603016019311100745226_01.pld' / Input file name
DATASET =                    0 / dataset number whose all SCD data were added
STARTIME= '2019-11-06T15:29:27.781' / Start time in UTC
ENDTIME = '2019-11-06T15:29:35.781' / End time in UTC
TEMP    =             -40.7000 / Temperature mean (degrees) rounded off to 1 dec
GAIN    =              13.5000 / eV/channel
SCD_FLTR=                    0 / 1 if device filtering done; 0 if not done
SCD_USED= '0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,' / SCDs used to add
MID_UTC = '2019-11-06T15:29:31.781' / Mid window UTC
SAT_ALT =              95.9600 / Sub-satellite point altitude (km)
SAT_LAT =             -54.7845 / Sub-satellite point latitude (deg)
SAT_LON =             -57.9510 / Sub-satellite point longitude (deg)
LST_HR  =                    3 / Local solar time - hour
LST_MIN =                   36 / Local solar time - minute
LST_SEC =                   43 / Local solar time - second
BORE_LAT=             -54.7834 / Boresight latitude (deg)
BORE_LON=             -57.9506 / Boresight longitude (deg)
V0_LAT  =             -54.0396 / Pixel corner 0 latitude (deg)
V1_LAT  =             -55.1298 / Pixel corner 1 latitude (deg)
V2_LAT  =             -55.5267 / Pixel corner 2 latitude (deg)
V3_LAT  =             -54.4286 / Pixel corner 3 latitude (deg)
V0_LON  =             -58.2091 / Pixel corner 0 longitude (deg)
V1_LON  =             -58.8845 / Pixel corner 1 longitude (deg)
V2_LON  =             -57.6847 / Pixel corner 2 longitude (deg)
V3_LON  =             -57.0328 / Pixel corner 3 longitude (deg)
SOLARANG=              110.874 / Angle between surface normal,sun vector (deg)
PHASEANG=              110.874 / Angle between boresight vector,sun vector (deg)
EMISNANG=    4.70507400000E-09 / Angle btwn boresight vector,emitted X-rays(deg)
END
```

Appendix C Header keywords in calibrated data files

Name of keyword	Description of keyword	Sample values for keyword
EXPOSURE	Integration time of the spectrum in seconds	8.0
RESPFILE	RMF file to be used for spectral fitting that contains the spectral redistribution function	Left blank here. Can be specified at the time of analysis using Xspec.
ANCRFILE	ARF file to be used for spectral fitting that contains the effective area information	Left blank here. Can be specified at the time of analysis using Xspec.
DETCHANS	Number of channels in the detector	2048
DATE	Date of generation of file	Sat Aug 8 04:19:16 2020
PROGRAM	IDL script that generated the FITS file	CLASS_add_scds.pro
SW_VERSN	L0-L1 processing software version	2.0
IPFILE	Input L0 file used for generating L1 8s file	CLA01D18CHO010470301 6019323000539997_13.pld
STARTIME	Start time in UTC of current spectrum	2019-11-18T23:59:25.268
ENDTIME	End time in UTC of current spectrum	2019-11-18T23:59:33.268
TEMP	Operating temperature	-40.7000
GAIN	Channel – Energy conversion in units of eV/channel	13.5
SCD_FLTR	Flag indicating whether device filtering done (1) or not (0)	1
SCD_USED	Detector ID of SCD added for generating the combined spectrum	0,1,2,3,4,5,6,7,8,9,10,11,12, 13,14,15
MID_UTC	Mid point in UTC of the time interval of the spectrum	2019-11-18T23:59:29.268
SAT_ALT	Altitude of the satellite from the lunar surface in kilometers	107.656 (between 70 – 130 km)
SAT_LAT	Latitude of the sub-satellite point in degrees	-60.3660 (between -90 - 90)
SAT_LON	Longitude of the sub-satellite point in degrees	138.303 (between -180 - 180)

Name of keyword	Description of keyword	Sample values for keyword
LST_HR	Local Solar Time - Hour	2 (between 0 - 23)
LST_MIN	Local Solar Time - Minutes	42 (between 0 - 59)
LST_SEC	Local Solar Time - Seconds	4 (between 0 - 59)
BORE_LAT	Latitude of the boresight point in degrees	-60.3544 (between -90 - 90)
BORE_LON	Longitude of the boresight point in degrees	138.303 (between -180 - 180)
V0_LAT	Latitude of top left pixel corner in degrees	-60.1454 (between -90 - 90)
V1_LAT	Latitude of bottom left pixel corner in degrees	-61.1820 (between -90 - 90)
V2_LAT	Latitude of bottom right pixel corner in degrees	-60.5525 (between -90 - 90)
V3_LAT	Latitude of top right pixel corner in degrees	-59.5255 (between -90 - 90)
V0_LON	Longitude of top left pixel corner in degrees	137.040 (between -180 - 180)
V1_LON	Longitude of bottom left pixel corner in degrees	138.302 (between -180 - 180)
V2_LON	Longitude of bottom right pixel corner in degrees	139.580 (between -180 - 180)
V3_LON	Longitude of top right pixel corner in degrees	138.301 (between -180 - 180)
SOLARANG	Angle between the surface normal and the sun vector in degrees	41.4637 (between 0 – 180; values < 90 refer to dayside and need to be used for spectral analysis; values > 90 belong to nightside and can be used for background)
PHASEANG	Angle betwen the boresight vector and the sun vector in degrees	41.4637 (between 0 - 180)
EMISNANG	Angle betwen the boresight vector and emitted X-rays in degrees	6.10004990000E-10 (Nadir pointing observations to be used and hence values < 1 degree are acceptable.)

Appendix D FITS header of ARF file

```
SIMPLE  =                    T / Written by IDL:  Tue Dec 28 14:52:22 2021
BITPIX  =                    8 /
NAXIS   =                    0 /
EXTEND  =                    T / File contains extensions
DATE    = 'Tue Dec 28 14:52:22 2021' / file creation date
END

XTENSION= 'BINTABLE'           / Written by IDL:  Tue Dec 28 14:52:22 2021
BITPIX  =                    8 /
NAXIS   =                    2 / Binary table
NAXIS1  =                   12 / Number of bytes per row
NAXIS2  =                 2048 / Number of rows
PCOUNT  =                    0 / Random parameter count
GCOUNT  =                    1 / Group count
TFIELDS =                    3 / Number of columns
TFORM1  = '1E      '           / Real*4 (floating point)
TFORM2  = '1E      '           / Real*4 (floating point)
TFORM3  = '1E      '           / Real*4 (floating point)
TTYPE1  = 'E_LOW   '           / label for field
TUNIT1  = 'ENERGY  '           / Units of column 1
TTYPE2  = 'E_HIGH  '           / label for field
TUNIT2  = 'ENERGY  '           / Units of column 2
TTYPE3  = 'SPECRESP'           / label for field
TUNIT3  = 'cm ^ 2  '           / Units of column 3
TELESCOP= 'Chandrayaan-2'      / telescope (mission) name
INSTRUME= 'CLASS   '           / instrument name
FILTER  = 'Al      '           / filter information
CCLS0001= 'CPF     '           / OGIP class of calibration file
CDTP0001= 'DATA    '           / OGIP code for contents
HDUCLASS= 'OGIP    '           / format conforms to OGIP/GSFC conventions
HDUCOC  = 'CAL/GEN/92-019'     / document describing the format
HDUCLAS1= 'RESPONSE'           / response of instrument
HDUCLAS2= 'SPECRESP'           / dataset contains spectral response
HDUVERS1= '1.0.0   '           / version of famoly format
HDUVERS2= '1.1.0   '           / version number of the format
EFF_FILE= 'class_effarea.txt'  / Efficiency file from which created
GAINUSED=              13.5000 / Gain used in this file
SCD_USED=                   16 / No:of SCDs for effarea
ANCRFILE= 'class_arf_v1.arf'   / Anc. Resp. file (ARF)
EXTNAME = 'SPECRESP'           / extension name
CREATOR = 'CLASSPOC'           / person who created this file
END
```

Appendix E FITS header of RMF file

```
SIMPLE  =                    T / Written by IDL:  Thu Nov 12 16:34:15 2020
BITPIX  =                    8 /
NAXIS   =                    0 /
EXTEND  =                    T / File contains extensions
PRO     = 'class_rmfgen.pro'   / IDL pro to create this file
GAINUSED=              13.5000 / Gain in eV/channel used in this RMF file
END


XTENSION= 'BINTABLE'           / Written by IDL:  Thu Nov 12 16:34:15 2020
BITPIX  =                    8 /
NAXIS   =                    2 / Binary table
NAXIS1  =                   10 / Number of bytes per row
NAXIS2  =                 2048 / Number of rows
PCOUNT  =                    0 / Random parameter count
GCOUNT  =                    1 / Group count
TFIELDS =                    3 / Number of columns
ORIGINAT= 'CLASSPOC'           / Originator this of FITS file
TFORM1  = '1I      '           / Integer*2 (short integer)
TTYPE1  = 'CHANNEL '           / label for field
TFORM2  = '1E      '           / Real*4 (floating point)
TTYPE2  = 'E_MIN   '           / label for field
TUNIT2  = 'keV     '           / Units of column 2
TFORM3  = '1E      '           / Real*4 (floating point)
TTYPE3  = 'E_MAX   '           / label for field
TUNIT3  = 'keV     '           / Units of column 3
EXTNAME = 'EBOUNDS '           / Extension name
TELESCOP= 'Chandrayaan-2'      / Telescope or mission name
INSTRUME= 'CLASS   '           / Instrument name
DET     = 'SCD     '           / Detector
PRO     = 'class_rmfgen.pro'   / IDL pro to create this file
HDUCLASS= 'OGIP    '           / Format conforms mostly to OGIP standards
HDUVERS = '1.2.0   '           / Version of format
HDUCLAS1= 'RESPONSE'           / Dataset contains response information
HDUCLAS2= 'EBOUNDS '           / Extension contains energy
CHANTYPE= 'PHA     '           / Type of detector channels
DETCHANS=                 2048 / Total number of PI channels in the full matrix
FILTER  = 'none    '           / filter not specified
END


XTENSION= 'BINTABLE'           / Written by IDL:  Thu Nov 12 16:34:15 2020
BITPIX  =                    8 /
NAXIS   =                    2 / Binary table
NAXIS1  =                   22 / Number of bytes per row
NAXIS2  =                 2048 / Number of rows
PCOUNT  =              2837844 / Random parameter count
GCOUNT  =                    1 / Group count
TFIELDS =                    6 / Number of columns
TFORM1  = '1E      '           / Real*4 (floating point)
TTYPE1  = 'ENERG_LO'           / label for field
TUNIT1  = 'keV     '           / Units of column 1
TFORM2  = '1E      '           / Real*4 (floating point)
```

```
TTYPE2  = 'ENERG_HI'           / label for field
TUNIT2  = 'keV     '           / Units of column 2
TFORM3  = '1I      '           / Integer*2 (short integer)
TTYPE3  = 'N_GRP   '           / label for field
TFORM4  = '1I      '           / Integer*2 (short integer)
TTYPE4  = 'F_CHAN  '           / label for field
TFORM5  = '1I      '           / Integer*2 (short integer)
TTYPE5  = 'N_CHAN  '           / label for field
TFORM6  = '1PE(2048)'          / Real*4 (floating point), variable length
TTYPE6  = 'MATRIX  '           / label for field
EXTNAME = 'MATRIX  '           / Extension name
INSTRUME= 'CLASS   '           / instrument name
HDUCLASS= 'OGIP    '           / format conforms to OGIP/GSFC conventions
HDUCLAS1= 'RESPONSE'           / Dataset contains a response matrix
HDUCLAS2= 'RSP_MATRIX'         / Extension contains response matrix
HDUVERS = '1.3.0   '           / version number of the format
CHANTYPE= 'PHA     '           / Type of detector channels
DETCHANS=                 2048 / Total number of PI channels in the full matrix
TLMIN   =                    0 / Channel number of first channel
LO_THRES=          1.00000e-07 / Lowest value in MATRIX
TELESCOP= 'Chandrayaan-2'      / telescope (mission) name
END
```

Appendix F Sample 'calibrated' data product label


```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<?xml-model href="http://pds.nasa.gov/pds4/pds/v1/PDS4_PDS_1B00.sch"
schematypens="http://purl.oclc.org/dsdl/schematron"?><?xml-model
href="https://isda.issdc.gov.in/pds4/isda/v1/ch2_ldd_ISDA_1000.sch"
schematypens="http://purl.oclc.org/dsdl/schematron"?
><Product_Observational
xmlns:isda="https://isda.issdc.gov.in/pds4/isda/v1"
xmlns:xs="http://www.w3.org/2001/XMLSchema-instance"
xs:schemaLocation="http://pds.nasa.gov/pds4/pds/v1
https://pds.nasa.gov/pds4/pds/v1/PDS4_PDS_1B00.xsd
https://isda.issdc.gov.in/pds4/isda/v1
https://isda.issdc.gov.in/pds4/isda/v1/ch2_ldd_ISDA_1000.xsd"
xmlns="http://pds.nasa.gov/pds4/pds/v1">
  <Identification_Area>
    <logical_identifier>
urn:isro:isda:ch2_cho:cla_calibrated:ch2_cla_l1_20191117t223217771_20191
117t223225771
    </logical_identifier>
    <version_id>1.0</version_id>
    <title>CHANDRAYAAN-2 Orbiter CLASS Experiment</title>
    <information_model_version>1.11.0.0</information_model_version>
    <product_class>Product_Observational</product_class>
    <Modification_History>
      <Modification_Detail>
        <modification_date>2020-11-05</modification_date>
        <version_id>1.0</version_id>
        <description>
        CLASS PDS4 product label created by URSC CLASS DP team
        </description>
      </Modification_Detail>
    </Modification_History>
  </Identification_Area>
  <Observation_Area>
    <Time_Coordinates>
      <start_date_time>2019-11-17T22:32:17.771Z</start_date_time>
```

```
      <stop_date_time>2019-11-17T22:32:25.771Z</stop_date_time>
    </Time_Coordinates>
    <Primary_Result_Summary>
      <purpose>Science</purpose>
      <processing_level>Calibrated</processing_level>
    </Primary_Result_Summary>
    <Investigation_Area>
      <name>Chandrayaan-2</name>
      <type>Mission</type>
      <Internal_Reference>
        <lidvid_reference>
        urn:isro:isda:context:investigation:mission.chandrayaan2::1.0
        </lidvid_reference>
        <reference_type>data_to_investigation</reference_type>
      </Internal_Reference>
    </Investigation_Area>
    <Observing_System>
      <name>Observing System</name>
      <Observing_System_Component>
        <name>Chandrayaan-2 Orbiter</name>
        <type>Spacecraft</type>
        <description>
        Chandrayaan-2 Orbiter is an Orbiter craft under the Chandrayaan-
        2 Spacecraft consisting of eight scientific instruments.
        </description>
      </Observing_System_Component>
      <Observing_System_Component>
        <name>CLASS</name>
        <type>Instrument</type>
        <description>
CLASS is an X ray fluorescence experiment to map the elemental
abundances of the major rock forming elements on the lunar surface. The
operating energy range 0.5 keV to 20 keV covers the XRF lines from Mg,
Al, Si, Ca, Ti and Fe as well as Na, Cr etc which may be detected.  The
spatial resolution is 12.5 km x 12.5 km from a 100 km orbit. In order to
```

```
convert the XRF line flux to abundances, the incident solar spectrum is
measured simultaneously with the X ray Solar Monitor (XSM) experiment on
Chandrayaan-2 Orbiter.
        </description>
      </Observing_System_Component>
    </Observing_System>
    <Target_Identification>
      <name>Moon</name>
      <type>Satellite</type>
      <description>Moon is a natural satellite of Earth.</description>
    </Target_Identification>
    <Mission_Area>
      <isda:Geometry_Parameters>
        <isda:System_Level_Coordinates>
          <isda:upper_left_latitude unit="deg">
          -72.4357
          </isda:upper_left_latitude>
          <isda:upper_left_longitude unit="deg">
          150.175
          </isda:upper_left_longitude>
          <isda:upper_right_latitude unit="deg">
          -71.8457
          </isda:upper_right_latitude>
          <isda:upper_right_longitude unit="deg">
          152.299
          </isda:upper_right_longitude>
          <isda:lower_left_latitude unit="deg">
          -73.4915
          </isda:lower_left_latitude>
          <isda:lower_left_longitude unit="deg">
          152.166
          </isda:lower_left_longitude>
          <isda:lower_right_latitude unit="deg">
          -72.8816
```

```
        </isda:lower_right_latitude>
        <isda:lower_right_longitude unit="deg">
        154.349
        </isda:lower_right_longitude>
      </isda:System_Level_Coordinates>
    </isda:Geometry_Parameters>
  </Mission_Area>
</Observation_Area>
<File_Area_Observational>
  <File>
    <file_name>
    ch2_cla_l1_20191117T223217771_20191117T223225771.fits
    </file_name>
    <creation_date_time>2020-11-05T09:11:31</creation_date_time>
    <file_size unit="byte">23040</file_size>
    <records>2048</records>
    <md5_checksum>373c31738c235de2335d7424a8bc2cc1</md5_checksum>
    <comment>
    This file contains the combined spectrum from available detectors
    </comment>
  </File>
  <Header>
    <local_identifier>header_Primary</local_identifier>
    <offset unit="byte">0</offset>
    <object_length unit="byte">2880</object_length>
    <parsing_standard_id>FITS 3.0</parsing_standard_id>
  </Header>
  <Header>
    <local_identifier>header_Data</local_identifier>
    <offset unit="byte">2880</offset>
    <object_length unit="byte">5760</object_length>
    <parsing_standard_id>FITS 3.0</parsing_standard_id>
  </Header>
```

```
    <Table_Binary>
      <local_identifier>data</local_identifier>
      <offset unit="byte">8640</offset>
      <records>2048</records>
      <description>
      The records count is the number of rows in this table
      </description>
      <Record_Binary>
        <fields>2</fields>
        <groups>0</groups>
        <record_length unit="byte">6</record_length>
        <Field_Binary>
          <name>CHANNEL</name>
          <field_location unit="byte">1</field_location>
          <data_type>SignedMSB2</data_type>
          <field_length unit="byte">2</field_length>
          <description>Channel number</description>
        </Field_Binary>
        <Field_Binary>
          <name>COUNTS</name>
          <field_location unit="byte">3</field_location>
          <data_type>IEEE754MSBSingle</data_type>
          <field_length unit="byte">4</field_length>
          <unit>counts</unit>
          <description>Counts in 8s</description>
        </Field_Binary>
      </Record_Binary>
    </Table_Binary>
  </File_Area_Observational>
</Product_Observational>
```

Appendix G Visualization of PDS4 data products using PDS4 Viewer

PDS4Viewer tool is used for the visualisation of PDS4 data products.

The tool can be downloaded from https://pdssbn.astro.umd.edu/toolsrc/pds4_viewer/. The tool is available for Windows, Linux and Mac OS X.

The current version is available at the following link https://pdssbn.astro.umd.edu/toolsrc/pds4_viewer/1.1/

Once the downloaded zip file is unzipped, the 'pds4_viewer' executable file will be available. In Linux, the following command should be executed to view the PDS4 data product

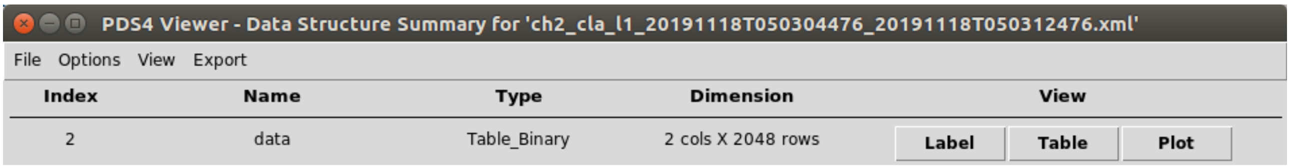
pds4_viewer <lable_filename>
OR
pds4_viewer

The first command directly opens the file whereas the second command provides a GUI to select the file to be viewed.

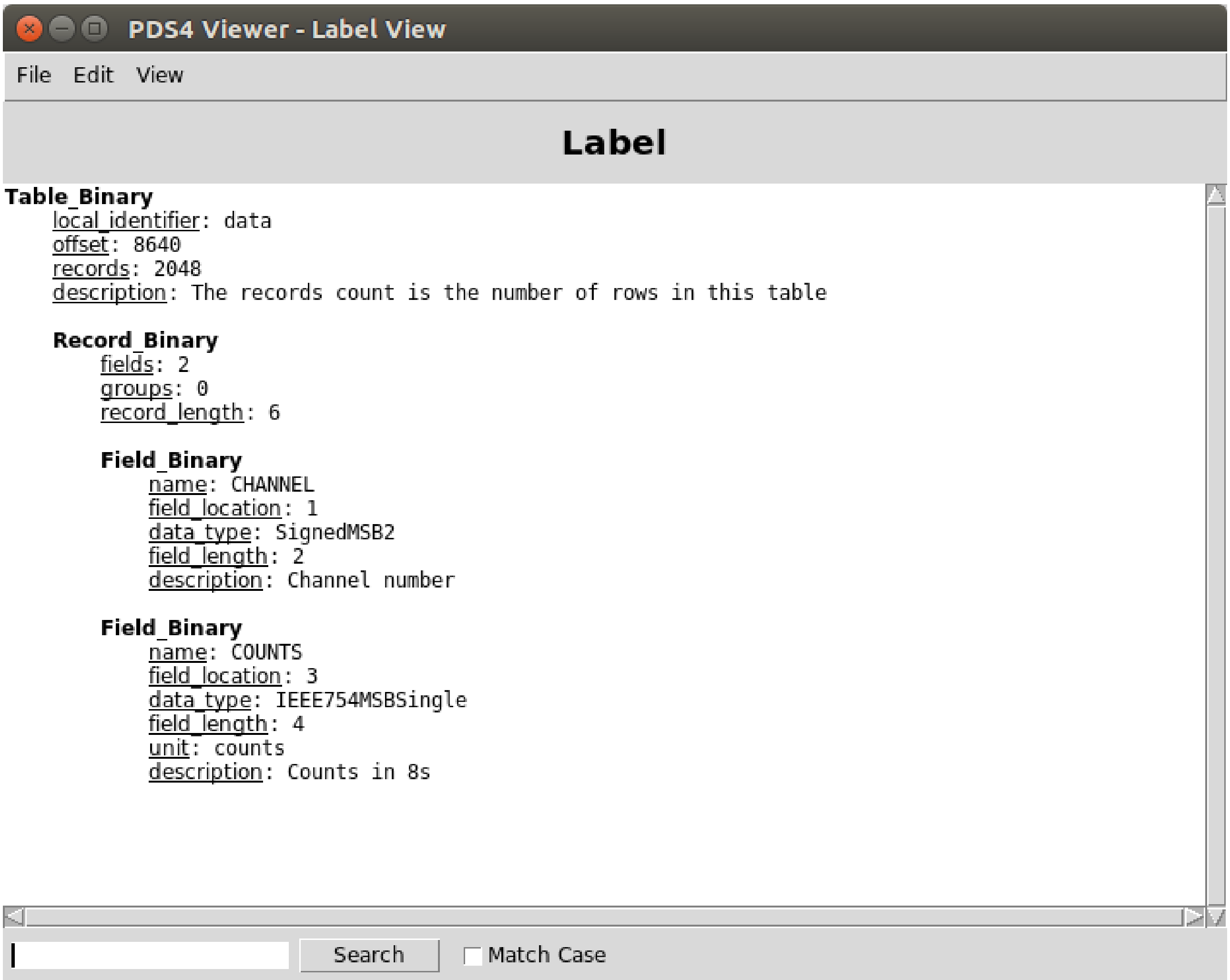
Complete file paths to be provided wherever required. The label (XML) file should be used for viewing.

Following screenshots explain the usage of the PDS4Viewer tool.

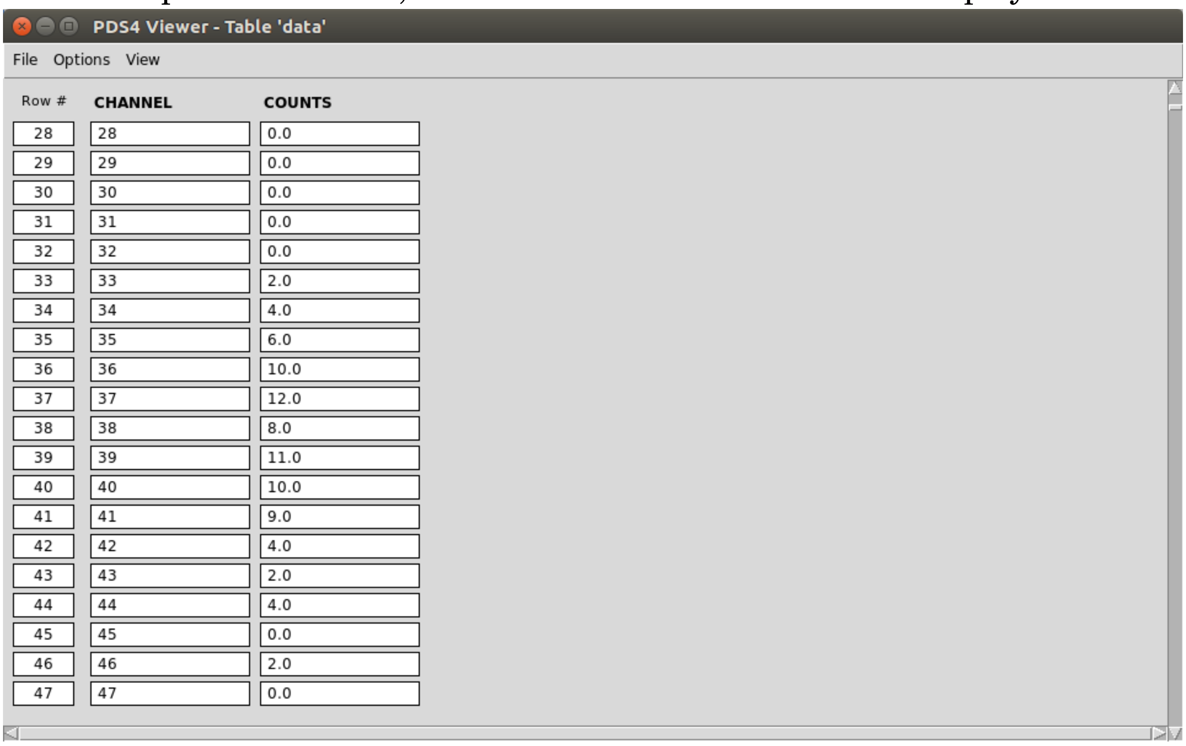
Once the file is selected the following screen comes up.



The user can choose 'Label' button which displays the label file contents as shown below.

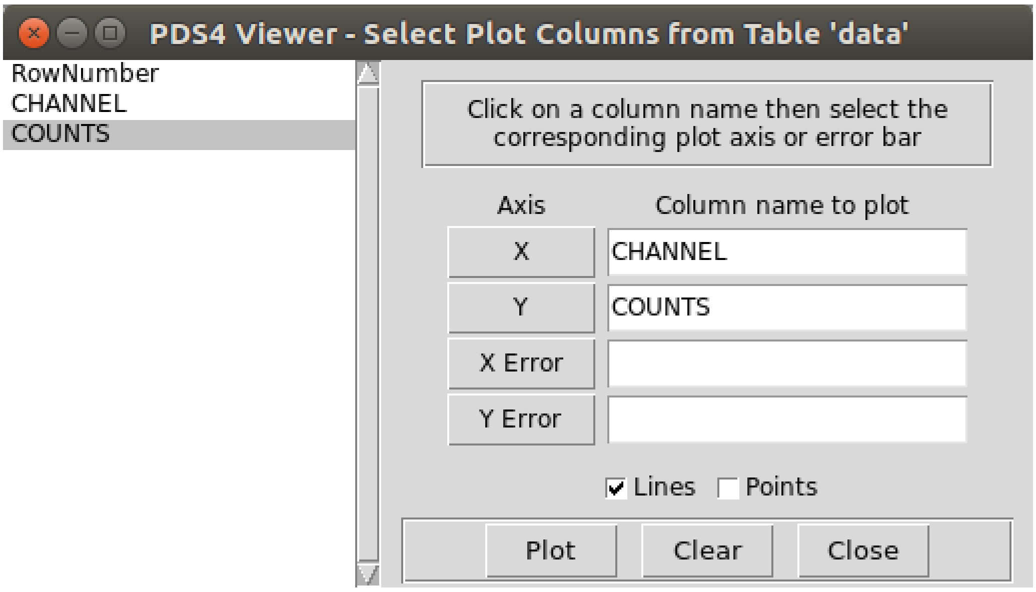


If the ‘Table’ option is selected, then the data file contents will be displayed



Row #	CHANNEL	COUNTS
28	28	0.0
29	29	0.0
30	30	0.0
31	31	0.0
32	32	0.0
33	33	2.0
34	34	4.0
35	35	6.0
36	36	10.0
37	37	12.0
38	38	8.0
39	39	11.0
40	40	10.0
41	41	9.0
42	42	4.0
43	43	2.0
44	44	4.0
45	45	0.0
46	46	2.0
47	47	0.0

If the 'Plot' option is selected, the following screen is displayed and the user can choose the columns to be plotted.



Once the columns are selected and the 'Plot' button is clicked, the following plot window is displayed.