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To Planetary Science Archive
Interface control document

[Rosetta] - [Earth Based]

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1 Introduction

1.1 Purpose and Scope

The purpose of this EAICD (Experimenter to (Science) Archive Interface Control Document) is twofold. Firstly, it provides all the instruments involved in the 67P/Churyumov-Gerasimenko's Earth based observation campaign using both type of the polarimetry (POL hereafter), more precisely imaging-polarimetry (IPOL) and spectro-polarimetry (PMOS). A description of the data, including data sources and destinations, is also provided. Then, it is the official interface between the instrument teams and the archiving authority.

1.2 Archiving Authorities

The Planetary Data System Standard is used as archiving standard by

- NASA for U.S. planetary missions, implemented by PDS
- ESA for European planetary missions, implemented by the Research and Scientific Support Department (RSSD) of ESA

1.1.1 ESA's Planetary Science Archive (PSA)

ESA implements an online science archive, the PSA,

- to support and ease data ingestion
- to offer additional services to the scientific user community and science operations teams as e.g.
    - search queries that allow searches across instruments, missions and scientific disciplines
    - several data delivery options as
        - direct download of data products, linked files and data sets
        - ftp download of data products, linked files and data sets

The PSA aims for online ingestion of logical archive volumes and will offer the creation of physical archive volumes on request.

1.3 Contents

This document explains the data flow of the Earth based POL instruments that performed observation of the comet 67P/Churyumov-Gerasimenko (67P hereafter) during the rendez-vous of the Rosetta spacecraft with the comet from the acquisition until the insertion into the PSA for ESA. It includes information on how data were processed, formatted, labeled and uniquely identified.
The document discusses general naming schemes for data volumes, data sets, data and label files. Standards used to generate products are explained. Software that may be used to access products is explained further on.
The design of the data set structure and data products is given. Examples are given in the appendix.

1.4 Intended Readership

The staff of the archiving authority (Planetary Science Archive, ESA, RSSD, design team) and any potential user of the Earth based POL data. However, people without any experience of the concerned POL instruments may not be able, based only on this document and the archived data, to work with the archived data. These instruments are complex and one has to familiarize himself with the associated user manuals (including the annexes) and reduction pipeline cookbook before starting to work on these raw uncalibrated data.

1.5 Scientific Objectives

A worldwide Earth based observing campaign of the 67P comet was performed in support of in-situ's data acquired during the last stage of the Rosetta mission.
Several techniques were used during this campaign and one of them is polarimetry. Polarimetry is a technique based on the measurement of the polarization's plane deviation of the light. The purpose of Earth based instruments using polarimetry involved in this campaign was to provide information on the physical and chemical properties of 67P's coma and tail in one go. While imaging polarimetry (IPOL) measures the polarization state of the light from a scene at a given wavelength, the spectro-polarimetry (PMOS) studies the wavelength dependence of this polarization state.
Finally, Earth based observations are by definition large-scale data compared to in-situ ones. Thus, this campaign is complementary to local observations performed by Rosetta instruments and should permit to contextualize these latter observations.

1.6 Applicable Documents

Planetary Data System Preparation Workbook, February 1, 1995, Version 3.1, JPL, D-7669, Part1
Planetary Data System Standards Reference, June 1, 1999, Version 3.3, JPL, D-7669, Part 2
Earth based Archive Generation, Validation and Transfer Plan, [September 15, 2017]

1.7 Relationships to Other Interfaces

N/A

1.8 Acronyms and Abbreviations

ACS	**A**dvanced **C**amera for **S**urveys
arcsec	**arc-sec**ond
BTA	**B**ig **T**elescope **A**lt-azimuthal
BNAO	**B**ulgarian **N**ational **A**stronomical **O**bservatory
ESO	**E**uropean **S**outhern **O**bservatory
FIT	**F**lexible **I**mage **T**ransport
FoReRo2	**Fo**cal-**Re**ducer-**Ro**zhen-**2**-channel
FORS2	**FO**cal **R**educer and low dispersion **S**pectrograph **2**
HST	**H**ubble **S**pace **T**elescope
ISIS	**I**ntermediate dispersion **S**pectrograph and **I**maging **S**ystem
IPOL	**I**maging **POL**arimetry
MJD	**M**odified **J**ulian **D**ay
pix	**pix**el
POL	**POL**arimetry
PMOS	**P**olarimetric **M**ulti**-O**bject **S**pectroscopy (= spectro-polarimetry)
PSA	**P**lanetary **S**cience **A**rchive
SAO RAS	**S**pecial **A**strophysical **O**bservatory of the **R**ussian **A**cademy of **S**ciences
SCORPIO-2	**S**pectral **C**amera with **O**ptical **R**educer for **P**hotometric and **I**nterferometric **O**bservations **- 2**

UT1	**U**nit **T**elescope **1**
UTC	**U**niversal **T**ime **C**oordinated
VLT	**V**ery **L**arge **T**elescope
WFC	**W**ide **F**ield **C**hannel
WHT	**W**illiam **H**erschel **T**elescope

1.9 Contact Names and Addresses

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PSA Permanent point of contact: psahelp@cosmos.esa.int

2 Overview of Instrument Design, Data Handling Process and Product Generation

The main particularity, complexity, of this Earth based observation campaign relies on the numerous different telescopes and instruments involved in it: 62 instruments installed on 38 different telescopes were used in this campaign (see Snodgrass et al. 2017, table 1), thus allowing to get a large amount of varied data that will bring new insights on the cometary science but also to contextualize the Rosetta mission.
One of the multiple technique used in the campaign is POL, divided into imaging polarimetry (IPOL) and spectro-polarimetry (PMOS). Overall, IPOL data are much more numerous. Five instruments, installed on five different telescopes were involved: (i) the FoReRo2 instrument at the BNAO, (ii) the WFC/ACS instrument aboard the HST, (iii) the SCORPIO-2 instrument mounted on the BTA of the SAO RAS, (iv) the FORS2 instrument mounted on ESO's VLT UT1 and (v) the ISIS instrument of the WHT. In this particular dataset, FoReRo2, WFC/ACS and ISIS data deal with IPOL while SCORPIO-2 and FORS2 data are either IPOL or PMOS. Following paragraphs and the Table 1 shortly describe and summarize the main charactersitics of data and instruments. More detailed description and additional information are given in some documents provided in the "DOCUMENT" directory. Some of these documents are available on the following websites:

BNAO-ROZHEN – FoReRo2 (in bulgarian): http://www.astro.bas.bg/forero/papers/jock2.pdf
ESO-VLT – FORS2: http://www.eso.org/sci/facilities/paranal/instruments/fors/overview.html
HST – ACS-WFC: http://www.stsci.edu/hst/acs/
SAO-RAS-BTA – SCORPIO-2: https://www.sao.ru/hq/lsfvo/devices/scorpio-2/descript_eng.html
WHT – ISIS: http://www.ing.iac.es/PR/inst.php?inst=ISIS

Instrument name	Observatory	IPOL or PMOS?	Wavelength range	Spatial sampling
FoReRo2	BNAO-ROZHEN	IPOL	Near-UV to Near-IR	≥ 0.25 arcsec/pix
FORS2	ESO-VLT	IPOL & PMOS	330 – 1100 nm	≥ 0.125 arcsec/pix
ACS-WFC	HST	IPOL	350 – 1100 nm	~ 0.05 arcsec/pix
SCORPIO_2	SAO-RAS-BTA	IPOL & PMOS	360 – 1000 nm	~ 0.18 arcsec/pix
ISIS	WHT	IPOL	300 – 1100 nm	≥ 0.14 arcsec/pix

Table 1 - Summary of instruments main characteristics

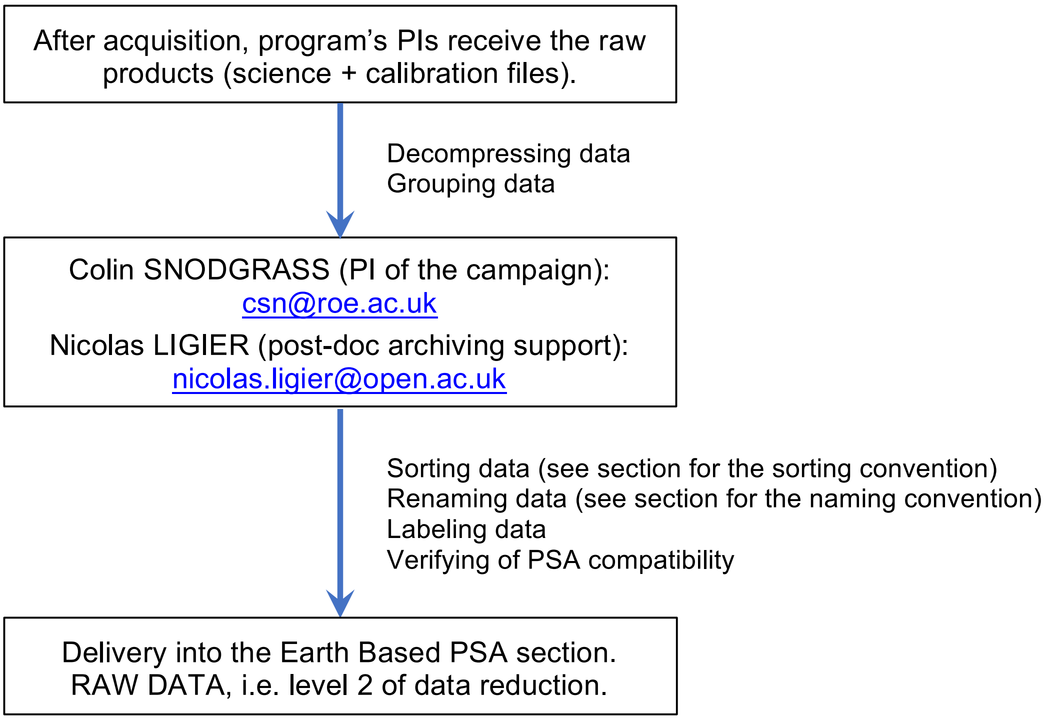
FoReRo2 is a focal reducer adapting its detector's imaging elements to the characteristic size of the object or of the seeing disk. FoReRo2 is a multimode instrument which allows simultaneous observations in the red and blue spectral range using 5 observing modes: (i) broad-band imaging, (ii) narrow-band imaging, (iii) long slit spectrography with a grism, (iii) interferometry with Fabry-Perot interferometers and, finally, (v) imaging polarimetry. The instrument was initially at the Max-Planck-Institute for Aeronomy and is now attached to the 2m telescope in the BNAO Rozhen.
The ACS instrument is a third-generation instrument and was installed in the HST in 2002. Its primary purpose was to increase HST imaging discovery efficiency by about a factor of 10, with a combination of detector area and quantum efficiency that surpasses previous instruments. ACS has three independent imaging capabilities: high resolution, ultraviolet and WFC. These cameras use a broad assortment of filters designed to address a large range of scientific goals. In addition, coronagraphic, polarimetric, and grism capabilities have made the ACS a versatile and powerful instrument.
SCORPIO-2 is a multimode focal reducer allowing various observations of extended and stellar object to be performed at the primary focus of the SAO RAS 6-m telescope. The instrument currently has 5 observing modes: (i) direct imaging, (ii) long-slit spectroscopy, (iii) long slit spectropolarimetry, (iv) broad-band polarimetry and (v), finally, 3D spectroscopy with scanning Fabry-Perot interferometer. Two other modes are under construction: 3D spectroscopy with an integral-field unit and multi slit spectroscopy.

FORS2 is an all-dioptric instrument for the wavelength range 330 – 1100 nm and provides an image scale of 0.25’’/pixel or of 0.125’’/pixel depending on the binning. FORS2 is equipped with a mosaic of two 2048 times 4096 CCDs particularly sensitive in the red part of the spectrum. FORS2 offers many observing modes, such as long-slit spectroscopy, direct imaging, PMOS, IPOL and many others (see documentation).
ISIS is a dual-arm spectrograph used for IPOS and PMOS. Each arm is a conventional spectrograph, with interchangeable reflection gratings, and a "horizontal" optical layout. The optical components of the two arms are optimised for specific wavelength ranges: the upper, blue, arm is optimised for the range 300 – 600 nm, whilst the lower, red, arm is optimised for the range 500 – 1000 nm.

2.1 Scientific Objectives

Comets are commonly considered as the most pristine objects in the Solar System. From Mars 2014 until September 2016, the Rosetta spacecraft and its impressive payload (21 instruments in total, 11 on the orbiter and 10 on the lander *Philae*) was fully dedicated to the *in-situ* study of 67P’s nucleus and its close environment, providing unprecedented results. Parallel to the Rosetta mission, a ground-based observation campaign including numerous instruments using some different scientific techniques was performed. The main scientific objectives of this very large coordinated campaign were to provide (1) essential data for mission planning, (2) large-scale context information for the coma and far beyond, and (3) also a way to directly compare 67P with other comets.
This dataset is about instruments using the POL technique, which provides information about the physical and chemical properties of the target. Hence, with a spatial sampling around 0.1 arcsec/pix, the data presented in this dataset should provide strong constraints on 67P’s dust coma and tail produced by its nucleus activity.

2.2 Data Handling Process



2.3 Product Generation

See section 2.2. Contact Nicolas LIGIER (see section 1.9) for further information.

2.4 Overview of Data Products

2.4.1 Pre-Flight Data Products

N/A

2.4.2 Sub-System Tests

N/A

2.4.3 Instrument Calibrations

Before starting, please note that calibration files are not provided at level 2 but at level 3 dataset, i.e. in this case: EAR-C-MULTI-3-67P-POL-V1.0.
Reduction pipelines are generally described in documents furnished in the DOCUMENT subdirectory, except ACS/WFC for which the reduction process is available on the STScI's website (see section 2). The reduction pipelines of ACS/WFC and FORS2 data are particularly complex. For ACS/WFC data, the reduction process requires to install the HSTCAL and DrizzlePac packages. Python and a C compiler are necessary to install the HSTCAL package from source, while DrizzlePac requires at least Python 2.6, PyFITS v3.0 and Numpy v1.6. For FORS2 data, the reduction process needs ESO software requiring installation in dedicated servers with specific OSes with the following minimal requirements: 64 bits, 32 Gb RAM, 4 CPU cores, 1Tb HD and Mac OS, Fedora or Scientific Linux. Moreover, future users should consider that (1) the calibration reversibility is not possible and (2) the level 3 data should NOT be taken at face value.

2.4.4 Other Files written during Calibration

N/A

2.4.5 Data Products

Science files and calibration files are the two types of data products in this dataset. Science products consist in cometary files (67P) and standard stars (STD). The data format is FIT for every single file.

2.4.6 Software

As this delivery only concerns raw uncalibrated data, no additional software is required. Such software will be described in the EAICD concerning the delivery of calibrated (level 3 of data reduction) and higher-level data (level 4 of data reduction).

2.4.7 Documentation

The DOCUMENT folder provides every existing user manuals and data reduction pipeline manuals for the different instrument. When existing, published reference scientific paper will be also provided. An additional document has been written for ACS/WFC to help future users to better understand this particular dataset. All documentation is provided in PDF format.

Following is the list of the available PDF documents:

- EAICD_C67PEARTH_POL_V1_0
- BNAO_ROZHEN_FORERO2_REF_N1
- BNAO_ROZHEN_FORERO2_REF_N2
- ESO_VLT_FORS2_ IPOL_TUTO_V1
- ESO_VLT_FORS2_PIPELINE_MANU
- ESO_VLT_FORS2_ PMOS_TUTO_V1
- ESO_VLT_FORS2_REF_PAPER
- ESO_VLT_FORS2_USER_MANU_P99
- HST_ACS_WFC_ADDITIONAL_INFO
- HST_ACS_WFC_DATA_HANDBOOK
- HST_ACS_WFC_INSTRU_HANDBOOK
- SAO_RAS_SCORPIO2_PAPER_N1

- SAO_RAS_SCORPIO2_PAPER_N2
- SAO_RAS_SCORPIO2_REDUC_N1
- SAO_RAS_SCORPIO2_REDUC_N2
- WHT_ISIS_USER_MANU_V1

2.4.8 Derived and other Data Products

The ephemeris information of 67P/Churyumov-Gerasimenko during the campaign are given in the SPICE dataset in the PSA/PDS, with the following DATA_SET_ID: RO-RL-E-M-A-C-SPICE-6-[V1.0]. Most relevant information is located in the meta-kernel in the EXTRAS/MK/ directory of that dataset. Further details and information can be found in the SPICE dataset's DATA subdirectory.

2.4.9 Ancillary Data Usage

N/A

3 Archive Format and Content

3.1 Format and Conventions

3.1.1 Deliveries and Archive Volume Format

The volumes are organized the standard way, one data set on one volume. In consultation with archive scientists, we will produce separate volumes for EDR (**E**dited **D**ata **R**ecord, raw data, level 2), RDR (**R**educed **D**ata **R**ecord, calibrated data, level 3) and DDR (**D**erived **D**ata **R**ecord, processed and evaluated data, level 4) data. Volumes will be delivered by FTP.

3.1.2 Data Set ID Formation

At this moment: EAR-C-MULTI-2-67P-POL-V1.0

→ "EAR" is about the fact that the data come from Earth-based instruments,
→ "C" is about the object's type, in this case a Comet,
→ "MULTI" is about the fact that the data come from multiple instruments,
→ "2" is about the data reduction level, in this RDR which means raw data,
→ "67P" is about the target of the data, i.e. the comet 67P/Churyumov-Gerasimenko,
→ "POL" is about the scientific method employed to acquire the data, in this case polarimetry,
→ and "V1.0" is about the version of this data set, in this case the version 1.0

3.1.3 Data Directory Naming Convention

The directory tree of the "DATA" directory is divided into several subdirectories. In the case of this data set, there are three layers. From the most global to the most specifi, these layers are:

1) The telescope name (ex: VLT),
2) The instrument name (ex: FORS2),
3) The date of acquisition, following the convention <year>_<month>_<day> (ex: 2016_01_10).

3.1.4 Filenaming Convention

One of the main highlight of this Earth based observation campaign is certainly the huge diversity of telescopes (38) and instruments (62) involve in it. However, in terms of archiving, it represents the main difficulty as there is no worldwide file-naming convention. Consequently, no file-naming convention has been set up for this dataset, except that the data are alle using the FIT format.

3.2 Standards Used in Data Product Generation

3.2.1 PDS Standards

The PDS3 standards are used.

3.2.2 Time Standards

The time standard used is UTC.

3.2.3 Reference Systems

N/A

3.2.4 Other Applicable Standards

N/A

3.3 Data Validation

Work in progress with ESA's archive scientists.

3.4 Content

3.4.1 Volume Set

N/A

3.4.2 Data Set

See section 3.1.3 for further information on the data set naming convention.

3.4.3 Directories

3.4.3.1 Root Directory

The root directory of the data set is equal to the DATA_SET_ID keyword value. It contains the files AAREADME.TXT and VOLDESC.CAT.

3.4.3.2 Calibration Directory

According to the PDS standards, this directory has to be named "CALIB". It contains subdirectories for each instrument used and a file named CALINFO.TXT. In the precise case of this data set, there is no calibration file in the subdirectories as all the calibration files are provided in the level 3 dataset, here: EAR-C-MULTI-3-67P-POL-V1.0. The CALINFO.TXT file provides supplementary information about how to get the primary calibration files.

3.4.3.3 Catalog Directory

This directory contains standard PDS catalog files:

- CATALOG.TXT
- DATASET.CAT
- INST_FORERO2.CAT
- INST_FORS2.CAT
- INST_HSTACS.CAT
- INST_ISIS.CAT
- INST_SCORPIO2.CAT
- INSTHOST_BNAO2M.CAT
- INSTHOST_HST.CAT
- INSTHOST_OBS060T1.CAT
- INSTHOST_SAOBTA.CAT
- INSTHOST_WHT.CAT
- MISSION.CAT
- REF.CAT
- SOFTWARE.CAT

3.4.3.4 Index Directory

This directory contains standard PDS index files:

- INDXINFO.TXT
- INDEX.LBL
- INDEX.TAB

3.4.3.5 Browse Directory and Browse Files

No browse files so no browse directory.

3.4.3.6 Geometry Directory

N/A

3.4.3.7 Software Directory

N/A

3.4.3.8 Gazetteer Directory

N/A

3.4.3.9 Label Directory

N/A

3.4.3.10 Document Directory

Along with the DOCINFO.TXT, we provide documents using the PDF or DOC formats. Inside the latter document(s), images are referenced and stored in extra files using the PNG format. All the documents exclusively relative to the instruments are stored in a subdirectory named "INSTDOC".

3.4.3.11 Extras Directory

N/A

3.4.3.12 Data Directory

Whatever the data set of the Earth based campaign of 67P, the DATA directory is always organized with the following structure:

```
<DATA>
    ||    <telescope name>
    ||        ||    <instrument name>
    ||        ||        ||    <acquisition date>
    ||        ||        ||    <acquisition date>
    ||    <telescope name>
    ||        ||    <instrument name>
    ||        ||        ||    <acquisition date>
    ||        ||        ||    …
```

Some sub-subdirectories may exist depending on the type of files (67P, STD) and other divisions based on parameters, such as the wavelength domain or the filter used, may also exist. In any case, the last division is either IPOL or PMOS.

Finally, a file named OBSERVING_NOTES.TXT is provided in the DATA directory. This document provides a fixed table containing general information about the data archived.

4 Detailed Interface Specifications

4.1 Structure and Organization Overview

The structure and the organization are already defined in earlier sections (3.1.3 and 3.4.3.12).

4.2 Data Sets, Definition and Content

Most of the content of the data set corresponds to the data. Each data file uses the FIT format and is associated to a LBL file containing information useful to understand the data file and contextualize its acquisition. Following is a table summing the different observations per telescope and per instrument.

Telescope	Instrument	Technique(s)	Program ID	Principal investigator's name(s)
BNAO-ROZHEN	FoReRo2	IPOL	-	G. BORISOV and P. NIKOLOV
ESO-VLT	FORS2	IPOL and PMOS	096.C-0821	S. BAGNULO
HST	ACS-WFC	IPOL	Id = 13863 Id = 14261	D. HINES
SAO-RAS-BTA	SCORPIO_2	IPOL and PMOS	-	N. KISELEV, V. ROSENBUSH and A. IVANOVA
WHT	ISIS	IPOL	-	C. SNODGRASS, S. BAGNULO and A. FITZSIMMONS

Table 2 - List of instruments, with main information, involved in this dataset.

4.3 Data Product Design

4.3.1 File Characteristics Data Elements

Following is an example of the file characteristics data elements section existing in a LBL file:

```
RECORD_TYPE          =  FIXED_LENGTH
RECORD_BYTES         =  2880
FILE_RECORDS         =  2956
FILE_NAME            = "JCIS01D8Q_RAW.FIT"
DATA_FORMAT          =  FITS
```

Every LBL file in the "DATA" directory contains the keywords `RECORD_TYPE`, `RECORD_BYTES`, `FILE_RECORDS`, `FILE_NAME` and `DATA_FORMAT`. In the case of this data set, the fixed length record type and the fits data format are always used and the record bytes is constantly equal to 2880. Thus, only the `FILE_RECORDS` and the `FILE_NAME` keywords differ between the LBL file.

4.3.2 Data Object Pointers Identification Data Elements

Following is an example of the data object pointers identification data elements existing in a LBL file:

```
^HEADER              = ("JCIS01D8Q_RAW.FIT",1)
^IMAGE               = ("JCIS01D8Q_RAW.FIT",11)
```

Since attached LBL file are used, pointers refer to a position in the corresponding FIT file.

4.3.3 Instrument and Detector Descriptive Data Elements

Following is an example of the keywords contained in a LBL file describing the main characteristics of the instrument and the telescope used to acquire the data:

```
INSTRUMENT_HOST_ID   = "HST"
INSTRUMENT_HOST_NAME = "HUBBLE SPACE TELESCOPE"
INSTRUMENT_ID        = "HSTACS"
INSTRUMENT_NAME      = "ADVANCED CAMERA FOR SURVEYS"
```

```
TELESCOPE_DIAMETER   =  2.40 <m>
TELESCOPE_LATITUDE   = "UNK"
TELESCOPE_LONGITUDE  = "UNK"
```

4.3.4 Structure Definition of Instrument Parameter Objects

N/A

4.3.5 Data Object Definition

Following is an example of the data object definition section existing in a LBL file:

```
OBJECT                 =  HEADER
  BYTES                      =  28800
  HEADER_TYPE                =  FITS
  INTERCHANGE_FORMAT         =  BINARY
  RECORDS                    =  10
  DESCRIPTION                = "Header of the file"
END_OBJECT             =  HEADER
OBJECT                 =  IMAGE
  OFFSET                     =  32768                        /* BZERO header */
  SCALING_FACTOR             =  1                           /* BSCALE header */
  LINE_SAMPLES               =  2070                        /* NAXIS1 header */
  LINES                      =  2046                        /* NAXIS2 header */
  UNIT                       = "DATA NUMBER"
  SAMPLE_BITS                =  16                          /* BITPIX header */
  SAMPLE_TYPE                =  MSB_UNSIGNED_INTEGER
  LINE_DISPLAY_DIRECTION     =  UP
  SAMPLE_DISPLAY_DIRECTION =  RIGHT
  DESCRIPTION                = "HST ACS-WFC raw science file"
END_OBJECT             =  IMAGE
```

4.3.6 Description of Instrument

N/A

4.3.7 Parameters Index File Definition

The index files are automatically generated by the PVV program

4.3.8 Mission Specific Keywords

Following are an example of specific, additional keywords that may be useful to scientists working on such Earth based cometary observation program:

```
TARGET_HELIOCENTRIC_DISTANCE      =  3.5 <AU>
GEOCENTRIC_DISTANCE               =  2.7 <AU>
```

These keywords may be primordial to contextualize and interpret the data.

5 Appendix: Available Software to read PDS files

N/A

6 Appendix: Example of Directory Listing of Data Set X

N/A