European Space Agency

To Planetary Science Archive
Interface control document

[Rosetta] - [Earth Based]

Document No.

Issue 1.0

1st June 2020

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Approved by: Principal Investigator

Distribution List

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Change Log

Date	Sections Changed	Reasons for Change

TBD ITEMS

Section	Description

Change Record

Issue	Date	Change	Responsible
Issue 1.0	1st July 2019	Final draft	N. LIGIER
Issue 1.0	1st June 2020	Revised draft	N. LIGIER

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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. First, it provides all the integral field spectroscopic instruments involved in the 67P/Churyumov-Gerasimenko's Earth based observation campaign, with a detailed description of the data, including data sources and destinations. 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 describes the data flow of the Earth based integral field spectroscopic 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 integral field spectroscopy data. However, people without any experience of the concerned IFS 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 IFS. An Earth based integral field spectrograph allows to observe the entirety of 67P's coma and tail in one go, and for each pixel mesures the intensity of the light as a function of wavelength. Hence, each observation corresponds to a 3D-cube (X,Y,λ) where each spatial pixel of the image has a full spectrum and permits to associate a spectral information to a spatial location. Finally, Earth based 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

AO	**A**daptive **O**ptics
ESO	**E**uropean **S**outhern **O**bservatory
FoV	**F**ield **of V**iew
IFS	**I**ntegral **F**ield **S**pectroscopy
IFU	**I**ntegral **F**ield **U**nit
FIT	**F**lexible **I**mage **T**ransport
mas	**m**illi-**a**rc**s**econd
MUSE	**M**ulti**-U**nit **S**pectroscopic **E**xplorer
NFM	**N**arrow **F**ield **M**ode
PI	**P**rincipal **I**nvestigator
PSA	**P**lanetary **S**cience **A**rchive
SINFONI	**SIN**gle **F**aint **O**bject **N**ear-IR **I**nvestigation
SPIFFI	**SP**ectrometer for **I**nfrared **F**aint **F**ield **I**maging
UT	**U**nit **T**elescope
UTC	**U**niversal **T**ime **C**oordinated
S/N	**S**ignal **/ N**oise
VLT	**V**ery **L**arge **T**elescope
WFM	**W**ide **F**ield **M**ode

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 of this Earth based observation campaign relies on the numerous different telescopes and instruments involved in it. Indeed, 62 instruments installed on 38 different telescopes were used in this campaign (Snodgrass et al. 2017, table 1), thus allowing to get a large amount of varied data that bring new insights on the cometary science but also contextualizing the Rosetta data. One of the multiple technique used in the campaign is IFS. Two instruments, both installed on the fourth UT of the ESO/VLT at the Paranal Observatory (Chile), were involved: MUSE and SINFONI (Figure 1). These instruments, combining high spatial and spectral resolutions, are complementary in terms of wavelength range; while MUSE covers the optical domain (475 – 935 nm), SINFONI investigates the near-infrared one (1.1 – 2.45 μm). Following paragraphs and the Table 1 shortly describe and summarize the main characteristics of these instruments. More detailed description and supplementary information are given by the documentation present in the "DOCUMENT" directory of this data set, mainly available online: http://www.eso.org/sci/facilities/paranal/instruments.html

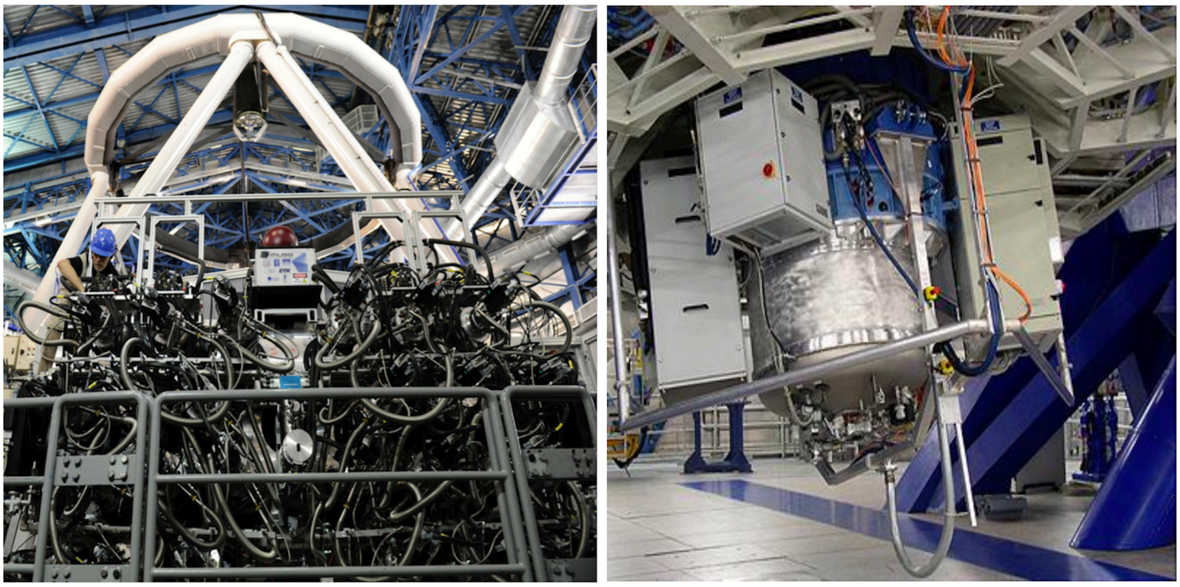


Figure 1 - MUSE (left) and SINFONI (right) instruments at the UT4 of the VLT.

MUSE is a second-generation VLT instrument located on the Nasmyth platform B of the VLT UT4. It is a large-format IFS, based on image-slicing technology, having a modular structure composed of 24 identical IFU modules that together sample a contiguous 1 arcmin^2 FoV in WFM sampled at 0.2"/pixel. Spectrally, the instrument samples most of the optical domain, with a mean spectral resolution around 3000. In the future, a NFM will also be made available, and will cover a ~7.5 arcsec^2 FoV sampled at 0.025"/pixel with laser tomography AO correction. MUSE was built by a Consortium involving institutes from France, Germany, The Netherlands, Switzerland and ESO.

SINFONI is a near-infrared IFS fed by a curvature sensing adaptive optics module. The spectrograph operates with 4 gratings (J, H, K, H+K) providing a spectral resolution around 2000, 3000, 4000 in J, H, K, respectively, and 1500 in H+K. The SINFONI FoV on the sky is sliced into 32 slitlets. Pre-optics allow to choose the angular size of the slices on the sky. The choices are 250 mas, 100 mas and 25 mas, leading to FoVs on the sky of 8"×8", 3"×3" and 0.8"×0.8" respectively. Each one of the 32 slitlets is imaged onto 64 pixels. Typical limiting magnitudes (S/N = 10 in 1h on source) are around 17–18 mag. SINFONI was built by a Consortium involving institutes from Germany, Netherlands and ESO.

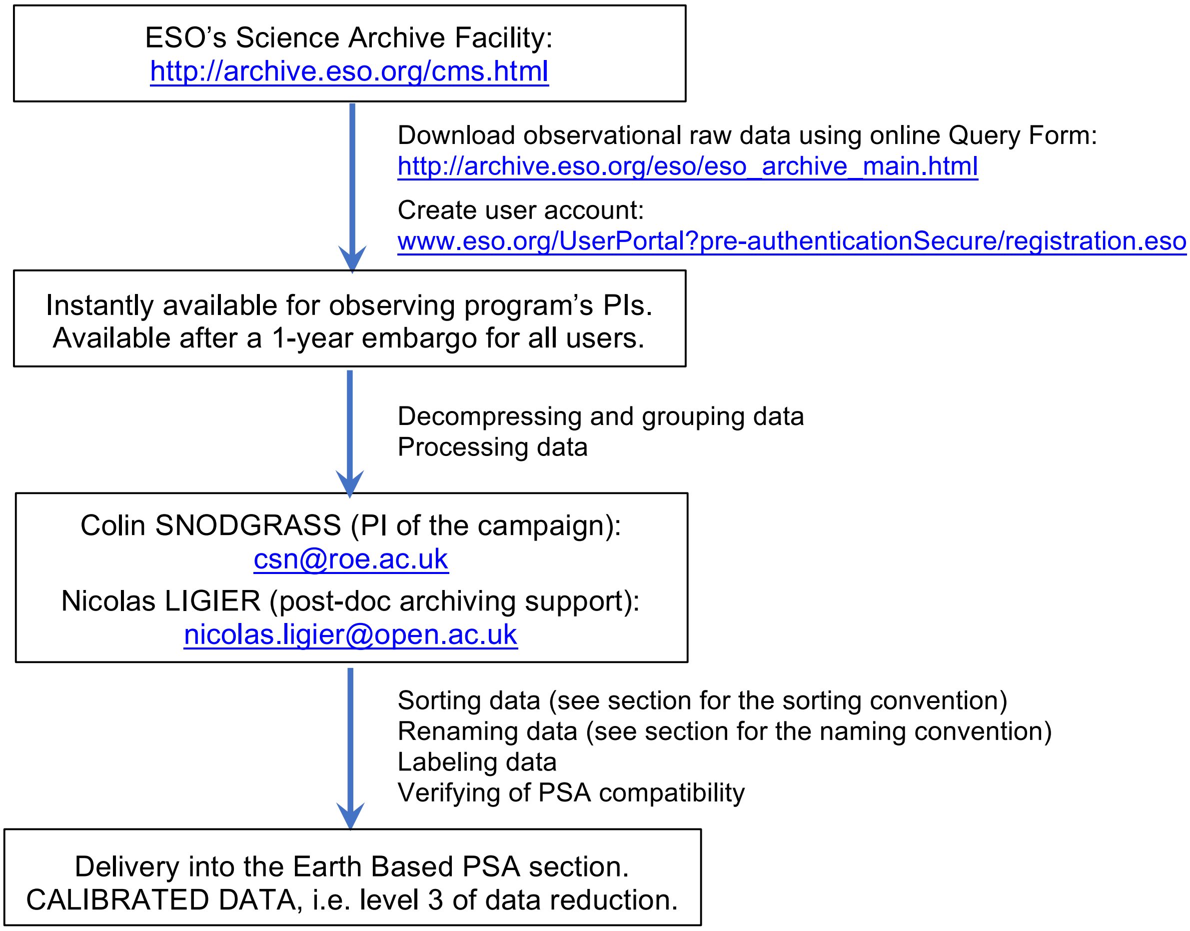
Instrument name	Observatory	Wavelengths	Spectral resolution	Spatial sampling
MUSE	ESO-VLT	465 – 930 nm	1700 – 3400	200 mas
SINFONI	ESO-VLT	1.1 – 2.45 μm	1500 – 4000	250, 100 & 25 mas

Table 1 - Summary of MUSE and SINFONI main characteristics

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 IFS technique, which allows to combine a spectral information to a spatial one. Hence, with a spatial sampling about few dozens of mas, the data of MUSE and SINFONI should provide important information on the compositional variation across the gas, the dust coma and the tail produced by 67P's 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

ESA's archiving policy is to ideally make available all the files that observers got during acquisitions. However, due to the huge amount that calibration files represent in this Earth based campaign, in agreement with ESA's archiving scientists, it has been decided to only archive calibration files that are not already available on an existing archiving website.

In the case of this data set, calibration files are available on the ESO's Science Archive Facility. A text file is furnished in each sub-directory of the CALIB directory explaining how to request these files from ESO's website. Before making such a request, an account needs to be first created at the following website: http://www.eso.org/UserPortal/pre-authenticationSecure/registration.eso

Finally, the data reduction pipeline is very well described in documents provided in the documentation sub-directory. However, this reduction process needs future 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 data processing is quite complex, (2) the calibration reversibility is not possible, and finally (3) the level 3 data should be taken at face value.

2.4.4 Other Files written during Calibration

N/A

2.4.5 Data Products

Data products consist in calibrated science data of the comet and its close environment, i.e. its coma and tail, taken at different dates. After processing, MUSE and SINFONI data are 3D-cubes (X,Y,λ), with wavelength as third dimension. The data format is FIT for both instruments. The free software QFitsView is very useful to display the data. You can download it at: www.mpe.mpg.de/~ott/QFitsView

2.4.6 Software

As this delivery concerns calibrated data, additional software could be required (see section 2.4.3). Information about such software should be available on concerned websites. If not, and if required by reviewers, such software could be described in a new version of this EAICD.

2.4.7 Documentation

At least, we will provide user manuals and data reduction pipeline manuals for each instrument in the "DOCUMENT" directory. When existing, published reference scientific paper will be also provided. The format of the documentation will be PDF, DOC (this file) and PNG for images used to illustrate in this document. Following is the list of the available PDF and PNG documents:

- EAICD_C67PEARTH_IFS_V1_0.PDF
- MUSE_PIPELINE_MANU_V0_17.PDF
- MUSE_REFLEX_TUTO_V10_0.PDF
- MUSE_USER_MANU_P96.PDF
- SINFONI_PIPELINE_MANU_V19_8.PDF
- SINFONI_PIPELINE_PAPER.PDF
- SINFONI_REFERENCE_PAPER.PDF
- SINFONI_REFLEX_TUTO_V1_8.PDF
- SINFONI_USER_MANU_P96.PDF
- MUSE_UT4.PNG
- SINFONI_UT4.PNG

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. The volumes will be delivered by FTP.

3.1.2 Data Set ID Formation

At this moment: EAR-C-MULTI-3-67P-IFS-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,
→ "3" is about the data reduction level, in this EDR which means reduced data,
→ "67P" is about the target of the data, i.e. the comet 67P/Churyumov-Gerasimenko,
→ "IFS" is about the scientific method employed to acquire the data, in this case IFS,
→ 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 specific, these layers are:

1) The telescope name (ex: VLT),
2) The instrument name (ex: MUSE),
3) The date of acquisition, following the convention <year>_<month>_<day> (ex: 2016_03_03).

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) involved. 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. However, the day and the time (UTC) of acquisition is in the name of the file.

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 the 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 files in the subdirectories as these files are already freely available on an existing archiving website. Instead, TXT files named INFO_CALIB_*** are provided to explain how to get these files.

3.4.3.3 Catalog Directory

This directory contains standard PDS catalog files:

- CATALOG.TXT
- DATASET.CAT
- INST_MUSE.CAT
- INST_SINFONI.CAT
- INSTHOST_OBS060T4.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>
    ||      ||      ||      ||  <67P>
    ||      ||      ||      ||  <STD>
    ||      ||      ||      ||  <SKY>
    ||      ||      ||  <acquisition date>
    ||      ||      ||      ||  <67P>
    ||      ||      ||      ||  <STD>
    ||      ||      ||      ||  <SKY>
    ||  <telescope name>
    ||      ||  <instrument name>
    ||      ||      ||  <acquisition date>
    ||      ||      ||      ||  <67P>
    ||      ||      ||      ||  …
```

See section 3.1.3 for further information on the data set naming convention.
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	Spectral band/range and spectral resolution	Program ID	Principal investigator's name(s)
ESO-VLT	MUSE	Wavelength: 475 – 935 nm Resolution: 1700 – 3400	096.C-0160 096.C-0855	A. GUILBERT-LEPOUTRE
ESO-VLT	SINFONI	Wavelength: H+K band Resolution: ~1500	096.C-0160	A. GUILBERT-LEPOUTRE

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         =  998368
FILE_NAME            = "67P_SCI_20160303T032743.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:

```
^DATA_PRIMARY_HEADER = ("67P_SCI_20160303T032743.FIT",1)
^DATA_IMAGE          = ("67P_SCI_20160303T032743.FIT",36)
^STAT_IMAGE_HEADER   = ("67P_SCI_20160303T032743.FIT",499201)
^STAT_IMAGE          = ("67P_SCI_20160303T032743.FIT",499203)
```

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   = "OBS060T4"
INSTRUMENT_HOST_NAME = "PARANAL OBSERVATORY 8.2-M YEPUN VERY LARGE TELESCOPE
        (VLT)-UT4"
INSTRUMENT_ID        = "MUSE"
INSTRUMENT_NAME      = "MULTI-UNIT SPECTROSCOPIC EXPLORER (MUSE)"
TELESCOPE_DIAMETER   =  8.2 <m>
TELESCOPE_LATITUDE   = -24.6270 <deg>                    /* GEOLAT header */
TELESCOPE_LONGITUDE  = -70.4040 <deg>                    /* GEOLON header */
```

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                 =  DATA_PRIMARY_HEADER
  BYTES                      =  100800
  HEADER_TYPE                =  FITS
  INTERCHANGE_FORMAT         =  BINARY
  RECORDS                    =  35
  DESCRIPTION                = "Primary header of the file and the DATA image"
END_OBJECT             =  DATA_PRIMARY_HEADER
OBJECT                 =  DATA_IMAGE
  OFFSET                     =  0     /* expected value as no info in header */
  SCALING_FACTOR             =  1     /* expected value as no info in header */
  LINE_SAMPLES               =  317                     /* NAXIS1 header */
  LINES                      =  308                     /* NAXIS2 header */
  BANDS                      =  3681                    /* NAXIS3 header */
  UNIT                       = "DATA NUMBER"
  SAMPLE_BITS                =  32
  SAMPLE_TYPE                =  IEEE_REAL
  LINE_DISPLAY_DIRECTION     =  UP
  SAMPLE_DISPLAY_DIRECTION   =  RIGHT
  DESCRIPTION                = "ESO-VLT MUSE calibrated file: DATA part"
END_OBJECT             =  DATA_IMAGE
OBJECT                 =  STAT_IMAGE_HEADER
  BYTES                      =  5760
  HEADER_TYPE                =  FITS
  INTERCHANGE_FORMAT         =  BINARY
  RECORDS                    =  2
  DESCRIPTION                = "Header of the STAT image"
END_OBJECT             =  STAT_IMAGE_HEADER
OBJECT                 =  STAT_IMAGE
  OFFSET                     =  0     /* expected value as no info in header */
  SCALING_FACTOR             =  1     /* expected value as no info in header */
  LINE_SAMPLES               =  317                     /* NAXIS1 header */
  LINES                      =  308                     /* NAXIS2 header */
  BANDS                      =  3681                    /* NAXIS3 header */
  UNIT                       = "DATA NUMBER"
  SAMPLE_BITS                =  32
  SAMPLE_TYPE                =  IEEE_REAL
  LINE_DISPLAY_DIRECTION     =  UP
  SAMPLE_DISPLAY_DIRECTION   =  RIGHT
  DESCRIPTION                = "ESO-VLT MUSE calibrated file: STAT part"
END_OBJECT             =  STAT_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      =  2.5 <AU>
GEOCENTRIC_DISTANCE               =  1.5 <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