PDS Data review
DATA package: nasa:pds:gbo-palomar:pharo-pluto
Reviewer: Xiao-Duan Zou (Planetary Science Institute)
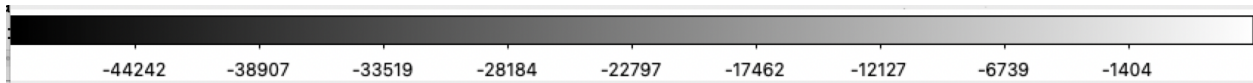Date: June 30 2021

1. Dateset:
- Format: PDS4
- Version: 1.0
- Overview: Pluto's Opposition Surge during 2018 and 2019, v1.0. RAW Data was taken with the 5 m Hale telescope using the Palomar High Angular Resolution Observer adaptive optics system at Palomar Observatory. This data set contains raw image files of the Pluto-Charon system, associated dark frames, flat fields and standard stars in FITS format.

2. Documents:
   - Only one description with XML label and a paper under revision, which is not attached.
   - Value of the images are not explained.
   - All the observation sequences or targets are not documented
   - Need definition for understanding the cards and values in header
   - The image label is not sufficient to understand the fits file

3. Images:
   - 129 image
   - 1024 x 1024
   - What are the values? Why all negative in some images? image ph0001.fit
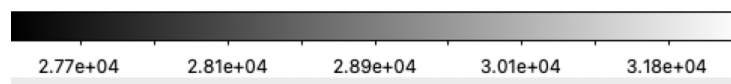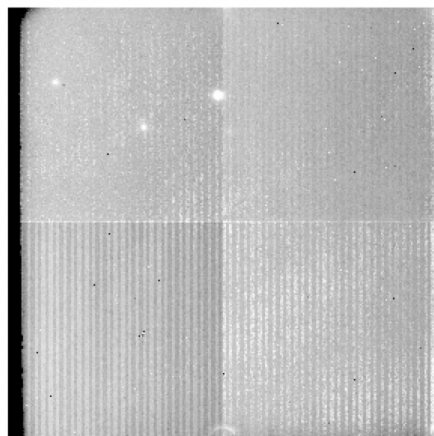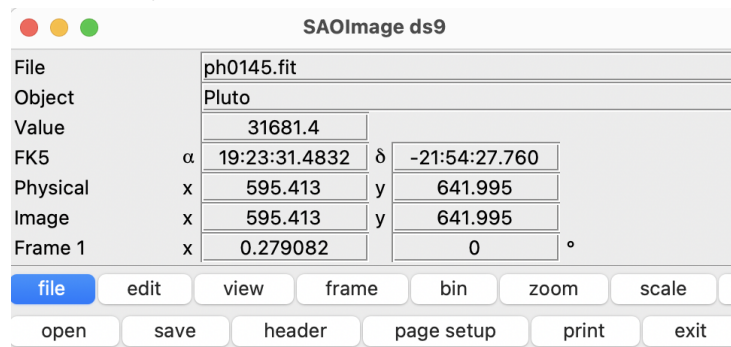

   - Read the XML label by python tool: *pds4_tools.read* and *pds4_tools.view*

- Readable by DS9

- Readable by astropy.os.fits

No.	Name	Ver	Type	Cards	Dimensions	Format
0	PRIMARY	1	PrimaryHDU	84	(1024, 1024)	float32

- Header information: no related documentation

```
SIMPLE  =                    T / conforms to FITS standard
BITPIX  =                  -32 / array data type
NAXIS   =                    2 / number of array dimensions
NAXIS1  =                 1024
NAXIS2  =                 1024
COMMENT   FITS (Flexible Image Transport System) format is defined in 'Astronomy
COMMENT   and Astrophysics', volume 376, page 359; bibcode: 2001A&A...376..359H
OBJECT  = 'Pluto   '
ORIGIN  = 'Cornell-IR'
```
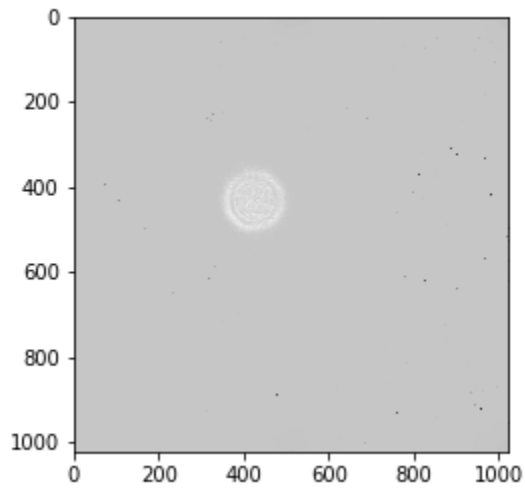
```
DATE-OBS= '2018-07-31'        / UTC from LINUX
TIME-OBS= '07:02:40'          / UTC from LINUX
OBSERVER= 'Buratti, Kramer'
INSTRUME= 'PHARO   '
TELESCOP= 'Hale 200-inch'
RIOTTF  = '%2u, %3d sec'      / RIOPCI FPGA Program File
PHAROTTF= '%2u, %3d sec'      / PHARO FPGA Program File
WRITEMOD=                2 / 0=ALL,1=END,2=DIF,3=SUB
STARTROW=                0
STARTCOL=                0
T_SCAN  =            80712 / Detector total scan time (msec)
T_INT   =            79296 / Detector integration time (msec)
T_EFF   =            79296 / Effective integration time (msec)
T_FRAME =             1316 / Frame clocking time
T_FRGAP =              100 / Pause time between frames
T_SHUTOP=                0 / Shutter open time
NENDPTFR=                1 / N End Pt. Frames
NPAUSEFR=               55 / N Pause Frames
SLIT    = '40" Field'        / Stepper mech names
LYOT    = 'Std Cross'
FILTER  = 'K      '
GRISM   = 'Open   '
SHUTTER = 'Open    '
CAROUSEL= '40 mas  '
SLITPOS =                7 / Stepper mech positions
LYOTPOS =                3
FILTPOS =                4
GRISPOS =                3
SHUTPOS =                2
CAROPOS =                1
SLITSTEP=             2400 / Stepper mech step numbers
LYOTSTEP=              793
FILTSTEP=             1200
GRISSTEP=              800
SHUTSTEP=               56
CAROSTEP=                0
TIME_TCS= '07:00:10.6'        / UTC FROM TCS
WCSAXES =                2 / WCS AXES
RADECSYS= 'ICRS    '          / SYSTEM OF REF. COORD
EQUINOX =            2000. / EQUINOX OF REF. COORD
CTYPE1  = 'RA---TAN'          / AXIS TYPE
CTYPE2  = 'DEC--TAN'          / AXIS TYPE
CUNIT1  = 'DEGREES '          / PHYSICAL UNITS
CUNIT2  = 'DEGREES '          / PHYSICAL UNITS
CRPIX1  =              430 / REFERENCE PIXEL IN X
CRPIX2  =              430 / REFERENCE PIXEL IN Y
```

```
CD1_1   =       1.111092E-05 / ROTATION MATRIX
CD2_1   =       4.243604E-08 / ROTATION MATRIX
CD1_2   =      -4.243604E-08 / ROTATION MATRIX
CD2_2   =       1.111092E-05 / ROTATION MATRIX
LONPOLE =              180. / LONG OF POLE
CRVAL1  =         290.8792 / R.A.
CRVAL2  =         -21.91008 / DEC.
HOURANGL=         5.877917 / HOUR ANGLE
RA_OFFS =       -0.002240181 / R.A. OFFSET
DEC_OFFS=        0.000867152 / DEC. OFFSET
RA_RATE =       -2.638889E-07 / R.A. RATE (DEGREES/HOUR)
DEC_RATE=       -5.787037E-08 / DEC. RATE (DEGREES/HOUR)
AIR_MASS=         1.762591
CR_ANGLE=         -219.7812
FOCUS_MM=           51.97
TUBEL_MM=            0.
WFS_DELX=             0. / Offset WFS to PHARO (arcsec)
WFS_DELY=            0.
FSM_IGN =            0. / FSM SERVO GAINS
FSM_PGN =            0.
DM_IGN  =            0. / DM SERVO GAINS
DM_PGN  =            0.
FSM_ON  =             T
DM_ON   =             T
FSM_RATE=             0 / WFS FRAMES PER FSM UPDATE
WFS_RATE=            0 / HZ
LOG_DATA=            0 / BINARY ENCODED
RECONST = '      '
AO_QUAL =             0. / AO QUALITY MEASURE
```

Where "object" is empty value:

ph0026.fit