PDS Data Review
DART mission shape models

Yaeji Kim

Sep 15, 2023

Documentation

- [Page 14] When elaborating the dtm folder, it only says: *dtm   - contains the digital terrain models as FITS FTM files.*
  However, the dtm folder also includes slp files which are FITS binary table files. The descriptions on each folder should be revised, or details should be added.

- Likewise, Shape folder also includes alb files which are FITS binary table files [1].

- [Table 6] Recommend to add the unit of the values in Table 6.

[1]

The data products are organized under each collection into folders by type:

dtm   - contains the digital terrain models as FITS FTM files
gravity   - contains the gravity ancillary data as FITS binary table files
shape   - contains the shape files (OBJ)
tilt   - contains the tilt ancillary data as FITS binary table files

[2]

Table 6. Data Type Identifiers

PLANEn (Image Cube) Evaluated at vertices	TTYPE Data Column (Ancillary File) Evaluated at facet centers	Description String (Ancillary Filename)	MAP_NAME (Ancillary File)
Latitude	LATITUDE	N/A	N/A
Longitude	LONGITUDE	N/A	N/A
Radius	RADIUS	N/A	N/A
X Coordinate	N/A	N/A	N/A
Y Coordinate	N/A	N/A	N/A
Z Coordinate	N/A	N/A	N/A
Height above plane normal	N/A	N/A	N/A
Sigma	Sigma (see Table 7)	N/A	N/A
Albedo	ALBEDO	alb	albedo-intensity*
Quality	N/A	N/A	N/A
Normal vector X	NORMAL VECTOR_X	nvf	normal vector
Normal vector Y	NORMAL VECTOR_Y	nvf	normal vector
Normal vector Z	NORMAL VECTOR_Z	nvf	normal vector
Gravity vector X	GRAVITY VECTOR_X	grv	gravity vector
Gravity vector Y	GRAVITY VECTOR_Y	grv	gravity vector
Gravity vector Z	GRAVITY VECTOR_Z	grv	gravity vector
Gravitational magnitude	GRAVITATIONAL_MAGNITUDE	grm	gravitational magnitude
Gravitational potential	GRAVITATIONAL_POTENTIAL	pot	gravitational potential
Elevation	ELEVATION	elv	elevation
Slope	SLOPE	slp	slope
Facet tilt	FACET TILT	fti	facet tilt
Facet tilt direction	FACET TILT DIRECTION	fdi	facet tilt direction
Mean tilt	MEAN TILT	mti	mean tilt
Mean tilt direction	MEAN TILT DIRECTION	mdi	mean tilt direction

FITS DTM files (3D)

- Tried to open and read the file with the PDS4 viewer

- discovered that for all Array_2D_Images, (1) the Axis_Array elements values are wrong, and the (2) offsets are wrong after the first Array_2D_Image. → resolved by the DART team (Sep 6, 2023)

- Re-checked that the redelivered XML file works properly in the PDS4 viewer [1].

- Found the label has a unit issue [2]

[2]

All elements have the same unit (m/s^2)

[1]

Updated xml file

Results with the redelivered xml file

FITS DTM files (3D)

- abled to visualize the image data and read the header files with PDS4 viewer, SAOImageDS9 and Python

- cross-checked if the header of the DTM files corresponds to the documentation.
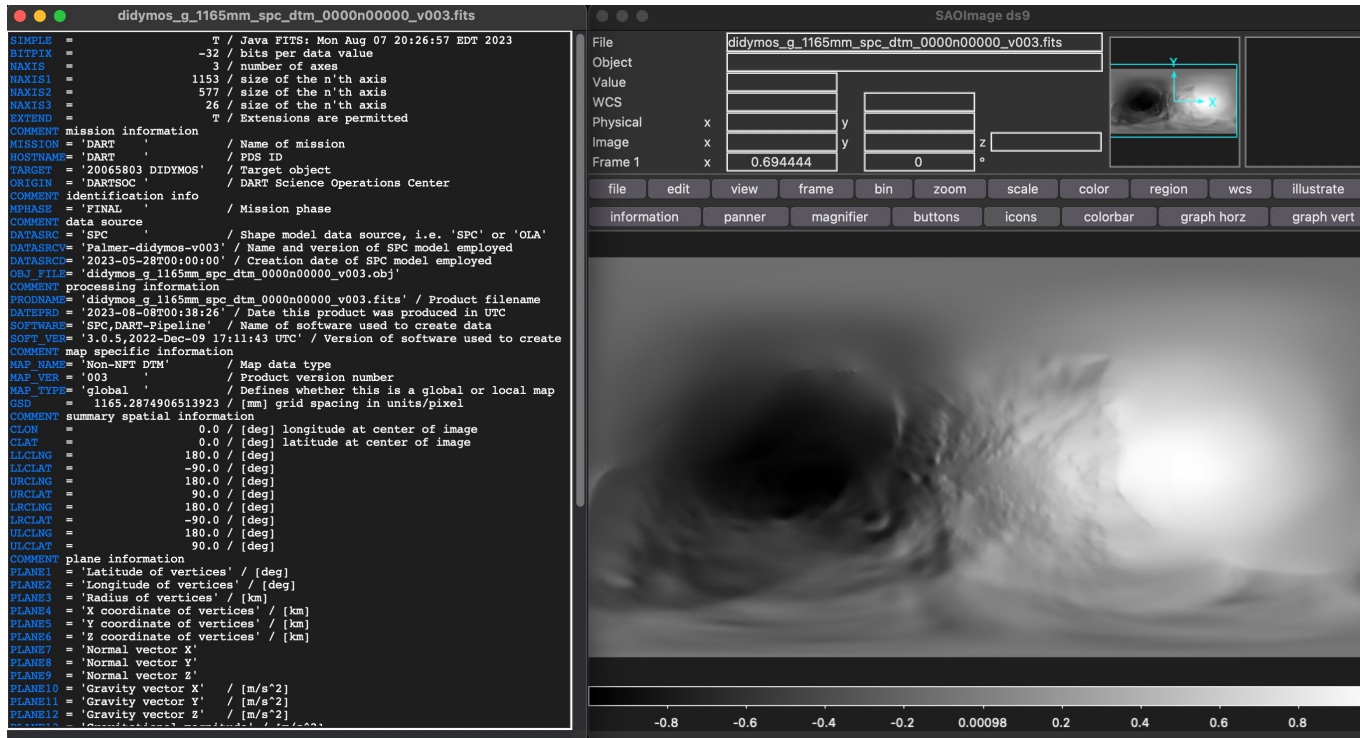
Results screenshot from SAOImageDS9


```
didymos_g_1165mm_spc_dtm_0000n00000_v003.fits
FITS Header Information:
--------------------------
SIMPLE: True
BITPIX: -32
NAXIS: 3
NAXIS1: 1153
NAXIS2: 577
NAXIS3: 26
EXTEND: True
COMMENT: mission information
MISSION: DART
HOSTNAME: DART
TARGET: 20065803 DIDYMOS
ORIGIN: DARTSOC
COMMENT: identification info
MPHASE: FINAL
COMMENT: data source
DATASRC: SPC
DATASRCV: Palmer-didymos-v003
DATASRCD: 2023-05-28T00:00:00
OBJ_FILE: didymos_g_1165mm_spc_dtm_0000n00000_v003.obj
COMMENT: processing information
```
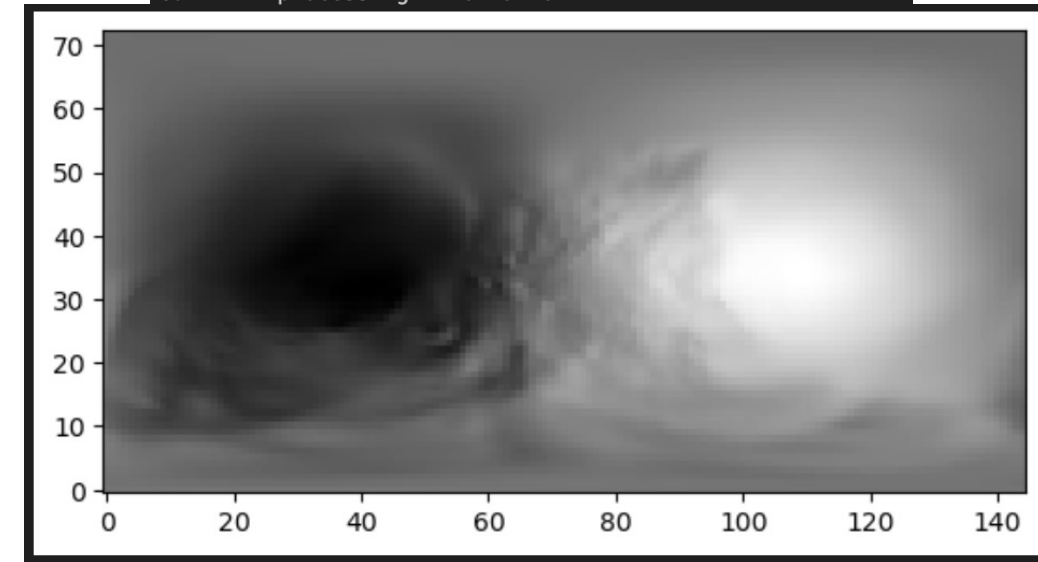

Results screenshot from Python

FITS binary table files (2D) xx_slp_xx (dtm folder)

Results screenshot from Python

- abled to read the binary table with PDS4 viewer and Python

- cross-checked if the header of the DTM files corresponds to the documentation.

- The label for xx_slp_xx.xml has incorrect information: 1) the unit of slope (m/s^2 >> degree), 2) the unit of SIGMA is not labeled (degree)

- checked if Python and PDS4 viewer provide the same plot


```
didymos_g_1165mm_spc_slp_0000n00000_v003.fits
FITS Header Information:
-----------------------
XTENSION: BINTABLE
BITPIX: 8
NAXIS: 2
NAXIS1: 24
NAXIS2: 3145728
PCOUNT: 0
GCOUNT: 1
TFIELDS: 6
TFORM1: 1J
TTYPE1: FACET_NUM
TFORM2: 1E
TTYPE2: LATITUDE
TUNIT2: DEGREES
TFORM3: 1E
TTYPE3: LONGITUDE
TUNIT3: DEGREES
TFORM4: 1E
TTYPE4: RADIUS
TUNIT4: KILOMETERS
TFORM5: 1E
TTYPE5: SLOPE
TUNIT5: DEGREES
TFORM6: 1E
TTYPE6: SIGMA
TUNIT6: DEGREES
```

```
Field_Binary
    name: FACET_NUM
    field_location: 1
    data_type: SignedMSB4
    field_length: 4
    description: facet number.

Field_Binary
    name: LATITUDE
    field_location: 5
    data_type: IEEE754MSBSingle
    field_length: 4
    unit: deg
    description: latitude at facet center

Field_Binary
    name: LONGITUDE
    field_location: 9
    data_type: IEEE754MSBSingle
    field_length: 4
    unit: deg
    description: longitude at facet center

Field_Binary
    name: RADIUS
    field_location: 13
    data_type: IEEE754MSBSingle
    field_length: 4
    unit: km
    description: radius at facet center

Field_Binary
    name: SLOPE
    field_location: 17
    data_type: IEEE754MSBSingle
    field_length: 4
    unit: m/s^2                    Wrong unit (-> degree)
    description:
        slope relative to gravity at facet center.
        The slope is the result of assuming uniform density for the
        taking into account the rotation rate of the asteroid. For
        we also take into account the gravitational effect of Didyn

Field_Binary
    name: SIGMA
    field_location: 21
    data_type: IEEE754MSBSingle
    field_length: 4                 Unit is not labeled
    description: sigma error
```

Search   Match Case

PDS4 Viewer - Data Structure Summary for '/Users/yaejikim/PDS_DATA/DART/data_derived_didymos_model_v003/dtm/didymos_g_...

Index	Name	Type	Dimension	View		
2	didymos_g_1165mm_spc_slp_0000...	Table_Binary	6 cols X 3145728 rows	Label	Table	Plot

PDS4 Viewer - Table 'didymos_g_1165mm_spc_slp_0000n00000_v003'

PDS4 Viewer - Plot from 'didymos_g_1165mm_spc_slp_0000n00000_v0...

Pixel X   Y

Row #	FACET_NUM	LATITUDE	LONGITUDE	RADIUS
0	0	27.754	81.064	0.376929
1	1	27.7497	81.1714	0.376926
2	2	27.8194	81.2328	0.37672
3	3	27.8145	81.3404	0.376716
4	4	27.8845	81.4019	0.376509
5	5	27.8793	81.5096	0.376503
6	6	27.9493	81.5714	0.376297
7	7	27.9439	81.6791	0.376293
8	8	28.0139	81.7412	0.376088
9	9	28.008	81.8491	0.376084
10	10	28.0775	81.912	0.375879
11	11	28.0714	82.02	0.375876
12	12	28.1412	82.0825	0.37567
13	13	28.1352	82.19	0.375666
14	14	28.2052	82.2533	0.375458
15	15	28.1991	82.3615	0.375455
16	16	28.2689	82.4251	0.375252
17	17	28.2624	82.5329	0.375254

Results screenshot from PDS4 viewer

FITS binary table files (2D) xx_elv_xx, xx_pot_xx (gravity folder)

- abled to read the binary table with PDS4 viewer and Python

- cross-checked if the header of the DTM files corresponds to the documentation.

- The label for xx_elv_xx.xml has incorrect information: 1) the unit of elevation (M/S^2 >> m), 2) the unit of gravitational potential (M/S^2 >> J/KG), 3) the unit of SIGMA is not labeled (m)

- checked if Python and PDS4 viewer provide the same plot

Results screenshot from Python

didymos_g_1165mm_spc_elv_0000n00000_v003.fits
FITS Header Information:

XTENSION: BINTABLE
BITPIX: 8
NAXIS: 2
NAXIS1: 24
NAXIS2: 3145728
PCOUNT: 0
GCOUNT: 1
TFIELDS: 6
TFORM1: 1J
TTYPE1: FACET_NUM
TFORM2: 1E
TTYPE2: LATITUDE
TUNIT2: DEGREES
TFORM3: 1E
TTYPE3: LONGITUDE
TUNIT3: DEGREES
TFORM4: 1E
TTYPE4: RADIUS
TUNIT4: KILOMETERS
TFORM5: 1E
TTYPE5: ELEVATION
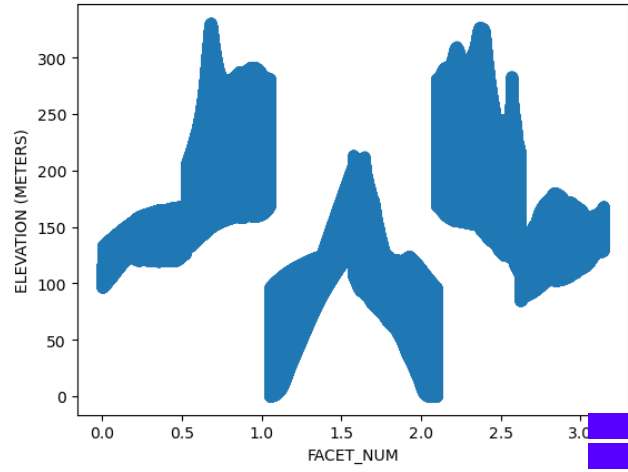TUNIT5: METERS
TFORM6: 1E
TTYPE6: SIGMA
TUNIT6: METERS

Results screenshot from PDS4 viewer

Wrong unit (-> meters)

Unit is not labeled

FITS binary table files (2D) xx_grm_xx, xx_grv_xx (gravity folder)

Results screenshot from Python

- abled to read the binary table with PDS4 viewer and Python

- cross-checked if the header of the DTM files corresponds to the documentation.

- The label for xx_grm_xx.xml and xx_grv_xx.xml has incorrect information: 1) the unit of SIGMA is not labeled (M/S^2)

- checked if Python and PDS4 viewer provide the same plot

```
didymos_g_1165mm_spc_grm_0000n00000_v003.fits
FITS Header Information:
------------------------
XTENSION: BINTABLE
BITPIX: 8
NAXIS: 2
NAXIS1: 24
NAXIS2: 3145728
PCOUNT: 0
GCOUNT: 1
TFIELDS: 6
TFORM1: 1J
TTYPE1: FACET_NUM
TFORM2: 1E
TTYPE2: LATITUDE
TUNIT2: DEGREES
TFORM3: 1E
TTYPE3: LONGITUDE
TUNIT3: DEGREES
TFORM4: 1E
TTYPE4: RADIUS
TUNIT4: KILOMETERS
TFORM5: 1E
TTYPE5: GRAVITATIONAL MAGNITUDE
TUNIT5: M/S^2
TFORM6: 1E
TTYPE6: SIGMA
TUNIT6: M/S^2
```


Results screenshot from PDS4 viewer

PDS4 Viewer - Data Structure Summary for '/Users/yaejikim/PDS_DATA/DART/data_derived_di

Index	Name	Type	Dimension
2	didymos_g_1165mm_spc_grm_0000...	Table_Binary	6 cols X 3145728 rows

PDS4 Viewer - Plot from 'didymos_g_1165mm_spc_grm_0000n00000_v003'

Pixel X [   ]   Y [   ]

PDS4 Viewer - Label View

Label

field_location: 5
data_type: IEEE754MSBSingle
field_length: 4
unit: deg
description: latitude at facet center

Field_Binary
name: LONGITUDE
field_location: 9
data_type: IEEE754MSBSingle
field_length: 4
unit: deg
description: longitude at facet center

Field_Binary
name: RADIUS
field_location: 13
data_type: IEEE754MSBSingle
field_length: 4
unit: km
description: radius at facet center

Field_Binary
name: GRAVITATIONAL MAGNITUDE
field_location: 17
data_type: IEEE754MSBSingle
field_length: 4
unit: m/s^2
description: gravitational magnitude at facet cen

Field_Binary
name: SIGMA
field_location: 21
data_type: IEEE754MSBSingle
field_length: 4
description: sigma error

Unit is not labeled
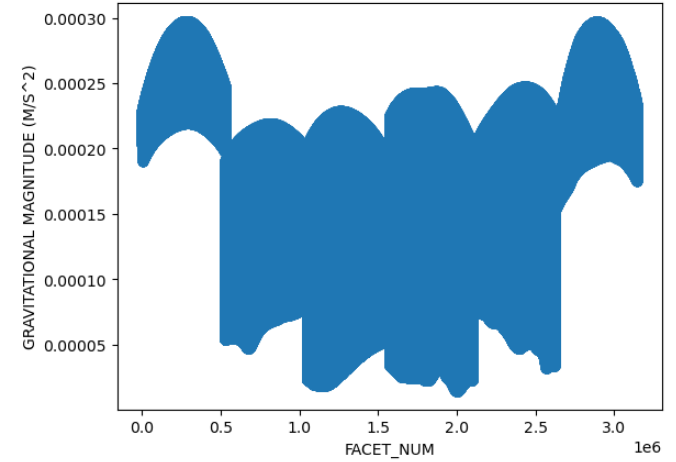
FITS binary table files (2D)
xx_alb_xx (shape folder)

- abled to read the binary table with PDS4 viewer and Python

- cross-checked if the header of the DTM files corresponds to the documentation.

- The label for xx_alb_xx.xml has incorrect information: 1) the unit of albeo should be unitless (M/S^2 >> unitless)

FITS binary table files (2D)
xx_are_xx, xx_div_xx, xx_fdi_xx, xx_fti_xx, xx_mdi_xx, xx_mht_xx, xx_mti_xx, xx_nvf_xx, xx_rdi_xx, xx_rti_xx, xx_tiv_xx (tilt folder)

- All files in 'tilt folder' also have the same label issue (see the below)

Field_Binary
name: FACET AREA
field_location: 17
data_type: IEEE754MSBSingle
field_length: 4
unit: m/s^2   Wrong unit
description: Area of the facet

Field_Binary
name: SIGMA   Unit is not labeled
field_location: 21
data_type: IEEE754MSBSingle
field_length: 4
description: sigma error

Field_Binary
name: TILT DIRECTION VARIATION
field_location: 17
data_type: IEEE754MSBSingle
field_length: 4
unit: m/s^2
description:
          The variation of the mean
          the facet center

Field_Binary
name: SIGMA
field_location: 21
data_type: IEEE754MSBSingle
field_length: 4
description: sigma error

Field_Binary
name: TILT DIRECTION
field_location: 17
data_type: IEEE754MSBSingle
field_length: 4
unit: m/s^2
description:
          The clockwise angle of the norma
          of the asteroid after the normal
          the x,y component of the radial

Field_Binary
name: SIGMA
field_location: 21
data_type: IEEE754MSBSingle
field_length: 4
description: sigma error

Field_Binary
name: FACET TILT
field_location: 17
data_type: IEEE754MSBSingle
field_length: 4
unit: m/s^2
description: Angle separating the

Field_Binary
name: SIGMA
field_location: 21
data_type: IEEE754MSBSingle
field_length: 4
description: sigma error

Field_Binary
name: MEAN TILT DIRECTION
field_location: 17
data_type: IEEE754MSBSingle
field_length: 4
unit: m/s^2
description:
          Direction of area averaged til
          mean normal vector from the +
          projected into the plane defi
          to the facet center

Field_Binary
name: SIGMA
field_location: 21
data_type: IEEE754MSBSingle
field_length: 4
description: sigma error

Field_Binary
name: MAXIMUM RELATIVE HEIGHT
field_location: 17
data_type: IEEE754MSBSingle
field_length: 4
unit: m/s^2
description:
          Maximum relative heigh
          measured from the face

Field_Binary
name: SIGMA
field_location: 21
data_type: IEEE754MSBSingle
field_length: 4
description: sigma error

Field_Binary
name: MEAN TILT
field_location: 17
data_type: IEEE754MSBSingle
field_length: 4
unit: m/s^2
description:
          area averaged tilt
          facet center

Field_Binary
name: SIGMA
field_location: 21
data_type: IEEE754MSBSingle
field_length: 4
description: sigma error

Field_Binary
name: NORMAL_VECTOR_X
field_location: 17
data_type: IEEE754MSBSingle
field_length: 4
unit: m/s^2
description: x component of normal vector at

Field_Binary
name: SIGMA_X
field_location: 21
data_type: IEEE754MSBSingle
field_length: 4
description: x component sigma error

Field_Binary
name: NORMAL_VECTOR_Y
field_location: 25
data_type: IEEE754MSBSingle
field_length: 4
unit: m/s^2
description: Y component of normal vector at facet cent

Field_Binary

Field_Binary
name: RELATIVE TILT DIRECTIO
field_location: 17
data_type: IEEE754MSBSingle
field_length: 4
unit: m/s^2
description:
          direction of the
          of the mean norma
          vector is project
          to the facet cent

Field_Binary
name: SIGMA
field_location: 21
data_type: IEEE754MSBSingle
field_length: 4
description: sigma error

Field_Binary
name: RELATIVE TILT
field_location: 17
data_type: IEEE754MSBSingle
field_length: 4
unit: m/s^2
description:
          magnitude of the tilt relative
          determined via a tilt ellipse
          facet center

Field_Binary
name: SIGMA
field_location: 21
data_type: IEEE754MSBSingle
field_length: 4
description: sigma error

Field_Binary
name: TILT VARIATION
field_location: 17
data_type: IEEE754MSBSingle
field_length: 4
unit: m/s^2
description: mean tilt variation within a tilt el

Field_Binary
name: SIGMA
field_location: 21
data_type: IEEE754MSBSingle
field_length: 4

OBJ files (Shape model) – PDS4 viewer

- tried to open .obj file with the PDS4 viewer.

- faced an issue when using Table [1] and Plot tabs [2].

- cross-checked if the label [3] of the obj file corresponds to the documentation.

PDS4 Viewer - Data Structure Summary for '/Users/yaejikim/PDS_DATA/DART/data_derived_didymos_model_v003/shape/didymos_g_1165mm_spc_obj...

Index	Name	Type	Dimension	View		
1	Vertex Table	Table_Character	4 cols X 1579014 rows	Label	Table	Plot
2	Facet Table	Table_Character	4 cols X None rows	Label	Table	Plot

PDS4 Viewer - An Error Occurred!

An Error Occurred! [1]

```
Now processing a Table_Character structure: Vertex Table
Error: An error occurred during data read-in.
Traceback (most recent call last):
  File "pds4_tools/viewer/summary_view.pyc", line 171, in _reify_structure
  File "pds4_tools/extern/cached_property.pyc", line 86, in __get__
  File "pds4_tools/reader/table_objects.pyc", line 363, in data
  File "pds4_tools/reader/read_tables.pyc", line 945, in read_table_data
  File "<string>", line 3, in raise_from
ValueError: Unable to convert field 'X Coordinate' to data_type 'ASCII_Real': "c
```

PDS4 Viewer - An Error Occurred!

An Error Occurred! [2]

```
Now processing a Table_Character structure: Vertex Table
Error: An error occurred during data read-in.
Traceback (most recent call last):
  File "pds4_tools/viewer/summary_view.pyc", line 171, in _reify_structure
  File "pds4_tools/extern/cached_property.pyc", line 86, in __get__
  File "pds4_tools/reader/table_objects.pyc", line 363, in data
  File "pds4_tools/reader/read_tables.pyc", line 945, in read_table_data
  File "<string>", line 3, in raise_from
ValueError: Unable to convert field 'X Coordinate' to data_type 'ASCII_Real': "c
```

Ok   Copy

PDS4 Viewer - Label View

Label [3]

```
Table_Character
    local_identifier: Vertex Table
    offset: 2775
    records: 1579014
    description:
        The VERTEX_TABLE is the first part, describing the positions of th
        shape model.  The floating point numbers x1 y1 z1 are the coordina
        and so on (vertices are implicitly numbered beginning with 1).  Th
        center of mass, and the axes are the principle axes of the shape m
        are kilometers.

    record_delimiter: Carriage-Return Line-Feed

    Record_Character
        fields: 4
        groups: 0
        record_length: 66

        Field_Character
            name: Vertex Flag
            field_number: 1
            field_location: 1
            data_type: UTF8_String
            field_length: 1
            description: A 'v', indicating this record contains the coordinates of

        Field_Character
            name: X Coordinate
            field_number: 2
            field_location: 4
            data_type: ASCII_Real
            field_length: 19
            description: X coordinate of the vertex

        Field_Character
            name: Y Coordinate
            field_number: 3
            field_location: 25
            data_type: ASCII_Real
            field_length: 19
            description: Y coordinate of the vertex
```
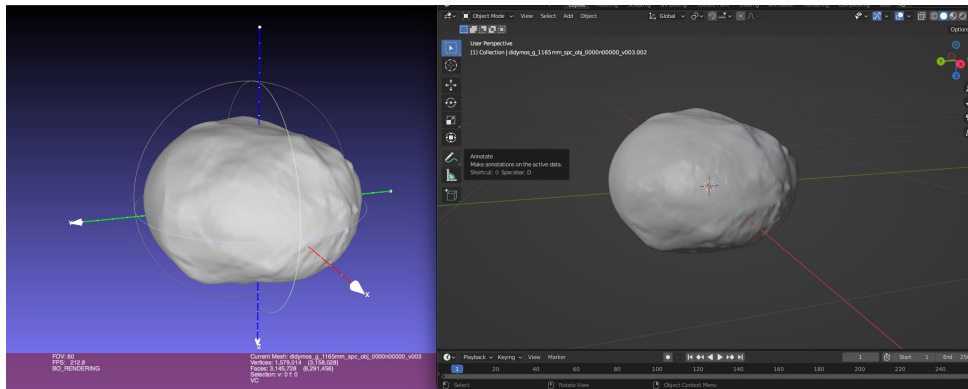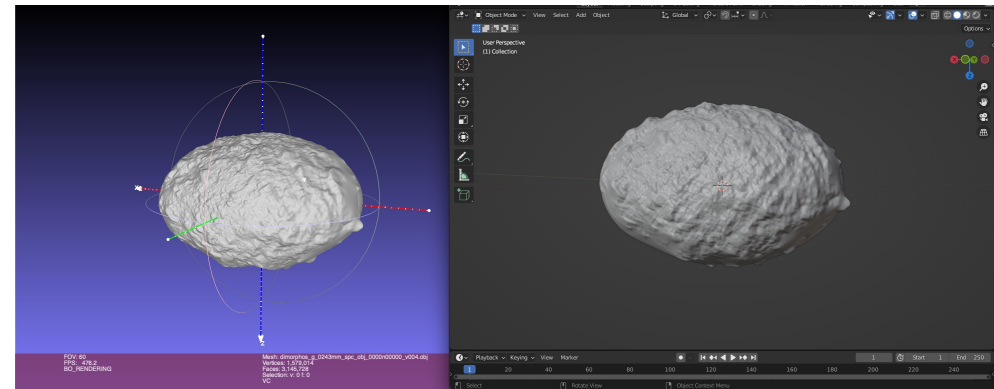
OBJ files (Shape model) – Blender and MeshLab

- able to open and read the .obj file with other software (Blender and MeshLab); tested at MacOS Monterey Version 12.3

- checked that there is not no mesh issues (i.e., holes) in the shape models

- checked that the spin poles (z-axis) are consistent with the shortest principal axes

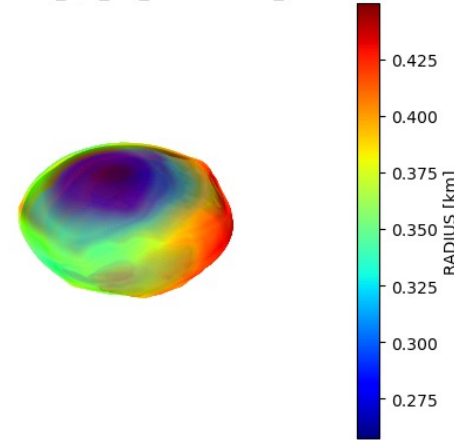Didymos: MeshLab (left) and Blender (right)
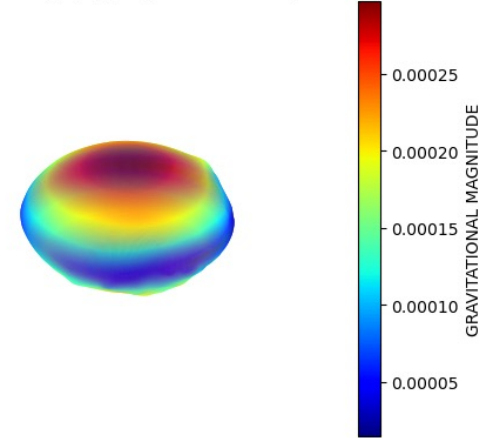

Dimorphos: MeshLab (left) and Blender (right)

OBJ files (Shape model) overlaying binary fits file (values)

- Able to open and read .obj files and .fits files in Python using the modules (i.e., pywavefront and astropy.io.fits)

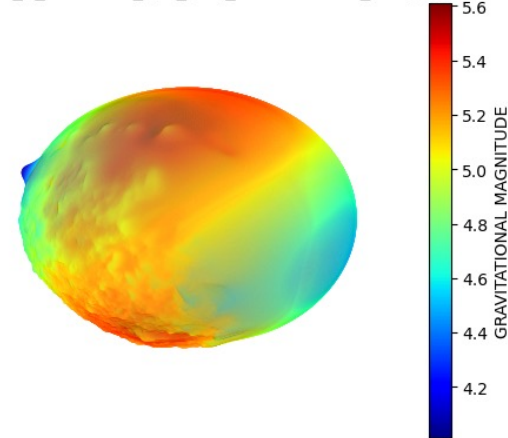- Able to overlay the data from the fits table to the shape model.

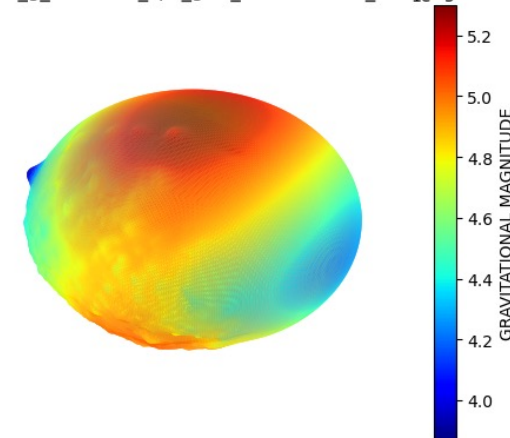didymos_g_1165mm_spc_alb_0000n00000_v003.fits

didymos_g_4657mm_spc_grm_0000n00000_v003.fits

dimorphos_g_0250mm_spc_grm_0000n00000_v003.fits

dimorphos_g_0980mm_spc_grm_0000n00000_v003.fits

Key highlights

- Label issue: wrong units
- OBJ file open issue with PDS4 viewer
- Minor issues and suggestions for 'dart_shapemodel_sis.pdf'