FITS FORMAT FOR PLANETARY SURFACESBRIDGING THE GAP BETWEEN FITS WORLD COORDINATE SYSTEMS AND GEOGRAPHICAL INFORMATION SYSTEMS

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Introduction: The amount of available data is rapidly increasing for planetary investigations and planetary surface research continues to evolve from mostly visual assessment to more automated quantitative analysis.

Both geologists and now more astronomers are involved in mapping planetary surfaces. Geologists, for their mapping and analysis needs, commonly use Geographical Information Systems (GIS). In general, GIS applications excel in data interoperability even though some have historically been anchored to Earth's spatial description. Astronomers, in contrast, are well known for their open and flexible formats and software for quantitative analysis of huge data sets. Unfortunately, the astronomy domain is not accustomed to supporting data for three-dimensional planetary surfaces.

We will describe here how Flexible Image Transport System (FITS) World Coordinate System (WCS) [1] metadata can be translated for the planetary domain to allow FITS data to interoperate with GIS applications.

FITS: The option to use FITS within the planetary domain could be an opportunity to allow more seamless sharing of data across these different domains and potentially homogenize methods from acquisition, to visualization, while giving more chances to optimize data processing.

- FITS has been defined for data acquisition and archiving in astronomical observatories and is used for spatial telescope data.
- FITS is compatible with PDS archiving specifications.
- FITS is one of the standard formats in the Virtual Observatory (VO).
- FITS is supported by a large number of open libraries and software tools.

FITS WCS: FITS WCS representation simplifies the spatial coordinate description with respect to historical terrestrial references.

PROs

- There is no need for oblique projection definitions [3,4] as they may be obtained by setting specific projection parameters.
- There is no need for East or West positive longitude definitions as the pixel conversion in world coordinates is set by a common oriented matrix.
- FITS does offer the possibility to fully describe multiple reference systems using alternative WCS definitions (meters, degrees, East and West longitude, etc.)[5].

CONs

- WCS does not record information about the body shape and orientation, and reference surface.

PDS/ISIS dictionaries as Mapped to FITS:

Table 1. Projections

FITS	FITS projection name	PDS/ISIS projection name
SFL	Sanson-Flamsteed	Sinusoidal
ZEA	Zenithal Equal-Area	Lambertazimuthalequalarea
COO	Conic orthomorphic	Lambertconformal
CAR	plate carre	Equirectangular
MER	Mercator	Mercator
SIN	Orthographic	Orthographic
AZP	Zenithal perspective	Pointperspective
STG	Stereographic	Polarstereographic

Table 2. Parameters for cylindrical projections (without rotation, coordinates in degrees)

FITS parameter	ISIS conversion	PDS conversion
CRPIX1	Samples / 2 + 0.5	LINE_SAMPLES / 2 + 0.5
CRPIX2	Lines / 2 + 0.5	LINES / 2 + 0.5
CRVAL1	CenterLongitude	CENTER_LONGITUDE
CRVAL2	CenterLatitude	CENTER_LATITUDE
CD1_1, CD2_2	1 / Scale	1 / MAP_RESOLUTION

Table 3. Parameters for sinusoidal projections (without rotation, coordinates in degrees)

FITS parameter	ISIS conversion	PDS conversion
CRPIX1	Samples / 2 + 0.5	LINE_SAMPLES / 2 + 0.5
CRPIX2	-MinimumLatitude * Scale	-MINIMUM_LATITUDE* MAP_RESOLUTION
CRVAL1	CenterLongitude	CENTER_LONGITUDE
CRVAL2 = 0.0	0.0	0.0
CD1_1, CD2_2	1 / Scale	1 / MAP_RESOLUTION

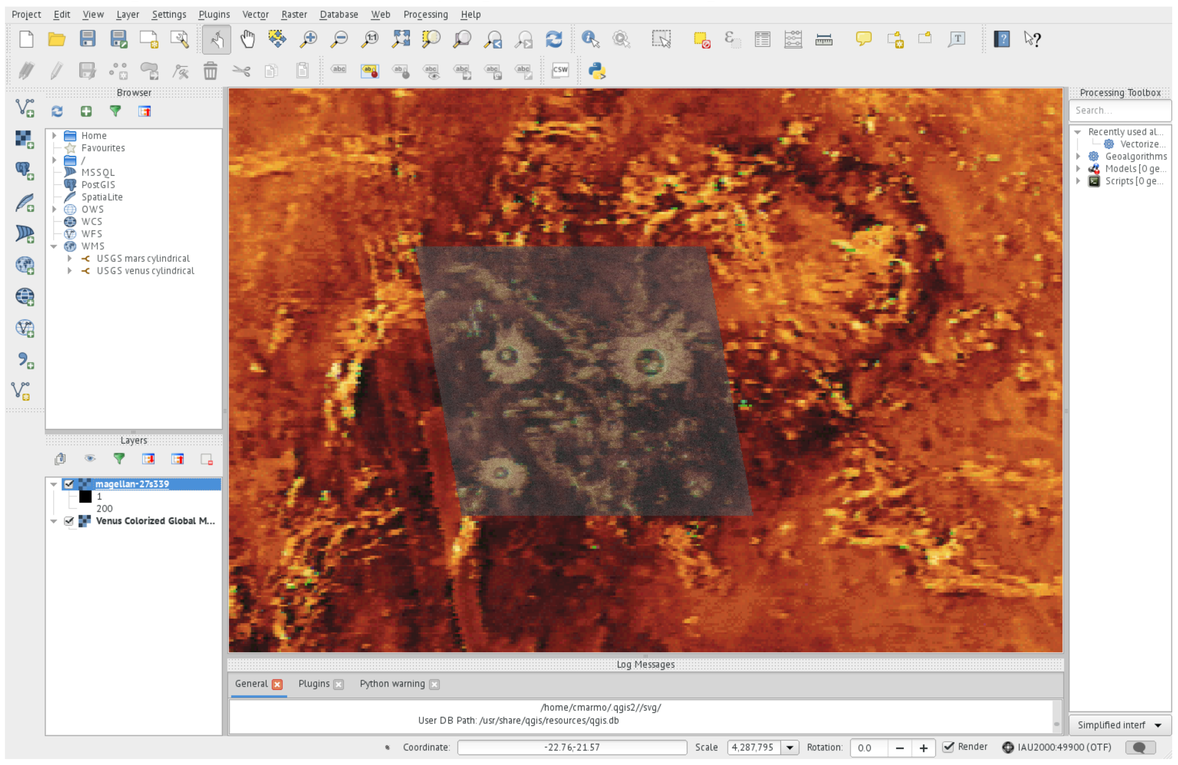
FITS and GDAL: The Geospatial Data Abstraction Library, released by the Open Source Geospatial Foundation, offers powerful data conversion and processing capabilities[6]. Any application which supports the GDAL library can now easily recognize planetary data formats.

GDAL has support for FITS via the popular CFITSIO library [7]. The CFITSIO library automatically manages conversion between different data types in FITS, but currently CFITSIO rescaling causes overflows with GDAL and has been disabled. To follow updates to the GDAL FITS driver, please see: https://github.com/epn-vespa/gdal.

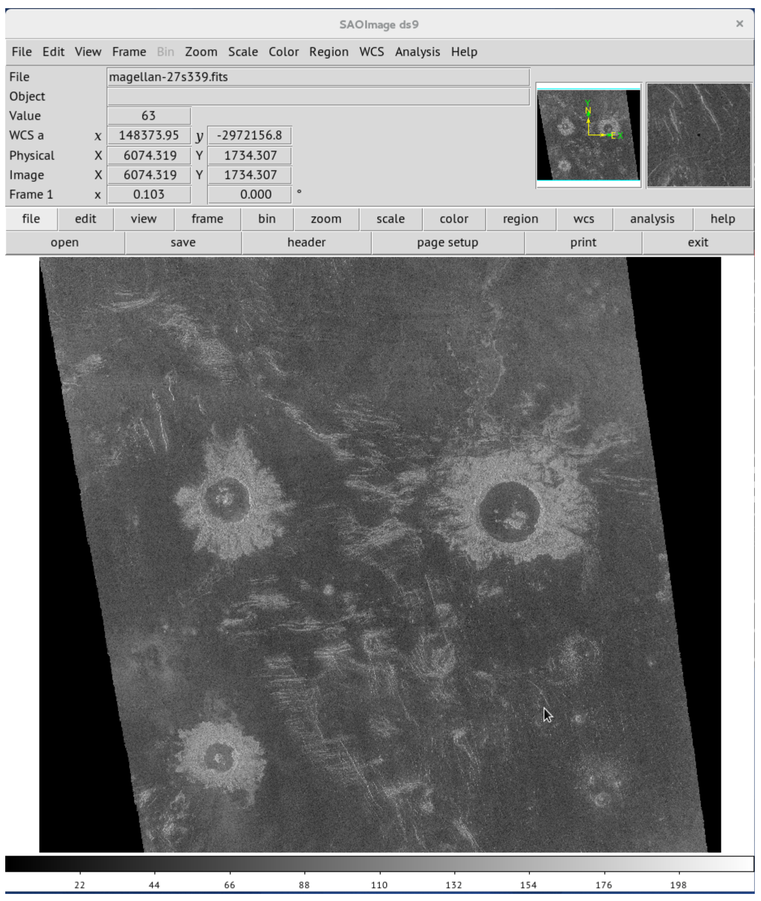
An alternative approach to convert FITS into GDAL as a first step for FITS visualization within GIS software, is Virtual Header Format (VRT) [2].

VRT files can describe the map projection and body size in a standardized "well known text" (WKT) projection string. For FITS VRT examples and conversion tools please see: https://github.com/epn-vespa/fits2vrt.

Venus Magellan FITS raster displayed on QGIS using a VRT header



Venus Magellan FITS raster displayed on ds9 (linear coordinates are traceable)



Future work: In the framework of the European Virtual Observatory project (VESPA) [9] a FITS convention for planetary data will be proposed [10] following the International Astronomical Union (IAU) Working Group on Cartographic Coordinates and Rotational Elements (WGCCRE) schema, to allow FITS to support shape and orientation of planetary bodies. Once the proposed geospatial extensions are fully agreed upon and added into FITS, the GDAL library will be updated to properly map these new keywords.

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[10] https://epn-vespa.github.io/geofits/.