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Geology & Planetary Mapping
Winter School

Planetary coordinate reference systems & mapping

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EU Horizon 2020 grant #871149

Background: Collins et al. (2013) / NASA / USGS

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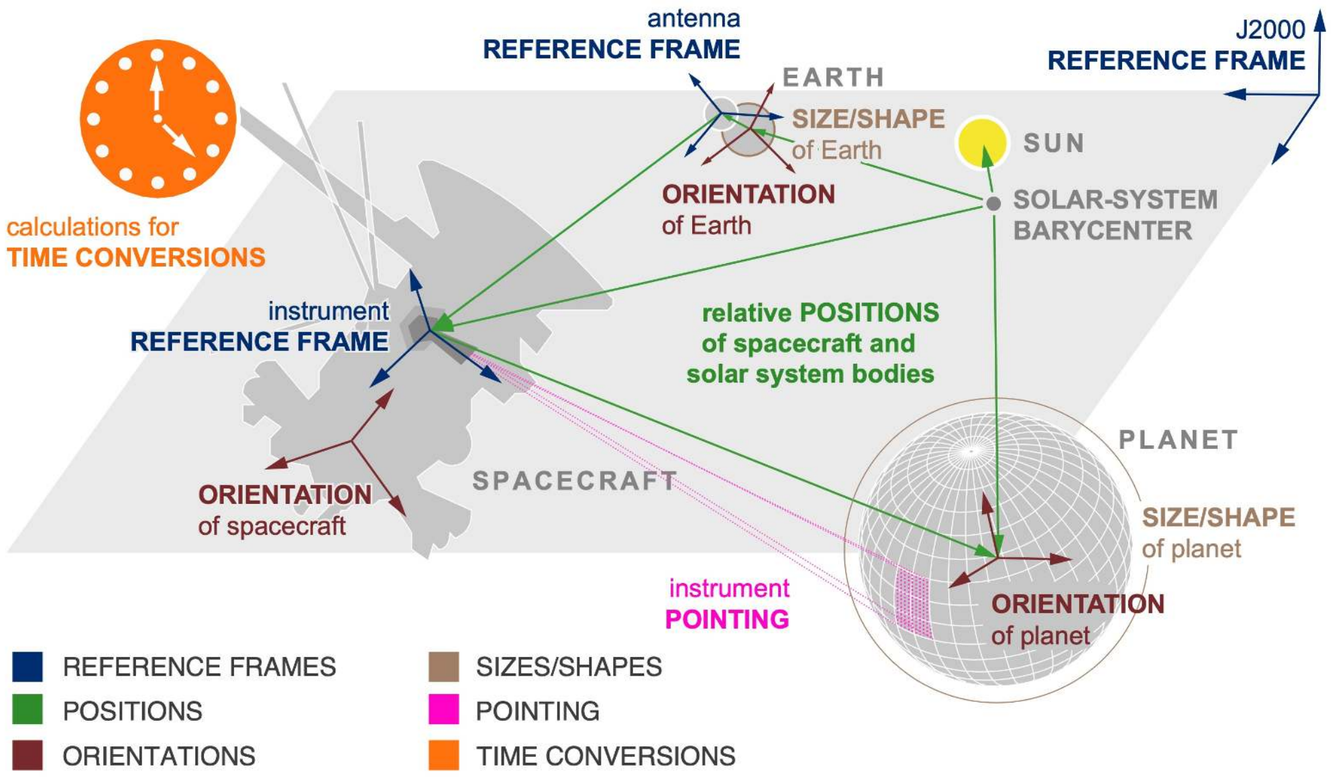
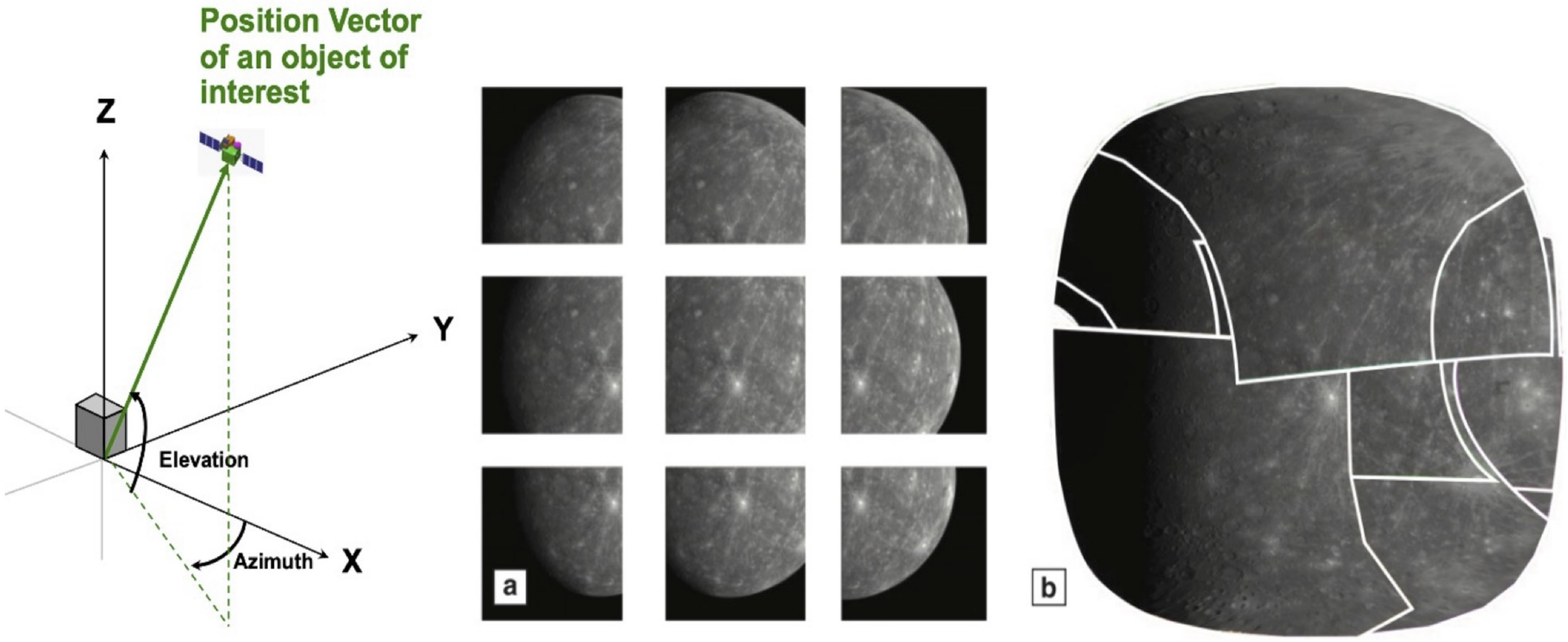
Reference frames



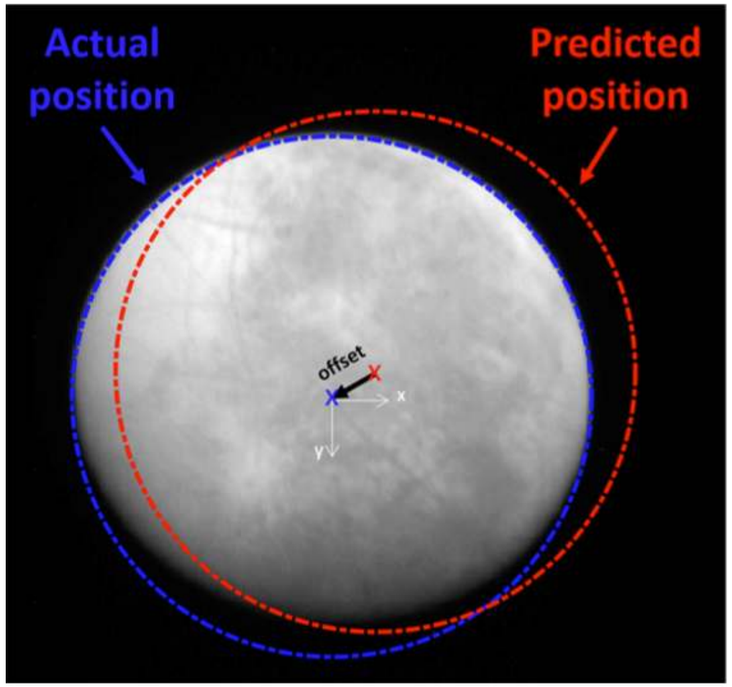
Source: Hare et al. (2018). See also NASA/JPL/NAIF.

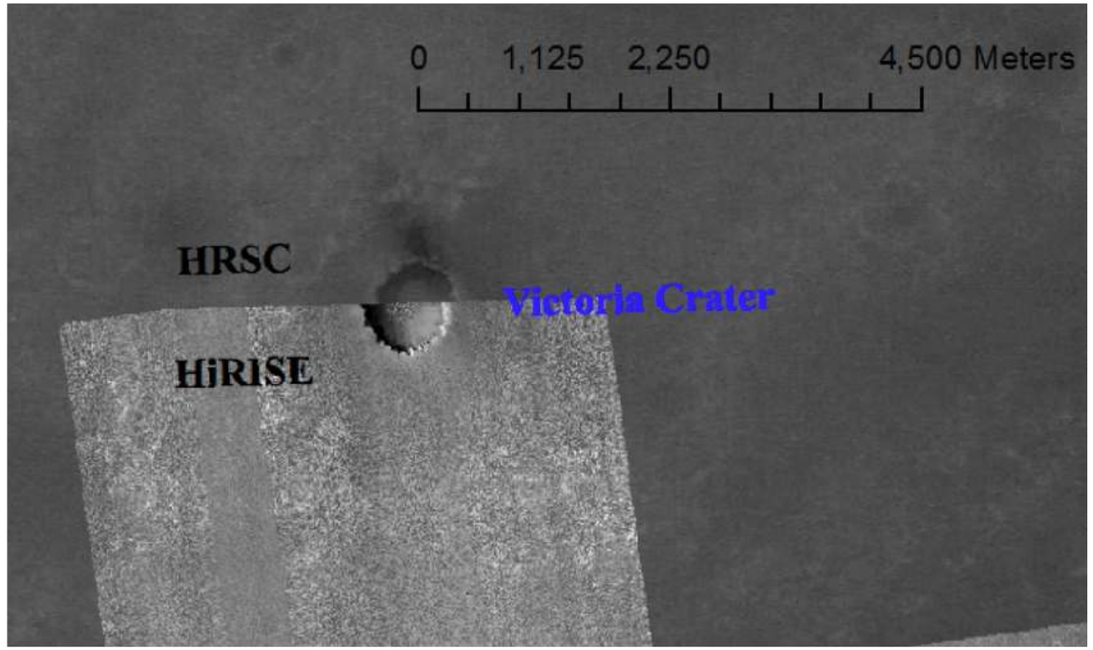
Pointing & imaging



Source: Hare et al. (2018), NASA/JPL/NAIF.

Pointing & errors





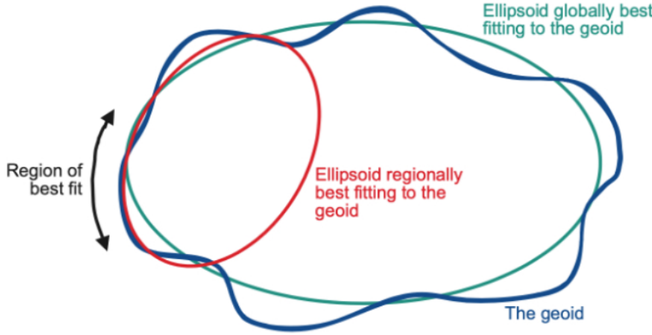
Source: Source: Belgacem et al. (2020); Tao et al. (2016). .

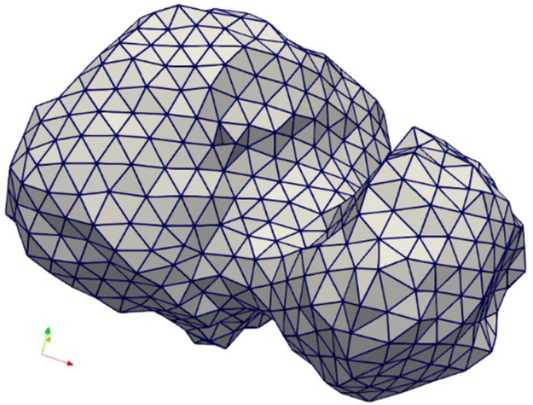
Basic terminology

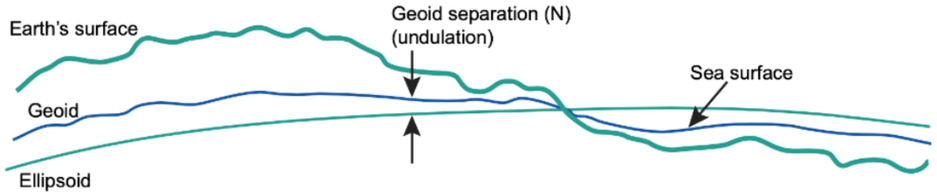
Many definitions, but to keep it short:

- **Map projection**: A model of the surface
- **CRS**: A model of the surface, and its reference body
- **GIS**: A computing / management/ visualisation / analysis system to deal with:
- data with a CRS = (digital/ised) geospatial data

Reference surfaces





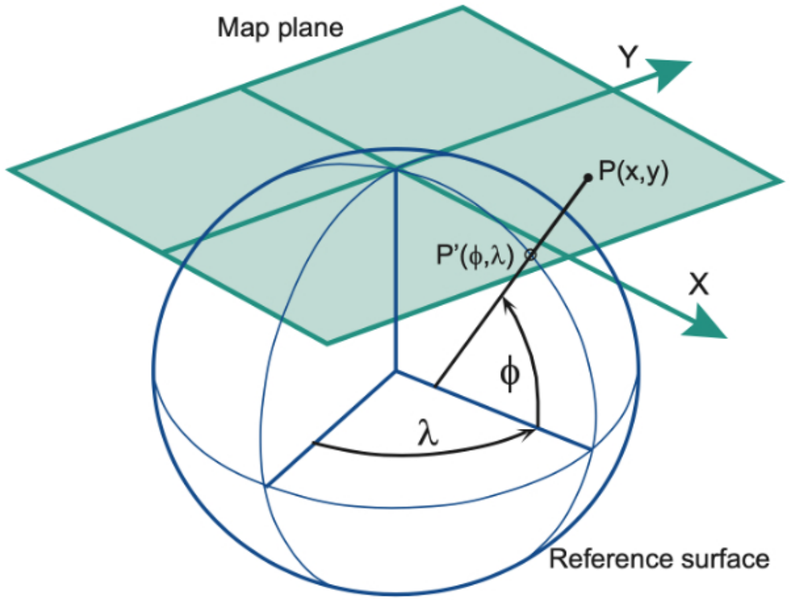


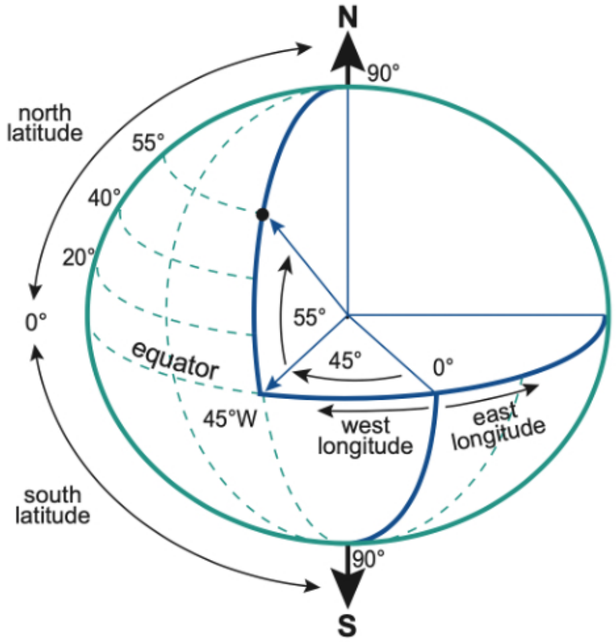
Source: Knippers, (2009), L. Penasa.

Reference time(scale)

- Depending on the context/timescale, time might be neglibile
- In reality, obviously it plays a (big) role
- Or not: e.g. Earth plates moving (little, ~cm/y ~dm/y)

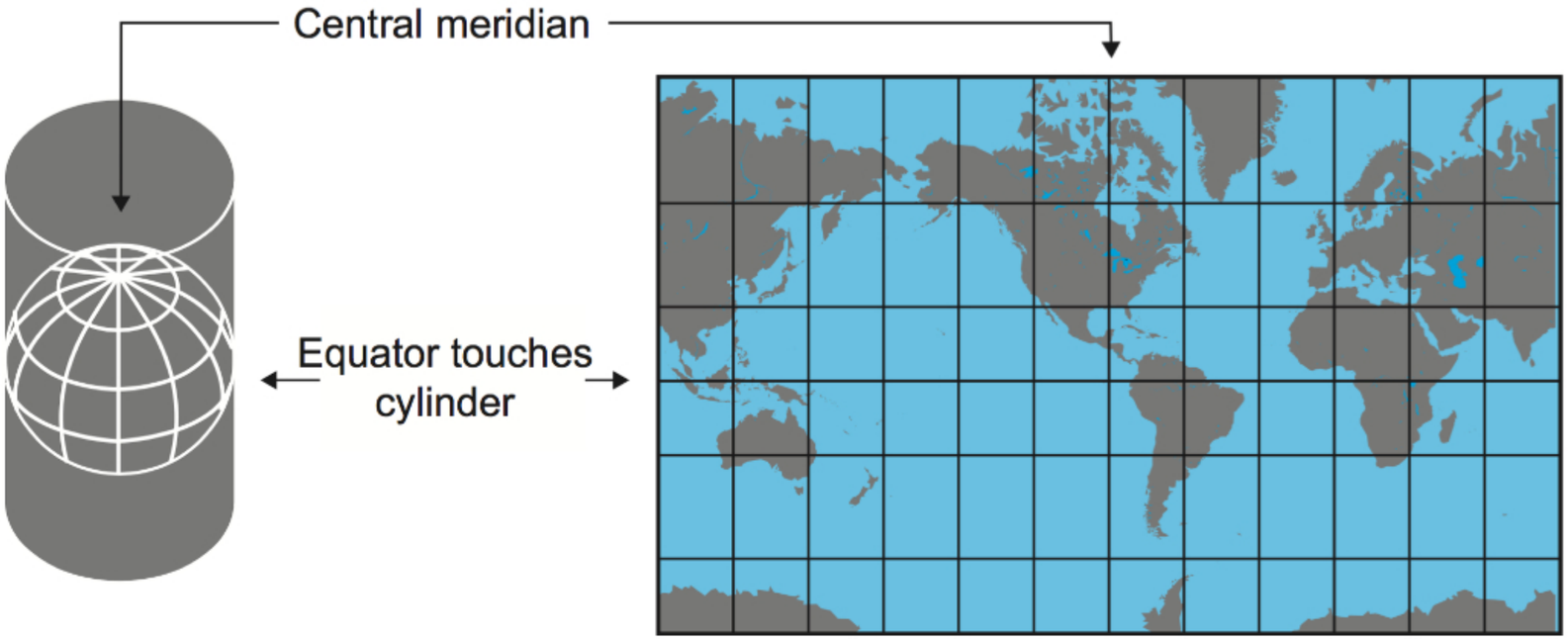
Map projections





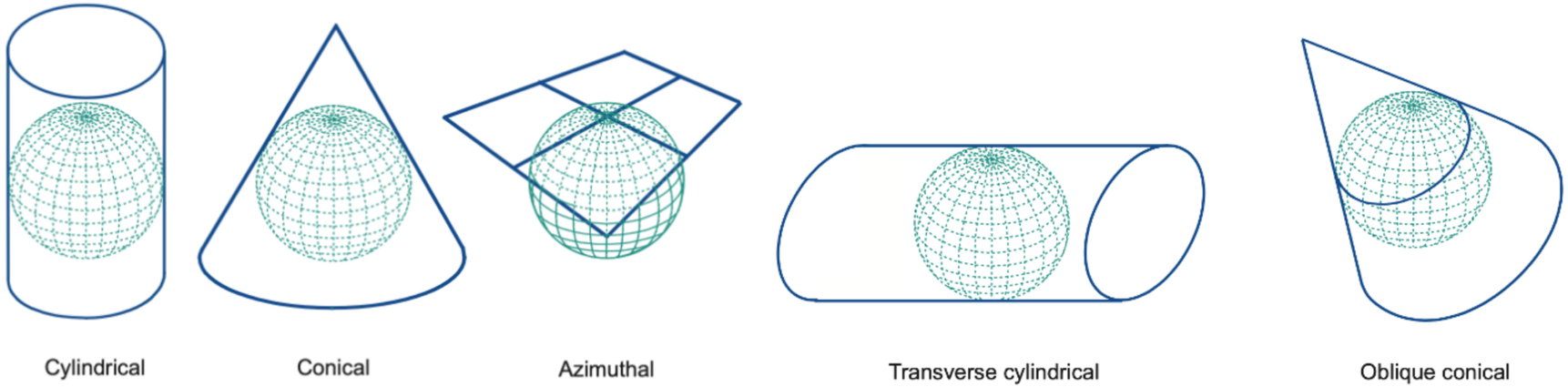
Source: Knippers, (2009).

Map projections



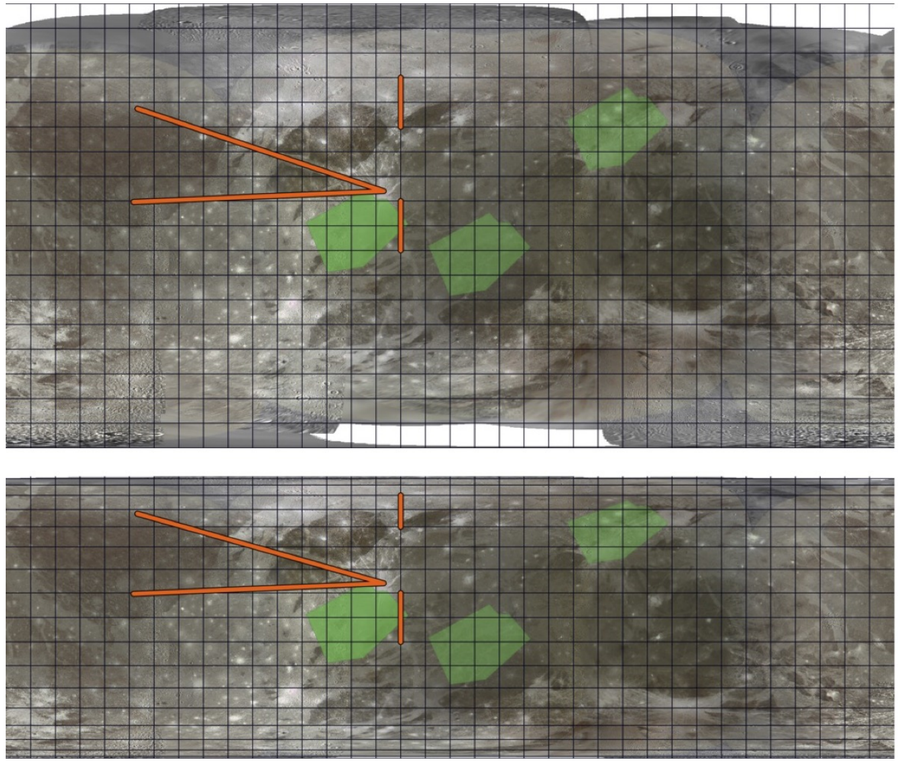
Source: Hare et al. (2018).

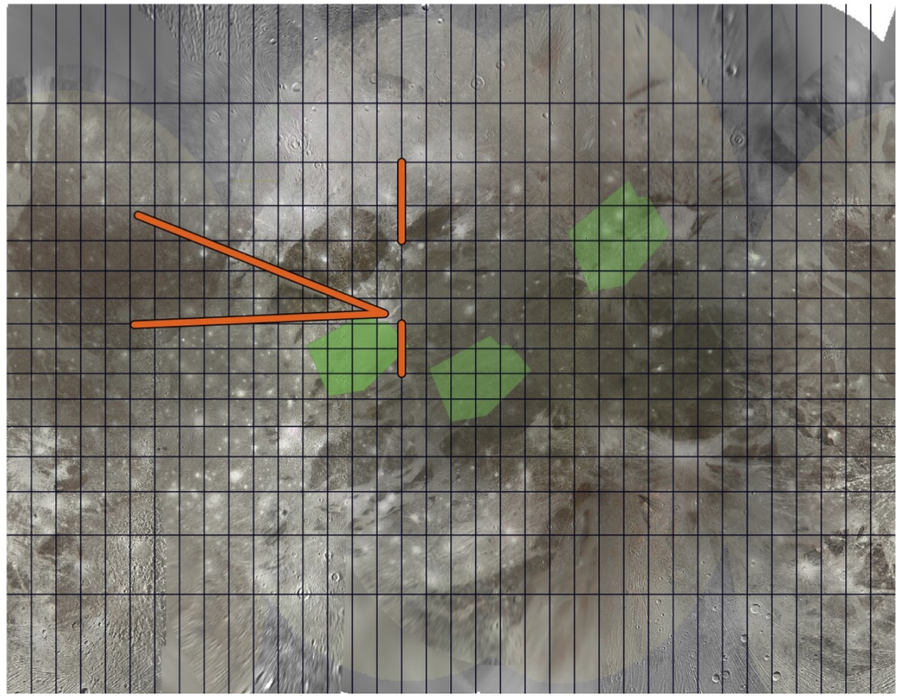
Map projection classes



Source: Knippers, (2009).

Map projection properties





Source: NASA/USGS.

Map projection properties

- Area → Equal Area
- Distance → Equidistant
- Angles/Shape → Conformal

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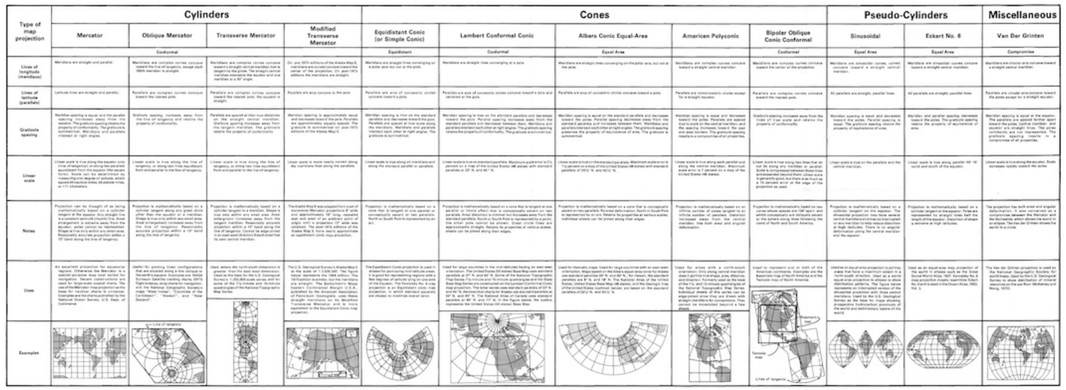
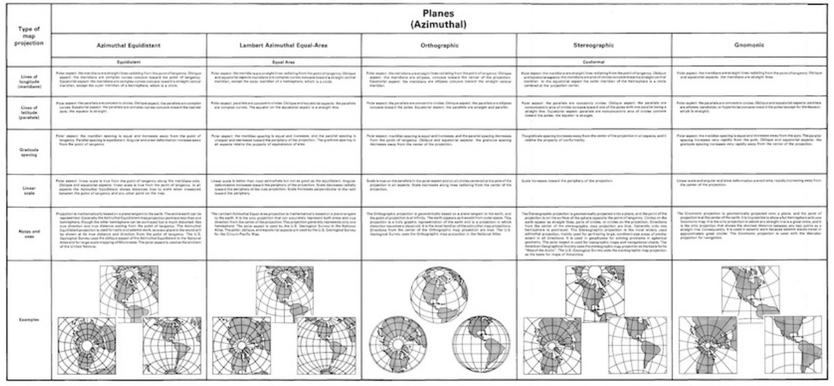
Map projection properties



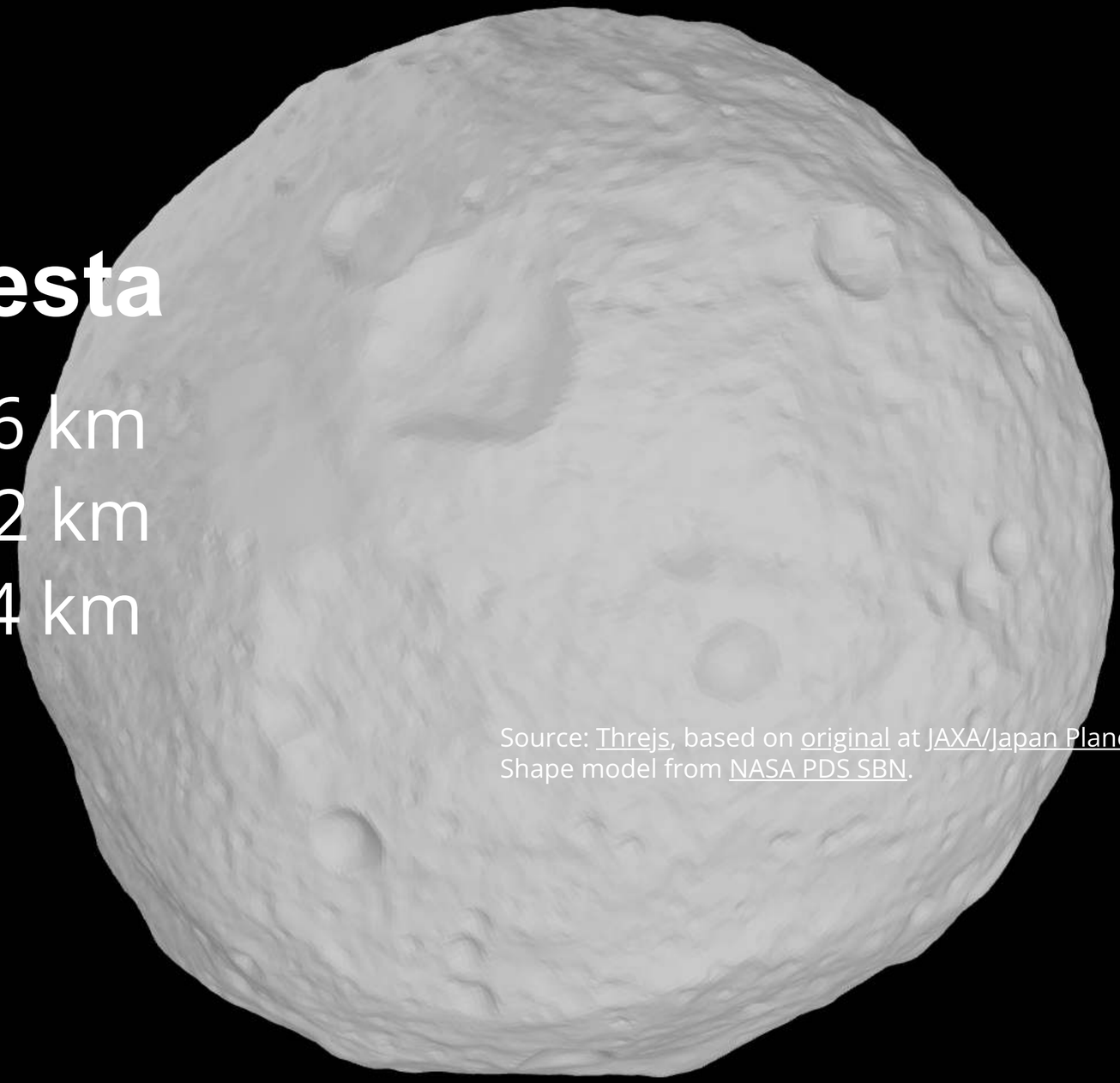


See also: Snyder (1982).

Earth globe

E.g. Vesta

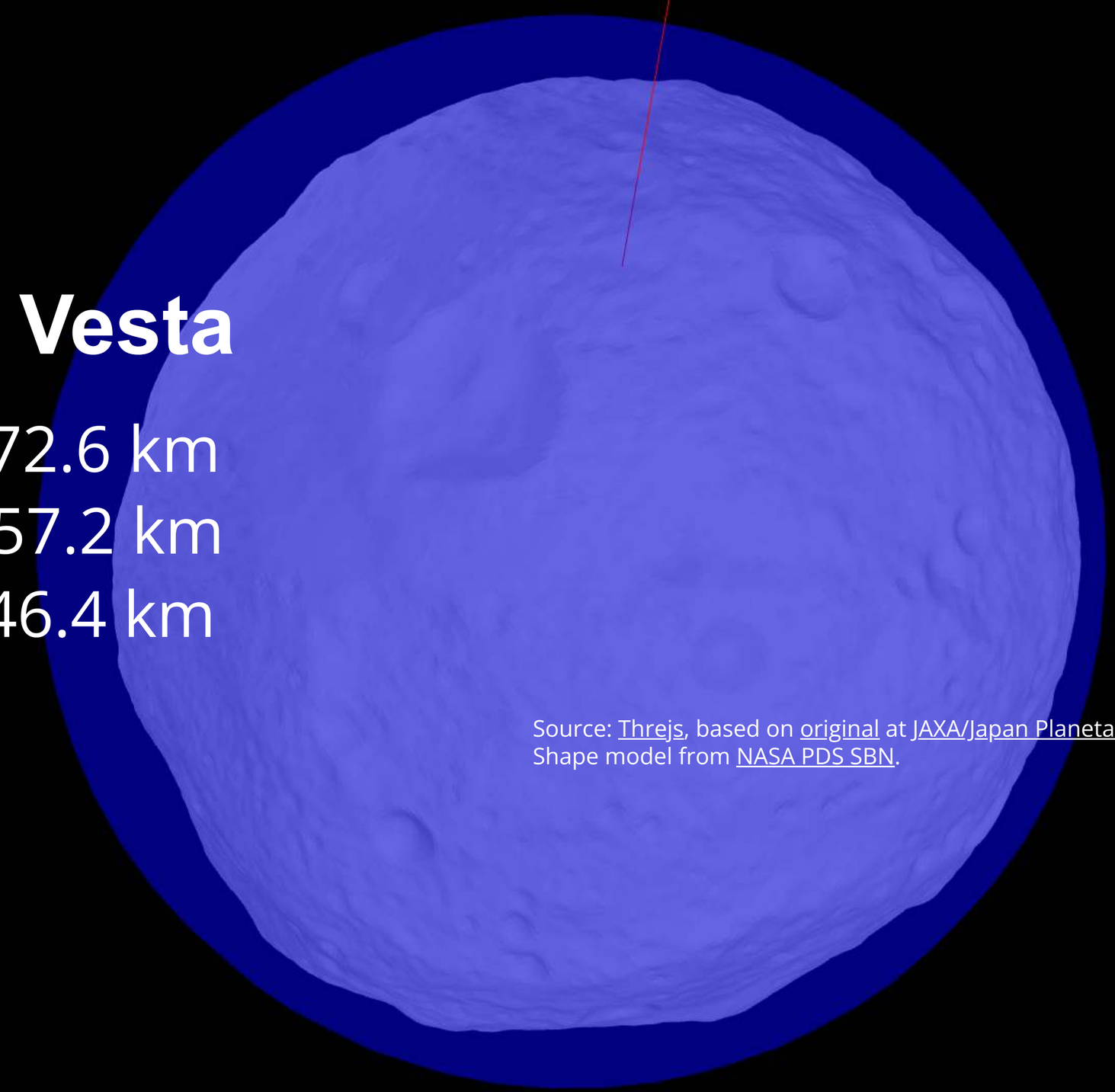
a = 572.6 km
b = 557.2 km
c = 446.4 km



Source: Threjs, based on original at JAXA/Japan Planetarium Association.
Shape model from NASA PDS SBN.

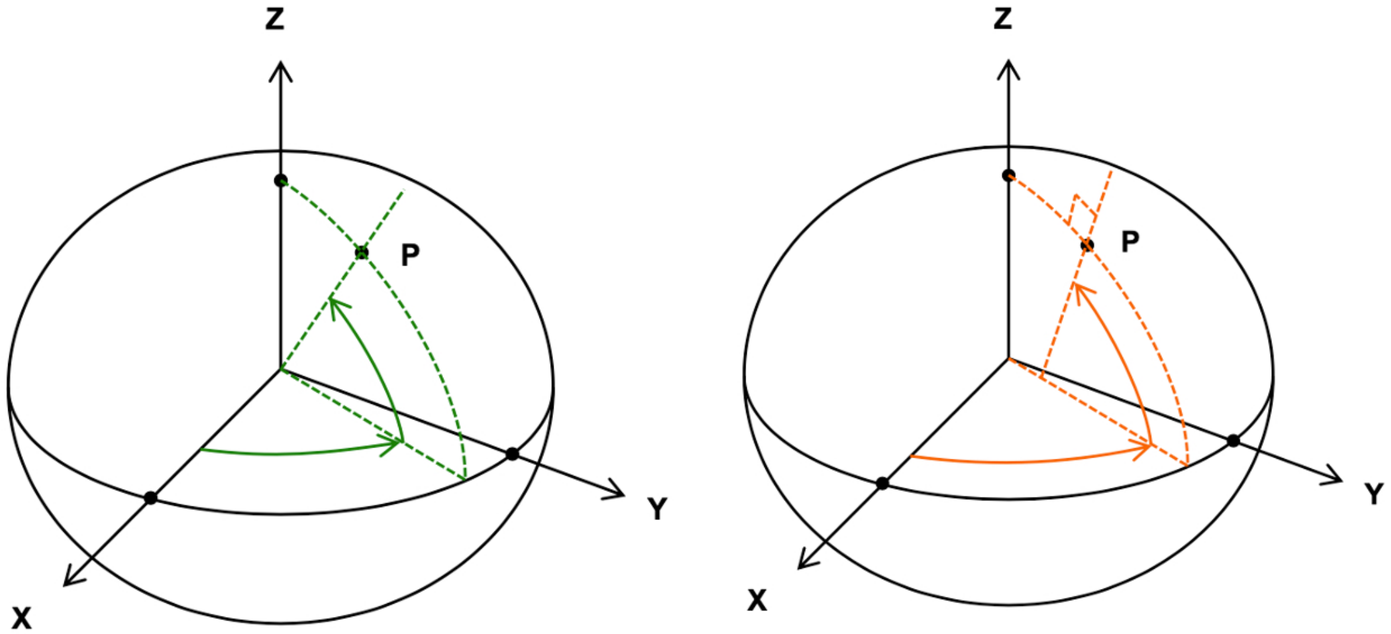
E.g. Vesta

a = 572.6 km
b = 557.2 km
c = 446.4 km

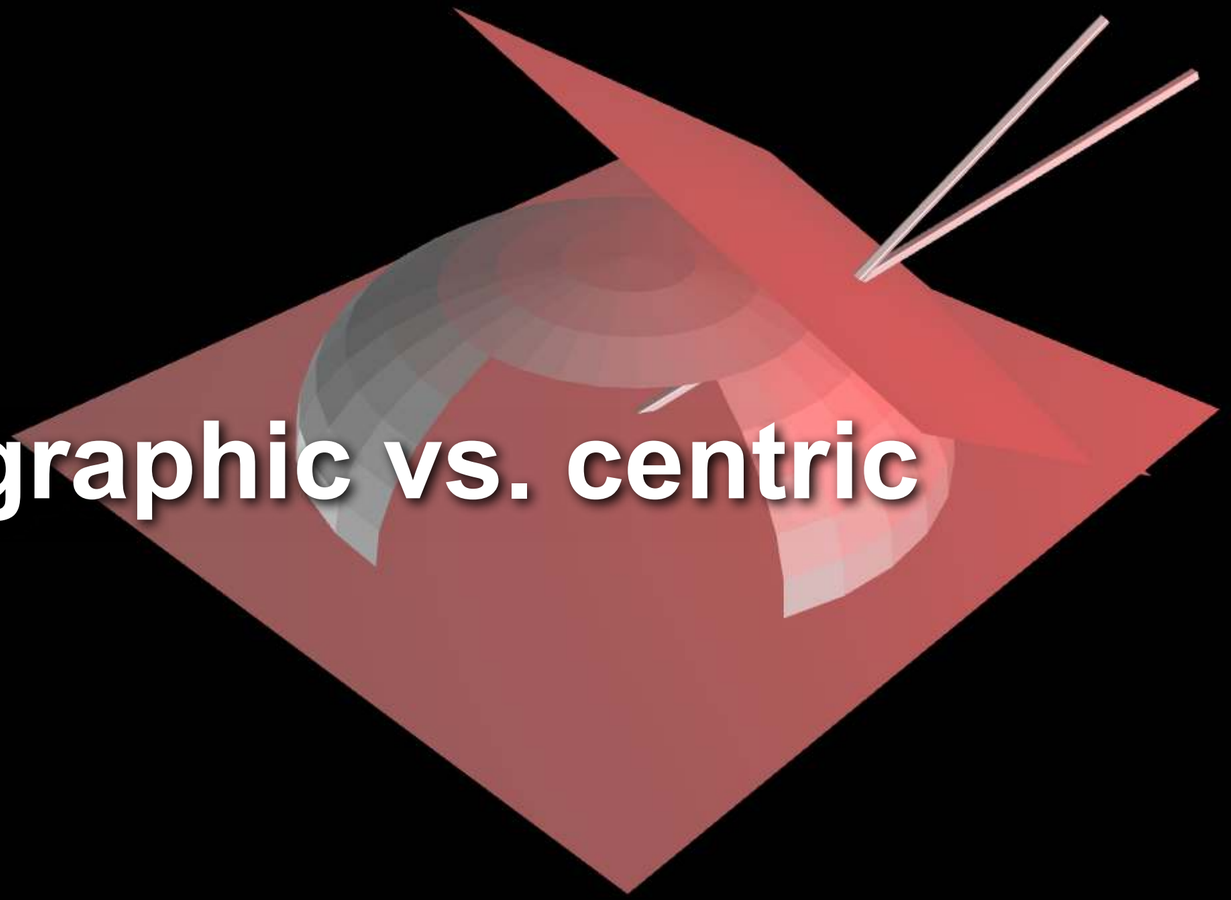


Source: Threjs, based on original at JAXA/Japan Planetarium Association.
Shape model from NASA PDS SBN.

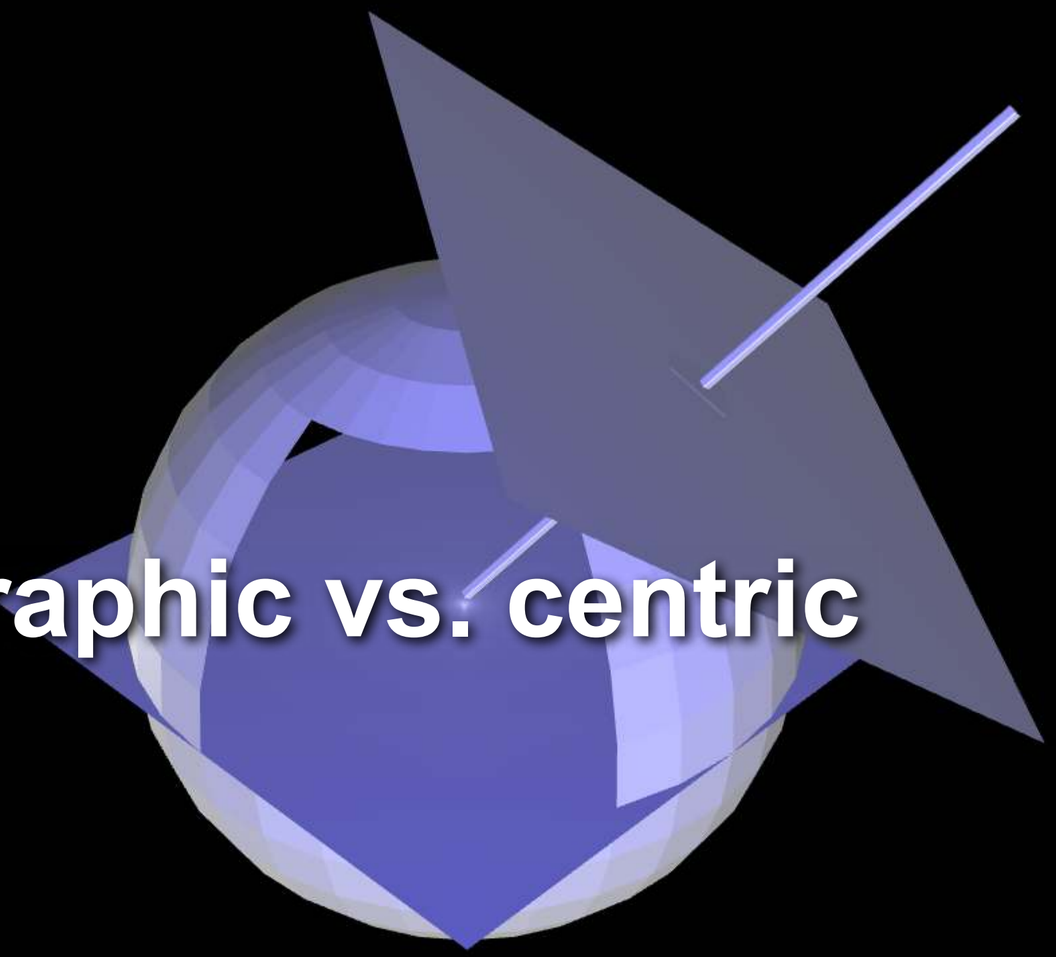
Planetocentric v.s -graphic / -detic



Source: NAIF/JPL.



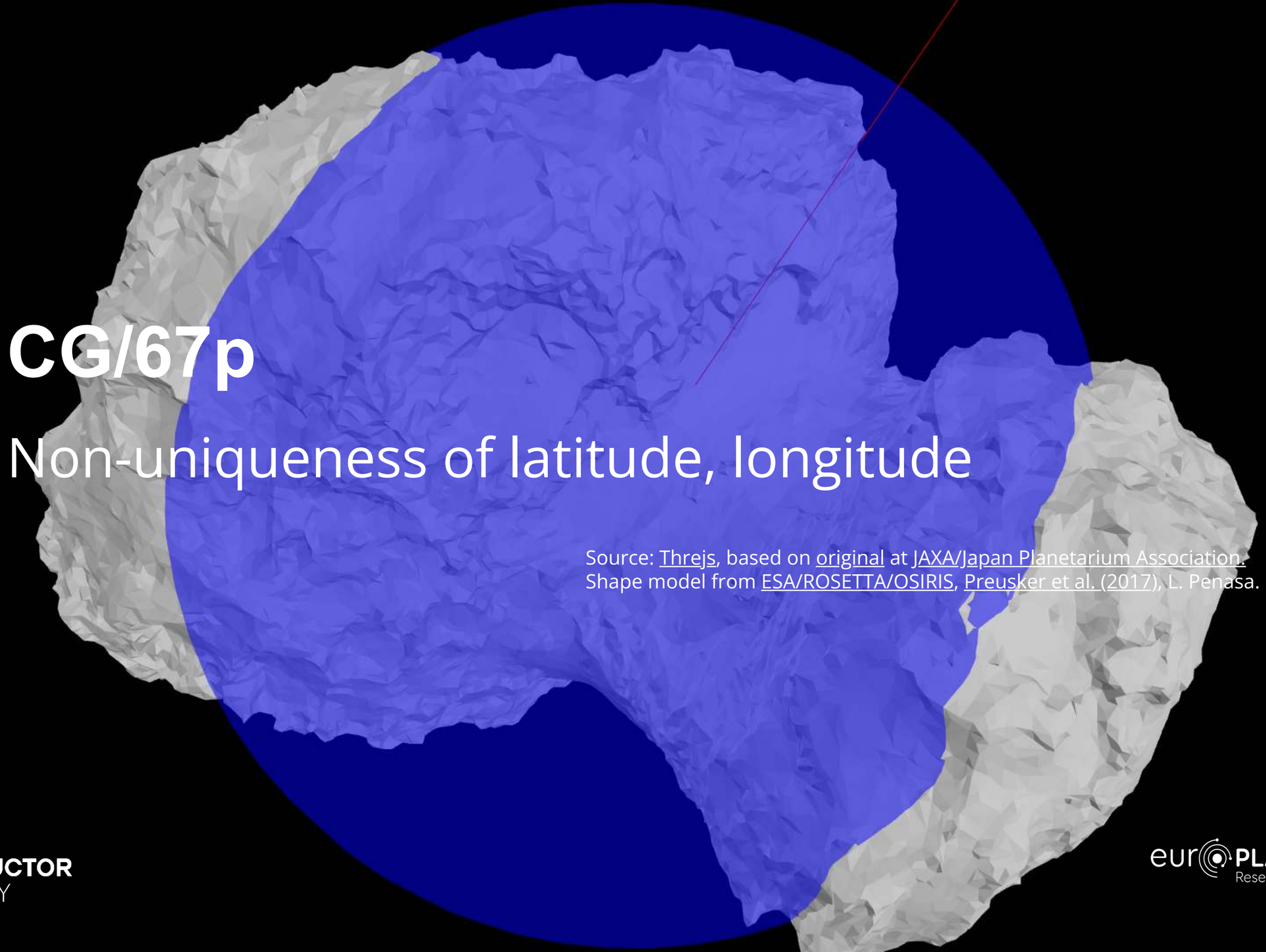
Planetographic vs. centric



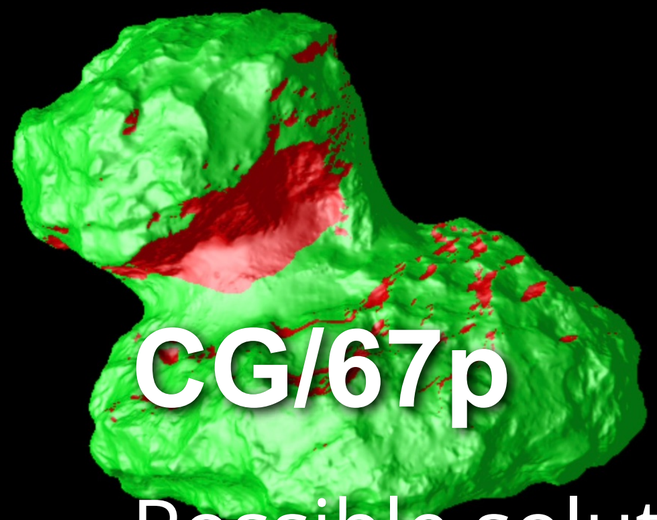
Planetographic vs. centric

CG/67p

Non-uniqueness of latitude, longitude

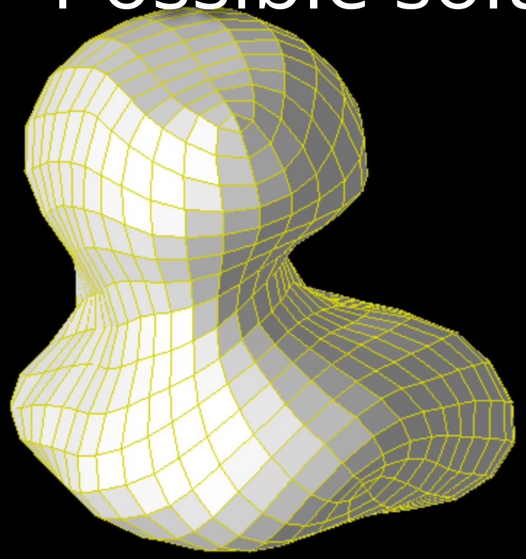


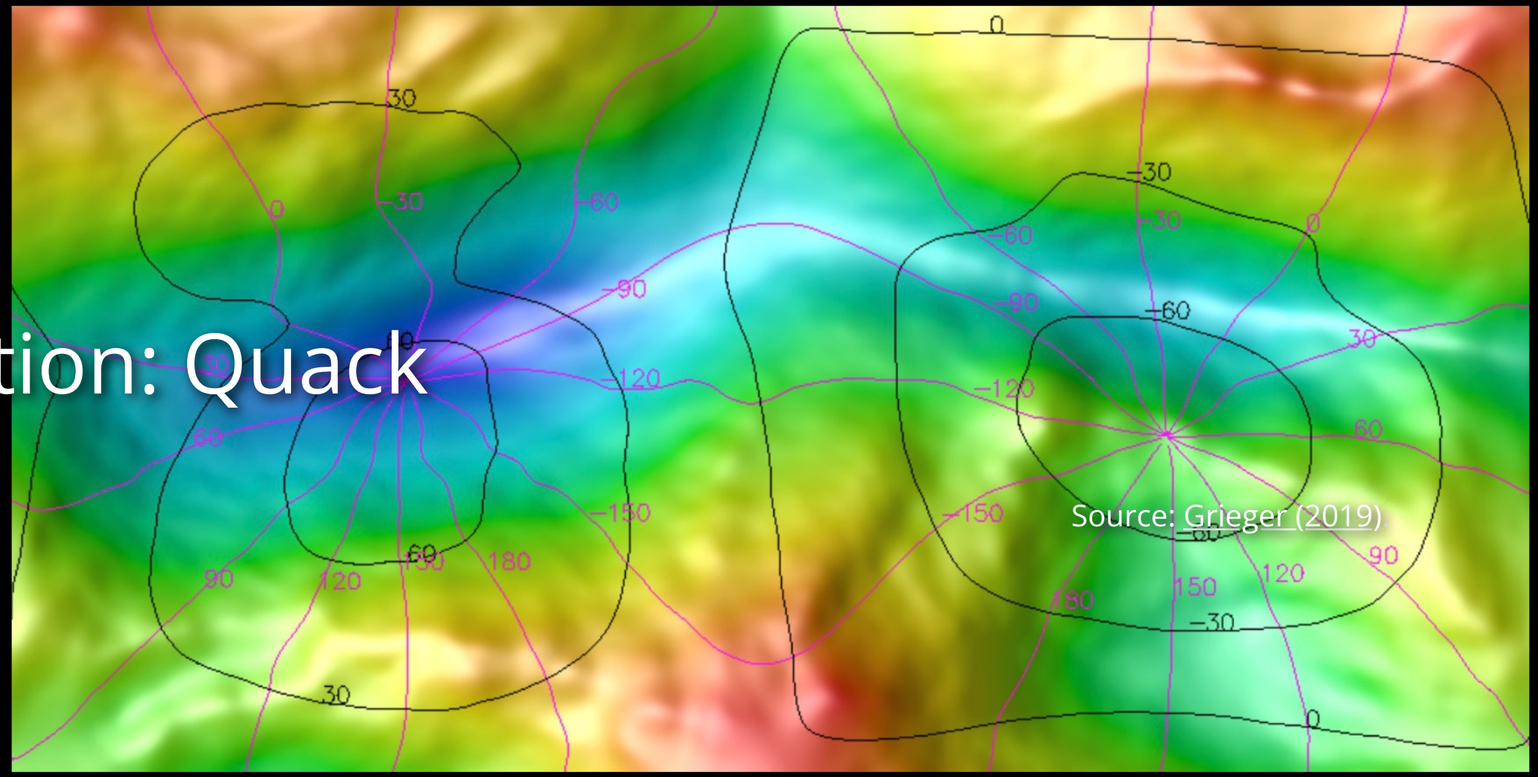
Source: Threjs, based on original at JAXA/Japan Planetarium Association.
Shape model from ESA/ROSETTA/OSIRIS, Preusker et al. (2017), L. Penasa.



CG/67p

Possible solution: Quack

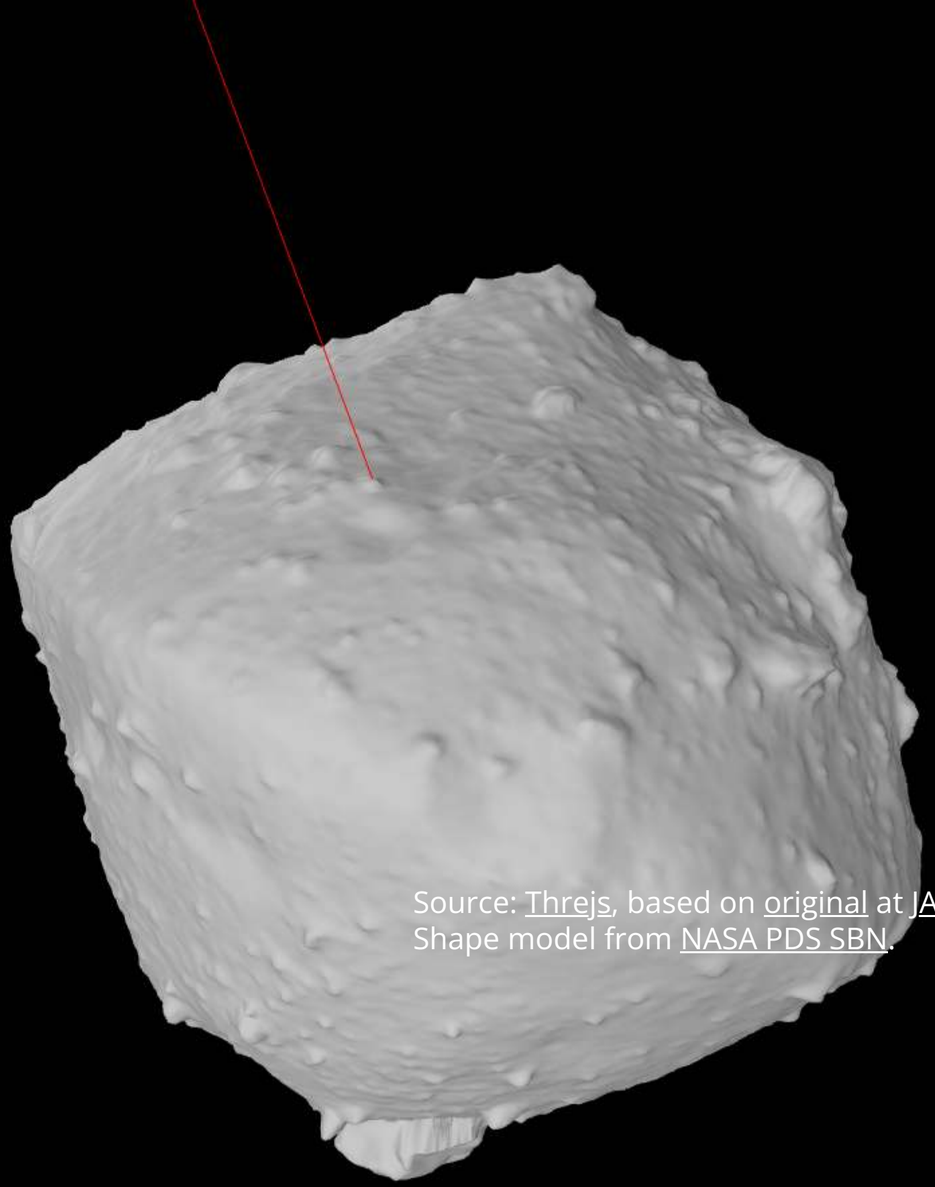




Source: Grieger (2019)

Ryugu

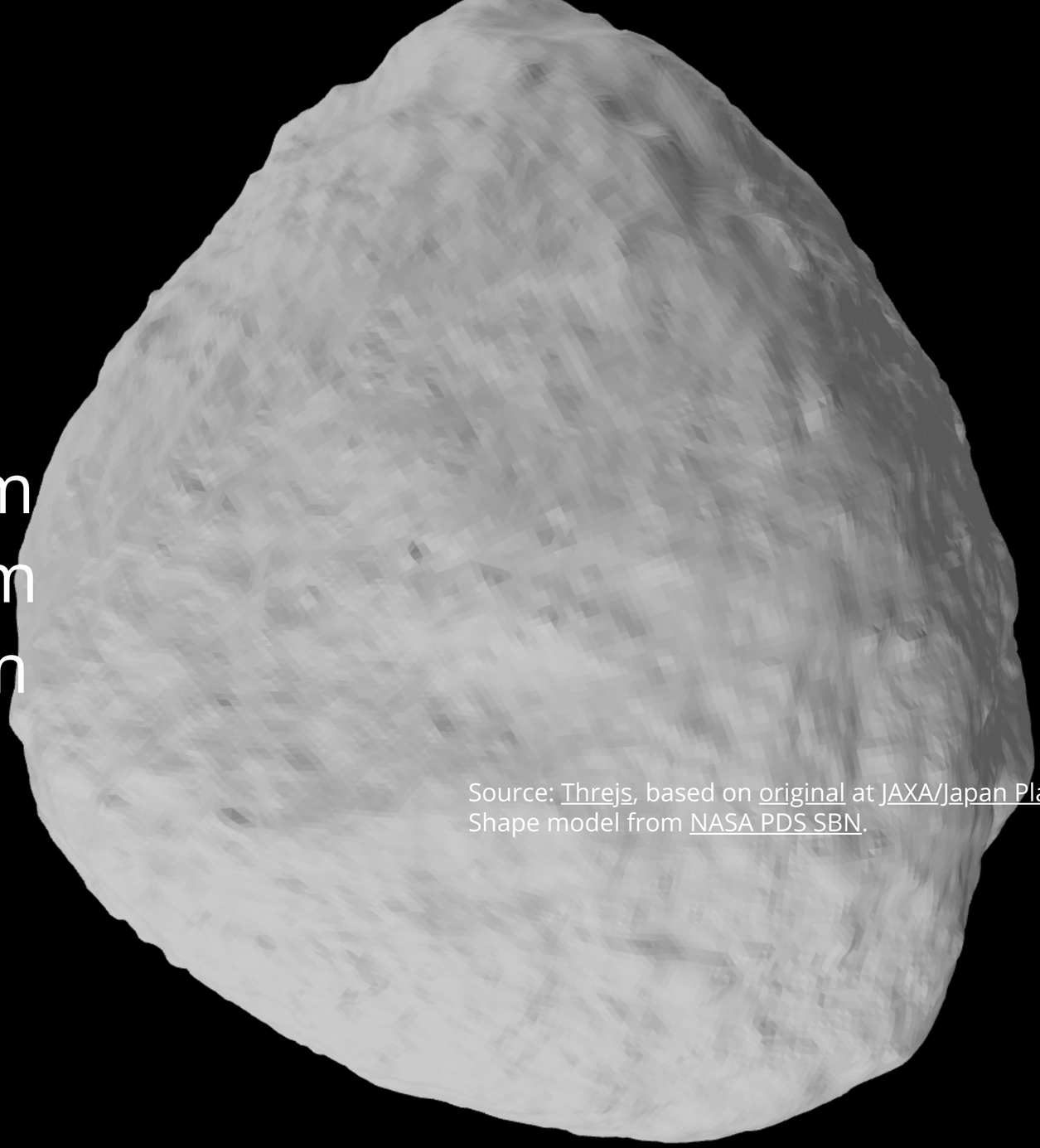
a= 1004 m
b = 876 m



Source: Threjs, based on original at JAXA/Japan Planetarium Association.
Shape model from NASA PDS SBN.

Bennu

a = 565 m
b = 535 m
c = 508 m



Source: Threjs, based on original at JAXA/Japan Planetarium Association.
Shape model from NASA PDS SBN.

Eros

a= 33 km

b = 13 km

Source: Threjs, based on original at JAXA/Japan Planetarium Association.
Shape model from NASA PDS SBN.

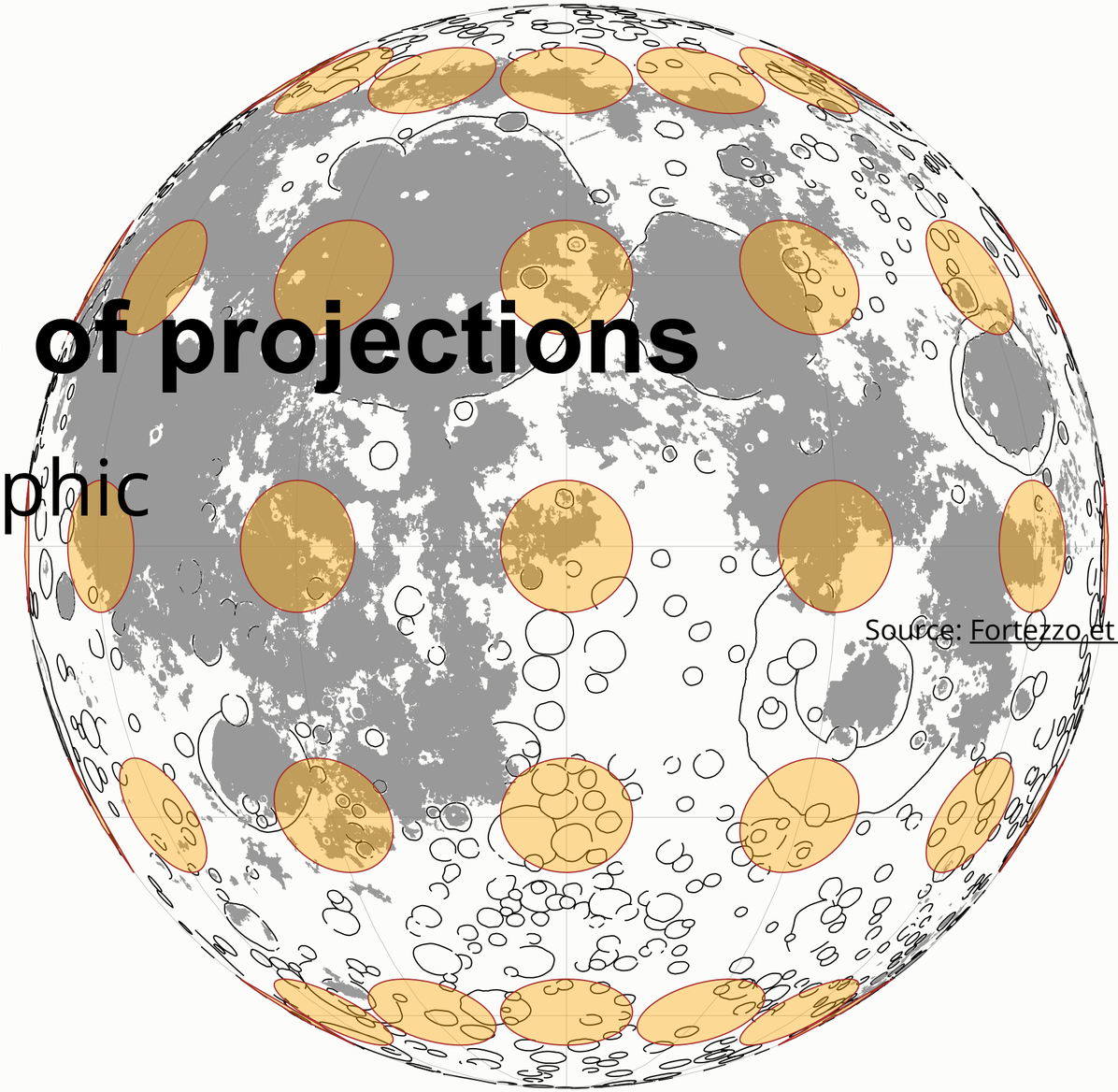
Itokawa

a= 540m
b= 270m
c= 210m

Source: Threjs, based on original at JAXA/Japan Planetarium Association.
Shape model from NASA PDS SBN.

Choice of projections

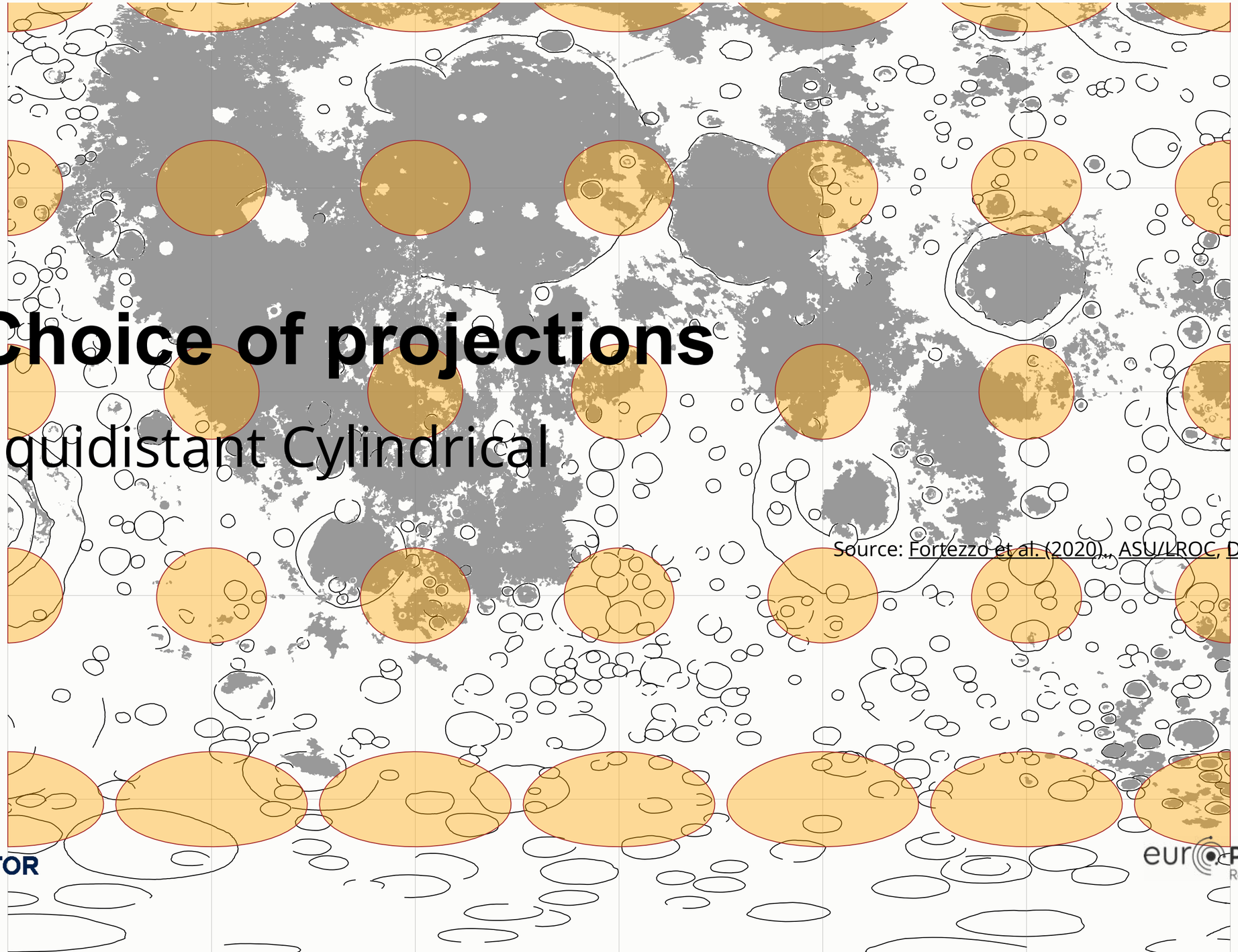
Orthographic



Source: Fortezzo et al. (2020)., ASU/LROC, D3

Choice of projections

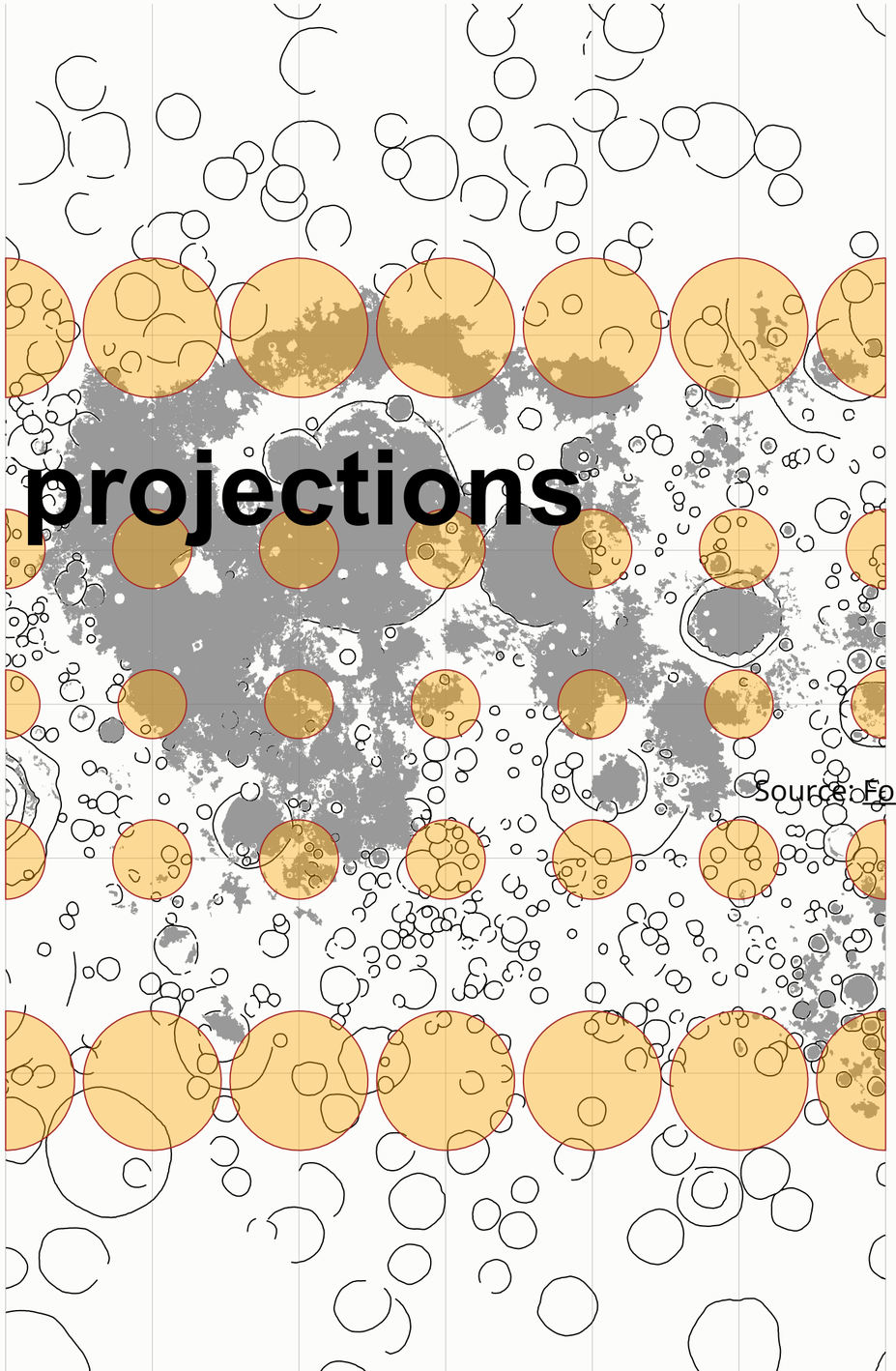
Equidistant Cylindrical



Source: Fortezzo et al. (2020)., ASU/LROC, D3

Choice of projections

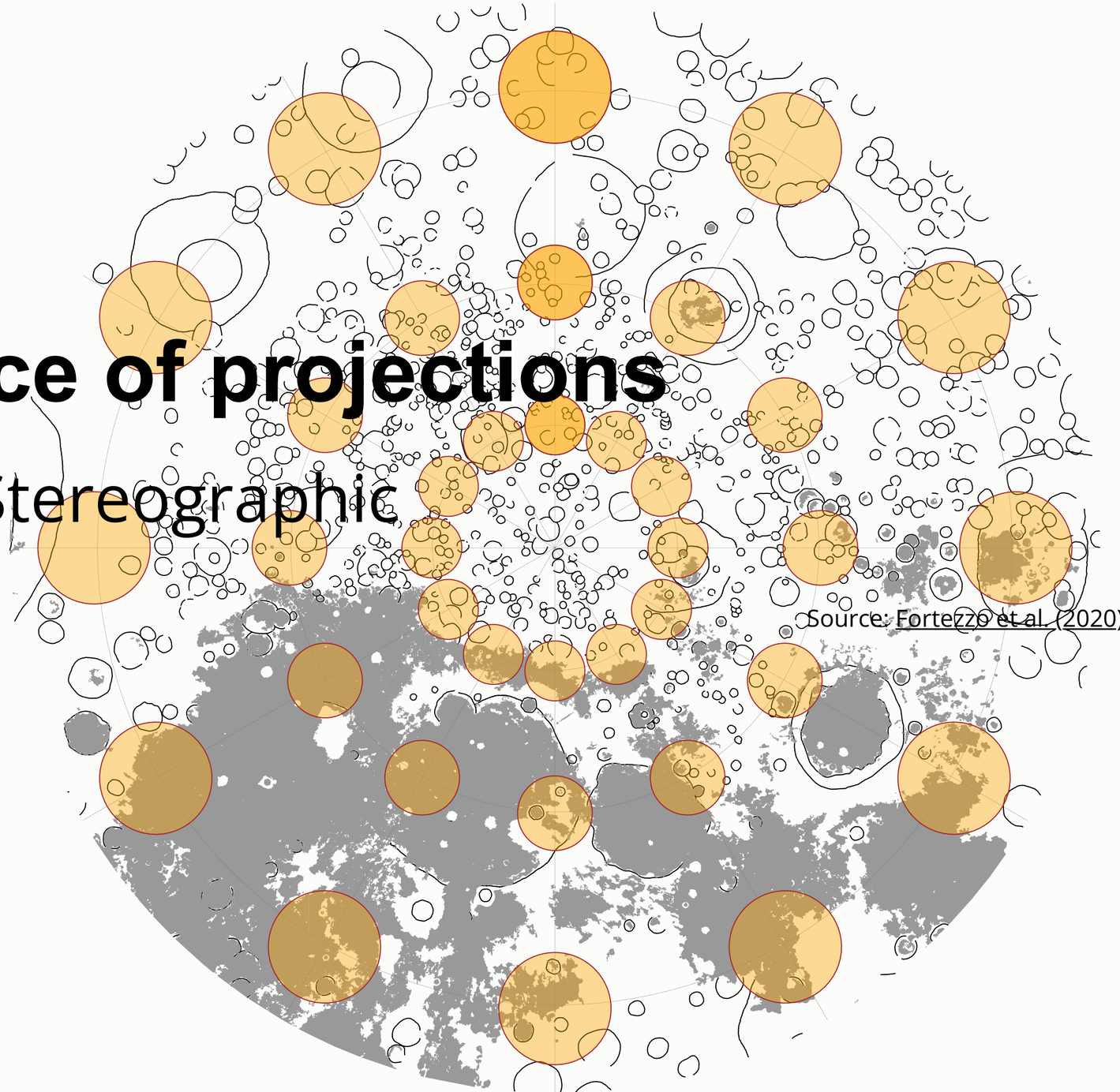
Mercator



Source: Fortezzo et al. (2020)., ASU/LROC, D3

Choice of projections

Polar Stereographic



Source: Fortezzo et al. (2020)., ASU/LROC, D3

Deformation & extent

Equidistant Cylindrical

Source: NASA/LRO/LOLA/ASU/USGS.

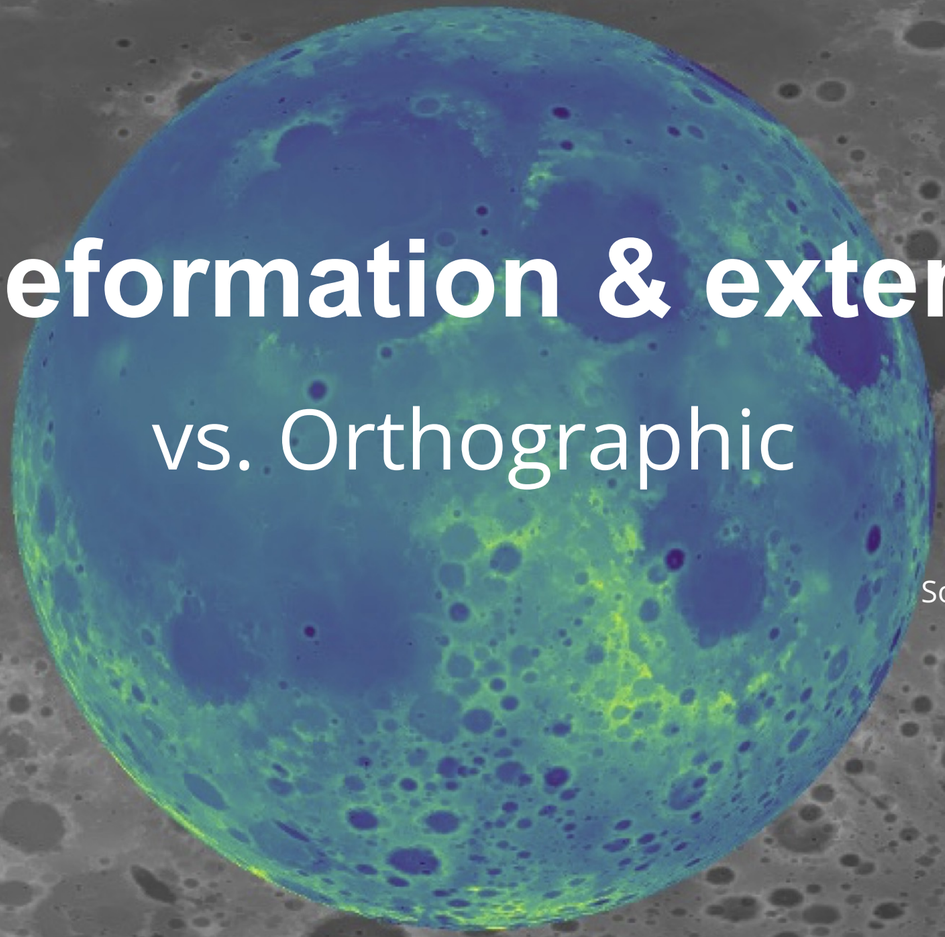
Deformation & extent

vs. Orthographic

Source: NASA/LRO/LOLA/ASU/USGS.

Deformation & extent

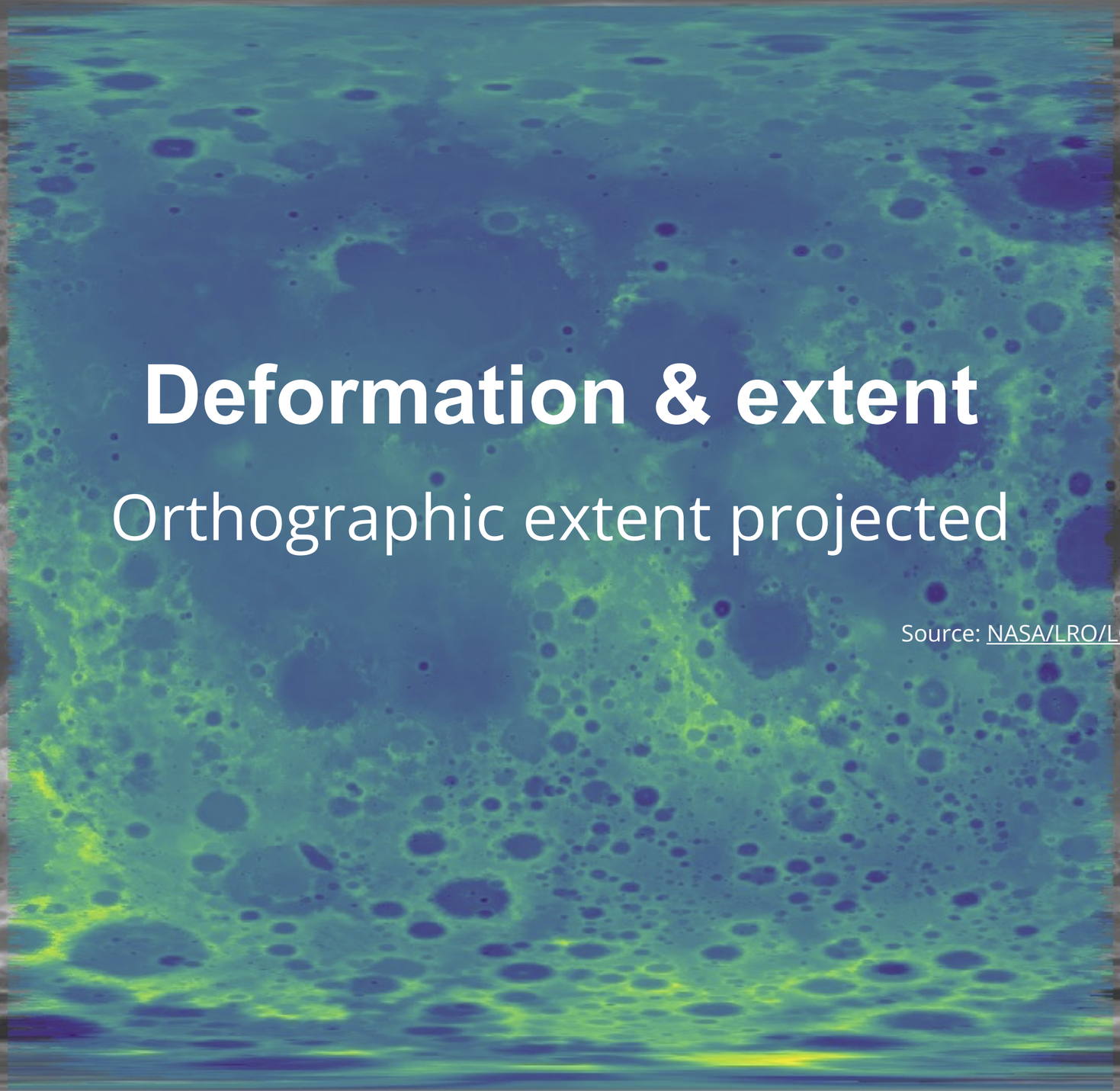
vs. Orthographic



Source: NASA/LRO/LOLA/ASU/USGS.

Deformation & extent

Orthographic extent projected

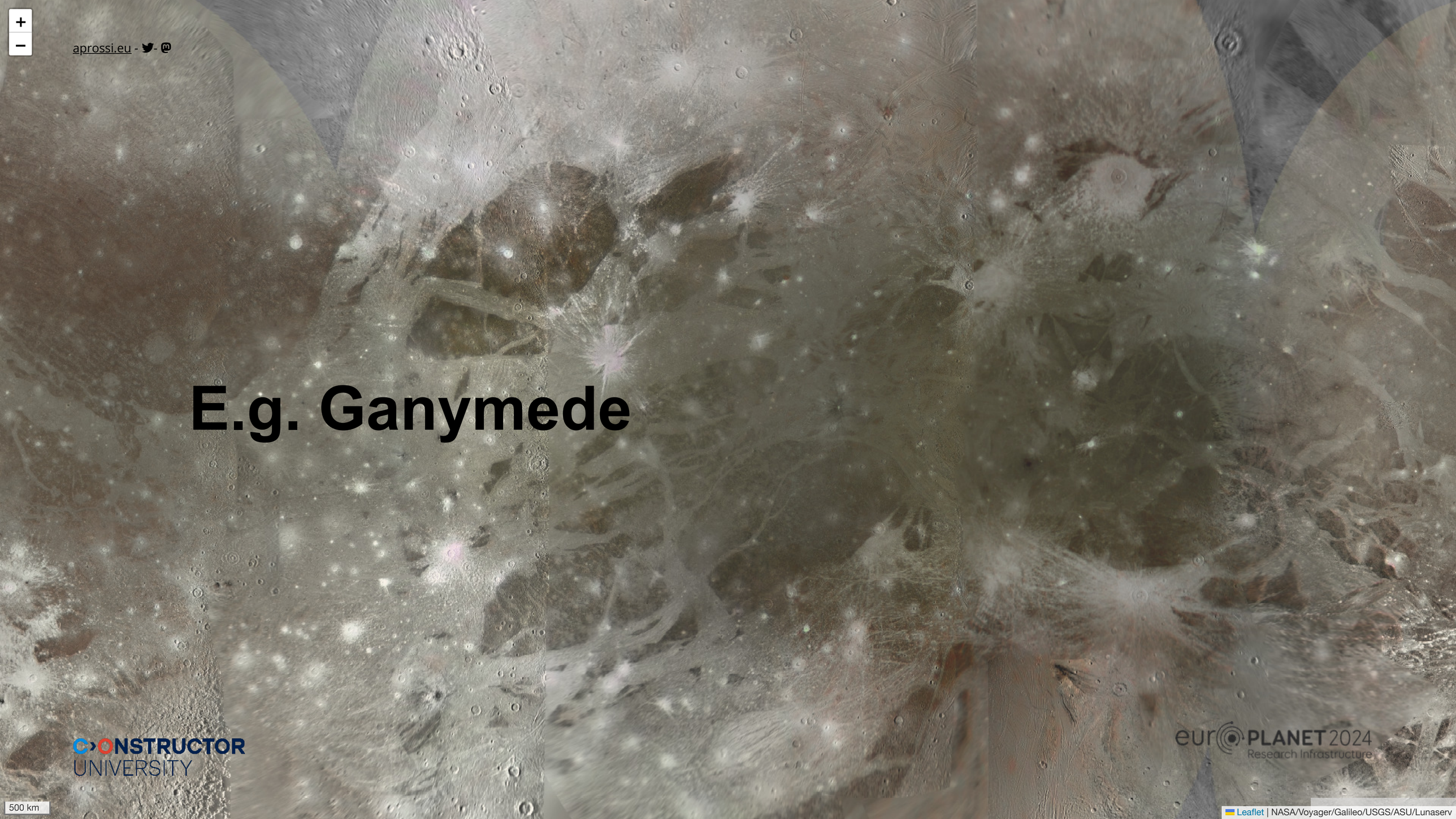


Source: NASA/LRO/LOLA/ASU/USGS.

Deformation & extent

(the other hemisphere)

Source: NASA/LRO/LOLA/ASU/USGS.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−
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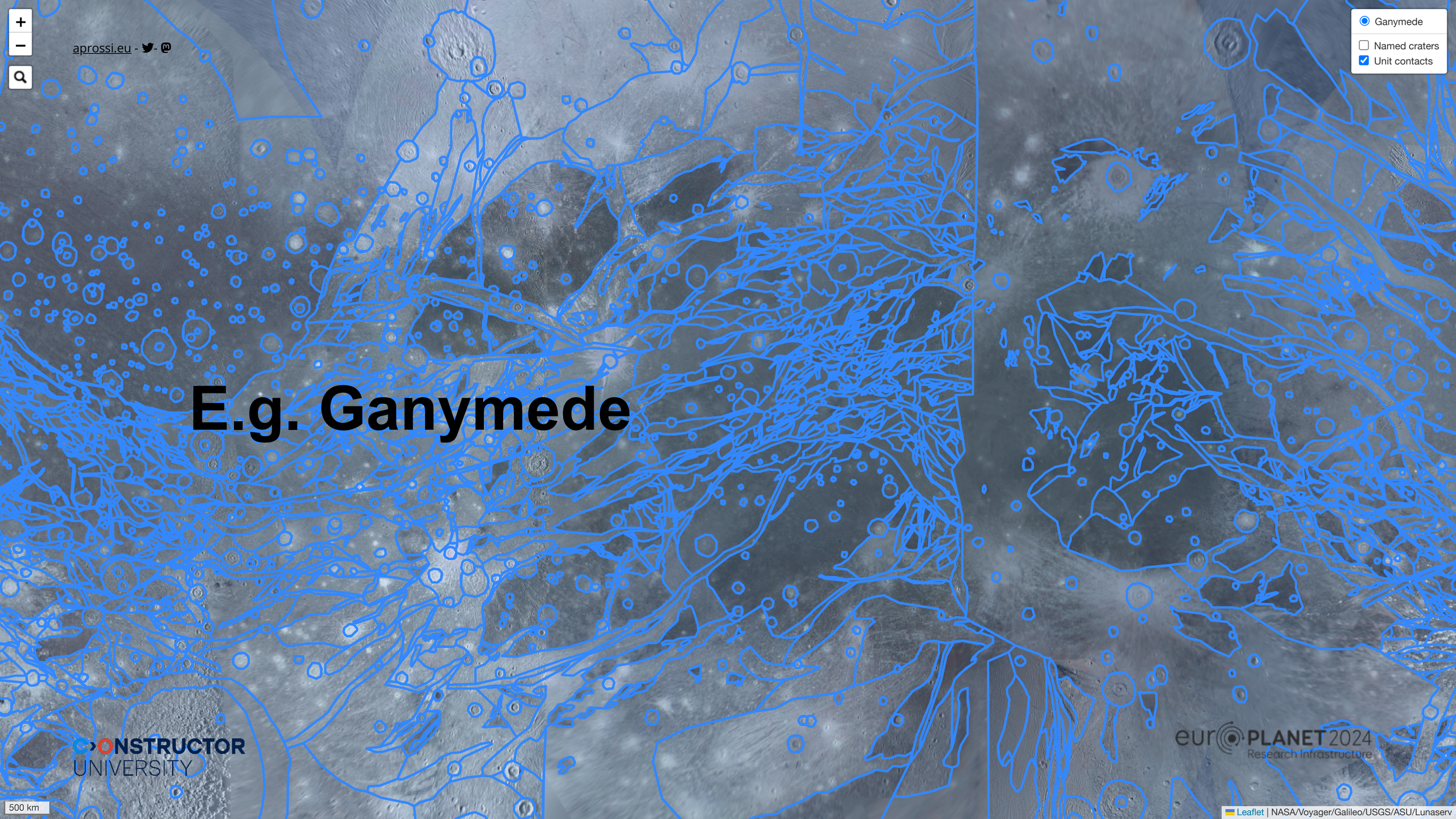
E.g. Ganymede
CONSTRUCTOR UNIVERSITY
500 km
europlanet 2024 Research Infrastructure
Leaflet | NASA/Voyager/Galileo/USGS/ASU/Lunaserv


aprossi.eu -
Ganymede
Named craters
Unit contacts
E.g. Ganymede
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EUROPLANET 2024 Research Infrastructure
500 km
Leaflet | NASA/Voyager/Galileo/USGS/ASU/Lunaserv


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Equidistant Cylindrical - Clon 180
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Leaflet | NASA/Voyager/Galileo/USGS/ASU/Lunaserv


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Equidistant Cylindrical - Clon 0
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Leaflet | NASA/Voyager/Galileo/USGS/ASU/Lunaserv

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Cylindrical Equal Area - Clon 0

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Orthographic - Clon 0

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Orthographic - Clon 180

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Robinson - Clon 0

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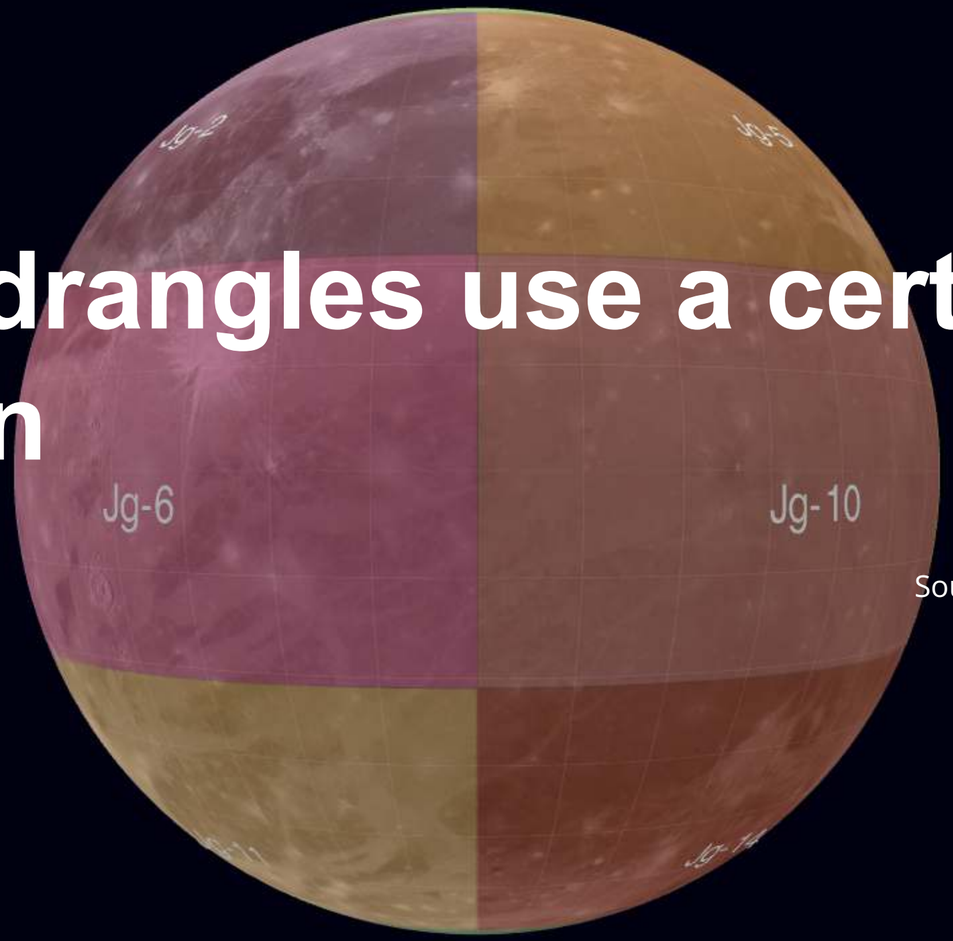
Choosing projections

Source: NASA/Voyager/Galileo/USGS.

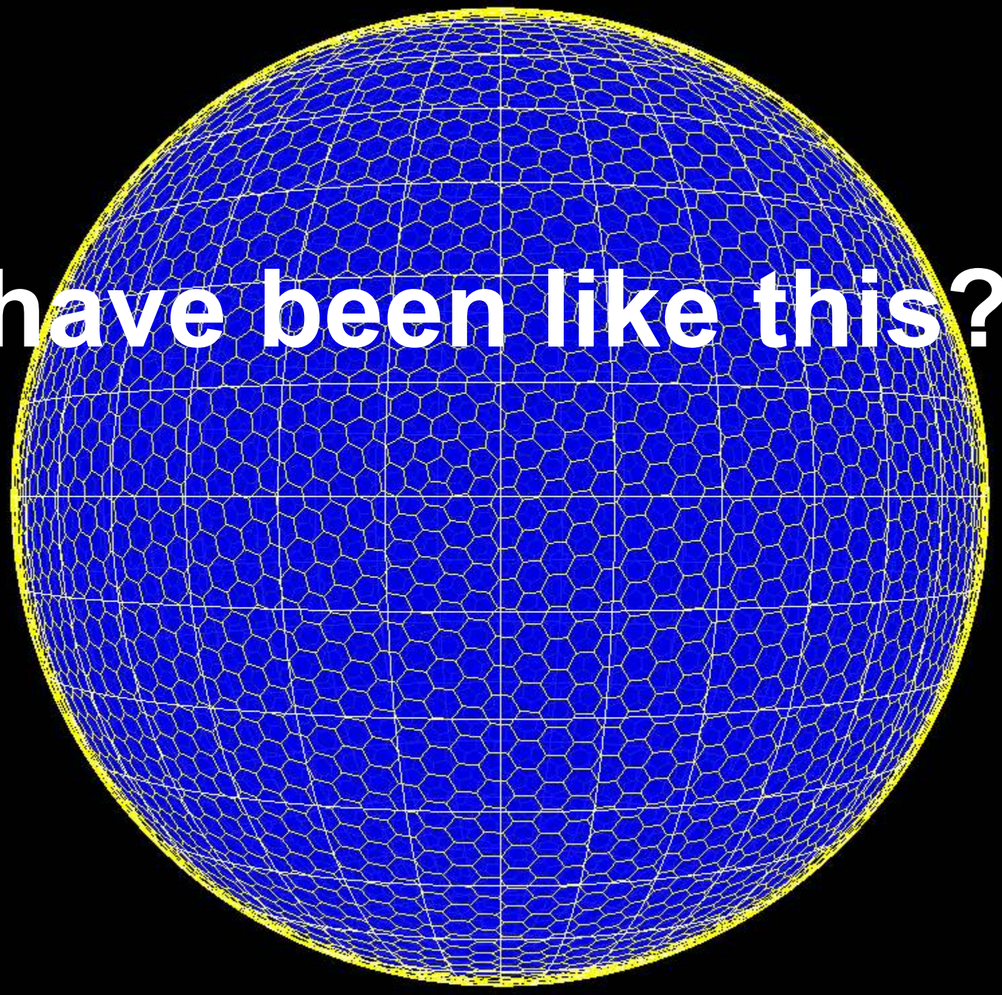
Why quadrangles use a certain projection



Source: NASA/Voyager/Galileo/USGS.

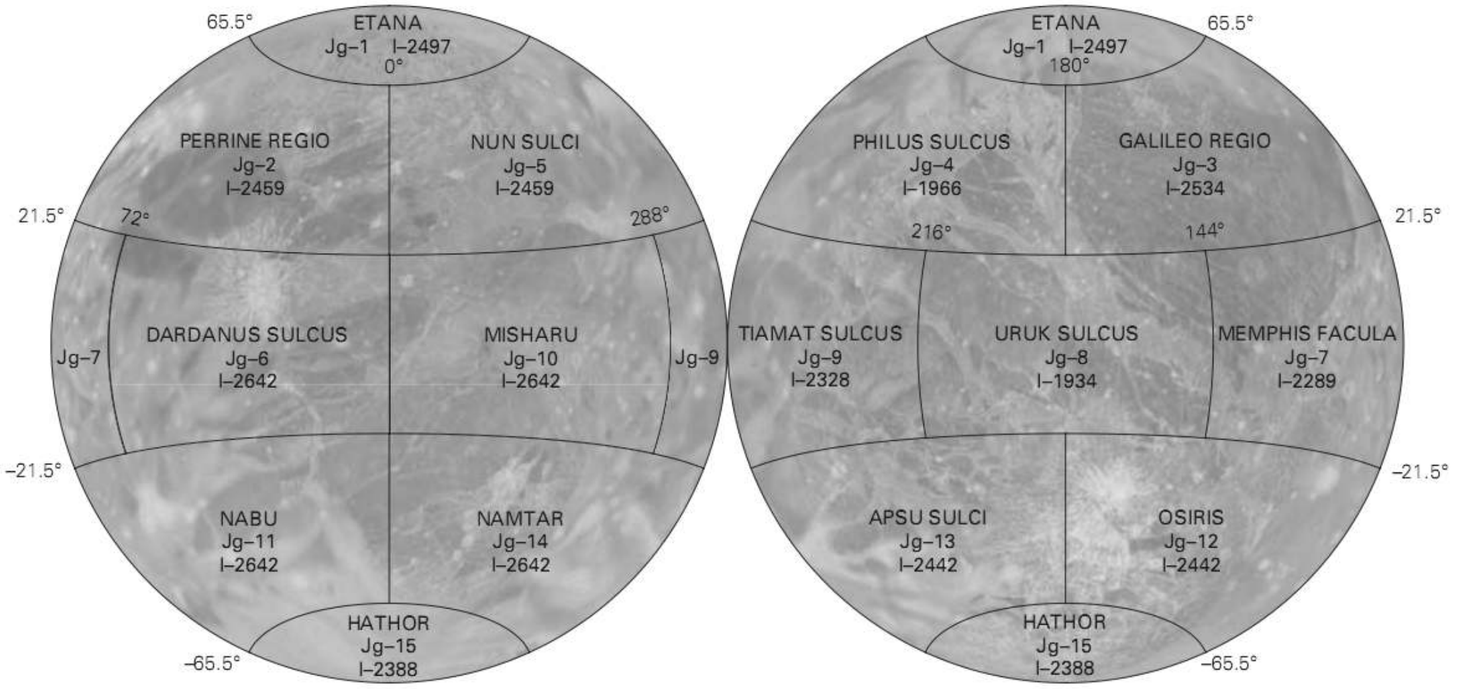
Could it have been like this?

Possibly...



Source: Three-geojson, h3

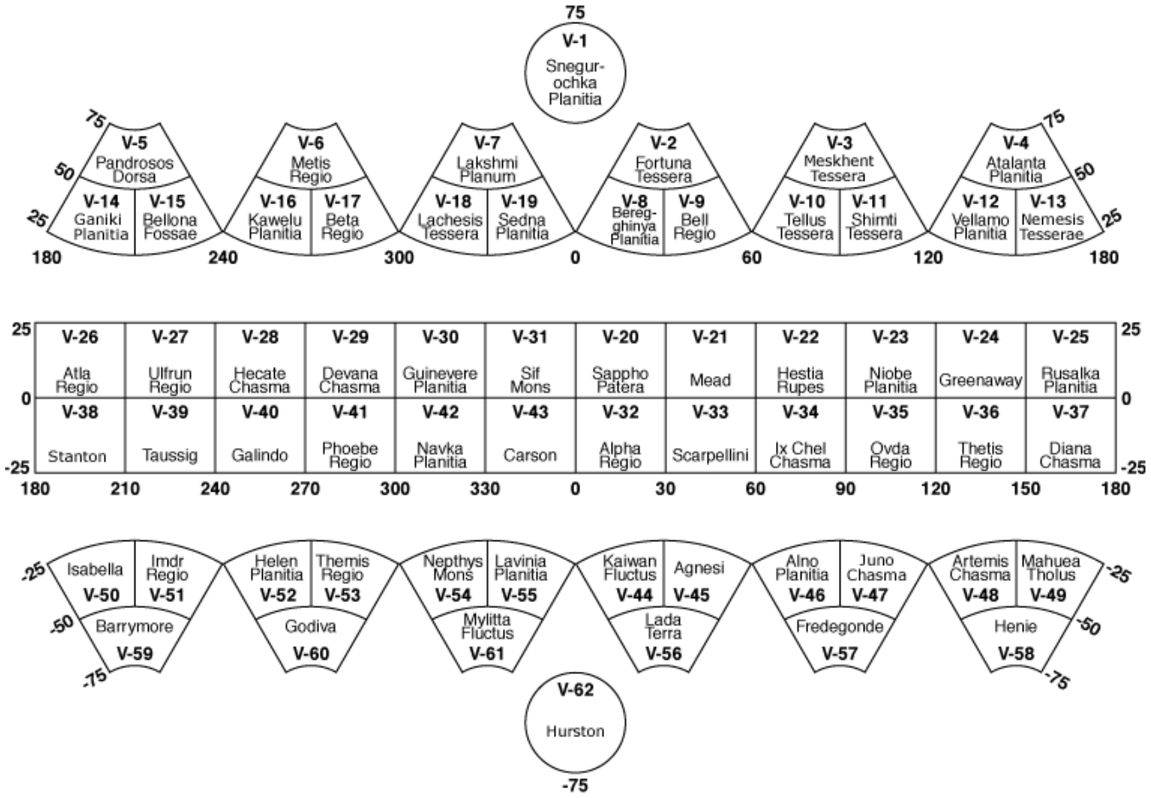
Ganymede: Quadrangles



QUADRANGLE LOCATION
Number preceded by I refers to published geologic map

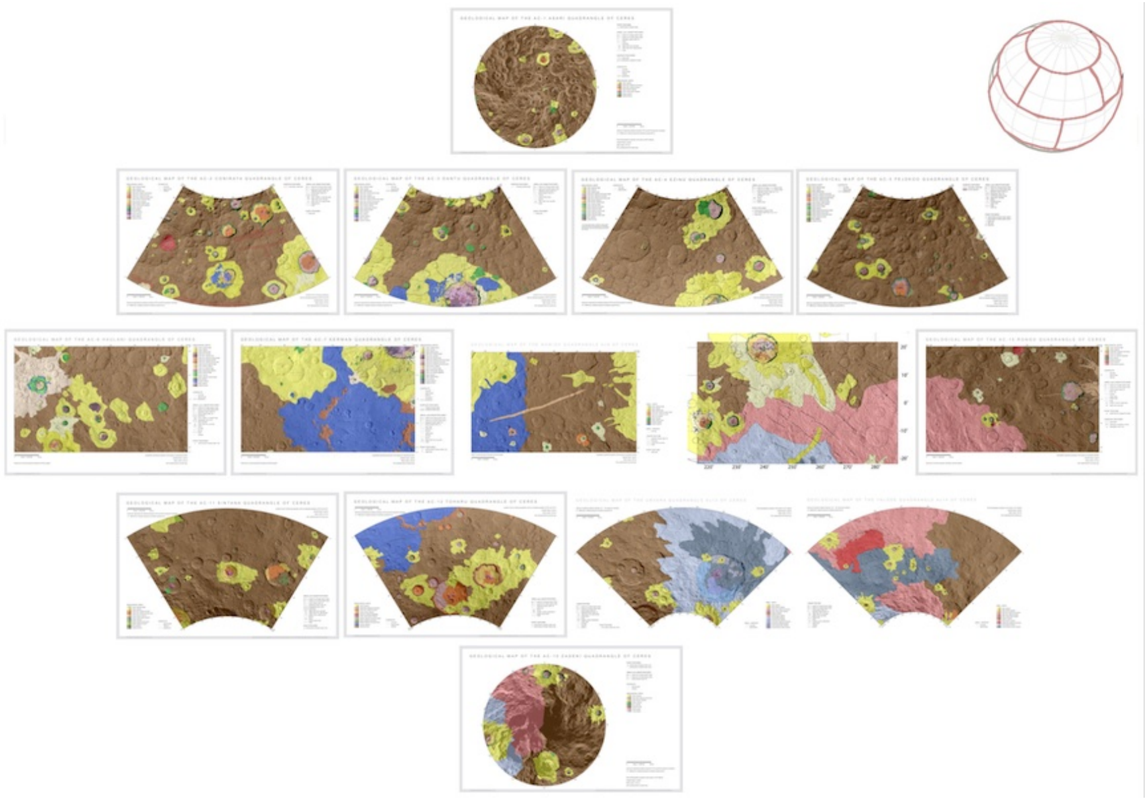
Source: USGS/wikipedia.

Venus: Quadrangles



Source: USGS.

Vesta: Quadrangles



Source: Naß and van Gasselt, (2023).

Venus: specific aspects

- IAU reference body
- East-positive longitude (0-360), planetocentric latitude
- In most GIS applications: de facto standard Est+, planetocentric & sphere
- See also e.g. IAU OGC registry

Jupyter and Saturn system satellites: specific aspects

- IAU reference body
- West-positive longitude (0-360), planetographic latitude
- In most GIS applications: de facto standard Est+, planetocentric & sphere
- See also e.g. IAU OGC registry, IAU/USGS Gazetteer

Small bodies: specific aspects

- IAU reference body / shape models
- Variable complexity
- In most GIS applications for e.g. Ceres, Vesta, planetocentric & sphere
- See also PDS SBN CRS

Relevant references

Georgiadou, P.Y., Knippers, R.A., Kraak, M.J., Sun, Y., Weir, M.J.C. and van Westen, C.J. Principles of geographic information systems (Chapter 4.2 on spatial referencing), 2nd edition, ITC Educational Textbook, ITC, Enschede, 2001. Available online.

Hare, T.M., Skinner, J.A., Kirk, R.L. (2018). Cartography Tools. In: Rossi, A., van Gasselt, S. (eds) Planetary Geology, DOI: 10.1007/978-3-319-65179-8_4

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See also: https://github.com/europlanet-gmap/winter-school-2024/tree/main/crs