3D Earth and Celestial Bodies

MATLAB Implementation

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Contents

1 Download and Installation

1.1 Download from MATLAB Central's File Exchange

The `planet3D` function is available for download on MATLAB® Central's File Exchange at https://www.mathworks.com/matlabcentral/fileexchange/86483-3d-planets-and-celestial-bodies-planet3d.

1.2 Download from GitHub

The `planet3D` function is available for download on GitHub® at https://github.com/tamaskis/planet3D-MATLAB.

1.3 Files Included With Download

There are five files and one folder (storing the images) included in the downloaded `zip` file:

1. `3D Earth and Celestial Bodies - MATLAB Implementation - MATLAB Implementation.pdf` – *this PDF*
2. `EXAMPLES.M` – *examples for using the* `planet3D` *function*
3. **`Images`** – ***Folder that stores images needed to render celestial bodies. DO NOT DELETE. KEEP IN THE SAME FOLDER AS `planet3D.m`***
4. `LICENSE` – *license for the* `planet3D` *function*
5. **`planet3D.m`** – ***MATLAB function for drawing Earth and the major celestial bodies in the solar system***
6. `README.md` – *markdown file for GitHub documentation*

1.4 Accessing the `planet3D` Function in a MATLAB Script

There are **three** options for accessing the `planet3D` function in a MATLAB script:

1. Copy the `planet3D` function to the *end* of your MATLAB script.
2. Place the `planet3D.m` file in the same folder as the MATLAB script.
3. Place the `planet3D.m` file into whatever folder you want, and then use the `addpath(folderName)` command[1] where the `folderName` parameter is a string that stores the filepath of the folder that `planet3D.m` is in *relative to* the folder that your script is in.

In all three cases, the `Images` folder *must* be in the same folder as `planet3D.m`.

[1] https://www.mathworks.com/help/matlab/ref/addpath.html

2 planet3D

Creates high-resolution renderings of the Earth and the major celestial bodies in our solar system for space mechanics applications.

Syntax

```
planet3D(planet)
planet3D(planet,position)
planet3D(planet,position,units)
planet3D(planet,position,units,background)
```

NOTE: If you don't want to specify `position` or `units`, for example, but *do* want to specify `background`, then you would use the syntax `planet3D(planet,[],[],background)`. The empty brackets are needed as placeholders, because `background` can only be read correctly if it is the *fourth* passed parameter. However, we don't need placeholders if we aren't "skipping over" parameters. For example, if we wanted to specify just the `position`, we could use the syntax `planet3D(planet,position)`.

Description

`planet3D(planet,position,units,background)` draws a celestial body.

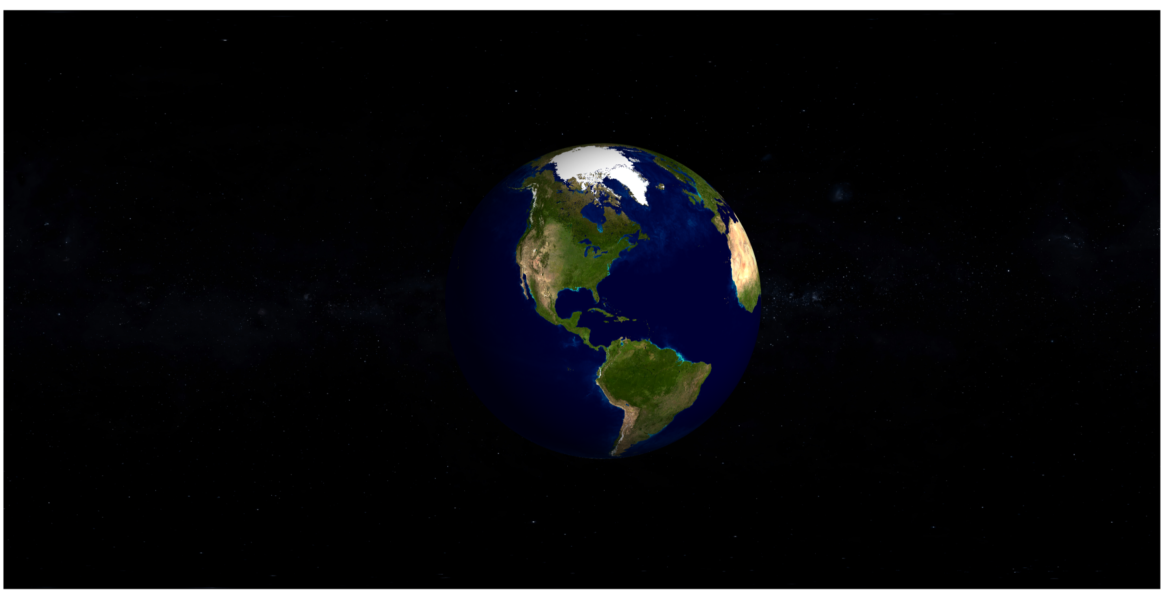
`planet`	`'Sun'`, `'Moon'`, `'Mercury'`, `'Venus'`, `'Earth'`, `'Earth Cloudy'`, `'Earth Night'`, `'Earth Night Cloudy'`, `'Mars'`, `'Jupiter'`, `'Saturn'`, `'Uranus'`, `'Neptune'`, or `'Pluto'`.
`position` *(optional)*	Specifies the position of the celestial body. If `position` is not specified, the function defaults to $(0, 0, 0)$. NOTE: If you are also specifying `units`, make sure you input `position` in the correct units (i.e. in the units you intend to use).
`units` *(optional)*	Specifies the units the celestial body should be drawn in. Units available are `'km'`, `'AU'`, `'m'`, `'ft'`, `'mi'`, and `'nmi'`.
`background` *(optional)*	Specifies the background to use. Backgrounds available are `'Stars'`, `'Milky Way'`, and `'Black'`.

3 Example Plots

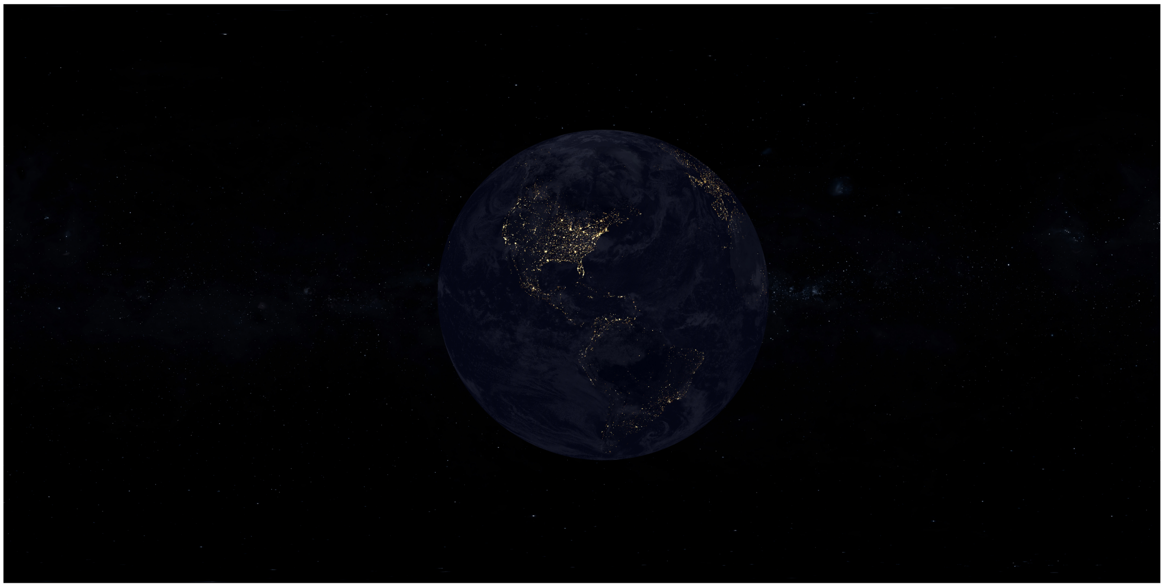
3.1 Earth

3.1.1 | Earth (With Clouds)

3.1.2 | Earth (No Clouds)



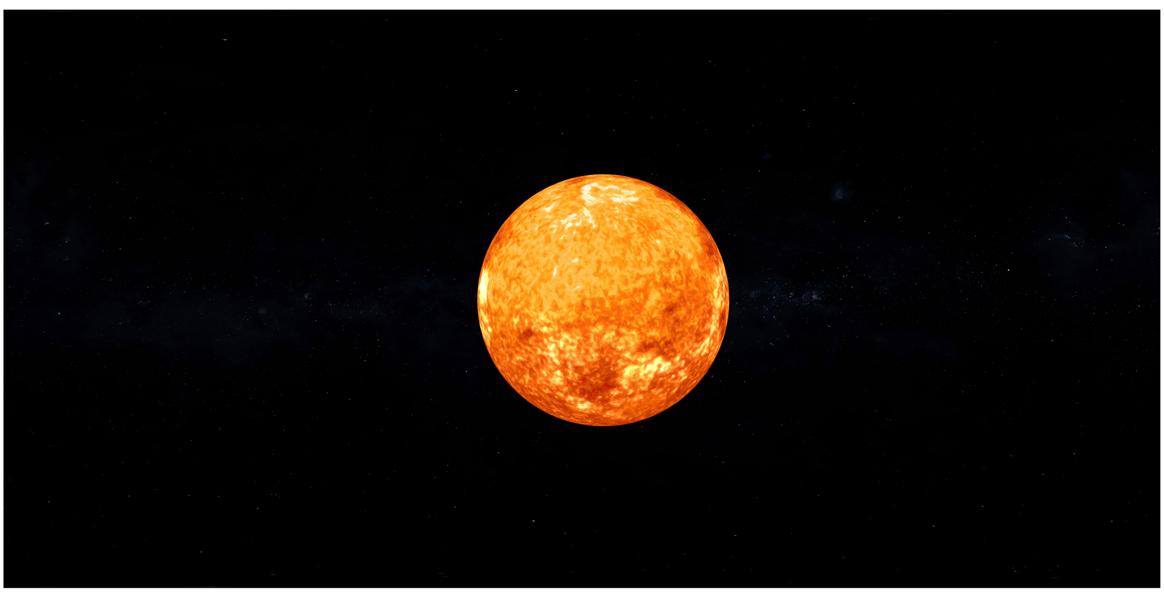
3.1.3 | Earth (Night, With Clouds)



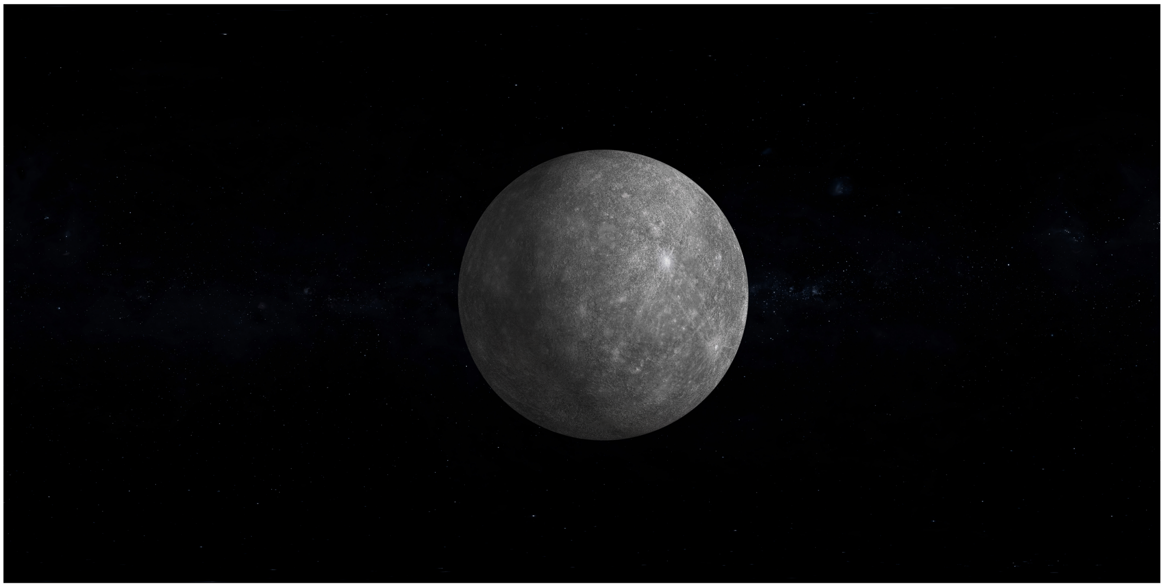
3.1.4 | Earth (Night, No Clouds)

3.2 Moon

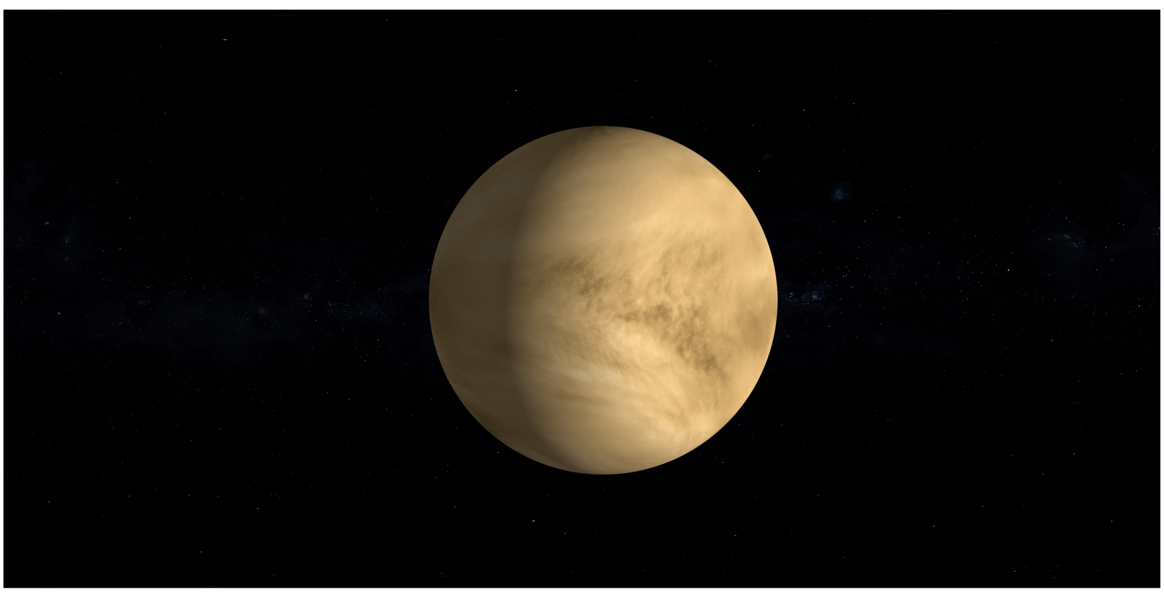
3.3 Sun



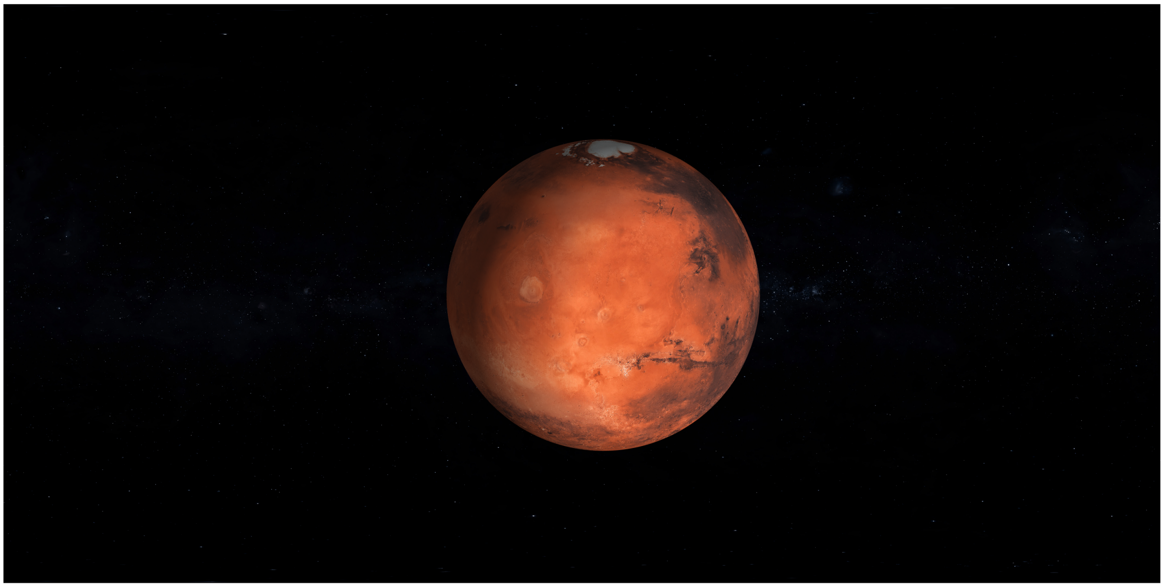
3.4 Mercury



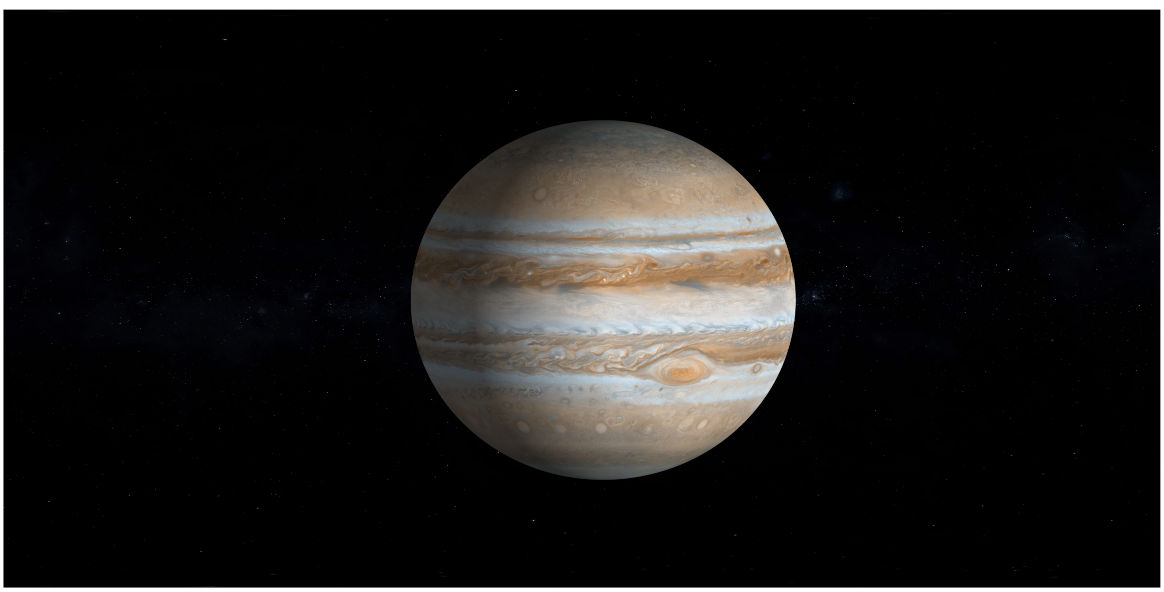
3.5 Venus



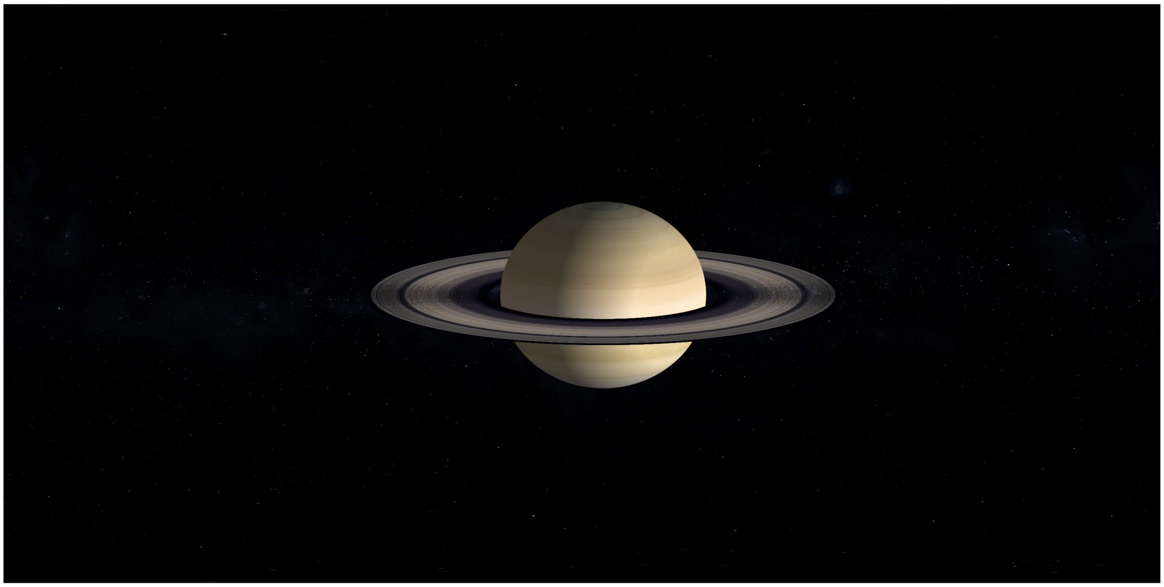
3.6 Mars



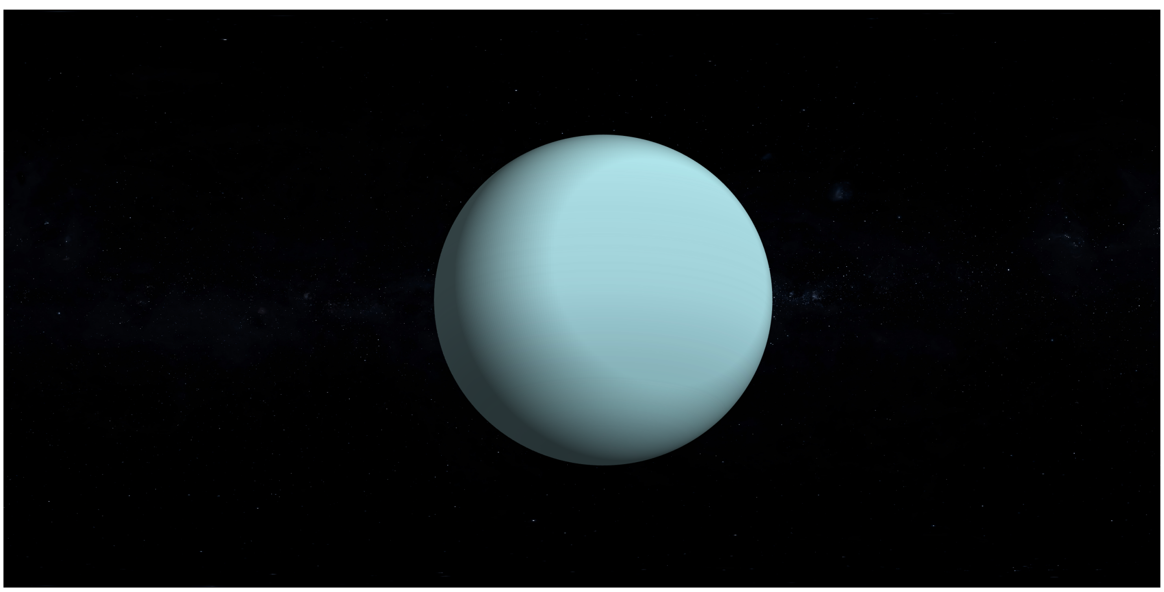
3.7 Jupiter



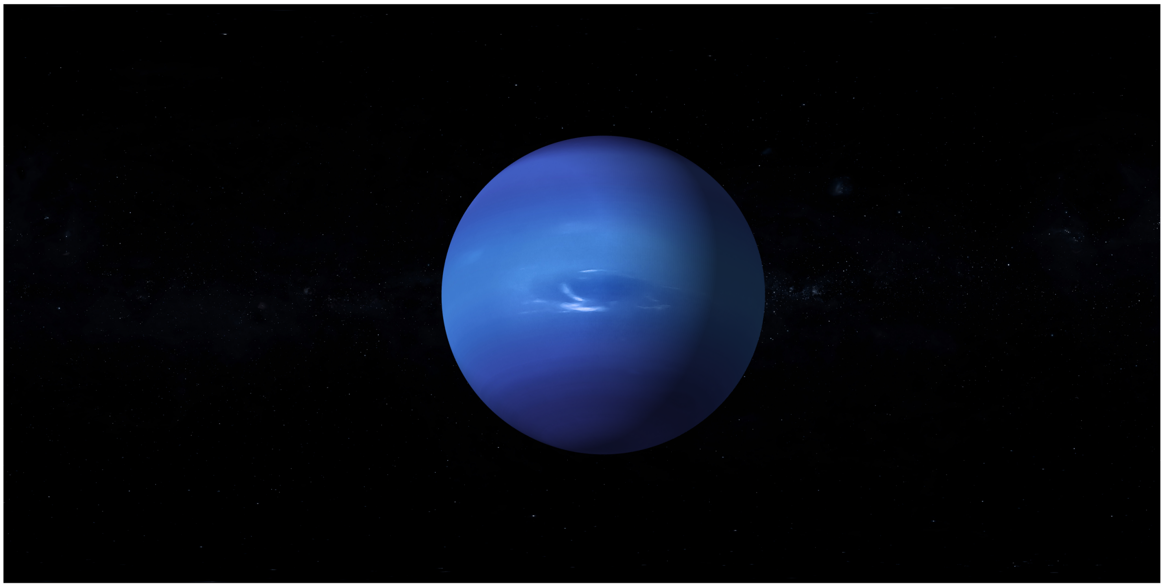
3.8 Saturn



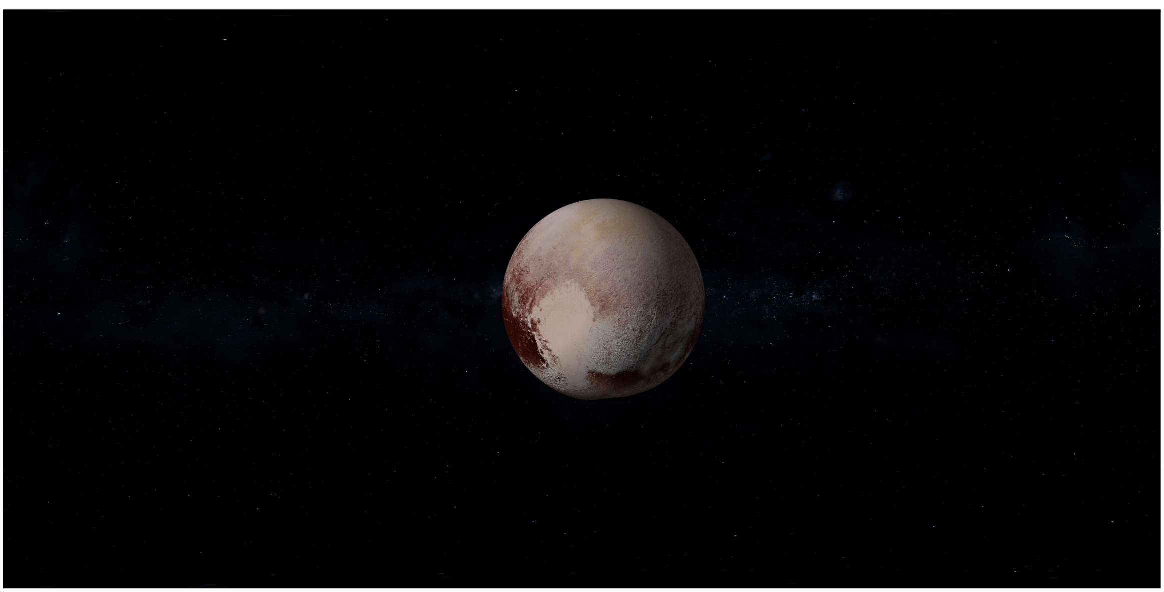
3.9 Uranus



3.10 Neptune



3.11 Pluto



A Data and Constants

A.1 Astronomical Data

Planet/Body	Equatorial Radius		Flattening	
	Value [km]	Source	Value	Source
Sun	696000	[13, Table D-5, p. 1043]	0.000 009	[11]
Moon	1738.0	[13, Table D-3, p. 1041]	0.0012	[7]
Mercury	2439.0	[13, Table D-3, p. 1041]	0.0000	[6]
Venus	6052.0	[13, Table D-3, p. 1041]	0.000	[14]
Earth	6378.1363	[13, Table D-3, p. 1041]	0.003 352 813 1	[13, Table D-3, p. 1041]
Mars	3397.2	[13, Table D-3, p. 1041]	0.006 476 30	[13, Table D-3, p. 1041]
Jupiter	71492.0	[13, Table D-4, p. 1042]	0.064 874 4	[13, Table D-4, p. 1042]
Saturn	60268.0	[13, Table D-4, p. 1042]	0.097 962 4	[13, Table D-4, p. 1042]
Uranus	25559.0	[13, Table D-4, p. 1042]	0.022 927 3	[13, Table D-4, p. 1042]
Neptune	24764.0	[13, Table D-4, p. 1042]	0.0171	[13, Table D-4, p. 1042]
Pluto	1151.0	[13, Table D-4, p. 1042]	.0.0	[13, Table D-4, p. 1042]

A.2 Semi-Minor Axes

For MATLAB's `ellipsoid` function, we need the semi-minor axis, b, which can be calculated as

$$b = a(1 - f)$$

where a is the semi-major axis (assumed to be the equatorial radius) and f is the flattening [3, p. 7-4 (p. 73 in PDF)].

A.3 Saturn's Rings

Saturn's rings range from $7000\ \mathrm{km}$ to $80000\ \mathrm{km}$ from the surface of the planet [9].

A.4 Unit Conversions

Kilometers to Astronomical Units [13]:

$$1\ \mathrm{AU} = 149597870\ \mathrm{km} \quad \rightarrow \quad \boxed{1\ \mathrm{km} = \frac{1}{149597870}\ \mathrm{AU}}$$

Kilometers to Meters:

$$\boxed{1\ \mathrm{km} = 1000\ \mathrm{m}}$$

Kilometers to Feet:

$$1 \text{ km} = \left(\frac{1000 \text{ m}}{1 \text{ km}}\right)\left(\frac{100 \text{ cm}}{1 \text{ m}}\right)\left(\frac{1 \text{ in}}{2.54 \text{ cm}}\right)\left(\frac{1 \text{ ft}}{12 \text{ in}}\right) \quad \rightarrow \quad \boxed{1 \text{ km} = \frac{100000}{30.48} \text{ ft}}$$

Kilometers to Miles:

$$1 \text{ km} = \left(\frac{100000/30.48 \text{ ft}}{\text{km}}\right)\left(\frac{1 \text{ mi}}{5280 \text{ ft}}\right) \quad \rightarrow \quad \boxed{1 \text{ km} = \frac{100000}{160934.4} \text{ mi}}$$

Kilometers to Nautical Miles:

$$1 \text{ nmi} = 1852 \text{ m} = 1.852 \text{ km} \quad \rightarrow \quad \boxed{1 \text{ km} = \frac{1}{1.852} \text{ nmi}}$$

B Image Sources

Image	File Name	Source	Copyright/License
Sun	`Sun.png`	[10]	CC Attribution 4.0 International (CC BY 4.0) [1, 10]
Moon	`Moon.png`	[10]	CC Attribution 4.0 International (CC BY 4.0) [1, 10]
Mercury	`Mercury.png`	[10]	CC Attribution 4.0 International (CC BY 4.0) [1, 10]
Venus	`Venus.png`	[10]	CC Attribution 4.0 International (CC BY 4.0) [1, 10]
Earth (Day)	`Earth.png`	[12]	none [5, 12]
Earth (Night)	`Earth Night.png`	[10]	CC Attribution 4.0 International (CC BY 4.0) [1, 10]
Clouds	`Clouds.png`	[10]	CC Attribution 4.0 International (CC BY 4.0) [1, 10]
Mars	`Mars.png`	[10]	CC Attribution 4.0 International (CC BY 4.0) [1, 10]
Jupiter	`Jupiter.png`	[10]	CC Attribution 4.0 International (CC BY 4.0) [1, 10]
Saturn	`Saturn.png`	[10]	CC Attribution 4.0 International (CC BY 4.0) [1, 10]
Saturn Rings	`Saturn Rings.png`	[10]	CC Attribution 4.0 International (CC BY 4.0) [1, 10]
Uranus	`Uranus.png`	[10]	CC Attribution 4.0 International (CC BY 4.0) [1, 10]
Neptune	`Neptune.png`	[10]	CC Attribution 4.0 International (CC BY 4.0) [1, 10]
Pluto	`Pluto.png`	[8]	none [8]
Milky Way	`Milky Way.png`	[10]	CC Attribution 4.0 International (CC BY 4.0)
Stars	`Stars.png`	[10]	CC Attribution 4.0 International (CC BY 4.0)

C References for Code

3D Earth Example (`earth_example.m`) [4]:

- Use of `ellipsoid` function to render the Earth.

Earth-sized Sphere with Topography (`earth_sphere`) [2]:

- Handling of unit conversions.

References

[1] *Attribution 4.0 International (CC BY 4.0)*. creative commons. https://creativecommons.org/licenses/by/4.0/. (accessed: January 27, 2021).

[2] Will Campbell. *Earth-sized Sphere with Topography*. MATLAB Central File Exchange. https://www.mathworks.com/matlabcentral/fileexchange/27123-earth-sized-sphere-with-topography. (accessed: January 22, 2021).

[3] *Department of Defense World Geodetic System 1984*. Tech. rep. NIMA TR8350.2. https://apps.dtic.mil/sti/pdfs/AD1000581.pdf. National Imagery and Mapping Agency, 2004.

[4] Ryan Gray. *3D Earth Example*. MATLAB Central File Exchange. https://www.mathworks.com/matlabcentral/fileexchange/13823-3d-earth-example. (accessed: January 22, 2021).

[5] *Image Use Policy*. NASA visible earth. https://visibleearth.nasa.gov/image-use-policy. (accessed: January 23, 2021).

[6] *Mercury Fact Sheet*. NASA. https://nssdc.gsfc.nasa.gov/planetary/factsheet/mercuryfact.html. (accessed: January 22, 2021).

[7] *Moon*. Wikipedia. https://en.wikipedia.org/wiki/Moon. (accessed: January 22, 2021).

[8] *Pluto Color Map*. NASA Jet Propulsion Laboratory. https://www.jpl.nasa.gov/images/pluto-color-map/. (accessed: January 23, 2021).

[9] *Rings of Saturn*. Wikipedia. https://en.wikipedia.org/wiki/Rings_of_Saturn. (accessed: January 22, 2021).

[10] *Solar Textures*. Solar System Scope. https://www.solarsystemscope.com/textures/. (accessed: January 22, 2021).

[11] *Sun*. Wikipedia. https://en.wikipedia.org/wiki/Sun. (accessed: January 22, 2021).

[12] *The Blue Marble: Land Surface, Ocean Color and Sea Ice*. NASA visible earth. https://visibleearth.nasa.gov/images/57730/the-blue-marble-land-surface-ocean-color-and-sea-ice/57731l. (accessed: January 22, 2021).

[13] David A. Vallado. *Fundamentals of Astrodynamics and Applications*. 4^{th}. Hawthorne, CA: Microcosm Press, 2013.

[14] *Venus Fact Sheet*. NASA. https://nssdc.gsfc.nasa.gov/planetary/factsheet/venusfact.html. (accessed: January 22, 2021).