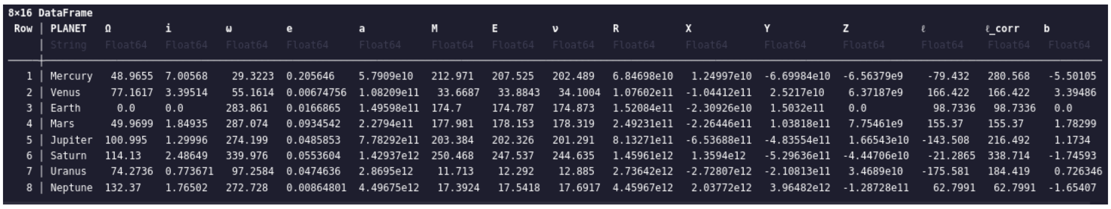
# Assignment #1 - Astronomia de Sistemas Planetários

Arthur Araujo Galdino dos Santos

Disponível em: https://github.com/araujoarthur/psastronomyclass/blob/main/A1/V3/A1V4.ipynb

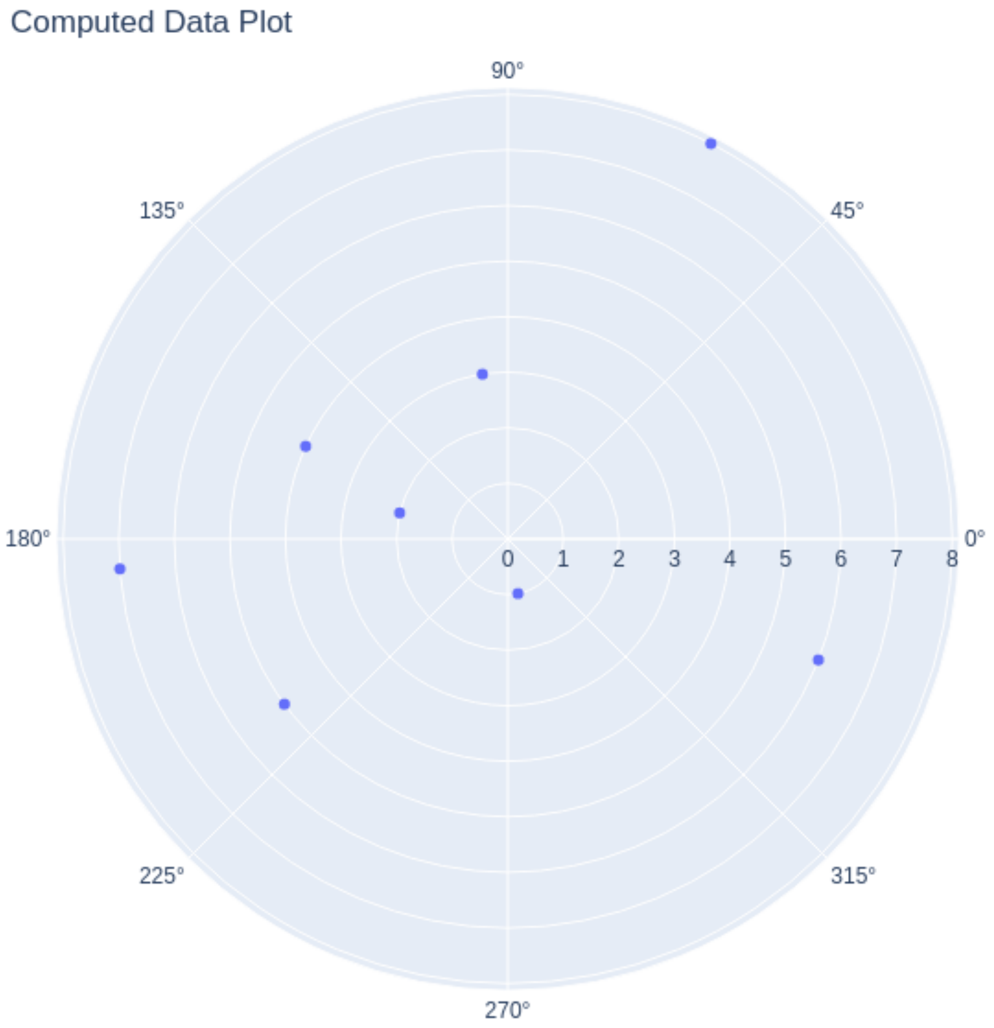
Porque a inclinação do plano orbital e a longitude do nodo ascendente são iguais as 0 no dado disponibilizado, as coordenadas tem sinal invertido em relação as fornecidas por sistemas de calculo de dados. Por este motivo há um segundo arquivo que usa omega = 180.378 e i ~ 0.0067 que pode ser encontrado aqui

## Tabela de Elementos Orbitais e Posições



```
8×16 DataFrame
 Row │ PLANET   Ω         i         ω         e           a           M         E         ν         R           X            Y            Z            ℓ         ℓ_corr    b
     │ String   Float64   Float64   Float64   Float64     Float64     Float64   Float64   Float64   Float64     Float64      Float64      Float64      Float64   Float64   Float64
─────┼──────────────────────────────────────────────────────────────────────────────────────────────────────────────────────────────────────────────────────────────────────────
   1 │ Mercury   48.9655  7.00568    29.3223  0.205646    5.7909e10   212.971   207.525   202.489   6.84698e10   1.24997e10  -6.69984e10  -6.56379e9    -79.432   280.568   -5.50105
   2 │ Venus     77.1617  3.39514    55.1614  0.00674756  1.08209e11   33.6687   33.8843   34.1004  1.07602e11  -1.04412e11   2.5217e10    6.37187e9    166.422   166.422    3.39486
   3 │ Earth      0.0     0.0       283.861   0.0166865   1.49598e11  174.7     174.787   174.873   1.52084e11  -2.30926e10   1.5032e11    0.0           98.7336   98.7336   0.0
   4 │ Mars      49.9699  1.84935   287.074   0.0934542   2.2794e11   177.981   178.153   178.319   2.49231e11  -2.26446e11   1.03818e11   7.75461e9    155.37    155.37     1.78299
   5 │ Jupiter  100.995   1.29996   274.199   0.0485853   7.78292e11  203.384   202.326   201.291   8.13271e11  -6.53688e11  -4.83554e11   1.66543e10  -143.508   216.492    1.1734
   6 │ Saturn   114.13    2.48649   339.976   0.0553604   1.42937e12  250.468   247.537   244.635   1.45961e12   1.3594e12   -5.29636e11  -4.44706e10   -21.2865  338.714   -1.74593
   7 │ Uranus    74.2736  0.773671   97.2584  0.0474636   2.8695e12    11.713    12.292    12.885   2.73642e12  -2.72807e12  -2.10813e11   3.4689e10   -175.581   184.419    0.726346
   8 │ Neptune  132.37    1.76502   272.728   0.00864801  4.49675e12   17.3924   17.5418   17.6917  4.45967e12   2.03772e12   3.96482e12  -1.28728e11    62.7991   62.7991  -1.65407
```

## Plot Polar:



```
In [ ]: using DataFrames, PlotlyJS, Statistics
        const au = 149597870700.0
        ;
```

## Utility Functions

In [ ]:

```
"""
arcCorrection(::Float64) : Float64

Receives an arc and return it if smaller than or equal to 360°, else retu

[Suboptimal. Won't solve problems like ARC < 0. But works for this assign
"""
function arcCorrection(ARC::Float64)
    if ARC >= 360.0
        return mod(ARC,360.0)
    else
        return Float64(ARC)
    end
end
"""
tt(::Integer, ::Integer, ::Integer, ::Integer, ::Integer) : Float64

Receives a day value, a month value, an year value, an hour value and a m
"""
function tt(d::Integer, m::Integer, y::Integer, h::Integer, mm::Integer)
    return 367 * y - floor(7*(y + ((m+9)/12) )/4) + floor(275*m/9) + d -
end

"""
E(::Float64, ::Float64, [::Float64]) : Float64

Receives the mean anomaly, the eccentricity and optionally [for recursive
Outputs an eccentric anomaly value in degrees.
"""
function E(M::Float64, EC::Float64, Ẽ::Float64=M)
    M_rad = deg2rad(M)
    Ẽ_rad = deg2rad(Ẽ)

    ΔE_rad = ((M_rad - Ẽ_rad) + EC * sin(Ẽ_rad))/(1 - (EC * cos(Ẽ_rad)))
    E_deg = rad2deg(Ẽ_rad + ΔE_rad)

    if abs(ΔE_rad) > 5E-6
        return E(M, EC, E_deg)
    else
        return E_deg
    end
end

"""
ν(::Float64, ::Float64) : Float64

Receives the eccentricity and the eccentric anomaly in degrees and return
"""
function ν(EC::Float64, E::Float64)
    return 2 * atand(sqrt((1 + EC)/(1 - EC))*tand(E/2))
end

"""
polarReferentialFix(::Float64) : Float64

Receives an angle and return it's equivalent counter clock-wise.
[Not optimal, won't solve problems like congruent angles (<360), but work
"""
function polarReferentialFix(ang::Float64)
    if 0 > ang
        return 360 + ang
    else
        return ang
        return any
    end
end

"""
sunDistance(::Float64, ::Float64, ::Float64) : Float64

Receives Major SemiAxis, Eccentricity and True Anomaly (the former in met
"""
function sunDistance(MSA::Float64, EC::Float64, ν::Float64)
    return (MSA * (1 - EC^2))/(1 + EC * cosd(ν))
end


"""
cartesian_X(::Float64, ::Float64, ::Float64, ::Float64) : Float64

Receives the distance between the Sun and the given body (R), the longitu
the true anomaly (v) and the tilt relative to the ecliptic (i) and output
"""
function cartesian_X(R::Float64, Ω::Float64, ω::Float64, v::Float64, i::F
    return (R * ( ( cosd(Ω) * (cosd(ω + v)) ) - ( sind(Ω) * (sind(ω + v))
end

"""
cartesian_Y(::Float64, ::Float64, ::Float64, ::Float64) : Float64

Receives the distance between the Sun and the given body (R), the longitu
the true anomaly (ν) and the tilt relative to the ecliptic (i) and output
"""
function cartesian_Y(R::Float64, Ω::Float64, ω::Float64, ν::Float64, i::F
    return R * ((sind(Ω) * cosd(ω + ν)) + (cosd(Ω) * sind(ω + ν) * cosd(i
end

"""
cartesian_Z(::Float64, ::Float64, ::Float64, ::Float64)

Receives the distance between the Sun and the given body (R), the perihel
tilt relative to the ecliptic (i) and outputs the rectangular coordinate
"""
function cartesian_Z(R::Float64, ω::Float64, ν::Float64, i::Float64)
    return R * sind(ω + ν) * sind(i)
end

"""
ℓ(::Float64, ::Float64) : Float64

Receives the X and Y coordinates and outputs the ecliptic longitude ℓ in
"""
function ℓ(XX::Float64, YY::Float64)
   return atand(YY, XX)
end

"""
Receives the X, Y and X coordinates and outputs the ecliptic latitude b i
"""
function b(XX::Float64, YY::Float64, ZZ::Float64)
    return atand((ZZ)/(sqrt((XX^2) + (YY^2))))
end
```

Out[ ]:

```
b
```

```
In [ ]: function Mercury(t)
            mercuryDict = Dict()
            mercuryDict["PLANET"] = "Mercury"
            mercuryDict["Ω"] = 48.3313 + 3.24587E-5 * t
            mercuryDict["i"] = 7.0047 + 5.00E-8 * t
            mercuryDict["ω"] = 29.1241 + 1.01444E-5 * t
            mercuryDict["a"] = 0.387098*au
            mercuryDict["e"] = 0.205635 + 5.59E-10 * t
            mercuryDict["M"] = arcCorrection(168.6562 + 4.0923344368 * t)
            mercuryDict["E"] = arcCorrection(E(mercuryDict["M"], mercuryDict["e"]
            mercuryDict["ν"] = polarReferentialFix(ν(mercuryDict["e"], mercuryDic
            mercuryDict["Dist_Sun"] = sunDistance(mercuryDict["a"], mercuryDict["
            mercuryDict["X_COORD"] = cartesian_X(mercuryDict["Dist_Sun"], mercury
            mercuryDict["Y_COORD"] = cartesian_Y(mercuryDict["Dist_Sun"], mercury
            mercuryDict["Z_COORD"] = cartesian_Z(mercuryDict["Dist_Sun"], mercury
            mercuryDict["ℓ"] = ℓ(mercuryDict["X_COORD"], mercuryDict["Y_COORD"])
            mercuryDict["ℓ_corr"] = polarReferentialFix(ℓ(mercuryDict["X_COORD"],
            mercuryDict["b"] = b(mercuryDict["X_COORD"], mercuryDict["Y_COORD"],

            return mercuryDict
        end

        function Venus(t)
            venusDict = Dict()
            venusDict["PLANET"] = "Venus"
            venusDict["Ω"] = 76.6799 + 2.46590E-5 * t
            venusDict["i"] = 3.3946 + 2.75E-8 * t
            venusDict["ω"] = 54.8910 + 1.38374E-5 * t
            venusDict["a"] = 0.723330 * au
            venusDict["e"] = 0.006773 - 1.302E-9 * t
            venusDict["M"] = arcCorrection(48.0052 + 1.6021302244 * t)
            venusDict["E"] = arcCorrection(E(venusDict["M"], venusDict["e"]))
            venusDict["ν"] = polarReferentialFix(ν(venusDict["e"], venusDict["E"]
            venusDict["Dist_Sun"] = sunDistance(venusDict["a"], venusDict["e"], v
            venusDict["X_COORD"] = cartesian_X(venusDict["Dist_Sun"], venusDict["
            venusDict["Y_COORD"] = cartesian_Y(venusDict["Dist_Sun"], venusDict["
            venusDict["Z_COORD"] = cartesian_Z(venusDict["Dist_Sun"], venusDict["
            venusDict["ℓ"] = ℓ(venusDict["X_COORD"], venusDict["Y_COORD"])
            venusDict["ℓ_corr"] = polarReferentialFix(ℓ(venusDict["X_COORD"], ven
            venusDict["b"] = b(venusDict["X_COORD"], venusDict["Y_COORD"], venusD

            return venusDict
        end

        function Earth(t)
            earthDict = Dict()
            earthDict["PLANET"] = "Earth"
            earthDict["Ω"] = 0.0
            earthDict["i"] = 0.0
            earthDict["ω"] = 282.9404 + 4.70935E-5 * t
            earthDict["a"] = au
            earthDict["e"] = 0.016709 - 1.151E-9 * t
            earthDict["M"] = arcCorrection(356.0470 + 0.9856002585 * t)
            earthDict["E"] = arcCorrection(E(earthDict["M"], earthDict["e"]))
            earthDict["ν"] = polarReferentialFix(ν(earthDict["e"], earthDict["E"]
            earthDict["Dist_Sun"] = sunDistance(earthDict["a"], earthDict["e"], e
            earthDict["X_COORD"] = cartesian_X(earthDict["Dist_Sun"], earthDict["
            earthDict["Y_COORD"] = cartesian_Y(earthDict["Dist_Sun"], earthDict["
            earthDict["Z_COORD"] = cartesian_Z(earthDict["Dist_Sun"], earthDict["
            earthDict["ℓ"] = ℓ(earthDict["X_COORD"], earthDict["Y_COORD"])
            earthDict["ℓ_corr"] = polarReferentialFix(ℓ(earthDict["X_COORD"], ear
            earthDict["b"] = b(earthDict["X_COORD"], earthDict["Y_COORD"], earthD
            return earthDict
        end

        function Mars(t)
            marsDict = Dict()
            marsDict["PLANET"] = "Mars"
            marsDict["Ω"] = 49.5574 + 2.11081E-5 * t
            marsDict["i"] = 1.8497 - 1.78E-8 * t
            marsDict["ω"] = 286.5016 + 2.92961E-5 * t
            marsDict["a"] = 1.523688 * au
            marsDict["e"] = 0.093405 + 2.516E-9 * t
            marsDict["M"] = arcCorrection(18.6021 + 0.5240207766 * t)
            marsDict["E"] = arcCorrection(E(marsDict["M"], marsDict["e"]))
            marsDict["ν"] = polarReferentialFix(ν(marsDict["e"], marsDict["E"]))
            marsDict["Dist_Sun"] = sunDistance(marsDict["a"], marsDict["e"], mars
            marsDict["X_COORD"] = cartesian_X(marsDict["Dist_Sun"], marsDict["Ω"]
            marsDict["Y_COORD"] = cartesian_Y(marsDict["Dist_Sun"], marsDict["Ω"]
            marsDict["Z_COORD"] = cartesian_Z(marsDict["Dist_Sun"], marsDict["ω"]
            marsDict["ℓ"] = ℓ(marsDict["X_COORD"], marsDict["Y_COORD"])
            marsDict["ℓ_corr"] = polarReferentialFix(ℓ(marsDict["X_COORD"], marsD
            marsDict["b"] = b(marsDict["X_COORD"], marsDict["Y_COORD"], marsDict[

            return marsDict
        end

        function Jupiter(t)
            jupyterDict = Dict()
            jupyterDict["PLANET"] = "Jupiter"
            jupyterDict["Ω"] = 100.4542 + 2.76854E-5 * t
            jupyterDict["i"] = 1.3030 - 1.557E-7 * t
            jupyterDict["ω"] = 273.8777 + 1.64505E-5 * t
            jupyterDict["a"] = 5.20256 * au
            jupyterDict["e"] = 0.048498 + 4.469E-9 * t
            jupyterDict["M"] = arcCorrection(19.8950 + 0.0830853001 * t)
            jupyterDict["E"] = arcCorrection(E(jupyterDict["M"], jupyterDict["e"]
            jupyterDict["ν"] = polarReferentialFix(ν(jupyterDict["e"], jupyterDic
            jupyterDict["Dist_Sun"] = sunDistance(jupyterDict["a"], jupyterDict["
            jupyterDict["X_COORD"] = cartesian_X(jupyterDict["Dist_Sun"], jupyter
            jupyterDict["Y_COORD"] = cartesian_Y(jupyterDict["Dist_Sun"], jupyter
            jupyterDict["Z_COORD"] = cartesian_Z(jupyterDict["Dist_Sun"], jupyter
            jupyterDict["ℓ"] = ℓ(jupyterDict["X_COORD"], jupyterDict["Y_COORD"])
            jupyterDict["ℓ_corr"] = polarReferentialFix(ℓ(jupyterDict["X_COORD"],
            jupyterDict["b"] = b(jupyterDict["X_COORD"], jupyterDict["Y_COORD"],


            return jupyterDict
        end

        function Saturn(t)
            saturnDict = Dict()
            saturnDict["PLANET"] = "Saturn"
            saturnDict["Ω"] = 113.6634 + 2.38980E-5 * t
            saturnDict["i"] = 2.4886 - 1.081E-7 * t
            saturnDict["ω"] = 339.3939 + 2.97661E-5 * t
            saturnDict["a"] = 9.55475 * au
            saturnDict["e"] = 0.055546 - 9.499E-9 * t
            saturnDict["M"] = arcCorrection(316.9670 + 0.0334442282 * t)
            saturnDict["E"] = arcCorrection(E(saturnDict["M"], saturnDict["e"]))
            saturnDict["ν"] = polarReferentialFix(ν(saturnDict["e"], saturnDict["
            saturnDict["Dist_Sun"] = sunDistance(saturnDict["a"], saturnDict["e"]
            saturnDict["X_COORD"] = cartesian_X(saturnDict["Dist_Sun"], saturnDic
            saturnDict["Y_COORD"] = cartesian_Y(saturnDict["Dist_Sun"], saturnDic
            saturnDict["Z_COORD"] = cartesian_Z(saturnDict["Dist_Sun"], saturnDic
            saturnDict["Z_COORD"] = cartesian_Z(saturnDict["Dist_Sun"], saturnDic
            saturnDict["ℓ"] = ℓ(saturnDict["X_COORD"], saturnDict["Y_COORD"])
            saturnDict["ℓ_corr"] = polarReferentialFix(ℓ(saturnDict["X_COORD"], s
            saturnDict["b"] = b(saturnDict["X_COORD"], saturnDict["Y_COORD"], sat


            return saturnDict
        end

        function Uranus(t)
            uranusDict = Dict()
            uranusDict["PLANET"] = "Uranus"
            uranusDict["Ω"] = 74.0005 + 1.3978E-5 * t
            uranusDict["i"] = 0.7733 + 1.9E-8 * t
            uranusDict["ω"] = 96.6612 + 3.0565E-5 * t
            uranusDict["a"] = (19.18171 - 1.55E-8 * t) * (au)
            uranusDict["e"] = 0.047318 + 7.45E-9 * t
            uranusDict["M"] = arcCorrection(142.5905 + 0.011725806 * t)
            uranusDict["E"] = arcCorrection(E(uranusDict["M"], uranusDict["e"]))
            uranusDict["ν"] = polarReferentialFix(ν(uranusDict["e"], uranusDict["
            uranusDict["Dist_Sun"] = sunDistance(uranusDict["a"], uranusDict["e"]
            uranusDict["X_COORD"] = cartesian_X(uranusDict["Dist_Sun"], uranusDic
            uranusDict["Y_COORD"] = cartesian_Y(uranusDict["Dist_Sun"], uranusDic
            uranusDict["Z_COORD"] = cartesian_Z(uranusDict["Dist_Sun"], uranusDic
            uranusDict["ℓ"] = ℓ(uranusDict["X_COORD"], uranusDict["Y_COORD"])
            uranusDict["ℓ_corr"] = polarReferentialFix(ℓ(uranusDict["X_COORD"], u
            uranusDict["b"] = b(uranusDict["X_COORD"], uranusDict["Y_COORD"], ura

            return uranusDict
        end

        function Neptune(t)
            neptuneDict = Dict()
            neptuneDict["PLANET"] = "Neptune"
            neptuneDict["Ω"] = 131.7806 + 3.0173E-5 * t
            neptuneDict["i"] = 1.7700 - 2.55E-7 * t
            neptuneDict["ω"] = 272.8461 - 6.027E-6 * t
            neptuneDict["a"] = (30.05826 + 3.313E-8 * t) * (au)
            neptuneDict["e"] = 0.008606 + 2.15E-9 * t
            neptuneDict["M"] = arcCorrection(260.2471 + 0.005995147 * t)
            neptuneDict["E"] = arcCorrection(E(neptuneDict["M"], neptuneDict["e"]
            neptuneDict["ν"] = polarReferentialFix(ν(neptuneDict["e"], neptuneDic
            neptuneDict["Dist_Sun"] = sunDistance(neptuneDict["a"], neptuneDict["
            neptuneDict["X_COORD"] = cartesian_X(neptuneDict["Dist_Sun"], neptune
            neptuneDict["Y_COORD"] = cartesian_Y(neptuneDict["Dist_Sun"], neptune
            neptuneDict["Z_COORD"] = cartesian_Z(neptuneDict["Dist_Sun"], neptune
            neptuneDict["ℓ"] = ℓ(neptuneDict["X_COORD"], neptuneDict["Y_COORD"])
            neptuneDict["ℓ_corr"] = polarReferentialFix(ℓ(neptuneDict["X_COORD"],
            neptuneDict["b"] = b(neptuneDict["X_COORD"], neptuneDict["Y_COORD"],

            return neptuneDict
        end
```

```
Out[ ]: Neptune (generic function with 1 method)
```

```
In [ ]: gt = tt(1, 7, 2053, 0, 35)
```

```
Out[ ]: 19540.024305555555
```

In [ ]:
```
iteratorBodies = [Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune]

dfBodies = DataFrame(Mercury(gt))

for iterableBody ∈ iteratorBodies
    push!(dfBodies, iterableBody(gt))
end

dfBodiesCopy = copy(dfBodies)
show(dfBodies, allcols=true)
```

```
8×16 DataFrame
 Row │ Dist_Sun     E          M          PLANET    X_COORD      Y_COORD
Z_COORD      a           b          e          i          Ω          ν
ω         ℓ          ℓ_corr
     │ Float64     Float64    Float64    String    Float64      Float64
Float64      Float64     Float64    Float64    Float64    Float64    Float
64   Float64   Float64    Float64
─────┼─────────────────────────────────────────────────────────────────────────
─────────────────────────────────────────────────────────────────────────
────────────────────────────────────

   1 │ 6.84698e10  207.525    212.971    Mercury    1.24997e10   -6.69984e10
-6.56379e9   5.7909e10   -5.50105   0.205646   7.00568    48.9655  202.4
89    29.3223   -79.432   280.568
   2 │ 1.07602e11    33.8843    33.6687  Venus     -1.04412e11    2.5217e10
6.37187e9   1.08209e11   3.39486   0.00674756  3.39514    77.1617   34.10
04   55.1614   166.422   166.422
   3 │ 1.52084e11  174.787    174.7      Earth     -2.30926e10    1.5032e11
0.0          1.49598e11   0.0        0.0166865   0.0         0.0      174.87
3   283.861      98.7336   98.7336
   4 │ 2.49231e11  178.153    177.981    Mars      -2.26446e11    1.03818e11
7.75461e9    2.2794e11    1.78299    0.0934542   1.84935    49.9699  178.31
9   287.074     155.37     155.37
   5 │ 8.13271e11  202.326    203.384    Jupiter   -6.53688e11   -4.83554e11
1.66543e10  7.78292e11    1.1734     0.0485853   1.29996    100.995   201.29
1   274.199    -143.508   216.492
   6 │ 1.45961e12  247.537    250.468    Saturn     1.3594e12    -5.29636e11
-4.44706e10  1.42937e12  -1.74593    0.0553604   2.48649    114.13    244.6
35   339.976    -21.2865  338.714
   7 │ 2.73642e12   12.292     11.713    Uranus    -2.72807e12   -2.10813e11
3.4689e10    2.8695e12    0.726346  0.0474636  0.773671   74.2736    12.88
5    97.2584   -175.581   184.419
   8 │ 4.45967e12   17.5418    17.3924  Neptune    2.03772e12    3.96482e12
-1.28728e11  4.49675e12  -1.65407    0.00864801  1.76502    132.37     17.6
917  272.728     62.7991    62.7991
```

# Plotting

In [ ]:
```
graphData = DataFrame()
graphData[!, "RADIUS"] = [i for i in 1:8]
graphData[!, "PLANET"] = dfBodies.PLANET
graphData[!, "COORD"] = dfBodies.ℓ

show(graphData)
```

```
8×3 DataFrame
 Row │ RADIUS  PLANET   COORD
     │ Int64   String   Float64
─────┼──────────────────────────────────
   1 │      1  Mercury   -79.432
   2 │      2  Venus     166.422
   3 │      3  Earth      98.7336
   4 │      4  Mars      155.37
   5 │      5  Jupiter  -143.508
   6 │      6  Saturn    -21.2865
   7 │      7  Uranus   -175.581
   8 │      8  Neptune    62.7991
```

In [ ]:

```
plot(scatterpolar(graphData, r=:RADIUS, theta=:COORD, color=:PLANET, mode
```

Out[ ]:

**WebIO not detected.**

**Please read the troubleshooting guide for more information on how to resolve this issue.**

**https://juliagizmos.github.io/WebIO.jl/latest/troubleshooting/not-detected/**

# Data from NASA's SPICE Software

http://spice.esac.esa.int/webgeocalc/#OrbitalElements For Orbital Elements.

Kernel: (all GENERIC)
Orbiting Object: [Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune]
Center of Motion: Sun
Reference Frame:ECLIPJ2000
Time System: UTC
Time Format: Calendar date and time
Input Times: Single Time
Time: 2053-07-01T00:00:00.00 // Easier Calc
(True Anomaly and Sun Distance from NASA Horizons)

http://spice.esac.esa.int/webgeocalc/#StateVector For Position

Kernel: (all GENERIC)
Target: [Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune]
OBSERVER: Sun
Frame Name:ECLIPJ2000
Time System: UTC
Time Format: Calendar date and time
Input Times: Single Time
Time: 2053-07-01T00:35:00.00

In [ ]:

```julia
# Subsetting my DataFrame

subsetBodies = dfBodies[:, [:M, :PLANET, :a, :e, :Ω, :ν, :ω]]
subsetPositions = dfBodies[:, [:PLANET, :X_COORD, :Y_COORD, :Z_COORD, :ℓ,
rename!(subsetPositions, :X_COORD => :X)
rename!(subsetPositions, :Y_COORD => :Y)
rename!(subsetPositions, :Z_COORD => :Z)
show(subsetBodies, allcols=true)
println("\n\n")
show(subsetPositions, allcols=true)
```

```
8×7 DataFrame
 Row │ M         PLANET   a           e           Ω         ν         ω
     │ Float64   String   Float64     Float64     Float64   Float64   Flo
at64
─────┼────────────────────────────────────────────────────────────────────
──────
   1 │ 212.971   Mercury  5.7909e10   0.205646     48.9655  202.489    2
9.3223
   2 │  33.6687  Venus    1.08209e11  0.00674756   77.1617   34.1004   5
5.1614
   3 │ 174.7     Earth    1.49598e11  0.0166865     0.0     174.873   28
3.861
   4 │ 177.981   Mars     2.2794e11   0.0934542    49.9699  178.319   28
7.074
   5 │ 203.384   Jupiter  7.78292e11  0.0485853   100.995   201.291   27
4.199
   6 │ 250.468   Saturn   1.42937e12  0.0553604   114.13    244.635   33
9.976
   7 │  11.713   Uranus   2.8695e12   0.0474636    74.2736   12.885    9
7.2584
   8 │  17.3924  Neptune  4.49675e12  0.00864801  132.37     17.6917  27
2.728


8×7 DataFrame
 Row │ PLANET   X            Y            Z            ℓ          ℓ_corr
b
     │ String   Float64      Float64      Float64      Float64    Float64
Float64
─────┼────────────────────────────────────────────────────────────────────
─────────────
   1 │ Mercury   1.24997e10  -6.69984e10  -6.56379e9    -79.432    280.568
-5.50105
   2 │ Venus    -1.04412e11   2.5217e10     6.37187e9    166.422    166.422
3.39486
   3 │ Earth    -2.30926e10   1.5032e11     0.0           98.7336    98.733
6   0.0
   4 │ Mars     -2.26446e11   1.03818e11    7.75461e9    155.37     155.37
1.78299
   5 │ Jupiter  -6.53688e11  -4.83554e11   1.66543e10  -143.508    216.492
1.1734
   6 │ Saturn    1.3594e12   -5.29636e11  -4.44706e10   -21.2865   338.714
-1.74593
   7 │ Uranus   -2.72807e12  -2.10813e11   3.4689e10   -175.581    184.419
0.726346
   8 │ Neptune   2.03772e12   3.96482e12  -1.28728e11    62.7991    62.799
1  -1.65407
```

```
In [ ]: MercurySPICE = Dict(
            "PLANET" => "Mercury",
            "Ω" => 48.26394929,
            "ω" => 29.27515022,
            "a" => 68126020.15398264E3, #Convert from KM
            "e" => 0.20565023,
            "M" => 216.96933818,
            "i" => 7.00184025,
            "X" => 14911091.80597833E3,
            "Y" => -66118957.10648166E3,
            "Z" => -6772425.47931979E3,
            "ℓ" => -77.29130718,
            "ℓ_corr" => polarReferentialFix(-77.29130718),
            "b" => -5.70597146,
            "ν" => 205.2995670038993,
            "R" => 6.778207702727926E10
        )

        VenusSPICE = Dict(
            "PLANET" => "Venus",
            "Ω" => 76.53136424,
            "ω" => 55.23916999,
            "a" => 107611084.49418102E3,
            "e" =>      0.00676238,
            "M" => 35.04145354,
            "i" => 3.39427835,
            "X" => -104794789.27783182E3,
            "Y" => 23615111.32284366E3,
            "Z" => 6370740.54597109E3,
            "ℓ" => 167.30073594,
            "ℓ_corr" => 167.30073594,
            "b" => 3.39397305,
            "ν" => 35.50022680504404,
            "R" => 1.074549503179932E11
        )

        EarthSPICE = Dict(
            "PLANET" => "Earth",
            "Ω" => 180.37840376,
            "ω" => 282.44577374,
            "a" => 152082619.11011820E3,
            "e" => 0.01751289,
            "M" => 175.94943770,
            "i" => 0.00672579,
            "X" => 23561118.31566819E3,
            "Y" => -150246452.29559687E3,
            "Z" => 17654.89506852E3, # For me there's no reason for earth to be z
            "ℓ" => -81.06449477,
            "ℓ_corr" => polarReferentialFix(-81.06449477),
            "b" => 0.00665092,
            "ν" => 176.0882921447710,
            "R" => 1.517150540821351E11
        )

        MarsSPICE = Dict(
            "PLANET" => "Mars",
            "Ω" => 49.39843323,
            "ω" => 286.91935417,
            "a" => 249239379.40676948E3,
            "e" => 0.09351113,
            "M" => 178.47274288,
            "i" => 1.84548902,
            "X" => -225897389.22283340E3
```

```
    "X" => -223897389.22283340E3,
    "Y" => 105028364.72766489E3,
    "Z" => 7728701.20609896E3,
    "ℓ" => 155.06447561,
    "ℓ_corr" => 155.06447561,
    "b" => 1.77697751,
    "ν" => 178.7280093491614,
    "R" => 2.491828348843164E11
)

JupiterSPICE = Dict(
    "PLANET" => "Jupiter",
    "Ω" => 100.58171490,
    "ω" => 274.90404577,
    "a" => 813294159.49340240E3,
    "e" => 0.04738841,
    "M" => 202.30773215,
    "i" => 1.30343505,
    "X" => -659099013.85965610E3,
    "Y" => -476188208.77358800E3,
    "Z" => 16731227.13450408E3,
    "ℓ" => -144.15250724,
    "ℓ_corr" => polarReferentialFix(-144.15250724),
    "b" => 1.17878243,
    "ν" => 199.9601671373209,
    "R" => 8.128464215333256E11

)

SaturnSPICE = Dict(
    "PLANET" => "Saturn",
    "Ω" => 113.47181865,
    "ω" => 338.79130237,
    "a" => 1453474979.37304350E3,
    "e" => 0.05327919,
    "M" => 251.78553602,
    "i" => 2.48725019,
    "X" => 1350310213.83293800E3,
    "Y" => -535972188.34747136E3,
    "Z" => -44528446.49176982E3,
    "ℓ" => -21.64937666,
    "ℓ_corr" => polarReferentialFix(-21.64937666),
    "b" => -1.75558099,
    "ν" => 245.8333400468297,
    "R" => 1.453559593042406E12
)

UranusSPICE = Dict(
    "PLANET" => "Uranus",
    "Ω" => 73.95336561,
    "ω" => 98.96809742,
    "a" => 2738027824.74679600E3,
    "e" => 0.05082914,
    "M" => 9.66654791,
    "i" => 0.77187598,
    "X" => -2732305452.18072700E3,
    "Y" => -173487143.73558030E3,
    "Z" => 34730880.73453543E3,
    "ℓ" => -176.36689403,
    "ℓ_corr" => polarReferentialFix(-176.36689403),
    "b" => 0.72679545,
    "ν" => 10.71881736629351,
    "R" => 2.737747592415333E12
)
```

```
,

NeptuneSPICE = Dict(
    "PLANET" => "Neptune",
    "Ω" => 132.05175038,
    "ω" => 269.26791696,
    "a" => 4460940793.96299800E3,
    "e" => 0.00585937,
    "M" => 20.48466102,
    "i" => 1.76743947,
    "X" => 2089979961.21707370E3,
    "Y" => 3938941296.74271060E3,
    "Z" => -129298881.91905070E3,
    "ℓ" =>  62.04983143,
    "ℓ_corr" => 62.04983143,
    "b" => -1.66093168,
    "ν" => 20.08143075194107,
    "R" => 4.461423855999846E12
)

dfSPICE = DataFrame(MercurySPICE)
push!(dfSPICE, VenusSPICE)
push!(dfSPICE, EarthSPICE)
push!(dfSPICE, MarsSPICE)
push!(dfSPICE, JupiterSPICE)
push!(dfSPICE, SaturnSPICE)
push!(dfSPICE, UranusSPICE)
push!(dfSPICE, NeptuneSPICE)

dfSPICEcopy = DataFrame(dfSPICE)

subsetBodies = dfBodies[!, [:PLANET, :Ω, :a, :e, :i, :M]]
dfSPICEpos = dfSPICE[!, [:PLANET, :X, :Y, :Z, :ℓ, :ℓ_corr, :b]]
dfSPICE = dfSPICE[!, [:PLANET, :Ω, :a, :e, :i, :M]]
printstyled("\n\nSPICE Data\n", color=:red)
show(dfSPICE, allcols=true)
```

```
SPICE Data
8×6 DataFrame
 Row │ PLANET   Ω         a           e           i           M
     │ String   Float64   Float64     Float64     Float64     Float64
─────┼──────────────────────────────────────────────────────────────────────
   1 │ Mercury   48.2639  6.8126e10   0.20565     7.00184     216.969
   2 │ Venus     76.5314  1.07611e11  0.00676238  3.39428      35.0415
   3 │ Earth    180.378   1.52083e11  0.0175129   0.00672579  175.949
   4 │ Mars      49.3984  2.49239e11  0.0935111   1.84549     178.473
   5 │ Jupiter  100.582   8.13294e11  0.0473884   1.30344     202.308
   6 │ Saturn   113.472   1.45347e12  0.0532792   2.48725     251.786
   7 │ Uranus    73.9534  2.73803e12  0.0508291   0.771876      9.66655
   8 │ Neptune  132.052   4.46094e12  0.00585937  1.76744      20.4847
```

In [ ]:

```
printstyled("\n\nMy Calculated Data\n", color=:green)
show(subsetBodies, allcols=true, allrows=true)
```

```
My Calculated Data
8×6 DataFrame
 Row │ PLANET   Ω         a           e           i         M
     │ String   Float64   Float64     Float64     Float64   Float64
─────┼──────────────────────────────────────────────────────────────────────
   1 │ Mercury   48.9655  5.7909e10   0.205646    7.00568   212.971
   2 │ Venus     77.1617  1.08209e11  0.00674756  3.39514    33.6687
   3 │ Earth      0.0     1.49598e11  0.0166865   0.0       174.7
   4 │ Mars      49.9699  2.2794e11   0.0934542   1.84935   177.981
   5 │ Jupiter  100.995   7.78292e11  0.0485853   1.29996   203.384
   6 │ Saturn   114.13    1.42937e12  0.0553604   2.48649   250.468
   7 │ Uranus    74.2736  2.8695e12   0.0474636   0.773671   11.713
   8 │ Neptune  132.37    4.49675e12  0.00864801  1.76502    17.3924
```

## Comparsion Between Calculated Orbital Elements and SPICE Generated Orbital Elements

In [ ]:

```
dfDifferenceGENtoSPICE = subsetBodies[!, Not(:PLANET)] .- dfSPICE[!, Not(
dfRateGENtoSPICE = subsetBodies[!, Not(:PLANET)] ./ dfSPICE[!, Not(:PLANE
dfStatisticsRate = describe(dfRateGENtoSPICE)
dfRateGENtoSPICE[!, "PLANET"] = ["Mercury", "Venus", "Earth", "Mars", "Ju
show(dfRateGENtoSPICE, allcols=true, allrows=true)
println("\n")
show(dfStatisticsRate, allcols=true, allrows=true)

function percentualDifference(n1::Float64, n2::Float64)
    return (n1 - n2)/(n1 + n2)
end
```

```
8×6 DataFrame
 Row │ Ω        a         e         i         M         PLANET
     │ Float64  Float64   Float64   Float64   Float64   String
─────┼─────────────────────────────────────────────────────────────────
   1 │ 1.01454  0.850028  0.999979  1.00055   0.98157   Mercury
   2 │ 1.00824  1.00555   0.997808  1.00025   0.960826  Venus
   3 │ 0.0      0.983662  0.952813  0.0       0.992899  Earth
   4 │ 1.01157  0.914544  0.999391  1.00209   0.997244  Mars
   5 │ 1.00411  0.956962  1.02526   0.997332  1.00532   Jupiter
   6 │ 1.0058   0.983416  1.03906   0.999693  0.994767  Saturn
   7 │ 1.00433  1.04802   0.933787  1.00233   1.21171   Uranus
   8 │ 1.00241  1.00803   1.47593   0.99863   0.849046  Neptune

5×7 DataFrame
 Row │ variable  mean      min       median    max      nmissing  eltype
     │ Symbol    Float64   Float64   Float64   Float64  Int64     DataTyp
e
─────┼──────────────────────────────────────────────────────────────────────────
──
   1 │ Ω         0.881375  0.0       1.00507   1.01454         0  Float64
   2 │ a         0.968776  0.850028  0.983539  1.04802         0  Float64
   3 │ e         1.053     0.933787  0.999685  1.47593         0  Float64
   4 │ i         0.875109  0.0       0.999973  1.00233         0  Float64
   5 │ M         0.999172  0.849046  0.993833  1.21171         0  Float64
```

Out[ ]:

```
percentualDifference (generic function with 1 method)
```

In [ ]:

```
percentualDiffDF = percentualDifference.(subsetBodies[!, Not(:PLANET)], d
percentualDiffDF .*= 100
```

Out[ ]: 8 rows × 5 columns

| | Ω | a | e | i | M |
|---|---|---|---|---|---|
| | Float64 | Float64 | Float64 | Float64 | Float64 |
| **1** | 0.721586 | -8.10646 | -0.00104721 | 0.0273907 | -0.930078 |
| **2** | 0.410151 | 0.276872 | -0.109705 | 0.0126521 | -1.99785 |
| **3** | -100.0 | -0.823636 | -2.41636 | -100.0 | -0.356319 |
| **4** | 0.575052 | -4.46349 | -0.0304695 | 0.104556 | -0.138007 |
| **5** | 0.205112 | -2.19921 | 1.24713 | -0.133573 | 0.265239 |
| **6** | 0.289342 | -0.836144 | 1.91569 | -0.0153299 | -0.262319 |
| **7** | 0.216064 | 2.34453 | -3.42402 | 0.116158 | 9.57215 |
| **8** | 0.120425 | 0.399743 | 19.2222 | -0.0685692 | -8.16389 |

Generally, the SPICE values are higher than mine (withot high expression unless in case of Earth's elements)

In [ ]:

```
describe(percentualDiffDF)
```

Out[ ]: 5 rows × 7 columns

| | variable | mean | min | median | max | nmissing | eltype |
|---|---|---|---|---|---|---|---|
| | Symbol | Float64 | Float64 | Float64 | Float64 | Int64 | DataType |
| **1** | Ω | -12.1828 | -100.0 | 0.252703 | 0.721586 | 0 | Float64 |
| **2** | a | -1.67598 | -8.10646 | -0.82989 | 2.34453 | 0 | Float64 |
| **3** | e | 2.05043 | -3.42402 | -0.0157583 | 19.2222 | 0 | Float64 |
| **4** | i | -12.4946 | -100.0 | -0.0013389 | 0.116158 | 0 | Float64 |
| **5** | M | -0.251384 | -8.16389 | -0.309319 | 9.57215 | 0 | Float64 |

In [ ]:

```
printstyled("My Data (Positions)\n", color=:blue)
show(subsetPositions, allcols=true)
println("\n\n")
printstyled("SPICE Data (Positions)\n", color=:magenta)
show(dfSPICEpos, allcols=true)
```

```
My Data (Positions)
8×7 DataFrame
 Row │ PLANET   X            Y            Z            ℓ          ℓ_corr
b
     │ String   Float64      Float64      Float64      Float64    Float64
Float64
─────┼──────────────────────────────────────────────────────────────────
─────────────
   1 │ Mercury   1.24997e10  -6.69984e10  -6.56379e9    -79.432    280.568
-5.50105
   2 │ Venus    -1.04412e11   2.5217e10    6.37187e9    166.422    166.422
3.39486
   3 │ Earth    -2.30926e10   1.5032e11    0.0           98.7336   98.733
6   0.0
   4 │ Mars     -2.26446e11   1.03818e11   7.75461e9    155.37    155.37
1.78299
   5 │ Jupiter  -6.53688e11  -4.83554e11   1.66543e10  -143.508   216.492
1.1734
   6 │ Saturn    1.3594e12   -5.29636e11  -4.44706e10   -21.2865  338.714
-1.74593
   7 │ Uranus   -2.72807e12  -2.10813e11   3.4689e10   -175.581   184.419
0.726346
   8 │ Neptune   2.03772e12   3.96482e12  -1.28728e11    62.7991   62.799
1  -1.65407


SPICE Data (Positions)
8×7 DataFrame
 Row │ PLANET   X            Y            Z            ℓ          ℓ_corr
b
     │ String   Float64      Float64      Float64      Float64    Float64
Float64
─────┼──────────────────────────────────────────────────────────────────
───────────────
   1 │ Mercury   1.49111e10  -6.6119e10   -6.77243e9    -77.2913  282.709
-5.70597
   2 │ Venus    -1.04795e11   2.36151e10   6.37074e9    167.301    167.301
3.39397
   3 │ Earth     2.35611e10  -1.50246e11   1.76549e7    -81.0645  278.936
0.00665092
   4 │ Mars     -2.25897e11   1.05028e11   7.7287e9     155.064    155.064
1.77698
   5 │ Jupiter  -6.59099e11  -4.76188e11   1.67312e10  -144.153   215.847
1.17878
   6 │ Saturn    1.35031e12  -5.35972e11  -4.45284e10   -21.6494  338.351
-1.75558
   7 │ Uranus   -2.73231e12  -1.73487e11   3.47309e10  -176.367   183.633
0.726795
   8 │ Neptune   2.08998e12   3.93894e12  -1.29299e11    62.0498   62.049
8  -1.66093
```

In [ ]:

```
positionsDif = subsetPositions[!,Not(:PLANET)] .- dfSPICEpos[!,Not(:PLANE
positionsDif[!, "PLANET"] = dfSPICEpos[!, "PLANET"]

positionsDif = positionsDif[:, [:PLANET, :X, :Y, :Z, :ℓ, :b]]
```

Out[ ]: 8 rows × 6 columns

| | PLANET | X | Y | Z | ℓ | b |
|---|---|---|---|---|---|---|
| | String | Float64 | Float64 | Float64 | Float64 | Float64 |
| 1 | Mercury | -2.41136e9 | -8.79454e8 | 2.08633e8 | -2.14065 | 0.204918 |
| 2 | Venus | 3.83106e8 | 1.60185e9 | 1.12778e6 | -0.8785 | 0.000882178 |
| 3 | Earth | -4.66537e10 | 3.00567e11 | -1.76549e7 | 179.798 | -0.00665092 |
| 4 | Mars | -5.48924e8 | -1.21013e9 | 2.59061e7 | 0.305615 | 0.00601605 |
| 5 | Jupiter | 5.41129e9 | -7.36568e9 | -7.69184e7 | 0.644035 | -0.0053869 |
| 6 | Saturn | 9.08513e9 | 6.33634e9 | 5.788e7 | 0.362924 | 0.00964992 |
| 7 | Uranus | 4.23527e9 | -3.73263e10 | -4.18327e7 | 0.785682 | -0.000449759 |
| 8 | Neptune | -5.22637e10 | 2.58776e10 | 5.70601e8 | 0.749298 | 0.00686008 |

In [ ]:
```
positionsRatio = subsetPositions[!,Not(:PLANET)] ./ dfSPICEpos[!,Not(:PLA
```

Out[ ]: 8 rows × 6 columns

| | X | Y | Z | ℓ | ℓ_corr | b |
|---|---|---|---|---|---|---|
| | Float64 | Float64 | Float64 | Float64 | Float64 | Float64 |
| 1 | 0.838284 | 1.0133 | 0.969194 | 1.0277 | 0.992428 | 0.964087 |
| 2 | 0.996344 | 1.06783 | 1.00018 | 0.994749 | 0.994749 | 1.00026 |
| 3 | -0.980114 | -1.00049 | 0.0 | -1.21796 | 0.353966 | 0.0 |
| 4 | 1.00243 | 0.988478 | 1.00335 | 1.00197 | 1.00197 | 1.00339 |
| 5 | 0.99179 | 1.01547 | 0.995403 | 0.995532 | 1.00298 | 0.99543 |
| 6 | 1.00673 | 0.988178 | 0.9987 | 0.983236 | 1.00107 | 0.994503 |
| 7 | 0.99845 | 1.21515 | 0.998796 | 0.995545 | 1.00428 | 0.999381 |
| 8 | 0.974993 | 1.00657 | 0.995587 | 1.01208 | 1.01208 | 0.99587 |

In [ ]:

```
positionsPercentDiff = percentualDifference.(subsetPositions[!,Not(:PLANE
positionsPercentDiff .*= 100
```

Out[ ]: 8 rows × 6 columns

| | X | Y | Z | ℓ | ℓ_corr | b |
|---|---|---|---|---|---|---|
| | Float64 | Float64 | Float64 | Float64 | Float64 | Float64 |
| **1** | -8.7971 | 0.66066 | -1.56441 | 1.36588 | -0.380036 | -1.82848 |
| **2** | -0.183123 | 3.28031 | 0.00885047 | -0.263242 | -0.263242 | 0.0129946 |
| **3** | -9957.51 | 4.06544e5 | -100.0 | 1017.58 | -47.7142 | -100.0 |
| **4** | 0.121351 | -0.579434 | 0.167316 | 0.0984476 | 0.0984476 | 0.168992 |
| **5** | -0.412199 | 0.767465 | -0.230394 | -0.223887 | 0.148965 | -0.229017 |
| **6** | 0.335281 | -0.594622 | -0.0650344 | -0.845271 | 0.0536026 | -0.275593 |
| **7** | -0.0775638 | 9.71279 | -0.0602604 | -0.223238 | 0.21347 | -0.0309508 |
| **8** | -1.26617 | 0.327409 | -0.22114 | 0.600164 | 0.600164 | -0.20694 |

# PLotting SPICE Data

In [ ]:

```
dfSPICEposRadius = Dict("ℓ" => dfSPICEpos[!,"ℓ"],
"RADIUS" => [i for i in 1:8])
plot(scatterpolar(dfSPICEpos, r=:RADIUS, theta=:ℓ, mode="markers"))
```

Out[ ]:

**WebIO not detected.**

**Please read the troubleshooting guide for more information on how to resolve this issue.**

**https://juliagizmos.github.io/WebIO.jl/latest/troubleshooting/not-detected/**

In [ ]:

```
myPositionsIDX = copy(subsetPositions)
myPositionsIDX[!, "PLANET"] .*= "_CALC" #String concatenation in jl is *
dfSPICEposIDX = copy(dfSPICEpos)
dfSPICEposIDX[!, "PLANET"] .*= "_SPICE"
;
```

In [ ]:

```
FullPosDF = DataFrame()
append!(FullPosDF, dfSPICEposIDX)
append!(FullPosDF, myPositionsIDX)
sort!(FullPosDF, [order(:PLANET)])
;
```

In [ ]:

```
show(dfBodiesCopy, allcols=true)
dfBodiesCopy = dfBodiesCopy[!, [:PLANET, :Ω, :i, :ω, :e, :a, :M, :E, :ν,
rename!(dfBodiesCopy, :Dist_Sun => :R)
rename!(dfBodiesCopy, :X_COORD => :X)
rename!(dfBodiesCopy, :Y_COORD => :Y)
rename!(dfBodiesCopy, :Z_COORD => :Z)
;
```

```
8×16 DataFrame
 Row │ Dist_Sun    E         M         PLANET   X_COORD      Y_COORD
Z_COORD      a           b          e           i         Ω         ν
ω         ℓ          ℓ_corr
     │ Float64     Float64   Float64   String   Float64      Float64
Float64      Float64     Float64    Float64     Float64   Float64   Float
64   Float64   Float64    Float64
─────┼───────────────────────────────────────────────────────────────────
──────────────────────────────────────────────────────────────────────────
────────────────────────────────────
   1 │ 6.84698e10  207.525   212.971   Mercury   1.24997e10  -6.69984e10
-6.56379e9   5.7909e10   -5.50105   0.205646    7.00568    48.9655  202.4
89    29.3223   -79.432   280.568
   2 │ 1.07602e11   33.8843   33.6687   Venus    -1.04412e11   2.5217e10
6.37187e9   1.08209e11   3.39486   0.00674756  3.39514    77.1617   34.10
04   55.1614   166.422   166.422
   3 │ 1.52084e11  174.787   174.7     Earth    -2.30926e10   1.5032e11
0.0         1.49598e11   0.0       0.0166865   0.0         0.0     174.87
3   283.861     98.7336   98.7336
   4 │ 2.49231e11  178.153   177.981   Mars     -2.26446e11   1.03818e11
7.75461e9   2.2794e11    1.78299   0.0934542   1.84935    49.9699  178.31
9   287.074    155.37    155.37
   5 │ 8.13271e11  202.326   203.384   Jupiter  -6.53688e11  -4.83554e11
1.66543e10  7.78292e11   1.1734    0.0485853   1.29996   100.995   201.29
1   274.199   -143.508   216.492
   6 │ 1.45961e12  247.537   250.468   Saturn    1.3594e12   -5.29636e11
-4.44706e10  1.42937e12  -1.74593   0.0553604   2.48649   114.13    244.6
35   339.976    -21.2865  338.714
   7 │ 2.73642e12   12.292    11.713   Uranus   -2.72807e12  -2.10813e11
3.4689e10   2.8695e12    0.726346  0.0474636   0.773671   74.2736   12.88
5    97.2584  -175.581   184.419
   8 │ 4.45967e12   17.5418   17.3924  Neptune   2.03772e12   3.96482e12
-1.28728e11  4.49675e12  -1.65407   0.00864801  1.76502   132.37     17.6
917  272.728      62.7991   62.7991
```

In [ ]:

```julia
dfBodiesWOEcc = DataFrame(dfBodiesCopy[!, Not(:E)])
dfSPICEcopySorted = dfSPICEcopy[:, [:PLANET, :Ω, :i, :ω, :e, :a, :M, :ν,
println("\n\n")
#show(dfSPICEcopySorted, allcols=true)
#show(dfBodiesWOEcc, allcols=true)

# Just making things clear. No time to refactor, sry.
completeCalculated = copy(dfBodiesWOEcc)
completeSPICE = copy(dfSPICEcopySorted)
;
```

In [ ]:

```julia
completeSPICE[!, "PLANET"] .*= "_SPICE" # Concatenation in Julia is made
completeCalculated[!, "PLANET"] .*= "_CALC"
;
```

In [ ]:

```
mergedData = DataFrame()

append!(mergedData, completeSPICE)
append!(mergedData, completeCalculated)

sort!(mergedData, [order(:PLANET)])

show(mergedData, allcols=true)

mergedDataWork = copy(mergedData)
;
```

```
16×15 DataFrame
 Row │ PLANET         Ω         i          ω         e          a
M          ν         R           X            Y            Z            ℓ
ℓ_corr    b
     │ String         Float64   Float64     Float64   Float64     Float64
Float64    Float64   Float64     Float64      Float64      Float64      F
loat64    Float64   Float64
─────┼─────────────────────────────────────────────────────────────────────────
─────────────────────────────────────────────────────────────────────────────
─────────────────────────────────────
   1 │ Earth_CALC       0.0     0.0         283.861   0.0166865   1.49598
e11  174.7      174.873   1.52084e11  -2.30926e10   1.5032e11    0.0
98.7336   98.7336   0.0
   2 │ Earth_SPICE    180.378   0.00672579  282.446   0.0175129   1.52083
e11  175.949    176.088   1.51715e11   2.35611e10  -1.50246e11   1.76549e
7    -81.0645  278.936    0.00665092
   3 │ Jupiter_CALC   100.995   1.29996     274.199   0.0485853   7.78292
e11  203.384    201.291   8.13271e11  -6.53688e11  -4.83554e11   1.66543e
10  -143.508   216.492    1.1734
   4 │ Jupiter_SPICE  100.582   1.30344     274.904   0.0473884   8.13294
e11  202.308    199.96    8.12846e11  -6.59099e11  -4.76188e11   1.67312e
10  -144.153   215.847    1.17878
   5 │ Mars_CALC       49.9699  1.84935     287.074   0.0934542   2.2794e
11   177.981    178.319   2.49231e11  -2.26446e11   1.03818e11   7.75461e
9    155.37    155.37     1.78299
   6 │ Mars_SPICE      49.3984  1.84549     286.919   0.0935111   2.49239
e11  178.473    178.728   2.49183e11  -2.25897e11   1.05028e11   7.7287e9
155.064   155.064    1.77698
   7 │ Mercury_CALC    48.9655  7.00568      29.3223  0.205646    5.7909e
10   212.971    202.489   6.84698e10   1.24997e10  -6.69984e10  -6.56379e
9    -79.432   280.568   -5.50105
   8 │ Mercury_SPICE   48.2639  7.00184      29.2752  0.20565     6.8126e
10   216.969    205.3     6.77821e10   1.49111e10  -6.6119e10   -6.77243e
9    -77.2913  282.709   -5.70597
   9 │ Neptune_CALC   132.37    1.76502     272.728   0.00864801  4.49675
e12   17.3924    17.6917  4.45967e12   2.03772e12   3.96482e12  -1.28728e
11    62.7991   62.7991  -1.65407
  10 │ Neptune_SPICE  132.052   1.76744     269.268   0.00585937  4.46094
e12   20.4847    20.0814  4.46142e12   2.08998e12   3.93894e12  -1.29299e
11    62.0498   62.0498  -1.66093
  11 │ Saturn_CALC    114.13    2.48649     339.976   0.0553604   1.42937
e12  250.468    244.635   1.45961e12   1.3594e12   -5.29636e11  -4.44706e
10   -21.2865  338.714   -1.74593
  12 │ Saturn_SPICE   113.472   2.48725     338.791   0.0532792   1.45347
e12  251.786    245.833   1.45356e12   1.35031e12  -5.35972e11  -4.45284e
10   -21.6494  338.351   -1.75558
  13 │ Uranus_CALC     74.2736  0.773671     97.2584  0.0474636   2.8695e
12    11.713     12.885   2.73642e12  -2.72807e12  -2.10813e11   3.4689e1
0   -175.581   184.419    0.726346
  14 │ Uranus_SPICE    73.9534  0.771876     98.9681  0.0508291   2.73803
e12    9.66655   10.7188  2.73775e12  -2.73231e12  -1.73487e11   3.47309e
10  -176.367   183.633    0.726795
  15 │ Venus_CALC      77.1617  3.39514      55.1614  0.00674756  1.08209
e11   33.6687    34.1004  1.07602e11  -1.04412e11   2.5217e10    6.37187e
9    166.422   166.422    3.39486
  16 │ Venus_SPICE     76.5314  3.39428      55.2392  0.00676238  1.07611
e11   35.0415    35.5002  1.07455e11  -1.04795e11   2.36151e10   6.37074e
9    167.301   167.301    3.39397
```

In [ ]:

```
show(mergedDataWork, allcols=true)
```

```
16×15 DataFrame
 Row │ PLANET         Ω         i           ω         e           a
M          ν         R           X            Y            Z            ℓ
ℓ_corr    b
     │ String         Float64   Float64     Float64   Float64     Float64
Float64    Float64   Float64     Float64      Float64      Float64      F
loat64    Float64   Float64
─────┼───────────────────────────────────────────────────────────────────
─────────────────────────────────────────────────────────────────────────
─────────────────────────────────────

   1 │ Earth_CALC       0.0     0.0         283.861   0.0166865   1.49598
e11  174.7      174.873   1.52084e11  -2.30926e10   1.5032e11    0.0
98.7336   98.7336   0.0
   2 │ Earth_SPICE    180.378   0.00672579  282.446   0.0175129   1.52083
e11  175.949    176.088   1.51715e11   2.35611e10  -1.50246e11   1.76549e
7    -81.0645  278.936    0.00665092
   3 │ Jupiter_CALC   100.995   1.29996     274.199   0.0485853   7.78292
e11  203.384    201.291   8.13271e11  -6.53688e11  -4.83554e11   1.66543e
10  -143.508   216.492    1.1734
   4 │ Jupiter_SPICE  100.582   1.30344     274.904   0.0473884   8.13294
e11  202.308    199.96    8.12846e11  -6.59099e11  -4.76188e11   1.67312e
10  -144.153   215.847    1.17878
   5 │ Mars_CALC       49.9699  1.84935     287.074   0.0934542   2.2794e
11   177.981    178.319   2.49231e11  -2.26446e11   1.03818e11   7.75461e
9    155.37    155.37     1.78299
   6 │ Mars_SPICE      49.3984  1.84549     286.919   0.0935111   2.49239
e11  178.473    178.728   2.49183e11  -2.25897e11   1.05028e11   7.7287e9
155.064   155.064    1.77698
   7 │ Mercury_CALC    48.9655  7.00568      29.3223  0.205646    5.7909e
10   212.971    202.489   6.84698e10   1.24997e10  -6.69984e10  -6.56379e
9    -79.432   280.568   -5.50105
   8 │ Mercury_SPICE   48.2639  7.00184      29.2752  0.20565     6.8126e
10   216.969    205.3     6.77821e10   1.49111e10  -6.6119e10   -6.77243e
9    -77.2913  282.709   -5.70597
   9 │ Neptune_CALC   132.37    1.76502     272.728   0.00864801  4.49675
e12   17.3924    17.6917  4.45967e12   2.03772e12   3.96482e12  -1.28728e
11    62.7991   62.7991  -1.65407
  10 │ Neptune_SPICE  132.052   1.76744     269.268   0.00585937  4.46094
e12   20.4847    20.0814  4.46142e12   2.08998e12   3.93894e12  -1.29299e
11    62.0498   62.0498  -1.66093
  11 │ Saturn_CALC    114.13    2.48649     339.976   0.0553604   1.42937
e12  250.468    244.635   1.45961e12   1.3594e12   -5.29636e11  -4.44706e
10   -21.2865  338.714   -1.74593
  12 │ Saturn_SPICE   113.472   2.48725     338.791   0.0532792   1.45347
e12  251.786    245.833   1.45356e12   1.35031e12  -5.35972e11  -4.45284e
10   -21.6494  338.351   -1.75558
  13 │ Uranus_CALC     74.2736  0.773671     97.2584  0.0474636   2.8695e
12    11.713     12.885   2.73642e12  -2.72807e12  -2.10813e11   3.4689e1
0   -175.581   184.419    0.726346
  14 │ Uranus_SPICE    73.9534  0.771876     98.9681  0.0508291   2.73803
e12    9.66655   10.7188  2.73775e12  -2.73231e12  -1.73487e11   3.47309e
10  -176.367   183.633    0.726795
  15 │ Venus_CALC      77.1617  3.39514      55.1614  0.00674756  1.08209
e11   33.6687    34.1004  1.07602e11  -1.04412e11   2.5217e10    6.37187e
9    166.422   166.422    3.39486
  16 │ Venus_SPICE     76.5314  3.39428      55.2392  0.00676238  1.07611
e11   35.0415    35.5002  1.07455e11  -1.04795e11   2.36151e10   6.37074e
9    167.301   167.301    3.39397
```

Mercury is consistent. Remove from DataFrame.

In [ ]:

```
delete!(mergedDataWork, 7:8)
show(mergedDataWork, allcols=true)
```

```
14×15 DataFrame
 Row │ PLANET         Ω         i           ω         e           a
M           ν          R           X            Y            Z           ℓ
ℓ_corr    b
     │ String         Float64   Float64     Float64   Float64     Float64
Float64    Float64    Float64     Float64      Float64      Float64      F
loat64    Float64   Float64
─────┼─────────────────────────────────────────────────────────────────────
─────────────────────────────────────────────────────────────────────────
─────────────────────────────────────

   1 │ Earth_CALC       0.0      0.0         283.861   0.0166865   1.49598
e11  174.7      174.873   1.52084e11  -2.30926e10   1.5032e11    0.0
98.7336   98.7336   0.0
   2 │ Earth_SPICE    180.378   0.00672579  282.446   0.0175129   1.52083
e11  175.949    176.088   1.51715e11   2.35611e10  -1.50246e11   1.76549e
7    -81.0645  278.936    0.00665092
   3 │ Jupiter_CALC   100.995   1.29996     274.199   0.0485853   7.78292
e11  203.384    201.291   8.13271e11  -6.53688e11  -4.83554e11   1.66543e
10  -143.508   216.492    1.1734
   4 │ Jupiter_SPICE  100.582   1.30344     274.904   0.0473884   8.13294
e11  202.308    199.96    8.12846e11  -6.59099e11  -4.76188e11   1.67312e
10  -144.153   215.847    1.17878
   5 │ Mars_CALC       49.9699  1.84935     287.074   0.0934542   2.2794e
11   177.981    178.319   2.49231e11  -2.26446e11   1.03818e11   7.75461e
9    155.37    155.37     1.78299
   6 │ Mars_SPICE      49.3984  1.84549     286.919   0.0935111   2.49239
e11  178.473    178.728   2.49183e11  -2.25897e11   1.05028e11   7.7287e9
155.064   155.064    1.77698
   7 │ Neptune_CALC   132.37    1.76502     272.728   0.00864801  4.49675
e12   17.3924    17.6917  4.45967e12   2.03772e12   3.96482e12  -1.28728e
11    62.7991   62.7991  -1.65407
   8 │ Neptune_SPICE  132.052   1.76744     269.268   0.00585937  4.46094
e12   20.4847    20.0814  4.46142e12   2.08998e12   3.93894e12  -1.29299e
11    62.0498   62.0498  -1.66093
   9 │ Saturn_CALC    114.13    2.48649     339.976   0.0553604   1.42937
e12  250.468    244.635   1.45961e12   1.3594e12   -5.29636e11  -4.44706e
10   -21.2865  338.714   -1.74593
  10 │ Saturn_SPICE   113.472   2.48725     338.791   0.0532792   1.45347
e12  251.786    245.833   1.45356e12   1.35031e12  -5.35972e11  -4.45284e
10   -21.6494  338.351   -1.75558
  11 │ Uranus_CALC     74.2736  0.773671     97.2584  0.0474636   2.8695e
12    11.713     12.885   2.73642e12  -2.72807e12  -2.10813e11   3.4689e1
0   -175.581   184.419    0.726346
  12 │ Uranus_SPICE    73.9534  0.771876     98.9681  0.0508291   2.73803
e12    9.66655   10.7188  2.73775e12  -2.73231e12  -1.73487e11   3.47309e
10  -176.367   183.633    0.726795
  13 │ Venus_CALC      77.1617  3.39514      55.1614  0.00674756  1.08209
e11   33.6687    34.1004  1.07602e11  -1.04412e11   2.5217e10    6.37187e
9    166.422   166.422    3.39486
  14 │ Venus_SPICE     76.5314  3.39428      55.2392  0.00676238  1.07611
e11   35.0415    35.5002  1.07455e11  -1.04795e11   2.36151e10   6.37074e
9    167.301   167.301    3.39397
```

Earth is consistent, deleting it.

In [ ]:

```
delete!(mergedDataWork, 1:2)
show(mergedDataWork, allcols=true)
```

```
12×15 DataFrame
 Row │ PLANET         Ω         i         ω         e           a
M          ν         R           X            Y            Z            ℓ
ℓ_corr    b
     │ String         Float64   Float64   Float64   Float64     Float64
Float64    Float64   Float64     Float64      Float64      Float64      F
loat64    Float64   Float64
─────┼─────────────────────────────────────────────────────────────────────
───────────────────────────────────────────────────────────────────────────
─────────────────────────────────

   1 │ Jupiter_CALC   100.995   1.29996   274.199   0.0485853   7.78292e1
1  203.384    201.291   8.13271e11  -6.53688e11  -4.83554e11   1.66543e10
-143.508   216.492    1.1734
   2 │ Jupiter_SPICE  100.582   1.30344   274.904   0.0473884   8.13294e1
1  202.308    199.96    8.12846e11  -6.59099e11  -4.76188e11   1.67312e10
-144.153   215.847    1.17878
   3 │ Mars_CALC       49.9699  1.84935   287.074   0.0934542   2.2794e11
177.981    178.319   2.49231e11  -2.26446e11   1.03818e11   7.75461e9
155.37    155.37     1.78299
   4 │ Mars_SPICE      49.3984  1.84549   286.919   0.0935111   2.49239e1
1  178.473    178.728   2.49183e11  -2.25897e11   1.05028e11   7.7287e9
155.064   155.064    1.77698
   5 │ Neptune_CALC   132.37    1.76502   272.728   0.00864801  4.49675e1
2   17.3924    17.6917  4.45967e12   2.03772e12   3.96482e12  -1.28728e11
62.7991   62.7991   -1.65407
   6 │ Neptune_SPICE  132.052   1.76744   269.268   0.00585937  4.46094e1
2   20.4847    20.0814  4.46142e12   2.08998e12   3.93894e12  -1.29299e11
62.0498   62.0498   -1.66093
   7 │ Saturn_CALC    114.13    2.48649   339.976   0.0553604   1.42937e1
2  250.468    244.635   1.45961e12   1.3594e12   -5.29636e11  -4.44706e10
-21.2865  338.714   -1.74593
   8 │ Saturn_SPICE   113.472   2.48725   338.791   0.0532792   1.45347e1
2  251.786    245.833   1.45356e12   1.35031e12  -5.35972e11  -4.45284e10
-21.6494  338.351   -1.75558
   9 │ Uranus_CALC     74.2736  0.773671   97.2584  0.0474636   2.8695e12
11.713      12.885   2.73642e12  -2.72807e12  -2.10813e11   3.4689e10   -1
75.581   184.419    0.726346
  10 │ Uranus_SPICE    73.9534  0.771876   98.9681  0.0508291   2.73803e1
2    9.66655   10.7188  2.73775e12  -2.73231e12  -1.73487e11   3.47309e10
-176.367   183.633    0.726795
  11 │ Venus_CALC      77.1617  3.39514    55.1614  0.00674756  1.08209e1
1   33.6687    34.1004  1.07602e11  -1.04412e11   2.5217e10    6.37187e9
166.422   166.422    3.39486
  12 │ Venus_SPICE     76.5314  3.39428    55.2392  0.00676238  1.07611e1
1   35.0415    35.5002  1.07455e11  -1.04795e11   2.36151e10   6.37074e9
167.301   167.301    3.39397
```

Neptune is consistent. Deleting it.

```
In [ ]: delete!(mergedDataWork, 5:6)
        show(mergedDataWork, allcols=true)
```

```
10×15 DataFrame
 Row │ PLANET         Ω         i         ω         e           a
M          ν         R           X            Y            Z            ℓ
ℓ_corr   b
     │ String         Float64   Float64   Float64   Float64     Float64
Float64    Float64   Float64    Float64      Float64      Float64      F
loat64    Float64  Float64
─────┼─────────────────────────────────────────────────────────────────────
─────────────────────────────────────────────────────────────────────────
────────────────────────────────
   1 │ Jupiter_CALC   100.995   1.29996   274.199   0.0485853   7.78292e1
1  203.384    201.291   8.13271e11  -6.53688e11  -4.83554e11   1.66543e10
-143.508   216.492   1.1734
   2 │ Jupiter_SPICE  100.582   1.30344   274.904   0.0473884   8.13294e1
1  202.308    199.96    8.12846e11  -6.59099e11  -4.76188e11   1.67312e10
-144.153   215.847   1.17878
   3 │ Mars_CALC       49.9699  1.84935   287.074   0.0934542   2.2794e11
177.981    178.319   2.49231e11  -2.26446e11   1.03818e11   7.75461e9
155.37    155.37    1.78299
   4 │ Mars_SPICE      49.3984  1.84549   286.919   0.0935111   2.49239e1
1  178.473    178.728   2.49183e11  -2.25897e11   1.05028e11   7.7287e9
155.064   155.064   1.77698
   5 │ Saturn_CALC    114.13    2.48649   339.976   0.0553604   1.42937e1
2  250.468    244.635   1.45961e12   1.3594e12   -5.29636e11  -4.44706e10
-21.2865  338.714  -1.74593
   6 │ Saturn_SPICE   113.472   2.48725   338.791   0.0532792   1.45347e1
2  251.786    245.833   1.45356e12   1.35031e12  -5.35972e11  -4.45284e10
-21.6494  338.351  -1.75558
   7 │ Uranus_CALC     74.2736  0.773671   97.2584  0.0474636   2.8695e12
11.713     12.885   2.73642e12  -2.72807e12  -2.10813e11   3.4689e10   -1
75.581   184.419   0.726346
   8 │ Uranus_SPICE    73.9534  0.771876   98.9681  0.0508291   2.73803e1
2    9.66655   10.7188  2.73775e12  -2.73231e12  -1.73487e11   3.47309e10
-176.367   183.633   0.726795
   9 │ Venus_CALC      77.1617  3.39514    55.1614  0.00674756  1.08209e1
1   33.6687    34.1004  1.07602e11  -1.04412e11   2.5217e10    6.37187e9
166.422   166.422   3.39486
  10 │ Venus_SPICE     76.5314  3.39428    55.2392  0.00676238  1.07611e1
1   35.0415    35.5002  1.07455e11  -1.04795e11   2.36151e10   6.37074e9
167.301   167.301   3.39397
```

Saturn is consistent. Deleting it.

```
In [ ]: delete!(mergedDataWork, 5:6)
        show(mergedDataWork, allcols=true)
```

```
8×15 DataFrame
 Row │ PLANET         Ω         i         ω         e           a
M          ν         R           X            Y            Z           ℓ
ℓ_corr   b
     │ String         Float64   Float64   Float64   Float64     Float64
Float64    Float64   Float64     Float64      Float64      Float64     Fl
oat64   Float64  Float64
─────┼───────────────────────────────────────────────────────────────────
─────────────────────────────────────────────────────────────────────────
─────────────────────────────

   1 │ Jupiter_CALC   100.995   1.29996   274.199   0.0485853   7.78292e1
1  203.384    201.291   8.13271e11  -6.53688e11  -4.83554e11  1.66543e10
-143.508  216.492  1.1734
   2 │ Jupiter_SPICE  100.582   1.30344   274.904   0.0473884   8.13294e1
1  202.308    199.96    8.12846e11  -6.59099e11  -4.76188e11  1.67312e10
-144.153  215.847  1.17878
   3 │ Mars_CALC       49.9699  1.84935   287.074   0.0934542   2.2794e11
177.981    178.319   2.49231e11  -2.26446e11   1.03818e11  7.75461e9    1
55.37    155.37    1.78299
   4 │ Mars_SPICE      49.3984  1.84549   286.919   0.0935111   2.49239e1
1  178.473    178.728   2.49183e11  -2.25897e11   1.05028e11  7.7287e9
155.064  155.064  1.77698
   5 │ Uranus_CALC     74.2736  0.773671   97.2584  0.0474636   2.8695e12
11.713     12.885   2.73642e12  -2.72807e12  -2.10813e11  3.4689e10   -17
5.581  184.419  0.726346
   6 │ Uranus_SPICE    73.9534  0.771876   98.9681  0.0508291   2.73803e1
2    9.66655   10.7188  2.73775e12  -2.73231e12  -1.73487e11  3.47309e10
-176.367  183.633  0.726795
   7 │ Venus_CALC      77.1617  3.39514    55.1614  0.00674756  1.08209e1
1   33.6687    34.1004  1.07602e11  -1.04412e11   2.5217e10   6.37187e9
166.422  166.422  3.39486
   8 │ Venus_SPICE     76.5314  3.39428    55.2392  0.00676238  1.07611e1
1   35.0415    35.5002  1.07455e11  -1.04795e11   2.36151e10  6.37074e9
167.301  167.301  3.39397
```

In [ ]:

```
dfBodiesToPlot = DataFrame()
dfBodiesToPlot = copy(dfBodiesCopy[!, [:PLANET,:ℓ, :X, :Y]])
dfBodiesToPlot[!, "SOURCE"] .= 1
dfBodiesToPlot[!,"RADIUS"] = [i for i in 1:8]
dfSPICEPlot = copy(dfSPICEcopy[:, [:PLANET, :ℓ, :X, :Y]])
dfSPICEPlot[!, "SOURCE"] .= 2
dfSPICEPlot[!,"RADIUS"] = [i for i in 1:8]

show(dfSPICEPlot, allcols=true)
println("\n\n")
show(dfBodiesToPlot, allcols=true)

plotFrame = DataFrame()
append!(plotFrame, dfBodiesToPlot)
append!(plotFrame, dfSPICEPlot)
```

```
8×6 DataFrame
 Row │ PLANET   ℓ          X            Y            SOURCE  RADIUS
     │ String   Float64    Float64      Float64      Int64   Int64
─────┼──────────────────────────────────────────────────────────────
   1 │ Mercury   -77.2913   1.49111e10  -6.6119e10        2       1
   2 │ Venus     167.301   -1.04795e11   2.36151e10        2       2
   3 │ Earth     -81.0645   2.35611e10  -1.50246e11        2       3
   4 │ Mars      155.064   -2.25897e11   1.05028e11        2       4
   5 │ Jupiter  -144.153   -6.59099e11  -4.76188e11        2       5
   6 │ Saturn    -21.6494   1.35031e12  -5.35972e11        2       6
   7 │ Uranus   -176.367   -2.73231e12  -1.73487e11        2       7
   8 │ Neptune    62.0498   2.08998e12   3.93894e12        2       8
```

```
8×6 DataFrame
 Row │ PLANET   ℓ          X            Y            SOURCE  RADIUS
     │ String   Float64    Float64      Float64      Int64   Int64
─────┼──────────────────────────────────────────────────────────────
   1 │ Mercury   -79.432    1.24997e10  -6.69984e10        1       1
   2 │ Venus     166.422   -1.04412e11   2.5217e10         1       2
   3 │ Earth      98.7336  -2.30926e10   1.5032e11         1       3
   4 │ Mars      155.37    -2.26446e11   1.03818e11        1       4
   5 │ Jupiter  -143.508   -6.53688e11  -4.83554e11        1       5
   6 │ Saturn    -21.2865   1.3594e12   -5.29636e11        1       6
   7 │ Uranus   -175.581   -2.72807e12  -2.10813e11        1       7
   8 │ Neptune    62.7991   2.03772e12   3.96482e12        1       8
```

Out[ ]: 16 rows × 6 columns

| | PLANET | ℓ | X | Y | SOURCE | RADIUS |
|---|---|---|---|---|---|---|
| | String | Float64 | Float64 | Float64 | Int64 | Int64 |
| **1** | Mercury | -79.432 | 1.24997e10 | -6.69984e10 | 1 | 1 |
| **2** | Venus | 166.422 | -1.04412e11 | 2.5217e10 | 1 | 2 |
| **3** | Earth | 98.7336 | -2.30926e10 | 1.5032e11 | 1 | 3 |
| **4** | Mars | 155.37 | -2.26446e11 | 1.03818e11 | 1 | 4 |
| **5** | Jupiter | -143.508 | -6.53688e11 | -4.83554e11 | 1 | 5 |
| **6** | Saturn | -21.2865 | 1.3594e12 | -5.29636e11 | 1 | 6 |
| **7** | Uranus | -175.581 | -2.72807e12 | -2.10813e11 | 1 | 7 |
| **8** | Neptune | 62.7991 | 2.03772e12 | 3.96482e12 | 1 | 8 |
| **9** | Mercury | -77.2913 | 1.49111e10 | -6.6119e10 | 2 | 1 |
| **10** | Venus | 167.301 | -1.04795e11 | 2.36151e10 | 2 | 2 |
| **11** | Earth | -81.0645 | 2.35611e10 | -1.50246e11 | 2 | 3 |
| **12** | Mars | 155.064 | -2.25897e11 | 1.05028e11 | 2 | 4 |
| **13** | Jupiter | -144.153 | -6.59099e11 | -4.76188e11 | 2 | 5 |
| **14** | Saturn | -21.6494 | 1.35031e12 | -5.35972e11 | 2 | 6 |
| **15** | Uranus | -176.367 | -2.73231e12 | -1.73487e11 | 2 | 7 |
| **16** | Neptune | 62.0498 | 2.08998e12 | 3.93894e12 | 2 | 8 |

In [ ]:

```
plot([scatterpolar(dfSPICEPlot, r=:RADIUS, theta=:ℓ, marker=attr(color=:g
      scatterpolar(dfBodiesToPlot, r=:RADIUS, theta=:ℓ, marker=attr(color
    ], Layout(title="SPICE Generated and Manually Calculated Data [Polar]



    #TODO: Check on variation (SPICE's Lat goes from -90 to +90. SPICE's
```

Out[ ]:

**WebIO not detected.**

**Please read the troubleshooting guide for more information on how to resolve this issue.**

**https://juliagizmos.github.io/WebIO.jl/latest/troubleshooting/not-detected/**

In [ ]:

```
plot([scatter(dfSPICEPlot, x=:X, y=:Y, marker=attr(color=:green), mode="m
scatter(dfBodiesToPlot, x=:X, y=:Y, marker=attr(color=:red), mode="marker
text=["Mercury", "Venus", "Earth", "Mars", "Jupiter", "Saturn", "Uranus",
```

Out[ ]:

**WebIO not detected.**

**Please read the troubleshooting guide for more information on how to resolve this issue.**

**https://juliagizmos.github.io/WebIO.jl/latest/troubleshooting/not-detected/**

In [ ]:

```
mergedDataEarthSolve = copy(mergedData)
delete!(mergedDataEarthSolve, 3:16)
;
```

In [ ]:

```
show(mergedDataEarthSolve, allcols=true)
```

```
2×15 DataFrame
 Row │ PLANET       Ω        i           ω        e          a
M        ν        R           X            Y            Z          ℓ
ℓ_corr    b
     │ String       Float64  Float64     Float64  Float64    Float64
Float64  Float64  Float64     Float64      Float64      Float64    Float6
4   Float64   Float64
─────┼─────────────────────────────────────────────────────────────────────
─────────────────────────────────────────────────────────────────────────
─────────────────────────

   1 │ Earth_CALC     0.0     0.0         283.861  0.0166865  1.49598e11
174.7    174.873  1.52084e11  -2.30926e10   1.5032e11   0.0          98.73
36   98.7336  0.0
   2 │ Earth_SPICE  180.378  0.00672579  282.446  0.0175129  1.52083e11
175.949  176.088  1.51715e11   2.35611e10  -1.50246e11  1.76549e7  -81.06
45  278.936   0.00665092
```

In [ ]:

```
cleanTable = DataFrame(dfBodiesCopy)

show(cleanTable, allcols=true)
```

```
8×16 DataFrame
 Row │ PLANET   Ω         i         ω         e           a           M
E         ν         R           X            Y            Z            ℓ
ℓ_corr    b
     │ String   Float64   Float64   Float64   Float64     Float64     Flo
at64   Float64   Float64   Float64     Float64      Float64      Float64
Float64    Float64   Float64
─────┼─────────────────────────────────────────────────────────────────
───────────────────────────────────────────────────────────────────────
────────────────────────────────────

   1 │ Mercury   48.9655  7.00568    29.3223  0.205646    5.7909e10   21
2.971   207.525   202.489   6.84698e10   1.24997e10  -6.69984e10  -6.5637
9e9    -79.432   280.568   -5.50105
   2 │ Venus     77.1617  3.39514    55.1614  0.00674756  1.08209e11   3
3.6687   33.8843   34.1004  1.07602e11  -1.04412e11   2.5217e10    6.3718
7e9    166.422   166.422    3.39486
   3 │ Earth      0.0     0.0       283.861   0.0166865   1.49598e11  17
4.7     174.787   174.873   1.52084e11  -2.30926e10   1.5032e11    0.0
98.7336   98.7336   0.0
   4 │ Mars      49.9699  1.84935   287.074   0.0934542   2.2794e11   17
7.981   178.153   178.319   2.49231e11  -2.26446e11   1.03818e11   7.7546
1e9    155.37    155.37     1.78299
   5 │ Jupiter  100.995   1.29996   274.199   0.0485853   7.78292e11  20
3.384   202.326   201.291   8.13271e11  -6.53688e11  -4.83554e11   1.6654
3e10  -143.508   216.492    1.1734
   6 │ Saturn   114.13    2.48649   339.976   0.0553604   1.42937e12  25
0.468   247.537   244.635   1.45961e12   1.3594e12   -5.29636e11  -4.4470
6e10   -21.2865  338.714   -1.74593
   7 │ Uranus    74.2736  0.773671   97.2584  0.0474636   2.8695e12    1
1.713    12.292    12.885   2.73642e12  -2.72807e12  -2.10813e11   3.4689
e10   -175.581   184.419    0.726346
   8 │ Neptune  132.37    1.76502   272.728   0.00864801  4.49675e12   1
7.3924   17.5418   17.6917  4.45967e12   2.03772e12   3.96482e12  -1.2872
8e11    62.7991   62.7991  -1.65407
```

In [ ]: