Sushant Problem | AAE632 | FSG1

Problem PSG1

Given: L_1 Lyapunov orbit at $\xi = 0.01$ and $\eta = 0$

Find: a) Eigenvalues and eigenvectors again. IC for off the periodic orbit but on stable manifold.

b) Propagate backwards in time and globalize stable manifold. Globalize both half manifolds; plot in configuration space.

c) Select other fixed fixed on x-axis. Compute stable manifold and plot $y=0$ on far side of moon. How close to Moon

d) Produce unstable manifolds too.

Solution:

a) We have derived these orbits multiples times so I will not rederive it or its eigenvalues

$\lambda_1 = 2.5611 \times 10^3 \qquad \lambda_2 = 3.9045 \times 10^{-4} \qquad \lambda_3 = \lambda_4 = 1$

$\lambda_5 = 0.9899 + 0.1421i \qquad \lambda_6 = 0.9899 - 0.1421i$

$$V^{W^s} = \frac{V^s}{\sqrt{x^2+y^2+z^2}} = \begin{bmatrix} 0.8657 \\ 0.5006 \\ 0 \\ -2.6734 \\ -1.3288 \\ 0 \end{bmatrix}$$

Let $x^* = 40$ km

$$x^s = \begin{bmatrix} 0.847 \\ 0.0001 \\ 0 \\ -0.0003 \\ -0.0784 \\ -0 \end{bmatrix}$$

Note, that we discovered that a reasonably small perturbation was sufficient to create the manifolds.

continued...

b) See Figure: G1.1, G1.2

c) The other point on the x-axis is ½ a period.

The closest approach when crossing x-axis the second time is 5.2481×10^4 km

See Figure: G1.3, G1.4

There manifold slowly merge into the periodic orbit. It does about a quater of a revolution

d) See figures: G1.5, G1.6, G1.7, G1.8, G1.9 and G1.10

The method to produce stable and unstable is similar, but you will have to propogate forward in time

PSG1

Part b)

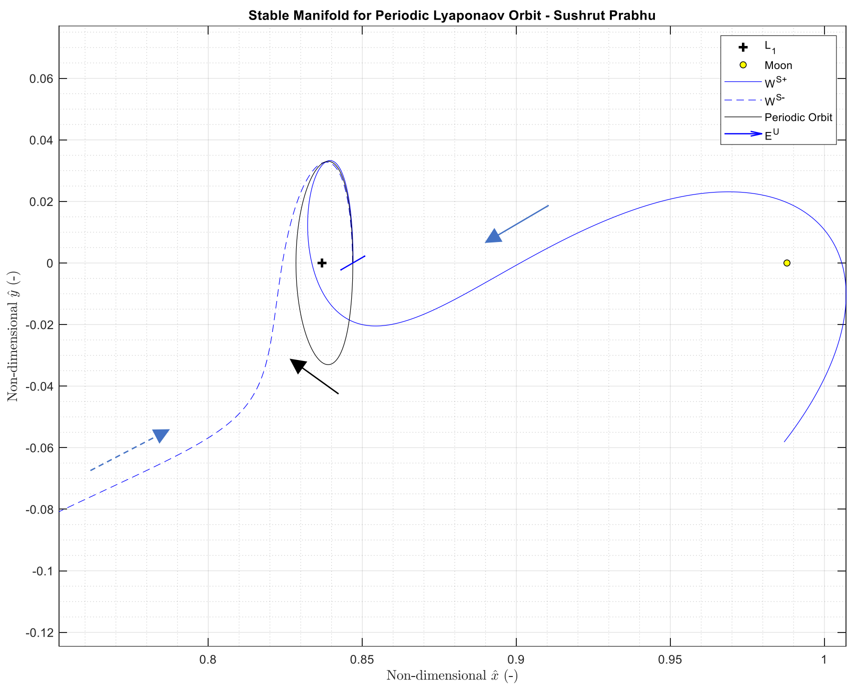


Figure G1.1: Stable manifold starting at the y = 0 on the Lunar side.

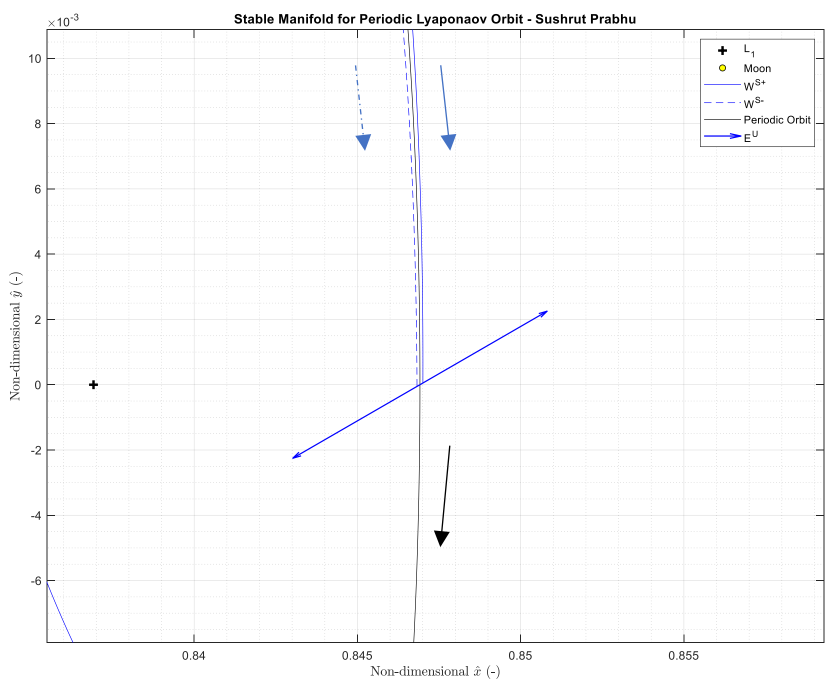


Figure G1.2: Stable manifold starting at the y = 0 on the Lunar side zoomed in view.

Part c)

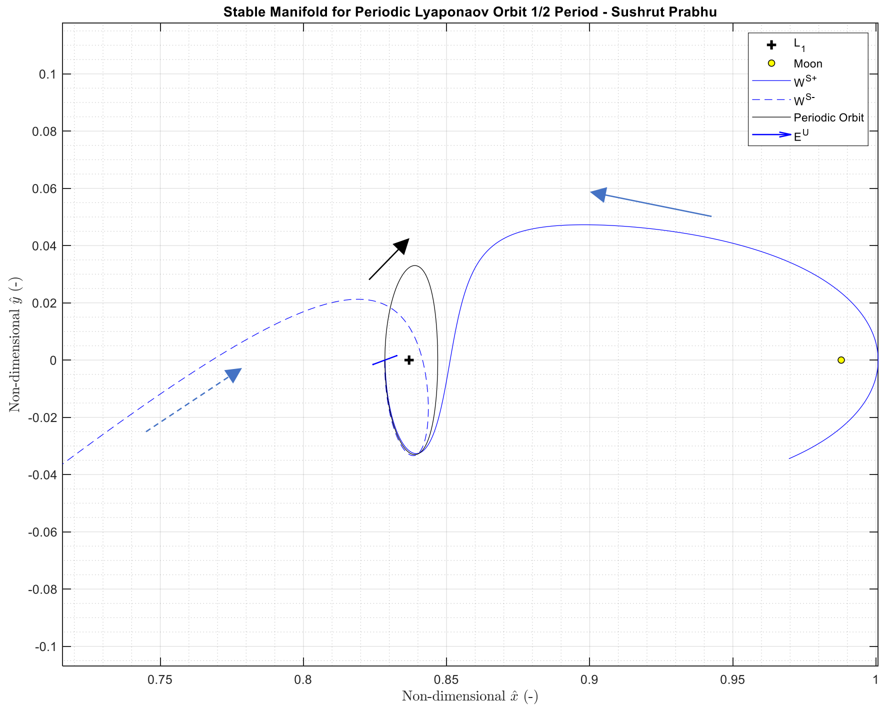


Figure G1.3: Stable manifold starting at the y = 0 on the Earth side.

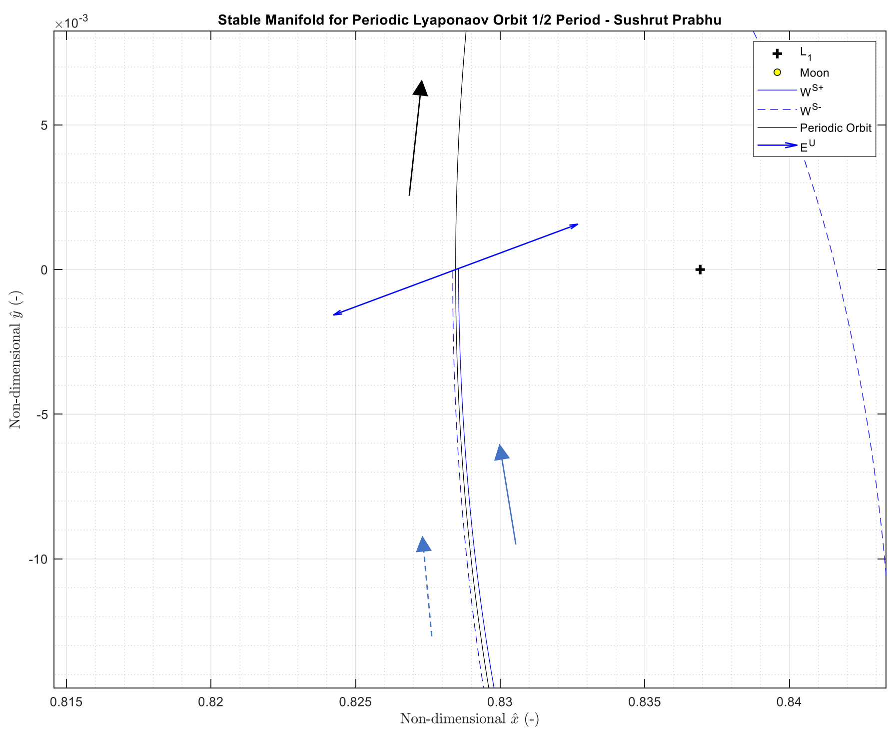


Figure G1.4: Stable manifold starting at the y = 0 on the Earth side zoomed in view.

Part d)

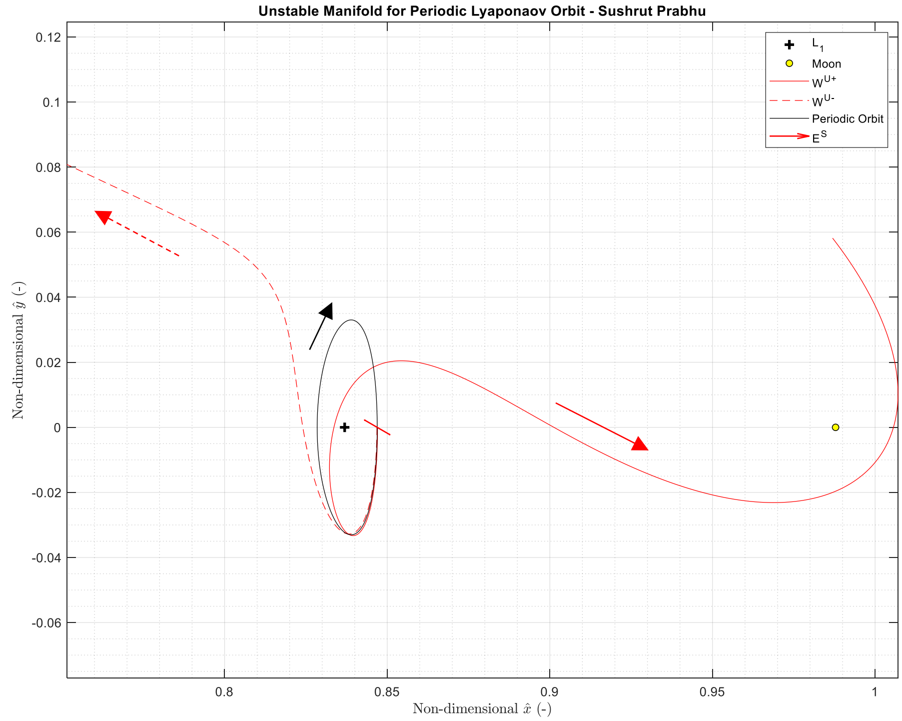


Figure G1.5: Unstable manifold starting at the y = 0 on the Lunar side.

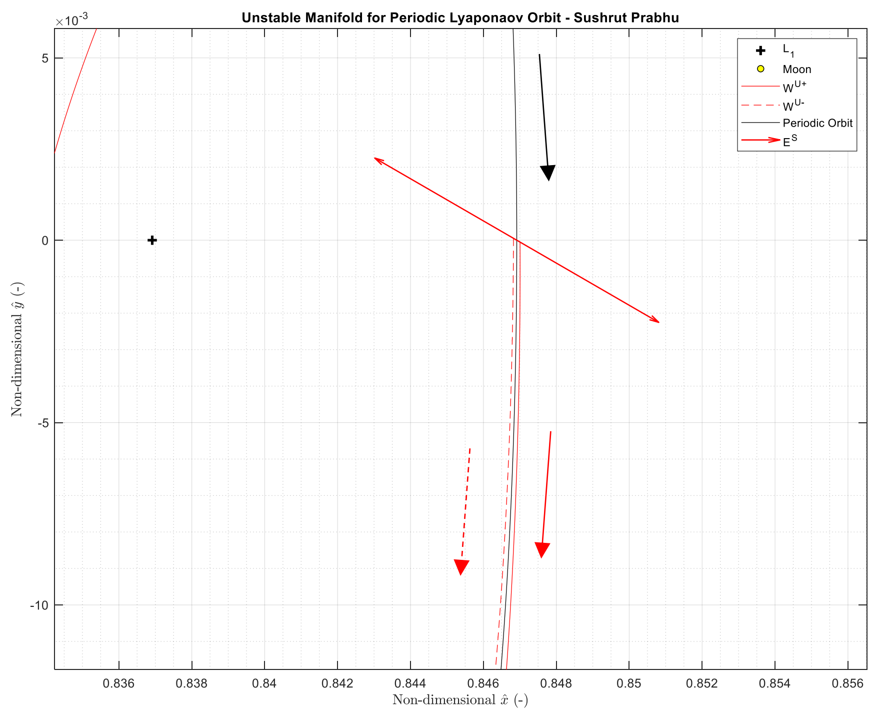


Figure G1.6: Unstable manifold starting at the y = 0 on the Lunar side zoomed in view.

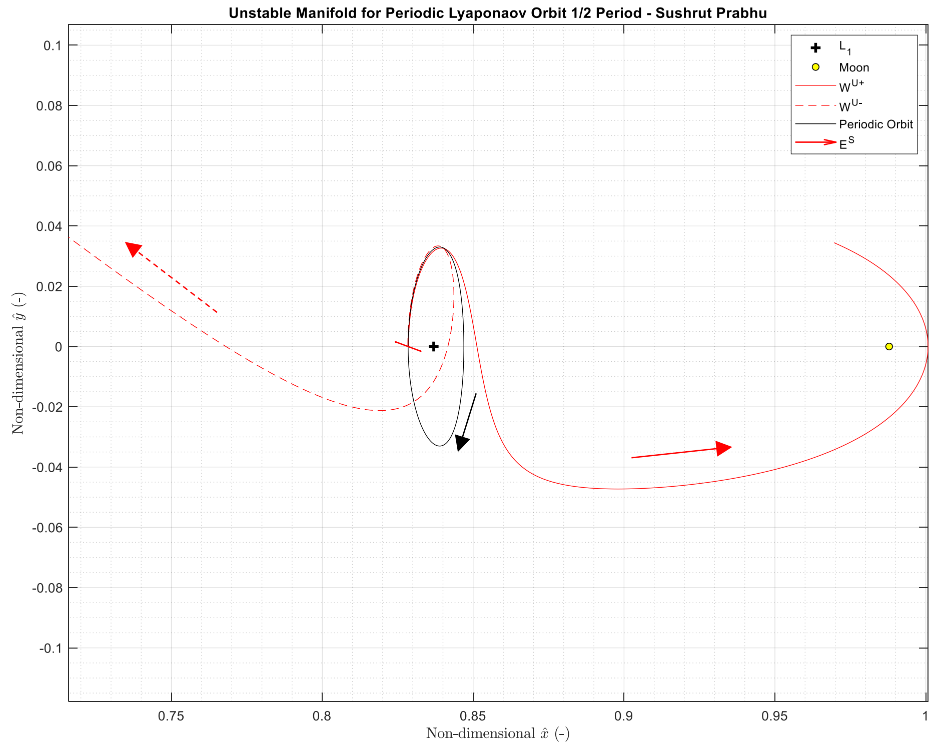


Figure G1.7: Unstable manifold starting at the y = 0 on the Earth side.

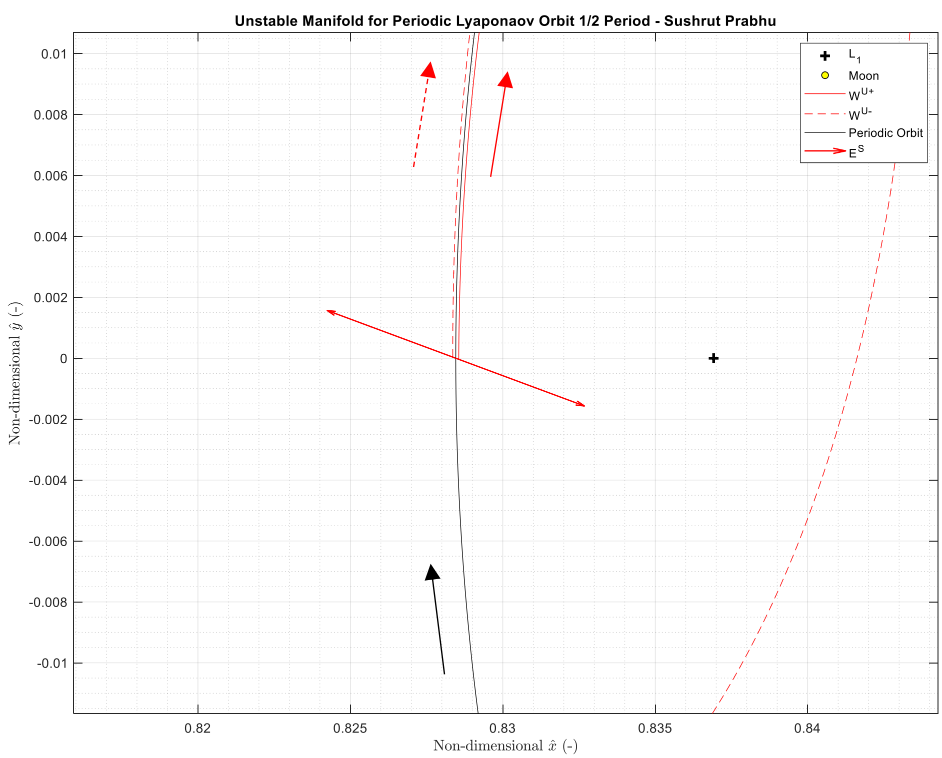


Figure G1.8: Unstable manifold starting at the y = 0 on the Earth side zoomed in view.

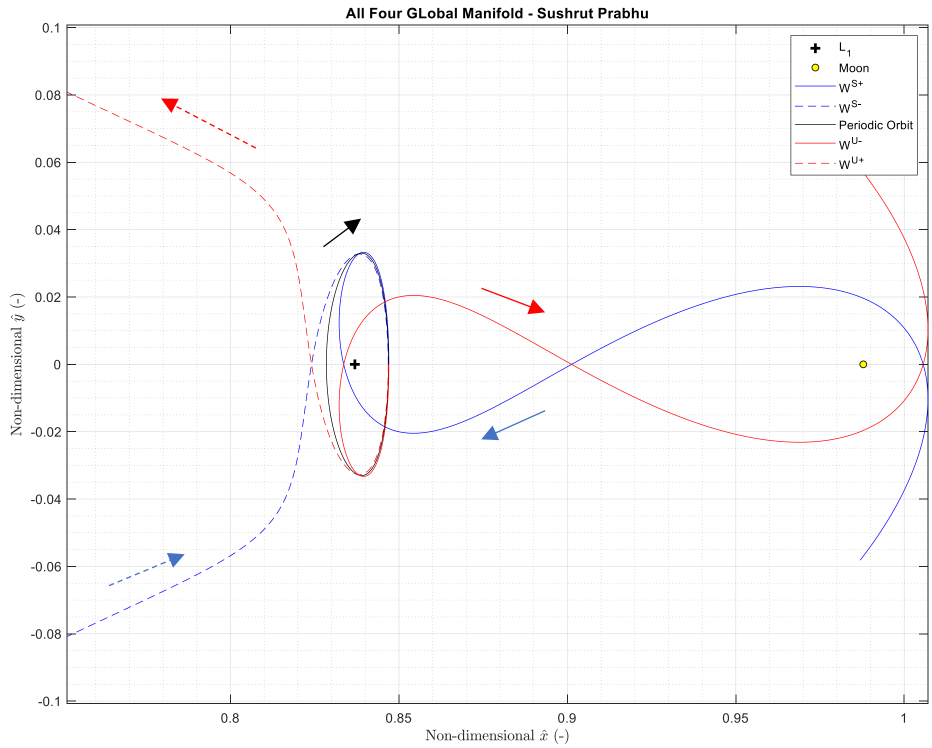


Figure G1.9: All four manifolds on the Lunar side.

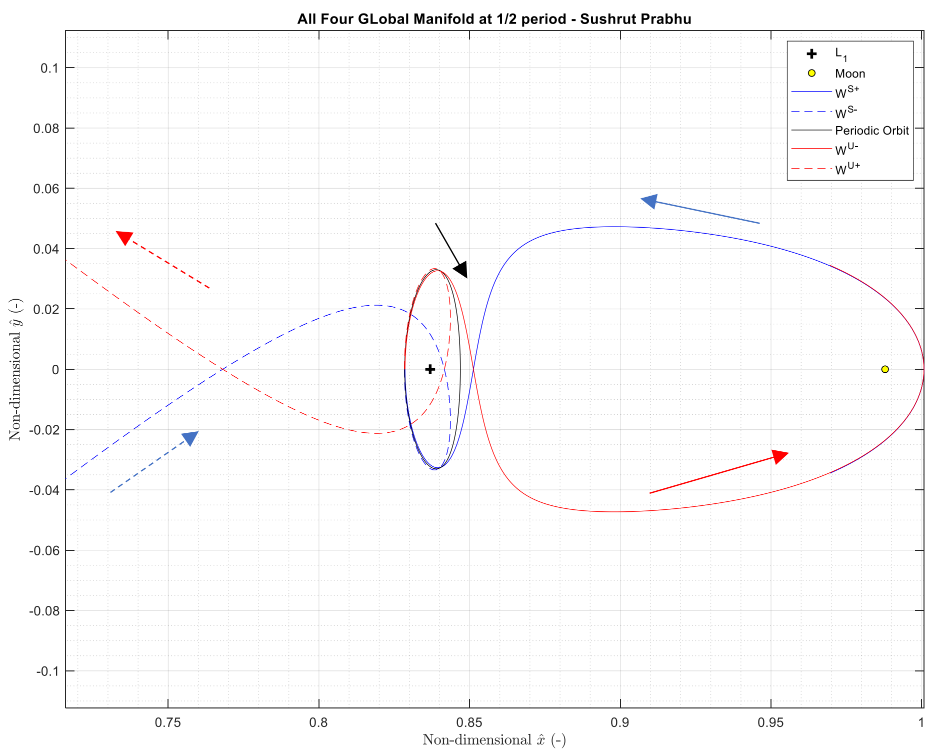


Figure G1.10: All four manifolds on the Earth side.

Table of Contents

PSG1 1
Part a 1
Part b 2
Part c 4
Part d 6

PSG1

```
clear
close all
clc

SS = SolarS;
systems = {'-', 'Earth-Moon'};
param = {'l* (km)','m* (kg)','miu' , 't*', 'gamma_1', 'L_1', 'gamma_1
 (km)', 'L_1 (km)'};
G = 6.6738*10^-20;
options=odeset('RelTol',1e-13, 'AbsTol',1e-15); % Sets integration
 tollerance

dim_vals = num2cell(zeros(length(param),1));
dim_vals = [systems; param',dim_vals];

% System Constants
[dim_vals{2,2}, dim_vals{3,2}, dim_vals{5,2}] =
 charE(SS.dM_E,0,SS.mMoon/G,SS.mEarth/G);        % Earth Moon
dim_vals{4,2} = SS.mMoon/dim_vals{3,2}/G;   % miu

% Lagrange Point 1
dim_vals{6,2} = abs(L1_NRmethod(dim_vals{4,2}*.7,dim_vals{4,2},
 10^-8));
dim_vals{7,2} = 1-dim_vals{4,2} - dim_vals{6,2};
dim_vals{8,2} = dim_vals{6,2}*dim_vals{2,2};
dim_vals{9,2} = dim_vals{7,2}*dim_vals{2,2};
```

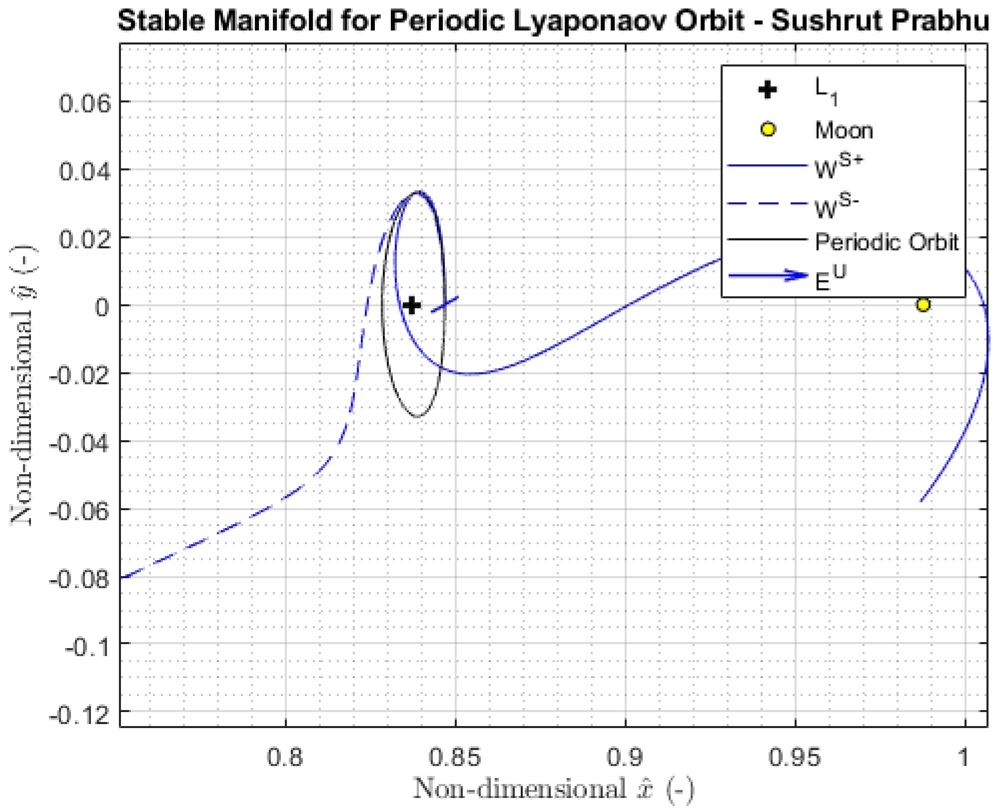
Part a

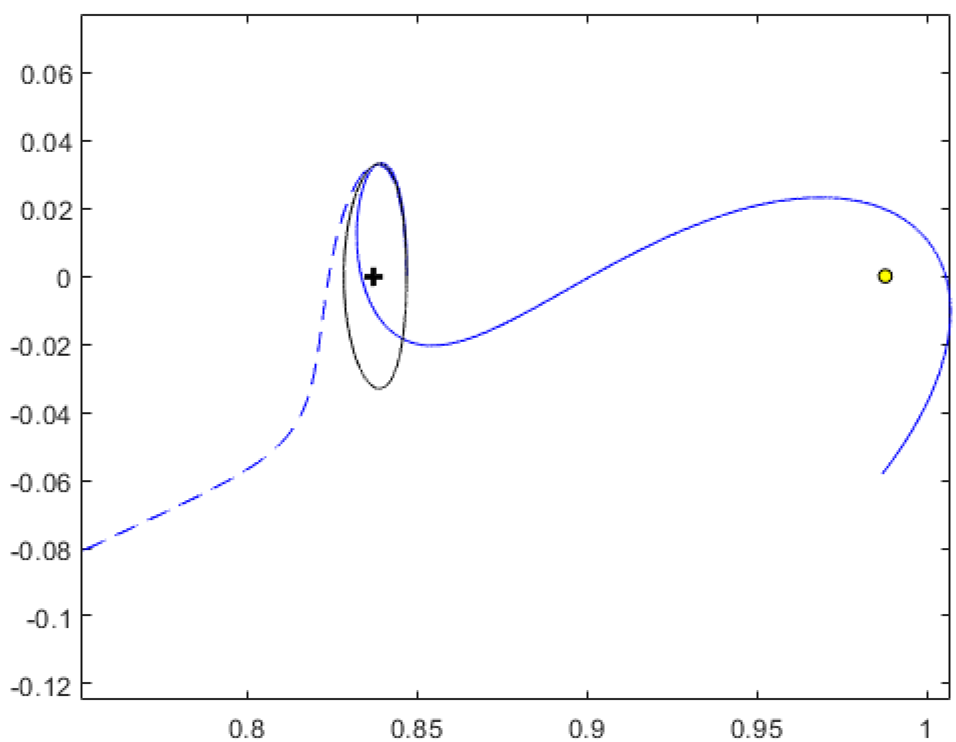
```
xi = 0.01;
y = [dim_vals{7,2}+xi 0 0 0 -.082 0];
t_end = 2.711/2;

[yn,t_end] = Target3d_per([0
 0],y(1:3),y(4:6),t_end,dim_vals{4,2},"planar", 10^-13,"");

STM0 = eye(6);
STM0 = STM0(:)';
IC = [yn, STM0];
```

```
G = [1 0 0 0 0 0; 0 -1 0 0 0 0; 0 0 1 0 0 0; 0 0 0 -1 0 0; 0 0 0 0 1
 0;0 0 0 0 0 -1];
Omega = [0 1 0; -1 0 0; 0 0 0];

[~,y]=ode45(@cr3bp_STM_df3d,[0 t_end],IC,options,dim_vals{4,2});
[~,yfull]=ode45(@cr3bp_STM_df3d,[0 t_end*2],IC,options,dim_vals{4,2});

stm_12 = reshape(y(end,7:end),6,6)';
monodromy = G* [zeros(3,3), -eye(3);eye(3), -2*Omega]*stm_12' *
 [-2*Omega, eye(3); -eye(3), zeros(3,3)]*G*stm_12;

[V,D] = eig(monodromy);
D = diag(D);

V_ws = V(:,2)/norm(V(1:3,2));       % Normalized v stable
```

Part b

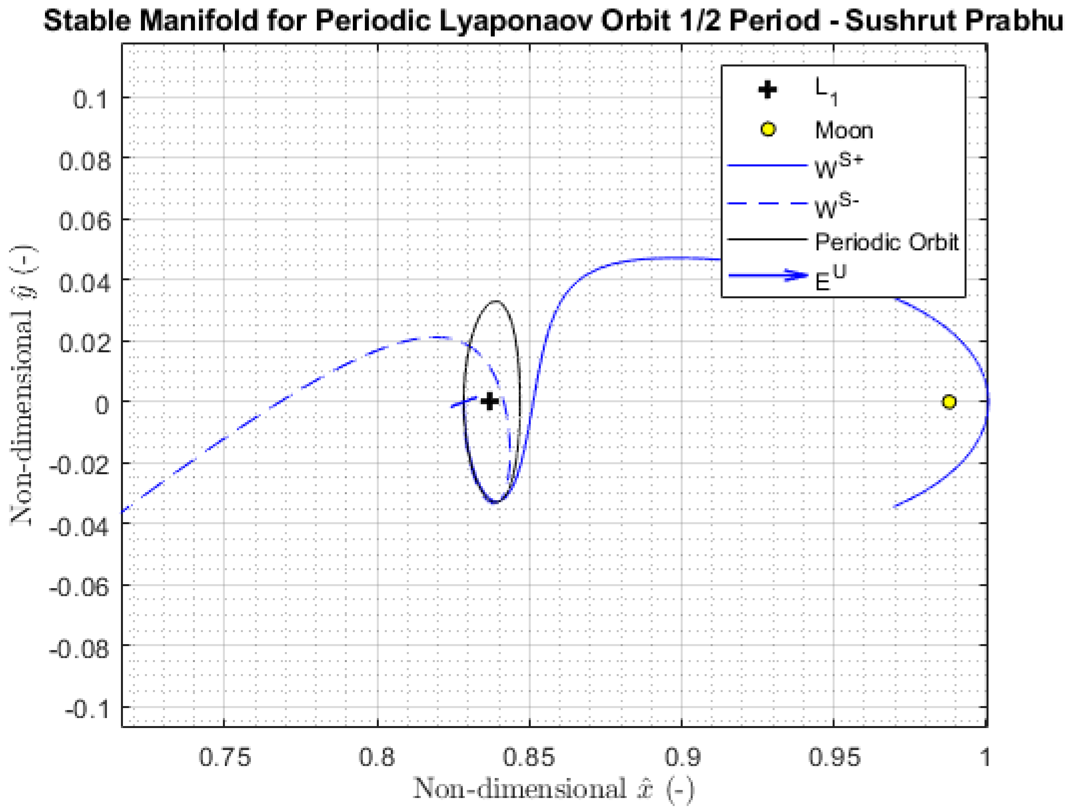
```
d = 40/dim_vals{2,2};
x_star = y(1,1:6);
t_end2 = 2.5;

xs1 = x_star + d*V_ws';
[~,y1] = ode45(@cr3bp_df,[t_end2 0],xs1,options,dim_vals{4,2});

xs2 = x_star - d*V_ws';
[~,y2] = ode45(@cr3bp_df,[t_end2 0],xs2,options,dim_vals{4,2});

figure
plot(dim_vals{7,2},0,'+k','LineWidth',2,'MarkerSize',7)
hold on
plot(1-dim_vals{4,2},0,'ko','MarkerSize',5,'MarkerFaceColor','y')
plot(y1(:,1),y1(:,2),'b')
plot(y2(:,1),y2(:,2),'--b')
plot(yfull(:,1),yfull(:,2),'k')
axis equal
quiver(y(1,1),y(1,2),V_ws(1)*.005,V_ws(2)*.005,'b','LineWidth',1)
quiver(y(1,1),y(1,2),-V_ws(1)*.005,-V_ws(2)*.005,'b','LineWidth',1)
grid on
grid minor
title('Stable Manifold for Periodic Lyaponaov Orbit - Sushrut Prabhu')
xlabel("Non-dimensional $$\hat{x}$$ (-)","Interpreter", "latex")
ylabel("Non-dimensional $$\hat{y}$$ (-)","Interpreter", "latex")
legend('L_1','Moon','W^S^+','W^S^-','Periodic Orbit','E^U')

figure
plot(dim_vals{7,2},0,'+k','LineWidth',2,'MarkerSize',7)
hold on
plot(1-dim_vals{4,2},0,'ko','MarkerSize',5,'MarkerFaceColor','y')
plot(y1(:,1),y1(:,2),'b')
plot(y2(:,1),y2(:,2),'--b')
plot(yfull(:,1),yfull(:,2),'k')
axis equal
```

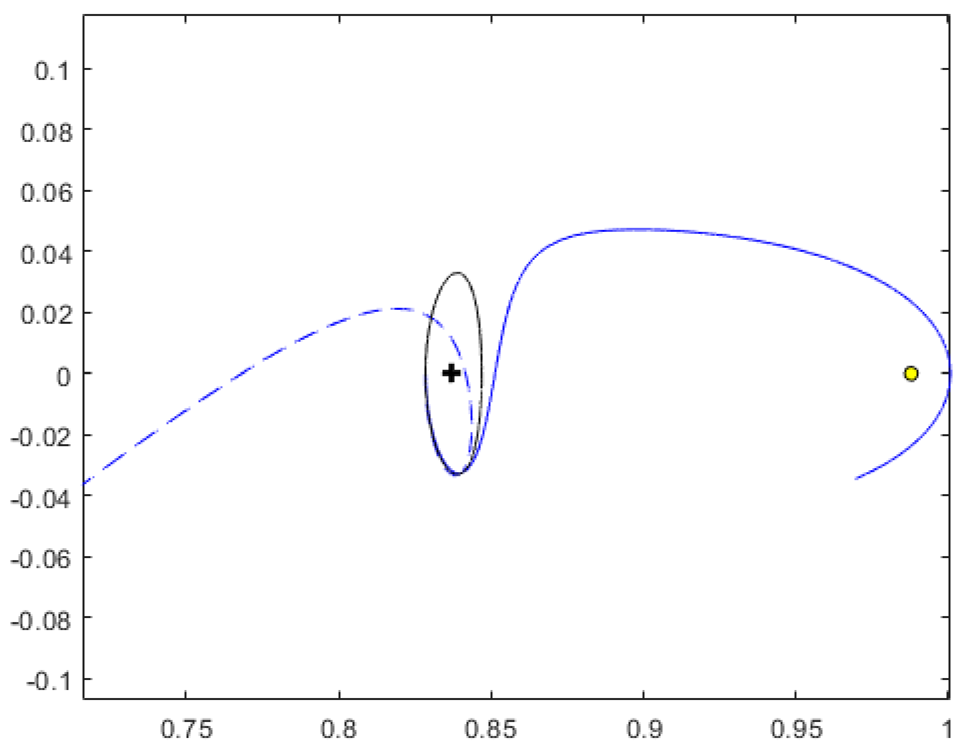

Stable Manifold for Periodic Lyaponaov Orbit - Sushrut Prabhu
L_1
Moon
W^{S+}
W^{S-}
Periodic Orbit
E^U
Non-dimensional $\hat{y}$ (-)
Non-dimensional $\hat{x}$ (-)



Part c

```
phi = y(:,7:end);
phi_t = reshape(phi(end,:),6,6)';
V_t2 = phi_t*V;
t_end2 = 2.5;

V_ws = V_t2(:,2)/norm(V_t2(1:3,2));      % Normalized v stable

x_star = y(end,1:6);

xs1 = x_star + d*V_ws';
[~,y1] = ode45(@cr3bp_df,[t_end2 0],xs1,options,dim_vals{4,2});

xs2 = x_star - d*V_ws';
[~,y2] = ode45(@cr3bp_df,[t_end2 0],xs2,options,dim_vals{4,2});


moon_dist = y1(:,1:2) - [1-dim_vals{4,2},0];
closest_app = min(vecnorm(moon_dist,1,2))*dim_vals{2,2};


figure
plot(dim_vals{7,2},0,'+k','LineWidth',2,'MarkerSize',7)
hold on
plot(1-dim_vals{4,2},0,'ko','MarkerSize',5,'MarkerFaceColor','y')
plot(y1(:,1),y1(:,2),'b')
plot(y2(:,1),y2(:,2),'--b')
plot(yfull(:,1),yfull(:,2),'k')
axis equal
quiver(y(end,1),y(end,2),V_ws(1)*.005,V_ws(2)*.005,'b','LineWidth',1)
quiver(y(end,1),y(end,2),-V_ws(1)*.005,-
V_ws(2)*.005,'b','LineWidth',1)
grid on
grid minor
title('Stable Manifold for Periodic Lyaponaov Orbit 1/2 Period -
 Sushrut Prabhu')
xlabel("Non-dimensional $$\hat{x}$$ (-)","Interpreter", "latex")
ylabel("Non-dimensional $$\hat{y}$$ (-)","Interpreter", "latex")
legend('L_1','Moon','W^S^+','W^S^-','Periodic Orbit','E^U')

figure
plot(dim_vals{7,2},0,'+k','LineWidth',2,'MarkerSize',7)
hold on
plot(1-dim_vals{4,2},0,'ko','MarkerSize',5,'MarkerFaceColor','y')
plot(y1(:,1),y1(:,2),'b')
plot(y2(:,1),y2(:,2),'--b')
plot(yfull(:,1),yfull(:,2),'k')
axis equal
```

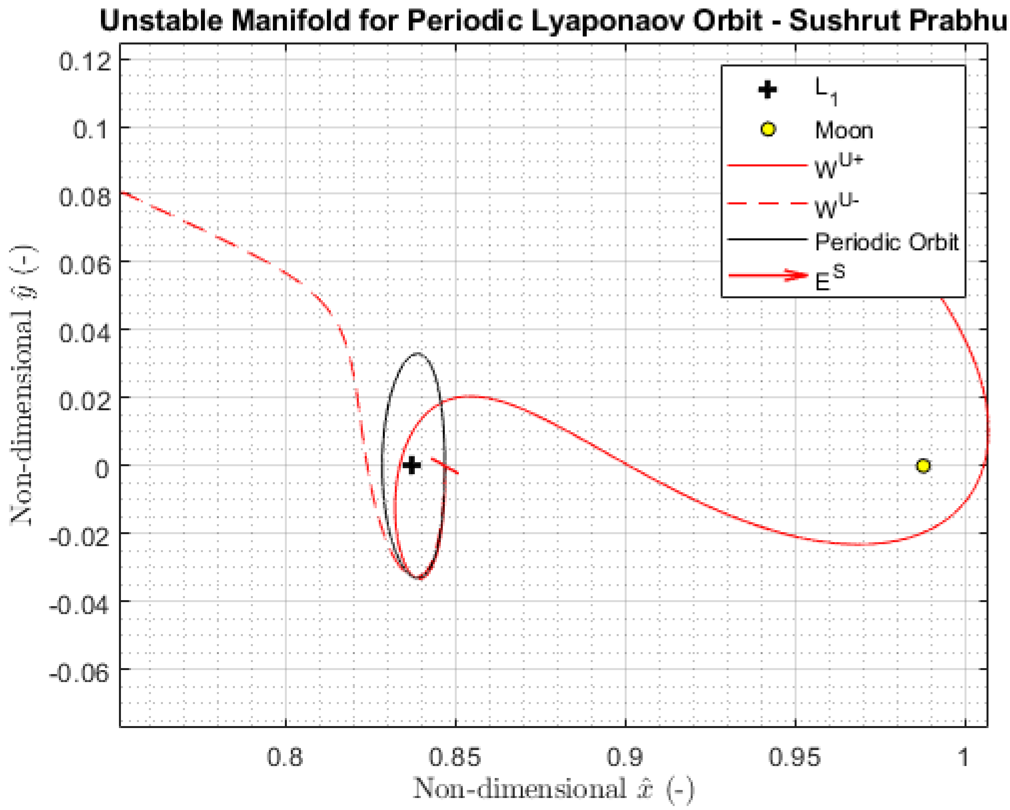

Stable Manifold for Periodic Lyaponaov Orbit 1/2 Period - Sushrut Prabhu
L_1
Moon
W^{S+}
W^{S-}
Periodic Orbit
E^U
Non-dimensional $\hat{y}$ (-)
Non-dimensional $\hat{x}$ (-)
0.1
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.1
0.75
0.8
0.85
0.9
0.95
1

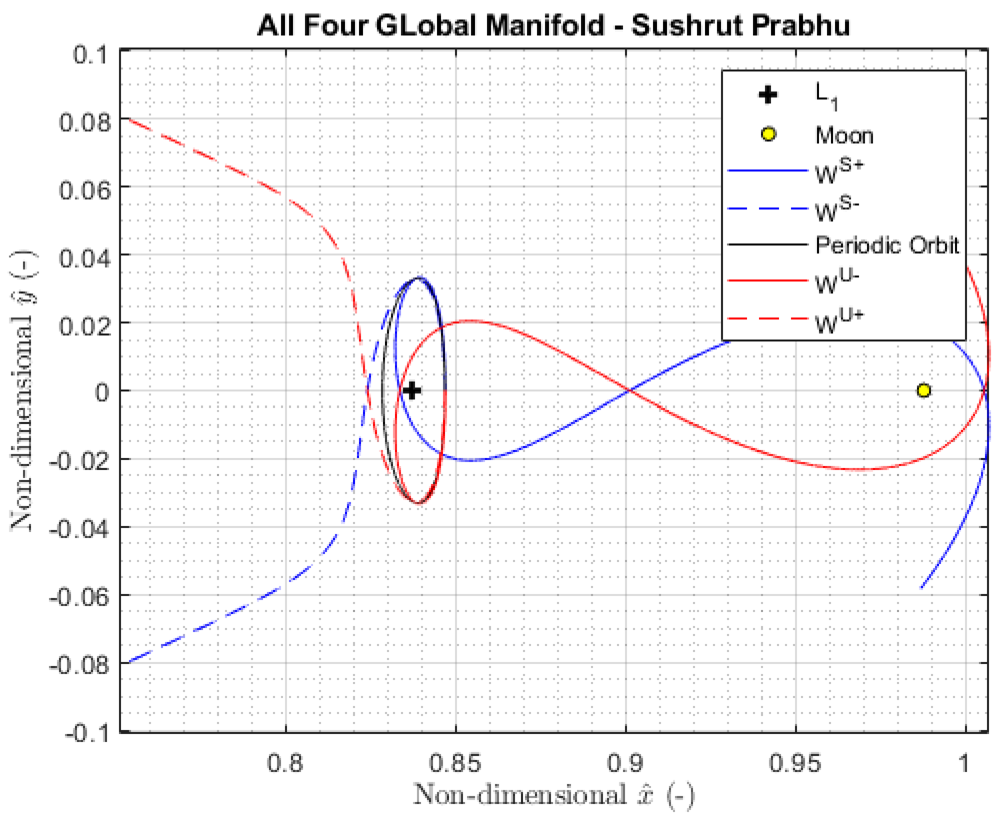

0.1
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.1
0.75
0.8
0.85
0.9
0.95
1

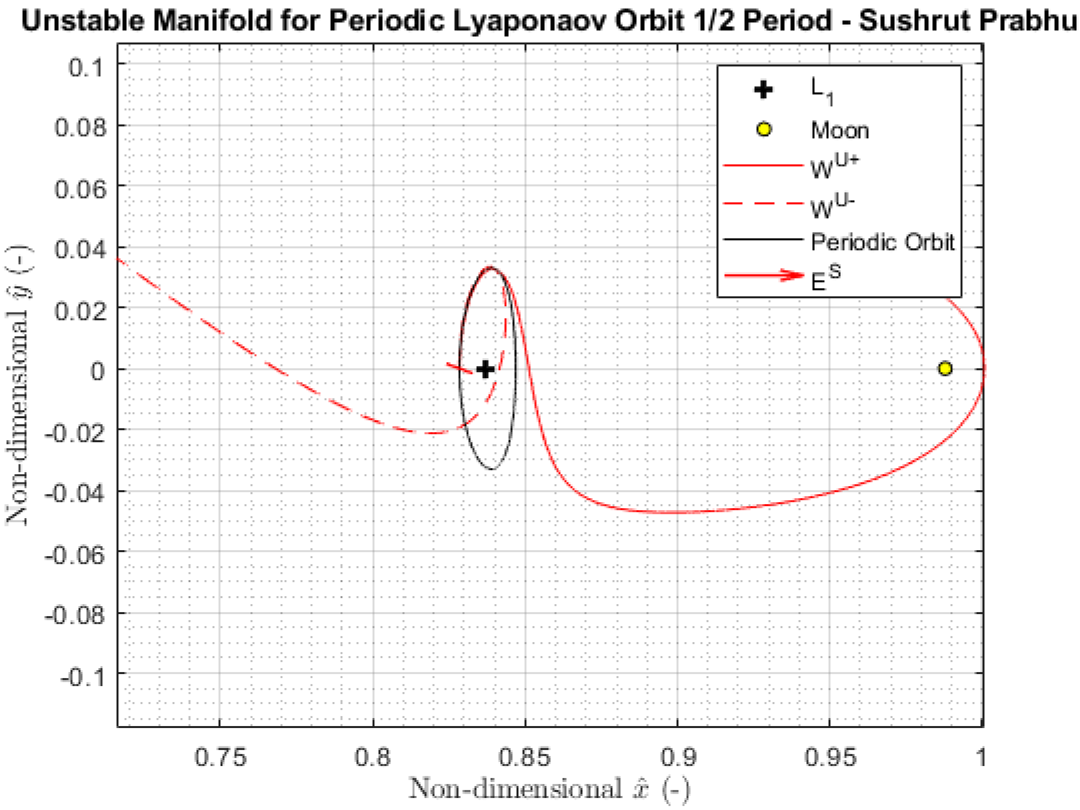
Part d

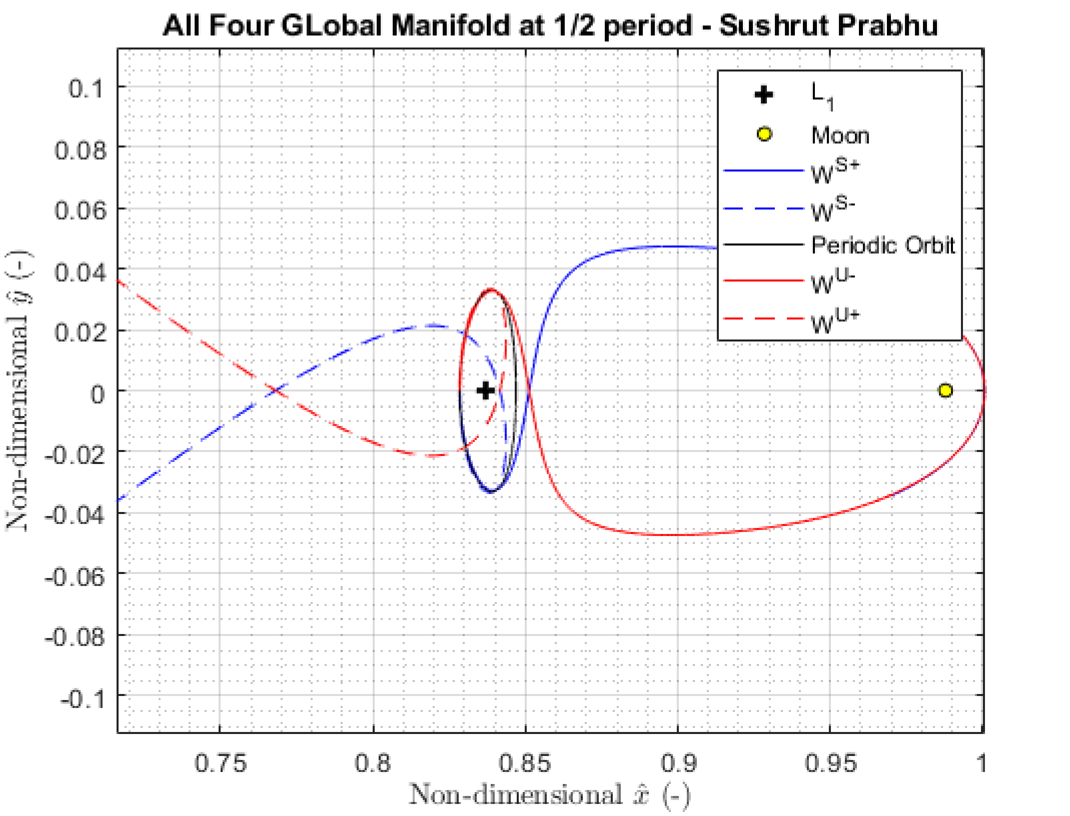
```
V_wu = V(:,1)/norm(V(1:3,1));      % Normalized v unstable
d = 40/dim_vals{2,2};
x_star = y(1,1:6);
t_end2 = 2.5;

xu1 = x_star + d*V_wu';
[~,y1] = ode45(@cr3bp_df,[0 t_end2],xu1,options,dim_vals{4,2});

xu2 = x_star - d*V_wu';
[~,y2] = ode45(@cr3bp_df,[0 t_end2],xu2,options,dim_vals{4,2});

figure
plot(dim_vals{7,2},0,'+k','LineWidth',2,'MarkerSize',7)
hold on
plot(1-dim_vals{4,2},0,'ko','MarkerSize',5,'MarkerFaceColor','y')
plot(y1(:,1),y1(:,2),'r')
plot(y2(:,1),y2(:,2),'--r')
plot(yfull(:,1),yfull(:,2),'k')
axis equal
quiver(y(1,1),y(1,2),V_wu(1)*.005,V_wu(2)*.005,'r','LineWidth',1)
quiver(y(1,1),y(1,2),-V_wu(1)*.005,-V_wu(2)*.005,'r','LineWidth',1)
grid on
grid minor
title('Unstable Manifold for Periodic Lyaponaov Orbit - Sushrut
 Prabhu')
xlabel("Non-dimensional $$\hat{x}$$ (-)","Interpreter", "latex")
ylabel("Non-dimensional $$\hat{y}$$ (-)","Interpreter", "latex")
legend('L_1','Moon','W^U^+','W^U^-','Periodic Orbit','E^S')

figure(2)
plot(y1(:,1),y1(:,2),'r')
plot(y2(:,1),y2(:,2),'--r')
grid on
grid minor
title('All Four GLobal Manifold - Sushrut Prabhu')
xlabel("Non-dimensional $$\hat{x}$$ (-)","Interpreter", "latex")
ylabel("Non-dimensional $$\hat{y}$$ (-)","Interpreter", "latex")
legend('L_1','Moon','W^S^+','W^S^-','Periodic Orbit','W^U^-','W^U^+')


V_wu = V_t2(:,1)/norm(V_t2(1:3,1));      % Normalized v stable
x_star = y(end,1:6);
t_end2 = 2.5;

xu1 = x_star + d*V_wu';
[~,y1] = ode45(@cr3bp_df,[0 t_end2],xu1,options,dim_vals{4,2});

xu2 = x_star - d*V_wu';
[~,y2] = ode45(@cr3bp_df,[0 t_end2],xu2,options,dim_vals{4,2});

figure
```

```
plot(dim_vals{7,2},0,'+k','LineWidth',2,'MarkerSize',7)
hold on
plot(1-dim_vals{4,2},0,'ko','MarkerSize',5,'MarkerFaceColor','y')
plot(y1(:,1),y1(:,2),'r')
plot(y2(:,1),y2(:,2),'--r')
plot(yfull(:,1),yfull(:,2),'k')
axis equal
quiver(y(end,1),y(end,2),V_wu(1)*.005,V_wu(2)*.005,'r','LineWidth',1)
quiver(y(end,1),y(end,2),-V_wu(1)*.005,-
V_wu(2)*.005,'r','LineWidth',1)
grid on
grid minor
title('Unstable Manifold for Periodic Lyaponaov Orbit 1/2 Period -
 Sushrut Prabhu')
xlabel("Non-dimensional $$\hat{x}$$ (-)","Interpreter", "latex")
ylabel("Non-dimensional $$\hat{y}$$ (-)","Interpreter", "latex")
legend('L_1','Moon','W^U^+','W^U^-','Periodic Orbit','E^S')

figure(4)
plot(y1(:,1),y1(:,2),'r')
plot(y2(:,1),y2(:,2),'--r')
grid on
grid minor
title('All Four GLobal Manifold at 1/2 period - Sushrut Prabhu')
xlabel("Non-dimensional $$\hat{x}$$ (-)","Interpreter", "latex")
ylabel("Non-dimensional $$\hat{y}$$ (-)","Interpreter", "latex")
legend('L_1','Moon','W^S^+','W^S^-','Periodic Orbit','W^U^-','W^U^+')
```


Unstable Manifold for Periodic Lyaponaov Orbit - Sushrut Prabhu
L_1
Moon
W^{U+}
W^{U-}
Periodic Orbit
E^S
Non-dimensional $\hat{y}$ (-)
Non-dimensional $\hat{x}$ (-)
0.12
0.1
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
0.8
0.85
0.9
0.95
1


All Four GLobal Manifold - Sushrut Prabhu
L_1
Moon
W^{S+}
W^{S-}
Periodic Orbit
W^{U-}
W^{U+}
Non-dimensional $\hat{y}$ (-)
Non-dimensional $\hat{x}$ (-)
0.1
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.1
0.8
0.85
0.9
0.95
1


Unstable Manifold for Periodic Lyaponaov Orbit 1/2 Period - Sushrut Prabhu
L1
Moon
WU+
WU-
Periodic Orbit
ES
Non-dimensional ŷ (-)
Non-dimensional x̂ (-)


All Four GLobal Manifold at 1/2 period - Sushrut Prabhu
L1
Moon
WS+
WS-
Periodic Orbit
WU-
WU+
Non-dimensional ŷ (-)
Non-dimensional x̂ (-)

Published with MATLAB® R2018a

Sushrut Prabhu | AAE 632 | PSG2

PSG2

Given: Earth-Moon 3 body problem

Find: a) Plot 3D Halo. Check periodic? Correct if needed

Are the orbits periodic?

b) Check perpendicular crossing. Check if they meet perpendicular crossing. Use continuation to find another orbit between the two halo orbits.

c) Lyapunov orbits, the bifurcating orbits were noted. Do these Halo orbit come from this?

Solution:

a) There are a couple of ways to check if orbit is periodic. Propogate for multiple periods and see if it is periodic. Yes, they are periodic

See Figure: G2.1, G2.2, G2.3, and G2.4

This orbit stays in that range for just under 5 periods. So this may be a propogation of numerical error

For perpendicular crossing stop the orbit after crossing the x-axis. The check velocity at $y = 0$. If $\dot{y} = 0$ then it is a perpendicular crossing. These orbits cross perpendicularly

continued...

b) The targetor we need to build is one that aims for a 3d perpendicular crossing.

Note: we can only change x_0, $\dot{y}_0$, and t ← time of flight

$$\therefore\ \delta x_f = \frac{\partial x}{\partial x_0}\delta x_0 + \frac{\partial x}{\partial \dot{y}_0}\delta \dot{y}_0 + \dot{x}\,\delta t$$

$$\therefore\ \delta z_f = \frac{\partial z}{\partial x_0}\delta x_0 + \frac{\partial z}{\partial \dot{y}_0}\delta \dot{y}_0 + \dot{z}\,\delta t$$

$$\therefore\ \delta \dot{y}_f = \frac{\partial \dot{y}}{\partial x_0}\delta x_0 + \frac{\partial \dot{y}}{\partial \dot{y}_0}\delta \dot{y}_0 + \ddot{y}\,\delta t$$

We have 3 equations and 3 unknown so the targetor should be relatively easier.

$$\therefore \begin{bmatrix} \delta x_f \\ \delta z_f \\ \delta \dot{y}_f \end{bmatrix} = \begin{bmatrix} \phi_{11} & \phi_{15} & \dot{x} \\ \phi_{31} & \phi_{35} & \dot{z} \\ \phi_{51} & \phi_{55} & \ddot{y} \end{bmatrix} \begin{bmatrix} \delta x_0 \\ \delta \dot{y}_0 \\ \delta t \end{bmatrix}$$

No, correction was need as the targetor yielded the same initial conditions

We use same targetor to get a new halo orbit. Select z_0 between the two Halo orbits and then target x_0, $\dot{y}_0$, and t. For the initial guess we can use average values of the two orbits

See figure: 62.1, 62.2, 62.3, and 62.4

<u>continued..</u>

c) Bifurcations occur when eigenvalue combination change in the Monodromy matrix. So we can reduce the step size to see where this actually occurs. See figure: G2.5.

It occurs at $x_0 = 0.8555$. But not the intial position of the halo orbits we have is on the Earth side. The x_0 position we have is on the Lunar side. So we can propogate this orbit for half a period to get $x_0 = 0.8233$.

Now use the targetor above to target at various z_0 values. Using a linear fit of the previous 2 orbits to guess the next.

See figures: G2.6, G2.7, G2.8, and G2.9 So the orbits given are a result of the bifurication at $x_0 = 0.8233$

PSG2

Part b)

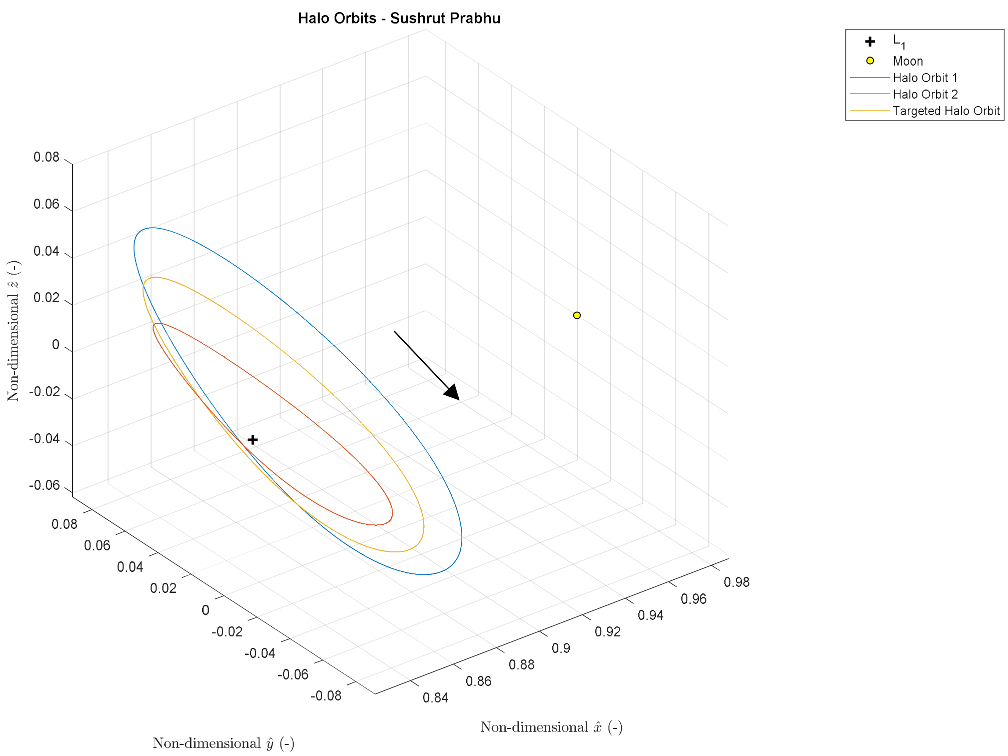


Figure G2.1: The two given halo orbits and one in between them.

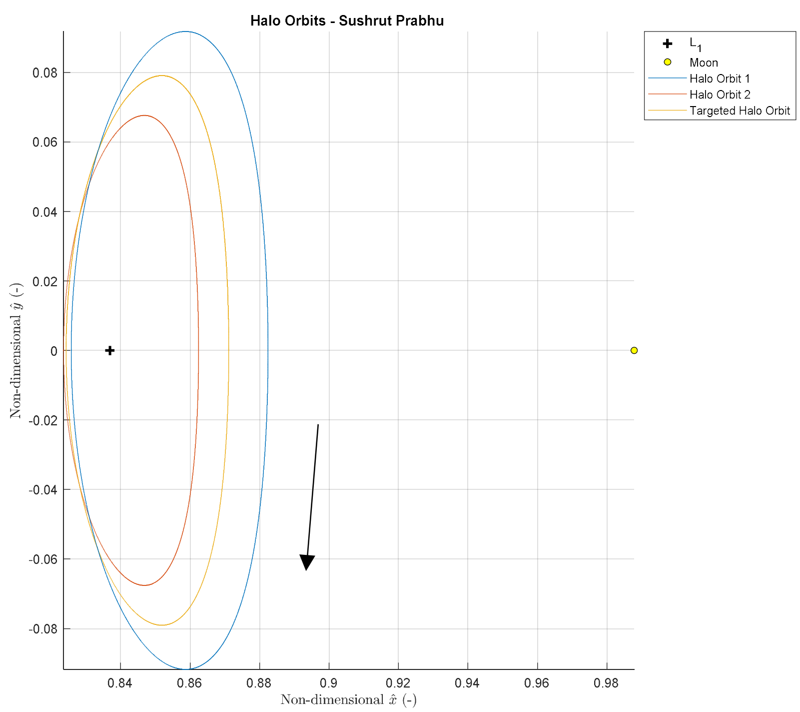


Figure G2.2: The x-y view of the two given halo orbits and one in between them.

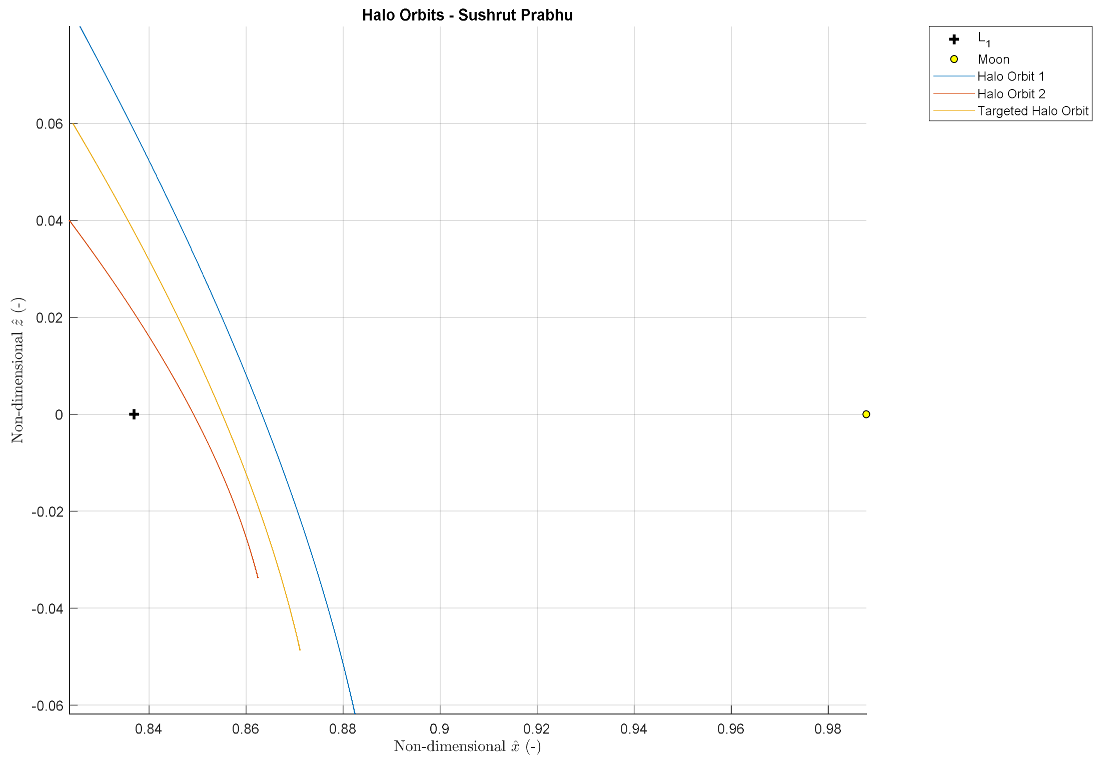


Figure G2.3: The x-z view of the two given halo orbits and one in between them.

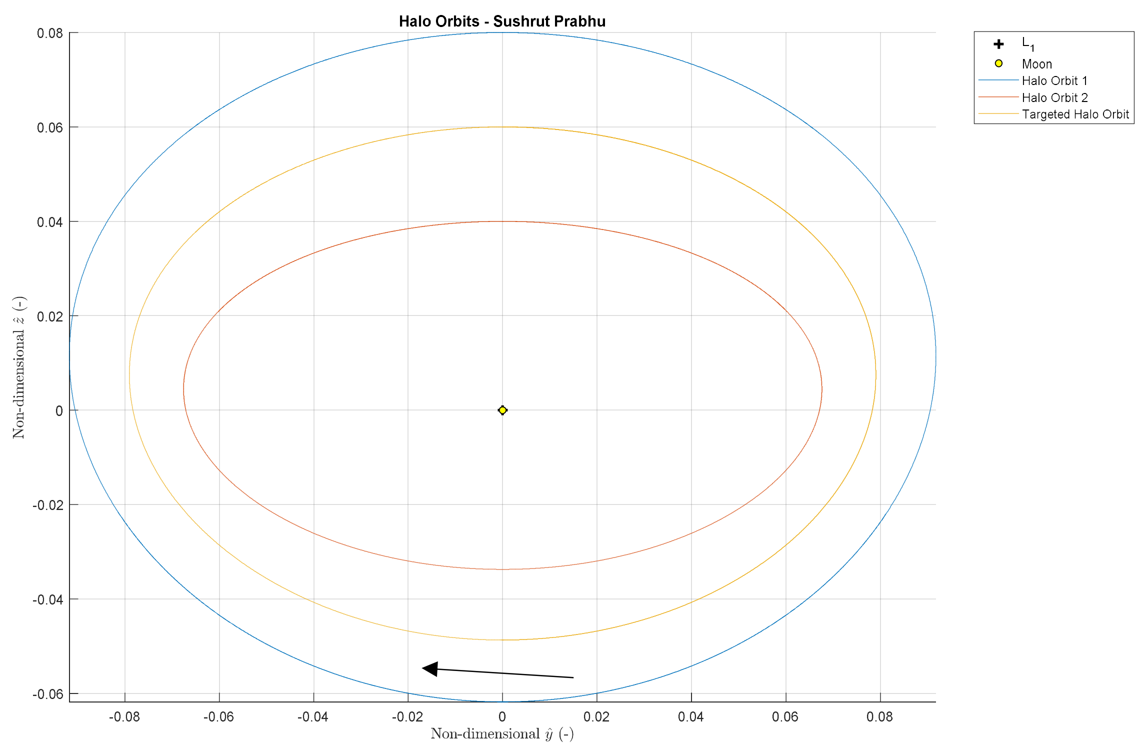


Figure G2.4: The y-z view of the two given halo orbits and one in between them

Part c)

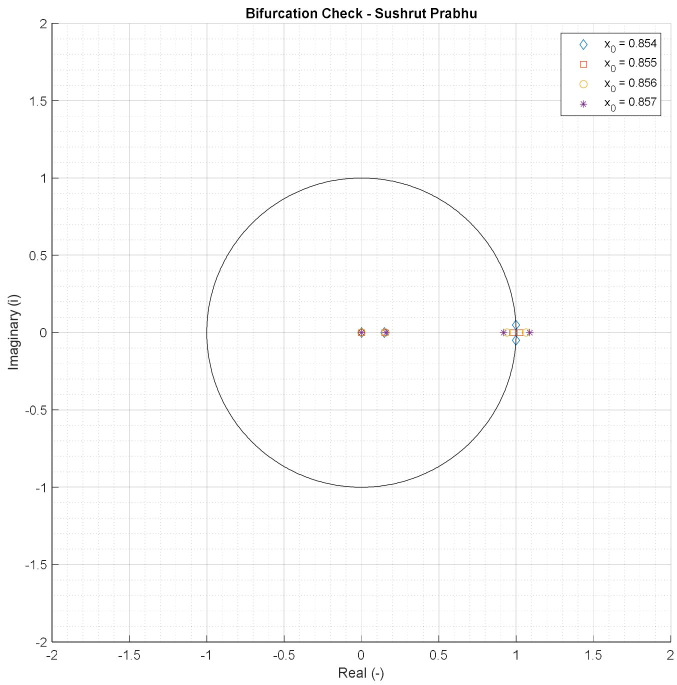


Figure G2.5: The bifurcation check with the eigenvalues of Monodromy.

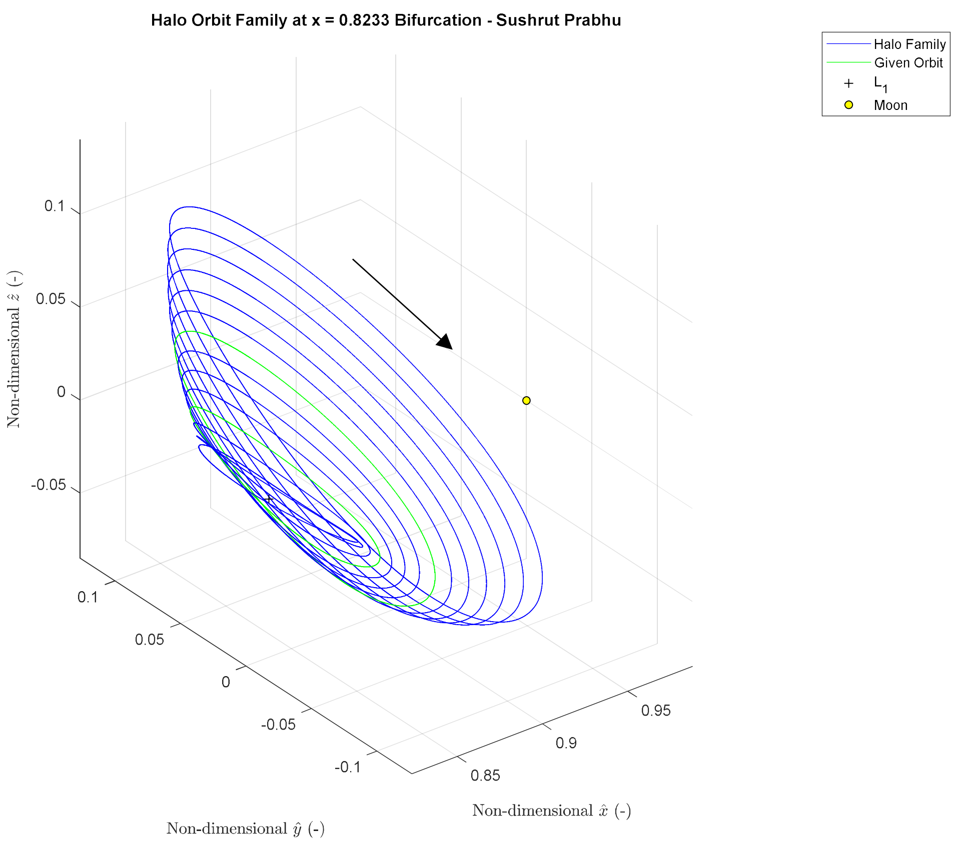


Figure G2.6: The Halo orbit family with the two given Halo orbits.

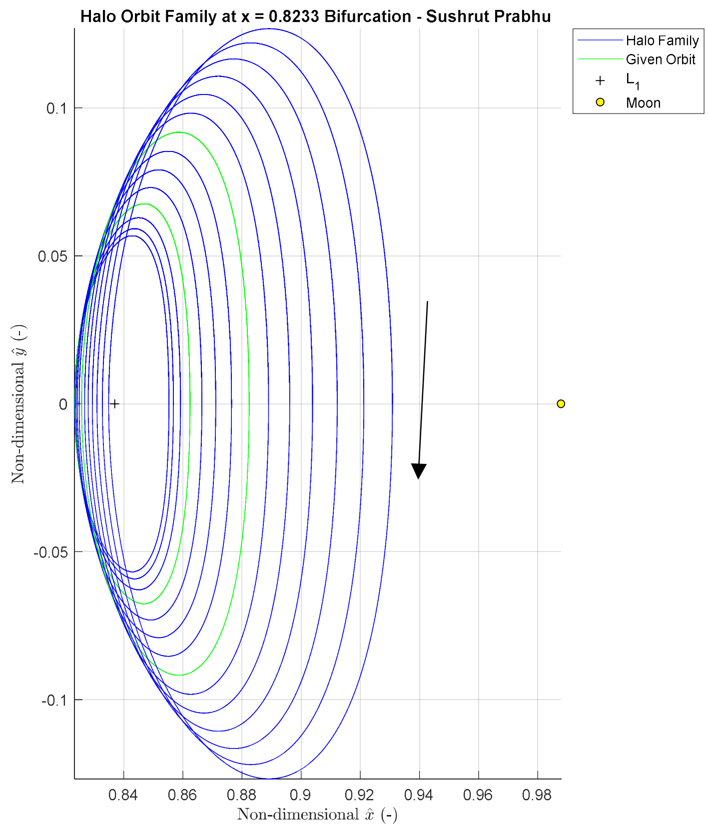


Figure G2.7: The Halo orbit family with the two given Halo orbits (x-y view).

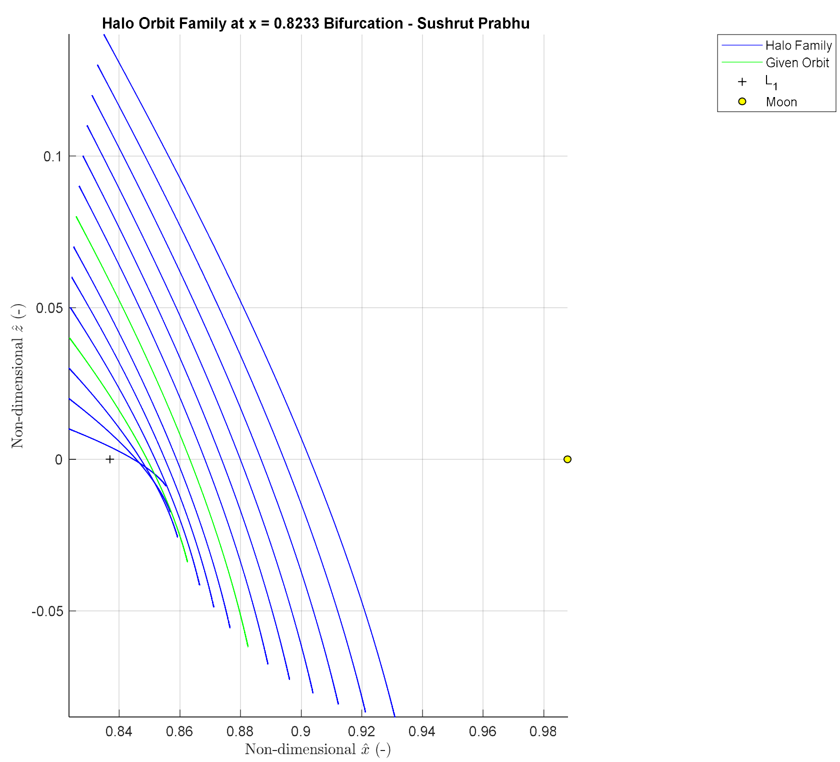


Figure G2.8: The Halo orbit family with the two given Halo orbits (x-z view).

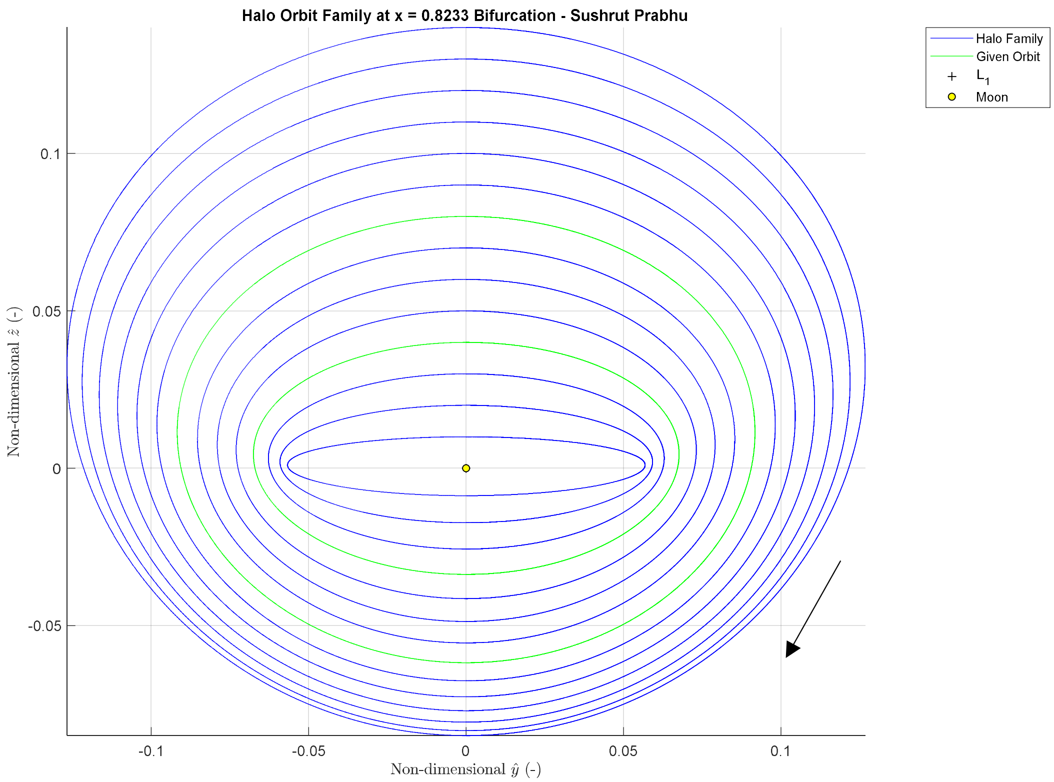


Figure G2.8: The alo orbit family with the two given Halo orbits (x-z view).

Table of Contents

PSG2 1
Part a) 1
Part b) 2
Part c) 3
Target Halo 7

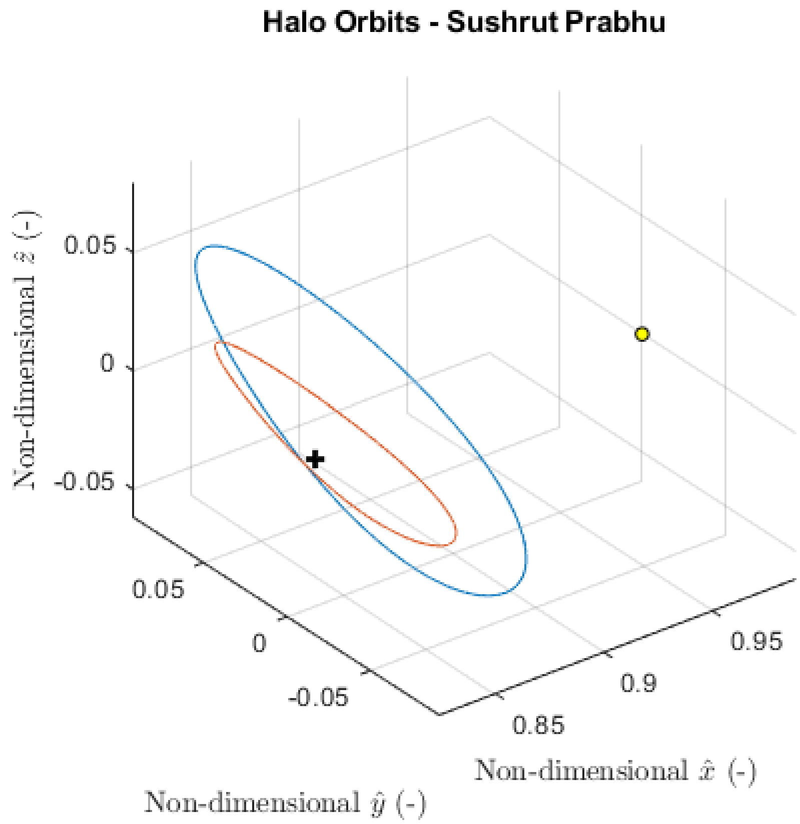
PSG2

```
clear
close all
clc

SS = SolarS;
systems = {'-', 'Earth-Moon'};
param = {'l* (km)','m* (kg)','miu' , 't*', 'gamma_1', 'L_1', 'gamma_1
 (km)', 'L_1 (km)'};
G = 6.6738*10^-20;
options=odeset('RelTol',1e-13, 'AbsTol',1e-15); % Sets integration
 tollerance

dim_vals = num2cell(zeros(length(param),1));
dim_vals = [systems; param',dim_vals];

% System Constants
[dim_vals{2,2}, dim_vals{3,2}, dim_vals{5,2}] =
 charE(384431.4584485,0,4902.799140594719/G,398600.4480734463/G);
   % Earth Moon
dim_vals{4,2} = 4902.799140594719/dim_vals{3,2}/G;   % miu

% Lagrange Point 1
dim_vals{6,2} = abs(L1_NRmethod(dim_vals{4,2}*.7,dim_vals{4,2},
 10^-8));
dim_vals{7,2} = 1-dim_vals{4,2} - dim_vals{6,2};
dim_vals{8,2} = dim_vals{6,2}*dim_vals{2,2};
dim_vals{9,2} = dim_vals{7,2}*dim_vals{2,2};
```

Part a)

```
IC1 = [0.82575887090385 0 0.08 0 0.19369724986446 0];
IC2 = [0.82356490862838 0 0.04 0 0.14924319723734 0];
t_end1 = 2.77648121127569;
t_end2 = 2.75330620148158;


% [IC1, t_end_half] = Target3d_per([0
 0],IC1(1:3),IC1(4:6),t_end1/2,dim_vals{4,2}, "planar", 10^-13, "");
% t_end1 = t_end_half*2*4;
%
```

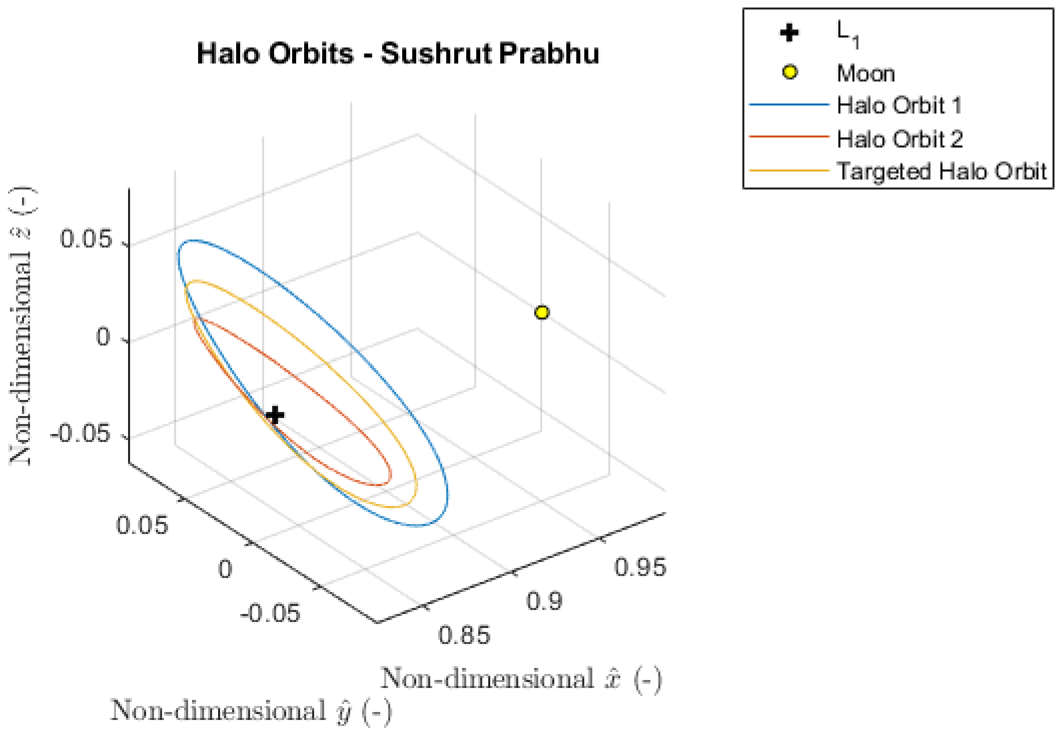
```
% [IC2, t_end_half] = Target3d_per([0
 0],IC2(1:3),IC2(4:6),t_end2/2,dim_vals{4,2}, "planar", 10^-13, "");
% t_end2 = t_end_half*2*4;

[~,y1]=ode45(@cr3bp_df,[0 t_end1],IC1,options,dim_vals{4,2});
[~,y2]=ode45(@cr3bp_df,[0 t_end2],IC2,options,dim_vals{4,2});

per1 = dot(y1(end,1:3),y2(end,1:3));
per2 = dot(y2(end,1:3),y2(end,1:3));

figure
plot3(dim_vals{7,2},0,0,'+k','LineWidth',2,'MarkerSize',7)
hold on
plot3(1-dim_vals{4,2},0,0,'ko','MarkerSize',5,'MarkerFaceColor','y')
plot3(y1(:,1),y1(:,2),y1(:,3))
plot3(y2(:,1),y2(:,2),y2(:,3))
axis equal
grid on
xlabel("Non-dimensional $$\hat{x}$$ (-)","Interpreter", "latex")
ylabel("Non-dimensional $$\hat{y}$$ (-)","Interpreter", "latex")
zlabel("Non-dimensional $$\hat{z}$$ (-)","Interpreter", "latex")
title('Halo Orbits - Sushrut Prabhu')
```



Part b)

```
IC3 = (IC1+IC2)/2;
```

```
[IC3, t_end_half] = Target3d_per([0 0
 0],IC3(1:3),IC3(4:6),t_end1/2,dim_vals{4,2}, "z0", 10^-13, "");
t_end3 = t_end_half*2;
[~,y3]=ode45(@cr3bp_df,[0 t_end3*1.5],IC3,options,dim_vals{4,2});

figure(1)
plot3(y3(:,1),y3(:,2),y3(:,3))
legend('L_1','Moon','Halo Orbit 1', 'Halo Orbit 2','Targeted Halo
 Orbit')
```

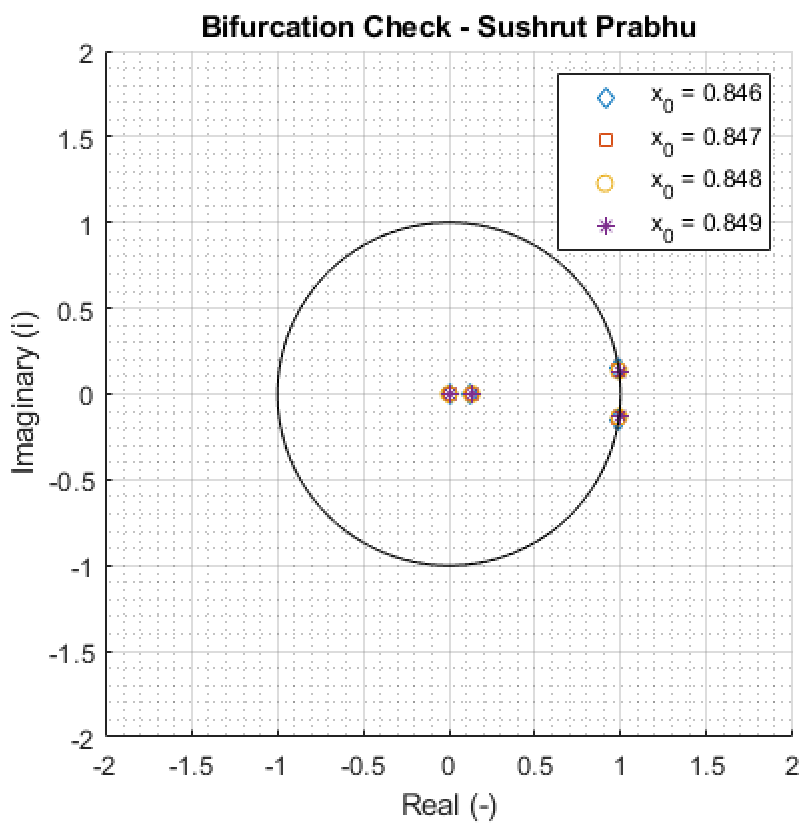


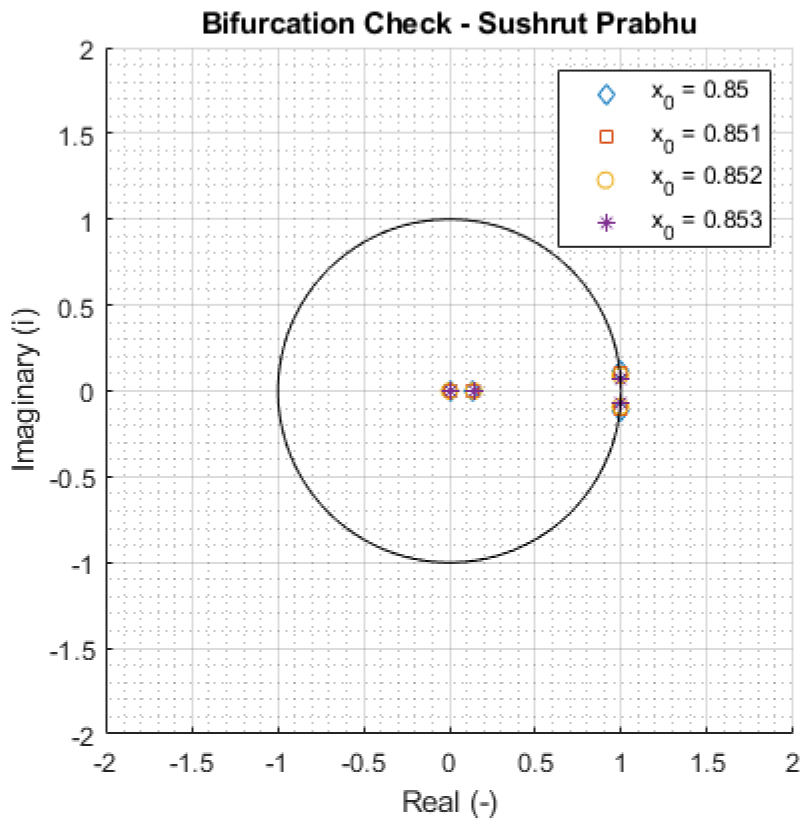
Part c)

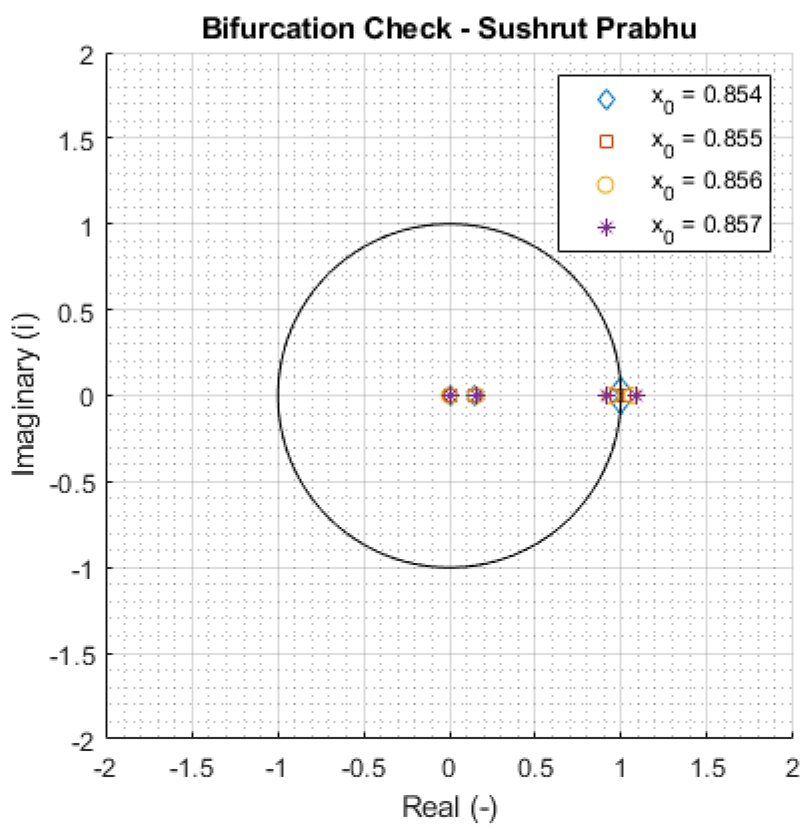
```
x_unit = cos(0:.01:(2*pi));
y_unit = sin(0:.01:(2*pi));

y = [.845, 0, 0, 0, -.08, 0];

x0_step = 0.001;
k = 1;
t_end = 2.72;
G = [1 0 0 0 0 0; 0 -1 0 0 0 0; 0 0 1 0 0 0; 0 0 0 -1 0 0; 0 0 0 0 1
 0;0 0 0 0 0 -1];
Omega = [0 1 0; -1 0 0; 0 0 0];
IC_end = [];
```

```
while k < 15
    % Inital Guess
    IC = [y(1,1:3),y(1,4:6)];

    if k > 2
        m = (yd0_vec(k-2) - yd0_vec(k-1)) / (x0_vec(k-2) -
 x0_vec(k-1));
        c = yd0_vec(k-1) - m*x0_vec(k-1);
        yg = m*(x0_step+y(1))+c;
        IC = [y(1,1:3),0,yg,0];
    end

    ICm = IC + [x0_step, 0, 0, 0, 0, 0];
    [t,y] = ode45(@cr3bp_df,[0 t_end],ICm,options,dim_vals{4,2});

    t_end = t(find(y(:,2)>0,1));
    clear t

    rv_des = [0 0]';    % y = 0 and xfdot = 0
    [yn,t_end] =
 Target3d_per(rv_des,ICm(1:3),IC(4:6),t_end,dim_vals{4,2},"planar",
 10^-13,"");

    % Final plot and solution
    IC_stm = eye(6);
    IC_stm = IC_stm(:)';
    IC = [yn(1,1:6), IC_stm];
    t_end = t_end;
    [~,y] = ode45(@cr3bp_STM_df3d,[0 t_end],IC,options,dim_vals{4,2});

    % Method 2
    stm_12 = reshape(y(end,7:end),6,6);
    monodromy = G* [zeros(3,3), -eye(3);eye(3),
 -2*Omega]*stm_12.'*[-2*Omega, eye(3); -eye(3), zeros(3,3)]*G*stm_12;

    [V,D] = eig(monodromy);
    Dvec(k,:) = diag(D)';

    t_end = 2*t_end;
%     [t,y] = ode45(@cr3bp_df,[0
 t_end],yn(1,1:6),options,dim_vals{4,2});
%
    x0_vec(k) = y(1,1);
    yd0_vec(k) = y(1,5);
    IC_end = [IC_end; y(end,1:6)];

    if rem(k,4) == 0
        figure
        hold on
        plot(real(Dvec(k-3,:)),imag(Dvec(k-3,:)),'d')
        plot(real(Dvec(k-2,:)),imag(Dvec(k-2,:)),'s')
        plot(real(Dvec(k-1,:)),imag(Dvec(k-1,:)),'o')
        plot(real(Dvec(k,:)),imag(Dvec(k,:)),'*')
        plot(x_unit,y_unit,'k')
```

```
        axis equal
        grid on
        grid minor
        xlim([-2 2])
        ylim([-2 2])
        legend(['x_0 = ' num2str(x0_vec(k-3))],['x_0 = '
 num2str(x0_vec(k-2))],['x_0 = ' num2str(x0_vec(k-1))],['x_0 = '
 num2str(x0_vec(k))])
        xlabel('Real (-)')
        ylabel('Imaginary (i)')
        title('Bifurcation Check - Sushrut Prabhu')
    end

    k = k+1;
end
```



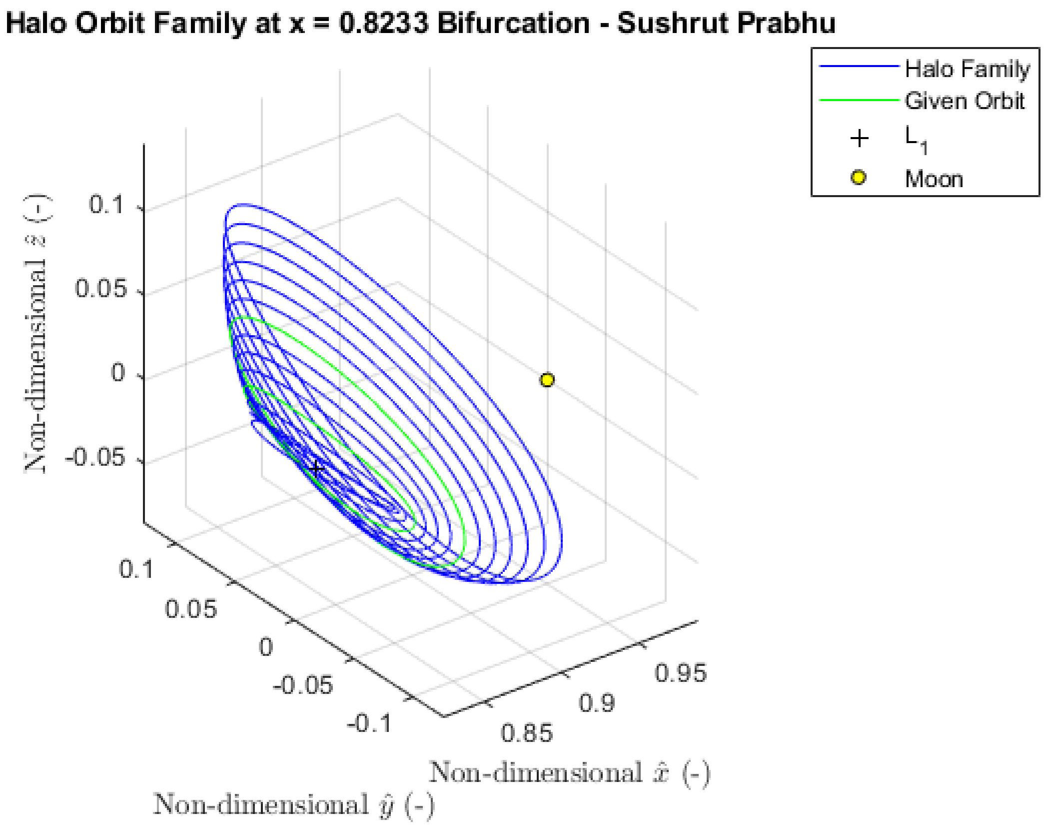

Bifurcation Check - Sushrut Prabhu
Imaginary (i)
Real (-)
x0 = 0.85
x0 = 0.851
x0 = 0.852
x0 = 0.853
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2


Bifurcation Check - Sushrut Prabhu
Imaginary (i)
Real (-)
x0 = 0.854
x0 = 0.855
x0 = 0.856
x0 = 0.857
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2

Target Halo

```
y_halo = [0.8233, 0, 0, 0, 0.127531244599002, 0];
z_step = 0.005;
k = 1;
l = 1;
IC_vec= [];

figure

while k < 30

    IC_guess = y_halo(1,:) + [0 0 z_step 0 0 0];

    [IC_halo, t_end_half] = Target3d_per([0 0
 0],IC_guess(1:3),IC_guess(4:6),t_end1/2,dim_vals{4,2}, "z0",
 10^-13, "");
    IC_vec = [IC_vec; IC_halo];
    t_end3 = t_end_half*2;
    [~,y_halo]=ode45(@cr3bp_df,[0
 t_end3*1.5],IC_halo,options,dim_vals{4,2});

    if rem(k,2) == 0
        if IC_halo(3) == 0.04 || IC_halo(3) == 0.08
            colour = 'g';
            l = l+1;
        else
            colour = 'b';
        end
        ly_plt = plot3(y_halo(:,1),y_halo(:,2),y_halo(:,3),colour);
        hold on
    end

    if rem(k,2) == 0
        if k == 2 || k == 8

 set(get(get(ly_plt,'Annotation'),'LegendInformation'),'IconDisplayStyle','on');
        else

 set(get(get(ly_plt,'Annotation'),'LegendInformation'),'IconDisplayStyle','off');
        end
    end

    k= k+1;
end

plot3(dim_vals{7,2},0,0,'+k')
plot3(1-dim_vals{4,2},0,0,'ko','MarkerSize',5,'MarkerFaceColor','y')
axis equal
grid on
xlabel("Non-dimensional $$\hat{x}$$ (-)","Interpreter", "latex")
ylabel("Non-dimensional $$\hat{y}$$ (-)","Interpreter", "latex")
zlabel("Non-dimensional $$\hat{z}$$ (-)","Interpreter", "latex")
```

```
title("Halo Orbit Family at x = 0.8233 Bifurcation - Sushrut Prabhu")
legend('Halo Family', 'Given Orbit','L_1','Moon')
```



Published with MATLAB® R2018a

PSG3

Find a) Remake Henon Map $\mu = 0.5$ and $J_c = 4.5$

b) Using the identify periodic orbits and plot.

c) Reduce Jacobi Constant. How does it change?

i) Onset of Choatic

ii) Plot quasi periodic and periodic orbit

d) Change μ. what change?

e) Plot Lyapunov Jacobi in Earth-Moon system

Solution:

a) To create the map you just need to stop the integration when we hit the hyper plane.

The hyper plane is 2D because we will be plotting a 2D orbit. Furthermore, by constraining the elements we can understand the behaviours.

By constraining elements we reduce the problem to 2-D. $C = C_0$ and $y = 0$: x and $\dot{x}$ are free and $\dot{y}$ is constrained by C

See Figure: G3.1

The quasi-Periodic Orbit is one has a periodi pattern $x_0 = -0.609$ and $\dot{y}_0 = 2.4216$ ← From Jacobi constraint

See Figure: G3.2 and G3.3

Continued...

b) After zooming into periodic patterns on the map we can approximate the x_0 values.

$x_0 = -0.6333$ } Then use a targeter to check periodic orbit and Jacobi.
$x_0 = -0.3078$

See Figure: G3.4

I used a simple planar targetor that doesn't account for Jacobi Constant so my Jacobi constant is accurate to 10^{-6}. This is not too bad but you can build a targeter that constrains the Jacobi constant. See Figures: Propogate for multiple orbits. These stay around P_1 for 10-15 orbits

c) The Jacobi value I chose was $C = 3.8$

i) Some parts of the map become more chotic. But there are still some patterns

ii) There is some periodic behaviour around $x_0 = -0.6615$ See Figure: G3.5 and G3.7
There is also quasi-periodic behavior around $x_0 = -0.609$ See Figure: G3.5 and G3.6
There seem to be fewer periodic behaviours in this Jacobi constant

Continued...

d) The new value of gravitational constant $\mu = 0.75$
I am using the sam Jacobi constant $C = 3.8$
The map changes a lot there are some new patterns that emerge and there are still periodic behaviourss. There are some new solutions that emerge
See Figures: G3.8, G3.9, G3.10
You have to zoom in to notice some of these patterns

e) Yes, you can see the Lyaponov orbit.
The, map looks different to all the previous ones. The Lyponov orbit would be at $x_0 = 0.935$ This what is expected.
You can see the zoomed in view too
See Figure: G3.11 and G3.12

PSG3

Part a)

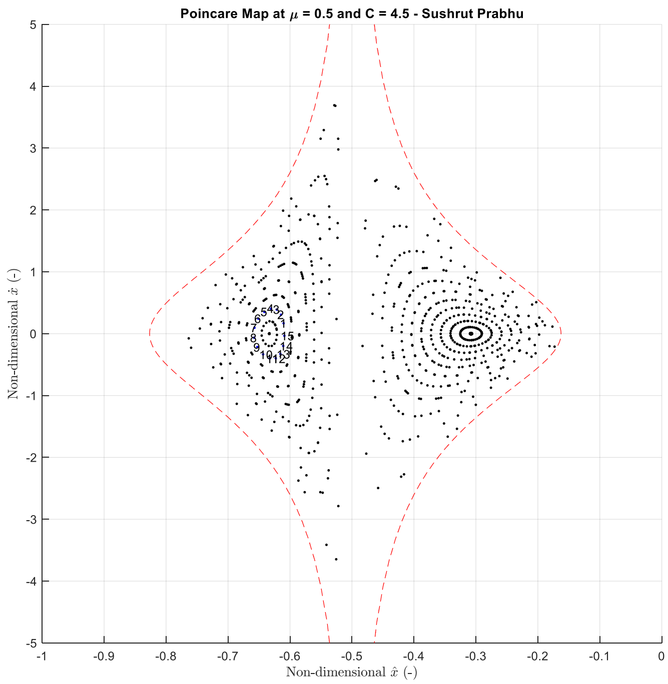


Figure G3.1: The Poincare map of the Henon problem.

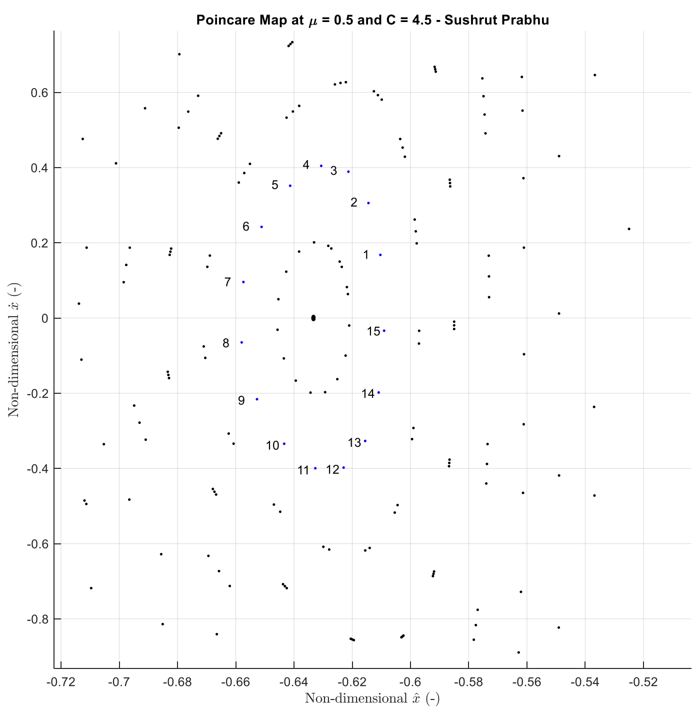


Figure G3.2: The Poincare map of the Henon problem zoomed in at the quasi periodic orbit.

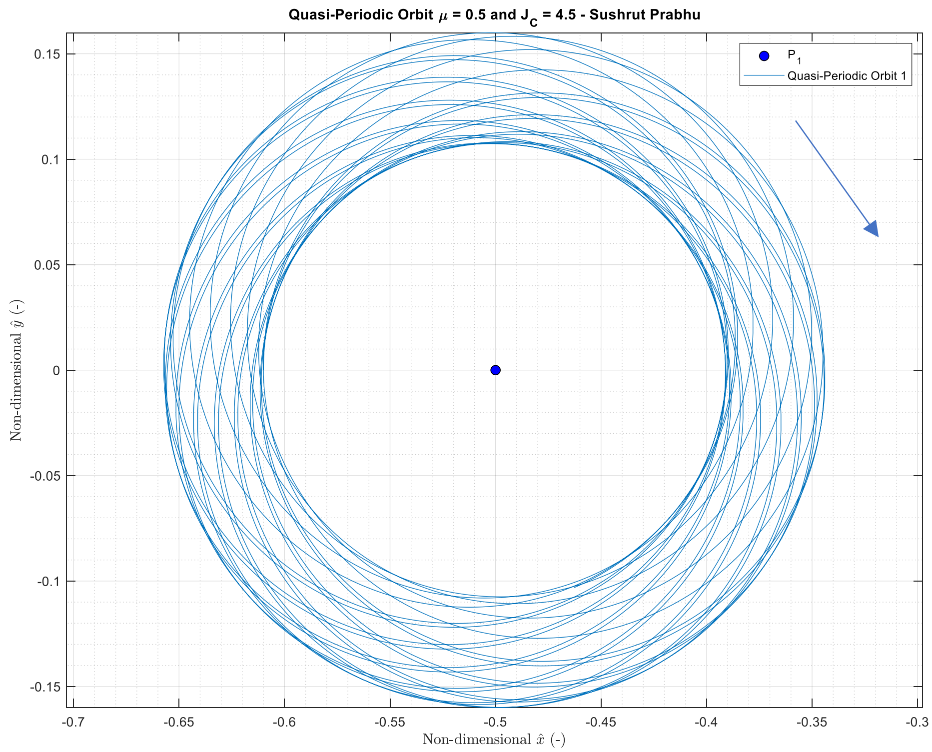


Figure G3.3: The quasi-periodic orbit from the above Poincare map.

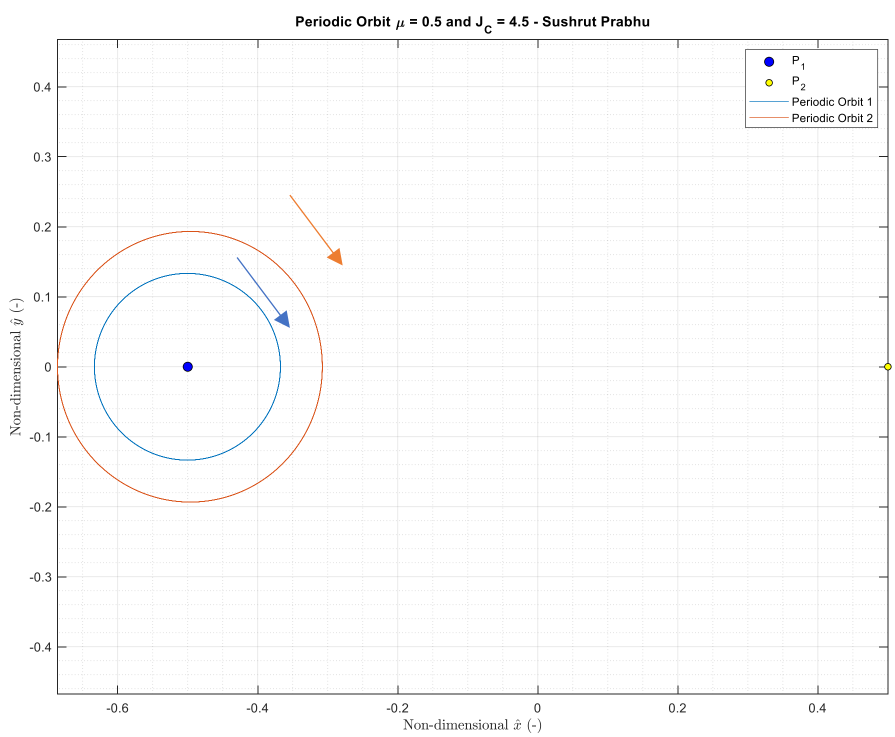


Figure G3.4: The two periodic orbits from the above Poincare map.

Part b)

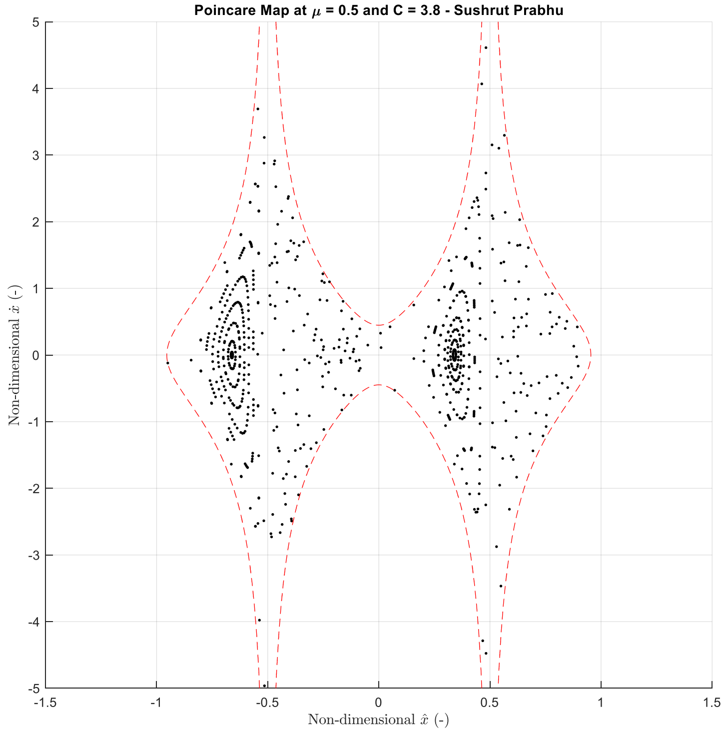


Figure G3.5: The Poincare map with different Jacobi.

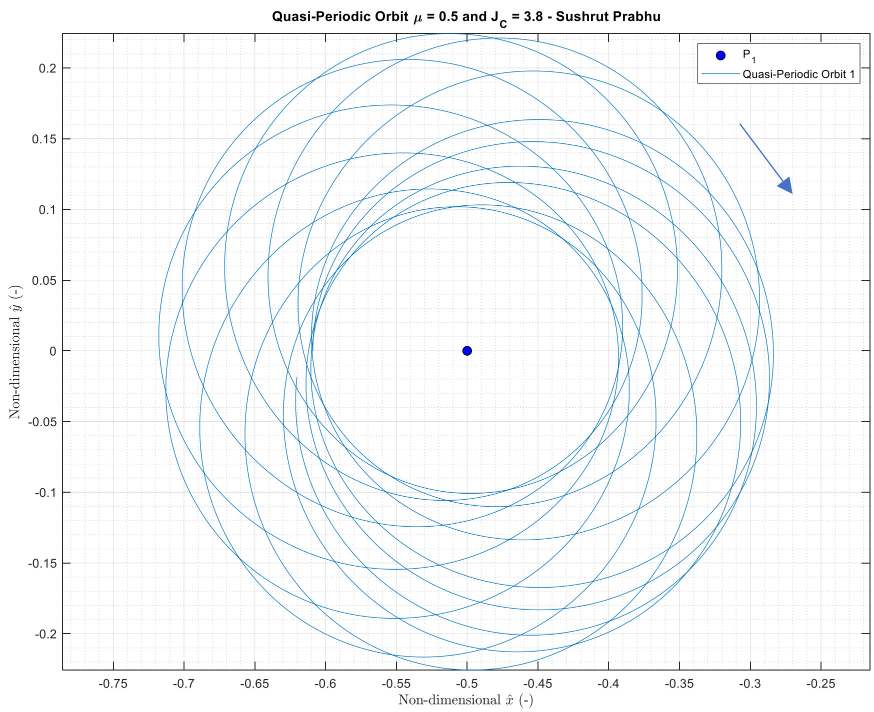


Figure G3.6: The quasi-periodic orbit from the above Poincare map.

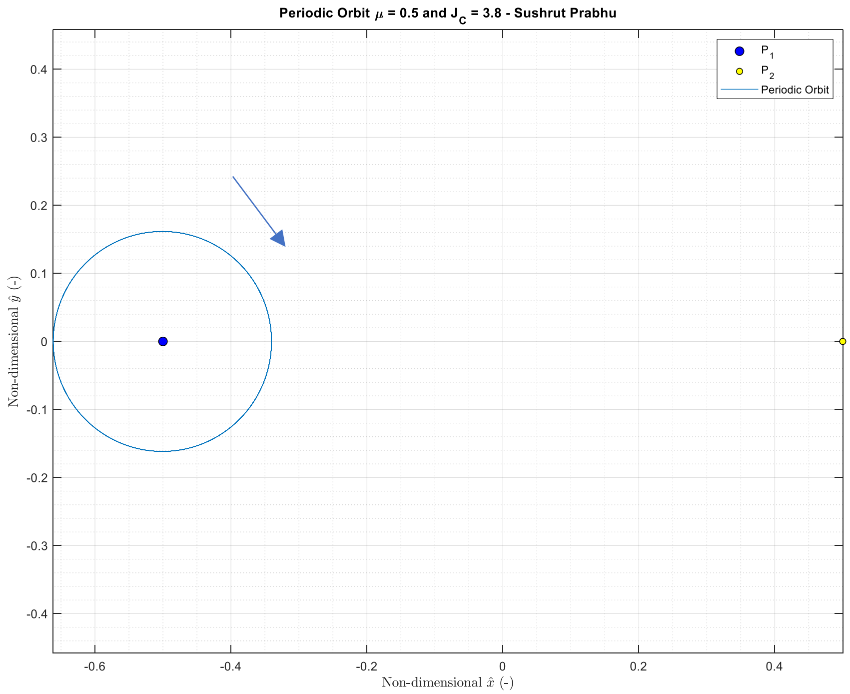


Figure G3.7: The periodic orbit on the left side from the above map.

Part c)

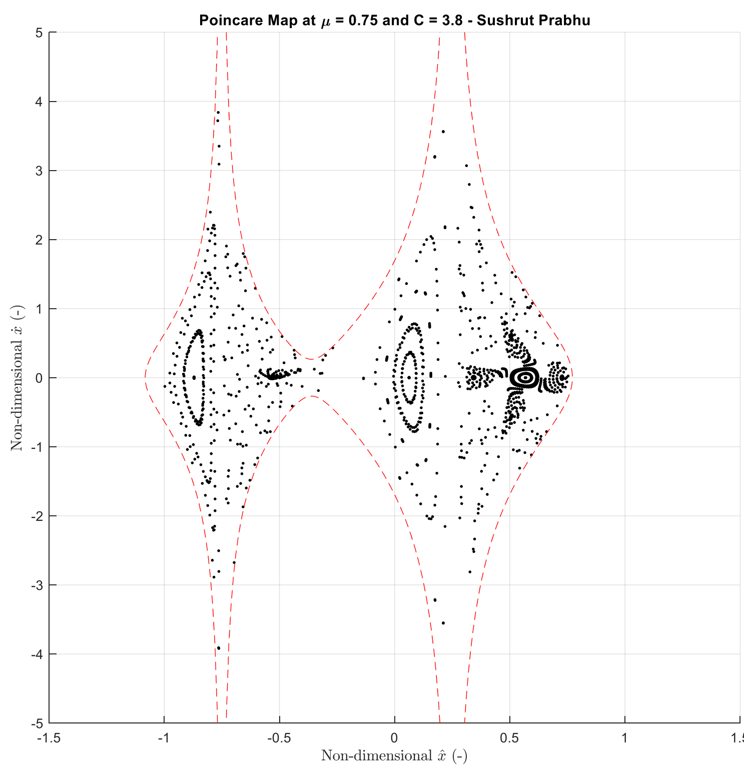


Figure G3.8: Poincare map of a different gravitational constant.

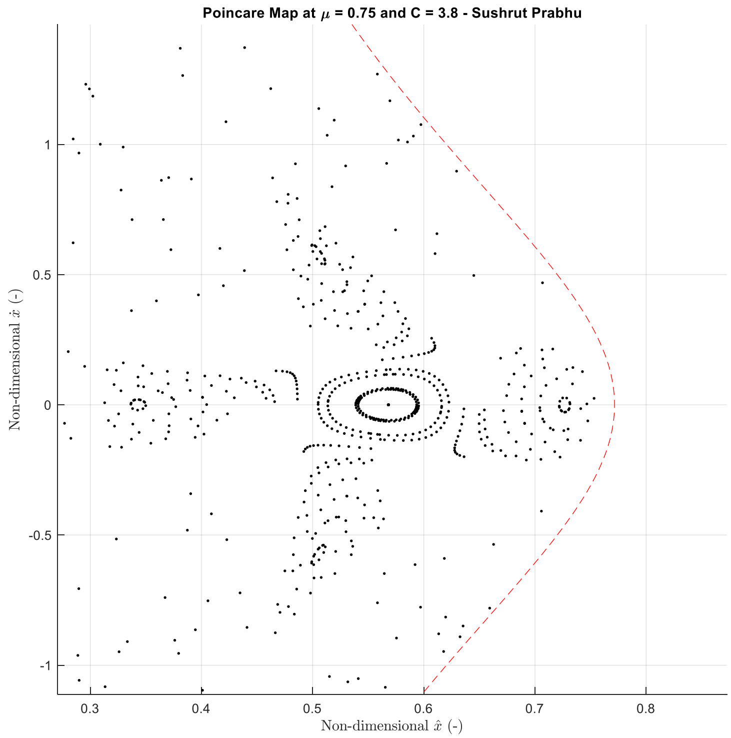


Figure G3.9: Poincare map of a different gravitational constant.

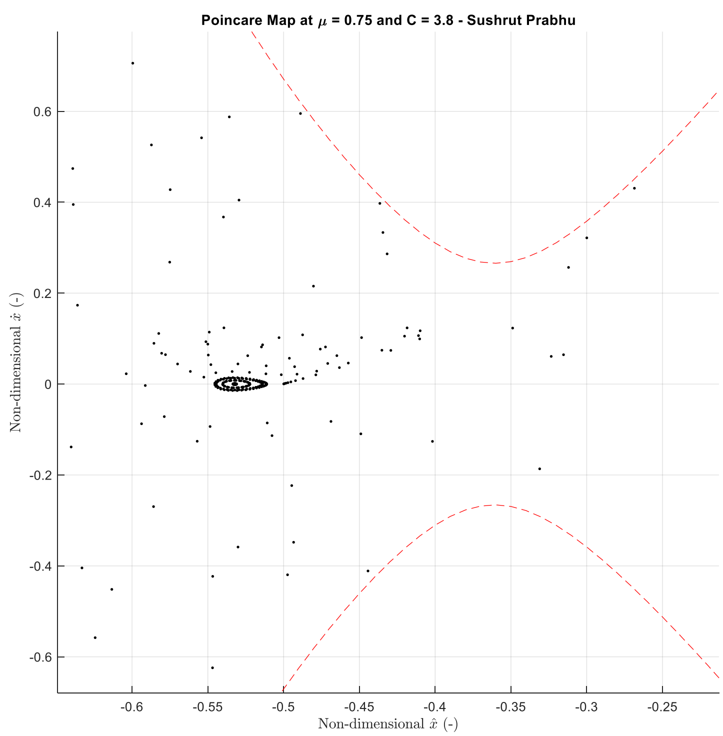


Figure G3.10: Poincare map of a different gravitational constant zoomed at periodic orbits.

Part d)

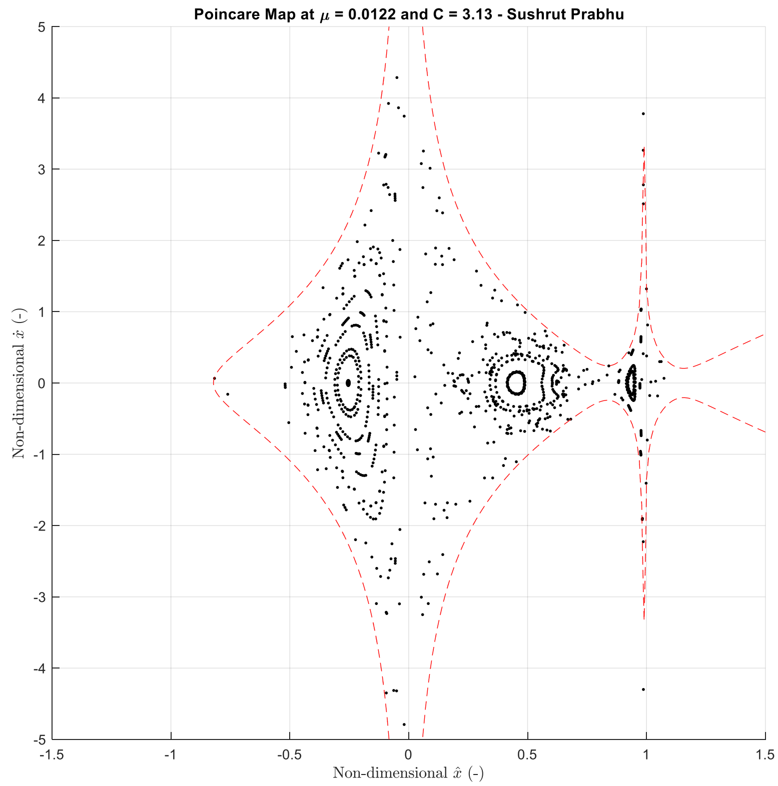


Figure G3.11: Poincare map of Earth Moon.

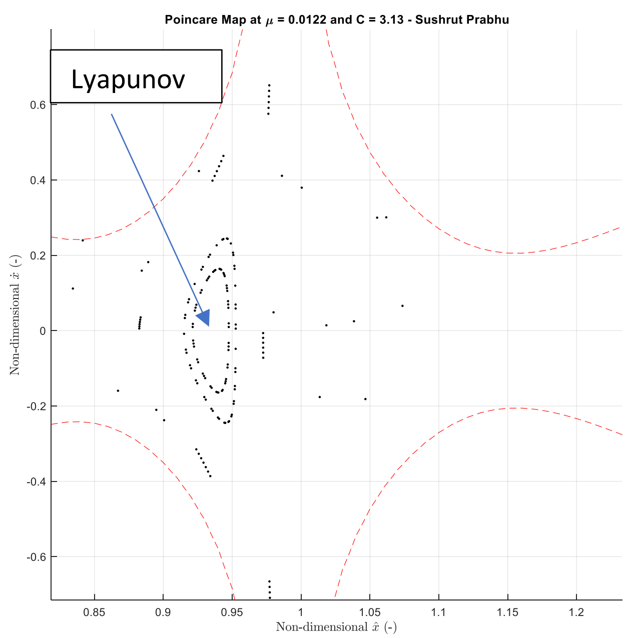


Figure G3.12: Poincare map of Earth Moon zoomed at Lyponov.

Table of Contents

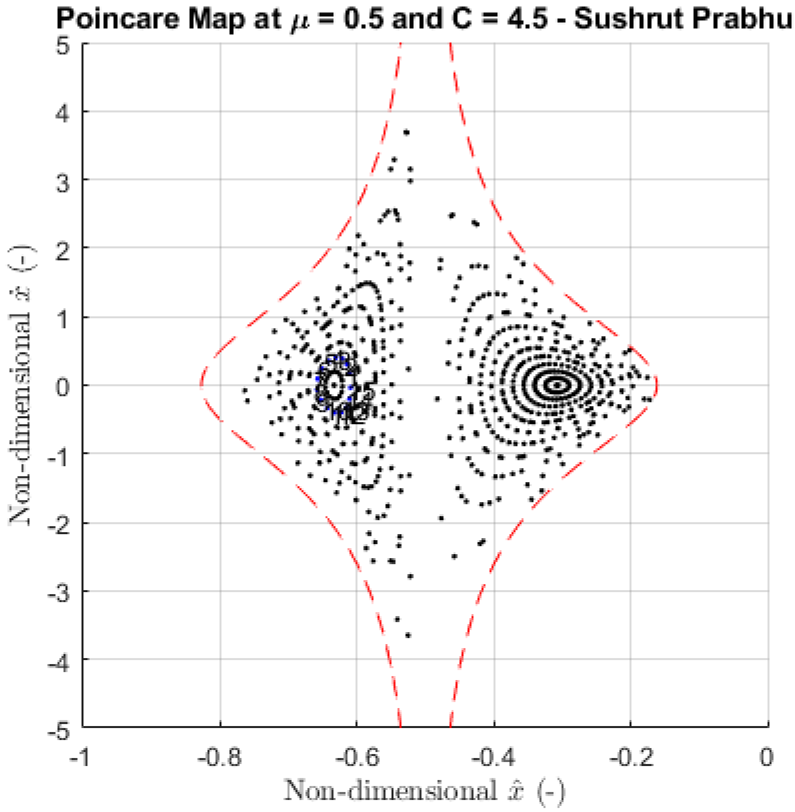
PSE1 1
Part a) 2
Quasi 3
Part b) 4
Part c i) 5
Part d) 9
Part e) 11

PSE1

```
clear
close all
clc

SS = SolarS;
systems = {'-', 'Earth-Moon'};
param = {'l* (km)','m* (kg)','miu' , 't*', 'gamma_1', 'L_1', 'gamma_1
 (km)', 'L_1 (km)','gamm_2', 'L_2', 'gamma_2 (km)', 'L_2 (km)'};
G = 6.6738*10^-20;
options=odeset('RelTol',1e-12, 'AbsTol',1e-15,'Events',@myEvent); %
 Sets integration tollerance
options2=odeset('RelTol',1e-12, 'AbsTol',1e-15); % Sets integration
 tollerance

dim_vals = num2cell(zeros(length(param),1));
dim_vals = [systems; param',dim_vals];

% System Constants
[dim_vals{2,2}, dim_vals{3,2}, dim_vals{5,2}] =
 charE(SS.dM_E,0,SS.mMoon/G,SS.mEarth/G);        % Earth Moon
% dim_vals{4,2} = SS.mMoon/dim_vals{3,2}/G;   % miu
dim_vals{4,2} = .5;   % miu

% Lagrange Point 1
dim_vals{6,2} = abs(L1_NRmethod(dim_vals{4,2}*.7,dim_vals{4,2},
 10^-8));
dim_vals{7,2} = 1-dim_vals{4,2} - dim_vals{6,2};
dim_vals{8,2} = dim_vals{6,2}*dim_vals{2,2};
dim_vals{9,2} = dim_vals{7,2}*dim_vals{2,2};


% Lagrange Point 2
dim_vals{10,2} = abs(L2_NRmethod(dim_vals{4,2}*1.1,dim_vals{4,2},
 10^-8));
dim_vals{11,2} = 1 + dim_vals{10,2};
dim_vals{12,2} = dim_vals{10,2}*dim_vals{2,2};
dim_vals{13,2} = dim_vals{11,2}*dim_vals{2,2};
```

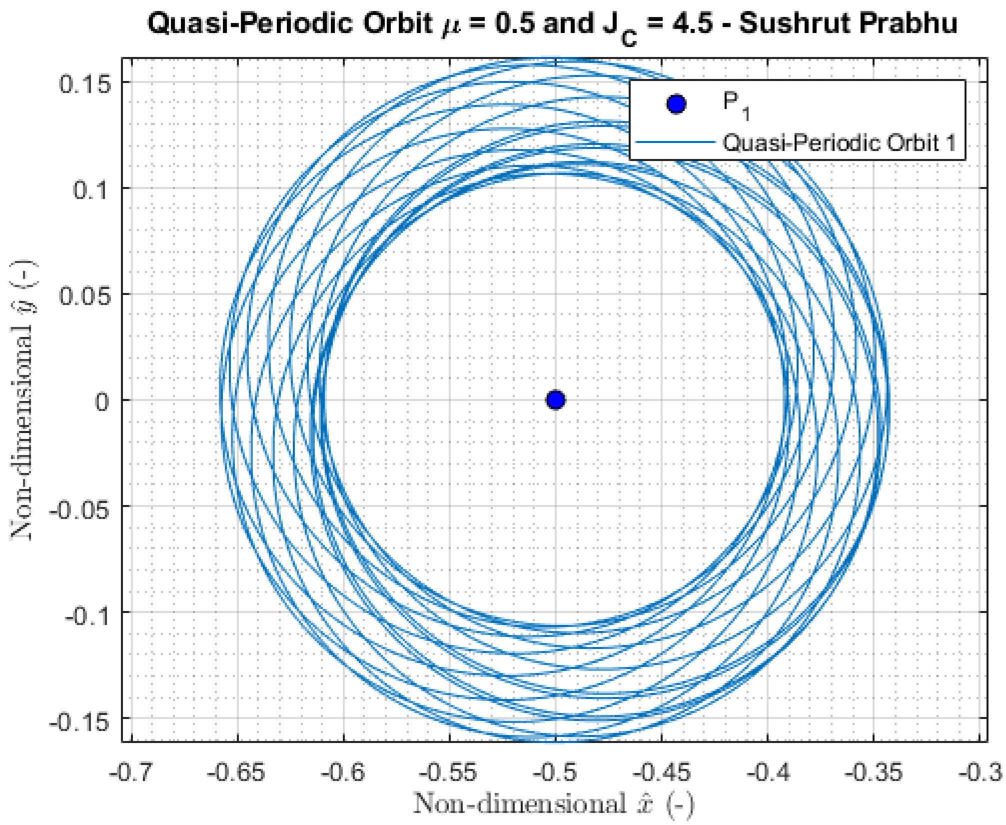
Part a)

```
C0 = 4.5;
tol = 10^-13;

figure(1)
hold on
for x0 = [linspace(-.525,-.633,10), linspace(-.3095,-.483,12)]
ydot_0 = sqrt(Jacobi_C(x0,0,0,0,dim_vals{4,2})-C0);
t_end = 10;
y = [x0 0 0 0 ydot_0 0];
x_xdot = [];
y1 = [];
k = 1;
stop = [];
error = 10^-13;
    while error < 10^-10
        IC = y(end,:);
        [~,y] = ode45(@cr3bp_df,[0 t_end],IC,options,dim_vals{4,2});
        error = abs(C0 -
 Jacobi_C(y(end,1),y(end,2),y(end,3),norm(y(end,4:6)),dim_vals{4,2}));
        if rem(k,2) == 0
            x_xdot = [x_xdot;y(end,1),y(end,4)];
        end

        k = k+1;
        if k > 100
            error = 1;
        end
    end
    if x0 == -.609
        plot(x_xdot(1:15,1),x_xdot(1:15,2),'.b')
        for n = 1:15
            text(x_xdot(n,1)*1.01,x_xdot(n,2)*1.01,num2str(n))
        end
    else
        plot(x_xdot(:,1),x_xdot(:,2),'.k')
    end


end
% JC Limit
[X,V] = meshgrid(-1:0.01:0,-5:0.01:5);
C = Jacobi_C(X,0,0,V,dim_vals{4,2});

contour(X,V,-C,-[C0 C0],'--r');
axis square
xlabel("Non-dimensional $$\hat{x}$$ (-)","Interpreter", "latex")
ylabel("Non-dimensional $$\dot{x}$$ (-)","Interpreter", "latex")
grid on
title('Poincare Map at \mu = 0.5 and C = 4.5 - Sushrut Prabhu')
```



Quasi

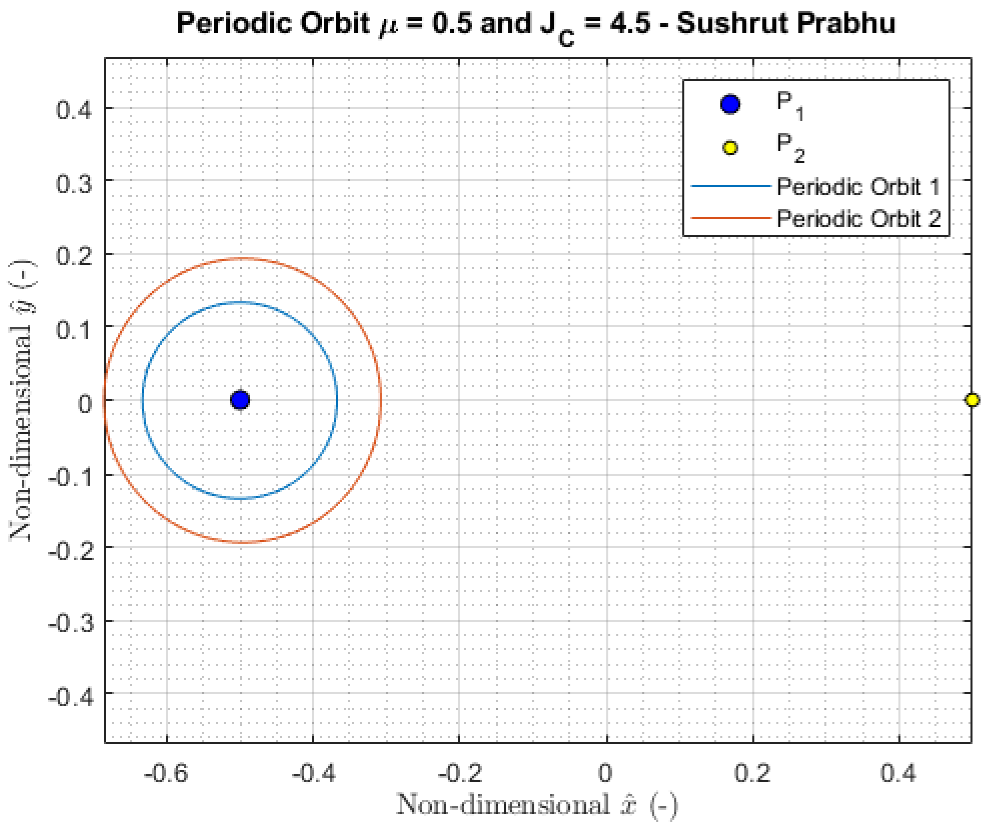
```
x0 = -0.609;
ydot_0 = sqrt(Jacobi_C(x0,0,0,0,dim_vals{4,2})-C0);

[~,yq] = ode45(@cr3bp_df,[0 7],[x0 0 0 0 ydot_0
 0],options2,dim_vals{4,2});

figure
plot(-dim_vals{4,2},0,'ko','MarkerSize',7,'MarkerFaceColor','b')
hold on
plot(yq(:,1),yq(:,2))
title('Quasi-Periodic Orbit \mu = 0.5 and J_C = 4.5 - Sushrut Prabhu')
xlabel("Non-dimensional $$\hat{x}$$ (-)","Interpreter", "latex")
ylabel("Non-dimensional $$\hat{y}$$ (-)","Interpreter", "latex")
legend('P_1','Quasi-Periodic Orbit 1')
grid on
grid minor
axis equal
```



Part b)

```
r_guess = -.6333192;
v_guess = sqrt(Jacobi_C(r_guess,0,0,0,dim_vals{4,2})-C0);
[IC_final,t_end] = Target3d_per([0 0],[r_guess 0 0],[0 v_guess
 0],0.25,dim_vals{4,2},"planar", 10^-10, "");

[~,y1] = ode45(@cr3bp_df,[0
 t_end*10],IC_final,options2,dim_vals{4,2});

r_guess = -.3078;
v_guess = sqrt(Jacobi_C(r_guess,0,0,0,dim_vals{4,2})-C0);
[IC_final,t_end] = Target3d_per([0 0],[r_guess 0 0],[0 v_guess
 0],0.25,dim_vals{4,2},"planar", 10^-10, "");

[~,y2] = ode45(@cr3bp_df,[0
 t_end*10],IC_final,options2,dim_vals{4,2});


figure
plot(-dim_vals{4,2},0,'ko','MarkerSize',7,'MarkerFaceColor','b')
hold on
plot(1-dim_vals{4,2},0,'ko','MarkerSize',5,'MarkerFaceColor','y')
plot(y1(:,1),y1(:,2))
plot(y2(:,1),y2(:,2))
```

```
axis equal
title('Periodic Orbit \mu = 0.5 and J_C = 4.5 - Sushrut Prabhu')
xlabel("Non-dimensional $$\hat{x}$$ (-)","Interpreter", "latex")
ylabel("Non-dimensional $$\hat{y}$$ (-)","Interpreter", "latex")
legend('P_1','P_2','Periodic Orbit 1','Periodic Orbit 2')
grid on
grid minor

J_C0 =
 Jacobi_C(y1(1,1),y1(1,2),y1(1,3),norm(y1(1,4:6)),dim_vals{4,2});
J_Cend =
 Jacobi_C(y1(end,1),y1(end,2),y1(end,3),norm(y1(end,4:6)),dim_vals{4,2});
```

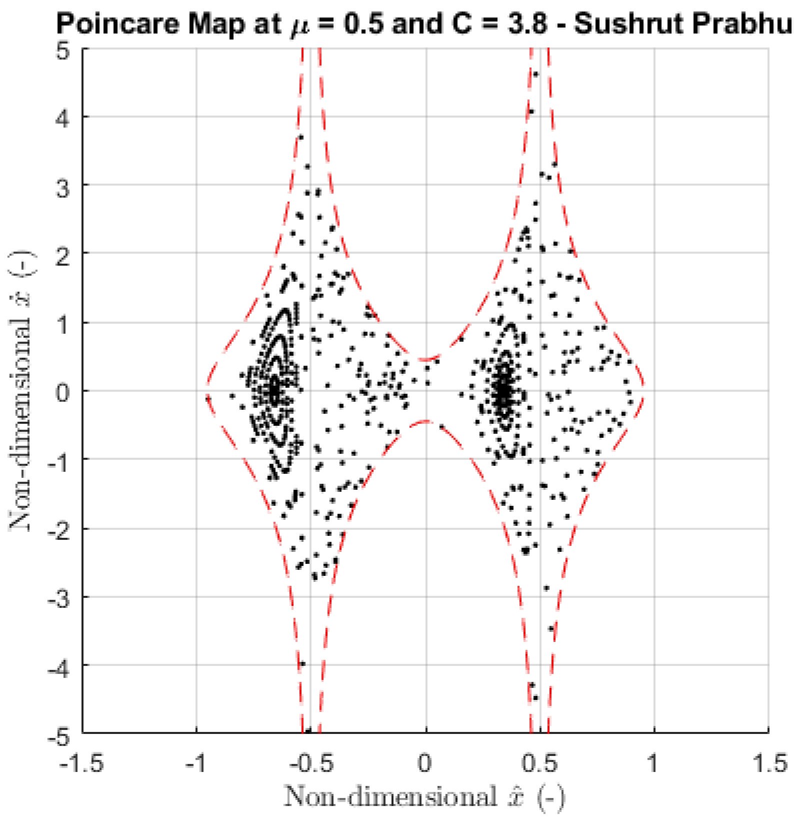


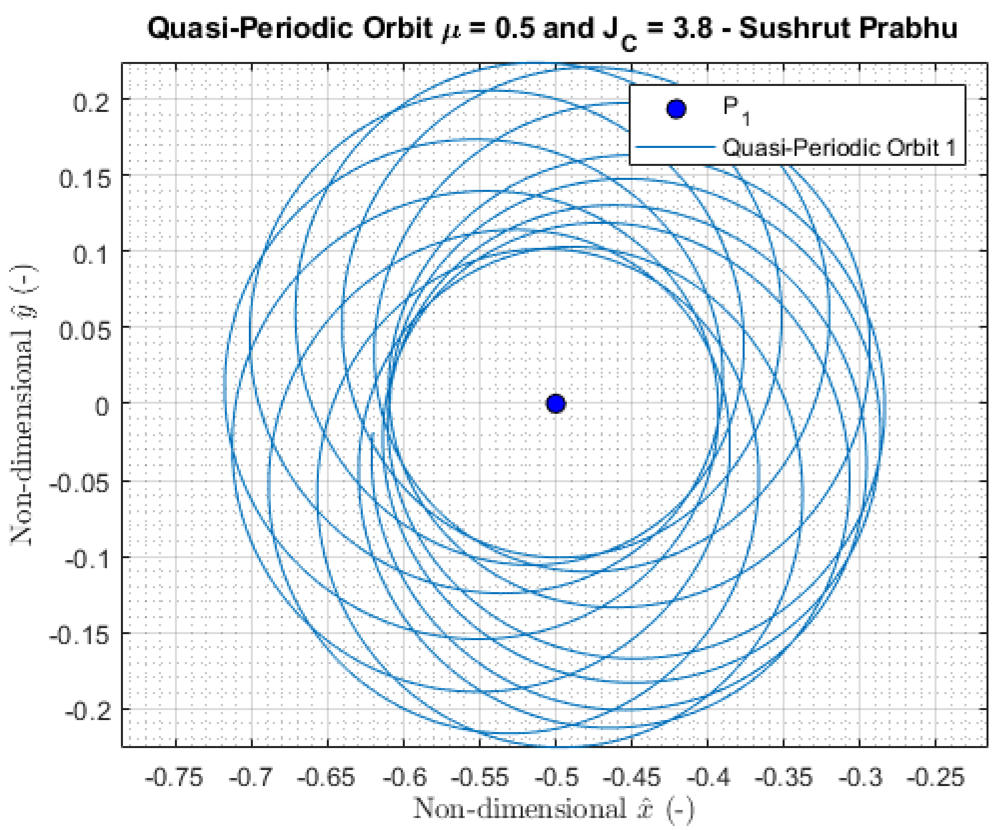
Part c i)

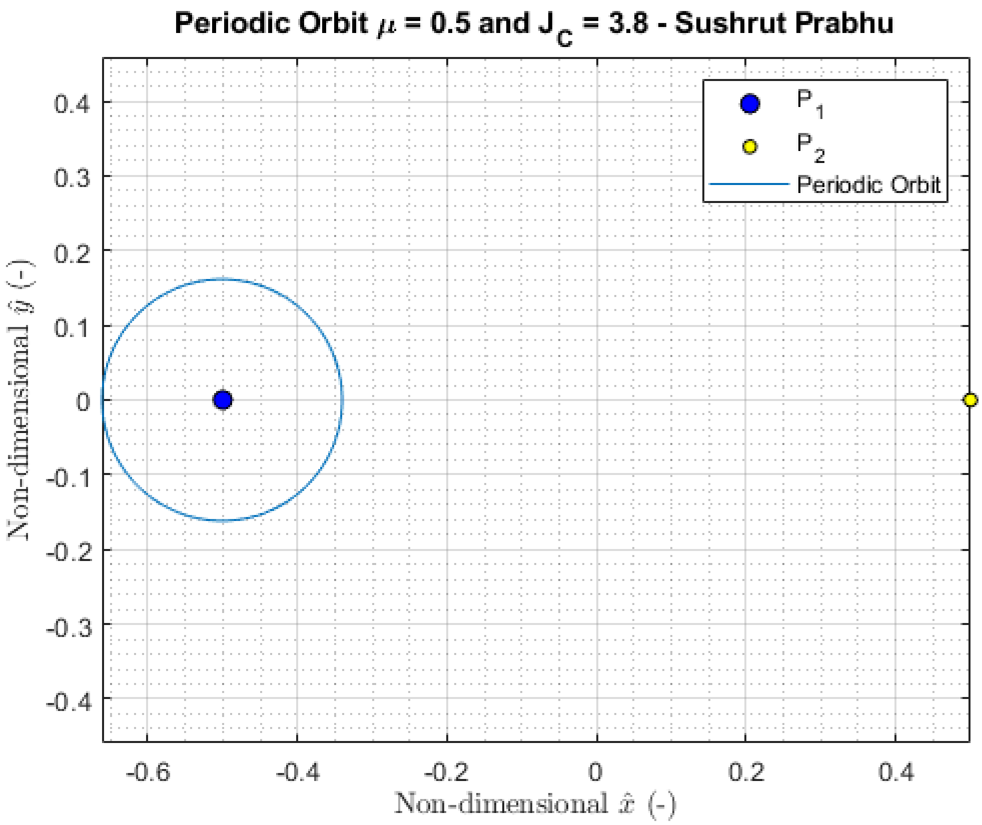
```
C0 = 3.8;
tol = 10^-13;

figure
hold on
for x0 = [linspace(-.525,-.665,8),linspace(.3095,.48,8),
 linspace(-.3095,-.48,5), linspace(.525,.633,5)]
    ydot_0 = sqrt(Jacobi_C(x0,0,0,0,dim_vals{4,2})-C0);
    t_end = 10;
    y = [x0 0 0 0 ydot_0 0];
    x_xdot = [];
```

```
    y1 = [];
    k = 1;
    stop = [];
    error = 10^-13;

        while error < 10^-10
            IC = y(end,:);
            [~,y] = ode45(@cr3bp_df,[0
 t_end],IC,options,dim_vals{4,2});
%             y1 = [y1;y(:,1:2)];
            error = abs(C0 -
 Jacobi_C(y(end,1),y(end,2),y(end,3),norm(y(end,4:6)),dim_vals{4,2}));
            if rem(k,2) == 0
                x_xdot = [x_xdot;y(end,1),y(end,4)];
            end

            k = k+1;
            if k > 100
                error = 1;
            end
        end

    plot(x_xdot(:,1),x_xdot(:,2),'.k')

%     f1 = figure;
%     plot(y1(:,1),y1(:,2))
%
%     close(f1)
end

% JC Limit
[X,V] = meshgrid(-1.5:0.01:1.5,-5:0.01:5);
C = Jacobi_C(X,0,0,V,dim_vals{4,2});

contour(X,V,-C,-[C0 C0],'--r');
axis square
xlabel("Non-dimensional $$\hat{x}$$ (-)","Interpreter", "latex")
ylabel("Non-dimensional $$\dot{x}$$ (-)","Interpreter", "latex")
grid on
ylim([-5,5])
title('Poincare Map at \mu = 0.5 and C = 3.8 - Sushrut Prabhu')


% Part c ii)
% Quasi
x0 = -0.609;
ydot_0 = sqrt(Jacobi_C(x0,0,0,0,dim_vals{4,2})-C0);

[~,yq] = ode45(@cr3bp_df,[0 7],[x0 0 0 0 ydot_0
 0],options2,dim_vals{4,2});

figure
plot(-dim_vals{4,2},0,'ko','MarkerSize',7,'MarkerFaceColor','b')
hold on
```

```
plot(yq(:,1),yq(:,2))
title('Quasi-Periodic Orbit \mu = 0.5 and J_C = 3.8 - Sushrut Prabhu')
xlabel("Non-dimensional $$\hat{x}$$ (-)","Interpreter", "latex")
ylabel("Non-dimensional $$\hat{y}$$ (-)","Interpreter", "latex")
legend('P_1','Quasi-Periodic Orbit 1')
grid on
grid minor
axis equal

r_guess = -.661457051;
v_guess = sqrt(Jacobi_C(r_guess,0,0,0,dim_vals{4,2})-C0);
[IC_final,t_end] = Target3d_per([0 0],[r_guess 0 0],[0 v_guess
 0],0.25,dim_vals{4,2},"planar", 10^-10, "");

[~,yp] = ode45(@cr3bp_df,[0
 t_end*10],IC_final,options2,dim_vals{4,2});

figure
plot(-dim_vals{4,2},0,'ko','MarkerSize',7,'MarkerFaceColor','b')
hold on
plot(1-dim_vals{4,2},0,'ko','MarkerSize',5,'MarkerFaceColor','y')
plot(yp(:,1),yp(:,2))
axis equal
title('Periodic Orbit \mu = 0.5 and J_C = 3.8 - Sushrut Prabhu')
xlabel("Non-dimensional $$\hat{x}$$ (-)","Interpreter", "latex")
ylabel("Non-dimensional $$\hat{y}$$ (-)","Interpreter", "latex")
legend('P_1','P_2','Periodic Orbit')
grid on
grid minor

J_C0 =
 Jacobi_C(yp(1,1),yp(1,2),yp(1,3),norm(yp(1,4:6)),dim_vals{4,2});
J_Cend =
 Jacobi_C(yp(end,1),yp(end,2),yp(end,3),norm(yp(end,4:6)),dim_vals{4,2});
```


Poincare Map at μ = 0.5 and C = 3.8 - Sushrut Prabhu
Non-dimensional $\dot{x}$ (-)
Non-dimensional $\hat{x}$ (-)

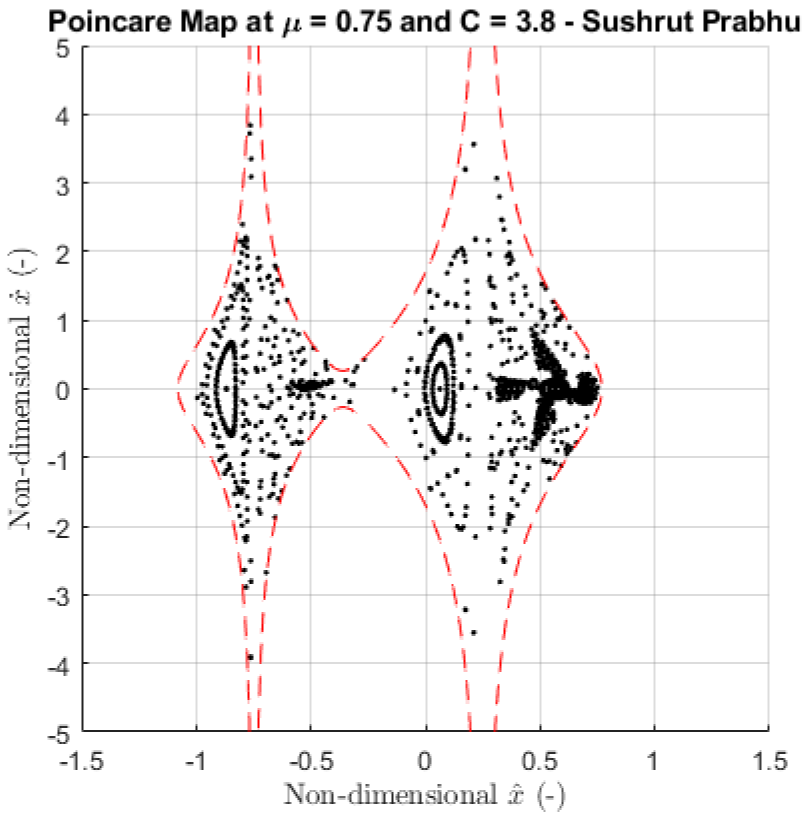

Quasi-Periodic Orbit μ = 0.5 and J_C = 3.8 - Sushrut Prabhu
P_1
Quasi-Periodic Orbit 1
Non-dimensional $\hat{y}$ (-)
Non-dimensional $\hat{x}$ (-)



Part d)

```
dim_vals{4,2} = .75;

tol = 10^-13;

figure
hold on
for x0 = [linspace(-1,-.7,8),linspace(0,.22,8), linspace(-.6,-.5,10),
 linspace(.35,.65,12)]
    ydot_0 = sqrt(Jacobi_C(x0,0,0,0,dim_vals{4,2})-C0);
    t_end = 10;
    y = [x0 0 0 0 ydot_0 0];
    x_xdot = [];
    y1 = [];
    k = 1;
    stop = [];
    error = 10^-13;

        while error < 10^-10
            IC = y(end,:);
            [~,y] = ode45(@cr3bp_df,[0
 t_end],IC,options,dim_vals{4,2});
%              y1 = [y1;y(:,1:2)];
```

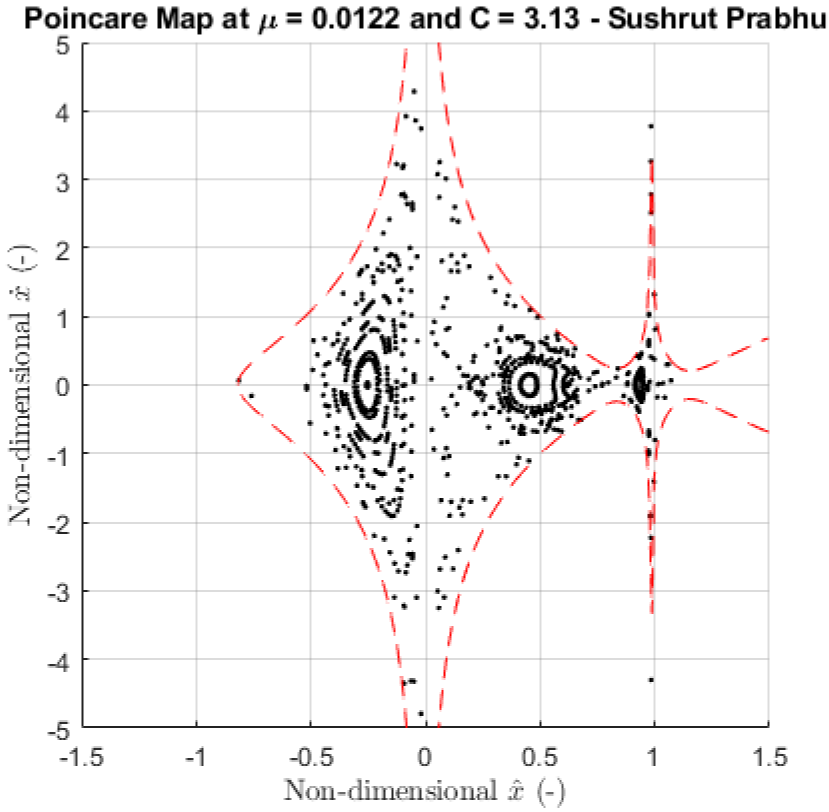
```
            error = abs(C0 -
Jacobi_C(y(end,1),y(end,2),y(end,3),norm(y(end,4:6)),dim_vals{4,2}));
            if rem(k,2) == 0
                x_xdot = [x_xdot;y(end,1),y(end,4)];
            end

            k = k+1;
            if k > 100
                error = 1;
            end
        end

    plot(x_xdot(:,1),x_xdot(:,2),'.k')

end

% JC Limit
[X,V] = meshgrid(-1.5:0.01:1.5,-5:0.01:5);
C = Jacobi_C(X,0,0,V,dim_vals{4,2});

contour(X,V,-C,-[C0 C0],'--r');
axis square
xlabel("Non-dimensional $$\hat{x}$$ (-)","Interpreter", "latex")
ylabel("Non-dimensional $$\dot{x}$$ (-)","Interpreter", "latex")
grid on
ylim([-5,5])
title('Poincare Map at \mu = 0.75 and C = 3.8 - Sushrut Prabhu')
```



Part e)

```
dim_vals{4,2} = SS.mMoon/dim_vals{3,2}/G;   % miu
C0 = 3.13;

tol = 10^-13;

figure
hold on
for x0 = [linspace(-.6,-.05,12),linspace(0.85,.98,5),
 linspace(0.05,.85,12)]
    ydot_0 = sqrt(Jacobi_C(x0,0,0,0,dim_vals{4,2})-C0);
    t_end = 10;
    y = [x0 0 0 0 ydot_0 0];
    x_xdot = [];
    y1 = [];
    k = 1;
    stop = [];
    error = 10^-13;

        while error < 10^-10
            IC = y(end,:);
            [~,y] = ode45(@cr3bp_df,[0
 t_end],IC,options,dim_vals{4,2});
```

```
            error = abs(C0 -
Jacobi_C(y(end,1),y(end,2),y(end,3),norm(y(end,4:6)),dim_vals{4,2}));
            if rem(k,2) == 0
                x_xdot = [x_xdot;y(end,1),y(end,4)];
            end

            k = k+1;
            if k > 100
                error = 1;
            end
        end

    plot(x_xdot(:,1),x_xdot(:,2),'.k')

end

% JC Limit
[X,V] = meshgrid(-1:0.01:1.5,-5:0.01:5);
C = Jacobi_C(X,0,0,V,dim_vals{4,2});

contour(X,V,-C,-[C0 C0],'--r');
axis square
xlabel("Non-dimensional $$\hat{x}$$ (-)","Interpreter", "latex")
ylabel("Non-dimensional $$\dot{x}$$ (-)","Interpreter", "latex")
grid on
ylim([-5,5])
title('Poincare Map at \mu = 0.0122 and C = 3.13 - Sushrut Prabhu')
xlim([-1.5 1.5])
```



Published with MATLAB® R2018a

Target3d

Periodic orbit targeter

```
function  [IC_final,t_end, tb] = Target3d(r_des,r,v,t_end,miu, tol,
 pl)
% Initialization
% t = 0:.001:t_end;
options=odeset('RelTol',1e-13, 'AbsTol',1e-15); % Sets integration
 tollerance
error = 2*tol;
phi_0 = eye(6);
phi_0 = phi_0(:)';
i = 1;
v0 = v;

if pl == "plot"
    figure
    plot3(r(1),r(2),r(3),'*')
    hold on
end

while error > tol
    % Non-linear propgation with phi
    IC = [r,v,phi_0];
    [~,y] = ode45(@cr3bp_STM_df3d,[0 t_end],IC,options,miu);

    % Phi at final time
    phi_t = y(:,7:end);
    phi_tf = reshape(phi_t(end,:),6,6)';

    K = -phi_tf(1:3,4:6);
    Fx = r_des - y(end,1:3)' ;
    delv1 = K.' * (K*K.')^-1 * Fx;

    IC = [r, v - delv1'];
    [~,yn] = ode45(@cr3bp_df,[0 t_end],IC,options,miu);
    v = yn(1,4:6);

    error = max(abs(yn(end,1:3)-r_des'));

    tb{:,i} = {v-v0, norm(v-v0), Fx, norm(Fx)};
    i = i+1;

    if pl == "plot"
        if error > tol
            pl3 = plot3(yn(:,1),yn(:,2),yn(:,3),'-.b');
            if i > 2
 set(get(get(pl3,'Annotation'),'LegendInformation'),'IconDisplayStyle','off');
            end
        else
```

```
            plot3(yn(:,1),yn(:,2),yn(:,3))
        end
    end

    if i > 20
        error = tol/2;
        fprintf("Did not Coverge")
    end
end

IC_final = IC;

end
```

Not enough input arguments.

Error in Target3d (line 7)
*error = 2*tol;*

Published with MATLAB® R2018a

A_t

Intermediate caluclation for STM

```
function A = A_t(x,y,z,miu)

if isnan(z)
    [Uxx,Uyy,~,Uxy,~,~]= Unn(x,y,0,miu);
    A = [zeros(2,2), eye(2,2); Uxx, Uxy, 0, 2; Uxy, Uyy, -2, 0];
else
    [Uxx,Uyy,Uzz,Uxy,Uxz,Uyz]= Unn(x,y,z,miu);
    A = [zeros(3,3), eye(3,3); Uxx, Uxy,Uxz, 0, 2,0; Uxy, Uyy, Uyz, 0,
 -2, 0; Uxz, Uyz, Uzz, 0, 0, 0];
end

end
```

```
Not enough input arguments.

Error in A_t (line 5)
if isnan(z)
```

Published with MATLAB® R2018a

acc_nonlin

Non-linear acceleration for STM

```
function acc = acc_nonlin(r,v,miu)

dd = sqrt((r(1)+miu)^2 + r(2)^2 + r(3)^2);
rr = sqrt((r(1)+miu-1)^2 + r(2)^2 + r(3)^2);

acc(1) = 2*v(2) + r(1) - (1-miu)*(r(1)+miu)/dd^3 - miu*(r(1)-1+miu)/
rr^3;
acc(2) = -2*v(1) + r(2) - (1-miu)*r(2)/dd^3 - miu*r(2)/rr^3;
acc(3) = -(1-miu)*r(3)/dd^3 - miu*r(3)/rr^3;
```

```
Not enough input arguments.

Error in acc_nonlin (line 5)
dd = sqrt((r(1)+miu)^2 + r(2)^2 + r(3)^2);
```

Published with MATLAB® R2018a

cr3bp_STM_df2d

2d STM

```
function dx = cr3bp_STM_df2d(t,x,miu)
dx = zeros(20,1);

d = sqrt((x(1)+miu)^2 + x(2)^2);
r = sqrt((x(1)+miu-1)^2 + x(2)^2);
phi = reshape(x(5:end),4,4)';

dx(1) = x(3);
dx(2) = x(4);
dx(3) = 2*x(4) + x(1) - (1-miu)*(x(1)+miu)/d^3 - miu*(x(1)-1+miu)/r^3;
dx(4) = -2*x(3) + x(2) - (1-miu)*x(2)/d^3 - miu*x(2)/r^3;

phi_dot = [A_t(x(1),x(2),NaN,miu)*phi]';

dx(5:end) = phi_dot(:);
end
```

```
Not enough input arguments.

Error in cr3bp_STM_df2d (line 6)
d = sqrt((x(1)+miu)^2 + x(2)^2);
```

Published with MATLAB® R2018a

cr3bp_STM_df3d

3d STM

```
function dx = cr3bp_STM_df3d(t,x,miu)

dx = zeros(42,1);

d = sqrt((x(1)+miu)^2 + x(2)^2);
r = sqrt((x(1)+miu-1)^2 + x(2)^2);
phi = reshape(x(7:end),6,6)';

d = sqrt((x(1)+miu)^2 + x(2)^2 + x(3)^2);
r = sqrt((x(1)+miu-1)^2 + x(2)^2 + x(3)^2);

dx(1) = x(4);
dx(2) = x(5);
dx(3) = x(6);
dx(4) = 2*x(5) + x(1) - (1-miu)*(x(1)+miu)/d^3 - miu*(x(1)-1+miu)/r^3;
dx(5) = -2*x(4) + x(2) - (1-miu)*x(2)/d^3 - miu*x(2)/r^3;
dx(6) = -(1-miu)*x(3)/d^3 - miu*x(3)/r^3;

phi_dot = [A_t(x(1),x(2),x(3),miu)*phi]';

dx(7:end) = phi_dot(:);
end
```

```
Not enough input arguments.

Error in cr3bp_STM_df3d (line 7)
d = sqrt((x(1)+miu)^2 + x(2)^2);
```

Published with MATLAB® R2018a

Characteristic Elements

```
function [lstar, mstar, tstar] = charE(D1,D2,m1,m2)
G = 6.6738*10^-20;

lstar = D1+D2;
mstar = m1 + m2;

tstar = sqrt(lstar^3/G/mstar);
```

```
Not enough input arguments.

Error in charE (line 5)
lstar = D1+D2;
```

Published with MATLAB® R2018a

cr3bp_df

```
function dx = cr3bp_df(t,x,miu)

dx = zeros(6,1);

d = sqrt((x(1)+miu)^2 + x(2)^2 + x(3)^2);
r = sqrt((x(1)+miu-1)^2 + x(2)^2 + x(3)^2);

dx(1) = x(4);
dx(2) = x(5);
dx(3) = x(6);
dx(4) = 2*x(5) + x(1) - (1-miu)*(x(1)+miu)/d^3 - miu*(x(1)-1+miu)/r^3;
dx(5) = -2*x(4) + x(2) - (1-miu)*x(2)/d^3 - miu*x(2)/r^3;
dx(6) = -(1-miu)*x(3)/d^3 - miu*x(3)/r^3;


end
```

```
Not enough input arguments.

Error in cr3bp_df (line 6)
d = sqrt((x(1)+miu)^2 + x(2)^2 + x(3)^2);
```

Published with MATLAB® R2018a

horner_alg

```
function [alpha,beta] = horner_alg(n,a,z0)
alpha = a(1);
beta = 0;

for k = 2:n
   beta = alpha + z0*beta;
   alpha = a(k) + z0*alpha;
end


end
```

```
Not enough input arguments.

Error in horner_alg (line 3)
alpha = a(1);
```

Published with MATLAB® R2018a

```
function C = Jacobi_C(x,y,z,v,miu)

d = sqrt((x+miu).^2 + y.^2 +z.^2);
r = sqrt((x-1+miu).^2 + y.^2 + z.^2);
C = x.^2 + y.^2 + 2*(1-miu)./d + 2*miu./r - v.^2;

end
```

```
Not enough input arguments.

Error in Jacobi_C (line 3)
d = sqrt((x+miu).^2 + y.^2 +z.^2);
```

Published with MATLAB® R2018a

Gamma1 Newton Rhapson

```
function g1_n1 = L1_NRmethod(g1_n, miu, acc)

err = acc*2;
pz = [-1,(3-miu),(2*miu-3),miu,-2*miu,miu];
while (err > acc)
    [fn,fn_p] = horner_alg(6,pz,g1_n);

    g1_n1 = g1_n - fn/fn_p;

    err = abs(g1_n1-g1_n)/abs(g1_n);
    g1_n = g1_n1;
end

end
```

```
Not enough input arguments.

Error in L1_NRmethod (line 4)
err = acc*2;
```

Published with MATLAB® R2018a

Gamma2 Newton Rhapson

```
function g2_n1 = L2_NRmethod(g2_n, miu, acc)

err = acc*2;
pz = [1,(3-miu),(3-2*miu),-miu,-2*miu,-miu];
while (err > acc)
    [fn,fn_p] = horner_alg(6,pz,g2_n);

    g2_n1 = g2_n - fn/fn_p;

    err = abs(g2_n1-g2_n)/abs(g2_n);
    g2_n = g2_n1;
end

end
```

```
Not enough input arguments.

Error in L2_NRmethod (line 4)
err = acc*2;
```

Published with MATLAB® R2018a