```
close all; clearvars; clc;
set(0,'defaulttextInterpreter','latex');
set(groot,'defaultAxesTickLabelInterpreter','latex');
set(groot,'defaultLegendInterpreter','latex');

%% 3) Estimate the height of EUV wave for the 7 December 2007 event

Image_A = load('20071207_A_Dif_0435_0415.mat').data;

Image_B = load('20071207_B_Dif_0435_0415.mat').data;

figure(1)
imshow(Image_A, [-50 180])
axis off
axis equal
colormap(gca,'jet')
% title('Stereo A')

figure(2)
imshow(Image_B, [-50 180])
axis off
axis equal
colormap(gca,'jet')
% title('Stereo B')

figure(3)
Image_A_zoom = Image_A([500:900],[350:700]);
imshow(Image_A_zoom, [-50 180])
axis off
axis equal
colormap(gca,'jet')
% title('Stereo A - zoom')

figure(4)
Image_B_zoom = Image_B([600:950],[820:1120]);
imshow(Image_B_zoom, [-50 180])
axis off
axis equal
colormap(gca,'jet')
% title('Stereo B - zoom')

%% Coordinates of STEREO-A and STEREO-B in km

% Heliospheric distances
dist_A = 0.966587; % [AU]
dist_B = 1.026675; % [AU]

AU = 149597870.691; % [km]

% Stereo A coordinates
X_AA = dist_A*AU;
Y_AA = 0;
Z_AA = 0;
```

```
% Stereo B coordinates
X_BB = dist_B*AU;
Y_BB = 0;
Z_BB = 0;

%Determine Cartesian coordinates (in km) of point N in the coordinate
%system of STEREO-B

p = 'Original';

switch p
    case 'Original'
        i_N = 680;
        j_N = 1000.179;
    case 'North'
        i_N = 679;
        j_N = 1013;
    case 'Western'
        i_N = 715;
        j_N = 971;
    case 'Eastern'
        i_N = 706;
        j_N = 1037;
end

figure(5)
imshow(Image_B, [-50 180])
hold on
plot(j_N, i_N,'s','MarkerSize', 15, 'MarkerFaceColor', 'y', 'MArkerEdgeColor',↙
'k');
hold on
axis off
axis equal
colormap(gca,'jet')
% title('Stereo B - zoom')
xlim([850 1140])
ylim([610 900])

rad_B = 593; % Radius of Sun in pixels
% Central pixel of the Sun
Xc_B = 700;
Yc_B = 700;
R = 701407; % [km] Radius of Sun in kilometers
rad_circle_B=rad_parallel_cut(rad_B); % Radiuses in pixels at Sun parallels
nanleft_B = Xc_B - rad_circle_B; % Part of the grid on the left that does not cover↙
the Sun
dist_top_B = Yc_B - rad_B; % Distance from the top edge to the beginning of Sun

[X_NB Y_NB Z_NB] = coord_pixel_to_real(i_N,j_N,nanleft_B,dist_top_B,rad_circle_B,R,↙
rad_B);

% Determine the ensemble of points C of wave crest, as viewed from STEREO-B
```

```
X_CB = [];
Y_CB = [];
Z_CB = [];

% Pointing vectors in the coordinate system of stereo-B
l_bb = X_NB - X_BB;
m_bb = Y_NB - Y_BB;
n_bb = Z_NB - Z_BB;

N_stop = 520;

for k=1:N_stop

    X_CB(k) = X_NB + (k-1)*1250;

    Y_CB(k) = m_bb/l_bb*(X_CB(k)-X_BB)+Y_BB;

    Z_CB(k) = n_bb/l_bb*(X_CB(k)-X_BB)+Z_BB;

end

% Transform coordinates of point C in the coordinate system of STEREO-B to HEEQ

% Direction cosines
phi_A = deg2rad(20.620); % [rad]
phi_B = deg2rad(-21.424); % [rad]
theta_A = deg2rad(-2.535); % [rad]
theta_B = deg2rad(3.089); % [rad]
lx_A = cos(phi_A)*cos(theta_A);
mx_A = cos(-phi_A+pi/2)*cos(theta_A);
nx_A = cos(pi/2-theta_A);
ly_A = cos(pi/2+phi_A);
my_A = cos(phi_A);
ny_A = 0;
lz_A = cos(pi/2+theta_A)*cos(phi_A);
mz_A = cos(pi/2+theta_A)*cos(-phi_A+pi/2);
nz_A = cos(theta_A);
lx_B = cos(phi_B)*cos(theta_B);
mx_B = cos(-phi_B+pi/2)*cos(theta_B);
nx_B = cos(pi/2-theta_B);
ly_B = cos(pi/2+phi_B);
my_B = cos(phi_B);
ny_B = 0;
lz_B = cos(pi/2+theta_B)*cos(phi_B);
mz_B = cos(pi/2+theta_B)*cos(-phi_B+pi/2);
nz_B = cos(theta_B);

X_C_HEEQ = lx_B.*X_CB+ly_B.*Y_CB+lz_B.*Z_CB;

Y_C_HEEQ = mx_B.*X_CB+my_B.*Y_CB+mz_B.*Z_CB;

Z_C_HEEQ = nx_B.*X_CB+ny_B.*Y_CB+nz_B.*Z_CB;
```

```
% Transform coordinates of point C in HEEQ to the coordinate system of STEREO-A

X_CA = lx_A.*X_C_HEEQ+mx_A.*Y_C_HEEQ+nx_A.*Z_C_HEEQ;

Y_CA = ly_A.*X_C_HEEQ+my_A.*Y_C_HEEQ+ny_A.*Z_C_HEEQ;

Z_CA = lz_A.*X_C_HEEQ+mz_A.*Y_C_HEEQ+nz_A.*Z_C_HEEQ;

% Transfromation from cartesian coordinates in km to pixels

i_M_vec = [];
j_M_vec = [];

rad_A = 630; % Radius of Sun in pixels
Xc_A = 700;
Yc_A = 700;
rad_circle_A=rad_parallel_cut(rad_A); % Radiuses in pixels at Sun parallels
nanleft_A = Xc_A - rad_circle_A; % Part of the grid on the left that does not cover↙
the Sun
dist_top_A = Yc_A - rad_A; % Distance from the top edge to the beginning of Sun

for i=1:length(X_CA)

[i_M_vec(i) j_M_vec(i)] = coord_real_to_pixel(rad_A, dist_top_A,nanleft_A,↙
rad_circle_A, Y_CA(i), Z_CA(i), R);

end

figure(6)
imshow(Image_A, [[-50 180]])
hold on
plot(j_M_vec, i_M_vec,'k' ,'LineWidth', 2.5);
axis off
axis equal
colormap(gca,'jet')
% title('Stereo A')

switch p
    case 'Original'
        i_M = 623;
        j_M = 574;
    case 'North'
        i_M = 617;
        j_M = 552;
    case 'Western'
        i_M = 654;
        j_M = 499;
    case 'Eastern'
        i_M = 648;
        j_M = 594;
end
```

```
figure(7)
imshow(Image_A, [-50 180])
hold on
plot(j_M_vec, i_M_vec,'k' ,'LineWidth', 4.5);
plot(j_M, i_M,'s','MarkerSize', 15, 'MarkerFaceColor', 'm', 'MArkerEdgeColor',↙
'm');
axis off
axis equal
colormap(gca,'jet')
% title('Stereo A')
xlim([350 700])
ylim([500 900])

[X_MA_pt Y_MA_pt Z_MA_pt] = coord_pixel_to_real(i_M,j_M,nanleft_A,dist_top_A,↙
rad_circle_A,R,rad_A);

% Transform the coordinates of STEREO-A in HEEQ system

[X_A_HEEQ, Y_A_HEEQ, Z_A_HEEQ] = to_HEEQ([X_AA, Y_AA, Z_AA] , phi_A, theta_A);

% Transform the coordinates of STEREO-B into HEEQ system

[X_B_HEEQ, Y_B_HEEQ, Z_B_HEEQ] = to_HEEQ([X_BB, Y_BB, Z_BB] , phi_B, theta_B);

%  Transform the coordinates of point M from coordinate system of STEREO-A into the↙
HEEQ system

X_M_HEEQ = lx_A.*X_MA_pt+ly_A.*Y_MA_pt+lz_A.*Z_MA_pt;

Y_M_HEEQ = mx_A.*X_MA_pt+my_A.*Y_MA_pt+mz_A.*Z_MA_pt;

Z_M_HEEQ = nx_A.*X_MA_pt+ny_A.*Y_MA_pt+nz_A.*Z_MA_pt;

% Transform the coordinates of point N in coordinate system of STEREO-B in HEEQ↙
system

X_N_HEEQ = lx_B.*X_NB+ly_B.*Y_NB+lz_B.*Z_NB;

Y_N_HEEQ = mx_B.*X_NB+my_B.*Y_NB+mz_B.*Z_NB;

Z_N_HEEQ = nx_B.*X_NB+ny_B.*Y_NB+nz_B.*Z_NB;

% Find X_C_HEEQ, Y_C_HEEQ, Z_C_HEEQ

Y = @(X) (X*(Y_M_HEEQ-Y_A_HEEQ)-X_A_HEEQ*Y_M_HEEQ+Y_A_HEEQ*X_M_HEEQ)/(X_M_HEEQ-↙
X_A_HEEQ);

Z = @(X) (X*(Z_M_HEEQ-Z_A_HEEQ)-X_A_HEEQ*Z_M_HEEQ+Z_A_HEEQ*X_M_HEEQ)/(X_M_HEEQ-↙
X_A_HEEQ);

fun = @(X) (((X*(Y_M_HEEQ-Y_A_HEEQ)-X_A_HEEQ*Y_M_HEEQ+Y_A_HEEQ*X_M_HEEQ)/(X_M_HEEQ-↙
X_A_HEEQ))-Y_B_HEEQ)/(Y_N_HEEQ-Y_B_HEEQ)-(((X*(Z_M_HEEQ-Z_A_HEEQ)-↙
X_A_HEEQ*Z_M_HEEQ+Z_A_HEEQ*X_M_HEEQ)/(X_M_HEEQ-X_A_HEEQ))-Z_B_HEEQ)/(Z_N_HEEQ-↙
```

```
Z_B_HEEQ);

X_C_HEEQ = fzero(fun, 0);

Y_C_HEEQ = Y(X_C_HEEQ);

Z_C_HEEQ = Z(X_C_HEEQ);

% Determination of height of EUV wave

height = sqrt(X_C_HEEQ^2 + Y_C_HEEQ^2 + Z_C_HEEQ^2)-R;


%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%% FUNCTIONS %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

function [X, Y, Z] = to_HEEQ(X1, Fi, Theta)
    X=X1*cos(Fi)*cos(Theta);
    Y=X1*sin(Fi)*cos(Theta);
    Z=X1*sin(Theta);
end

function out=rad_parallel_cut(rad)
    out=zeros(2*rad+1,1);
    for it=1:rad+1;
        out(it)=fix(sqrt((rad^2-(rad-it+1)^2)));
    end
    out(rad+2:end)=flipud(out(1:rad));
end

function [i j] = coord_real_to_pixel(rad, dist_top,nanleft, rad_circle, Y, Z, R);
    i=rad+dist_top-fix(Z*(rad/R));
    j=fix(nanleft(i-dist_top)+rad_circle(i-dist_top)+Y*(rad/R));
end

function [X, Y, Z] = coord_pixel_to_real_out_sphere(i,j,R,rad,cenX,cenY)
    Y=-(cenX-j+1)*(R/rad);      %Axis OY is directed to the right (j - change of columns)
    Z=(cenY-i+1)*(R/rad);      %Axis OZ is directed to the top    (i - change of rows)
    X=0;                       %Axis OX is directed to satellite A (to us)
end

function [X Y Z] = coord_pixel_to_real(i,j,nanleft,dist_top,rad_circle,R,rad)
    Y=(j-nanleft(i-dist_top)-rad_circle(i-dist_top))*(R/rad);  %Axis OY is directed to the right (j - change of columns)
    Z=(-(i-rad-dist_top))*(R/rad);           %Axis OZ is directed to the top    (i - change of rows)
    X=sqrt(R^2-Y^2-Z^2);                     %Axis OX is directed to satellite A (to us)
end
```