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This Routines Demos the steps taken for all sky calibration

```
clear all;

% Things to improve
% 1. Add legends to some of the plots
% 2. Create Az-El stencil by yourself
% 3. Add fish-eye distortion function/parameter while calibrating
```

Toggle figures on or off

```
toggle = 1; % ON
% toggle = 0; % OFF
```

Step 1: Collect star catalogue

```
starCatFITS = [initialize_root_path,filesep,'energy-height-
conversion',...
        filesep,'Tools',filesep,'External Tools',filesep,...
       'skymap',filesep,'hipparcos_extended_catalogue_J2000.fit'];

stars = get_star_catalogue(starCatFITS); % Star catalogue [INPUT]
```

Step 2: Collect information about the camera

```
% Automatically calculating the darkest frame, so that we have a
 clearer sky
% %%??
fileStr = 'C:\Users\nithin\Downloads\20080326.001_bc_15sec-
full_v2.h5';
[totalIntensity,timeArr]=estimate_darkest_frame(fileStr);
```

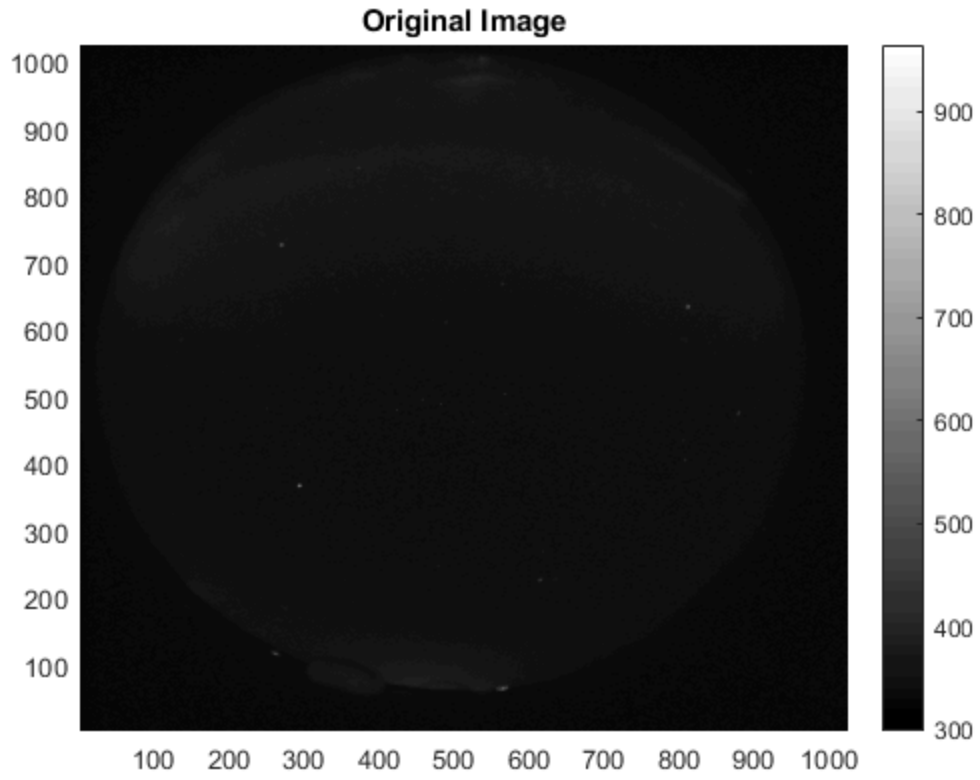
```
[val,indx]=min(totalIntensity);
timeStr = datestr(timeArr(indx));

% Get the time of the image
time = timeArr(indx); % [INPUT]

% Get camera location
dasc.sensorLoc = h5read(fileStr,'/DASC/sensorloc'); % [INPUT]
```

Step 3: Calculate star positions at camera location

```
% Approximate star position can be calculated using this function
[stars.az,stars.el] =
 RADec2AzEl(rad2deg(stars.RA),rad2deg(stars.DEC),...
    dasc.sensorLoc(1),dasc.sensorLoc(2),datestr(time,'yyyy/mm/dd
 HH:MM:ss'));

% Storing the location of a known star. In this case: the pole star .

polarisIndx = find(stars.HIP==11767); % The index of polaris star in
 the star catalogue

polaris.az = stars.az(polarisIndx);
polaris.el = stars.el(polarisIndx);

% A more accurate calculation can be made using the following function
% It takes more time though.
[polaris.azAccurate,polaris.elAccurate] = get_star_az_el...
    (stars.RA(polarisIndx),stars.DEC(polarisIndx),...

 stars.pmRA(polarisIndx),stars.pmDEC(polarisIndx),stars.parallax(polarisIndx),...

 stars.RV(polarisIndx),time,deg2rad(dasc.sensorLoc(1)),deg2rad(dasc.sensorLoc(2)),
```

Step 4: Get Image/ FITS File or Matrix

```
asiPath = 'C:\Users\nithin\Documents\GitHub\LargeFiles\DASC
\20080326\';
asi1File = 'PKR_DASC_0000_20080326_103958.000.FITS';
image1 = fitsread([asiPath,asi1File]); %% [INPUT]
display_image(toggle,image1,[],'Original Image');
```



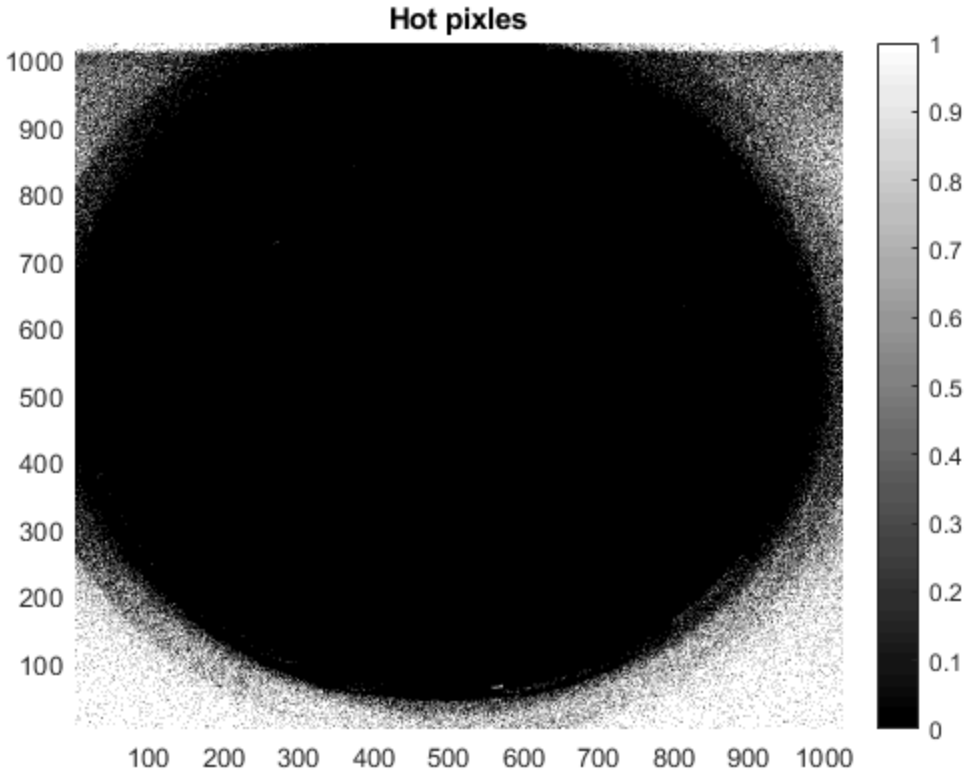
%%?? Get initial Azimuth - Elevation dasc.az = modify_matrix_size((h5read(fileStr,'/DASC/az-CalData'))',1024,1024); dasc.el = modify_matrix_size((h5read(fileStr,'/DASC/elCalData'))',1024,1024); dasc.az(dasc.az==0) = nan; dasc.el(dasc.az==0) = nan;

```
[dasc.az, dasc.el] = get_AzEl_grid(size(image1,1));
```

[xNew,yNew] = get_aer_stars(dasc.az,dasc.el,0,0,0,1,1.5); azNew = wrapTo360(atan2d(xNew,yNew)); elNew = 90 - xNew./(sind(azNew)); figure; imagesc(azNew); caxis([0 360]); figure; imagesc(elNew); caxis([0 90]);

Step 4.1. Remove hot pixels If one needs to remove hot pixels one can attach another image that is separated in time

```
asi2File = 'PKR_DASC_0000_20080326_133018.000.FITS';
image2 = fitsread([asiPath,asi2File]);
[hotPixels] = identify_hot_pixels(image1, image2, 10);
%
% image1(logical(hotPixels(:))) = nan;
display_image(toggle,hotPixels,[],'Hot pixles');
% display_image(toggle,image1,[],'Hot pixles removed');
```



Step 4.2. Remove background

```
[image1BkgRem,backgroundRow, imRowNoise, pRow, muRow, a] =
 remove_background(image1,5);
display_image(toggle,image1BkgRem,[0 100],'Image with background
 removed from row');
display_image(toggle,backgroundRow, [200 800], 'Background with stars
 removed (After Row fits)');
display_image(toggle,imRowNoise,[0 10],'Noise (row fit)');

[image1BkgRem,background1, imColNoise] =
 remove_background(image1BkgRem');
image1BkgRem = image1BkgRem';
imColNoise = imColNoise';
background1 = background1'; %Background of the image i.e. without the
 stars.
display_image(toggle, image1BkgRem, [0 100], 'Image with background
 removed from row and column');
display_image(toggle,background1, [0 50], 'Background with stars
 removed (After Row and Col fits)');
display_image(toggle,imColNoise,[0 10],'Noise (col fit)');
```

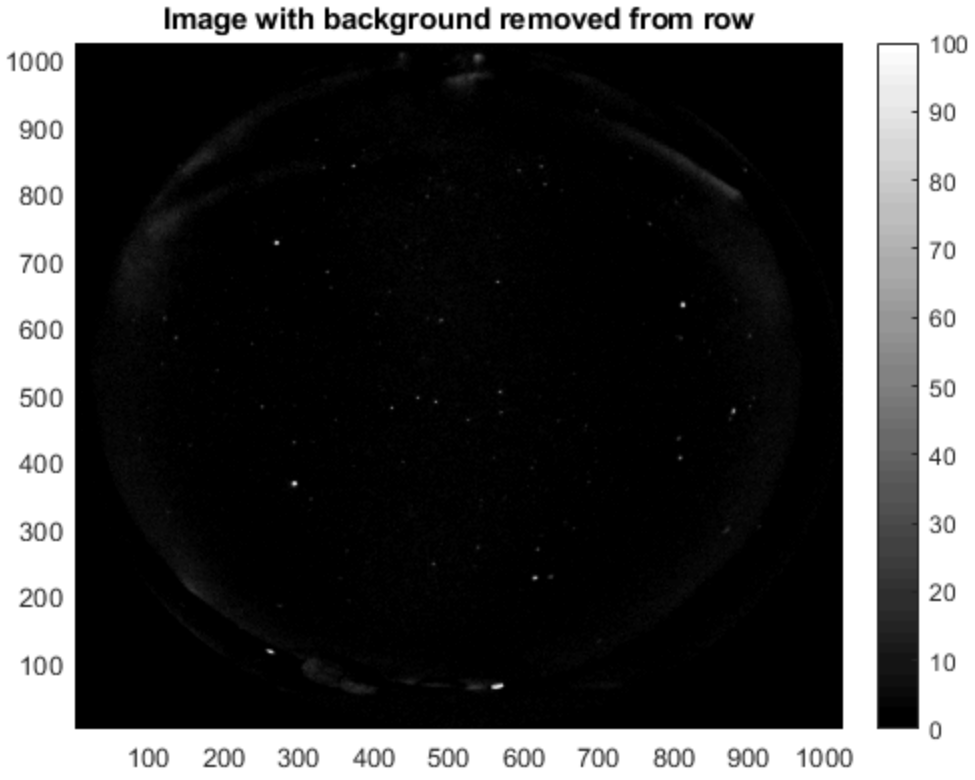
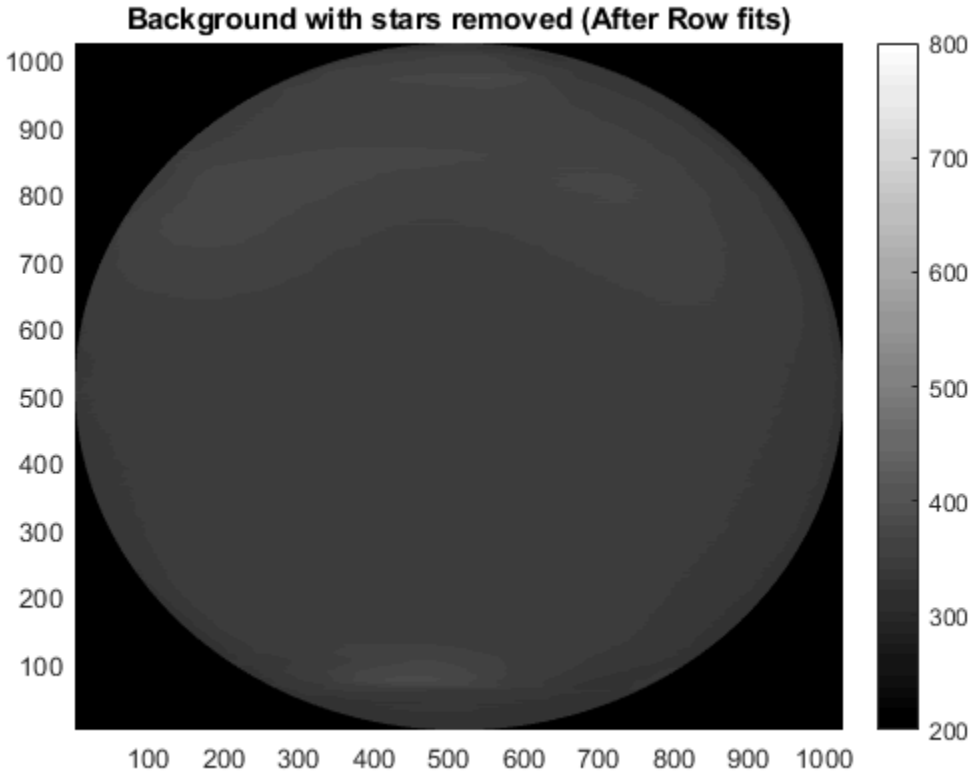
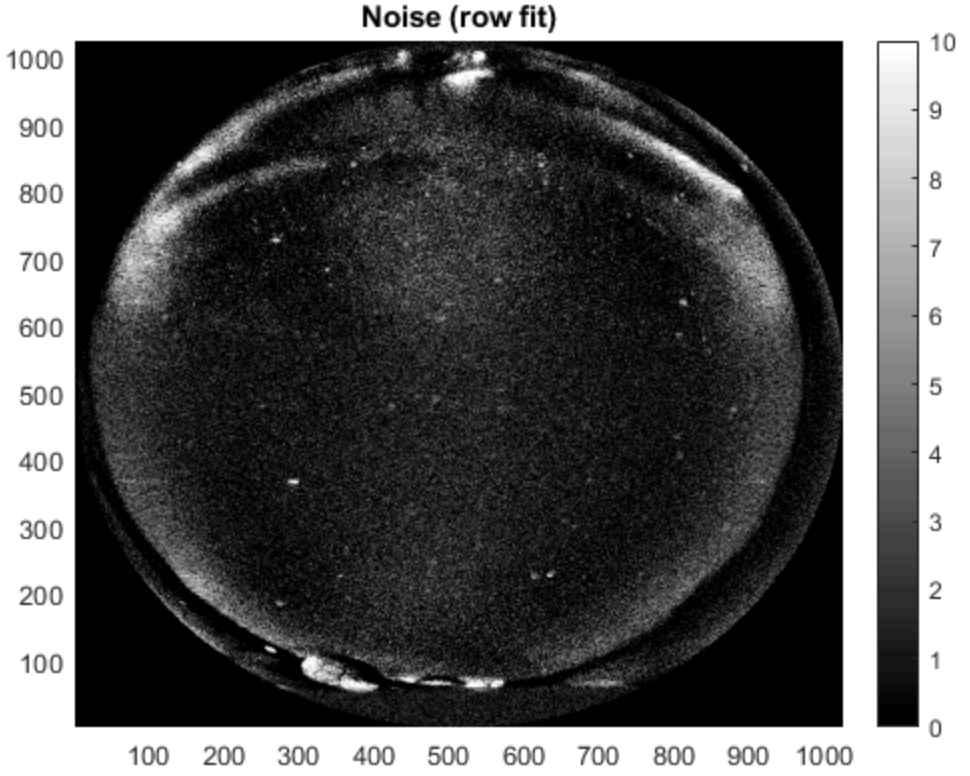


Image with background removed from row
1000
900
800
700
600
500
400
300
200
100
100 200 300 400 500 600 700 800 900 1000
100
90
80
70
60
50
40
30
20
10
0


Background with stars removed (After Row fits)
1000
900
800
700
600
500
400
300
200
100
100 200 300 400 500 600 700 800 900 1000
800
700
600
500
400
300
200


Noise (row fit)
1000
900
800
700
600
500
400
300
200
100
100 200 300 400 500 600 700 800 900 1000
10
9
8
7
6
5
4
3
2
1
0

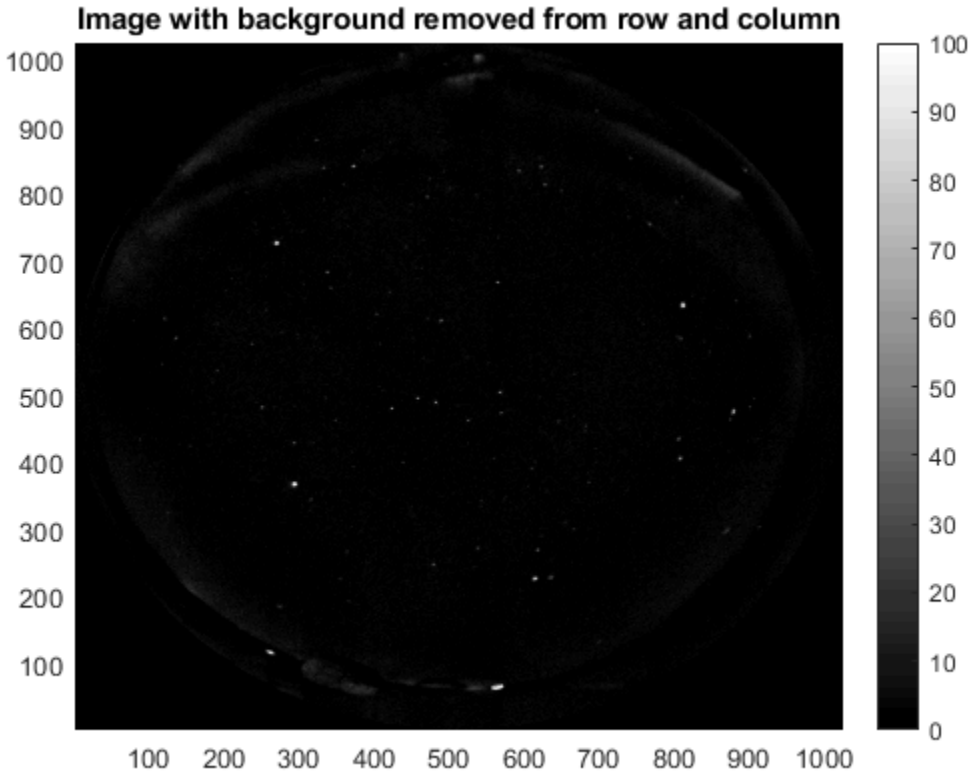
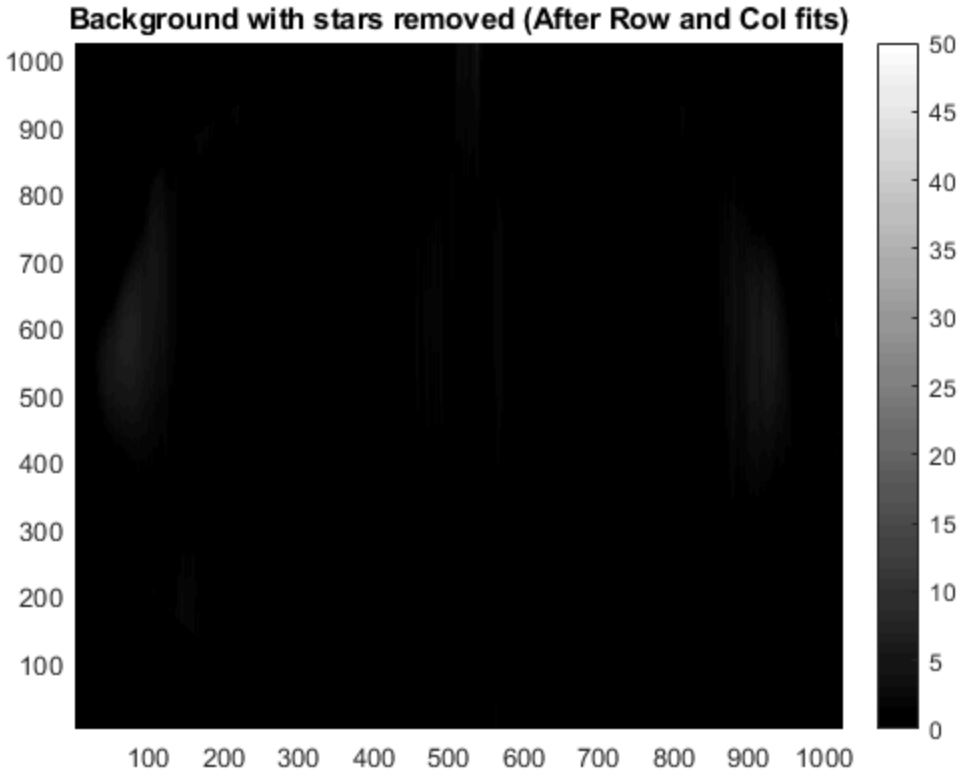
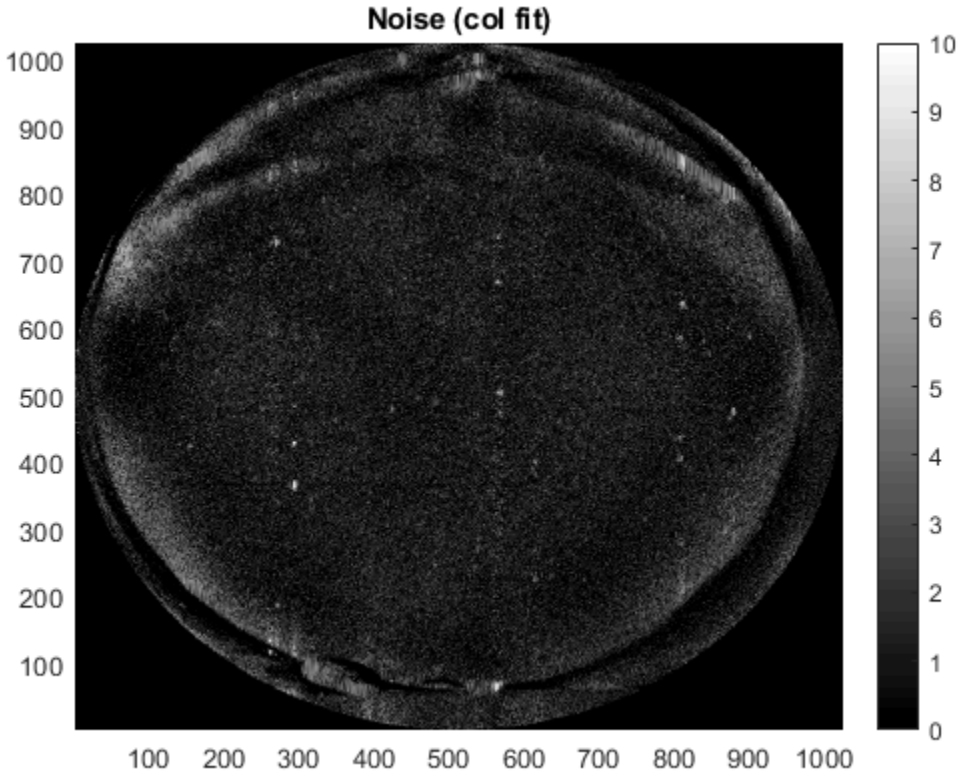


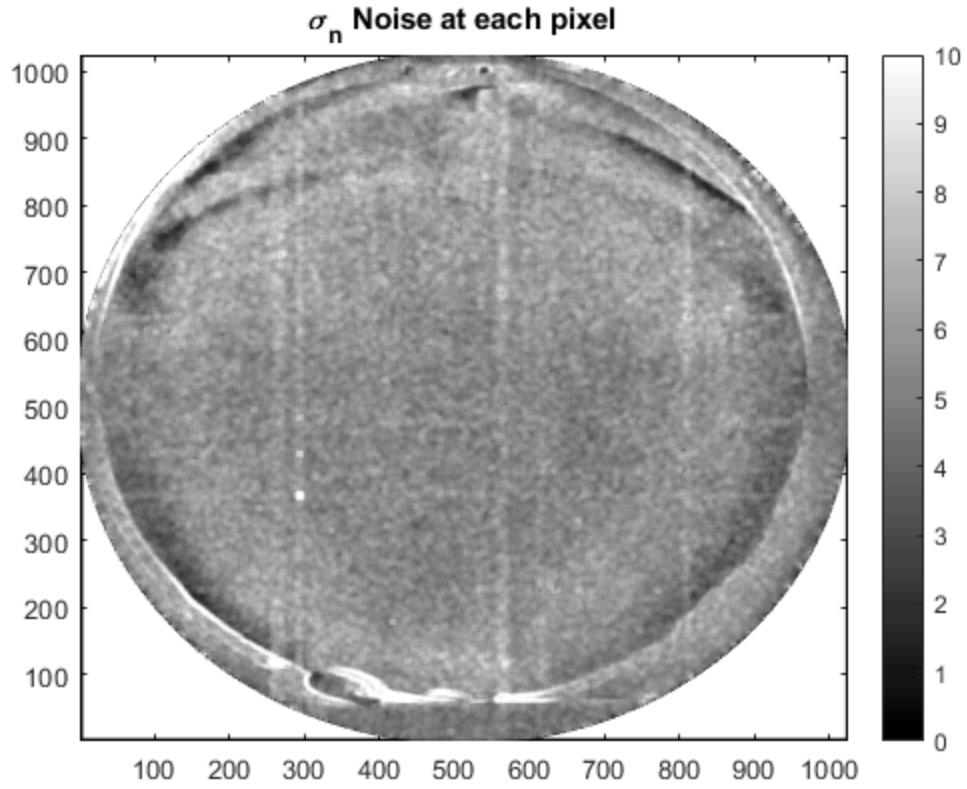
Image with background removed from row and column
1000
900
800
700
600
500
400
300
200
100
100 200 300 400 500 600 700 800 900 1000
100
90
80
70
60
50
40
30
20
10
0


Background with stars removed (After Row and Col fits)
1000
900
800
700
600
500
400
300
200
100
100 200 300 400 500 600 700 800 900 1000
50
45
40
35
30
25
20
15
10
5
0


Noise (col fit)
1000
900
800
700
600
500
400
300
200
100
100 200 300 400 500 600 700 800 900 1000
10
9
8
7
6
5
4
3
2
1
0

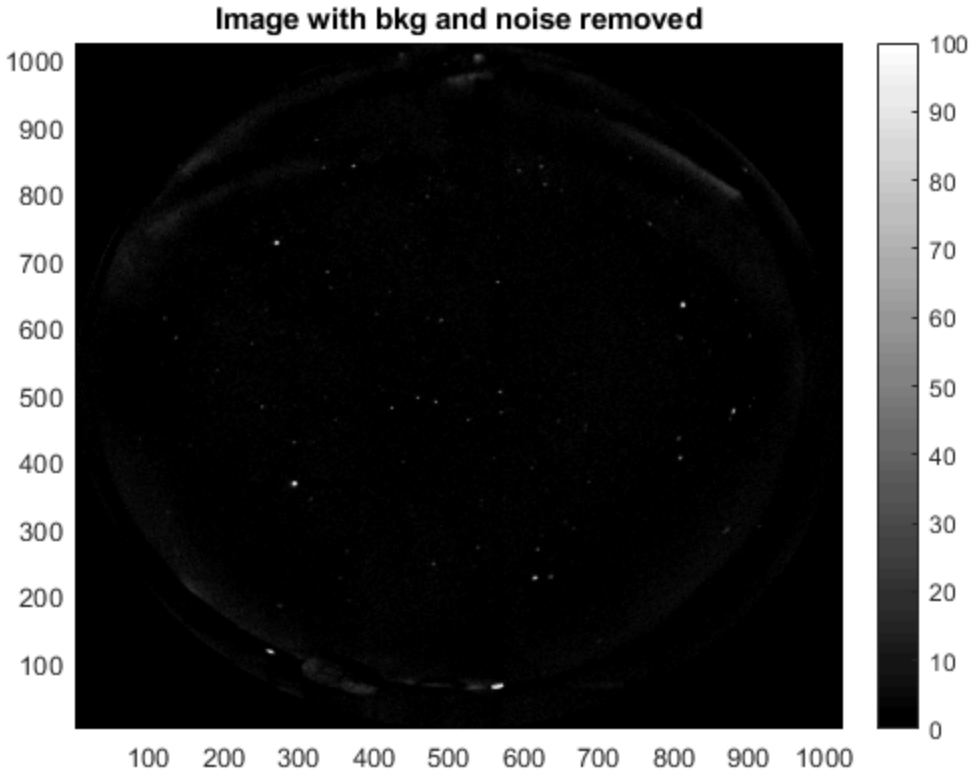
Step 4.3. Calculate noise at each pixel

```
fnoise = @(x) nanstd(x(:));
totalNoise = imColNoise+imRowNoise;
totalNoise(totalNoise==0)=nan;
sigma_n = nlfilter(totalNoise,[9 9],fnoise); % calculating std
 deviation from neighbouring pixels!
display_image(toggle, sigma_n, [0 10], '\sigma_n Noise at each
 pixel');
```



Step 4.4. Removing noise spikes

```
image1NoiseRem = remove_noise_spikes(image1BkgRem, sigma_n);
display_image(toggle, image1NoiseRem, [0 100], 'Image with bkg and
 noise removed');
```

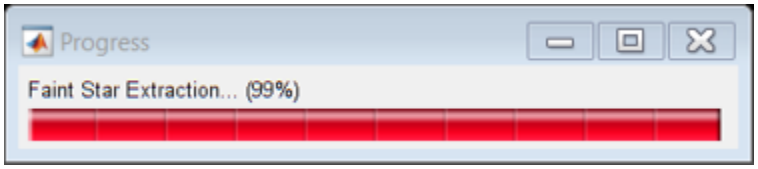


Step 4.5. Removing hot pixels See step 4.1

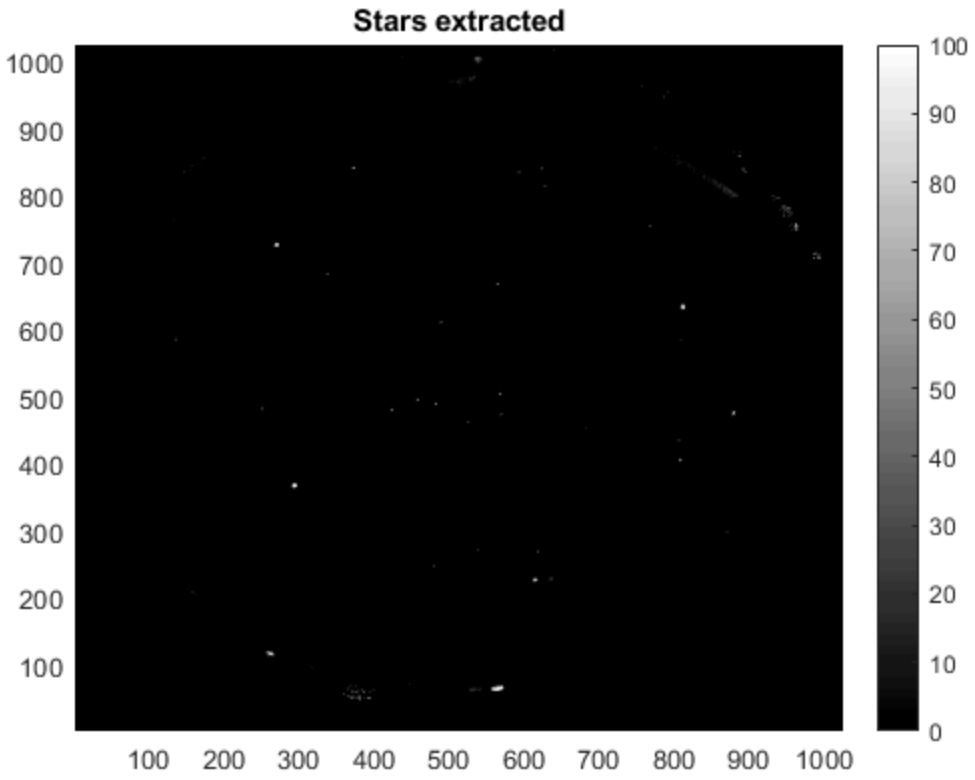
```
image1BkgRem(logical(hotPixels(:)))= nan;
```

Step 5: Extract stars

```
starImage = faint_star_extracter(image1BkgRem, sigma_n);
starImage(starImage <= 20) = 0;
```

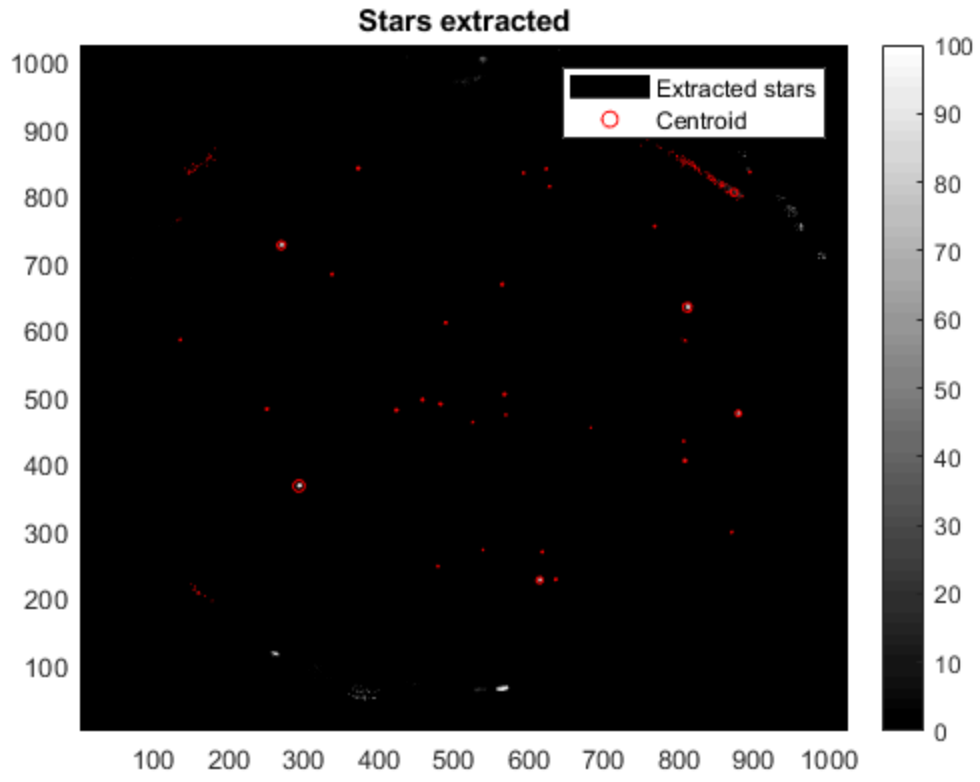



```
display_image(toggle, starImage, [0 100], 'Stars extracted');
```



Step 5.1. Extract stars

```
imstarStruct = extract_stars(starImage);
dascstar = filter_stars(imstarStruct, 22.5); % remove points in the
 corners of the image
if toggle == 1
    hold on;
    scatter(dascstar.location(:,1),
 dascstar.location(:,2),20*dascstar.brightness, 'r');
    legend('Extracted stars', 'Centroid');
end
```



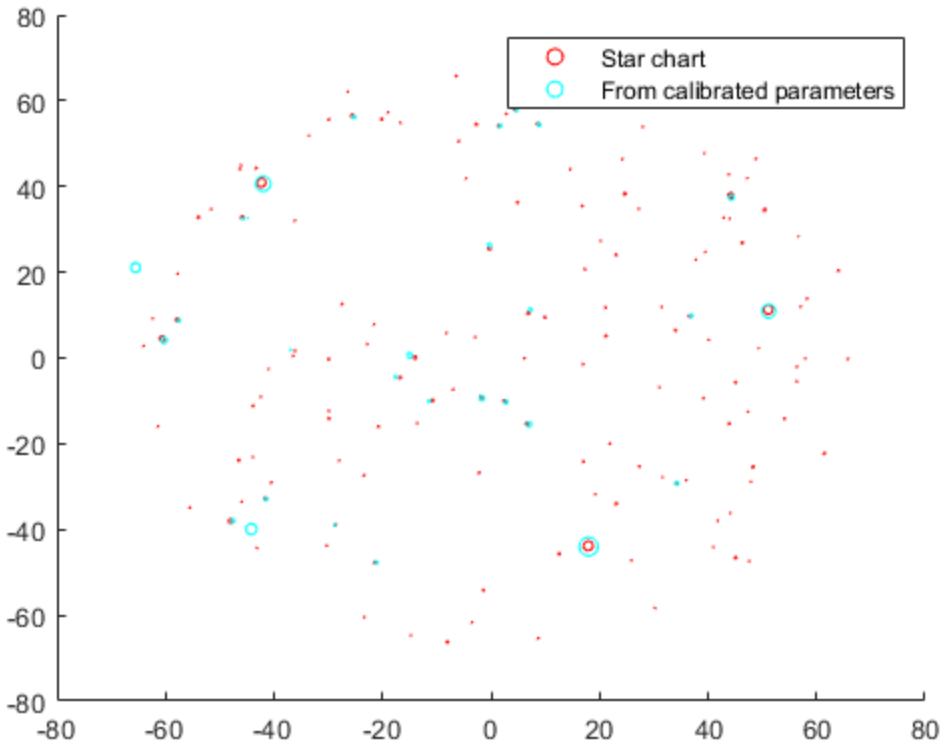
Step 5.2. Get real stars in the above format

```
realstar = get_actual_stars(stars, 22.5, 4, 0, 0, 0, 1);
```

Step 6: Calibrate stars from camera with stars from the star chart

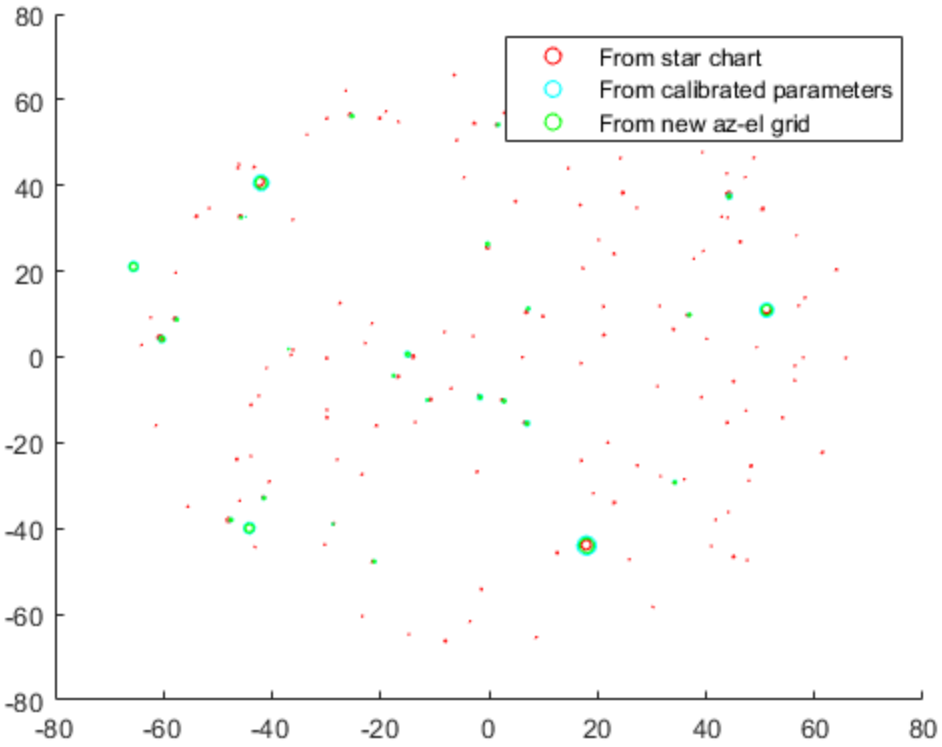
```
[dascstarCal,calPar,fval] = calibrate_stars(realstar,dascstar,dasc.az,
 dasc.el);

Optimization terminated: average change in the fitness value less than
 options.FunctionTolerance.
Optimization terminated: average change in the fitness value less than
 options.FunctionTolerance.
Optimization terminated: average change in the fitness value less than
 options.FunctionTolerance.

if toggle == 1
    figure;
    plot_aer_stars(realstar.locationAzEl(:,1),
 realstar.locationAzEl(:,2),...
        realstar.brightness*50, 'r', 0, 0, 0, 1, 0);
    hold on;
    plot_aer_stars(dascstarCal.locationAzEl(:,1),
 dascstarCal.locationAzEl(:,2),...
```

```
        dascstarCal.brightness*50, 'c',...
    calPar(1), calPar(2), calPar(3), calPar(4), calPar(5), calPar(6));
    legend('Star chart','From calibrated parameters');
end
```



Step 7: Transform the stars identified from image to new Az El values

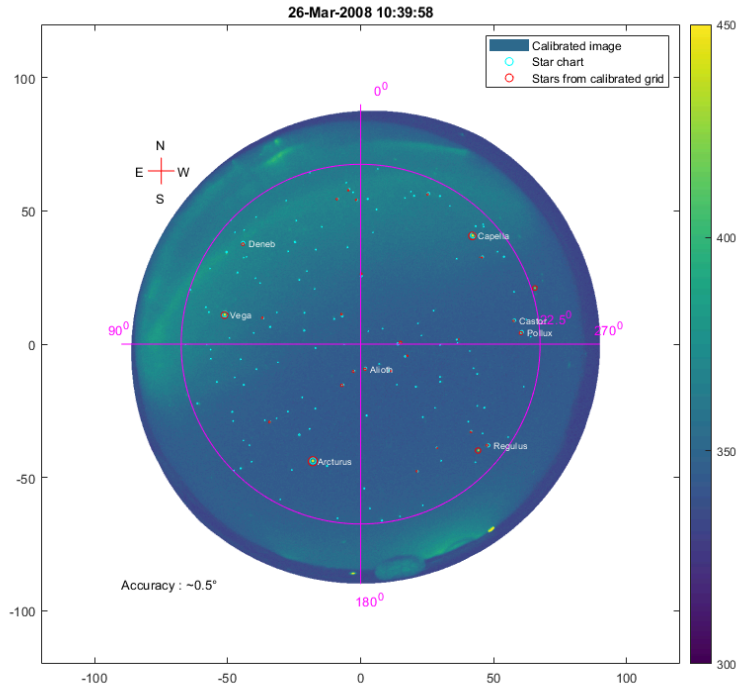
```
[dascStarAz, dascStarEl] =
 calculate_new_AzEl(dascstarCal.locationAzEl(:,1),...
    dascstarCal.locationAzEl(:,2),calPar);
if toggle == 1
    hold on;
    plot_aer_stars(dascStarAz, dascStarEl,
 dascstarCal.brightness*30, 'g', 0, 0, 0, 1);
    legend('From star chart','From calibrated parameters','From new
 az-el grid');
end
```



Step 7: Rotate the initial Az-El stencil according to the above calibrated parameters

```
[dasc.azCal, dasc.elCal] = calculate_new_AzEl(dasc.az,dasc.el,calPar);

if toggle == 1
    indx = dasc.elCal>0;
    h = figure;
    resize_figure(h,300,300);
    dsign = -1;
    p(1) = plot_DASC_aer(image1(indx), dasc.azCal(indx),
 dasc.elCal(indx), 1024, dsign);
    colorbar;
    colormap(viridis);
    xlim([-120,+120]);
    ylim([-120,+120]);
    hold on;
    p(2) = plot_aer_stars(realstar.locationAzEl(:,1),
 realstar.locationAzEl(:,2),...
        realstar.brightness*80, 'c', 0, 0, 0, dsign);
    hold on;
    p(3) = plot_aer_stars(dascStarAz, dascStarEl,
 dascstarCal.brightness*50, 'r', 0, 0, 0, dsign);
```

```
    hold on;
    plot_grid_aer([0, 90], 22.5, 'm');
    caxis([300 450]);

    plot_star_names(realstar, 8, 'w', 0, 0, 0, dsign);
    legend([p(1), p(2), p(3)], 'Calibrated image','Star chart','Stars
 from calibrated grid');
    title(timeStr);
    accuracy = (median(min(pdist2([dascStarAz,dascStarEl],...
        realstar.locationAzEl(1:length(dascStarAz),:))))');
    text(-90,-90,['Accuracy : ~',...
        num2str(accuracy,1),'°']);
end
```



Functions

```
function [totalIntensity,timeArr]=estimate_darkest_frame(h5FileStr)

asi = permute(h5read(h5FileStr,'/DASC/ASI'),[3 2 1]);
timeArr = unixtime2matlab((h5read(h5FileStr,'/DASC/time'))');
totalIntensity = sum(sum(asi,3),2);

end

function display_image(toggle,image,clim,titleStr)

    if toggle==1
```

```
        if nargin<4
            titleStr = '';
        end

        figure;
        h=pcolor(image);
        set(h,'EdgeColor','none');
        colorbar;
        colormap(get_colormap('k','w'))
        title(titleStr);

        if ~(nargin<3) && ~isempty(clim)
            caxis(clim);
        end
    end

end

function [hotPixels] = identify_hot_pixels(image1, image2, threshold)

    if nargin<3
        threshold = 2;
    end

    temp = image1 - image2;
    temp2 = temp;
    hotPixels=zeros(size(temp2));
    hotPixels(abs(temp2)<=threshold) = 1;
end

function [ASINew, background, ASINoise, pRow, muRow, a] =
 remove_background(ASI, nPoly)

% Remove background along the row

if nargin < 2
    nPoly = 3;
end

% ASINew, background
rowIndx = 1:1:size(ASI,2);
colIndx = 1:1:size(ASI,1);
ASINew = zeros(size(ASI));
background = zeros(size(ASI));
ASItemp = ASI;
ASINoise = zeros(size(ASI));
pRow = zeros([length(rowIndx),nPoly+1]);
% First iteration
for ifit = 1:2
    for i = rowIndx
        lchord = sqrt(512.^2-(abs(512-i)).^2);
        fitRangeIndx =512-round(lchord)+1:1:512+round(lchord);
        x = colIndx(fitRangeIndx);
        y = ASItemp(i,fitRangeIndx);
```

```
        if length(fitRangeIndx)>10
            pRow(i,:)=polyfit(x,y,nPoly);
        end
        muRow(i,:)=mean(y);
        stdRow(i,:) = std(y);
        a(i).fitRangeIndx = fitRangeIndx;
        background(i,fitRangeIndx) =
 polyval(pRow(i,:),colIndx(fitRangeIndx));
        if ifit==1
            brightStarIndx = ASItemp(i,:) >
 (background(i,:)+1*stdRow(i,:));
            if length(find(brightStarIndx)>0)
                ASItemp(i,brightStarIndx) = nan;
                ASItemp(i,fitRangeIndx) =
 interp_nans(ASItemp(i,fitRangeIndx)')';
            end
        else
            ASINew(i,fitRangeIndx) = ASI(i,fitRangeIndx)-
background(i,fitRangeIndx);
            ASINoise(i,fitRangeIndx) = ASItemp(i,fitRangeIndx)-
background(i,fitRangeIndx);
        end

    end
end

end

function ASI = remove_noise_spikes(ASI, sigma_n)

    for i=3:1:size(ASI,1) - 2
        for j = 3:1:size(ASI,2) - 2
            A = ASI(i,j);
            B1 = ASI(i,j-1);    B2 = ASI(i,j-2);
            C1 = ASI(i-1,j);    C2 = ASI(i-2,j);
            D1 = ASI(i,j+1);    D2 = ASI(i,j+2);
            E1 = ASI(i+1,j);    E2 = ASI(i+2,j);
            s = sigma_n(i,j);
            singleSpike = (A > 2*s)*(B1 < 2*s)*(C1 < 2*s)*(D1 <
 2*s)*(E1 < 2*s);
            doubleSpike(1) = (A > 3*s)*((B1>2*s)*(B2<2*s))*...
                not((C1>2*s))*not((D1>2*s))*...
                not((E1>2*s));
            doubleSpike(2) = (A > 3*s)*not((B1>2*s))*...
                ((C1>2*s)*(C2<2*s))*not((D1>2*s))*...
                not((E1>2*s));
            doubleSpike(3) = (A > 3*s)*not((B1>2*s))*...
                not((C1>2*s))*((D1>2*s)*(D2<2*s))*...
                not((E1>2*s));
            doubleSpike(4) = (A > 3*s)*not((B1>2*s))*...
                not((C1>2*s))*not((D1>2*s))*...
                ((E1>2*s)*(E2<2*s));
            ASI(i,j) = not(singleSpike).*A;
            ASI(i,j) = not(sum(doubleSpike)).*A;
```

```
            ASI(i,j-1) = not(doubleSpike(1)).*B1;
            ASI(i-1,j) = not(doubleSpike(2)).*C1;
            ASI(i,j+1) = not(doubleSpike(3)).*D1;
            ASI(i+1,j) = not(doubleSpike(4)).*E1;
        end
    end


end

function [starImage] = faint_star_extracter(ASI, sigma_n)

    mSz = 7;
    MSz = 9;
    dSz = (MSz-mSz)/2;
    if mod(dSz,1)
        error('mSz-MSz has to be even');
    end

    starImage = zeros(size(ASI));

    multiWaitbar('Faint Star Extraction...',0);
    id = 1./size(ASI,1);
     % For faint stars
    for i=1:1:size(ASI,1) - MSz
        for j = 1:1:size(ASI,2) - MSz
        M = ASI(i:i+MSz-1,j:j+MSz-1);
        in = M(1+dSz:dSz+mSz,1+dSz:dSz+mSz);
        out = M;
        out(1+dSz:dSz+mSz,1+dSz:dSz+mSz)=0;
        sig_n = sigma_n(i+dSz+ceil(mSz/2),j+dSz+ceil(mSz/2));
        mu_in = nanmean(in(:));
        mu_out = nanmean(out(:));
        % Condition
        if mu_in > 2*sig_n && mu_out < 2*sig_n
            starImage(i:i+MSz-1,j:j+MSz-1) = M;
        end

        end
    multiWaitbar('Faint Star Extraction...','Increment',id);
    end

end


function imstar = extract_stars(image)
% Image should be post all processing
binaryImage = zeros(size(image));
binaryImage(image>0)=1;
[labelImage, numSpots] = bwlabel(binaryImage);
props =
 regionprops(labelImage,image,'Centroid','Area','MeanIntensity');
for i =1:1:numSpots
    imstar.ID(i,1) = i;
```

```
    imstar.location(i,:) = props(i).Centroid;
    imstar.brightness(i,1) = props(i).Area.*props(i).MeanIntensity;
end
imstar.brightness = imstar.brightness./max(imstar.brightness); %
 Relative magnitude
imstar.size = size(image);
end

function [newstar, I] = filter_stars(imstar, elMax, astrometryFileStr)
    % Function sorts stars according to brightness, and defines a FoV
 of
    % interest.

    % Input
    % imstar: A structure of star extracted from image
    % elMax : Stars below this elevation will not be considered
    % astrometryFileStr : A text file written in the format necessary
    %                     for astrometry web utility: http://
nova.astrometry.net/upload

    % Output
    % newstar: A structure with stars sorted according to intensity
    % I      : Sorting index

    if nargin<3
        astrometryFileStr = []; % File containing text that can
 uploaded to astrometry
    end
    % Restricting the field of view.
    FOV  = (90-elMax)*2;
    % Assuming fish eye
    imLength = imstar.size(1);
    LengthperElevation = imLength/180;
    p.min = round(imLength/2) - round(LengthperElevation*FOV/2);
    p.max = round(imLength/2) + round(LengthperElevation*FOV/2);

    selectedStarIndx =(imstar.location(:,1)>p.min &...
        imstar.location(:,1)<p.max & ...
        imstar.location(:,2)>p.min & ...
        imstar.location(:,2)<p.max);

    newstar.location = imstar.location(selectedStarIndx,:);
    newstar.brightness = imstar.brightness(selectedStarIndx)';

    % Sorting the stars based on its magnitude.
    [newstar, I] = sort_star(newstar);

    if ~isempty(astrometryFileStr)
    dlmwrite(astrometryFileStr,round(newstar.location));
    end

end

function [newstar, I] = sort_star(newstar)
```

```
    % Function that sorts stars according to brightness
    [newstar.brightness, I] = sort(newstar.brightness,'descend');
    newstar.brightness = newstar.brightness';
    newstar.location = newstar.location(I,:);
end

function realstar =
 get_actual_stars(stars,elCutOff,magCutOff,dx,dy,drot, dsign)
    if nargin < 7
        dsign = 1;
    end

    starfilter=stars.vmag<magCutOff & stars.el>elCutOff;
    [x,y] = get_aer_stars(stars.az(starfilter), stars.el(starfilter),
 dx, dy, drot, dsign);
    realstar.location = [x, y]; %pixel location
    realstar.brightness = stars.relIntensity(starfilter);
    realstar.locationAzEl = [stars.az(starfilter),
 stars.el(starfilter)];
    realstar.name = stars.name(starfilter);
    [realstar, I] = sort_star(realstar); %s
    realstar.locationAzEl = realstar.locationAzEl(I,:);
    realstar.name = realstar.name(I);
end

function [x,y] = get_aer_stars(az,el,dx,dy,drot,dsign,dr,k)
    if nargin <8
        k = 0; % k is the distortion parameter
    end
    if nargin <7
        dr = 0; % Determines the field of view in the image
    end
    if nargin<6
        dsign = 1;
    end
    az = rotate_array(az,drot);
    r = (90-el);
    x = dx + dsign.*((r+dr).*sind(az) + (k*10^-6).*r.^2);
    y = dy + (r+dr).*cosd(az) + (k*10^-6).*r.^2;
end

function [dascstar,x,fval] =
 calibrate_stars(realstar,dascstar,azOld,elOld)
    dloc = round(dascstar.location);
    dascstar.brightness = dascstar.brightness./
max(dascstar.brightness);
    lindx = sub2ind(size(azOld),dloc(:,2),dloc(:,1));
    %                               rows(y)   cols(x)
    dascstar.locationAzEl = [azOld(lindx), elOld(lindx)];
    minElFilter = find(dascstar.locationAzEl(:,2)>=22.5);
    dascstar.locationAzEl = dascstar.locationAzEl(minElFilter,:);
    dascstar.brightness = dascstar.brightness(minElFilter);
    dascstar.location = dascstar.location(minElFilter,:);
    ndasc = length(dascstar.brightness);
```

```
    starIndx = true(1,ndasc);

    % dx, dy translation of center point
    % drot - rotation along azimuth
    % dr - is field of view (radius)
    % k - radial distortion coefficient
    %     dx   dy   drot    dr     k =0
    lb = [-10, -10, -180,  -10,    -100 ];
    ub = [+10, +10, +180,  +10,    +100 ];
    nvars = 5;
    options = optimoptions('ga','MaxGenerations',20000);

    dsign = [-1, +1];
    for k = 1:2
        [y(k,:),fval(k),exitflag] = ga(@starDistance,nvars,[],[],[],
[],...
            lb,ub,[],options);
    end

    [~,minIndx] = min(fval);
    x = [y(minIndx,1), y(minIndx,2), y(minIndx,3), dsign(minIndx),...
        y(minIndx,4), y(minIndx,5)];

    % Removing planets and other objects not in the star database
    [x2, y2] = get_aer_stars(dascstar.locationAzEl(:,1),...
        dascstar.locationAzEl(:,2),x(1),x(2),x(3),x(4),x(5),x(6));
    D2 = pdist2([x2, y2], realstar.location(1:ndasc,:));
    dmin2 = min(D2');
    unmatchedObjects = dmin2 > 0.5; %Objects do not match if greater
 than 1 deg off
    nMatched = sum(~unmatchedObjects);

    if nMatched>10
        starIndx = ~unmatchedObjects;
        k = minIndx;
        [y2, fval, ~] = ga(@starDistance,nvars,[],[],[],[],...
            lb,ub,[],options);
        x = [y2(1,1), y2(1,2), y2(1,3), dsign(minIndx), y2(1,4),
 y2(1,5)];
    else
        warning(['Number of stars available should be more than 10. N
 = ',...
            num2str(nMatched),'. Redoing the calculation']);
        [dascstar,x,fval] =
 calibrate_stars(realstar,dascstar,azOld,elOld);
    end

    function dmin=starDistance(x)
        [x1,y1] = get_aer_stars(dascstar.locationAzEl(starIndx,1),...

 dascstar.locationAzEl(starIndx,2),x(1),x(2),x(3),dsign(k),x(4));
        dascstar.newxy = [x1,y1];
        D =
 pdist2(dascstar.newxy,realstar.location(1:sum(starIndx),:));
```

```
            dmin = sum(min(D));
        end

    end

    function [azNew, elNew] = calculate_new_AzEl(azOld,elOld,x)

        [xNew,yNew] =
     get_aer_stars(azOld,elOld,x(1),x(2),x(3),x(4),x(5),x(6));
        azNew = wrapTo360(atan2d(xNew,yNew));
        elNew = 90 - xNew./(sind(azNew));
        indx = elNew<=0;
        azNew(indx) = nan;
        elNew(indx) = nan;

    end

    function p = plot_aer_stars(az,el,relIntensity,colorStr, dx, dy, drot,
     dsign, dr, k)
        if nargin<10
            k = 0; %radial distortion
        end
        if nargin<9
            dr = 0; % Extent of the radius/ FoV
        end
        if nargin<8
            dsign = 1;
        end
        [x,y] = get_aer_stars(az, el, dx, dy, drot, dsign, dr, k);
        p = scatter(x,y,relIntensity,colorStr);
    end

    function plot_star_names(sortedStars, n, color, dx, dy, drot ,dsign)
        if nargin < 3 || isempty(color)
            color = 'c';
        end
        if nargin <2 || isempty(n)
            n = 5;
        end

        hold on;
        starNames =
     string(extractBetween((sortedStars.name(1:1:n)),'(',')'));
        for i = 1:1:n
            [x,y] = get_aer_stars(sortedStars.locationAzEl(i,1),
     sortedStars.locationAzEl(i,2),...
                dx,dy,drot,dsign);
            t=text(x,y,strcat("  ",starNames(i)));
            t.Color = color;
            t.FontSize = 7;
        end
    end

    function [az, el] = get_AzEl_grid(imageSize)
```

```
    x = linspace(-90,90,imageSize);
    y = linspace(-90,90,imageSize);

    [X, Y] = meshgrid(x,y);

    az = wrapTo360(atan2d(X,Y));
    el = 90 - X./(sind(az));

    indx = el<=0;
    az(indx) = nan;
    el(indx) = nan;

end
```

Published with MATLAB® R2018b