# Lab 7

In this lab we would like to identify and isolate the signals that HERA searches for. The signal from the sky is known to be very steady in time, as opposed to the background contamination which can vary based on the time of day or rotation of the Earth.

```
clear;
clc;

load('hera_data.mat')
%Use just XX polarized light, as it has the highest magnitude of visibility
pol = 1;
range = 1:1378;
%Make an array of complex numbers from the visdata struct
visdata_re = visdata.r(pol, :, 1, :);
visdata_im = visdata.i(pol, :, 1, :);
visdata_complex = complex(visdata_re, visdata_im);
```

```
visdata_mag = abs(visdata_complex);
visdata_time1 = visdata_mag(:, :, 1, range);
```

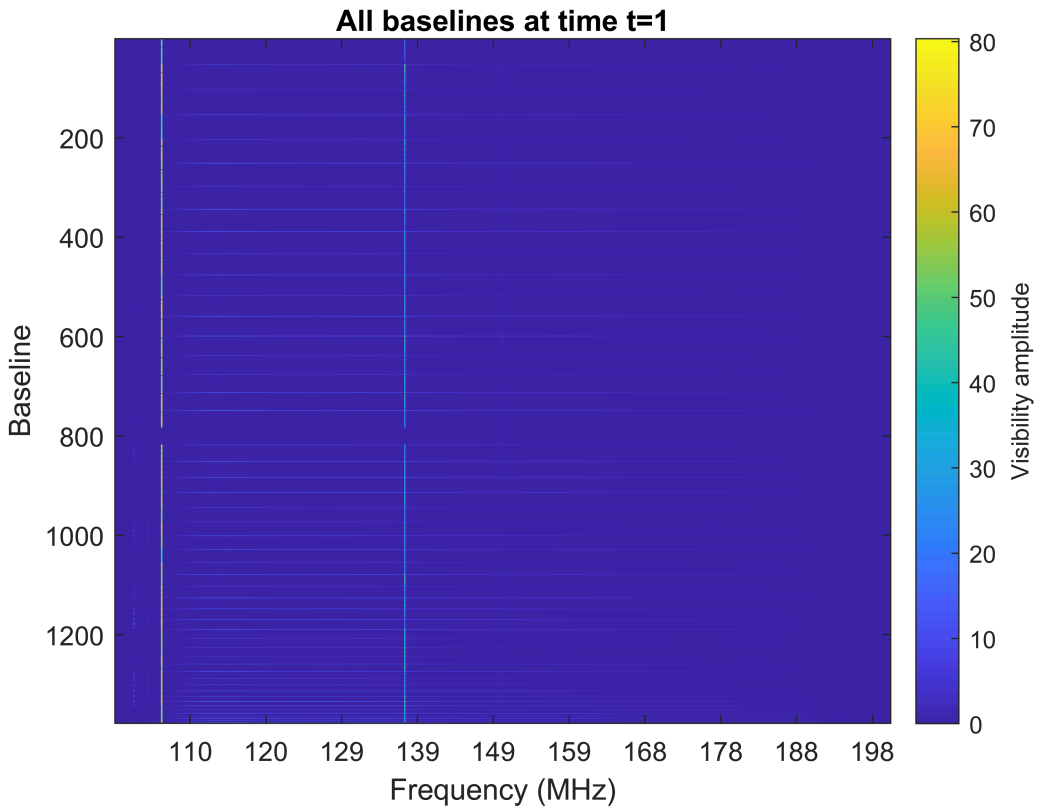
We are given data from all 1,378 baselines for 60 instances in time, which is represented by a vector of length 1,378 * 60 (where every 1,378 entries represents a diferent value of time). Again, time is given in units of Julian days, which is shown here. The time t=1 corresponds to the first entry in time_array, and is the time which corresponds to the first 1,378 entries in the [baseline pairs * times] column of the array visdata:

```
time_1 = time_array(1);
fprintf('%.6f\n', time_1)
```

```
2458108.125574
```

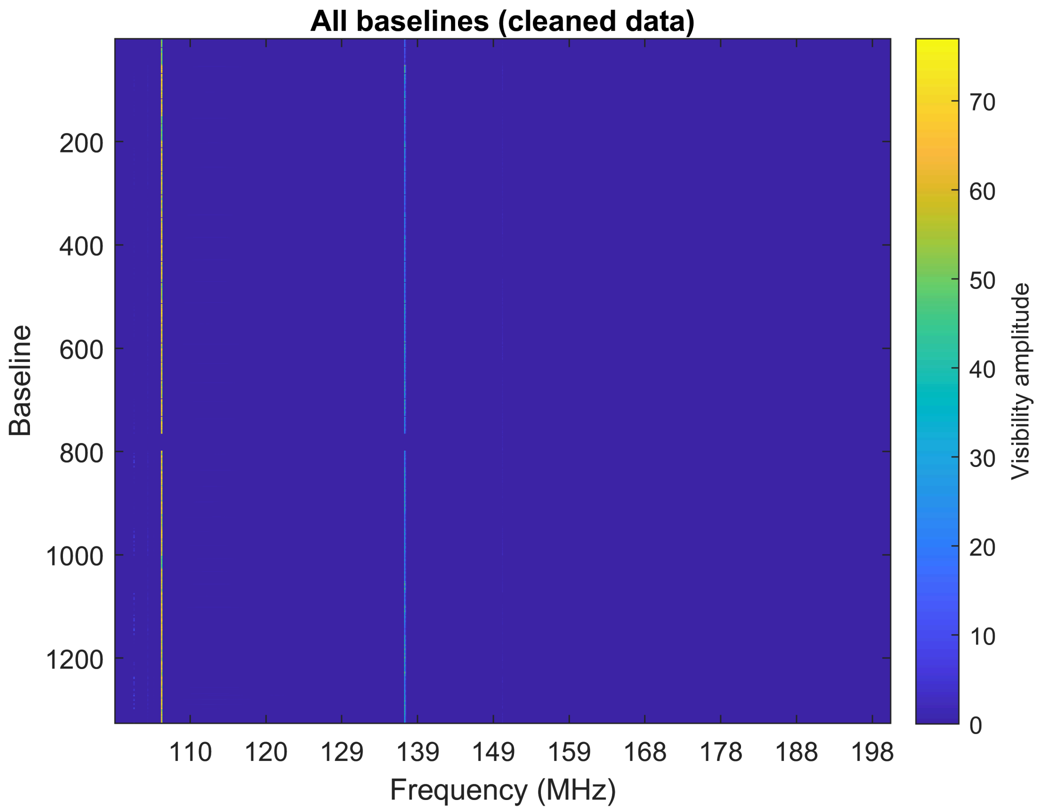
By plotting the complex magnitude of the visibility of the first 1,378 baselines in this vector against frequency, we can create a plot which shows the readings of all baselines at time t = 1:

```
%Plot the raw data for time 1
clf;
imagesc(squeeze(visdata_time1)')
xt = get(gca, 'XTick');
set(gca, 'XTick', xt, 'XTickLabel', round(xt/10.24 + 100));
xlabel('Frequency (MHz)');
ylabel('Baseline')
c = colorbar;
c.Label.String = "Visibility amplitude";
title('All baselines at time t=1')
```




We can remove these horizontal streaks of data, which correspond to baselines comprised of one antenna being correlated with itself. To do this, we simply remove all data with indices corresponding to baselines with the same antenna paired with itself.

```
commonpair_indices = baselines(:, 1) == baselines(:, 2);
clean_data = visdata_time1(:, :, :, ~commonpair_indices);
clean_img = squeeze(clean_data)';
clf;
imagesc(clean_img);
xt = get(gca, 'XTick');
set(gca, 'XTick', xt, 'XTickLabel', round(xt/10.24 + 100));
xlabel('Frequency (MHz)');
ylabel('Baseline')
c = colorbar;
c.Label.String = "Visibility amplitude";
title('All baselines (cleaned data)')
```

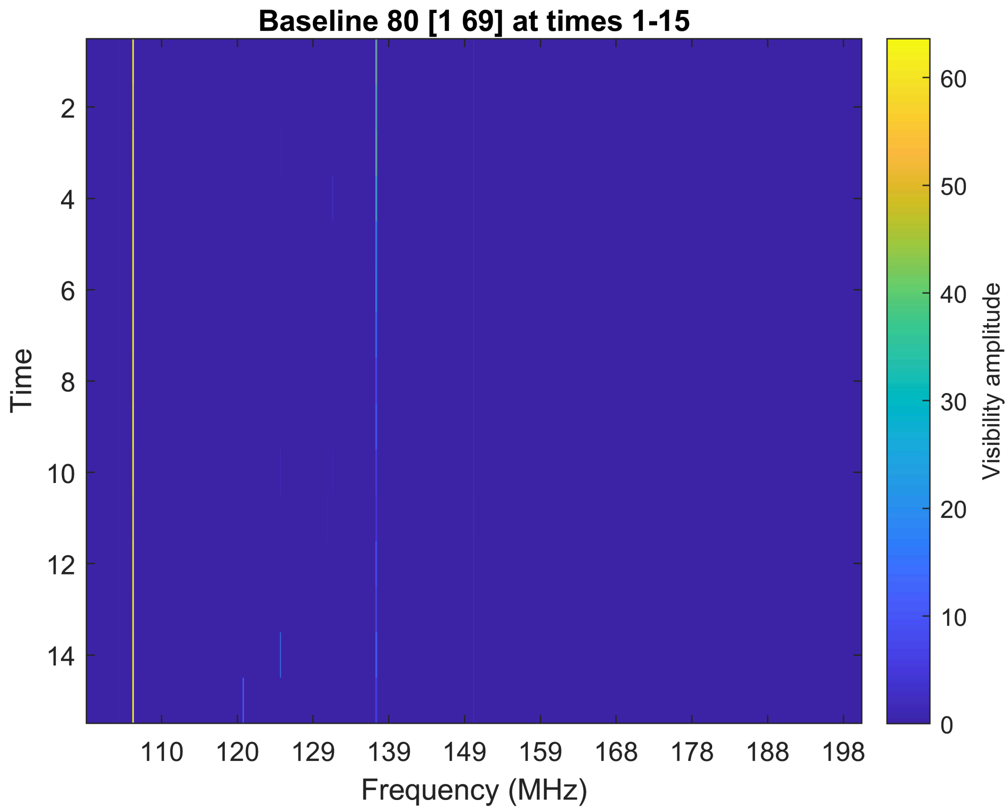



Now we would like to observe the data recieved by a single baseline over several instances of time.

```
%Choose a specific pair of antennas (X, Y), or just choose a baseline N
baseline = [1 69];
if isscalar(baseline)
    bl = baseline;
    antennas = baselines(bl, :);
else
    bl = find(ismember(baselines, baseline, "rows"))
    antennas = baseline;
end
```

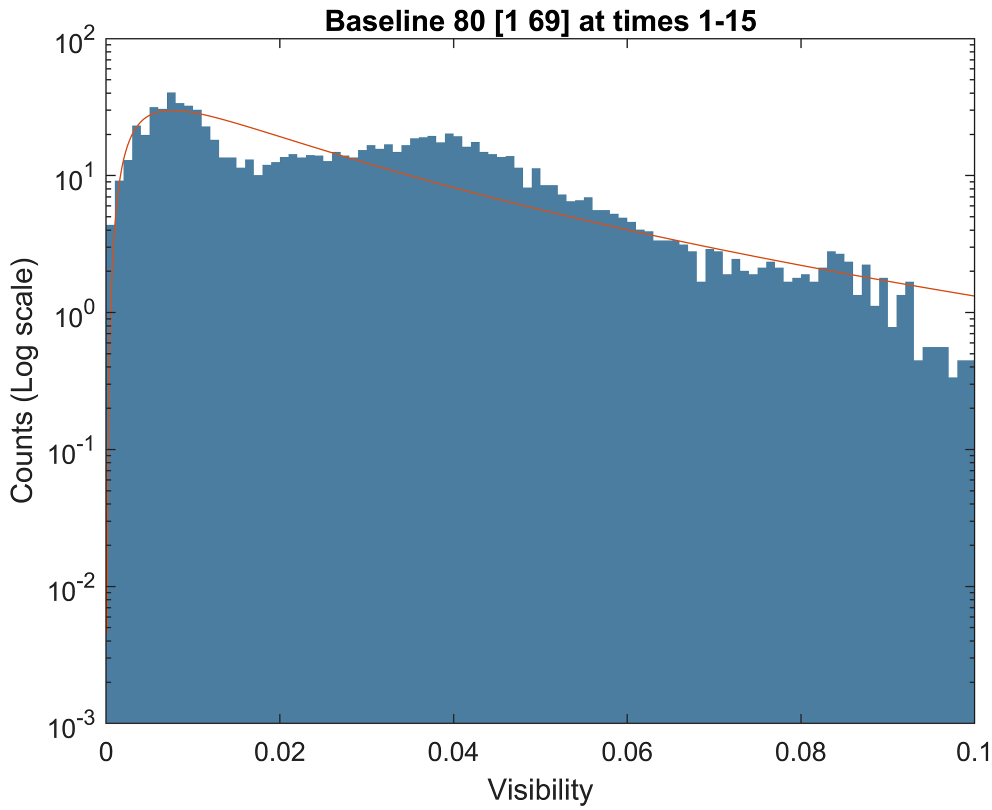
```
bl = 80
```

```
baseline_waterfall_data = visdata_mag(:, :, :, bl:1378:end);
waterfall_img = squeeze(baseline_waterfall_data)';

clf;
imagesc(waterfall_img);
xt = get(gca, 'XTick');
set(gca, 'XTick', xt, 'XTickLabel', round(xt/10.24 + 100));
xlabel('Frequency (MHz)');
yticks('auto');
ylabel('Time');
c = colorbar;
c.Label.String = "Visibility amplitude";
title(['Baseline ' num2str(bl) ' ' mat2str(antennas) ' at times 1-15']);
```

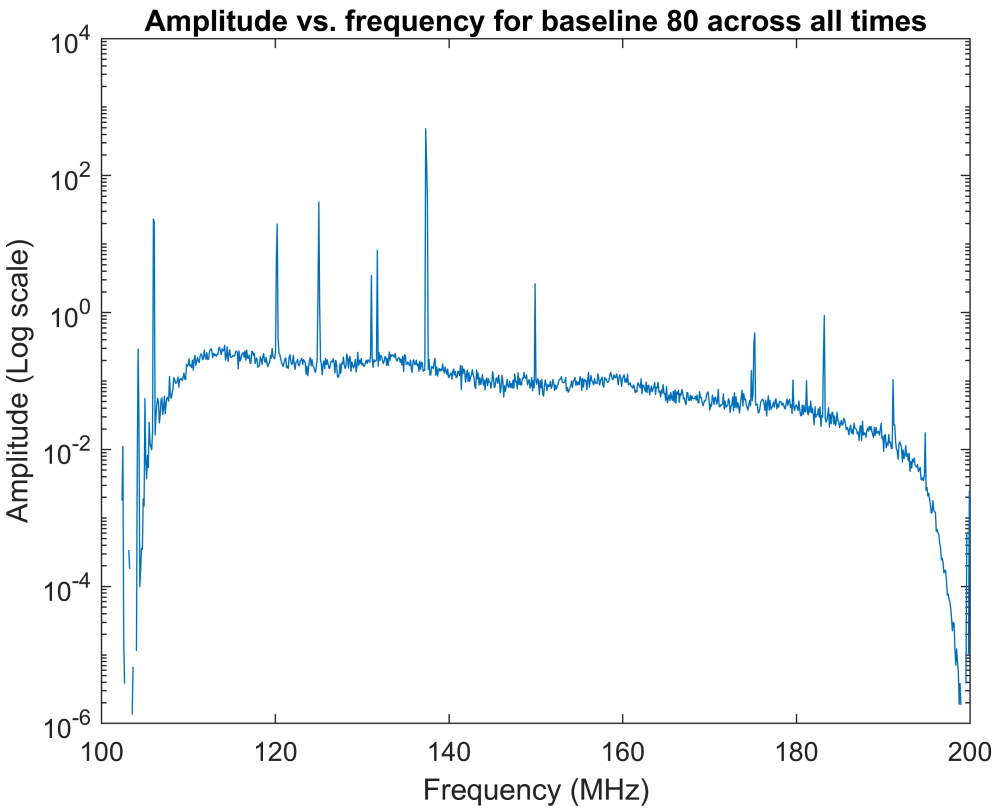



The signal from this baseline looks like it varies in time, with signals appearing in the 120-130 MHz range from t=14 to t=15.

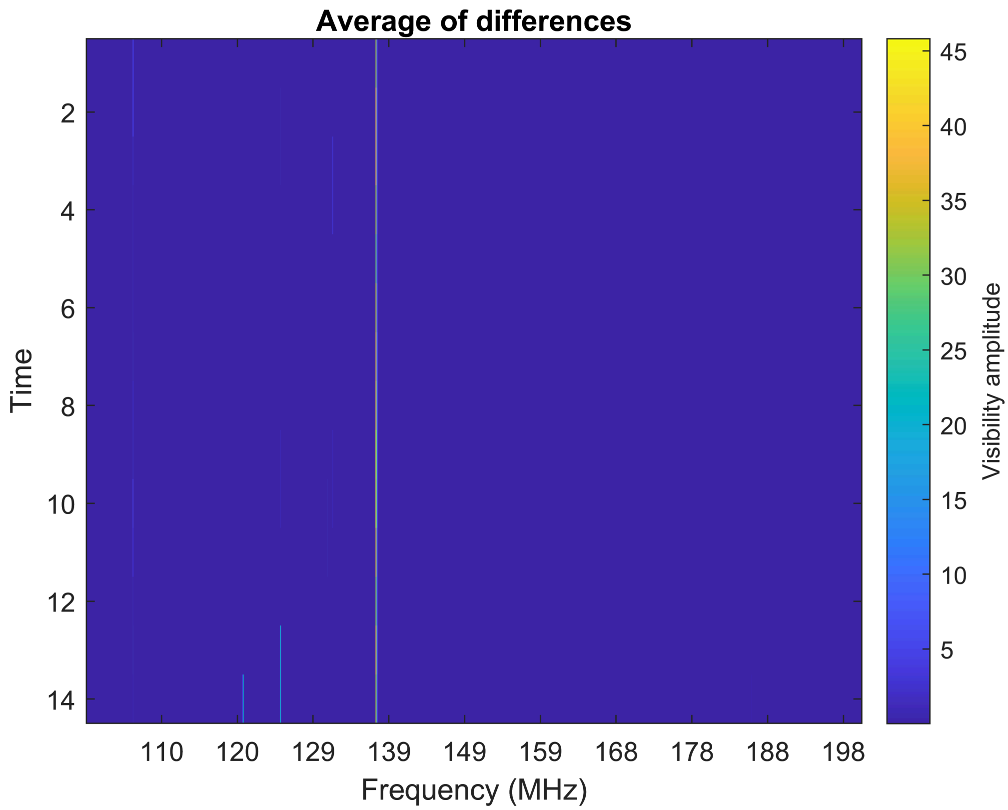
```
clf;
nbins = 100;
waterfall_img_limit = waterfall_img(:, 200:800);
maxval = 0.1;
histogram(waterfall_img_limit(waterfall_img_limit < maxval), nbins, 'EdgeColor', 'none', 'Norma

PD = fitdist(reshape(waterfall_img_limit, [], 1), 'Lognormal');
xs = linspace(0, maxval, 1000);
ys = lognpdf(xs, PD.mu, PD.sigma);

plot(xs, ys);

set(gca, 'YScale', 'log')
xlabel('Visibility');
ylabel('Counts (Log scale)');
xlim([0 maxval])
title(['Baseline ' num2str(bl) ' ' mat2str(antennas) ' at times 1-15']);
```



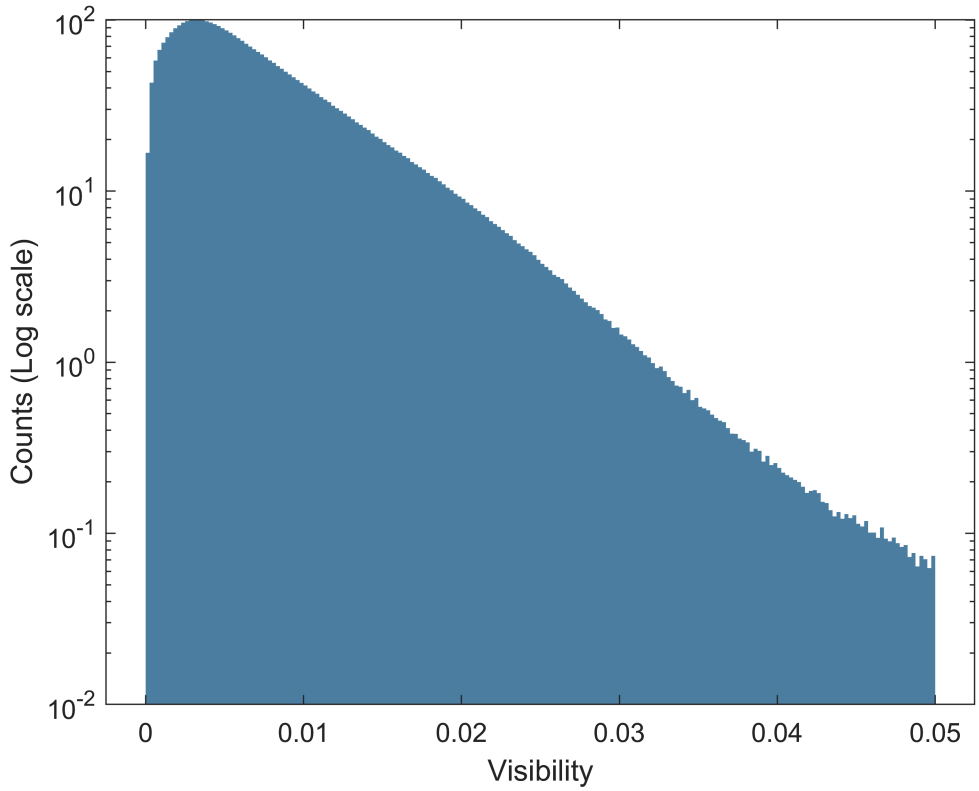

```
vis = squeeze(visdata_complex);

%Differenced times for time 1

diffs = zeros(1024, 14, 1378);
for ii = 1:1378
    diffs(:, :, ii) = diff(vis(:, ii:1378:end), 1, 2);
end

amplitude1 = sum(abs(diffs(:, :, bl)), 2);
clf;
semilogy(freq_array ./ 1e6, amplitude1(1:1024))
xlabel('Frequency (MHz)');
ylabel('Amplitude (Log scale)')
title(['Amplitude vs. frequency for baseline ' num2str(bl) ' across all times'])
```




```
%remove vaa from data
clean_diffs = abs(diffs(:, :, ~commonpair_indices));

averages = mean(abs(clean_diffs), 3);
clf;
imagesc(averages');
xt = get(gca, 'XTick');
set(gca, 'XTick', xt, 'XTickLabel', round(xt/10.24 + 100));
xlabel('Frequency (MHz)');
yticks('auto');
ylabel('Time');
c = colorbar;
c.Label.String = "Visibility amplitude";
title('Average of differences');
```




```
%Average per frequency
avg_val = mean(averages, 1);
clf;
nbins = 200;
maxval = 0.05;
clean_diffs_lim = clean_diffs(200:800, :, :);
cl = clean_diffs_lim(clean_diffs_lim < maxval);
histogram(cl, nbins, 'EdgeColor', 'none', 'Normalization', 'pdf');

PD = fitdist(reshape(cl, [], 1), 'Lognormal');
xs = linspace(0, maxval, 1000);
ys = lognpdf(xs, PD.mu, PD.sigma);

set(gca, 'YScale', 'log')
xlabel('Visibility');
ylabel('Counts (Log scale)');
```




```
%xlim([0 0.05])
%xlim([0 maxval])


% times_vis = [];
% for ii = 1:1378
%     times_vis = [times_vis; vis(:, ii:1378:end)];
% end
% times_vis
```