Fast Camera Image Analysis

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Introduction

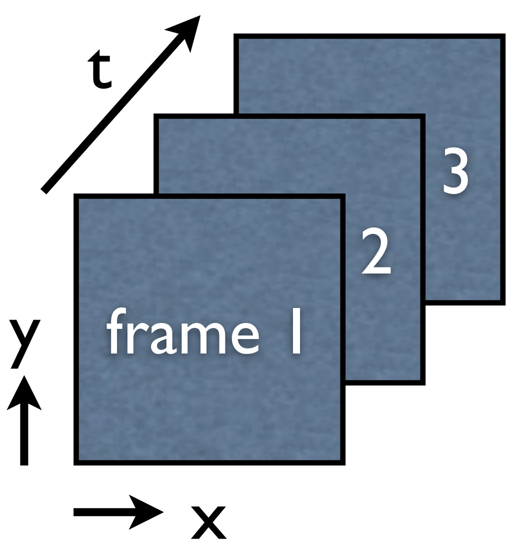
A high speed camera is used to image the visible light in CTX. The camera is begins recording at the specified trigger time, and records until the data buffer is filled. The images are mapped to device coordinates. Various ‘movies’ of light fluctuations can be made by simple signal analysis in space and time.

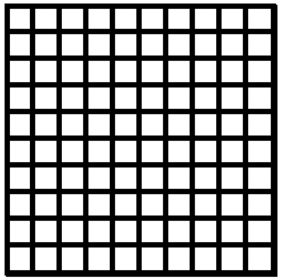
Statistics of the light fluctuations are calculated, and correlations with other diagnostics are performed.

In real device coordinates, the azimuthal wavenumber spectrum is calculated. It is found that very little power exists for small scale fluctuations.

Camera

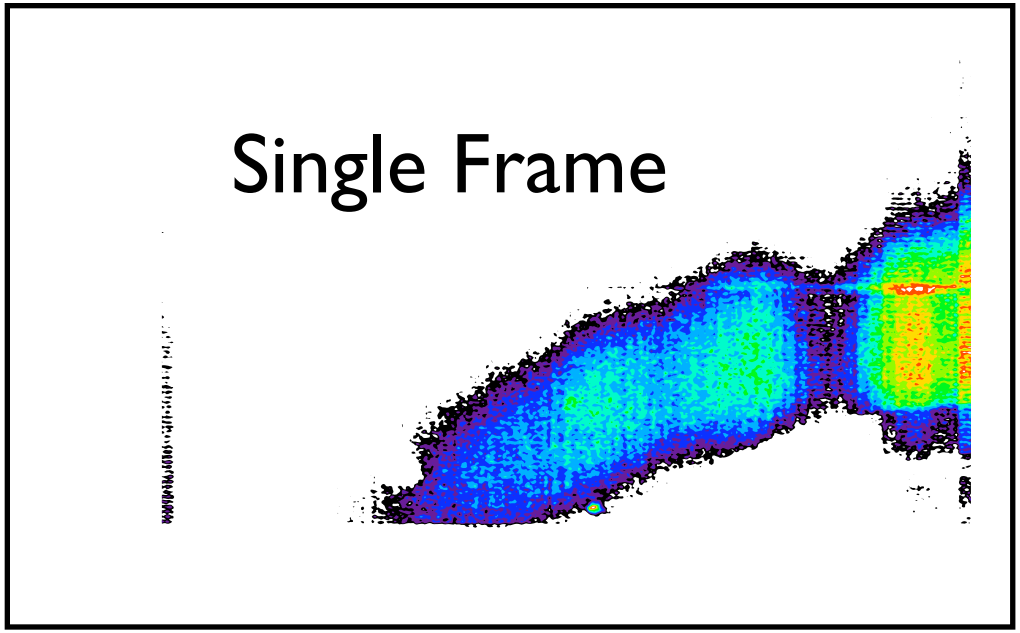
- Phantom v7.1 High Speed Camera
- Frame rate used was 10,000 fps. 10kHz Sampling Rate. 5kHz Nyquist Frequency.
- Images stored as '.tif' files.

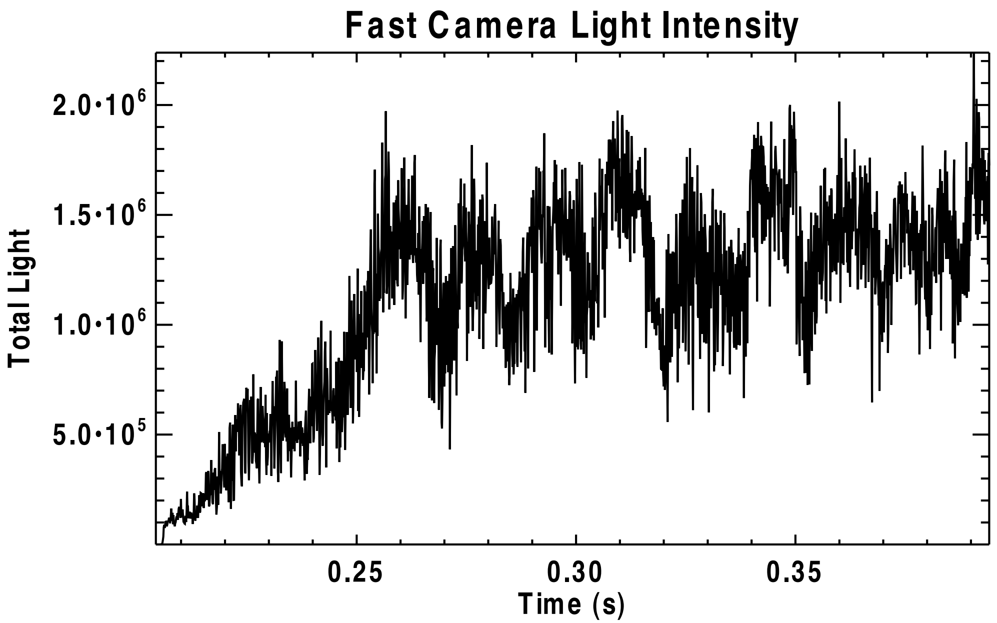




Each image is a grid, and filtering can be done in x, y or t.

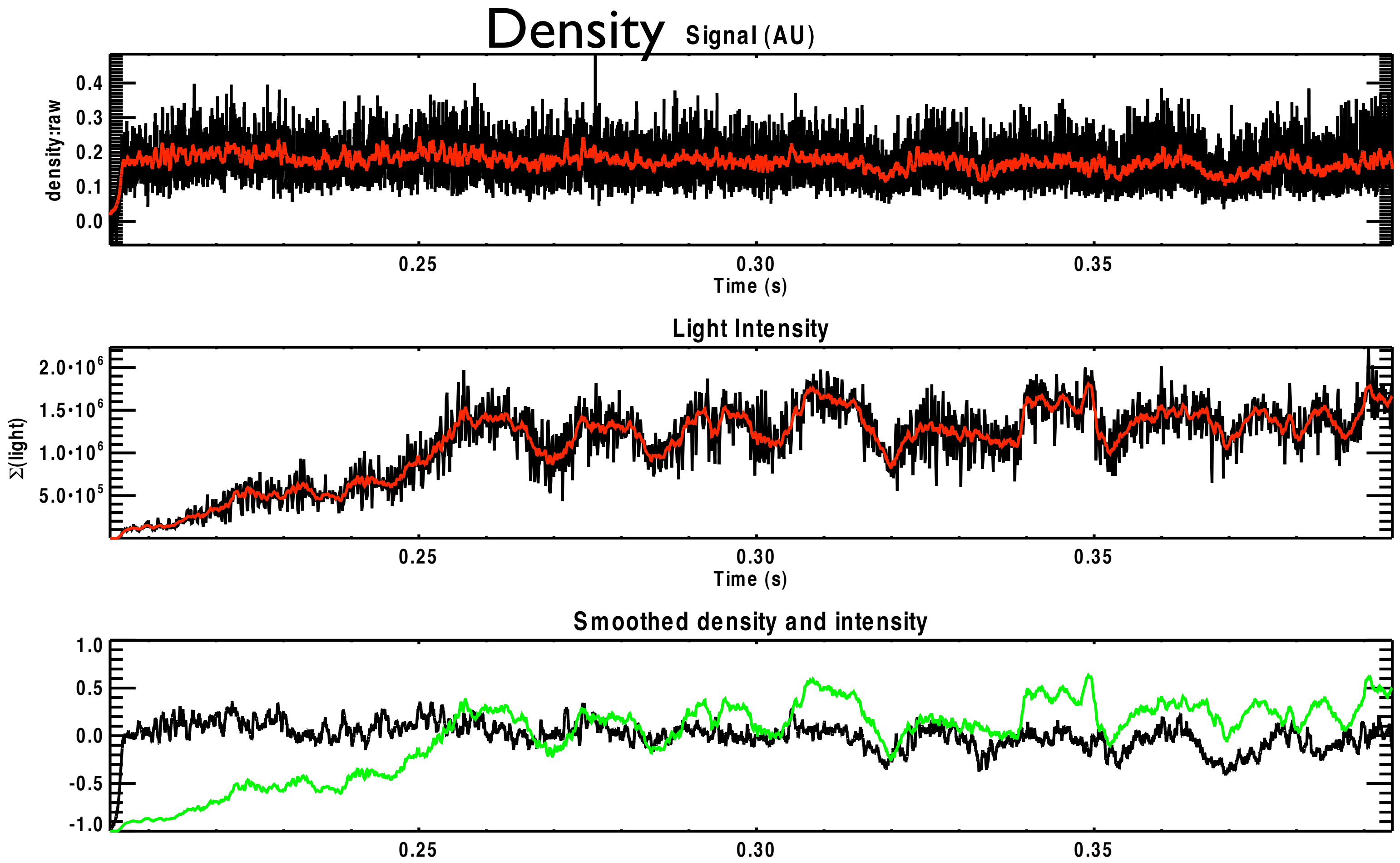
Total Light in Time





- Total light recorded in time.
- The large amplitude, low frequency fluctuations are attributed to magnet ripple.
- The higher frequency fluctuations peak near 1.5=2.0 kHz and are plasma fluctuations associated with ExB rotation of m=1,2 density perturbations.

Light and Density Low Frequency Fluctuations are Correlated

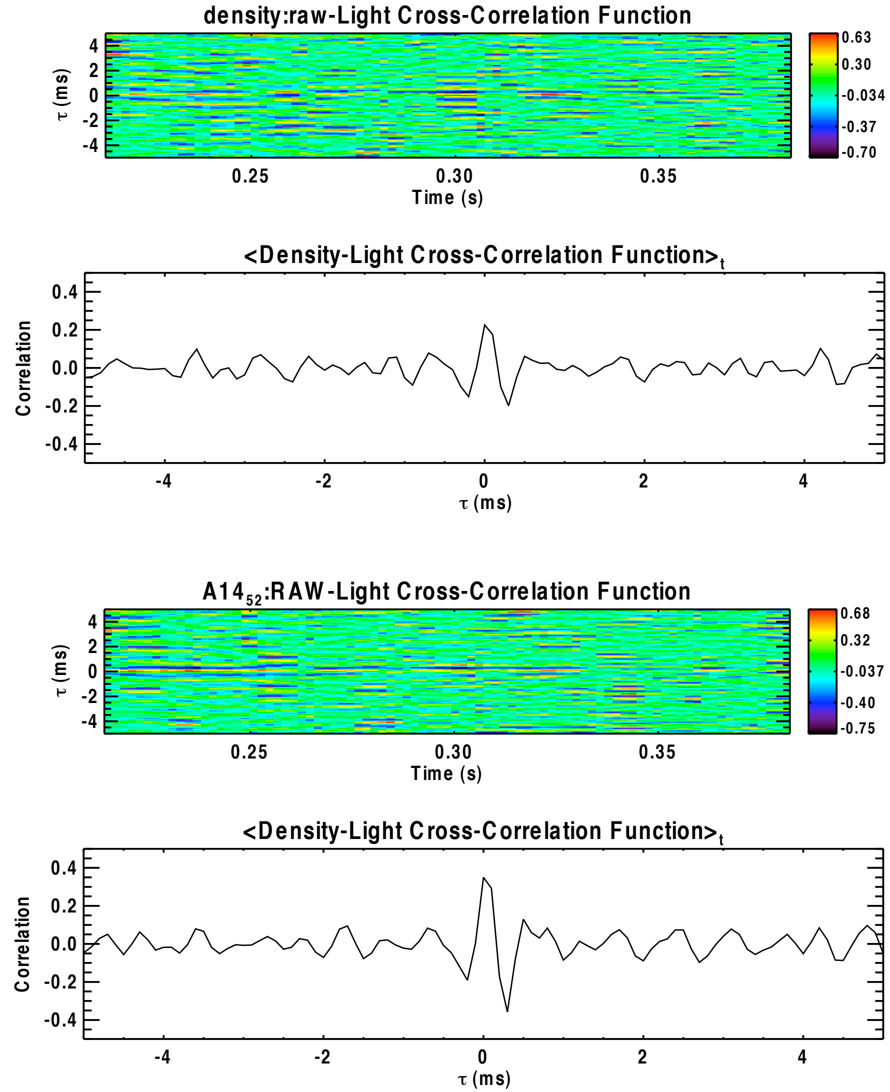


What About the ‘High’ Frequency?

- We know that density and polar loss are well correlated, with zero lag time.
- We will see that light is well correlated with density with zero lag time, as well as polar loss ‘in the neighborhood’ of the camera.

High Frequency Density and Light are Well Correlated

- This confirms two things.
- One: density fluctuations and light fluctuations are well correlated.
- Two: The zero-lag of the two signals means we can ‘sync’ the camera with other diagnostics.



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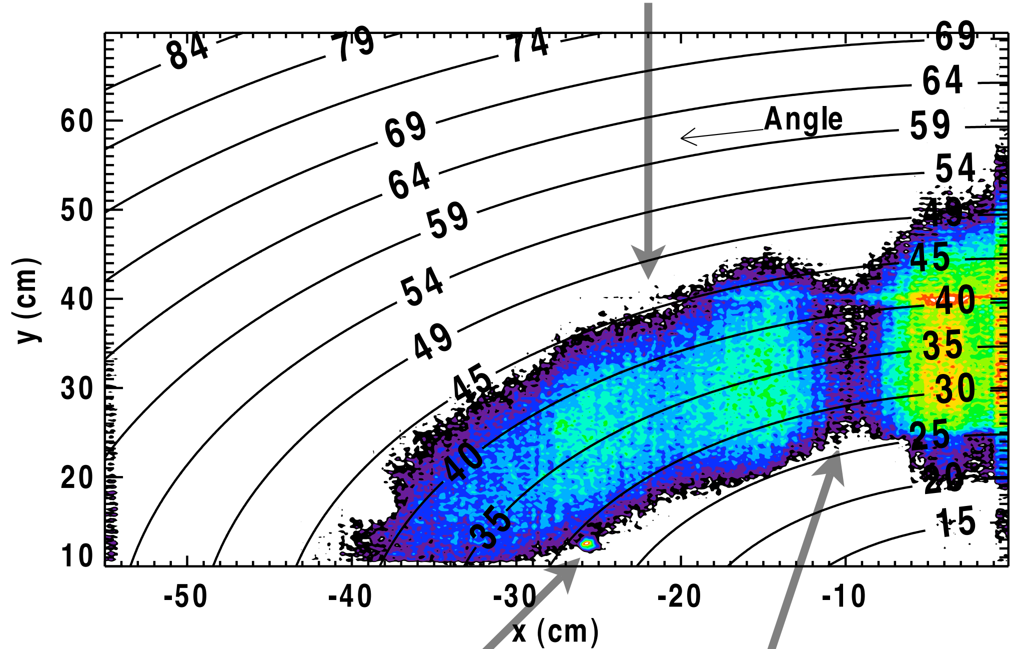
Mapping to Real CTX Coordinates

- A view of the magnet cap at L=25cm is used to 'match' the image to real coordinates.
- Certain features are not plasma fluctuations.

Horizontal noise line: didn't do a session reference for the camera.

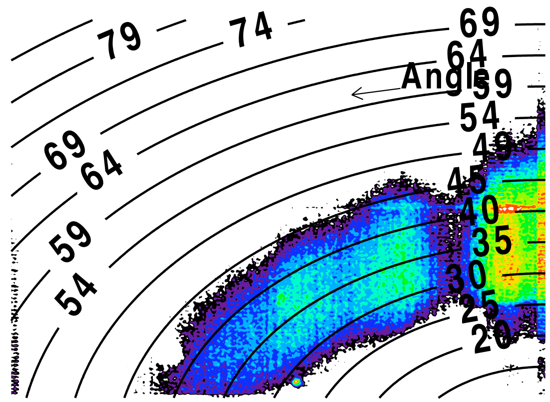


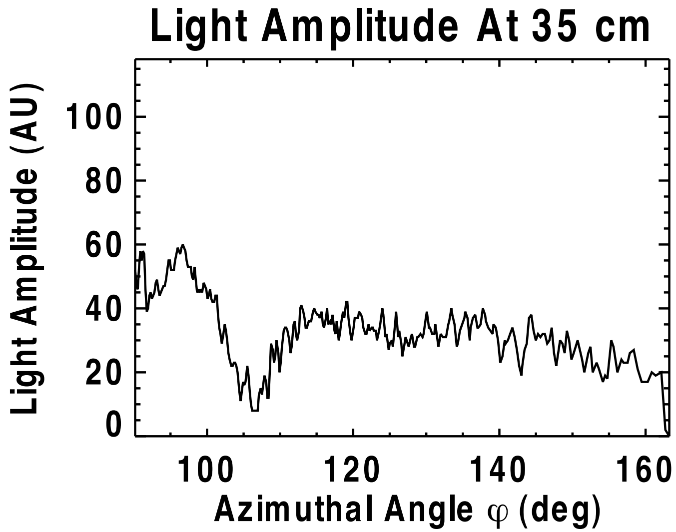
Hot tungsten filament.

View obstructed by port-hole screen to shield from microwave interference.

Light Amplitude at a Single Radius

- The light amplitude as a function of angle is calculated by selecting pixels which exist on a arc through the grid of pixels.
- Large scale features and trends as well as small scale fluctuations are clearly seen in the light intensity.
- This light intensity is calculated for each frame of the movie, and at multiple radial locations.





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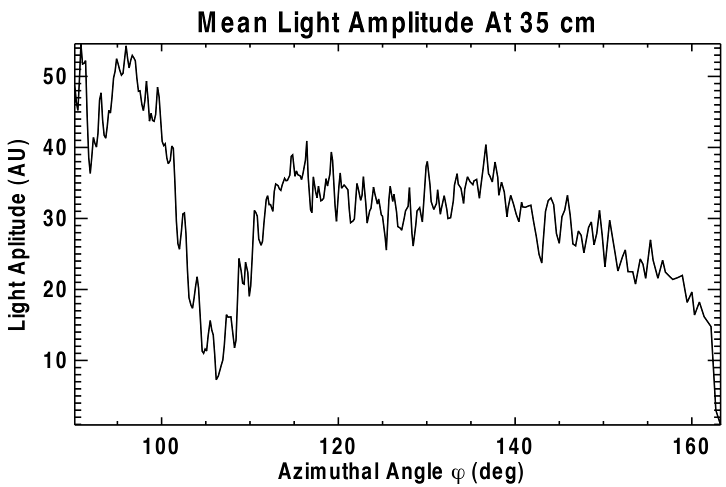
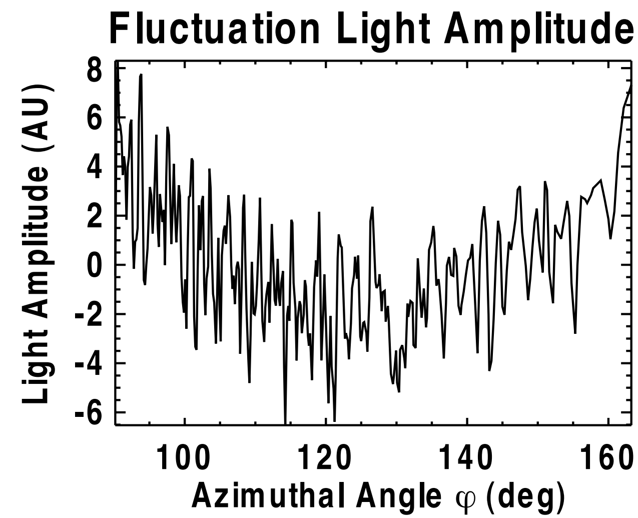
Mean Light Amplitude at a Single Radius

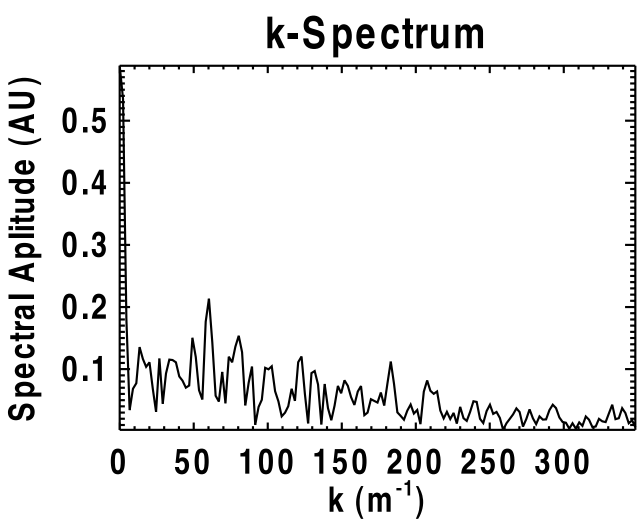
- The mean light as a function of angle for 35cm radius is calculated for 500 frames.
- The individual amplitudes are also stored.
- The deviation from this mean should reveal the fluctuations which we care about!



Light Fluctuations at a Single Radius From One Frame

- Because the angle axis is non-uniformly gridded, it is interpolated to a regularly spaced grid, allowing the FFT to be used.
- It is found that there is always a strong low wavenumber component, and a broad higher wavenumber spectrum.
- To watch the light fluctuations in an animation typically shows a large fraction of one period of a sinusoid, or a ‘see-saw’ type motion.





Wavenumber Spectrum in Time

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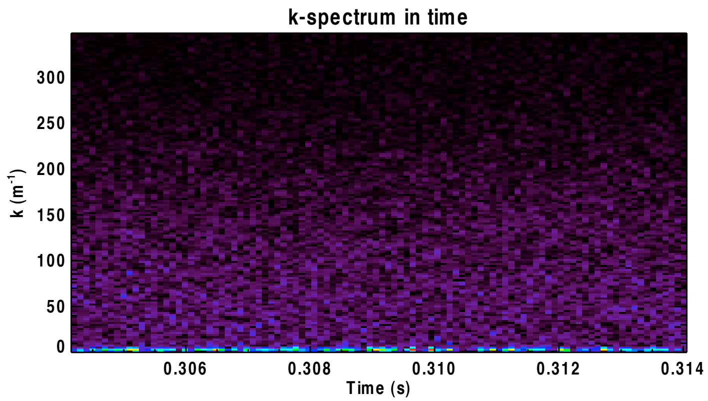

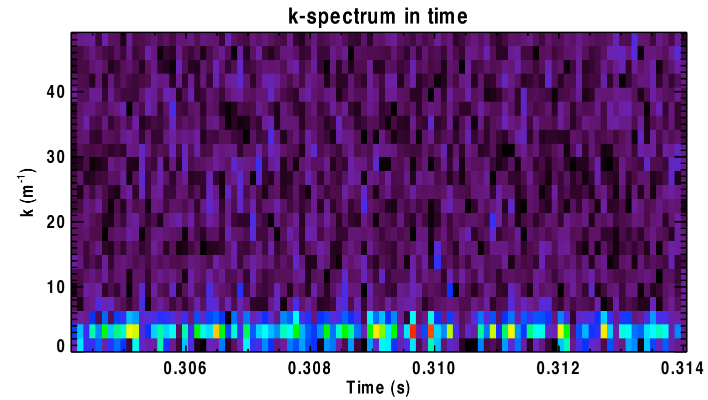

Summary

- These images were recorded with a ‘threshold’ frame rate, i.e. poor signal/noise ratio.
- We didn’t do a session reference.
- We had physical objects obscuring the view.
- No filtering in time or space has been done for this data.
- However, we can still get useful information from the images.

Summary II

- With time-filtering the images by high-pass filtering the time signature of each pixel, we can more easily see the plasma dynamics (already done).
- With bench testing, we can determine the spatial noise fluctuation level. This can justify any spatial filtering.
- With improved microwave interference reduction, eliminating the obstructions in the views and justifiable spatial filtering of the images, we should be able to go to higher frame rates.
- At higher frame rates, we should be able to see structures as they move through the view.