About 2 years ago Stuart Jeffereries made an interesting discovery. If you take a high frequency wavepacket, say at 6 mHz the time–distance diagram splits. Here you see the envelope of the auto–correlation function. The envelope shows two bumps for each skip. The splitting is clear in the second and third skips.

If you take a cross–section of this auto–correlation function at any fixed distance you get the correlation function that clearly shows the splitting.

What causes the splitting is the question that I will try to address in the next few minutes.

These are high frequency oscillations. They penetrate the photosphere, travel through the chromosphere until they are reflected back by the corono–chromospheric boundary.

When you are observing at the photosphere the wavepacket crosses the observing level twice. So the intuitive hypothesis that was proposed was that we should see atleast two correlation maxima one should give the time the wavpacket takes to return to the observing level after its trip through the convection zone, the other at its return after it is reflected from the chromosphere–corono boudary.

So the time difference between the two correlation maxima should give delta t , that is the time it takes the wavepacket to travel through the chromosphere.

This is very exciting. It opens a whole new array of possibilities to probe the structure of the chromosphere and transition region locally through a new approach.

However, this simple, intuitive ideas runs into several difficulties.

The first of the difficulties is computing delta t.

It happens that there are two different methods.

The first method is to compute the envelope of the correlation function and fit a function that is a sum of two Gaussians. Get the position of the maxima for each Gaussian. The difference in the position is delta t.

The second method is to fit a function that is a sum of two modelled correlation functions and fit it to the correlation function itselft. Then compute the envelopes to the fit individual correlation functions. The position of the maxima of the two envelopes gives you delta t.

The two methods give two different answers.

One of them aught to be incorrect. Which?

In a general theorem on functions I could show that the first method is incorrect and the second is correct.

We need not get into the details of this theorem. Just to let you know I had real fun working on it.

Now we run into another difficulty. If you theoretically compute the travel time using chromospheric models, the result is close to 11 minutes. The second method gives 6 minutes.

Are we seeing something remarkable? It was difficult, or let us say scary to make a claim that the chromosphere is only a 1000 kms.

This is when it became important to ask the next question. Is this simple–intuitive hypothesis correct?

In the pursuit of this question we found that there are alternative ways in which we can make the time–distance diagram to split.

The phenomenon is 'dispersion'. The phenomenon orginates due to the dispersion of the medium, but not all dispersive media exhibit it. Polytropes are dispersive, but they do not show dispersion.

'Dispersion' occurs when the phase travel time is a non–linear function of frequency. In polytropes, phase travel time is independent of frequency.

'Dispersion' weakened the hypothesis, but still did not say anything about its validity.

If the hypothesis is intuitive. Why should'nt there be a correlation when the wavepacket returns to the photosphere after its travel in the chromosphere. I agonized over this issue for while, because all these investigations contribute toward understanding what is travel time.

The problem lies in a series of assumptions that make up this hypothesis. The belief is that time–distance provides the shortest time to travel between two locations. This turns out to be true only when the observing plane lies above the upper turning point; which it true for low frequencies roughly below 5 mHz. When the observing plane lies within the propogating region this assumption can be shown to be incorrect. I will avoid the mathematical details, but give a heuristic argument which should be convincing enough.

When you observe within the propagating region, you invariably measure a signal that is an interference pattern between the waves in the upgoing and downgoing wavepackets.

The interference here is between waves in the dotted wavepacket and the solid line wavepacket. The interference at A recurs only at B, after the wavepacket has crossed the observing plane for the second time after encountering both the upper and lower turning points. Hence, the correlation maximum occurs not at B–prime but at B. So the travel time you measure is always the time taken by the wavepacket to to traverse the cavity twice.

Mathematically, you can prove this in various ways, one of which is to ask the question, what happens when you lower the observing plane from above the turning point to below it.

The only variable that changes is the amplitude of the modes. You can then show that this operation does not alter the travel time.

As an example you can take a box with constant sound speed, or even better an adiabatic polytrope. The solutions are Laguerre polynomials. So you can construct the power spectrum above the upper turning point. Here you see the mode amplitudes as a function of frequency at l=125.

When you lower the observing plane 2 Mm below the surface. The mode amplitudes get modulated. This is the interference pattern. This interference pattern can be washed out if you introduce the excitation and damping mechanisms. In the pure case, you will get a correlation function that has several peaks in the envelope. You can show that the modulation is a cosine on a Gaussian envelope. The central peak represents the travel time for the wavepacket to traverse the cavity twice. Do the side peaks mean anything? In general, no.

In conclusiion: The simple–intuitive hypothesis is flawed.

2. If you intend to do time–distance at high frequencies you have to make sure that you consider the path of the wavepacket through the chromosphere.