Physicist Response, Leaning Out of Windows

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The 'response-diagram' attached shows investigations into the functions of one of the ion traps in the TITAN experiment. The top figure shows an investigation of the ways in which we can achieve stable trajectories in the machine, and the bottom shows the series of spectra I took on a detector to complete this investigation. When we met, Marina and I discussed her interest in diagrams and different ways of classifying scientific findings. I found the idea of reorganizing scientific classifications - which I may take for granted - according to some other principal to be an interesting idea. My goal for this project was to take as input something from Marina's art and use a different organizing principle to do something scientifically interesting with it. I chose her mural, Your Kingdom to Command, in which she classified organisms according to form, instead of the system normally used in biology. I converted Marina's mural into a colour palette digitally (see Fig. 1), and used the colours and positions within the palette to assign a set of frequencies and voltages to each. I then used this set of frequencies and voltages to explore the quality of ion motion inside one of the ion traps at the TITAN experiment. Ion motion inside this trap is either stable, meaning the ions will be collected and then ejected from the trap and we will detect them on the other side, or the motion is unstable in which case they will get lost in the trap by hitting the walls, and we will not see them on the detector. A set of equations called the Mathieu equations govern this motion and tell us, for some combination of frequency and voltage, if the motion is stable or not. However, there are several other factors which may affect the motion, which are not considered in the theoretical equations. So I recorded a spectrum for each of these somewhat arbitrarily chosen frequency-voltage combinations in order to see which combinations produce stable motion. Fig. 2 shows an example of a typical spectrum, in which we see the number of ions counted on the vertical axis and the time in microseconds on the horizontal axis. The dip in the middle shows a bunch of potassium ions hitting the detector. In the long figure in my 'response-diagram', you can see all the spectra for each frequency-voltage combination plotted together. You can see that sometimes the dip is there, indicating a combination that produces stable motion, and sometimes the dip is not there, indicating a combination that produces unstable motion.

Usually we classify stable and unstable motion using a stability diagram. The equations governing the motion of the particle can be plotted using two variables called a and q, which

Figure 1: Colour palette from Your Kingdom to Command.

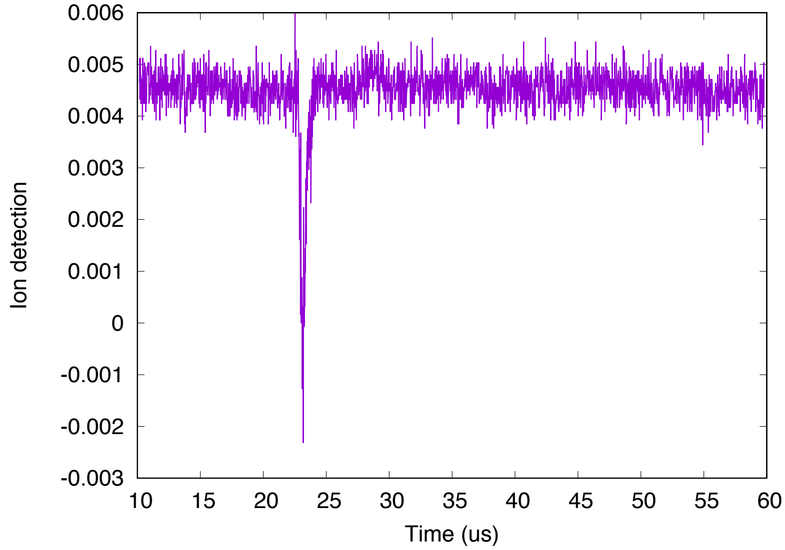


Figure 2: An example spectrum taken on the detector after the ion trap. The dip shows that the ions were not lost inside the trap.

allow us to visualize where motion is stable and where it is not. Such a diagram is shown in Fig. 3, where the shaded areas are regions of stable motion, and the red circle shows the region most frequently used. In our case, the parameter a is zero, and the value of q depends on the combination of frequency and voltage chosen. Fig. 4 shows a zoomed in version of the previous diagram, focusing on the stability region most commonly used.

The top of my 'response-diagram' shows the usual stability region with dots along the horizontal axis representing each measurement I made. From the spectra, it was possible to map out the area in which we have stable ion motion in our machine, and this area is shown by the blue vertical lines. This was a surprising result - I expected the stability region to be larger than the theoretical one, not smaller. My guess is that imperfections in the electromagnetic fields inside the machine, due to the machining of the electrodes and mechanical misalignments, reduce the possible stable trajectories.

The second interesting result was that the location of the dip in the spectra moves slightly from spectrum to spectrum. If you look closely at the lower part of my 'response-diagram', you can see that the inverted peaks are not exactly aligned. This may just be a result of the statistical nature of these measurements, but it may also point to an instability in one of our power supplies, which can affect the efficiency of the entire experiment.

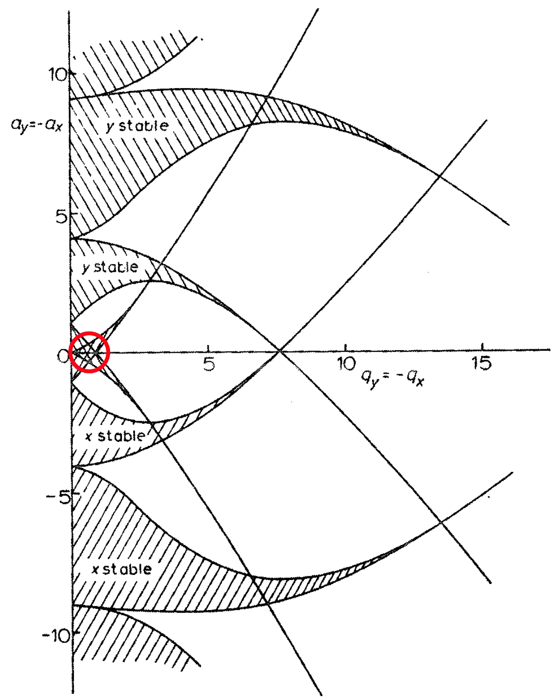


Figure 3: Mathieu stability diagram with the region normally used circled, modified from P. H. Dawson, Quadrupole Mass Spectrometry and its Applications, Elsevier Scientific Pub. Co., Amsterdam, 1976.

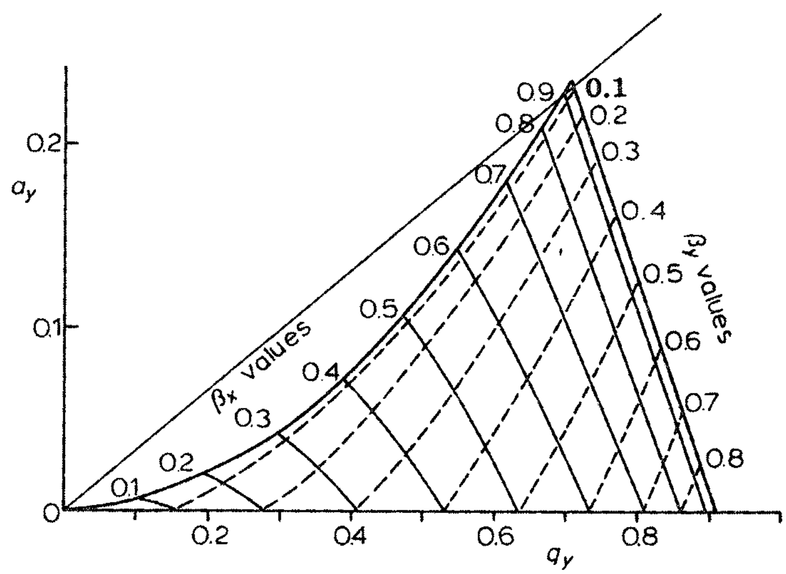
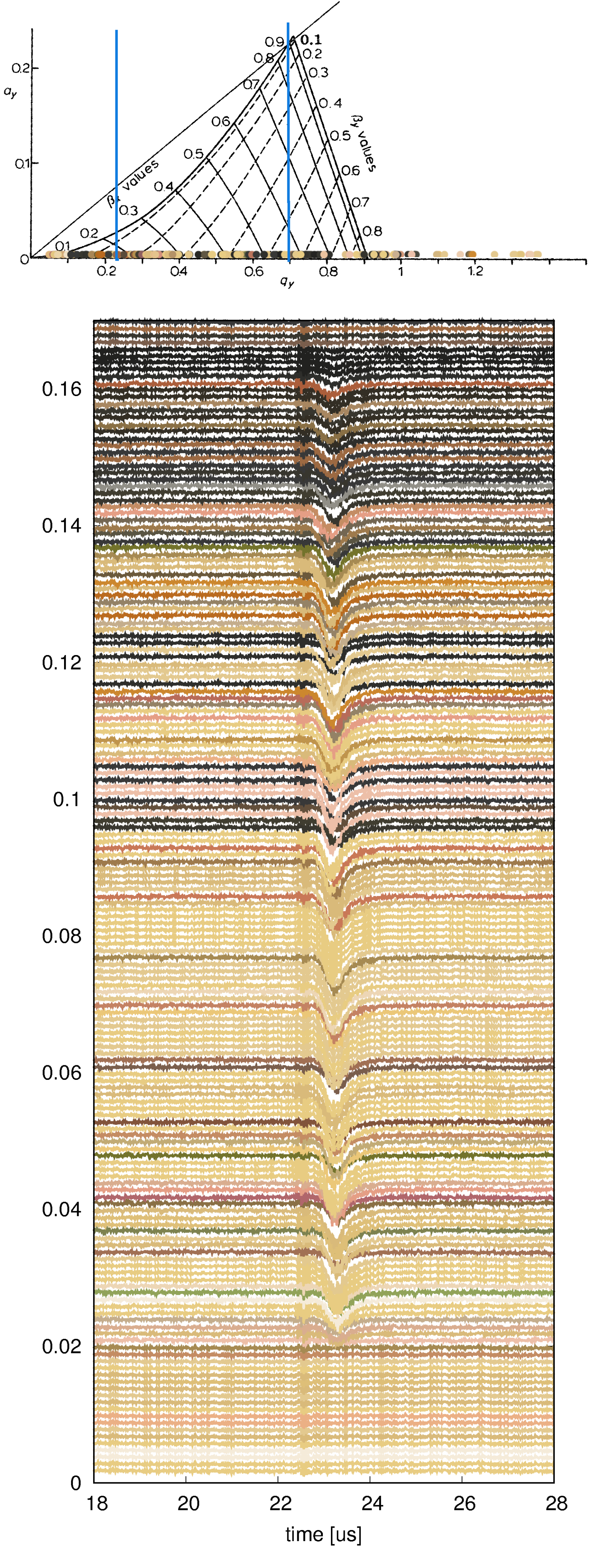


Figure 4: The region of the stability diagram normally used, taken from P. H. Dawson, Quadrupole Mass Spectrometry and its Applications, Elsevier Scientific Pub. Co., Amsterdam, 1976.



a_y
0.2
0.1
0
q_y
0.2
0.4
0.6
0.8
1
1.2
β_x values
β_y values
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
0.16
0.14
0.12
0.1
0.08
0.06
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