Summer Research Report Part 3 - Heatmaps

August 11, 2022

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1.1.1 Heat map for Plating 1, Culture 3, DIV 4

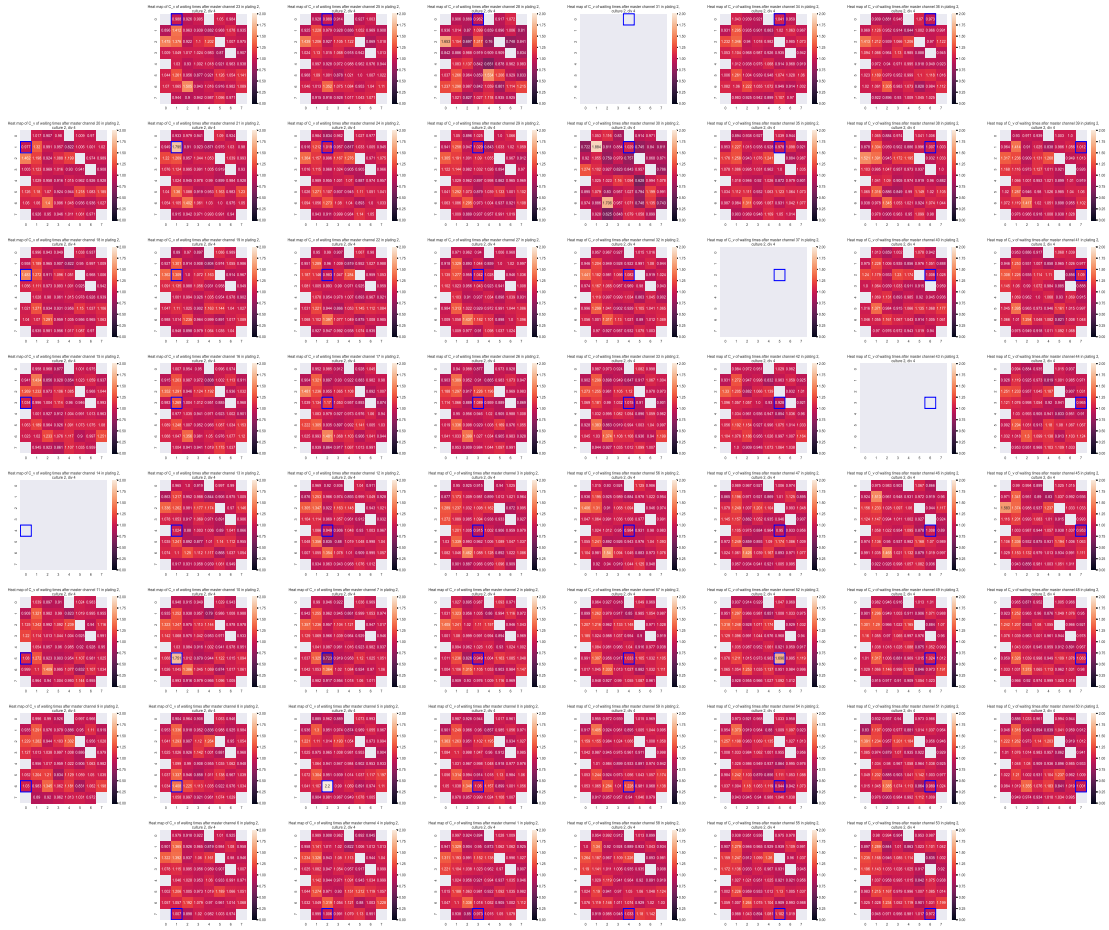
We see that the C_v tends to go up with DIVs, and remains around 1 for early DIVs. This is in line with what we would expect from Poisson channels which are independent of each other, because then the times at which a master channel spike are arbitrary, and so the waiting time till the first occurrence of any given channel should follow an exponential distribution. [PROOF REQUIRED]

1.1.2 Heat map for Plating 1, Culture 3, DIV 13

1.1.3 Heat map for Plating 1, Culture 3, DIV 25

1.2 Heat maps for Plating 2, Culture 2

1.2.1 Heat map for Plating 2, Culture 2, DIV 4



1.2.2 Heat map for Plating 2, Culture 2, DIV 19

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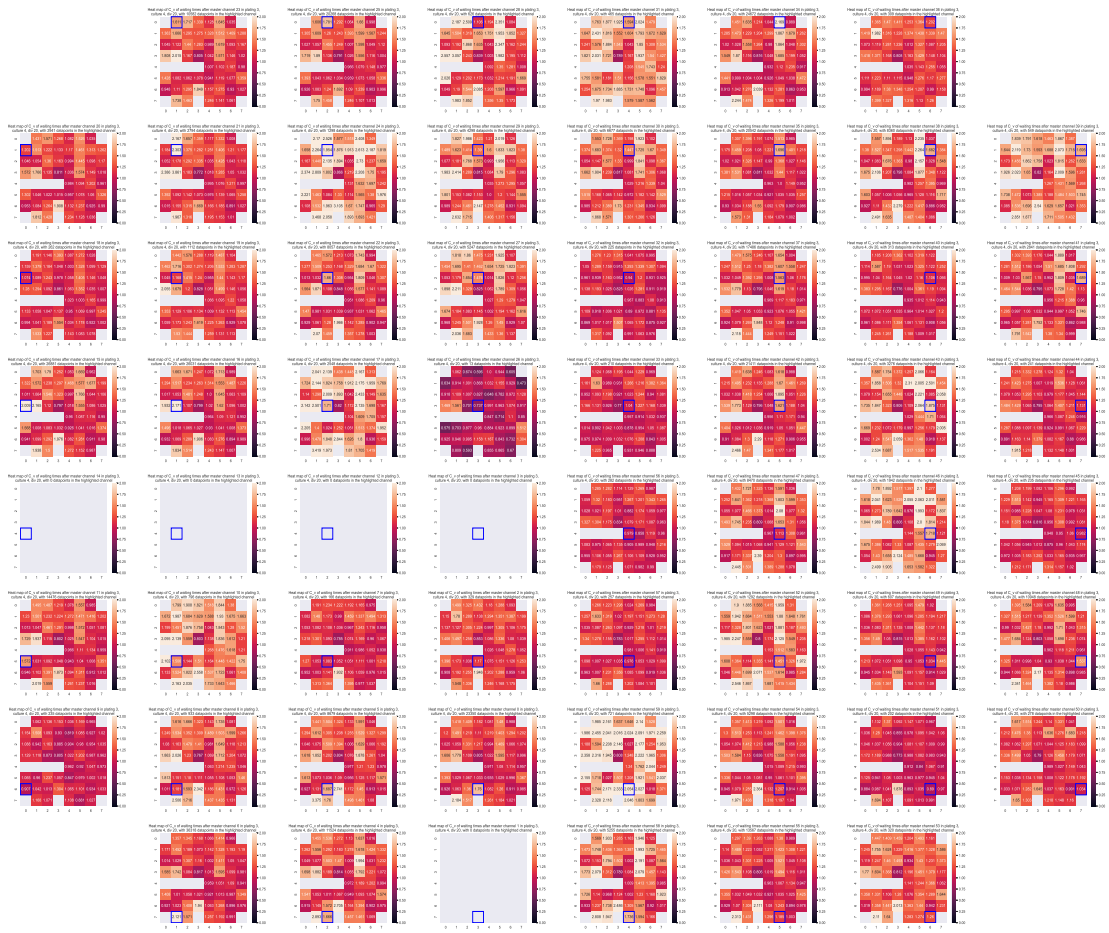
1.3 Heat maps for Plating 3, Culture 4

1.3.1 Heat map for Plating 3, Culture 4, DIV 7

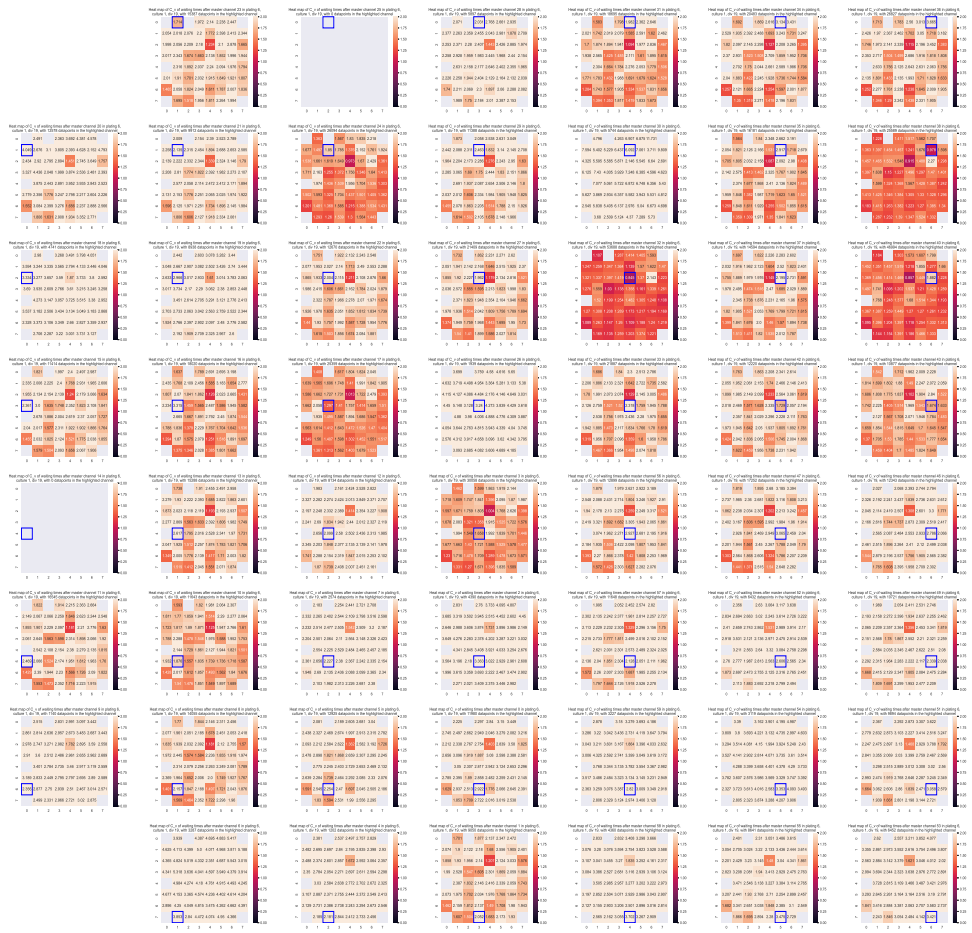
1.3.2 Heat map for Plating 3, Culture 4, DIV 20



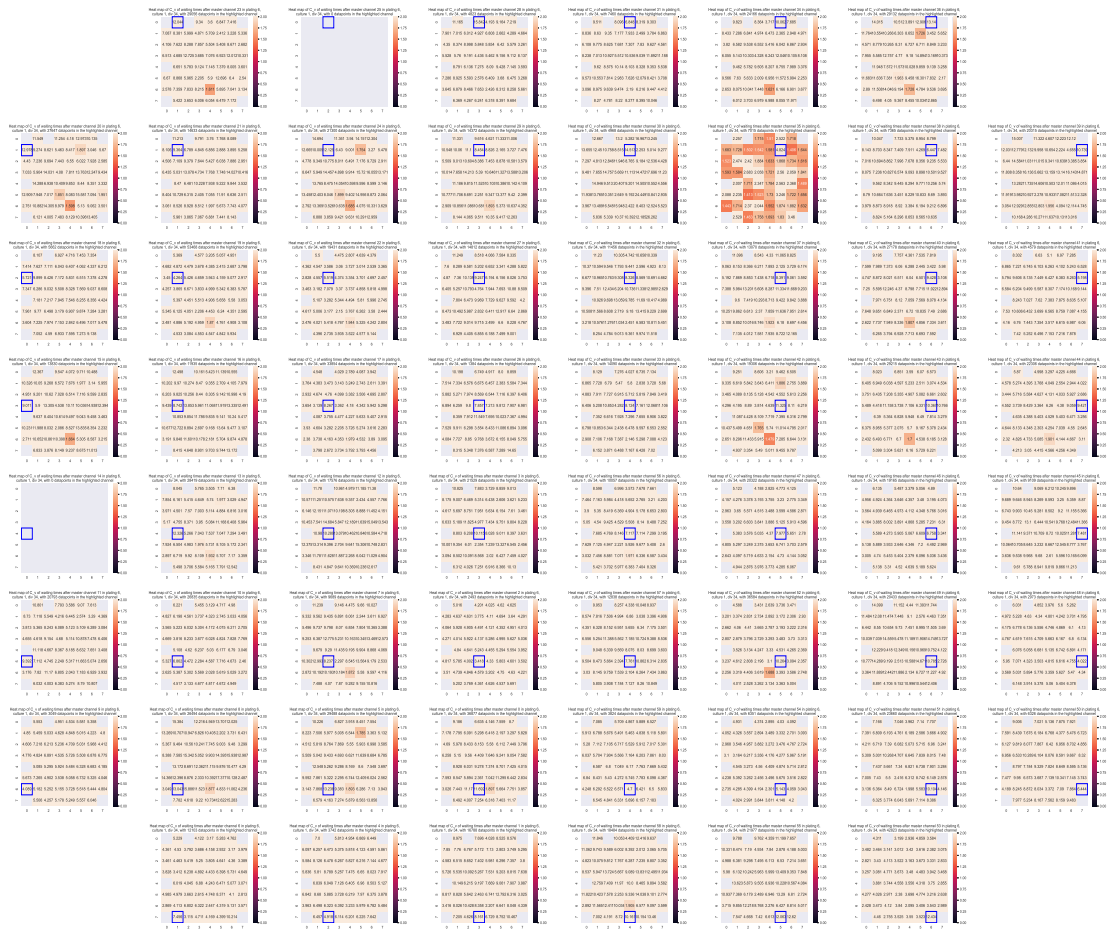
1.4 Heat maps for Plating 6, Culture 1

1.4.1 Heat map for Plating 6, Culture 1, DIV 4

1.4.2 Heat map for Plating 6, Culture 1, DIV 19



1.4.3 Heat map for Plating 6, Culture 1, DIV 34



2 Heatmap of heatmaps (C_v measured for waiting time between master channel and first occurence, in a fixed time interval)

We see that C_v's tend to get larger as time progresses. This could be due to the probabilistic nature of neuron connections. There could be some probability that they fail to fire, which may result in neurons firing after each other regularly sometimes, and not other times.

In order to try to combat this, we want to try and filter out any failed firings, and try see if below a certain threshold fixed time interval, the target channel fires regularly after the master channel.

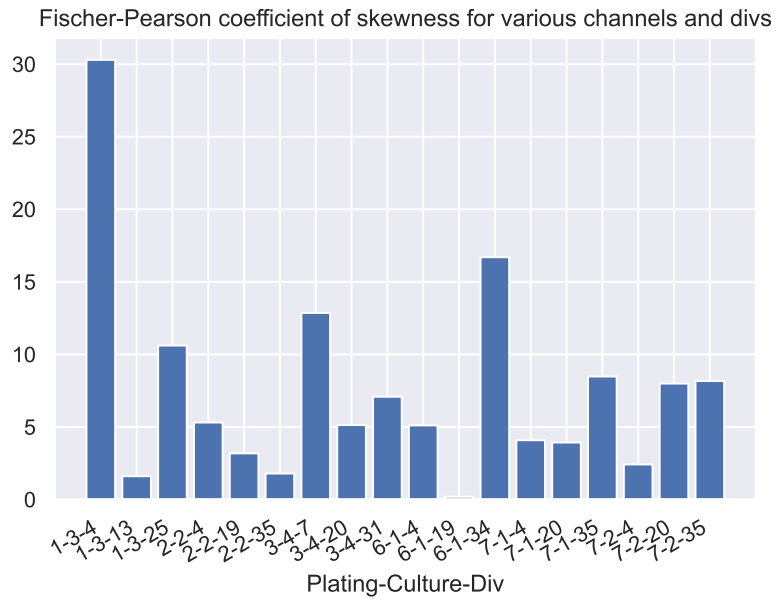
The fixed time interval is determined by the expected time interval between spikes of the most common channel in the div divided by 10, after filtering out any times above 1 (since the data is significantly right-skewed). As an example, in plating-culture-div-masterChannel 1-3-25-23, the most common channel (49) has only about 10% of time intervals greater than its mean, so the mean seems too high. If we filter out this 10%, we end up with a mean which is a tenth of the size!

In order to measure the skewness, we use the adjusted Fisher-Pearson standardized moment coefficient:

$$m_i = \frac{1}{N}\sum_{n=1}^{N}(x[n]-\bar{x})^i$$

$$G_1 = \frac{k_3}{k_2^{3/2}} = \frac{\sqrt{N(N-1)}}{N-2}\frac{m_3}{m_2^{3/2}}$$

2.1 Skewness of channels



Instead we will choose the fixed time interval by dividing the median of the most commonly occurring channel by 8.

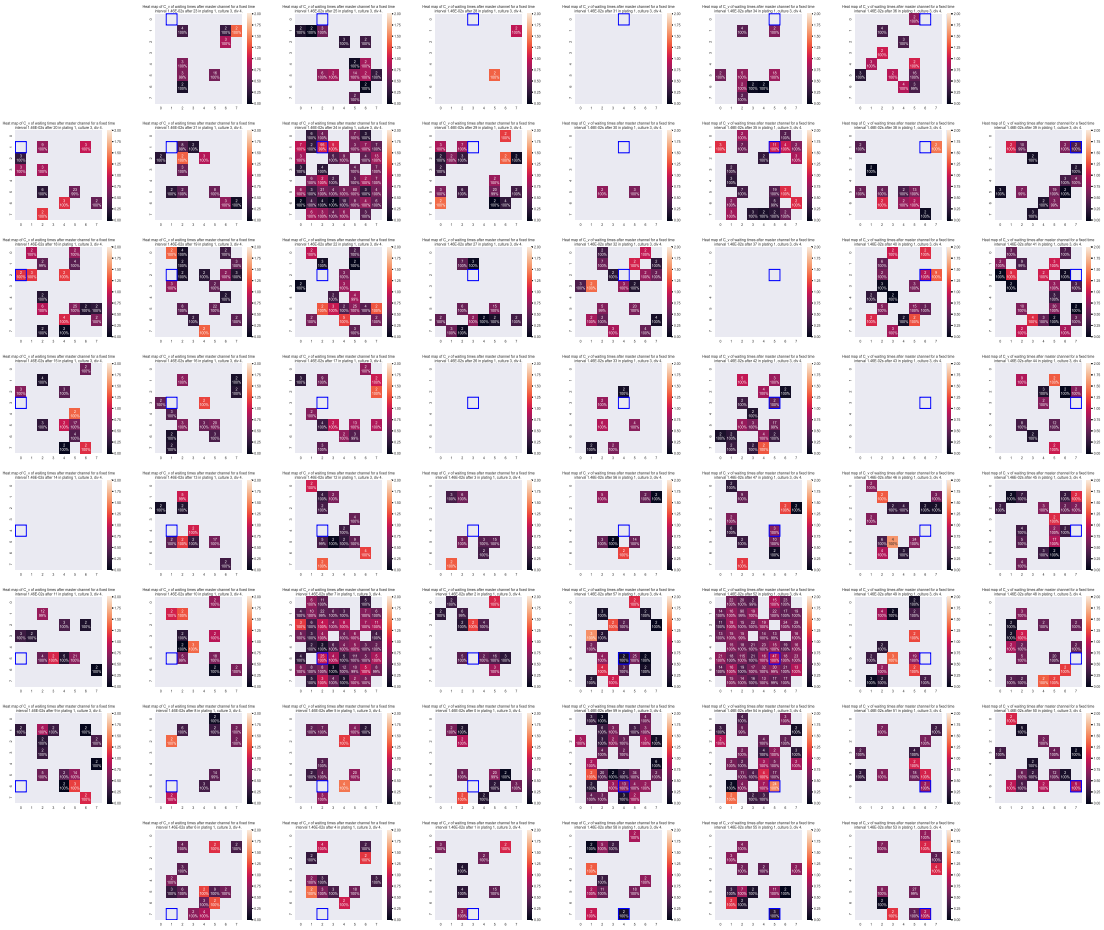
Given a uniform distribution $U \sim [0, x]$, the $C_v = \frac{\sigma}{\mu} = \frac{\sqrt{12}}{6}$

The colours correspond to C_v, the top number is the number of times the channel spikes in the fixed time interval after a master channel spiking, and the bottom number is the proportion of fixed time intervals which contain less than 2 spikes of that channel.

The first number in the following heatmaps corresponds to the number of spikes of that channel which occur within the fixed time interval of a master channel spiking. The second number is the proportion of fixed time intervals after a master channel spikes, in which there are less than 2 spikes of the target channel, as a percentage.

2.2 Heat maps for Plating 1, Culture 3

2.2.1 Heat map for Plating 1, Culture 3, DIV 4

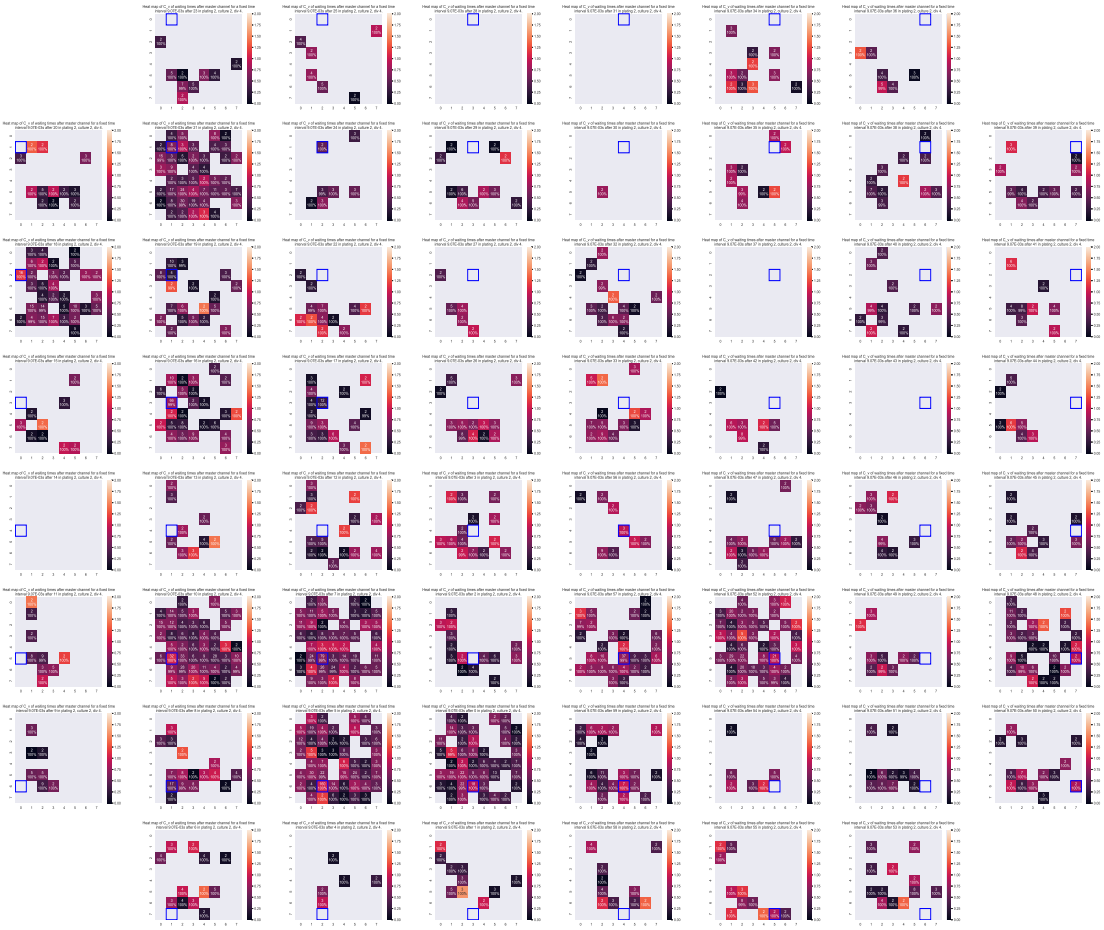


2.2.2 Heat map for Plating 1, Culture 3, DIV 13

2.2.3 Heat map for Plating 1, Culture 3, DIV 25

2.3 Heat maps for Plating 2, Culture 2

2.3.1 Heat map for Plating 2, Culture 2, DIV 4

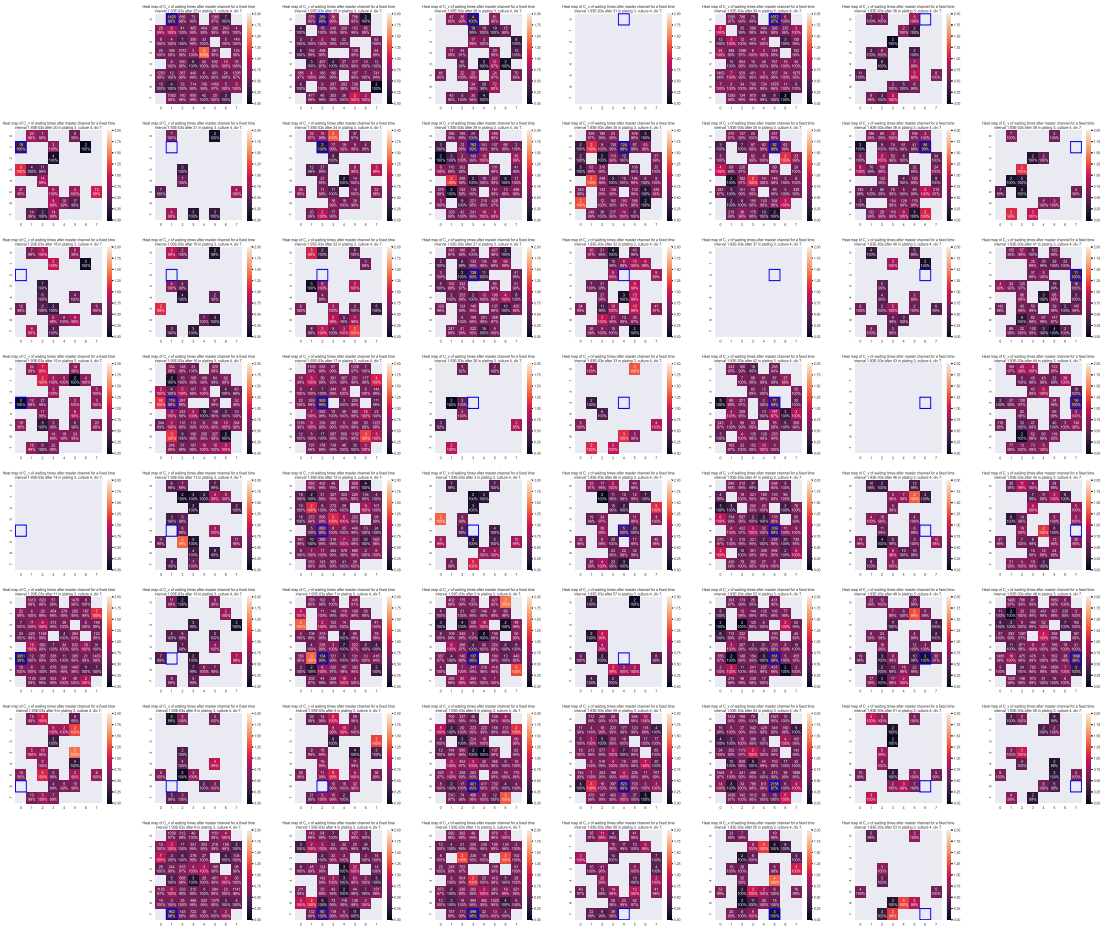


2.3.2 Heat map for Plating 2, Culture 2, DIV 19

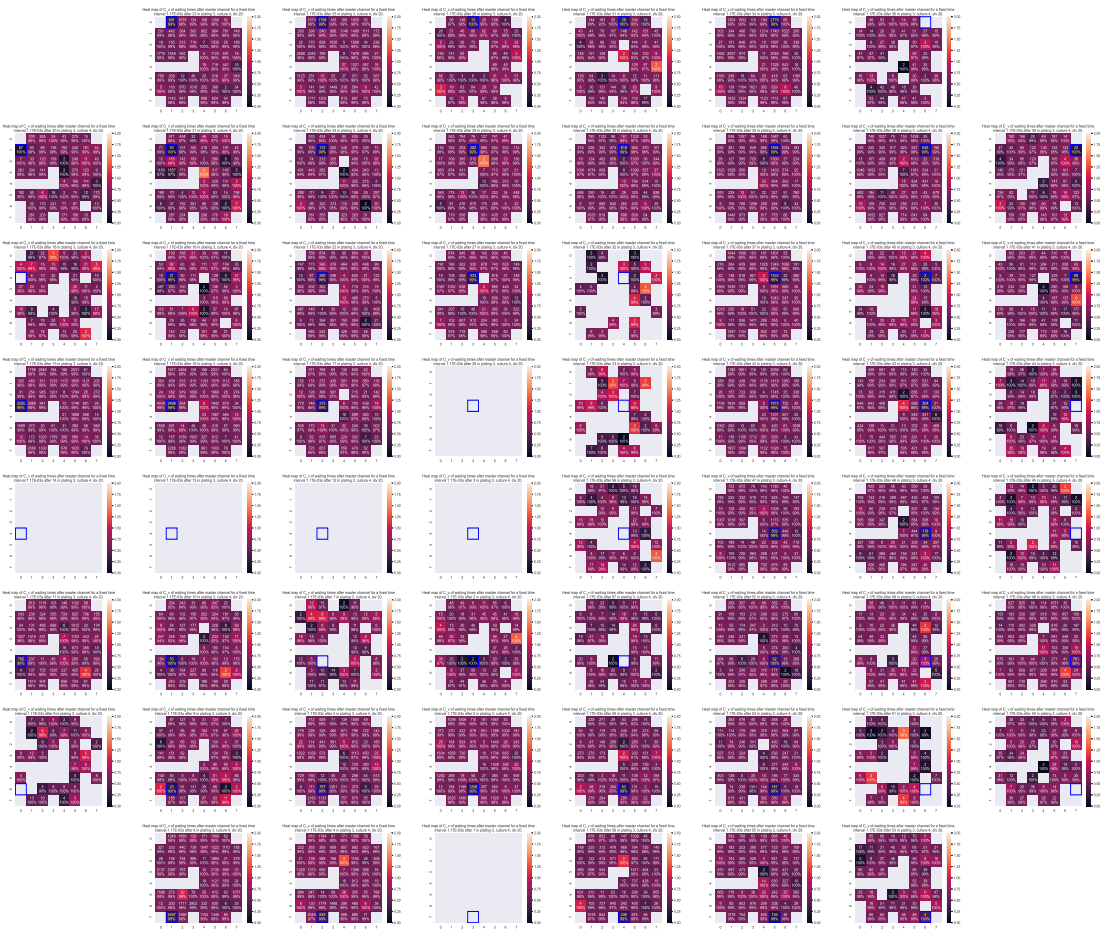
2.3.3 Heat map for Plating 2, Culture 2, DIV 35

2.4 Heat maps for Plating 3, Culture 4

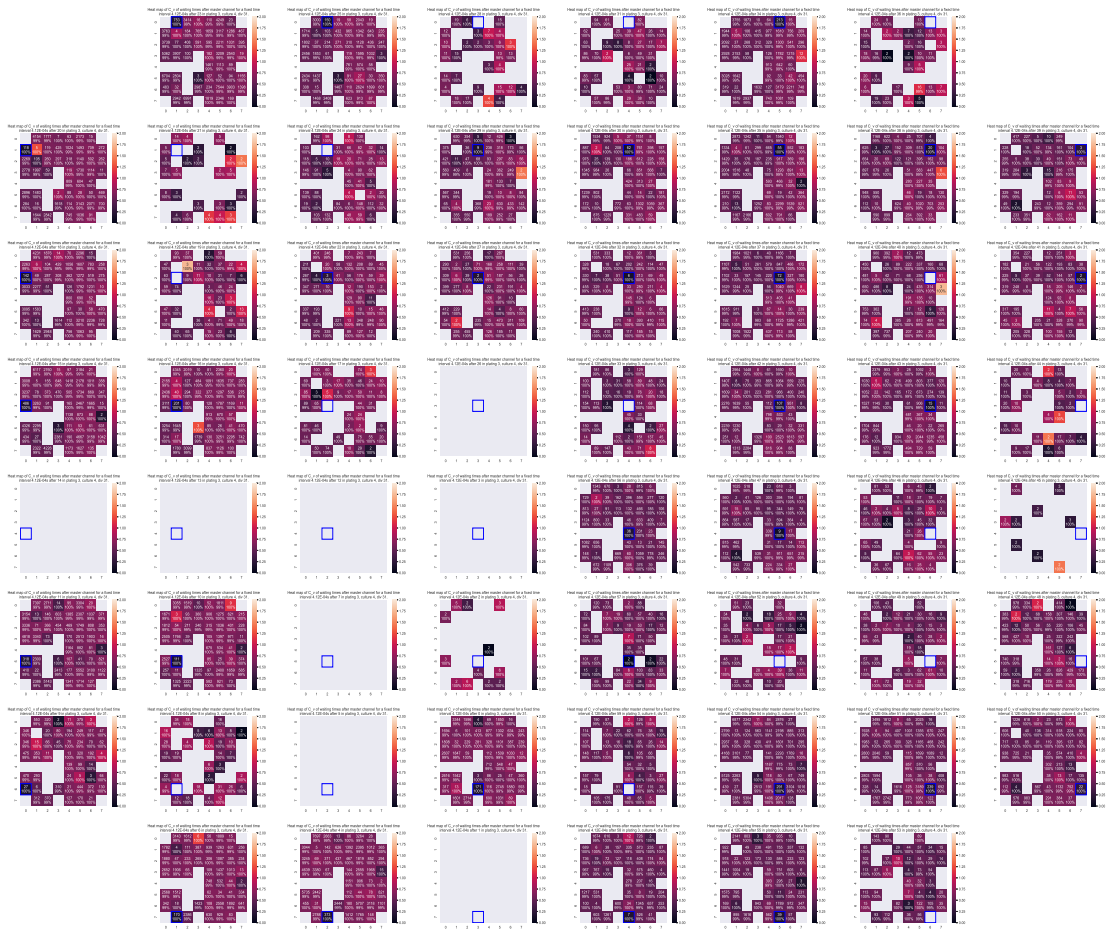
2.4.1 Heat map for Plating 3, Culture 4, DIV 7



2.4.2 Heat map for Plating 3, Culture 4, DIV 20

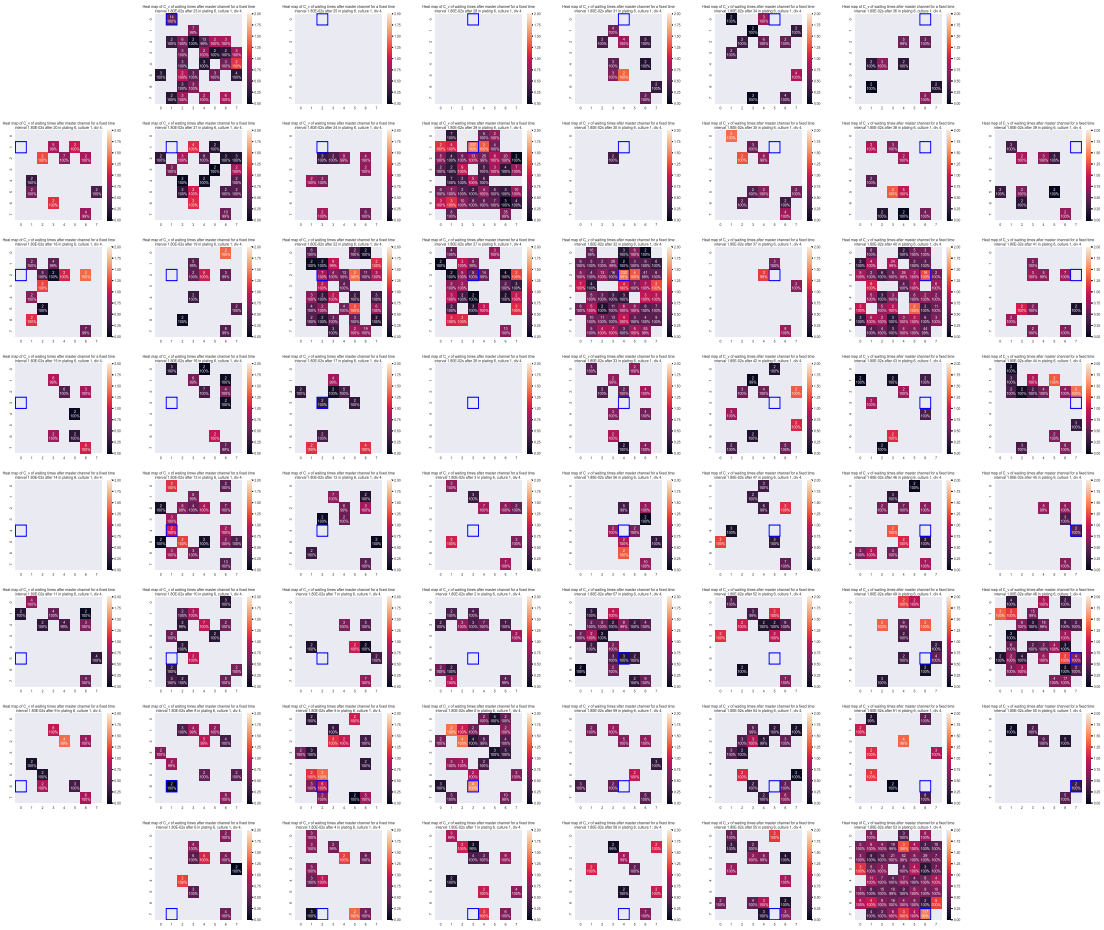


2.4.3 Heat map for Plating 3, Culture 4, DIV 31

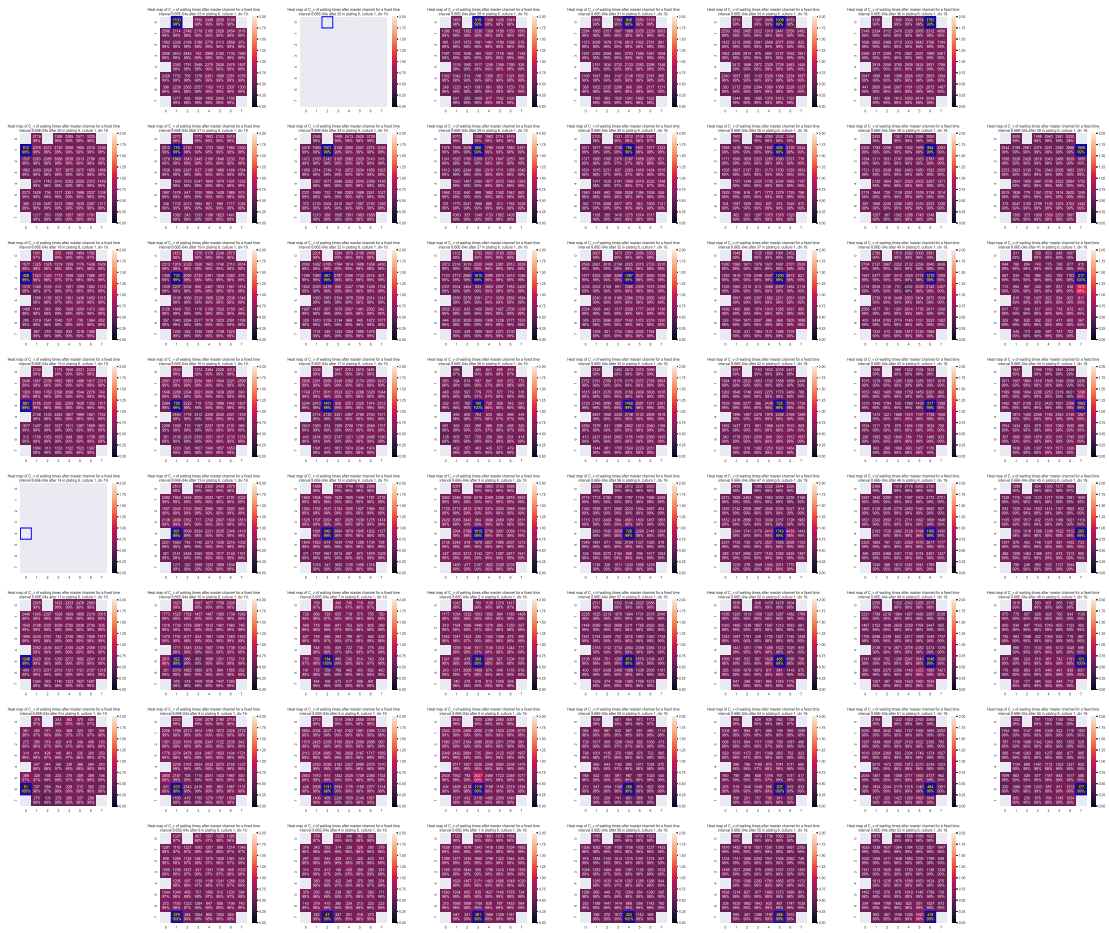


2.5 Heat maps for Plating 6, Culture 1

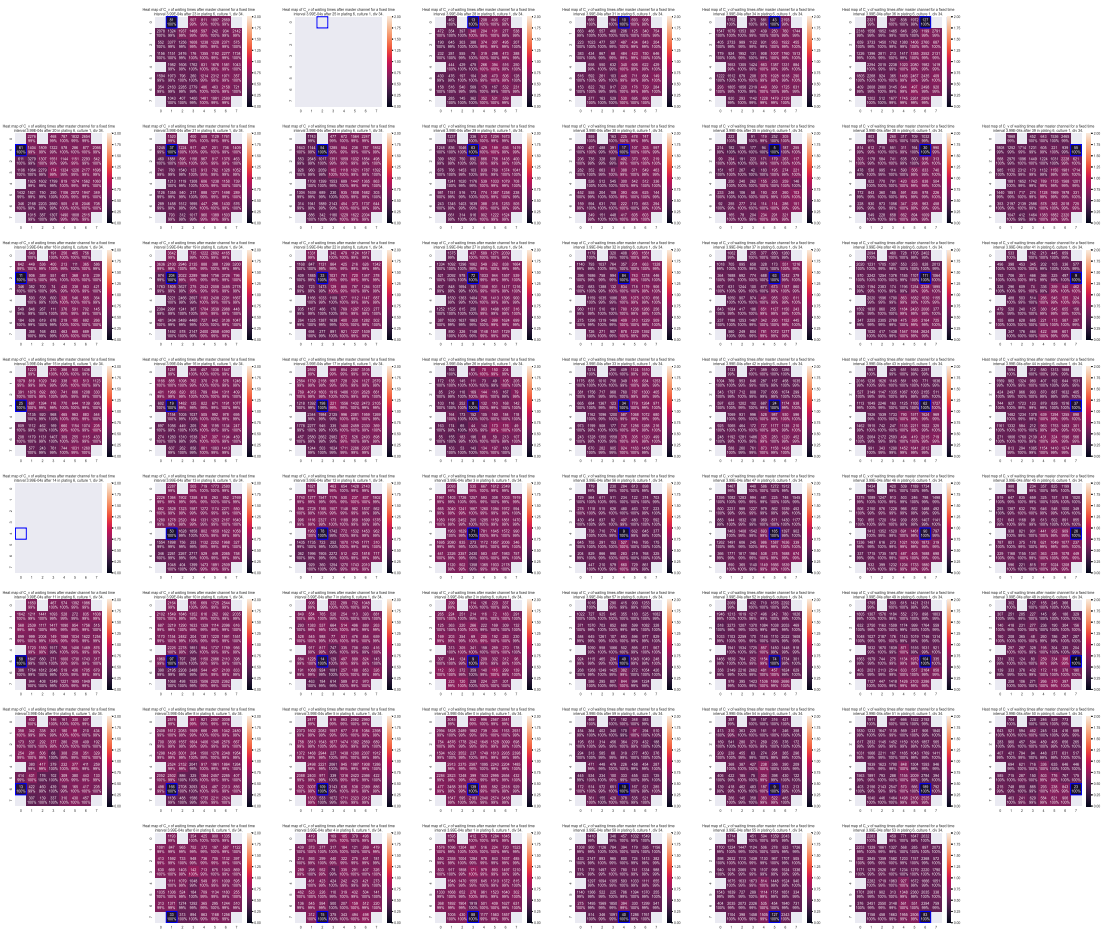
2.5.1 Heat map for Plating 6, Culture 1, DIV 4



2.5.2 Heat map for Plating 6, Culture 1, DIV 19



2.5.3 Heat map for Plating 6, Culture 1, DIV 34

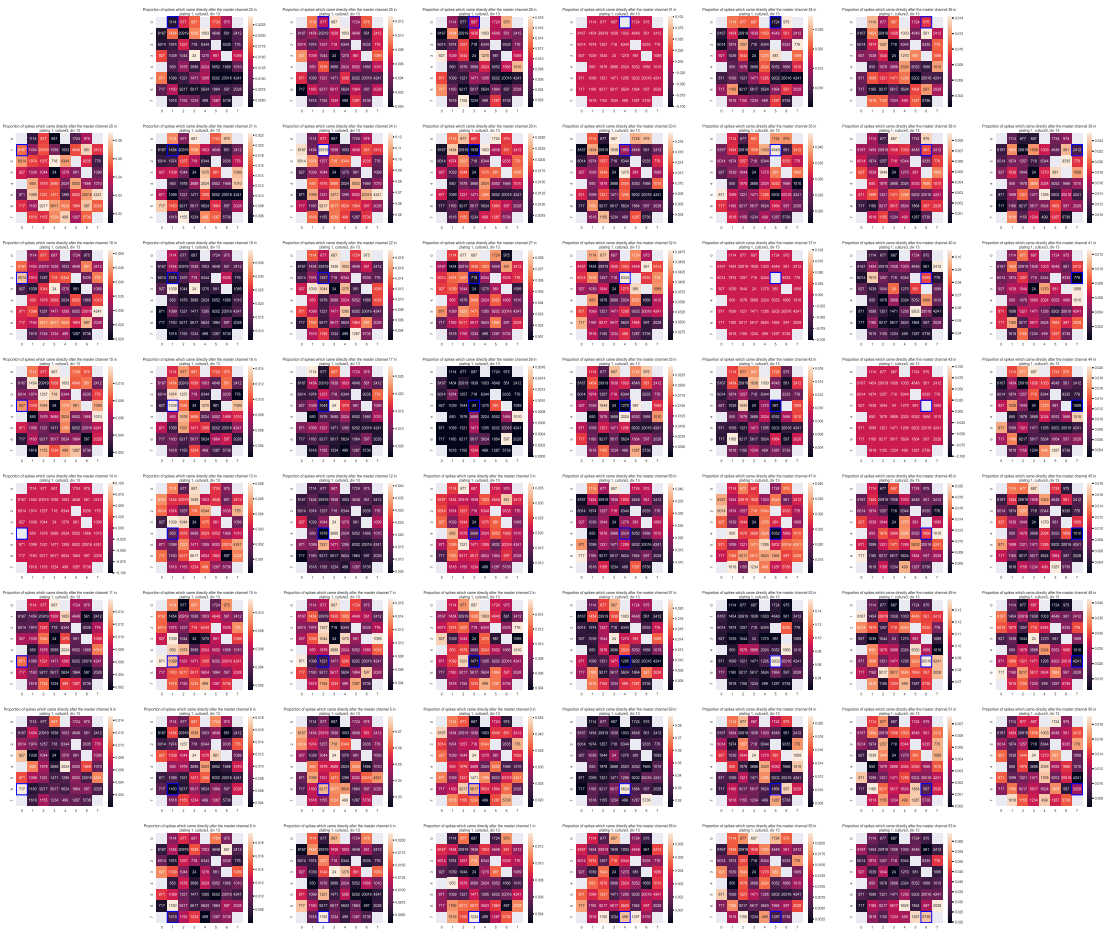


3 Heatmap of heatmaps (Proportion of spikes which occur directly after master channel)

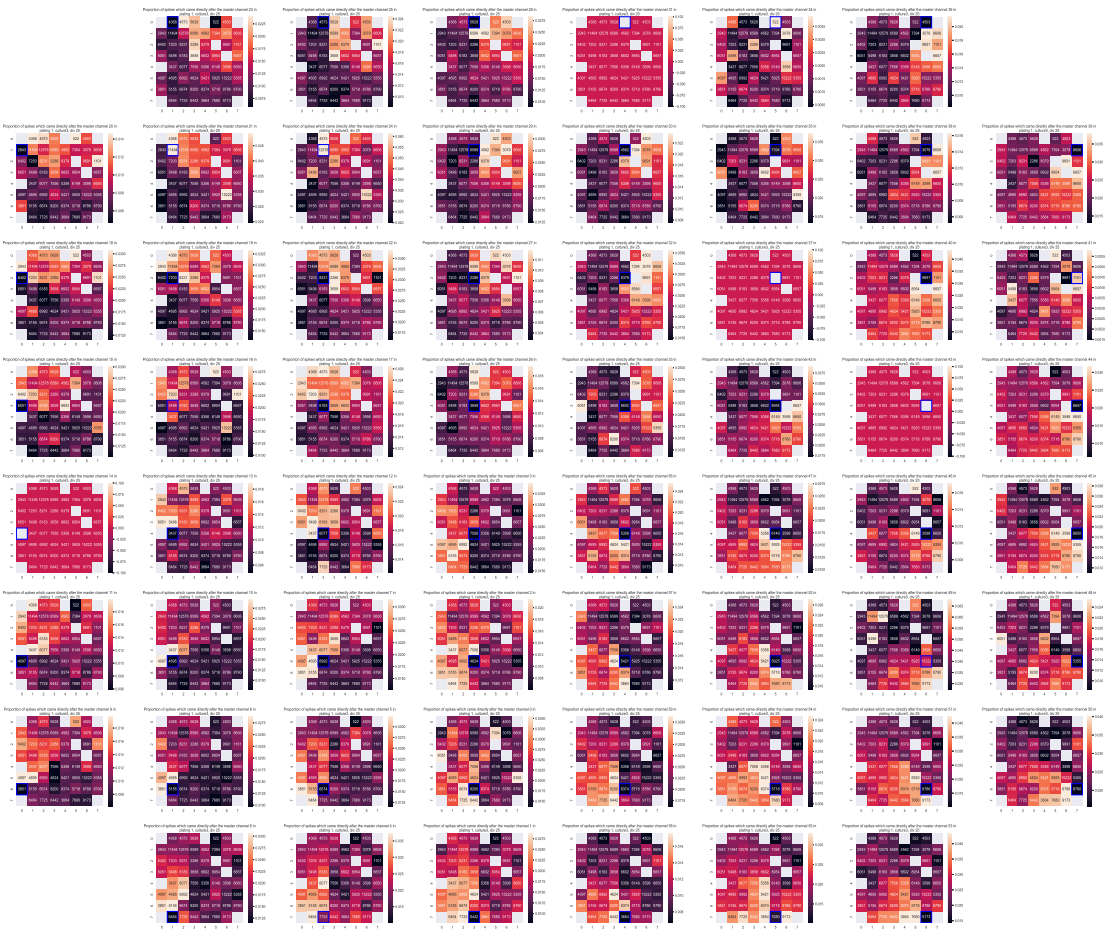
3.1 Heat maps for Plating 1, Culture 3

3.1.1 Heat map for Plating 1, Culture 3, DIV 4

3.1.2 Heat map for Plating 1, Culture 3, DIV 13

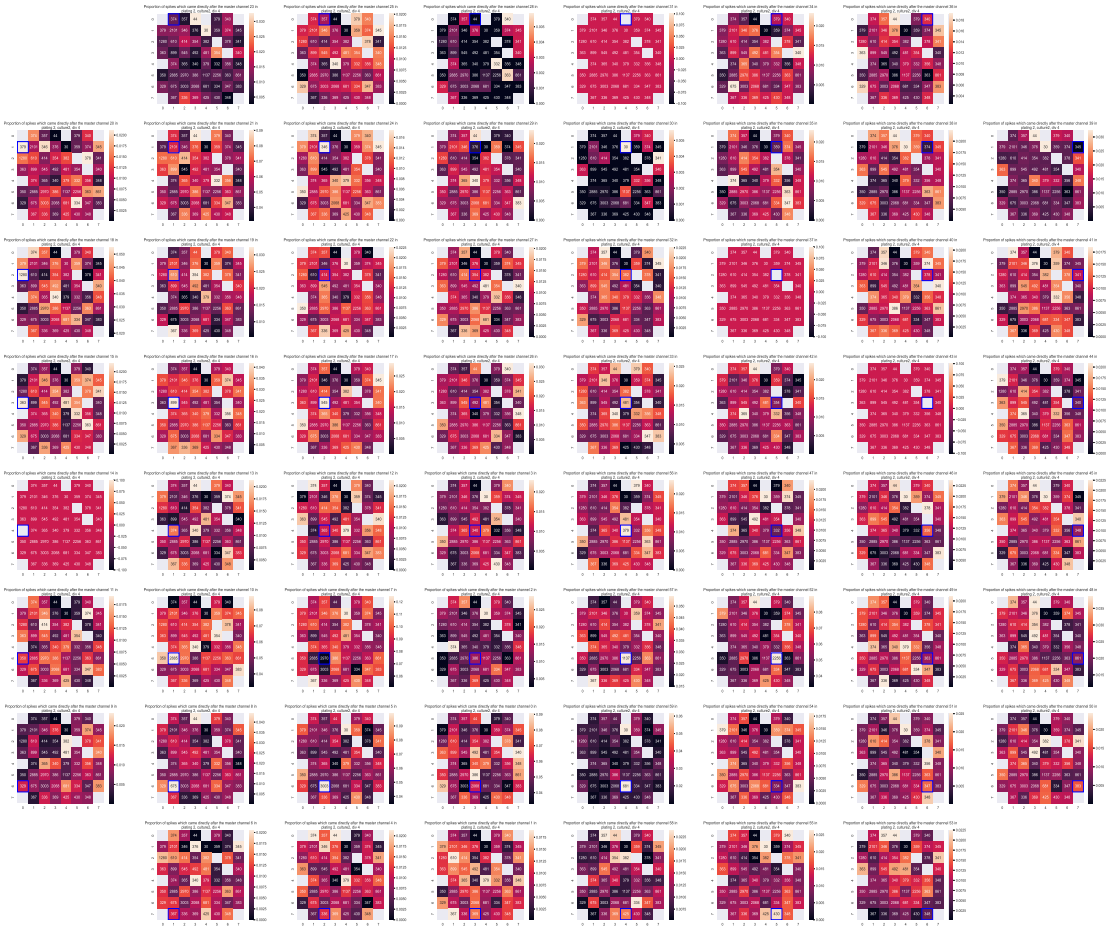


3.1.3 Heat map for Plating 1, Culture 3, DIV 25

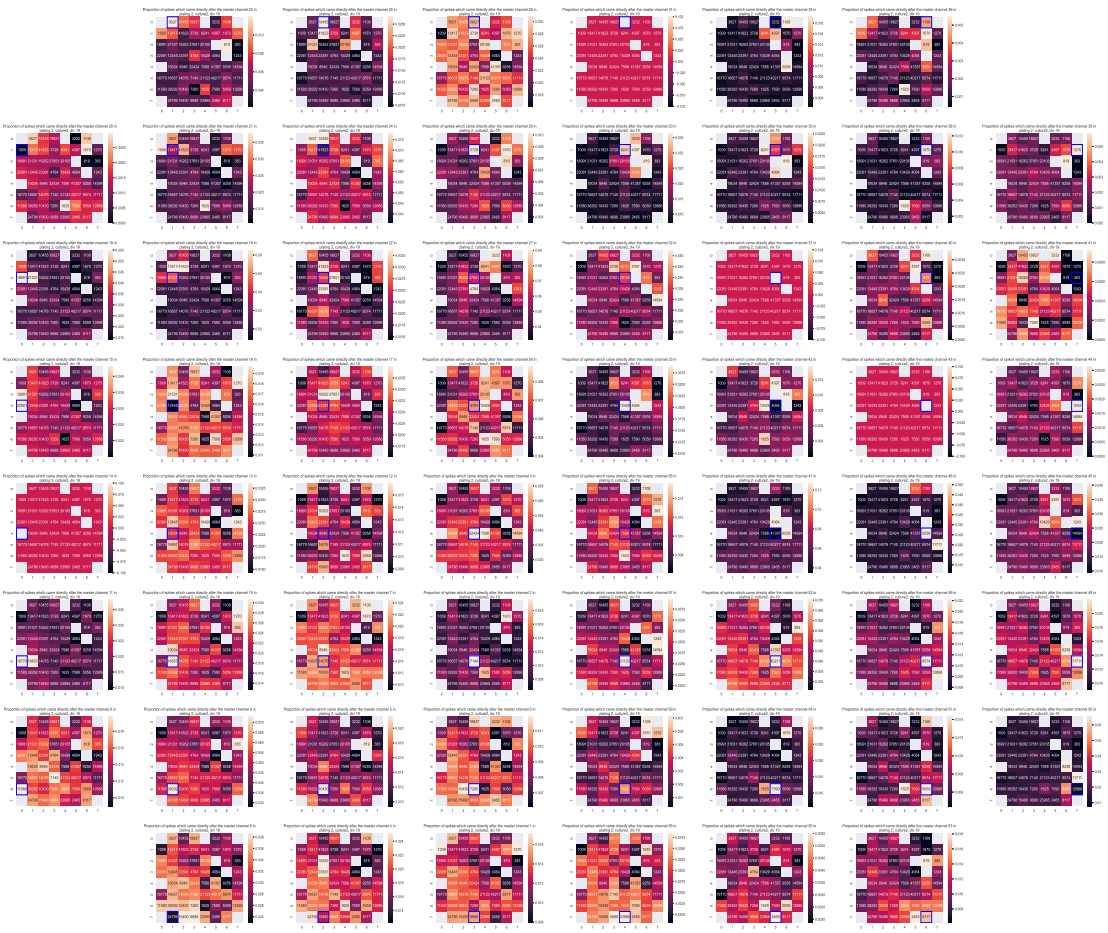


3.2 Heat maps for Plating 2, Culture 2

3.2.1 Heat map for Plating 2, Culture 2, DIV 4



3.2.2 Heat map for Plating 2, Culture 2, DIV 19

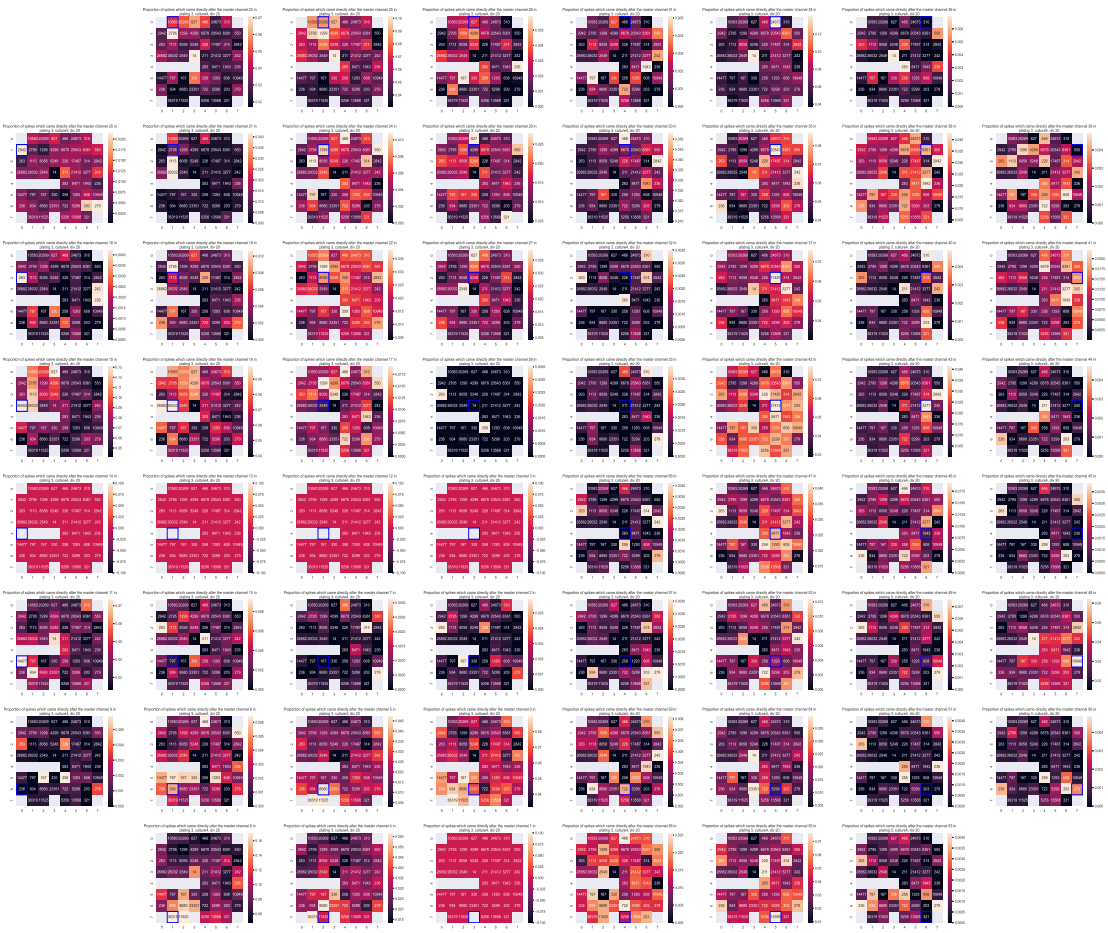


3.2.3 Heat map for Plating 2, Culture 2, DIV 35

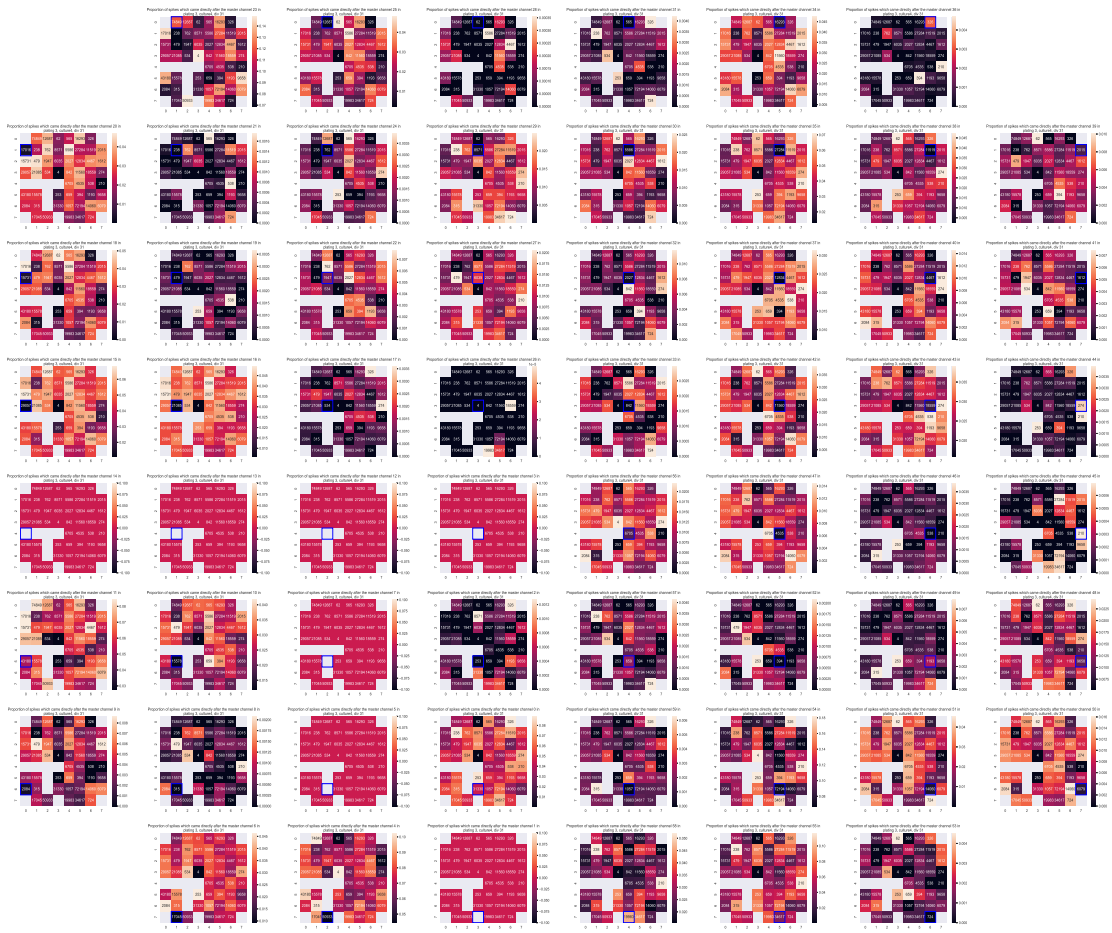
3.3 Heat maps for Plating 3, Culture 4

3.3.1 Heat map for Plating 3, Culture 4, DIV 7

3.3.2 Heat map for Plating 3, Culture 4, DIV 20

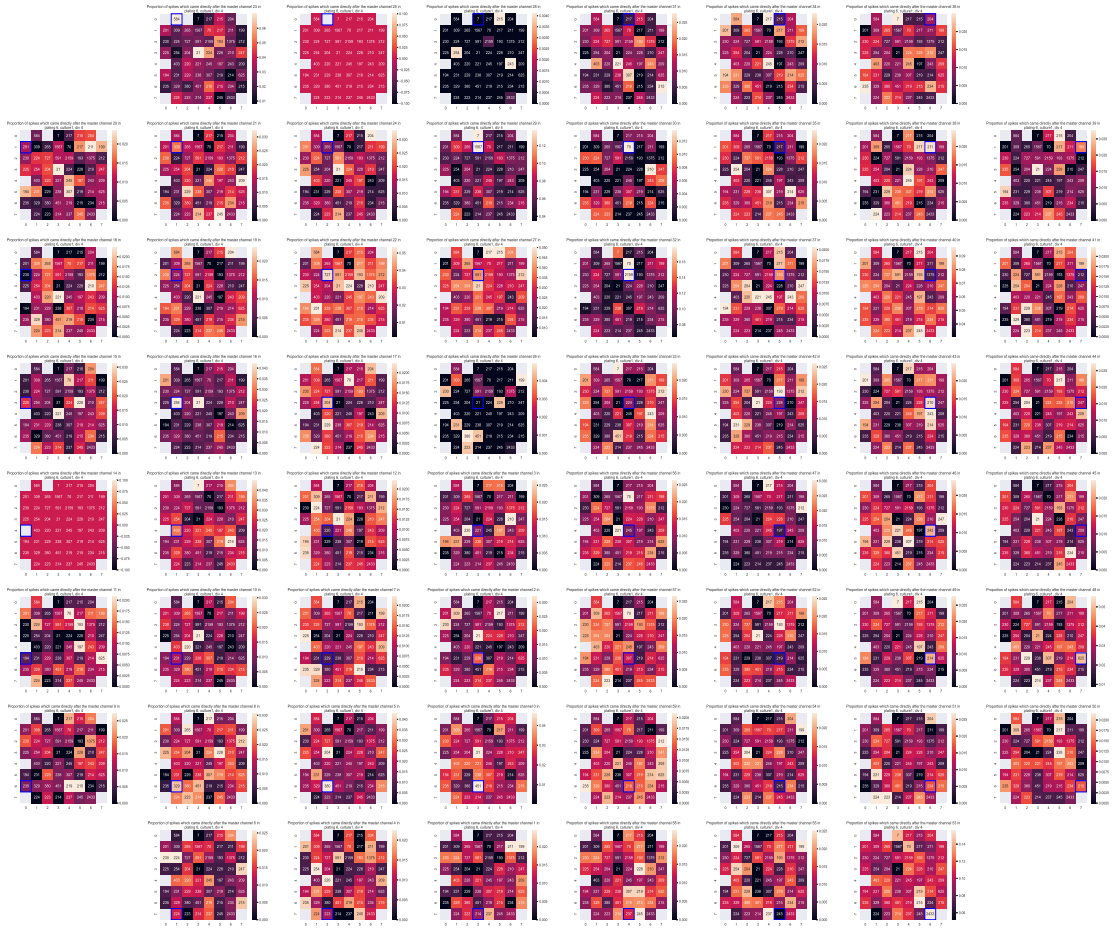


3.3.3 Heat map for Plating 3, Culture 4, DIV 31

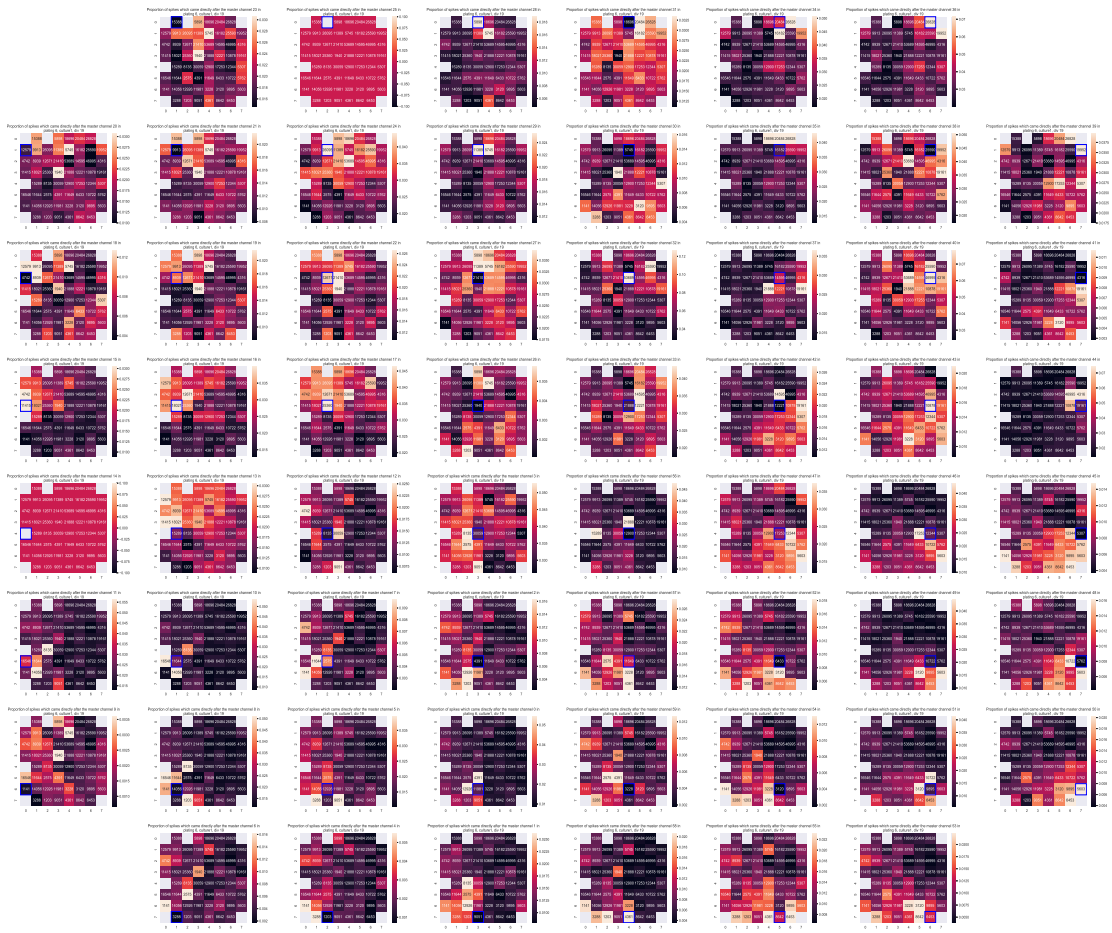


3.4 Heat maps for Plating 6, Culture 1

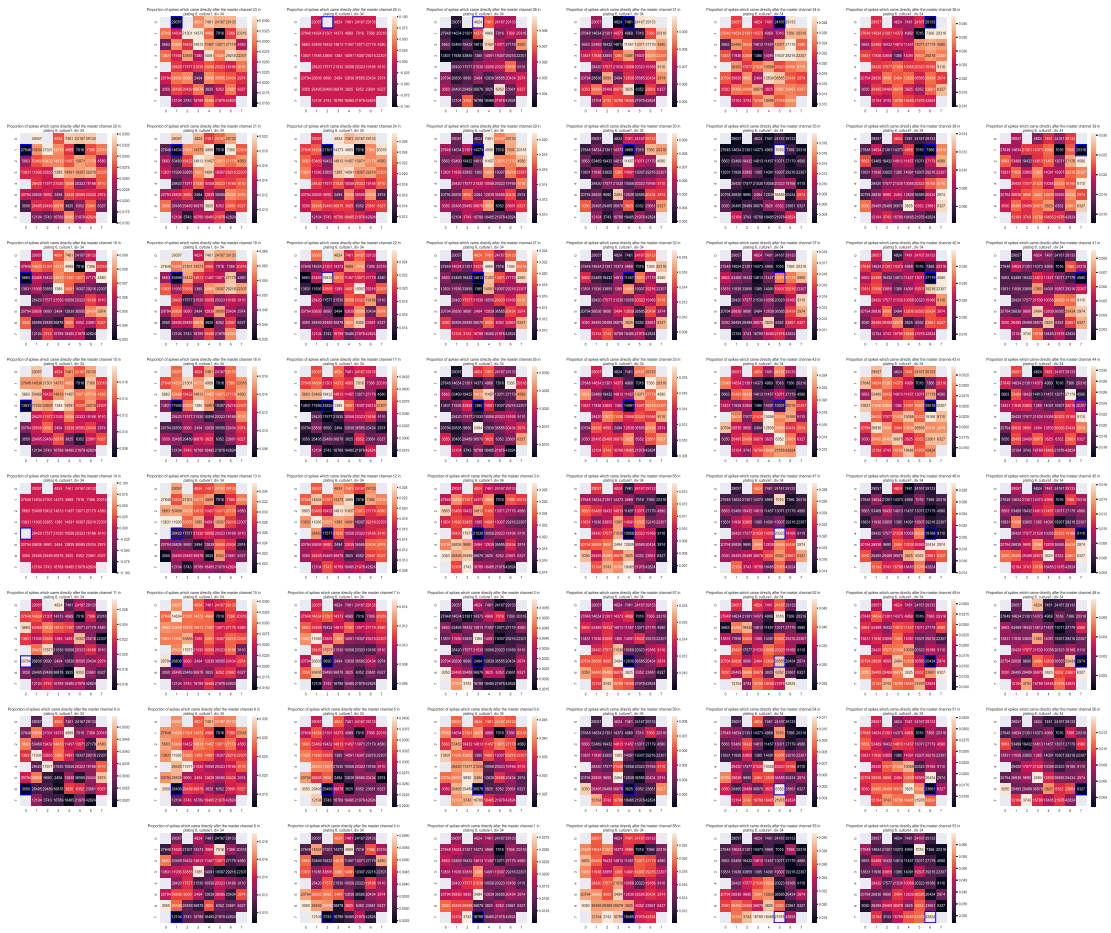
3.4.1 Heat map for Plating 6, Culture 1, DIV 4



3.4.2 Heat map for Plating 6, Culture 1, DIV 19



3.4.3 Heat map for Plating 6, Culture 1, DIV 34



4 Ratio of observed vs expected first spikes after master channel

We wish to find out if the number of first occurences of other channels spiking after the master channel spikes is comparable to that of independtly spiking Poisson channels.

In order to do this, we work out the expected probability of a channel spiking directly after a master channel spiking, which if modelled with a Multinomial distribution is

$$\hat{p_i} = \frac{t_i}{\sum_i t_i}$$

where t_i is the total number of spikes of spike i

This is compared with the observed proportion of a channel i spiking directly after the master channel:

$$\tilde{p_i} = \frac{o_i}{t_m}$$

where o_i is the observed number of spikes of channel i after the master channel, and m is the master channel.

So then if they really are independent then the ratio $\frac{\tilde{p_i}}{\hat{p_i}}$ would be 1. If it is greater than 1, then the ith channel spikes after m more often than expected.

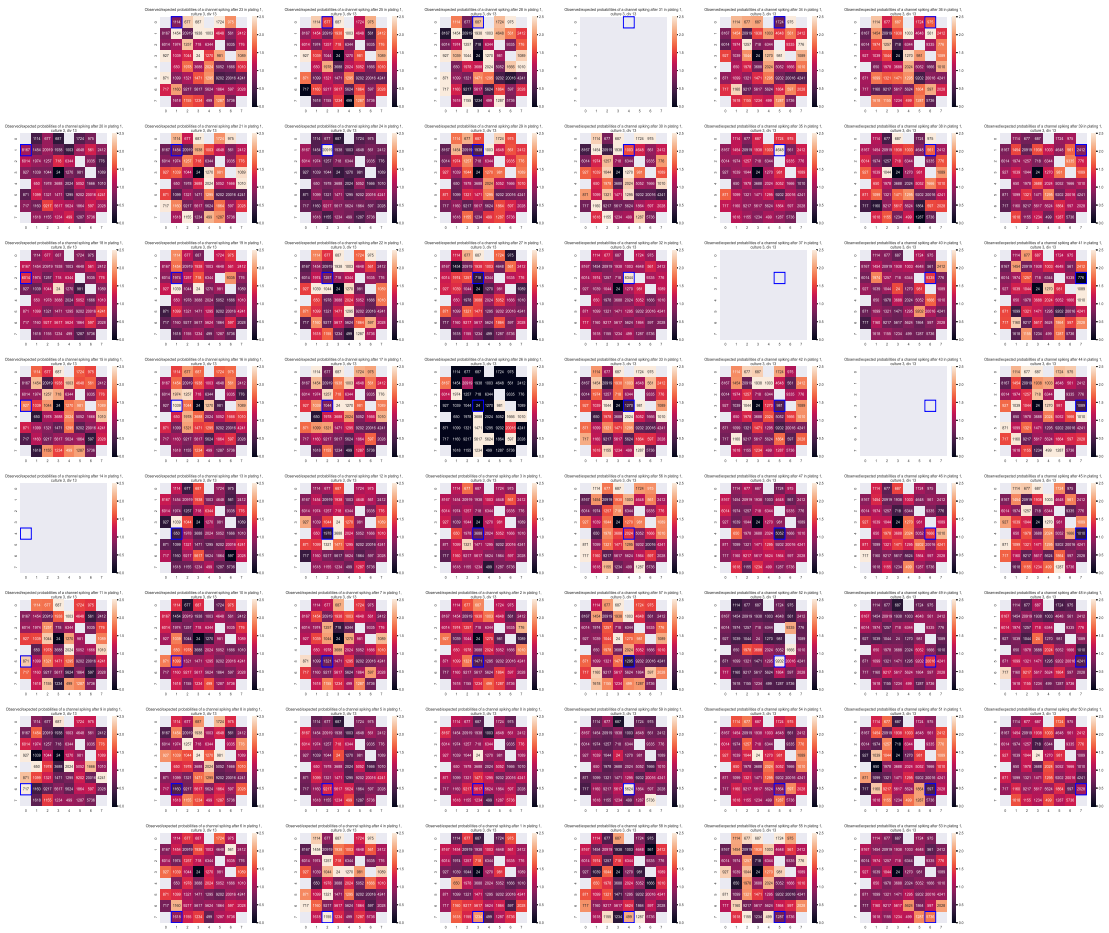
When these are less than 1, this is due to others being more biased to spike after the master channel.

The heatmaps are annotated with the t_i and are coloured with the ratio of observed/expected proportions.

4.1 Heat maps for Plating 1, Culture 3

4.1.1 Heat map for Plating 1, Culture 3, DIV 4

4.1.2 Heat map for Plating 1, Culture 3, DIV 13



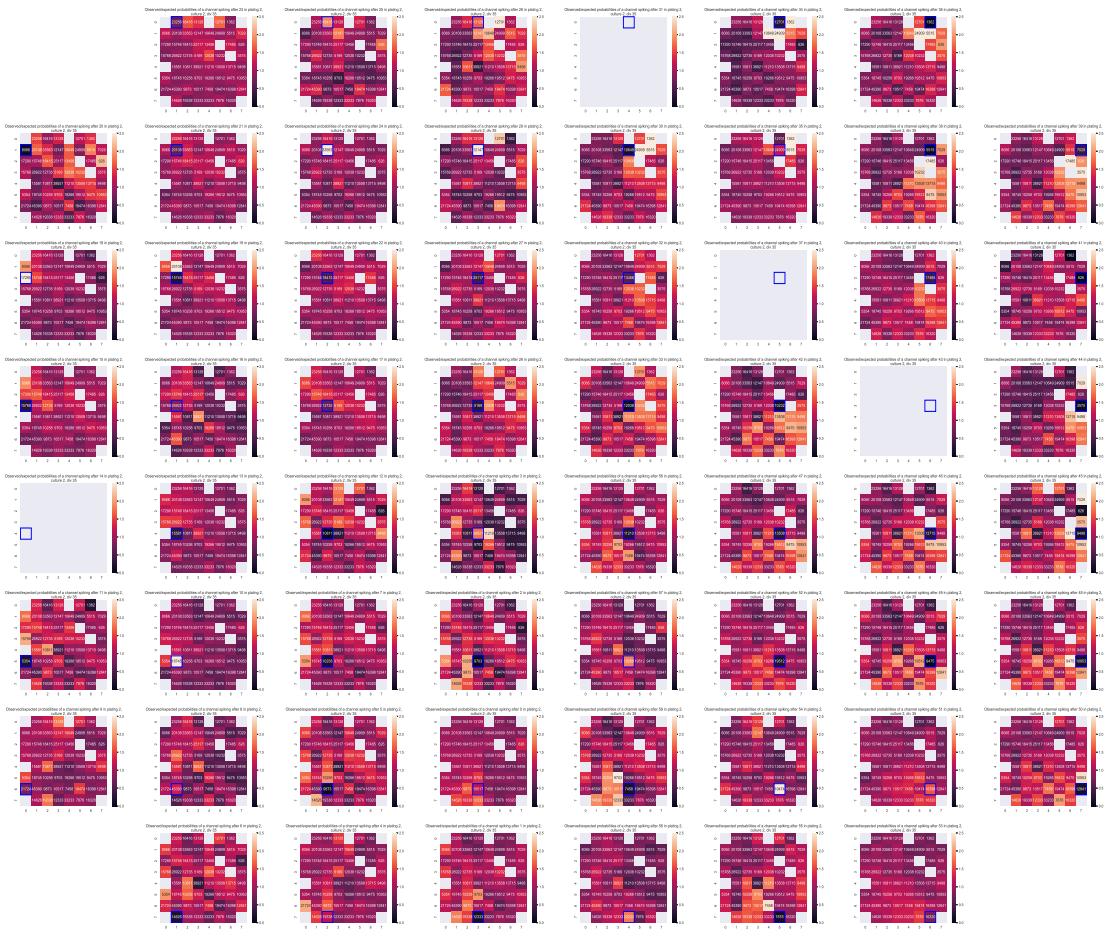
4.1.3 Heat map for Plating 1, Culture 3, DIV 25

4.2 Heat maps for Plating 2, Culture 2

4.2.1 Heat map for Plating 2, Culture 2, DIV 4

4.2.2 Heat map for Plating 2, Culture 2, DIV 19

4.2.3 Heat map for Plating 2, Culture 2, DIV 35

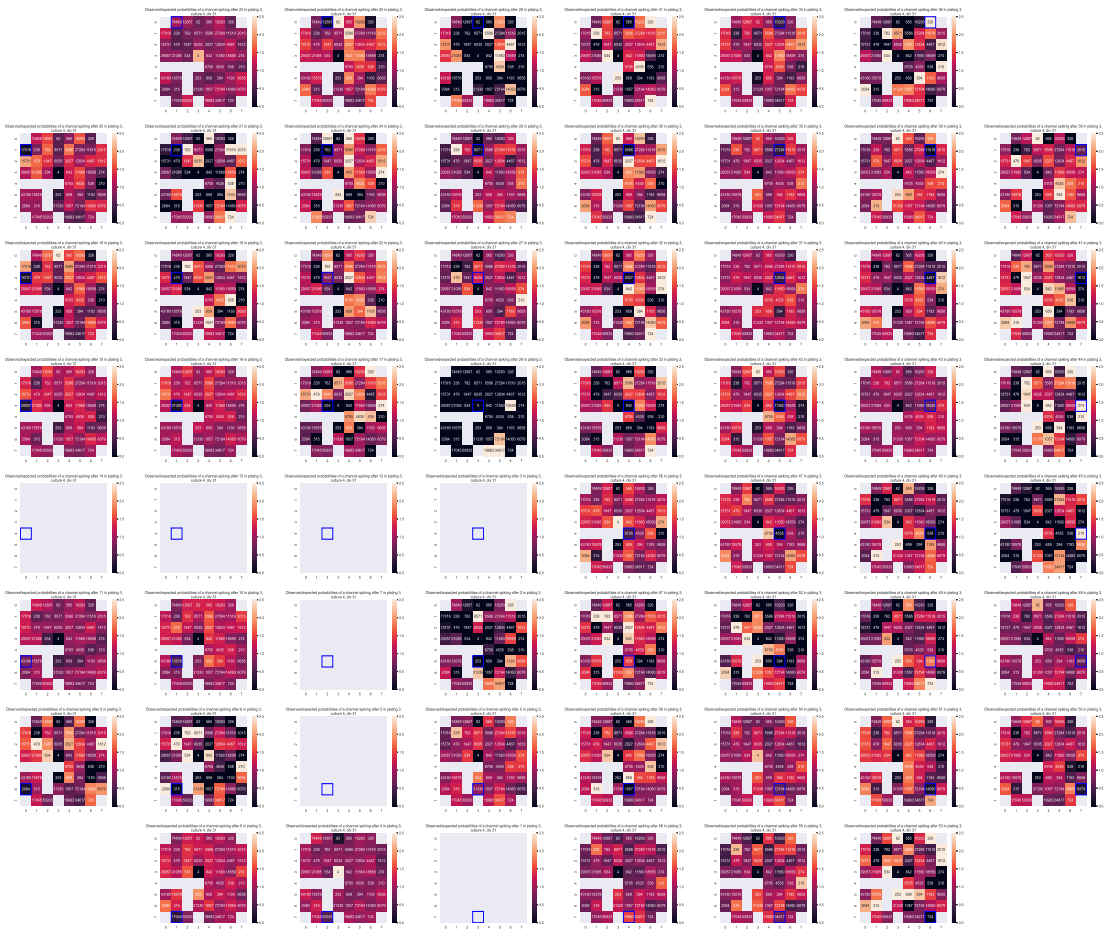


4.3 Heat maps for Plating 3, Culture 4

4.3.1 Heat map for Plating 3, Culture 4, DIV 7

4.3.2 Heat map for Plating 3, Culture 4, DIV 20

4.3.3 Heat map for Plating 3, Culture 4, DIV 31



4.4 Heat maps for Plating 6, Culture 1

4.4.1 Heat map for Plating 6, Culture 1, DIV 4

4.4.2 Heat map for Plating 6, Culture 1, DIV 19

4.4.3 Heat map for Plating 6, Culture 1, DIV 34

5 Chi-squared test

The closer the p-value is to zero, the more the data fits the expected data under the null-hypothesis of independently occurring Poisson spikes.

The heatmaps are coloured w.r.t. a p-value corresponding to the following Pearson's Chi-squared test: H_0: The channels are independently occuring Poisson spikes H_1: They are not.

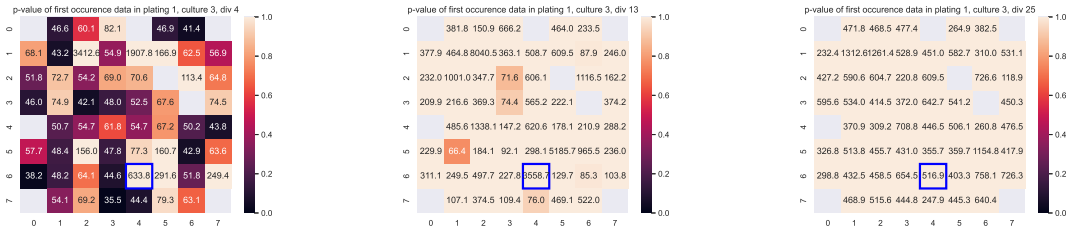


Figure 1: Chi-squared test for plating-culture 1-3

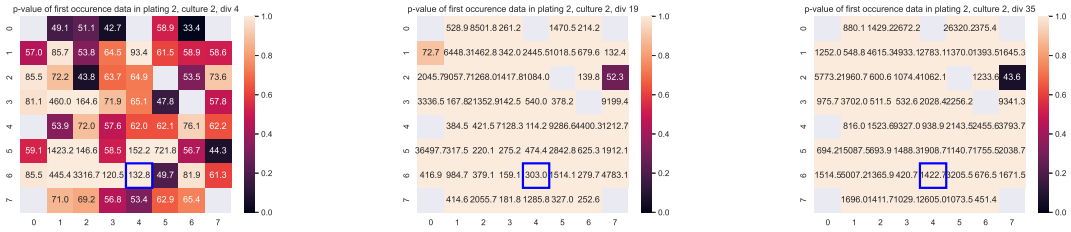


Figure 2: Chi-squared test for plating-culture 2-2

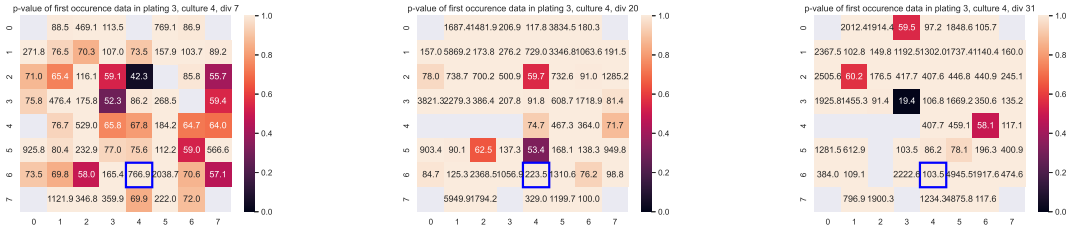


Figure 3: Chi-squared test for plating-culture 3-4

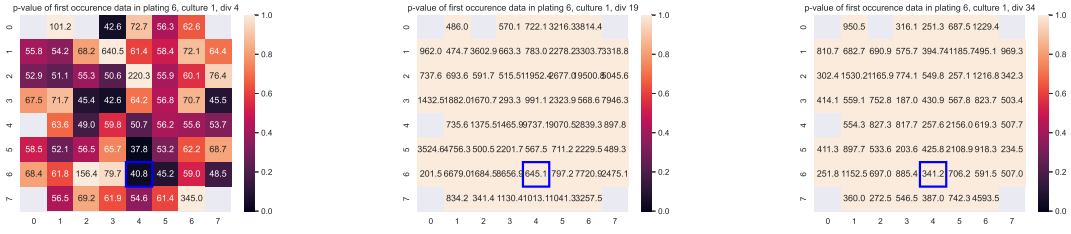


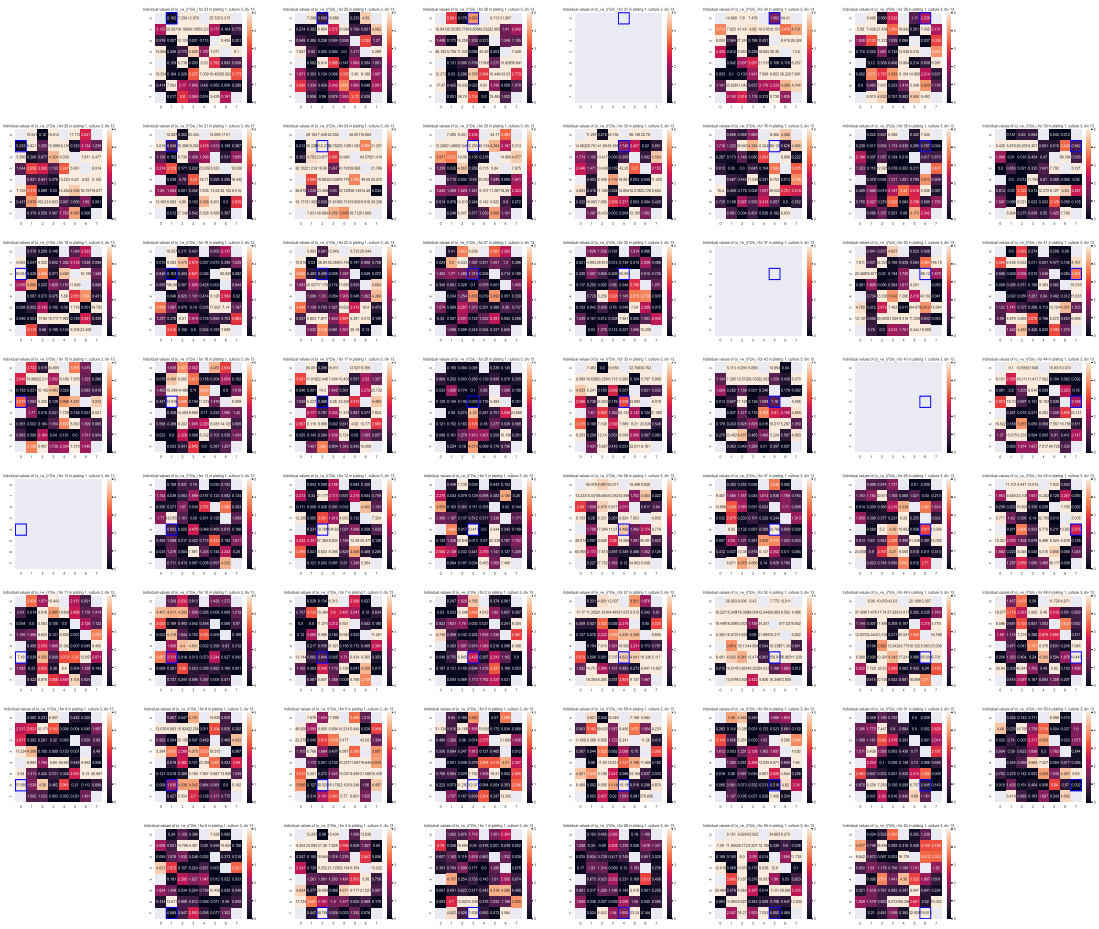
Figure 4: Chi-squared test for plating-culture 6-1

6 Chi-squared summands

6.1 Heat maps for Plating 1, Culture 3

6.1.1 Heat map for Plating 1, Culture 3, DIV 4

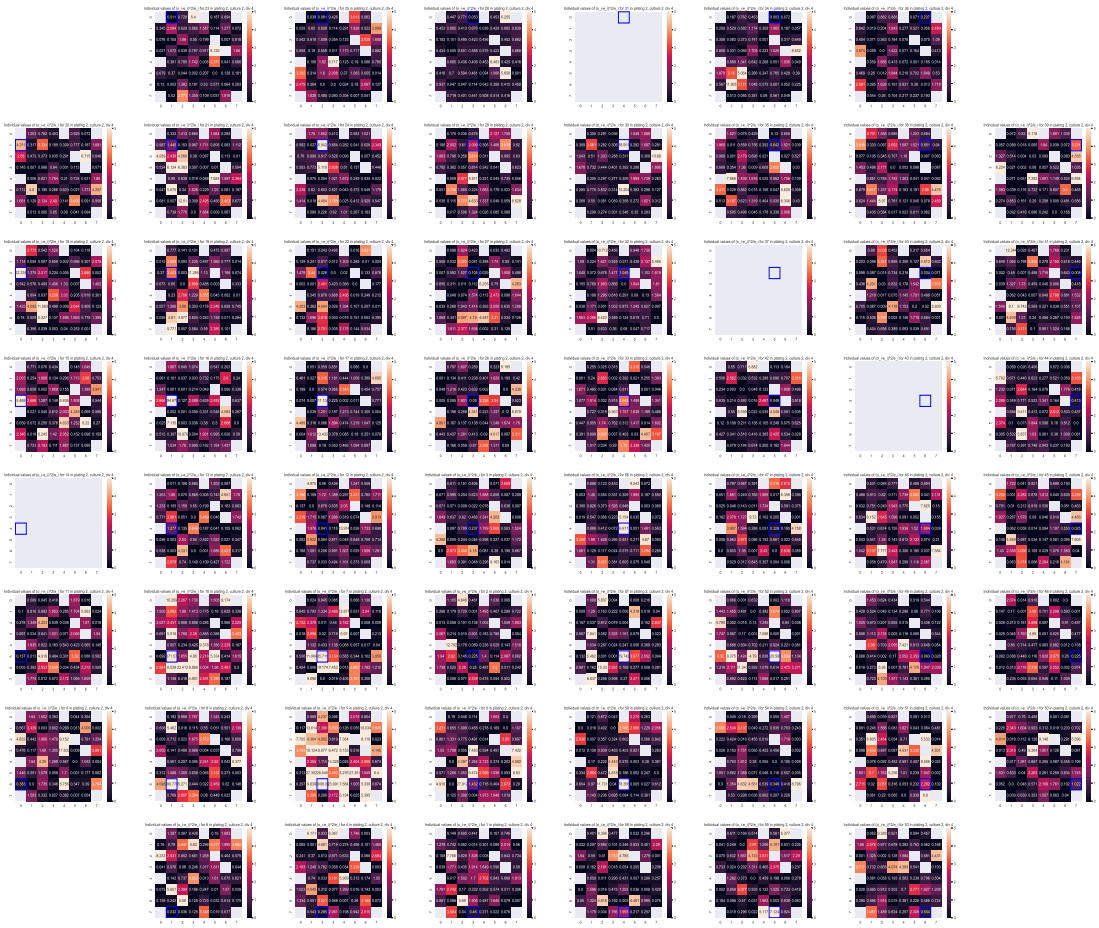
6.1.2 Heat map for Plating 1, Culture 3, DIV 13



6.1.3 Heat map for Plating 1, Culture 3, DIV 25

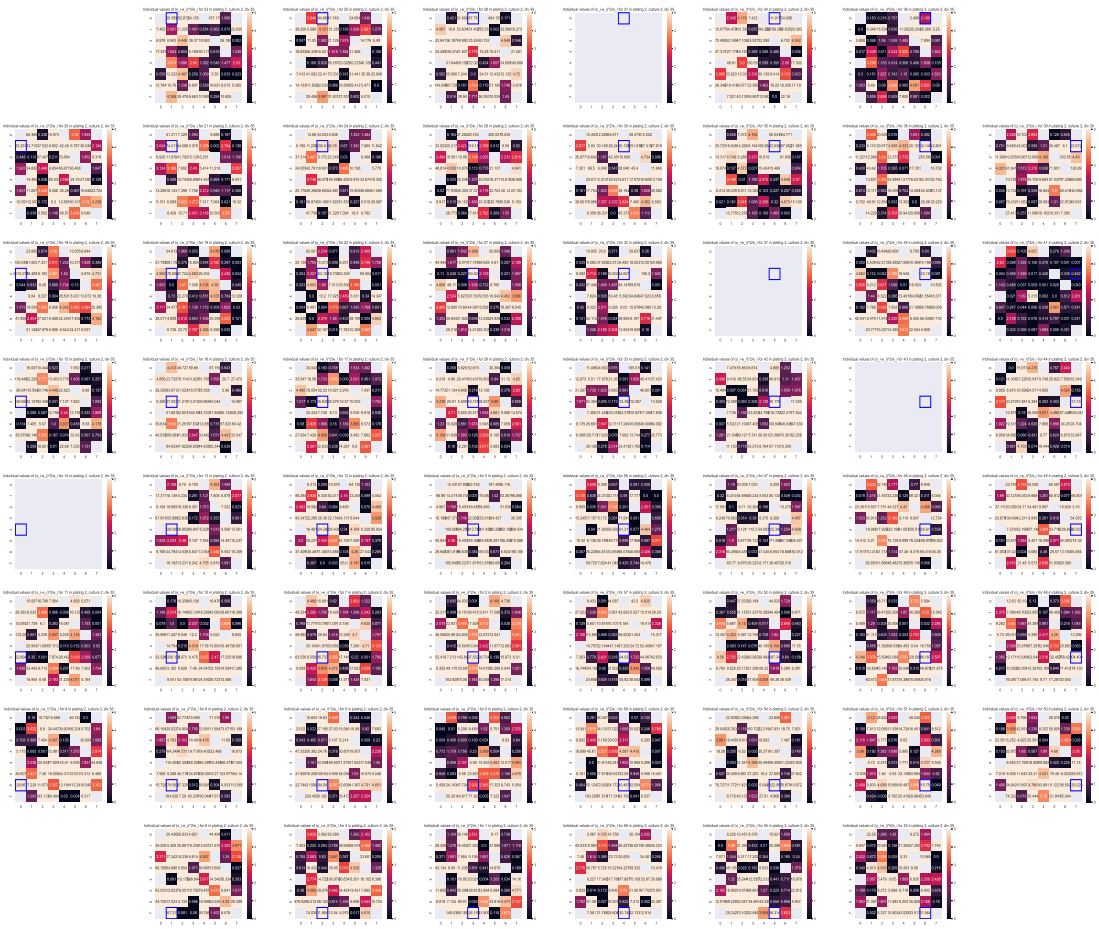
6.2 Heat maps for Plating 2, Culture 2

6.2.1 Heat map for Plating 2, Culture 2, DIV 4



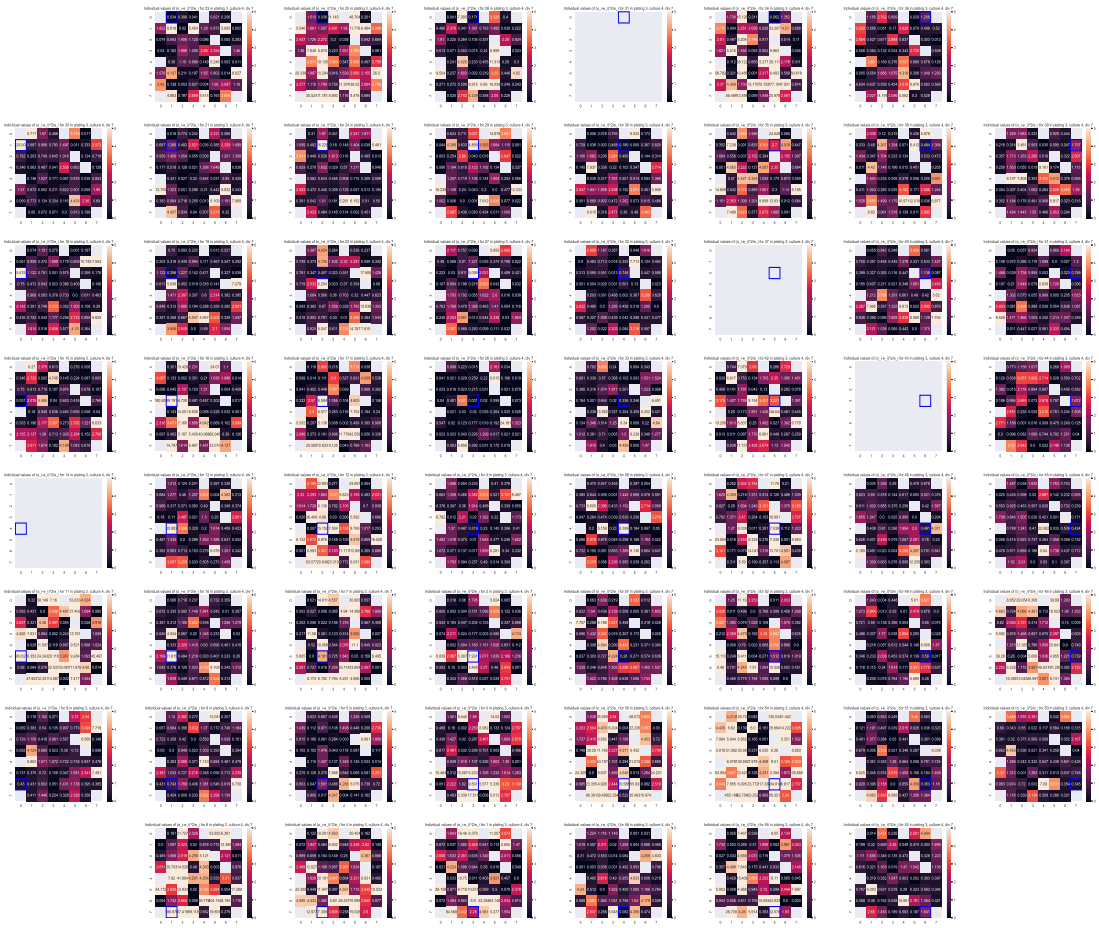
6.2.2 Heat map for Plating 2, Culture 2, DIV 19

6.2.3 Heat map for Plating 2, Culture 2, DIV 35

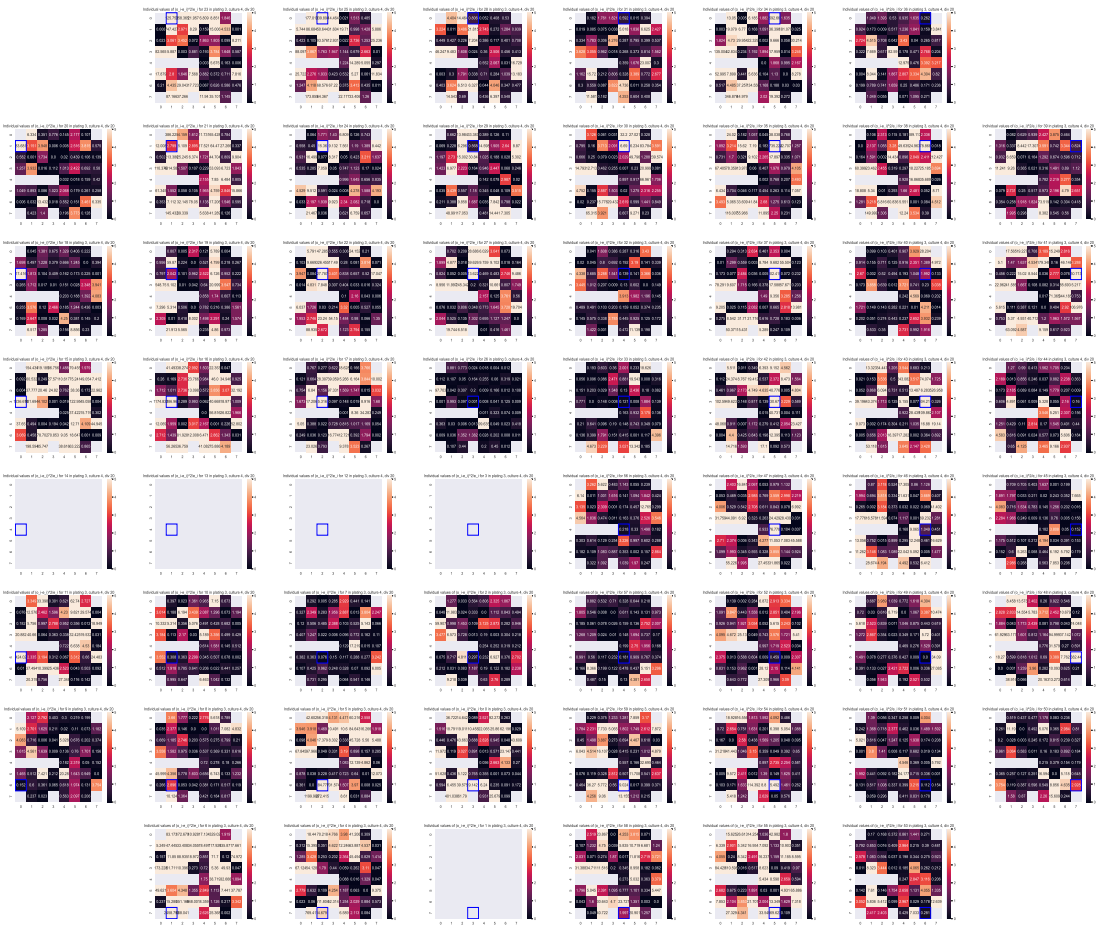


6.3 Heat maps for Plating 3, Culture 4

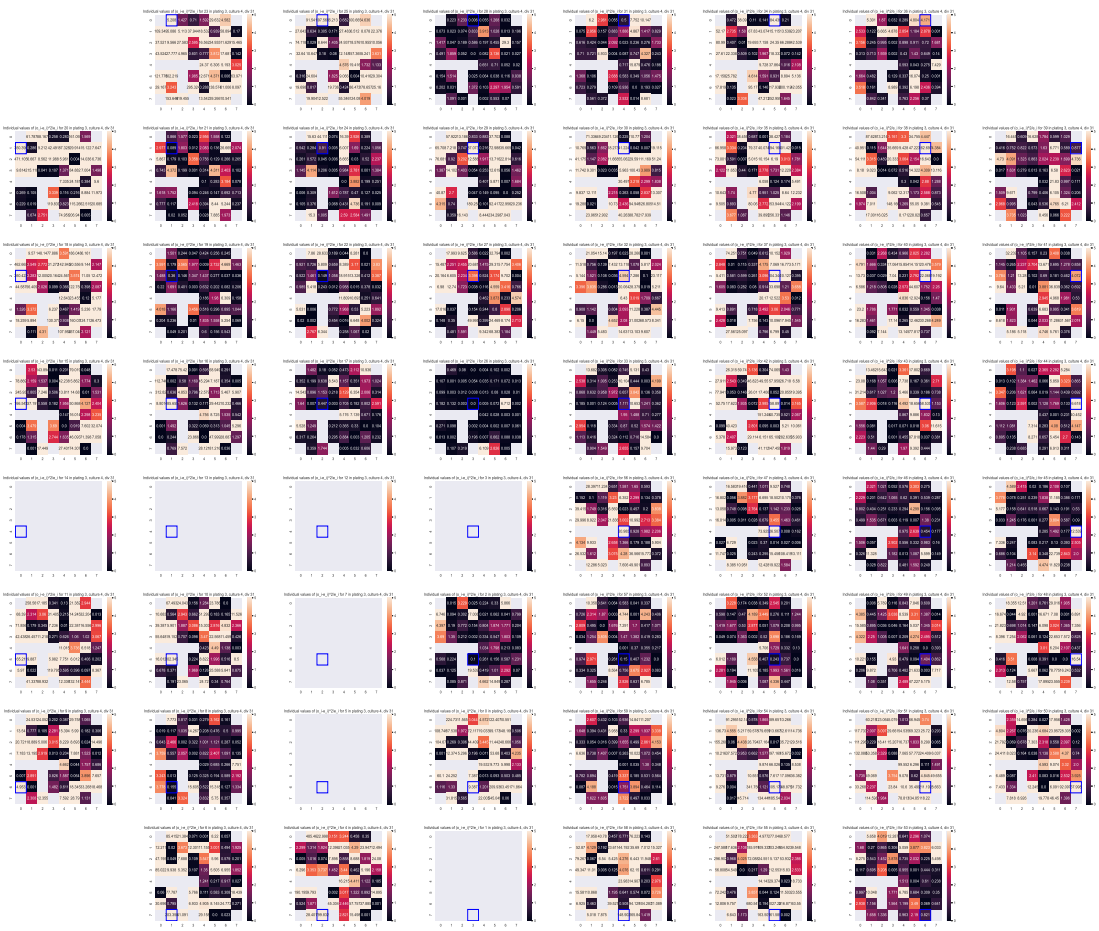
6.3.1 Heat map for Plating 3, Culture 4, DIV 7



6.3.2 Heat map for Plating 3, Culture 4, DIV 20

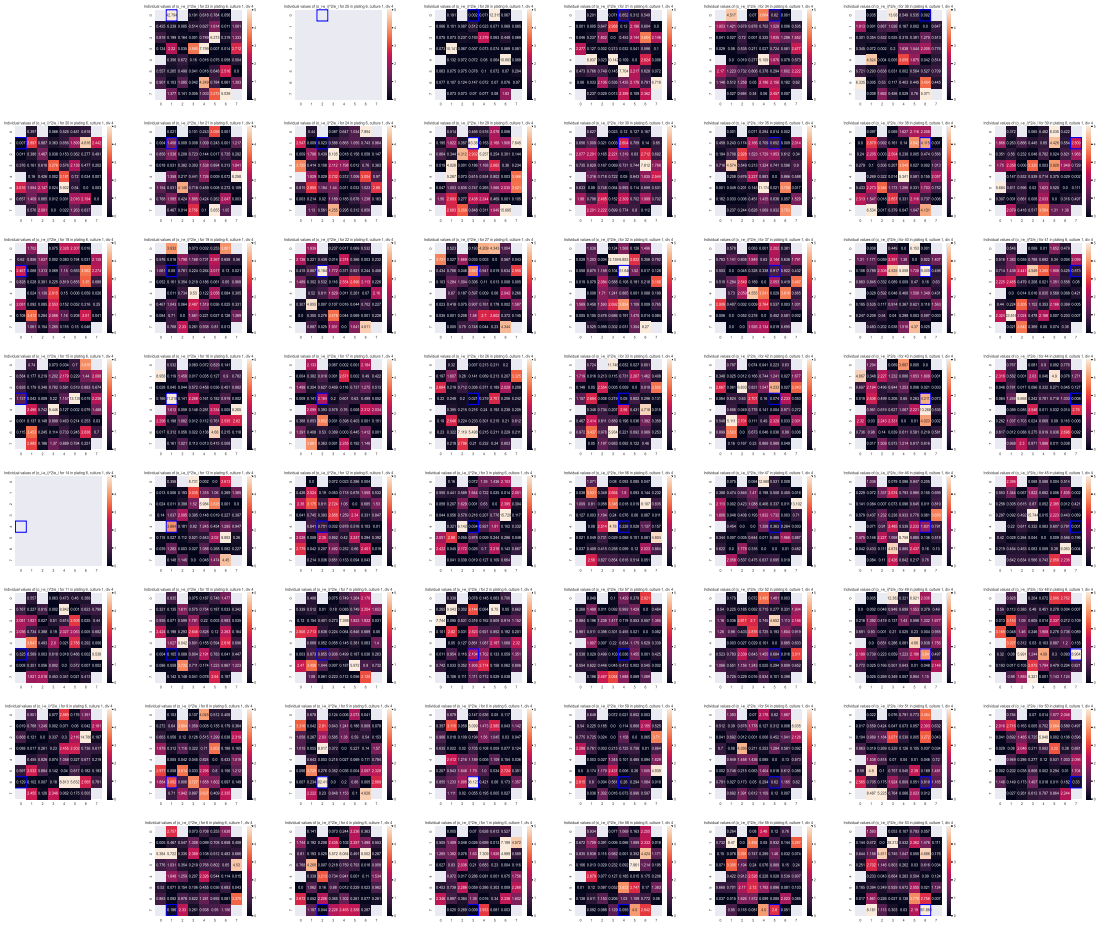


6.3.3 Heat map for Plating 3, Culture 4, DIV 31



6.4 Heat maps for Plating 6, Culture 1

6.4.1 Heat map for Plating 6, Culture 1, DIV 4



6.4.2 Heat map for Plating 6, Culture 1, DIV 19

6.4.3 Heat map for Plating 6, Culture 1, DIV 34