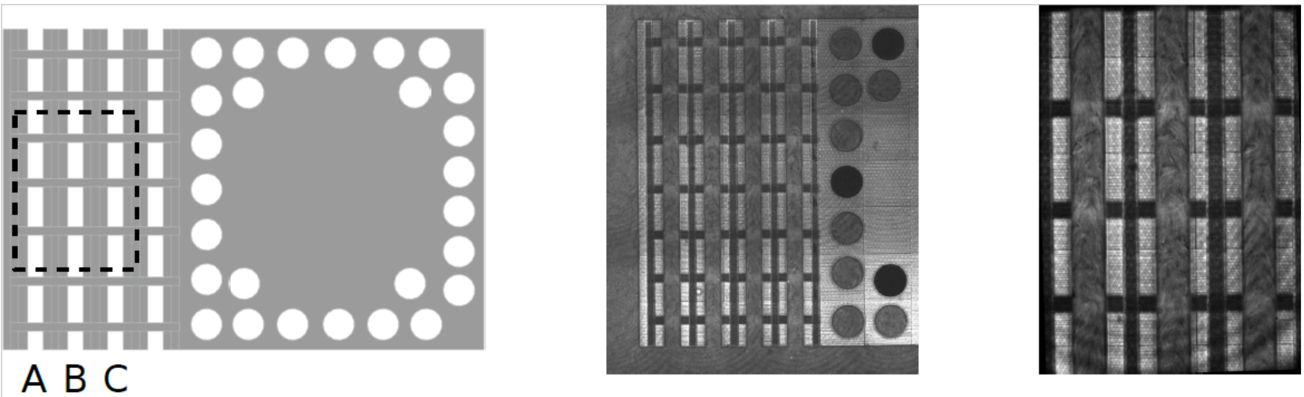
Active fluid flow in straight channels

In a narrow channel, active fluid often self-organize into directional flows due to geometrical constraints. What determines the flow rate? Our previous study suggests that the channel width also plays an important role. In the same active fluid sample, we measured the flow rates in channels with various lengths and found a nonmonotonic dependence, where flow rate peaks at $W = 150$ um. The intrinsic activity is likely a factor. As a control experiment, we can fix channel width and see if flow rate varies with fluid activity (we should have data showing different flow rates at the same width, in different active nematics sample).

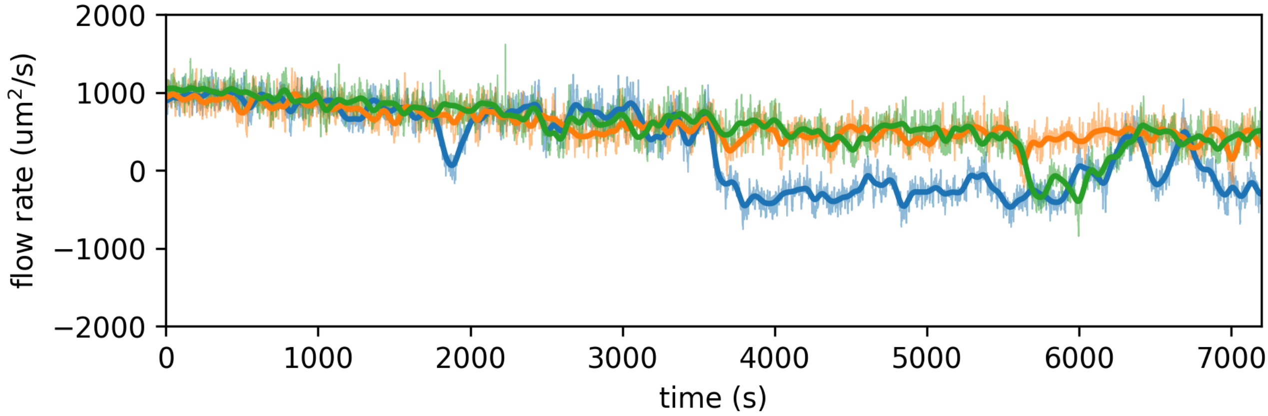
Are activity and channel width the only major factors? Are there other random, detailed factors that can alter the flow behavior significantly, such as defects on the channel walls? This can be tested with an experiment where we fix both channel width and activity. In this note, we summarize the result of this test, which shows that width and activity are indeed the major factors.

The identical channel design is shown in the following figure, along with the actual grid printed by a 2-photon 3D printer.

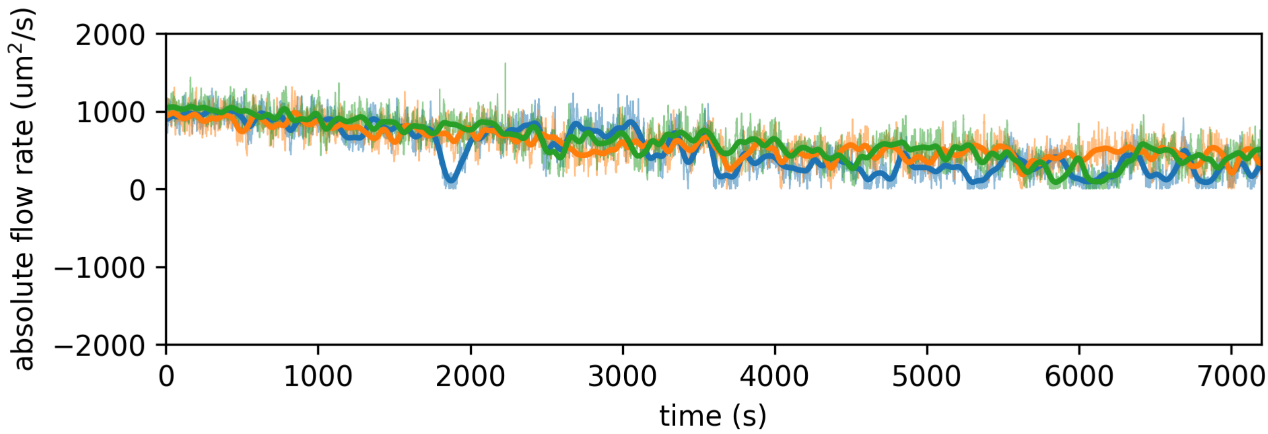


2000 um x 100 um

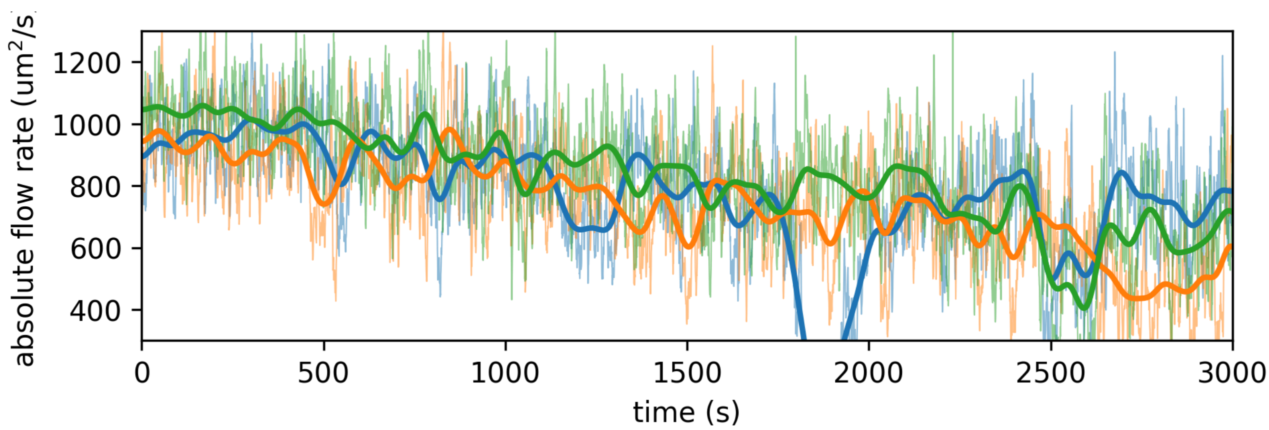
Each channel is 100 um wide and 2000 um long. In a field of view, we can include 3 of such channels and measure the flow rates simultaneously. We took videos for 2 hours in total, and the flow rate time series is shown below. In the first hour, the flows in all the 3 channels are in the same direction and of the same magnitude for most of the time. In the second hour, we observe flow reversals in channel A and C.



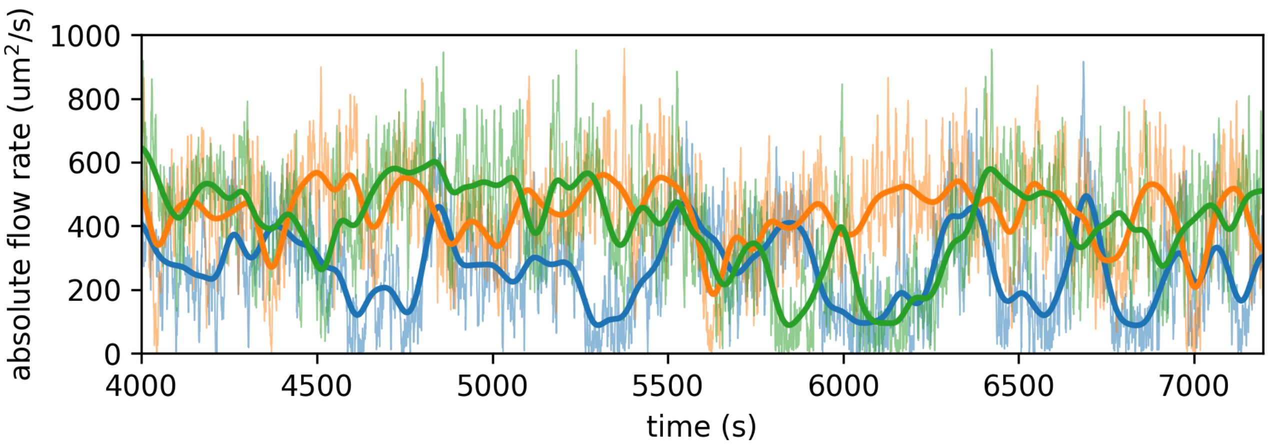
To compare the flow rete magnitude, we take the absolute values of the flow rate data as shown below. We can see that in the second hour where the reversals happen, the 3 flow rates are not as consistent as in the first hour, although the magnitudes stay relative close.



Zoom-in of [0, 3000]:



Zoom-in of [4000, 7200]:



absolute flow rate (um²/s)
1000
800
600
400
200
0
4000
4500
5000
5500
6000
6500
7000
time (s)