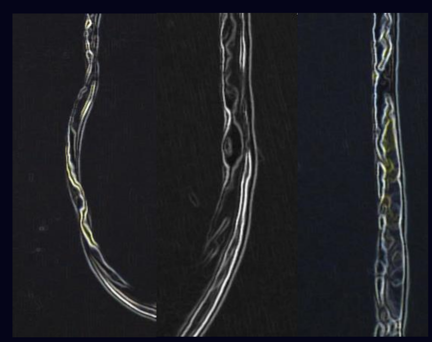
Unstable Rivulet Meandering on an Inclined Plane

Yi-Min Zeng (曾義閔), Hsiu-Chi Chou (周修麒)
TA: Jun-Yi Tsai (蔡俊毅), Hao-Wei Hu (胡皓為), Advisor: Lin I (伊林)
Department of Physics, National Central University

Background

Previous studies mainly focus on the statistical, phase diagram for transition from stable / unstable regime and analysis for meandering rivulets.

Raindrops on the car window



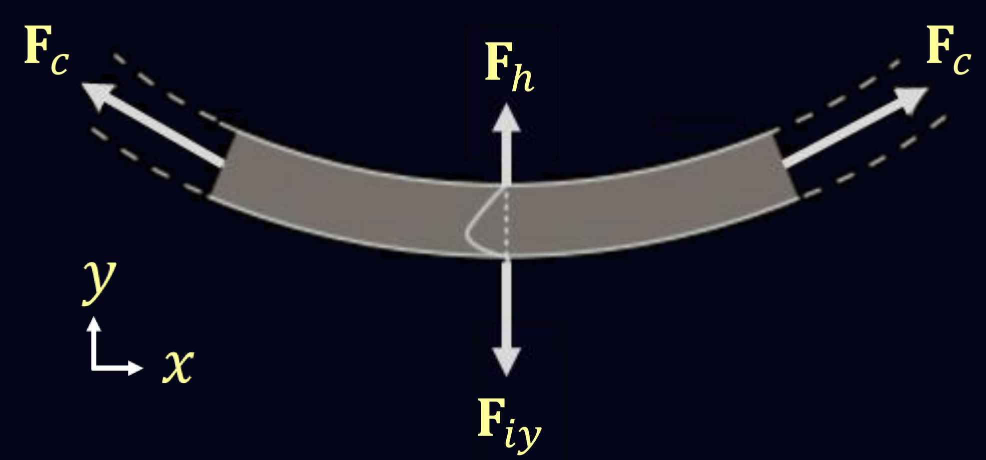
Experiments with diverse flow rates

Goal

1. Changing flow rate but fixing inclination angle at 10°.
2. Observing evolution of unstable rivulet meandering on inclination plane.

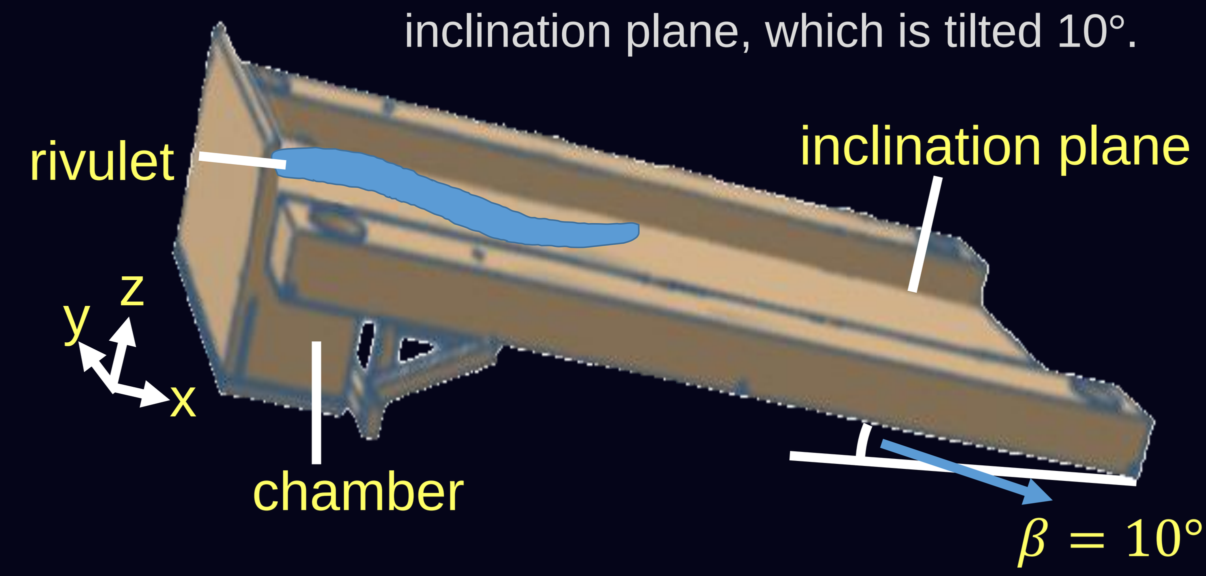
Meandering mechanism

Four mechanisms determine motion of the rivulet, gravity, inertial force ($\mathbf{F}_i$), capillary force ($\mathbf{F}_c$), and hysteresis of wetting (hysteresis force $\mathbf{F}_h$). The onset of meandering rivulet is that inertial force in y direction is larger than the sum of hysteresis force and capillary force. As the flow rate increases, stream of rivulet meandering on the plane and forms a non-stopped motion on the plate.



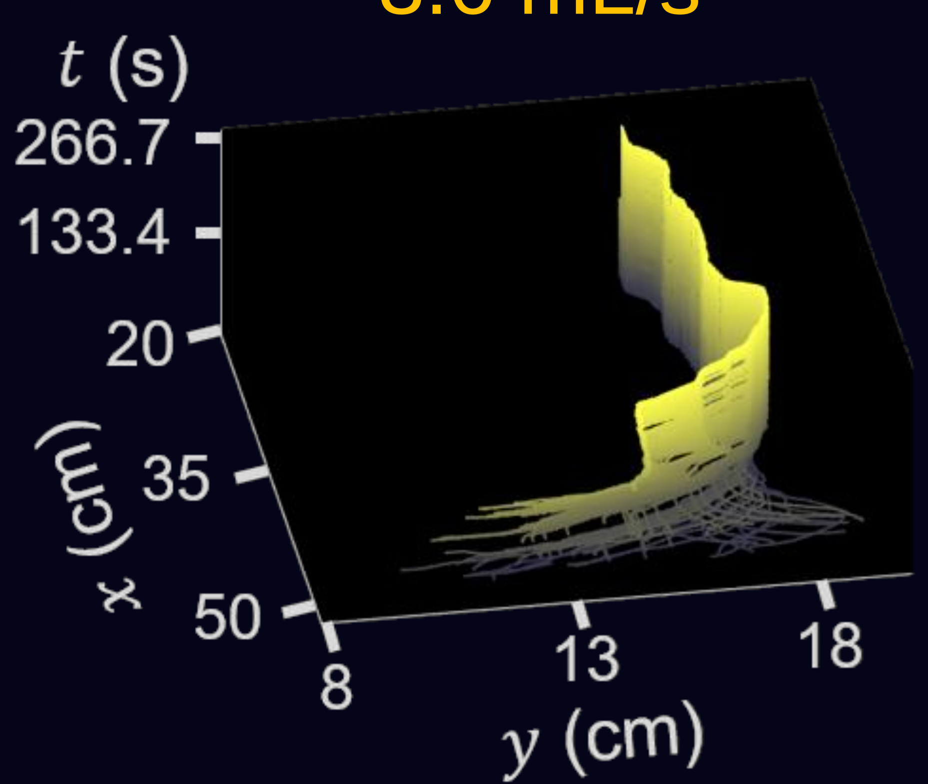
Setup

Water is injected from bottom of chamber, which is used to rectify injected water. Then, water flows out from a hole, and meander on the inclination plane, which is tilted 10°.

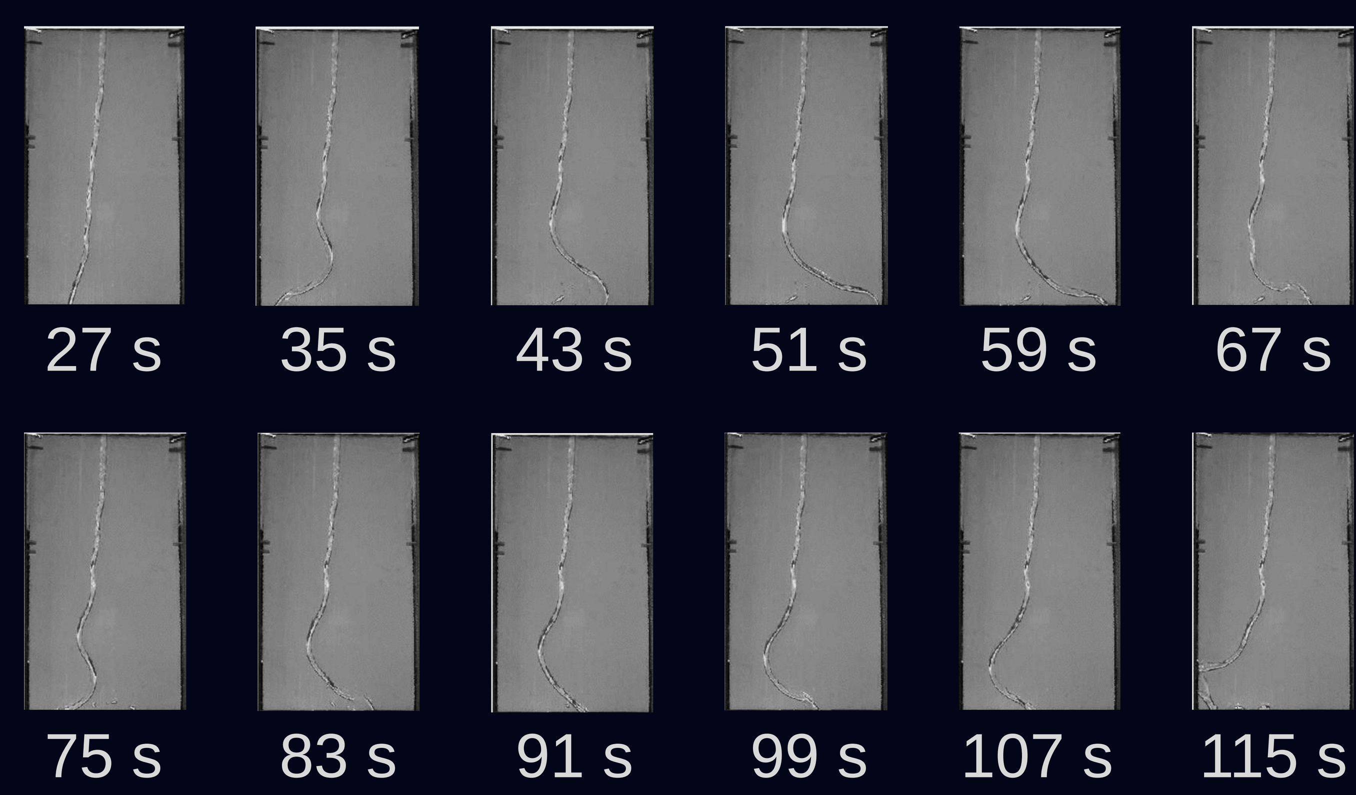


Evolution of rivulet under different flow rates v

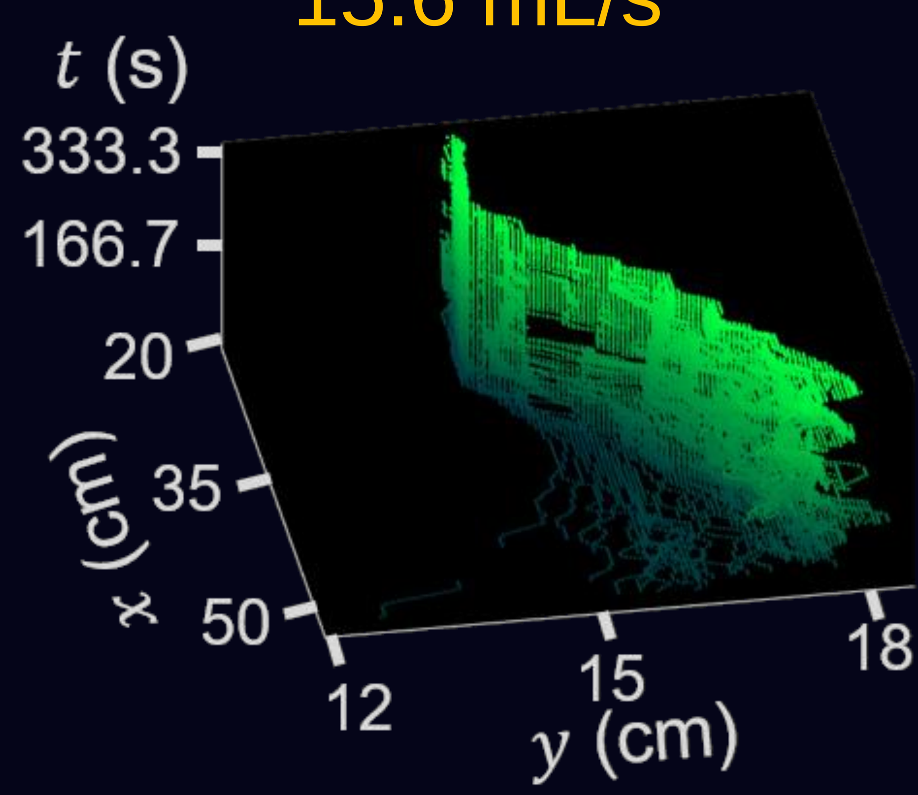
3.6 mL/s

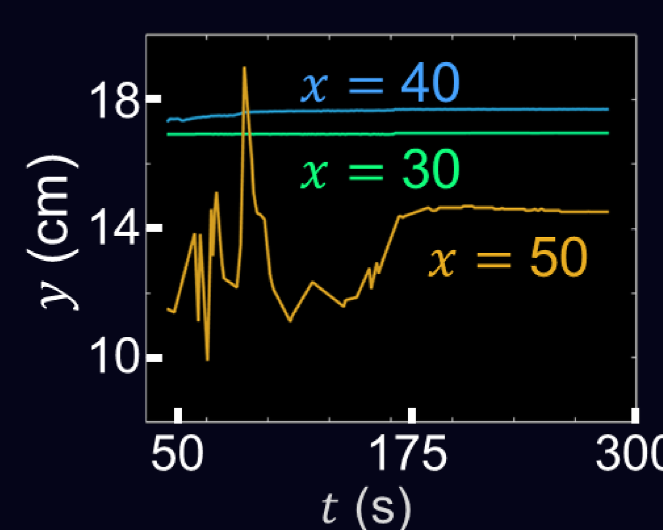


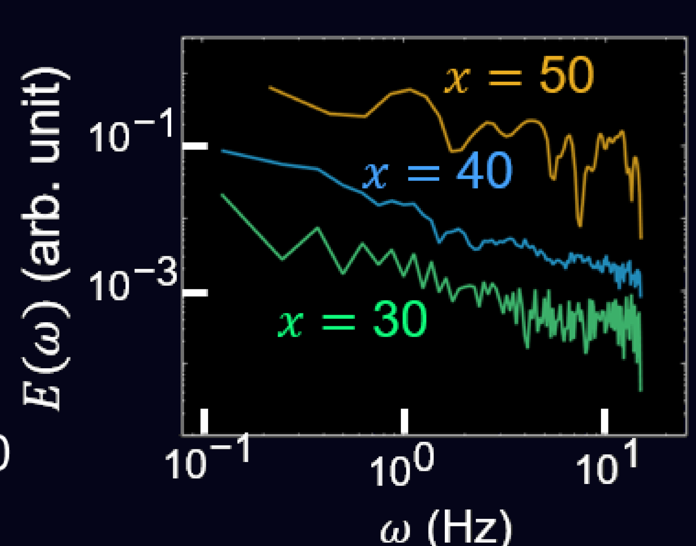
Sequential snapshots of rivulets under v = 6.4 mL/s



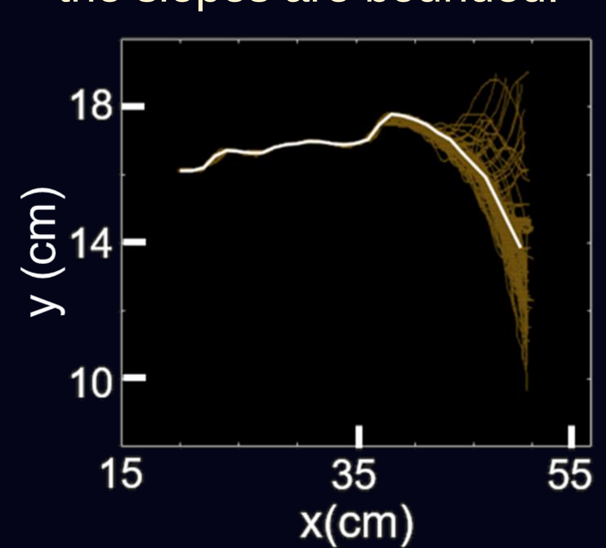
15.6 mL/s

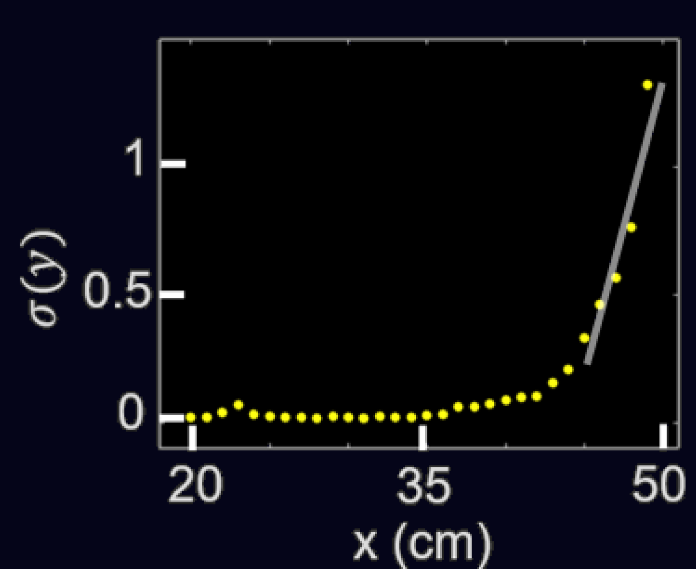






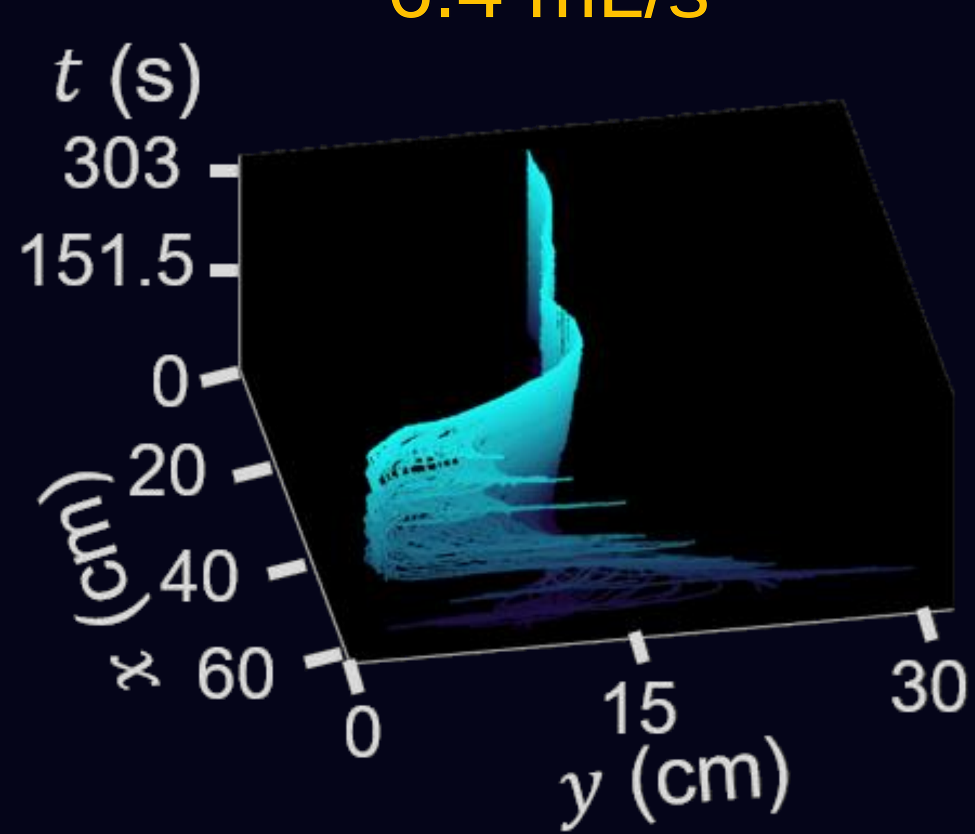
With Fast Fourier Transform (FFT) by choosing different cross sections (y-t planes), we acquire spectra (with double log scales) which show that $E(\omega) \propto \omega^m, m = const.$ and find that the slopes are bounded.

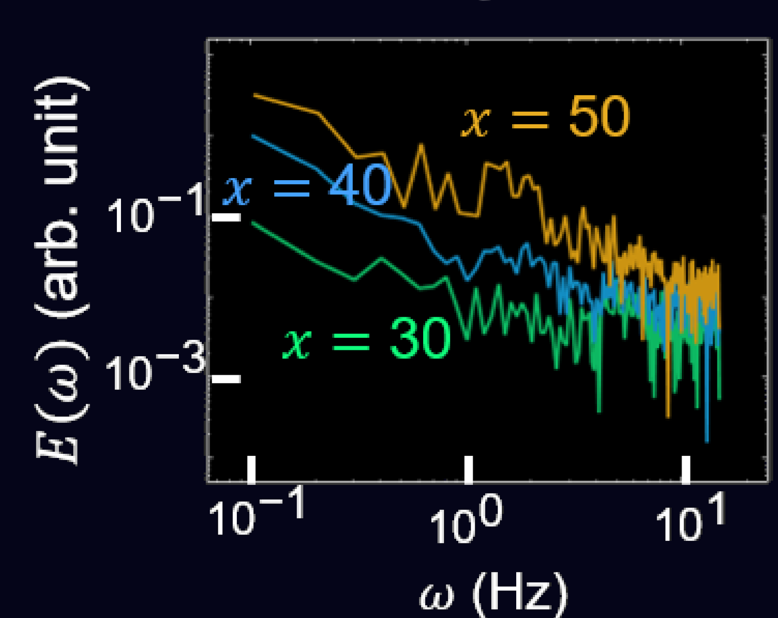


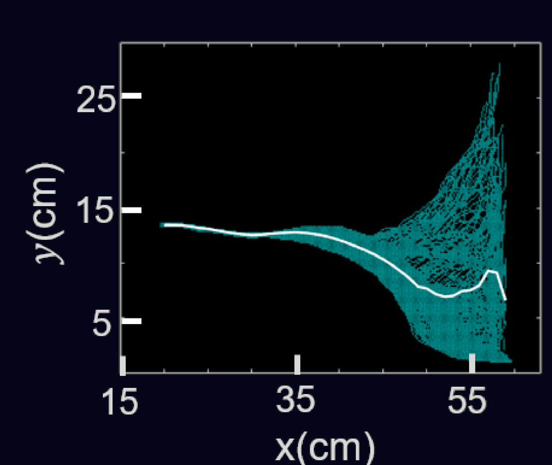


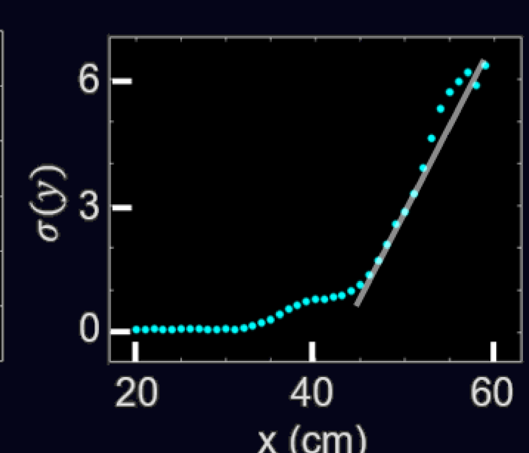
The white line shows the mean path of rivulet ($\bar{y}$). By using standard deviation, which is defined as $\sigma(y) = \sqrt{\overline{(y-\bar{y})^2}}$, the degree of oscillation is acquired.

6.4 mL/s

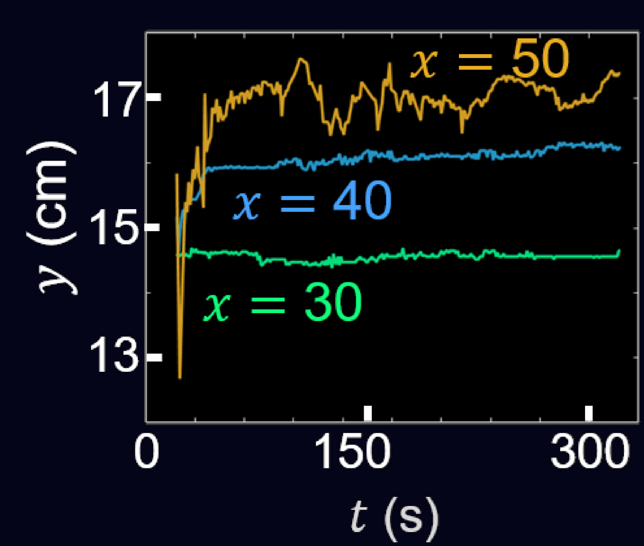


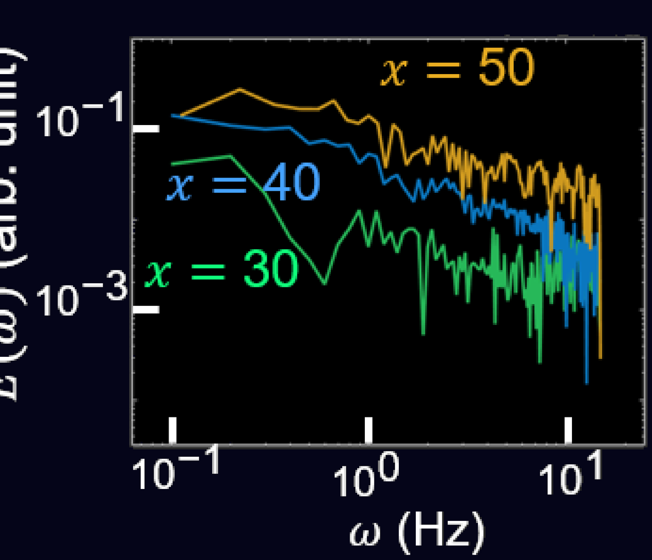




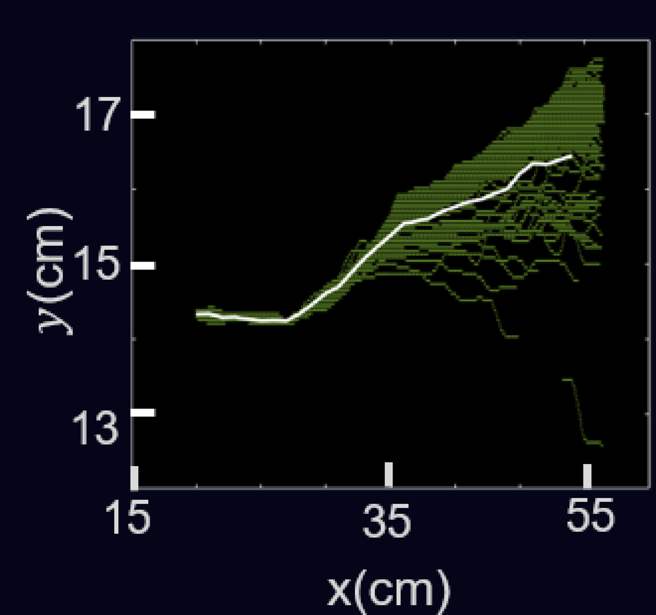


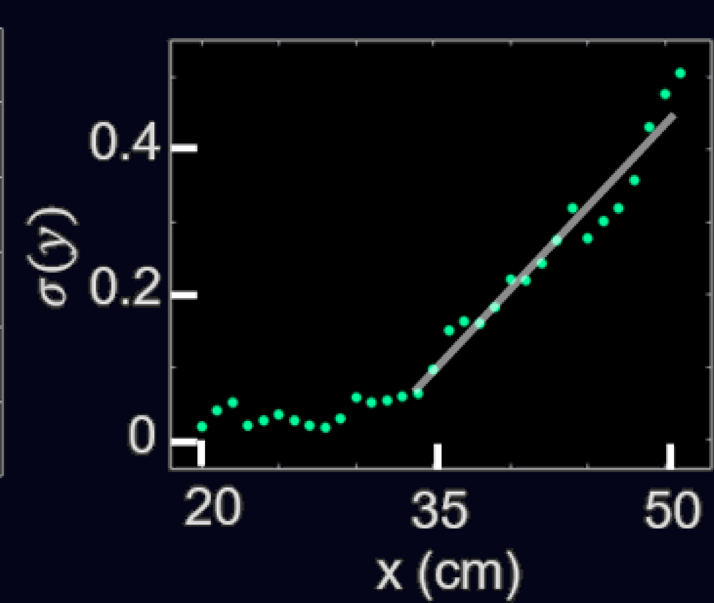
Standard deviation becomes larger while x increases and it means that oscillation becomes stronger which accords with results of FFT.





Spectra show that maximum of $E(\omega)$ decreases as x becomes larger. This implies that the amplitude of rivulet oscillation becomes larger (the motion becomes stronger).





Standard deviation decrease as flow rate superposes a certain threshold since the effect of x direction inertial force dominates. Under this condition, the motion of rivulet becomes stable.

Conclusion

- Motion of the rivulet is determined by gravity, inertia, capillary force, and hysteresis of wetting.
- Slow frequency dominates oscillation of the rivulet.
- $E(\omega) \propto \omega^m, m = const.$ in spectrums.
- Standard deviation increases as x becomes larger in unstable cases.
- As inertia increases, the motion tends to be stable.

References

[1] M. Edalatpour *et al. Applied energy*, Managing water on heat transfer surfaces: A critical review of techniques to modify surface wettability for applications with condensation or evaporation, **222**, pp. 967-992, (2018)
[2] Nolwenn Le Grand-Piteira,* Adrian Daerr, and Laurent Limat, Meandering Rivulets on a Plane: A Simple Balance between Inertia and Capillarity, *PRL*, **96**, 254503 (2006)

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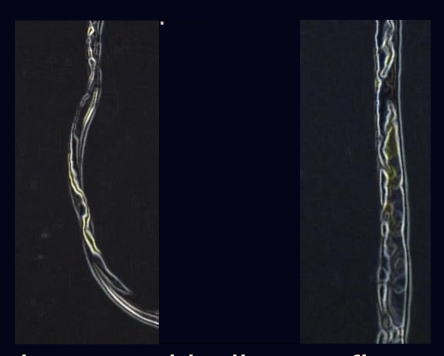

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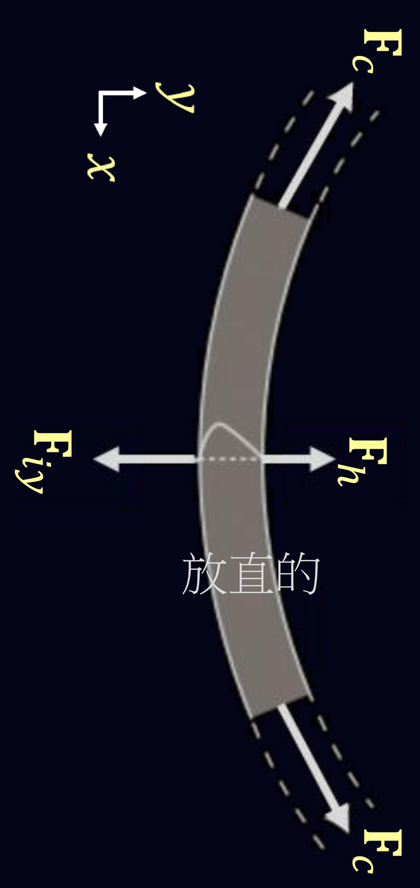

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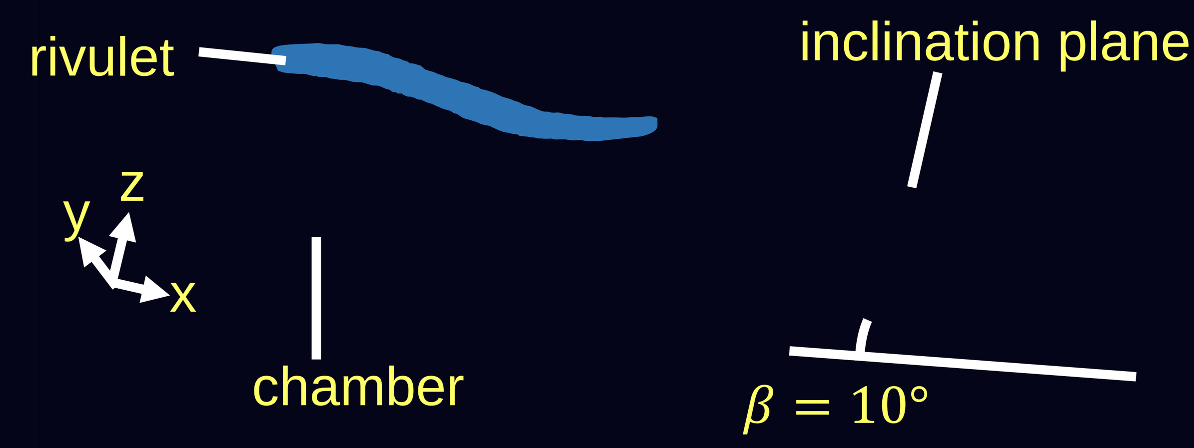

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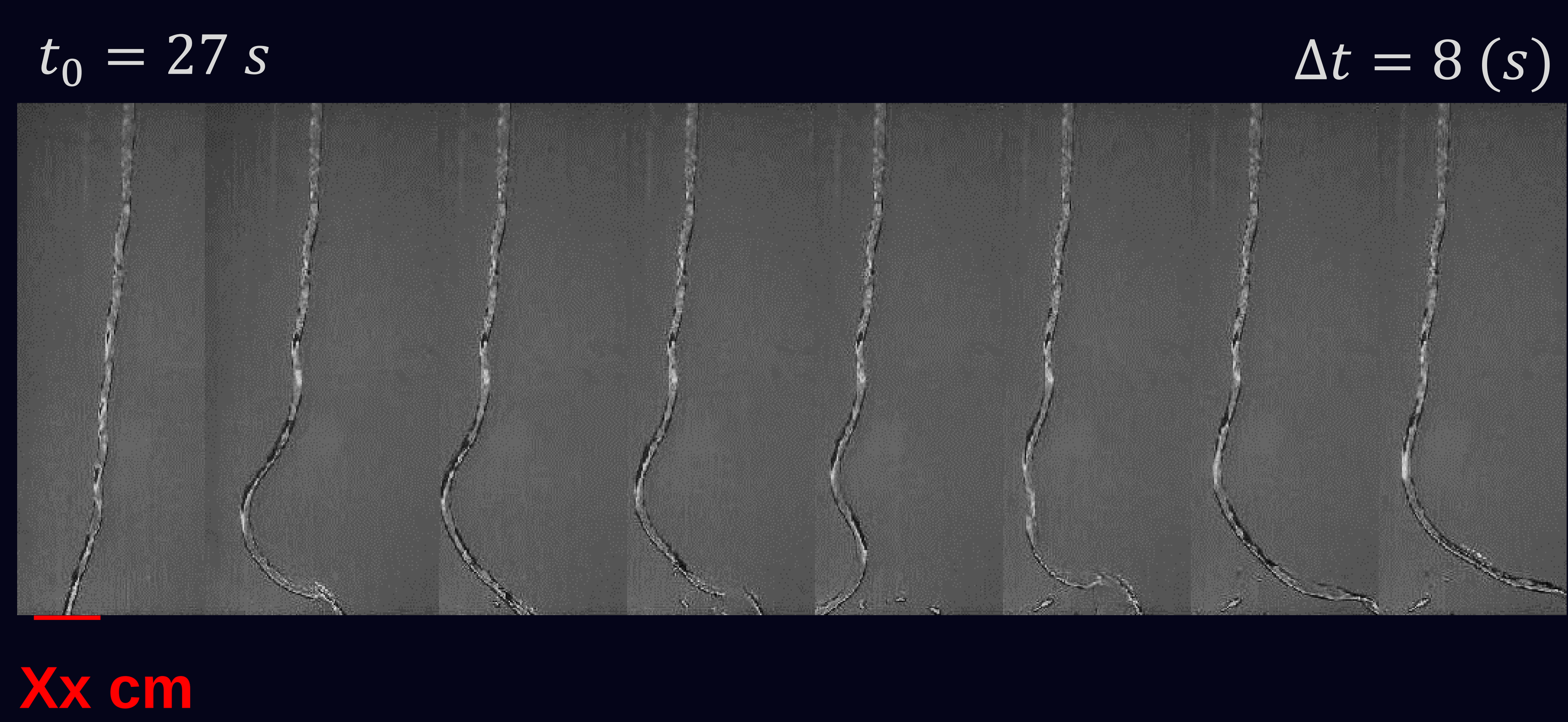

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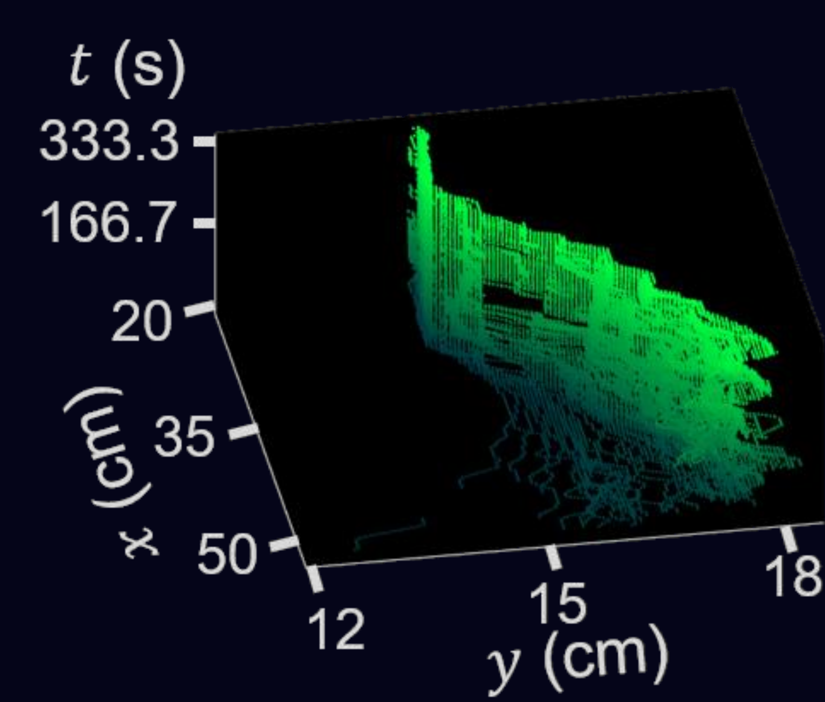

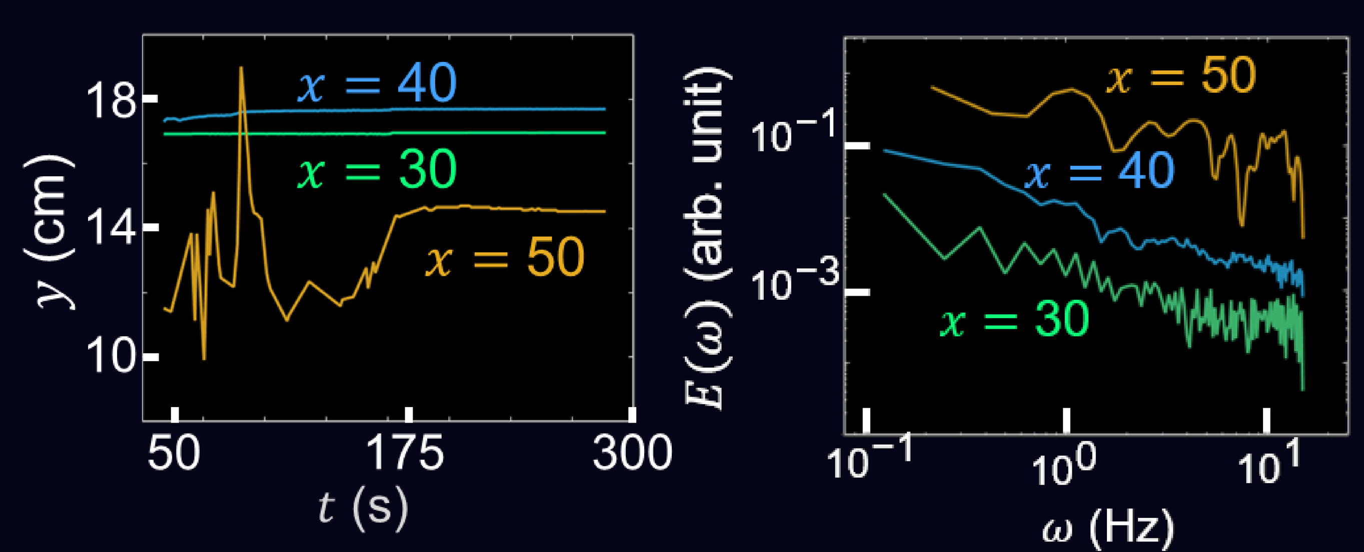

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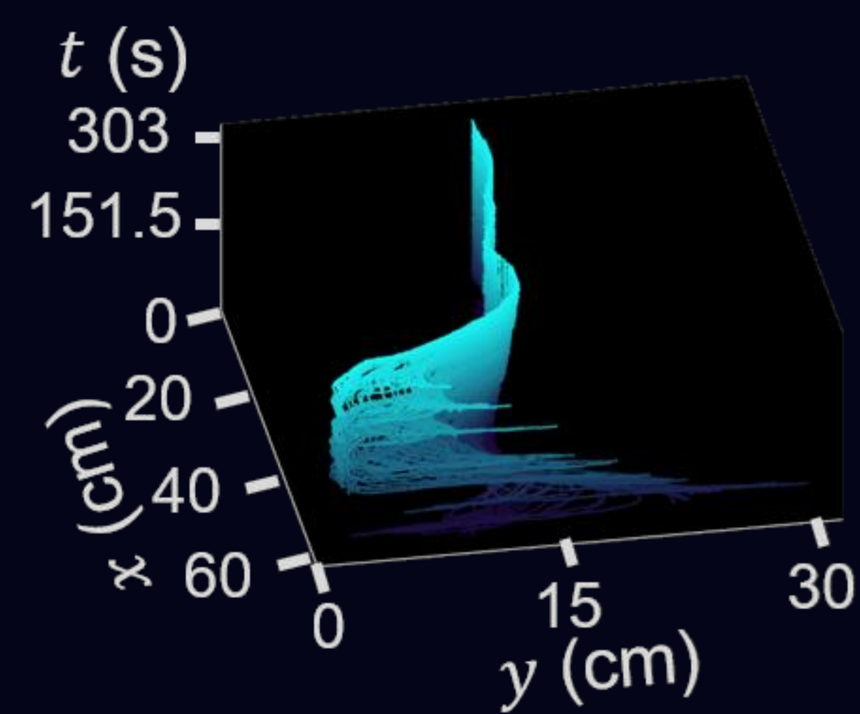

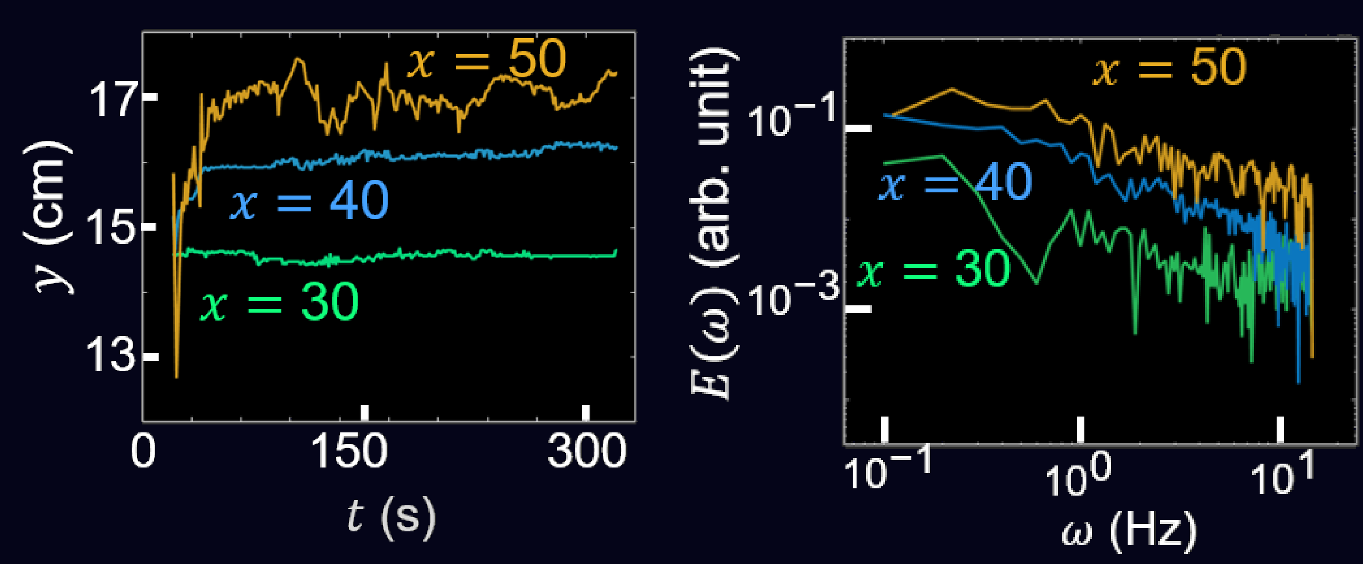

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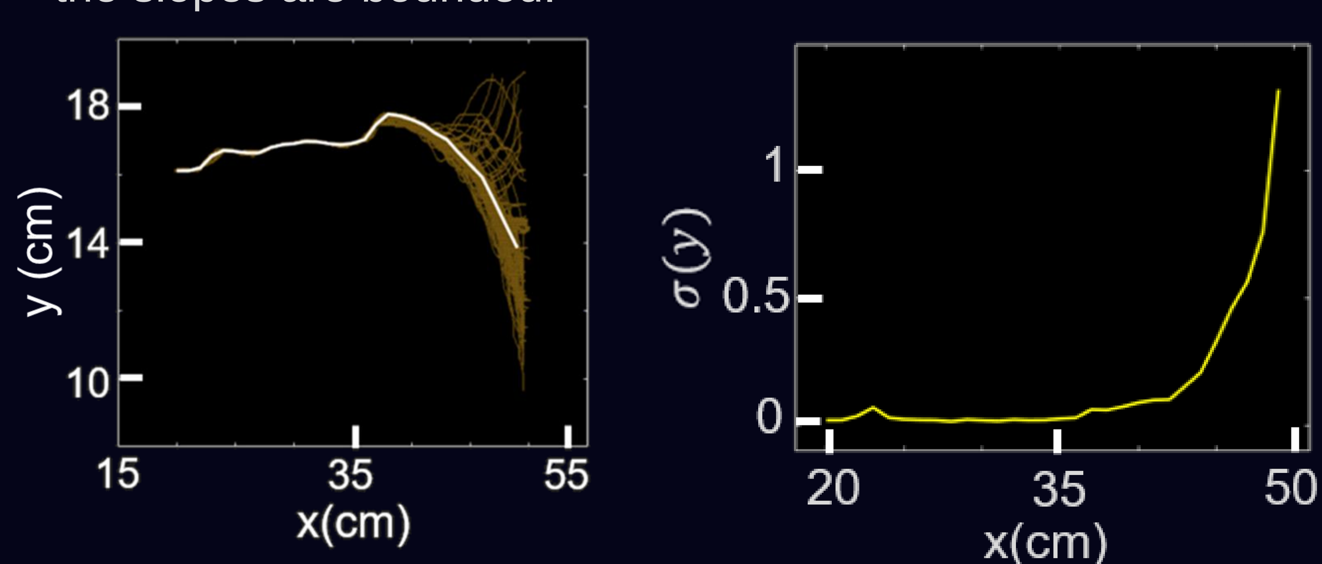

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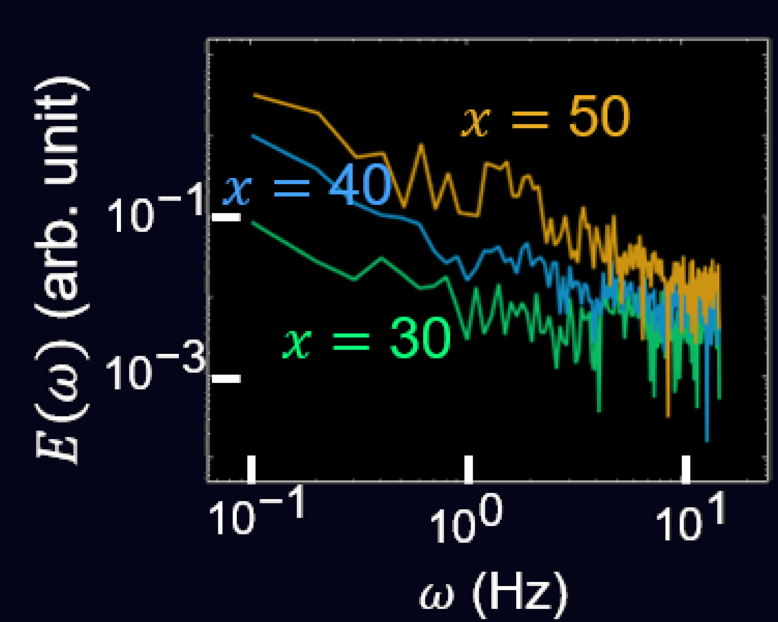

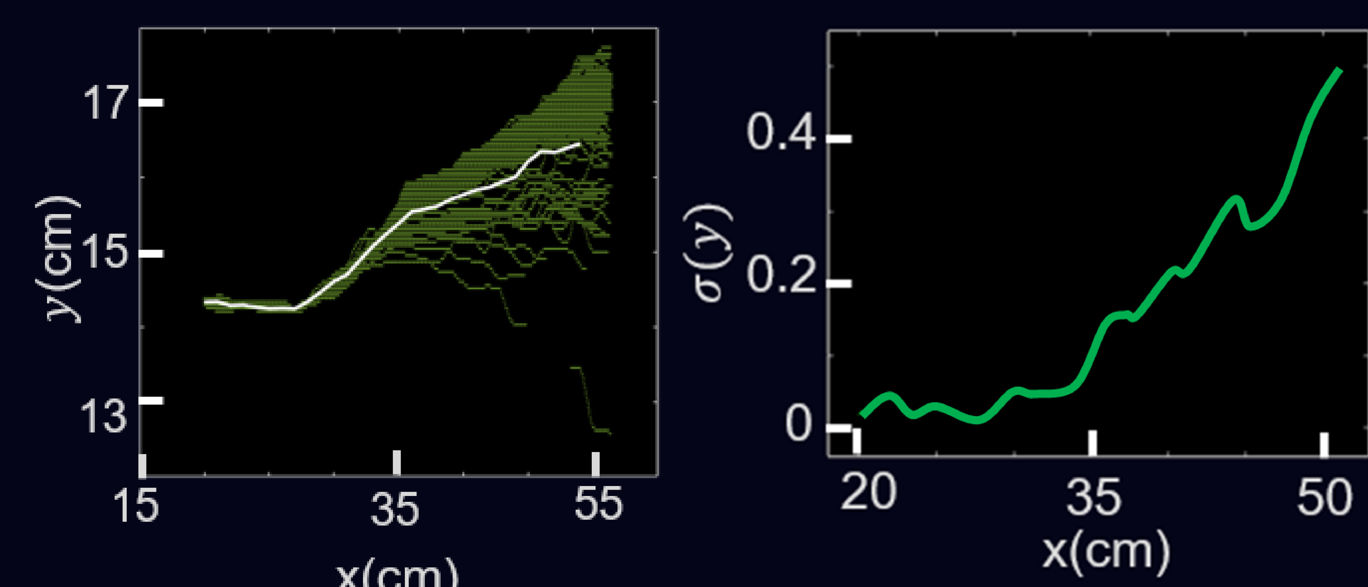

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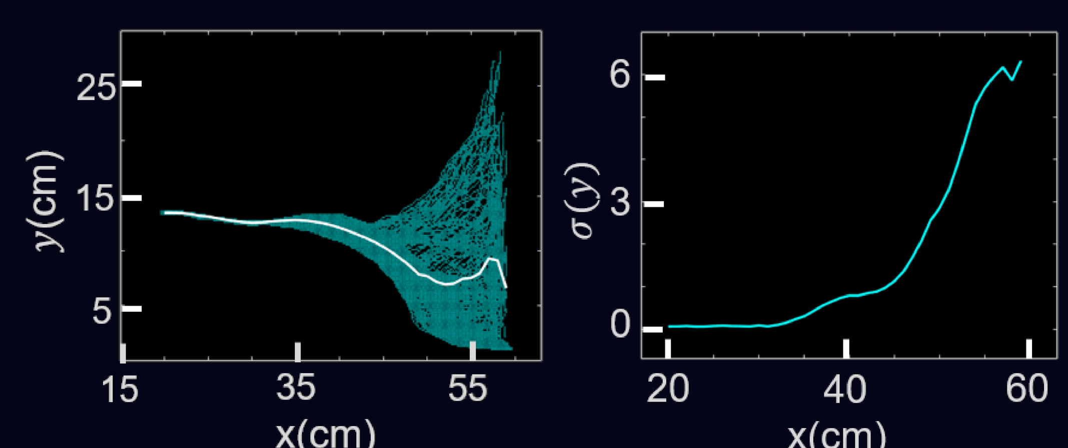

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References

[1] Auther name Int..L Multiphase Flow, **18**, 455, (1992)
[2] M. Edalatpour, *et al.*, Applied energy, **222**, 967 (2018)
[3] Nolwenn Le Grand-Piteira, *et al.*, PRL, **96**, 254503 (2006)