Mathematical Modelling of Heating and Evaporation of spheroidal droplets in Diesel engine-like conditions

Dr Vladimir Zubkov

Senior Lecturer

School of Computing, Engineering and Mathematics, University of Brighton

Associate Member

Wolfson College, Oxford University

EPSRC
Engineering and Physical Sciences Research Council

University of Brighton
Advanced Engineering Centre

Engineering at Brighton

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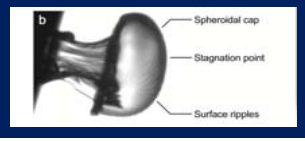
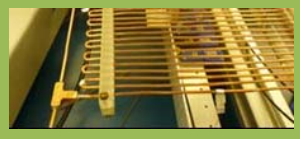
Advanced Engineering Centre – an applied thermo-fluids research team, with a focus on transport

Droplets and sprays



Combustion

Heat and mass transfer



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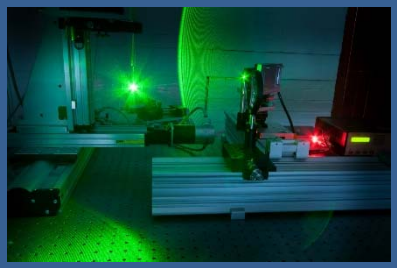
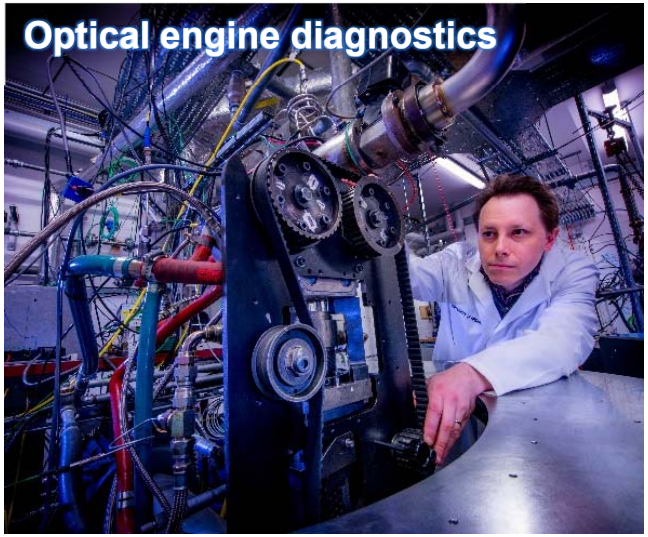
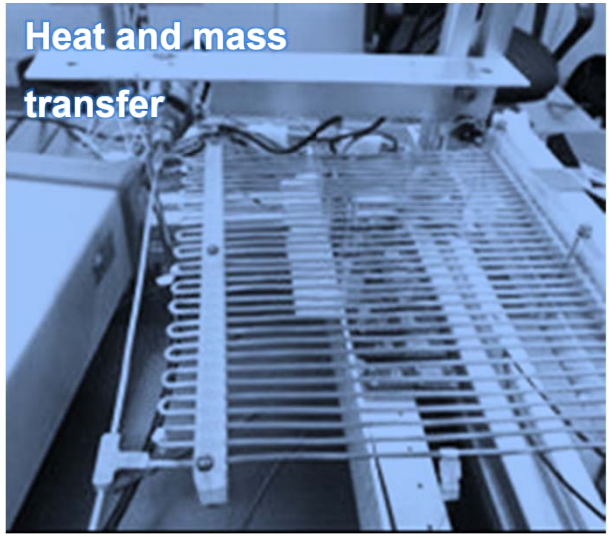
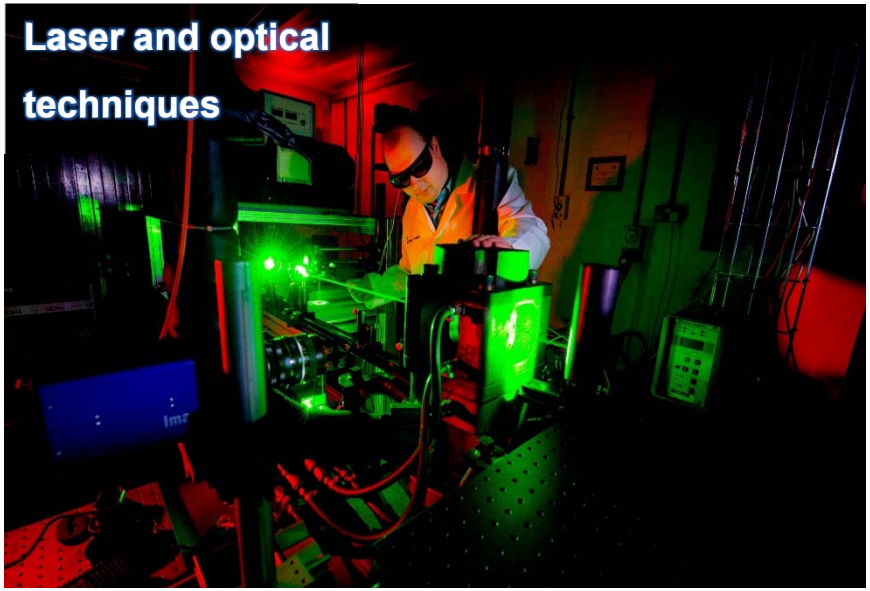


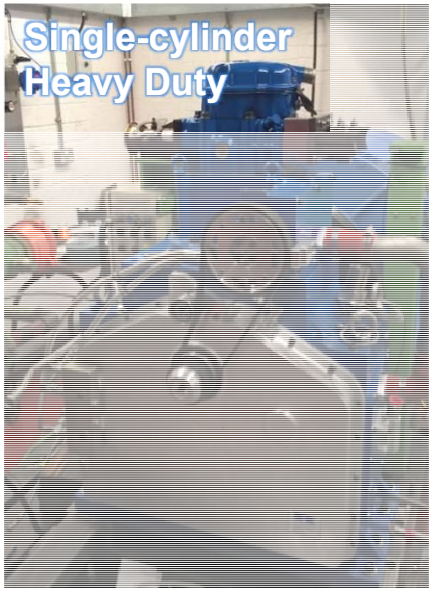
Advanced Engineering Centre combines expertise in both modelling and experimental techniques

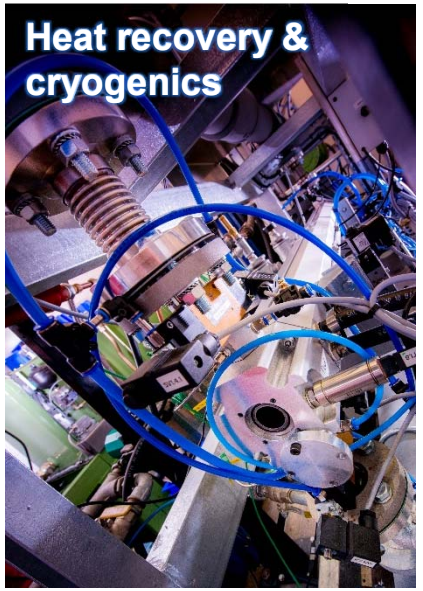
Our experimental capability spans light and heavy duty engines, with particular expertise in imaging techniques







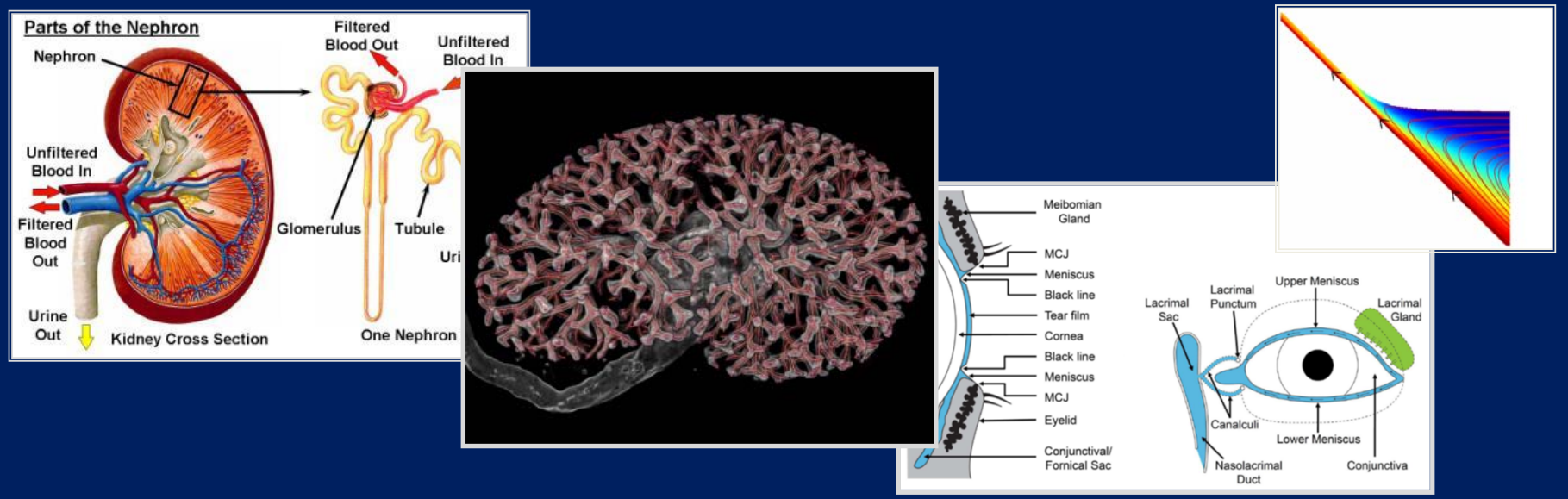




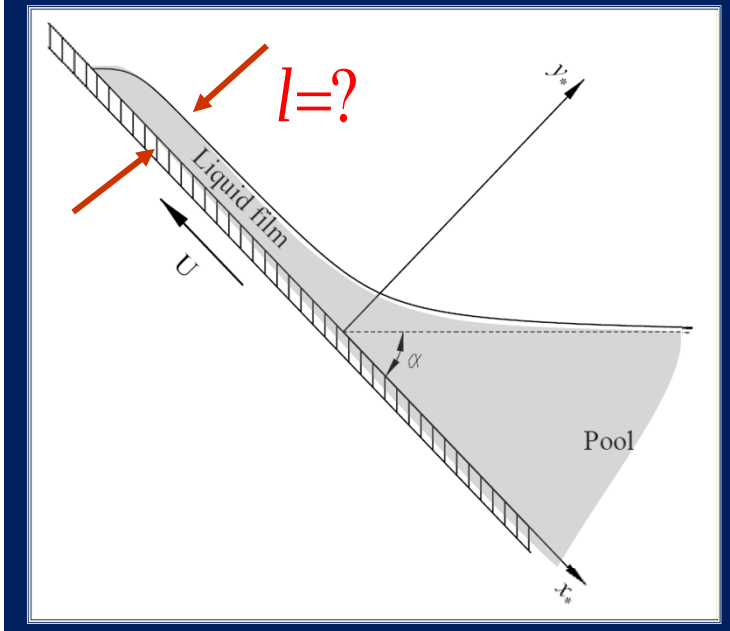
Microgravity

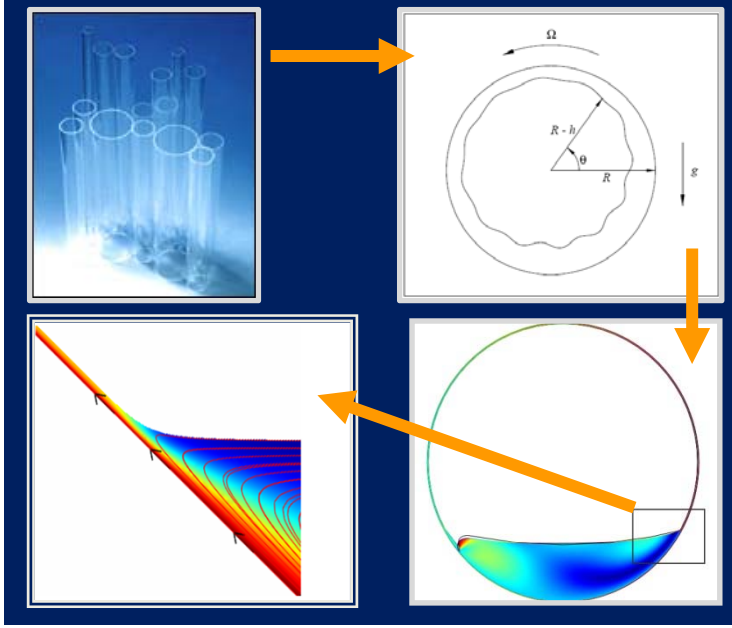
Hybrid heat pipe for space and ground applications

My research projects



The drag-out problem





Model includes

- Gravity;
- Capillarity;
- Perfect Wettability.

If α is small, then lubrication approximation can be used, and the Stokes set can be reduced to a single equation

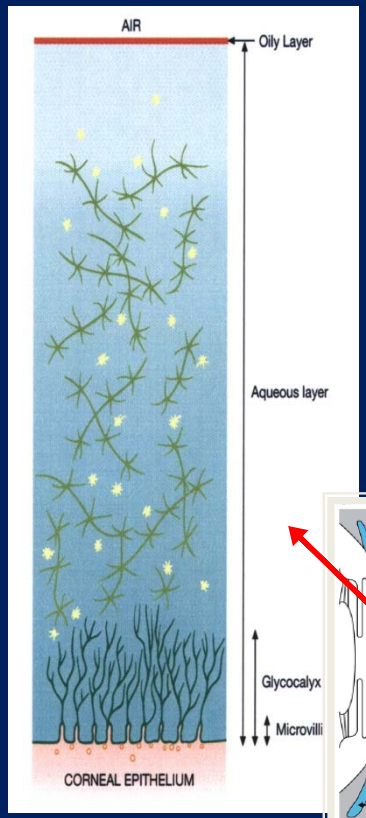
$$\frac{\partial h}{\partial t}+\frac{\partial}{\partial x}\left(-h+\frac{h^3}{3}-\frac{h^3}{3}\frac{\partial h}{\partial x}+\frac{h^3}{3D}\frac{\partial^3 h}{\partial x^3}\right)=0,$$

E.S. Benilov, V.S. Zubkov (2008) *J. Fluid. Mech.*

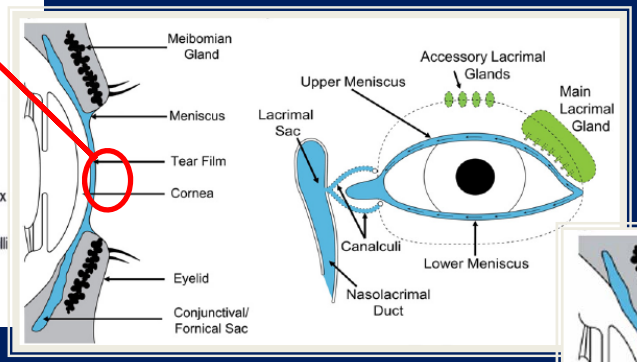
E.S. Benilov, S.J. Chapman, J.B. McLeod, J.R. Ockendon and V.S. Zubkov, (2009) *J. Fluid Mech.*

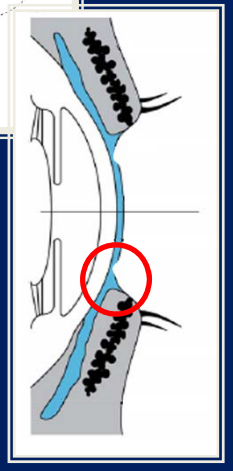
The Human Tear Film Modelling

Tear Film

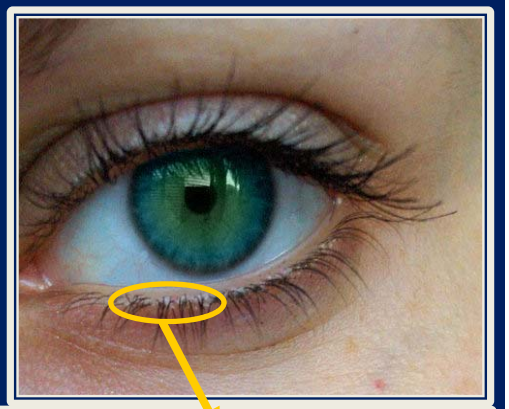


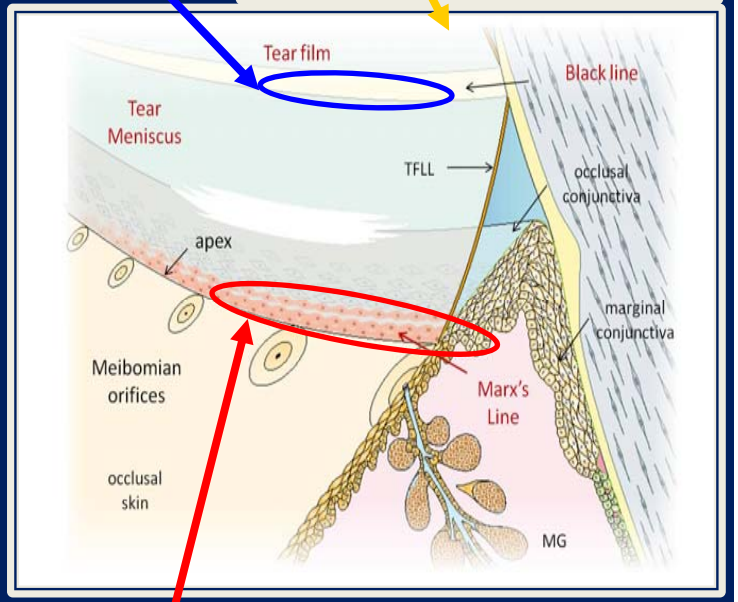
Dry Eye Syndrome





What is the salt concentration here?



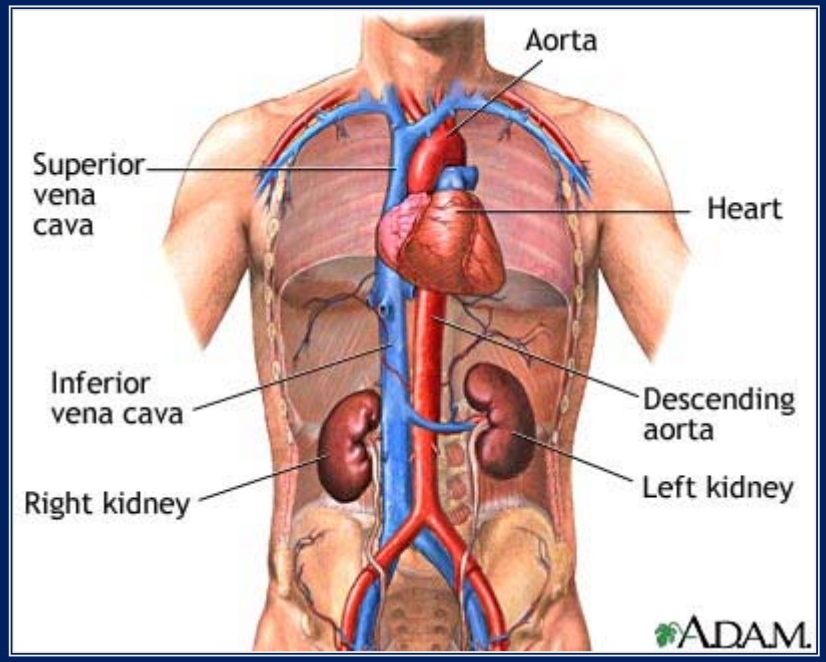


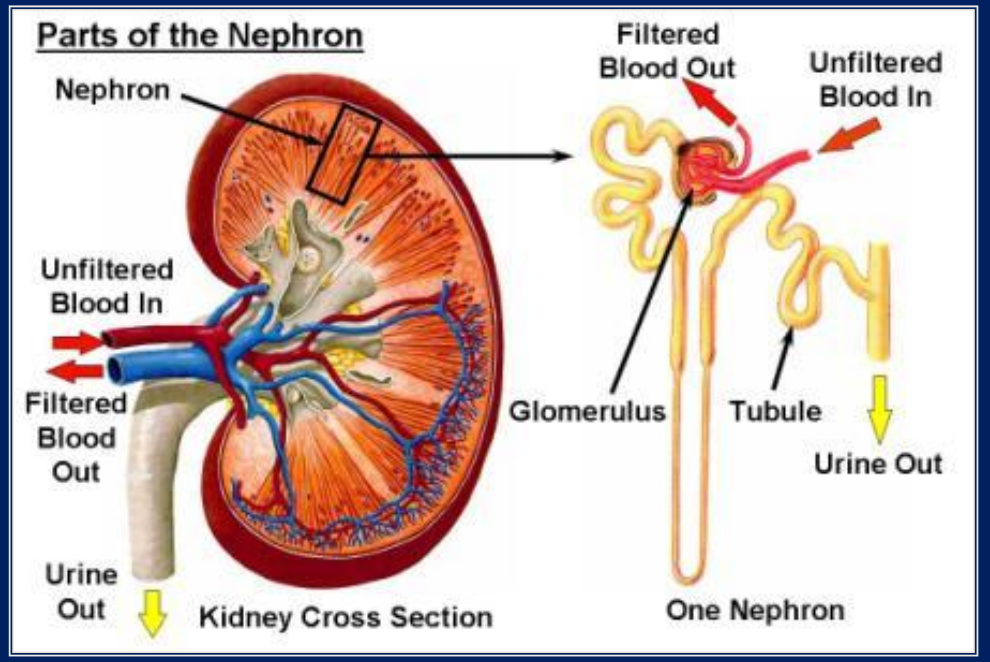
Why epithelial cells die here?

<u>Composition of the tear film:</u>

- lipid layer
- aqueous layer
- salts

Mathematical model of Kidney Development



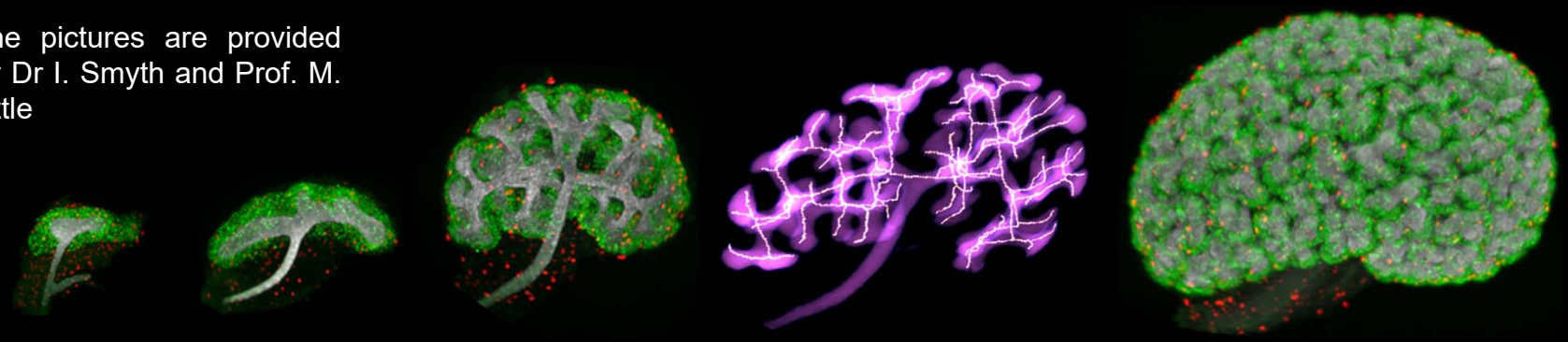


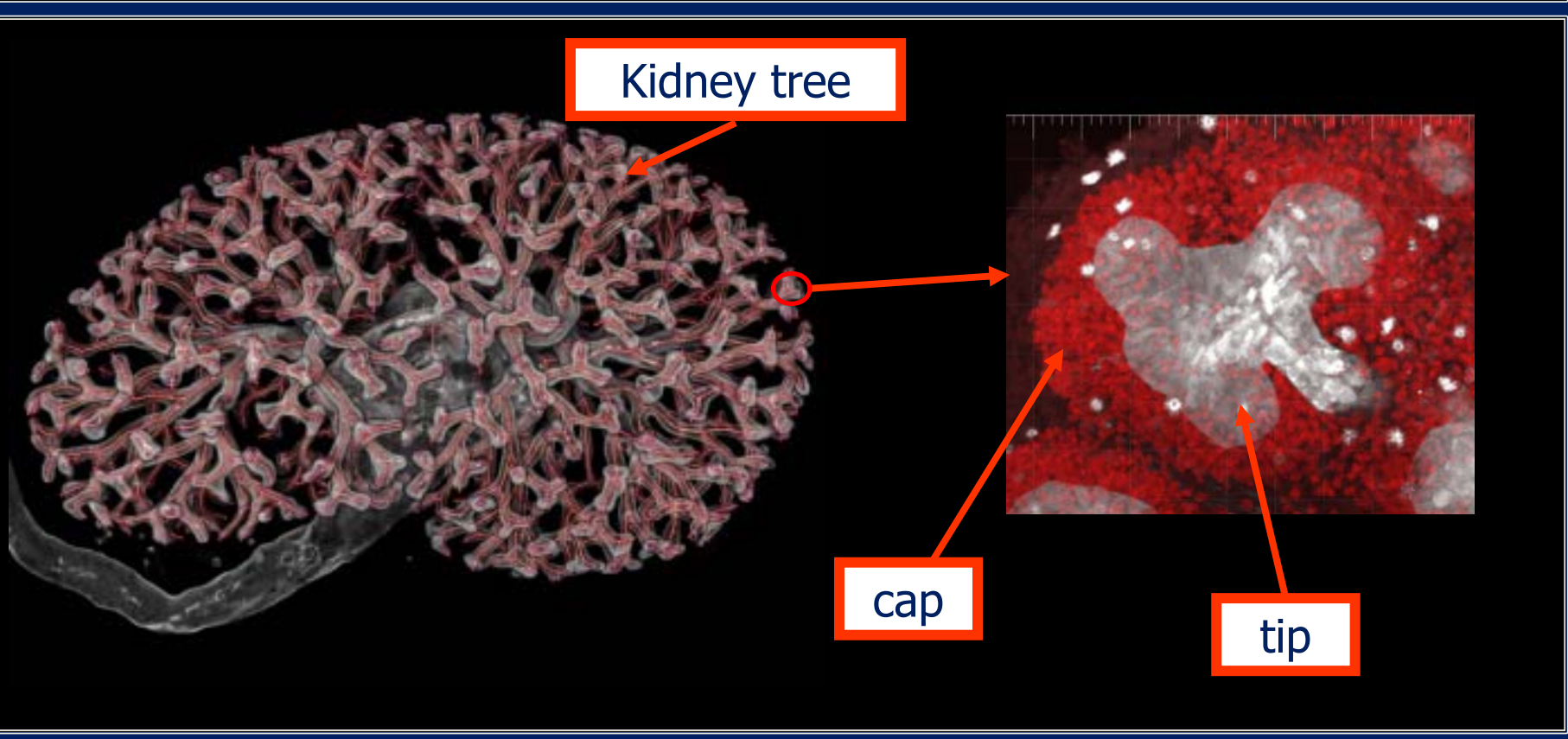
unckidneycenter.org

Mammalian kidneys are vital organs that filter wastes such as urea from the blood and excrete them, with water, as urine.

Kidney morphogenesis (observations)

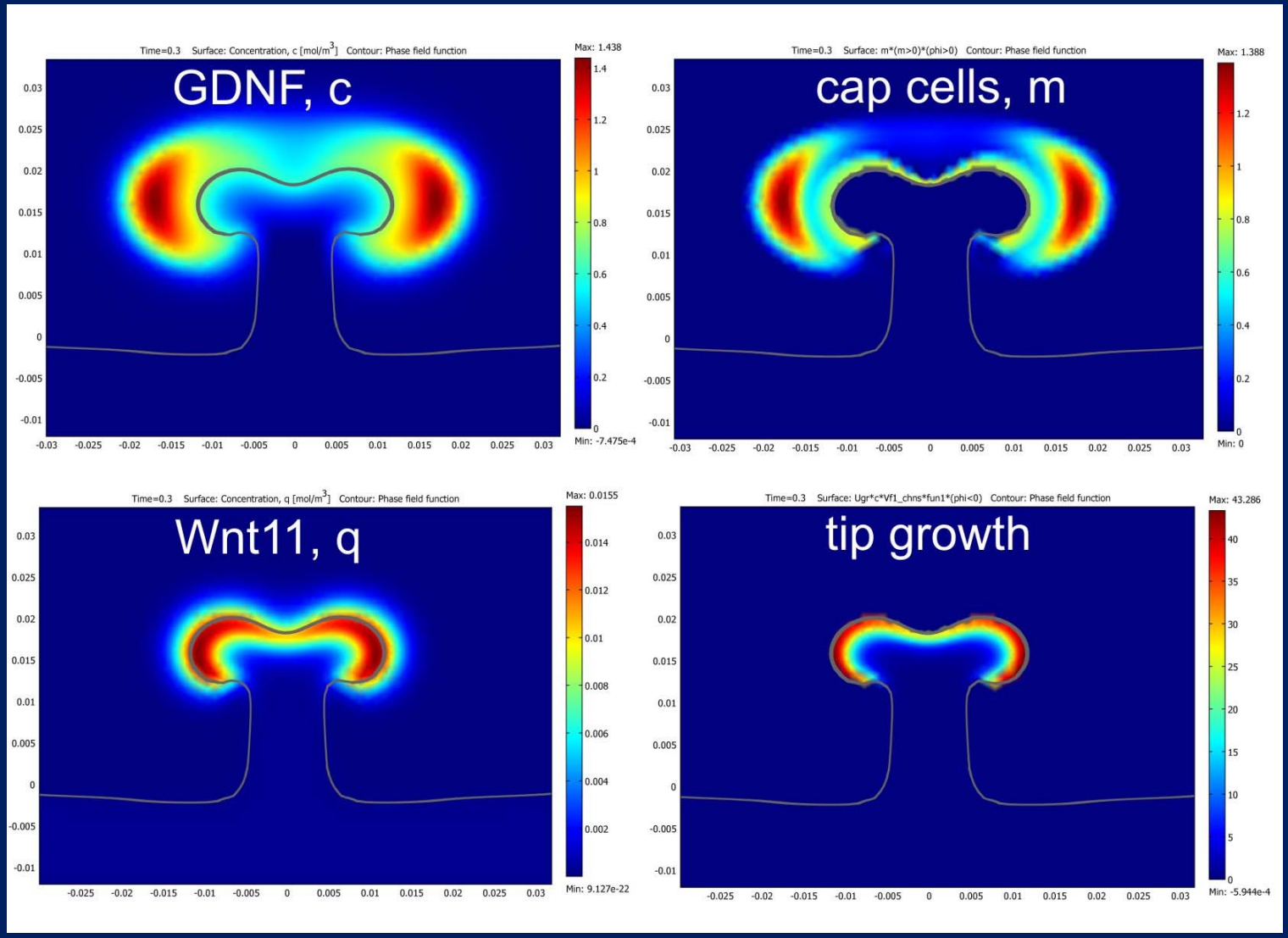
The pictures are provided by Dr I. Smyth and Prof. M. Little



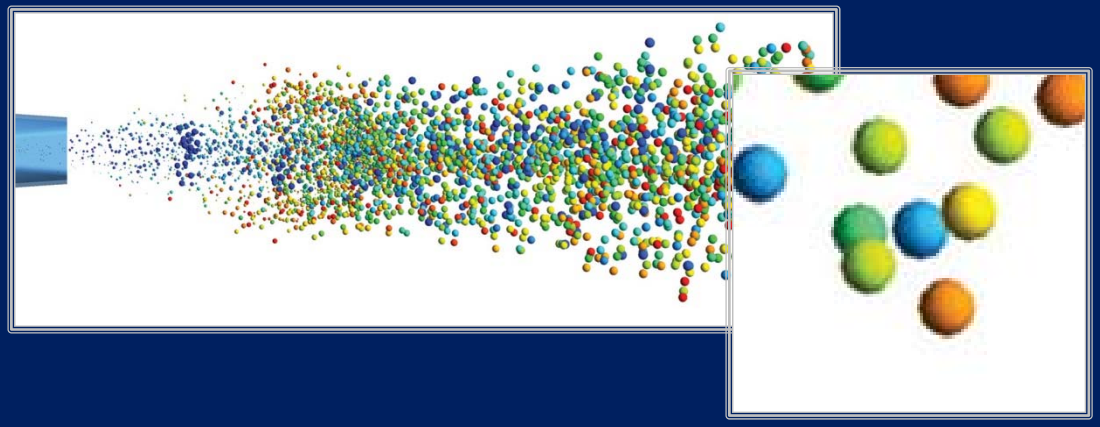


Mathematical Modelling

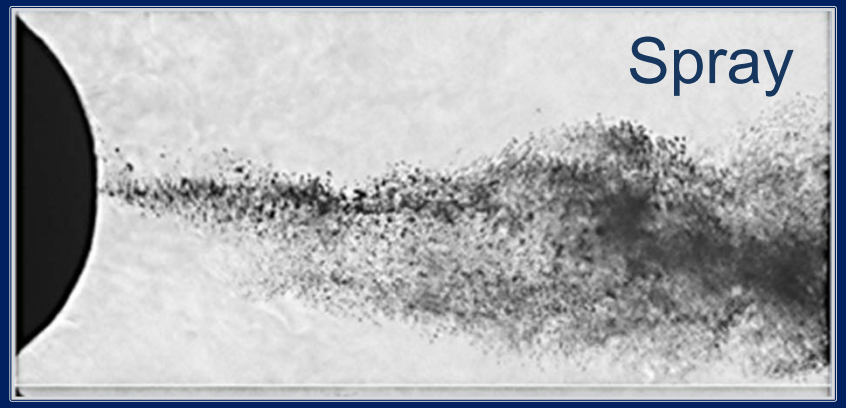
First branching of the Bud (gray curve is the boundary of the epithelial explant): http://www.youtube.com/watch?v=reKsKVaBLis



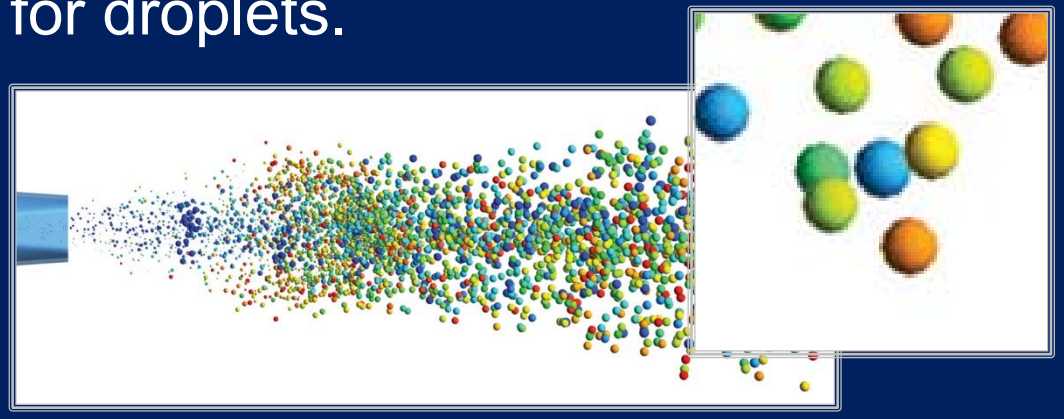
Mathematical Modelling of Heating and Evaporation of spheroidal droplets

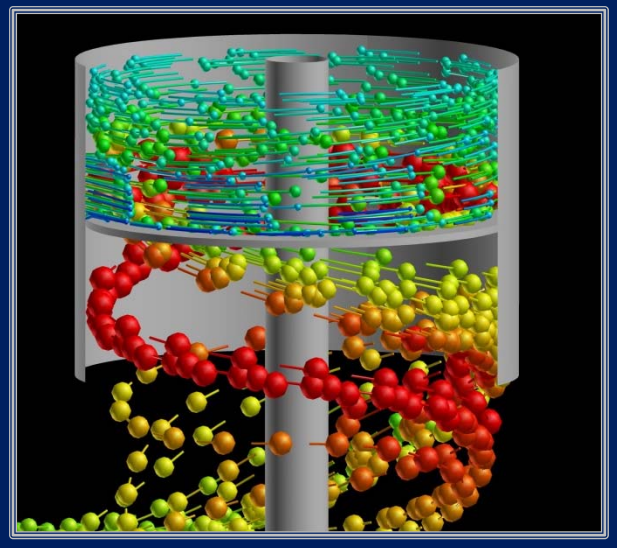


Problem Statement



Current mathematical models of sprays use spherical approximation for droplets.





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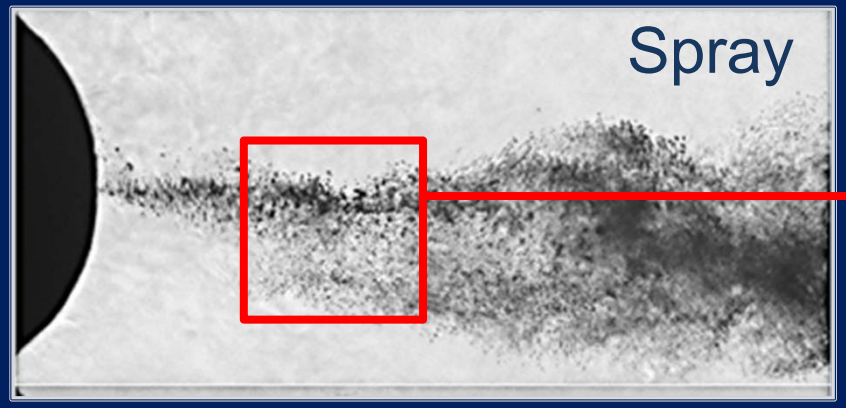
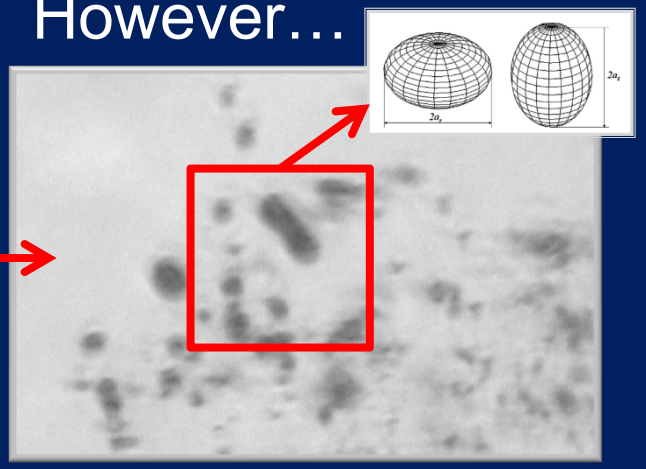


However…



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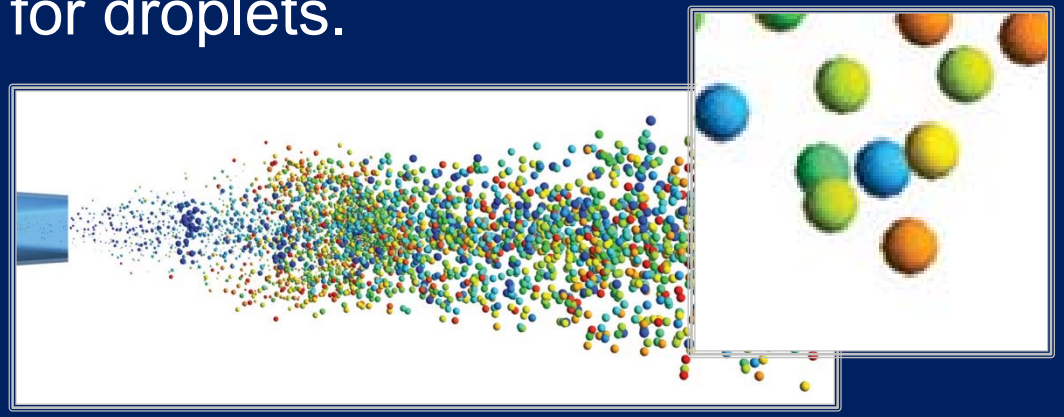
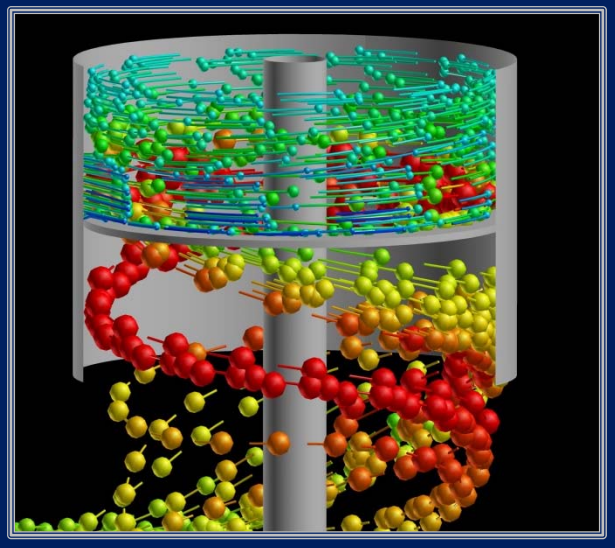
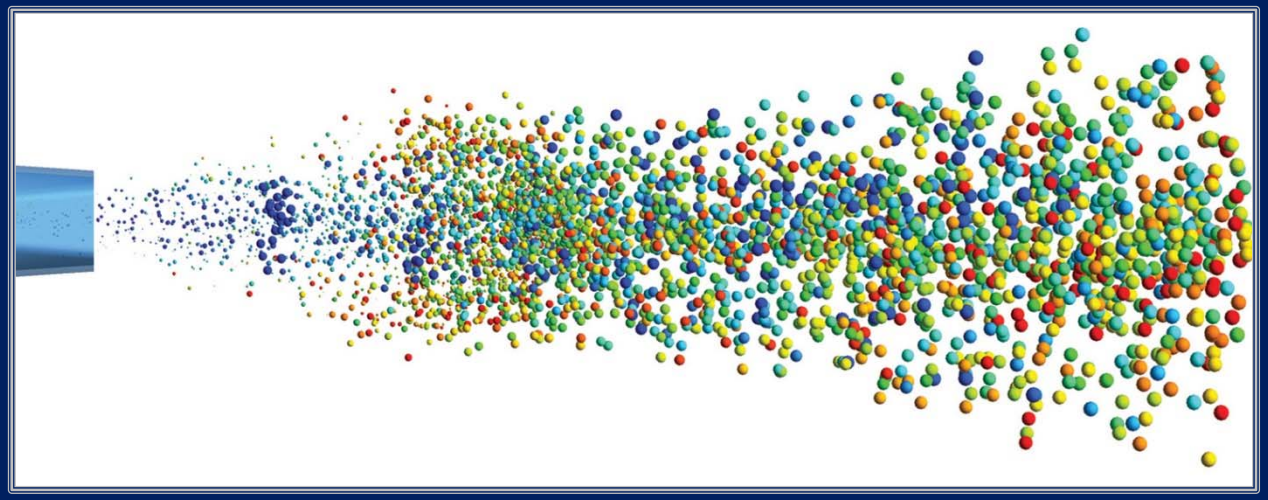


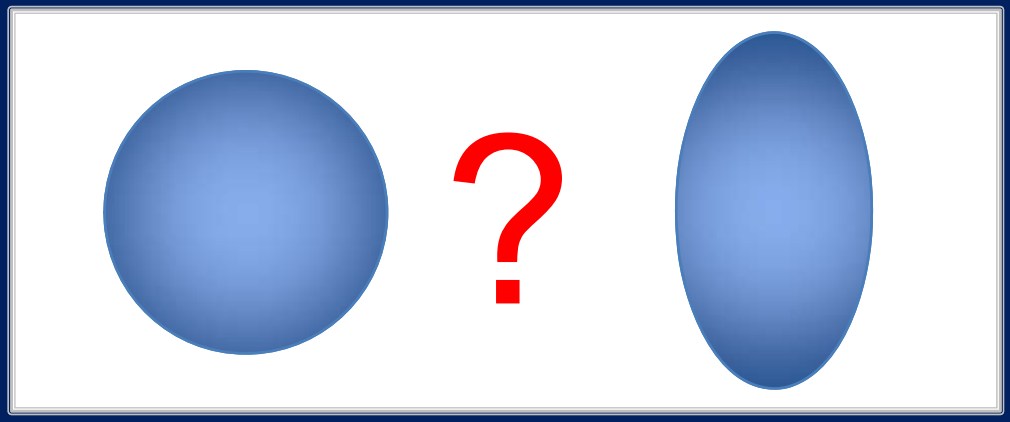


Problem Statement

Can the spherical approximation of droplets be used?

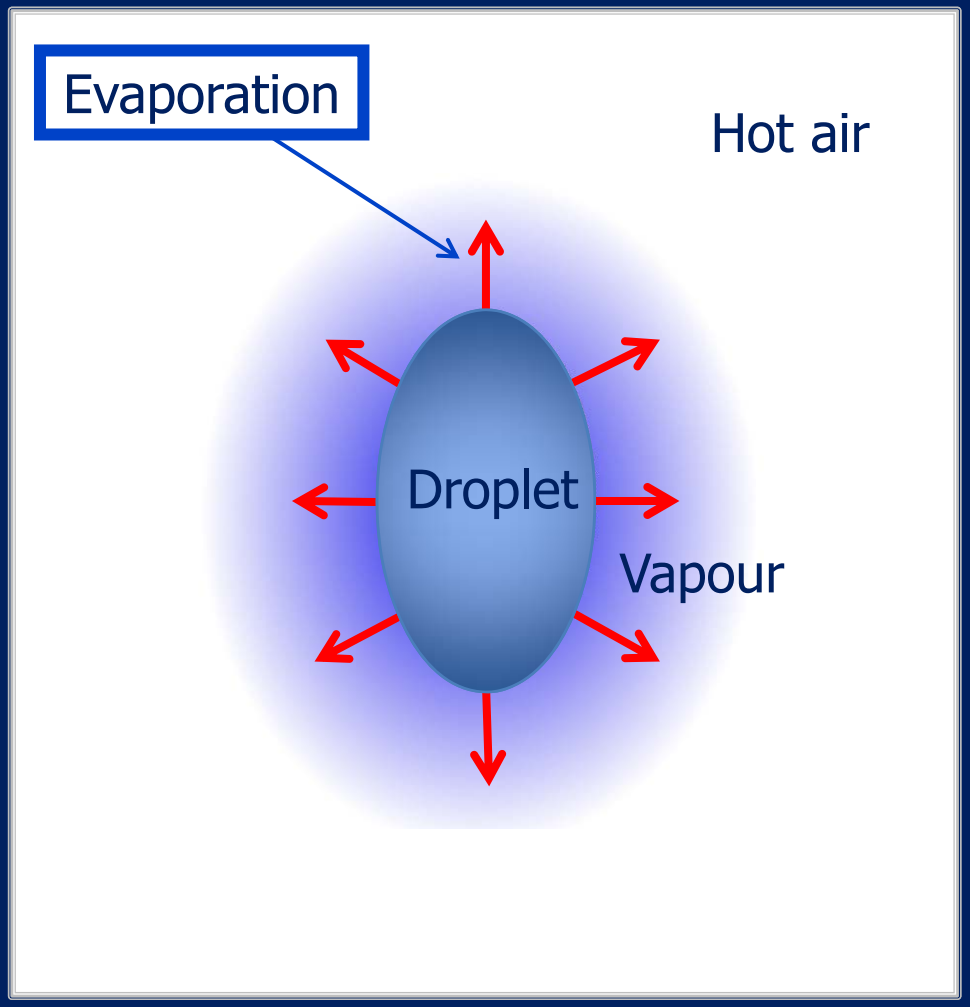


We will consider heating and evaporation of a single non-spherical droplet and compare it with a spherical one.



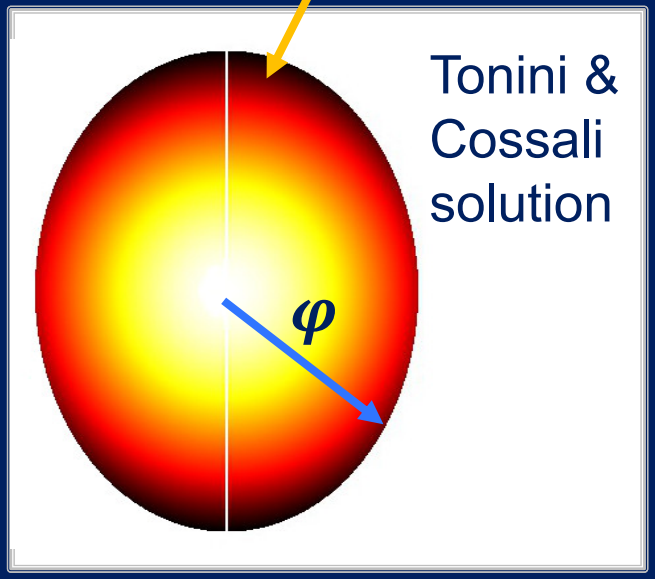
Mathematical Modelling

Heating and evaporation of a single non-spherical droplet.



Mathematical Model

T– temperature:



Heat capacity

$$\rho C_p \frac{\partial T}{\partial t} = \nabla(k \nabla T)$$

Droplet density

Thermal conductivity

Boundary conditions at the drop surface:

$$-\mathbf{n}(-\mathrm{k}\nabla T) = \mathrm{h}\left(T_g - T\right) - q$$

Evaporation

Normal to the surface

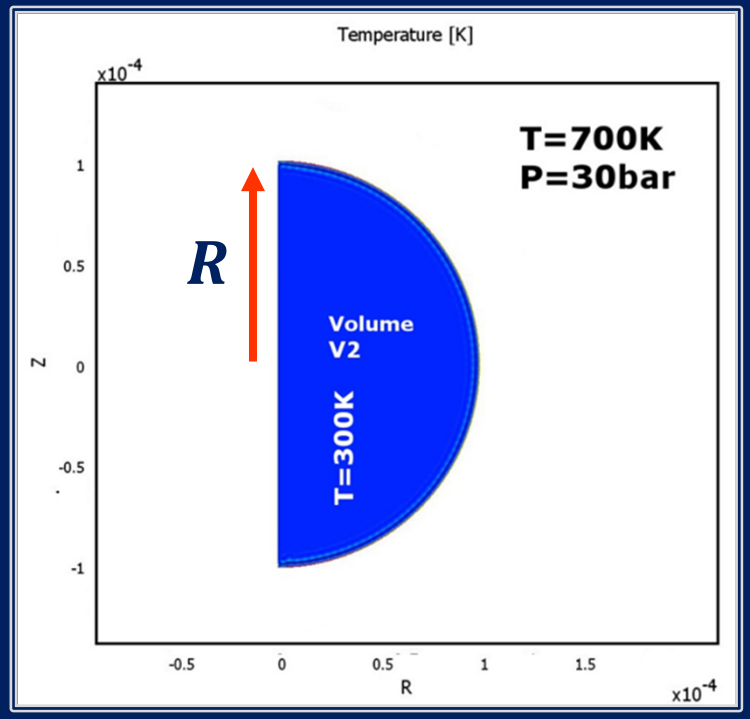
Heat transfer coefficient

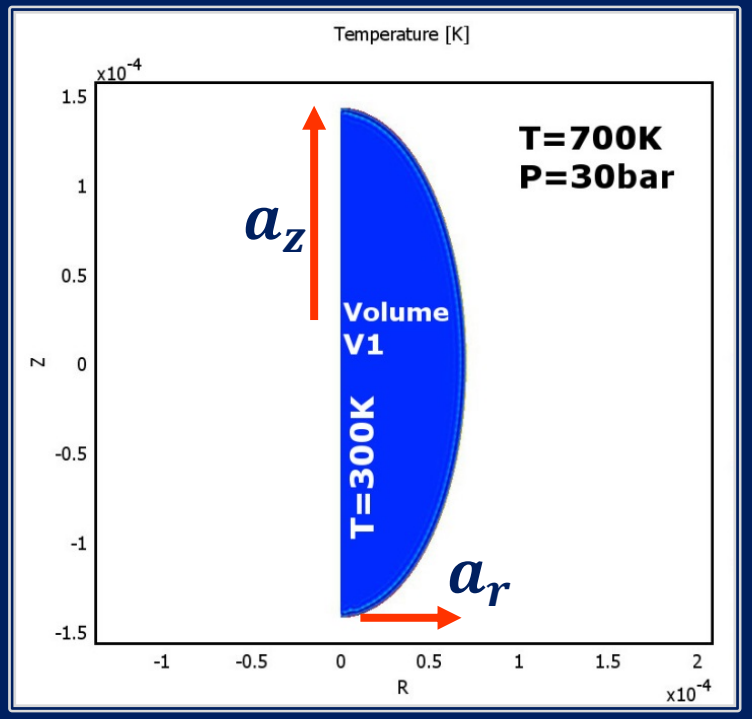
Latent Heat of vaporisation

$$\dot{\varphi} = -U(T, x, y, z)$$

Defined by S. Tonini, G.E. Cossali (2014) solution for the gas phase

Model parameters



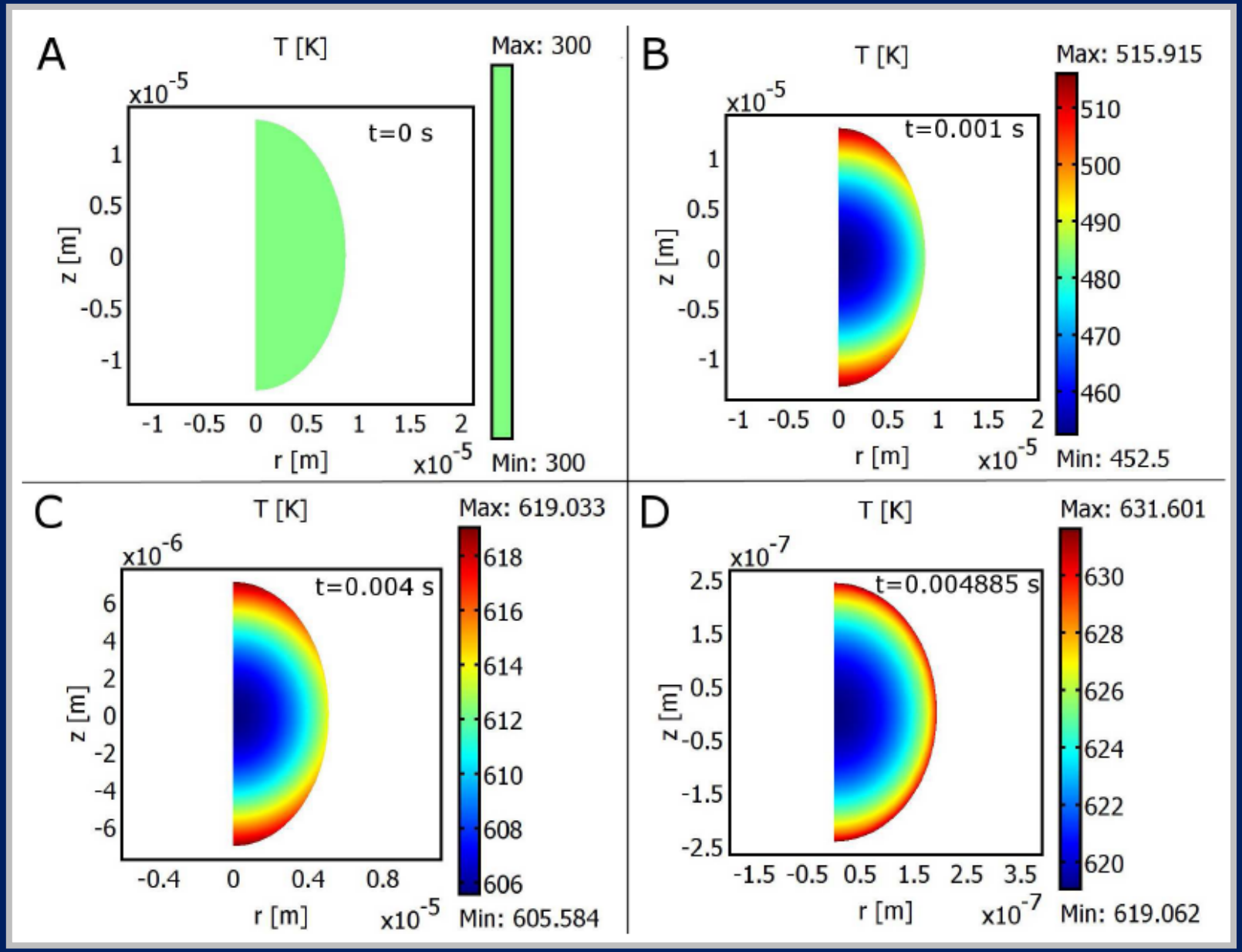


$$V_1 = V_2$$

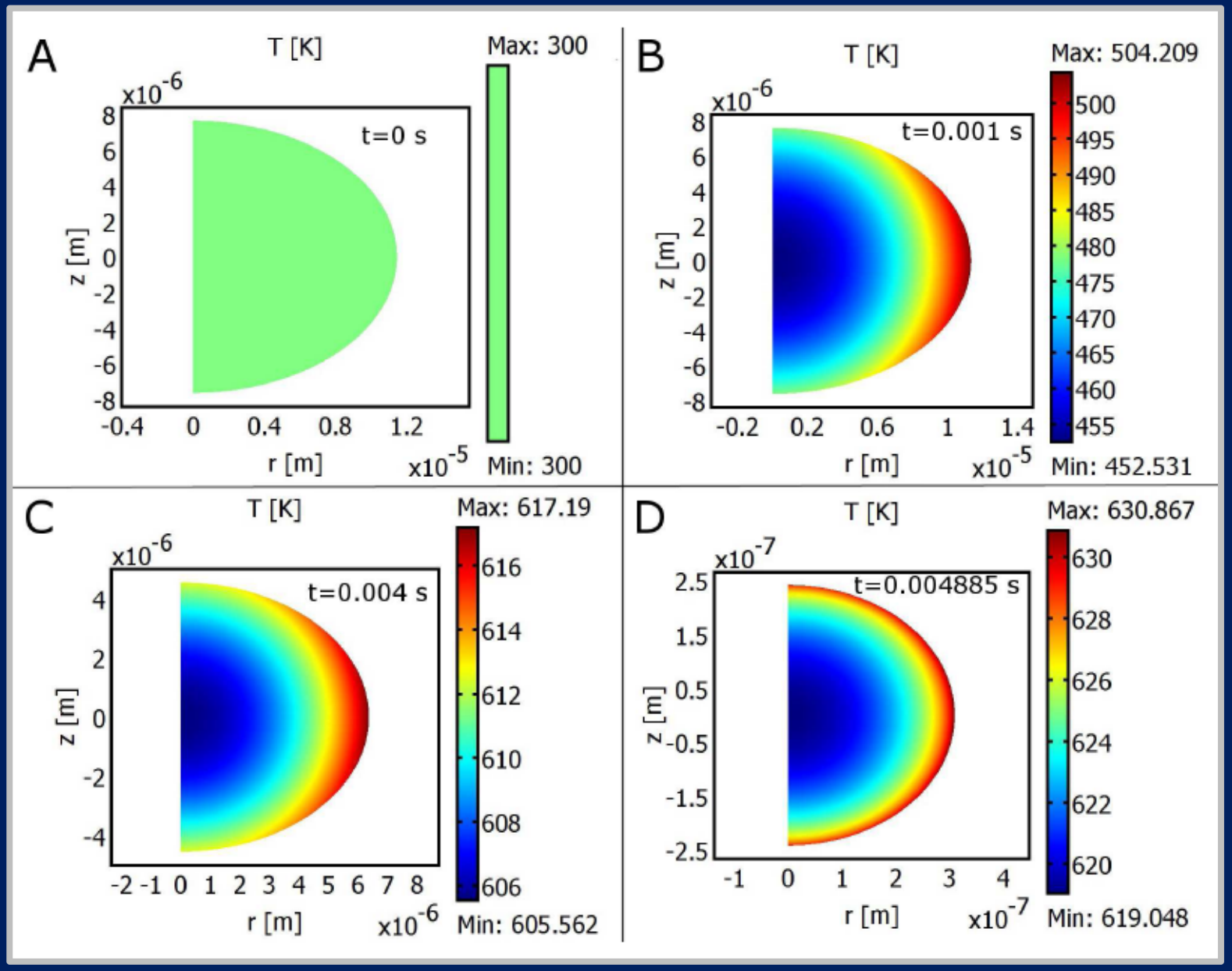
$$a_z/a_r = 1.5$$

$$R = 10\mu\text{m}$$

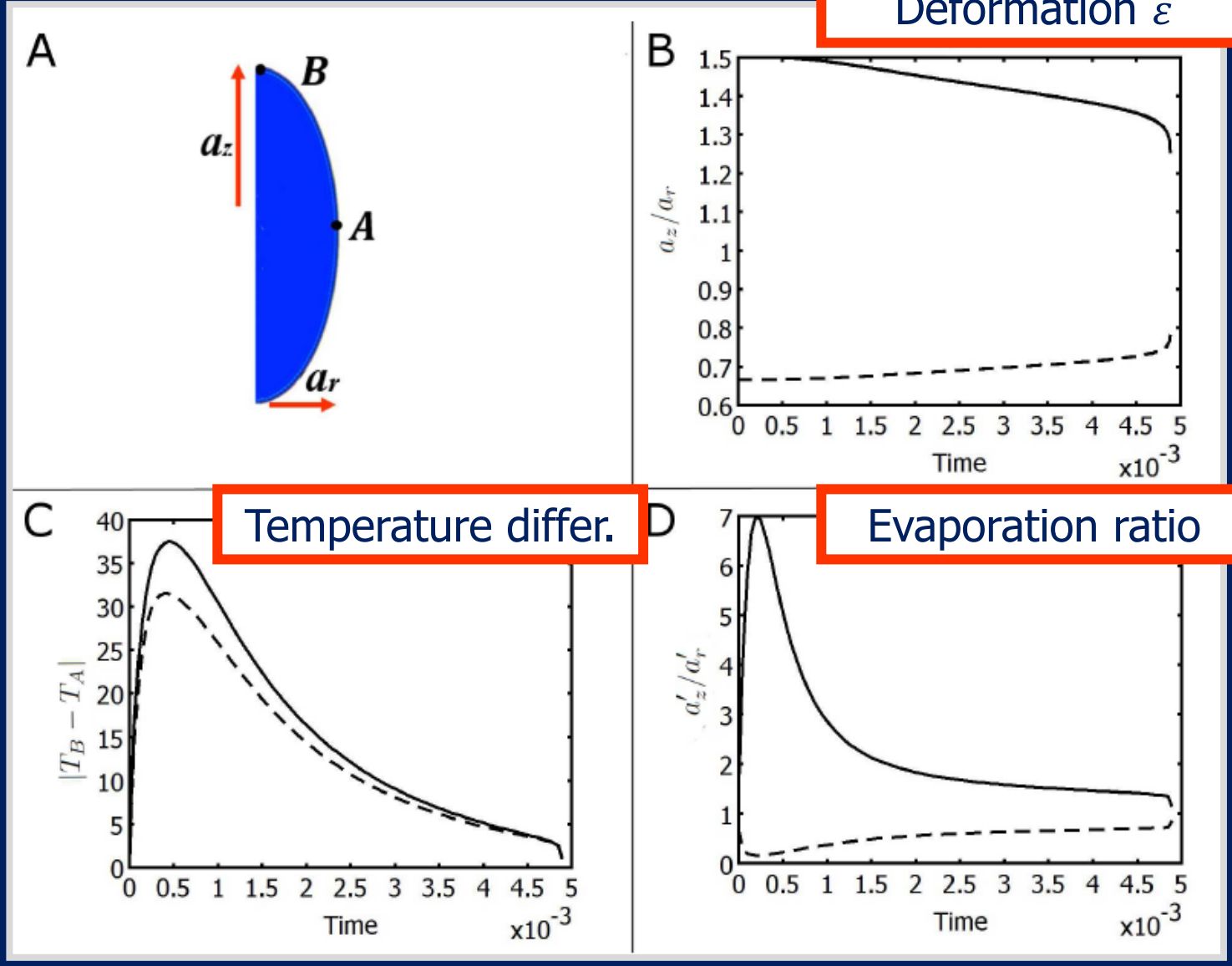
Results: Prolate droplet



Results: Oblate droplet



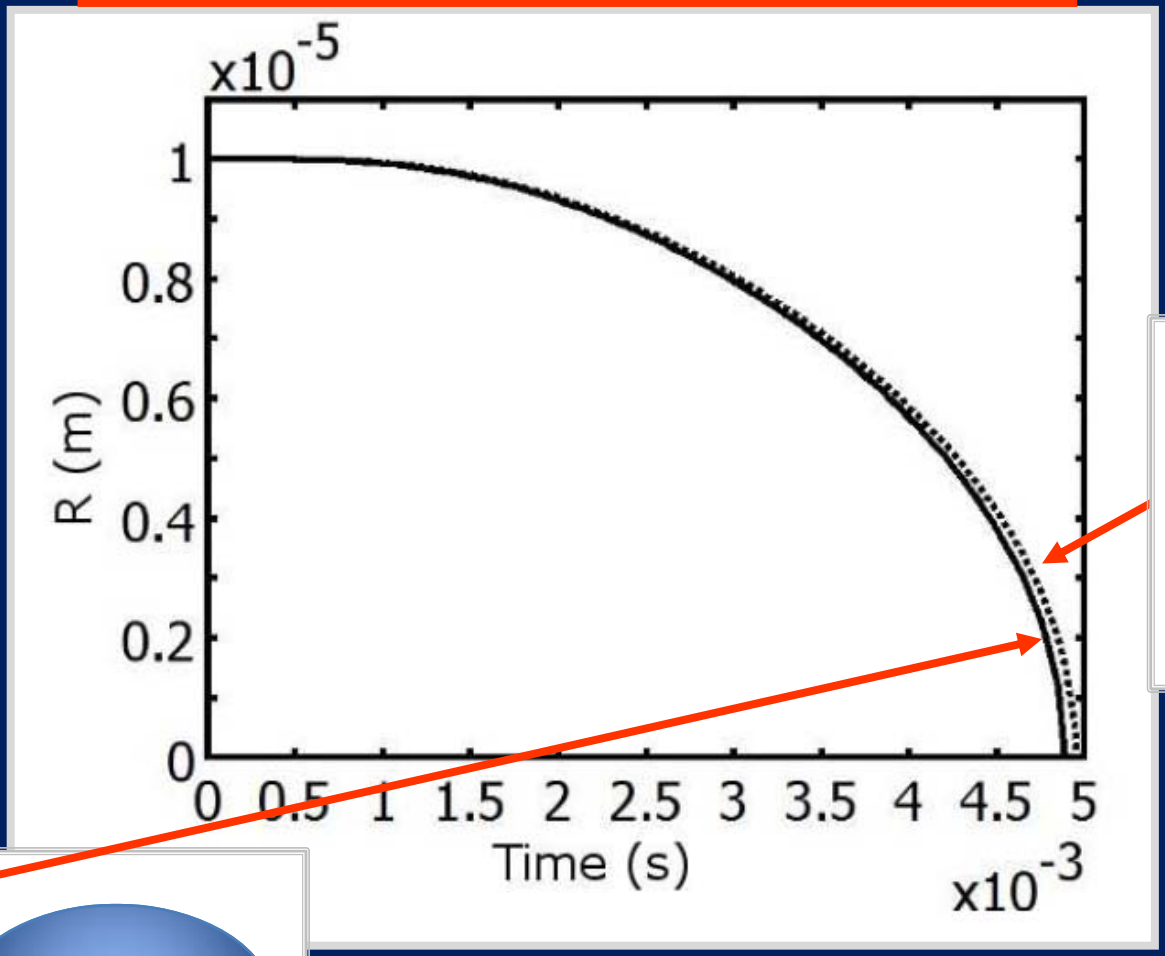
Results



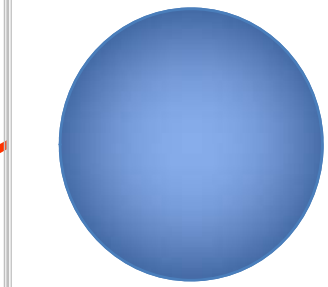
ε is constant if surface T is uniform

Results. Droplet evaporation time

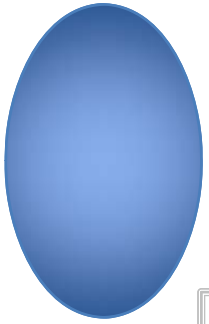
Effective droplet radius

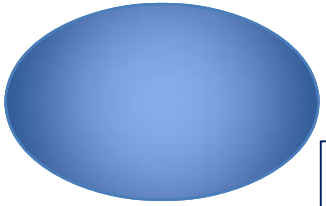


$\varepsilon = 1$



$\varepsilon = 1.5$





$\varepsilon = 2/3$

Conclusion

- Local temperatures can vary noticeably along the droplet surface.
- Droplet becomes more spherical.
- The effect of droplet non-sphericity on the evaporation time of droplets was shown to be relatively small for the range of parameter values under consideration.

Acknowledgements

The authors are grateful to EPSRC (UK) (Project EP/K020528/1) for the financial support of this project.

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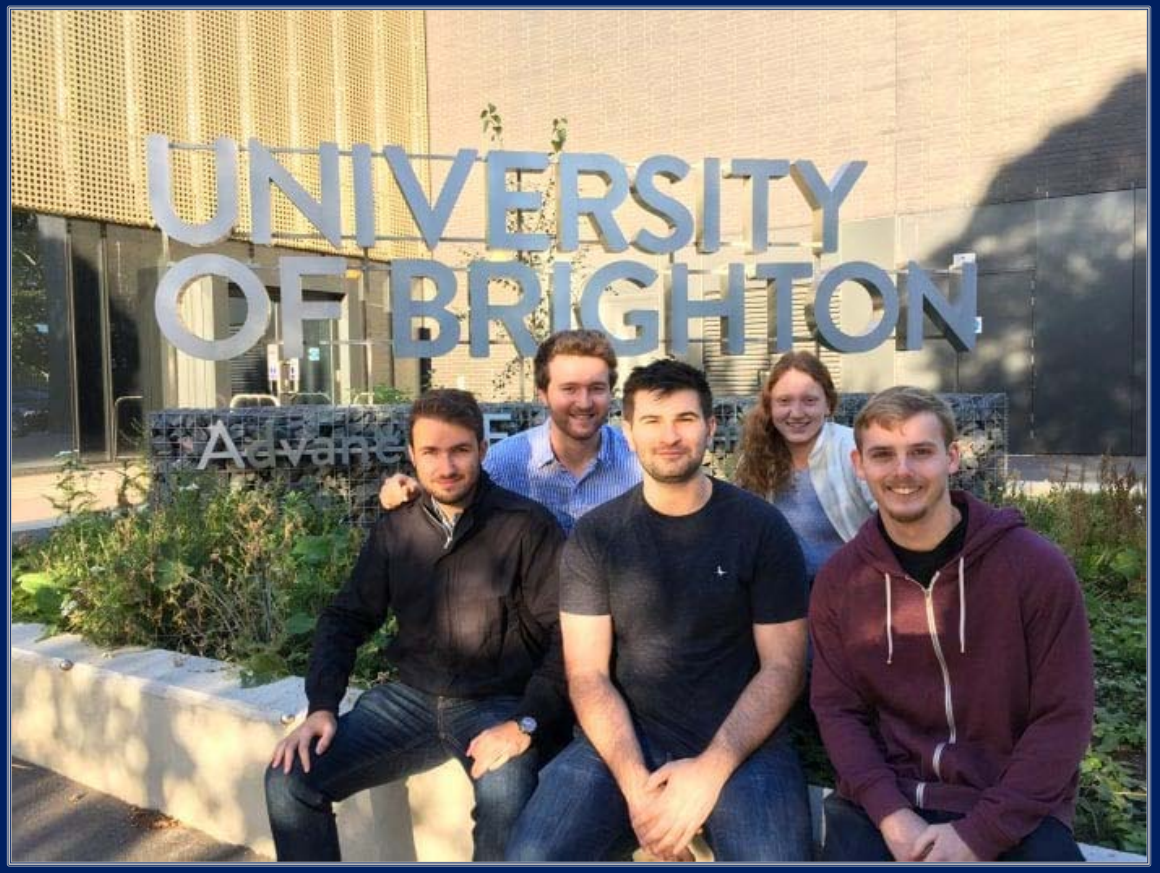
Thank you!



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