Trypanosome Motility in a Suspension of Soft Particles

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Introduction

Trypanosomes are unicellular eukaryotic parasites, which cause e.g. human african trypanosomiasis (sleeping sickness). The parasite body has an attached flagellum whose actuation results in periodic bending of the flagellum, such that the organism is able to propel forward. Propulsion and adaptation of the parasite to various environments are vital for its survival and spread during its life cycle [1]. It is therefore important to better understand the influence of surrounding components such as confinement or the presence of red blood cells (RBC) on trypanosome locomotion.

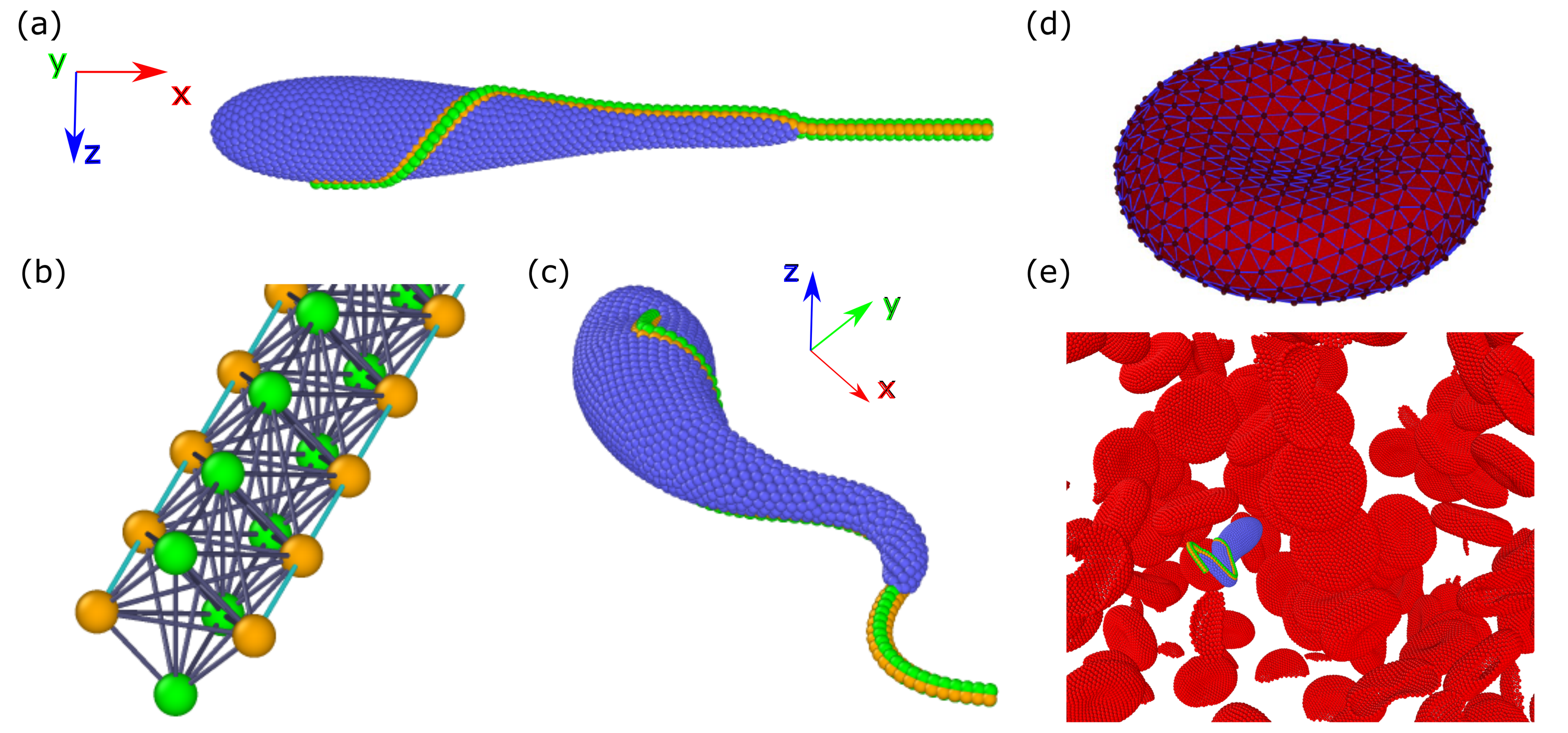

Figure: (a) Trypanosome model [3]. Membrane particles in dark blue, flagellum particles in green (passive) and orange (active). The passive flagellum particles are part of the membrane. (b) Sketch of the flagellum model. (c) Trypanosome with actuated flagellum. (d) Sketch of a triangulated RBC, where the network vertices are connected by springs, from [2]. (e) Swimming trypanosome within a RBC suspension.

Role of the actuation wave

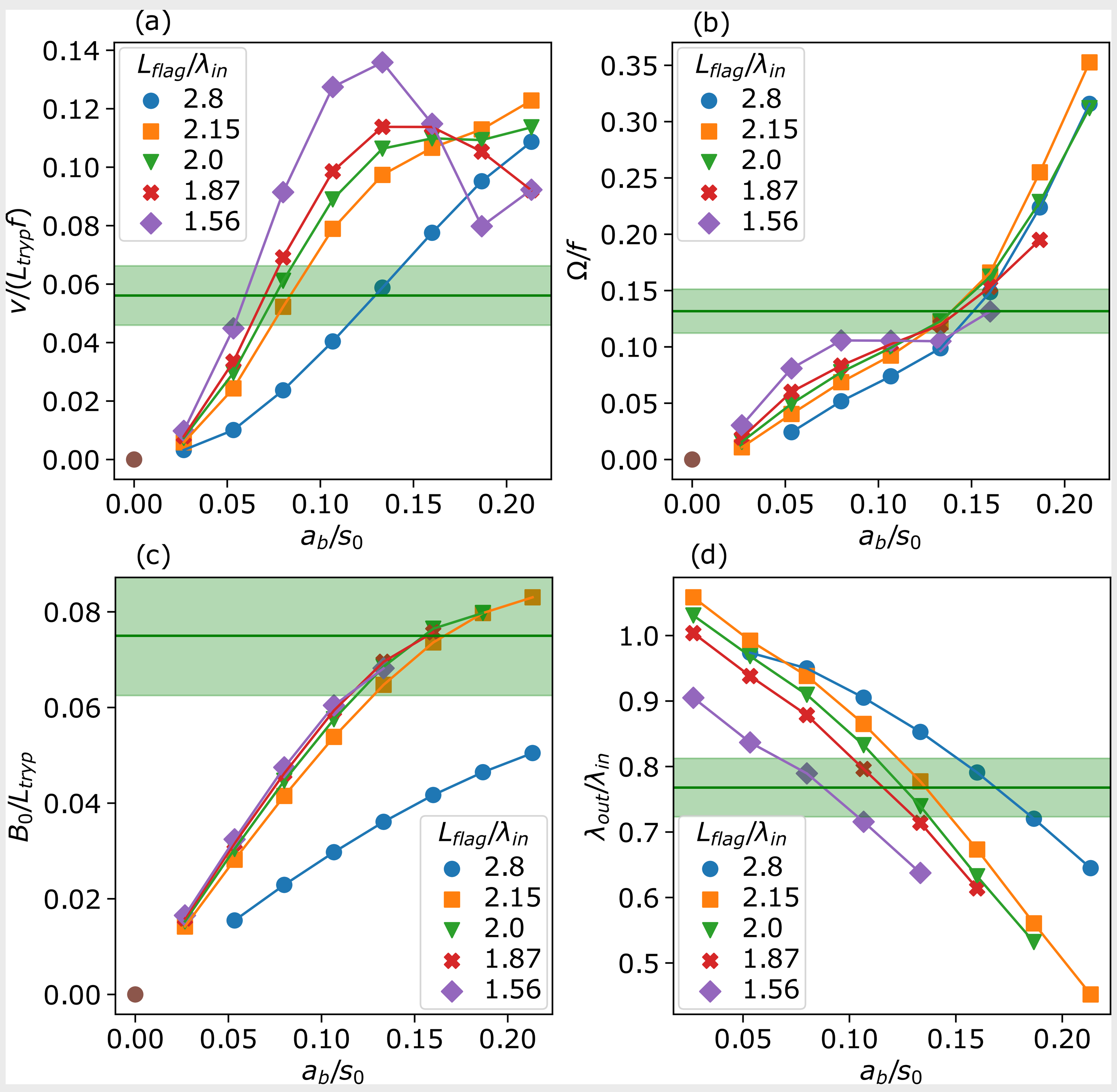

Figure: (a)-(d) Swimming velocity v, rotation frequency Ω, deformation wave amplitude B_0 and deformation wavelength λ_{out} against the amplitude a_b of the actuation wave. The different symbols indicate different number of waves along the whole flagellum with a constant contour length L_{flag}. The horizontal line represents experimental measurements with the bar showing the standard deviation.

- The swimming velocity v increases with the actuation amplitude a_b until it reaches a local maximum
- For small values of a_b the increase in v is due to an increase of B_0
- Rotation frequency increases with increasing a_b and does not saturate in the investigated parameter range

Conclusion and Outlook

Our trypanosome model generates propulsion through the periodic bending of the flagellum with the swimmer rotating around its own swimming axis. Using this model we can investigate the effect of specific parasite features, such as the beating plane of the flagellum, on its locomotion in complex environments. The next step is to study trypanosome behavior in a suspension of RBCs.

Model

Soft Body Model [2]

- RBCs and trypanosome body are represented by a triangulated network of vertices which are connected by springs that introduce shear elasticity (μ_b)
- In addition, bending rigidity, and local and global area and volume conservation are also imposed

Fluid Model

- Smoothed Dissipative Particle Dynamics (SDPD)
- Mesoscale hydrodynamics method which incorporates dissipative interactions and thermal fluctuations
- RBCs and the trypanosome are embedded into the fluid, represented by a collection of SDPD particles

Flagellum Model [4]

- Sections of 4 particles are connected by springs and placed next to each other
- Each line of particles can be considered as a filament. Two opposite filaments are called active while the other two are called passive filaments
- Equilibrium length of the springs of the active filaments changes as

$$s_i^j = s_0 \pm a_b \sin\left(\frac{2\pi}{\lambda_{in}} s_0 i - \omega t\right)$$

- The beating amplitude B_0 and wavelength λ_{out} of the bending wave can be modulated by the amplitude a_b and the wavelength λ_{in} of the actuation wave
- Velocity of a single filament under the low amplitude approximation is given by

$$v \propto B_0^2 \frac{\omega}{\lambda} \propto a_b^2 \omega \lambda^3$$

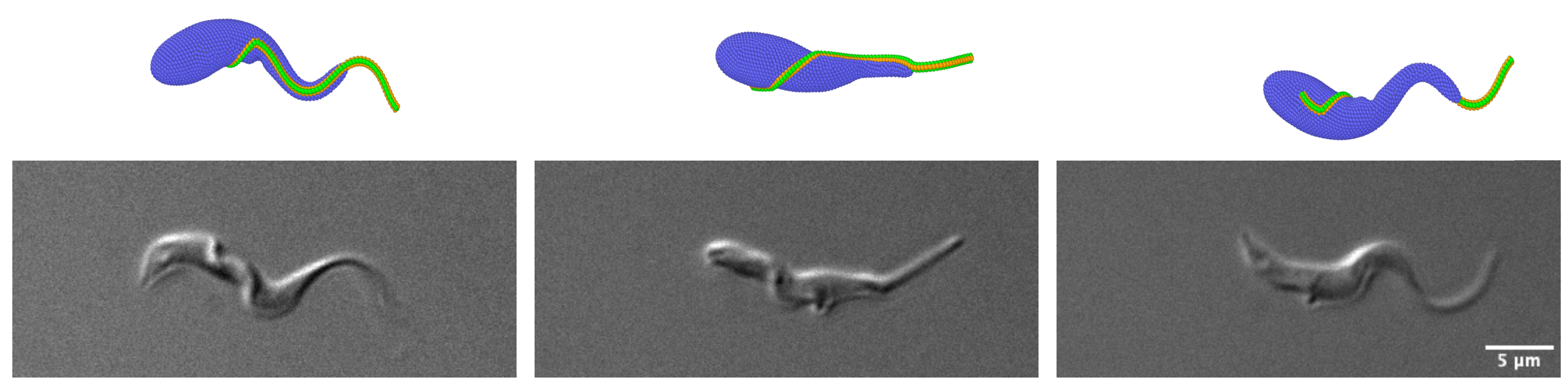

Figure: Time series of half a rotation of simulated (upper) and real (lower) trypanosome.

Normal vs tangential beating

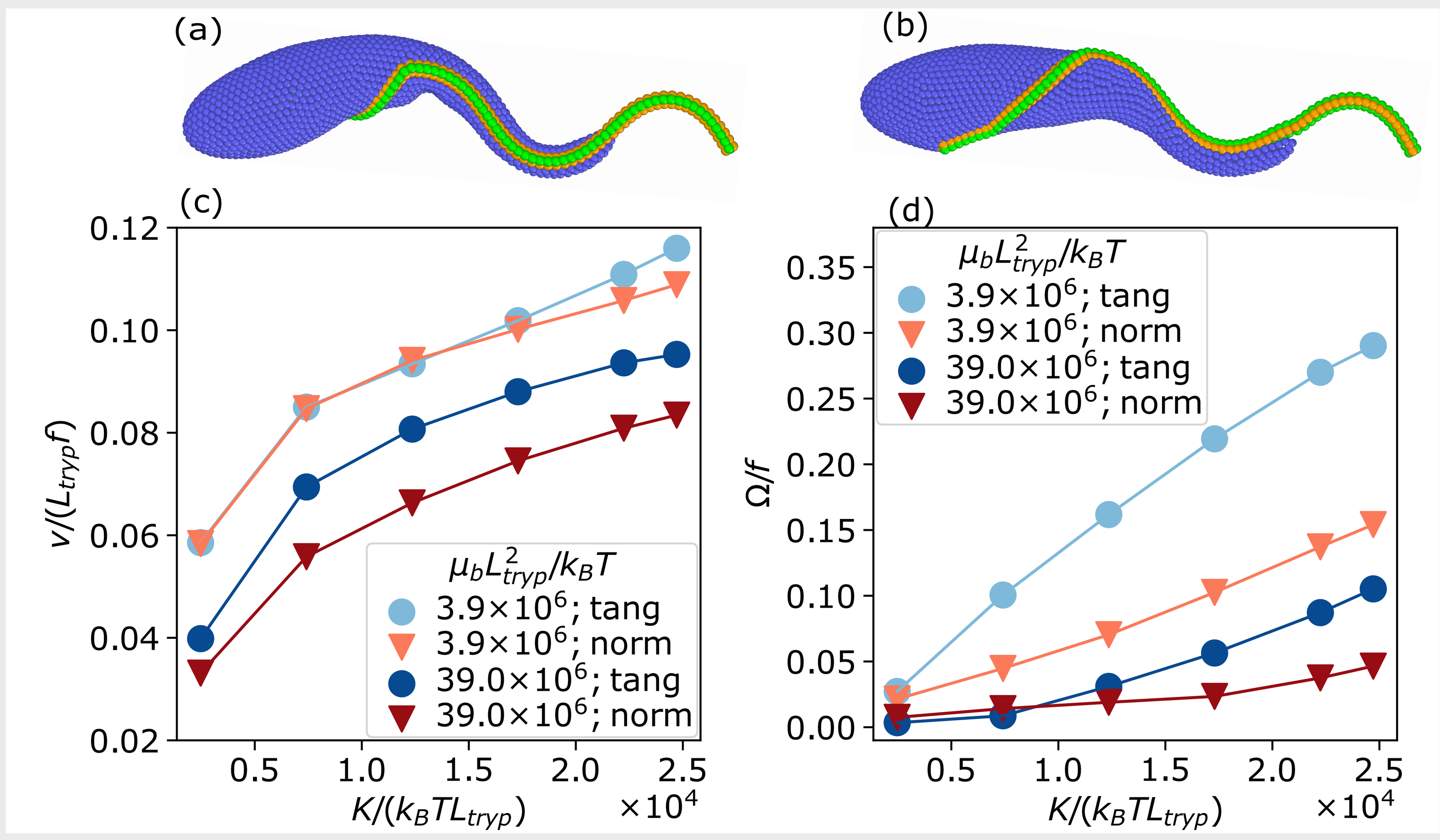

Figure: (a)-(b) Visualisation of the normal and tangential beating. (c)-(d) Swimming velocity and rotation frequency against the flagellum stiffness K for different body stiffness μ_b (light vs dark) and beating planes (blue vs red).

- The model allows for tangential and normal beating plane by choosing either the orange or green filament pair to be active
- The velocity increases for tangential beating but only weakly
- The rotation frequency increases significantly for tangential beating
- The parasite swims and rotates faster with a stiffer flagellum and softer body

References

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[4] Rode, S., Elgeti, J., & Gompper, G. (2019). Sperm motility in modulated microchannels. New Journal of Physics, 21(1), 013016