Synchronizing an oscillatory medium
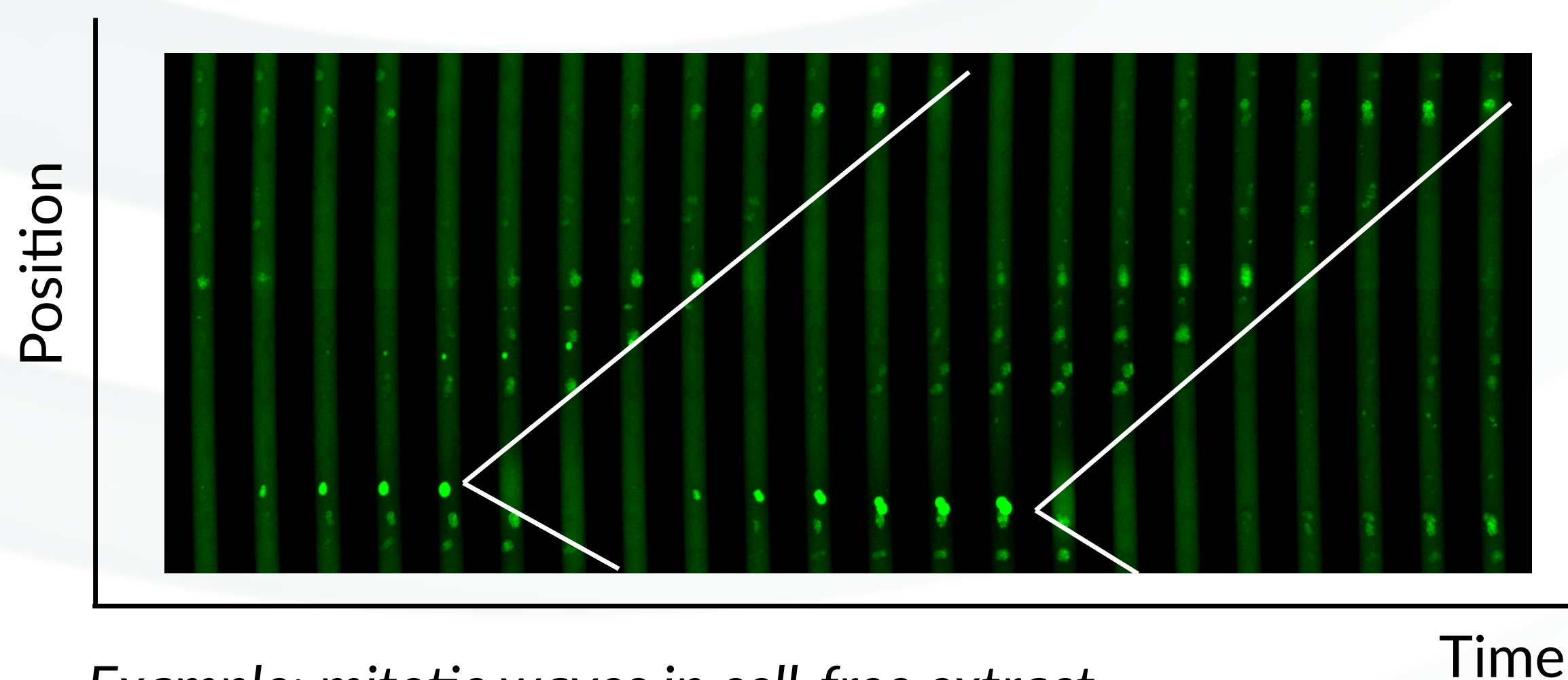## The speed of pacemaker-generated waves

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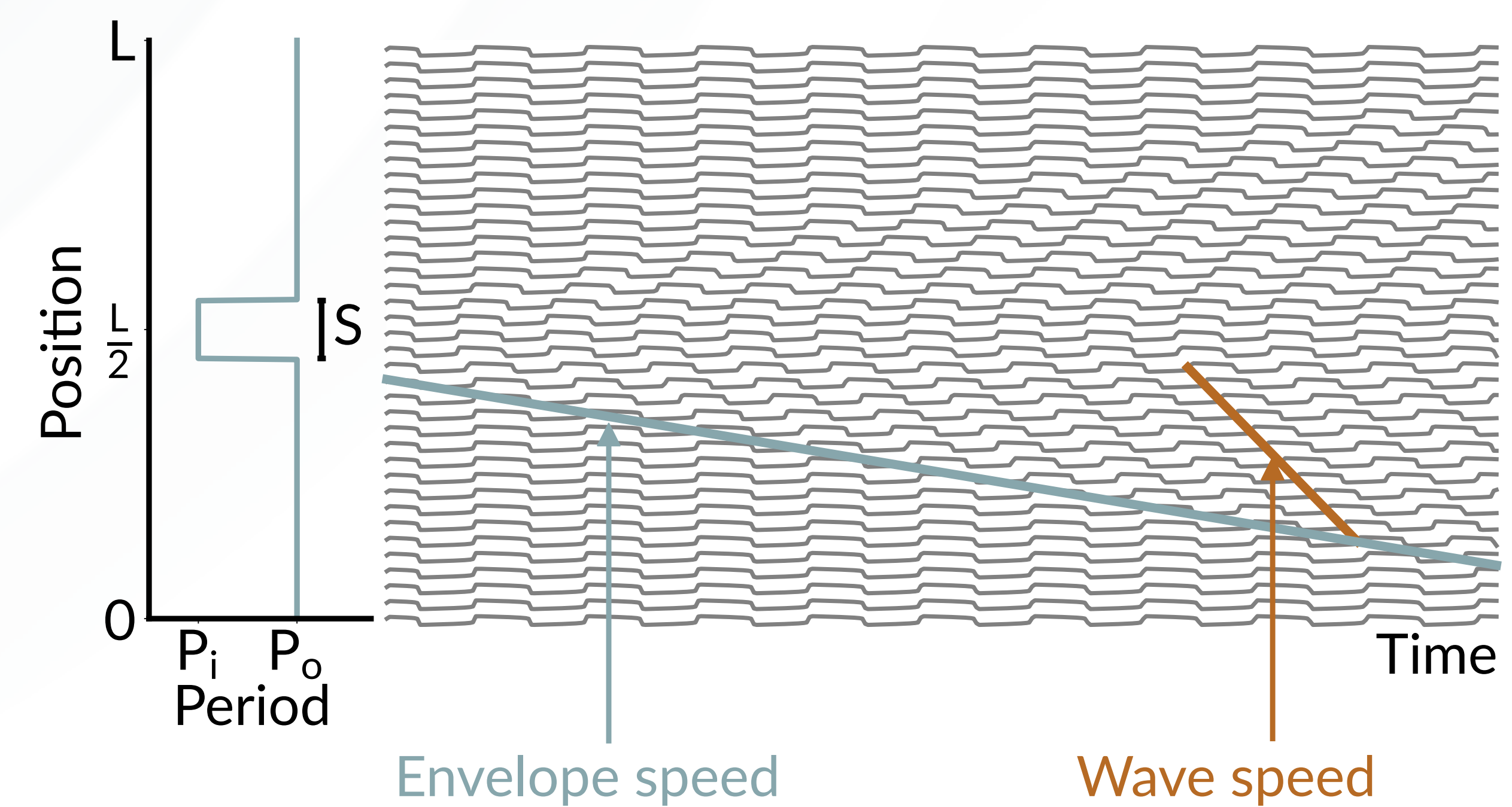*now at EMBL Heidelberg, jan.rombouts@embl.de

Introduction

Waves are present in many physical, chemical and biological systems, from the Belousov-Zhabotinsky reaction to mitotic waves in cell-free extracts of *Xenopus* eggs. Such waves may act to transmit information over large distances.

Example: mitotic waves in cell-free extract. Kymograph from Nolet et al., eLife, 2020.

Waves in oscillatory media are often generated by pacemakers: regions with a higher oscillation frequency
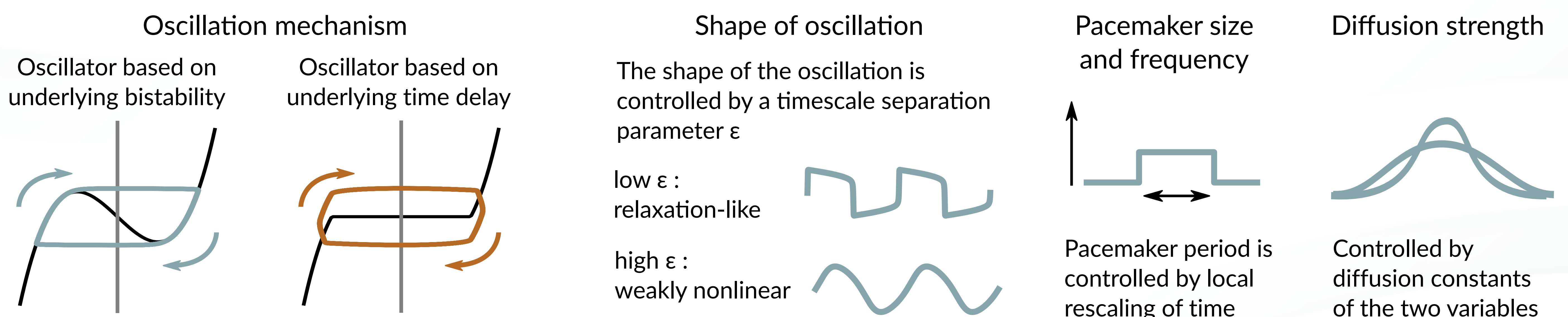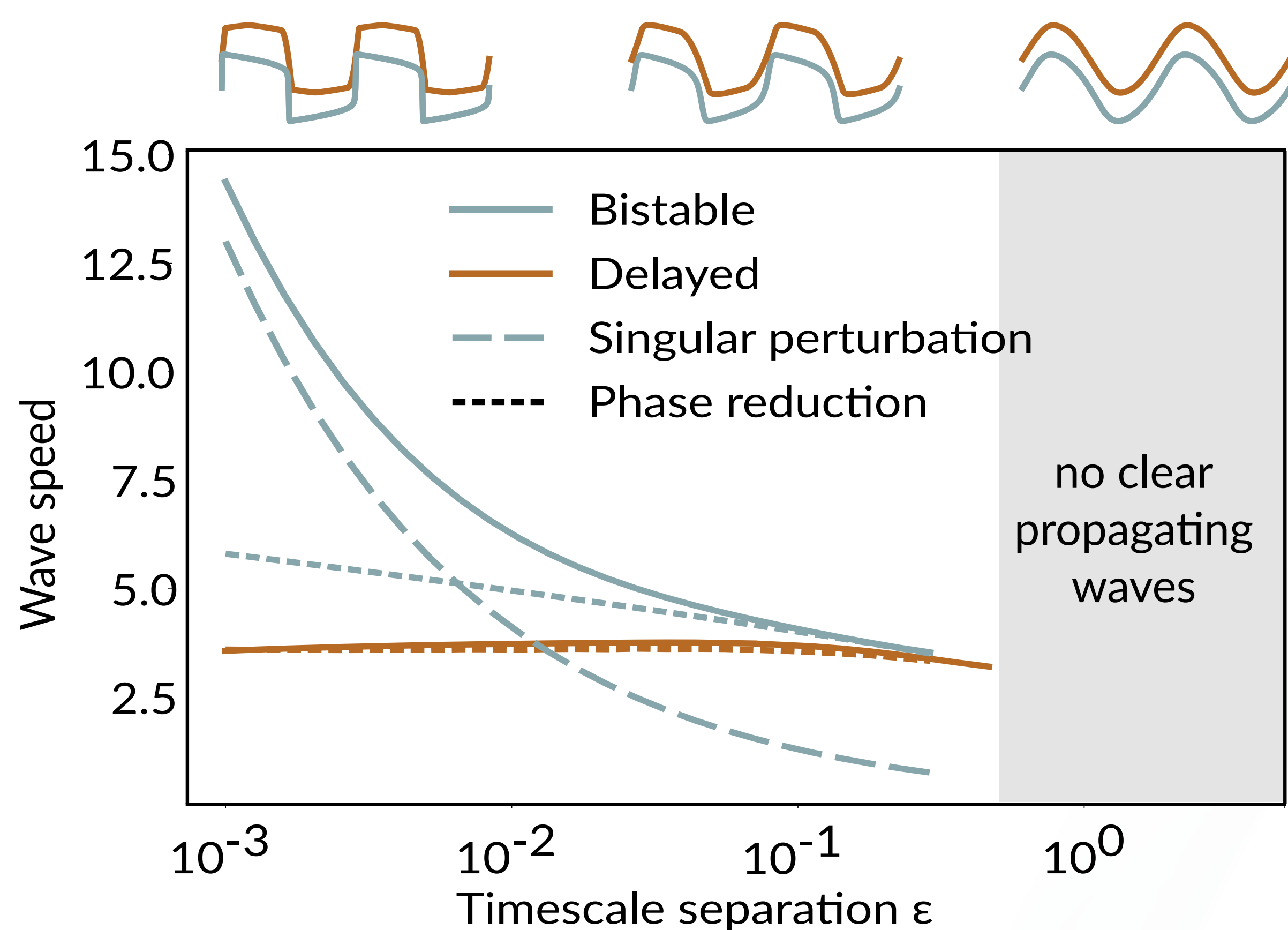

Question & approach

Which factors determine the speed of these waves?

• Reaction-diffusion system with two variables based on the FitzHugh-Nagumo model
• Systematically vary different properties to assess their effect on wave propagation, wave speed and envelope speed
• Numerical simulation of the PDEs, compared with analytical approximations based on the singular perturbation and phase reduction methods
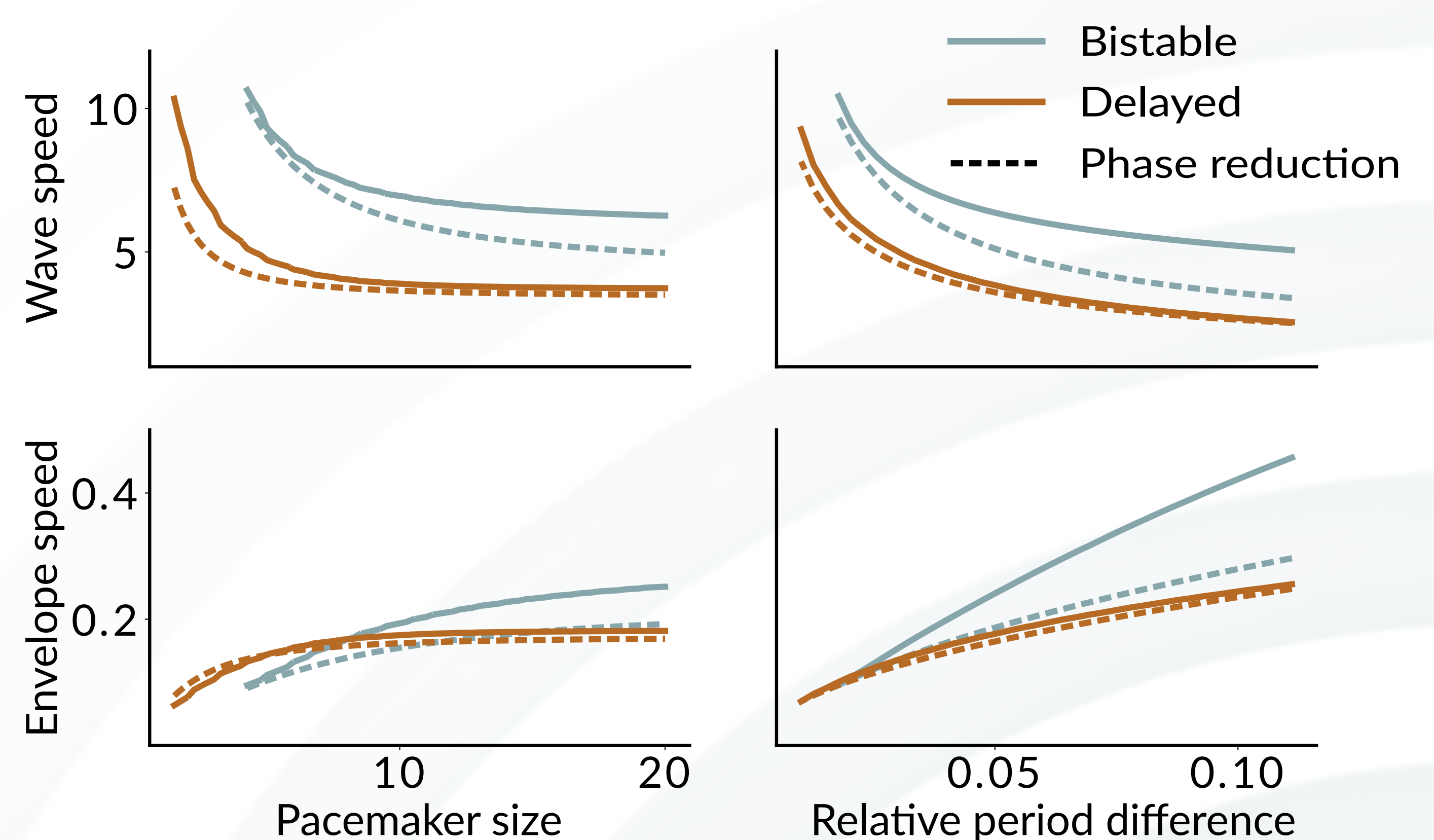
Factors that affect the wave speed

Oscillation mechanism

Oscillator based on underlying bistability

Oscillator based on underlying time delay

Shape of oscillation

The shape of the oscillation is controlled by a timescale separation parameter ε

low ε : relaxation-like

high ε : weakly nonlinear

Pacemaker size and frequency

Pacemaker period is controlled by local rescaling of time

Diffusion strength

Controlled by diffusion constants of the two variables

Main results

• Bistable and delayed oscillator show different wave speed dependence on timescale separation even though their time series are similar
• Timescale separation is the main determinant of wave speed, but only for the bistable oscillator
• Waves do not always propagate linearly

• Larger pacemakers, and those with a larger period difference with the medium, send out slower waves but take over the medium faster
• The phase reduction method provides a good approximation for the delayed oscillator
• Higher diffusion strength speeds up waves, but the effect is different for bistable and delayed oscillator

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