Modes of temperature response in vertebrate development

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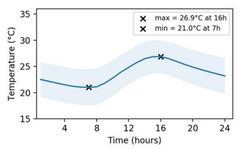
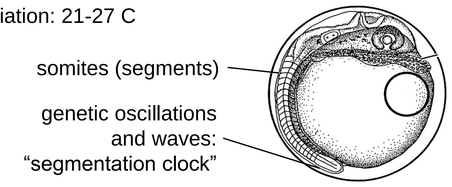
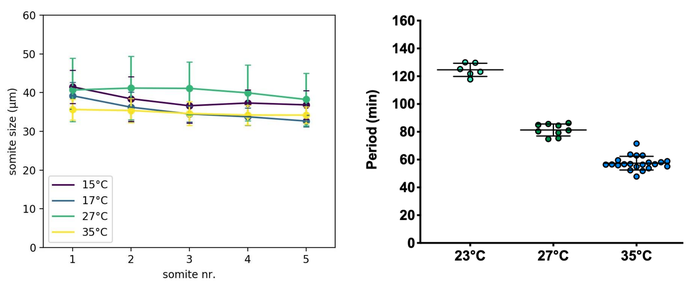
Introduction

Medaka segmentation at different temperatures:
- **temperature compensated morphology**
- **responsive segmentation clock**

Natural temperature variation: 21-27 C

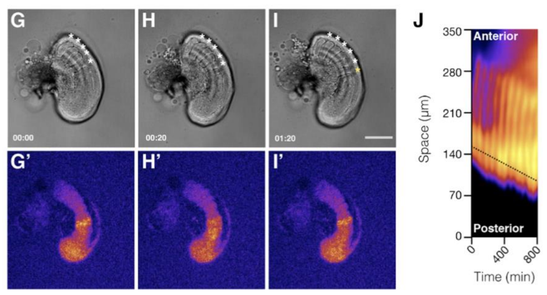




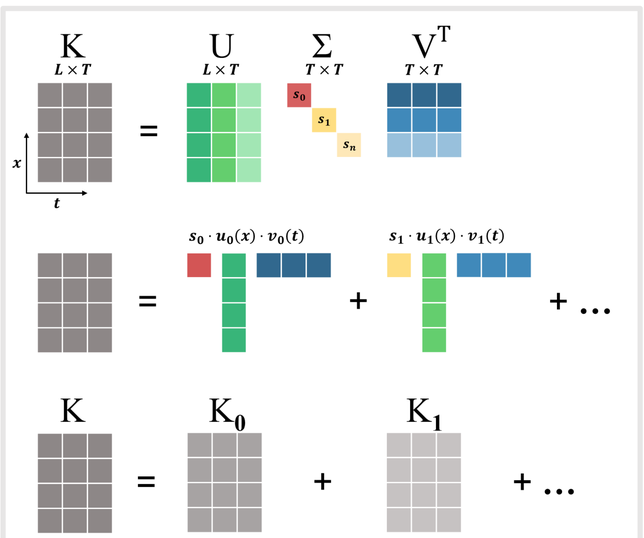


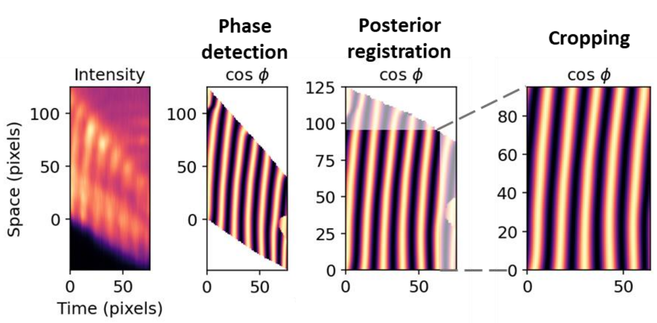
Methods

Kymographs of Her7-Venus oscillations in tail explants



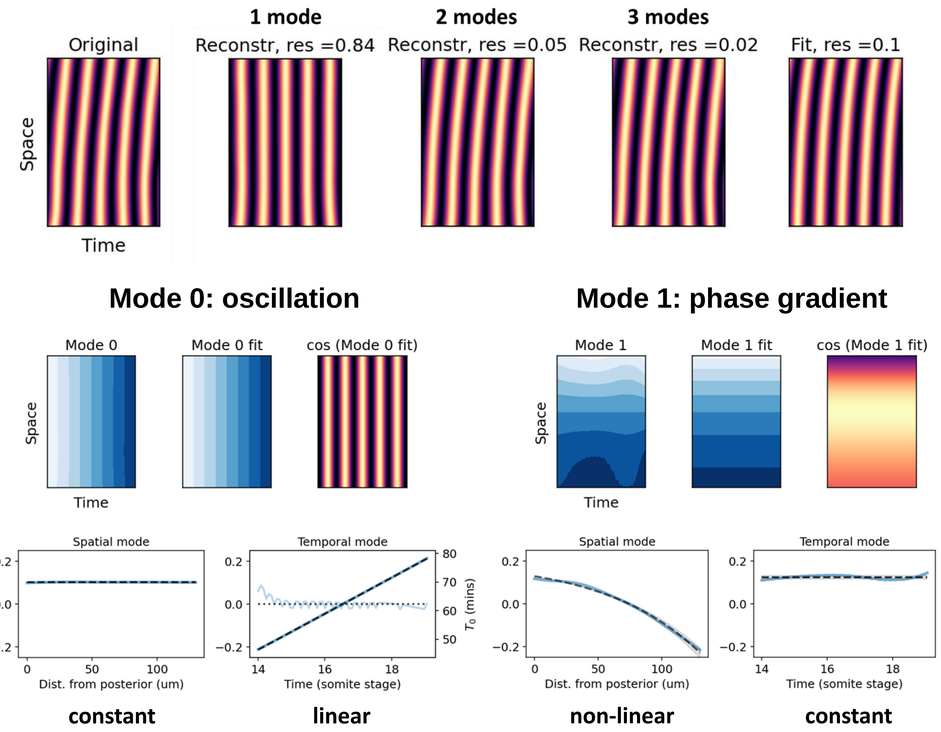
Analysis: Singular Value Decomposition (SVD)



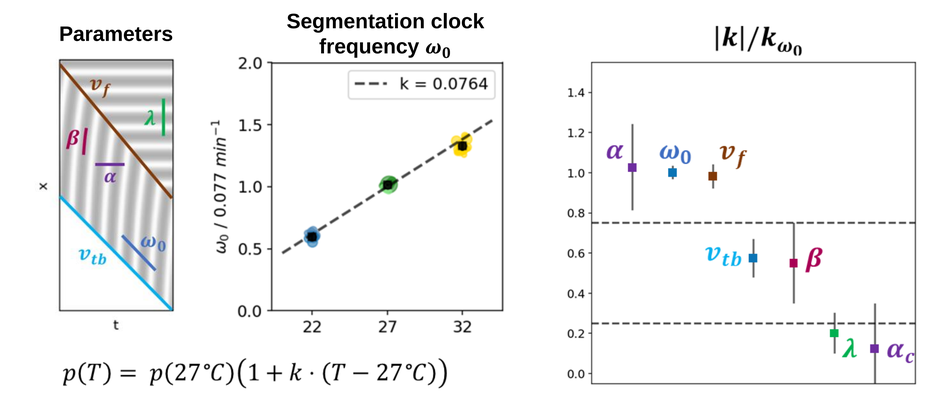


Results

1. Spatiotemporal dynamics is separable and is captured by two SVD modes



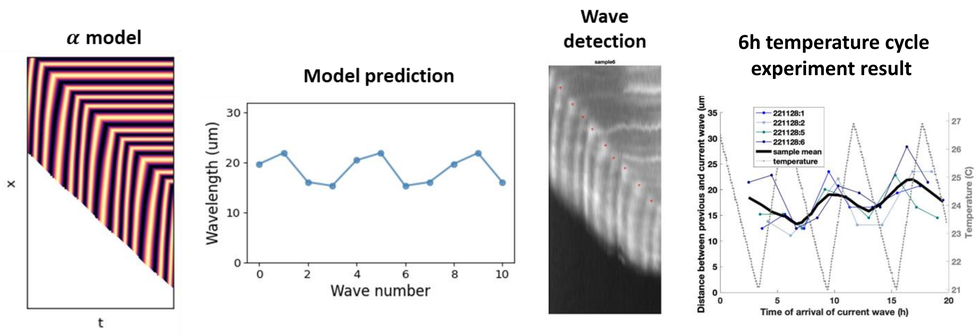
2. Identification of temperature sensitive and robust parameters



$$p(T) = p(27°C)\left(1 + k \cdot (T - 27°C)\right)$$

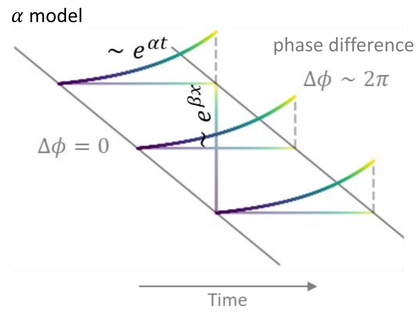
- Parameters are linear in temperature
- Pattern wavelength λ is compensated
- Slowing down per cycle α_c is compensated

3. Model correctly predicts compensation breaking with short temperature cycles



Discussion

- **Phase description** is a convenient and insightful approach to describing oscillatory dynamics irrespective of mechanistic details.
- We have established **SVD** as an unbiased way to analyze and parametrize phase kymograph data.
- We obtained simple **modes** that represent the dynamics of segmentation clock as a sum of a temporal oscillation and a spatial phase gradient.
- These modes correspond to the phenomenological **alpha model** proposed earlier [2]. In this model, the process of segmentation is driven by phase differences between local oscillators and a globally synchronized tissue-scale oscillator. This results in exponential phase gradients.



- We identified three groups of parameters:
  temperature sensitive: frequency of the clock ω_0, slowing down α, front velocity v_f;
  weakly sensitive: spatial phase gradient β and growth velocity v_{tb};
  temperature compensated: pattern wavelength λ and slowing down per cycle α_c.
- We used the alpha model and experimental temperature dependencies for analytic and numerical **modelling** of the system, starting with the compensated regime. We then **predicted** that compensation in the pattern wavelength can by broken by short temperature cycles. This prediction was confirmed by experiment with 6-hour cycles.

References

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2. Lauschke VM, Tsiairis CD, François P, Aulehla A. *Nature.* (2013) 493(7430):101-5.
3. Zhang W, Scerbo P, Delagrange M, Candat V, Mayr V, Vriz S, Distel M, Ducos B, Bensimon D. *Commun Biol. (*2022) 5(1):113.

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