Characters changing speed: the Covariomorph model and its impact on phylogenetic trees

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Evolution Meetings - June 23, 2025

LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

EVOLUTION MEETINGS

Phylogenetic inference using morphology

- Morphological datasets are analyzed using the Mk model [Lewis, 2001].
- Extensions like ACRV (e.g., +Γ) allow for among-character rate variation.
- But they assume constant rates for characters across all lineages.
- Do all characters evolve at the same speed in all lineages?

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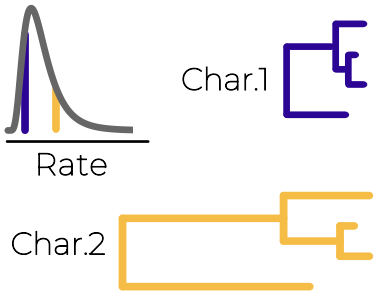

[Heckeberg et al., in press]

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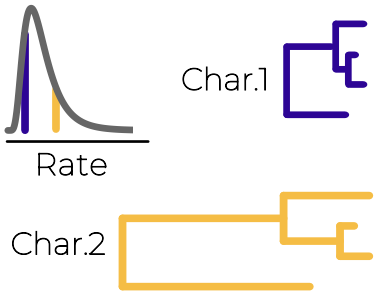

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Lineage-specific rate variation

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- We need a model that captures **heterotachy**: changes in rate across both characters and lineages.

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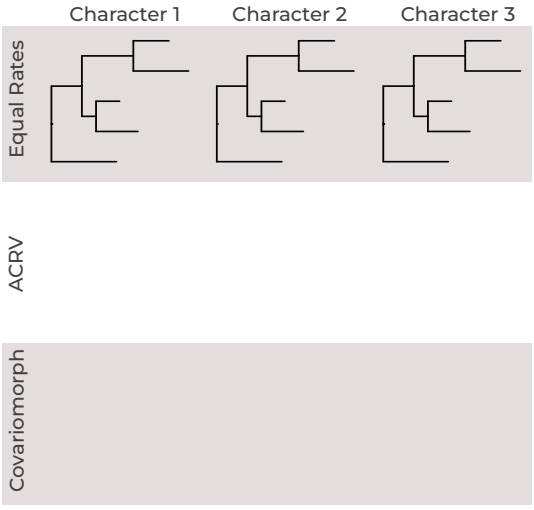

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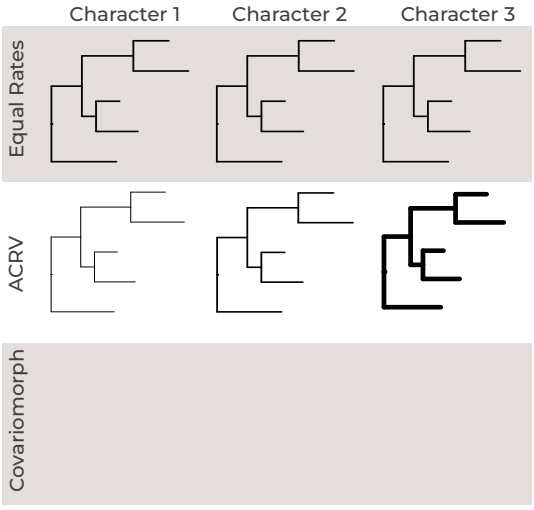

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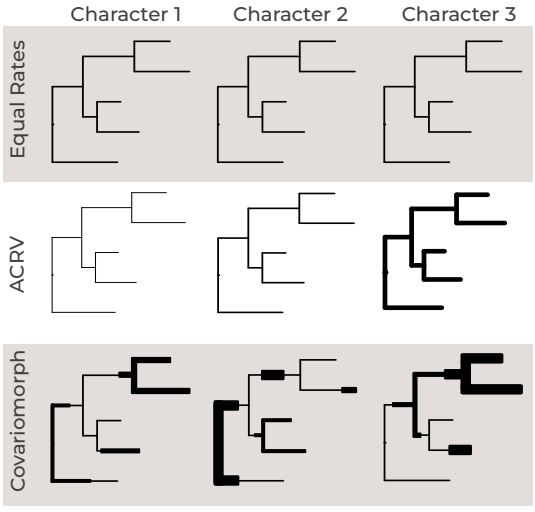

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[Khakurel and Höhna, submitted]

Covariomorph model

- Generalizes the covarion idea for morphology.
- Characters can switch between rate regimes (e.g., slow, medium, and fast).
- Unifies character-level and lineage-level rate variation in one framework.

$$Q_{CMP} = \begin{pmatrix} * & r_s & \frac{\delta}{2} & 0 & \frac{\delta}{2} & 0 \\ r_s & * & 0 & \frac{\delta}{2} & 0 & \frac{\delta}{2} \\ \frac{\delta}{2} & 0 & * & r_m & \frac{\delta}{2} & 0 \\ 0 & \frac{\delta}{2} & r_m & * & 0 & \frac{\delta}{2} \\ \frac{\delta}{2} & 0 & \frac{\delta}{2} & 0 & * & r_f \\ 0 & \frac{\delta}{2} & 0 & \frac{\delta}{2} & r_f & * \end{pmatrix}$$

Example for 3-rate category ($m = 3$).

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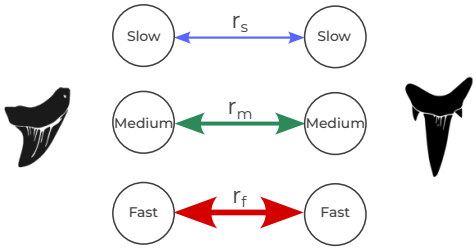

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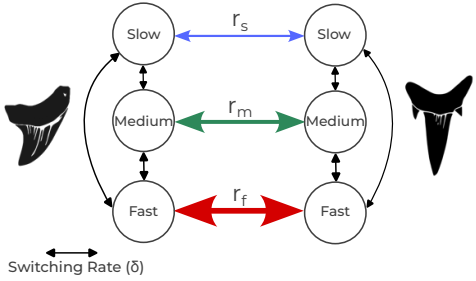

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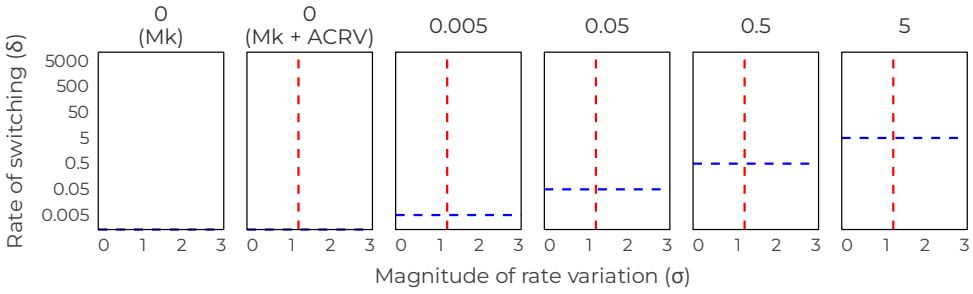

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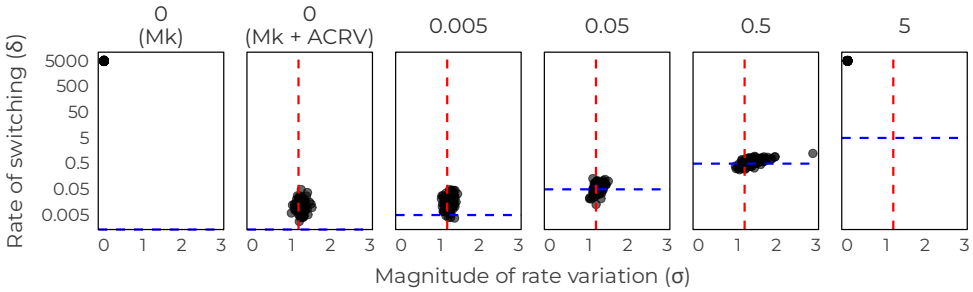

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- In limiting cases, Covariomorph simplifies to Mk or ACRV.

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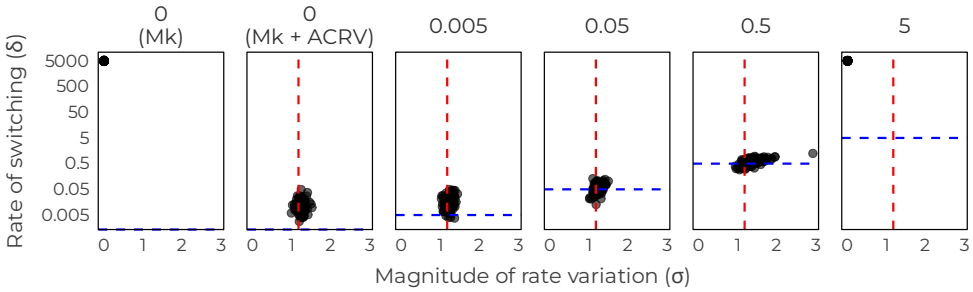

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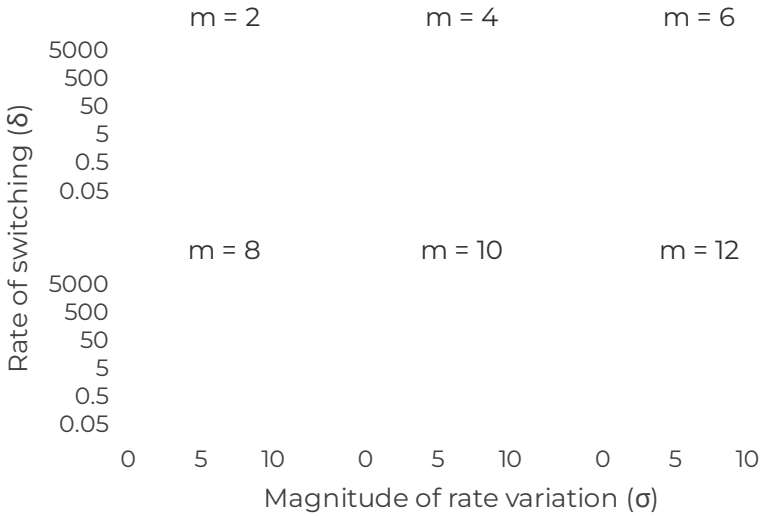

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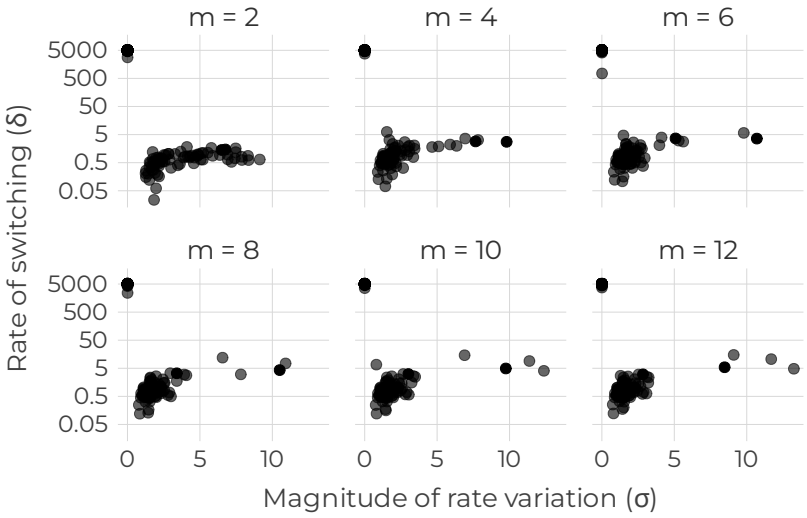
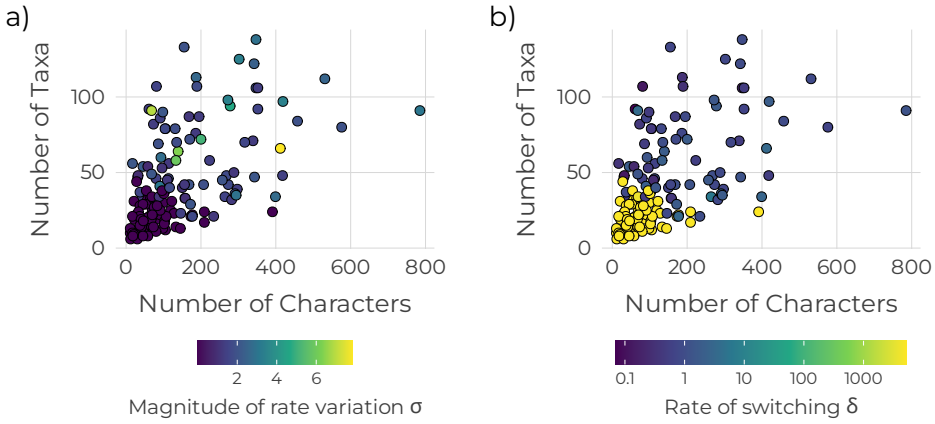


Association between dataset size and heterotachy

Larger datasets show more rate switching.



Focal data set of Rays

- **Rays**: 52 taxa, 124 characters [Marramà et al., 2023]
- Additional rate categories $m = \{14, 16, 18\}$
- Explored posterior distributions of δ, σ, and the tree length and topology.
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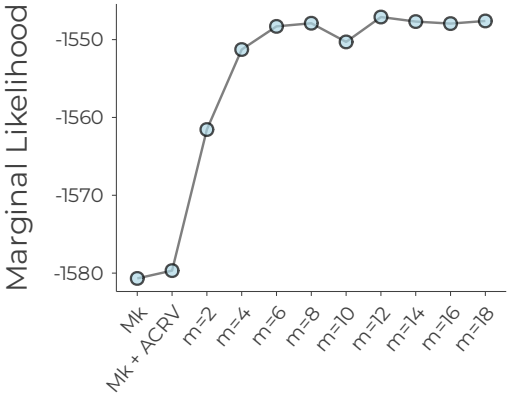
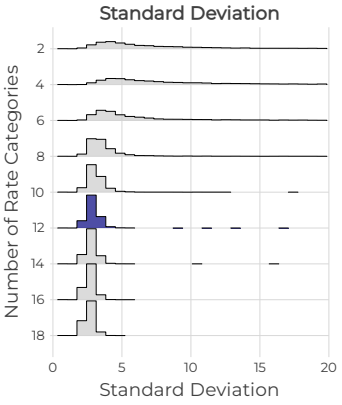


Parameter estimates



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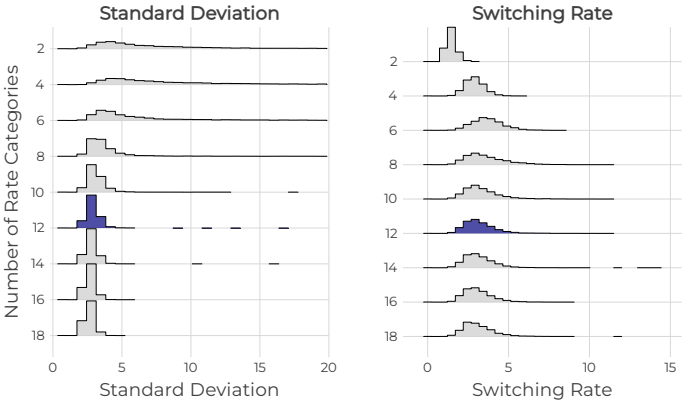

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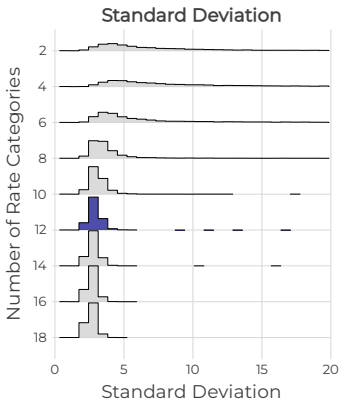
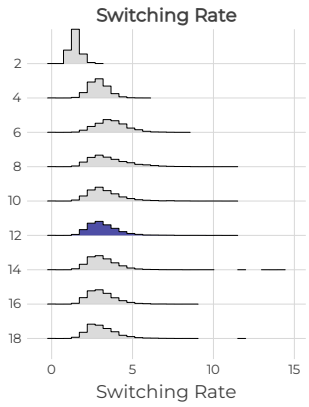
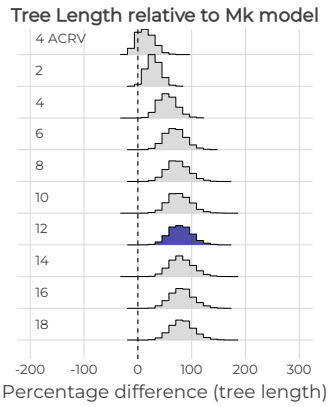
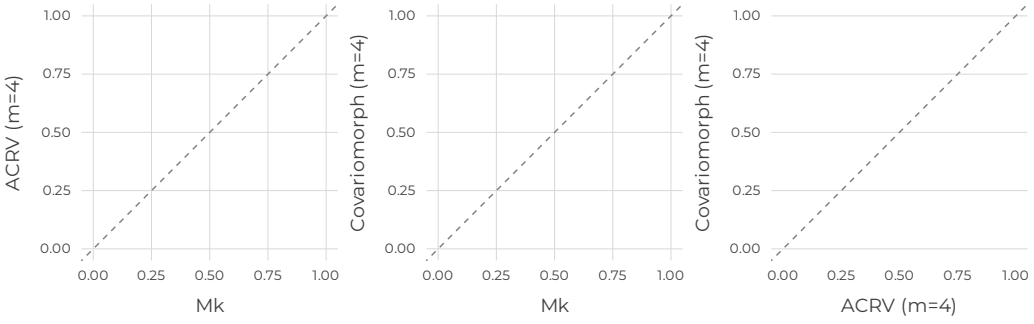






Topological impact

Incorporating heterotachy affects clade support and posterior topology.



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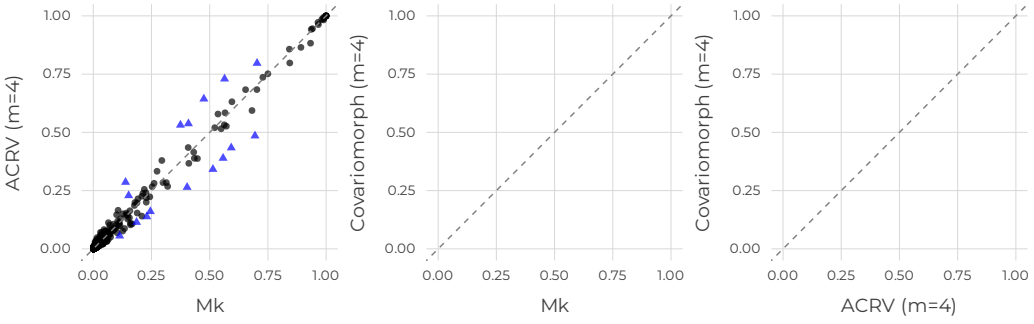

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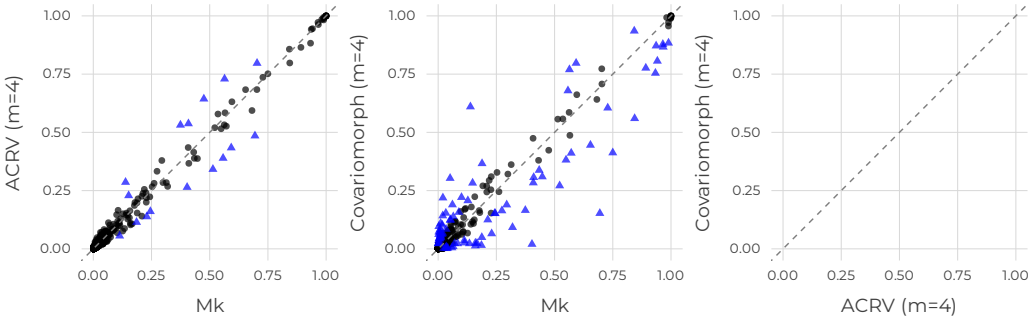

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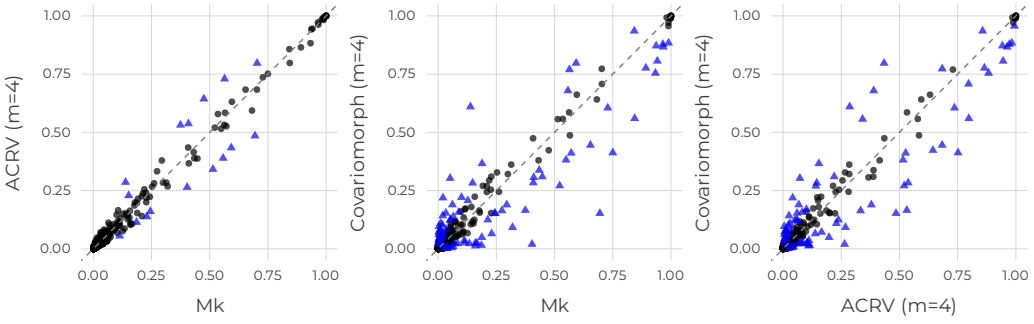

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Thank you!

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Preprint coming soon!

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