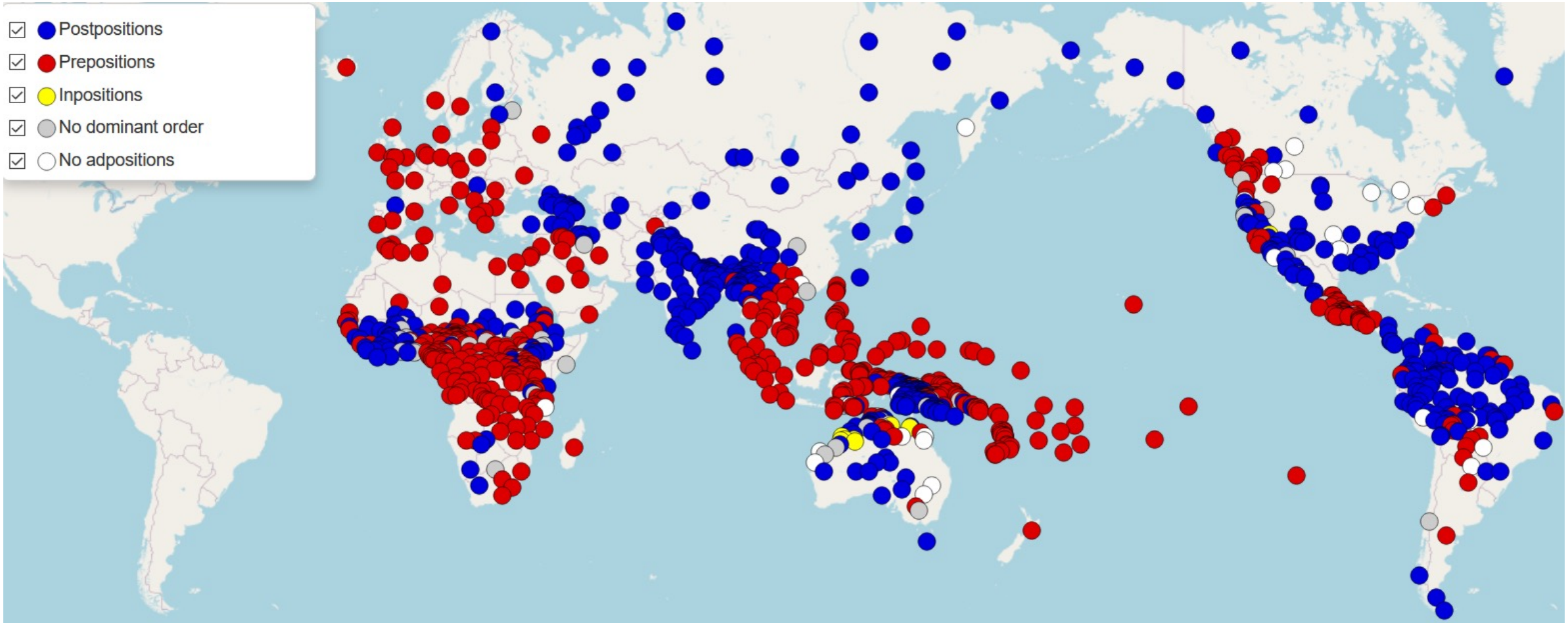
Typological Word Order Correlations with Logistic Brownian Motion

Kai Hartung
Gerhard Jäger
Sören Gröttrup
Munir Georges

Word-Order Traits in Languages



World Atlas of Languages (Dryer and Haspelmath, 2013)

Aim:

- Probing for universal correlation patterns in the evolution of word-order traits
- Testing if cross-family models can capture correlation patterns not found in single-family models.

using a Logistic Brownian Motion Model

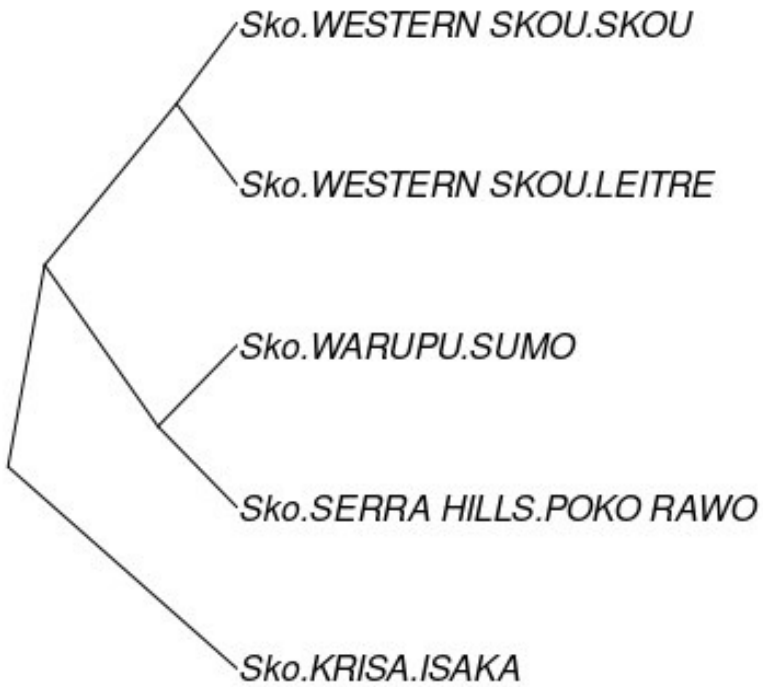
Word-Order Traits in Languages

- Adjective-Noun
- Adposition-Noun
- Demonstrative-Noun
- Genitive-Noun
- Numeral-Noun
- Object-Verb
- Relative Clause-Noun
- Subject-Verb

28 binary trait pair combinations
derived from WALS (Dryer and Haspelmath, 2013)

Language Families

- Evolutionary history in the form of phylogenetic trees
- 33 language families
- 768 languages in total
- Provided by Jäger (2018)



Logistic Brownian Motion

$$x \sim MultiNormal(a, V),$$

trait values x,

means a,

Variance-Covariance matrix $V = R \otimes C$

Logistic Brownian Motion

$$\boldsymbol{x \sim Binomial(p)}$$

$$\boldsymbol{inv\_logit(p)} \sim MultiNormal(a, V),$$

trait values x,

value probabilities p,

means a,

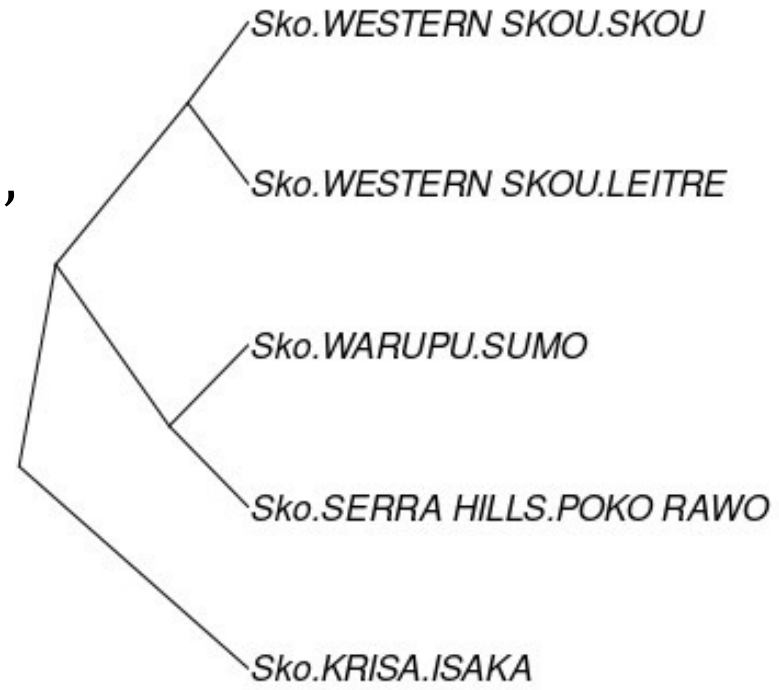
Variance-Covariance matrix $V = R \otimes C$

Logistic Brownian Motion

$$x \sim Binomial(p)$$

$$inv\_logit(p) \sim MultiNormal(a, V),$$

$$V = R \otimes C$$

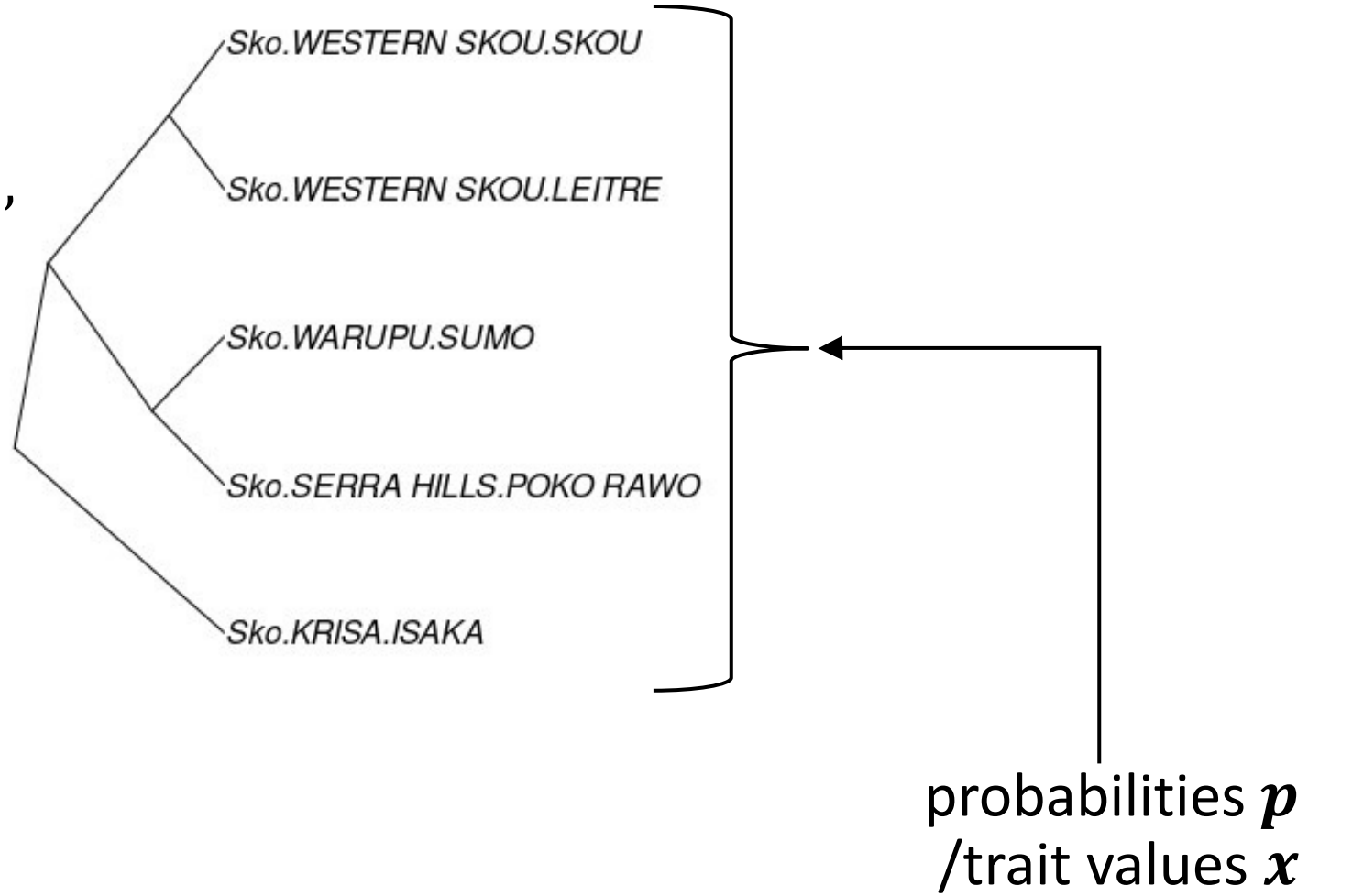


Logistic Brownian Motion

$$\boldsymbol{x} \sim Binomial(\boldsymbol{p})$$

$$inv\_logit(\boldsymbol{p}) \sim MultiNormal(a, V),$$

$$V = R \otimes C$$

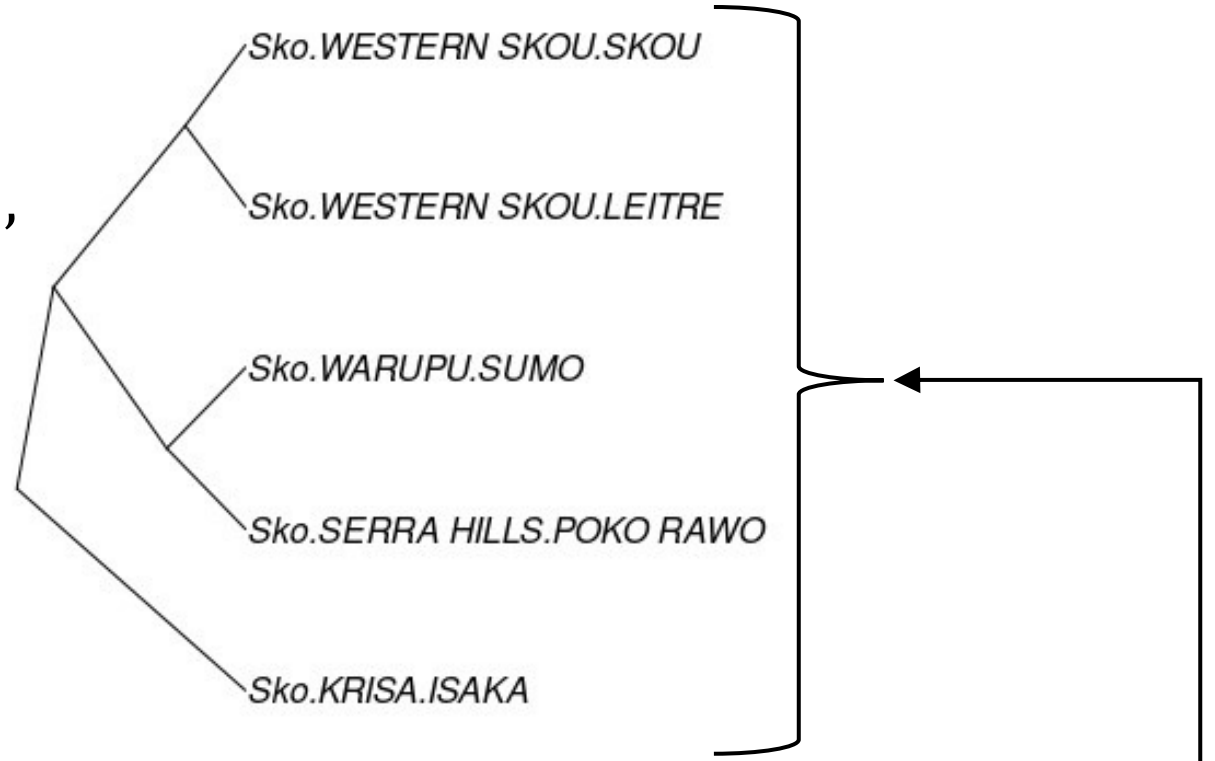


Logistic Brownian Motion

$$x \sim Binomial(p)$$

$$inv\_logit(p) \sim MultiNormal(\boldsymbol{a}, V),$$

$$V = R \otimes C$$



means $\boldsymbol{a}$
/root values

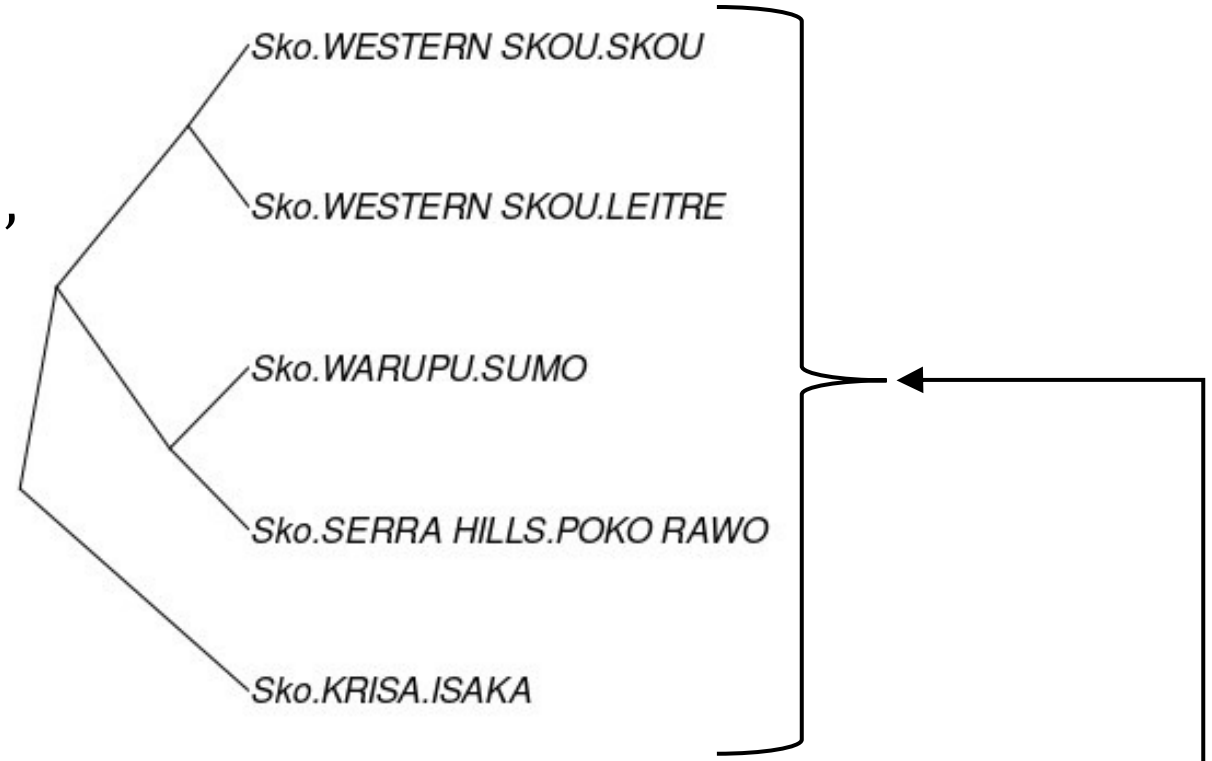
probabilities p
/trait values x

Logistic Brownian Motion

$$x \sim Binomial(p)$$

$$inv\_logit(p) \sim MultiNormal(a, \boldsymbol{V}),$$

$$\boldsymbol{V} = R \otimes C$$



means a
/root values

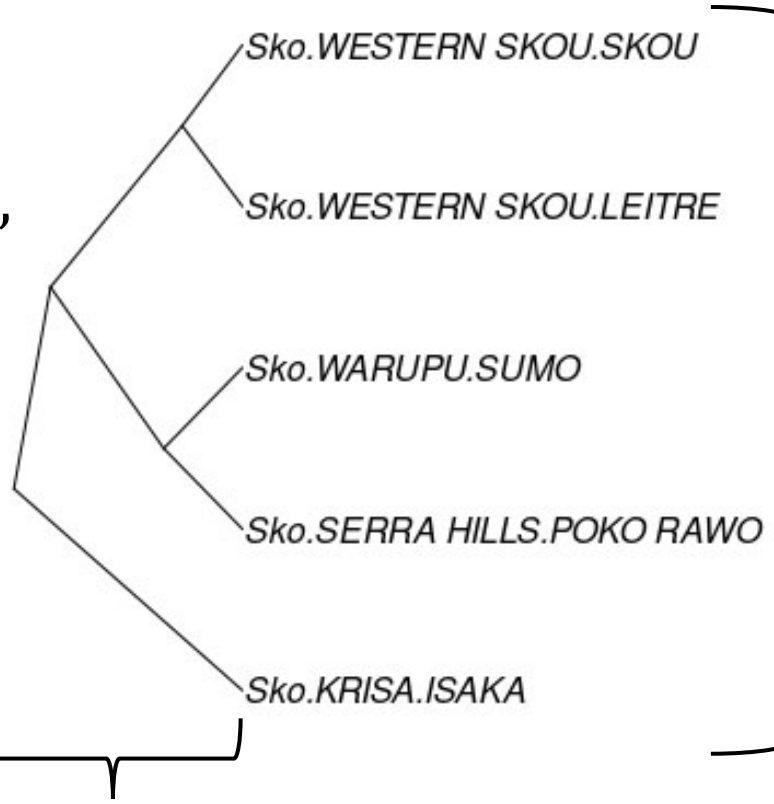
probabilities p
/trait values x

Logistic Brownian Motion

$$x \sim Binomial(p)$$

$$inv\_logit(p) \sim MultiNormal(a, \boldsymbol{V}),$$

$$\boldsymbol{V} = R \otimes \boldsymbol{C}$$



means a
/root values

Variance-Covariance matrix $\boldsymbol{C}$
/shared history

probabilities p
/trait values x

Logistic Brownian Motion

$$x \sim Binomial(p)$$

$$inv\_logit(p) \sim MultiNormal(a, \boldsymbol{V}),$$

$$\boldsymbol{V} = \boldsymbol{R} \otimes C$$

Trait correlation $\boldsymbol{R}$

$$\boldsymbol{R} = \begin{bmatrix} \sigma^2{}_{11} & \sigma_{21} \\ \sigma_{12} & \sigma^2{}_{22} \end{bmatrix}$$

Setup

1. Models for each single family:

Correlated:

$$R = \begin{bmatrix} \sigma^2{}_{11} & \sigma_{21} \\ \sigma_{12} & \sigma^2{}_{22} \end{bmatrix}$$

Independent:

$$R = \begin{bmatrix} \sigma^2{}_{11} & 0 \\ 0 & \sigma^2{}_{22} \end{bmatrix}$$

Setup

1. Models for each single family:

Correlated:

$$R = \begin{bmatrix} {\sigma^2}_{11} & \sigma_{21} \\ \sigma_{12} & {\sigma^2}_{22} \end{bmatrix}$$

Independent:

$$R = \begin{bmatrix} {\sigma^2}_{11} & 0 \\ 0 & {\sigma^2}_{22} \end{bmatrix}$$

---

2. Models across all families:

Lineage-specific correlation:

$$R_f = \begin{bmatrix} {\sigma^2}_{11_f} & \sigma_{21_f} \\ \sigma_{12_f} & {\sigma^2}_{22_f} \end{bmatrix},$$

for each family $f \in F$

Universal correlation:

$$R = \begin{bmatrix} {\sigma^2}_{11} & \sigma_{21} \\ \sigma_{12} & {\sigma^2}_{22} \end{bmatrix}$$

Universal independence:

$$R = \begin{bmatrix} {\sigma^2}_{11} & 0 \\ 0 & {\sigma^2}_{22} \end{bmatrix}$$

Results

- Single Family Models:
  - No trait pairs correlated consistently across language families
  - Observation consistent for Bayes Factors, WAIC, LOOIC

Results

- Single Family Models:
  - No trait pairs correlated consistently across language families
  - Observation consistent for Bayes Factors, WAIC, LOOIC

- Cross-Family Models:
  - Bayes Factors:

    Lineage-specific correlations valued much higher than universal models
  - Information Criteria:

    Contrarily, universal models valued much higher than lineage-specific

Conclusions

- Single-Family models and Bayes Factors for Universal models are in favour of only lineage-specific correlations
- However, Information Criteria for Universal models are in favour of universal correlations

=> No clear evidence in favour of any universal trait correlations

References

Matthew S. Dryer and Martin Haspelmath, editors. 2013. WALS Online. Max Planck Institute for Evolutionary Anthropology, Leipzig.

Gerhard Jäger. 2018. A bayesian test of the lineage-specificity of word order correlations. In 12th International Conference on Language Evolution (Evolang XII), Torun