Using simulated data to evaluate models of Indo-European vocabulary evolution

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- Basic idea: The more vocabulary a group of related languages have in common, the shorter the time since they split up
- Recent approaches tend to use extremely complicated methods of inference

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- Recent examples for Indo-European:
  - Bouckaert et al. (2012, amended in Bouckaert et al. 2013) support "Anatolian hypothesis" with age larger than 8000 BP
  - Chang et al. (2015) support "Steppe hypothesis" with age around 6000 BP
  - Heggarty et al. (2023) infer yet another scenario, with age around 8000 BP

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- Complicated inference methods make a lot of assumptions
- The effect of those is very hard to gauge by inspection only

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- However, amount of historic data that can be used for testing is very limited
- Furthermore, methods usually use most historic data already for choosing the model parameters

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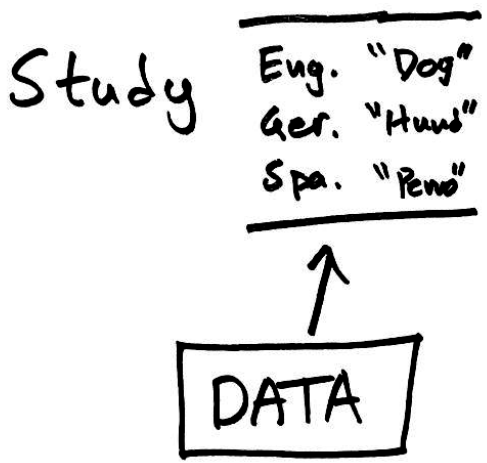

Way forward: Realistic simulated data

I.e. Chang et al (2015)
Bouckaert et al (2012)

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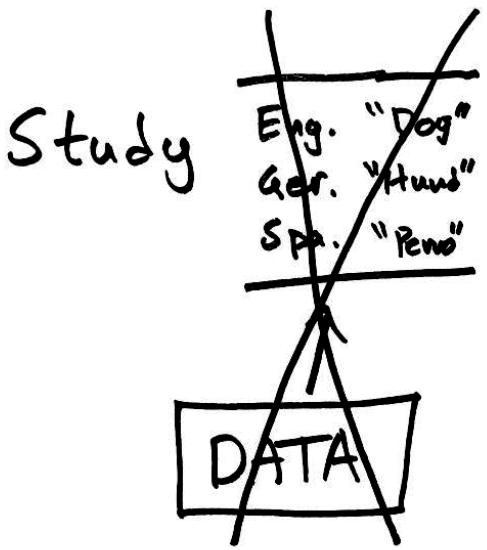

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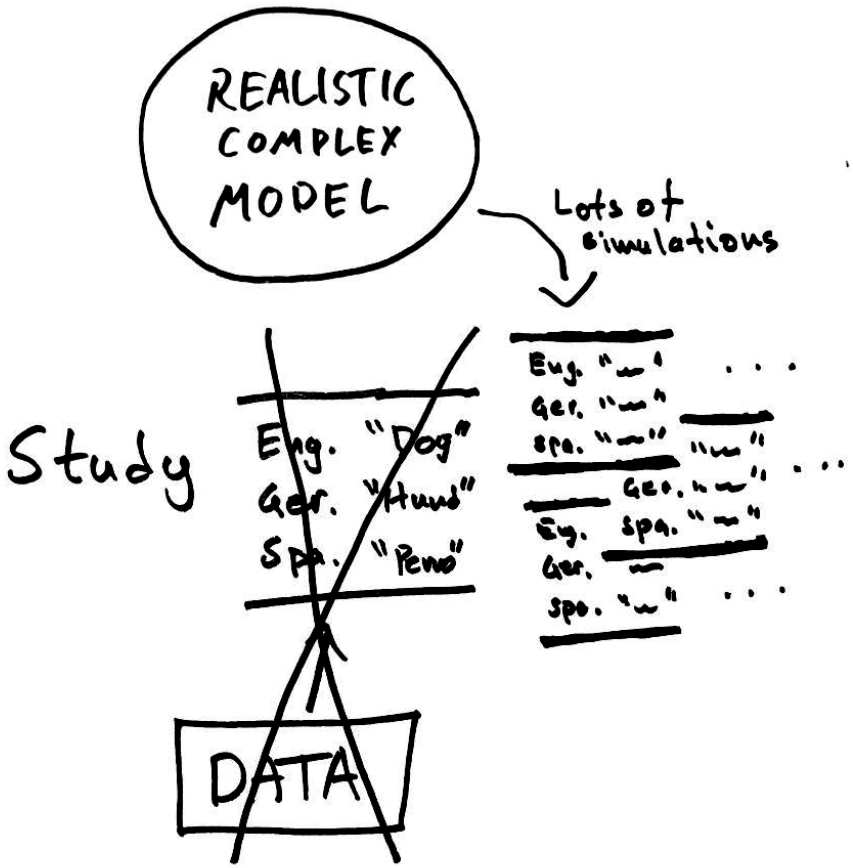

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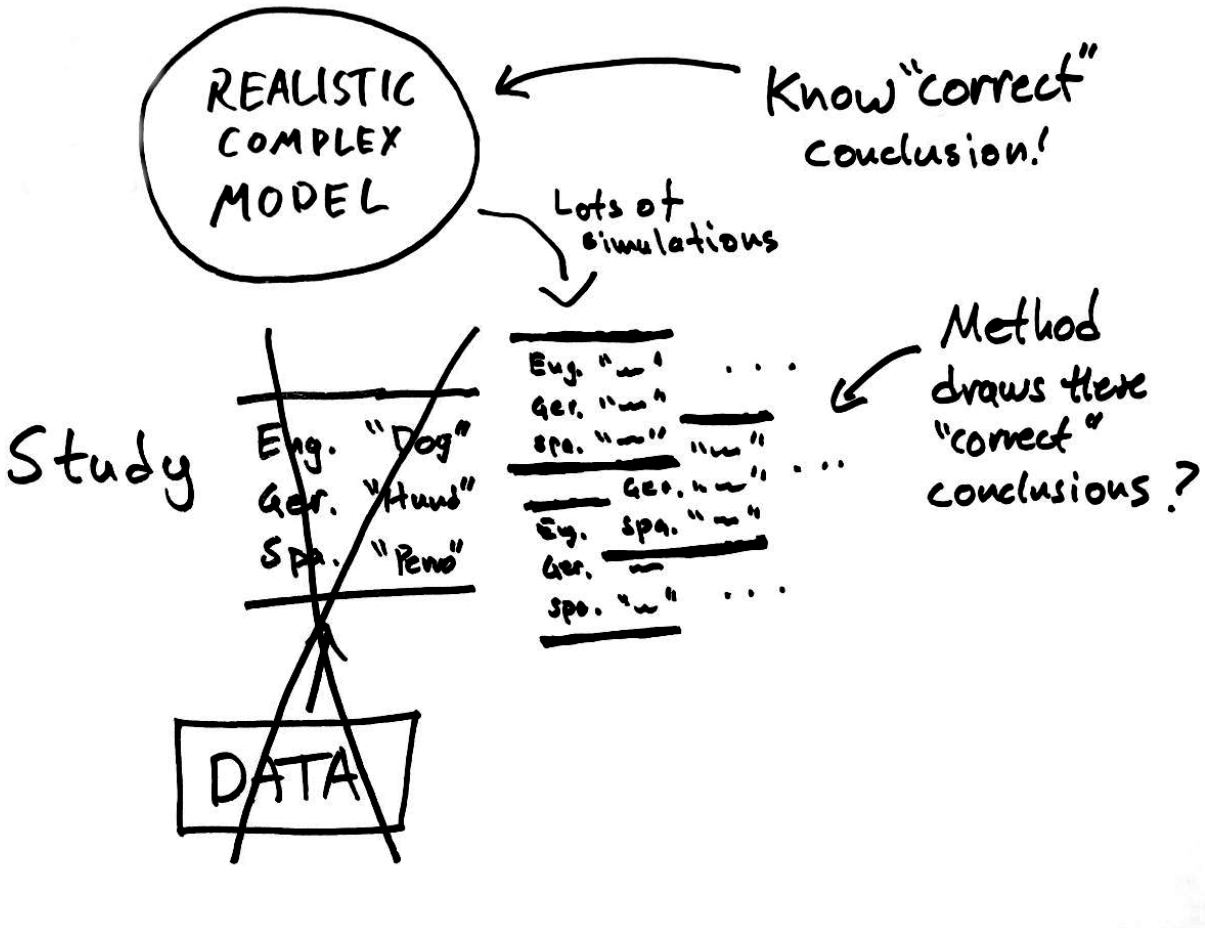

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- That means: If we are to trust an inference method, it has to work on all data that *could have* evolved in a similar way as the Indo-European data evolved

Our simulation model

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We are using our simulation model to evaluate the methods of Chang et al. (2015) and Bouckaert et al. (2012) (not Heggarty et al. 2023 yet since it is too recent)

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- NB these nodes do not invalidate analysis — a good model should be able to cope with any linguistic history!

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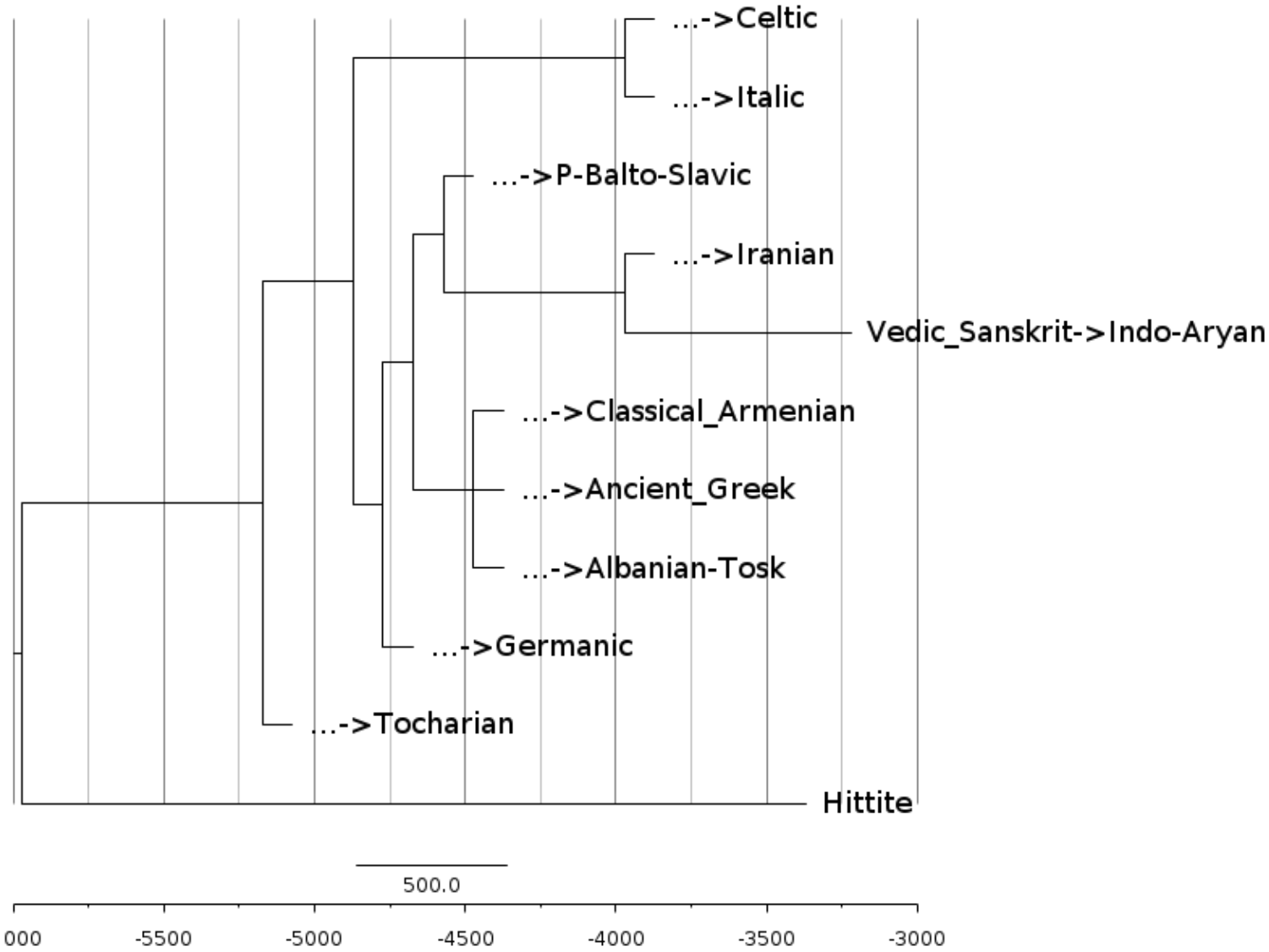
- Chosen date: **2750 BP** (1400y of divergence)

Our base tree – uppermost branches



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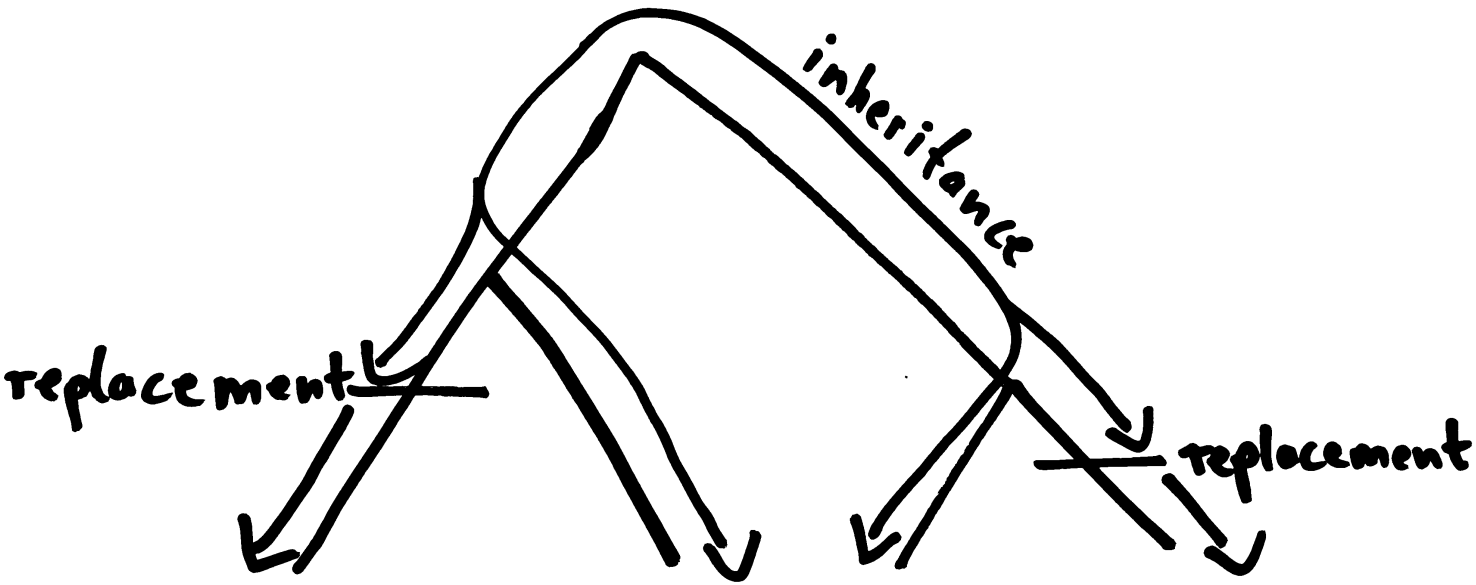
- The change rates per meanings are estimated from historic data provided by Lees (1953) and Swadesh (1955)

Multistate model



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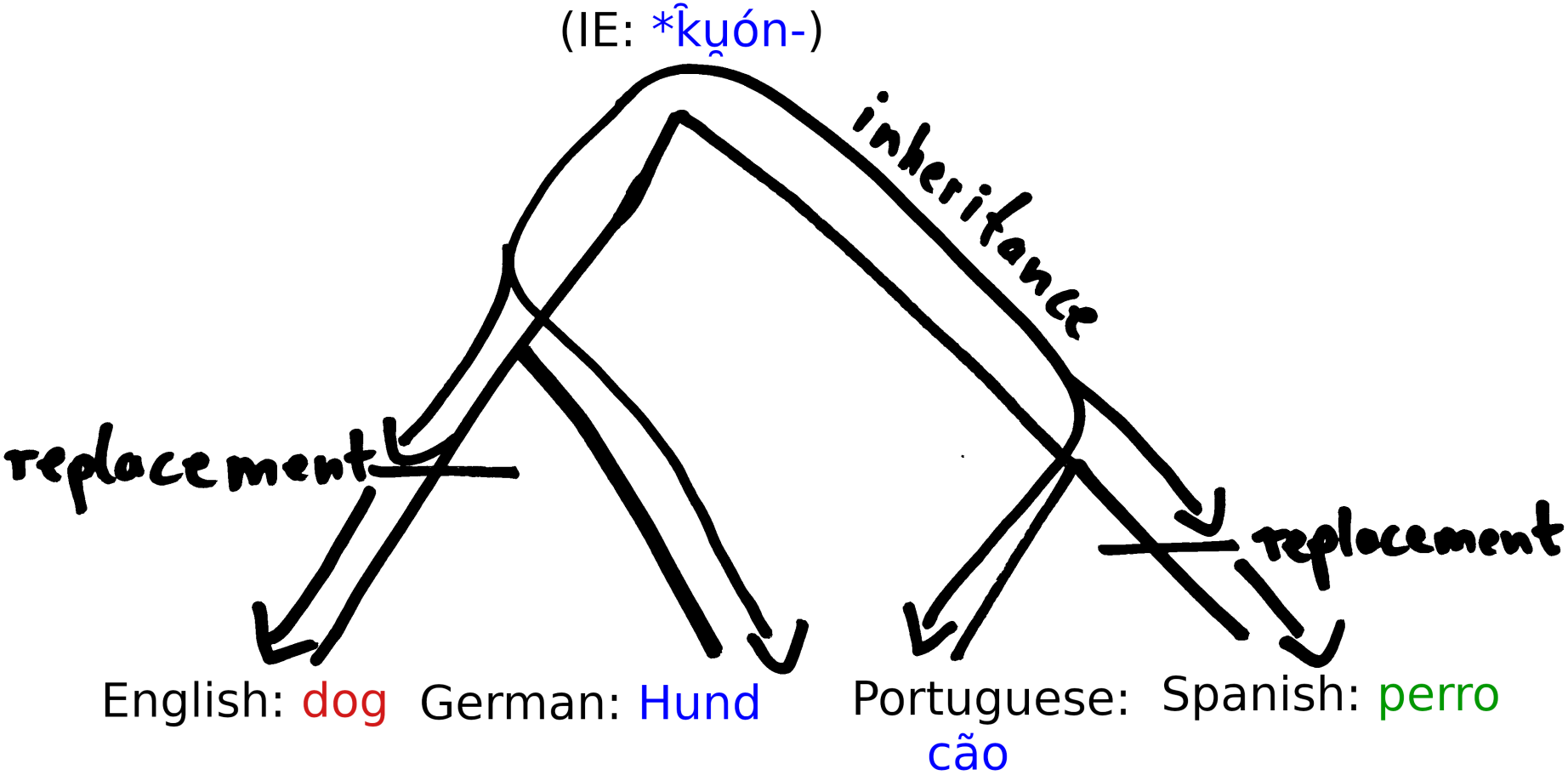
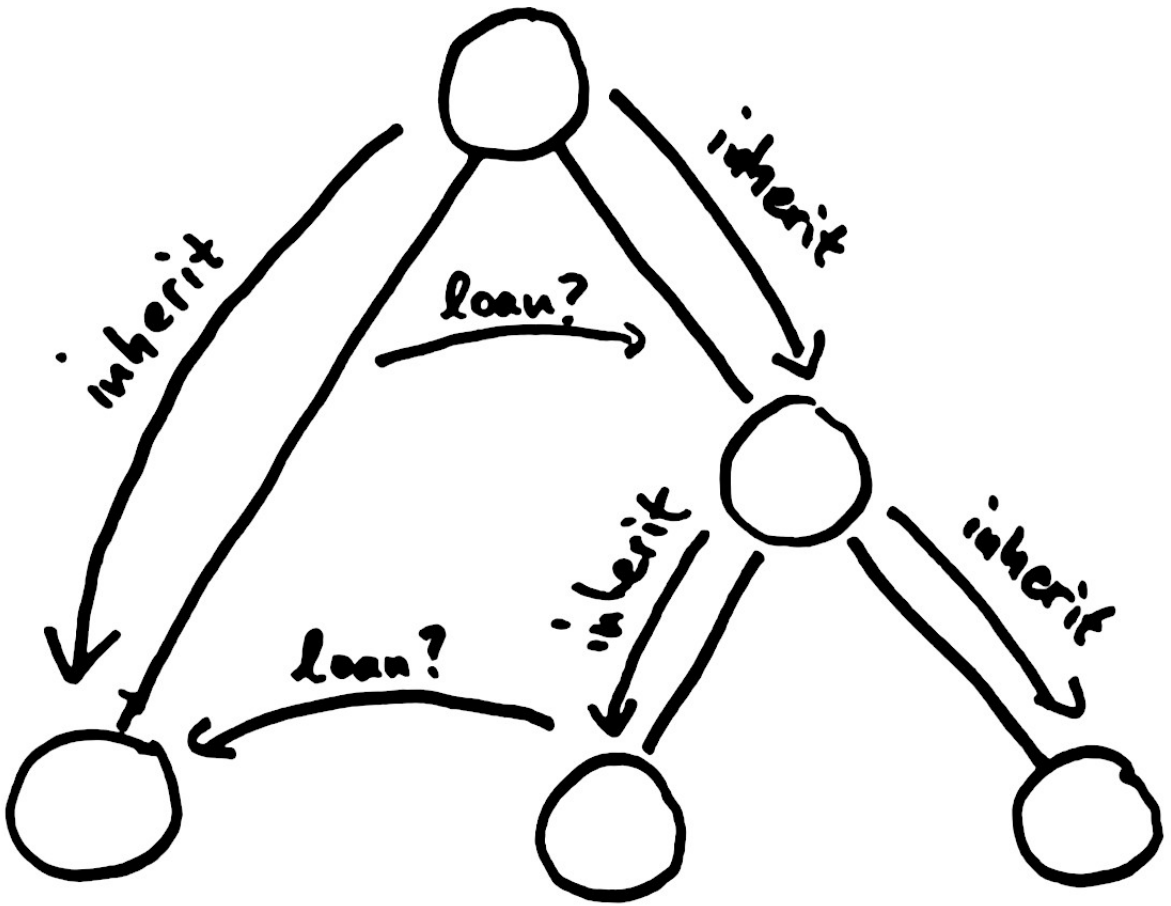


Including loan word process



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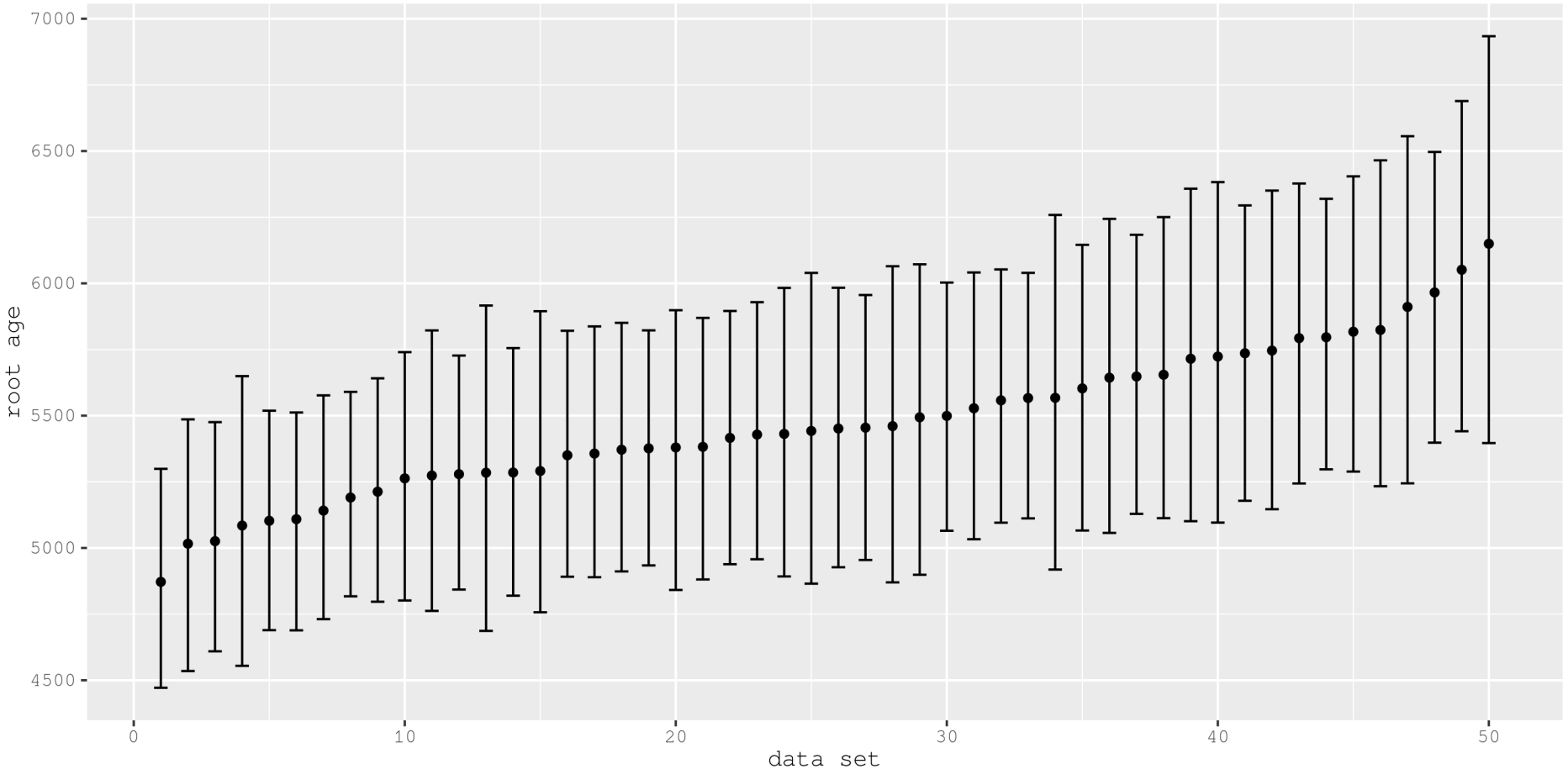
- We just replace the data in the XML-files used by Chang et al. and run them with the Beast-software (Drummond et al. 2012)

Main results for Chang et al.



Inferences of the age of Indo-European (HPD-intervalls and means) from Chang et al.'s main analysis A1 on 50 data sets simulated on our tree

Additional study: Old tree

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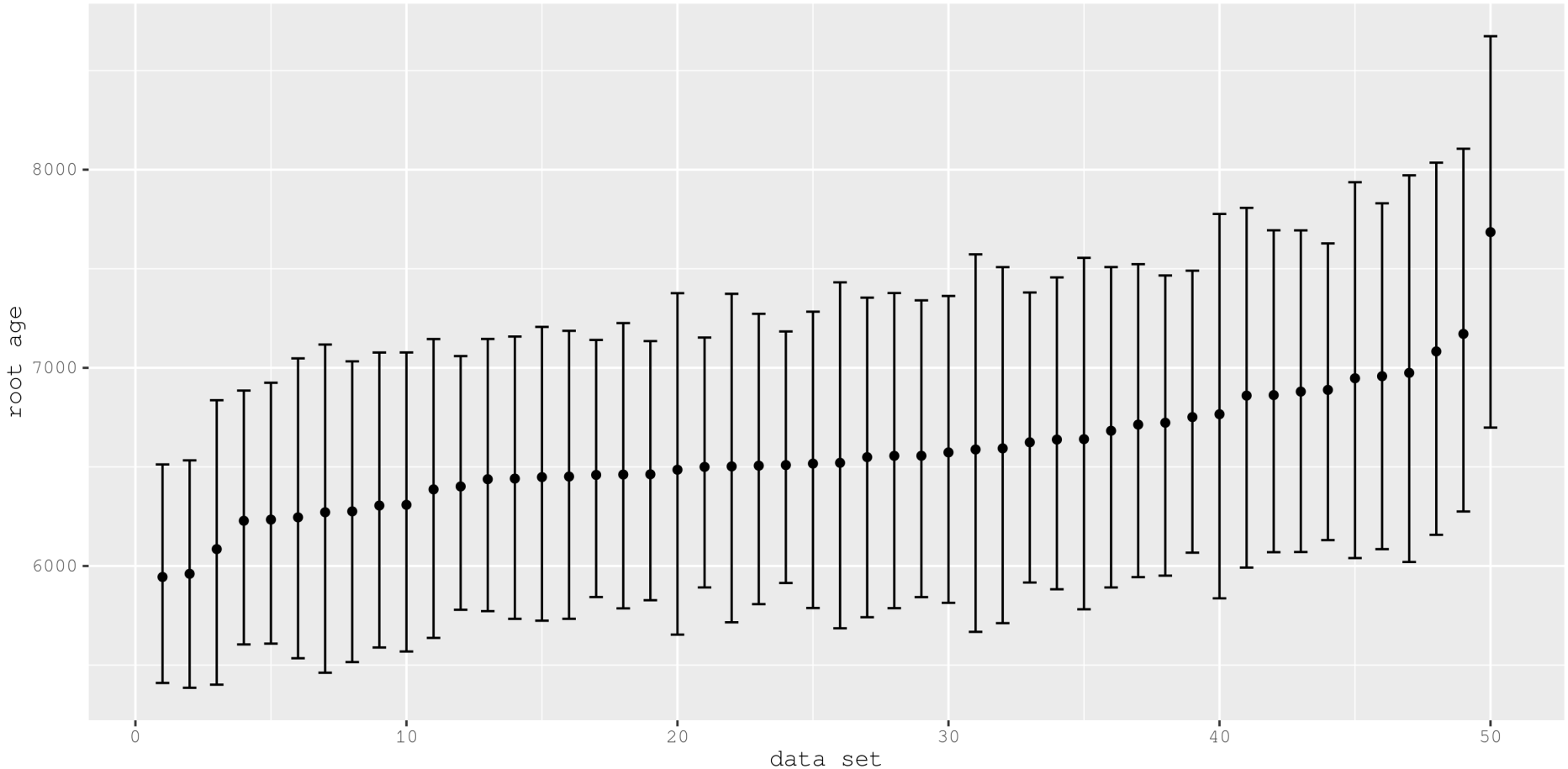
- *Not* as reasonable as our main tree, but still useful as a test

Results for Chang et al. on old tree



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- Since the root age of the old tree (7850 years) is closer to the Anatolian hypothesis, we would want Chang et al. to give negative Bayes factors, that is to not prefer the Steppe hypothesis

Bayes factor test – results

Method	very strong	strong	substantial	weak	negative
A1	39	5	3	2	1
A2	34	5	6	2	3
A3	42	1	6	0	1

Table: Support that the Bayes factor indicates for the Steppe over the Anatolian hypothesis

For most data sets, Chang et al. (2015)'s methods strongly favour the Steppe hypothesis, but there is some fluctuation

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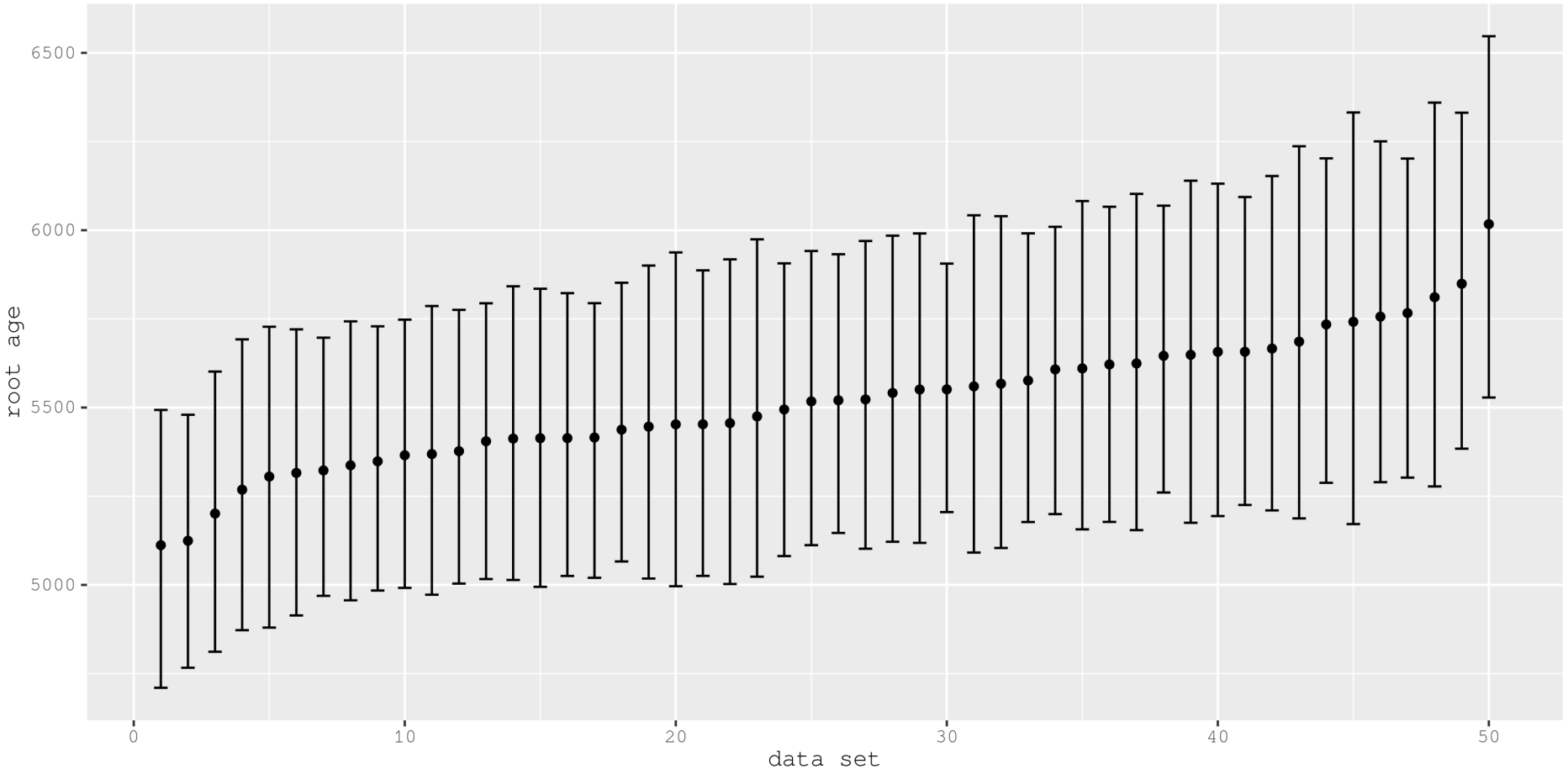
Results Bouckaert et al.



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- Both Chang et al. and Bouckaert et al. tend to underestimate the true tree age by a large margin
- There is considerable fluctuation of the inference depending on the data set (depending on the "randomness" in the data)
- If our simulation model was the "true model", Chang et al.'s method would not be able to correctly distinguish between the Steppe and the Anatolian hypothesis

Our interpretation of results

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1. The realisticness of our simulation model has been disproven
2. It has been shown that that the methods give correct inferences on data sets produced by a variety of different realistic simulation models

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- However, we believe this particular finding should not be overinterpreted – it does *not* imply that the true historic age of Indo-European must be high
- Using other realistic simulated data, maybe the methods would overestimate the tree age

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- Build more refined realistic simulation models, including, for instance, semantic shifts and dialect continua
- Try to evaluate more studies, such as Heggarty et al. (2023)

The end

Thank you for listening!

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