Can the Fisher-Lande Process Account for Birds-of-Paradise and Other Sexual Radiations?

$$\begin{pmatrix} \Delta\bar{z} \\ \Delta\bar{y} \end{pmatrix} = \begin{pmatrix} G & B \\ B & H \end{pmatrix} \begin{pmatrix} \beta_z \\ \beta_y \end{pmatrix}$$

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Argument

- Models of the FLP have been successful, but
- Their predictions are seldom (never?) tested.
- The Phenotypic Tango, a more general version of the model, offers some improvements.
- Its predictions can be evaluated with simulations, but
- Can the Phenotypic Tango account for actual sexual radiations (e.g., the bird-of-paradise radiation)?
- What about popular generic models (BM & OU)? Can they account for the b-o-p radiation?
- Conclusions
- Some directions for the future

Fisher's Insight

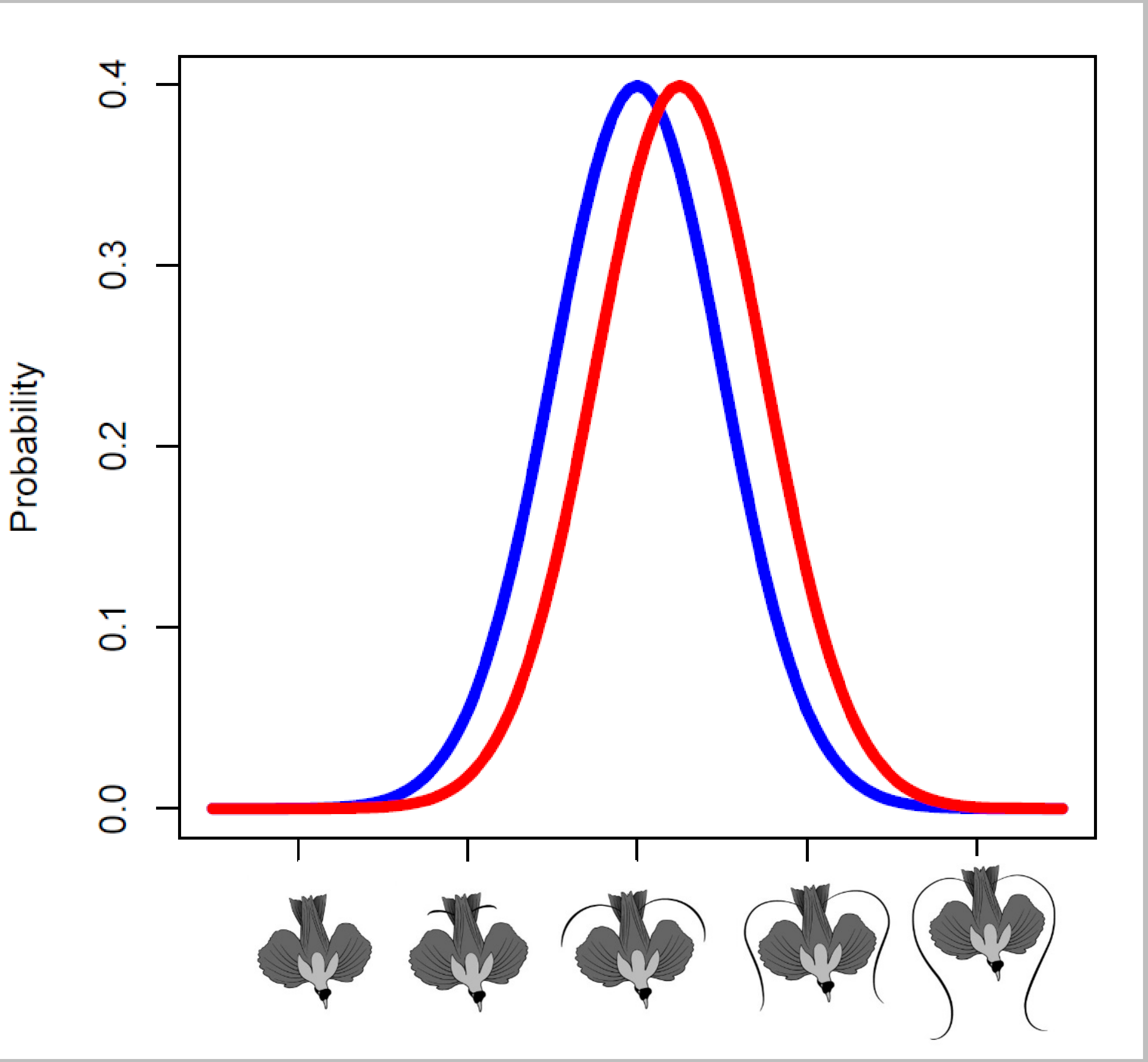
Ronald A. Fisher (1890-1962)

"The two characteristics affected by such a process, namely plumage development in the male, and sexual preference for such development in the female, must thus advance together … with ever-increasing speed."

Fisher 1915, 1930

Lande's model: coevolving within-population distributions of ornaments and preferences

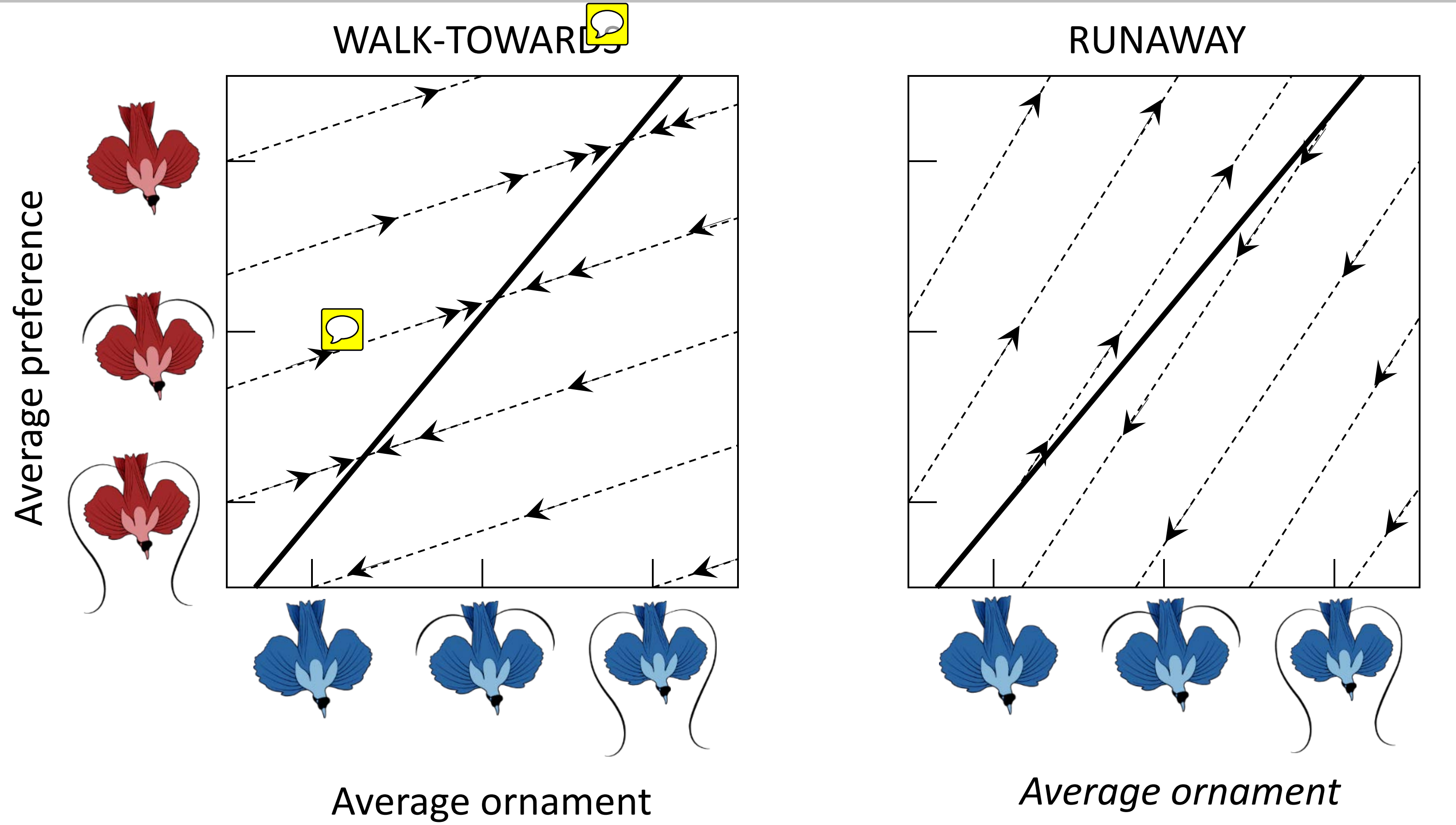
Russell Lande



Ingredients of the Fisher-Lande Process

- A male ornament affects male survival and – via female preference - mating success,
- Female mating preference is based on the ornament but does not affect the survival or fecundity of the female.
- Both traits are heritable and – because of assortative mating and sexual selection on males – genetically correlated.

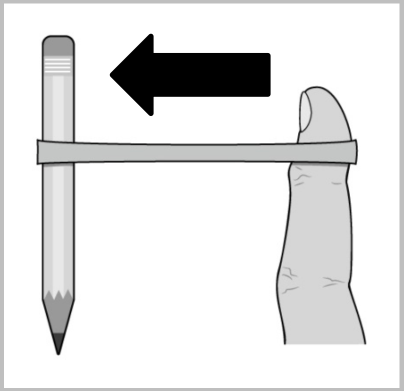
Walk-towards and Runaway Outcomes

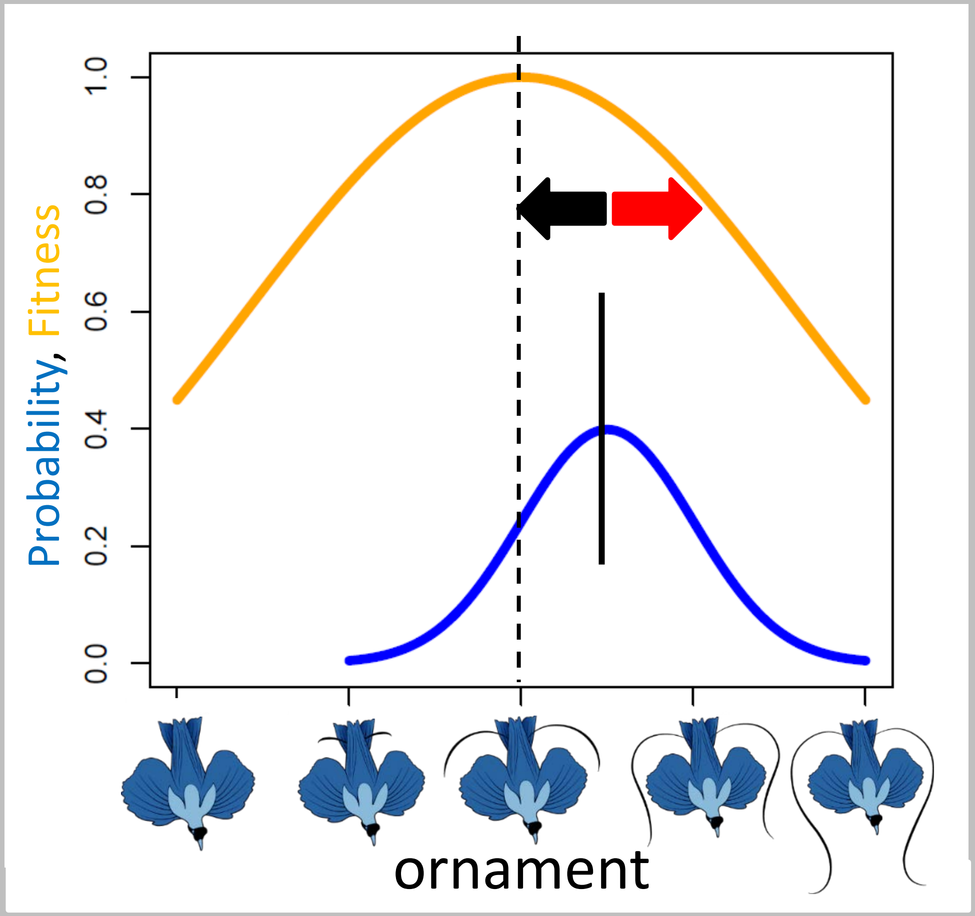


Lande 1981

Stabilizing natural selection towards an intermediate ornament optimum

balanced by opposing sexual selection



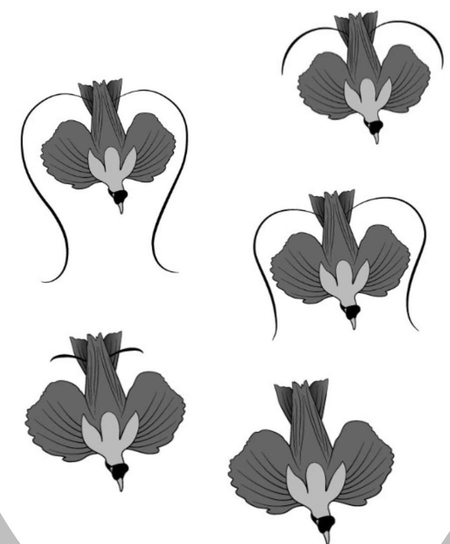


Problem: failure to connect the models with real sexual radiations

models

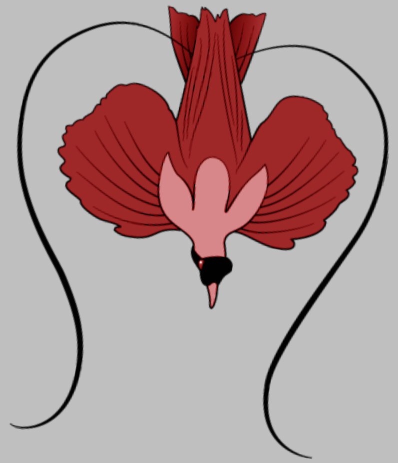
$$\begin{pmatrix} \Delta\bar{z} \\ \Delta\bar{y} \end{pmatrix} = \begin{pmatrix} G & B \\ B & H \end{pmatrix} \begin{pmatrix} \beta_z \\ \beta_y \end{pmatrix}$$

nature



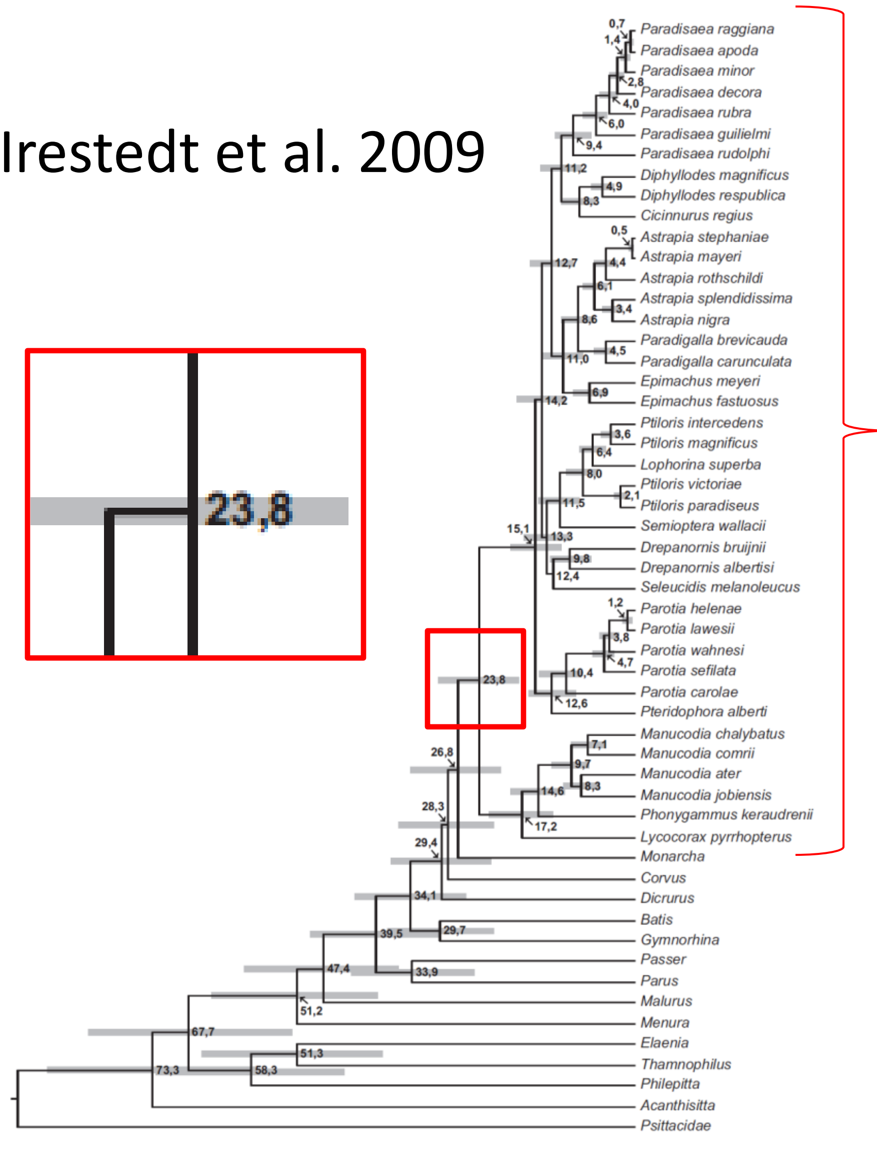
Solution: Birds-of-Paradise, an Iconic Sexual Radiation

- Time-calibrated phylogeny
- Male display and female choice
- Morphological components of male display
- Data on male morphology



Diversification over 23 million years

Irestedt et al. 2009



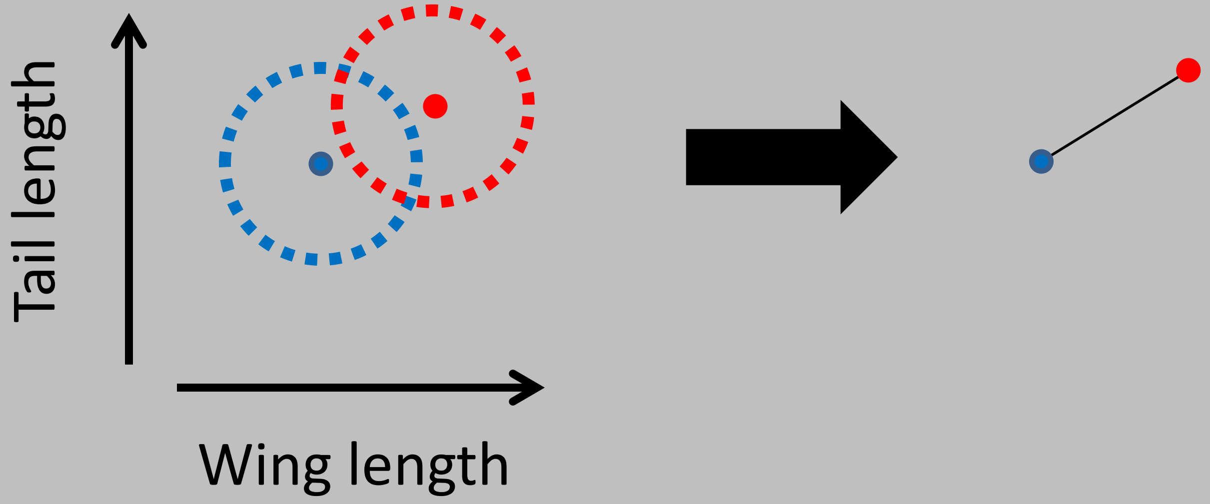
Special features of plumage presented during male displays

https://www.facebook.com/Birds.Lovers.1/videos/1003571246388699/

Phenotypic tango: a more general model of the FLP

- Two male display traits (ornaments)
- Two female preference traits
- Selection on female preference
- Finite population size

Graphical Conventions



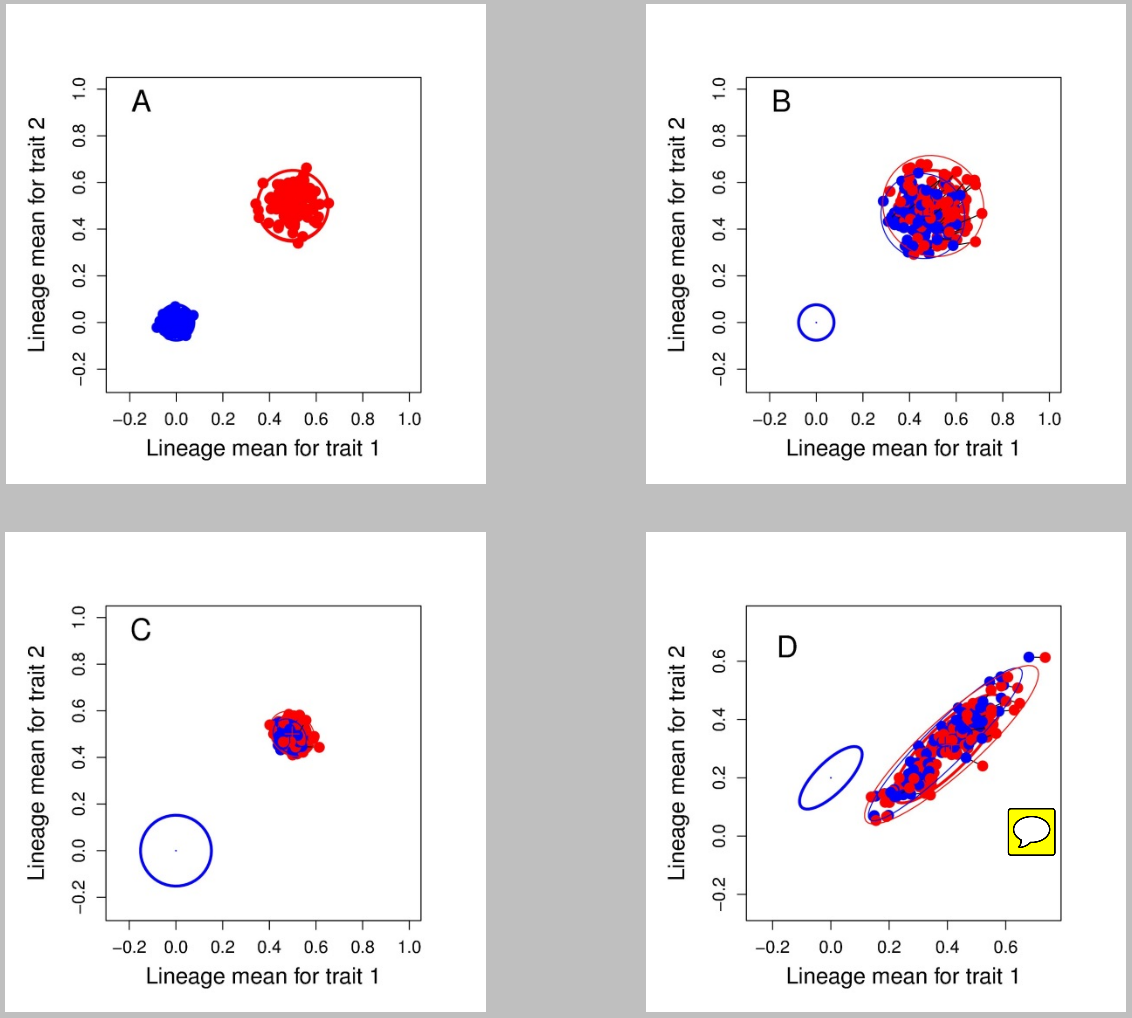
Phenotypic tango: a more general model of the FLP

- GOOD NEWS! - Model more general than past versions

- BAD NEWS! – No analytical solution for model

- MORE GOOD NEWS! – Can determine the model's behavior with simulations

Phenotypic tango: evaluating the model's behavior with simulations



Phenotypic tango: evaluating the model's behavior with simulations

For animations, see

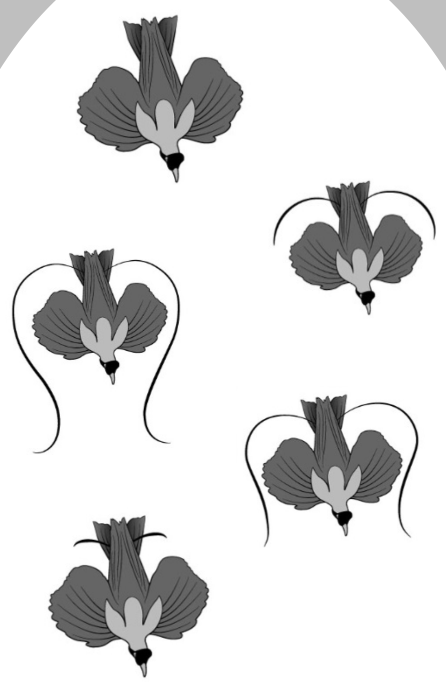
http://phenotypicevolution.com/?p=221

These animations will not run in Chrome

Accounting for the Bird-of-Paradise radiation with the Phenotypic Tango model

$$\begin{pmatrix} \Delta\bar{z} \\ \Delta\bar{y} \end{pmatrix} = \begin{pmatrix} G & B \\ B & H \end{pmatrix} \begin{pmatrix} \beta_z \\ \beta_y \end{pmatrix}$$

data



Phenotypic differentiation in the genus **Paradisaea** *over 9 million years*

rudolphi

guilielmi

rubra

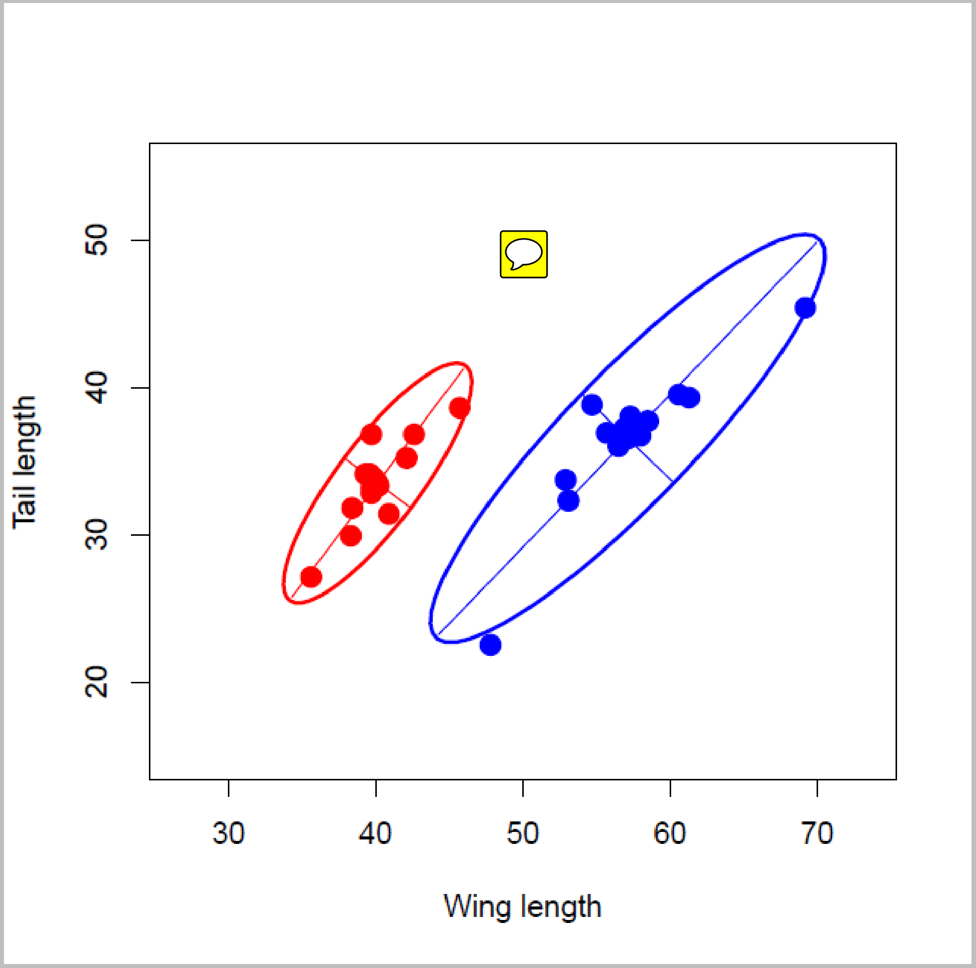
decora

minor

apoda

raggiana

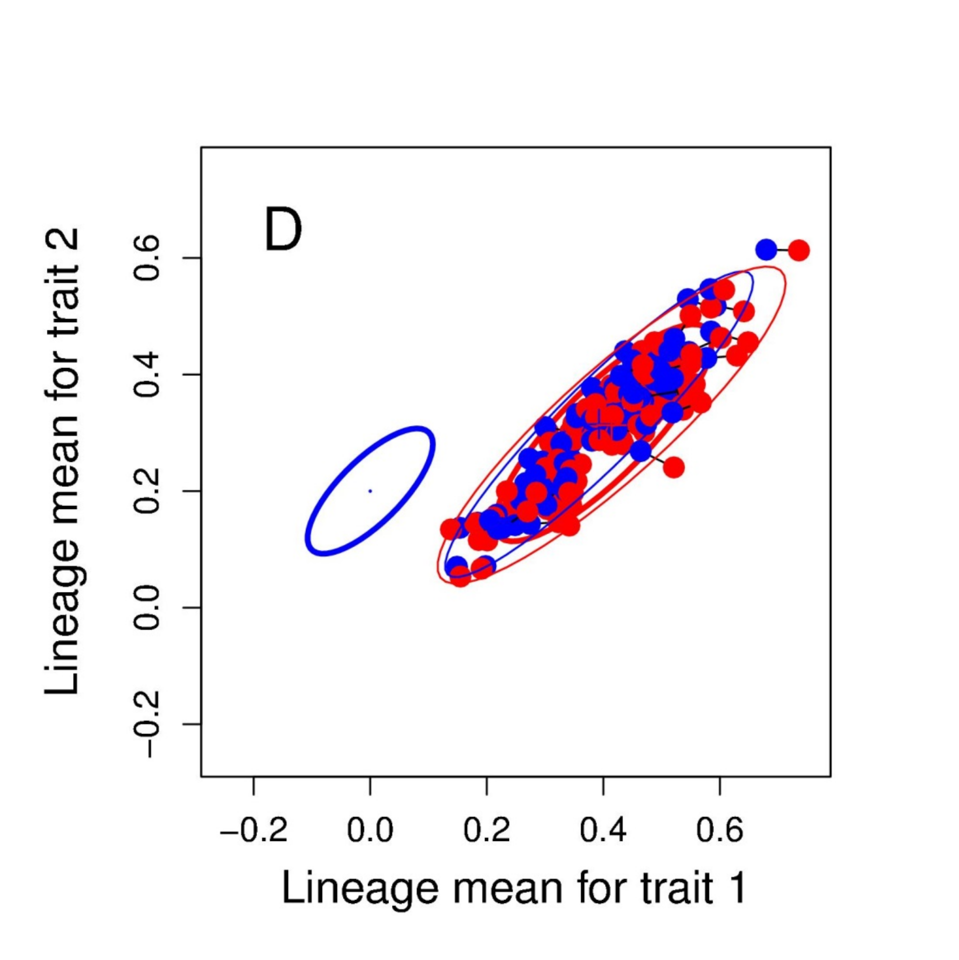
How much evolution? ± 12 phenotypic standard deviations in 188,000 generations



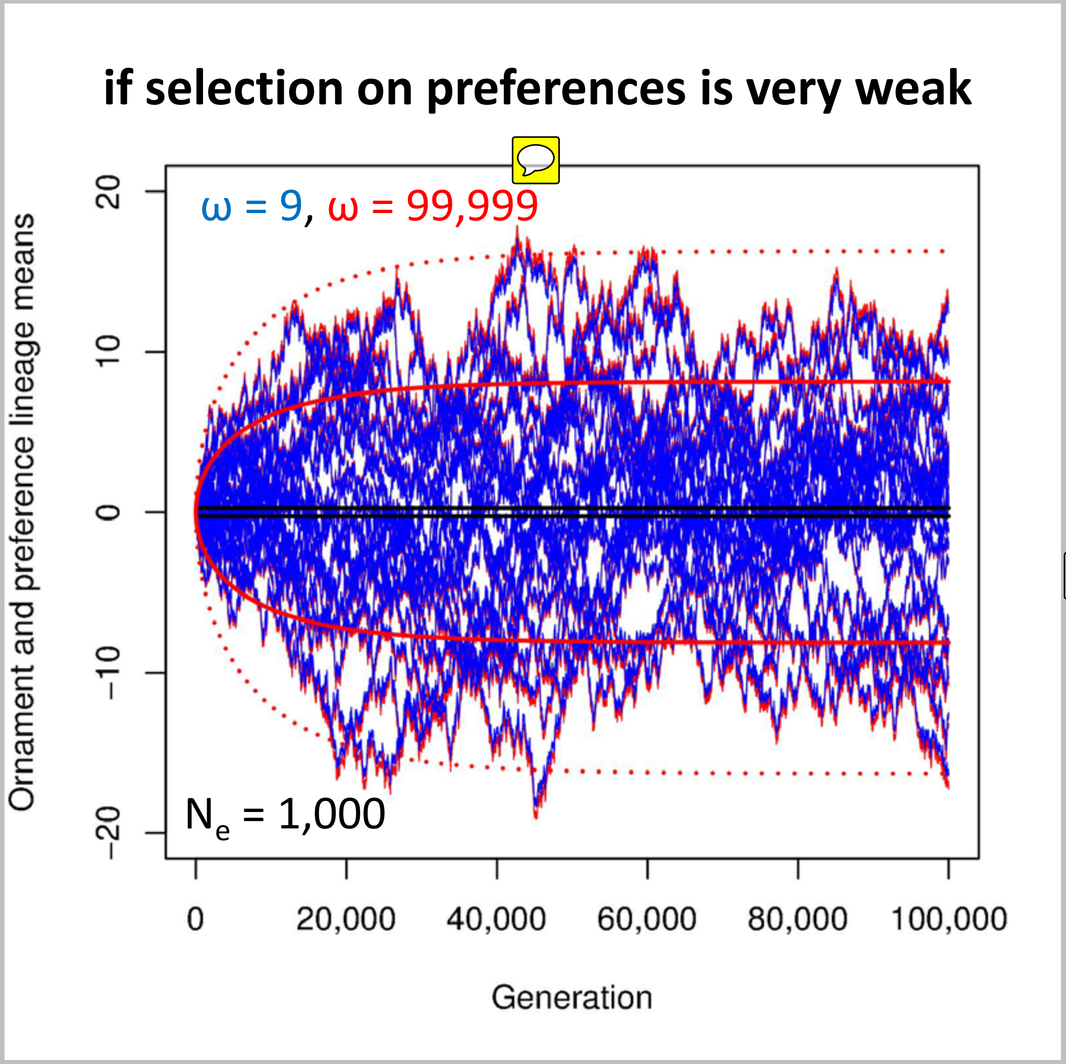
Mary LeCroy

LeCroy 1981

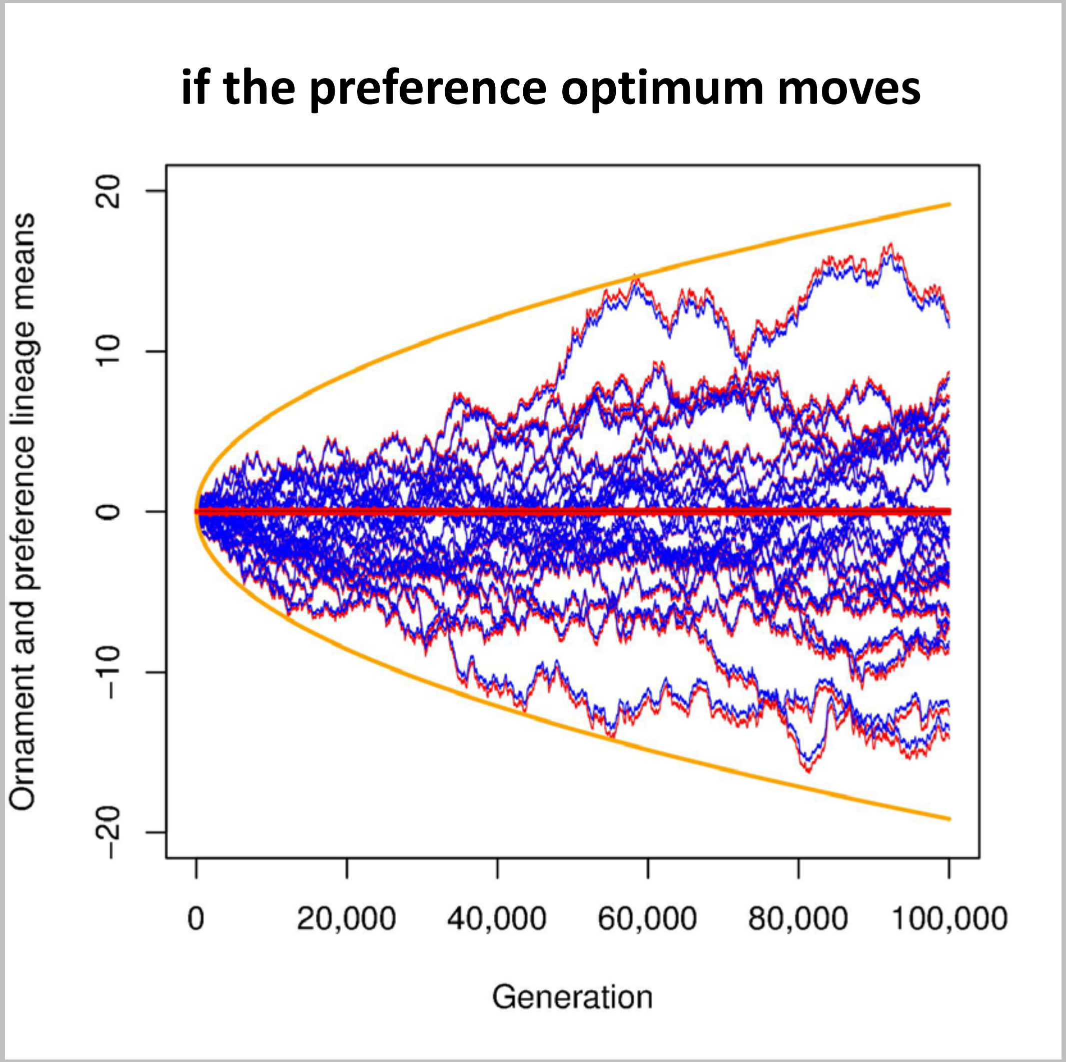
The Phenotypic Tango can account for bivariate patterns in the data



*The **Phenotypic Tango** can account for the observed amount of diversification*



The Phenotypic Tango can account for the observed amount of diversification



Conclusions using the Phenotypic Tango model

- Evolving preferences control the evolution of ornaments
- Can account for diversification patterns in single and multiple ornaments
- To account for the extent of ornament diversification on right timescale, we need to invoke:
  - Very weak stabilizing selection on preferences and relatively small effective population sizes
  - Or natural selection optima must move at a modest rate

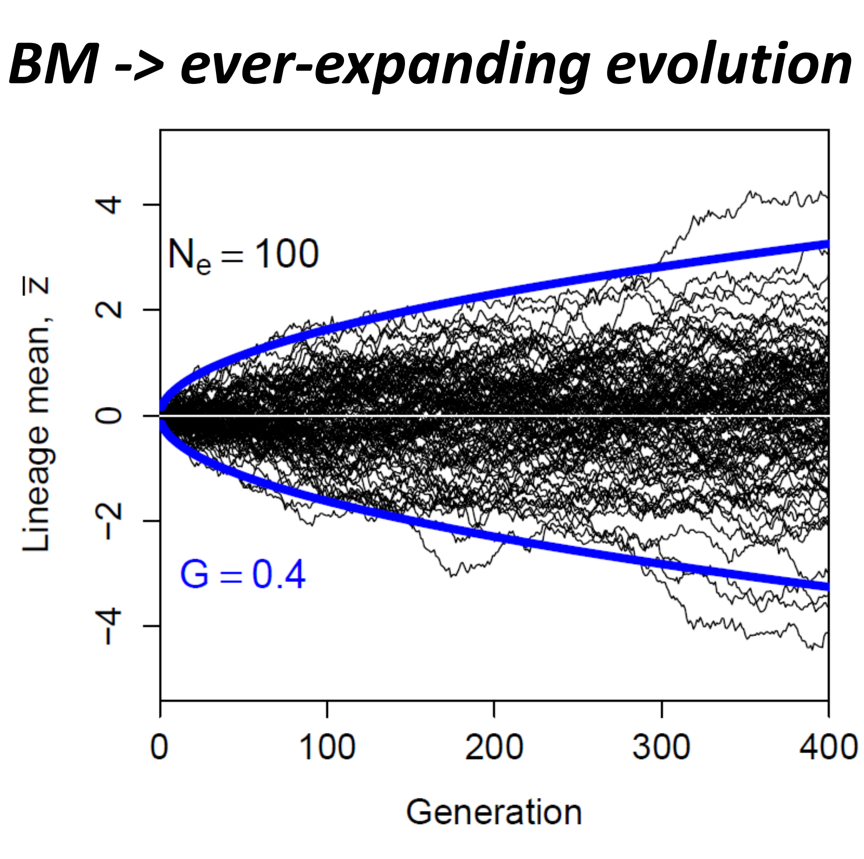
Accounting for the Bird of Paradise radiation with generic models: Brownian motion & Ornstein-Uhlenbeck

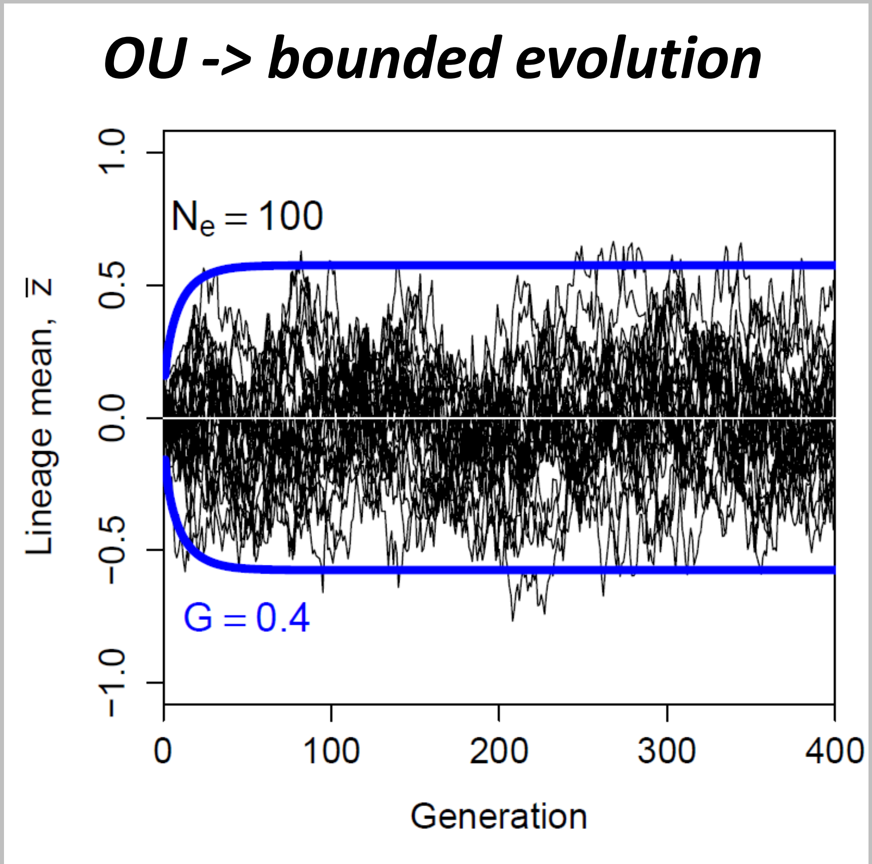
- GOOD NEWS! – Analytical solutions available.
- BAD NEWS! – The parameters we estimate confound inheritance, selection, and pop. size.
- GOOD NEWS! – We can account for phylogeny.
- GOOD NEWS! – We can use likelihood to compare alternative models

Accounting for the Bird-of-Paradise radiation with generic models

- The contrast between Brownian Motion (BM) and Ornstein-Uhlenbeck (OU) models
- Testing model predictions on the Bird-of-Paradise tree
- Do we need more than one selection regime (poor man's version of moving optimum) to account for the data?
- Can we use this framework to estimate FLP parameters?

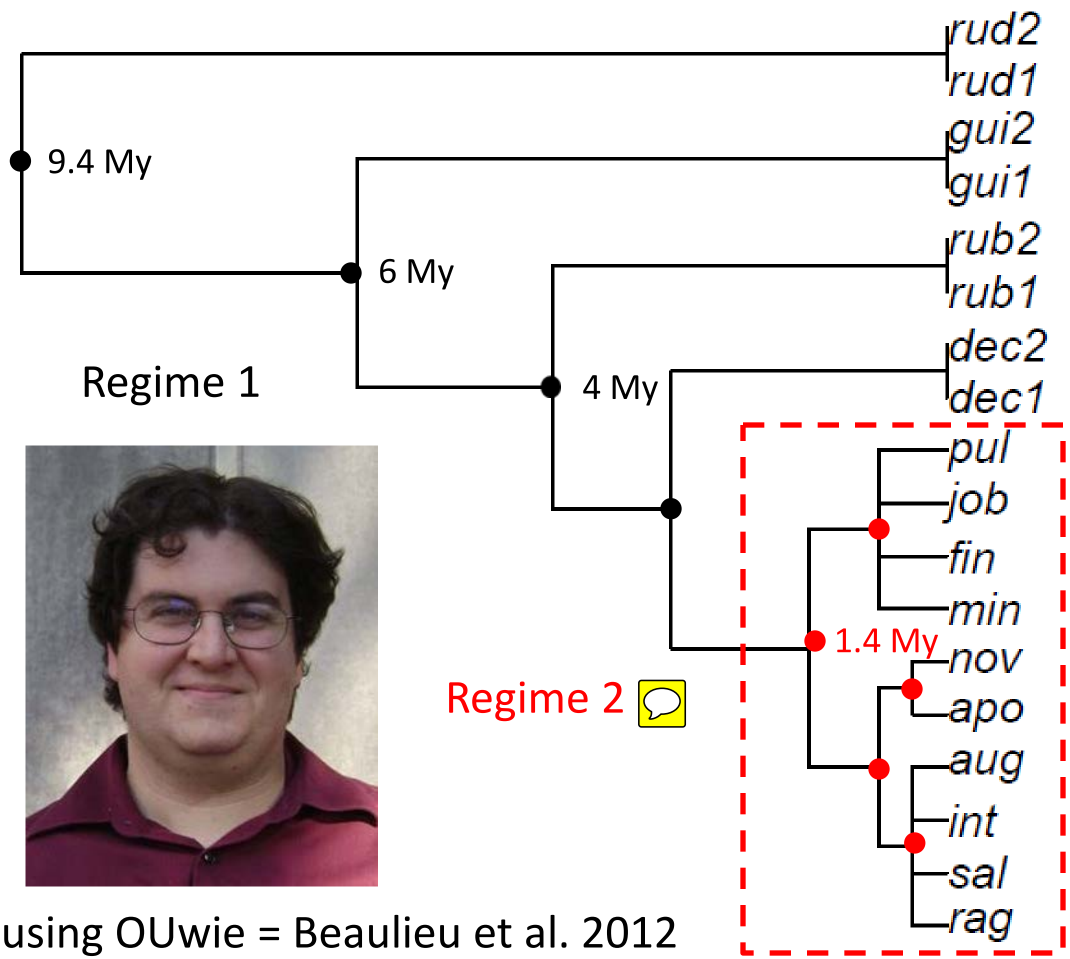
Contrasting model predictions



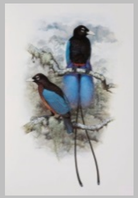


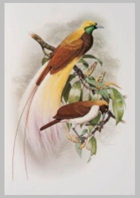
Two versions: genetic drift or Brownian motion of peak

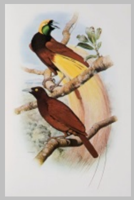
Tree for the genus Paradisaea: two hypothetical selection regimes



using OUwie = Beaulieu et al. 2012







Tests of alternative generic models: using generic BM & OU parameters in OUwie

Table 3. Comparison of Brownian Motion and Ornstein-Uhlenbeck model fits			
model	ΔAICc	Regime 1	Regime 2
BMS	**0.00**	$\boldsymbol{\sigma^2 = 3.18}$	$\boldsymbol{\sigma^2 = 110.81}$
OUM	**1.11**	$\boldsymbol{\sigma^2 = 443.51}$, **θ = 52.60, α = 12.49**	$\boldsymbol{\sigma^2 = 443.51}$, **θ = 59.29, α = 12.49**
OU1	**3.80**	$\boldsymbol{\sigma^2 = 165.39}$, **θ = 55.13, α = 3.14**	
BM1	**6.08**	$\boldsymbol{\sigma^2 = 72.42}$	

σ^2 = stochastic diversification rate = increase in among-lineage variance in trait means per 200,000 generations

θ = phenotypic optimum

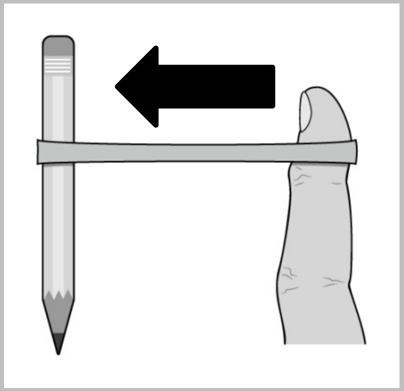
α = restoring force, the rubber band in the OU process

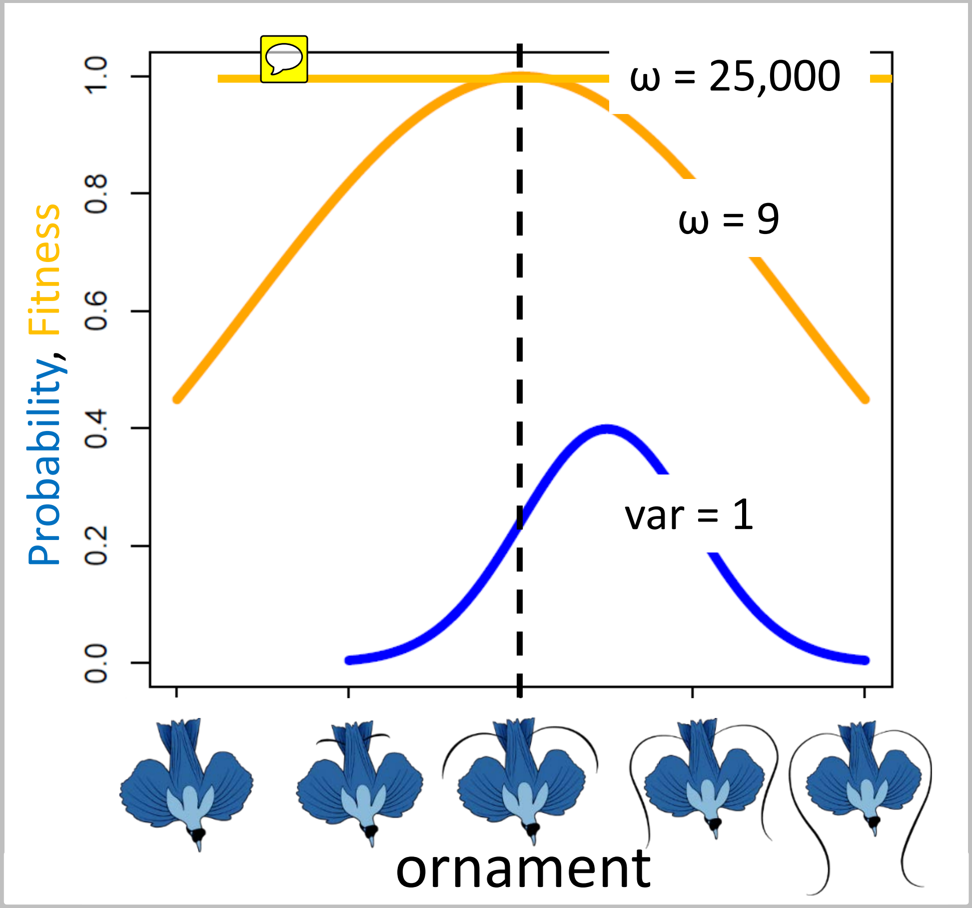
Tests of alternative generic models: using quantitative genetic parameters

Table 4. Comparison of Brownian Motion and Ornstein-Uhlenbeck model fits			
model	AICc	Regime 1	Regime 2
BMS	**0.00**	**N_e = 25,157; var_θ = 0.000016**	**N_e = 722; var_θ = 0.00055**
OUM	**1.11**	**ω = 6,404**	
OU1	**3.80**	**ω = 25,477**	
BM1	**6.08**	**N_e = 1,105; var_θ = 0.00036**	

Under the genetic drift interpretation of BM, $\sigma^2 = tG/N_e$, solve for N_e; or under moving optimum interpretation of BM, $\sigma^2 = t\, var_\theta$, solve for var_θ.
Using the OU models, solve $\alpha = tG/(\omega + P)$ for ω = width of fitness function, analogous to a variance.

Visualizing very weak stabilizing selection



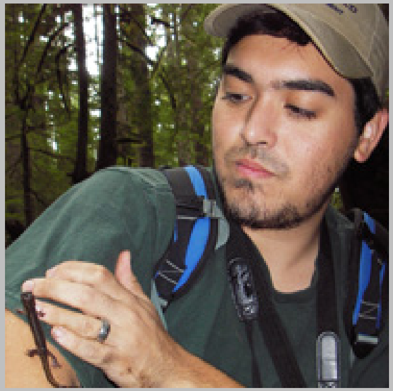


Conclusion using generic models (OUwie): need moving peaks

- Brownian motion of a natural selection optimum for preferences is the best-fitting and most plausible model for the data.
- This conclusion is consistent with results using the Phenotypic Tango model.
- BM of an intermediate optimum may be a reasonable model for adaptive radiations in general.

The Future

- Need solution for Phenotypic Tango model
- Need a version of the model that includes peak movement
- Need better data and more of it
- Need testing framework for model that incorporates prior information and estimates multivariate quantitative genetic parameters



bayou

Uyeda & Harmon 2014

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NIMBioS
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