Unsuspected structural diversity in multilayers producing iridescent colours in hummingbirds

A new light on an old question

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- Courtship / Mate choice
- Crypsis / Masquerade
- Disruptive colouration
- Aposematism
- Aggressive display

Iridescent colour

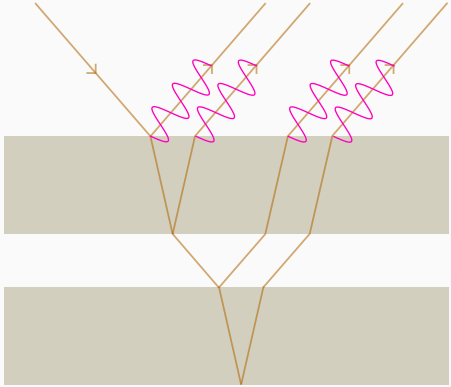
Colour that changes depending on the angle of illumination or observation.

Calypte anna, from a Mick Thompson video (CC-by-nc)

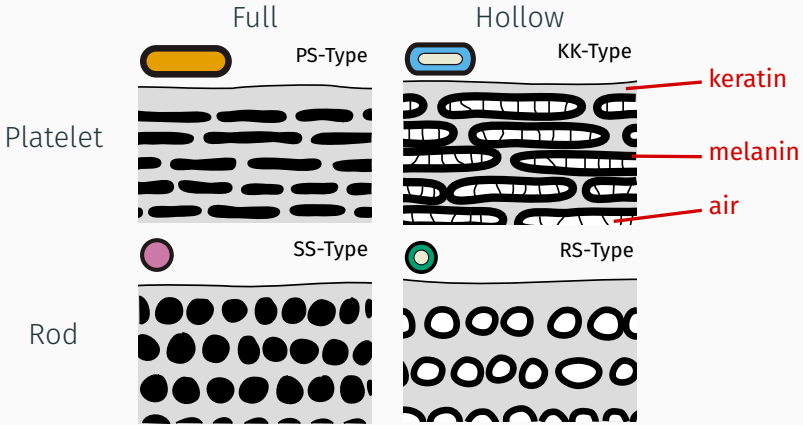
What are the structural causes of the diversity in iridescent signals in hummingbirds?

Dürrer (1975): Schillerfarben der Vogelfeder als Evolutionsproblem

Iridescence is produced by interferences in multilayer structures:

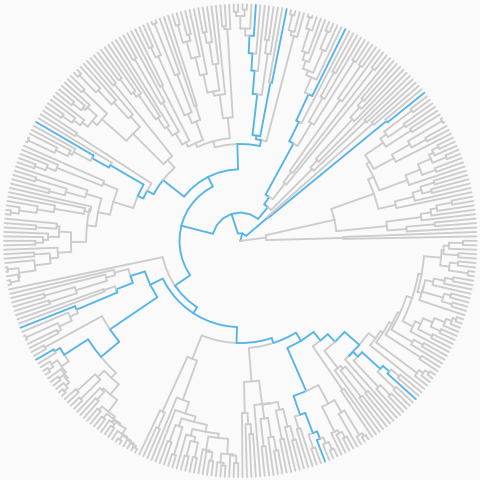


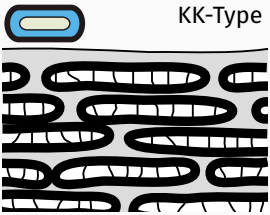
4 main types of melanosomes:



Dürrer (1975): Schillerfarben der Vogelfeder als Evolutionsproblem

(*Amazilia cyanura* melanosomes, from Dürrer 1975)

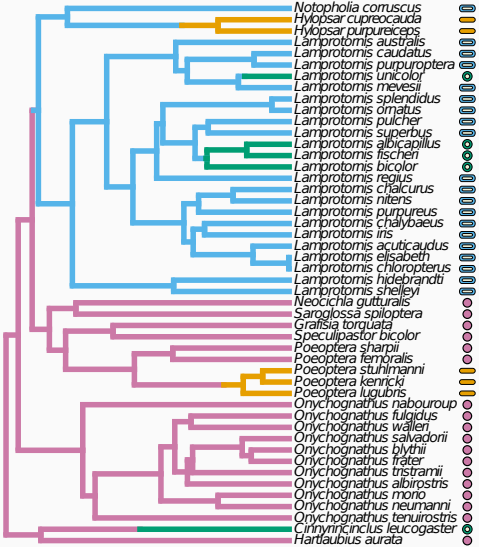


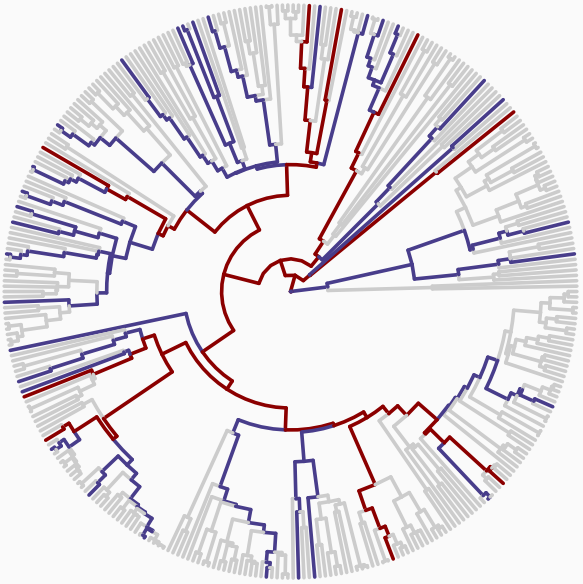


Greenewald *et al.* 1960, Schmidt and Ruska 1962, Dürrer 1975, Shawkey *et al.* 2009

Melanosome types in the African starlings (*Sturnidae*):

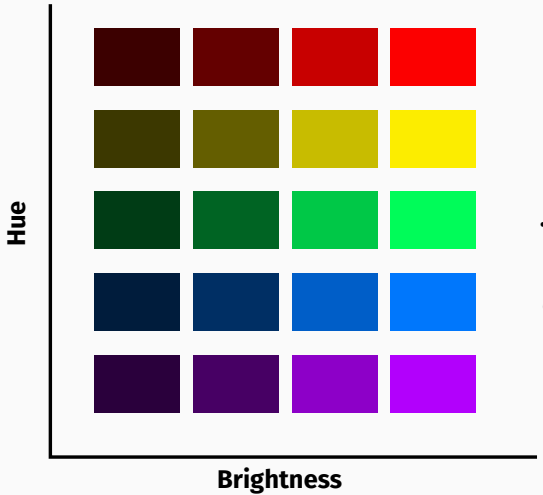
Adapted from Maia *et al.*, PNAS 2013

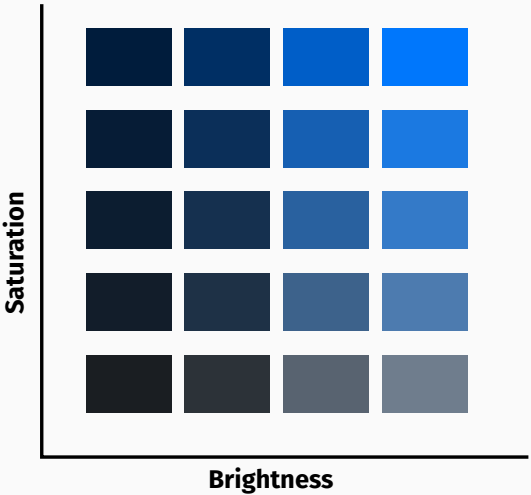




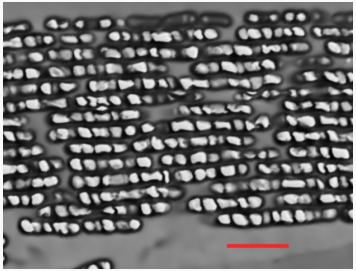
Literature

Own measurements

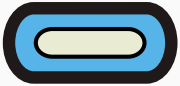

Hue
Brightness

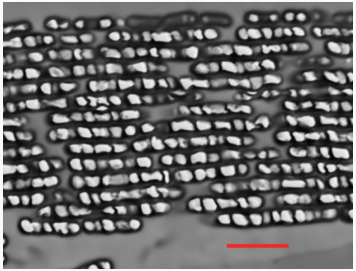

Saturation
Brightness

Transmission Electron Microscopy



Hollow / KK-Type





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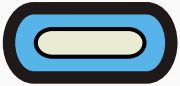
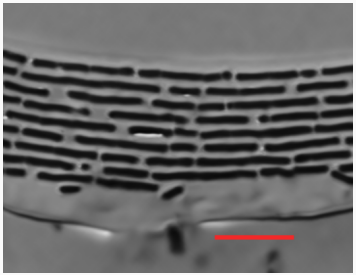
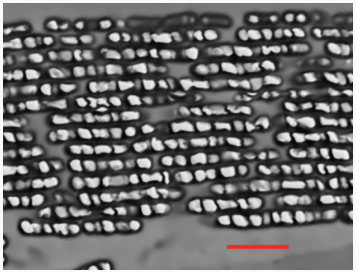
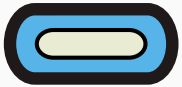


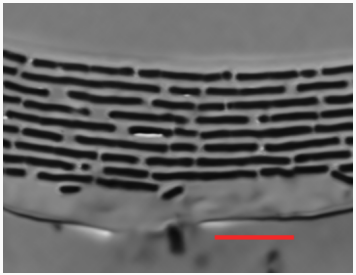


Full / PS-Type

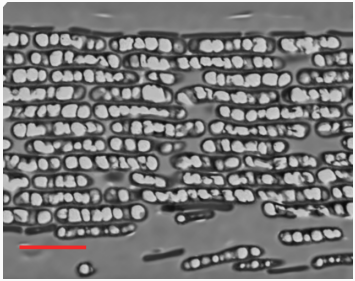


Hollow / KK-Type



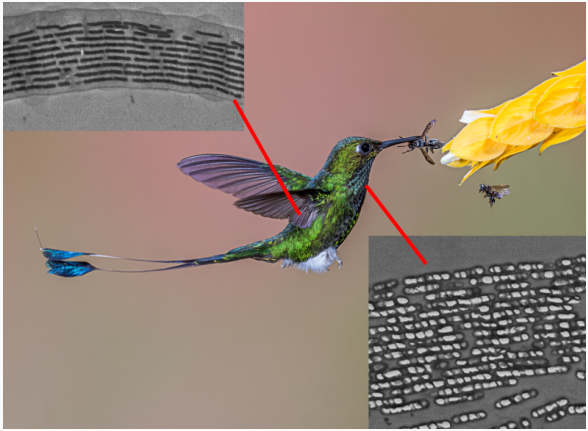


Full / PS-Type

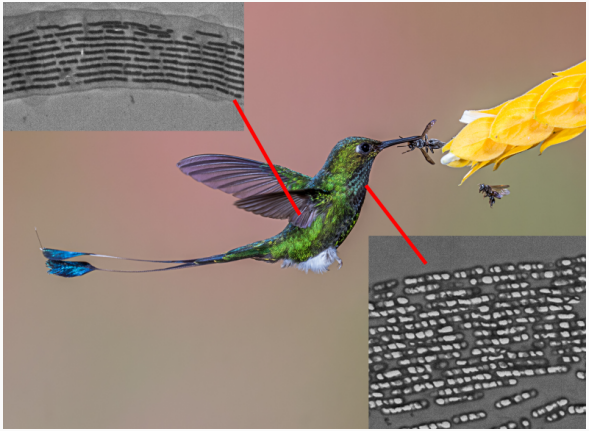


Outer

raggedleft = 1 µm



Multiple melanosome types per species depending on the patch!

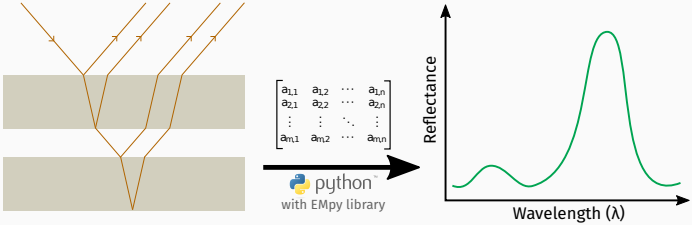


Multiple melanosome types per species depending on the patch!

Outer type more common on patches used in communication such as throat and crown

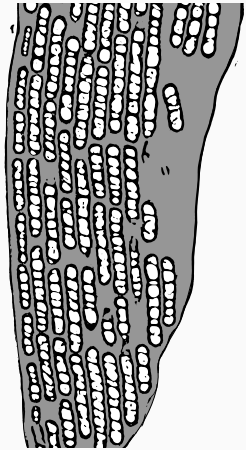
➜ Different types of colours?

Optical simulations



Simulation results depend on many parameters:

- Number of layers
- Size of air gaps within melanosomes
- Size of melanin borders of melanosomes
- Size of keratin gaps between melanosomes
- Angle of the multilayer structures



Multilayer structure in *Lophornis ornatus* throat feathers

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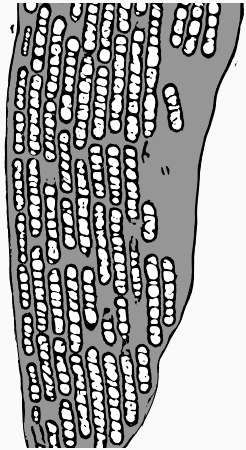


Multilayer structure in *Lophornis ornatus* throat feathers

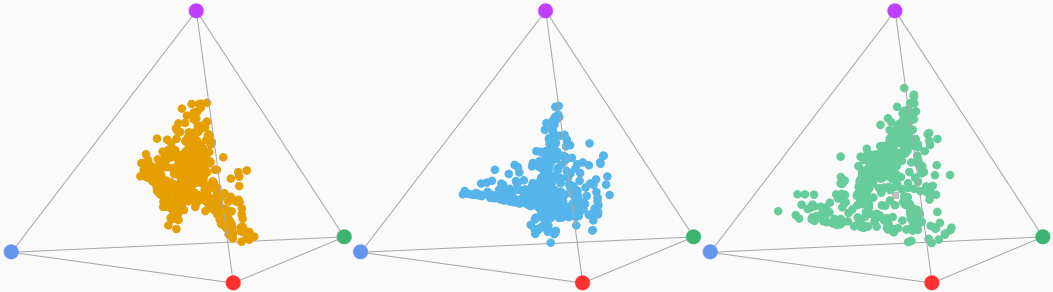
➔ Monte Carlo simulations

Monte Carlo simulations:

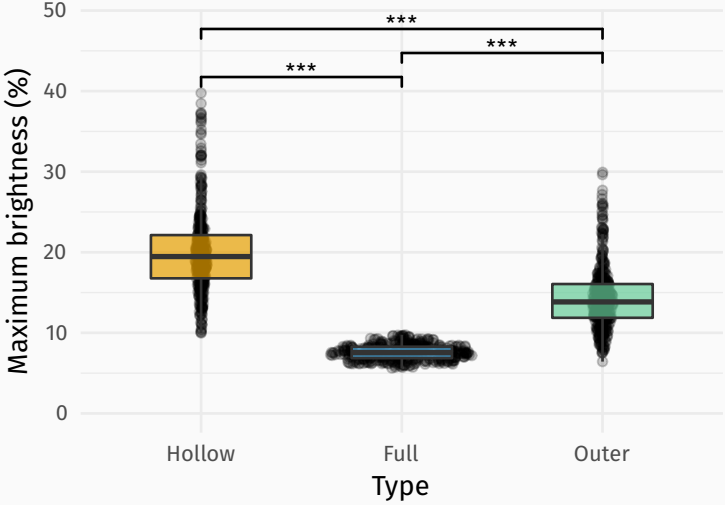
1. Random draw of parameters (parameters range derived from TEM measurements)
2. Run simulations process
3. Repeat enough times to explore the full range of possibilities

Monte Carlo simulations:

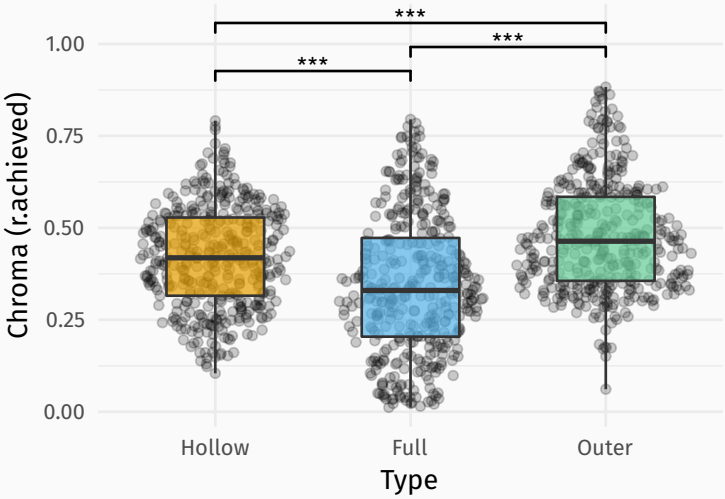
Hue in avian colour space (using Endler & Mielke 2005):



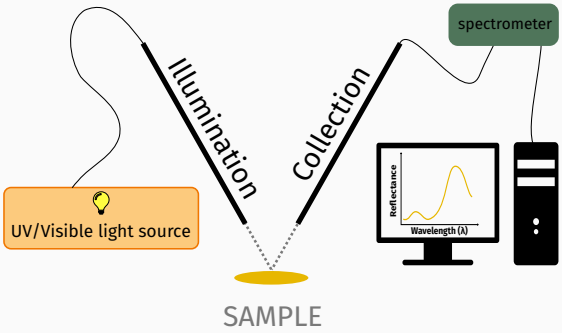
Monte Carlo simulations:

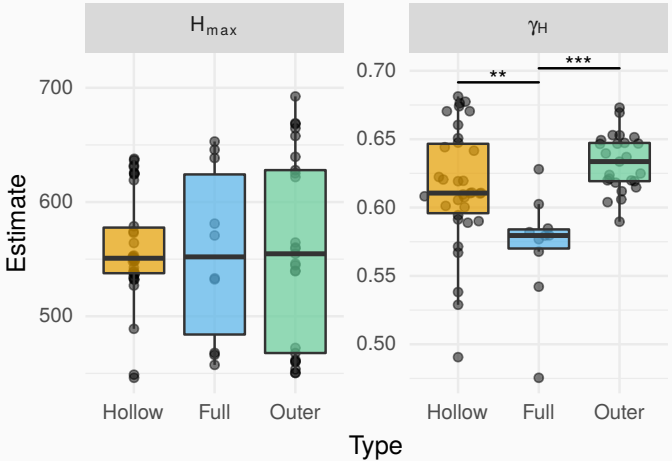


Monte Carlo simulations:

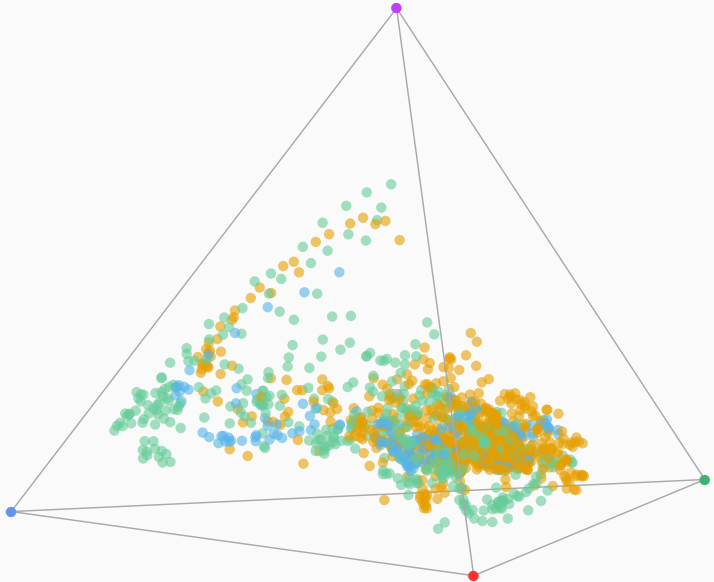


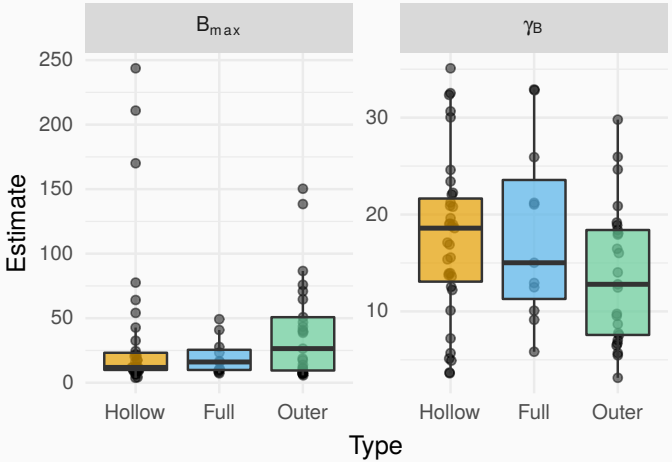
Influence of structures on colour





H_{max}: Maximum hue
γ_H: Angular dependency of hue


Empty
Full
Outer



- B_{max}: Maximum brightness
- γ_B: Angular dependency of brightness

Conclusion

Hummingbirds use more diverse structures than previously thought:

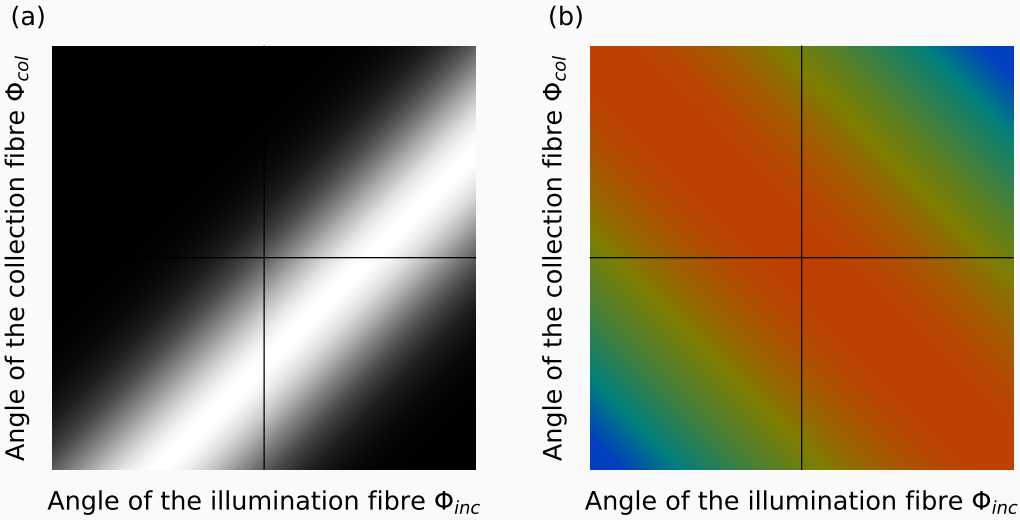
- 3 different types of multilayer structures instead of just one
- Multiple types depending on the patch location

Hummingbirds use a unique structure type to produce colours that maximize both brightness and saturation

Acknowledgments

- Doris Gomez
- Marianne Elias
- Christine Andraud
- Claire Doutrelant
- Willy Daney de Marcillac
- Serge Berthier
- Chakib Djediat


Thank you
for your attention!



Gruson *et al.*, Interface focus, in review.