New insights in the measurement and characterization of iridescent colours

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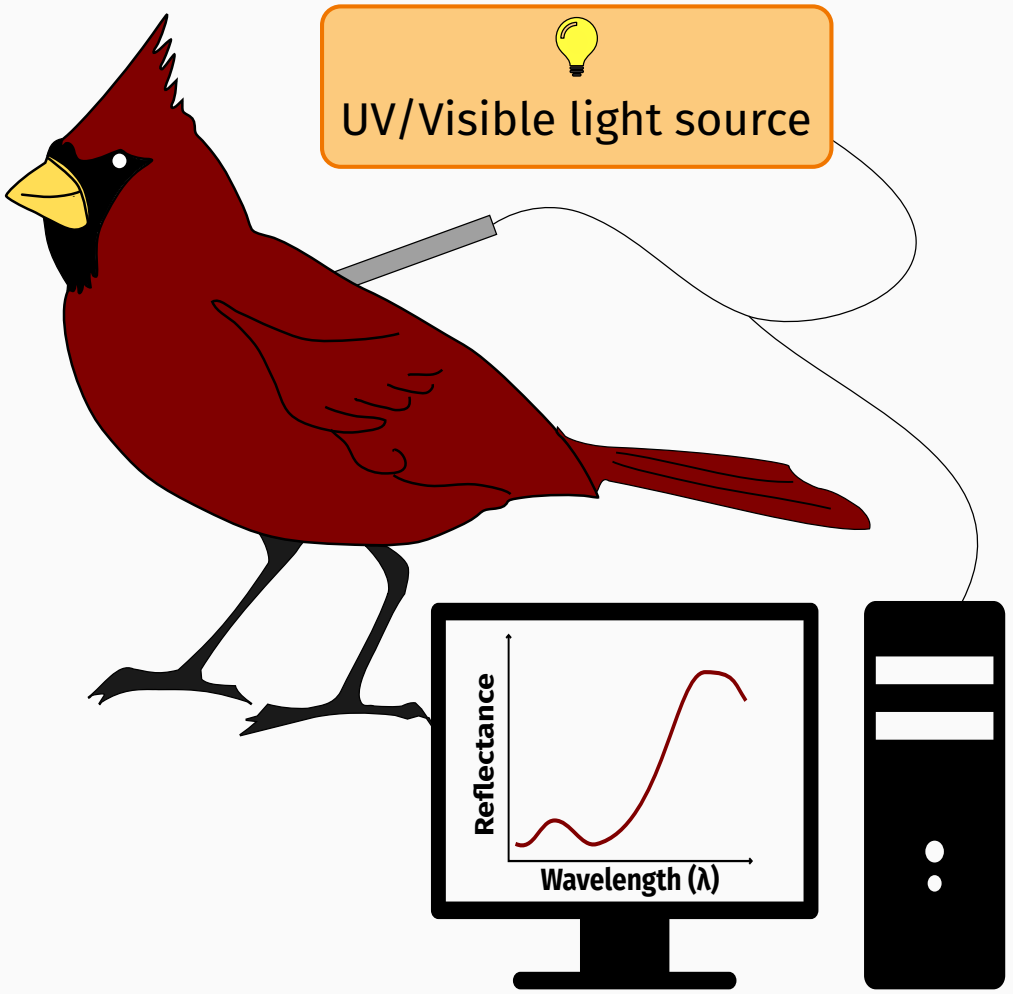
CENTRE D'ECOLOGIE FONCTIONNELLE & EVOLUTIVE

- Inter/intraspecific communication
- Phenotypic plasticity
- Local adaptation
- Evolutionary trade-offs

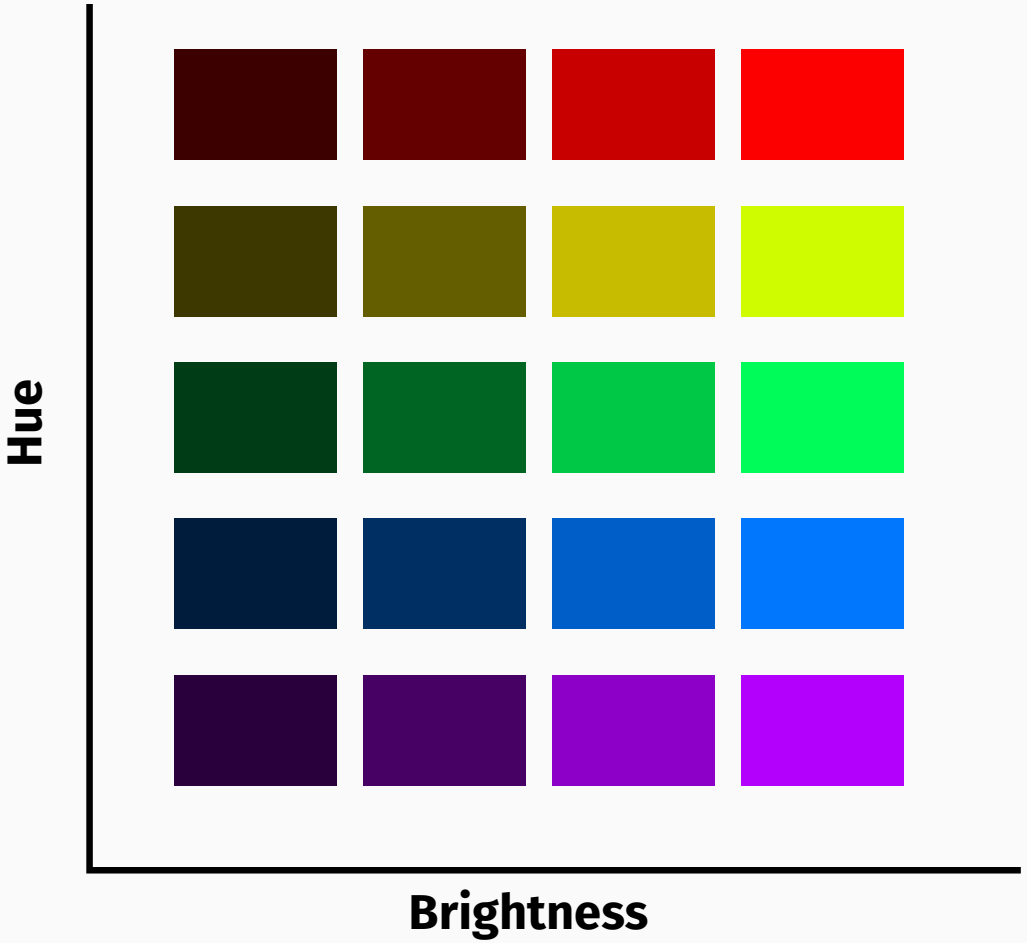
How do we traditionally measure colours?



- Visible/UV light source
- Fixed bifurcated probe at 45°
- Spectrophotometer

Usual indices to describe non-iridescent colours

- Hue
- Brightness



What are iridescent colours?

Iridescent colour

Colour that changes depending on the angle of illumination or observation (≈ glittering / shining colours).







Cuckoo wasp, by Frank Vassen

Functions of iridescent colours?

- More conspicuous/efficient communication signal?
- More versatile communication signal?
- Non-communication role?

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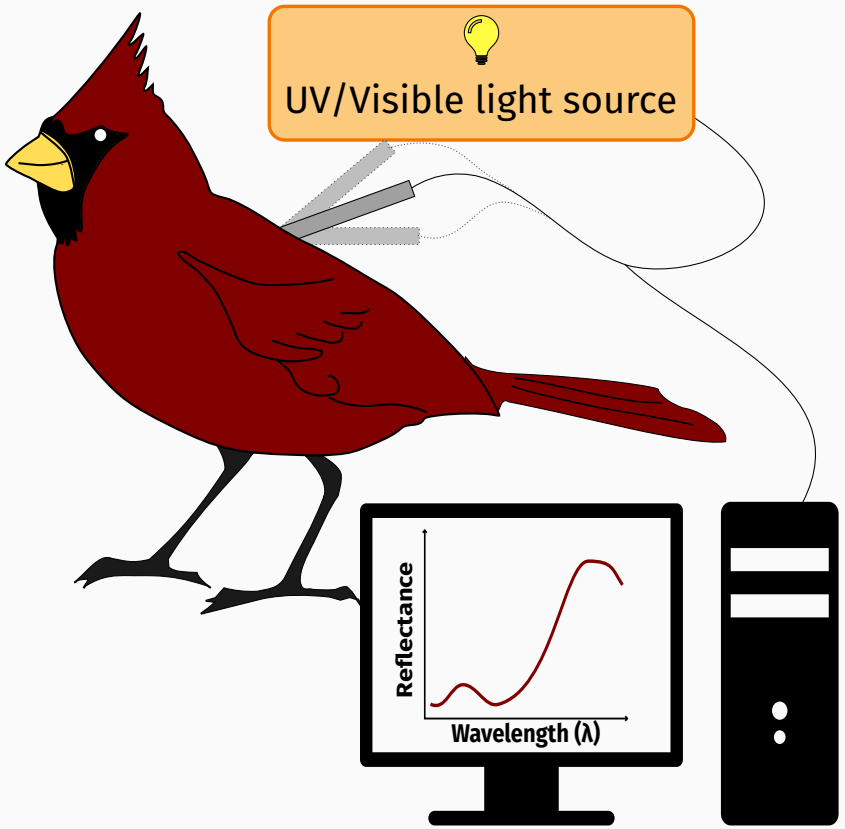
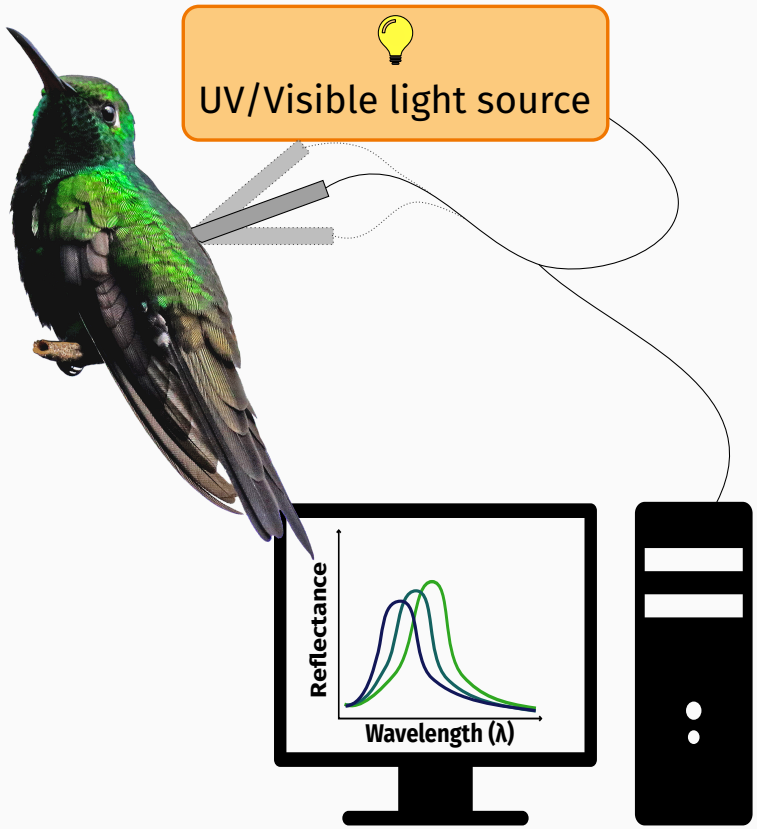
➔ We need a reliable method to measure iridescent colours

Traditional colours:



➔ One spectrum whatever the angle

Iridescent colours:



⚠ Multiple spectra depending on the angle

Consequences:

- Very low repeatability of measurements
- Analysis of a possibly biologically irrelevant signal feature
- Underestimation of signal diversity (all samples may look black)

How to measure iridescent colours?

Iridescent colour

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

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➜ Observation and illumination angles need to be controlled.

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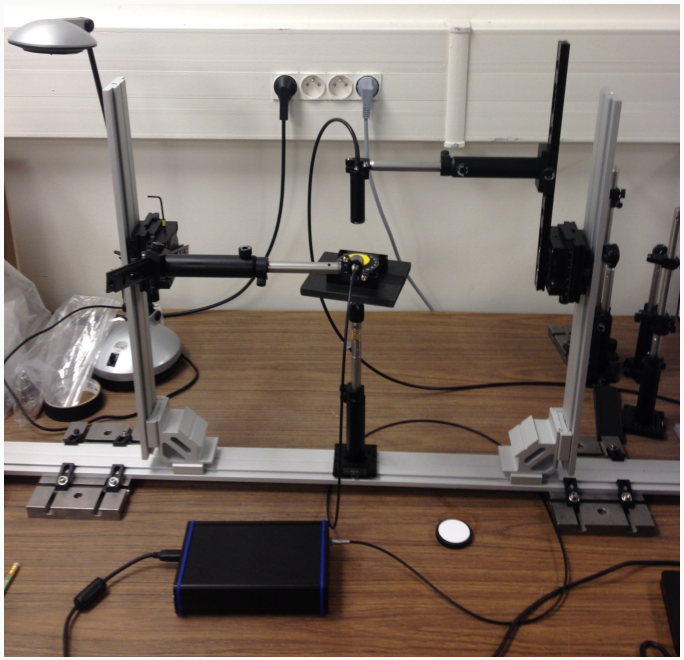
GONIO-SPECTROPHOTO-METER



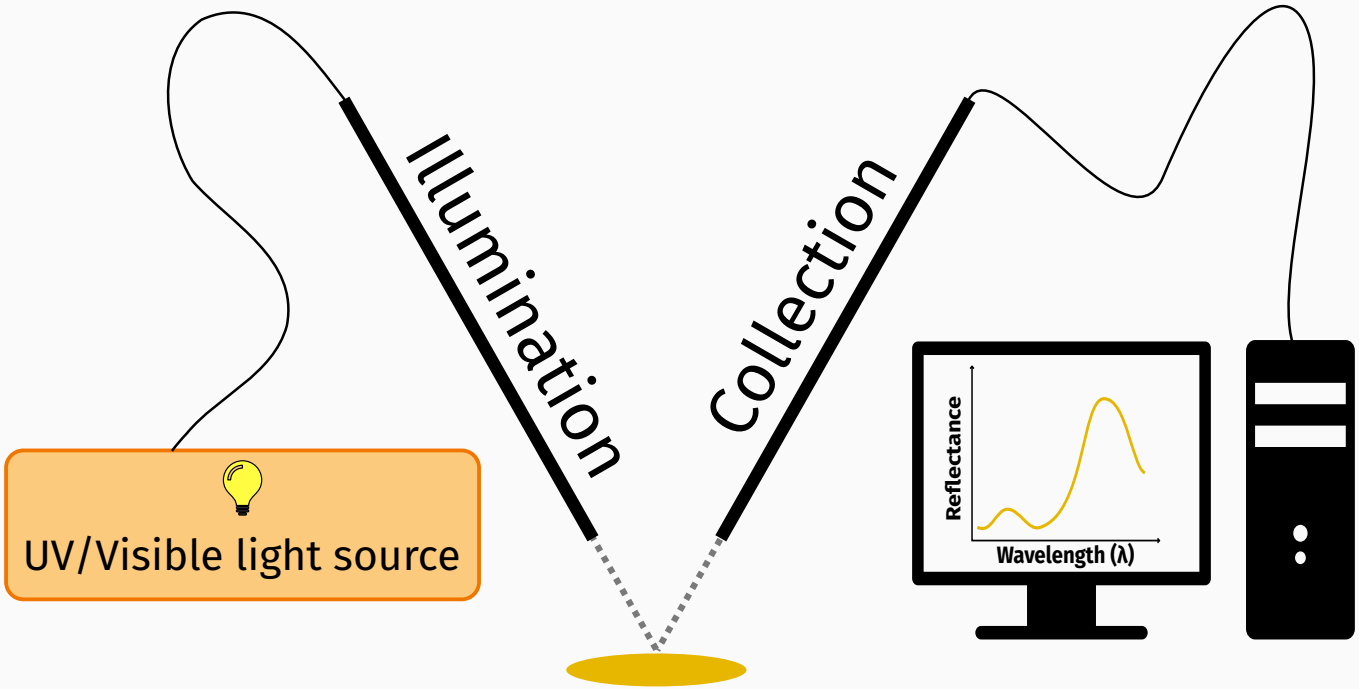
Built in 2017 at the optics lab in Jussieu drawing inspiration from Meadows *et al.* (2011).

Behav Ecol Sociobiol (2011) 65:1317–1327
DOI 10.1007/s00265-010-1135-5

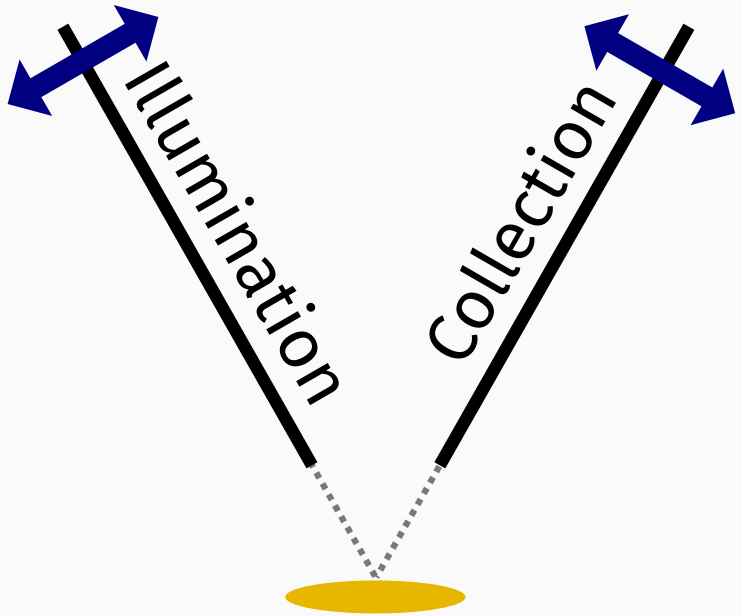
METHODS

Quantifying iridescent coloration in animals: a method for improving repeatability

Melissa G. Meadows · Nathan I. Morehouse · Ronald L. Rutowski · Jonathan M. Douglas · Kevin J. McGraw



- Two separate fibres: illumination & collection
- Allows for precise rotation of fibres and sample



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Quantifying iridescent coloration in animals: a method for improving repeatability

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⚠ NO real quantification of angular dependency of hue and brightness

⚠ NO statistical method to study iridescent colours

Questions

- Which angles to test?
- Which variables to quantify the ”shiny” effect of iridescent colours?

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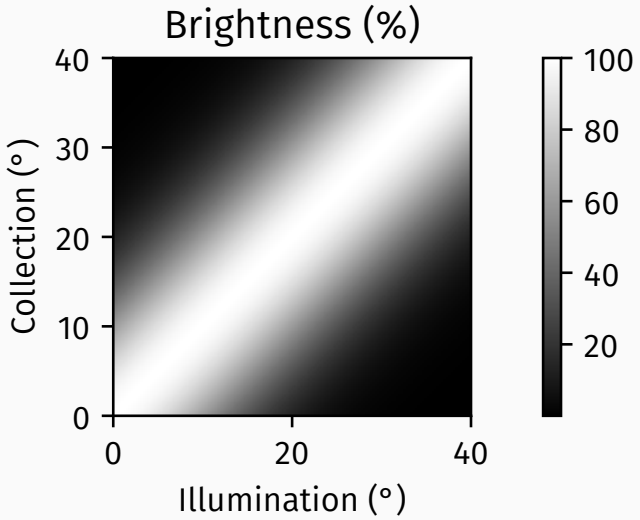
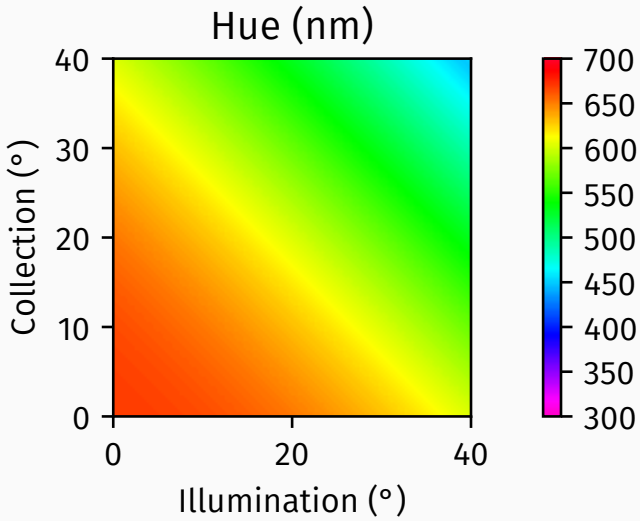
If we try every 5° combinations, $\left(\frac{180}{5}\right)^2 = 1296$ measurements for each sample!

Through simulations and analytical calculus:



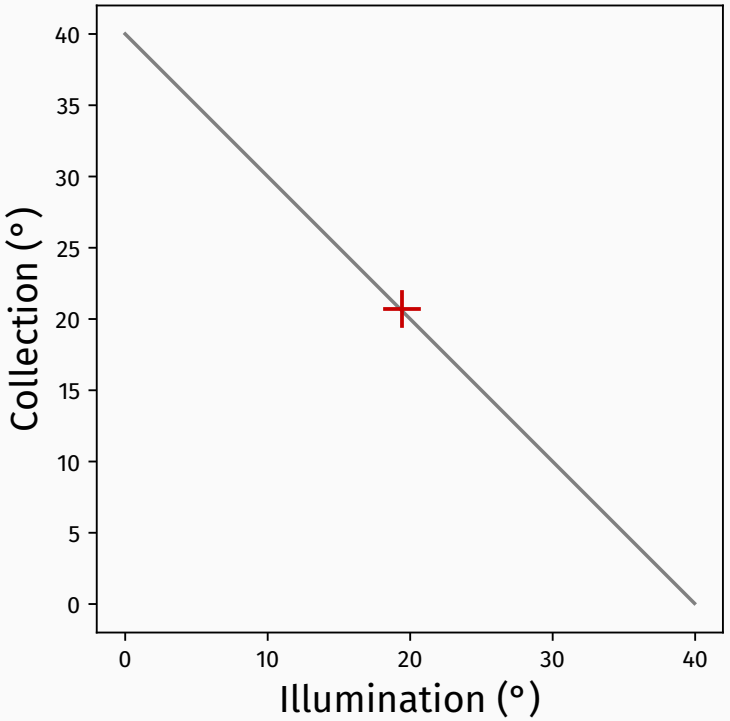


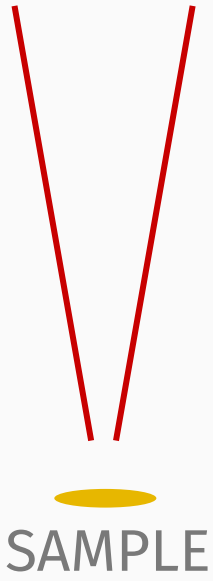
Brightness

Constant along $I = C$

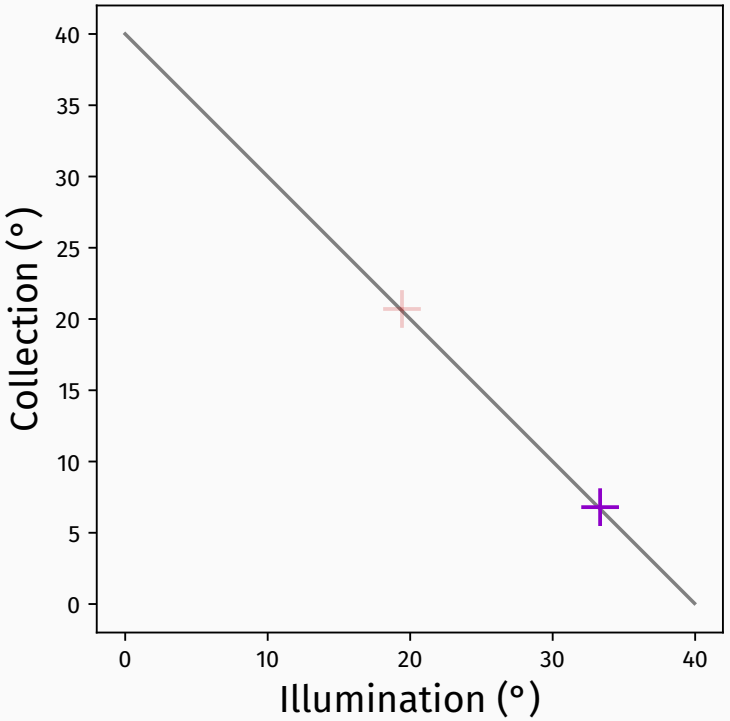
Hue

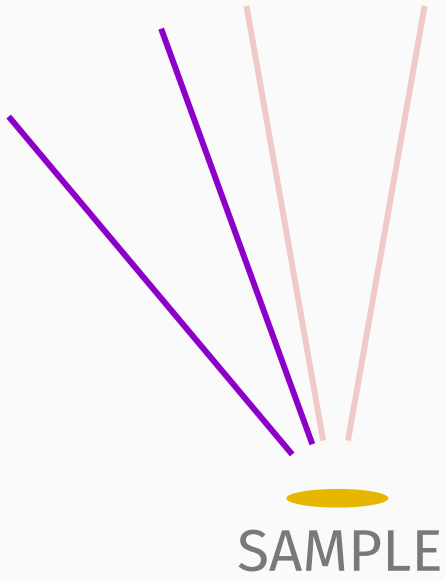
Constant along $I + C = constant$





- $I + C = cst \rightarrow$ analysis of brightness





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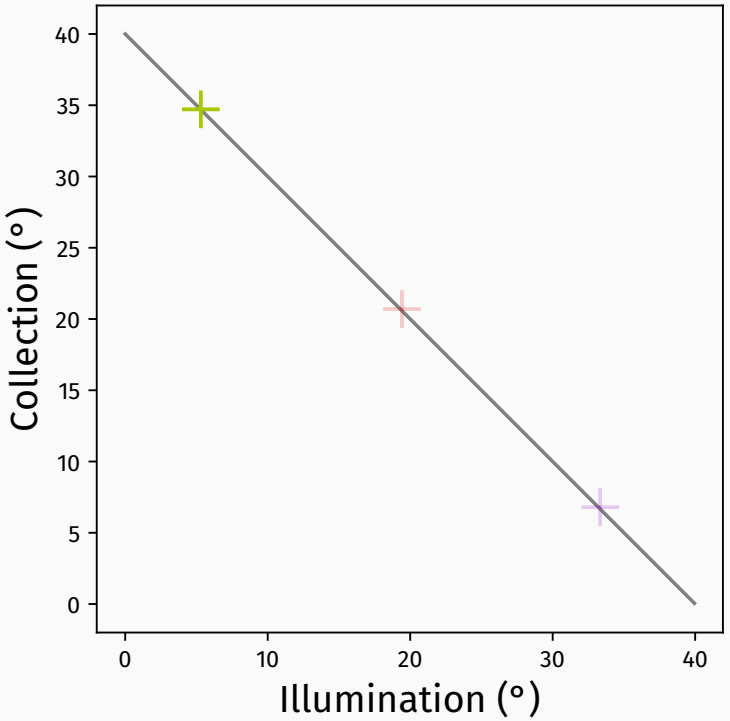

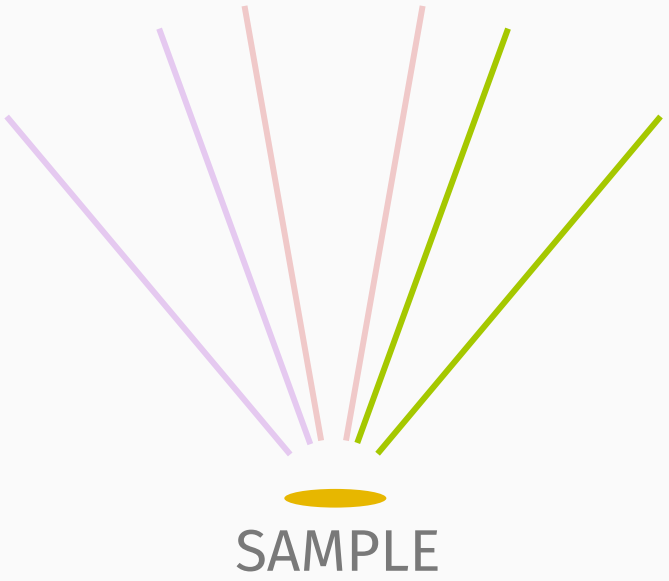

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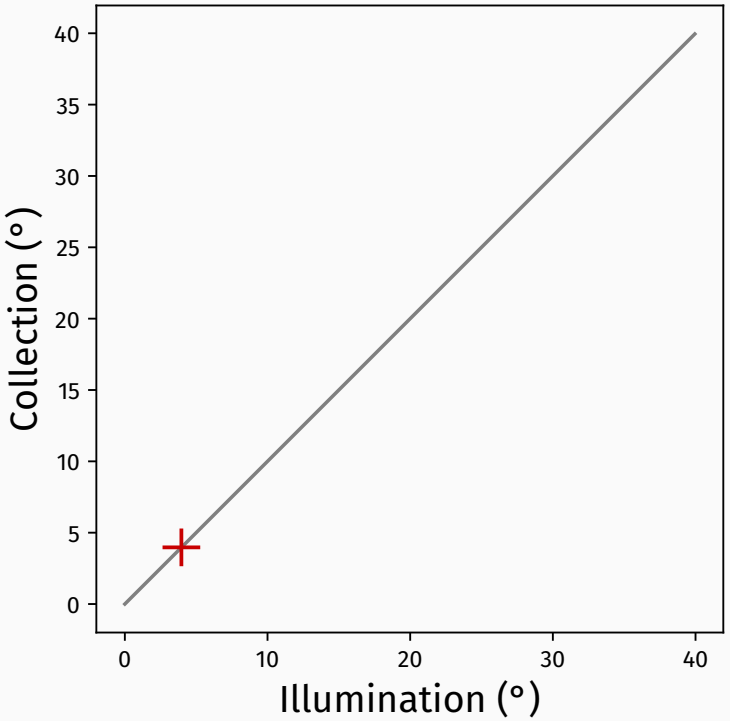
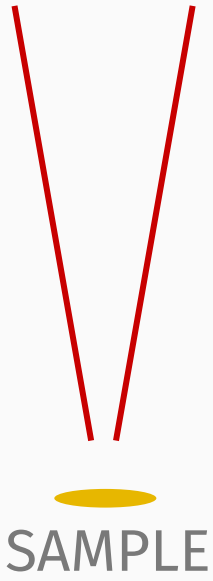
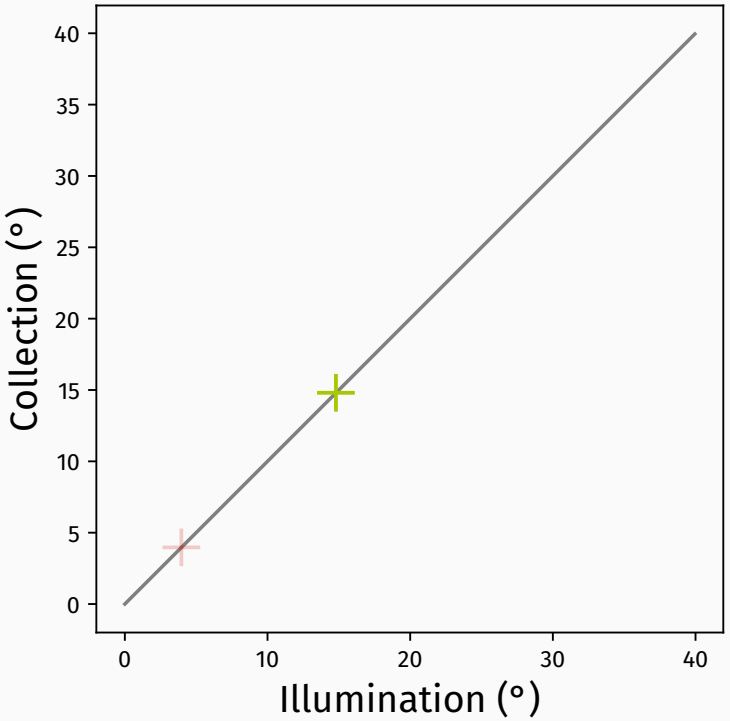
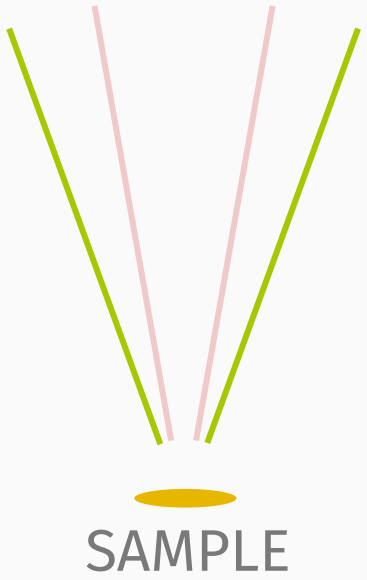




- $I = C \rightarrow$ analysis of hue





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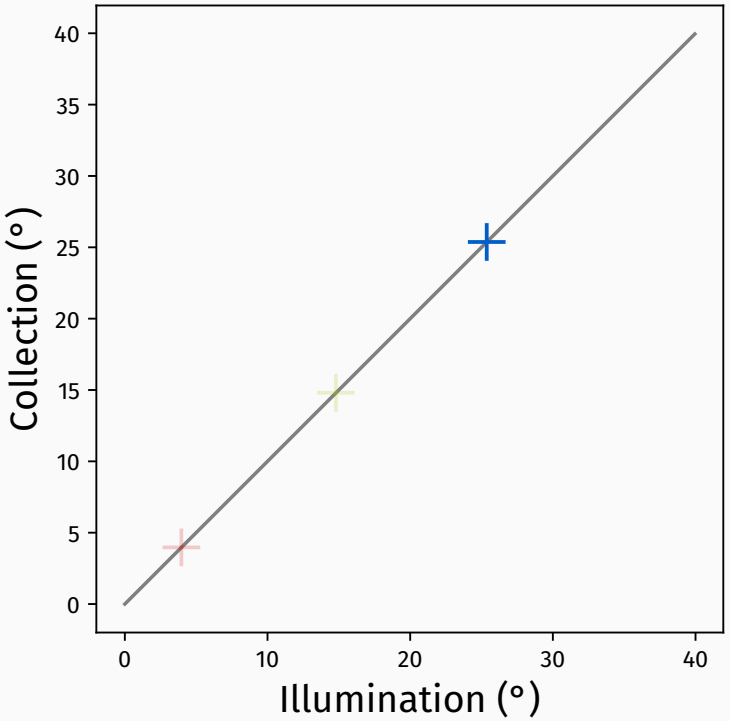
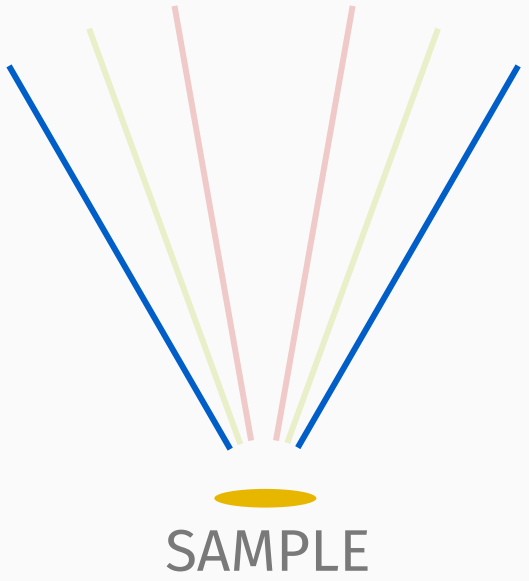
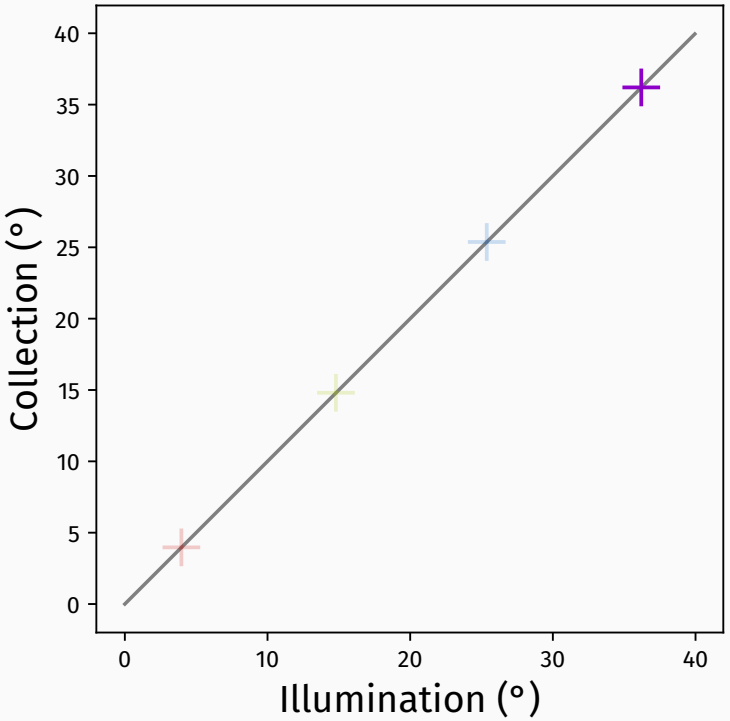
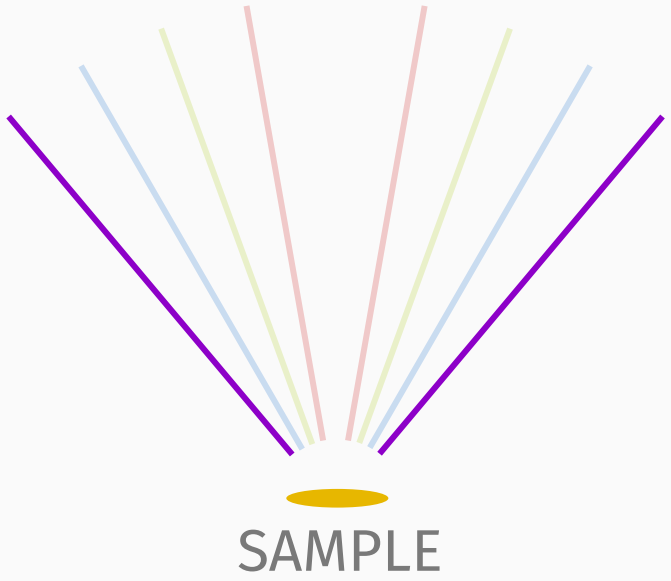


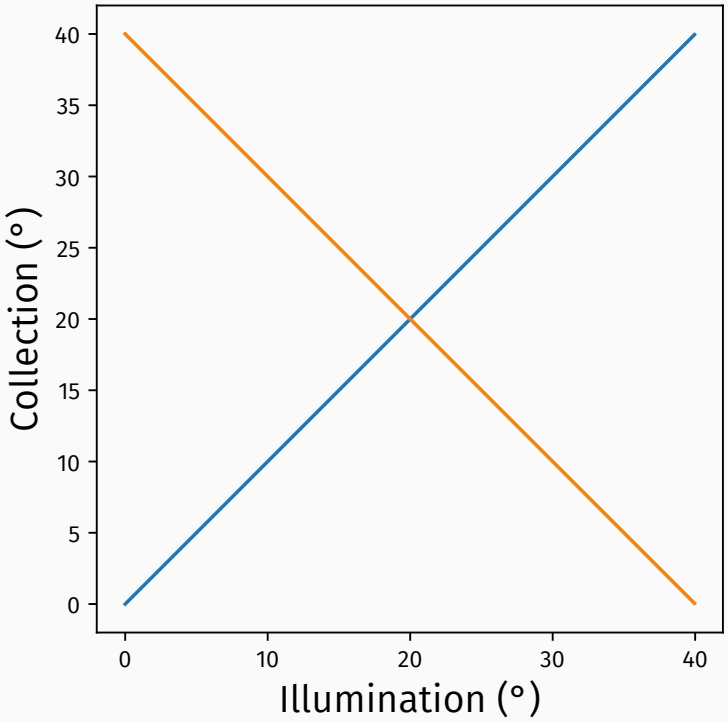


- $I = C \rightarrow$ analysis of hue



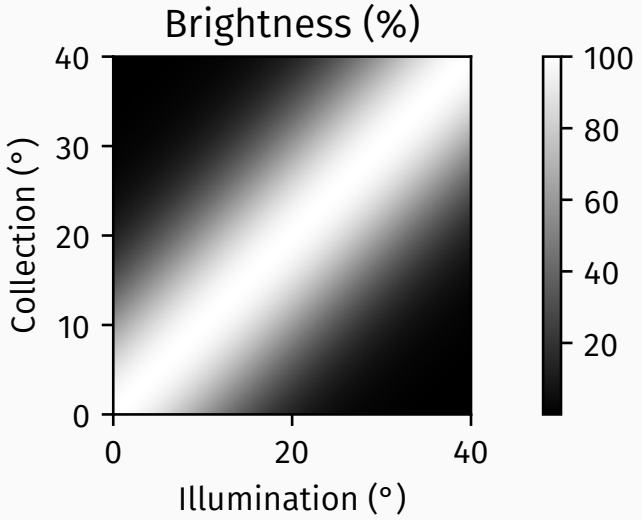


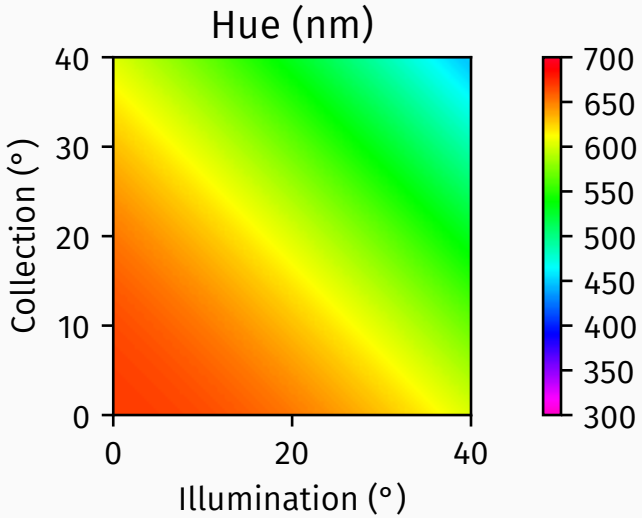
- $I = C \rightarrow$ analysis of hue



- $I + C = cst \rightarrow$ analysis of brightness
- $I = C \rightarrow$ analysis of hue

➔ 22 measurements / sample





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

- H_{max}: Maximum hue
- α: Angular dependency of hue

Estimation of parameters with non-linear regression.

Test case: hummingbirds feathers

Measurement of 69 patches from 36 hummingbird species $\times 2$:

Variable		Relative SD
Hue	H_{max}	0.26%
	α	2.7%
Brightness	B_{max}	16%
	σ	23%

- Very accurate measurements for hue
- Higher uncertainty for brightness...

Variable		Relative SD	Repeat.	p-value
Hue	H_{max}	0.26%	0.998	< 0.0001
	α	2.7%	0.131	0.30
Brightness	B_{max}	16%	0.892	< 0.0001
	σ	23%	0.708	0.009

- Very accurate measurements for hue
- Higher uncertainty for brightness... but still usable for interspecific studies!

Conclusion

- To measure iridescent colours, we need a goniospectrophotometer.
- We've shown 4 variables are enough to summarize the entire angle dependency of iridescent colours
- We can now study the characteristics and functions of iridescent colours

Phanaeus vindex, by Sebastian Eder

What's next:

- Test this approach with very different iridescent materials
- Find a way to use new indices with vision models

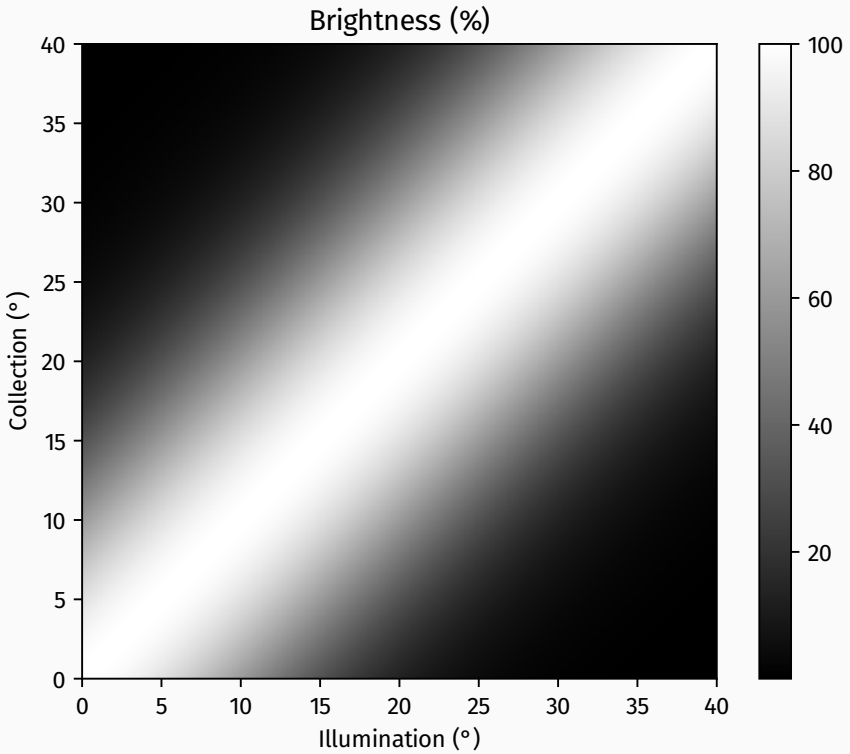
Acknowledgments

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

Video excerpt from PBS documentary: "Super Hummingbirds" (2016)

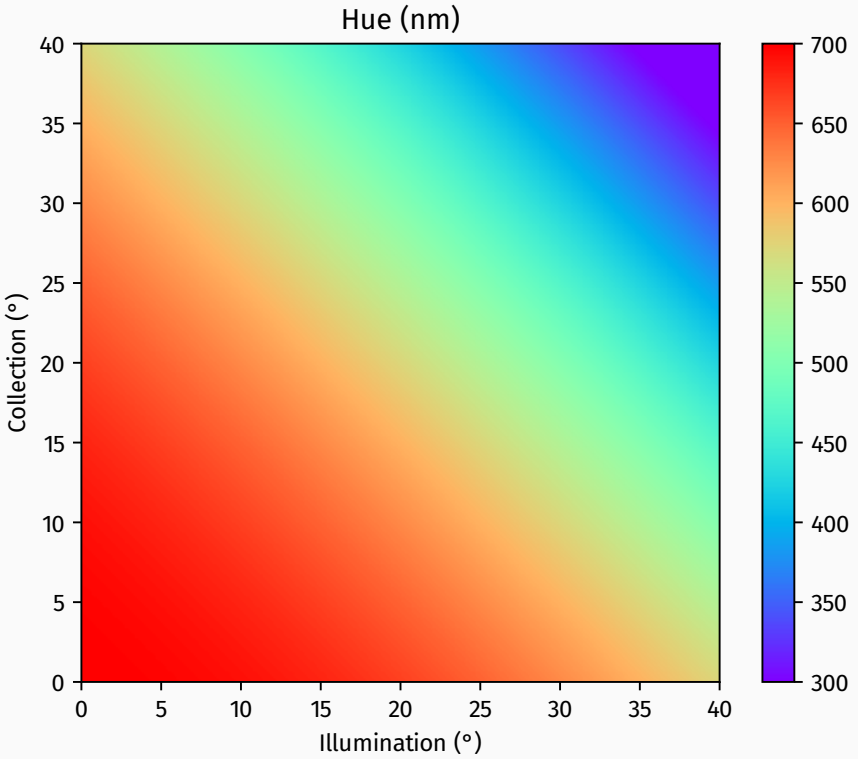

Thank you
for your attention!

$$B = B_{max} \exp -\frac{(normale - \mu)^2}{2\sigma^2}$$



- $normale = \frac{I - C}{2}$
- B_{max}: Maximum brightness
- μ: Orientation of the multilayer structure
- σ: Angular dependency of brightness

$$H = H_{max} \cos(\alpha \times span)$$



- $span = I + C$
- H_{max}: Maximum hue
- α: Angular dependency of hue

Iridescence is caused by interferences a on multilayer structure.