

**Supplementary File S1.** A method for approximation of measurements to a Gaussian plane.

Approximation was made using the following two-dimensional Gaussian function ([https://en.wikipedia.org/wiki/Gaussian\\_function](https://en.wikipedia.org/wiki/Gaussian_function)):

$$Z(\text{reflectance}) = A \exp(- (a(x - x_0)^2 - 2b(x - x_0)(y - y_0) + c(y - y_0)^2)),$$

where we set

$$a = \cos^2\theta/(2\sigma_x^2) + \sin^2\theta/(2\sigma_y^2)$$

$$b = \sin 2\theta/(4\sigma_x^2) + \sin 2\theta/(4\sigma_y^2)$$

$$c = \sin^2\theta/(2\sigma_x^2) + \cos^2\theta/(2\sigma_y^2).$$

In these equations, the coefficient A is the amplitude,  $x_0$ ,  $y_0$  is the center,  $\sigma_x^2$ ,  $\sigma_y^2$  are the X and Y spreads and the angle  $\theta$  corresponds to rotation of the blob.

For the approximations, coefficients A,  $x_0$ ,  $y_0$ ,  $\sigma_x^2$ ,  $\sigma_y^2$  and  $\theta$  were changed. As the initial value, a set of values that yielded the best fit to an average of all measurements, including those of fore- and hindwings measured under different wavelength conditions (e.g., UV and green light), was used. For approximation, a software “solver” program in Excel 2003 (Microsoft) was used.

**Supplementary File S2.** Determination of azimuth and elevation of the surface of a wing scale.

Calculation of azimuth ( $\gamma$ ) and elevation ( $\delta$ ) of the surface of the wing scale ( $\Delta ABC$  in the attached figure) from the X and Y components of tilt angles measured ( $\alpha$  and  $\beta$ , respectively).

In the attached figure,

$$a = 1/\tan\alpha \quad (1)$$

$$b = 1/\tan\beta \quad (2).$$

From the Pythagorean theorem,

$$c = a^2/(a^2+b^2)^{(1/2)} \quad (3)$$

$$d = ab/(a^2+b^2)^{(1/2)} \quad (4).$$

Here,

$$\tan\gamma = c/d$$

substituting (3), (4)

$$= a/b$$

and substituting (1), (2)

$$= \tan\beta/\tan\alpha$$

Results in

$$\gamma(\text{azimuth}) = \arctan(\tan\beta/\tan\alpha).$$

Further,

$$\tan\delta = 1/d$$

substituting (4)

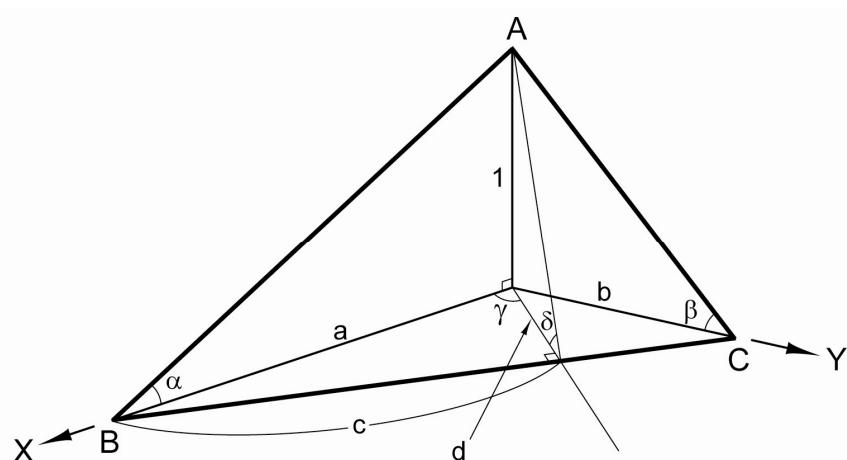
$$= (a^2+b^2)^{(1/2)}/ab$$

and substituting (1), (2)

$$= (\tan^2\alpha + \tan^2\beta)^{(1/2)}$$

Results in

$$\delta(\text{elevation}) = \arctan((\tan^2\alpha + \tan^2\beta)^{(1/2)}).$$



**Supplementary File S3.** Original data used for statistical analyses.

Table S1. Reflected light.

Individual	Azimuth				Maximum reflectance				Intensity of directionality			
	Forewing		Hindwing		Forewing		Hindwing		Forewing		Hindwing	
	Green	UV	Green	UV	Green	UV	Green	UV	Green	UV	Green	UV
R1	65	59	6	7	0.59	0.28	1.03	0.40	0.12	0.06	0.20	0.08
R2	61	60	19	19	0.82	0.46	0.86	0.59	0.17	0.10	0.18	0.12
R3	67	64	8	9	1.00	0.58	1.12	0.75	0.21	0.12	0.23	0.16
R4	60	56	18	20	0.89	0.54	1.15	0.73	0.19	0.11	0.22	0.15
R5	55	51	26	28	0.75	0.45	1.18	0.94	0.16	0.09	0.25	0.20
R6	59	56	19	21	0.92	0.67	1.20	0.88	0.19	0.14	0.24	0.18
R7	56	53	15	18	0.76	0.41	1.02	0.50	0.16	0.08	0.21	0.11
R8	58	54	31	32	0.70	0.43	0.78	0.45	0.15	0.09	0.16	0.09
R9	61	57	12	13	0.94	0.53	1.44	0.79	0.20	0.11	0.28	0.16
R10	58	57	19	21	0.55	0.33	0.93	0.47	0.12	0.07	0.19	0.10
Average	60	57	17	19	0.79	0.47	1.07	0.65	0.17	0.10	0.22	0.14
StDev	4	4	8	8	0.15	0.12	0.19	0.19	0.03	0.03	0.04	0.04

Table S2. Tilt angle of the wing scale.

Individual	Forewing		Hindwing	
	Azimuth	Elevation	Azimuth	Elevation
T1	40	37	10	32
T2	47	46	20	38
T3	39	38	0	38
T4	42	37	14	35
T5	42	44	25	37
T6	49	57	19	43
T7	54	51	24	40
T8	46	41	28	36
T9	50	37	14	32
T10	42	48	16	37
Average	45	44	17	37
StDev	5	7	8	3

Table S3. Curvature of the wing scale.

Individual	Forewing	Hindwing
C1	18.0	7.9
C2	18.9	3.3
C3	16.8	4.7
C4	15.4	4.3
C5	16.1	3.5
C6	19.3	3.5
C7	19.9	4.0
C8	18.5	6.3
C9	18.9	5.3
C10	16.1	5.6
Average	17.8	4.8
StDev	1.6	1.5