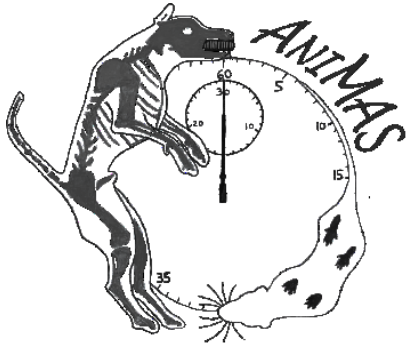
Manchester Metropolitan University



Mammalian Whiskers and the Euler Spiral

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Manchester Metropolitan University

EPSRC Engineering and Physical Sciences Research Council

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UCL

I measure morphological parameters (i.e. the shape) of whiskers.

Why?

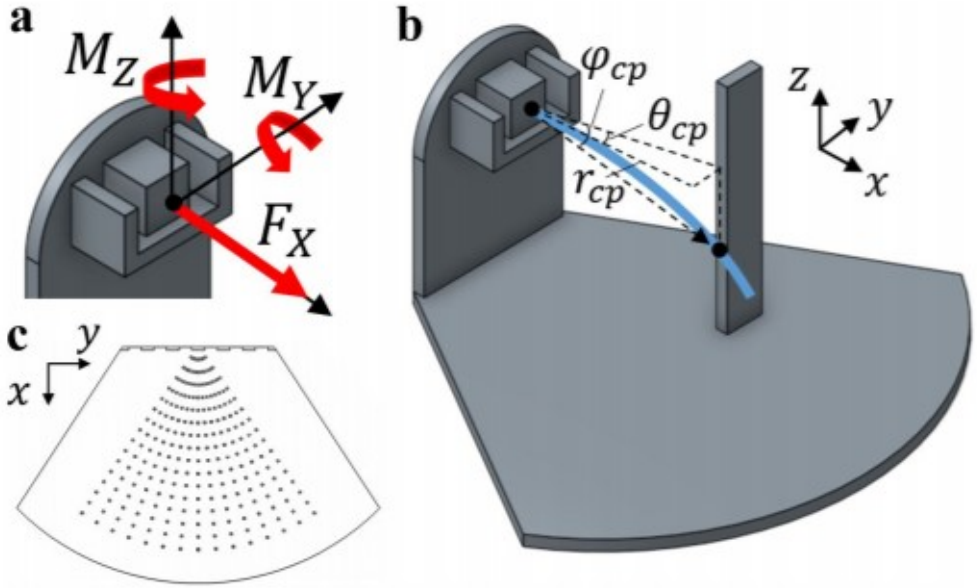
Behavioural/Environmental Adaptations



Are there measurable variations in whisker morphology across different species that we can categorise according to their behaviour and/or environment?

Superficial Differences

Modelling: Neuroscience and Robotics



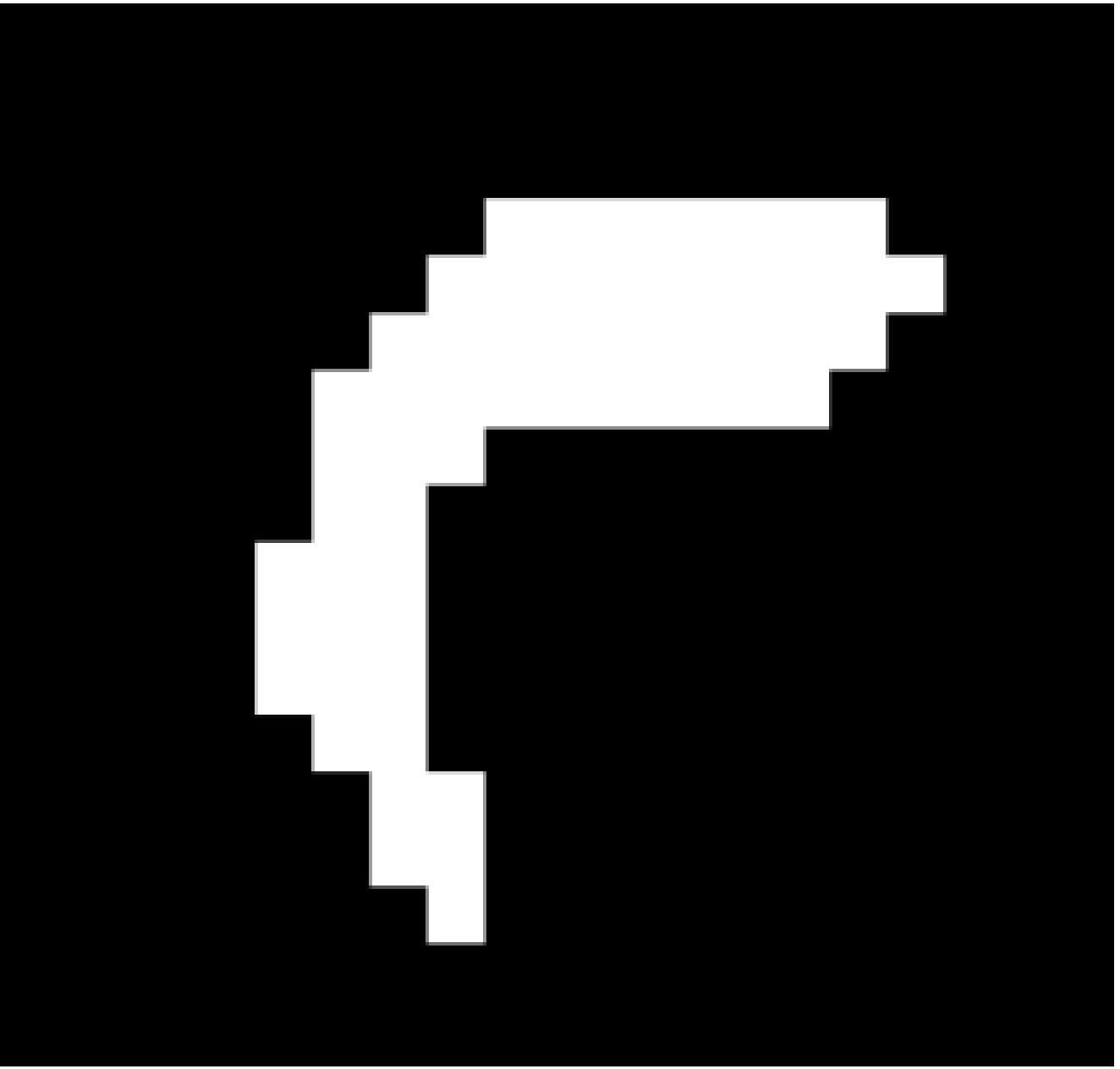
Neuro sci picture

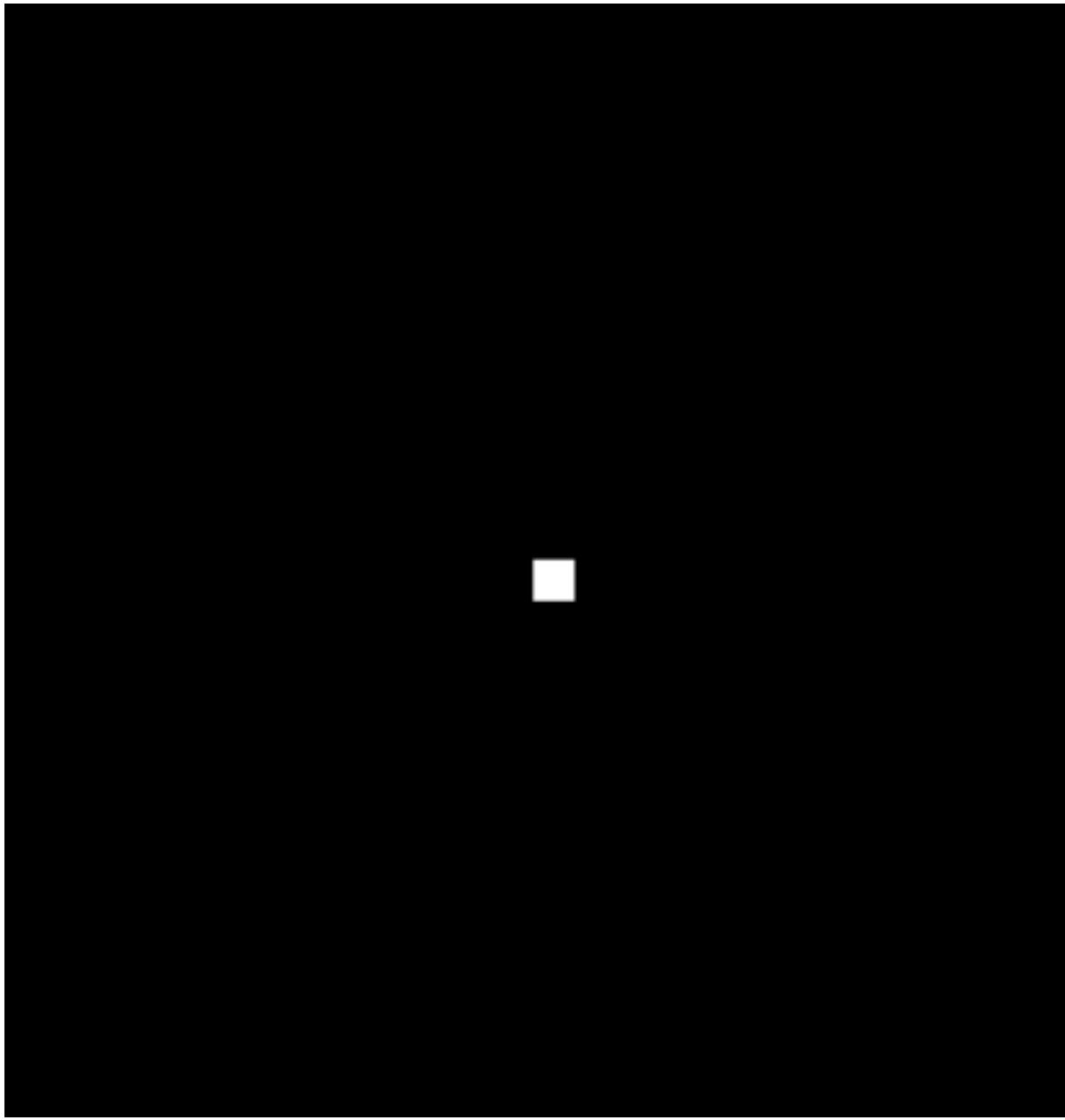
Emnett, Graff and Hartmann 2018.

So we started measuring rat whiskers.

How did we measure whiskers?

Attempts to scan rat whiskers in 3D were problematic





Measuring Whiskers

Rat whiskers are really flat.

Small mammal whiskers are circular in cross section.

(Knutsen, Biess & Ahissar, 2008; Towal et al., 2011)

Scan Results

Whiskers Scanned

- 167 whiskers from 8 rats scanned.
- Combined with data from Mitra Hartmann group.
- Total of 523 whiskers from 15 rats.
- Average of 17 whiskers per grid location.

Focus on Curvature

- Whiskers are obviously curved.
- Measuring, defining and comparing curvature is hard.
- Mechanically important.

Issues with Quadratic Curves

- Visual observation shows that many whiskers are not quadratic.

- No reference to whisker length.

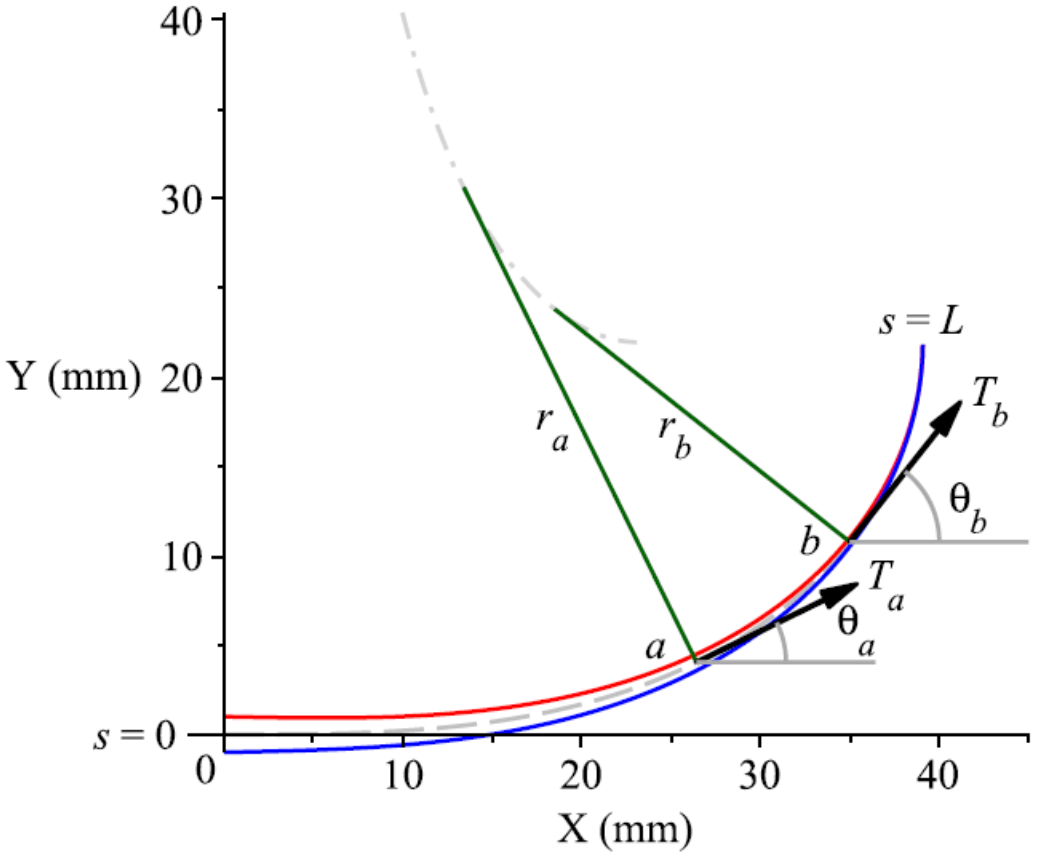
Plane Model Curves

$$y(x) = Ax^2 + Bx + C$$

$$k(s) = As + B$$

7 whiskers rejected for RSD > 0.8% of length.

Normalising Whisker Length

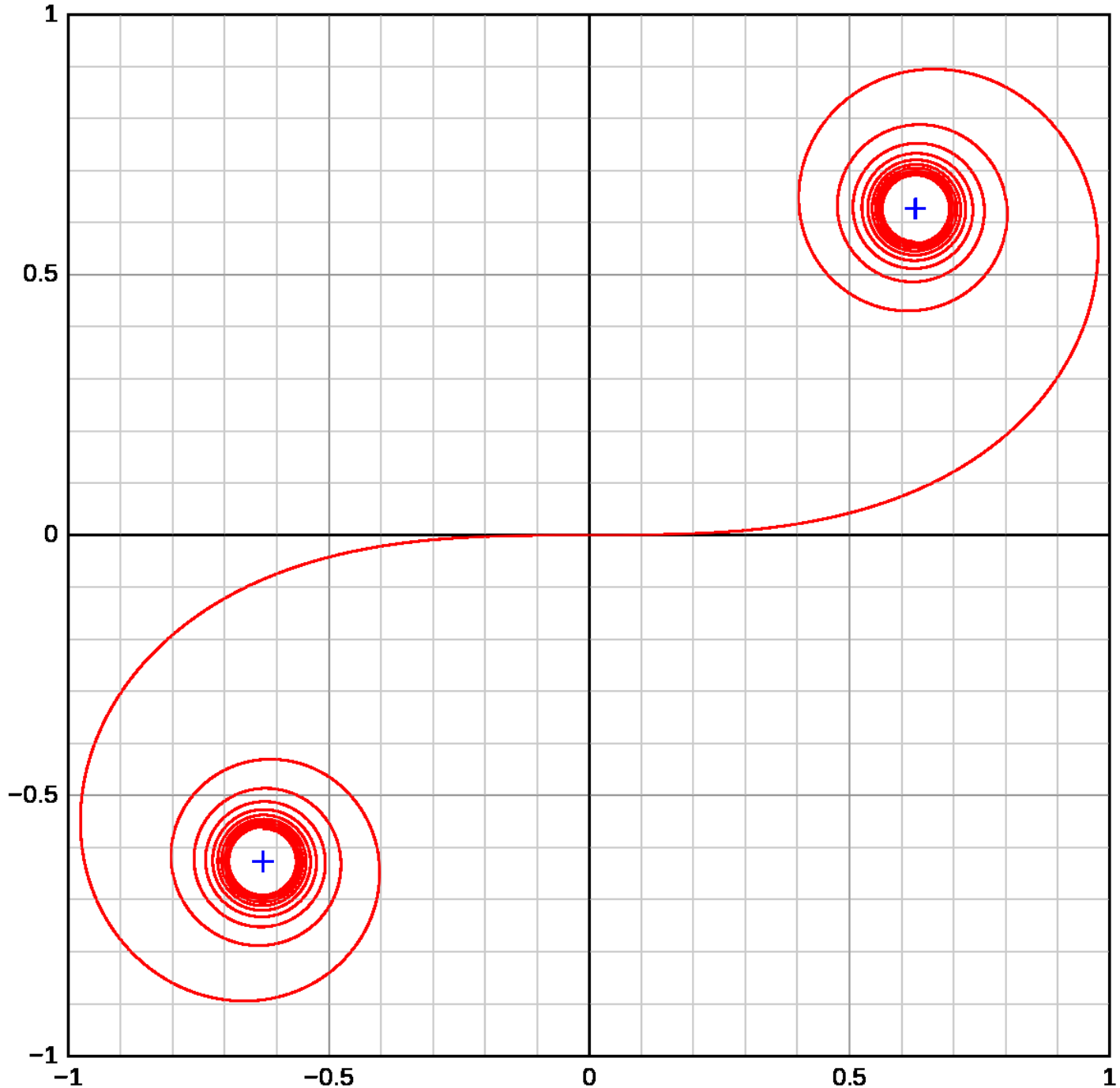


Normalised whiskers described by Fresnel equations.

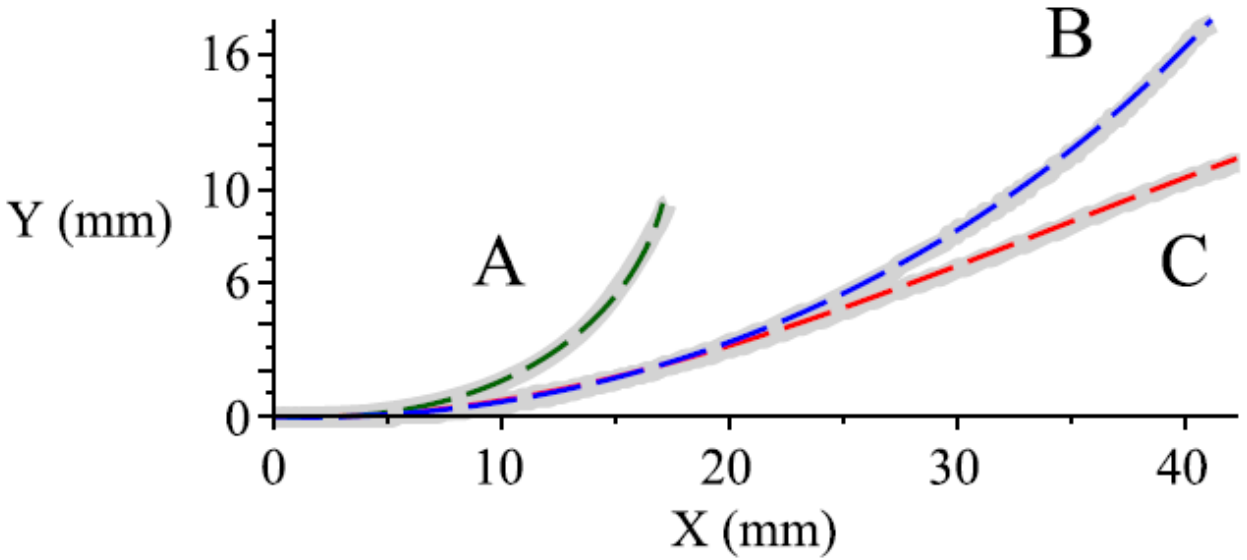
Fresnel equations describe the Euler spiral.

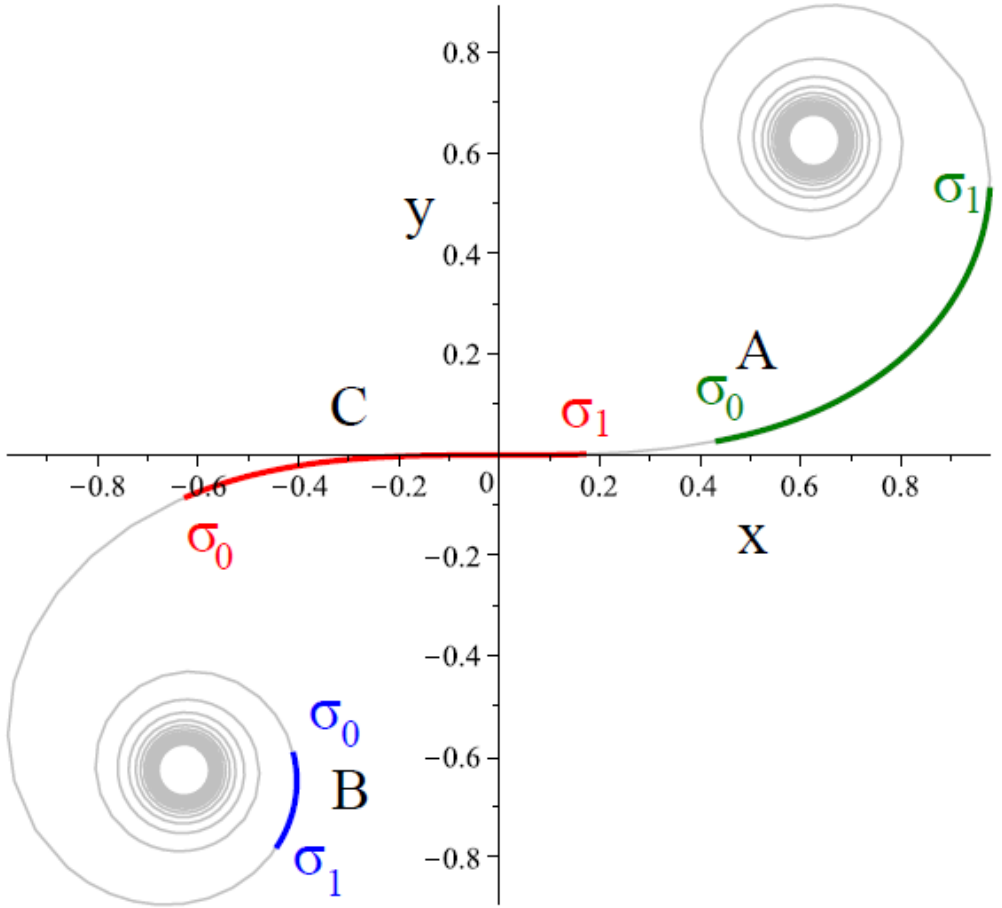
Any whisker can be mapped onto a section of a universal Euler spiral.

What the hell are Fresnel integrals?

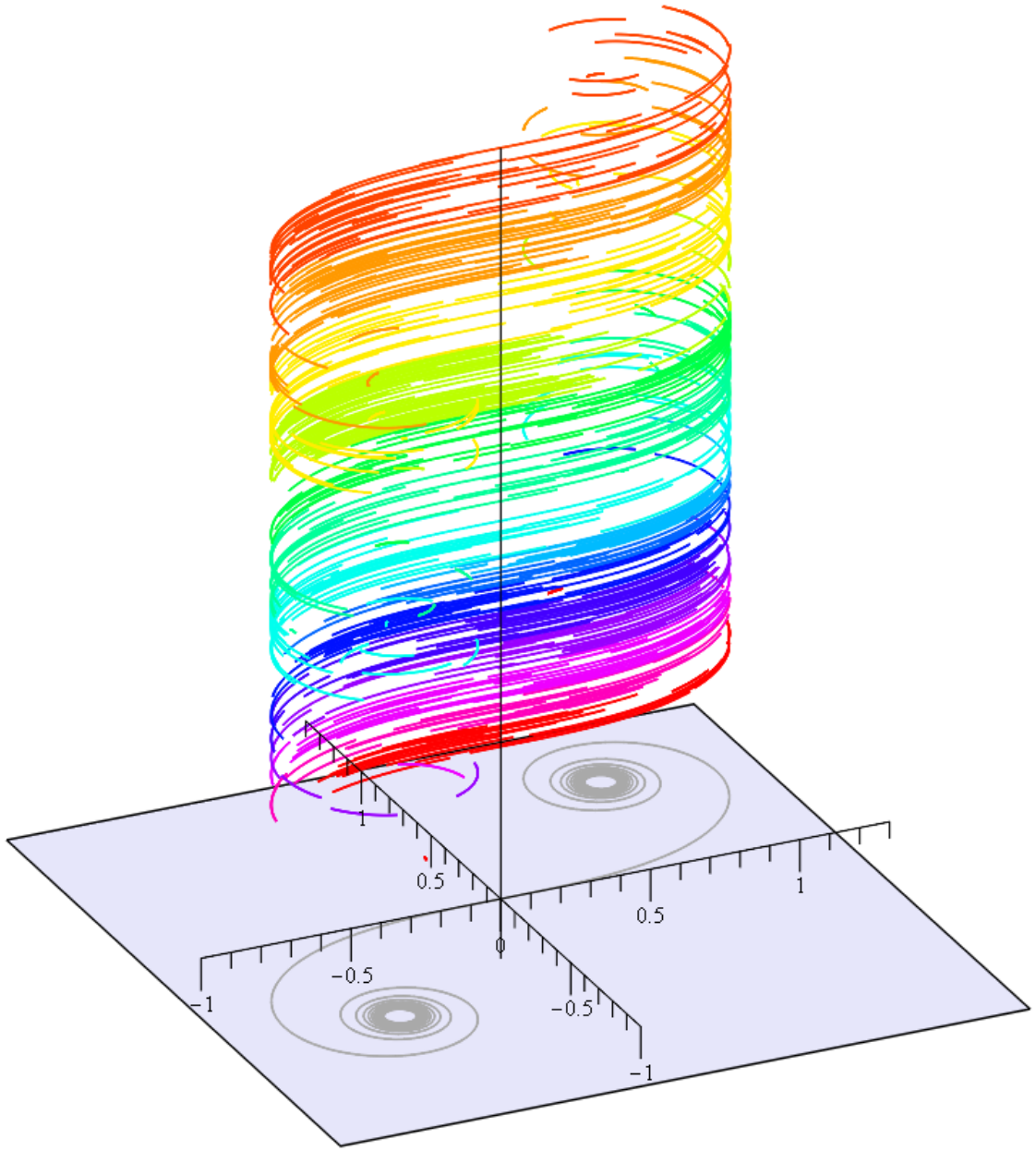

1
0.5
0
−0.5
−1
−1
−0.5
0
0.5
1

Mapping onto the Euler Spiral





Mapping whiskers onto the Euler spiral allows rat whiskers of any size to be compared on shape alone.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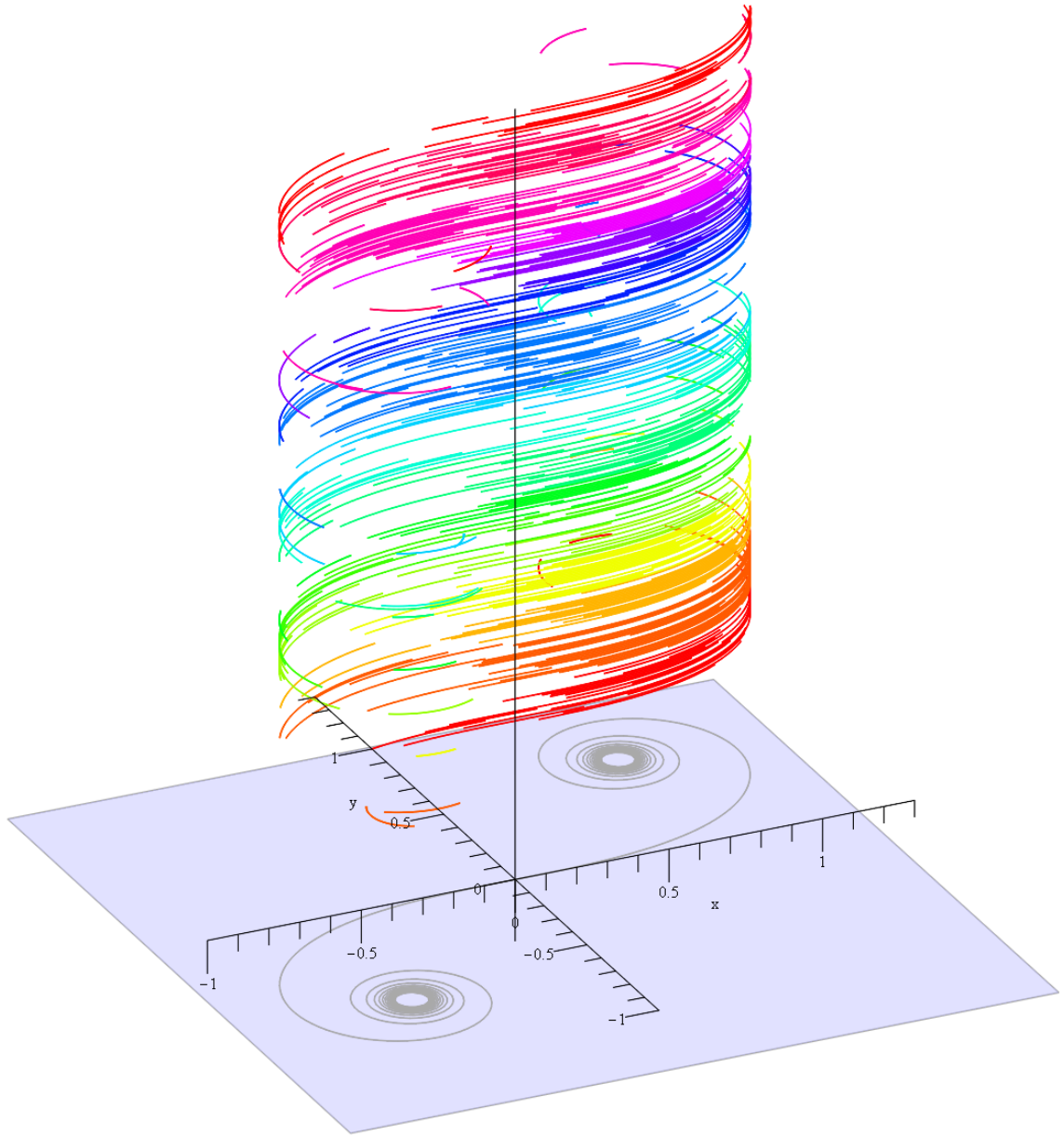
y
1
0.5
0
−0.5
−1
x
0.5
1
0
−0.5
−1

Euler Spiral and Curvature Comparison

- Mapping to the Euler spiral allows rat whiskers of any size to be compared according to their shape.
- 428 whiskers from 13 species scanned, also good fit with plane model curves.
- Can directly compare shape of different species' whiskers.

Euler Spirals, a Model for Whiskers

- Plane model curves provide a good approximation for Rat and other mammal whiskers.
- Mapping normalised whiskers onto the Euler spiral allows different sized whiskers to be compared by shape alone.
- Limited variation observed so far between species in terms of curvature.
- Linear change of curvature may hint at underlying mechanisms of whisker growth and function.

Acknowledgements

Imagine the happy faces of our colleagues and logos of grant awarding bodies.