

# Interaction rules underlying group decisions in homing pigeons



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# Collective animal behaviour





# Collective decision making

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## Ant colonies

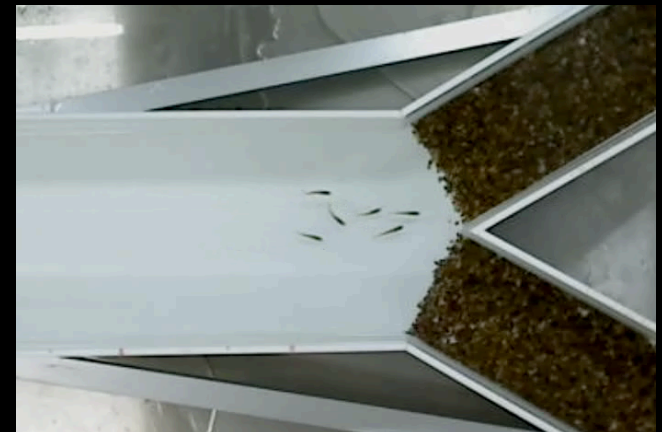


Deneubourg *et al.*, 1990

## Cockroaches

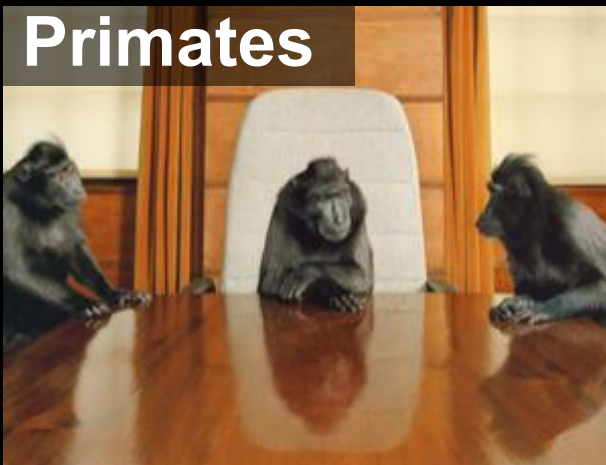


## Fish



Ward *et al.* PNAS 2011

## Primates



Sueur *et al.*, PLoS ONE 2012

# Collective movement

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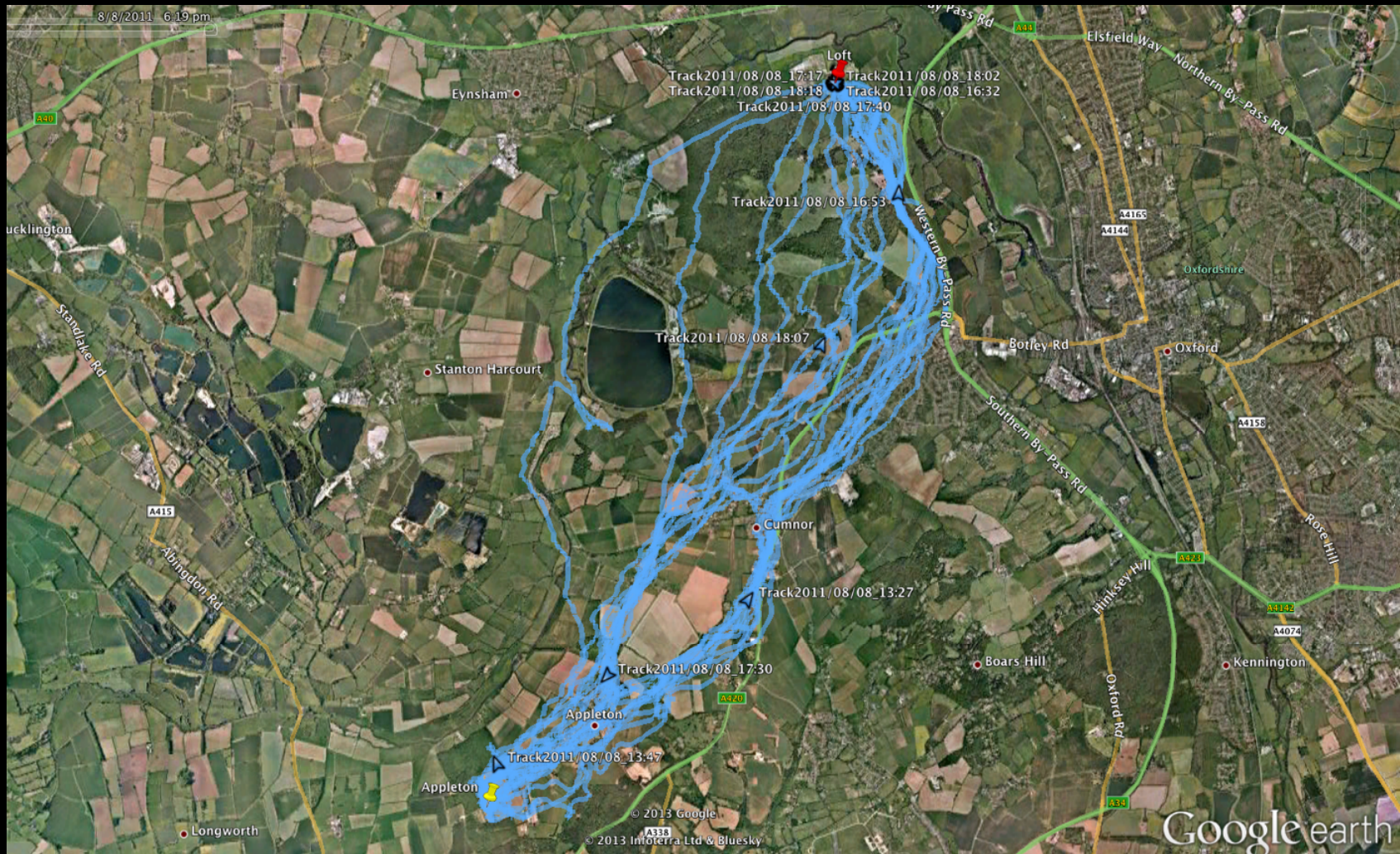




# Homing pigeons

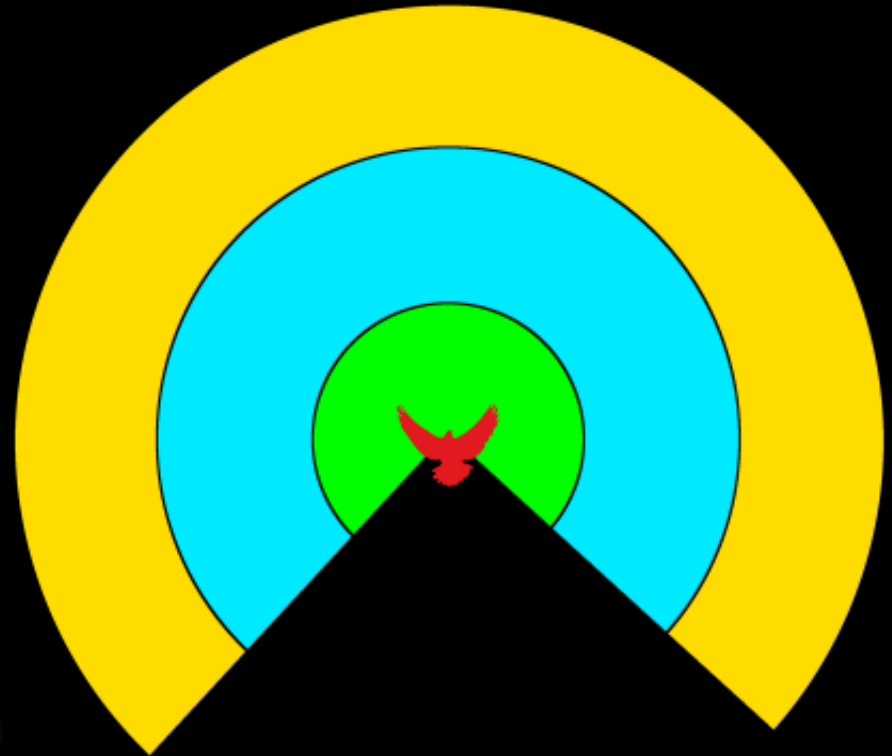


## Collective decision from collective movement



# Birds as self propelled particles

- Birds move at **constant speed**
- The bird will **turn away** from a neighbour in the green zone
- The bird will **align** with a neighbour in the blue zone
- The bird will **turn towards** a neighbour in the yellow zone
- When there are multiple neighbours in one zone, the bird will **react to the centre of mass of all the neighbours** in that zone



$$\vec{x}_i(t+1) = \vec{x}_i(t) + v_0 \vec{u}_i(t+1)$$

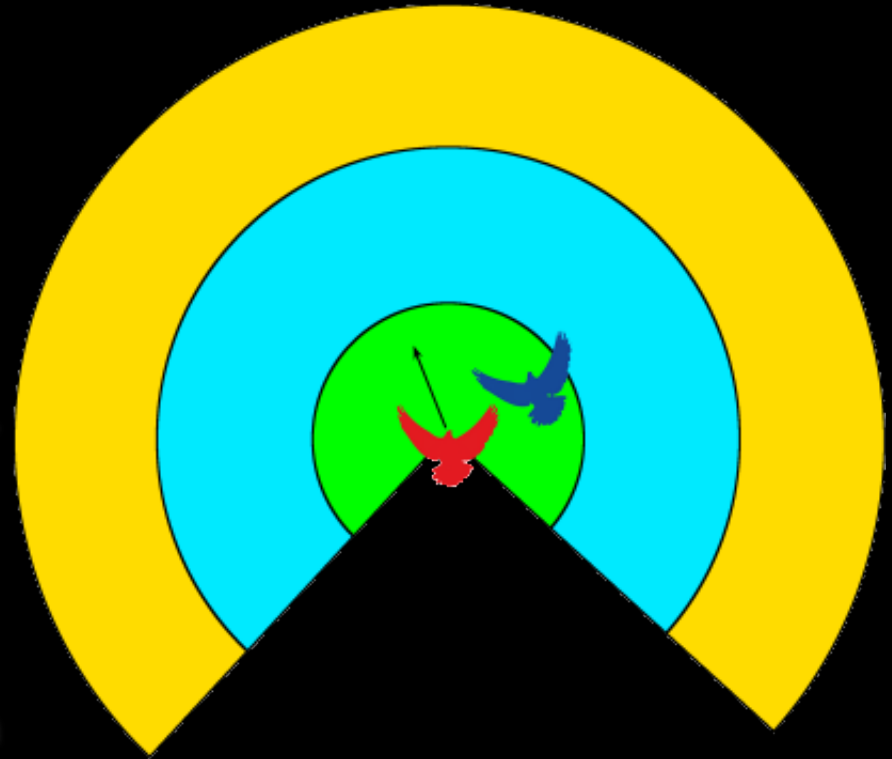
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**Repulsion zone**  
**Alignment zone**  
**Attraction zone**



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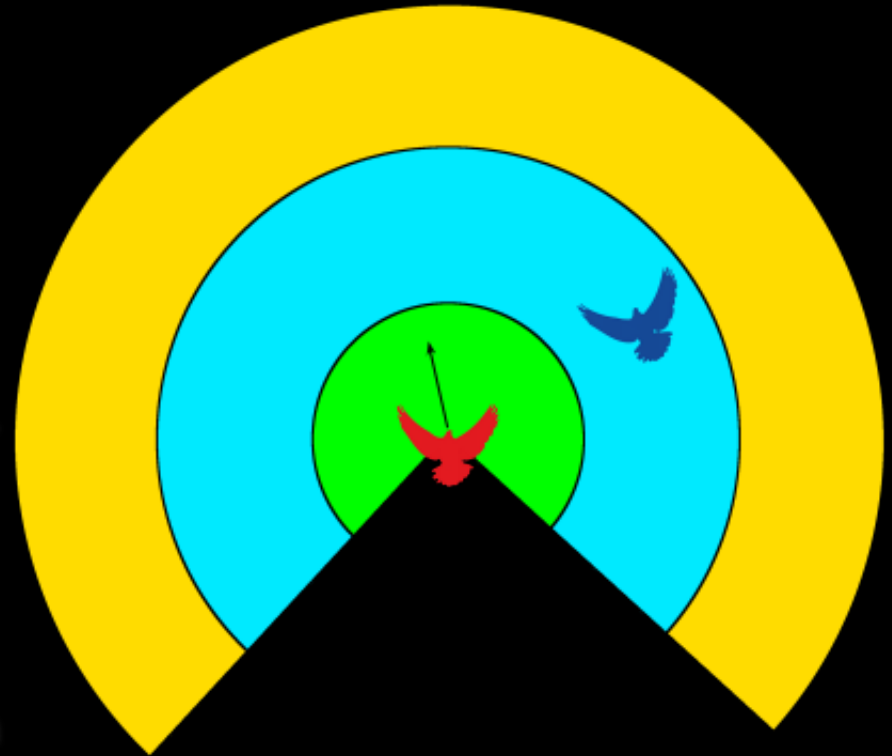
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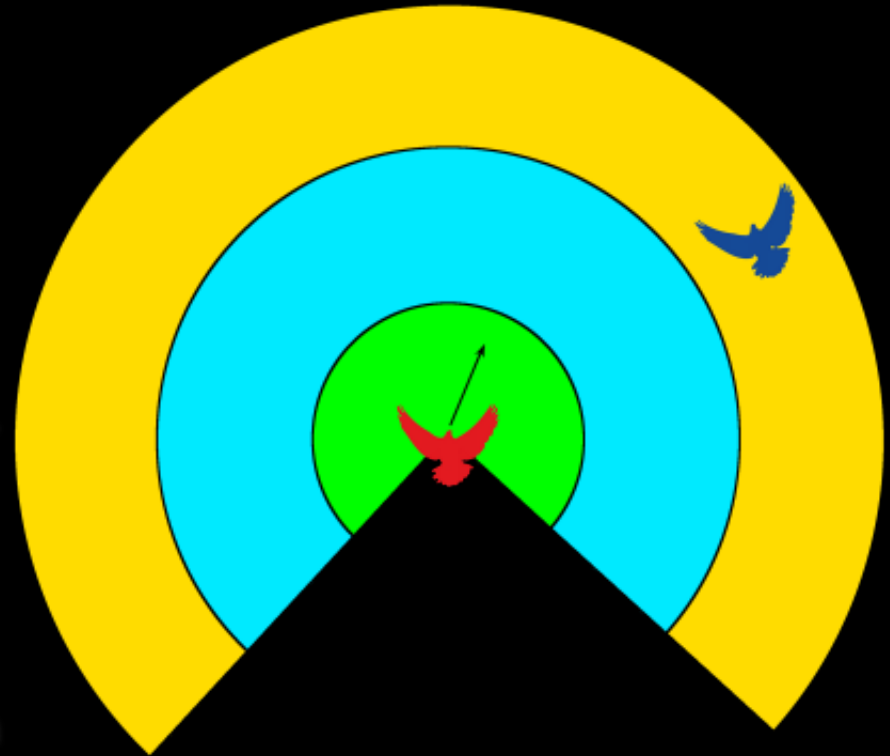
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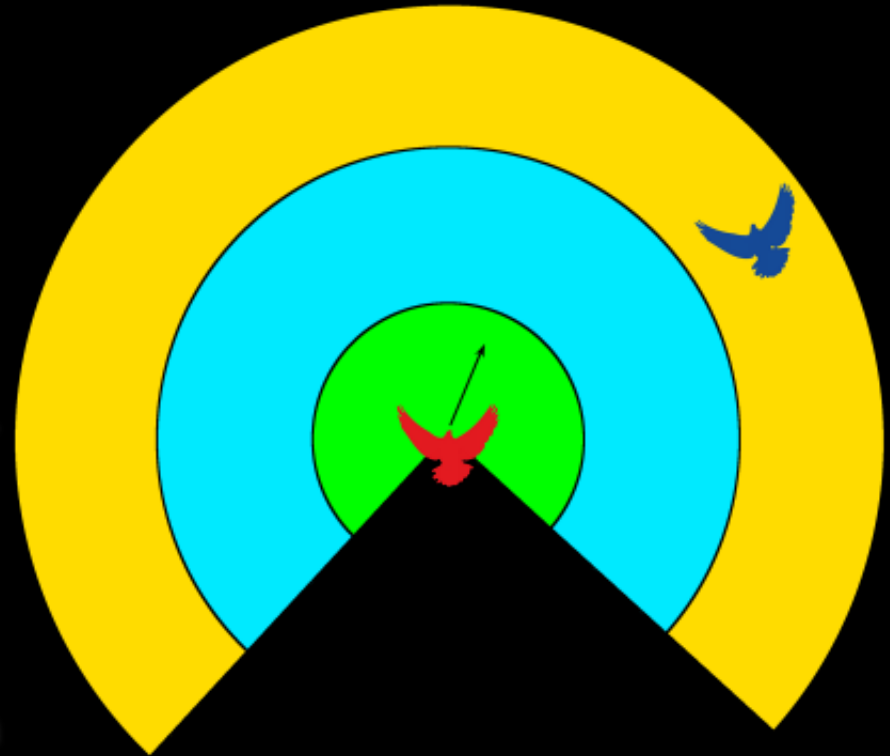
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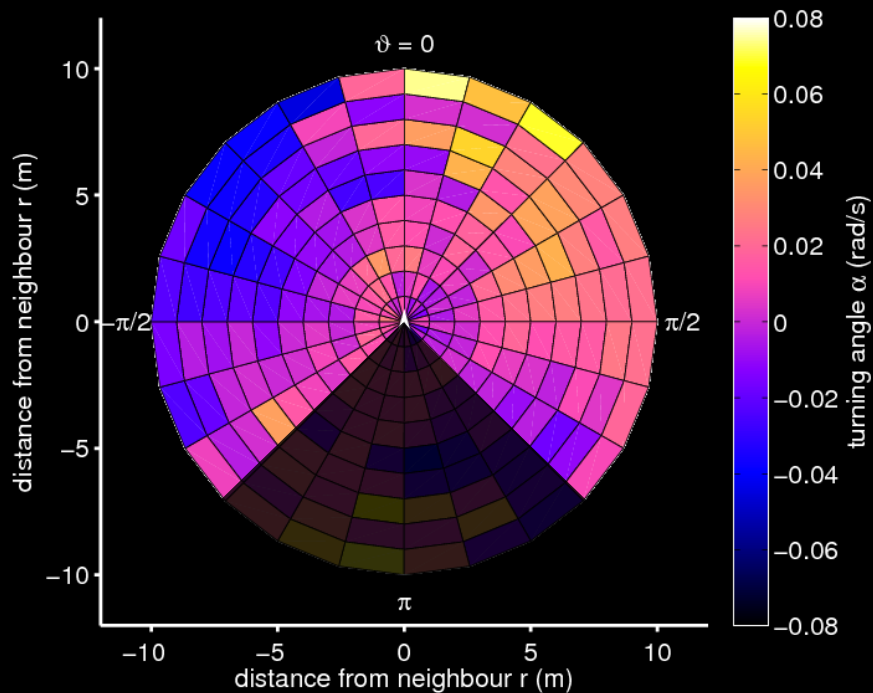
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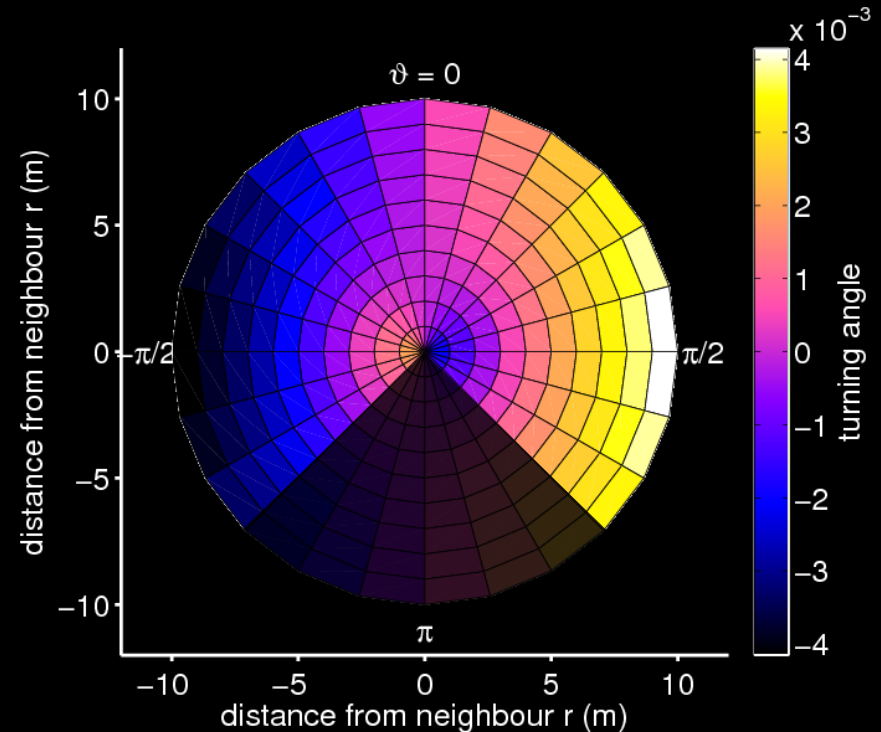


# Turning **mediates both** attraction **and** repulsion

## Empirical data

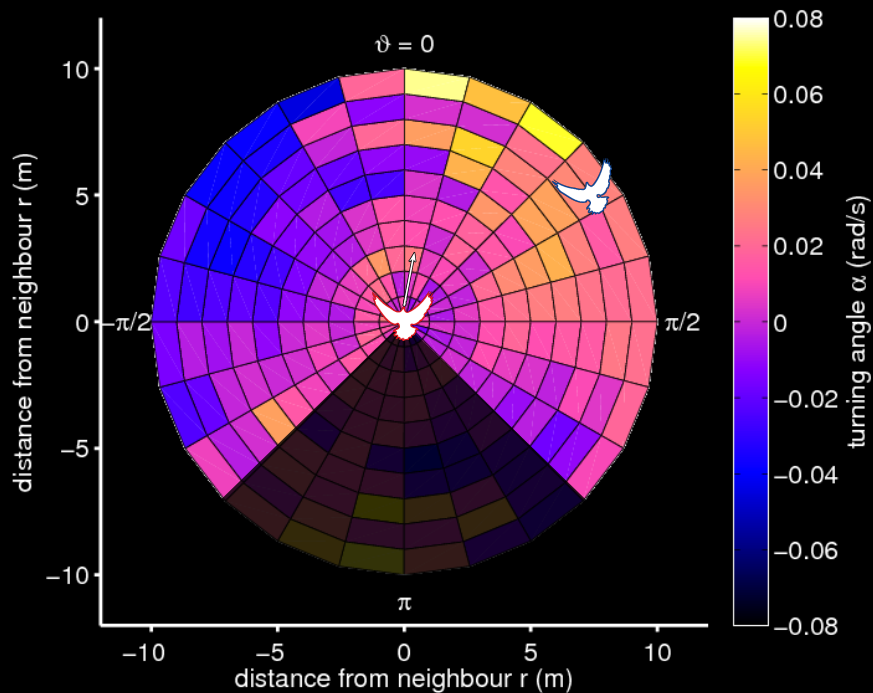


## Fitted function

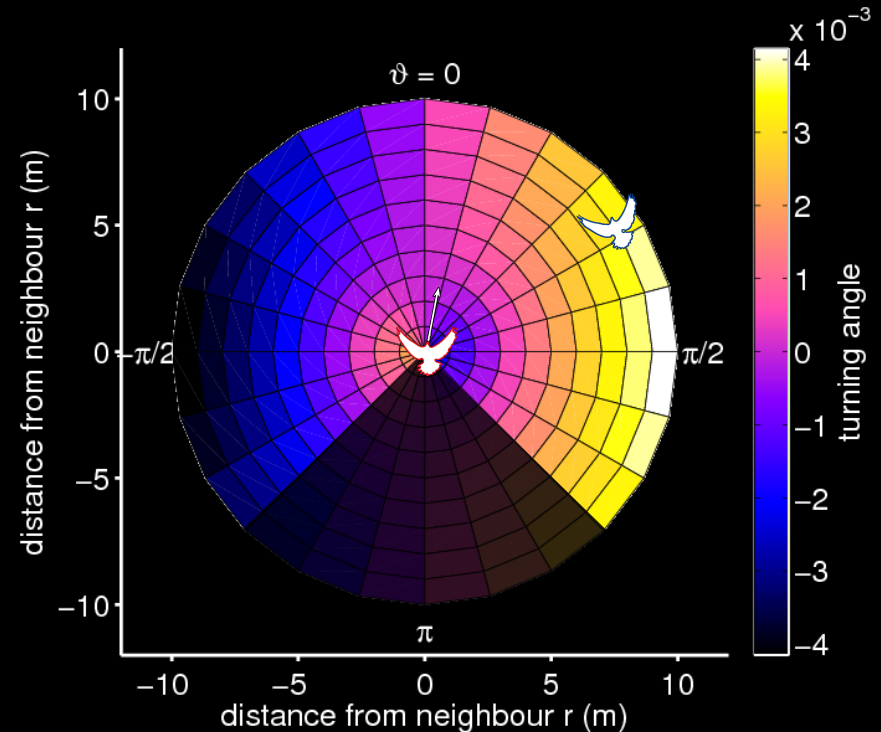


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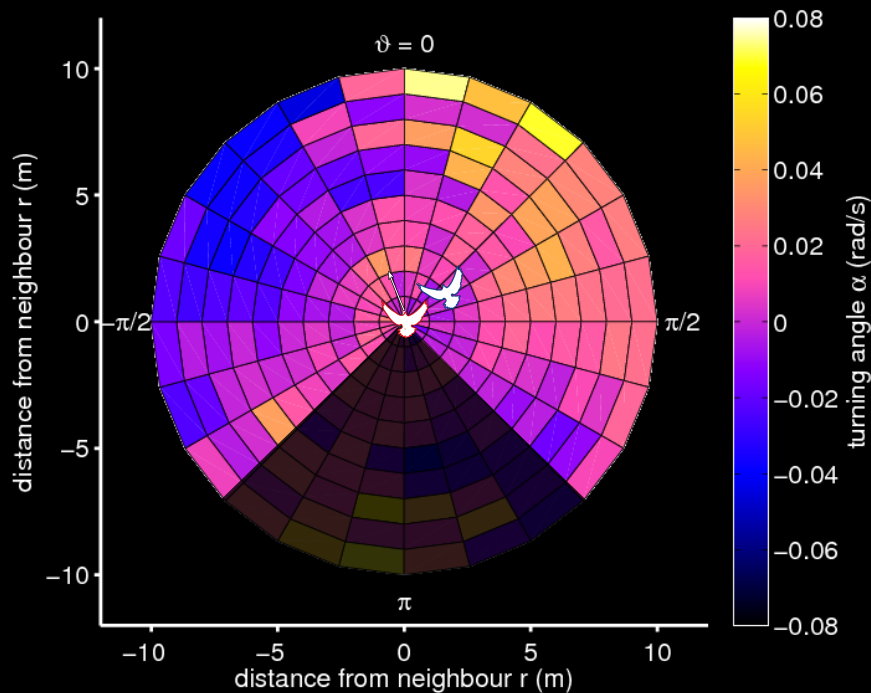


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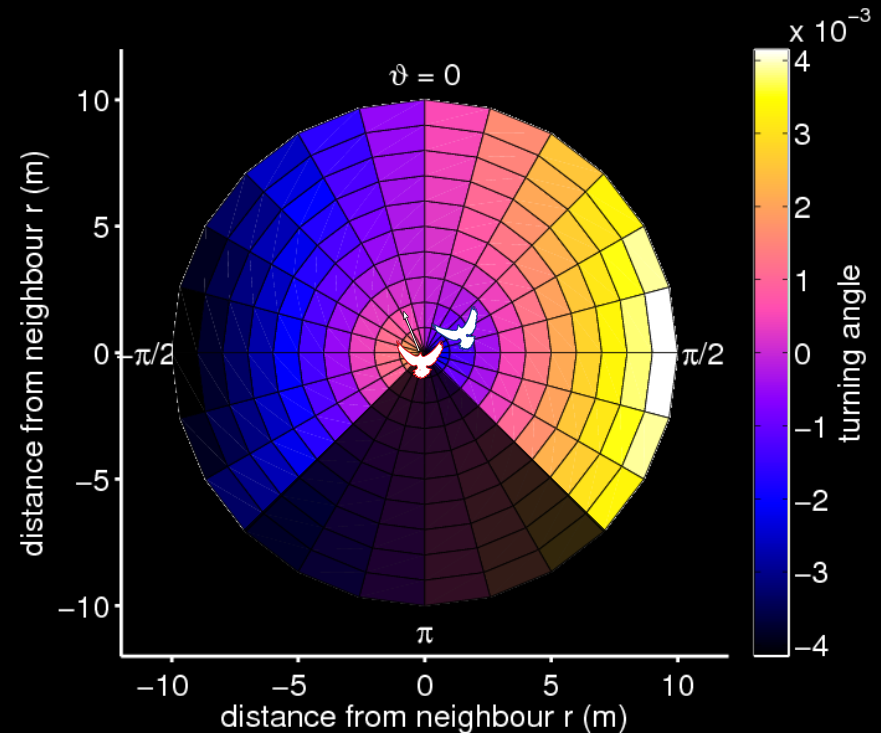


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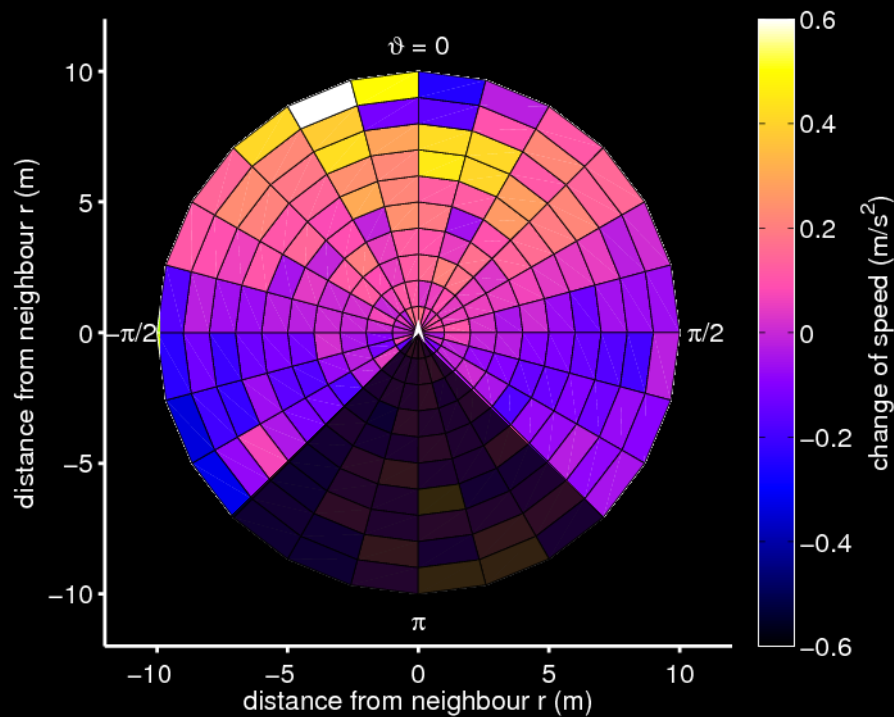


## Fitted function

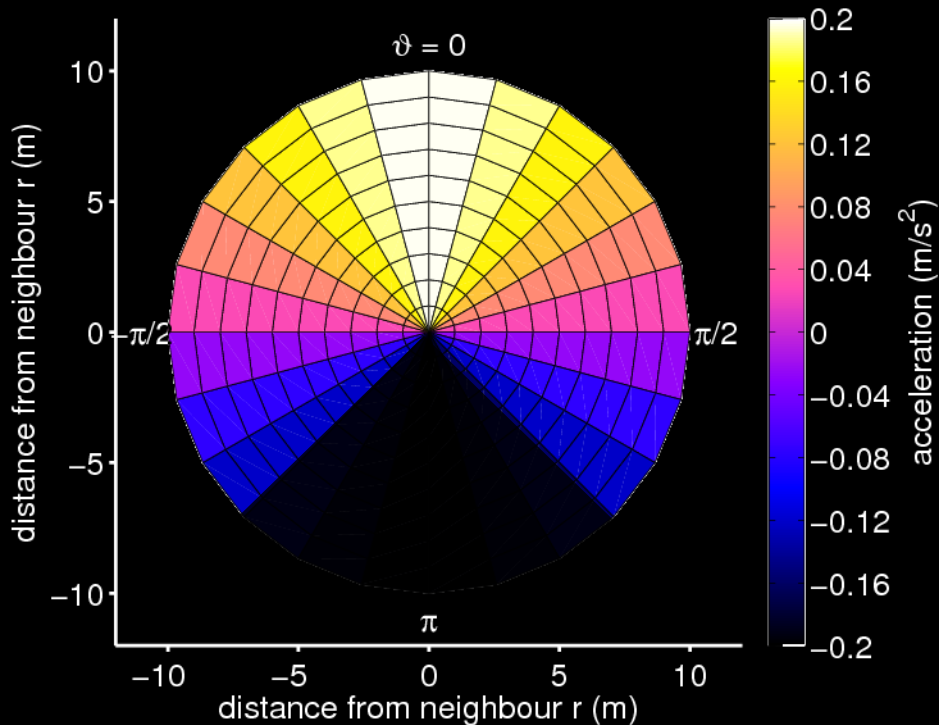


# Acceleration **mediates** attraction (but not repulsion)

## Empirical data



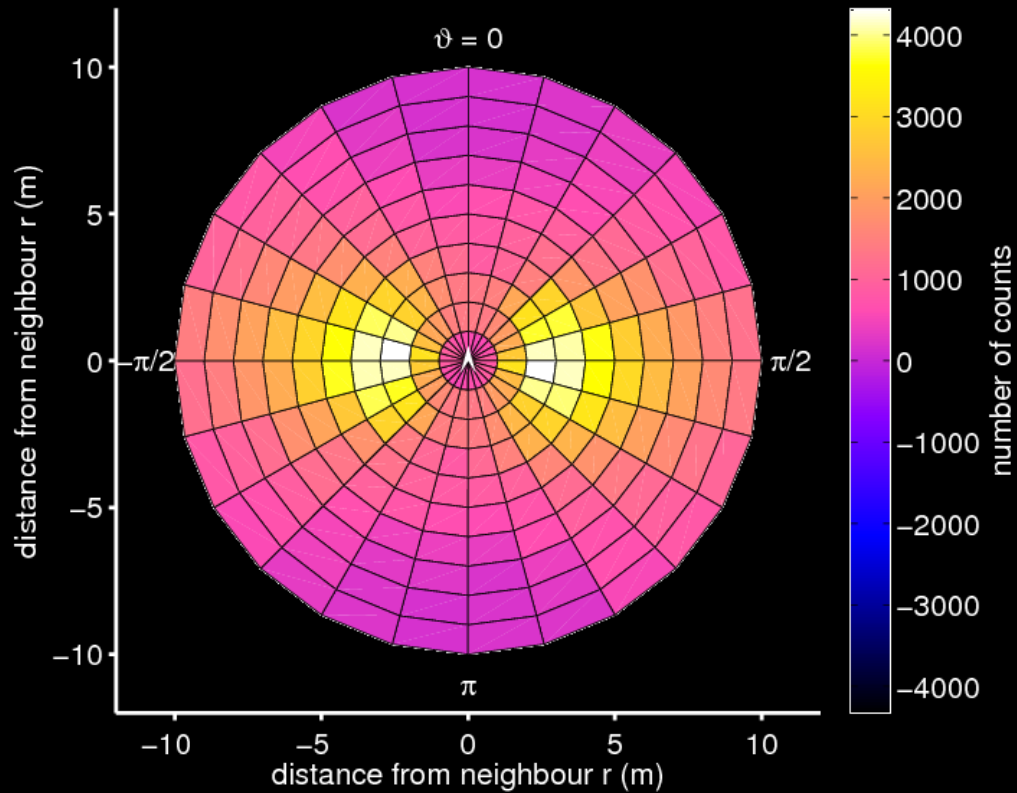
## Fitted function





# Relative position

## Birds fly side by side

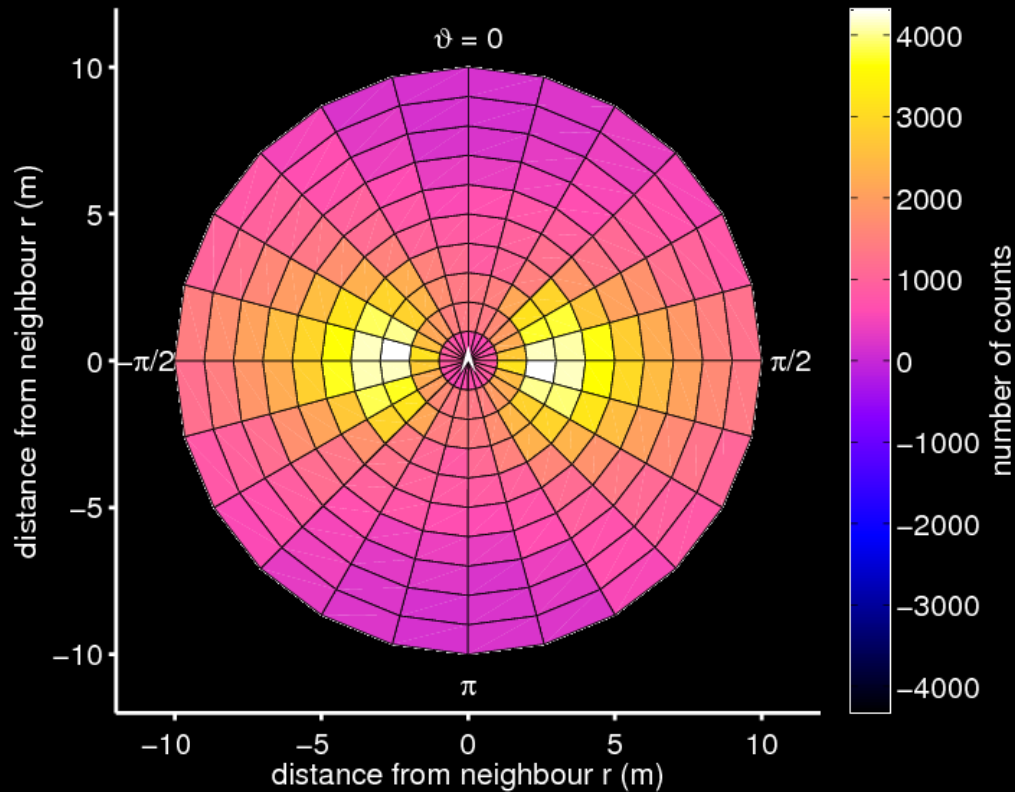


# Relative position

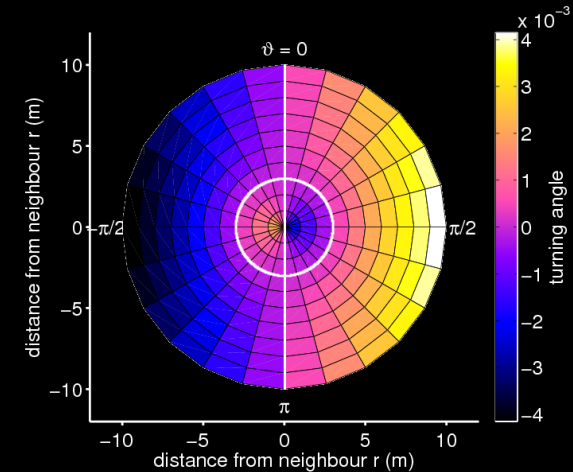


Birds fly side by side

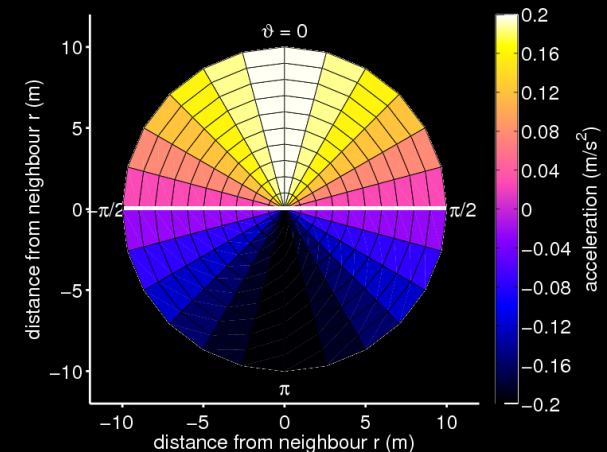
This is a direct **consequence of the interaction rules**



Turning is zero



Acceleration is zero

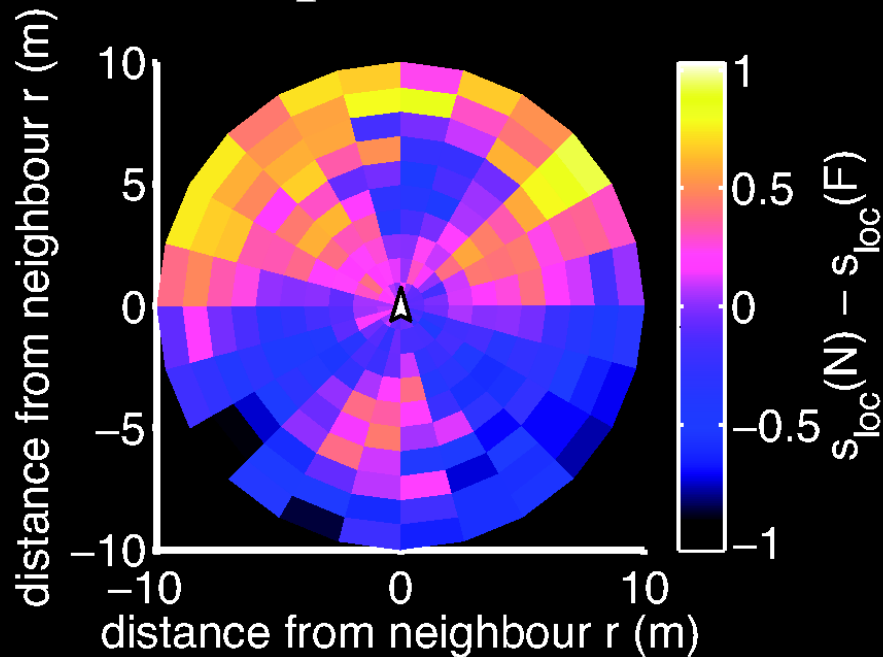


# Relative position

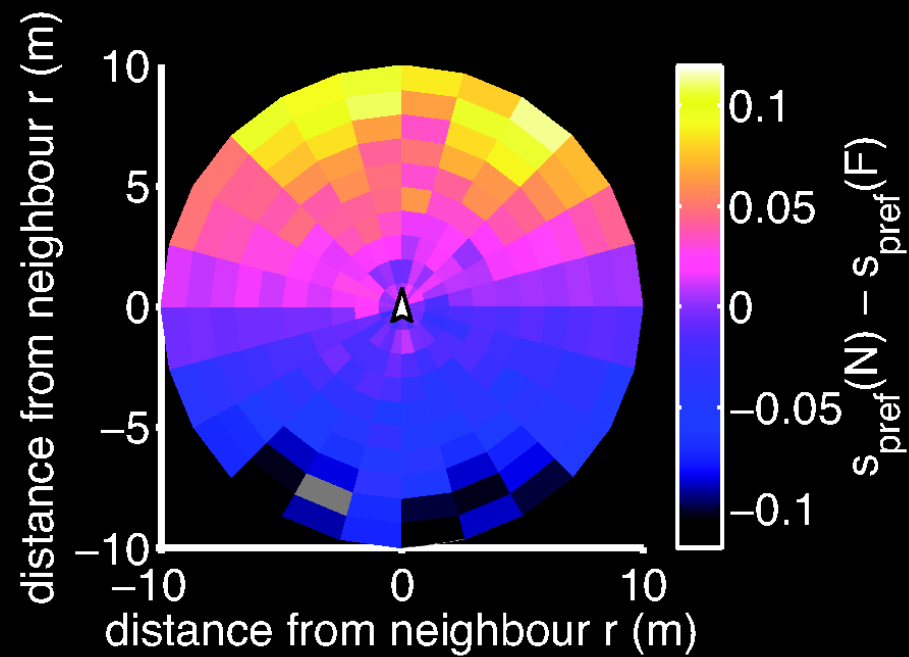


The **faster bird** (the bird that flies at higher speed when alone) **is more likely to get in front**

## Empirical data



## Simulation



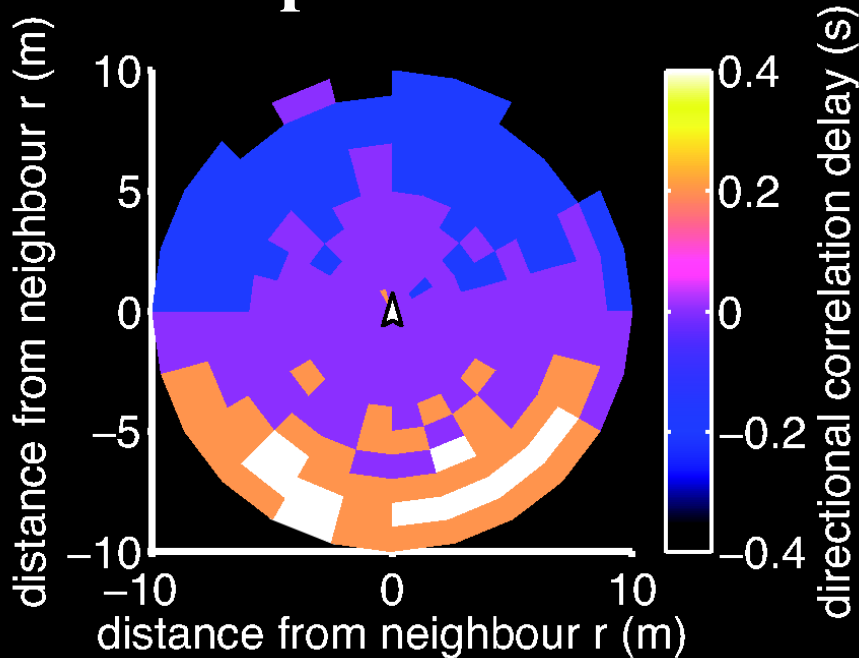


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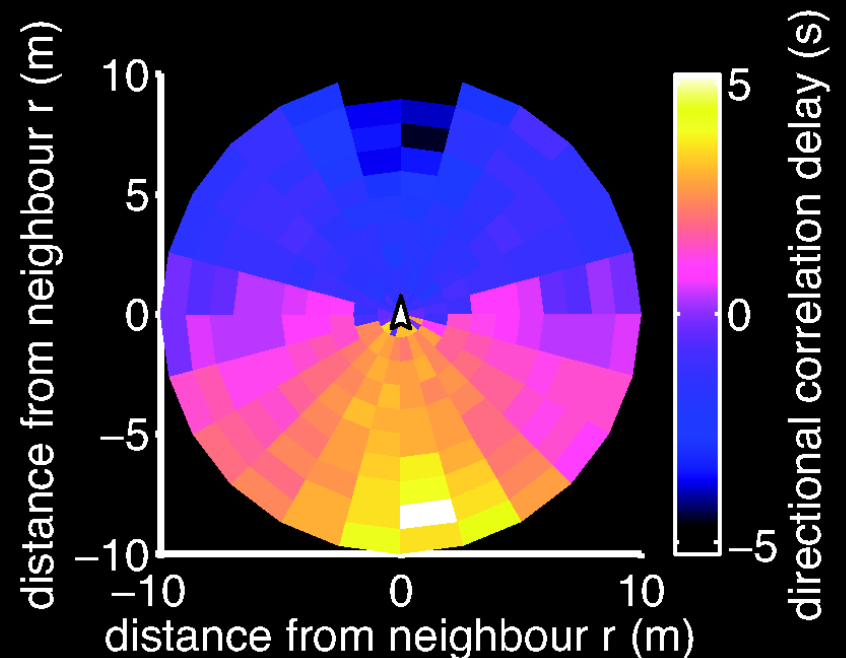


**The bird in front typically anticipates the changes of direction, while the bird behind follows.**

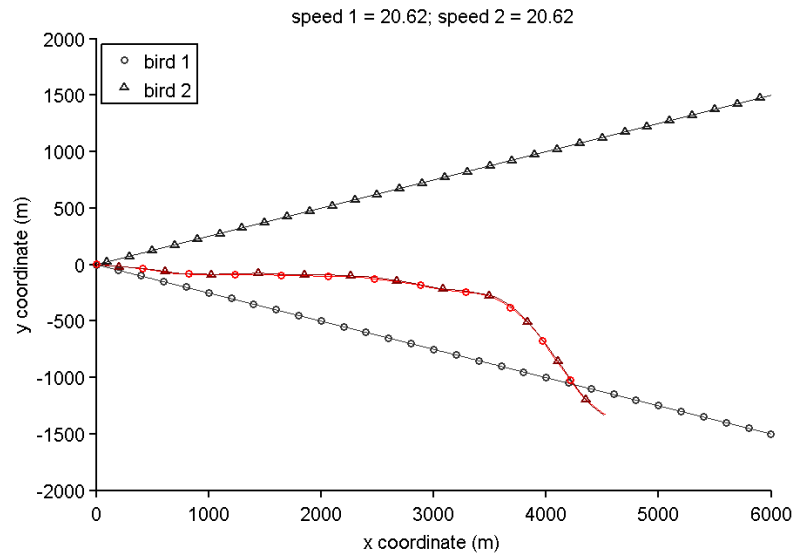
## Empirical data



## Simulation



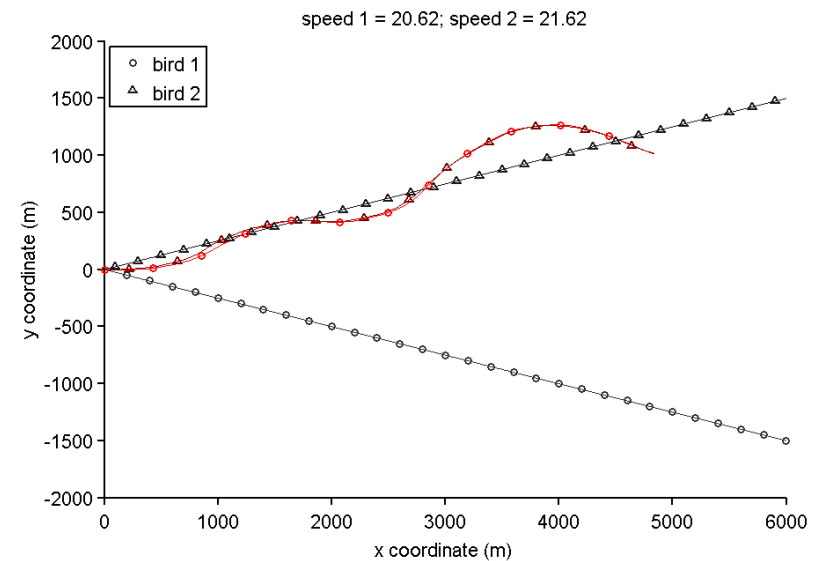
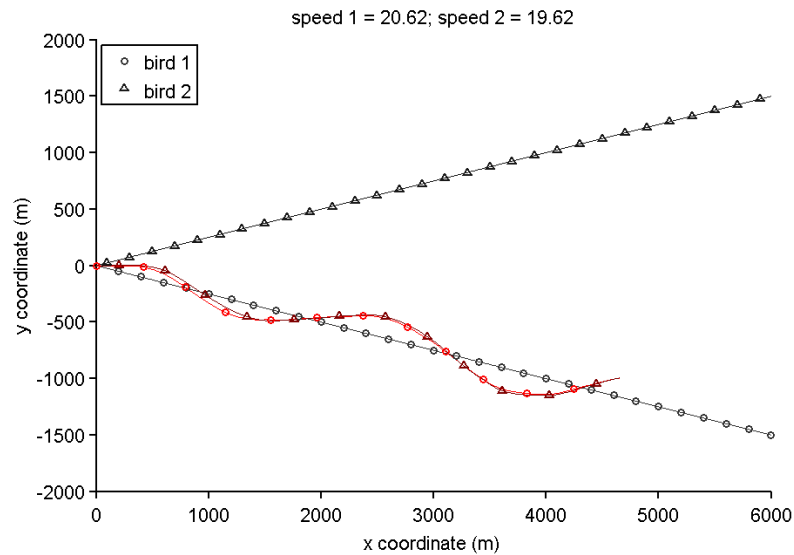
# Who decides?



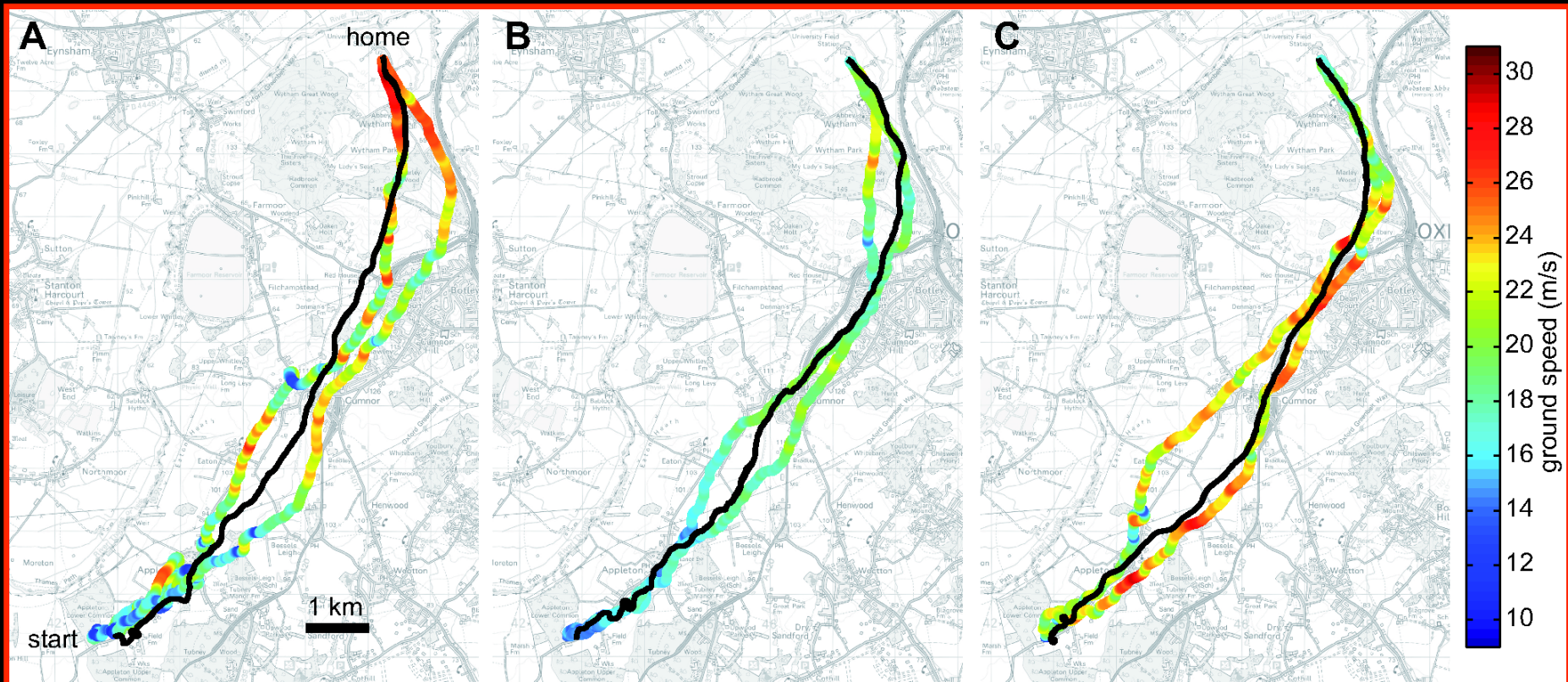
← The two birds have the same preferred speed

Bird 1 is faster

Bird 2 is faster



# Who decides?





# Summary

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- We track **pairs of pigeons with high-resolution GPS**, while they home together from a familiar site.
- We observe **attraction**, mediated by both turning in the direction of the neighbour and by changing speed, and **repulsion**, mainly mediated through direction changes.
- The interactions between **pigeons** mean they primarily **travel side by side**.
- Traveling side by side promotes compromise, as both birds respond to each other, but **if one bird gets in front it will lead changes in direction**.
- Our model further predicts, and observations confirm, that **a faster bird will be slightly in front and thus dominate the choice of homing route**.
- Our results provide a **mechanistic explanation of how group decisions emerge from individual differences** in homing flight behaviour.