Leopards, Drums & the Origin of the Universe

David Skinner UNIVERSITY OF CAMBRIDGE

Vectors have a length & direction



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$$\begin{pmatrix} 1\\1 \end{pmatrix} = \begin{pmatrix} 1\\0 \end{pmatrix} + \begin{pmatrix} 0\\1 \end{pmatrix}$$

points northeast

We can multiply vectors by scalars...

 $2\mathbf{a}$

a



...and we can add vectors together









- values f(x) are an infinite 'list of components'



In which 'direction' does it 'point'?

- we need to choose some basis functions







Joseph Fourier



Joseph Fourier





direction = tone quality



Temperature Maps of the Cosmic Microwave Background (CMB)



2003:WMAP

2013: Planck





The Planck Satellite European Space Agency What it sees

Expand CMB in a set of basis functions on the sky







The appropriate basis function depends on the situation







Alan Turing



Alan Turing



Animal coat patterns are close to basis functions on the hide



Alan Turing





(a)

















[Xu, Vest & Murray]







Harmonic Analysis

b

 $\mathbf{a} + \mathbf{b}$







