



FLEET

ARC CENTRE OF EXCELLENCE IN
FUTURE LOW-ENERGY
ELECTRONICS TECHNOLOGIES

Scientific Data Presentation: Seeing data in a new light

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Talk overview

Colour perception

- Why it matters
- Human colour response
- Colour-blindness
- Colour theory

Colour maps

- Linear
- Divergent
- Cyclic

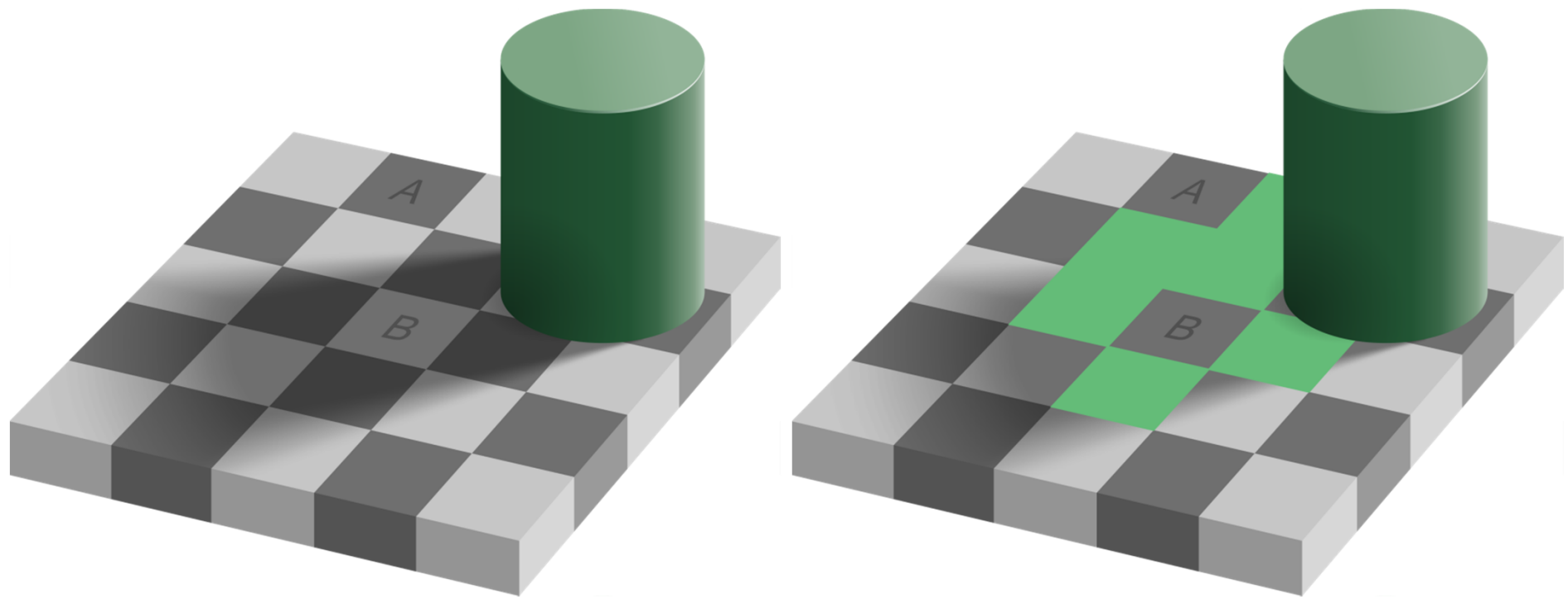
Summary

Helpful resources

Why is data perception important?

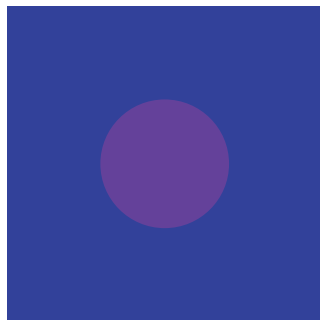
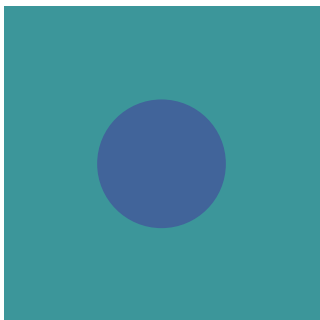
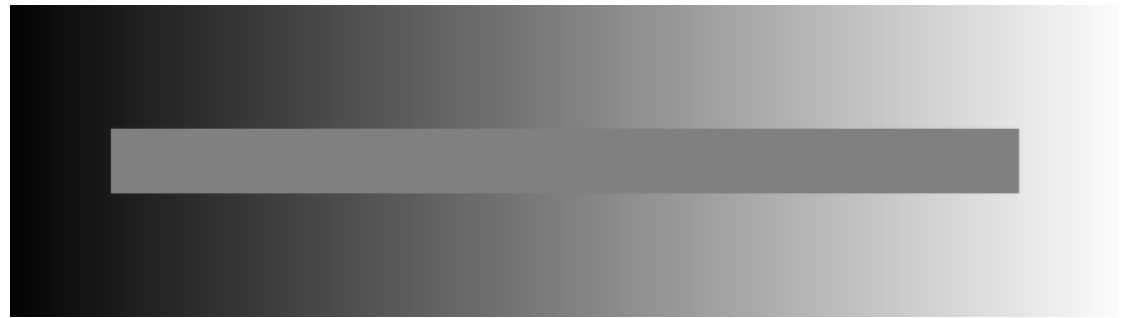
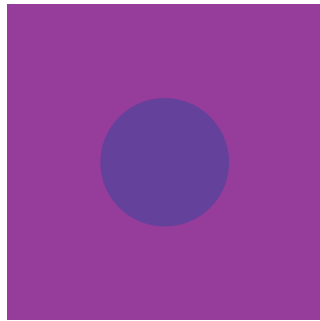
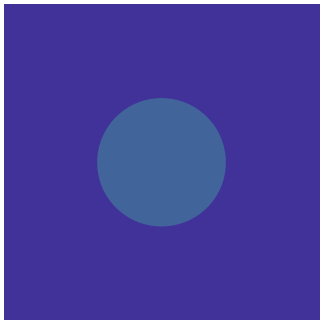
- Plots aid and inform our interpretation, when data is presented clearly, it is more likely to be understood.
- They say a picture is worth a thousand words and certainly a well-designed picture can communicate ideas more effectively.
- How you *present* data is not the same as how you *perceive* data. Artefacts of the representation can be thought to be physical, and “features” may not even exist.

Adelson's Checkerboard



The squares A and B are the same shade of grey.

Why is this? Lateral inhibition!



Local brightness perception is affected by the difference in surrounding brightness not just the brightness itself.

Images inspired by “The Brain from top to bottom”

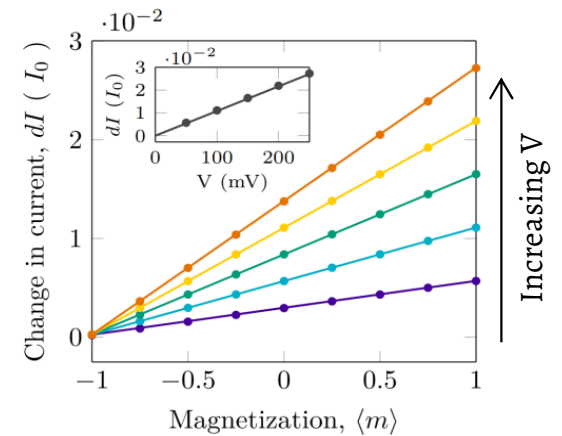
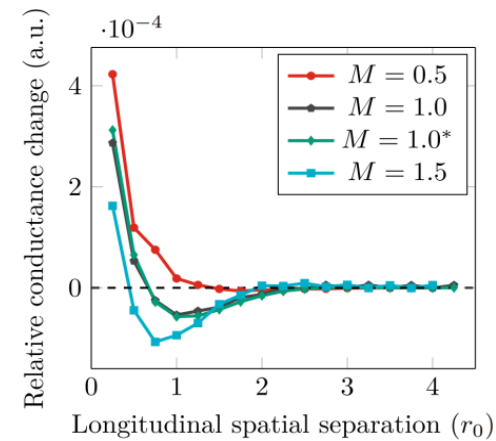
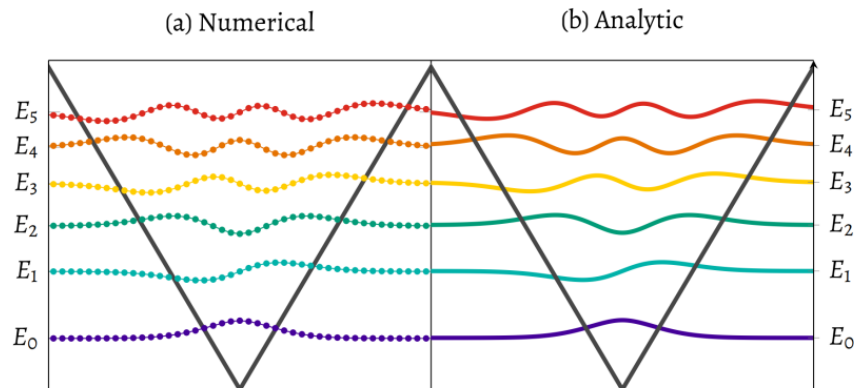
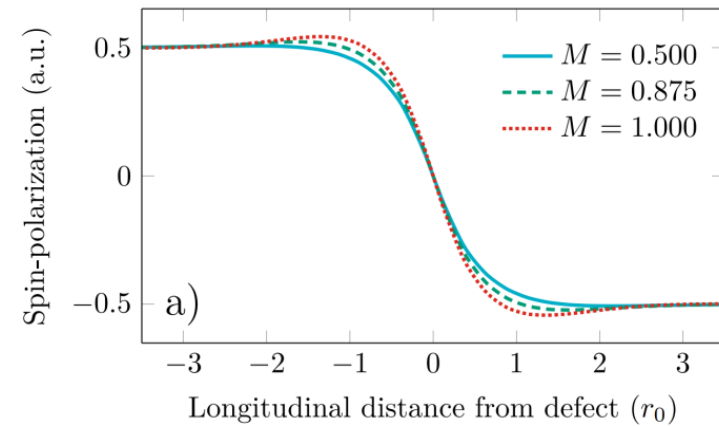
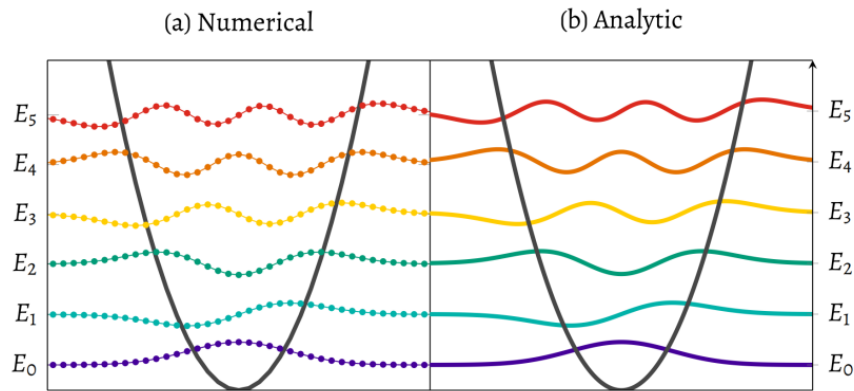
Colour-blindness in FLEET

Australia wide, approximately 1 in 12 males, and 1 in 200 females are colour-blind (either red-green 99.5% or blue-yellow 0.5%).

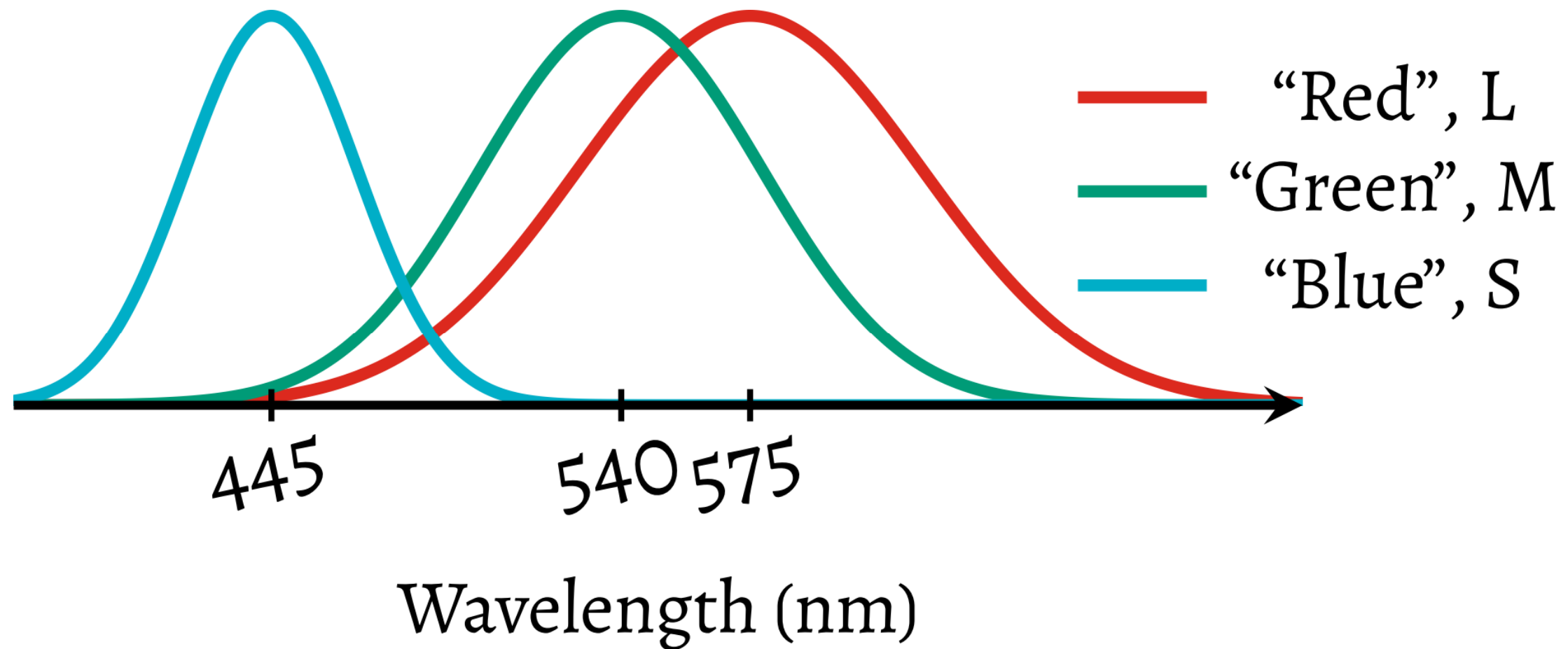
In FLEET the stats are unknown: **Reasons for colour-blind safe:**

- w% Red-Green Male
 - x% Red-Green Female
 - y% Blue-Yellow Male
 - z% Blue-Yellow Female
- More inclusive
 - Literally no reason not to
 - Seriously, don't be mean

Caveat: exceptions always exist



Typical human spectral response



Terminology

Luminance:

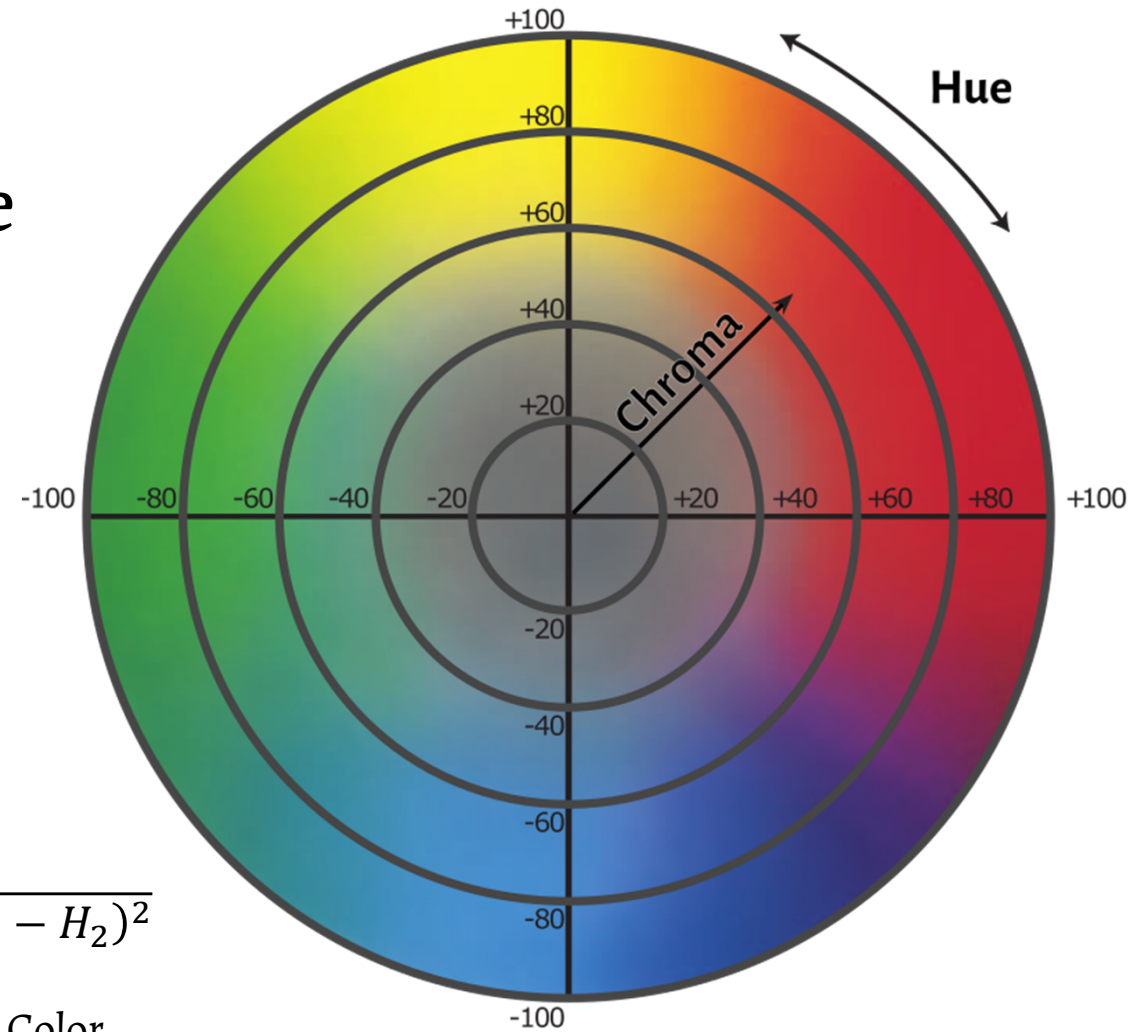
Brightness, from black to white

Chroma:

The saturation, a scale between grey and colourful

Hue:

The “colour” as imagined on the rainbow.

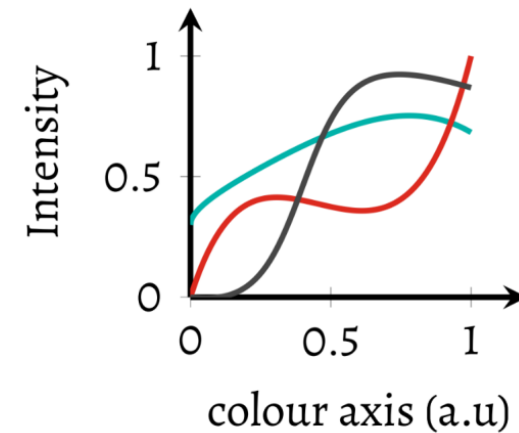
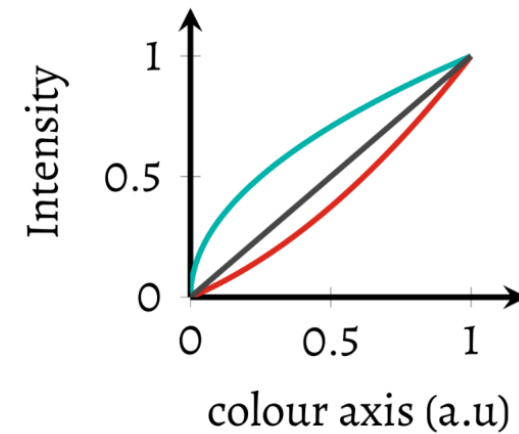


$$\text{Colour distance, } \Delta E = \sqrt{(L_1 - L_2)^2 + (C_1 - C_2)^2 + (H_1 - H_2)^2}$$

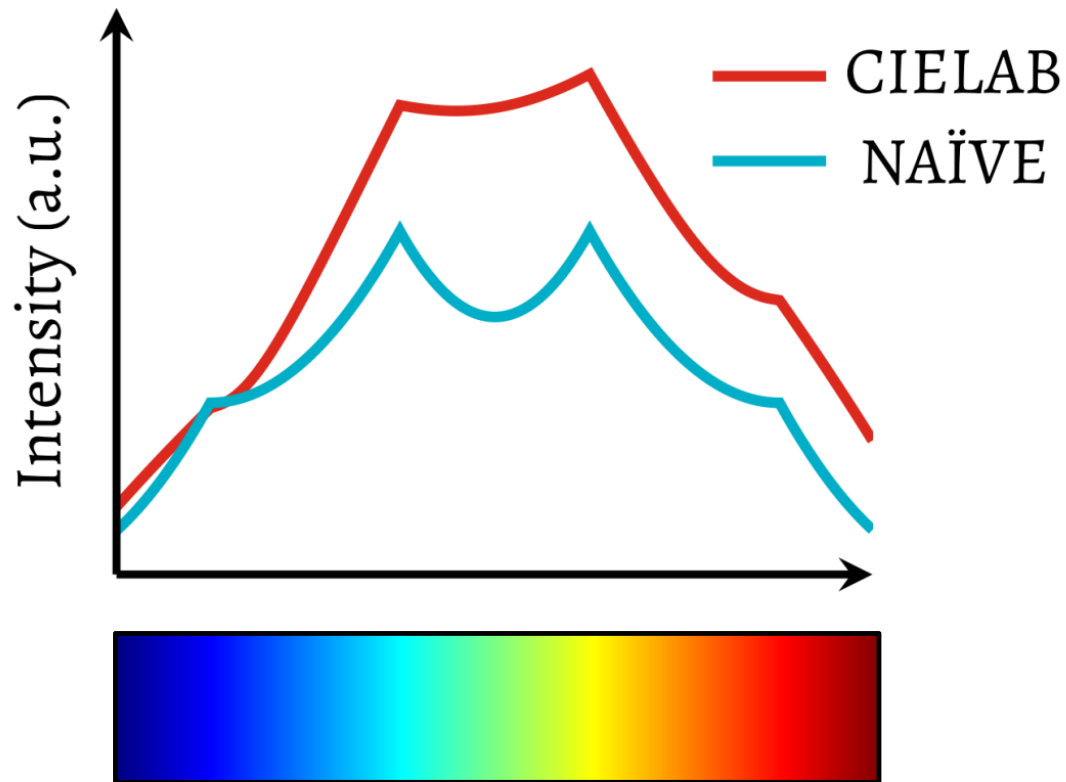
Modified image taken from x-rite: A Guide to Understanding Color

Linear/sequential colour maps

- Linear colour maps convey magnitude or strength of a signal by their luminance.
- It is greatly important that sequential data be represented as such, the colour map should be smooth and monotonic, preferably across the various colour deficiencies.



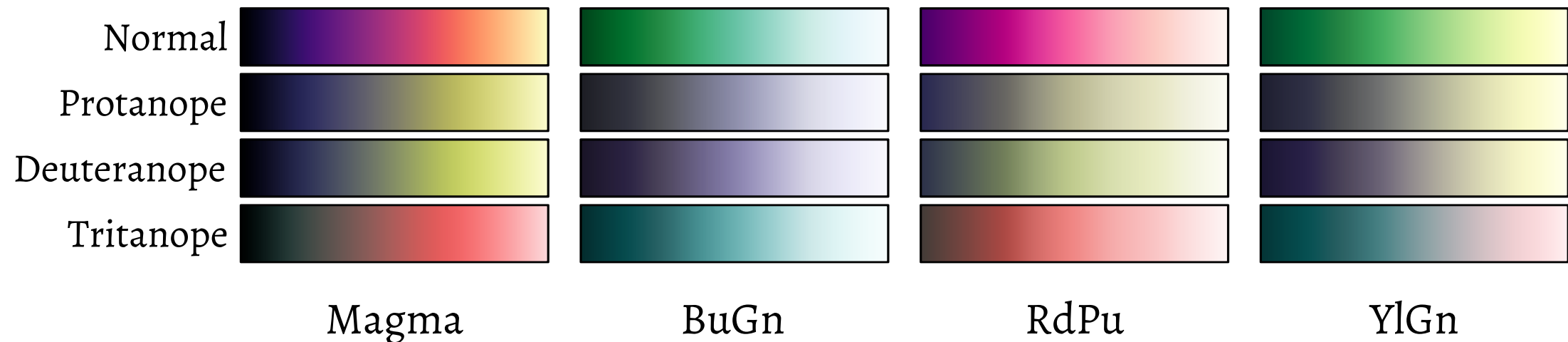
Bad choice of colour map: Jet



Jet strongly favours cyan and yellow, causing these to “pop” when viewed.

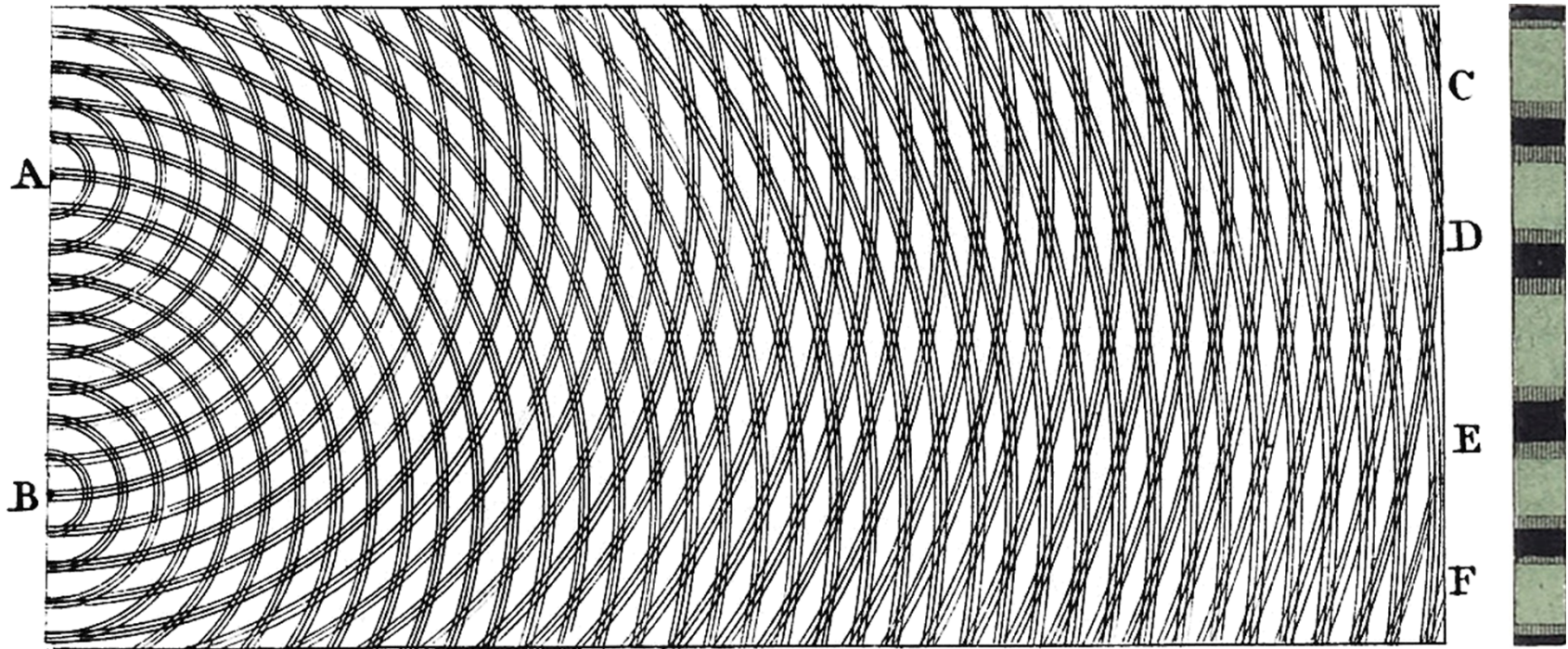
The intensity of the light doesn't correspond to the magnitude of the data whatsoever leading to spurious interpretation.

Linear/sequential colour maps



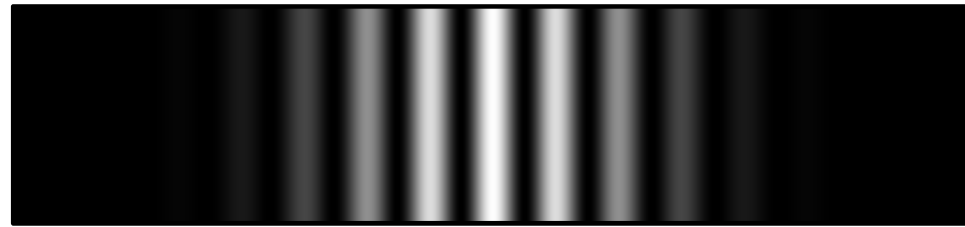
As long as the intensity varies from zero to one, *all* single hue and many double hue colourmaps are colour-blind friendly to some extent. Extra hue adds more depth but sacrifices accessibility, is it really needed?

Young's double slit experiment



Figures 267, 442(A) in “A Course of Lectures on Natural Philosophy and the Mechanical Arts” Thomas Young 1807

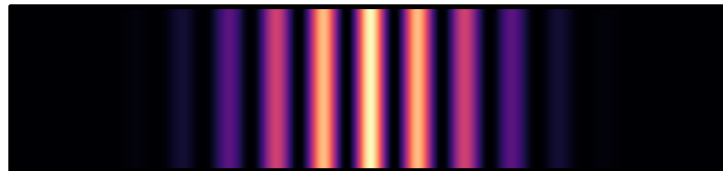
Young's double slit experiment



True intensity ("gray" colour map)



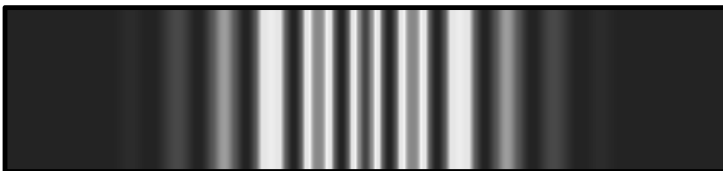
Jet colour map



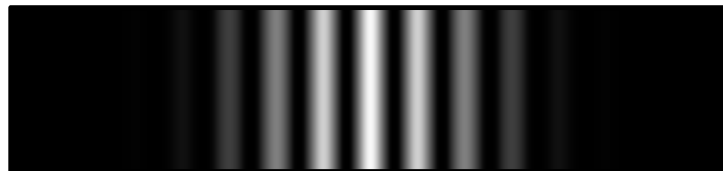
Magma colour map



BuGn colour map



Jet intensity



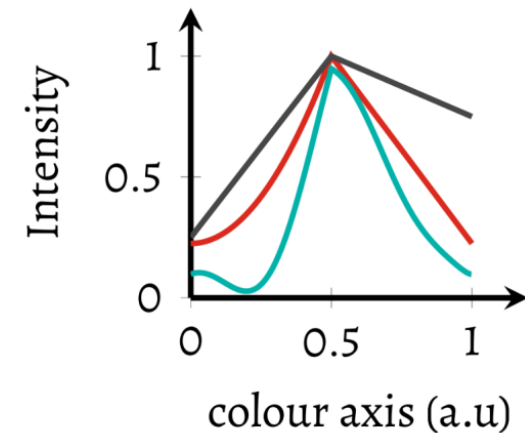
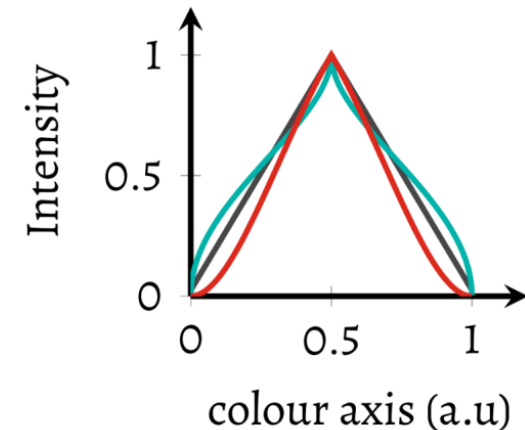
Magma intensity



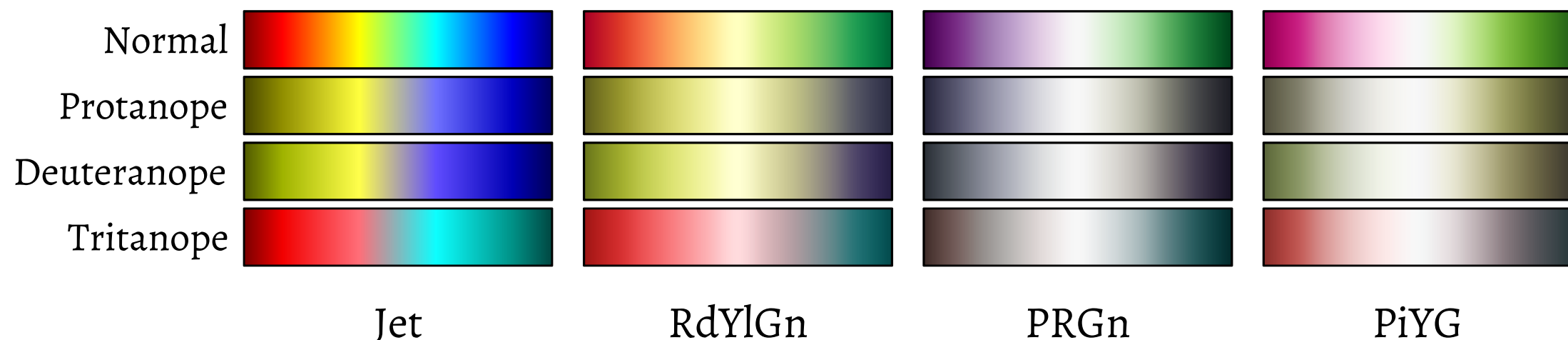
BuGn intensity

Divergent colour maps

- Divergent colour maps, like sequential, communicate their magnitude with luminance.
- Different signs are communicated with hue, and should be chosen well to accommodate colour-blindness.
- To prevent sign bias, they should be as symmetric as possible.



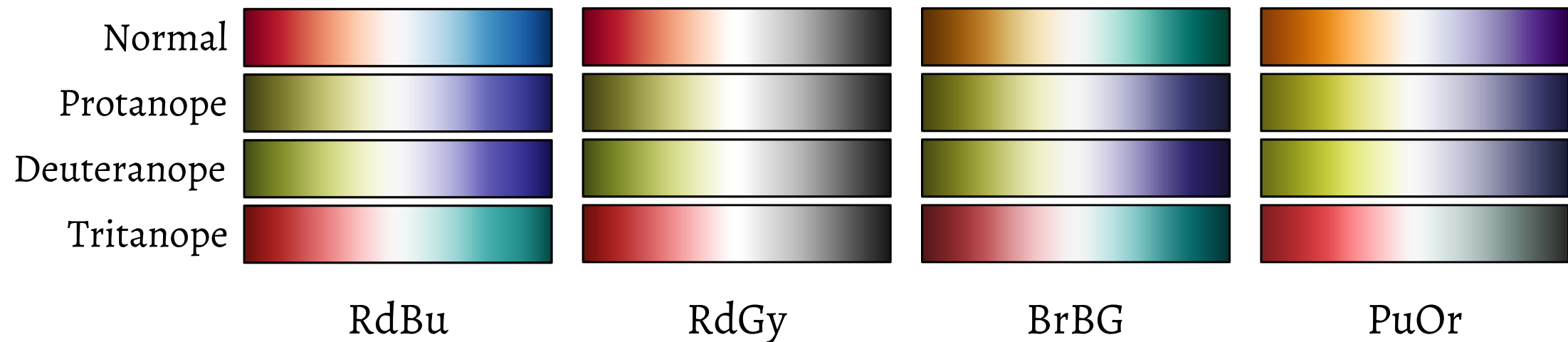
Divergent colour maps to avoid



Many divergent maps use hues that are incompatible with colour-blindness.

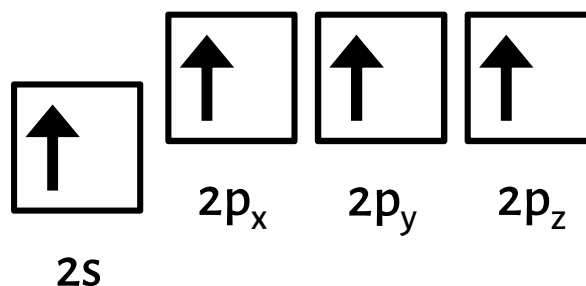
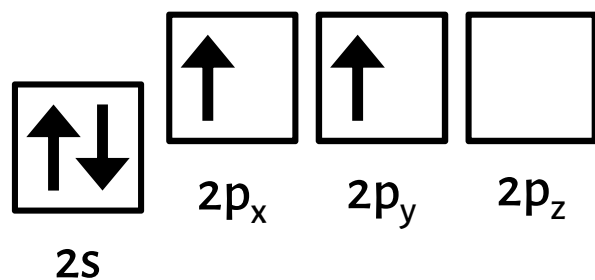
Jet should be avoided at all costs. It is not good in any metric.

Divergent colour maps to embrace

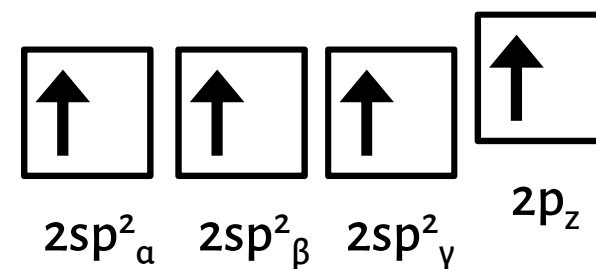


Good divergent colour maps use two hues that are discriminable.
Use of these colour maps will ensure your data is accessible to everyone.

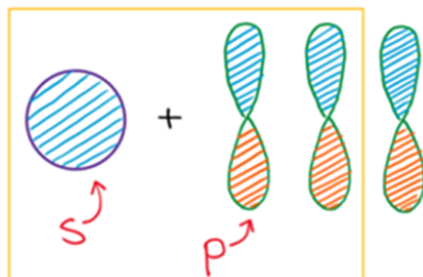
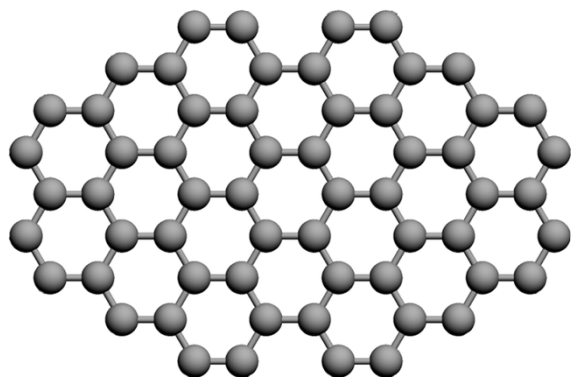
Graphene; sp^2 orbitals



Electron is promoted;
increased entropy

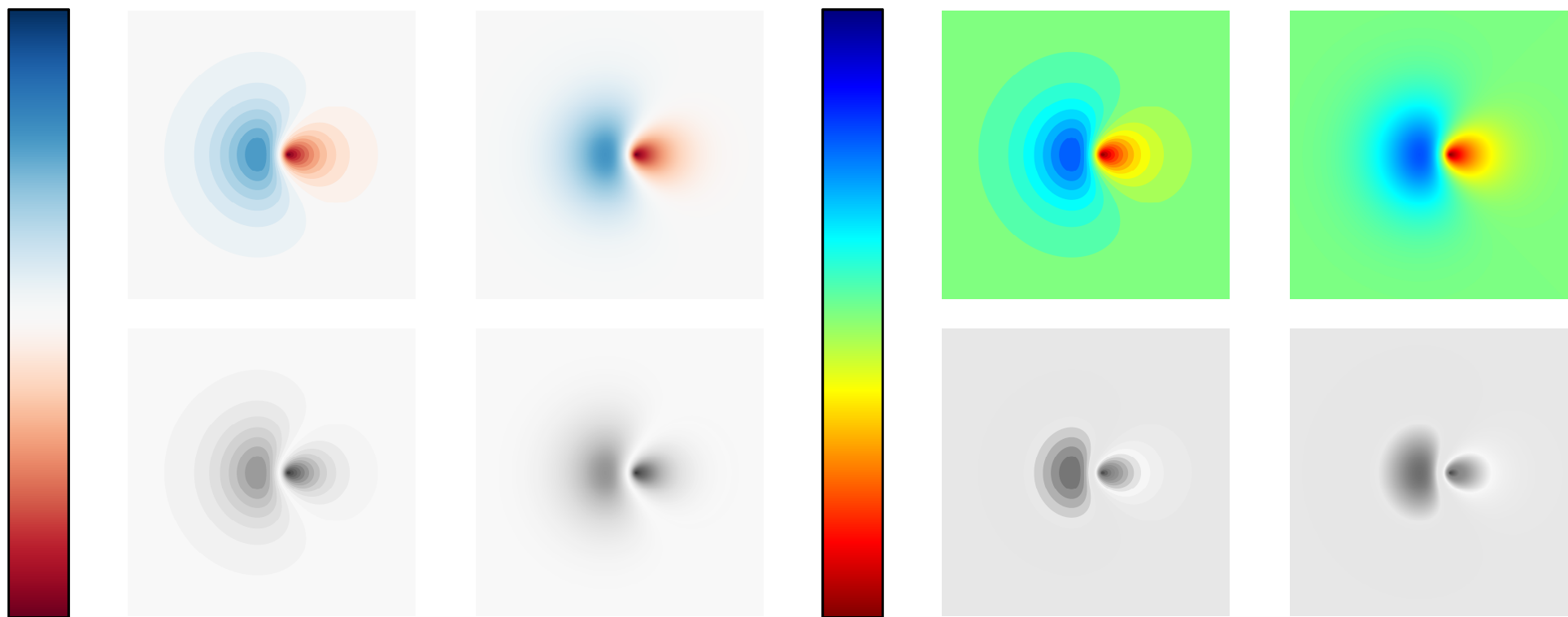


Planar symmetry
causes hybridization



Orbital sketches taken from organicchemistrytutor.com

Example data; sp^2 orbitals



NB: printing divergent data through white will also use less ink, yay environment!

Cyclic colour maps

- Useful for data with cyclical values
- For full-colour vision we can generate (approximately) constant intensity/luminance colour maps.
- If we introduce luminance to take the place of hue, then we can also generate colour-blind friendly cyclic maps.



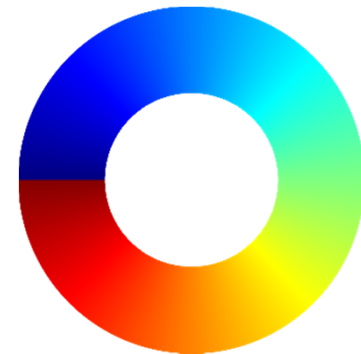
ColorCET C7



Twilight



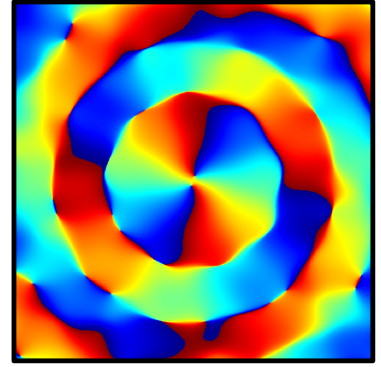
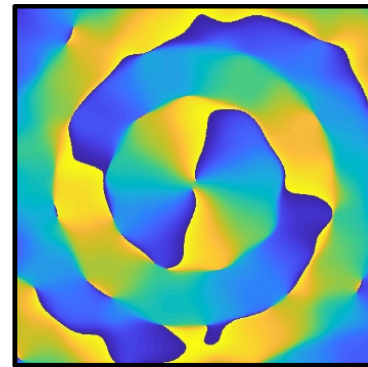
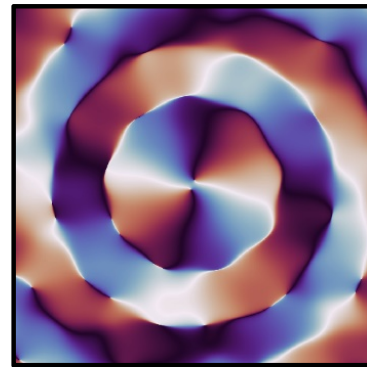
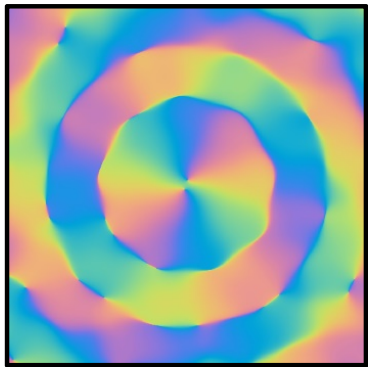
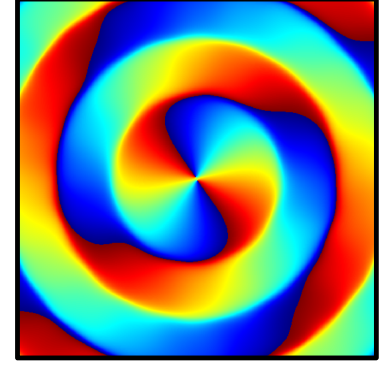
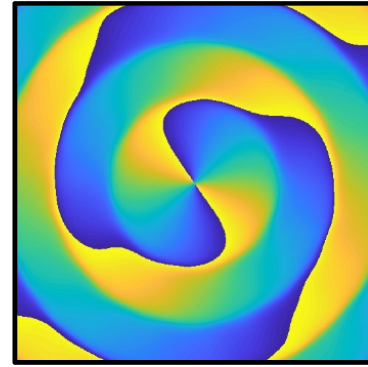
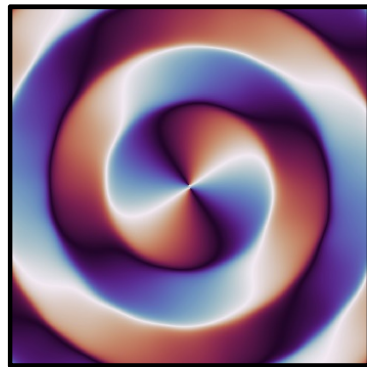
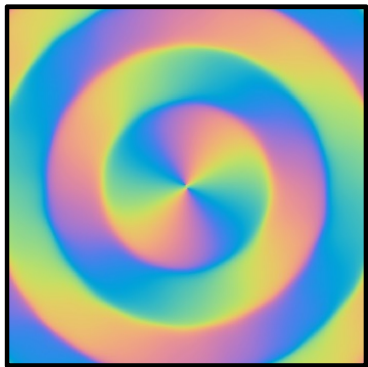
Parula



Jet



Example data; phase of twisted light



Data courtesy of
Hugh Sullivan, ACEx

Key takeaways

- Colour blindness affects 1 in 12 males, 1 in 200 females
- Sequential colour maps for sequential data
- Divergent colour maps for divergent data
- Cyclic colour maps for cyclic data

(It's that simple!)

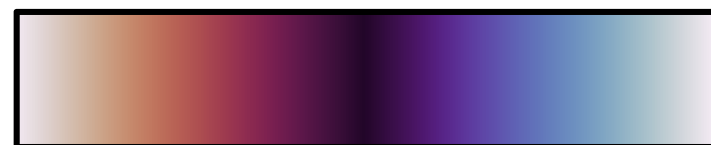
Great colour maps



Linear: Magma



Divergent: RdBu



Cyclic: Twilight

Info slide, and special thanks

Useful websites/programs

- Colorbrewer
- Matplotlib
- ColorCET
- Colorspace
- Colorblinding

Special thanks

- Jackson Smith for listening to several iterations of this talk
- Tim DuBois for opening my eyes to data perception
- To all of you for listening to this talk.

If you want tips, my resources, or generally just want to talk, my contact email is jesse.vaitkus@rmit.edu.au