The InPTA inclusive plotting colour scheme

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What is Colourblindness?

Colourblindness is the decreased ability to see colour or differentiate colour, and is pervasive throughout the human population to various degrees. It usually occurs due to the variation in the functionality of cone cells in the human retina. Though most variations of colourblindness are inherited conditions, it can also be caused due to damage to the retina, optic nerve or parts of the brain. There is also a natural decrease in colour sensitivity with old age. Forms of colourblindness vary from 10 percent of all individuals in some populations to at least 2 percent in others.[1]

Humans usually have 3 types of cones; L, M and S peaking at 564–580 nm, 534–545 nm, and 420–440 nm respectively, roughly corresponding to red, green and blue. [2]

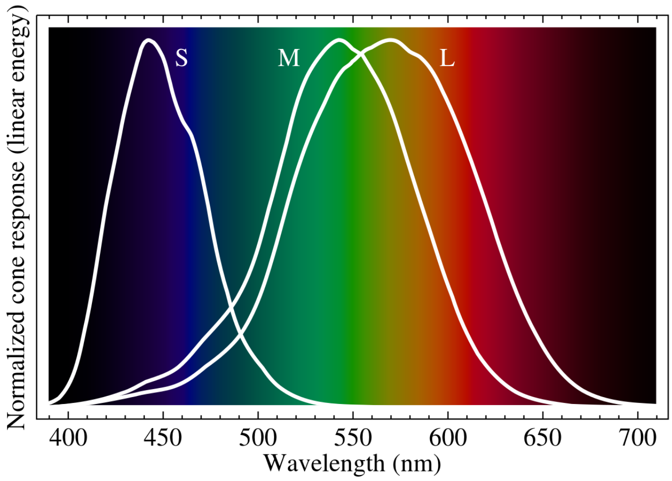
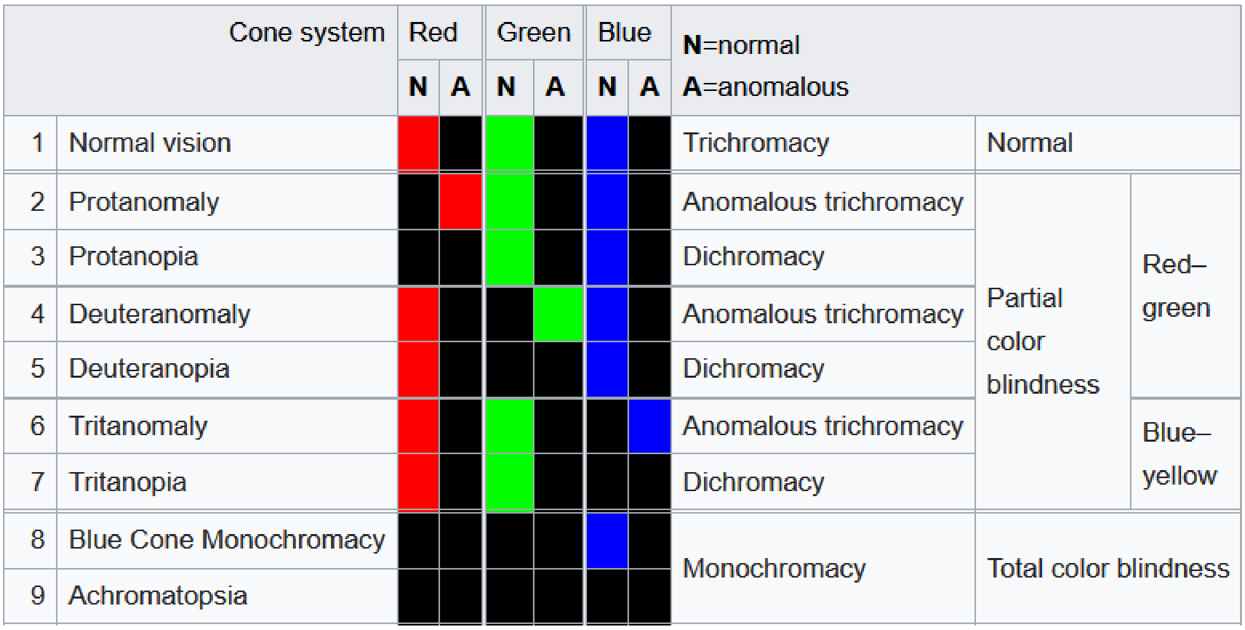


Figure 1: *three types of cones and their sensitivity range (Wikimedia commons)*

Most conditions associated with colourblindness fall under the following categories

- **Dichromacy**: Able to see 2 of the 3 primary colours, and their combination
- **Anomalous trichromacy**: Able to see 3 primary colours, but their colour matches differ from trichromats.
- **Monochromacy**:Total colourblindness, inability to distinguish colour.



	Cone system	Red		Green		Blue		N=normal A=anomalous		
		N	A	N	A	N	A			
1	Normal vision							Trichromacy	Normal	
2	Protanomaly							Anomalous trichromacy	Partial color blindness	Red–green
3	Protanopia							Dichromacy		
4	Deuteranomaly							Anomalous trichromacy		
5	Deuteranopia							Dichromacy		
6	Tritanomaly							Anomalous trichromacy		Blue–yellow
7	Tritanopia							Dichromacy		
8	Blue Cone Monochromacy							Monochromacy	Total color blindness	
9	Achromatopsia									

Figure 2: Different colour perception variations based on cones. (Wikimedia commons)

Pairs of colours which may be hard to distinguish are called "Confusion Colours", these can be plotted on a chromaticity diagram based on the various kinds of colourblindness as lines. Each point on the line will appear metameric (perceived matching of colors with different spectral power distributions.) to the person with a particular variation. These confusion lines are used to simulate colour charts of how a particular colour will be perceived by a person with a particular variation, and such charts are then used to generate colourblind friendly schemes by choosing colours which do not lie on the confusion lines. [3]

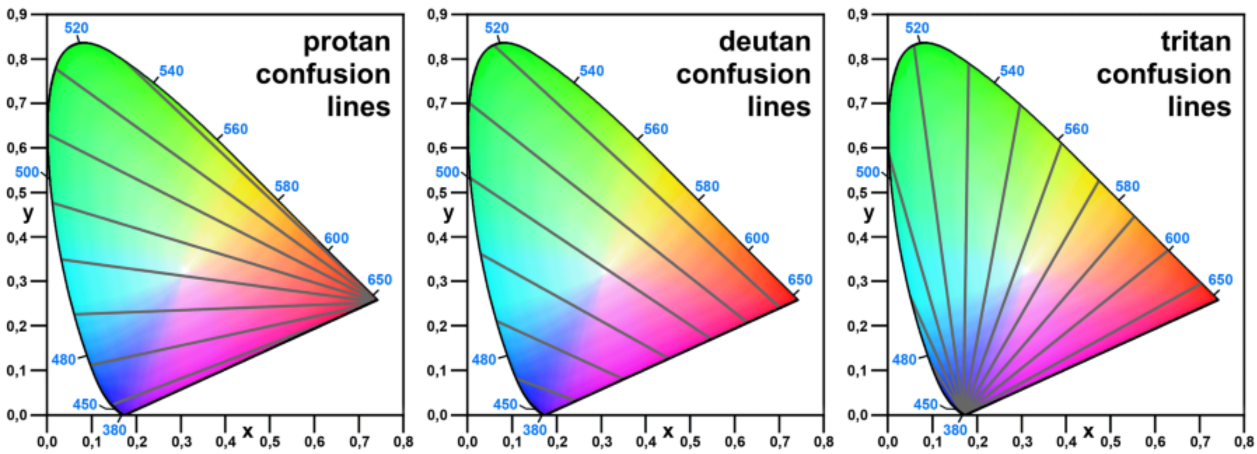


Figure 3: *some examples of confusion lines plotted on chromaticity diagrams (Wikimedia commons)*

Motivation for an inclusive colour palette

Modern astronomy heavily relies on data representation and visualisation in all forms of communication, may it be simple plots, 3D renders, images or coloured/highlighted text. [4] This is also true for pulsar timing publications where often timing residuals, DM values,etc are overplotted. Not being able to distinguish and discriminate between colours can affect a researcher's lived experience in varied ways all the way from a minor inconvenience to a debilitating and frustrating challenge while parsing data. It can also lead to miscommunication and misunderstanding of the data.

To ameliorate this and make our publications, presentations and all publicly available documents accessible to as many variations of colour sensitivity as we can whenever possible, we adopt and prescribe the following colour scheme to anyone who may wish to make use of it for their projects.

The InPTA scheme

This scheme was adopted for InPTA DR1 and can be used in future projects and colours can be reassigned as per need. [5] Our plots often involve overplotting residuals and DMs from multiband observations. Therefore these values may need the most amount of contrast.

We use David Nichols' excellent online tool which uses confusion lines to simulate how a particular colour (given as a hex code) would be perceived by people with some of the most common colour perception variations.

- Band 3 narrowband: #D81B60
- Band3+5 or band 5 narrowband: #1E88E5
- Band3 wideband: #17CE87
- Band3+5 or Band 5 wideband: #EAB106

We also use a set of other colours which fit well with the above four for other plots and values these are:

- #9600B1
- #80D41E
- #51A2B6
- #34661F
- #E27031

The ranges used above provide sufficient contrast for overlapping plots to be distinguishable for people with monochromacy, we recommend that users check their plots by consulting the comprehensive chart given below and adding a monochromatic filter in an image manipulation tool of their choice to test for contrast.

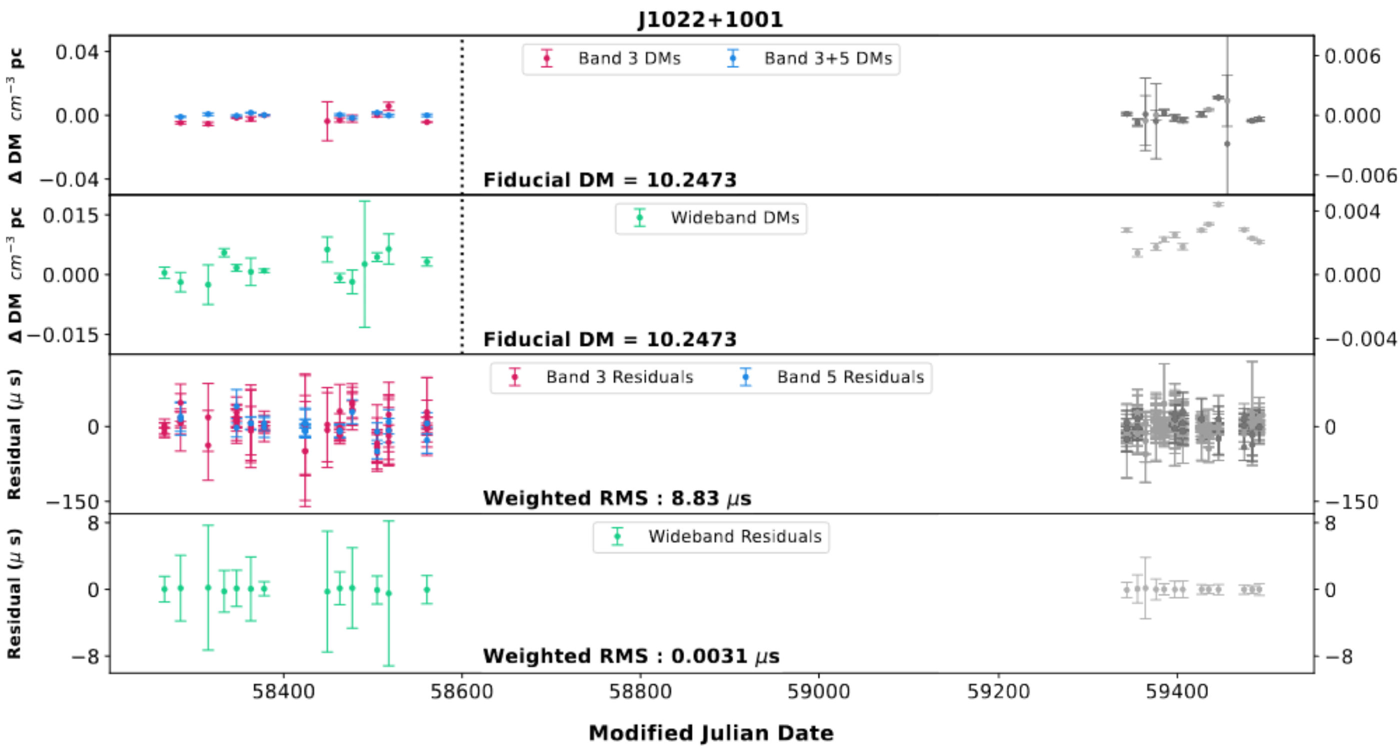


Figure 4: *A plot from InPTA DR1 which utilises the above scheme, right side of the image has a monochrome filter applied to demonstrate that overlapping points have enough contrast to be distinguishable for for people with monochromacy*

Figure 5: *A chart showing how the 'true' colours will be perceived by people with the most common forms of colourblindness; protanopia, deuteranopia, tritanopia and deuteranomaly. No scheme is perfect, however the range of suggested colours is wide enough that a maximally inclusive choice can be made based on this chart.*

References

[1] Wong B. Points of view: Color blindness. Nature Methods). 2011;8(6). Available from: https://doi.org/10.1038/nmeth.1618.

[2] Mollon JD. Color Vision. Annual Review of Psychology. 1982;33(1):41-85. PMID: 6977310. Available from: https://doi.org/10.1146/annurev.ps.33.020182.000353.

[3] FOMINS OM Sergejs. Multispectral Analysis of Color Vision Deficiency Tests. MATERIALS SCIENCE (MEDŽIAGOTYR). 2011;17(1). Available from: https://doi.org/10.5755/j01.ms.17.1.259.

[4] Smith DA, Melrose J. Astronomy with the color blind. The Physics Teacher. 2014;52(9):566-7. Available from: https://doi.org/10.1119/1.4902210.

[5] Tarafdar P, K N, Rana P, Singha J, Krishnakumar MA, Joshi BC, et al.. The Indian Pulsar Timing Array: First data release; 2022.