

I. Introduction and Guidelines

Colour blindness (or colour vision deficiency, CVD) refers to a reduced capacity or complete incapacity to distinguish colours and affects approximately one in 12 men and one in 200 women [1]. The most common type of CVD is the red-green colour blindness, which despite its name, does not only affect the visibility of red and green but the whole spectrum of colours, as red and green are part of every other colour to some extent. There are different types of CVD (Figure 1): Protanomaly (red-weakness) or Protanopia (red-blindness), Deuteranomaly (green-weakness) or Deuteranopia (green-blindness), as well as Tritanomaly (blue-weakness) or Tritanopia (blue-blindness) and Achromatopsia (monochromacy).

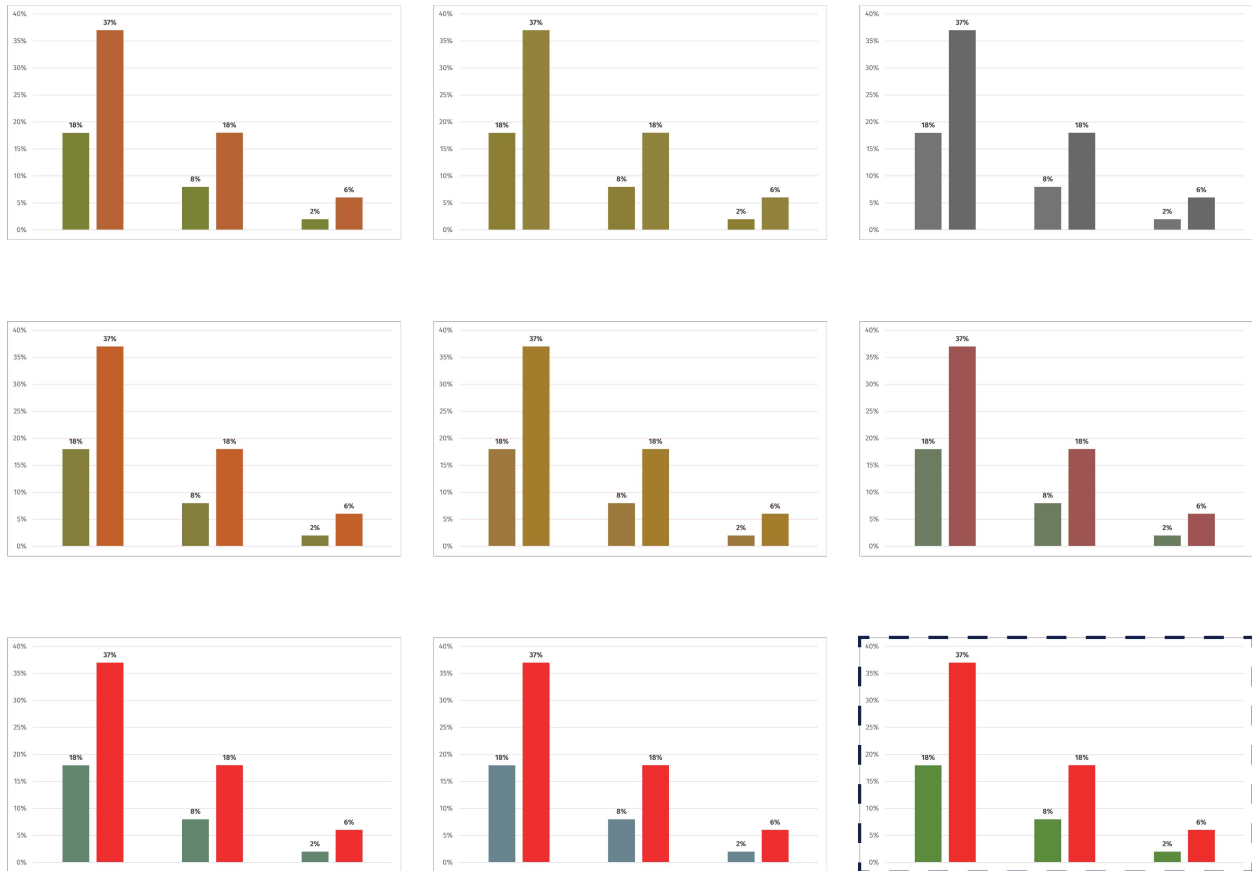


Figure 1. CVD simulation for different types of colour blindness. The original plot is highlighted at the bottom right with a dashed line. First column represents Anomalous Trichromacy (from top to bottom: red-weak, green-weak and blue-weak CVD), middle column represents Dichromatic vision (from top to bottom: red-blind, green-blind and blue-blind CVD) and right column represents Monochromatic vision (monochromacy and blue cone monochromacy). Simulations performed with [1].

Considering that the [Cherenkov Telescope Array](#) is a diverse collaboration with more than 1,500 members, whose work reaches the public worldwide, and keeping in mind the principles of CTA's [Astrodiversity](#) project, we encourage all CTA members to keep the following best practices in selecting suitable patterns and colour palettes for the publication of scientific and outreach plots in papers, posters and presentations, as well as to provide inclusive descriptions:

1. Use **different shapes/markers** for your data points (circles, squares, triangles...), as well as **different line styles** (solid, dashed, dot dashed lines...; Figure 2). Use large shapes and thick lines to improve visibility. In case of pie charts or histograms, fill each section with some patterns (Figure 3).

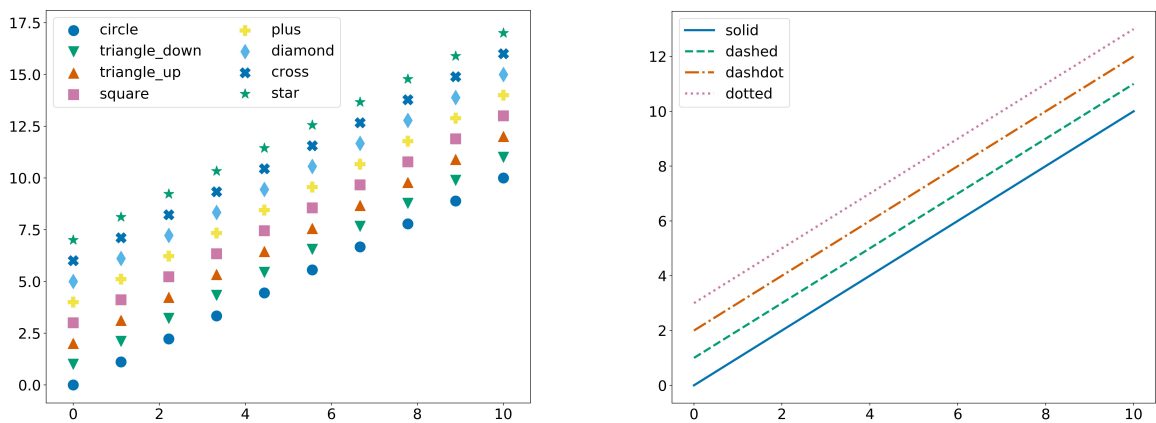


Figure 2. Example of markers (left) and line styles (right) available on Matplotlib.

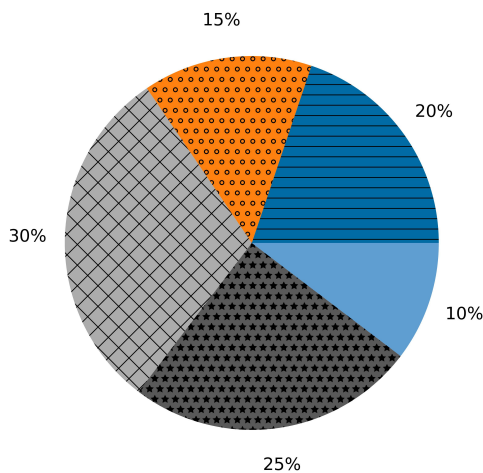


Figure 3. Example of a pie chart showing different patterns. Created on Matplotlib.

3. When giving an **oral or written description**, avoid describing the results of a plot based only on the colour and use the shapes instead (e.g. “the dashed line represents...,” instead of “the green line represents...”). If that is not possible (e.g. with skymaps), try to use colour blind friendly palettes (see Point 4).
4. In Matplotlib, use colour blind friendly **colormaps**, such as the default “viridis” or the new “cividis”¹ (Figure 4 – upper panel) and avoid those already known for being problematic (e.g., “jet”). Apply the same rule for **colorcycles**: in this case, you can set the Matplotlib style “tableau-colobblind10” or “seaborn-colobblind” (Figure 4 – bottom panel). See Section II.

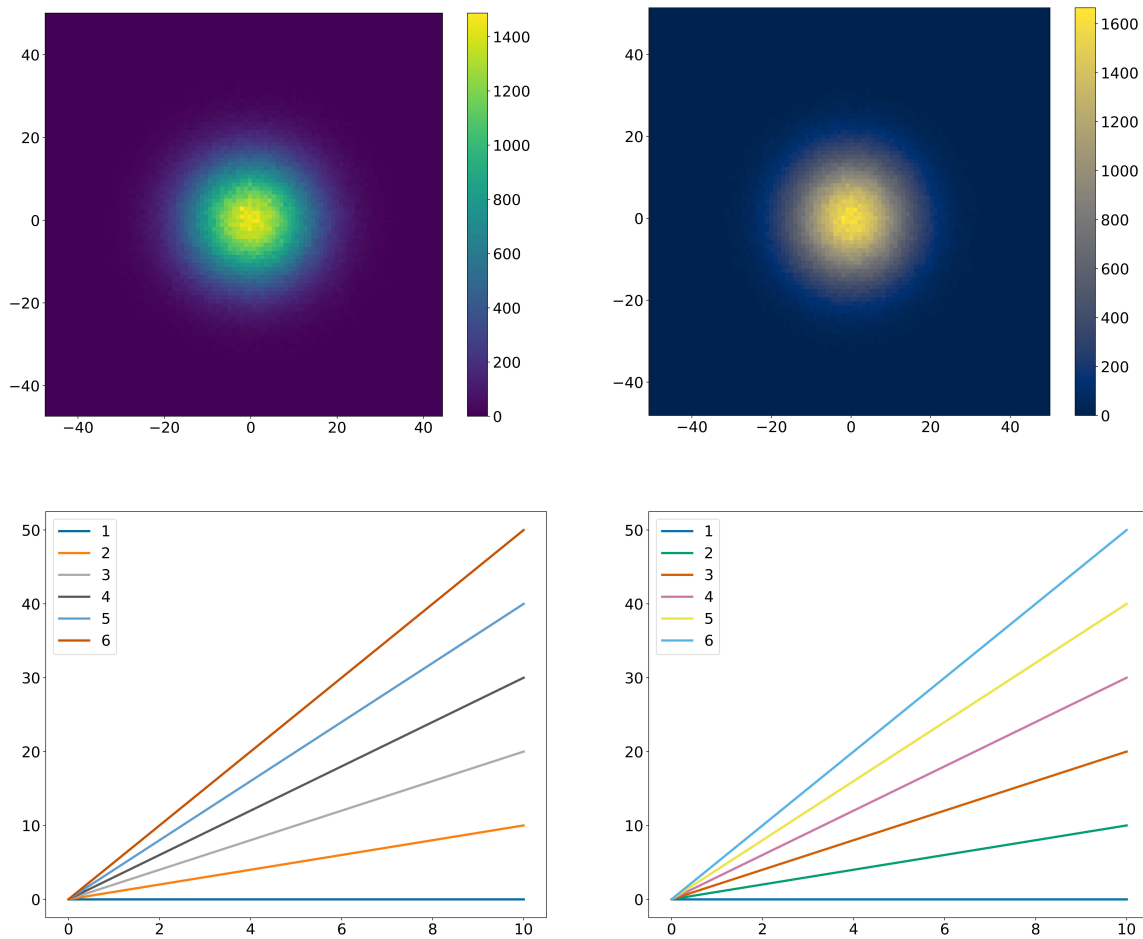


Figure 3. CVD friendly *colormaps* (upper panel: “viridis” on the left and “cividis” on the right) and *colorcycles* (bottom panel: “tableau-colobblind10” on the left and “seaborn-colorblind” on the right).

¹ “cividis” is a new *colormap* created with the aim of providing the same colour view to all users, regardless of whether or not they have some type of red-green colour blindness. It was created based on simulations from “viridis” (see [2] in Section II).

5. **Find an appropriate colour palette** with online tools, such as [ColorBrewer2.0](#).
6. Check if your plot is understandable for everybody with online colour blindness **simulators**, like the one you can find at www.color-blindness.com (more information about CVD also included).

II. Support Material and References

- Matplotlib uses by default a style with the colour blind friendly *colormap* “viridis.” In order to change the *colormap* to “cividis,” you can simply add the option `cmap= 'cividis'` to your code. The default style, however, does not use a CVD friendly *colorcycle* and hence, to change it to “tableau-coloblind10” or “seaborn-coloblind”, you need to load the following packages:

```
import matplotlib.style as style
style.use('tableau-colorblind10')
```

or

```
import matplotlib.style as style
style.use('seaborn-colorblind')
```

- [Matplotlib Markers](#)
- [Matplotlib Line Style](#)
- [Matplotlib Hatch Demo](#)

[1] Colour Blindness simulator and CVD information: <https://www.color-blindness.com/>

[2] Nuñez J.R., Anderton C.R., Renslow R.S. (2018), “*Optimizing color maps with consideration for color vision deficiency to enable accurate interpretation of scientific data.*” PLoS ONE 13(7): e0199239. <https://doi.org/10.1371/journal.pone.0199239>

[3] Automatic colour palette online creator: <https://colorbrewer2.org/>

[4] <https://towardsdatascience.com/two-simple-steps-to-create-colorblind-friendly-data-visualizations-2ed781a167ec>

III. Contact

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