



**cherenkov
telescope
array**

BEST PRACTICES FOR COLOUR BLIND FRIENDLY PUBLICATIONS & DESCRIPTIONS

[CTAO Astrodiversity Project](#) | Last update: October 2020

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1 Introduction

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).

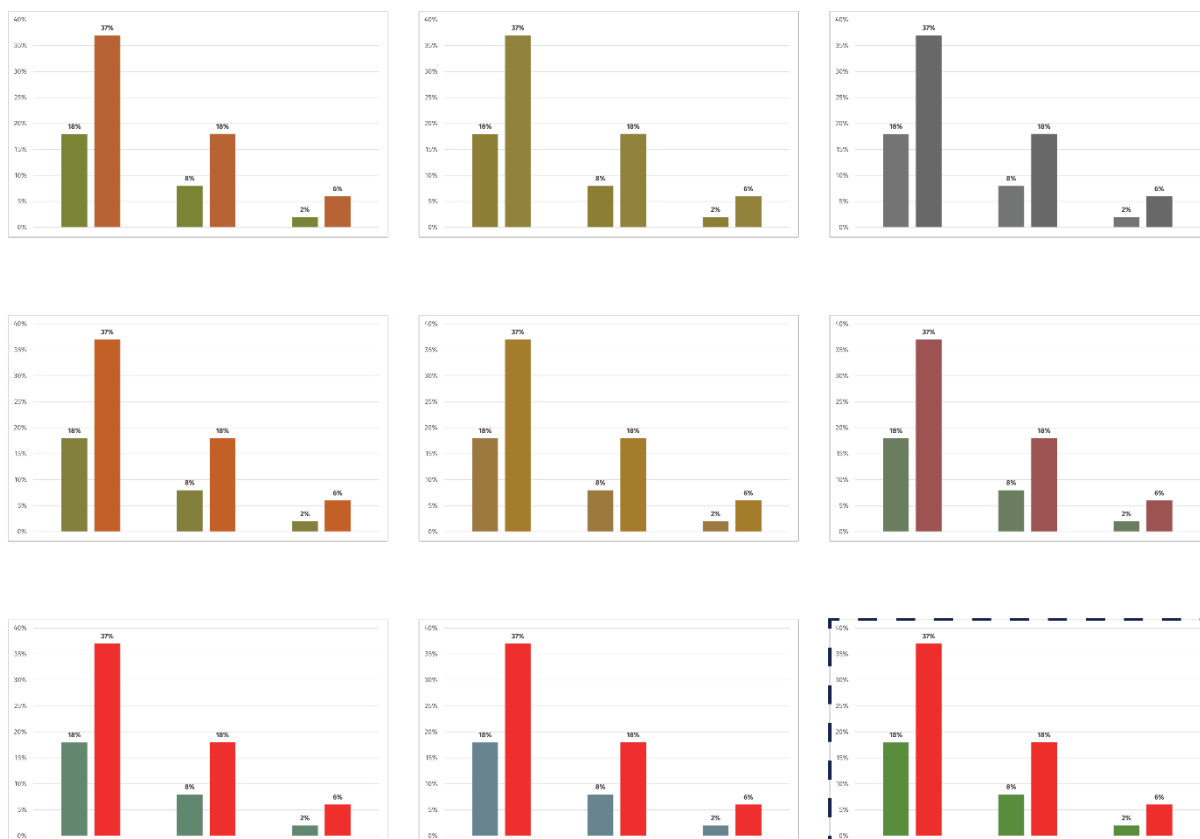


Figure 1. CVD simulation for different types of colour blindness. The original plot is highlighted at the bottom right with a dashed line. First column represents Anomalous Trichromacy (from top to bottom: red-weak, green-weak and blue-weak CVD), middle column represents Dichromatic View (from top to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

The Cherenkov Telescope Array Observatory (CTAO) development would not be possible without the support of [shareholders worldwide](#), as well as the cooperation of scientists and engineers from around the world contributing to the definition of the instrument design and the scientific programme of the first, open ground-based gamma-ray observatory. We are proud of our diversity and aim to be a reference for inclusion and respect in science, as well as to work internationally to achieve equity in our field. Diversity in scientific groups is not only morally fair, but also beneficial for the working environment, increasing creativity and providing different points of view that help to approach and solve problems diversely. Based on this idea, the CTAO created the [Astrodiversity programme](#) in 2019 – an initiative to develop and support activities organized under the diversity and inclusion framework.

The “**Best Practices for Colour Blind Friendly Publication & Descriptions**” was created as part of the CTAO’s Astrodiversity Project. All CTAO members and partners are encouraged to follow these best practices.

1.1 Purpose

The **purpose** of this document is to provide clear and simple guidelines to facilitate the creation and dissemination of colour-blind friendly figures and descriptions in and beyond the scientific field. Tips for using Python are also provided. The document will be updated with further information or support material, if needed.

1.2 Scope

These guidelines are considered during the review of material by the Outreach, Education and Communication Office of the Cherenkov Telescope Array Observatory (CTAO), as well as by the Speakers and Publication Office (SAPO) of the Cherenkov Telescope Array Consortium (CTAC). Thus, it is internally applied in scientific and outreach papers, posters and presentations, among other materials.

The document is [publicly available at the CTAO website](#) so that anybody, independently of their membership, can read, share and follow the guidelines to reach a more inclusive workspace.

2 Guidelines

Below, we include 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).

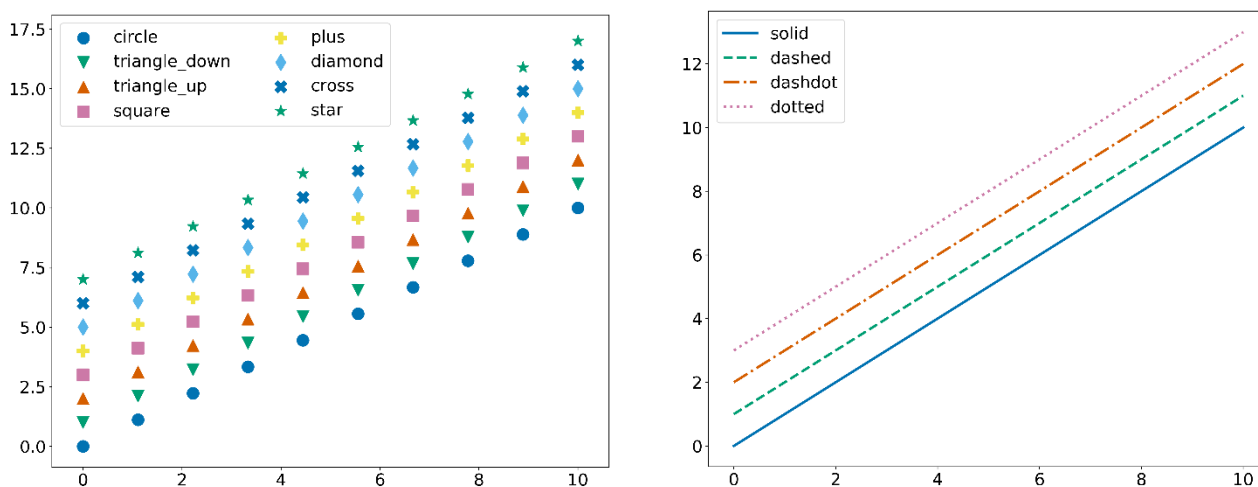


Figure 2. Example of markers (left) and line styles (right) available on Matplotlib. Credit: R. López-Coto (INFN-Padova, now at IAA-CSIC).

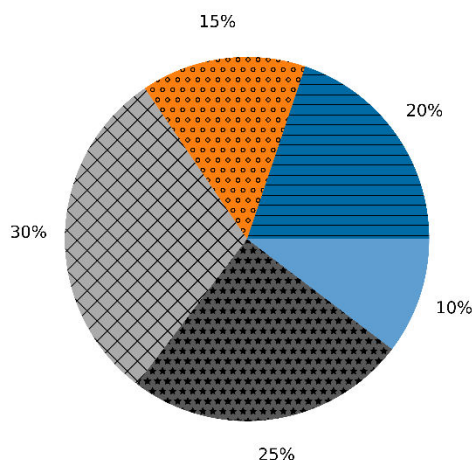


Figure 3. Example of a pie chart showing different patterns. Created on Matplotlib. Credit: R. López-Coto (INFN-Padova, now at IAA-CSIC).

2. When giving an **oral or written description**, avoid describing the results of a plot based only on the colour and use the shapes instead. For example, use “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 3).
3. In Matplotlib, use colour blind friendly **colormaps**, such as the default “viridis” or the new “cividis”¹ (Figure 4) and avoid those already known for being problematic, such as “jet.” Apply the same rule for **colorcycles**: in this case, you can set the Matplotlib style “tableau-colobind10” or “seaborn-colobind” (Figure 5). See Section 3 for support material.

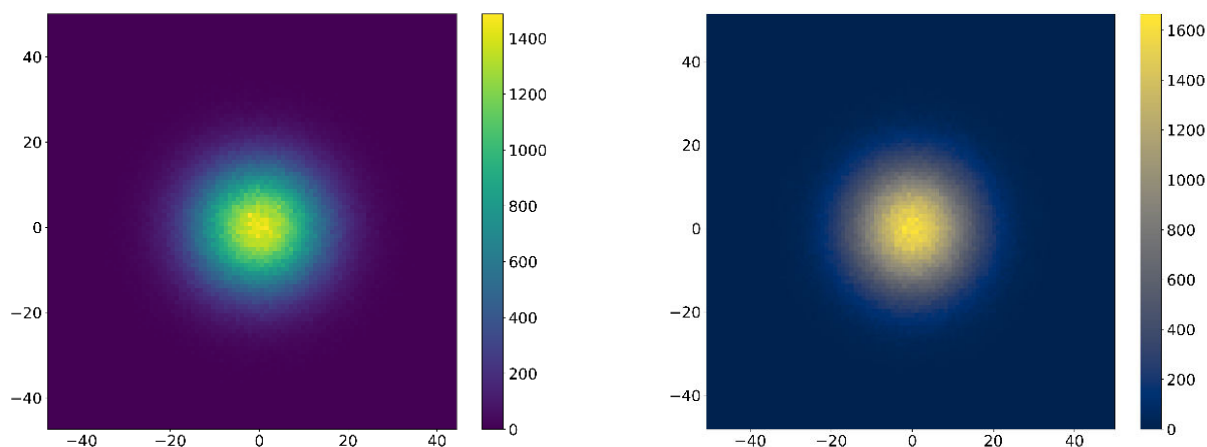


Figure 4. CVD friendly colormaps. On the left, “viridis” and on the right, “cividis.” Credit: R. López-Coto (INFN-Padova, now at IAA-CSIC).

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 3).

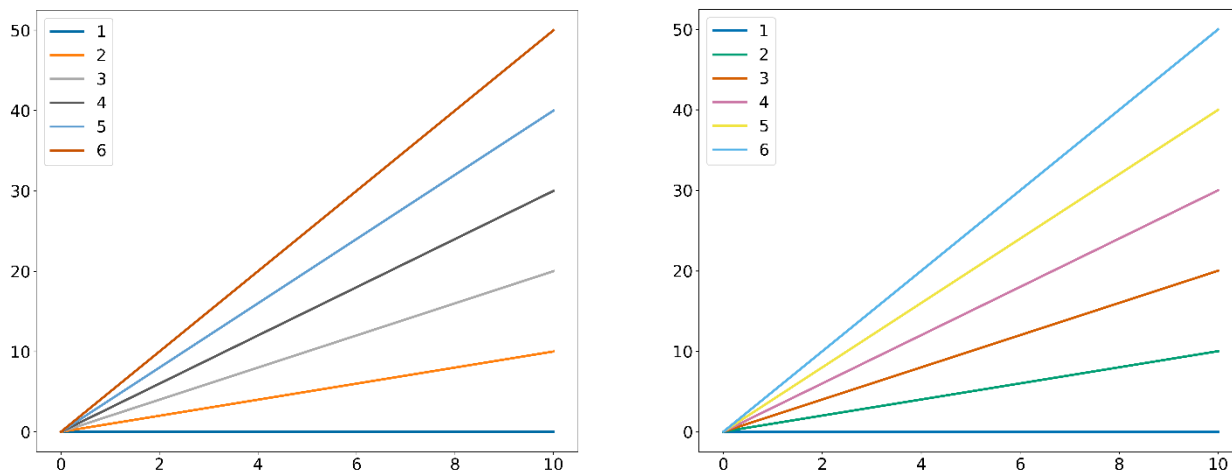


Figure 5. CVD friendly *colorcycles*. On the left, “tableau-coloblind10” and on the right, “seaborn-colorblind.” Credit: R. López-Coto (INFN-Padova, now at IAA-CSIC).

4. Find an appropriate colour palette with online tools, such as [ColorBrewer2.0](https://colorbrewer2.org/).
5. 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).

3 Support Material

- 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](#)

4 References

- [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>

5 Citation

If you want to cite this document, please use:

- **Long reference (bibliography):** Cherenkov Telescope Array Observatory (CTAO). (October, 2020). *Best Practices for Colour Blind Friendly Publications & Descriptions*.
- **Citation in the text:**
First citation: (Cherenkov Telescope Array Observatory [CTAO], 2020)
Subsequent citations: (CTAO, 2020)

6 Contact

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