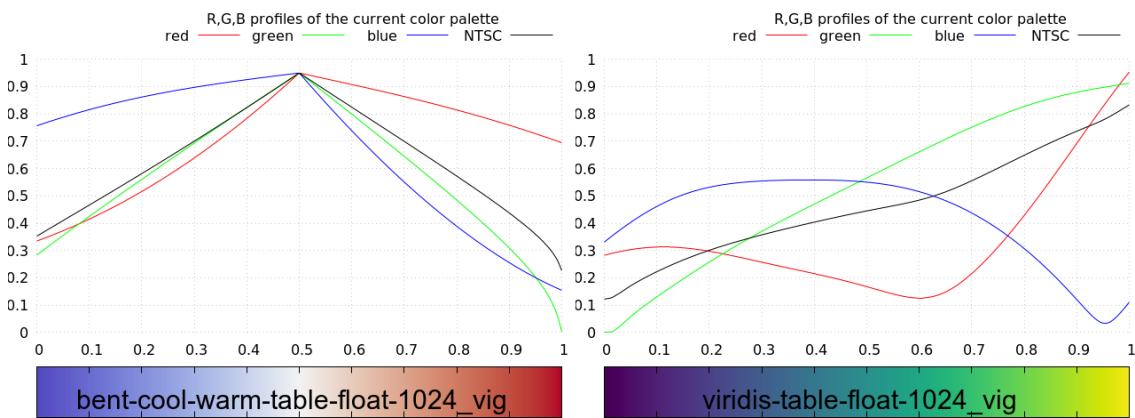


1 Background

On his web page, Kenneth Moreland suggests a number of continuous and diverge color palettes to improve scientific visualization.¹ Contrasting to other approaches, they aim for a smooth variation of the hue between the extremes of a scale displayed. While this reduces the brightness of the colors to choose from, their continuous transient hue offers a better visual inspection already when print in color. Contrasting to classical "jet" or "rainbow" palettes (*vide infra*), they retain their information if the output is constrained to gray scale (e.g., if xeroxed).



Where possible, this project renders Kenneth Moreland's set of .cvs palette information accessible to gnuplot as .plt files.

2 How to use the .plt palettes

The color palettes are provided with a varying number of explicitly defined colors. This range spans from eight up to 1024. For smaller color palettes, a copy-paste of their content into an already existing gnuplot script file may be an option. More convenient however, especially while working with larger color palettes, is to access them from gnuplot by adding the command

```
load "example_palette=plt"
```

at any point prior to the [s]plot instruction.

Each sub-folder contains the corresponding .plt files. The number in the file name indicates the number of explicitly defined colors in the file.

3 Palettes at disposition

For the display of continuous data, conversions of eight color palettes are provided: black-body, extended-black-body, inferno, kindlmann, extended-kindlmann, magma, plasma, and viridis.

¹<http://www.kennethmoreland.com/color-advice/>

On the other hand, palette bent-cool-warm is designed with diverge data sets in mind where highlighting the transition across a critical value is important. This may be useful to indicate relative velocities, or pressures below / above a threshold, for example. It is complemented by smooth-cool-warm. While again designed as diverging palette, the transition around the mid point now is gradual. Thus, for data close at this transition, expect less detail displayed there with palette smooth-cool-warm , than with palette bent-cool-warm.

The display of the palette's action is based on synthetic data computed for the Bessel function $f(x, y) = x^2 + y^2$ with a grid of 500×500 points in the (x, y) -plane. 1024 levels in the orthogonal z-direction accommodate the highest number of explicitly defined colors per palette file available ($n = 1024$). Next to it, a diagram depicts how the R, G, and B channel sum up to yield the RGB color displayed. In addition, the NTSC luminance value is traced. This is indicative about how the calculated result would look like for an output constrained to gray-scale. Thirdly you see the Bessel plot a twice, actually simulating the gray-scale output.

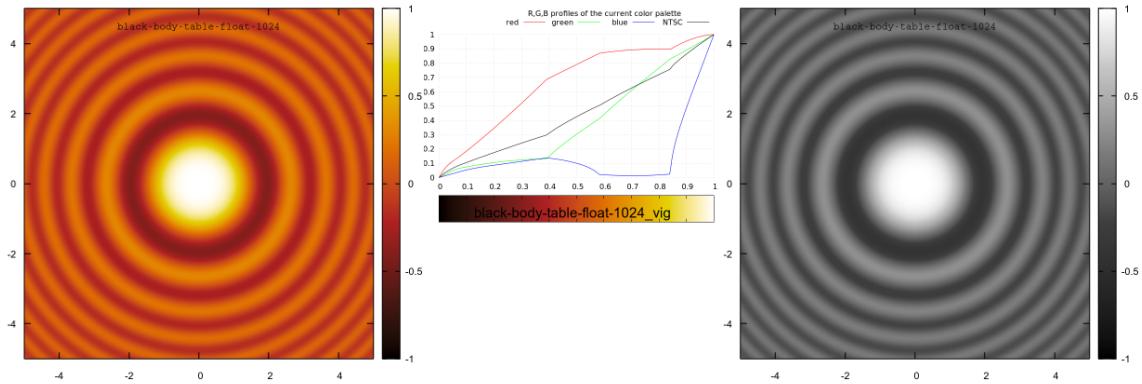


Figure 1: Kenneth Moreland's continuous palette black-body used to display the Bessel function $f(x, y) = x^2 + y^2$. This and the plots following are based on the explicit gnuplot instructions set sample 500 and set isosample 1024 to accommodate up to 1024 colors explicitly defined in the palettes.

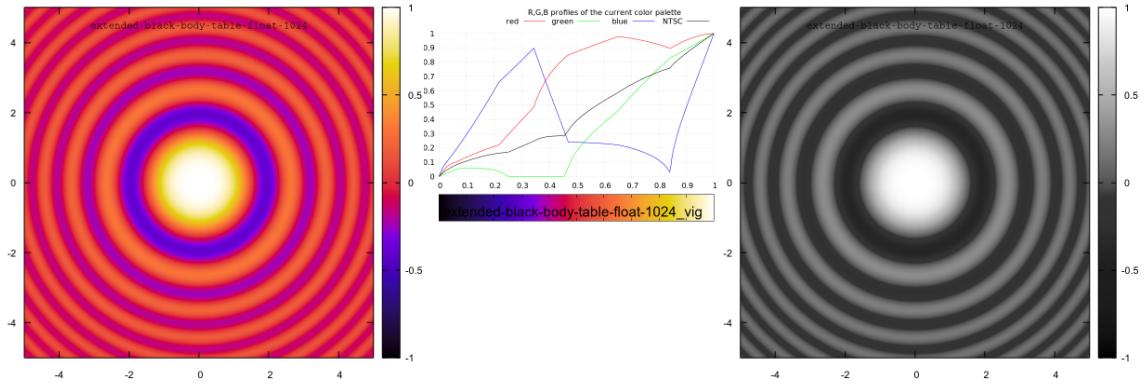


Figure 2: Application of Kenneth Moreland's continuous palette `extended-black-body`.

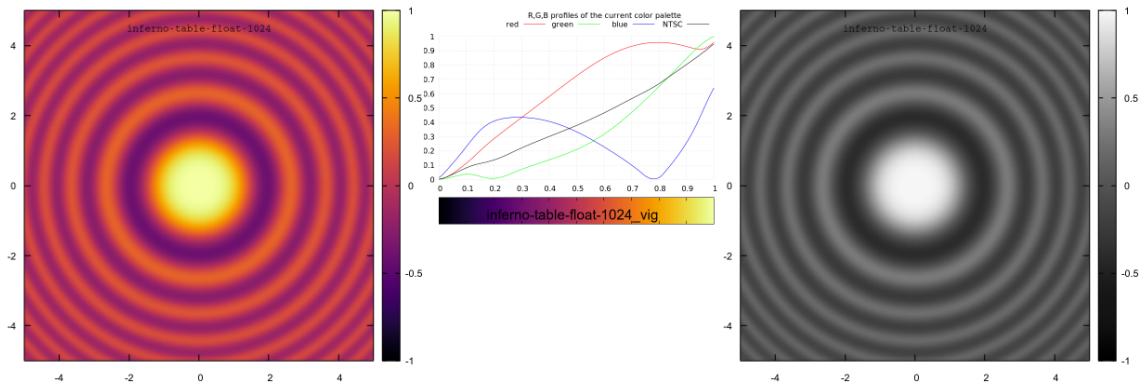


Figure 3: Application of Kenneth Moreland's continuous palette `inferno`.

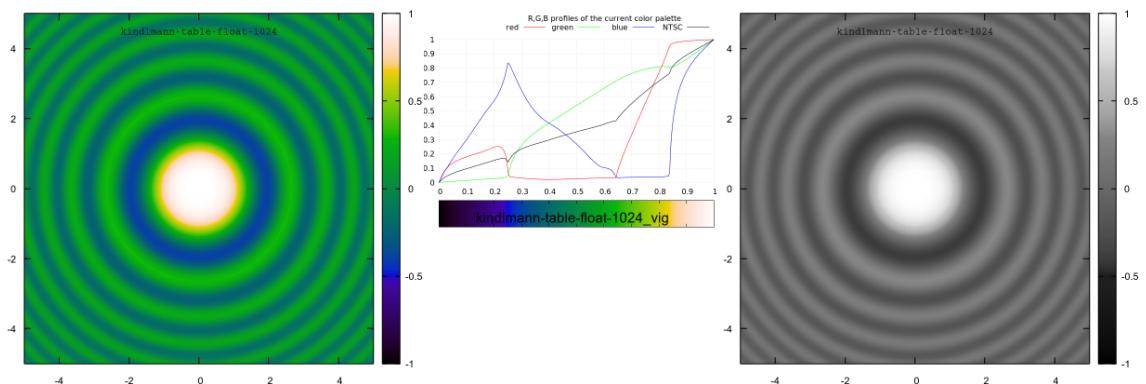


Figure 4: Application of Kenneth Moreland's continuous palette `kindlmann`.

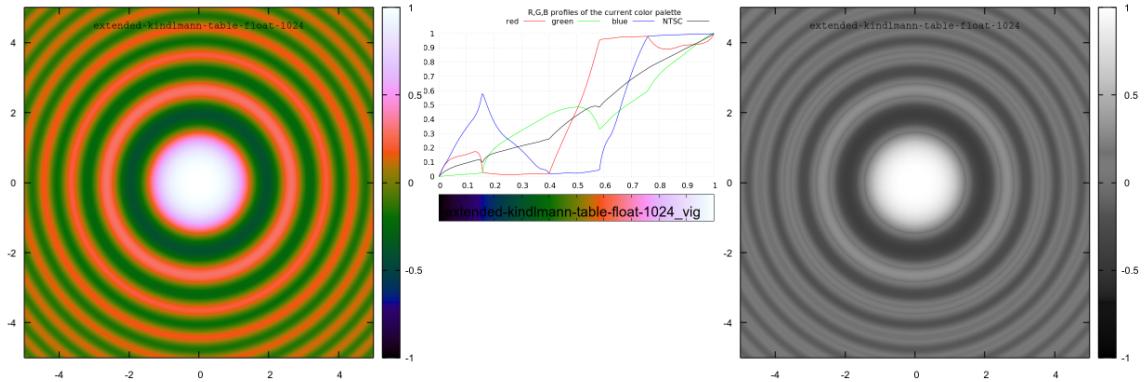


Figure 5: Application of Kenneth Moreland's continuous palette extended-kindlmann.

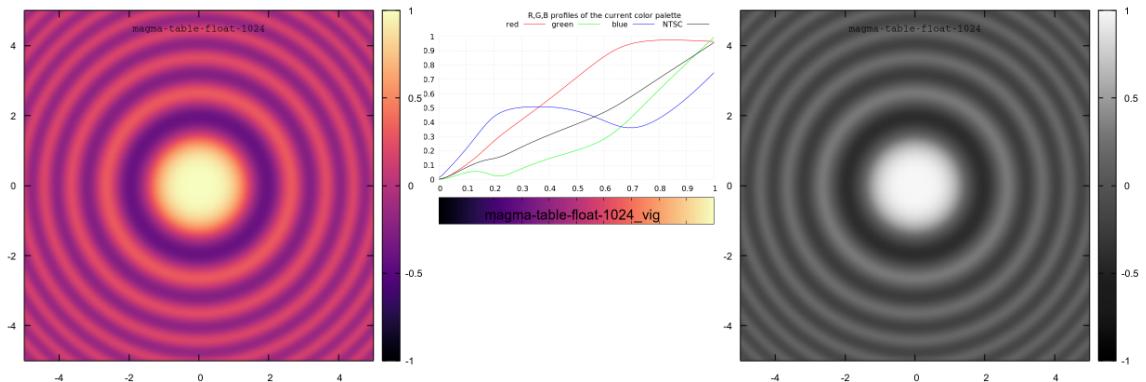


Figure 6: Application of Kenneth Moreland's continuous palette magma.

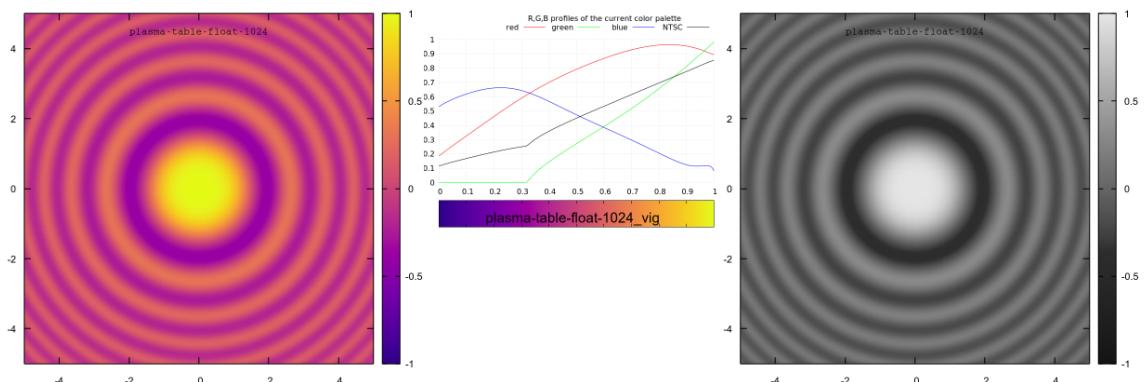


Figure 7: Application of Kenneth Moreland's continuous palette plasma.

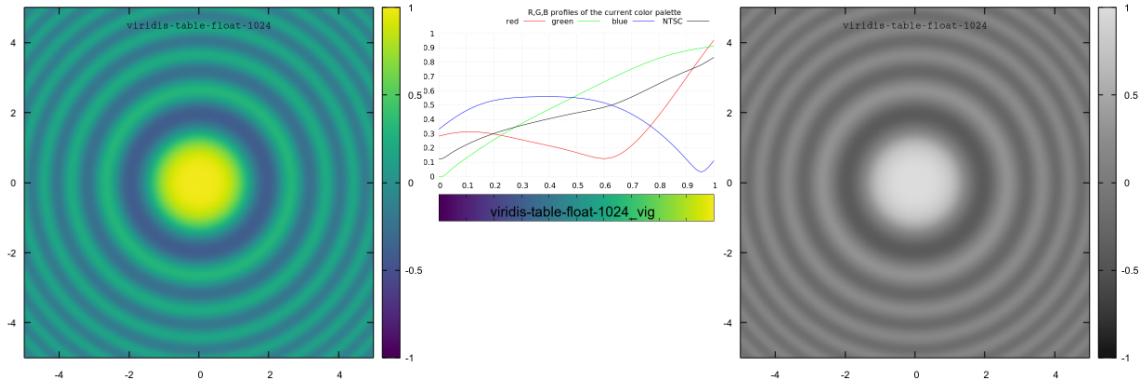


Figure 8: Application of Kenneth Moreland’s continuous palette `viridis`.

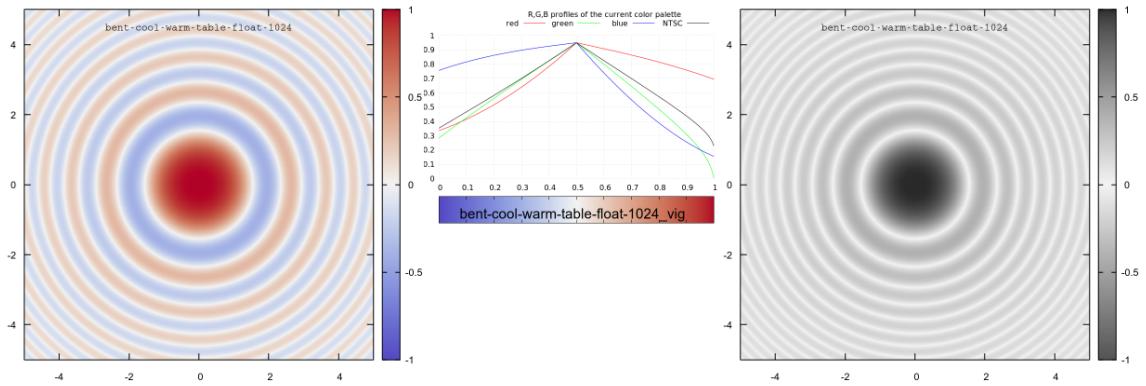


Figure 9: Application of Kenneth Moreland’s diverging palette `bent-cool-warm`, which accentuates the mid-point.

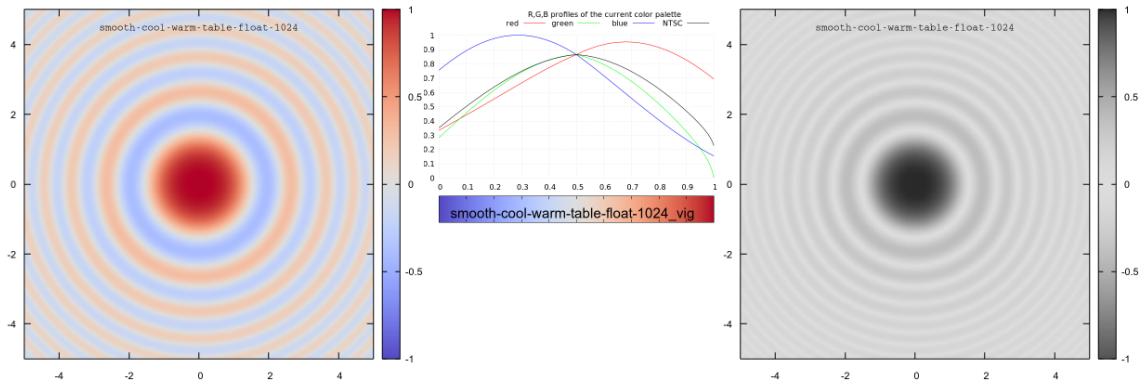


Figure 10: Application of Kenneth Moreland’s diverging palette `smooth-cool-warm`.

4 Comparison with other palettes

A few palettes are compared to those provided by Moreland. They again rely on the high level of isosamples (set iso 1024) in z -, and samples (set samples 500) in x - and y -direction.

Repositories like gnuplot-colorbrewer,² and gnuplot-palettes³ host alternative palettes, too.

- For the display of continuous data, either one of the following instructions prior to the [s]plot instruction may initiate palettes already included in gnuplot:

```
set palette gray    # gnuplot's gray palette
set pm3d map        # access to gnuplot's default rainbow palette
set palette cubehelix start 0 cycles -1. saturation 1
```

Note that palette cubehelix equally counters some cases of color blindness, too.

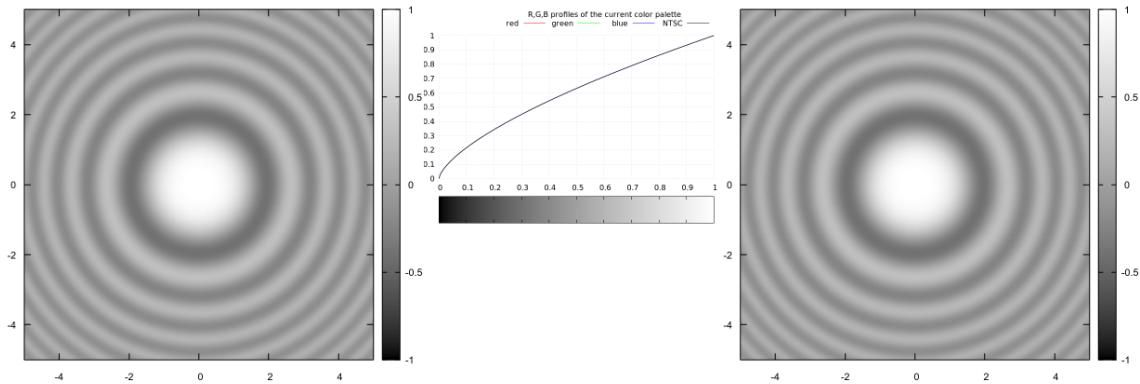


Figure 11: Gnuplot's gray palette (set palette gray) displaying the Bessel function $f(x, y) = x^2 + y^2$.

²<https://github.com/aschn/gnuplot-colorbrewer>

³<https://github.com/Gnuplotting/gnuplot-palettes>

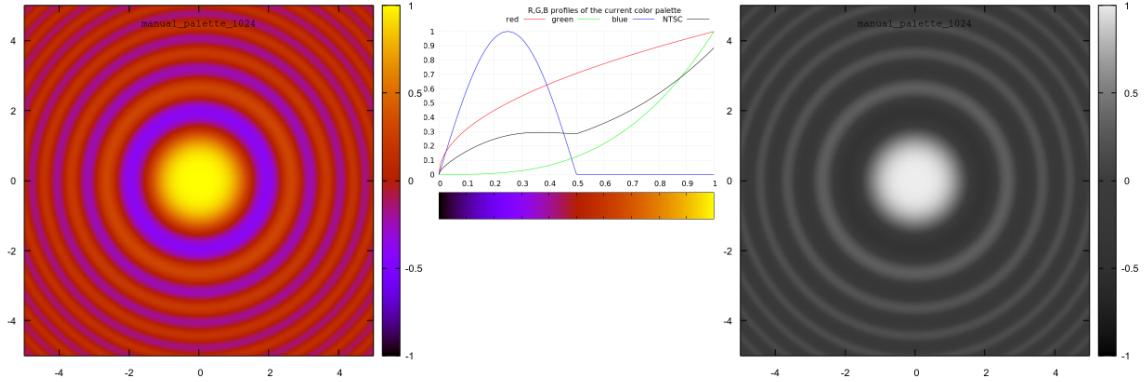


Figure 12: Gnuplot's default rainbow palette (set palette; set pm3d).

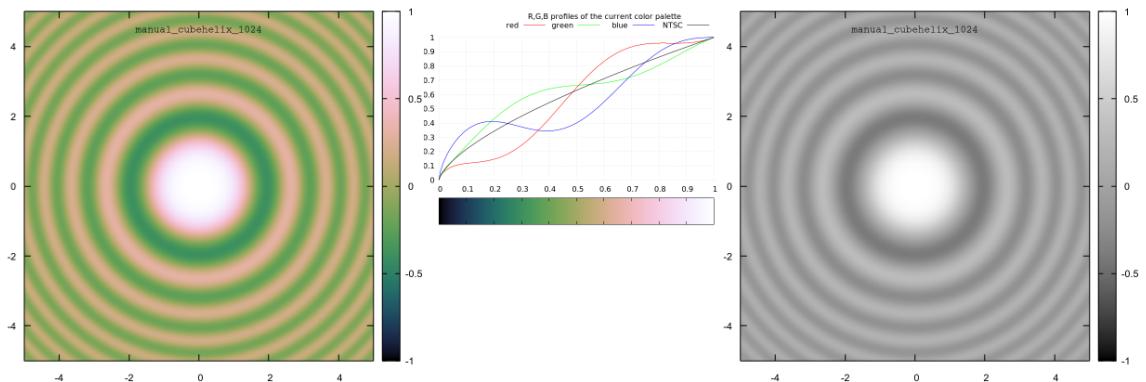


Figure 13: Gnuplot's cubehelix palette (set palette cubehelix start 0 cycles -1. saturation 1)

As a contrasting example, `jet.pal` (provided by `gnuplot-palettes`) mimics an elder matlab default palette with the perceptual problems meanwhile addressed by palettes by Moreland and others. address. Its definitions relevant here are:

```
set palette defined (0  0.0 0.0 0.5, \
1  0.0 0.0 1.0, \
2  0.0 0.5 1.0, \
3  0.0 1.0 1.0, \
4  0.5 1.0 0.5, \
5  1.0 1.0 0.0, \
6  1.0 0.5 0.0, \
7  1.0 0.0 0.0, \
8  0.5 0.0 0.0 )
```

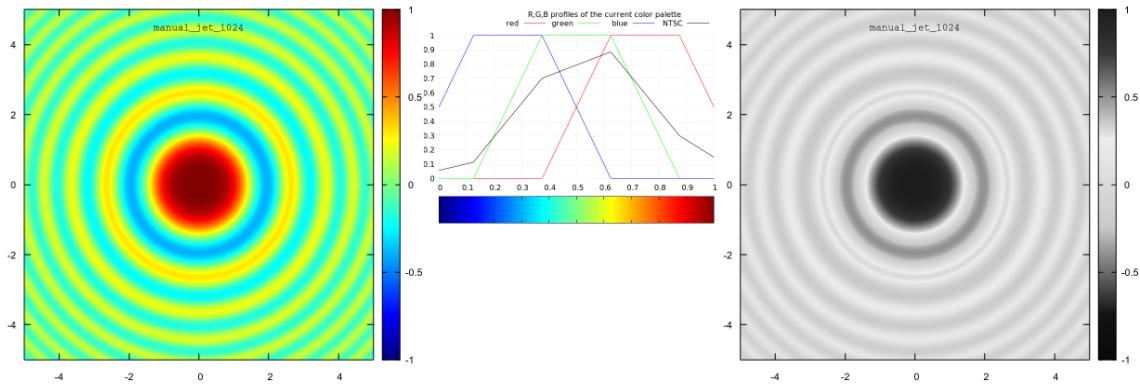


Figure 14: Display of the same Bessel function with defined with the external `jet.pal` palette from gnuplotting.org's repository. Note how the ease to assign levels from the reference bar to the map is depends on the color-space accessed.

- For diverge data, using a blue-white-red transient is a good choice *to begin with*. For the RGB color space by the `pngcairo` terminal, these palettes may be defined by 'named colors' as with either of the example instructions below. Similar as seen with Moreland's palettes, it is helpful to decrease the maximal luminosity, though (second example).

```
set palette defined (-1 "blue", 0 "white", 1 "red")
set palette defined (-1 "blue", 0 "light-gray", 1 "red")
```

5 Generation of the data

Departing from Moreland's RGB palettes defined as *floating numbers*, script `csv2plt.py` (sub-folder `tools`) reformatted the entries to five decimals. Script `RGB_check.py` provided a control if the RGB tuples converted stay within the permitted interval of $[0, 1]$.

Script `palette_decomposition.py` provided a quick channel-wise decomposition of the RGB color space, complemented by the NTSC luminosity. Each synopsis per `.plt` file displays this

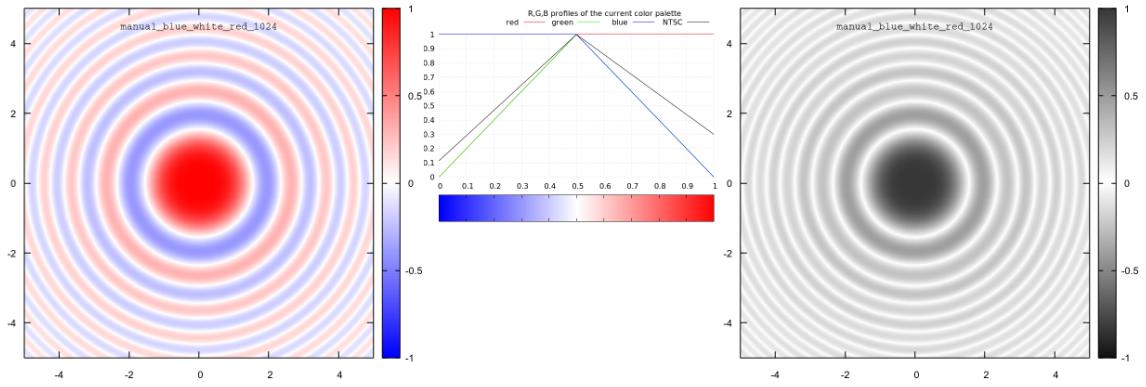


Figure 15: Manually set up diverging blue–white–red color palette displaying the Bessel function.

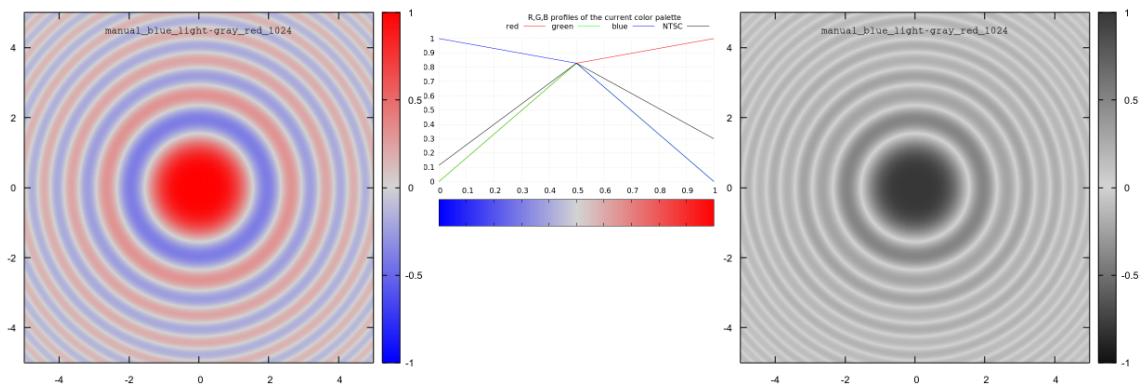


Figure 16: Slightly improved version of the earlier diverging three-level color palette by exchange of "white" by "light-gray" as central transition.

result in between the test plots in color and gray-scale.

Script `bessel_test_center.py` computed the synthetic data of the Bessel function $f(x, y) = x^2 + y^2$ eventually displayed as color plot. It called ImageMagick to convert this result into gray-scale, and concatenated the two plots with the diagram by `palette_decomposition.py`.

6 Comparison of similar palettes

Gnuplot's rapid scrutiny about the contribution of R, G, and B channel of a palette, reported as .png, allows a programmatic visual comparison of palettes with each other. This task addressed by script `vignette_comparison.py`, to be run right after `palette_decomposition.py`, without provision of parameters from the CLI by

```
python3 vignette_comparison.py
```

Each pairwise comparison yields a new file named in the pattern of `diff_fileA_fileB.png`. Differences identified by ImageMagick will be indicated with bright red pixels. This reveals, for example, palette `magma.pal` provided by gnuplotting.org⁴ / gnuplot-palettes differs from all `magma.plt` definitions derived from Kenneth Moreland's palettes based on floating numbers in this repository as illustrated below, or with animation `magma_diff.gif` (in sub-folder `extra_palette_tests`).

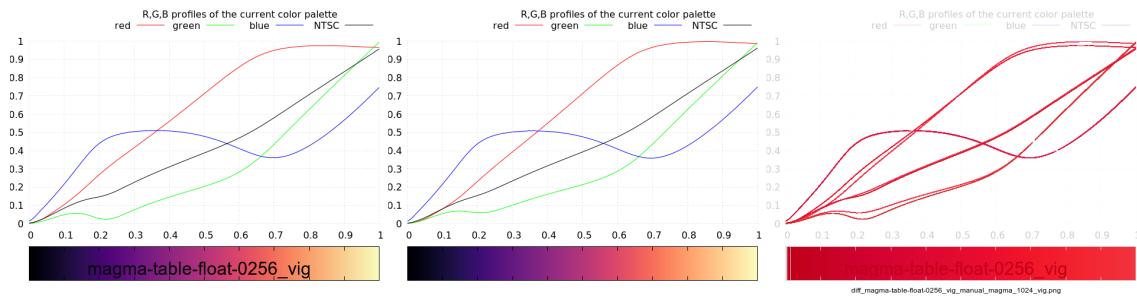


Figure 17: Comparison of two `magma` palettes: Kenneth Moreland's `magma` palette (256 colors, floating RGB definition, left hand side). Gnuplotting's definition of `magma` (256 colors, floating RGB definition, center). Difference plot by ImageMagick's compare of the two former (right hand).

Sub-folder `extra_palette_tests/magma_testing/` includes further details about this analysis and an animated .gif about all tests performed relevant here. This and all other data processing was run under Linux (Xubuntu 18.04.3 LTS) with CPython (3.6.8, October 7, 2019), gnuplot (5.2.7beta, last modified 2019-05-14), and ImageMagick (6.9.7-4 Q16).

7 Vector-based export

It is possible to engage gnuplot's `set terminal pdfcairo` instruction to provide a native export of the results as the resolution independent .pdf format. This was tested for the palette maps

⁴<http://www.gnuplotting.org/>

of 512 explicitly defined colors with now 256 iso samples computed by gnuplot for the same Bessel function. While this document contains only the example for the continuously smooth viridis palette, tests with this and the other palettes are stored in sub-folder pdf-tests.

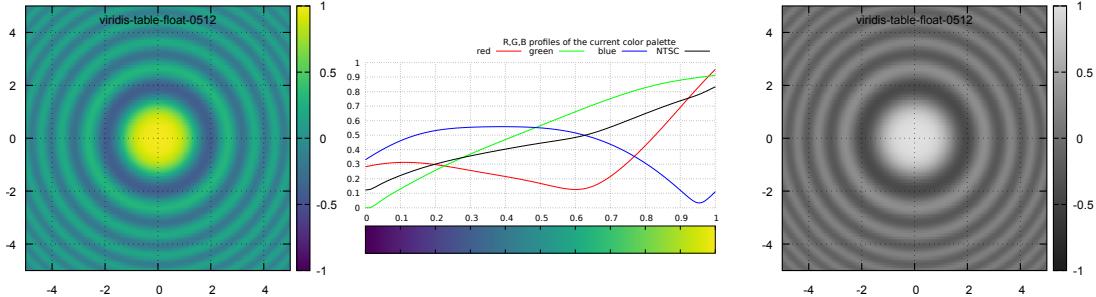


Figure 18: Test of Kenneth Moreland's RGB definition of palette `viridis-table-float-0512` with gnuplot's set terminal `pdfcairo` instruction and 256 isosamples.

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