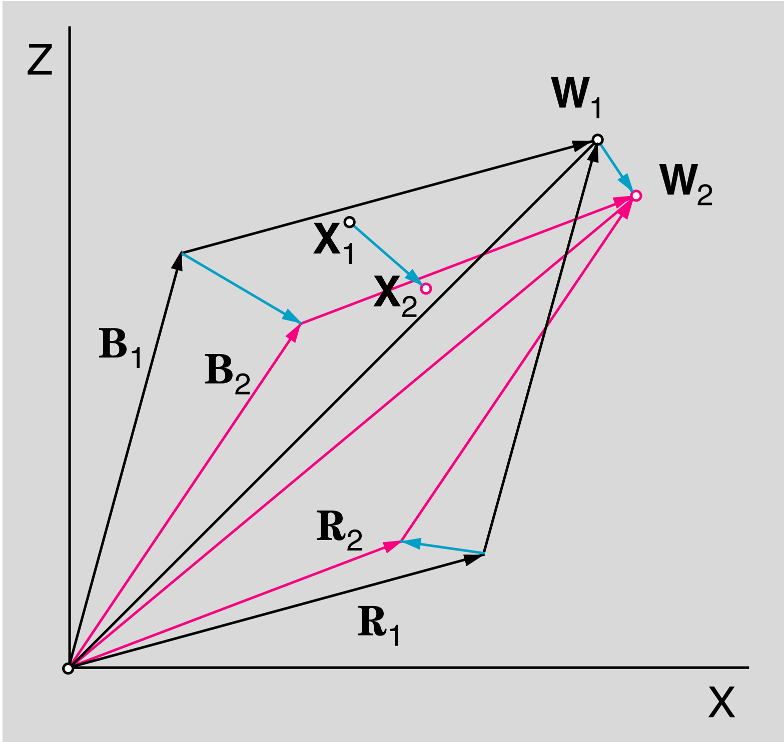
Gernot Hoffmann

RGB Gamut Compression by Matrix Mapping



Contents

1. Introduction

Colors in wide gamut RGB color spaces like ProPhotoRGB cannot be reproduced correctly on monitors, which are mostly near to sRGB.
Page 3 shows the CIE chromaticity diagram with gamut triangles for sRGB, ProPhotoRGB and additionally for OptiRGB, the author's private color space.
The wide gamut content can be shown desaturated by gamut compression, using matrix mapping in the CIE color space XYZ.
The mathematics are described in the next chapter.

Plates
Each plate contains two halfplanes for constant Lab hue
Asterisks for L*,a* and b* are omitted
Chroma is indicated by c=sqrt(a*²+b*²)

Compression
OptiRGB to sRGB
ProPhotoRGB to sRGB

Gamut boundaries
Outer: OptiRGB or ProPhotoRGB
Inner: sRGB

Desaturation factor
No desaturation for 0.0
Complete gamut compression for 1.0
More than 0.5 is not recommended for ProPhotoRGB

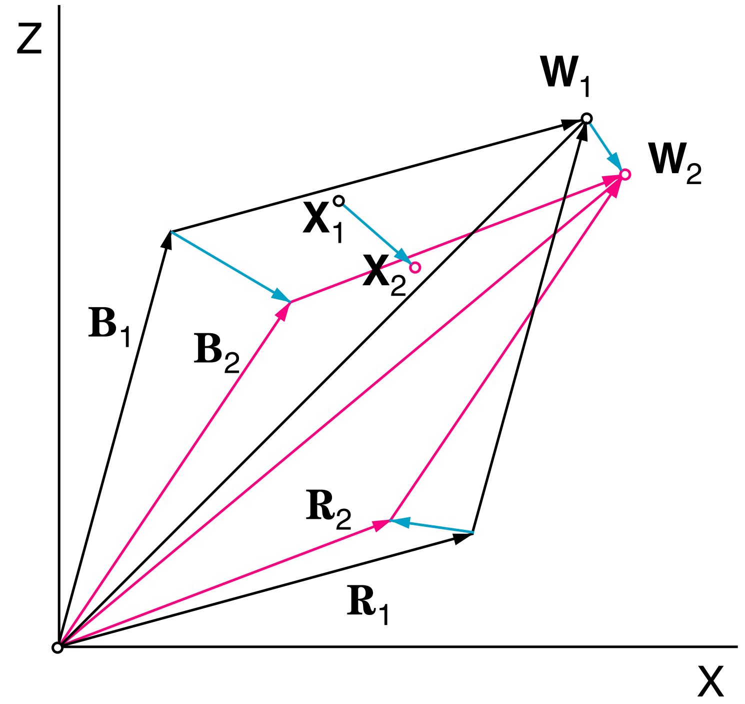
Hue shift
The small numbers show the hue shift in degrees
A positive value means: the new color is rotated counterclockwise

New color
The circles show the color after the compression

Photoshop
A plate can be loaded by Photoshop in mode Lab. Lab values for the old color (square) and the new color (circle) are indicated by the Info Palette.

2. Mathematics

The diagram shows a 2D representation of the 3D CIE color space XYZ. An arbitrary color is described either in cartesian coordinates X,Y,Z or by numbers R,G,B in a non-orthogonal vector base $\mathbf{R},\mathbf{G},\mathbf{B}$.



$$\mathbf{X} = \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} \qquad \mathbf{R} = \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

$$\mathbf{X} = \mathbf{C}_{xr}\,\mathbf{R}$$

$$\mathbf{X} = R\mathbf{R} + G\mathbf{G} + B\mathbf{B}$$

$$\mathbf{C}_{xr} = [\mathbf{R},\mathbf{G},\mathbf{B}]$$

In order to desaturate a color $\mathbf{X}_1$ it has to be shifted to $\mathbf{X}_2$ towards the gray axis.
This is an affine transform by a matrix **K**. The nine unknowns are found by mapping the base vectors, which maps as well the white point $\mathbf{W}_1$ to $\mathbf{W}_2$.

$$\mathbf{X}_2 = \mathbf{K}\,\mathbf{X}_1$$

$$\mathbf{R}_2 = \mathbf{K}\,\mathbf{R}_1$$

$$\mathbf{G}_2 = \mathbf{K}\,\mathbf{G}_1$$

$$\mathbf{B}_2 = \mathbf{K}\,\mathbf{B}_1$$

$$[\mathbf{R}_2,\mathbf{G}_2,\mathbf{B}_2] = \mathbf{K}[\mathbf{R}_1,\mathbf{G}_1,\mathbf{B}_1]$$

$$\mathbf{C}_{xr2} = \mathbf{K}\,\mathbf{C}_{xr1}$$

$$\mathbf{K} = \mathbf{C}_{xr2}\,\mathbf{C}_{xr1}^{-1}$$

For a partly desaturation by a factor d=0...1 the new base vectors are calculated by a linear interpolation.
d=0 means no compression. d=1 means full compression.

$$\mathbf{R}_2^* = \mathbf{R}_1 + d(\mathbf{R}_2 - \mathbf{R}_1)$$

$$\mathbf{G}_2^* = \mathbf{G}_1 + d(\mathbf{G}_2 - \mathbf{G}_1)$$

$$\mathbf{B}_2^* = \mathbf{B}_1 + d(\mathbf{B}_2 - \mathbf{B}_1)$$

$$\mathbf{K} = \mathbf{C}_{xr2}^*\,\mathbf{C}_{xr1}^{-1}$$

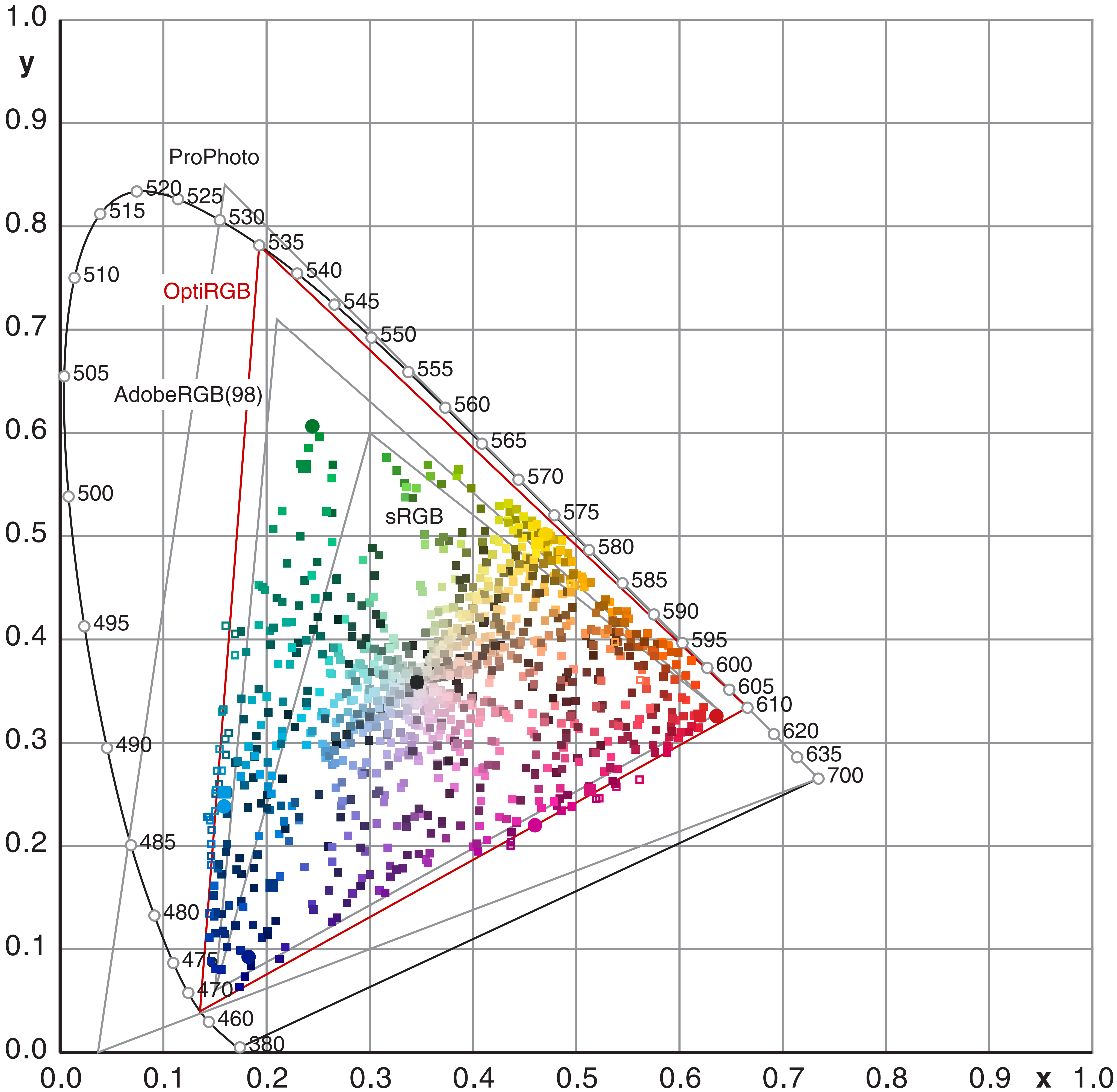
3. Chromaticity diagram

The CIE chromaticity diagram shows the gamut triangles for the color spaces sRGB, AdobeRGB(98), OptiRGB and ProPhotoRGB.

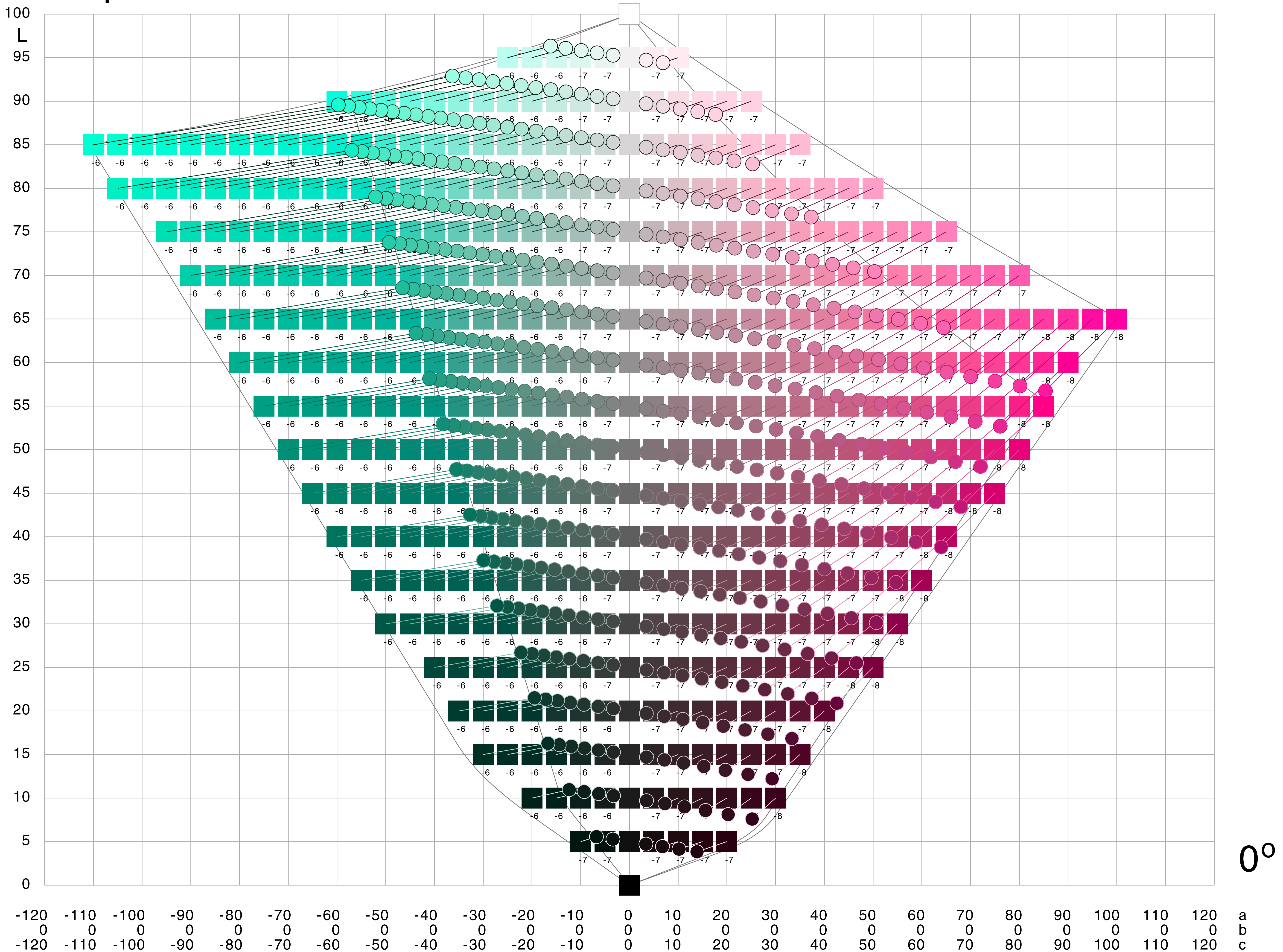
Furtheron, the coordinates of common spot inks and CMYK inks are shown:

Filled	In gamut for OptiRGB
Stroked	Out of gamut for OptiRGB
Square	Spot ink
Big square	ISO Coated CMYK inks
Big Circle	Inkjet Mutoh RJ6100 Pigment ink

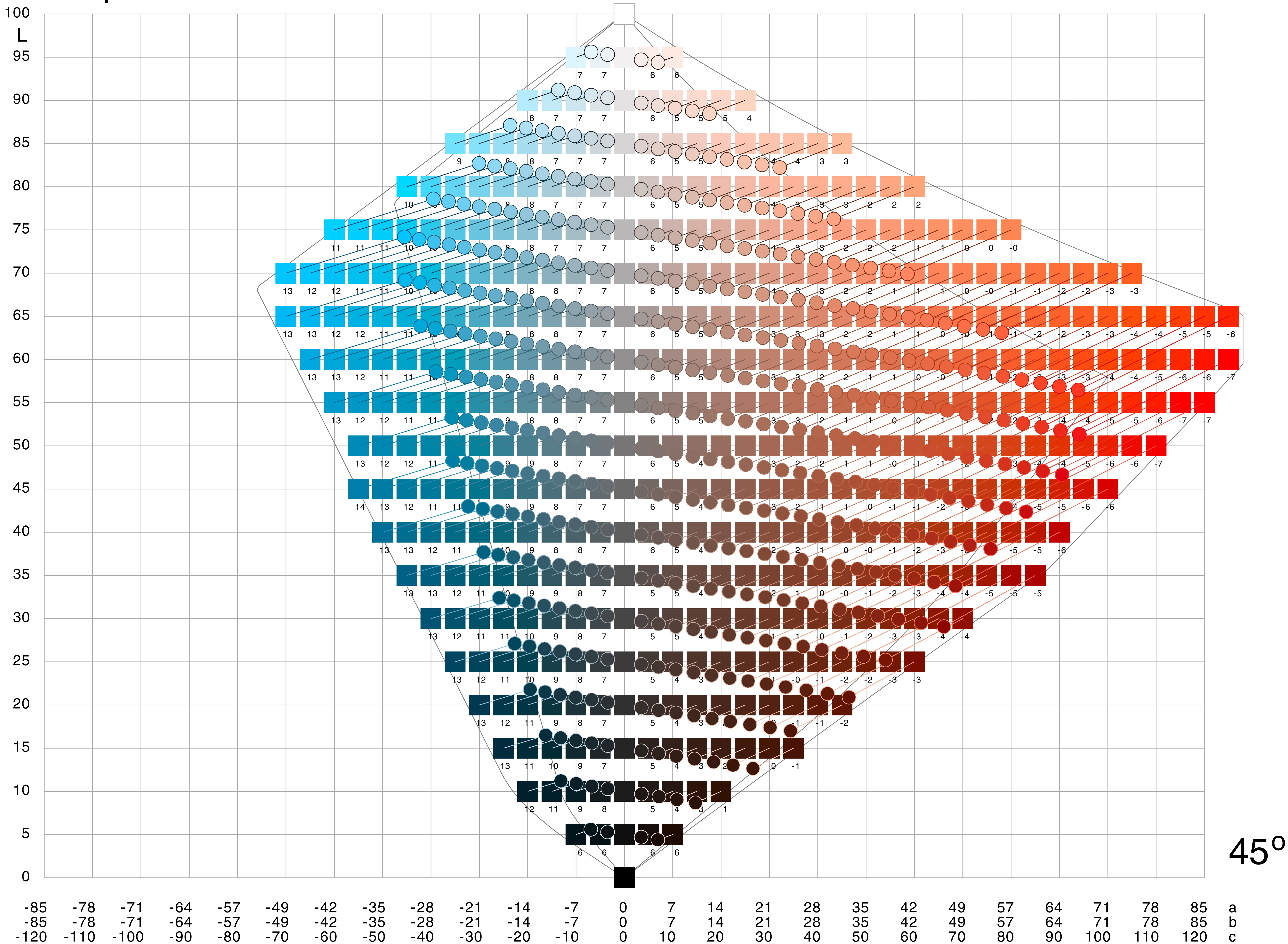
All these inks together represent the real word surface colors. One can hardly find more vibrant colors in any real environment than the highly saturated spots.



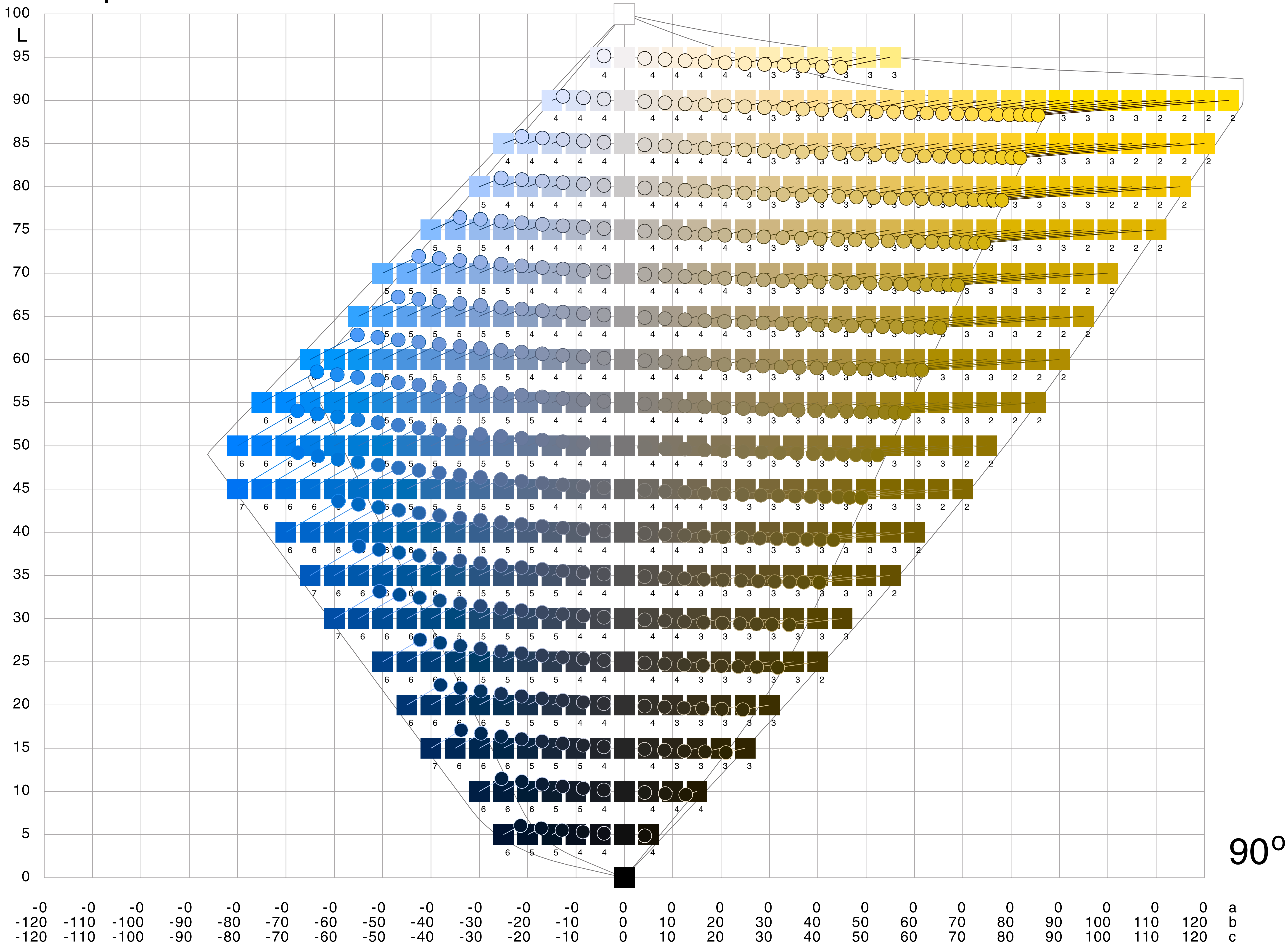
4.1 OptiRGB / 0° / d=1



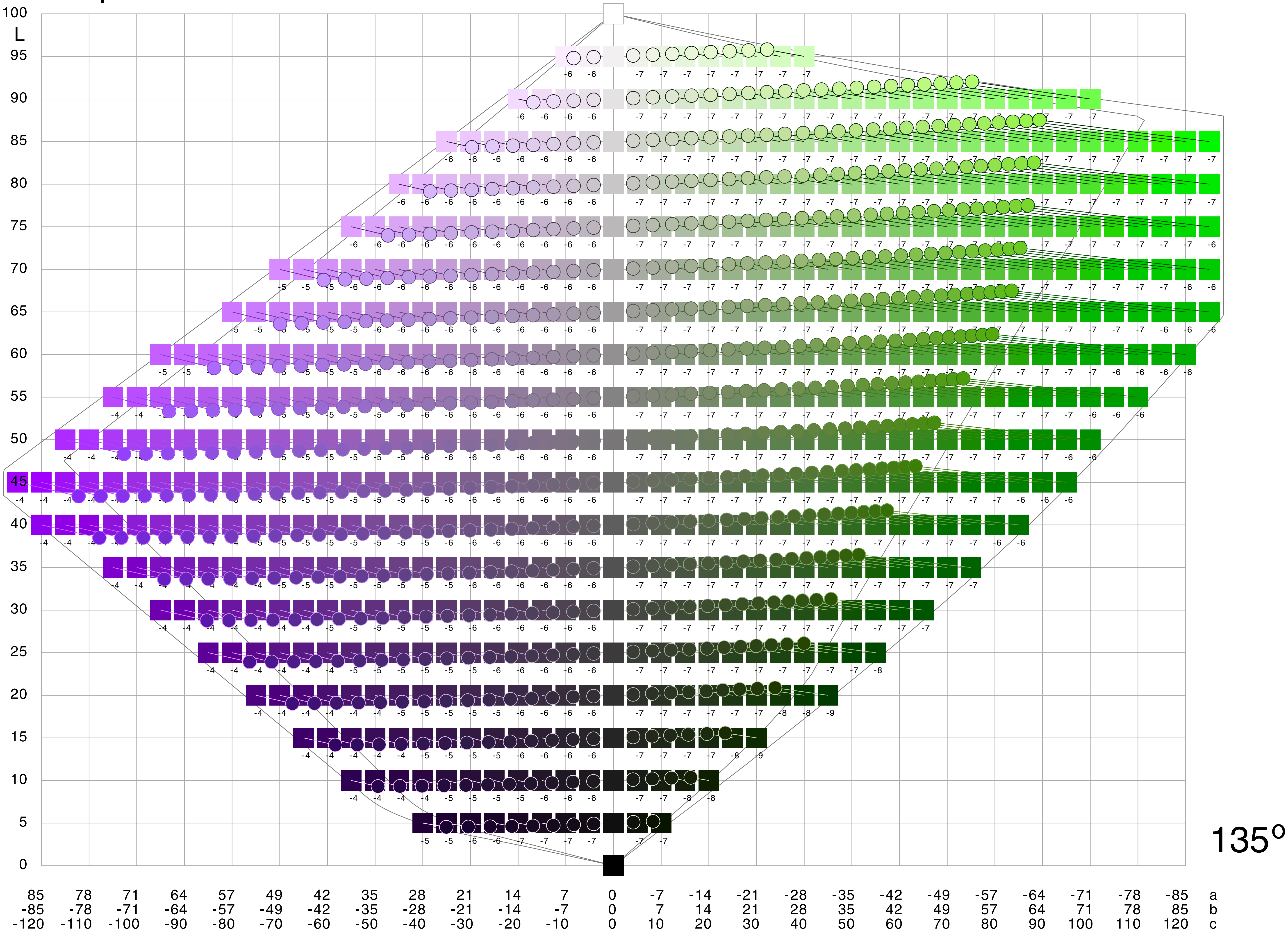
4.2 OptiRGB / 45° / d=1



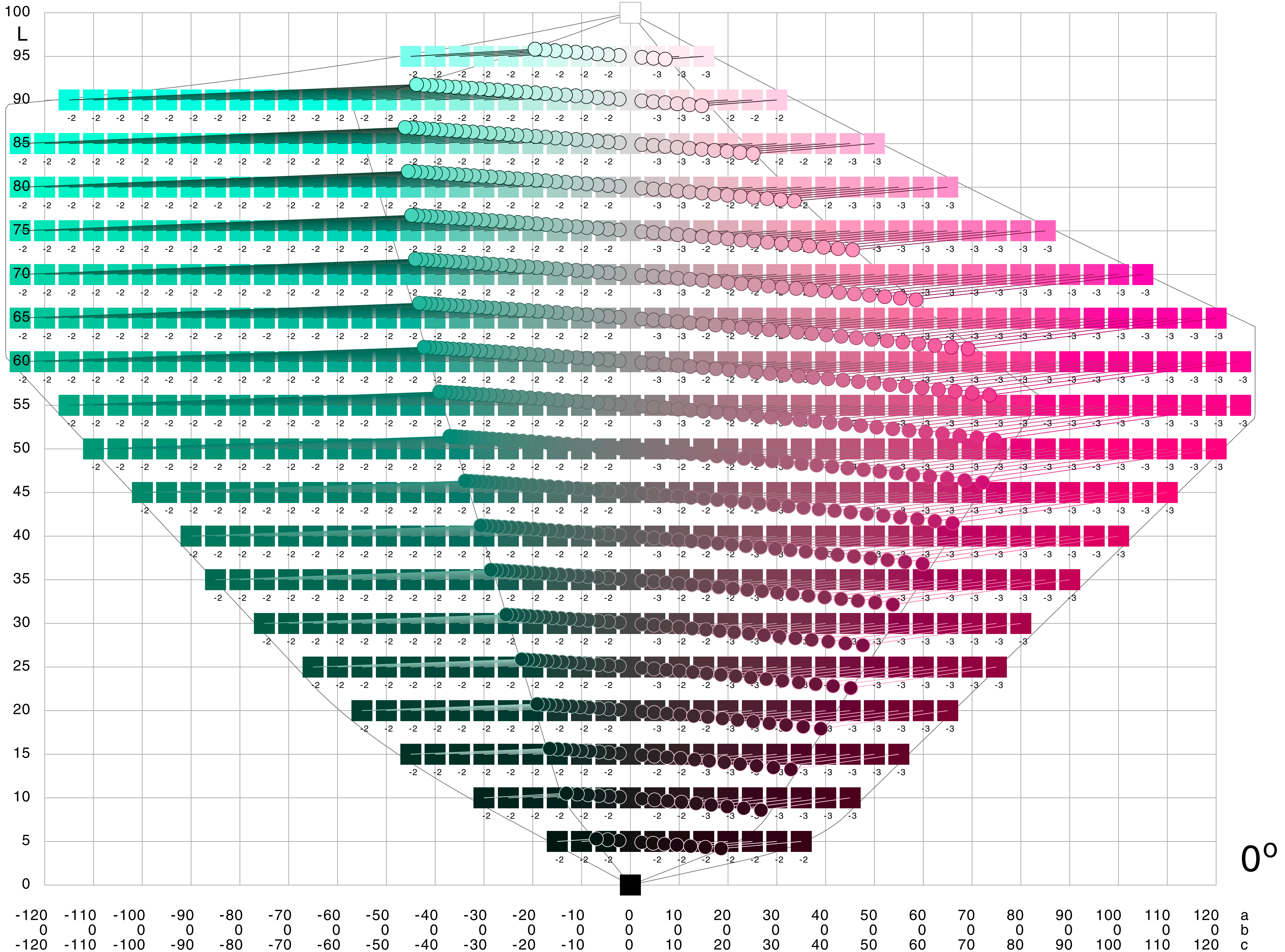
4.3 OptiRGB / 90° / d=1



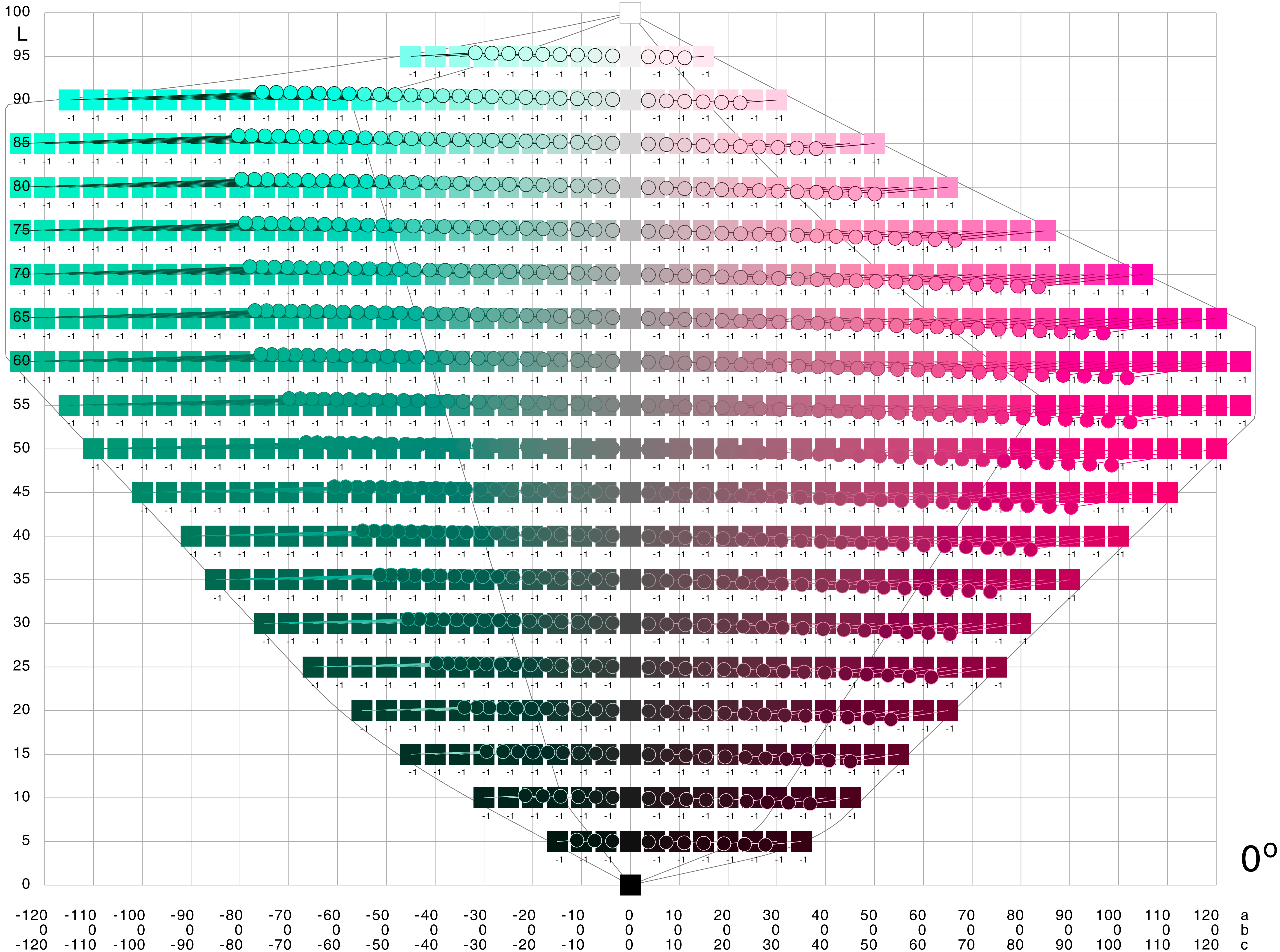
4.4 OptiRGB / 135° / d=1



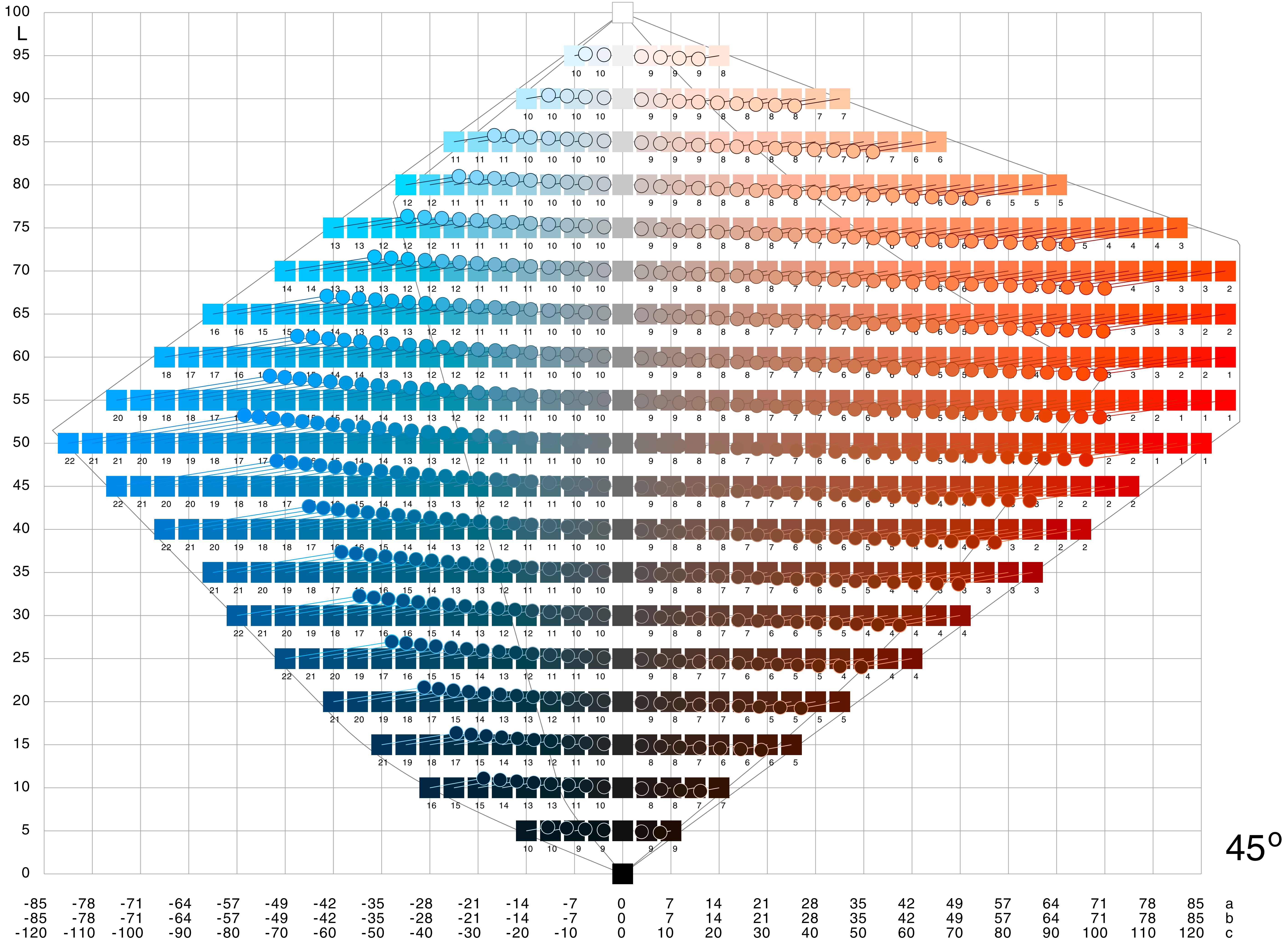
5.1 ProPhotoRGB / 0° / d=1



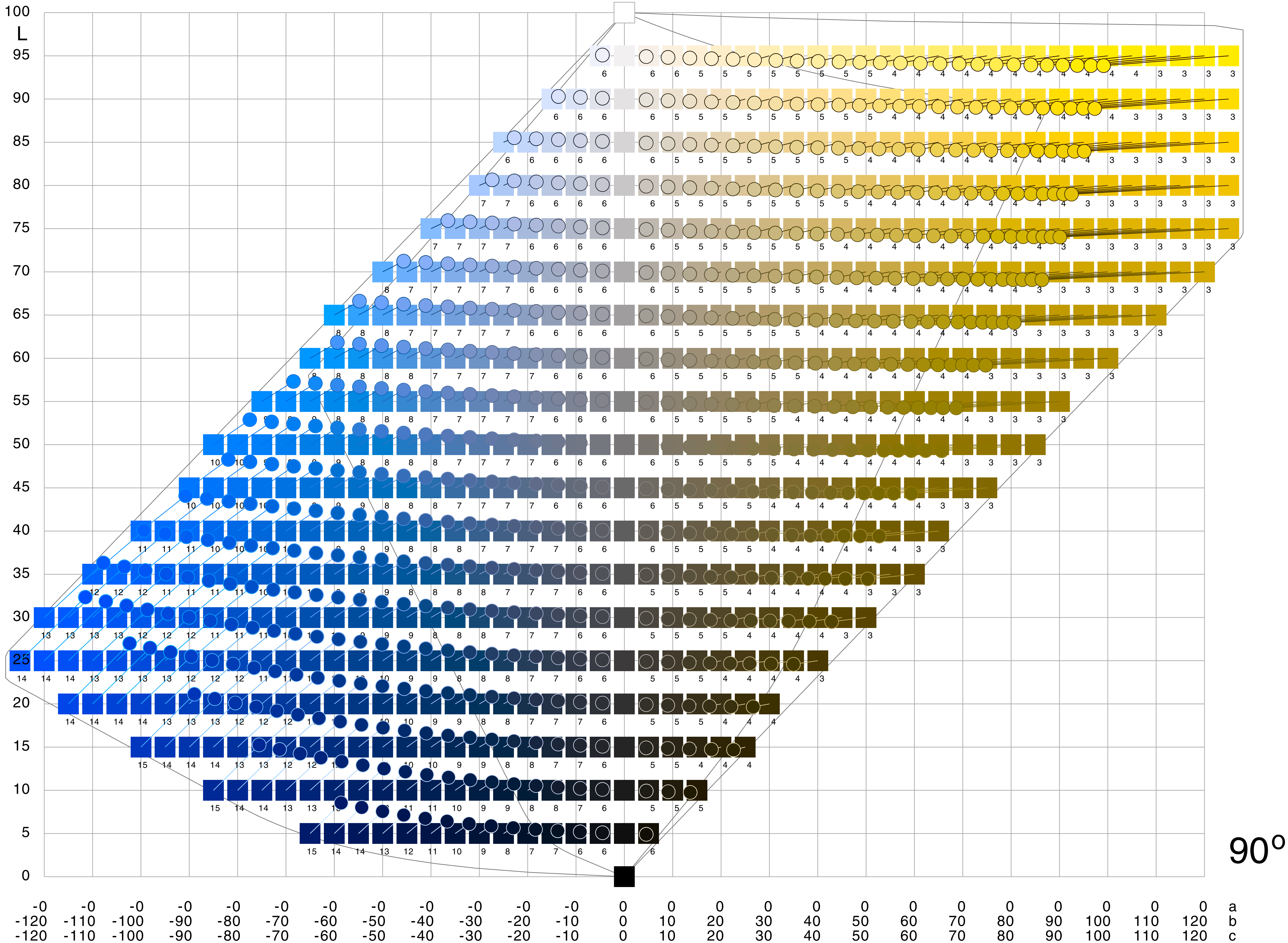
6.1 ProPhotoRGB / 0° / d=0.5



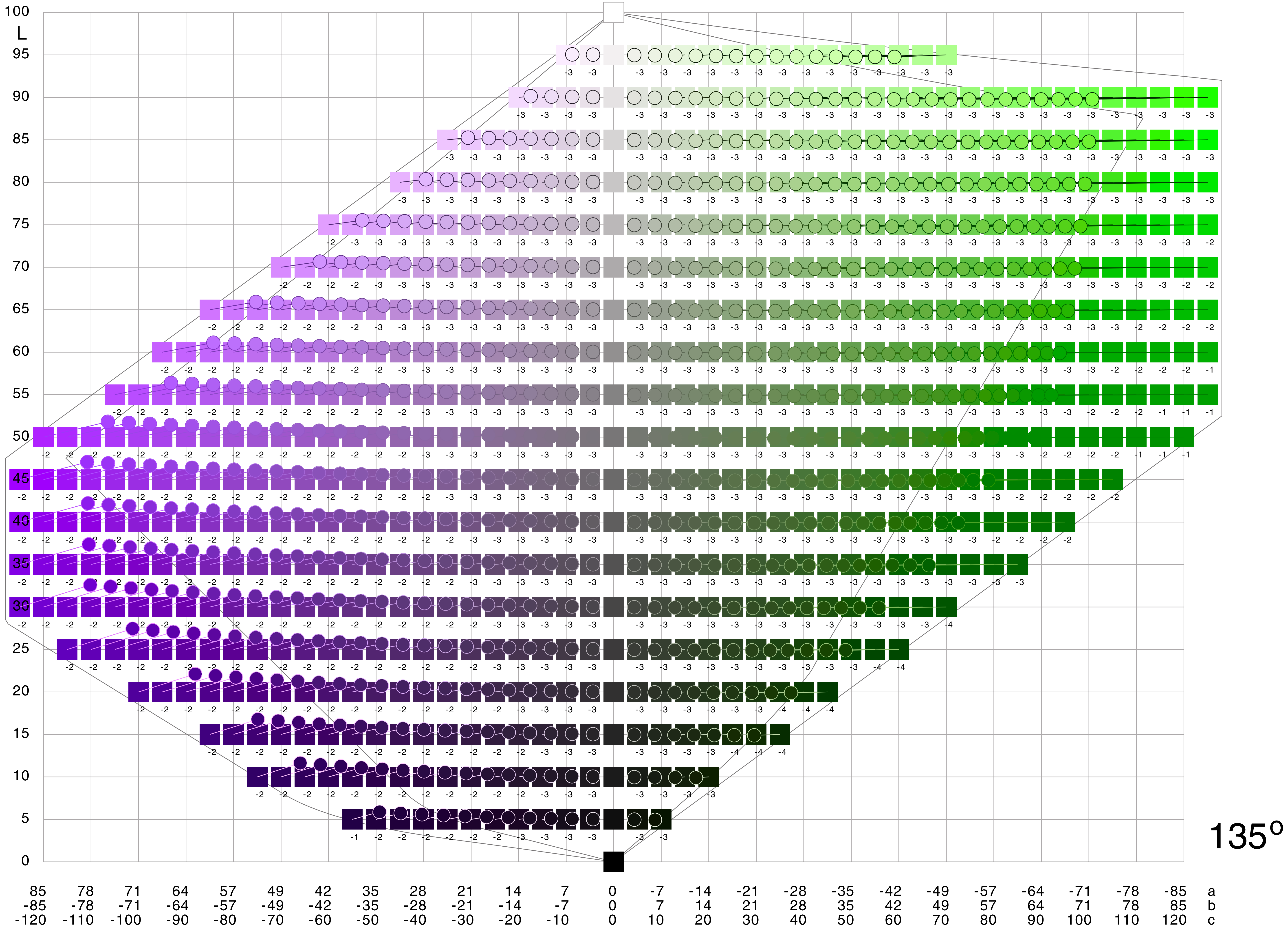
6.2 ProPhotoRGB / 45° / d=0.5



6.3 ProPhotoRGB / 90° / d=0.5



6.4 ProPhotoRGB / 135° / d=0.5



7. Conclusions

RGB gamut compressions by matrix mapping can produce considerable shifts of CIELab lightness and hue.

ProPhotoRGB is a wide gamut RGB space where the primaries Green and Blue are out of human gamut. The primary Red is practically out of gamut, nearly unvisible for limited power.
Such a gamut should not be desaturated completely. That was the reason for the introduction of the desaturation factor.

8. References

These docs contain plenty references for standard textbooks, PostScript programming and the necessary data for the color spaces and transforms.

[1] G.Hoffmann
CIE (1931) Color Space
http://www.fho-emden.de/~hoffmann/ciexyz29082000.pdf

[2] G.Hoffmann
CIELab Color Space
http://www.fho-emden.de/~hoffmann/cielab03022003.pdf

This doc:
http://www.fho-emden.de/~hoffmann/gamcomp18062006.pdf

Gernot Hoffmann
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