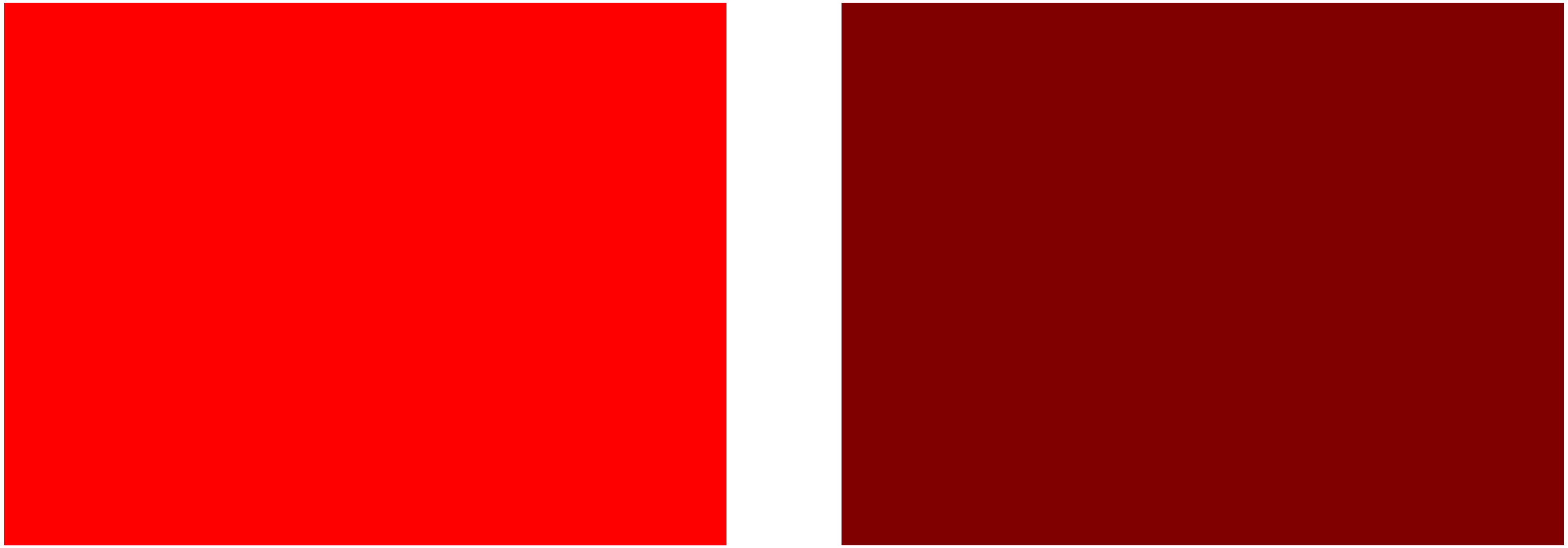
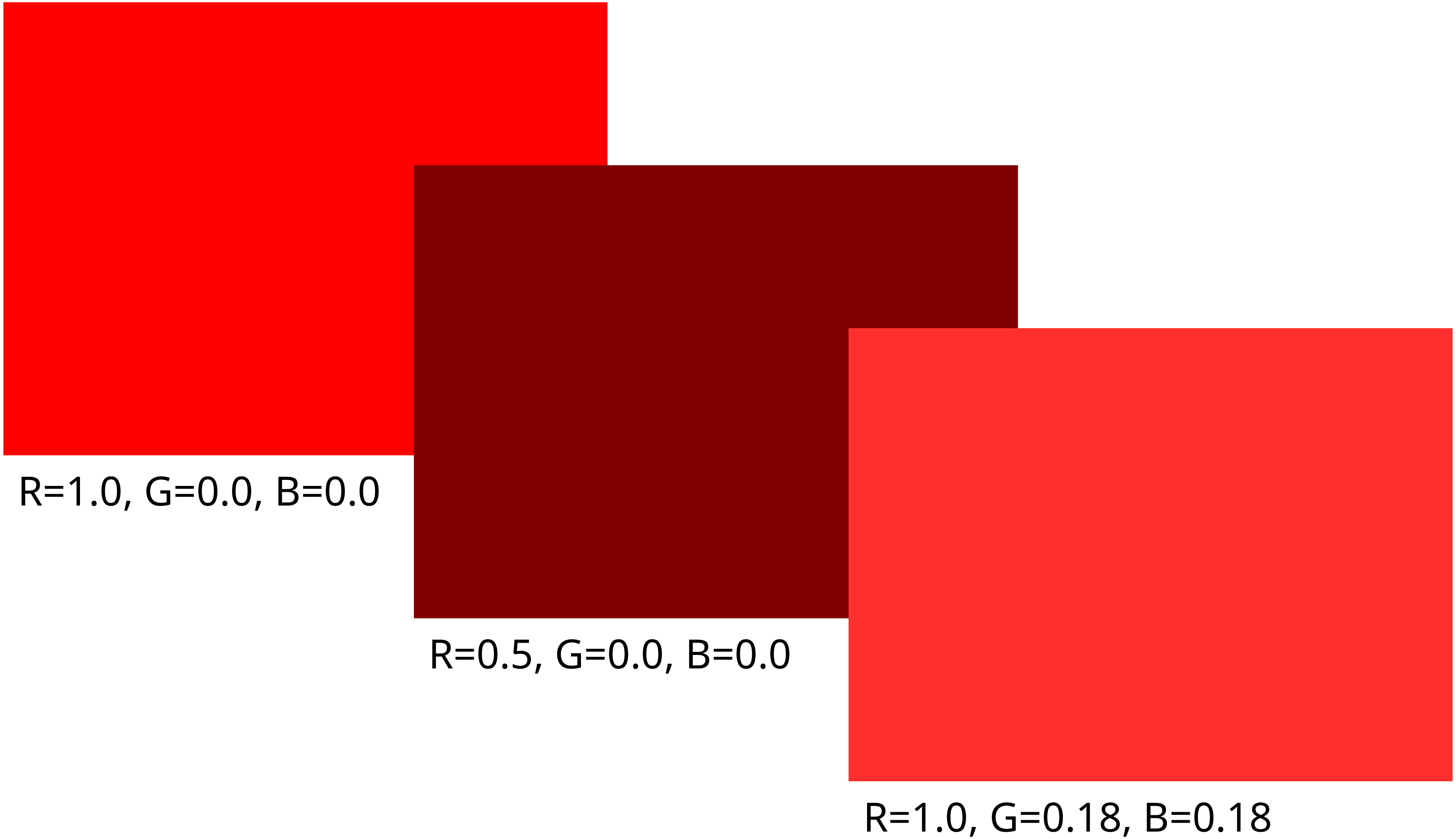
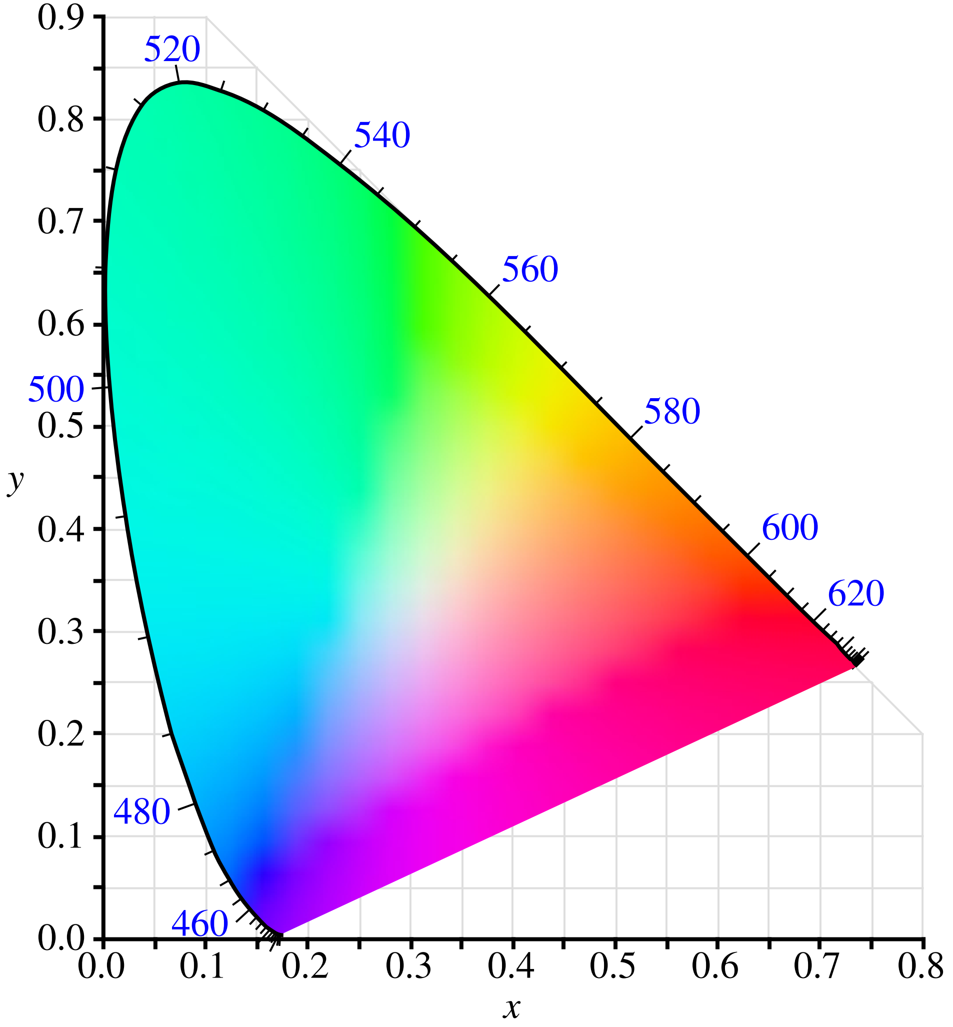
What even is color?

Xaver Hugl



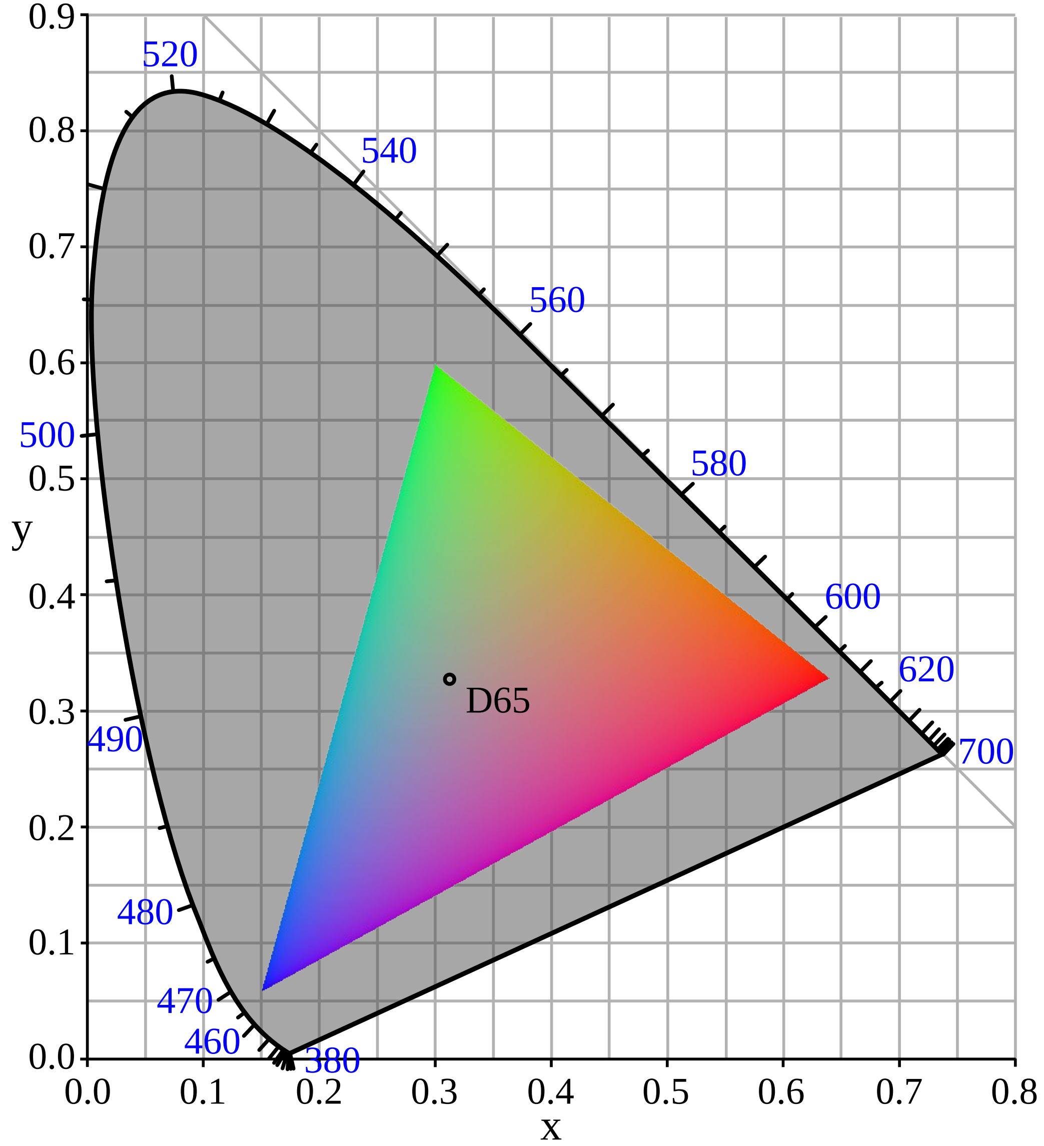

R=1.0, G=0.0, B=0.0
R=0.5, G=0.0, B=0.0
R=1.0, G=0.18, B=0.18



0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
y
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
x
520
540
560
580
600
620
500
480
460

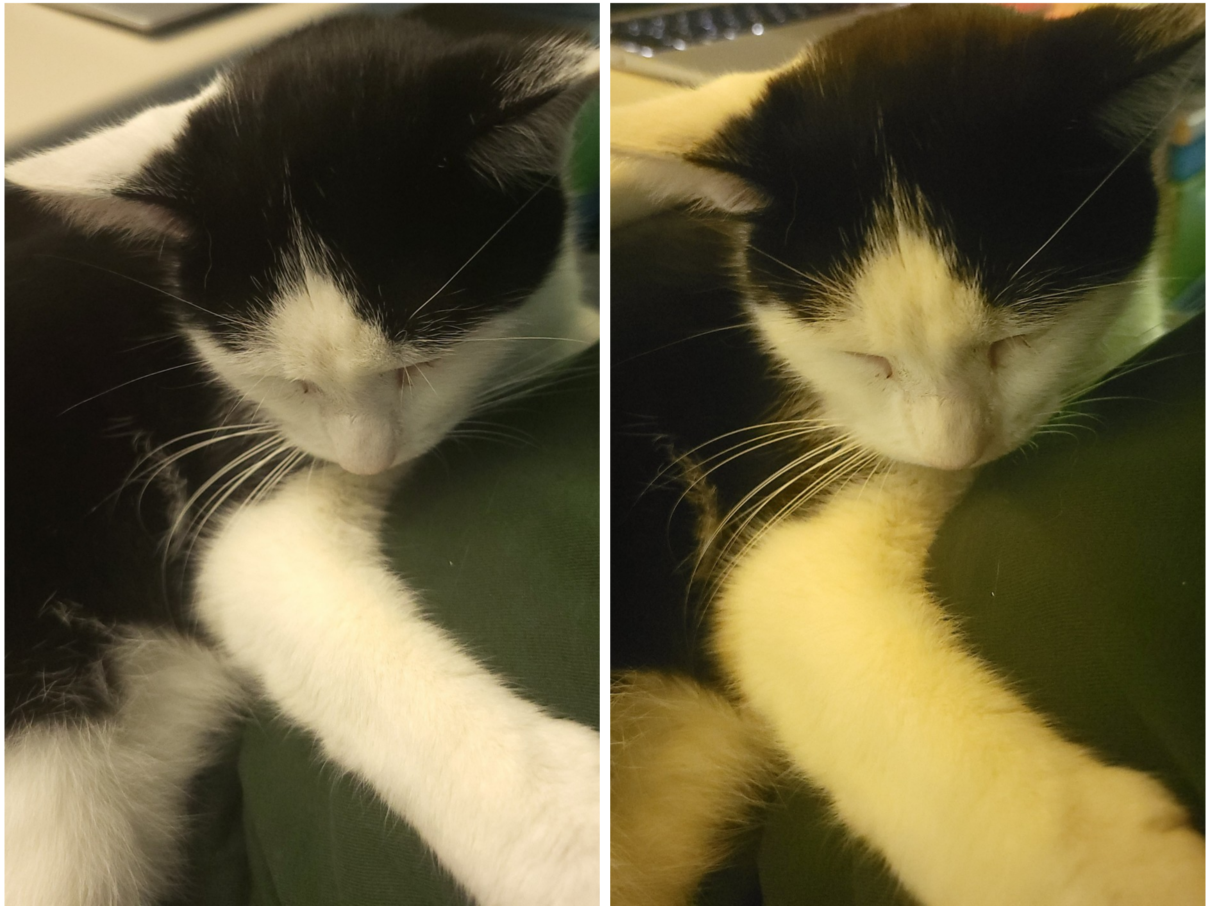
CIE XYZ

sRGB


0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
y
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
x
520
540
560
580
600
620
700
500
490
480
470
460
380
D65

White point

Depending on the environment, “white” can mean a very different color



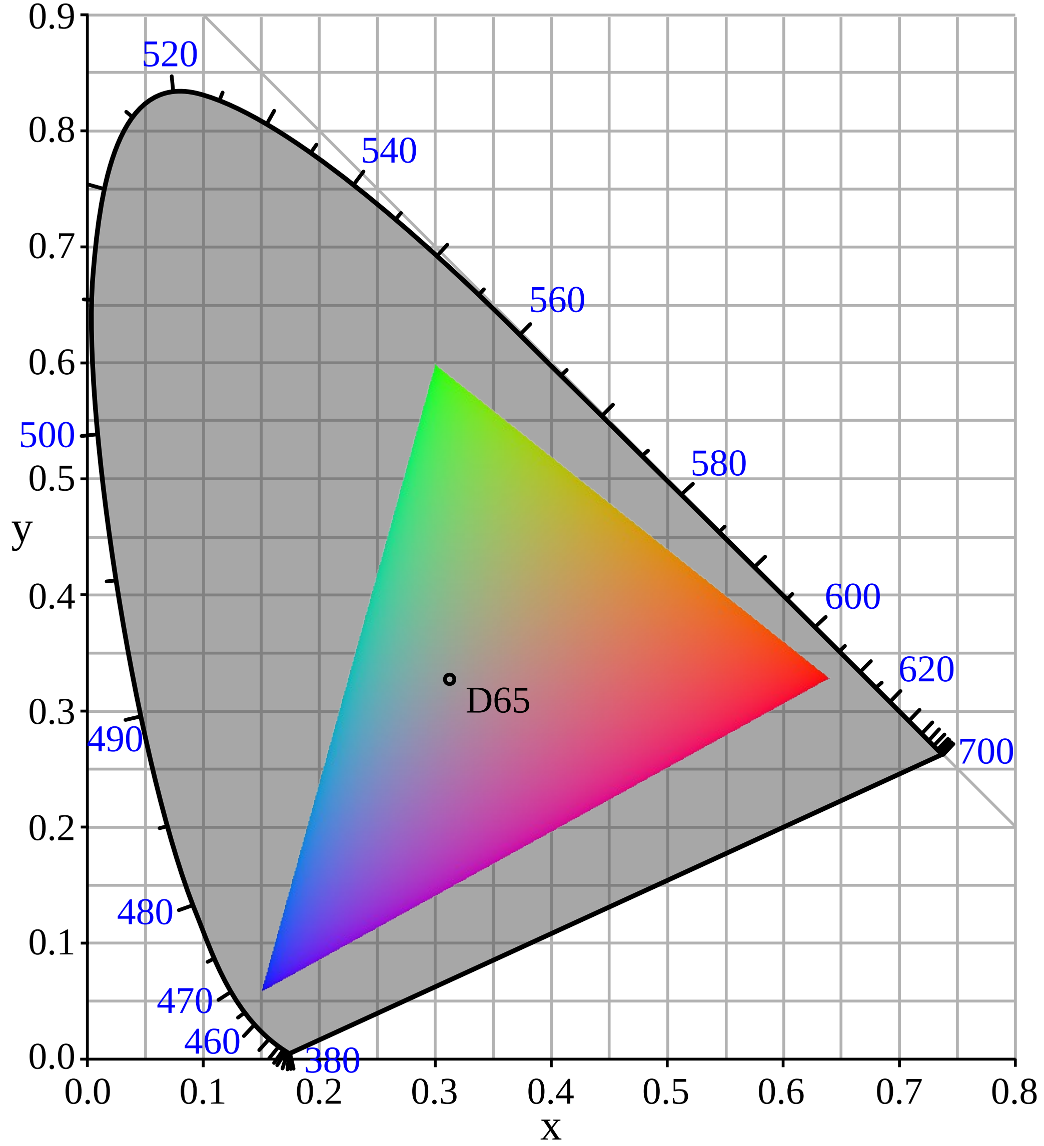
RGB white point
R=1.0, G=1.0, B=1.0

really results in

R=0.2126

G=0.7152

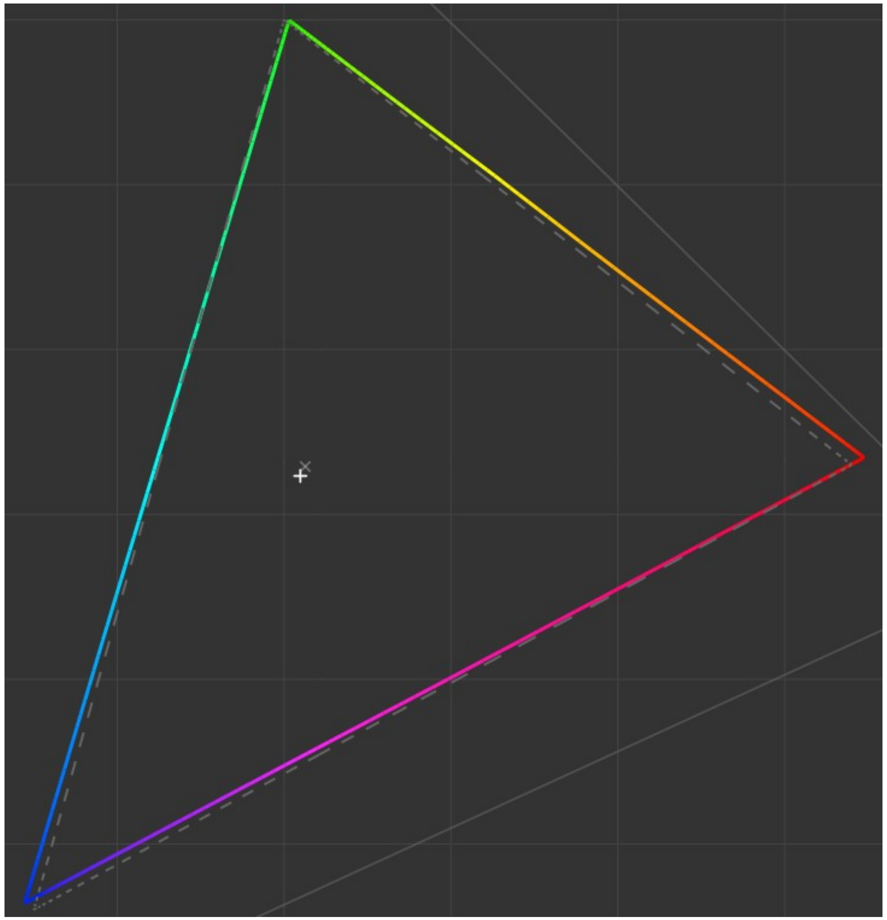
B=0.0722

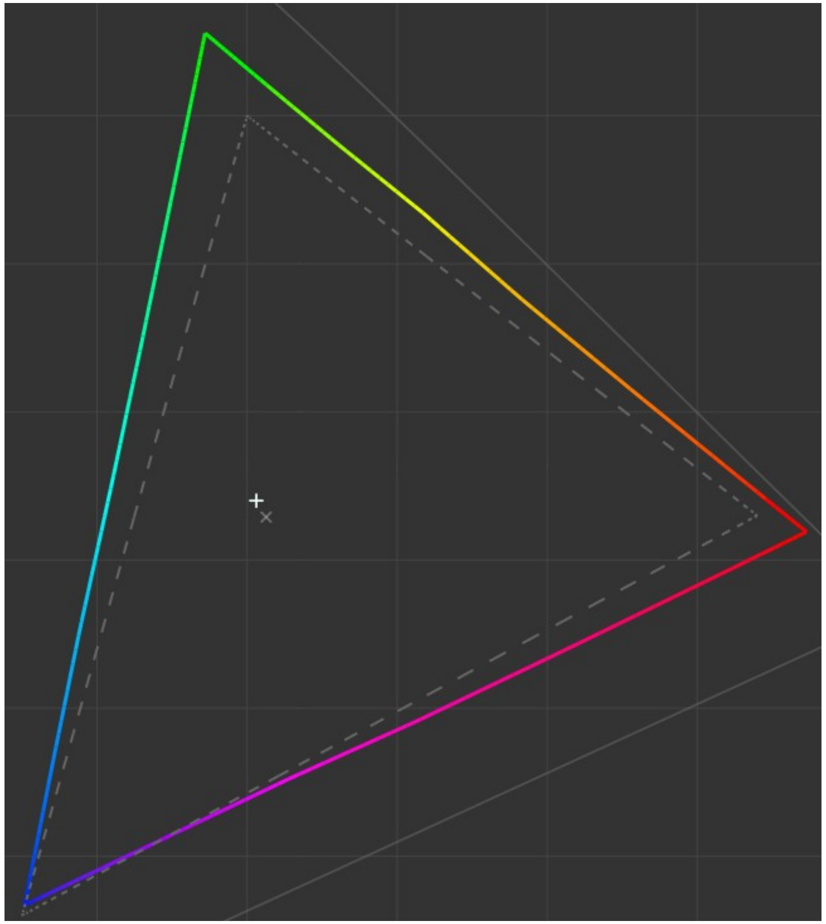


In practice…

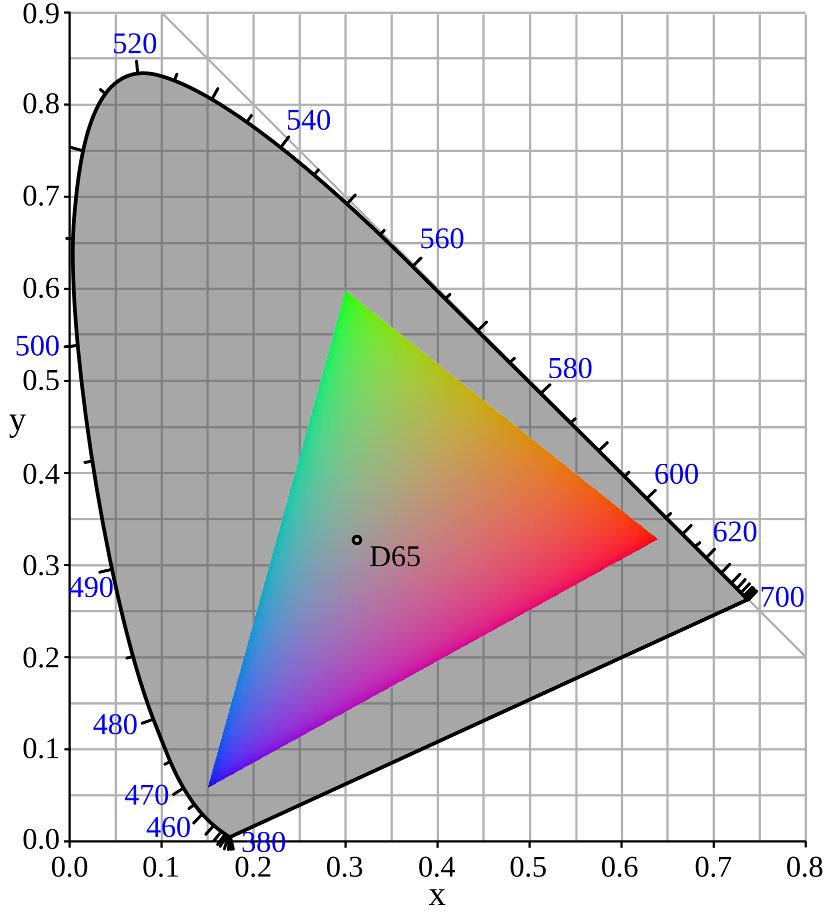
sRGB is a lie!

Displays aren’t perfect sRGB

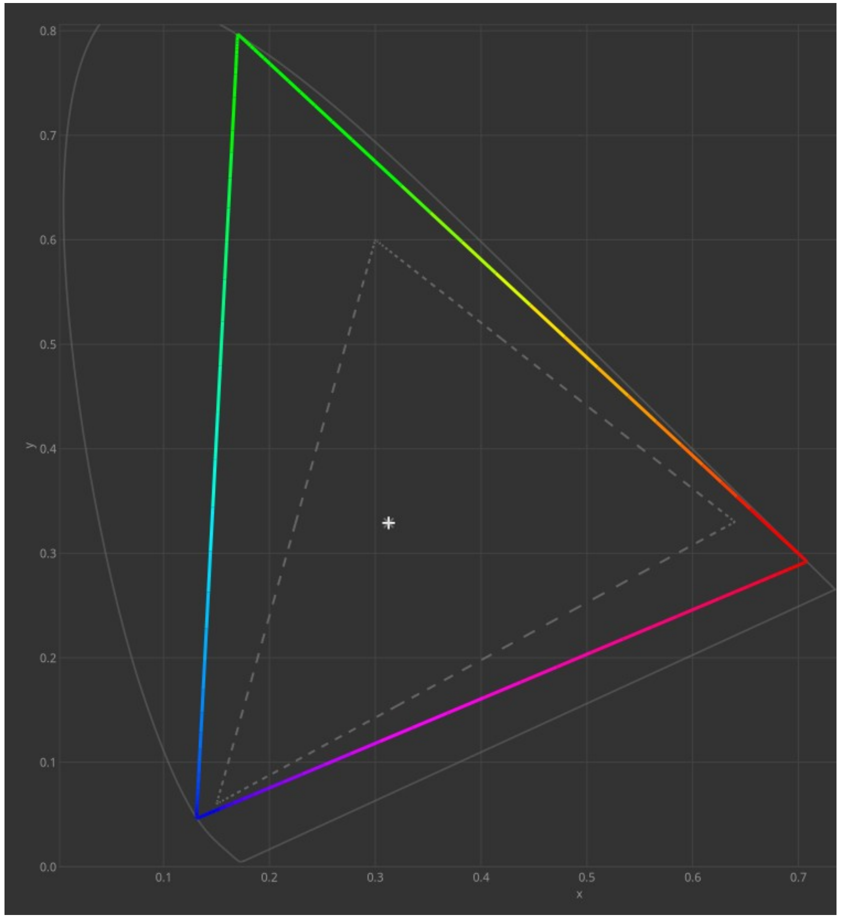

Regular Laptop display


Expensive gaming monitor

sRGB is limiting



sRGB



Rec.2020

Color Management:

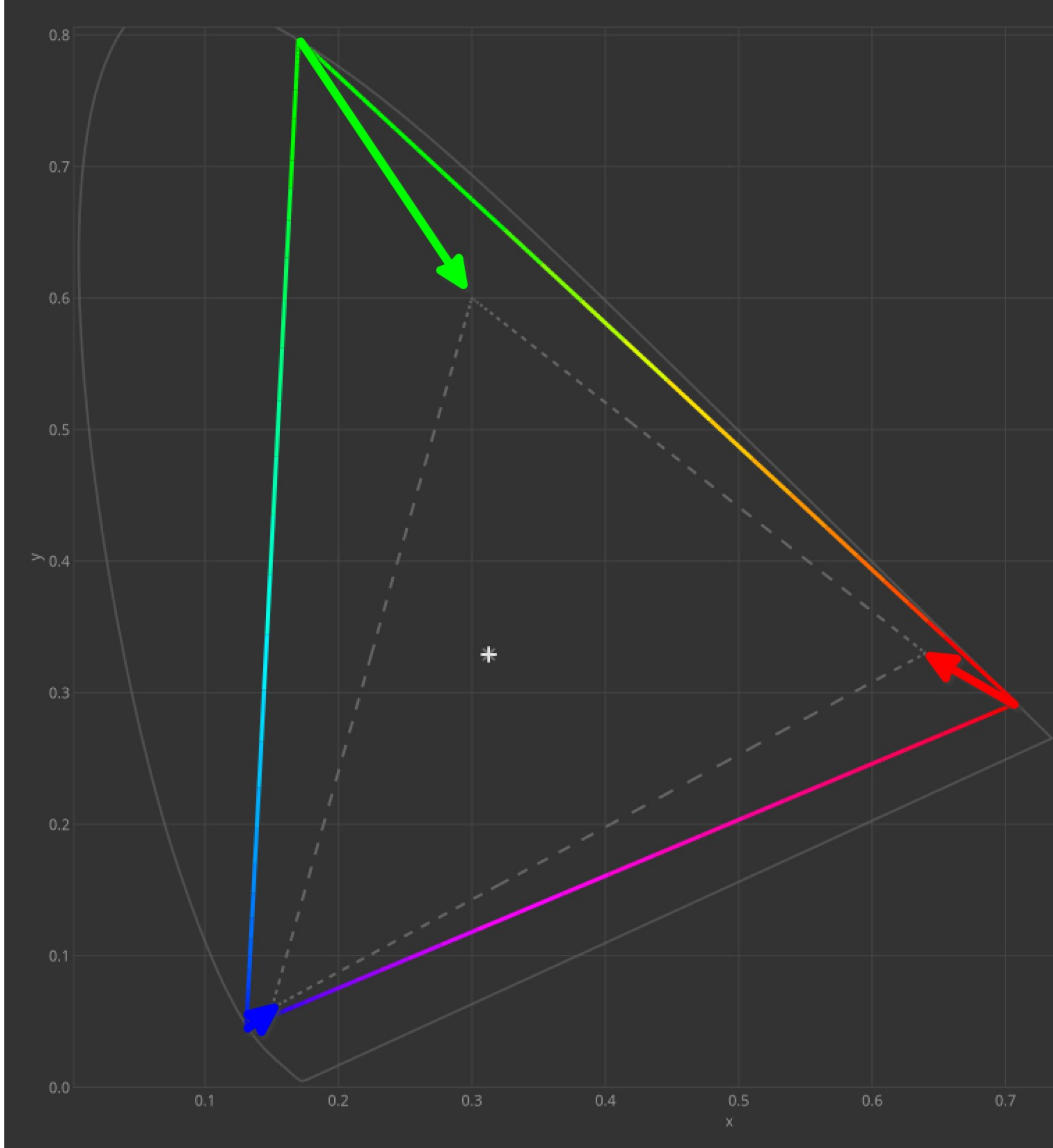
Translate RGB values from one color space to another

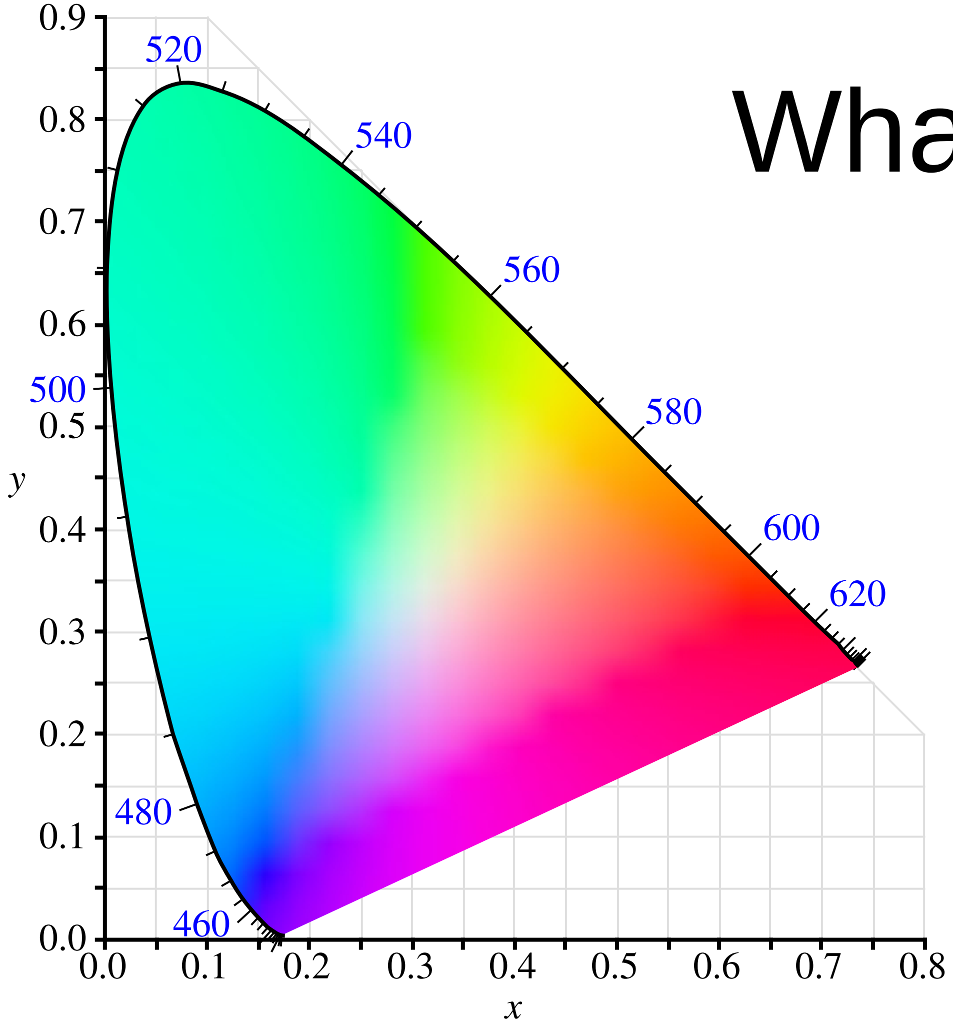
$$\begin{array}{c}\text{Linear RGB}\\ \text{in sRGB}\end{array} \bullet \boxed{\begin{array}{c}\text{sRGB} \rightarrow \text{XYZ}\\ \text{matrix}\end{array}} \bullet \boxed{\begin{array}{c}\text{XYZ} \rightarrow \text{Rec.2020}\\ \text{matrix}\end{array}} = \begin{array}{c}\text{Linear RGB}\\ \text{in Rec.2020}\end{array}$$

$$\begin{array}{c}\text{Linear RGB}\\ \text{in Rec.2020}\end{array} \bullet \boxed{\begin{array}{c}\text{Rec.2020} \rightarrow \text{XYZ}\\ \text{matrix}\end{array}} \bullet \boxed{\begin{array}{c}\text{XYZ} \rightarrow \text{sRGB}\\ \text{matrix}\end{array}} = \begin{array}{c}\text{Linear RGB}\\ \text{in sRGB}\end{array}$$

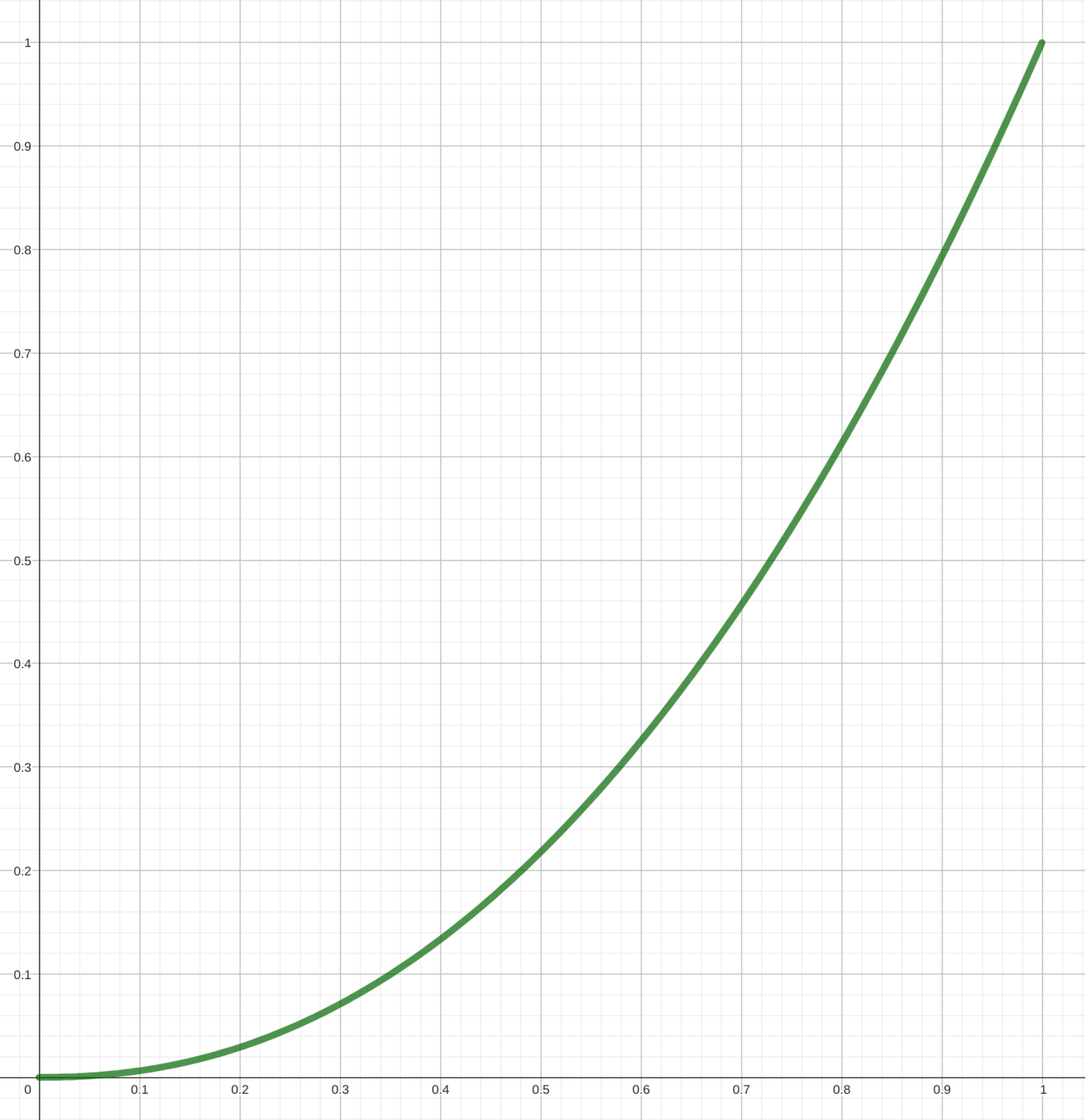
Gamut Mapping

Map colors that can't be represented in the target color space





What about brightness?



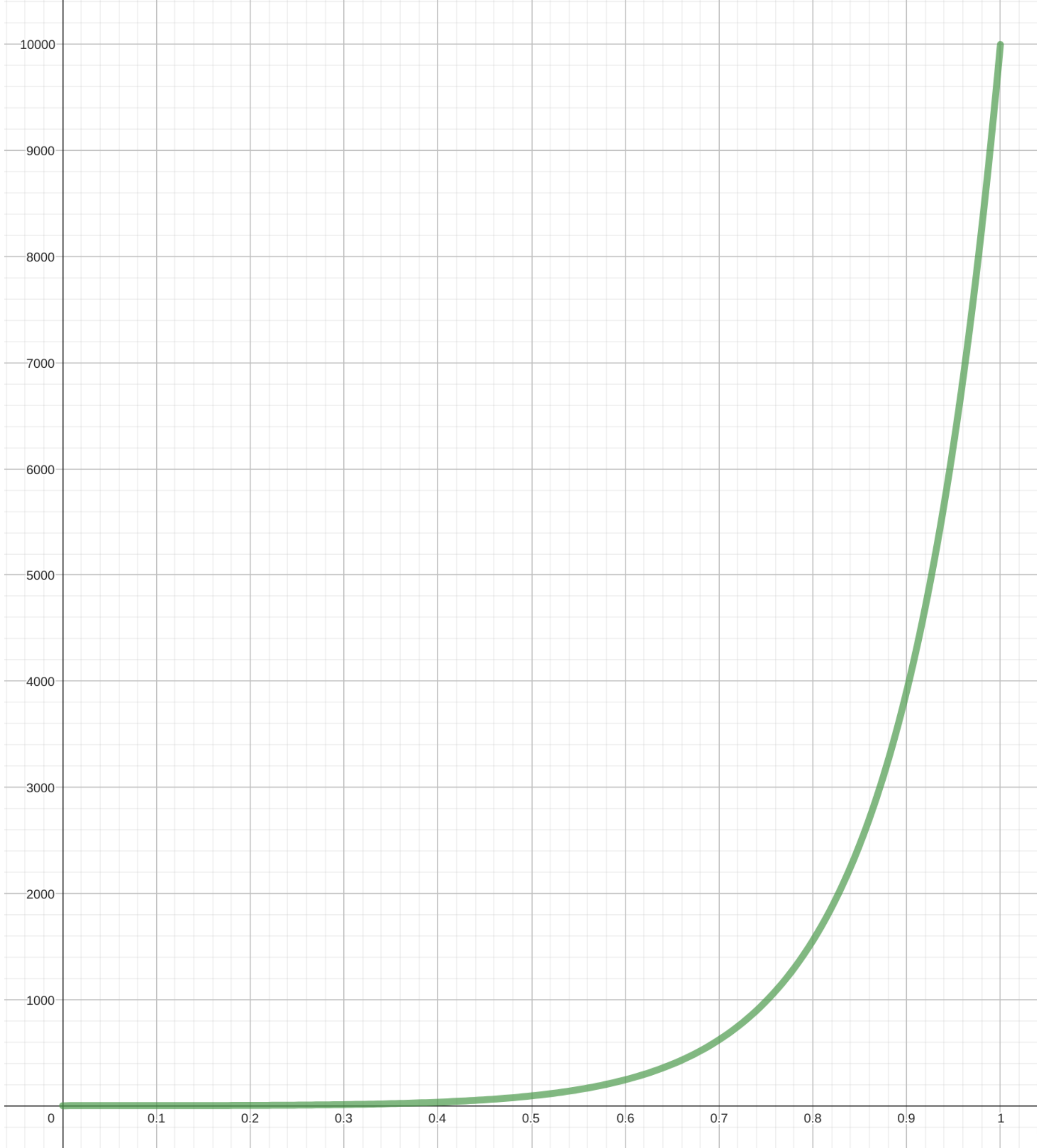
sRGB EOTF

EOTF =
Electro-Optical Transfer Function

$$O = E^{2.2}$$

PQ EOTF

Perceptual Quantizer
Follows human brightness perception more closely than sRGB



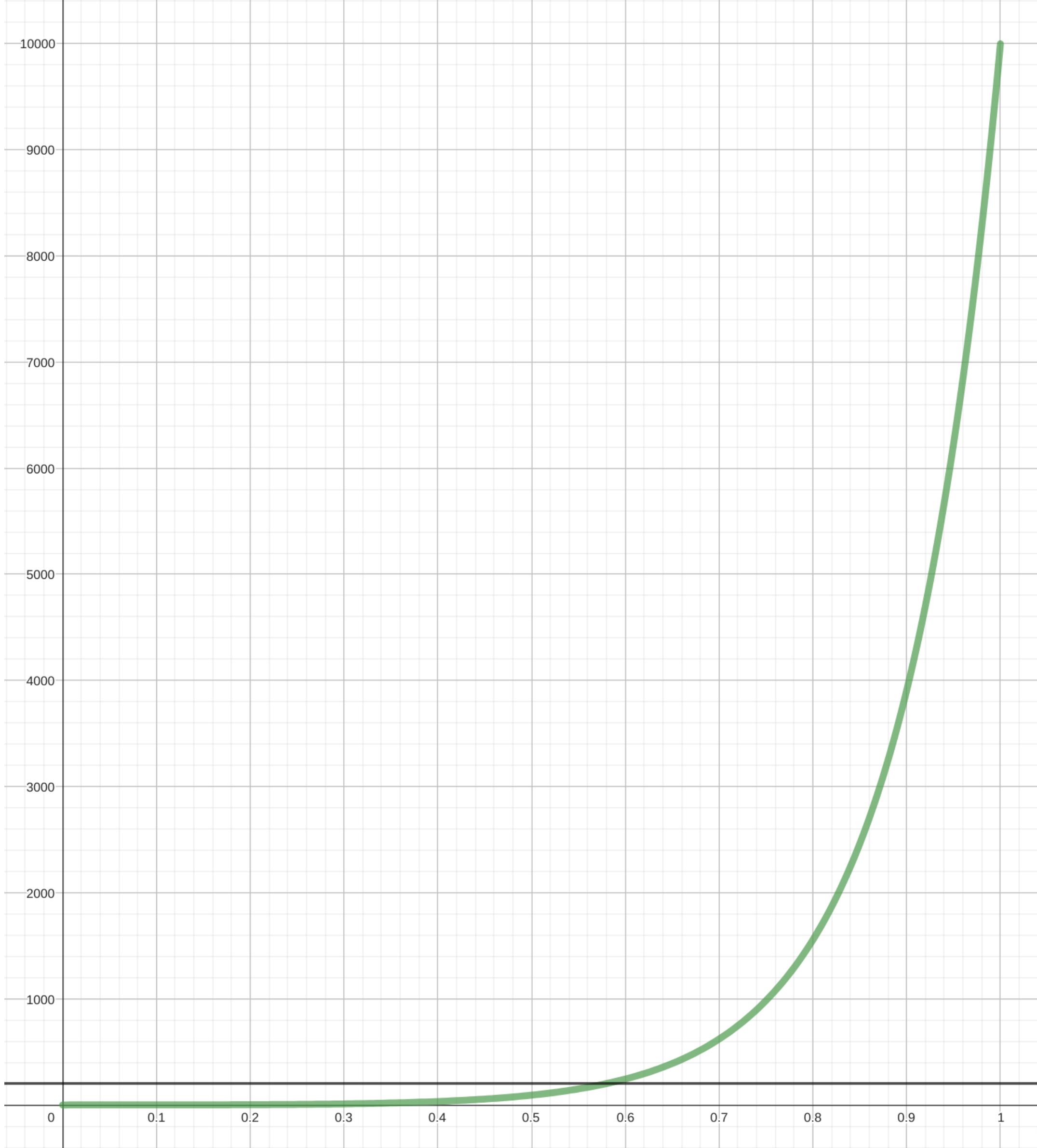
HDR

High Dynamic Range

SDR

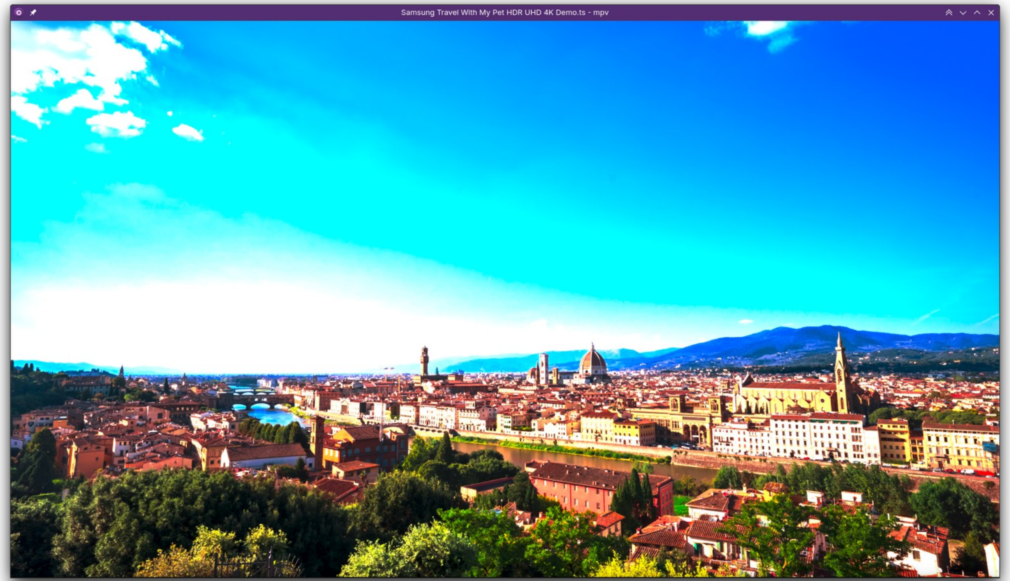
Standard Dynamic Range

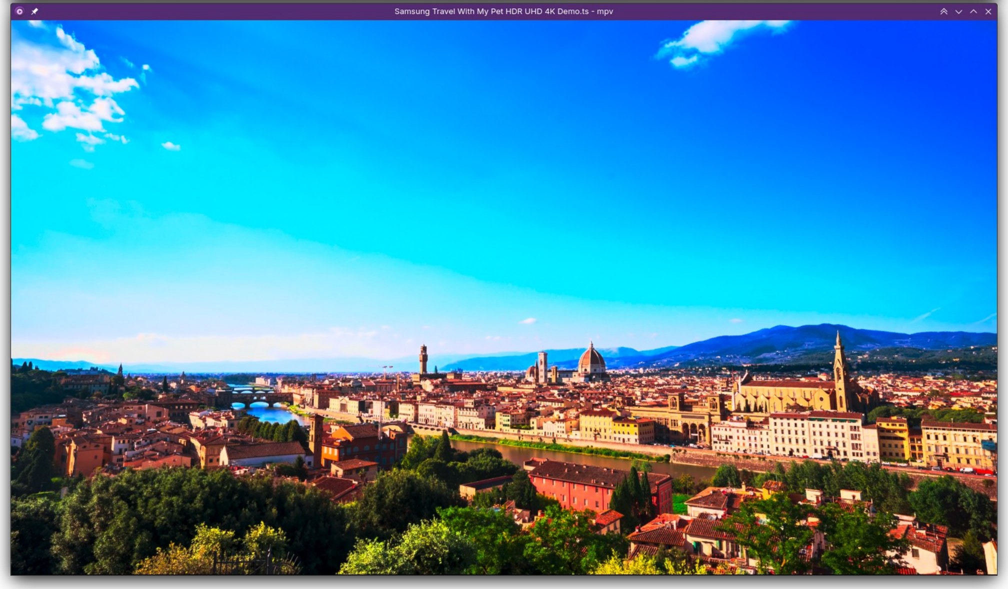
SDR White



Tone Mapping

Map brightness levels that can’t be represented in the target color space





What to do in practice?

If your app is okay with sRGB: Nothing.

Application images, assumed to be sRGB
→ KWin → Color Profile → Display

If your app needs more:

Use the Wayland color management protocol!

Application images + Wayland image description
→ KWin → Color Profile → Display

Color management protocol is still WIP

Set the environment variable
KWIN_ENABLE_XX_COLOR_MANAGEMENT=1

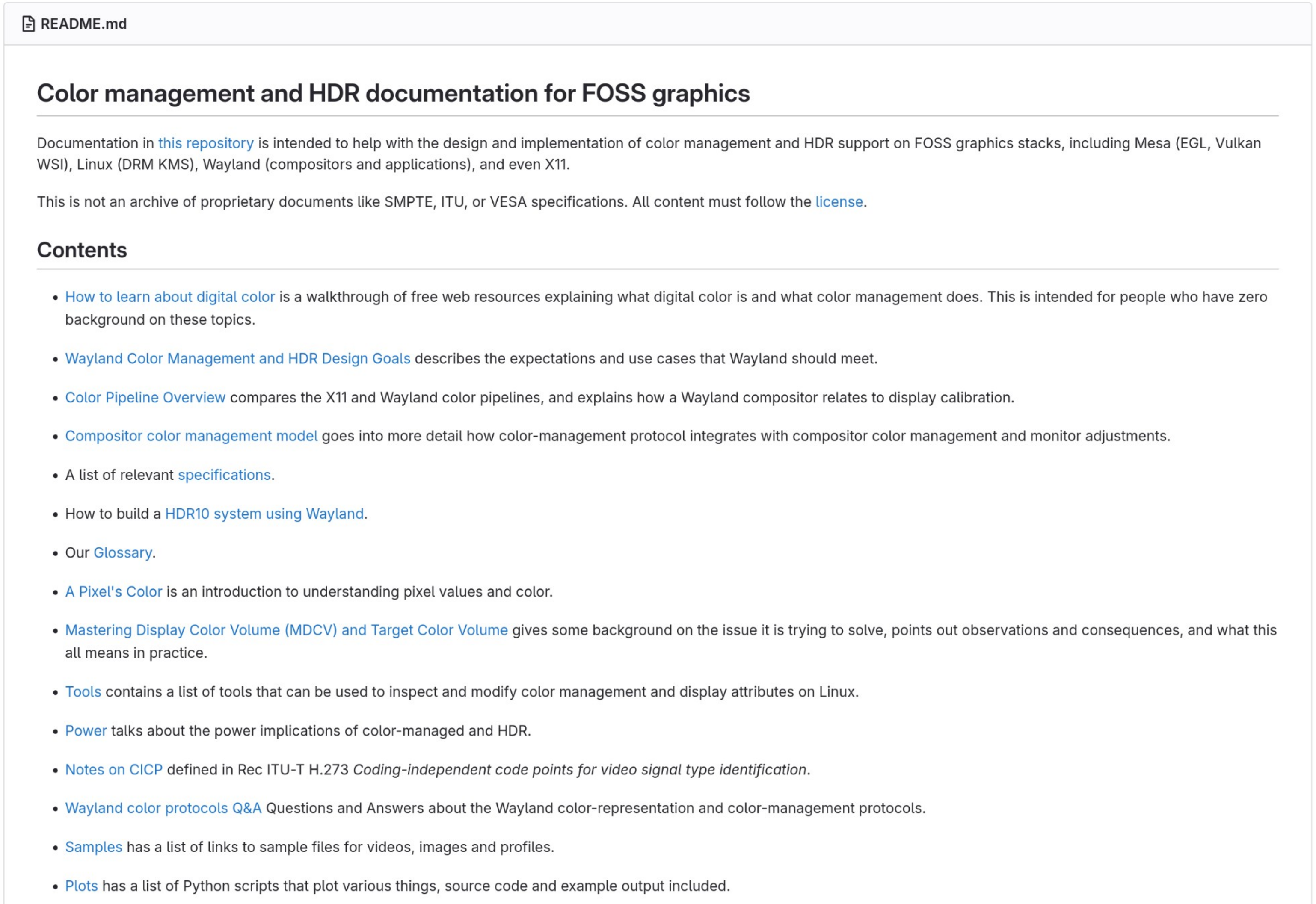
to expose support for the protocol

For experiencing HDR, there’s an earlier protocol

1. Start games in gamescope with --hdr-enabled
2. Play HDR videos with https://github.com/Zamundaaa/VK_hdr_layer:

```
ENABLE_HDR_WSI=1 mpv --vo=gpu-next --gpu-api=vulkan –target-colorspace-hint /path/to/video
```

https://gitlab.freedesktop.org/pq/color-and-hdr



README.md

Color management and HDR documentation for FOSS graphics

Documentation in this repository is intended to help with the design and implementation of color management and HDR support on FOSS graphics stacks, including Mesa (EGL, Vulkan WSI), Linux (DRM KMS), Wayland (compositors and applications), and even X11.

This is not an archive of proprietary documents like SMPTE, ITU, or VESA specifications. All content must follow the license.

Contents

- How to learn about digital color is a walkthrough of free web resources explaining what digital color is and what color management does. This is intended for people who have zero background on these topics.
- Wayland Color Management and HDR Design Goals describes the expectations and use cases that Wayland should meet.
- Color Pipeline Overview compares the X11 and Wayland color pipelines, and explains how a Wayland compositor relates to display calibration.
- Compositor color management model goes into more detail how color-management protocol integrates with compositor color management and monitor adjustments.
- A list of relevant specifications.
- How to build a HDR10 system using Wayland.
- Our Glossary.
- A Pixel's Color is an introduction to understanding pixel values and color.
- Mastering Display Color Volume (MDCV) and Target Color Volume gives some background on the issue it is trying to solve, points out observations and consequences, and what this all means in practice.
- Tools contains a list of tools that can be used to inspect and modify color management and display attributes on Linux.
- Power talks about the power implications of color-managed and HDR.
- Notes on CICP defined in Rec ITU-T H.273 *Coding-independent code points for video signal type identification*.
- Wayland color protocols Q&A Questions and Answers about the Wayland color-representation and color-management protocols.
- Samples has a list of links to sample files for videos, images and profiles.
- Plots has a list of Python scripts that plot various things, source code and example output included.