SSI

An Introduction to the Spectral Similarity Index

(SMPTE ST 2122)

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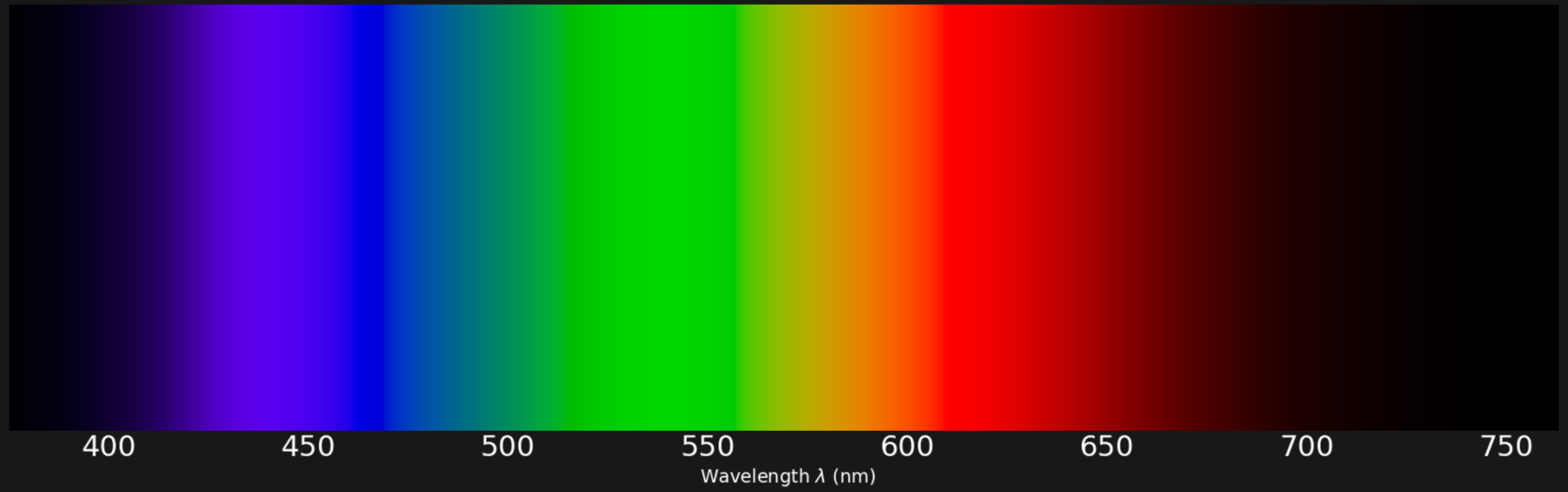
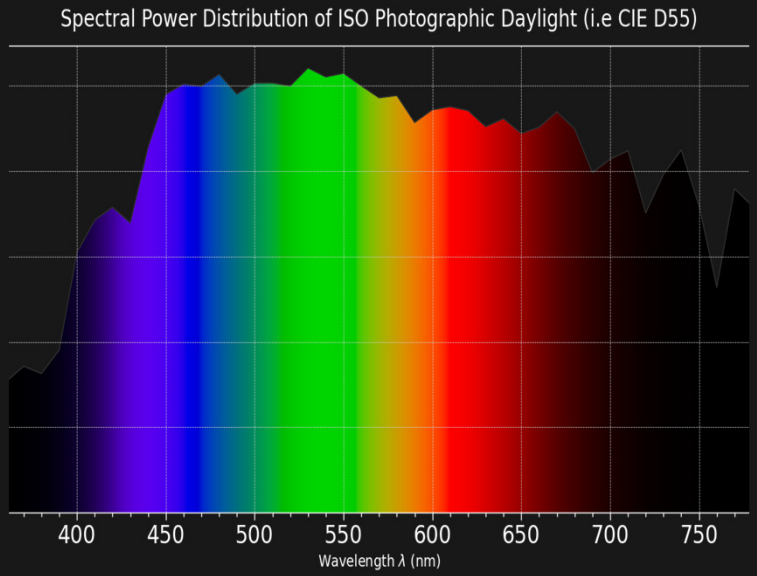
Color and lighting

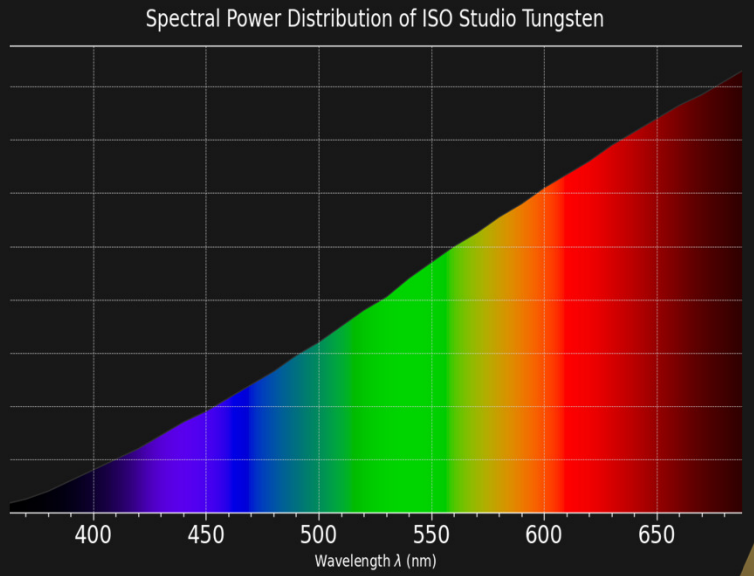
- Color is the sensing of power distribution across the visible spectrum



Color and lighting

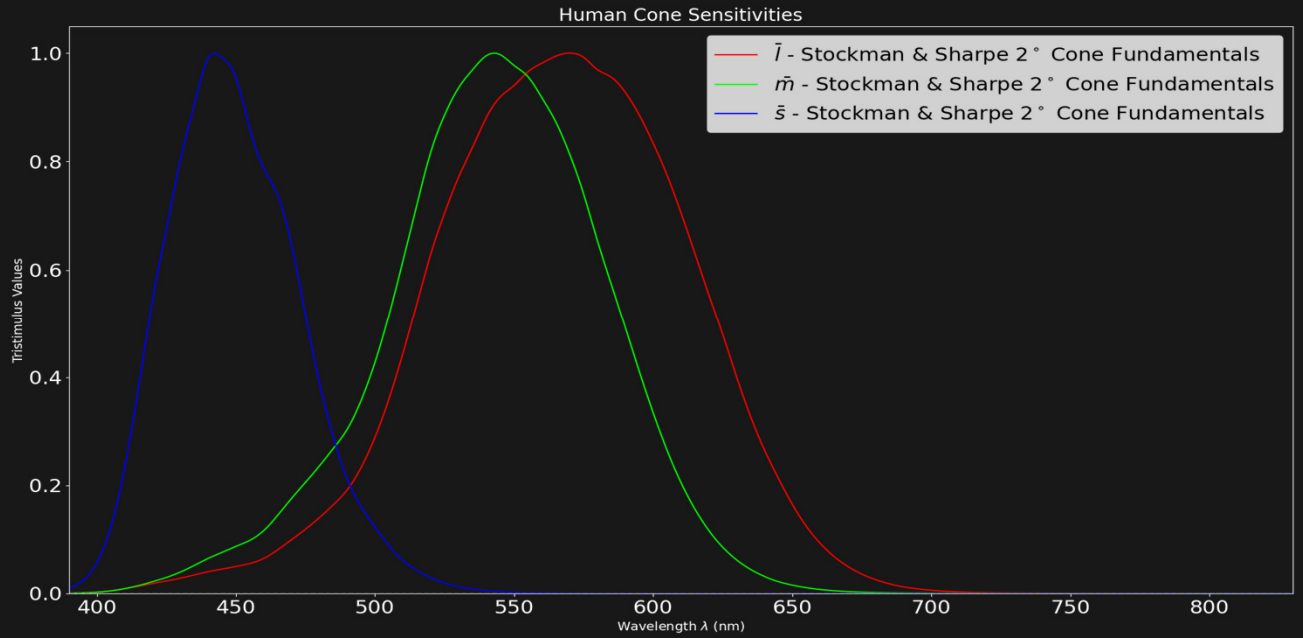
- Light is characterized by its spectral power distribution (SPD) across the visible spectrum





Color and lighting

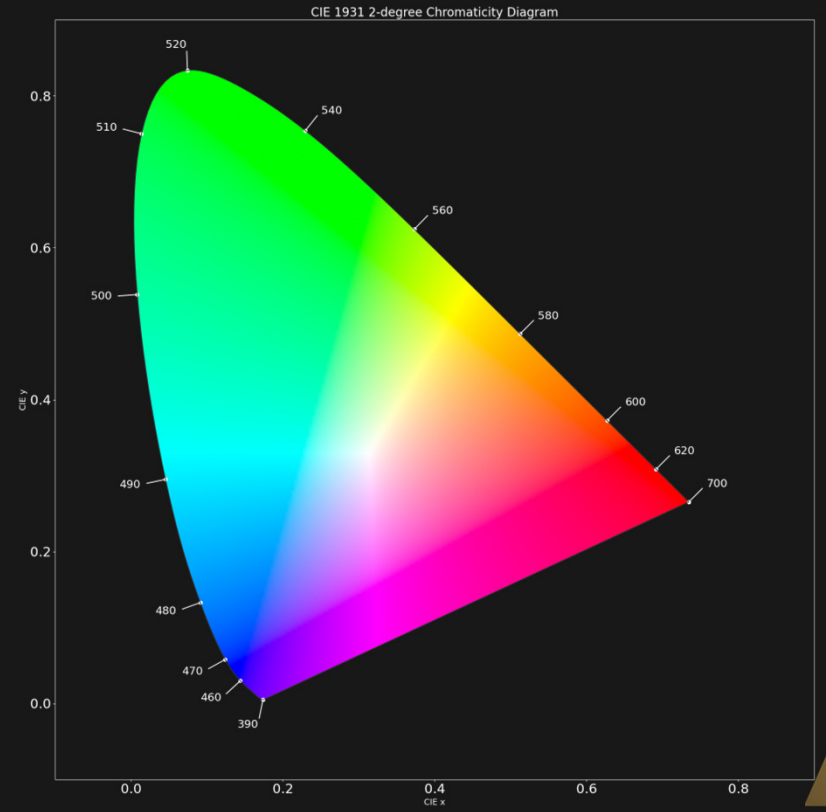
- Human vision and cameras are trichromatic



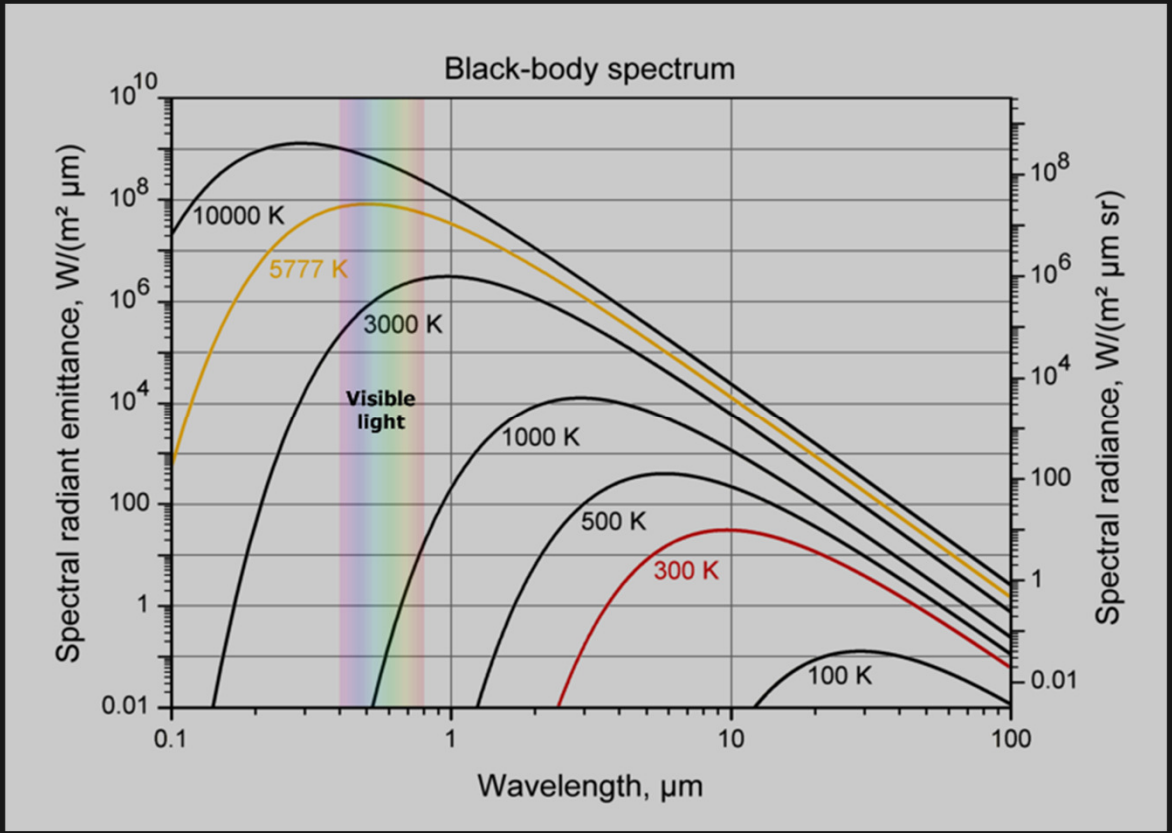
(Spectral sensitivities [normalized responsivity spectra] of human cone cells)

Color and lighting

- Chromaticity is color (independent of luminance) *as perceived by the human visual system*



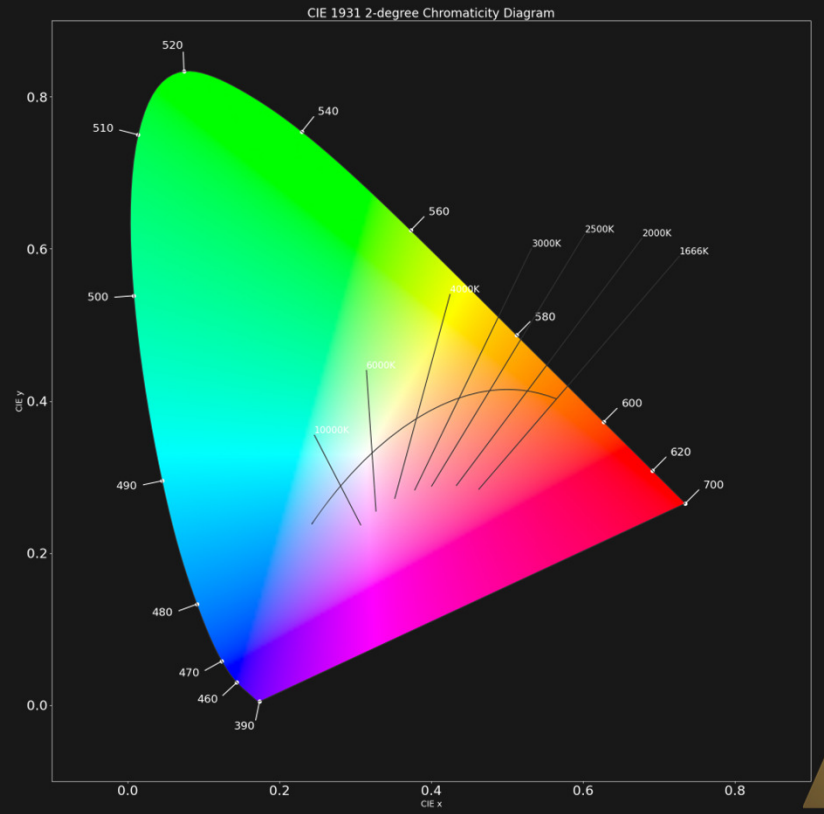
“Natural” lighting – blackbody emission



WWW.SUN.ORG/ENCYCLOPEDIA/BLACK-BODY-RADIATION

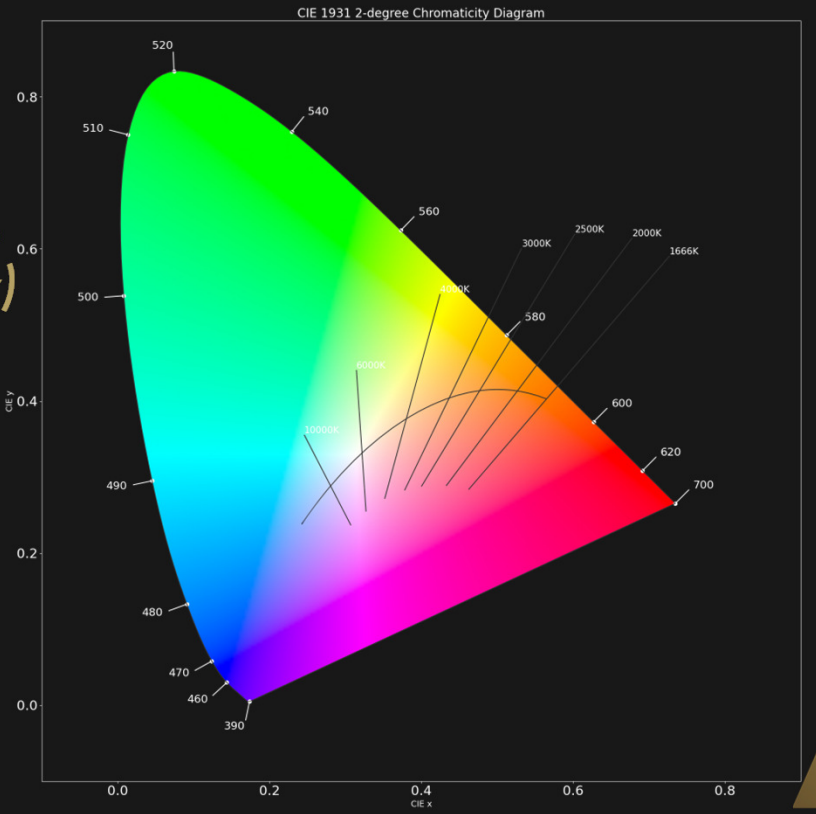
Color and lighting

- Blackbody (Planckian) chromaticity locus



Color and lighting

- How to describe color?
  - Correlated color temperature (CCT)
    (only a one-dimensional value — doesn't specify chromaticity)
  - Chromaticity (x, y)
    (only a two-dimensional value — doesn't specify spectrum)
  - Spectrum
    (relative power
    at each wavelength)

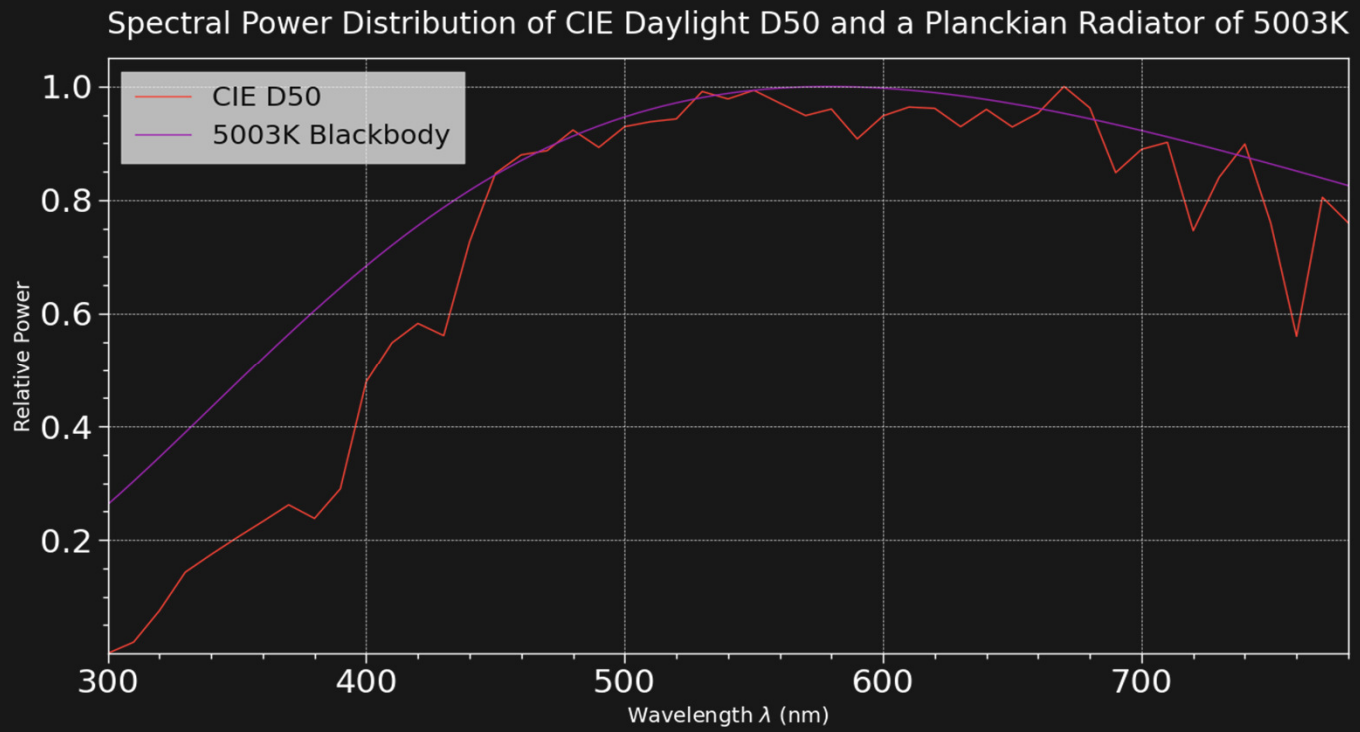


Color-rendering metrics

- Metrics have been developed to quantify illuminants' ability to faithfully reveal the colors of surfaces reflecting them in comparison with natural (blackbody or daylight) lighting
  - However, these indices are typically either based on human vision (e.g. CRI, CQS, TM-30) or three-chip broadcast-television cameras (e.g. TLCI, TLMF)
  - Photographic film and single-sensor digital cameras used in motion-picture production have different spectral sensitivities than human vision and television cameras, and differ from each other, so the existing indices do not adequately quantify illuminants for cinematography
  - The inadequacies of these metrics are especially evident with LED's

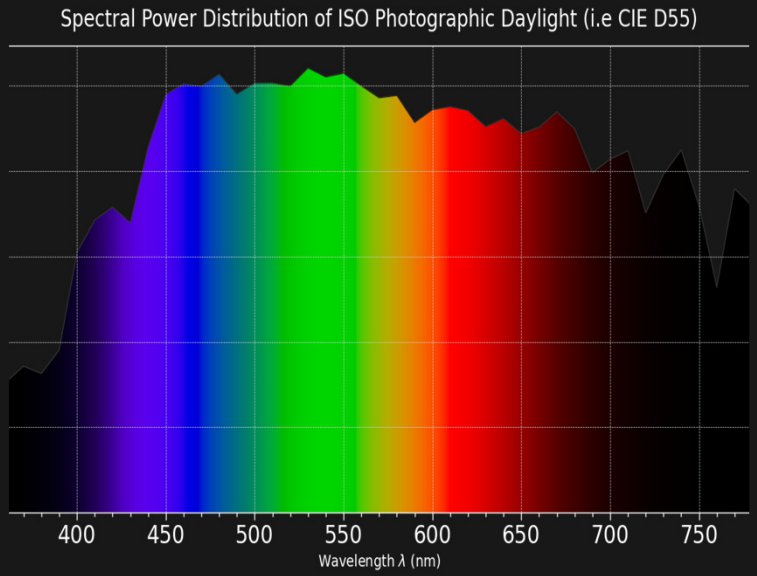
“Natural” lighting – Daylight

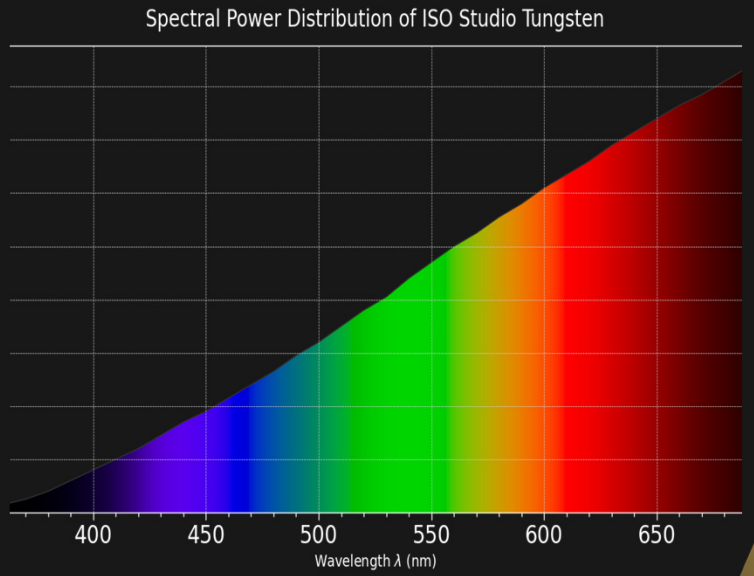
- Daylight compared to blackbody (Planckian) emission



Traditional motion-picture lighting

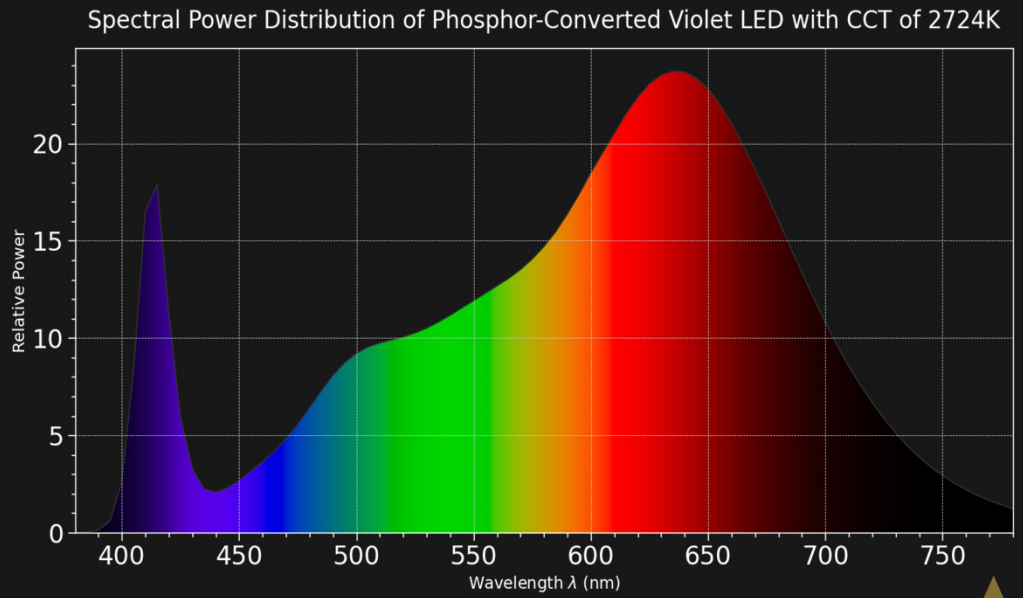
- The motion-picture imaging chain was built around natural light – daylight and incandescent (tungsten) illumination





LED lighting

- Newer lighting technologies such as LED have non-Planckian SPD's
  - LED lighting offers many practical benefits
  - *But,* it differs significantly from standard photographic sources (ISO 7589), which can cause unpredictable color reproduction that cannot easily be "fixed in post"



Problems with LED lighting

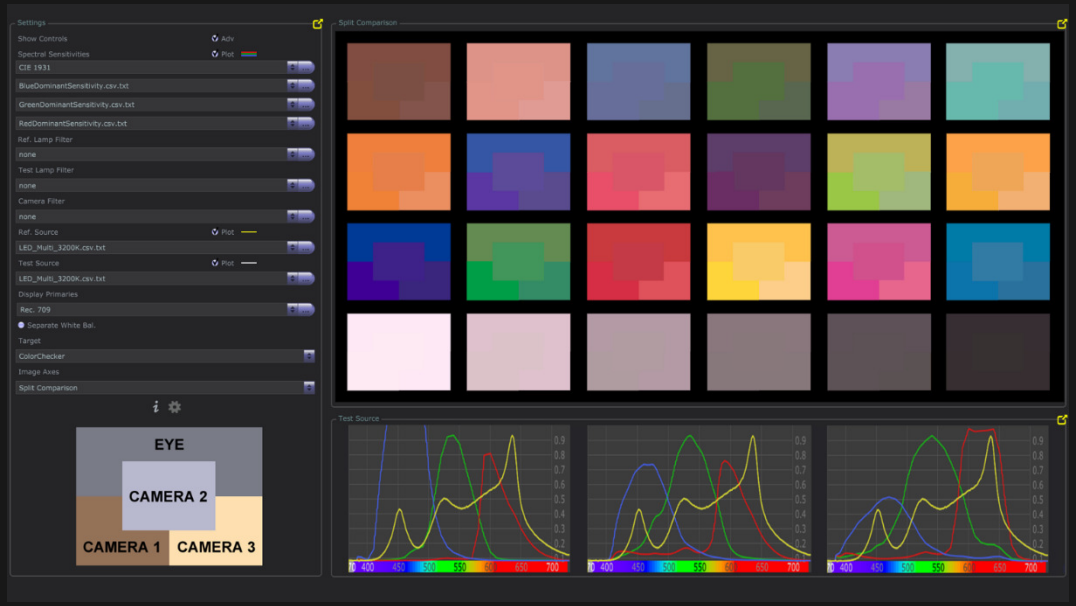
- Over- and under-represented wavelengths cannot be corrected with camera filters or in postproduction by primary color correction

Tungsten
3200K

LED
CCT = 3200K

Existing metrics and LED lighting

- The inadequacies for cinematography of existing metrics are particularly evident with LED illuminants, due to their multimodal SPD's



A problem

- The anchor of color cinematography – standard lighting – has come unmoored with non-Planckian light sources such as LED
- Previously-existing color-rendering metrics were designed for human vision or television cameras, *not* cinema cameras
  - They are unreliable predictors of the color-rendering capability of LED lighting in cinema production
- There is no spectral-sensitivity standard for cinema cameras
  - Digital cinema cameras see light differently than human vision, and than each other, so a metric for cinema lighting quality cannot presume a particular set of sensitivities — that is, no metric to evaluate lighting based on a single set of spectral sensitivities will work for any camera

A problem

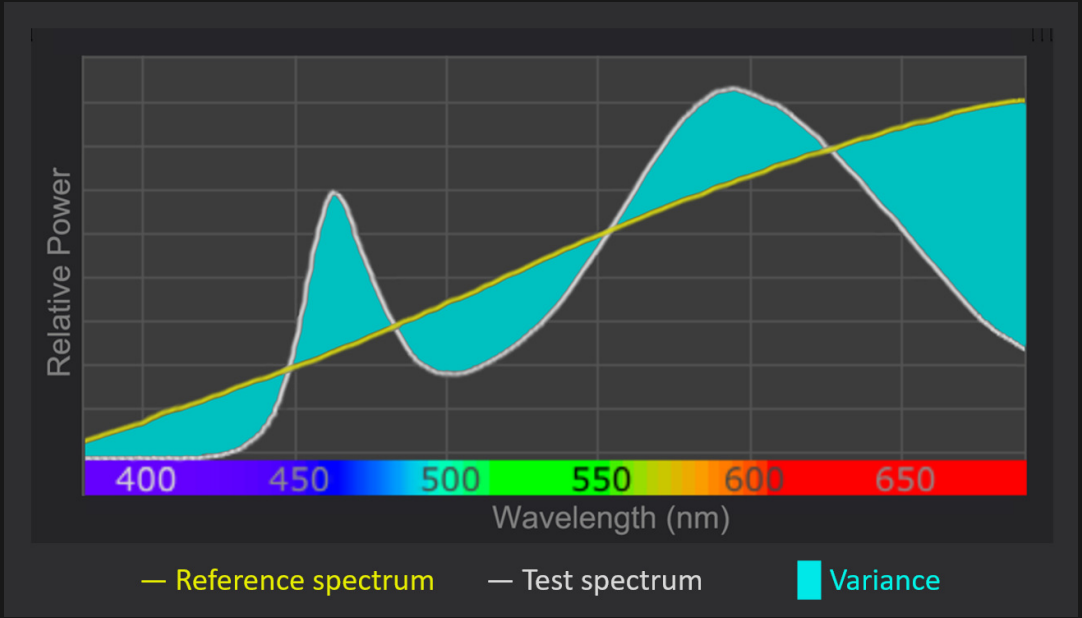
- Thus cinematographers had no tools to reliably predict color rendering
- The Academy's Science and Technology Council investigated the problem
  - We worked with DP's, lighting manufacturers, and other experts
- Conclusion: A metric was needed that compares a cinema light source to a known, trusted, reference source, independent of camera sensitivities, and expresses its similarity to it
  - Knowing that a source's SPD is similar to that of a reference (such as daylight or tungsten) would provide confidence that color rendering will match that by the reference source

A solution: SSI

- Result: The Academy developed the Spectral Similarity Index
  - Standardized as SMPTE ST 2122 — SSI
  - A tool for cinematographers that quantifies the predictability of light sources

SSI

- The SSI compares the SPD of a source to that of a specified reference source (typically blackbody at a specified color temperature, or CIE daylight at a specified CCT)



SSI measurement

- Determination of the SSI of a light source requires measurement of the spectral power distribution (SPD, or spectrum) of the source and of the reference against which it is compared
- This is measured with a *spectrometer* (or spectroradiometer)
  - A *colorimeter* (which measures only *x, y* chromaticity) cannot do this

SSI calculation

- The test and reference spectra are considered across the range of 375 to 675 nm (at intervals not exceeding 5 nm); a relative difference vector is calculated, weighted, and smoothed; and the SSI is calculated and expressed as a value ≤ 100 (where 100 indicates a spectrum equivalent to that of the reference)
- The precise calculation is defined by SMPTE ST 2122:2020 (doi.org/10.5594/SMPTE.ST2122.2020) and summarized in oscars.org/sites/oscars/files/ssi_overview_2020-09-16.pdf
- The Academy provides an online SSI calculator, which allows spectral data to be copy-and-pasted from a spreadsheet:
  oscars.org/ssi-calculator

SSI values

- The SSI value is always denoted with respect to the reference against which it was measured, which is indicated (as defined by the SMPTE standard and summarized in the Academy overview) within square brackets
- Examples:

SSI[P3200] = 86

SSI[CIE D55] = 78

SSI measurements

- We encourage lighting manufacturers to quote the SSI values of their lights on their spec sheets and collateral material along with other measurements, and encourage spectrometer manufacturers to include SSI calculation in their devices
- SSI can be measured on-set with an SSI-capable spectrometer, such as:
  - Asensetek Lighting Passport
  - Sekonic C-800-U Spectromaster Spectrometer
  - UPRtek CV600 Cinema & Stage Spectral Color Meter

Spectral Similarity Index key features

- Primarily intended for cinematographic use;
  purpose-built for the improved evaluation of motion-picture lighting
- Indicates the similarity of a test illuminant's spectrum
  to that of a reference illuminant
- A measure of the predictability of color rendering
  in cinematographic reproduction
- Independent of any spectral sensitivity
- Standardized as SMPTE ST 2122
- Adopted by manufacturers of cinema lighting and spectrometers

Summary

- LED lighting does not conform to characteristics of natural lighting
- Existing rendering-quality metrics were designed for human vision and/or broadcast-television cameras, and are not reliable for cinema cameras, especially with LED's
- SSI is expressly designed to compare cinema lighting to reference sources, providing cinematographers a better "confidence factor" in their choice of lighting
- As cinema lighting manufacturers work to improve the spectral quality of their LED-based fixtures, SSI can be a better metric for defining performance targets and gauging development progress

SSI

For more information:

oscars.org/ssi

Including:

- "Academy Spectral Similarity Index (SSI): Overview," an 8-page white paper providing additional detail on the motivation for the development of SSI, and an explanation of how it is calculated and how the value must be expressed
- SSI calculator
- Additional information about the Academy's prior work investigating solid-state (LED) lighting