Implementing individual CMFs in ICC.1 and ICC.2

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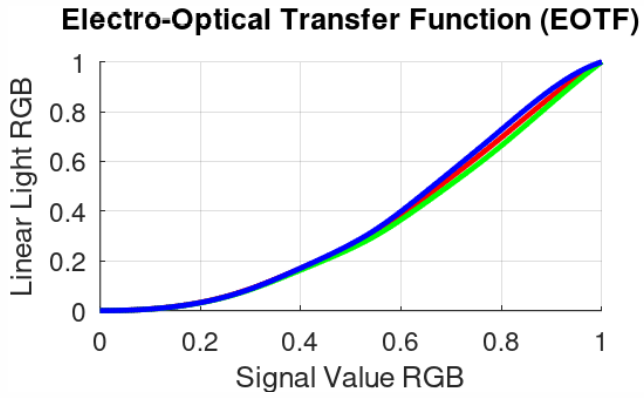
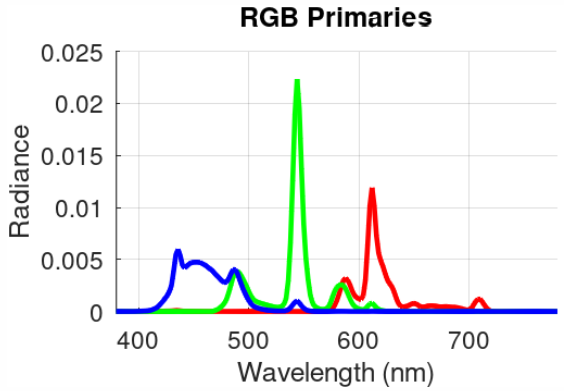
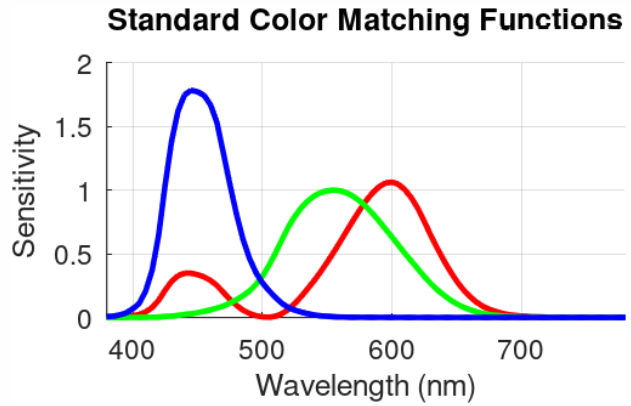
Elements of display color management

Display RGB Values

Standard Tristimulus XYZ Values



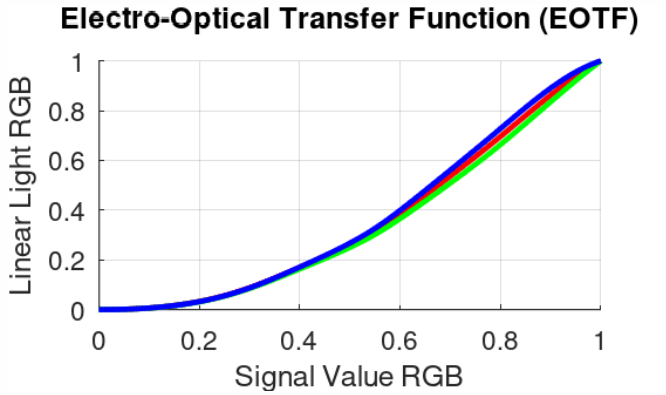


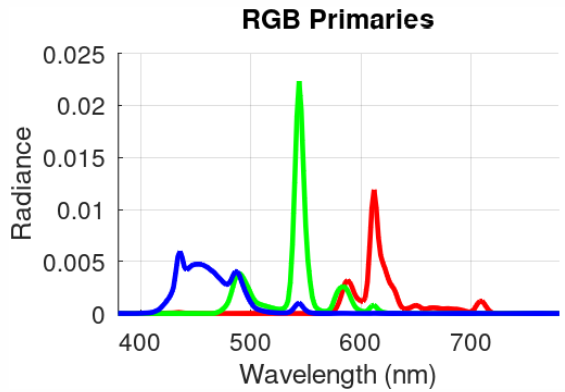


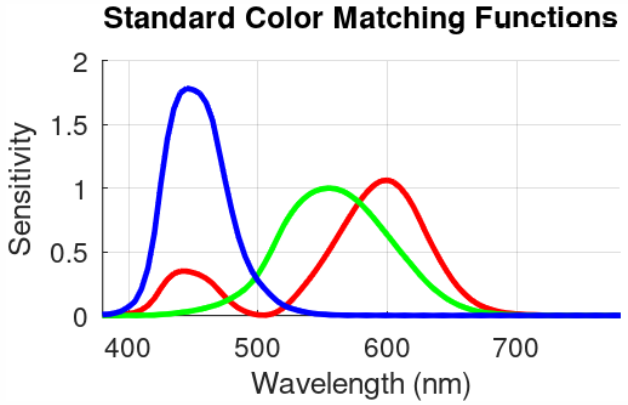
Math for display color management

$$\begin{bmatrix} r_{signal} \\ g_{signal} \\ b_{signal} \end{bmatrix}$$

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$$







$$\begin{aligned} r_{light} &= eotf_r(r_{signal}) \\ g_{light} &= eotf_g(g_{signal}) \\ b_{light} &= eotf_b(b_{signal}) \end{aligned}$$

$$\begin{bmatrix} e_{\lambda 1} \\ \vdots \\ e_{\lambda n} \end{bmatrix} = \begin{bmatrix} r_{\lambda 1} & r_{\lambda 1} & r_{\lambda 1} \\ \vdots & \vdots & \vdots \\ r_{\lambda n} & r_{\lambda n} & r_{\lambda n} \end{bmatrix} \begin{bmatrix} r_{light} \\ g_{light} \\ b_{light} \end{bmatrix}$$

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \mathbf{C} \begin{bmatrix} \bar{x}_{\lambda 1} & \cdots & \bar{x}_{\lambda n} \\ \bar{y}_{\lambda 1} & \cdots & \bar{y}_{\lambda n} \\ \bar{z}_{\lambda 1} & \cdots & \bar{z}_{\lambda n} \end{bmatrix} \begin{bmatrix} e_{\lambda 1} \\ \vdots \\ e_{\lambda n} \end{bmatrix} = \mathbf{O} \begin{bmatrix} e_{\lambda 1} \\ \vdots \\ e_{\lambda n} \end{bmatrix}$$

Plugging math into an ICC.1 profile

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \mathbf{C} \begin{bmatrix} \bar{x}_{\lambda 1} & \cdots & \bar{x}_{\lambda n} \\ \bar{y}_{\lambda 1} & \cdots & \bar{y}_{\lambda n} \\ \bar{z}_{\lambda 1} & \cdots & \bar{z}_{\lambda n} \end{bmatrix} \begin{bmatrix} r_{\lambda 1} & r_{\lambda 1} & r_{\lambda 1} \\ \vdots & \vdots & \vdots \\ r_{\lambda n} & r_{\lambda n} & r_{\lambda n} \end{bmatrix} \begin{bmatrix} eotf_r(r_{signal}) \\ eotf_g(g_{signal}) \\ eotf_b(b_{signal}) \end{bmatrix}$$

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} X_r & X_g & X_b \\ Y_r & Y_g & Y_b \\ Z_r & Z_g & Z_b \end{bmatrix} \begin{bmatrix} eotf_r(r_{signal}) \\ eotf_g(g_{signal}) \\ eotf_b(b_{signal}) \end{bmatrix}$$

redMatrixColumnTag
greenMatrixColumnTag
blueMatrixColumnTag

redTRCTag
greenTRCTag
blueTRCTag

ICC.1 profile tags

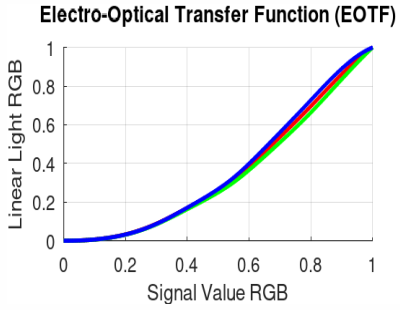
Elements of custom observer display color management

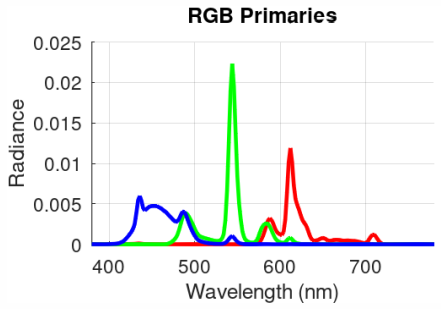
Display RGB Values

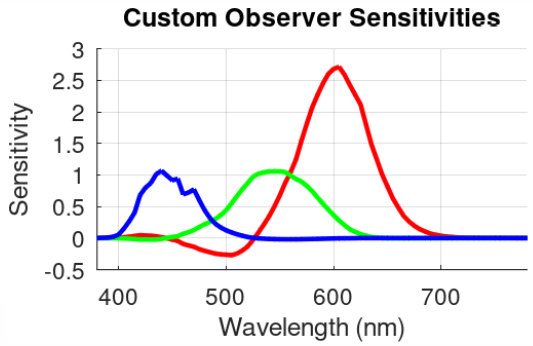
Custom Matching Values

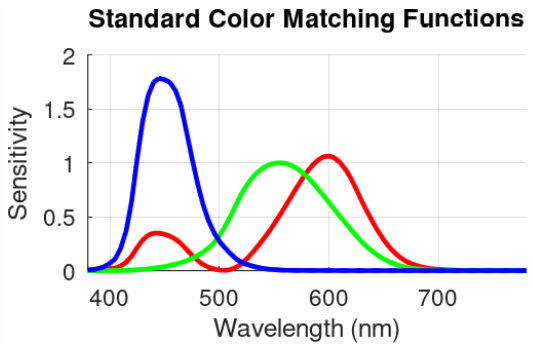
Conversion using "Magic Decoder Rings"

"Equivalent" Standard Tristimulus XYZ Values

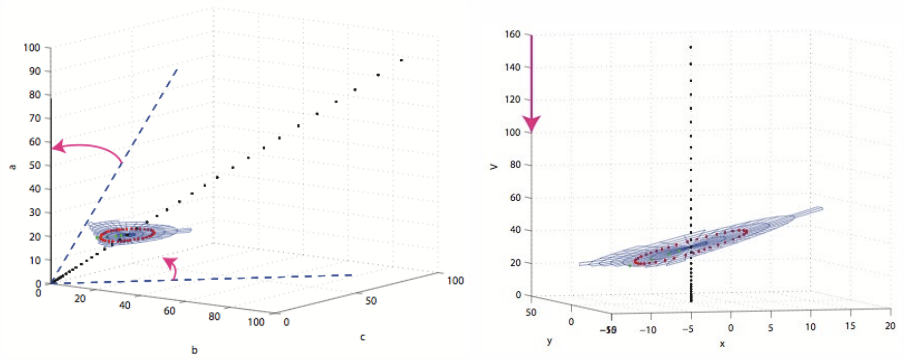




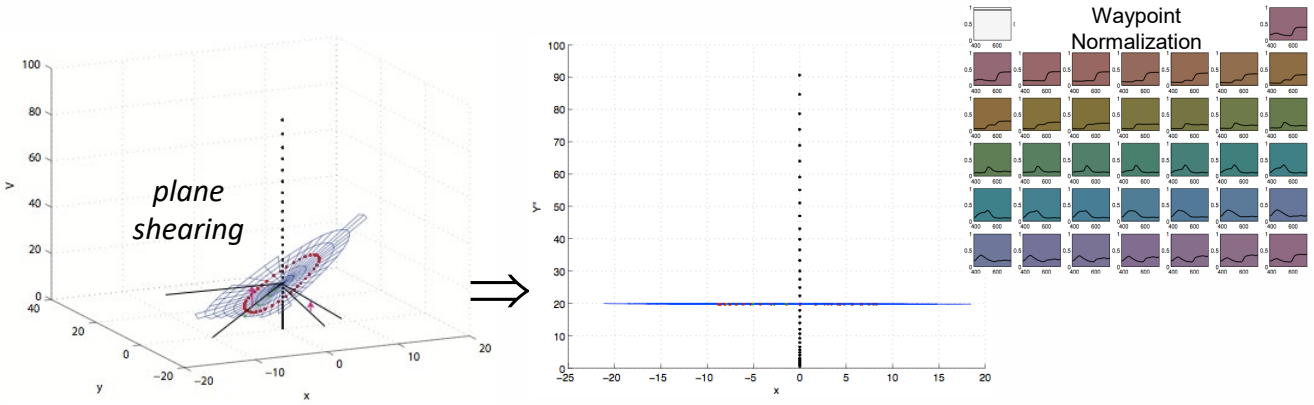




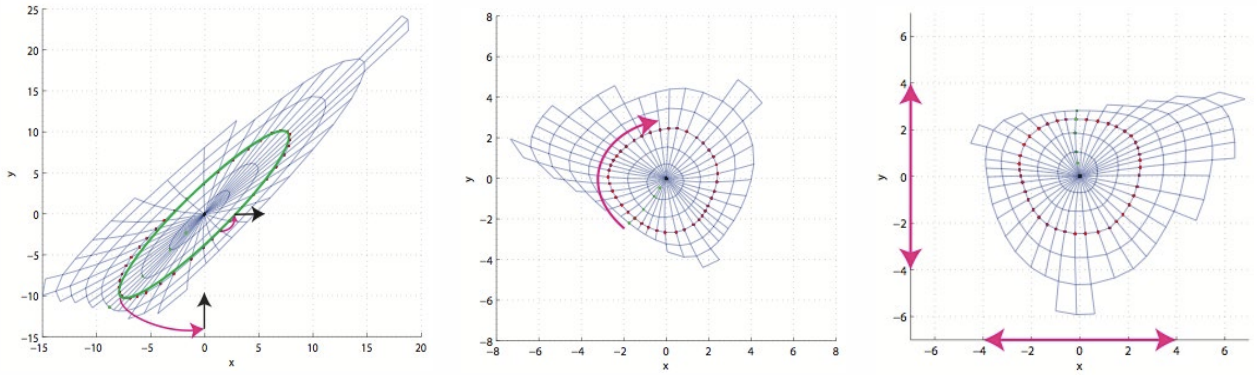
Waypoint Normalization as a “Magic Encoding Space”



White Point Normalization



Lightness Normalization



Hue and Chroma Normalization

$$\begin{bmatrix} W \\ p \\ t \end{bmatrix} = \mathbf{A}_{\mathbf{O}_{cf},ill} \begin{bmatrix} l \\ m \\ s \end{bmatrix}$$

$$\begin{bmatrix} W \\ p \\ t \end{bmatrix} = \mathbf{A}_{\mathbf{O}_{cmf},ill} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$$

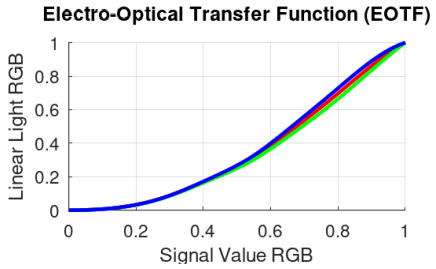
$$\mathbf{A}_{\mathbf{O},ill}\mathbf{O} = \mathbf{A}_{\mathbf{MO},ill}\mathbf{MO}$$

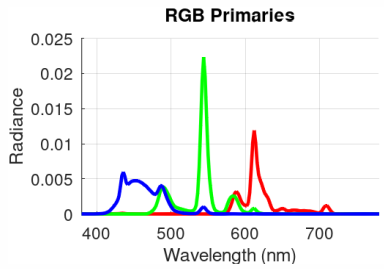
Waypoint Normalization $(norm_{Wpt})$ uses a sequence of linear transforms to adjust sensor/XYZ values to an approximately observer/illuminant invariant representation (W, p, t) concatenated into single transform matrix $\mathbf{A}_{\mathbf{O},ill} = norm_{Wpt}(\mathbf{O}, ill)$

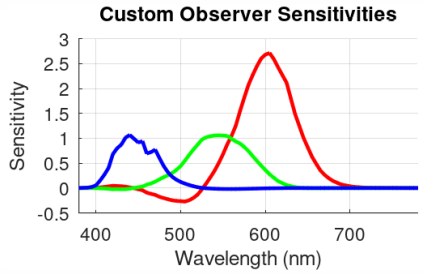
Math for custom observer display color management

$$\begin{bmatrix} r_{signal} \\ g_{signal} \\ b_{signal} \end{bmatrix}$$

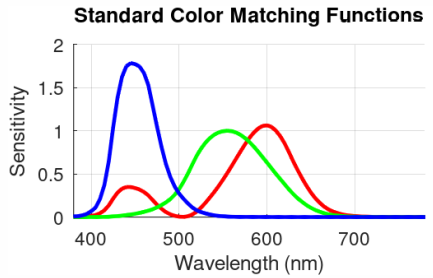
$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$$







$\mathbf{O}_{ind}$



$\mathbf{O}_{std}$

$$r_{light} = eotf_r(r_{signal})$$
$$g_{light} = eotf_g(g_{signal})$$
$$b_{light} = eotf_b(b_{signal})$$

$$\mathbf{A}_{\mathbf{O}_{ind},ill} = norm_{Wpt}(\mathbf{O}_{ind}, ill)$$

$$\mathbf{A}_{\mathbf{O}_{std},D50} = norm_{Wpt}(\mathbf{O}_{std}, D50)$$

$$\begin{bmatrix} e_{\lambda 1} \\ \vdots \\ e_{\lambda n} \end{bmatrix} = \begin{bmatrix} r_{\lambda 1} & r_{\lambda 1} & r_{\lambda 1} \\ \vdots & \vdots & \vdots \\ r_{\lambda n} & r_{\lambda n} & r_{\lambda n} \end{bmatrix} \begin{bmatrix} r_{light} \\ g_{light} \\ b_{light} \end{bmatrix}$$

$$\begin{bmatrix} l_{ind} \\ m_{ind} \\ s_{ind} \end{bmatrix} = \mathbf{O}_{ind} \begin{bmatrix} e_{\lambda 1} \\ \vdots \\ e_{\lambda n} \end{bmatrix}$$

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \mathbf{A}^{-1}_{\mathbf{O}_{std},D50} \mathbf{A}_{\mathbf{O}_{ind},ill} \begin{bmatrix} l_{obs} \\ m_{obs} \\ s_{obs} \end{bmatrix}$$

Note: The lms values for the Waypoint illuminant (ill) should match the lms values for the display white point

Plugging custom observer math into an ICC.1 profile

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \mathbf{A}_{\mathbf{O}_{std},D50}^{-1}\mathbf{A}_{\mathbf{O}_{ind},ill}\mathbf{O}_{ind}\begin{bmatrix} r_{\lambda 1} & r_{\lambda 1} & r_{\lambda 1} \\ \vdots & \vdots & \vdots \\ r_{\lambda n} & r_{\lambda n} & r_{\lambda n} \end{bmatrix}\begin{bmatrix} eotf_r\left(r_{signal}\right) \\ eotf_g\left(g_{signal}\right) \\ eotf_b\left(b_{signal}\right) \end{bmatrix}$$

Note: The concatenation of these tree terms can be determined as a single psychophysical experiment

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} X_r & X_g & X_b \\ Y_r & Y_g & Y_b \\ Z_r & Z_g & Z_b \end{bmatrix}\begin{bmatrix} eotf_r\left(r_{signal}\right) \\ eotf_g\left(g_{signal}\right) \\ eotf_b\left(b_{signal}\right) \end{bmatrix}$$

$\mathbf{A}_{\mathbf{O}_{std},D50}^{-1}\mathbf{A}_{\mathbf{O}_{ind},ill}$

chromaticAdaptationTag

redMatrixColumnTag
greenMatrixColumnTag
blueMatrixColumnTag

redTRCTag
greenTRCTag
blueTRCTag

ICC.1 profile tags

Plugging custom observer math into ICC.2 profiles (Part 1)

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \mathbf{A}^{-1}_{\mathbf{O}_{std},D50}\mathbf{A}_{\mathbf{O}_{ind},ill}\mathbf{O}_{ind} \begin{bmatrix} r_{\lambda 1} & r_{\lambda 1} & r_{\lambda 1} \\ \vdots & \vdots & \vdots \\ r_{\lambda n} & r_{\lambda n} & r_{\lambda n} \end{bmatrix} \begin{bmatrix} eotf_r\left(r_{signal}\right) \\ eotf_g\left(g_{signal}\right) \\ eotf_b\left(b_{signal}\right) \end{bmatrix}$$

customToStandardPccTag

spectralViewingConditionsTag

emissionMatrixElement

curveSetElement

AToB1Tag of type multiProcessElementType

Observer PCC Profile

Display Profile

Note: For performance purposes the observer and display primary matrices are concatenated into a 3x3 matrix before applying the color transform

Plugging custom observer math into ICC.2 profiles (Part 2)

$$\begin{bmatrix} r_{signal} \\ g_{signal} \\ b_{signal} \end{bmatrix} = \begin{bmatrix} eotf_r^{-1}(r_{light}) \\ eotf_g^{-1}(g_{light}) \\ eotf_b^{-1}(b_{light}) \end{bmatrix}, \qquad \begin{bmatrix} r_{light} \\ g_{light} \\ b_{light} \end{bmatrix} = \left(\mathbf{O}_{ind} \begin{bmatrix} r_{\lambda 1} & r_{\lambda 1} & r_{\lambda 1} \\ \vdots & \vdots & \vdots \\ r_{\lambda n} & r_{\lambda n} & r_{\lambda n} \end{bmatrix} \right)^{-1} \mathbf{A}_{\mathbf{O}_{ind},ill}^{-1} \, \mathbf{A}_{\mathbf{O}_{std},D50} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$$

curveSetElement

inverseEmissionMatrixElement

standardToCustomPccTag

spectralViewingConditionsTag

BToA1Tag of type multiProcessElementType

Display Profile

Observer PCC Profile

Note: For performance purposes the observer and display primary matrices are concatenated and inverted as a 3x3 matrix before applying the color transform

Combining ICC.1 and ICC.2 into a single display profile

```
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<IccProfile>
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 <Tags>
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  <copyrightTag> <multiLocalizedUnicodeType>

  <mediaWhitePointTag> <XYZArrayType>

  <redColorantTag> <XYZArrayType>
  <greenColorantTag> <XYZArrayType>
  <blueColorantTag> <XYZArrayType>

  <redTRCTag> <curveType>
  <greenTRCTag> <curveType>
  <blueTRCTag> <curveType>

  <chromaticAdaptationTag> <s15Fixed16ArrayType>

  <embeddedV5ProfileTag> <embeddedProfileType> <IccProfile>
    <Header>
    <Tags>
      <profileDescriptionTag> <multiLocalizedUnicodeType>

      <AToB1Tag> <multiProcessElementType>
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          <CurveSetElement InputChannels="3" OutputChannels="3">
          <EmissionMatrixElement InputChannels="3" OutputChannels="3">
        </MultiProcessElements>
      </multiProcessElementType> </AToB1Tag>

      <BToA1Tag> <multiProcessElementType>
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          <CurveSetElement InputChannels="3" OutputChannels="3">
        </MultiProcessElements>
      </multiProcessElementType> </BToA1Tag>

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      <mediaWhitePointTag> <XYZType>

    </Tags>
  </IccProfile> </embeddedProfileType> </embeddedV5ProfileTag>

 </Tags>
</IccProfile>
```
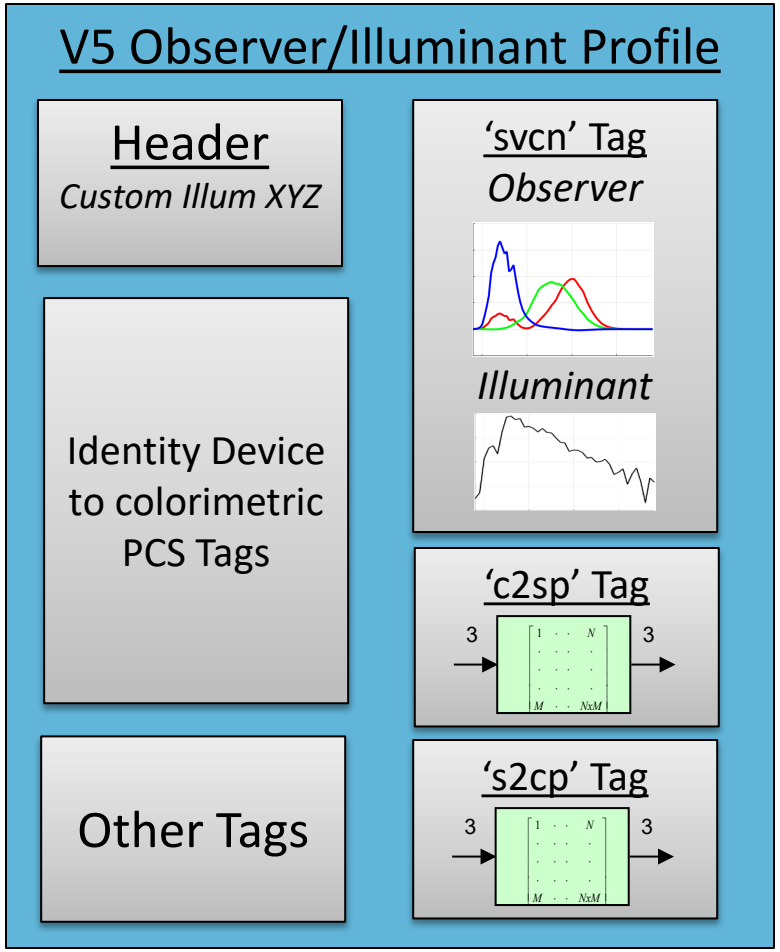

ICC.2 Profile Connection Condition (PCC) Tags

- **Profile Connection Condition Tags**
  - These tags provide additional information needed for conversions between spectral and colorimetric color representations
- **The spectralViewingConditions (svcn) tag**
  - Provides a spectral representation of the illuminant (light source) and color matching functions (CMF) for the observer
- **The customToStandardPcc (c2sp) tag**
  - Provides a transform from custom observer/illuminant colorimetry to colorimtry for the standard 1931 2-degree observer under D50 lighting
- **The standardToCustomPcc (s2cp) tag**
  - Provides a transform from colorimetry for the standard 1931 2-degree observer under D50 lighting to custom observer/illuminant colorimetry

- **These tags are required whenever spectral or custom colorimetry is used by a profile**
- **Sometimes PCC information from other profiles can be substituted to allow for alternate observer/illuminant color management**



Creating observer specific ICC.1 display profiles

- **The iccV5DspObsToV4Dsp command line tool from the DemoIccMAX project can be used to create an ICC.1 display profile from an ICC.2 (or embedded ICC.2 profile) and corresponding observer PCC profile**
- **This allows observer specific display color management to be utilized by legacy systems that don't support ICC.2 display profiles**

Thank You!

Questions?