CIE TC 1-81: Validity of Formulae for Predicting Small Colour Differences

Year Established: 2010

Terms of reference:

1. To evaluate available formulae for small colour differences (<~2.0 CIELAB).
2. To define a visual threshold colour difference

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In the following some fundamental problems are described.

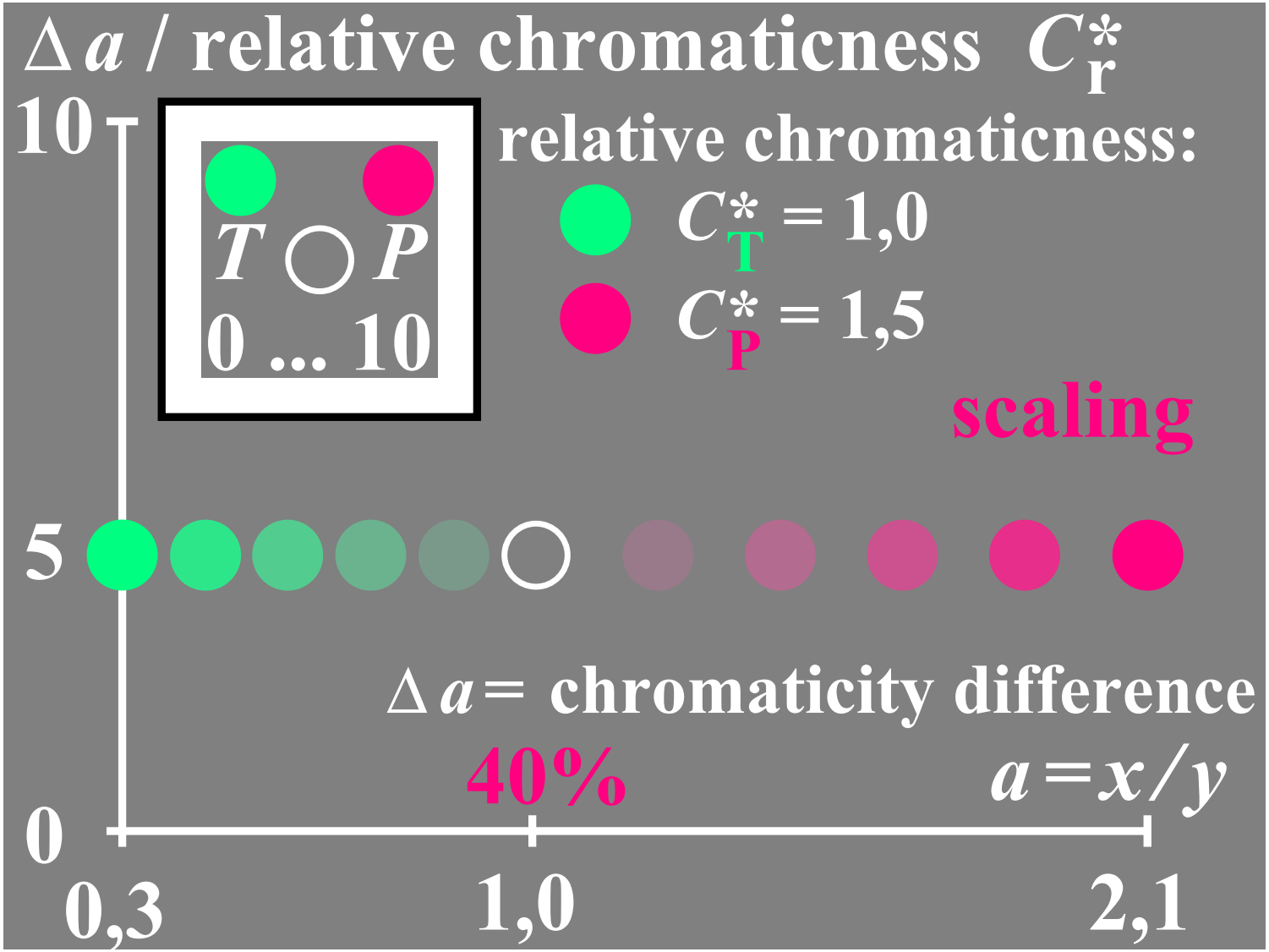

Fig. 1: Scaling of chroma between Grey (Z) and Red (P) or Green (T)
Result: The CIE chromaticity difference $\Delta a = x / y$ is constant.

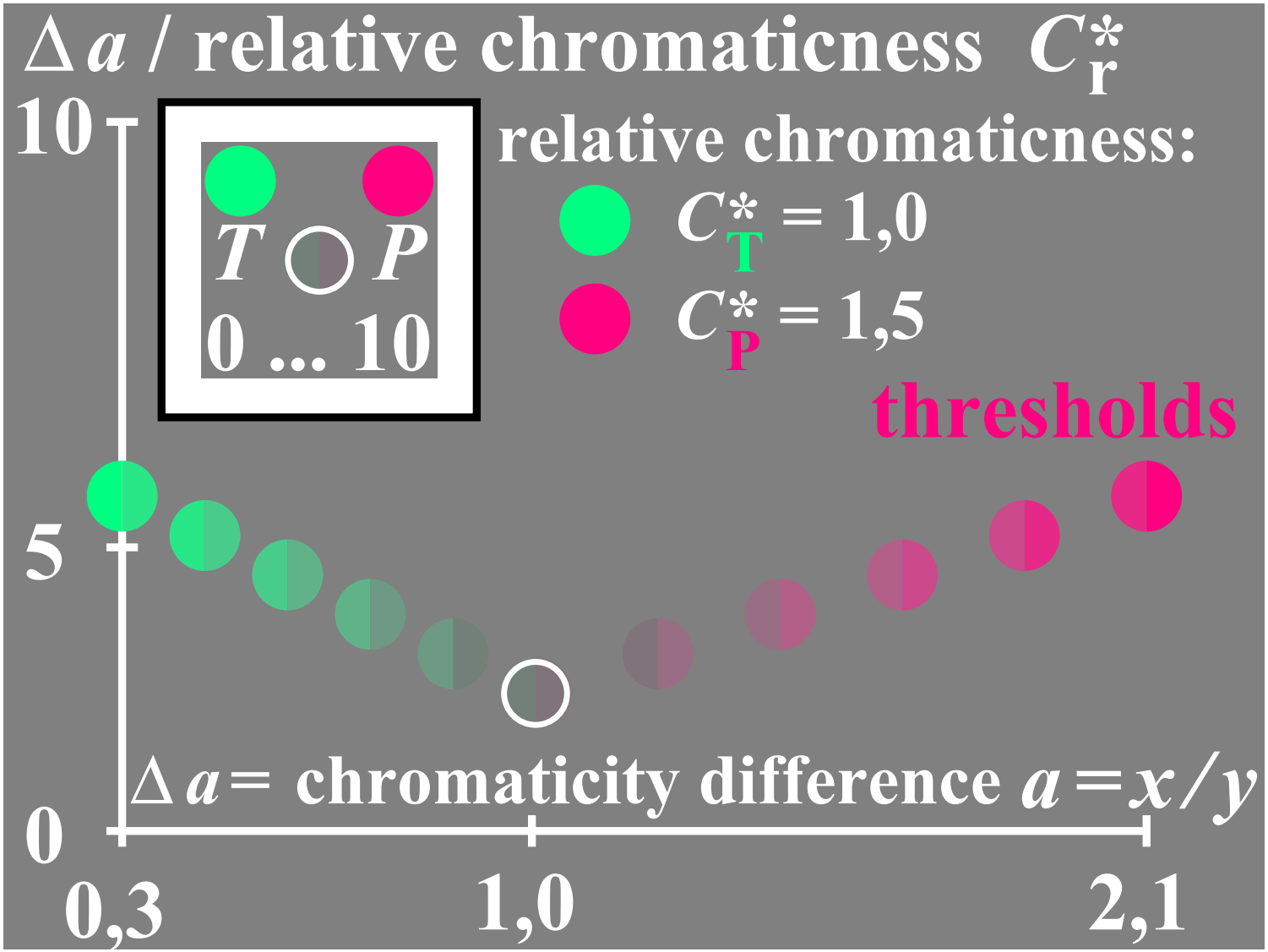

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Fig. 2: Colour thresholds of chroma between Red (P) and Green (T)
Result: The chromaticity difference $\Delta a = x / y$ increases with chroma

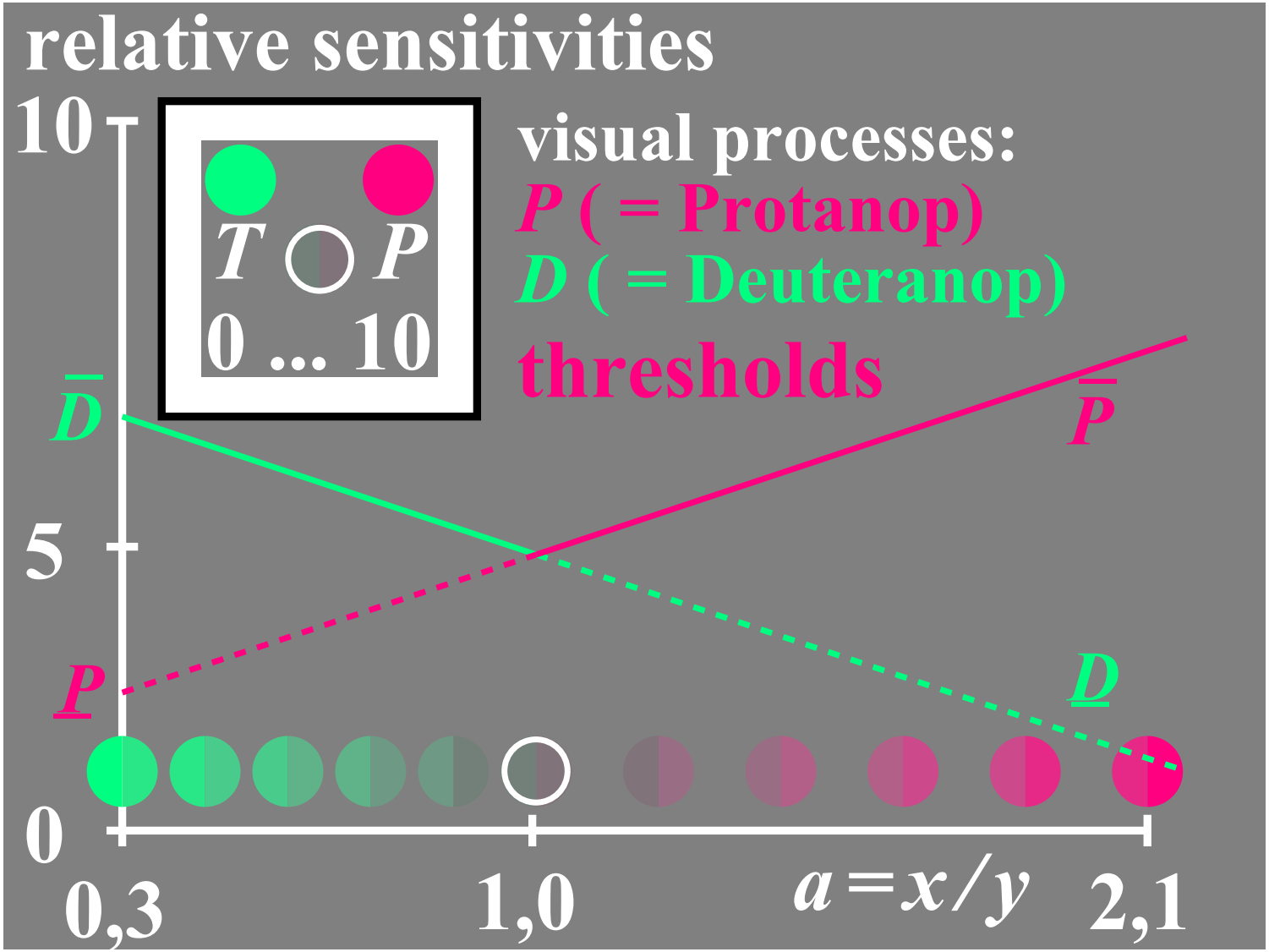

Fig. 3: Relative sensitivity of two physiological processes *P* and *D*
Assumption: The more sensitive may determine the threshold.

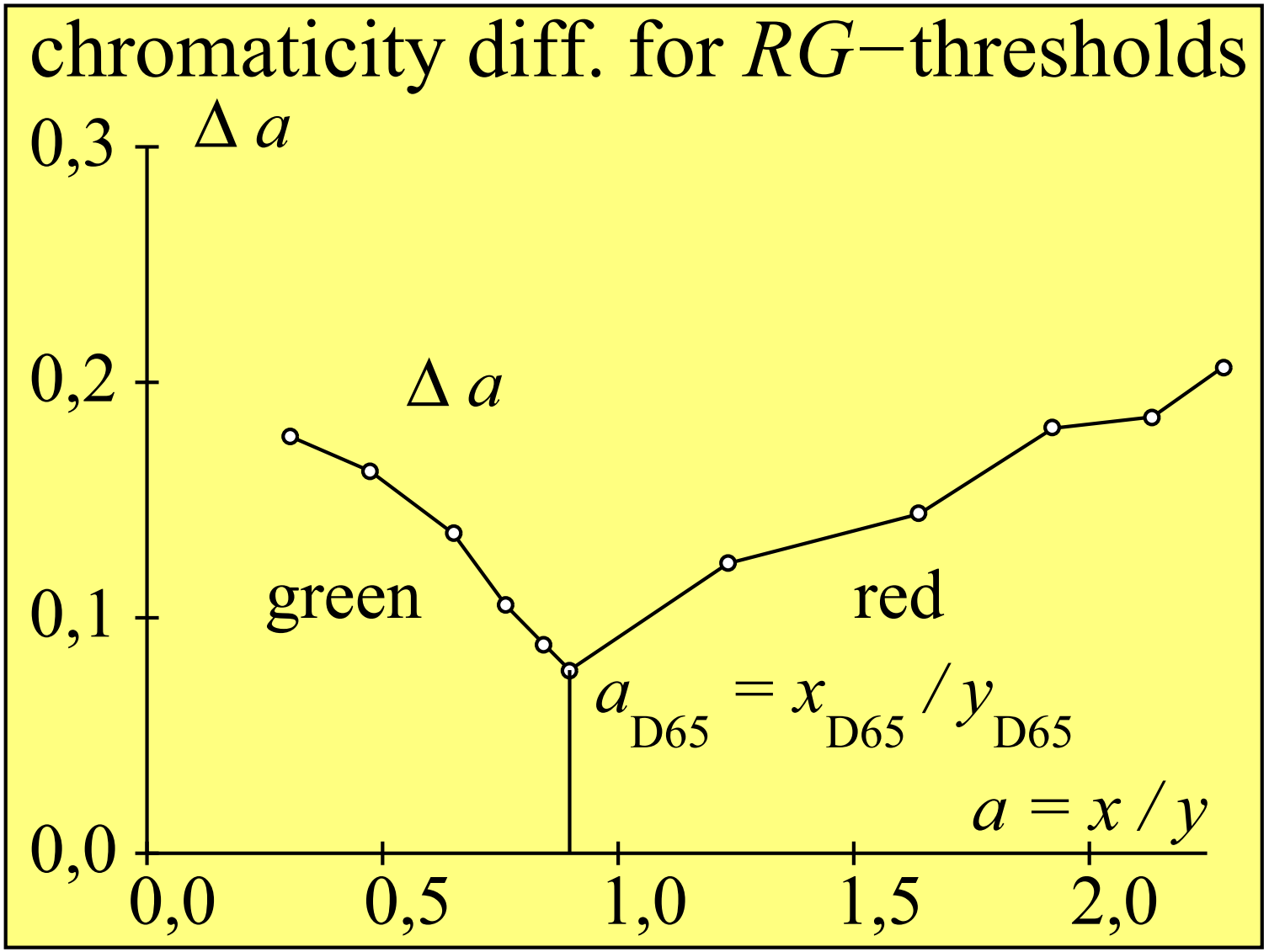

Fig. 4: Experimental chromaticity difference $\Delta a = x / y$ at threshold

The slope is about 0,5 for red and green, use $a'' = a_n + (a - a_n)/[1 + 0{,}5 |a - a_n|]$

color threshold formula LABJNDS 1985 (JND=just noticeable difference)

$$\Delta E^{*}_{\mathrm{JND}} = Y_0 \left[(\Delta Y)^2 + (a_0 \, \Delta a'' \cdot Y)^2 + (b_0 \, \Delta b'' \cdot Y)^2 \right]^{1/2} / \ (s + d \, Y^{\mathrm{e}})$$

$$a = x / y \qquad a_{\mathrm{n}} = x_{\mathrm{n}} / y_{\mathrm{n}} \qquad b = -\,0{,}4\, z / y \qquad b_{\mathrm{n}} = -\,0{,}4\, z_{\mathrm{n}} / y_{\mathrm{n}}$$

$$a'' = a_{\mathrm{n}} + (a - a_{\mathrm{n}}) / (1 + 0{,}5 \ | a - a_{\mathrm{n}} | \ )$$

$$b'' = b_{\mathrm{n}} + (b - b_{\mathrm{n}}) / (1 + 0{,}5 \ | b - b_{\mathrm{n}} | \ )$$

n = D65 or A (surround)

$$Y = (Y_1 + Y_2) / 2 \qquad \Delta Y = Y_1 - Y_2 \qquad \Delta a'' = a''_1 - a''_2 \qquad \Delta b'' = b''_1 - b''_2$$

$$s = 0{,}0170 \qquad d = 0{,}0058 \qquad e = 1{,}0$$

$a_0 = 1{,}0 \quad b_0 = 1{,}8 \quad Y_0 = 1{,}5$ *surround D65*

$a_0 = 1{,}0 \quad b_0 = 1{,}7 \quad Y_0 = 1{,}0$ *surround A*

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Fig. 5: Colour threshold formula of Richter (1985)
Best results according to *Kittelmann* (2010) for optimized a_0, b_0.

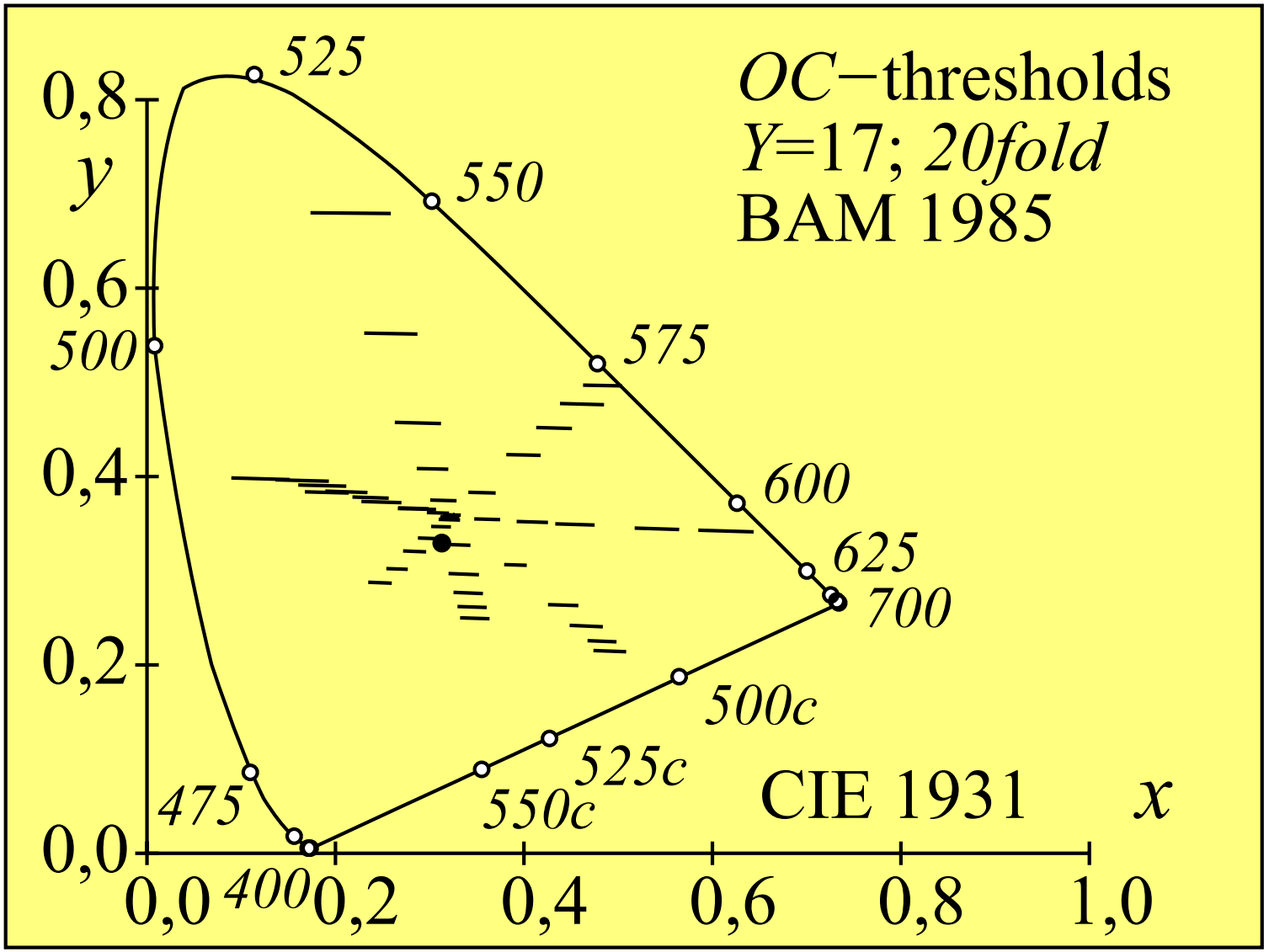

Fig. 6: Thresholds (20fold) in Red-Green direction for *Y*=17
The red-green differences $\Delta a = a_1 - a_2$ increase with chroma.

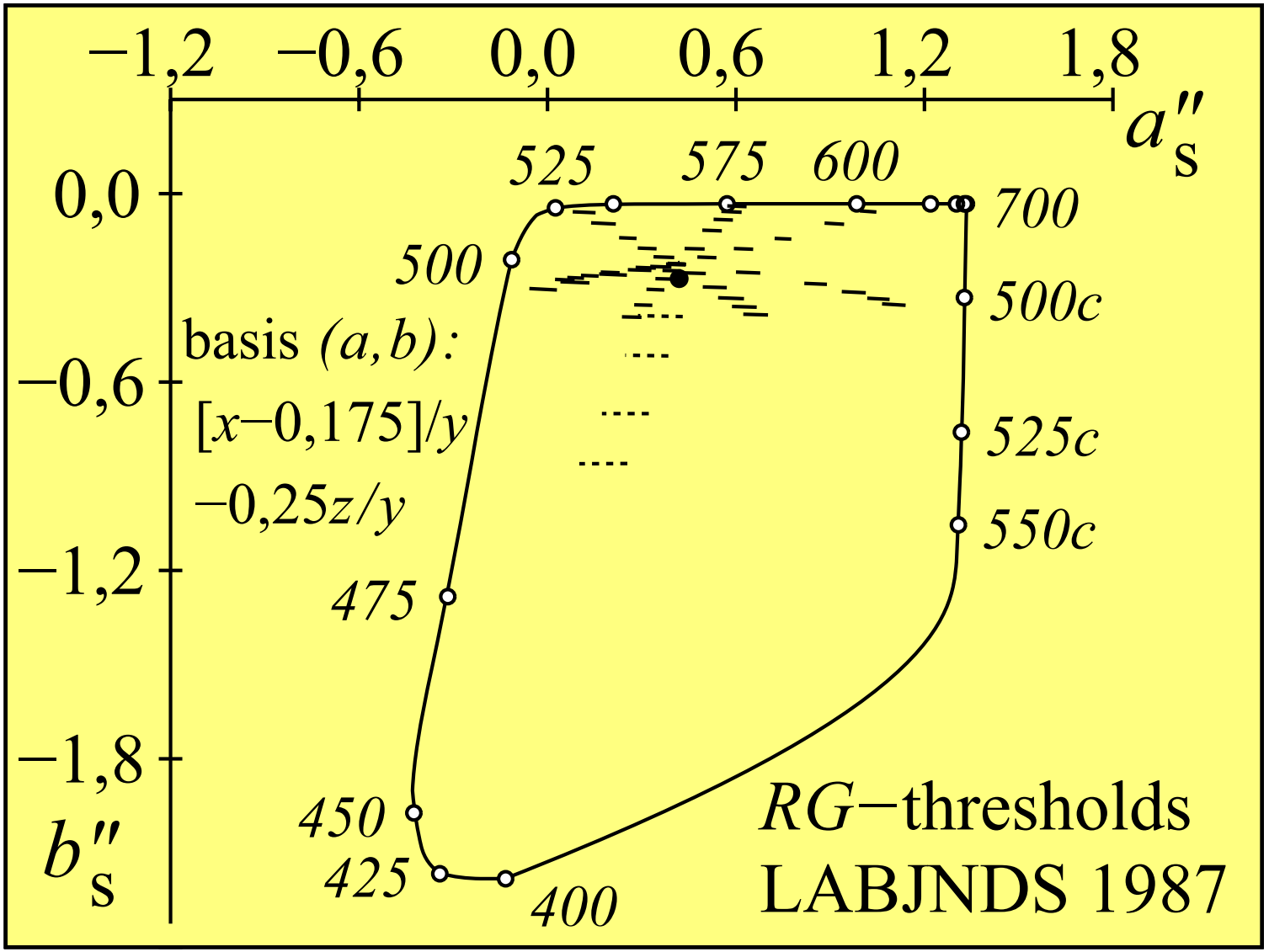

Fig. 7: Δ*a*" for colour thresholds with formula similar to Fig. 5

Result: The threshold formula (Fig. 4) is efficient for red-green

It is not possible to discuss here more properties of the threshold formula of Fig. 5, for example in Yellow-Blue and White-Black direction.

Remark: The slope in Yellow direction is smaller compared to 0.5. The slope in Blue direction is larger compared to 0.5. For simplicity this has not be included in the formula of Fig. 5.

For more information see Klaus Richter "Computergrafik und Farbmetrik - Colour Order Systems, PostScript and device independent CIE-Colours (in German)" with 500 colour pictures, VDE-Verlag with CD-ROM, 1999, ISBN 3-8007-1775-1, 288 pages, 2,6 MB, Format A5, see the URL http://130.149.60.45/~farbmetrik/BUA4BF.PDF