

# Color Analysis and Microfade Testing of the 1918 Curtiss Jenny U.S. Airmail Stamp

Presented by: Thomas Lam

Thomas Lam, Susan Smith,  
Scott Devine and Edward P. Vicenzi

Fifth International Symposium on Analytical Methods in Philately  
The Institute of Analytical Philately

October 17<sup>th</sup>, 2023



Smithsonian  
*National Postal Museum*



Smithsonian  
*Museum Conservation Institute*



Smithsonian National Postal Museum (NPM)  
Washington, DC



Smithsonian Museum Conservation Institute (MCI)  
Suitland, MD



# Gems exhibit in the William H. Gross Stamp Gallery



# The Inverted Jenny



NPM 0.217665.1



Stamp: 2 cm by 2.5 cm

In 1918, the Bureau of Engraving and Printing (BEP) issued the first bi-colored stamp for airmail, a special delivery postage stamp known as the Curtiss Jenny.

It is most famous for the printing error resulting in the Inverted Jenny, arguably the most iconic of American stamps. Its popularity and rarity make its protection particularly important.

Although we know that exposure to light can pose a risk to papers and inks, much remains unknown.

Smithsonian National Postal Museum (NPM) provided us an opportunity to do research on a non-inverted Jenny and access to the 1918 proofs within the NPM collection.

# Outline

1. Stamps and Proofs Studied  
Color Analysis by Foster and Freeman Video Spectral Comparator (VSC8000/HS)
2. Color Difference:  $\Delta E_{2000}$
3. Color Simulation
4. Color Analysis of the Paper, Blue, and Red
5. Microfade Testing (MFT) and MFT Interpretation
6. Light Exposure Calculation
7. Conclusion and Future Work



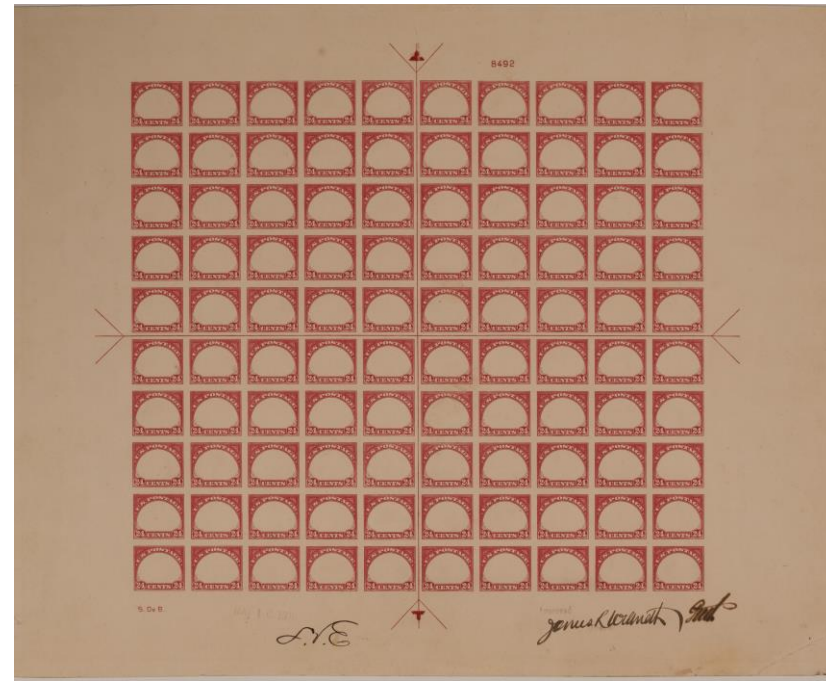
# 1918 Jenny Stamps in this Study



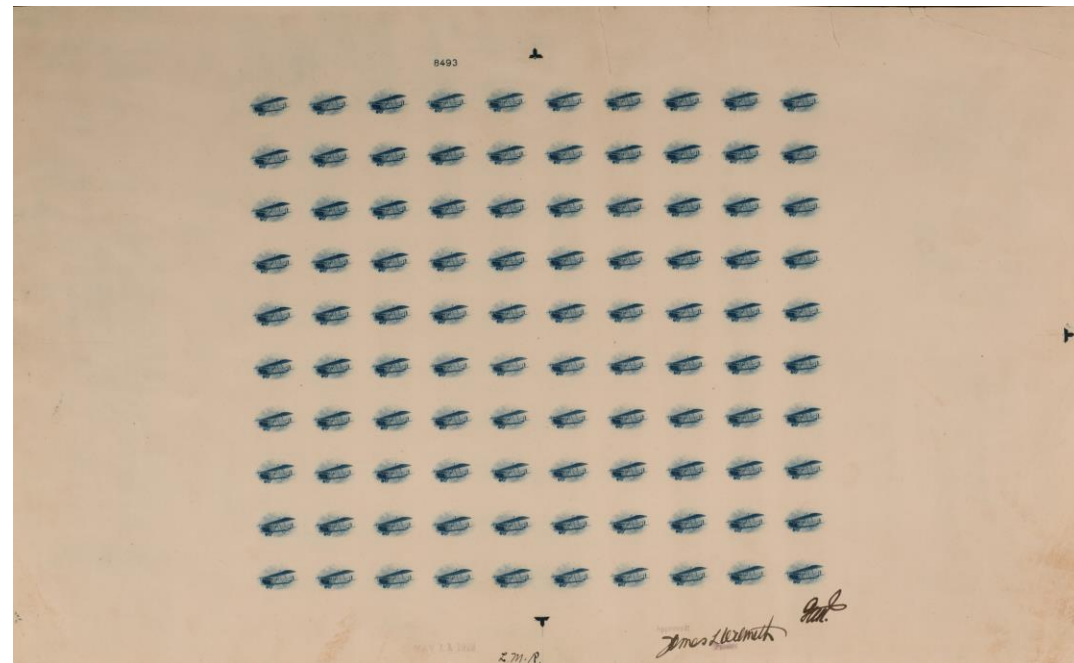
Magnetic frame made by Scott Devine



# Curtiss Jenny Plate Proofs

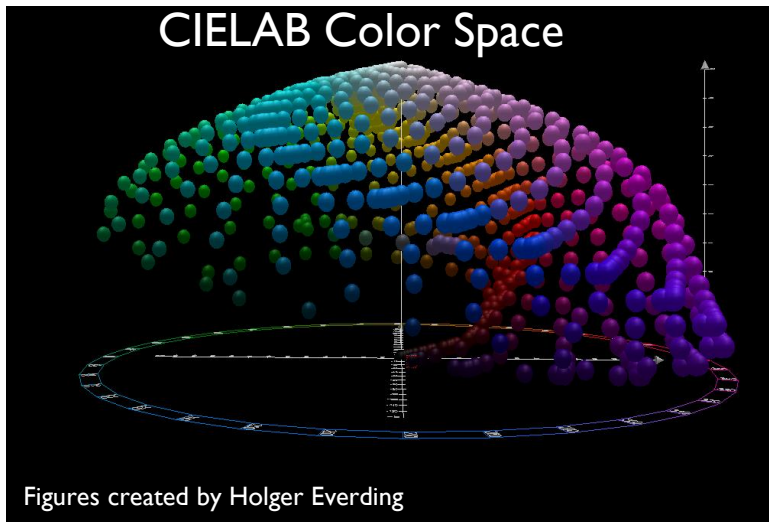
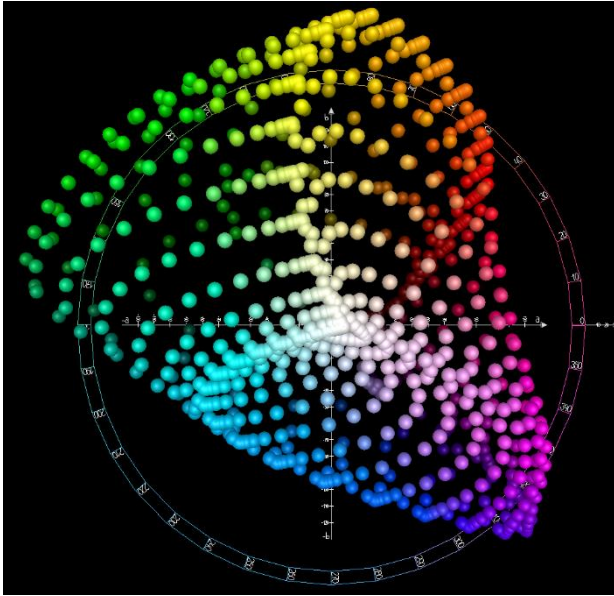


0.242263.15824



0.242263.15825

# Color Difference: $\Delta E_{00}$



Figures created by Holger Everding

$$\Delta E_{ab}^* = \sqrt{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}}$$

$$\Delta E_{00}^* = \left[ \frac{\Delta L'}{k_L S_L} \right]^2 + \left[ \frac{\Delta C'}{k_C S_C} \right]^2 + \left[ \frac{\Delta H'}{k_H S_H} \right]^2 + \left[ \frac{\Delta C'}{k_C S_C} \frac{\Delta H'}{k_H S_H} \right]^2$$

Lightness Correction

Chroma Correction

Hue Correction

Hue Dependent Rotation Function

Neutral Correction

\*Excel calculation sheet by Olivia Kuzio can be available upon request (please email [LamT@SI.edu](mailto:LamT@SI.edu)). We just ask that should you use the excel sheet please provide a citation to credit her:

Kuzio, O. (2018) Excel Sheet to Calculate DE2000 from CIE L\*, a\*, b\*.



# Revealing the Rainbow: An Introduction to the Science of Color

Thursday, October 12th, 4:00 PM ET. Online on Zoom.

[Register here](#)

Please join us as **Olivia R. Kuzio**, Professional Fellow at the Getty Conservation Institute, introduces the science of color.

Color is what we see...but it is also more than meets the eye. Color is an effect on the visual system and in the brain. Color is physically imparted on materials by colorants. Color is also a specific kind of light. Color is a manifestation, a response, and a perception. Color is simultaneously simple ("Bananas are yellow.") and complicated ("This paint looks different on my wall than it did at Home Depot."). Ultimately, color is central to the character and essence of the world we navigate every day.

In this world, where color can mean many things, this talk will consider how color is created, and introduce the ways in which this web of phenomena affects the description, categorization, measurement, and comparison of color.

**About Olivia R. Kuzio**

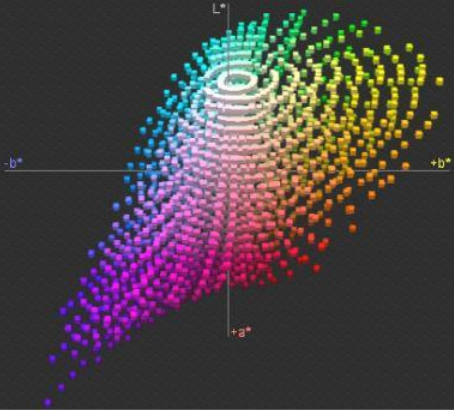


- Learn
- For Researchers
- Finding Guides
- Library
- Forensic Laboratory
- Maynard Sundman Lecture Series
- Symposia and Lectures
  - Blount Postal History Symposia
  - Delivered Under Fire: Absalom Markland and Freedom's Mail
  - Revealing the Rainbow: An Introduction to the Science of Color**

Olivia Kuzio's talk was recorded and should be uploaded to NPM YouTube channel by next calendar year

# Color Simulation using easyrgb.com

EASYRGB



EASYRGB provides a unique search engine to professionally handle color data and commercial colors references.

Check our **SOFTWARE** and the rich collection of information, tips, math and code examples, to find practical solutions to your color requirements.

Use Icon to Expand



### Find similar colors in different collections

Search through our database for similar colors in different collections. Find color alternatives across different suppliers, products or the best offer from your local paint dealer.

HELP TRY IT NOW



### Match color data to commercial colors

Match your RGBs and color data to color cards, paint lines, inks, fandecks, color standards and more... Transform computer colors in "real world" products and references.

HELP TRY IT NOW

### Create harmonies, themes and complements

From your RGBs and color data create colors complements, harmonies and themes. It can be used to easily define a Web site color theme or to select good trim and accent colors for your home decoration.

HELP TRY IT NOW



# Color Simulation using easyrgb.com

The screenshot displays the homepage of easyrgb.com. At the top left, the logo "EASYRGB" is visible. The main content area features a large 3D visualization of a color space (likely CIE L\*a\*b\*) with axes labeled L\*, a\*, and b\*. To the right of this visualization, text describes the site's purpose: "EASYRGB provides a unique search engine to professionally handle color data and commercial colors references." Below this, it encourages users to check out the "SOFTWARE" section for tips, math, and code examples.

On the right side, a dark navigation menu is open, listing various features and services. A white arrow points to the "Convert color data" option. The menu items are:

- Home
- Find similar colors
- Match color data
- Create complements
- Convert color data
- Software
- Math
- F.A.Q.
- Contact us
- IroGroup

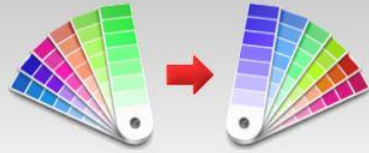
The main content area below the header is divided into three sections, each with a title, description, and "TRY IT NOW" button:

- Find similar colors in different collections:** Search through our database for similar colors in different collections. Find color alternatives across different suppliers, products or the best offer from your local paint dealer.
- Match color data to commercial colors:** Match your RGBs and color data to color cards, paint lines, inks, fan decks, color standards and more... Transform computer colors in "real world" products and references.
- Create harmonies, themes and complements:** From your RGBs and color data create colors complements, harmonies and themes. It can be used to easily define a Web site color theme or to select good trim and accent colors for your home decoration.



# Color Simulation using easyrgb.com

EASYRGB



Find similar colors



Match color data



Create complements



## Convert color data into different standards and color spaces

Use the form below to convert color data across different color standards and color spaces (RGB, CMYK, L\*a\*b, L\*ch, L\*uv, Hunter, XYZ etc.). Looking for color math or specific conversion formulas? Check our [math page](#) for some practical examples.

If you are not sure how to start, check our practical step-by-step [instructions](#).

Select data type ...

sRGB 0-255

Insert color data ...

R ( 0 ÷ 255 )

G

B

Or pick from saved ...

CONVERT

RESET

Drop down,  
Choose CIE L\*a\*b

Site  
Home  
Software  
Terms  
Privacy

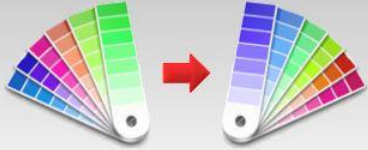
Tools  
Compare  
Match  
Create  
Convert

Support  
Contacts  
Math  
F.A.Q.  
Add colors

Help  
Compare  
Match  
Create  
Convert

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# Color Simulation using easyrgb.com



Find similar colors



Match color data



Create complements



## Convert color data into different standards and color spaces

Use the form below to convert color data across different color standards and color spaces (RGB, CMYK, L\*ab, L\*ch, L\*uv, Hunter, XYZ etc.). Looking for color math or specific conversion formulas? Check our [math page](#) for some practical examples.

If you are not sure how to start, check our practical step-by-step [instructions](#).

Select data type ...

CIE-L\*ab

D65 (daylight)

2° (1931)

Insert color data ...

L\*

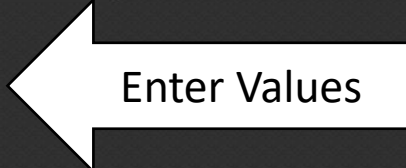
a\*

b\*

Or pick from saved ...

CONVERT

RESET



Site

- Home
- Software
- Terms
- Privacy

Tools

- Compare
- Match
- Create
- Convert

Support

- Contacts
- Math
- F.A.Q.
- Add colors

Help

- Compare
- Match
- Create
- Convert



# Color Simulation using easyrgb.com

← → ↻ easyrgb.com/en/convert.php#inputFORM

EASYRGB

Insert color data ...

Or pick from saved ...

CONVERT

MATCH

sRGB 0-255 = 162.450 -29.333 -4.273  
sRGB 0-1.0 = 0.63706 -0.11503 -0.01675  
RGB Adobe 98 = 137.586 0.000 0.000

HSL 0-1.0 = 0.97822 1.44071 0.26101  
HSV 0-1.0 = 0.97822 1.18057 0.63706  
HSI 0-1.0 = 0.97822 1.68299 0.16842

CMY 0-1.0 = 0.36294 1.11503 1.01675  
CMYK 0-1.0 = 0.00000 1.18057 1.02630  
CMYK 0-100 = 0.000 118.057 102.630

XYZ = 14.652 7.085 0.473  
Yxy = 7.085 0.65969 0.31900

CIE-L\*ab = 32.000 61.200 48.400  
CIE-L\*Ch(ab) = 32.000 78.026 38.339°  
CIE-L\*uv = 32.000 116.973 21.983  
CIE-L\*Ch(uv) = 32.000 119.021 10.644°

HunterLab = 26.618 53.942 16.749

CSS, HTML = #A20000

Java = new Color( 162,

.NET = Color.FromArgb

Objective-C = [UIColor colorWithRed:0.63706 green:0.00000 blue:0.00000 alpha:1.00000];

OpenGL = glColor3f( 0.63706f,

Swift = UIColor(red:0.63706,

Xojo = rgb( 162, 0, 0 )

CIE-L\*ab (D65/2°) = 32 61.2 48.4

sRGB 0-255 = 162.450 -29.333 -4.273 D65/2°  
sRGB 0-1.0 = 0.63706 -0.11503 -0.01675  
RGB Adobe 98 = 137.586 0.000 0.000

HSL 0-1.0 = 0.97822 1.44071 0.26101 352.16°  
HSV 0-1.0 = 0.97822 1.18057 0.63706  
HSI 0-1.0 = 0.97822 1.68299 0.16842

CMY 0-1.0 = 0.36294 1.11503 1.01675  
CMYK 0-1.0 = 0.00000 1.18057 1.02630 0.36294  
CMYK 0-100 = 0.000 118.057 102.630 36.294

XYZ = 14.652 7.085 0.473 D65/2°  
Yxy = 7.085 0.65969 0.31900

CIE-L\*ab = 32.000 61.200 48.400  
CIE-L\*Ch(ab) = 32.000 78.026 38.339°  
CIE-L\*uv = 32.000 116.973 21.983  
CIE-L\*Ch(uv) = 32.000 119.021 10.644°

HunterLab = 26.618 53.942 16.749

Pre-formatted code:

CSS, HTML = #A20000

Java = new Color( 162, 0, 0 )

.NET = Color.FromArgb( 255, 162, 0, 0 );

Objective-C = [UIColor colorWithRed:0.63706 green:0.00000 blue:0.00000 alpha:1.00000];

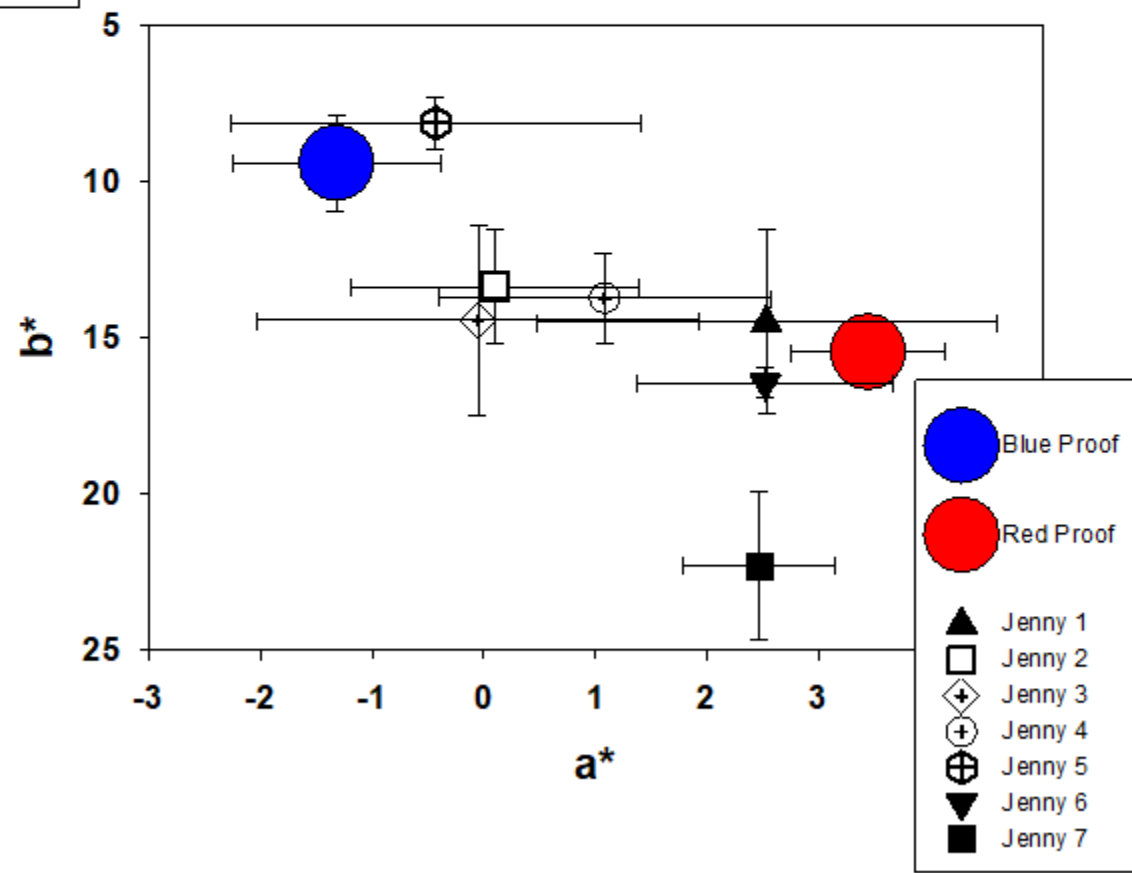
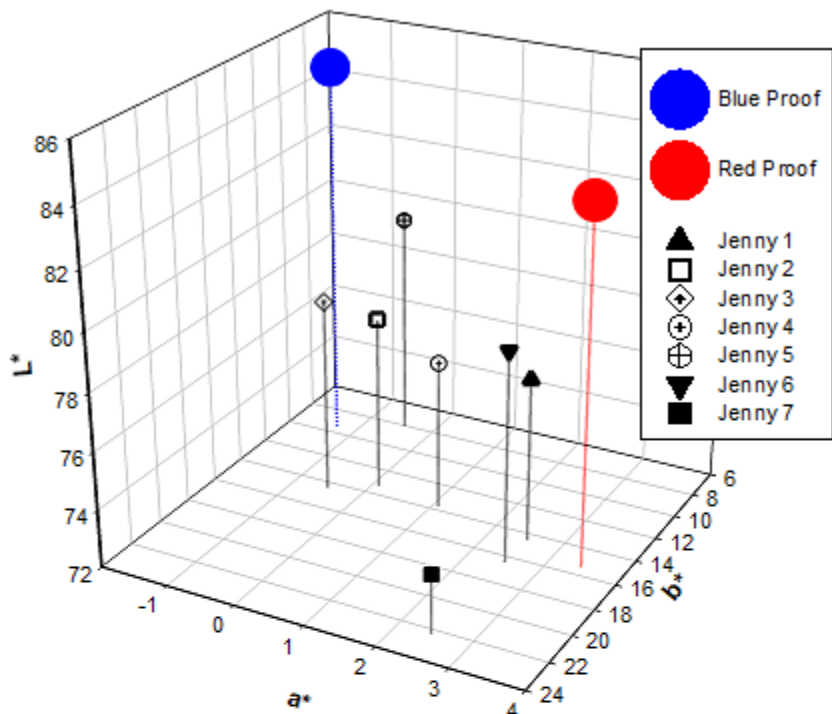
OpenGL = glColor3f( 0.63706f, 0.00000f, 0.00000f );

Swift = UIColor(red:0.63706, green:0.00000, blue:0.00000, alpha:1.00000)

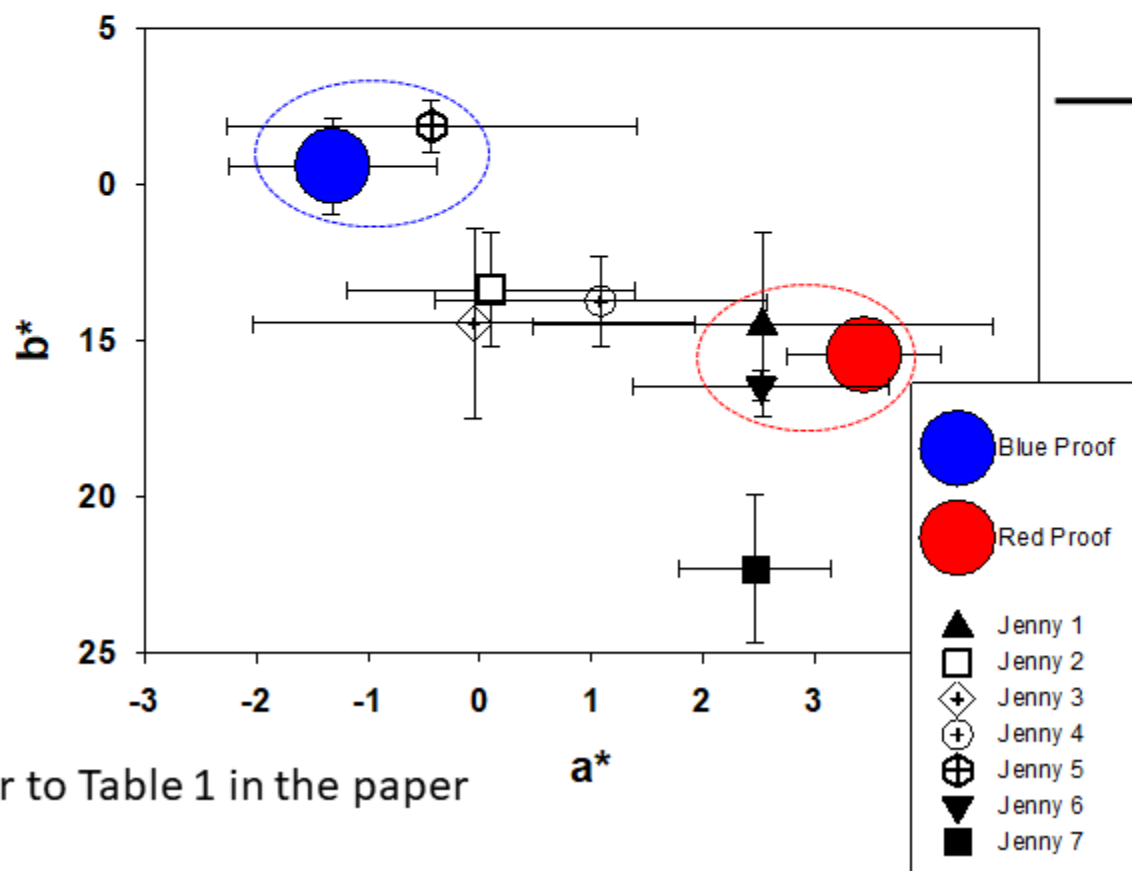
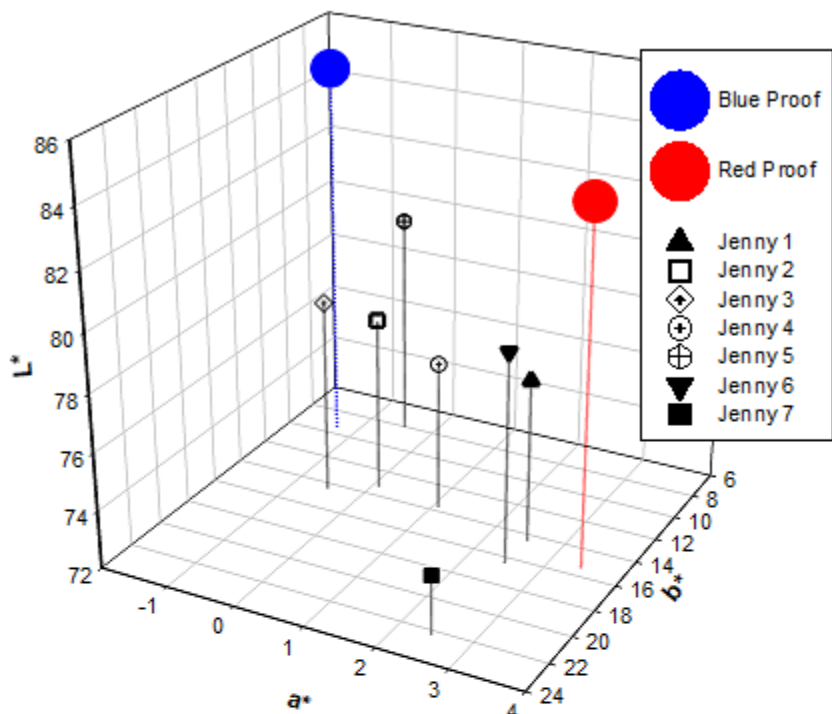
Xojo = rgb( 162, 0, 0 )



# Analysis of the Paper



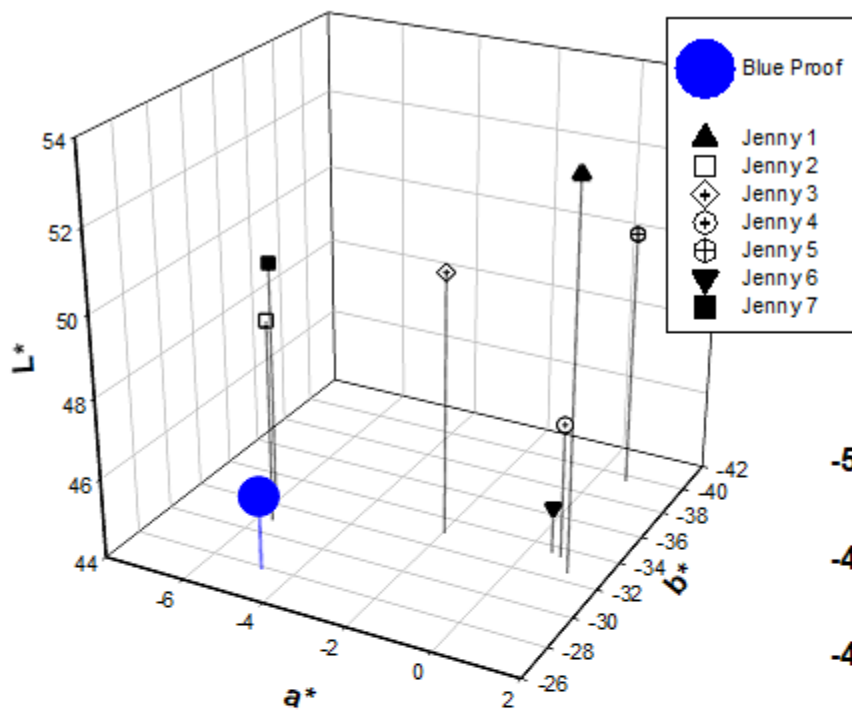
# Analysis of the Paper



		Simulated Color
Blue Proof		
Red Proof		
Jenny 1		
Jenny 2		
Jenny 3		
Jenny 4		
Jenny 5		
Jenny 6		
Jenny 7		

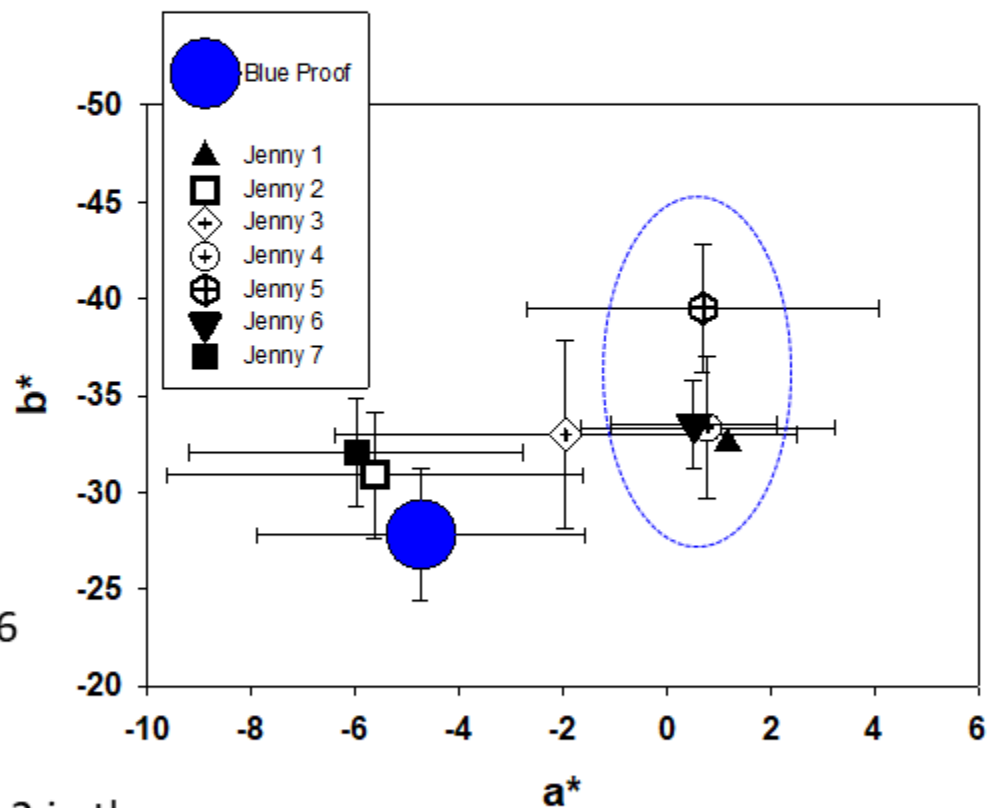
For further  $L^*$ ,  $a^*$ , and  $b^*$  details refer to Table 1 in the paper

# Analysis of the Blue Ink



ANOVA, Holm-Sidak

Jenny 1, Jenny 4, Jenny 5, and Jenny 6  
are statistically different

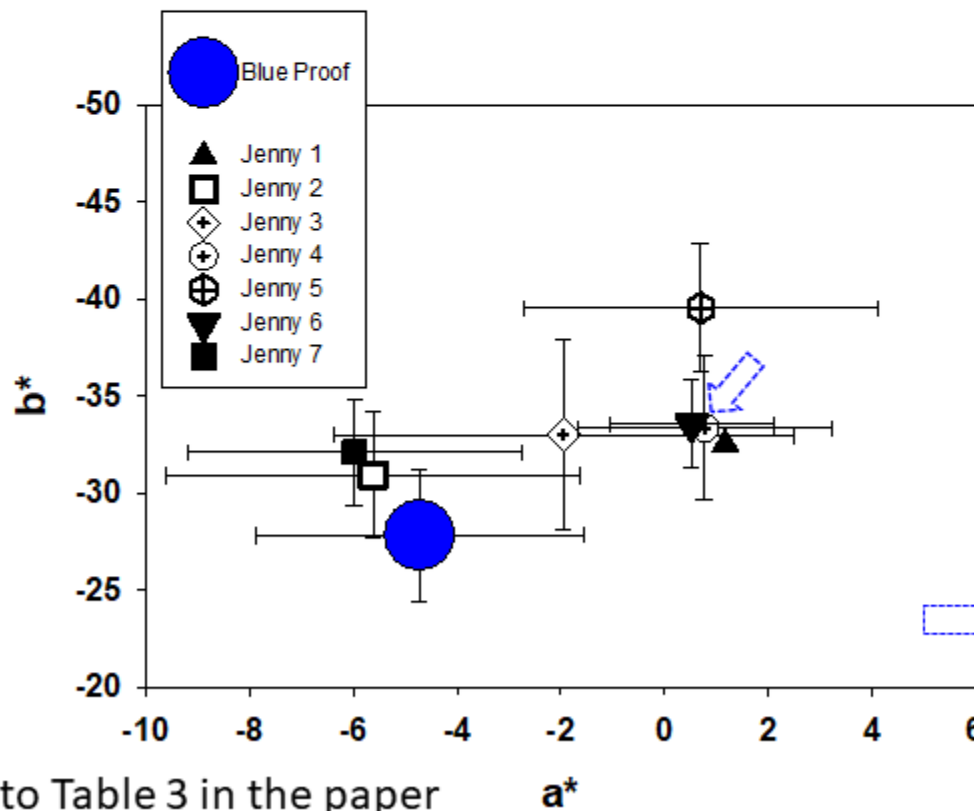
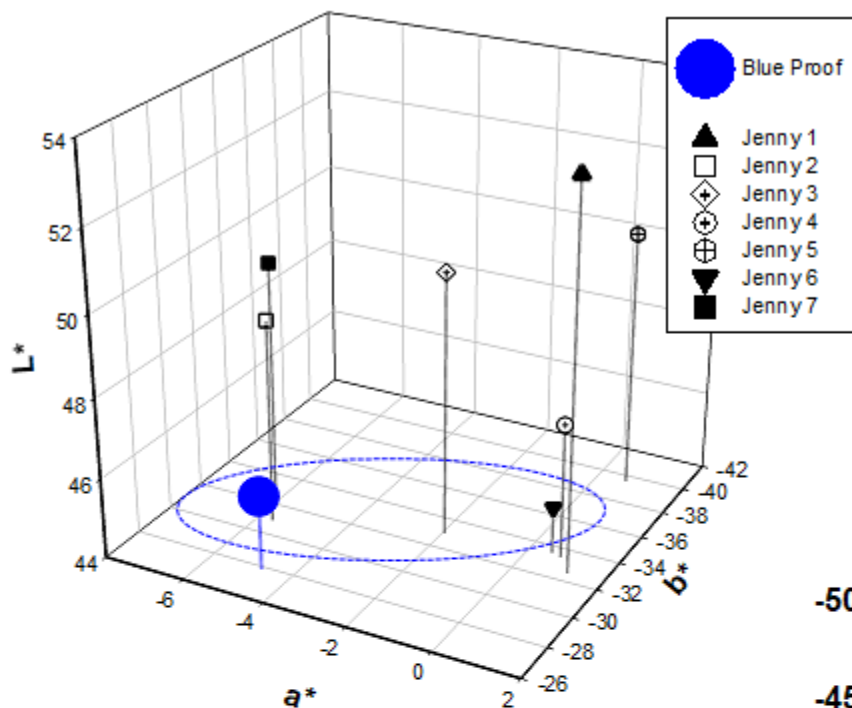


















For ANOVA, Holm-Sidak refer to Table 2 in the paper

For further  $L^*$ ,  $a^*$ ,  $b^*$ ,  $\sigma$  details refer to Table 1 in the paper



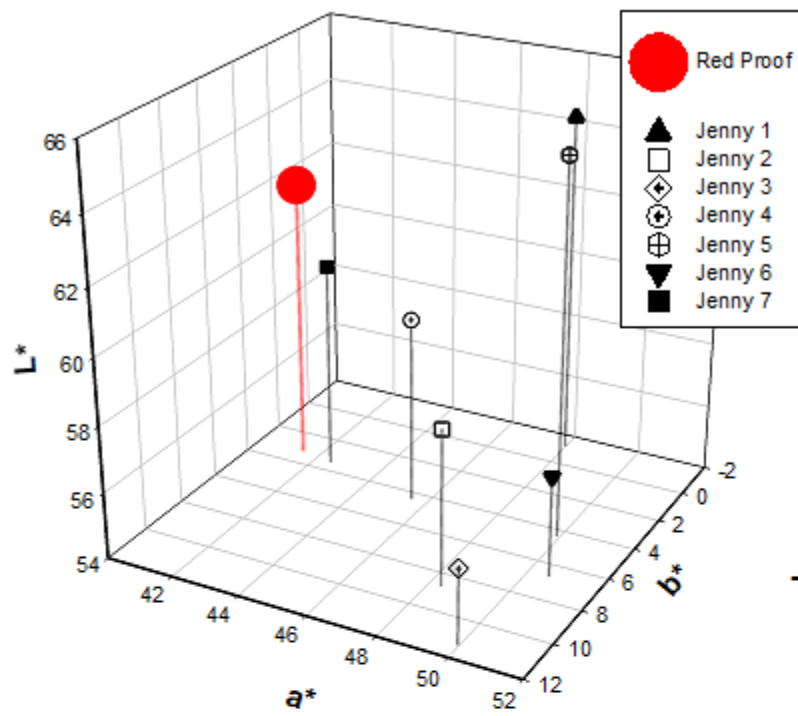
# Analysis of the Blue



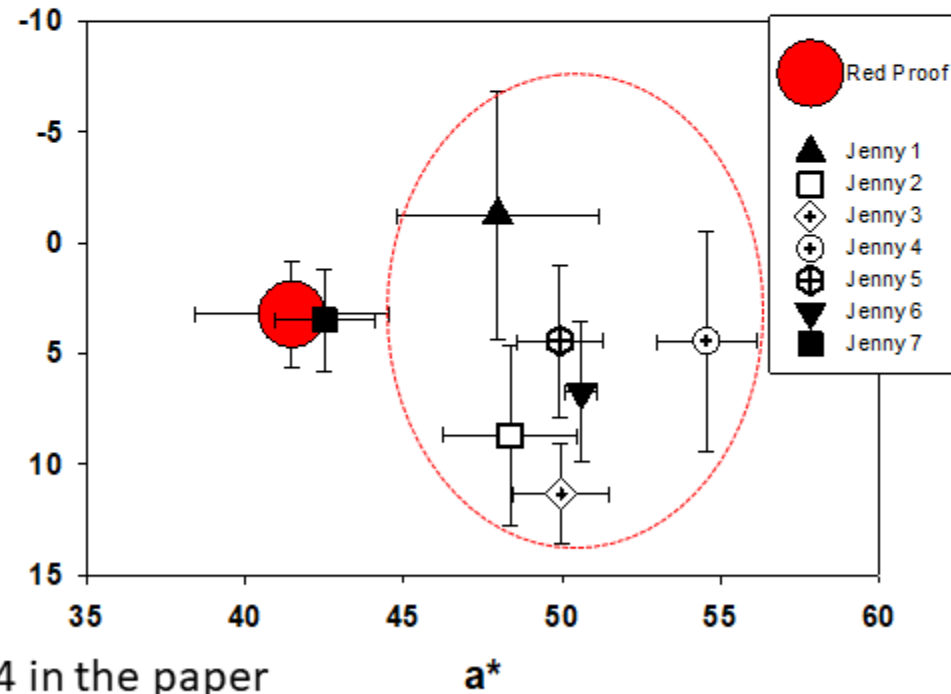
		$\Delta E_{00}^*$	Simulated Color
Blue Proof		NA	
Jenny 1		7.98	
Jenny 2		4.69	
Jenny 3		5.56	
Jenny 4		4.84	
Jenny 5		5.78	
Jenny 6		3.76	
Jenny 7		5.04	

For further  $L^*$ ,  $a^*$ ,  $b^*$ ,  $\sigma$  details refer to Table 3 in the paper

# Analysis of the Red Ink

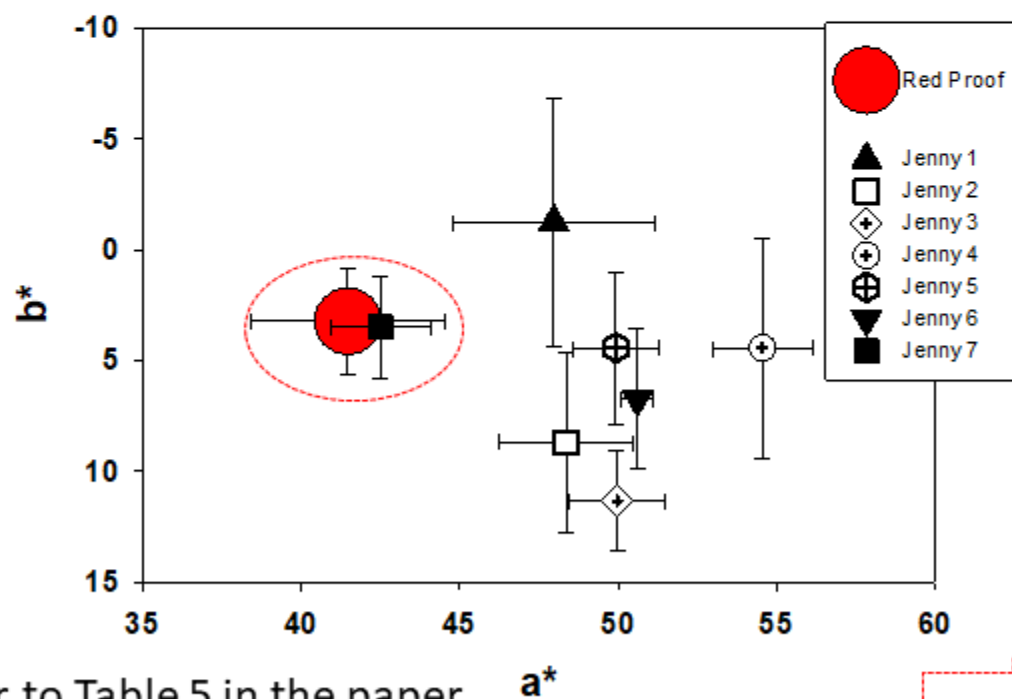
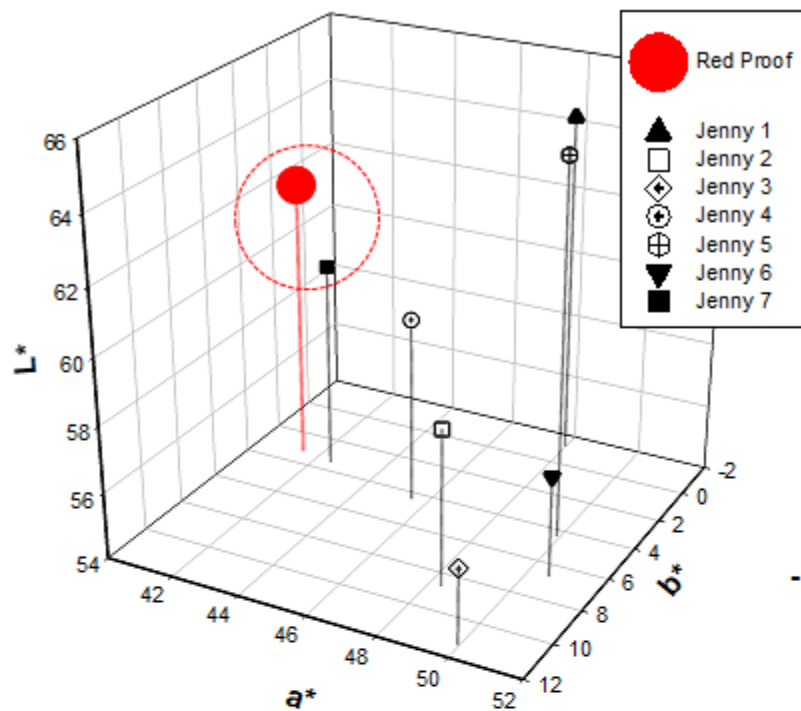


















ANOVA, Holm-Sidak  
 Jenny 1- 6  
 are statistically different



For ANOVA, Holm-Sidak refer to Table 4 in the paper  
 For further  $L^*$ ,  $a^*$ ,  $b^*$ ,  $\sigma$  details refer to Table 5 in the paper

# Analysis of the Red



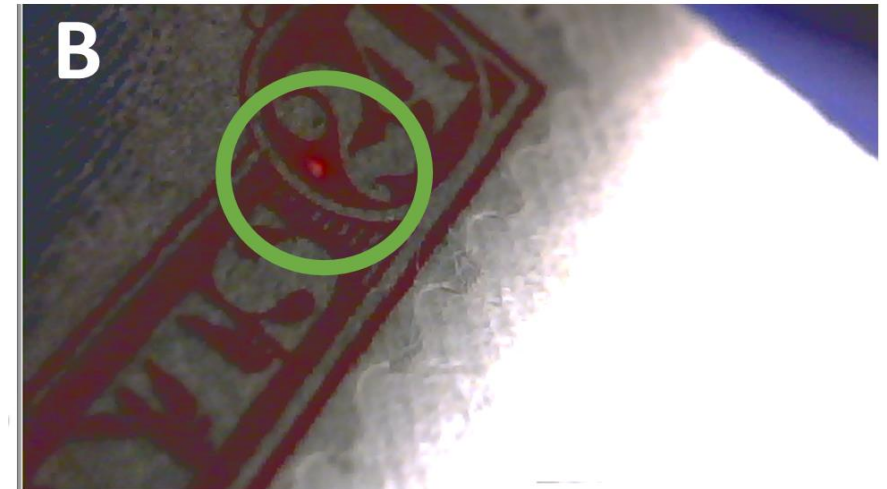
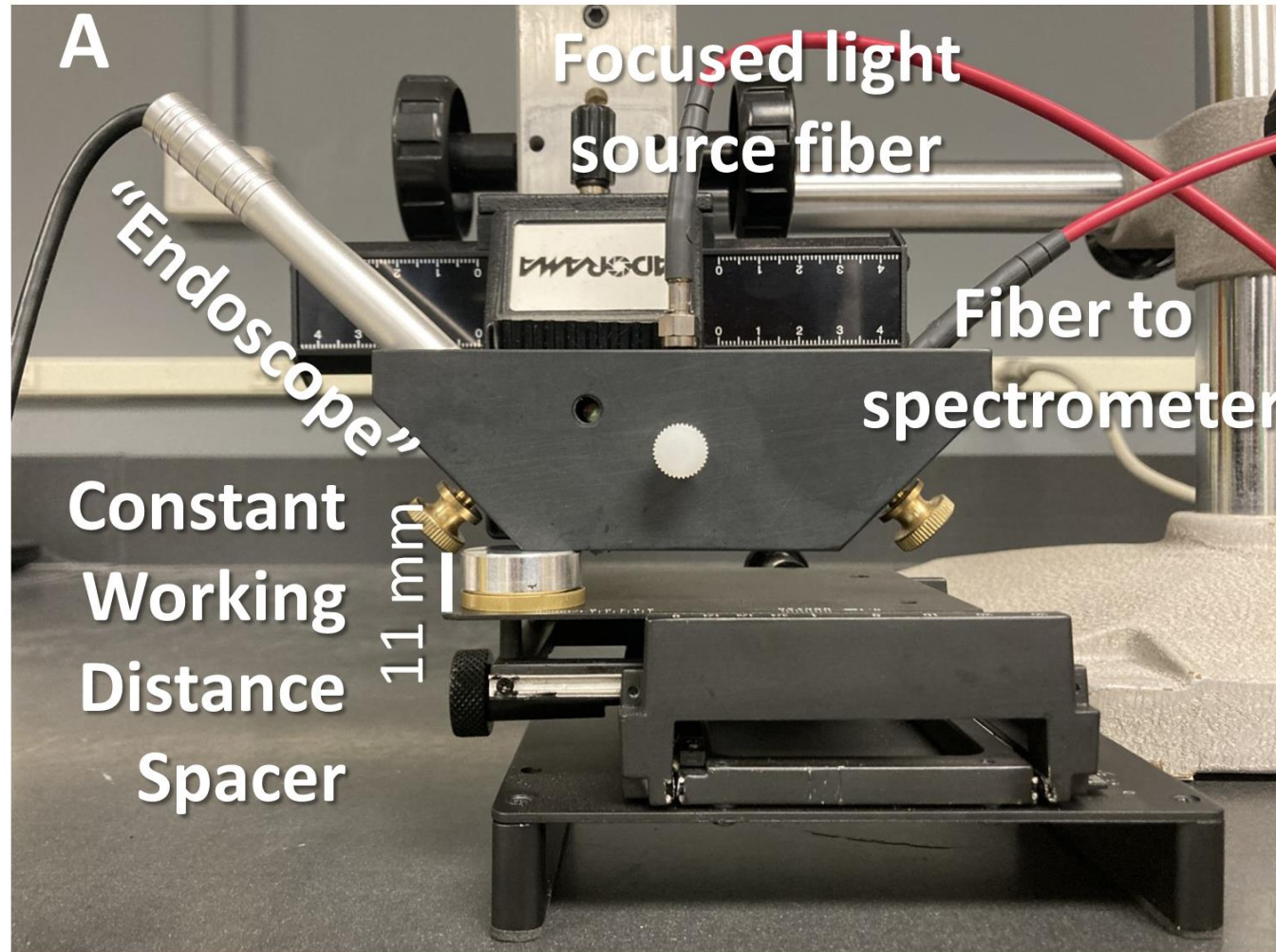
		$\Delta E_{00}^*$	Simulated Color
Red Proof		NA	
Jenny 1		5.49	
Jenny 2		5.39	
Jenny 3		7.40	
Jenny 4		5.61	
Jenny 5		4.19	
Jenny 6		6.03	
Jenny 7		3.48	

For further  $L^*$ ,  $a^*$ ,  $b^*$ ,  $\sigma$  details refer to Table 5 in the paper



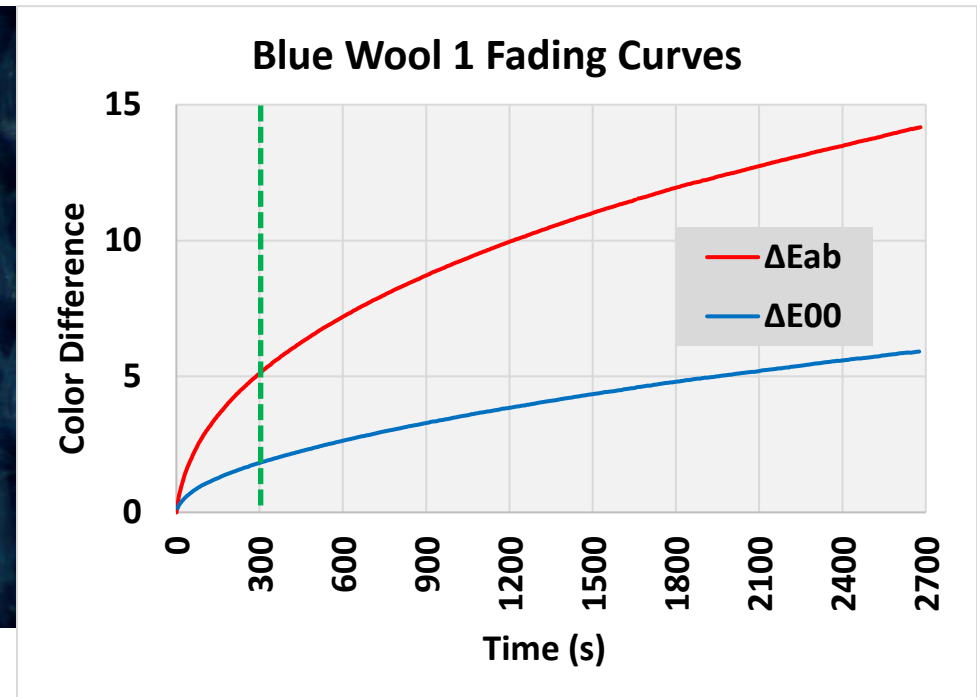
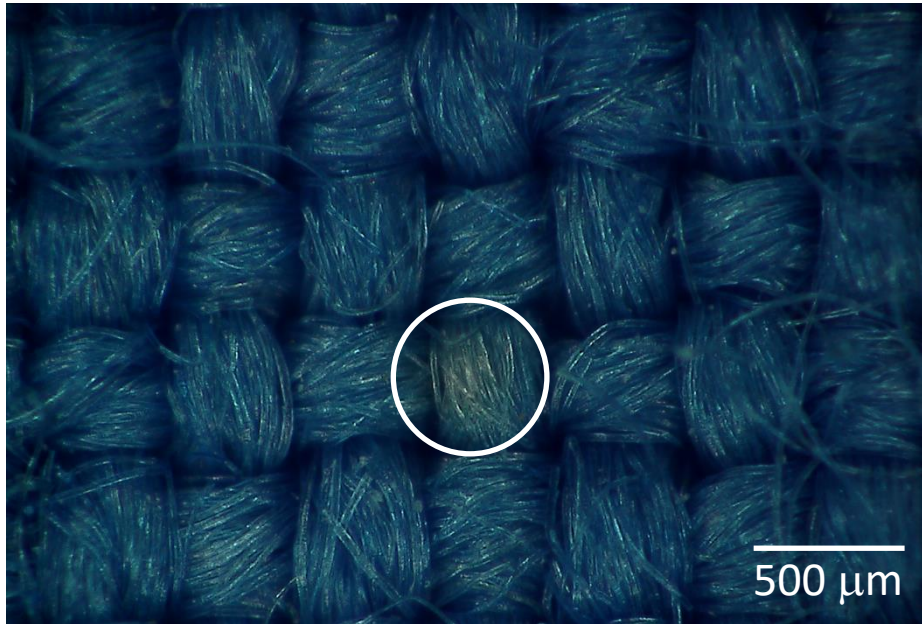


# Microfade Testing (MFT)

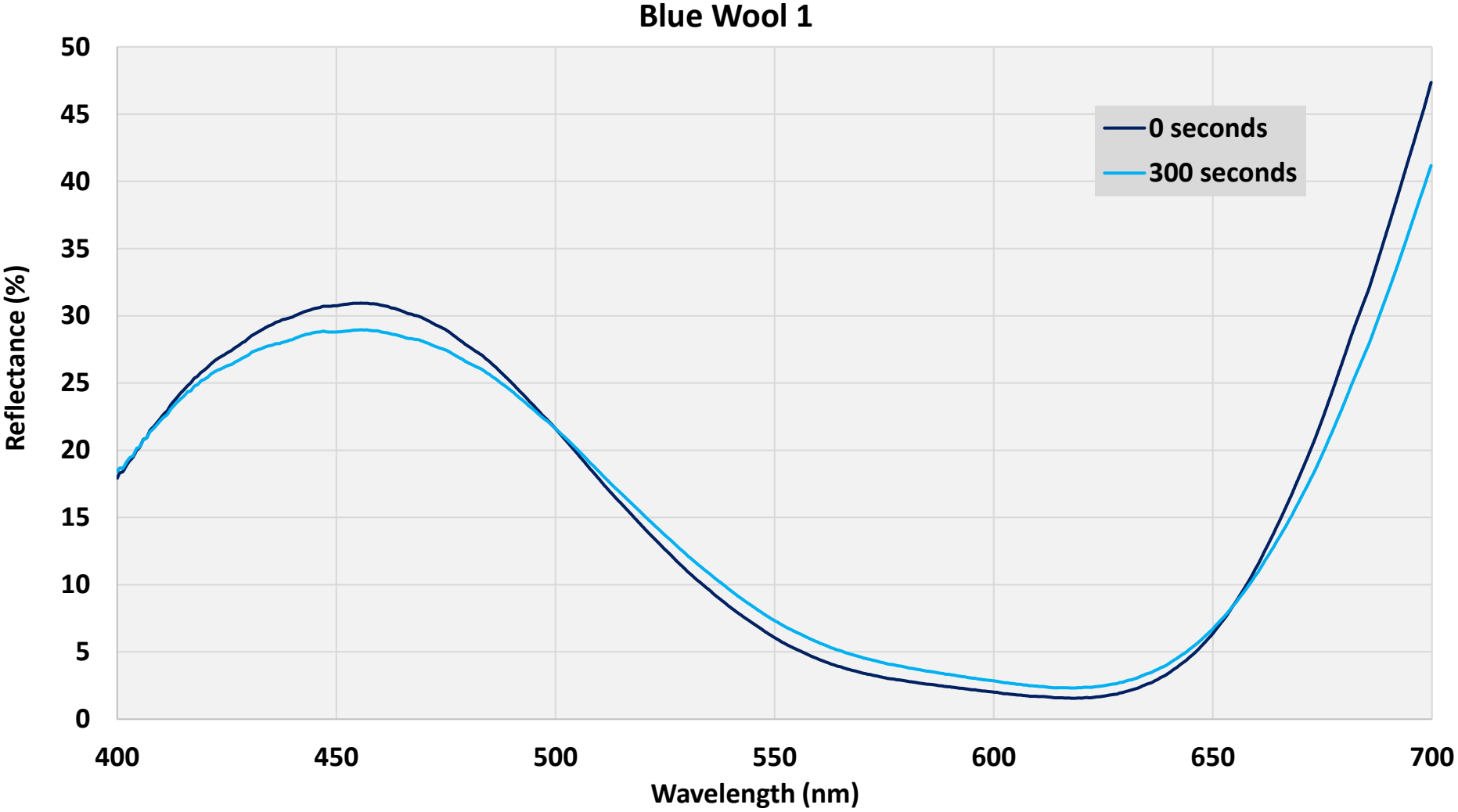


# Microfade Testing (MFT)

Direct light sensitivity assessment on actual objects using a focused source to induce accelerated fading



# Spectral Difference After MFT



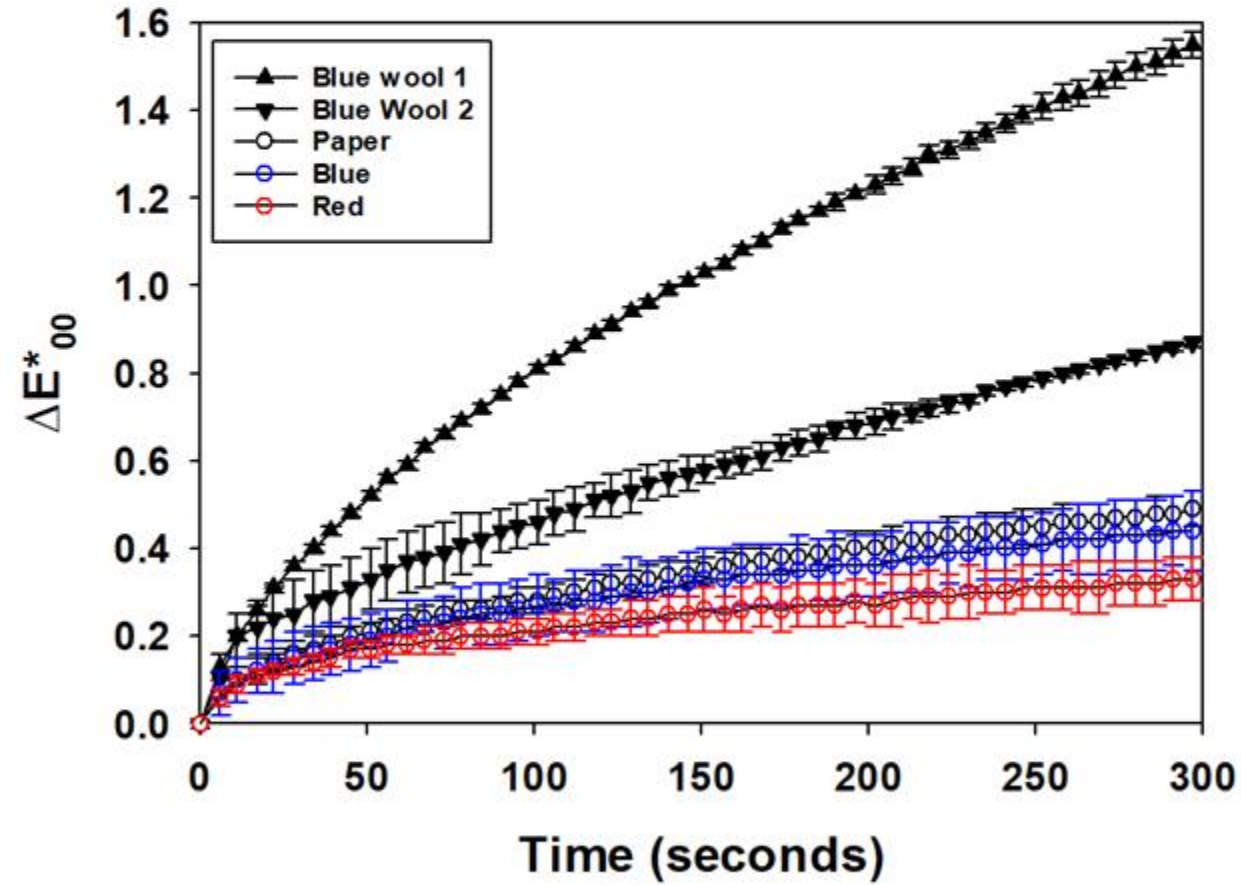


# Technique Comparisons on Ceramic Color Tiles

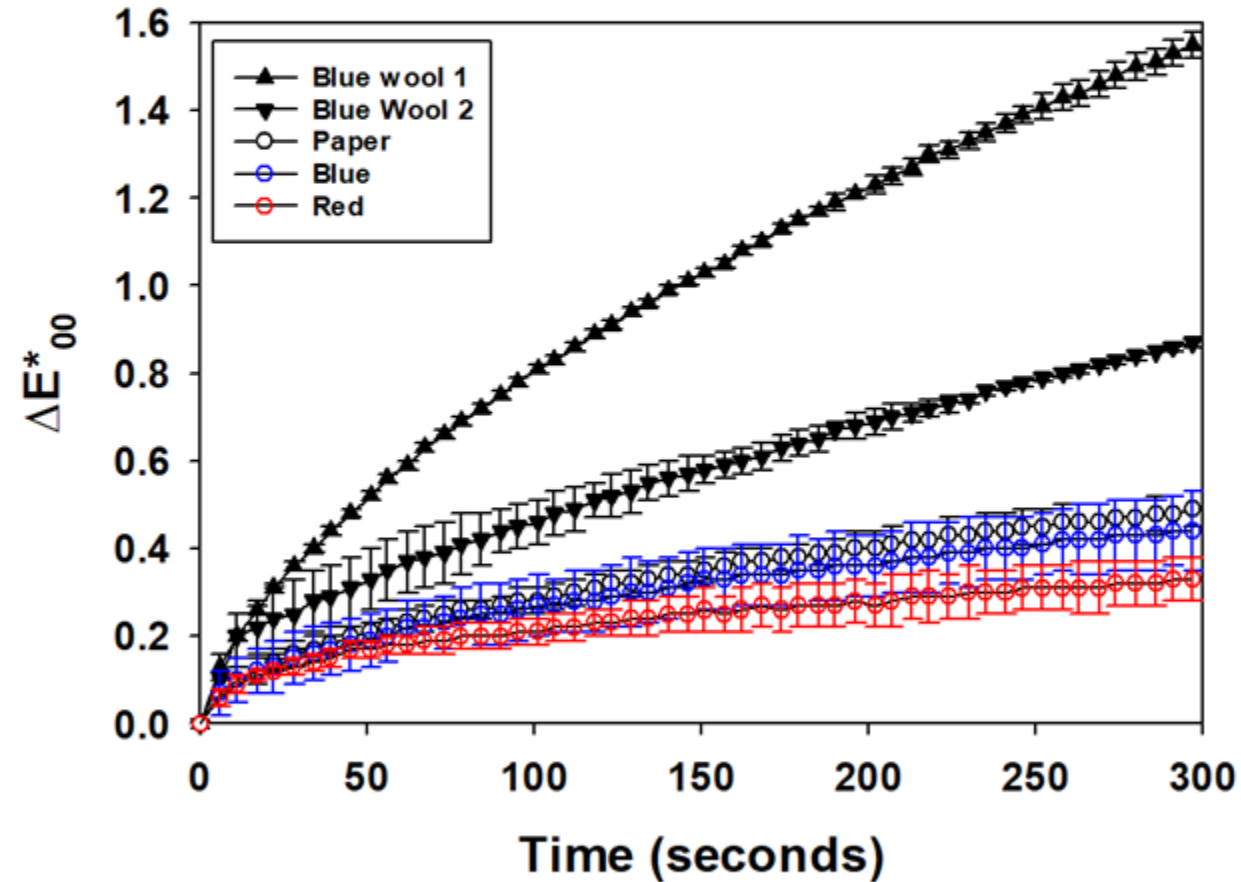
	Method	$\Delta E_{00}^*$	Simulated Color	Actual Color
Red Tile	VSC avg	2.36	L*=34.03, a*=64.13, b*=48.87	L*=32.00, a*=61.20, b*=48.40
	MFT avg	2.93	L*=30.68, a*=66.99, b*=52.89	
Green Tile	VSC avg	1.17	L*=26.75, a*=-19.17, b*=6.75	L*=27.00, a*=-18.10, b*=7.30
	MFT avg	5.77	L*=21.97, a*=-25.63, b*=7.88	
Blue Tile	VSC avg	1.81	L*=15.25, a*=19.88, b*=-38.95	L*=17.60, a*=19.00, b*=-39.20
	MFT avg	6.11	L*=10.56, a*=25.71, b*=-51.22	

Ceramic color tiles are from Hale Consultants  
Reference color measurements traceable to  
National Bureau of Standards (NBS) now  
National Institute of Standards and Technology (NIST)  
Normalized with white tile or white reference

# MFT of Jenny 7



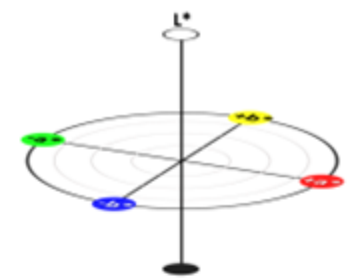
# MFT of Jenny 7



	$\Delta E_{00}^*$	Simulated Color
VSC Paper Color	NA	L*=74.03, a*=2.47, b*=22.30
MFT Paper Color	2.80	L*=71.77, a*=4.48, b*=24.11
VSC Blue Color	NA	L*=34.87, a*=-7.27, b*=-15.08
MFT Blue Color	3.65	L*=32.62, a*=-9.22, b*=-17.72
VSC Red Color	NA	L*=43.87, a*=39.77, b*=17.30
MFT Red Color	5.48	L*=47.60, a*=43.66, b*=25.5

White tile was used for both VSC and MFT measurements  
 Simulated MFT color is at the starting point

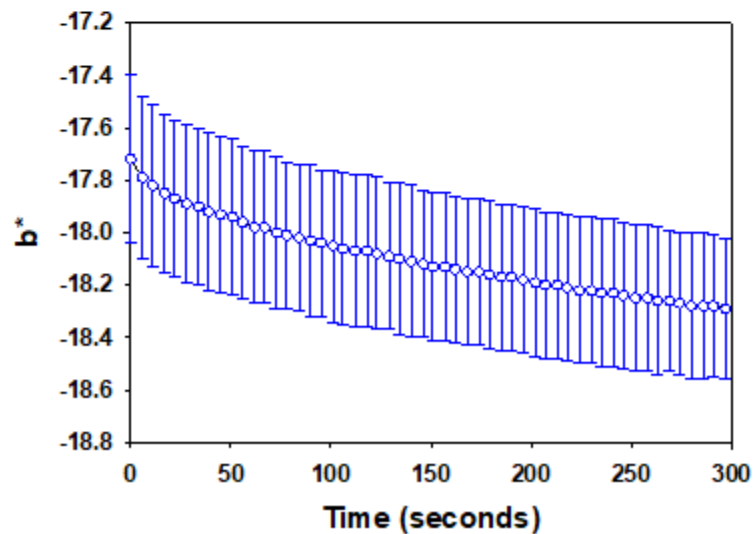
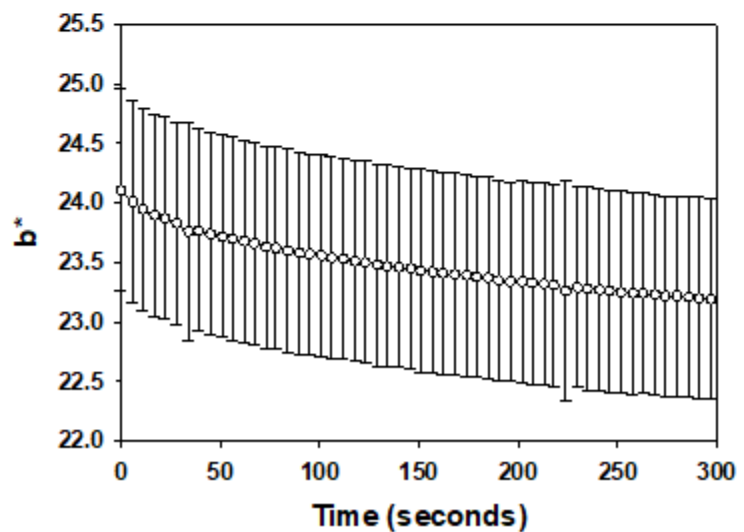
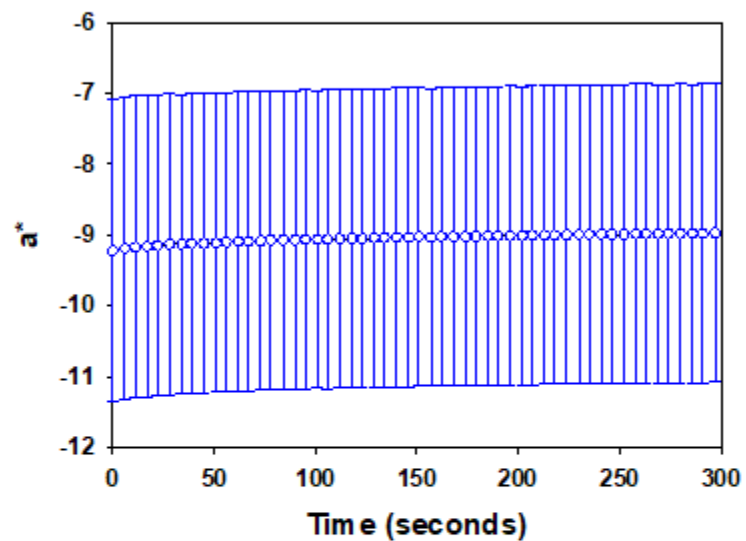
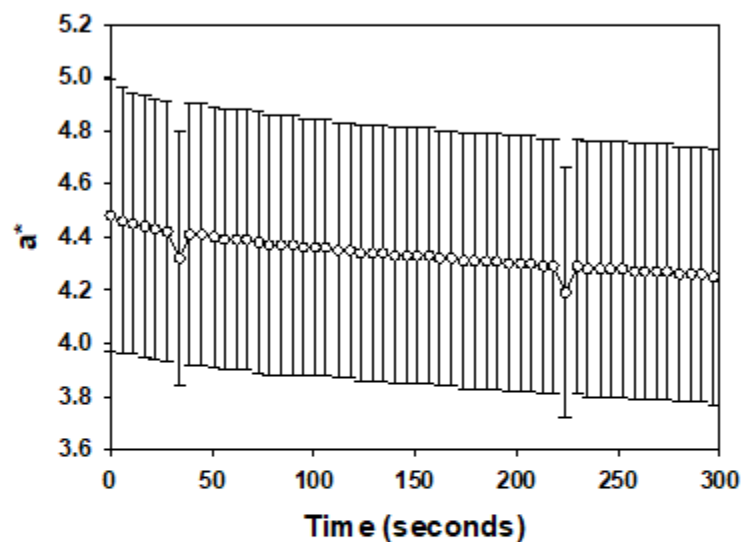


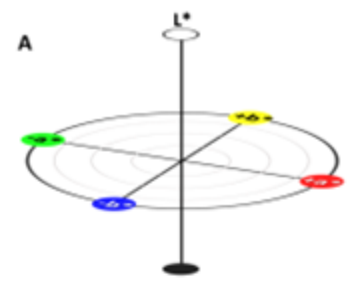


# MFT of Jenny 7

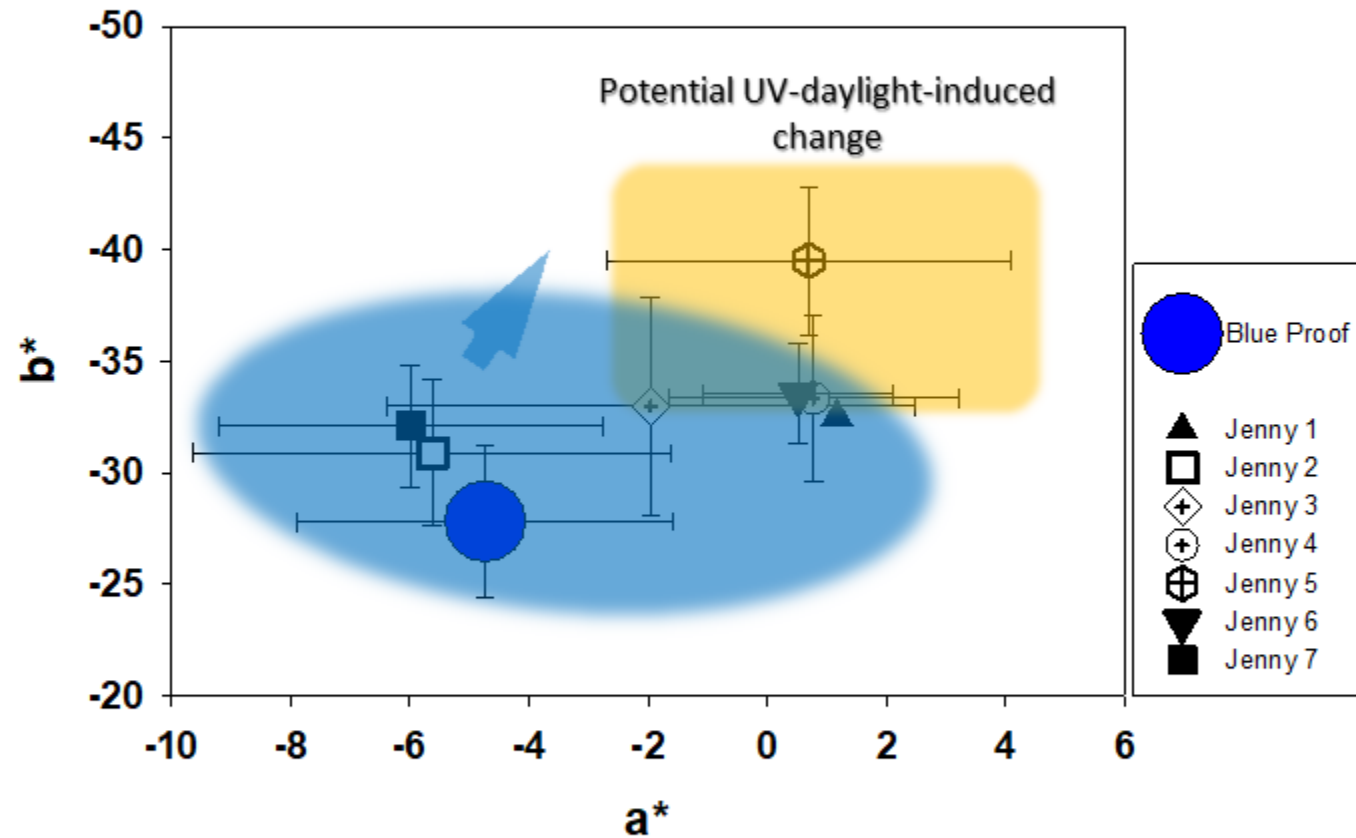
Paper

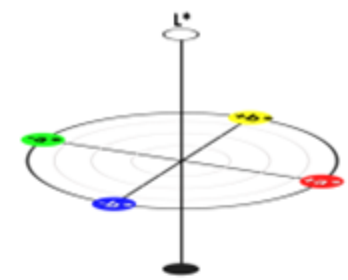
Blue





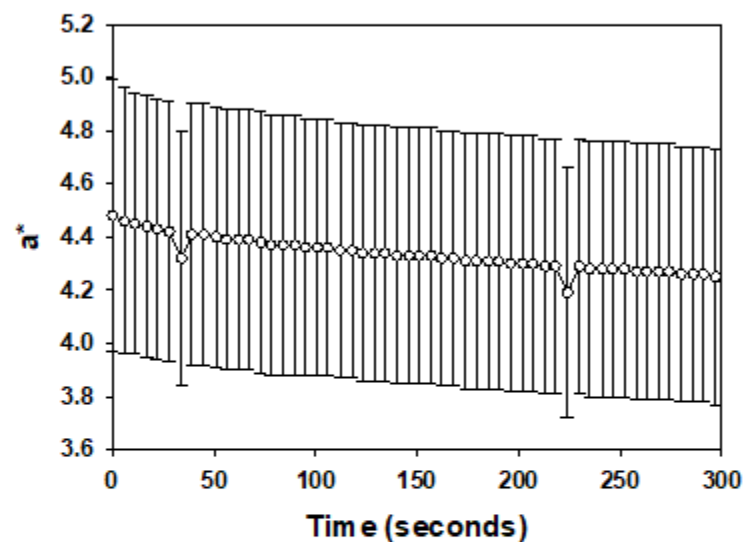
# MFT Interpretation for the Blue



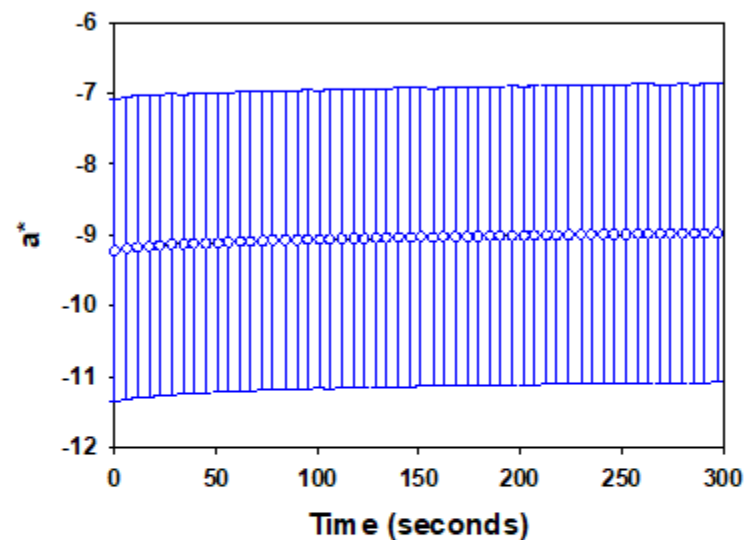


# MFT of Jenny 7

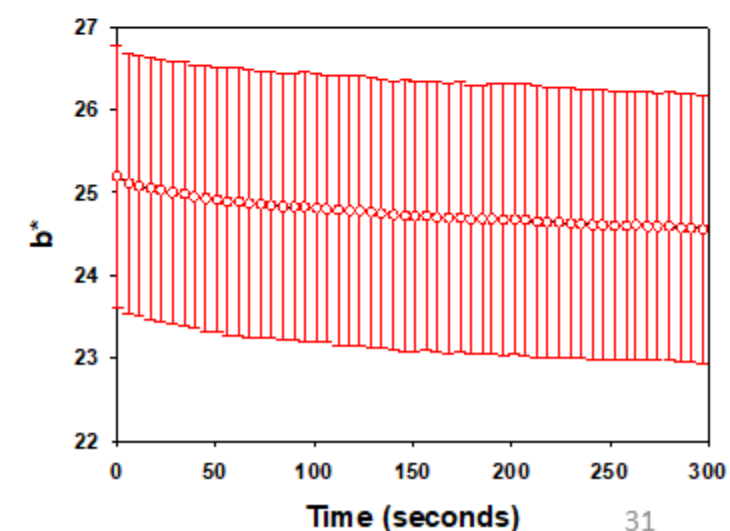
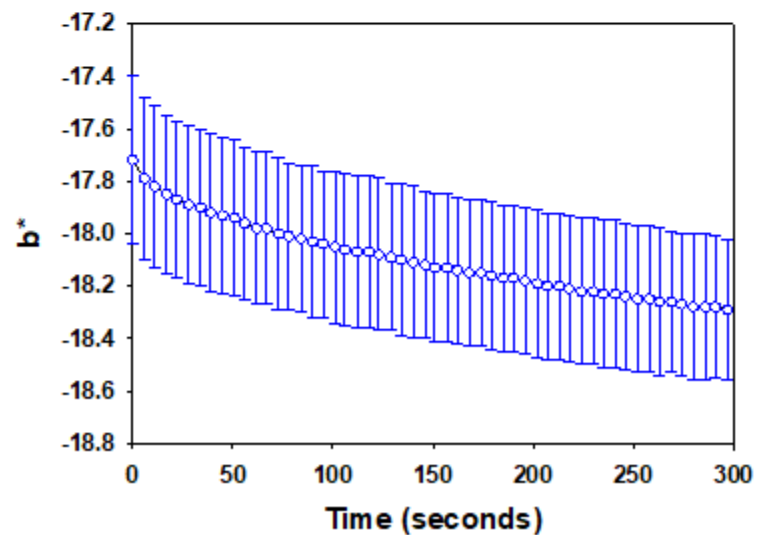
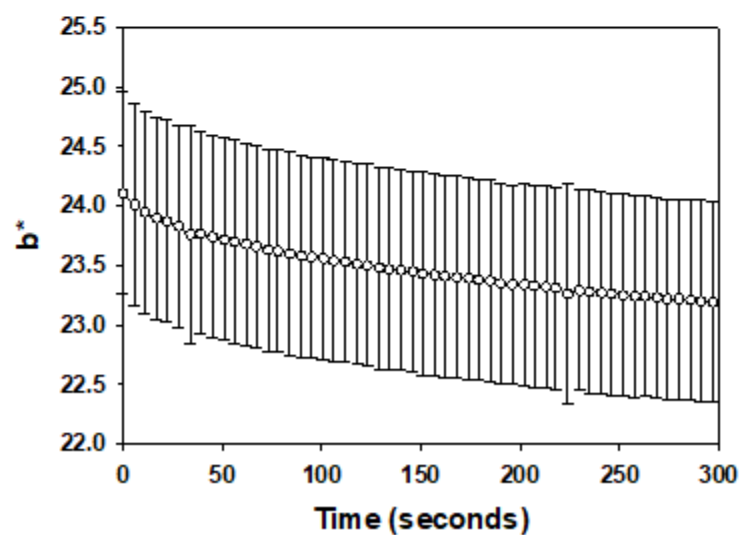
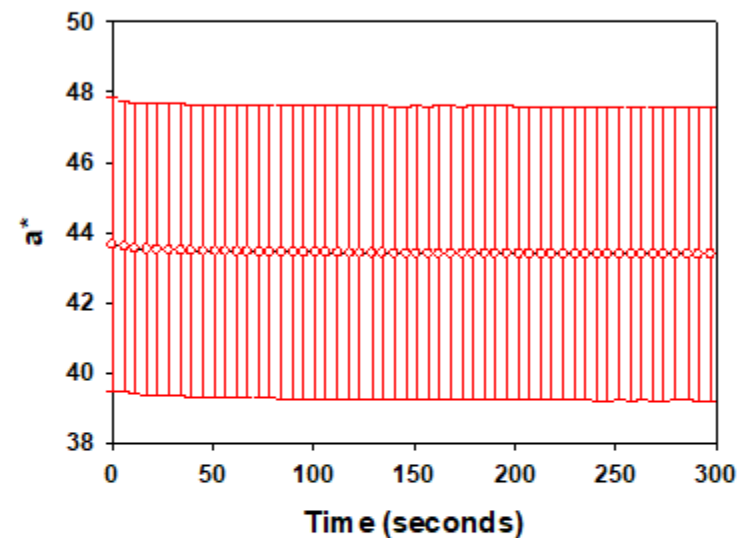
**Paper**



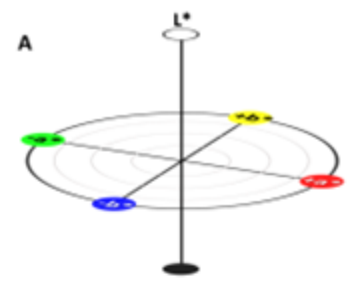
**Blue**



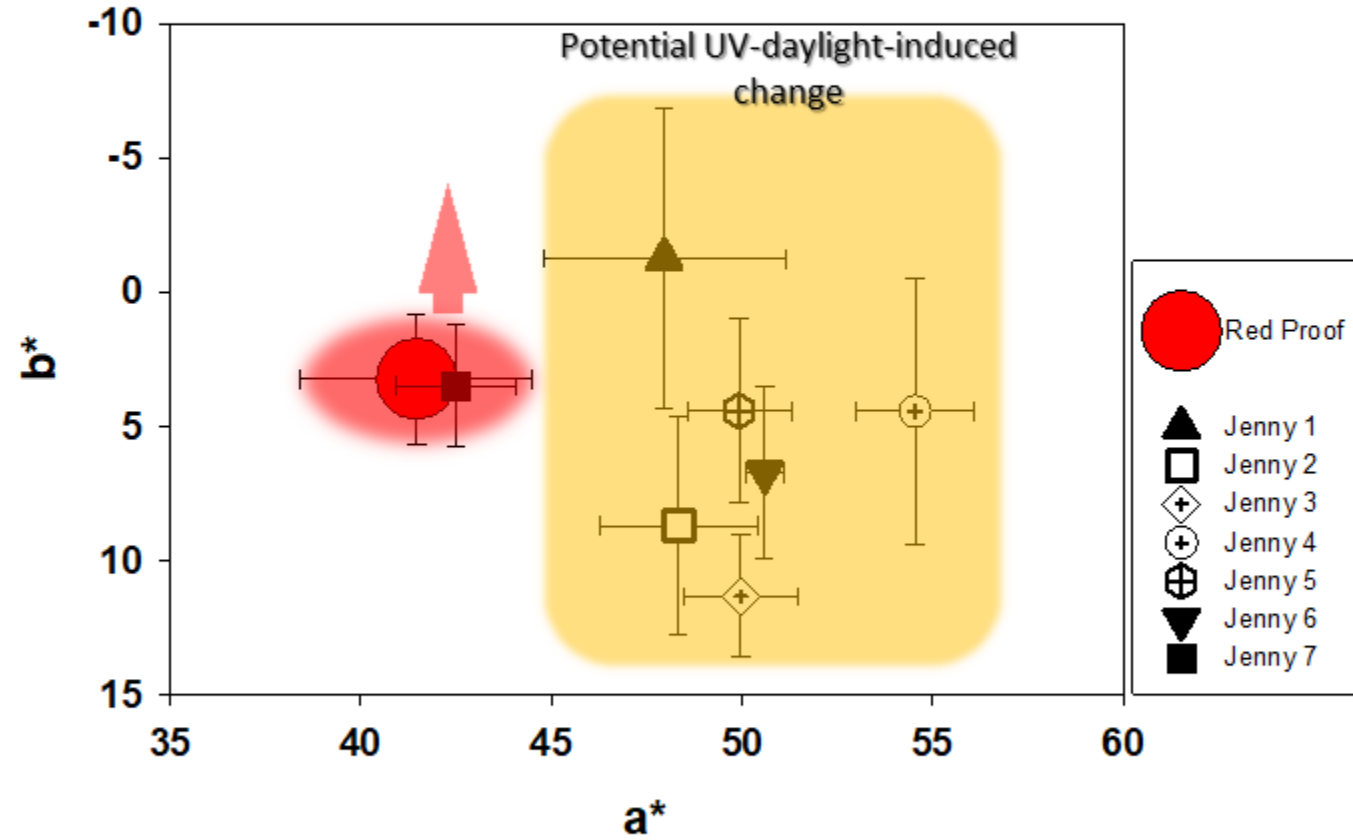
**Red**







# MFT Interpretation for the Red



# Calculation of Light Exposure

Each view 20 seconds

-

# Calculation of Light Exposure

Each view 20 seconds

≈ Exposure for a Day

100 views/day	0.56 h
250 views/day	1.4 h
500 views/day	2.8 h
1,000 views/day	5.5 h

# Calculation of Light Exposure

Each view 20 seconds

Exposure  
At 26.9 Candela Steradians or lux

≈ Exposure for a Day

100 views/day	0.56 h
250 views/day	1.4 h
500 views/day	2.8 h
1,000 views/day	5.5 h



# Calculation of Light Exposure

Each view 20 seconds

Exposure  
At 26.9 Candela Steradians or lux

	$\approx$ Exposure for a Day	10 yr Calculated Maximum Light Exposure
100 views/day	0.56 h	0.056 Mlux·h
250 views/day	1.4 h	0.14 Mlux·h
500 views/day	2.8 h	0.27 Mlux·h
1,000 views/day	5.5 h	0.55 Mlux·h

Well below the 1.2 Mlux·h, which is the max that blue wool 2 can handle (based on experimental data)

# Conclusions & Future Work

Through color simulation and color reference tiles, we gained confidence of the color measurements in VSC and MFT

Gained an understanding for the statistical spread of the colors within the 1918 Jenny Stamps

By understanding the statistical spread we were able to further interpret the MFT data

The calculated projected light exposure affirms the conservative NPM lighting is successfully protecting the Inverted Jenny

Further study the on the inorganic and organic chemistry of the stamp



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Thank you!  
Questions?