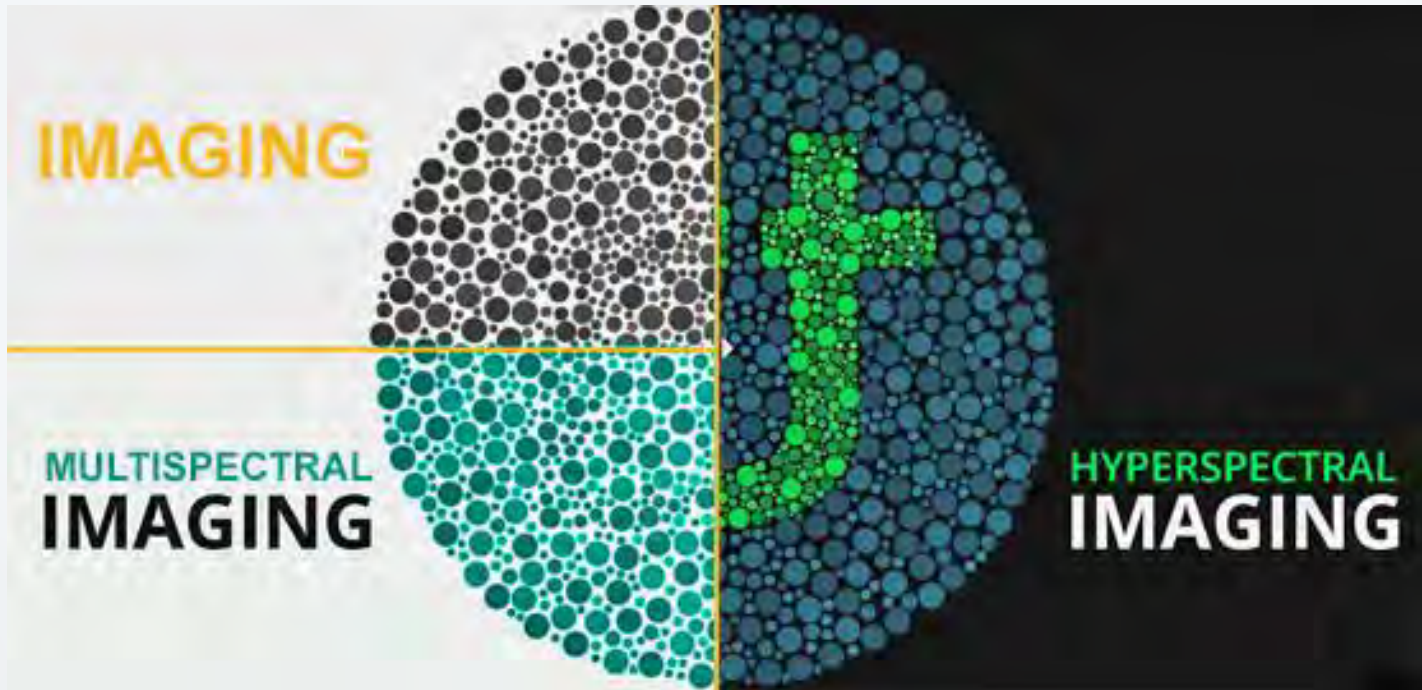


# *FRAMEWORK FOR QUALITY CONTROL OF SPECTRAL IMAGING DEVICES*



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# Imaging



3 bands: RGB



>3 bands < 20

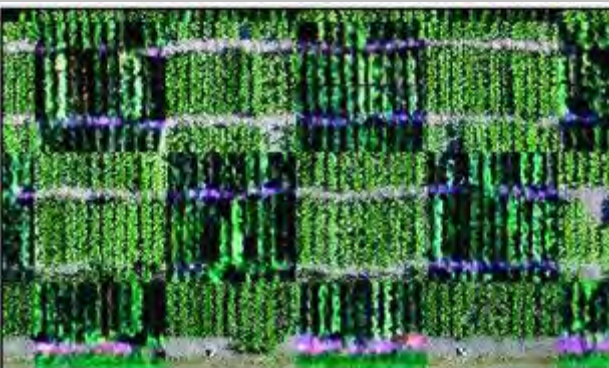


>20 bands

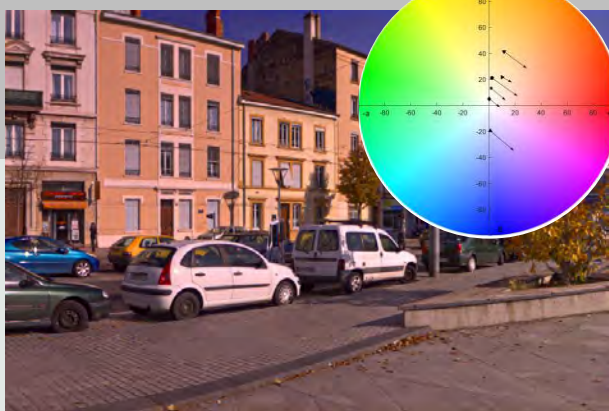




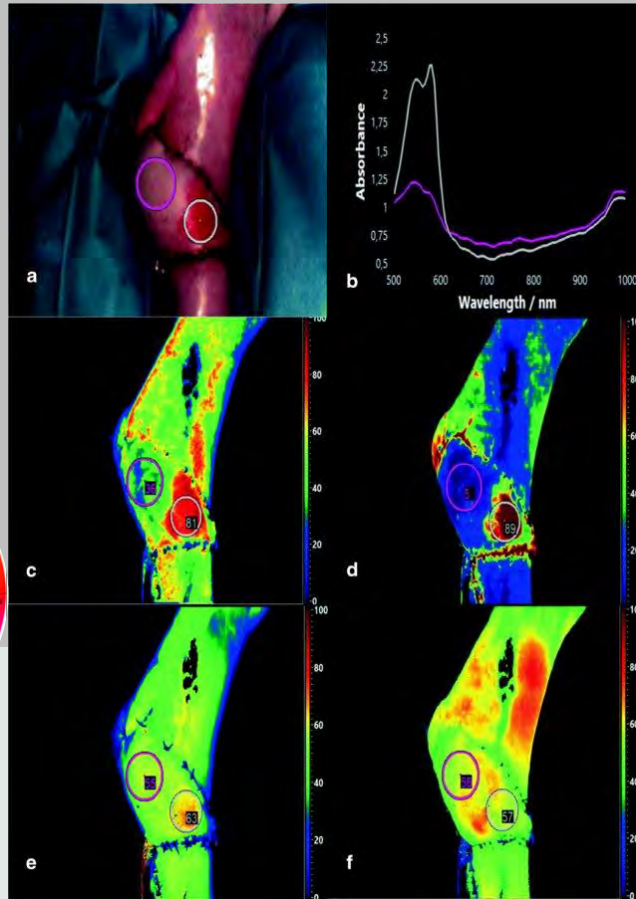
# Spectral Imaging applications



Ayman et al., 2016



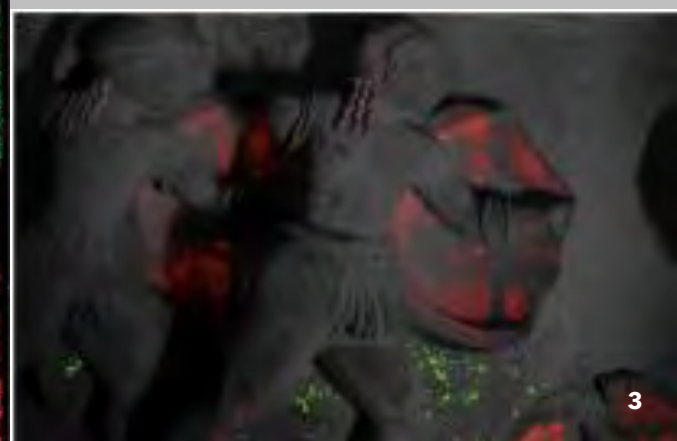
Raza et al., 2021



Schulz et al., 2021



Dooley et al., 2013



Alfeld et al., 2018



# Spectral Imaging

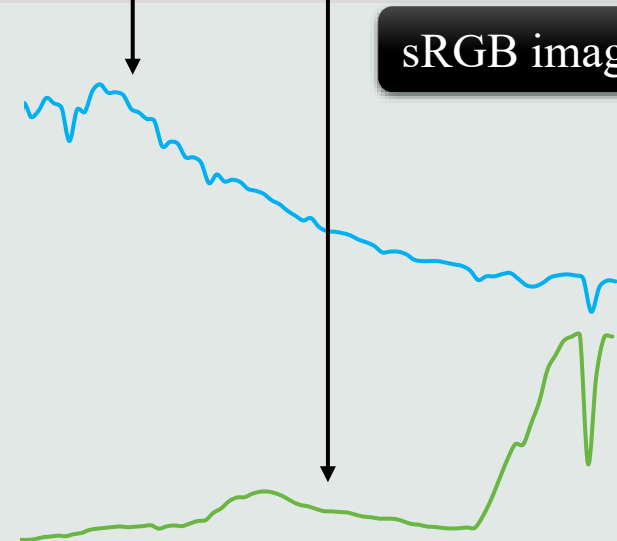
Radiometric data



CIE XYZ Coordinates



sRGB image



Photometric data



CIE Y Coordinates

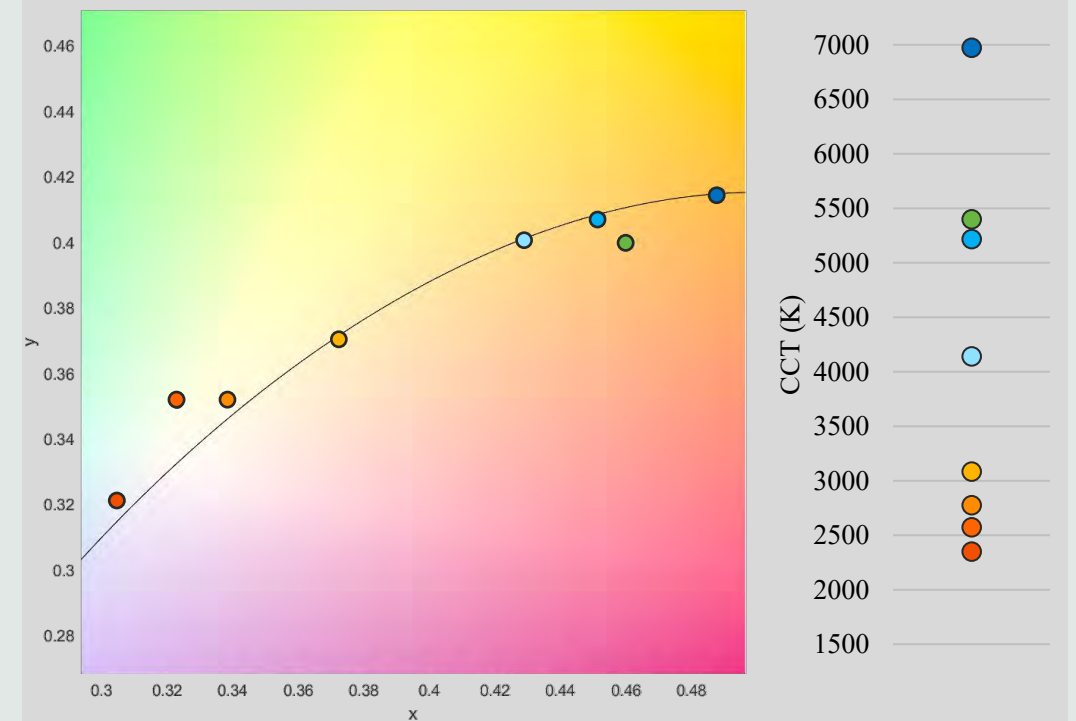
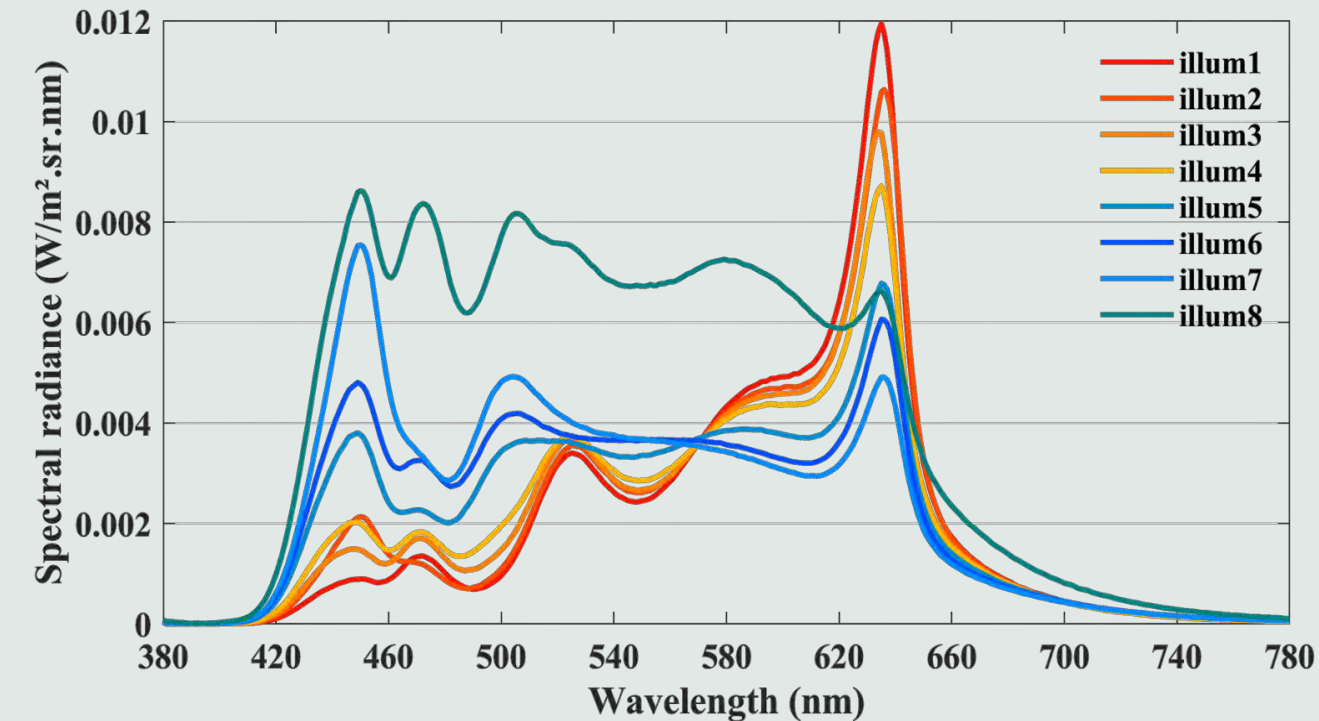
Colorimetric data



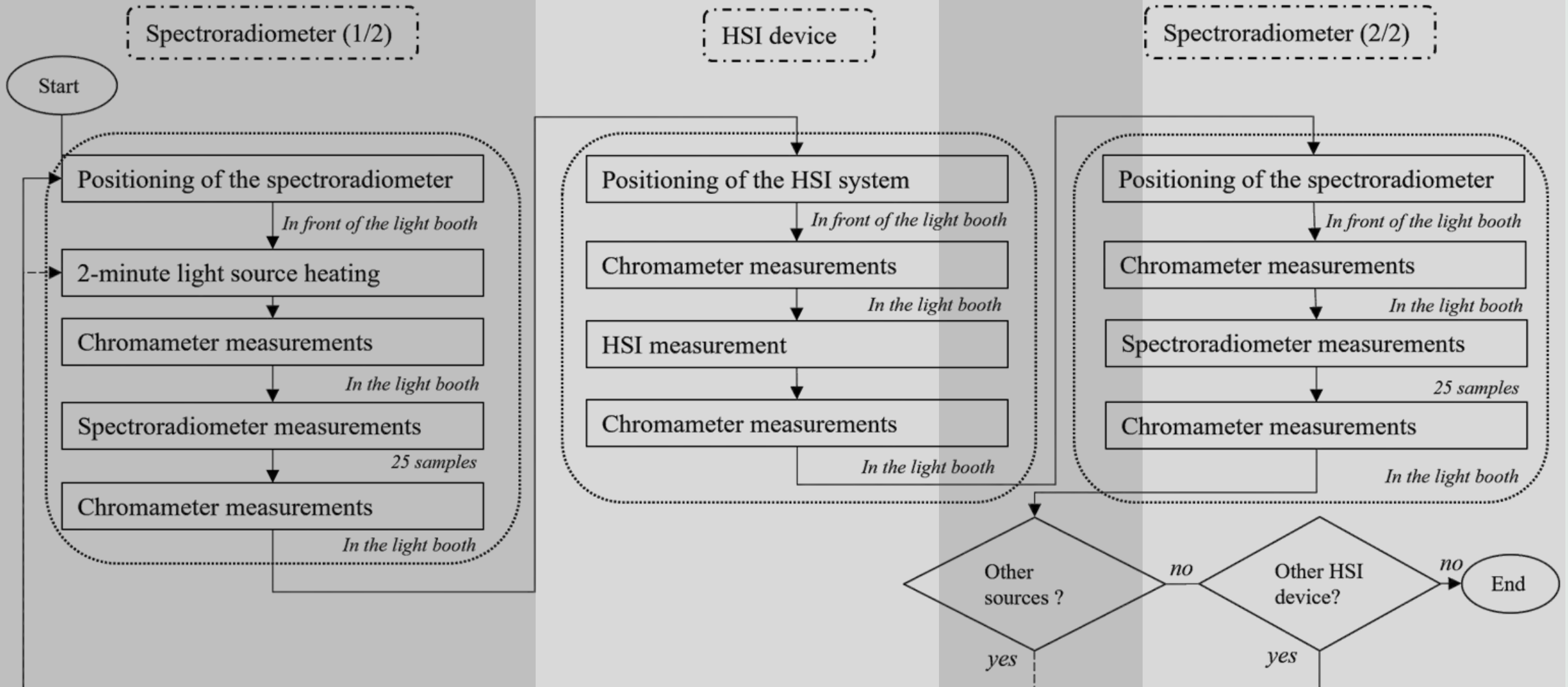
CIE LAB Coordinates

# Test stimuli

Specim-V10E ~60K€	Specim-FX10 ~20K€	Innospec GreenEye ~15K€
		
2184 px (y definition) 2.9 nm (spectral resolution) [394.6;1007.0nm]	1024 px (y definition) 5.5 nm (spectral resolution) [396.0;1004.0nm]	1312 px (y definition) 10 nm (spectral resolution) [355.8;1094.0nm]



# Measurement chronology





# Accuracy metrics

't' subscript = test data  
'r' subscript = reference data

Spectral radiance

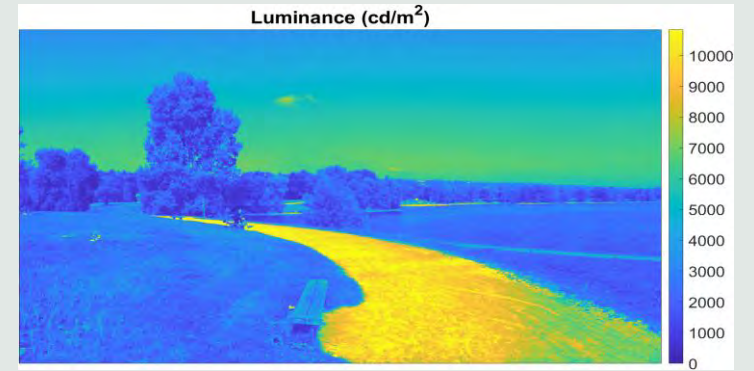


Radiometric data

Normalized Root Mean Square Deviation

$$NRMSD (\%) = \frac{\sqrt{\frac{1}{N} \sum_{\lambda_i} (s_{\lambda_i,t} - s_{\lambda_i,r})^2}}{\max(s_{\lambda_i,t}; s_{\lambda_i,r})} \times 100$$

CIE Y Coordinates



Photometric data

Mean Absolute Percentage Error

$$MAPE (\%) = \frac{100}{n} \sum_{i=1}^n \left| \frac{Y_{i,t} - Y_{i,r}}{Y_{i,r}} \right| \times 100$$

Naturalness Image Quality Evaluator (NIQE)

(Mittal et al., 2013)

Blind/Referenceless Image Spatial Quality Evaluator (BRISQUE)  
(Mittal et al., 2012)

CIE LAB Coordinates



Colorimetric data

sRGB image

$$\Delta E_{a^*b^*} = \sqrt{(L_{i,t} - L_{i,r})^2 + (a_{i,t} - a_{i,r})^2 + (b_{i,t} - b_{i,r})^2}$$

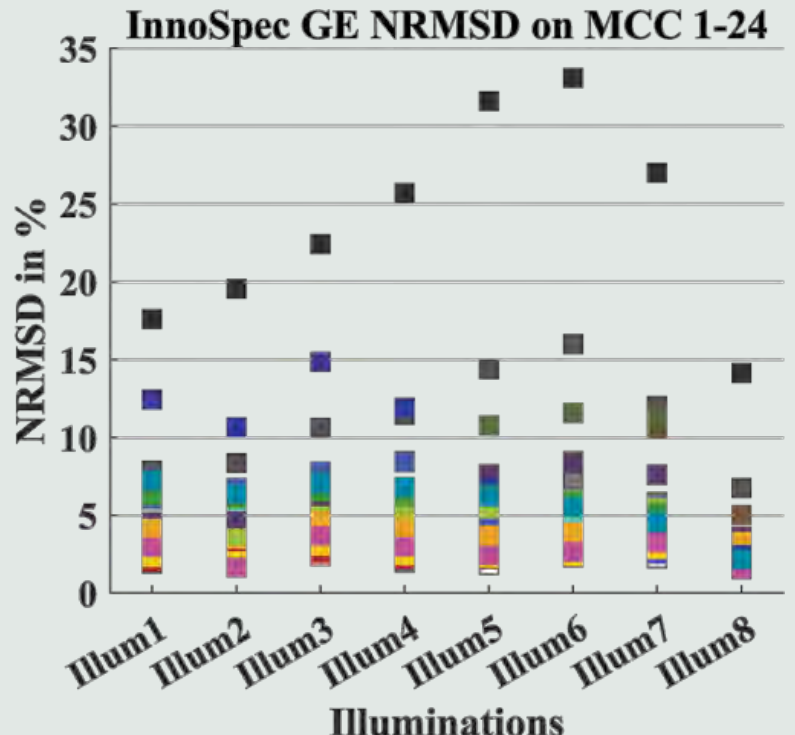
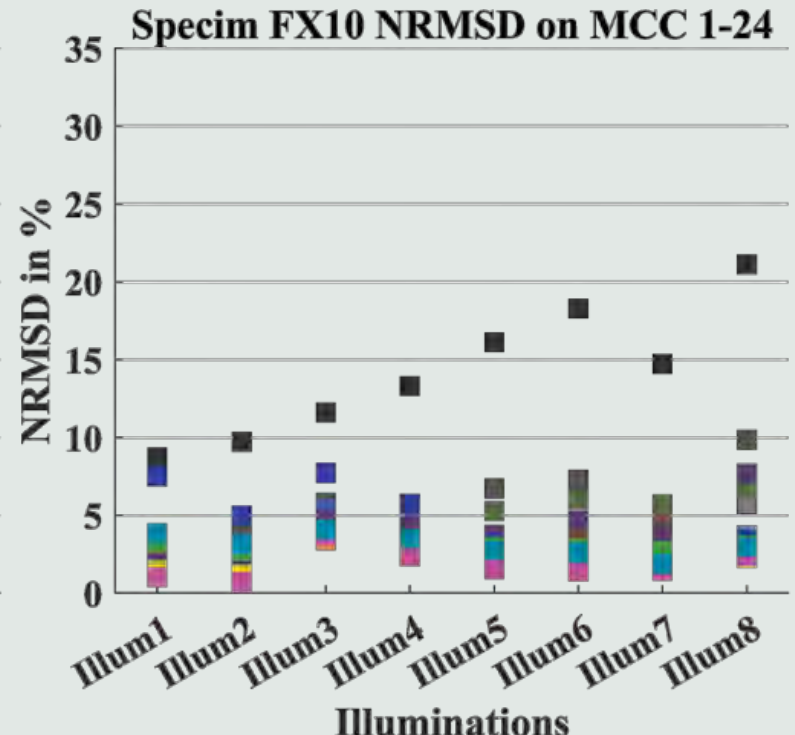
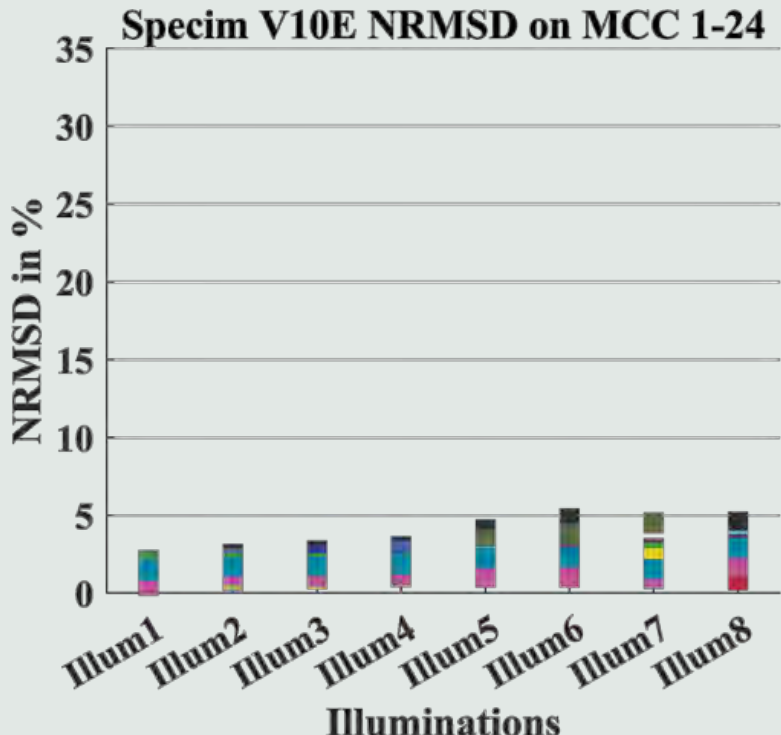
# Results: Radiometric accuracy

$$NRMSD (\%) = \sqrt{\frac{1}{N} \sum_{\lambda i} (s_{\lambda i, t} - s_{\lambda i, r})^2} / \max(s_{\lambda i, t}; s_{\lambda i, r})}$$

'i' subscript = test data

'r' subscript = reference data

NRMSD from literature: **1.9%-23%**  
(Foster & Amano, 2019; Vilaseca et al., 2014)





# Results: Radiometric accuracy

### Specim-V10E



median NRMSD = 1.91%,  
median absolute deviation = 0.43%

### Specim-FX10



median NRMSD = 2.7%,  
median absolute deviation = 0.99%

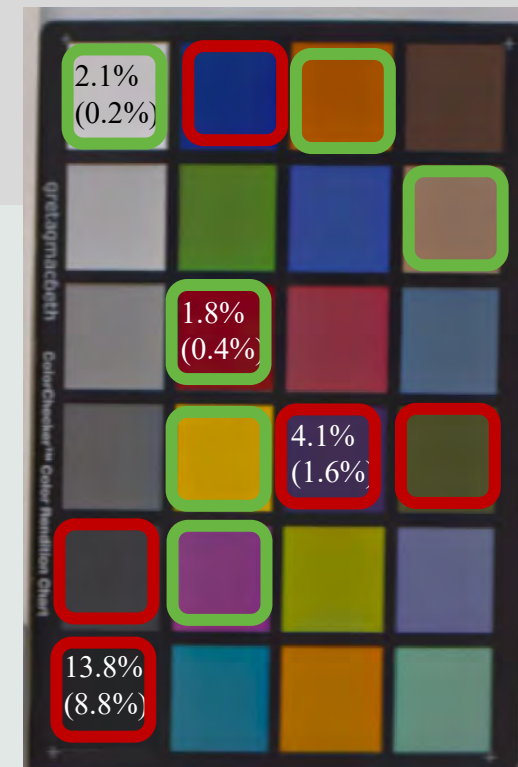
### Innospec GreenEye



median NRMSD = 4%,  
median absolute deviation = 1.71%

### NRMSD

2351 K	illum1	2.91% (0.85%)
2574 K	illum2	2.87% (0.45%)
2777 K	illum3	4.08% (1.51%)
3084 K	illum4	3.89% (0.8%)
4142 K	illum5	
5217 K	illum6	
6974 K	illum7	
5400 K	illum8	3.46% (0.96%)



# Results: Photometric accuracy

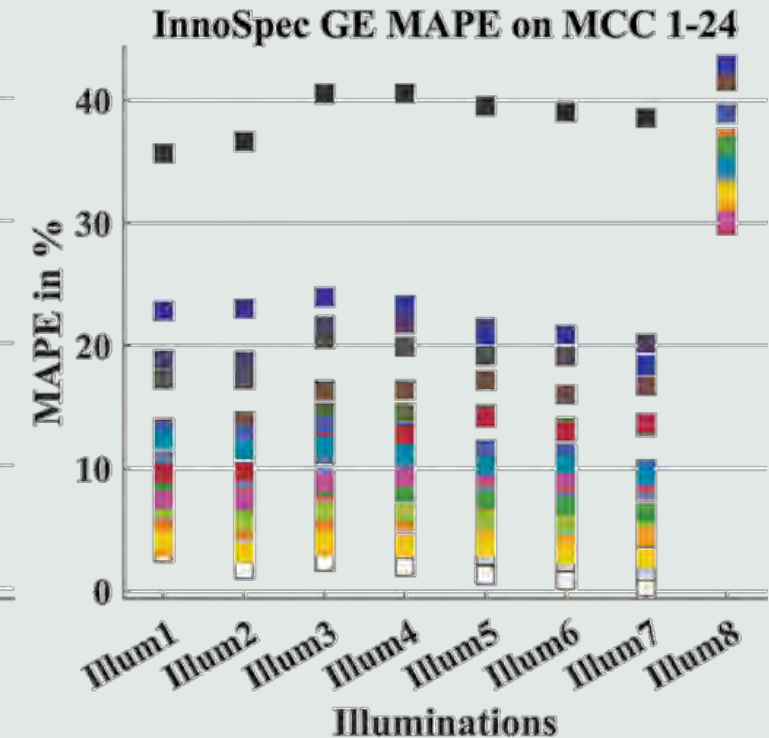
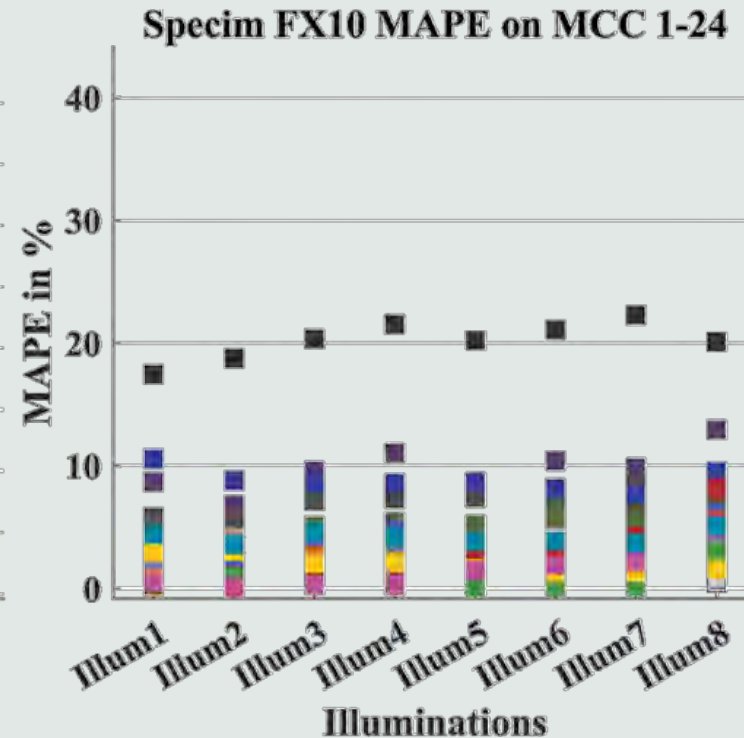
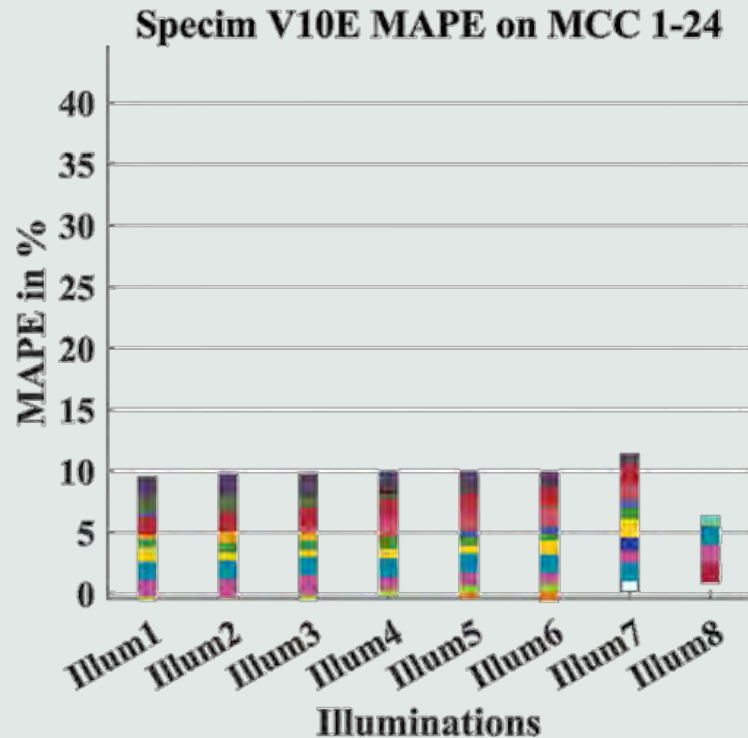
$$MAPE (\%) = \frac{100}{n} \sum_{i=1}^n \left| \frac{Y_{i,t} - Y_{i,r}}{Y_{i,r}} \right| \times 100$$

'i' subscript = test data

'r' subscript = reference data

MAPE from literature: **2.8%-20%**

Cai & Chung, 2011; Inanici & Galvin, 2004





# Results: Photometric accuracy

### Specim-V10E



median MAPE = 3.8%,  
median absolute deviation = 1.7%

### Specim-FX10



median MAPE = 2.8%,  
median absolute deviation = 1.6%

### Innospec GreenEye



median MAPE = 9.6%,  
median absolute deviation = 4.4%

## MAPE

2351 K — illum1

2574 K — illum2

2777 K — illum3

3084 K — illum4

4142 K — illum5

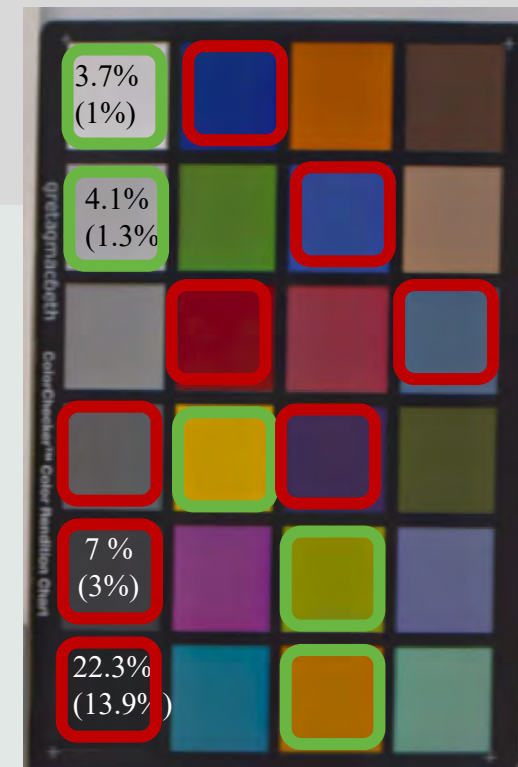
5217 K — illum6

6974 K — illum7

5400 K — illum8

4% (2.2%)

5.2% (3.1%)



# Results: Colorimetric accuracy

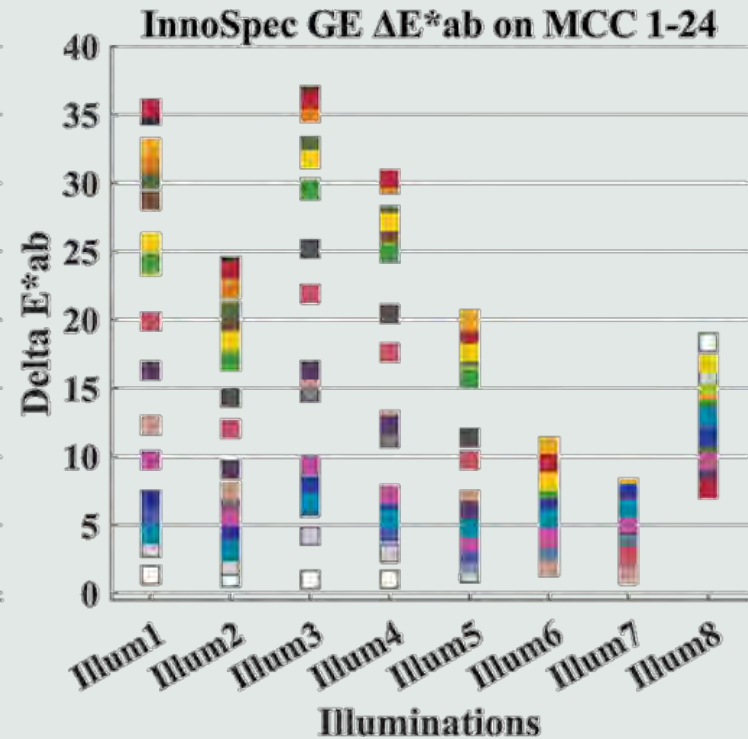
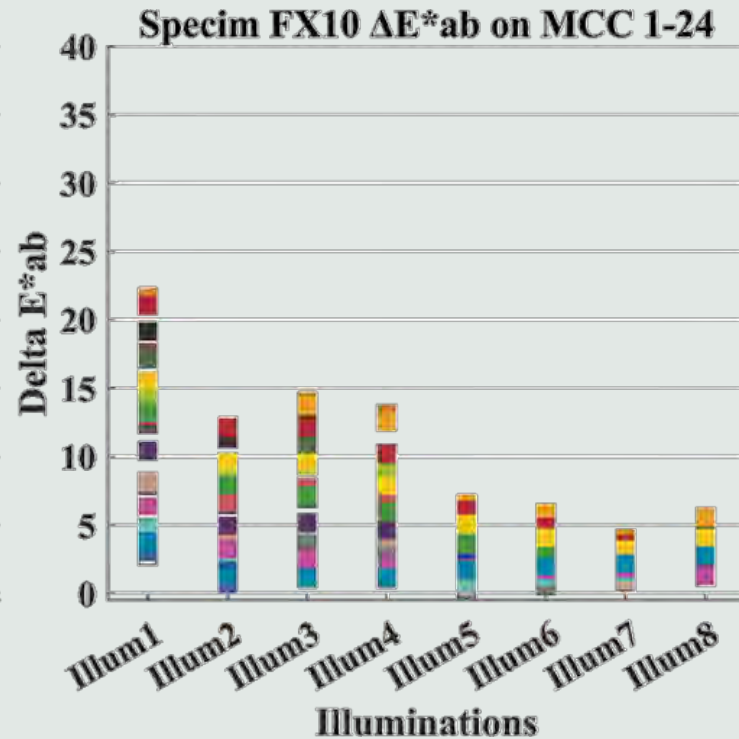
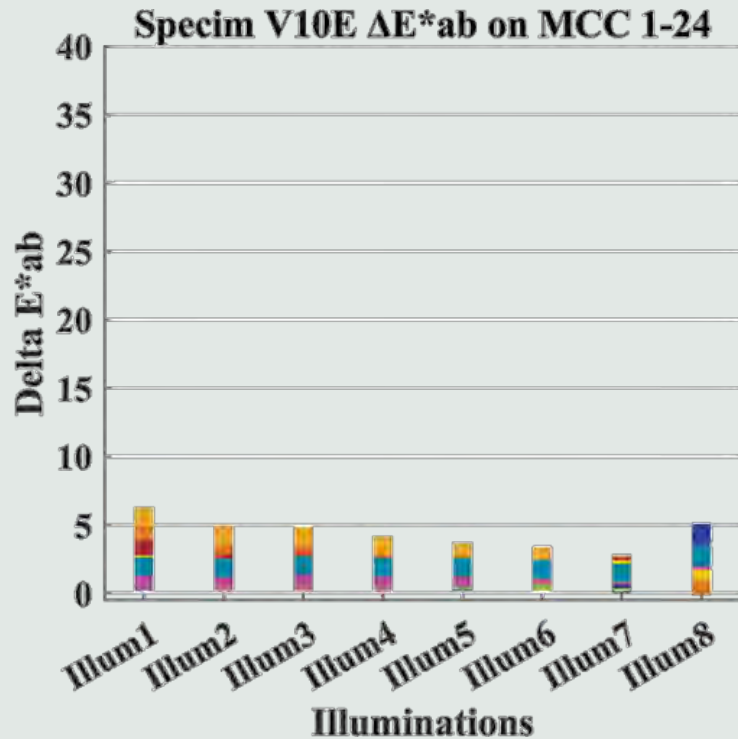


$$\Delta E_{a^*b^*} = \sqrt{(L_{i,t} - L_{i,r})^2 + (a_{i,t} - a_{i,r})^2 + (b_{i,t} - b_{i,r})^2}$$

'i' subscript = test data

'r' subscript = reference data

$\Delta E^*_{ab}$  non-perceptual limit for images: < 6  
Hordley et al., 2004; Meyer, 1988





# Results: Colorimetric accuracy

**Specim-V10E**



median  $\Delta E^*_{ab}$  = 1.5,  
median absolute deviation = 0.3

**Specim-FX10**



median  $\Delta E^*_{ab}$  = 3.1,  
median absolute deviation = 1.6

**Innospec GreenEye**



median  $\Delta E^*_{ab}$  = 8.2,  
median absolute deviation = 4.5

	$\Delta E^*_{ab}$
2351 K — illum1	5.3 (3.9)
2574 K — illum2	
2777 K — illum3	
3084 K — illum4	
4142 K — illum5	2 (1.5)
5217 K — illum6	2.1 (0.9)
6974 K — illum7	2.2 (1.0)
5400 K — illum8	

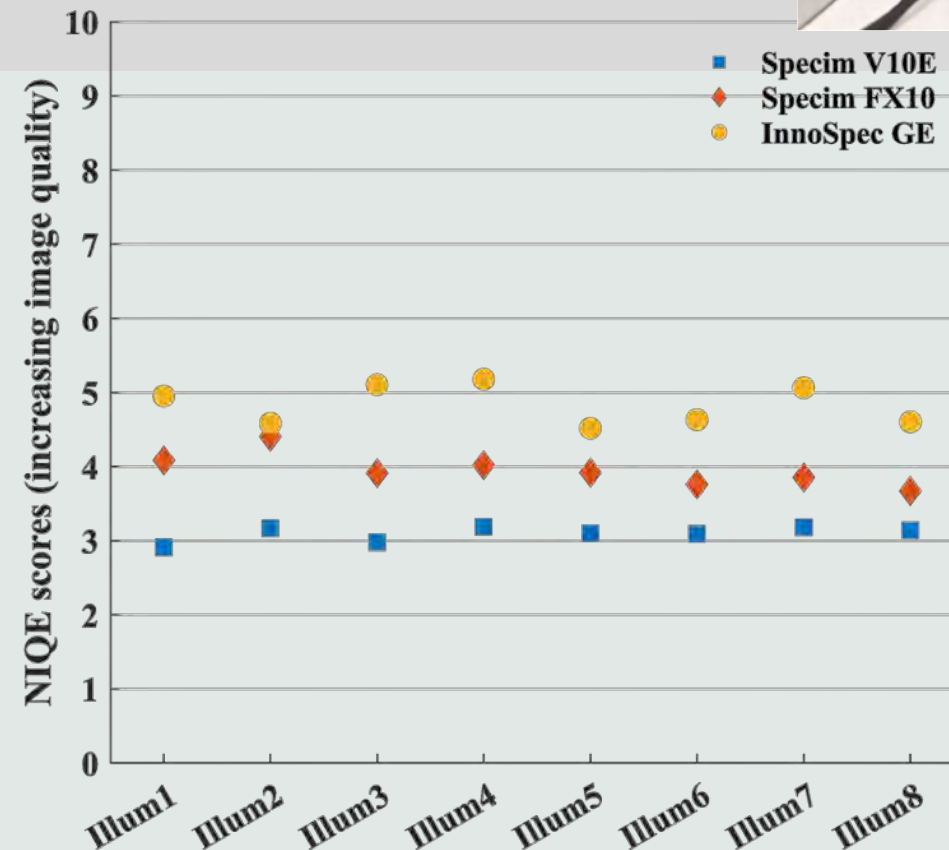
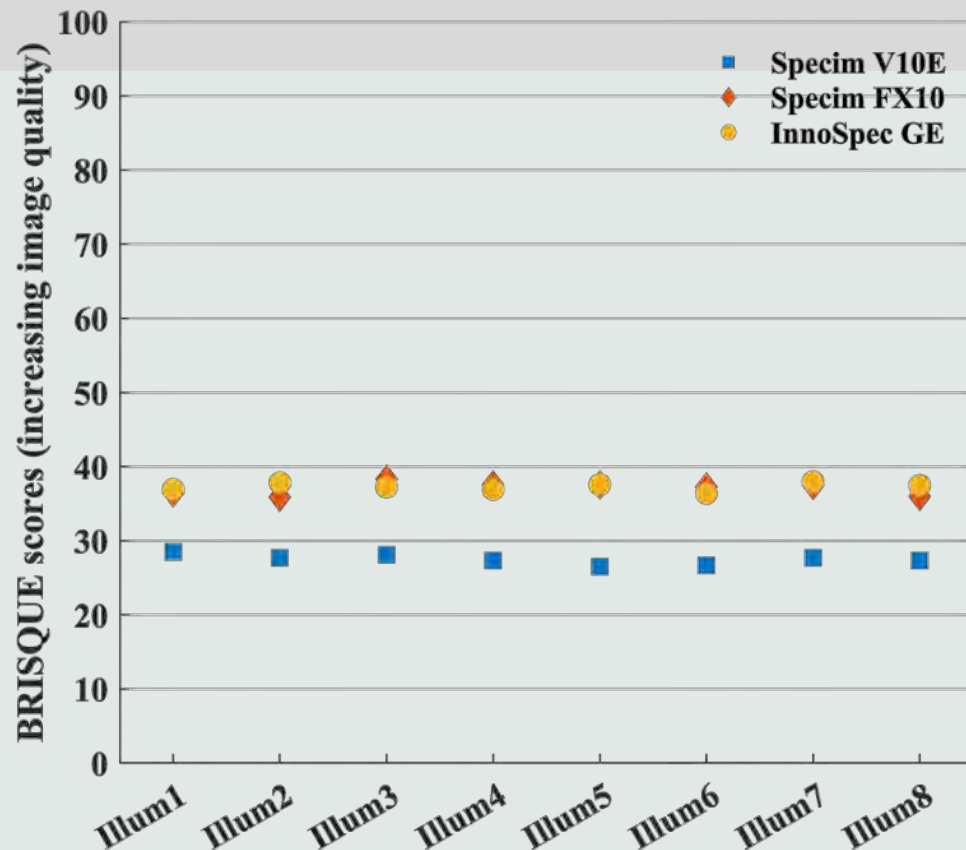


# Results: Image Quality

(BRISQUE) Blind/Referenceless Image Spatial Quality Evaluator (0-100)

(NIQE) Naturalness Image Quality Evaluator (0-10)

(Mittal et al., 2012,2013)





# Results: Image Quality

## Specim-V10E



median BRISQUE = 27.5,  
median absolute deviation = 0.3

median NIQE = 3.1,  
median absolute deviation = 0.09

## Specim-FX10



median BRISQUE = 37.3,  
median absolute deviation = 0.53

median NIQE = 3.9,  
median absolute deviation = 0.22

## Innospec GreenEye



median BRISQUE = 37.3,  
median absolute deviation = 0.42

median NIQE = 4.8,  
median absolute deviation = 0.27

- 2351 K — illum1
- 2574 K — illum2
- 2777 K — illum3
- 3084 K — illum4
- 4142 K — illum5
- 5217 K — illum6
- 6974 K — illum7
- 5400 K — illum8



# Results: Image Quality

## Specim-V10E



median BRISQUE = 27.5,  
median absolute deviation = 0.3

median NIQE = 3.1,  
median absolute deviation = 0.09

## Specim-FX10



median BRISQUE = 37.3,  
median absolute deviation = 0.53

median NIQE = 3.9,  
median absolute deviation = 0.22

## Innospec GreenEye



median BRISQUE = 37.3,  
median absolute deviation = 0.42

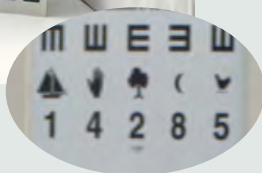
median NIQE = 4.8,  
median absolute deviation = 0.27

## Image under D65

2184 px (y definition)  
2.9 nm (spectral resolution)



Specim V10E

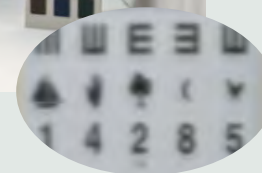


## Image under D65

1024 px (y definition)  
5.5 nm (spectral resolution)



Specim FX10



## Image under D65

1312 px (y definition)  
10 nm (spectral resolution)

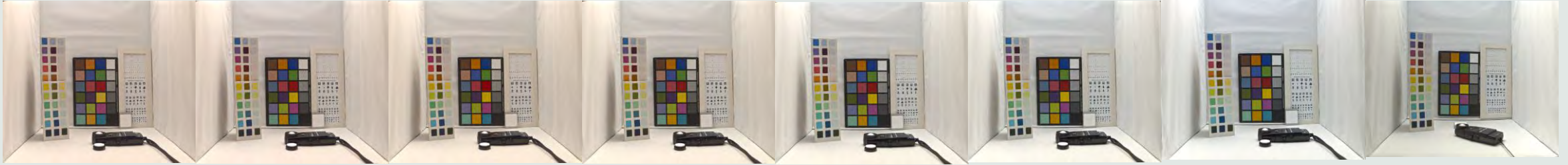


InnoSpecGE





# Conclusion

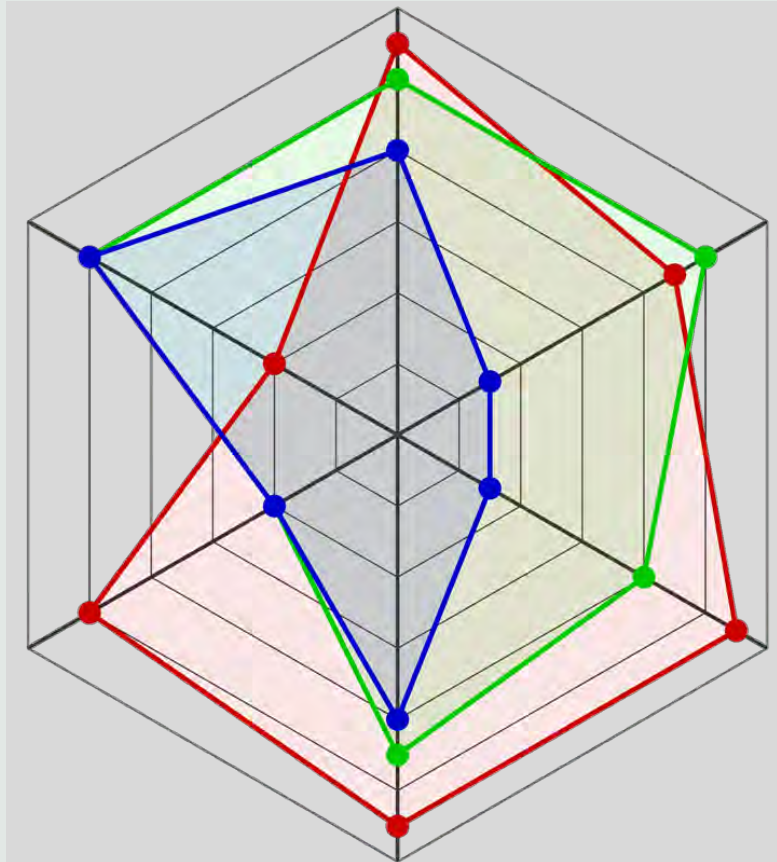


- Black color is always relatively less precise while white is the most precise.
- Radiometric, photometric, and colorimetric indices do not necessarily follow the same trends.
- For color images, statistically there is no link between the color temperature of the illumination and the image quality.
- NIQE scores are more suitable as an IQM for images generated through hyperspectral cameras.



# Conclusion

Spectral Accuracy



Portability

Photometric Accuracy

Price range

Colorimetric Accuracy

Image Quality



—●— Specim V10E —●— Specim FX10 —●— InnoSpec GE



*Thank you  
for your  
attention!*

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Accuracy of hyperspectral imaging systems for color and lighting research

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CORALIE CAUWERTS, MARIE DUBAIL

