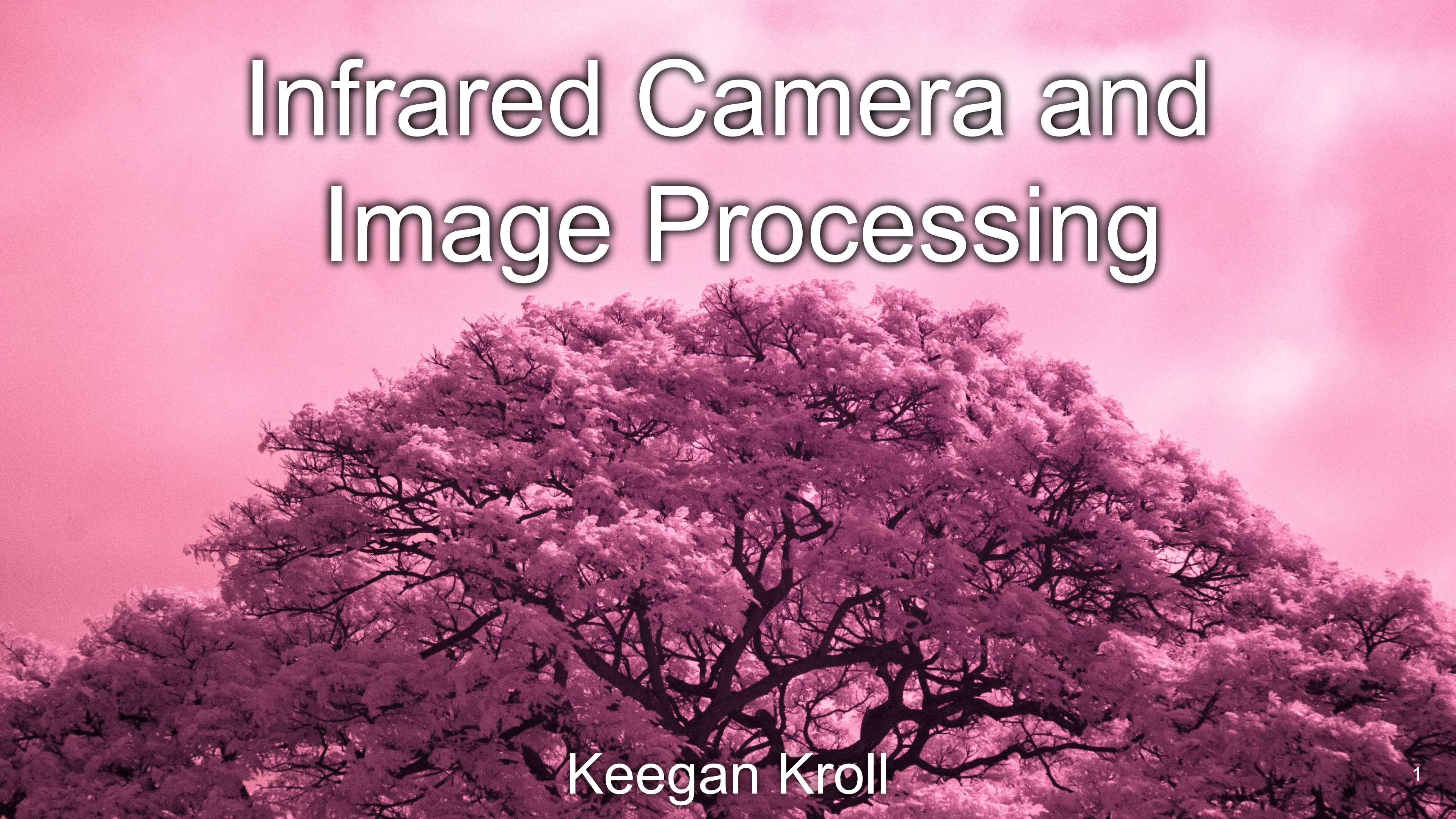
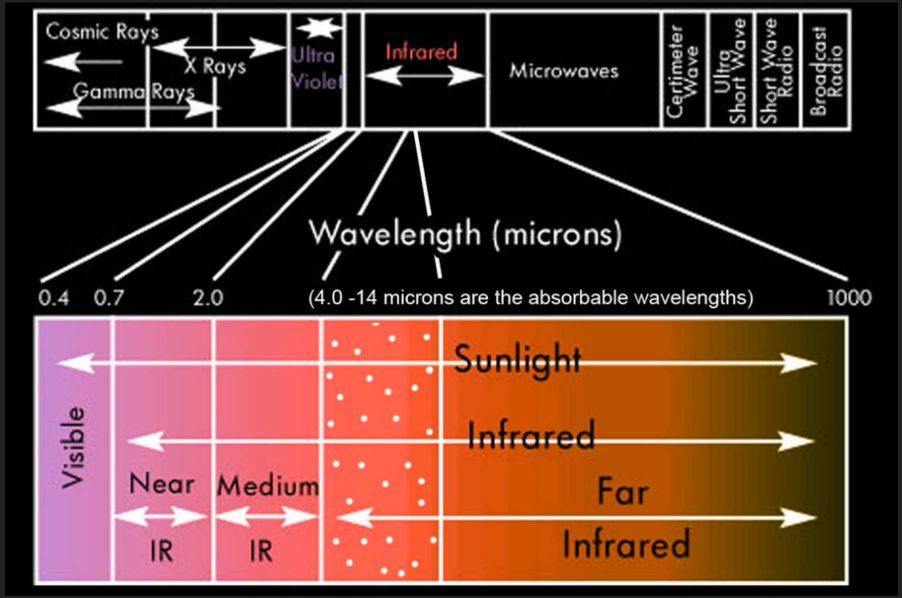
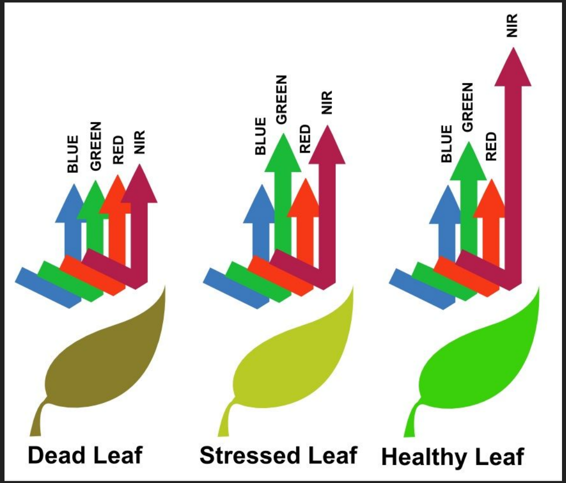


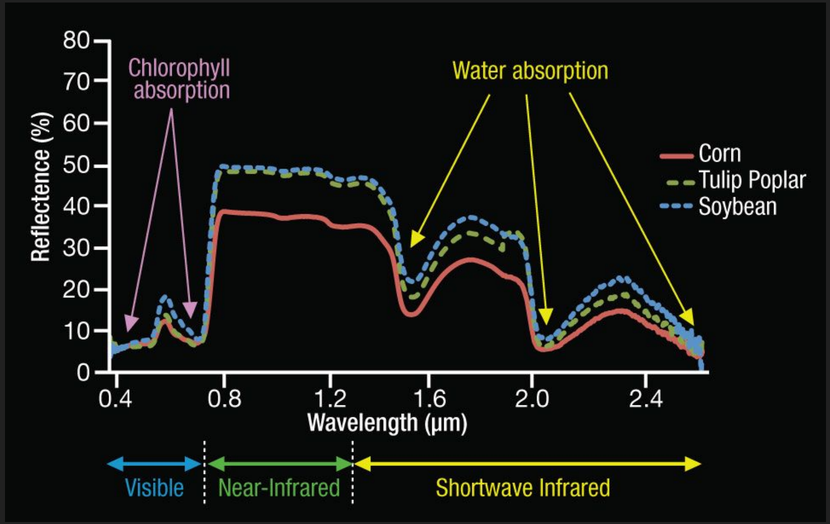
Infrared Camera and Image Processing

Keegan Kroll

Near-Infrared Photography

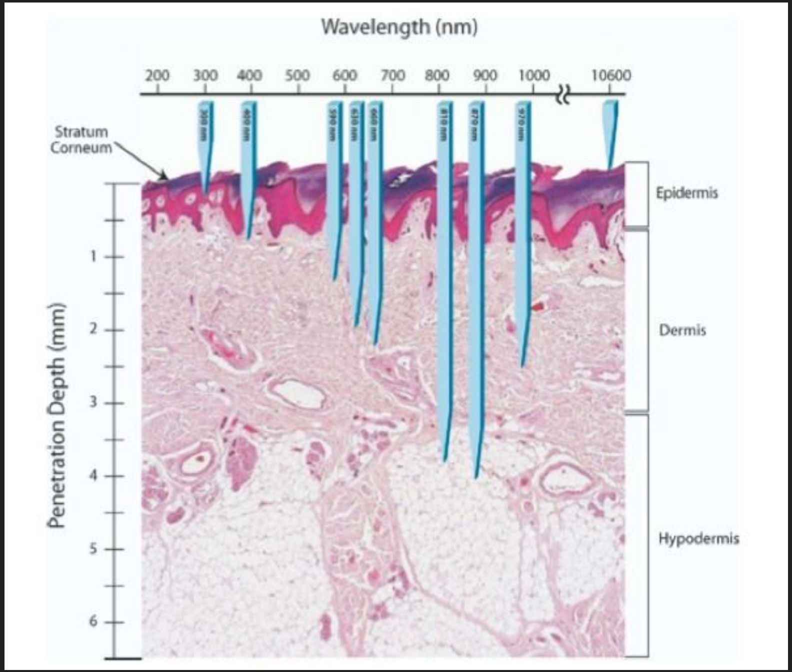


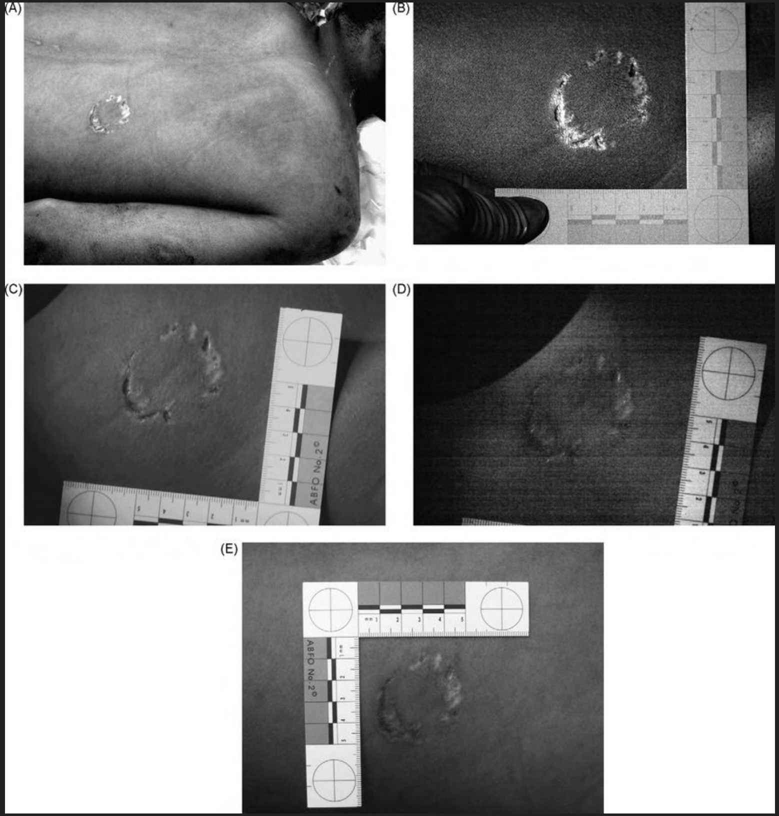




Near-Infrared and Aerochrome

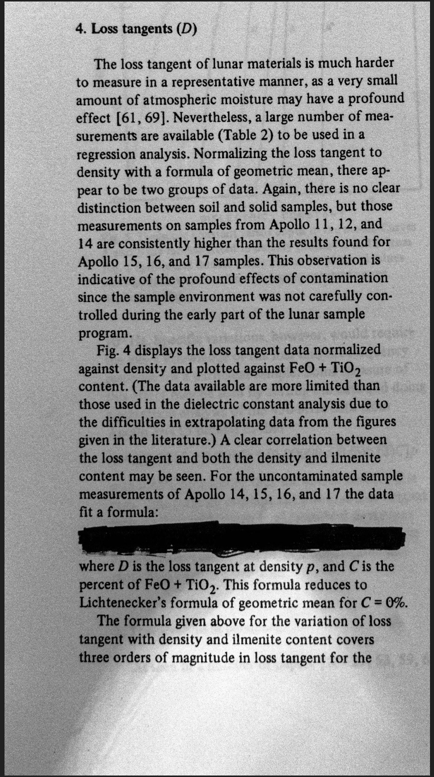
Near-Infrared Photography Applications





Near-Infrared Photography

Visible:



4. **Loss tangents (D)**

The loss tangent of lunar materials is much harder to measure in a representative manner, as a very small amount of atmospheric moisture may have a profound effect [61, 69]. Nevertheless, a large number of measurements are available (Table 2) to be used in a regression analysis. Normalizing the loss tangent to density with a formula of geometric mean, there appear to be two groups of data. Again, there is no clear distinction between soil and solid samples, but those measurements on samples from Apollo 11, 12, and 14 are consistently higher than the results found for Apollo 15, 16, and 17 samples. This observation is indicative of the profound effects of contamination since the sample environment was not carefully controlled during the early part of the lunar sample program.

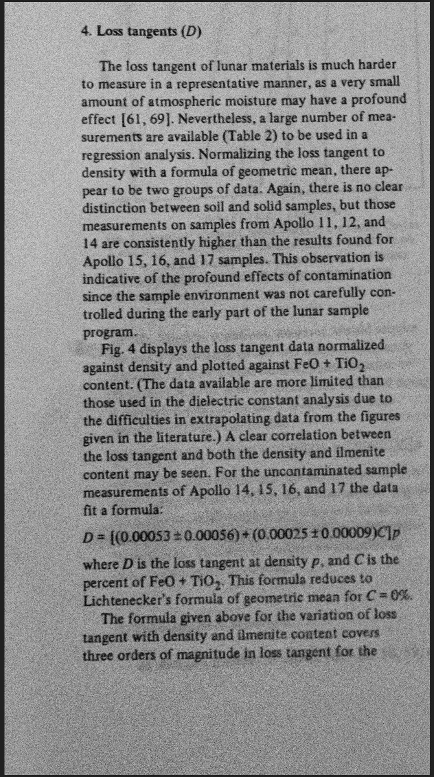
Fig. 4 displays the loss tangent data normalized against density and plotted against FeO + TiO_2 content. (The data available are more limited than those used in the dielectric constant analysis due to the difficulties in extrapolating data from the figures given in the literature.) A clear correlation between the loss tangent and both the density and ilmenite content may be seen. For the uncontaminated sample measurements of Apollo 14, 15, 16, and 17 the data fit a formula:

[redacted]

where D is the loss tangent at density p, and C is the percent of FeO + TiO_2. This formula reduces to Lichtenecker's formula of geometric mean for C = 0%.

The formula given above for the variation of loss tangent with density and ilmenite content covers three orders of magnitude in loss tangent for the

Infrared:



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$$D = [(0.00053 \pm 0.00056) + (0.00025 \pm 0.00009)C]p$$

where D is the loss tangent at density p, and C is the percent of FeO + TiO_2. This formula reduces to Lichtenecker's formula of geometric mean for C = 0%.

The formula given above for the variation of loss tangent with density and ilmenite content covers three orders of magnitude in loss tangent for the

Visible:

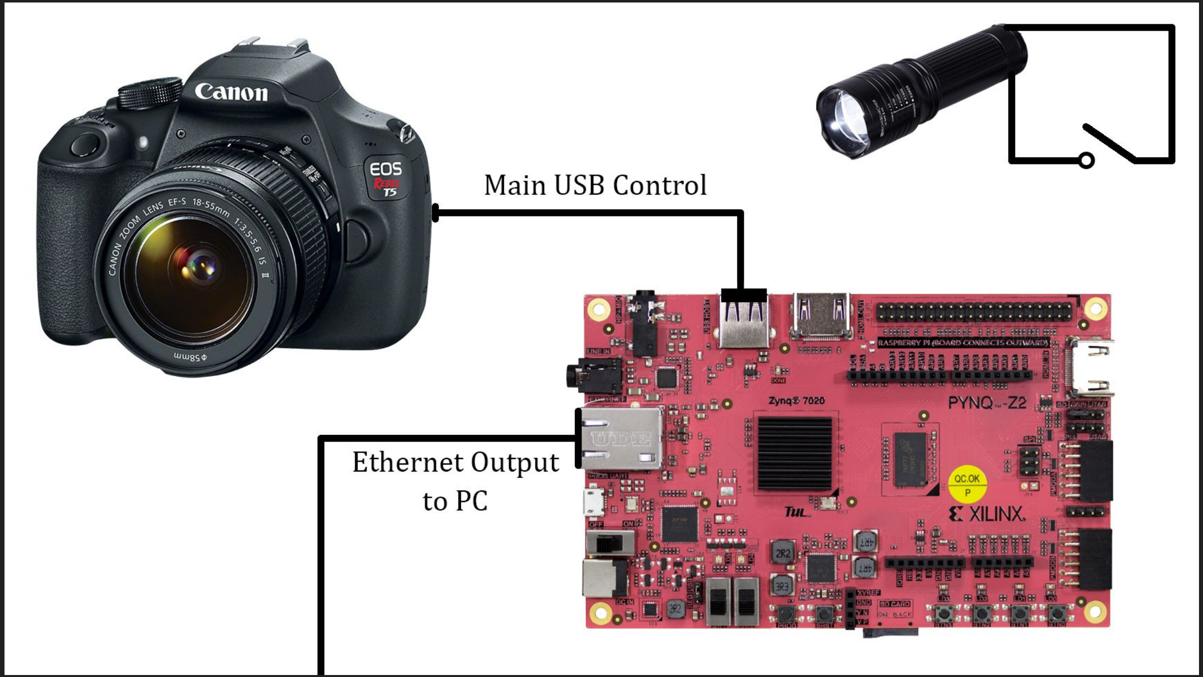
Infrared:

Project Design

Code Start:

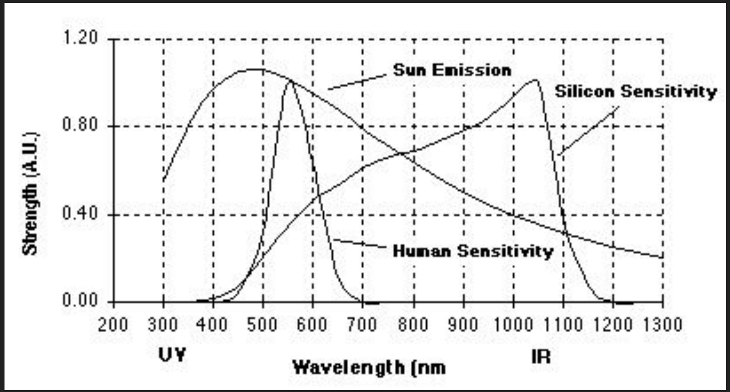
1. Camera
    a. Auto Focus
    b. Flash
    c. Shutter
2. Board
    a. Load Photo
    b. Process Multiple Ways
    c. Export and Display

Code End.



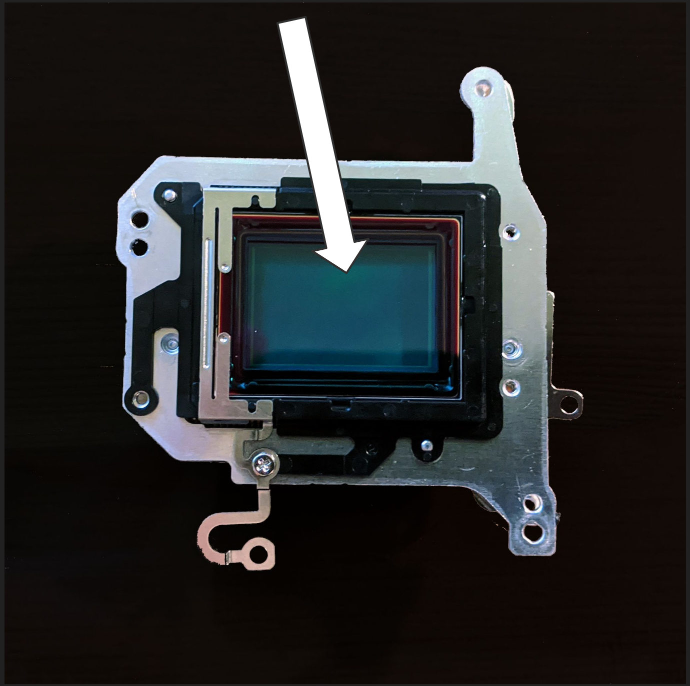
Project Specifications

Camera Type	Modified Canon EOS 1200D
Camera Output	RAW (.CR2), 5,184 × 3,456 Resolution
IR Filter Wavelength	760 nm to 1,200 nm
PYNQ Output	.PNG, 5,184 × 3,456
External Flash Wavelength	850 nm

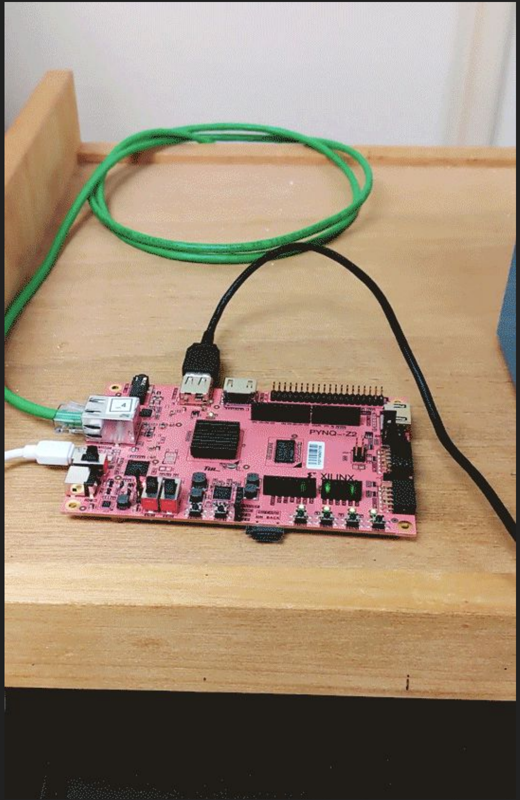


Camera Full-Spectrum Conversion

UV/IR Cut Filter



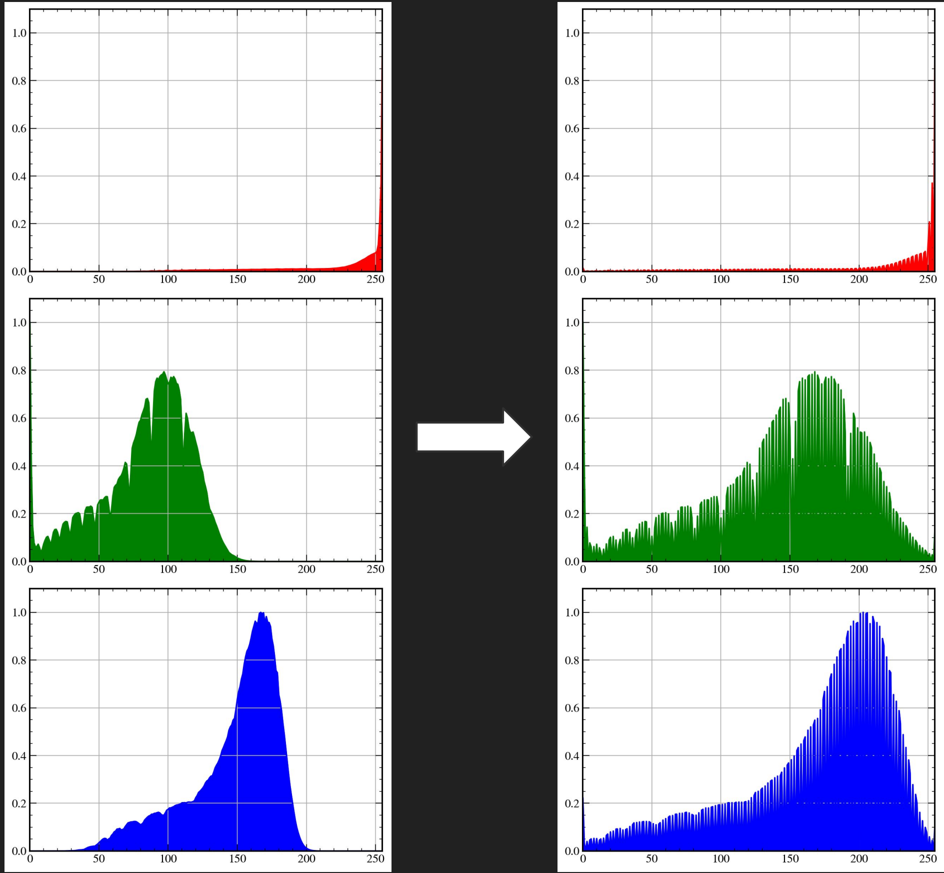
Board Controlled Features



Auto White Balance

Most important processing step for IR photos

```python
## AUTO WB ##
def auto_WB(RGB):
    wbalanced = np.zeros_like(RGB)
    colors = ("r", "g", "b")

    for i in range(3):
        hist, bins = np.histogram(RGB[..., i].ravel(), 256, (0, 256))

        bmin = np.min(np.where(hist>(hist.sum()*0.0005)))
        bmax = np.max(np.where(hist>(hist.sum()*0.0005)))

        wbalanced[...,i] = np.clip(RGB[...,i], bmin, bmax)
        wbalanced[...,i] = (wbalanced[...,i]-bmin) / (bmax - bmin) * 255

        hist, bins = np.histogram(wbalanced[..., i].ravel(), 256, (0, 256))

    return wbalanced
```



Discard 0.05% of histogram on each side and “stretch” remaining colors

Auto White Balance

Original

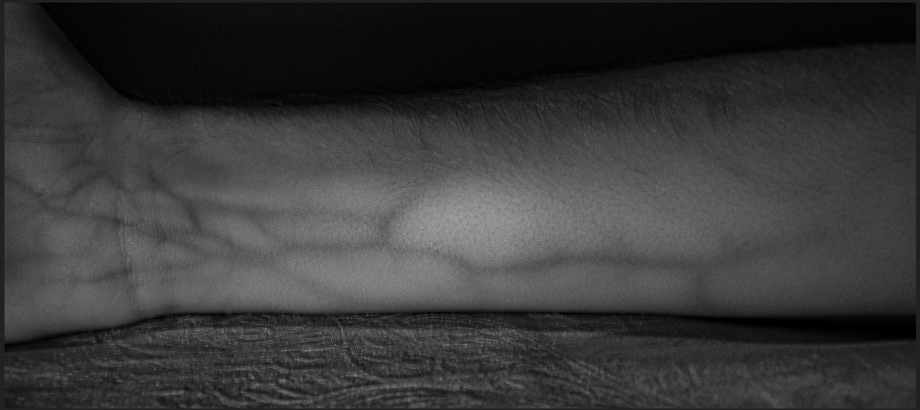
White Balanced

Further Processing

Red-Blue Channel Swap

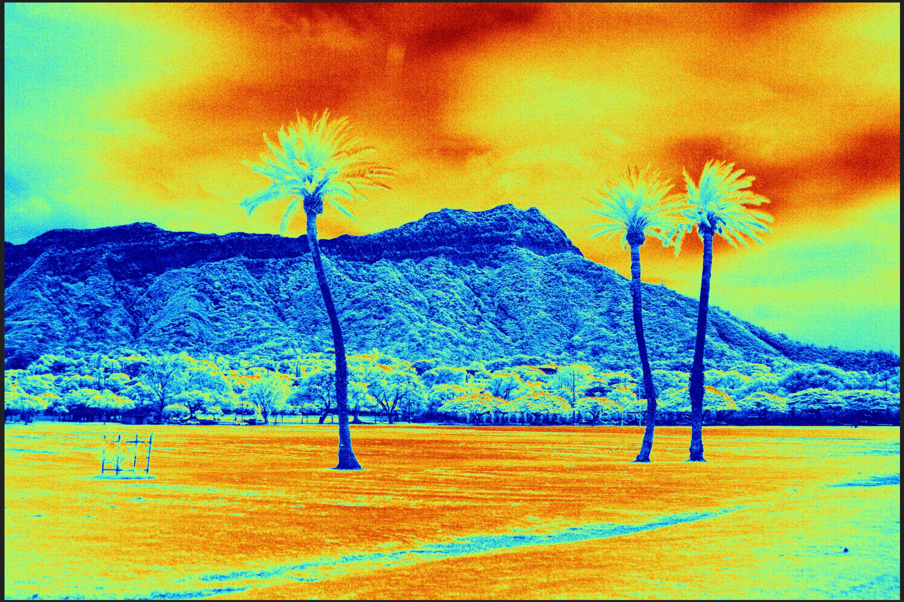
Further Processing

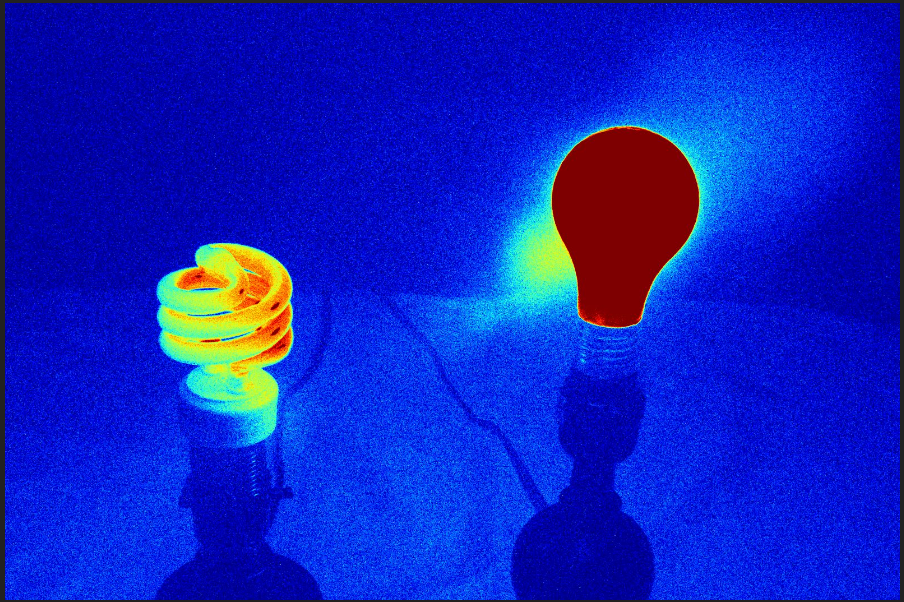
High-Contrast Black and White



Further Processing

Pseudo-Thermal

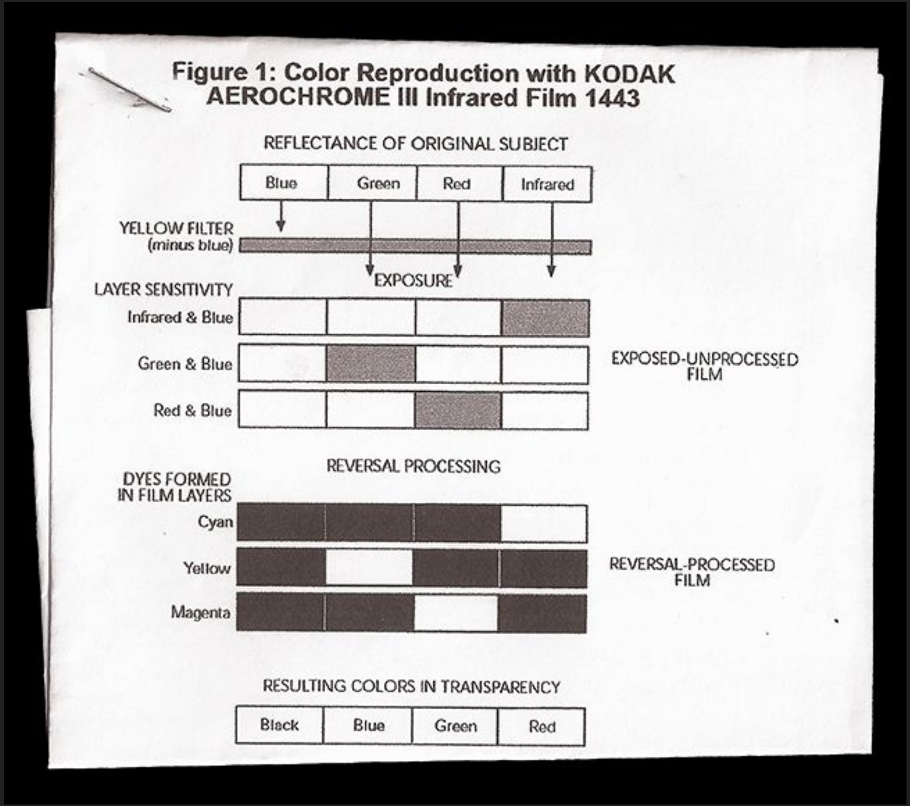




Further Processing

Night Vision (Inverted)

Aerochrome: Digital Recreation



Aerochrome: Digital Recreation

R-B & B-G
Channel Swap

Aerochrome Digital Recreation

Plant Health Analysis


Questions?