Overview

• The need for better calibration
• Understanding Camera Linearity
• Synthetic Magnitudes
• Performance
• Future Prospects
• Watec 902 Ultimate Cameras with gamma=LO
Why Revisit Calibration?

• Prompted by new color camera system
• Everything improves as calibration gets better
The Calibration Problem

• Typical calibration model is derived from reference stars, frequently parameterized as

\[ M_{\text{cat}} - M_{\text{raw}} = zp + \kappa \times \chi + CC \times (B - V) \]

Extrapolating this to meteor photometry is not always trivial
## The Calibration Problem

<table>
<thead>
<tr>
<th>Property</th>
<th>Reference Stars</th>
<th>Meteors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cameras</td>
<td>Linear CCD</td>
<td>Nonlinear video</td>
</tr>
<tr>
<td>Filters</td>
<td>UBVRI or ugriz</td>
<td>Unfiltered</td>
</tr>
<tr>
<td>Spectra</td>
<td>Thermal</td>
<td>Line dominated</td>
</tr>
<tr>
<td>Brightness range</td>
<td>Sweet spot</td>
<td>Very bright to very faint</td>
</tr>
</tbody>
</table>

Without proper linearity and color corrections, we do not know how wrong we are.
How bad is it?

Segregation between red and blue stars: 0.5 mags

What is the color of a meteor?
Just what does it mean when we say gamma=0.45?

TESTING THE GAMMA CORRECTION
Testing the Linearity

• We performed two sets of tests to check the response of the camera
  – NASA’s video calibration lab
  – LED with brightness controlled by an Arduino computer board
  – Total cost of LED setup is ~$100 and a few hours to run tests

• All tests done at ‘field’ settings
LED Test Results

- Linear and power-law components
- Power-law is consistent with gamma=0.45
- Eight cameras tested – results did vary
Setting our own standards

SYNTHETIC MAGNITUDES
Synthetic Magnitudes

- Do not transform the meteor flux into a standard system
- Instead, bring the reference stars into your detection system
- Calculations are easy to do with PySynPhot from STSci
- Need to use 3-part spectral types (e.g. G2V) whenever possible
Bandpasses

Sky 2000 catalog + bandpass models allow us to create 5-filter reference catalog normalized to Vega

Caveat: We do not have the equipment to measure the bandpasses ourselves
Utilizing our new synthetic magnitude catalog and gamma correction

PERFORMANCE WITH VIDEO DATA
Unfiltered

- ZP uncertainty is \(~ 0.06\) mag
- Systematics: 0.18 per star
- Accounts for systematic/modeling uncertainties in bandpass shape and stellar spectra, determined using wide field CCD observations
R-band

- ZP uncertainty is ~ 0.10 mag
Limiting Factors

• Better reference star data: assuming single spectrum for each spectral type is a modeling deficiency
• Better synthetic magnitudes: measure bandpasses in lab
• Saturation correction has not been determined
Conclusions

• Lab tests have helped to greatly improve our photometric calibration

• Specifically addresses linearity and color term systematics

• Test cameras at field settings before deployment— the results might surprise you
Acknowledgements

• Walt Lindblom in Video Calibration Lab
• Space Telescope Science Institute for SynPhot
• The rest of the MEO for supporting this effort