Roman SNe Calibration Requirements

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Roman Science Requirements: Type Ia SNe

Stage IV Dark Energy Experiment (DETF definition)
FOM should be 10x larger than Stage II

Roman Science Requirements Document:
Dark Energy Figure of Merit (FoM):

\[ \text{FoM}_{SNe} \geq \frac{\text{FoM}_{SNe,Ref}}{2} = 325 \]

where the reference FoMSNe,Ref \sim 650
Roman Science Requirements: Type Ia SNe

Most significant systematic effects are Count Rate Non-linearities & Zeropoints (Flux calibration)

Effect of systematic uncertainties on the SNe FoM. From Hounsell+ 2018
Roman Calibration

• Per-component transmission knowledge should be available
• No pre-flight, end-to-end, full aperture calibration
• No in-flight built-in end-to-end monitoring
=> Rely on standard stars monitoring & Relative Calibration System
WFI Calibration Activities

**Detector Calibrations**
- Darks for Imaging
- Darks for Spectroscopy
- Pixel-level Flat Field
- Subpixel response
- Read noise / correlation
- Classic non-linearity
- CRNL: Lamp-on/lamp-off
- CRNL: Direct Illumination
- Unstable Pixels
- Persistence
- Burn-in
- Gain
- Inter-pixel Capacitance (Linear)
- Inter-pixel Non-linearities

**Imaging Calibration**
- Photometric Uniformity (large-scale)
- Photometric Uniformity (small-scale)
- Bandpass Uniformity
- Temporal stability (touchstone)
- Spectrophotometric Response (absolute flux)
- Cross-Survey Calibration
- Geometric Distortion
- Absolute Astrometry
- PSF calibration

**Spectroscopic Calibration**
- Pointing Reconstruction
- Wavelength Zeropoint
- Dispersion Solution
- Trace Calibration
- Flux Calibration (position)
- Flux Calibration (wavelength)
- Spectrophotometric Stability
- Spectral PSF
Count rate non-linearity (CRNL) requirements

• 10% of the SN FoM is allocated to CRNL

=> knowledge: 0.3%
  • for count rates from 0.3 e/sec to $\sim 10^4$ e/sec i.e. 26 mag to 15 mag

=> If uncorrected, CRNL affects luminosity distance determination through
  • filter zeropoints & absolute color

=> Laboratory & in-flight measurements show that CRNL exhibits spatial variation over a detector

See also Greg Mosby’s presentation
In Flight: RCS: Relative Calibration System

lamp-on/lamp-off illumination
- provides stable pedestal flux above sky
- capability to set pedestal flux between a few to \( \sim 1000 \) e-/sec.
- measurements are made for source-affected pixels
- provides *averages per detector* for range of flux levels
- established analysis method
- flight heritage (HST/NICMOS)

direct flat field illumination
- illuminates focal plane at range of flux/wavelengths between 0.3 & 10000 e-/sec/pix
- precise knowledge of the ratio of any two flux levels
- enables local measurement of CRNL
  - e.g. superpixels of \( N \times N \) pixels
  - determination of spatial structure in CRNL

The RCS is the WFI on-board calibration hardware, designed to illuminate the focal plane with LEDs at six wavelengths approximately matching the filter set (see Josh Schlieder’s slides)
## Impact of LOLO and DI on Figure of Merit

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<th>Scenario</th>
<th>Figure of Merit Relative to Old Baseline of LOLO (F) + Direct (RZYjHF)</th>
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<td>No RCS</td>
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<tr>
<td>LOLO Only (WF)</td>
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<td>LOLO Only (RZYjHF)</td>
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<td>LOLO (WF) + Direct (Y)</td>
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<td>LOLO (WF) + Direct (ZJ)</td>
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<td>LOLO (WF) + Direct (RZJ)</td>
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<td>LOLO (RZYjHF) + Direct (RZY)</td>
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<td>LOLO (RY) + Direct (ZY)</td>
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- Simple fisher-matrix code (e.g., Astier+ 2011 A&A, 525A, 7A) for range of RCS scenarios.
- Considered a) DI only, b) LOLO only, c) both
- The dashed vertical line represents a 10% margin on the baseline FoM.
- When using LOLO with the W146 filter, we assume we can also use the LEDs for the Z087, Y106, J129, H158, and F184 filters.
- LOLO in W146 less effective than direct-illumination at these wavelengths, as it does not extend to as low count rates as DI (from Deustua+ 2021, RNAAS)
SNe Calibration Requirements: Photometric accuracy

From Science Requirements:
- 0.3% between 0.3 and 25000 e-/sec in a bandpass (11 mags)
- 0.5% for the ratio of any two bands

Essential:
- **SI system** calibration scale; not just a consistent system => cross calibration
- **Slope:** flux scale vs wavelength
- **Absolute Color:** broadband band-to-band zeropoint

Nice to have: knowledge of the absolute flux scale
Improving Spectrophotometric Calibration

• More standards with physics-based calibrations (NIST traceable): Vega, Sirius, Sun and CALSPEC stars to ~2 microns
  • NISTStars - Vis + NIR (NIST & STSCI, Deustua et al)
  • SCALA - Visible (LBNL & UH Aldering et al)
  • StarDICE - Visible (IN2P3, Herzenberg)

• More spectral types: DAWD, cooler, redder and fainter WD, A, G stars (matched to CALSPEC scale)
  • Gordon et al, Bohlin et al, Krick et al (to 8 microns)
  • Tremblay et al, Maiz Apellaniz et al, Suzuki et al (to 1.7 microns)

• More faint (~19 mag) WD standards on CALSPEC system
  • Calamida et al, Narayan et al.
  • Appleton & Deustua et al, Bohlin et al
end