Roman Wide-Field Instrument Reference Information

January 25, 2021

Information here pertains to the design early in Phase C

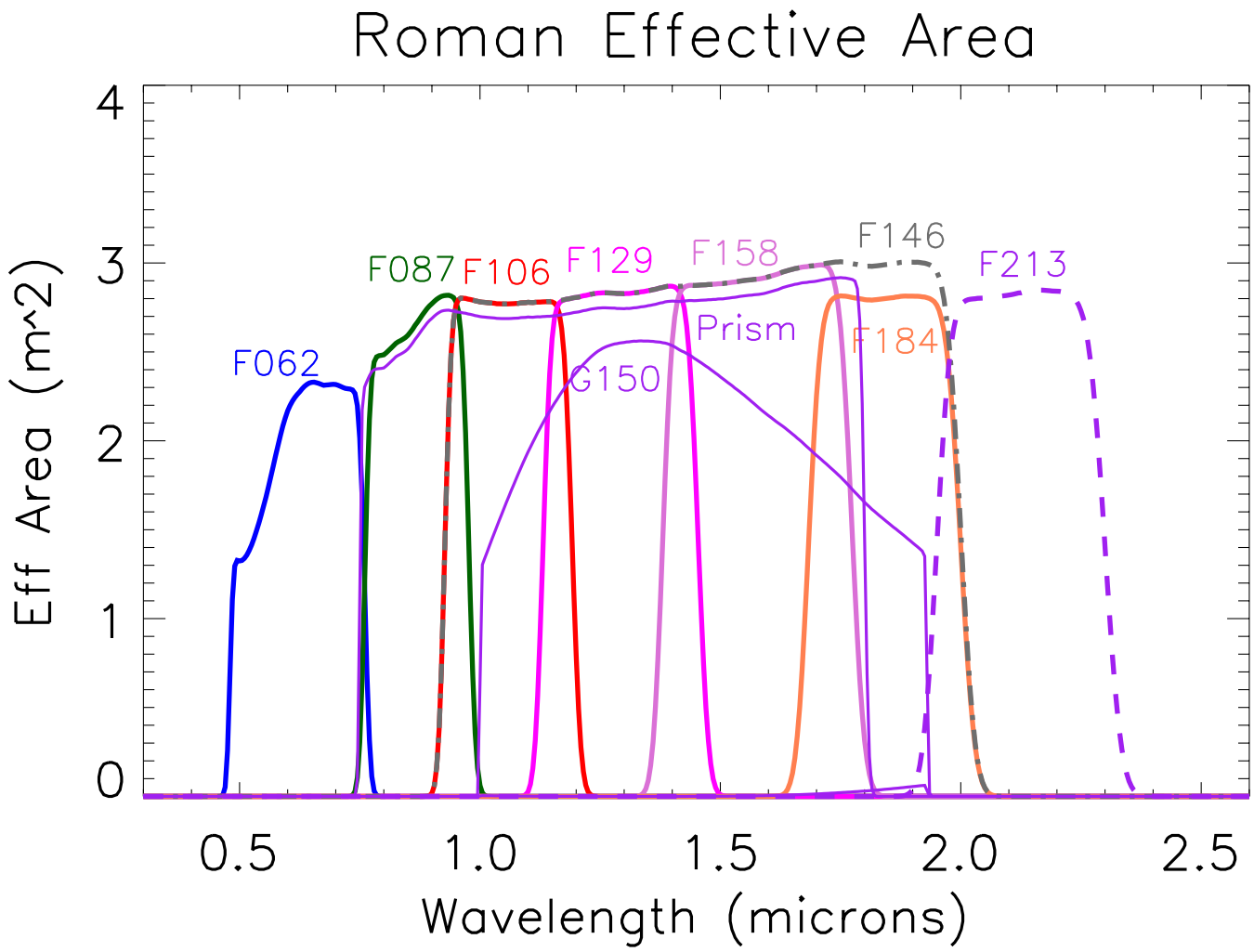
Wide-Field Instrument Overview

- Large imaging field of view (FOV) (0.8° x 0.4°)
- Spatial sampling: 0.11 arcsec/pixel; 288 Mpix focal plane
- Image stability: 1.0 nm RMS wave front error (WFE) variation in 180 sec
- Visible and Near-infrared (NIR) pass band (0.48 to 2.3μm)
- 8 imaging filters
- blank position for dark current, flat-field, and other calibrations w/internal light source
- Grating+prism (grism) for multi-object spectroscopy at medium spectral resolution
- Prism, lower-dispersion, for multi-object spectroscopy
- Guide star sensing interleaved with science data collection

WFI Filters and dispersers

Element name	Min (µm)	Max (µm)	Center (µm)	Width (µm)	R
F062	0.48	0.76	0.620	0.280	2.2
F087	0.76	0.977	0.869	0.217	4
F106	0.927	1.192	1.060	0.265	4
F129	1.131	1.454	1.293	0.323	4
F158	1.380	1.774	1.577	0.394	4
F184	1.683	2.000	1.842	0.317	5.81
F213	1.95	2.30	2.125	0.35	6.07
F146	0.927	2.000	1.464	1.030	1.42
G150	1.0	1.93	1.465	0.930	461λ(2pix)
P127	0.75	1.80	1.275	1.05	80-180 (2pix)

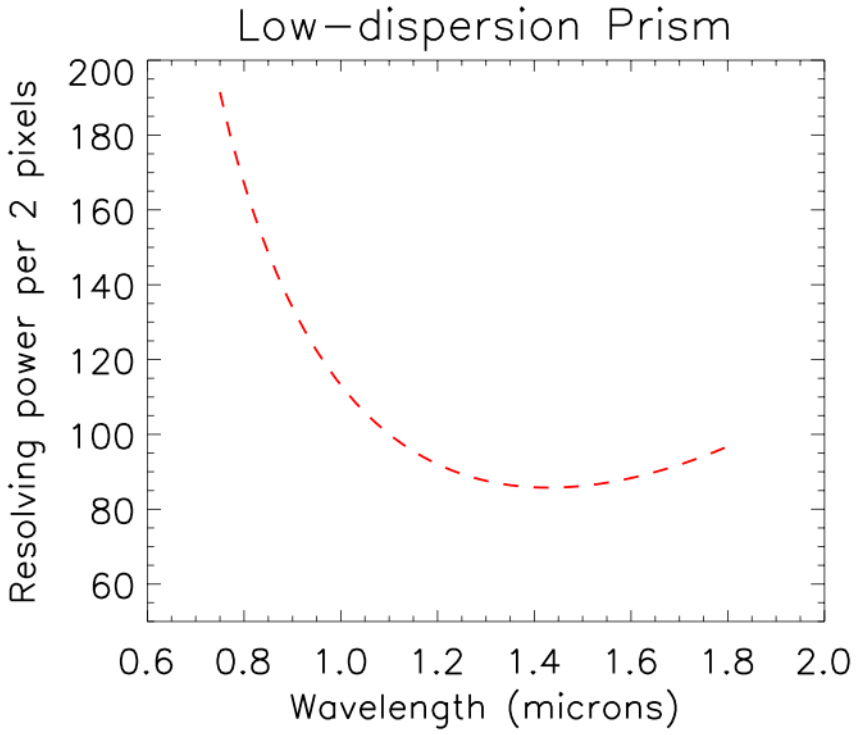
Effective area



Low-dispersion prism

- **The prism provides higher throughput and lower dispersion than the grism.**
- **The figure shows the resolving power per two pixels**
  - The FWHM of the LSF is ~2 pixels from 0.8-1.1μm and increases to ~3 pixels at either end of the spectrum.

Unlike the grism, which has constant dispersion and linearly increasing resolving power, the prism dispersion will vary with wavelength. The plot shows the dispersion at the center of the field, it varies slightly with field angle.



NIR detector characteristics

Representative values for flight candidate HgCdTe H4RG-10 detectors

Quantity	Spec. Value	Units	Typical actual
Dark Current	<0.1	e-/sec/pixel	<0.005
CDS Read Noise	<20	e- RMS	15-16
Total Noise in 180s		e- RMS	5-6
Quantum Efficiency	>80%	(avg 0.8-2.1µm)	~95%
Quantum Efficiency	>60%	(avg 0.6-0.8µm)	75-80%
Pixel operability	>95%	N/A	>99%
Total crosstalk	<12%	N/A	<8%

CDS noise is the RMS noise from the difference of two successive detector readouts
Total noise is uncertainty on slope fit for an exposure time of 180 sec

For more information on Roman detectors, see Mosby et al. 2020
https://doi.org/10.1117/1.JATIS.6.4.046001

NIR Detectors – inter-pixel capacitance

- **Inter-pixel capacitance**
  - Parasitic capacitance redistributes signal among neighboring pixels
  - Total flux is conserved, but:
    - correlates signal among pixels
    - Signal distribution is centered on pixel, not center of light
  - Useful references:
    - Moore et al 2006 Optical Engineering 45 076402
    - Fox et al 2009 PASP 121 743
    - Kannawadi et al 2016 PASP 128 095001

Results from sample of flight candidate detectors

Charge of 100 deposited in central pixel gives:		
0.20	1.90	0.21
1.84	91.19	1.82
0.22	1.98	0.22

Note that effect is not symmetric.
Individual detectors may exhibit greater asymmetry.

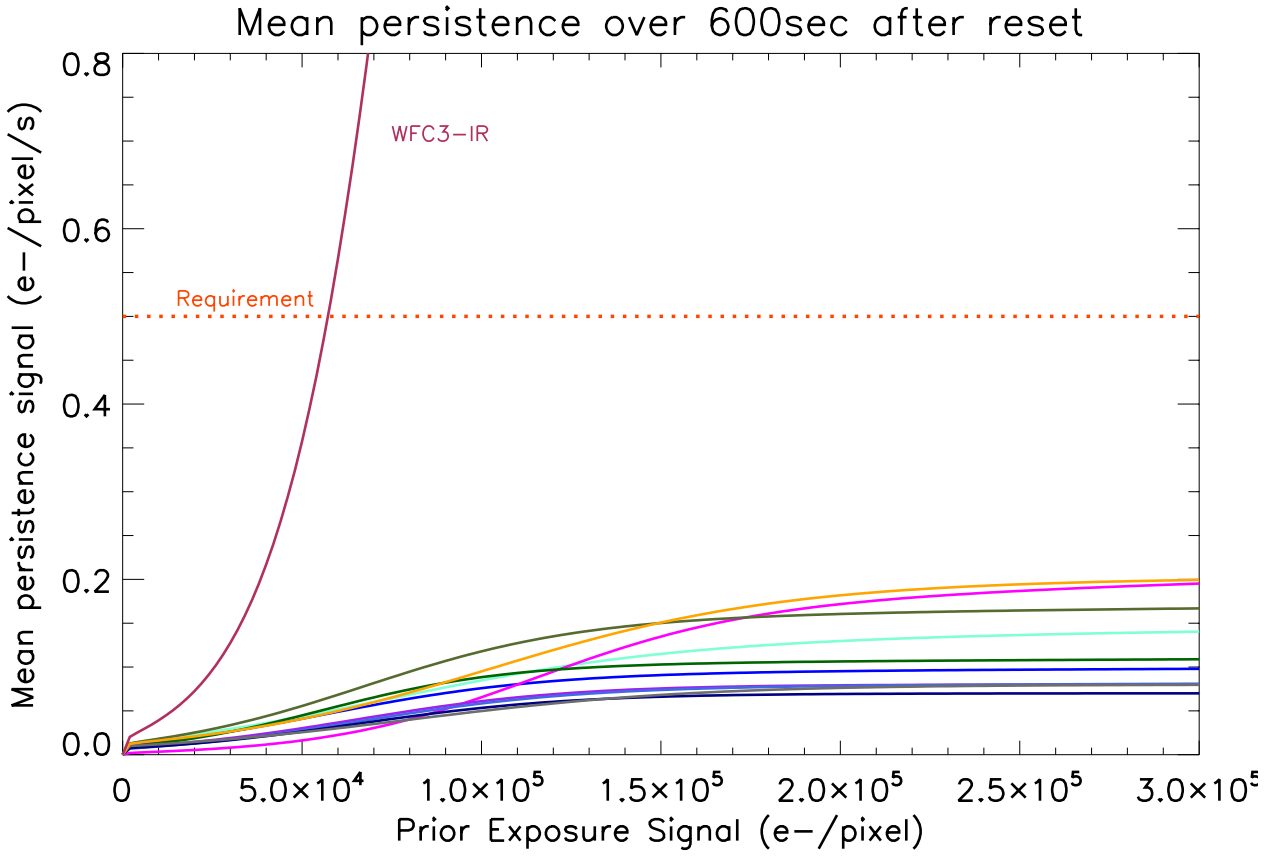
NIR Detector Information - Persistence

- **Persistence in Roman H4RG qualitatively similar to that in WFC3-IR detector**
- **Long et al 2013 found the following empirical description for the persistence signal:**

$$P(x,t) = A\left(\frac{x}{x_0}\right)^{\alpha}\left(\frac{t}{1000}\right)^{-\gamma}\frac{1}{1+e^{(x_0-x)/\delta x}}$$

ISR 2013-07: Characterizing Persistence in the WFC3 IR Channel: Observations of Omega Cen
http://www.stsci.edu/hst/wfc3/ins_performance/persistence/

NIR Detector Information - Persistence

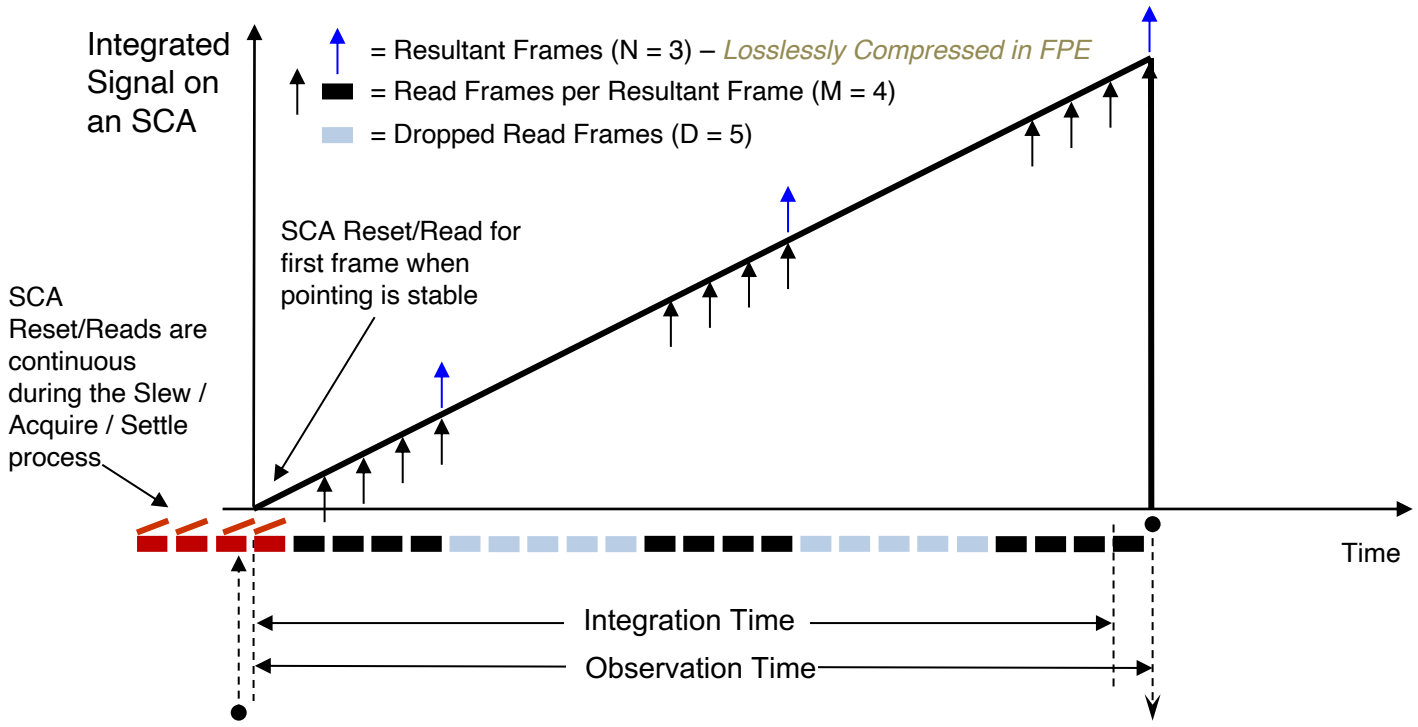


Persistence characteristics of the first 9 flight candidate detectors are plotted; all fall well below the requirement. The 6 flight SCAs received since this plot was made are similar.

WFC3-IR parameters from Long et al. (2013). The WFC3-IR persistence is 3.0-3.4 on this plot for prior signals > 1.x10^5 e-/pix

WFI multi-accum detector readout

- One of 18 parallel WF FPA detectors shown
- SCA reads are non-destructive (Read Only) after an initial stable Reset/Read
- Multi-Accum parameters are set based on Survey and Downlink requirements
- Multi-Accum commandable parameters: (sample settings shown in graphic)
  - M = # of frames averaged per resultant frame (black up-arrows)
  - N = # of resultant frames sent to ICDH (blue up-arrows; lossless compression in FPE)
  - D = # of read frames dropped between resultant frames



WFI Multi-Accum Cont.

- The periodic multi-accum sequence on the previous slide is an example. The actual implementation is table-driven, with the table specifying the operation to perform on each readout in the exposure. This enables logarithmic spacing of groups of reads, for example.
- The SCA readout employs 32 channels at a clock rate of 200kHz. Interleaving readout of a 16x16 pixel guide window every 256 rows of the full-frame readout gives a guide star update rate of ~5.8Hz and a full frame time of 3.04 seconds.

Variance estimate for multi-accum readout

$$\sigma^2_{total} = \frac{12(n-1)}{mn(n+1)}\sigma^2_{read} + \frac{6(n^2+1)}{5n(n+1)}(n-1)t_g f - \frac{2(m^2-1)(n-1)}{mn(n+1)}t_f f$$

σ^2_{total} = Total Variance for pixel

σ_{read} = Readnoise (1 read, not CDS)

m = number of used reads per group

d = number of 'dropped' reads per group

t_f = duration of 1 frame read

t_g = duration of group = $t_f \times (m + d)$

n = number of groups in integration

f = total flux in e-/sec

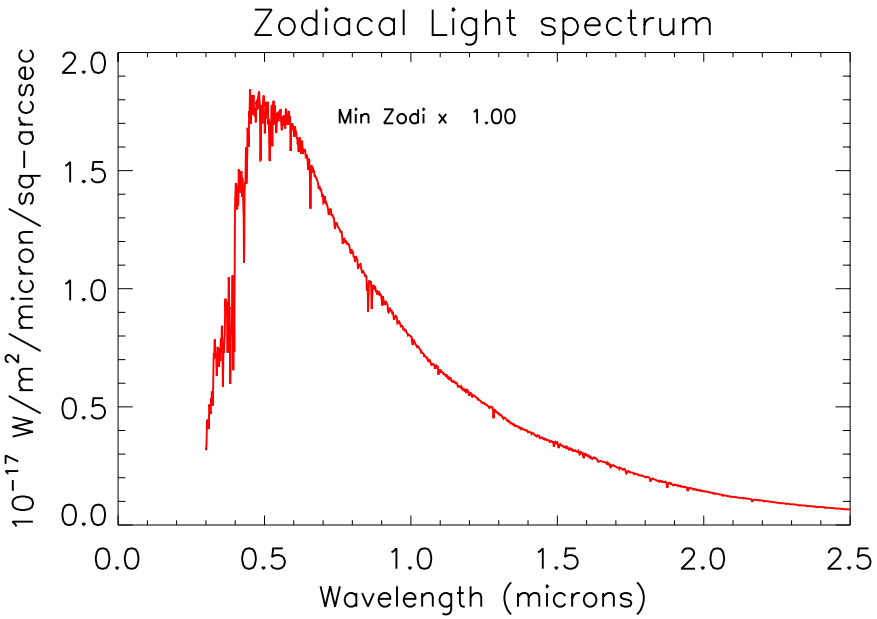
Ref: Rauscher et al. 2007 PASP 119 768

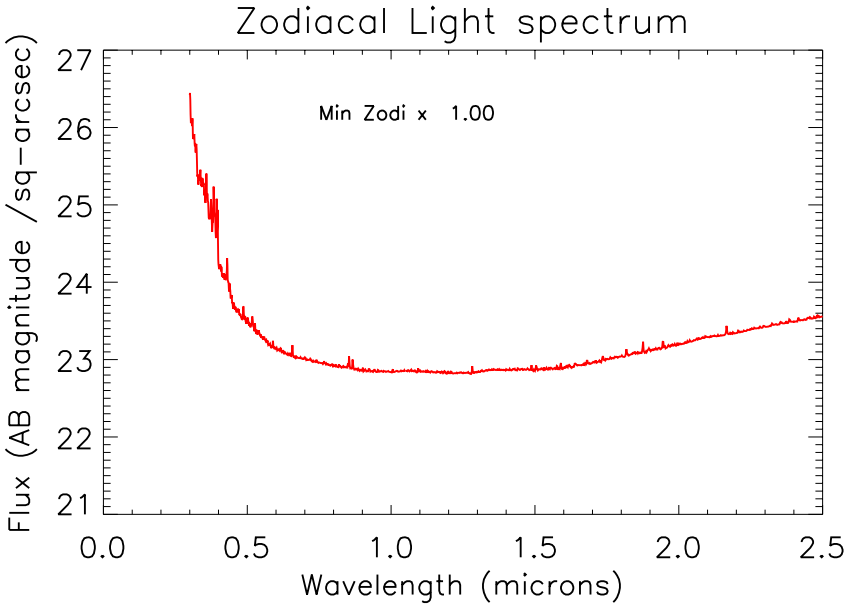
This is for Gaussian noise only!

Correlated noise requires 4th term: $\sigma^2_{noise\_floor}$

Presently assuming 5e- for σ_{noise_floor}

Zodiacal Light





Zodiacal light is sunlight scattered by dust.
Brightest in ecliptic plane, & brighter the closer the LOS to the Sun.

Typical Zodi intensity will be:
~1.5 x minimum in the HLS 2.5-7 x min for microlensing

Count rate per pixel at minimum zodiacal light									
F062	F087	F106	F129	F158	F184	F146	F213	Prism	Grism
0.27	0.27	0.29	0.28	0.26	0.15	0.85	0.13	0.95	0.65

Representative Continuum Sensitivity

Limiting point-source sensitivity (AB mag) in 1 hour of exposure time, Zodiacal light set at twice minimum.

Imaging, 5σ							
F062	F087	F106	F129	F158	F184	F146	F213
28.6	28.2	28.1	28.0	28.0	27.5	28.3	26.2

Spectroscopy, 10σ per pixel in continuum			
	0.8 μm	1.2 μm	1.5 μm
Grism	N/A	21.0	20.7
Prism	22.2	23.0	23.0

Representative Emission Line Sensitivity (grism)

Emission line flux detected at 6.5σ in one hour, with zodiacal light set at twice minimum.
Units are 10^{-17} ergs/cm^2/sec

Wavelength	Limiting flux for source half-light radius of 0, 0.2”	
µm	0.0”	0.2”
1.10	5.7	11.0
1.20	4.3	8.2
1.30	3.8	7.1
1.40	3.6	6.7
1.50	3.6	7.0
1.60	3.9	7.2
1.70	4.2	7.2
1.80	5.0	8.4