Laboratory testing and characterization of a hybrid fast/slow readout mode for the H2RG detectors in SCALES

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SCALES Project Goals

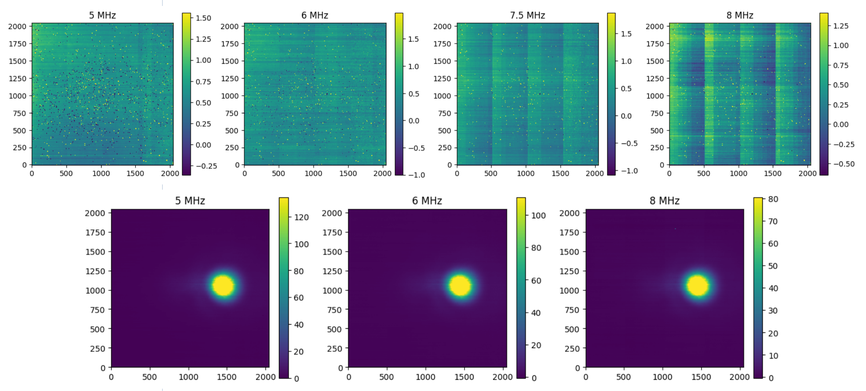
The upcoming SCALES (Slicer Combined with Array of Lenslets for Exoplanet Spectroscopy) instrument for W.M. Keck Observatory will enable new coronagraphic imaging and low-/mid-resolution IFS observations over the wavelength range from 2-5 microns. SCALES is optimized for exoplanet science and will enable new insights into colder and older exoplanet systems than are currently characterizable[1]. At the heart of the instrument are two HgCdTe Teledyne Imaging H2RG detectors, hardwired for slow mode operation (~100kHz pixel clock rate) with a fixed 4-channel readout. However, in ground-based operation at these wavelengths, such slow operation will accumulate a significant infrared background flux and reduce data quality.

To enable high quality observations without premature saturation on sky background, we operate the detectors using a Teledyne Imaging SIDECAR ASIC followed by an AstroBlank/Markury Scientific MACIE controller card, which allows the detector to be read out at faster pixel clock rates. This, in combination with the slow-mode H2RG, is what we characterize as hybrid fast-slow readout, enabling readout speeds at least 10 times greater than possible in slow-mode.

We test a novel hybrid fast/ slow readout mode for H2RG detectors to improve frame rates to avoid sky saturation during ground-based IR observations.

Detector Characterization in UCLA Test Cryostat

Fig. 1. Dark (top row) and Illuminated (source on - source off) (bottom row)
Imager CDS Results
Averaged over 10 results



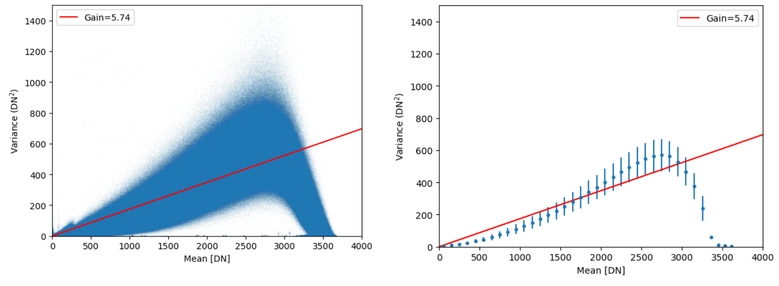


Fig. 2. Photon Transfer Curve for Imager detector, created using bias-subtracted UCLA data at a master clock rate of 5 MHz.

Variance and mean are computed temporally across 5 identical ramps.

Fig. 3. Dark (top row) and Illuminated (source on - source off) (bottom row)
IFS CDS Results
Averaged over 10 results

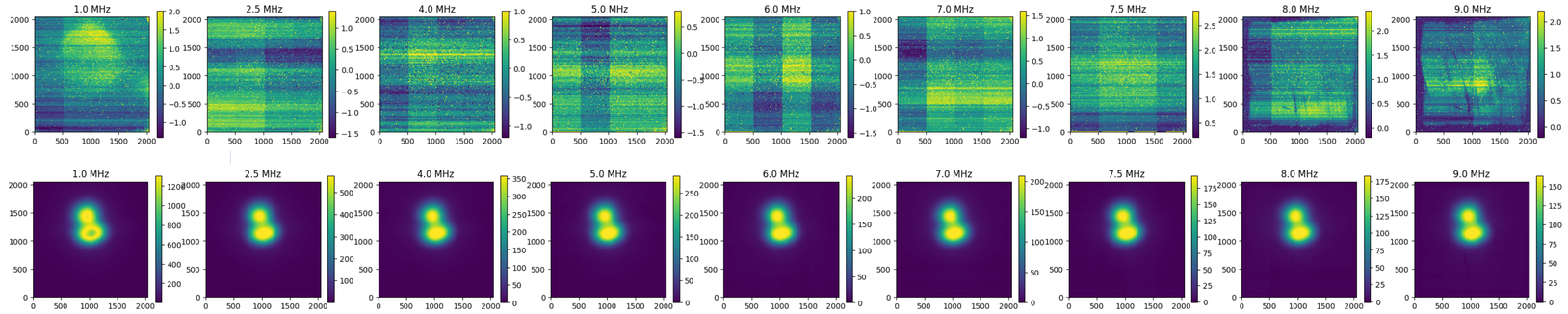


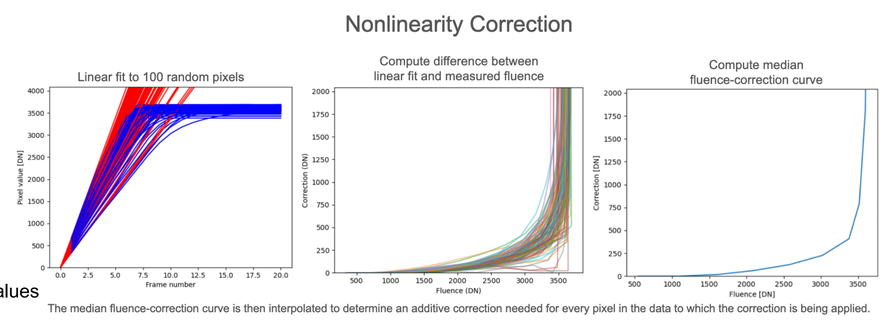
Table 1. CDS Noise

estimated as median of pixelwise standard deviation across N_frames CDS dark frames

Clock Rate (master, MHz)	Clock rate (Pixel, MHz)	Imager CDS Noise estimate (DN)	Imager CDS Noise estimate (e-)	IFS CDS Noise estimate (DN)	IFS CDS Noise estimate (e-)
5.0	1.0	1.751 *	10.05 *	0.598	3.432
7.5	1.5	0.857	4.919	0.675	3.875
8.0	1.6	0.775	4.449	0.676	3.880
9.0	1.8	1.394	8.002	0.656	3.765

* = N_{frames} =30
All others use N_{frames} = 10

The gain (in electrons/DN) is computed from the Imager photon transfer curves shown in Figure 2. Further testing of the IFS is necessary to experimentally determine its gain, and therefore the noise values in DN in the table above are converted to electrons using the experimentally determined Imager gain.



The median fluence-correction curve is then interpolated to determine an additive correction needed for every pixel in the data to which the correction is being applied.

Fig. 4. Demonstration of the nonlinearity correction derived from fully saturated ramps at a master clock rate of 5 MHz and determined to cosmetically improve data quality.

Timeline & Next Steps

As of summer 2025, testing of both detectors in the UCLA test cryostat is complete and has demonstrated satisfactory basic performance. The detector heads are currently being integrated with the rest of the SCALES instrument at University of California Observatories at UC Santa Cruz. The SCALES instrument is expected to be delivered to Keck Observatory for commissioning in 2026.

- 2022-Early 2024: Software development at UCLA using a MUX in place of H2RG detectors
- August 2024: Demonstration of cold performance of both detectors
- July 2024: H2RG detectors delivered to UCLA and installed in detector head hardware packages
- September-December 2024: Imager detector testing and characterization in UCLA test dewar
- January 2025: Imager detector delivered to UCSC for integration with SCALES instrument
- January-June 2025: IFS detector testing and characterization in UCLA test dewar
- June 2025: IFS detector delivered to UCSC for integration with SCALES instrument
- Late summer 2025: First simultaneous cryogenic operation of both detectors in SCALES instrument
- Late 2025: Pre-ship reviews and preparation of detector software for user-facing deployment
- Early 2026: SCALES commissioning and first light at Keck Observatory

Questions? Email pbenac@g.ucla.edu

REFERENCES

1. Skemer, A. J., et al. 2022, *Design of SCALES: a 2-5 micron coronagraphic integral field spectrograph for Keck Observatory.* SPIE Proceedings, Ground-based and Airborne Instrumentation for Astronomy IX.