Next Generation Scientific CMOS camera

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My work so far

- Working in the centre of Exoplanets and Habitability group at University of Warwick
- My research focusing mostly in instrumentation - studying sCMOS cameras
- Spent ~3 months in Andor Technology working in the R&D and Optical Product Engineering department
- Finding methods and techniques to optimise sCMOS cameras

Overview

- sCMOS Marana and iKon-L CCD
- sCMOS work and analysis
- Next steps at Andor
- Mission to Chile
- sCMOS vs CCD on sky - work in progress

sCMOS architecture

1. Photosensitive area /photodiode
2. On pixel amplifier to convert to voltage
3. Voltage is transferred to the column bus
4. Analog to digital signal conversion takes place
5. Final digitised signal is then readout

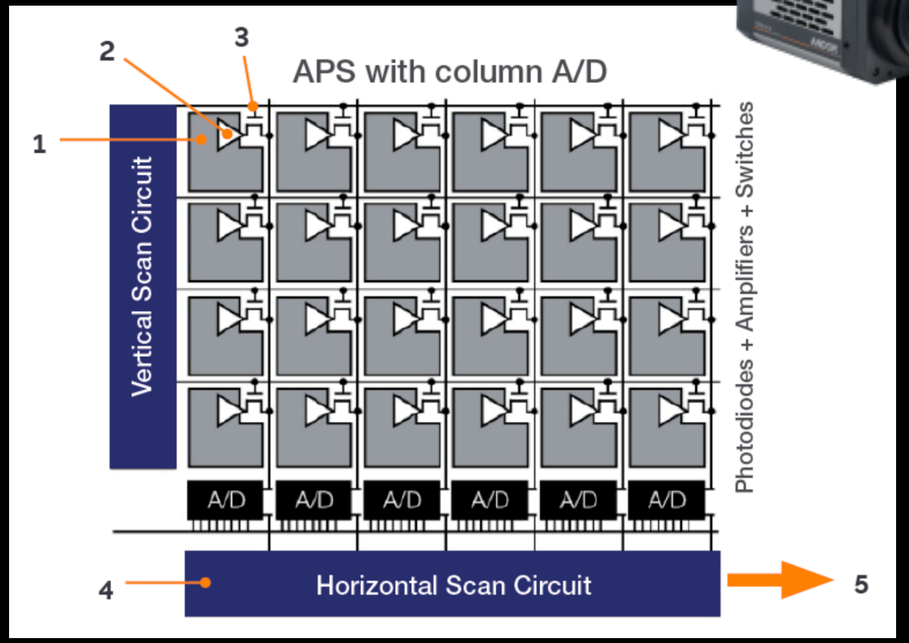


Image credit: Andor Technology

Marana sCMOS / iKon-L CCD

Sensor: Back-side illuminated GSENSE400 sensor from GPixel

Pixel size / sensor size: 11 x 11 um / 22.5 x 22.5 mm

Readout Rate: 100 / 200 MHz in HDR / FFR modes

Read Noise: 1.6 e-

Full Well Depth: 85000 e-

Dark current: 0.3-0.7 e-/pix/sec

Sensor: Back-side illuminated BEX2-DD deep depletion sensor from Teledyne e2v

Pixel size / Sensor size: 13.5 x 13.5 um / 27.6 x 27.6 mm

Readout Rate: 5 MHz

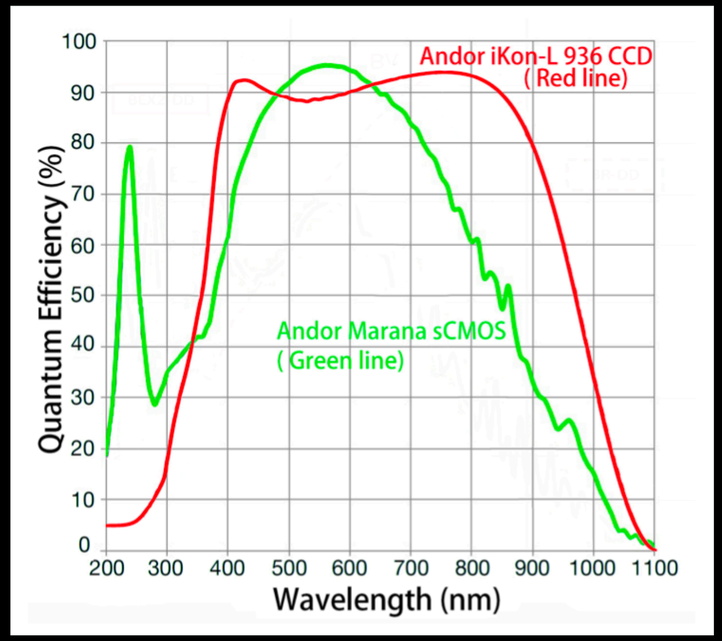
Read Noise: 2.9 e-

Full Well Depth: 100,000 e-

Dark current: 0.0003 e-/pix/sec

Deeper look

- Quickly compare the cameras (https://andor.oxinst.com/astronomy-calculator).
- We set for input the telescopic parameters of NGTS at Paranal Observatory such as f/#, Focal length, Telescope aperture and average seeing
- Both have up to >95% QE in the visible, image adapted by P. Qiu et al. (2021)



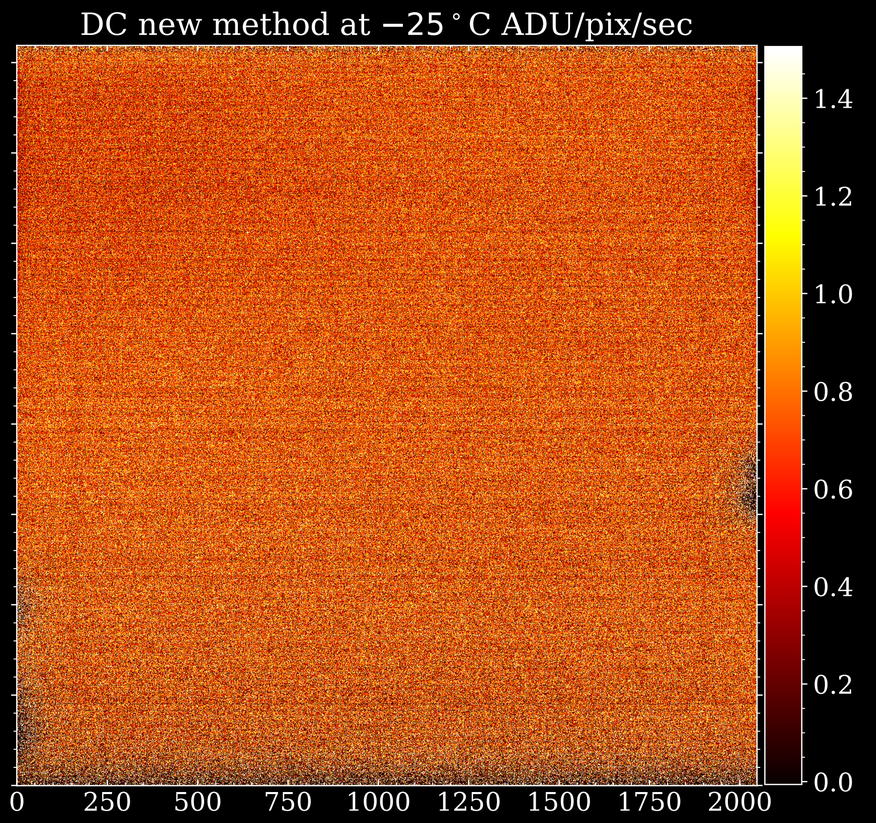
Andor Camera	Telescope Aperture (mm)	Focal Ratio (f/#)	Focal Length (mm)	CCD Size (mm) x	CCD Size (mm) y	Pixel Size (µm)	FOV (°) x	FOV (°) y	FOV (arcmin) x	FOV (arcmin) y	Image Scale (arcsec/pixel)	Calculated CCD Size (K) x	Calculated CCD Size (K) y	Telescope Focal Plane Image Size (mm) x	Telescope Focal Plane Image Size (mm) y	Approx. Min. Pixel Size (µm) to Avoid Over Sampling	Average Seeing (arcsec)	D of Image (mm), Square Sensor	D of Image (mm), Rectangular Sensor
Marana 4.2B-11	200	2.8	560	22.5	22.5	11	2.3	2.3	138.17	138.17	4.05	2.05	2.05	22.52	22.52	0.68	0.5	31.85	31.85
iKon-L	200	2.8	560	27.6	27.6	13.5	2.82	2.82	169.49	169.49	4.97	2.05	2.05	27.63	27.63	0.68	0.5	39.08	39.08

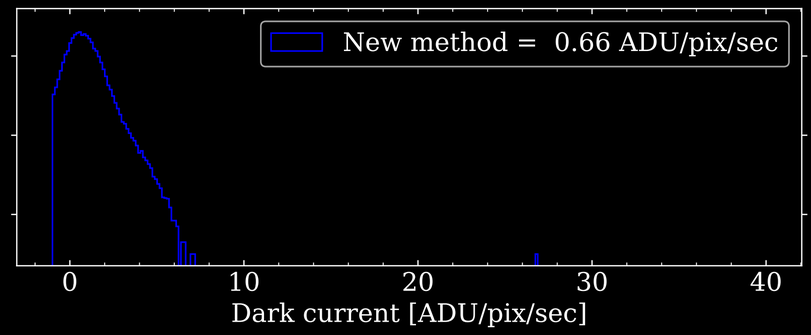
Extended Characterisation of Marana

- We characterise Marana for second time (and third and fourth time), while In Belfast
- The sCMOS comes with two modes: High dynamic range (16-bit) / Fastest frame rate (12-bit)
- Photon transfer and Linearity curves to obtain the input-to-output signal behaves
- Measuring the sensitivity and the maximum capacity (FWC) of each pixel
- Measuring the Read Noise of the camera
- Study the responsiveness of the pixels by measuring the Photon-Response Non-uniformity (PRNU)
- Study Dark signal Non-uniformities (DSNU) and dark current

What do we get?

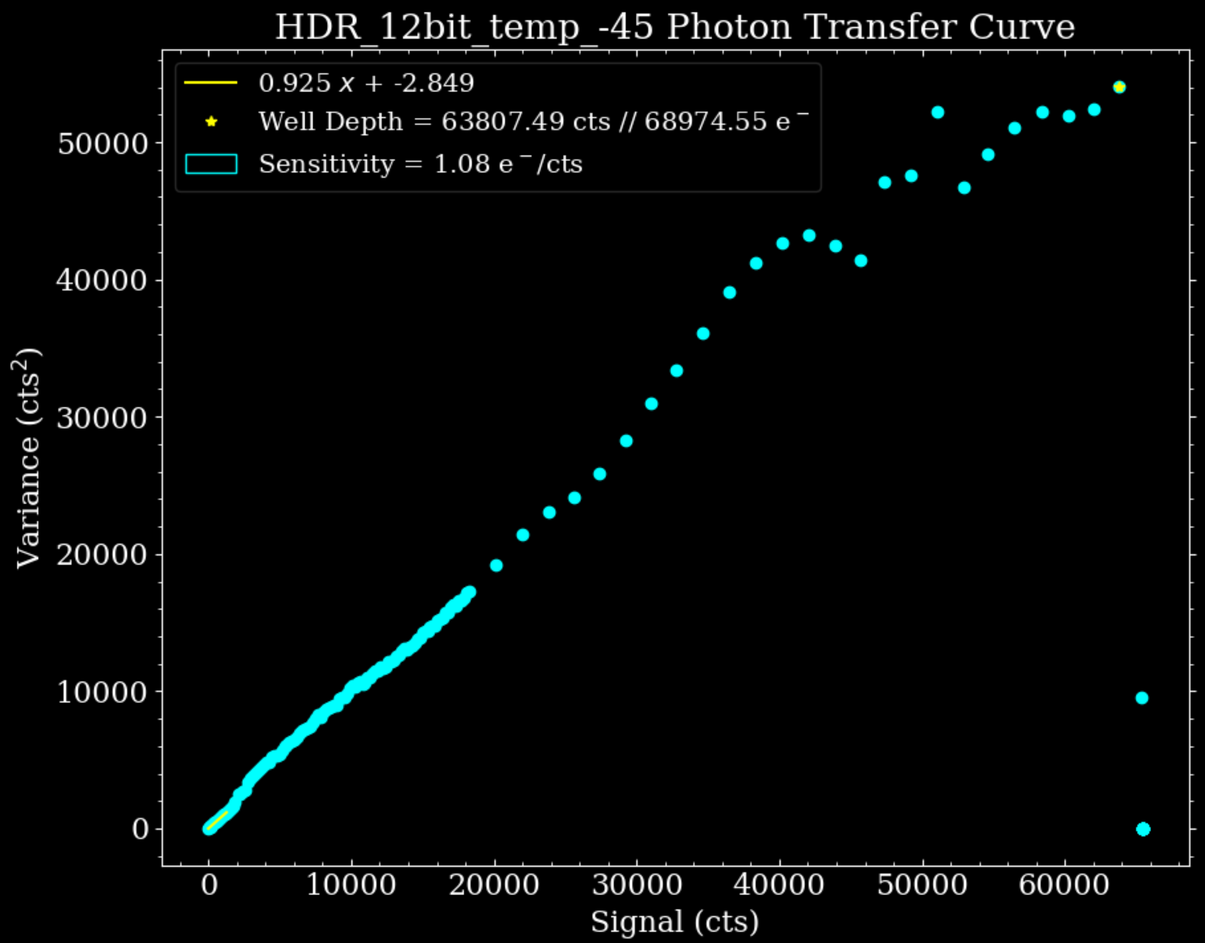
- The DSNU was found to be less than an electron (0.3 e-)
- The PRNU is also small (0.11%)
- Read Noise of (1.61 e-)
- The Dark current was found to be ~0.7 e-/pix/sec @-25 degrees across the full frame image





What do we get?

- Linearity and linearity error (fitted for 5-95% of the range) of the camera seems to be consisted with the results from Warwick (LE = 0.27%)
- PTC yields a sensitivity (or gain) of 1.08 e-/cts
- FWC at ~69000 e-



Plans for the next visit at Andor

- The next visit will take place after the trip in Chile
- Set up Quantum Efficiency apparatus and the control software
- Measure QE and Transmission for Marana
- Directly compare our results with GPixel
- Reduce Dark current by reducing the glow
- Adjust the Supply voltage (drain-to-drain) of the camera

QE set up (from last updates)

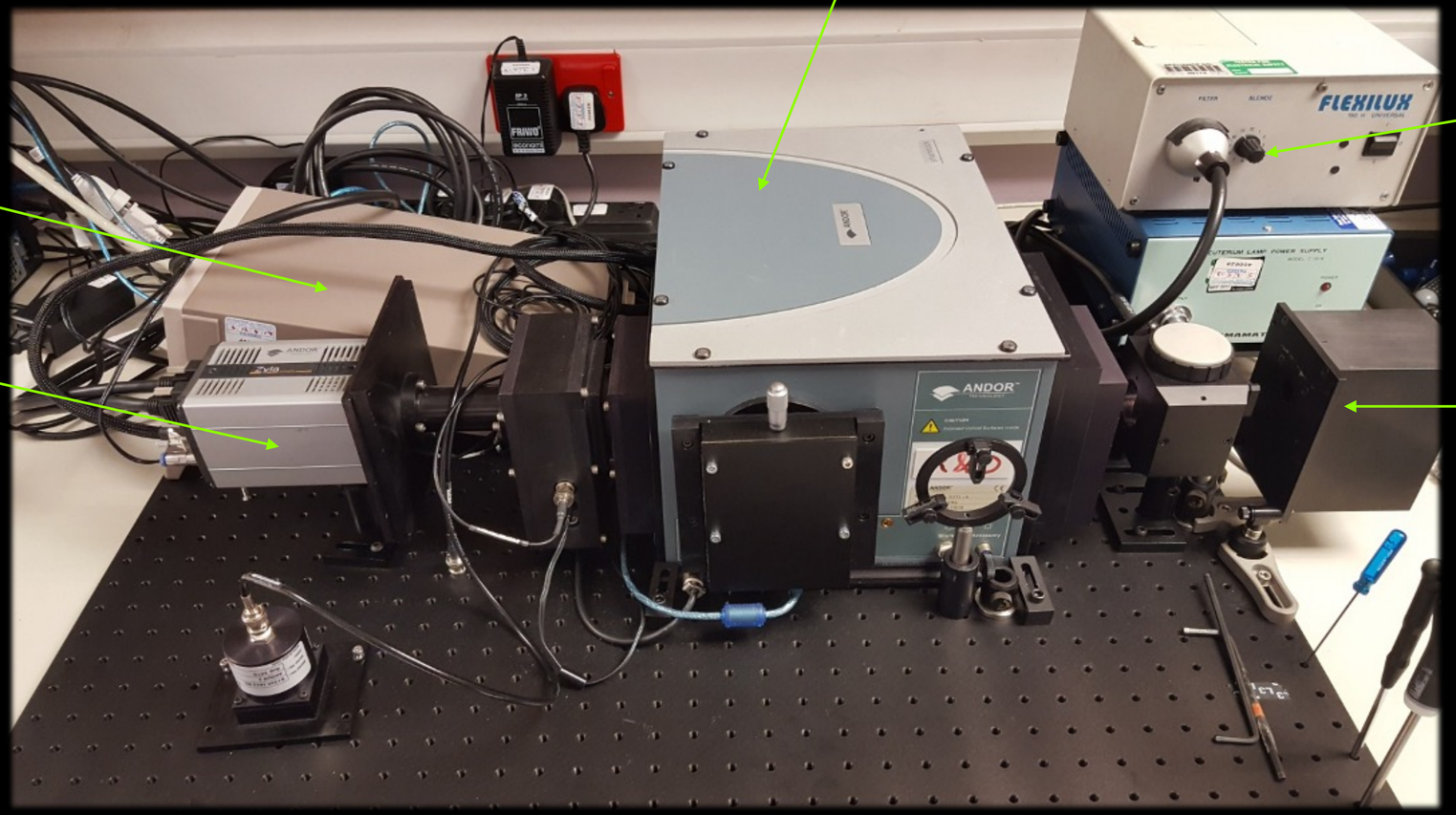
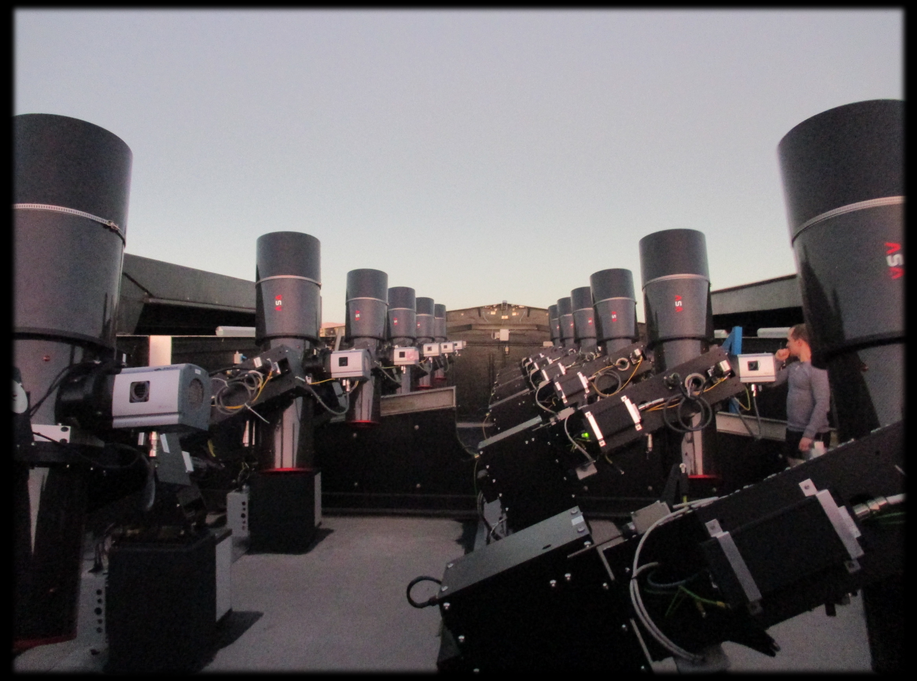


Image by Andrew Bingham & Richard Simms

Next steps in Chile

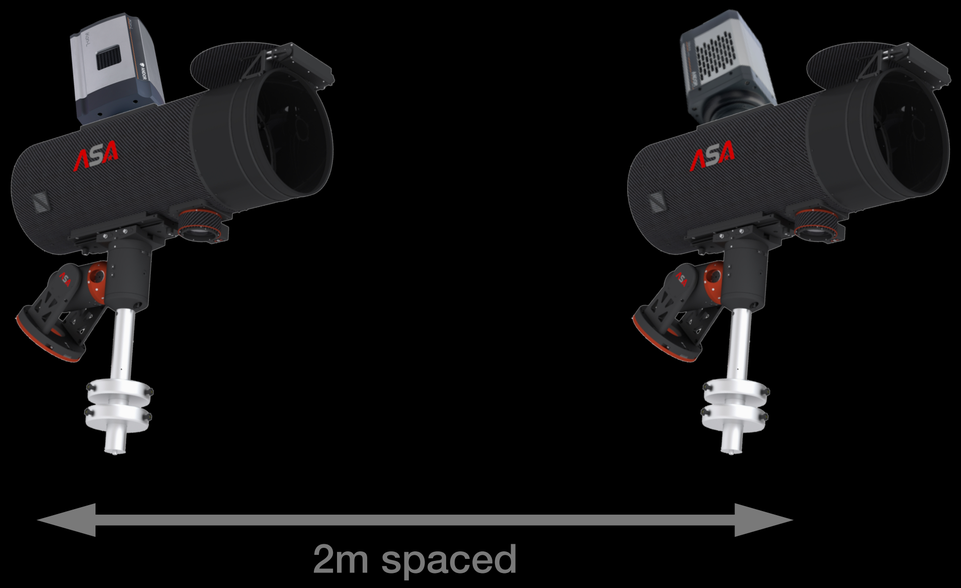
- Planning to travel to Chile this December
- We will need a computer, large RAM and extra storage space to store the data and run the software
- Test camera with the control software and ship it with the computer to ESO
- Use a second telescope with the iKon-L and do photometry

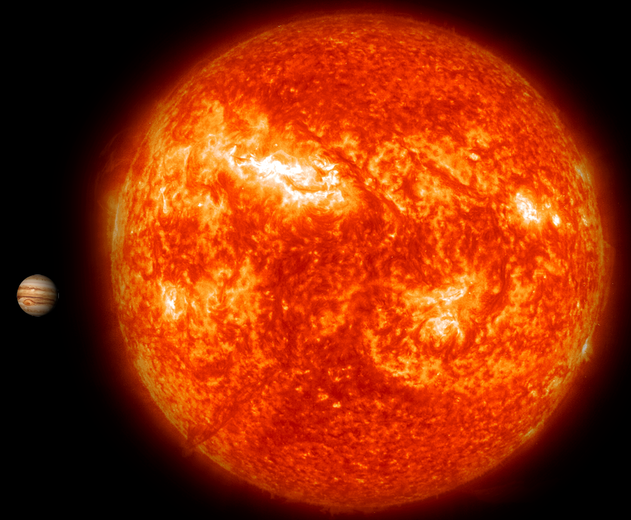


The NGTS facility at ESO Paranal (Credit:ESO/R. West)

Next steps in Chile

- Select a well-studied exoplanet of a bright host (e.g. V<6)
- Observe transiting signal and compare the noise performance from both cameras
- Photometric noise is completely uncorrelated (O’Brien et al. 2022)





Summary

- Characterise Marana extensively
- Open window for adjustments an optimisations on Marana to reduce dark current/glow and increase the dynamic range (Requires FPGA/R&D/Optical work)
- Marana sCMOS has much faster Readout Rate compare to iKon-L CCD (the more data the better)
- Marana has similar dynamic range with iKon-L
- We will measure QE and transmission on the next Andor visit
- Travel to Chile (work in progress)
- Conduct photometry with sCMOS and CCD and compare noise performance
- Second mission to Chile?

Thank you for listening
Any Questions?