Scientific CMOS sensors in Astronomy:
QHY600 and QHY411

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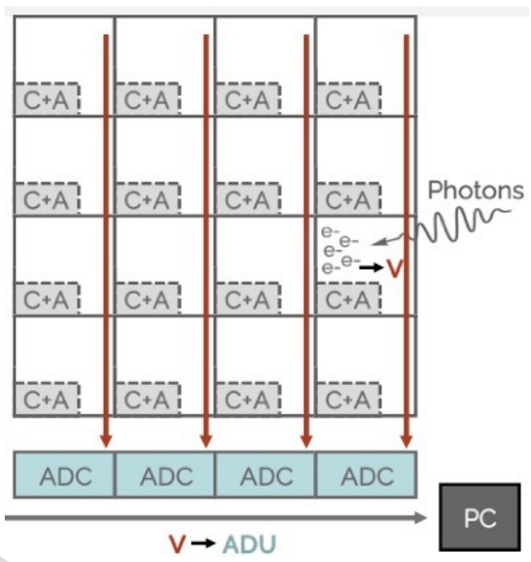
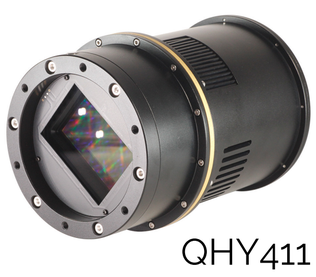
CMOS sensors: IMX455 and IMX411




QHY600

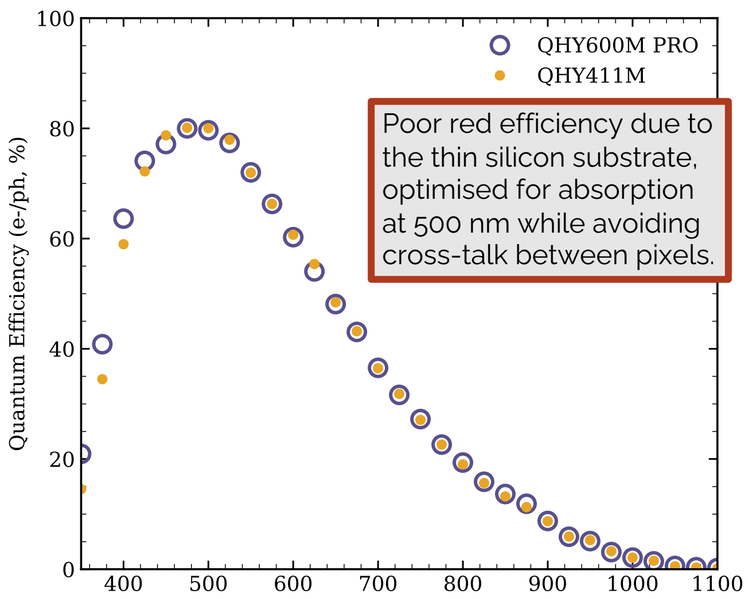

QHY411

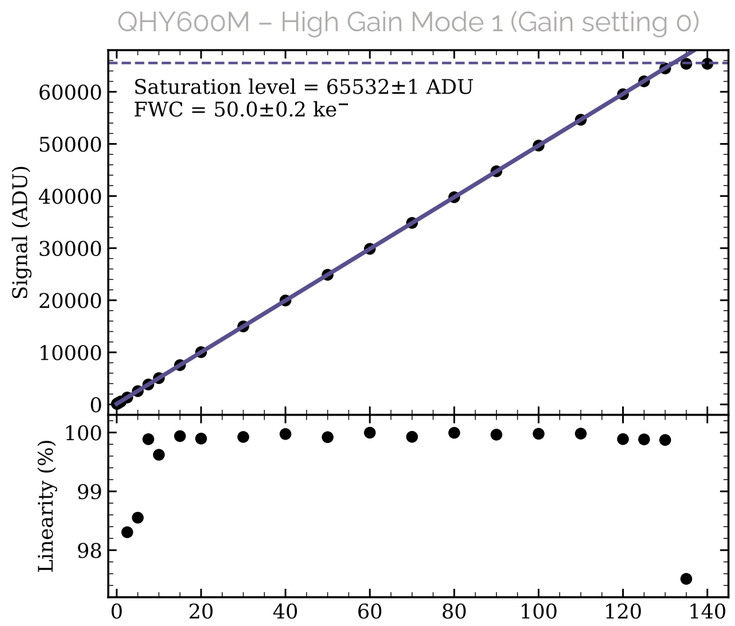
- Each pixel has its own amplifier+capacitor making charge transfer more efficient: **high frame rate**, **low readout time** (~10 ms).
- The exposures are triggered with a **rolling shutter**: less mechanical stress but a short delay time (~µs) between consecutive rows in the same frame.
- **Real 16-bit** A/D on-chip: High full well capacity despite their small pixels of 3.76 µm.
- Minimum exposure time of 40 µs: useful for **fast transients** like occultations or lucky imaging,
- Possibility to add a GPS trigger to achieve timestamp accuracy in the order of nanoseconds.

Feature	QHY600M	QHY411M
Sensor (Sony)	IMX455M	IMX411M
Sensor size	36 x 24 mm	54 x 40 mm
Pixel size	3.76 µm	
Efective área (px)	9576 x 6388	14304 x 10748
Raw 16-bit image size	120 MB	300 MB
Max full frame rate	2.5	1
Cooling (below ambient temperature)	Air (-30 °C)	Air (-35 °C) Water (-45 °C)

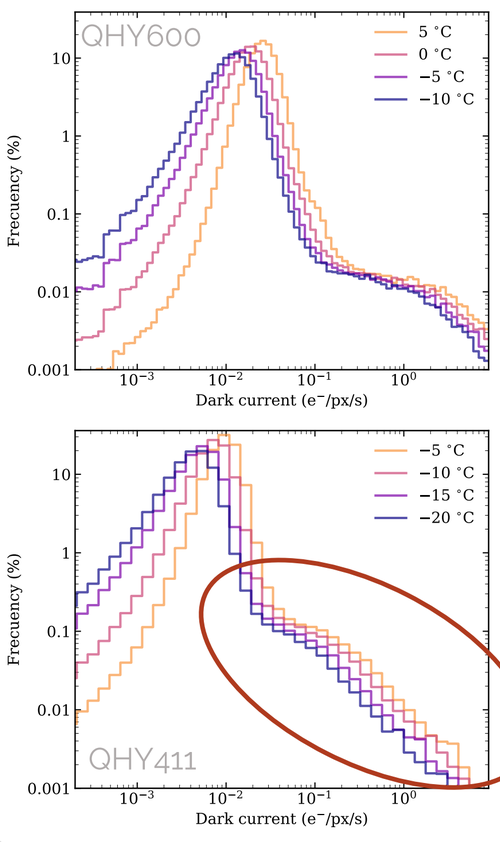
Instrument performance: Laboratory results

- **Optimised for visible**-light observations, with a QE peak of 80% at 475 nm. **Poorly efficient in the red** and blind in the NIR.
- The most suitable modes of operation for general use are #1 Gain setting 0 on the QHY600 and #4 Gain setting 0 on the QHY411, which have, respectively:
  - **readout noise (rms) of 3.5 e- and 3.8 e-**
  - full well capacity of 50 ke and 67 ke, giving a **high dynamic range.**
- They are **linear** over the entire range, with a deviation of less than 2%.
- **No charge persistence** effect has been observed.





Low DC and Salt & Pepper: An additional noise source



Median DC (e-/px/s)

T	QHY600M	QHY411M
5 ºC	0.025	
0 ºC	0.018	
-5 ºC	0.014	0.009
-10 ºC	0.011	0.007
-15 ºC		0.005
-20 ºC		0.004

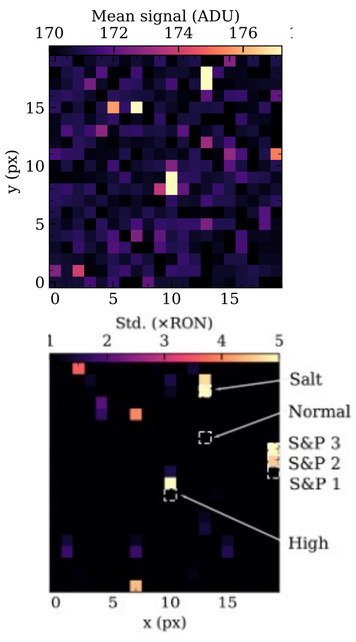
- Lower dark current (DC) than other sCMOS sensors: **Long exposures are possible** without increasing noise significantly.
- **No glow** is observed, even at the edges.

Warm pixels: A 0.024 % in the QHY600M and a 0.005 % in the QHY411M. They are:
- Linear with exposure time
- Stable over several weeks.

Random Telegraph Noise (**Salt & Pepper**)

A pattern of bright and dark pixels that appear and disappear from one frame to the next one is observed (~2 % of pixels).

It can affect the photometry of faint sources and sky background!



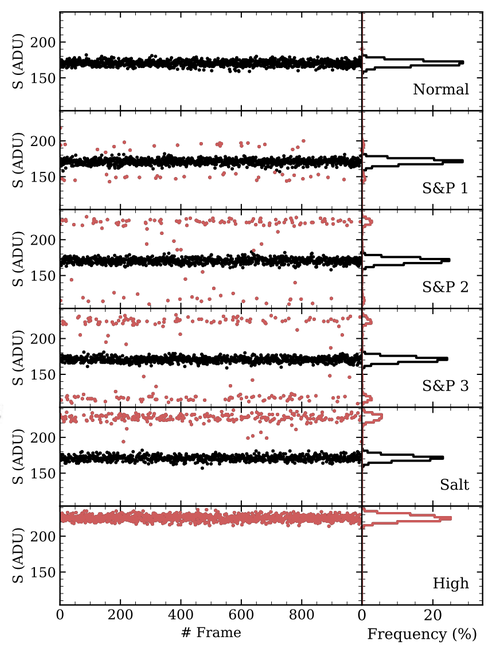


Figure:
Left: Average stack and standard deviation of 1000 consecutive bias frames (ROI 20 x 20 px). Relevant pixels are selected and their value in each of the 1000 frames is shown on the right plot. Outliers (3 x RON) are shown in red.

Normal pixel, all its bias values are in the average ± 3 x RON.

Low S&P, some symmetric outliers but close to the expected distribution.

High and non-symmetric S&P, slightly skewed average value.

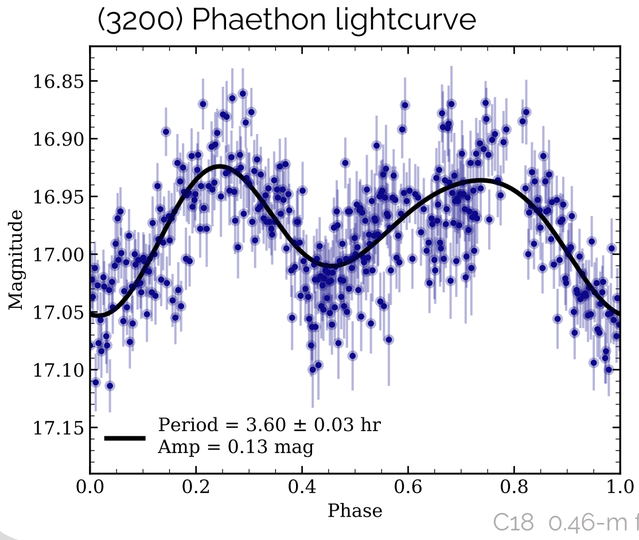
High and symmetrical S&P, not detectable in the average frame.

Only upward jumps (**salt**) are detected, **strongly biasing the photometry**.

Systematically **high value**, can be corrected by bias subtraction (full master frames needed!)

Science cases: Telescope observations

(3200) Phaethon lightcurve



C18 0.46-m f/2.2 QHY600M

Short focal length telescopes

Very suitable for use in short focal length telescopes: its small pixels allow good PSF sampling over a large FOV.

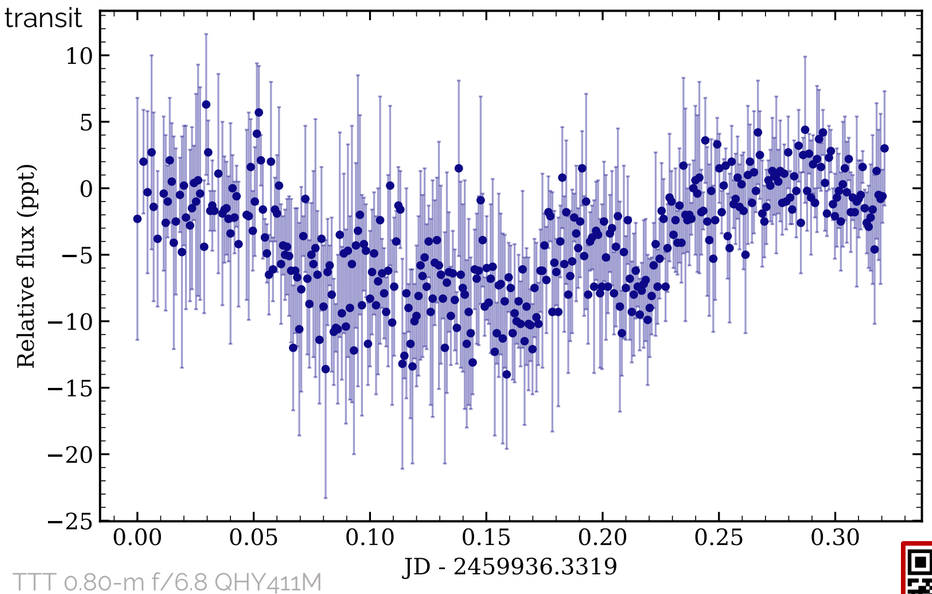
High uniformity in PSF shape and flux across the sensor: high photometric accuracy on moving objects.

Long focal length telescopes

Oversampled PSF allows photometric measurements of bright objects to be made with high accuracy, no defocusing needed.

High frame rate offers high-precision astrometric measurements on fast moving objects and high spatial resolution imaging (lucky imaging).

TOI-1135 exoplanet transit



TTT 0.80-m f/6.8 QHY411M

Scan the QR! Alarcon et al. 2023