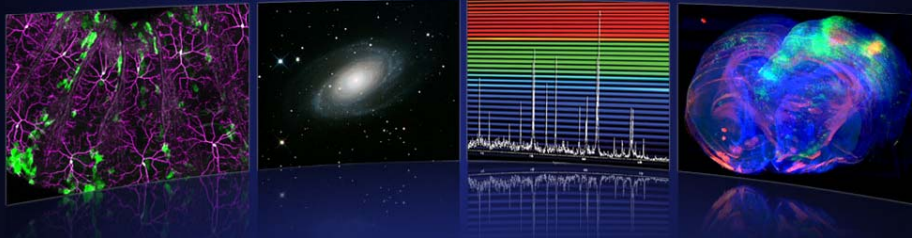


# ANDOR

an Oxford Instruments company



## High Performance, High Resolution Detector Solutions for Astronomy

2016

1

## Agenda

- Who is Andor?
- High performance Andor CCDs
- Apogee CCD range
- EMCCD technology
- sCMOS technology
- **NEW** iKon-XL - Very Large Area CCD Platform

## Pioneering and Leading High Performance Light Measurement

• Established 1989 (QUB spin out)

• 400 direct staff

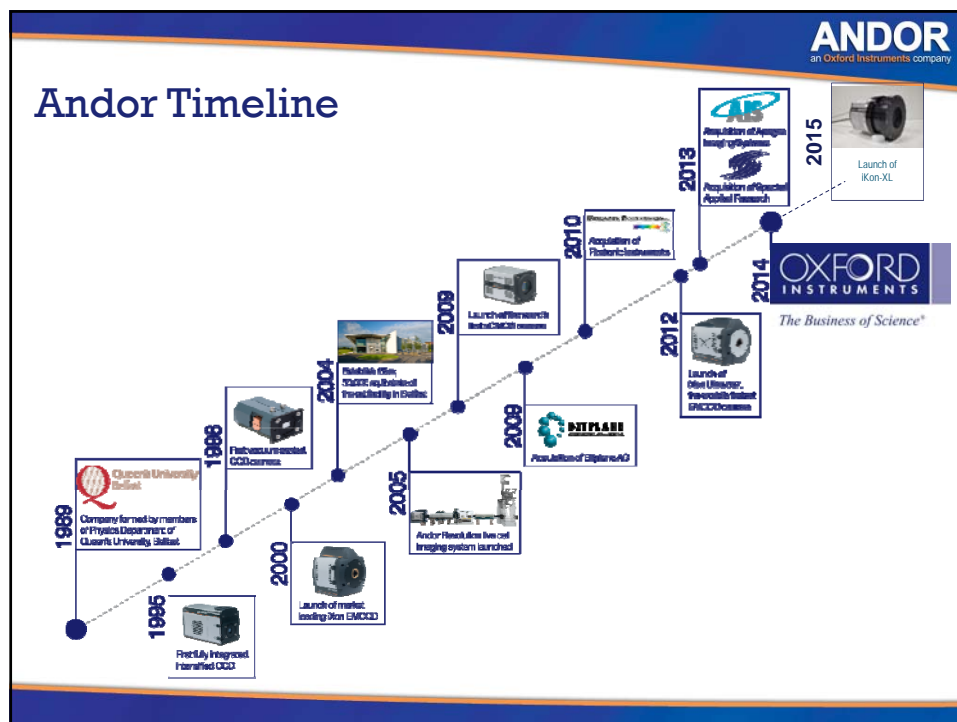


## Who am I ?

• Apologies that I could not be there in person !

**Paul Mc Grotty**  
Principal Engineer  
CCD and Spectroscopy solutions  
Andor technology  
[p.mcgrotty@andor.com](mailto:p.mcgrotty@andor.com)

- 6 years with Andor – prior experience in RF and telecoms
- Lead engineer on iXon Ultra and iKon-XL



## Andor Product Portfolio

### Low Light Imaging

High performance, ultrasensitive EMCCD, sCMOS and CCD

### Spectroscopy Solutions

Modular spectroscopy solutions: wide range of spectrographs and detectors.

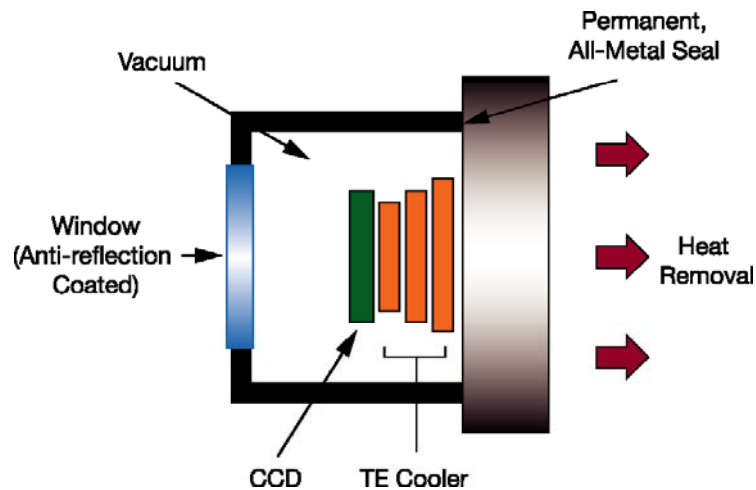
### Software

Complements Andor's product offerings through image acquisition, analysis and visualisation capabilities

### Microscopy Systems

High end modular confocal microscope systems

### Permanent Vacuum



### iKon - Full Frame CCD Cameras

- Up to 4 Megapixel
- Cooling to  $-100^{\circ}\text{C}$
- Extremely long exposures possible
- Low read noise, high dynamic range



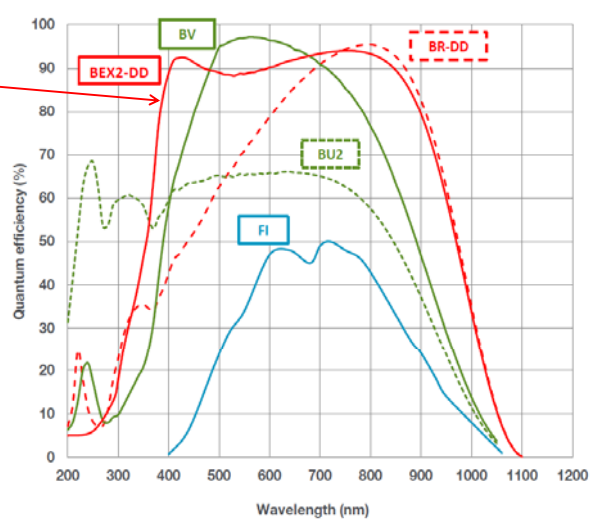
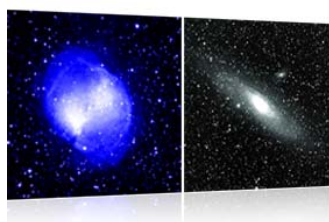
*Little Dumbbell Nebula, acquired using an iKon-L 4 MP CCD on the 1 meter telescope at Observatoire du Midi in France*

## Recently launched...extended QE range



## iKon QE Curves

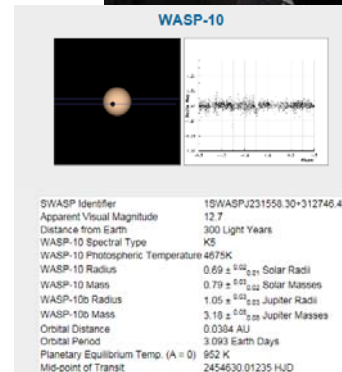
**NEW**  
Dual AR Coating  
+  
Deep Depletion





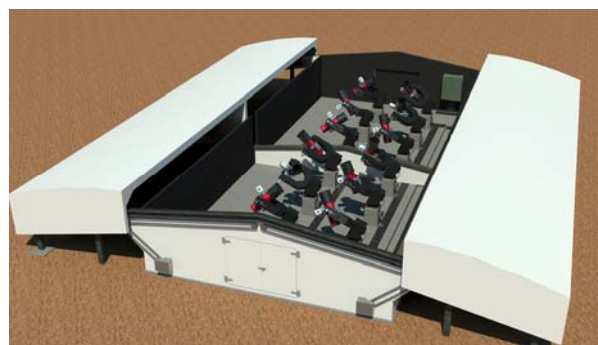
### SuperWasp

- The SuperWASP observatories each consist of an array of 8x iKon-L (4 Megapixel) CCD cameras
- These cameras are extremely widefield – up to 2000 times greater than a conventional astronomical telescope.
- The cameras continuously image the night sky, each camera capturing up to 100,000 stars per image

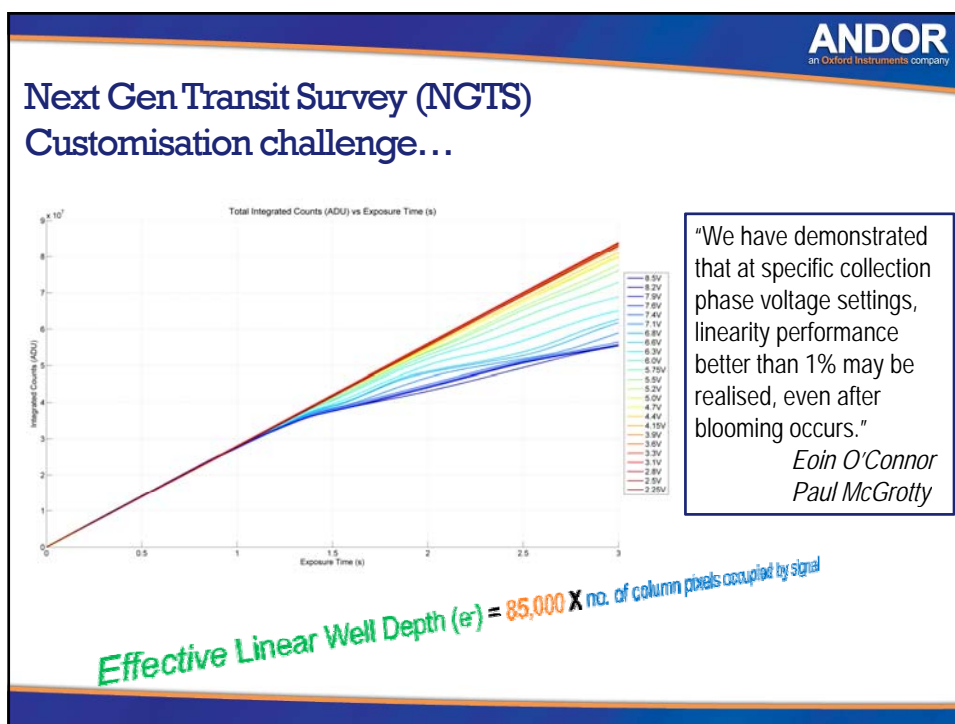
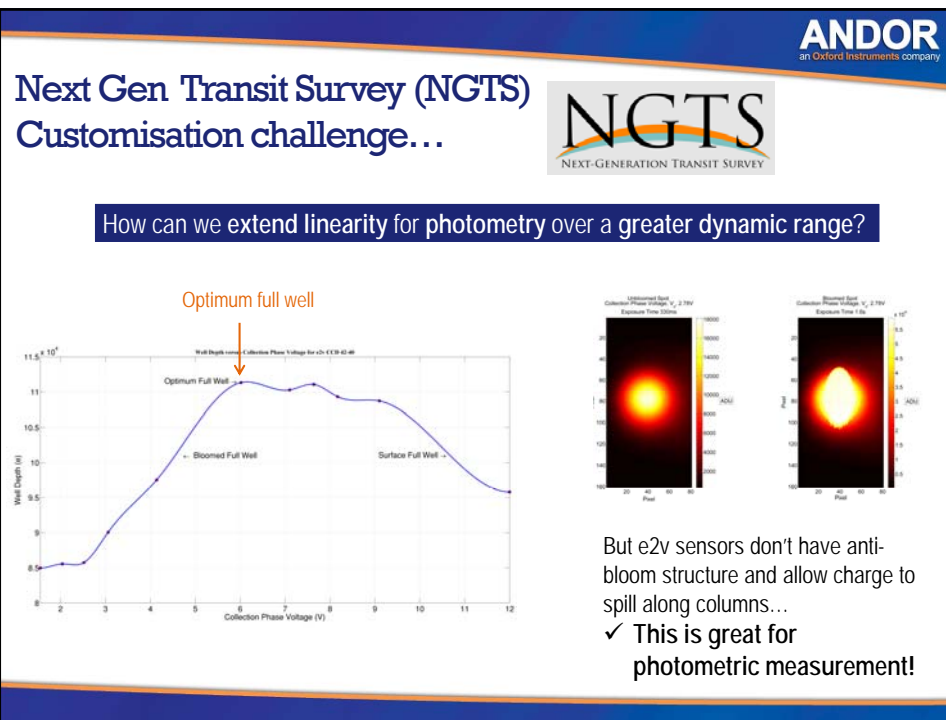


### NGTS

- The Next Generation Transit Survey consists of 12 x Ikon-L cameras each with their own robotic mounts
- As a development of the Superwasp, Deep Depleted sensors have been selected to improve IR performance.



ESO1502f  
R.west



## Apogee: Full Frame & Interline Cameras

### CCD Cameras

- Very wide range of sensor options
- Up to 29MP
- USB and Ethernet
- Manufactured in Andor's Belfast Factory



## Apogee Camera Portfolio



### Alta

- 35 °C cooling ( $\Delta 60$  °C)
- Full Frame & Interline
- 16 sensor options
  - Up to 16.8 MP
  - USB 2.0



### Aspen

- 45 °C cooling ( $\Delta 70$  °C)
- Full Frame & Interline
- 8 sensor options
  - Up to 16.8 MP
  - USB 2.0 & Ethernet

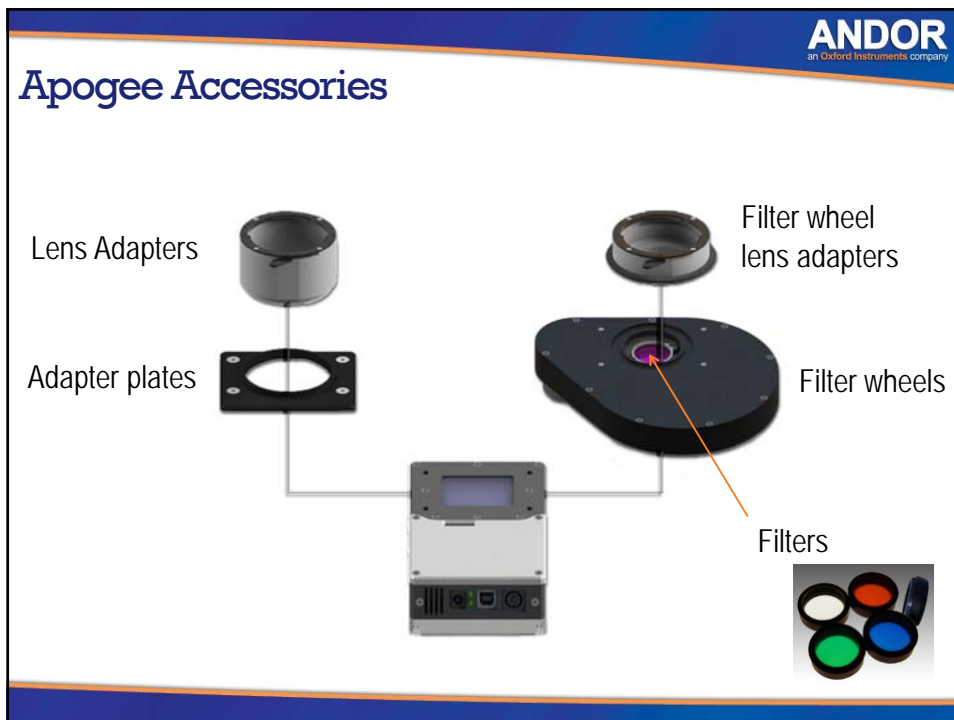


### Ascent

- Entry Level
- Interline Only
- 15 sensor options
  - Up to 29MP
  - USB 2.0







**iXon – Electron Multiplying Charge Coupled Device (EMCCD)**

...introduced ~ 14 years ago as a high-performance alternative to CCDs **at faster frame rates**


✓ Single photon sensitive; > 90% QE  
✓ 30-60 fps

**Applications**

- ✓ Lucky Imaging
- ✓ Wavefront sensors
- ✓ High time resolution astrophysics
- ✓ Solar astronomy
- ✓ Guide cameras

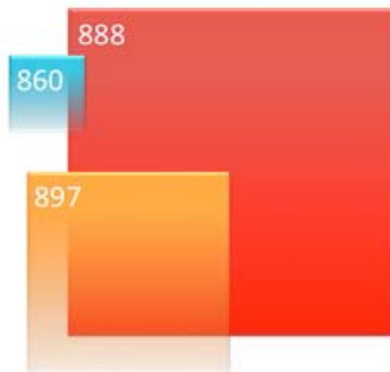
The diagram shows a timing diagram for the iXon camera, illustrating the sequence of events for a single frame. The diagram is labeled with 'e1', 'e2c', 'e2', 'e3', and 'e1' at the top, indicating the sequence of events. The diagram shows a series of pulses, with the first pulse being the longest and the subsequent pulses being shorter. The diagram is labeled 'LSI Vision' and '© 2003 technologies 2003'.

The image shows the iXon Ultra camera, a high-performance EMCCD camera. It is a black, rectangular device with a large, circular lens on the front. The camera is labeled 'iXon Ultra' and 'ANDOR'.

**iXon Ultra 888** 

**The Fastest  
Back-illuminated EMCCD**

- **3x Faster!**
  - ✓ 30 MHz readout
  - ✓ 26 fps from 1024 x 1024
  - ✓ 93 fps from 512 x 512 (Crop Mode)
  - ✓ 697 fps from 128 x 128 (Crop Mode)
- **Largest Field of View**  
EMCCD – 2.6x greater than 512 x 512 sensor.



**SOFIA**



Customisation program undertaken to provide a new Focal Plane Guide Camera, based on iXon 888



"Camera works as expected – factor of 100 improvement in S/N!!"

"We can now successfully guide on > 95% of the fields."

*Pasquale Temi & E.E. Becklin, NASA*

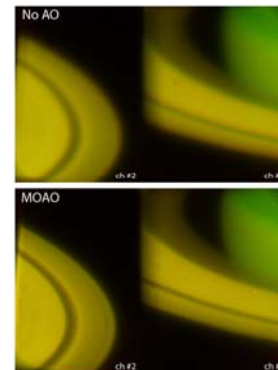
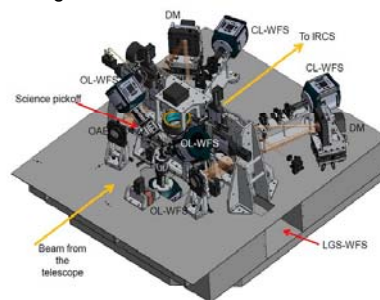
*Full environmental testing of the iXon 888*

## Raven project (Subaru Telescope)



Multiple iXon EMCCDs used as wavefront sensors in this Multi-Object Adaptive Optics (MOAO) approach

"What makes Raven special is its ability to measure wavefronts from three natural guide stars (NGS) over a 3x3 arcminute field and derive a correction for any other location in the field of regard."



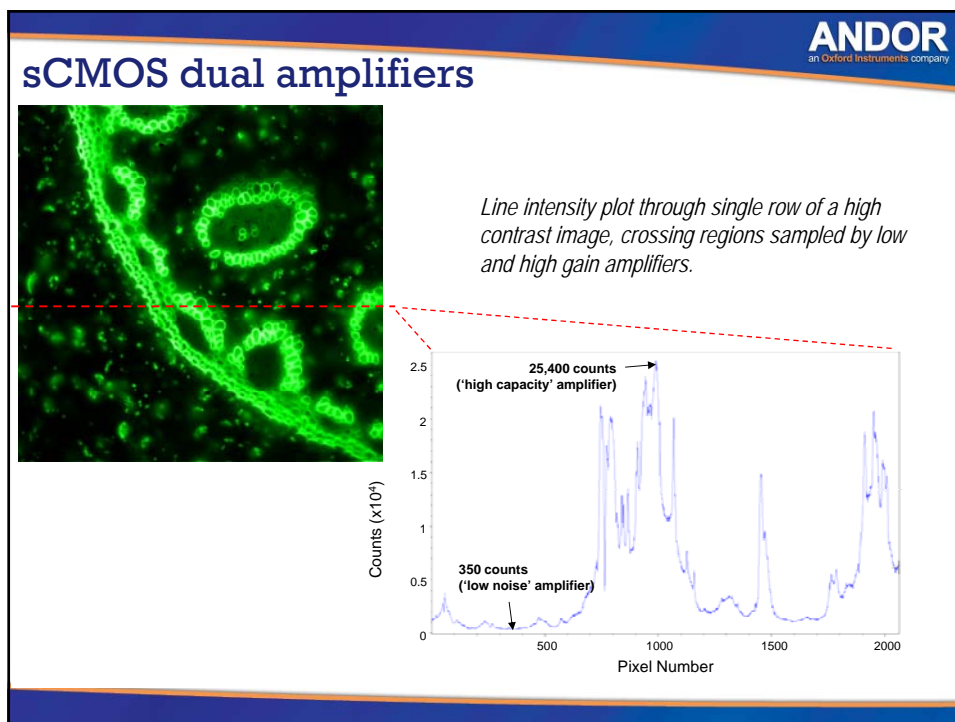
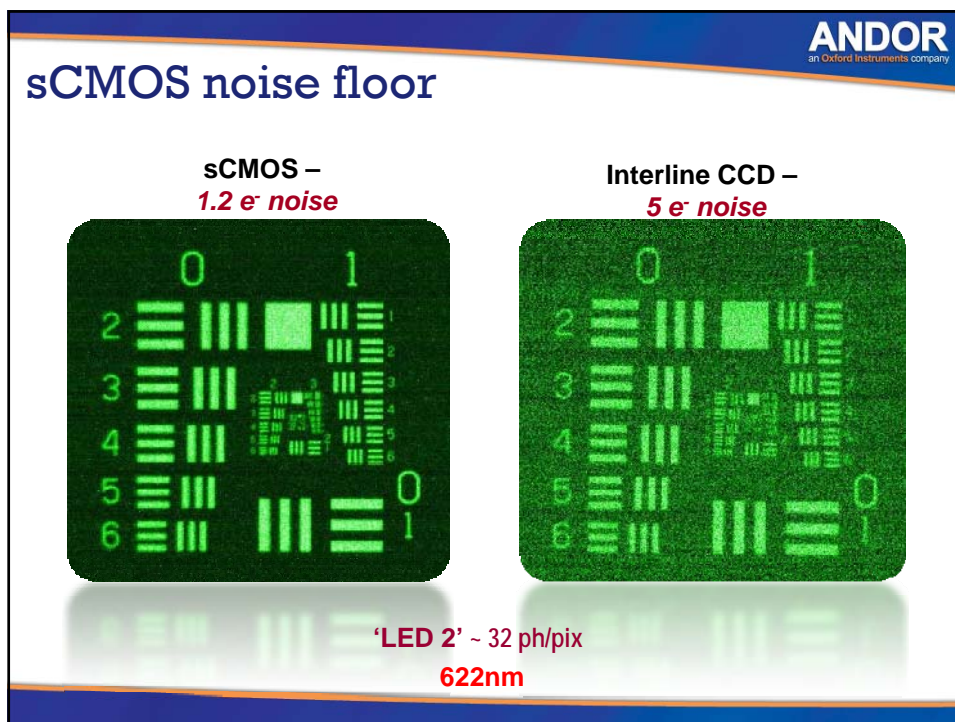
## Scientific CMOS (sCMOS)

Scientific CMOS (sCMOS) is *unique* in *simultaneously* offering...

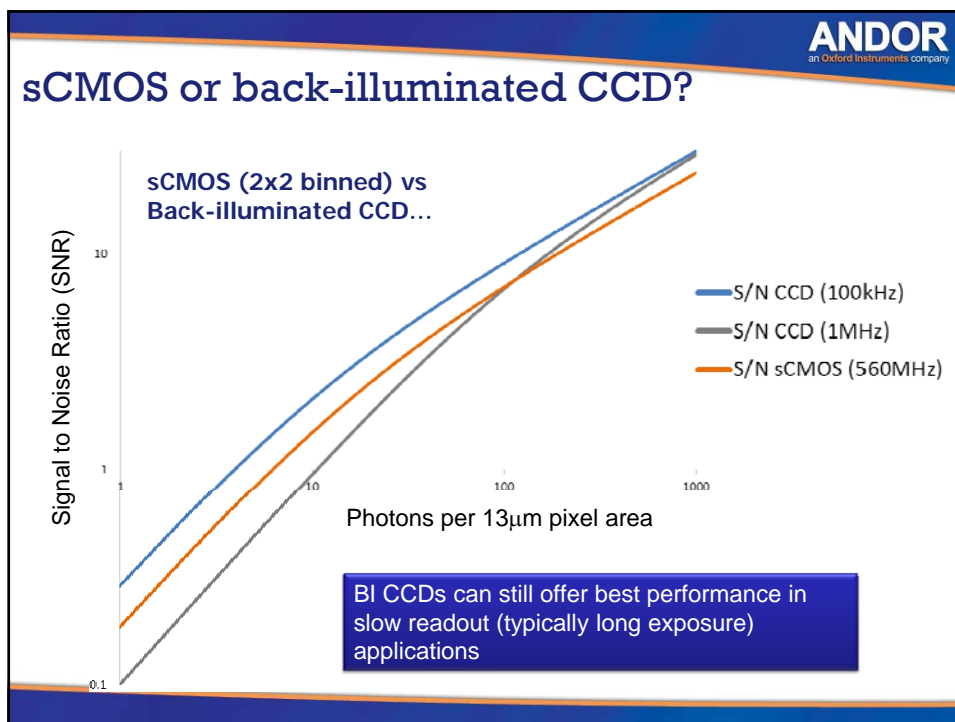
- Extremely low noise (without multiplication)
- Rapid frame rates
- Wide dynamic range
- High QE
- High resolution
- Large field of view
- Rolling *and* Global shutter modes











**NEW**

**iKon-XL**



## iKon-XL

**ColdSpace™**  
 Patent-Pending  
 technology

- ✓ Very Large Area Sensors  
-100 °C TE cooled!
- ✓ NO liquid nitrogen,
- ✓ NO cryo-cooler
- ✓ NO re-pumping




iKon XL

Large area CCD cameras


Extreme performance, no hassle

NEW



## iKon-XL – Further details

- ✓ Two performance variants:
  - 'Deep Cooled' to -100 °C – liquid cooling only
  - 'Flexi' version – liquid cooled to -75 °C; air cooled to -55 °C
- ✓ NO LN2, NO Cryo, NO re-pumping
- ✓ Extended Dynamic Range – Access lowest noise and full well depth simultaneously, with up to 18 bit digitization
- ✓ Up to 4 MHz readout per port (e2v sensors)
- ✓ Connection flexibility – USB3 or fibre optic.
- ✓ Balanced amplifiers – uniform multi-port readout.
- ✓ Easy user-replaceable shutter – on-site maintenance
- ✓ iRig-B timestamp – for time and positional accuracy and networking across multiple sites



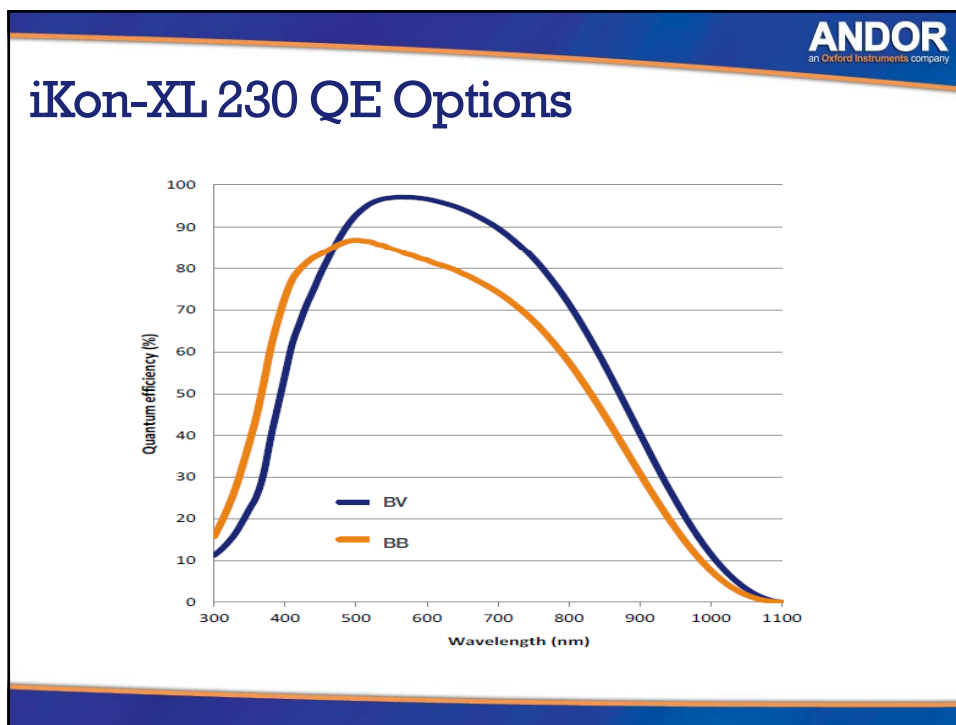
**iKon-XL 230**

**ANDOR**  
an Oxford Instruments company



**Key Specifications**

- 16.8 Megapixel sensor (CCD230-84)
- -100°C TE cooled
- 4.5 e<sup>-</sup> read noise
- 150,000 well depth
- Up to 4 MHz readout (quad port)

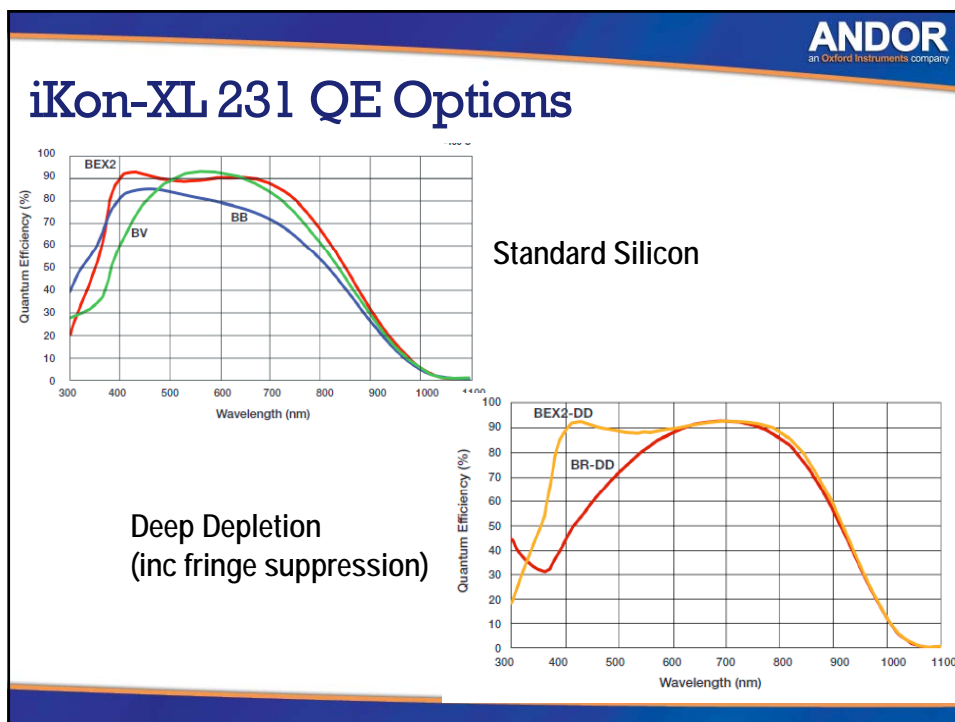


**iKon-XL 231**



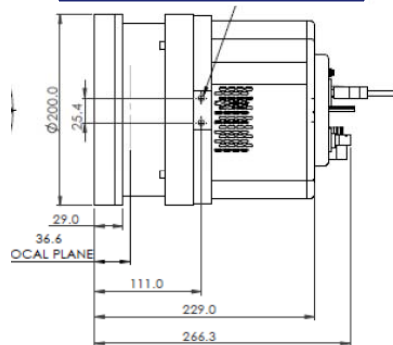
**Key Specifications**

- 16.8 Megapixel sensor (CCD231-84)
- -100°C TE cooled
- 2.1 e<sup>-</sup> read noise
- 350,000 well depth
- 166,700: 1 dynamic range
- Standard silicon or deep depletion

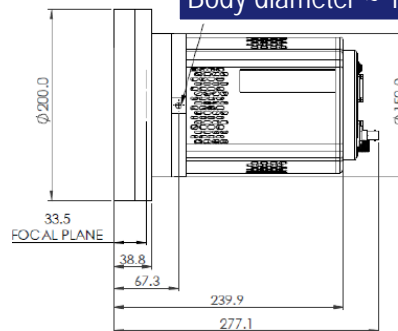


### Deep Cooled vs Flexi

'Deep Cooled'  
Weight = 12 kg  
Body diameter = 200mm



'Flexi'  
Weight = 8.25 kg  
Body diameter ~ 150mm



### iKon-XL - 'Extended Dynamic Range' Technology

#### UNIQUE INNOVATION

Access lowest noise and full well depth *simultaneously*,  
with up to **18 bit** digitization

CCD cameras always require software selection of amplifier gain to optimise either for low noise (weak signal) OR max well depth (bright signal). **Not both...**

**...until now.** iKon XL utilizes proprietary Andor CCD know-how to offer lowest read noise AND maximum well depth *in one image*.

e.g. CCD231-84 (4k x 4k 'astro')

$$\frac{\text{Pixel well depth}}{\text{Lowest read noise}} = \frac{350,000 \text{ e}^-}{2.1 \text{ e}^-} = 166,666:1$$

Requiring **18-bit**  
digitisation!!



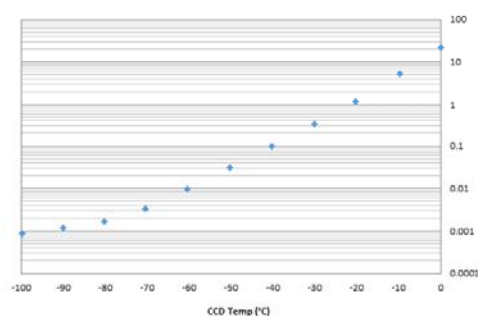
## iKon-XL – balanced output quadrants

### iKon XL ensures balanced sensor quadrants

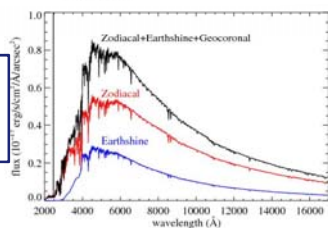
- ✓ Four physically separate ADCs and preamps with separate power supplies for each quadrant – prevents crosstalk.
- ✓ **Tracking Stability** - Four circuits maintained at the same operating temperature and experiencing the same operating conditions.
- ✓ **ADC Correction** - use an offset and gain algorithm to compensate in real time the video signal between quadrants as the image is read out at full speed.
- ✓ **Optional** – ADC correction is switchable under software control and can be disabled if the user so desires.



## iKon-XL – Cooling vs Dark Current



Sky background often imposes a practical limit



## Low Maintenance Advantage

**NO liquid nitrogen (LN2)** – many astronomers in the past have opted to build liquid nitrogen cameras in order to minimize darkcurrent. This requires ready access to LN2 supply and routine top up of LN2 levels in order to hold temperature, as well as carrying an additional safety concern. Many observatories are in remote locations and in some cases unmanned, making LN2 at best impractical, at worst impossible.

**NO cryo cooler** – as many astronomers will be aware, cryo coolers (e.g. Cryotiger) are notoriously unreliable. This is not a technology that can be relied upon for maintenance free operation in remote locations.

**No vacuum re-pumping** – iKon-XL sensor head is based on Andor's well tested UltraVac™ process, which carries a Mean Time Between Failure (MTBF) value of > 100 years!

**Field replaceable shutter** - No shutter is designed or specified for infinite usage! When it finally fails in a remote observing location, the shutter mounting of the iKon-XL has been purposefully designed such that the shutter can be easily replaced by the user on site.

## Voice of the customer

### Irig-B timestamp:

The camera will accept an external 1Hz time code. At the start of each exposure the camera FPGA will record the current time with 10nS resolution. This data is appended in the Metadata for the image.

### Ease of Use:

Compatible with Ascom drivers, supported by Red Logix.

Linux and windows SDK

Andor Solis windows application provides straightforward initial setup  
USB and fibre optic interface.

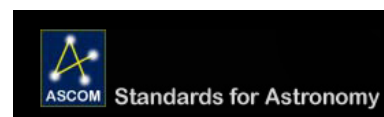
## iKon-XL applications

iKon XL Cameras already shipped and in use in China and Antarctica

### APPLICATIONS INCLUDE...

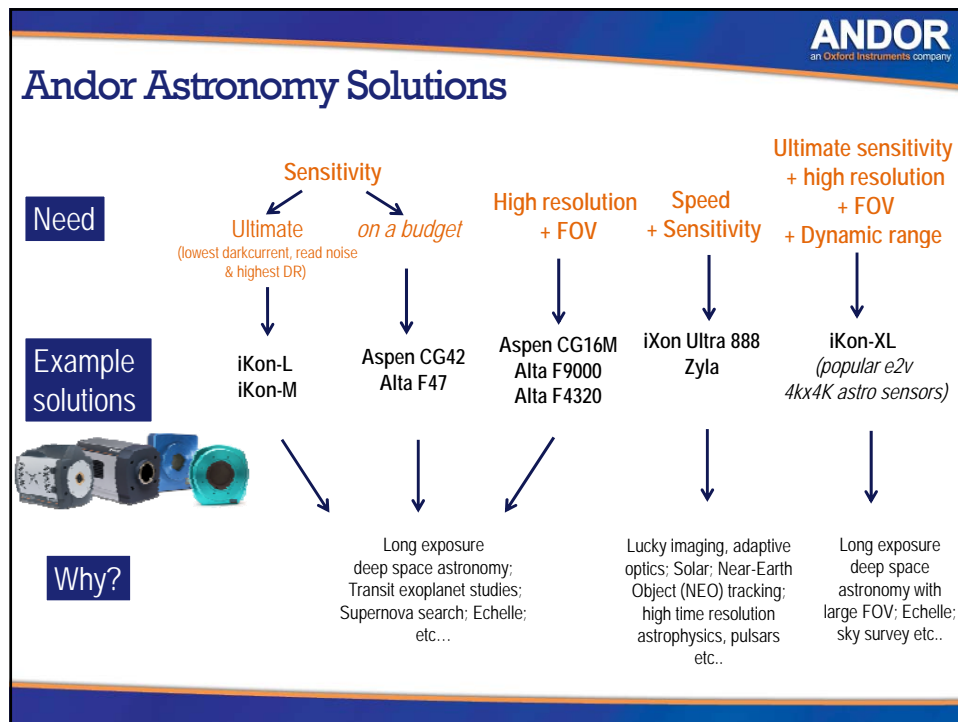
- Deep Space Observation
- Exoplanet Discovery
- Large Sky Surveys
  - Photometry
- Astro-spectroscopy (Echelle)
  - Supernova Detection
  - Debris Tracking

## ASCOM Support



- ASCOM is a many-to-many and language-independent architecture, supported by most astronomy devices which connect to Windows computers.
- Gives compatibility with range of astronomy softwares
- All CCDs and EMCCDs integrated (inc Apogee)





**Other applications**

- The iKon-L and XL product range have been developed for physical sciences and Astronomy
- The iKon-L has also been further developed as an OEM camera for ;
  - X-ray CT scanning
  - Gene sequencing
  - X-ray imaging with scintillators and direct detection
- The iKon-XL has been developed for X-ray detection

## X-ray Computed Tomography



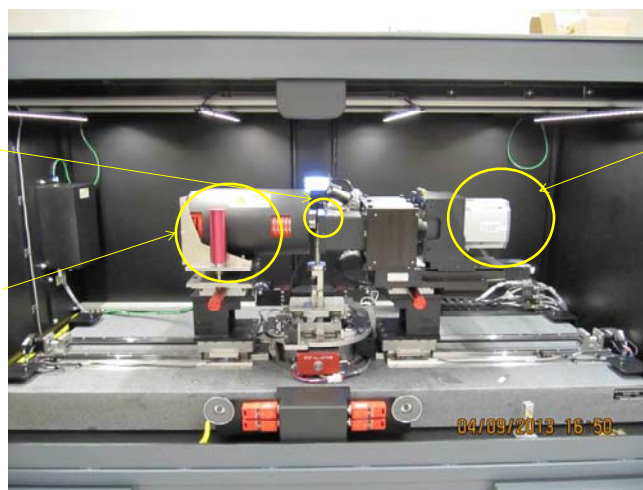
50

## X-ray Computed Tomography

Test  
Subject on  
turntable

Xray  
Source

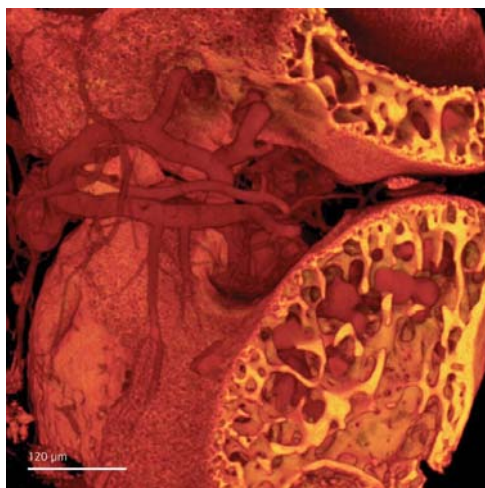
Camera



51

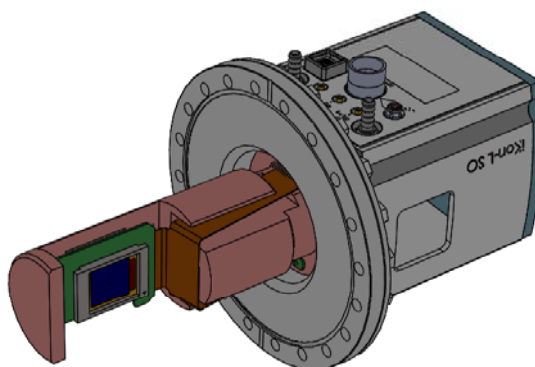


## Vascular and bone CT X-ray image



52

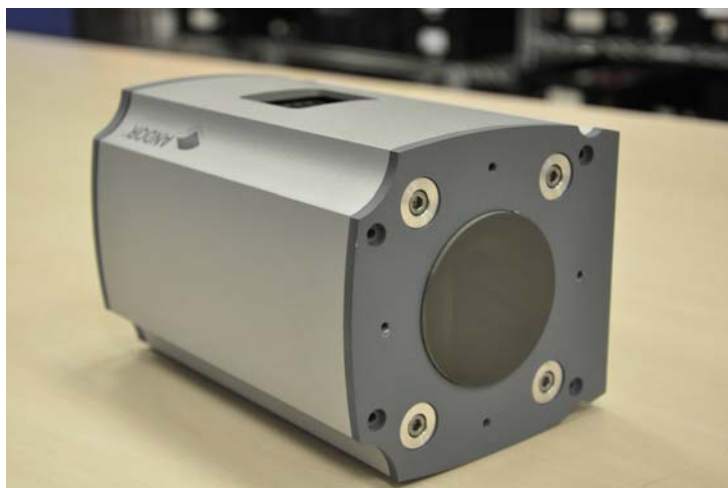
## Ikon-L direct detection



30mm x 30mm direct X-ray detection

53

## Fibre Optic coupled with Taper 1.5:1



54


## Ikon-XL direct detection



● 60mm x 60mm direct X-ray detection

55

## Adding value beyond the camera...



*Large data solutions....simplified*

- ✓ Enhanced convenience, afforded by simple, optimized GPU data management
- ✓ Optimal data throughput
- ✓ Accelerated real time processing frame rates
- ✓ Superb, easily accessible documentation and examples.

*"I'm really impressed. As with the Andor SDK3, you provide a clean interface, and the library is well designed. I'm particularly amazed about the documentation. Reading through it, it all made complete sense. It seems that lots of the tedious CUDA buffer management should be greatly simplified using GPU Express."*

Dr Benjamin Schmid, Huisken Lab, MPI of Molecular Cell Biology and Genetics, Dresden, Germany

## FUTURE - Funded sensor/camera development:

### Large area 16 Megapixel sCMOS

| Target specs:  |  |
|--|--|
| <ul style="list-style-type: none"> <li>• 4K x 4K</li> <li>• 12<math>\mu</math>m pixel</li> <li>• &lt; 2 e<sup>-</sup> rms read noise</li> <li>• Rolling and Global shutter</li> <li>• 80 fps from 4kx4k (rolling shutter)</li> </ul> | <ul style="list-style-type: none"> <li>• ~ 60% QE (&gt; 80% back-illuminated)</li> <li>• High dynamic range mechanism</li> <li>• &gt; 75K e<sup>-</sup> pixel well depth</li> <li>• Vacuum cooled</li> </ul> |

#### Applications

- Solar
- Near Earth Object (NEO) detection
- Lucky Imaging
- Transit studies
- High time resolution astrophysics (pulsars etc)
- Guide cameras

