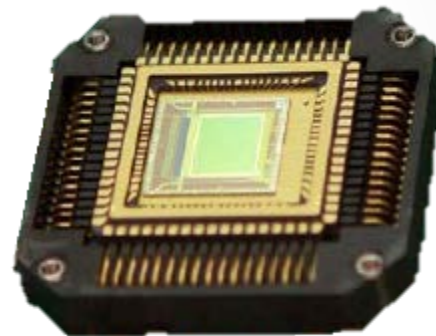




Selex ES

A Finmeccanica Company

# Next-generation performance of SAPHIRA HgCdTe APDs



Dani E. Atkinson, Donald N.B. Hall, Ian M. Baker,  
Sean B. Goebel, Shane M. Jacobson,  
Charles Lockhart, Eric A. Warmbier

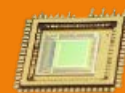
High Energy, Optical, and Infrared Detectors VII  
SPIE Astronomical Telescopes + Instrumentation  
27 Jun 2016 Edinburgh, Scotland

# SAPHIRA: Specs

- 320x256 with 24 $\mu$ m pitch (larger formats planned)
- Cutoff  $\lambda_c = 2.5\mu$ m, sensitivity down to 0.8 $\mu$ m.
- Fast readout, 20+ MHz max pixel rate, all 32 outputs brought to bear on any subarray.
- ROIC allows relatively simple clocking.

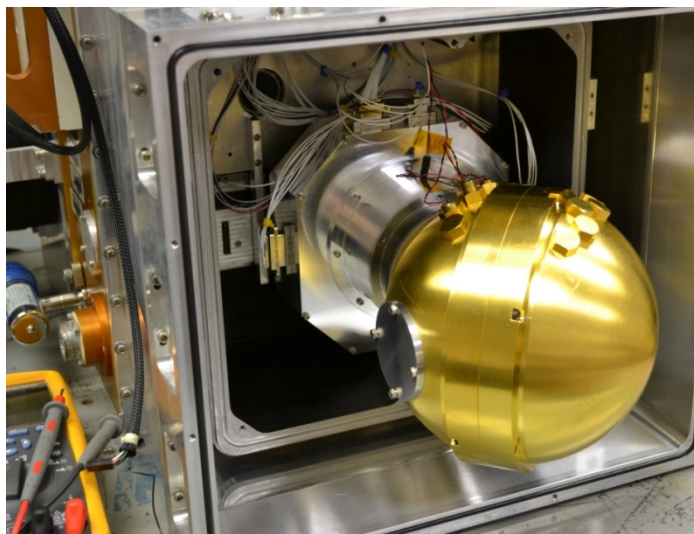
## New Performance Measurements

- With glow reduction, low dark current < 0.1 e<sup>-</sup>/s.
- High-temperature anneal eliminates gradient of tunneling current across detector at high bias.
- Avalanche gains to > 500.
- Photon counting pulse width distributions have been measured.

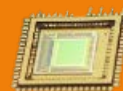
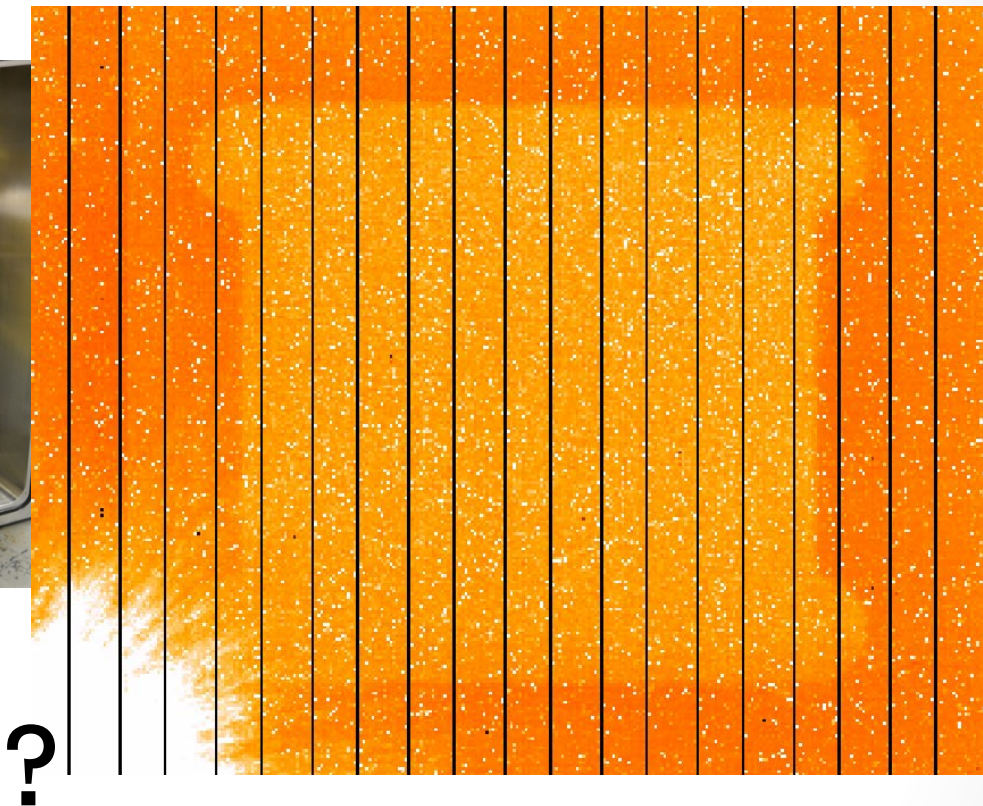


# Glow: Unexpected Point Source

- Original dark measurements completely glow-limited.



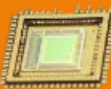
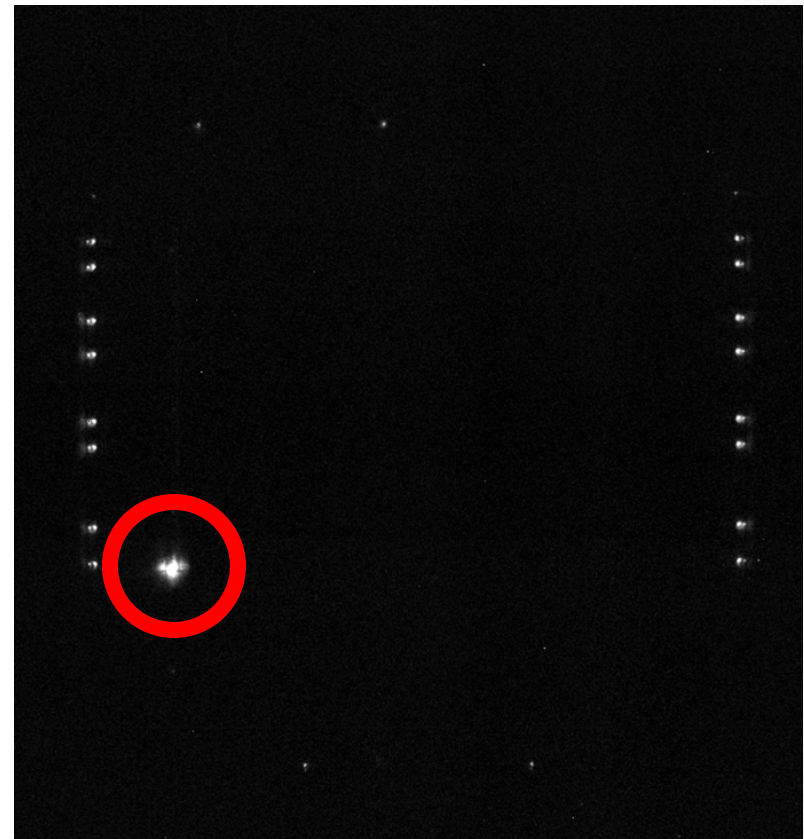
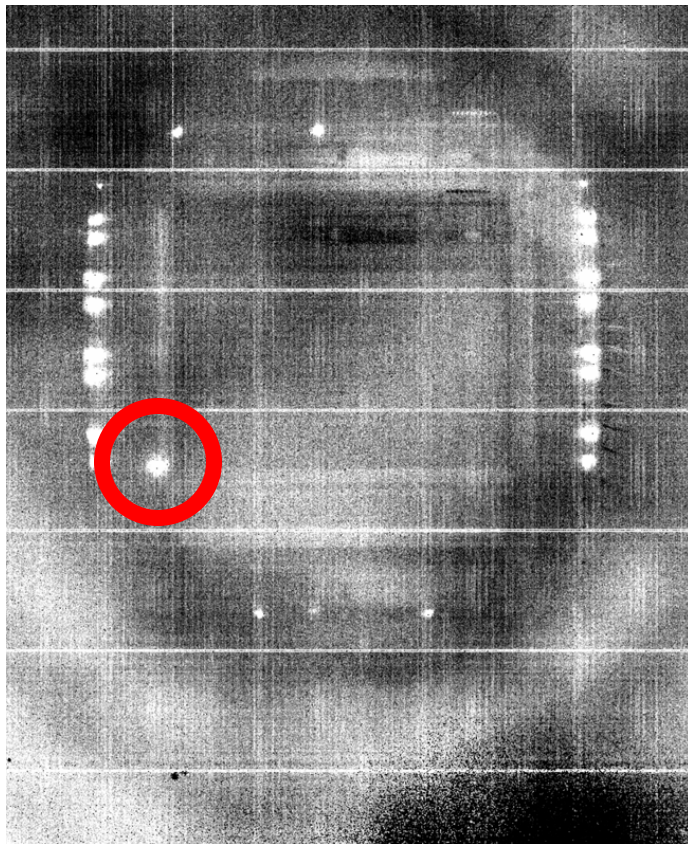
KSPEC Cryostat



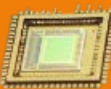
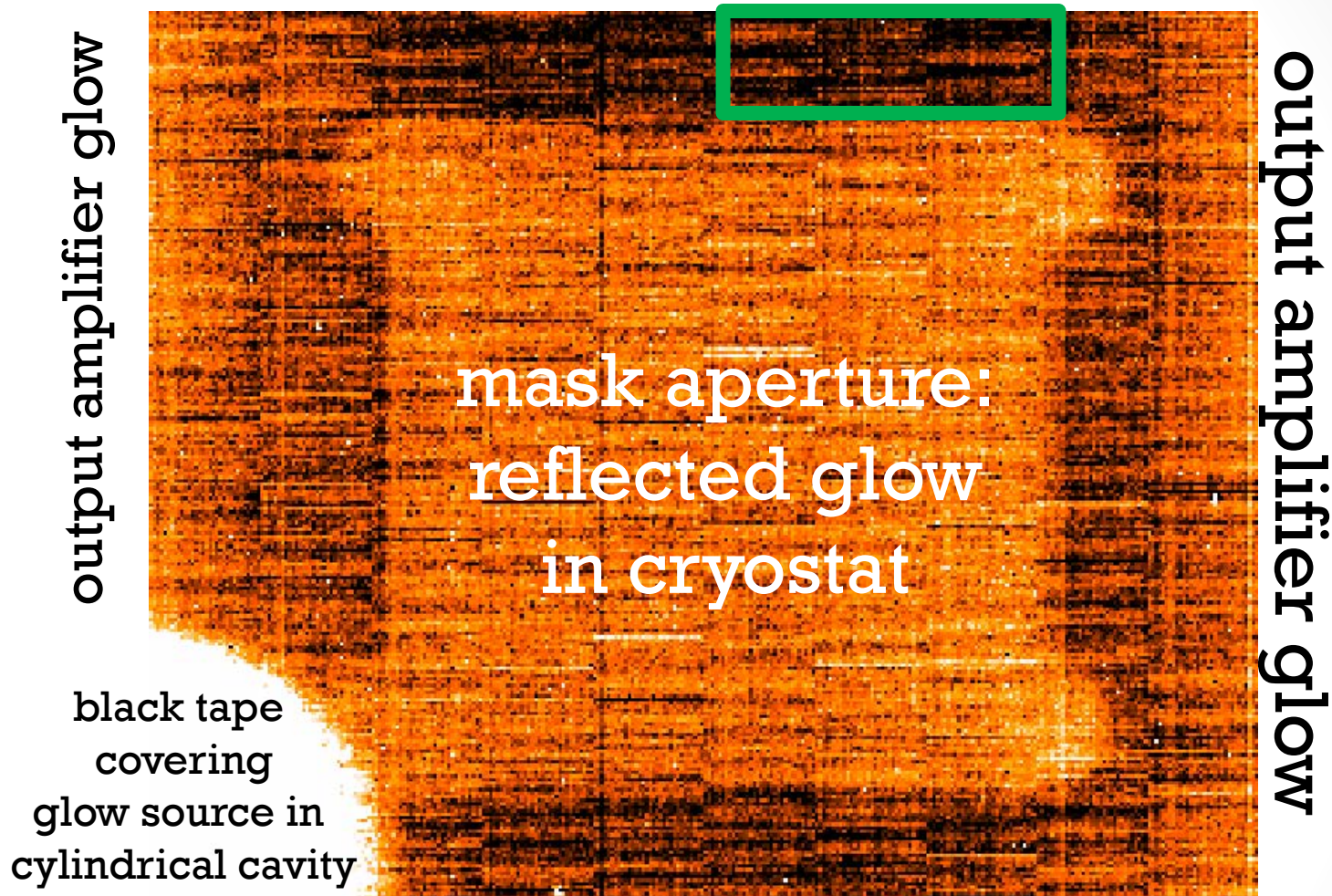


# Glow: Imaged w/ H4RG-15

- *J*-band @ 85K, VDD @ 5.5V
- Output amplifiers visible along sides.
- LLC glow source brightest and closer to detector!



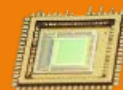
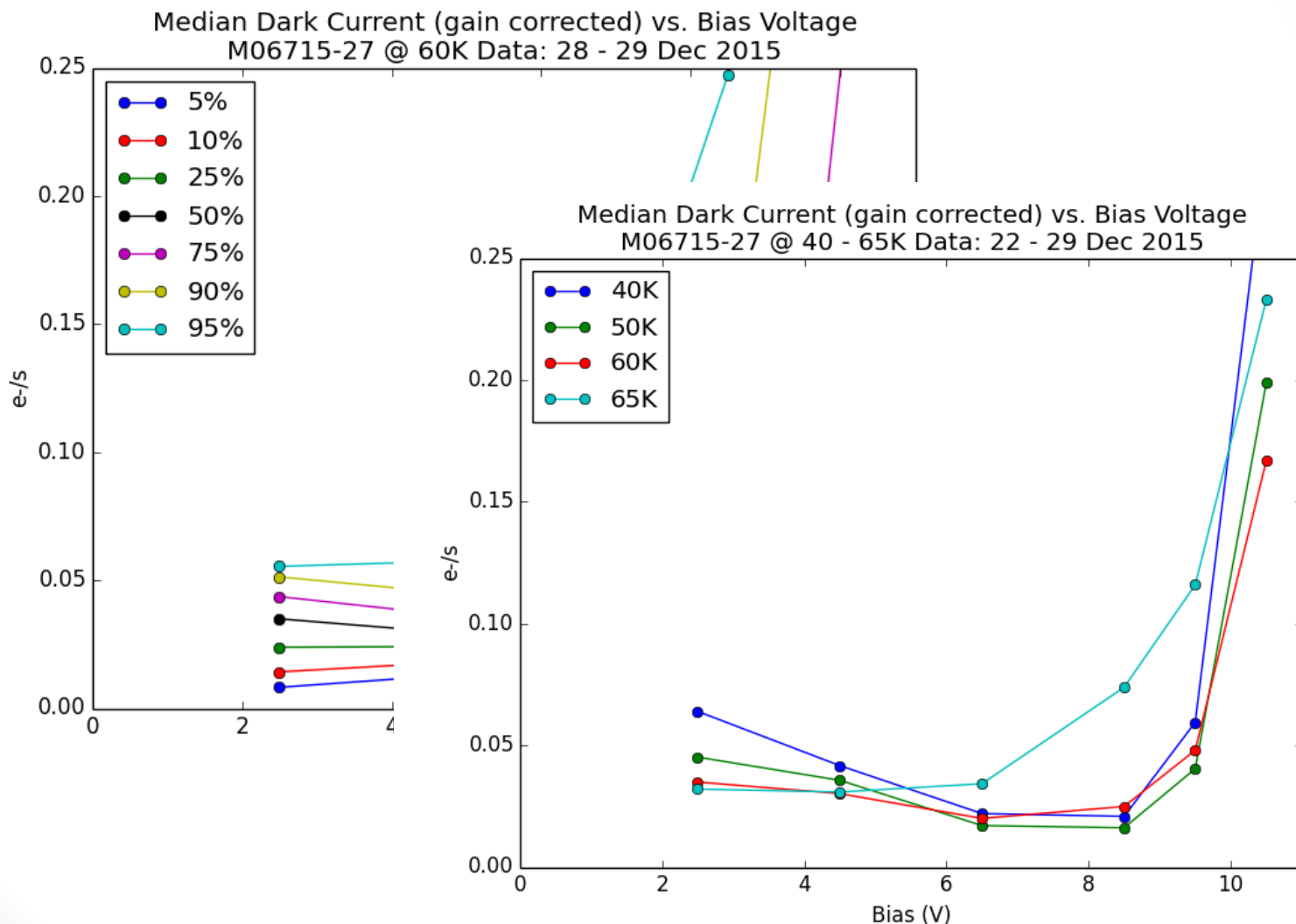
# Dark: Now with Anti-Glow Tape!





# Dark: New Limits

- 'Free' avalanche gain up to onset of tunneling.
- Low-bias dark likely still glow-limited.



# Cosmetics: High Temperature Anneal

Mark 10



no anneal

Mark 12



no anneal

Mark 13



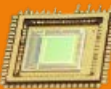
4 min anneal

Mark 14



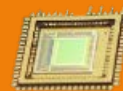
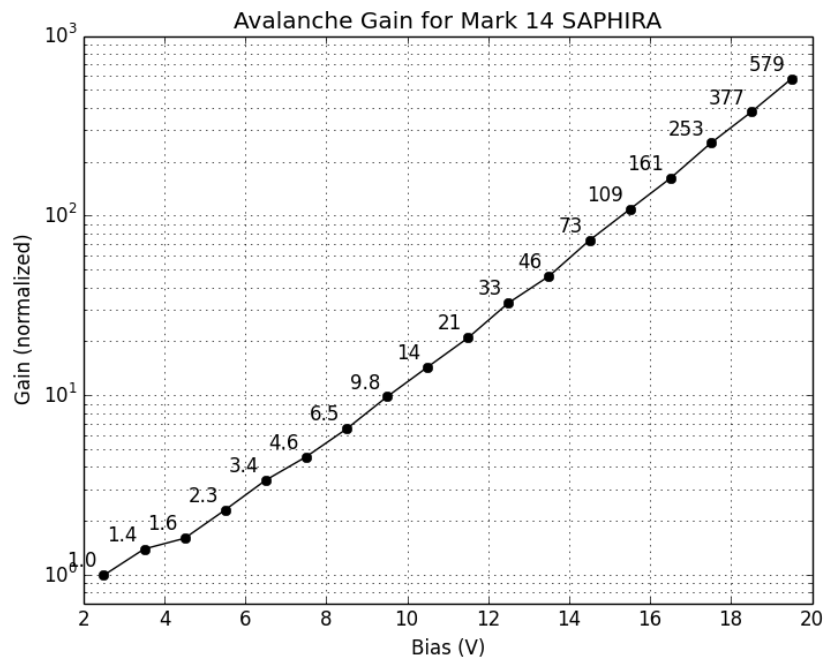
8 min anneal

Bias = 13.5V



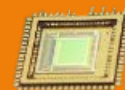
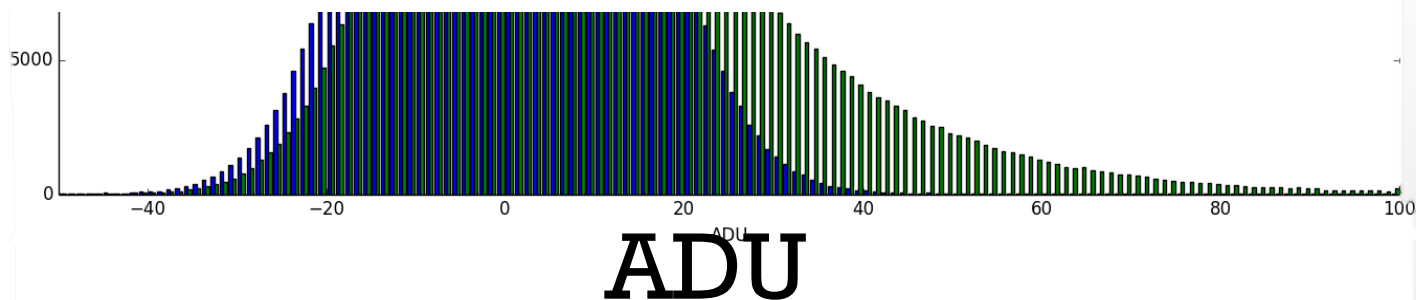
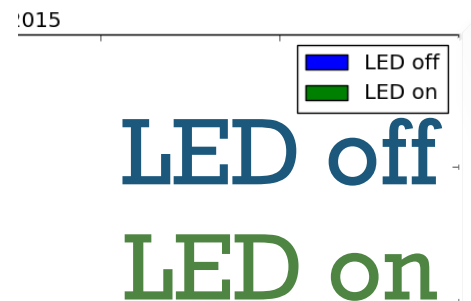
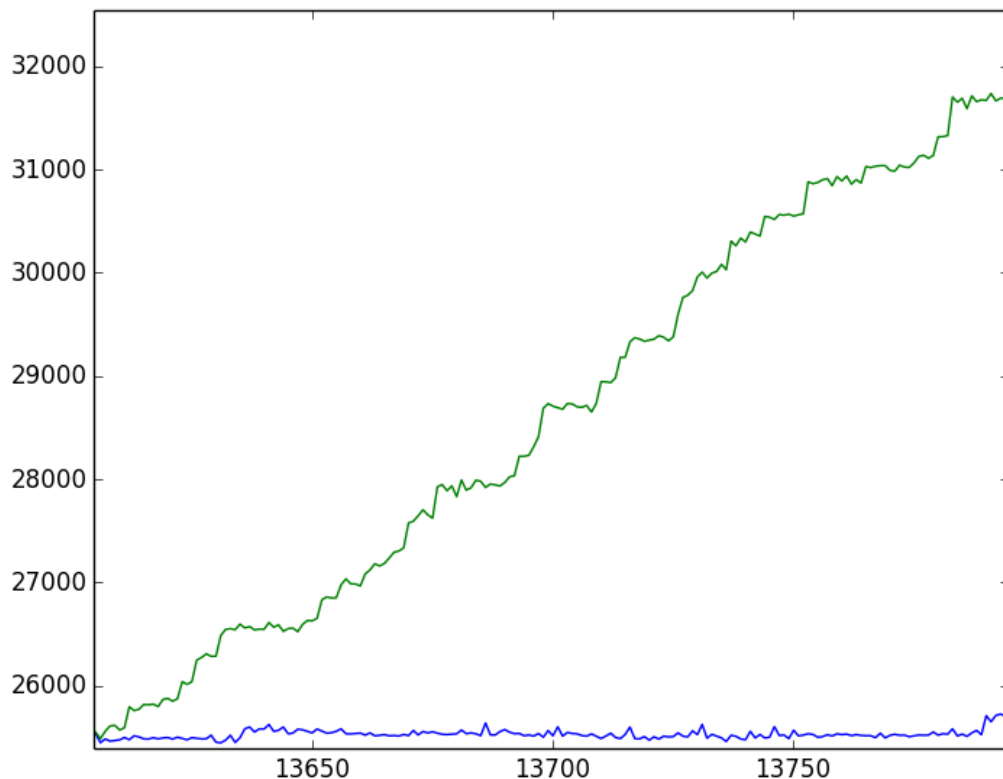
# PB-32: New Controller

- Bias voltage up to SAPHIRA's present 20V max.
- Two gain modes, low and high.
- At high gain, measured read noise is  $55\mu\text{V}$ .
- Pixel rate up to 2MHz.
- Allows us to operate the ME1000's read-reset-read mode.

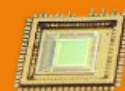
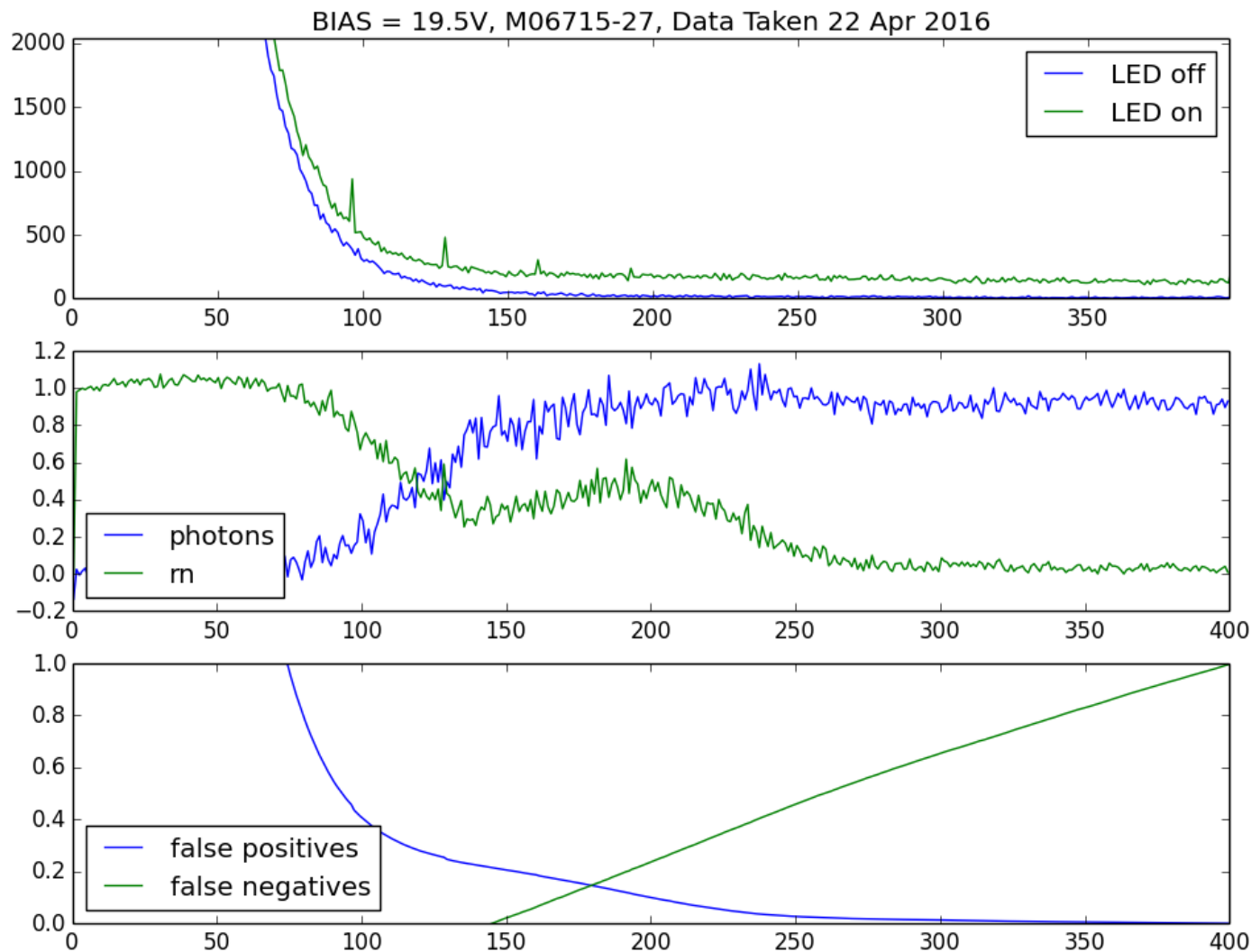




# Photon Counting: Pulse Heights



# Photon Counting: Pulse Heights



# SAPHIRA Deployments

## Subaru/SCE<sub>x</sub>AO

SAPHIRA as a speckle nulling imager and pyramid wavefront sensor for high-contrast imaging.

Evolutionary  
speckles at 1

Sean B. Goel

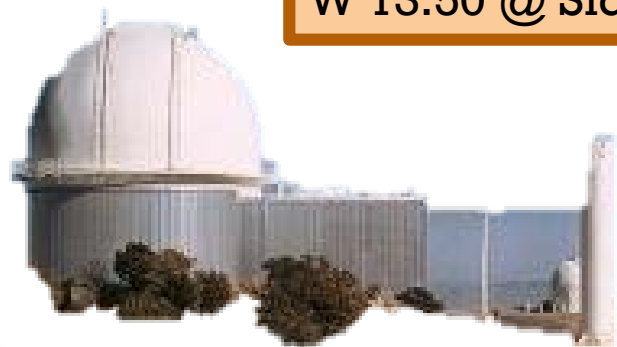
W 16:30 @ S

## VLT/Gravity

Development of the near-infrared eAPD array  
SAPHIRA achieving sub-electron read noise at  
millisecond full-frame readout[9909-40]

Gert Finger (ESO)

W 13:50 @ Sidlaw

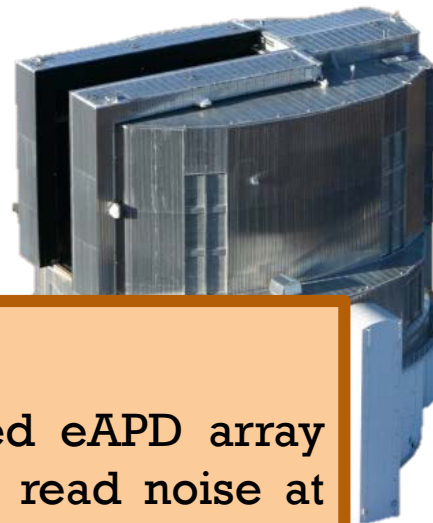


SAPHIRA as a tip-tilt guider and  
simultaneous NIR imager for  
automated surveying.

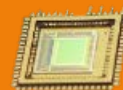
Robo-AO Kitt Peak [9909-48]

Maïssa Salama

Th 11:00 @ Sidlaw



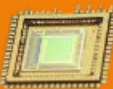
O





# Performance Summary!

- Old 'dark' measurements were entirely glow-limited. With glow suppression, we are down to  $\sim 0.03e^-/s$ .
- The new mark 13/14 detectors receive a high-temperature anneal that greatly improves cosmetic behavior at high bias.
- Avalanche gains can now reach over 500!
- Photon counting is contingent on how we discriminate photons from read noise, and is still being investigated.
- Performance in both low-background and high-background cases are being prepared for publication within the next year.



# SAPHIRA @ SPIE

Development of the near-infrared eAPD array SAPHIRA achieving sub-electron read noise at millisecond full-frame readout[9909-40]

Gert Finger (ESO) W 13:50 @ Sidlaw

Evolutionary timescales of AO-produced speckles at NIR wavelengths [9909-46]

Sean B. Goebel W 16:30 @ Sidlaw

First Light C-RED Camera [9907-86]

Philippe Feautrier W Poster @ Cromdale

Robo-AO Kitt Peak [9909-48]

Maïssa Salama Th 11:00 @ Sidlaw

## Acknowledgements

I am supported by a NASA Space Technology Research Fellowship, #NNX 13AL75H. Development of the SAPHIRA detectors and characterization thereof at UH is sponsored by NSF ATI award AST 1106391 and NASA ROSES APRA award #NNX 13AC13G.

