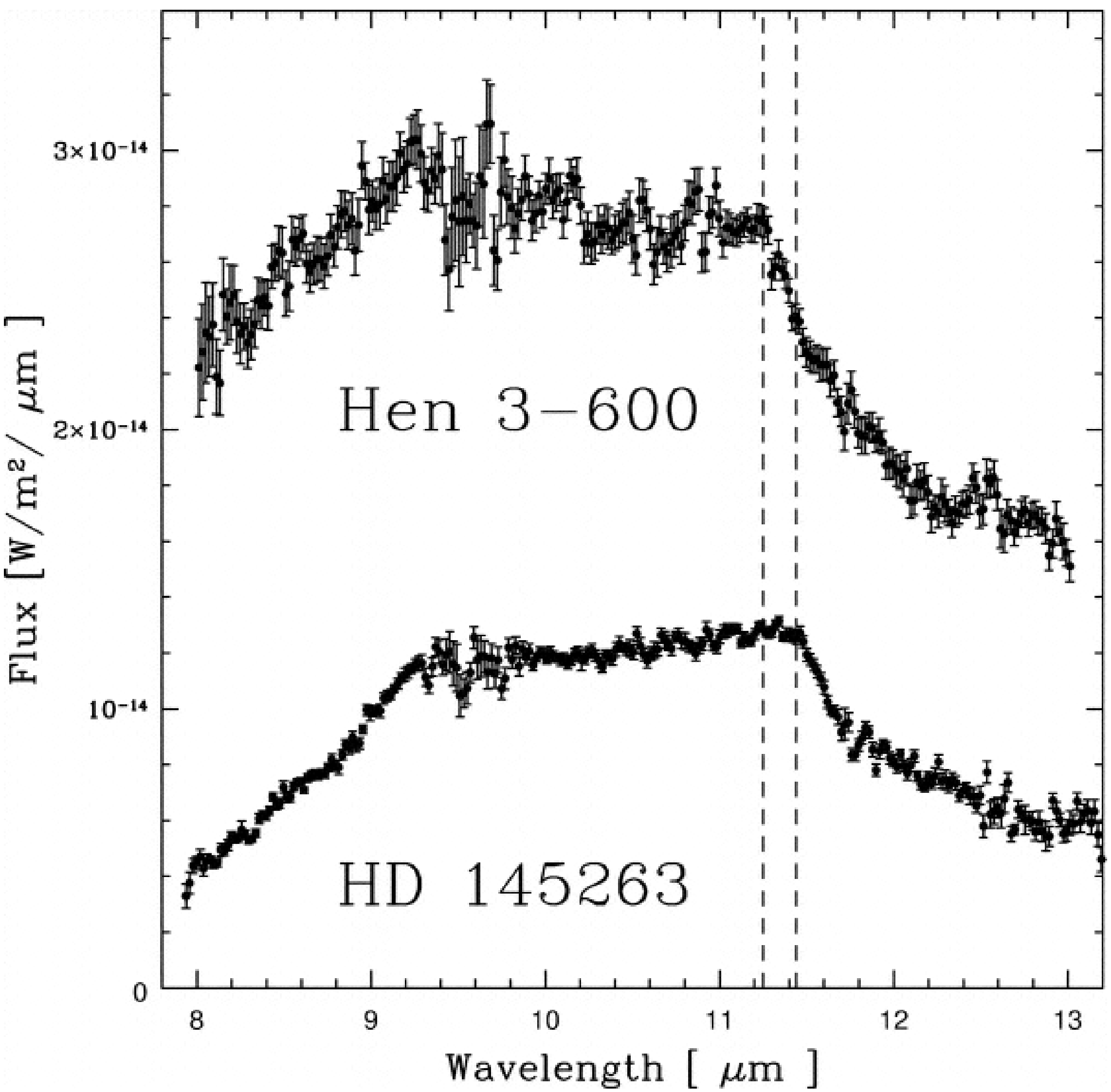
Journal Club 8 Nov. 2007

Bill Forrest will be reviewing the paper "Improvements in Operating the Raytheon 320 x 240 Pixel Si:As Impurity Band Conduction Mid-Infrared Array" by Sako, S.; Honda, M. et al. 2003 PASP, 115, 1407."

This is the detector used in COMICS/Subaru, Michelle/Gemini N, TRecs/Gemini S, and TIMMI-2/ESO. Bill speculates that the excellent S/N ratio Honda et al. show in their HD 145263 (lobster claw shown in Melissa's previous Thursday talk) 8-13 um spectrum uses the techniques reported in this paper.

Optimizing the Raytheon 320x240 Si:As Mid-IR Array

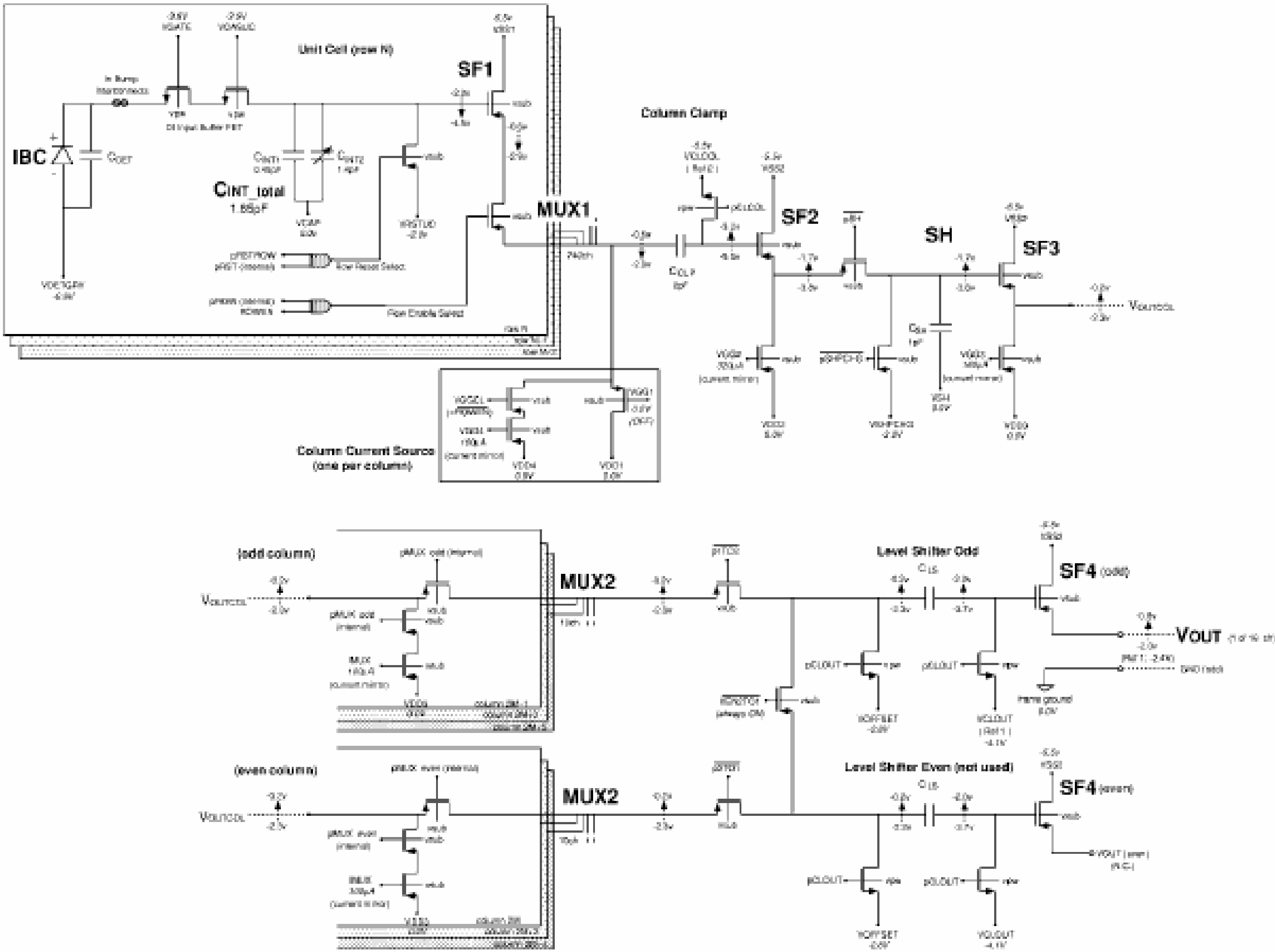


Observed 8 13 m spectrum of the Vega-like star candidate HD 145263 (*lower spectrum*) together with the T Tauri star Hen 3-600A (*upper spectrum*) for comparison (Honda et al. 2003). Large scatter in the 9.3 9.9 m region is due to the atmospheric ozone absorption. HD 145263 shows the 11.44 m shoulder, while Hen 3-600A shows the 11.24 m forsterite feature.

I think the great improvement in the HD 145263 spectrum may result From array optimization. TheSubaru 8m Itime was 1900 sec. vs. 12 sec for Spitzer. The flux at 10 um is 0.5 Jy.

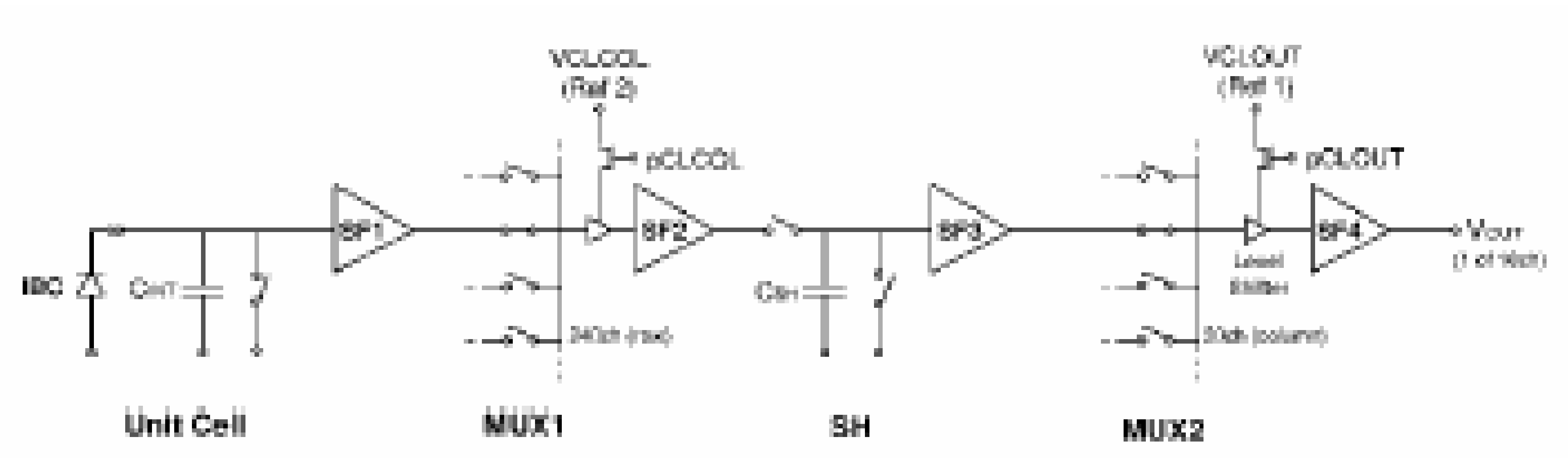
Sensitivity comparison, 8 m Subaru vs. 0.85 m Spitzer

- **The collecting area is obviously ~ 100 times bigger for Subaru**
  - » Equally important, the diffraction limited angular size is about 10 times smaller for Subaru
    - Solid angle 100 times smaller
- **Overcompensating these factors is the low temperature of Spitzer**
  - » 6 K vs. 273 K for Subaru
  - » Spitzer’s noise dominated by fluctuations in photons from the Zodiacal cloud
    - Temperature also near 273 K, but optical depth ~$\mathbf{10^{-7}}$
  - » Emissivity of Infrared Optimized telescope ~ 0.1
  - » Spitzer background intensity a million times lower at 10 microns
  - » Sensitivity to point sources about 20 times better
  - » 20^2 = 400, approximately equal to 1900/12

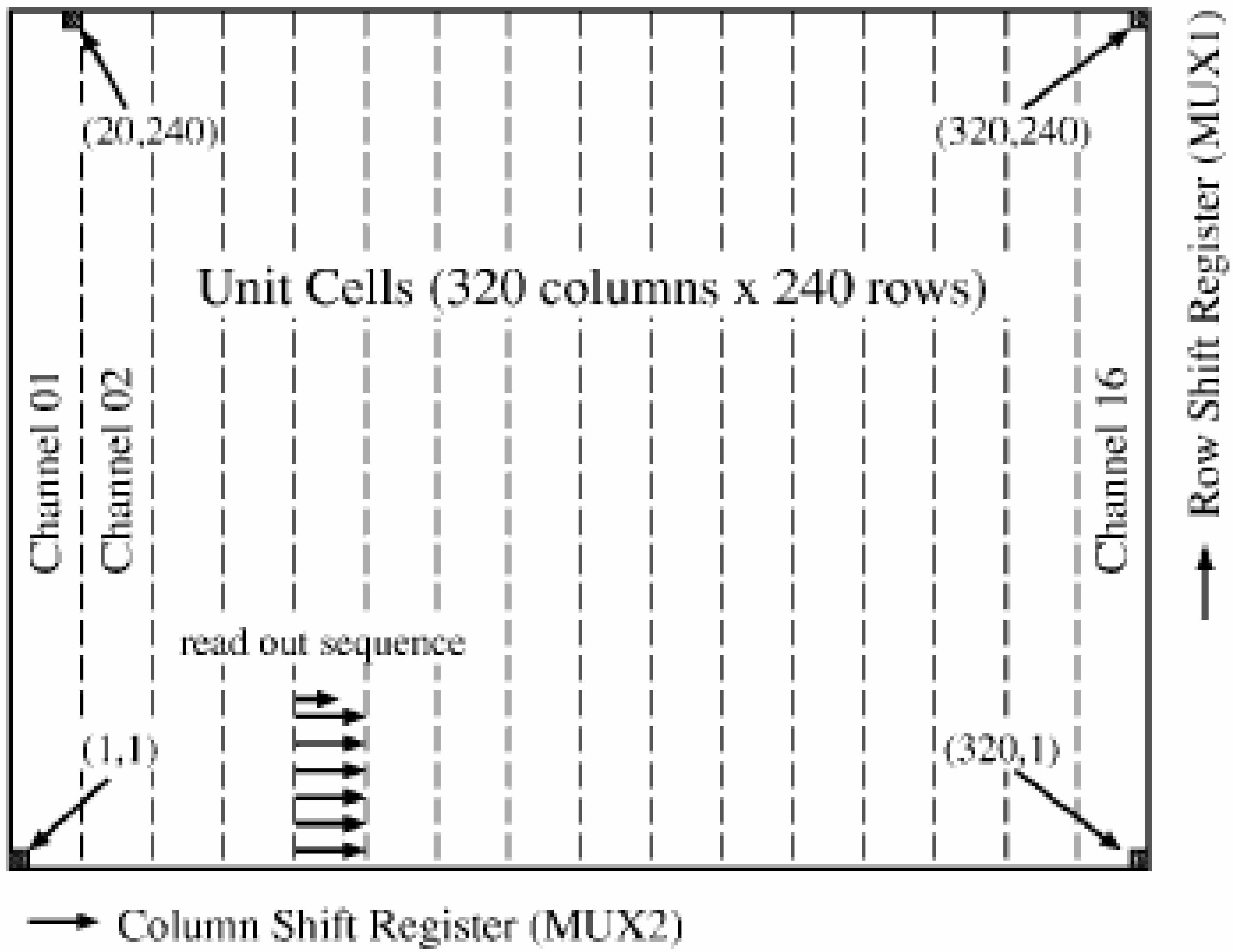


Circuit Schematic CRC 774 Raytheon Cryo-CMOS Read-out Integrated Circuit (Mux)

The CRC 774 is obviously quite complex, use the simplified schematic



Readout floor plan for CRC 774



Problems caused by bright objects
Stars, emission lines, high dark current pixels

(1) Pixels near bright star pulled down – gradation pattern only above star (later in time)
(2) Column pull-down
(3) Row pull-down
(4) Each output “channel” (every 20 columns) pulled down

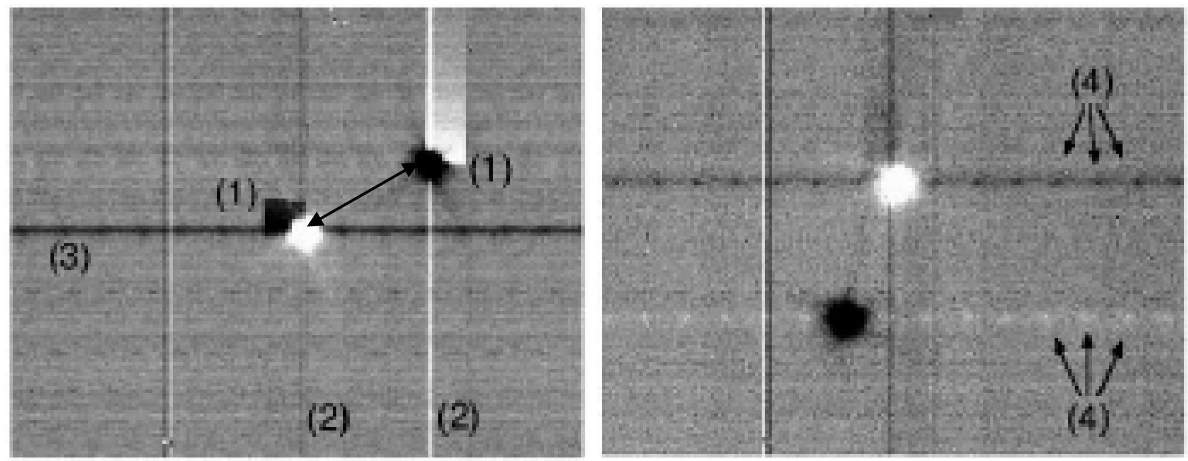
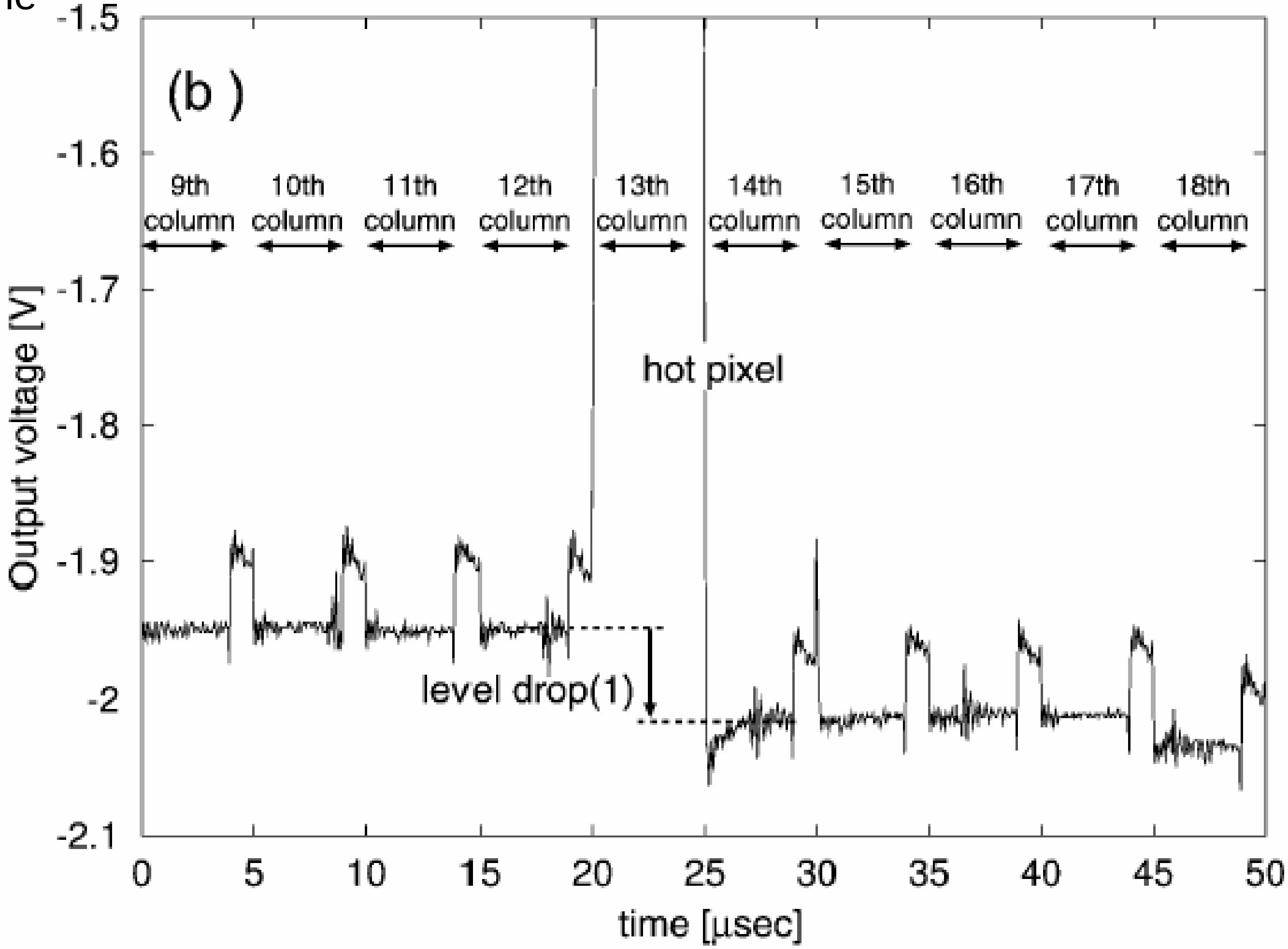


Fig. 4.—Images of bright stars obtained with the normal operation. These images were acquired by COMICS with the **secondary-mirror chopping**, and the off-beam images are subtracted from the on-beam image. The stellar brightness and the background flux in the left image differ from those of the right image. Four level-drop phenomena are seen in these images; a gradation pattern isolated within a channel that starts from the strong signal to the upper side (pattern 1), a level drop in the same column and row of the strong signal (patterns 2 and 3), and a level drop in the same positions as the strong signal in every channel (pattern 4). The intensities of level-drop phenomena depend on the stellar brightness and the background flux.

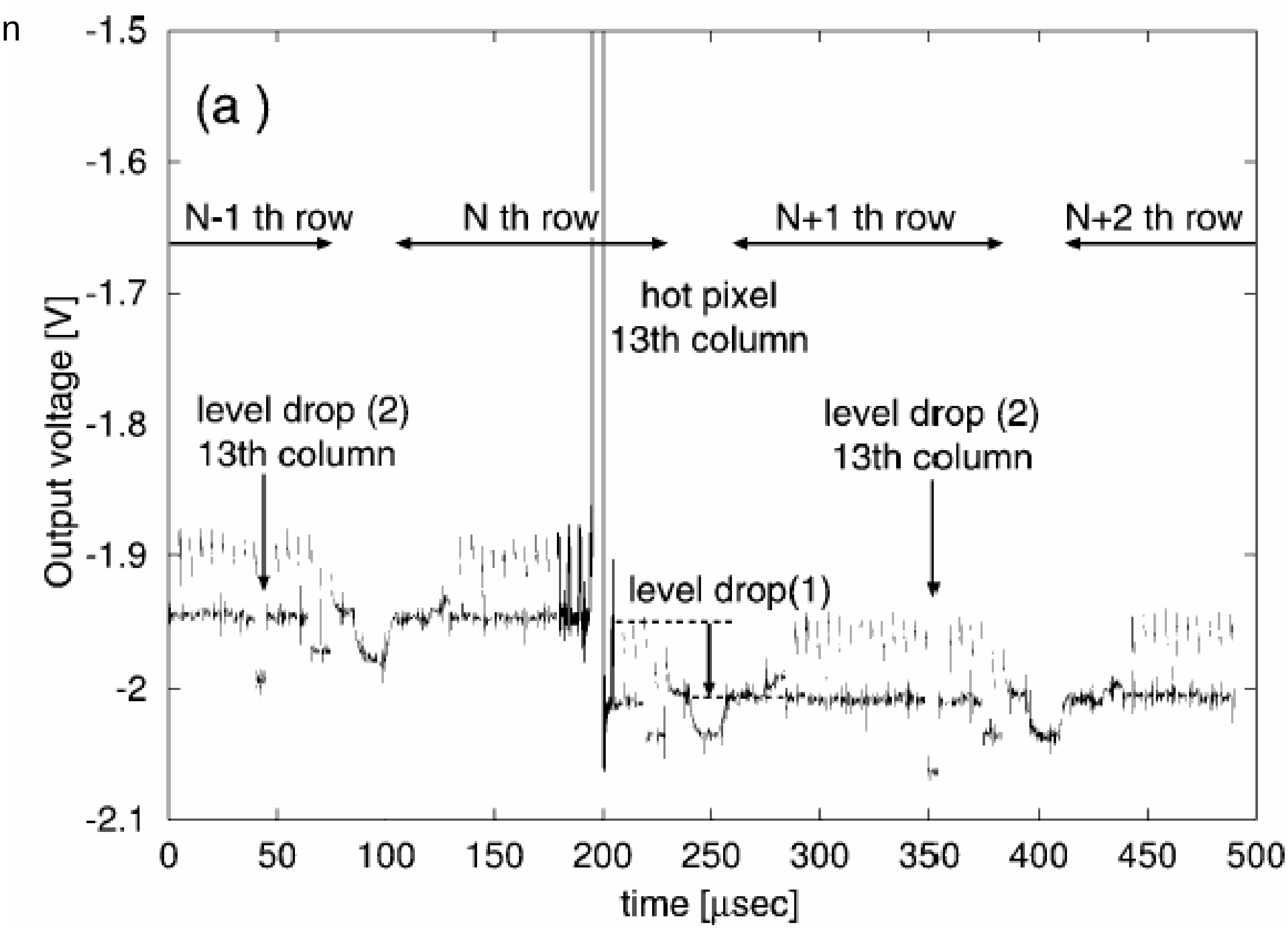
Following a hot pixel (or bright star), level drop (1) is seen

Level recovers gradually in a few milliseconds (few hundred pixels), giving the gradation pattern (1)

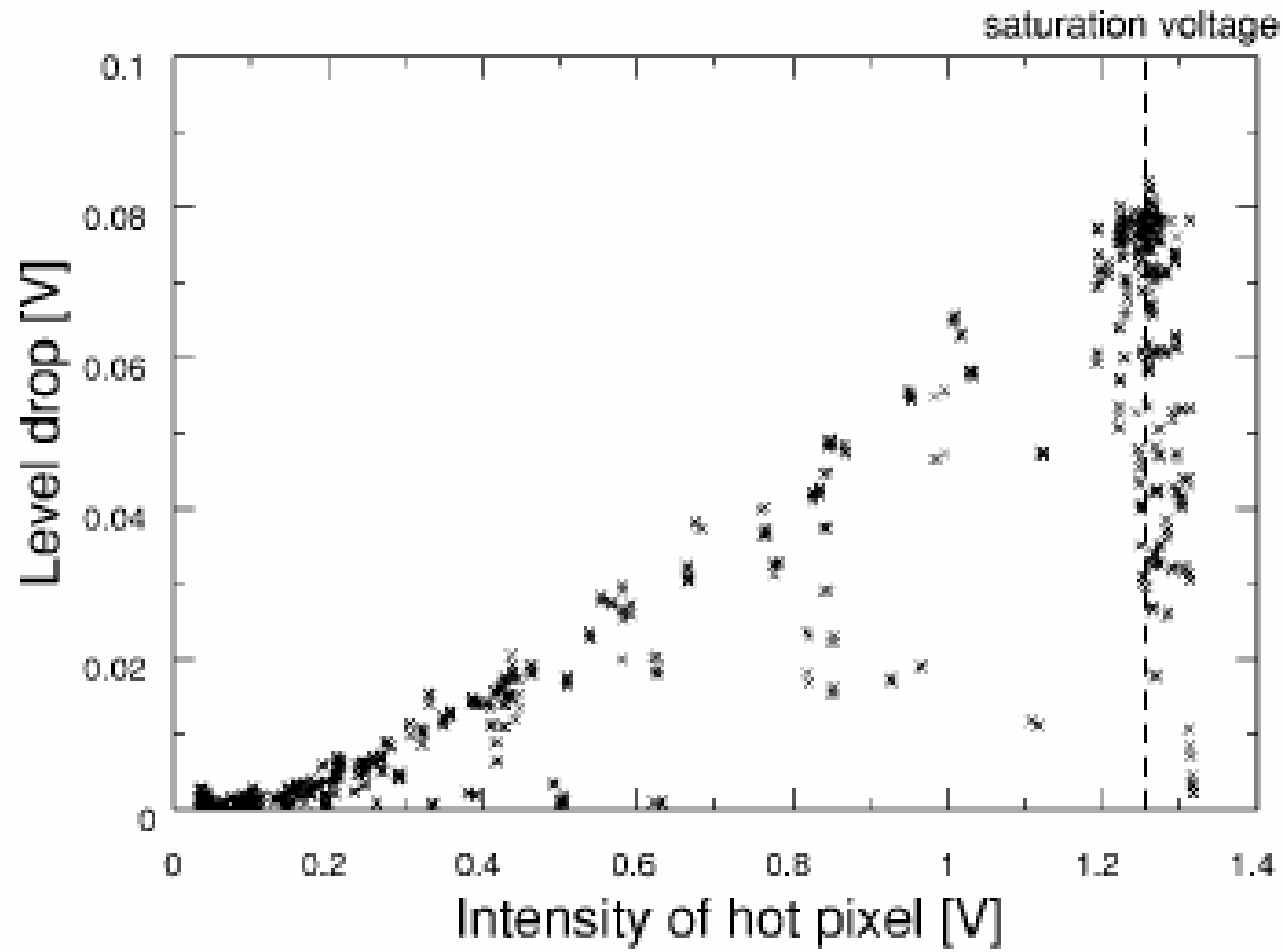


Column pulldown (level drop (2)) shows up before and after hot pixel

Signal recovers in a few tens of milliiseconds



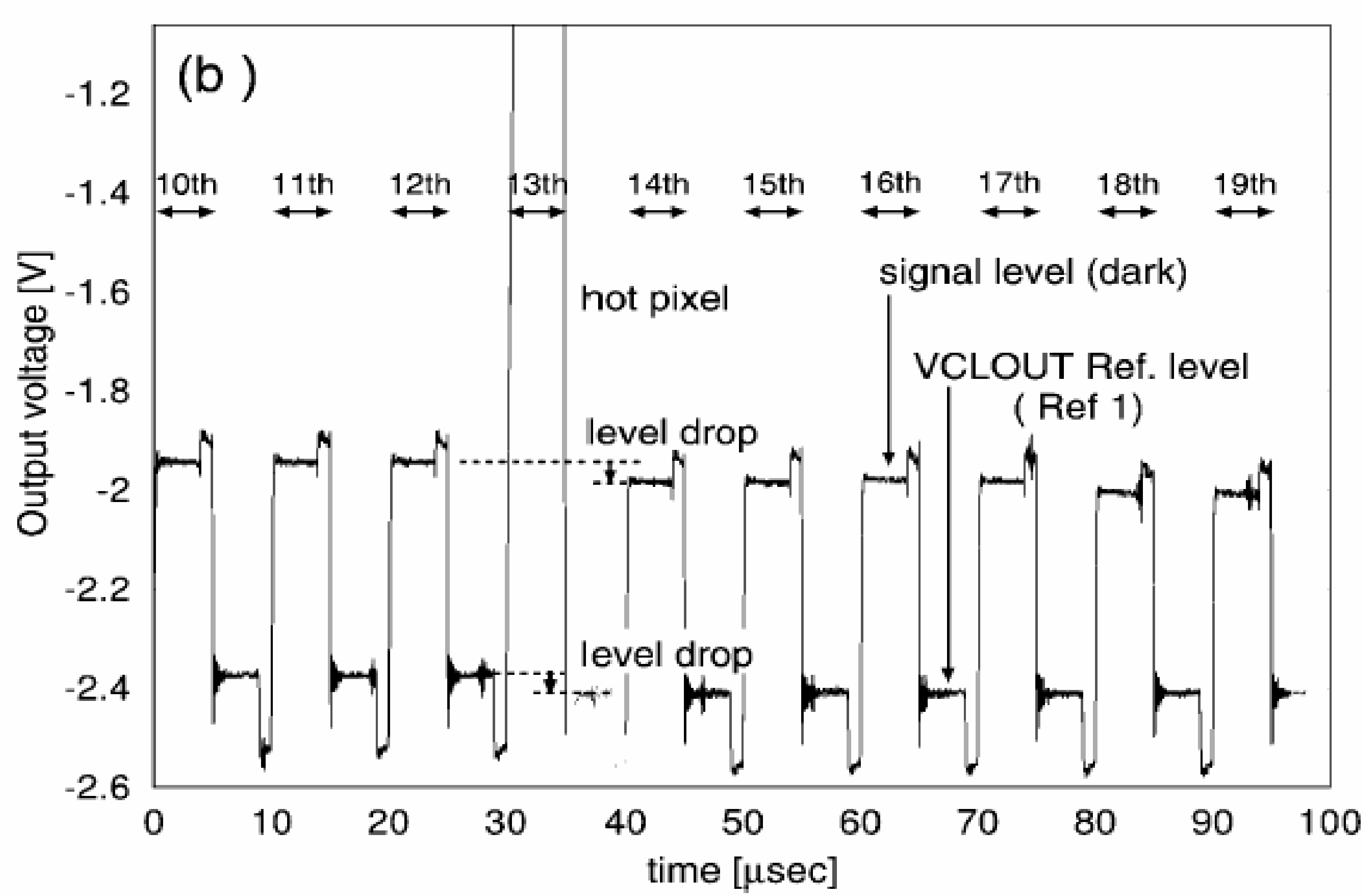
Pulldown (level drop) can't be predicted (scatter in plot) ➔ can't deconvolve from images



Level drop (1) in SF4 (the output, line-driver FET)

- **Happens no matter what column is addressed**
  - » This rules out SF1-3 and their bias voltages
- **To diagnose, cleverly clock pCLOUT**
  - » Every other pixel, turn it on
  - » Puts VCLOUT on the input to SF4
  - » VCLOUT is a solid, DC voltage
  - » The output of SF4 should be DC also
- **Note (next slide) output of SF4 drops after hot pixel**
  - » Either the **gain** or **offset** of SF4 has been affected
    - By thermal heating
    - Or electrical charging

Hot pixel causes same level drop from VCLOUT as from a real pixel



Gain and Offset of Source Follower 4 (SF4) “gain curve”

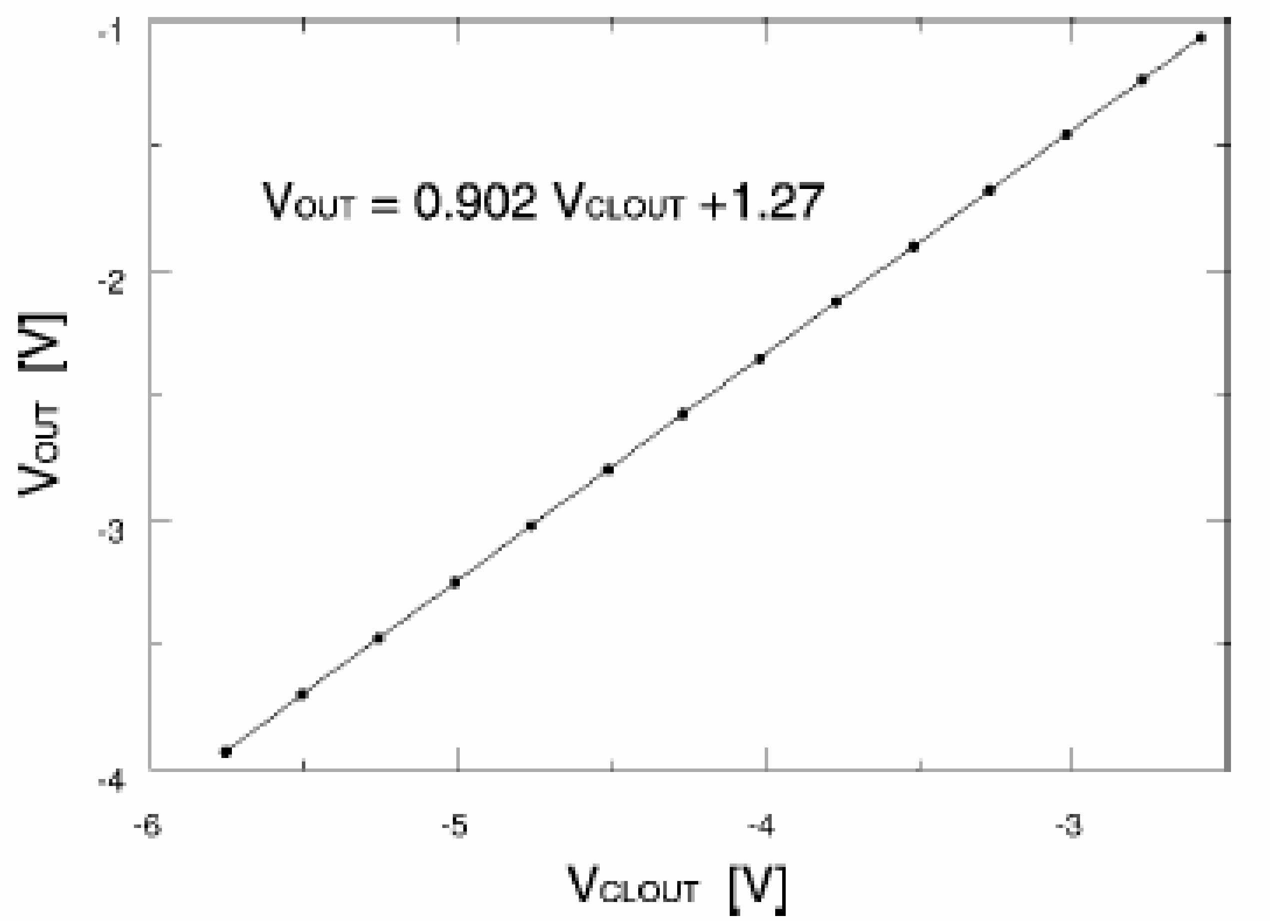
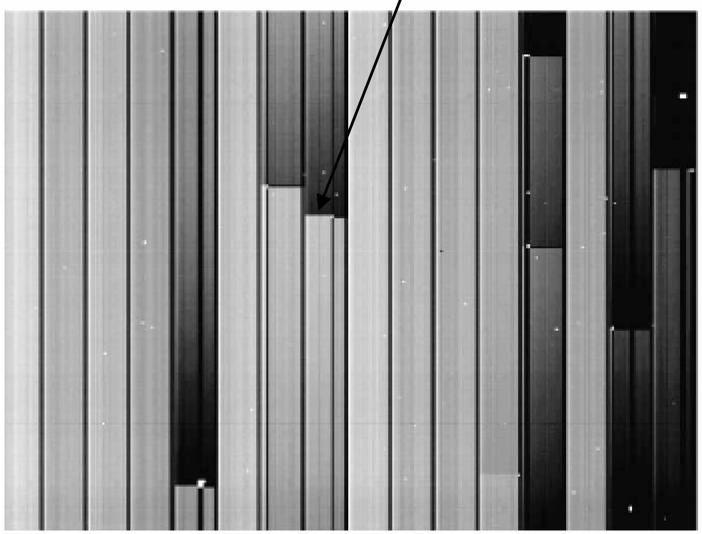


Fig. 17.—Relationship between *V*CLOUT and *V*OUT measured by turning on *pCLOUT*-switch. These data are best fitted by a linear function *V*OUT(*VCLOUT*) = 0.902**V*CLOUT + 1.27*V.

Clever trick, reference output signal to VCLOUT measured through SF4 – fixes pattern (1)

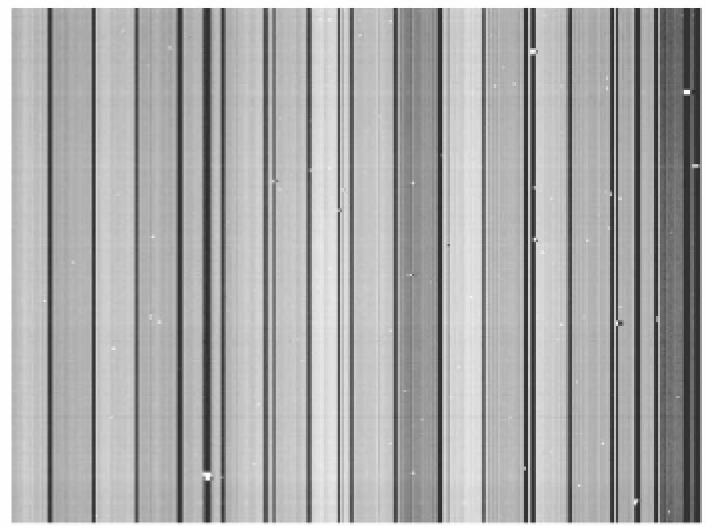
Before

Pattern (1)



After (signal – Ref1)

Indicates SF4 problem is offset (rather than gain)

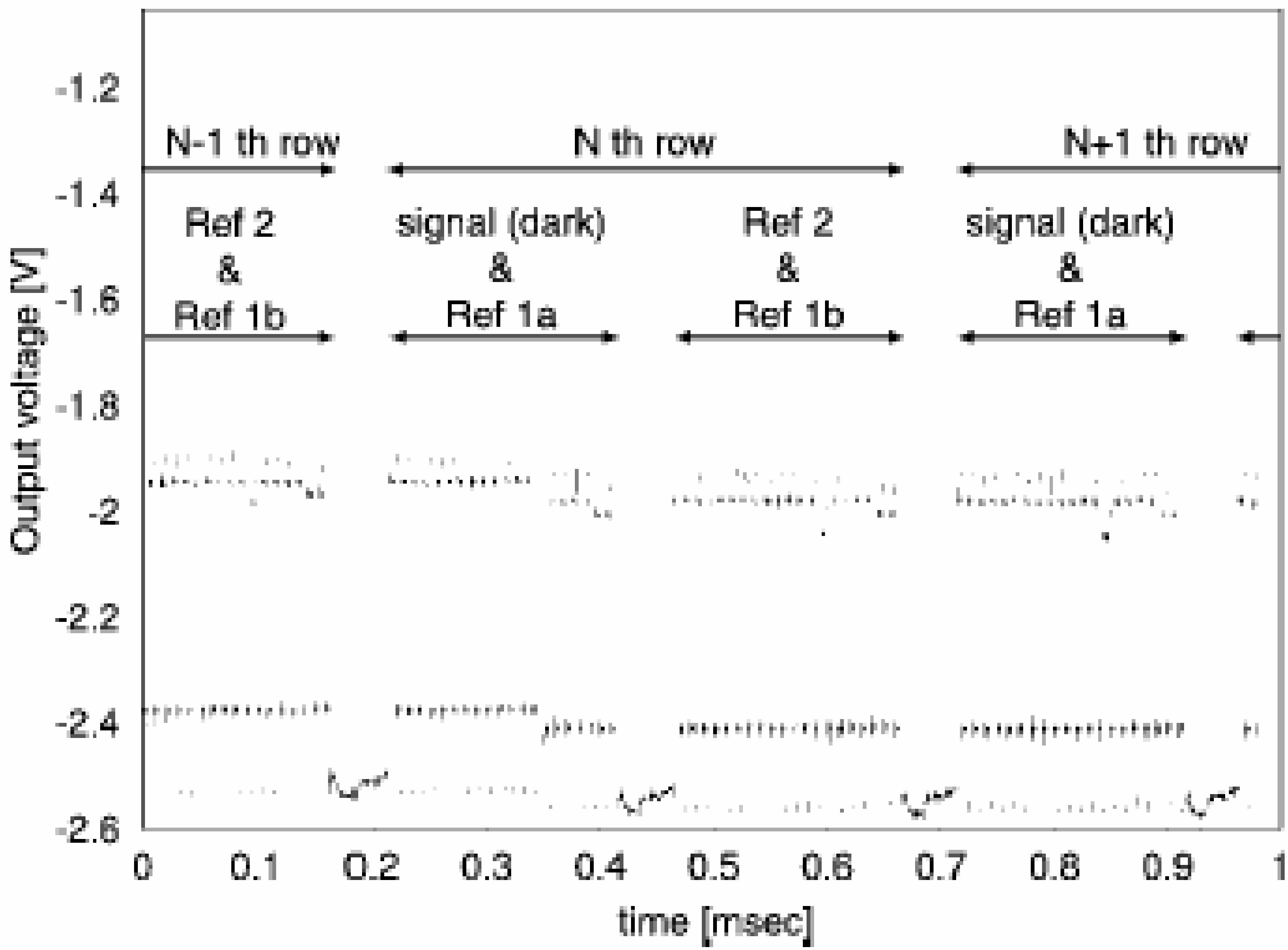


Down side: takes twice as long to read the array (I think)

Use VCLOL read through SF2/3/4 as Ref2

- **A similar trick using pCLOL/VCLOL shows pattern (2) (column pulldown) can be attributed to changes in either SF2 and/or SF3**
  - » Change in gain or offset
    - Caused by heating or electrical re-arrangement
- **Use both references to eliminate (1) and (2)**
  - » (signal – Ref1a) – (Ref2 – Ref1b) (see next slide)
  - » Correlated quadruple sampling
  - » Takes 4 times as long to read array (I think)

Correlated Quadruple Sampling waveform



Much improved images using CQS!

Upside: noise will be dominated by photon statistics (ground based, high background)
Downside: now it takes 4 times as long to read the array

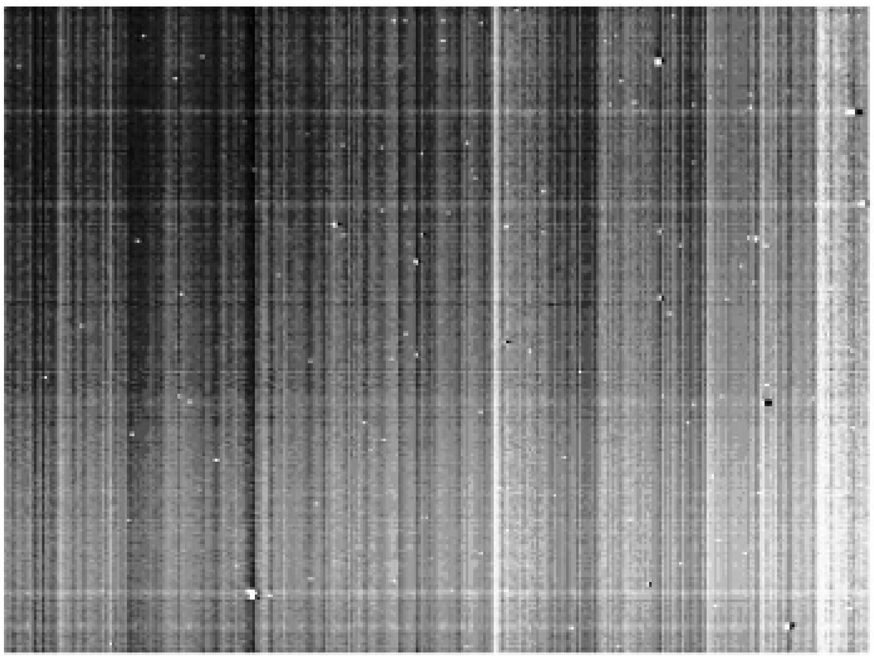


Fig. 14.—Dark image obtained with the CQS (*signal* - Ref1a) - (Ref2 -Ref1b). The level-drop phenomena of both patterns 1 and 2 completely disappear

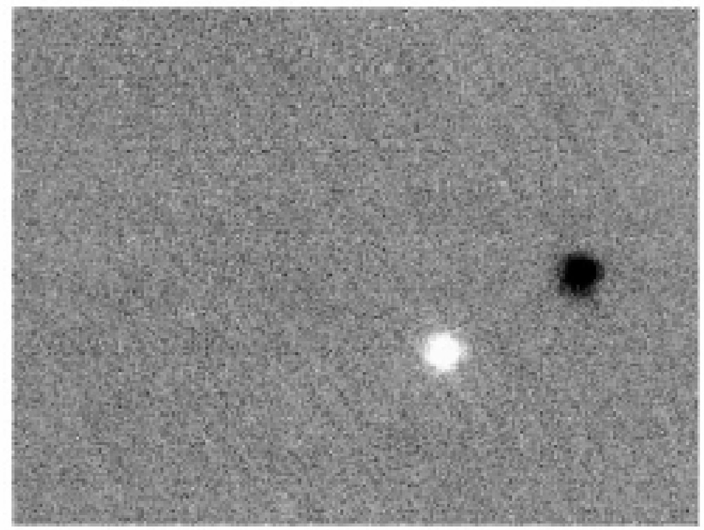


Fig. 15.—Image of a bright pointlike source taken with the CQS. Comparison with Fig. 4 clearly demonstrates the effectiveness of the CQS. Patterns 3 and 4 are not seen in this image because of the faintness of the object.