MIRI Detectors

Mid InfraRed Instrument

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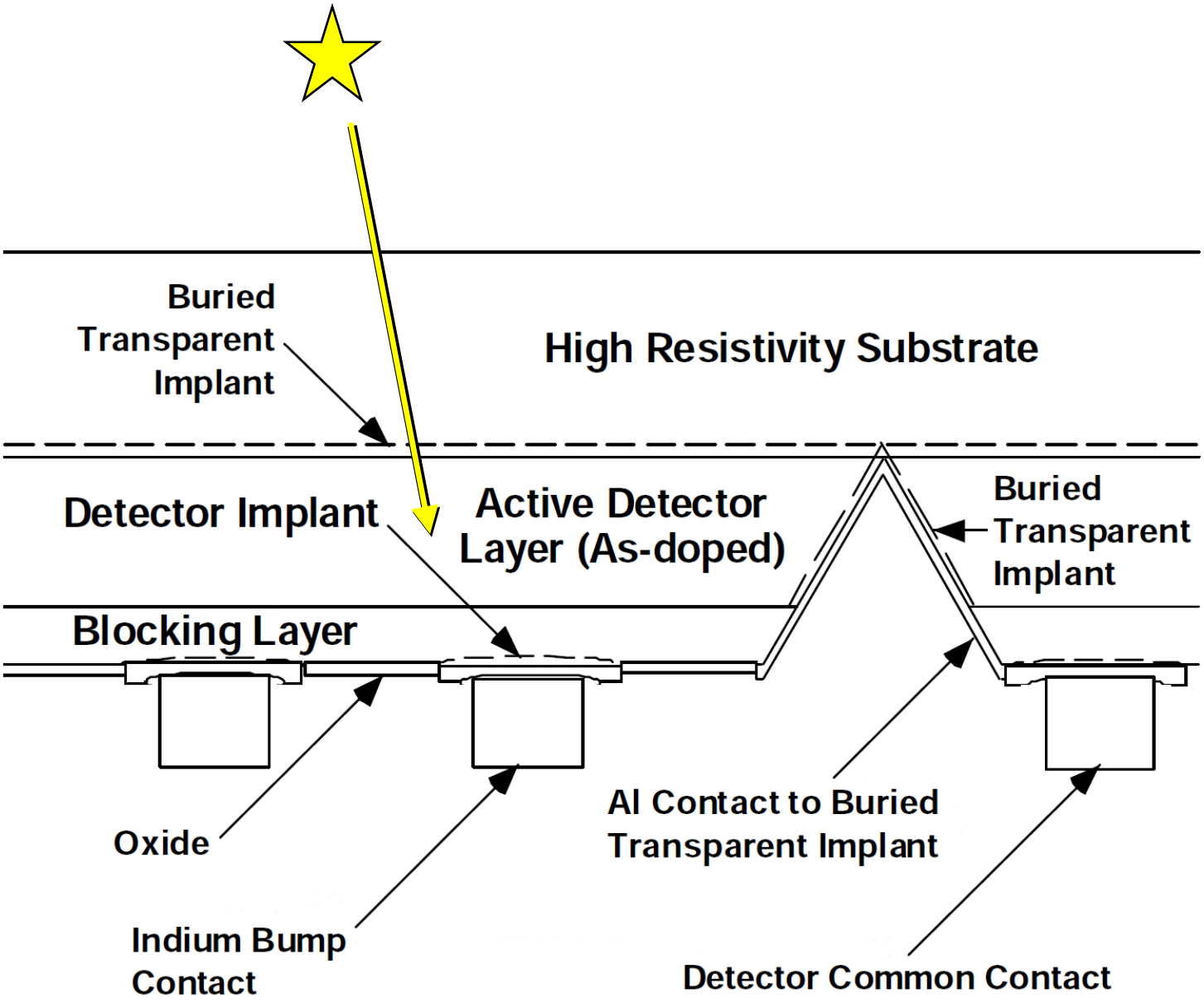
Detector Functionality

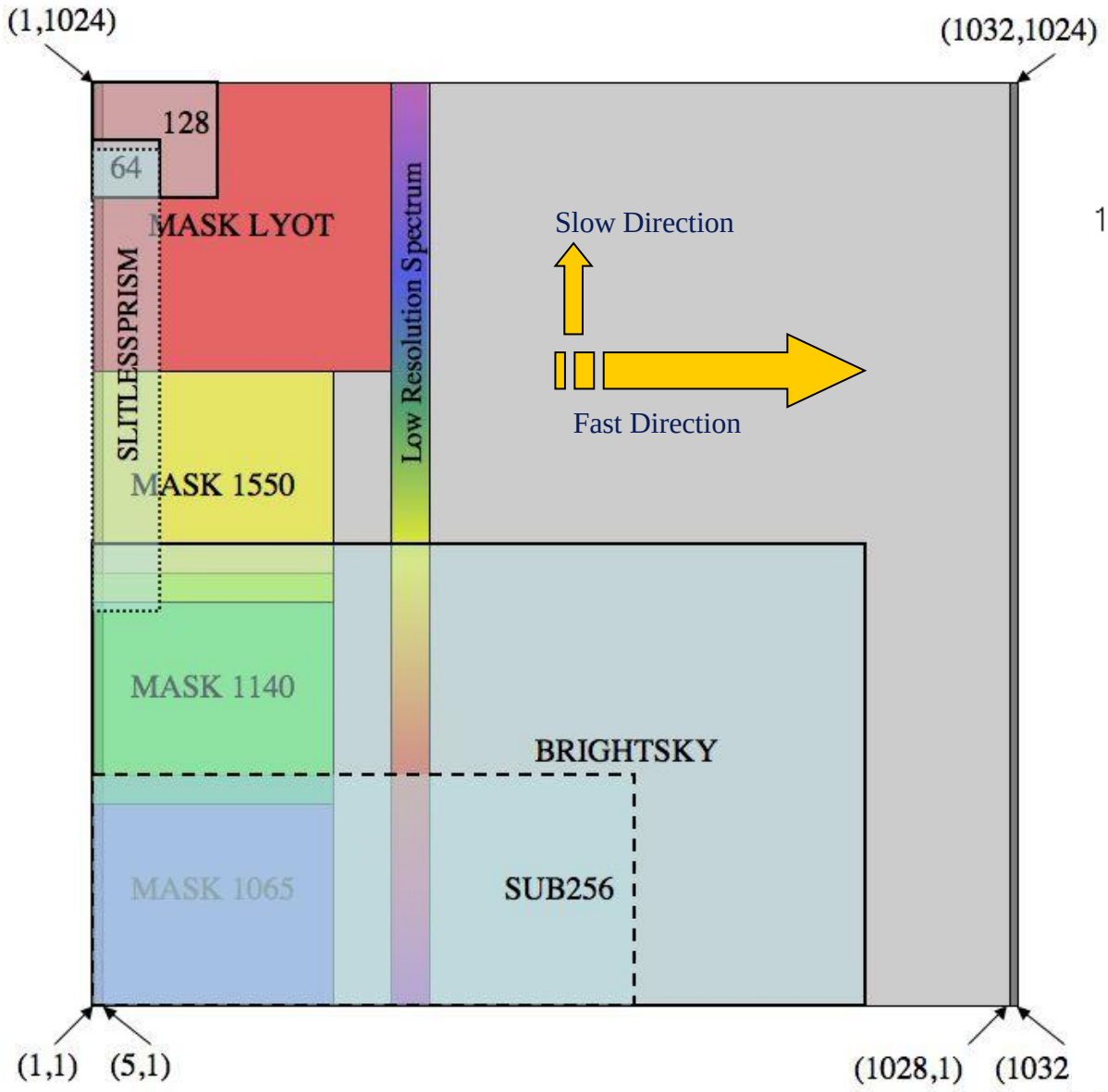
MIRI Detector Heritage

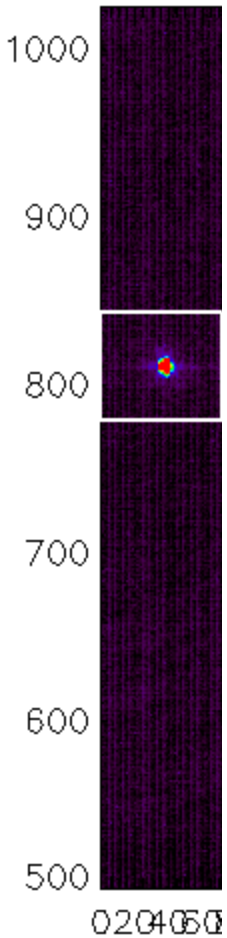
- MIRI arrays are the direct descendants of the long wavelength IRAC arrays
  - Same four science outputs and interleaving
  - Same readout procession
  - Same fundamental noise/power performance
  - Similar detector layer recipes
- Chief differences
  - Larger format, 1024^2 vs 256^2
  - Smaller pixel size, 25 μm vs 30 μm
  - Added reference pixels and output
  - Added odd/even row circuitry

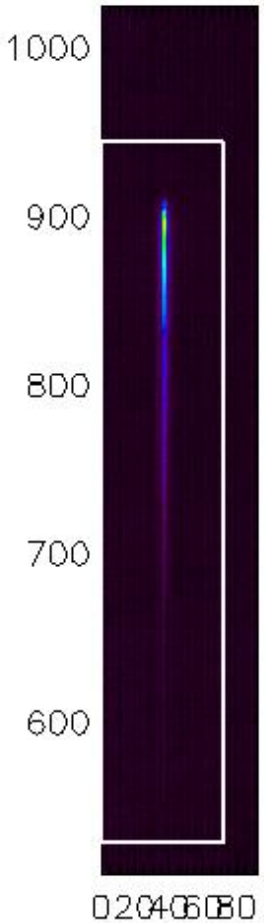
Detector Layer Schematic



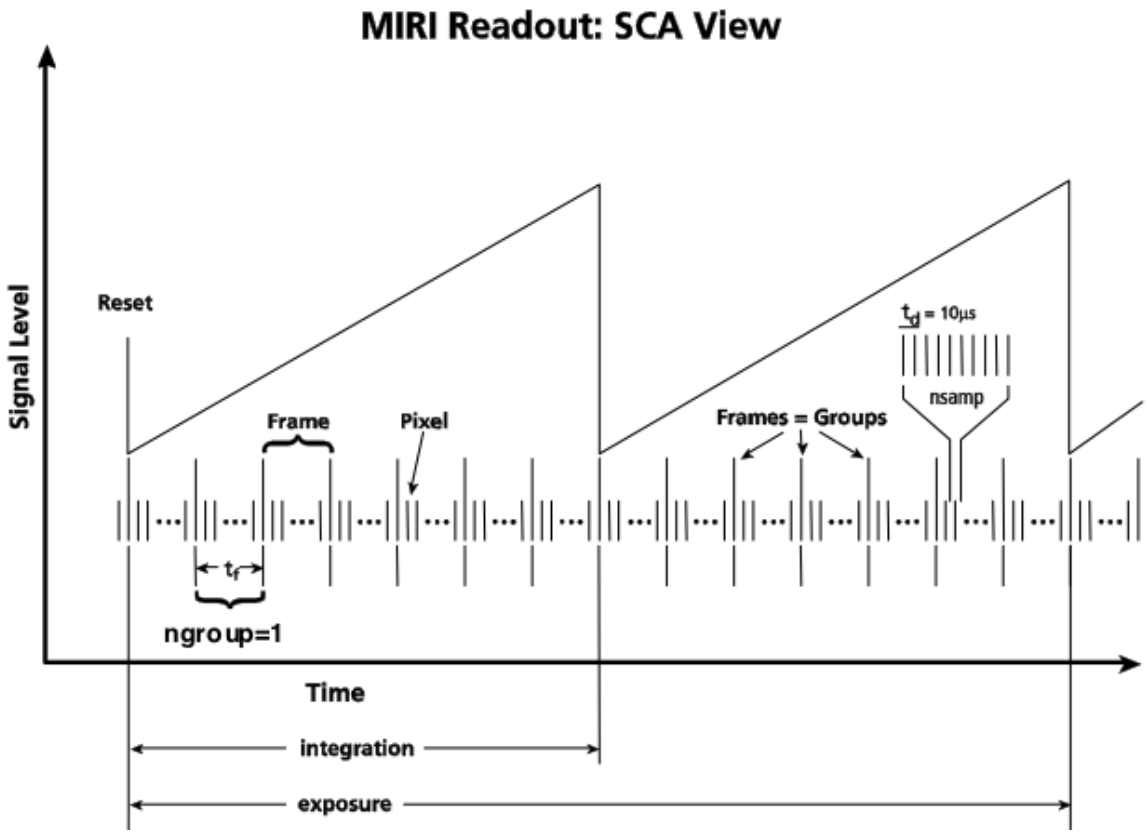
Readout and Subarray Schematic







Readout Technique



Samples/pixel = 1 or 10 (Fastmode vs Slowmode)
Frames = Groups for MIRI
Frames/Integration = 1 to 65535 (limited by CR hits to ~ 1000 sec)
Ints/Exposure = 1 to 65535

Exposure Time Calculations – 1

- Frame time depends on number of pixels read plus overhead
  - With current electronics and definitions, approximately:

$$(\text{RowStop} - \text{RowStart} + 1) * (\text{ColStop} + 3) * 10\ \mu s + 0.072\ \text{sec}$$

  - With new electronics and burst mode, assuming it works well:

$$(\text{RowStop} - \text{RowStart} + 1) * (\text{ColStop} - \text{ColStart} + 4 + \text{ColStart} // 5) * 10\ \mu s + 0.072\ \text{sec}$$

Subarray	Size Columns by Rows	Start Pos	FAST Frame Time	Max Flux F560W [mJy]	Max Flux F2550W [mJy]
FULL	1032x1024	(1,1)	2.775	17	360
BRIGHTSKY*	968x512	(1,37)	1.326	34	780
SUB256*	668x256	(1,37)	0.507	90	2150
SUB128	136x128	(1,889)	0.119	370	8400
SUB64	72x64	(1,779)	0.085	520	12000
SLITLESSPRISM	72x416	(1,529)	0.159	3000 using P750L at 7.5 µm	
MASK1065	288x224	(1,19)	0.240		
MASK1140	288x224	(1,245)	0.240		
MASK1550	288x240	(1,467)	0.252		
MASKLYOT	320x308	(1,715)	0.327		

* Only BRIGHTSKY and SUB256 will gain from burst mode if it is successful

Exposure Time Calculations – 2

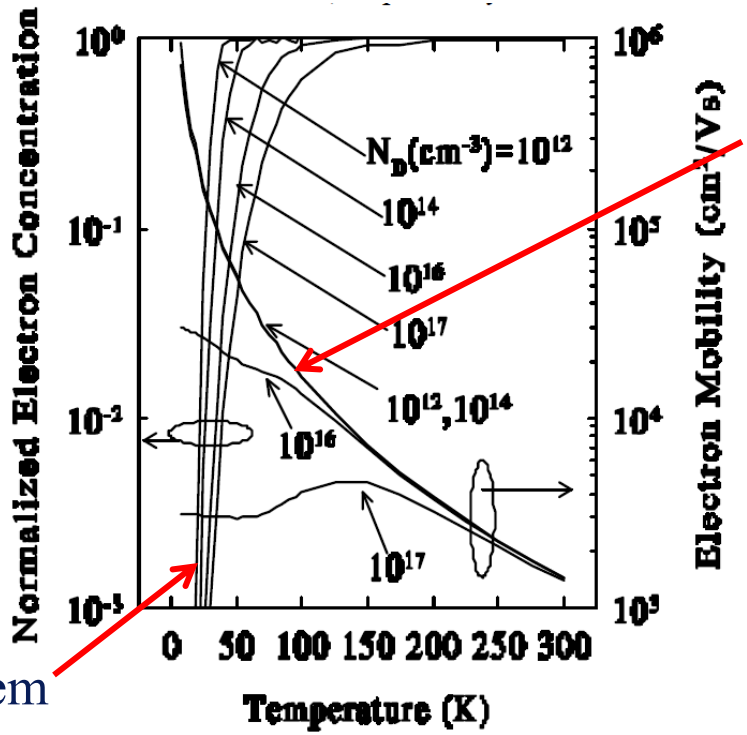
- Integration time is an integer multiple of frame time
  - No gaps or pauses between frames
- Exposure time is an integer multiple of integrations plus any intermediate reset frames (currently 0)
  - No gaps or pauses between ints/frames
- Timing within an exposure is completely deterministic and very well determined
- Between exposures is not controlled and is dependent on latency in the IC&DH system
  - We never do a partial frame read – next exposure start is forced to wait for a frame boundary
  - Time tagging should still be good enough to determine precise time gap

Detector Peculiarities

(Some figures shamelessly stolen from
James Colbert, Dan Dicken, and Tom Greene)

MIRI Detectors Are Cold!

- MIRI detectors operate well below silicon freezeout
- The fabrication processes of both the detector layer and the readout address this, but it is impossible to completely get around it



It's not that electrons can't move fast – in fact, they move faster

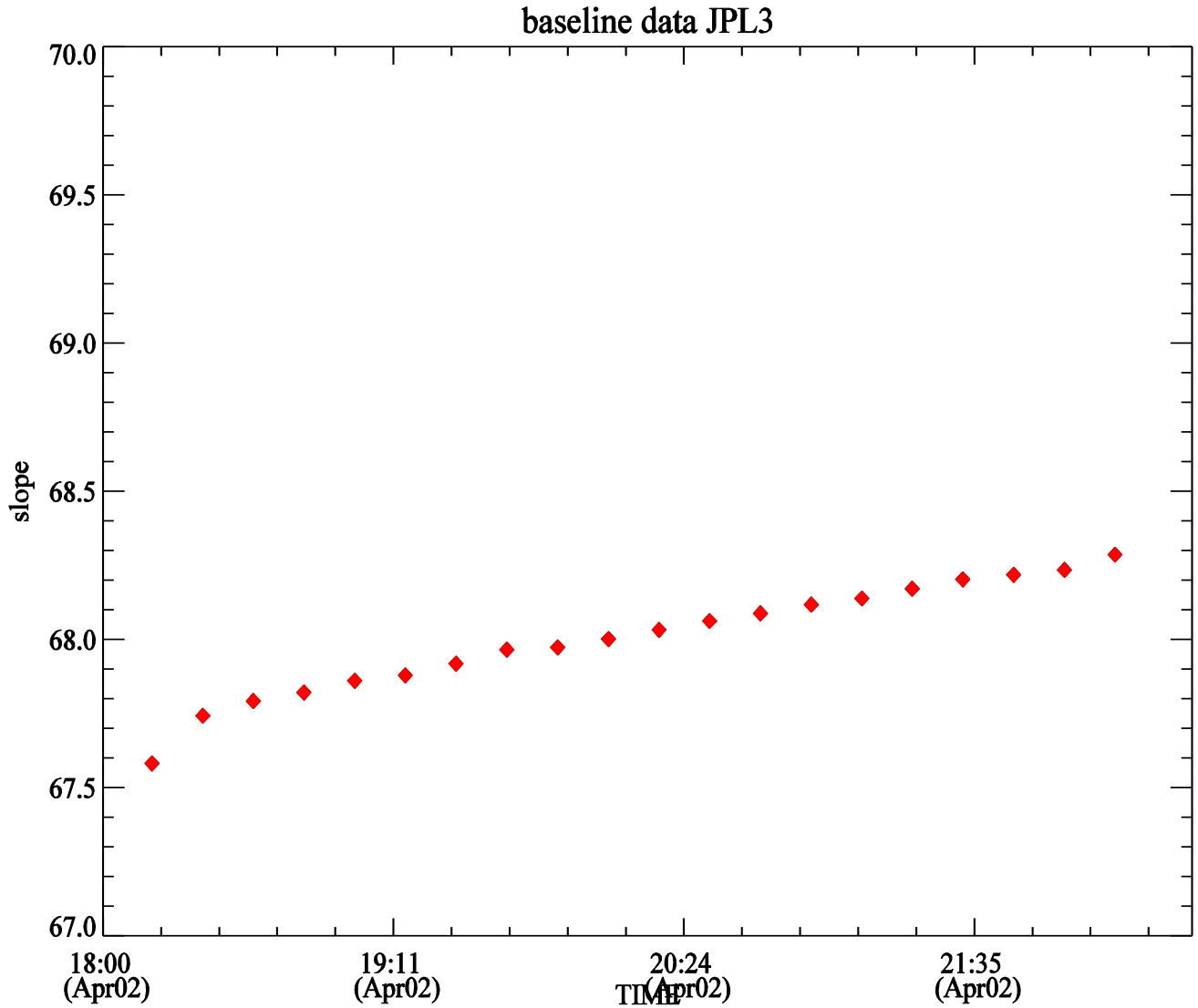
It's that none of them are free to move!

"12 Bad Habits"

- George Rieke has compiled a list of MIRI's most significant calibration-related misbehaviors:
  1. Nonlinearity (much progress has been made)
  2. Reset zero point drift (issue for nonlinearity correction)
  3. Response drifts during exposure (most serious bad habit)
  4. Reset anomaly (much progress has been made)
  5. Latent images
  6. Cosmic ray effects and anneal recovery
  7. Settling time after powering up
  8. Settling when changing operational mode (e.g. full to subarray)
  9. Last frame effect (good understanding, correction not clear)
  10. Extraneous signals from the readout: "MUX glow"
  11. Readout electronics slew rate limitations (electronic crosstalk, eliminated)
  12. Avalanche gain (much progress has been made)

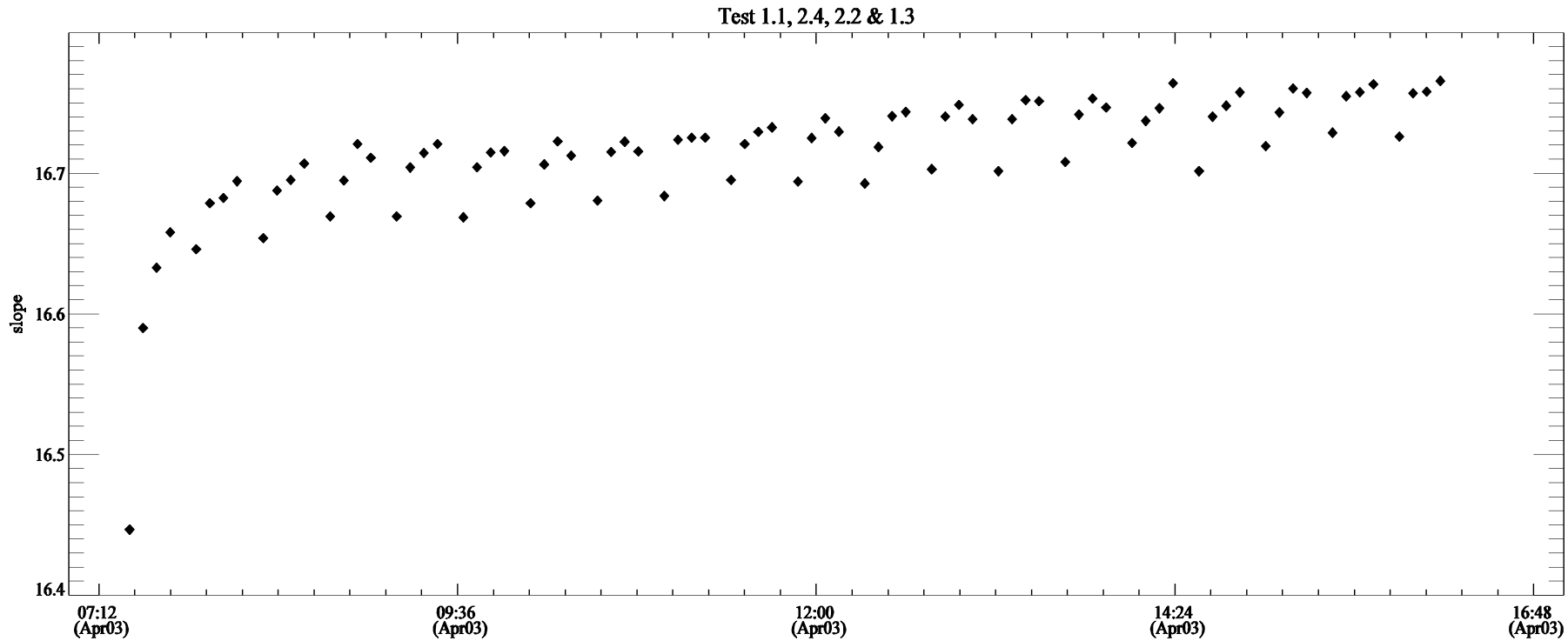
* Effects with significant impact on exoplanet science highlighted in red

3. Drifts In Apparent Response



- Constant illumination source, repeated single-int exposures for 4 hours

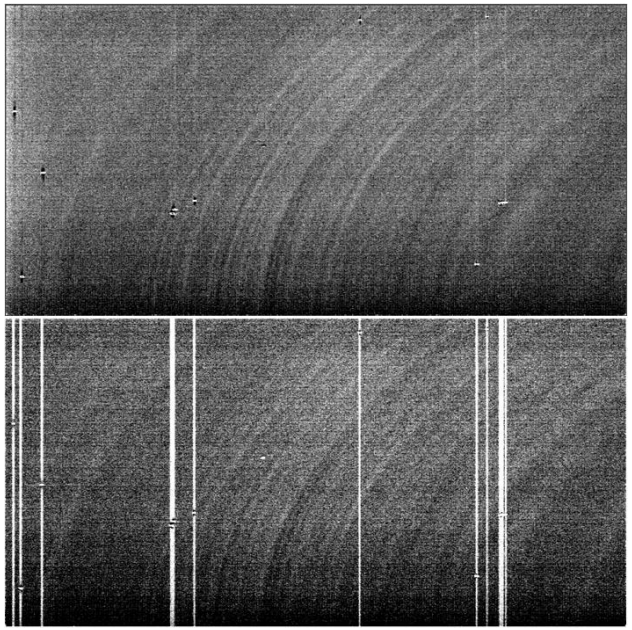
3. Drifts In Apparent Response



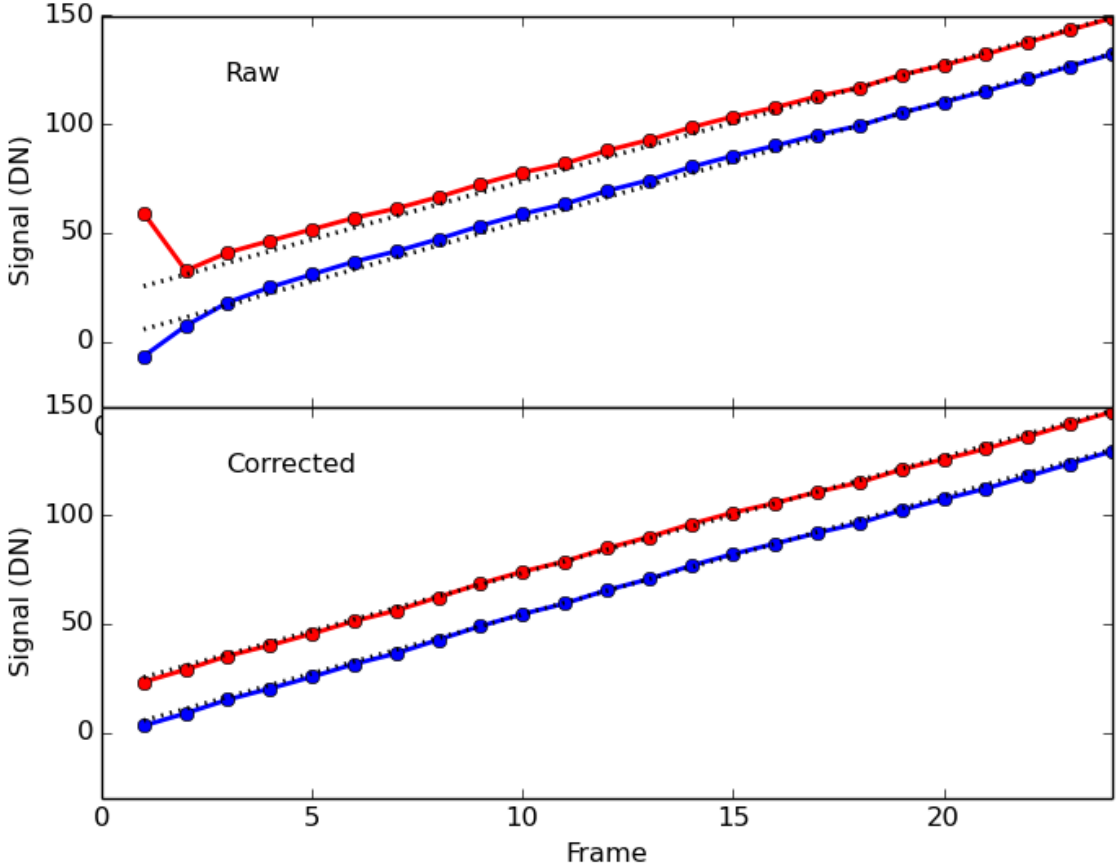
- Constant illumination source, repeated single-int exposures 9 hours, 5 minute pause between each block of 4 exposures
- Effect at the fraction of a percent level; under very active investigation

4. Reset Anomaly

Odd rows



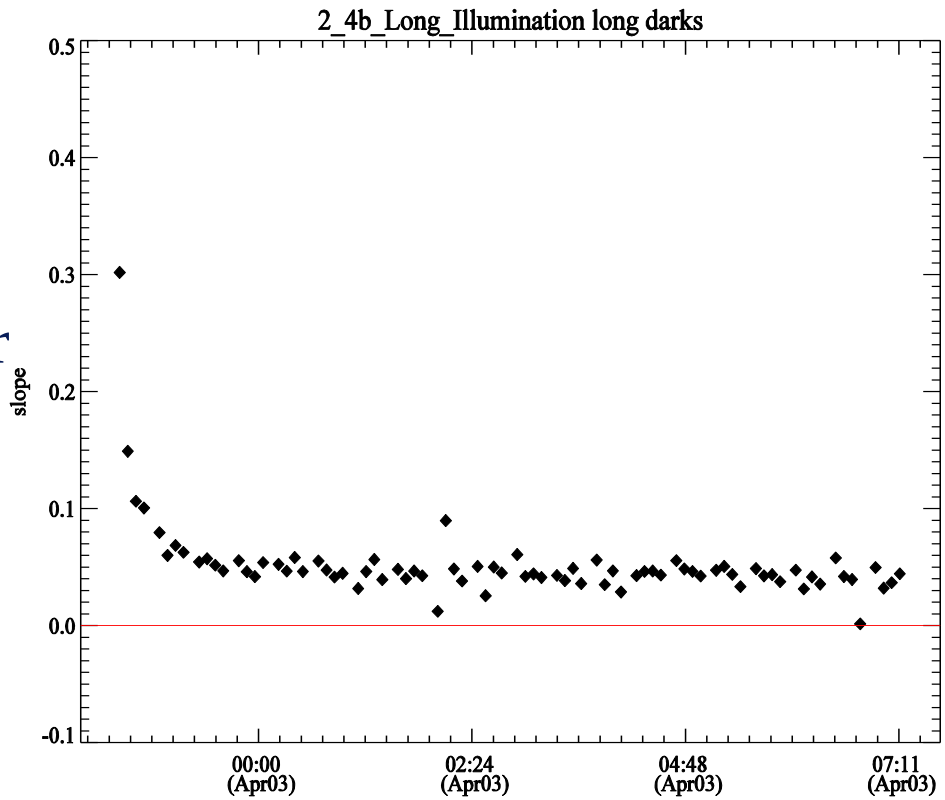
Even rows



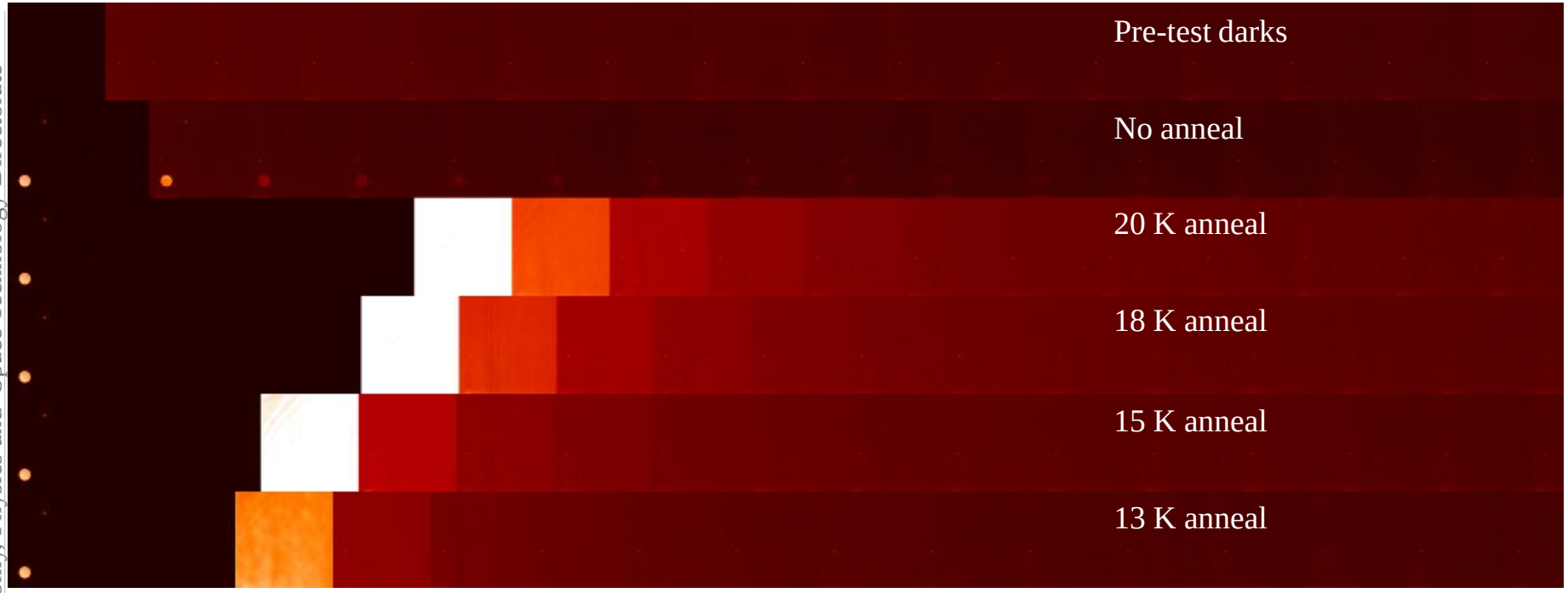
- "Left-overs" from previous resetting process contaminate beginning of subsequent integration
- Not flux dependent, can be corrected with information extracted from darks
  - Some flux dependence in multiple ints within an exposure – see latents

5. Persistence Recovery

- Timescales from a few seconds to a few hours
  - 8 sec major component
  - 2 min with 800x smaller amplitude
  - 10 min with even smaller amplitude (1x – 4x)
- Seen as "traditional" latents in subsequent exposures (after fitting slopes)
- Also seen as effects on a frame-by-frame basis

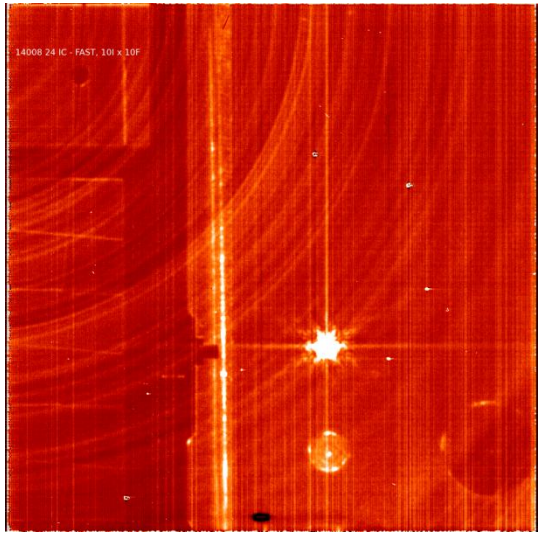


5. Persistence Recovery

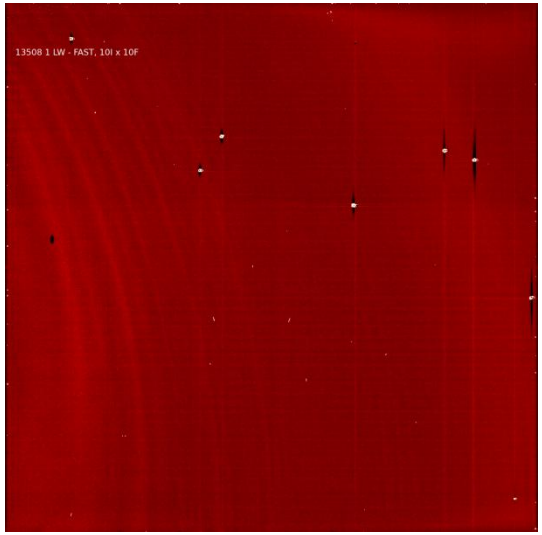


- "Low temperature" anneal may restore latent-free imaging in < ½ hr
- SNR performance is restored faster than the DC background
  - i.e. not a shot noise process

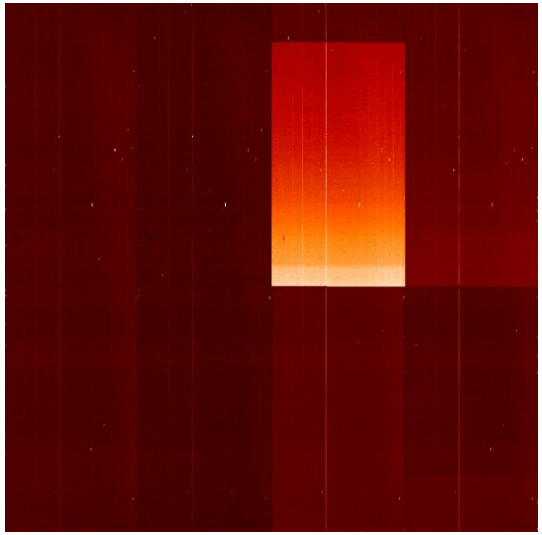
All the Usual Weird Stuff



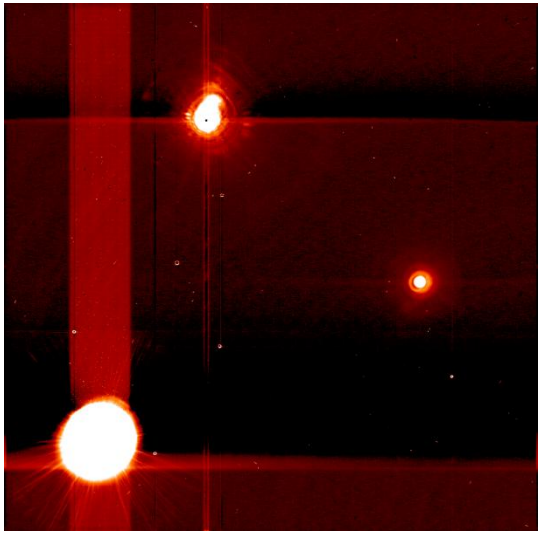
Tree rings + short-wavelength cross



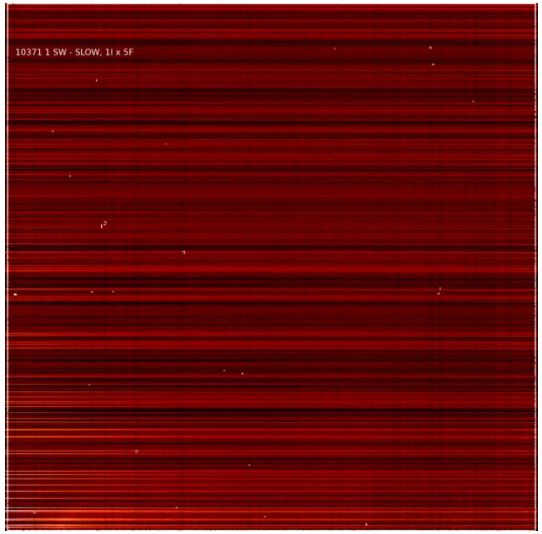
Column pull-down around shorted pixels



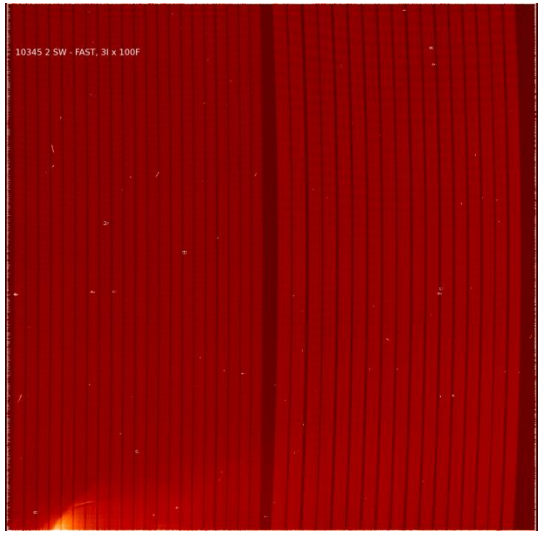
Cosmic ray strike in readout rather than detector



Bright source pull-down/up

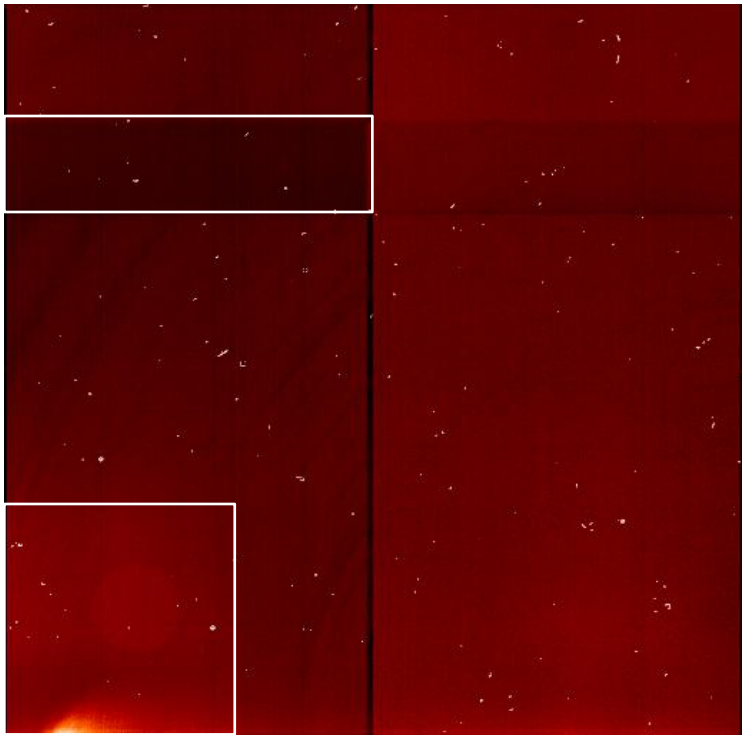


Power-on settling



Readout glow

A Few Final Cautions On Subarrays



- Reading a portion of the array is a very disruptive process
  - The subarrays themselves leave their own latents!
- As a result, 20 min (TBC) of settling time are required when changing readout modes (#8 of the bad habits)
- Recall that the overhead limits the utility of small subarrays
- Punchline: avoid using subarrays unless required to achieve your science

MIRI Detector Summary

- The MIRI detectors are very sensitive and very good cosmetically
- The horror show I just presented is the 1% stuff
- Extensive calibration efforts are ongoing and will continue throughout flight operations
- Continue to use the Spitzer/IRAC experience to estimate the likely experience with MIRI