Comparing and Contrasting Detectors: JWST NIR vs HST WFC3

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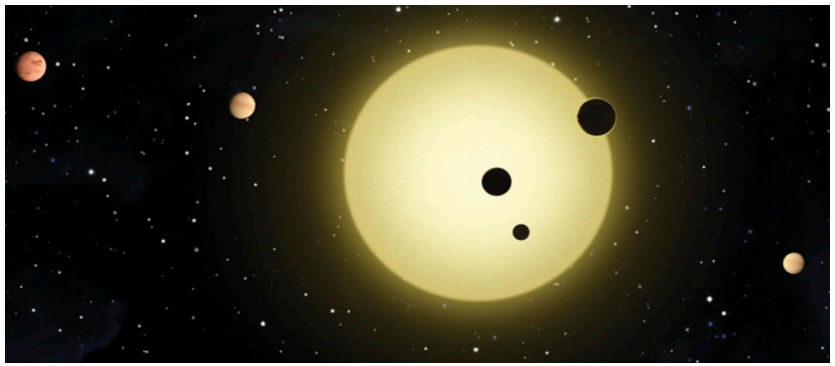

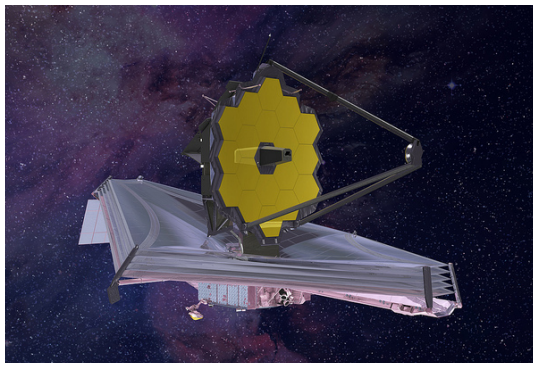

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Why this talk?

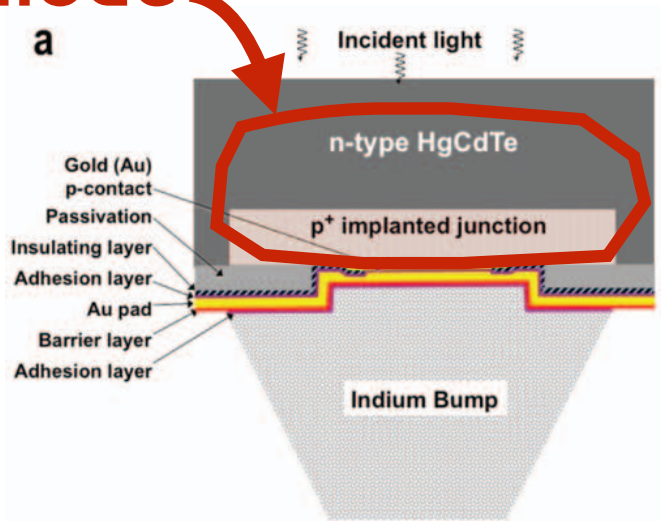
- HST WFC3 IR extensively used for transit observations today
- WFC3 uses a Teledyne H1R detector array
- JWST's 3 near-IR instruments (NIRCam, NIRSpec, FGS/NIRISS) use Teledyne H2RGs
- JWST will build on WFC3 experience vs. detectors
- To maximize the benefits, important to know…
  - what is likely to be the same
  - what is likely to be different, and
  - areas where more study now can pay off in better science later

What Is the Same?

Same Basic Detector Architecture

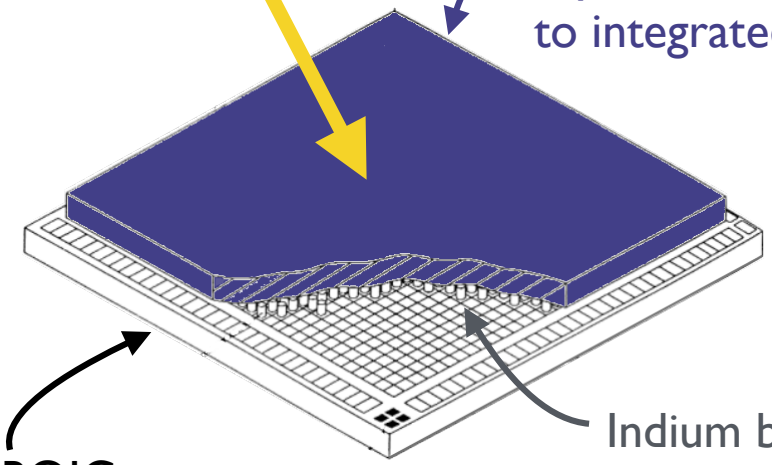
Each pixel is a little photodiode

photodiode



Light

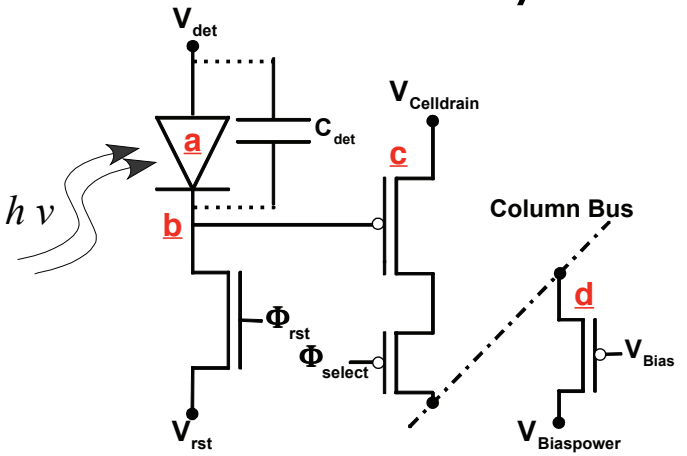
HgCdTe detector layer converts light to integrated charge



ROIC converts integrated charge to voltage

Indium bumps connect HgCdTe layer to silicon readout integrated circuit (ROIC)

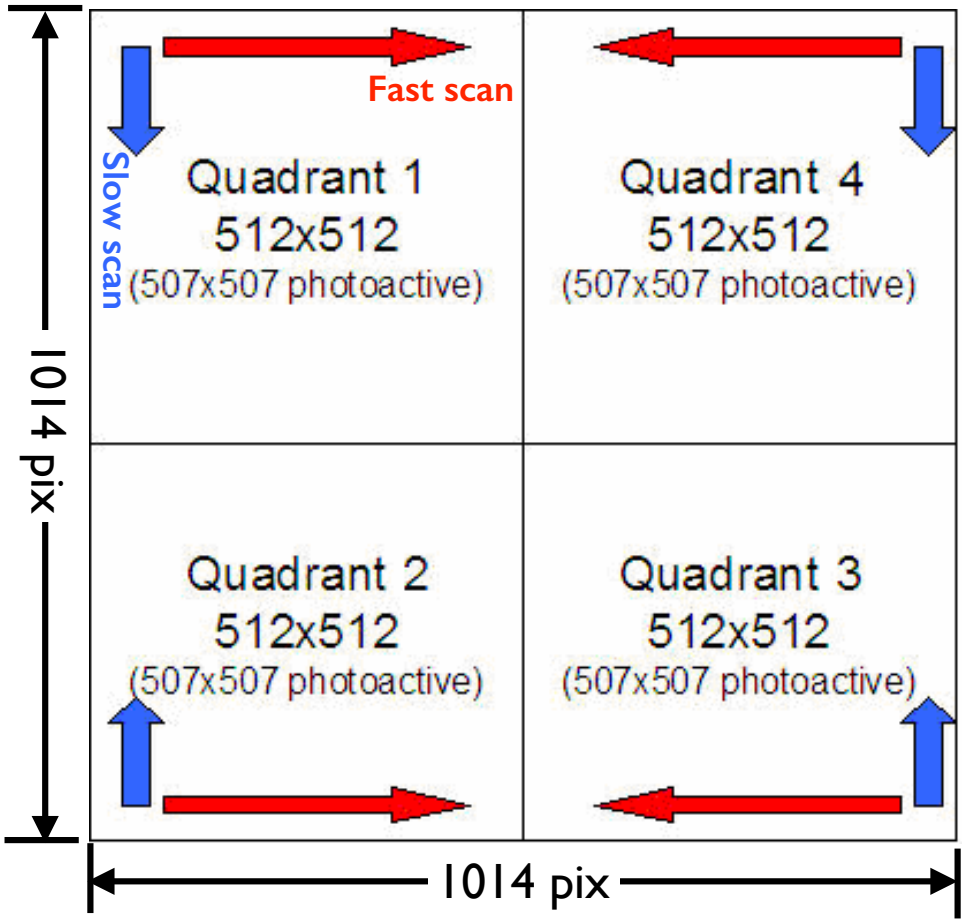
At the individual pixel level, the ROIC is substantially the same



What Is Different?

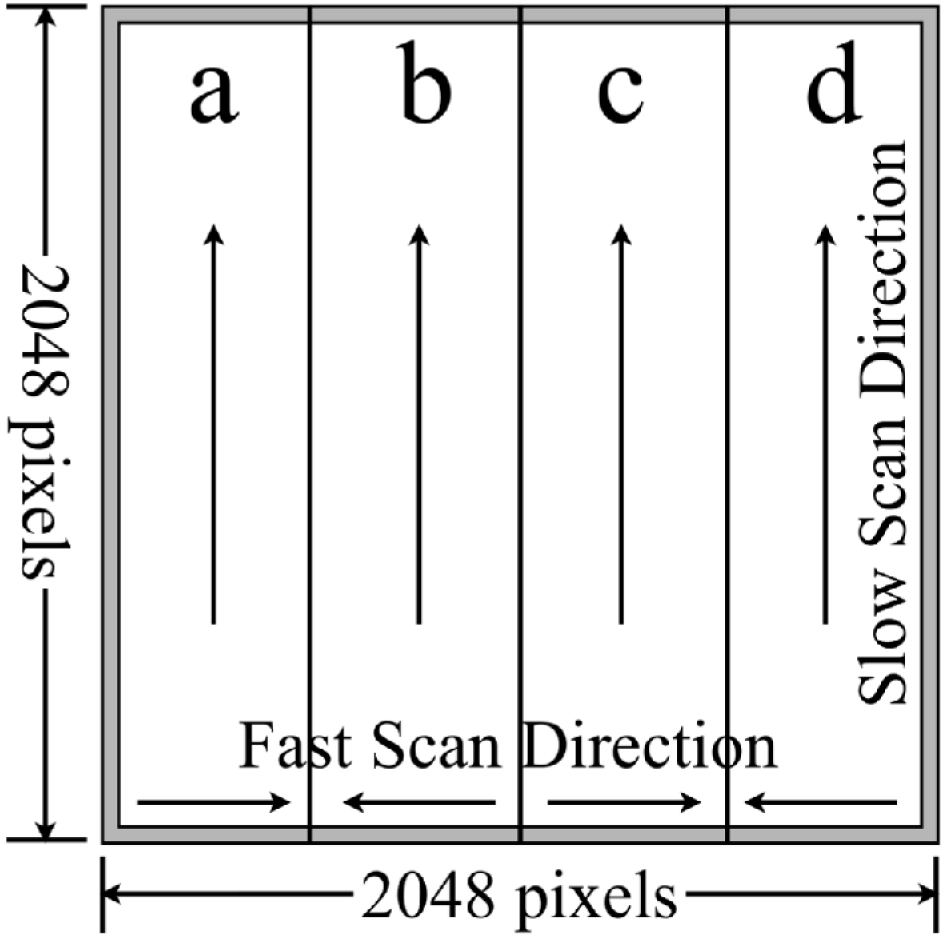
How pixels are arranged

WFC3 has "quadrants"



- 5 pixel wide border of non-photosensitive reference pixels on all sides

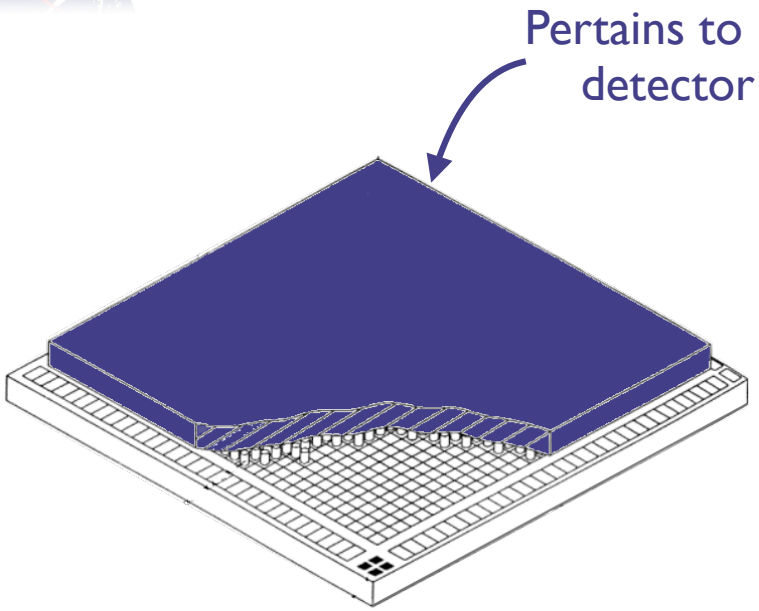
JWST has "stripes"

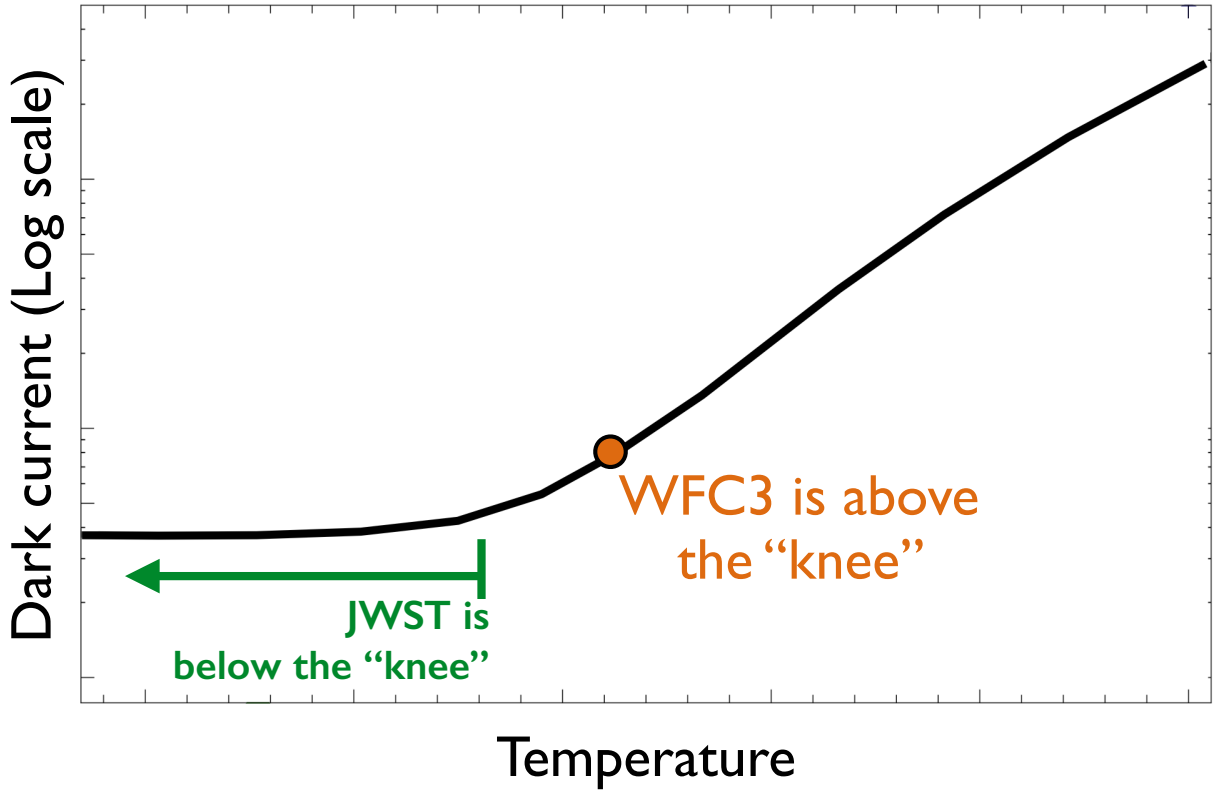


white = regular pixel gray = reference pixel

- 4 pixel wide border of non-photosensitive reference pixels on all sides

Operating temperature relative to "knee" in dark current



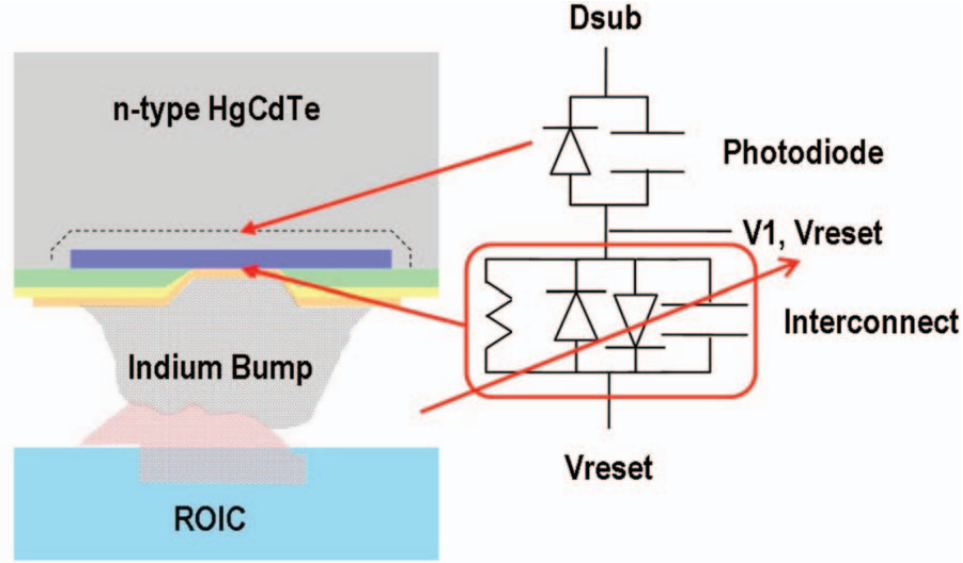


- Semiconductor defects that are thermally activated in WFC3 "frozen out" in JWST
- JWST's lower operating temperature should be beneficial
  - Lower dark current
  - Less persistence
  - Better reciprocity

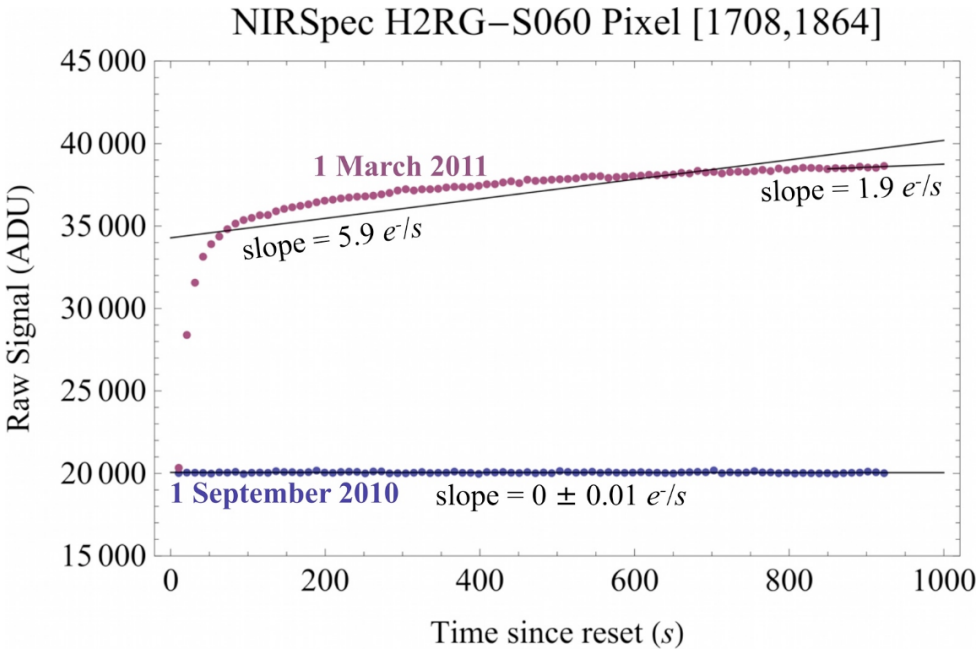
JWST operates 2.5 μm and 5 μm cutoff HgCdTe at T <~ 45 K. WFC3 operates 1.7 μm cutoff HgCdTe at T ~ 145 K. WFC3 is significantly warmer with respect to the HgCdTe bandgap energy.

Old vs. new HgCdTe "barrier layer" design

- WFC3 detector has the same design flaw that caused "first" JWST detectors to degrade in ~2010
  - WFC3 detector likely degraded somewhat between manufacture and launch
  - Now stable. T ~ 145 K operating temperature halts degradation mechanism
- Practical effect is that many WFC3 pixels have a little parasitic capacitor in series that is not there in JWST



May see fewer "RC-type" pixels in JWST



- **JWST should have less of these than WFC3**
- **Practical effect is that for the same source brightness, one infers higher slope immediately after reset compared to later on**
- **If this artifact is important, it would be beneficial to compare RC-pixel statistics for JWST and WFC3.**

Readout electronics

- WFC3 uses a discrete electronics box. JWST uses Teledyne SIDECAR ASIC.
- SIDECARs have many advantages
  - Physically small, low mass, low power dissipation, located close to detectors, very flexible programming, easy system engineering, etc…
- But, not necessarily higher performing in all areas. The controller can play a large role in determining how stable the system is
- More study might be desirable to understand…

- **How WFC3 bias stability compares to JWST**
- **How WFC3 photometric stability compares to JWST**

Summary

- In many ways, WFC3's IR channel is a good indicator for what to expect with JWST
- There are some differences, most of which should be beneficial in JWST
  - JWST's lower operating temperature will freeze out charge traps that would affect WFC3. Benefits should include lower dark current, lower persistence, and better reciprocity
  - JWST's more recent HgCdTe process has lower defect density. The benefits are as described above
  - JWST uses better indium barriers. The benefits should include fewer "RC-type" pixels.
- One area where more study might be beneficial is stability. The detector electronics play a significant role in determining how stable a detector system is (v.s. bias drifts and photometry). JWST's SIDECARs are completely different from WFC3's Ball electronics
  - Studies comparing the bias and photometric stability of WFC3 and JWST might be useful to informing data acquisition and calibration strategies for JWST.