Developing a (NIR) Photometry Error Budget for SNAP

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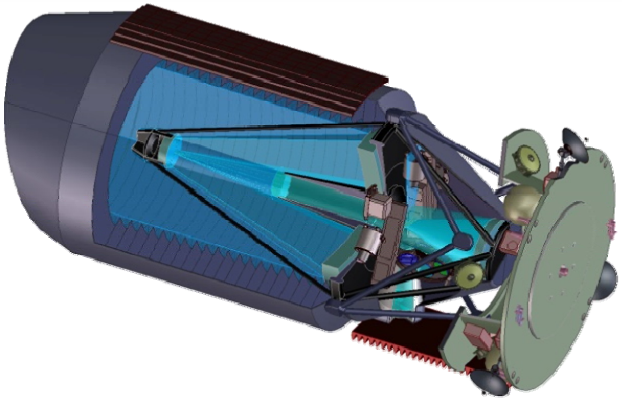
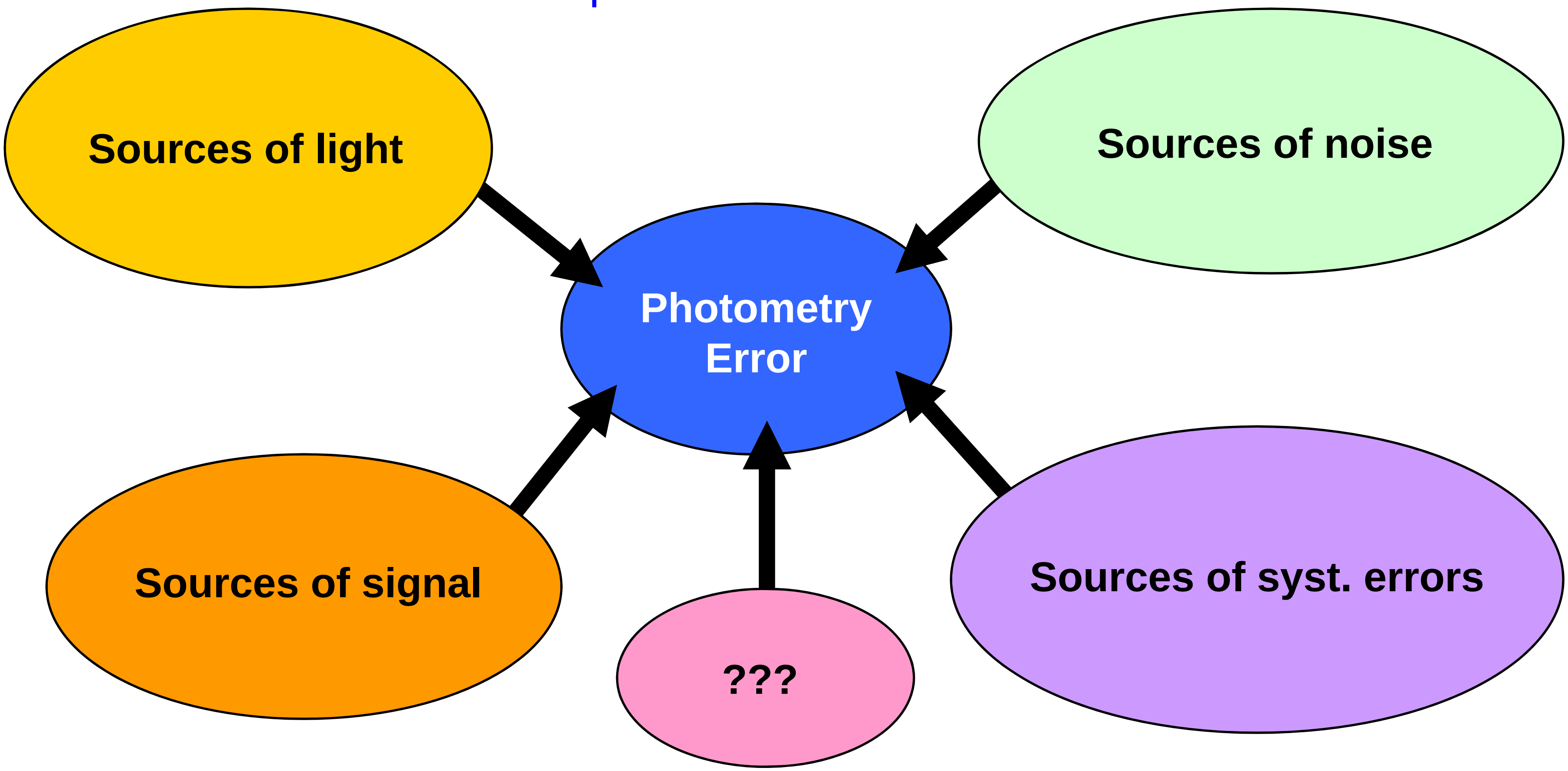


How to assemble a Photometry Error Budget?

High precision photometry requires detailed understanding of all photometric errors



Framework to assemble an error budget

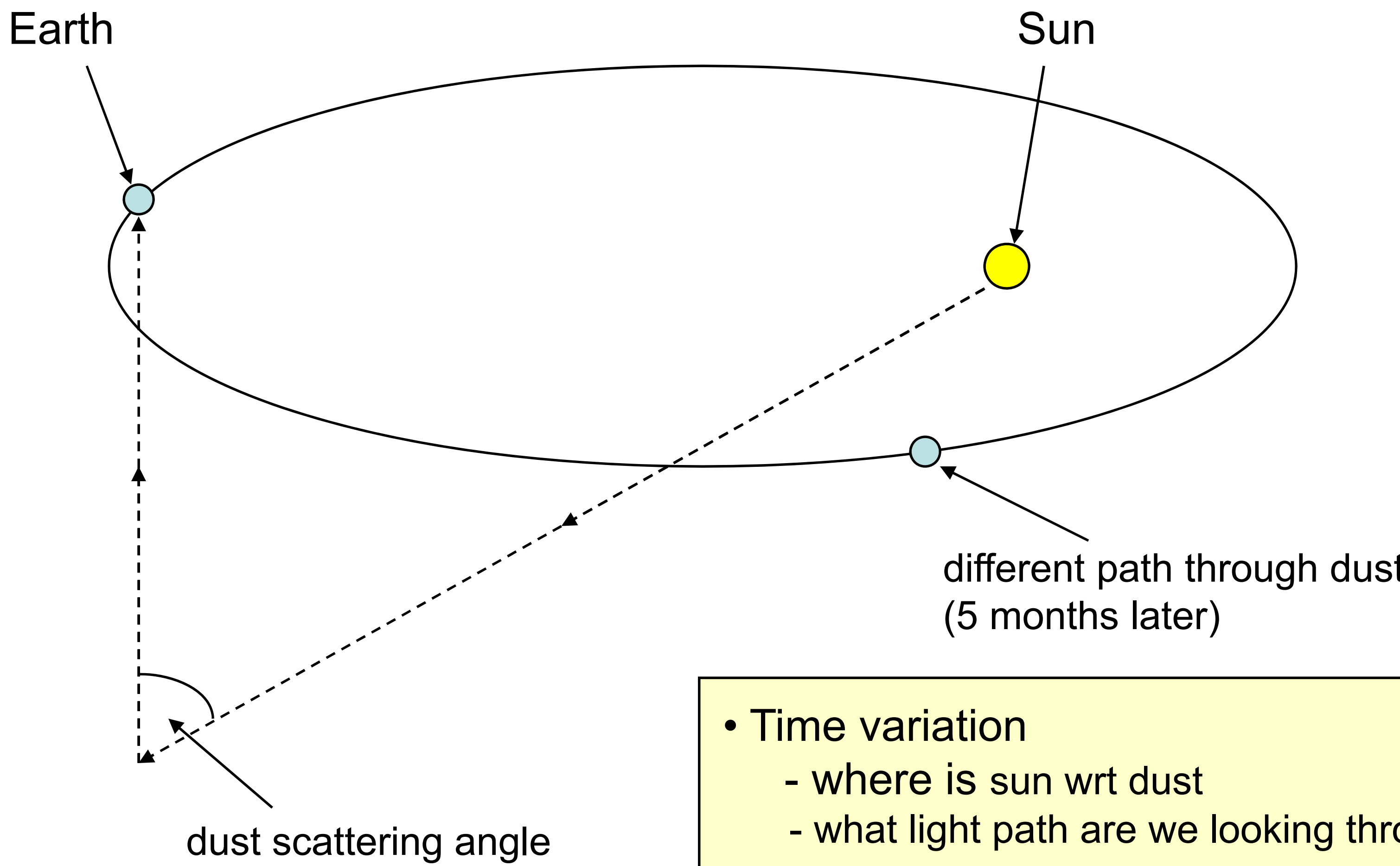
How to subtract SN from background sources (variable)?

Sources of Light

Estimate the magnitude of each contribution to estimate the photon noise (based on √N photon statistics)

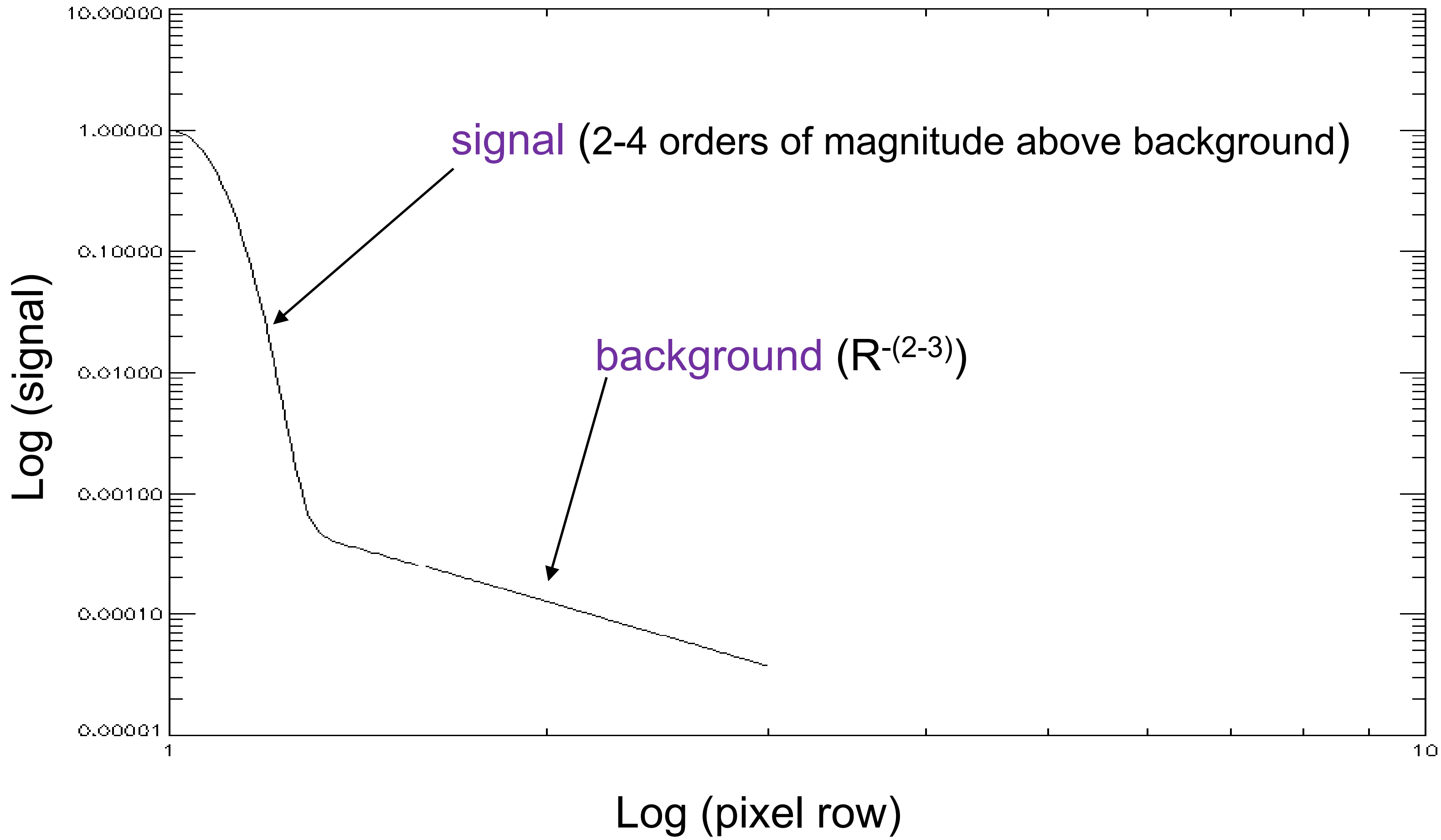
1. Host galaxy
   - magnitude of galaxy is affected by SN, measure before SN goes off
   - noise of galaxy
2. Zodiacal (from plane of solar system)
   - changes with time (with position of Earth)
   - is smooth with low brightness
3. Cirrus (galactic dust)
   - lumpy on degree scale, but dimmer than zodiacal
4. Potential glowing intergalactic dust (warm or cold): negligible
5. Telescope optics: depends on temperature (300K ?)
6. Reflectivity of optics
   - <100% due to micro ripples and roughness of mirrors → broad halo around objects, but drops as $R^{-(2\text{-}3)}$ → part of PSF around bright objects

Time variation of Zodiacal Light



- Time variation
  - where is sun wrt dust
  - what light path are we looking through?
- smooth with low brightness
  - spatial uniformity unpredictable
  - ≤5% (with episodic changes)

Reflectivity of Optics



- Tails in signal due to micro ripples and mirror roughness extend over arc minutes
  → usually 2-4 orders below peak
- Note: R^{-2} is really bad, with R^{-3} more typical

Sources of Noise

Well known in our detectors / electronics

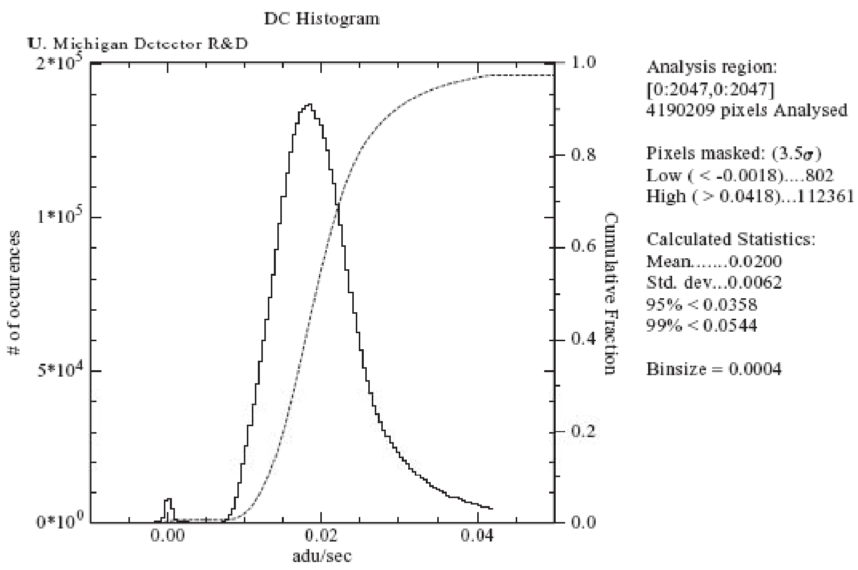
1. Dark current (DC)
   - for 1.7 µm cut-off HgCdTe, bulk limited dark current should be ~ 0.01 e^- /pix/s at 140K.
   - very low DC device (RSC H2RG-32-039) had peak DC of 0.01 e^- /pix/s at 140K.
   - for all HgCdTe devices from RSC, dark currents < 0.2 e^- /pix/s pixel *(< 0.05 e^-/pix/s for nearly all tested devices*) are consistently measured.

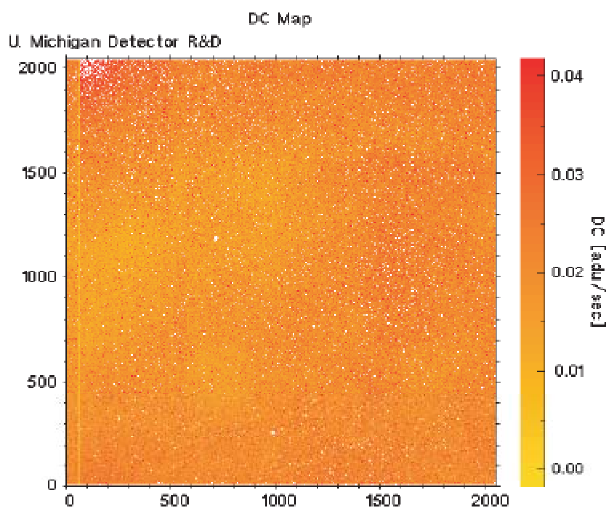
2. Read noise (RN)
   - ~ 6.5 e^- for 300 s exposures
   - can combine DC and RN into a total noise spec
3. Shot noise on signal (photon counting statistics)
   - bright sources are better

Dark Current

Dark current histogram

Dark current map



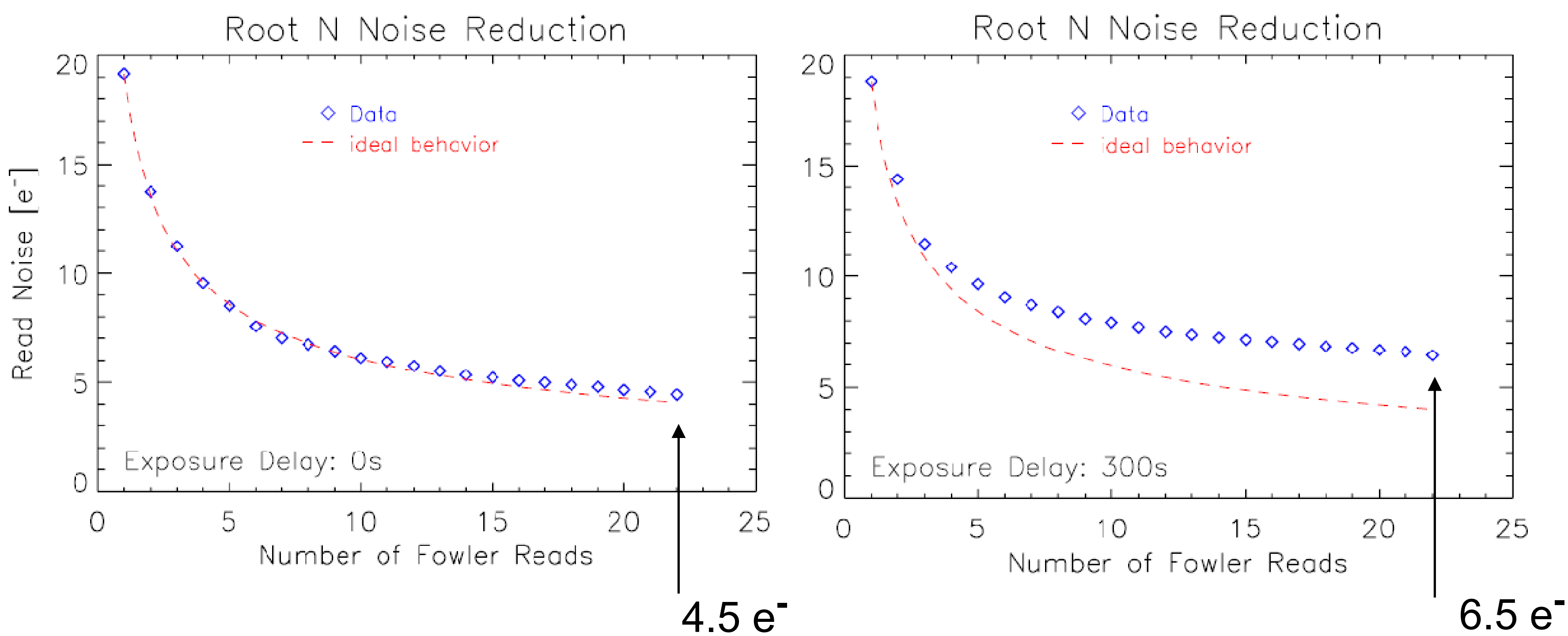


(Data are for Rockwell H2RG)

Read Noise Reduction through Multiple Sampling

Ideal Fowler-N sampling reduces read noise by $\sqrt{N}$

2k x 2k RVS detector at 130K



Increase in noise floor at longer sampling times is likely dominated by the shot noise in the dark current

Sources of Signal

Estimate contributions with simulations

1. Capacitive coupling
   - deterministically moves charge after charge collection
2. Lateral charge diffusion
   - random, occurring prior to charge collection

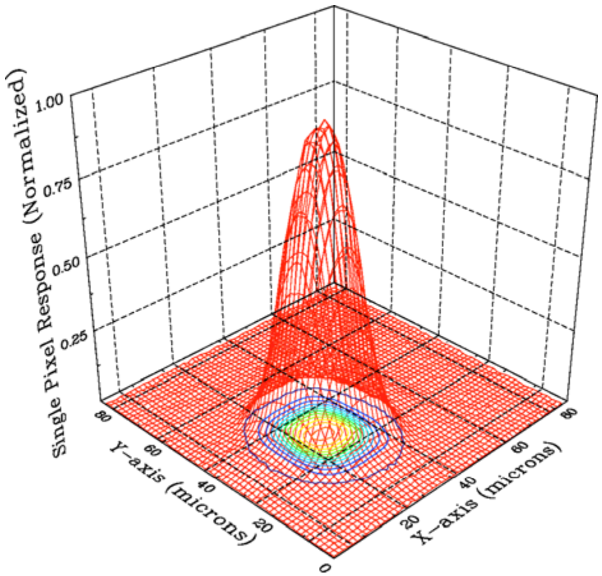
(1 and 2:) sub-pixel non-uniformity

3. Persistence
   - effect of dithering

Intra-pixel Variation

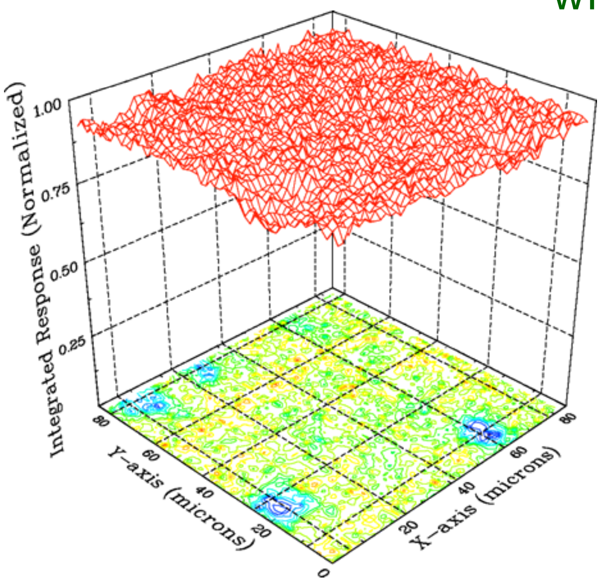
(RSC H2RG #102)

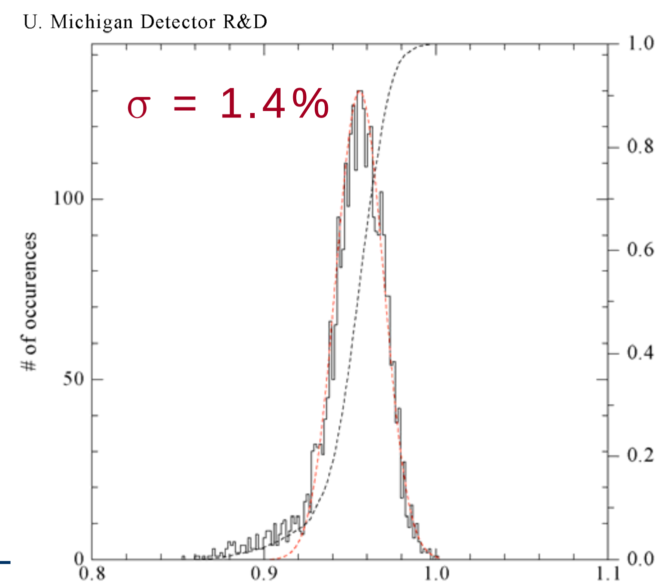
2D scan at best focus.



single pixel response is generally very uniform

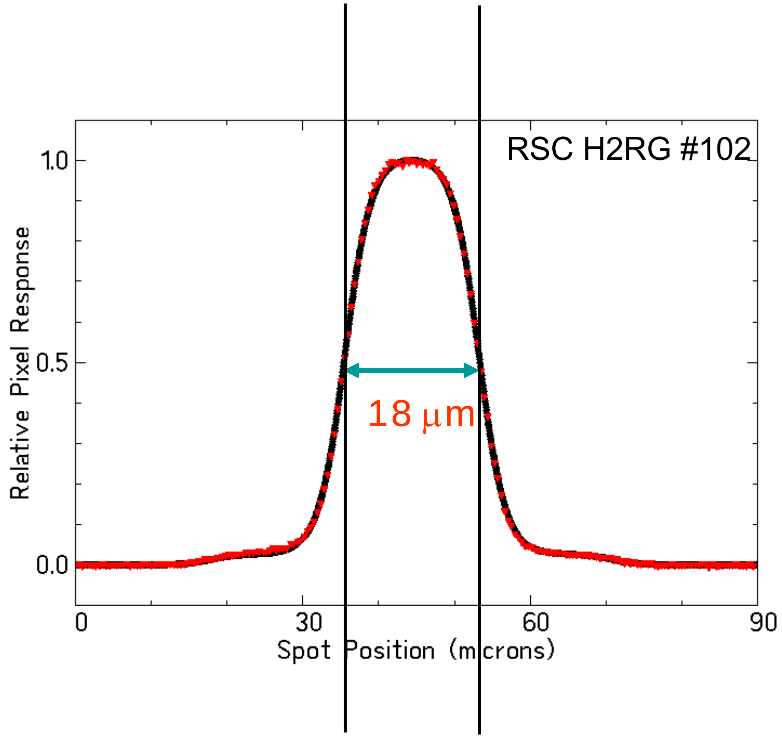
summing pixels gives a smooth response,
with dips tending to fall on pixel boundaries





Diffusion and Capacitive Coupling

Pixel Profile Reconstruction



start with square PRF (17.8 ± .1 μm)

convolve with spot PSF (1.4 μm)

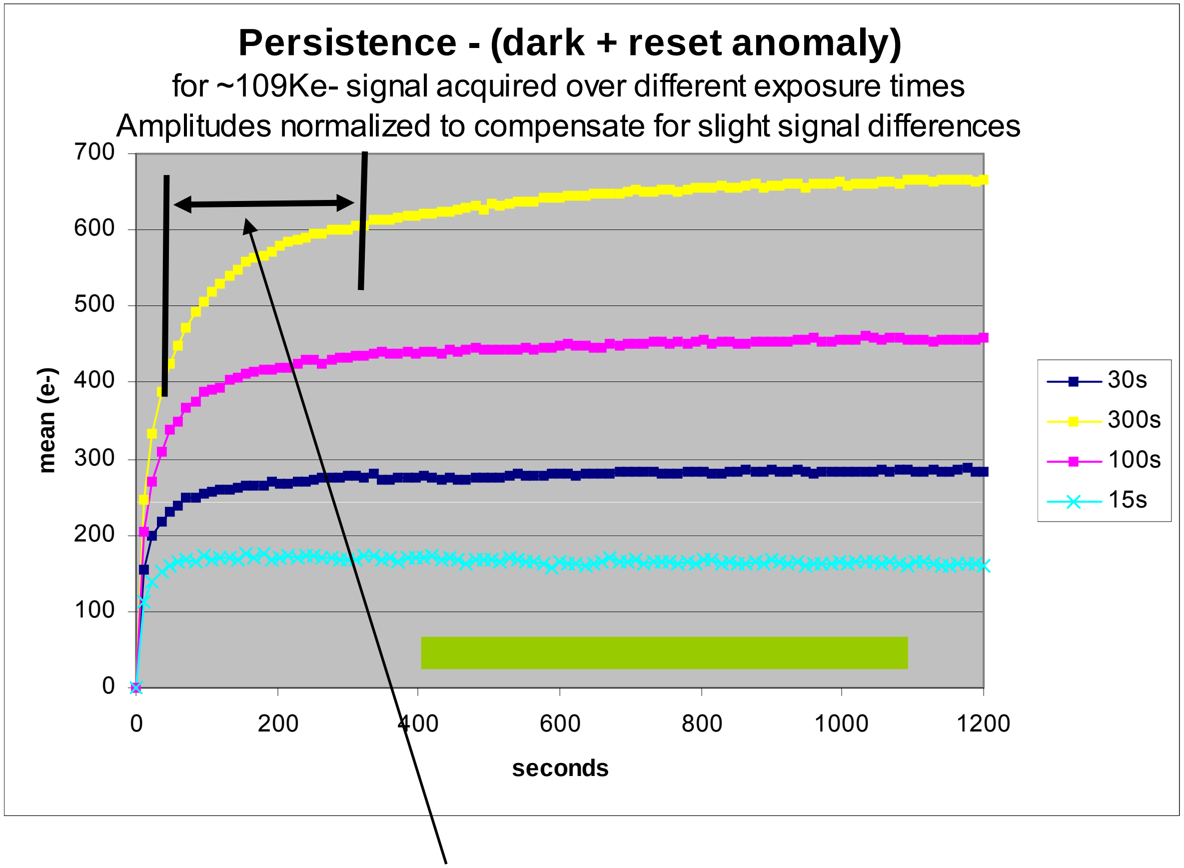
add charge diffusion (1.7 ±.02 μm)

add capacitive coupling (2.4 ±.1%)

compare to data

(correlated noise result: 2.2 ± .1%)

Persistence



Grade ‘B’ persistence from Rockwell:
~ 0.2% persistence in next frame

Persistence is the release of charge following illumination of HgCdTe arrays.

- Appears to be both flux and intensity dependent

Currently working to simulate persistence using VLT VMOS galaxy data and USNO-B stars in the SNAP north field.

- Combine SNAP frames with measured data to simulate persistence frames and develop persistence specification

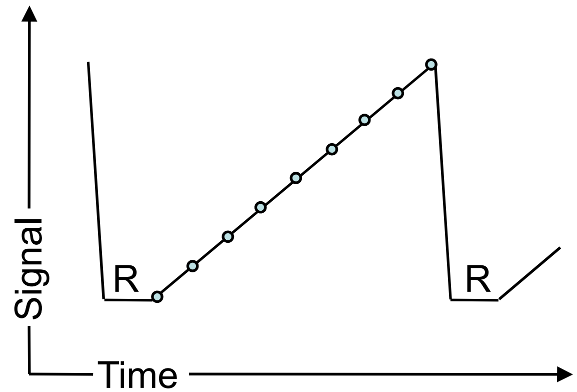
Sources of syst. Errors

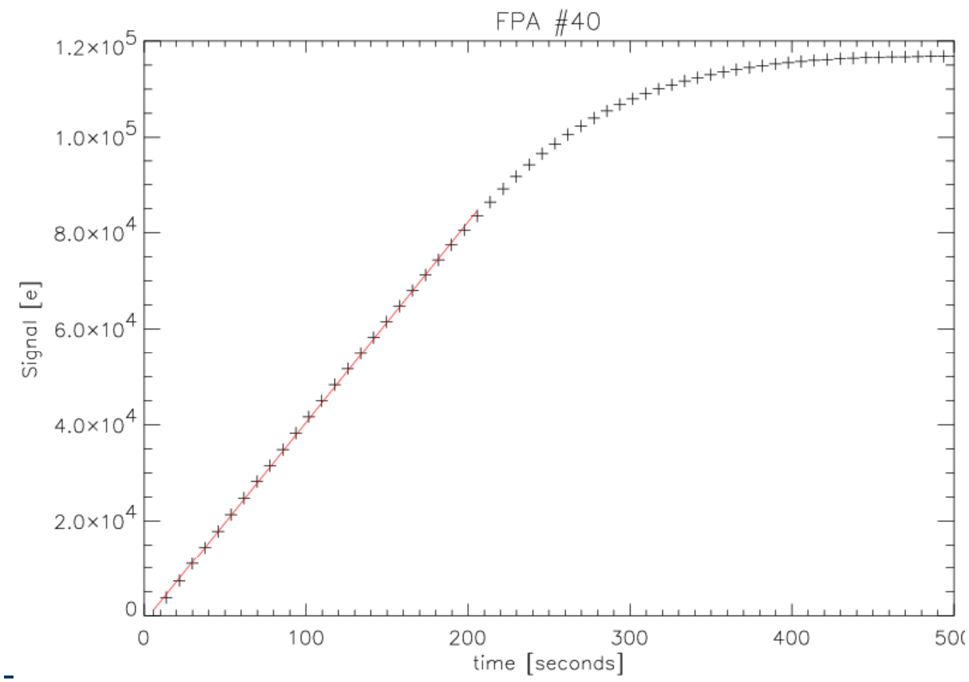
Estimate contributions due to calibration errors

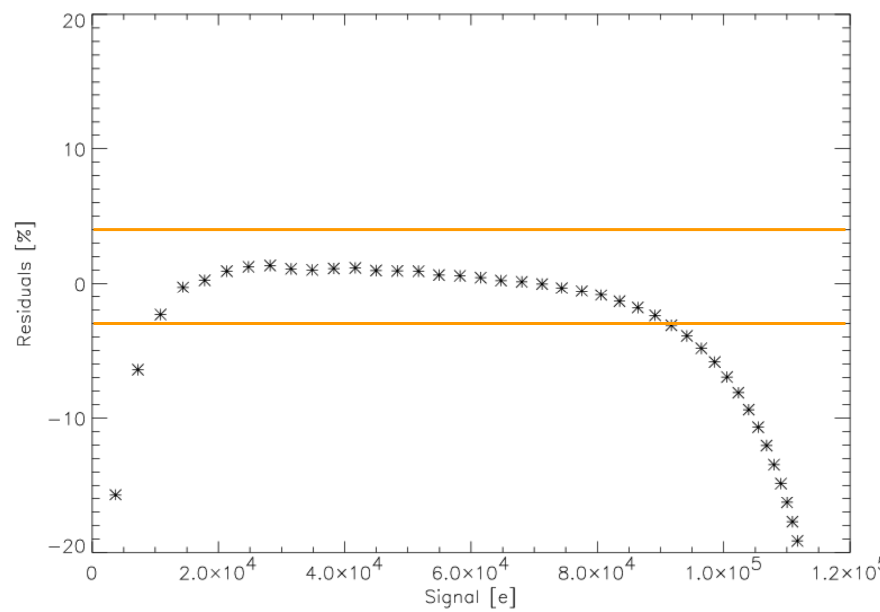
1. Non-linearity
   - well: saturation (<1%)
   - reciprocity (under investigation at UM)
2. Drift
   - temperature
   - bias voltage (whole detector is affected)
     - fluctuations in the baseline signal of detector can easily be traced with ‘real’ detector pixels (but not with the reference pixels).
3. Filter transmission
4. Telescope throughput
5. Aging
   - QE
6. Cosmic ray damage

Well Depth (RSC FPA H2RG-32-040)

We obtain image data by thermal illumination, i.e. the dewar window is optically dark but at room temperature. After reset the device is read continuously. Full **integration capacity of the array is 1.17·10^5 e** and the linearity is maintained within ±3% up to 80% of the full integration capacity, above which the count deviates below the regression line.





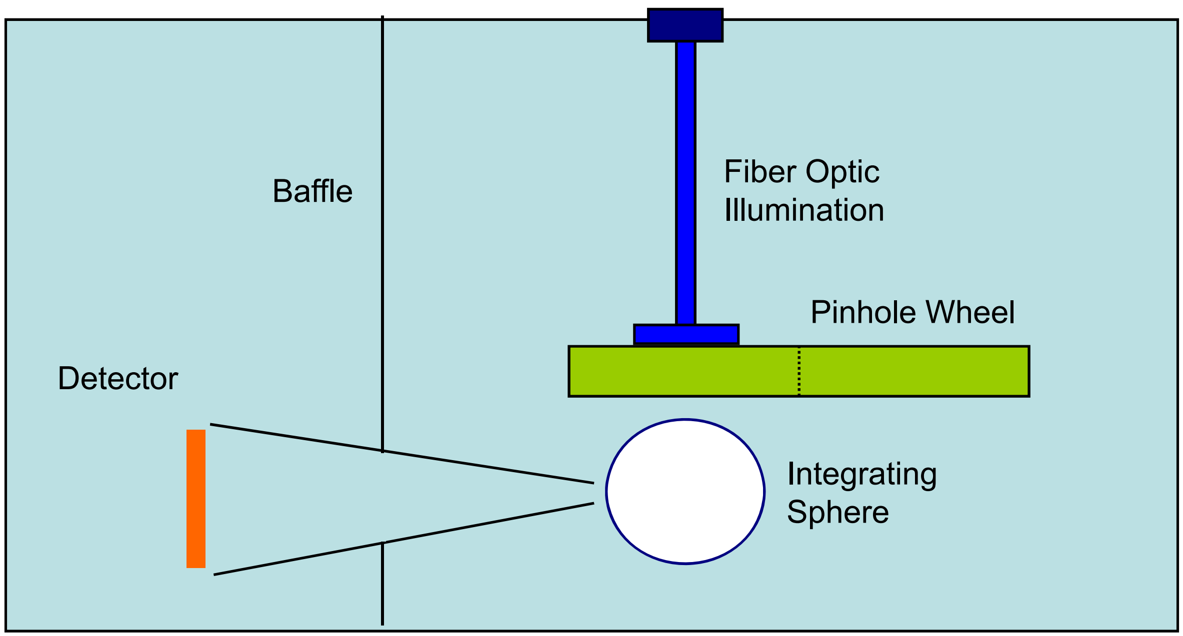


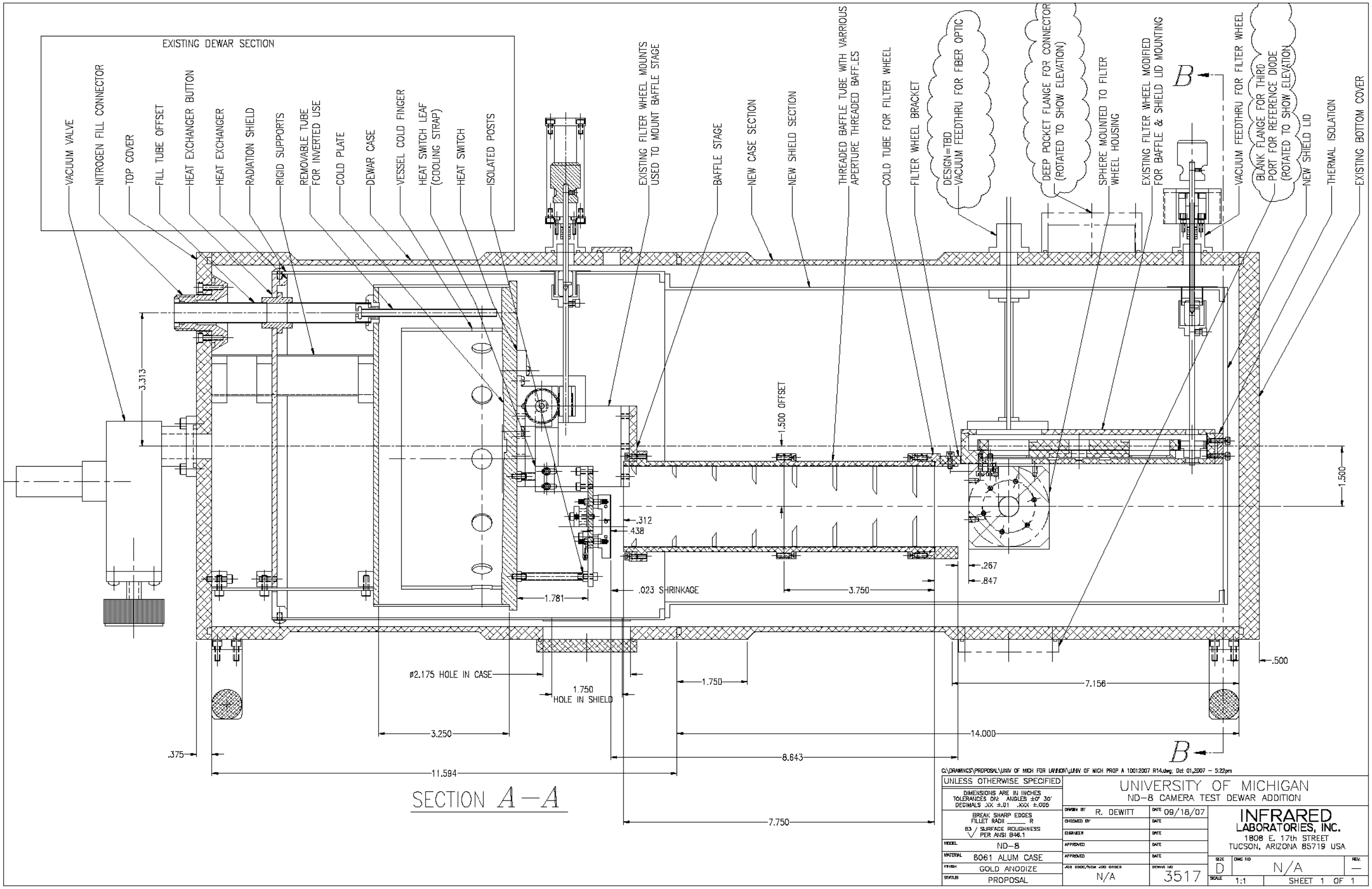
Intensity vs. Time Reciprocity

Calibration of SNAP photometry requires observation of many standardized stars over a wide range of magnitude.

ACS has had problems with reciprocity failure - long exposures on dim stars do not give the same signal as equivalent short exposures on bright stars.

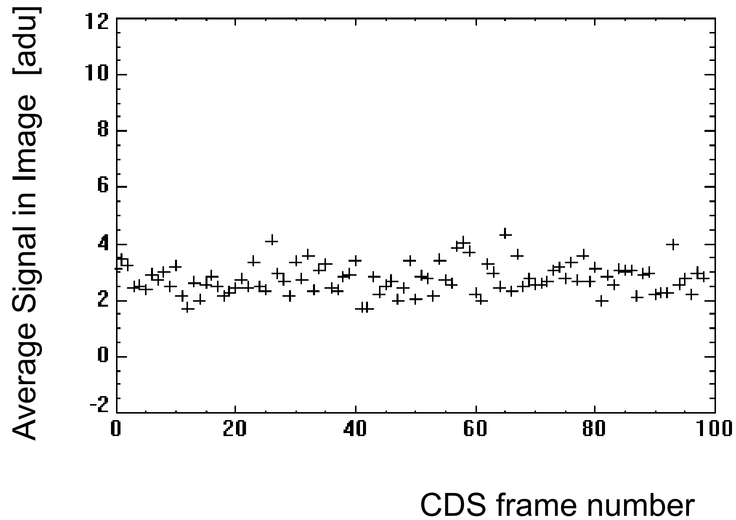
At UM we will study detector reciprocity with a specially constructed device



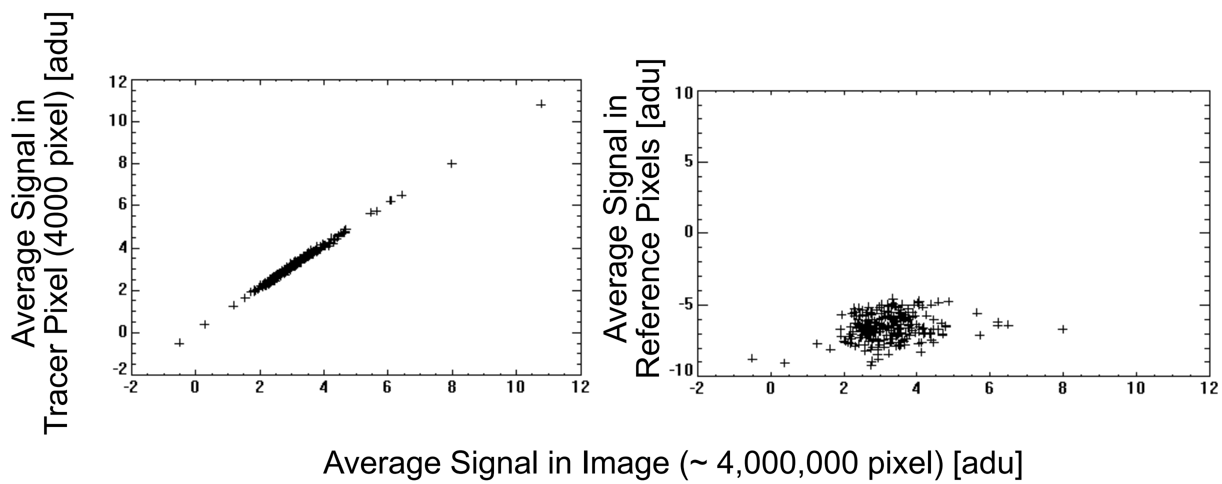

EXISTING DEWAR SECTION
VACUUM VALVE
NITROGEN FILL CONNECTOR
TOP COVER
FILL TUBE OFFSET
HEAT EXCHANGER BUTTON
HEAT EXCHANGER
RADIATION SHIELD
RIGID SUPPORTS
REMOVABLE TUBE FOR INVERTED USE
COLD PLATE
DEWAR CASE
VESSEL COLD FINGER
HEAT SWITCH LEAF (COOLING STRAP)
HEAT SWITCH
ISOLATED POSTS
EXISTING FILTER WHEEL MOUNTS USED TO MOUNT BAFFLE STAGE
BAFFLE STAGE
NEW CASE SECTION
NEW SHIELD SECTION
THREADED BAFFLE TUBE WITH VARRIOUS APERTURE THREADED BAFFLES
COLD TUBE FOR FILTER WHEEL
FILTER WHEEL BRACKET
DESIGN=TBD VACUUM FEEDTHRU FOR FIBER OPTIC
DEEP POCKET FLANGE FOR CONNECTOR (ROTATED TO SHOW ELEVATION)
SPHERE MOUNTED TO FILTER WHEEL HOUSING
EXISTING FILTER WHEEL MODIFIED FOR BAFFLE & SHIELD LID MOUNTING
VACUUM FEEDTHRU FOR FILTER WHEEL
BLANK FLANGE FOR THIRD PORT FOR REFERENCE DIODE (ROTATED TO SHOW ELEVATION)
NEW SHIELD LID
THERMAL ISOLATION
EXISTING BOTTOM COVER
B
3.313
1.500 OFFSET
1.500
.312
.438
.267
.847
1.781
.023 SHRINKAGE
3.750
.500
Ø2.175 HOLE IN CASE
1.750 HOLE IN SHIELD
1.750
7.156
3.250
14.000
.375
8.643
11.594
7.750
SECTION A—A
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
DRAWN BY R. DEWITT
09/18/07
ND-8
6061 ALUM CASE
GOLD ANODIZE
PROPOSAL
N/A
3517
UNIVERSITY OF MICHIGAN
ND-8 CAMERA TEST DEWAR ADDITION
INFRARED LABORATORIES, INC.
1808 E. 17th STREET
TUCSON, ARIZONA 85719 USA
D
N/A
1:1
SHEET 1 OF 1

Linearity and Stability (bias voltage)

We see fluctuations in the mean detector (dark) signal that are NOT caused by read-noise but rather reflect fluctuations in the biases.



The fluctuations can be traced with a small subset of (random) pixels (but NOT reference pixels).



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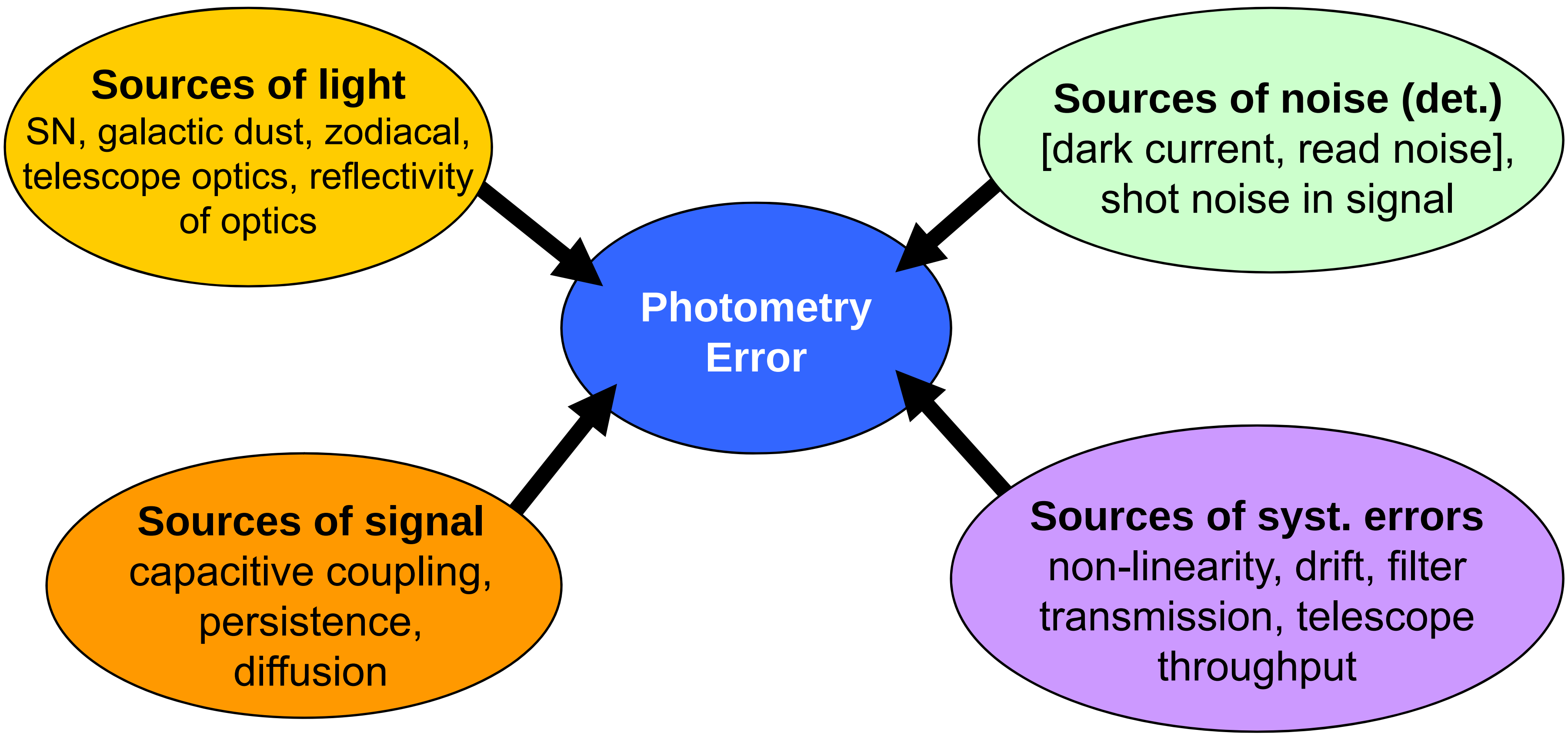

Need combined efforts from detector, simulation and calibration groups