CIB Fluctuations – Background Surface Brightness Measurement

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Euclid Photometric Calibration Workshop: 2016 Sep 22

Cosmic Infrared Background

- CIB = integrated light of galaxies (etc.) across all redshifts
- COBE/DIRBE measured absolute sky brightness at 1.25-240 μm with 0.7° beam
- Galaxy counts (high resolution) estimate CIB but are brightness / surface brightness limited
- CIB – Galaxy counts = other stuff???

Foregrounds

- Resolved Galaxies
- Galactic stars
- Galactic ISM
- Zodiacal Light

Fluctuations

- Total intensity measurements can be difficult, and foregrounds may be uncertain.
- Spatial structure (fluctuations) with respect to a mean intensity can avoid some systematic errors in measurement and foregrounds.

Source subtraction

- Masking is sufficient, ***if*** it doesn't wipe out most of the image.
- Otherwise modeling must be used to subtract sources and leave a background for analysis

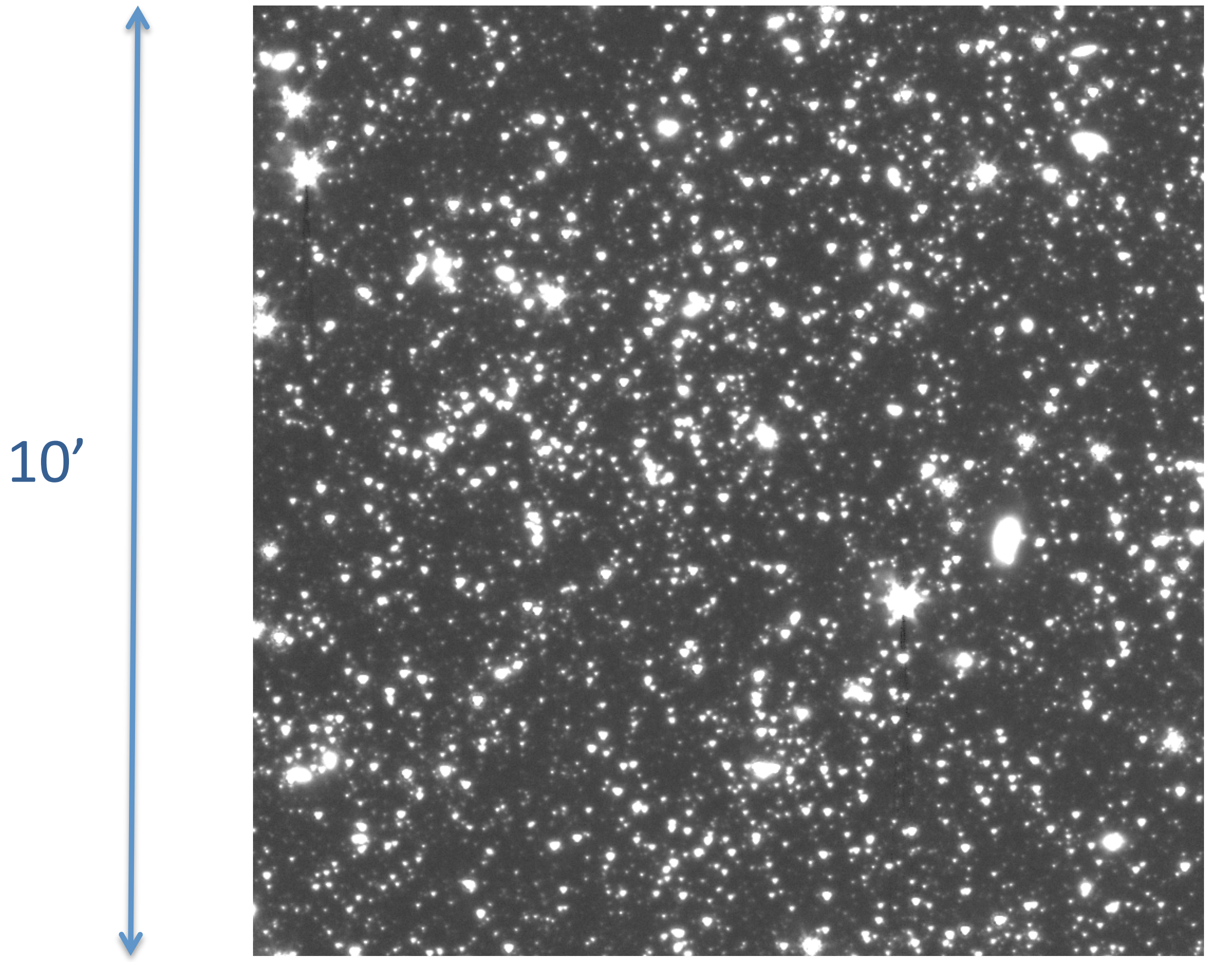
Fluctuation Analysis

- Source-subtracted & masked images
- 2-D FFT → 2-D power
- Average power in radial bins → power spectrum

- Cross power (cross correlation, coherence) between wavelengths

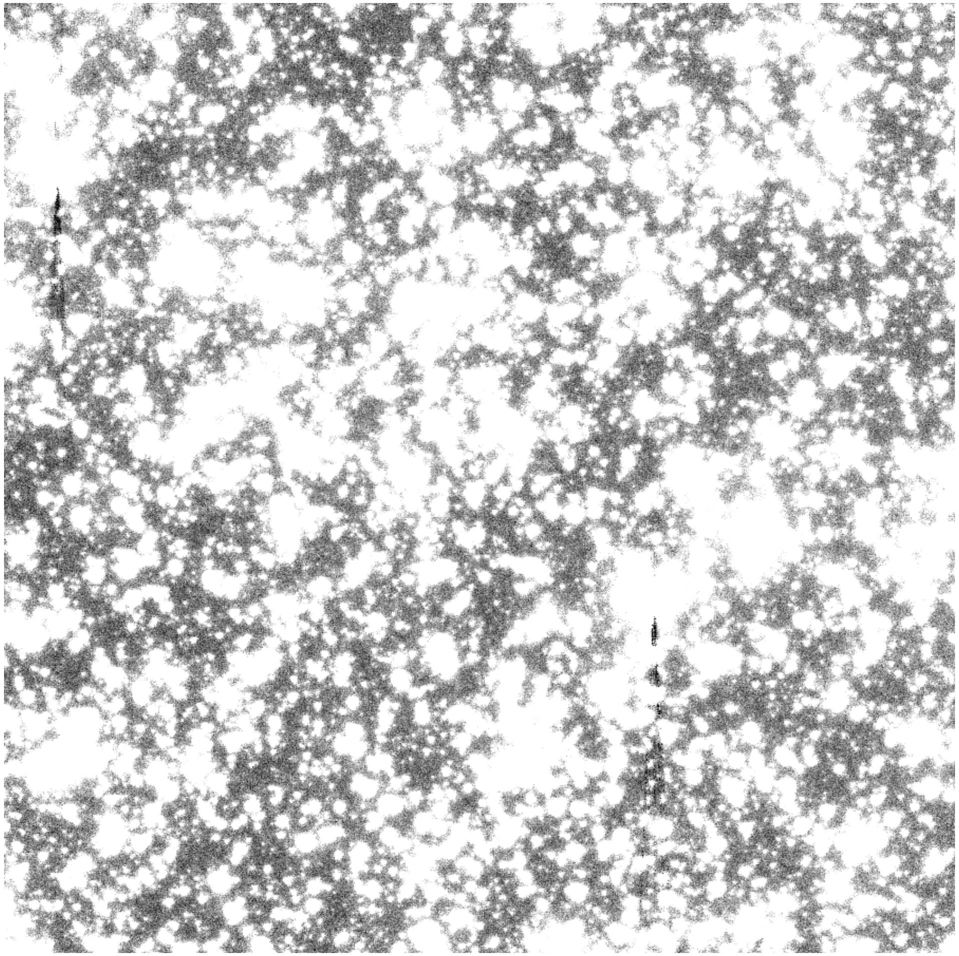
- Assessment of foreground contributions, noise (A-B), and systematics

Original IRAC Image



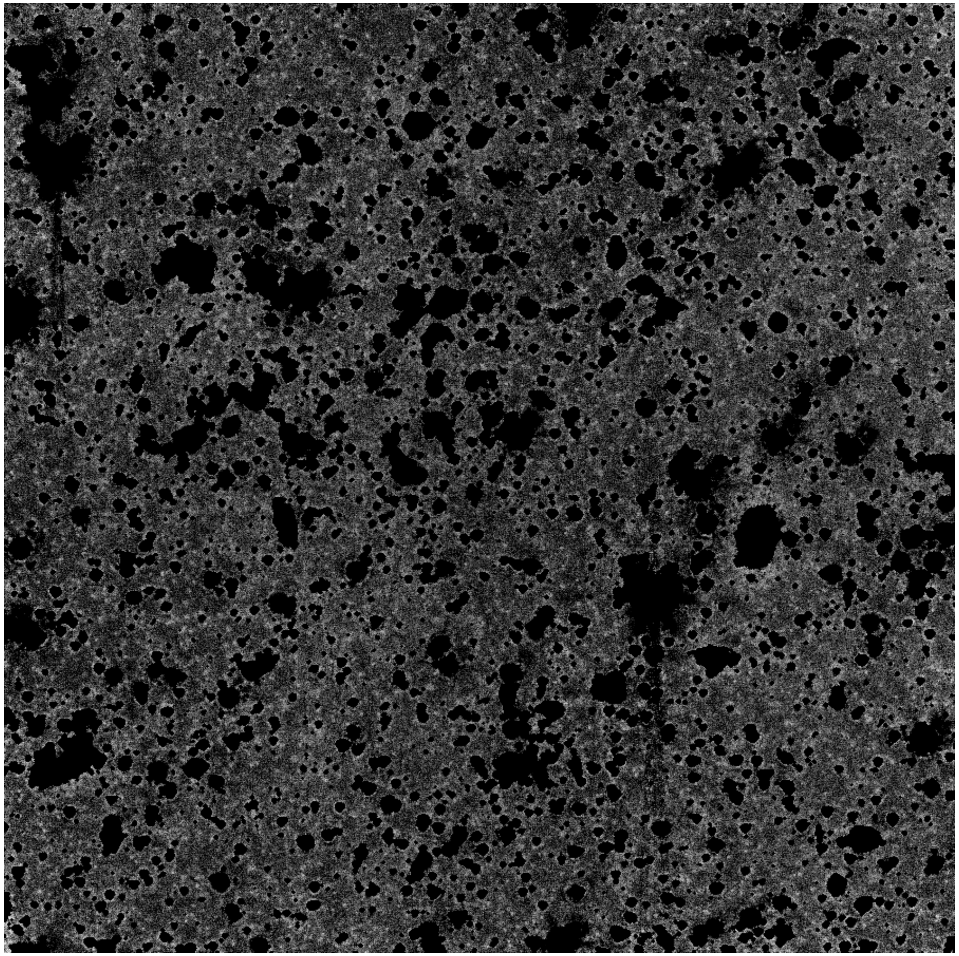
Example data from Arendt et al. (2016)

Original Image (10x deeper stretch)



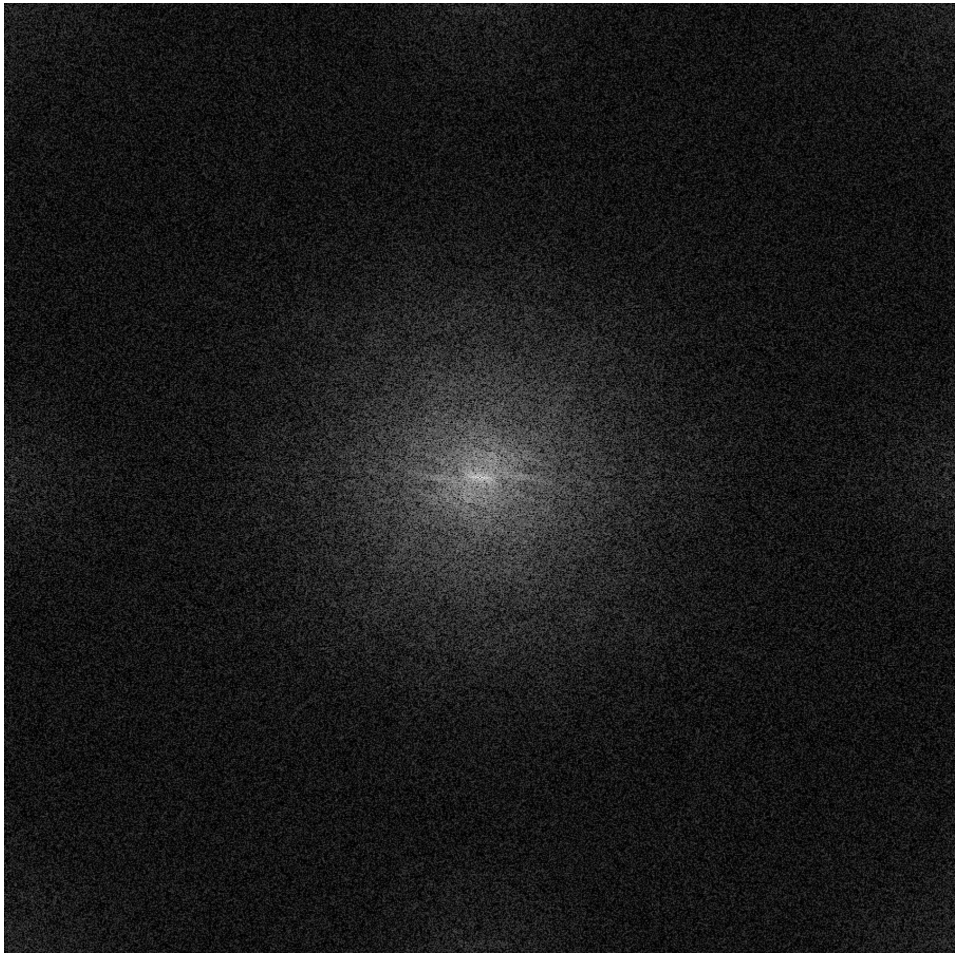
Example data from Arendt et al. (2016)

Source-Subtracted Masked Image



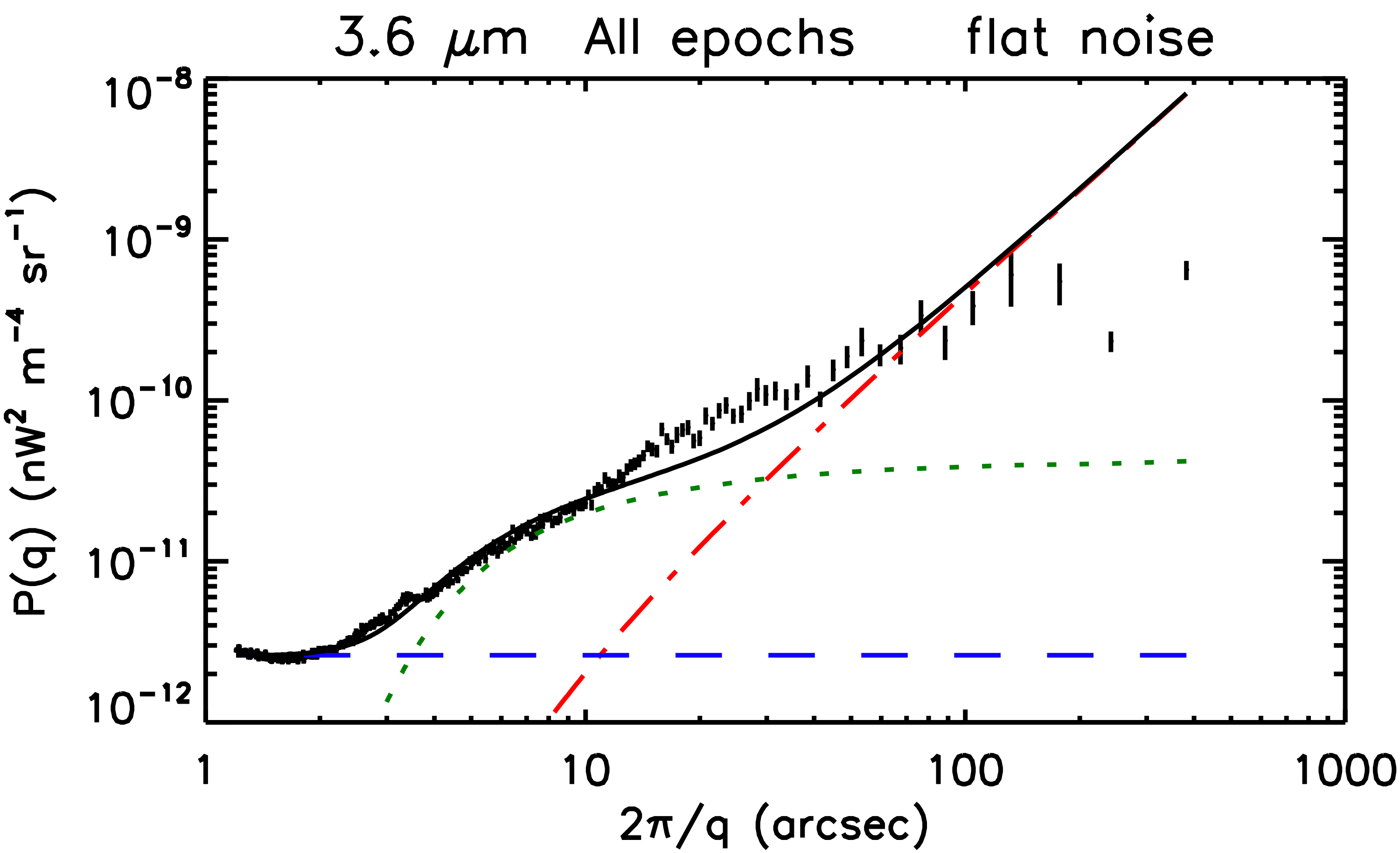
Example data from Arendt et al. (2016)

2-D FFT



Example data from Arendt et al. (2016)

Power Spectrum



Example data from Arendt et al. (2016)

Self-Calibration

- Self-Calibration (Fixsen et al. 2000)

  Least-squares approach to determining fixed parameters (detector and source) of a model of the data. Example:

- $D^i = G^p S^\alpha + F^p$

- D^i = datum *i*
- S^α = sky intensity at location α
- G^p, F^p = gain and offset of pixel *p*

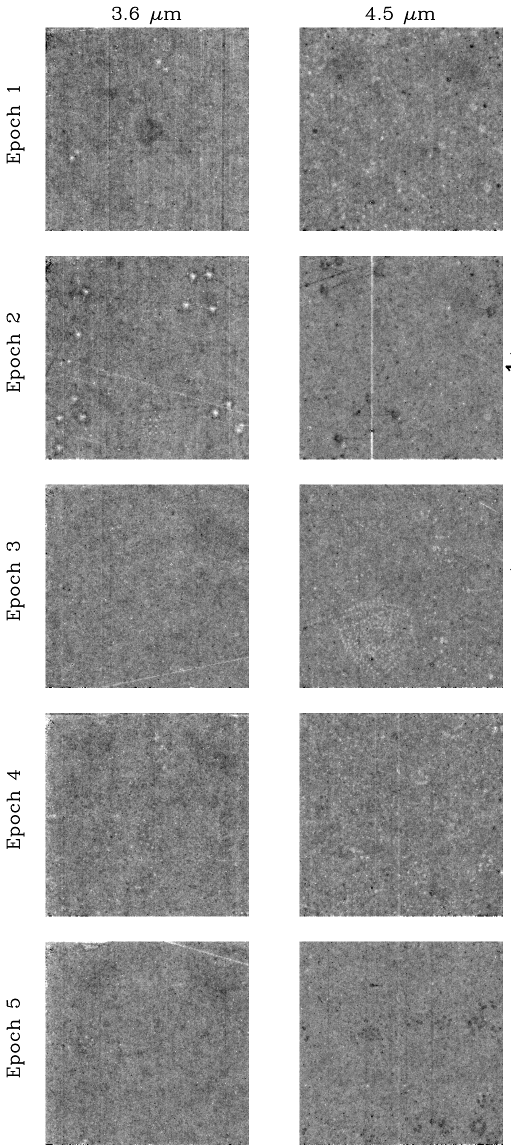
Spitzer/IRAC Self-Calibration

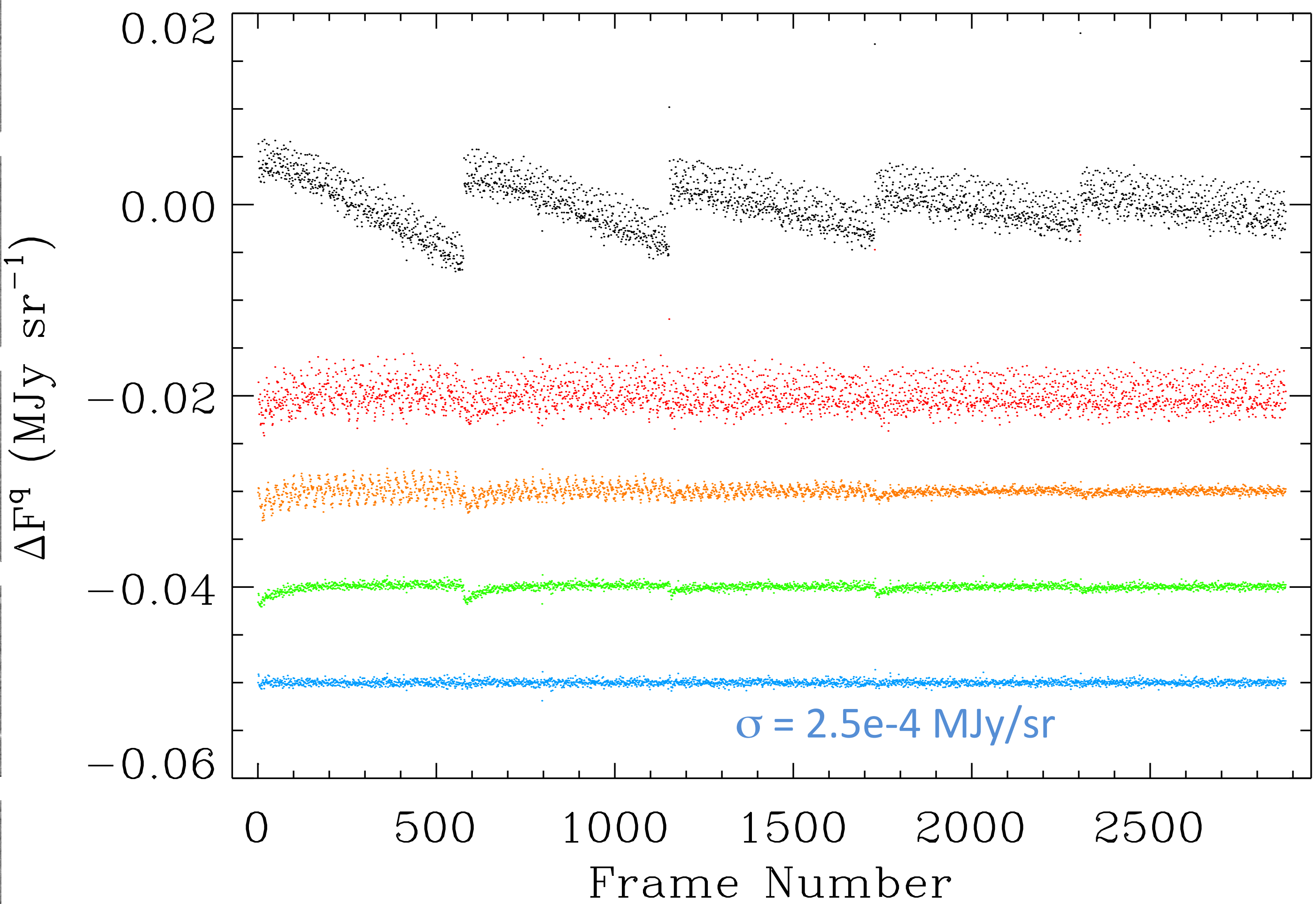
- IRAC is very stable. Gain is well determined by standard pipeline. Offsets are less well determined (detector and zodi).

- $D^i = S^\alpha + F^p + F^q$

- F^q = offset specific to frame *q*
  (i.e. temporal variation)

Offsets: F^p and F^q





Example data from Arendt et al. (2016)

Euclid (I)

- Desire to measure spatial structure of CIB at scales up to 1° (or larger) with NISP (also VIS).
- Expected fluctuation signal is at levels of ~5e-5 MJy/sr or 0.1 $nW/m^2/sr$
- Offsets (relative) need this accuracy when averaged over coadded data.
- Requires gain accuracy to $\sim 10^{-3}$ on all angular scales to avoid imprinting on the zodiacal light foreground
- Similar for other systematic effects: e.g. stray light, persistence.

Euclid (II)

- Will check standard data products
- Apply further self-calibration as needed
- Limited by observation strategy in the ability to separate instrument and sky variations in a non-degenerate manner.

Euclid (III)

- Dithering on a wide range of scales and in non-repetitive (non-degenerate) patterns is most helpful. Examples given in appendix slides and memo from Arendt, Kashlinsky, & Moseley (June 6, 2013)
- Polar deep survey and calibration fields will have rotation and depth amenable to self-calibration.
- Wide survey may be more challenging.

END

APPENDIX

Dithering, Randomness, & Sky Coverage

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Euclid Consortium Meeting (May 2014)

Why Dither?

1. To fill gaps between focal plane arrays, and to fill holes left by bad pixels.

2. To enable (or verify) calibration of the detector by having different pixels look at the same source. The sky itself can be used as a calibration target. It is continuously seen, and it is stable (apart from slow zodiacal light variation). Though it is not spatially uniform or bright. (Self-calibration of Spitzer data has been critical to measurements of the Cosmic IR Background.) [Fixsen, Moseley & Arendt 2000; Arendt, Fixsen & Moseley 2000]

Dither Pattern Scale

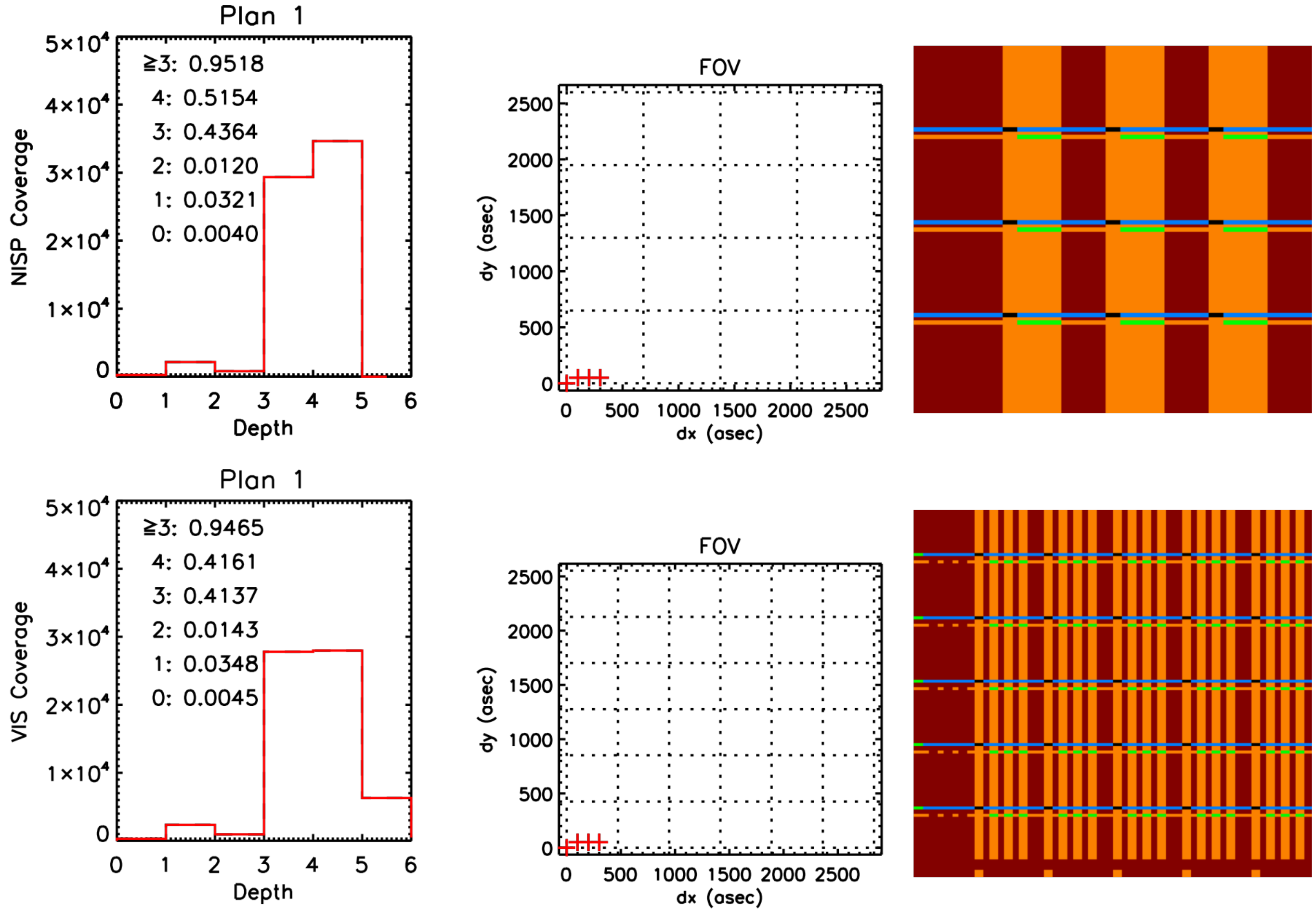
To be most effective, dither steps should directly sample scales of interest.

- Small dither steps make direct connections between nearby pixels. Large dither steps help connect distant pixels without incurring the large uncertainties of unreasonably long chains of intermediate pixels.
- A↔B (0 intermediate steps)
- A↔B↔C (1 intermediate steps)
- A↔B↔C↔... ... ↔Y↔Z (26 steps)
- A↔M↔Y↔Z (3 steps)

Shallow Surveys

- Several techniques can help develop good (cumulative) dither patterns across extended data sets.
- 1. Randomize dither pattern used at each pointing.
- 2. Execute only 2 dithers per pointing, but overlap survey rows (or columns) by 1/2 FOV. Also provides temporal coverage spanning minutes-to-hours (or days?) timescales.
- 3. Change survey cadence. Helps variation of large-scale dithers.

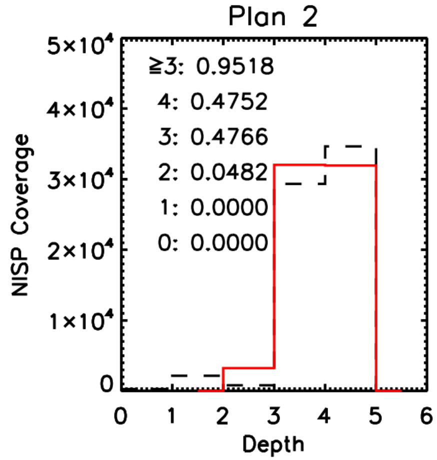
Redbook Pattern

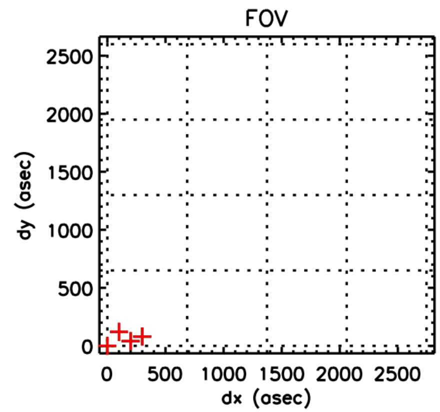


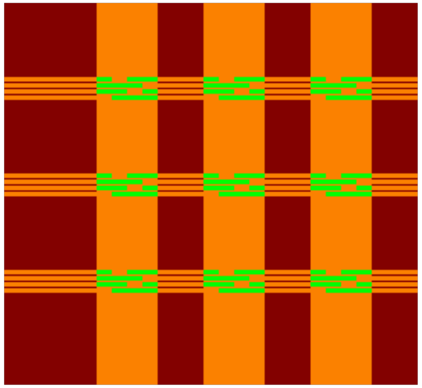
Fills gaps poorly.

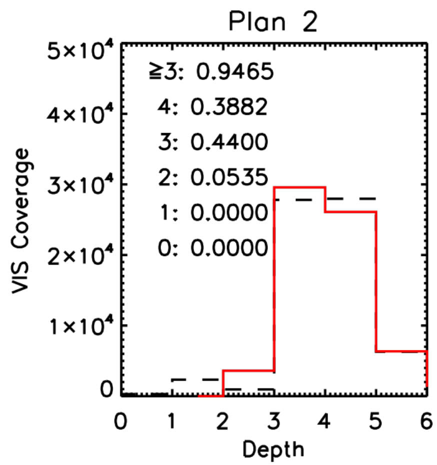
Contains only redundant short scale lengths.

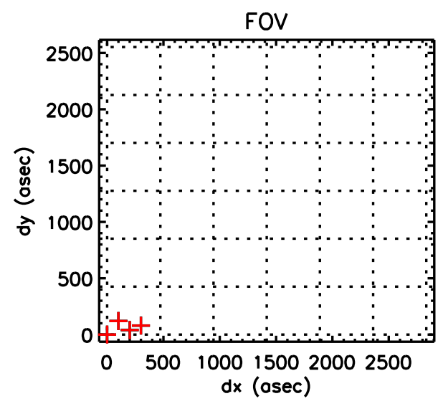
Irregular Fixed Pattern (small)

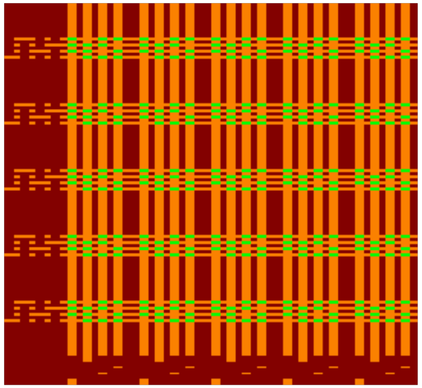








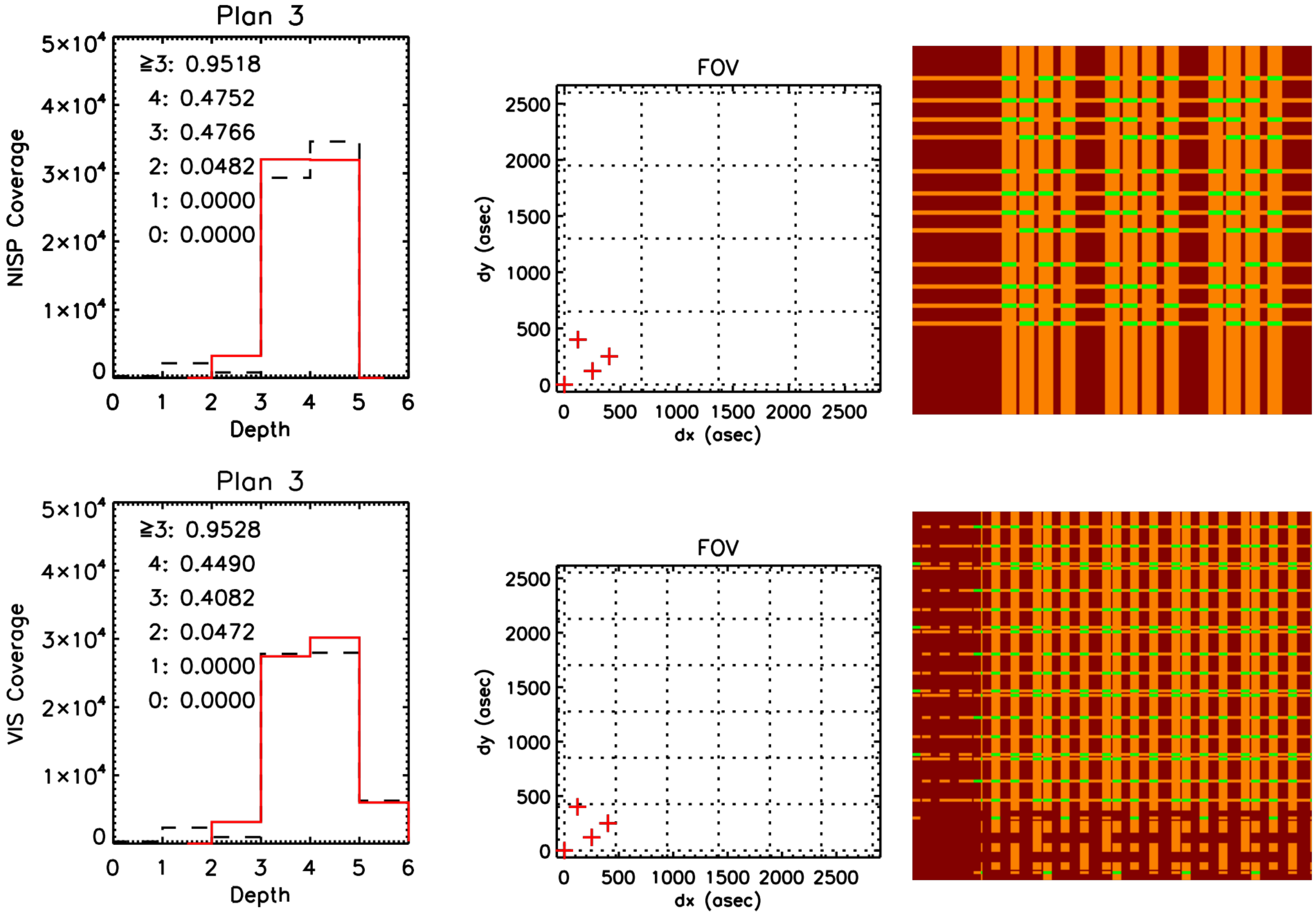




Fills gaps.

Contains varied, but still short scale lengths.

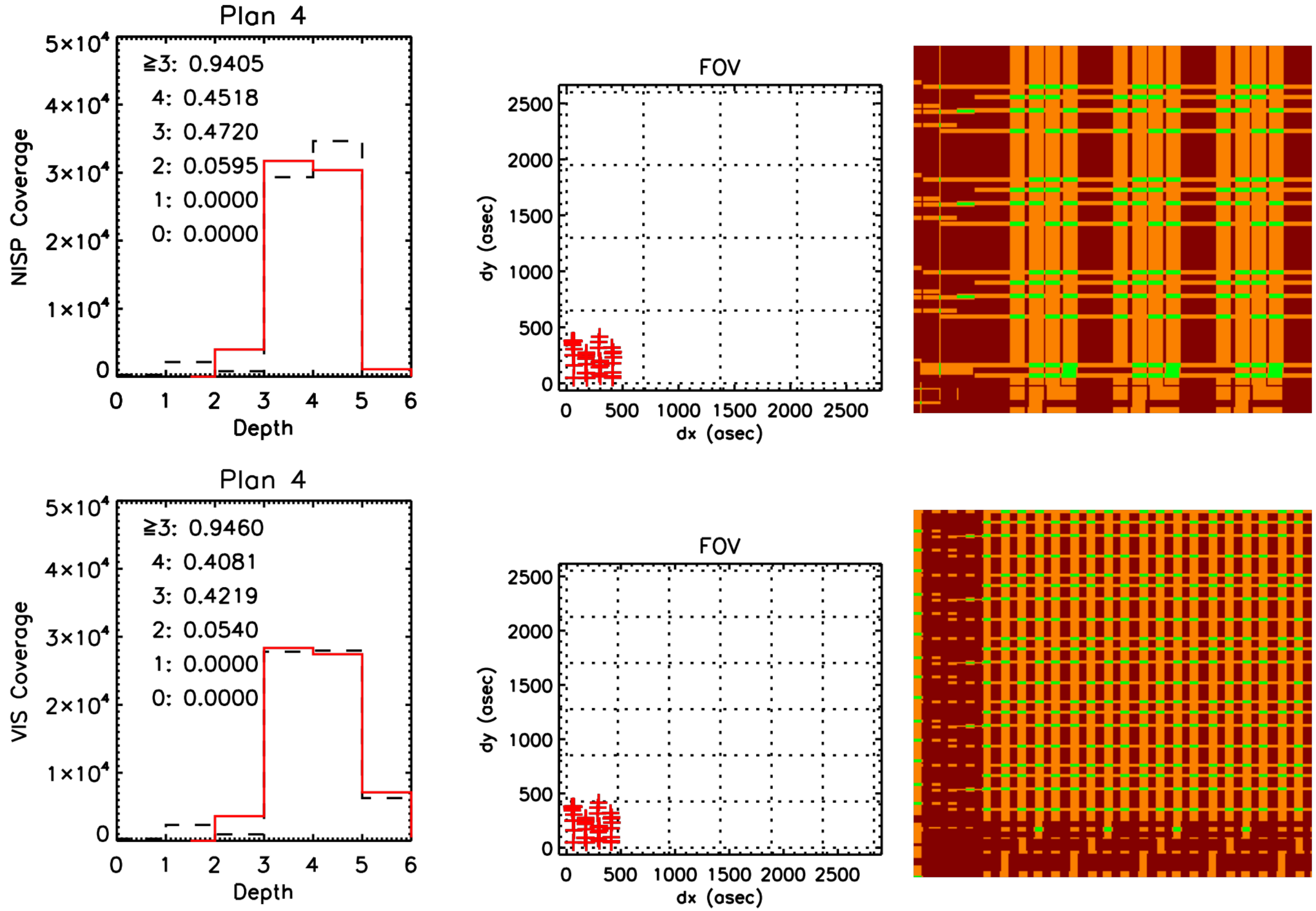
Irregular Fixed Pattern (not as small)



Fills gaps.

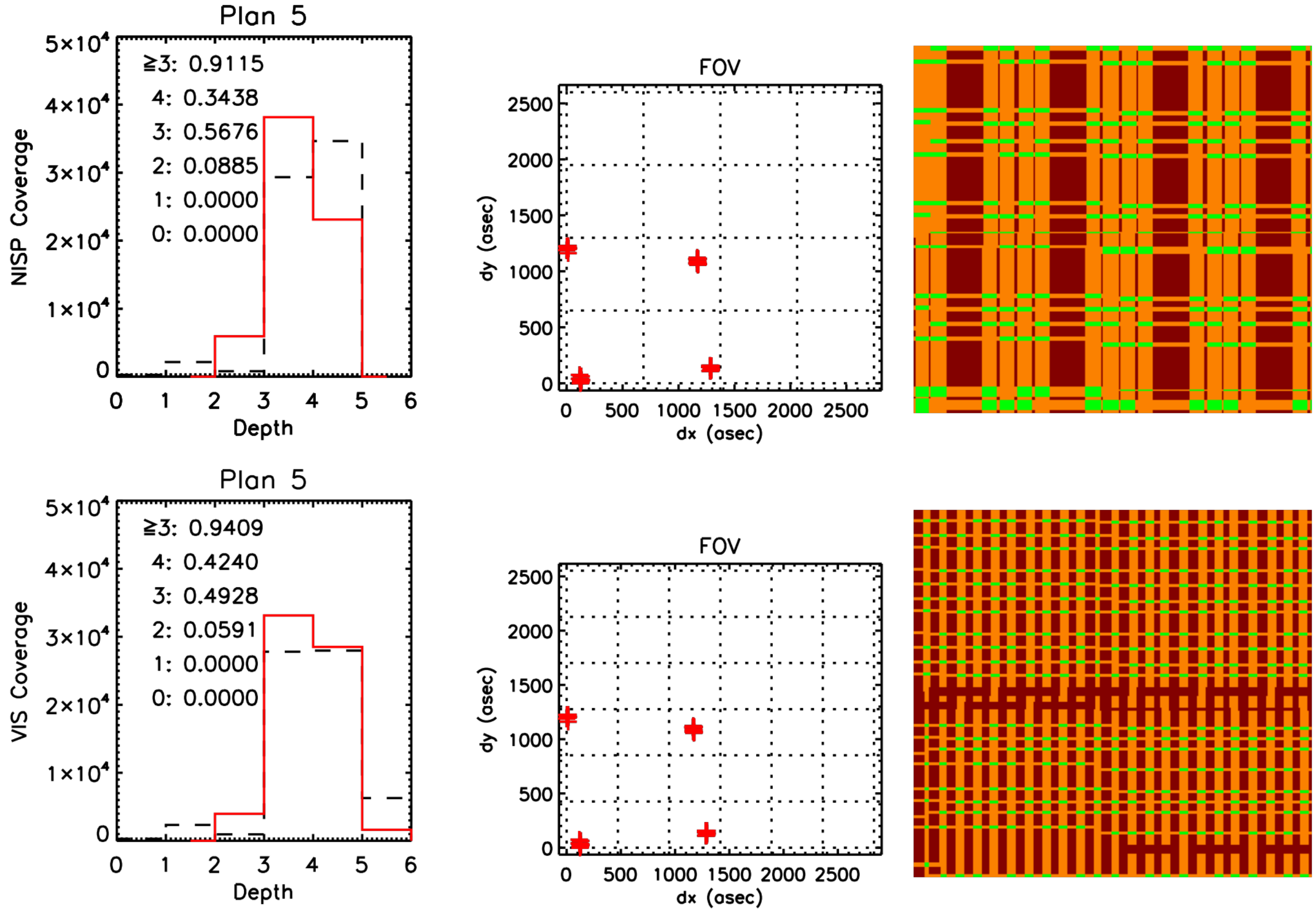
Samples scales up to size of one VIS detector.

Random Pattern



Cumulatively samples many different scales, up to size of one VIS detector.

Survey with ½ Field Increments + 1 Small Random Dither



Exchange dithering for overlapping survey coverage (including a small random dither step). This samples large scales (1/2 FOV) and small scales, but misses intermediate scales.