WFIRST
Optical Design Trade Space

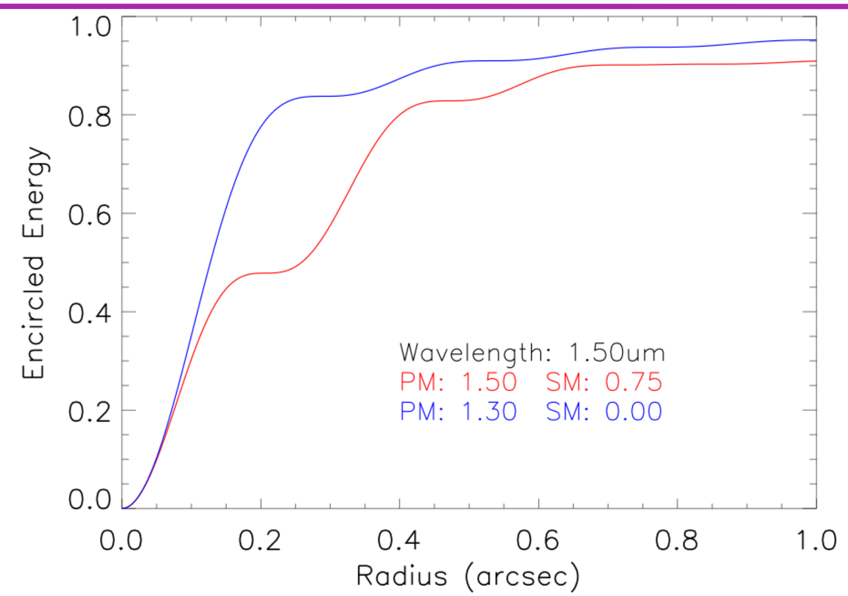
March 10, 2011

Optics Trade Space Overview

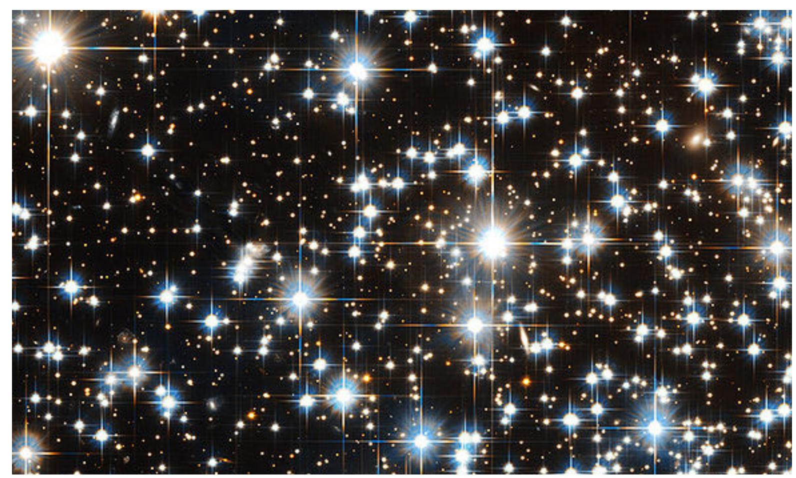
- Design trade space we have been exploring
  - Guiding rule – no overall cost increase from Omega; look for chances to match or improve performance at lower cost
- Example of alternative design [unobscured 1.3m aperture]
  - Layout
  - Comparison to Omega
- [Backup material]
  - Layout views
  - Channel design performance
  - Design residual comparison w/ Omega
- Key points:
  - Unobscured 1.3m aperture is not adding risk but adds value
  - Spectrometer design is the tall pole for defining the payload

Design Trade Space - #1 Aperture

- We found that a 1.3m uTMA is as sensitive and resolves better than a 50% linear obscured 1.5m TMA such as Omega
  - Pros:
    - Effectively reduces readnoise, zodi, dark current relative to signal, should increase survey rate
    - Improves ability to sense shapes for WL
    - Discussed 1.3m unobscured with industry; ~"cost neutral" with 1.5 obscured
    - Stray light rejection will be improved
    - Spider diffraction eliminated
      - Reduces confusion for microlensing
  - Cons:
    - Some alignment & stability tolerances may be tighter



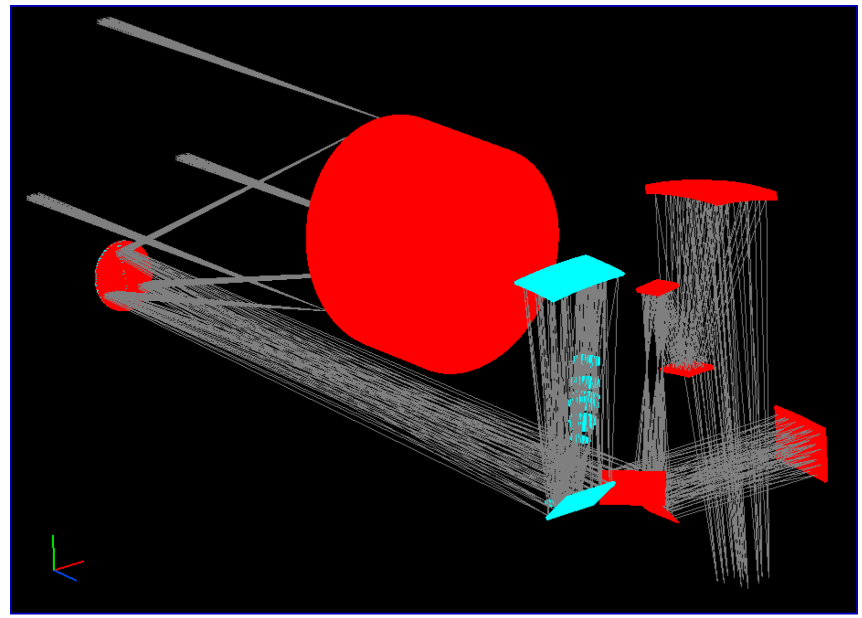
Encircled energy at 1.5μm for 1.5m 50% linear obscuration and 1.3m unobscured apertures



HST file image courtesy STScI

Design Trade Space - #2

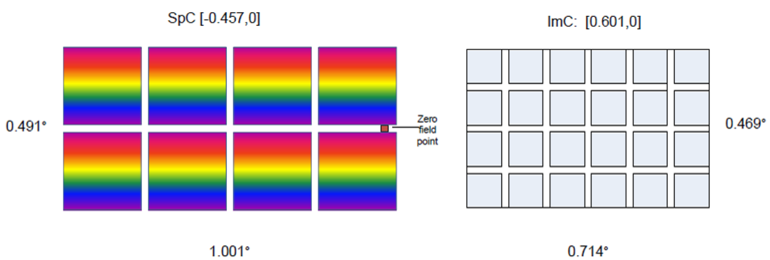
- Variables that are potentially in play for alternative designs:
  - 1.3m Unobscured vs. 1.5m Obscured TMA
  - # of channels (1..3)
  - Form [all focal, all afocal, hybrid/mixed]
  - Ratio of SpC/ImC area [range is 1-2]
- Caveat – Permutations of above are NOT necessarily cost neutral or equal risk!
- Example –”1c:” Afocal, 2 channel/2 focal length 1.3m uTMA, SpC/ImC area ratio=1.8; SpC uses refractive camera
  - Several other alternate designs being explored



3D layout view of “1c;” blue-SpC; Red – telescope & ImC

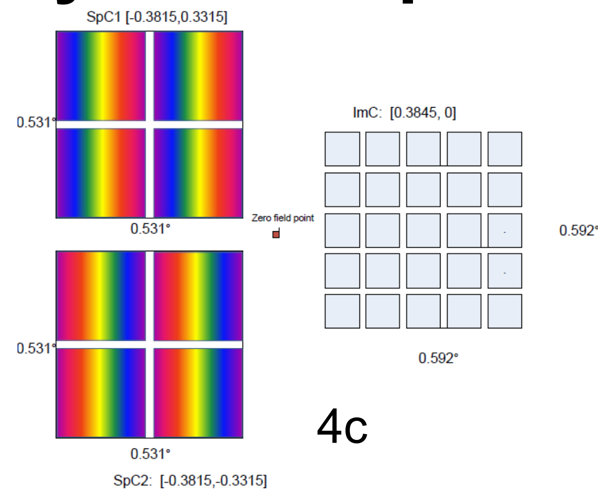
SpC = Spectrometer Channel
ImC = Imager Channel

Field Layout Comparison



1c

Channel field layout for Design 2c:
ImC: 6x4 @ 0.18"/p; SpC 4x2@0.416"/p
[xfield center, yfield center, degrees]

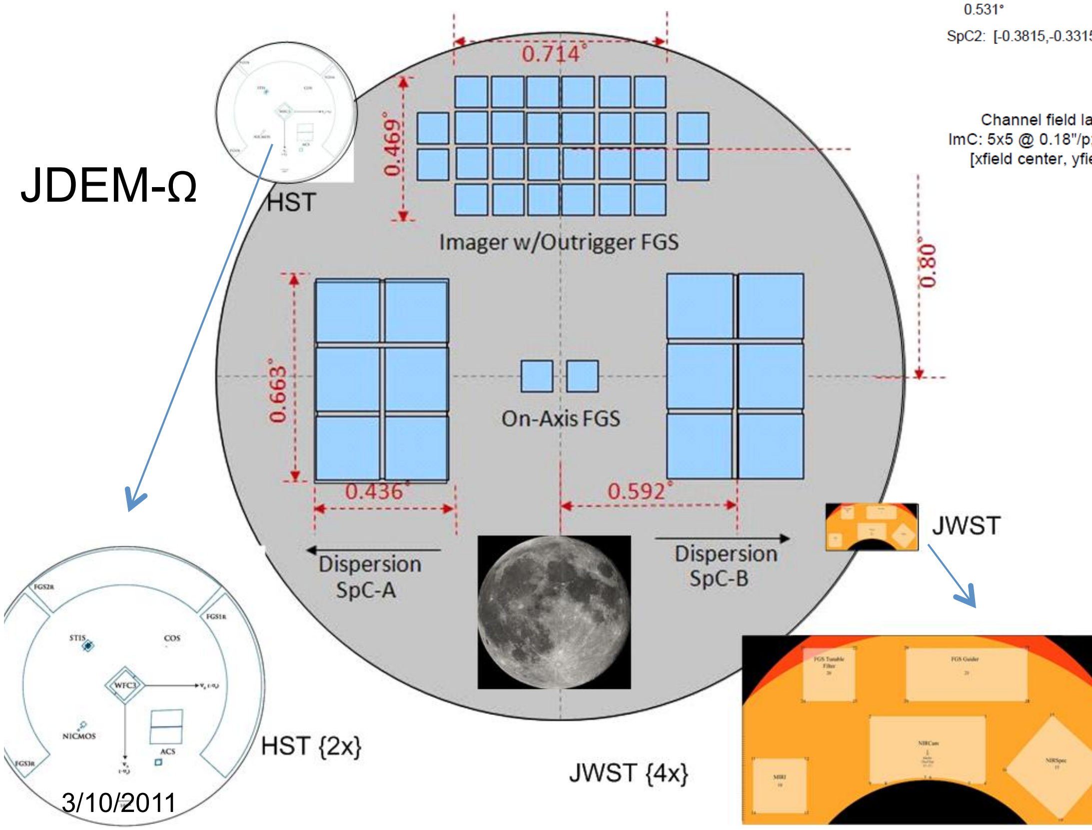


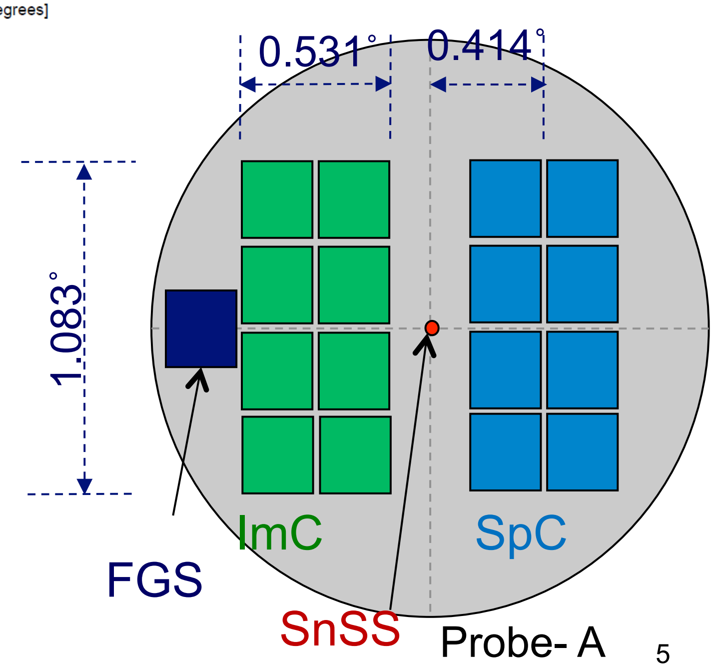
4c

Upper Left: alternate design 1c;
Bottom Left: JDEM-Ω
Bottom Right: Probe-A;
All are roughly to the same scale; Moon, HST, JWST shown with JDEM-Ω at same scale

Channel field layout for Design 4:
ImC: 5x5 @ 0.18"/p; SpC (2) 2x2@0.45"/p
[xfield center, yfield center, degrees]

JDEM-Ω





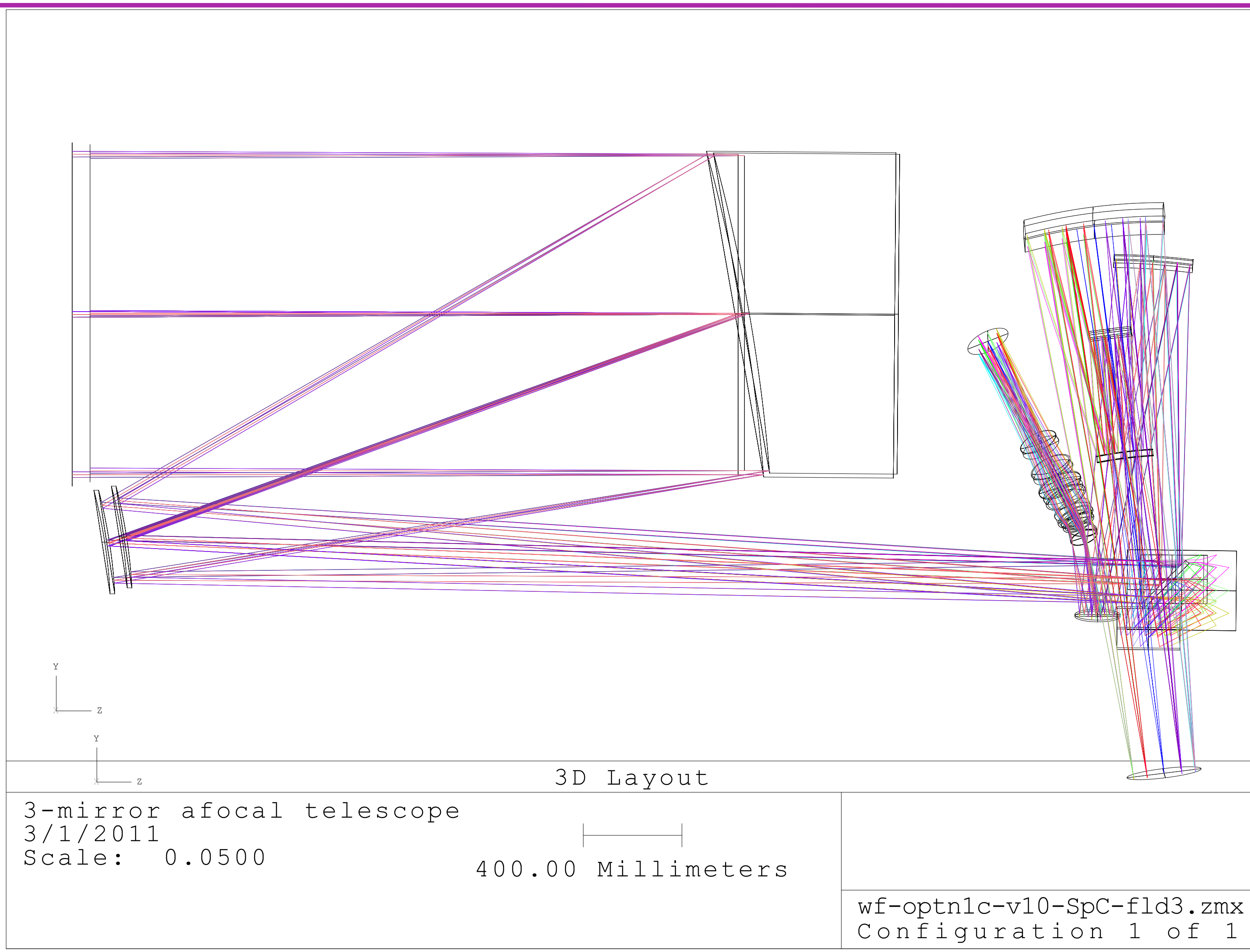
Alternative Design Performance

- ImC has same layout but improved PSF means more resolution and sensitivity
- Single SpC has slightly less overall sky coverage; simultaneous opposed dispersions not provided
- Similar overall design performance
- Slightly larger bounding volume [fits in EELV]

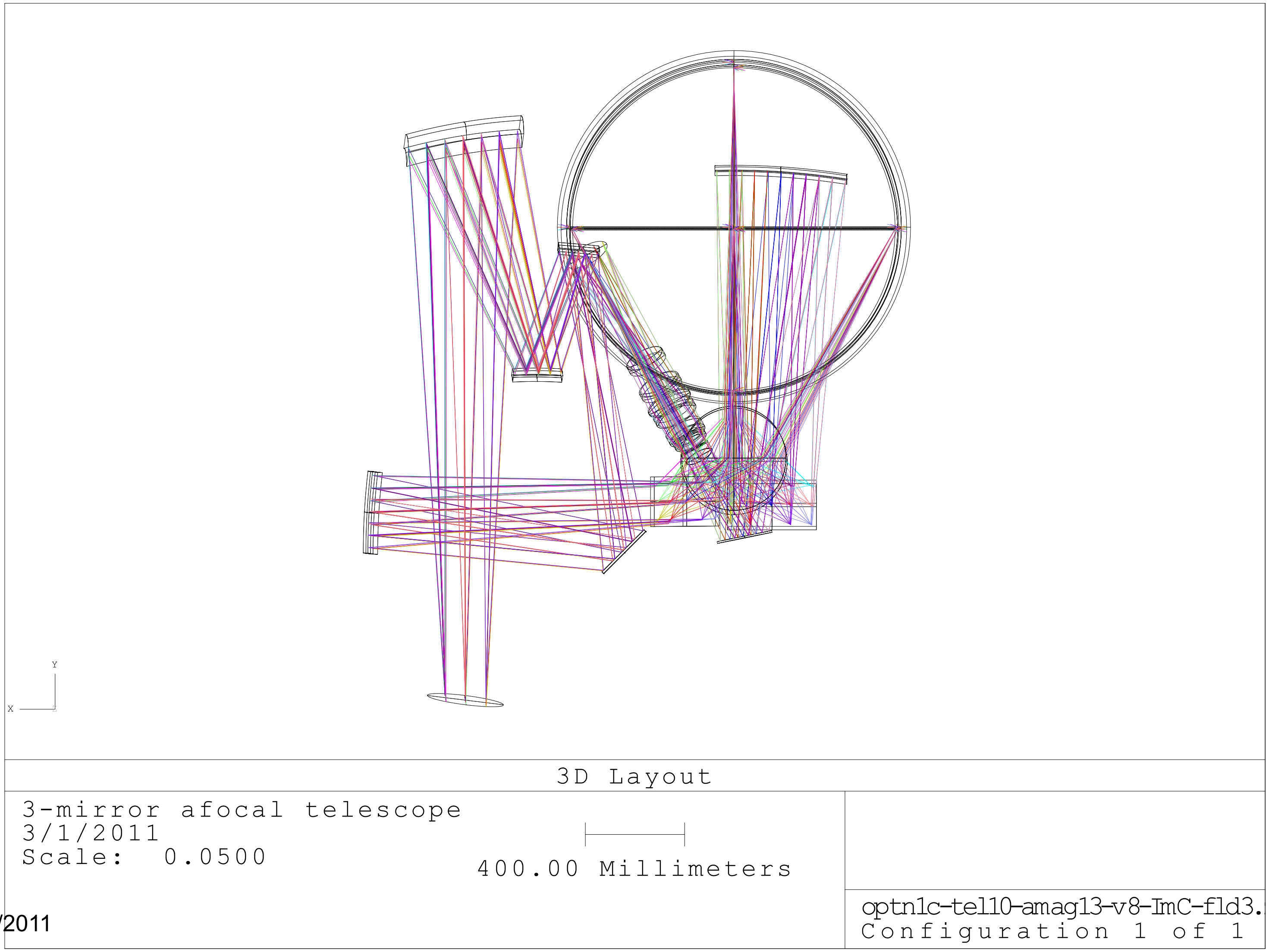
design name	**#1c**	**WFIRST DS, aka JDEM-Ω**
# channels	2	3
description (#science SCA: ImC then SpC #@pixel scale, arcsec)	33: 6x4 @0.18, 4x2@0.416	36: 6x4@0.18, 2(3x2)@.377
focal/afocal/hybrid	A	H (reflective)
Aperture type & Diameter, m	unobscured 1.3	obscured 1.5
ImC / SpC active field area (sq. deg.)	0.250 / 0.445	0.250 / 0.528
# optics in channel 1 (ImC)	8R+1T=9	5R+1T=6
# optics in channel 2 (SpC#1)	5R+7T=12	6R+8T=14
# optics in channel 3 (SpC#2)	n/a	6R+8T=14
total # science channel optics (PM/SM common)	19	30
field area ratio SpC/ImC	1.78	2.11
BAO prism spectroscopy mode	fixed single	fixed dual
total x extent (m)	2.2	1.83
total y extent (m) [along sun line]	2.6	2.25
total z extent (m) [along fairing axis]	4.72	5.24
total bounding rectangular volume (m^3)	27.00	21.61
ImC rms wfe (worst field point), nm	40	35
SpC rms wfe (worst field & wavelength), nm	103	122

Optics Backup Slides

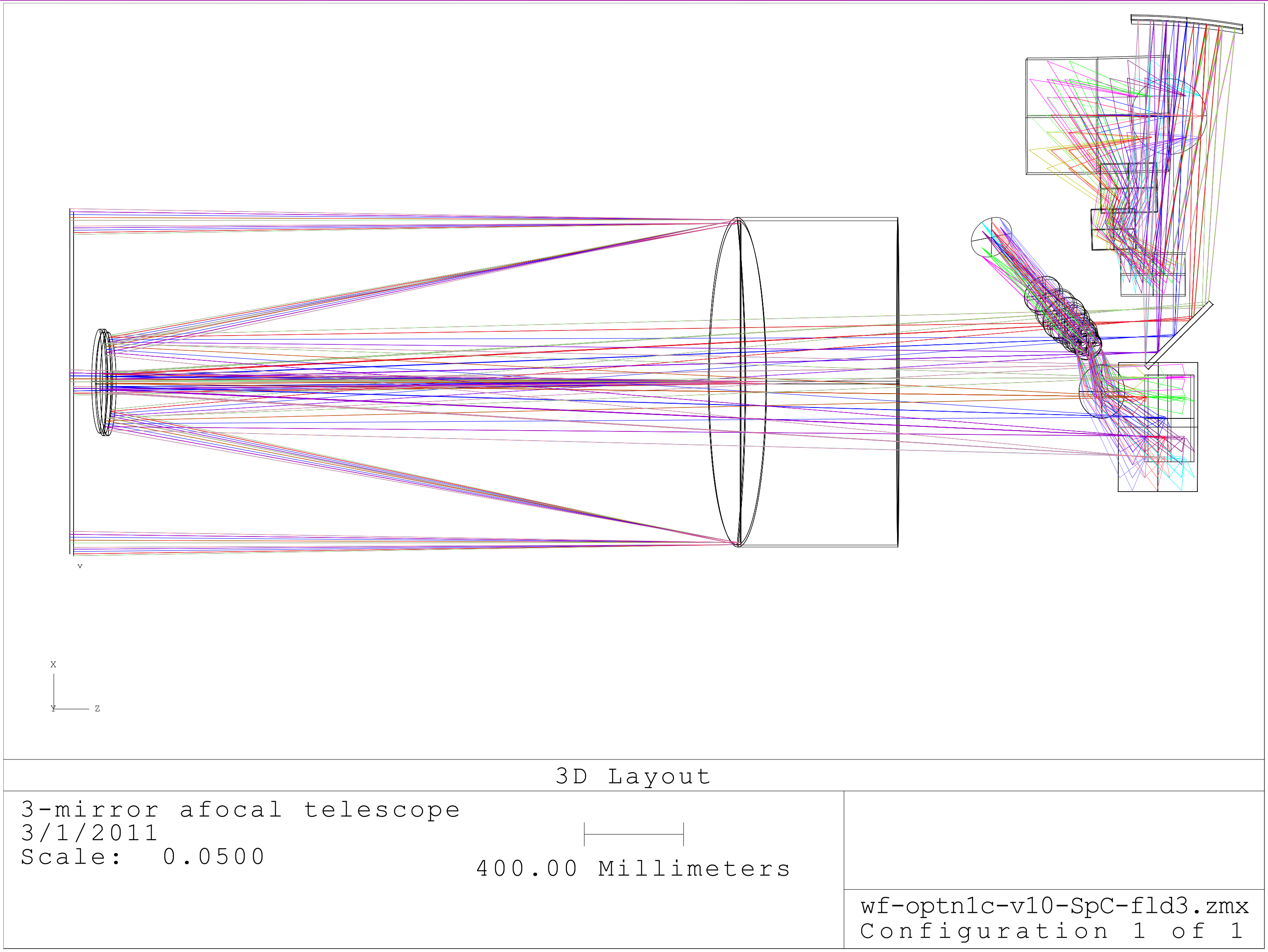
Y-Z Plane View (Side)



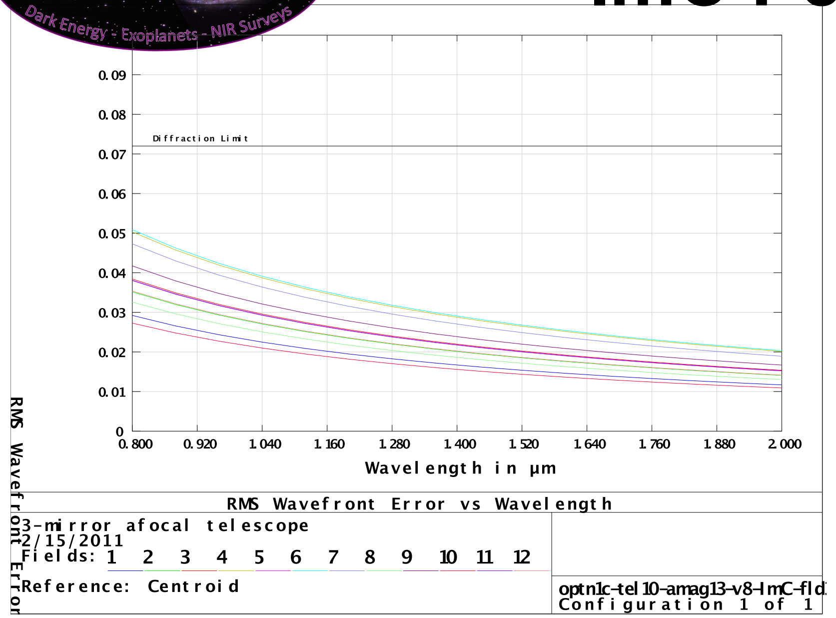
X-Y Plane View (Back)



1c Layout View – X-Z Plane View (Top)

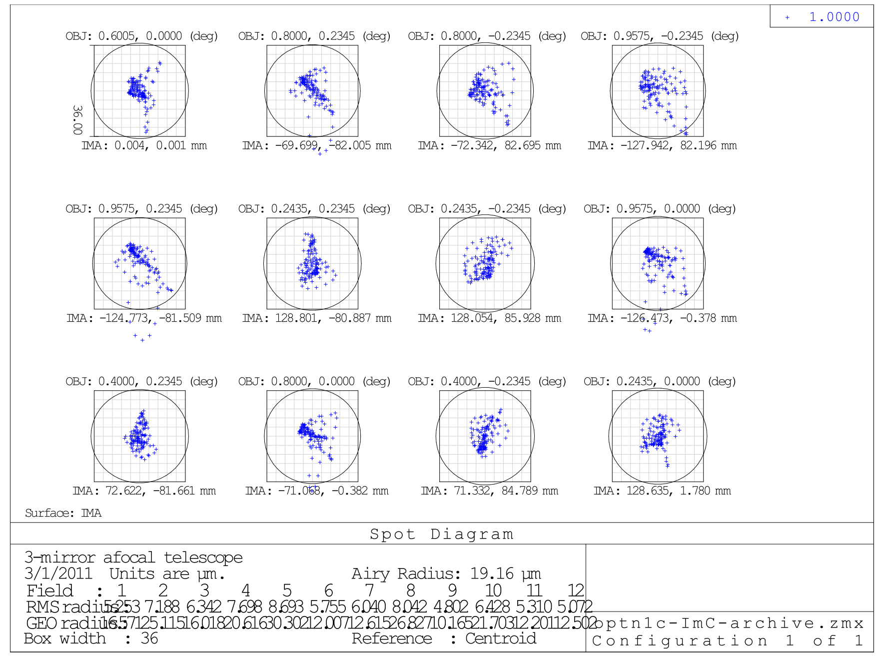


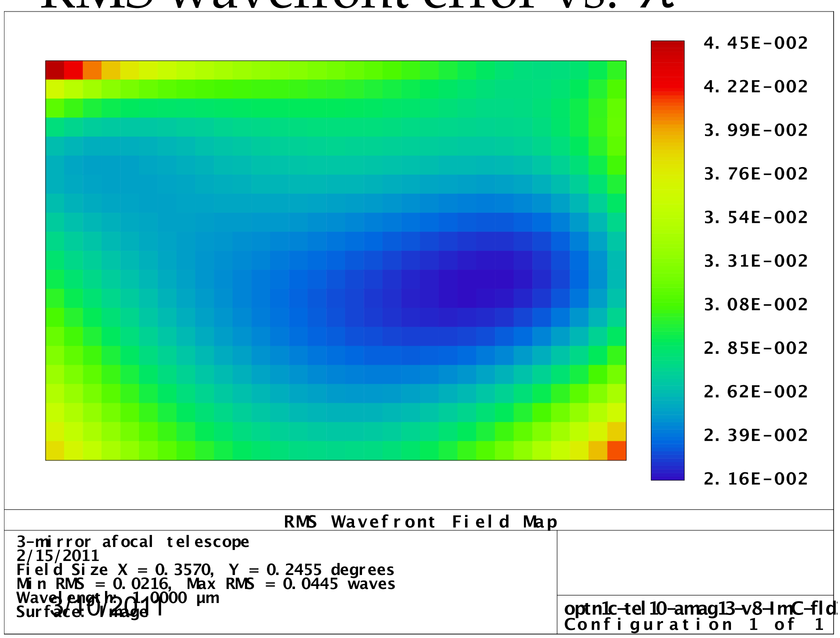
ImC Performance Details



RMS wavefront error vs. λ

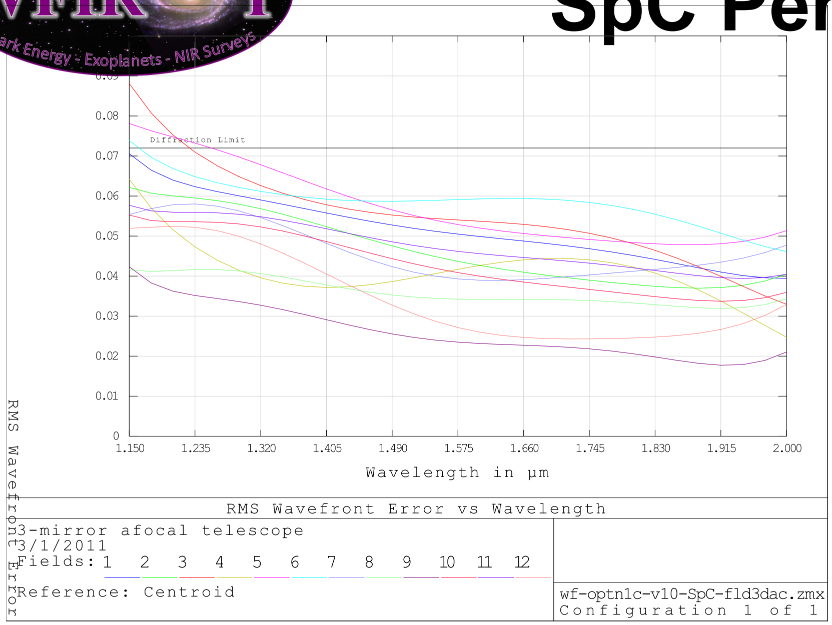
Spot Diagram





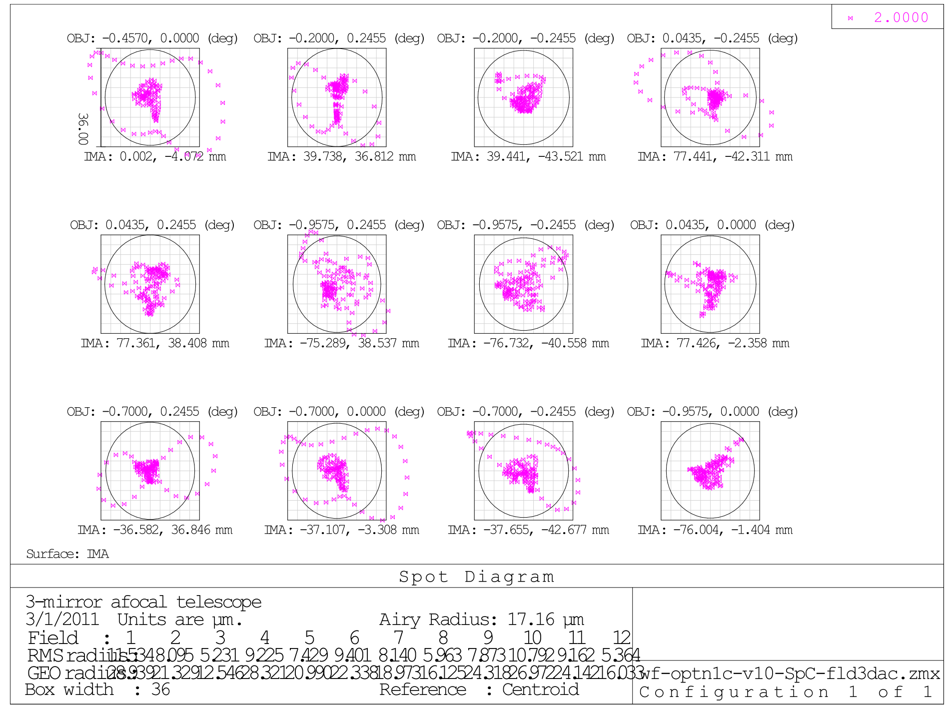
1 µm RMS wavefront map

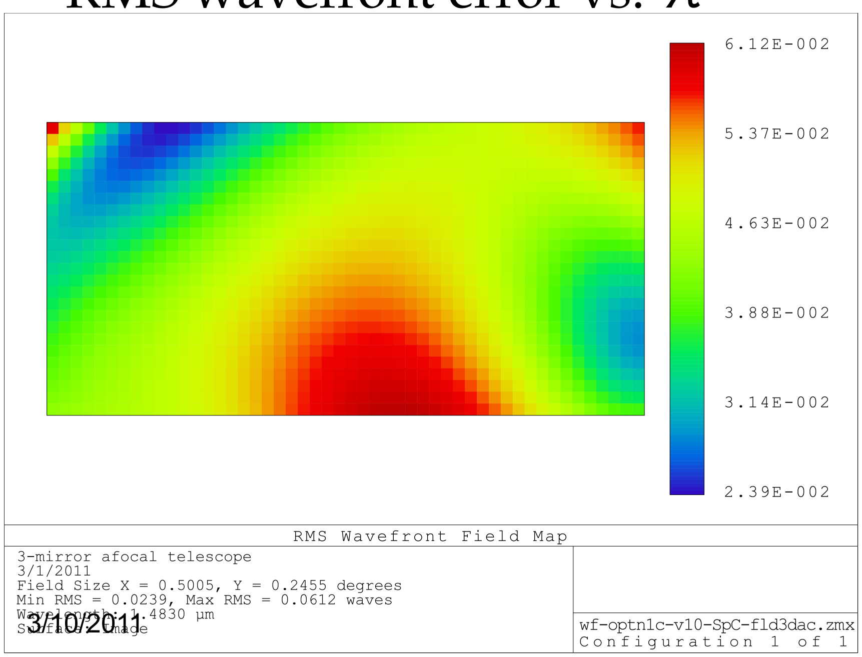
SpC Performance Details



RMS wavefront error vs. λ

Spot Diagram

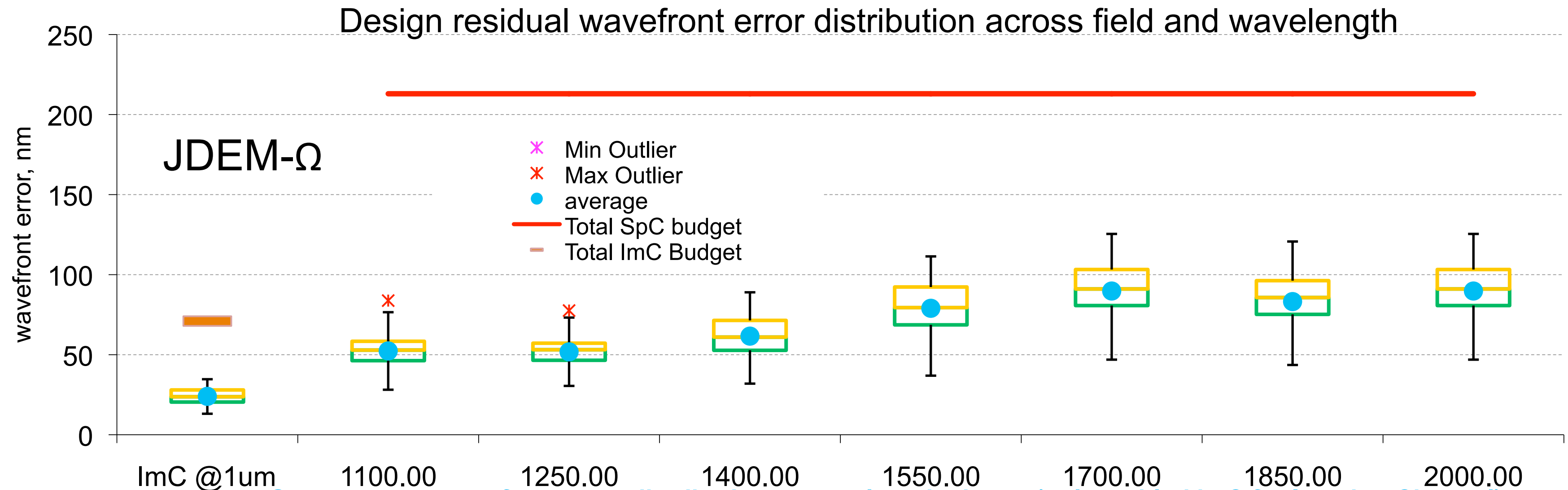




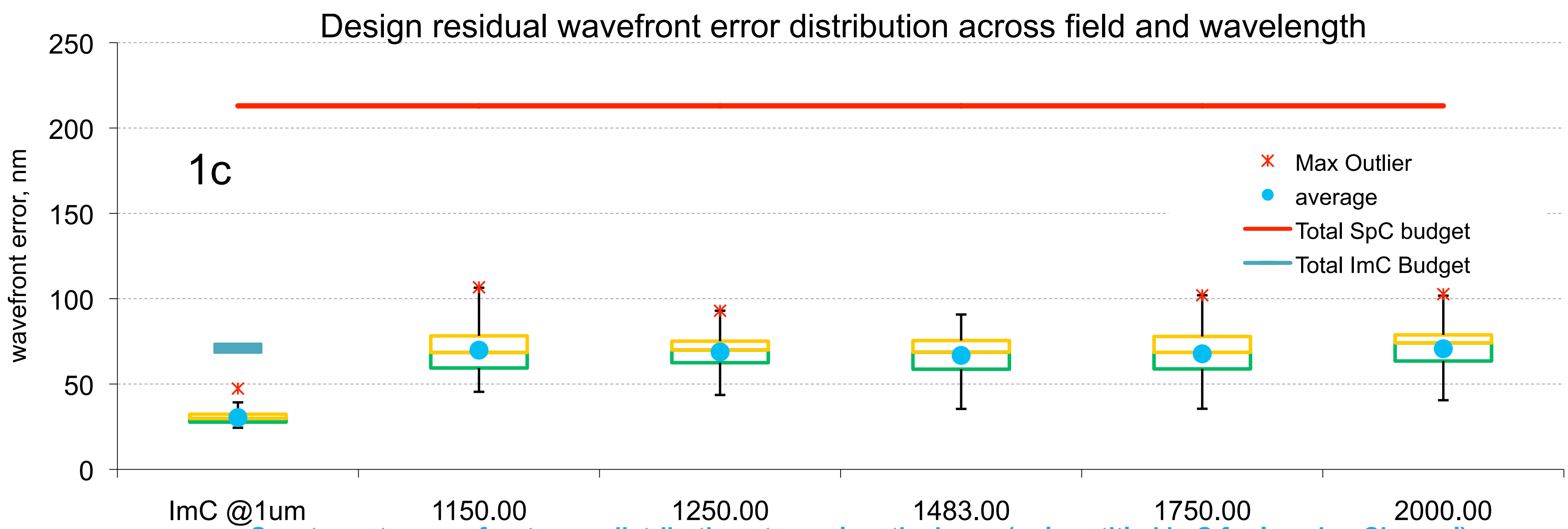
1.48 µm RMS wavefront map

Design Residual Comparison Omega & 1c

[Boxes Show 1st-3rd Quartile of Distribution]



Spectrometer wavefront error distribution at wavelength shown (unless titled imC for Imaging Channel)



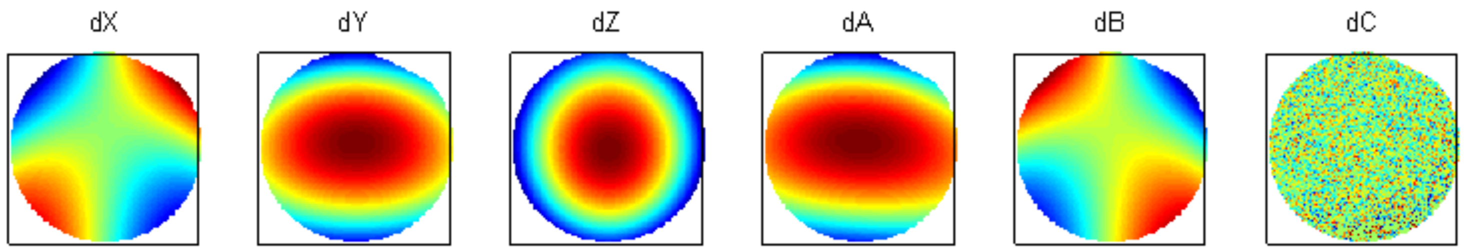
Spectrometer wavefront error distribution at wavelength shown (unless titled imC for Imaging Channel)

Secondary Mirror Wavefront Stability Sensitivities (No Boresight)

This is for design “4” [2(2x2) SpC@0.477”/pixel, 7x4 ImC @ 0.18”/pixel]

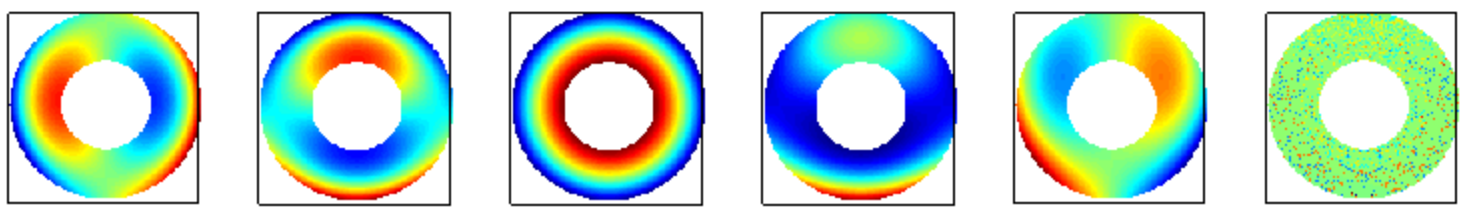
Z = axis of SM

Unobstructed 1.3m “4”



Coefficient: 1.5 2.5 6.3 1.7 1.2 0

50% Obstructed 1.5m Omega



Coefficient: 0.60 0.61 8.8 0.68 0.63 0

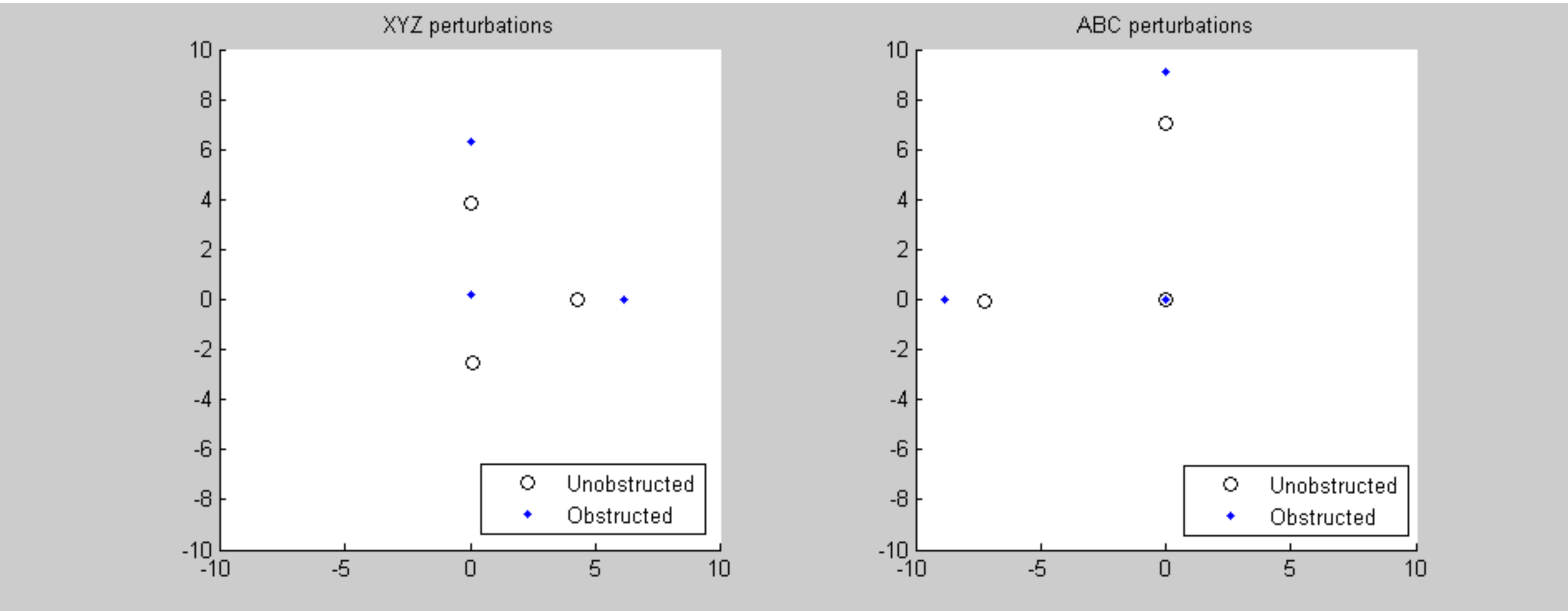
Units = nm/um um/urad

Unobstructed is ~ 2x to 4x **more** sensitive (RMSWE metric)

Chief Ray Sensitivities (i.e. Boresight)

SM position errors

SM angular errors



Units = m/m m/rad

Unobstructed 1.3m “4” is **less** sensitive than 1.5m 50% obstructed Omega (~ 20% less for tilts) ...

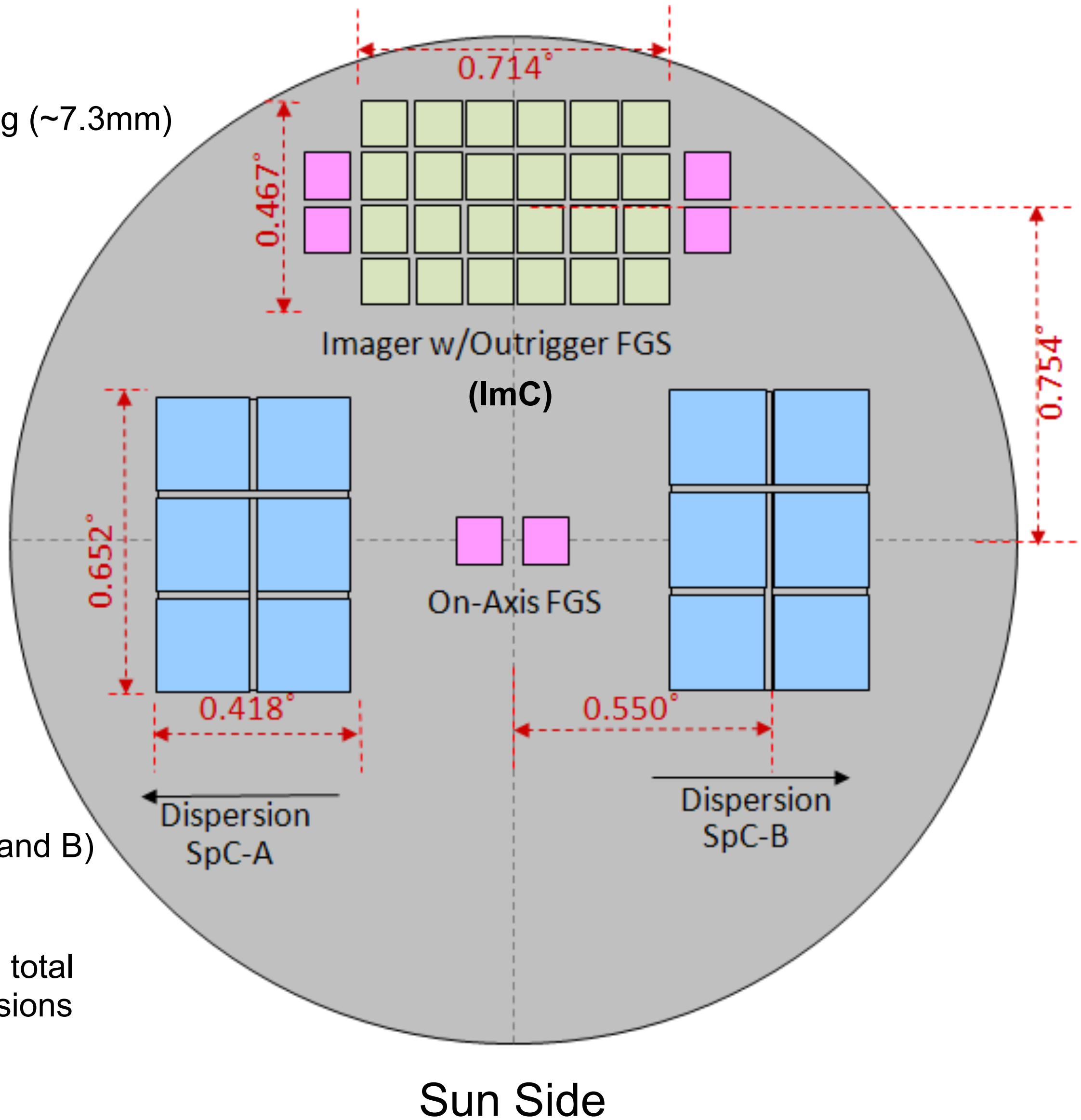
Likely due to SM having less magnification for Unobstructed.

Parallel ImC/SpC Mapping Issues for Omega

… a quick look that might provide some optimization thoughts

Here are the ImC and SpC FPA Layouts for Omega

- ImC = Imaging Channel
- 180 mas/pix
- SCA gaps ~1/5th SCA diag (~7.3mm)
- Active area: 0.25 deg^2
- **X-extent: 0.714°**
- **Y-extent: 0.467°**



- SpC = Spec Channel (A and B)
- 370 mas/pix
- SCA gaps ~3mm
- Active area: 0.528 deg^2 total
- Note the opposite dispersions
- **X-extent: 0.418°**
- **Y-extent: 0.0.652°**

Two Sci Ops Concepts Clearly Require Parallel Mapping of ImC and SpC FPAs

- BAO-only
  - SpC mapping is the integration time and roll-diversity driver, BUT
  - An ImC map at less depth is also required in at least one filter, and
  - There may be other NIR or WL_Ph-z survey rqts, including providing 2 filter ImC sky coverage over all imaged fields

- WL/BAO … a simultaneous technique survey
  - WL ImC mapping is the filter and random dither driver, will meet BAO ImC rqts, and requires no simultaneous SpC data, BUT
  - SpC data acquired in parallel during WL ImC mapping must meet BAO rqts

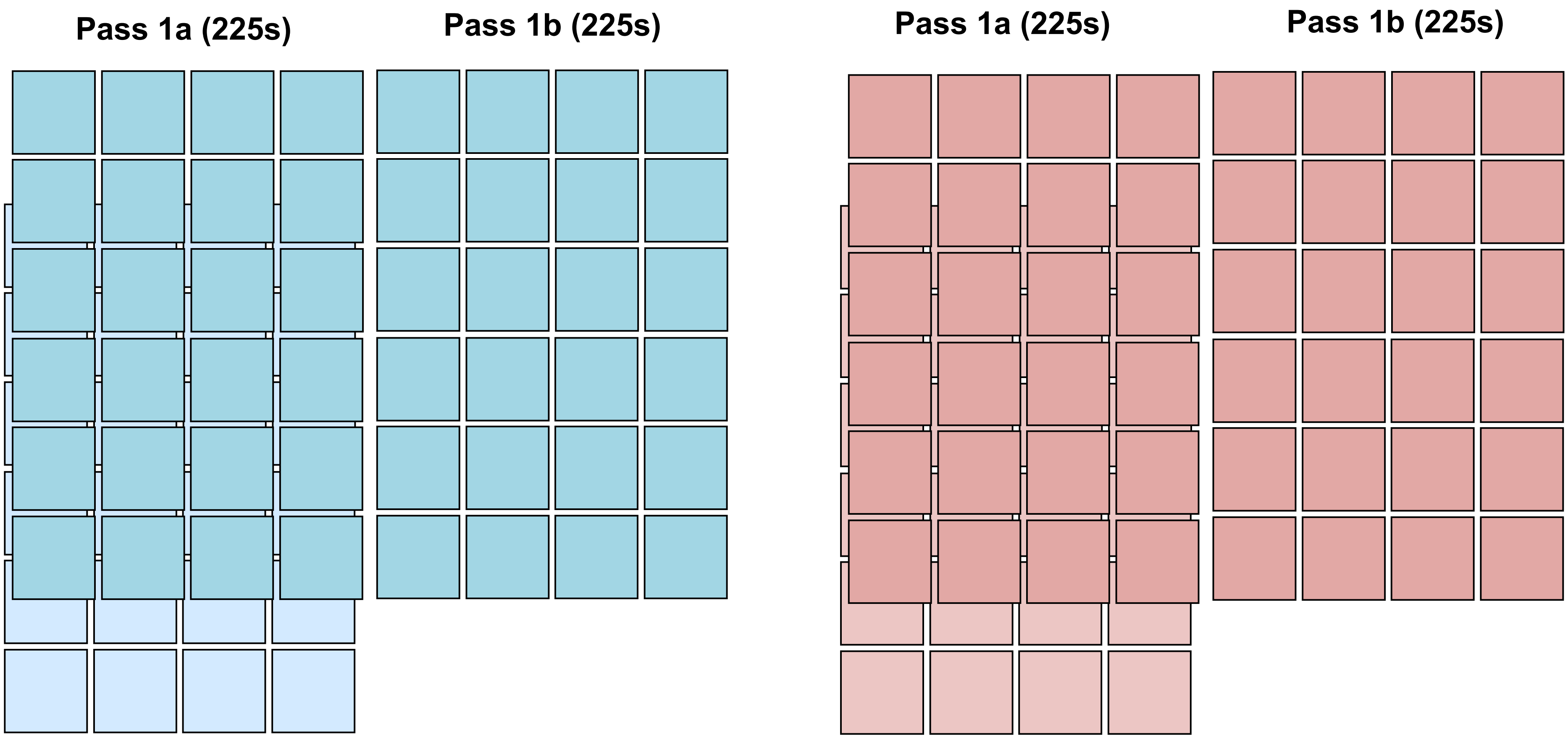
- Edge effects are ignored in the following discussions due to the large field coverage sizes planned.

Ω BAO-Only: Rough Filled Survey (RFS) Ops Concept

- BAO Data Set Rqts (from Ω … needs update):
  - 1800 s of SpC time;
  - 4 dispersion directions (two ~opposed, ~5° roll for other two);
  - ImC time of at least ~ ¼- ½ of SpC time in at least one NIR filter;
- Two passes at 0° and 5° roll provide 4 dispersion directions
- Each pass consists of two sub-passes (225s each) to fill SCA/FOV gaps
- Total integration time provided per pass is 900s (2 sub-passes x 2 SpC FOVs x 225s), so 1800s after 2 passes.

Ω BAO-Only: RFS SpC Maps, 0° Roll

- Even an SpC-driven Rough-Filled Survey leads to significant variations in the # of SpC looks/dispersions over the sky:

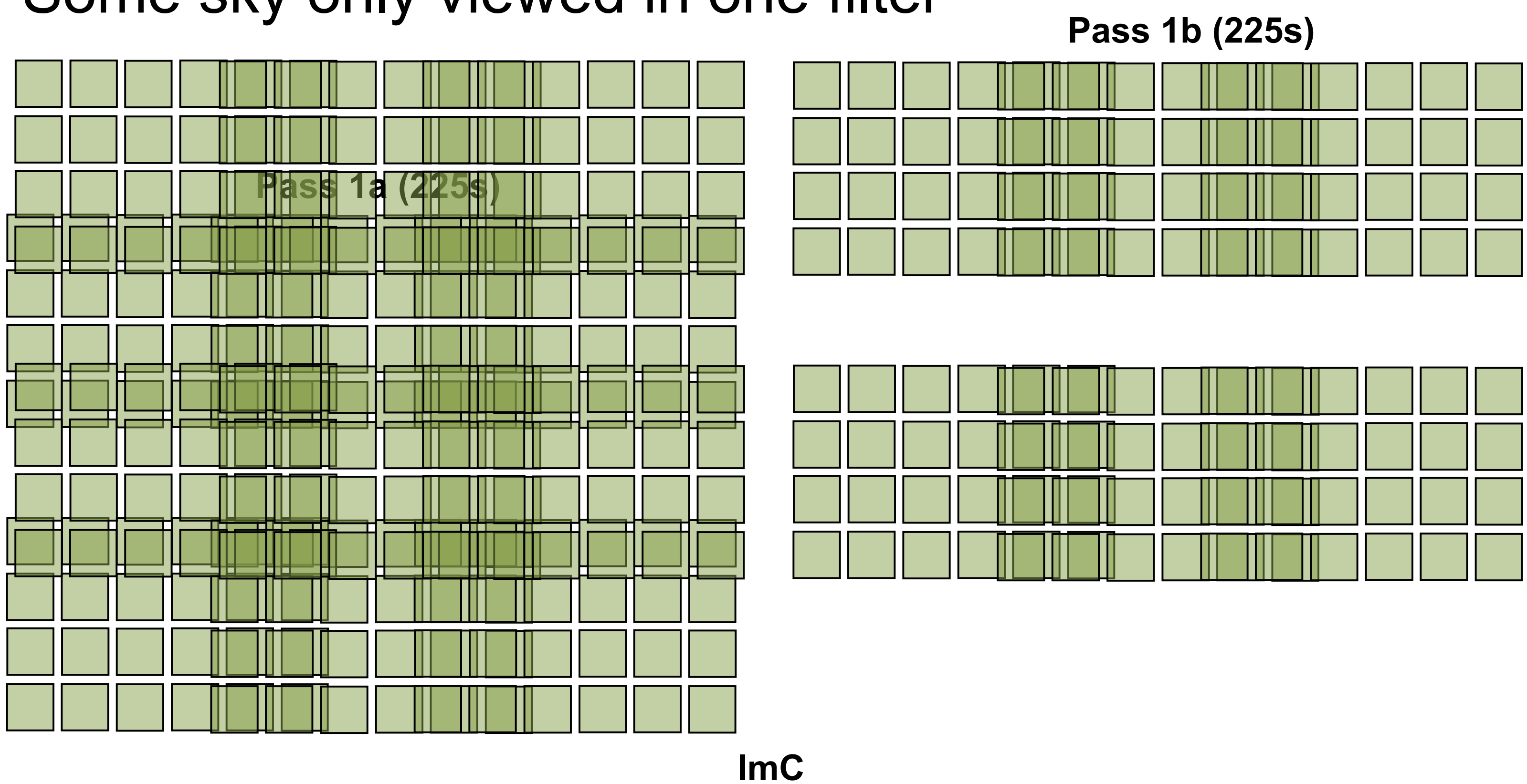


A-side SpC

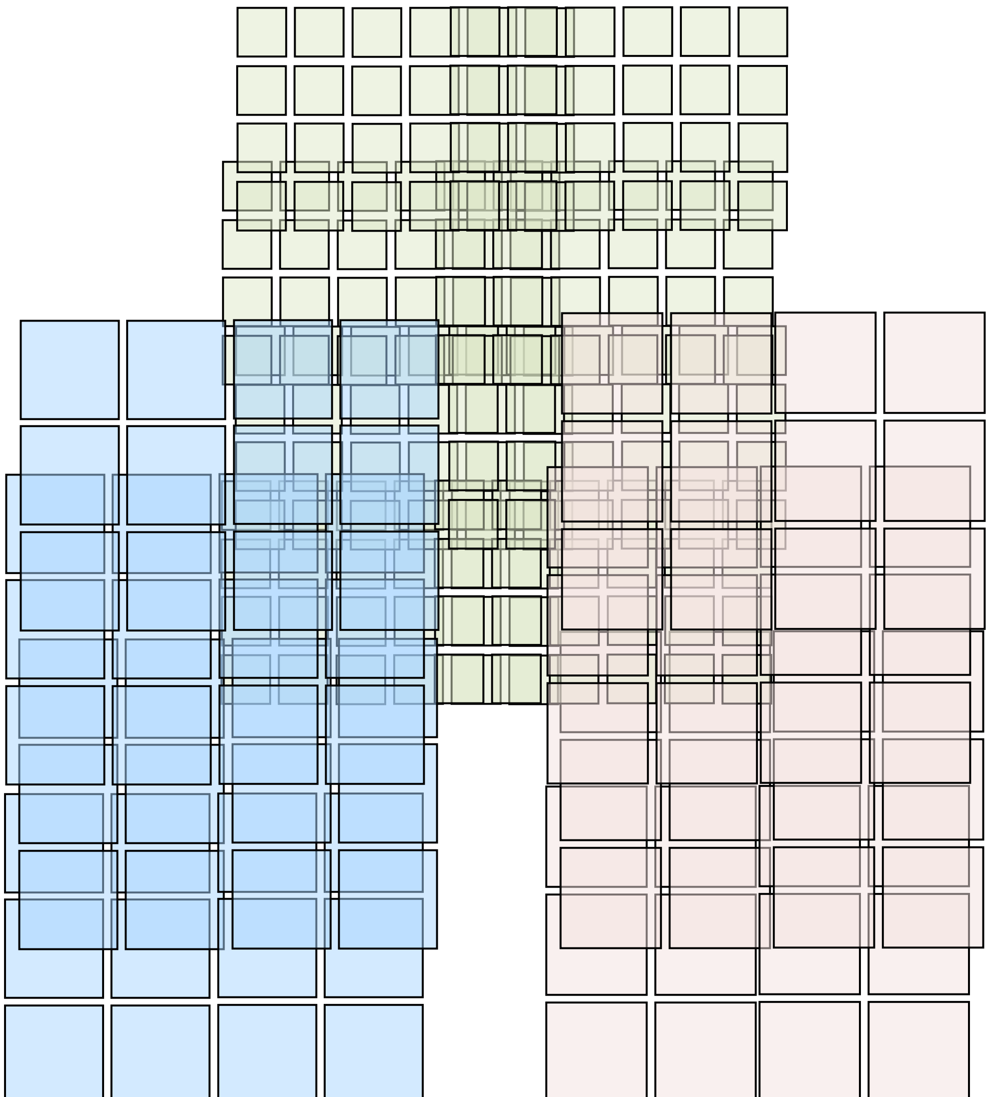
(Oppositely-dispersed) B-side SpC

Ω BAO-Only: RFS ImC Map

- SpC X/Y FOV drives ImC mapping steps;
- X/Y mismatch of SpC and ImC fields leads to ImC gaps;
- ImC gaps only partially filled in by 1a/b pass offsets;
- Some sky only viewed in one filter

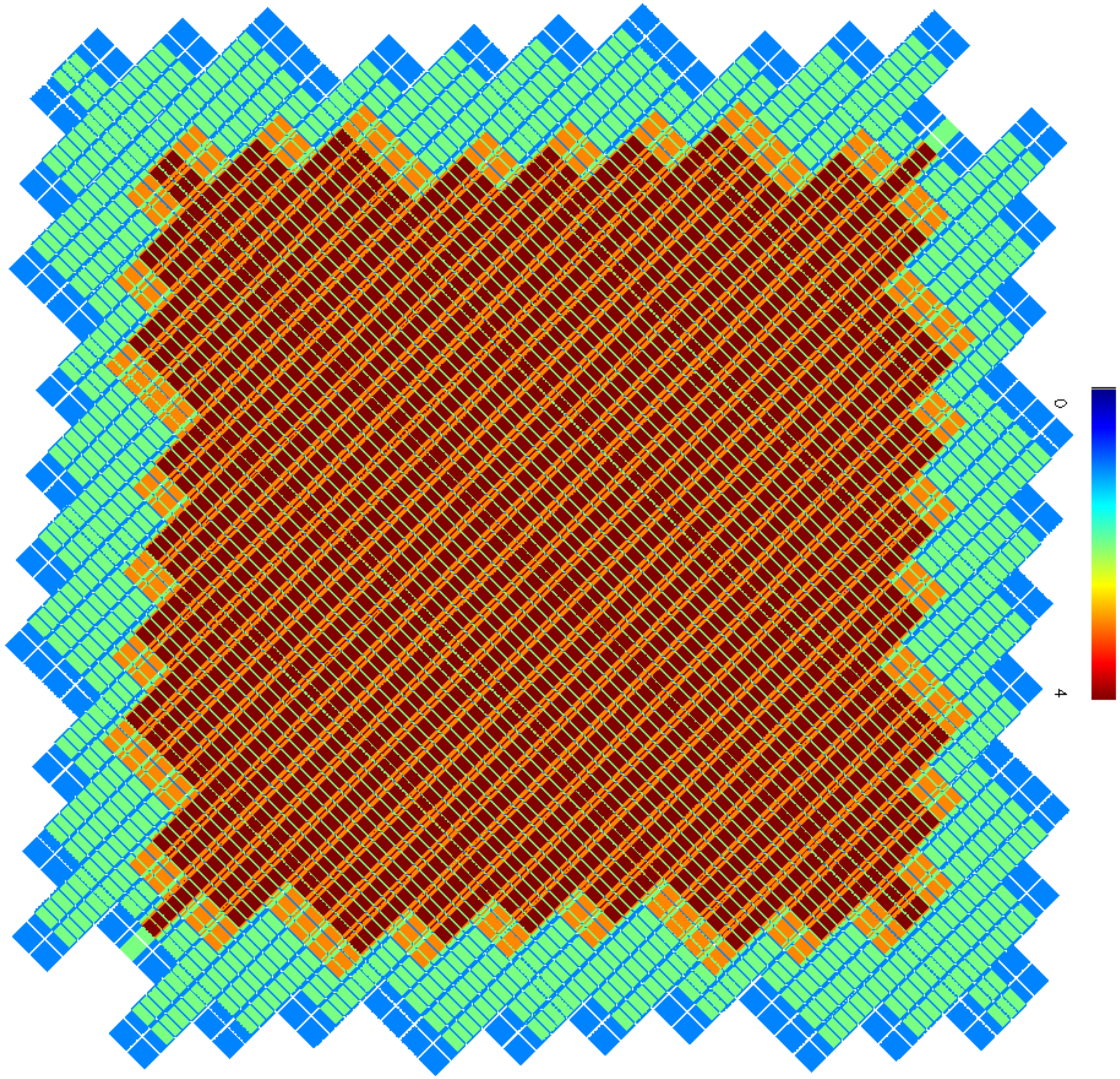


Ω BAO-Only: RFS ImC/SpC Maps

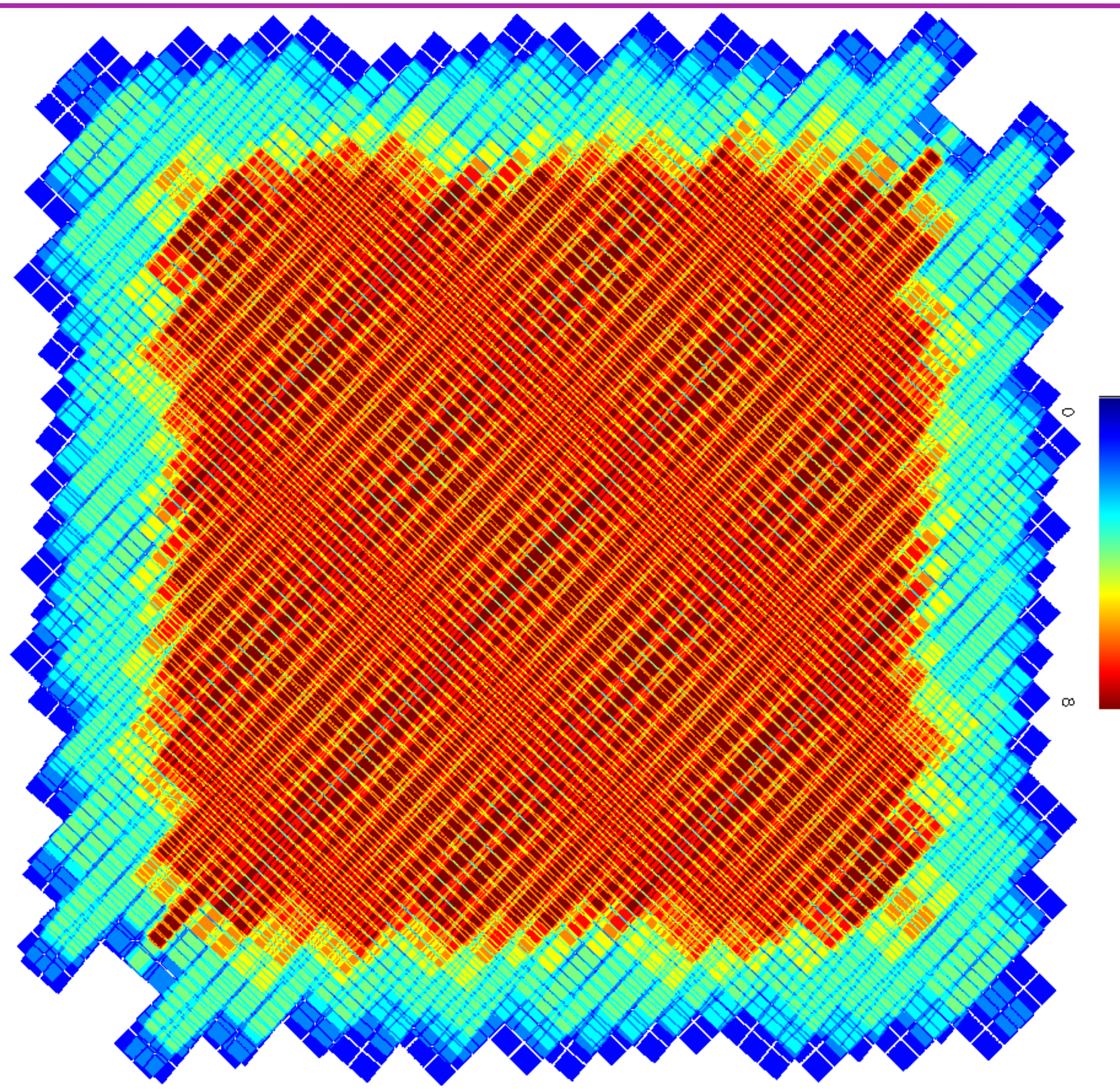


- Pass 1a/b showing mapping of ImC and SpC as would occur in real time;
- Pass 2a/b would be made at a roll angle of 5 degrees relative to Pass 1a/b;
- The two maps together provide the complete RFS sky mapping, as shown in the following simulations;
- Note that the simulations have not optimized the offset of the Pass 1a/b and 2a/b maps.

Ω BAO-Only: RFS SpC Sky Coverage (sim image after 0° roll pass only)



Ω BAO-Only: RFS SpC Sky Coverage (sim image after 0° and 5° roll passes)



Ω BAO-Only: RFS SpC Sky Coverage (sim stats after 0° and 5° roll passes)

N (combined) = # of looks after both roll passes combining SpC-A and SpC-B maps

N(combined)	fraction of sky
2	0.001
3	0.006
4	**0.028**
5	**0.090**
6	**0.220**
7	**0.298**
8	**0.357**

N (A or B) = number of hits broken out by A-side or B-side

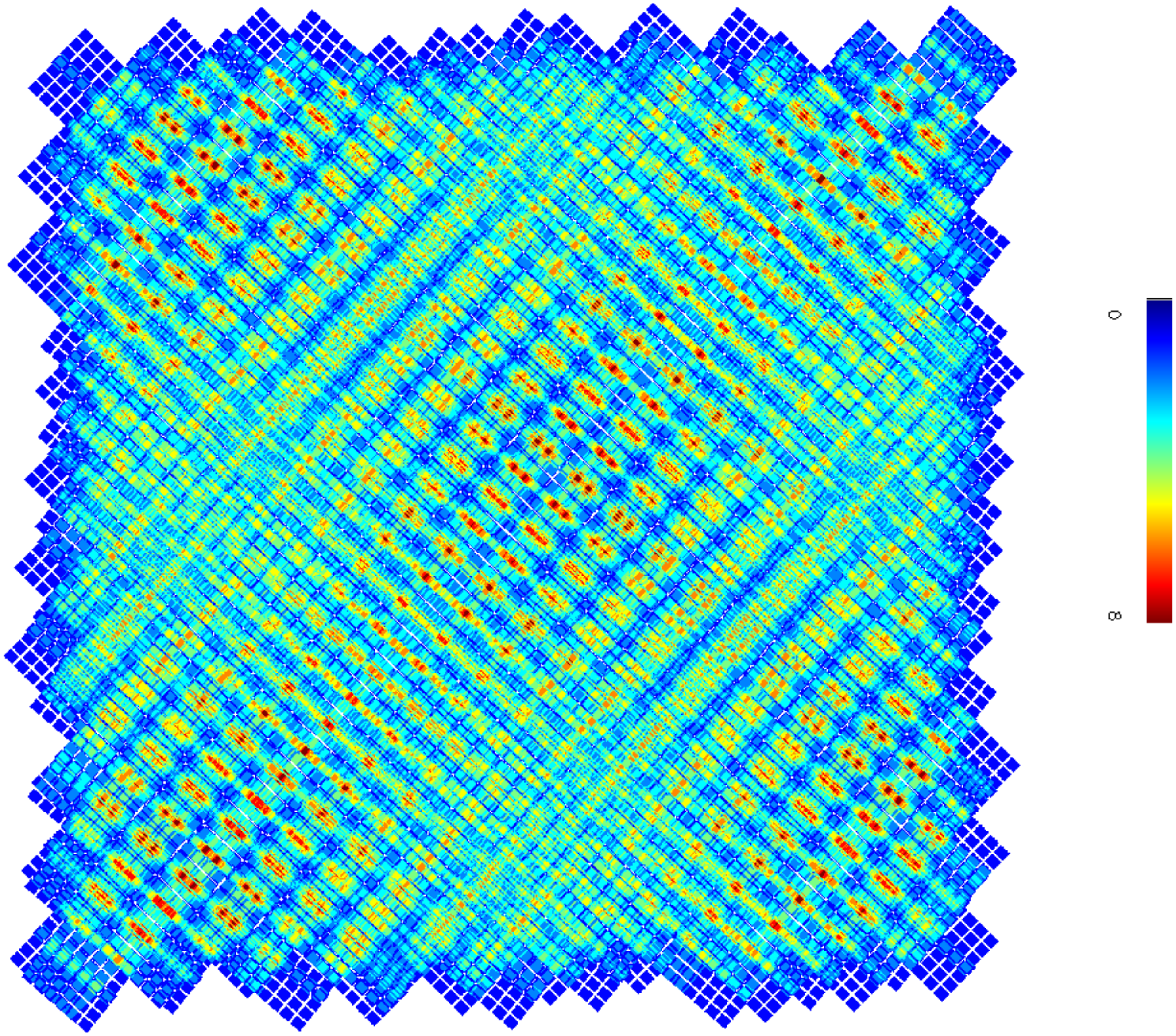
N(A)	N(B)	fraction of sky
1	2	0.003
1	3	0.003
2	1	0.003
2	**2**	**0.022**
2	**3**	**0.045**
2	**4**	**0.018**
3	1	0.003
3	**2**	**0.045**
3	**3**	**0.185**
3	**4**	**0.149**
4	**2**	**0.018**
4	**3**	**0.149**
4	**4**	**0.357**

A+B sides for one roll only

N(combined)	fraction of sky
0	0
1	0.022
2	**0.127**
3	**0.255**
4	**0.596**

N(A)	N(B)	fraction of sky
0	1	0.011
1	0	0.011
1	**1**	**0.127**
1	**2**	**0.127**
2	**1**	**0.128**
2	**2**	**0.596**

Ω BAO-Only: RFS ImC Sky Coverage (sim image after 0° and 5° roll passes)



Ω BAO-Only: RFS ImC Sky Coverage (sim stats after 0° and 5° roll passes)

N= number of hits
r1 = roll 1
r2 = roll 2

N(r1+r2)	fraction of sky
0	**0.010**
1	**0.078**
2	**0.226**
3	**0.301**
4	**0.209**
5	**0.113**
6	**0.050**
7	**0.010**
8	0.003

N(r1)	N(r2)	fraction of sky
0	0	0.010
0	1	0.0394
0	2	0.035
0	3	0.009
0	4	0.006
1	0	0.039
1	1	0.157
1	2	0.141
1	3	0.037
1	4	0.022
2	0	0.035
2	1	0.141
2	2	0.124
2	3	0.034
2	4	0.021
3	0	0.009
3	1	0.037
3	2	0.034
3	3	0.008
3	4	0.005
4	0	0.006
4	1	0.023
4	2	0.021
4	3	0.005
4	4	0.003

<for pass 1a/b only>

N(r1)	fraction of sky
0	0.098
1	0.396
2	0.355
3	0.093
4	0.057

Ω BAO-Only: RFS Coverage Issues and Mitigations

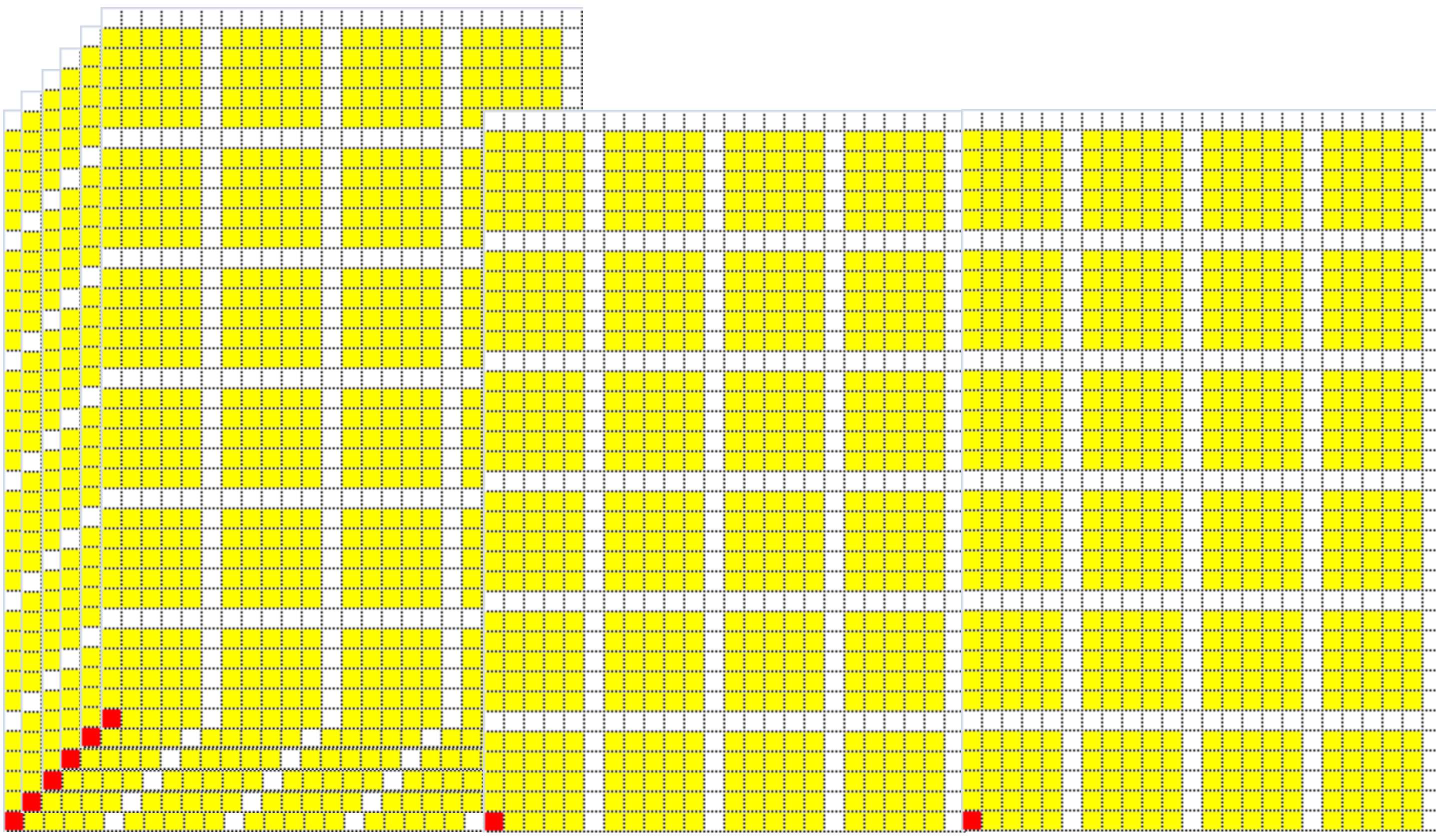
- ImC coverage issues: Areas of sky with one filter view
- Some Possible Mitigations: (still leaves substantial integration time variations)
  - Limit FOV steps to the lesser of the ImC or SpC size in both X and Y;
  - Tighten up the SpC mapping steps (reduce or eliminate SCA gap between FOVs in sims);
  - Provide additional steps/pass (e.g. 1a/b/c/d) w/shorter integration times;
  - Develop designs with more comparable ImC and SpC array footprints;
- SpC coverage issues: substantial variations in integration times and dispersion directions:
- Some Possible Mitigations: (this problem occurs even with optimized SpC RFS mapping)
  - If integration floor not acceptable, raise the integration time per step, or provide more steps/pass;
  - If dispersion direction diversity inadequate, provide more steps/pass?
  - Consider implementation of smooth filled spectroscopic survey FPA layout/ ops, and assess the impact on ImC/SpC sky coverage and rate?

Ω WL(/BAO): ImC Smooth Filled Survey (SFS) Concept

- WL Data Set Rqts (from Ω … needs update)
  - 600s of ImC Integration time in each of three NIR filters;
  - ≥4 random dithers req'd for each filter;
  - {Ph-z training data set and pointing history data set not addressed here}
- BAO Data Set Rqts … see p.5;
- Three 1/5th Smooth Filled Survey (SFS) passes are provided, each with a different ImC filter (and different roll angle for BAO);
  - In a 1/5th ImC SFS, the ImC is moved diagonally in step sizes that are 1/5th of an SCA's diagonal active area;
  - The spacing between SCAs is also 1/5th of an SCA's active area;
  - All SCAs are mapped in parallel. Six diagonal steps provide five looks along the diagonal and four looks everywhere else;
    - 150s per step x4 = the 600s required per filter
    - The 4 looks ensure that 4 random dithers are provided per filter.

Simple 1/5th Smooth Filled Survey (SFS) Mapping

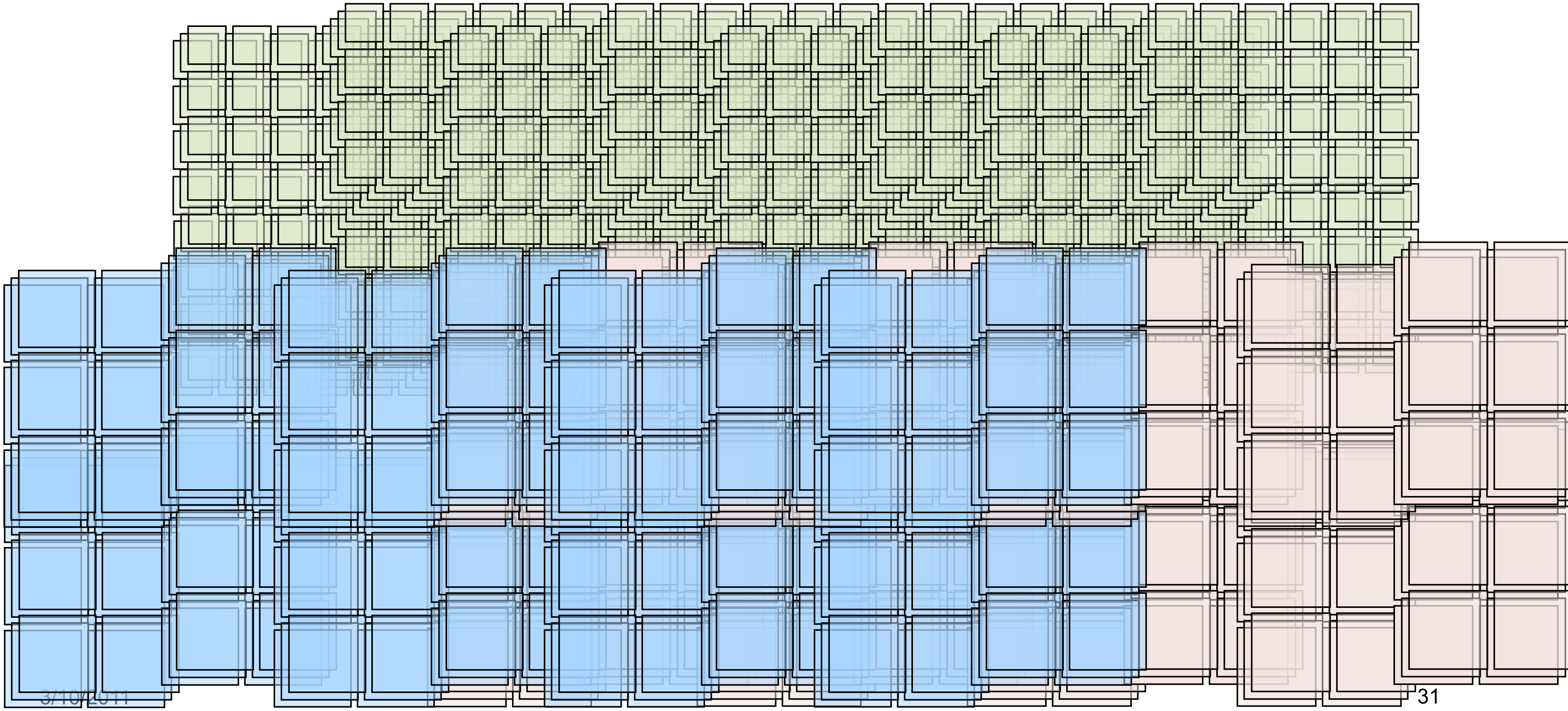
- 6 subcell steps are taken to map one/all SCAs (each SCA 6x6 w/gaps)
- 5 looks acquired on diagonals and 4 looks everywhere else;
- Then move ImC to any position that extends virtual SCA matrix, and repeat;
- Note: ½ FOV move in long ImC direction added to 3rd step (not shown); avoids SpC mapping gaps



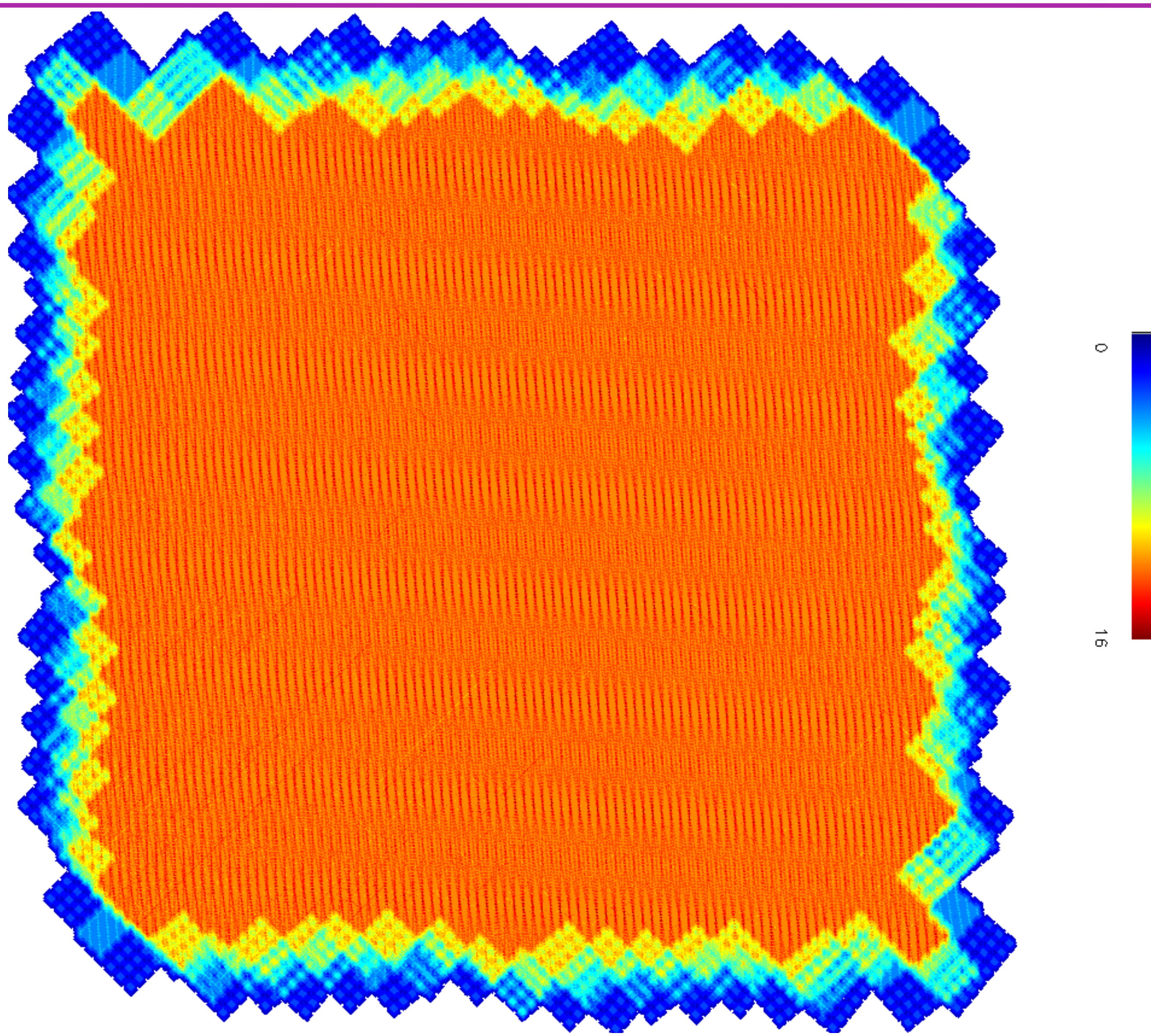
- Large yellow squares are SCAs, shown in 5x5 subcells;
- White squares are subcell-sized gaps between SCAs;
- Smaller size subcells and pointing moves will be required to provide SCA overlap to account for non-ideal pointing, SCA placement and optical distortions (particularly at the FOV step boundaries).

Ω WL(/BAO):
ImC SFS Mapping of ImC and SpC FOVs

- Note the FOV size of the ImC vs SpC SCAs … can't SFS SpC w/ImC;
- Note the ½ FOV move in long ImC direction after three integrations that is input to prevent SFS gaps;
- This pass is one of three, each done at a different roll angle per BAO rqts



Ω WL/BAO: SFS ImC Sky Coverage (sim image after 0° and ±5° roll passes)



Ω WL/BAO: SFS ImC Sky Coverage (sim stats after 0° and ±5° roll passes)

r1, r2, r3 = rolls -5, 0, and +5 degrees for three 1/5th smooth filled survey passes

N (r1+r2+r3) = combined number of ImC looks as a function of sky coverage

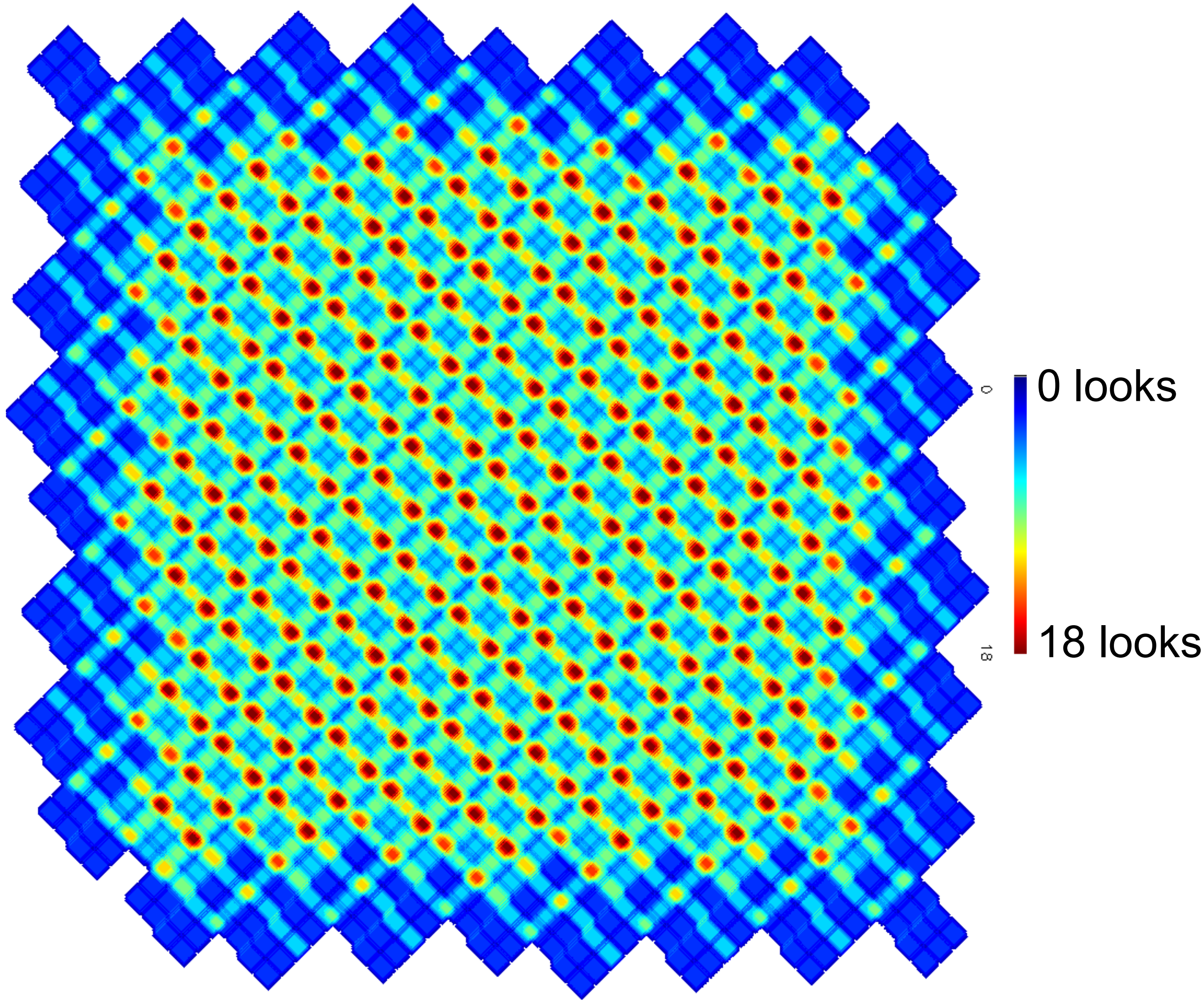
N(r1+r2+r3)	fraction of sky
11	0.004
12	**0.570**
13	**0.357**
14	**0.062**
15	0.008

N(r1)	N(r2)	N(r3)	fraction of sky
3	4	4	0.0011
3	4	5	0.0002
3	5	4	0.0002
4	3	4	0.0012
4	3	5	0.0003
4	4	3	0.0012
4	**4**	**4**	**0.5682**
4	**4**	**5**	**0.1182**
4	5	3	0.0002
4	**5**	**4**	**0.1192**
4	5	5	0.0208
5	3	4	0.0003
5	4	3	0.0003
5	**4**	**4**	**0.1193**
5	4	5	0.0208
5	5	4	0.0206
5	5	5	0.0075

Stats for a single roll pass

N (r1)	fraction of sky
4	**0.8294**
5	**0.1689**

Ω WL/BAO: SFS SpC Sky Coverage (sim image after 0° roll pass)

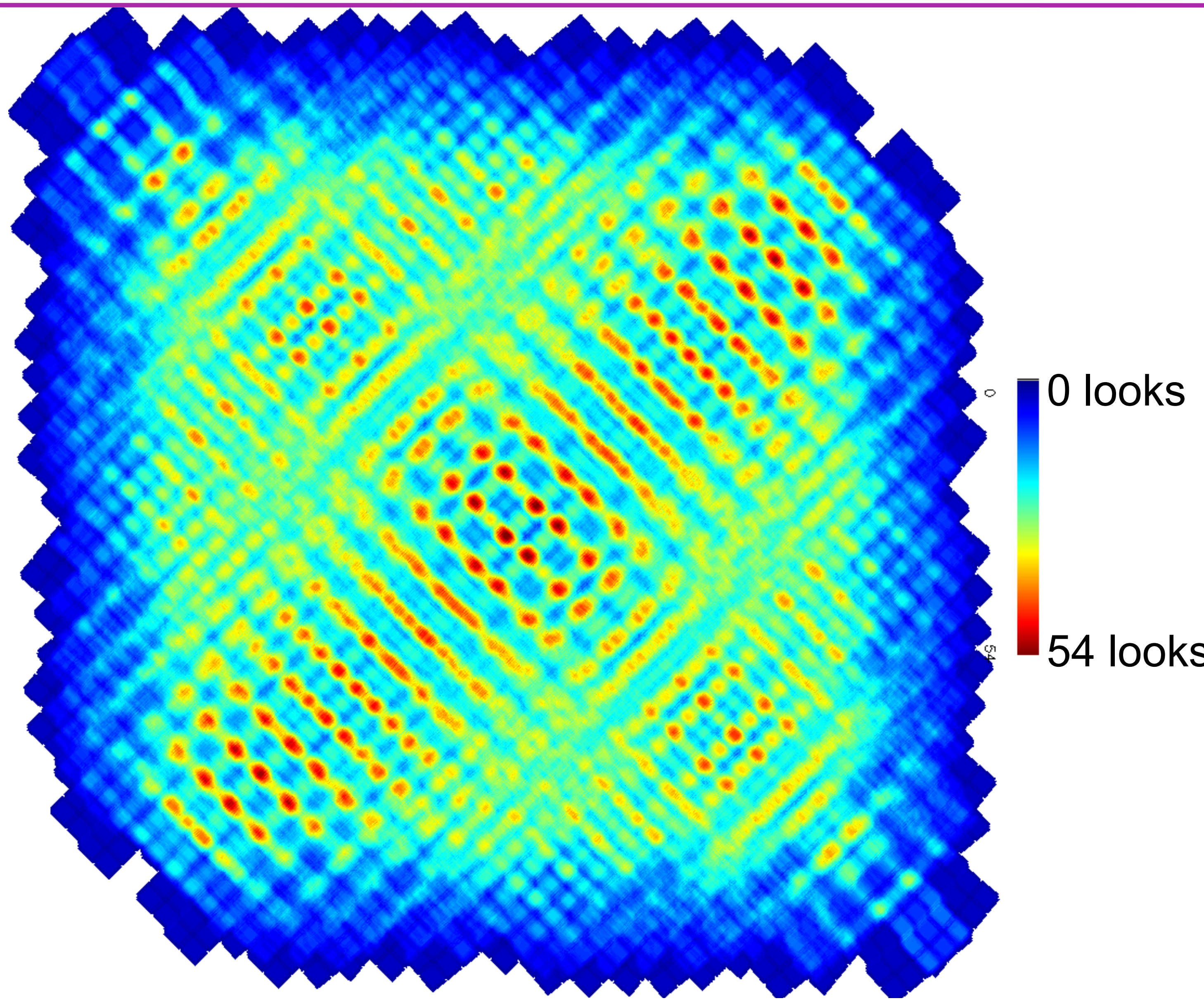


Ω WL/BAO: SFS SpC Sky Coverage (sim stats after 0° roll pass)

N(r1)	Fraction of Sky
3	0.007
4	0.051
5	0.123
6	0.137
7	0.113
8	0.118
9	0.120
10	0.074
11	0.036
12	0.068
13	0.014
14	0.042
15	0.011
16	0.036
17	0.011
18	0.039

Cutoff at 1% sky fraction

Ω WL/BAO: SFS SpC Sky Coverage (sim image after 0° and ±5° roll passes)



Ω WL/BAO: SFS SpC Sky Coverage (sim stats after 0° and ±5° roll passes)

N(r1+r2+r3)	fraction of sky
15	0.0100
16	0.0181
17	0.0271
18	0.0372
19	0.0466
20	0.0549
21	0.0602
22	0.0620
23	0.0615
24	0.0579
25	0.0539
26	0.0526
27	0.0517

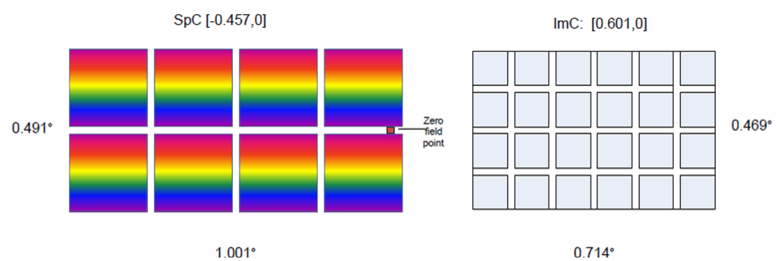
N(r1+r2+r3)	fraction of sky
28	0.0486
29	0.0467
30	0.0433
31	0.0393
32	0.0347
33	0.0313
34	0.0265
35	0.0226
36	0.0194
37	0.0151
38	0.0136
39	0.0108
40	0.0101
41	0.0073
42	0.0077

Cutoff at 1% sky fraction

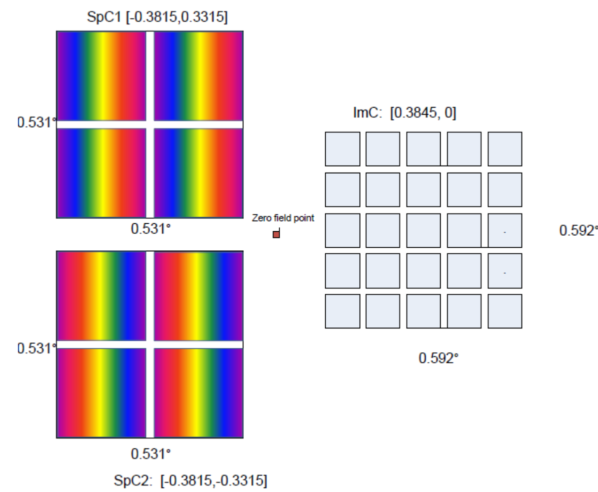
Ω WL/BAO: Coverage Issues and Mitigations

- ImC coverage issues: The coverage looks excellent, but the realities of ImC SCA location errors due to pointing, SCA focal plane placement, and optical distortions will need to be simulated and assessed.
- Some Possible Mitigations:
  - Reduce the gap size between the ImC SCAs, and move SCAs diagonally less than planned for 1/5th survey to provide SCA overlap of subcell coverage.
- SpC coverage issues: given the ~x2 SpC coverage area vs ImC, the three roll passes provided, and the Omega assumption that WL and BAO integration time rqts are comparable, a deep and dispersion-diverse BAO SpC data set is likely (details to be confirmed via sims).
- Some Possible Enhancements:
  - Offset the location of each of the three ImC SFS passes to better distribute SpC integrations times and dispersions.

Off-the-Cuff WL and BAO Mapping Thoughts re: Off-Axis FPA Layout Concepts (per Optics Presentation)



- Nearly equal ratio of ImC and SpC areas, and only one instantaneous dispersion direction, are key differences from Omega, along with improved FOV aspect ratio matching;
- 3 WL passes will only produce 3 different BAO dispersion directions instead of 6 … are 3 enough?;
- To get the opposed dispersion direction will require a 6 month wait, delaying completion of 3-pass WL/BAO mapping, or BAO-only mapping;
- The depth of the BAO SpC survey acquired during WL SFS mapping needs to be assessed since the mapping areas are now closer to equal;
- But closer ImC and SpC aspect ratios should improve ImC coverage during BAO-only mapping.



- Similar dispersion diversity and ImC/SpC area ratio to Omega, but with improved FOV aspect ratio;
- RFS and SFS tiling sims needed to assess different tiling approaches as a function of layout coverage details and integration time (and dispersion direction diversity) requirements

Throughput, stray light, and PSF benefits of off-axis apply to both, of course

MAPPING

BACKUP

Simple Pass Efficiency Comparison (NOT overall observing efficiencies)

- 450s stare plus 40s slew/settle …
- Pass Efficiency = 450/490 = 91.8%

- 225s + 40s + 225s + 40s …
- Pass Efficiency = 225/265 = 84.9%

- 150s + 40s + 150s + 40s + 150s + 40s …
- Pass Efficiency = 150/190 = 78.9%

- Note that this does not consider any risks related to more slewing/settling, does not address how the 40s might change due to slew size or settling accuracy changes, does not consider data rate changes, and does not consider mapping efficiencies (peak-valley of exposures times).

Questions for SDT Meeting 2

March 10, 2011

Requirements Derivation and Simulation/Validation (A, B, C) Flow

SCIENCE QUESTIONS

derivation

SURVEY CATALOG Rqts

Description of sky parameters to be captured after image processing

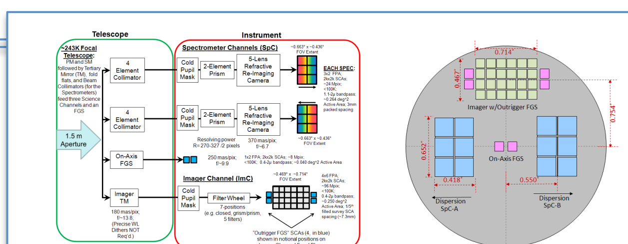
derivation

OBSERVED DATA SET Rqts

Description of images, calibration data, pointing histories, etc. to be produced by mission

derivation

OBSERVATORY SYSTEMS DESIGN AND OPS CONCEPTS



SCIENCE ANSWERS

simulation — A

Verify survey catalog can be analyzed to answer science questions

SURVEY CATALOG

simulation — B

Verify observed data sets can be processed to produce required survey catalog

OBSERVED DATA SETS

simulation — C

Verify Observatory Systems Design and Ops Concepts can transform sky truth into required observed data sets

Data Sets Simulating Sky Truth

Requirements Flow Block Diagram from Decadal Survey JDEM Omega RFI

JDEM Science Objectives

1) JDEM shall determine the cosmic equation of state and its change with time to a factor of at least 10 better than current Stage II experiments
2) JDEM shall determine the cosmic growth of structure to a factor of at least 100 better than current Stage II experiments **(Goal)**
3) JDEM shall perform spectroscopic and multi-band NIR imaging surveys to obtain ≥100 million galaxy redshifts and ≥1 billion galaxy images

BAO Measurement Requirements
- ≥20,000 deg^2 sky coverage (unallocated)
- ≥100 million galaxy redshifts
- Mis-identification rate ≤10%
- Redshift range $0.7<z<2.0$
- Redshift precision, $\sigma_z \leq 0.001(1+z)$
- BAO survey to be within a factor of two of the cosmic variance limit

BAO Data Set Parameters
- Slitless spectroscopy with R_θ=200-240 arcsec
- S/N ≥6.5 for ≥1.6×10^{-16} erg/cm^2-s emission lines at 2.0μm
- Spectroscopic bandpass $1.1 \leq \lambda \leq 2.0$μm for Hα (0.6563 μm) emission line redshifts
- Spectrometer pixel scale ≤0.5 arcsec
- Sys PSF EE50 radius <~0.35 arcsec
- Imaging S/N ≥10 for $H_{AB} \leq 23.5$ to provide redshift zero reference
- 4 dispersion directions required, two of them nearly opposed, to limit source confusion and redshift errors
- Number density $n>2\times10^{-4}$ galaxies / $(h^{-1}\ Mpc)^3$ to provide nP>1 at z = 2

SNe-Ia Measurement Requirements
- ≥~8 deg^2-yr field monitoring (unallocated)
- >~1500 SNe-Ia spectrally typed for redshift $0.2<z<1.3$
- Redshift error σ ≤0.005 per supernova, ≤0.005 bias
- Distance error (from lightcurve) $\sigma_L \leq 0.007$ per Δz=0.1 bin

SNe-Ia Data Set Parameters
- ~150 SNe-Ia per Δz=0.1 bin
- Minimum continuous monitoring time-span for an individual field: 1 yr
- Sampling cadence ≤5 days
- Cross filter color calibration ≤1%
- Five bands, $0.4 \leq \lambda \leq 1.7$μm
- Slitless spectroscopy λ/Δλ ~75 (S/N > 3 per 1nm bin) for redshift and typing
- Peak lightcurve S/N >30 at 25.4 mag
- Low galactic dust, E(B-V) ≤0.02

WL Measurement Requirements
- ≥10,000 deg^2 sky coverage (unallocated)
- ≥1 billion galaxy images
- Effective galaxy density >30/$arcmin^2$, shapes resolved plus photo-zs
- Additive shear error $<3\times10^{-4}$, Multiplicative shear error $<10^{-3}$
- Photo-z error distribution $<0.04(1+z)$, error rate <2%

WL Data Set Parameters
- Imaging noise magnitude >27.3, for each of 3 shape/color filter bands
- S/N ≥25 for galaxies ≤25.5 mag
- PSF second moment uncertainty $(I_{xx} + I_{yy}) < 10^{-3}$
- PSF second moment stability $(I_{xx} + I_{yy}) < 3\times10^{-4}$ over 1 hour
- System PSF EE50 radius <0.15 arcsec in each of 3 shape/color filter bands
- Near Nyquist System PSF sampling
- From Space: 3 shape/color filter bands $\sim 0.85 \leq \lambda \leq 1.7$μm
- From Ground: 4 color filter bands $\sim 0.4 \leq \lambda \leq 0.85$μm
- Spectroscopic training set redshift accuracy $\sigma_z < 0.01(1+z)$

Key JDEM Instrument Design Parameters
- Focal telescope; 1.5m diameter telescope aperture
- ≤243K telescope optical surfaces
- Bandpass 0.4 – 2.0 µm
- Pointing jitter <40 mas rms/axis
- Imager Pointing Knowledge <~4 mas rms/axis, post-processed relative knowledge over an exposure
- Coarse Pointing Accuracy <~3 arcsec rms/axis
- Fine (Relative/Revisit) Pointing Accuracy <~25 mas rms/axis

Imager Channel (ImC): Refractive, w/~180K Pupil Mask
- Effective Area: 0.750 m^2 (average including QE)
- 4x6 HgCdTe 2k x 2k SCAs, 80-100K, 0.18 arcsec/pixel
- 4 Outrigger FGS SCAs accommodated on ImC focal plane
- FOV (active area) = ~0.25 deg^2; Bandpass 0.4 – 2.0 µm
- 5 band filter set on wheel, shared by SNe and WL
- R=75 (2-pix) slitless disperser + "dark" position in same wheel
- System PSF 50% EE radius <~0.12 arcsec
- SCA gaps = 1/5th of active SCA area; enables filled survey

Slitless Spectrometer Channels (SpCs): Refractive
- Effective Area: 0.635m^2 (average including QE)
- 2 counter-dispersed channels provided, w/180K pupil masks
- 2x3 HgCdTe 2kx2k SCAs (per channel), 80-100K, 0.37 arcsec/pixel
- FOV (active area) = ~0.264 deg^2 (per channel) Bandpass 1.1-2.0µm; R (2-pixel) = 270-327
- SCA gaps = 3mm (maximizes fill factor)

Key Operations Design Parameters
- 5-year mission (programmatic constraint)
- Separate SN,WL/BAO-combined and BAO-only Operations
- Science Field of Regard: 80° to 120° off the Sun
- Calibration largely concurrent with observations
- Gimbaled antenna allows observing during downlink
- Slew/settle times 16-38 s (dithers vs ~0.7° slews)

SNe-Ia Field Survey (≥80% Obs. Efficiency; ~8 deg^2-yrs)
- 7 fields (~1.75 deg^2 total, ~95% square) monitored in 5-day cadence assuming 1/5th of each day available for SNe survey
- Total 4800 s of imaging, plus 4800 s for R=75 disperser
- Each filter used once in each 5-day period
- Fields located in low dust regions near ecliptic poles

WL/BAO Survey (≥75% Obs. Efficiency; ~3300 deg^2/yr)
- 600 s of integration provided in each of 3 shape/color bands
- 6x150 s looks per filled survey pass yield ≥4x150 s over field
- Steps between looks are 1/5th of SCA active area diagonal, with ½ Imager tangential FOV steps at middle and end of each filled survey pass
- ~6°x6° "Superfields" (SFs) are fully mapped every ~4 days
- Imager disperser acquires 100,000 galaxy photo-z training set

BAO-only Survey (≥75% Obs. Efficiency; ~6900 deg^2/yr)
- 900 s of Spec integration provided by each of two passes
- 2 x 225 s exposures are provided by each Spec in each pass
- Each pass is rolled relative to the other by ~2°-10°
- Steps are Spectrometer FOV-sized with interleaved smaller SCA gap-filling steps; ~6°x6° SFs are mapped every ~2 days
- Imager FOV gaps are avoided by offsetting the two roll passes

mas = milli-arcsecond

Excerpts from NWNH Report

An exoplanet microlensing program requires continuous monitoring of a few fields containing tens of millions of stars in the galactic bulge for long contiguous periods.

As a strawman example of how the first 5 years of a 10-year mission might be allocated, the panel imagines

- 2+ years dedicated to the cosmic acceleration program. These observations will provide over 8000 sq deg for the BAO survey (grism) and 4000 sq deg for the weak lensing (single band imaging) survey (about half of the JDEM/Omega program), and produce a large multi-band galaxy survey for public archives.2 (The weak lensing/ galaxy survey could be interleaved with about half-a-year's worth of repeated observations of polar fields to monitor high-redshift supernovae.)
- Dedicated microlensing campaigns of 100-days in each of the 5 years could accumulate a significant sample, even within the first few years of the mission.
- A galactic plane survey of one-half year, together with about
- 1 year allocated by open competition, would fill the initial 5 year timeline.

Imaging pixels should be no larger than 0.18-arcseconds. This will critically sample the diffraction-limited point-spread-function at λ = 2.1µm wavelength;

In order to contain the cost and risk of this facility, however, the panel recommends that the architecture of JDEM/Omega be adopted and modified only as is necessary to optimize the two core programs of cosmic acceleration and the microlensing search for planets.

Mindful of the priority of these two programs, planning for the operation of WFIRST should incorporate broader interests, including those of galactic and extragalactic surveys, stellar populations, and diverse GO programs: the panel imagines a newly appointed science working group to address these issues.

The committee considers the GI program to be an essential element of the mission, but firmly believes it should not drive the mission hardware design or implementation cost.

Observing in the near-IR from space offers powerful advantages, especially in the $1 < z < 2$ redshift range where these cosmological measurements are most effective. This includes the better angular resolution for defining galaxy shapes (weak lensing) and the accessiblility of the Hα emission line of hydrogen gas for redshift measurements (BAO) over the maximum volume that can be targeted. Why should WFIRST do all three methods? Supernovas give the best measurements … at low redshift. BAO excels over large volumes at higher redshift. …. Weak lensing makes a complementary measurement through the growth of structure.

Project Office Questions for SDT

- The Project Office has compiled many questions relating to the requirements, design, and operations concept for the mission. Task Team telecons can provide a forum for detailed discussion of these questions.
- Below is a sample of mission parameters we would like feedback on.
- Using the NWNH report and JDEM Omega as the baseline, we would like feedback on the range of parameter values that would be acceptable. When a parameter is contingent on other aspects of performance, we would like indications on that as well.
- It is expected that the perspectives of each observing technique will need to be reconciled across all of the observing techniques.
  - Pixel scale vs. field of view (within a cost-neutral trade).
  - Pointing stability, pointing knowledge, accuracy for revisits to a field, and dither accuracy. In particular, indicate the interplay of pixel scale with dither accuracy.
  - Number of filters required; bandpass of each filter; how much flexibility exists in the choice of filters?
  - Overall bandpass of the telescope and instruments.
  - Absolute PSF stability vs. knowledge of how PSF might be changing. For example: pointing knowledge throughout an exposure vs. actual pointing stability.