Big Dithers are Crucial for LSST Survey Uniformity

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Initial Results for Task CWG-2: "Full-sky Simulations with the Operations Simulator"

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The LSST Operations Simulator

Non-trivial survey design task to cover

20,000 square degrees divided into

2000 pointings, each observed

~150 times in each of 6 filters.

Feasibility shown via Operations Simulator (OpSim) that decides where the telescope should point next and simulates realistic atmospheric and telescope behavior **meta-data** over the full 10-year survey (over 1 million exposures).

Challenge: *OpSim does not resolve LSST pointings, which are circles covering a hexagonal tiling of the sphere.*

Task CWG-2: "Full-sky Simulations with the Operations Simulator"
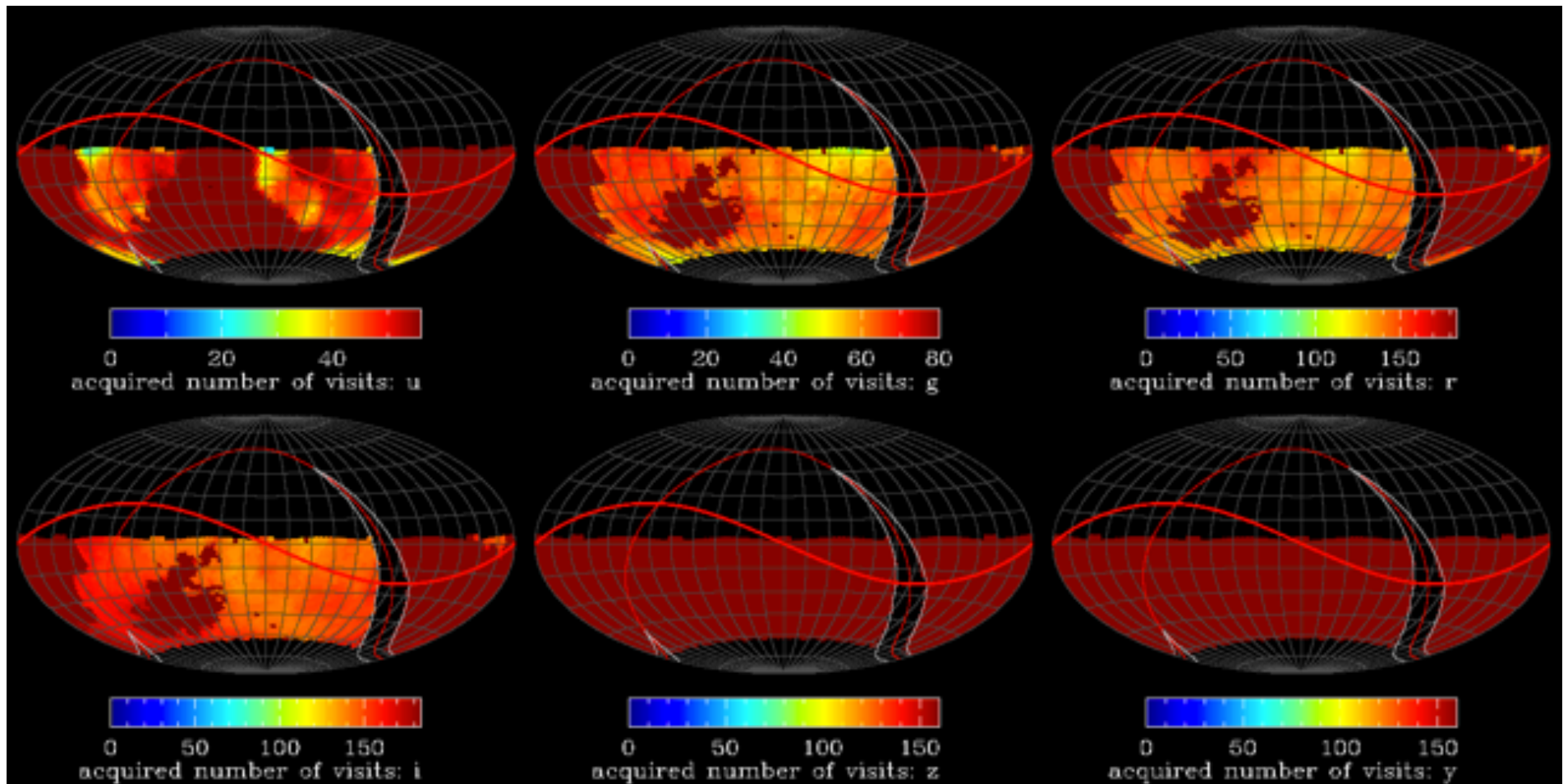

OpSim output shows number of visits ($\approx$depth^2) for
LSST pointings centered on hexagonal tiling of the sky
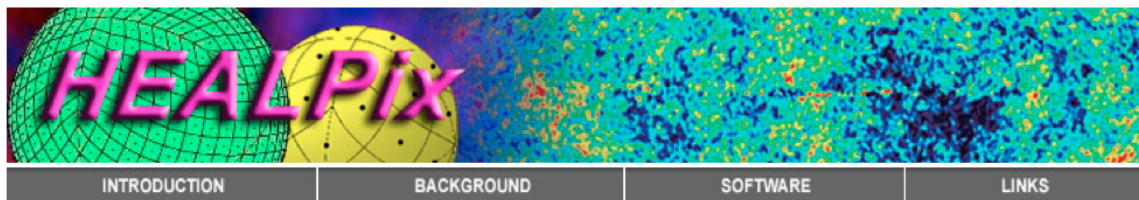
HEALPix is an acronym for **H**ierarchical **E**qual **A**rea iso**L**atitude **Pix**elization of a sphere. As suggested in the name, this pixelization produces a subdivision of a spherical surface in which each pixel covers the same surface area as every other pixel. The figure below shows the partitioning of a sphere at progressively higher resolutions, from left to right. The green sphere represents the lowest resolution possible with the HEALPix base partitioning of the sphere surface into 12 equal sized pixels. The yellow sphere has a HEALPix grid of 48 pixels, the red sphere has 192 pixels, and the blue sphere has a grid of 768 pixels (~7.3 degree resolution).

Another property of the HEALPix grid is that the pixel centers, represented by the black dots, occur on a discrete number of rings of constant latitude, the number of constant-latitude rings is dependent on the resolution of the HEALPix grid. For the green, yellow, red, and blue spheres shown, there are 3, 7, 15, and 31 constant-latitude rings, respectively.
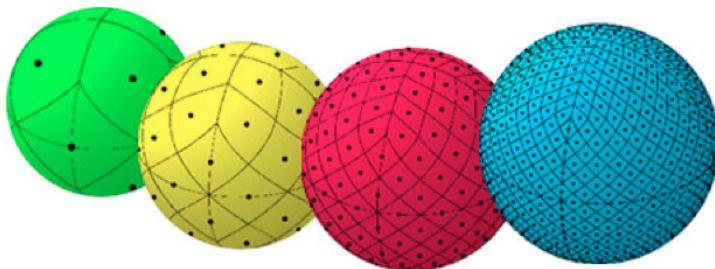
HEALPix turns the sphere into a vector of equal-area pixels ordered by declination. Good for fast spherical harmonic transforms.

We use HEALPix at level 128 with 196608 pixels on the sphere to resolve each ~circular LSST FOV into~50 pixels.
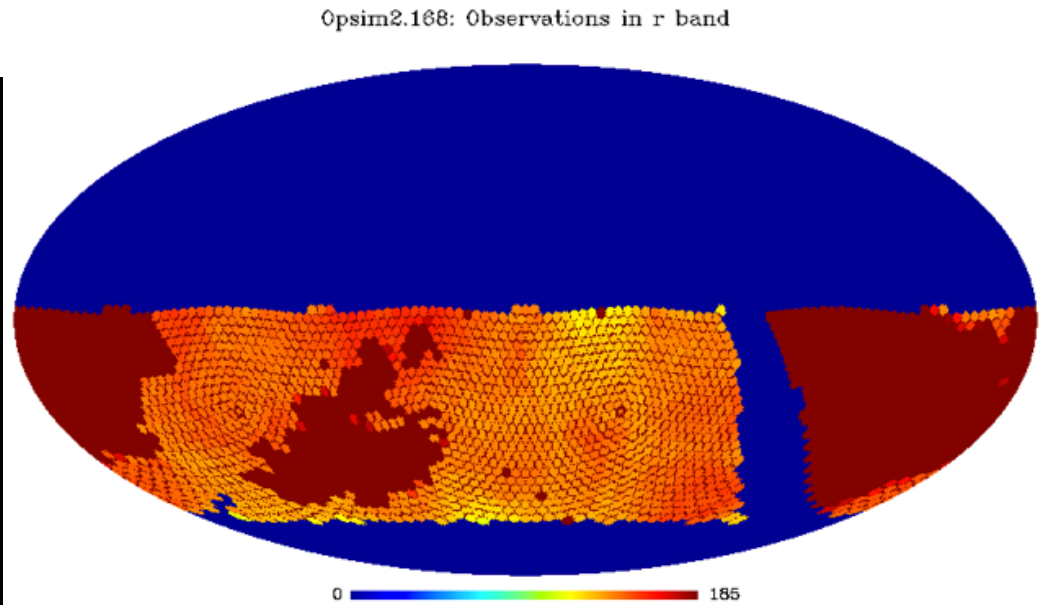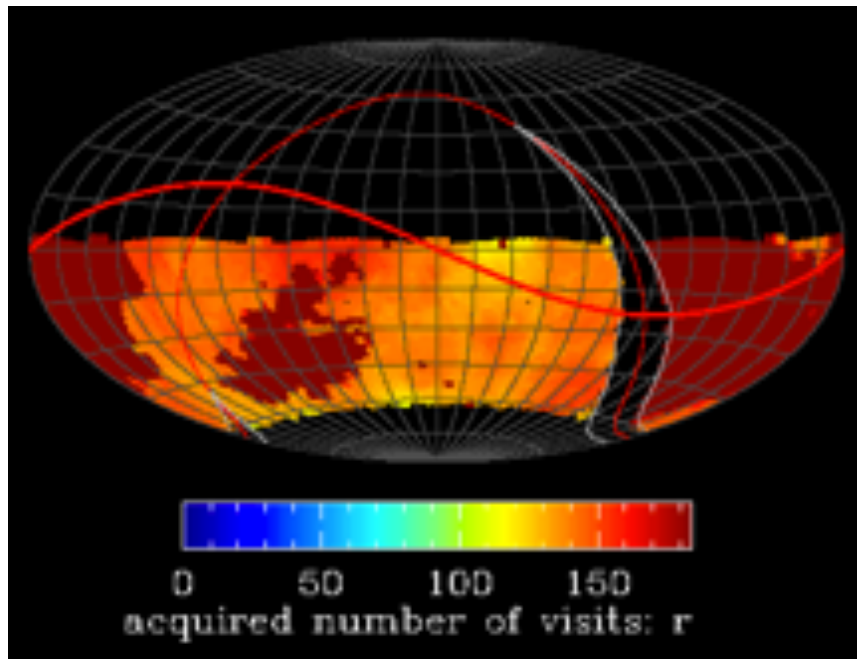
see http://healpix.jpl.nasa.gov/index.shtml, ArXiv:astro-ph/0409513, ArXiv:astro-ph/9905275

# Task CWG-2: "Full-sky Simulations with the Operations Simulator"
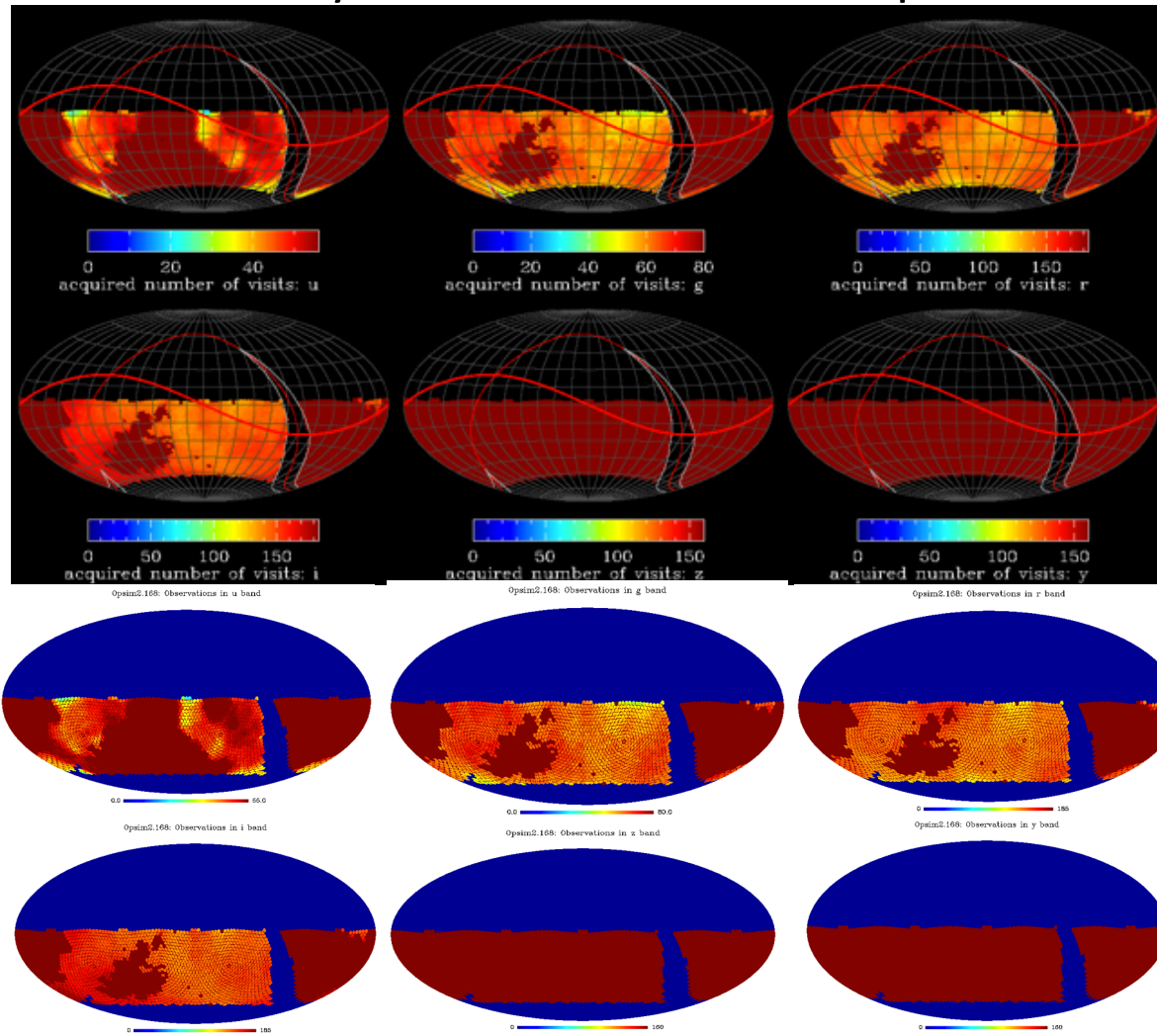
We match this, except for shift from Aitoff to Mollweide projection

Task CWG-2: "Full-sky Simulations with the Operations Simulator"

Opsim2.168: Observations in r band
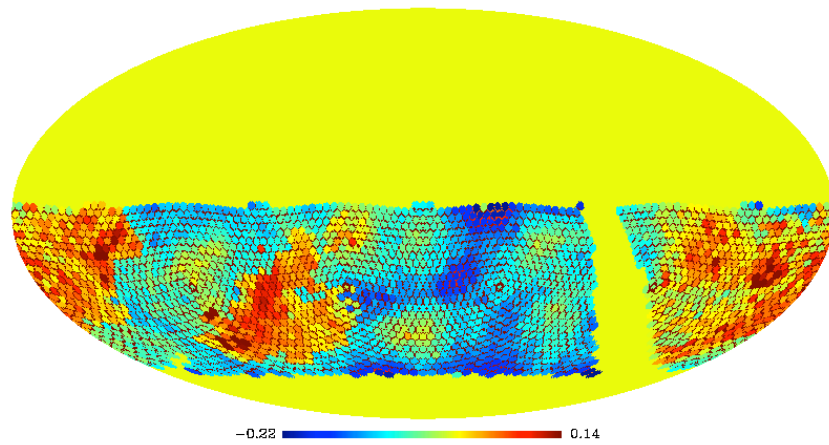
acquired number of visits: r

We match this in detail, but resolving LSST FOV with HEALPIX reveals expected honeycomb pattern of overlapping regions (16% of survey area) that receive double coverage

Opsim2.168: Observations in r band

0 — 185

Delta N / N_ave — 27.500 Cutoff

−0.22 — 0.14
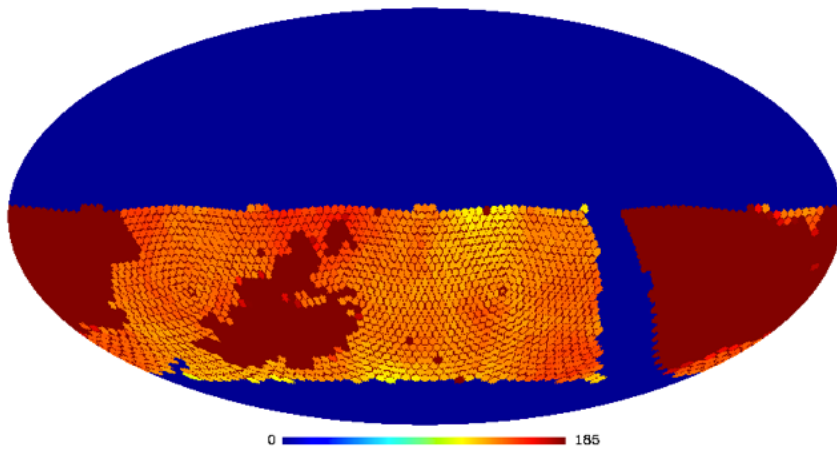
But we don't care about r-band depth!

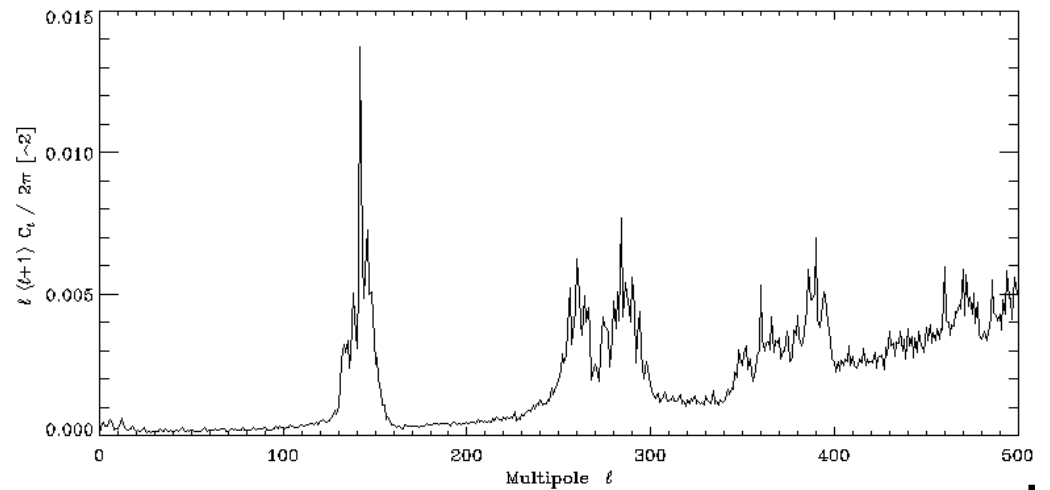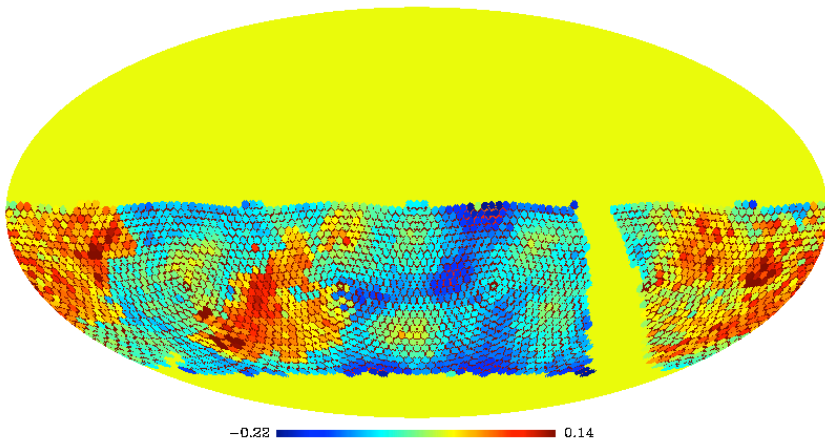Convert it to predicted galaxy δN/<N> i.e. fake large-scale structure (right skymap).

We currently use:

- MUSYC R-band number counts
- Official OpSim 5 sigma point source depths with optimal coadds (much smarter than 2" mag limits but surely imperfect)
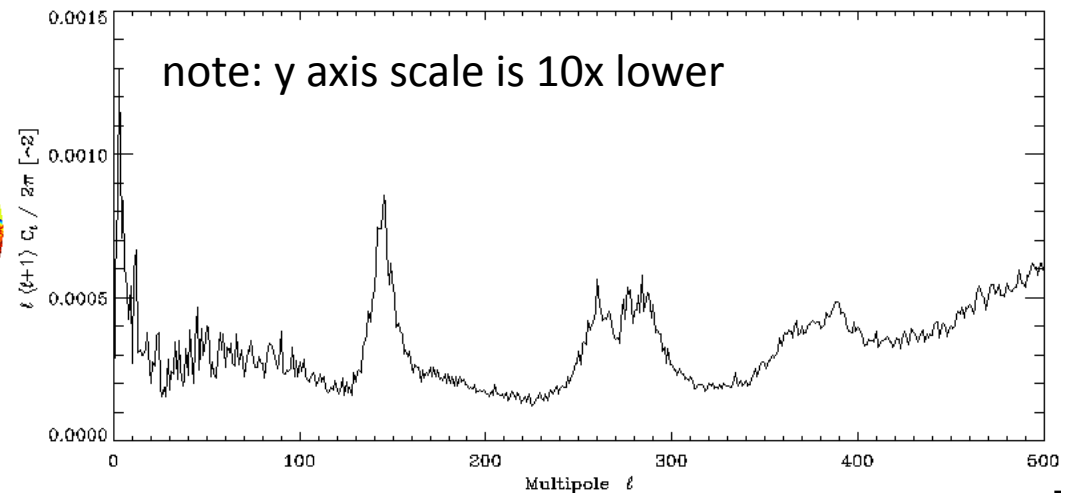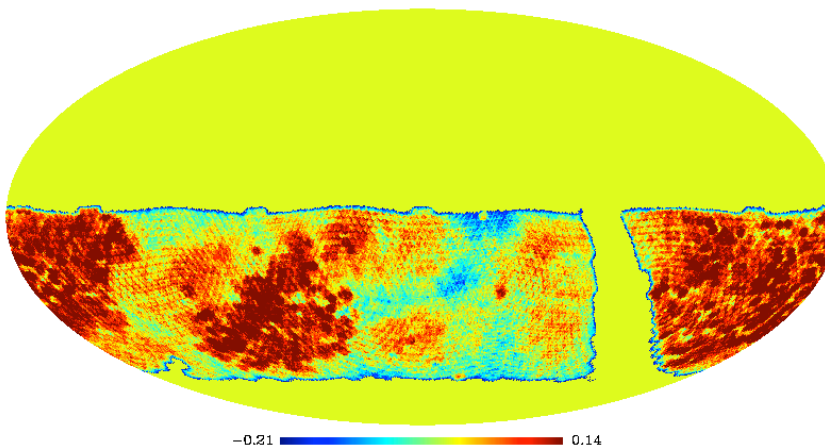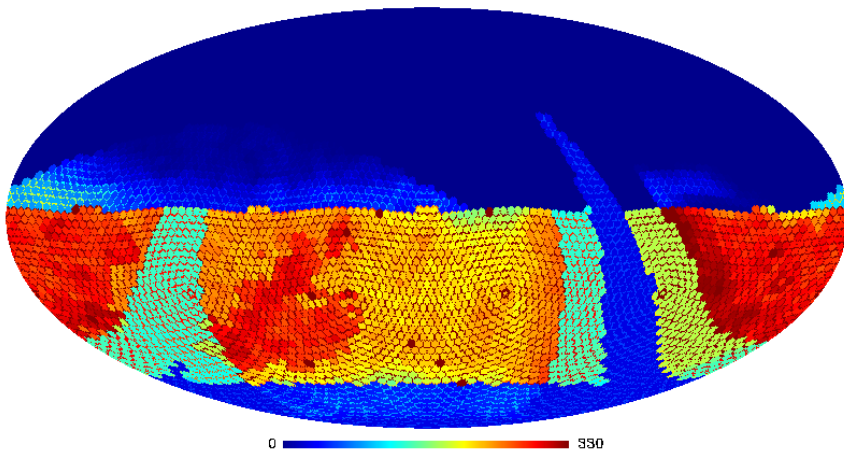- Fleming (1995) formula to model incompleteness & Malmquist bias
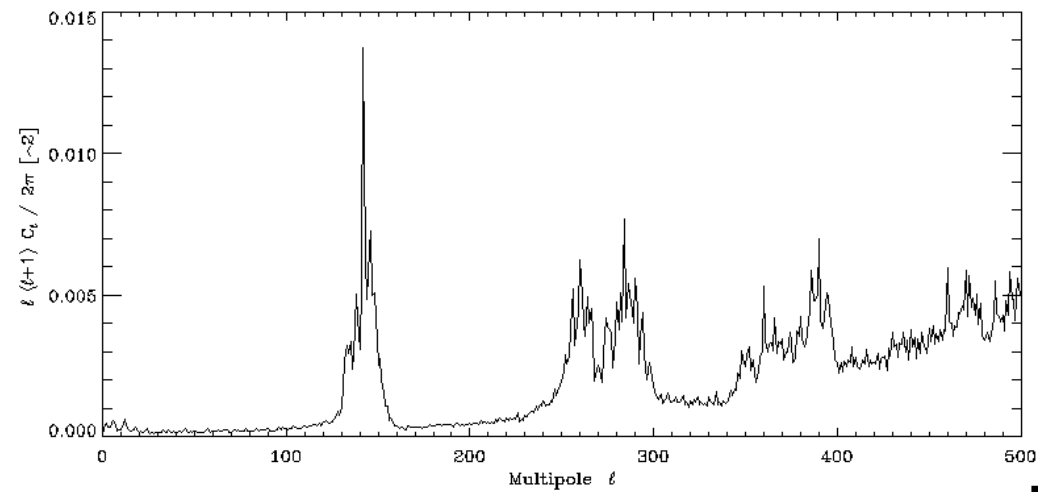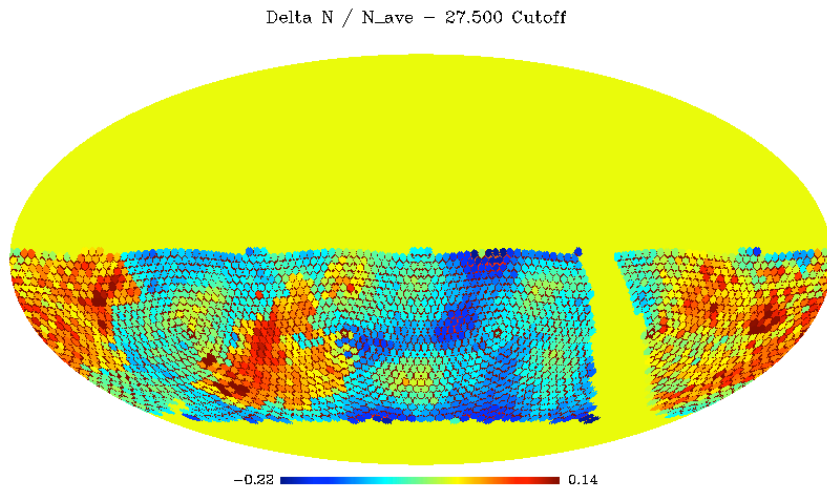
Delta N / N_ave − 27.500 Cutoff

HEALPIX shows the angular power spectrum of δN/<N>. Features at 100<l<300 cause systematic errors in B.A.O. studies of dark energy

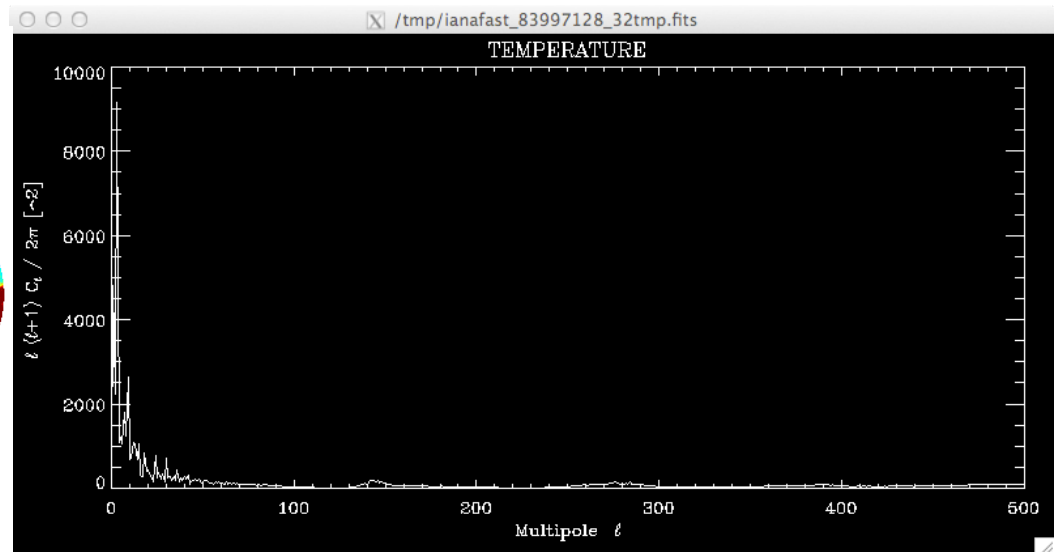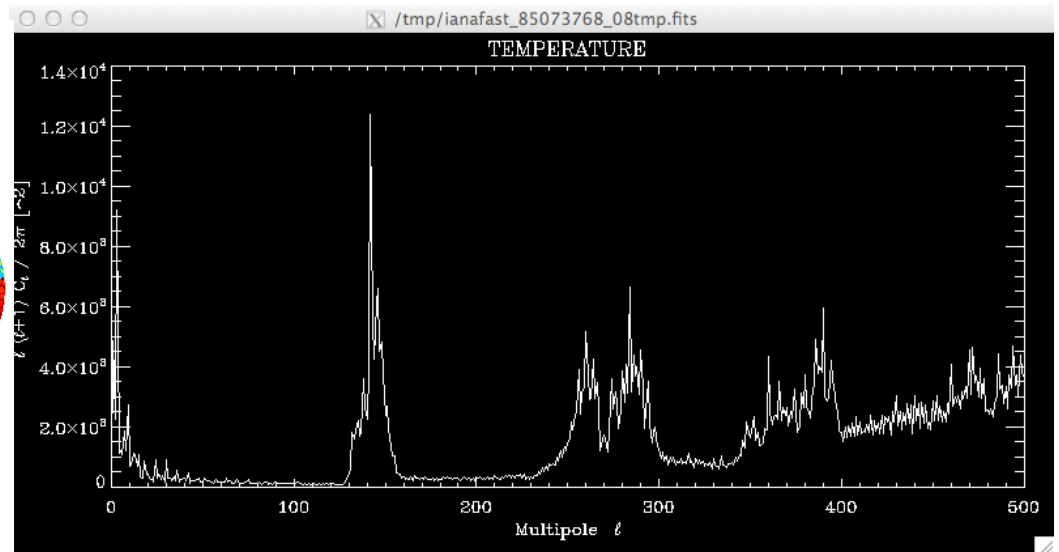HEALPIX shows the angular power spectrum of δN/<N>. Features at 100<l<300 cause systematic errors in B.A.O. studies of dark energy, **but large dithers reduce these by a factor of 10!!!**

Task CWG-2: "Full-sky Simulations with the Operations Simulator"

Now including mini-surveys & better color table, but C_l are just for "Main Survey".
Large (~FOV) dithers produce far more uniform coverage but are not desirable for Deep Drilling Fields.

Status Report on Task CWG-2:
"Full-sky Simulations with the Operations Simulator"

✓Use HEALPIX (at level nside=128) to subdivide each LSST pointing into about 50 sub-pointings, allowing us to track statistics such as number and depth of exposures in overlapping regions betwen pointings. Implement a large-dithering scheme as a post-processing of OpSim.

•Study the cadence of exposure of the overlapping regions to determine if the ~2X improvement causes a significant increase in the number of Type Ia supernovae with sufficient cadence for cosmological studies. As of now, only Deep Drilling Field supernovae are considered acceptable for cosmology. Underway, with David Cinabro & Rahul Biswas.

✓Use the built-in spherical harmonic transform capabilities of HEALPIX to study the angular power spectrum of depth variations and various sources of systematics using the simulated observational metadata (atmospheric conditions etc.) provided by OpSim. This will reveal the level of artificial power on the BAO scale.

•Work (ongoing) with *Jones, Yoachim* and *the OpSim team* to test alterations to the LSST survey to explore a variety of dithering schemes including rotational dithers to determine their effects on LSS systematics at the BAO scale and larger scales.
Bottom line: Big dithers are undesirable for the Deep Drilling Fields but crucial for Main Survey uniformity.