High Galactic Latitude Surveys with a 2.4 m Telescope

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Short Version

October 18, 2012

[Long tables of input assumptions in the long version]

Covered in this summary:

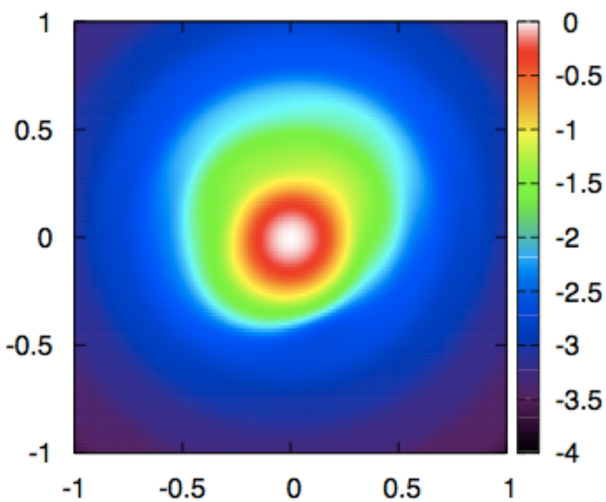
- Basic high Galactic latitude imaging survey parameters
  - Depth, area/time, resolution, etc.
- Weak lensing
  - Traces the growth of cosmic structure using coherent shape distortions of distant galaxies
  - Needs resolved galaxies, extremely well-characterized PSF
  - The main data set is the same as the high latitude imaging survey, but other data is needed (e.g. optical for photo-z; spectroscopic training samples)
- Redshift survey
  - BAO, redshift space distortions …
  - Done by slitless spectroscopy of some line (we use mainly Hα, in some redshift ranges other tracers may be available)
  - Cosmological utility is enhanced if we cover the same areas as the WL, but in a single channel instrument the data are acquired in series

Basic Parameters

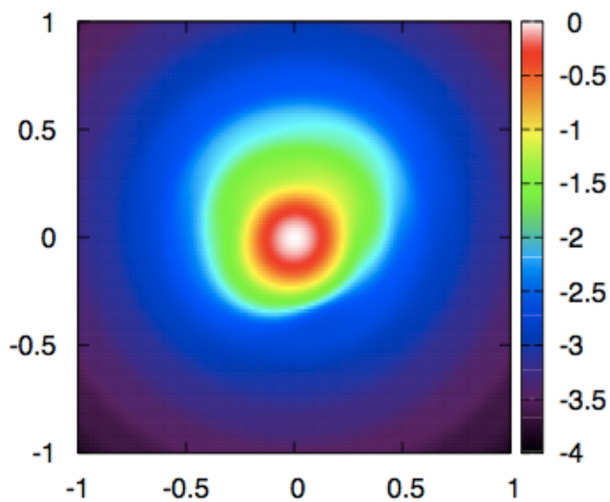
	DRM2	DRM1	DRM0
Collecting area (m^2)	0.91	1.27	3.37
Field of view (deg^2)	0.585	0.375	0.281
Etendue (m^2 deg^2)	0.53	0.48	0.95
N_{pix}	234 M	150 M	301 M
Detectors	14× H4RG	36× H2RG	18× H4RG
Primary mission duration (yr)	3	5	5?
Pixel scale *P* (arcsec)	0.18	0.18	0.11
Critical wavelength $\lambda_c = DP$ (μm)	0.94	1.11	1.24
PSF half light radius in J/H band (arcsec)	0.20/0.22	0.17/0.19	0.13/0.15
Telescope temperature (K)	205	205	250—280

Point spread functions

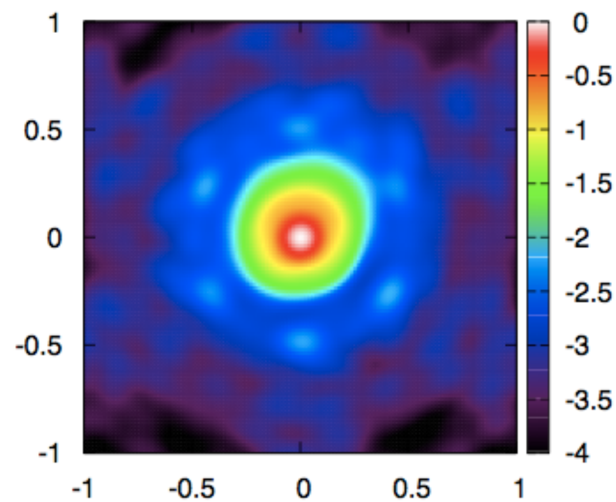
- Wavelength 1.2 μm, monochromatic
- Includes diffraction, pixel response, and jitter
- Aberrations: 71 nm rms wfe, equally distributed in focus, astigmatism, coma
    - This is a toy model based on the wfe budget, but a reasonable 1st pass for the core of the PSF
- Postage stamps are 2×2 arcsec
- Color scale is $\log_{10}$(intensity)



DRM2



DRM1



DRM0

PSF half light radius, r_{eff}

Units are arcsec

	DRM2	DRM1	DRM0
Z	0.174	0.148	0.111
Y	0.181	0.154	0.120
J	0.195	0.166	0.134
H	0.218	0.185	0.150
K [K_s]	0.252	0.214	[0.165]

DRM0 is 1.5—1.6x better than DRM2, and 1.2—1.3x better than DRM1.

Similar results for area-based measures of PSF size, but the measures based on astrometric centroiding are up to ~1.9x better for DRM0 than DRM2 in H band (where one can start to separate the central peak from the 1st diffraction ring). More details in the “long version”.

Survey Rates

- Compare DRM0 surveys under several assumptions:
  A. Assume the same point source depth as DRM2 (25.93/25.92/25.95/25.82 in YJHK). What is the survey rate?
  B. Assume the same extended source depth (i.e. for $r_{gal} >> r_{psf}$) as DRM2. What is the survey rate?
     - Takes longer than [A] because point sources gain from reduced background at higher resolution but extended sources do not.
  C. Assume the same exposure time as DRM2 (247 s). How much deeper/slower?
- The 250 K telescope calculation has a K_s band (λ_{max} = 2.15 μm) instead of K, the 280 K calculation drops this entirely.
- This provides the envelope of possible DRM0 surveys. We can select among these cases, interpolate, etc. later.

Results at T_{tel} = 250 K (imaging)

	Case A	Case B	Case C
Y	5 x 94 s **25.93**	5 x 131 s **26.39**	5 x 247 s **27.10**
J	6 x 84 s **25.92**	6 x 115 s **26.37**	6 x 205 s **27.02**
H	5 x 94 s **25.95**	5 x 131 s **26.40**	5 x 247 s **27.07**
K_s	5 x 147 s **25.82**	5 x 246 s **26.33**	5 x 247 s **26.33**
Time (days per 1000 deg^2)	**128** [87 without K_s]	**178** [113 without K_s]	**260** [195 without K_s]

- Table shows exposure times and depth (5σ pt src, AB mag)
- DRM2 uses **126** days per 1000 deg^2 (would be 94 days without K filter)
- Assumed a "K_s" filter at 1.83—2.15 μm in place of DRM1/2 K filter.

Results at T_{tel} = 280 K (imaging)

	Case A	Case B	Case C
Y	5 x 94 s **25.93**	5 x 131 s **26.39**	5 x 247 s **27.10**
J	6 x 84 s **25.92**	6 x 115 s **26.37**	6 x 205 s **27.02**
H	5 x 100 s **25.95**	5 x 152 s **26.40**	5 x 247 s **26.82**
Time (days per 1000 deg^2)	**88**	**118**	**195**

- Table shows exposure times and depth (5σ pt src, AB mag)
- DRM2 uses **126** days per 1000 deg^2 (would be 94 days without K filter)
- K/K_s filter deleted at this temperature – the thermal emission is nontrivial even in H band.

Weak Lensing Performance

		DRM2	DRM1	DRM0 (250 K)			DRM0 (280 K)		
Case				A	B	C	A	B	C
n_{eff} [gal / arcmin^2]	J	24	31	25	34	63	25	34	63
	H	27	33	31	46	70	31	46	62
	K or K_s	24	32	31	46	46	N/A	N/A	N/A
Time [days / 1k deg^2]		**126**	**131**	**128**	**178**	**260**	**88**	**118**	**195**

- The time includes the Y band imaging (for photo-z).
- This is still based on the COSMOS catalog. DRM0 Case C may suffer incompleteness and there will be a modest increase.
  - This is a somewhat nontrivial exercise to do right – a job for the SDT.

Key Issues:

*The WL-only constraints on DE parameters usually scale most strongly with the total number of galaxies – **if** the systematic errors are under control.*

The high-n_{eff} regime may open up new opportunities, e.g. in weighing high-z clusters – need to explore this quantitatively.

Hα Redshift Survey Performance

Mission	Exposure time	λ range [μm]	$z_{H\alpha}$ range	Time required [days / 1k deg^2]	Galaxies [gal/deg^2]	Galaxy survey rate [gal/yr]	nP @ 0.2h/Mpc	
							z = 1.6	z = 2.0
DRM2	6 x 567 s	1.70—2.40	1.59—2.66	83	2480	11 M	0.73	0.87
DRM1	6 x 530 s	1.50—2.40	1.28—2.66	127	4040	12 M	1.18	1.01
DRM0 (280 K PM/SM)	6 x 567 s	1.30—1.97	0.98—2.00	180	6080	12 M	2.09	1.80
	6 x 247 s	1.30—1.97	0.98—2.00	83	1970	9 M	0.68	0.60
	6 x 567 s	1.30—1.85	0.98—1.82	180	9550	19 M	3.94	
	6 x 247 s	1.30—1.85	0.98—1.82	83	3310	15 M	1.37	
DRM0 (250 K PM/SM)	6 x 567 s	1.50—2.10	1.28—2.20	180	10100	20 M	4.13	3.52
	6 x 247 s	1.50—2.10	1.28—2.20	83	3540	16 M	1.44	1.25
	6 x 567 s	1.30—2.00	0.98—2.05	180	12230	25 M	4.12	3.51
	6 x 247 s	1.30—2.00	0.98—2.05	83	4260	19 M	1.43	1.24

Comments on Redshift Survey

- What happens to drivers of WFIRST redshift survey?
  - [✗] Redshift range – lower than DRM1/2, more similar to Euclid
  - [✓] Data quality (e.g. filling gaps, multiple exposures) – similar to DRM1/2
  - [✓+] Survey density – somewhat better than DRM1/2 at fixed survey rate
  - Area was not the driver – wide/shallow survey to be done with a combination of Euclid + ground based assets. A 2.4 m telescope with a single focal length and reasonable sampling will not change this.
- Does not make sense to push into the thermal background.
  - In slitless mode, this impacts the entire volume – see e.g. 280 K, z=2 case.
- Need to understand how this ultimately propagates through to the science.
  - Fisher forecasts for cosmological parameters
  - Discovery space for high-nP surveys

Conclusions

- The 2.4 m option (DRM0) offers improvements over DRM1/2 in survey depth and angular resolution. These translate into gains in WL and redshift surveys.
  - But improvement is not nearly as good as the "textbook" scaling laws, e.g. PSF is not 2.4/(1.1 or 1.3) smaller.
  - 250 K telescope requires us to shorten λ, z range relative to DRM1/2; at 280 K we would stop at H band (red cutoff ~1.91 μm).
- The fast imaging surveys benefit only marginally from DRM0.
  - This is due to read noise in short exposures (remember: zodi flux ~ 0.3 e/p/s; 5.2 s per frame). Might consider e.g. 64 channel readout if these surveys are a priority.
- This is only a preliminary look at 2.4 m surveys.
  - We are one step beyond CAA and Princeton presentations, but lots of work to do before reaching DRM1/2 level of maturity.
  - Need to go back and make assumptions consistent with the current design, do simulations, coordinate with other science programs …