Science White Paper for LSST Deep-Drilling Field Observations
Using LSST Deep Drilling Fields to Improve Weak Lensing Measurements

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1 Science Goals

1.1 Concise List of Main Science Goals

1. Determining redshift distributions for main-survey galaxy samples, via higher-quality photometric redshifts and improved calibrations

2. Measuring galaxy number counts down to fainter limits than the main survey, critical for determining the effects of cosmic magnification

3. Testing shear measurement systematics

4. Improving measurements of the intrinsic size distribution of galaxies

5. Constraining the effect of intrinsic alignments on weak lensing measurements

1.2 Details of Main Science Goals

1.2.1 Determining Galaxy Redshift Distributions

Obtaining accurate and unbiased photometric redshifts (photo-z’s) will be important for a wide variety of LSST science, and is crucial for weak lensing studies. Other white papers are examining the improvements in photo-z measurements that can result from deeper photometry, particularly in $uzy$ (e.g. Gawiser et al. 2011). While this is very important for weak lensing, and we urge serious consideration of those conclusions, in order to avoid duplication we have focused instead on a different question: how well we can calibrate redshift distributions for the LSST main survey using only data in the deep drilling fields (DDFs).

The DDFs will yield higher-quality photo-z’s than can be obtained for the main LSST sample, due both to reduced measurement errors in flux measurements ($uzy$ bands in particular) and to the complementary spectroscopy and multi-wavelength imaging that will be available (see Gawiser et al. 2011 and Ferguson 2011 for details). These fields will serve as an ideal test bed for photo-z calibration and the investigation of systematics. Assuming we can mitigate these systematics, the uncertainty in main survey galaxy photometric redshifts will be set by the limited magnitude information available; DDF measurements could bring us to this statistical error floor, but not beyond.
The first task weak lensing science demands from photo-z’s is the ability to separate galaxies into several bins with largely non-overlapping redshift distributions. Division into only a few bins is sufficient to capture most of the cosmological information (Hu 1999). Improved photometric redshift algorithms can help to clean this selection up. The smaller photo-z errors are, the narrower the tomographic bins we can construct; and the narrower those bins are, the smaller the calibration error in e.g. $<z>$ will be. Being able to construct narrow bins is not absolutely necessary to the success of LSST.

However, accurately interpreting the measured weak lensing signal from each bin requires a very accurate determination of its redshift distribution; e.g., the mean $z$ must be known to $\sim 0.003(f_{\text{sky}}/0.025)^{-1/2}$ (Huterer et al. 2006), where $f_{\text{sky}}$ is the fraction of the sky the survey covers. It will be infeasible to determine these distributions directly via spectroscopic followup; even at $i \sim 22.5$, existing redshift samples are 30–60% incomplete, and this should only be worse at the LSST gold sample depth of $i = 25.3$. One option is to exploit large-scale-structure cross-correlations between objects in a photo-z bin and the bright objects in spectroscopic samples to reconstruct the actual redshift distribution in the photo-z bin (Newman 2008); another is to exploit bin-to-bin cross-correlations and baryonic acoustic oscillation measurements, which provides information on the redshifts and degree of overlap between bins (Zhan 2006).

In this white paper, we consider an alternative technique. Due to both the greater LSST imaging depth and the greater availability of multi-wavelength imaging, objects in a given galaxy sample in the DDFs will have much better-determined photometric redshifts than their counterparts in the main LSST survey. We can then use the distribution of the DDF photometric redshifts to estimate the true redshift distribution of the corresponding objects in the full survey. This substitution is complicated by sample variance: the fact that at any particular redshift, each field may be overdense or underdense (in dark matter and in galaxies) compared to the Universe as a whole. This effect is minimal when taking the LSST survey as a whole, but can be substantial in any given field. For instance, the publicly available QUICKCV code (Newman & Davis 2002) predicts that, for a typical sample of objects with correlation length $r_0 = 4h^{-1}\text{Mpc}$ comoving, the abundance of objects in a $\Delta z=0.1$ bin centered at $z = 1$ will vary by 5.7% from one deep drilling field to another; while there will be 13% fluctuations in the abundances of objects for a $\Delta z=0.01$ wide bin. These fluctuations from sample variance will modulate the redshift distribution inferred using objects in the DDFs alone.

It may well be possible to mitigate these effects by using the observed small-$\Delta z$ variations in the redshift distributions of spectroscopic samples in the DDFs to correct for sample variance on small-$\Delta z$ scales (Newman 2008), and by using differences in the photo-z distribution between the DDFs and the full survey to correct for the differences on larger scales. Here, we conservatively assume that this will not be possible, and hence any sample variance within the DDFs will result in a corresponding error in the reconstructed redshift distribution of a photometric sample. In that case, the effects of sample variance will be mitigated by covering a larger area with the DDFs (i.e., observing a larger number of fields). This driver will compete with the desirability of obtaining greater-depth data, which would enable a variety of new science compared to the main survey and improve the DDF photo-z’s used to estimate redshift distributions. Hence, a detailed optimization is required if we decide to utilize the DDF photo-z’s to estimate redshift distributions; we present a first analysis here.

In outline, a method we would use to determine redshift distributions by substituting DDF information for the main survey is:
1. Derive photometric redshifts for all objects in the main survey.

2. Using only a number of exposures equivalent to the main survey depth, derive DDF galaxy photo-z’s.

3. Bin galaxies in both samples according to their photo-z’s. Since we have done this using comparable data, there should be few, if any, systematic differences between the main survey sample and the DDF equivalent.

4. Calculate DDF galaxy photo-z’s using all the exposures and multi-wavelength information.

5. Use these higher quality photo-z’s to determine the true galaxy redshift distribution for each DDF redshift bin from step 3.

6. Use the galaxy redshift distributions derived from the DDFs as a substitute for the redshift distributions of the corresponding main survey samples.

If we require the degradation of weak lensing dark energy constraints due to uncertainties in the redshift distribution to be smaller than 50%, the uncertainty in the amplitude of the redshift distribution in any given $\Delta z = 0.1$ bin in $z$ will need to be smaller than $\sim 0.5\%$ (based on the methods presented in Ma et al. 2006). For a DDF substitution scheme to be sufficient for calculating LSST photometric redshifts, the sampling errors (including both shot noise and sample variance) in the redshift distribution must be below this level. Figure 1 shows the dependence of galaxy redshift distribution sampling error on the total DDF sky area, for each of five weak lensing tomography bins evenly spaced between redshifts 0 and 3. To achieve half percent-level errors in all bins, the DDFs must cover $\sim 1000 \text{deg}^2$ (see also Van Waerbeke et al. 2006 for comparable estimates). Covering an area so large would seriously compromise the DDF depth, which both this calibration and much other science depends on; in such a scenario, the exposure time for each DDF could be at most $\sim 2\times$ that in a main survey field.

However, the lowest redshift bin stands out as having the largest sampling error, primarily because it encloses the smallest comoving volume (and hence contains the smallest number of $\sim$-independent subvolumes). If we disregard that bin (which should be the easiest to calibrate via techniques such as cross-correlation or more conventional methods due to the availability of large, wide-area low-z surveys), the necessary level of accuracy can be achieved with $\sim 200 \text{deg}^2$ of DDF coverage. We emphasize that this prediction is conservative; if we can use the observed fluctuations in spectroscopic samples and the differences in photo-z distributions between the DDFs and main survey to account for the effects of sample variance, we will be limited only by the shot noise, which is negligible by comparison.

If we compensate for the effects of sample variance when performing the redshift distribution substitution, good results can be achieved with much less area devoted to DDFs, while DDF-based calibrations may actually be improved by reducing the number of deep-drilling fields (as this will increase depth and decrease the impact of photometric redshift errors). In either case, the gain obtainable by performing this substitution depends on the degree to which photo-z’s in the DDFs are improved compared to the main survey. We will provide more concrete predictions when detailed deep drilling photo-z quality simulations are completed.
Figure 1: Dependence of the sampling error for LSST main-survey-like samples on the total sky area surveyed in Deep Drilling Fields. If this error is small, we can use redshift distributions determined from high-quality photometric redshifts in the DDFs as a direct proxy for the true redshift distribution of the main survey sample, without loss of cosmological constraining power. In the presence of larger errors, more complicated methods relying on estimates of the mean density of the DDFs compared to main survey fields will be required. Five weak-lensing tomography bins evenly spaced between redshift 0 and 3 are used for the analysis. The sampling error plotted includes both shot noise and sample variance, with the shot noise subdominant in most of the cases. Different curves indicate different tomographic bins, with redshift increasing from bin 1 to 5. The horizontal and vertical lines are drawn to guide the eye. For sampling errors below 0.5%, mismatch between the DDF and main survey redshift distributions will affect cosmological parameter estimates by less than 50% of the nominal errors.

1.2.2 Determining the Effects of Cosmic Magnification

In addition to being a signal we are interested in for studying cosmology, weak gravitational lensing can be a contaminant for other measurements. In particular, magnification by large-scale structure will affect the apparent density of background objects, both by making them brighter (and hence bringing objects that would originally be below survey magnitude limits above them) and by reducing their apparent surface density. This effect, commonly referred to as "cosmic magnification", will cause an apparent cross-correlation in the locations of foreground and background objects on the sky, which can be a contaminant in attempts to study large-scale structure.

The amount of apparent correlation will depend on both a lensing kernel and the logarithmic slope of the number counts in a given sample at the survey magnitude limit. Determining that slope only from objects brighter than the survey limit will generally yield biased results (particularly if the slope varies with magnitude); however, the deep drilling fields will allow us to assess the abundance of objects fainter than the main survey magnitude limits, eliminating this obstacle. Essentially, we need to determine the abundance of galaxies that could be brightened into a given magnitude and
redshift bin to be able to predict the effects of magnification on large-scale structure measurements. The lensing kernel can be estimated readily using cross-correlation techniques (Newman 2008; faint objects will tend to be very distant, so even relatively coarse redshift information is sufficient for predicting their lensing accurately), but the faint-end slope can only be determined empirically.

The limiting factor for determining this slope will again be sample variance: the abundance of faint objects in the DDFs at a given magnitude should not match the mean in the main survey due to cosmic density fluctuations. Another white paper (Gawiser et al. 2011) looks at these issues in more detail, and concludes that if sampling error is the dominant uncertainty, then a minimum of 4 deep drilling fields (~ 40 deg$^2$) with each going ~ 0.5 mag deeper than the standard LSST field could determine the faint-end slope of galaxy number counts to the necessary accuracy; we refer the reader there for more details.

1.2.3 Testing Shear Measurement Systematics

We would like to be able to test how observational parameters such as seeing, PSF size and anisotropy, airmass, etc. will affect weak lensing measurements (e.g. the B-mode in the shear correlation function). Frequently, this is done by cutting up the input data spatially into regions that have different characteristics and comparing results from each subset. However, with multiple images at each location (especially ~ 100 for LSST), stacking will tend to average out any differences from one location to another, so this will not be an effective strategy. Another option is to split up the component images at each location into $N$ subsets, such as those with high and low seeing. However, in that case the signal-to-noise ratio in each subset will be smaller by a factor of $\sim \sqrt{N}$ compared to the full stack.

In the DDFs, however, we can split the exposures into multiple subsamples each with the full depth of the main survey. This allows for a more complete understanding of how different physical effects are affecting the shear measurement, while performing the analysis at the full depth of the main survey.

To perform such analyses, we require that the number of exposures in each DDF should be at least three times that of the main survey, allowing us to detect and confirm any trend in the main-survey-depth subsamples. Covering just a few such fields early in the survey will be very useful for understanding systematics and finding remedies for any potential problems. Any of the DDFs suggested in the LSS white paper (Gawiser et al. 2011) would be a good candidate, because we could test both photo-z and shear systematics with the same data.

1.2.4 Galaxy Intrinsic Size Distribution

The DDF observations can also be split according to seeing, allowing us to improve our calibration of the intrinsic galaxy size distribution. Here we take advantage of the higher total number of good-seeing exposures available in a DDF, compared to a main survey field. Since the number of resolved objects (i.e., those for which a meaningful size estimate can be extracted) is a strong function of the seeing, the DDFs will make it possible to measure morphological parameters for galaxies that are only marginally resolved in the full survey. If we can take advantage of the expected LSST top-quartile seeing (hence requiring that each DDF has at least four times the number of exposures as the main survey), we will be able to measure accurate shapes for the majority of objects down to the full depth of LSST. This will serve as an independent test of the multiplicative corrections
of shear measurements that will be applied. Figure 2 shows that DDF stacks with \( \sim 0.5'' \) effective seeing will be able to constrain sizes for a large fraction of the faint objects that are marginally resolved in the main survey.

Figure 2: The number of “resolved” (defined as having size greater than 1.1 times the stellar FWHM) galaxies as a function of magnitude and seeing, derived using the size-magnitude distribution determined using photometric redshift estimates and HST imaging in the COSMOS field (Ilbert et al. 2009). The large jump in the number of resolved faint (\( r < 27 \)) galaxies when seeing is better than \( \sim 0.5'' \) demonstrates the need to have at least 4\( \times \) greater depth in the DDFs than in the main survey, as this will allow accurate size measurements for most objects down to the full depth of the main survey.

Because the main survey fields will randomly sample the full range of atmospheric conditions, the odds of having survey-limit depth fields that feature the best resolution are vanishingly small; this analysis will only be possible in deep drilling fields. The total number of deep drilling fields required for this task is determined by the variation in the size-magnitude distribution of galaxies due to sample variance. As noted in section 1.2.1, the number of galaxies in a single redshift bin of width \( \Delta z = 0.1 \) will vary by \( \sim 6\% \) from field to field. Since the galaxy luminosity function is broad at the faint end, we are effectively averaging over several redshift bins at any point in size-magnitude space; hence a DDFs survey covering \( \sim 50 \text{deg}^2 \) (i.e. \( \sim 5 \) independent deep drilling fields) would bring the uncertainty in the size-magnitude distribution of galaxies down to \( \sim 2\% \).

Imaging a few deep drilling fields early during the survey will also be very helpful for this use case. At minimum, we would like to have strong constraints on the galaxy size distribution before mid-survey analyses.
1.2.5 Intrinsic Alignments

Weak lensing science will also benefit from the improved photo-z’s available in the Deep Drilling Fields via the better constraints on intrinsic alignments (both GI and II) that will be possible thanks to the much higher-quality photometric redshifts in these fields. These alignment effects become much easier to measure as photo-z errors decrease (Bridle & King 2007, Joachimi & Schneider 2009). We can use DDF-based estimates of the effect of these alignments on shear power spectra to calibrate and correct for the strength of these effects in the main LSST survey sample.

1.3 Supplementary Science

1. Reducing PSF systematics

PSF interpolation is one of the most critical steps in making shear measurements. The accuracy of the interpolation will be largely determined by the density of PSF stars in the focal plane. Because of the deeper photometry, more stars may be used to construct PSFs in the deep drilling fields, allowing more accurate interpolations as well as tests of any resulting systematics. We are currently working on quantifying the improvement that will result.

2. Calibrating the “low” end of the cluster mass function (below $10^{14} M_\odot$)

For individual clusters of galaxies, the detection threshold for weak lensing shear measurements depends directly on the density of background galaxies. Given the expected surface density of resolved objects in the main survey ($40 \sim 45 \text{arcmin}^{-2}$), lensing by individual low-mass ($M_{200} < 10^{14} M_\odot$) clusters will be difficult to measure. The shear signal from these galaxy clusters will only be marginally detectable at best in the main survey. In the deep drilling fields, the number density of resolved galaxies will be significantly higher, both because of the larger number of galaxies detected in deeper photometry, and because the depth reached when restricting to good-seeing exposures will be proportionally greater. Since distant galaxy clusters are distributed widely across the sky (typically $2 \sim 3 \text{deg}^{-2}$), there is no preference for particular fields as long as they are not too close to the plane of the galaxy (or in Virgo). An accurate determination of the low end of the cluster mass function at $z = 0.2$ and $z = 0.4$ will be possible with observations spanning a large enough volume at those redshifts. For the errors in the mass function in this regime to be $\sim 5\%$, an area of $\sim 200 \text{deg}^2$ would need to be surveyed (or $50 \text{deg}^2$ for $10\%$ errors).

2 Description of Proposed LSST Observations

2.1 List of Proposed Fields

If we are to use DDF redshift distributions as a substitute for those in the main survey, without having to rely on additional corrections for the effects of sample variance, it will be necessary to cover at least $200 \text{deg}^2$ in the deep drilling fields with uniform exposures. If we apply such corrections, a minimum of 5-10 fields ($50 \sim 100 \text{deg}^2$) should be sufficient in order to both measure redshift distributions and test our sample variance corrections. Other projects we consider above set a minimum depth requirement that each DDF should have at least $4 \times$ the exposure time of main survey data in the gri bands used for shape measurements; given the large photometric redshift gains from comparatively deeper uzy, this implies that we would wish a minimum of $5 \sim 10 \times$ the
exposure time in each extragalactic DDF as will be obtained for the main survey. If 10% of the survey time is devoted to DDFs which are suitable for extragalactic studies, it would be possible to cover 200 deg$^2$ with 10$\times$ the total exposure time per field. However, if less DDF time is available (e.g. half of the available time is devoted towards DDFs optimized for other purposes) or each field is observed for longer each (to take advantage of the science gains from uniquely deep photometry), we would need to compromise on the number of fields and rely on more complicated (but still promising) methods for calibrating redshift distributions.

Selecting fields with maximum multi-wavelength coverage will likely reduce photo-z systematics and be helpful to our proposed measurements; while large spectroscopic samples will be key for calibrating photo-z’s and compensating for the effects of sample variance. For optimal photometric redshift determination, the fields should be at high galactic latitude (to minimize reddening) and, ideally, at high ecliptic latitude as well (to maximize observability from space and minimize zodiacal background which will limit the depth of space-based IR observations), though PSF characterization tests could benefit from sampling some lower latitude fields as well, and fields near the celestial equator would have the benefit of observability from large telescopes in the Northern Hemisphere as well as Southern. Targeting very low redshift clusters which span an LSST pointing would be suboptimal, as they will somewhat skew the redshift distribution at extremely low z.

However, these constraints are essentially the same ones facing all other LSST extragalactic studies. Hence, weak lensing on its own does not provide unique drivers for a choice of field; in the interest of space we therefore have not repeated the analyses conducted for other white papers, but rather refer the reader to Gawiser et al. 2011 and Ferguson 2011 for examples of suitable fields.

2.2 Observing Plan, Cadence, Filters, and Expected Depth

We propose deep drilling to last the entire length of the main survey in order to minimize its impact on the main survey and maximize opportunities for supernova/transient follow-up observations. Reaching greater-than-main-survey depth in a few fields early on will be very helpful for testing shear systematics. Since some of the science cases above will rely on deep stacks to replicate the conditions at the 10-year depth of the regular survey, a cadence that is at least 3 times higher than the regular survey is strongly preferred. We propose that the DDFs be observed to greater depth by increasing the frequency of visits. The single-visit sequence of exposures would be the same as for the main survey, but the filter distribution would be somewhat altered. As in other extragalactic DDF science cases (e.g., Gawiser et al. 2011), it is key for us to obtain maximum-quality photo-z’s. Hence, we require imaging in all standard LSST filters and aim to reach as uniform as possible depth in all bands. This implies that we strongly prefer significantly deeper imaging in $uzy$ and moderately deeper imaging in $gri$ than the main survey. For the detection of shear systematics and measuring the faint galaxy size distribution, it will be important to ensure that $i$ and $z$-band observations, at least, are carried out to at least $4\times$ the number of exposures of the main survey.

The smallest number of deep extragalactic fields we could tolerate and achieve most of our science goals is 5; in that scenario, exposure time per field will be $22-44\times$ that of the main survey if 5-10% of the total survey time is devoted to DDFs. Following the near-equal-depth survey strategy of Gawiser et al. 2011, this would yield $5\sigma$ point source depths of 28.5/28.5/28.5/28.5/28.0/27.0 in $ugrizy$ for a total investment of $22\times$ the main survey time per pointing, or 0.38 mag deeper than these limits for $44\times$. For a scenario where we cover 200 deg$^2$ in the deep drilling fields we would be able to obtain $5-10\times$ the main survey exposure time per field, depending on the total amount of time allocated to extragalactic DDFs. If we quadruple the exposure time in $gri$ and allocate all
time remaining to improve the $u z y$ depth, this would yield depths of 27.3 – 27.8/ 28.3 / 28.5 / 27.8 / 27.2 – 27.7/ 25.9 – 26.4 in $ugrizy$, as compared to main survey depths of 26.3 / 27.5 / 27.7 / 27.0 / 26.2 / 24.9.

2.3 Observation-Time Cost

If we are to directly substitute DDF galaxy redshift distributions in place of those in the main survey, the area requirements are relatively steep. For the minimum area required for that method, $\sim 200 \text{deg}^2$, and devoting 0.5% of the total survey time to each DDF, we will spend 10% of all available LSST time on these DDFs. This is most likely not the optimal number; further comprehensive study is required. In particular, it would be difficult to obtain deep multi-wavelength followup data and spectroscopy over such a large area; we would be sacrificing quality of the DDF photometric redshifts in favor of quantity of area.

The rest of our science goals could be achieved by spending $\sim 5\% - 10\%$ of LSST time to survey 5–10 extragalactic fields more deeply, as proposed in other white papers (e.g. Gawiser et al. 2011).

3 Other Required or Relevant Observations

3.1 Other Required Observations

Although other multi-wavelength observations are not absolutely required to reach our deep drilling science goals, they will be very helpful especially for improving photometric redshift estimates. For this reason, targeting DDFs at fields with existing deep multi-wavelength data, as well as obtaining increased multi-wavelength coverage of the DDFs, is strongly encouraged.

For calibrating the high-quality photo-z’s to be obtained in the DDFs, spectroscopic samples will be absolutely critical. Our goal should always be to obtain spectroscopic redshifts for a fair/well-understood sample of galaxies spanning the full magnitude and color space covered by the objects for which we obtain photometric redshifts. However, this will require a very large amount of time on 8-10m telescopes; extrapolating from current surveys which obtain secure redshifts for 40–70% of objects with $i < 22.5$ in one-hour exposures, in the best case it would take $\sim 25$ Keck nights to obtain redshifts for at best $\sim 70\%$ out of a set of $\sim 100$ LSST gold sample ($i < 25.3$) objects. Utilizing other telescopes (particularly JWST) should help, but it is unlikely we will achieve the $\sim 99.9\%$ redshift success rates needed for simple calibration techniques; this would represent a reduction in redshift failure rates of two and a half orders of magnitude.

Even if we are unable to obtain statistically complete samples, every spectroscopic redshift obtained provides more information about the calibration of photo-z’s. They can be used to develop and test photo-z algorithms; we can hope that objects which fail to provide spec-z’s will still have SEDs within the range spanned by galaxies that do, but even if that is not true, the successful redshifts will help us to optimize photometric redshifts for similar objects. Even if we obtain spectroscopic samples that do not fairly sample the photometric galaxies, we can apply spectroscopic-photometric cross-correlation techniques (Newman 2008, Matthews & Newman 2010) to reconstruct the true $z$ distributions for each weak lensing redshift bin. However, this is still dependent upon having large amounts of spectroscopy, of order 50k-100k objects over at least 100 deg$^2$ (Matthews
& Newman 2010), though the objects do not need to be faint or correspond to a fair sample of redshifts. As a result, no matter how we will do calibration, we wish to have a large amount of spectroscopic data in the deep drilling fields, and targeting fields with existing deep spectroscopy will help us towards that goal.

We strongly advocate attempting to acquire as complete a spectroscopic calibration sample as possible in the LSST deep drilling fields, as this will both provide a check on and be useful for cross correlation techniques.

3.2 Other Relevant Observations

4 Specific Needs for LSST and for Deep Drilling

4.1 Need for LSST

Since our main science goal is to support LSST weak lensing science by calibrating photometric redshift distributions and by probing systematic errors in shear measurement, it is critical to use the identical filter set and telescope system. Other existing or future multi-wavelength surveys in the same area will provide great support for our science goals, but no other telescope can exactly match the photometric response, PSF, observing cadence, etc. of LSST.

4.2 Need for Deep Drilling

As detailed in our main science goals, we need to obtain imaging in each filter at a level deeper than will be reached by the main survey in order to improve our knowledge of photometric redshifts, explore possible weak lensing systematics, and limit the impact of weak lensing-induced correlations on large-scale structure measurements. We cannot accurately measure number count slopes at the main survey limits without deeper data; nor is it possible to sub-divide the observations in a main survey field and retain a sensitivity equal to the main survey. No region of the main survey will be uniformly of sufficient image quality to determine the galaxy size distribution for the faintest galaxies. By taking advantage of the deep drilling fields’ greater depth, and presuming they will yield accurate photometric redshifts and will cover sufficient area, the galaxy redshift distribution of the main survey can be determined to a sufficiently high precision using only redshift information in the deep drilling fields alone. This directly translates into stronger dark energy constraints.

5 Feasibility

5.1 General Feasibility

Our proposed deep drilling observations only differ from the main survey in the number of exposures and the time allocation among filters. In addition, we expect the distributions of airmass, sky brightness, and seeing to match those of the main survey. Hence, our observations should be as feasible as the main survey.
5.2 Bright Objects and Extinction

Since we are not specifying field centers here, we cannot identify the brightest objects in them; we refer the reader to other white papers which look into this in more detail. We expect the largest fraction of the weak lensing DDFs to be at high galactic latitude and low extinction. However, some variation in extinction will be inevitable and will need to be calibrated out.

5.3 Unresolved Feasibility Issues

A few critical issues are in need of further study. These include,

- Optimization of the area and depth of the DDFs (including filter exposure time distribution)
- Exploration of whether observing deep drilling fields with lower galactic latitude (and therefore higher PSF star density, albeit also higher extinction) will be useful for constraining PSF systematics, or whether those tests will already be possible with main survey data.

6 Other Issues

6.1 Relevance to LSST Commissioning

We strongly advocate obtaining deep imaging on at least one DDF during commissioning and/or very early in the main survey in order to test shear measurement systematics and catch any potential problems that depend on observing conditions. These observations do not necessarily need to reach the full final depth of a deep drilling field, but a minimum of $3 - 4$ times the standard number of exposures will be required to explore systematics.

6.2 Other Relevant Information

7 References Cited


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