Requirements text relevant to LCR-1554

"Remove Duplicate Requirement in OSS"

SRD (LPM-17)

Sect. 3.4.0.4 “Galaxy shear measurement accuracy, and PSF ellipticity residuals” incl. Table 27

possible systematic errors.

3.4.0.4 Galaxy shear measurement accuracy, and PSF ellipticity residuals

The important angular scales for weak lensing two-point shear correlation probes of dark energy are 10 arcminute to several degrees, where the cosmic shear correlation signal can get as small as 10^{-6} at low redshift and several degree scales. The hemisphere sky coverage of LSST is needed in order to achieve the required statistical precision in these shear correlations, and to suppress cosmic variance. As explained in section 2.1, for the LSST "gold" sample of 4 billion galaxies (defined by $i < 25.3$), the resulting random component of the shear cross correlation noise level is about 3×10^{-7} over this angular range up to several degrees. It is thus important that the systematic component be less than about 30% of this noise (to become negligible when added in quadrature). The requirement then is that the galaxy shear extraction algorithm (and system hardware) be capable of delivering this level of galaxy shear systematics residual. Because of the dominant galaxy shape shot noise, the shear errors in a large sample are dominated by PSF errors at the galaxy positions (together with errors in model fitting given the PSF). This then leads to a requirement on the residual PSF ellipticity correlations on these angular scales.

A limit to the effectiveness of the PSF-correction schemes is our knowledge of the delivered PSF within each image, which is sampled at high Galactic latitude roughly three times per square arcminute by a high S/N ratio star and must be interpolated at the positions of the galaxies. (There is a color dependence, such that the stellar PSF must also be interpolated to the colors of the galaxies, but we do not address that issue here.)

To address these systematics, we first define ellipticity components

$$e_1 = \frac{\sigma_1^2 - \sigma_2^2}{\sigma_1^2 + \sigma_2^2}, \tag{10}$$

and

$$e_2 = \frac{2\sigma_{12}^2}{\sigma_1^2 + \sigma_2^2}, \tag{11}$$

where σ_1^2 and σ_2^2 are the 2nd moments of the stellar image along some set of perpendicular axes, and σ_{12}^2 is the covariance (again, for the best-fit elliptical Gaussian). A PCA fit to the ellipticity components' dependence on the position within each CCD is made, and we examine the residuals. It is the *correlation of these residuals* δe_1 and δe_2, not their mean size, which

sets the level of weak lensing systematics. We define the residual ellipticity auto and cross correlation functions

$$E_1(\theta) = \langle \delta e_1^{(i)} \delta e_1^{(j)} \rangle, \tag{12}$$

$$E_2(\theta) = \langle \delta e_2^{(i)} \delta e_2^{(j)} \rangle, \tag{13}$$

and

$$E_X(\theta) = \langle \delta e_1^{(i)} \delta e_2^{(j)} \rangle, \tag{14}$$

where angle brackets indicate averaging over all pairs of stars i and j at a given angular separation θ. Again, we use the natural limit of the atmosphere as a guide. Observations indicate that the residuals E_1, E_2, and E_X are $\sim 10^{-4}$ at scales of an arcminute and smaller for a 10-second exposure at 0.7 arcsec delivered seeing, falling below shot noise levels at $\theta = 5$ arcmin. It is a requirement that LSST images not degrade this quality significantly. The defocus spectrum from atmosphere induced seeing, combined with optics astigmatism and FPA (focal plane array) non-flatness, produces so-called “B mode" shear (non-zero E_X). Using as priors the measured FPA non-flatness, the wavefront curvature measurements for that image, and the optics astigmatism vs. defocus data, one can optimally fit the PSF over the image. Similarly, requirements on these instrument parameters can be deduced from the science requirements on the residual ellipticity correlations.

Specification: Using the full survey data, the E_1, E_2, and E_X residual PSF ellipticity correlations averaged over an arbitrary FOV must have the median less than TE1 for $\theta \leq 1$ arcmin, and less than TE2 for $\theta \geq 5$ arcmin. No more than TEF % of images will have these medians larger than TE3 for $\theta \leq 1$ arcmin, and TE4 for $\theta \geq 5$ arcmin (Table 27).

Quantity	Design Spec	Minimum Spec	Stretch Goal
TE1	2×10^{-5}	3×10^{-5}	1×10^{-5}
TE2	1×10^{-7}	3×10^{-7}	5×10^{-8}
TEF	15%	15%	10%
TE3	4×10^{-5}	6×10^{-5}	2×10^{-5}
TE4	2×10^{-7}	5×10^{-7}	1×10^{-7}

TABLE 27: These residual PSF ellipticity correlations apply to the r and i bands.

The residual ellipticity correlations vary smoothly so it is sufficient to specify limits in these two angular ranges. On 1 arcmin to 5 arcmin scales, these residual ellipticity correlations put LSST systematics a factor of a few below the weak lensing shot noise, i.e. statistical errors will dominate over systematics. On larger scales, the noise level imposed by nature due to shot noise plus cosmic variance is almost scale-independent, whereas the atmospheric contribu-

tion to systematics becomes negligible. Therefore the specifications on 5 arcmin scales apply to all larger scales as well (as per section 2.1.1). On scales larger than the field of view, sources of systematic error have less to do with the instrumentation than with the operations (due to the seeing distribution), software, and algorithms. It is recommended that the scheduler attempt to match the seeing distribution in each patch of sky, so that at the end of the survey at most a small fraction of patches will have substantially better or worse seeing than average.

3.5 Data Processing and Management Requirements

Detailed requirements on data processing and management will be described in the LSST System Requirements Document (for example, specifications for catalog completeness and reliability). Here, only a rough guidance is provided. There will be three main categories of data products:

- **Level 1** data products are generated continuously every observing night, including alerts to objects that have changed brightness or position.
- **Level 2** data products will be made available as annual Data Releases and will include images and measurements of positions, fluxes, and shapes, as well as variability information such as orbital parameters for moving objects and an appropriate compact description of light curves.
- **Level 3** data products will be created by the community, including project teams, using suitable Applications Programming Interfaces (APIs) that will be provided by the LSST Data Management System. The Data Management System will also provide at least 10% of its total capability for user-dedicated processing and user-dedicated storage. The key aspect of these capabilities is that they will reside “next to" the LSST data, avoiding the latency associated with downloads. They will also allow the science teams to use the database infrastructure to store their results.

One of the most fundamental advantages of LSST survey is the use of individual images and corresponding modeling of varying observing conditions (such as seeing and the background emission) in order to reduce systematic errors in measured parameters. Many types of systematic errors (those that do not decrease with exposure time or source brightness; e.g., errors in photometry due to imperfect point-spread-function modeling or due to flatfield errors) that will be present in individual visits will be uncorrelated between different observations (for

LSR (LSE-29)

Sect. 1.4.1 “Full Survey Performance”

Requirements LSR-REQ-0096, LSR-REQ-0097

1.4 Full Survey Performance

1.4.1 Full Survey Performance

ID: LSR-REQ-0096

Requirement: Integrated over all survey observations made over a 10 year period the LSST shall meet all specifications for **skyCoverage** and **overallEllipticityCorrelations**.

1.4.1.1 Ellipticity Correlations

ID: LSR-REQ-0097

Requirement: Using the full survey data, the E1 and E2 (see SRD for definitions) distributions averaged over an arbitrary FOV shall have medians less than **TE1** for theta ~ 1 arcmin, and less than **TE3** for theta < 5 arcmin. No more than **TEF** % of images shall have these medians for E1 and E2 larger than **TE2** for theta ~ 1 arcmin, or larger than **TE4** for theta < 5 arcmin.

Discussion: The requirements specified here require the full survey data set to exist before they can be met. Thus these are intended to ensure that the LSST system design enables that these requirements can be met after the 10-year survey. Prior to survey start, they will be verified to the extent possible using simulations incorporating the as-built telescope and camera performance characteristics.

Description	Value	Unit	Name
The fraction of PSF ellipticity correlation residuals that can exceed the outlier limits on 1 and 5 arcminutes scales, over an arbitrary field, of view shall be no more than	15	percent	TEF
Median residual PSF ellipticity correlations averaged over an arbitrary field of view for separations less than 1 arcmin shall be no greater than **TE1.**	2.0e-5	arcminuteSeparationCorrelation	TE1
Median residual PSF ellipticity correlations averaged over an arbitrary field of view for separations less than 5 arcmin shall be no greater than **TE2.**	1.0e-7	arcminuteSeparationCorrelation	TE2
The outlier limit on the PSF ellipticity correlation residuals on 1 arcminute scales shall be no more than **TE3.**	4.0e-5	arcminute OutlierLimit	TE3
The outlier limit on the PSF ellipticity correlation residuals on 5 arcminute scales shall be no more than **TE4.**	2.0e-7	arcminute OutlierLimit	TE4

1.4.1.2 Sky Coverage

ID: LSR-REQ-0098

Requirement: Integrated over all survey observations made over a 10 year period the LSST shall meet all specifications for **skyCoverage.**

OSS (LSE-30)

Sect. 3.1.5.6.2, “Full Survey Data Properties”
(in 3.1.5, “Data Products” / 3.1.5.6, “Data Properties”)

Requirements OSS-REQ-0389 and
OSS-REQ-0390, “Ellipticity Correlations”

and

Sect. 3.2.5, “Image Ellipticity” (in 3.2, “Optical System”)

Requirement OSS-REQ-0234, “10-year Ellipticity
Residuals”

3.1.5.6.2 Full Survey Data Properties

ID: OSS-REQ-0389

Specification: Integrated over all survey observations made over a 10 year period the LSST shall meet all specifications for **overallEllipticityCorrelations**.

3.1.5.6.2.1 Ellipticity Correlations

ID: OSS-REQ-0390

Specification: Using the full survey data, the **E1** and **E2** (see SRD for definitions) distributions averaged over an arbitrary FOV shall have medians less than **TE1** for theta ~ 1 arcmin, and less than **TE3** for theta < 5 arcmin. No more than **TEF** % of images shall have these medians for **E1** and **E2** larger than **TE2** for theta ~ 1 arcmin, or larger than **TE4** for theta < 5 arcmin.

Discussion: The requirements specified here require the full survey data set to exist before they can be met. Thus these are intended to ensure that the LSST system design enables that these requirements can be met after the 10-year survey. Prior to survey start, they will be verified to the extent possible using simulations incorporating the as-built telescope and camera performance characteristics.

Description	Value	Unit	Name
Median residual PSF ellipticity correlations averaged over an arbitrary field of view for separations less than 5 arcmin shall be no greater than **TE2.**	1.0e-7	arcminuteSeparationCorrelation	TE2
The fraction of PSF ellipticity correlation residuals that can exceed the outlier limits on 1 and 5 arcminutes scales, over an arbitrary field, of view shall be no more than	15	percent	TEF
The outlier limit on the PSF ellipticity correlation residuals on 5 arcminute scales shall be no more than **TE4.**	2.0e-7	arcminuteOutlierLimit	TE4
Median residual PSF ellipticity correlations averaged over an arbitrary field of view for separations less than 1 arcmin shall be no greater than **TE1.**	2.0e-5	arcminuteSeparationCorrelation	TE1
The outlier limit on the PSF ellipticity correlation residuals on 1 arcminute scales shall be no more than **TE3.**	4.0e-5	arcminuteOutlierLimit	TE3

3.1.6 Data Archiving

3.1.6.1 Data Archiving

ID: OSS-REQ-0167

Specification: The LSST project shall create and manage an archive of all its public data products and the raw data necessary to reproduce them. In addition, the archive shall contain all necessary engineering

Description	Value	Unit	Name
saturated stars.			
The fraction of PSF ellipticity measurements allowed to exceed the ellipticity outlier limit for bright isolated non-saturated stars.	5	percent	EF1
The maximum median residual ellipticity amplitude outlier limit on scales between 1 and 5 arcmin.	1.0e-6	unitless	SE6
The maximum residual ellipticity correlation amplitude over 5 arcmin scales.	5.0e-7	unitless	SE4
The maximum median residual ellipticity amplitude outlier limit on scales less than or equal to 1 arcmin.	4.0e-4	unitless	SE5
Fraction of allowed PSF measurements of isolated bright stars to exceed the ellipticity residual correlation amplitude outlier limit.	10	percent	EF2

3.2.5.2 10-year Ellipticity Residuals

ID: OSS-REQ-0234

Specification: Over the total number of visits in the full set of survey data (or 10 year equivalent stack), the residual ellipticity correlations of bright isolated point sources in the r-band or i-band, after correction, shall have the properties defined in the **overallEllipticity** table below.

Description	Value	Unit	Name
Median residual PSF ellipticity correlations averaged over an arbitrary field of view for separations less than 5 arcmin shall be no greater than **TE2.**	1.0e-7	arcminuteSeparationCorrelation	TE2
The fraction of PSF ellipticity correlation residuals that can exceed the outlier limits on 1 and 5 arcminutes scales over an arbitrary field of view shall be no more than **TF1**.	15	percent	TF1
The outlier limit on the PSF ellipticity correlation residuals on 5 arcminute scales shall be no more than **TE4.**	2.0e-7	arcminute OutlierLimit	TE4
Median residual PSF ellipticity correlations averaged over an arbitrary field of view for separations less than 1 arcmin shall be no greater than **TE1.**	2.0e-5	arcminuteSeparationCorrelation	TE1

Description	Value	Unit	Name
The outlier limit on the PSF ellipticity correlation residuals on 1 arcminute scales shall be no more than **TE3.**	4.0e-5	arcminute OutlierLimit	TE3

3.3 System Throughput

The LSST system throughput shall allow efficient collection of the science data over a wide range of wavelengths, from near the atmospheric cutoff in the blue to the band gap of silicon in the red.

3.3.1 Filter Response

3.3.1.1 Filter Response

ID: OSS-REQ-0235

Specification: Evaluation of the filter response shall use the area weighted mean response function as defined in Document-16295 using the r-band beam defined in LSE-11.

Discussion: The following definitions apply to the filter response requirements below

1. The "filter response" function of a given point on the filter substrate refers to the net wavelength response integrated over the incident optical beam centered at that point that has been normalized to a unity mean between the "in-band" wavelength limits as defined for each filter. The normalized response function can have values greater than unity by no more than **maxFiltRipple** due to response wiggles within the in-band region.
2. The area weighted mean response function (as defined in Document-16295) is used combine the filter response functions for points on the filter substrate into an average response.
3. The r-band beam footprints defined in LSE-11 have been designated the nominal beam footprints for use in evaluating filter performance. That footprint definition includes the annulus and beam angles at both surfaces of each filter. The r-band filter annulus is typically within a few percent of the filter annulus for the other bands. The u-band second surface is 7% smaller. The incident angle of the beam varies linearly from the outer edge of the annulus to the inner edge of the annulus.

3.3.1.1.1 Filter Out of Band Constraints

ID: OSS-REQ-0237

Specification: Each of the 6 defined filters must block it's out of band transmission according to the specifications in the table below.

Discussion: For leakage that occurs in the wavelength region beyond 1050 the response of 100 micron thick silicon at -100 C can be multiplied against the filter response in the total integrated leak evaluation.

Description	Value	Unit	Name
The average leakage in any 10nm segment between 300-1200nm outside the wavelength span one FWHM from the central wavelength shall be no more than **fLeak_10nm.**	0.01	percent	fLeak_10nm