Cadence Note: Brown Dwarf Astrometry

John Gizis for Stars, Milky Way & Local Volume (SMWLV)

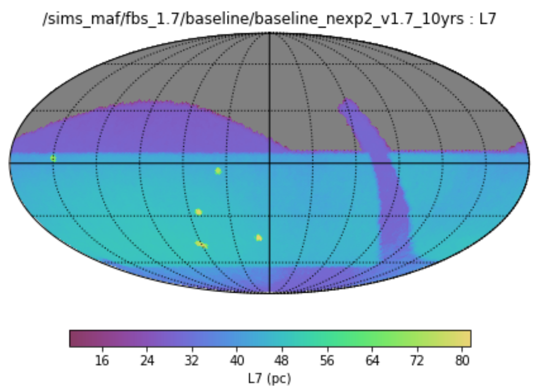
The Vera C. Rubin Observatory Legacy Survey of Space and Time (LSST) will carry out its science goal of "Mapping the Milky Way" through both astrometry and photometry. LSST will be able to measure proper motions and parallaxes beyond Gaia's faint limit of G~21. The LSST Science Requirements (SRD) require 10 mas astrometry, but the Dark Energy Survey has demonstrated that appropriate modeling of the camera distortions [1] and atmospheric turbulence [2] reduce astrometric uncertainties to ~5 mas. High quality astrometry imposes cadence restraints, requiring 1) sampling a long baseline in time, 2) including high parallax factor observations near the meridian early and late in the night, and 3) minimizing differential color refraction (DCR) by observing at low airmass and avoiding correlations between the parallax and DCR angles. The Project has already included a set of generic *ugrizy* astrometry metrics addressing these concerns in the Jones report [3] and we emphasize the importance of these metrics for the SRD requirements and Galactic science. Here, we examine a specific science case, measuring *the brown dwarf luminosity function*, and evaluate different cadence strategies. Unlike many SMWLV science cases, all directions on the sky are good because the targets lie in the immediate solar neighborhood (<50-100 pc) and only red filters contribute.

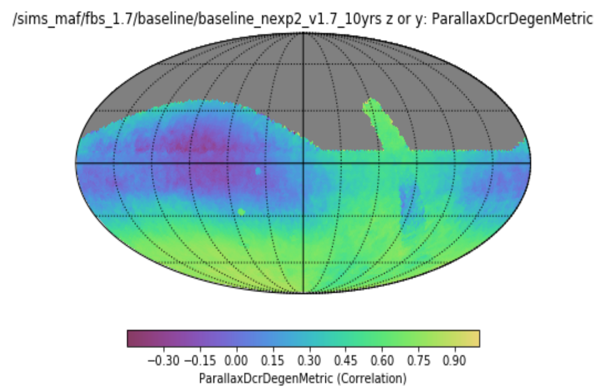
Science Case

It is now estimated that the star formation process creates one brown dwarf below the hydrogen-burning limit (~0.075 solar masses) for every six stars above the hydrogen-burning limit. Measurements of the luminosity function -- the number of objects per cubic parsec (space density) as a function of their absolute magnitude, spectral type, or effective temperature -- is a key tool in investigating their physics. The luminosity function depends on the mass function (star formation at the extreme low-mass end), star formation history, and evolution that in turn depends on both interior and atmosphere physics.

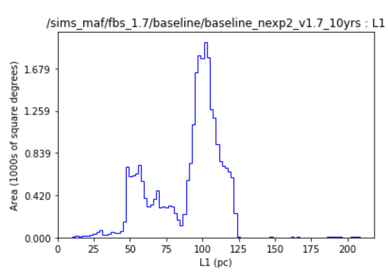
The Gaia Catalog of Nearby Stars [4] is a parallax-selected catalog that includes over 330,000 stars, representing an estimated 92% of stars within 100 pc with spectral type M9 or earlier. For cooler spectral types L and T, Gaia becomes incomplete at closer limits: The Gaia L8 dwarf sample is only complete to 10 pc. Brown dwarf luminosity functions are based on distance limits of 15-25 pc and samples of ground-based or Spitzer parallaxes [5,6,7,8]. The current luminosity function points to the need for larger samples. A dip around spectral type L3 may be linked to the hydrogen-burning limit [3,8]. At cooler temperatures, the L/T transition is a key problem. Saumon & Marley [9] predict a pileup at 1300K due to atmospheric cloud clearing changing the cooling rate -- a prediction that is confirmed by [6] using very wide temperature bins but complicated by [5], who instead see a narrow gap at 1300K and pileups elsewhere. The problem is interpreting small statistical samples -- some ~10-20 objects per spectral type bin for late L and early T dwarfs -- that in turn depend on selection by photometry and/or proper motion of previous sky surveys, which will be addressed by LSST's larger samples.

LSST Baseline Survey Results

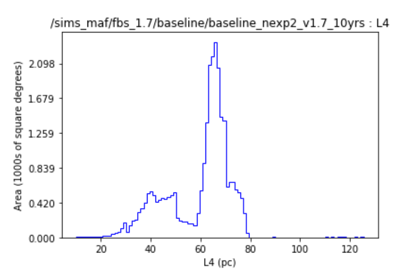




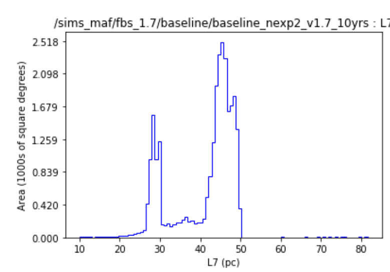
Our metrics calculate the distance for which LSST parallax signal-to-noise is at least 10 for each healpix as a function of spectral type, and sums the resulting volume to make a simplified model for comparing cadence strategies. The absolute *i*, *z*, *y* magnitudes are based on the mean Pan-STARRS photometry for each spectral type [10]. Results for representative spectral types are shown below with total number (N) obtained by multiplying by [6]'s space densities. *In the WFD region, LSST outperforms Gaia for the early L dwarfs and the ground-based parallax sample for mid-Ls to mid-Ts. The ~100 objects per spectral type for cool Ls and warm Ts is an order of magnitude increase on existing work.* The secondary peak with smaller limiting distances is the non-WFD areas. Deep drilling fields represent a very small volume. T9 dwarfs are faint in even *z*, *y*.



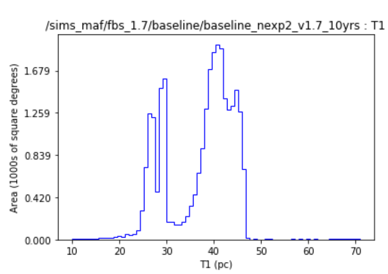
L1: 2.4×10^6 pc^3 N~1500



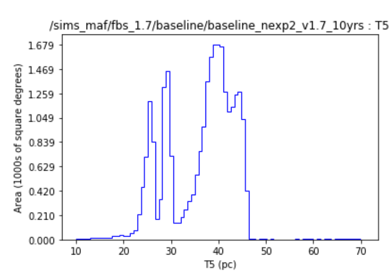
L4: 6.6×10^5 pc^3 N~440



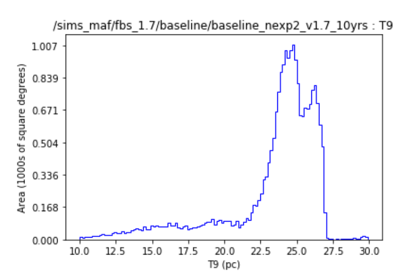
L7: 2.1×10^5 pc^3 N~130



T3: 1.6×10^5 pc^3 N~40



T5: 1.5×10^5 pc^3 N~170



T9: 3.2×10^4 pc^3 N~60

Cadence Comparisons and Recommendations

We select the L4 or L7 volume for each simulation divided by the L4 or L7 baseline volume for each family (V1.5, 1.6, 1.7) as the Figures of Merit (F_{L4},F_{L7}). L4 dwarfs are intrinsically brighter and are at a larger distance for a given limiting magnitude, and therefore are more sensitive to the parallax factor sampling. In general, more area on the sky and/or more *z, y* filter observations increase the volume, but varying at the few percent level. Extreme possibilities are shown by the *zy*-heavy simulation ($F_{L4} = 1.19$,$F_{L7} = 1.10$) or footprint newA (F_{L7}=1.10) down to the stuck rolling cadence (both 0.84), but these do not meet the SRD. DCR/Parallax correlations do not appear to be a major concern in existing simulations over most of the sky.

We recommend the single snap: The gain for a single 30s snap over 2x15s is 4-6% ($F_{L4} = 1.06$,$F_{L7} = 1.04$) in all families, enabling better parallax factor sampling in *z,y* or more mini-survey coverage (but see the bright star cadence note.)

We recommend studying astrometric performance in commissioning: Improving the astrometric base atmospheric accuracy (i.e., new algorithms with Gaia reference) from 10 mas to 5 mas improves the metric for V1.7 baseline simulations by 7-15% which is better than any plausible cadence changes. All other proper motion based science would also be improved.

We identify tension with other uses of twilight time: An extreme example is the V1.7 nightly NEO object search (V1.7 pattern 1), which has a large negative impact ($F_{L4} = 0.90$, $F_{L7} = 0.94$). Patterns 3,4 and 7 have the smallest impact and would be most acceptable.

[Q1] WFD footprint and [Q2] Use of additional time: **We favor increasing WFD and/or using mini-surveys on Galactic science.** However, the tradeoff between sky coverage and WFD depth is complex, and we include the results for all simulations in a spreadsheet. Simulations without any low galactic latitude coverage and/or minimum coverage in WFD have very large negative impacts (V1.5 big_sky, no_uiy, big_sky_dust, V1.6 barebones, dm_heavy, ddf_heavy) and we recommend against them. WFD larger Footprints and mini-surveys that increase the coverage in Galactic Plane (and/or the northern hemisphere) have significant improvements (bulges family, newA, newB); combo_dust is a good V1.6 potential scheduler. The new_rolling (V1.17.1) cases with plane coverage have small but positive impacts. Note the illustrative contrast between the very poor parallax performance of the standard big_sky ($F_{L4} = 0.88$, $F_{L7} = 0.90$) with big_sky at WFD cadence ($F_{L4} = 1.02$, $F_{L7} = 1.06$). Brown dwarf astrometry disfavors adding more pencil beam surveys in the form of DDFs (wfd_depth family, V1.6 ddf_heavy). Most small adjustments, such as the V1.7 footprint_tune family, have no importance to this science case, with changes of ~1% over baseline.

[Q3] *u-band to 50s* has a modest negative impact (u_long_50) due to the corresponding reduction in red observations, but may have positive effects on other SMWLV science cases.

[Q4]: This science case gains with redder distributions (V1.5 filter_dist 8 “redder”, filter_dist 5 “zy heavy”) but loses with bluer distributions (V1.5 bluer_footprint). **We see red filter reductions as highly undesirable and strongly recommend against them.**

[Q5]: *Filter Visits*: The pairs of visits do not affect our science case. Reserving the end of the night (when parallax factors are high) for third observations is a potential concern. However, we find no impact when 30 minutes (V1.5 third_obs) is reserved. We do see small negative impacts as the reserved time increases, reaching 1% in the 120 minute case. Strategies (V1.5 good_seeing) that select against quality *y* observations are negative at the few percent level.

[Q6/Q7]: We find little effect for rolling cadence (in V1.7) or the dithering strategies. Dithering is desirable.

References:

[1] Bernstein, G., et al. 2017, PASP, 129, 7
[2] Fortino, W.F., et al. 2021, ApJ, in press
[3] Jones, L., et al. 2020, PSTN-051
[4] Smart, R. L, et al. 2021, A&A, in press
[5] Best, W.M., et al. 2021, AJ, 161, 42
[6] Kirkpatrick et al. 2021, ApJS, 253, 7
[7] Kirkpatrick, J.D., et al. 2019, ApJS, 240, 19
[8] Bardalez Gagliuffi, D.C., et al. 2019, ApJ, 883, 205
[9] Saumon, D. & Marley, M.E. 2020, ApJ, 689. 1327
[10] Best, W.M., et al. 2018, ApJS, 234, 1

Github for numbers, plots, and code:
https://github.com/jgizis/LSST-BD-Cadence

Spreadsheet with results: Link

Astrometry metrics coding by Peter Yoachim.

F_L4	F_L7	Simulation	Remarks	
		V1.7 Family		
1.06	1.04	fbs_1.7/baseline/baseline_nexp1_v1.7_10yrs.db	1 snap better	
1	1	fbs_1.7/baseline/baseline_nexp2_v1.7_10yrs.db	V1.7 baseline	
1	1.001	fbs_1.7/ddf_dither/ddf_dither0.00_v1.7_10yrs.db	dither neutral	
1	1	fbs_1.7/ddf_dither/ddf_dither0.05_v1.7_10yrs.db		
1	1	fbs_1.7/ddf_dither/ddf_dither0.10_v1.7_10yrs.db		
1.002	1.001	fbs_1.7/ddf_dither/ddf_dither0.30_v1.7_10yrs.db		
1	1	fbs_1.7/ddf_dither/ddf_dither0.70_v1.7_10yrs.db		
1.002	1.001	fbs_1.7/ddf_dither/ddf_dither1.00_v1.7_10yrs.db		
1.003	1.001	fbs_1.7/ddf_dither/ddf_dither1.50_v1.7_10yrs.db		
1.002	1	fbs_1.7/ddf_dither/ddf_dither2.00_v1.7_10yrs.db		
1	1	fbs_1.7/euclid_dither/euclid_dither1_v1.7_10yrs.db		
1.002	1.001	fbs_1.7/euclid_dither/euclid_dither2_v1.7_10yrs.db		
1	1	fbs_1.7/euclid_dither/euclid_dither3_v1.7_10yrs.db		
0.999	1	fbs_1.7/euclid_dither/euclid_dither4_v1.7_10yrs.db		
1	1	fbs_1.7/euclid_dither/euclid_dither5_v1.7_10yrs.db		
0.992	1.013	fbs_1.7/footprint_tune/footprint_0_v1.710yrs.db	nearby sample insensitive to these footprints	
0.995	1.014	fbs_1.7/footprint_tune/footprint_1_v1.710yrs.db		
0.991	1.01	fbs_1.7/footprint_tune/footprint_2_v1.710yrs.db		
0.995	1.012	fbs_1.7/footprint_tune/footprint_3_v1.710yrs.db		
0.998	1.003	fbs_1.7/footprint_tune/footprint_4_v1.710yrs.db		
0.995	1.012	fbs_1.7/footprint_tune/footprint_5_v1.710yrs.db		
0.997	1.01	fbs_1.7/footprint_tune/footprint_6_v1.710yrs.db		
0.991	1.008	fbs_1.7/footprint_tune/footprint_7_v1.710yrs.db		
0.982	1.003	fbs_1.7/footprint_tune/footprint_8_v1.710yrs.db		
1.005	1.006	fbs_1.7/pair_times/pair_times_11_v1.7_10yrs.db		
1	1	fbs_1.7/pair_times/pair_times_22_v1.7_10yrs.db		
0.994	0.994	fbs_1.7/pair_times/pair_times_33_v1.7_10yrs.db		
0.984	0.989	fbs_1.7/pair_times/pair_times_44_v1.7_10yrs.db		
0.97	0.978	fbs_1.7/pair_times/pair_times_55_v1.7_10yrs.db		
1.002	1.001	fbs_1.7/rolling/rolling_scale0.2_nslice2_v1.7_10yrs.db	Rolling Cadence neutral	

1	1.001	fbs_1.7/rolling/rolling_scale0.2_nslice3_v1.7_10yrs.db		
1	1	fbs_1.7/rolling/rolling_scale0.4_nslice2_v1.7_10yrs.db		
1.003	1.002	fbs_1.7/rolling/rolling_scale0.4_nslice3_v1.7_10yrs.db		
1.001	1	fbs_1.7/rolling/rolling_scale0.6_nslice2_v1.7_10yrs.db		
1.003	1.003	fbs_1.7/rolling/rolling_scale0.6_nslice3_v1.7_10yrs.db		
1.002	1.002	fbs_1.7/rolling/rolling_scale0.8_nslice2_v1.7_10yrs.db		
1.006	1.007	fbs_1.7/rolling/rolling_scale0.8_nslice3_v1.7_10yrs.db		
1	1.001	fbs_1.7/rolling/rolling_scale0.9_nslice2_v1.7_10yrs.db		
1.005	1.006	fbs_1.7/rolling/rolling_scale0.9_nslice3_v1.7_10yrs.db		
1	1.001	fbs_1.7/rolling/rolling_scale1.0_nslice2_v1.7_10yrs.db		
1.005	1.006	fbs_1.7/rolling/rolling_scale1.0_nslice3_v1.7_10yrs.db		
0.998	1	fbs_1.7/rolling_nm/rolling_nm_scale0.2_nslice2_v1.7_10yrs.db		
0.998	1	fbs_1.7/rolling_nm/rolling_nm_scale0.2_nslice3_v1.7_10yrs.db		
0.998	1	fbs_1.7/rolling_nm/rolling_nm_scale0.4_nslice2_v1.7_10yrs.db		
1.004	1.003	fbs_1.7/rolling_nm/rolling_nm_scale0.4_nslice3_v1.7_10yrs.db		
1.003	1.004	fbs_1.7/rolling_nm/rolling_nm_scale0.6_nslice2_v1.7_10yrs.db		
1.006	1.006	fbs_1.7/rolling_nm/rolling_nm_scale0.6_nslice3_v1.7_10yrs.db		
1.002	1.004	fbs_1.7/rolling_nm/rolling_nm_scale0.8_nslice2_v1.7_10yrs.db		
1.009	1.01	fbs_1.7/rolling_nm/rolling_nm_scale0.8_nslice3_v1.7_10yrs.db		
1.003	1.005	fbs_1.7/rolling_nm/rolling_nm_scale0.9_nslice2_v1.7_10yrs.db		
1.006	1.007	fbs_1.7/rolling_nm/rolling_nm_scale0.9_nslice3_v1.7_10yrs.db		
1.003	1.006	fbs_1.7/rolling_nm/rolling_nm_scale1.0_nslice2_v1.7_10yrs.db		
1.011	1.013	fbs_1.7/rolling_nm/rolling_nm_scale1.0_nslice3_v1.7_10yrs.db		
0.904	0.941	fbs_1.7/twi_neo/twi_neo_pattern1_v1.7_10yrs.db	Twilight NEO conflicts	
0.953	0.972	fbs_1.7/twi_neo/twi_neo_pattern2_v1.7_10yrs.db	with high parallax observations	
0.971	0.984	fbs_1.7/twi_neo/twi_neo_pattern3_v1.7_10yrs.db		
0.98	0.987	fbs_1.7/twi_neo/twi_neo_pattern4_v1.7_10yrs.db		
0.956	0.974	fbs_1.7/twi_neo/twi_neo_pattern5_v1.7_10yrs.db		
0.96	0.976	fbs_1.7/twi_neo/twi_neo_pattern6_v1.7_10yrs.db		
0.97	0.981	fbs_1.7/twi_neo/twi_neo_pattern7_v1.7_10yrs.db		
1	1.002	fbs_1.7/twi_pairs/twi_pairs_mixed_repeat_v1.7_10yrs.db	Pairs neutral	

1	1	fbs_1.7/twi_pairs/twi_pairs_mixed_v1.7_10yrs.db		
0.997	0.999	fbs_1.7/twi_pairs/twi_pairs_repeat_v1.7_10yrs.db		
1	1	fbs_1.7/twi_pairs/twi_pairs_v1.7_10yrs.db		
0.992	0.993	fbs_1.7/u_long/u_long_ms_30_v1.7_10yrs.db		
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0.967	0.978	fbs_1.7/u_long/u_long_ms_60_v1.7_10yrs.db		
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0.99	0.996	fbs_1.7/wfd_cadence_drive/cadence_drive_gl200_gcbv1.7_10yrs.db		
0.982	0.991	fbs_1.7/wfd_cadence_drive/cadence_drive_gl200v1.7_10yrs.db		
1.014	1.011	fbs_1.7/wfd_cadence_drive/cadence_drive_gl30_gcbv1.7_10yrs.db		
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		V1.7.1 Extension to V1.7 family		
1.012	1.01	fbs_1.7.1/new_rolling/baseline_nexp2_v1.7.1_10yrs.db		
0.997	1.009	fbs_1.7.1/new_rolling/bulge_roll_scale0.90_nslice2_fpw0.9_nrw1.0v1.7_10yrs.db		
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0.992	0.999	fbs_1.7.1/new_rolling/six_stripe_scale0.90_nslice6_fpw0.9_nrw0.0v1.7_10yrs.db		
		V1.6 FAMILY		
1.003	1.005	fbs_1.6/even_filters/even_filters_alt_g_v1.6_10yrs.db	neutral for even filters	
0.999	1	fbs_1.6/even_filters/even_filters_altv1.6_10yrs.db		

1.009	1.008	fbs_1.6/even_filters/even_filters_g_v1.6_10yrs.db		
1.004	1.006	fbs_1.6/even_filters/even_filtersv1.6_10yrs.db		
0.941	0.92	fbs_1.6/potential_schedulers/barebones_nexp2_v1.6_10yrs.db		
0.997	0.958	fbs_1.6/potential_schedulers/barebones_v1.6_10yrs.db		
1	1	fbs_1.6/potential_schedulers/baseline_nexp1_v1.6_10yrs.db		
0.937	0.955	fbs_1.6/potential_schedulers/baseline_nexp2_scaleddown_v1.6_10yrs.db	two snaps signficantly worse, and less area	
0.944	0.963	fbs_1.6/potential_schedulers/baseline_nexp2_v1.6_10yrs.db	two snaps signficantly worse.	
0.948	0.995	fbs_1.6/potential_schedulers/combo_dust_nexp2_v1.6_10yrs.db		
1.002	1.038	fbs_1.6/potential_schedulers/combo_dust_v1.6_10yrs.db		
0.883	0.923	fbs_1.6/potential_schedulers/ddf_heavy_nexp2_v1.6_10yrs.db	2 snaps bad, heavy DDF bad	
0.939	0.963	fbs_1.6/potential_schedulers/ddf_heavy_v1.6_10yrs.db	Heavy DDF bad	
0.913	0.935	fbs_1.6/potential_schedulers/dm_heavy_nexp2_v1.6_10yrs.db	2 snaps bad	
0.963	0.97	fbs_1.6/potential_schedulers/dm_heavy_v1.6_10yrs.db	DM heavy does poorly	
0.949	0.974	fbs_1.6/potential_schedulers/mw_heavy_nexp2_v1.6_10yrs.db	2 snaps bad	
1.002	1.008	fbs_1.6/potential_schedulers/mw_heavy_v1.6_10yrs.db	MW heavy neutral for this science case	
0.932	0.973	fbs_1.6/potential_schedulers/rolling_exgal_mod2_dust_sdf_0.80_nexp2_v1.6_10yrs.db	2 snaps bad	
0.982	1.014	fbs_1.6/potential_schedulers/rolling_exgal_mod2_dust_sdf_0.80_v1.6_10yrs.db	Rolling Exgal neutral to slight loss	
0.93	0.965	fbs_1.6/potential_schedulers/ss_heavy_nexp2_v1.6_10yrs.db	2 snaps bad	
0.991	1.007	fbs_1.6/potential_schedulers/ss_heavy_v1.6_10yrs.db	SS neutral	
1.001	1.002	fbs_1.6/rolling_fpo/rolling_fpo_2nslice0.8_v1.6_10yrs.db	Rolling neutral	
1.002	1.003	fbs_1.6/rolling_fpo/rolling_fpo_2nslice0.9_v1.6_10yrs.db		
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0.99	0.99	fbs_1.6/rolling_fpo/rolling_fpo_3nslice0.8_v1.6_10yrs.db		
0.99	0.99	fbs_1.6/rolling_fpo/rolling_fpo_3nslice0.9_v1.6_10yrs.db		
0.989	0.987	fbs_1.6/rolling_fpo/rolling_fpo_3nslice1.0_v1.6_10yrs.db		
0.998	0.994	fbs_1.6/rolling_fpo/rolling_fpo_6nslice0.8_v1.6_10yrs.db		
0.995	0.993	fbs_1.6/rolling_fpo/rolling_fpo_6nslice0.9_v1.6_10yrs.db		
0.998	0.994	fbs_1.6/rolling_fpo/rolling_fpo_6nslice1.0_v1.6_10yrs.db		
		V1.5 Family		

0.989	1.032	fbs_1.5/alt_roll_dust/alt_dust_v1.5_10yrs.db	Rolling cadence poor in V1.5, but not V1.6 or V1.7	
0.967	1.025	fbs_1.5/alt_roll_dust/alt_roll_mod2_dust_sdf_0.20_v1.5_10yrs.db		
0.974	1.031	fbs_1.5/alt_roll_dust/roll_mod2_dust_sdf_0.20_v1.5_10yrs.db		
0.946	0.965	fbs_1.5/baseline/baseline_2snaps_v1.5_10yrs.db	2 snaps bad	
1	1	fbs_1.5/baseline/baseline_v1.5_10yrs.db	BASELINE=1 by definition	
1.001	1.047	fbs_1.5/bulge/bulges_bs_v1.5_10yrs.db	L7 gains in volume with wider area, although little effect for L4.	
1.007	1.054	fbs_1.5/bulge/bulges_bulge_wfd_v1.5_10yrs.db		
1	1.046	fbs_1.5/bulge/bulges_cadence_bs_v1.5_10yrs.db		
1.005	1.052	fbs_1.5/bulge/bulges_cadence_bulge_wfd_v1.5_10yrs.db		
1.002	1.051	fbs_1.5/bulge/bulges_cadence_i_heavy_v1.5_10yrs.db		
1.002	1.051	fbs_1.5/bulge/bulges_i_heavy_v1.5_10yrs.db		
0.965	0.977	fbs_1.5/daily_ddf/daily_ddf_v1.5_10yrs.db	DDF concern	
0.988	0.99	fbs_1.5/dcr/dcr_nham1_ug_v1.5_10yrs.db		
0.993	0.996	fbs_1.5/dcr/dcr_nham1_ugr_v1.5_10yrs.db		
0.989	0.992	fbs_1.5/dcr/dcr_nham1_ugri_v1.5_10yrs.db		
0.99	0.992	fbs_1.5/dcr/dcr_nham2_ug_v1.5_10yrs.db		
0.989	0.992	fbs_1.5/dcr/dcr_nham2_ugr_v1.5_10yrs.db		
0.981	0.991	fbs_1.5/dcr/dcr_nham2_ugri_v1.5_10yrs.db		
0.911	0.919	fbs_1.5/filter_dist/filterdist_indx1_v1.5_10yrs.db	Reducing red filters very bad!	
1.022	0.988	fbs_1.5/filter_dist/filterdist_indx2_v1.5_10yrs.db		
0.936	0.935	fbs_1.5/filter_dist/filterdist_indx3_v1.5_10yrs.db		
0.954	0.947	fbs_1.5/filter_dist/filterdist_indx4_v1.5_10yrs.db		
1.194	1.1	fbs_1.5/filter_dist/filterdist_indx5_v1.5_10yrs.db	Increasing red filters good	
0.978	0.956	fbs_1.5/filter_dist/filterdist_indx6_v1.5_10yrs.db		
0.973	0.958	fbs_1.5/filter_dist/filterdist_indx7_v1.5_10yrs.db		
1.084	1.029	fbs_1.5/filter_dist/filterdist_indx8_v1.5_10yrs.db	Increasing red filters good	
1	1.003	fbs_1.5/footprints/footprint_add_mag_cloudsv1.5_10yrs.db		
0.938	0.949	fbs_1.5/footprints/footprint_big_sky_dustv1.5_10yrs.db	Shallow big sky poor parallax performance	

0.901	0.913	fbs_1.5/footprints/footprint_big_sky_nouiyv1.5_10yrs.db		
0.888	0.907	fbs_1.5/footprints/footprint_big_skyv1.5_10yrs.db	Big sky reduced coverage very bad!	
1.024	1.06	fbs_1.5/footprints/footprint_big_wfdv1.5_10yrs.db	Big sky at WFD does well	
0.864	0.901	fbs_1.5/footprints/footprint_bluer_footprintv1.5_10yrs.db	Bluer bad	
1.018	1.029	fbs_1.5/footprints/footprint_gp_smoothv1.5_10yrs.db	positive impact, place at WFD-like coverage	
1.051	1.095	fbs_1.5/footprints/footprint_newAv1.5_10yrs.db	new A does well.	
1.008	1.056	fbs_1.5/footprints/footprint_newBv1.5_10yrs.db		
0.995	0.991	fbs_1.5/footprints/footprint_no_gp_northv1.5_10yrs.db		
0.999	0.999	fbs_1.5/footprints/footprint_standard_goalsv1.5_10yrs.db		
0.838	0.837	fbs_1.5/footprints/footprint_stuck_rollingv1.5_10yrs.db	Stuck rolling very bad as expected!	
0.971	0.978	fbs_1.5/goodseeing/goodseeing_gi_v1.5_10yrs.db	Good seeing has small negative impact	
0.97	0.976	fbs_1.5/goodseeing/goodseeing_gri_v1.5_10yrs.db		
0.984	0.989	fbs_1.5/goodseeing/goodseeing_griz_v1.5_10yrs.db		
0.981	0.985	fbs_1.5/goodseeing/goodseeing_gz_v1.5_10yrs.db		
0.986	0.987	fbs_1.5/goodseeing/goodseeing_i_v1.5_10yrs.db		
0.987	0.993	fbs_1.5/greedy_footprint/greedy_footprint_v1.5_10yrs.db		
0.965	0.98	fbs_1.5/rolling/rolling_mod2_sdf_0.10_v1.5_10yrs.db	Rolling cadence does poorly in V1.5 but no impact in V1.6, V1.7	
0.96	0.975	fbs_1.5/rolling/rolling_mod2_sdf_0.20_v1.5_10yrs.db		
0.938	0.964	fbs_1.5/rolling/rolling_mod3_sdf_0.10_v1.5_10yrs.db		
0.94	0.965	fbs_1.5/rolling/rolling_mod3_sdf_0.20_v1.5_10yrs.db		
0.914	0.95	fbs_1.5/rolling/rolling_mod6_sdf_0.10_v1.5_10yrs.db		
0.92	0.954	fbs_1.5/rolling/rolling_mod6_sdf_0.20_v1.5_10yrs.db		
0.977	0.982	fbs_1.5/same_filt/baseline_samefilt_v1.5_10yrs.db	small negative impact	
0.992	0.988	fbs_1.5/short_exp/short_exp_2ns_1expt_v1.5_10yrs.db		
0.985	0.983	fbs_1.5/short_exp/short_exp_2ns_5expt_v1.5_10yrs.db		
0.984	0.98	fbs_1.5/short_exp/short_exp_5ns_1expt_v1.5_10yrs.db		
0.964	0.968	fbs_1.5/short_exp/short_exp_5ns_5expt_v1.5_10yrs.db	too many short exposures has negative impact	

1.003	1.001	fbs_1.5/spiders/spiders_v1.5_10yrs.db	neutral	
0.988	0.99	fbs_1.5/third_obs/third_obs_pt120v1.5_10yrs.db	has a small impact on parallaxes via twilight time	
1	1	fbs_1.5/third_obs/third_obs_pt15v1.5_10yrs.db	other third obs are neutral!	
1.001	1	fbs_1.5/third_obs/third_obs_pt30v1.5_10yrs.db		
1	1	fbs_1.5/third_obs/third_obs_pt45v1.5_10yrs.db		
0.995	0.995	fbs_1.5/third_obs/third_obs_pt60v1.5_10yrs.db		
0.994	0.995	fbs_1.5/third_obs/third_obs_pt90v1.5_10yrs.db		
0.979	1.012	fbs_1.5/twilight_neo/twilight_neo_mod1_v1.5_10yrs.db	twilight neo impact in V1.5 is small to negligible, but see V1.7	
0.995	1.014	fbs_1.5/twilight_neo/twilight_neo_mod2_v1.5_10yrs.db		
0.993	1.007	fbs_1.5/twilight_neo/twilight_neo_mod3_v1.5_10yrs.db		
0.992	1.003	fbs_1.5/twilight_neo/twilight_neo_mod4_v1.5_10yrs.db		
0.98	0.987	fbs_1.5/u60/u60_v1.5_10yrs.db		
0.992	0.999	fbs_1.5/var_expt/var_expt_v1.5_10yrs.db	neutral	
0.998	1.025	fbs_1.5/wfd_depth/wfd_depth_scale0.65_noddf_v1.5_10yrs.db		
0.974	1.006	fbs_1.5/wfd_depth/wfd_depth_scale0.65_v1.5_10yrs.db	WFD parallaxes degraded	
1.002	1.023	fbs_1.5/wfd_depth/wfd_depth_scale0.70_noddf_v1.5_10yrs.db		
0.978	1.005	fbs_1.5/wfd_depth/wfd_depth_scale0.70_v1.5_10yrs.db		
1.009	1.021	fbs_1.5/wfd_depth/wfd_depth_scale0.75_noddf_v1.5_10yrs.db		
0.986	1.004	fbs_1.5/wfd_depth/wfd_depth_scale0.75_v1.5_10yrs.db		
1.013	1.011	fbs_1.5/wfd_depth/wfd_depth_scale0.80_noddf_v1.5_10yrs.db		
0.992	0.998	fbs_1.5/wfd_depth/wfd_depth_scale0.80_v1.5_10yrs.db		
1.02	1.009	fbs_1.5/wfd_depth/wfd_depth_scale0.85_noddf_v1.5_10yrs.db		
0.995	0.996	fbs_1.5/wfd_depth/wfd_depth_scale0.85_v1.5_10yrs.db		
1.019	1.007	fbs_1.5/wfd_depth/wfd_depth_scale0.90_noddf_v1.5_10yrs.db		
1	1	fbs_1.5/wfd_depth/wfd_depth_scale0.90_v1.5_10yrs.db		
1.017	1.003	fbs_1.5/wfd_depth/wfd_depth_scale0.95_noddf_v1.5_10yrs.db		
0.996	0.988	fbs_1.5/wfd_depth/wfd_depth_scale0.95_v1.5_10yrs.db		
1.023	1.002	fbs_1.5/wfd_depth/wfd_depth_scale0.99_noddf_v1.5_10yrs.db	WFD parallaxes improved	
1.003	0.99	fbs_1.5/wfd_depth/wfd_depth_scale0.99_v1.5_10yrs.db		