Efficiency for Using Fibers

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Abstract

Analytical calculations with a very simple model show that the efficiency of fiber usage climbs fairly rapidly as the ELG target density increases from 2000/sq. deg. to 3000/sq. deg. when each portion of the sky is covered five to six times. Simluations show that the fiber usage efficiency generally increases when a partially realistic model is used so that the pixel positions shift from one pass to the next. The calculations are done with square arrays and square pixels, but the general conclusions should hold for circular tiles and pixels.

The efficient use of fibers requires that as few fibers as possible go unassigned, consistent with some prioritization among the LRGs, QSOs, and ELGs. We calculate here our efficiency for capturing four galaxy types, LRGs, QSO-targets, QSO-Lyman-alpha-forest, and ELGs under the following assumptions:

1. Highest priority is given to Lyman-alpha forest QSOs, which are known once their first spectrum is observed.

2. Lyman-alpha forest QSOs (QSO-IIs) require five observations.

3. The next highest priority is given to LRGs because of their large bias.

4. LRGs require two observations.

5. After that, priority is give to target-QSOs (QSO-Is).

6. Lowest priority is given to ELGs.

7. Very naive tiling is assumed: The pixels are assumed to fill the footprint perfectly. Repeated observations are made with fixed pixel locations.

8. Pure Poisson fluctuations are assumed.

Table 1: Distribution of galaxies per pixel with LRGs as 350/deg^2, for QSO-Is 175/deg^2, for QSO-IIs 75/deg^2. For ELGs here we have taken 2500/deg^2. The QSO-II are only the real ones (40/sq. deg)

number	LRG	ELG	QSO I	QSO II
0	0.60496	0.03952	0.77779	0.94418
1	0.30405	0.12768	0.19546	0.05423
2	0.07641	0.20627	0.02456	0.00156
3	0.01280	0.22215	0.00206	0.00003
4	0.00161	0.17944	0.00013	
5	0.00016	0.11596	0.00001	
6	0.00001	0.06244	-.00000	
7		0.02882		
8		0.01164		
9		0.00418		
10		0.00135		
11		0.00040		
12		0.00011		

1 Analytical Calculations

With these assumptions, everything can be calculated without any simulations. All we need is the density of the galaxy types. For LRGs we assume 350/deg^2, for QSO-Is 175/deg^2, for QSO-IIs 75/deg^2. Of the QSO-II targets, we expect 35 to be fakes. With 5000 fibers in an 7.18 deg^2 instrumented field, these correspond to 0.50 LRGs/pixel, 0.25 QSO-Is per pixel, and 0.11 QSO-IIs per pixel of which 0.057 should be real. We shall consider a number of values for the density of ELGs. With 11000 tilings of 7.18 deg^2, we cover nearly 80,000 deg^2 or an average of 5.67 coverings. Initially, we will consider a combination of coverings by 5 and by 6, though in practice it isn't possible to achieve such a covering. Inevitably there will be areas covered 7 times and 4 times.

With Poisson statistics, we can calculate the probabilities for the distributions of the various kinds of galaxies:

Losses occur when there are too few targets and a fiber has no galaxy to measure. Thus, if we increase the number of ELG targets, we will get more observed galaxies, even if the fraction of the targets we observe decreases.

We compute the probabilty of occurrence for every combination of LRGs, QSO-Is, QSO-IIs, and ELGs, just multiplying together the Poisson distributions from Table 1. Then for each combination, we determine what we would observe using our priotization. Thus, for example, if we allow 6 observations, the combination of 1 LRG, 1 QSO-I, 1 QSO-II, and 2 ELGS, will result in 0 LRGs, 1 QSO-I, 1 QSO-II, and 0 ELGs.

The results for various values of the ELG density and for 5 or 6 observations per pixel are given in Table 2 We see that with five passes we get 85% of the LRGs, 92% of the QSO-Is and 94% of the QSO-II's. The number of ELGs measured depends dramatically on the ELG density. Given the numbers of LRGs and QSOs measured, there are only so many fibers left for ELGs. With five passes, only 3.24 ELGs per pixel can be reached. At 3000 ELGs/sq. deg., we get 85% of that number, but if the ELG density is only 2000/sq. deg, we get instead 68%.

Table 2: Performance as function of observations per pixel and ELG density. The available number of LRGs per pixel is 0.56. The number of QSO-i's is 0.28 and the number of QSO-II's is 0.12.

ELG $\deg^{-2}$	LRG/pixel	QSO-I/pixel	QSO-II/pixel	ELG/pixel
5 passes				
1500.	0.459	0.231	0.056	1.760
2000.	0.459	0.231	0.056	2.206
2500.	0.459	0.231	0.056	2.568
3000.	0.459	0.231	0.056	2.849
3500.	0.459	0.231	0.056	3.060
4000.	0.459	0.231	0.056	3.211
4500.	0.459	0.231	0.056	3.318
5000.	0.459	0.231	0.056	3.390
5500.	0.459	0.231	0.056	3.439
6000.	0.459	0.231	0.056	3.470
6 passes				
1500.	0.472	0.245	0.056	1.925
2000.	0.472	0.245	0.056	2.464
2500.	0.472	0.245	0.056	2.931
3000.	0.472	0.245	0.056	3.320
3500.	0.472	0.245	0.056	3.634
4000.	0.472	0.245	0.056	3.877
4500.	0.472	0.245	0.056	4.060
5000.	0.472	0.245	0.056	4.193
5500.	0.472	0.245	0.056	4.288
6000.	0.472	0.245	0.056	4.354

We see that our prioritization fixes the number of LRGs, QSO-Is, and QSO-IIs, and only the number of ELGs varies as we increase the ELG density. We observe that the maximimum number of ELGs we could get in 5 observations is $5 - 0.459 \times 2 - 0.231 - 0.056 \times 5 - 0.044 = 3.527$ (the 0.044 is from bad QSOs), while for six observations it is 4.132. From these numbers we calculate the number of unused fibers and the fraction they represent:

Table 3: Unused fiber fraction as a function of ELG density

ELG deg^{-2}	available ELG/pixel	observed ELG/pixel	Unused Fiber Percentage
5 passes			
1500.	2.154	1.760	35.3
2000.	2.872	2.206	26.3
2250.	3.231	2.398	22.5
2500.	3.590	2.568	19.1
2750.	3.949	2.718	16.1
3000.	4.308	2.849	13.5
4000.	5.744	3.211	6.2
5000.	7.180	3.390	2.7
6000.	8.616	3.470	1.1
6 passes			
1500.	2.154	1.925	42.6
2000.	2.872	2.464	33.6
2250.	3.231	2.707	29.6
2500.	3.590	2.931	25.9
2750.	3.949	3.135	22.5
3000.	4.308	3.320	19.4
4000.	5.744	3.877	10.1
5000.	7.180	4.193	4.8
6000.	8.616	4.354	2.1

The dependence of the observed density of ELGs as a function of the ELG target density is shown in Fig. 1. We see that the observed density is rising rapidly when the target density is about 2500 deg $^{-2}$.

The dependence of the fraction of unused fibers as a function of the target density for ELGs is shown in Fig. 2.

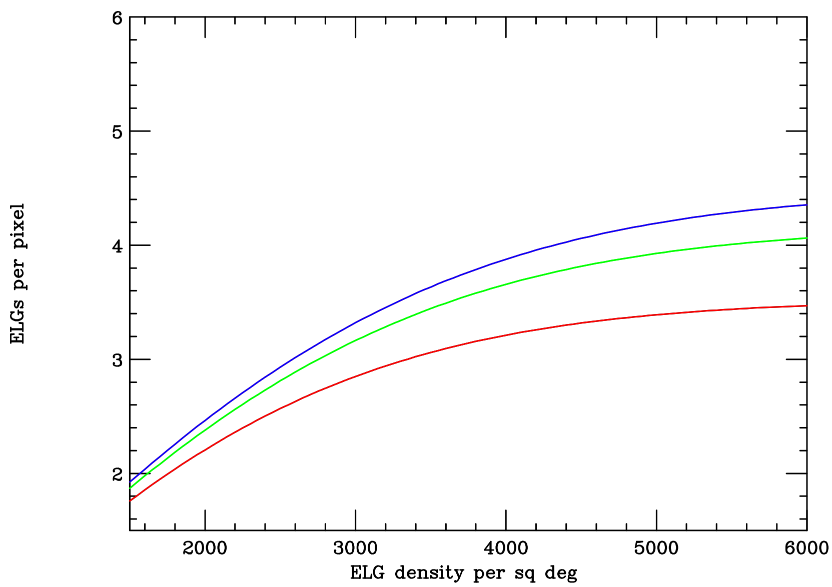

Figure 1: Observed number of ELGs per pixel as function of the target density for ELGs. The density of LRGs and QSOs is as described in the note. The red curve shows the observed density when the coverage is five times, the blue when it is six times, and the green shows the average for coverage of 5.67, obtained by interpolatiion.

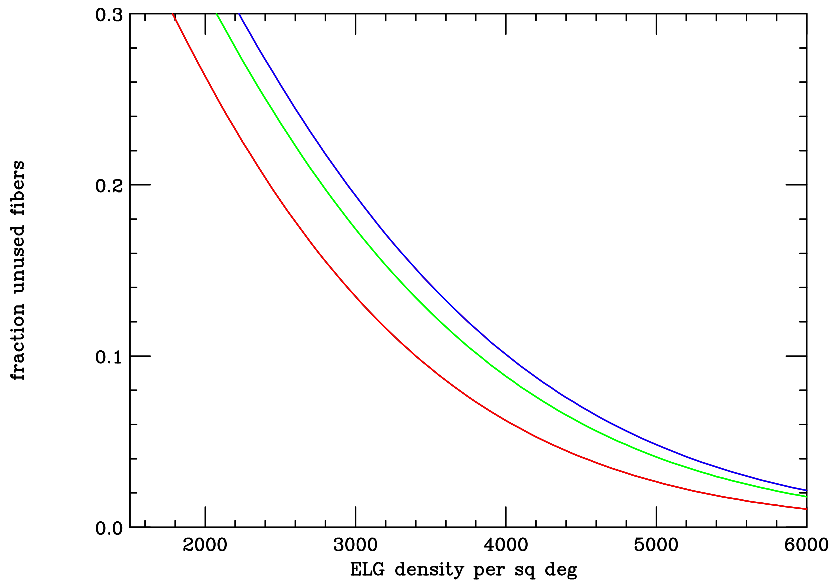

Figure 2: The fraction of unused fibers as function of the target density for ELGs. The density of LRGs and QSOs is as described in the note. The red curve shows the observed density when the coverage is five times, the blue when it is six times, and the green shows the average for coverage of 5.71, obtained by interpolatiion.

All these calculatons are very crude. They assume no correlations among the galaxies. The ignore tiling and assume that the pixels are observed repeatedly 5 or 6 times in the very same location. However, we can use these as a point of reference for simulations that do include these omitted effects.

2 Simulations

In the previous section, each pixel's location was the same for every one of the five or six passes. This isn't realistic. A simple simulation illustrates more general features. I take square pixels fit snugly against each other so a single pass covers the entire area. Then subsequent passes are offset by varying amounts. If the offset is nearly zero, then we should reproduce the analytical results of the previous section. With about 300×300 squre pixels, each covering 8 sq. deg., I find the following with zero offset, with five passes and standard densities for LRGs and QSOs, and 3000 ELGs/sq.deg.:

Table 4: Results of a simulation with about 300 x 300 square cells each with area 8 sq. deg. and five passes. The ELG density is 3000/sq. deg. The pixels are kept in fixed locations for all five observations.

observations	LRG	QSO I	QSO II	ELG
0	0.073	0.043	0.009	2.11
1	0.017	0.240	0	2.75
2	0.478	0	0.0001	0
3	0	0	0.0001	0
4	0	0	0	0
5	0	0	0.113	0

Now with the same parameters, but offsetting the four final passes by a half-cell in four diagonal directions, I find

Generally, the dithering has improved the results. However, it has also caused us to miss some of the observations of the Lyman-alpha forest QSOs.

The exact prescription for choosing fiber assignments in the above is

1. If there is a QSO II, assign the fiber to it. In fact, we take the first QSO II if there is more than one. We should also not go beyond 5 observations of the QSO II.

Table 5: Results of a simulation with about 300 x 300 square cells each with area 8 sq. deg. and five passes. The ELG density is 3000/sq. deg. The pixels are shifted by ± 0.01 deg in the x and y directions, i.e. diagonally away from the position for the first observation. Somewhat improved results are obtained.

observations	LRG	QSO I	QSO II	ELG
0	0.024	0.017	0.002	1.98
1	0.024	0.267	0.001	2.88
2	0.519	0	0.003	0
3	0	0	0.006	0
4	0	0	0	0.006
5	0	0	0.104	0

2. If the fiber is not yet assigned and there is an LRG that already has one exposure, assign the fiber to it. Again, we take the first such LRG.

3. If the fiber is not yet assigned and there is an LRG with no exposures, assign the fiber to it, again taking the first such LRG.

4. If the fiber is not yet assigned and there is a QSO I with no exposures, assign the fiber to it, again taking the first such QSO I.

5. If the fiber is not yet assigned and there is an ELG with no exposures, assign the fiber to it.

Simulations carried out with six passes yield better results, of course. These are consistent with the analytical calculations of the previous section. Now with the same parameters, but offsetting the four final passes by a half-cell in four diagonal directions, I find

Table 6: Results of a simulation with about 300 x 300 square cells each with area 8 sq. deg. and six passes. The ELG density is 3000/sq. deg. The pixels are kept in fixed locations for all six observations.

observations	LRG	QSO I	QSO II	ELG
0	0.025	0.025	0.009	1.57
1	0.048	0.259	0	3.29
2	0.494	0	0.0002	0
3	0	0	0	0
4	0	0	0.0001	0
5	0	0	0.113	0

Table 7: Results of a simulation with about 300 x 300 square cells each with area 8 sq. deg. and six passes The ELG density is 3000/sq. deg. The pixels are shifted by ± 0.01 deg in the x and y directions, i.e. diagonally away from the position for the first two observation. Somewhat improved results are obtained.

observations	LRG	QSO I	QSO II	ELG
0	0.011	0.009	0.002	1.34
1	0.014	0.275	0.0001	3.52
2	0.542	0	0.004	0
3	0	0	0.002	0
4	0	0	0.006	0
5	0	0	0.108	0