BGS survey simulations

how I learned to stop worrying and love bright time

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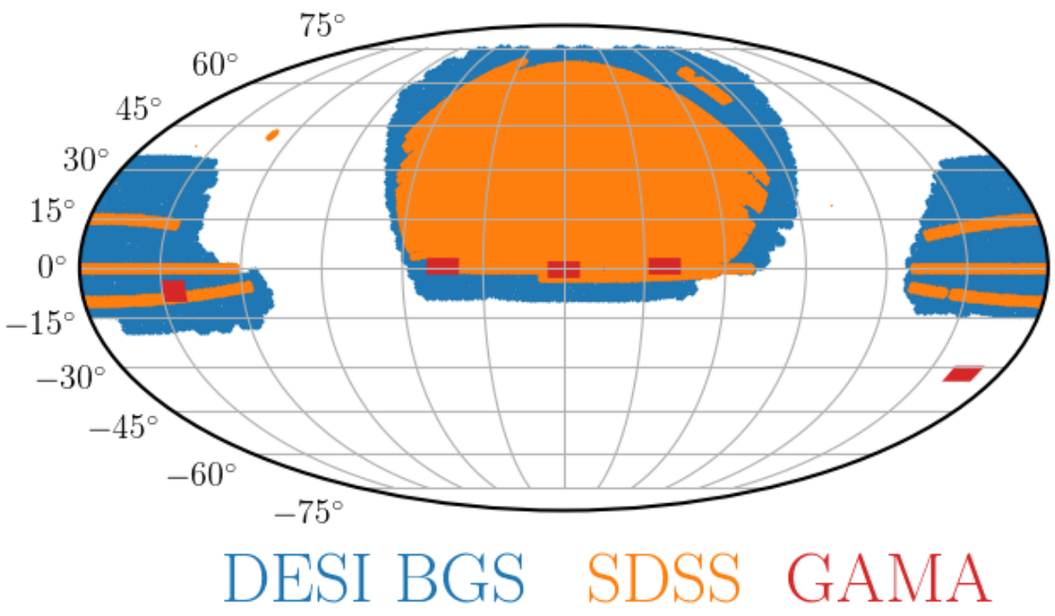
berkeley desi meeting july 2019

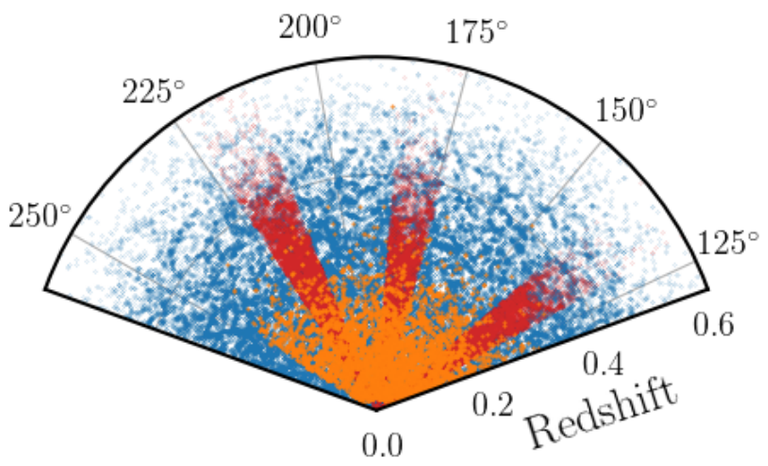
*the **Bright Galaxy Survey** will observe…*

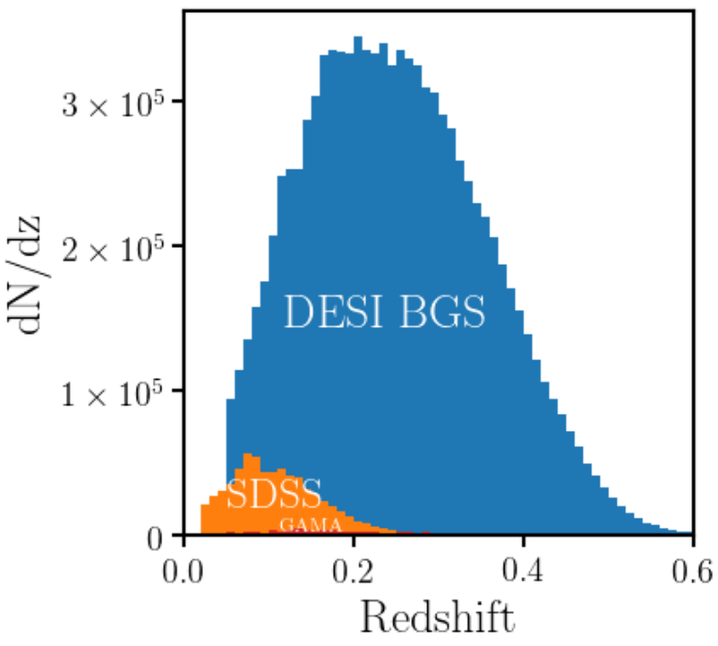
10 million galaxy spectra over 14,000 deg²

~2 magnitudes deeper than SDSS main survey

~800 deg² to r < 19.5 and ~600 deg² 19.5 < r < 20.







the Bright Galaxy Survey will observe…

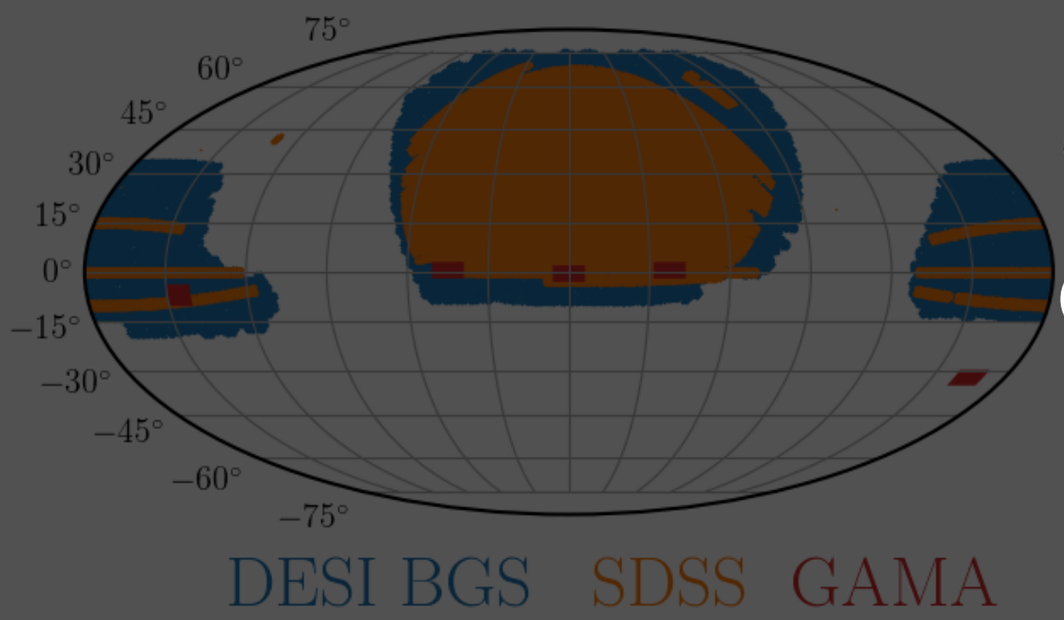
10 million galaxy spectra over 14,000 deg²

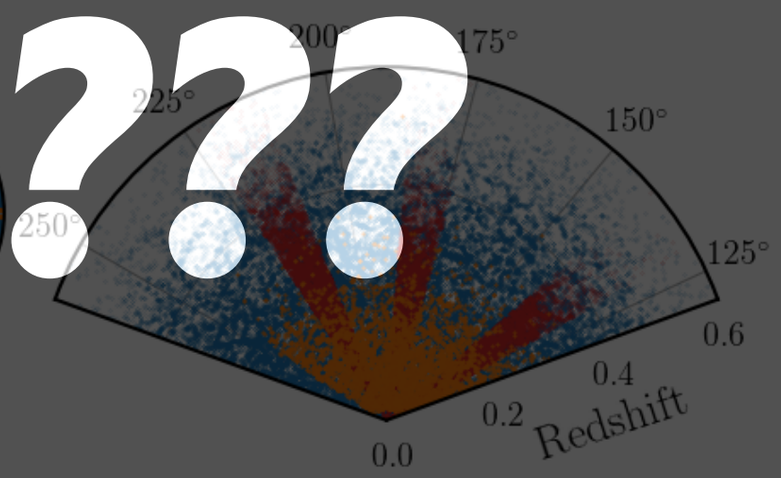
~2 magnitudes deeper than SDSS main survey

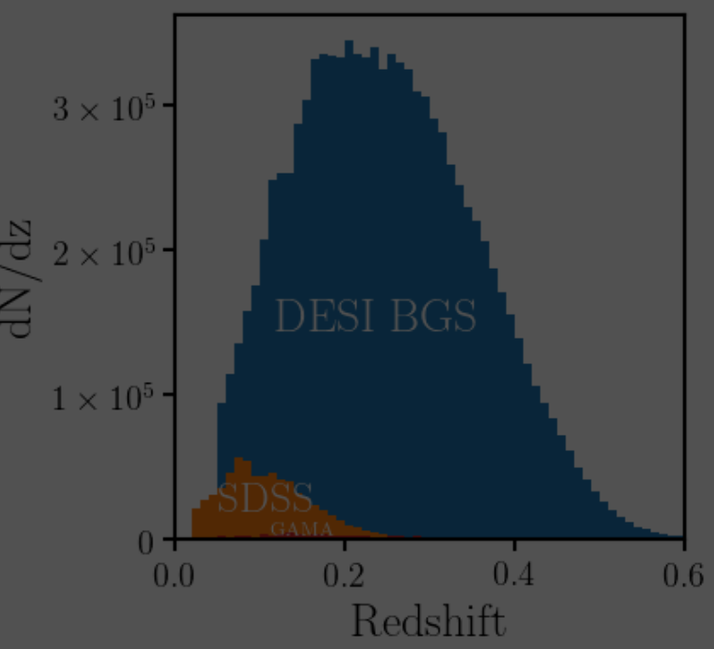
first extragalactic survey during bright time

~800 deg² to r < 19.5 and ~600 deg² 19.5 < r < 20.

(bright sky) = 2.5 x (dark sky) @ 7000A







…forecasts based on sky brightness from

UVES dark sky

+

*Krisciunas & Schaefer (**1991**)*

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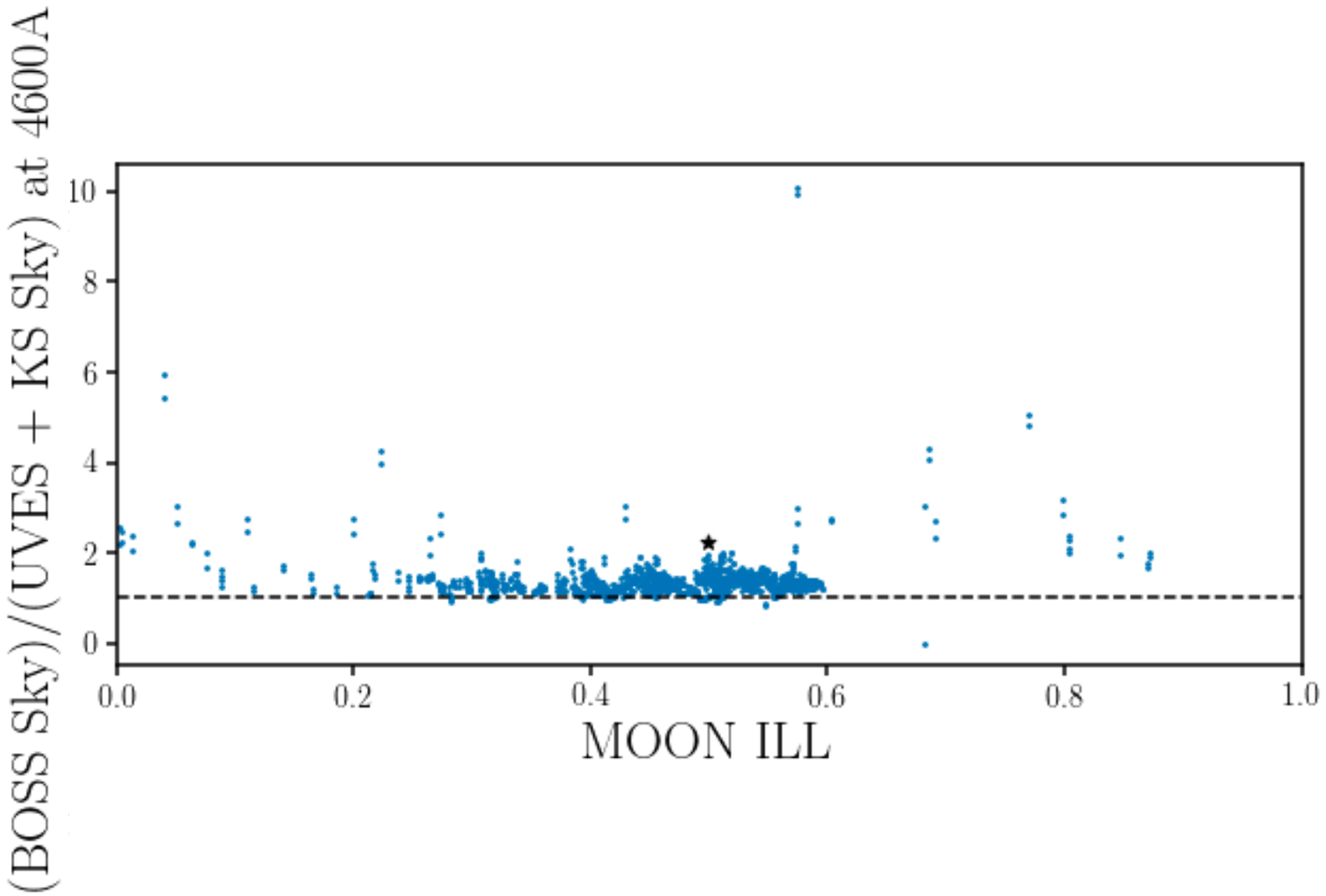
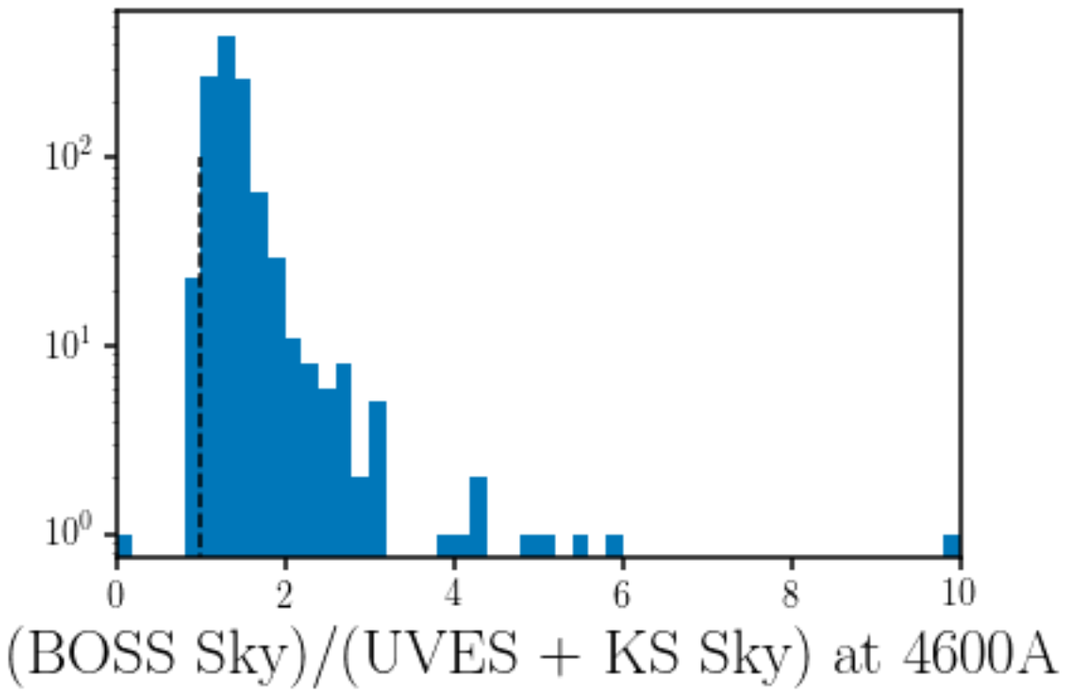
Everett Collection

PAN AM

*UVES dark sky + Krisciunas & Schaefer (**1991**)*
underestimates the sky brightness*





**according to BOSS sky spectra*

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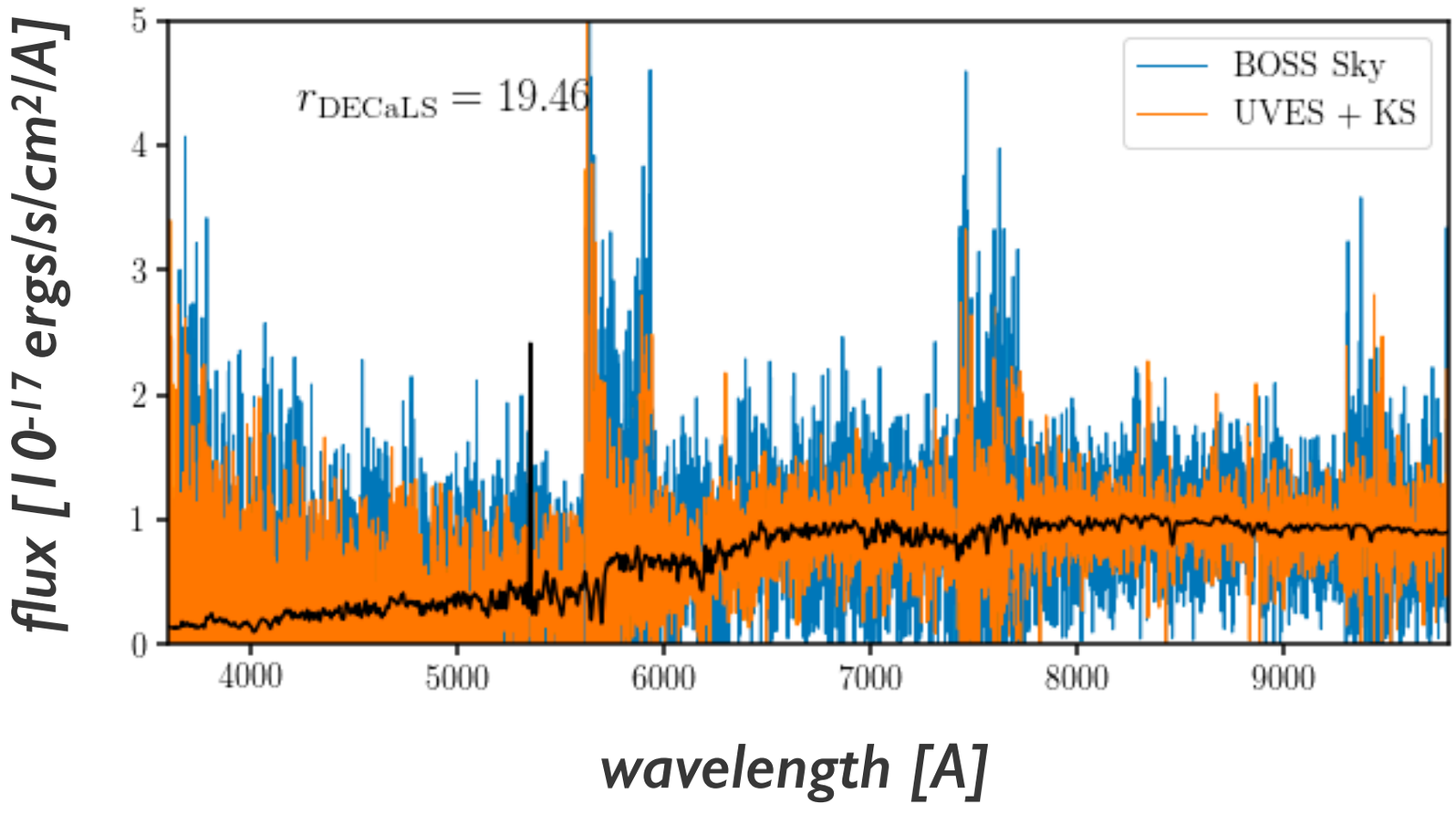
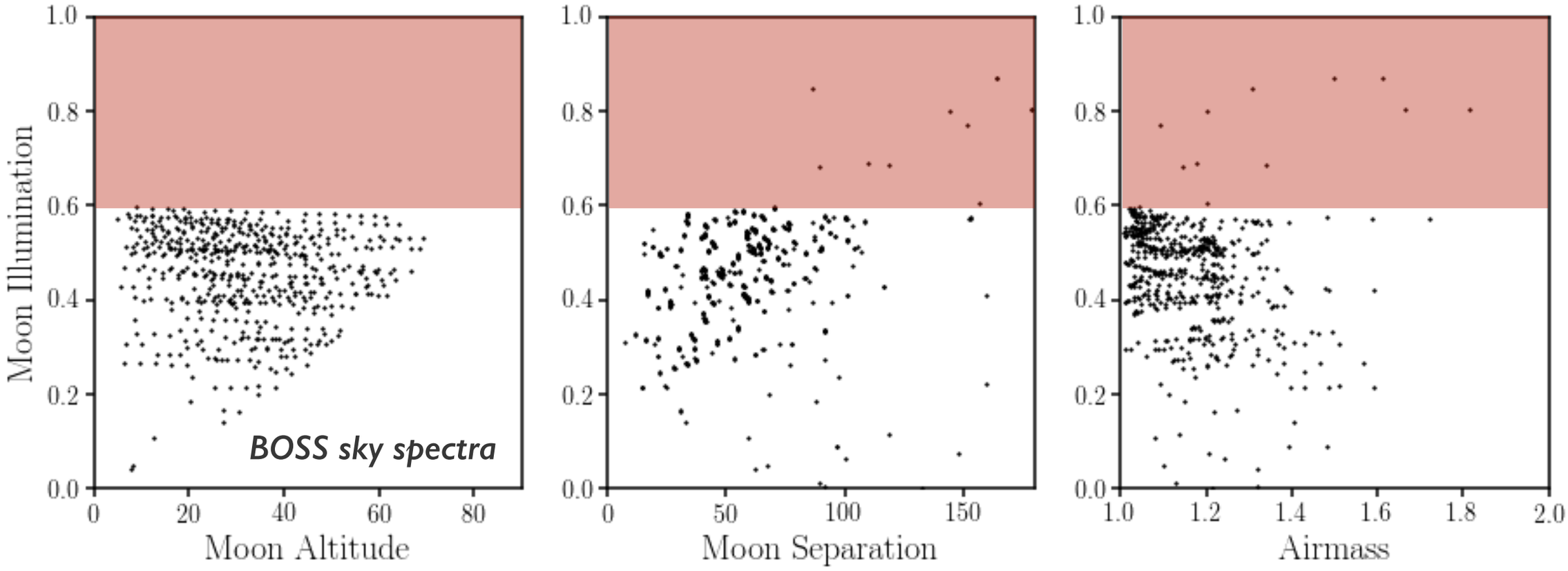
***underestimates** the sky brightness*



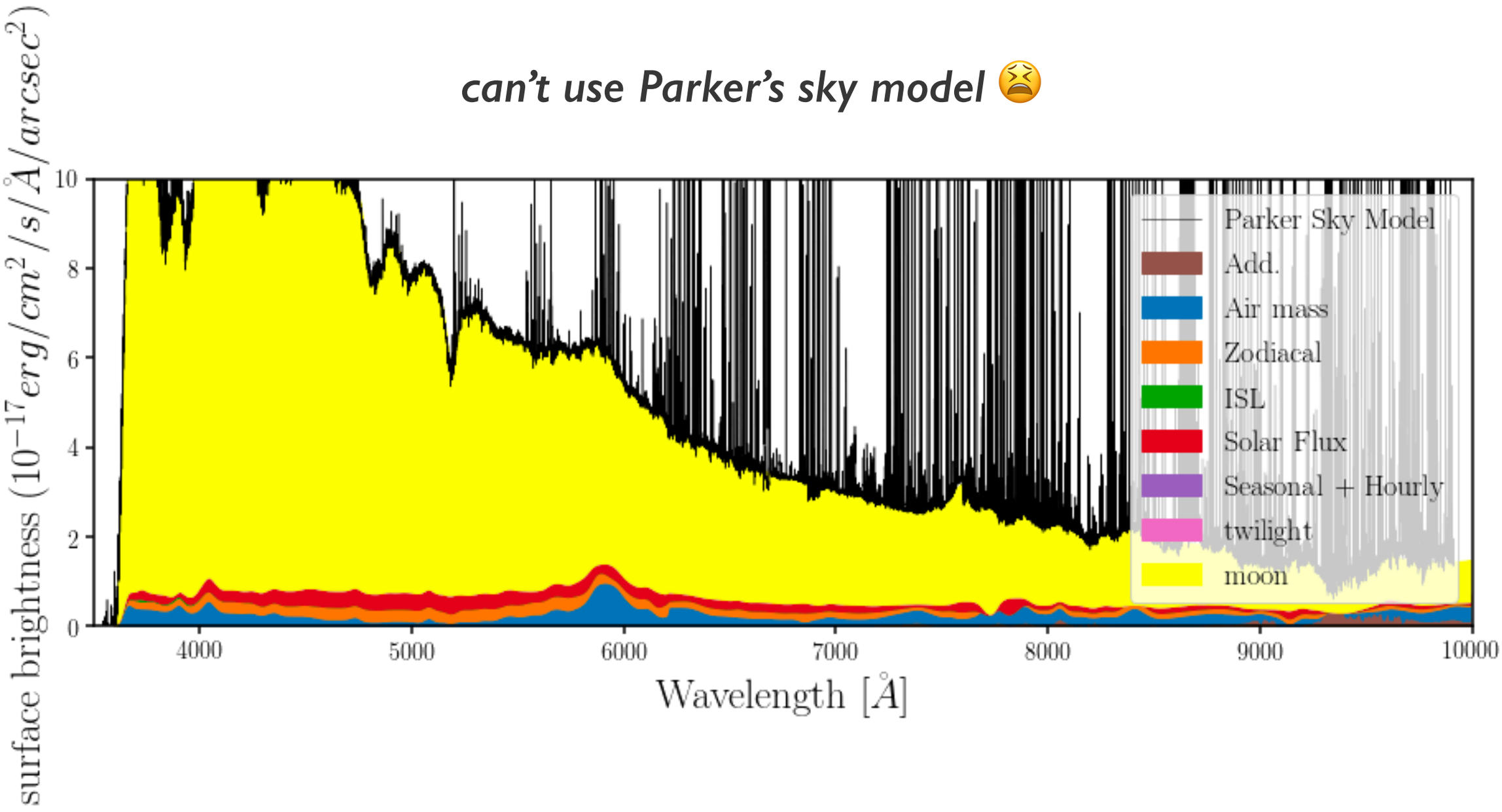
**according to BOSS sky spectra*

BOSS sky spectra do not fully span the observing conditions of BGS



BGS exposures often above moon illumination of 0.6

can't use Parker's sky model 😫



credit: Parker's thesis

improved sky model = *(UVES dark sky) + (re-fit KS model) + (twilight model)*

2019 lunar eclipse (credit: manu schaan)

improved sky model = *(UVES dark sky)* + *(re-fit KS model)* + *(twilight model)*

$$B_{\rm moon} = f(\rho)\ I^{*}10^{-0.4k\,X(Z_m)}[1-10^{-0.4k\,X(Z)}]$$

scattering function: $f(\rho) = C_R\,[1.06+\cos^2(\rho)] + 10^{C_{M,0}-\rho/C_{M,1}}$

re-fit $C_R, C_{M,0}, C_{M,1}$ *to BOSS sky spectra*

2019 lunar eclipse (credit: manu schaan)

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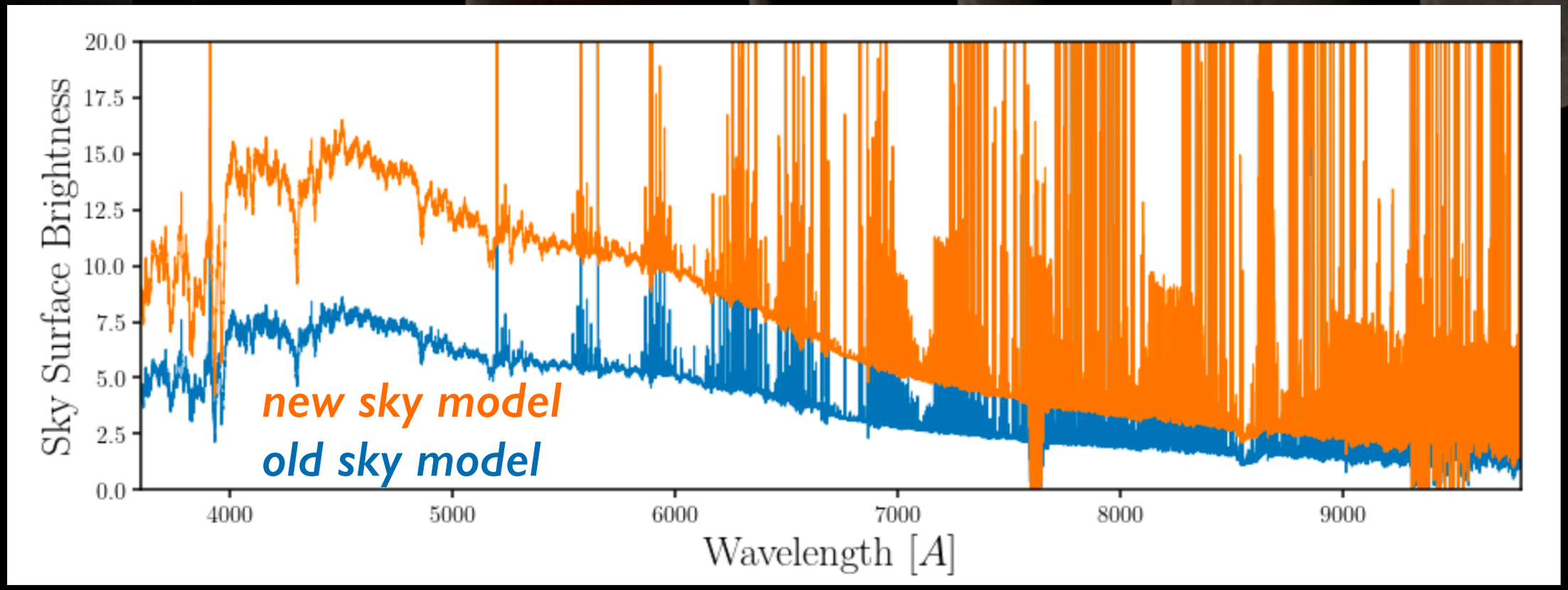
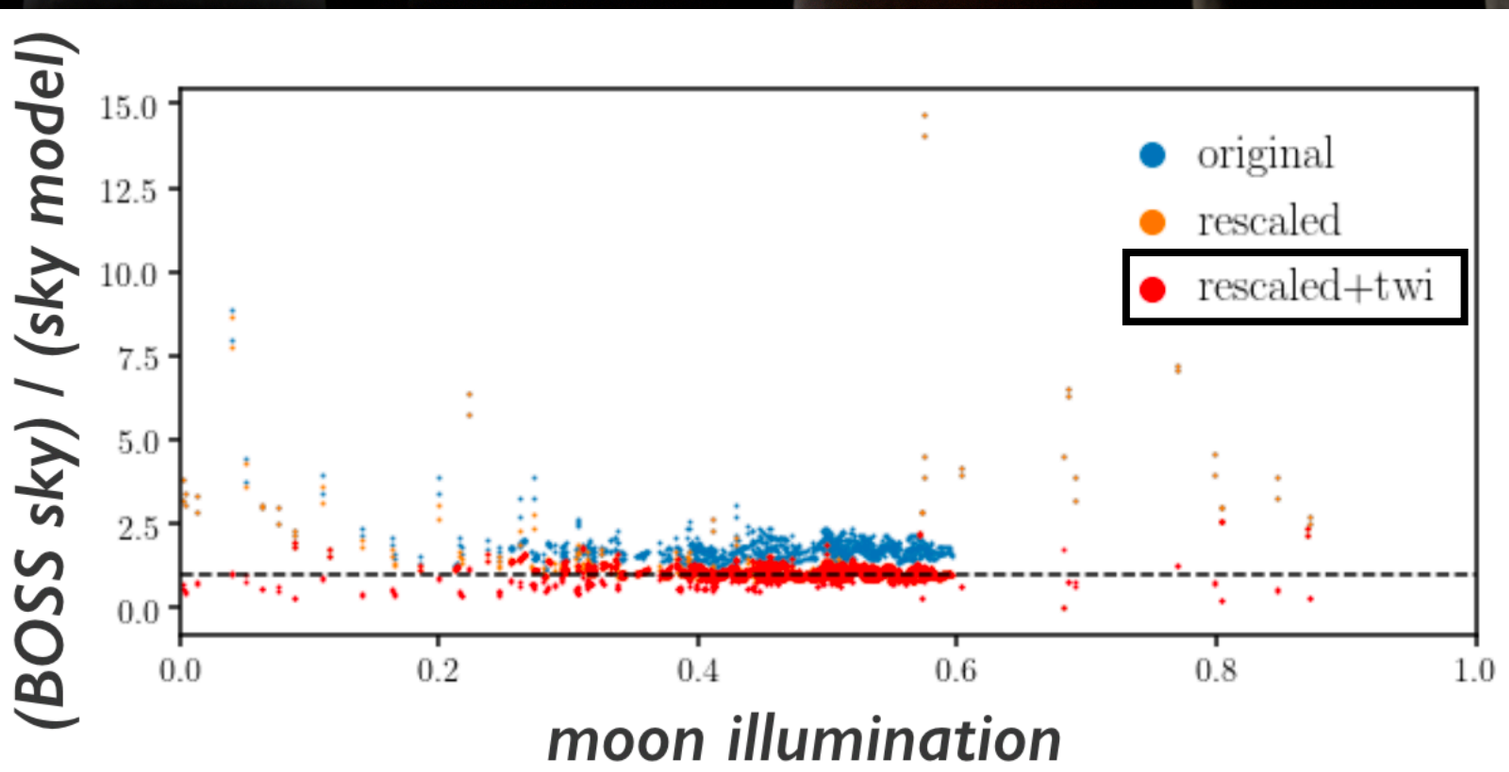
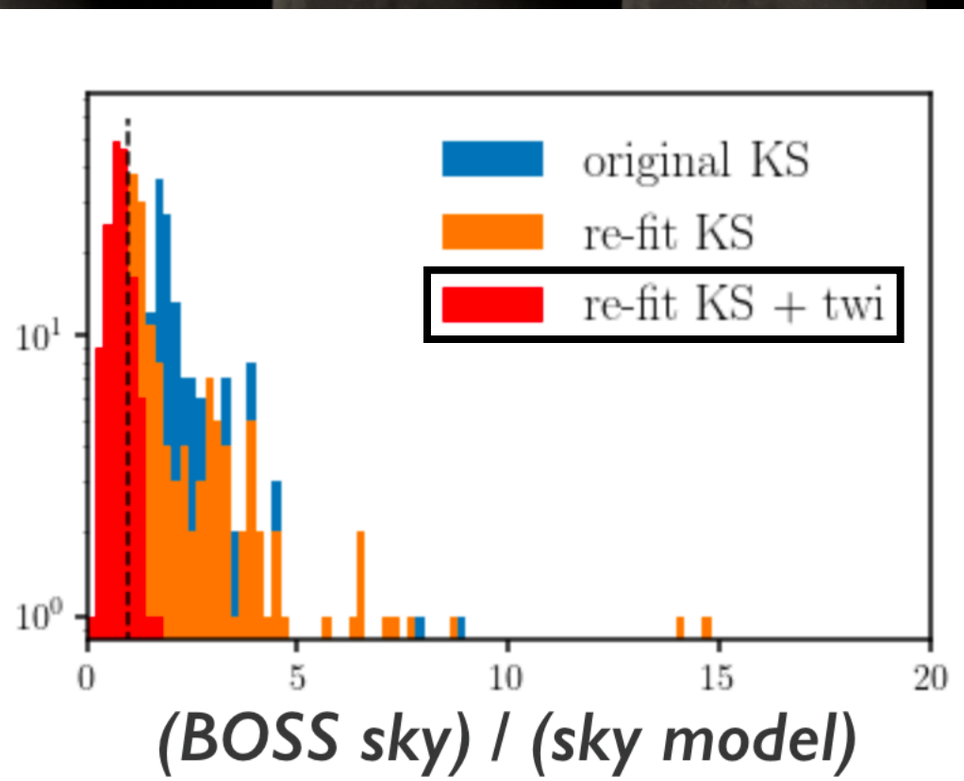


improved sky model = *(UVES dark sky)* + *(re-fit KS model)* + *(twilight model)*

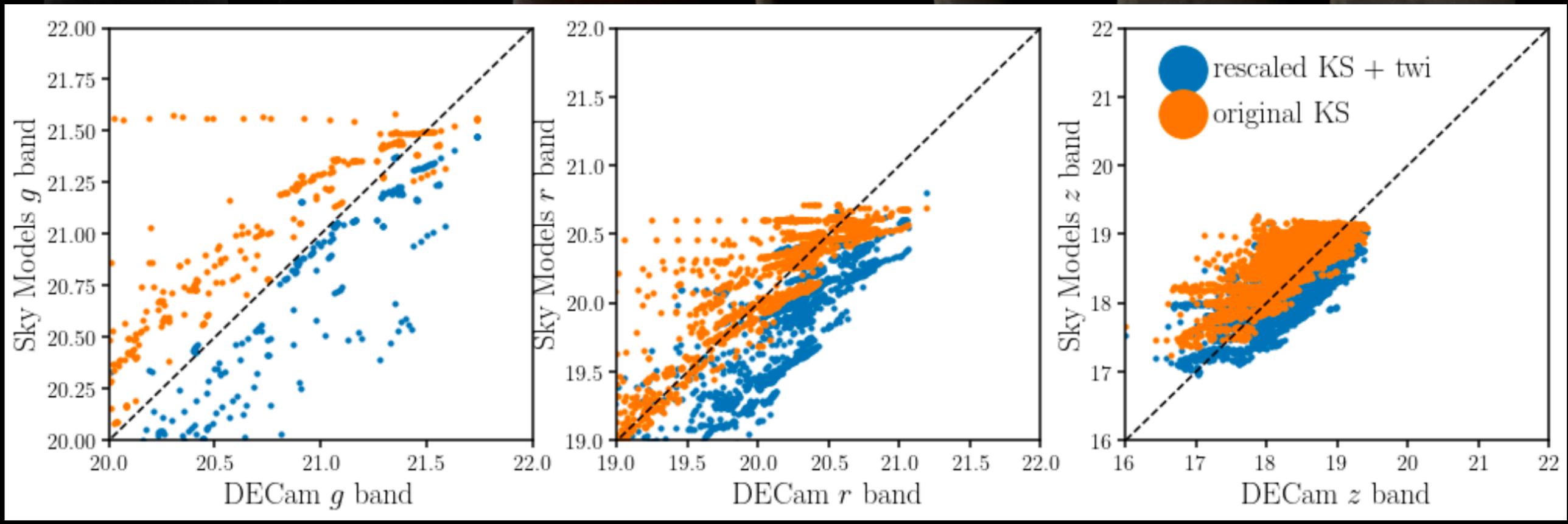
better reproduces BOSS sky





improved sky model = *(UVES dark sky)* + *(re-fit KS model)* + *(twilight model)*

and also DECam sky



source spectra

AGES templates matched to Legacy photometry

add emission line fluxes from GAMA DR3

match DECaLS r-band 1” aperture flux

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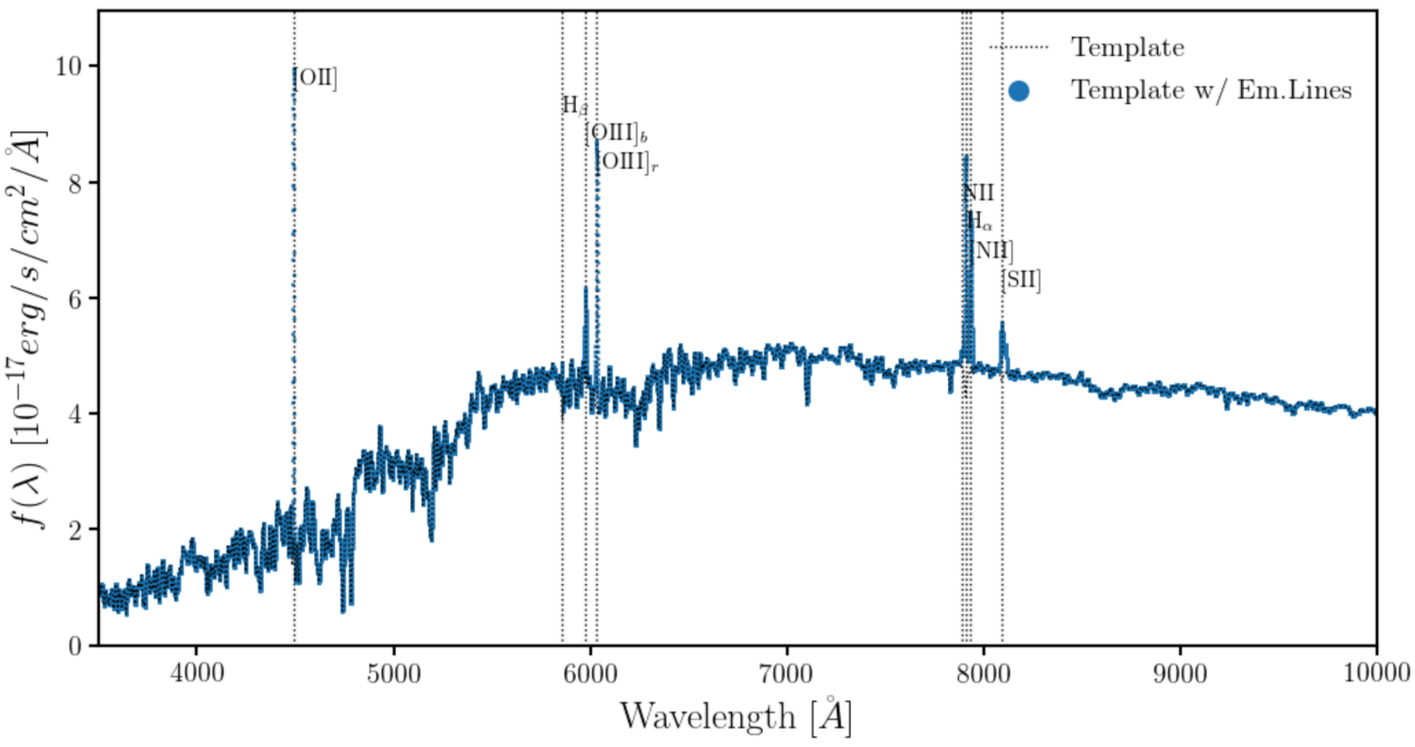

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add emission line fluxes from GAMA DR3

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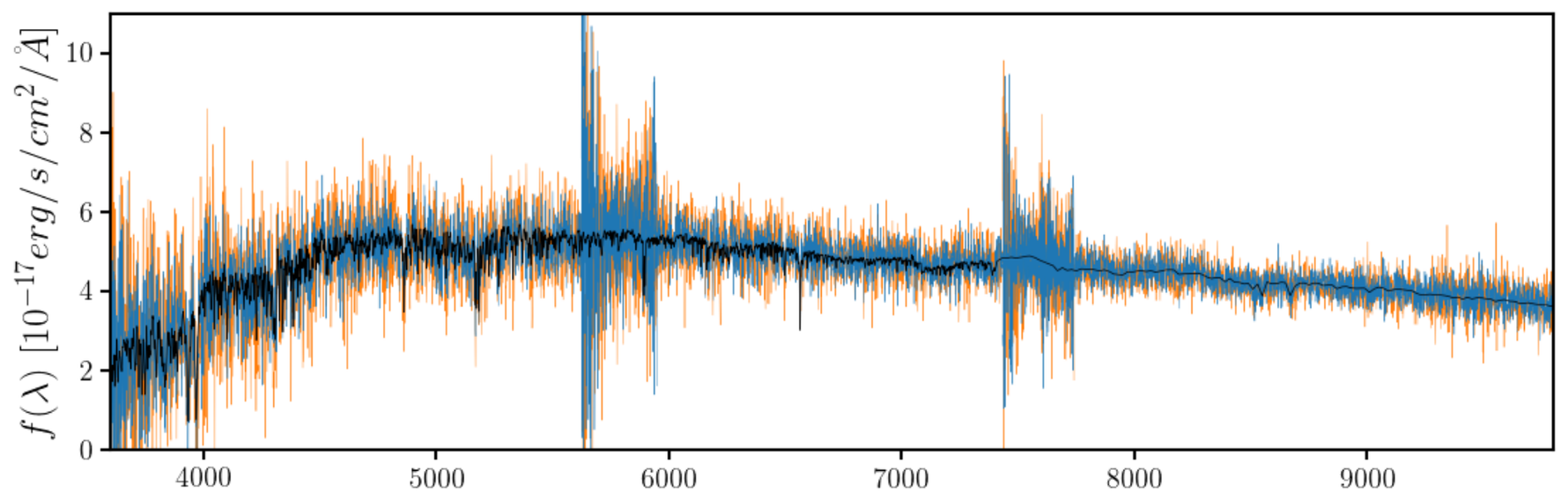
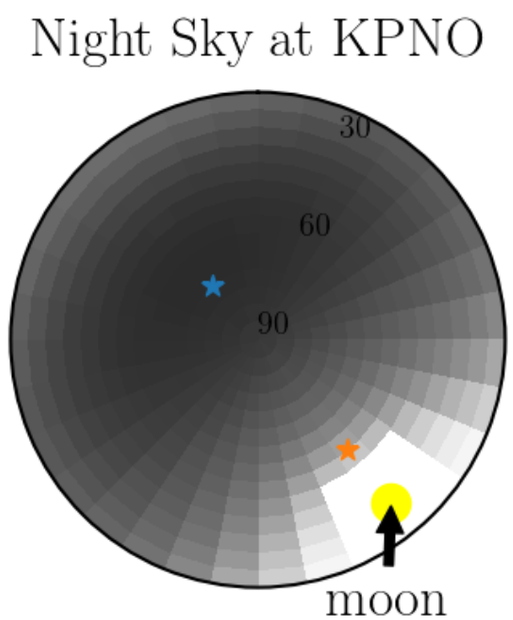
improved sky model

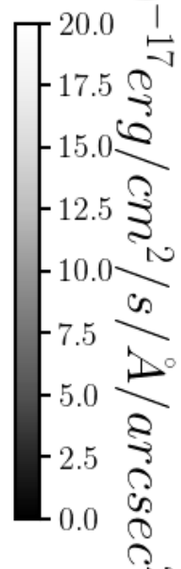
instrument model
github.com/desihub/specsim

realistic BGS spectra

messing up the spectra







improved sky model

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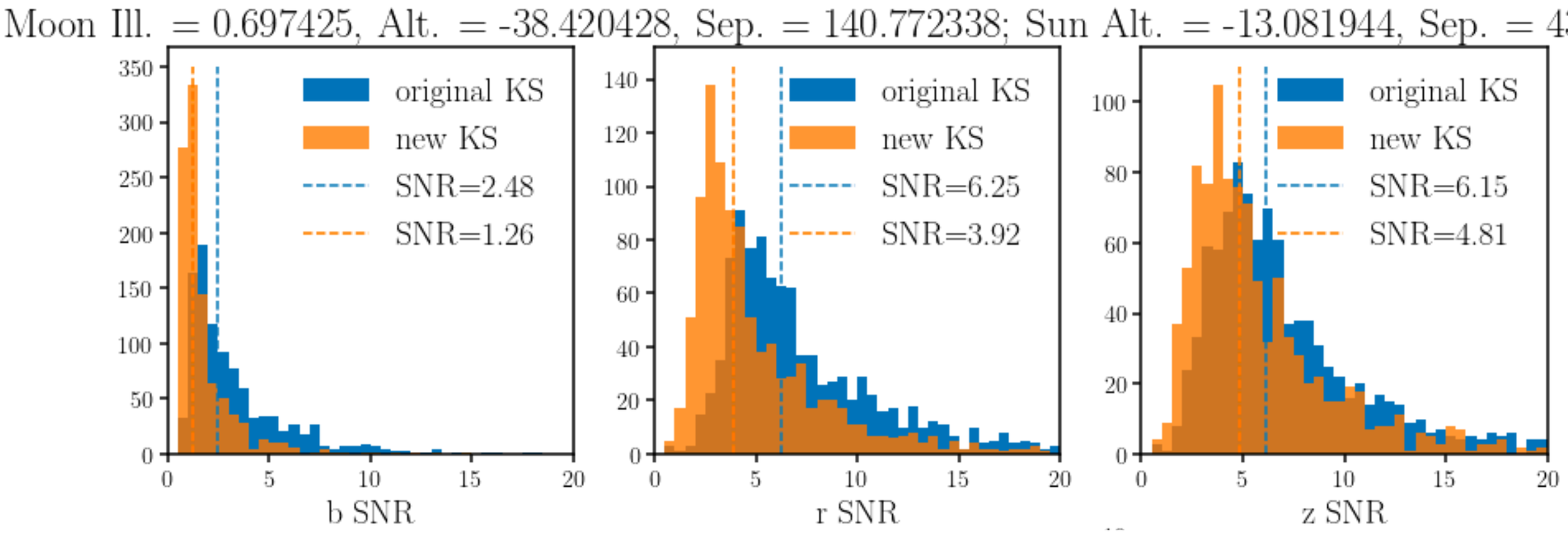
realistic BGS spectra

messing up the spectra

improved sky model reduces the signal-to-noise of BGS spectra



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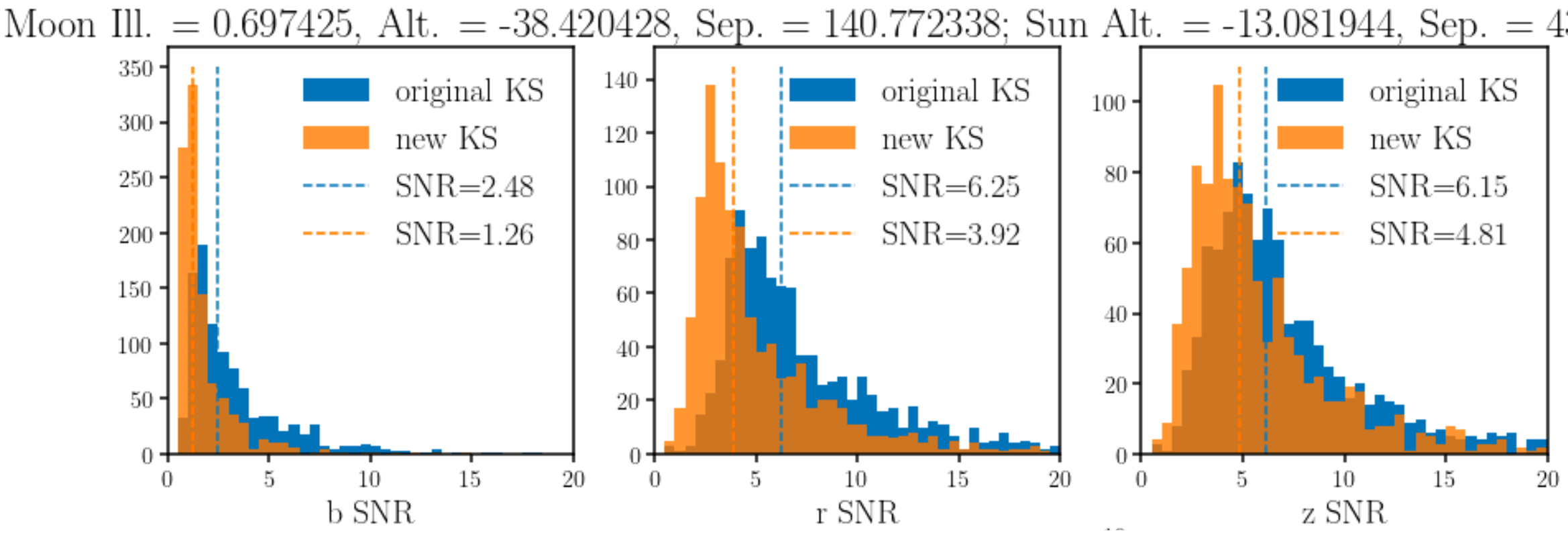
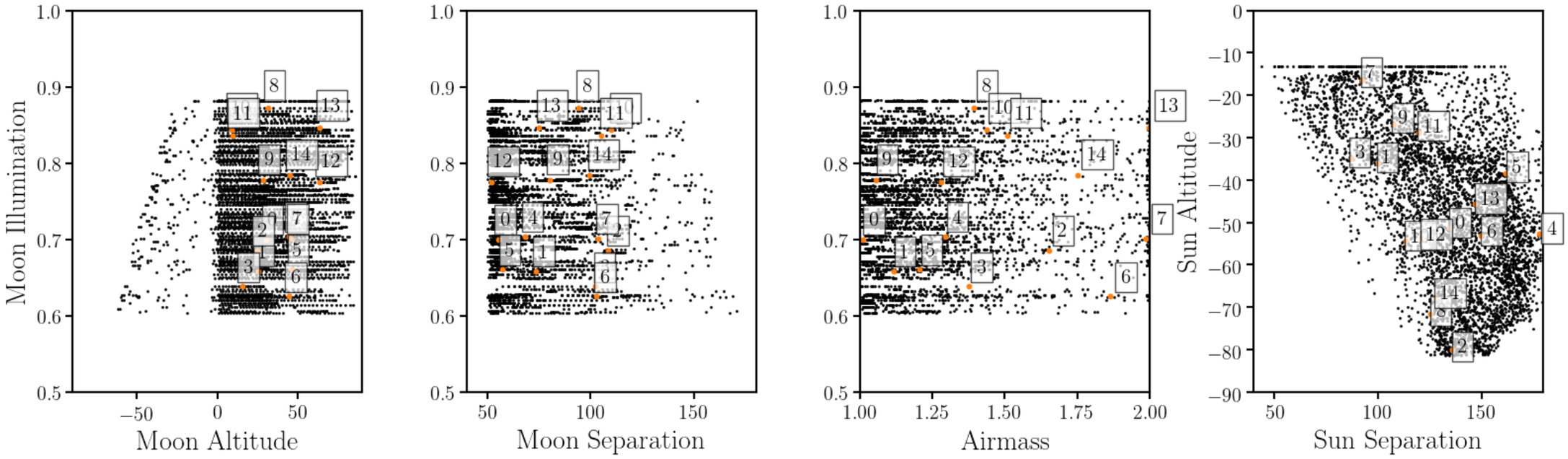


how does this impact redshift success rates?

redshift success rate for BGS exposures from surveysim

Table 1: 15 exposures sampled from surveysim exposures

	$t_{\rm exp}$	airmass	moon frac.	moon alt.	moon sep.	sun alt.	sun sep.
0.	423	1.01	0.70	30.35	55.33	-51	135
1.	461	1.12	0.66	25.11	73.55	-36	100
2.	919	1.65	0.69	24.71	108.65	-80	136
3.	558	1.38	0.64	15.69	102.49	-35	87
4.	547	1.29	0.70	44.69	68.22	-53	178
5.	662	1.21	0.66	46.10	57.50	-38	162
6.	976	1.86	0.63	44.70	102.59	-53	150
7.	1099	1.99	0.70	45.85	103.62	-16	93
8.	722	1.39	0.87	31.68	94.16	-72	126
9.	407	1.05	0.78	28.34	80.18	-27	107
10.	765	1.44	0.84	8.69	109.87	-54	113
11.	826	1.51	0.84	9.64	105.27	-29	120
12.	611	1.28	0.77	63.42	51.97	-54	121
13.	824	2.00	0.85	63.64	75.12	-46	147
14.	1170	1.75	0.78	45.32	99.55	-68	128



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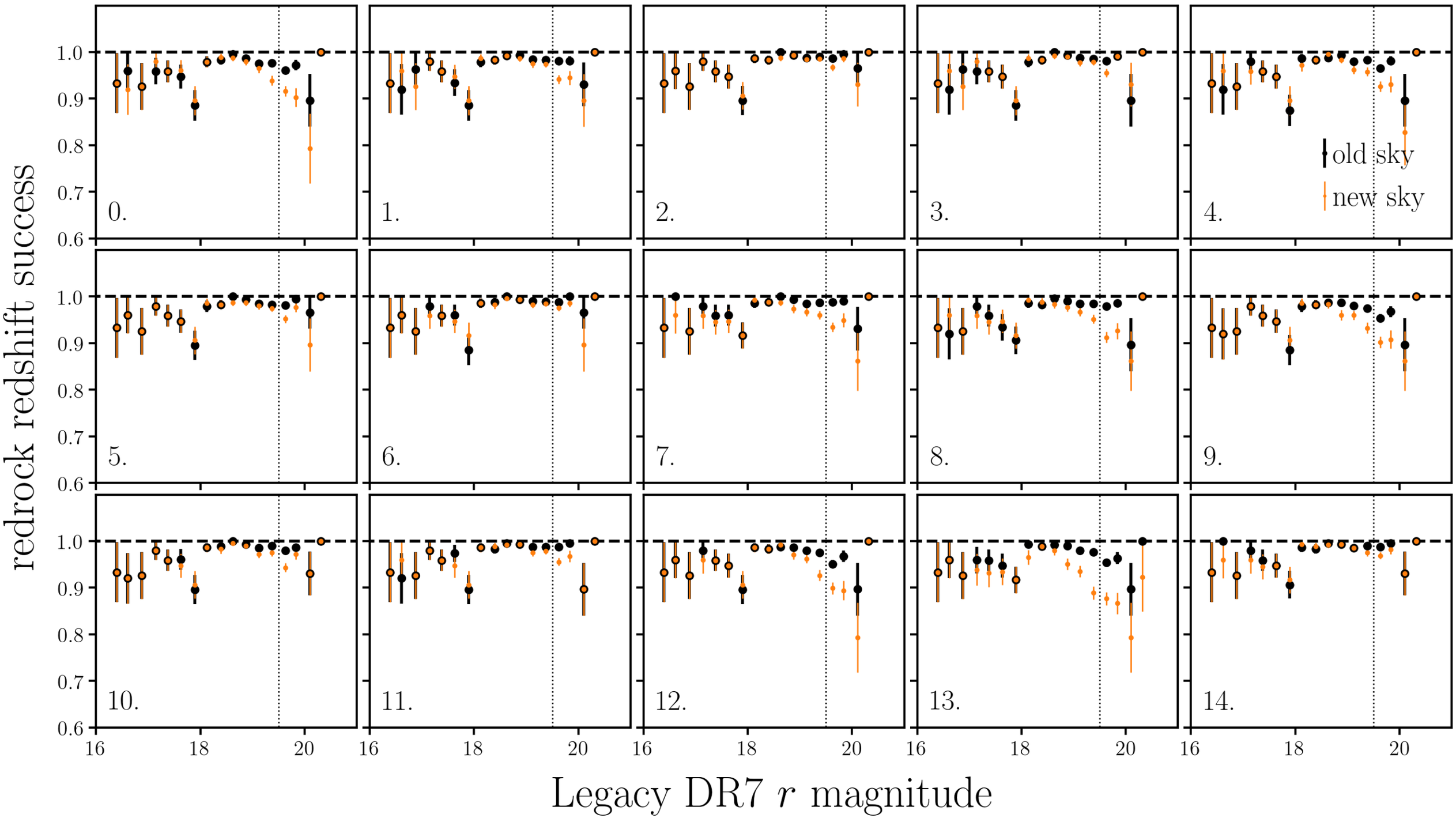

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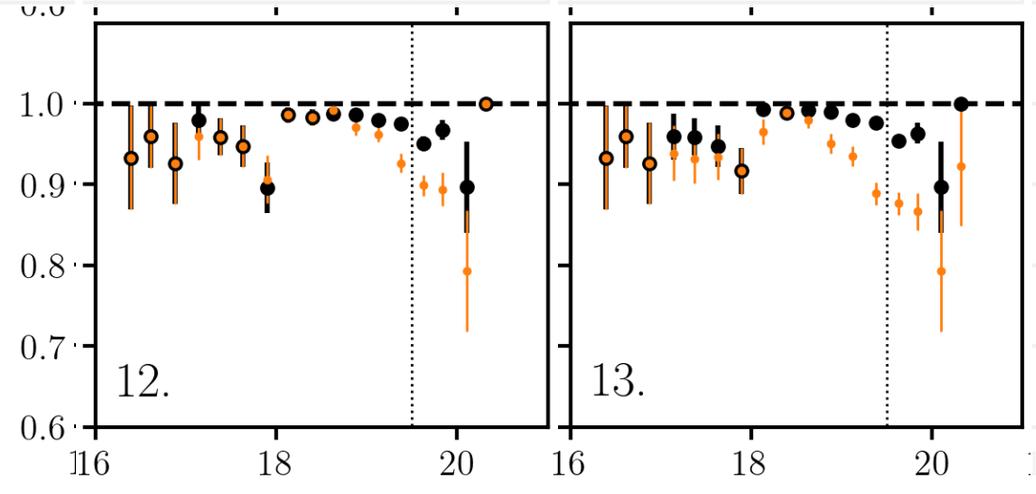


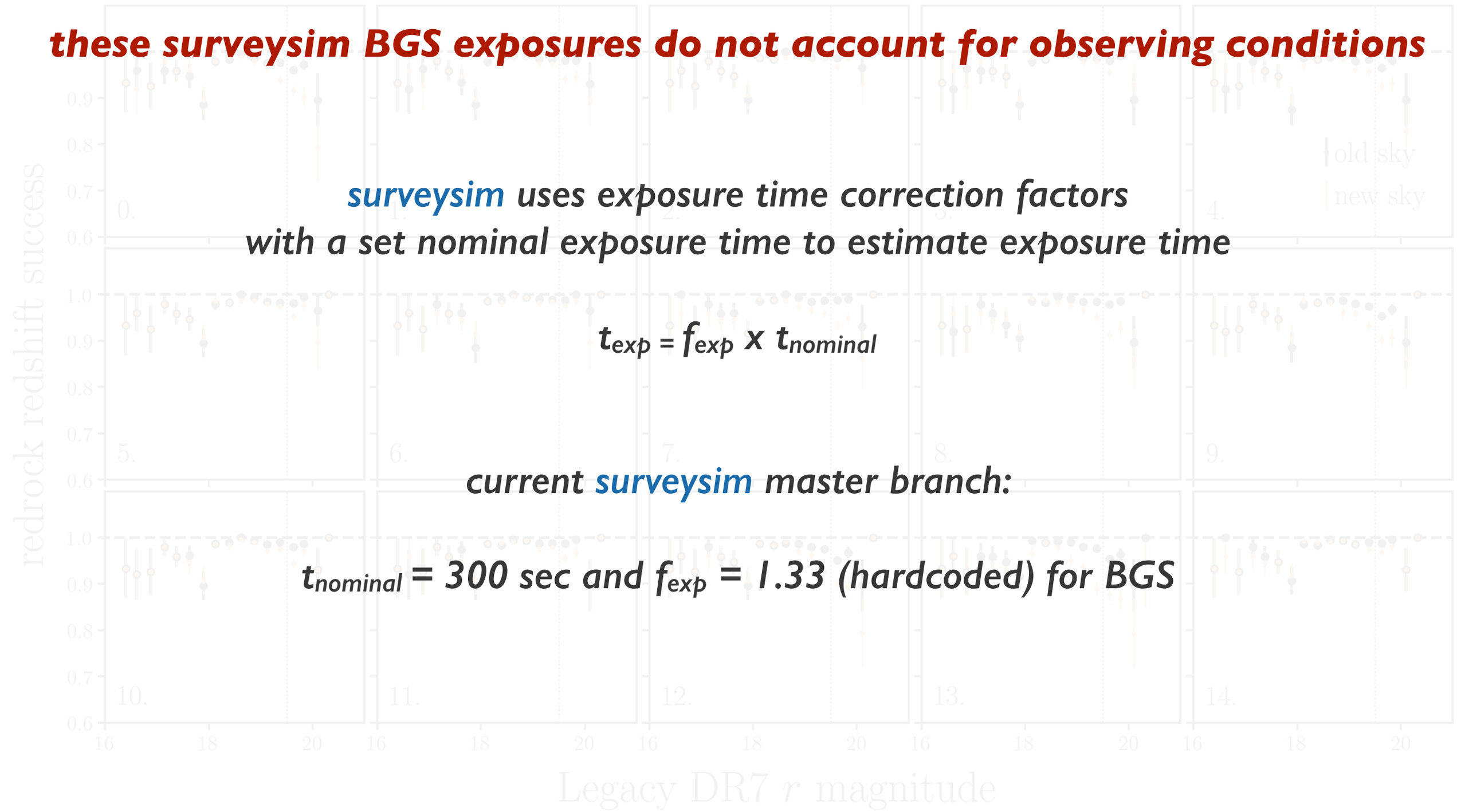
these surveysim BGS exposures do not account for observing conditions

surveysim uses exposure time correction factors
with a set nominal exposure time to estimate exposure time

$$t_{exp} = f_{exp} \times t_{nominal}$$

current surveysim master branch:

$t_{nominal}$ *= 300 sec and* f_{exp} *= 1.33 (hardcoded) for BGS*



$$\mathrm{SNR} = \frac{S \times t}{\sqrt{(S + sky + n_{pix} \times DC) \times t + n_{pix} \times RN^2}}$$

for low source flux and noise dominated by sky — i.e. BGS

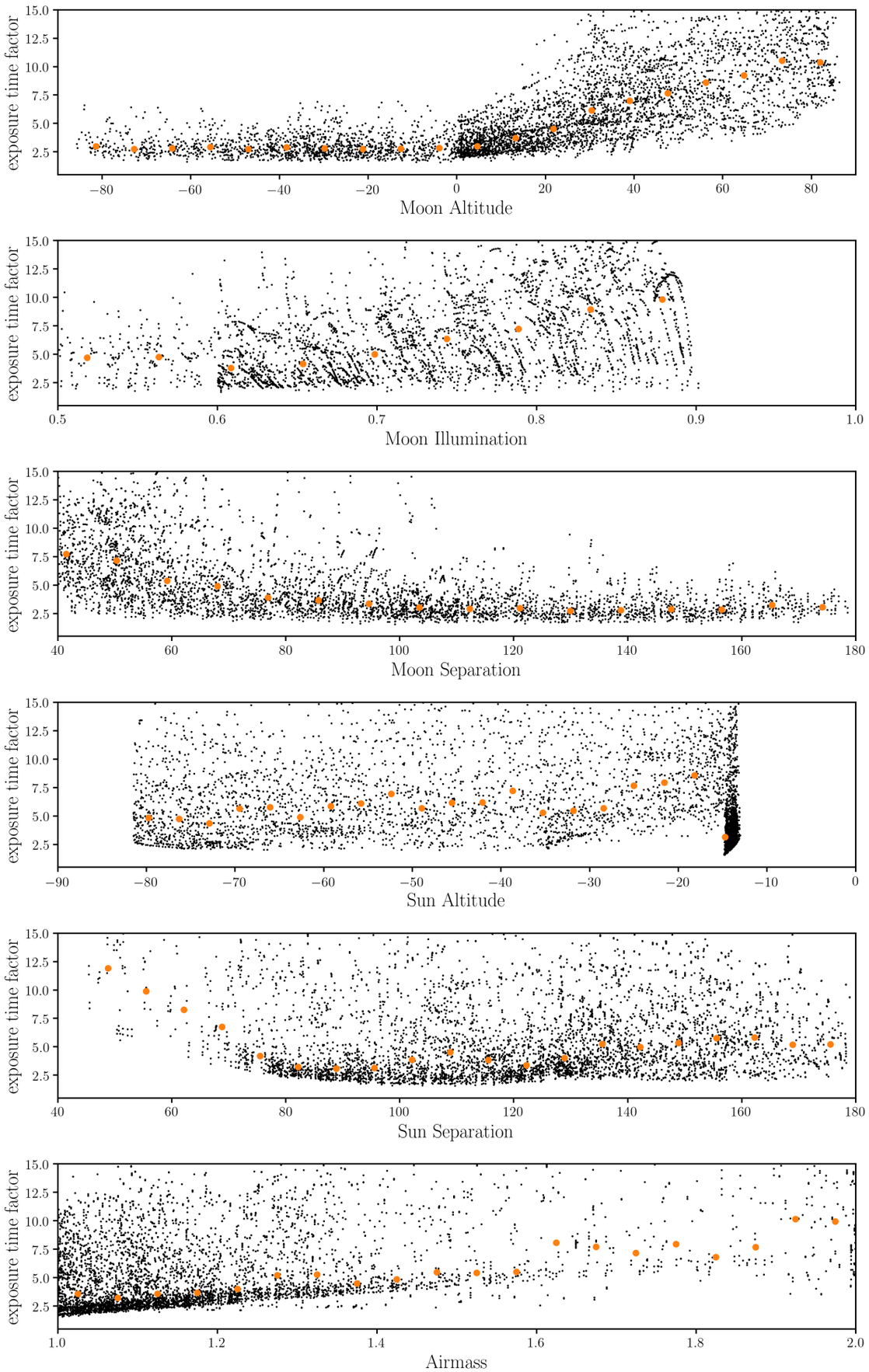
$$\mathrm{SNR} \approx S \times \sqrt{\frac{t}{sky}}$$

to keep SNR the same $t_{\mathrm{bright}} = t_{\mathrm{nominal}} \times \frac{(sky_{\mathrm{bright}})}{(sky_{\mathrm{nominal}})}$

credit: Parker's thesis

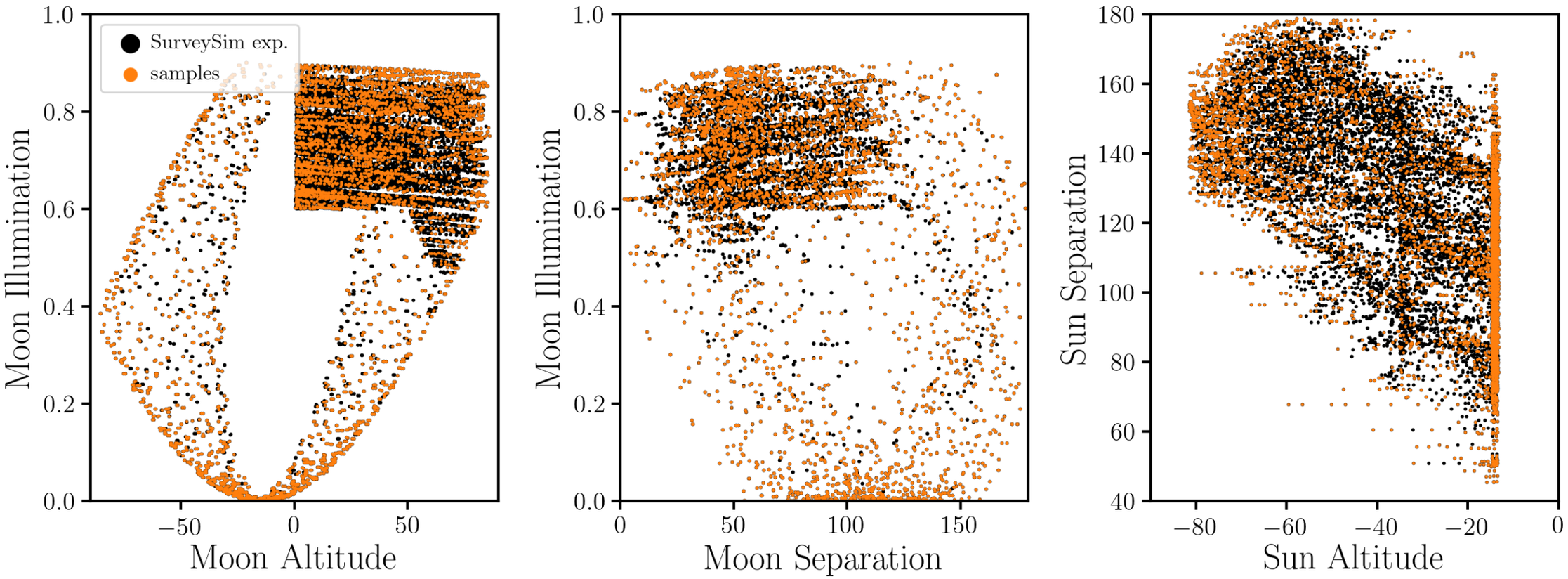
exposure time correction factor as a function of observing conditions

$$f_{\rm exp} = \frac{(sky_{\rm bright})}{(sky_{\rm nominal})}$$



at 4500A

$$f_{\rm exp} = \frac{(sky_{\rm bright})}{(sky_{\rm nominal})} \sim GP(\theta_{obs} = \text{observing condition})\ \text{emulator}^{*,**}$$



***GP training set** sampled from the convex hull of exposures⁺*

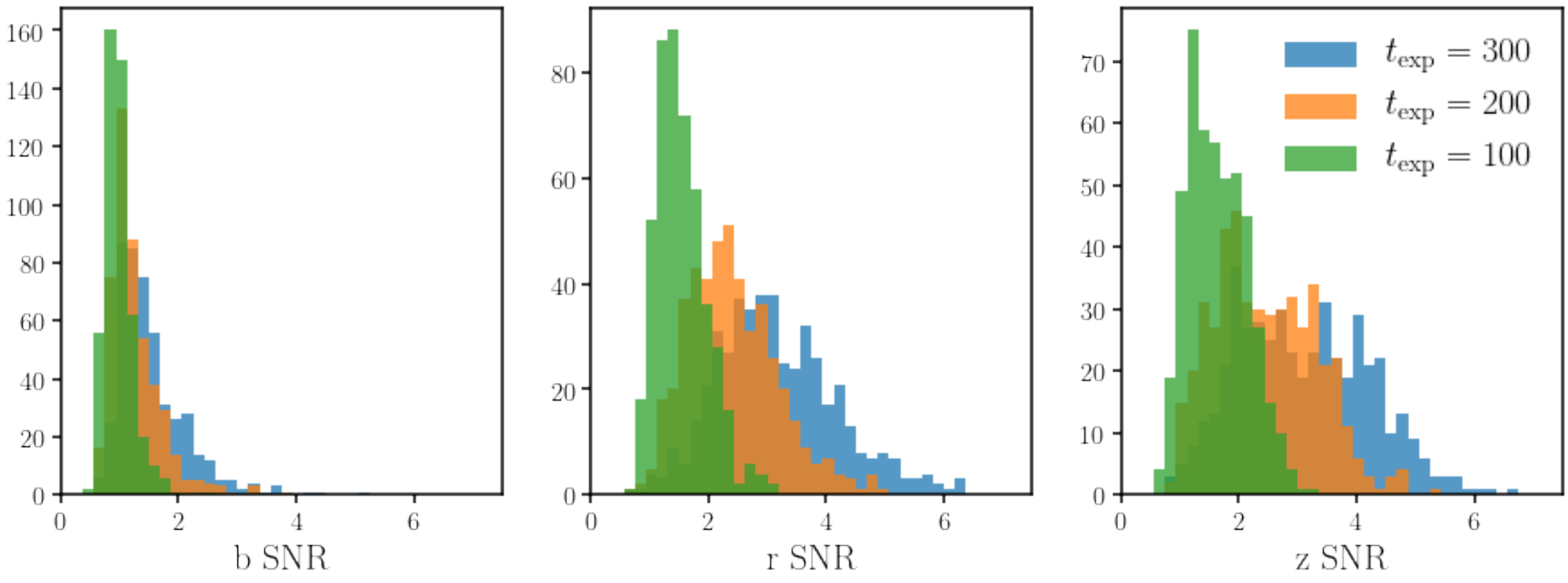
**sky model is slow*

*** GP emulator needs to be validated*

+ why not a simple grid? good question — that would have been simpler

$$t_{\text{bright}} = t_{\text{nominal}} \times \frac{(sky_{\text{bright}})}{(sky_{\text{nominal}})}$$

do we need $t_{nominal}$ = 300 sec?



$t_{nominal}$ = 150 sec sufficient to achieve SNR~1 for r~19.5 galaxies*

**needs to be double checked*

exposure time correction factor GP(θ_{obs}) implemented in*

changhoonhahn / **desisurvey**
forked from desihub/desisurvey

```
def bright_exposure_factor(moon_frac, moon_alt, moon_sep, sun_alt, sun_sep, airmass):
    """ calculate exposure time correction factor based on airmass and moon and sun
    parameters.

    Parameters
    ----------
    moon_frac : float
        Illuminated fraction of the moon, in the range [0,1].
    moon_alt : float
        Altitude angle of the moon above the horizon in degrees, in the
        range [-90,90].
    moon_sep : array
        Separation angle between field center and moon in degrees, in the
        range [0,180].
    sun_alt : float
        Altitude angle of the sunin degrees
    sun_sep : array
        Separation angle between field center and sun in degrees
    airmass : array
        Airmass used for observing this tile, must be >= 1.

    Returns
    -------
    float
        Dimensionless factor that exposure time should be increased to
        account for increased sky brightness due to scattered moonlight.
        Will be 1 when the moon is below the horizon.

    """
```

* *"implement" is putting it generously*

surveysim with GP(θ_{obs}) and $t_{nominal}$ = 150sec

```
module load python
source activate surveysim_test # actiate conda environment

# set DESISURVEY_OUTPUT
export DESISURVEY_OUTPUT=${SCRATCH}/desi/output

# load up desi environment
source /project/projectdirs/desi/software/desi_environment.s

# unload desi_environment's version of desisurvey
module unload desisurvey

# install forked desisurvey
cd $forked_desisurvey_directory
python setup.py install --user

# run surveyinit if you haven't already (takes ~50mins)
surveyinit --verbose
# now run surveysim!
surveysim --config-file ~/config.yaml
# with more bells and whistles: (--twilight enables twilight
surveysim --config-file configfile.yaml --name surveysim_for
```

yes, it's that easy. we should all be running survey sims!

surveysim with GP(θ_{obs}) and $t_{nominal}$ = 150sec

5283 total BGS fields, average 2.83 passes

****UPDATE****

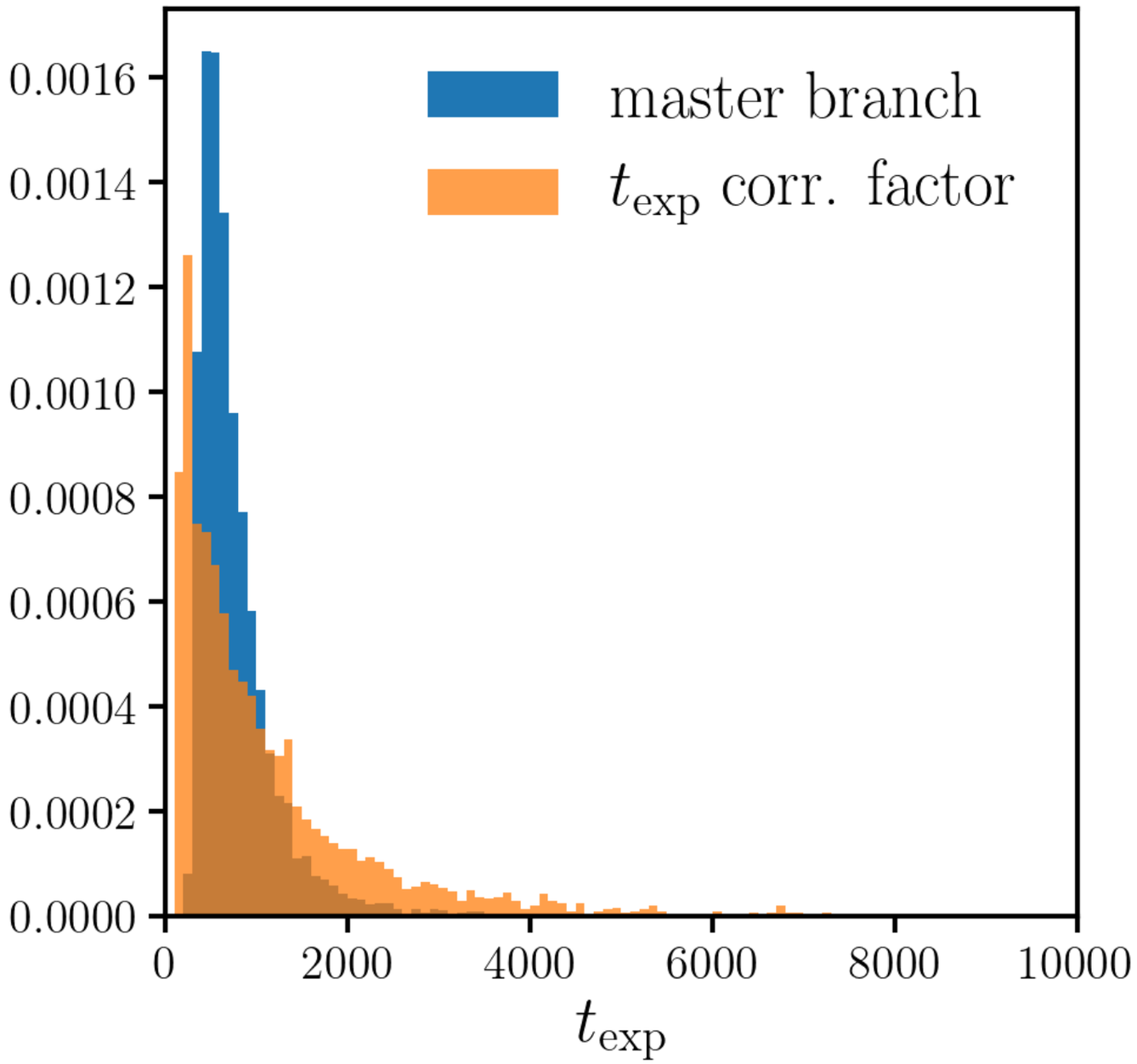
1-pass	**0.074770376**
2-pass	0.31799636
≧ 3-pass	0.60646924

---

surveysim master branch f_{exp} = 1.33 $t_{nominal}$ = 150sec

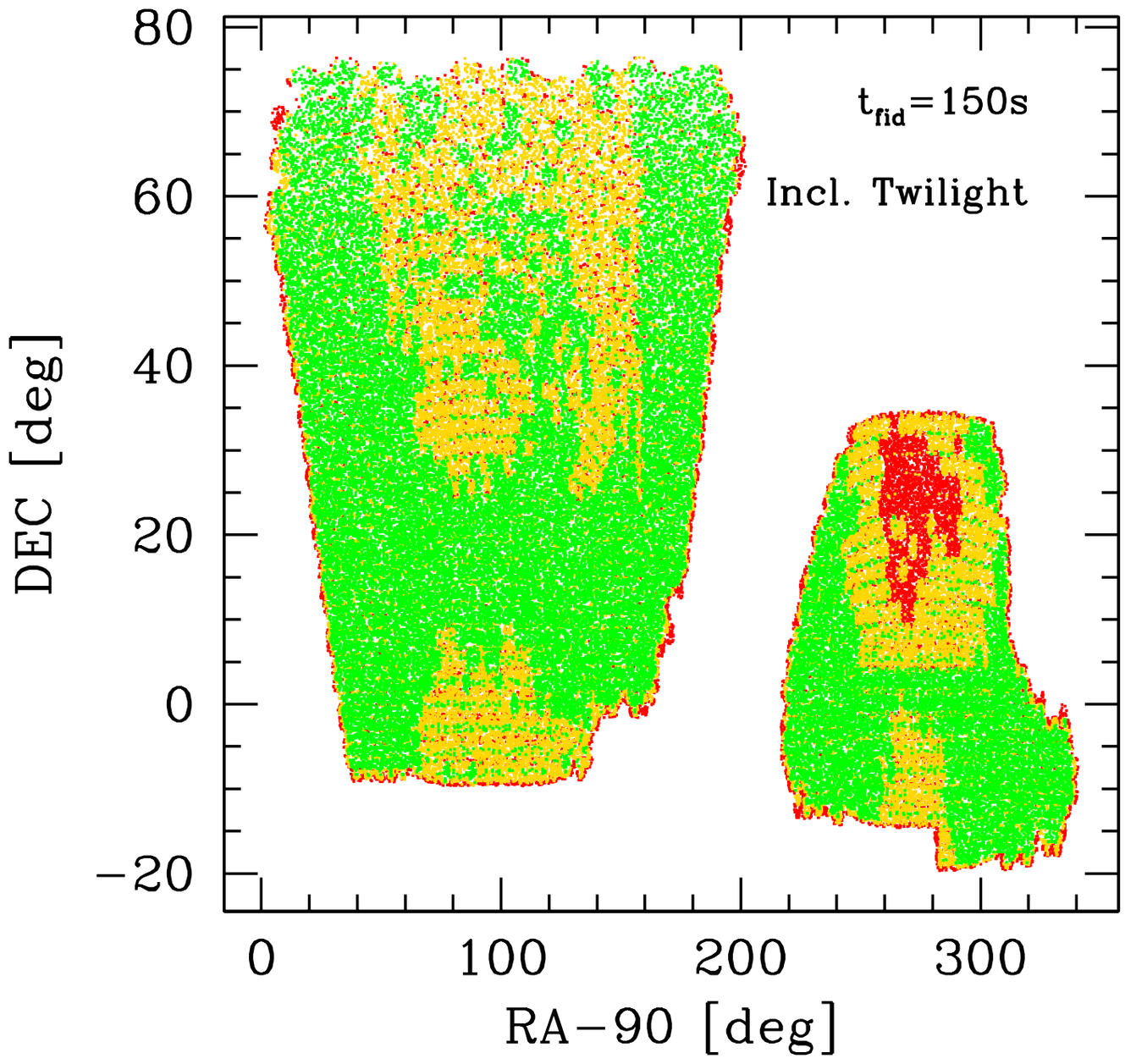
5318 total BGS fields, average 2.85 passes

surveysim with $GP(\theta_{obs})$ and $t_{nominal}$ = 150sec



surveysim with GP(θ_{obs}) and $t_{nominal}$ = 150sec

****UPDATE****



to-do / wish list

- *resolve redrock failure for galaxies w/ strong emission lines*
- *speed up sky model*
- *validate exposure time factor emulator*
- *validate nominal exposure time*
- *properly implement f_{exp} into desisurvey + surveysim*
- *re-do z success calculations with updated BGS exposures*
- *redshift success rate with no emission lines*
- *redshift success rate with low Halpha*
- *redshift success rate as a function of surface brightness*
- *redshift success rate with as a function of galaxy color/type*
- *redshift success rate for imperfect sky subtraction*

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to-do / wish list

data *: set of realistic BGS spectra simulated for observing conditions of the updated BGS surveysim exposures*

hack day?

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