ZTF Filter Transmission
and ghosts in dome flats

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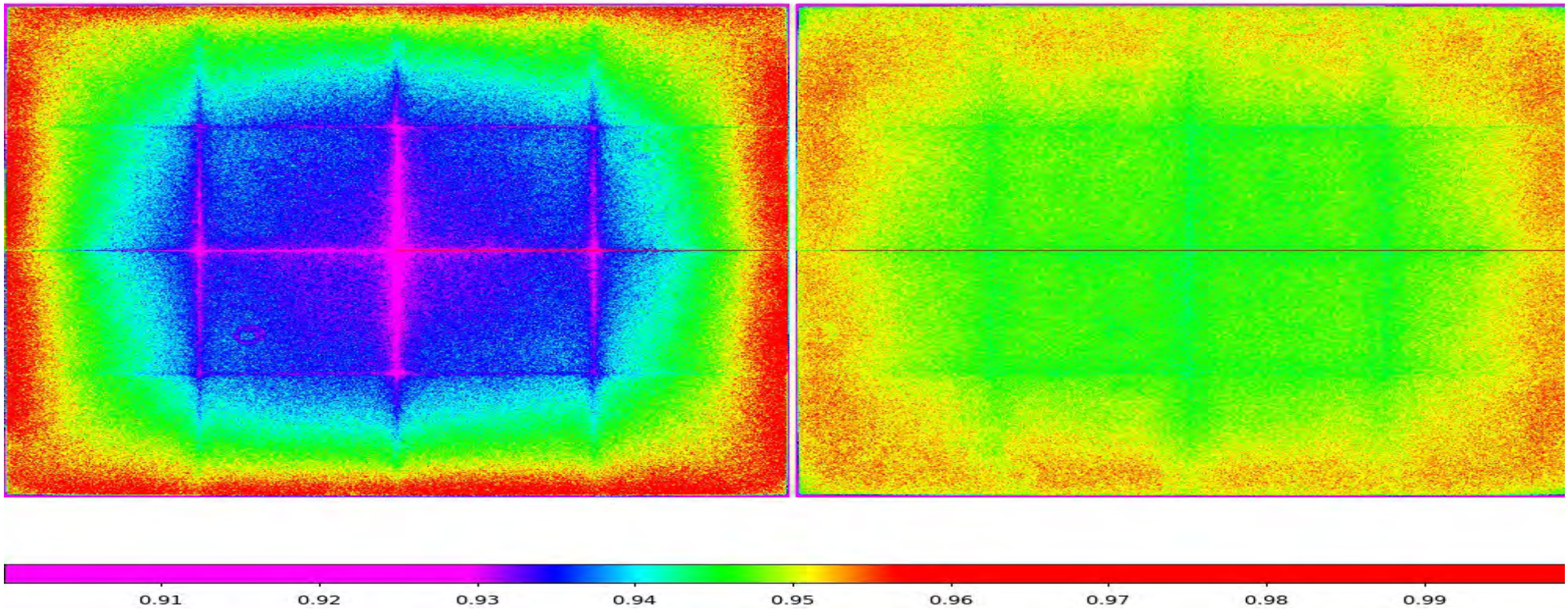
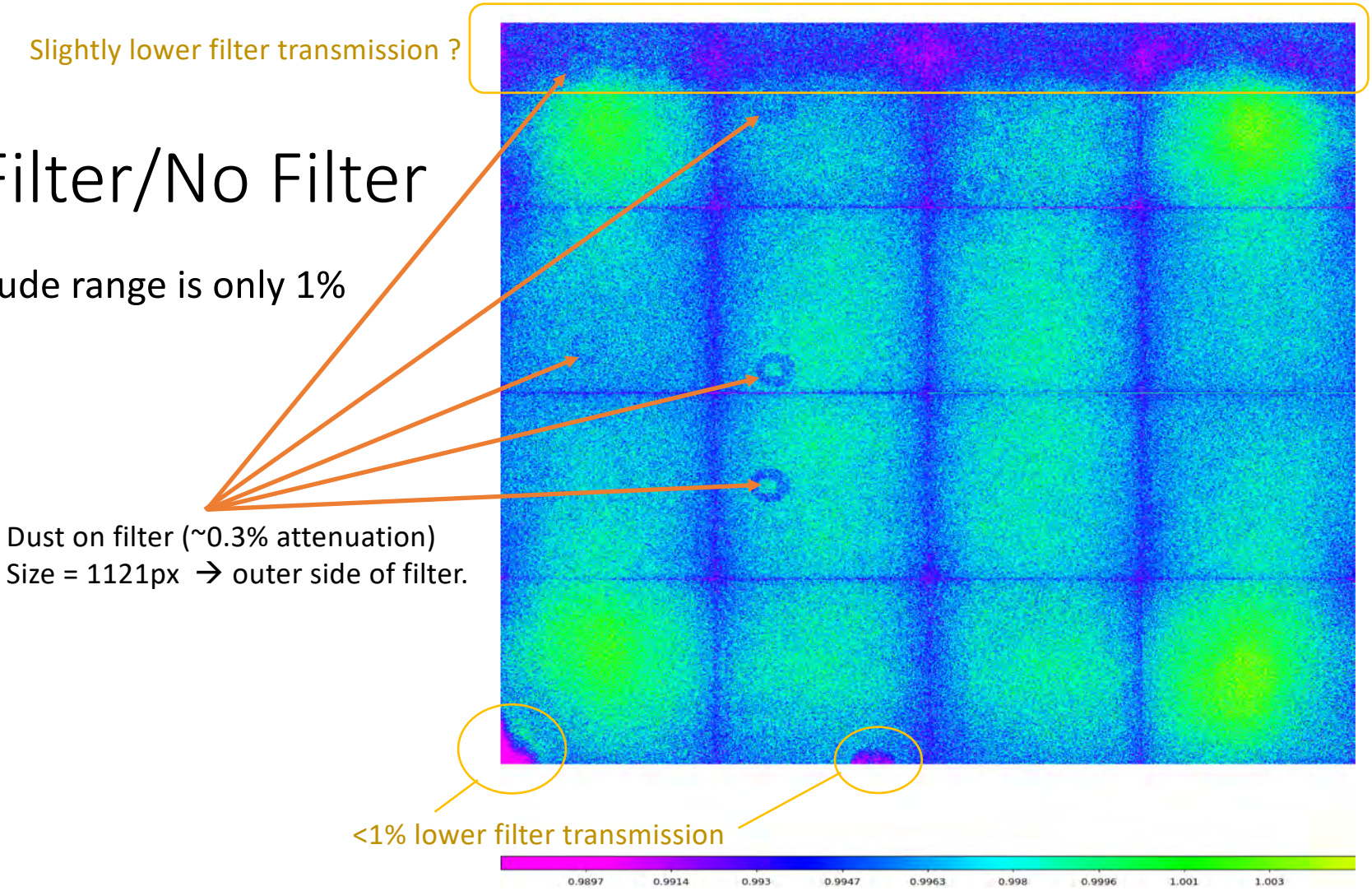
ZTF-g and ZTF-r scaled mosaic.
No Filter/Filter

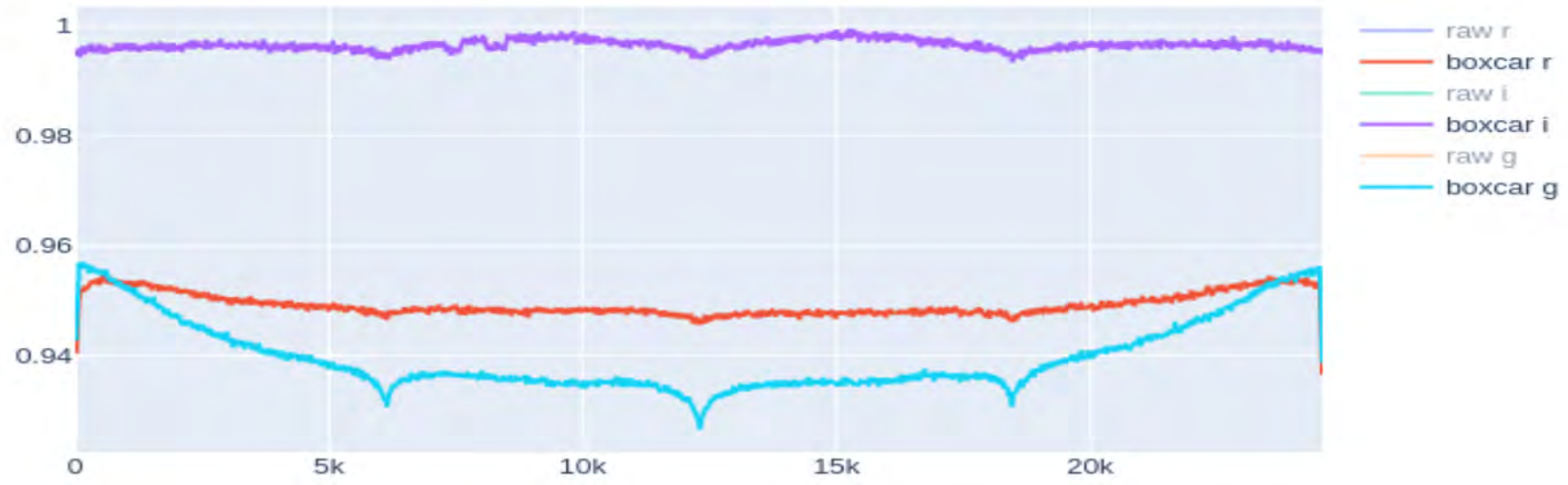


ZTF-I Filter/No Filter

N.B: amplitude range is only 1%



Line Profile Mosaic (+150 y-pixel offset from center)



Is ghosting an additive or multiplicative error?

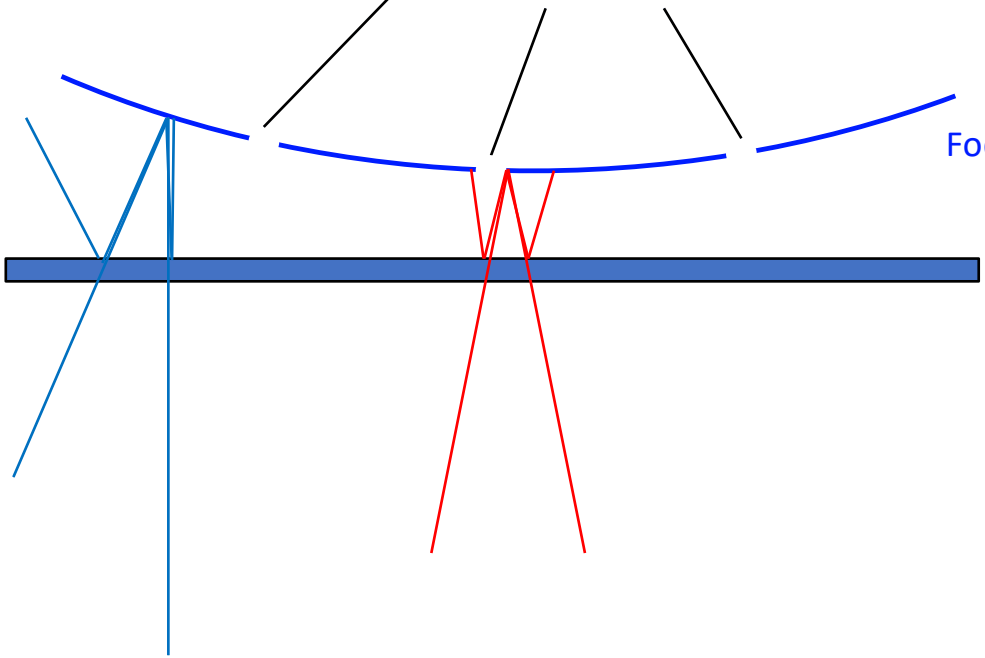
- Light reflected by the CCD or optical surfaces is not usually returned to the same pixel. This is corrected by flat fields, however…
- Pixels also receive some of the light that has been removed from other pixels by reflections. Since this component of the flat field signal is not dependent on the system throughput from sky to that pixel, it is an additive error.
- If the reflections resulted in a spatially uniform change in flat field intensity then it could be treated as simply a throughput variation which would be removed by flat field normalization.
- However there are several reason's ghosting is spatially variable…

Sources of spatial structure in ghosting

- Ghosting is occurring at all optical interfaces, but the strength of the effect is given by their reflectivity, and the shape of the surface which may tend to either concentrate or spread out the light.
- Sky and Illuminator flats both suffer from this effect.
- Sky presents a larger solid angle (limited by dome slit) to produce scattering form dust on the corrector than the flat field screen which is more tightly baffled. However scattered light from pupil can produce little structure at small spatial scales and is probably not the dominant error.

CCD-Filter Ghost

Gaps reduce ghosting where light falls in crack or is absorbed by black border painted onto field flatteners. Paint reflectance may be wavelength dependent.



Focal plane as seen from exterior (curvature exaggerated)

Light is pushed towards edges.
Vignetted area both loses light to edges, and gains light from unvignetted central areas.

Sky vs. Dome flats

The illuminator was requested by the ZTF science team because sky flats were actively deprecated by other wide field imaging projects. This comparison explains why….

Dome:

- Temporal stability (dependent on lamp design)
- Flat as we care to make it.
- Smaller solid angle seen by corrector → less scattered light from corrector.
- Wavelength selectable

Sky:

- Intensity and spectral content variations in time and space: airmass, moon, aerosols, cloud, airglow, stars, zodiacal light
- Wider solid angle seen by corrector
- Spectrum close to solar (thus more “Star like”) though varies with rayliegh scattering.

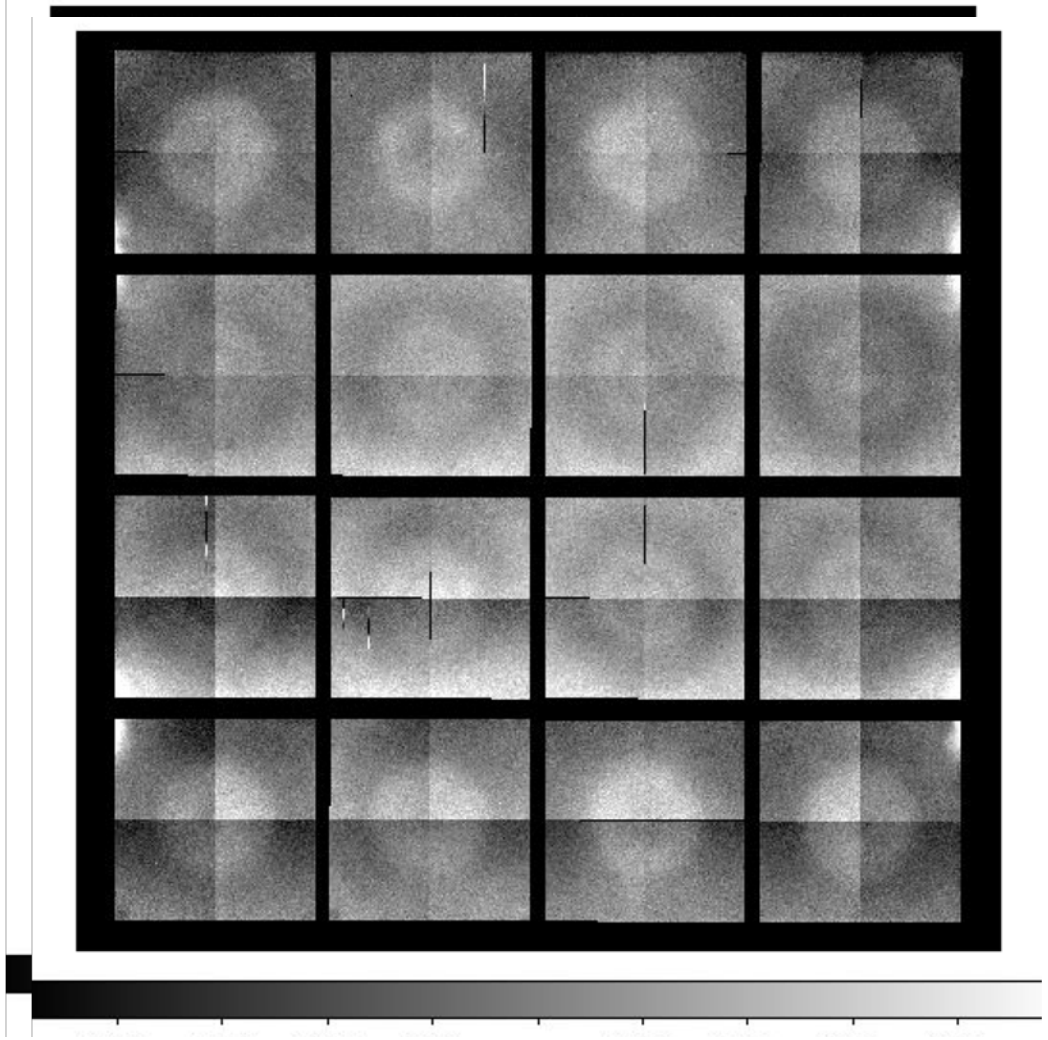
Telescope is very well baffled so light from sky and illuminator is same by the time it reaches focal plane and thus filter ghosting should be *identical* except for effect of different spectral content.

At this time we have no evidence that sky flats provide better photometric accuracy than illuminator flats. i.e. photometric comparisons with other surveys have not been performed using both methods.
There are *differences* as identified by Jason Surace, but it not clear that sky flats are better. These differences appear to be due to spectral energy distribution, so re-tuning the weighting of LED flats taken within a passband to match the stellar spectra should improve photometry.

Sky/illuminator flat ratio by Jason Surace

Jason wrote:

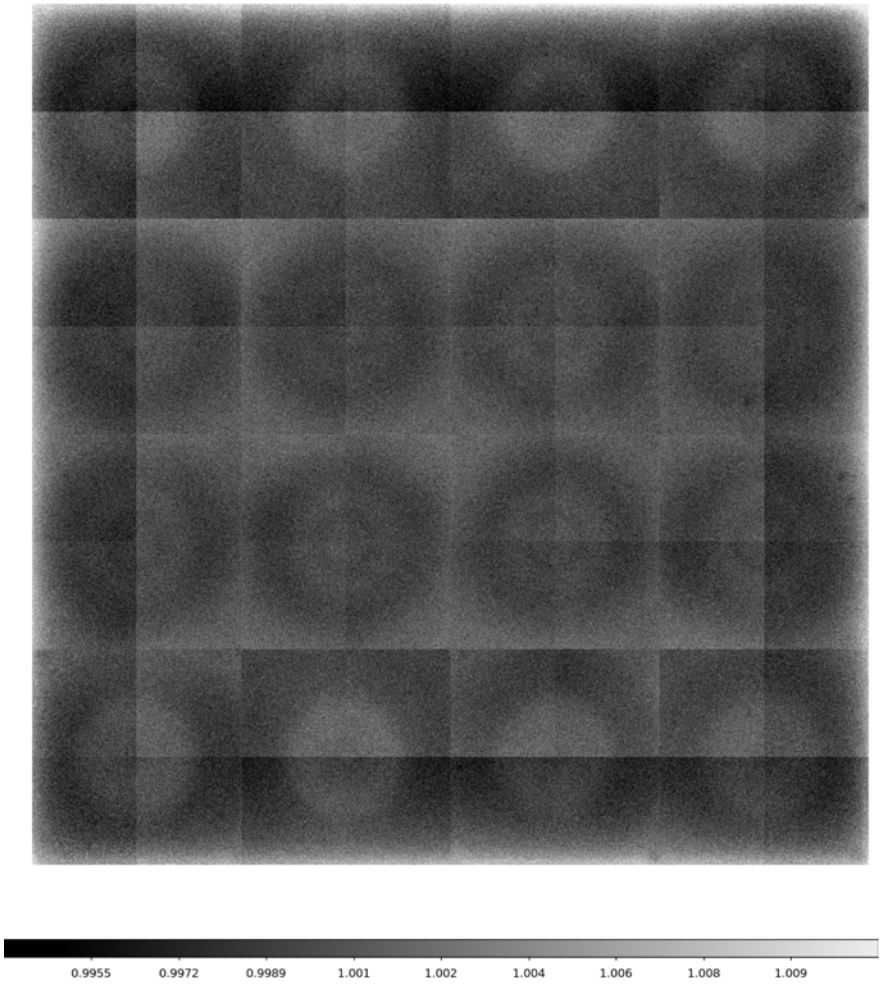
"To compare the two sets of flats, I have quad-by-quad taken the ratio of skyflat to high frequency (i.e."dome") flats created by the online pipeline in the same night. In order to ensure consistent normalization, both sets of flats were renormalized to a mean of one, excluding the outer 60 pixels in each quad. This should be sufficient to exclude most of the edge scattering."



Ratio 621nm/633nm LEDs with R-filter

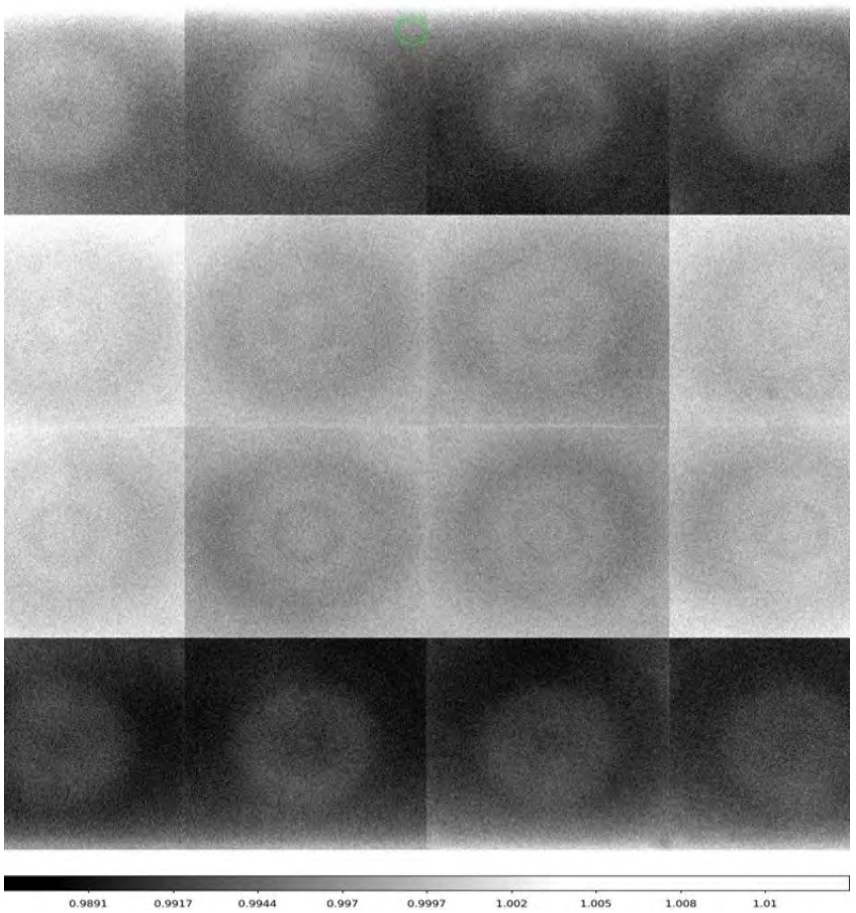
This illustrates how slope of QE curve varies spatially. The similarity to the Sky/LED ratio image made by Jason Surace supports the hypothesis that the pattern is due to differences in the spectral energy distribution due to spatial variation in slope of QE curve.

Each quadrant has been normalized to have mean=1. The next slide shows the ratio image without this normalaization…

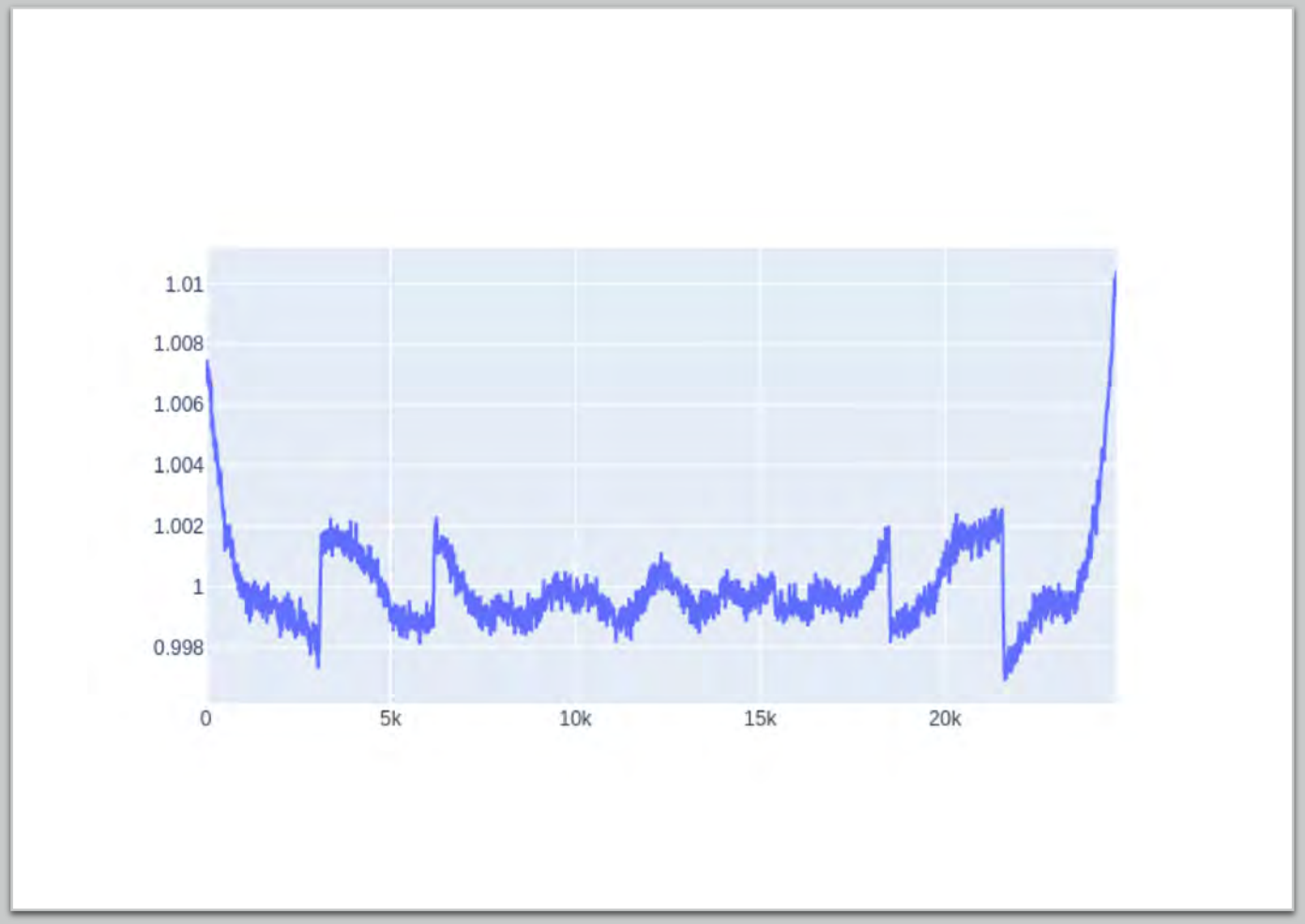


621nm/633nm ratio – no quadrant normalization

When the ratio is made without normalizing each quadrant, the spatially averaged QE dependence remains visible.



Cross section view across y-axis, with per-quadrant normalization



Flat field illuminator

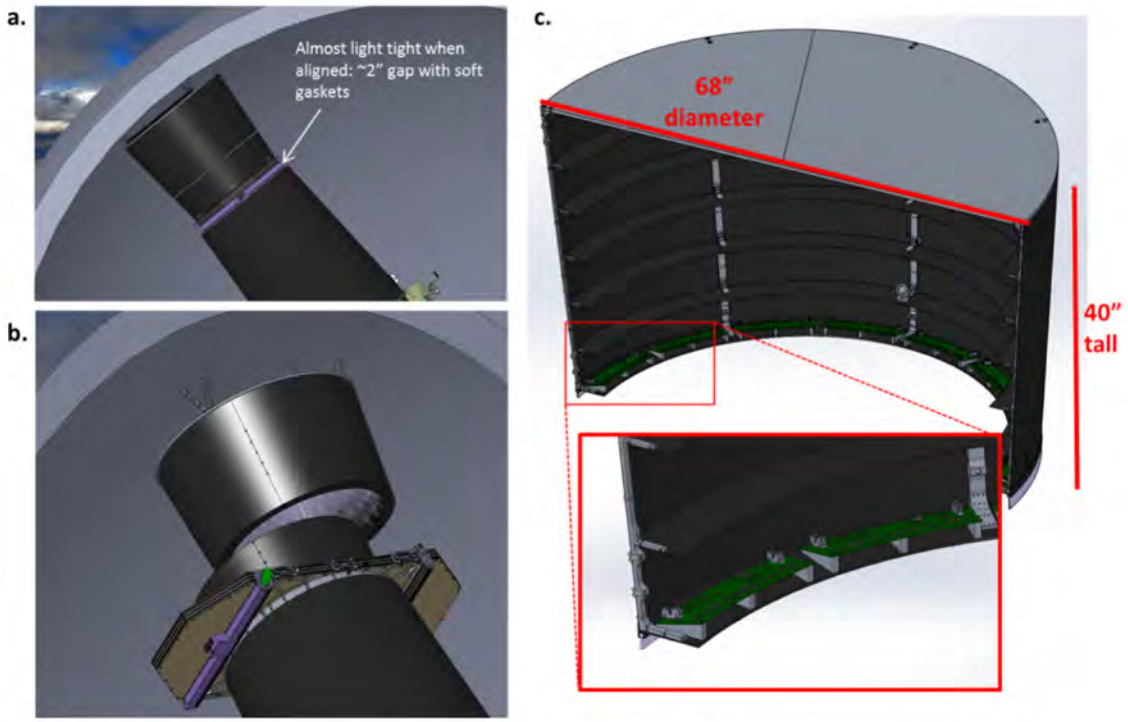


Figure 2: ***CAD of FFI system. The telescope aligned to FFI (a), in the dome. The telescope approaching the FFI (b). A cutaway of the FFI with boards installed (c) – note that in reality, on 8 boards are installed in the FFI, and the white screen sits opposite of the illuminator modules.***

Solid angles for light scattering off corrector

- Dome aperture is slightly wider than illuminator screen
- Only telescope baffle limits sky solid angle vertically.

→Much larger solid angle for sky than illuminator so more scattering off corrector.

Dome lit admits greater angle in vertical direction