The Collimated Beam Projector (CBP)

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Outline

Purpose of the CBP

CBP design and operation

Collecting data with the CBP

Results

Troubles, lessons, and the future

The flat field is not enough

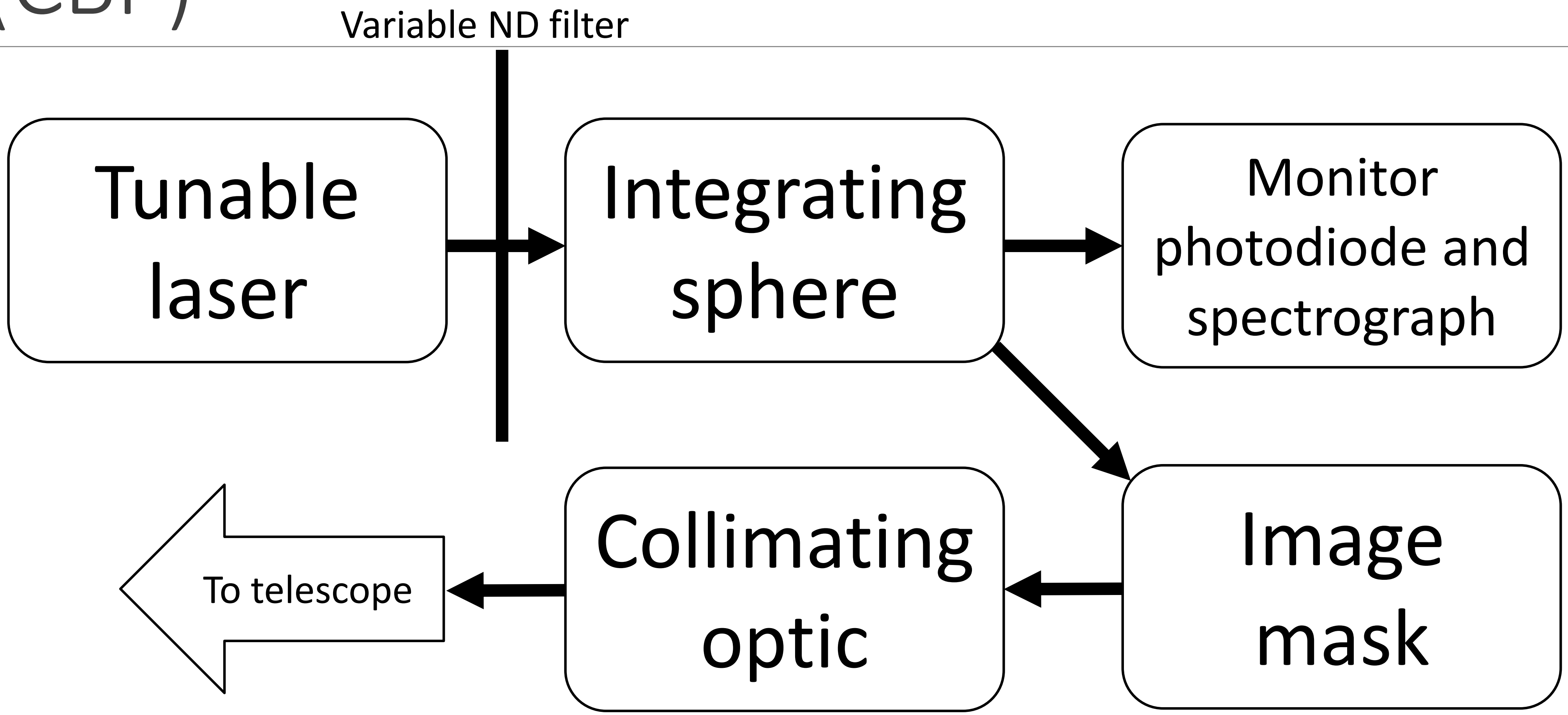
Traditional broadband flat fields use a non-collimated light source to illuminate the focal plane

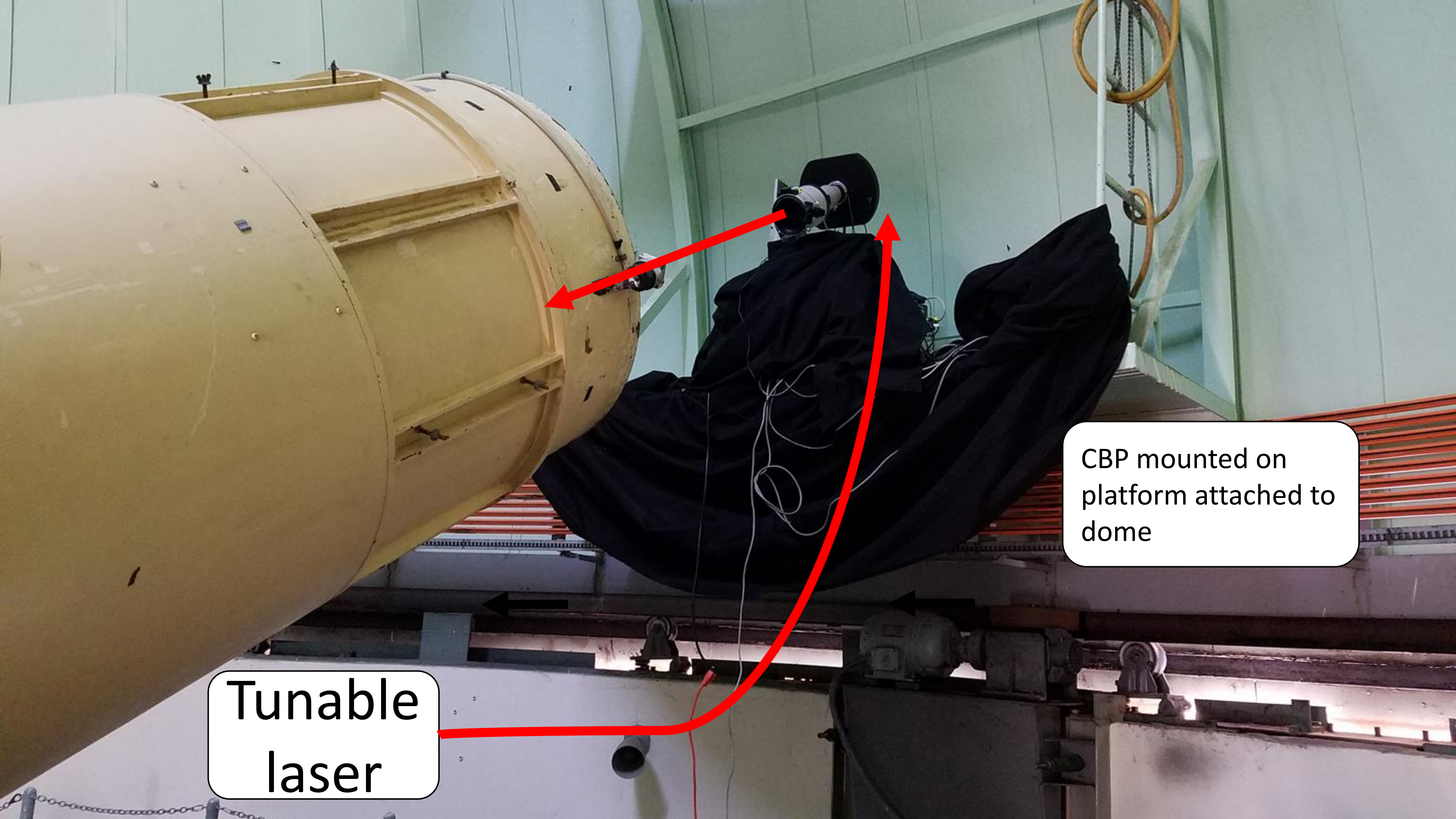
Can use monochromatic flat fields to estimate instrumental throughput as a function of wavelength

Primary issue:

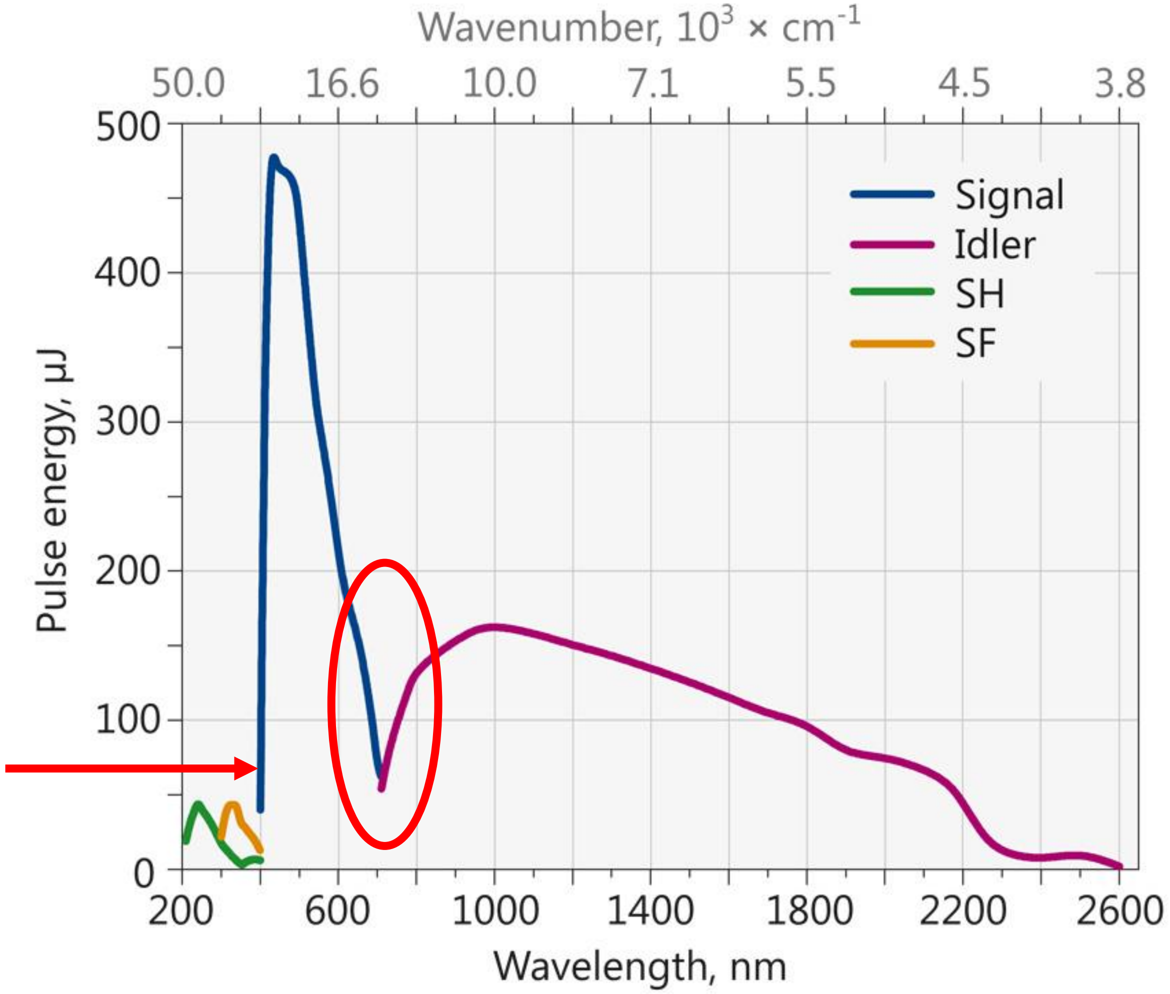
- Ghosted light paths are different than those produced by collimated beams
- Wavelength dependent ghosting can masquerade as QE variation

Enter the Collimated Beam Projector (CBP)




CBP mounted on platform attached to dome
Tunable laser

Tunable light source

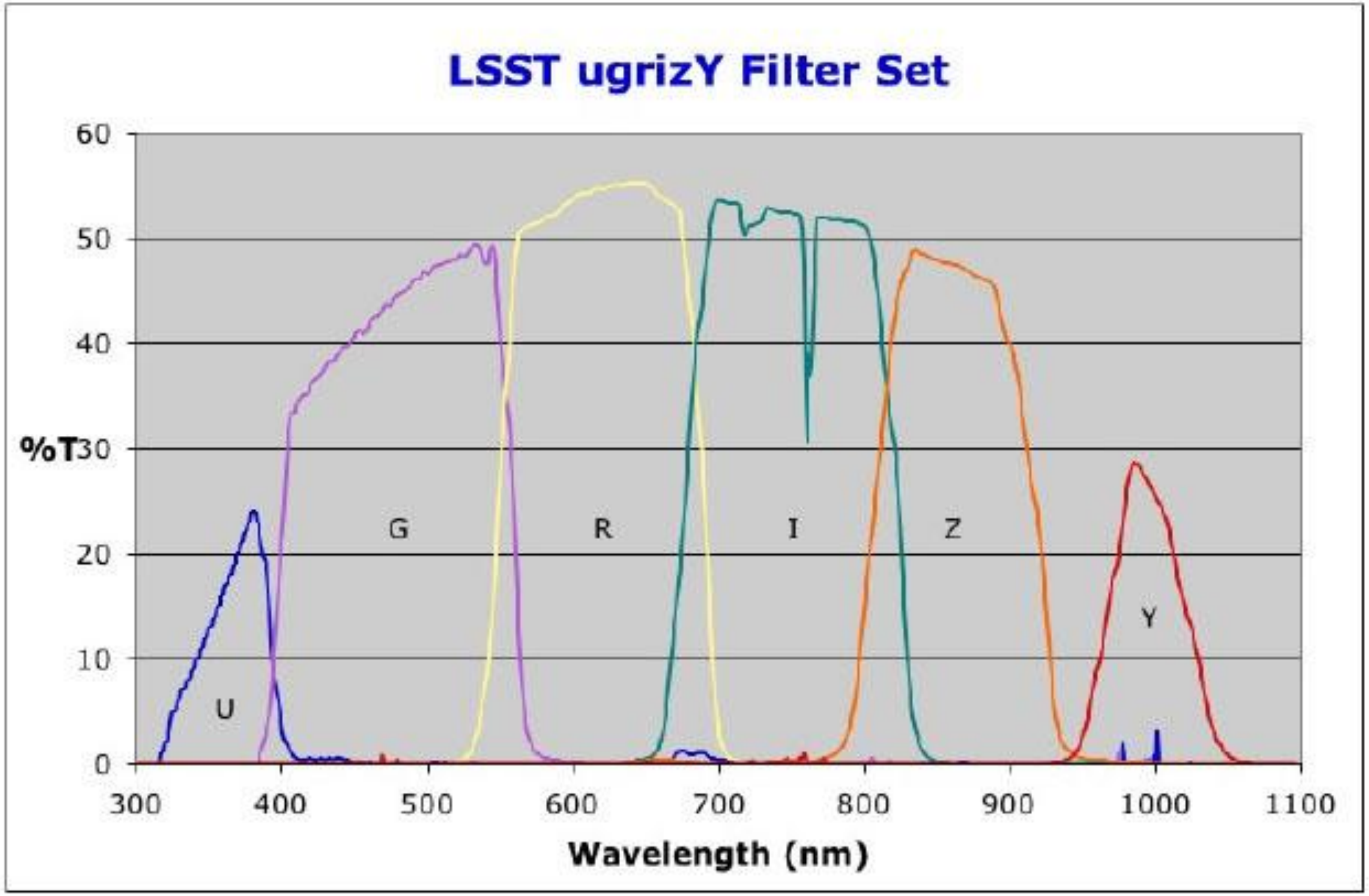


Approx. 400nm

Ekspla NT-242:
1 kHz rep rate
1064nm pump

https://ekspla.com/product/nt242-series-tunable-wavelength-nanosecond-lasers/

LSST filters



Key point:

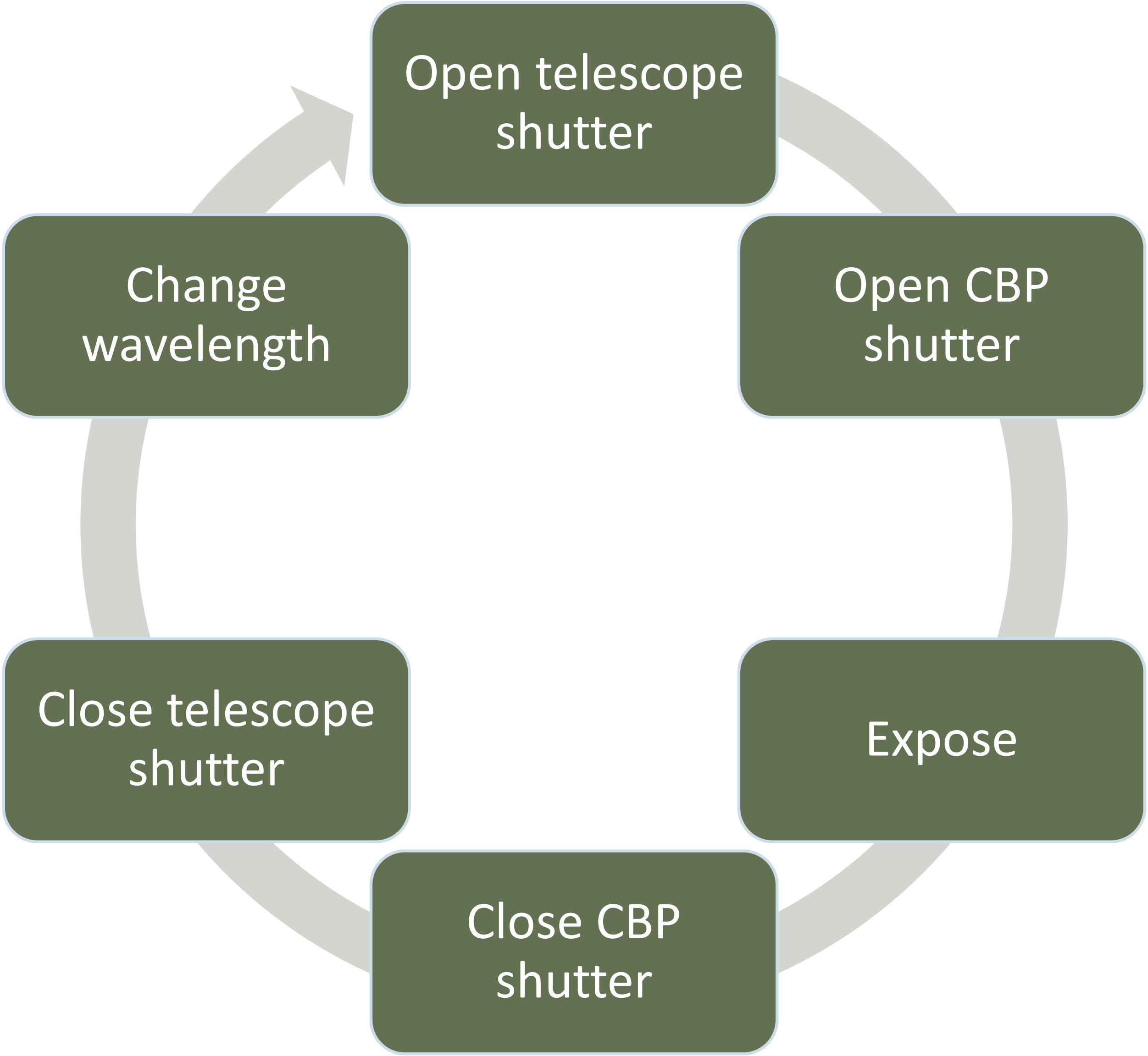
Use the NIST-traceable photodiode as metrology standard, NOT light source

$$\frac{\text{Charge collected on CCD}}{\text{Charge collected on photodiode}} \quad \text{(X correction factor)}$$

<u>Challenge: measuring the transfer function of the CBP system</u>

The Data

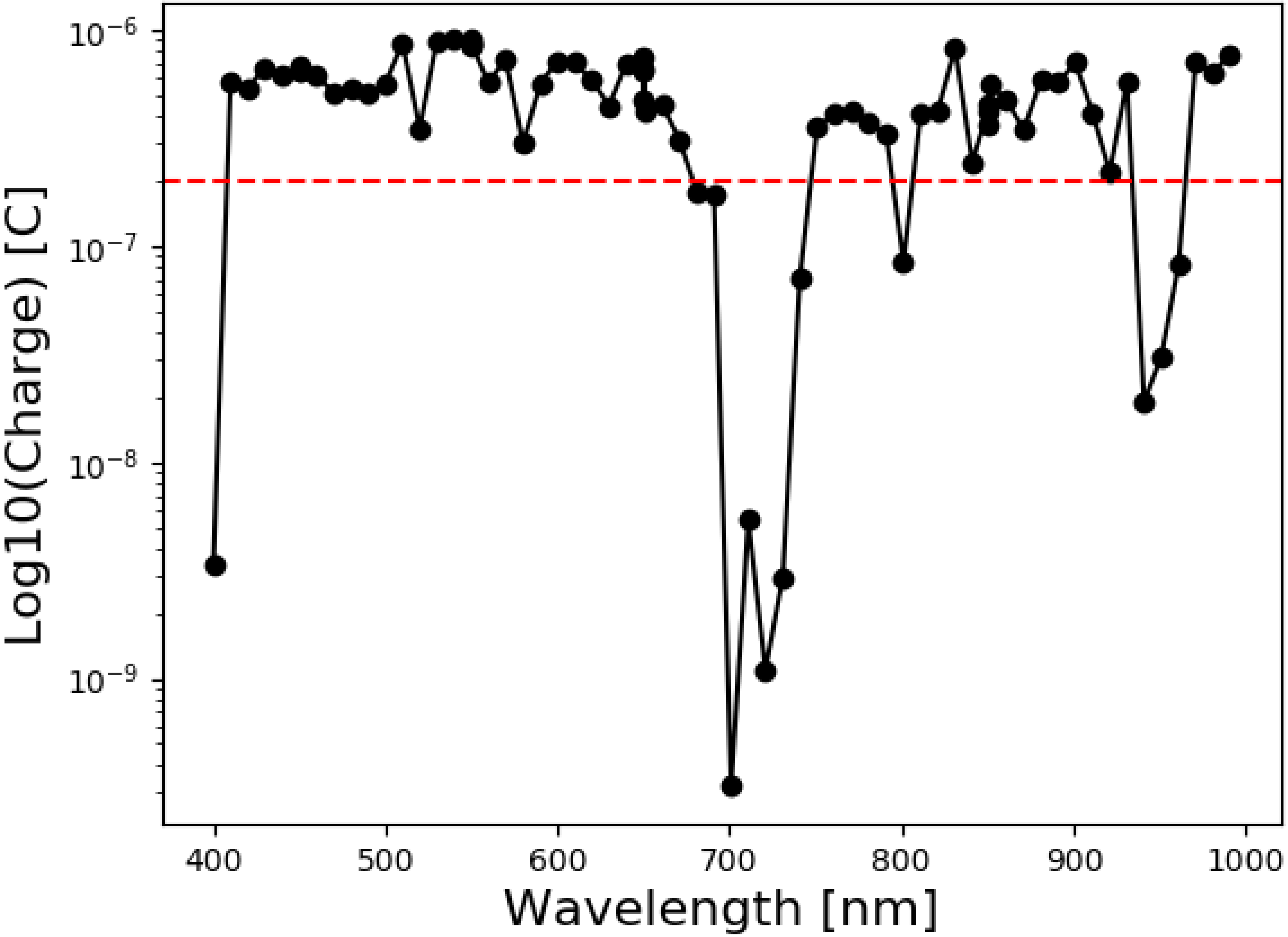
Taking data: SMARTS 0.9m, CTIO, Chile

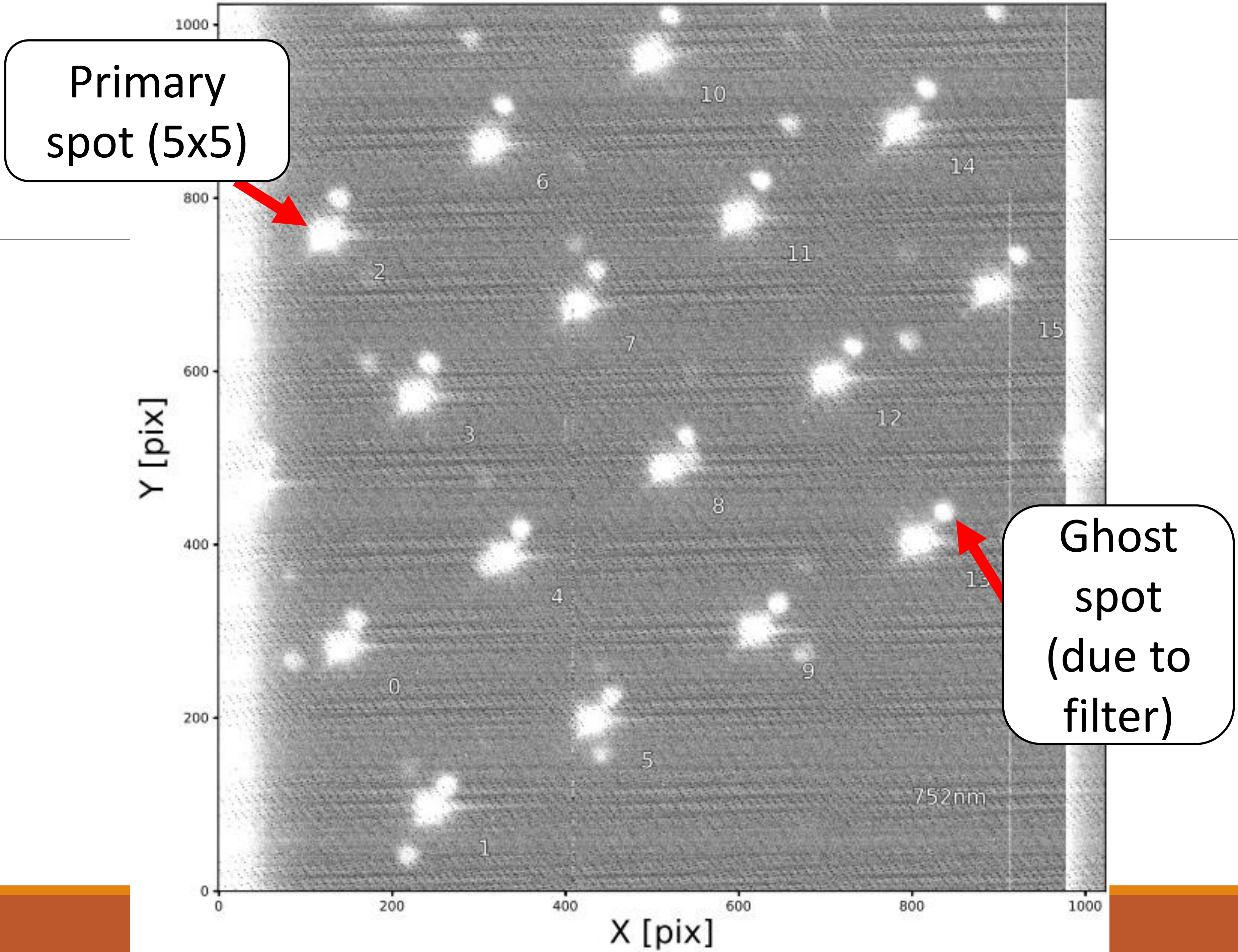


Charge homogeneity

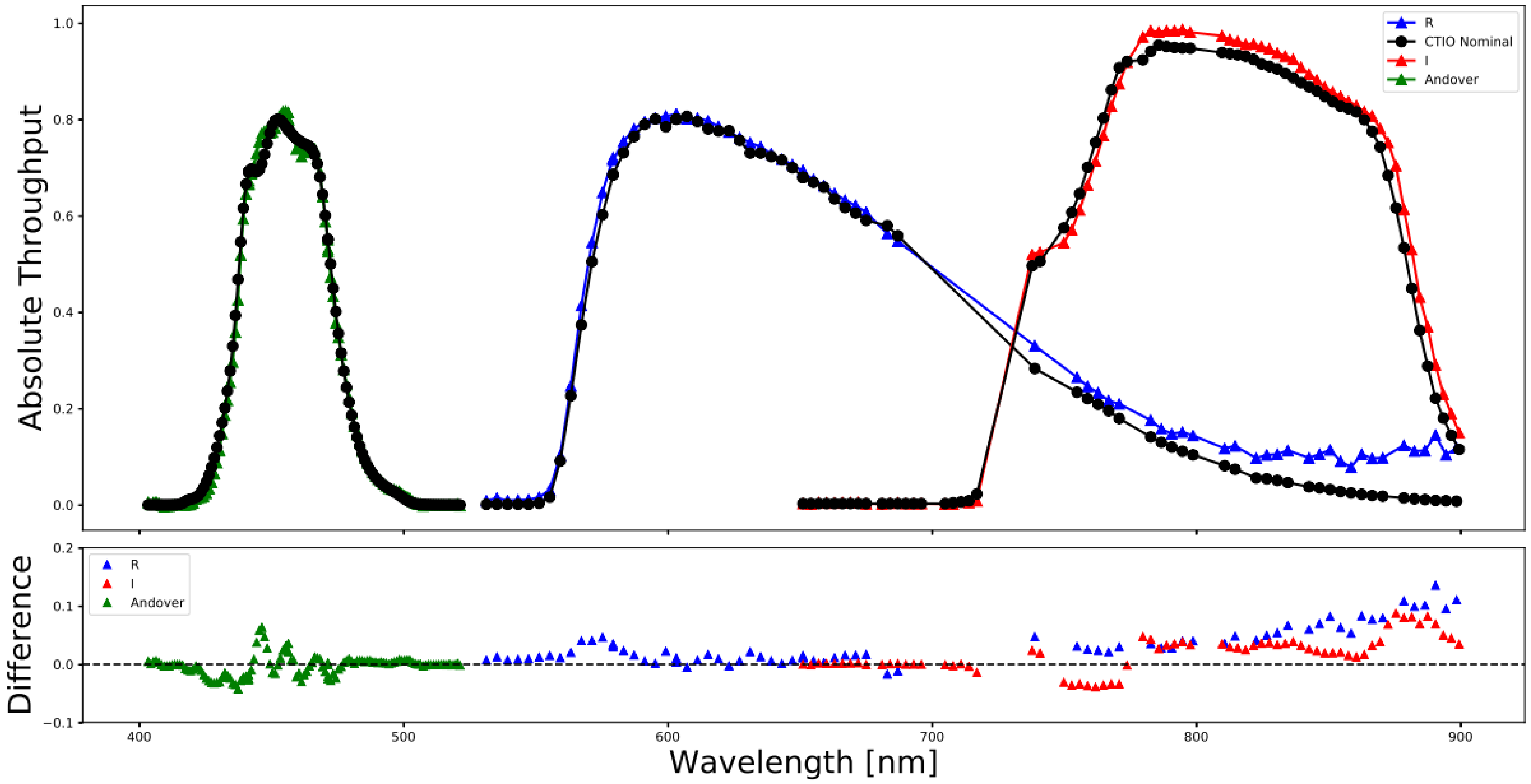
$$\frac{\text{Charge collected on CCD}}{\text{Charge collected on photodiode}}$$

Goal: avoid divide-by-zero errors




Primary spot (5x5)
Ghost spot (due to filter)
Y [pix]
X [pix]
752nm
0
1
2
3
4
5
6
7
8
9
10
11
12
14
15
0
200
400
600
800
1000

The results (so far)



Current Difficulties and Places for Improvement

Harvard CBP Specific

Challenges for the Harvard CBP

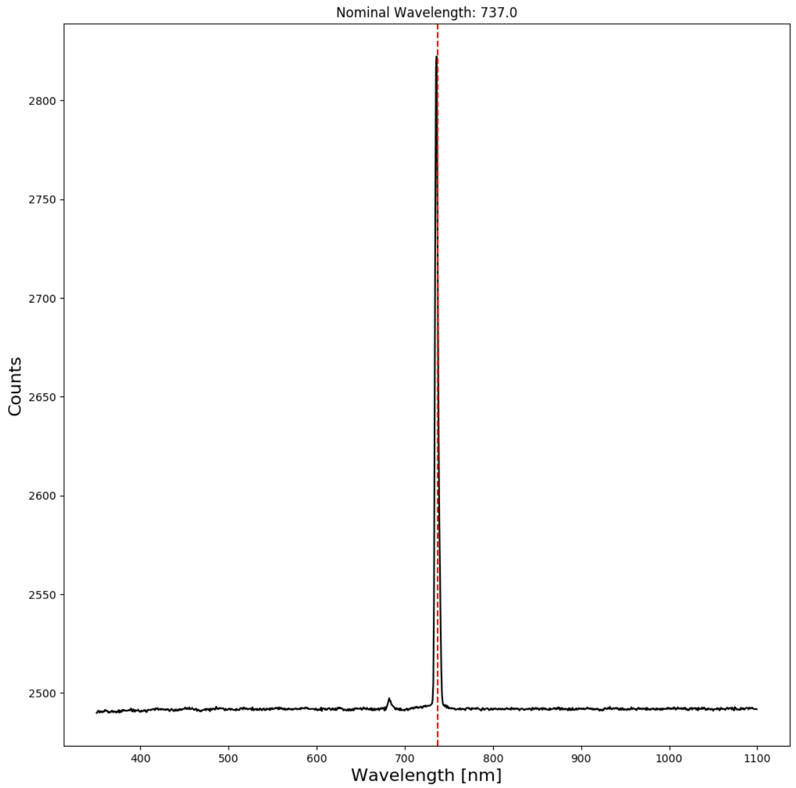
Alignment (equatorial vs AltAz + dome rotation)

Contamination from signal into idler beam

Temperature monitoring

Change from refracting to reflecting optics?

Fix tunable laser (or find new light source)



Questions and Challenges for the LSST CBP

General CBP challenges

Vignetting* corrections between days (more after this)

Output of tunable light source in blue (<400nm)

Spot-to-spot comparison map

Using a CBP to flat-field Ronchi data for atmospheric transmission

How broad can light source FWHM be, and still achieve effective bandpass measurements (alternatively, a method for including observed FWHM in bandpass extraction)

Impact of OPO degeneracy point on filter scans of *r* and *i*

Where should we take the CBP next?

“Vignetting” correction issue

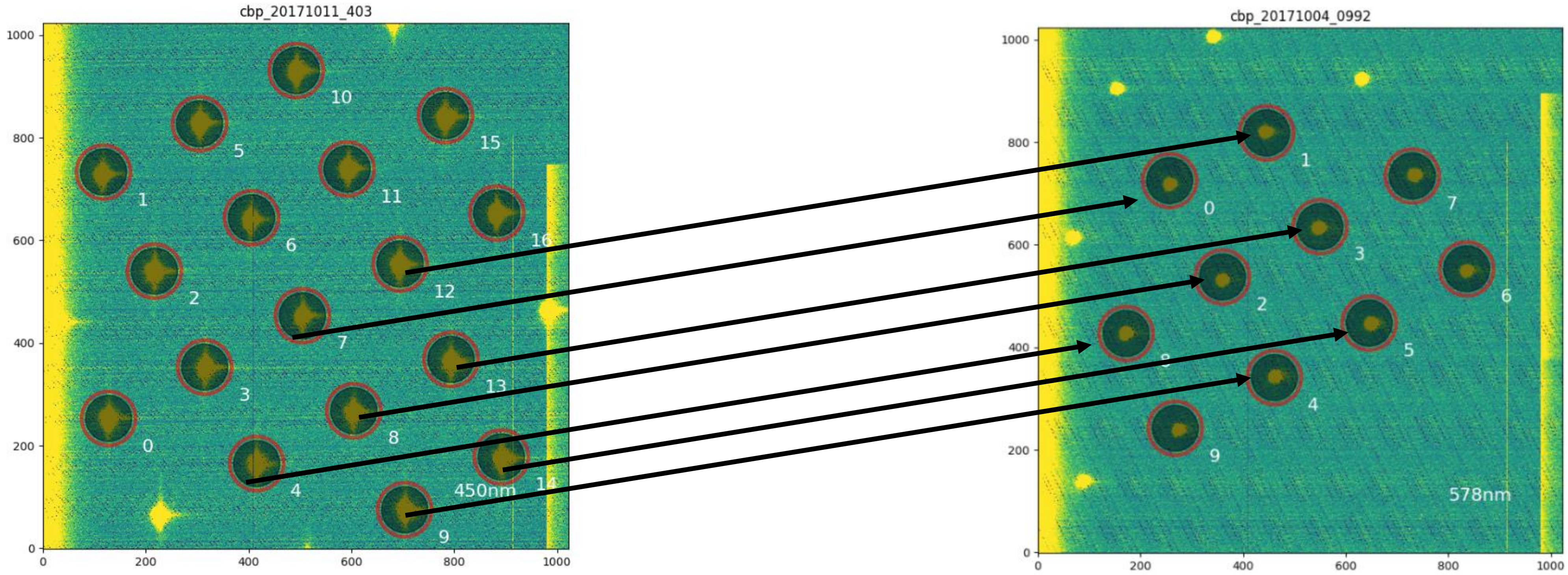
In order to make accurate synthetic colors, we need to be able to put 2 different filters (w/ scans taken on different nights) onto same flux scale. That is, we need to know that the peak I-band throughput is 80% of the peak R-band throughput (don’t care about what the overall multiplicative offset is, though).

Spot Matching

Create a map that links same spots on CBP mask between different runs

No-filter scan image taken on 2017-10-11

No-filter scan image taken on 2017-10-04

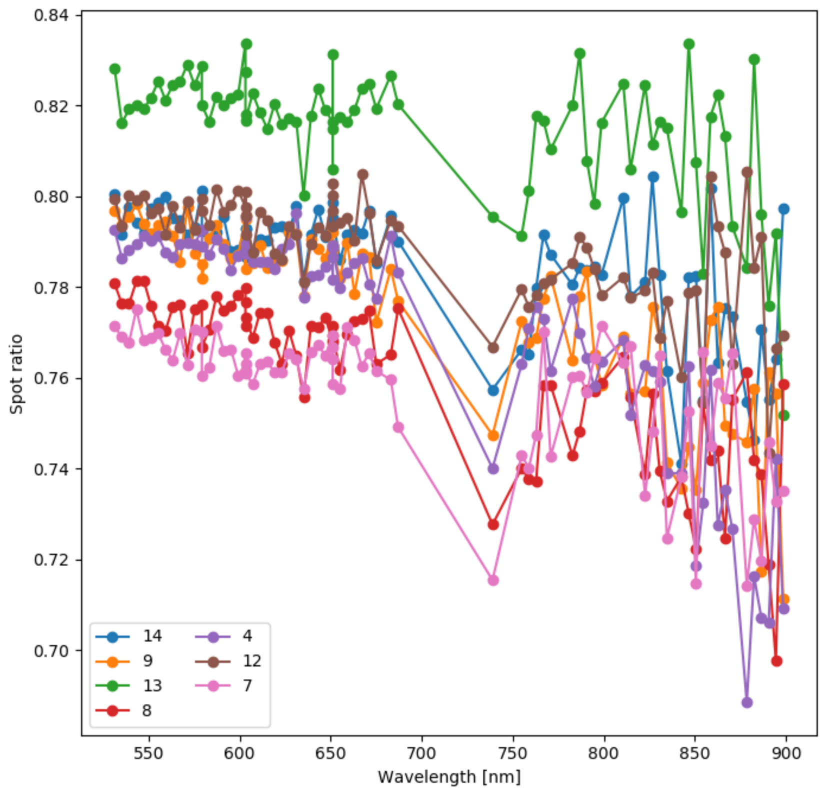


Inconsistent raw throughput ratios

Nofilter/nofilter

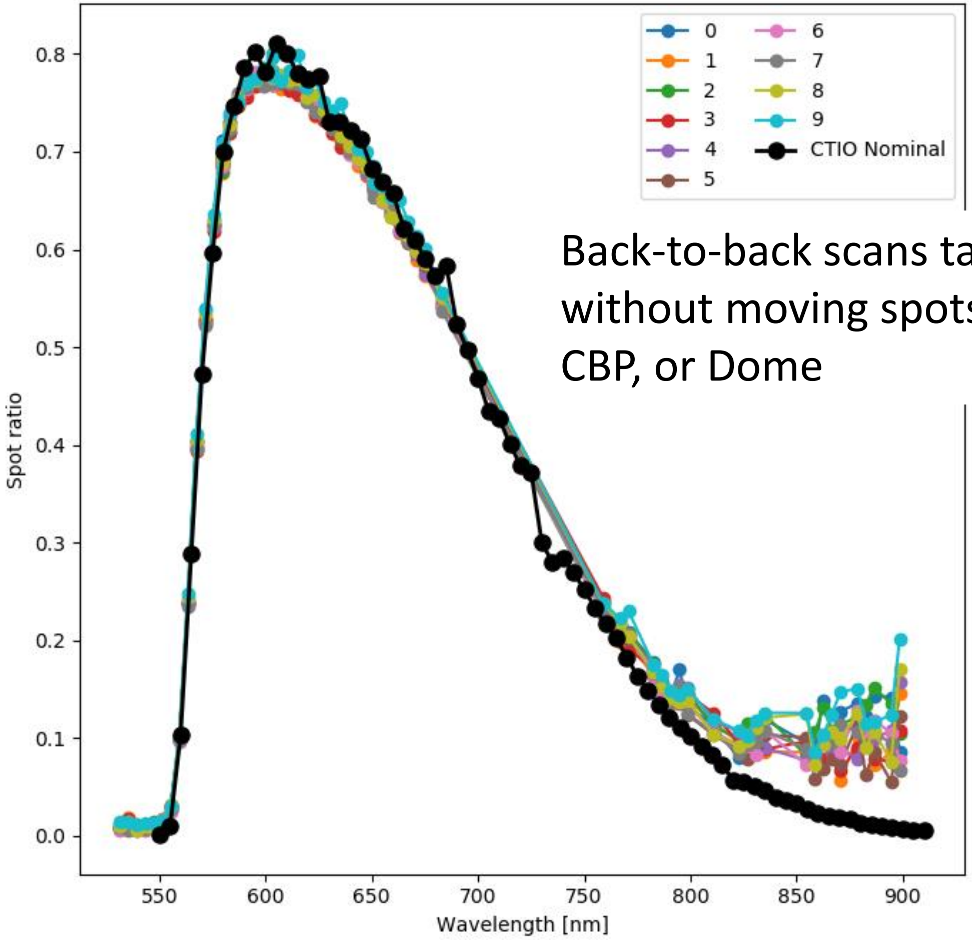
Plot is ratio of raw throughputs of each spot

Note that not only are there large (>20%!) offsets between nights, but also not consistent spot-to-spot



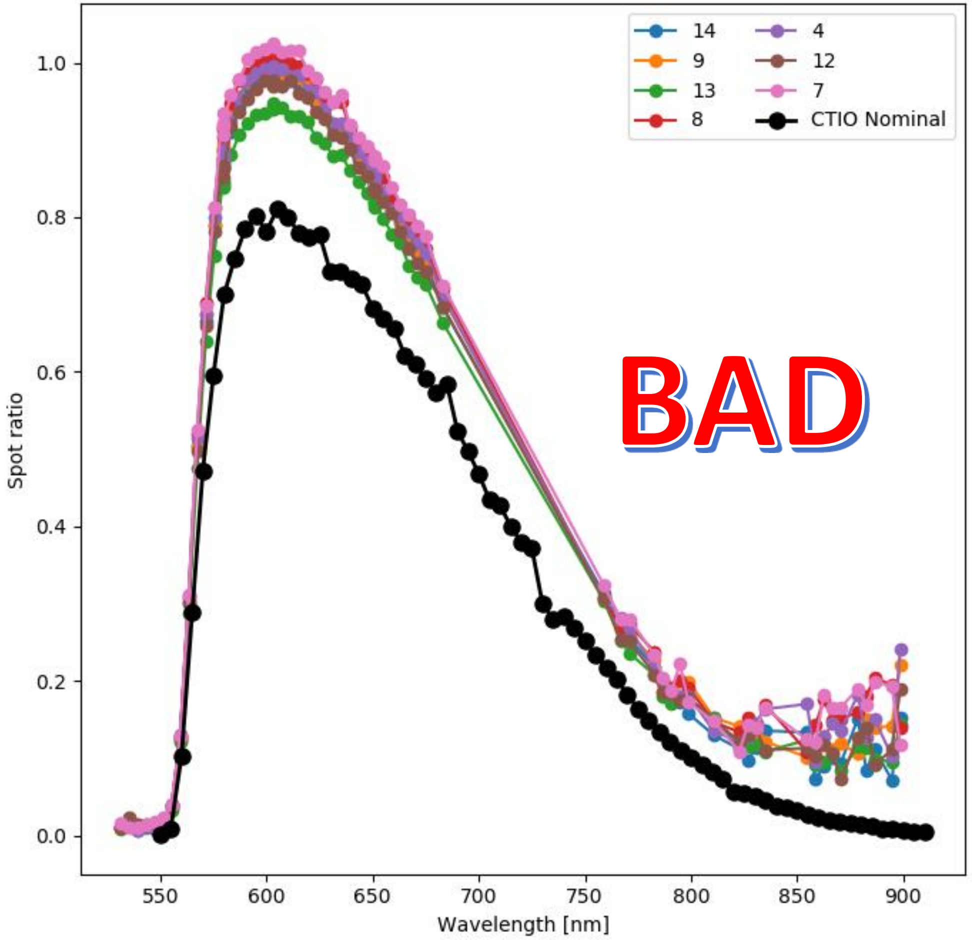
How does it affect throughput measurements

Our “flagship” R-band curve



Back-to-back scans taken without moving spots, CBP, or Dome

Same curve, but made by dividing an R-band scan by the 2017-10-11 no-filter scan

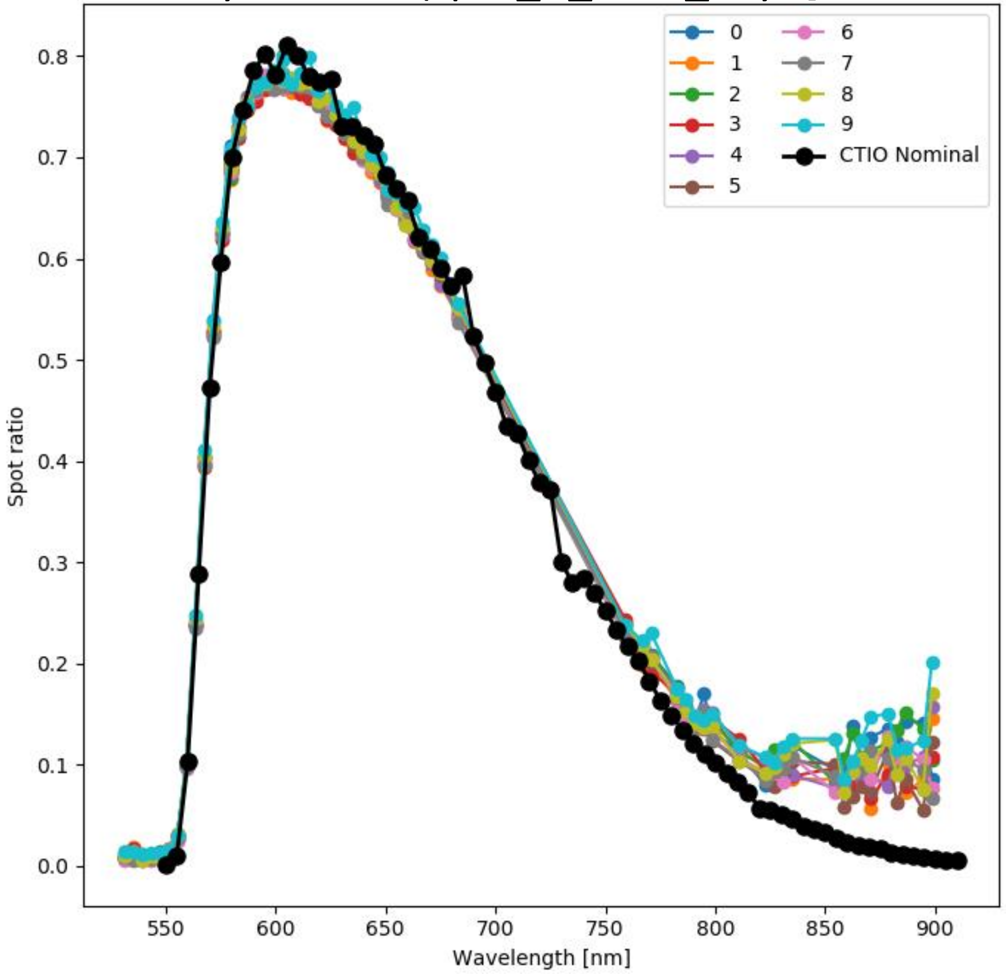


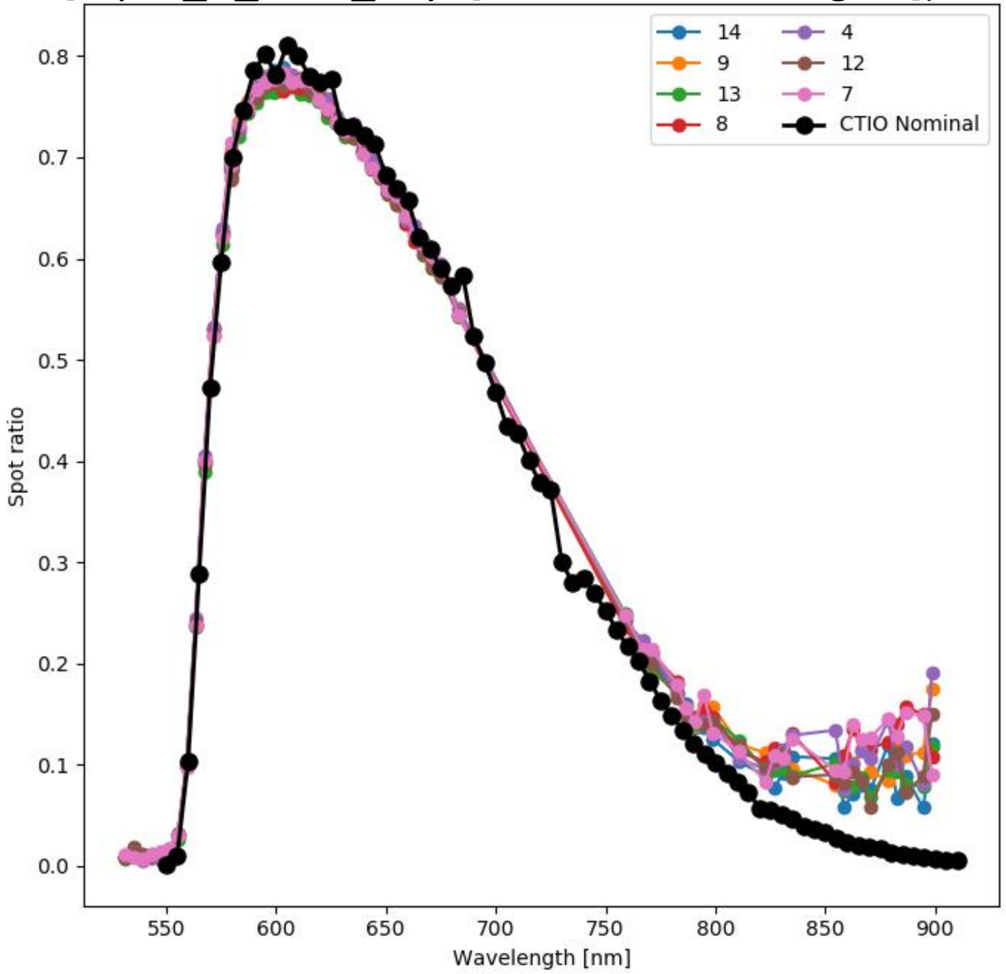
BAD

Can we correct for it?

In this case, the nofilter 2017-10-11 image is corrected by data from the nofilter 2017-10-04 run

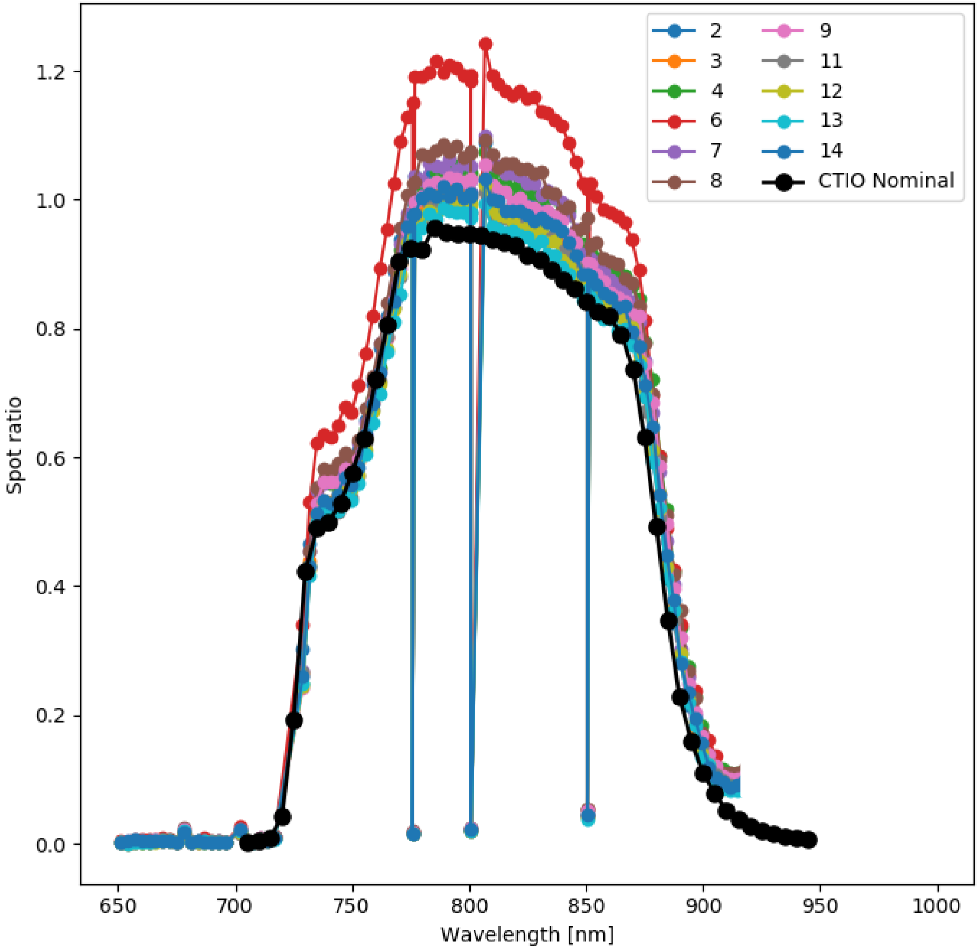
Same pair as before, but this time, each spot has a “vignetting”(=overall multiplicative scaling) applied. Correction factor is found by MEDIAN(spot_A_Nofil_dayX[common wavelengths]/spot_A_Nofil_dayY[common wavelengths])



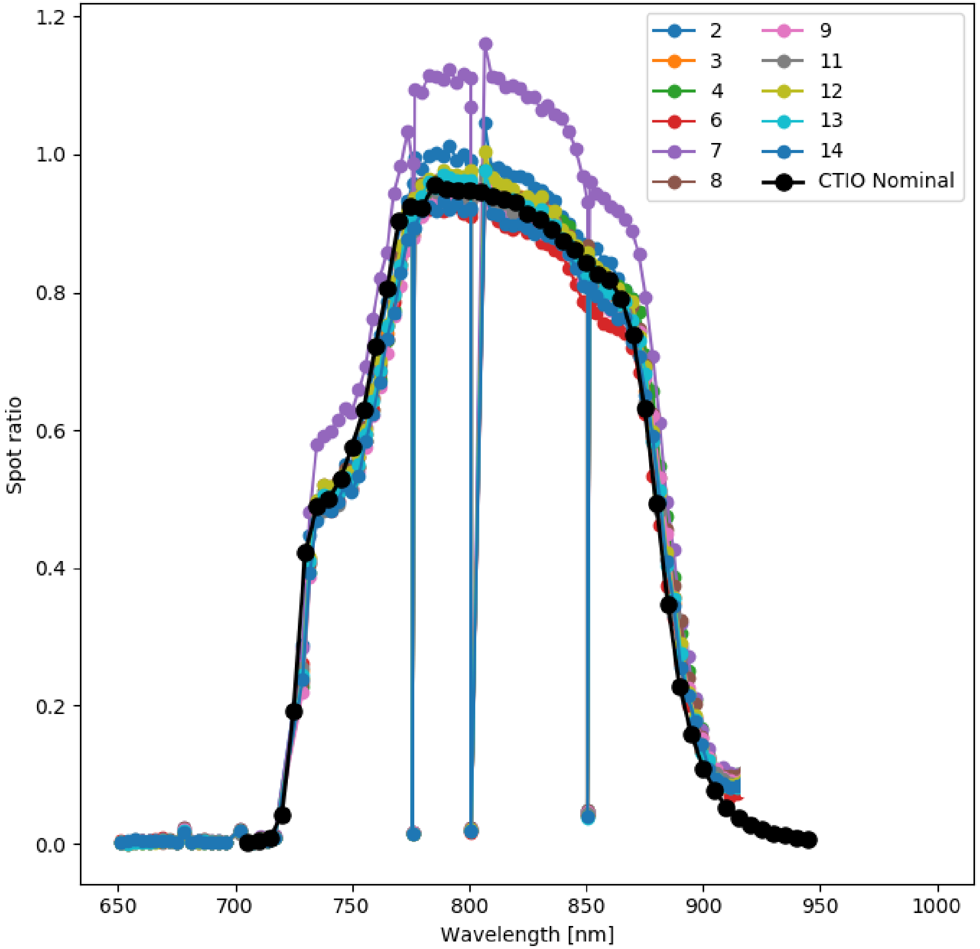


Application to I band

Spot-spot ratio of an I band scan from 2017-10-07 to the no filter scan on 2017-10-11



Same, but with a vignetting correction (based on a single wavelength no-filter image taken on 2017-10-07)



Conclusion

Large steps in the maturity of the CBP

There are a number of systematics in the existing CBP data that have been identified, and are in the process of being quashed

Unfortunately, the set of data taken at CTIO in 2017 is probably *not* going to provide us with final filter curves with uncertainties <1%

There also exist a number of broader challenges with regard to CBP data, which hopefully DESC can provide some input on