



Impact of Differential Chromatic Refraction (DCR) on DES 5YR

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Overview



- What is DCR/ λ -dependent seeing?
- Impact on SN Ia PSF Photometry
- DCR Coordinate for DES 5YR
- DCR Shape/Seeing for DES 5YR

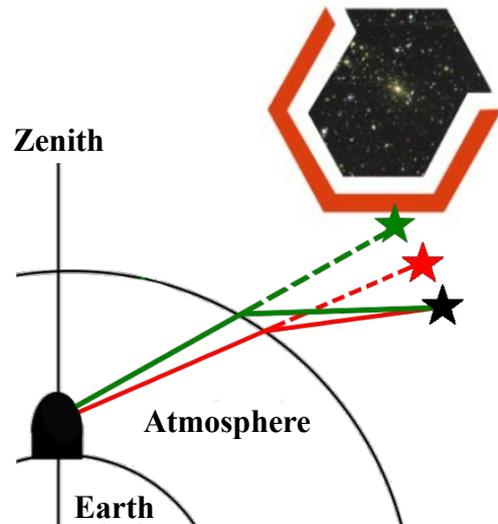


What is DCR/ λ -dependent seeing?

- Ground-based observations suffer from λ -dependent atmospheric effects and correcting for these could be important in future analysis

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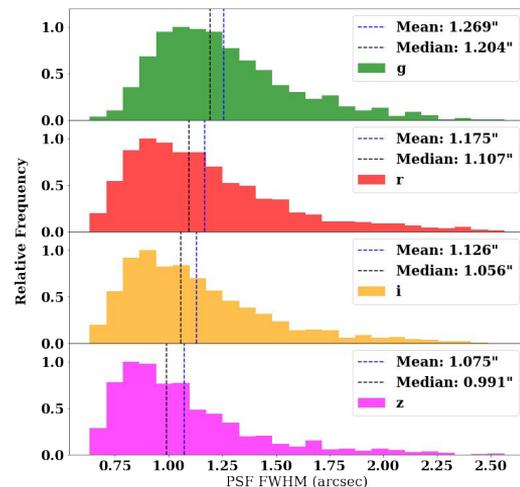
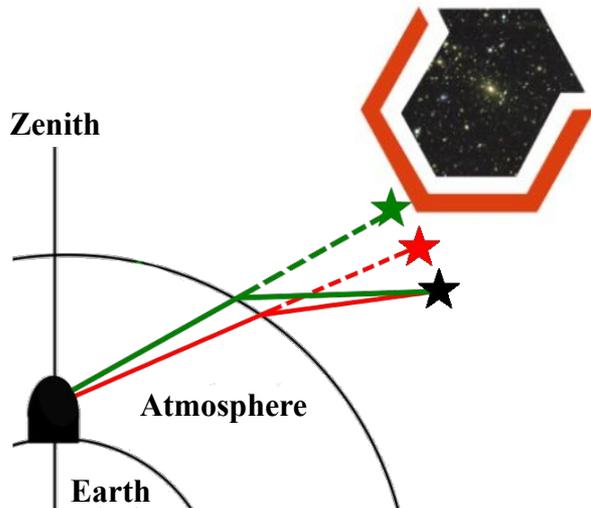
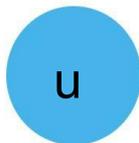
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- Differential Chromatic Refraction (DCR)
 - Positional offsets of celestial objects are caused by the wavelength dependence of atmospheric refraction



What is DCR/ λ -dependent seeing?

- Ground-based observations suffer from λ -dependent atmospheric effects and correcting for these could be important in future analysis
- Differential Chromatic Refraction (DCR)
 - Positional offsets of celestial objects are caused by the wavelength dependence of atmospheric refraction
- λ -Dependent Seeing
 - Changes in the refractive index due to atmospheric turbulence
 - Atmospheric convolution kernel size $\theta \propto \lambda^\alpha$, $\alpha = -0.2$

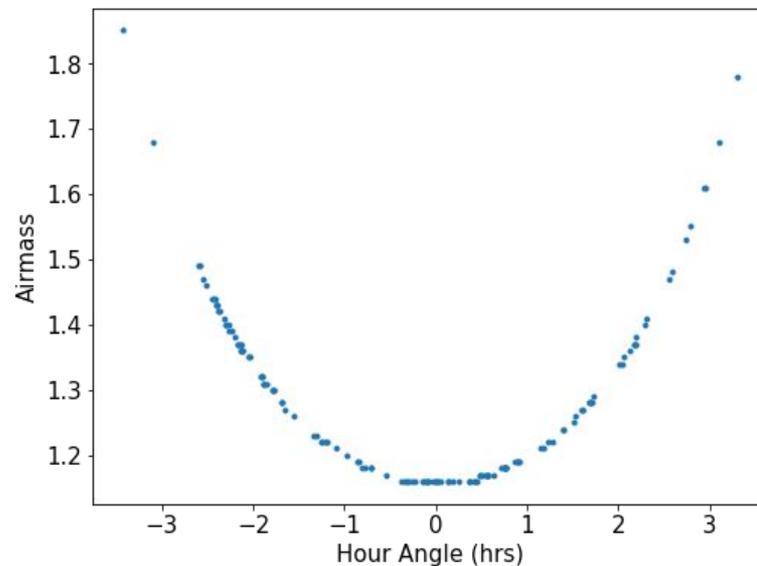
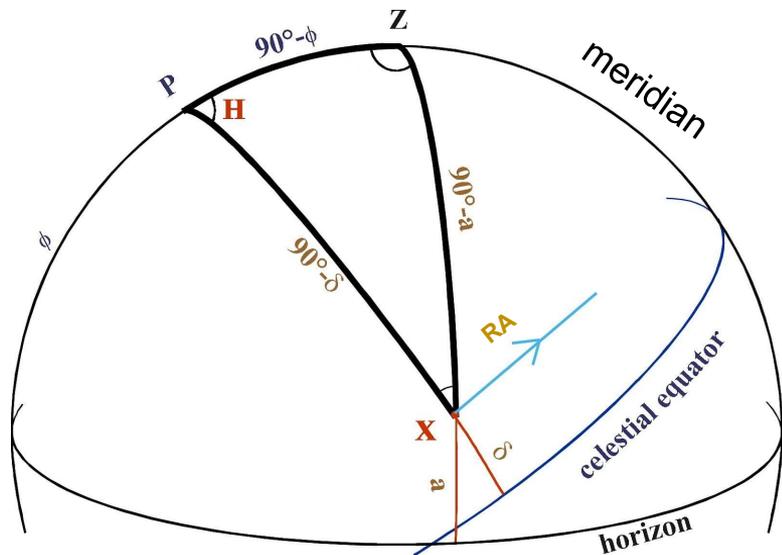
PSF sizes





Hour Angle and Air Mass

- DCR causes shifts in the altitude of an object based on the air mass, the amount of air along the line of sight (1.0 at zenith)



Left: An object located at position X with reference to the North Celestial Pole (P), zenith (Z), latitude (ϕ), altitude (a), declination (δ), and right ascension. Right: Field SN-S1 DES g-band

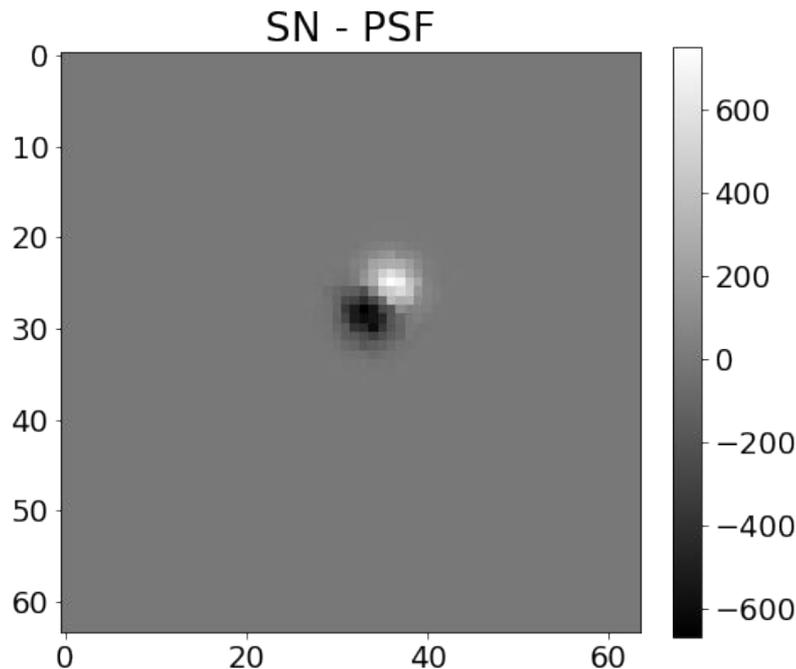
PSF Photometry



$$F_{\text{SN}} = \frac{\sum_i F_i P_i}{\sum_i P_i^2}$$

F_i : Flux of SN in pixel

P_i : Flux of PSF in pixel



Impact on Photometry



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- λ -Dependent Seeing effects
 - Causes different PSF and SN shapes (**Seeing**)

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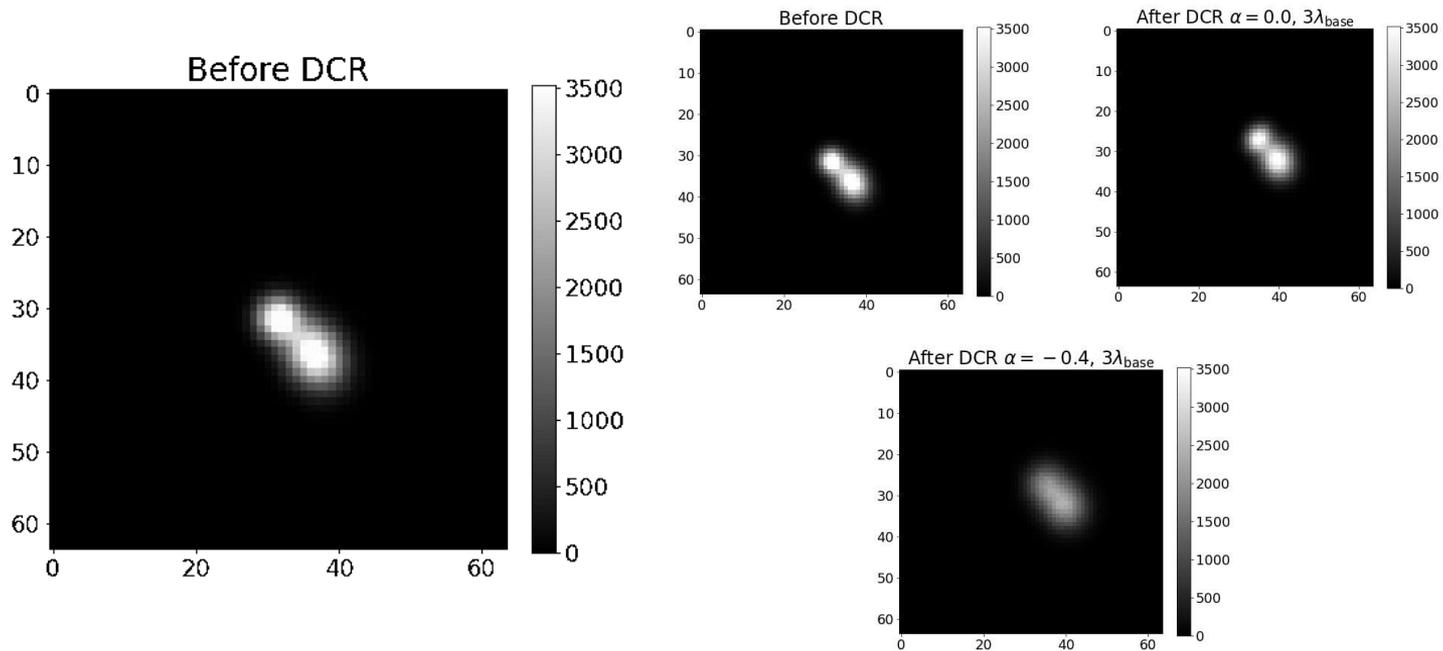


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 - Different SN and PSF shapes (DCR Shape) DES 5YR
 - Host galaxy also assumed stationary, thus mean galaxy coordinate different from those in individual observations (Mean Galaxy Subtraction)
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Visualization of Effects



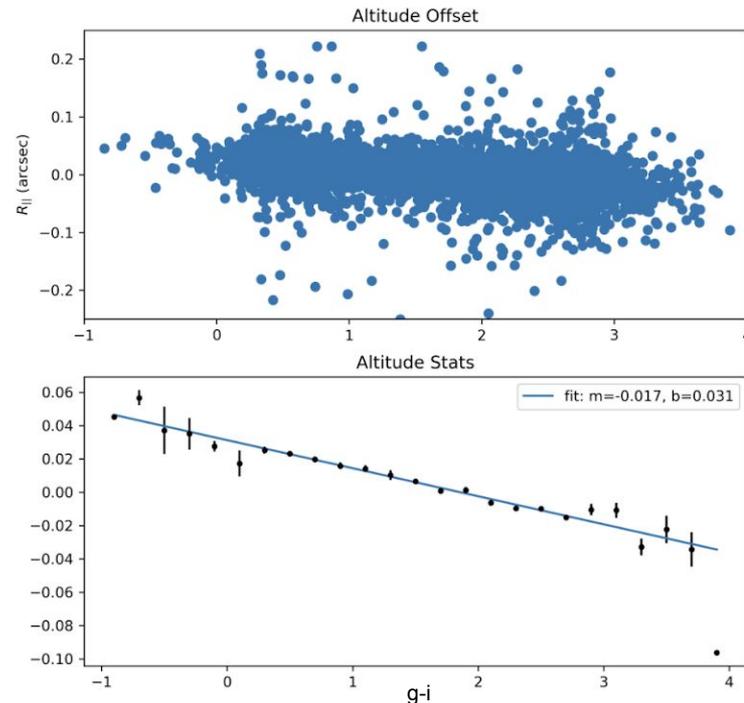
Left: Animation showing an image before and after adding DCR effects. Right: Each step individual starting with the original image and after adding DCR Coordinate Shift and DCR Shape Change for different α values

Implementing Corrections: Coordinate Bias (Maria)



1. Beginning with all the DES5YR exposures we calculate the difference in altitude (offset) for the position of stars on the CCD and the reference position
2. All the stellar offsets and their $g-i$ color for a given exposure are used to calculate a best-fit line for the data

EXPNUM: 231593 AIRMASS: 1.09 FIELD: SN-C1 HOUR ANGLE -01:44:37.2

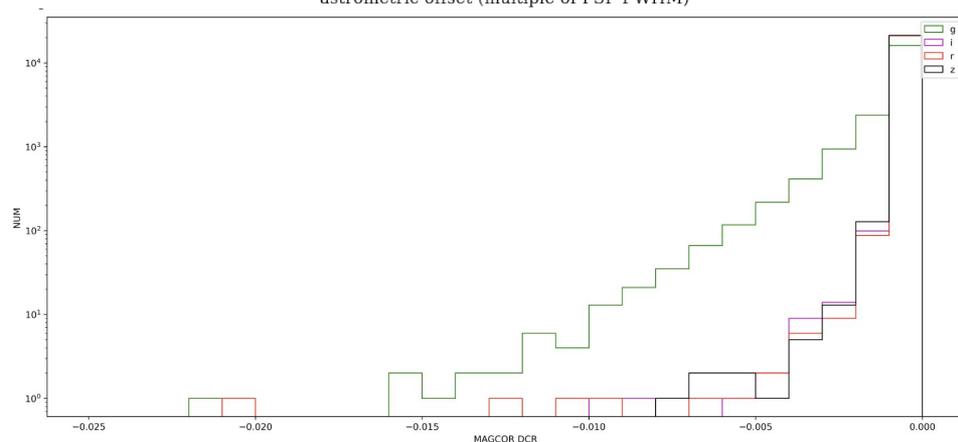
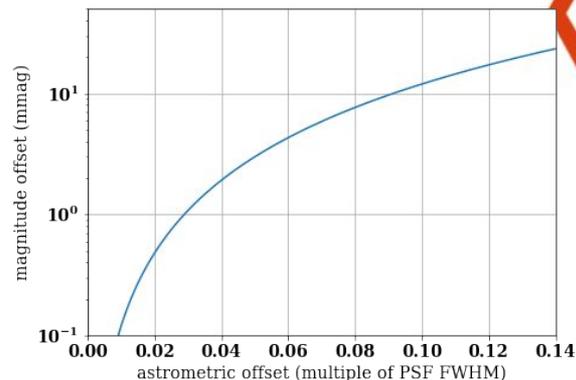


Top: The the $g-i$ color of a star vs the positional difference from the reference point. Bottom: Binned statistics that give bestfit

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3. We then take the interpolated g-i color of a SNIa from SALT2 to calculate an offset for each exposure that the SNIa was detected
4. This is enough for DiffImg, however, since SMP fits each band to a global RA/DEC we are overestimating the correction
 - Thus, we remove the average shift for a SNIa candidate
5. We then fit for the photometric bias using GalSim to produce a Moffat PSFs and perform PSF photometry by shifting the PSFs



Top: Plot of mag offsets as a function of astrometric offset from Jason. The astrometric offset is the $FWHM * DCR_offset$ Bottom: Histogram of the SMP photometric correction [mag] for every DES5YR exposure sorted by band.



DCR Shape/Seeing (Jason)

Using GalSIM for image simulations:

1. SN/star/galaxy profile defined
2. Convolved with PSF that has atmospheric seeing properties (DCR, λ)
3. WCS coordinates put onto images
4. PSF photometry performed (using DES filters - g, r)

PSF ref star: K5V, g-i = 1.53

- Using g-i magnitude (star spectra) as a proxy for SN Ia effective wavelength
- Centering reference star PSF (K5V) onto SN Ia after DCR/Seeing
- Using a Moffat profile for the PSF, not Gaussian
- PSF FWHM changes after DCR/Seeing

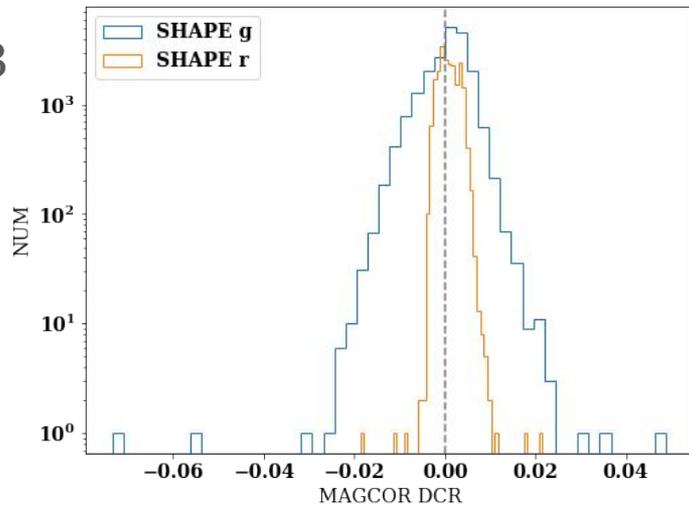
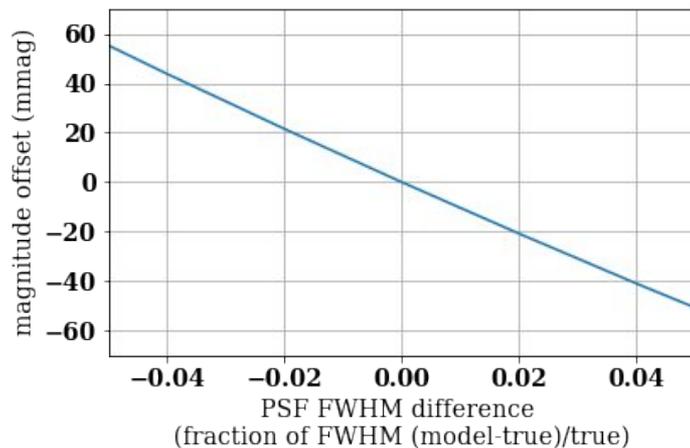
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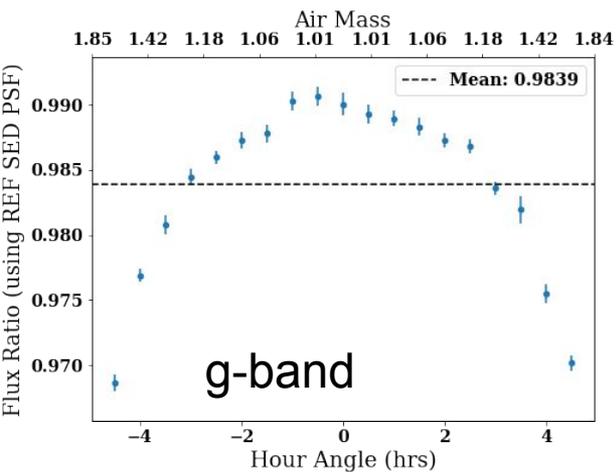
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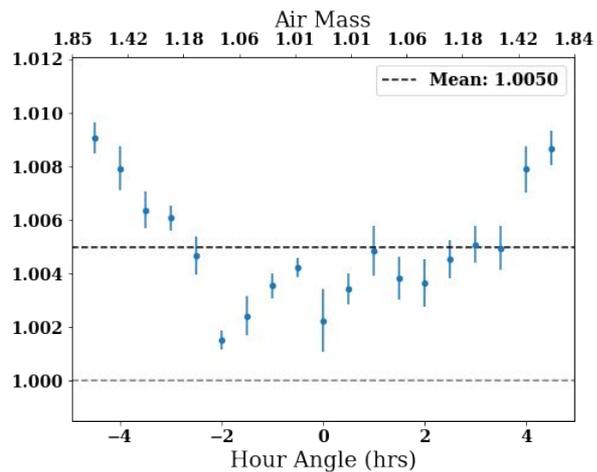




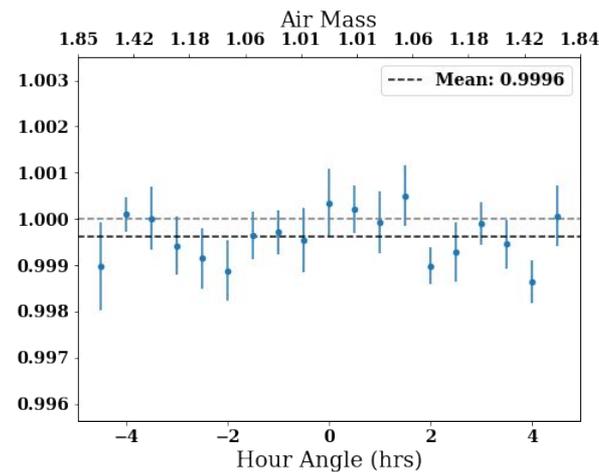
$g-i = -1.01$, Spectrum: uko5v



$g-i = 3.01$, Spectrum: ukm4v

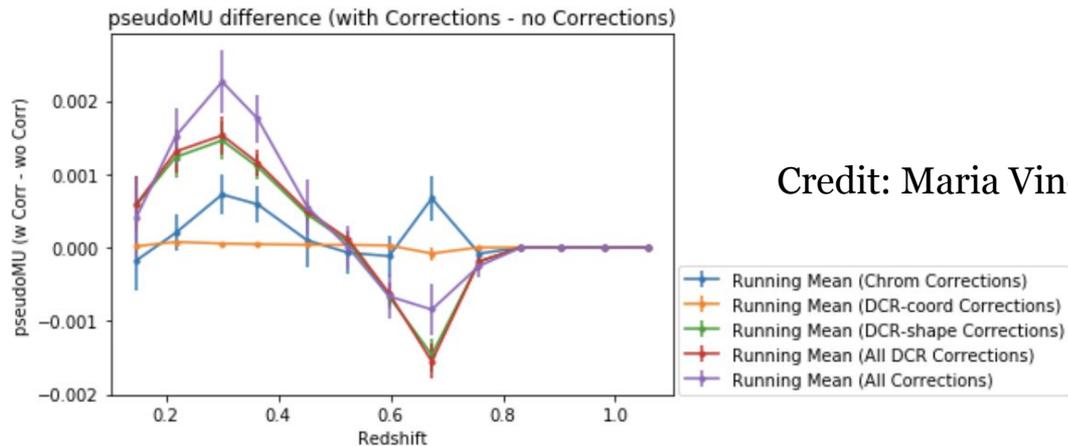


$g-i = 1.53$, Spectrum: ukk5v

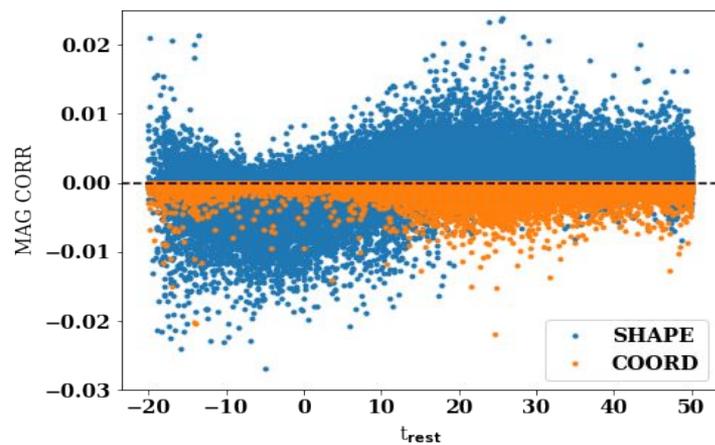
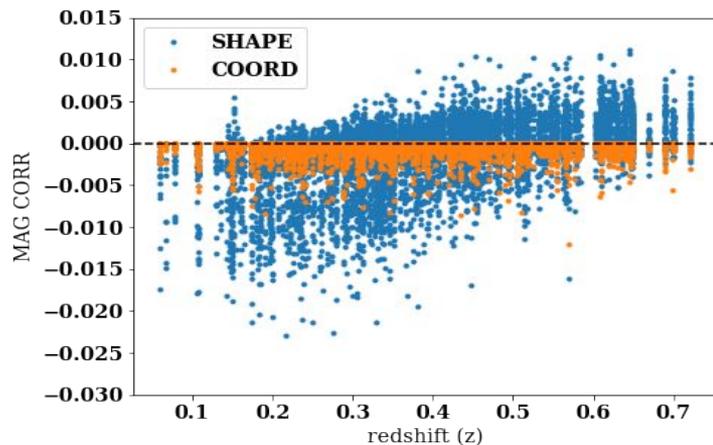


$$\alpha = -0.2$$

Impact On Cosmology

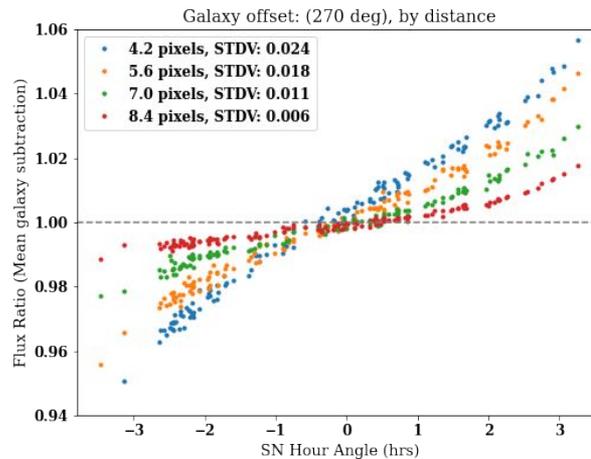
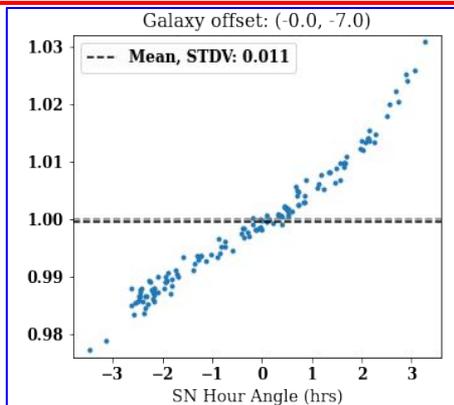
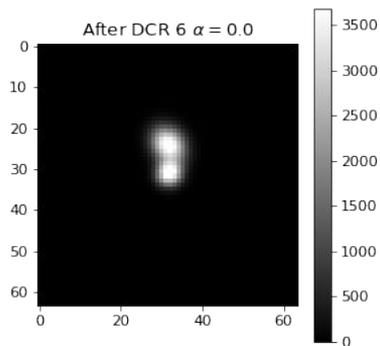
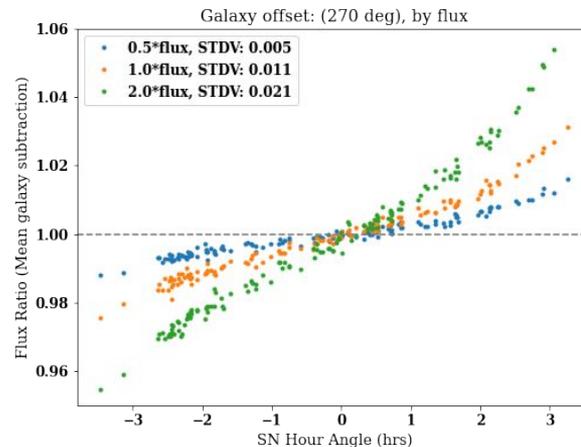
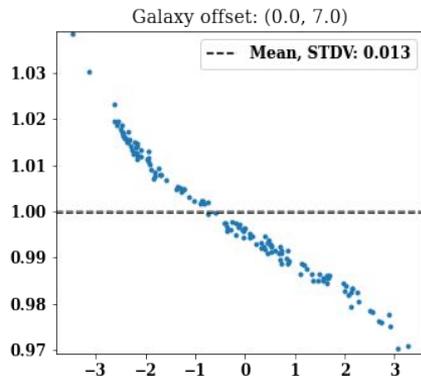
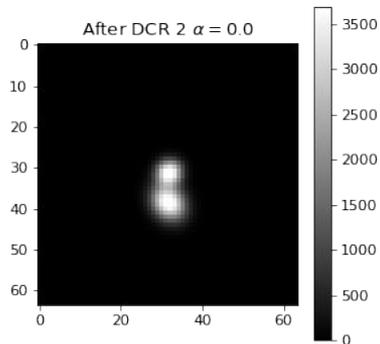


Credit: Maria Vincenzi



Mean galaxy subtraction

- Galaxy orientation, distance, flux varied



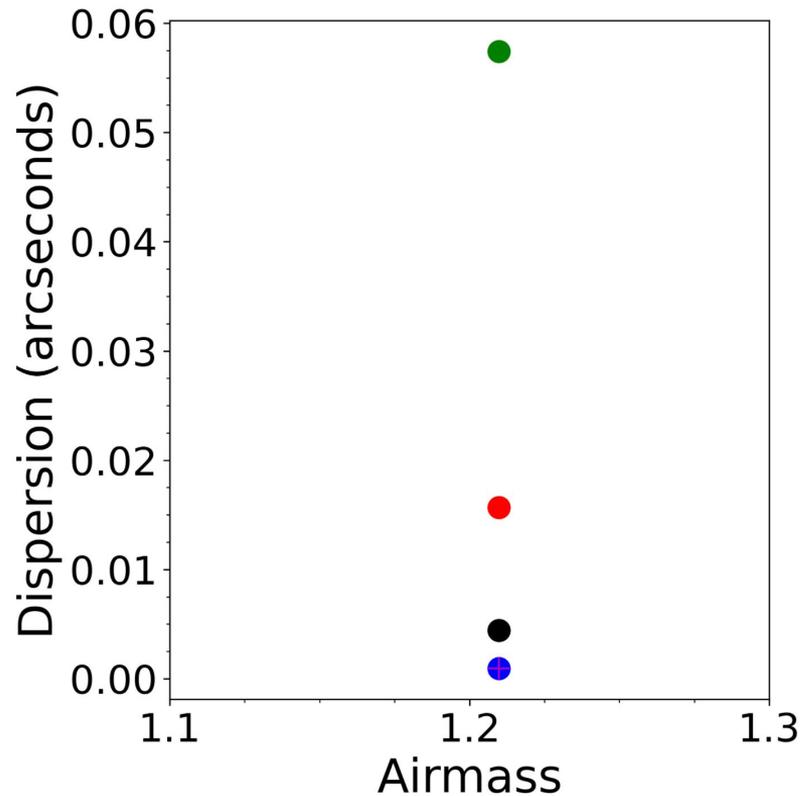


Questions?

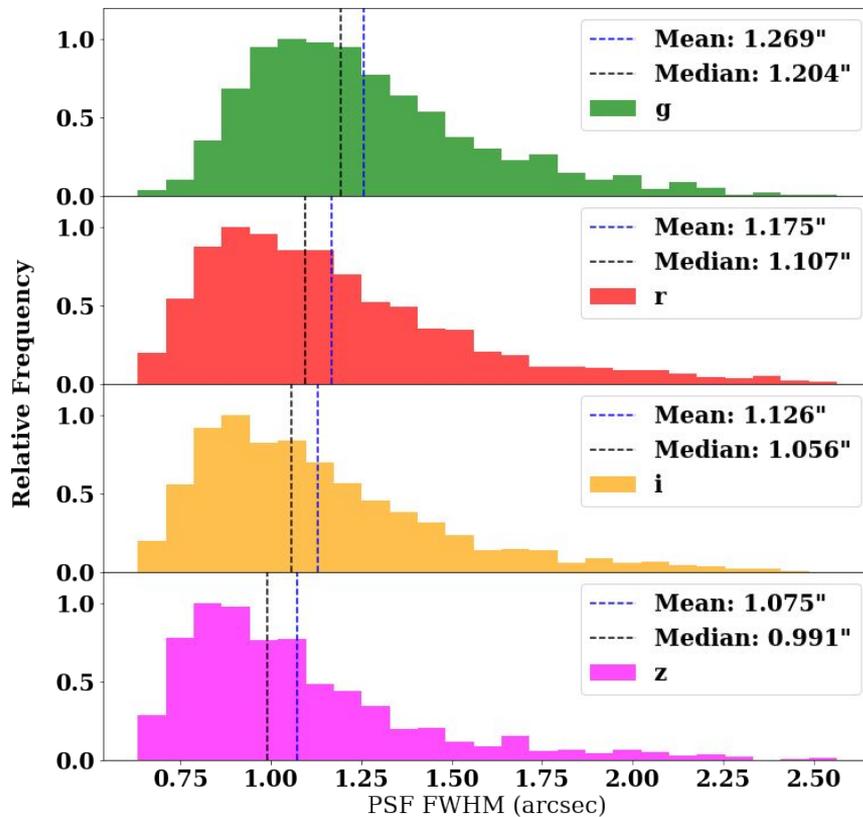
Extra Slides: DCR on a SN Spectrum



DCR for the Hsiao spectrum at Phase 0 in the DECam photometric system at an air mass of $AM=1.21$ ($Z=34.3^\circ$).



PSF FWHM distribution





Effective wavelength (base wavelength)

- Chose a reference star whose SED returns a g-i magnitude of 1.6.
- Chosen reference star: K5V

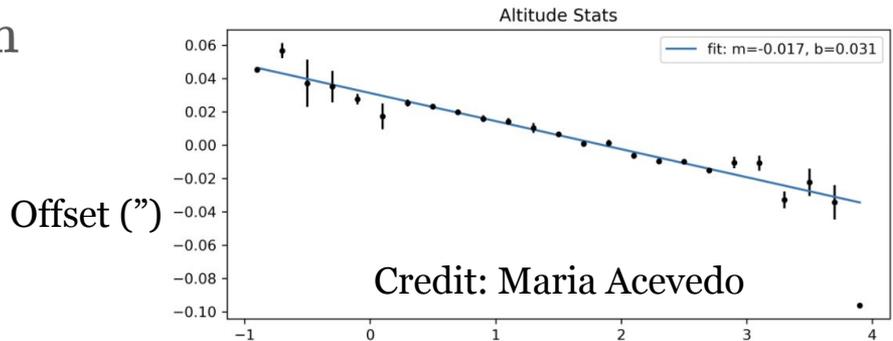
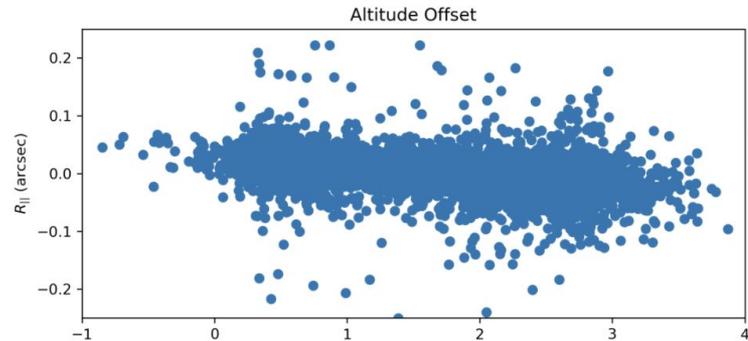
$$\lambda_{\text{eff}} = \frac{\int_0^{\infty} \lambda S(\lambda) F(\lambda) d\lambda}{\int_0^{\infty} S(\lambda) F(\lambda) d\lambda}$$

$S(\lambda)$: Flux, $F(\lambda)$: Filter Function

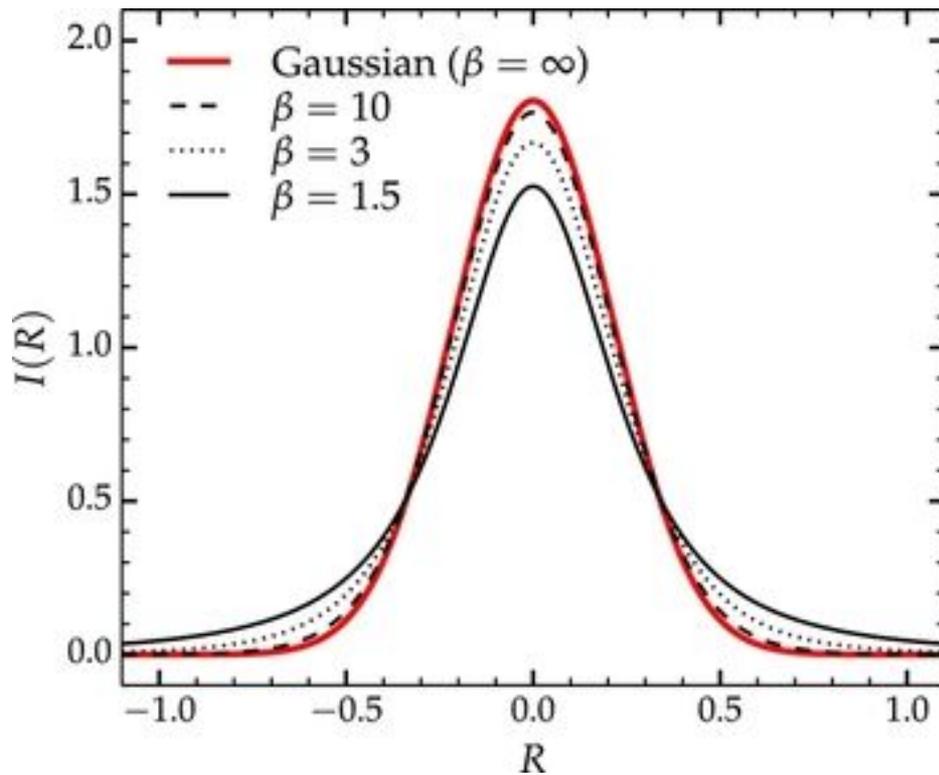
$$\lambda_{\text{eff}} = 490.8 \text{ nm}, 643.2 \text{ nm}$$

For DES g-band, r-band

EXPNUM: 231593 AIRMASS: 1.09 FIELD: SN-C1 HOUR ANGLE -01:44:37.2:



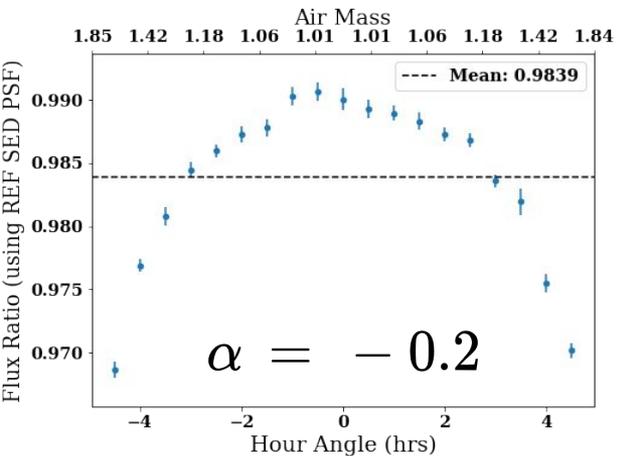
Gaussian vs. Moffat



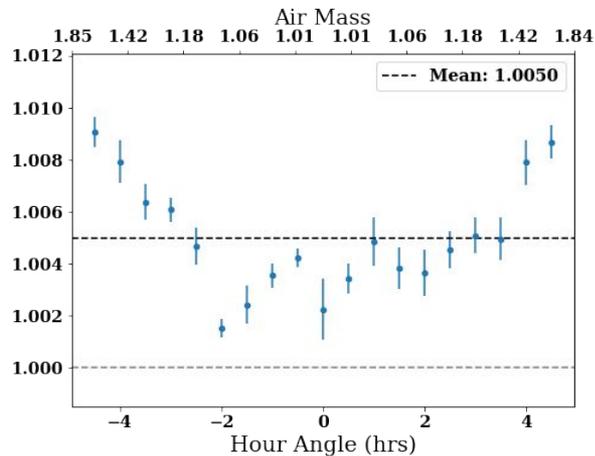
$$f(x, y) = A \exp\left(-\left(\frac{(x - x_0)^2}{2\sigma_X^2} + \frac{(y - y_0)^2}{2\sigma_Y^2}\right)\right)$$

$$f(r; \alpha, \beta) = 2 \frac{\beta - 1}{\alpha^2} \left[1 + \left(\frac{r^2}{\alpha^2}\right)\right]^{-\beta}$$

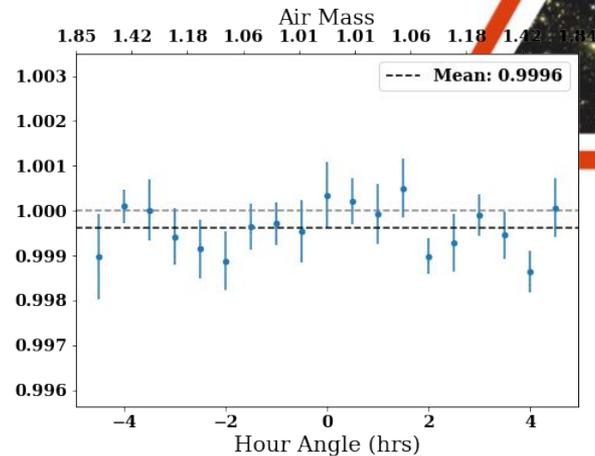
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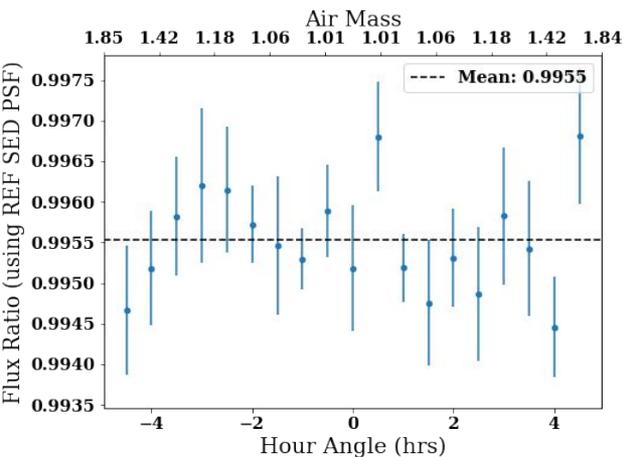
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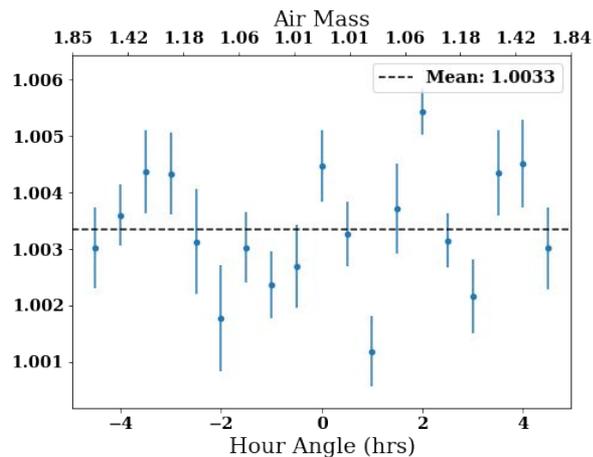
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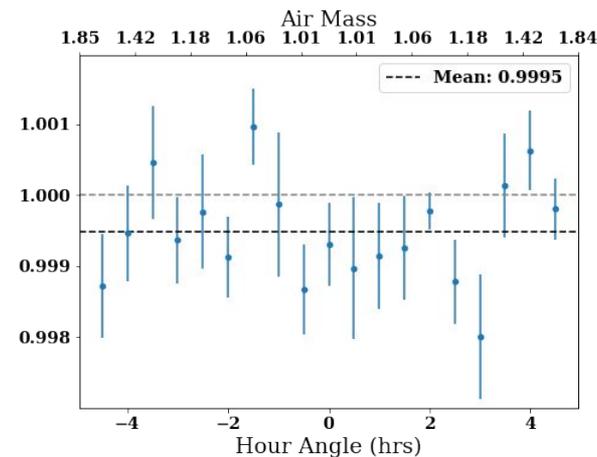
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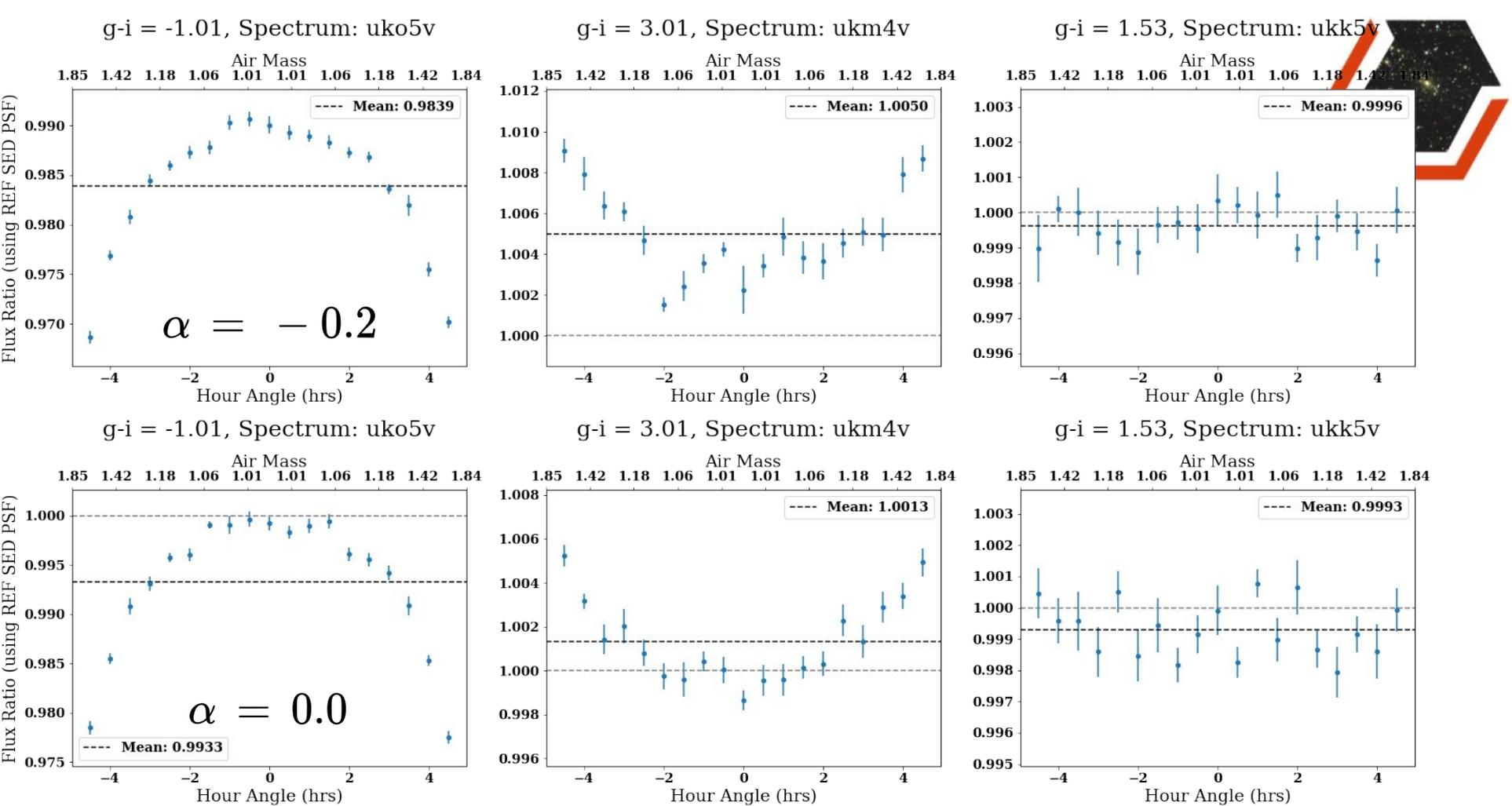


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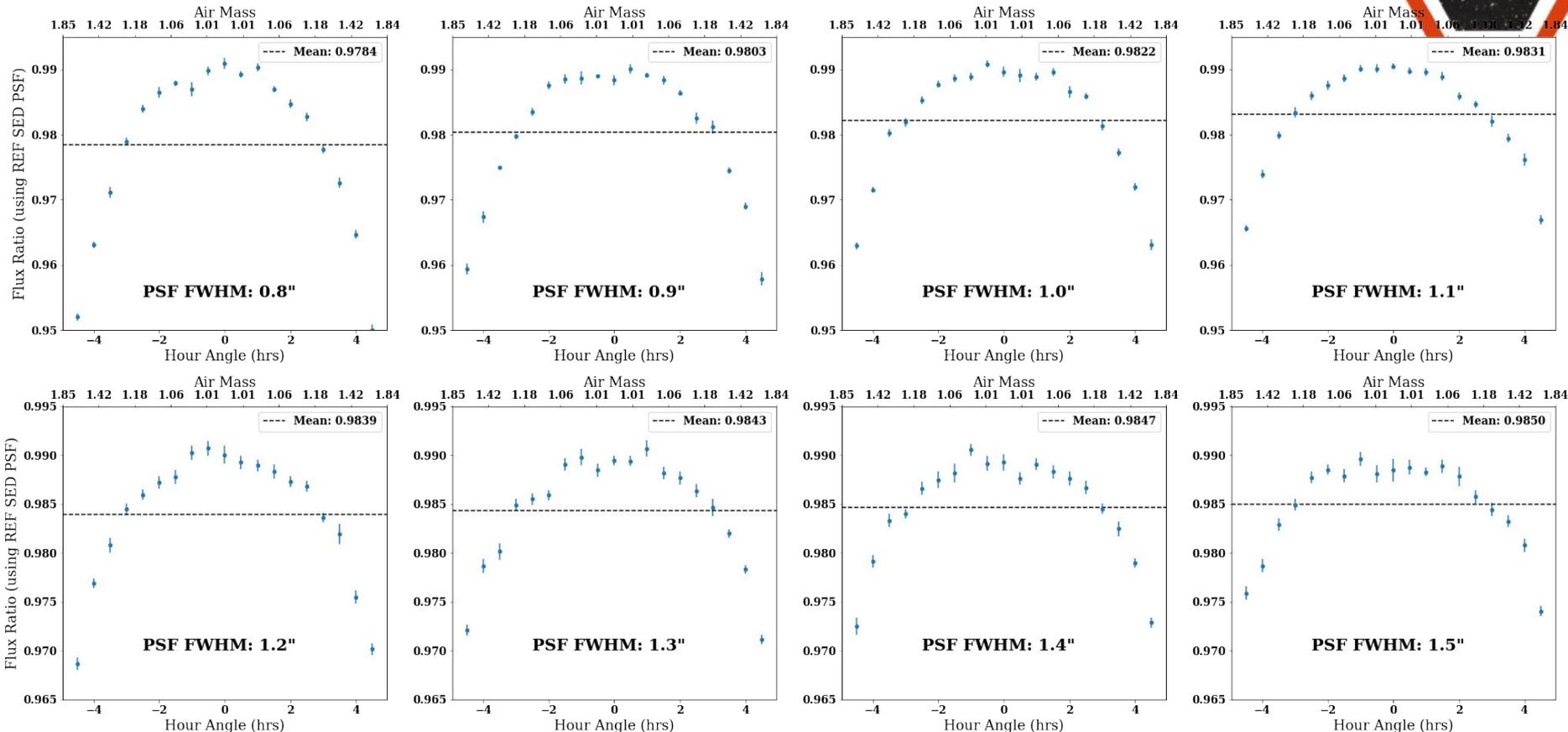


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$g-i = -1.01$, g-band, by PSF FWHM (before) $\alpha = -0.2$



Impact on cosmology

