SDSS Photometric Calibration Revisited

A look in the rear view mirror

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18 April 2012

Cosmology with SN

- The desire to determine SN magnitudes from measurements of different parts of the spectrum is a driver for precise photometric calibration.
- Comparison of different experiments requires an "absolute" calibration.
- Photometry is typically difference photometry relative to field stars.
- SN magnitudes vary by ~7%
  - Errors are reduced by averaging many SN.
  - Random calibration errors are a minor concern.
  - Even small systematic biases can cause problems.

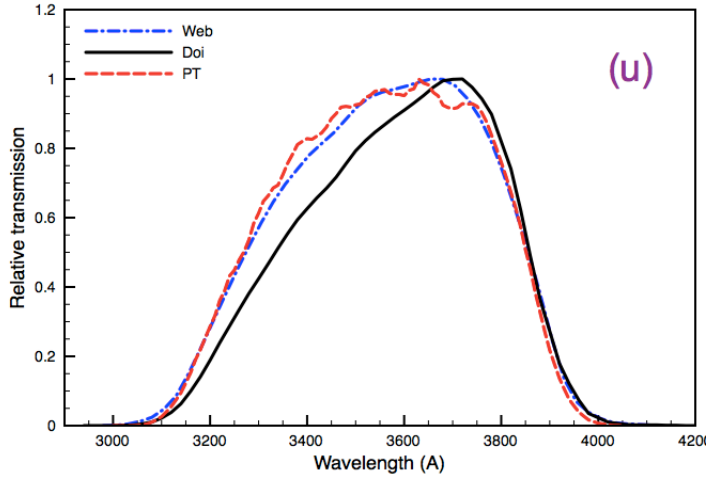
SDSS SN Calibration Strategy

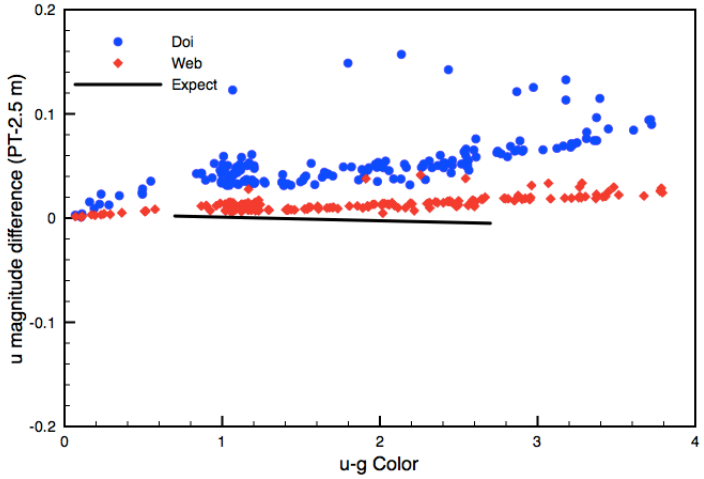
- Report "native magnitudes"
- Measure filter response (relative throughput)
- Calibrate absolute response with standard stars whose
  - Spectrum is well measured.
  - Photometric response of the SDSS telescope is measured.
- Measurements of the standard stars are reported as an "AB offset"
- Consider only stripe 82

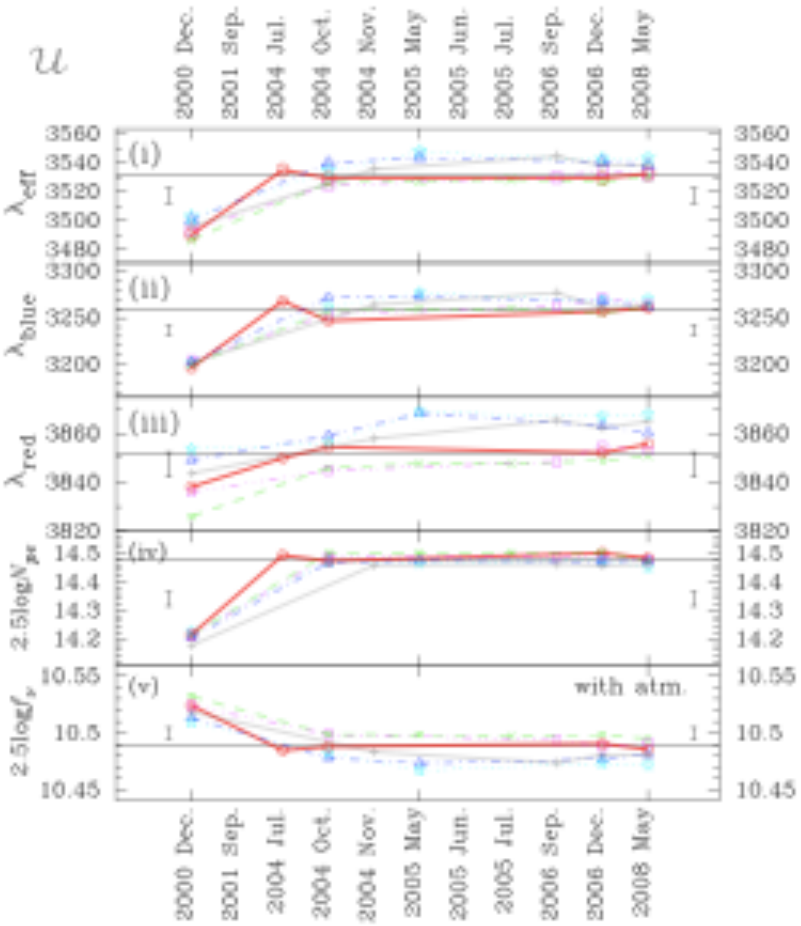
Details

- The Photometric Telescope (PT)
  - Measures atmospheric extinction based on primary standards (the USNO standards).
  - Measures unknown field stars for use as secondary calibration standards.
- The 2.5 m Survey Telescope is calibrated using the secondary calibration standards measured by the PT.
- The 2.5 m Telescope is normally operated in drift scan mode.

Filter Measurements

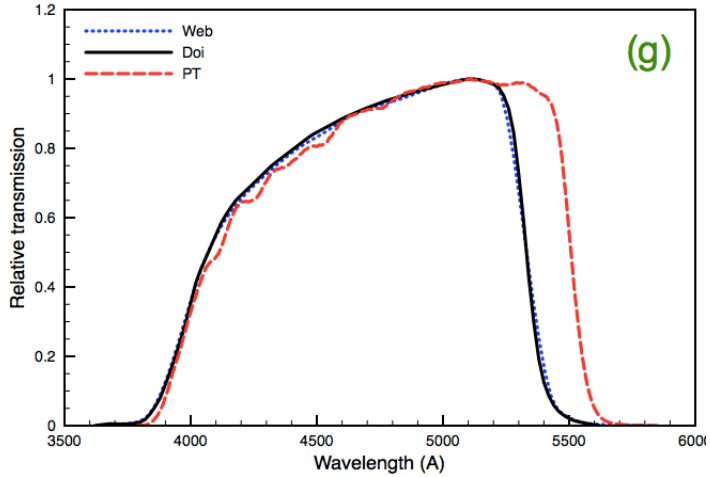


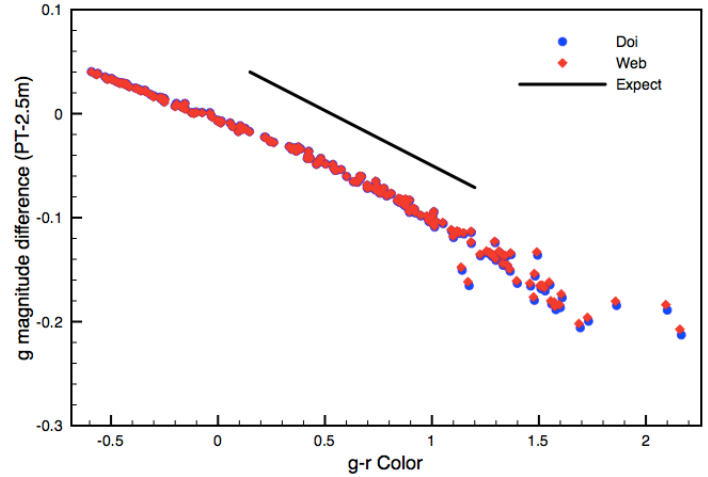


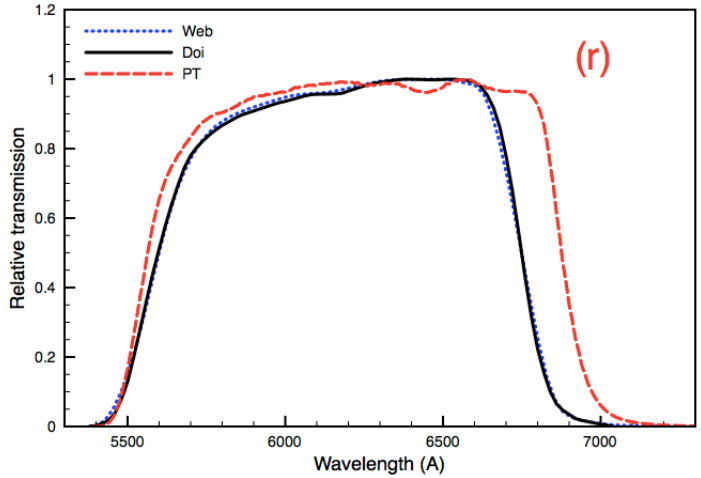


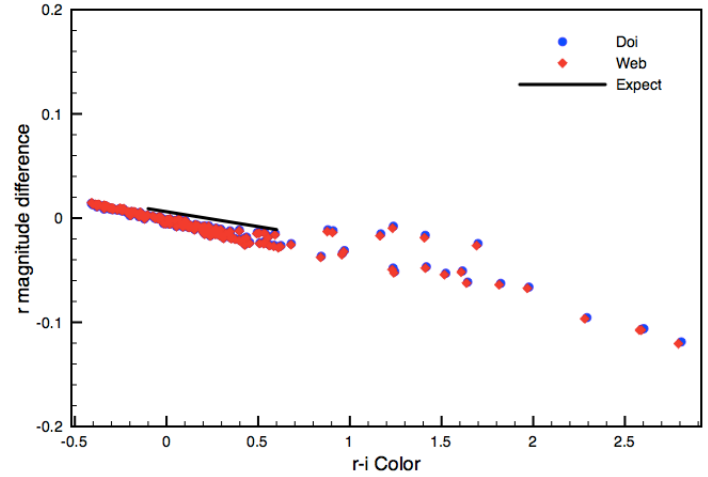
From Doi (2010)

More Filters

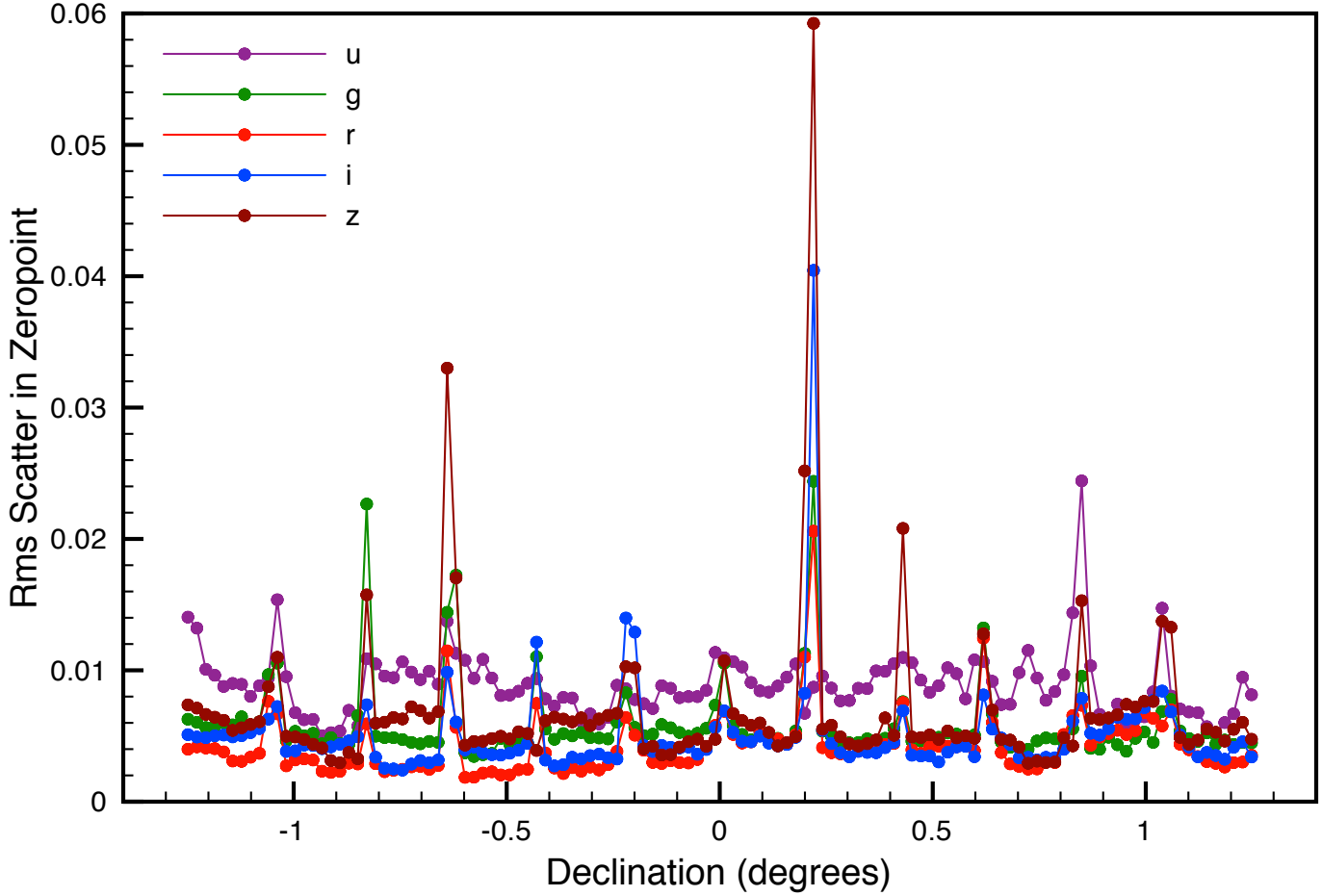




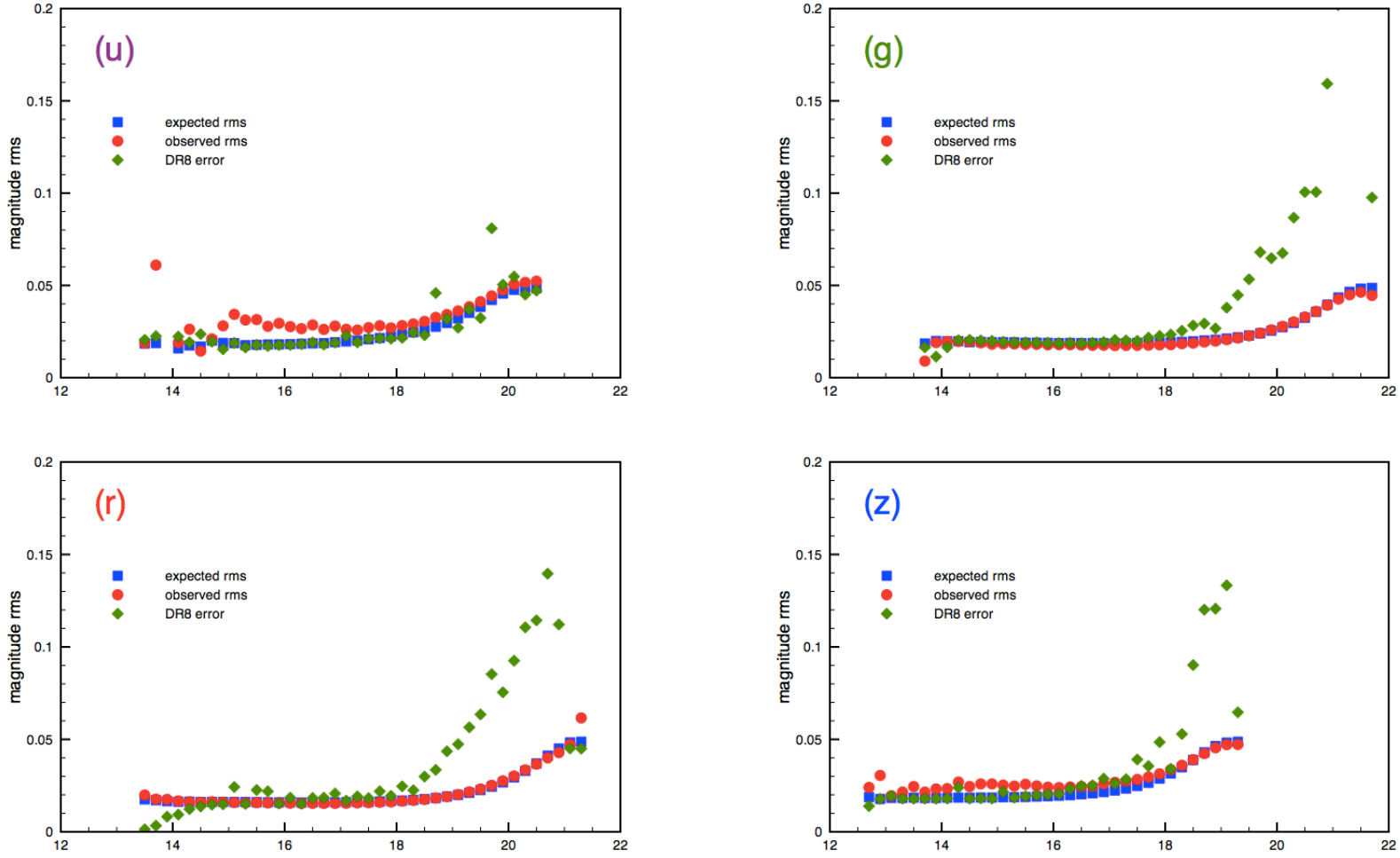




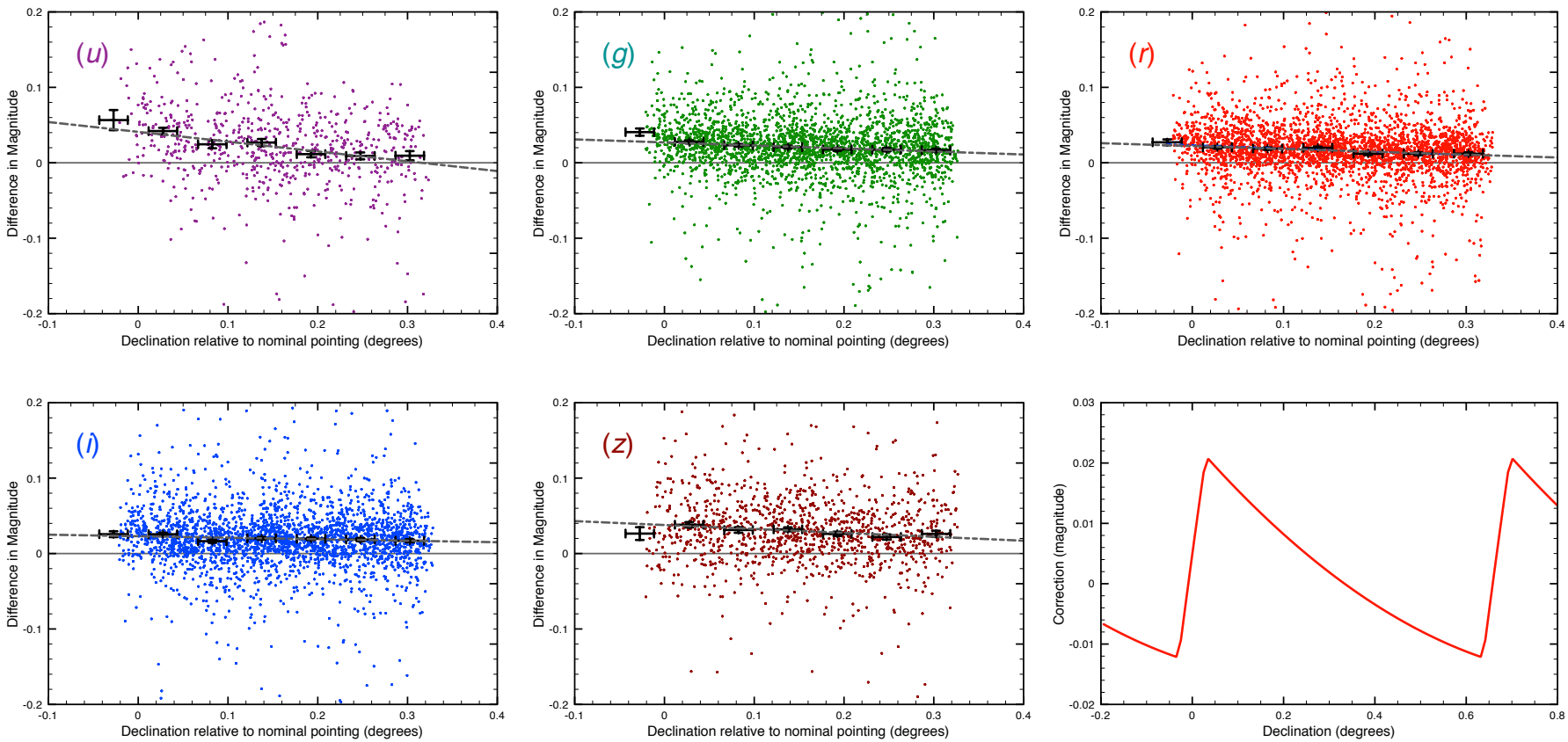
Flat-field Stability



Rms Measurement Variation



PT Flat Field



What is the Ideal Star Flat Dither Pattern?

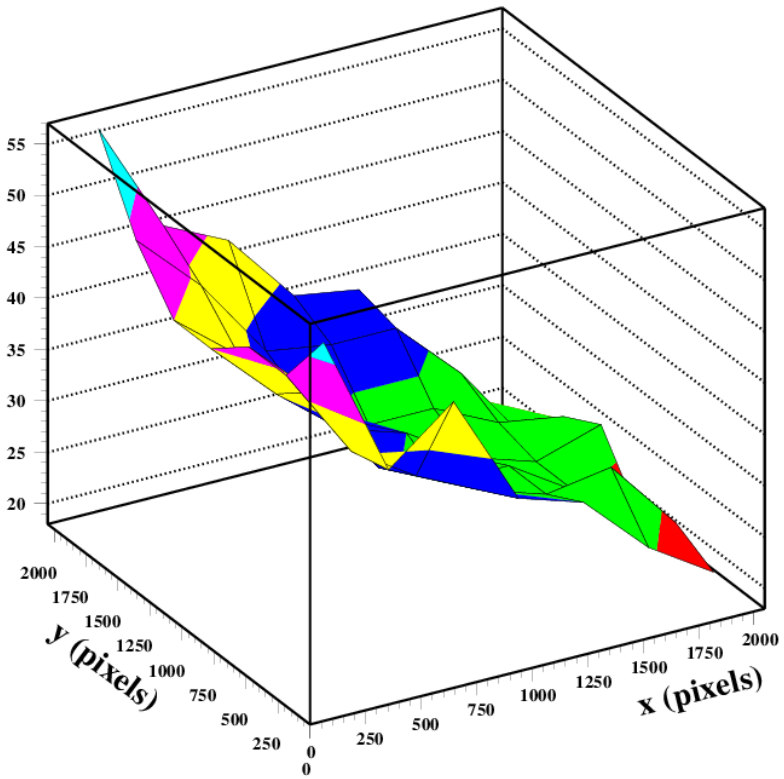
- Rely on dome flats for high spatial scales.
- Dither by 1/2, 1/4, 1/8, …?

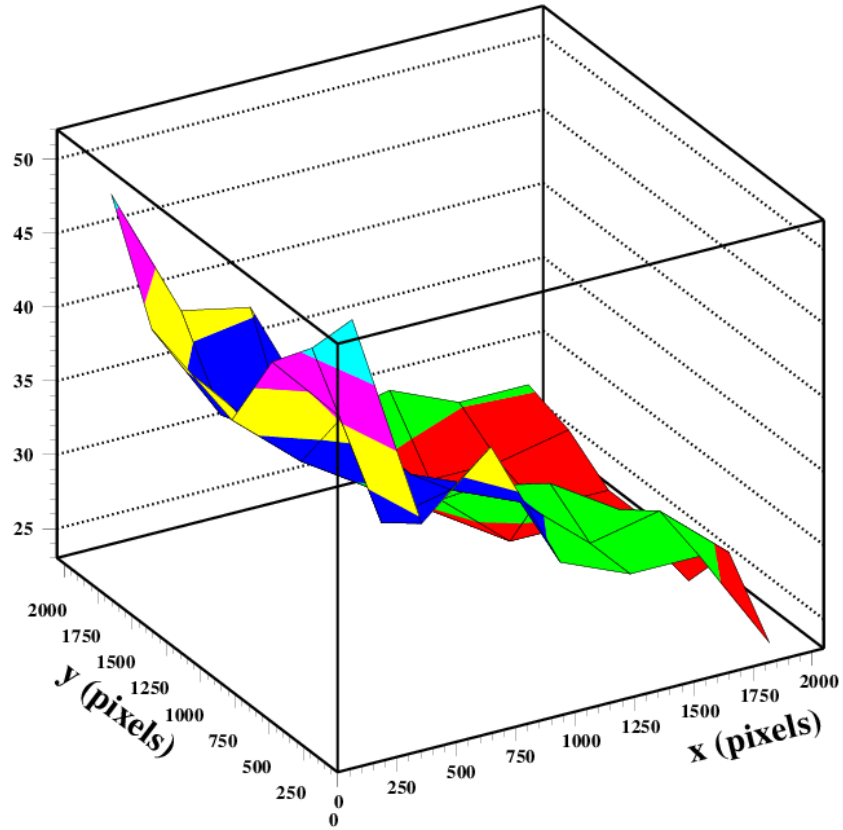
$$f(x) = \sum_n a_n e^{inkx}$$

$$f(x+h) - f(x) = \sum_n a_n \left(1 - e^{inkh}\right) e^{inkx}$$

$$\Rightarrow a_n = \frac{1}{1 - e^{inkh}} \int e^{-inkx} \left[f(x+h) - f(x) \right] dx$$

PT Response Map

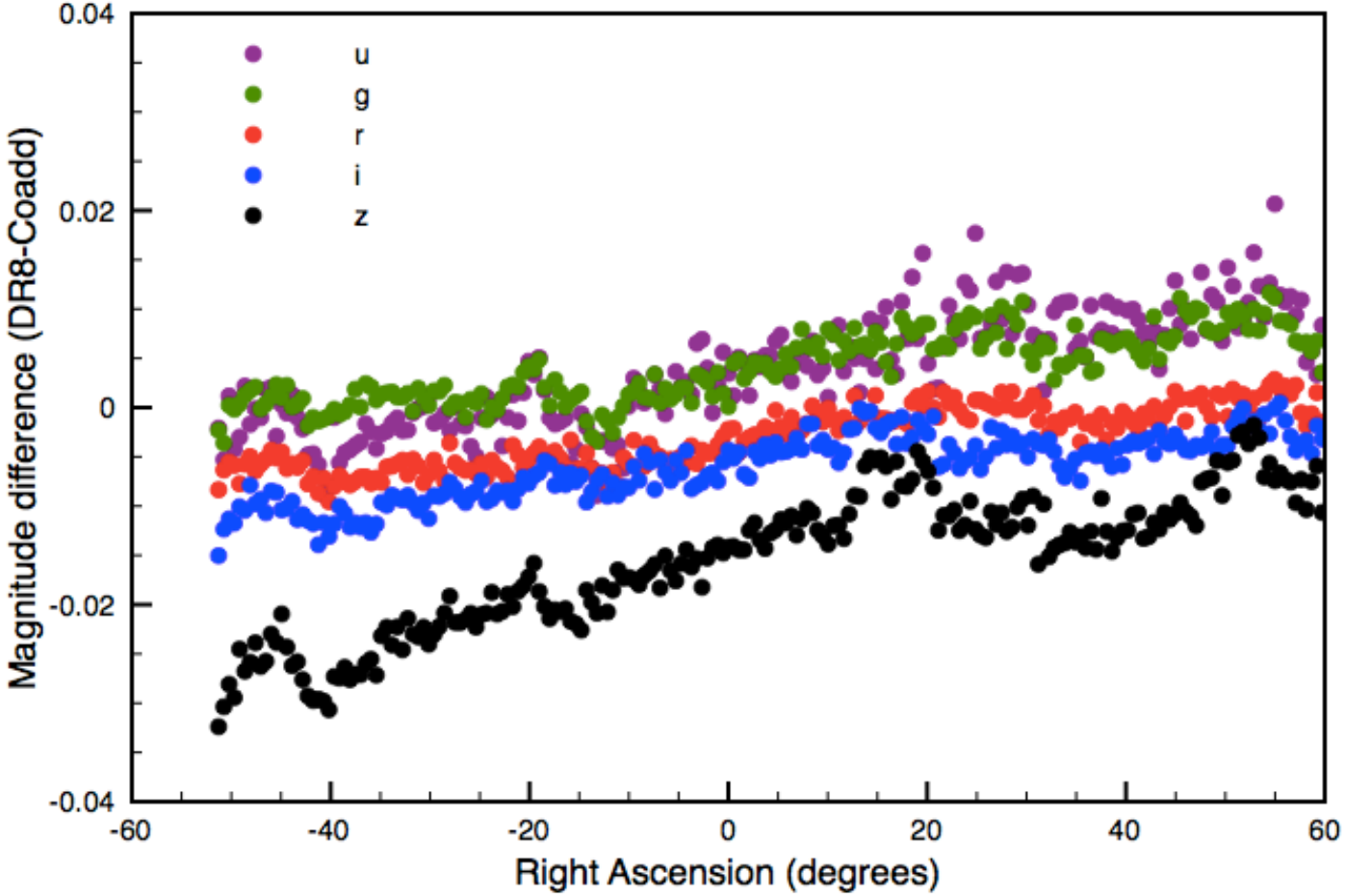




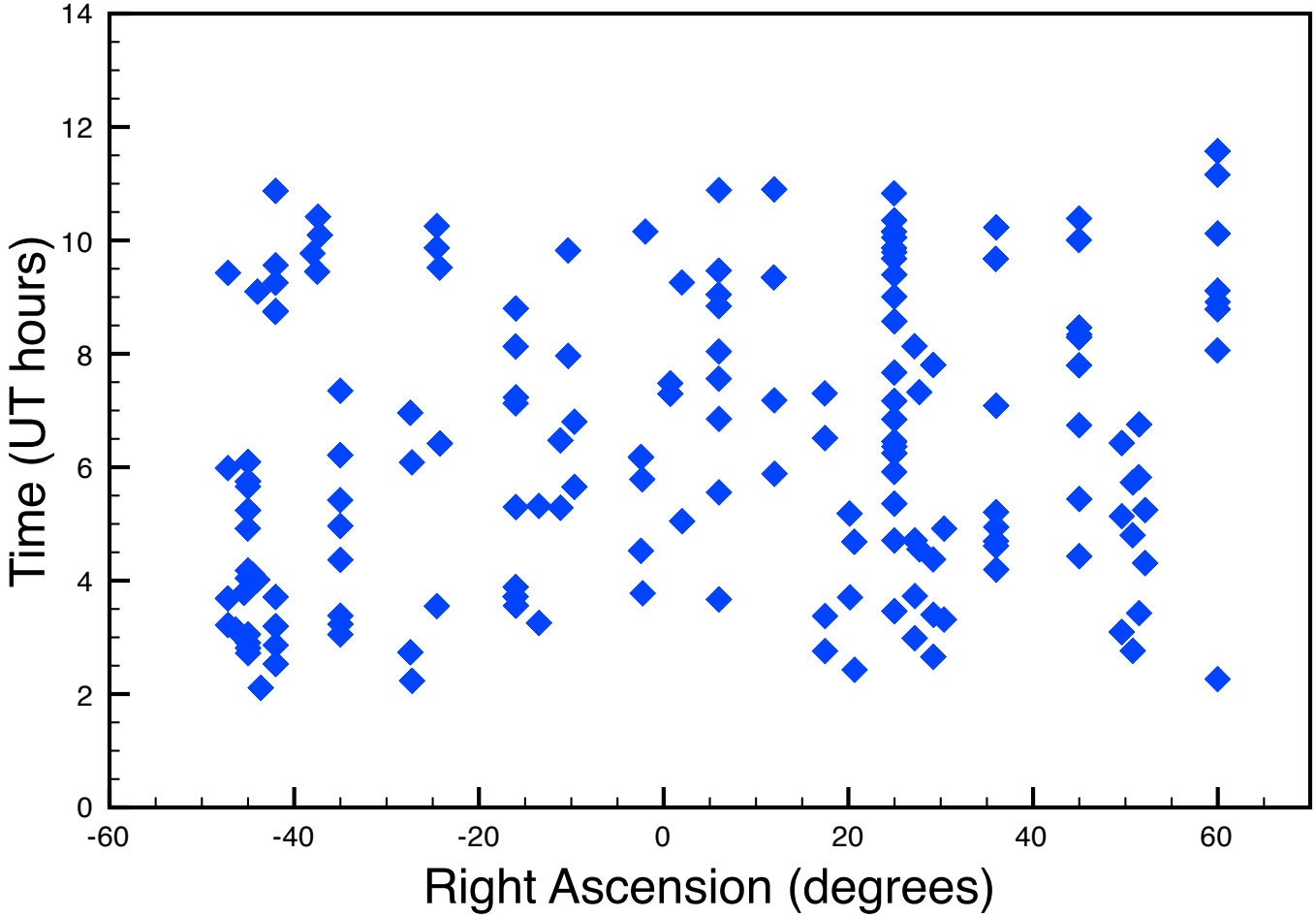
A Tale of 2 Catalogs

- Stripe 82 Coadd (Ivezic)
  - Uses PT response for magnitude (r-band)
  - Uses stellar locus for colors
  - Multiple measurements, outliers & variables rejected
- DR8 (Ubercal)
  - "Insensitive" to PT response
  - Color uncalibrated
  - Single epoch catalog

Coadd/DR8 Comparison

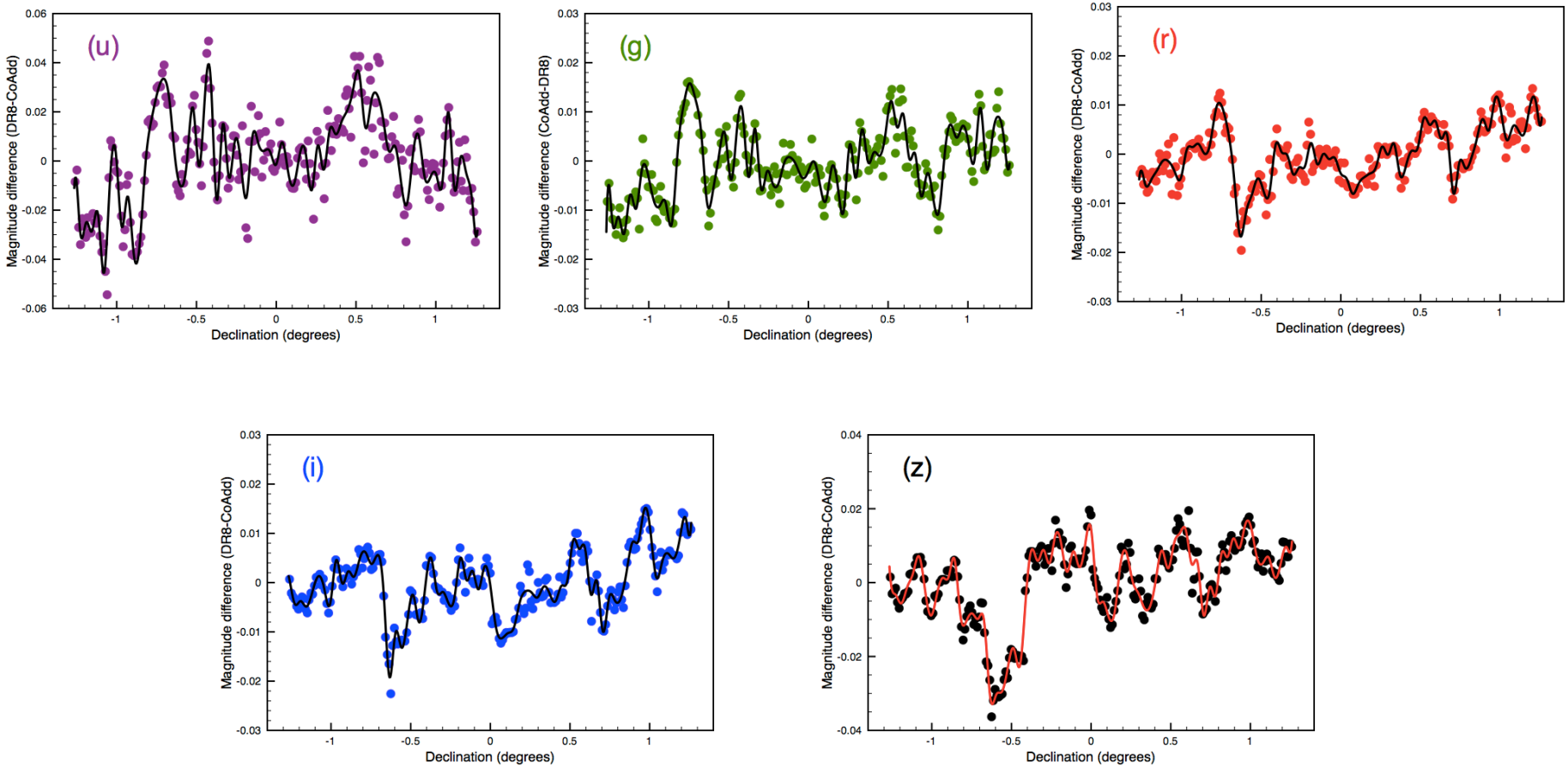


PT Observation Times

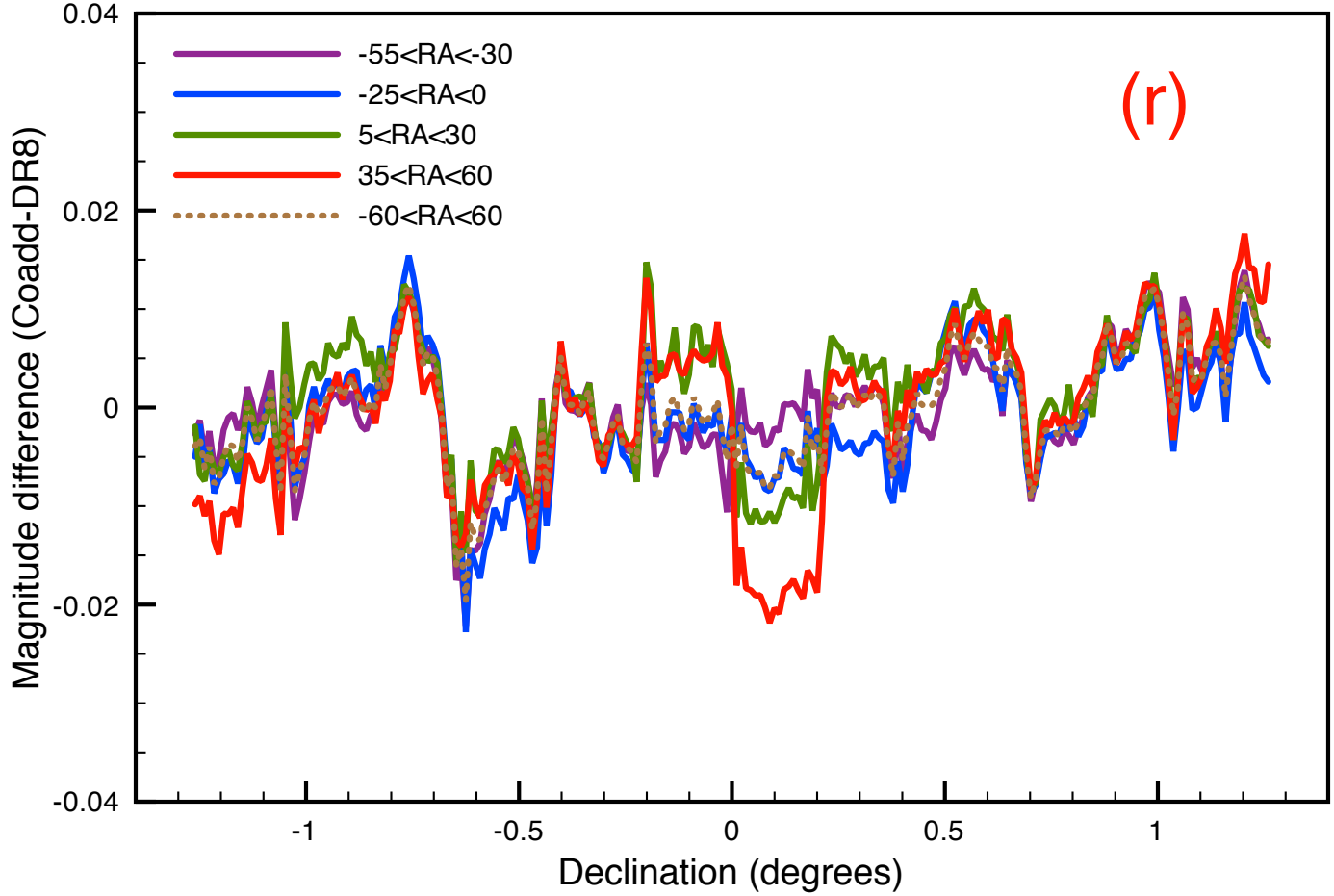


Comparison Coadd/DR8

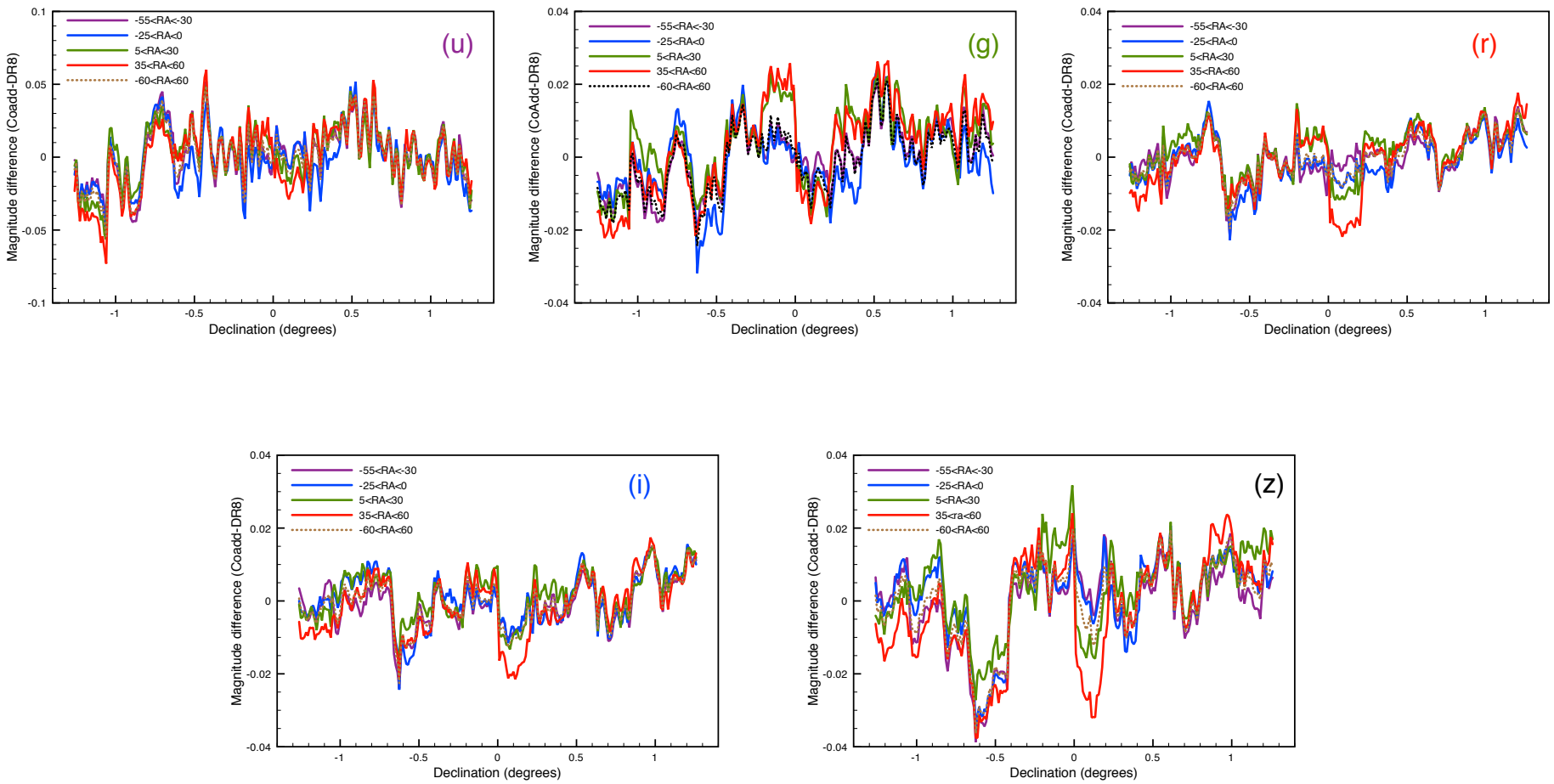
fits as a function of declination



Variability of the Calibration



All 5 Bands


(u)
(g)
(r)
(i)
(z)
-55<RA<-30
-25<RA<0
5<RA<30
35<RA<60
-60<RA<60
Magnitude difference (Coadd-DR8)
Magnitude difference (CoAdd-DR8)
Declination (degrees)

AB Offsets

Standard	*u*	*g*	*r*	*i*	*z*
Solar	-0.0660	0.0202	0.0052	0.0207	0.0125
Solar Error	0.0068	0.0035	0.0027	0.0057	0.0070
BD+17°4708	-0.0541	0.0158	-0.0021	0.0099	-0.0054
WD Average	-0.0455	0.0173	0.0037	0.0168	0.0059
WD Error	0.0149	0.0014	0.0030	0.0035	0.0057

Error	*u*	*g*	*r*	*i*	*z*
PT Measurement	0.0026	0.0015	0.0013	0.0025	0.0018
Color Transform	0.0029	0.0009	0.0008	0.0009	0.0017
HST Measurement	0.0056	0.0031	0.0022	0.0050	0.0066
SDSS Filters	?	?	?	?	?
HST Calibration	?	?	?	?	?

Conclusions

- Calibration is only as good as the weakest link (PT filters & flat field).
- Atmospheric extinction measurements are needed more frequently than once per night.
- Star flats are critical for precise flat-fields.
- "Frequent" calibrations are necessary (filters & flat field? & atmospheric extinction?)
- Redundancy is a key to understanding
  - Many standard stars
  - Multiple overlapping "star flats"
  - Cross-calibration with other surveys
- A transparent calibration technique is important.

Stellar Color/Color Plots