New developments in aerosol measurements using stellar photometry

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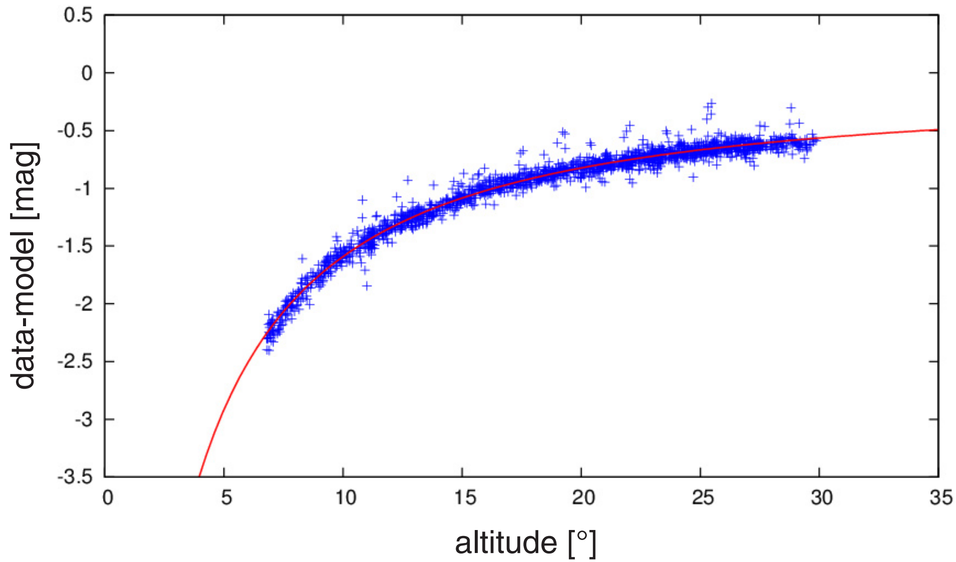
Aerosols from wide-field photometry

- fit extinction as a function of airmass
- get instrumental parameters simultaneously
- subtract molecular contribution
- can we reach 0.01 precision in VAOD with noninvasive method?



$$m_{inst} = M m_{cat} + Z_i + k_i A + c_1(B-V)(c_2(B-V)+1) + R_1 r(R_2 r + 1) + k_c A(B-V) + k_{A2} A^2$$

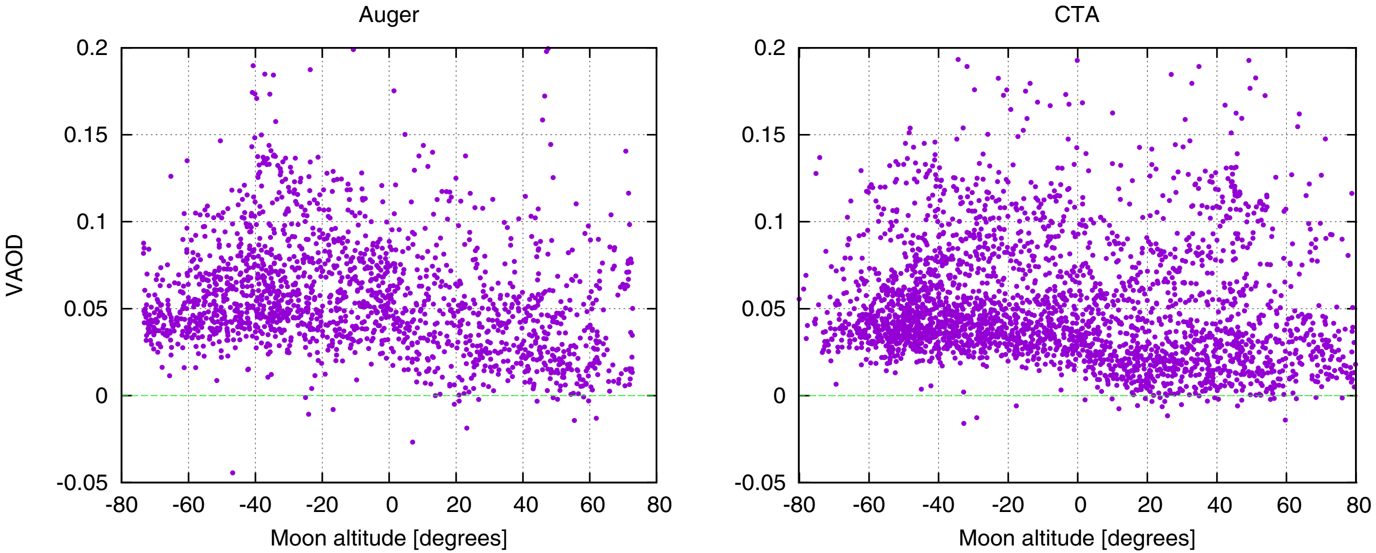
– A: airmass $B-V$: color index ($m_{cat} = B$) r: radial position on frame

– M, c_1, c_2, R_1, R_2, k_c, k_{A2} held constant; (Z,k)-pair for each scan

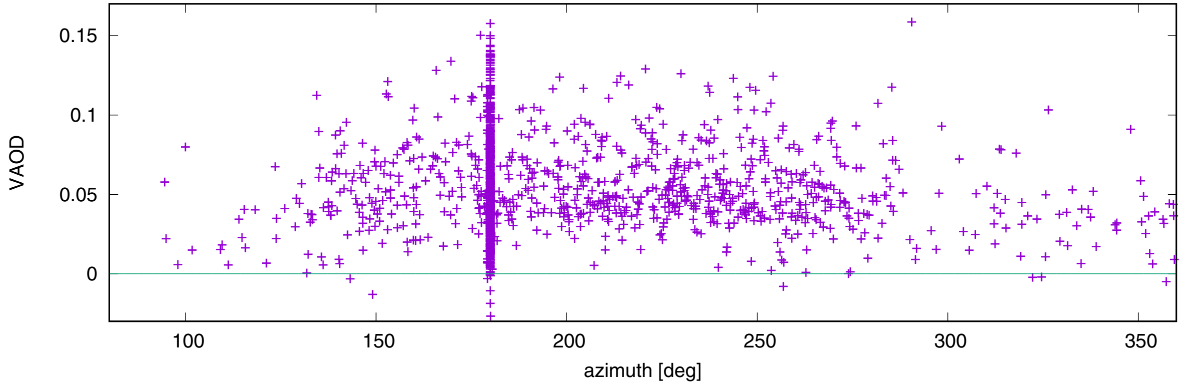
FRAMs and data:

- Auger (Argentina): since 2005, suitable for VAOD since 03/2013, dedicated aerosol measurements since 01/2016
- CTA (Chile) since 09/2017
- see Petr Janeček's talk for details

"Moon effect" in both CTA and Auger data

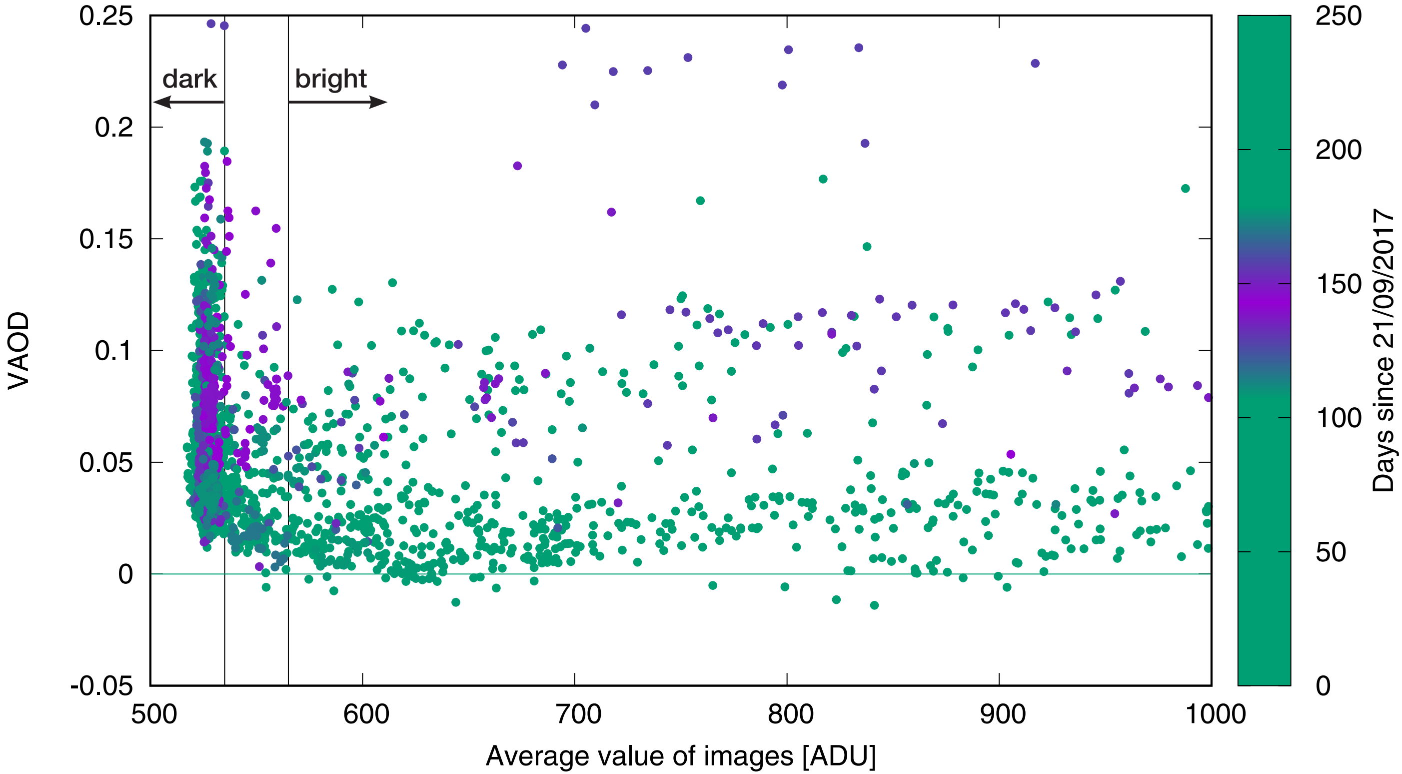


also a small "Malargue effect"



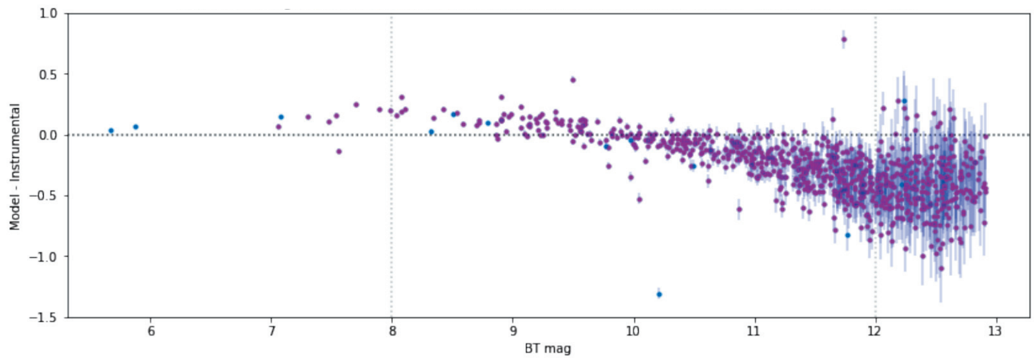
Moon effect = background effect

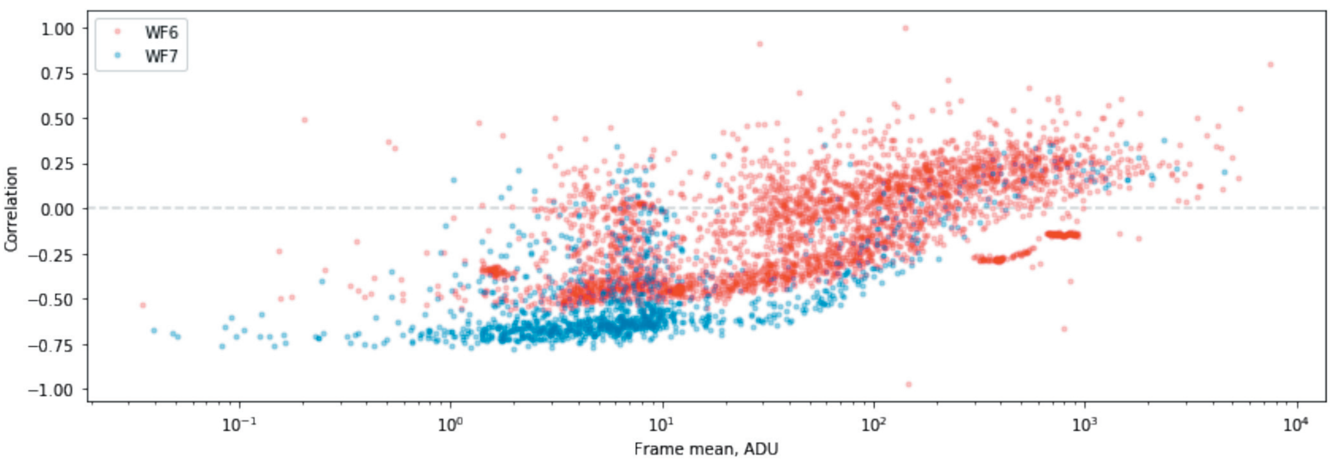
- sort into two classes "dark" and "bright"
  - "upper branch" seems related to a period of higher aerosols



CCD nonlinearity: the cause of background problem?

- Relation between incoming light and ADU counts not linear
  - manifests as non-linear measured/catalog magnitude relation
- Stronger for smallest fluxes -> explains correlation with background

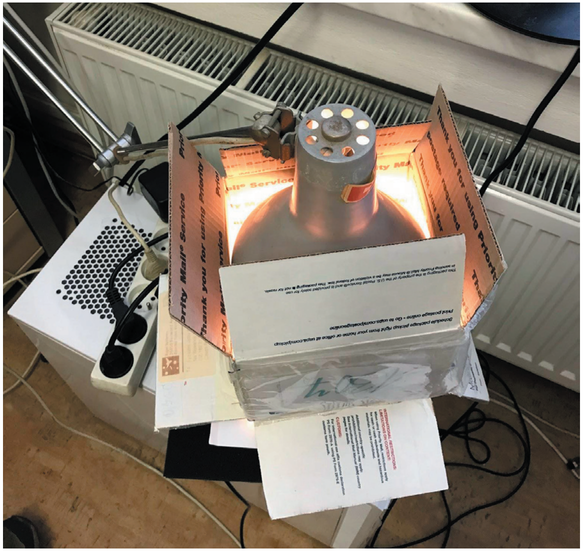


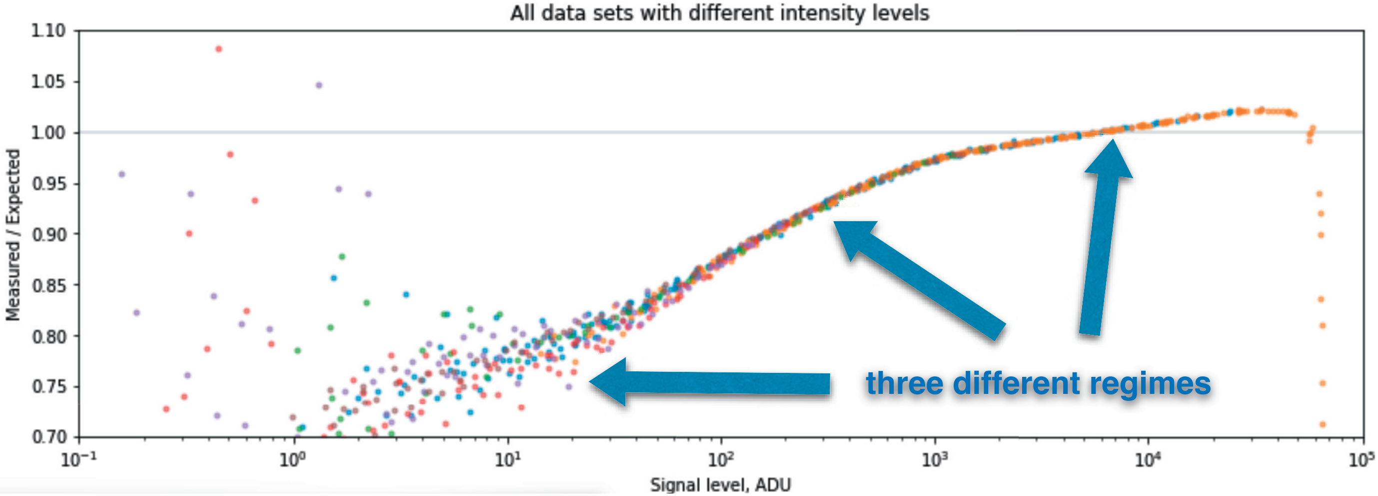


CCD nonlinearity

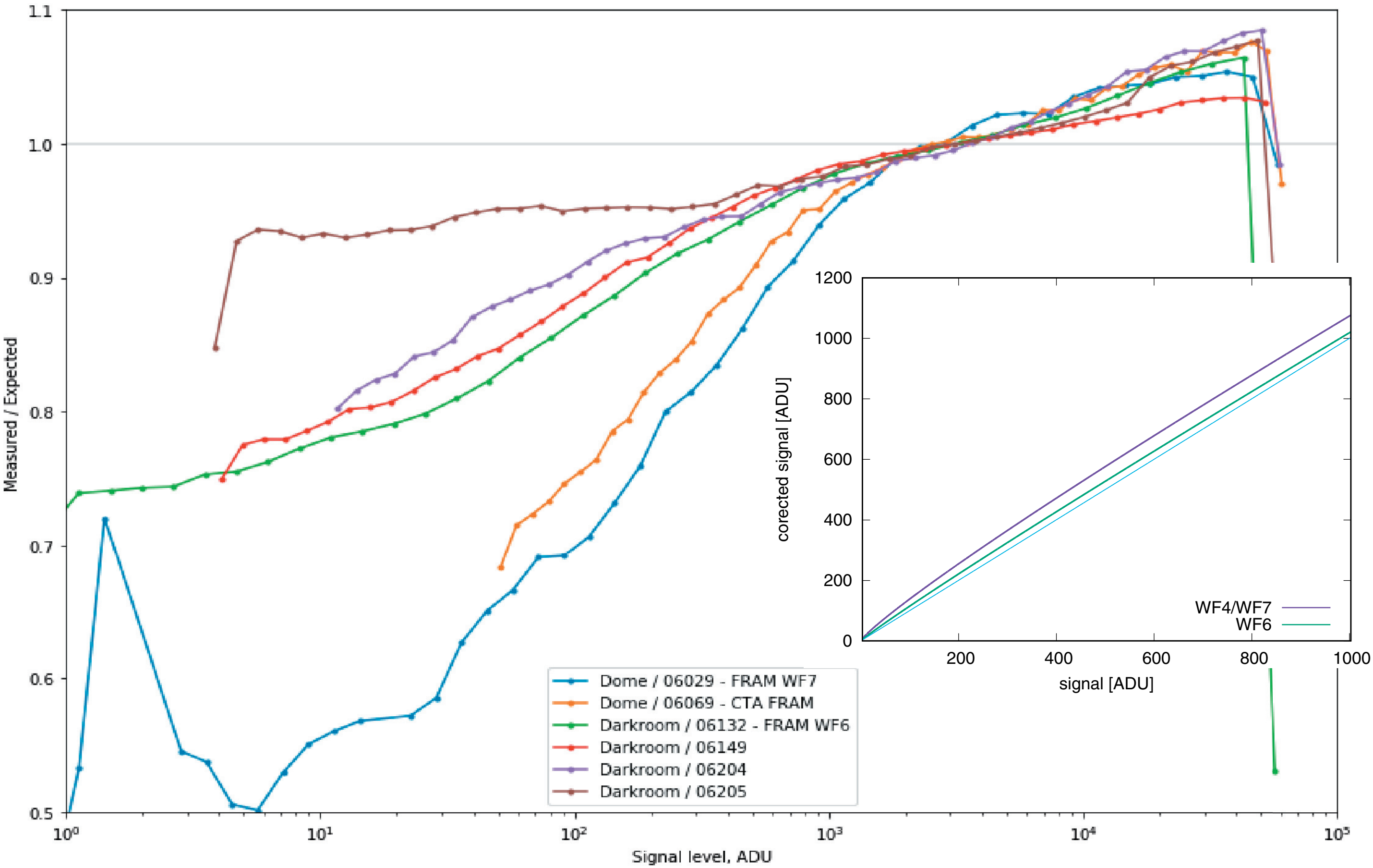
• Confirmed by laboratory measurement (using different intensity levels/exposures)
- now actual darkroom, light source ...

• For installed cameras (Auger/CTA) curves must be determined remotely using moonlit sky/dome interior



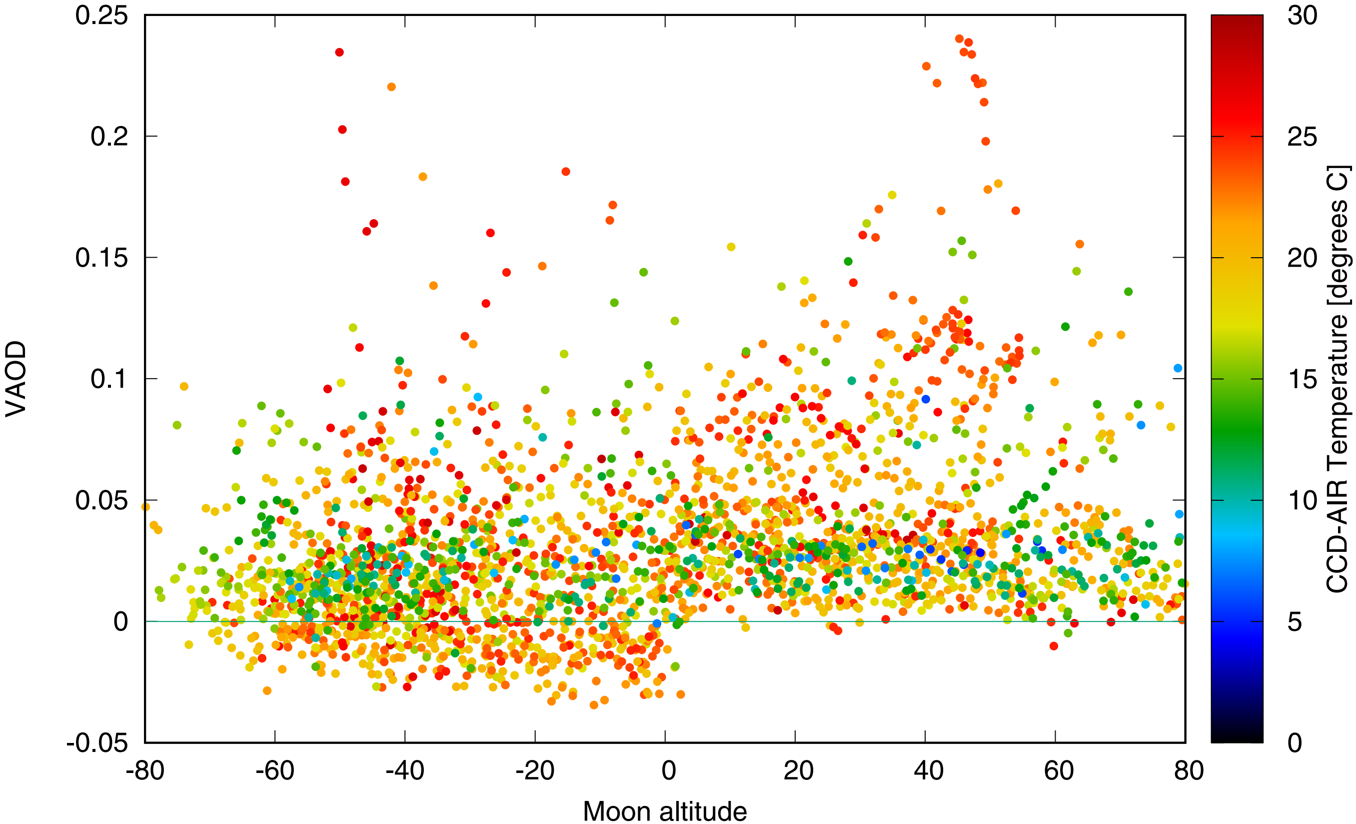


Nonlinearity varies between cameras



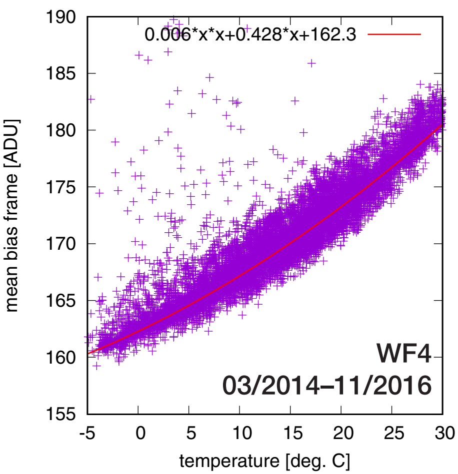
Data processed with Non-linearity Correction (NLC)

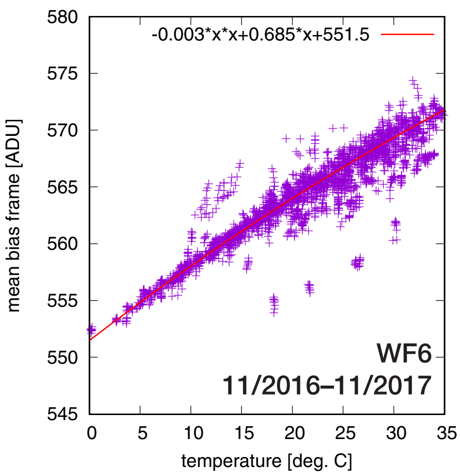
- small spread for bright scans, large for dark scans
  - depends on outside temperature of CCD

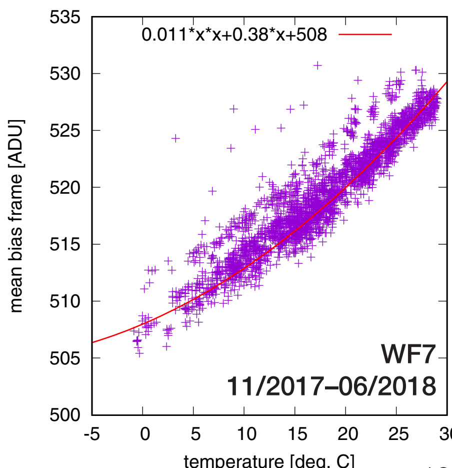


Temperature corrections for bias signal

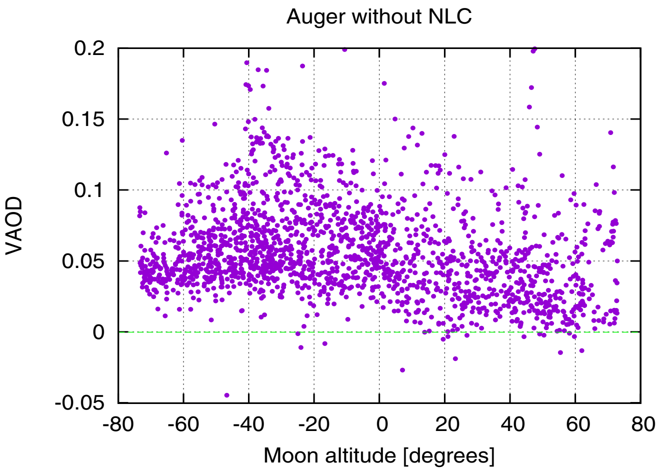
- small dependence of bias signal on the temperature of camera electronics
- not stabilized, but measured and fitted
- important only in presence of NLC
- "overscan" of dark areas of CCD chip implemented: bias level for each image

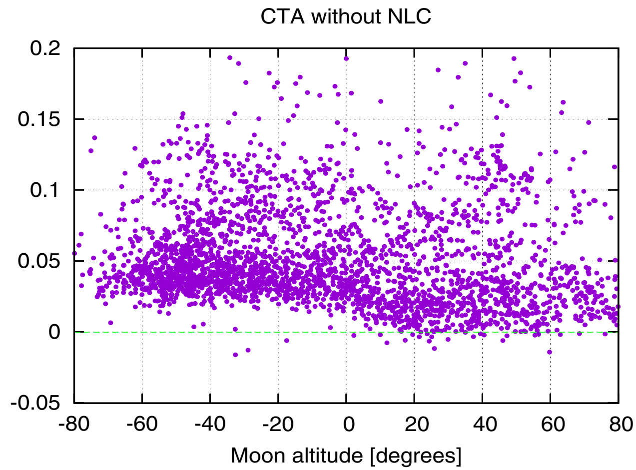


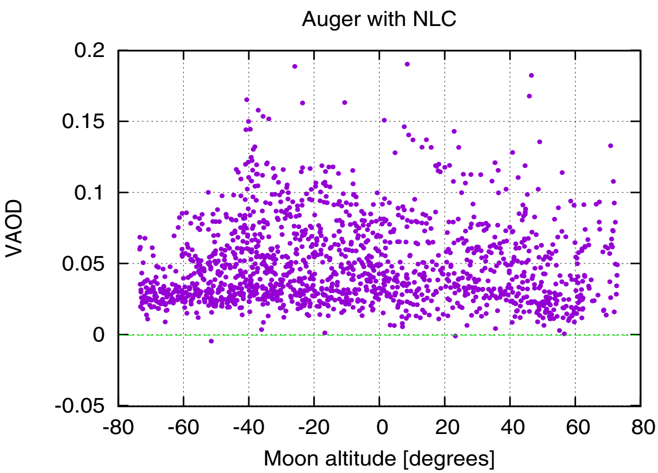


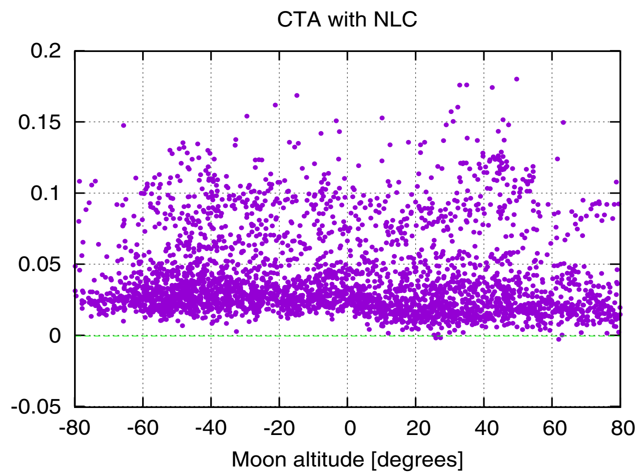


Corrected bias + non-linearity = almost perfect!



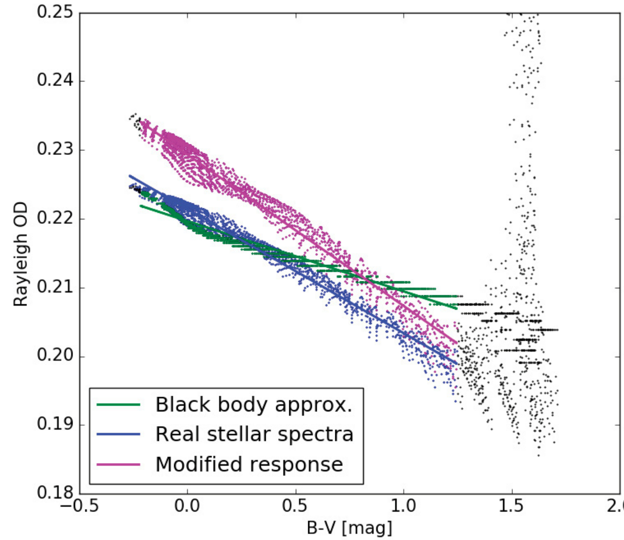


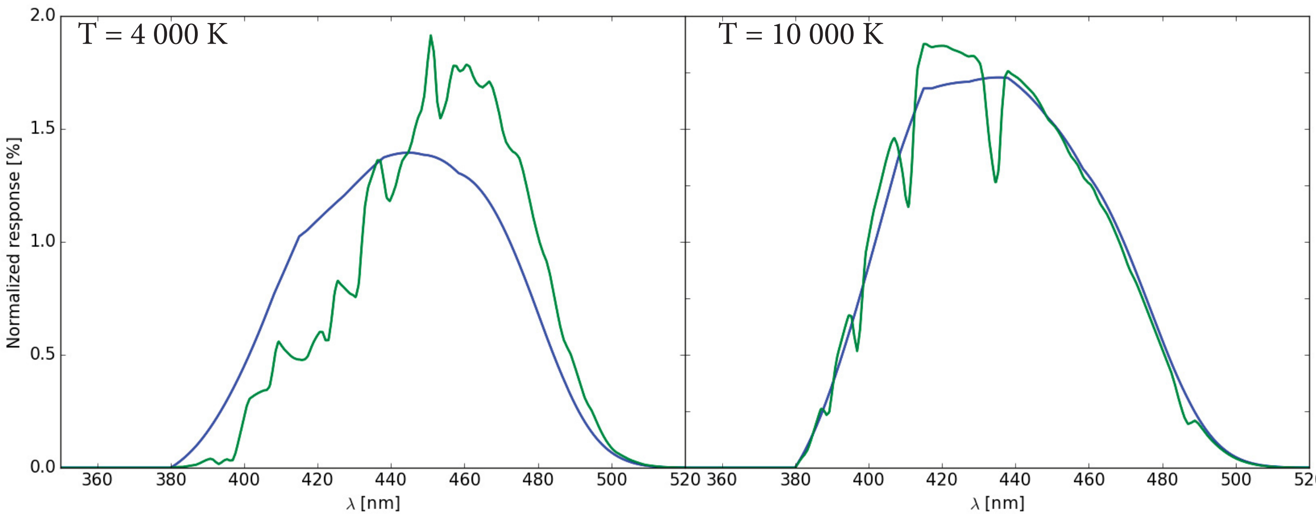




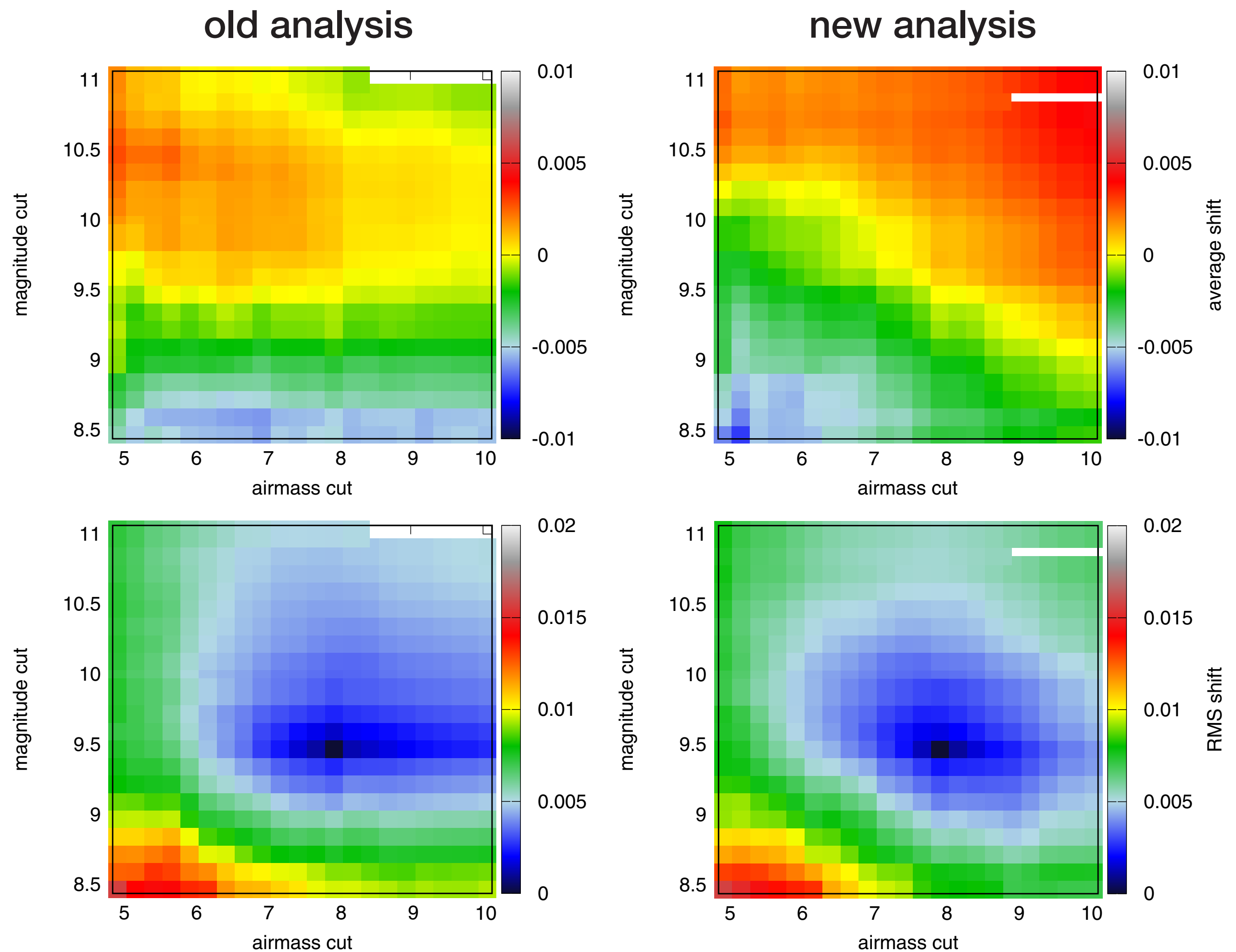
Realistic stellar spectra and molecular subtraction

- B-V dependence fitted on a set of spectra
- good k_c agreement (WF4: data 0.017, model 0.019)
- ready to include molecular absorption for V and R



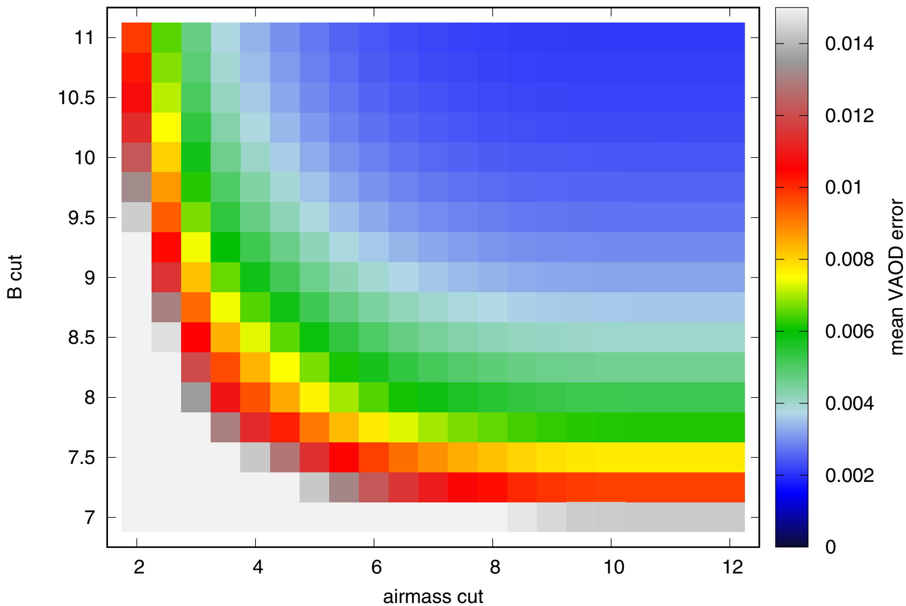


Dependence of VAOD on choice of cuts on stars



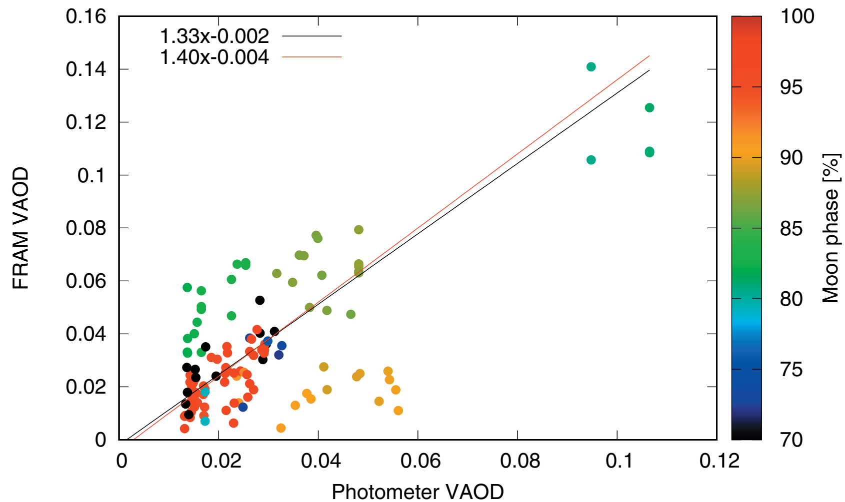
How to choose the cuts?

- B<6.5 mag overexposed (lower exposure? very few stars...)
- including stars B>10 does not help much (Tycho2 errors)
- including airmass >8 does not help much (hard to see stars)
  - @ airmass 8 stars 7 times fainter (need for dynamical range!)
- cut on apparent, not catalogue brightness? (possible systematics in star populations/ catalog?)
- largest known systematics on VAOD (0.005)



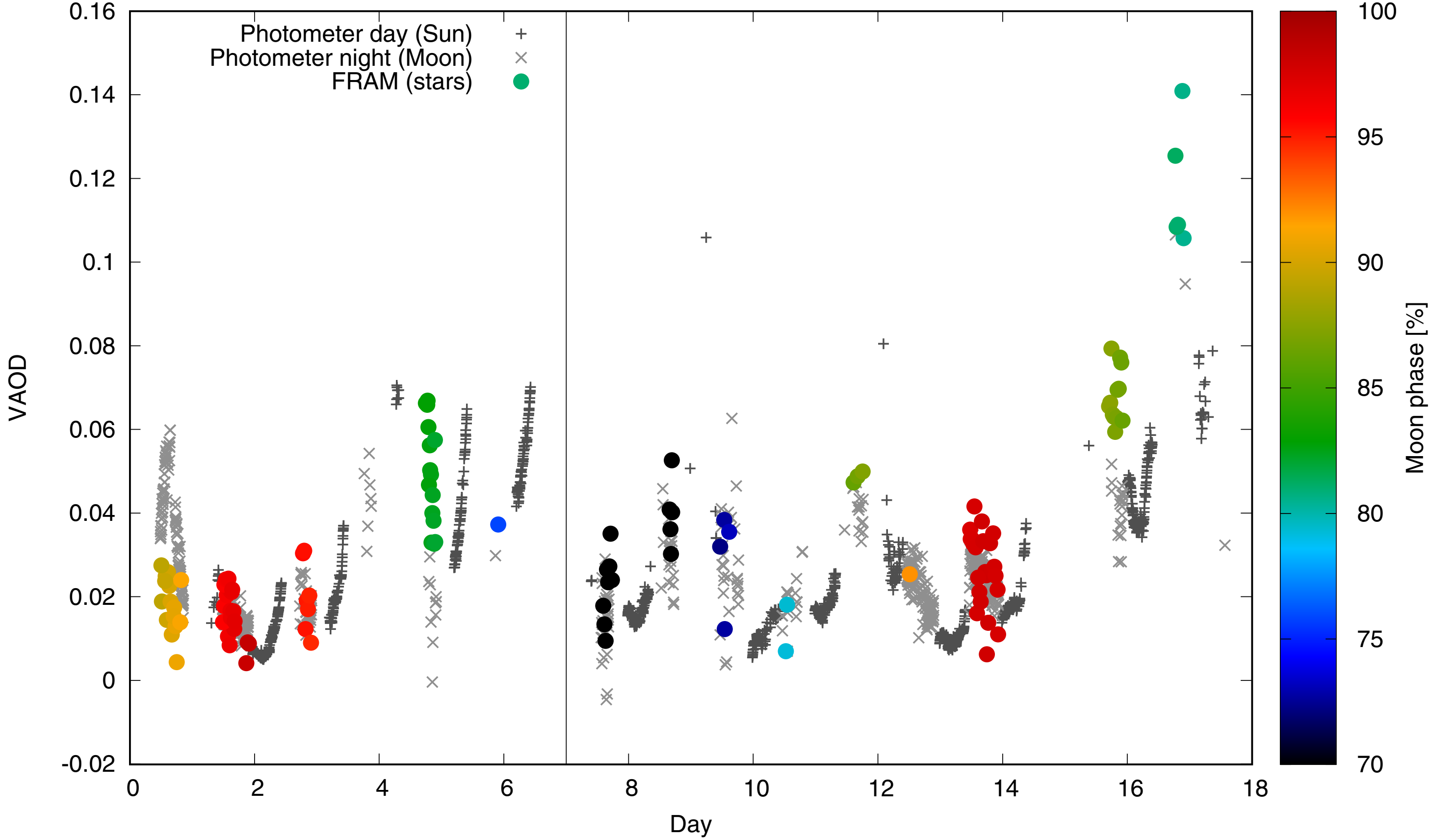
Sun/Moon Photometer campaign 03–05/2017 @ Auger

- absolutely calibrated
  = one direction
- unc. <0.01 day, <0.04 night
  - Moon illumination issues
- calibration in GSFC



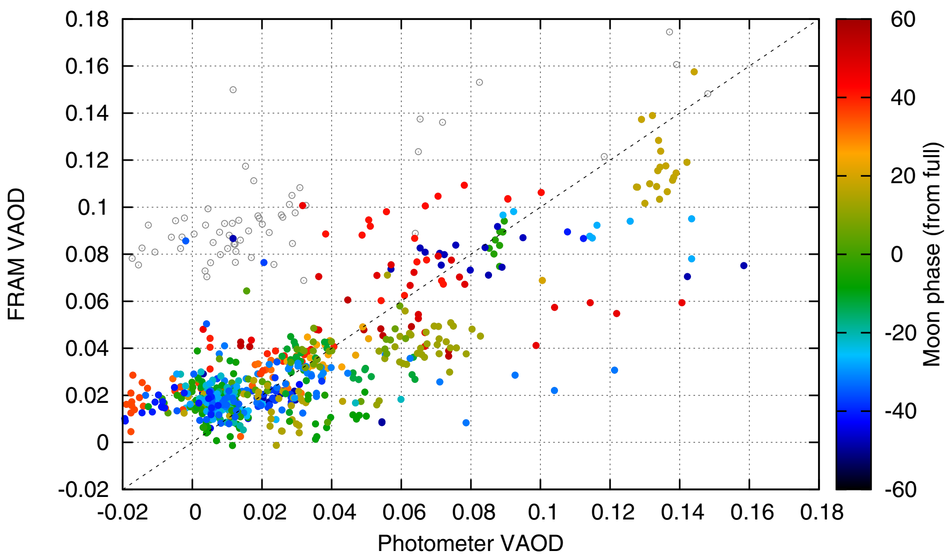
- bad weather, very small data sample
- only a few overlapping points for same Moon phase from different cycles

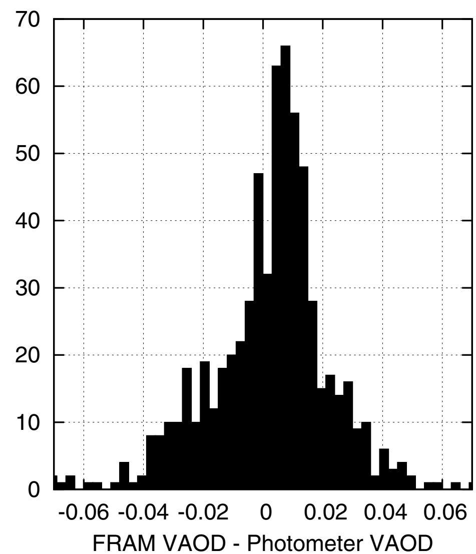
FRAM vs. Photometer @ Auger: time series



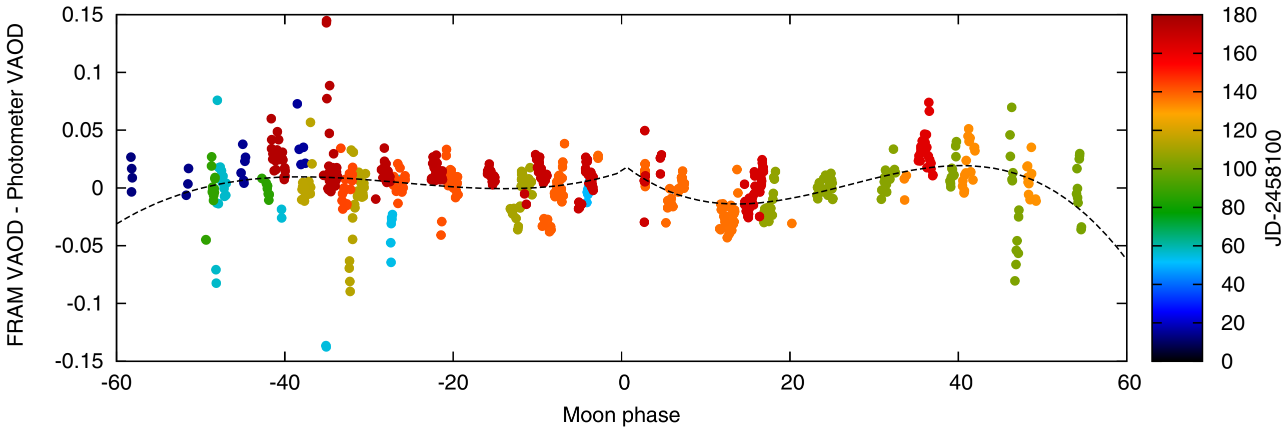
Sun/Moon Photometer @ CTA

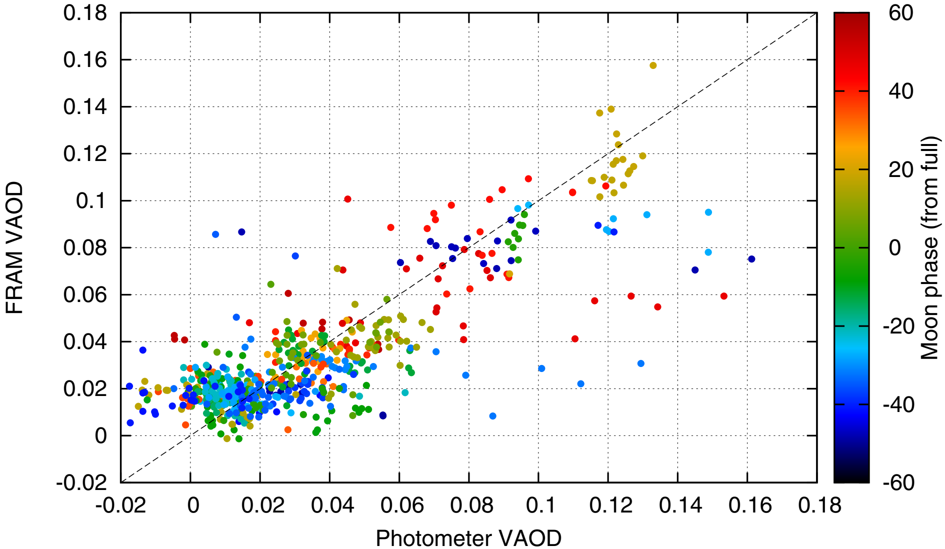
- concurrent measurements 11/2017-07/2018 (and continue)
- FRAM outliers cut (see Petr's talk)
- 68 % of differences within 0.02
- Photometer calibration highly preliminary!

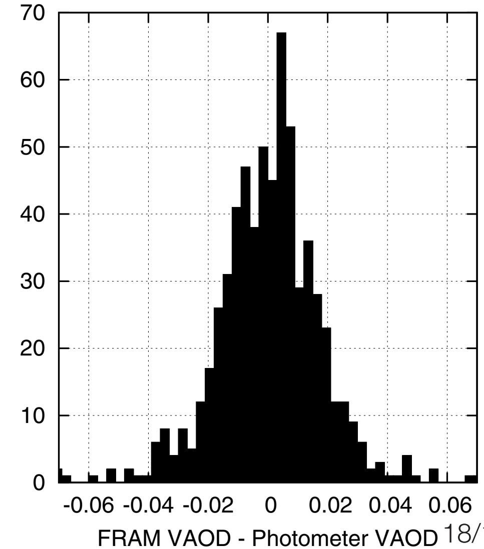




Moon phase correction using FRAM data?







Precision of measurements

- Statistical error of single measurements:
    - Auger 0.003–0.008
    - CTA 0.002–0.004 (larger FoV)

- Systematics? Known: ~0.007
    - 0.003 from molecular absorption (use MODTRAN/GDAS)
    - 0.003 from freedom in fitting the telescope parameters
    - 0.005 from the choice of cuts on maximal airmass/magnitude
    - ? from system spectral response
    - ? from possible trends in stellar properties/catalogs
    - ? from bias instability
    - ? from star rejection algorithm
    - ? from residual cloud contamination
    - what is the outlier effect on CTA?

- Ultimately limited by Tycho2: APASS project abandoned? GAIA broad bandpasses unsuitable ...