How do we know what calibration data we need?

Jakob Nordin (HU Berlin)

Why precision photometry?

There will be many surveys looking for nearby transients. The legacy winner will be the team to present the best data.

Running ZTF will be *much* easier with good photometry.

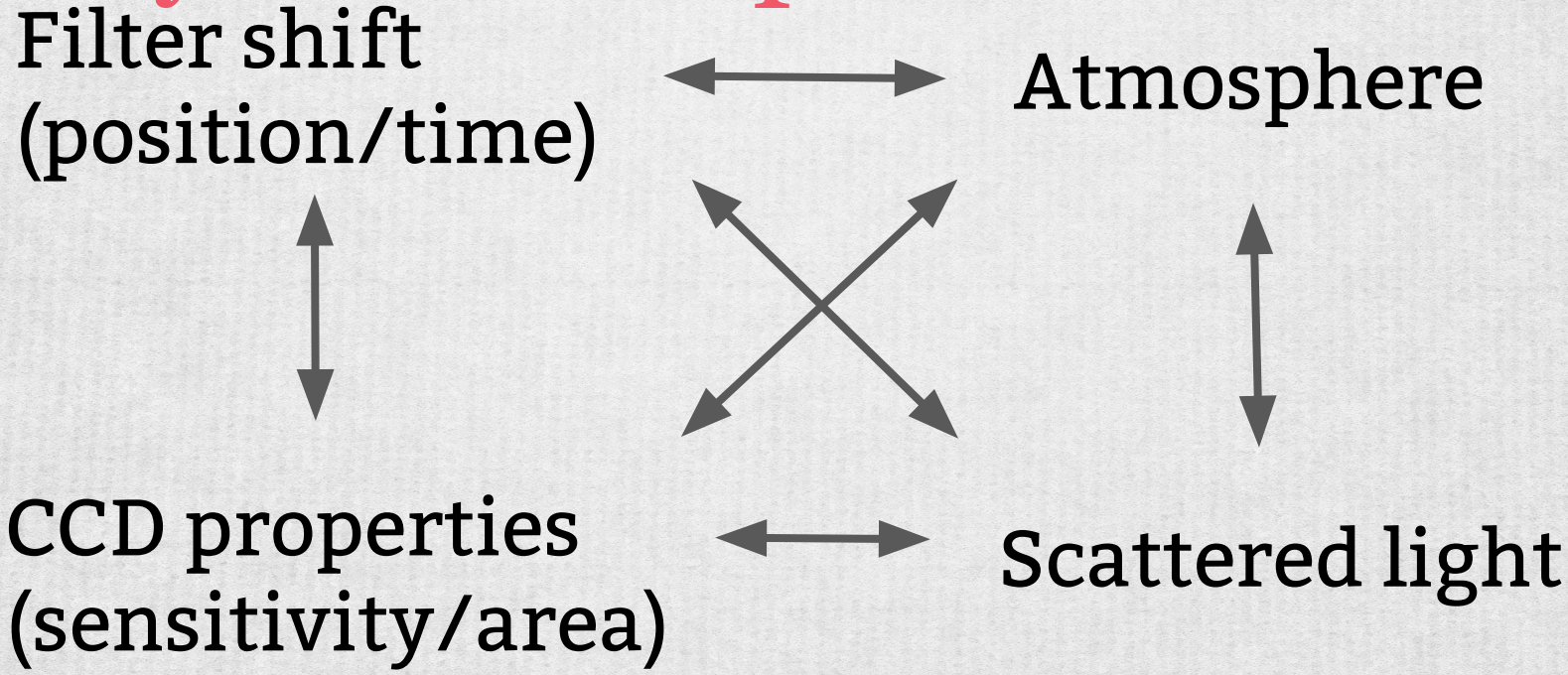
Learn from previous surveys, and get necessary calibration data from the beginning.

What this is not about:

- Image subtraction
- PSF photometry
- Astrometry
- Algorithms
- Compression

These problems require a lot of hard work, but can be solved - assuming the necessary data exists

Why is sub-% photo. hard?

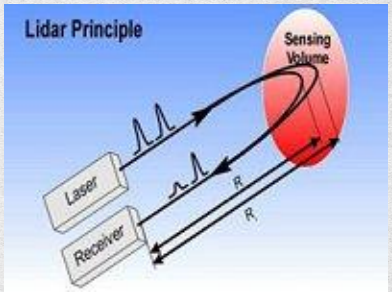


Degenerate for calibration data, bias for science
Eg: filter shifts masking as sensitivity change

What could be done?

Filter shift
(position/time)

Atmosphere



CCD properties
(sensitivity/area)

Scattered light

1. External atmospheric monitoring

What could be done?

Filter shift
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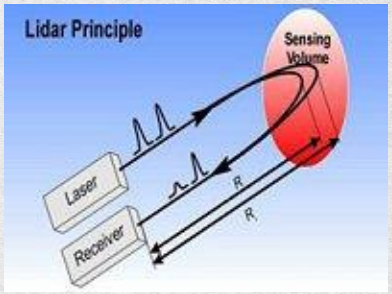

DONE! OR?

CCD properties
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Scattered light

1. External atmospheric monitoring

What could be done?

Filter
(posit

osphere

47 Tucanae/NGC104
(Nasa/ESO)

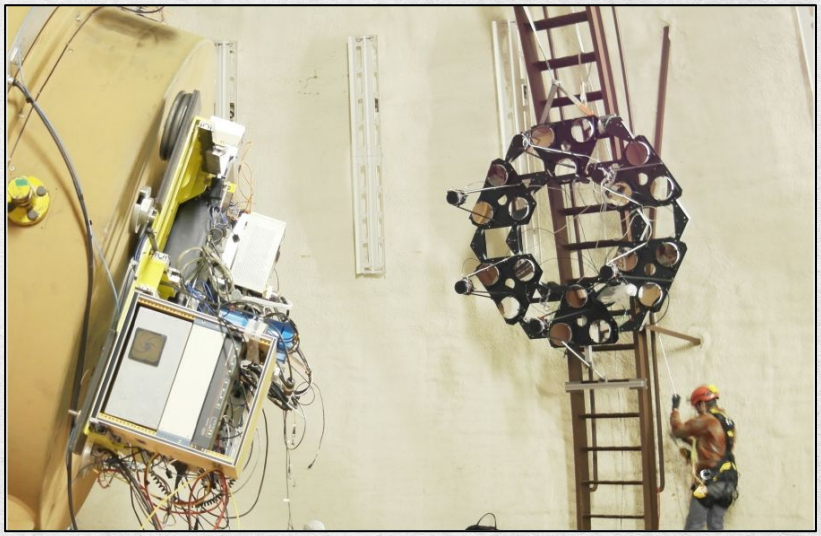
CCD properties
(sensitivity/area)

Scattered light

2. Star (L) flats - dithered observations of suitably dense star fields during “infinitesimal” time.

What could be done?

Filter shift
(position/time)



CCD properties
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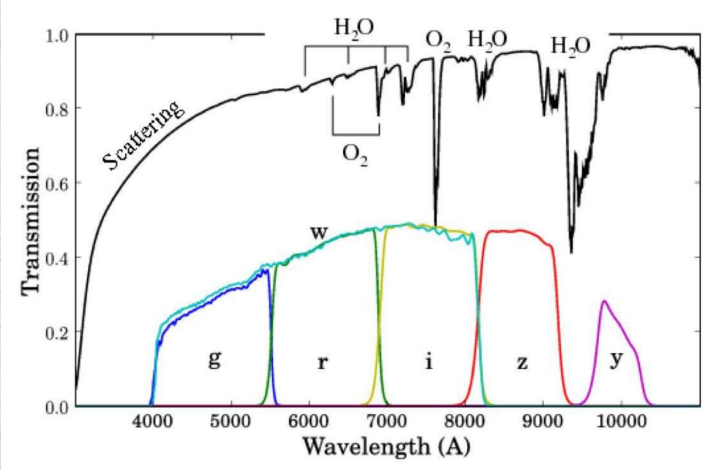
3. In-situ, physical calibration device - direct measurement of flux throughput at wavelength.

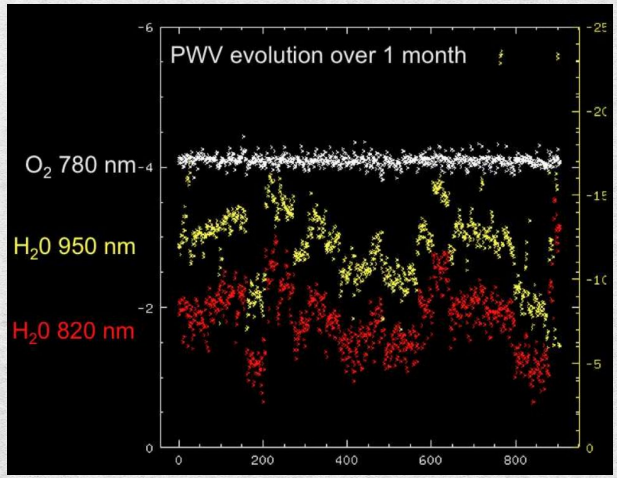
I. Atmosphere

Clouds, rayleigh, aerosols, and line absorption all vary at different scales (wave, time, area). What can we do w/o atmosphere monitoring?

- O2 constrained using satellite data
- Fit aerosol model using P48 data?
- Water using SEDmachine?

Old...





Stubbs+ 2007

II. SuperNova Legacy Survey

Currently at millimag level, dominated by fundamental standards. Summary of lessons:

- Calibration takes work
- PSF err. quadratic w. astrometry err.
- *Using two-week stacked twilight flats leaves 10% gradient/0.5 deg (scattered light)!*
- Starflats ~twice yearly
- 4-14 A filter variations across FoV "inevitable for large filters"

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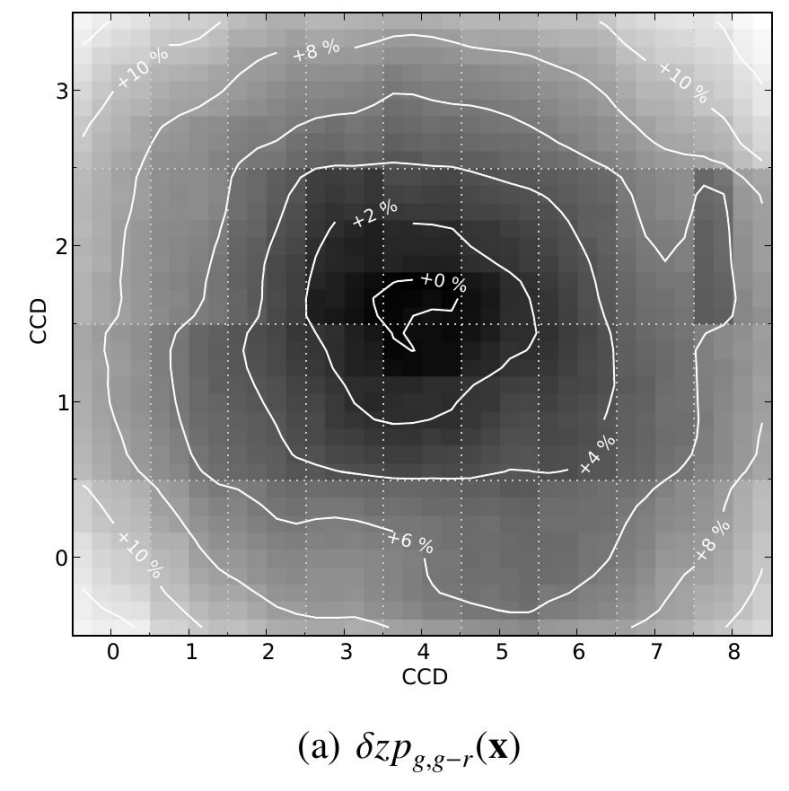
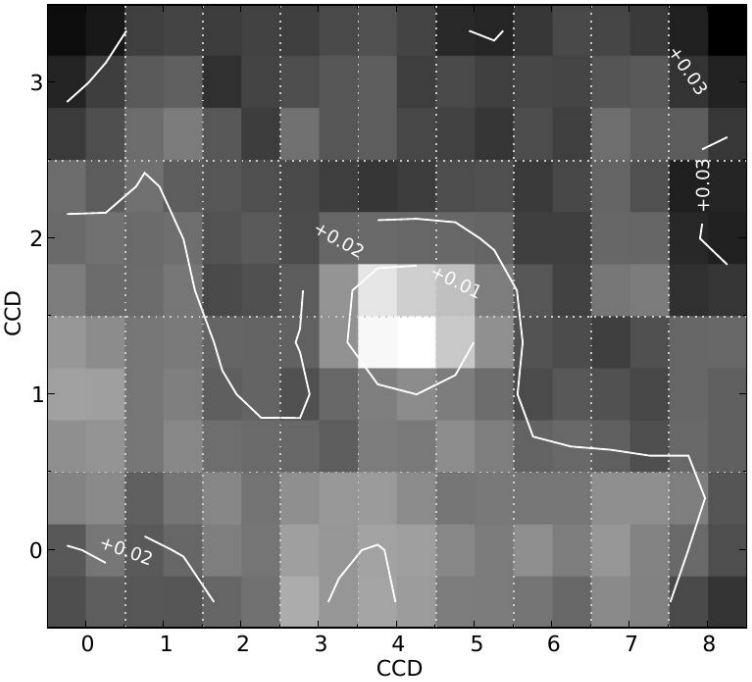


(a) $\delta zp_{g,g-r}(\mathbf{x})$



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III. Gaia/PS1/ZTF

Using star catalogs from Gaia/PanStarrs will allow calibration of smaller CCD patches.

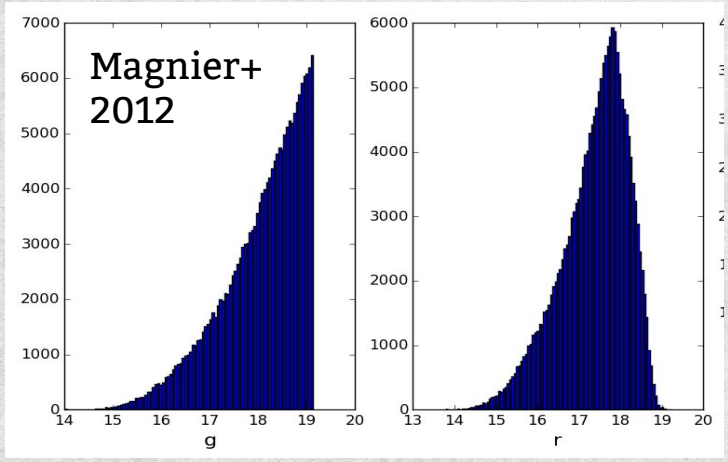
How well will this work? Related to questions regarding eg. domeflat requirements.

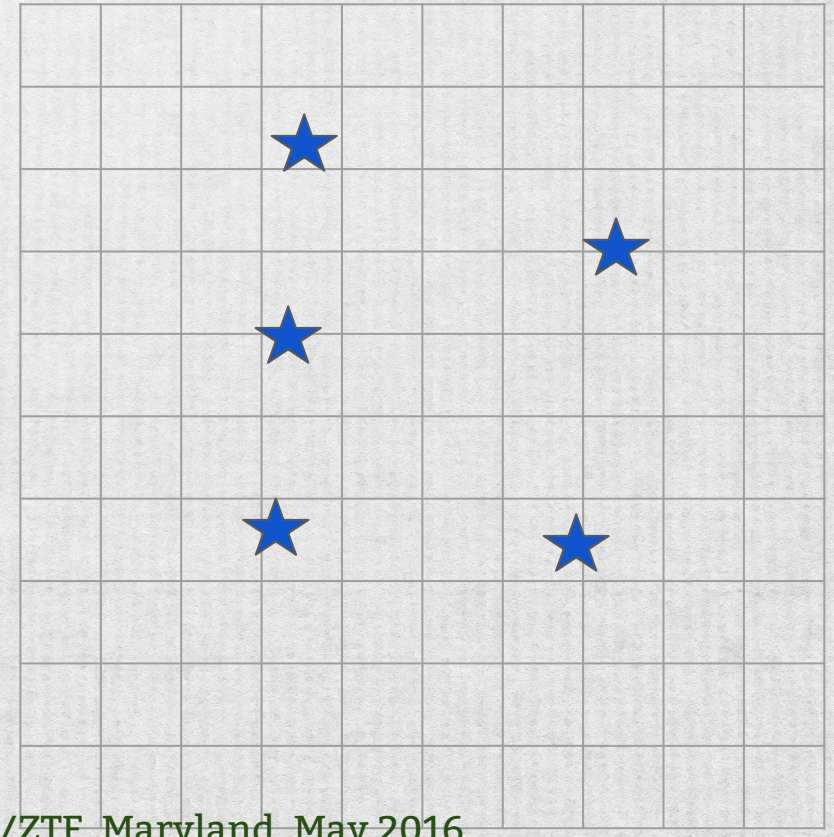
We can simulate the full chain of future observation/calibration/systematics!

Use with real data (HU/OKC GitHub).

III. Gaia/ZTF simulations

1. Randomize stars according to observed magnitude/color distributions
2. Get Gaia uncertainties
3. Apply atmospheric extinction model
4. Estimate ZTF photometry+stat err
5. Add sensitivity/atmosphere variations
6. Add other exposures
7. Fit nightly solution





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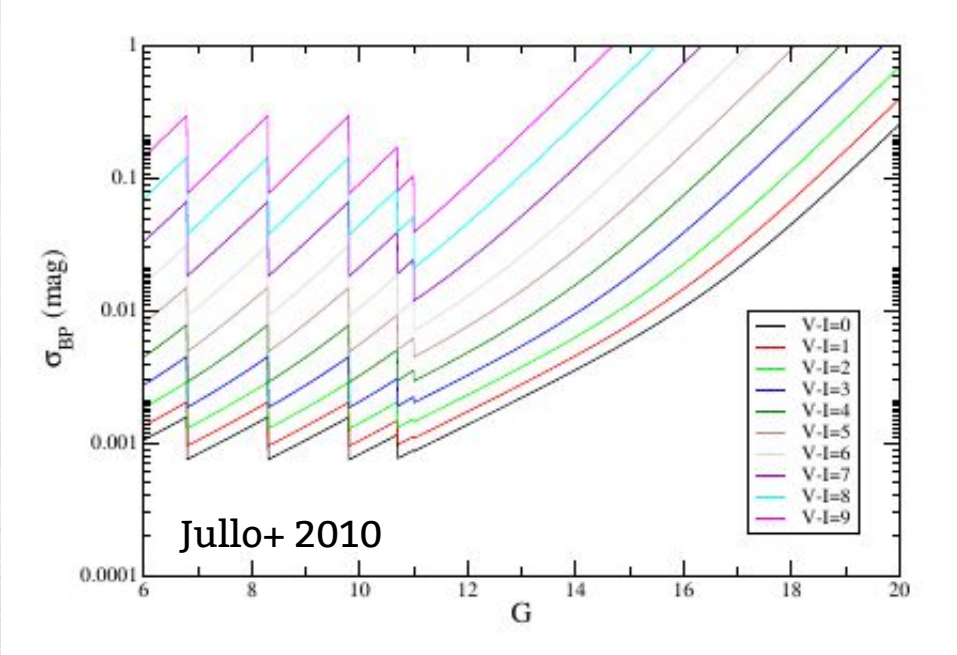

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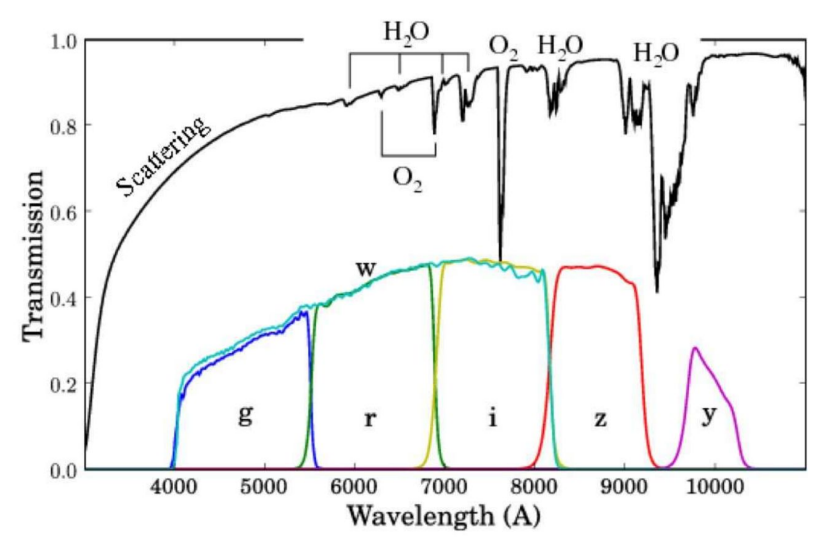

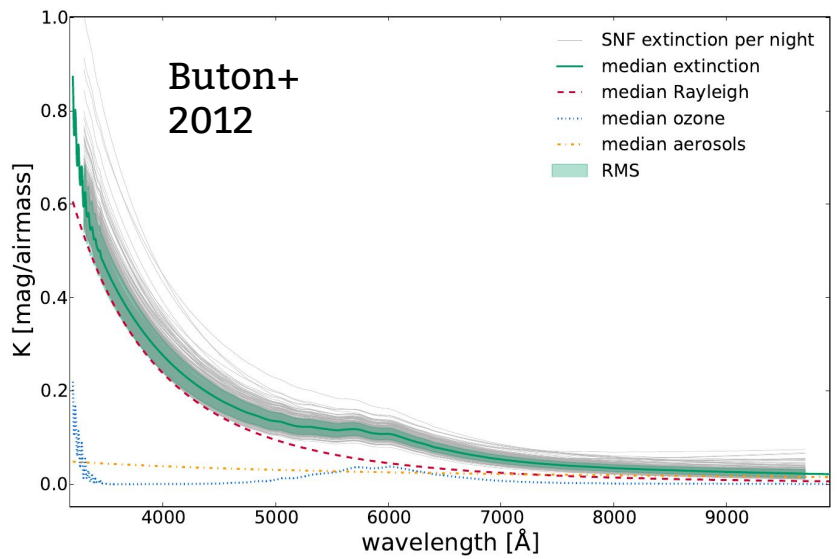

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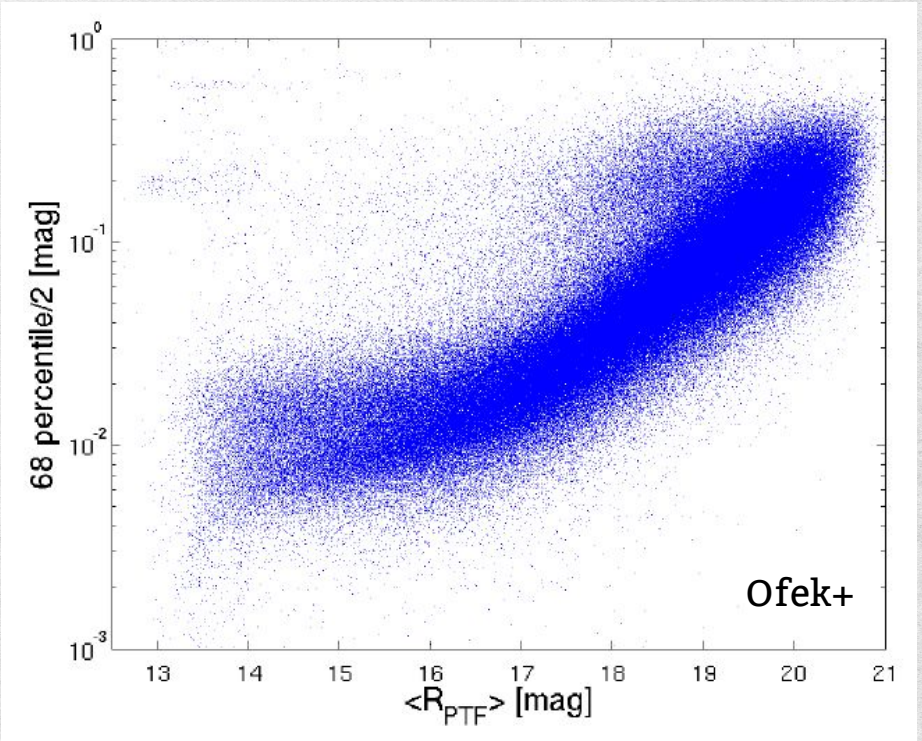

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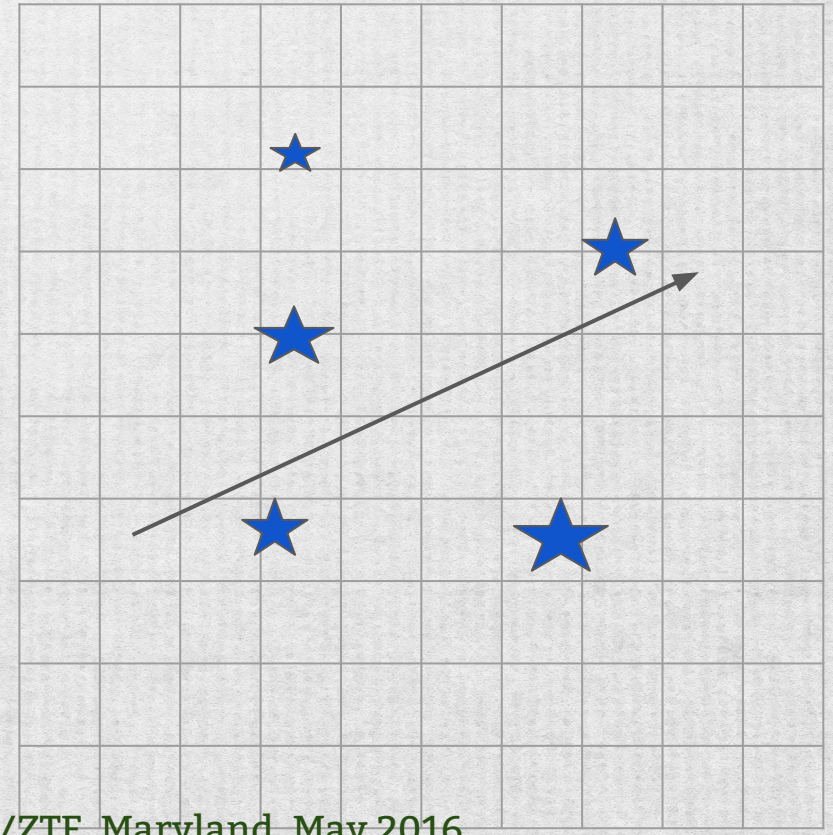

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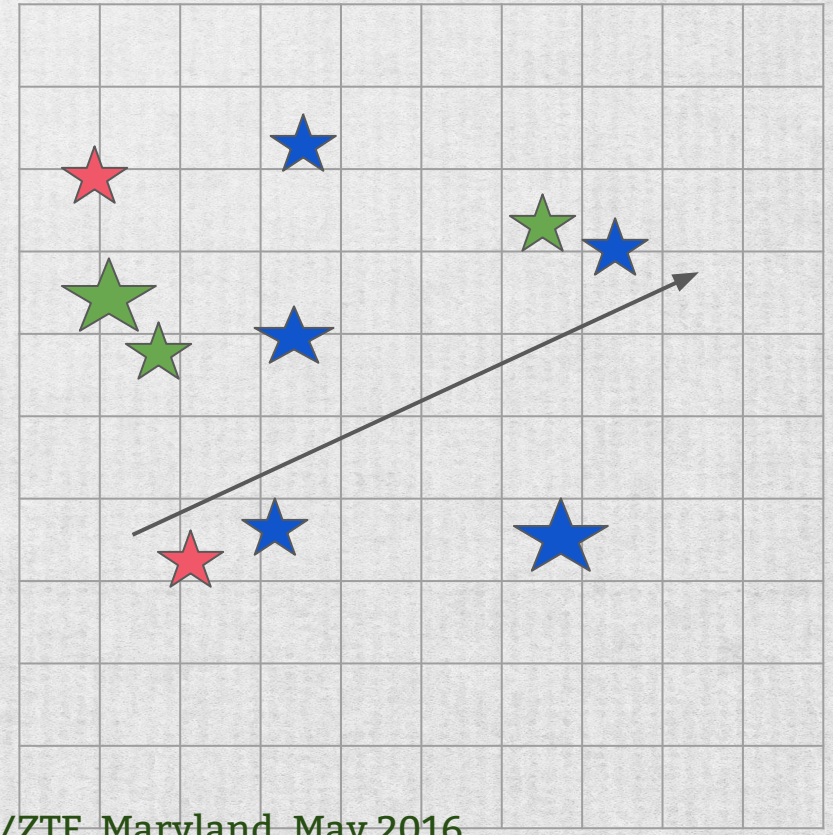

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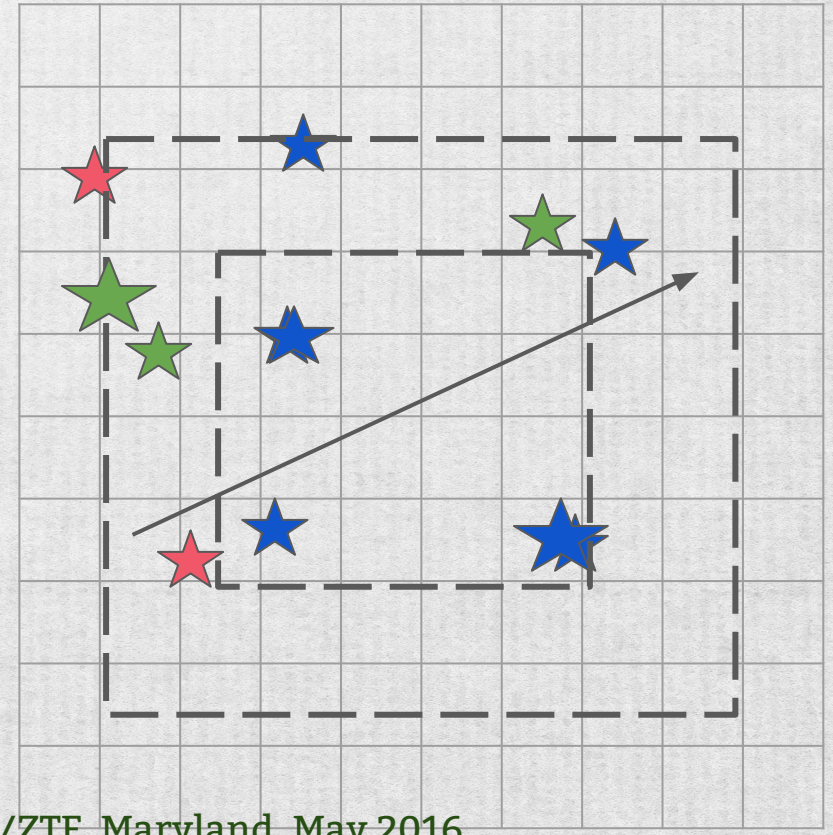
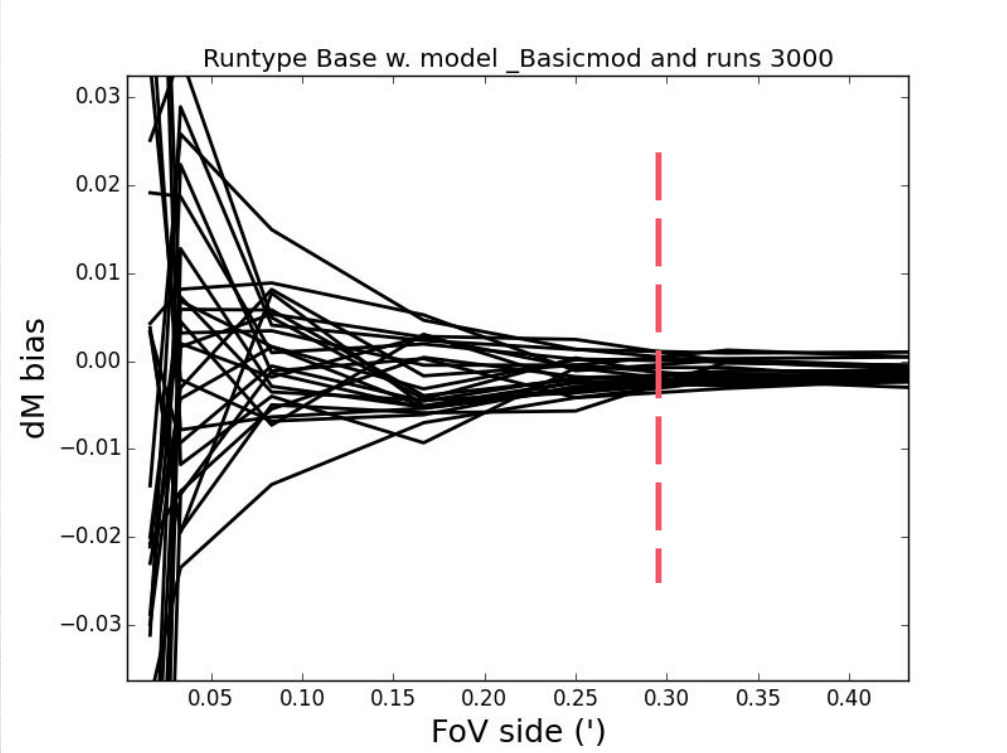
6. Add other exposures
7. Fit nightly calibration (zp + color terms), examine solution vs. eg. area



III. Gaia/ZTF simulations

How many pixels do we need to include to find enough stars to reach a target?

Find a limit around 0.3'x0.3' (w/o systematics!).
This is the minimal size for which we will need stable flatfields and throughput.



III. Gaia/ZTF simulations

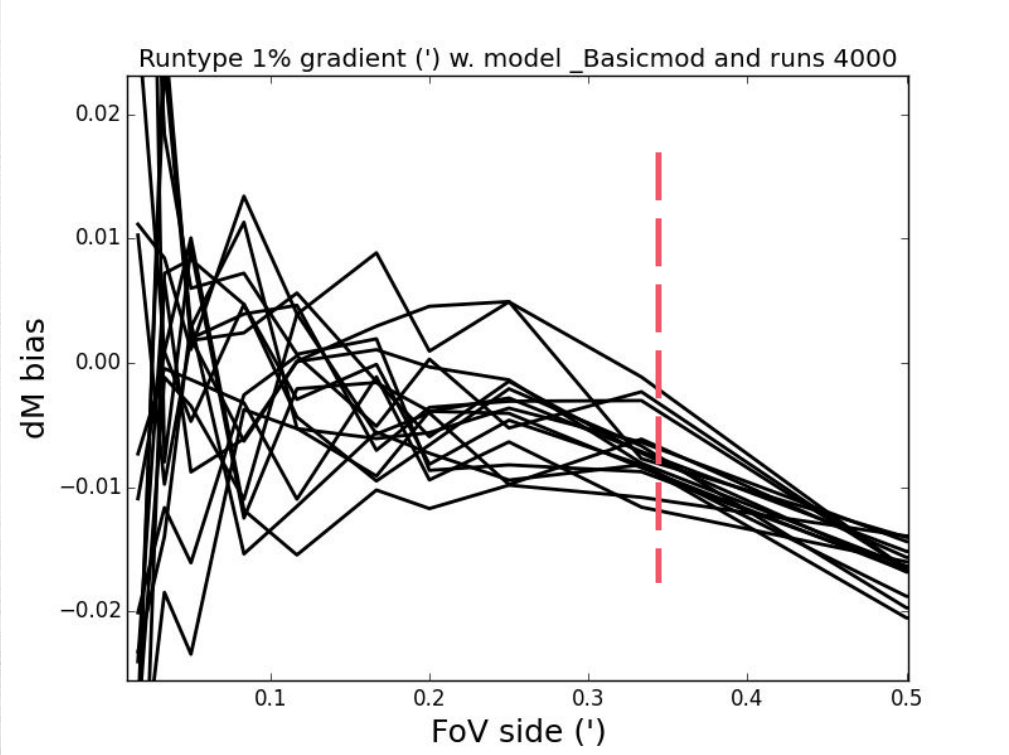
Several potential bias scenarios to investigate.

E.g. how does a 1% gradient at arcmin scales relate to zp bias? Increasing with patch size.

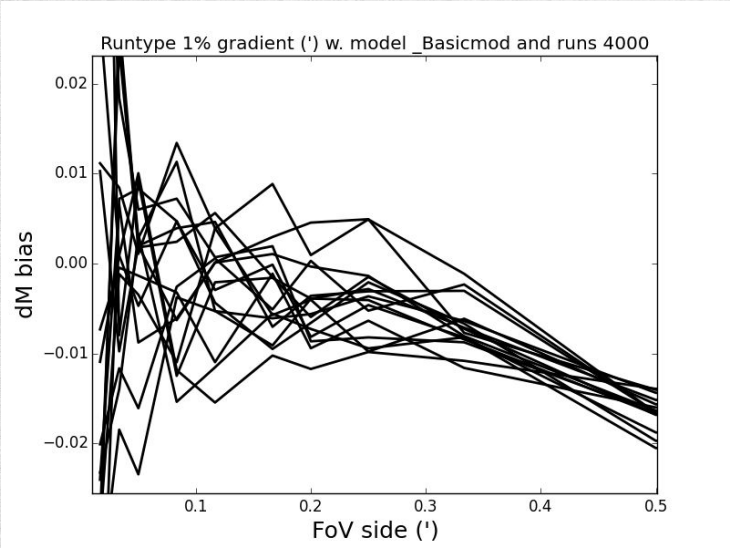
Existing variations:

- Filter mods
- Atmosphere model

Need input!

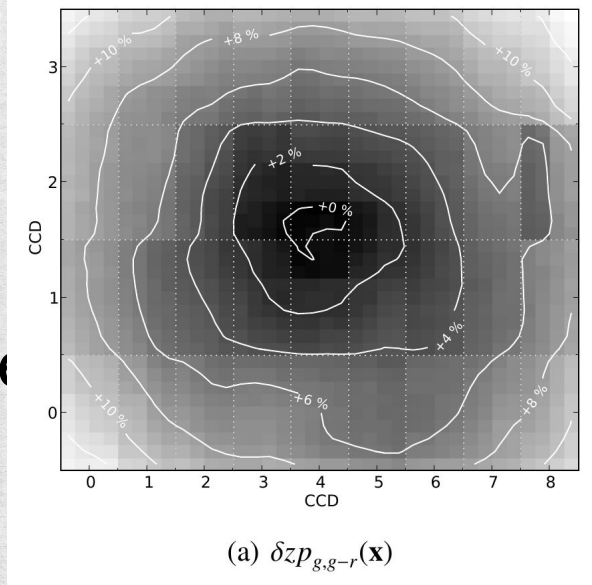


Tying together: Starflats



Already 1% var. on arcmin scales cause significant biases for calibration patches of the size needed, even assuming Gaia/PS.

CFHT/Megacam found twilight flat limits at this leve
-> *ZTF will require starflats.*



(a) $\delta zp_{g,g-r}(\mathbf{x})$

Next steps, part 1

We should get the necessary calibration data for ZTF.

Now have a simulation framework for determining impact. Need simulation input regarding atmosphere, filter expectations and optical model?

Even w. PanStarrs/Gaia catalogues, scattered light will require ZTF starflats. Not much time on-sky, but dedicated analysis. Start frequent during commissioning, can decrease frequency as stability is confirmed. Obtain iPTF starflats!

Next steps, part 2

Use (i)PTF data to study sensitivity maps, fit aerosol absorption model (g) and zeropoint variability. First step to investigate impact of multi-night skyflats. Catalogue interface?

Atmosphere monitoring coming to Palomar! What filters/grating/observations to use, ...?

SEDmachine (spectrum + rainbow camera) could provide a wealth of calibration data.

Next steps, part 3

In-site throughput/filter measurements are possible but hard. Hope to avoid if we do the things above! Find objects with emission lines at filter edges, monitor throughout ZTF for significant changes.

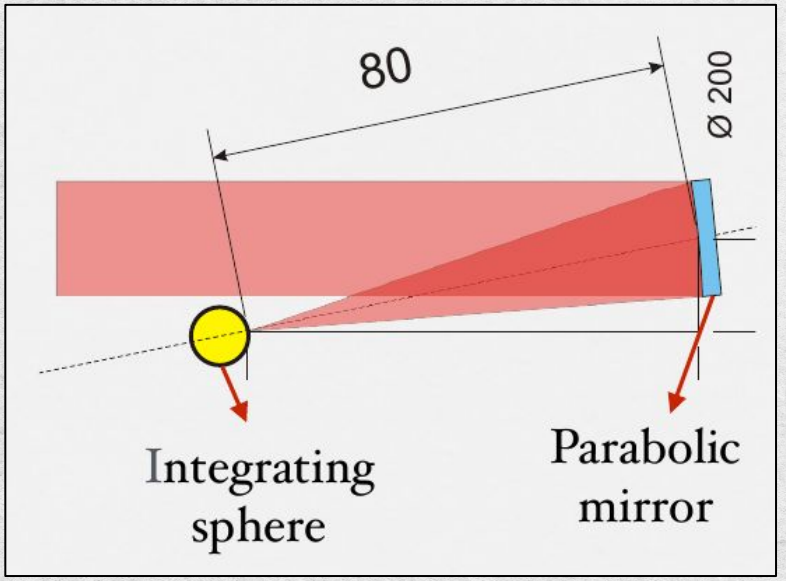
Conclusions:

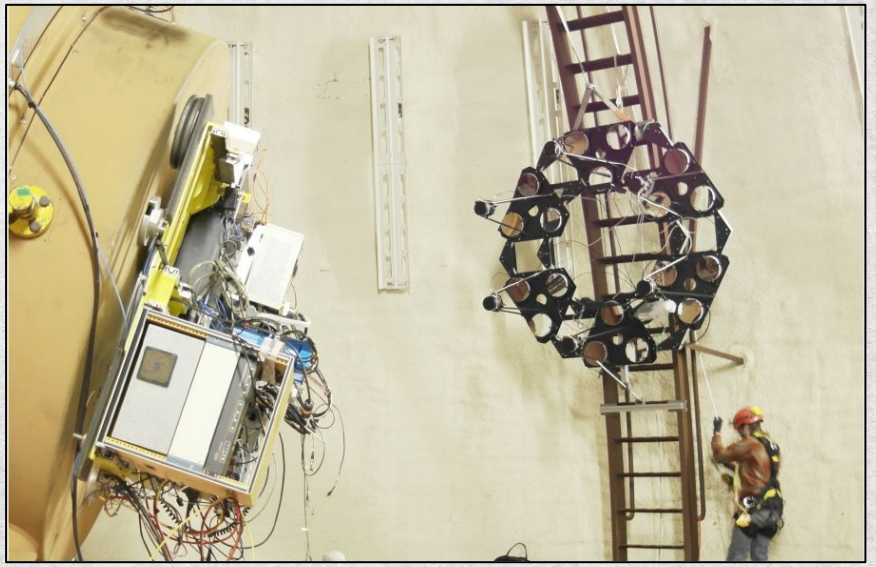
The path to ZTF calibration is reasonable well defined, but still limited by lack of manpower.
We run simulations to determine optimal strategy.

Backup

SCALA

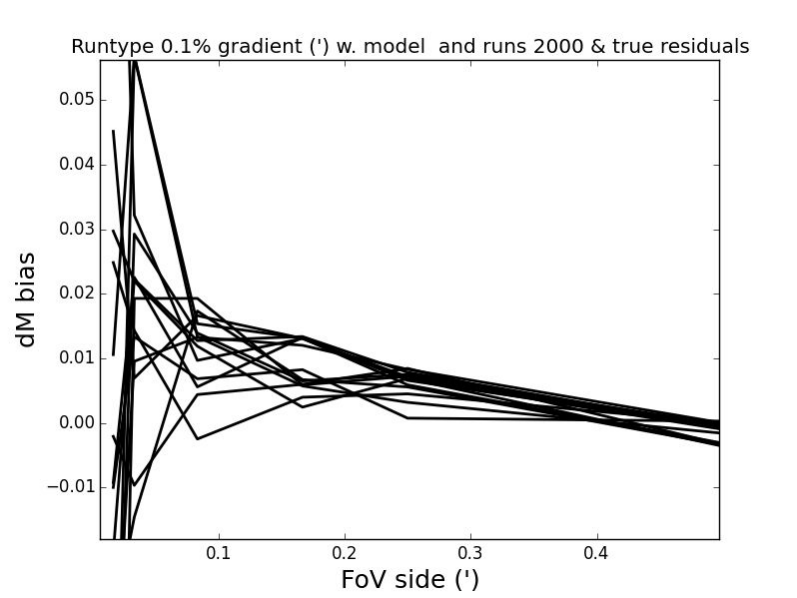
Physical calibration of the SNIFS IFU, goal of ~1% color calibration
Concept for a portable version exists





Jakob Nordin (HU Berlin)

iPTF/ZTF, Maryland, May 2016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dM bias
FoV side (')
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0.03
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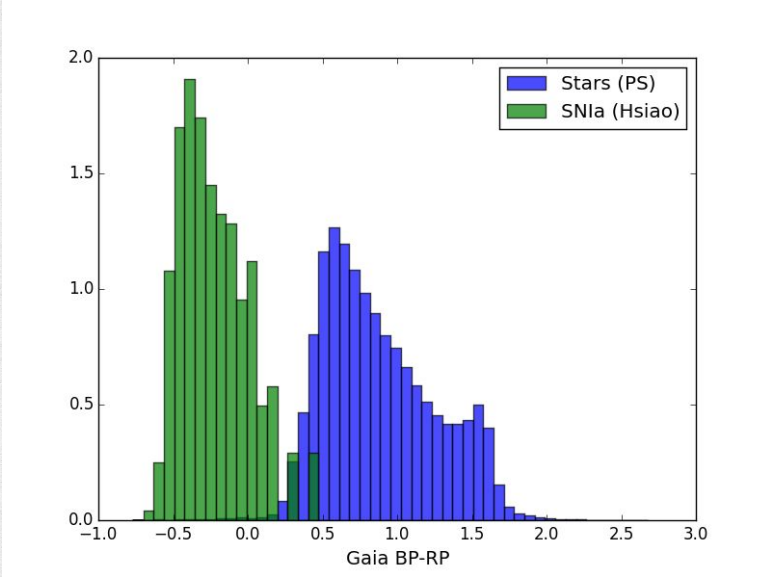
0.4


Stars (PS)
SNIa (Hsiao)
Gaia BP-RP
2.0
1.5
1.0
0.5
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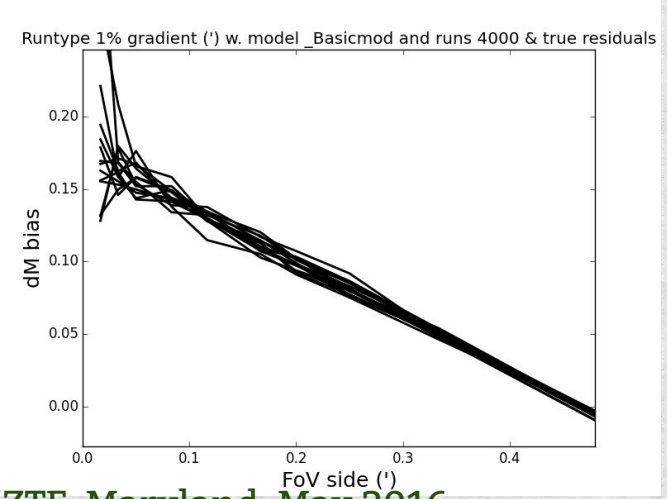
0.5
1.0
1.5
2.0
2.5
3.0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dM bias
FoV side (')
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0.15
0.10
0.05
0.00
0.0
0.1
0.2
0.3
0.4