Generating LSST synthetic photometry from XP spectra

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Stellar variability, stellar multiplicity:
periodicity in time & motion
Sofia, Bulgaria
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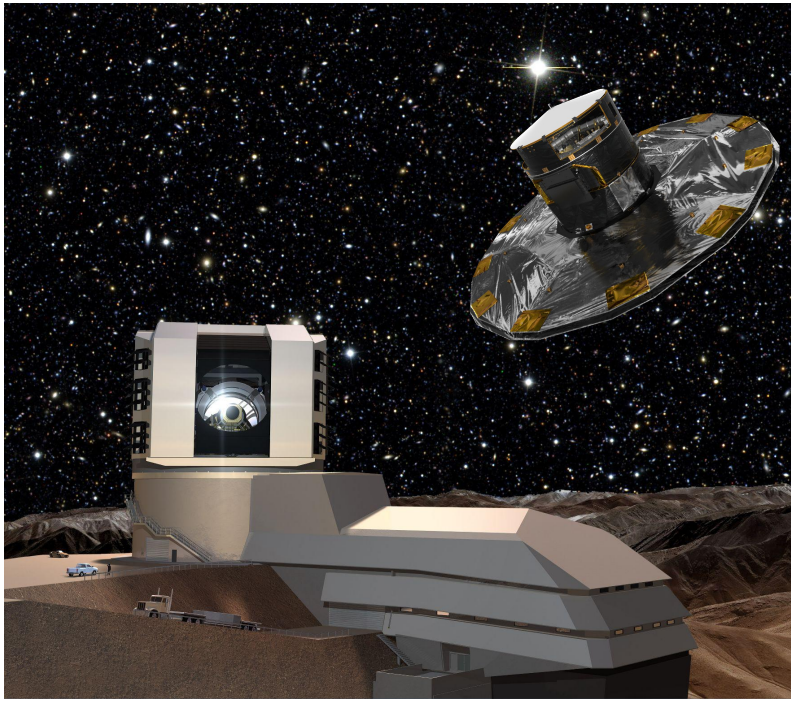
Gaia-LSST synergy

- Can’t wait for the LSST DR1?
  - Prepare for the survey
  - Test Pipelines
  - Optimize cadence/survey strategy

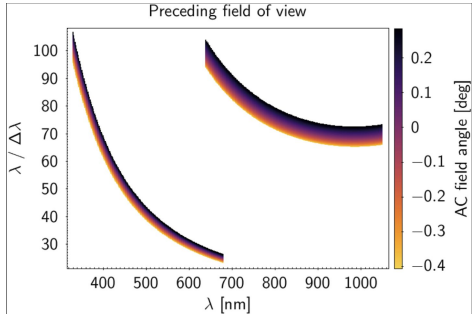
- Generate all-sky bright-LSST survey to accompany the main survey
- provide a longer/extended baseline for the combined Gaia+LSST photometry (~15yrs)

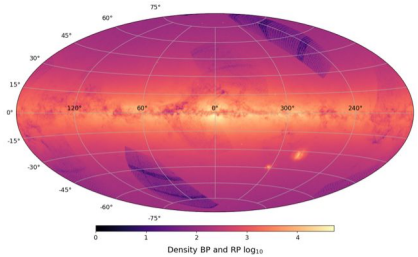


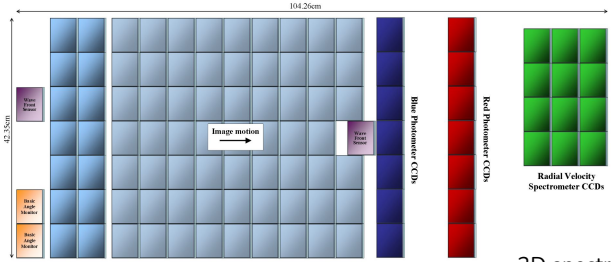
Gaia XP spectra

- 2 photometers
- 330-680 nm
- 640-1050 nm
- 2 fields of view
- 7 CCDs/photometer

- 2 windowing strategies
- 5 gate configurations
- time-dependent
- *a total of >25k effective instruments*

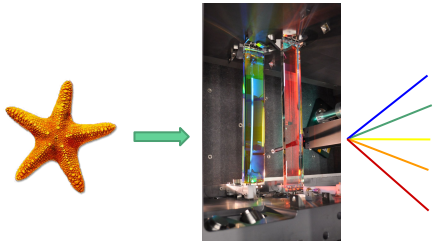




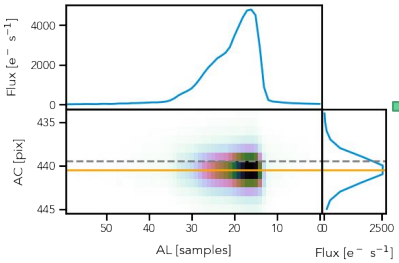


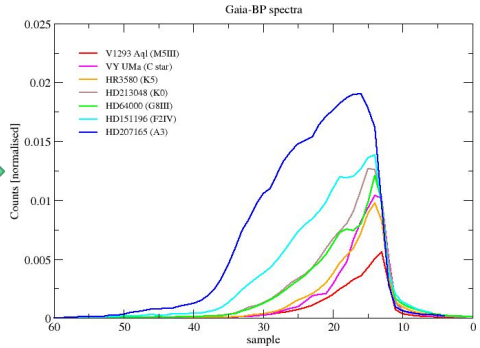
- DR3: 220M (G<17.65 mag) *mean* spectra
- all sky coverage
- published data depend on quality...
- represented as a continuous function defined by an array of coeff. applied to a set of basis functions

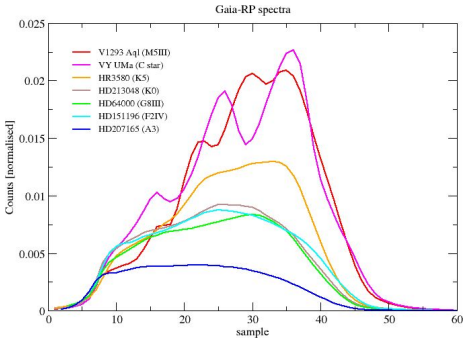
De Angeli +22, Montegriffo +22



2D spectrum, binning in AC & AL

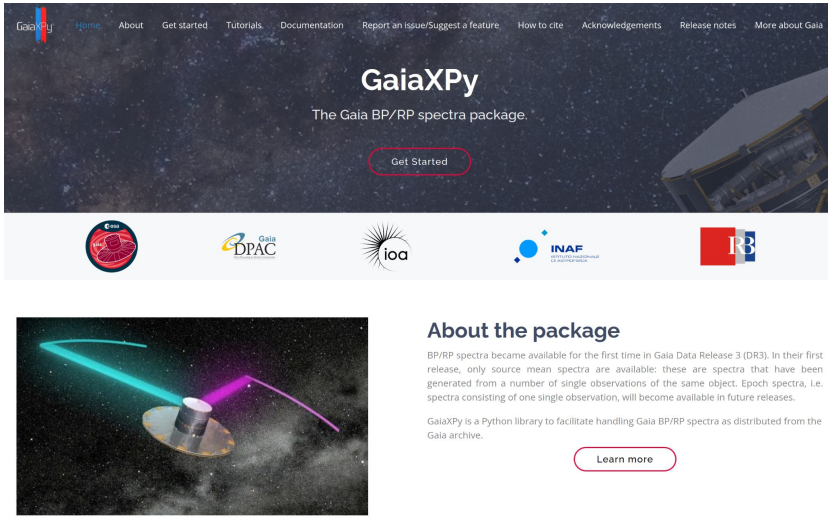






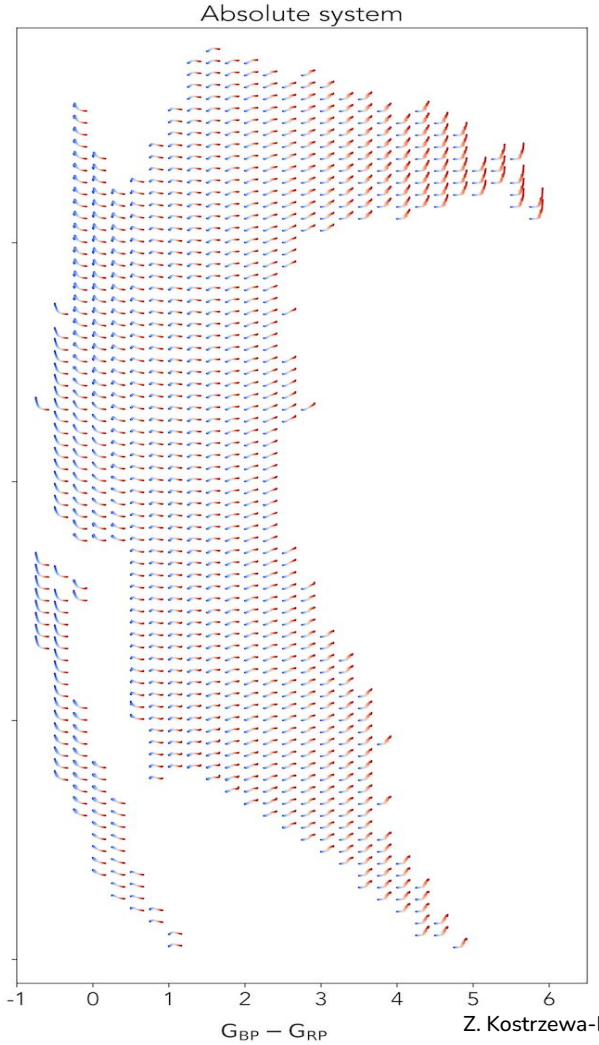
gaiaxpy

- *gaiaxpy*:
  - converter -> to sampled spectrum
  - calibrator -> to absolute system
  - generator -> synthetic photometry
- only for systems covered by XP range:
  - SDSS, DES, PanSTARRS, Hipparcos, HST, JWST, Skymapper ... LSST ...
- synth. phot. also available in the Gaia Archive
  - gaiadr3.synthetic_photometry_gspc



XP caveats

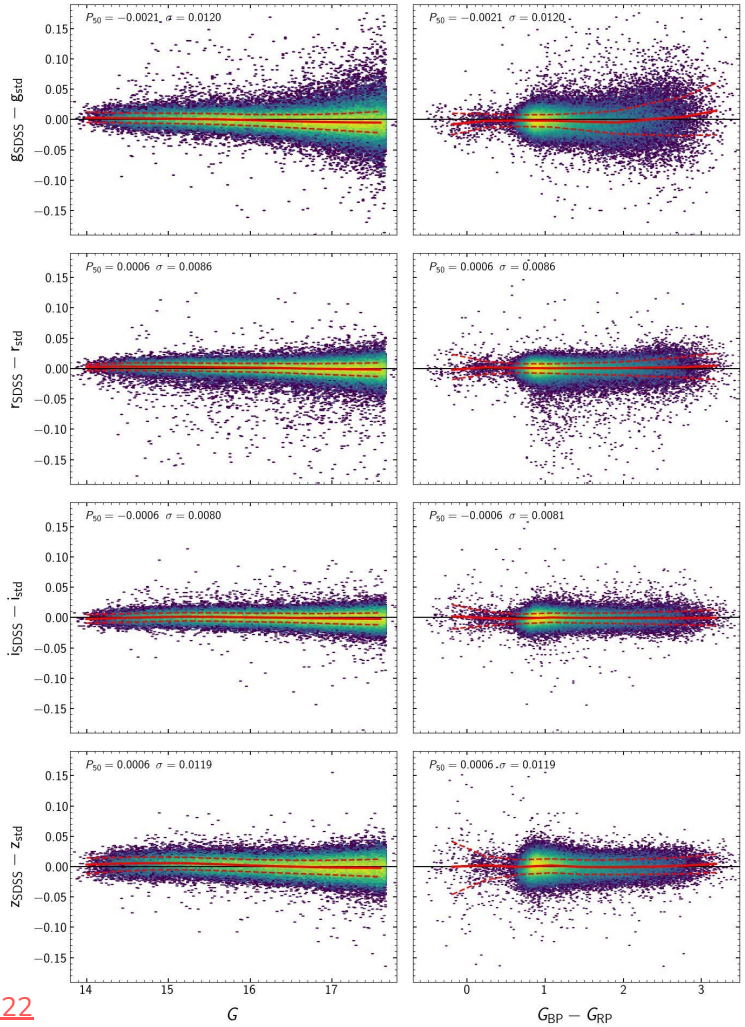
- underestimated errors in internally calibrated spectra, particularly affecting bright sources (G<11.5 mag)
- correlation between coefficients/samples: wavy patterns in sampled spectra
- crowding effects/blending
- magnitude terms
  - <400 nm
  - around 500-600 nm
  - >950 nm
- color term (λ<400nm), result of structured BP TC
- wiggles in externally calibrated spectra...
- *...due to the fact that the mission is ongoing and the data are not final*



Z. Kostrzewa-Rutkowska

XP caveats

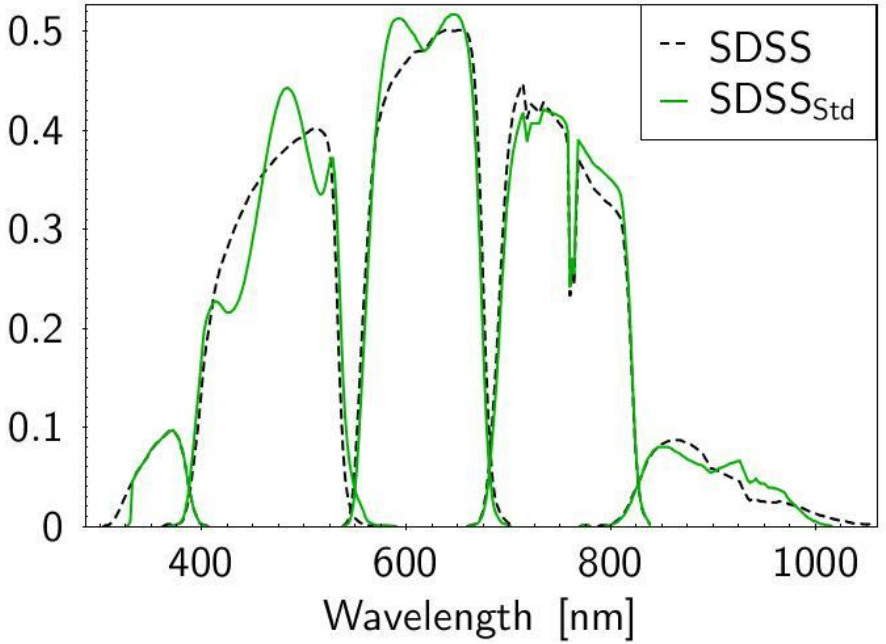
- underestimated errors in internally calibrated spectra, particularly affecting bright sources (G<11.5 mag)
- correlation between coefficients/samples: wavy patterns in sampled spectra
- crowding effects/blending/extended objects
- magnitude terms (λ~580nm)
  - <400 nm
  - around 500-600 nm
  - >950 nm
- color term (λ<400nm), result of structured BP TC
- wiggles in externally calibrated spectra
- *...due to the fact that the mission is ongoing and the data are not final*



- Montegriffo +22

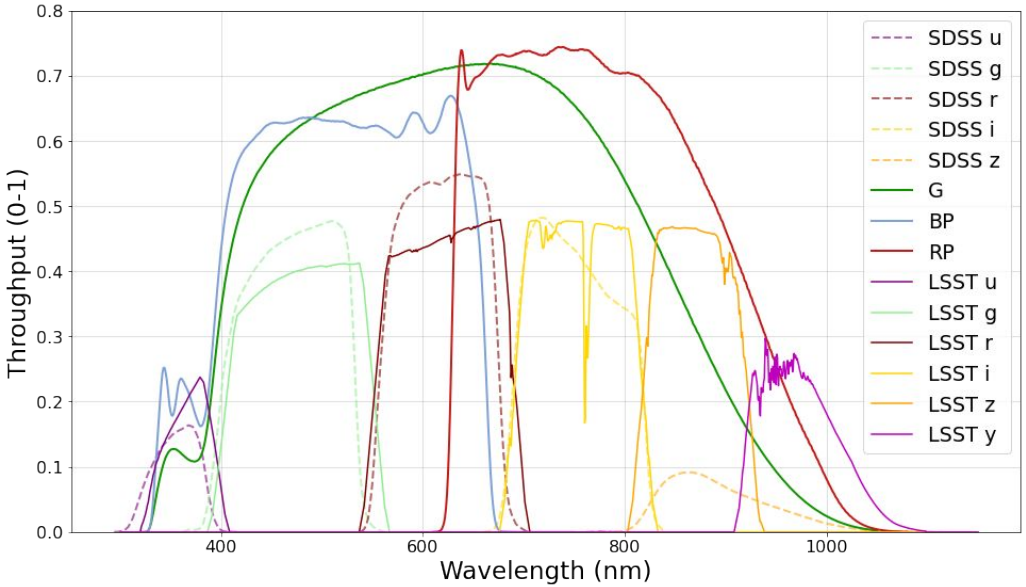
Synthetic photometry

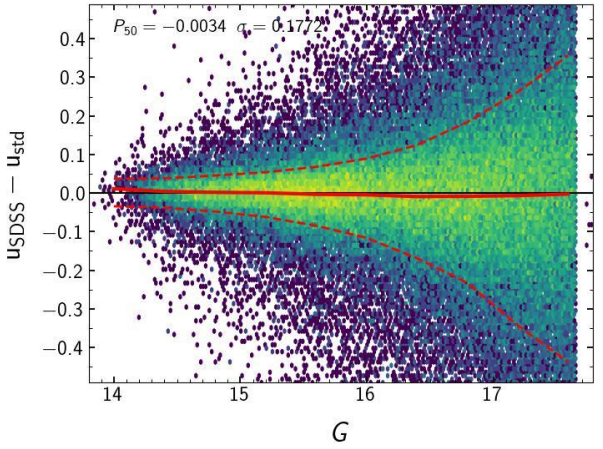
- gaiaxpy convolves XP spectra with throughputs
- residuals wrt. SDSS are corrected through addition of a background term and filter TC tweaking (or poly transformation in the UV bands)
- process known as *standardization*

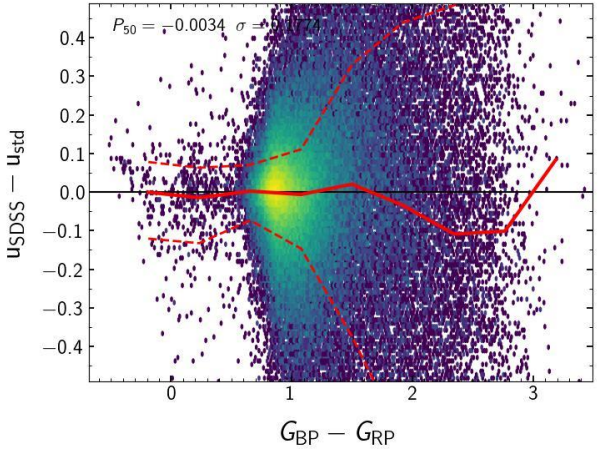


XP spectra and LSST

- LSST *ugrizy* (& SDSS *ugriz*) bands not covered completely (330 < λ<1050 nm)
- obviously, no LSST photometry (yet), standardization not an option if we want to reduce the residuals

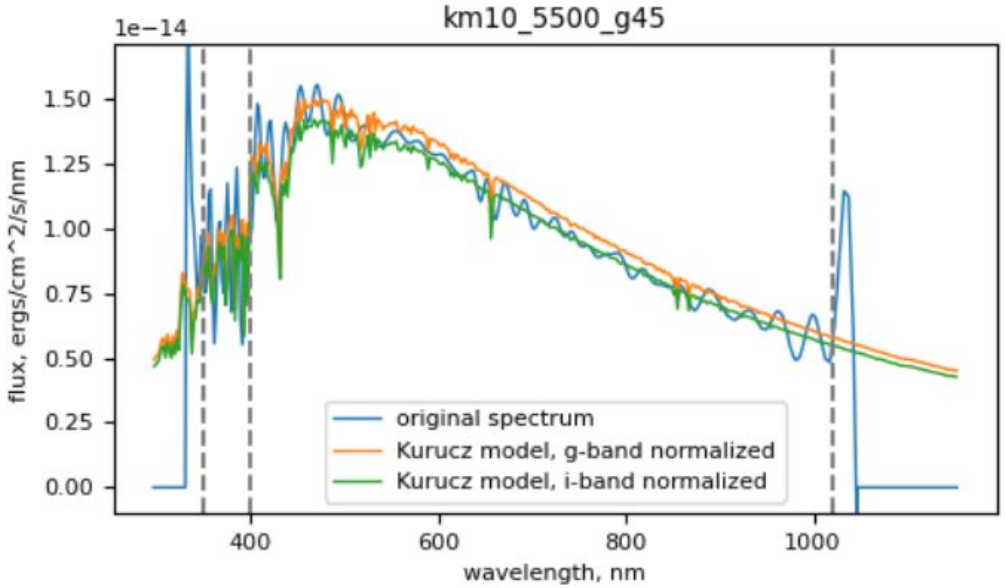






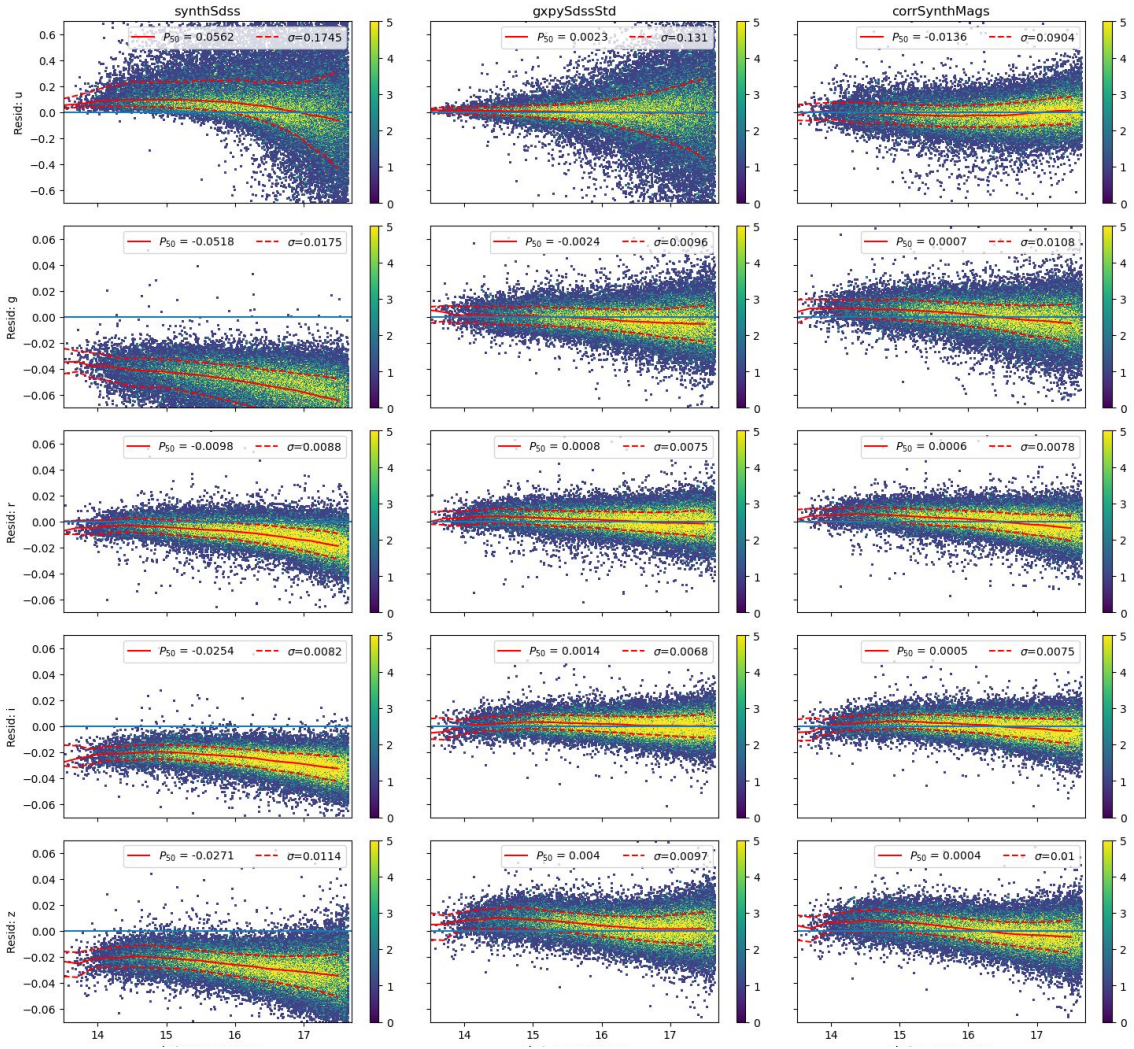
How?

- SDSS S82 (Thanjavur +21) standards as the reference
  - random errors ~< 0.01 mag
  - ~130k stars in total with XP spectra & passing quality cuts)
- gaiaxpy -> absolute spectra from the internally-calibrated continuously-represented mean spectra
- extend/replace XP spectra short/long of ~350 & 1020 nm with extincted model spectra
  - *GSPphot/GSPspec* as input
- we *correct abs. XP spectra* w. equidistantly placed gaussians

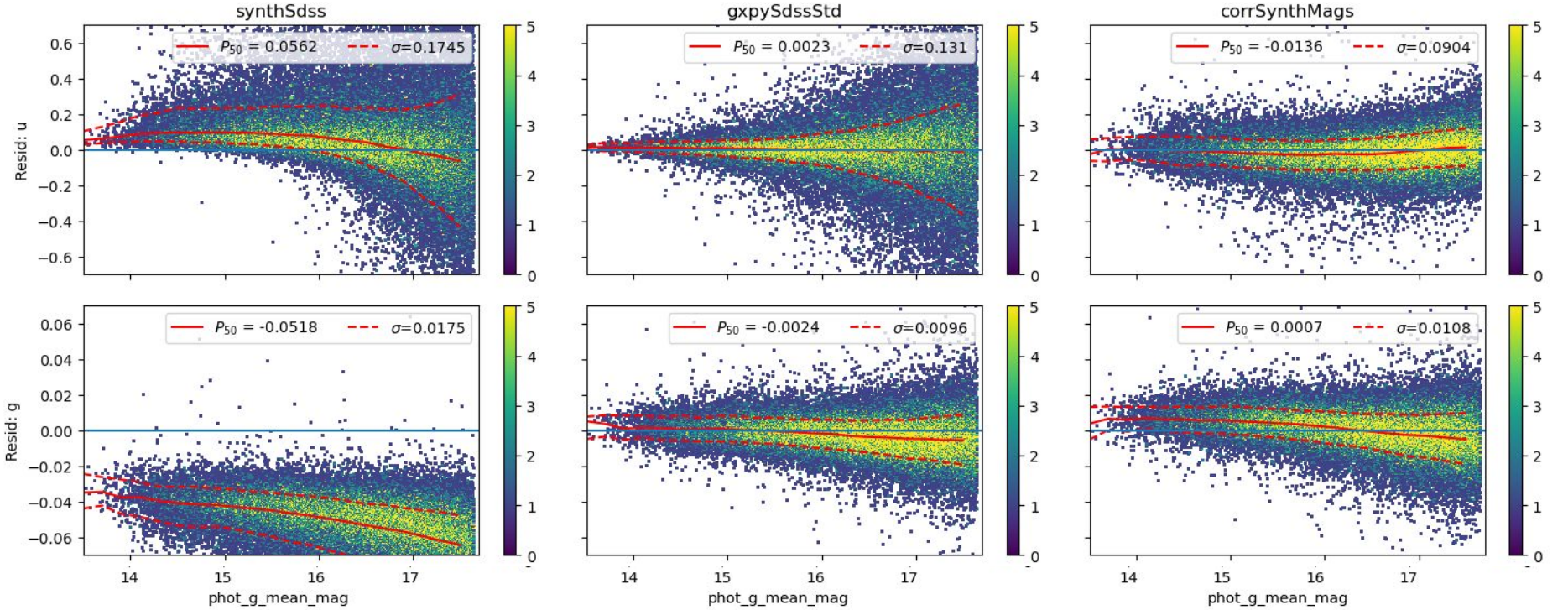


Validation

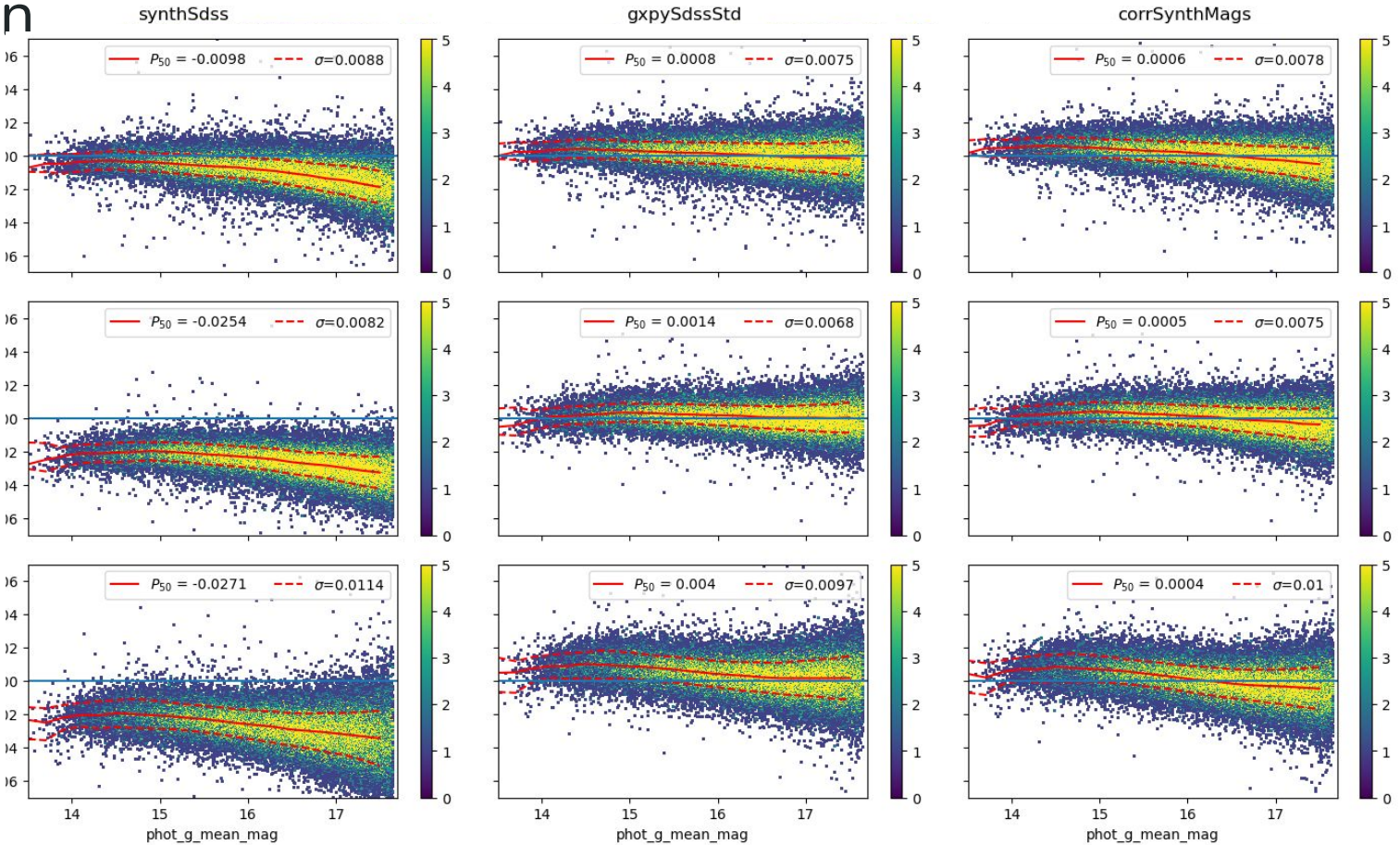
- extensions
  - λ<400 nm
  - λ>1020 nm
- same stars in each panel
- ~130k stars



Validation

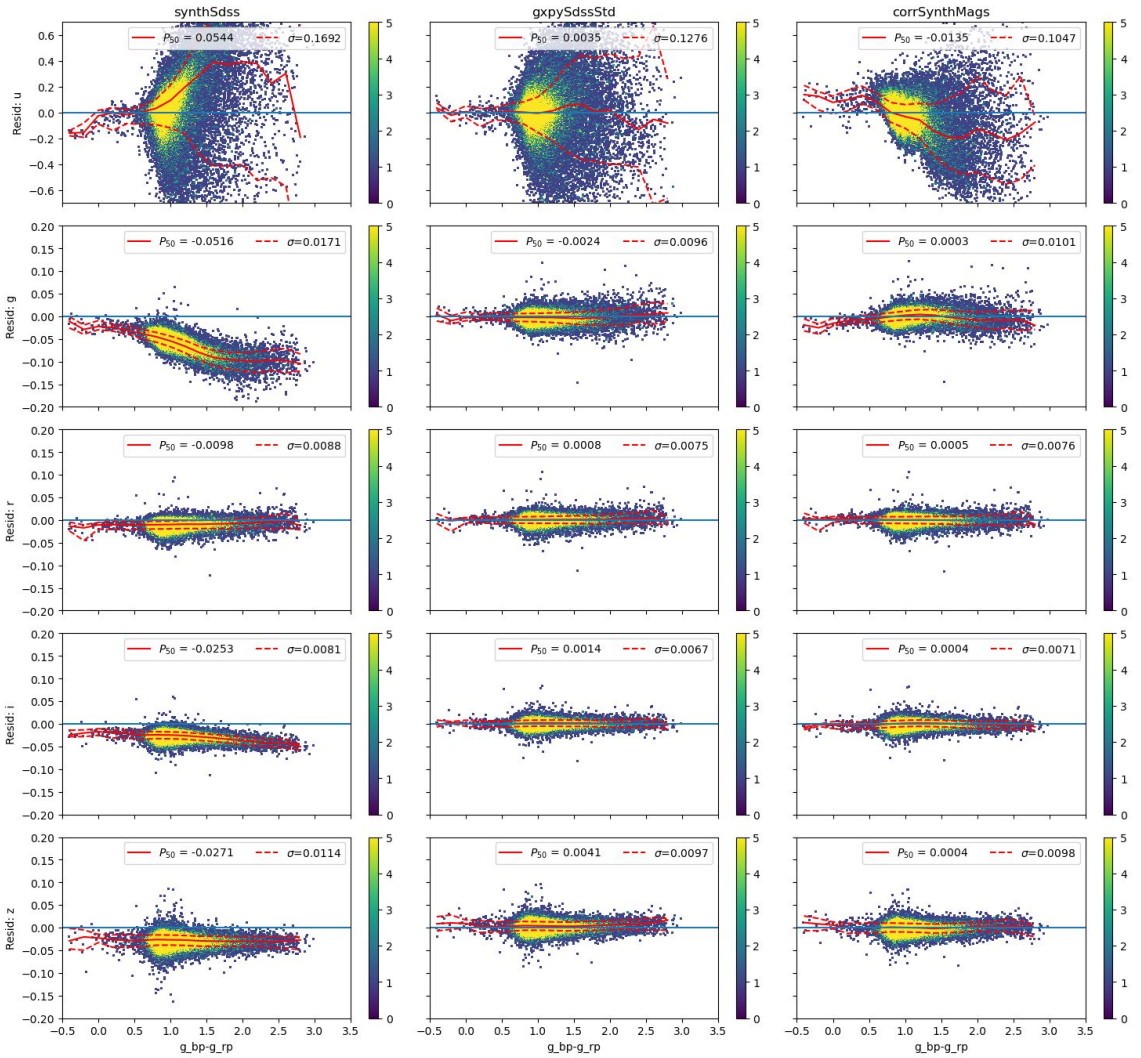

synthSdss
gxpySdssStd
corrSynthMags
P_{50} = 0.0562
σ=0.1745
P_{50} = 0.0023
σ=0.131
P_{50} = -0.0136
σ=0.0904
P_{50} = -0.0518
σ=0.0175
P_{50} = -0.0024
σ=0.0096
P_{50} = 0.0007
σ=0.0108
Resid: u
Resid: g
phot_g_mean_mag

Validation

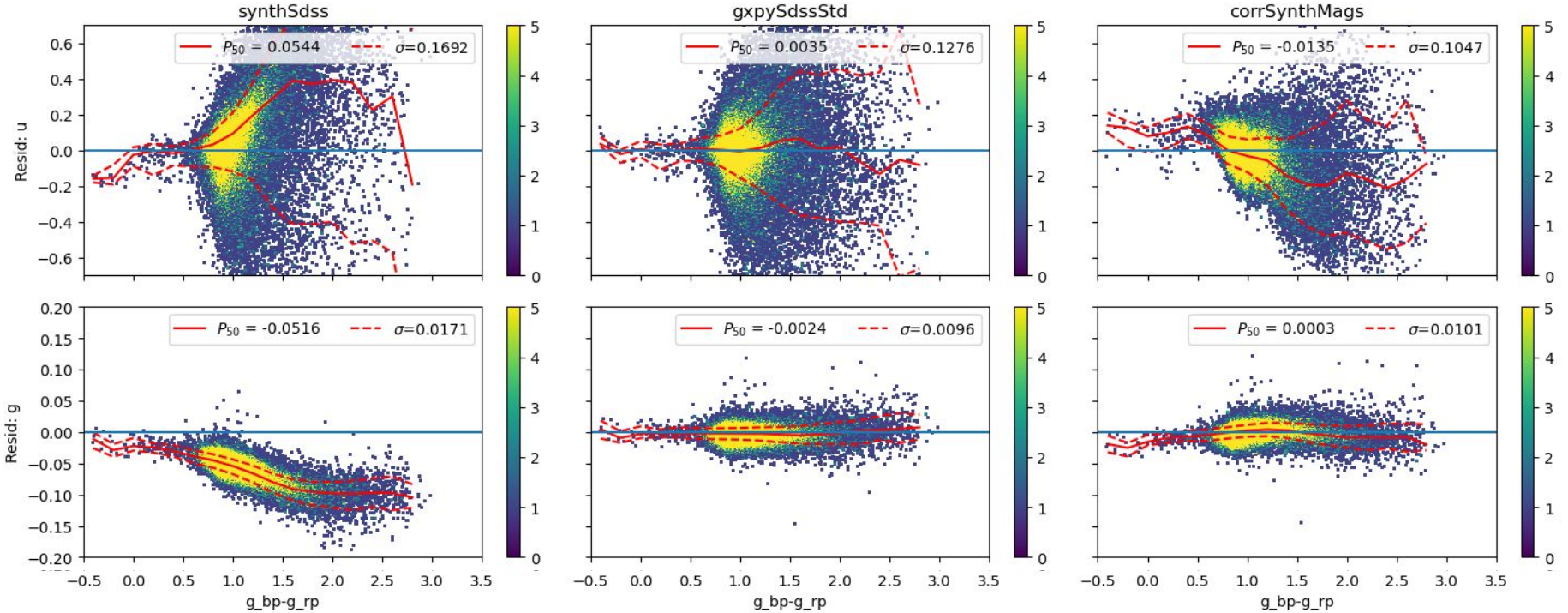

synthSdss
gxpySdssStd
corrSynthMags
P_{50} = -0.0098 σ=0.0088
P_{50} = 0.0008 σ=0.0075
P_{50} = 0.0006 σ=0.0078
P_{50} = -0.0254 σ=0.0082
P_{50} = 0.0014 σ=0.0068
P_{50} = 0.0005 σ=0.0075
P_{50} = -0.0271 σ=0.0114
P_{50} = 0.004 σ=0.0097
P_{50} = 0.0004 σ=0.01
phot_g_mean_mag
phot_g_mean_mag
phot_g_mean_mag

Validation

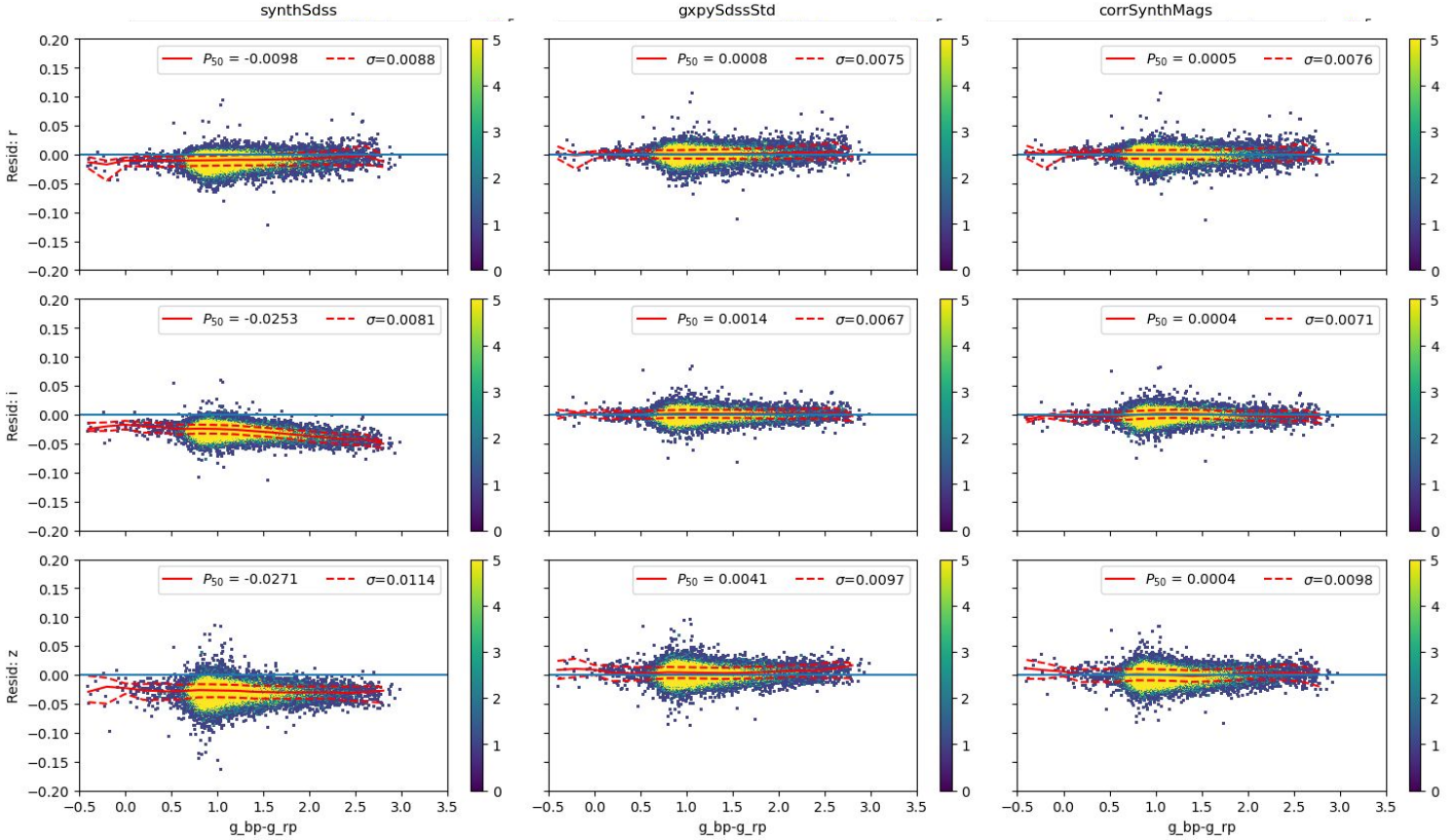
- extensions
  - λ<400 nm
  - λ>1020 nm
- same stars in each panel
- ~130k stars



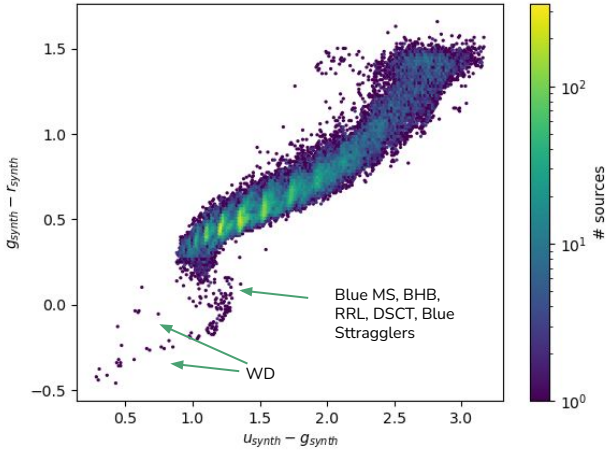
Validation

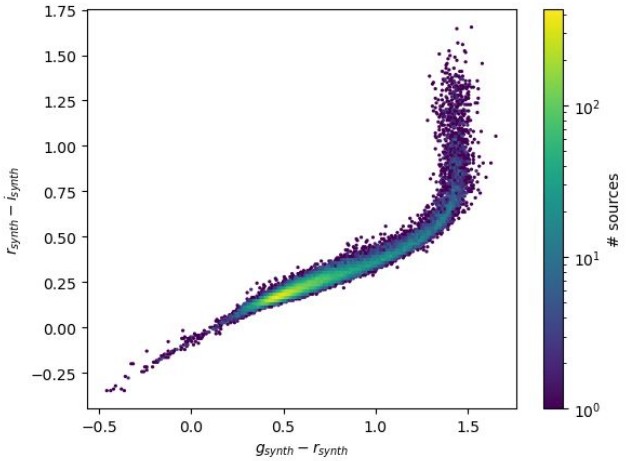

synthSdss
gxpySdssStd
corrSynthMags
P_{50} = 0.0544
σ=0.1692
P_{50} = 0.0035
σ=0.1276
P_{50} = -0.0135
σ=0.1047
P_{50} = -0.0516
σ=0.0171
P_{50} = -0.0024
σ=0.0096
P_{50} = 0.0003
σ=0.0101
Resid: u
Resid: g
g_bp-g_rp

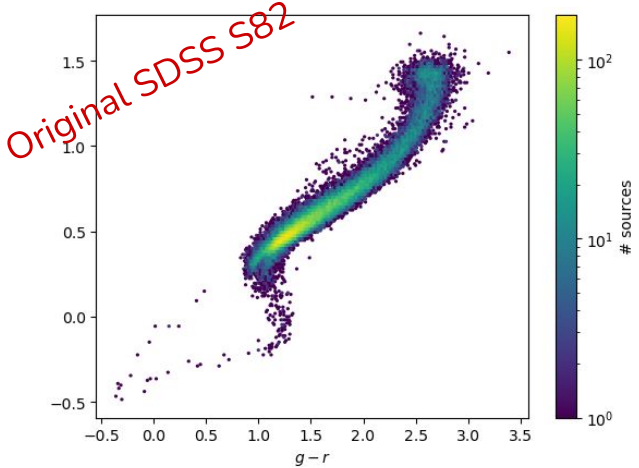
Validation

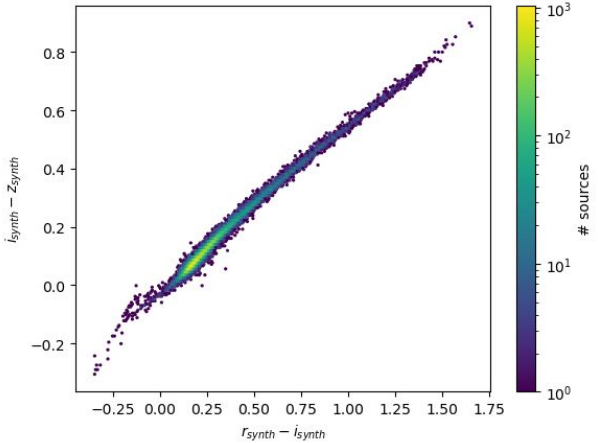

synthSdss
gxpySdssStd
corrSynthMags
Resid: r
Resid: i
Resid: z
P_{50} = -0.0098
σ=0.0088
P_{50} = 0.0008
σ=0.0075
P_{50} = 0.0005
σ=0.0076
P_{50} = -0.0253
σ=0.0081
P_{50} = 0.0014
σ=0.0067
P_{50} = 0.0004
σ=0.0071
P_{50} = -0.0271
σ=0.0114
P_{50} = 0.0041
σ=0.0097
P_{50} = 0.0004
σ=0.0098
g_bp-g_rp

Validation


Blue MS, BHB,
RRL, DSCT, Blue
Sttragglers
WD
$g_{synth} - r_{synth}$
$u_{synth} - g_{synth}$
sources

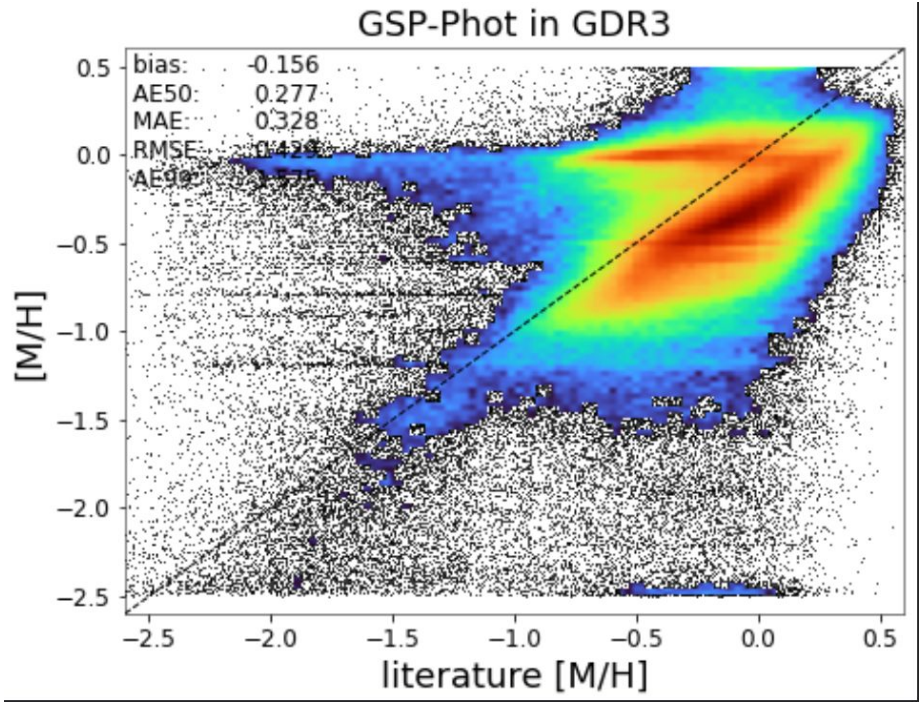

$r_{synth} - i_{synth}$
$g_{synth} - r_{synth}$
sources


Original SDSS S82
$g - r$
sources


$i_{synth} - z_{synth}$
$r_{synth} - i_{synth}$
sources

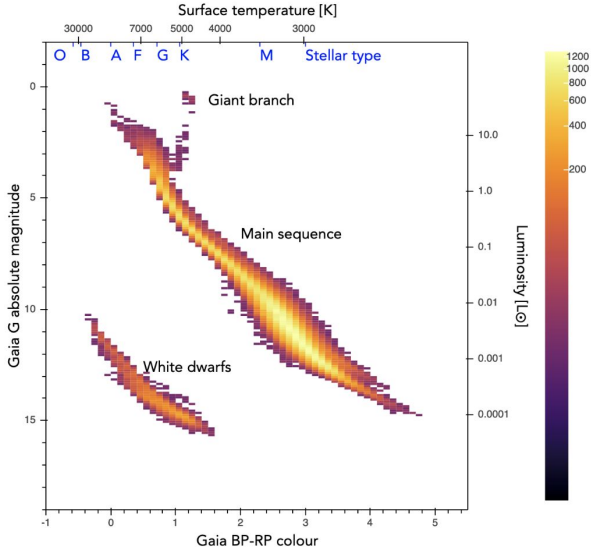
ToDo list

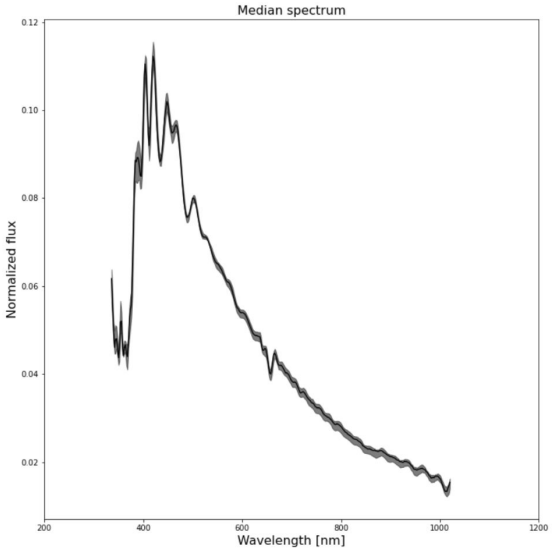
- work with basis functions instead of absolute spectra
- use more appropriate stellar atm. models
- include the underestimation of the nominal errors on XP fluxes
- extend the sample to sources brighter than *r*~14.5
  - should work even if “mixing” surveys
- more validation!



Andrae ‘23 priv. comm.

[Thanks and check out the interactive XP spectrum HRD!](gaiaxp.irb.hr)





LSST@Europe5

LSST@Europe5: "Towards LSST Science, Together!" conference will be held in Poreč, Croatia, September 25–29, 2023. We look forward to welcoming you in historic and picturesque Poreč, a UNESCO heritage site. Please save the date!

This conference aims to build on the successful outcomes of the first four meetings in the UK, Serbia, France, and Italy, and to further collaboratively develop LSST science opportunities. We anticipate that the Rubin Construction and Operations teams will report on the observatory construction status, data products and updated timelines. We also plan to put the emphasis on in-kind contributions, and particularly on those originating in Europe.

The meeting will be conducted in a hybrid format to enable access for remote participants and the wider Rubin/LSST community. We are planning for up to 300 in-person participants, and anticipate funds for enhancing participation by junior researchers.

The organizers wish to express their gratitude to B612 Foundation and LSST Corporation for providing financial support for the meeting.

Registration is open. Abstract submission and requests for travel support will become available soon.

Correction of extended spectra

- corrected XP flux

spectrum corrected by an unknown function

$$F_b^* = \int_0^\infty \phi_b(\lambda) F_\nu^{G,*}(\lambda)\,\mathrm{d}\lambda$$

- Taylor exp.:

$$F_\nu^{G,*}(\lambda, C_0(\lambda), C_1(\lambda)) = C_0(\lambda) + (1 + C_1(\lambda)) F_\nu^G(\lambda)$$

background noise

multiplicative. correction

- Find functions C that minimize the difference between the SDSS & synth. mags
- we choose Gaussians:
  - σ = 100 nm
  - 300 < λ [nm]<1200 every 50 nm

$$\chi^2(C_0, C_1) = \sum_i \sum_{b \in \{u,g,r,i,z\}} \left(F_{b,i}^{SDSS} - F_{b,i}^*(C_0, C_1)\right)^2$$