Synthetic LSST magnitudes derived from Gaia XP spectra

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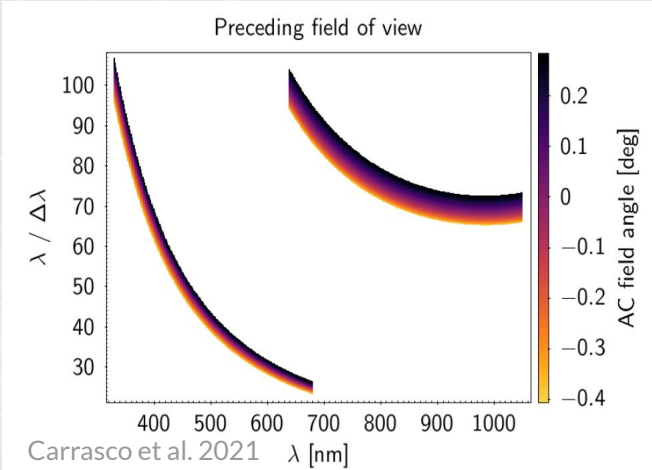
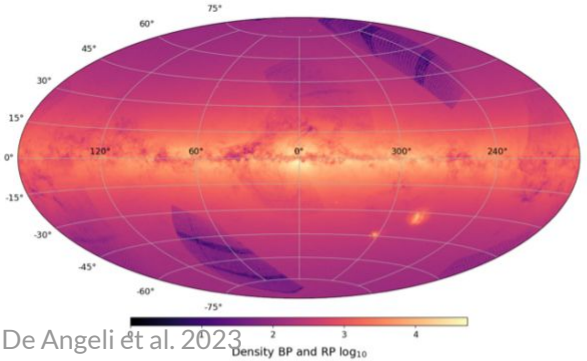
Gaia XP spectra and LSST

- ~220 million sources in the DR 3, spanning the range 13.5<mag_G<17.5;
- Two spectrometers:
  - BP spectrometer: λ = [330, 680] nm, λ/Δλ) varying from 100 at the blue end to 25 at the red end;
  - RP spectrometer: λ = [640, 1050] nm, λ/Δλ from 100 at the blue end to 65 at the red end.
  - The resolution depends not only on the wv but also on the CCD;
- Each spectrum is an average of a number of epoch spectrum;



Carrasco et al. 2021

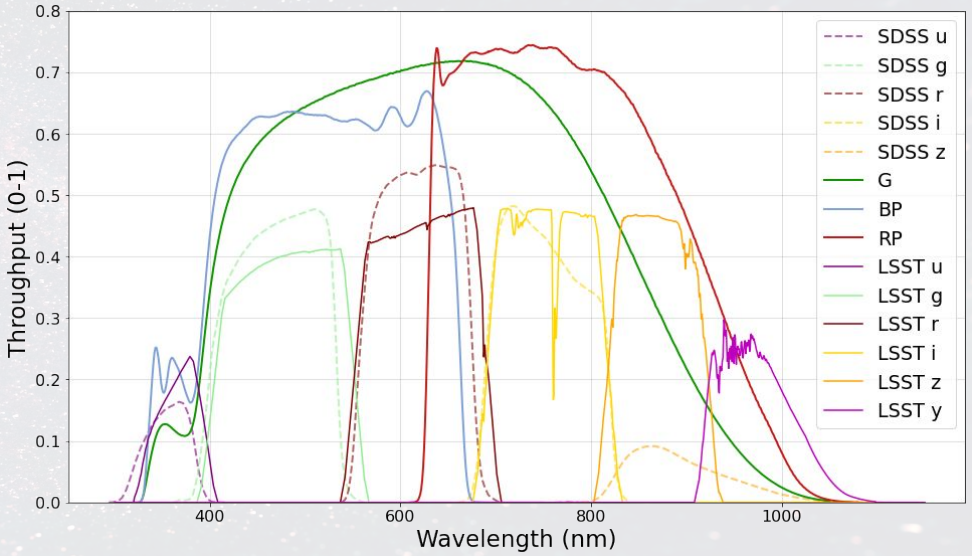


De Angeli et al. 2023

Using Gaia XP spectra we can produce a catalogue of synthetic LSST magnitudes

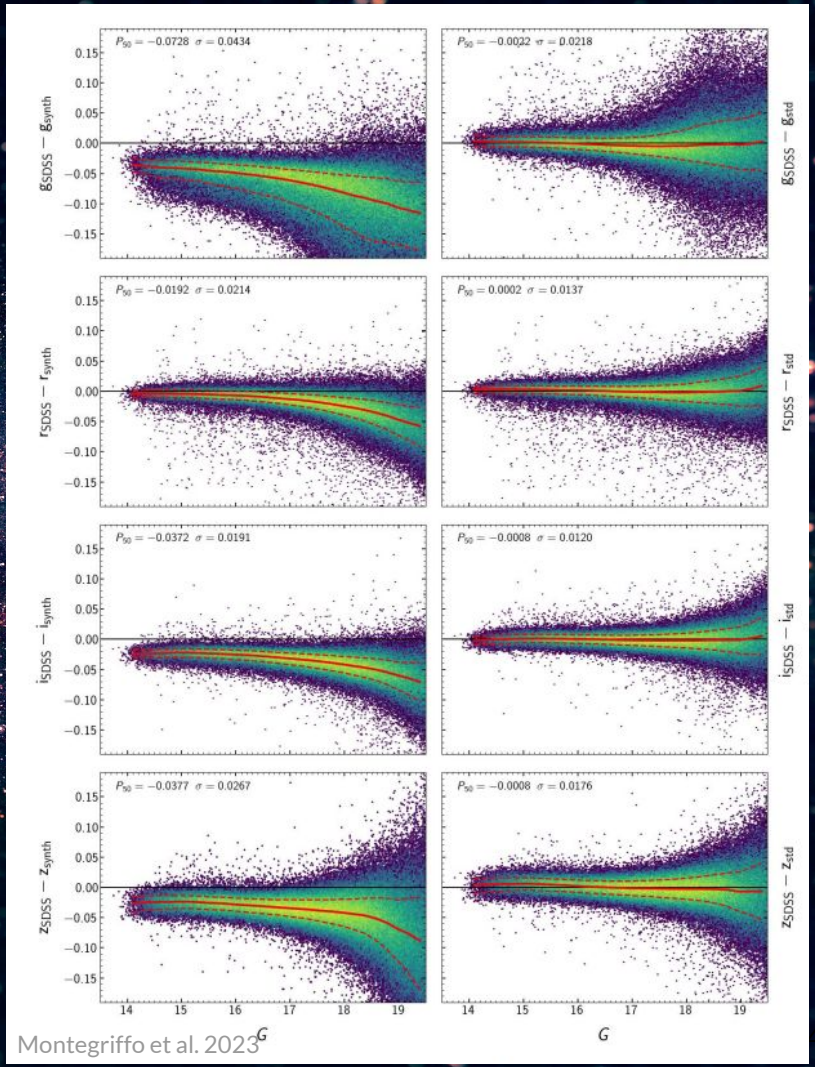
This catalogue will allow us:

- To test LSST scientific pipelines before the beginning of Rubin Observatory work;
- To extend magnitude range at the bright end (~13.5 - 17.5 mag_G for Gaia XP);
- To extend time range of observations (combine Gaia observations with LSST; in future Gaia Data Releases will include epoch spectra as well).



Synthetic photometry from Gaia XP spectra

- Spectra are stored in a continuous form, as a linear combination of up to 55 basis functions, in pseudo-wv and pseudo-flux system;
- *gaiaxpy* package can be used for external calibration, conversion to a sampled form and synthetic magnitude calculation for a number of photometric systems (SDSS, DES, HST, LSST);
- *gaiaxpy* uses continuous representation for magnitude calculation;
- **There is a number of known magnitude and color-dependent systematics, as well as a number of poorly understood systematics that do not have a clear correlation with neither magnitude, color or spectrum shape.**



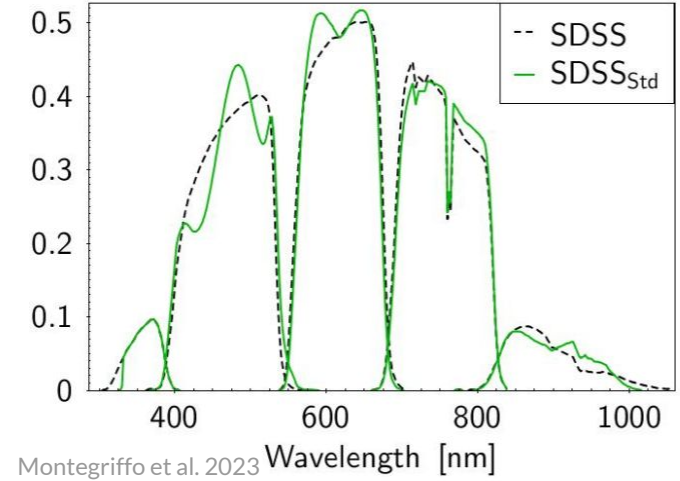
Montegriffo et al. 2023

Synthetic photometry from Gaia XP spectra: troubleshooting

- We use *rubin_sim* package for producing magnitudes -> we have to use sampled spectra;
- Continuous to sampled calibration produces so called “wiggles” (mostly below 400 nm)
- For high-precision science (e.g. MW structure studies) we have to correct magnitude and color-dependent systematics;
- Gaia XP spectra do not cover the full wv range of LSST filters;
- We don’t have real LSST data for calibration and validation (yet).

Solution:

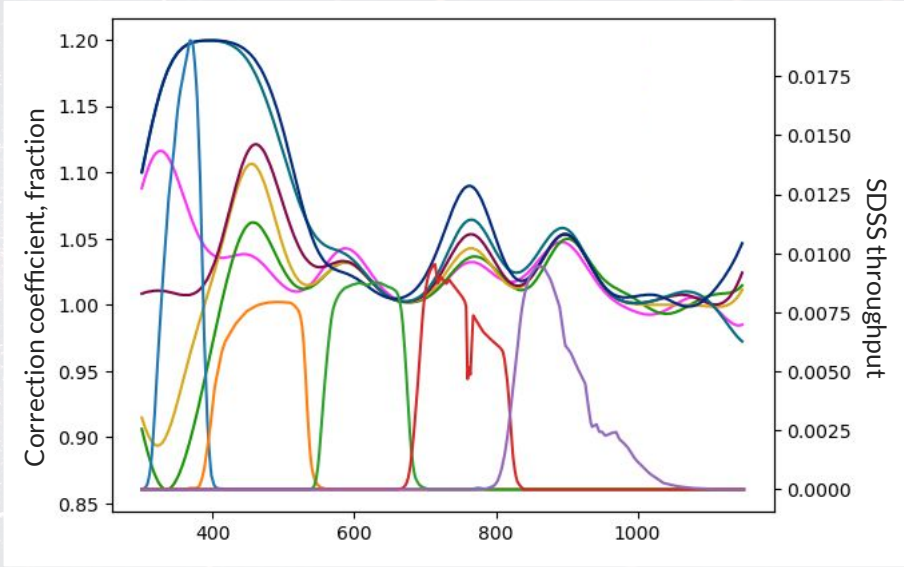
- We extend/replace wiggly spectrum tails with synthetic stellar atmosphere model spectra (Kurucz);
- We use SDSS Stripe 82 (Thanjavur et al. 2021) catalogue for calibration and validation:
  - random photometric errors < 0.01 mag;
  - calibration against multiple external catalogues;
  - >50k sources after crossmatch with Gaia XP dataset.
- Unlike Montegriffo et al. 2023, we tweak spectra, not filters.



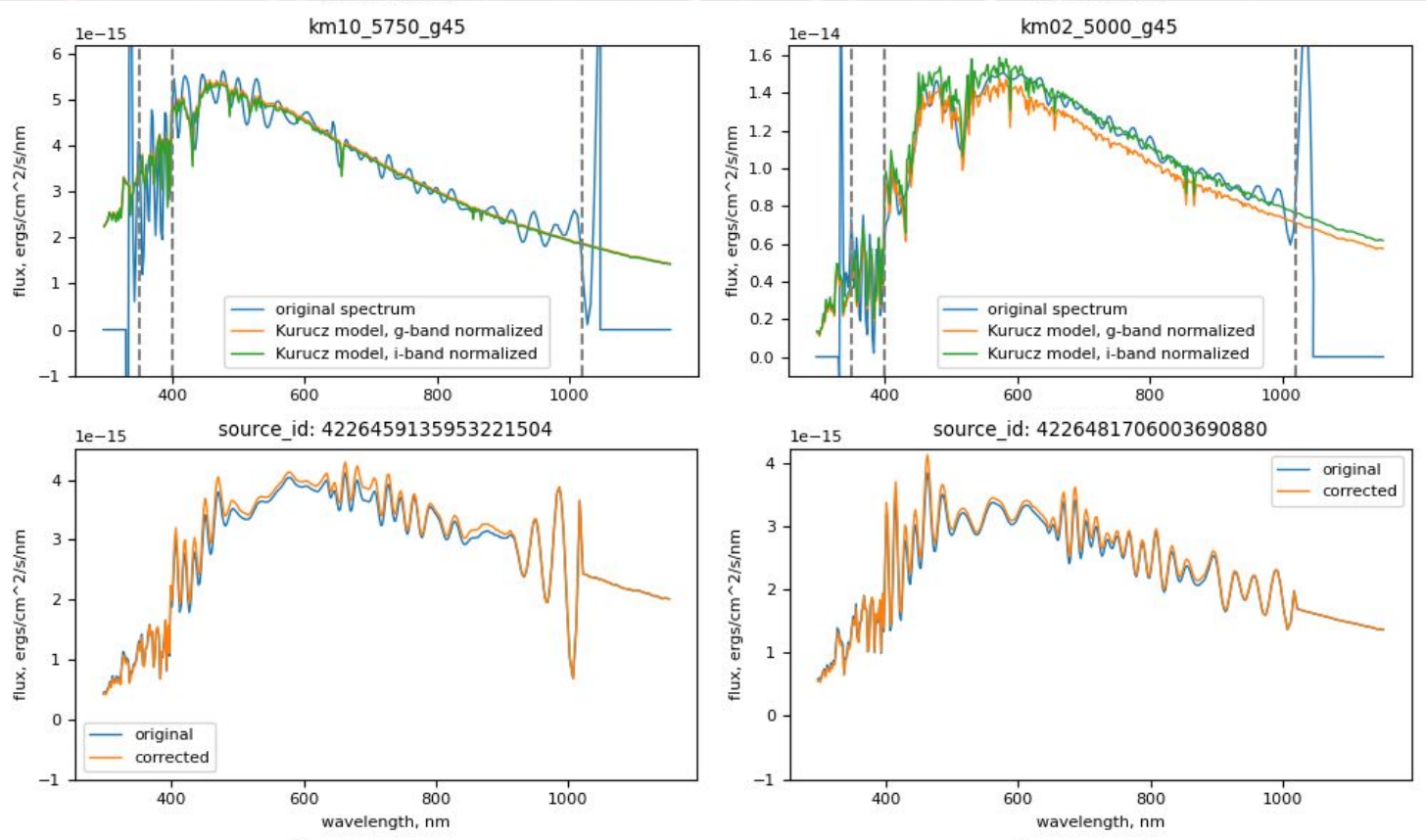
Montegriffo et al. 2023

Troubleshooting: correction

- To account for systematics, we use Stripe 82 magnitudes to produce correction curve(s);
- We tried polynomial fitting, ML approach and sum-of-gaussians approach with different parametrizations;
- The last one is our approach of choice (*currently*)



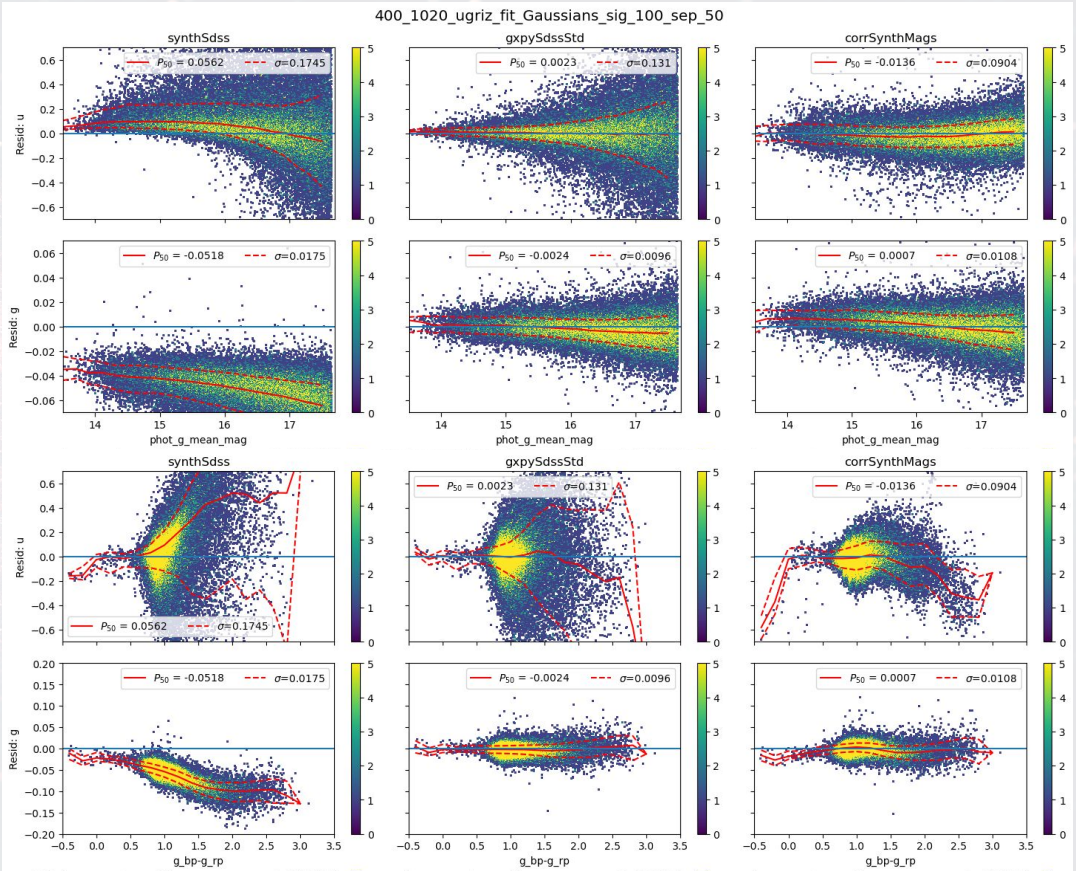
Extension and correction: what it looks like



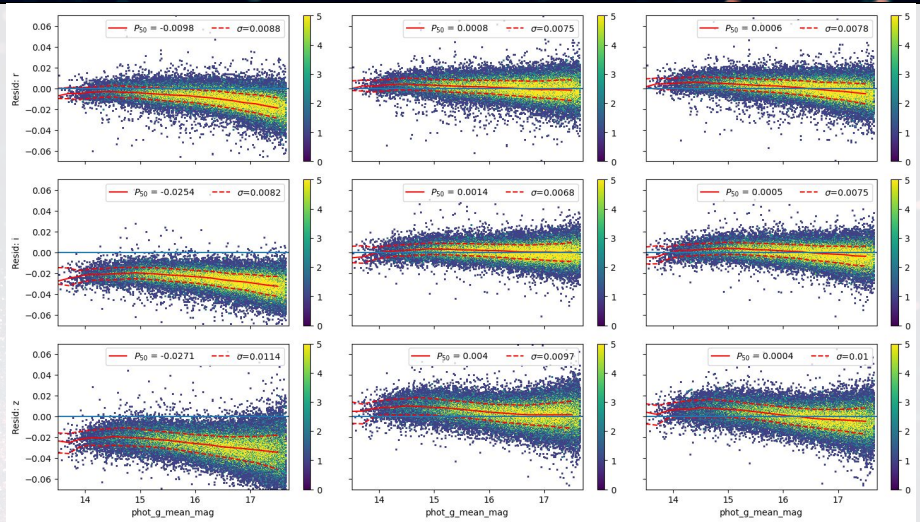
Correction results

Residuals from Gaia G_mag

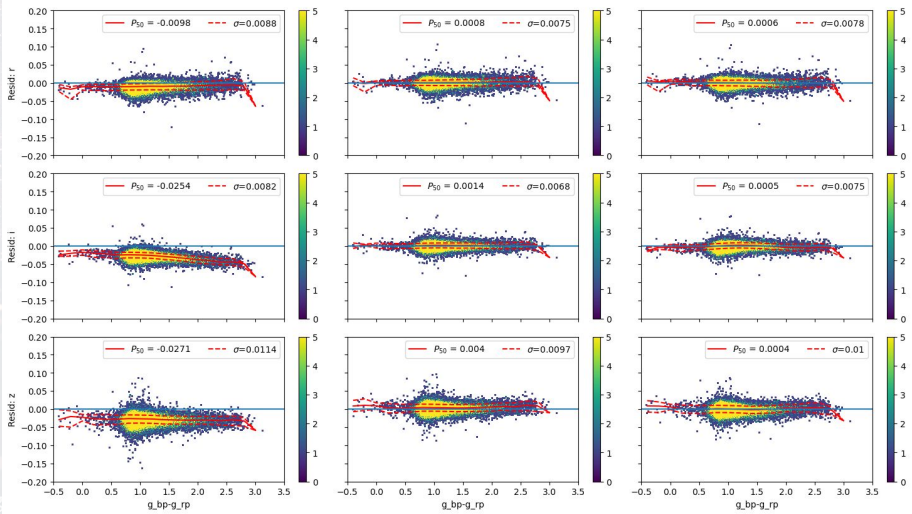
Residuals from Gaia bp-rp color



Residuals from Gaia G_mag



Residuals from Gaia bp-rp color



Alex Razim, Synth LSST mag

Conclusions

Deliverables:

- A synthetic LSST magnitudes catalogue for ~220 millions of sources for which Gaia XP spectra are present;
- A correction procedure for Gaia XP spectra to account for wv range incompleteness and systematic biases, with several tail extension types;

To do list:

- Correction on continuous spectra;
- Improve correction to account for magnitude and color terms;
- In the future: calibration on LSST data.