Atmospheric Parameters from Gaia BP/RP Spectra Using FERRE and Follow-ups

Methods & Catalogs & Follow-ups

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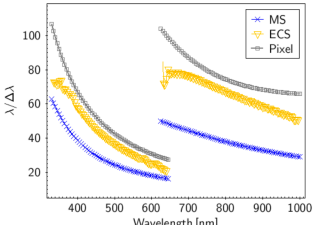
Outline

- **Introduction to the Gaia XP spectra**
- **Method**
  - **Model spectra fit (FERЯE)**
  - **Systematic flux prediction (Neural Network)**
- **Results of the systematic flux corrections**
  - **Improvement on atmospheric parameters**
  - **Improvement on relative spectrophotometry**
- **Follow-ups for the extremely metal-poor stars**
  - **ALFOSC, HIRES**

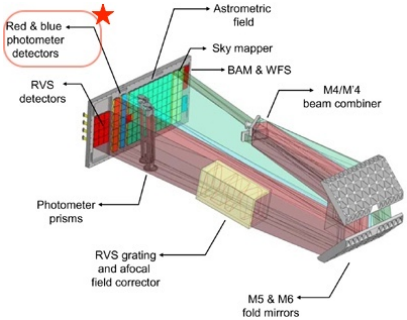
Introduction to the Gaia XP spectra

Information & specialty

- **Gaia DR3, stellar spectra:**
  - **RVS spectrometer**
  - **blue photometer,** $330 \sim 690$ **nm**
  - **red photometer,** $640 \sim 1050$ **nm**
- **Wavelength range:** $330 \sim 1050$ **nm;**
- **Very low resolution:** $20 \sim 70$ (**Montegriffo et al. 2021**);
- **Very large data set:** ~ 220 **million sources;**

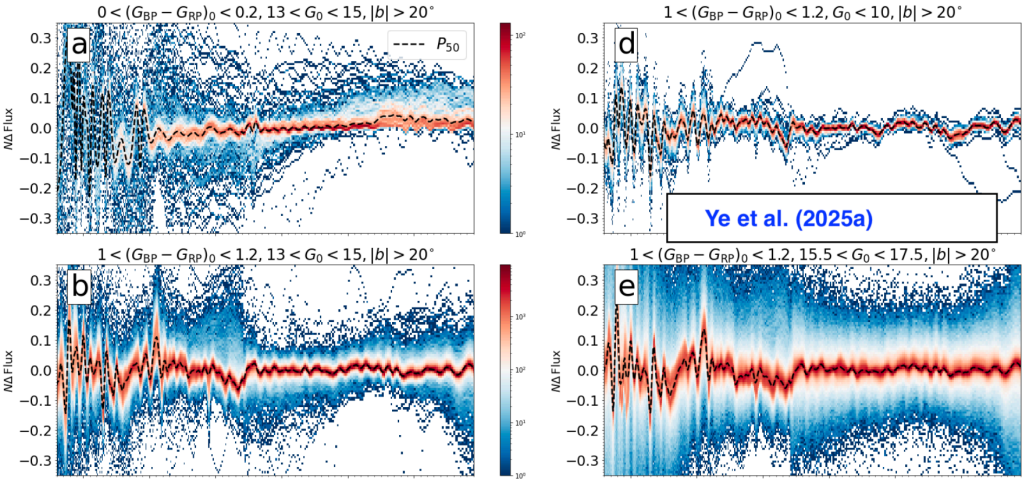


→ **Figure.18 in Montegriffo et al. 2021; see also the Table.1 in this paper.**



Introduction to the Gaia XP spectra

Systematic patterns in externally calibrated XP: color, magnitude, extinction (Montegriffo et al. 2022; Huang et al. 2024)



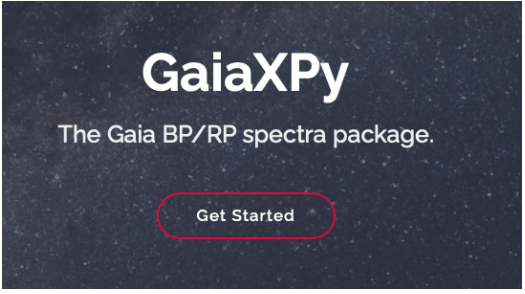
Method: Model spectra fit

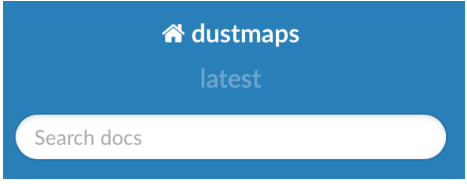
External callibration

- GaiaXPy:
  - **calibration: internal(Bp/Rp coefficients) → external(actual flux)**
  - **generation: magnitudes**

Dereddening

- dustmaps (Green 2018): **SFD 2-D map** (Schlegel et al. 1998); (Schlafly & Finkbeiner 2011)

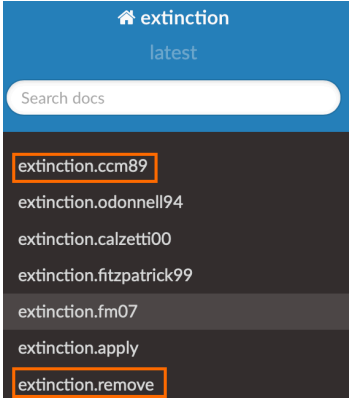




Method: Model spectra fit

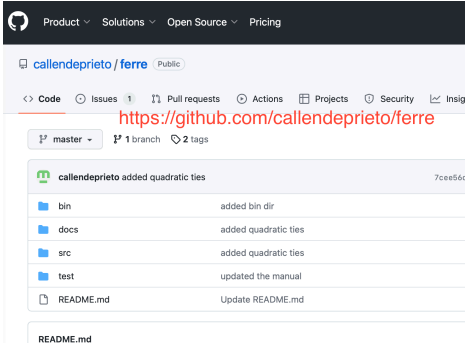
Dereddening

- extinction, ccm89 **extinction law** (Cardelli et al. 1989)

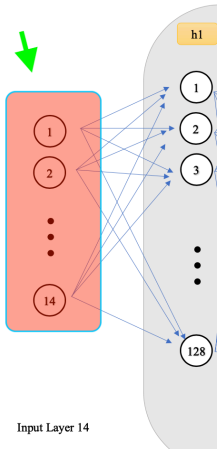


Models fit

- FERЯE: **traditional physical model matching** (Allende Prieto et al. 2006)



Method: Systematic flux prediction

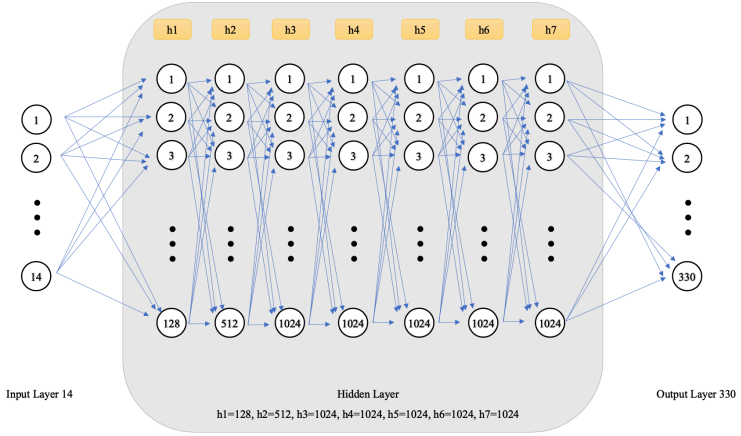


Input parameters: synthetic photometries by GaiaXPy + reddening

- **SkyMapper**
  - **metallicity-sensitive colors (Chiti et al. 2021) :**
    - $g - i$
    - $v - g - 0.9(g - i)$
    - $u - v - 0.9(g - i)$
  - u, v, g, i
- **Gaia photometric magnitudes:**
  - G, $G_{\rm BP}$, $G_{\rm RP}$, $G_{\rm RP} - G_{\rm RP}$, $G_{\rm BP} - G$, $G_{\rm RP} - G$
- $E(B - V)$

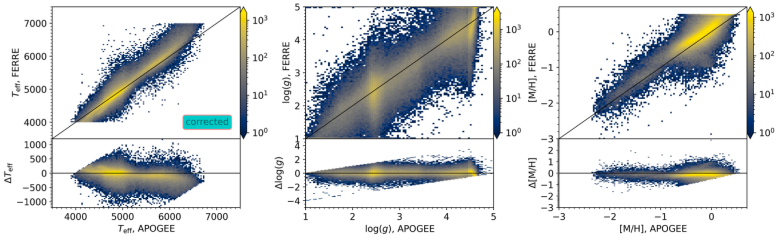
Method: Systematic flux prediction

- **A simple Neural Network based on** Pytorch (**Paszke et al. 2017**)

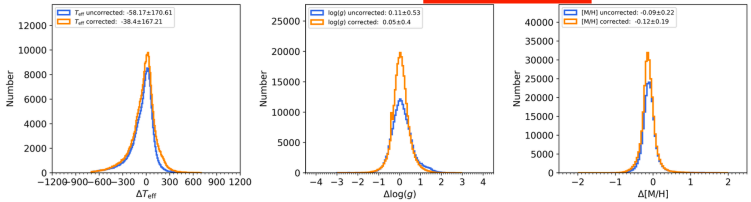


- **Loss function:** MSELoss
- **Optimizer:** Adam
- **APOGEE:** **Training sample**(60%) + **Validation sample**(20%) + **Testing sample**(20%)

Improvement on atmospheric parameters



Compare to APOGEE



Comparing with APOGEE

The mean value and standard deviation of: Ye et al. (2025a),

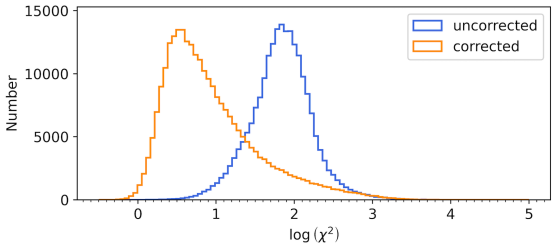
- $\Delta T_{\rm eff}$: -38 ± 167 **K**;
- $\Delta \log g$: 0.05 ± 0.40 **dex**;
- Δ[M/H]: -0.12 ± 0.19 **dex**.

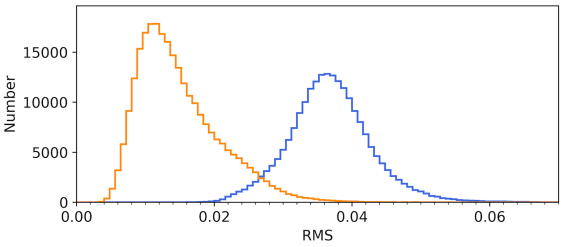
Comparing to other catalogs of XP spectra

- **MC performs better in the general parameter space;**
- **Beyond the normal ...**

Improvement on relative spectrophotometry

- **Compare to models**





Improvement on relative spectrophotometry

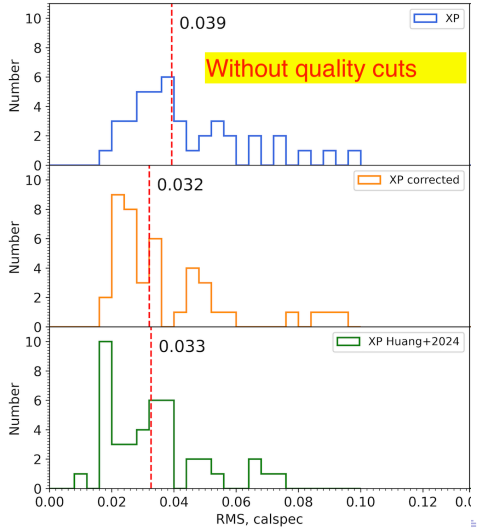
- **Compare to CALSPEC**

Match XP and CALSPEC

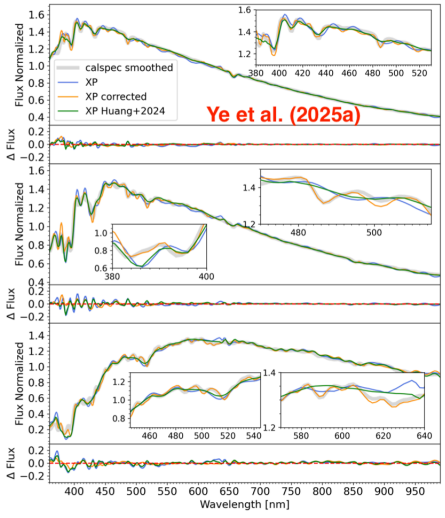
- **Match resolution: Gaussian convolution**
- **Match sampling in λ: interpolation**

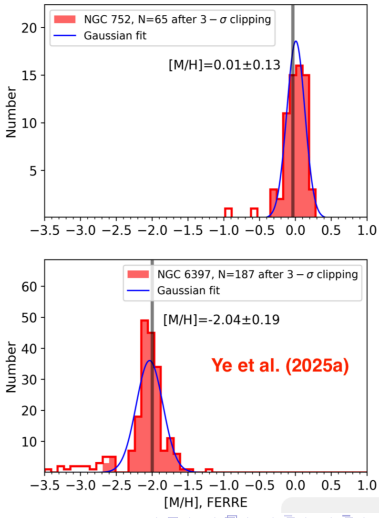
Comparison with literature

- **Compare with Huang et al. (2024), in which they provide a package to correct XP spectra.**
  - **Original XP in blue**
  - **Corrected by us in orange**
  - **Corrected by Huang et al. (2024) in green**



Improvement on relative spectrophotometry





Follow-ups for the extremely metal-poor stars

Selection

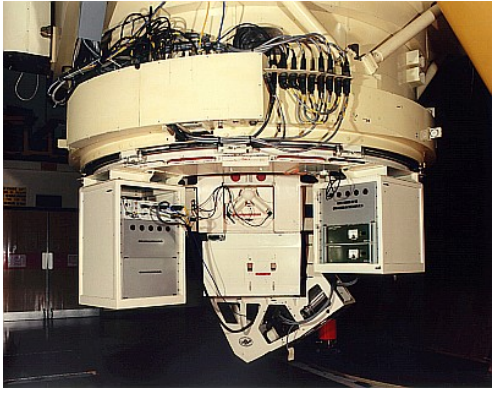
- **Choose stars with** $[\mathrm{M/H}] < -2.5$
- $T_{\mathrm{eff}} \sim 5000$
- **Magnitude:** $G < 15$ **mag**
- **Examine spectra by eye**
- **Observation date: February 16 and 17 in 2024, INT Service Time**

Observation

- **Telescope: Isaac Newton Telescope (INT) @ La Palma**
- **Spectrograph: Intermediate Dispersion Spectrograph (IDS)**

Data reduction & Analysis

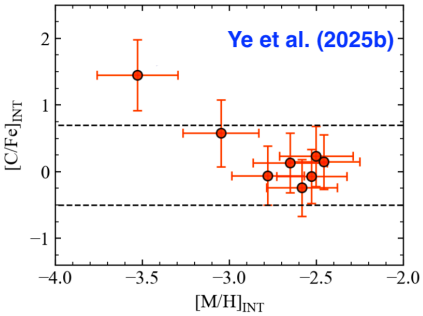
- IRAF, FERЯE

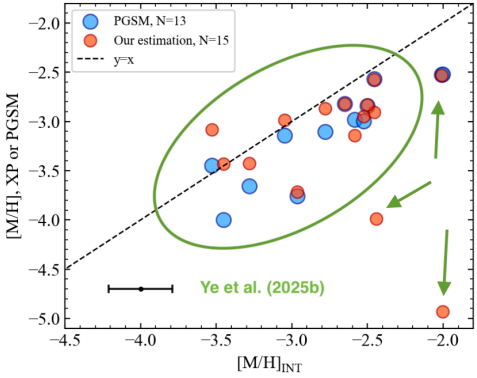


Follow-ups for the extremely metal-poor stars

Low/medium-Res follow-up

- **Follow-up EMP candidates using IDS/INT @ La Palma**
- **Efficiency of identifying EMP stars** $\rightarrow 63^{+19}_{-24}\%$ Ye et al. (2025b)
- **Identify new VMP/EMP stars**

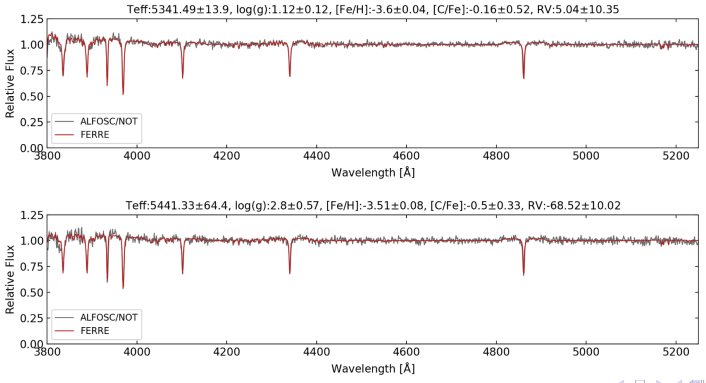




Follow-ups for the extremely metal-poor stars

Low/medium-Res follow-up

- **Construct metal-poor star sample based on Gaia XP** Ye+2025a, A&A, 695, A75 + SPECCLIP (**Zhao, Huang, 2026, ApJ, 998, 2, 189**)




THANKS !