[P3] The selection of spectrophotometric standards for PFS observations based on PanStarrs1 and Gaia

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Abstract

As a preparation of the PFS science operation (*see Tamura-san's talk, P2, P7, and P12*), we develop a strategy to homogeneously select standard stars of ideal spectral types (e.g., F-type stars) for the accurate spectrophotometric calibration from wide-field survey data. For this purpose, we make use of the latest data releases of Gaia and PanStarrs1 to cover most of the sky at Dec>-30 deg down to g~20-21. The photometric and astrometric data from the Gaia-PanStarrs1 cross-matched catalog will be processed by the publicly available brutus code (https://github.com/joshspeagle/brutus) to interpolate the table of bolometric correction calculated based on a grid of stellar isochrone models. We evaluate this method by a subset of stars with known stellar effective temperatures from the SDSS/SEGUE catalog. We find that the method recovers the SEGUE spectroscopic temperatures with a mean difference of ~100 K and the standard deviation of <250 K. We discuss the strength and limitation of this method for the development of the effective operation scheme of the PFS open-use programs.

Spectrophotometric standards for PFS

The PFS is capable of simultaneously obtaining ~2400 spectra of science and calibration objects. With a specially designed data reduction pipeline, the raw 2D images will be processed into calibrated 1D spectra. In the PFS open-use operation, a fraction of all the fibers will be used to observe spectrophotometric standards simultaneously with science targets to evaluate time-varying atmospheric absorptions as well as the instrument throughputs in every exposure. The PFS spectrophotometric standards should satisfy (1) the stellar continuum flux should be accurately evaluated without large contamination of absorption lines, (2) the sky coverage of the stars should be sufficiently wide and dense to cover all lines-of-sights that will be observed in open-use programs.

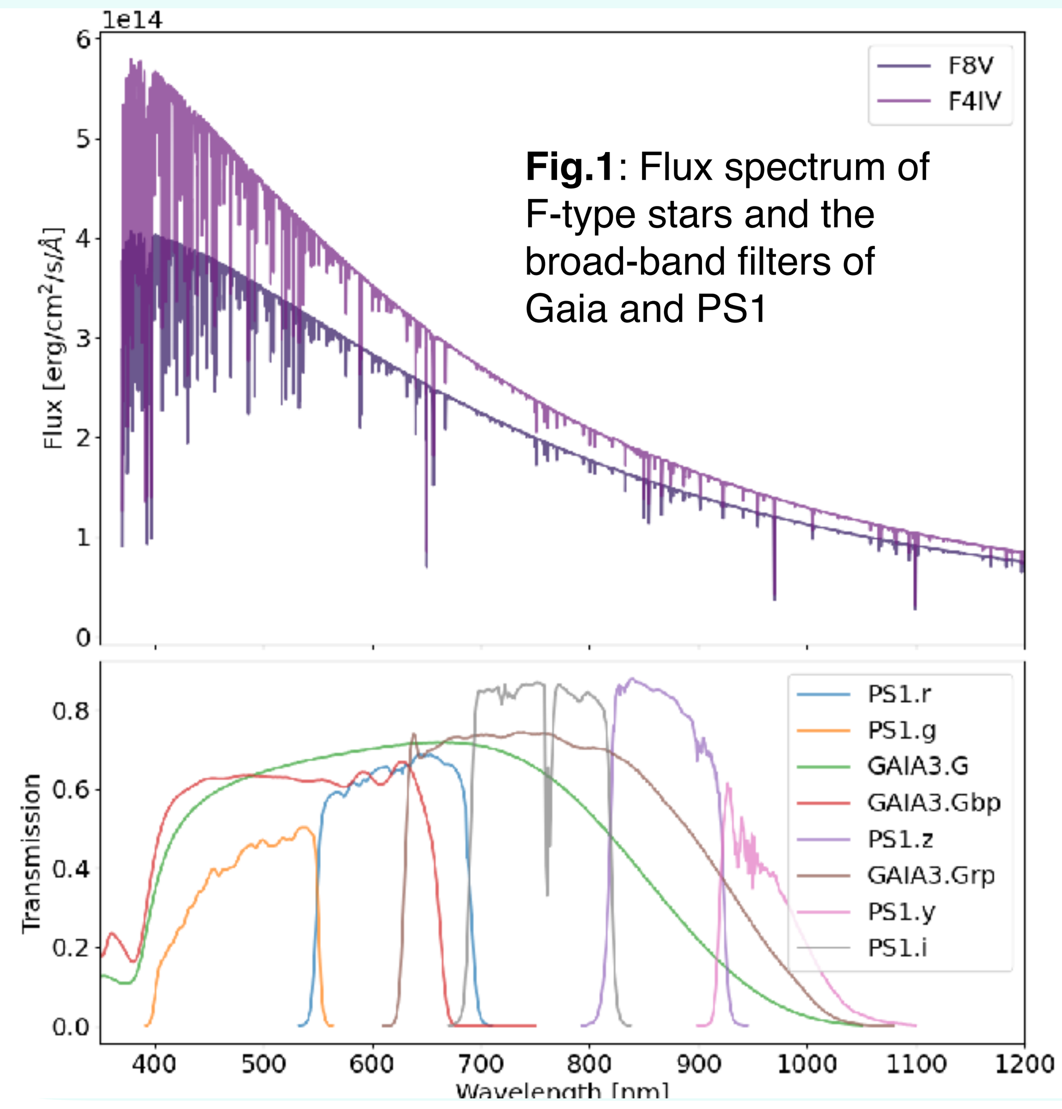


Fig.1: Flux spectrum of F-type stars and the broad-band filters of Gaia and PS1

F-type stars satisfy those requirements (Fig.2) and have frequently been used in wide-field surveys to date (e.g., SDSS). Here we present our strategy of using a public code, brutus[1] to select F-type stars in all sky based on Gaia and PanStarrs1 catalogs to make full use of PFS fibers.

The stellar parameter estimation algorithm

- The MIST stellar isochrone model[2] is used to pre-compute a grid of stellar structure and evolution as a function of following quantities (see **Fig.2**)
  - Metallicity ([Fe/H])
  - Age
  - Extinction (A(V))
  - Differential extinction (R(V))
  - Distance

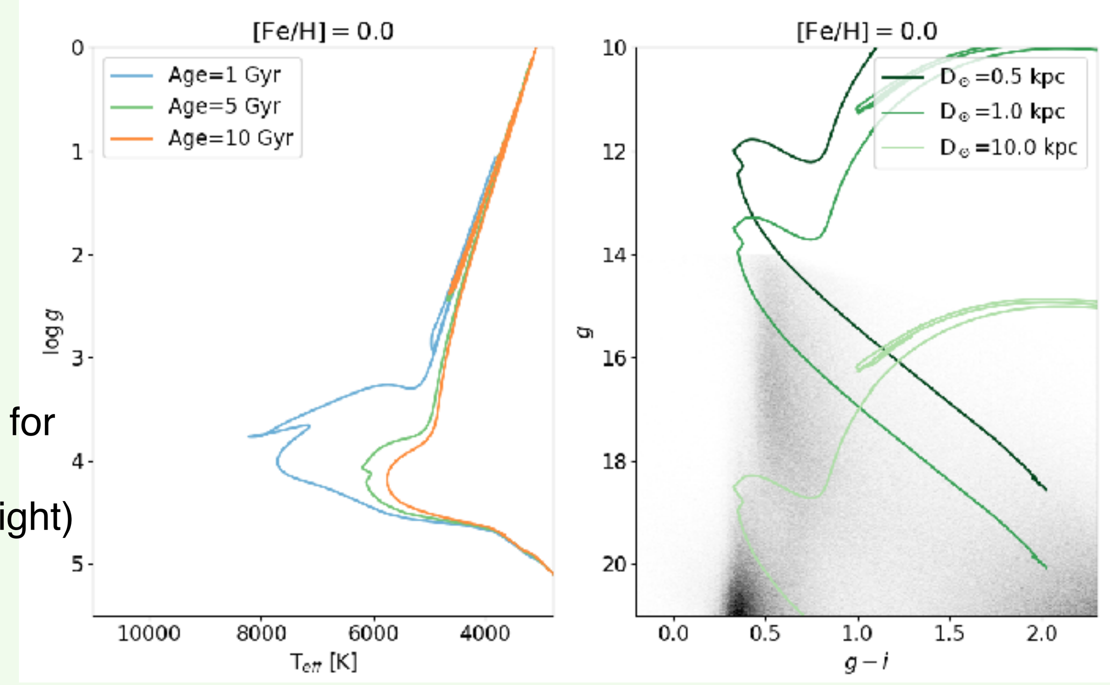
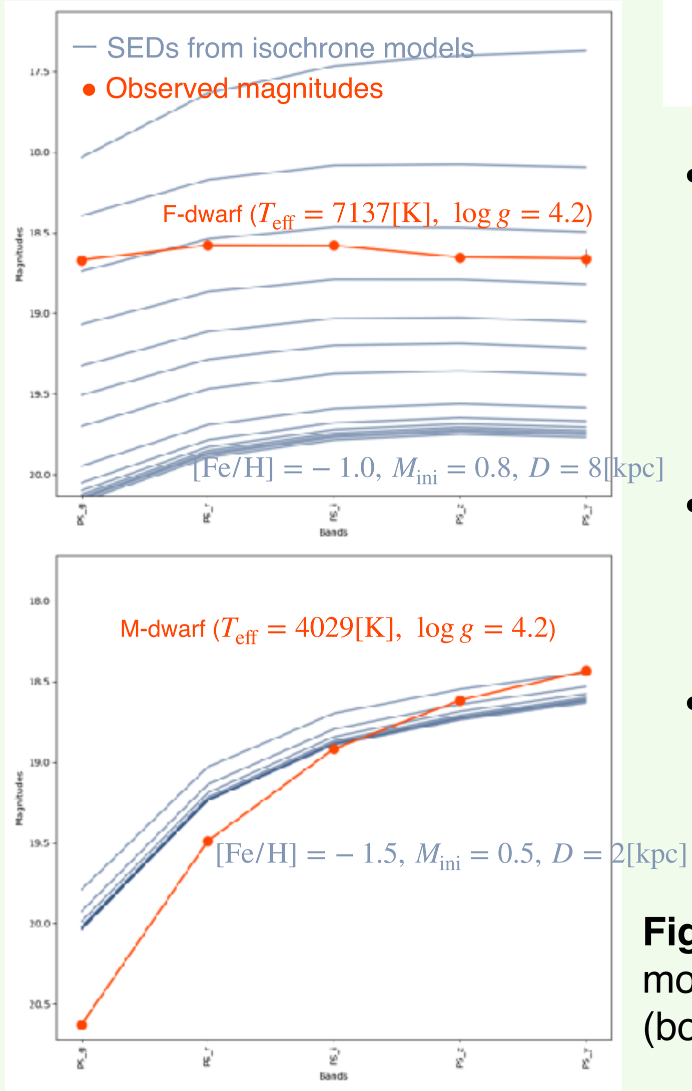


Fig.2: The MIST isochrone models for the Solar metallicity ([Fe/H]=0) and various ages (left) and distances (right)



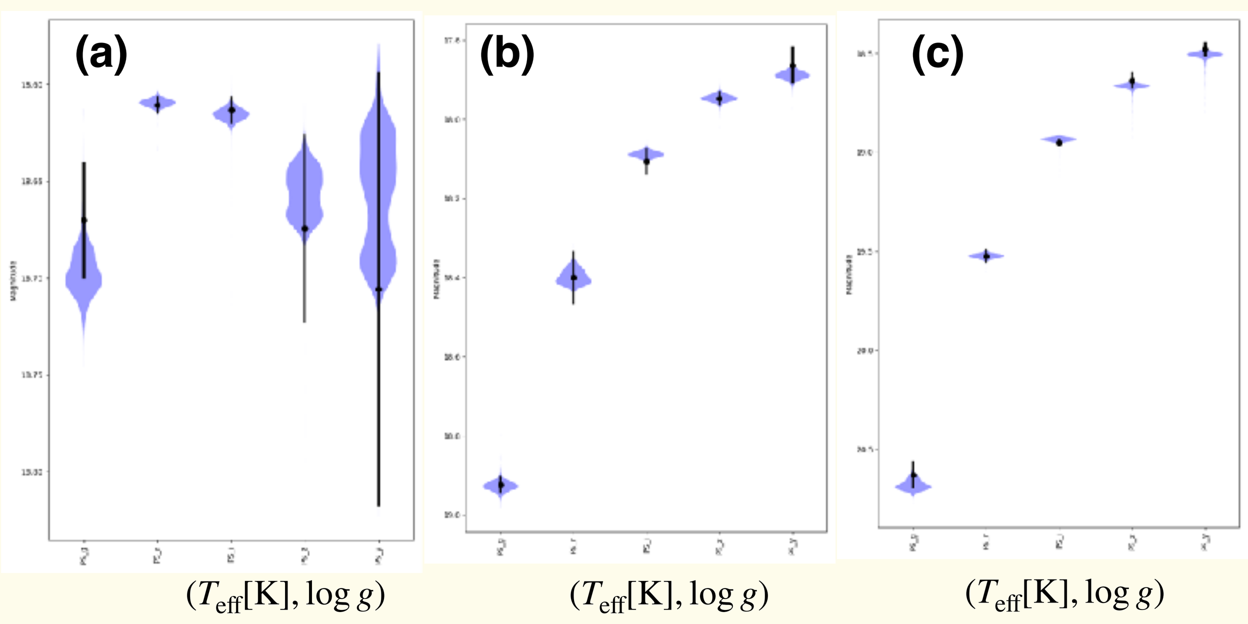
- For each set of stellar parameters (e.g., T_{eff}, logg, etc.) given by an isochrone, a spectral energy distribution (SED) are computed thanks to the neural network model implemented in the code.
- We first prepare tables of the stellar isochrone models and the SED models of a desired filter set (PanStarrs1 grizy).
- Given observed flux of the filters, posterior probabilities of stellar parameters are computed.

Fig.3: Observed magnitudes vs. SEDs from isochrone models. The models appropriate for F-dwarf (top) and M-dwarf (bottom) with various evolutionary phases are shown.

Validation of the stellar parameters

(1) Example fitting results

Fig. 4



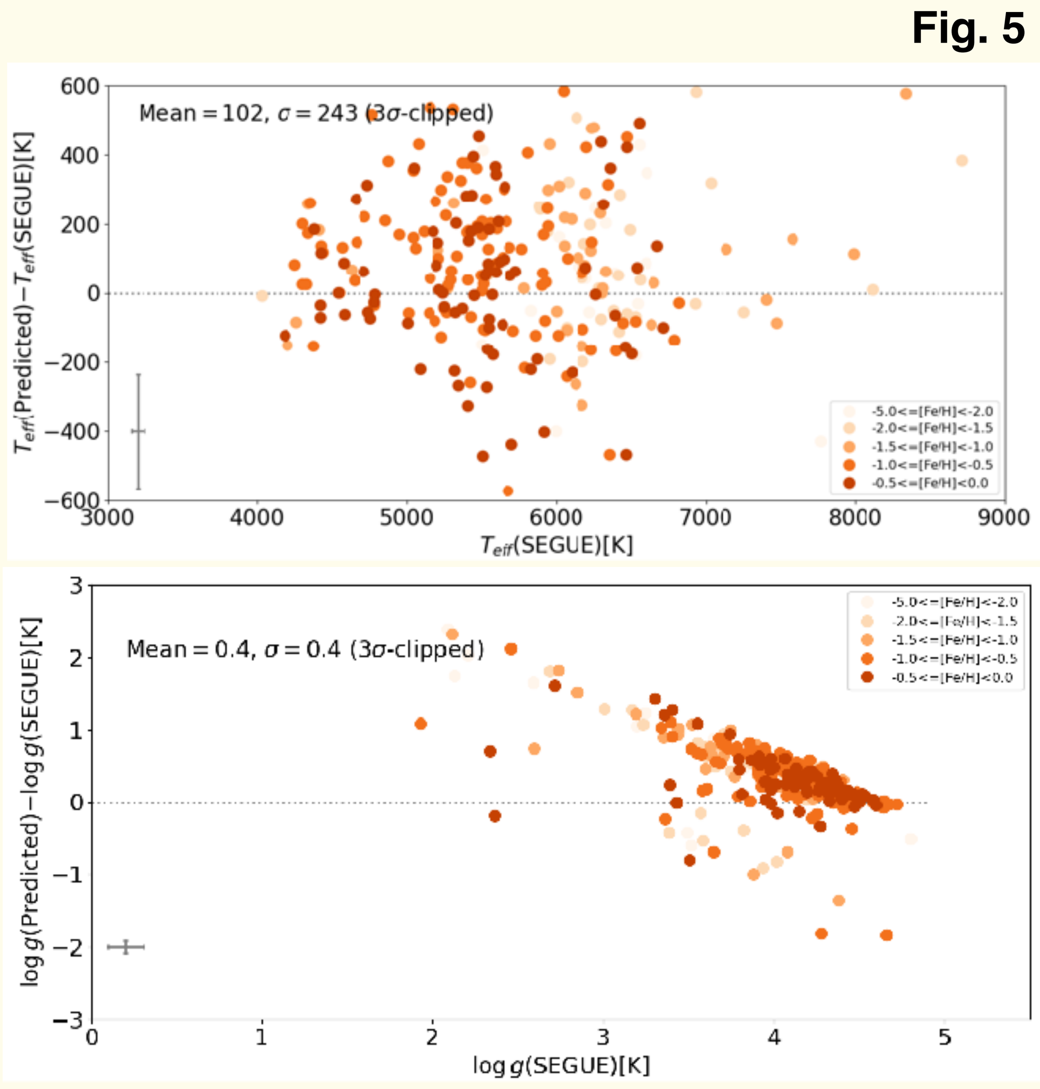
	$(T_{eff}[K], \log g)$	$(T_{eff}[K], \log g)$	$(T_{eff}[K], \log g)$
SEGUE	$(7137 \pm 82, 4.19 \pm 0.12)$	$(6907 \pm 75, 4.07 \pm 0.20)$	$(4029 \pm 22, 4.25 \pm 0.05)$
PS1	$(7264^{+366}_{-244}, 4.3^{+0.2}_{-1.4})$	$(6202^{+418}_{-343}, 4.5^{+0.1}_{-0.2})$	$(4021^{+140}_{-136}, 4.7^{+0.1}_{-0.1})$

We use a subset of SDSS/SEGUE catalog with known stellar parameters (e.g., T_{eff}, log*g*) from spectroscopy and PanStarrs1 photometry to validate the SED fitting method. **Fig. 4** shows the fitting results for **(a) F-type star at high Galactic latitude** (b=62), **(b) F-type star at low Galactic latitude** (b=14), **(c) M-type star at high Galactic latitude** (b=57). Galactic extinction makes the observed SEDs very different from the intrinsic SEDs. Since the brutus code takes into account the 3D Galactic extinction map and Galactic stellar distributions as priors, it correctly reproduces the spectroscopic (SEGUE) parameters.

(2) Overall accuracy

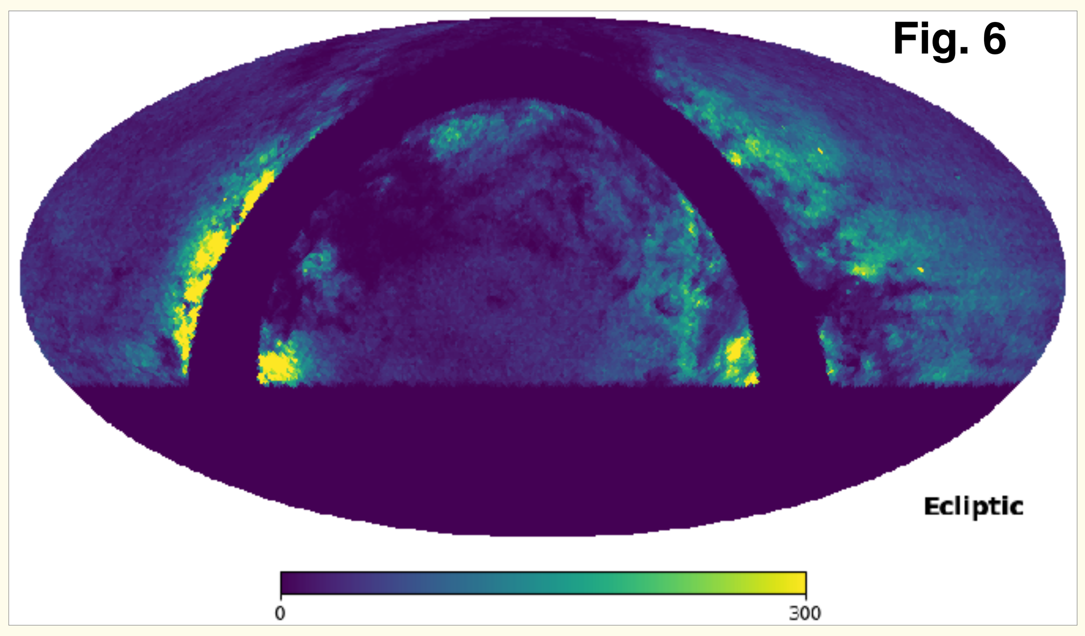
Fig. 5 shows the difference between predicted and spectroscopic stellar parameters (Top: Effective temperature, T_{eff}, Bottom: logg). A significant deviation can be seen at low log-g side where the algorithm over-predict the true logg. The scatters are similar for various [Fe/H] ranges.

Fig. 5



(3) Development plan

Fig. 6



The results of our validation based on the SDSS/SEGUE sample can be summarized as follows:

- The predicted parameters have a mean accuracy of ΔT_{eff}=102±243[K] and logg=0.4±0.4[dex]. An actual performance should be verified during upcoming PFS engineering observations.
- With the engineering data, updates of the fitting algorithm to optimize the success rate vs sky density are essential along with the data reduction pipeline development.
- Improvement in computation time is required. With the current scheme, it takes 2~3 seconds per star on average. To cover Dec>-30deg (|b|>10deg) as has been done with a simpler method (**Fig. 6** with ~0.2 billion stars), ~2 months with a 100-folds parallelized calculation is required.

Reference:

[1] https://github.com/joshspeagle/brutus, [2] https://waps.cfa.harvard.edu/MIST/