Stellar parameter estimation with Gaia (mostly BP/RP)

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Classification and AP estimation with Gaia

- probabilistic source classification
  - classes: e.g. star, binary, quasar, galaxy
  - uses: BP/RP; position/magnitude; parallax/proper motion
- source astrophysical parameters (APs)
  - for single and binary stars, quasars, and galaxies
- novelty detection (outlier analysis)
- performed by CU8 in the Gaia DPAC
Generalized Stellar Parametrizer (GSP-Phot)

- **Purpose:** Estimate intrinsic stellar parameters ($T_{\text{eff}}$, $\log g$, [Fe/H], [$\alpha$/Fe]) and line-of-sight extinction parameters ($A_0$, $R_0$) for individual stars
- Primarily using the BP/RP spectrophotometry (normalized)
- Three algorithms
  - Support Vector Machine (inverse mapping)
  - ILIUM (iterative local method using forward modelling)
  - Aeneas (Bayesian method), can also use the parallax
- Fit (“trained”) using synthetic/semi-empirical libraries
  - later will (also) use Gaia/GBOG observations
Gaia BP/RP spectrophotometry of synthetic stellar spectra

$T_{\text{eff}}$ and $A_0$ variation

$A_0 = 0, 0.1, 0.5, 1, 2, 3, 4, 5, 8, 10$

$(R_0=3.1)$

$T_{\text{eff}}$ and $A_0$ are “strong” APs
Gaia BP/RP spectrophotometry of synthetic stellar spectra

$T_{\text{eff}}$ and $[\text{Fe/H}]$ variation

$[\text{Fe/H}] = -3, -2, -1, 0, +0.5$

$(A_0=0)$

$[\text{Fe/H}]$ is a “weak” AP
AP accuracy (preliminary results)

• Accuracy (mean abs.) is a function of G and APs themselves
  ‣ $T_{\text{eff}}$ 3000:1000K, $A_0$ 0:10mag, [Fe/H] -2.5:+0.5dex, logg 2.5:5.5dex

• At G=15 for $A_0 < 1$mag
  ‣ $T_{\text{eff}}$ 60-110K, $A_0$ 0.05mag, [Fe/H] 0.15dex (0.5dex A stars), logg 0.25dex

• At G=15 averaged over all $A_0$
  ‣ $T_{\text{eff}}$ 110-180K, $A_0$ 0.07mag, [Fe/H] 0.4dex (0.7dex A stars), logg 0.3dex

• At G=19 for $A_0 < 1$mag
  ‣ $T_{\text{eff}}$ 250-400K, $A_0$ 0.1-0.15mag, [Fe/H] 0.35 (G/K stars), logg 0.4dex
AP accuracy G=15 (preliminary results)

red = mean absolute residual  
blue = absolute residual
AP accuracy vs. G (preliminary results)

$T_{\text{eff}}$, $\varepsilon_{T_{\text{eff}}}$, $A_0$, $\varepsilon_{A_0}$, $[\text{Fe/H}]$, $\varepsilon_{[\text{Fe/H}]}$, $\log g$, $\varepsilon_{\log g}$

50% and 90% bounds shown
Information beyond the spectrum

1) parallax, apparent magnitude (q)

2) HRD

- Combine information in a Bayesian model
  - \( p \) constrains \( T_{\text{eff}} \) and \( A_G \)
  - \( q \) constrains \( M_G + A_G \)
    \[ q \equiv G + 5 \log \omega = M_G + A_G - 5 \]
  - HRD prior constrains \( M_G \) and \( T_{\text{eff}} \)
Aeneas demonstration

- Infer \( T_{\text{eff}} \) and \( A_0 \) using BVJHK photometry and Hipparcos parallaxes for \( \sim 85,000 \) 2MASS/Hipparcos stars

- True APs for forward model fitting (training data):
  - \( T_{\text{eff}} \) from Valenti & Fischer (2005) from high-res. spectroscopy
  - artificially reddened to give \( A_0 \) variance
  - 5280 stars with \( T_{\text{eff}} = 4700-6600 \), \( A_0 = 0-2.5 \text{mag} \)

- See Bailer-Jones (2011), MNRAS 411, 425
AP estimation from BVJHK colours (only)

- “true” APs shown as red cross
- contours enclose 90%, 99% and 99.9% of posterior probability $P(\phi|p)$
- significant degeneracy between $T_{\text{eff}}$ and $A_0$
AP estimation from colours + q, HRD

- “true” APs shown as red cross
- contours enclose 90%, 99% and 99.9% of posterior probability $P(\phi|p, q)$
- significant degeneracy between $T_{\text{eff}}$ and $A_0$
Stellar APs in (final) Gaia catalogue

• class probabilities, $T_{\text{eff}}, A_0, \log g, [\text{Fe/H}], (R_0, [\alpha/\text{Fe}])$
  ‣ derived $M_G, L, M, R, \text{age}$ (in principle)
  ‣ uncertainty estimates, posterior PDF in some cases
  ‣ multiple sets of estimates (i.e. from each method)
  ‣ use of parallax, $G$, and physical reality (i.e. HRD prior) in some cases
• additional AP estimates for specific stars
  ‣ e.g. emission line stars, very cool stars; dedicated algorithms
• estimates based on the RVS spectra (for bright stars)

http://www.mpia.de/Gaia → Results