# Stellar parameter estimation with Gaia (mostly BP/RP)

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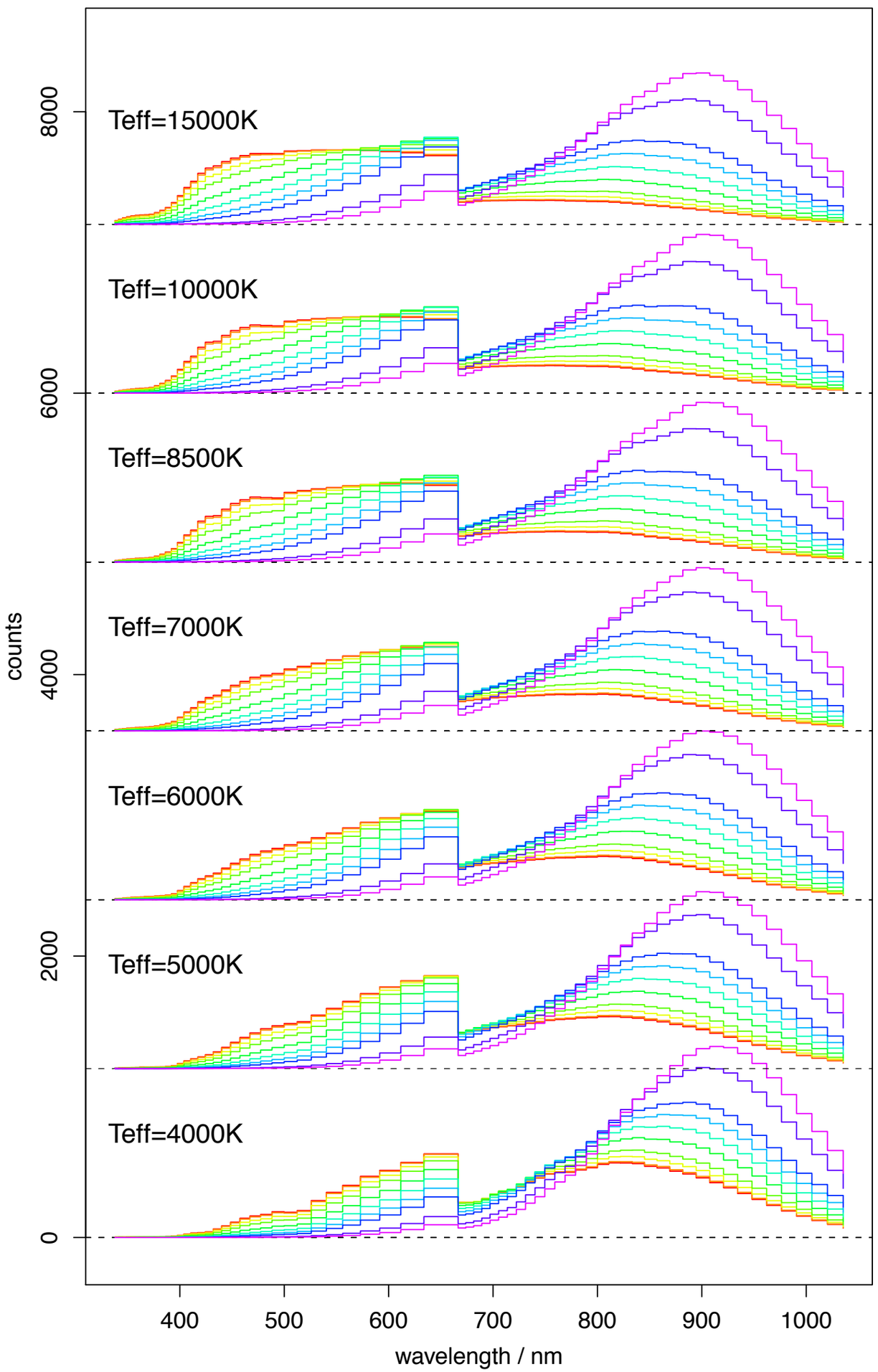
# Classification and AP estimation with Gaia

- 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 ($T_{eff}$, logg, [Fe/H], [α/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



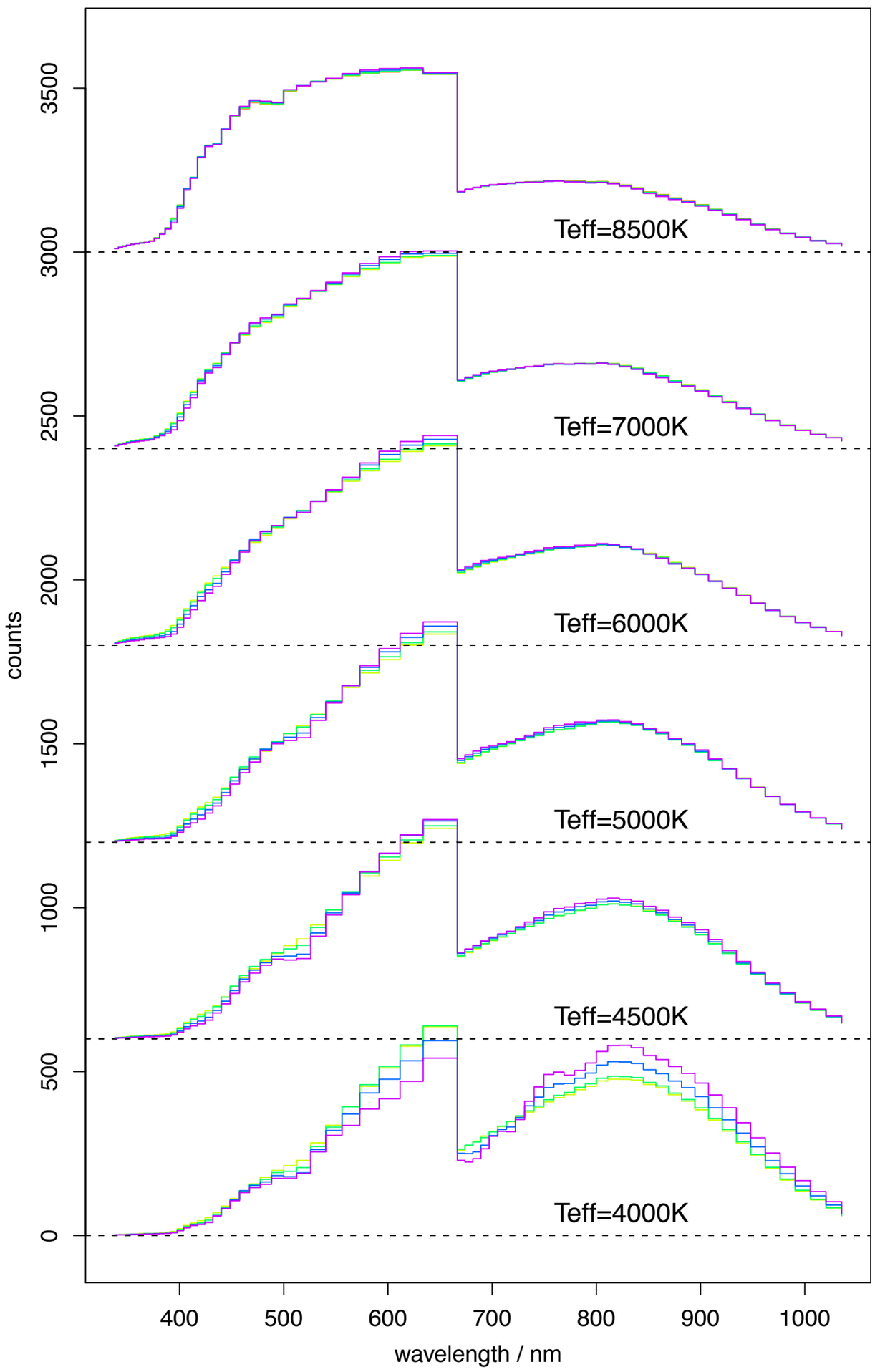

# Gaia BP/RP spectrophotmetry of synthetic stellar spectra

## *$T_{eff}$ and $A_0$ variation*

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

($R_0$=3.1)

$T_{eff}$ and $A_0$ are "strong" APs




# Gaia BP/RP spectrophotmetry of synthetic stellar spectra

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

[Fe/H] = -3, -2, -1, 0, +0.5

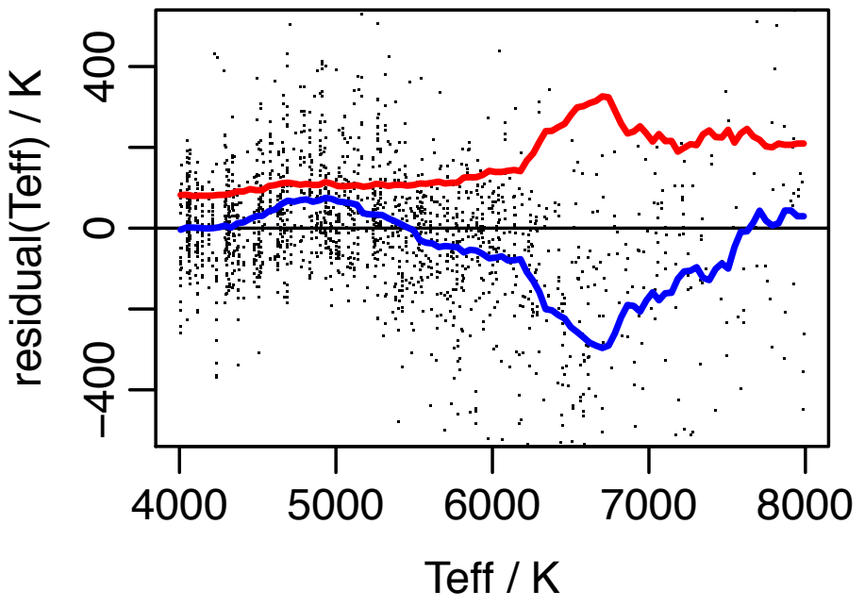
($A_0$=0)

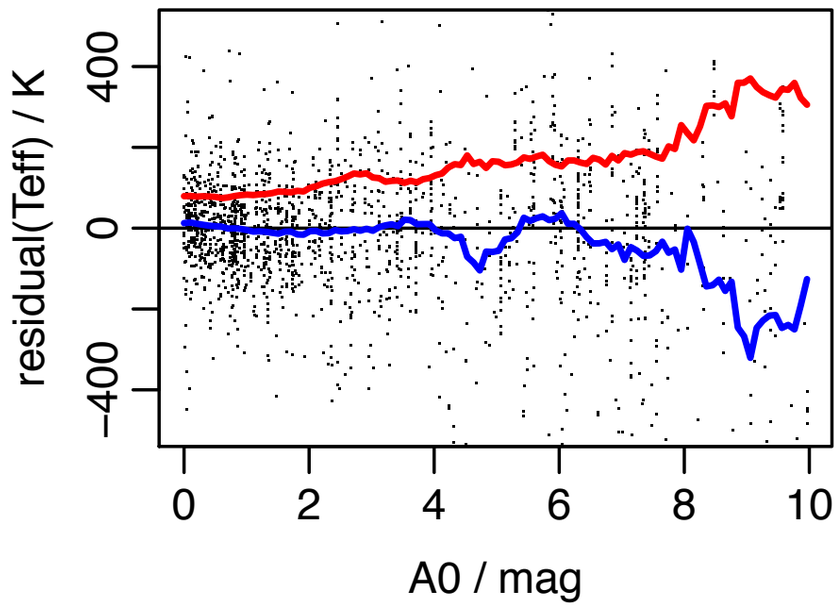
[Fe/H] is a "weak" AP

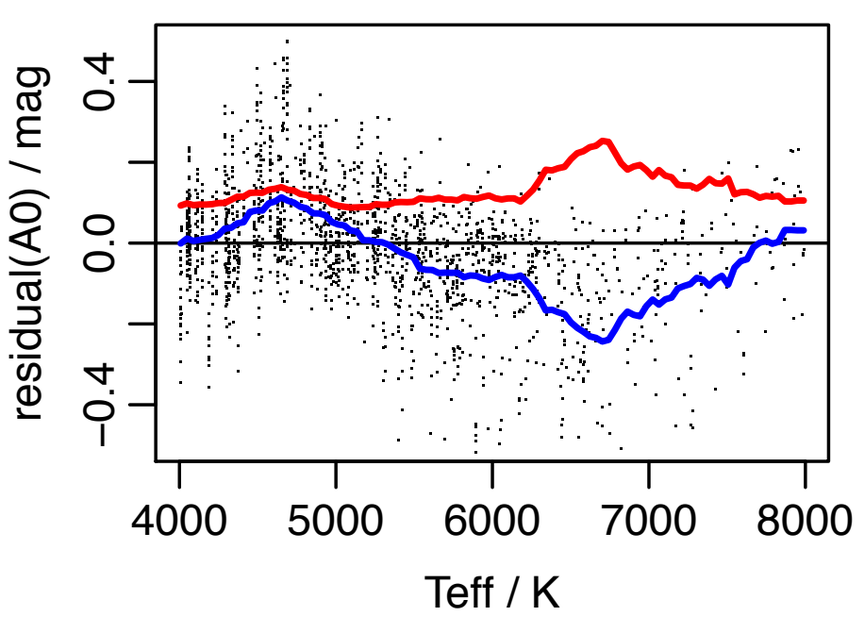
# AP accuracy (preliminary results)

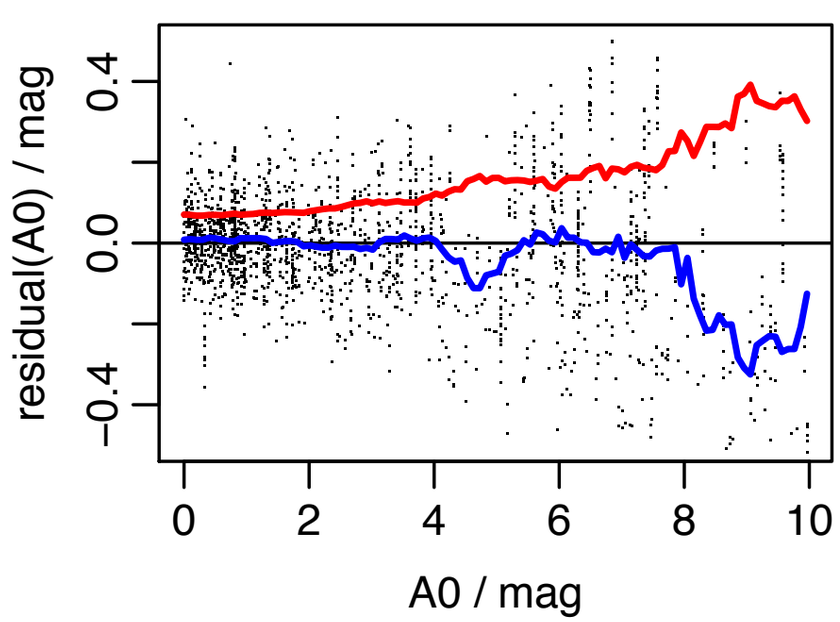
- Accuracy (mean abs.) is a function of G and APs themselves
  - $T_{eff}$ 3000:1000K, $A_0$ 0:10mag, [Fe/H] -2.5:+0.5dex, logg 2.5:5.5dex
- At G=15 for $A_0$ < 1mag
  - Teff 60-110K, $A_0$ 0.05mag, [Fe/H] 0.15dex (0.5dex A stars), logg 0.25dex
- At G=15 averaged over all $A_0$
  - Teff 110-180K, $A_0$ 0.07mag, [Fe/H] 0.4dex (0.7dex A stars), logg 0.3dex
- At G=19 for $A_0$ < 1mag
  - Teff 250-400K, $A_0$ 0.1-0.15mag, [Fe/H] 0.35 (G/K stars), logg 0.4dex

# AP accuracy G=15 (preliminary results)



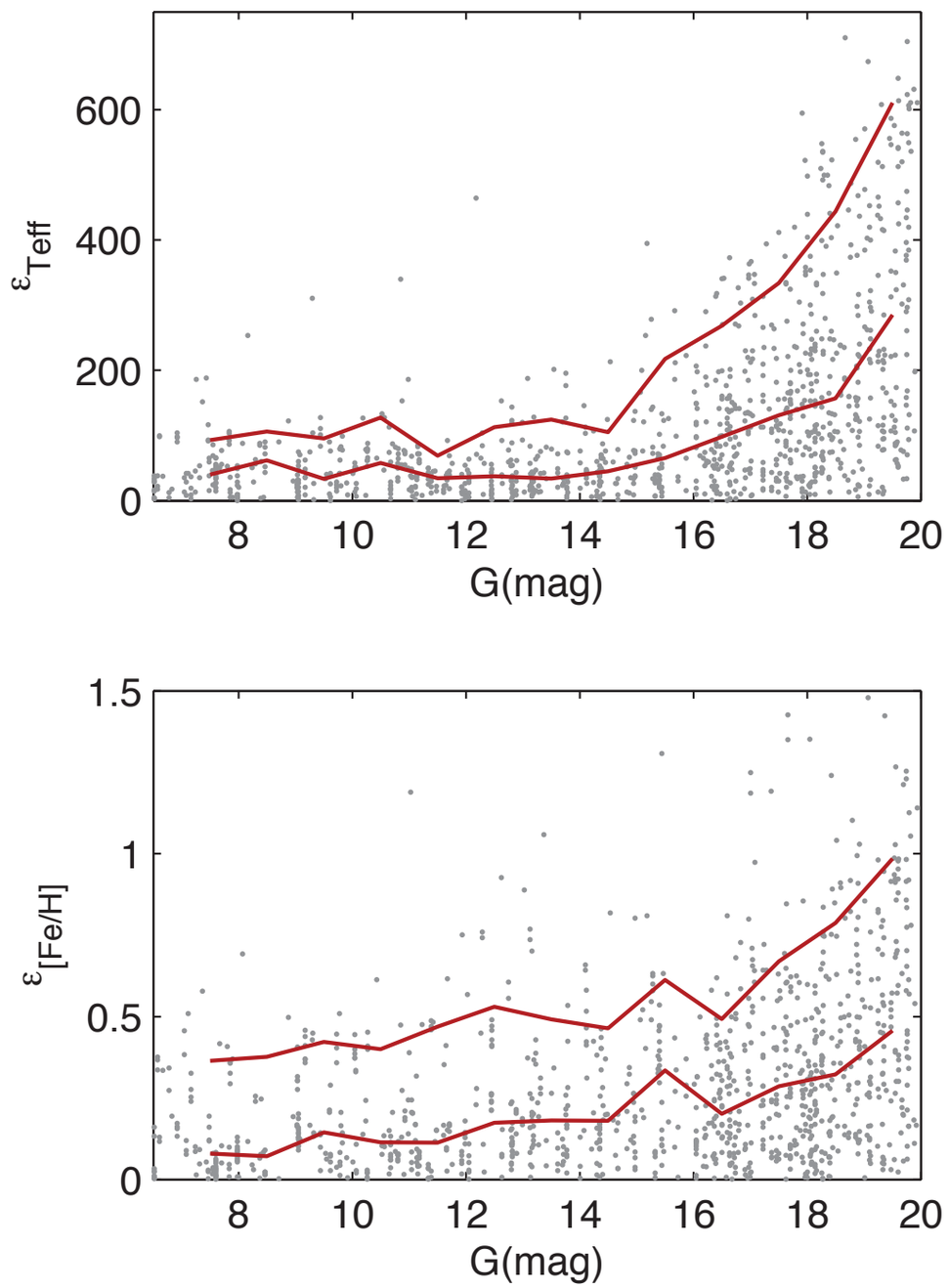



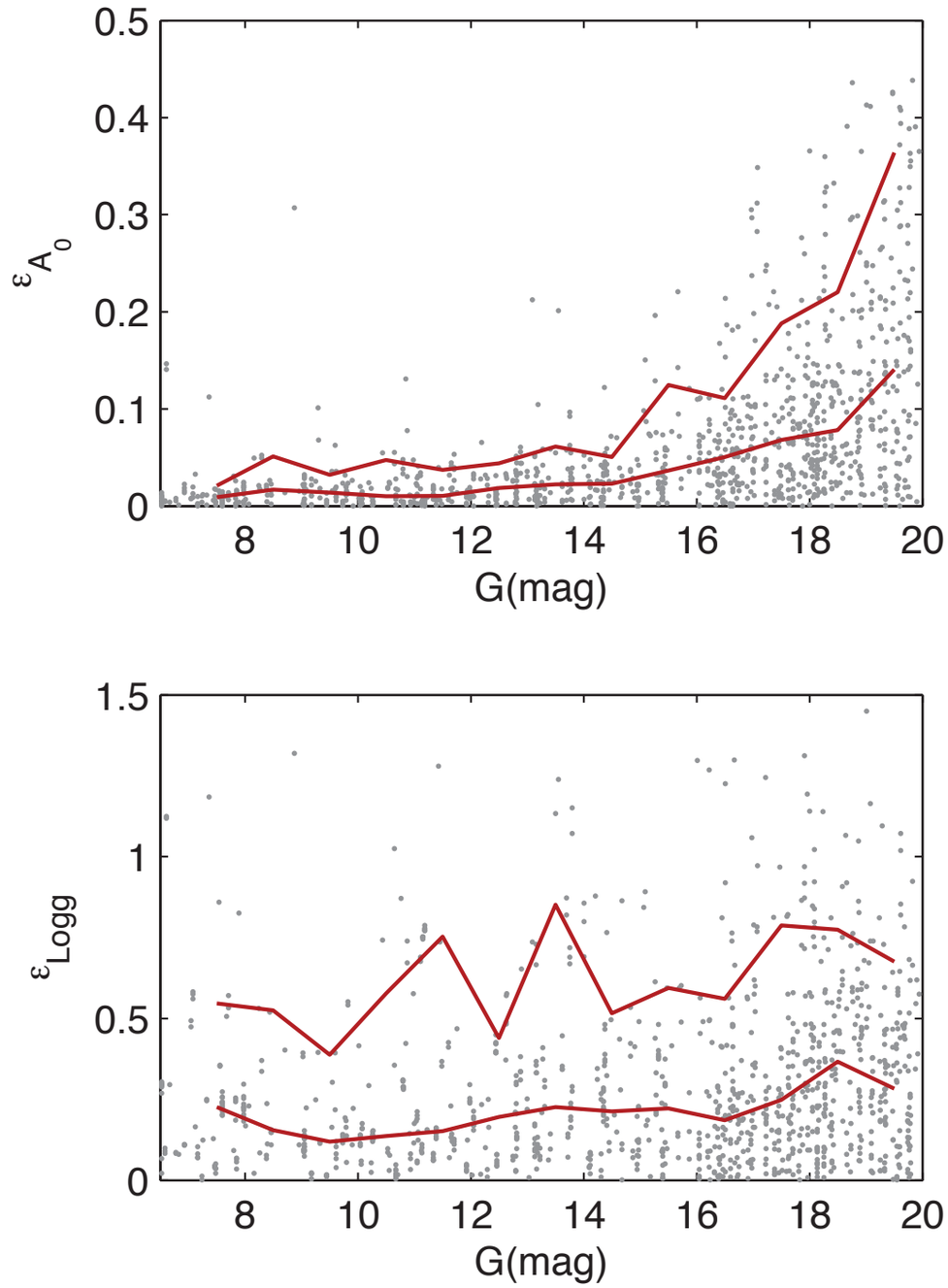

red = mean absolute residual

blue = absolute residual

# AP accuracy vs. G (preliminary results)

$T_{eff}$




$A_0$

[Fe/H]







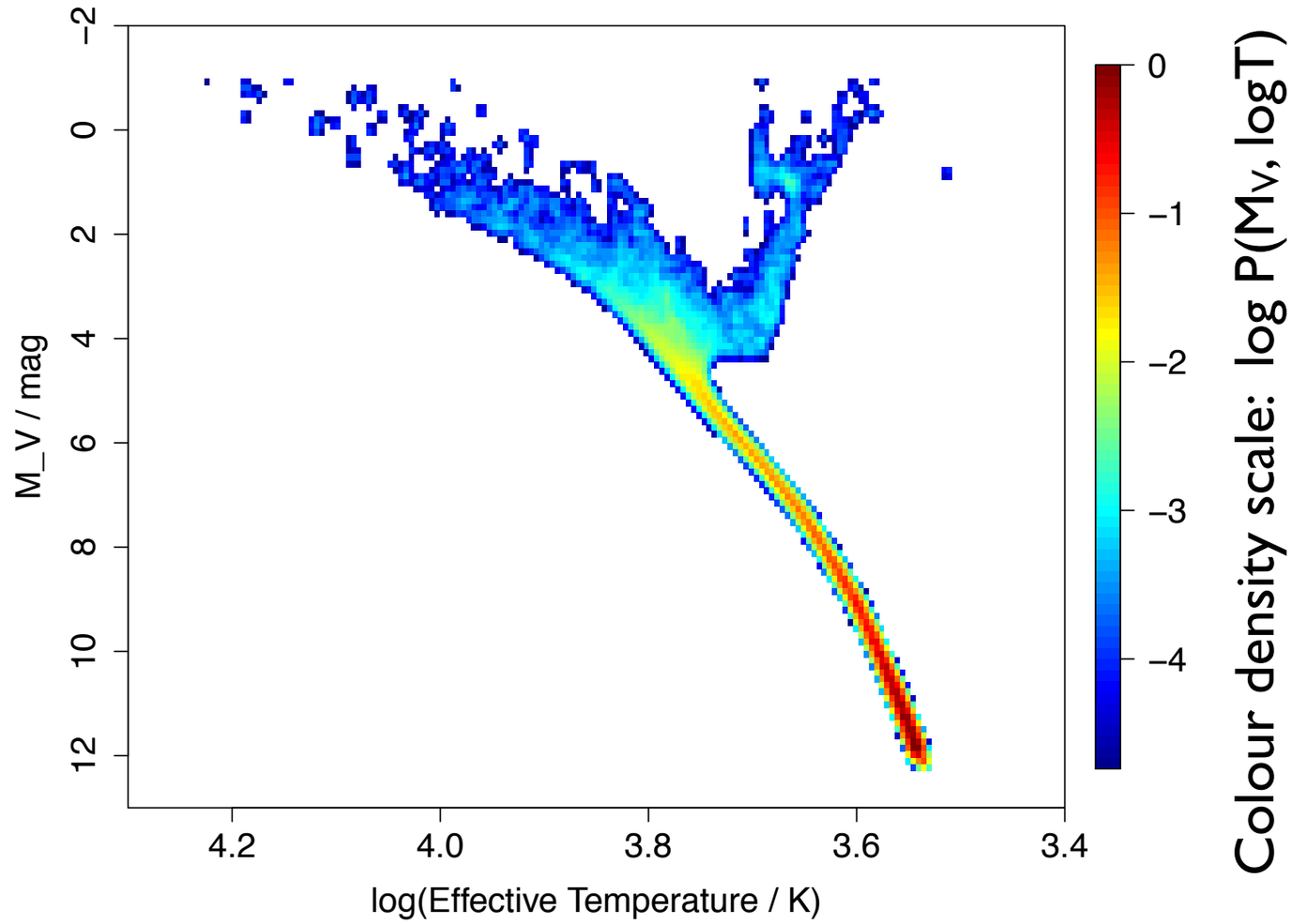
logg

50% and 90% bounds shown

# Information beyond the spectrum

1) parallax, apparent magnitude (q)

2) HRD

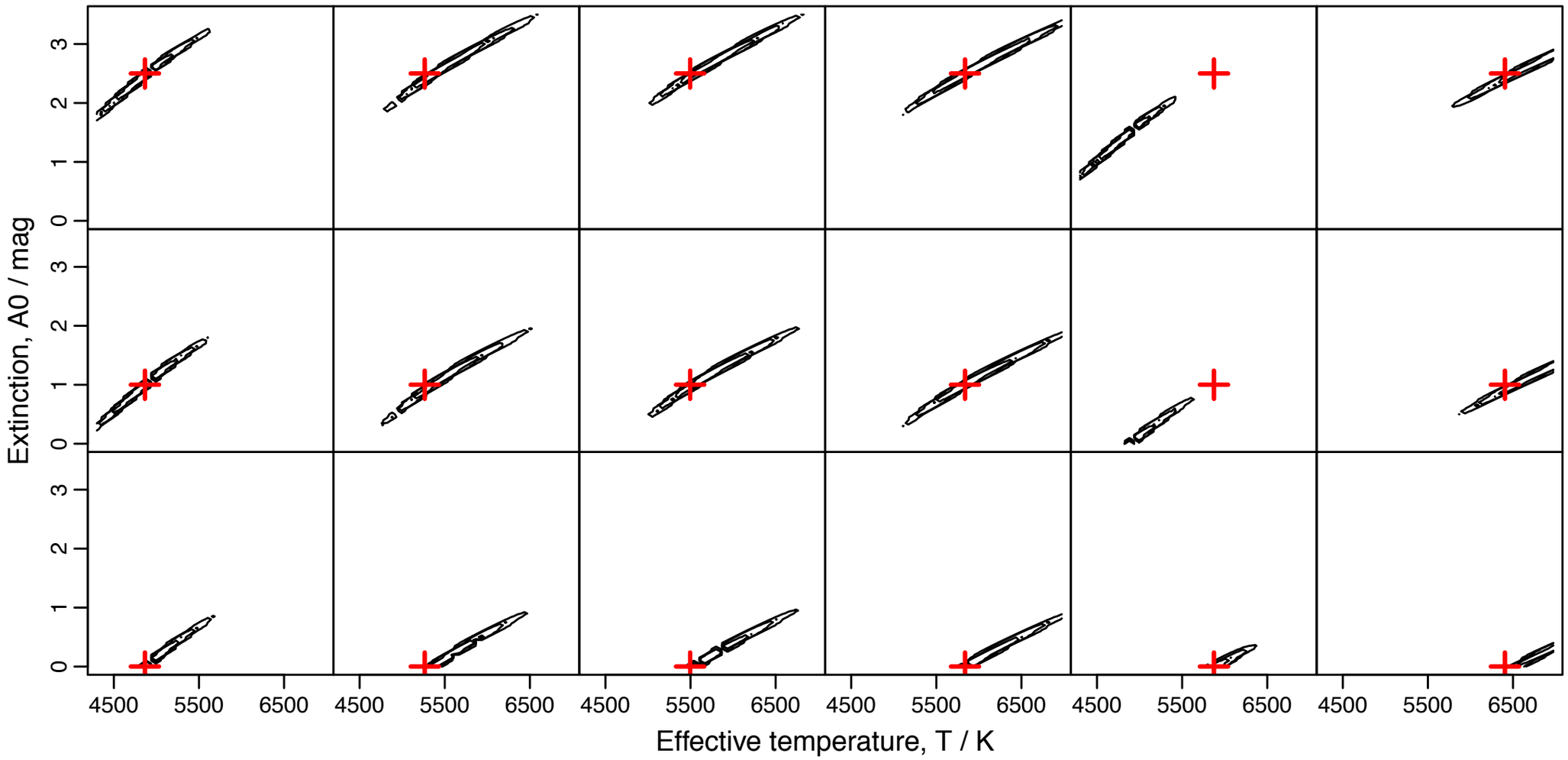



- Combine information in a Bayesian model
  - **p** constrains $T_{eff}$ and $A_G$
  - q constrains $M_G + A_G$ $\quad q \equiv G + 5\log\varpi = M_G + A_G - 5$
  - HRD prior constrains $M_G$ and $T_{eff}$

# Aeneas demonstration

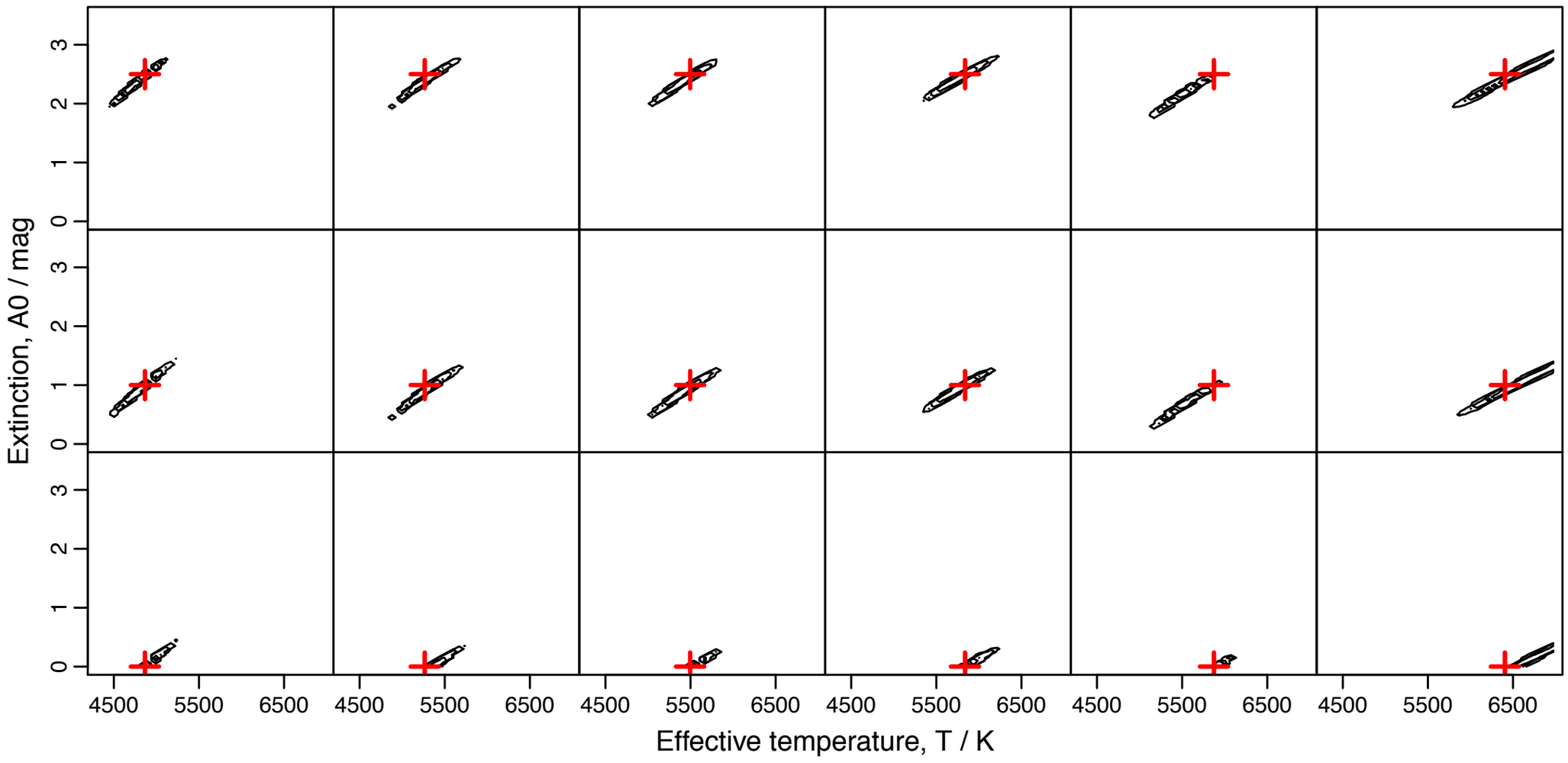
- Infer $T_{eff}$ and $A_0$ using BVJHK photometry and Hipparcos parallaxes for ~85 000 2MASS/Hipparcos stars
- True APs for forward model fitting (training data):
  - $T_{eff}$ from Valenti & Fischer (2005) from high-res. spectroscopy
  - artificially reddened to give $A_0$ variance
  - 5280 stars with $T_{eff}$ = 4700-6600, $A_0$ = 0-2.5mag
- 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 $P(\phi|\mathbf{p})$
- significant degeneracy between $T_{eff}$ 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 $P(\phi|\mathbf{p}, q)$
- significant degeneracy between $T_{eff}$ and $A_0$

# Stellar APs in (final) Gaia catalogue

- class probabilities, $T_{eff}$, $A_0$, logg, [Fe/H], ($R_0$, [α/Fe])
  - derived $M_G$, L, *M*, R, 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