A REVISED EFFECTIVE TEMPERATURE SCALE FOR THE KIC

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Motivation

- Effective temperature scale: fundamental ingredient for analyzing stellar populations
- Important for atmospheres
  - Photometric abundance, extinction, binarity, gravity indicators very useful for bulk populations
- Important for constraining interiors models

The Effective Temperature is a defined, average quantity

- Defined by $L=4\pi R^2\sigma T_{eff}^4$
- Fundamental T_{eff} are **measured** in systems of known L and R
- Spectroscopy is needed to infer metallicities for calibrating metallicity dependence

Two Approaches to Teff

PHOTOMETRY

- Theoretical: convolve filter response functions with theoretical SEDs (KIC)
  - Pro: permits estimation of abundance, log g
  - Con: models can be wrong
- Empirical: correlate colors with fundamental Teff measurements (MP)
  - Pro: sidesteps model issues
  - Con: sparse sampling of parameter space

SPECTROSCOPY

- Use wings of strong lines or Boltzmann/Saha solutions
  - Pro: tied to useful abundance, log g information; insensitive to extinction
  - Con: models can be wrong

Why photometry?

- Known offsets between absolute spectroscopic and fundamental Teff scales (Pinsonneault et al. 2004; Casagrande et al. 2010)
- Color-Teff relationships are calibrated relative to the fundamental scale
- **Cautions: absolute photometry critical; extinction, binaries, blends are all issues**

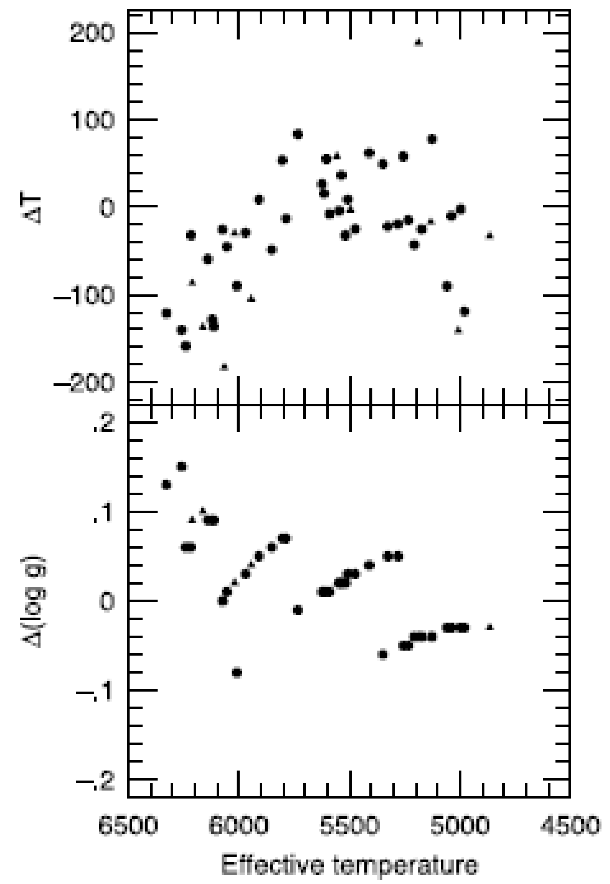


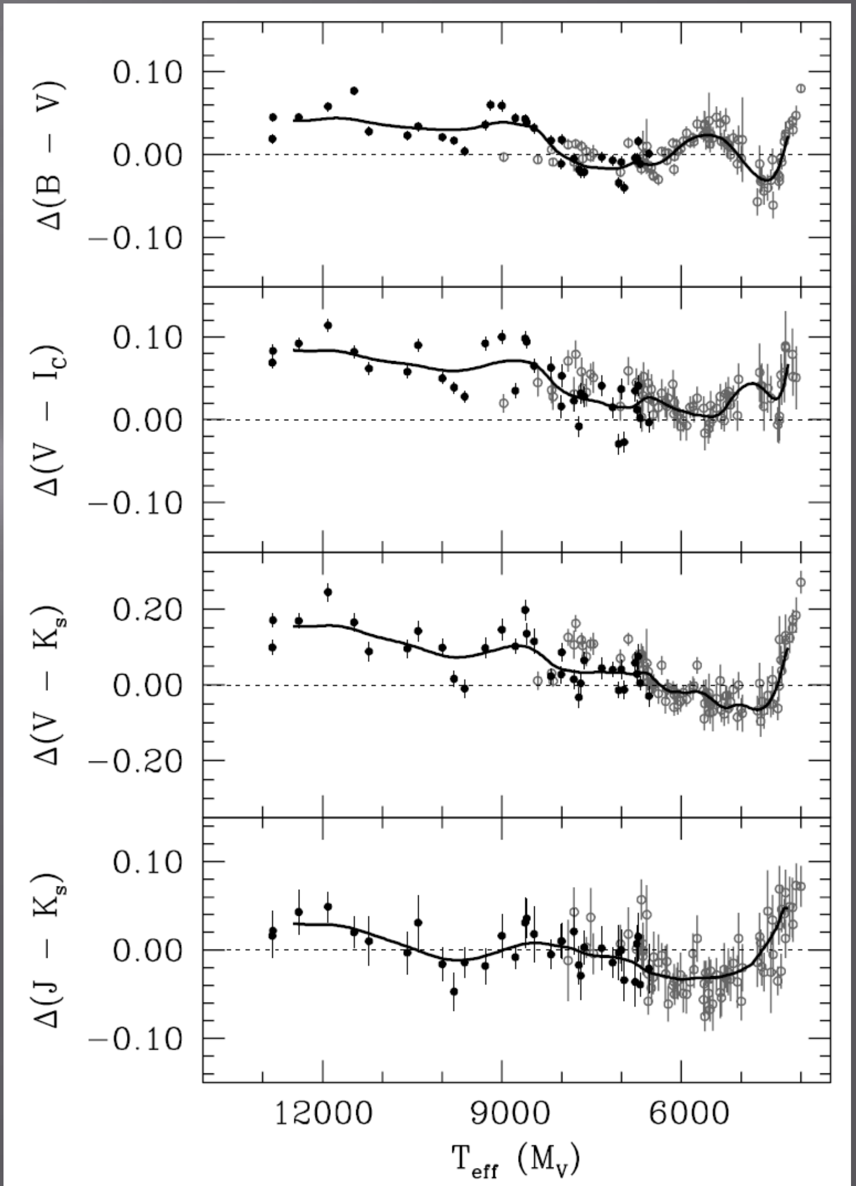
Fig. 4.—Differences in effective temperature (*top*) and gravity (*bottom*), in the sense of (isochrone − spectra), between spectroscopically determined parameters (PSC) and the Hyades isochrone at fixed M_V. While the agreement is good throughout most of the temperature range, the spectroscopic solution yields hotter temperatures and lower gravities than the isochrone. Filled circles are for the stars used to calibrate the empirical color corrections, while the triangles show other stars in the Paulson et al. sample not included in our Table 1.

Pinsonneault et al. 2004: Hyades photometry vs. spectroscopy

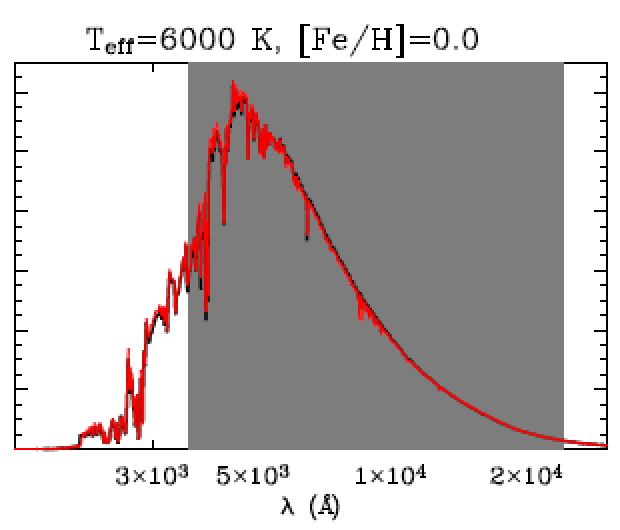
Cluster Calibration Approach

Correlate colors against fundamental Teffs

- Clusters are used to define the metallicity dependence (Pinsonneault et al. 2004; An et al. 2007, 2008)
- Rely on theory to predict *relative* metallicity, log g trends (Lejeune 1998)

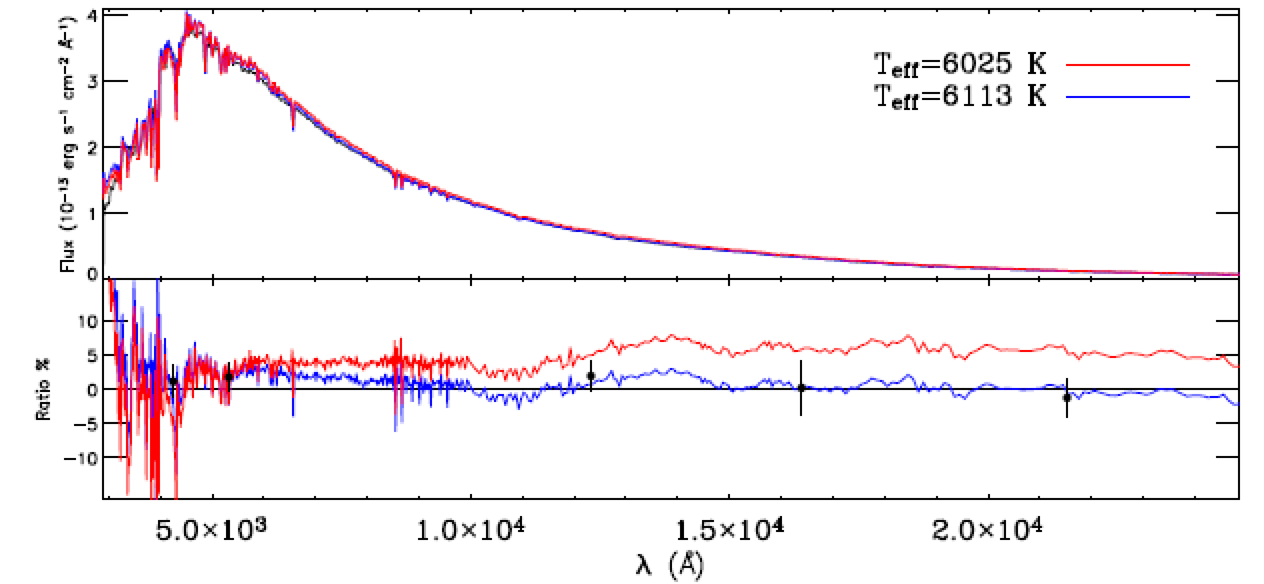


- Extension of fundamental measurements based on SED
  - For the right stars (4000 K–7000 K) JHK fluxes are in the RJ tail
- Becomes less reliable in rapidly rotating upper MS stars; JHK not on the Rayleigh-Jeans tail for cool stars



IRFM

Blackwell 1982;
Alonso 1995;
Casagrande et al. 2010

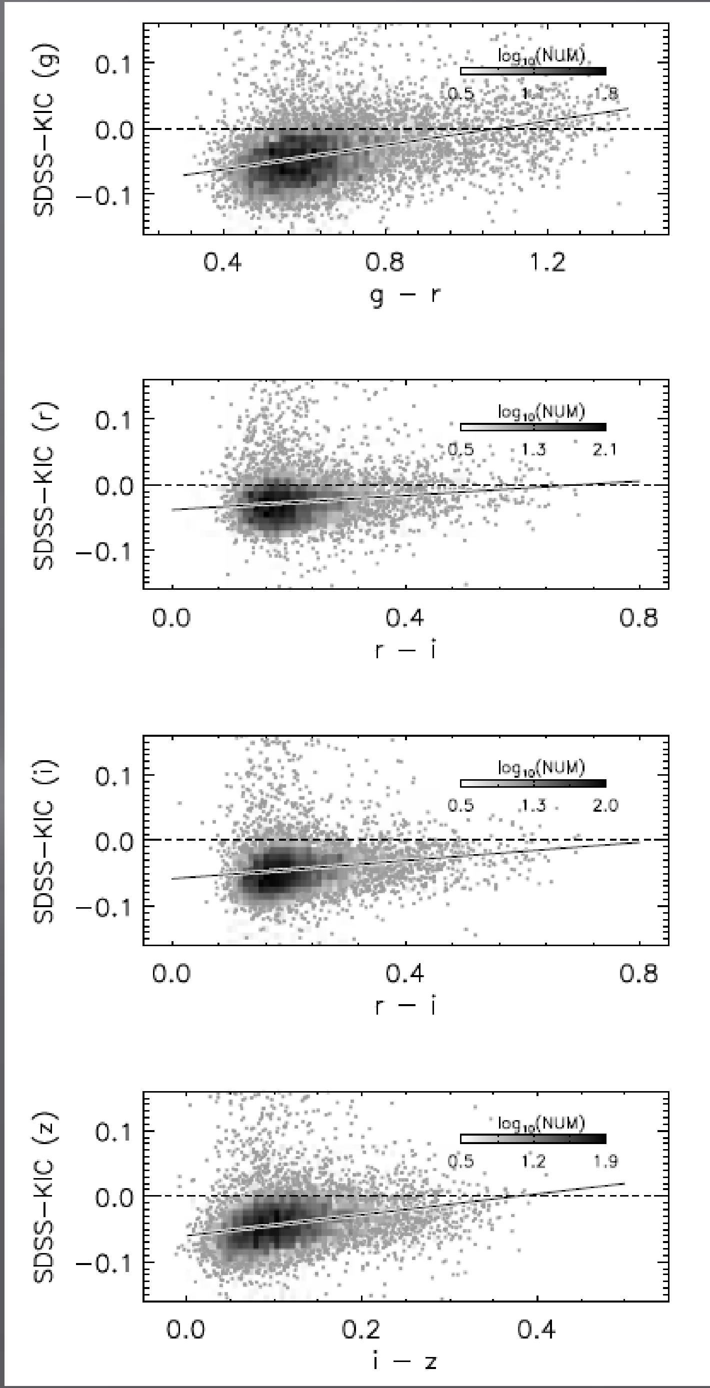


Our approach

- Compare two independent fundamental photometric systems (SDSS KIC , IRFM 2MASS) against the KIC and spectroscopy
- Test KIC photometry against SDSS DR8
- Choose metallicity insensitive filters, treat [Fe/H] as an unmeasured error source
- Neglect log g for hot stars, use theory for corrections for cool giants

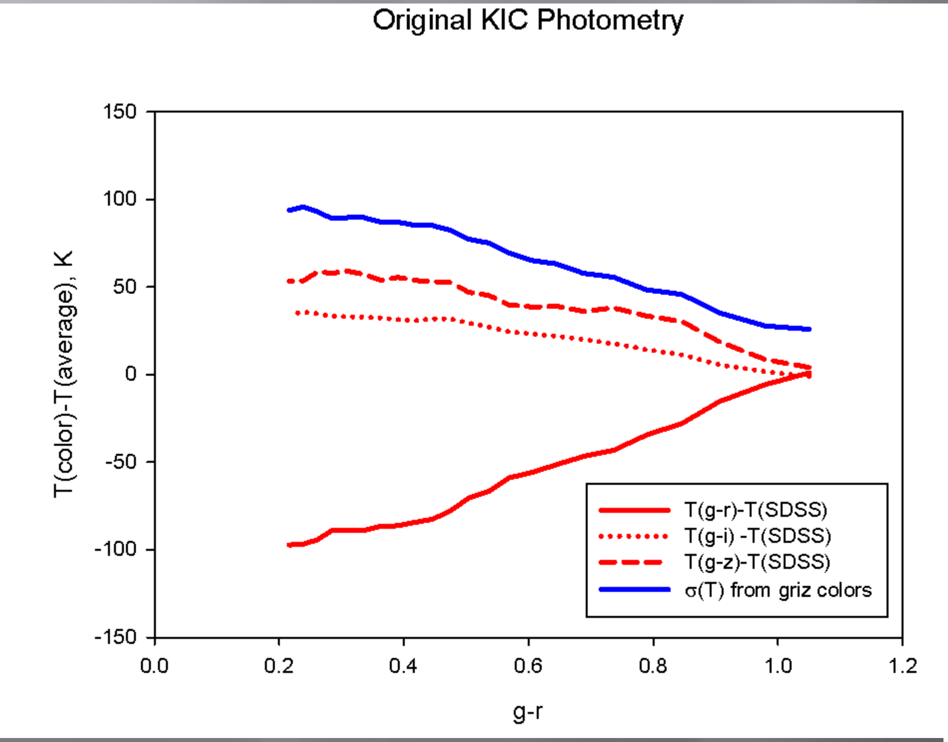
Zero-point differences between SDSS and the KIC

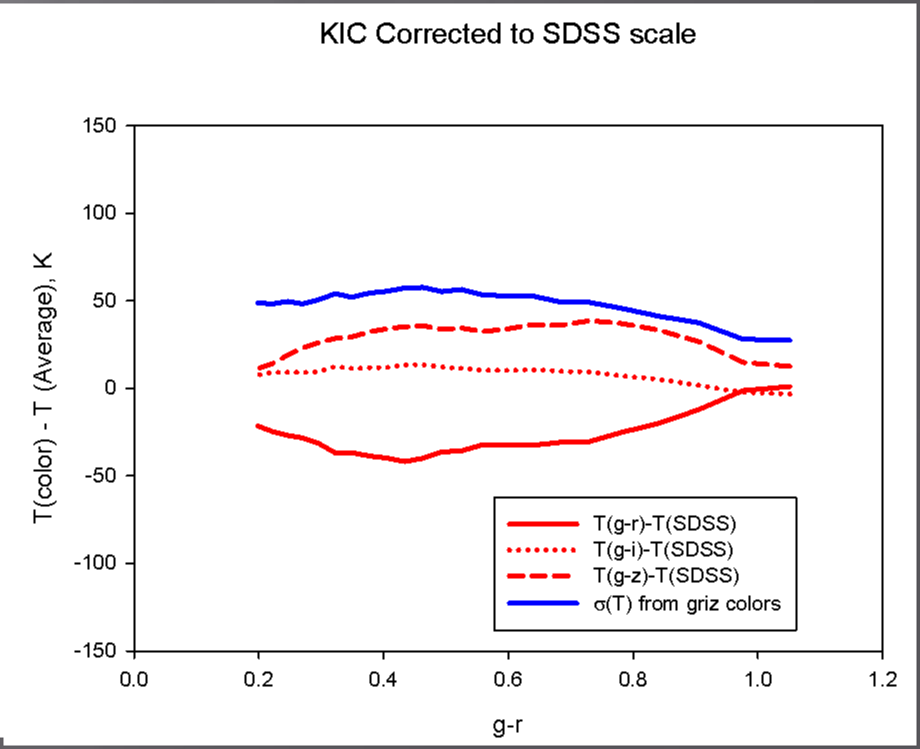
- The Sloan DR8 covers about 10% of the Kepler field
- Clear evidence of blending in ~4% of the overlap sample
- Explains some tragic Teff estimates



Recalibration Improves The Internal Consistency of Teffs from Different Colors

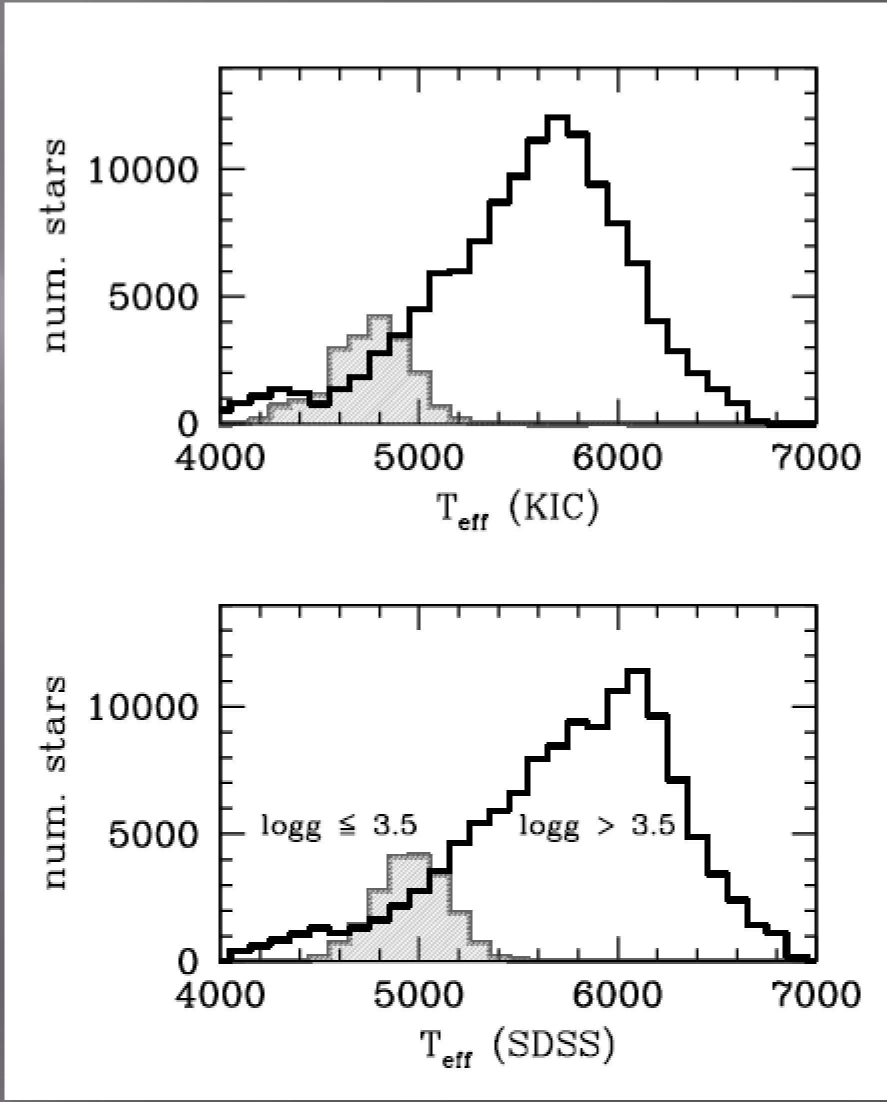
Average σ(T) drops from 75 K to 50 K
30 K estimated from photometric errors alone





Sample and Assumptions

- Include dwarfs in the long cadence sample with good 2MASS photometry
- Adopt mean [Fe/H] = -0.2
- Adopt KIC extinction map

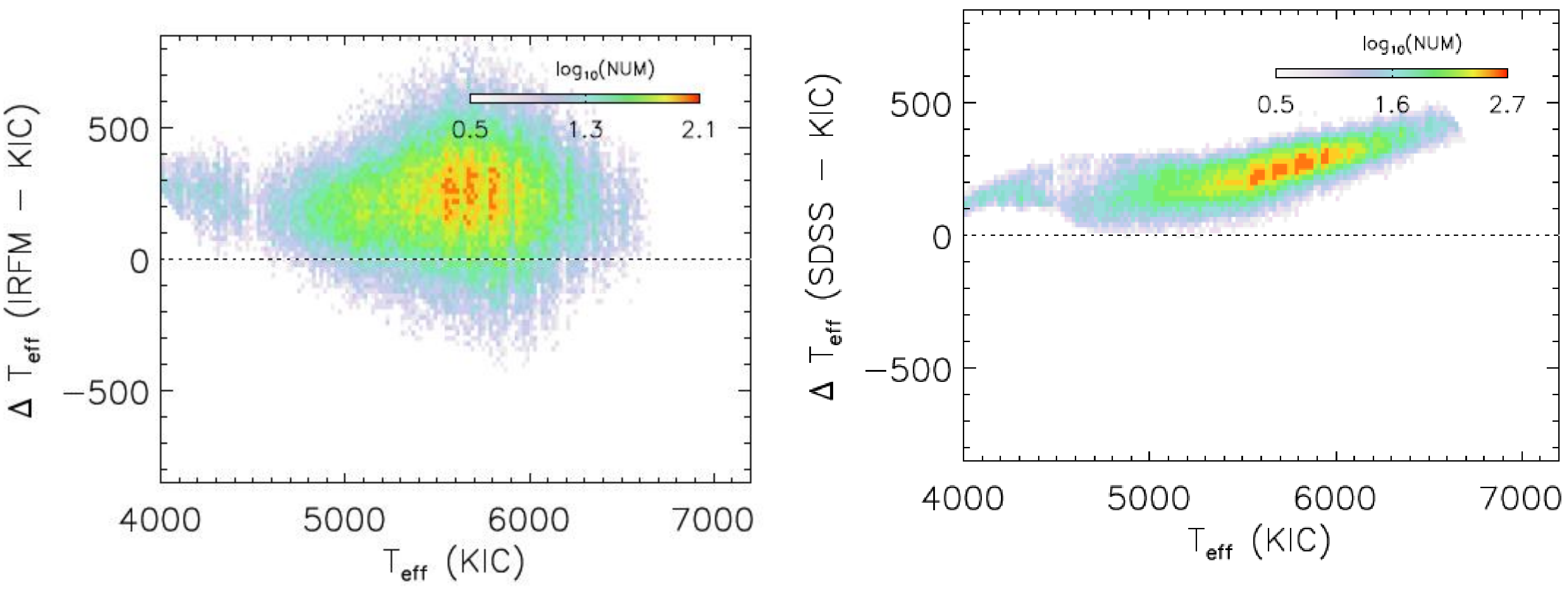


The KIC scale is too cool for dwarfs (*and giants)*

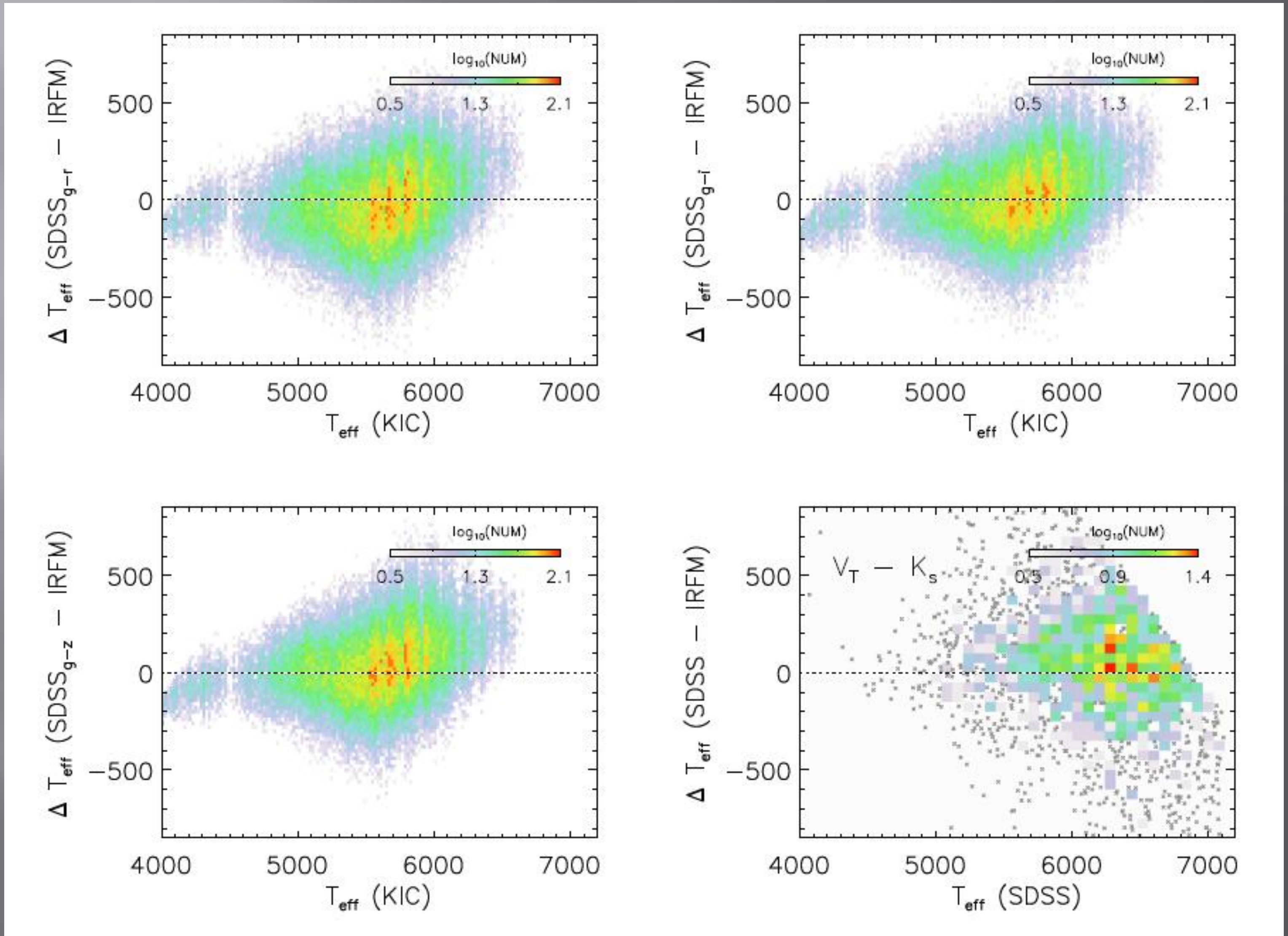
Zero-point shift of order 200 K

IRFM from J-K

SDSS from griz

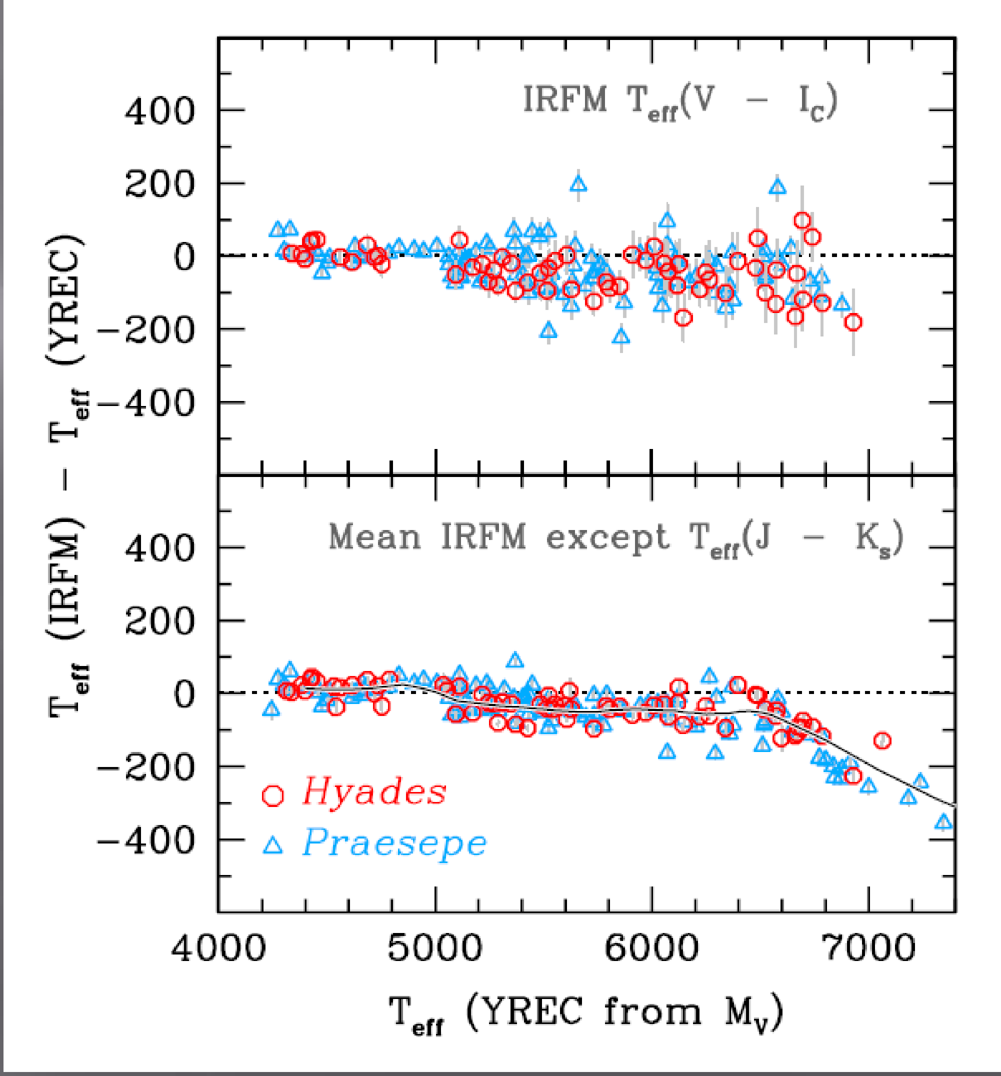


IRFM + SDSS consistent for cool stars, different at the hot end



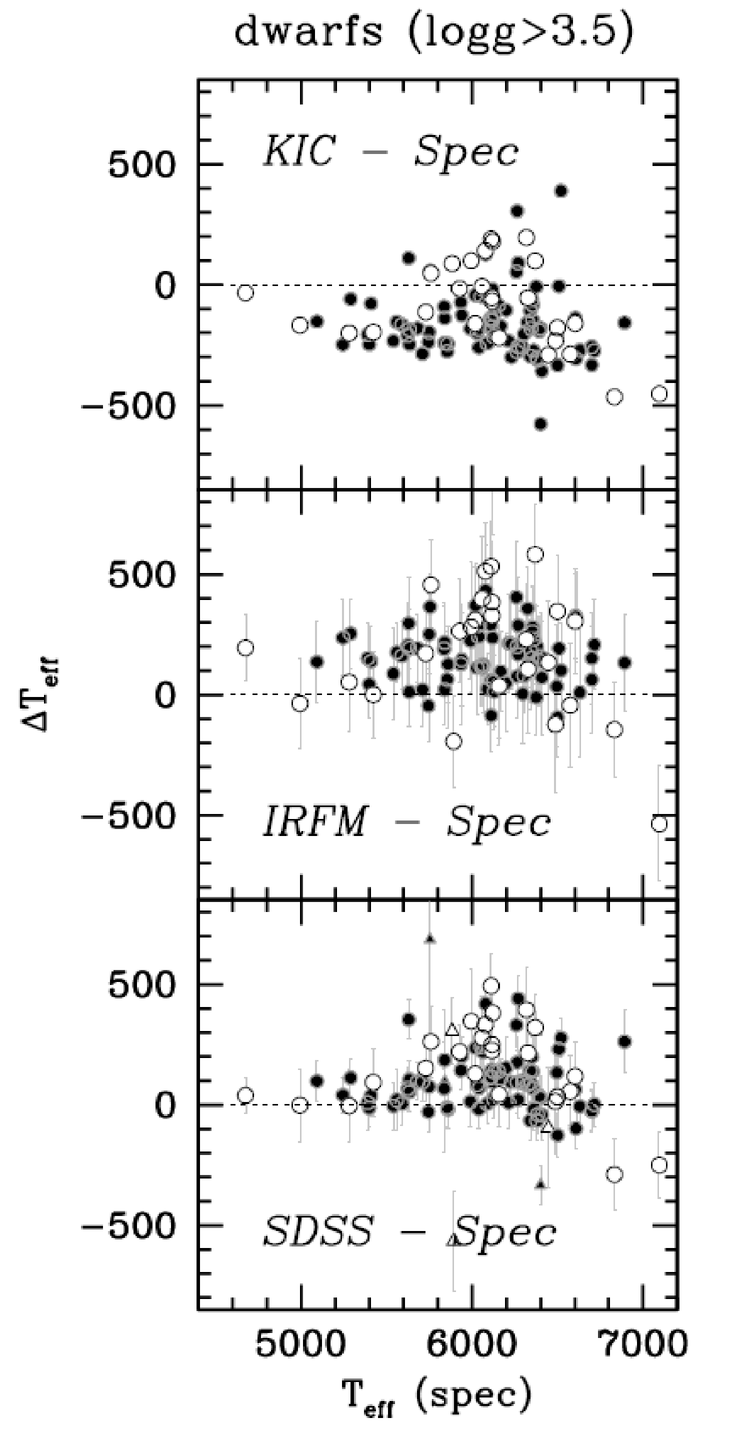
Cluster consistency test

- IRFM mean is consistent with SDSS for cool stars
- Differences are real for hot stars
- We recalibrated the hot star Teff to put them on the IRFM scale (100 K level correction)



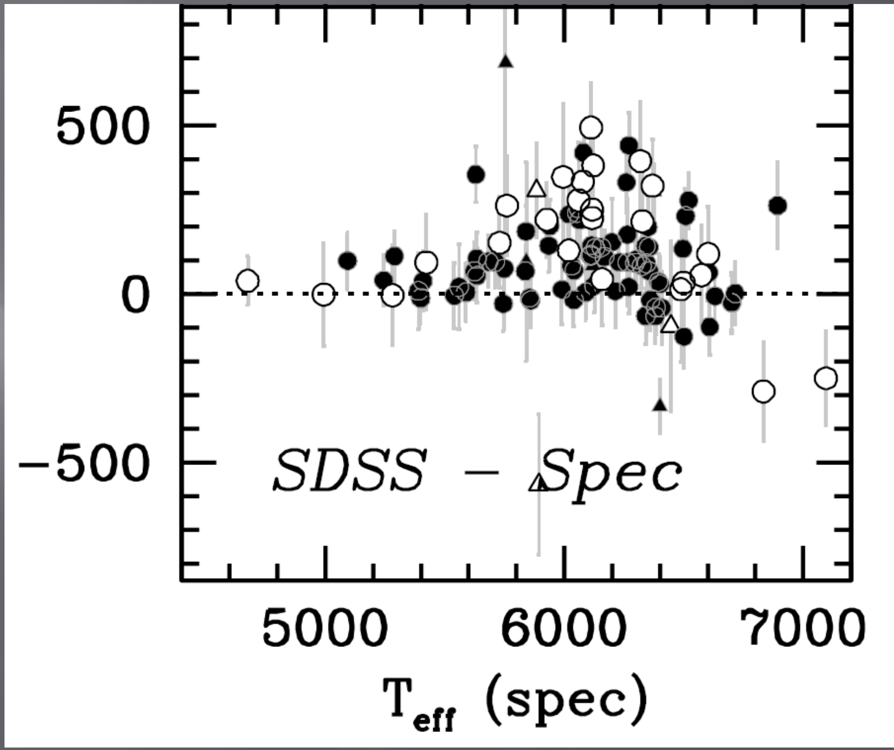
Spectroscopy

- Two large spectroscopic samples: B11, MZ11
- Both are cooler than the KIC (overall)
- Both are cooler than the SDSS/IRFM for hot dwarfs

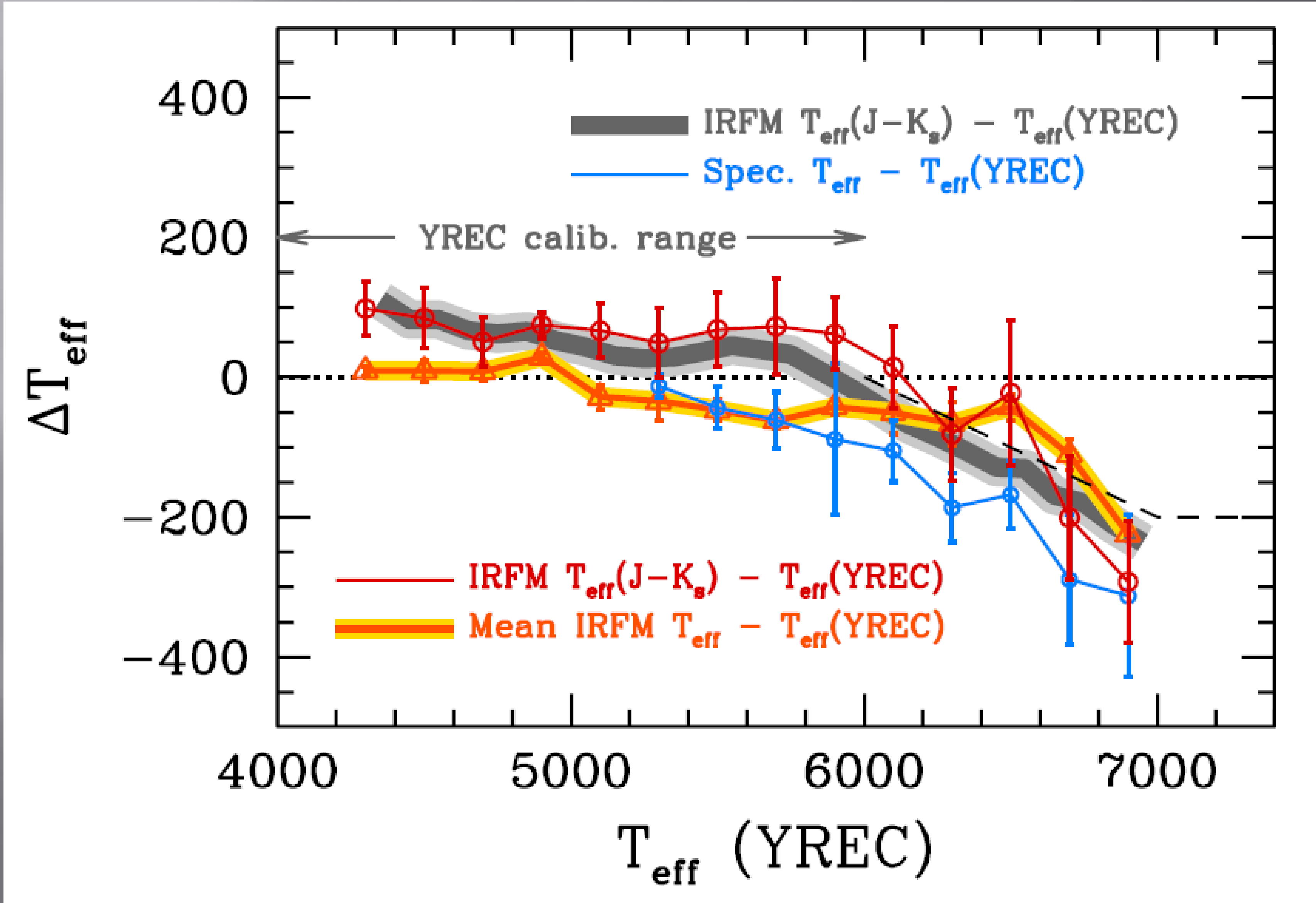


Spectroscopic Measurements have their own zero-point issues

- The two spectroscopic samples have different zero-points at the 100 K level and very different dispersions
- B11 is very close to the fundamental scale for cool dwarfs (50 K)



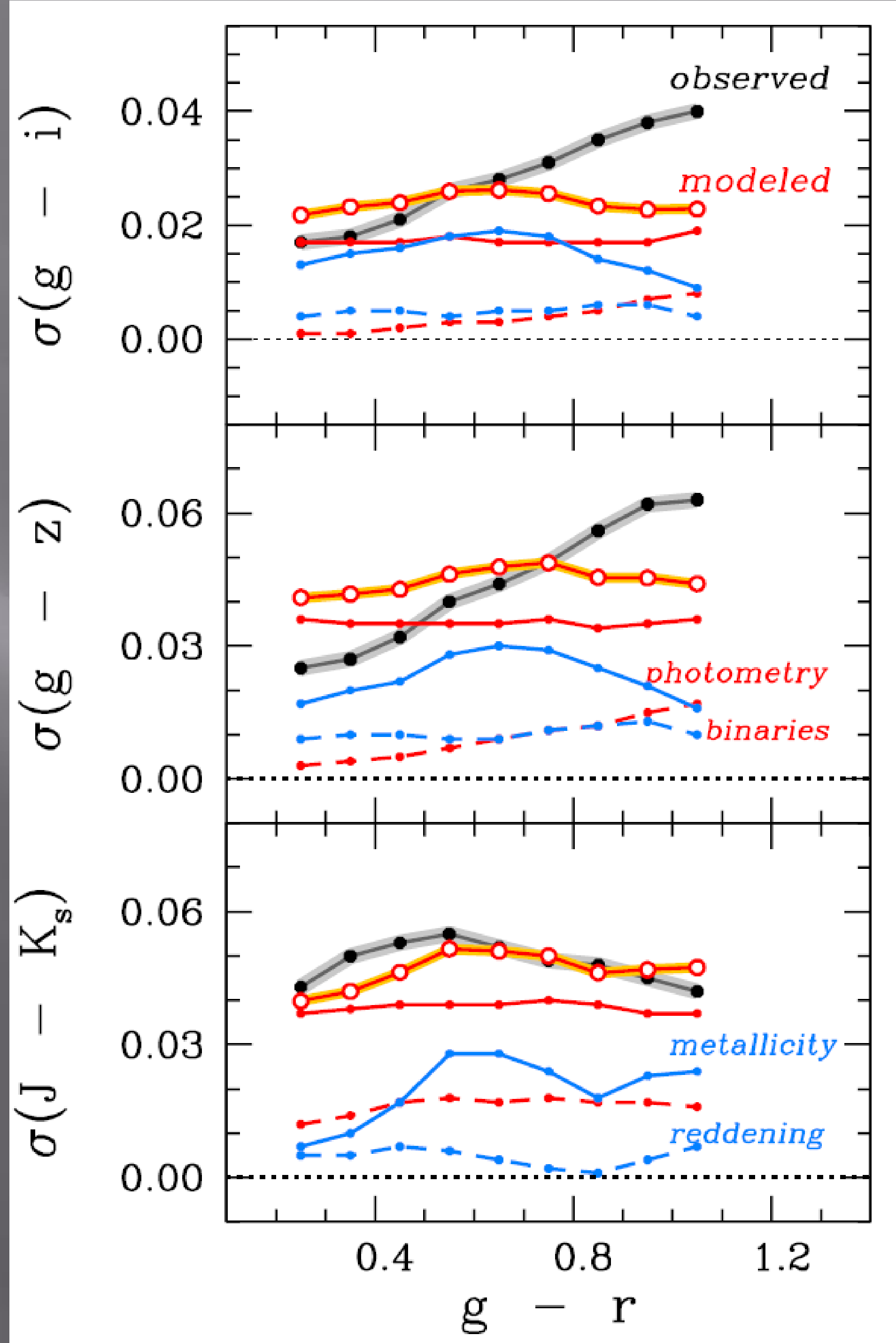
Systematic Error Assessment



Typical σ ~100 K

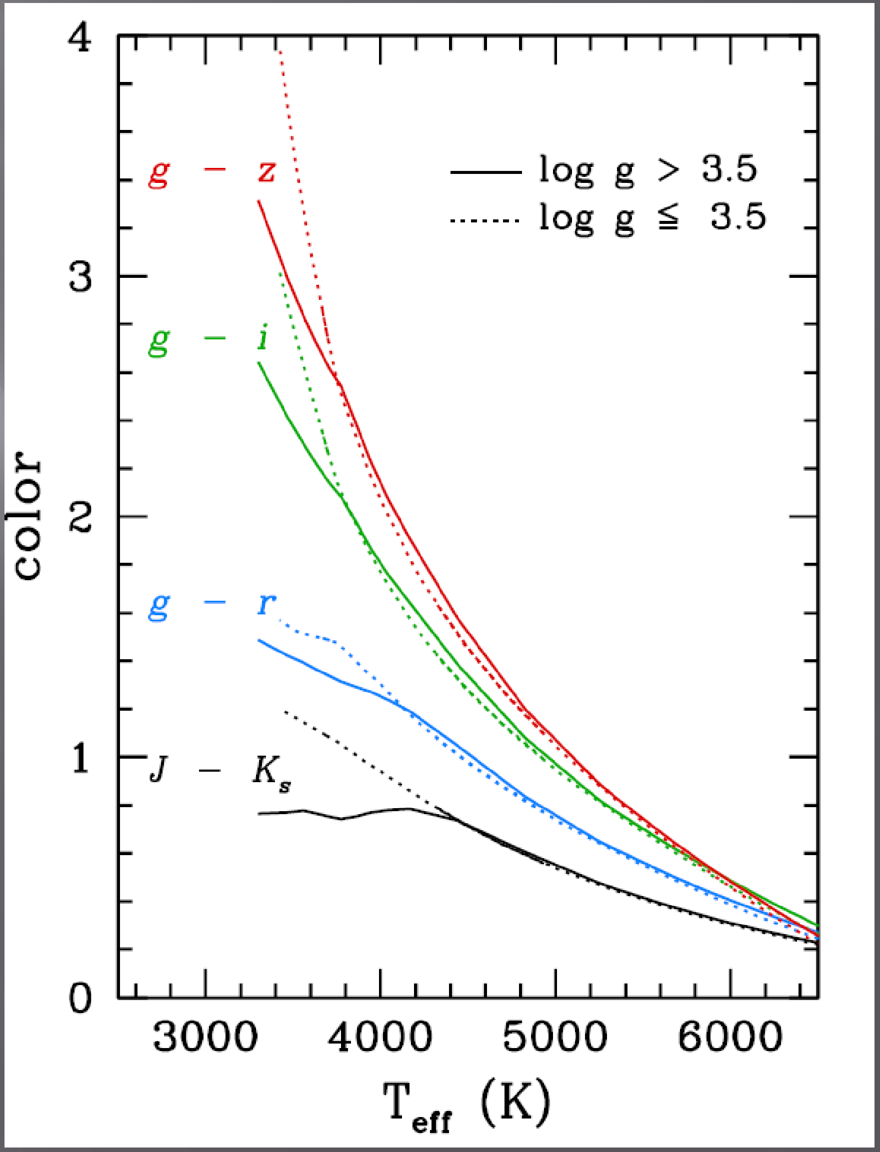
Color dispersion consistent with error model (hot stars)

Giant contamination impacts cool star dispersion

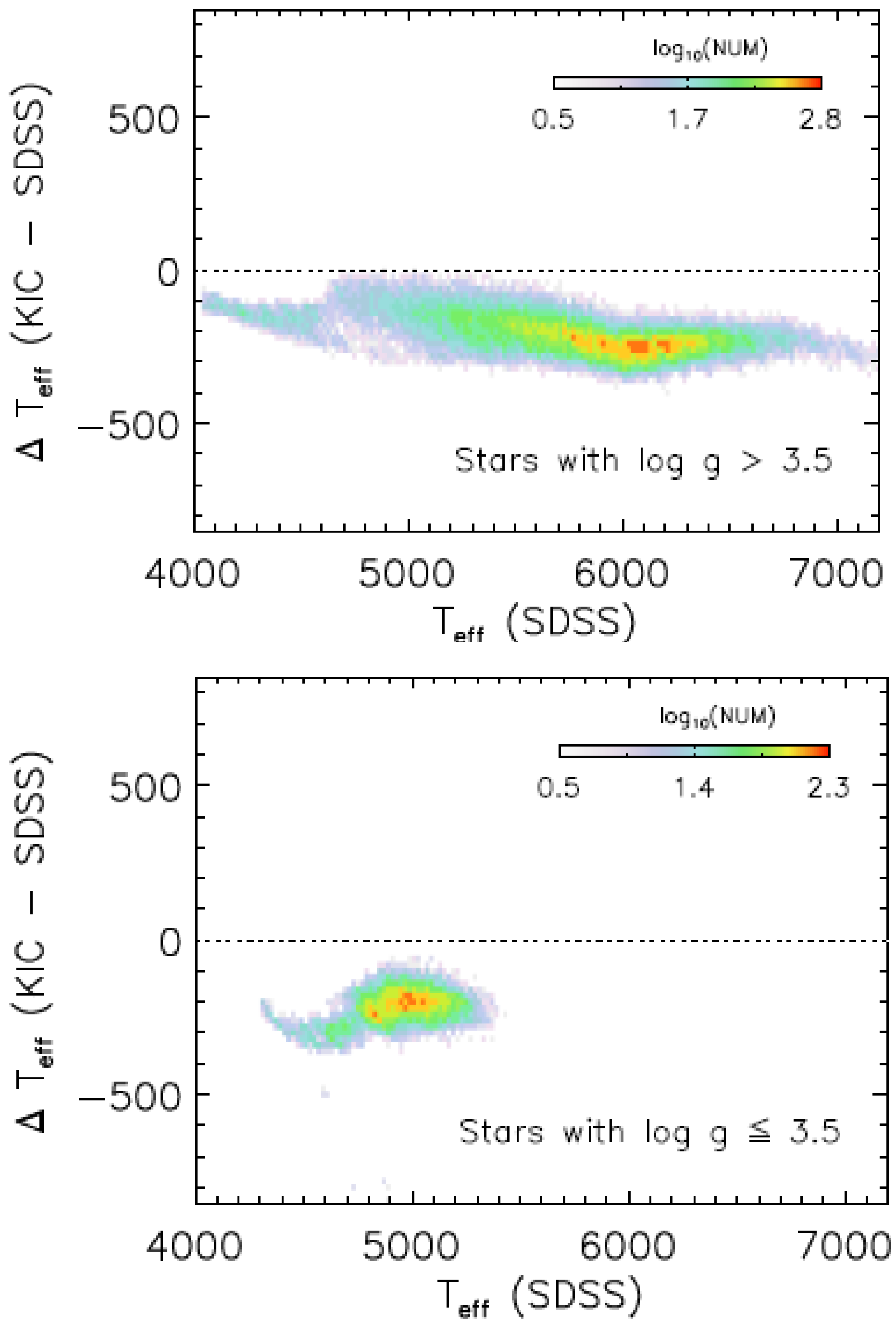


Bootstrapping to Giants

- Theoretical corrections applied to cool giants
- The net effect is a zero-point shift comparable to that for dwarfs



Bottom line: Comparisons with giants and dwarfs



The Table(s)

Table 7. Catalog with Revised T_{eff}

KIC ID	SDSS T_{eff} (K)	SDSS σ_{tot} (K)	SDSS σ_{ran} (K)	IRFM T_{eff} (K)	IRFM σ_{tot} (K)	IRFM σ_{ran} (K)	KIC T_{eff} (K)	KIC $\log g$ (dex)	KIC [Fe/H] (dex)	ΔT_{eff}[a] (K)	flag[b]
757076	5137	85	55	5150	98	94	5174	3.60	−0.08	0	0
757099	5523	97	34	5270	110	101	5589	3.82	−0.21	0	0
757137	4822	74	42	4536	101	99	4879	2.58	−0.08	49	0
757218	4728	79	17	4489	90	75	4555	2.28	−0.12	67	0
757231	4909	116	64	4974	111	89	4825	2.60	−0.08	24	0

Note. — Only a portion of this table is shown here to demonstrate its form and content. A machine-readable version of the full table is available.

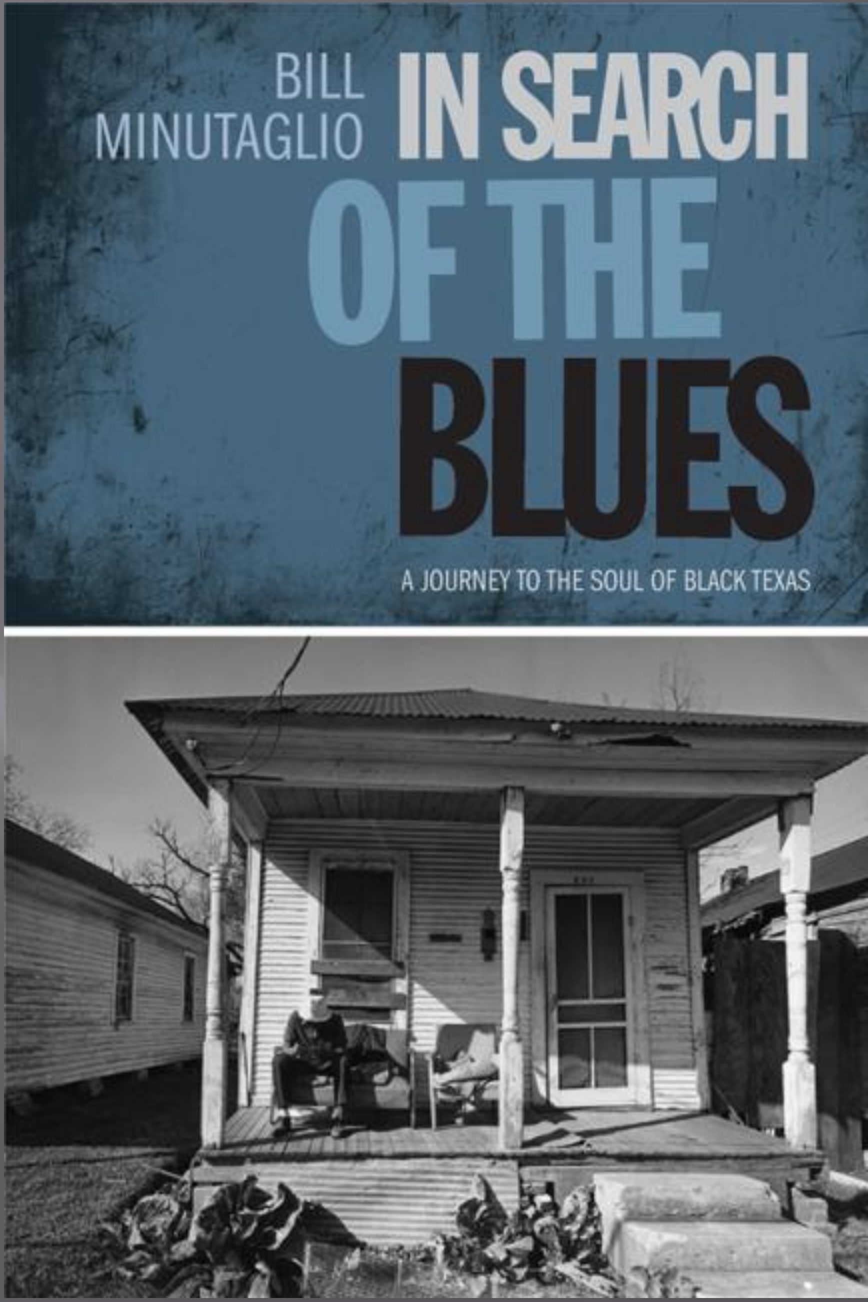
[a] T_{eff} correction for giants. The sense is that this correction factor has been subtracted from the SDSS T_{eff} estimate in the above table.

[b] Quality flag indicating stars with unusually discrepant SDSS T_{eff} estimates (see text).

Detailed procedures for estimating values for other stars provided

Metallicity : Weak link in the KIC

- Accurate photometric metallicities require good data in the blue
- More broadly, SDSS filters not optimized for stellar parameter determination
- Absolute photometry (esp. u, BVI) will be needed to take full advantage of Kepler



On Spectroscopic Temperature Measurements

- Highly useful in regions with strong extinction
- Calibration is essential (comparison to fundamental scale)
- Blind adoption of spectroscopic values will induce significant systematics and artificially inflated errors

APOGEE and Kepler

- The APOGEE project will be taking ~100,000 high resolution H-band spectra, mostly of red giants, over the next 3 years
- Main purpose: stellar populations
- Kepler / CoRoT have been identified as important asteroseismic targets
  - ~1,000+ seismic targets in Kepler this season
  - Large (complete for seismology) samples possible for next year
  - Let's talk!