WP122000 – Non-seismic diagnostics and model atmospheres

Thierry Morel (Institut d'Astrophysique et de Géophysique, Université de Liège, Belgium)

WP122100 – 3D/NLTE model atmospheres

M. Asplund (Germany)

WP122200 – Fundamental parameters, chemical abundances and 1D model atmospheres

C. Allende Prieto (Spain)

WP122300 – Limb-darkening coefficients

A. Claret (Spain)

WP122400 – Model atmospheres of M dwarfs

I. Hubeny (USA)

WP122500 – Interstellar extinction

D. Marshall (France)

Main deliverables:

- Procedures for deriving stellar parameters: L, T_{eff}, radii, chemical abundances, ... Targeted accuracy: T_{eff} to within 1% and R to within 2%.
- Grid of 1D/3D model atmospheres.
- Grid of limb-darkening coefficients.

WP122100 – 3D/NLTE model atmospheres

M. Asplund (Germany)

→

Grid of 3D model atmospheres

3D/NLTE corrections for the abundances of individual lines, stellar parameters and centre-to-limb variations

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WP122200 – Fundamental parameters, chemical abundances and 1D model atmospheres

C. Allende Prieto (Spain)

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Grid of 1D model atmospheres

Procedures for deriving T_{eff}, radii and detailed chemical abundances corrected for 3D/NLTE effects.

WP122100 – 3D/NLTE model atmospheres

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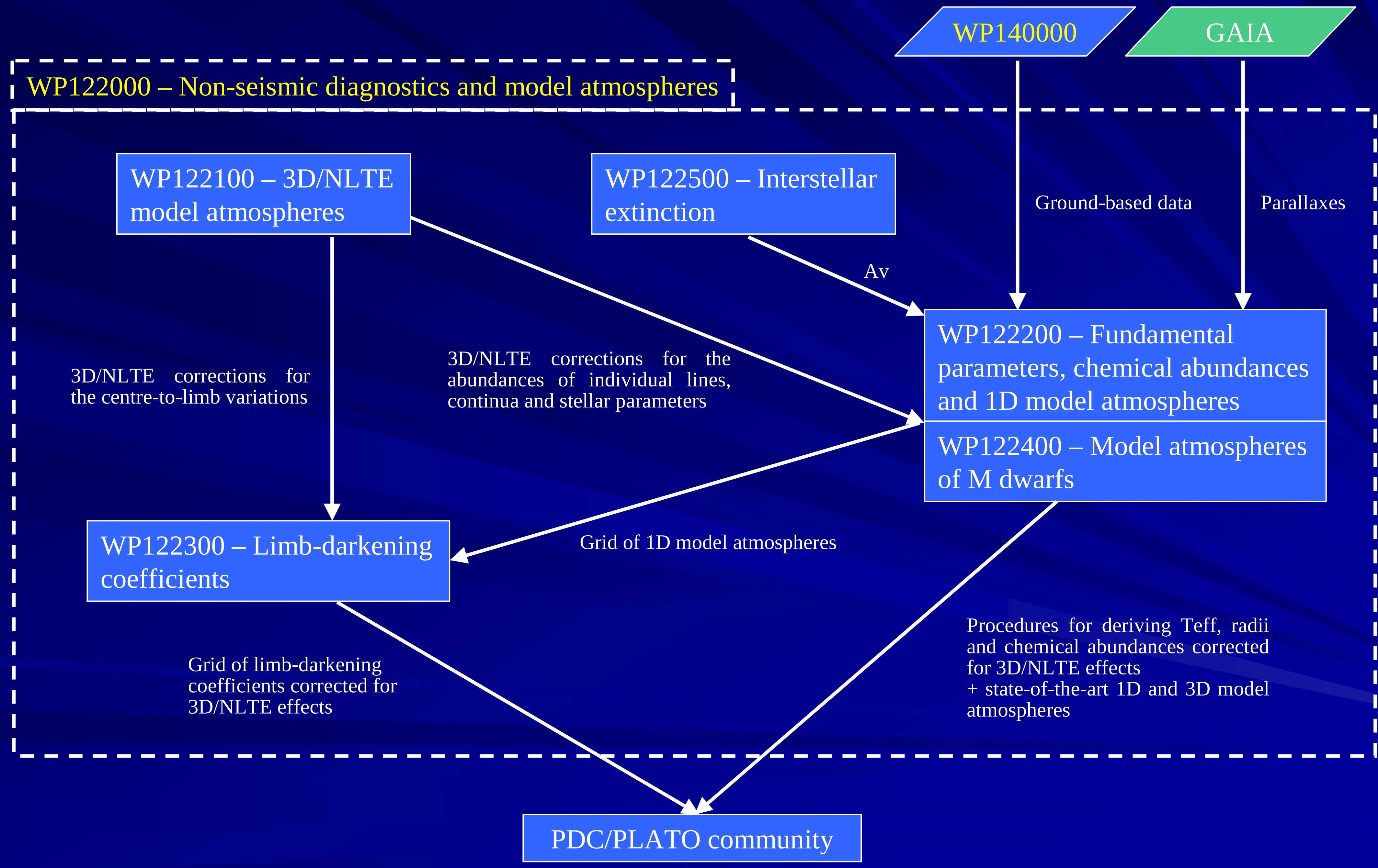
WP122500 – Interstellar extinction

D. Marshall (France)

→ A_V along line of sight


WP140000
GAIA
WP122000 – Non-seismic diagnostics and model atmospheres
WP122100 – 3D/NLTE model atmospheres
WP122500 – Interstellar extinction
Ground-based data
Parallaxes
Av
WP122200 – Fundamental parameters, chemical abundances and 1D model atmospheres
WP122400 – Model atmospheres of M dwarfs
3D/NLTE corrections for the centre-to-limb variations
3D/NLTE corrections for the abundances of individual lines, continua and stellar parameters
WP122300 – Limb-darkening coefficients
Grid of 1D model atmospheres
Procedures for deriving Teff, radii and chemical abundances corrected for 3D/NLTE effects + state-of-the-art 1D and 3D model atmospheres
Grid of limb-darkening coefficients corrected for 3D/NLTE effects
PDC/PLATO community

Determination of radius from non-seismic diagnostics

Three methods currently envisaged for determination of radius from non-seismic diagnostics *alone*:

- Classical method $R = f(L, T_{\rm eff})$
- From fitting of spectrophotometric data
- Interpolation in theoretical isochrones

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Classical method:

$R = (L/4\pi\sigma T_{\rm eff}^4)^{1/2}$

$\mathrm{Log}(L/L_{\rm sun}) = (M_{\rm bol,\,sun} - M_V - BC)/2.5$

$M_V = V + 5 + 5\log\pi - A_V$

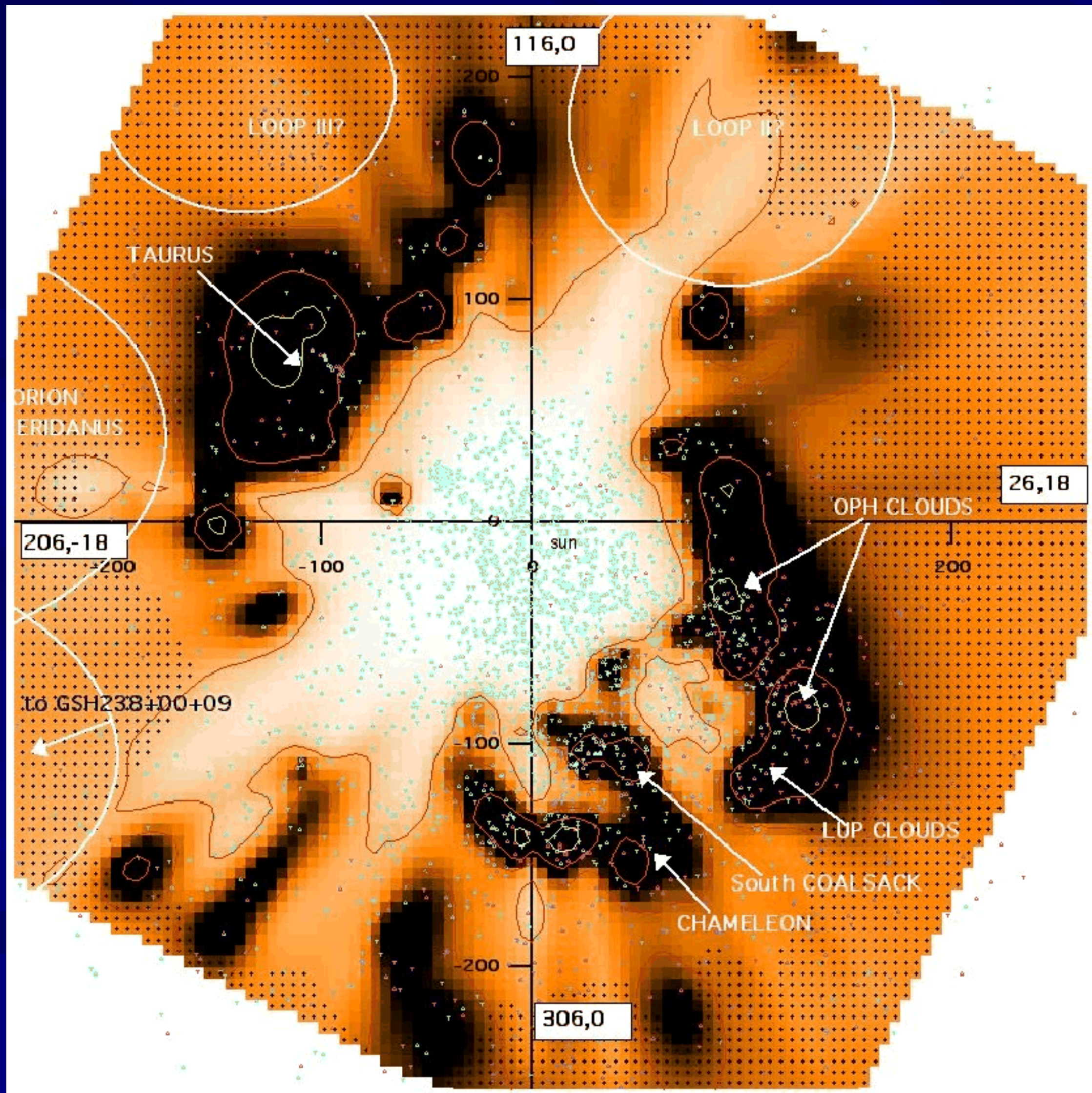
$\sigma\pi/\pi$ (GAIA) = 1% only for $V = 15$ mag. Assuming $\sigma\pi/\pi = 0$: $\sigma R/R = f(\sigma A_V, \sigma BC, \sigma T_{\rm eff})$

Achieving $\sigma R/R = 2\%$ requires:

> $\sigma T_{\rm eff} < 50$ and 35 K for solar-like and M stars, respectively
> σA_V and $\sigma BC < 0.015$ mag

Determination of radius – ‘classical’ method

σAv



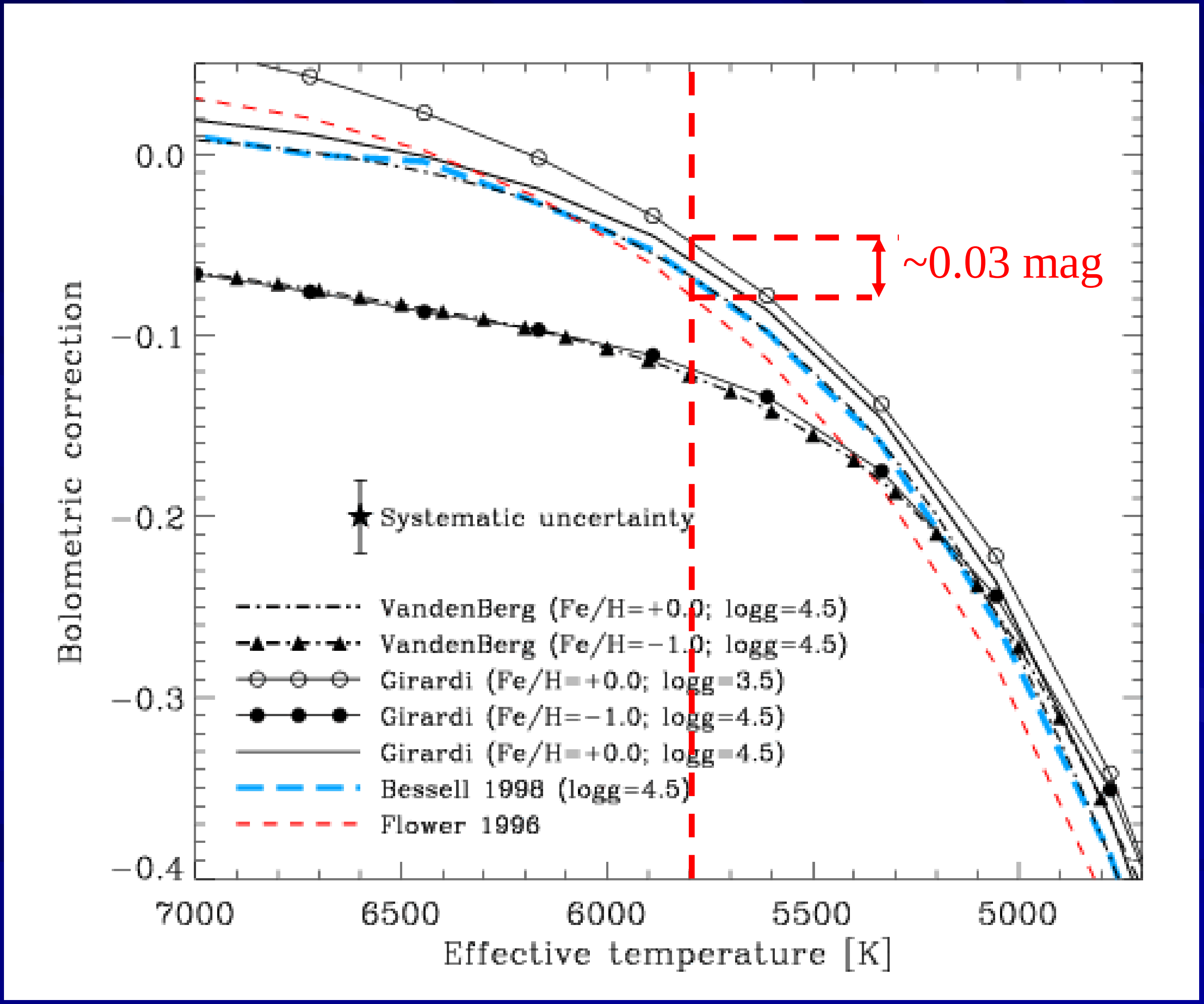
Local bubble: little extinction for $d < 75$ pc

(volume corresponding to G2 and M1 dwarfs with $V < 9$ and 14, respectively).

Vergely et al. (2010)

Determination of radius – ‘classical’ method

σBC

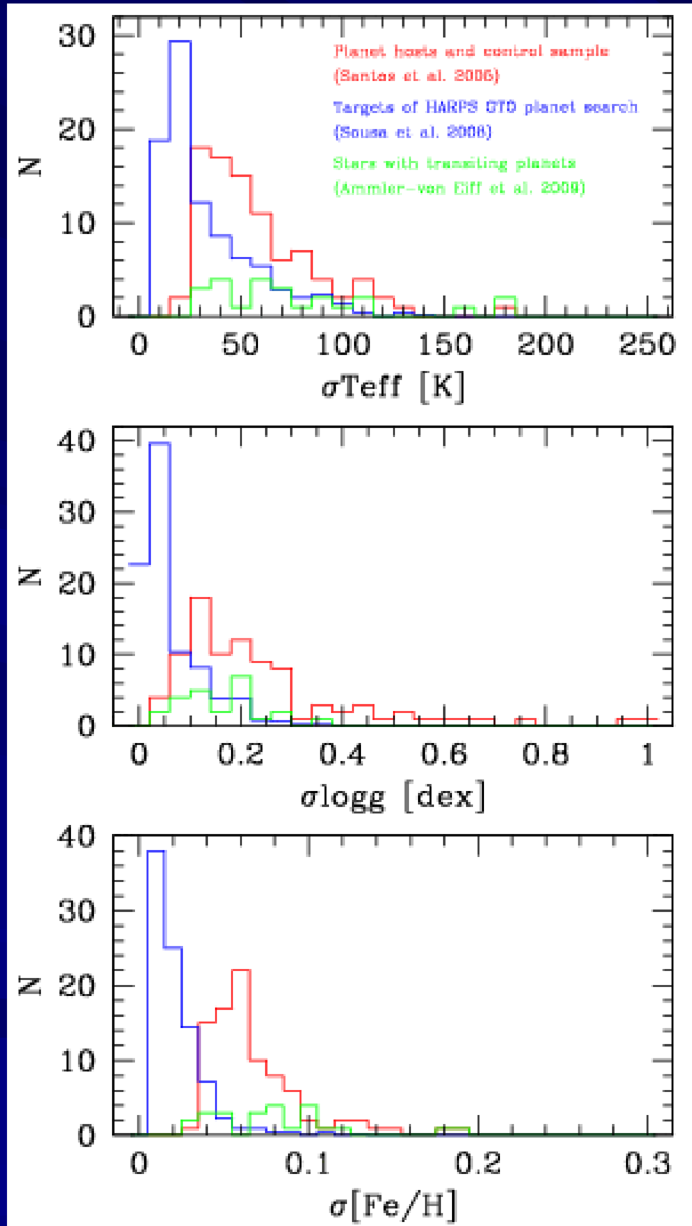


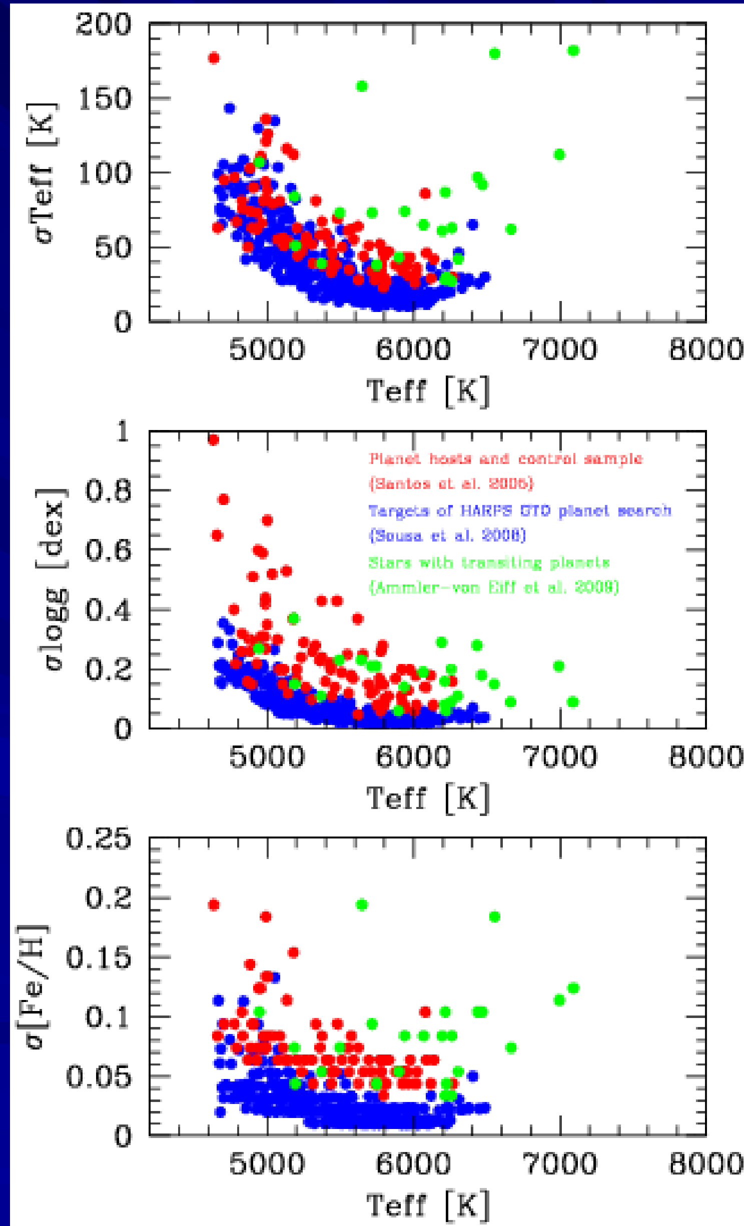
BC more uncertain for active stars

Bruntt et al. (2010)

Determination of radius – ‘classical’ method

σTeff
solar-like





Determination of radius – 'classical' method

σTeff
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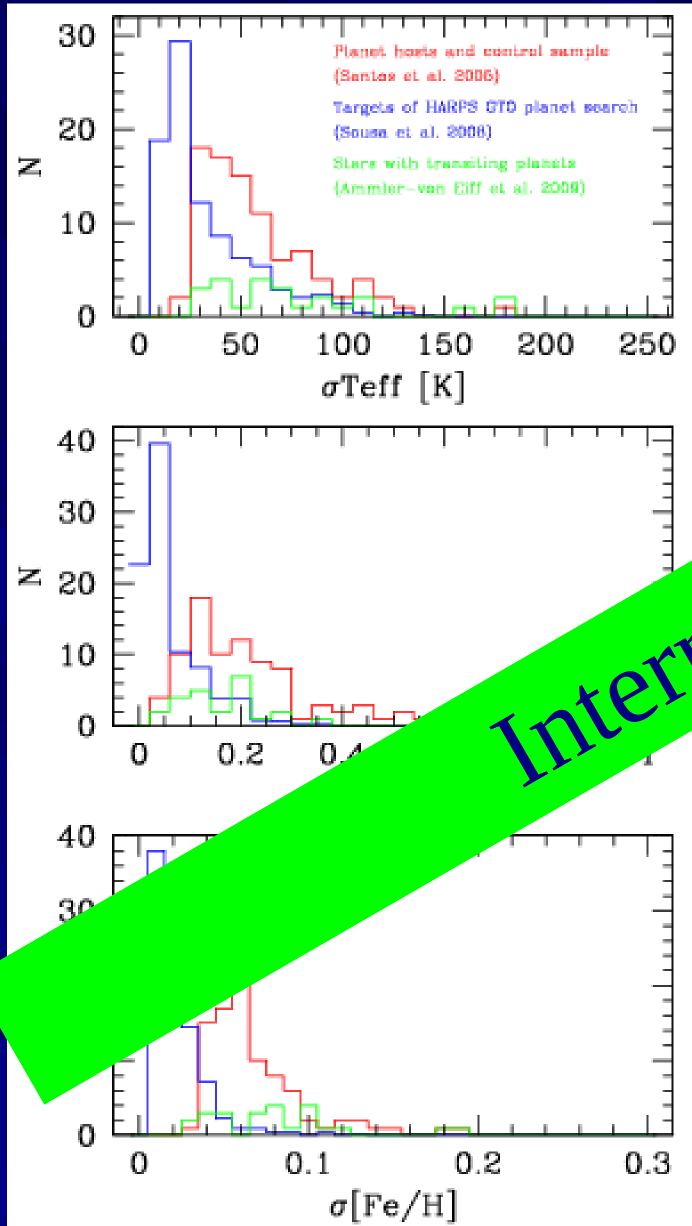
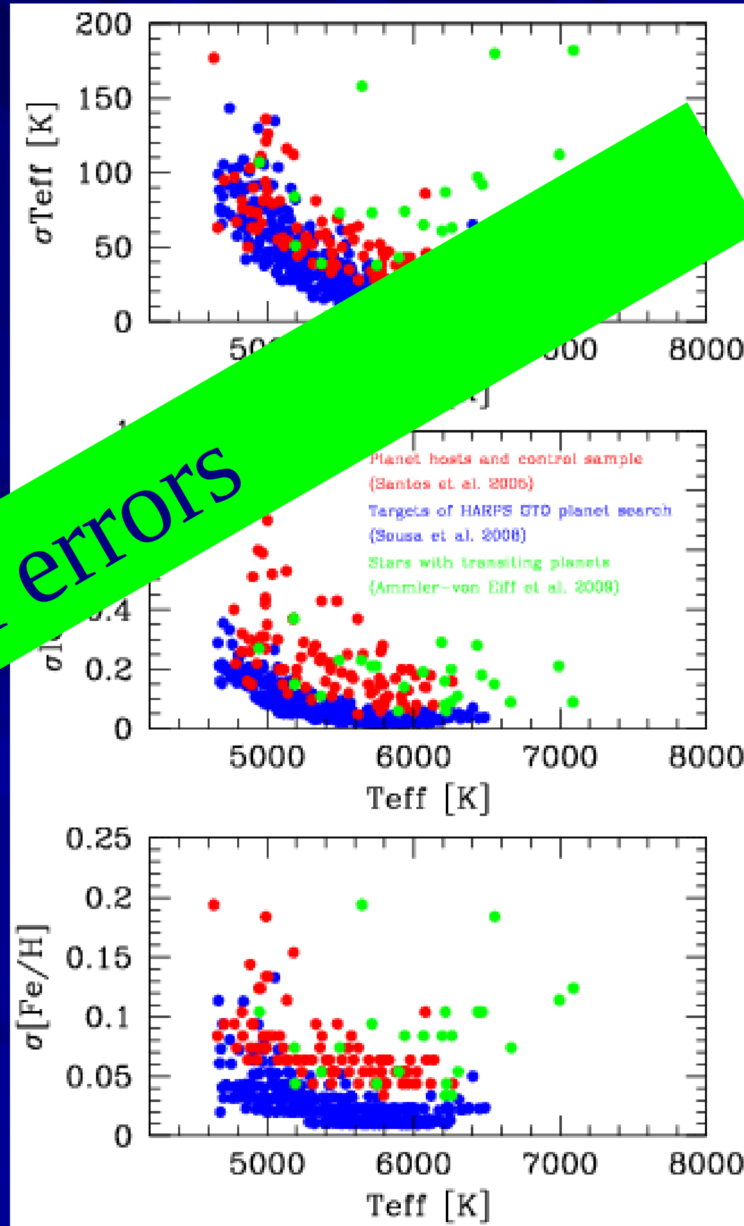
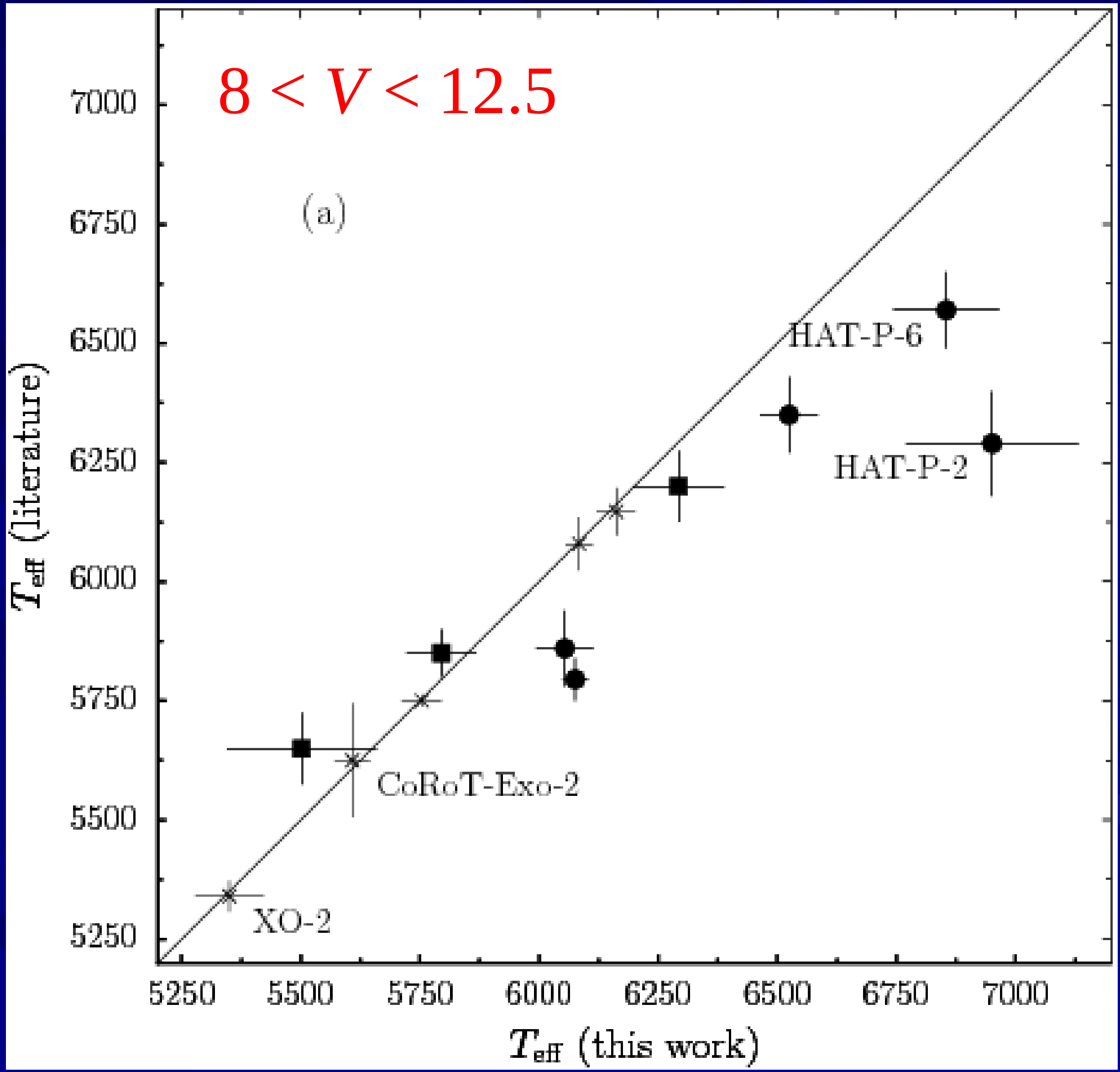




Internal errors

Determination of radius – ‘classical’ method

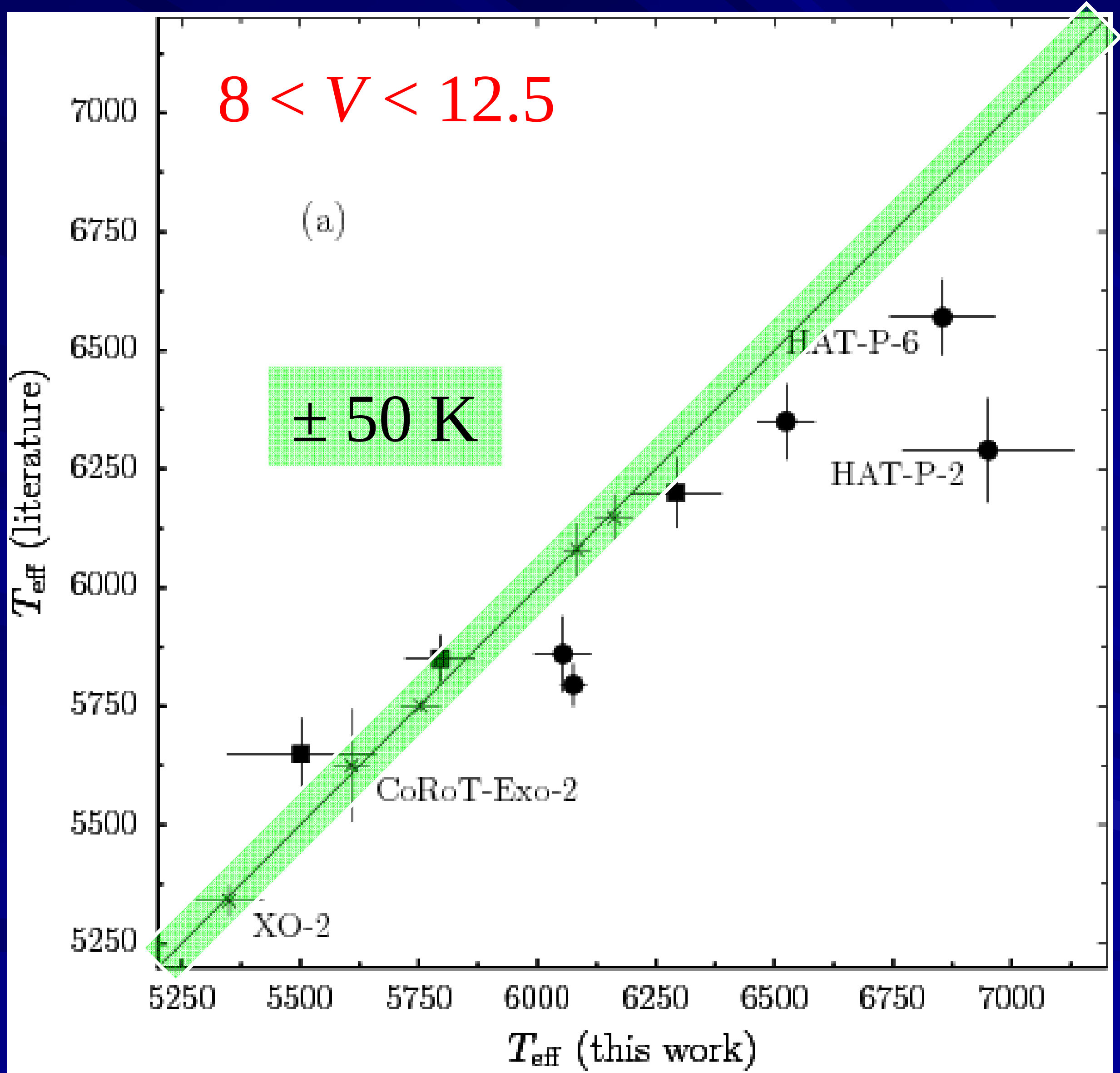
σTeff
solar-like



Ammler-von Eiff et al. (2009)

Determination of radius – ‘classical’ method

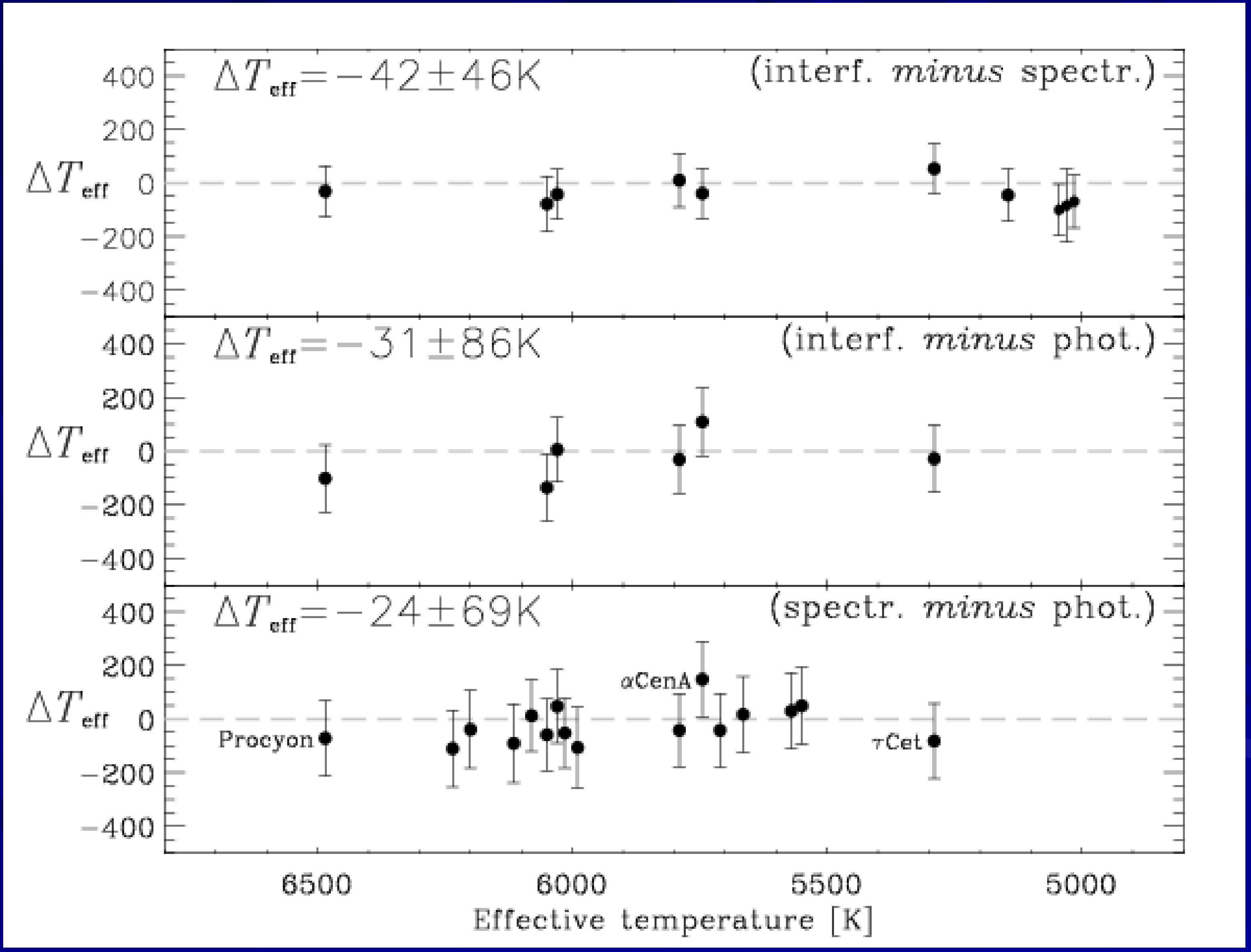
σTeff
solar-like



Ammler-von Eiff et al. (2009)

Determination of radius – ‘classical’ method

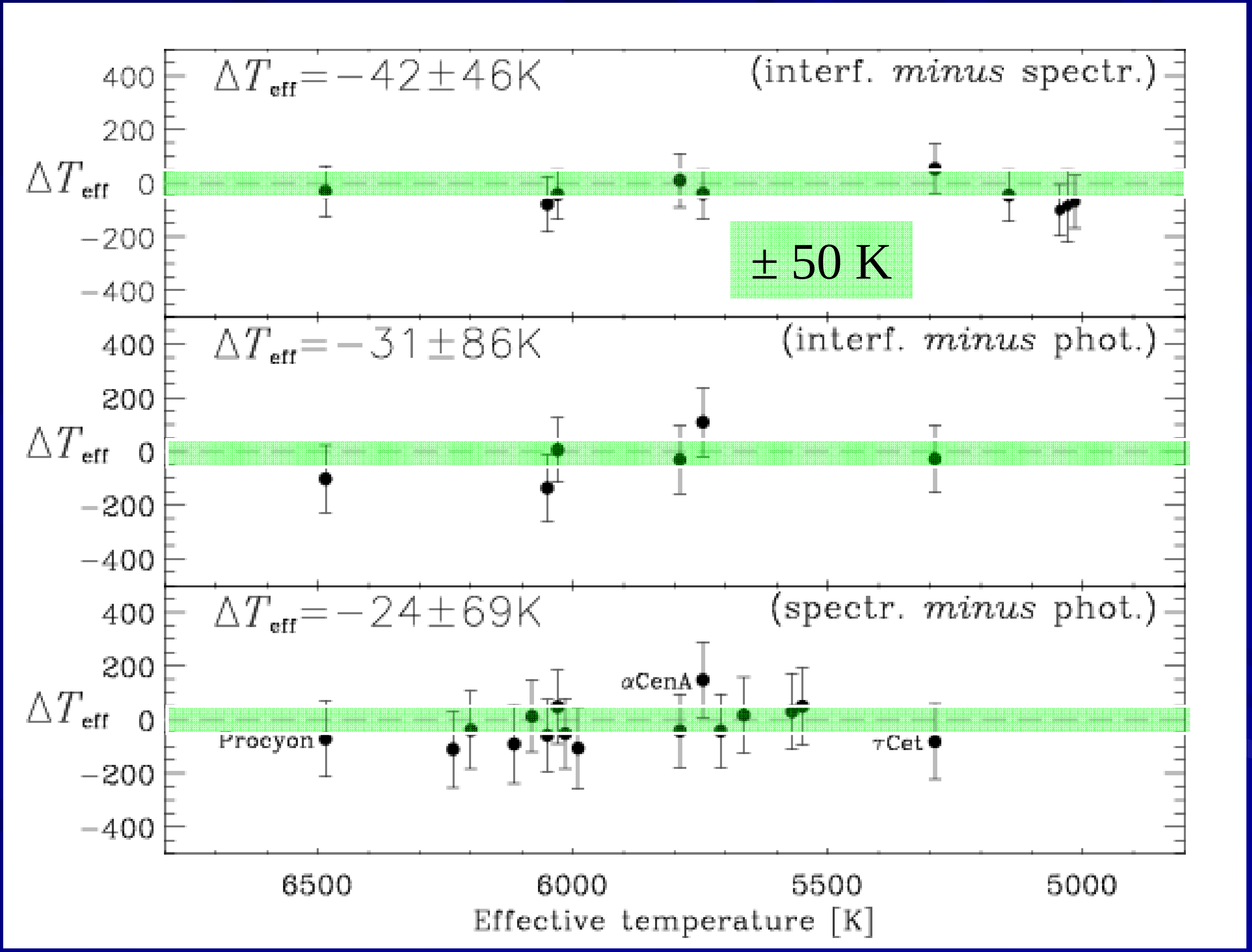
σT_{eff}
solar-like



Bruntt et al. (2010)

Determination of radius – ‘classical’ method

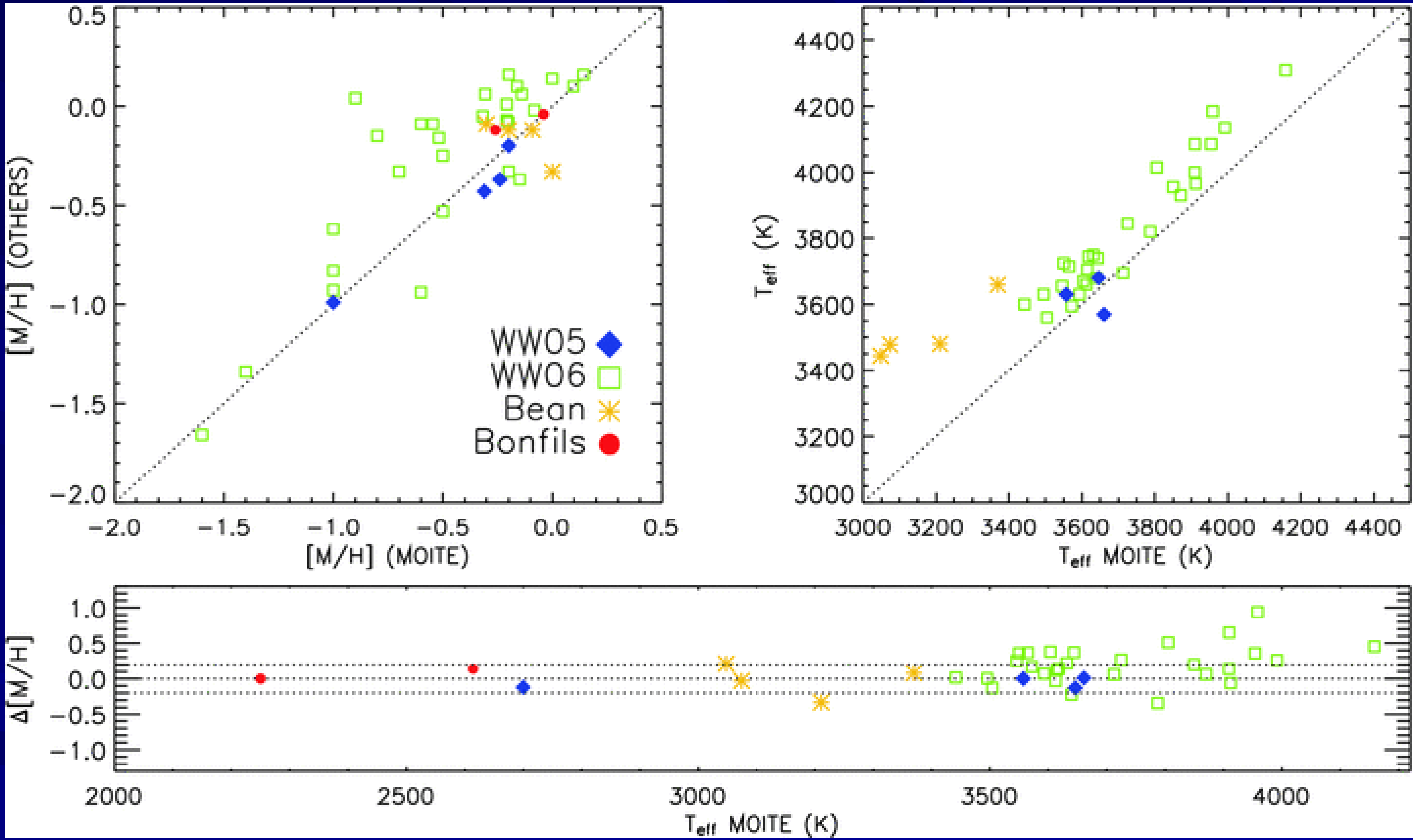
σTeff
solar-like



Bruntt et al. (2010)

Determination of radius – ‘classical’ method

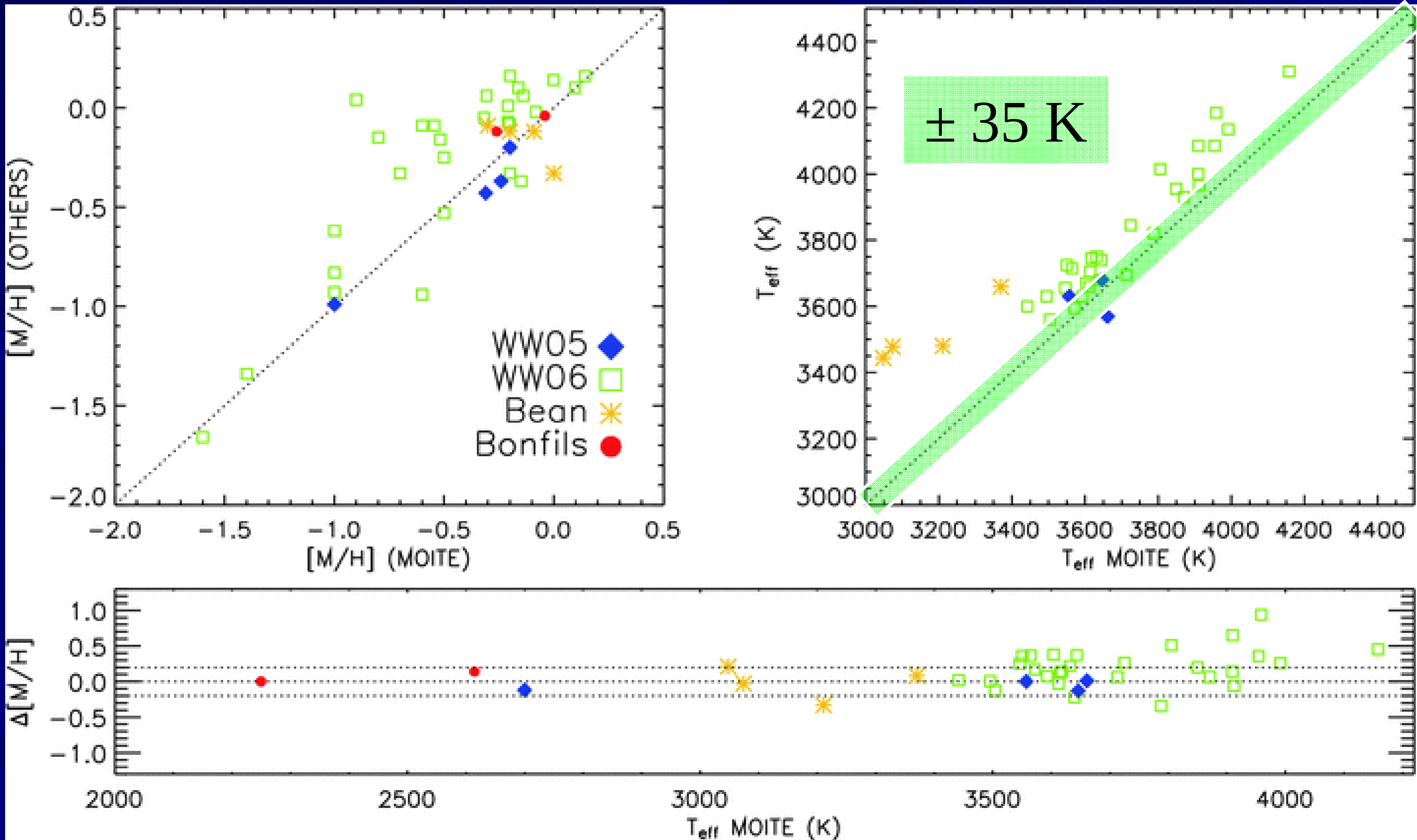
σTeff
M stars



Casagrande et al. (2008)

Determination of radius – ‘classical’ method

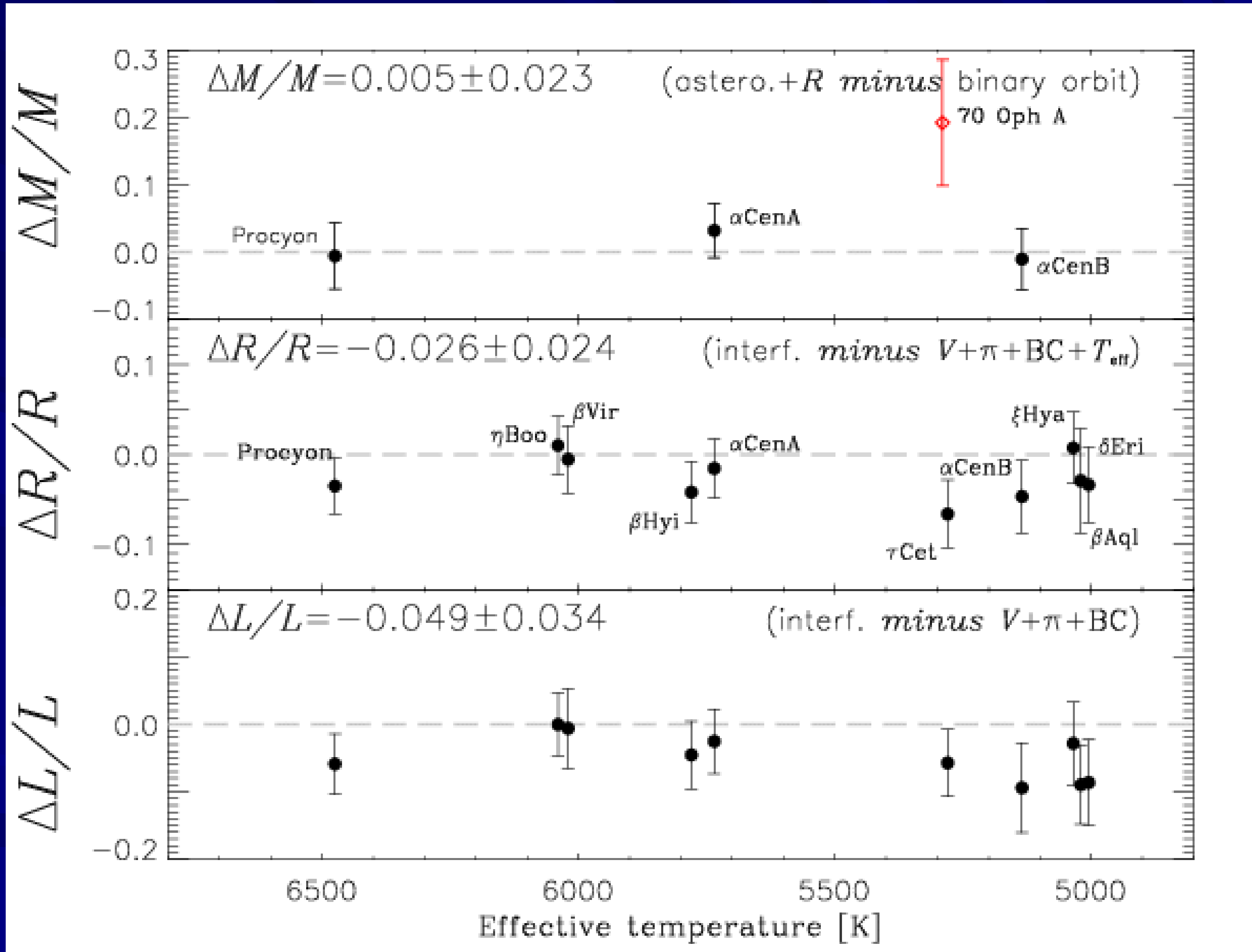
σTeff
M stars



Casagrande et al. (2008)

Determination of radius – ‘classical’ method

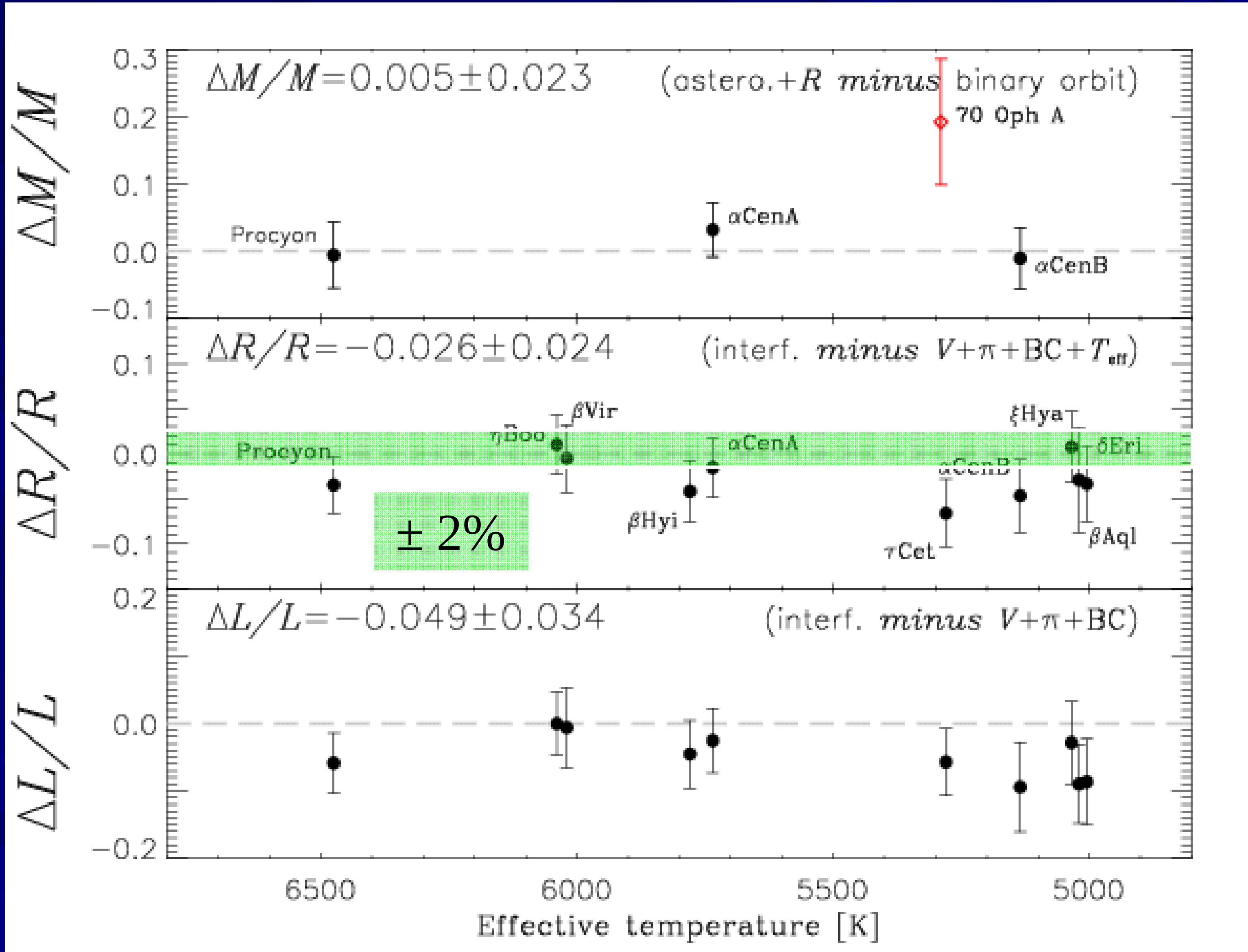
σR



Bruntt et al. (2010)

Determination of radius – 'classical' method

σR



Bruntt et al. (2010)

Determination of radius from spectrophotometric data

Fit high-quality spectrophotometric data using predictions of model atmospheres assuming for instance:

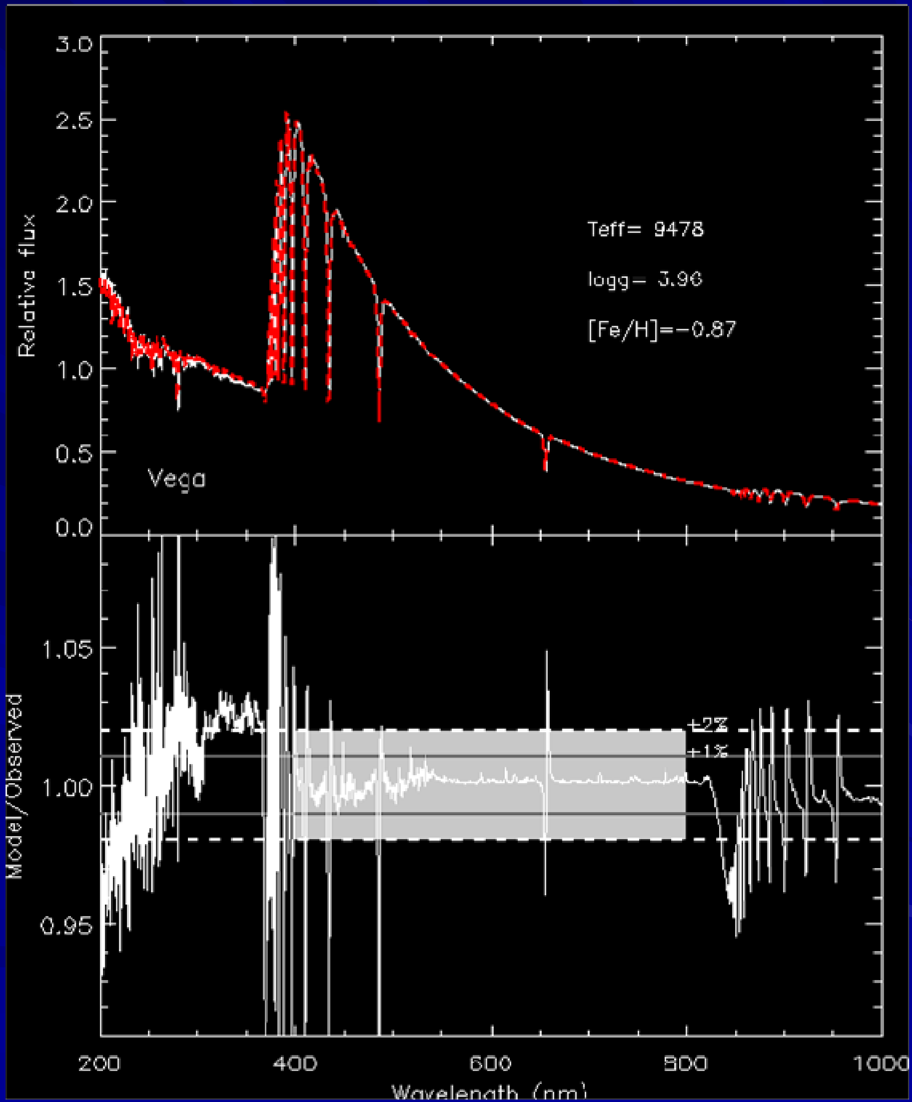
- T_{eff}, logg, [Fe/H] and A_V free parameters
- Only T_{eff} as free parameter, others derived independently.

Provides theoretical monochromatic fluxes, f_ν.

Comparing with absolute flux, F_{bol}, provides angular diameter.

Coupled with distance from GAIA provides radius, R.

σf_ν and $\sigma\theta$ ~ 2-4 %
σR ~ 1-2 %

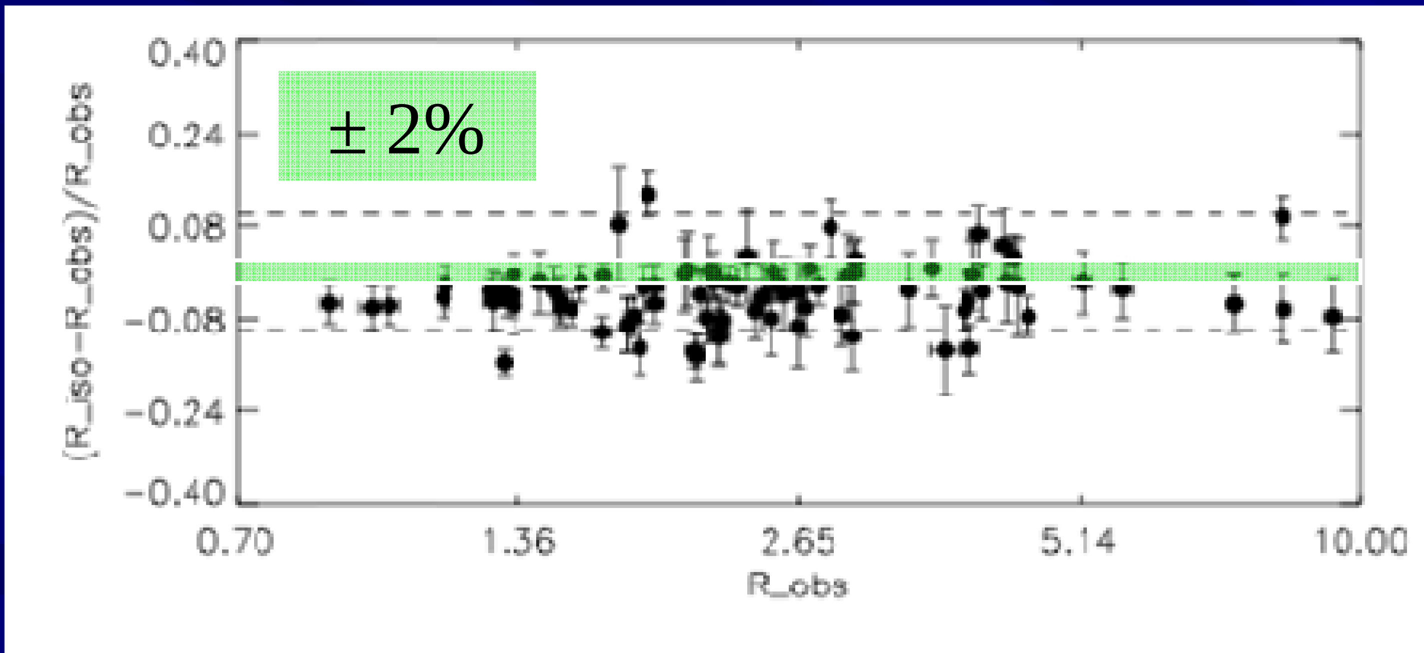


Determination of radius from interpolation in evolutionary tracks

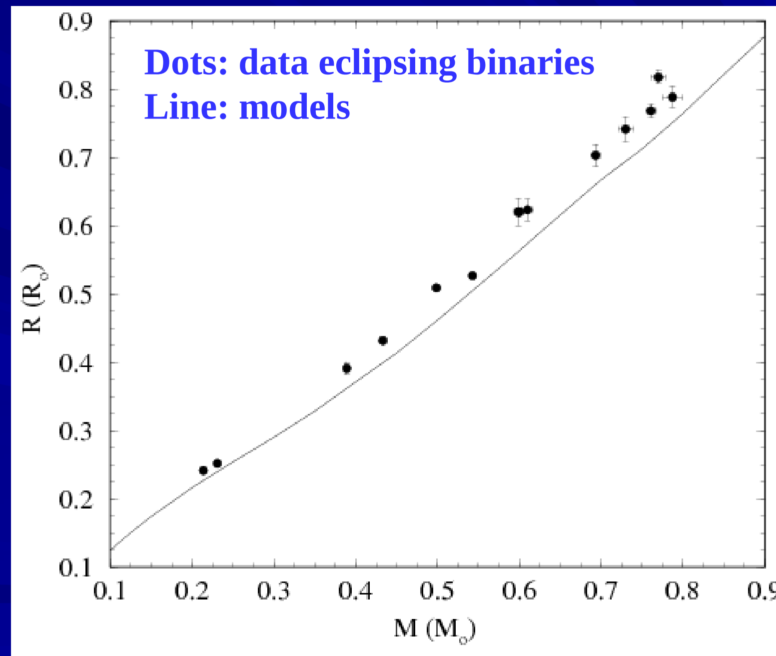
Locate star in e.g. (Mv, $B-V$) plane and find best match in theoretical isochrones for appropriate [Fe/H] and [α/Fe] through Bayesian analysis

σR/R~5-6%

Systematic errors may dominate



Allende Prieto & Lambert (1999)



Ribas et al. (2008)

Conclusions

From non-seismic diagnostics *alone*, achieving accuracy of 2% for radius quite challenging:

- ‘Classical’ method: T_{eff} must be known to within 50 K for solar like and 35 K for M stars (unrealistic in latter case). Accurate knowledge of A_V and BC also necessary (to within 0.015 mag).
- From spectrophotometry: most promising method, but sensitive to reddening and availability of space data a serious issue: currently only STIS, PHASES microsatellite in future (del Burgo et al. 2010)?
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BUT

Much more accurate parameters will eventually be obtained from combining non-seismic, seismic and/or transit diagnostics (e.g., Basu et al. 2010; Sozzetti et al. 2007).

Several independent methods can be used to narrow down errors in T_{eff} (excitation equilibrium, line-depth ratios, fitting of Balmer lines, IRFM, interferometry). 'Hybrid' analysis in which seismic constraints enter the spectroscopic analysis possible: e.g., Kepler 10-b, where σT_{eff} decreases from 150 to only 44 K (and T_{eff} 80 K lower) after using the more precise logg value from seismology (Batalha et al. 2011).

Non-seismic analysis expected to eventually provide T_{eff} to within 60 K and [Fe/H] to within 0.1 dex for the bright solar-like PLATO targets (M stars a concern).