# What influences the results?

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# Incomplete list of influences

- Atomic data
  - Log gf, damping constants, missing/bad lines, hyperfine structure, isotopes
- Model Atmosphere Physics
  - NLTE, convection, turbulence, spots, abundance clouds
- Code internals
  - Partition functions, continuous opacities, numerical precision
- Analysis Method
  - Equivalent widths, profile fitting, choice of lines and wavelength regions
- Data Quality
  - S/N, scattered light, continuum normalisation, telluric/interstellar lines
- Stellar properties
  - Binarity, variability

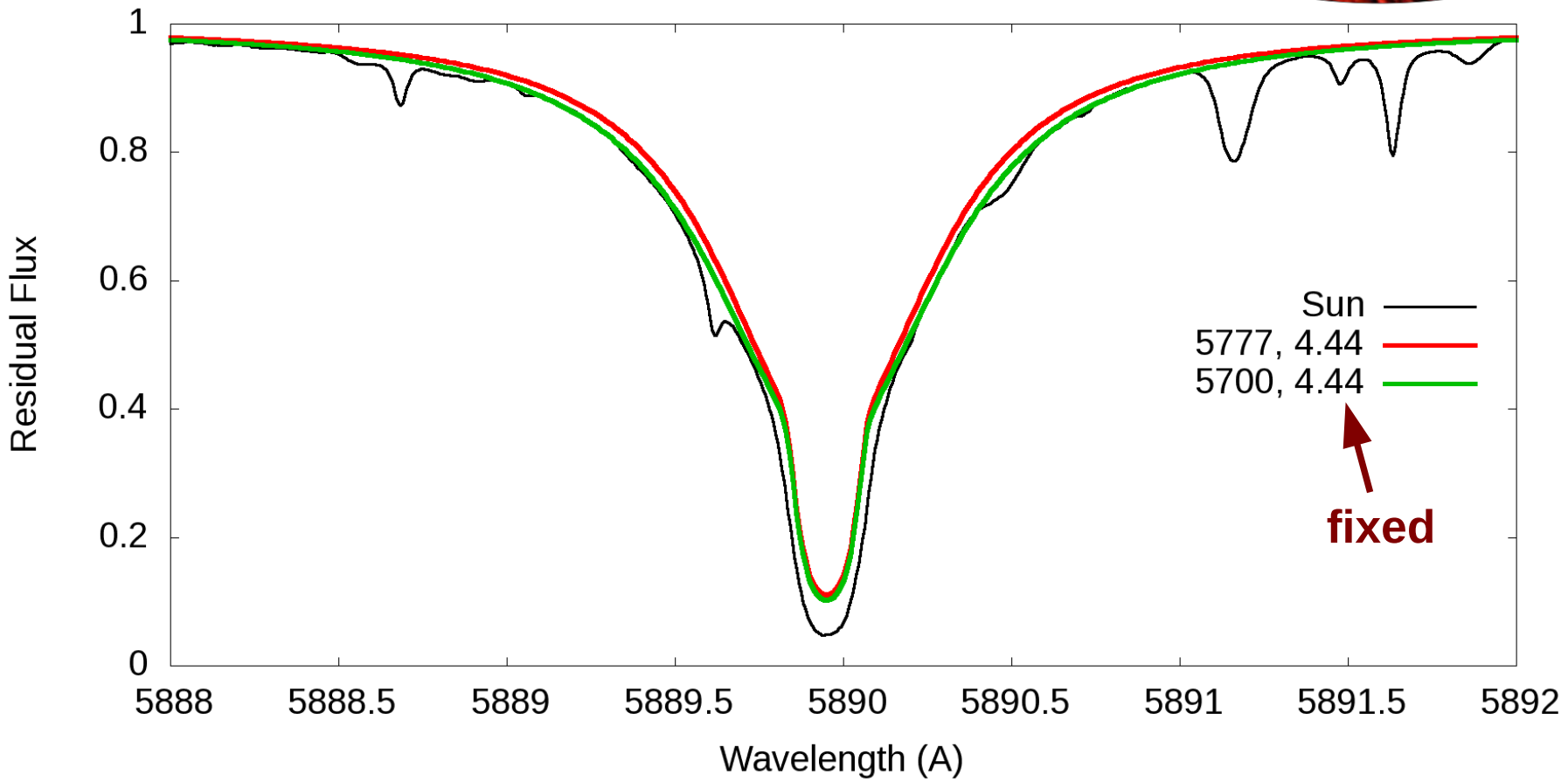

Something else!

# Need a reality check

- Fundamental stars can give accurate values of $T_{eff}$ and/or log *g* for selected stars only.
  - Except for the Sun, good to no better than 1~2 %
- Composition is not directly measured
  - Closest is the Sun via solar system material
    - Fe 7.50 ± 0.04 (photosphere) 7.45 ± 0.01 (meteorites) Asplund et al., 2009, ARA&A, 47, 481

Everything else is model dependent!

# Fixing log g

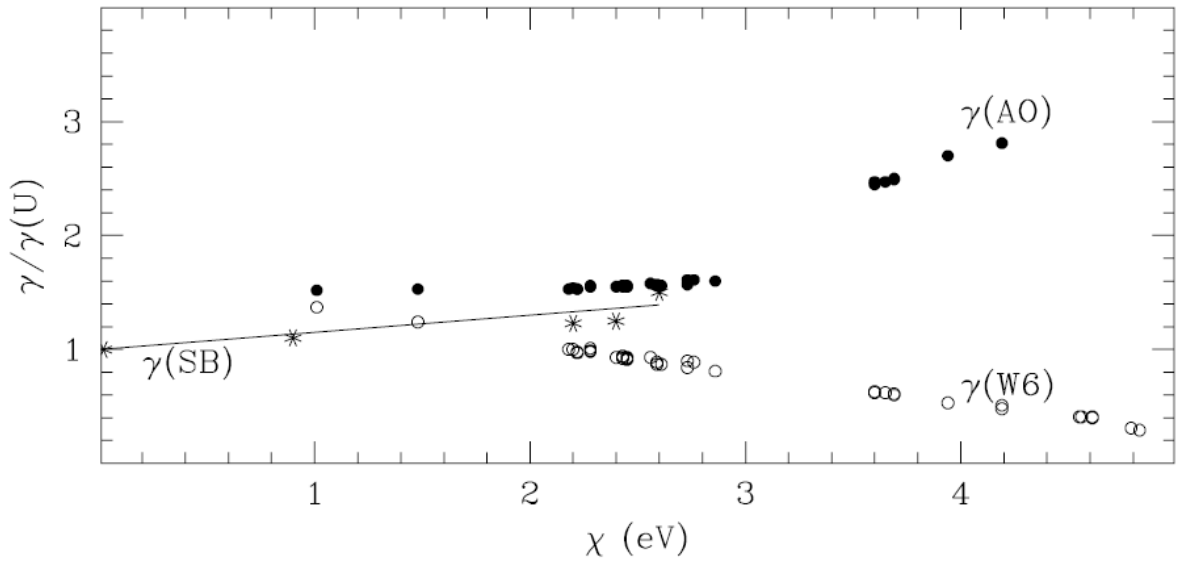

**Fixing log g can lead to incorrect other parameters**

# Astrophysical gf values

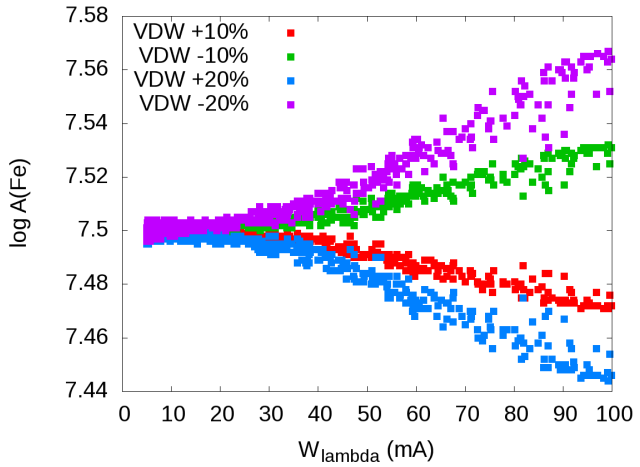
- Pros:
  - For Sun well known parameters
  - Differential results
    - Improved precision
- Cons:
  - Usually assumes shift only due to gf values
    - What about damping, microturbulence, etc?
- Widely-used and can give good results
  - But, values do depend on model and assumed parameters.

# Collisional Broadening

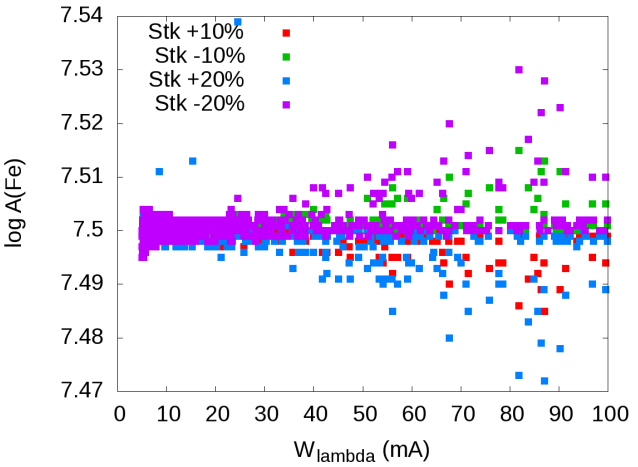
- Ryan 1998 (A&A, 331, 1051)
  - Even weak lines can be affected by damping
  - Damping errors depend on excitation potential
    - errors in $v_{mic}$ and $T_{eff}$



# Effect of damping

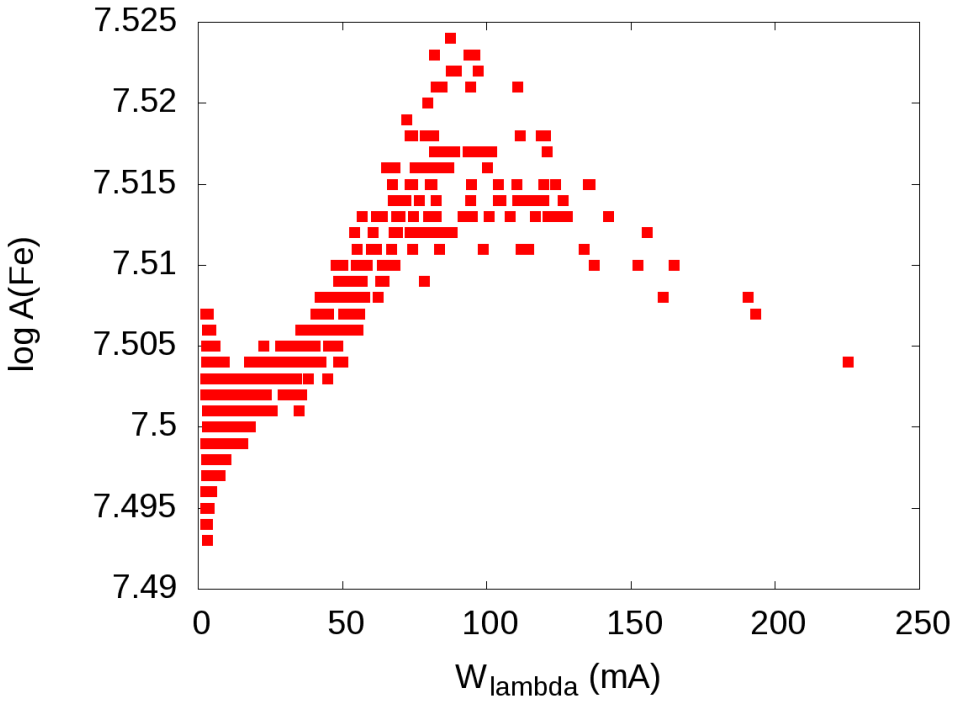


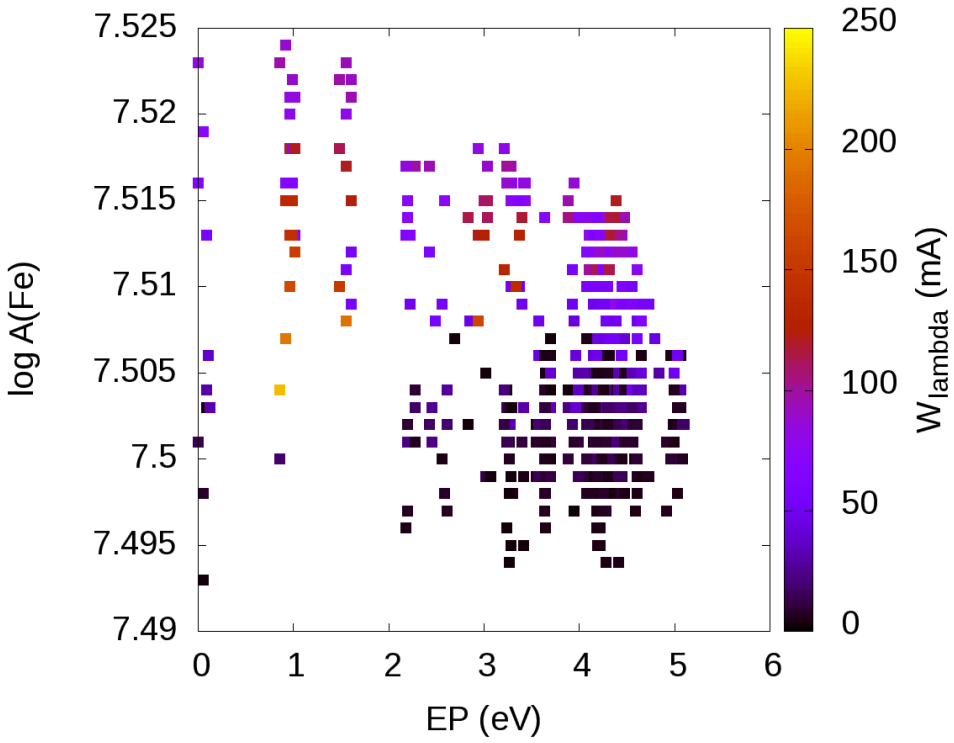

$T_{eff}$ 6000 K
Log g 4.5




- Errors in damping constants
  - van der Waals (left) and Stark (right)
- VDW could lead to errors in microturbulence

# Astrophysical gf Systematics



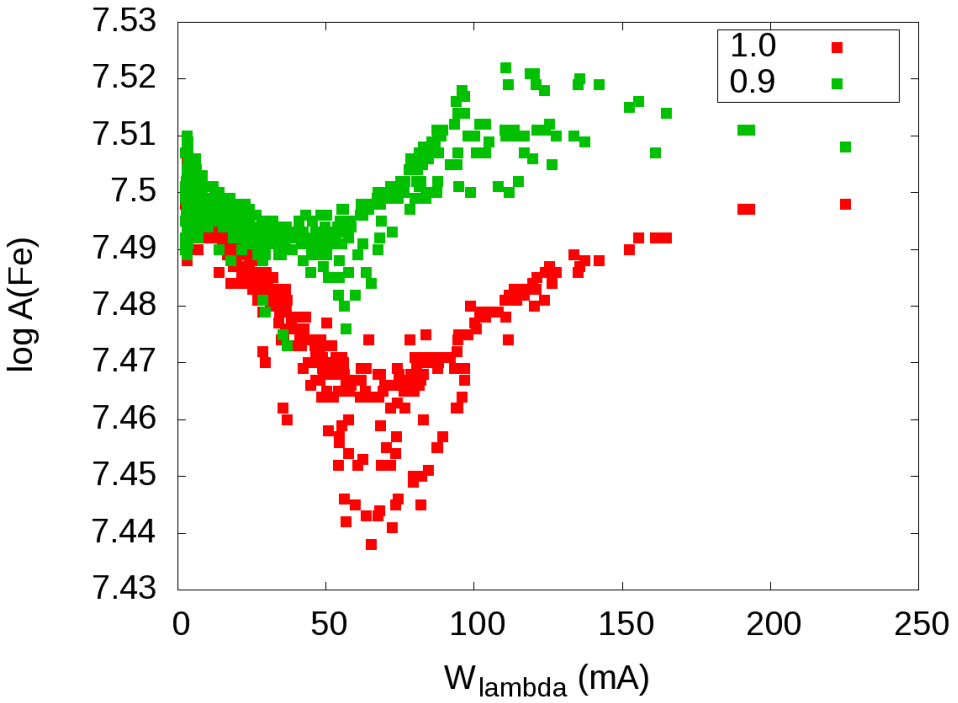

- Astrophysical gf values created at 6000 K but with +20% error in van der Waals damping.
  - Plots show difference in at 6500 K.

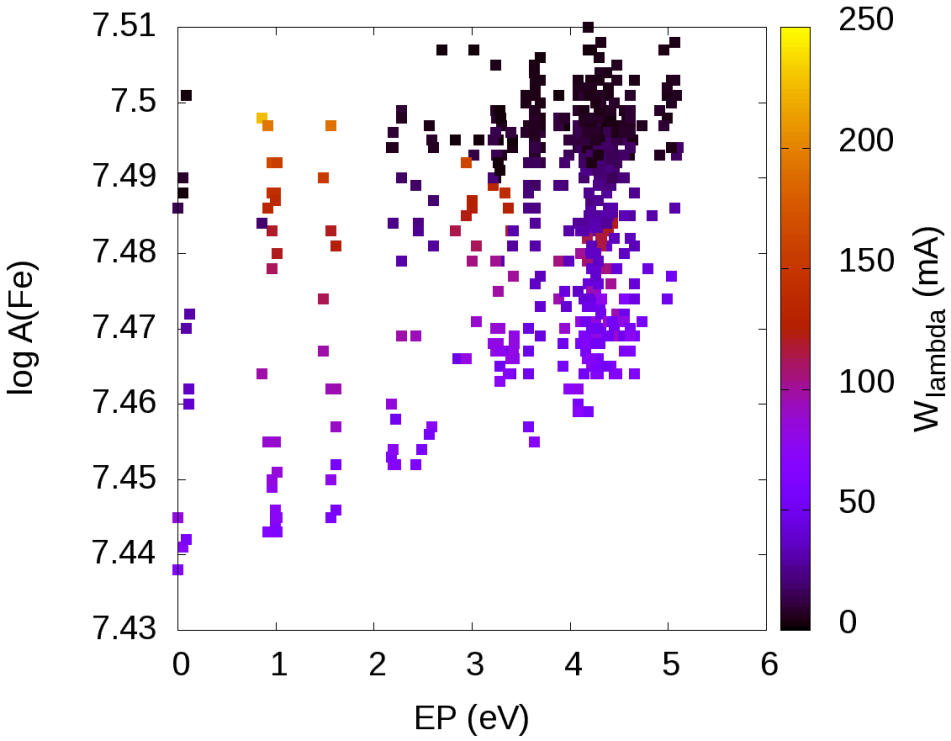
# Solar Microturbulence Value

- Edvardsson et al. 1993 (A&A, 275, 101) 1.15 km/s
- Bruntt et al. 2010 0.95 km/s
- Valenti & Fischer 2005  0.85 km/s
- Santos et al. 2004, (A&A, 415, 1153) 1.00 km/s
- Magain (1984)  0.85 km/s (centre of solar disk)
  - From Blackwell et al. 1984, (A&A,132, 236) using Holweger & Mueller 1974, (SoPh, 39, 19) Solar model

Which to use in Astrophysical gf determination?

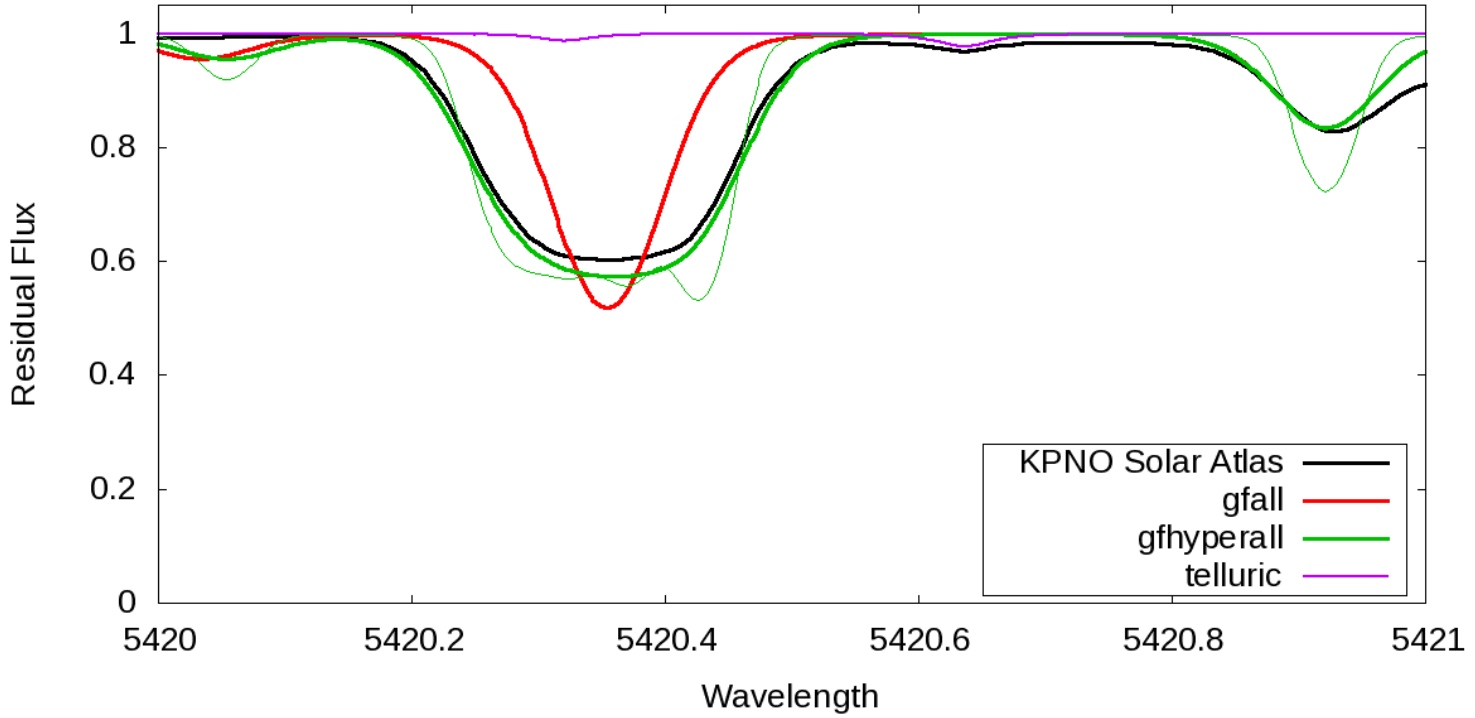
# Astrophysical gf Systematics




- Astrophysical gf values created at 6000 K but with microturbulence too low by 0.1 km/s.
  - 0.9 km/s instead of "*true*" 1.0 km/s
- Plots show difference at 6500 K

# Hyperfine Structure



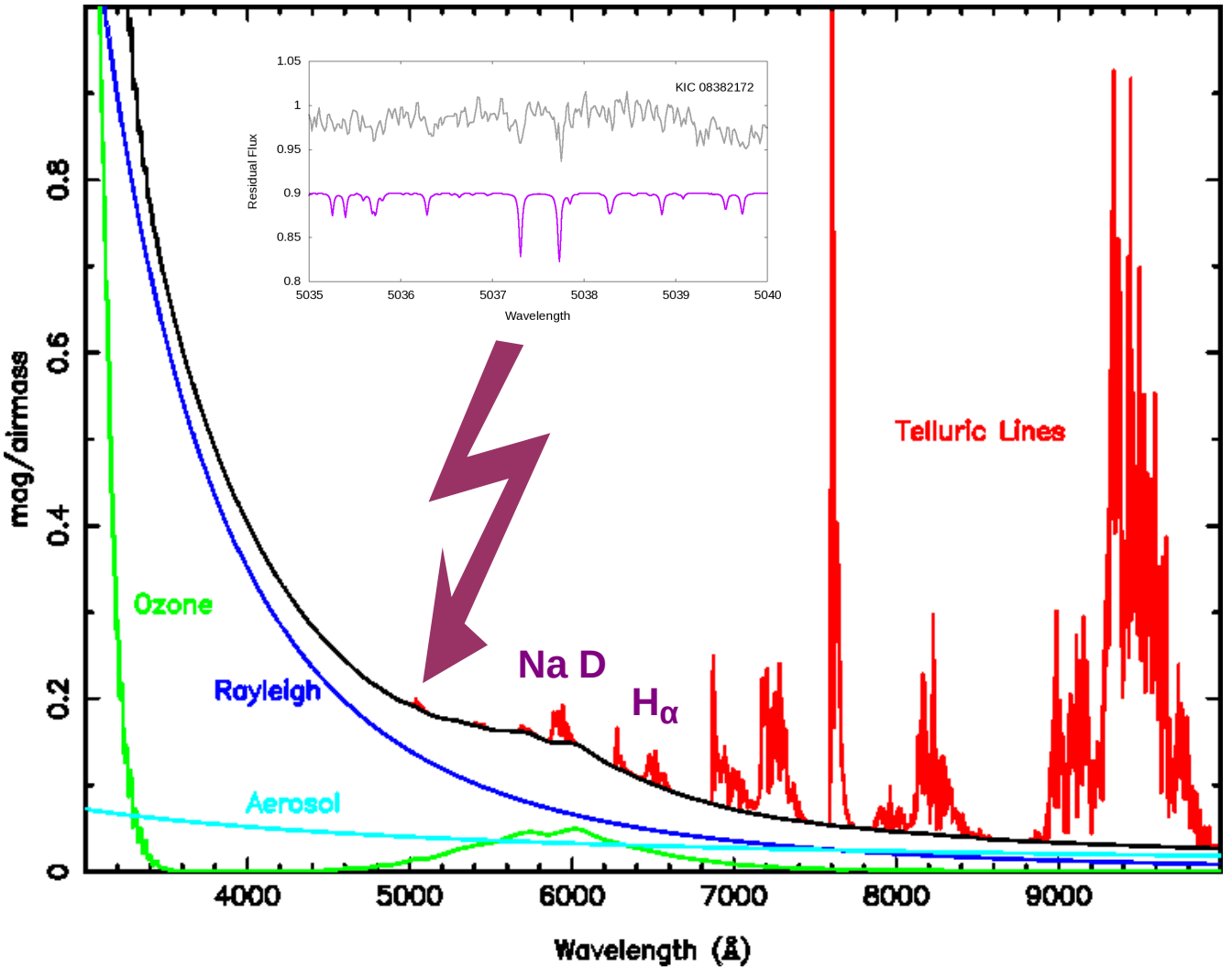

Solar Mn I line at 5420Å

- The splitting of energy levels in odd atomic elements
  - Multiple components to spectral lines
    - See Wahlgren, 2005, MSAIS, 8, 108

# Observational Systematics

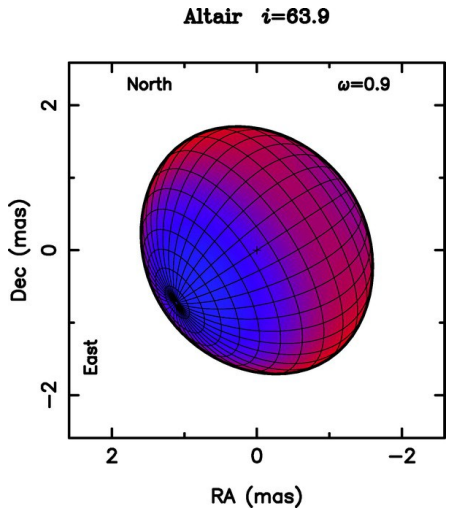
- Scattered light
  - Weakens spectral lines
    - incorrect abundances if not corrected for
- Noise affects continuum determination
  - Hides weak lines
    - Systematic over/under estimation of continuum?
  - Thus uncertainties and systematics in
    - Equivalent width measurements
    - Line profile fitting

# Telluric lines



# Stellar Physics

- Convection and Turbulence
- Rotation
  - Differential
  - Oblateness
  - Gravity darkening
- NLTE
- Inhomogeneity
  - Surface “spots”
  - Stratification “clouds”
  - Pulsations




Altair's surface temperature varies from 8740 K at the pole to 6890 K at equator. Peterson et al., 2006, ApJ, 636, 1087

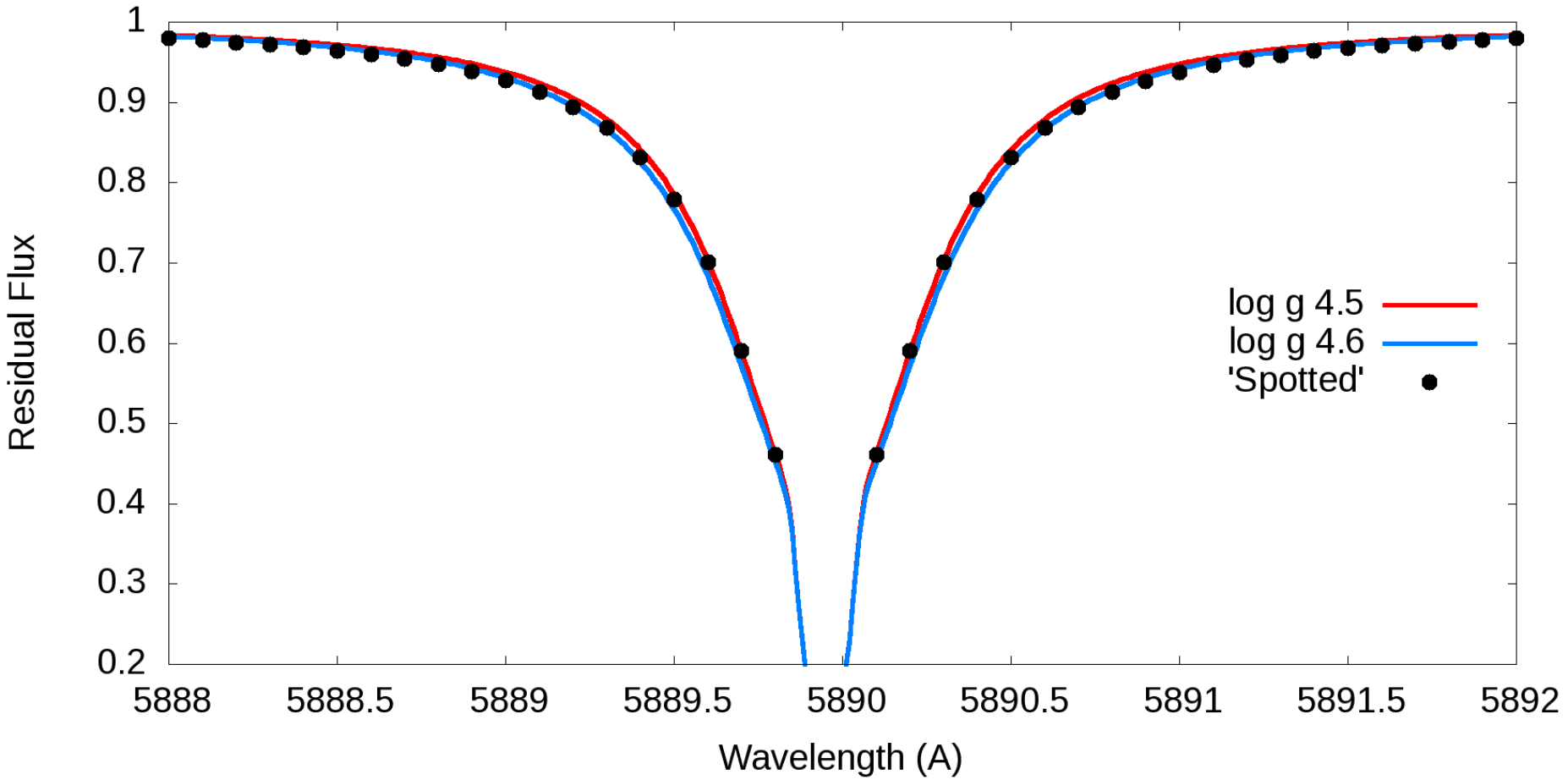
# Starspots

- Simulate a spotted stars with 5% spot coverage.
- Take 6000,4.5 and 5000,4.5 models
- Generate spectra and combine 95%, 5%
- Fit with single $T_{eff}$ model
- $H_{\alpha}$ gives 5950K. Agrees with Stefan's Law:

$$\left(0.95\times 6000^4 + 0.05\times 5000^4\right)^{1/4} = 5953$$

- But, what log g does Na D give?

# Effect of “Spot” on Na D line

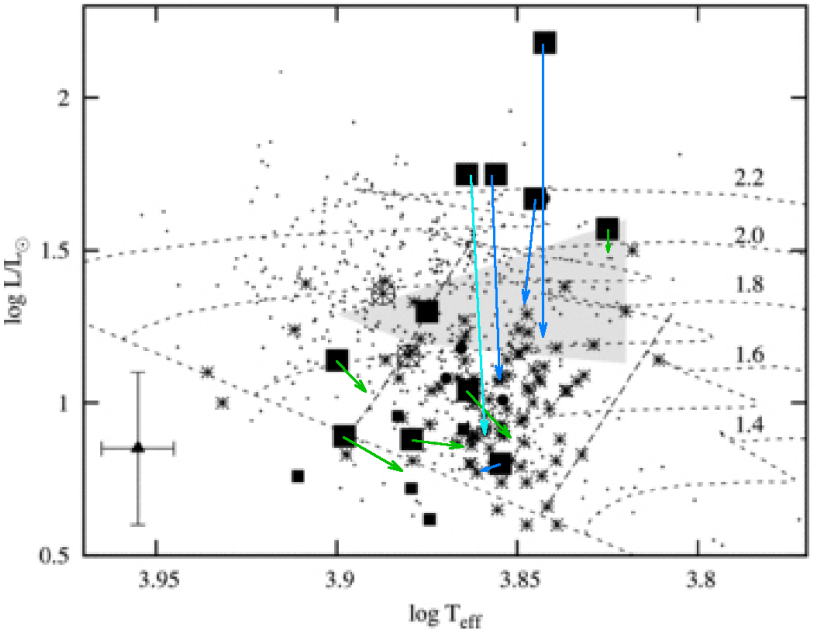



**Spectroscopic log g overestimated in spotted stars?**

# A few Examples from the Literature

# Log g of Am stars

- Literature values:
  - spectroscopic (blue)
  - photometric (green)
    - log L from log g
- compare to
  - *uvby Teff*
  - Hipparcos log L




Balona et al., 2011, MNRAS, 414, 792

An apparently modest error in log g (~0.5 dex) could cause a large errors in position in HR Diagram

# WASP-13

SPECTROSCOPICALLY-DETERMINED STELLAR PARAMETERS OF WASP-13

Spread in values

| | | SME | EW/ UCLSYN Doyle | C | ARES/ MOOG Sousa | Weighted Mean* |
|---|---|---|---|---|---|---|
| | | Unconstrained | | | | |
| $T_{\rm eff}$ (K) | 106 | $6003 \pm 65$ | $5955 \pm 75$ | $5919 \pm 30$ | $6025 \pm 21$ | $5989 \pm 16 \pm 48$ |
| $\log g$ | 0.17 | $4.16 \pm 0.08$ | $4.13 \pm 0.11$ | $4.02 \pm 0.06$ | $4.19 \pm 0.03$ | $4.16 \pm 0.03 \pm 0.07$ |
| $\log A$(Fe) | 0.06 | $7.54 \pm 0.06^{\dagger}$ | $7.60 \pm 0.09$ | $7.54 \pm 0.05^{\dagger}$ | $7.58 \pm 0.05^{\dagger}$ | $7.56 \pm 0.03 \pm 0.03$ |
| [Fe/H] | | $0.04 \pm 0.05$ | $0.10 \pm 0.09^{\dagger}$ | $0.04 \pm 0.02$ | $0.08 \pm 0.02$ | $0.06 \pm 0.01 \pm 0.03$ |
| $v \sin i$ (km s$^{-1}$) | | $5.79 \pm 0.08$ | $5.26 \pm 0.25$ | ... | ... | $5.74 \pm 0.08 \pm 0.38$ |
| $v_{\rm t}$ (km s$^{-1}$) | | $1.01 \pm 0.17^{\ddagger}$ | $0.95 \pm 0.10$ | $1.53 \pm 0.09$ | $1.28 \pm 0.10$ | $1.27 \pm 0.06 \pm 0.29$ |

- $H_{\alpha}$ 5950 ± 70 K;  log g(Transit) 4.10 ± 0.04
- SPC: 5982 ± 50 K (Torres et al. 2012, ApJ, 757, 161)
- IRFM: 5935 ± 183 K

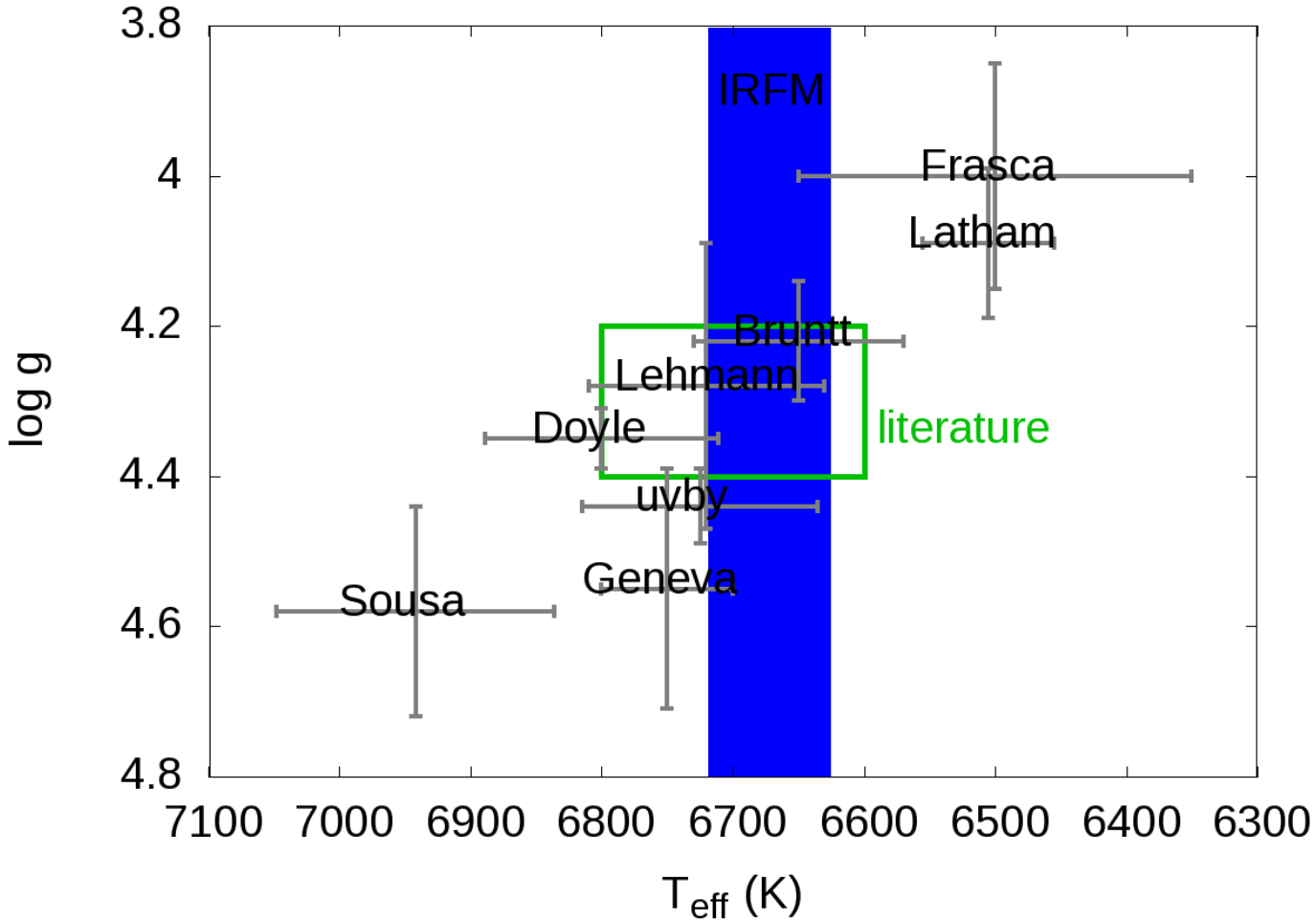
Gómez Maqueo Chew, et al., 2013, ApJ, accepted

# Θ Cyg

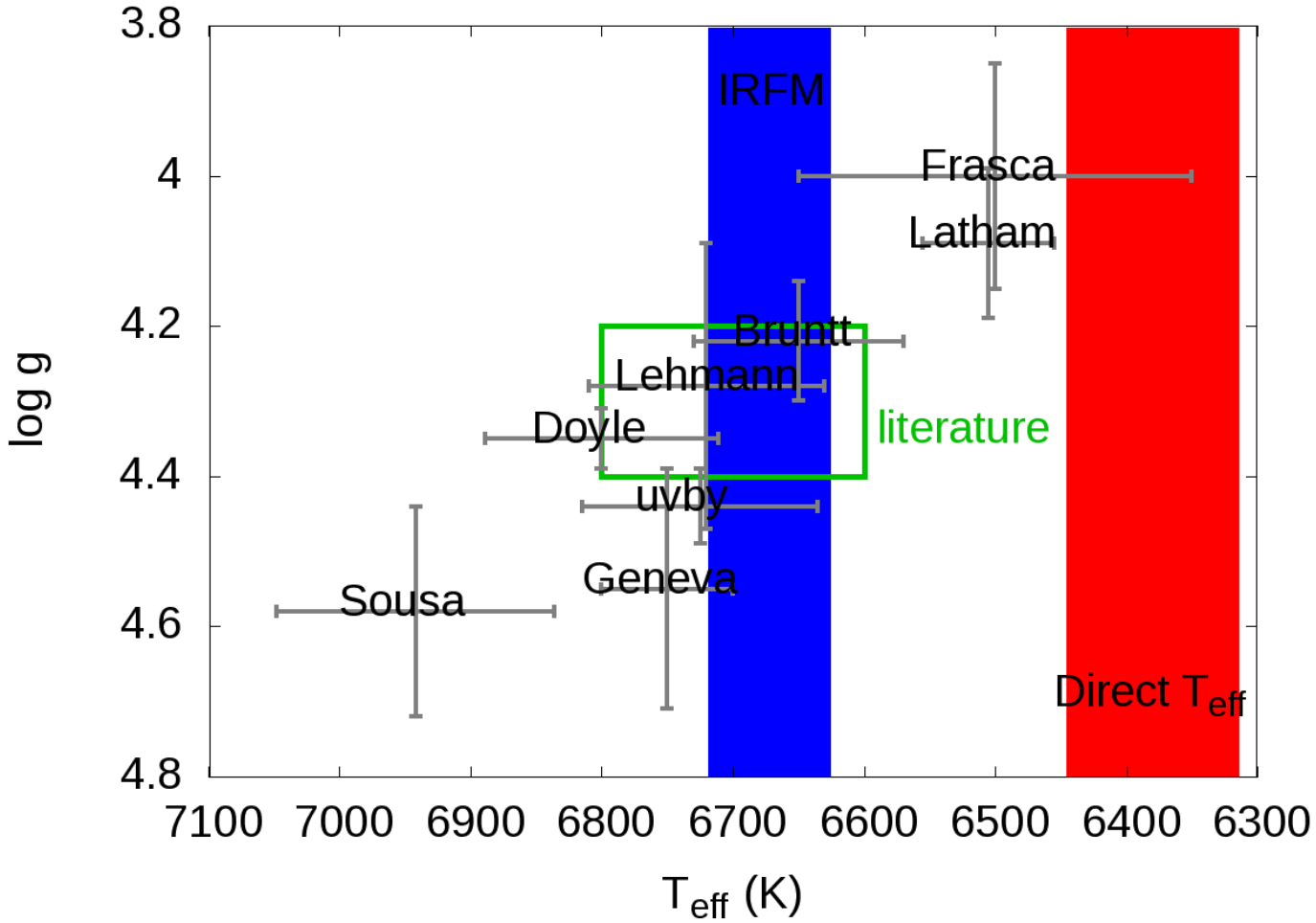
- 4-mag - Brightest in Kepler Field
  - Low-mass close companion
  - c.p.m. M-type wide companion
- Literature suggests it is a normal slowly-rotating solar-composition F5IV-type star
  - Teff ~ 6700 ± 100 K
  - Log g ~ 4.3 ± 0.1 dex
- Six Independent analyses...


Guzik et al. In prep

# Θ Cyg


3.8
4
4.2
4.4
4.6
4.8
log g
7100
7000
6900
6800
6700
6600
6500
6400
6300
T_eff (K)
IRFM
Frasca
Latham
Bruntt
Lehmann
Doyle
literature
uvby
Geneva
Sousa

# Θ Cyg


3.8
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4.6
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log g
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6400
6300
T_eff (K)
IRFM
Direct T_eff
literature
Frasca
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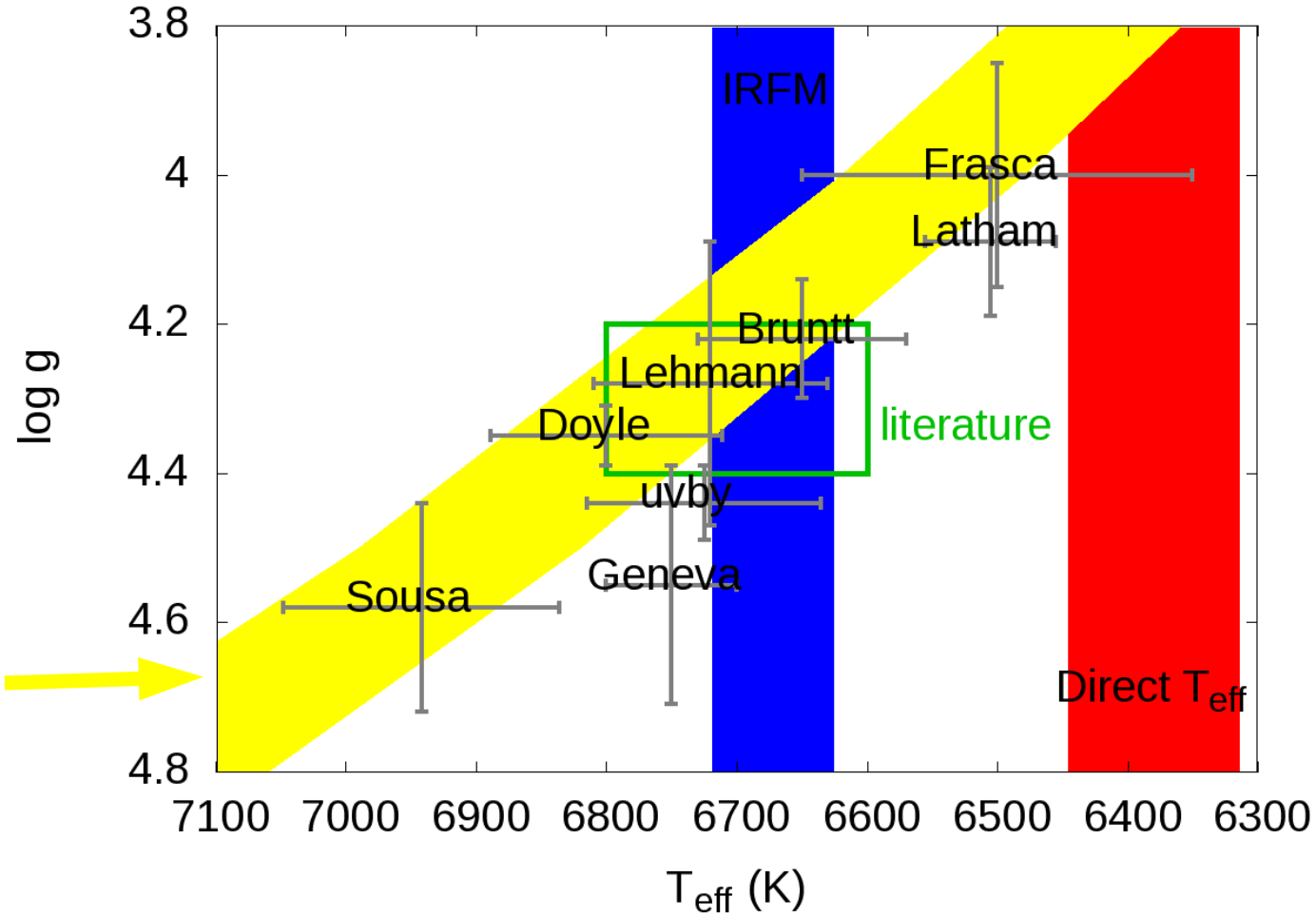
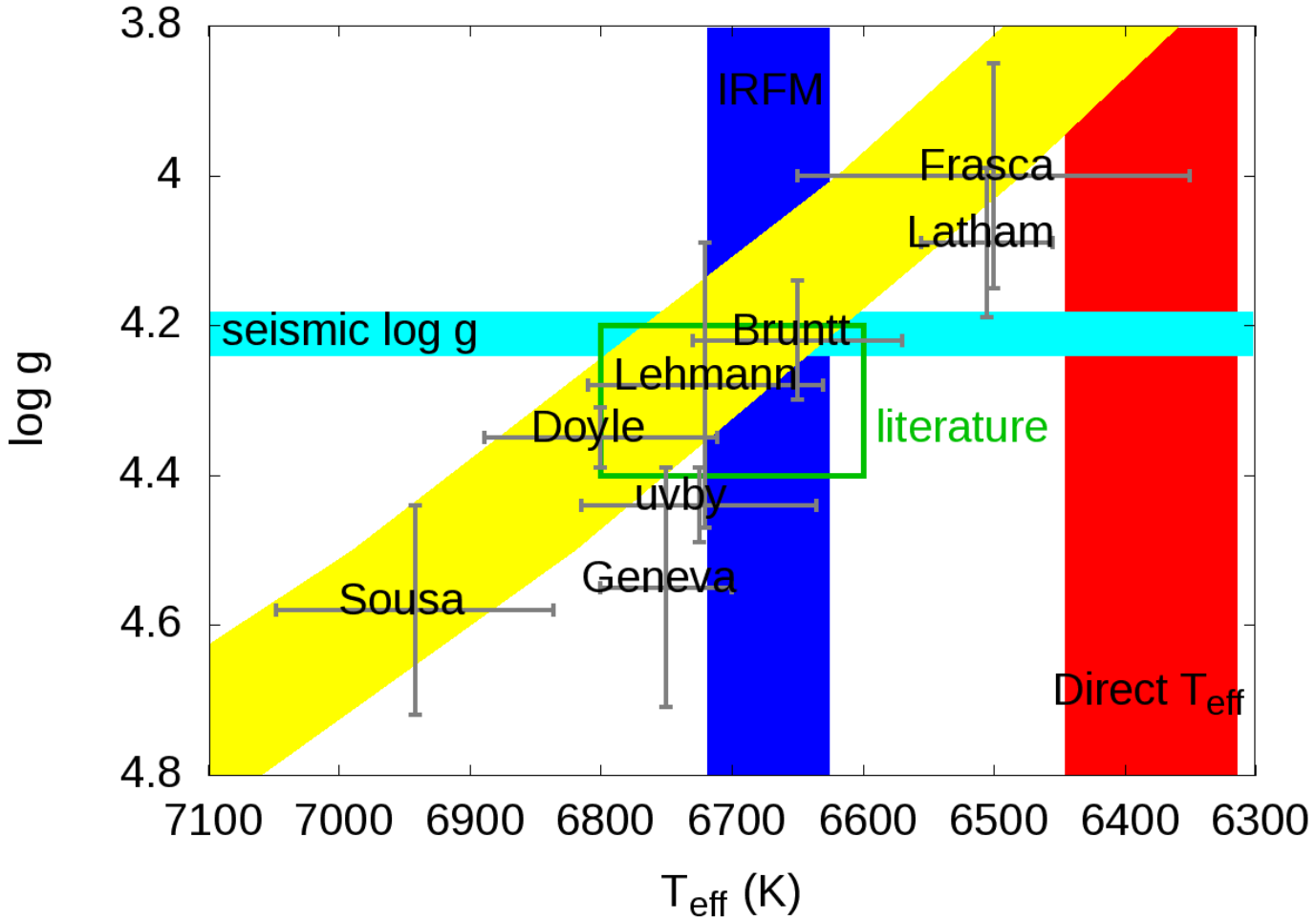



Fe I/Fe II Ionization balance

# Θ Cyg


3.8
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4.2
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log g
7100
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6400
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T_eff (K)
IRFM
Direct T_eff
seismic log g
literature
Frasca
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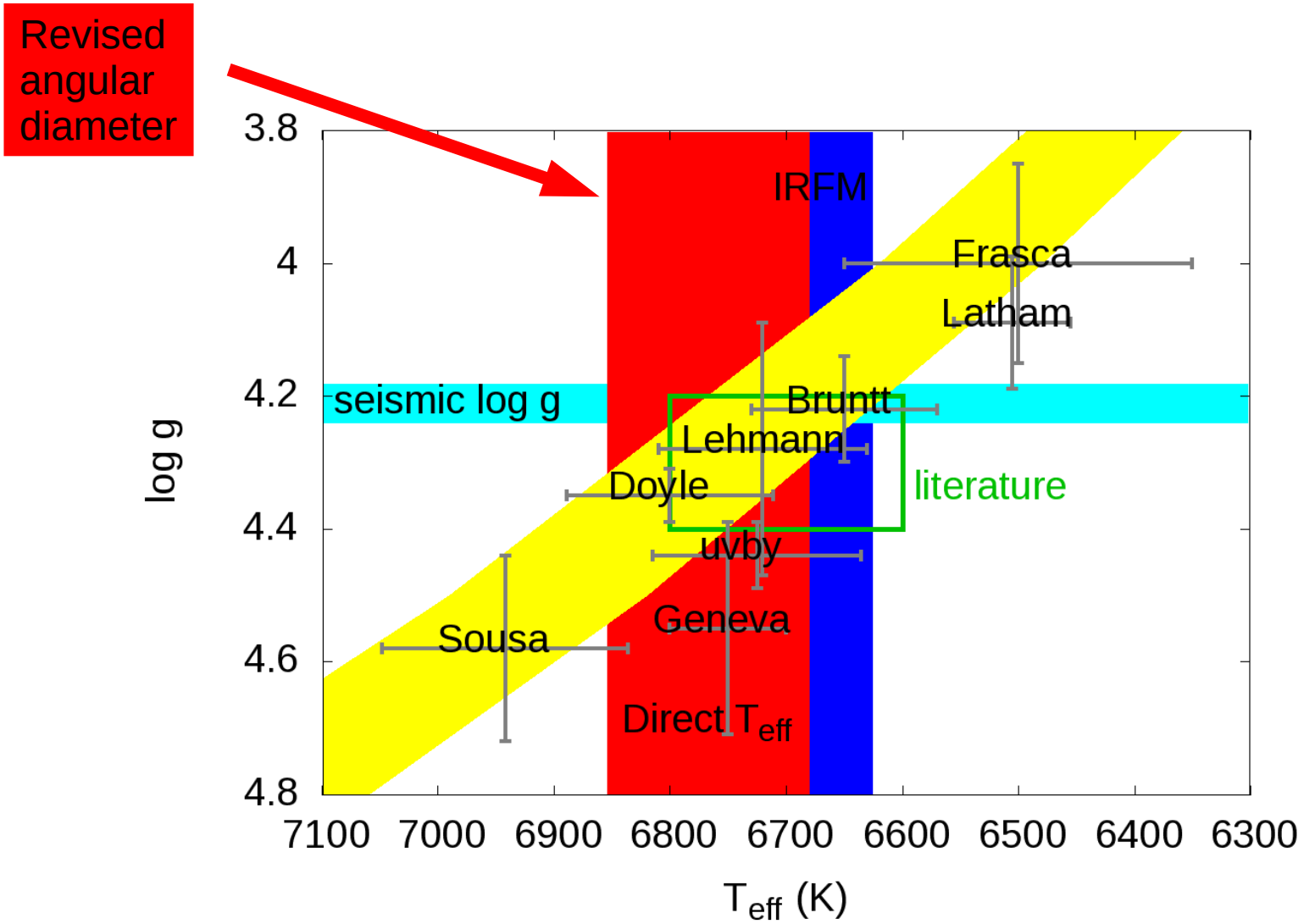
Sousa

# Θ Cyg


Revised angular diameter
IRFM
Frasca
Latham
seismic log g
Bruntt
Lehmann
Doyle
literature
uvby
Geneva
Sousa
Direct $T_{eff}$
log g
3.8
4
4.2
4.4
4.6
4.8
7100
7000
6900
6800
6700
6600
6500
6400
6300
$T_{eff}$ (K)

# Summary

- There are ***(too)*** many factors which influence the results.
- Use as many diagnostics as possible
  - Spectroscopic and photometric
- Realistically the typical errors:
  - $T_{\rm eff}$ ± 50~100K
  - log $g$ ± 0.1~0.2 dex
  - Abundances ± 0.05~0.10 dex

High precision fitting to high S/N data is possible, but overall accuracy of parameters is less certain.