# GAIA FGK BENCHMARK STARS

## LOOKING FOR THE REPRESENTATIVES OF THE STARS IN THE MILKY WAY

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*Blanco-Cuaresma, Hawkins, Cantat-Gaudin, Nordlander, Guiglion*

# MOTIVATION

- The need of reference stars to validate/calibrate methods to analyse the Gaia-related spectroscopic surveys is **evident and fundamental**.

# REQUIREMENTS FOR A STAR TO BE "GRANTED" AS BENCHMARK

- Accurate parallax
- Angular diameter
- Bolometric flux
- mass

*TEFF and LOGG from fundamental relations*

- High-res and high SNR spectra

*Metallicity and elemental abundances from spectroscopy*

- Typical Milky Way star

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- Accurate parallax
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*TEFF and LO*
*fundamenta*

- High-res and high SNR spectra

*Metallicity and elemental abundances from spectroscopy*

- Typical Milky Way star

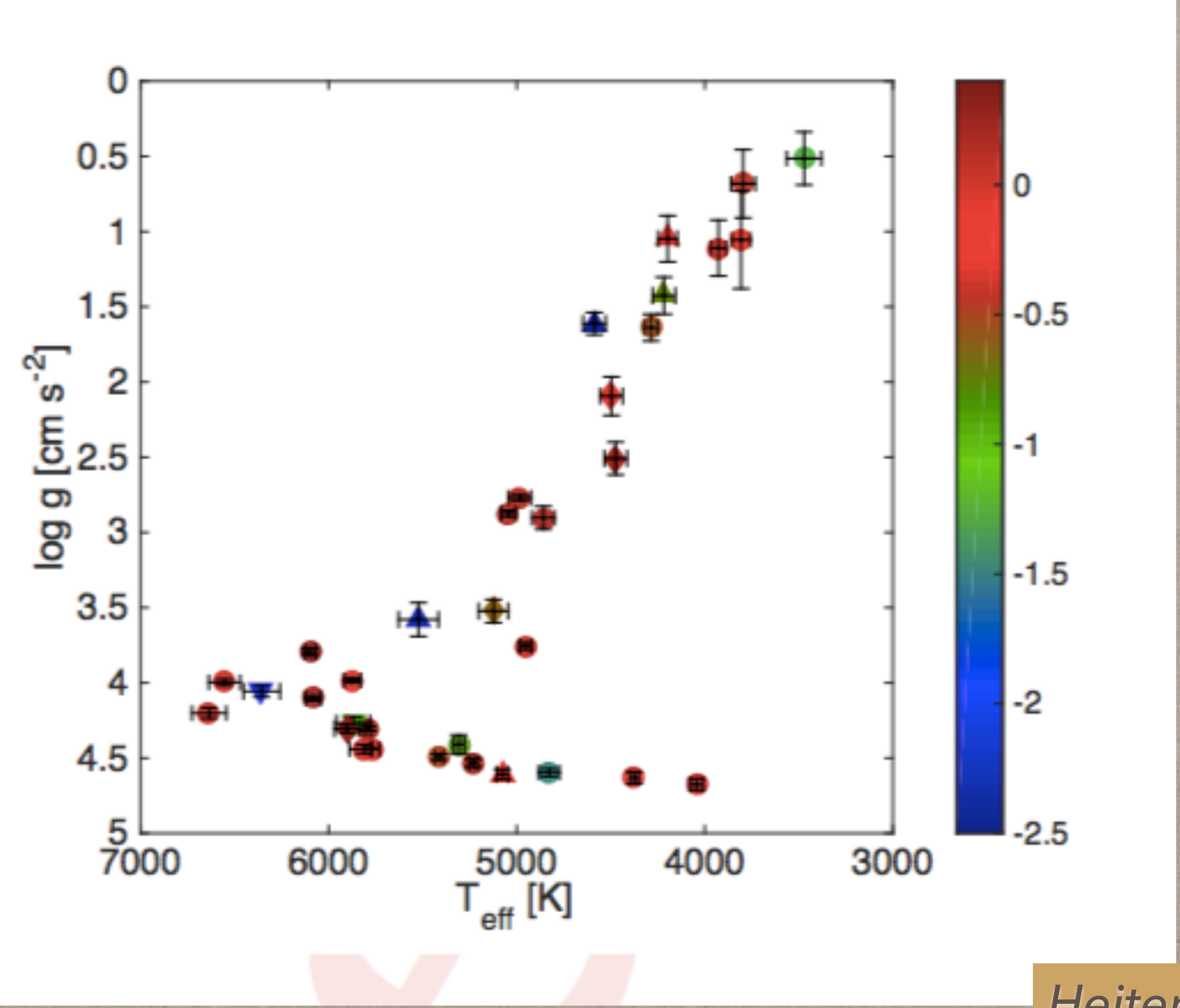
***Stars need to be close-by, bright and with a large angular size***

***Ideally seismic targets or binaries for the mass determination***

***Stars need to cover different parts of the HR diagram and have an extended metallicity distribution***

# GAIA BENCHMARK STARS FIRST SET

*34 very bright and well known stars, including the Sun*




*Heiter et al (submitted)*

# PARAMETERS

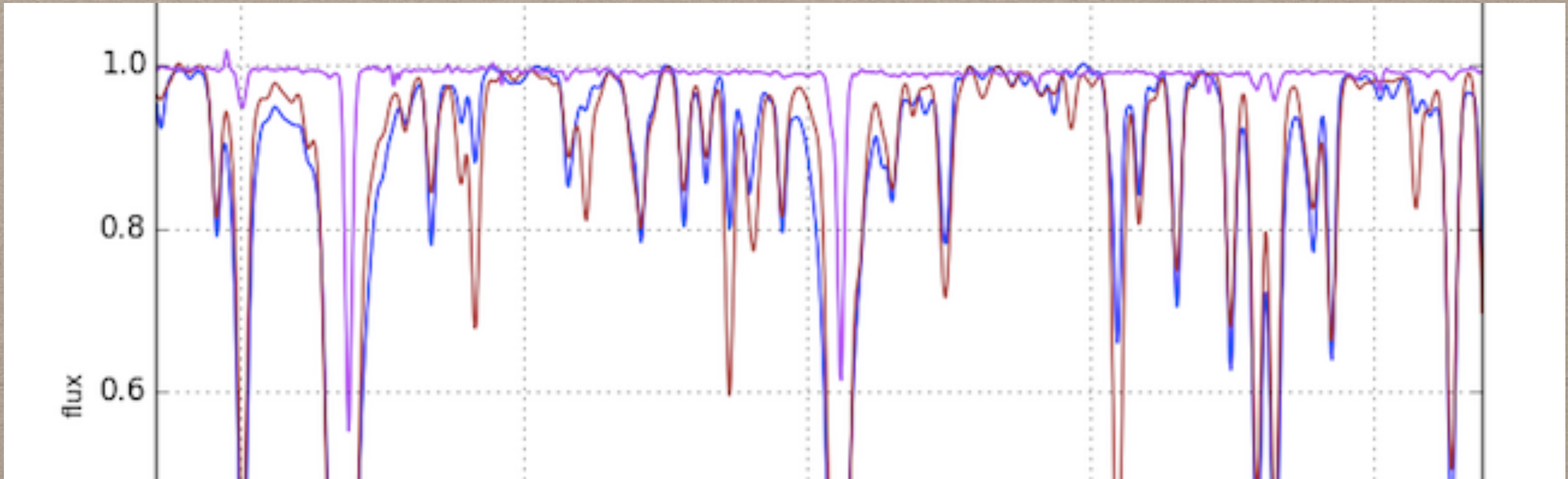
*I: Heiter et al 2015 (submitted)*
*II: Blanco-Cuaresma et al (2014)*
*III: Jofré et al (2014)*
*IV: Jofré et al 2015a (submitted)*
...

- Effective temperature and surface gravity from FUNDAMENTAL relations

$$L = 4\pi R^2 \sigma T_{\rm eff}{}^4,$$

$$g = GM/R^2$$

- Metallicity and abundances from high-resolution spectroscopy combining several classical methods



# PRODUCTS AND APPLICATIONS

- we have fundamental Teff and logg for 34 very different stars
- we provide abundances of Fe – Mg, Ca, Si, Ti, Sc, V, Cr, Mn, Co, Ni at
  - line-by-line basis
  - method-by-method basis
  - flags: which lines are recommended for different kind of stars

# PRODUCTS AND APPLICATIONS

- we have high-resolution spectra in long wavelength coverage : we ``create survey-like” spectra for several surveys  and projects
  - **Gaia-ESO (Smiljanic, Recio-Blanco)**
  - **Gaia (DPAC - CU8 - EPC)**
  - RAVE (Kordopatis)
  - GALAH (de Silva)
  - ESO - AMBRE (de Pascale)
  - SDSS (Schönrich/Bergemann)

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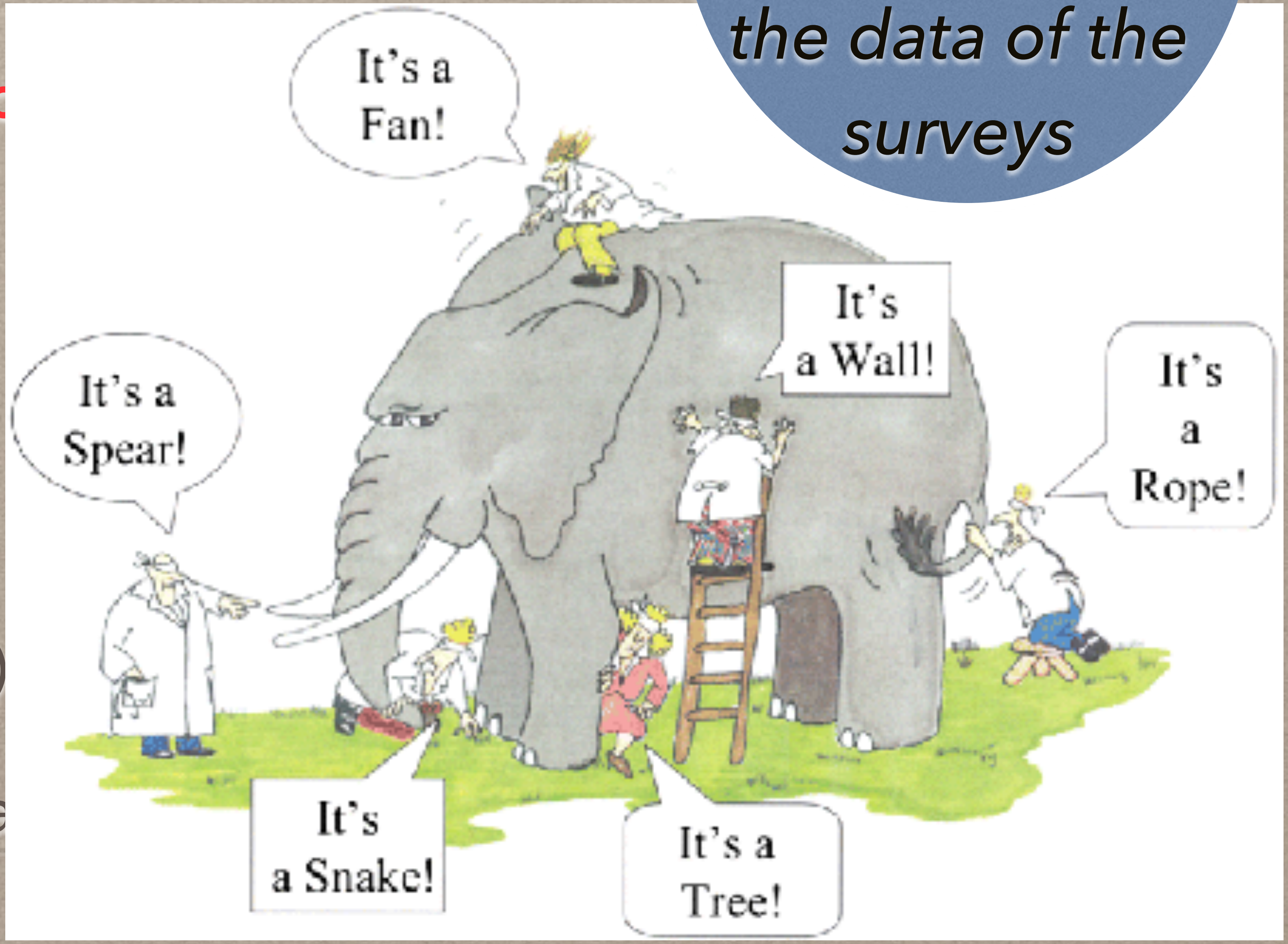
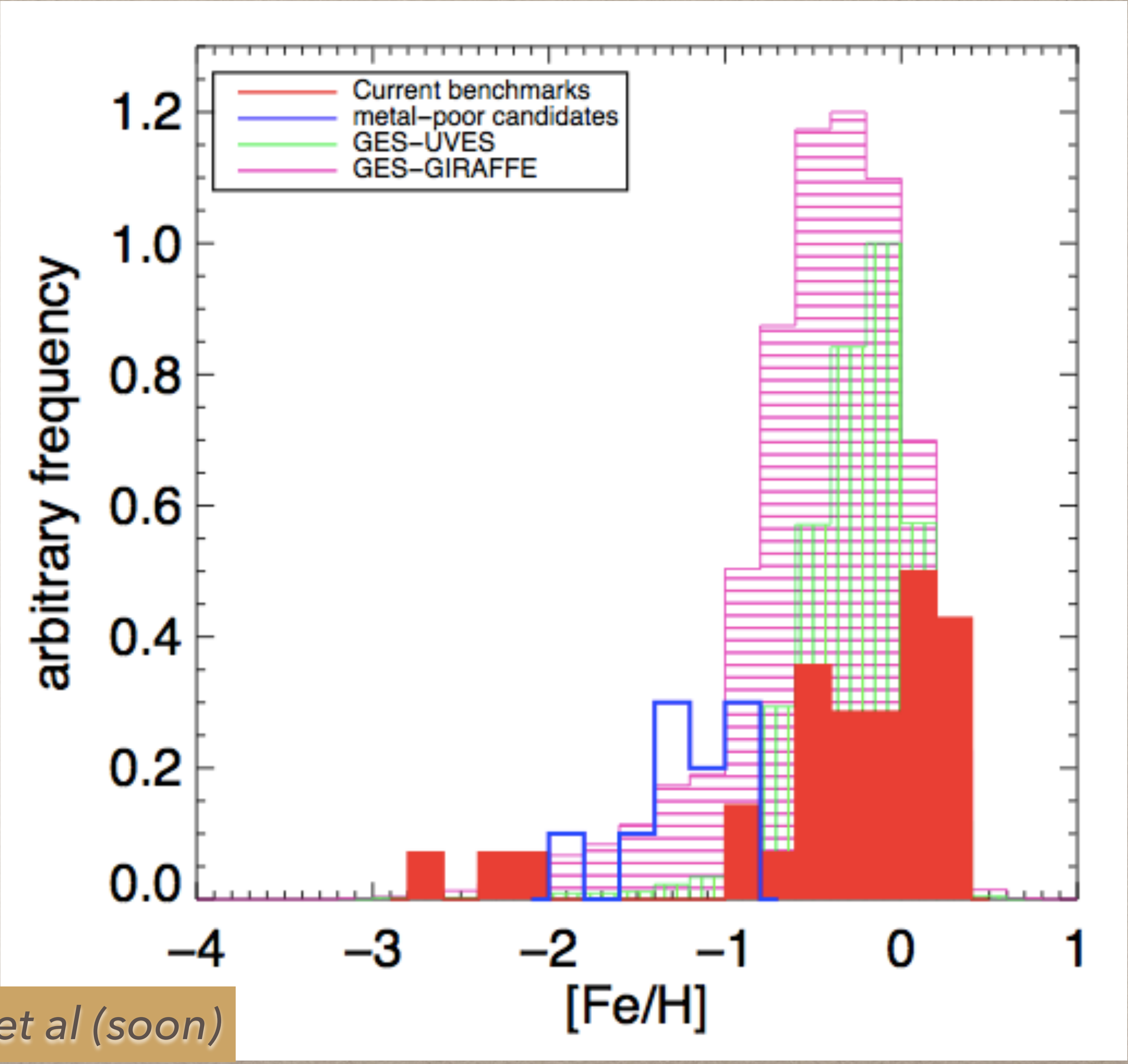
*a first step towards systematically linking/scaling the data of the surveys*



# LOOKING FOR THE BEST REPRESENTATIVE STARS IN THE MILKY WAY

***what is being improved***

*metallicity distribution*




*Hawkins, Jofré, et al (soon)*

# LOOKING FOR THE B
# REPRESENTATIVE ST
# MILKY WAY

Heiter et al (submitted)

| Name | $T_{\rm eff}$ | $u(T_{\rm eff})$ | $\%u(T_{\rm eff})$ | $\log g$ | $u(\log g)$ |
|---|---|---|---|---|---|
| | [K] | | | [cm s$^{-2}$] | |
| **F dwarfs** | | | | | |
| Procyon | 6554 | 84 | 1.28 | 4.00 | 0.02 |
| HD 84937 | 6356 | 97 | 1.52 | 4.06 | 0.04 |
| HD 49933 | 6635 | 91 | 1.38 | 4.20 | 0.03 |
| **FGK subgiants** | | | | | |
| $\delta$ Eri | 4954 | 30 | 0.61 | 3.76 | 0.02 |
| HD 140283 | [5522] | [105] | [1.91] | 3.58 | 0.11 |
| $\epsilon$ For | 5123 | 78 | 1.53 | [3.52] | [0.08] |
| $\eta$ Boo | 6099 | 28 | 0.45 | 3.79 | 0.02 |
| $\beta$ Hyi | 5873 | 45 | 0.77 | 3.98 | 0.02 |
| **G dwarfs** | | | | | |
| $\alpha$ CenA | 5792 | 16 | 0.27 | 4.31 | 0.01 |
| HD 22879 | 5868 | 89 | 1.52 | 4.27 | 0.04 |
| Sun | 5771 | 1 | 0.01 | 4.4380 | 0.0002 |
| $\mu$ Cas | 5308 | 29 | 0.54 | [4.41] | [0.06] |
| $\tau$ Cet | 5414 | 21 | 0.39 | [4.49] | [0.02] |
| $\alpha$ CenB | 5231 | 20 | 0.38 | 4.53 | 0.03 |
| 18 Sco | 5810 | 80 | 1.38 | 4.44 | 0.03 |
| $\mu$ Ara | [5902] | [66] | [1.12] | 4.30 | 0.03 |
| $\beta$ Vir | 6083 | 41 | 0.68 | 4.10 | 0.02 |
| **FGK giants** | | | | | |
| Arcturus | 4286 | 35 | 0.82 | [1.64] | [0.09] |
| HD 122563 | 4587 | 60 | 1.31 | 1.61 | 0.07 |
| $\mu$ Leo | 4474 | 60 | 1.34 | 2.51 | 0.11 |
| $\beta$ Gem | 4858 | 60 | 1.23 | 2.90 | 0.08 |
| $\epsilon$ Vir | 4983 | 61 | 1.21 | 2.77 | 0.02 |
| $\xi$ Hya | 5044 | 40 | 0.78 | 2.87 | 0.02 |
| HD 107328 | 4496 | 59 | 1.32 | 2.09 | 0.13 |
| HD 220009 | [4217] | [60] | [1.43] | [1.43] | [0.12] |
| **M giants** | | | | | |
| $\alpha$ Tau | 3927 | 40 | 1.01 | 1.11 | 0.19 |
| $\alpha$ Cet | 3796 | 65 | 1.71 | 0.68 | 0.23 |
| $\beta$ Ara | [4197] | [50] | [1.20] | [1.05] | [0.15] |
| $\gamma$ Sge | 3807 | 49 | 1.28 | 1.05 | 0.32 |
| $\psi$ Phe | [3472] | [92] | [2.65] | [0.51] | [0.18] |
| **K dwarfs** | | | | | |
| $\epsilon$ Eri | 5076 | 30 | 0.60 | 4.61 | 0.03 |
| Gmb 1830 | [4827] | [55] | [1.14] | 4.60 | 0.03 |
| 61 Cyg A | 4374 | 22 | 0.49 | 4.63 | 0.04 |
| 61 Cyg B | 4044 | 32 | 0.78 | 4.67 | 0.04 |

***what is being improved***

*- some cases with uncertain parameters*

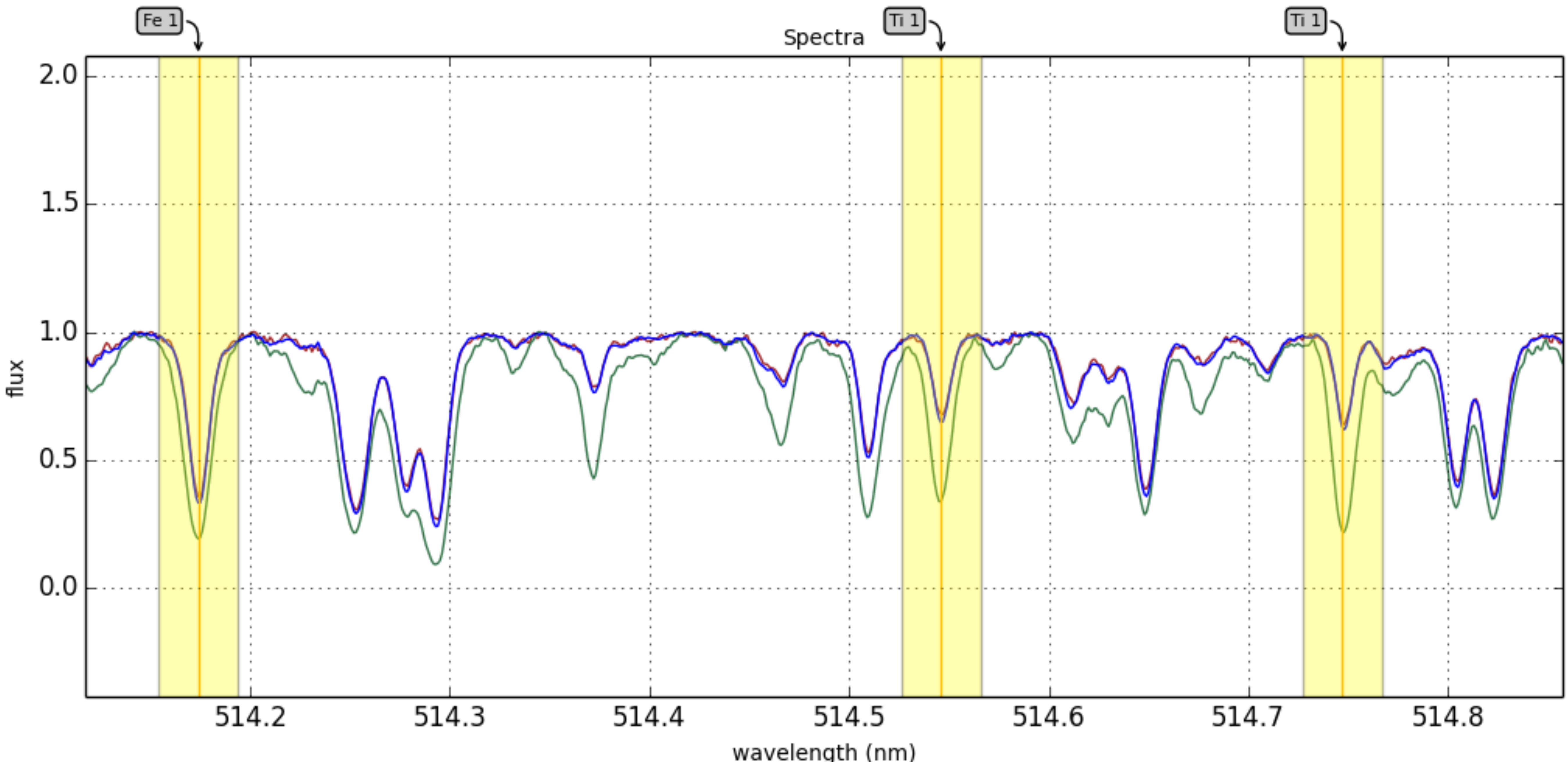
*- angular diameters are not homogeneous*

- Large observational campaigns with interferometry (CHARA and AMBER) to increase from 34 to 100 benchmark stars are on-going - so far ~20 new observations being analysed (PI: Karovicova)

# ARE THE 34 BENCHMARKS TYPICAL MILKY WAY STARS?

*How many benchmark stars twins are in e.g. the Gaia-ESO Survey?*

# FINDING TWINS - METHOD




400 pre-defined “golden" lines of 11 elements (Jofré et al 2014, 2015a) are used for finding twins

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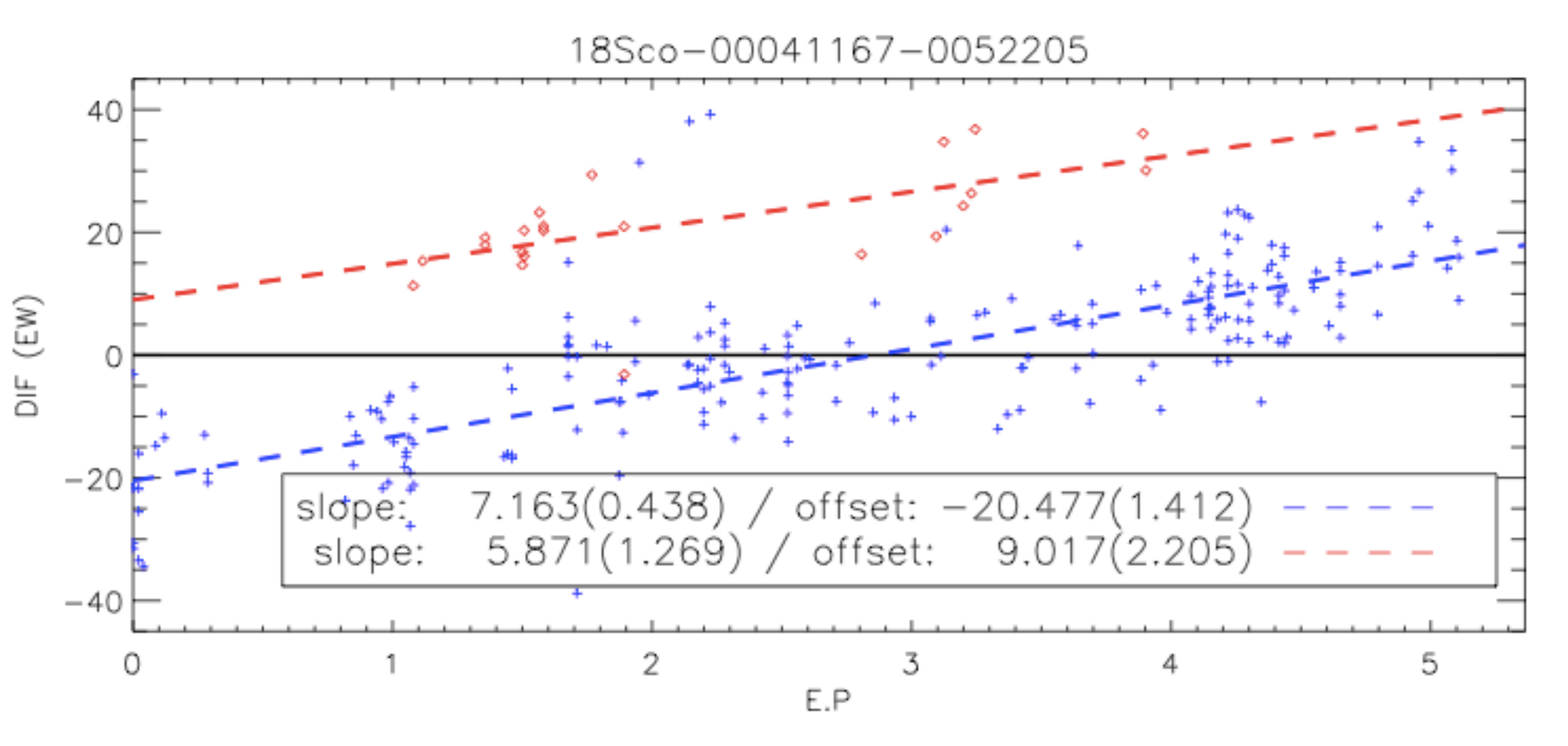

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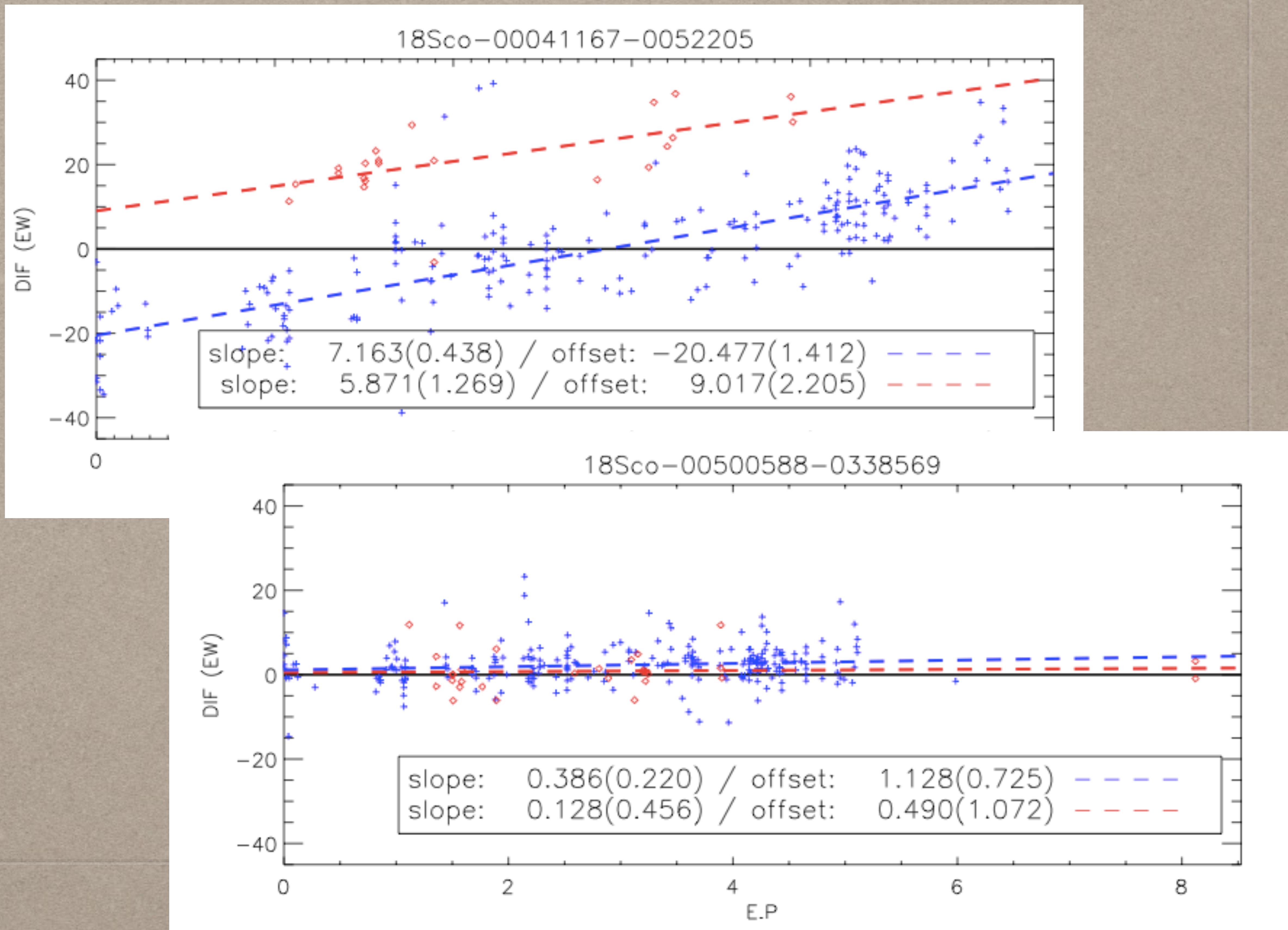
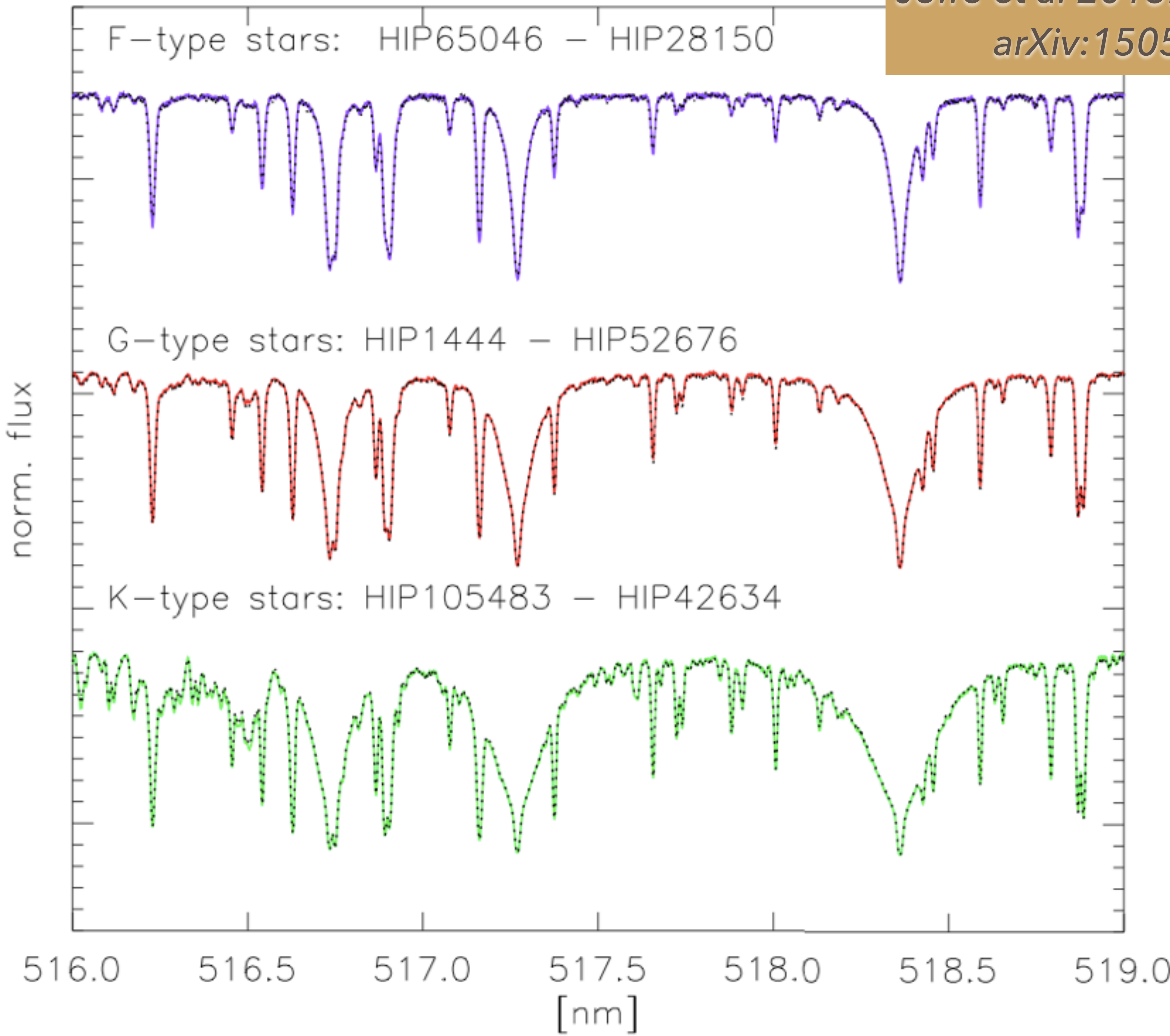
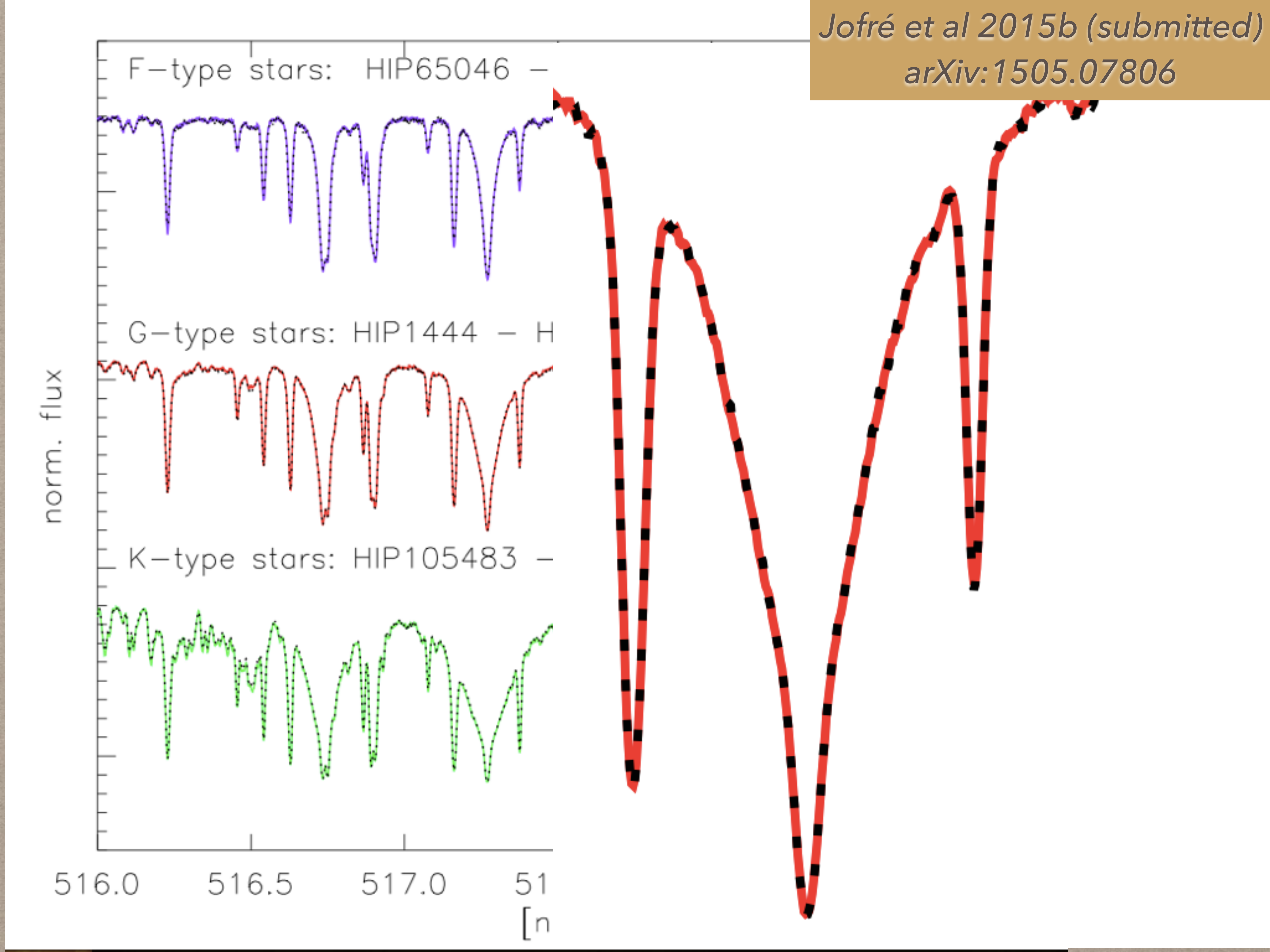
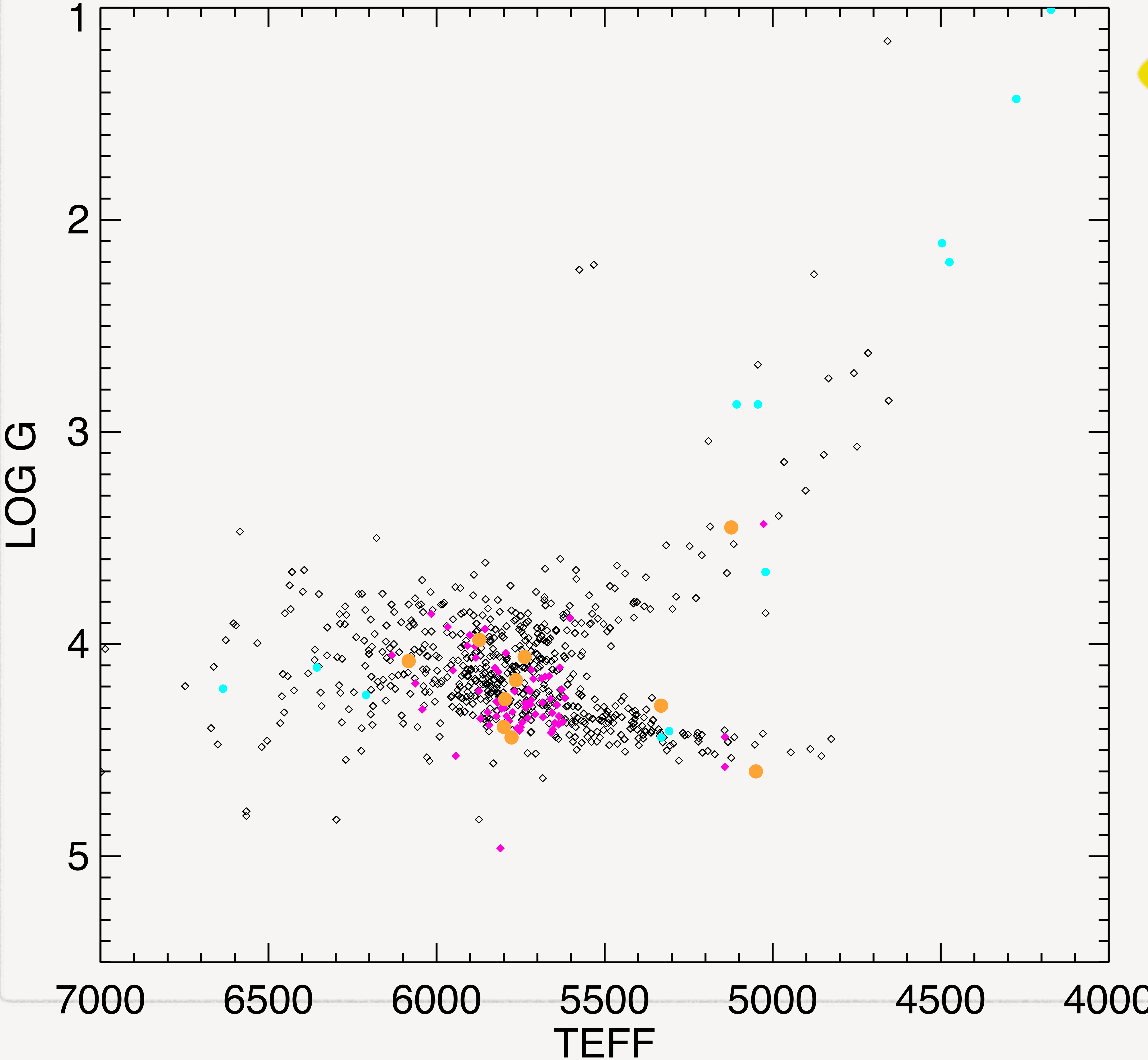


Jofré et al 2015b (submitted)
arXiv:1505.07806




Jofré et al 2015b (submitted)
arXiv:1505.07806
F−type stars: HIP65046 −
G−type stars: HIP1444 − H
K−type stars: HIP105483 −
norm. flux
516.0
516.5
517.0
51
[n

# DR4 MW UVES SNR>40

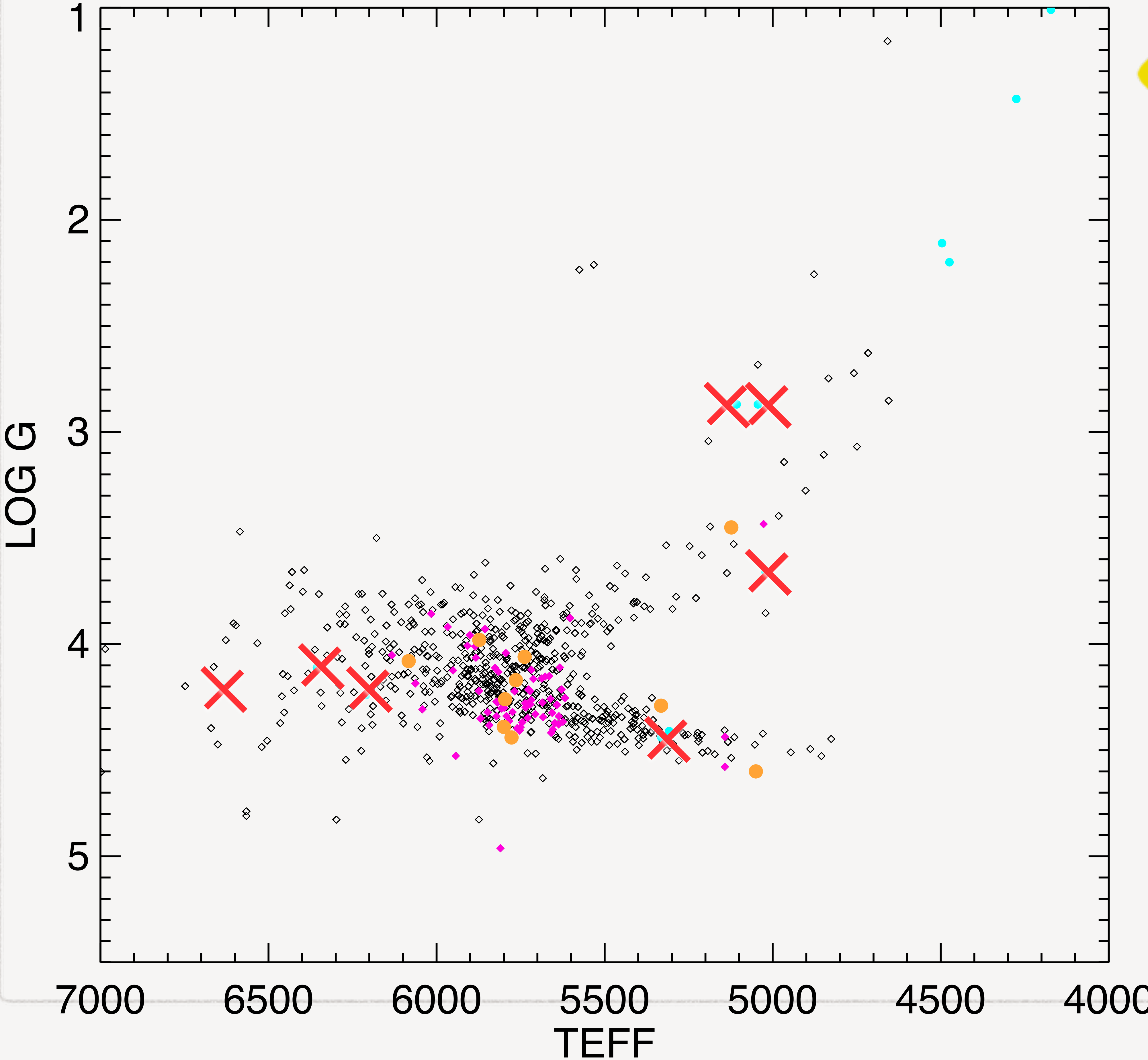



*~800 GES MW stars*

*~ 20 bmk GES spectra*

*~100 twins with 10 bmks*

# DR4 MW UVES SNR>40

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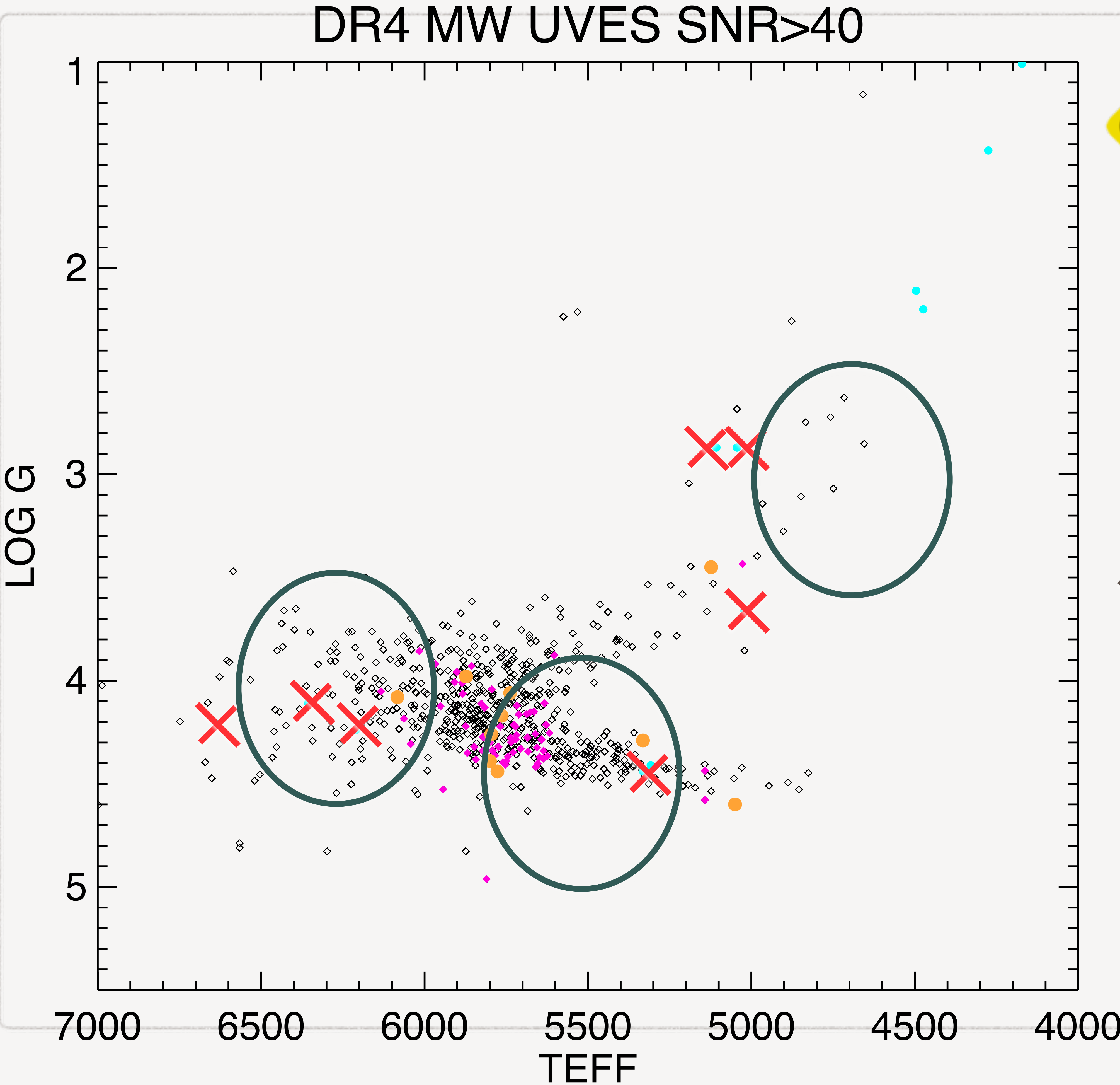


*~800 GES MW stars*

*~ 20 bmk GES spectra*

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# TWIN DISTANCES

Jofré et al 2015b (submitted)
arXiv:1505.07806

$$m_1 - m_2 = -5\log(d_1/d_2)$$

*Jofré et al 2015b (submitted)*
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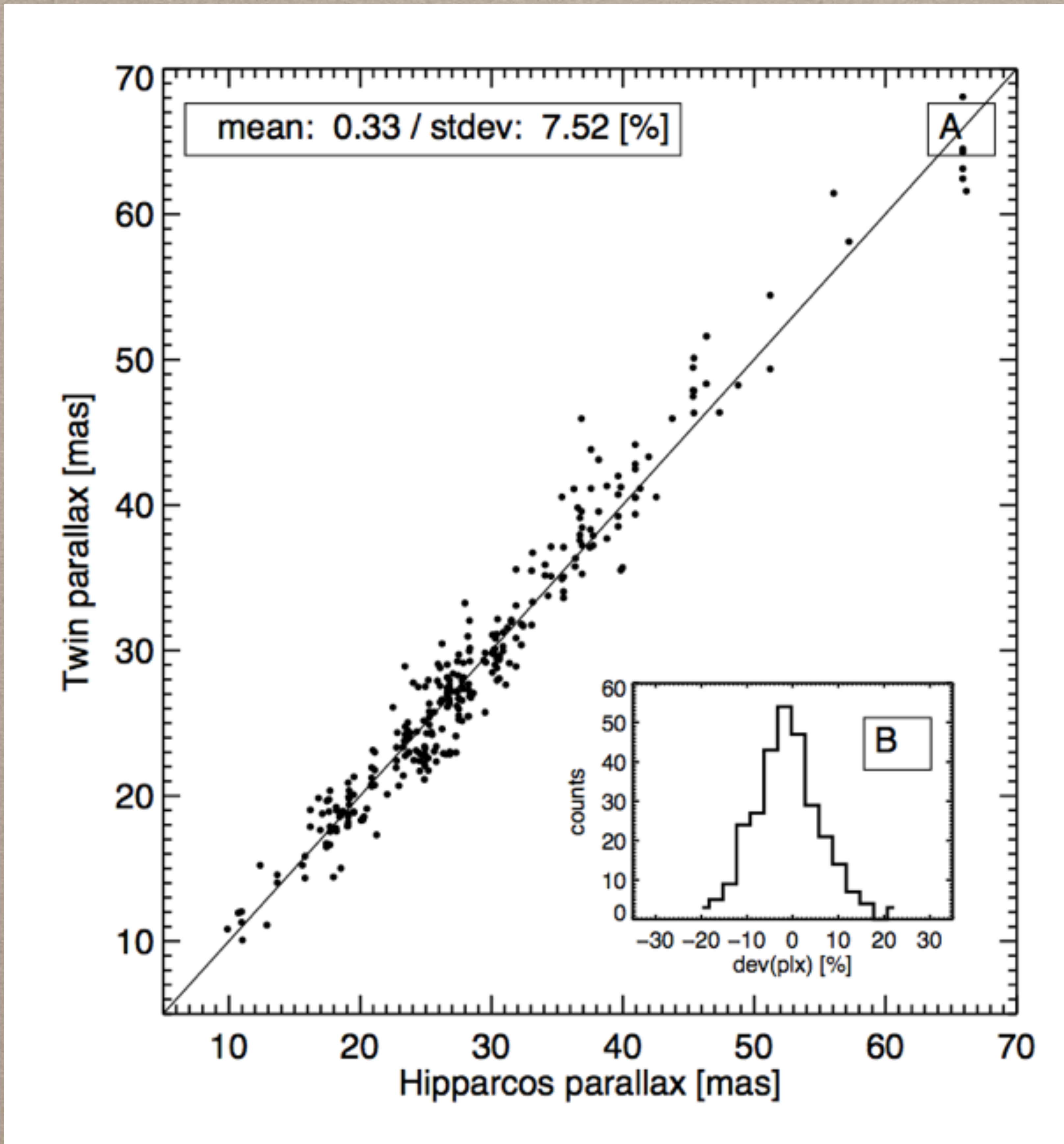
# TWIN DISTANCES

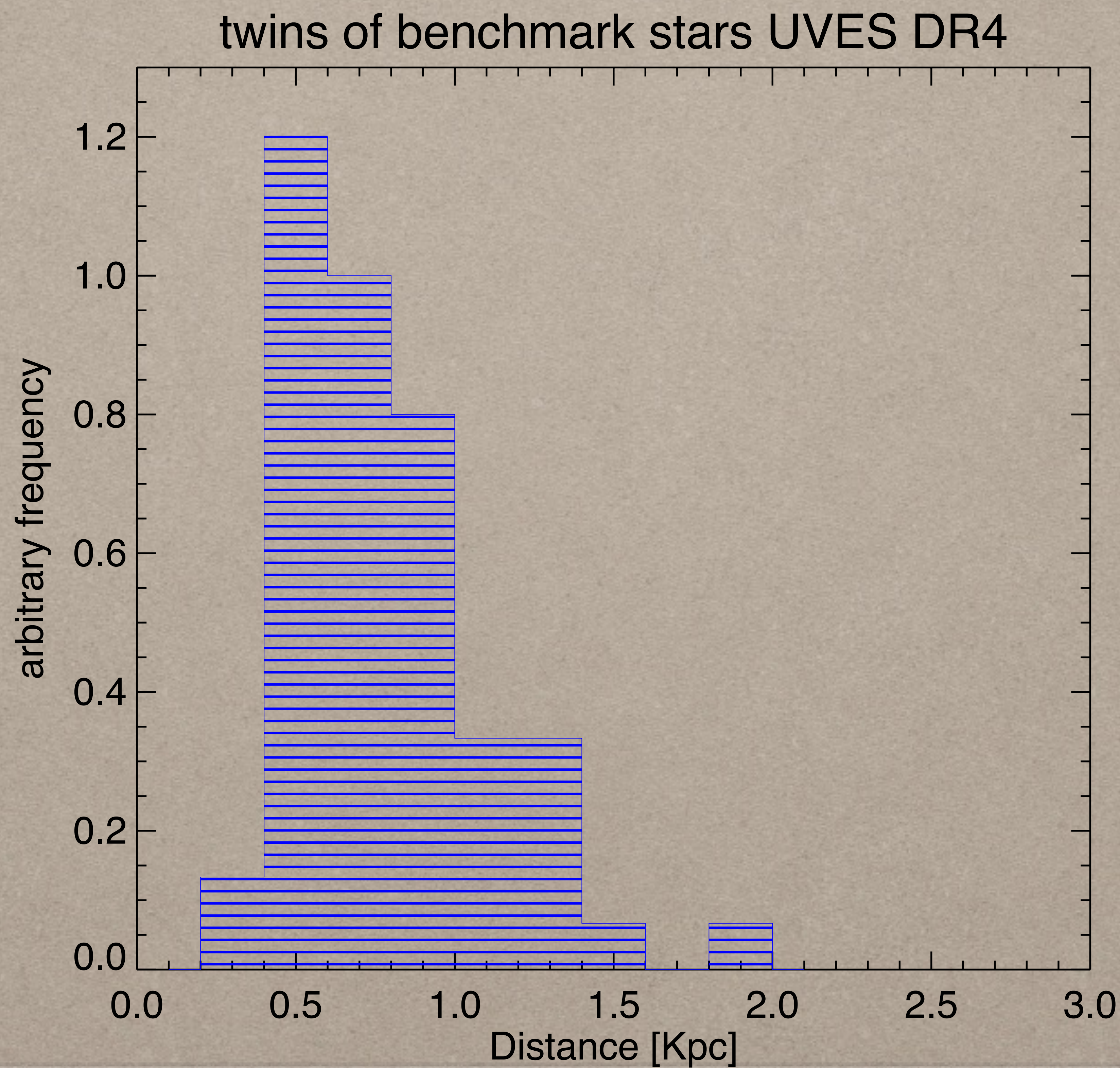



*Using a sample of ~500 HARPS Hipparcos stars*

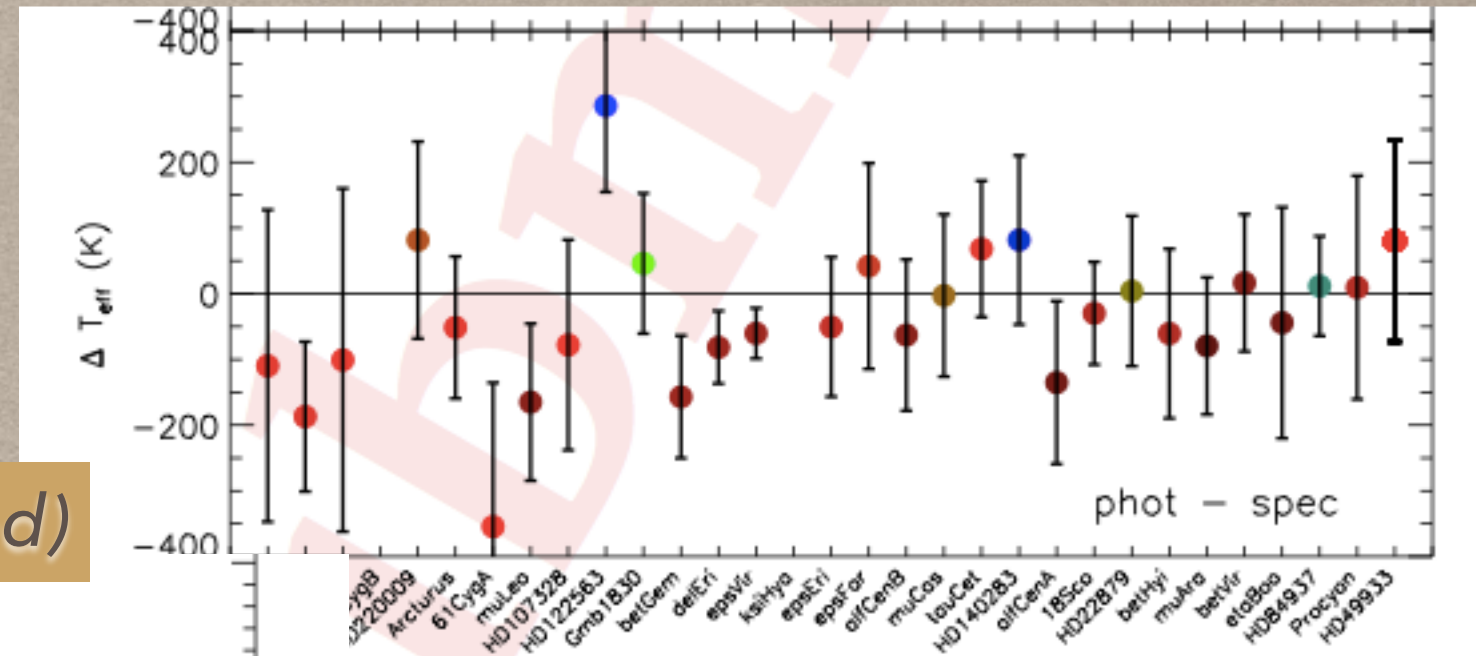
$(d_1/d_2)$

Fully independent of any stellar modelling

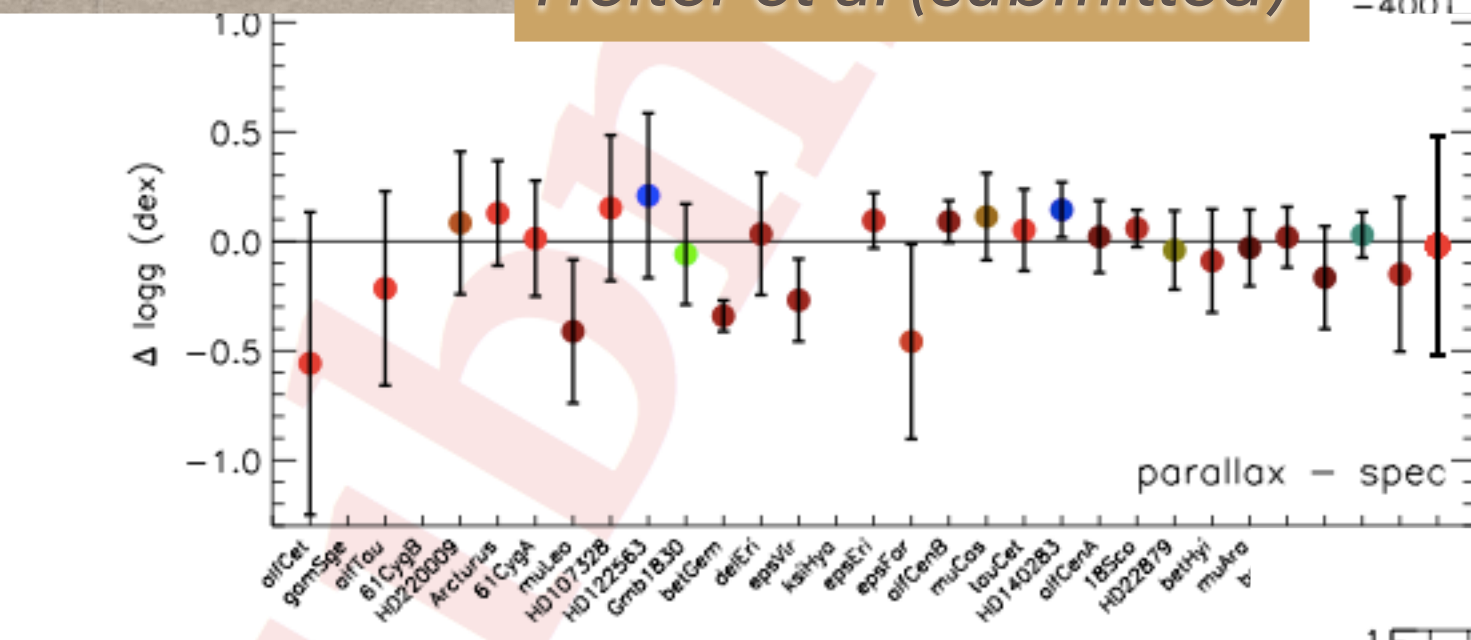
# SPACE DISTRIBUTION



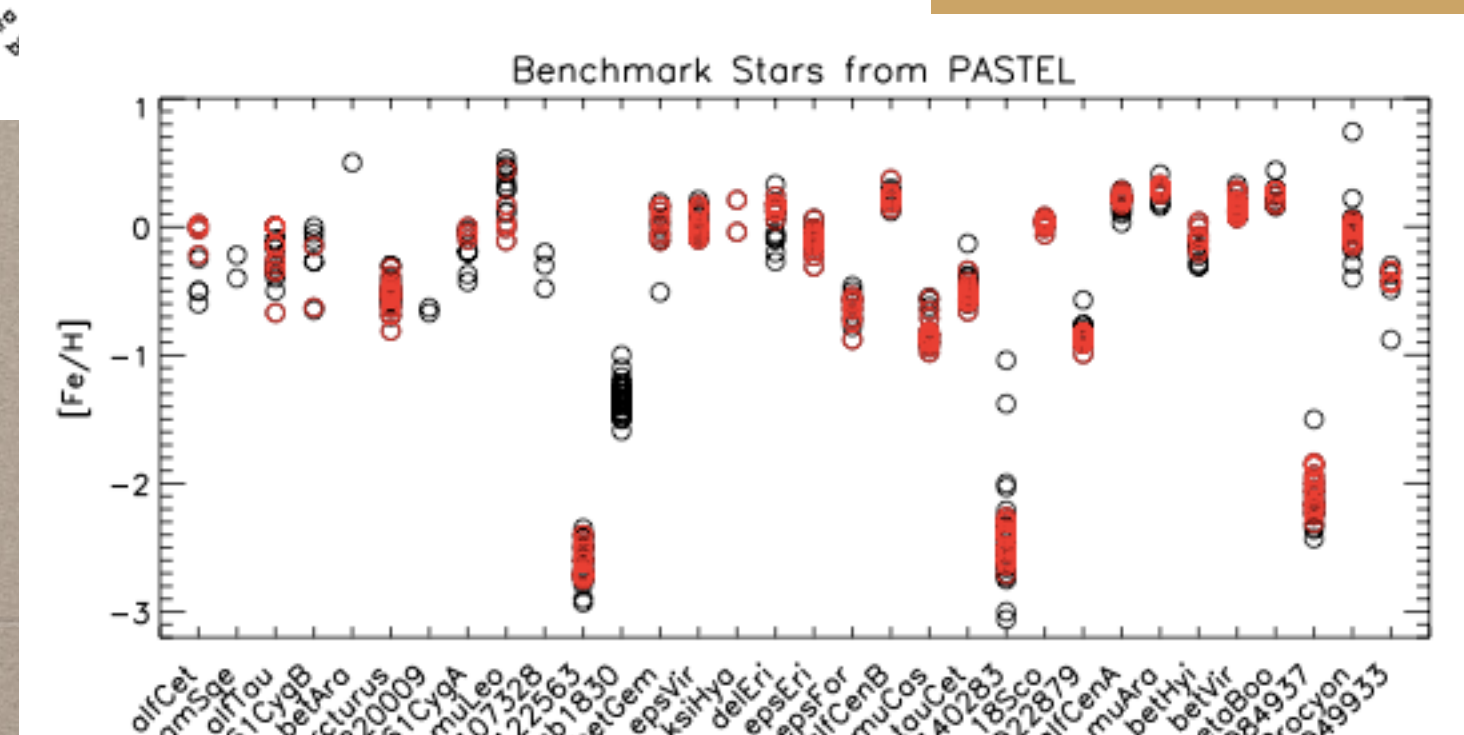

# DEFINING A SCALE HOMOGENEOUSLY BECAUSE ...




*Heiter et al (submitted)*




*Jofré et al 2014*




*there is*
*a mess in the parameters*
*of these*
*well-known stars ...*

# DEFINING A SCALE HOMOGENEOUSLY BECAUSE …

*…they produce a mess in abundances*

*Jofré et al 2015a (submitted)*