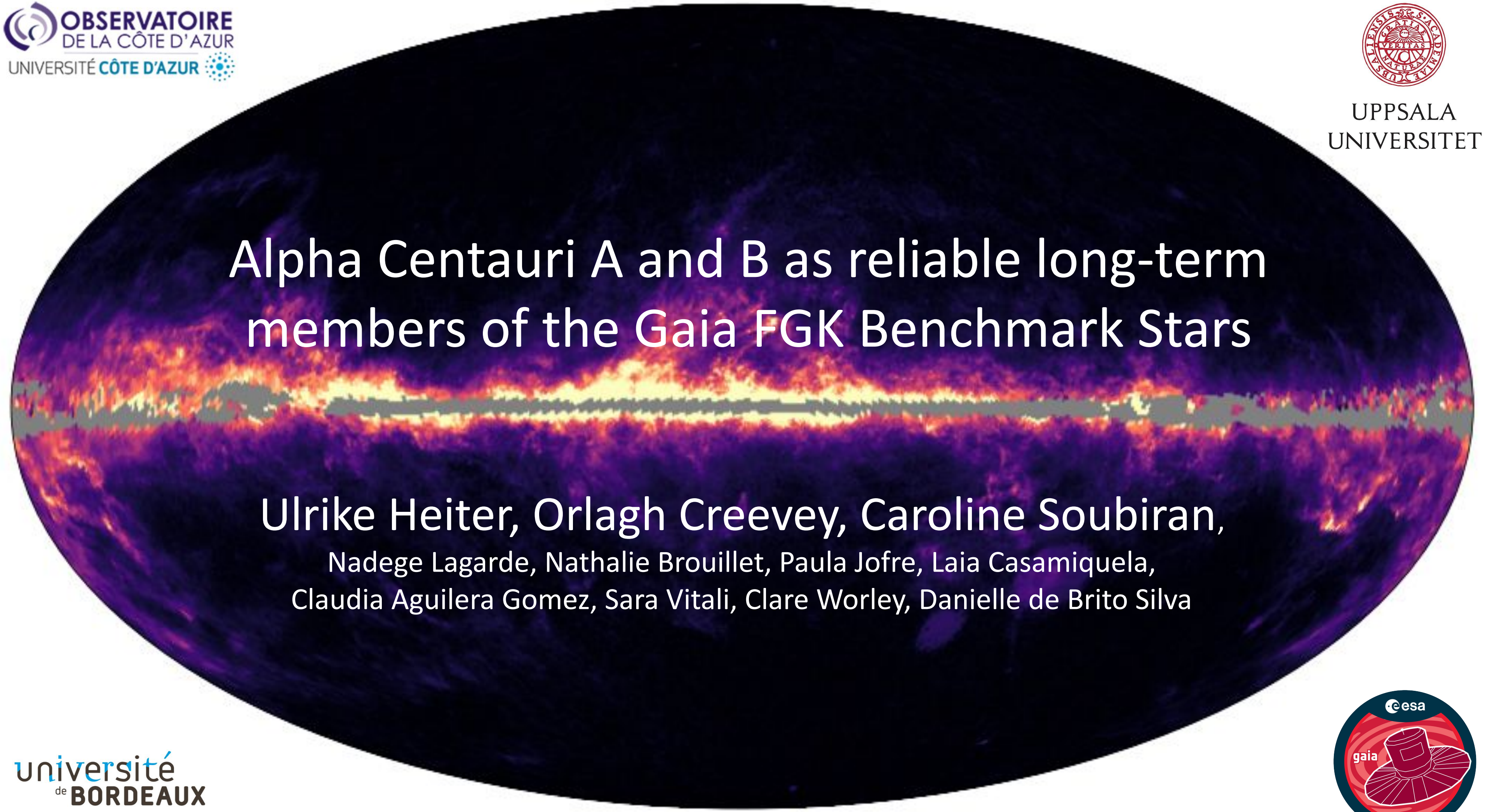

Alpha Centauri A and B as reliable long-term members of the Gaia FGK Benchmark Stars

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Outline

1. **Gaia FGK Benchmark Stars (GBS)**
2. Alpha Cen A / B
3. Conclusions

Gaia FGK Benchmark Stars (GBS): Motivation

GBS are reference stars with ***effective temperatures*** and ***surface gravities*** determined independently of spectroscopy, through fundamental relations.

The GBS were defined to **address the following needs**:

- **Gaia** needs to anchor its **stellar astrophysical parameters** on a set of well-characterized stars spanning the HR diagram and the full metallicity range of its stellar sources.
- **Large spectroscopic surveys** that derive atmospheric parameters and abundances automatically (e.g. RAVE, GALAH, Gaia-ESO, WEAVE, ...) need reference stars to assess and calibrate their results.
- The consistency of atmospheric parameters and abundances obtained with **different methods** needs to be evaluated with respect to reference values.
- **Stellar evolution models** need observational constraints from well-known stars.

Gaia FGK Benchmark Stars: Version 1 and Version 2

- T_{eff} and log g are determined through **fundamental relations**, based on limb-darkened angular diameter θ_{LD} – bolometric flux F_{bol} – parallax π – mass M:

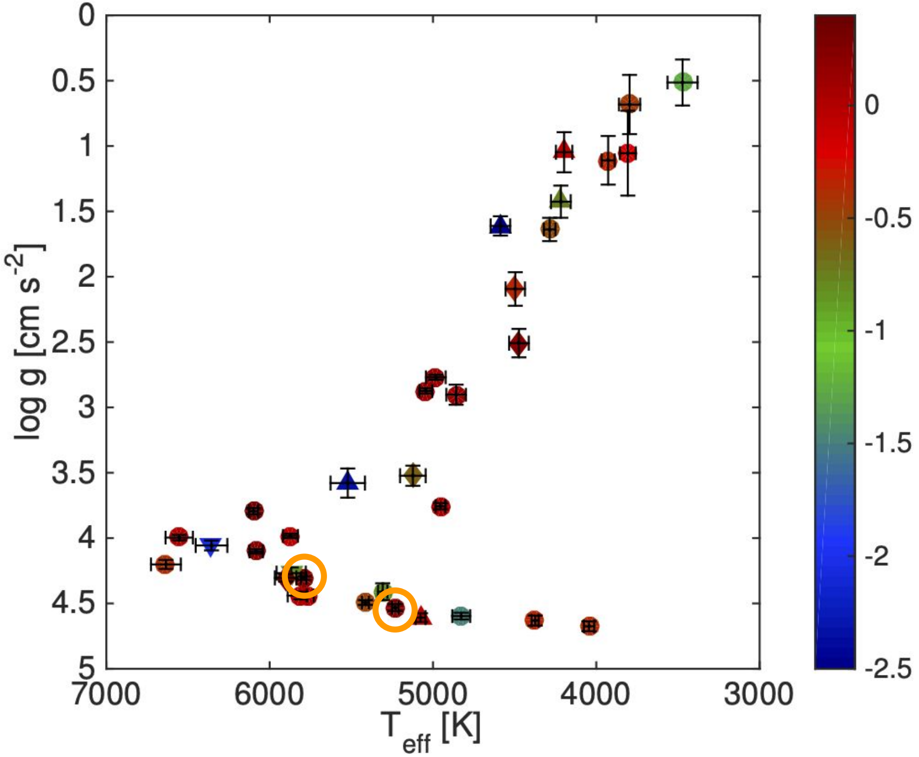
$$T_{\text{eff}} = \left(\frac{F_{\text{bol}}}{\sigma}\right)^{0.25} (0.5\theta_{\text{LD}})^{-0.5} \qquad g = \frac{GM}{(0.5\theta_{\text{LD}}/\pi)^2}$$

- **GBS V1**: Heiter+ 2015, **34 stars** (29 FGK, 5 M giants);
included **some stars** with indirect θ_{LD} (6) or F_{bol} (9), from calibrations,
all others: θ_{LD} from interferometry, F_{bol} from literature based on SED integration;
π from Hipparcos; M from manual fit to “Padova” and “Yonsei-Yale” models;
few metal-poor stars.

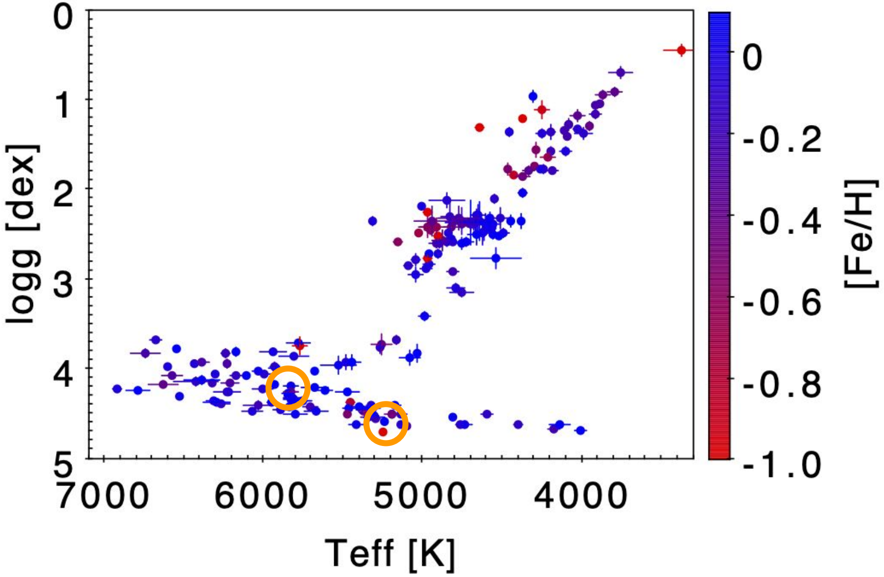
- **GBS V2**: Jofré+ 2018, **36 stars**; 3 stars from V1 were not recommended,
5 metal-poor stars with θ_{LD} and F_{bol} from IRFM were added;
metallicities and abundances of chemical elements were included.

Gaia FGK Benchmark Stars: Version 1 and Version 3 Kiel diagrams

GBS V1, Heiter+ 2015, 34 stars



GBS V3, Soubiran+ submitted, 192 stars



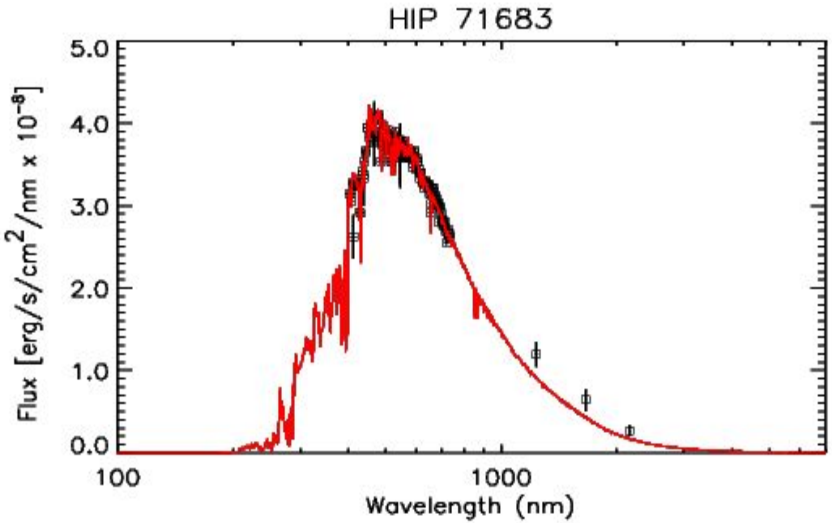
Gaia FGK Benchmark Stars: Version 3

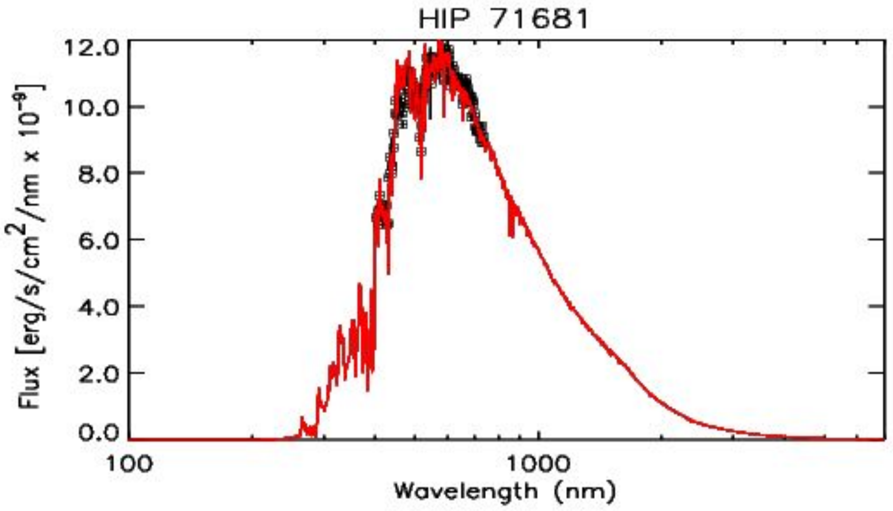
- 192 stars from literature search on interferometric diameters θ_{LD}
  - 30 stars from GBS V1+V2
  - ~100 stars from Salsi+2020 who used JMDC v2020 (Duvert+2016)
  - ~60 stars based on JMDC v2021 and PASTEL v2022 (Soubiran+2016)
  - new sources since 2015 include Creevey+2015, Ligi+2016, Baines+2018, 2021, Karovicova+2018, 2020, 2022, van Belle+2021
- Parallax π : Gaia DR3 for all but 10, Hipparcos, Kervella et al. 2017 (alpha Cen)
- Bolometric flux F_{bol} : SED fitting from a collection of spectro-photometric data
- Mass M : Use of Spins code and two different sets of evolution tracks

Gaia FGK Benchmark Stars V3: Bolometric flux

- Compiled fluxes: Virtual Observatory VOSA tool (Bayo+2008)
  - Catalogues that had photometry for at least 50 stars in our sample
  - E.g. 2MASS (Cutri+2003), GALEX (Bianchi+2017), synthetic photometry (Gaia Coll.+2023), various passbands
  - Between 15 and 400 flux points per star (median 101)
- Extinction derived from Vergely+2022 3D map
- Fitting of spectral energy distribution (SED) with Lejeune+1997 semi-empirical library of spectra (Creevey+2015)
  - Homogenous approach for full set of stars
  - Bootstrap (Monte-Carlo) approach to consider uncertainties in all atmospheric parameters + flux
  - Median and 68% percentiles were adopted as values and uncertainties

Gaia FGK Benchmark Stars V3: Bolometric flux





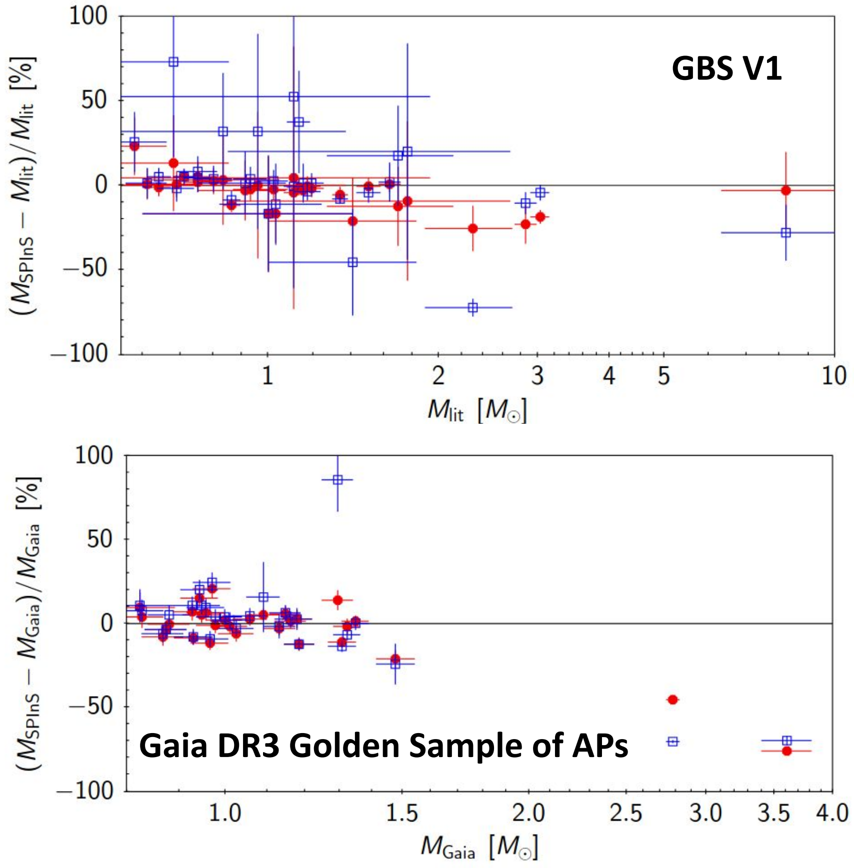
Photometry-converted-to-flux data and uncertainties (black) along with a fitted model (red).

Gaia FGK Benchmark Stars V3: Masses

- SPInS code (Lebreton & Reese 2020) applies a Bayesian approach to determine stellar parameters
- Input data: GBS V3 T_{eff}, luminosities and radii (from F_{bol}, θ_{LD}, π) + literature metallicities
- Stellar evolution models:
  - BaSTI (Pietrinferni+2004, 2006)
  - STAREVOL (Lagarde+2012, 2017)
- Main differences BaSTI / STAREVOL
  - Core convective overshooting for $M > 1.1\ M_\odot$: overshoot parameter linear / 0.05 and 0.2 / 0.1 below and above 1.7 / 2.0 $M_\odot$
  - Solar chemical composition: Grevesse+1993 / Asplund+2009
- Average of both results was adopted

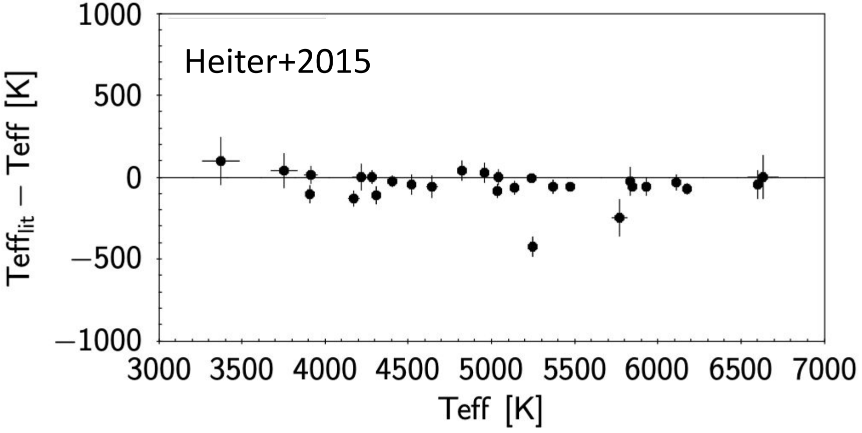
Gaia FGK Benchmark Stars V3: Masses

Comparison of our masses with
GBS V1 (Heiter+2015) and
Gaia DR3 (Gaia Coll., Creevey+2022)
for BASTI (red) and STAREVOL (blue)

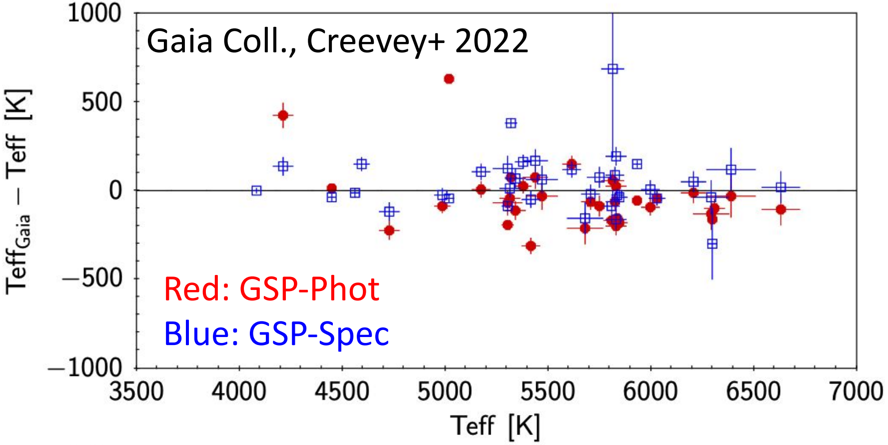


Gaia FGK Benchmark Stars V3: T_{eff} comparisons

GBS V1

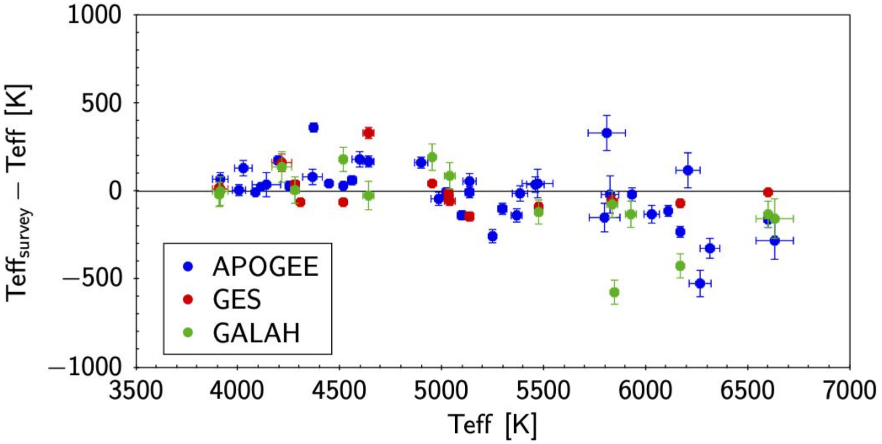


Gaia DR3 Golden Sample of APs



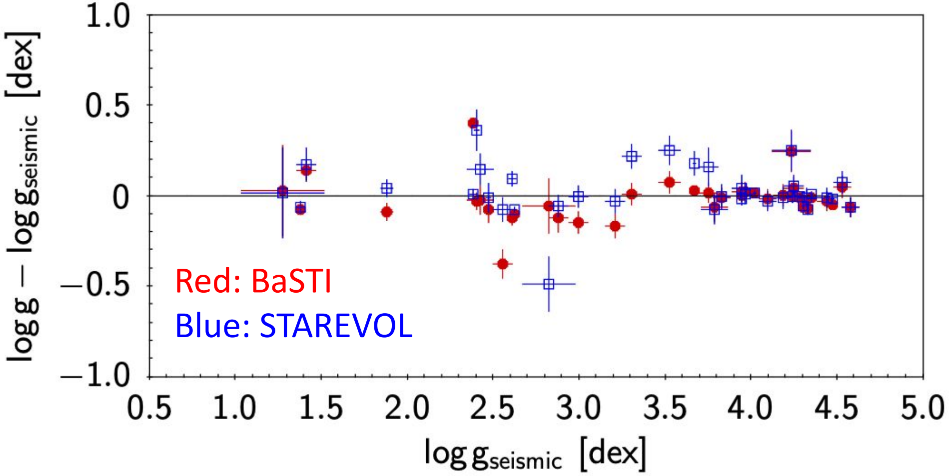
Spectroscopic surveys

Abdurro'uf+ 2022
Gilmore+ 2022
Buder+ 2021

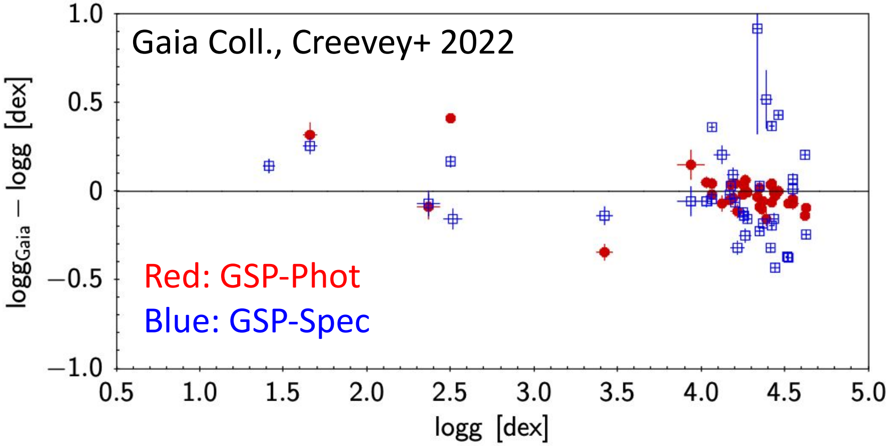


Gaia FGK Benchmark Stars V3: log *g* comparisons

Seismic, using ν_{max} from different sources



Gaia DR3 Golden Sample of APs



Spectroscopic surveys

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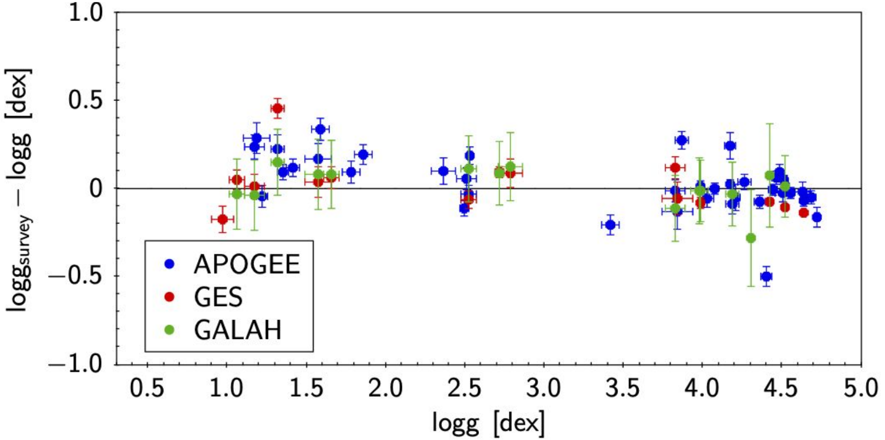


Outline

1. Gaia FGK Benchmark Stars (GBS)
2. **Alpha Cen A / B**
3. Conclusions

Alpha Cen A & B: Data and parameters

	π [mas]	θ_{LD} [mas]	F_{bol} [erg/s/cm^2 x 10^{-8}]	A_V [mag]
HIP 71683	747.17 ± 0.61	8.502 ± 0.038	2808.67 ± 6.50	0.011 ± 0.01
HIP 71681	747.17 ± 0.61	5.999 ± 0.025	901.69 ± 0.75	0.011 ± 0.01

	R [R☉]	L [L☉]	M [M☉]
HIP 71683	1.2234 ± 0.0056	1.5725 ± 0.0045	1.080 ± 0.007
HIP 71681	0.8632 ± 0.0037	0.5048 ± 0.0009	0.937 ± 0.014

GBS V3

	T_{eff} [K]	log$g$ [cgs]
HIP 71683	5844 ± 13	4.296 ± 0.005
HIP 71681	5237 ± 11	4.537 ± 0.007

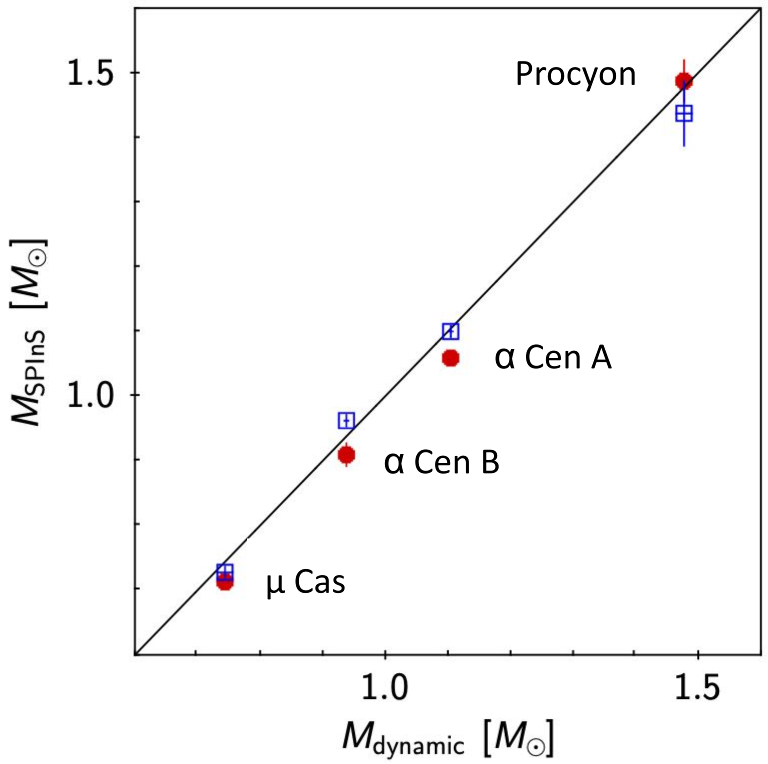
GBS V1

T_{eff} [K]	log$g$ [cgs]
5792 ± 16	4.31 ± 0.01
5231 ± 20	4.53 ± 0.03

Alpha Cen A & B: Comparison to dynamical masses

Comparison of our masses with dynamical masses
for BASTI (red) and STAREVOL (blue)

Reference for alpha Cen A&B:
Kervella+2016



Alpha Cen A & B: Exploring different input data

- F_{bol} with Av = 0 instead of 0.011

	F_{bol} [erg/s/cm^2 x 10^{-8}]	L [L⊙]	T_{eff} [K]
HIP 71683	2808 → 2785 [0.8%]	1.573 → 1.559 [0.9%]	5844 → 5831 [0.2%]
HIP 71681	902 → 895 [0.8%]	0.505 → 0.501 [0.8%]	5237 → 5226 [0.2%]

- Comparison of F_{bol} with Boyajian+2013 (used Av = 0 and **Pickles library**)
- Using parallax from Akeson+2021 instead of Kervella+2016, 747.17 mas → 750.81 mas

F_{bol}	Soubiran+	Boyajian+	
HIP 71683	2785 ± 10	2716 ± 27	2.5%
HIP 71681	895 ± 5	898 ± 12	0.3%

R [R⊙]
1.223 → 1.2175 [0.5%]
0.863 → 0.863 [0.5%]

Outline

1. Gaia FGK Benchmark Stars (GBS)
2. Alpha Cen A / B
3. **Conclusions**
    a. **GBS V3 set of well-characterized stars** is a powerful tool for calibration of parametrization methods, with number of stars increased by factor 5, more accurate T_{eff} and log g, based on more precise and homogeneous bolometric fluxes and Gaia DR3 parallaxes
    b. **Alpha Cen** is an ideal system as an anchor for G and K stars, e.g. for differential analysis
    c. Case of **alpha Cen validates** our “homogenous analysis” of the **GBS** set, which is also done in large scale surveys
    d. **Properties of alpha Cen A&B** are well-known, different input data have effects of less than 1%