Benchmarks in WP120

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benchmark, n. and adj.

A. n

1. A fixed point (esp. a cut or mark in a wall, building, etc.), used by a surveyor as a reference in measuring elevations.

Oxford English Dictionary

benchmark, n. and adj.

A. n

1. A fixed point (esp. a cut or mark in a wall, building, etc.), used by a surveyor as a reference in measuring elevations.

2.

a. In extended use. A point of reference, esp. one from which measurements may be made; something that serves as a standard by which other similar things may be measured or evaluated; *spec.* a standardized problem or test used for evaluation or comparison.

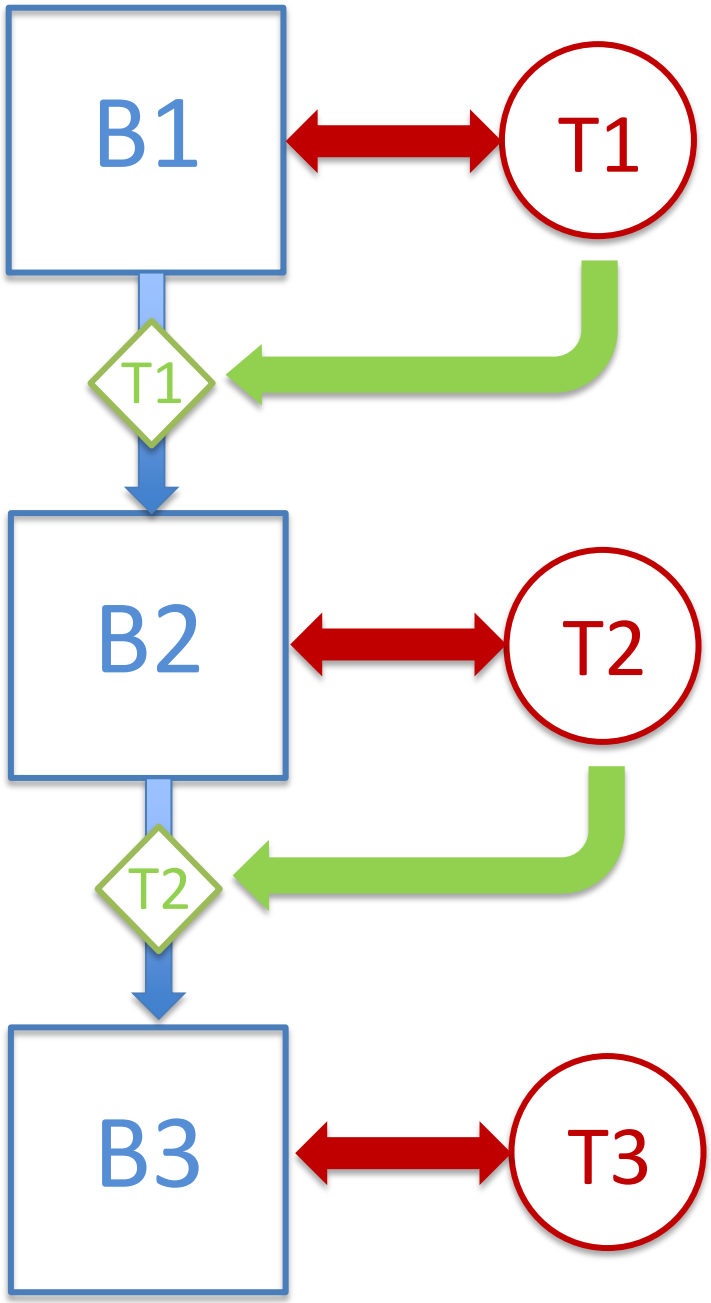
b. Computing. A test designed to evaluate or compare the performance of hardware or software; a piece of software, a data set, etc., designed or used for this purpose.

Oxford English Dictionary

Establishing a benchmark

- Careful parameter determination for a given star with a certain set of techniques, to be used to test less detailed analyses with similar techniques
- Careful parameter determination for a given star with a certain set of techniques, to be used to test analyses with totally independent (but perhaps more generally applicable) techniques

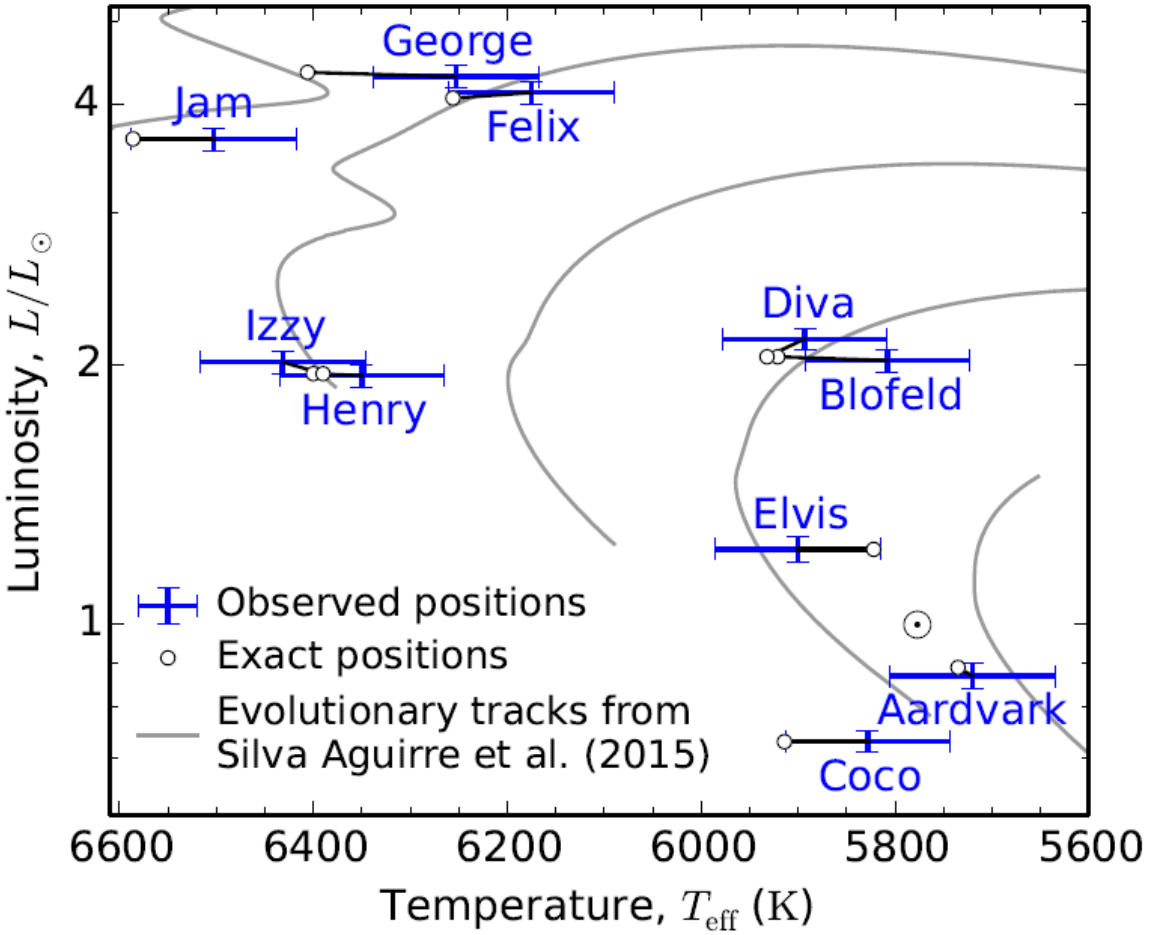
The benchmark ladder



Artificial benchmark stars
(aka H+H exercises)

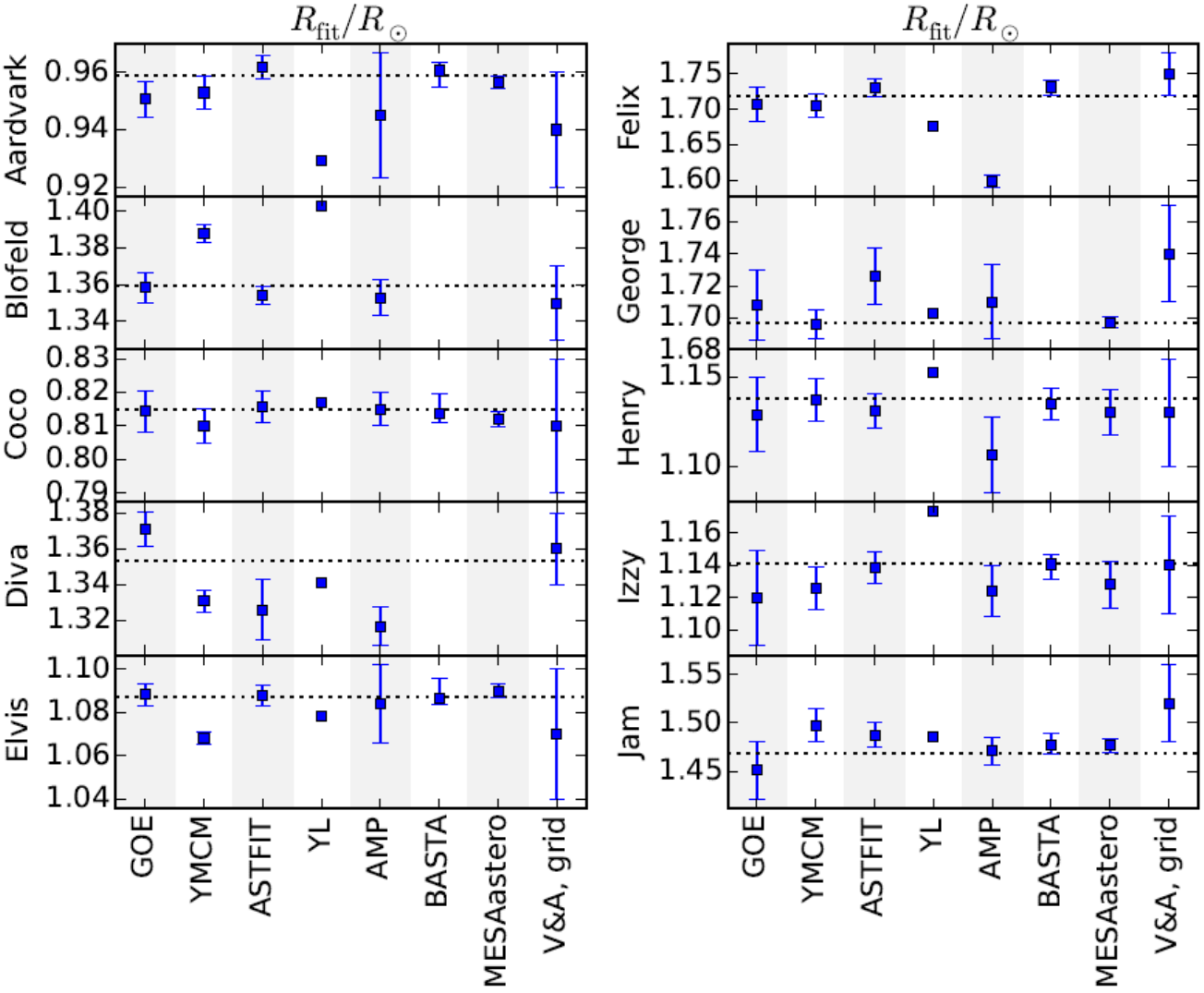
- Based on models with known properties (including end-to-end analyses)
- Data properties based on observed properties
- Test various analysis techniques
- Allows in-depth analysis of deficiencies in techniques
- Allows detailed MC statistical analysis to obtain PDF of inferred quantities

Artificial benchmark stars



Reese et al. (2016; A&A 592, A14)

Artificial benchmark stars



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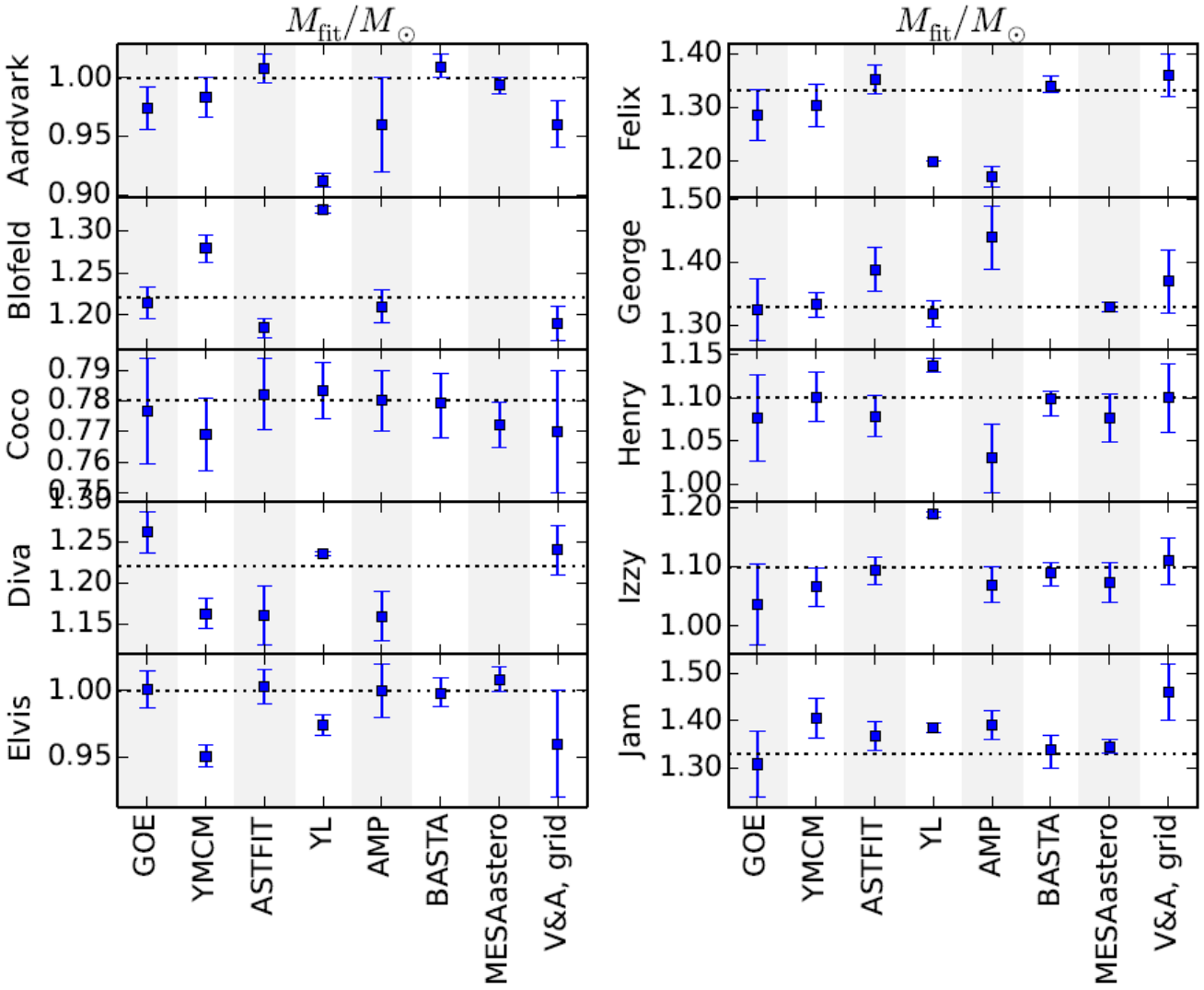

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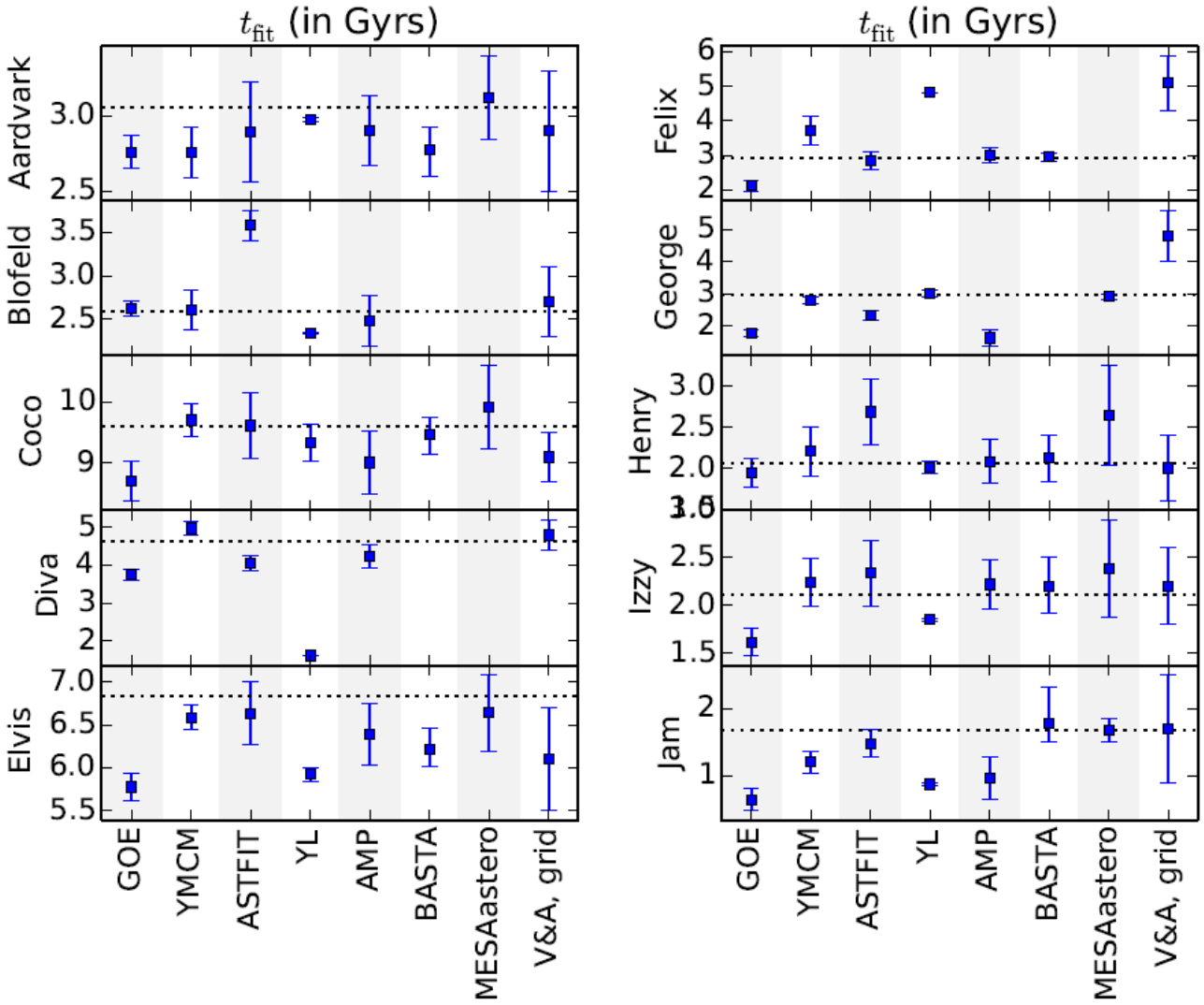
Artificial benchmark stars



Reese et al. (2016; A&A 592, A14)

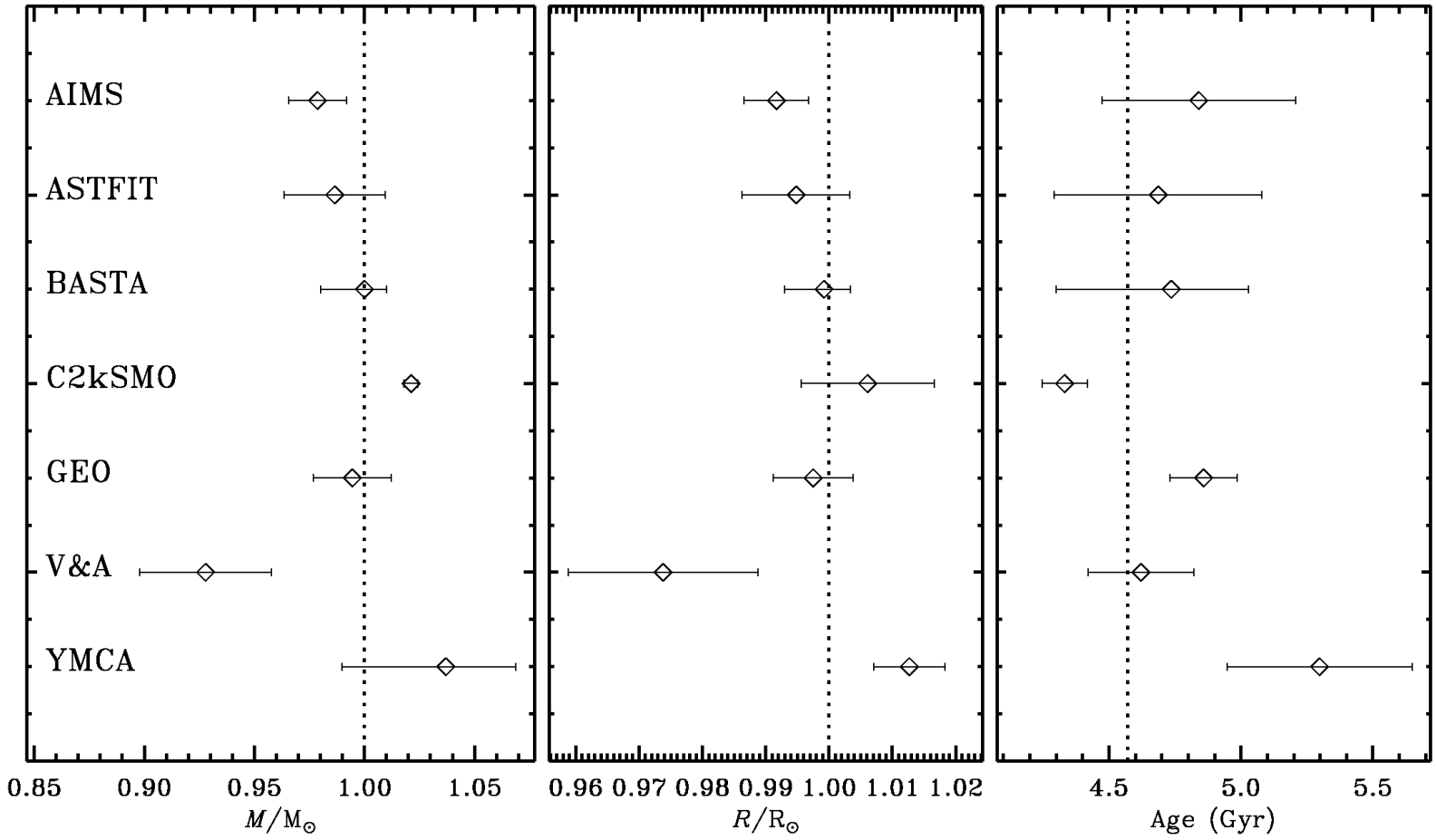
Solar benchmark: data

Degraded solar data:

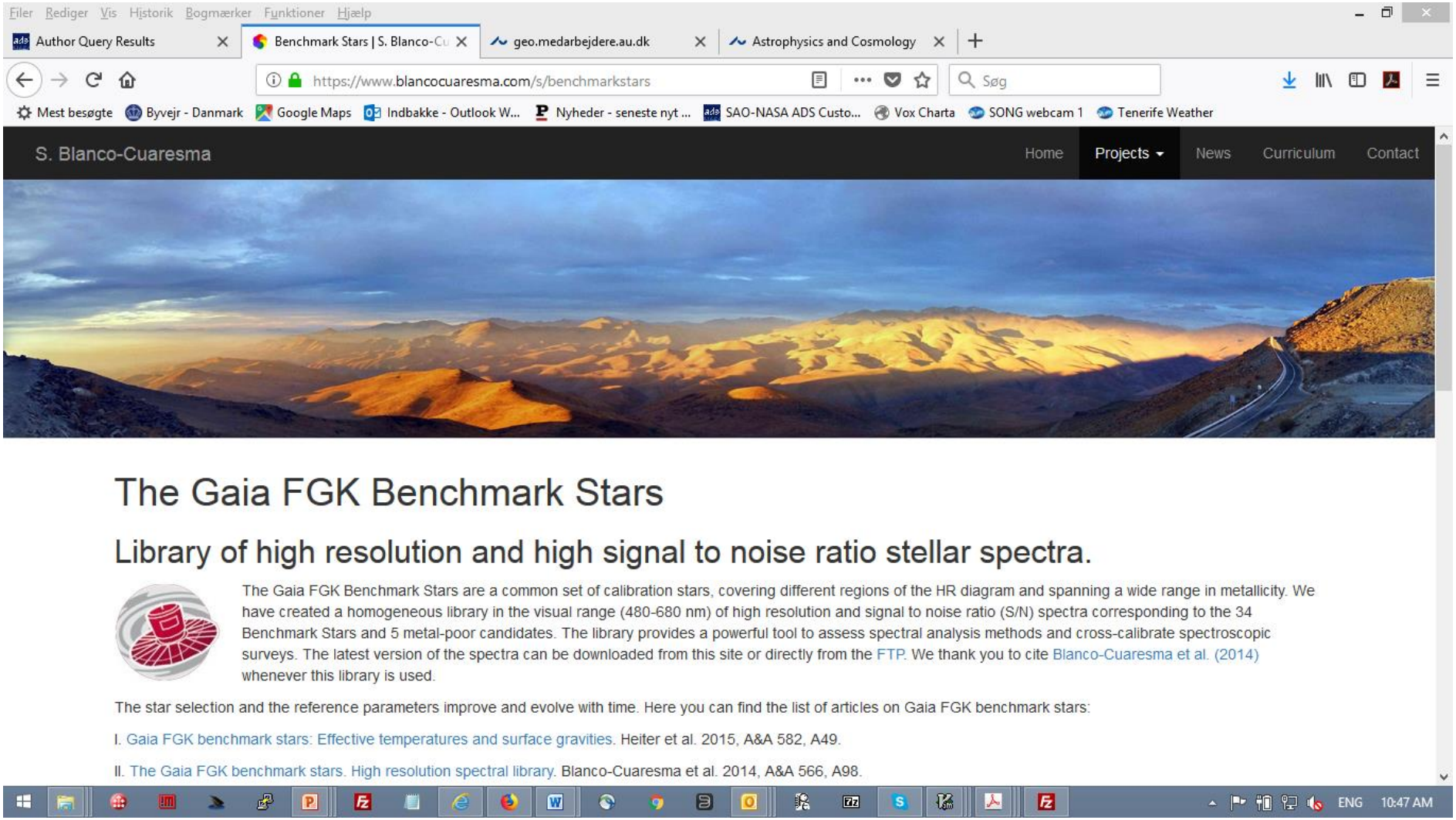
- Combined 1150 d green and red VIRGO data to match the *Kepler* band pass
- Add noise to correspond to magnitude Kp = 9.17
- Analyse data as for LEGACY stars

Lund et al. (2017; ApJ 835, 172)

Solar benchmark: frequency fits



Silva Aguirre et al. (2017; ApJ 835, 173)



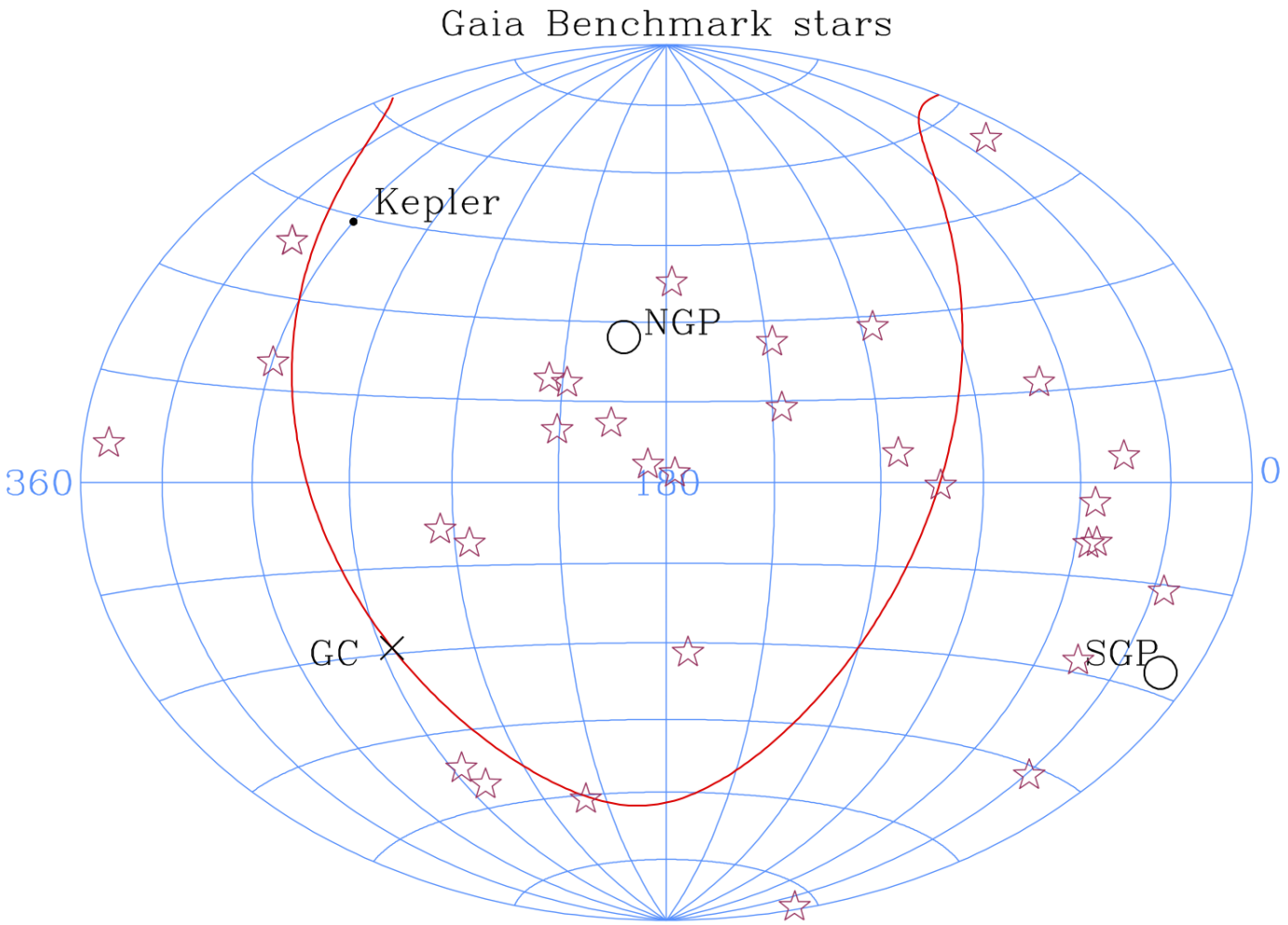
GBS: An important resource for PLATO Benchmarking

GBS

Heiter et al. (2015; A&A 582, A49)

Name	HD	RA (J2000)	Dec (J2000)	Spectral type	V mag	[Fe/H]†	u([Fe/H])‡
F dwarfs							
Procyon	61421	07 39 18.119	+05 13 29.96	F5IV-V	0.4	0.01	0.08
HD 84937	84937	09 48 56.098	+13 44 39.32	sdF5	8.3	–2.03	0.08
HD 49933	49933	06 50 49.832	–00 32 27.17	F2V	5.8	–0.41	0.08
FGK subgiants							
δ Eri	23249	03 43 14.901	–09 45 48.21	K1III-IV	3.5	0.06	0.05
HD 140283	140283	15 43 03.097	–10 56 00.60	sdF3	7.2	–2.36	0.10
ϵ For	18907	03 01 37.637	–28 05 29.60	K2VFe-1.3CH-0.8	5.9	–0.60	0.10
η Boo	121370	13 54 41.079	+18 23 51.79	G0IV	2.7	0.32	0.08
β Hyi	2151	00 25 45.070	–77 15 15.29	G0V	2.8	–0.04	0.06
G dwarfs							
α Cen A	128620	14 39 36.494	–60 50 02.37	G2V	0.0	0.26	0.08
HD 22879	22879	03 40 22.064	–03 13 01.12	F9V	6.7	–0.86	0.05
Sun						0.03	0.05
μ Cas	6582	01 08 16.395	+54 55 13.23	G5Vb	5.2	–0.81	0.03
τ Cet	10700	01 44 04.083	–15 56 14.93	G8.5V	3.5	–0.49	0.03
α Cen B	128621	14 39 35.063	–60 50 15.10	K1V	1.4	0.22	0.10
18 Sco	146233	16 15 37.269	–08 22 09.99	G2Va	5.5	0.03	0.03
μ Ara	160691	17 44 08.701	–51 50 02.59	G3IV-V	5.1	0.35	0.13
β Vir	102870	11 50 41.718	+01 45 52.99	F9V	3.6	0.24	0.07
FGK giants							
Arcturus	124897	14 15 39.672	+19 10 56.67	K1.5III	–0.1	–0.52	0.08
HD 122563	122563	14 02 31.845	+09 41 09.95	F8IV	6.2	–2.64	0.22
μ Leo	85503	09 52 45.817	+26 00 25.03	K2III	3.9	0.25	0.15
β Gem	62509	07 45 18.950	+28 01 34.32	K0IIIb	1.1	0.13	0.16
ϵ Vir	113226	13 02 10.598	+10 57 32.94	G8III	2.8	0.15	0.16
ξ Hya	100407	11 33 00.115	–31 51 27.44	G7III	3.5	0.16	0.20
HD 107328	107328	12 20 20.981	+03 18 45.26	K0IIIb	5.0	–0.33	0.16
HD 220009	220009	23 20 20.583	+05 22 52.70	K2III	5.0	–0.74	0.13
M giants							
α Tau	29139	04 35 55.239	+16 30 33.49	K5III	0.9	–0.37	0.17
α Cet	18884	03 02 16.773	+04 05 23.06	M1.5IIIa	2.5	–0.45	0.47
β Ara	157244	17 25 17.988	–55 31 47.59	K3Ib-II	2.8	–0.05	0.39
γ Sge	189319	19 58 45.429	+19 29 31.73	M0III	3.5	–0.17	0.39
ψ Phe	11695	01 53 38.741	–46 18 09.60	M4III	4.4	–1.24	0.39
K dwarfs							
ϵ Eri	22049	03 32 55.845	–09 27 29.73	K2Vk:	3.7	–0.09	0.06
Gmb 1830	103095	11 52 58.769	+37 43 07.23	G8Vp	6.4	–1.46	0.39
61 Cyg A	201091	21 06 53.952	+38 44 57.99	K5V	5.2	–0.33	0.38
61 Cyg B	201092	21 06 55.264	+38 44 31.40	K7V	6.0	–0.38	0.03

GBS



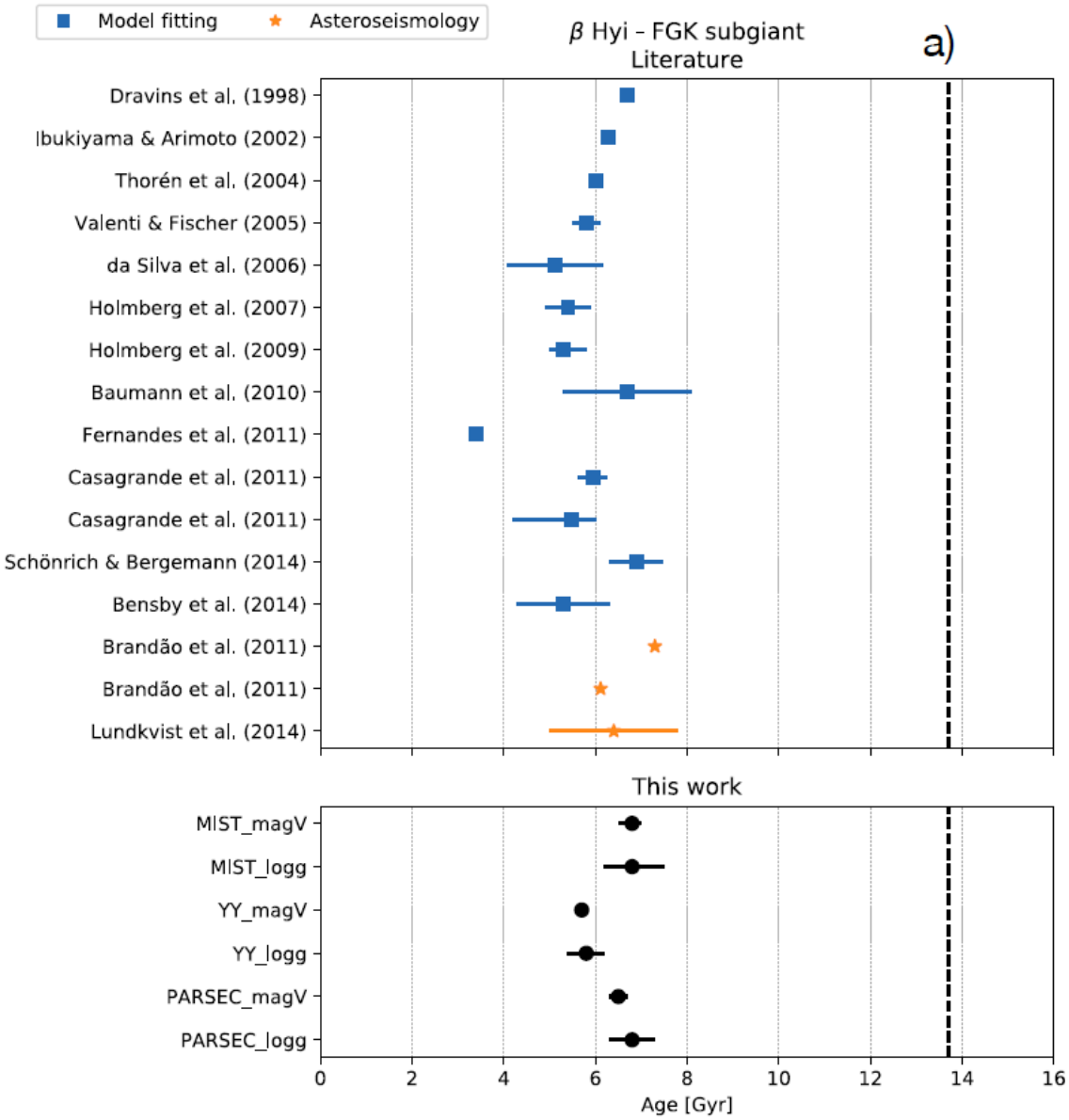
GBS and asteroseismology

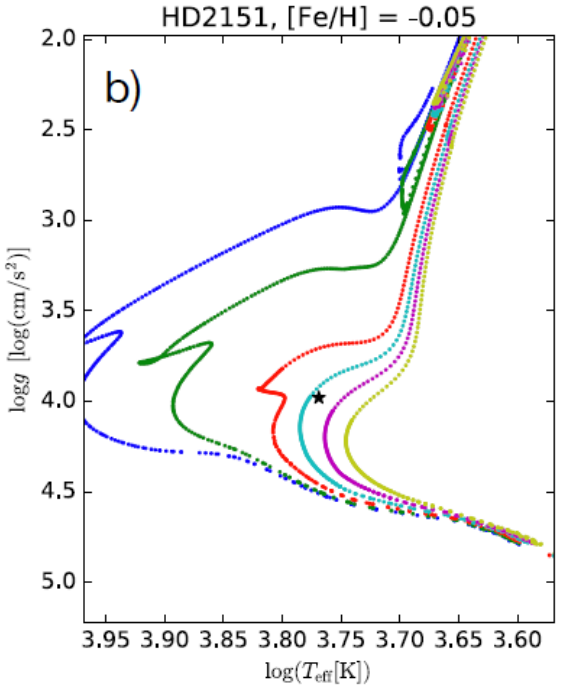
- Some stars observed from the ground
  - Needs renewed analysis and perhaps observations

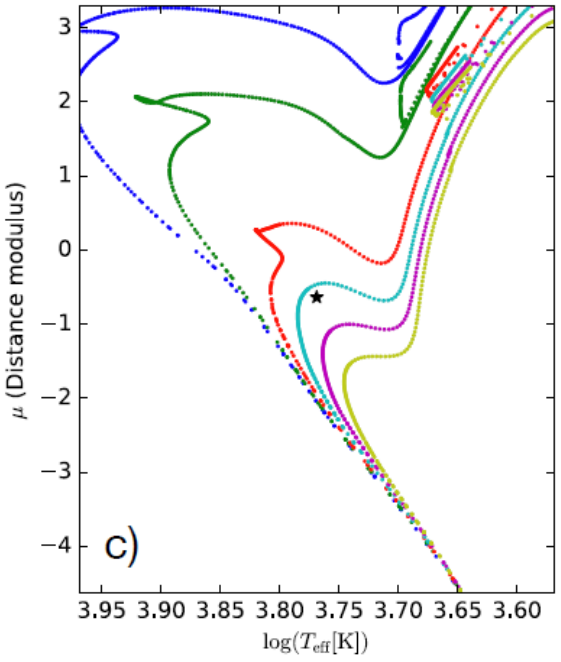
Heiter et al. (2015; A&A 582, A49)

Name	M [$M_\odot$]	$u(M)$	$\Delta\nu$ [μHz]	$u(\Delta\nu)$	Ref.
Procyon	1.40	0.06	55	1	1
HD 49933	1.14	0.10	85.2	0.5	2
δ Eri	1.32	0.04	43.8	0.1	3
η Boo	1.68	0.08	39.9	0.1	4
β Hyi	1.06	0.03	57.24	0.16	5
α Cen A	1.13	0.02	106	1	6
τ Cet	0.78	0.01	169.3	0.3	7
α Cen B	0.92	0.01	161.38	0.06	8
18 Sco	1.02	0.03	134.4	0.3	9
μ Ara	0.91	0.06	90	1	10
β Vir	1.41	0.05	72.07	0.10	11
Arcturus	0.62	0.08	0.83	0.05	12
β Gem	1.96	0.09	7.14	0.12	13
ξ Hya	2.94	0.15	7.11	0.14	14

βHyi





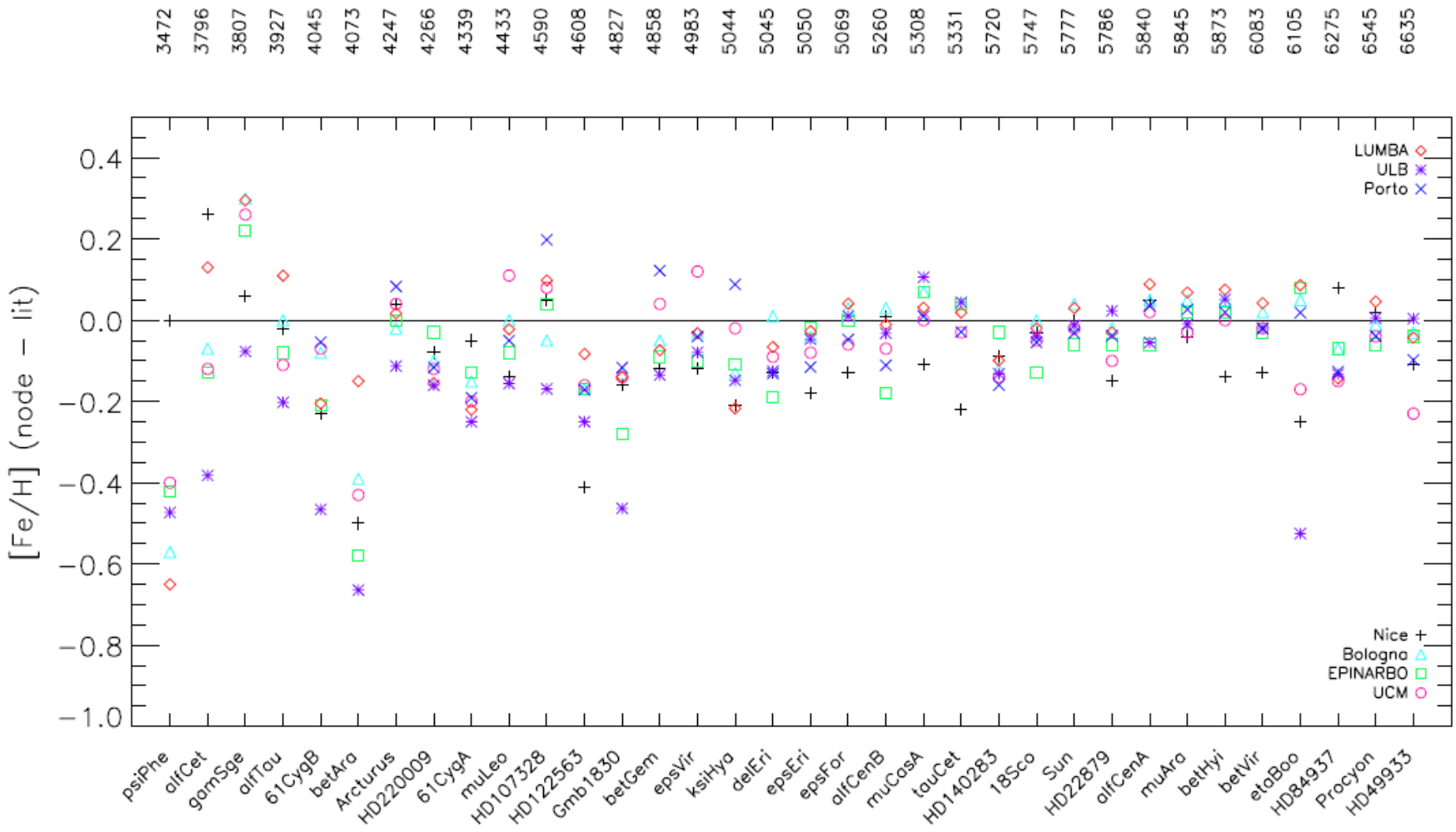


Sahlholdt et al. (in preparation)

GBS and asteroseismology

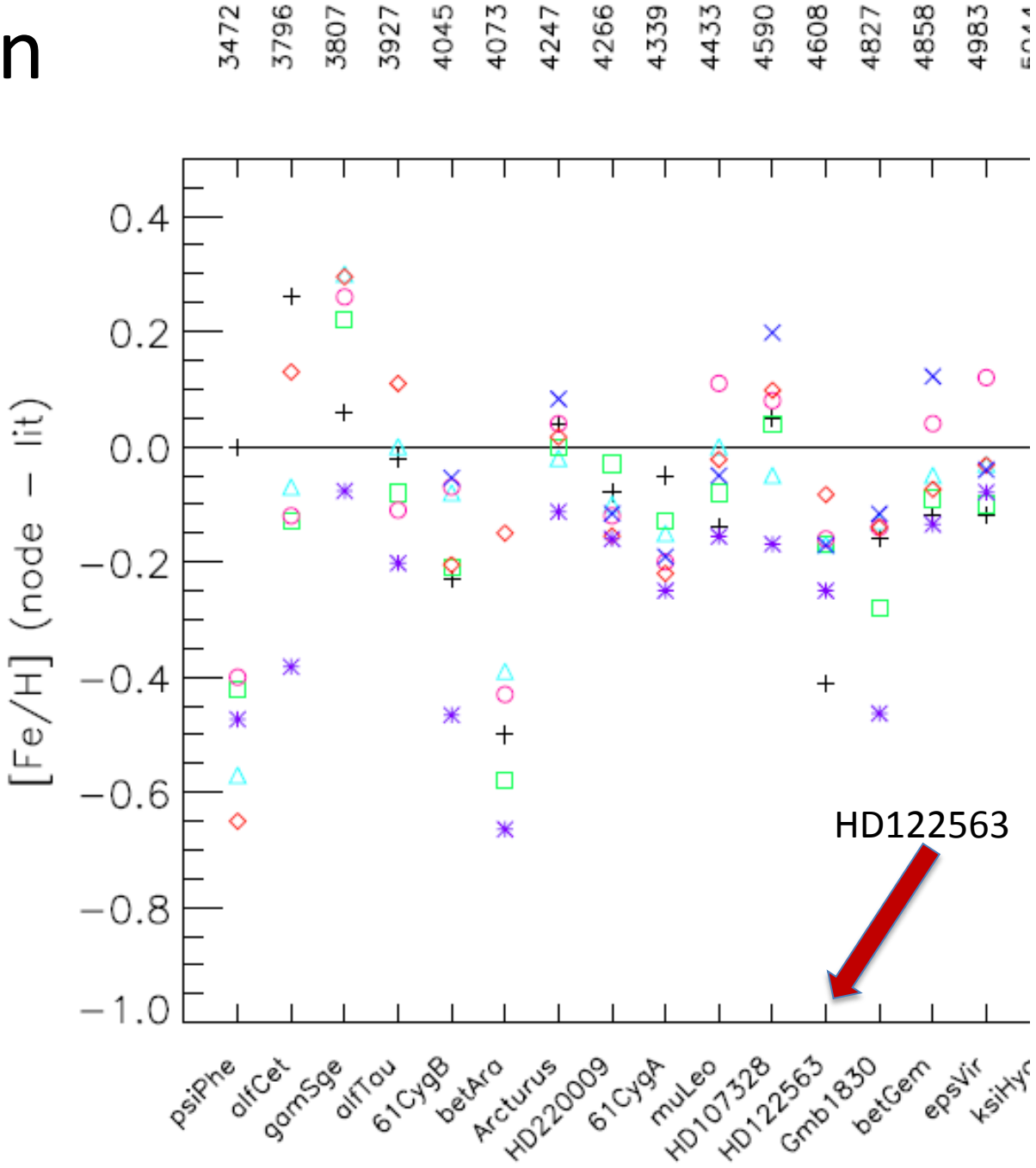
- Some stars observed from the ground
  - Needs renewed analysis and perhaps observations
- No GBS in the *Kepler* nominal field
- GBS in K2 fields?????
- GBS with TESS: almost all are high priority for asteroseismology

Composition of GBS



Jofre et al. (2014; A&A 564, A133)

Composition of GBS



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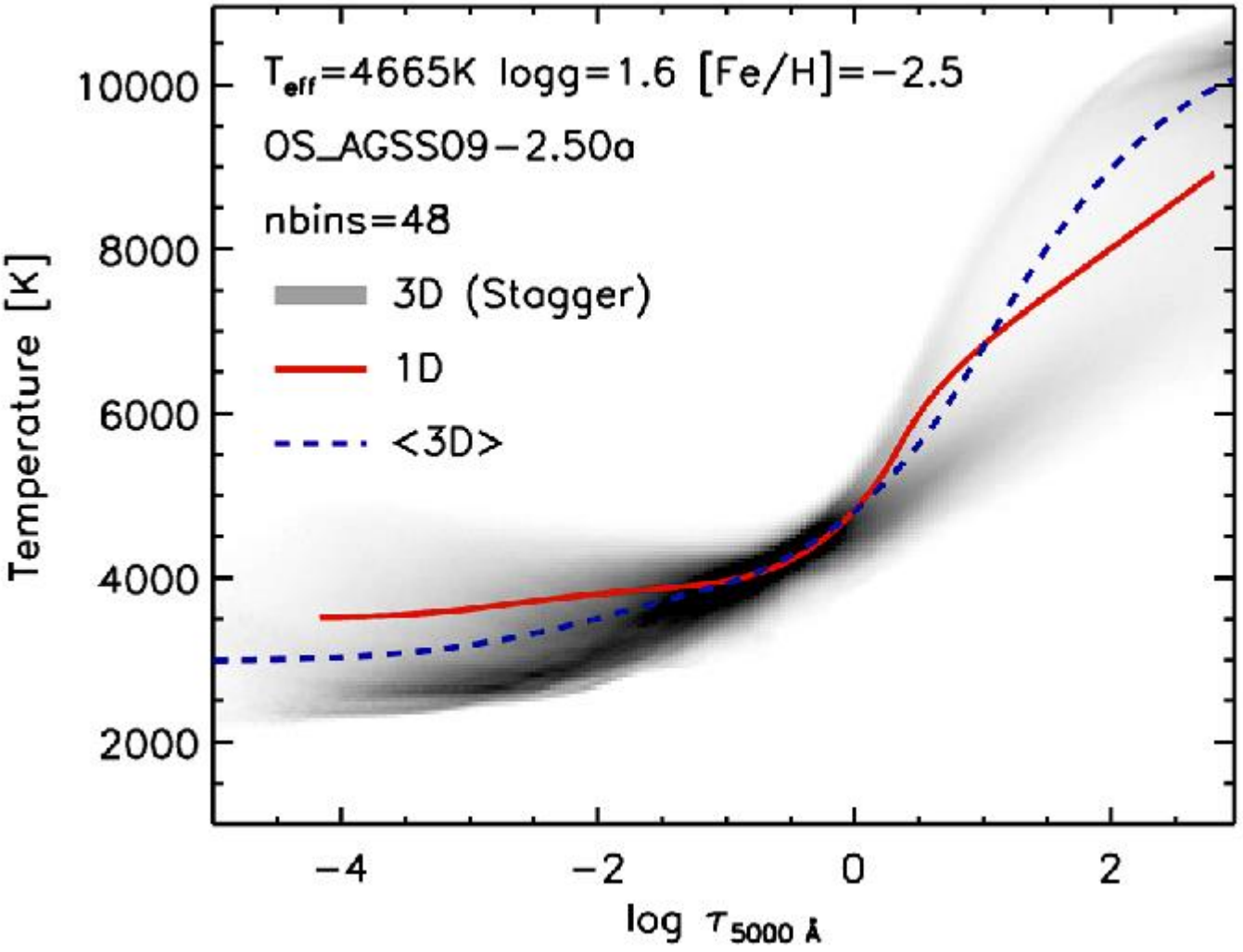
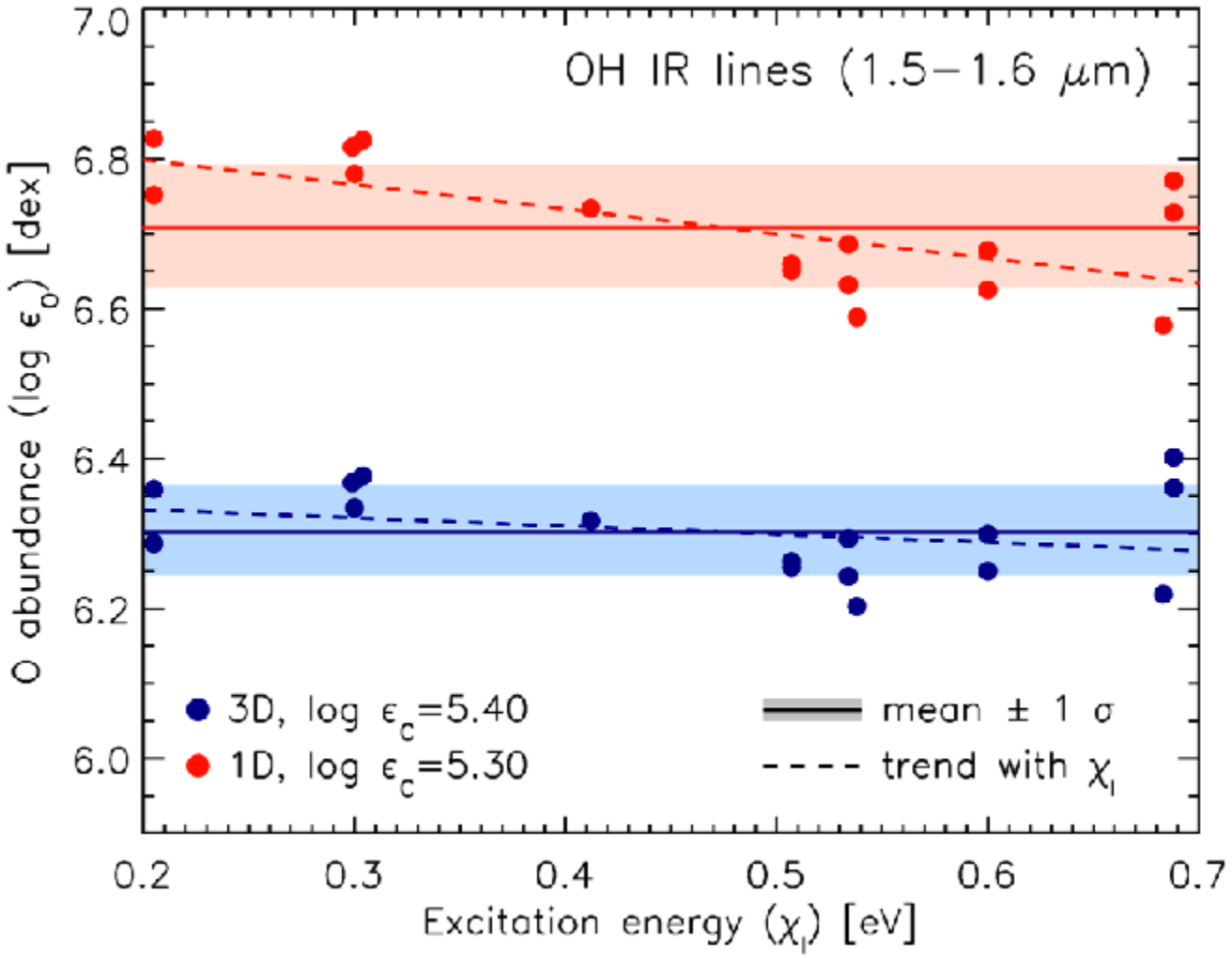
HD122563: metal-poor halo star



Collet et al.

HD122563: metal-poor halo star



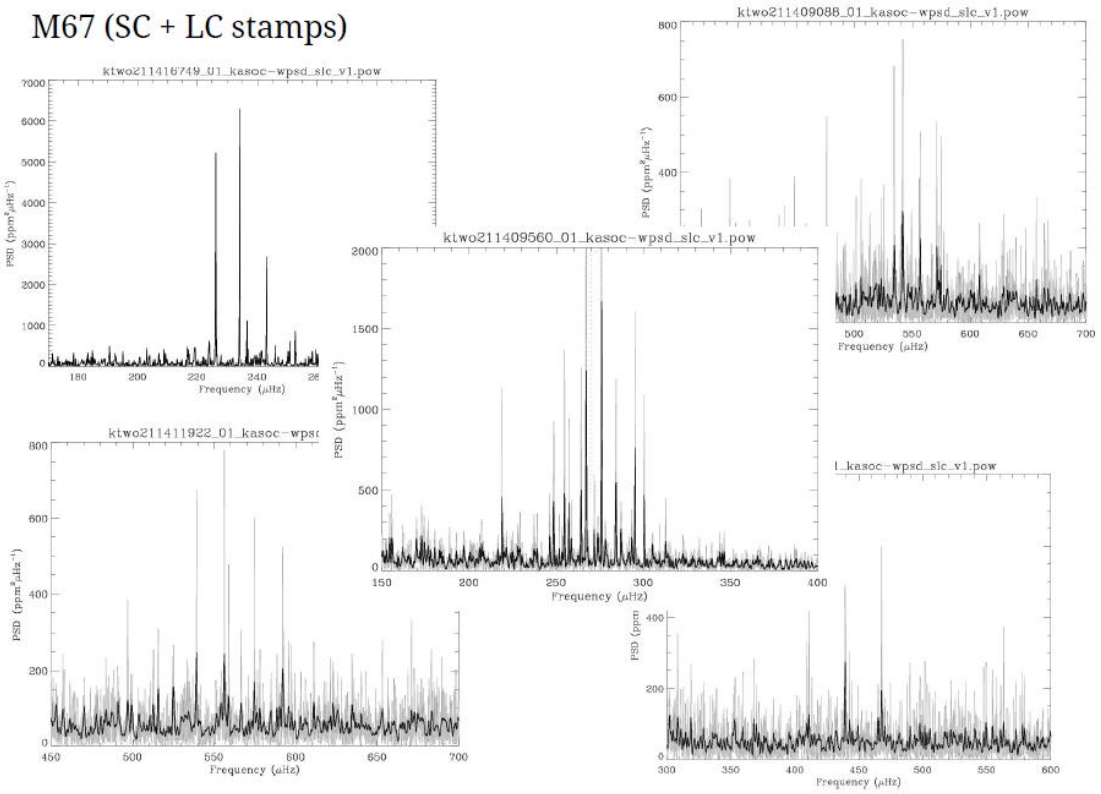
Collet et al.

Benchmarks in open clusters

- Independent age determination
- Better handle on composition

M67 red giants with K2

Lund et al.



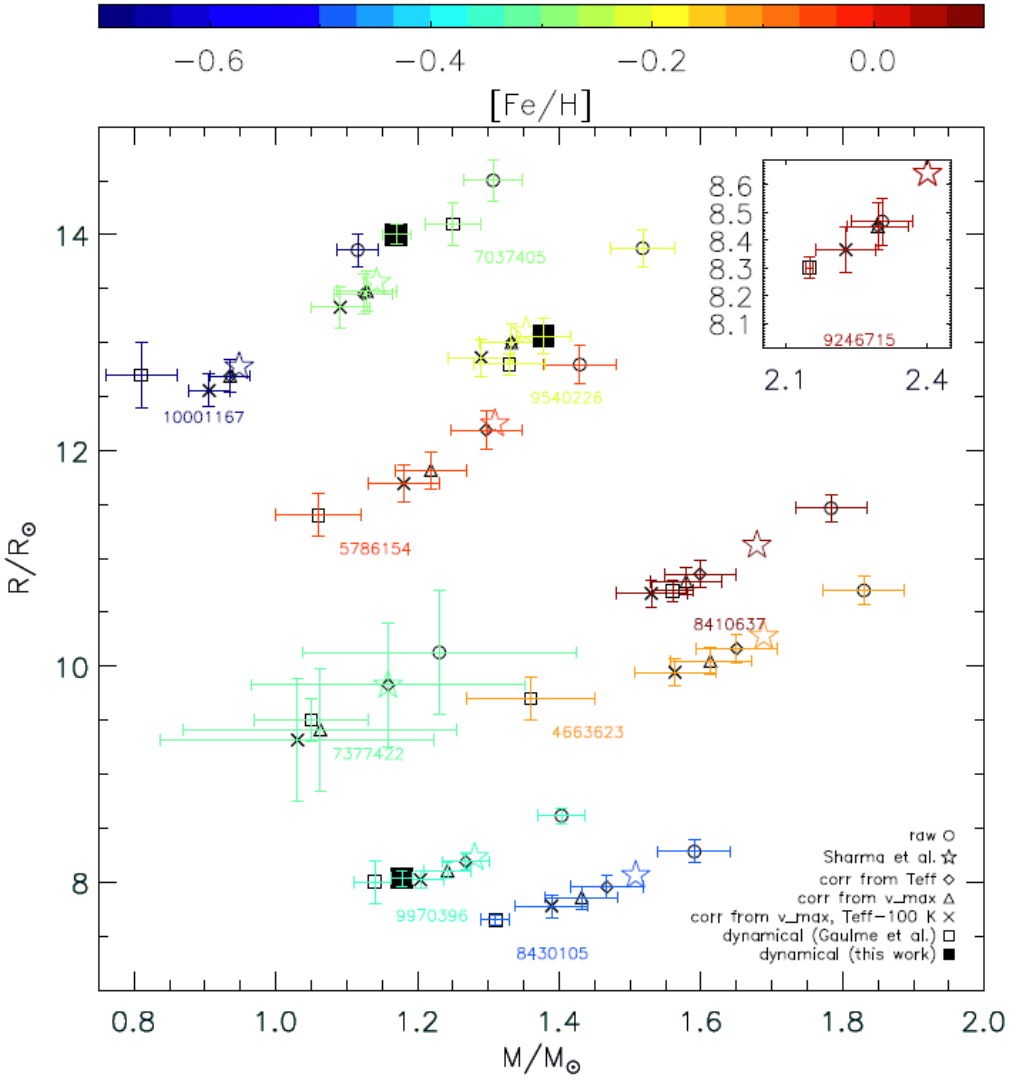
Benchmarks in open clusters

- Independent age determination
- Better handle on composition
- Further data from K2: Hyades, M67, ….
- Consider potential with TESS and PLATO (but PSF, confusion, will be an issue)

Benchmarks in eclipsing binaries

- Potentially accurate(?) masses and radii from binary orbits
- Compare with asteroseismic results
  - From *Kepler*: several red giants (see also talk by Gaulme)
  - Good potential with TESS
  - Excellent potential with PLATO (see talk by Lebreton)

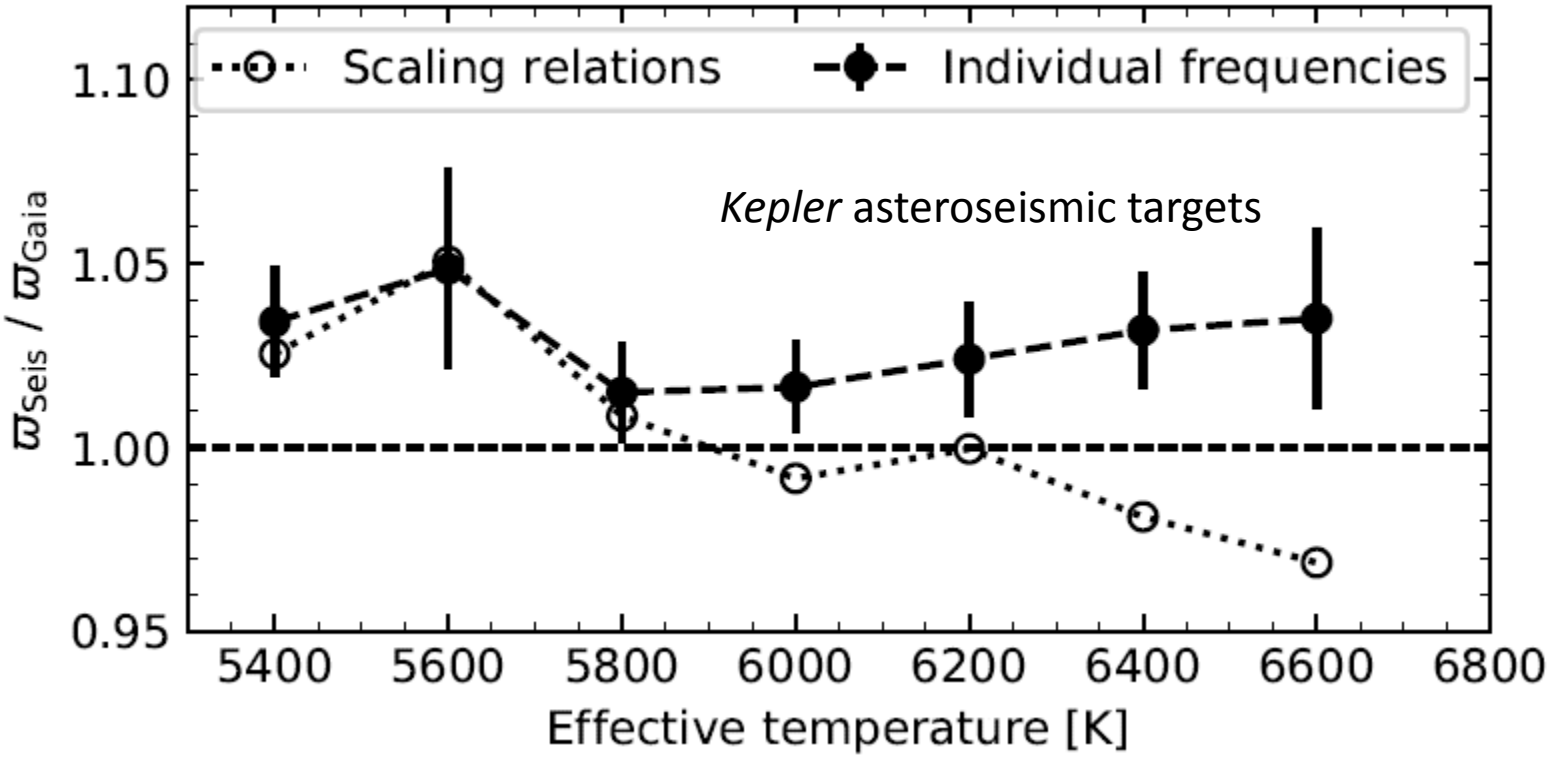
Kepler EB red giants



Brogaard et al. (2018; MNRAS 476, 3729)

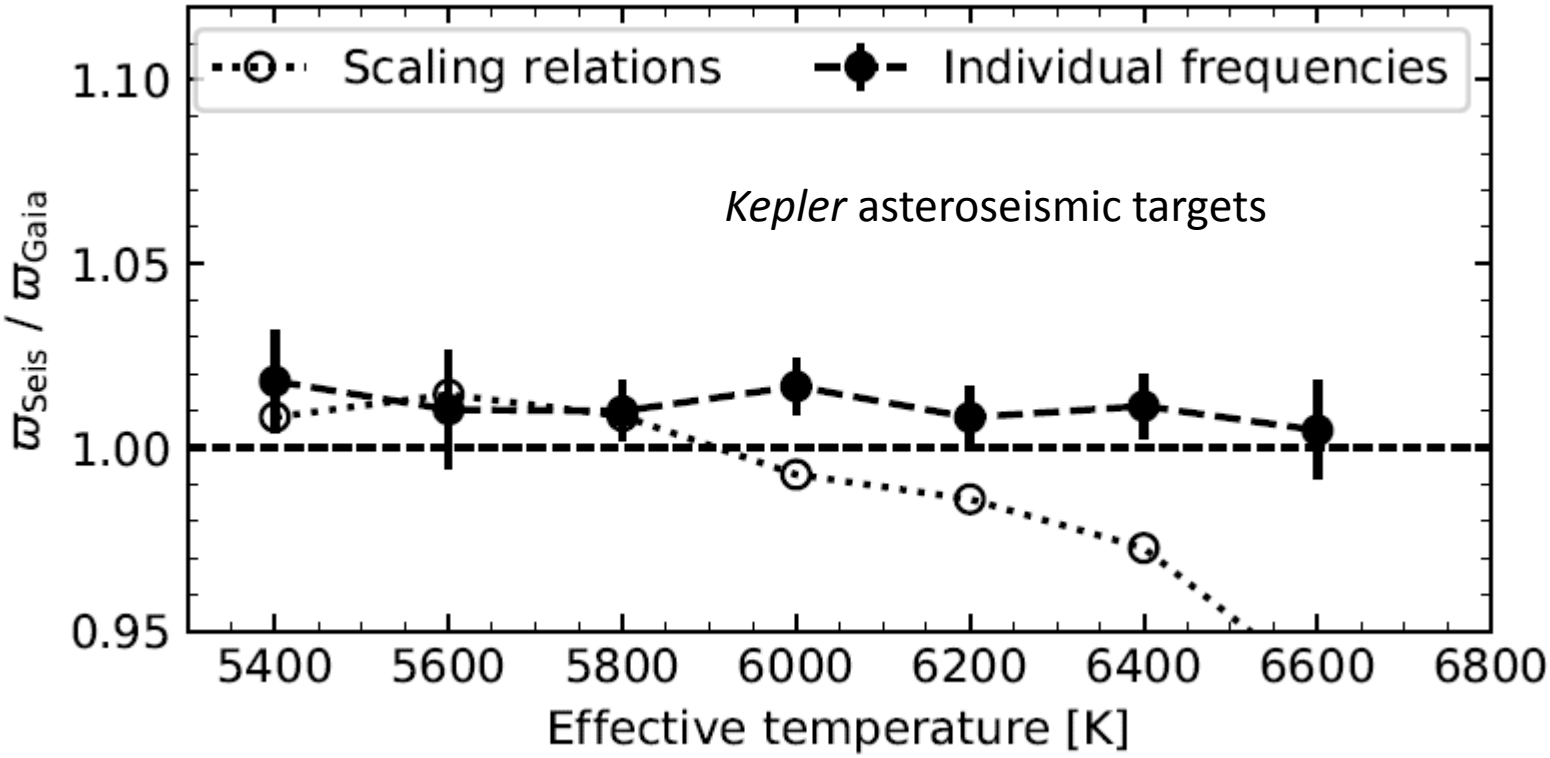
Gaia benchmarking of asteroseismology: DR1

$$\{R_{\rm seis}, T_{\rm eff}\} \rightarrow L_{\rm seis} \rightarrow \varpi_{\rm seis}$$



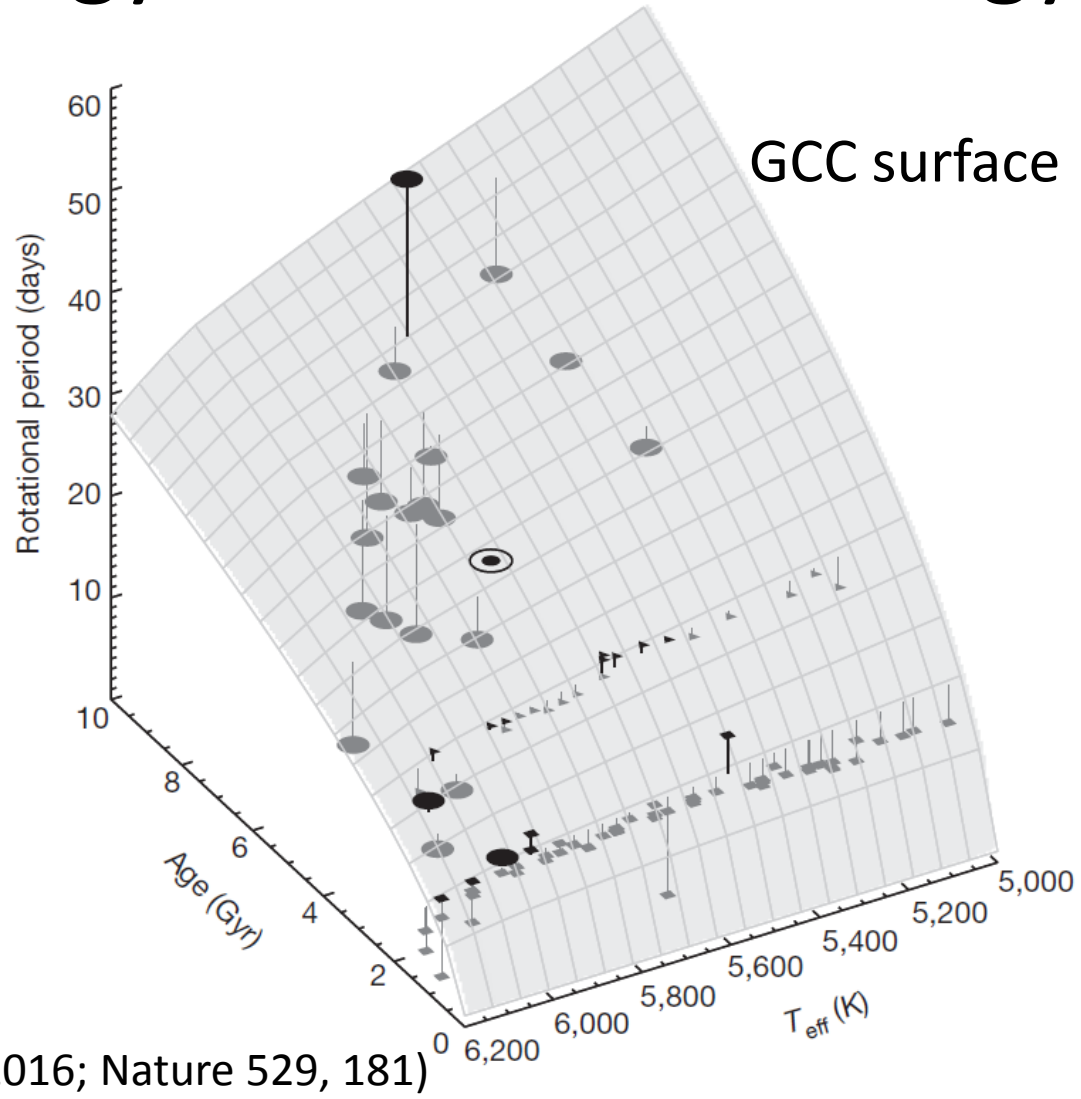
Sahlholdt et al. (2018; MNRAS 476, 1931)

Gaia benchmarking of asteroseismology: DR2



Sahlholdt et al. (in preparation)

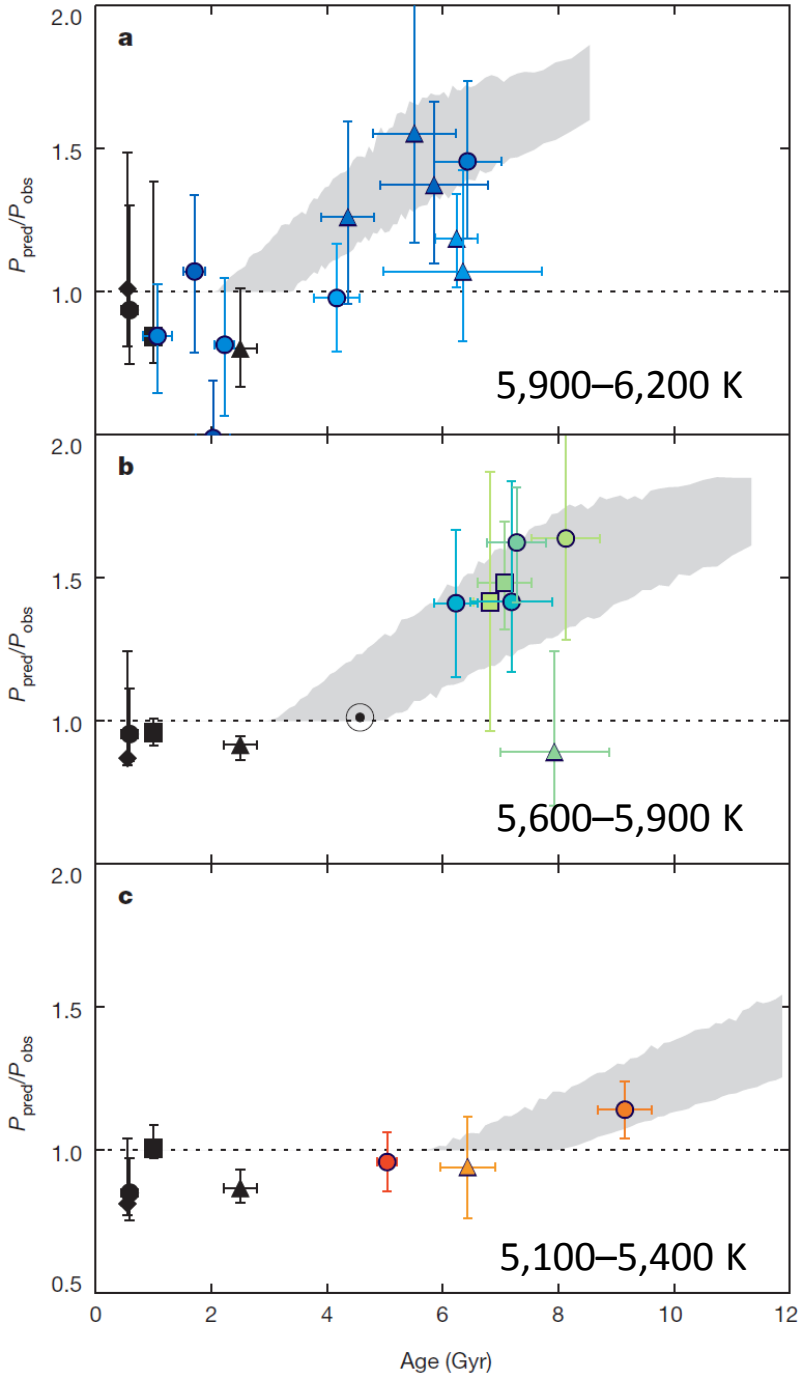
Asteroseismic benchmarking of gyrochromochronology



van Saders et al. (2016; Nature 529, 181)

Asteroseismic benchmarking of gyrochromochronology

See also talk by do Nascimento



van Saders et al. (2016; Nature 529, 181)

Possible actions

- Include bright *Kepler* asteroseismic targets amongst GBS (or PBS)
- Ensure detailed asteroseismic analysis of the TESS GBS
- Establish a Benchmark WG?