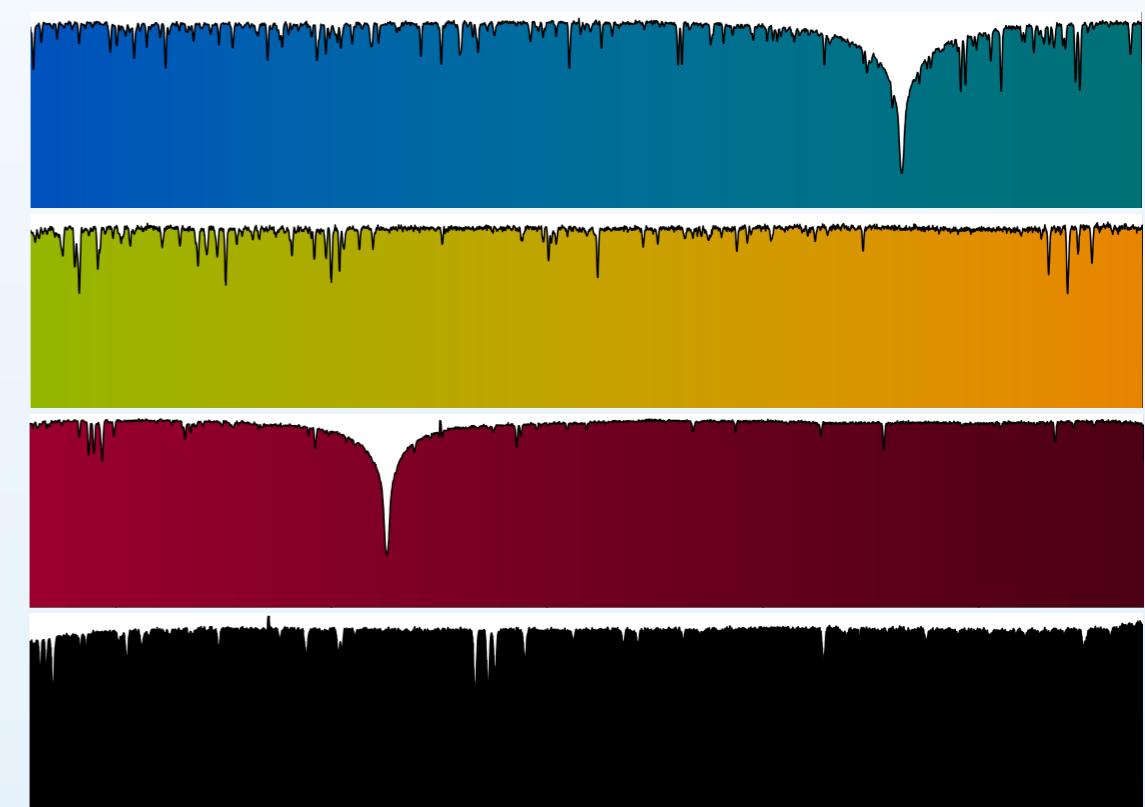
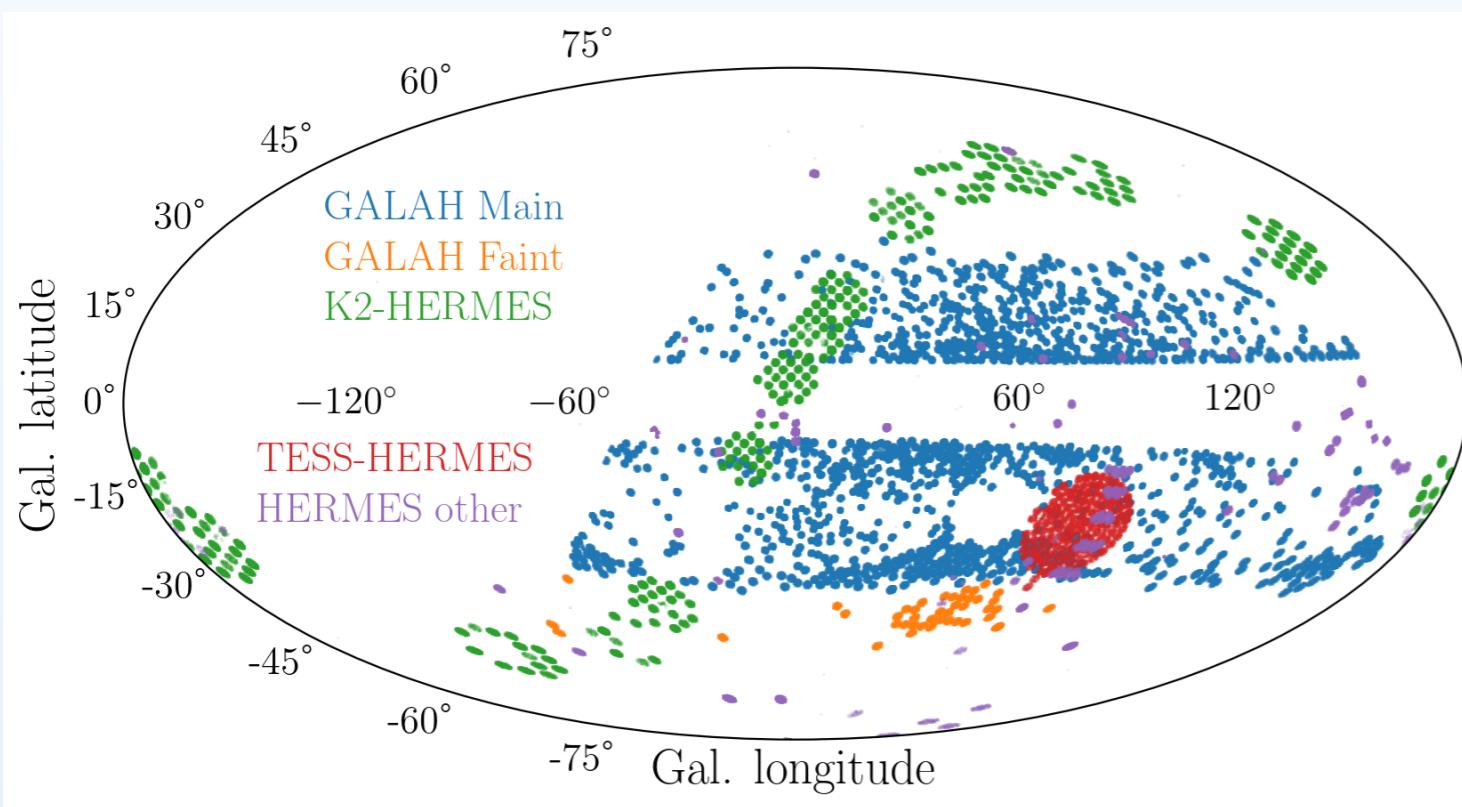


REFERENCE STARS AND VALUES FOR AND FROM GALAH (GALACTIC ARCHAEOLOGY WITH HERMES)

SVEN BUDER (ANU CANBERRA, HE/HIS, @ASTRO_SVEN)

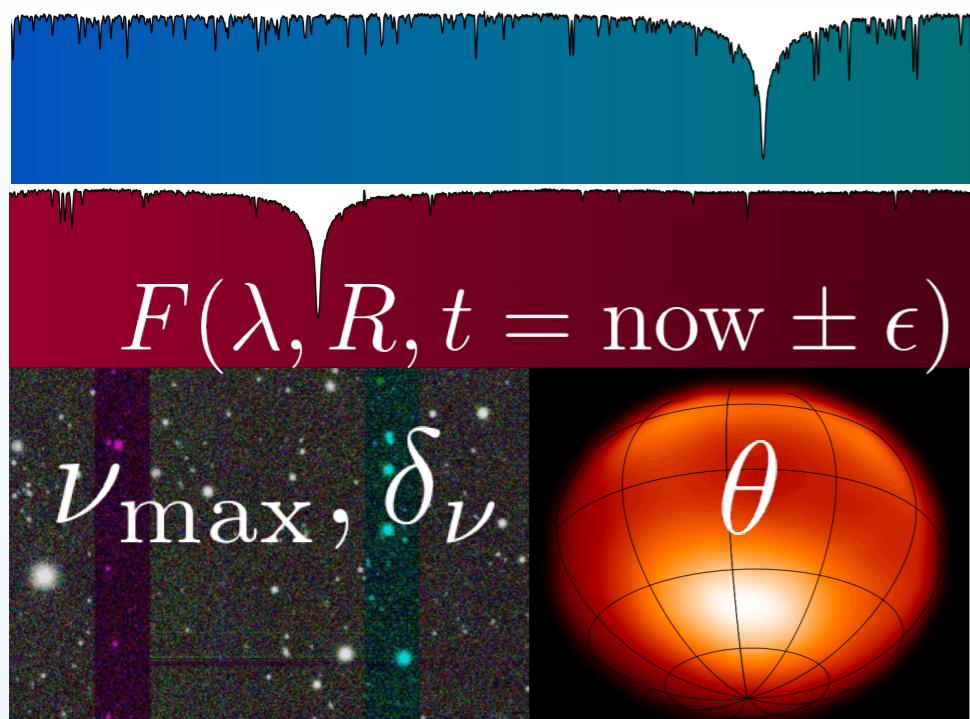


HERMES: R~28,000 for λ 470-490, 565-590, 650-675, 760-790 nm -> up to 30 element lines
400 stars per 2 deg FoV. Until now: 600k stars (200+ more nights scheduled)
Main survey: magnitude limited $9 < V < 12$ and $12 < V < 14$ from Australia
with excellent Gaia 5D information ($\sim 1.5\% \sigma$ unc.)
+ dedicated observations of K2, TESS, OCs/GCs

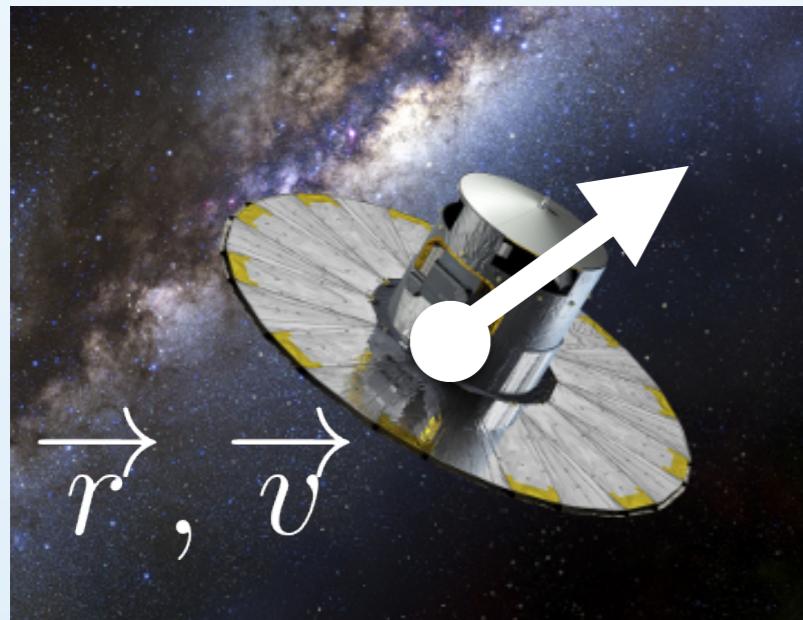
Reference values/stars for surveys

1. For which parameters **P** do we need references?
2. What are our possible observables **O**?
3. What are our most reliable/model-ind. ways **O** -> **P**?
4. What are our current best references for **P**?
5. What references are we missing?
6. How can we obtain the missing references?

Observables: O



with noise



Stellar modelling

Atmosphere modelling
(T_{eff} , $\log g$, 1D LTE,
 v_{mic} , $\log gf$, ...)

Scaling relations

Evolution modelling

What we want: P

Chemical composition
 $\mathbf{A}(\mathbf{X}, t)$
at least initial and surface
 $A(X) \rightarrow [X/H]$

Age & Evo. Status
 M, R

Dynamical Modelling

Orbits
 $\vec{r}(t) \& \vec{v}(t)$
 $\Phi(\vec{r}, t)$
 \vec{J}, E, e, \dots

Reference Stars/Values For GALAH

Accuracy

Precision

T_{eff}

$\log g$

[Fe/H]

A(X)

I will not discuss Age, M, R, v_{rad}

Reference Stars/Values For GALAH

T_{eff}

Accuracy

GBS, IRFM

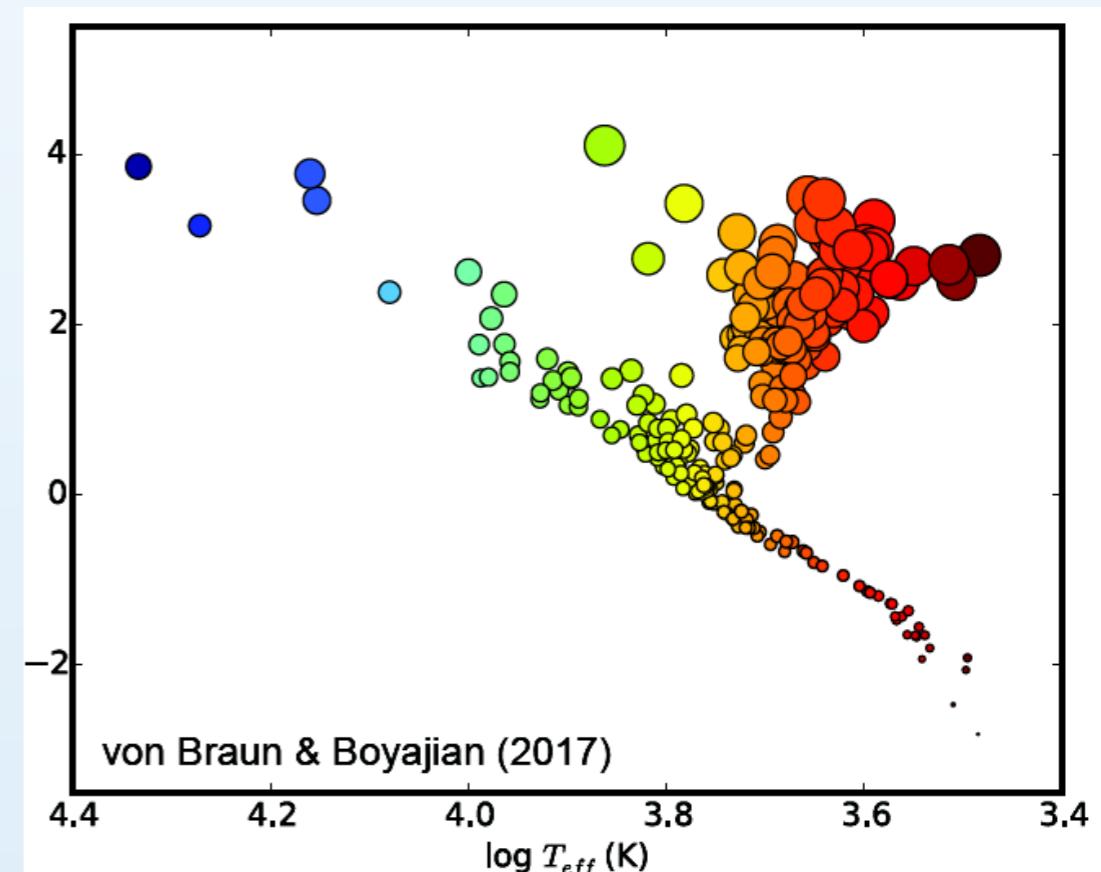
Precision

Not all GBS observable from Australia

GALAH: than 30 stars with θ

Need more observations
of θ and stars with θ !

Discrepancies of photometric
and spectroscopic T_{eff} ?



Reference Stars/Values For GALAH

$\log g$

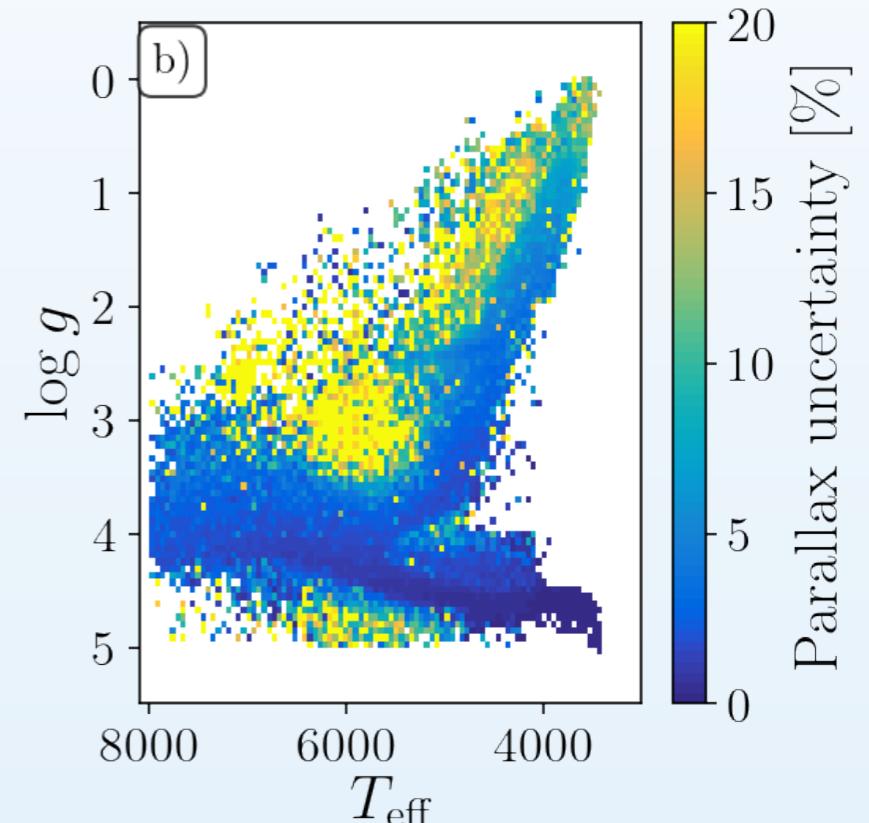
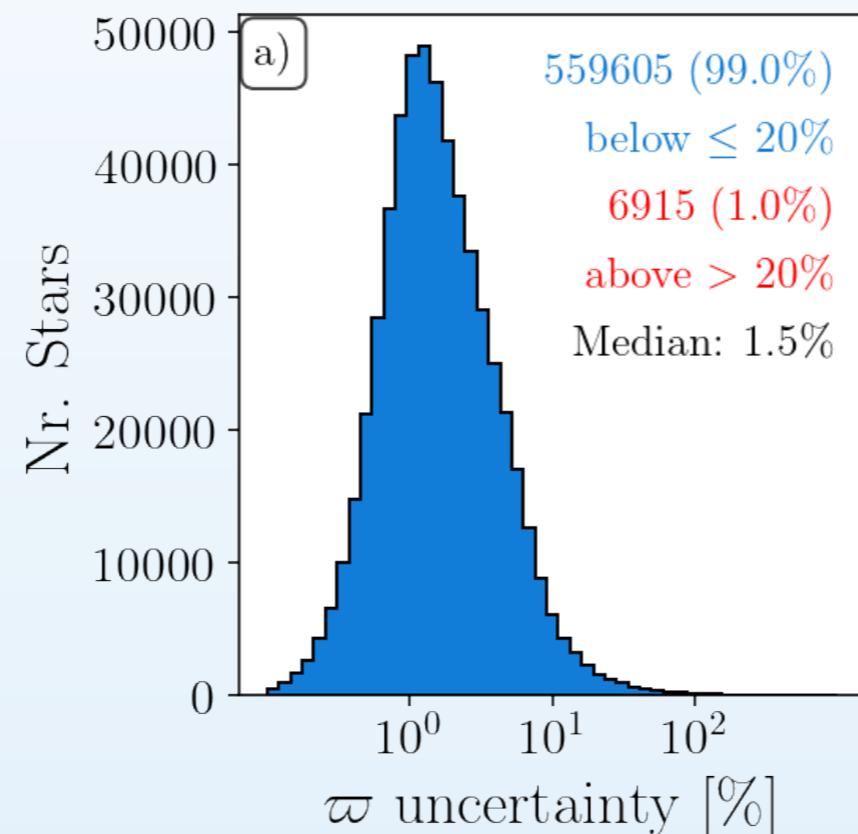
Accuracy

Precision

L_{bol} (*Gaia*, 2MASS)

Gaia parallaxes
extremely helpful!

But: $\log g$ still
depending on
M, BC, A and
binarity



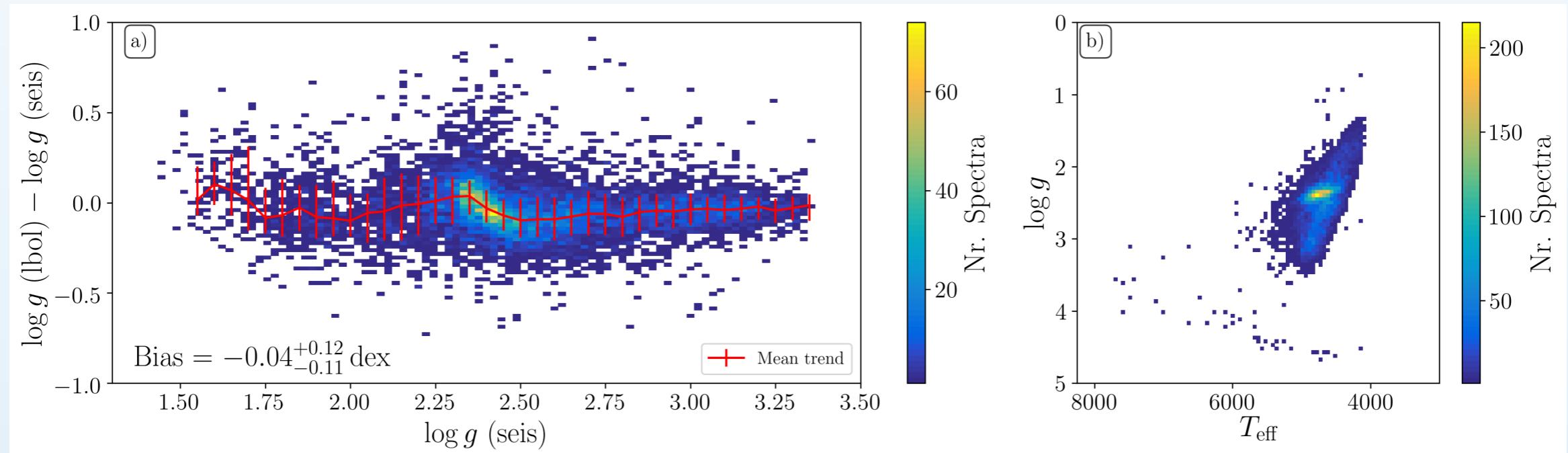
$$\log \frac{g}{g_{\odot}} = \log \frac{\mathcal{M}}{\mathcal{M}_{\odot}} + 4 \log \frac{T_{\text{eff}}}{T_{\text{eff}, \odot}} - \log \frac{L_{\text{bol}}}{L_{\text{bol}, \odot}}$$

Reference Stars/Values For GALAH

Accuracy Precision

log g K2 ν_{max}

Kepler/K2 ν_{max} extremely helpful! Similarly $\delta\nu$ and [C/N]^{*} to identify RC!



But: limited to giants due to K2 cadence
More to come from TESS? GALAH observed lots of K2+TESS targets!

Reference Stars/Values For GALAH

	Accuracy	Precision
[Fe/H]	GBS, OC/GC	

[Fe/H] estimates are not independent of spectroscopy

Different lines deliver different A(Fe).

What should be our standards for A(Fe)?

Accuracy of [Fe/H] as function of T_{eff} etc. with 30 GBS [Fe/H]?

Stellar evolutionary effects change surface abundance
as shown of OCs like M67

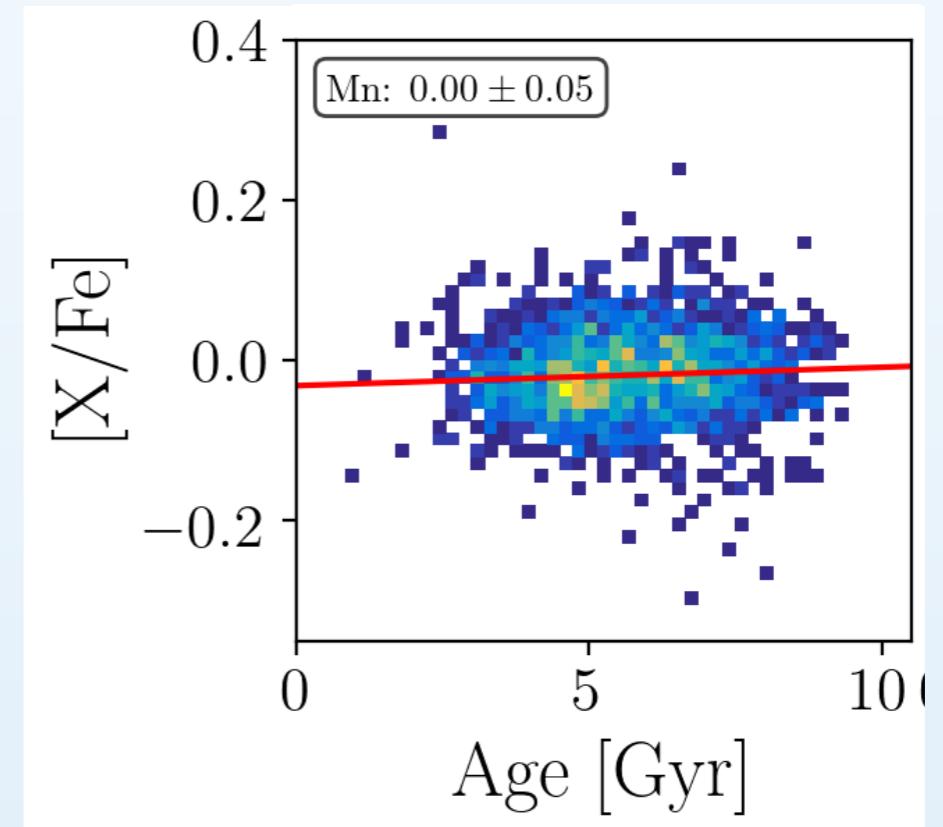
Many GCs have Multiple Stellar Populations

Reference Stars/Values For GALAH

Accuracy
A(X) only zero points

Sun/Skyflat/Vesta
Arcturus and other GBS
Solar Twins
Solar Circle
OCs/GCs
Overlap with
other surveys

Precision



Reference Stars/Values For GALAH

Accuracy

all parameters

Precision

$e_{\text{fit}}, e_{\text{repeat}}$

GALAH DR3*:

$$\ln \sigma = A + B \cdot S/N'$$

APOGEE DR16**:

$$\ln \sigma = A + B \cdot T'_{\text{eff}} + C \cdot S/N' + D \cdot [\text{M}/\text{H}]$$

More representative repeats: observe or add noise to high S/N

-> $\ln \sigma(S/N, \text{Teff}, \log g, [\text{Fe}/\text{H}], [\text{X}/\text{H}], \dots)$

More observations of OC stars at all evolutionary phases

Wide Binaries (El-Badry et al.)

*Buder et al. (2020)

What References do we lack?

Rare stars (e.g. metal-poor, accreted)
Stars with weird A(X), e.g. high/low/anti-correlated
Even worse: rare stars with weird A(X)

Reliable references for A(X) over the parameter space
-> different lines give different answers for A(X)
-> log gf, 3D NLTE effects, blending

More representative repeats

Knowledge if spectra originating from single/binary

Summary + Discussion Starters

- **GALAH**: 600k stars with excellent Gaia 5Ds, v_{rad} + 30 elements from Australian optical R~28k spectra selected with $9 < V < 12$ and $12 < V < 14$ plus K2+TESS+OC+GC follow-up
- **GALAH's reference stars/values** are:
 - Parameter estimation: *Gaia* distances + 2MASS K_s + M/BC/A K_s ($T_{\text{eff}}, [\text{Fe}/\text{H}]$) for logg
 - **Accuracy**: Sun + Arcturus + other GBS (T_{eff} , logg, [Fe/H], v_{broad}), K2 (logg)
 - Accuracy validation: IRFM T_{eff} , OCs, GCs,
Solar twins + Solar circle stars + APOGEE DR16 (A(X) zero points)
- **Precision**: Repeat observations (but more representative ones needed!)
- Precision validation: OCs, Wide Binaries
- **Reference stars** for all surveys should be:
 - **Representative**: well balanced selection (**Teff, logg, ages, all/major+rare A(X)**)
 - **Reliable**: Major interest: **M, R, age, A(X), v_{rad}** best observables: **F(λ, R), θ, v_{max}, δv**
 - **Reachable**: declination, magnitudes, within certain FoV + density
 - **Reusable**: high **S/N** spectra, all **λ**, high **R**, (usable by all surveys for acc.+prec.)