Leibniz-Institut für
Astrophysik Potsdam

Galactic Archaeology with CoRoT and APOGEE: CoRoGEE

592. Heraeus Seminar, 04.06.2015

Friedrich Anders (AIP)

Cristina Chiappini, Thaíse Rodrigues, Benoit Mosser, Andrea Miglio, Josefina Montalbán, Léo Girardi, Márica Valentini, Mathias Schultheis, Basílio Santiago, Anna Queiroz, Marie Martig, Matthias Steinmetz + **APOGEE & CoRoT**

Outline

PhD thesis @ AIP/UP started 09/2013

C. Chiappini

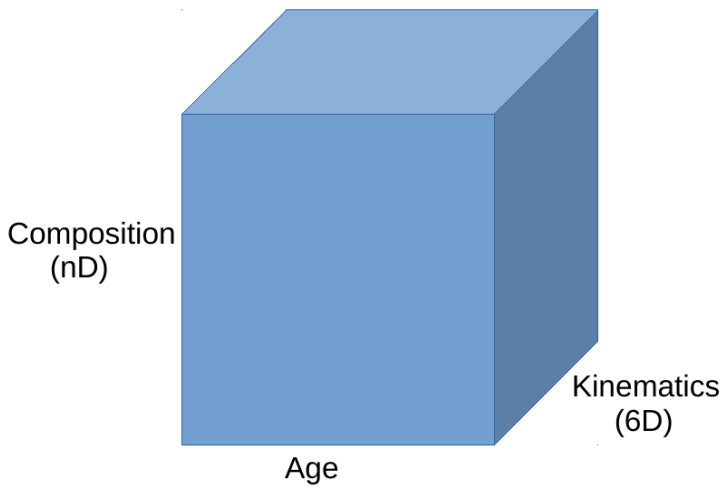
M. Steinmetz

Thanks for the Introductions...

- "Data-driven" Galactic Archaeology: Bland-Hawthorne, Kordopatis, Robin...
- Chemo-dynamical models: Just, Girardi, Sharma, Robin, Minchev, Binney...
- CoRoT: Miglio, Davies, Mosser...
- APOGEE: Majewski, Cunha, Allende, Johnson, Rodrigues...
- Dangers of "entry-level" seismology: Brogaard, Prada Moroni, Elsworth...
- Dangers of "industrial" spectroscopy: Ezzedine, Peterson, Jofre, Smith...
- Seismology–spectroscopy synergies: Miglio, Johnson, Stello, Valentini...
- Grid-based modelling: Prada Moroni, Silva, Casagrande, Rodrigues...
- Effect of Age uncertainties

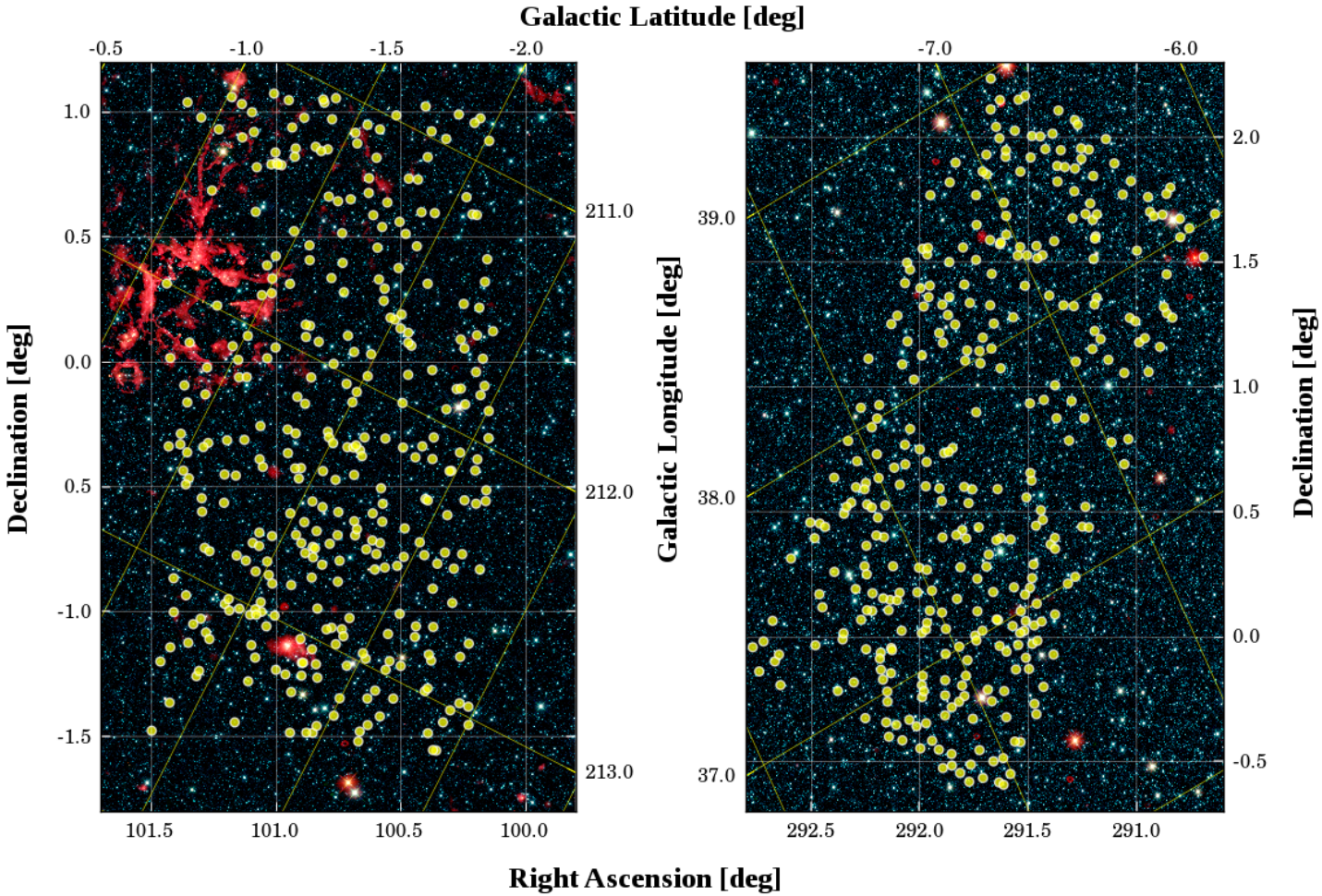
Inside your coffee cup - An analogy

Dissecting the Age-kinematics-abundance hypercube



- Galactic models make predictions for the distribution of stars in this multi-dim. space (or its subspaces)
- Basic problem of Galactic Archaeology: dimensionality reduction
- *Look for the most robust and telling slices of this hypercube to constrain models for a given dataset*

The DR12 CoRoT-APOGEE Sample



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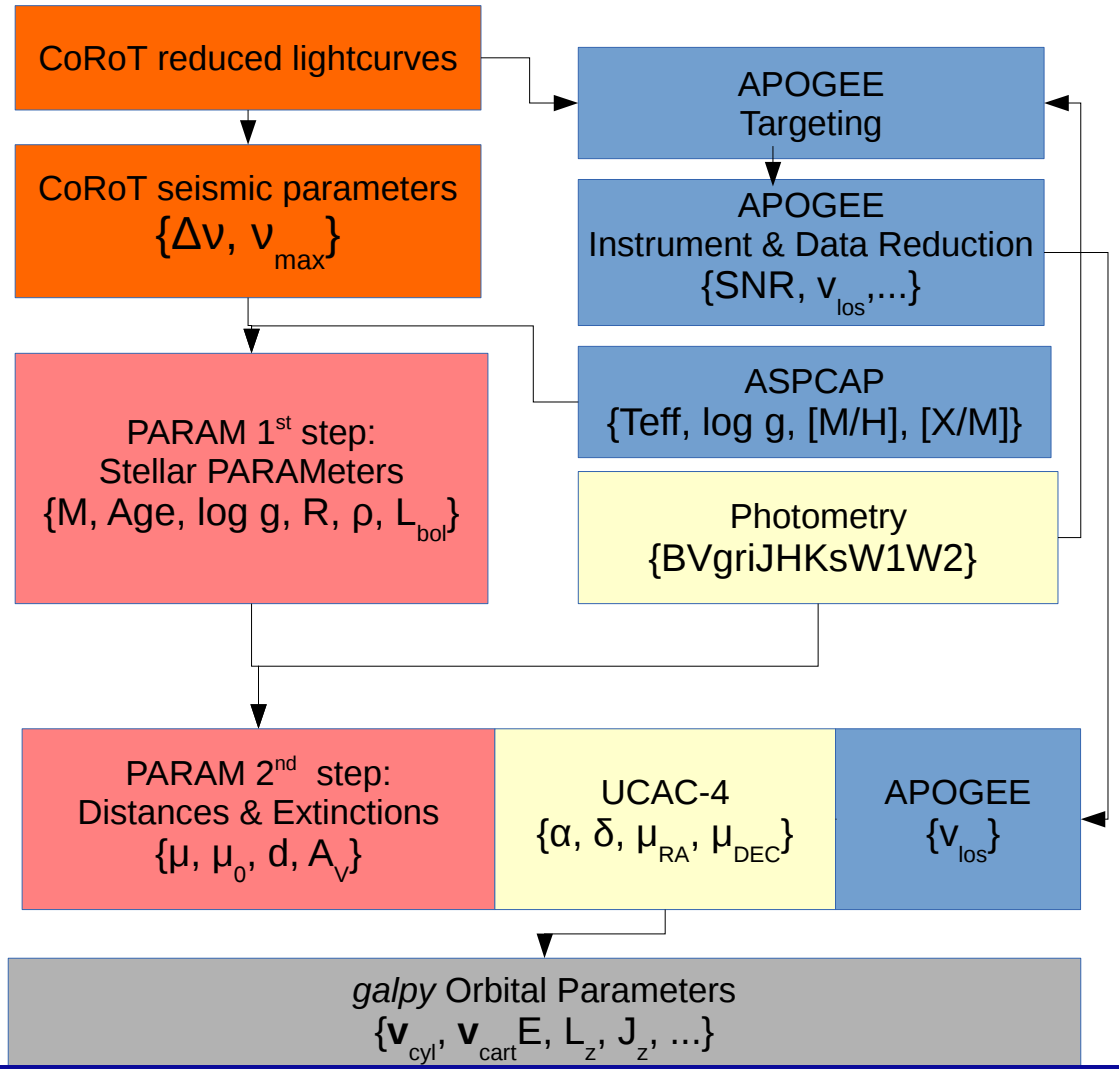

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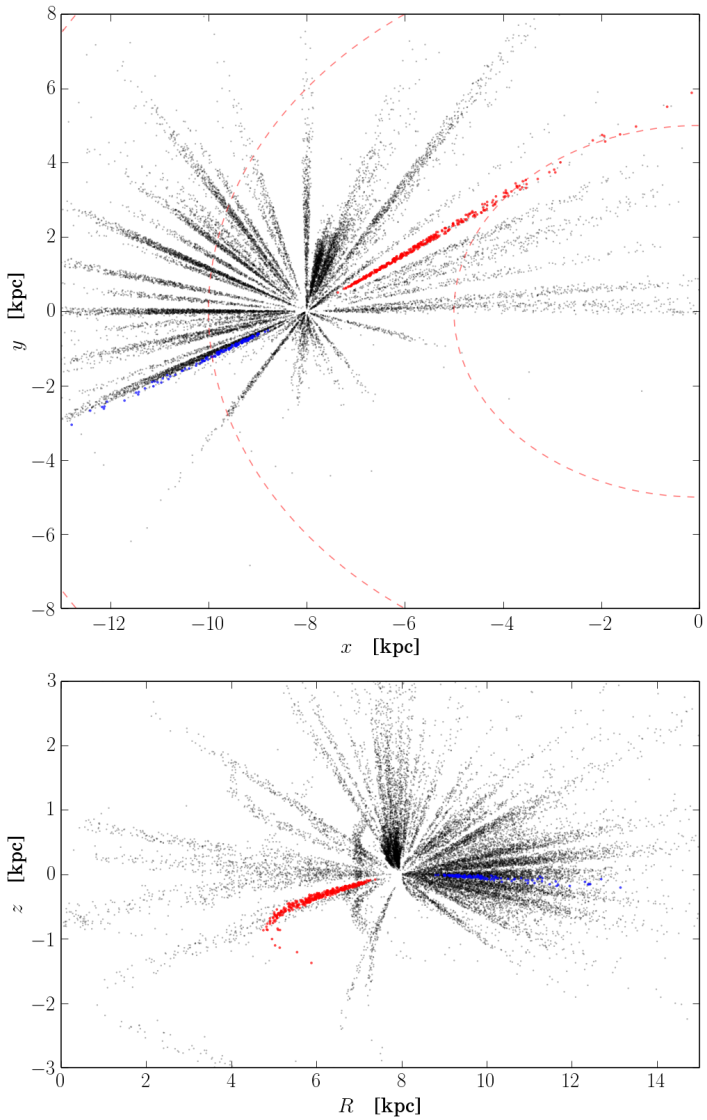
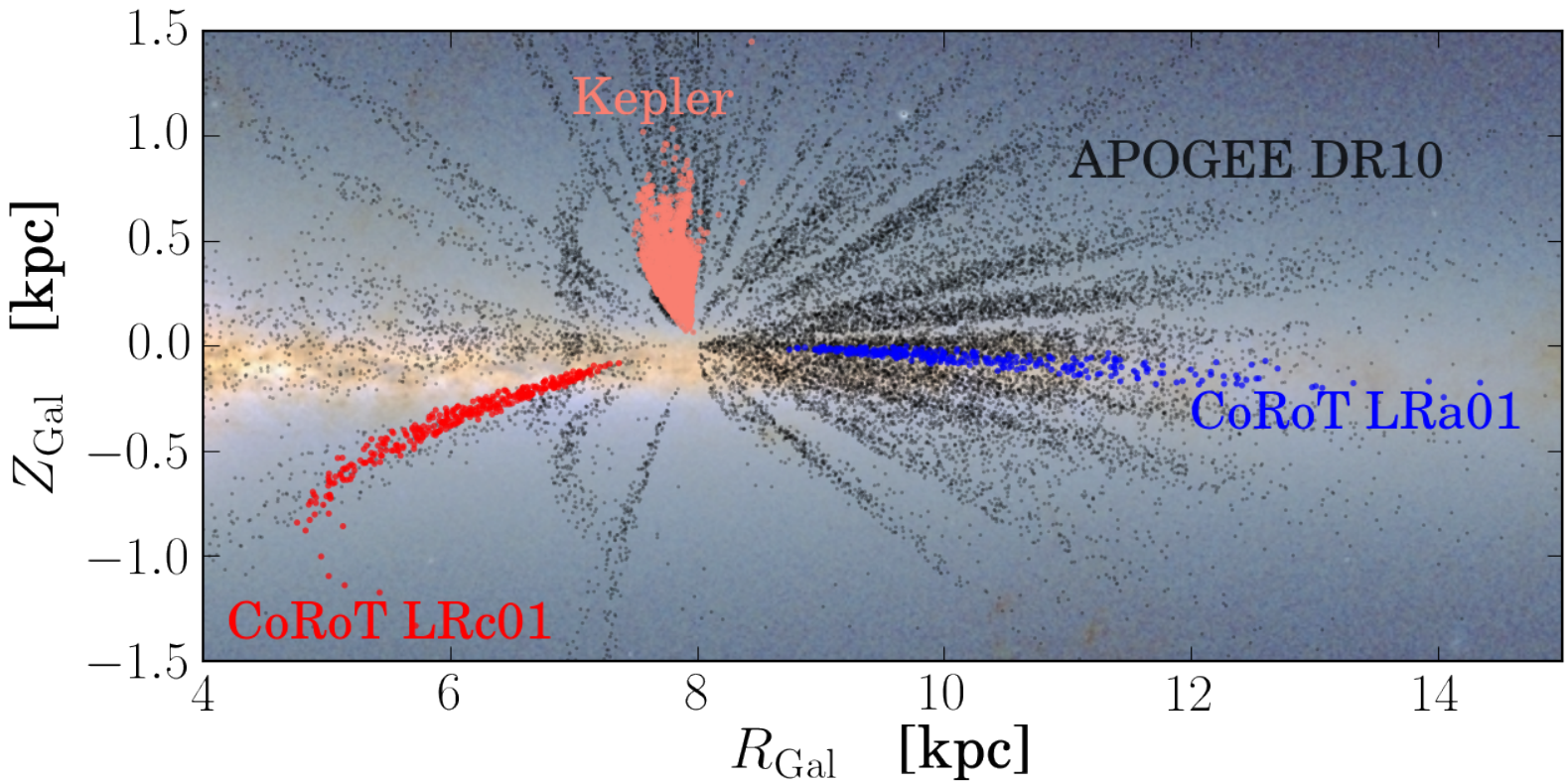
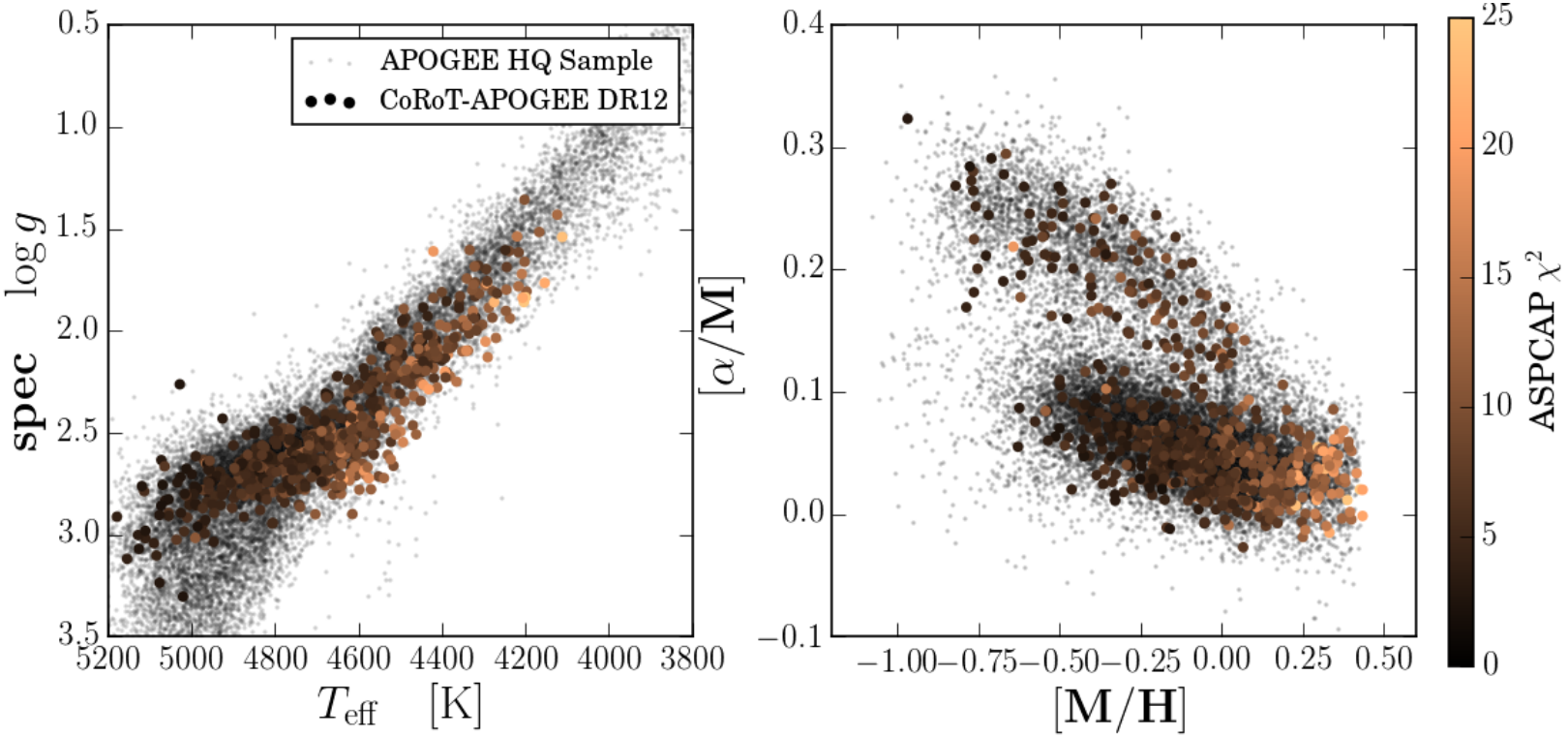


CoRoGEE stars	690
with "good" ASPCAP results	678
LRa01	333
LRc01	345
PARAM converged	623
Proper motions available	555
Good orbits ($\sigma(v_T) < 20$ km/s)	147

Advantage of the CoRoT-APOGEE Sample



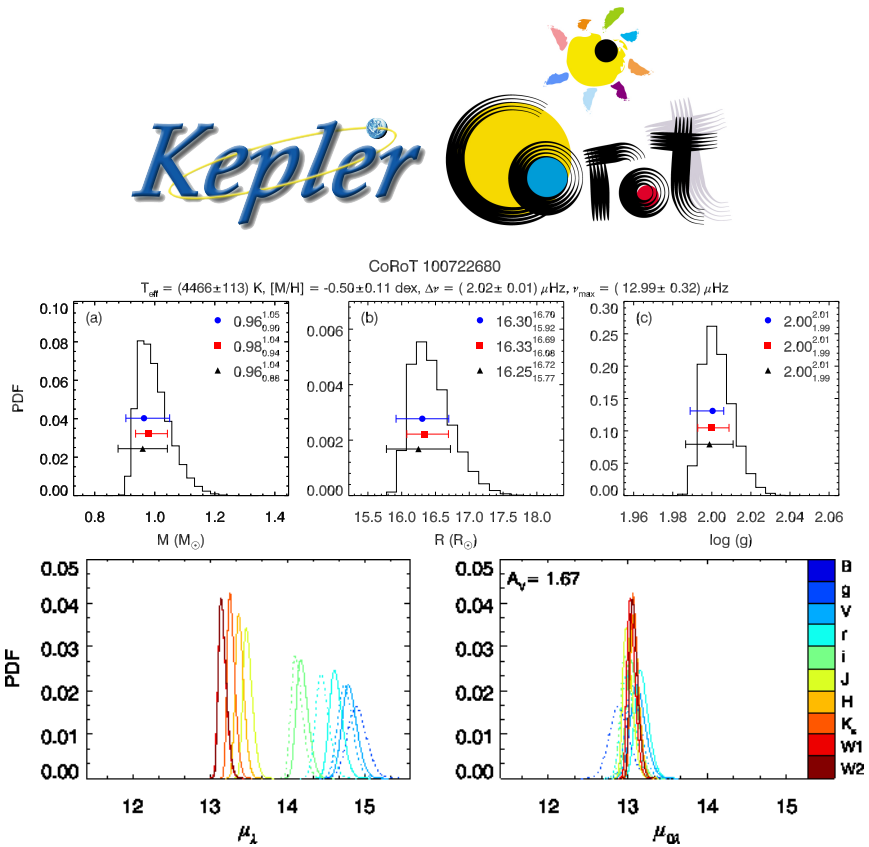
Sample Location in spectroscopic space



- APOGEE Stellar Parameter & Chemical Abundances Pipeline
- see Allende Prieto, Majewski talks

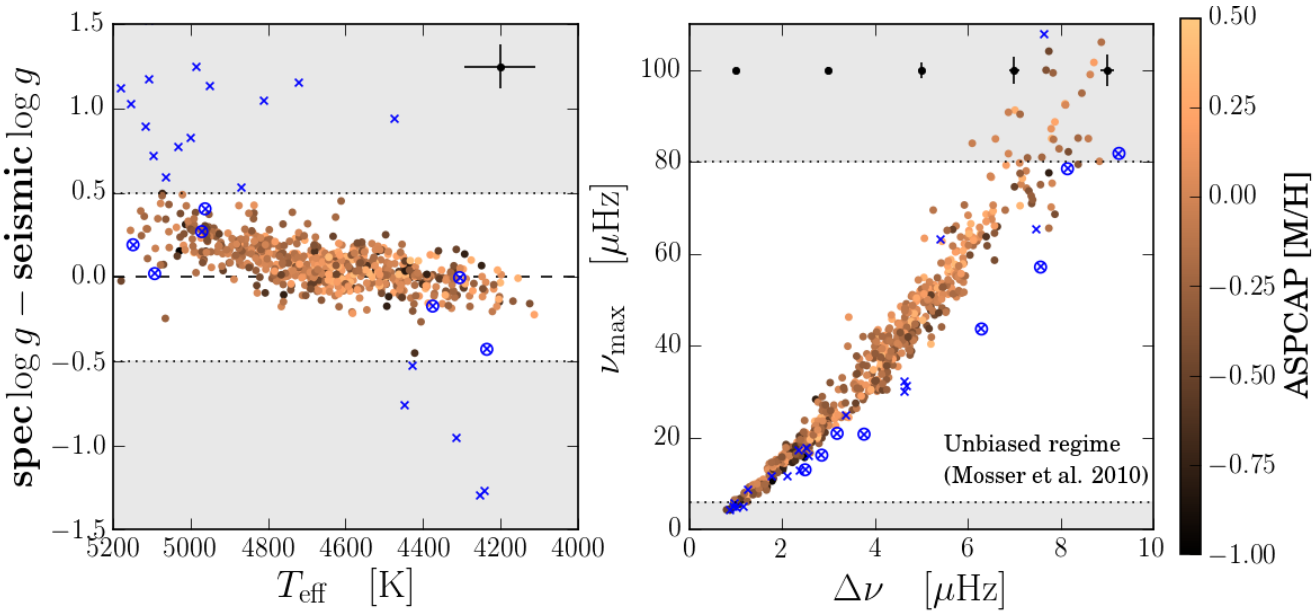
PARAM: Combining asteroseismology and spectroscopy

- **details in Thaíse's talk**
- $\frac{\Delta R}{R} \sim 3\%, \frac{\Delta M}{M} < 10\%$
- Precise (2%) distances + extinctions
- Typical age uncertainties $\sim 25\%$
- Use of evolutionary stage information possible



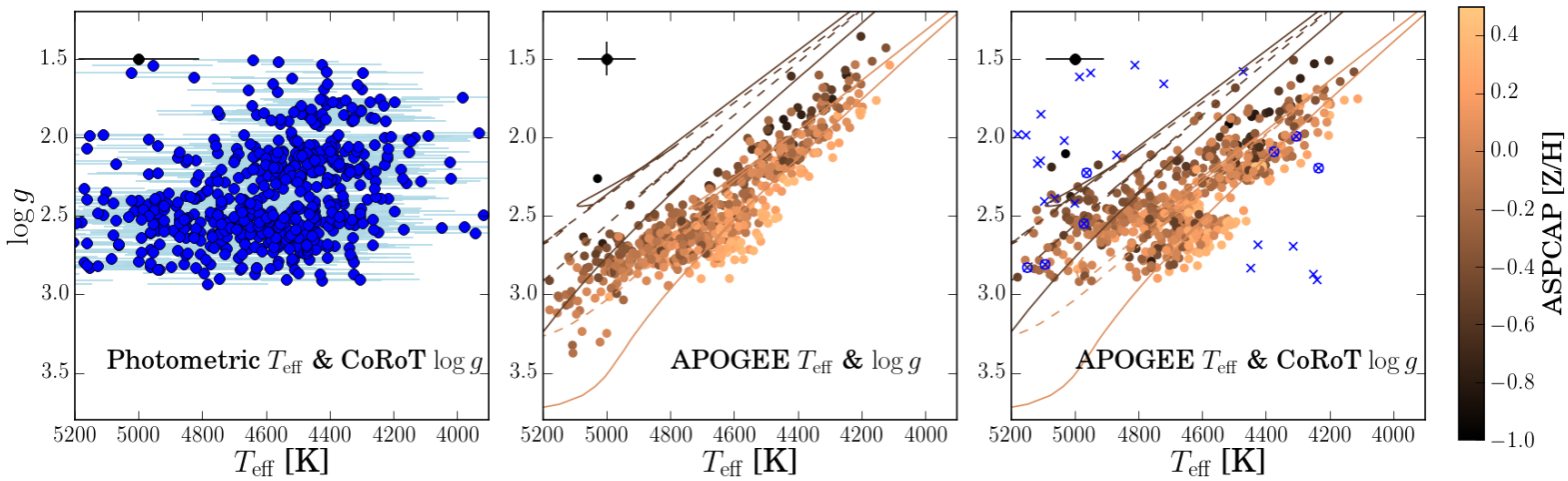
PARAM code: da Silva et al. (2006), Miglio et al. (2012), Rodrigues et al. (2014) Figure courtesy of T.S. Rodrigues

PARAM sanity checks: surface gravities



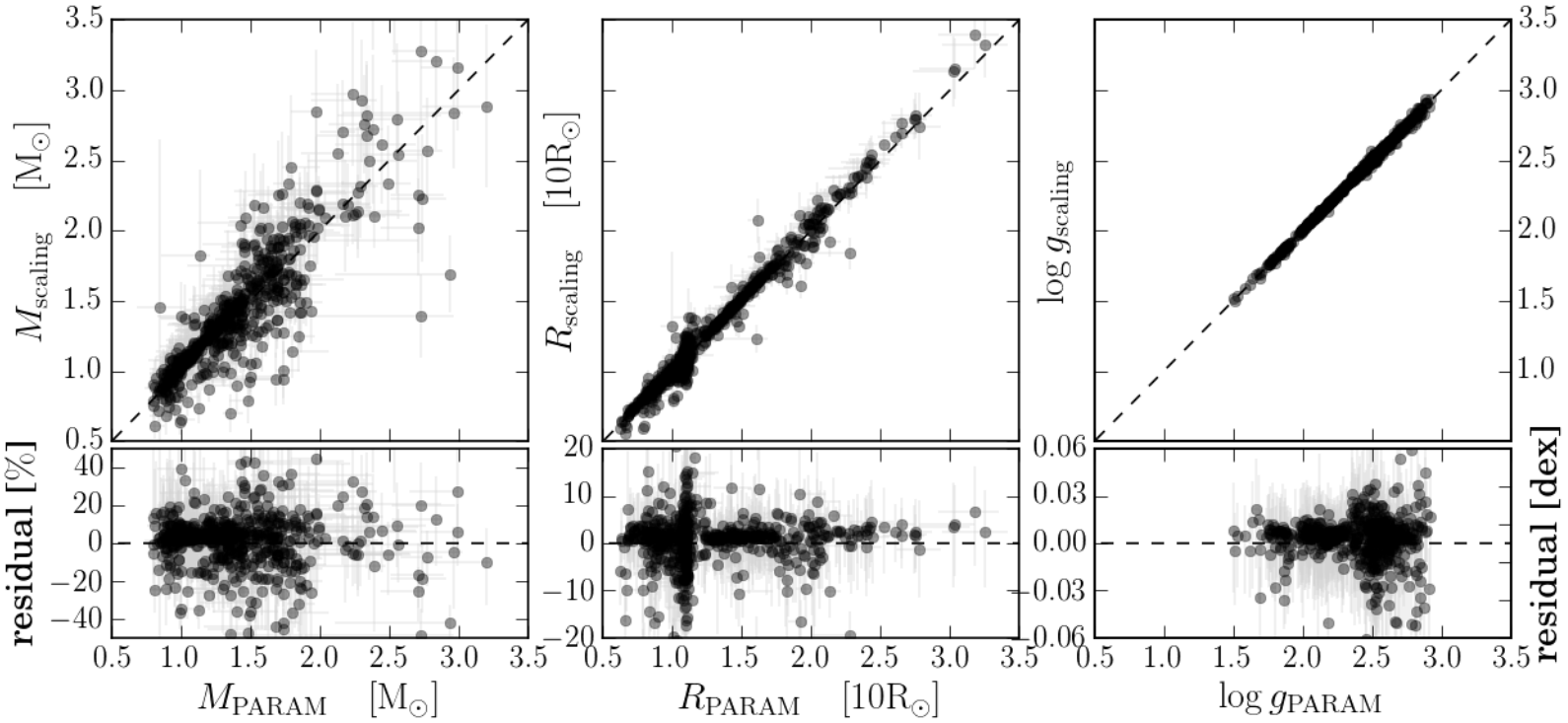
- PARAM serves as an outlier detection tool for seismic/spectroscopic results (e.g., noisy lightcurves)
- CoRoT data can extend the parameter regime for calibrating APOGEE $\log g$

PARAM sanity checks: *Kiel* diagram



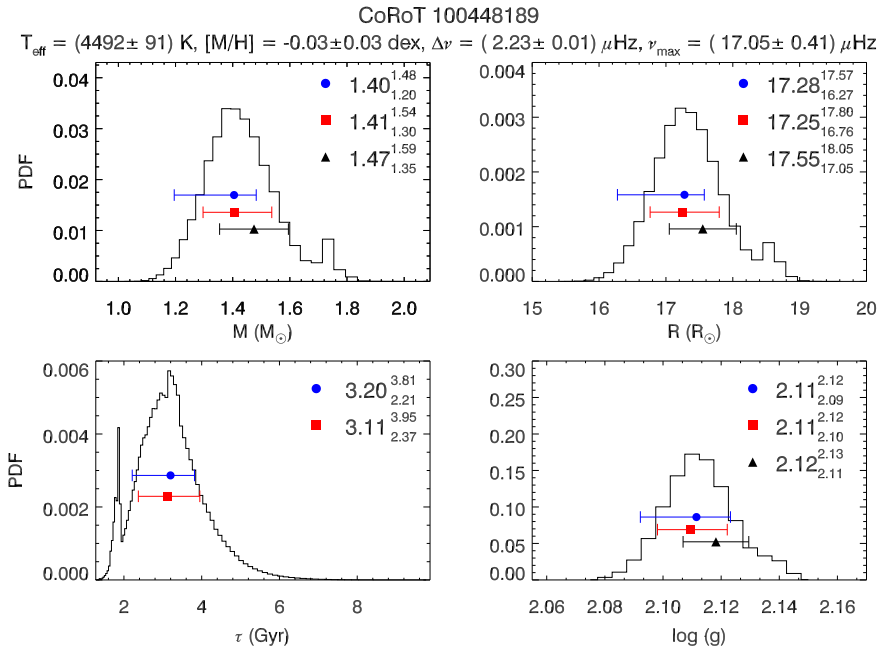
- Combination of asteroseismology and spectroscopy enhances yields more precise HRD
- PARAM detects unphysical stellar parameter combinations

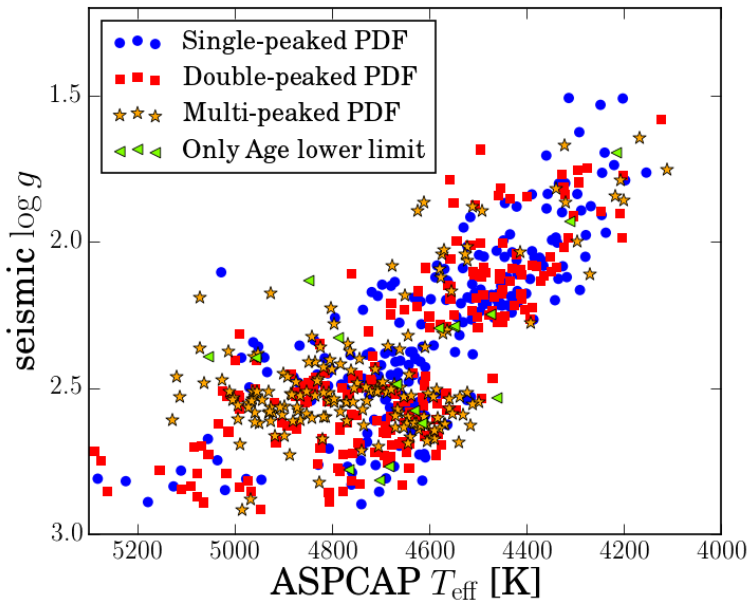
PARAM sanity checks: grid-based vs. scaling results



- In some cases considerable difference between Bayesian results and scaling relations
- mean differences and rms scatter: $(0.6 \pm 6.7)\%$ in mass, $(0.2 \pm 2.4)\%$ in radius, and 0.002 ± 0.008 dex $(0.1 \pm 0.3)\%$) in $\log g$

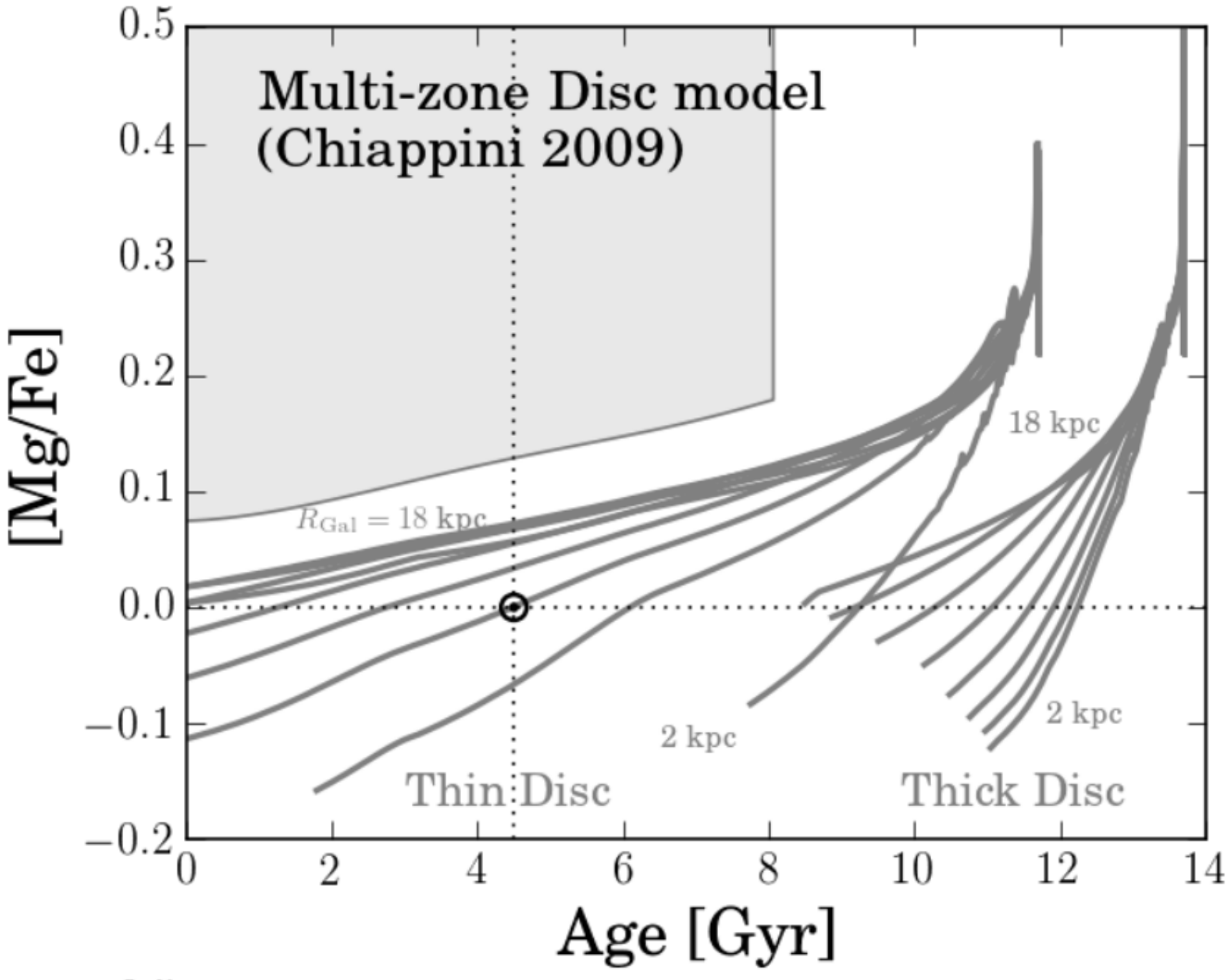
PARAM sanity checks: Multi-peaked Age PDFs



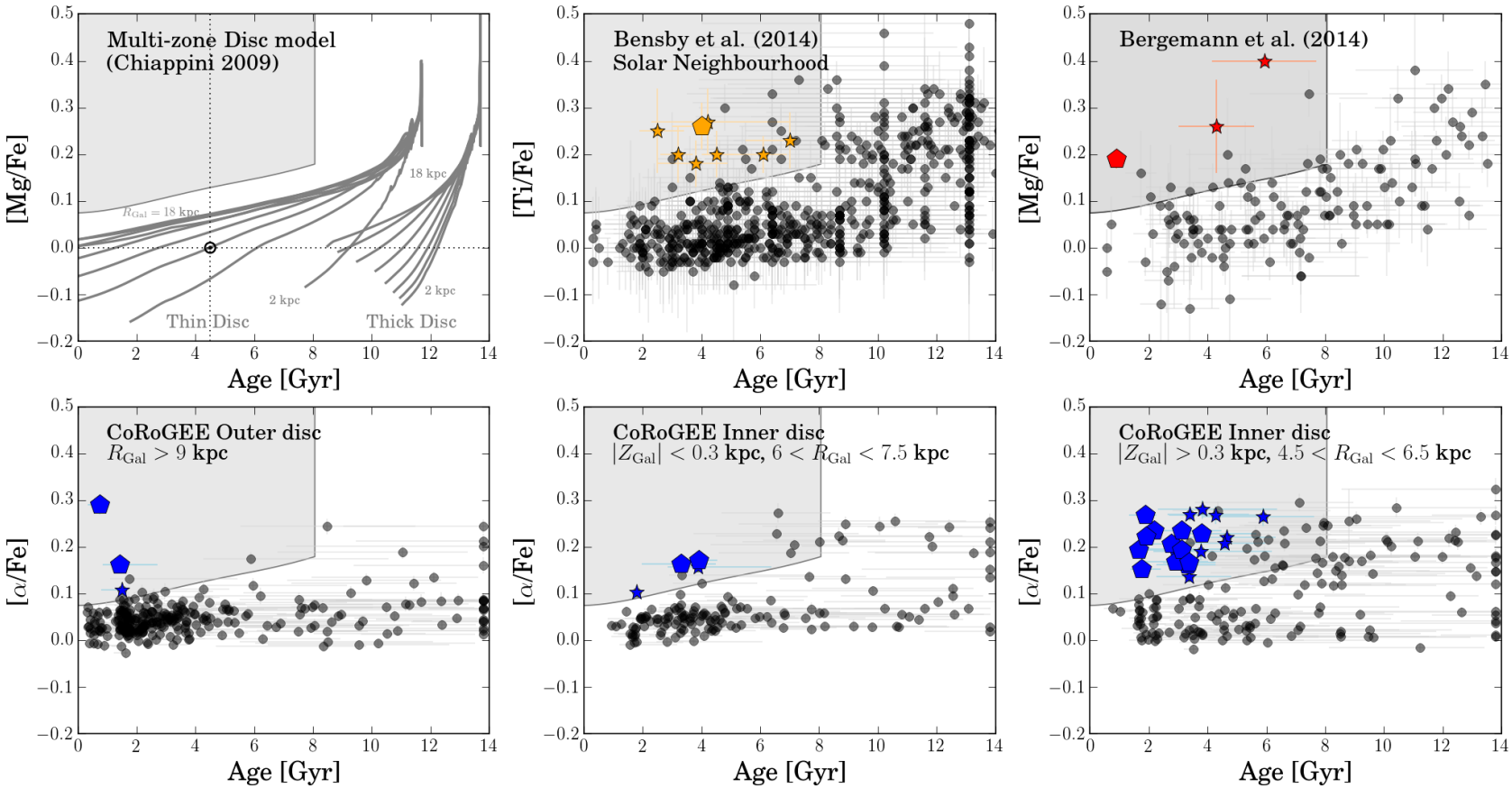


- CoRoGEE Age PDFs are typically non-trivial...
- More details in Thaíse's talk!

What typical models predict for [α/Fe]-vs.-age relation

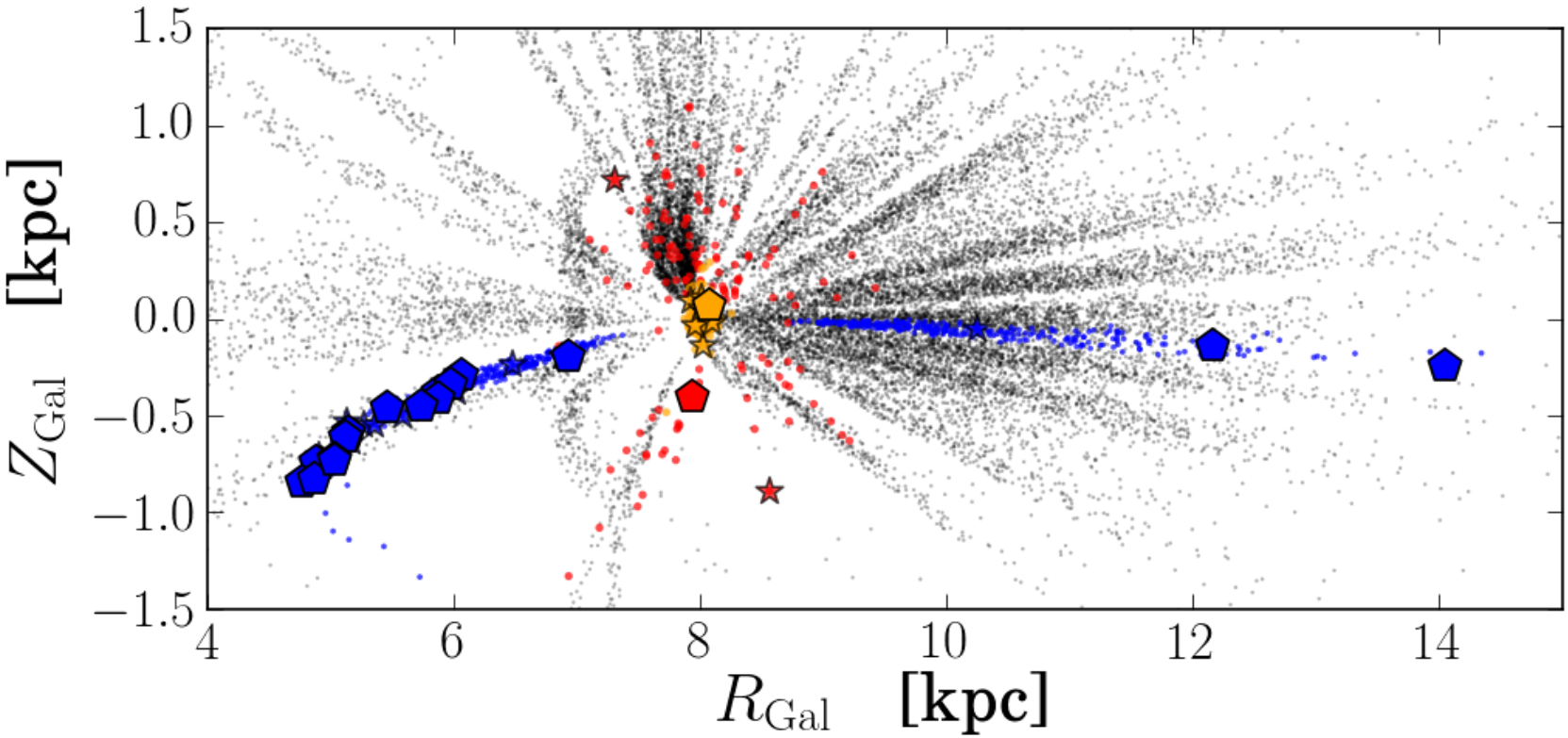


(Apparently) young [α/Fe]-enriched stars in CoRoGEE



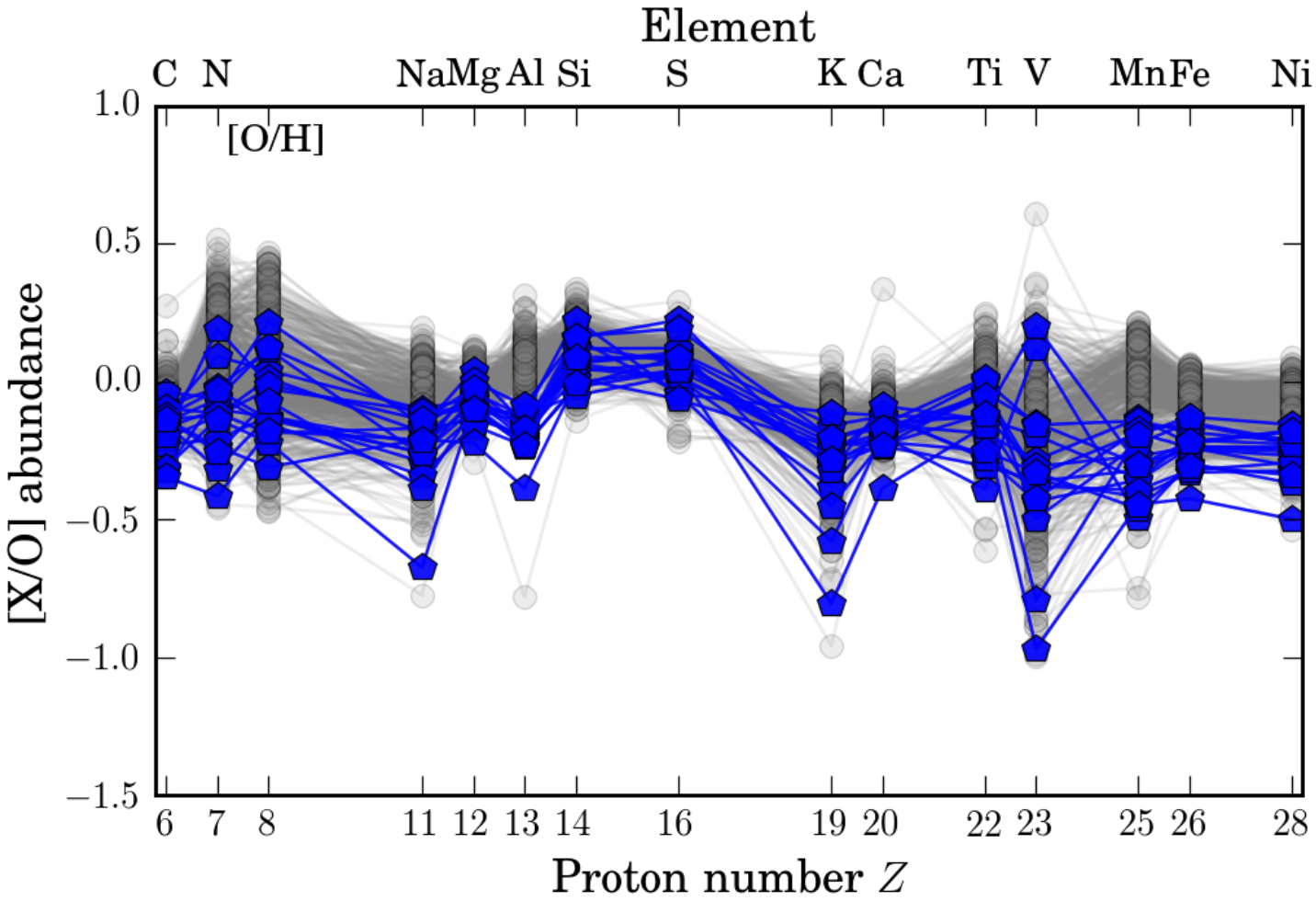
- Many more in the inner disc field!

(Apparently) young [α/Fe]-enriched stars



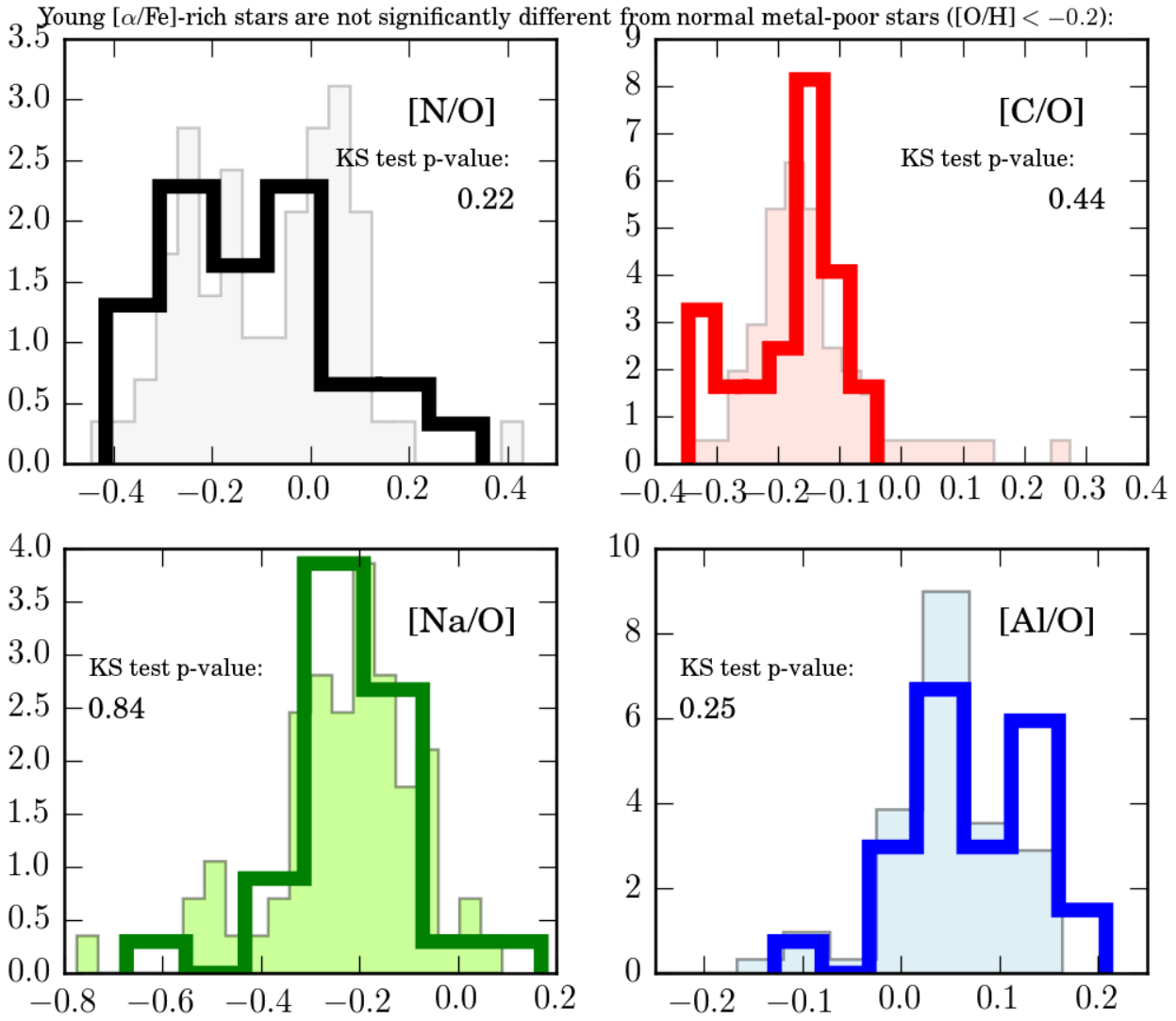
- Many more in the inner disc field!

Young [α/Fe]-enriched stars chemically different?



- At first sight, maybe...

No they're not...



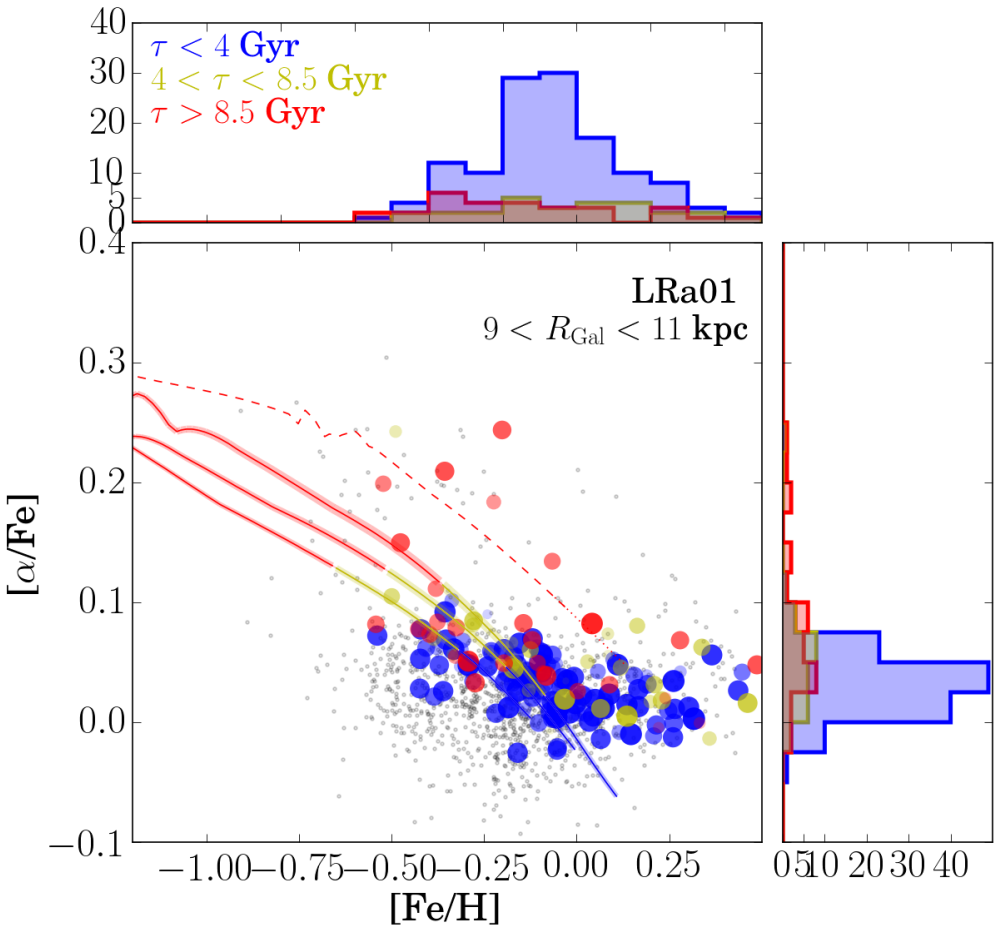
Re-checking the seismic parameters

APOGEE ID	$\Delta\nu$ [μHz]	ν_{max} [μHz]	Q^a	$\Delta\nu_i{}^b$ [μHz]	$\nu_{max_i}{}^b$ [μHz]	Flag^c	N_{APO}
							2σ-outliers
2M19232036+0116385	1.2 ± 0.01	8.11 ± 0.22	OK	1.27	8.0	1	1
2M19240121+0115468	2.71 ± 0.03	22.41 ± 0.58	OK	2.7	22.3	0	7
2M19253009+0100237	1.94 ± 0.04	14.72 ± 0.65	OK	1.97	14.7	2	3
2M19260245+0003446	2.78 ± 0.04	22.17 ± 0.64	poor	2.8	22.6	0	3
2M19261545+0011507	3.01 ± 0.04	23.90 ± 0.71	OK	3.01	24.8	0	7
2M19262657+0144163	4.56 ± 0.04	41.60 ± 0.93	poor	4.34	43.6	2	7
2M19263149+0159448	1.11 ± 0.01	6.79 ± 0.20	OK	1.14	6.74	1	3
2M19263197-0035004	0.97 ± 0.02	6.14 ± 0.31	OK	0.98	6.14	0	3
2M19263465+0004069	1.34 ± 0.03	8.88 ± 0.35	OK	1.34	8.88	0	3
2M19264111+0214048	2.46 ± 0.04	20.74 ± 0.73	OK	2.46	20.7	0	7
2M19280053+0016331	2.06 ± 0.04	16.69 ± 0.74	OK	2.00	16.7	0	7
2M19282189+0010322	5.21 ± 0.07	48.40 ± 1.41	OK	5.23	51.2	0	7
2M19283410+0006205	5.21 ± 0.11	47.68 ± 2.28	poor	4.80	47.7	1	7
2M19294723+0007020	2.70 ± 0.03	21.52 ± 0.51	OK	2.72	21.73	0	7
2M19305707-0008228	5.55 ± 0.03	53.17 ± 0.84	OK	5.40	52.4	2	3
2M06430619-0103534	2.23 ± 0.05	16.83 ± 0.77	OK	2.23	16.8	0	4
2M06442450-0100460	3.33 ± 0.09	30.93 ± 1.85	poor	3.06	30.9	1	4

- Drawing conclusions from small samples requires double- and triple-checking of all analysis steps...

The [α/Fe] vs. [Fe/H] diagram at different Galactocentric Distances: $11 < R_{\rm Gal} < 14$ kpc

- Trying to find signatures of migration with this diagram
- SMR stars seem to be dominantly young..
- What is the real shape of the [α/Fe] vs. [Fe/H] diagram at super-solar metallicities?
- Next step: new models



Summary & Future work

Summary

- Combining seismology and spectroscopy brings us one step further in obtaining meaningful ages
- Be very careful when interpreting small subsets
- Be even more skeptic when interpreting single data points
- New chemodynamical constraints can be formulated over a large range in Galactocentric distance and ages

Future work

- ongoing: detailed comparison with (semi-)cosmological N-body simulations using mock observation tools (see Sharma talk)
- use more individual element abundances
- Ultimate goal: constrain migration efficiency as a function of time and position