Relating Exoplanet Properties and Host Star Compositions using High Resolution NIR Spectroscopy

APOGEE-2

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Carnegie Science

in collaboration with

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Cayman Unterborn, Wendy Panero,
Scott Hull, Jennifer Johnson

Small Planets Are Diverse*

Best–Fit M–R Relations

Individual Mass and Radius Posteriors

< 1.6 R_{Earth}
< 4 R_{Earth}
< 8 R_{Earth}
Weiss & Marcy, 2014

Wolfgang, Rogers, & Ford 2016

Mass (M_{Earth})

Radius (R_{Earth})

Lopez-Morales et al. 2016,

Zeng, Sasselov, & Jacobsen 2016

***At least somewhat…**

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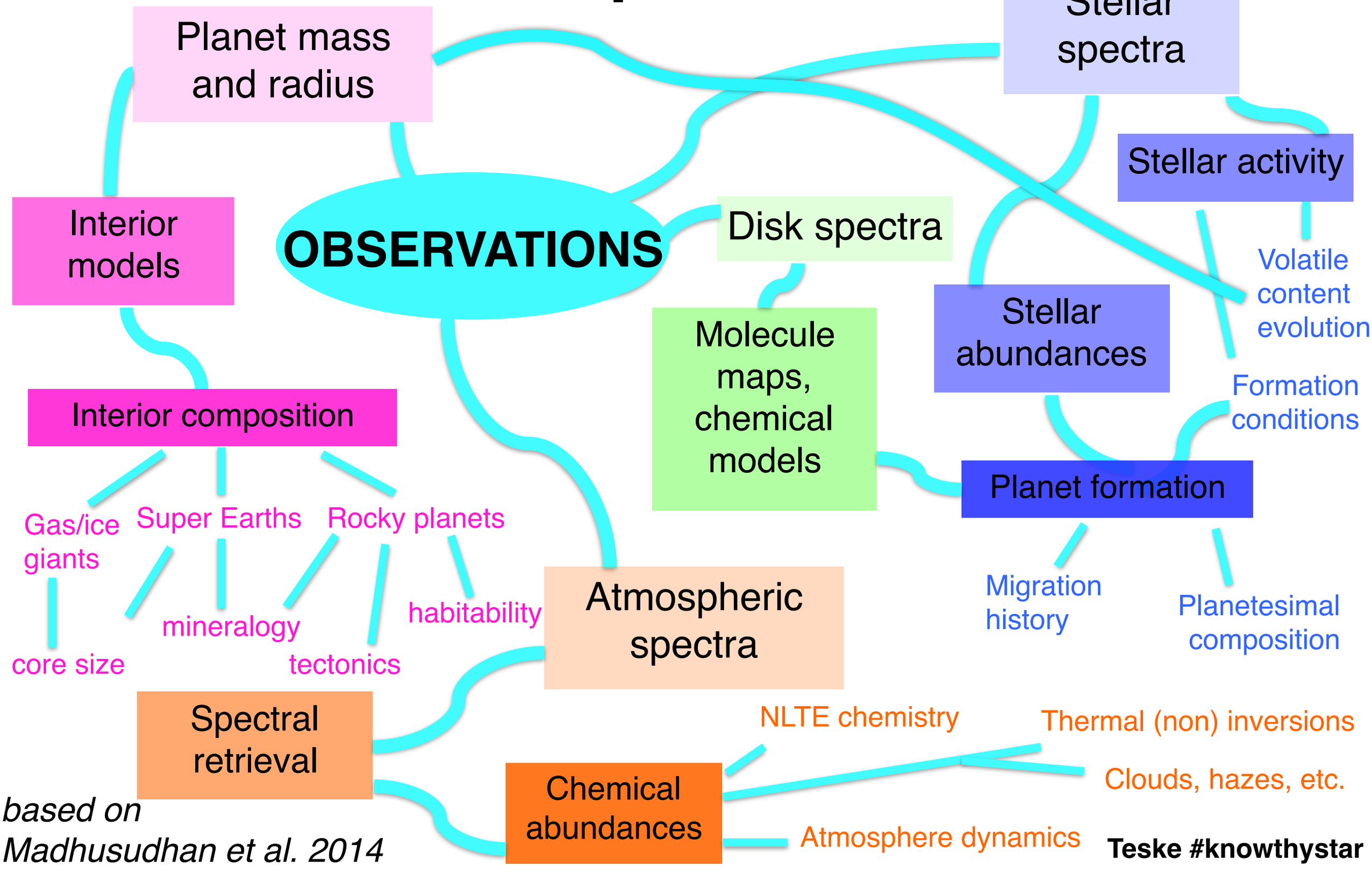
How do we learn about exoplanet composition?



based on Madhusudhan et al. 2014

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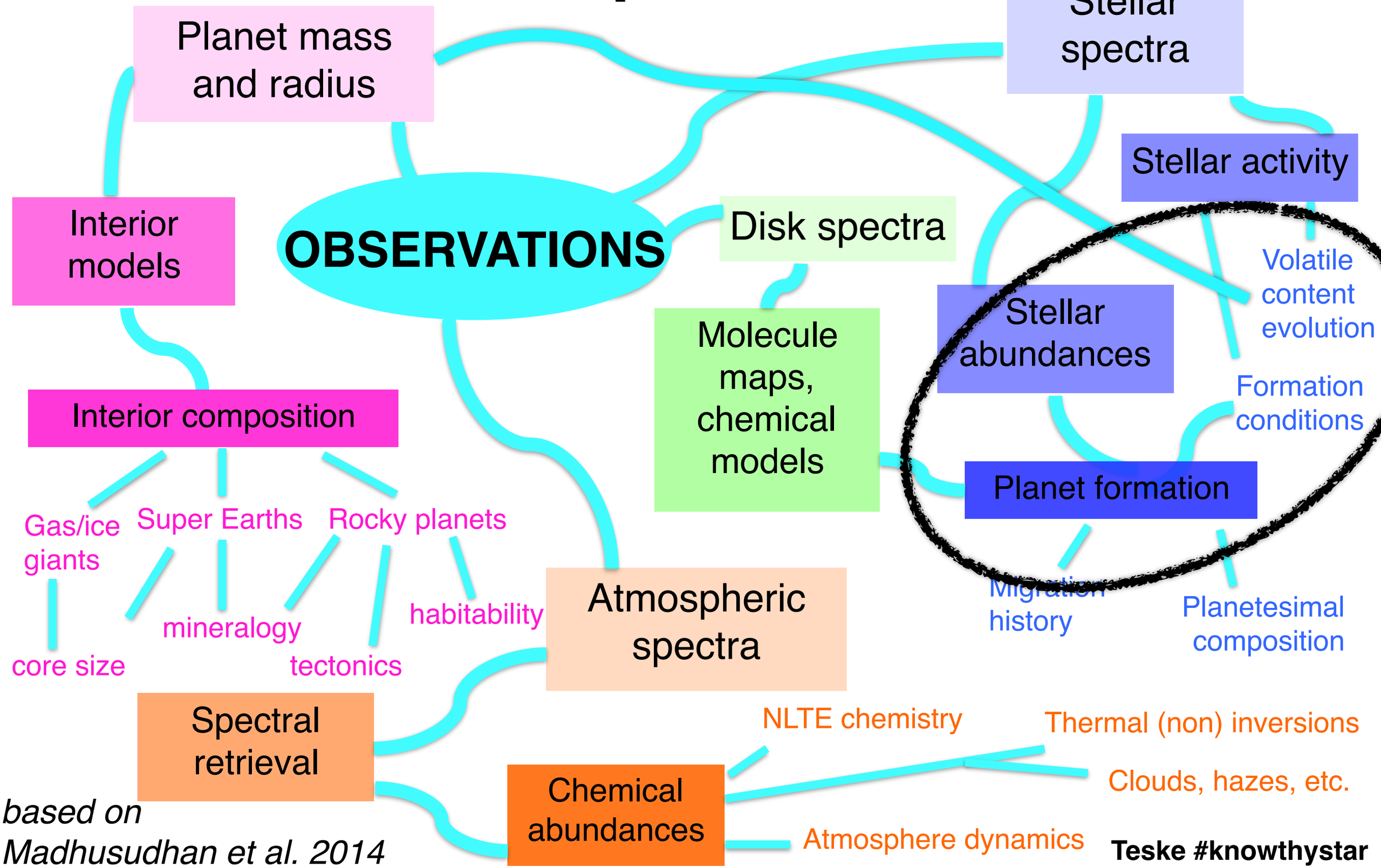
How do we learn about exoplanet composition?



based on Madhusudhan et al. 2014

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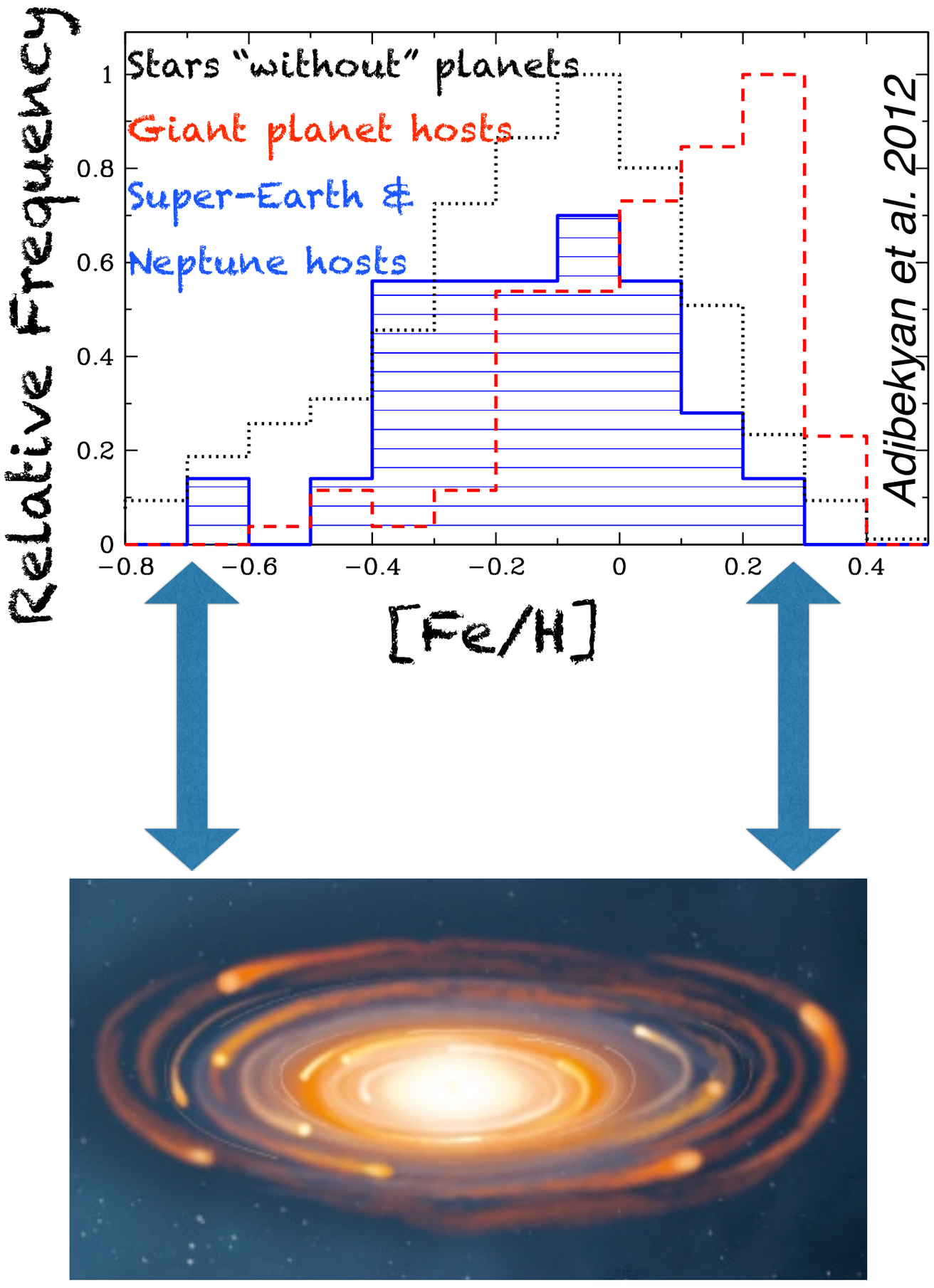
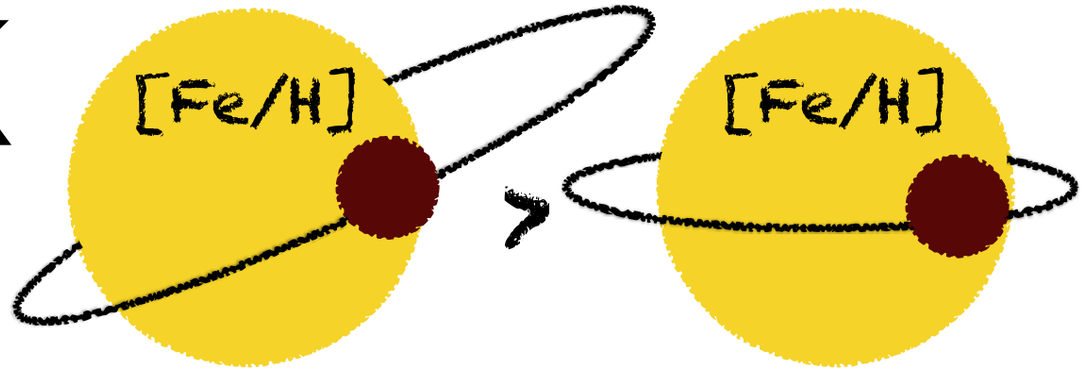
Host star [Fe/H]

Host star [Fe/H]



K



Dawson & Murray-Clay 2013

e

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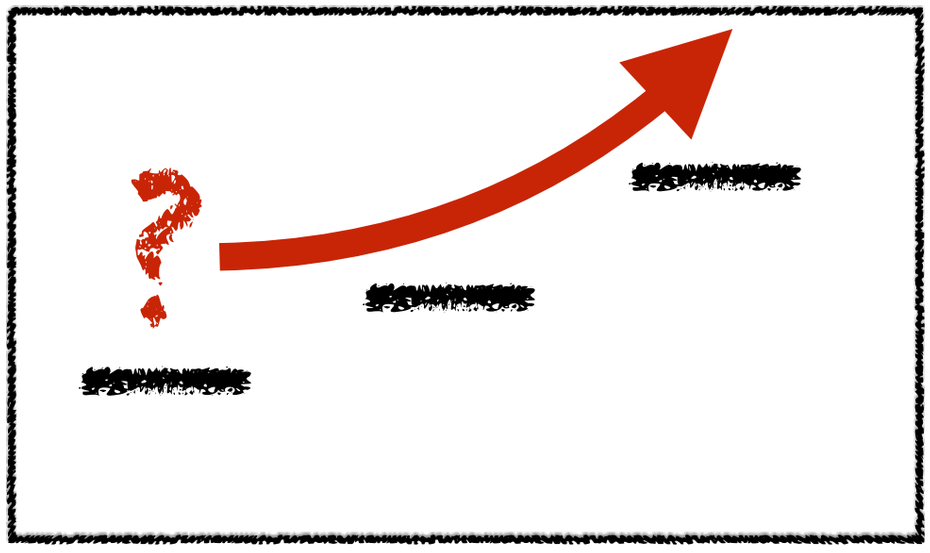
e

r!



Buchhave et al. 2014, Schlaufman 2015

see also Winn et al. 2017

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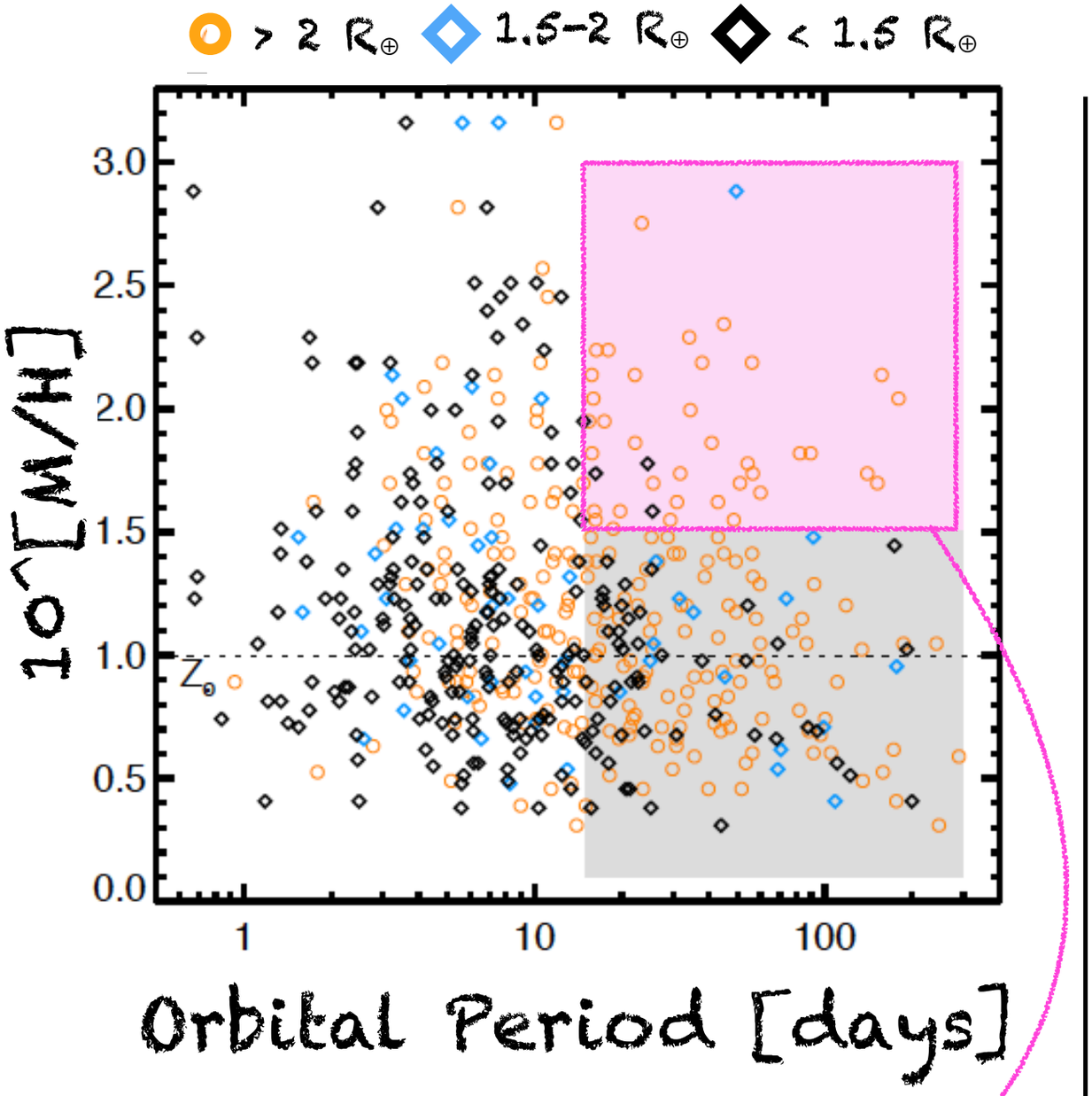
$[Fe/H]_{star}$ vs. $Period_{planet}$

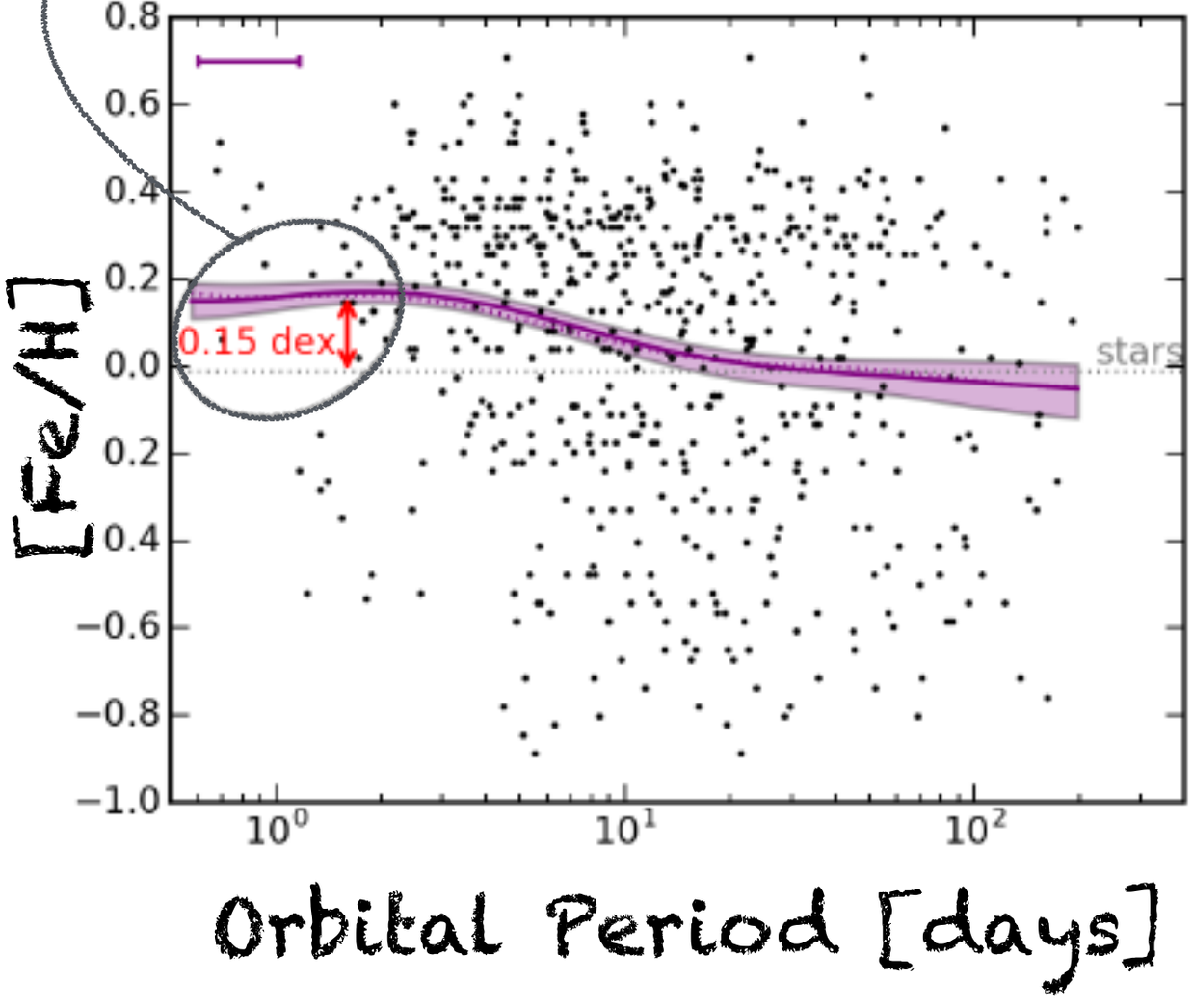
Dawson et al. 2015



No small, longer period planets around "metal-rich" stars → embryos grow faster farther out

Short period planets prefer metal-rich stars

Mulders et al. 2016



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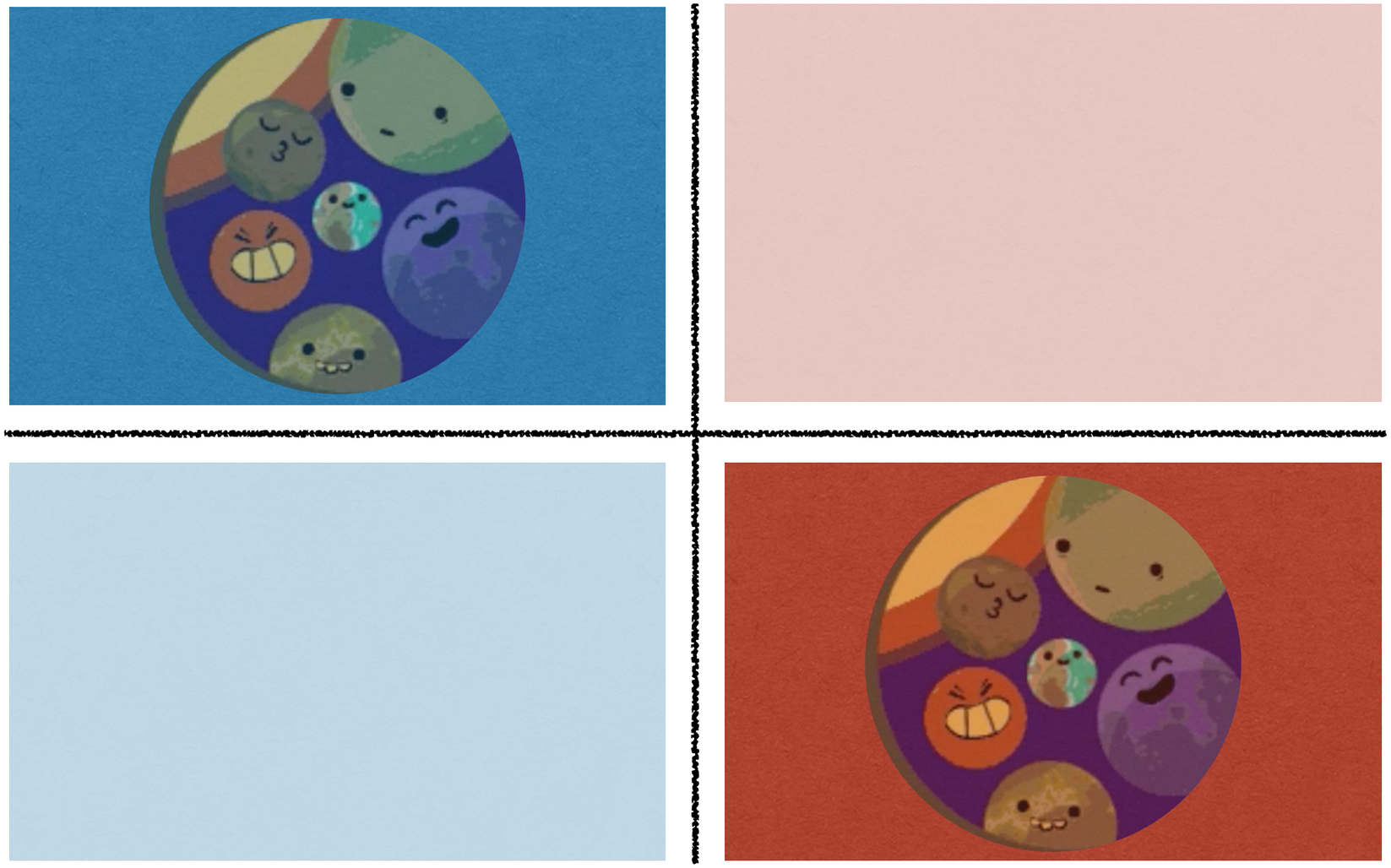
Two Distinct Orbital Period Regimes Inferred from Host Star [Fe/H] measured with APOGEE-2



Wilson, Teske et al., submitted

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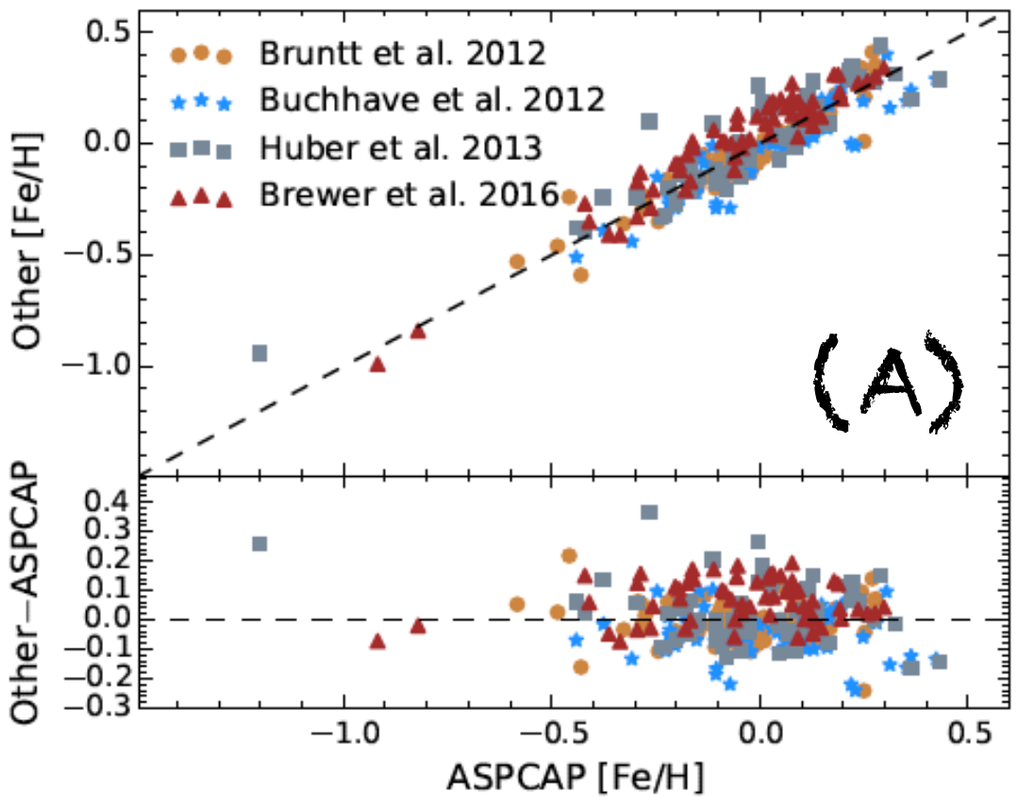
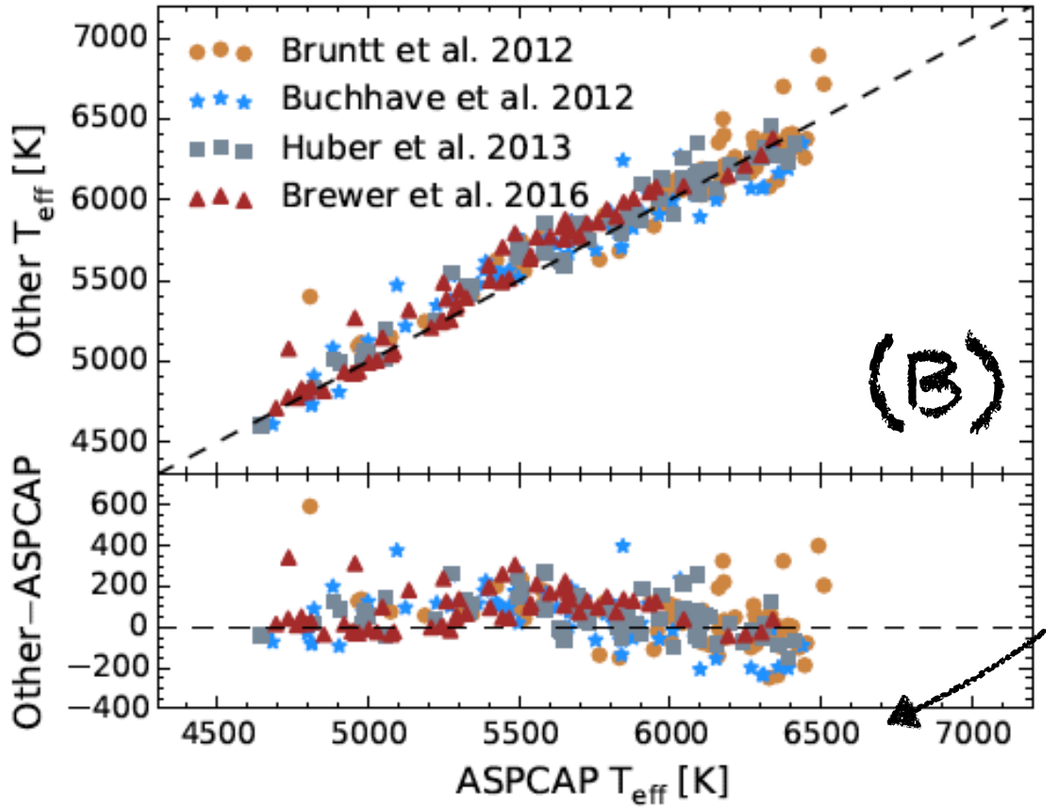
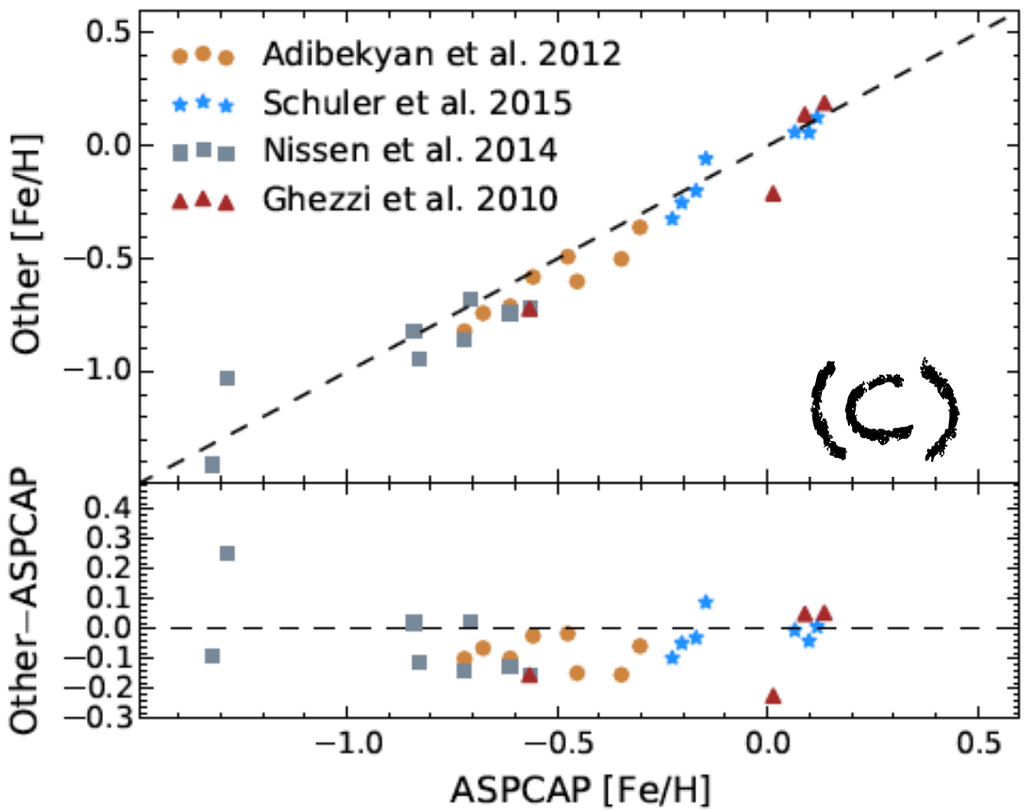
Now with APOGEE-2!

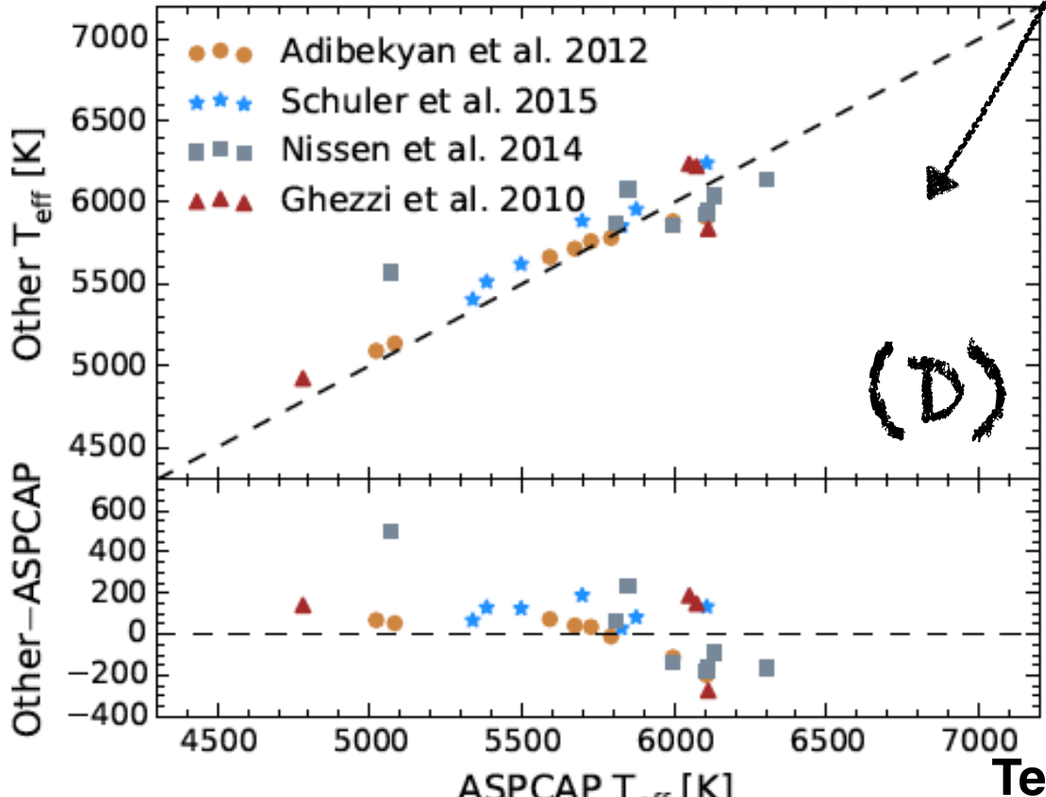
Wilson, Teske et al., submitted





Step 1
Validate ASPCAP results





Step 2
Make Quality Cuts to APOGEE KOI sample

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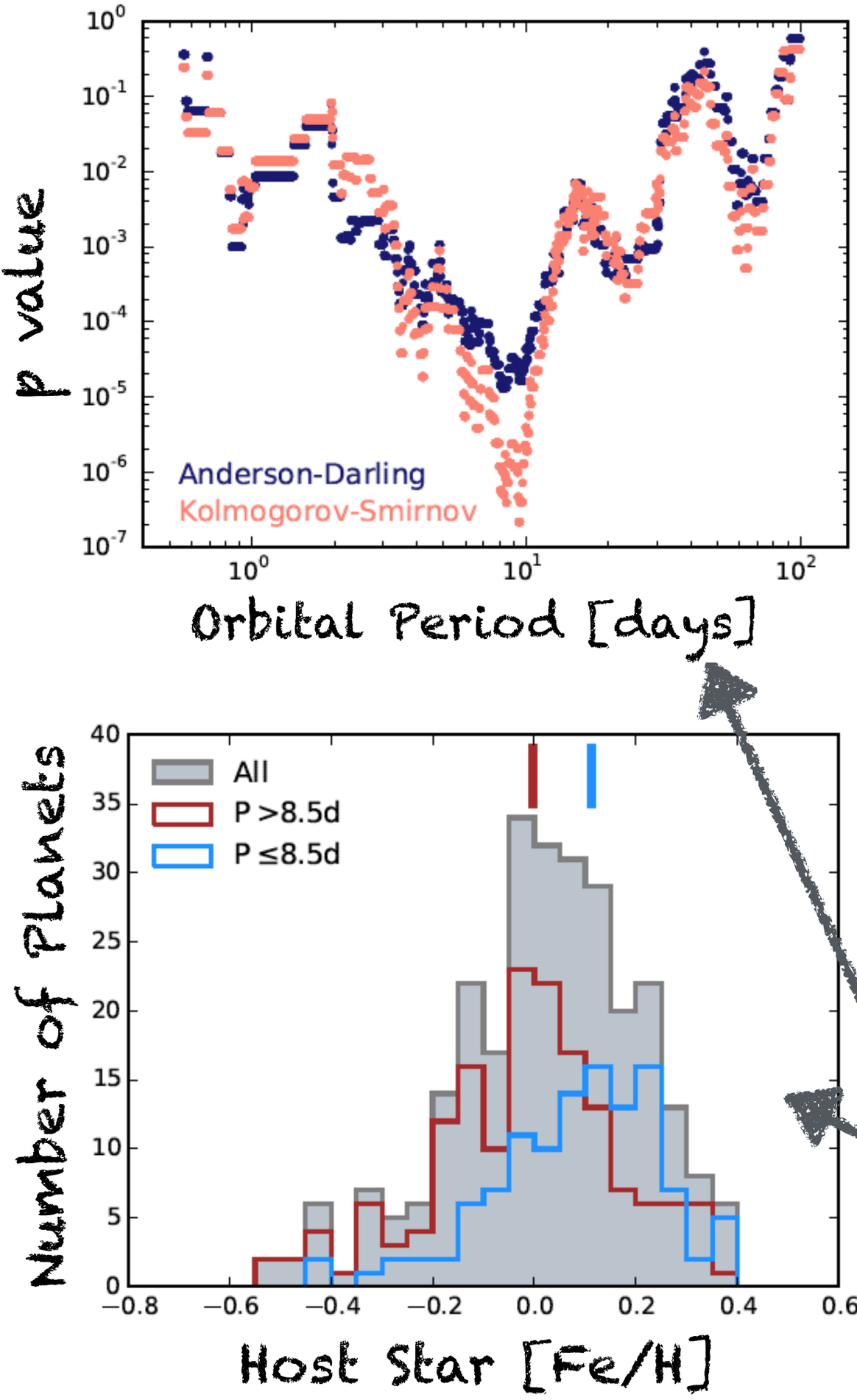
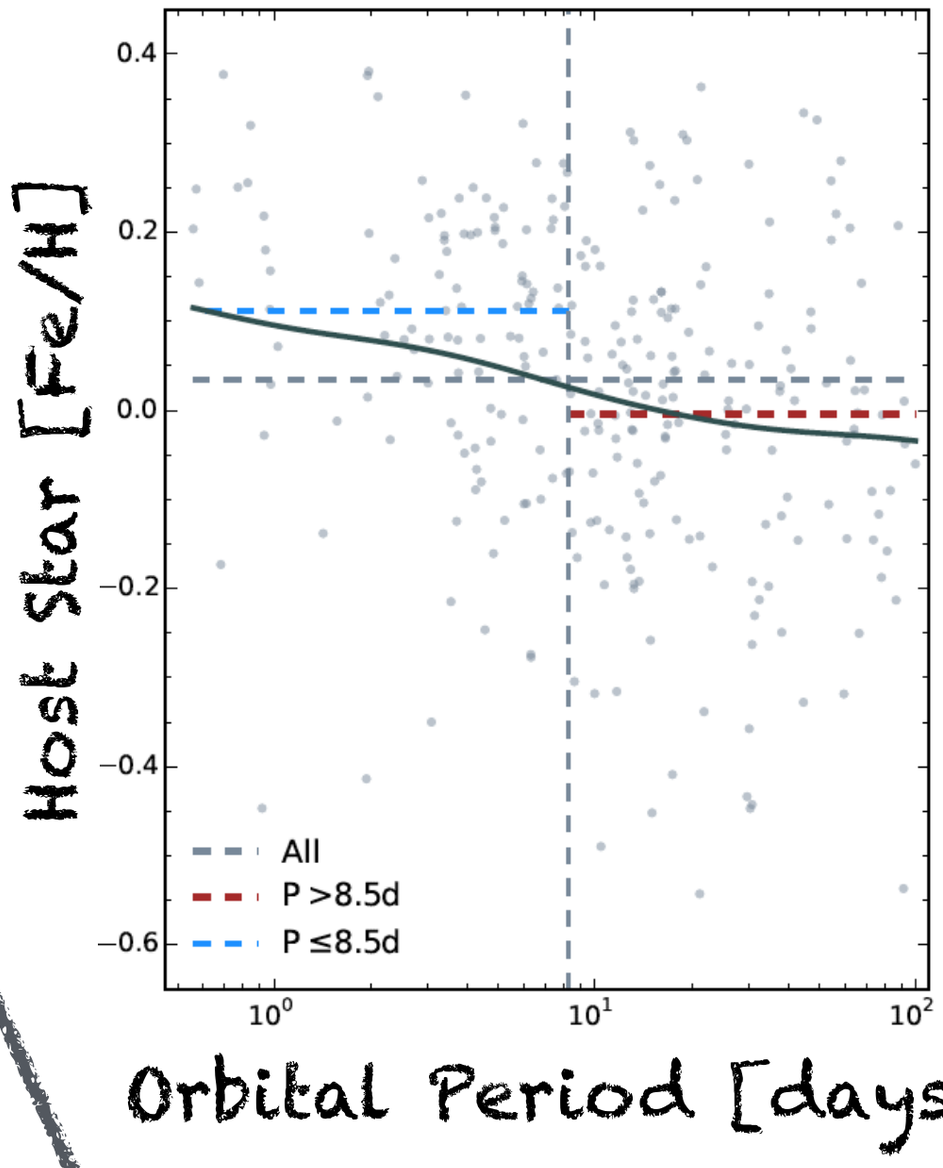
$[Fe/H]_{star}$ vs. $Period_{planet}$

Wilson, Teske et al., submitted





~300 KOI dwarfs

P_{crit} = 8.5 days (~0.08-0.1 AU)

Need ≤ 0.1 dex precision to detect

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$[Fe/H]_{star}$ vs. $Period_{planet}$

[Fe/H]

dust | dust

[Fe/H] X

[Fe/H]

gas | gas

[Fe/H] ?

[Fe/H]

[Fe/H] X

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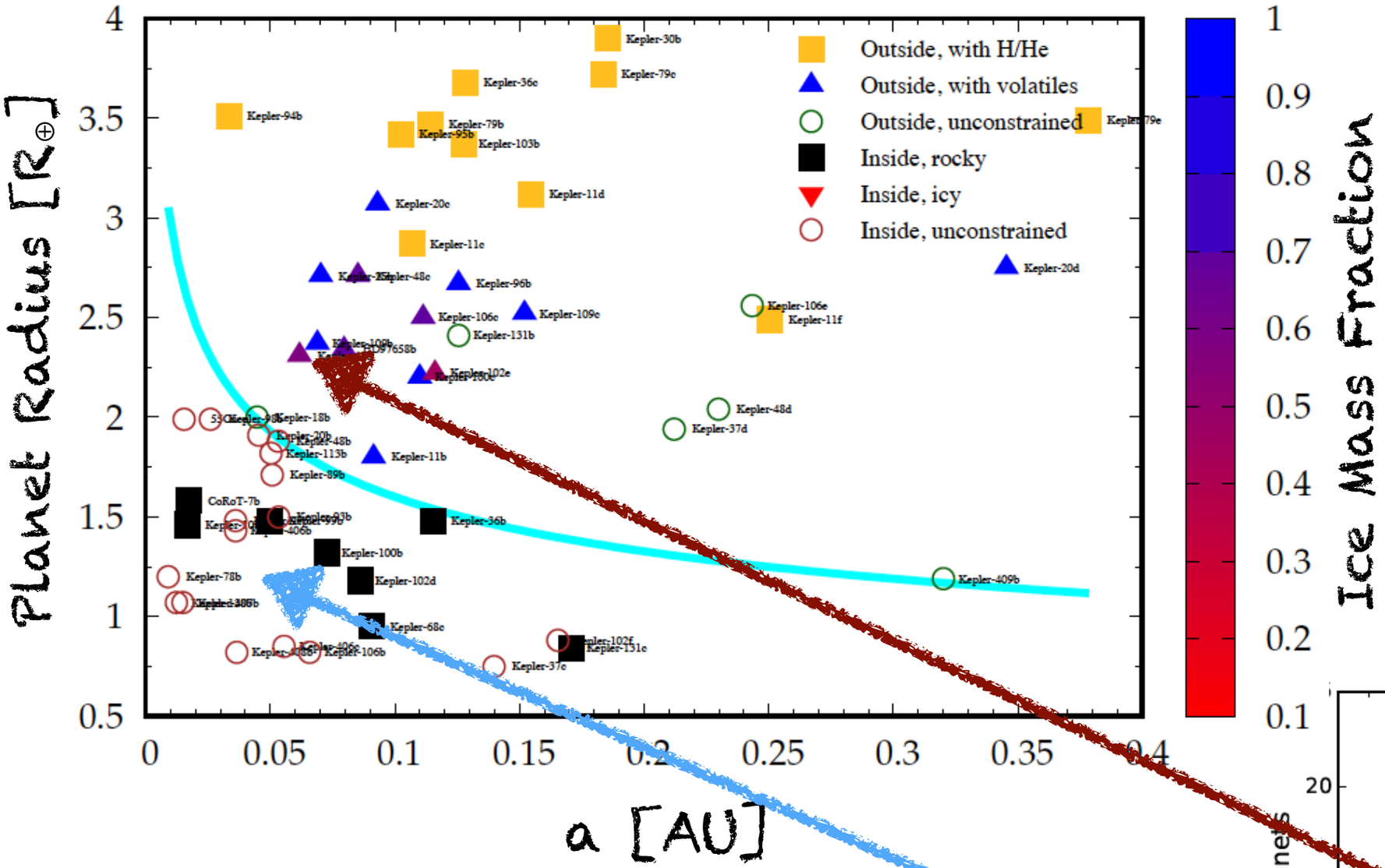
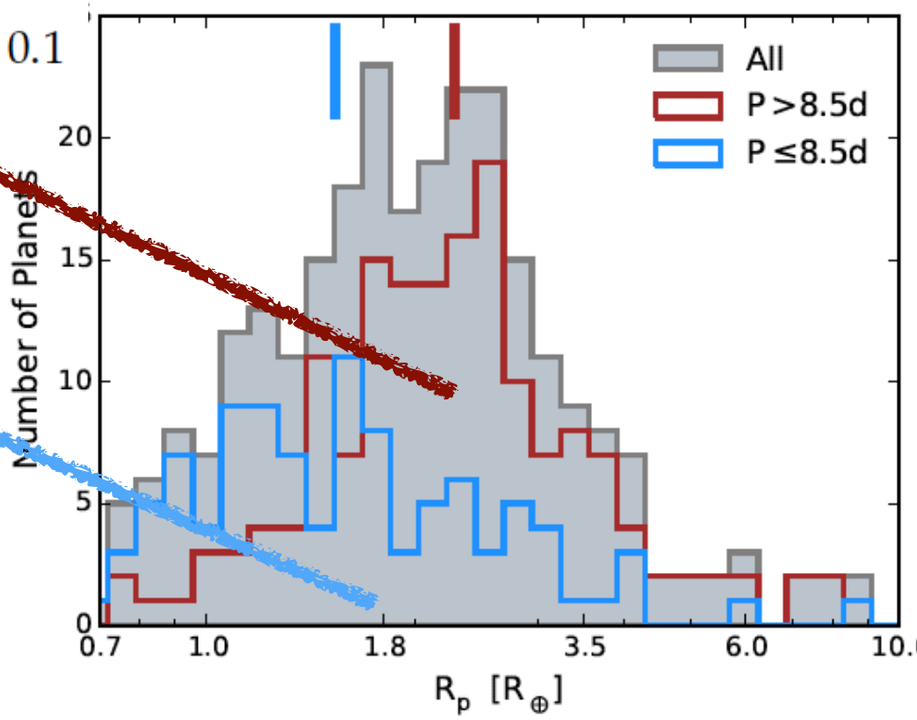
Jin & Mordasini 2017
based on Fulton et al. 2017
see also Owen & Wu 2017, 2013

$[Fe/H]_{star}$ vs. $Period_{planet}$

vs. R_{planet}





Wilson, Teske et al., submitted

Small planets around more metal-rich stars orbit closer in and are predominantly rocky

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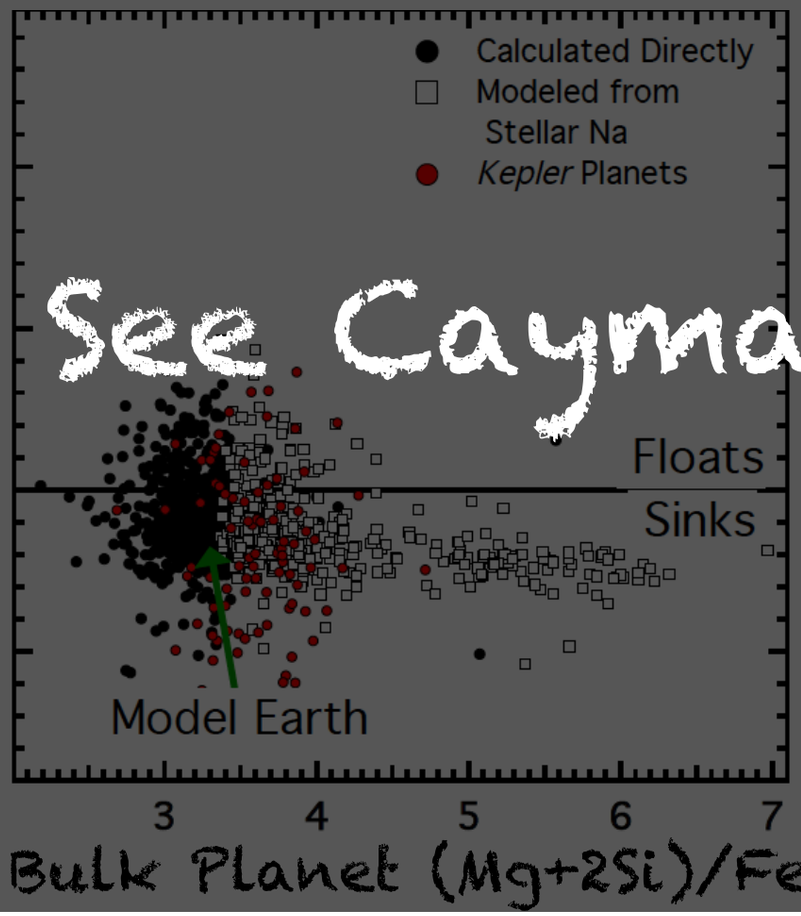
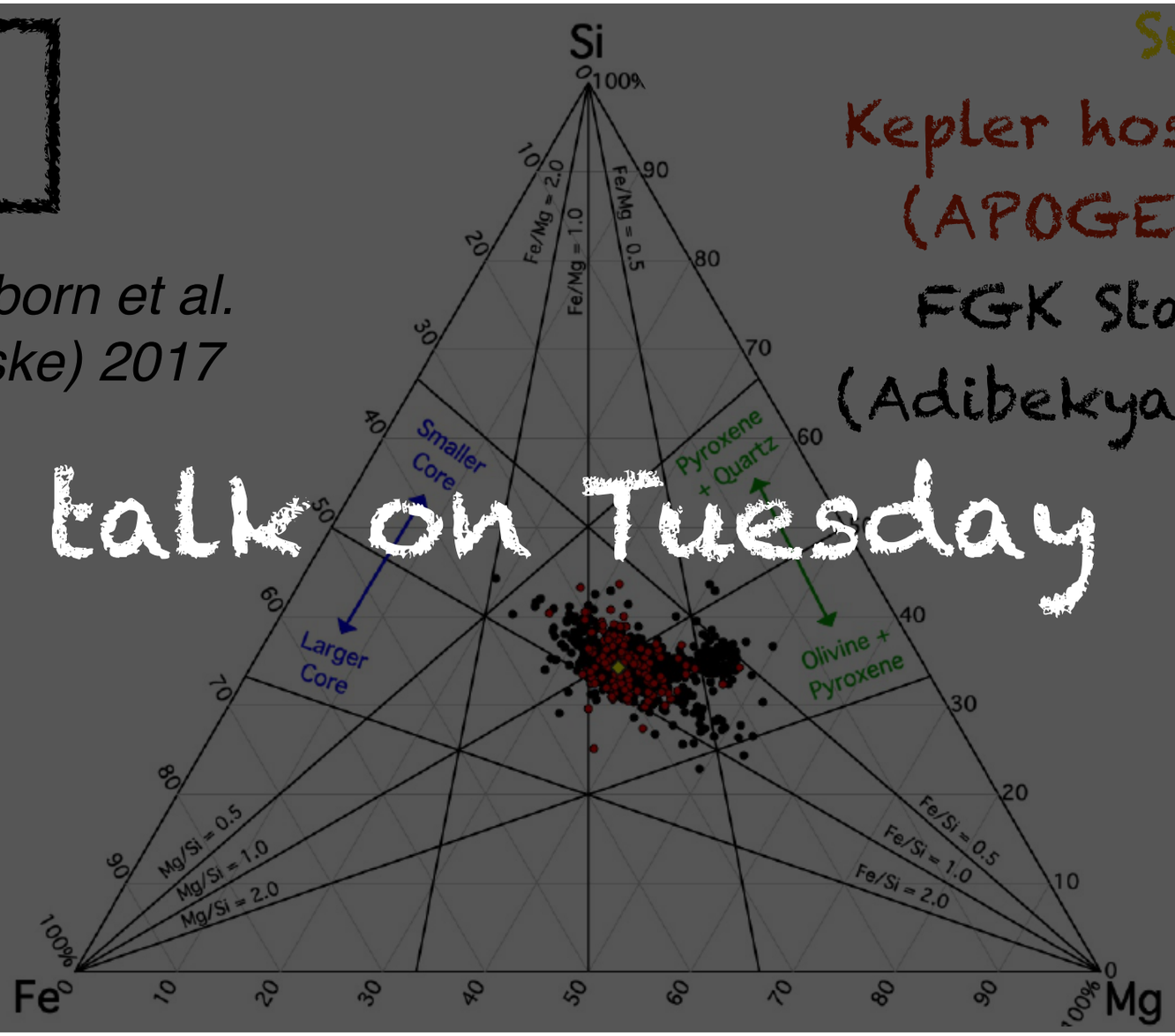
Host star Mg, Si



Unterborn et al. (+Teske) 2017



Sun

Kepler hosts (APOGEE)

FGK Stars (Adibekyan)

See Cayman's talk on Tuesday

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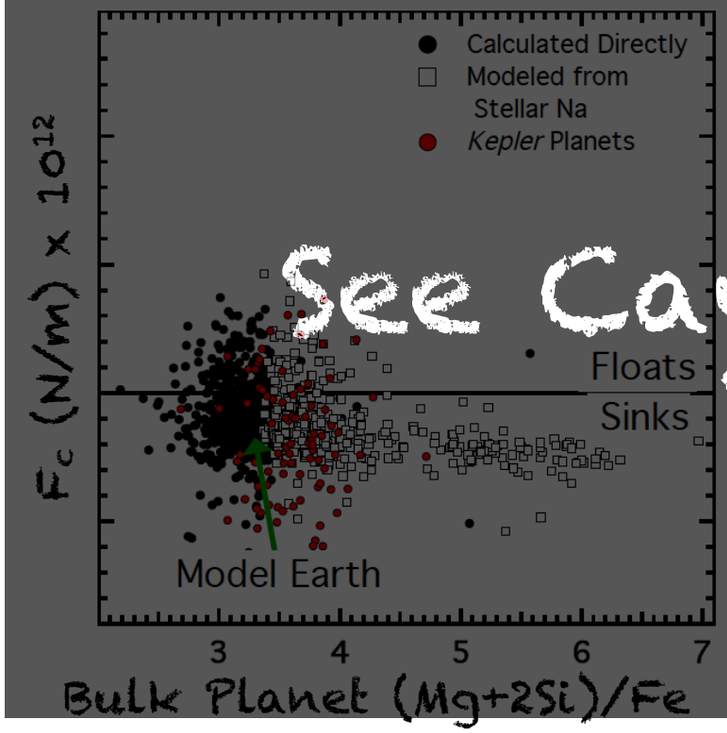
Host star Mg, Si



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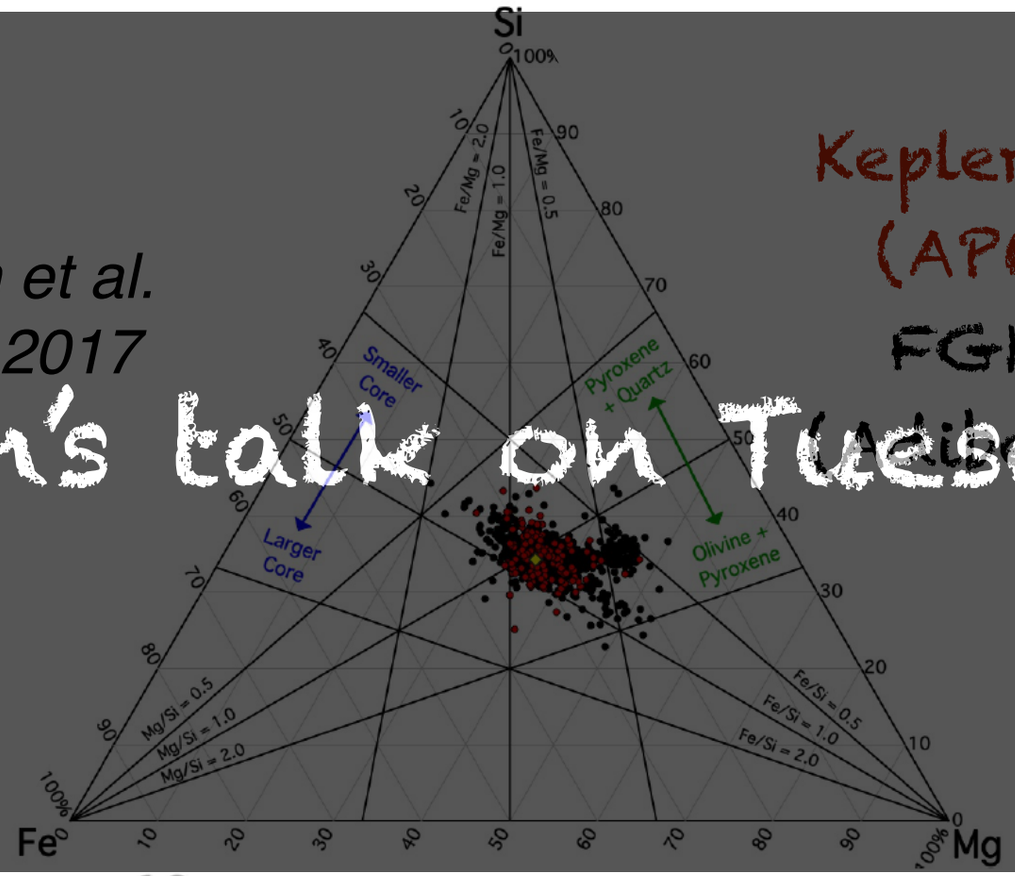

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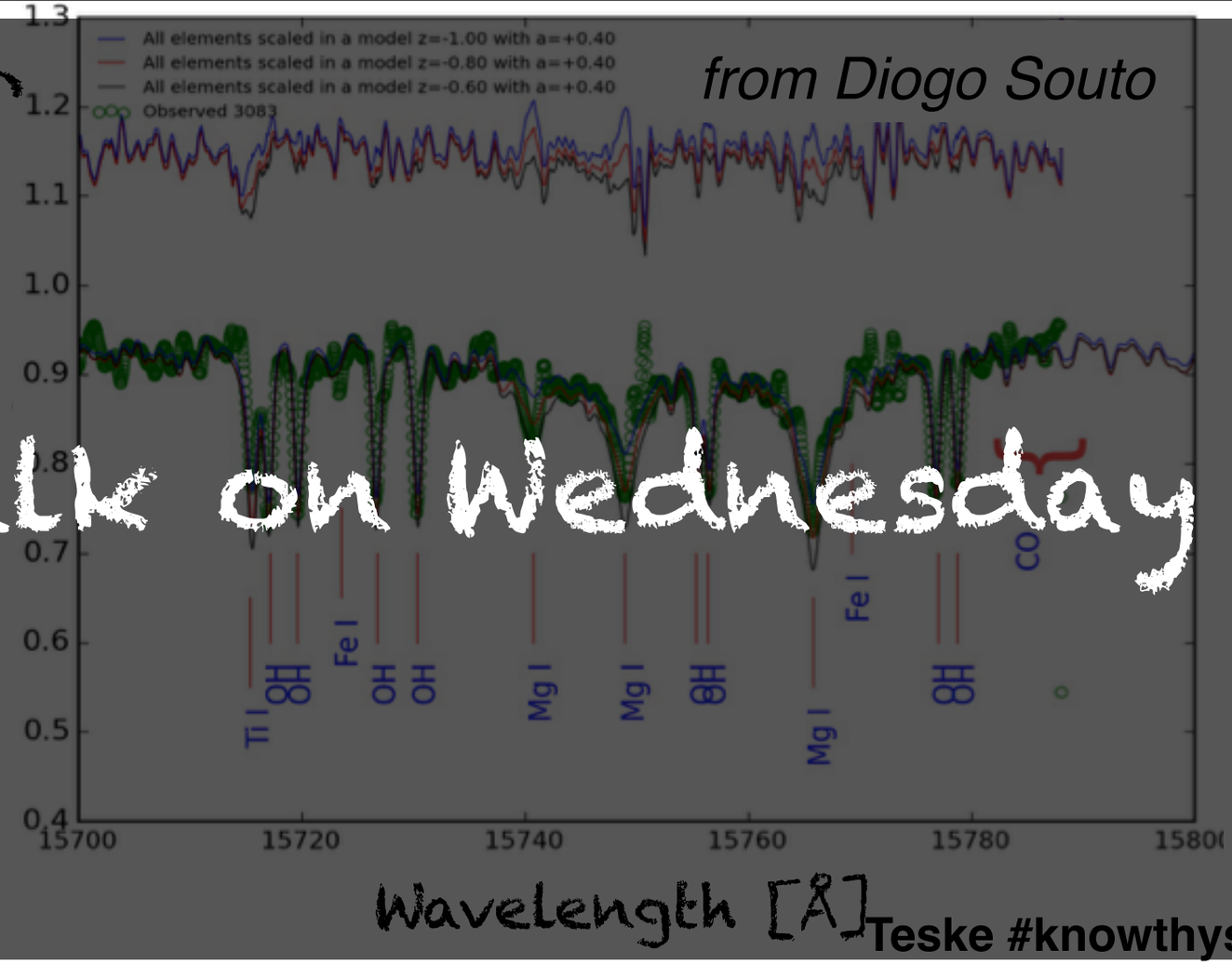
Kepler hosts (APOGEE)

FGK Stars

(Adibekyan)

See Cayman's talk on Tuesday

M dwarf abundances



from Diogo Souto

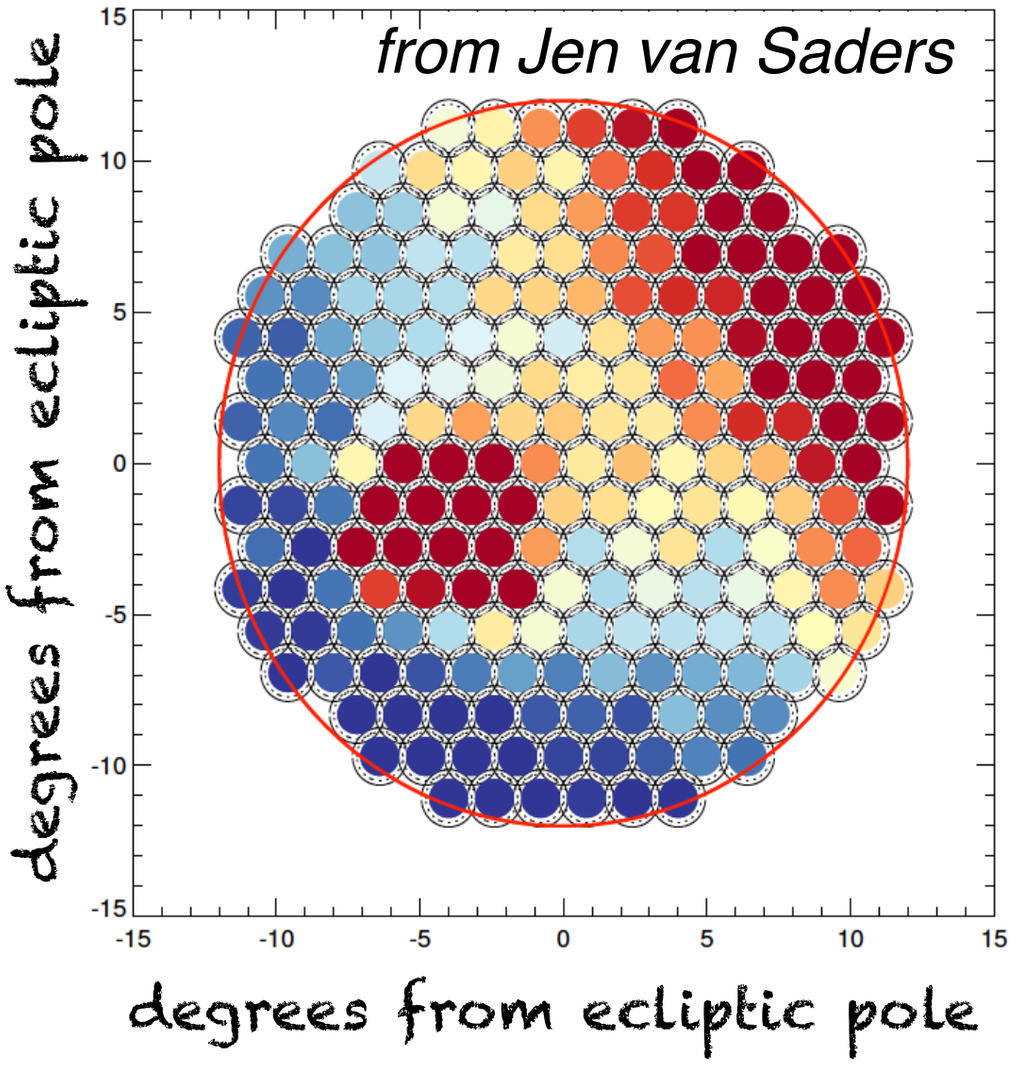
See Katia's talk on Wednesday

APOGEE has started to break open this field!

Measuring Si, Mg, Ca, Ti, O, C, and more.

Looking Ahead to TESS

Looking Ahead to TESS



18A: Begin pilot CIW program to observe TESS SCVZ, various science cases (one is exoplanets). Single epoch, 7<Hmag<11. Awarded 6 nights = 25-30 plates x 200 stars/plate.

APOGEE-2S & Beyond!

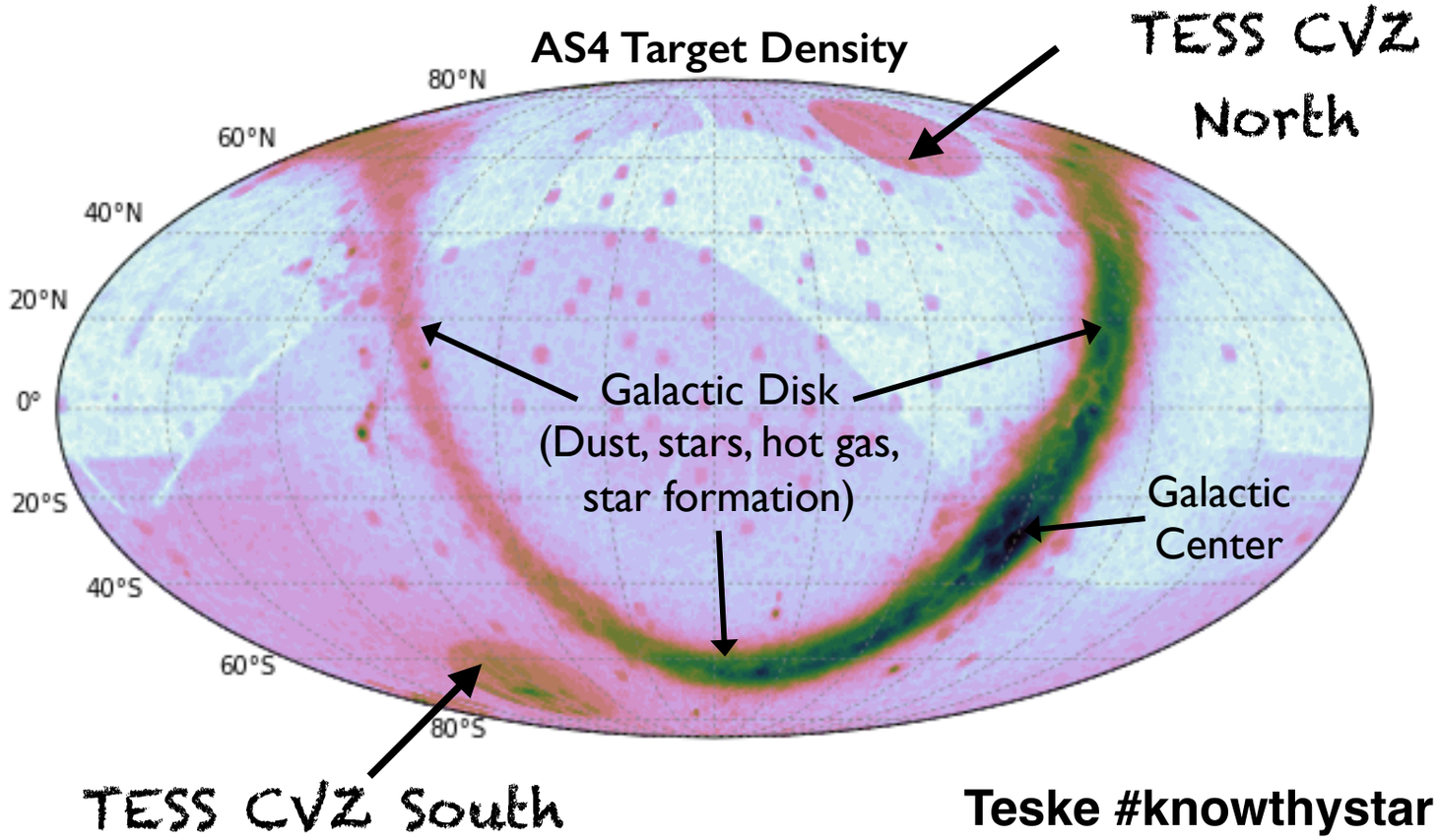
Join us! **AS4 —> AS^4**

All-Sky Synoptic Spectroscopic Survey

PI Juna Kollmeier

1st ever all sky, multi-epoch survey w/ both NIR and optical spectroscopy.

Initial survey plan, credit Gail Zasowski



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A cautionary note about stellar spectroscopy…

it's a bit of a (dark) art.

- Keith Hawkins

Test	Expected σ dex	Max σ dex	Min σ dex	comment
1. Line list	0.05	0.6	0.0	EW are not affected by position of core of line but number of HFS components might be important
2. Continuum	0.3	0.6	0.05	absolute abundance is very dependent but methods should not re-normalise
3. HFS	0.08	0.4	0.0	differences in abundances between HFS:N and HFS:Y are similar for all methods
4. v_{mic}	0.2	1.2	0.01	maximum difference corresponds to 1 km/s range in v_{mic}, dependency decreases when HFS is considered
5. α-enhancement	0.02	0.1	0.001	cool stars are more affected than metal-poor warm stars
6. Atmosphere model interpolation	0.01	0.04	0.002	obtained from models with 1% difference in temperature and 5-10% difference in gas pressure.
7. Blends	0.02	0.1	0.0	maximum difference is found for EW methods for cool dwarf star
8.1. Same EWs	0.02	0.06	0.001	weak lines are more affected
8.2. Same syntheses	0.07	0.12	0.001	convolution is more important than the choice of mask

e.g., Jofré et al. 2017

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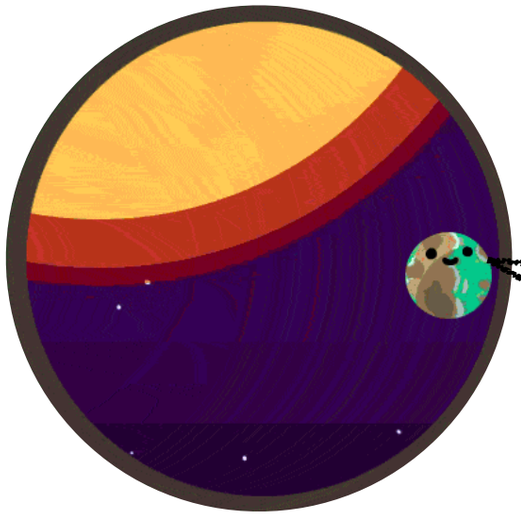
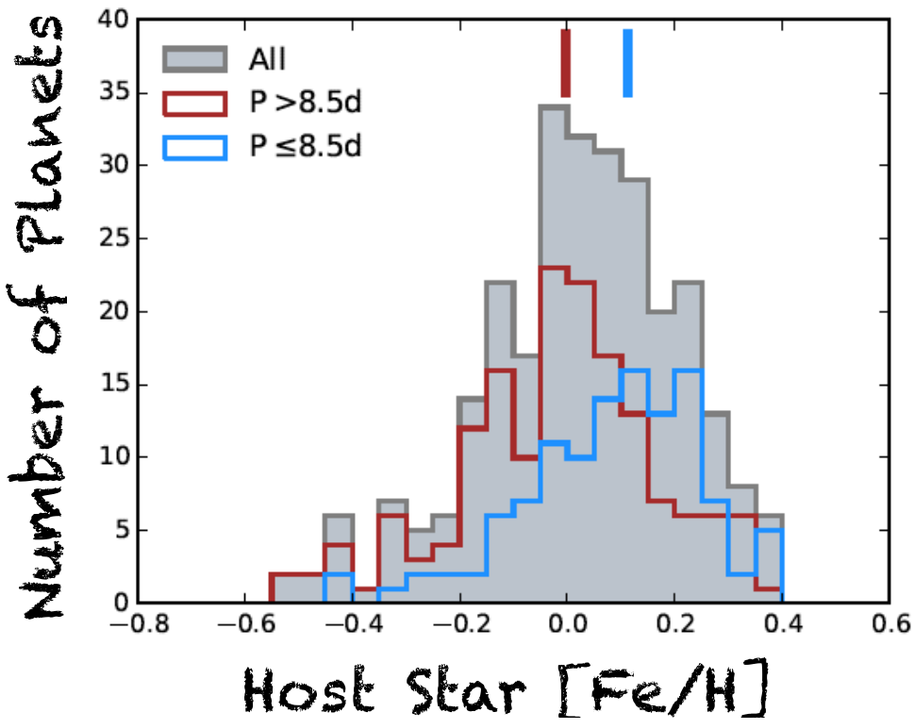
Take Aways





Host star abundances† can help constrain when/where/from what material planets formed.

†If in doubt, find a ~~Parseltongue~~ stellar spectroscopist.

NIR spectroscopy from APOGEE-2

+ASPCAP = reliable FGK dwarf star [Fe/H] at ~0.05 dex level!

We find a correlation between planet *P* and $[Fe/H]_{star}$ characterized by P_{crit}=8.5 days, with **shorter period planets orbiting more metal rich stars.** Maybe this is related to Fulton radius gap (shorter period = smaller)?

AS4+TESS✷ have the potential to significantly expand our knowledge of (small) planet formation and composition.

✷Ask me about the caveat.

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