The Metallicity Distribution and Hot Jupiter Rate of the *Kepler* field: Hectochelle High-resolution Spectroscopy of 776 *Kepler* Stars

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Affiliation: Harvard CfA, UT Austin, Columbia University

Know-thy-star conference, Pasadena: Oct. 10, 2017

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HJ rate from RV

$\approx\ 2 \times$ HJ rate from transits

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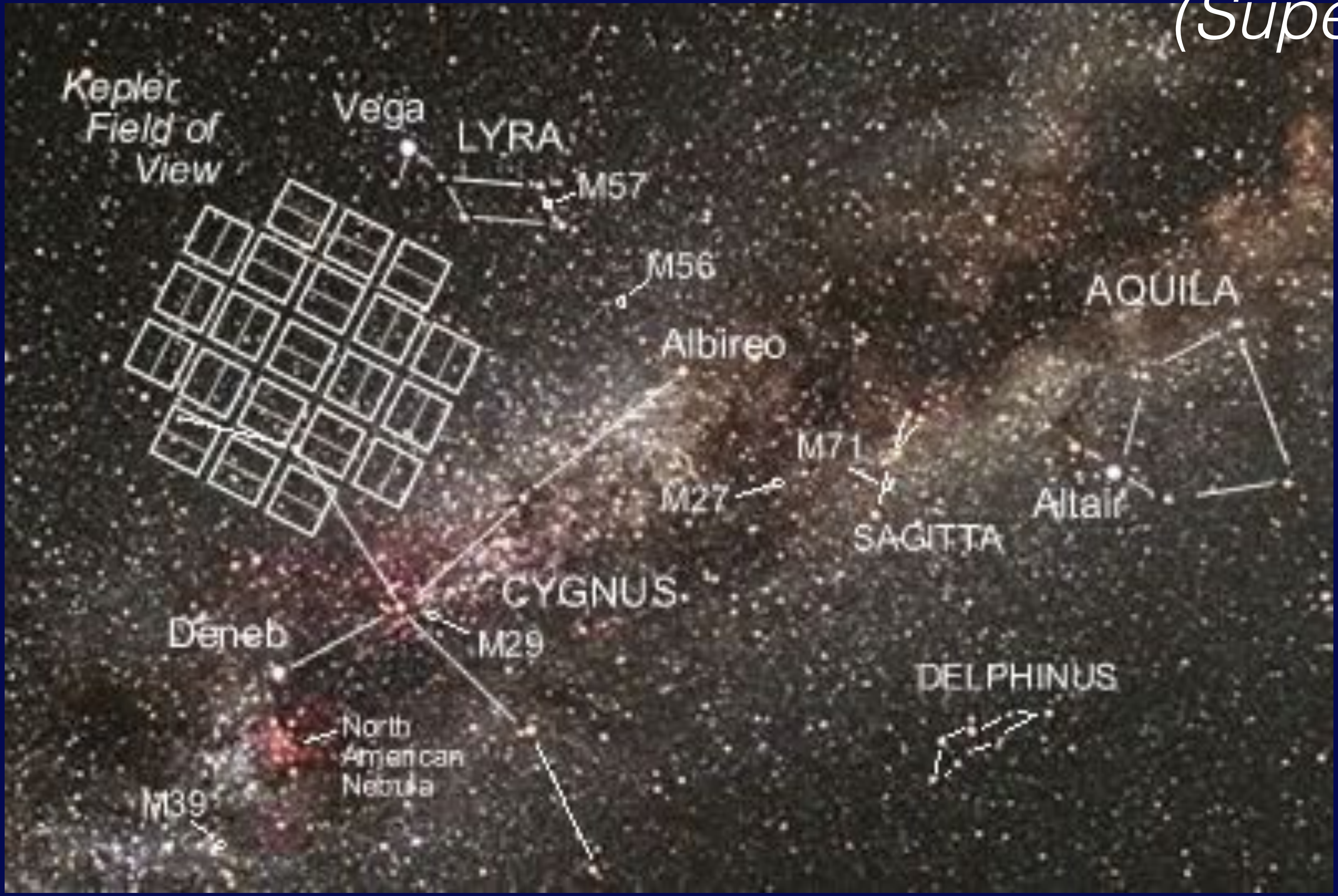
(SuperLupus, Kepler)



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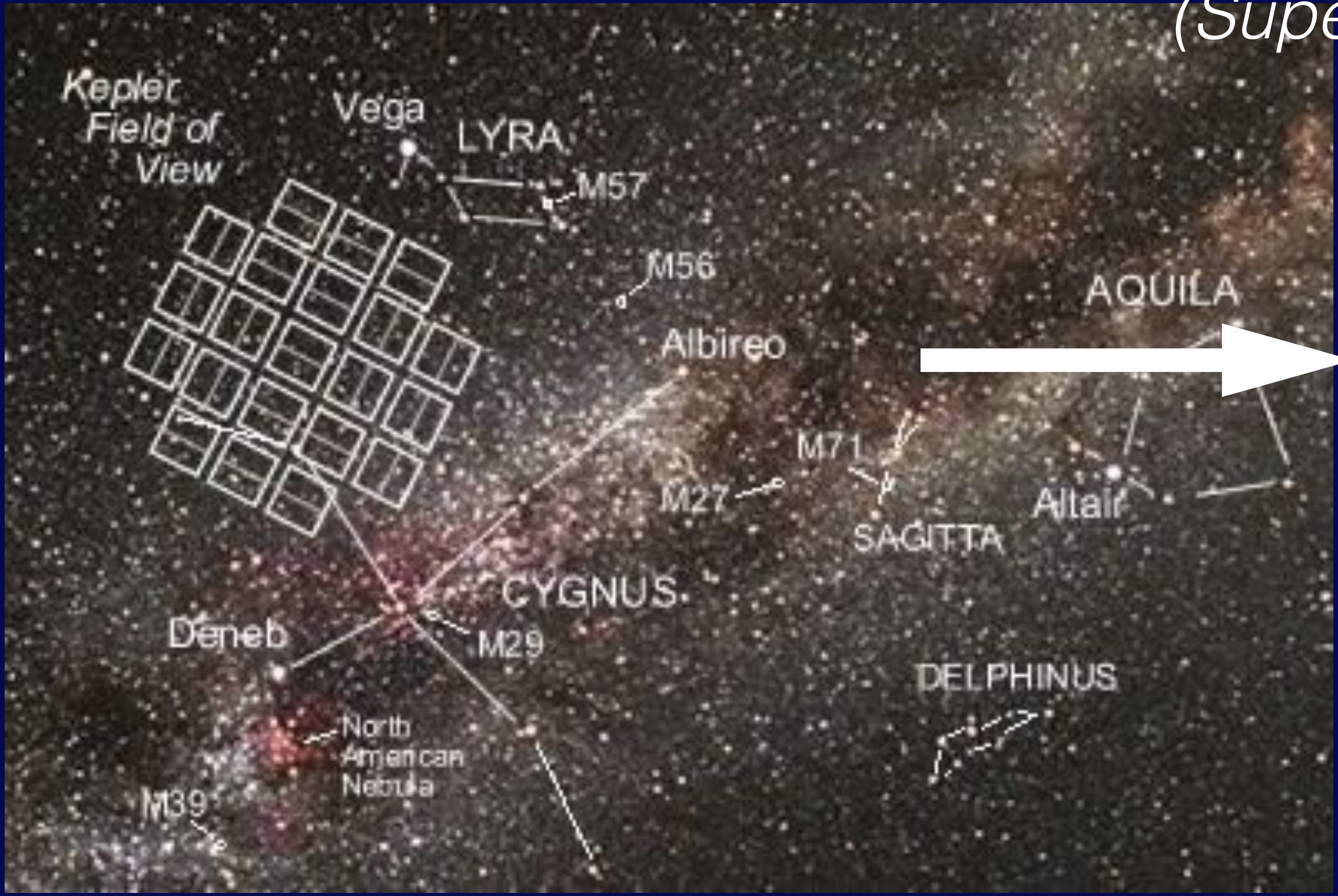

metal poor?

- **Stellar metallicity and HJ rate are positively correlated.**

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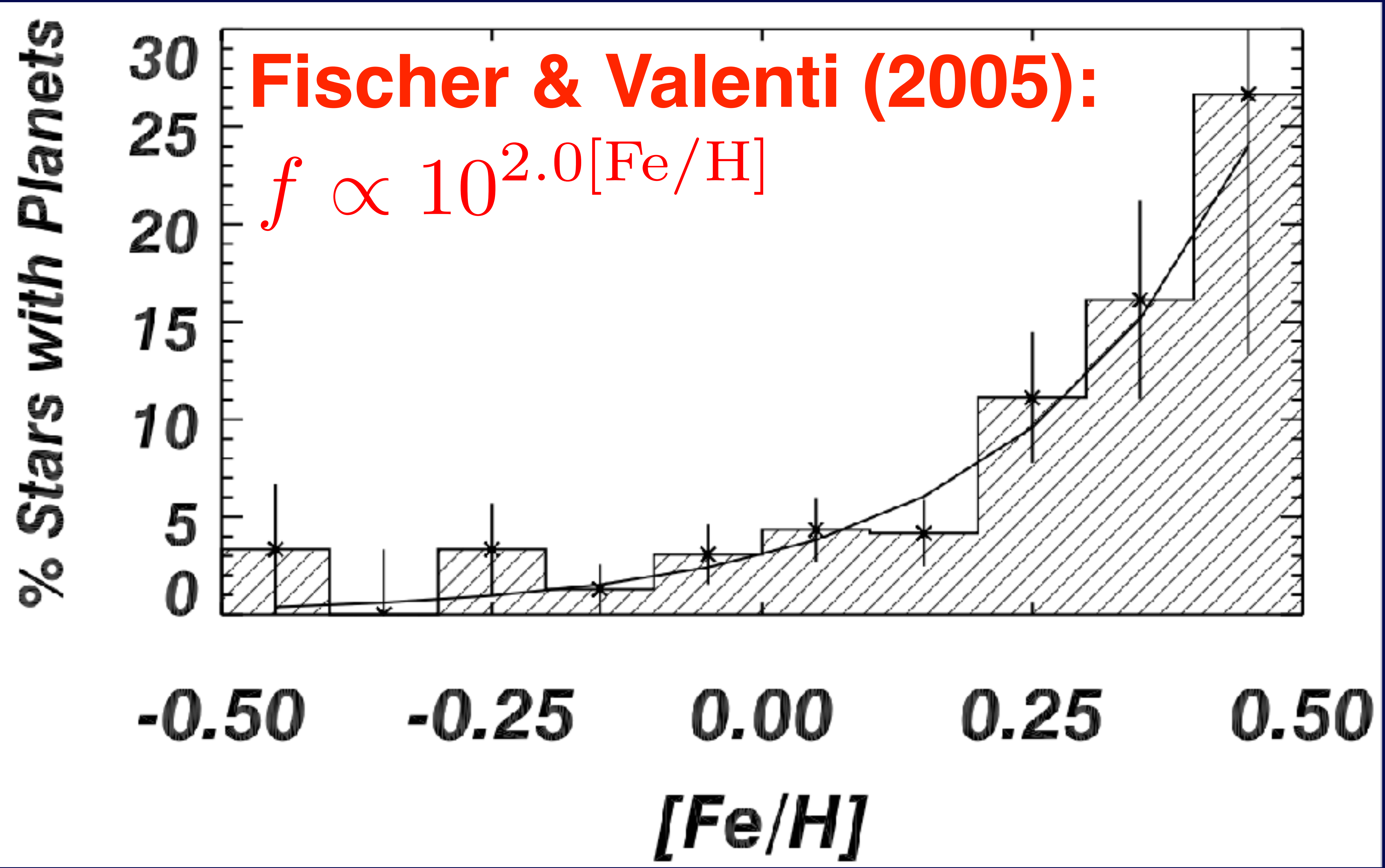

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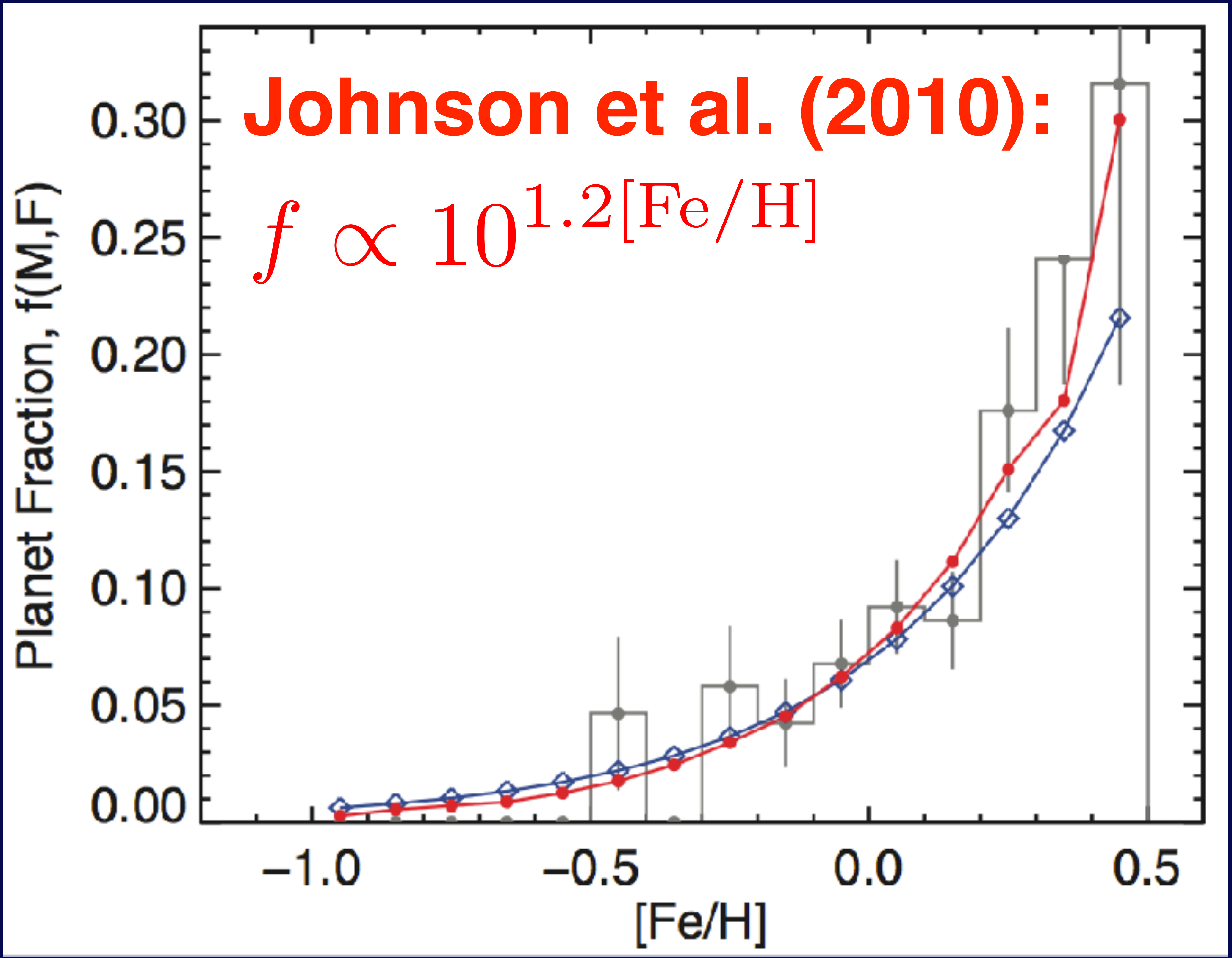

Assumption:

Transit surveys report lower HJ rate
because their target stars are slightly more metal poor.

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↓

Test:

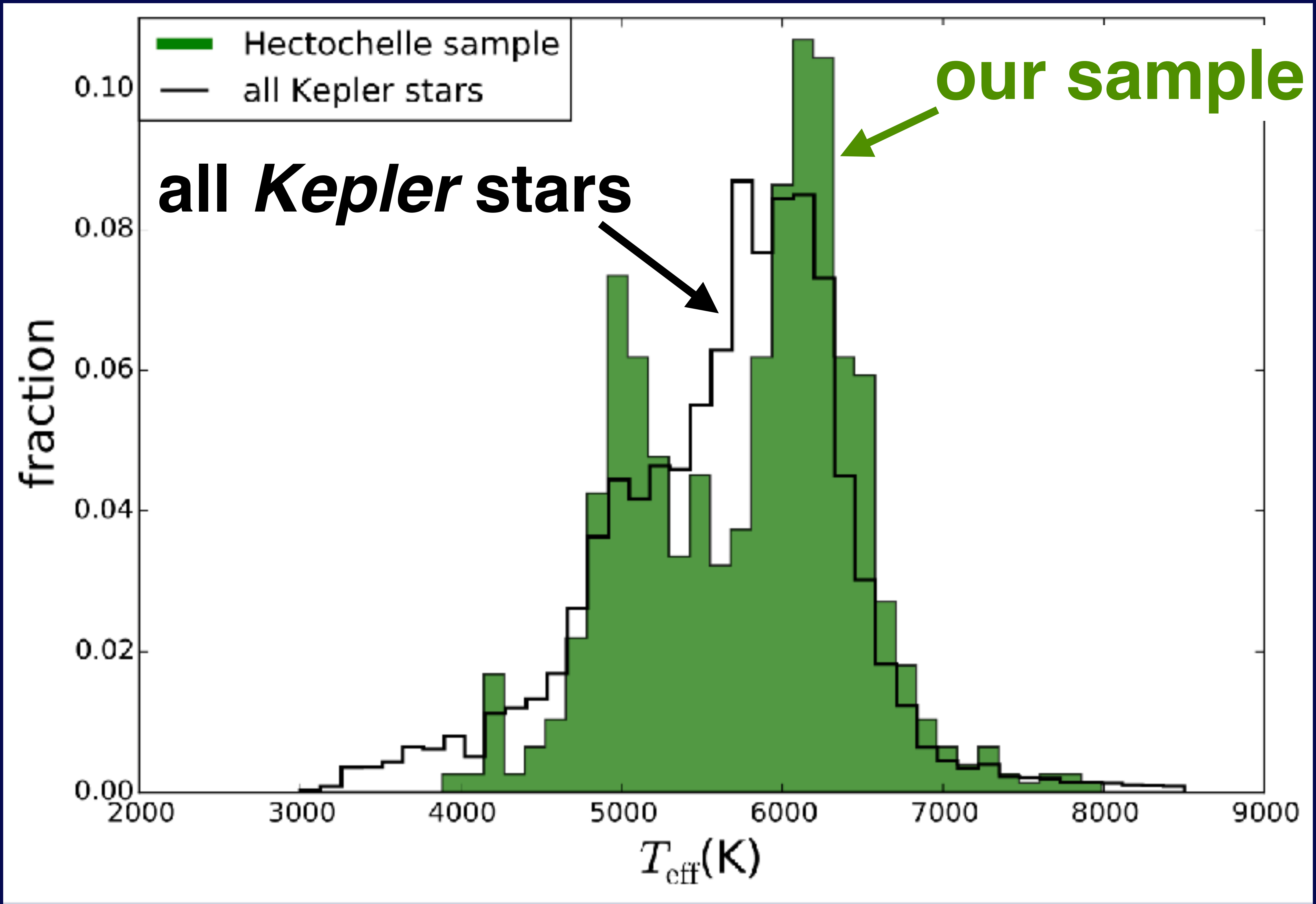
by measuring the stellar metallicity distribution of the *Kepler* field, and comparing with that of the solar neighborhood.

- **Sample**

Instrument: Hectochelle(240 fibers) on MMT.

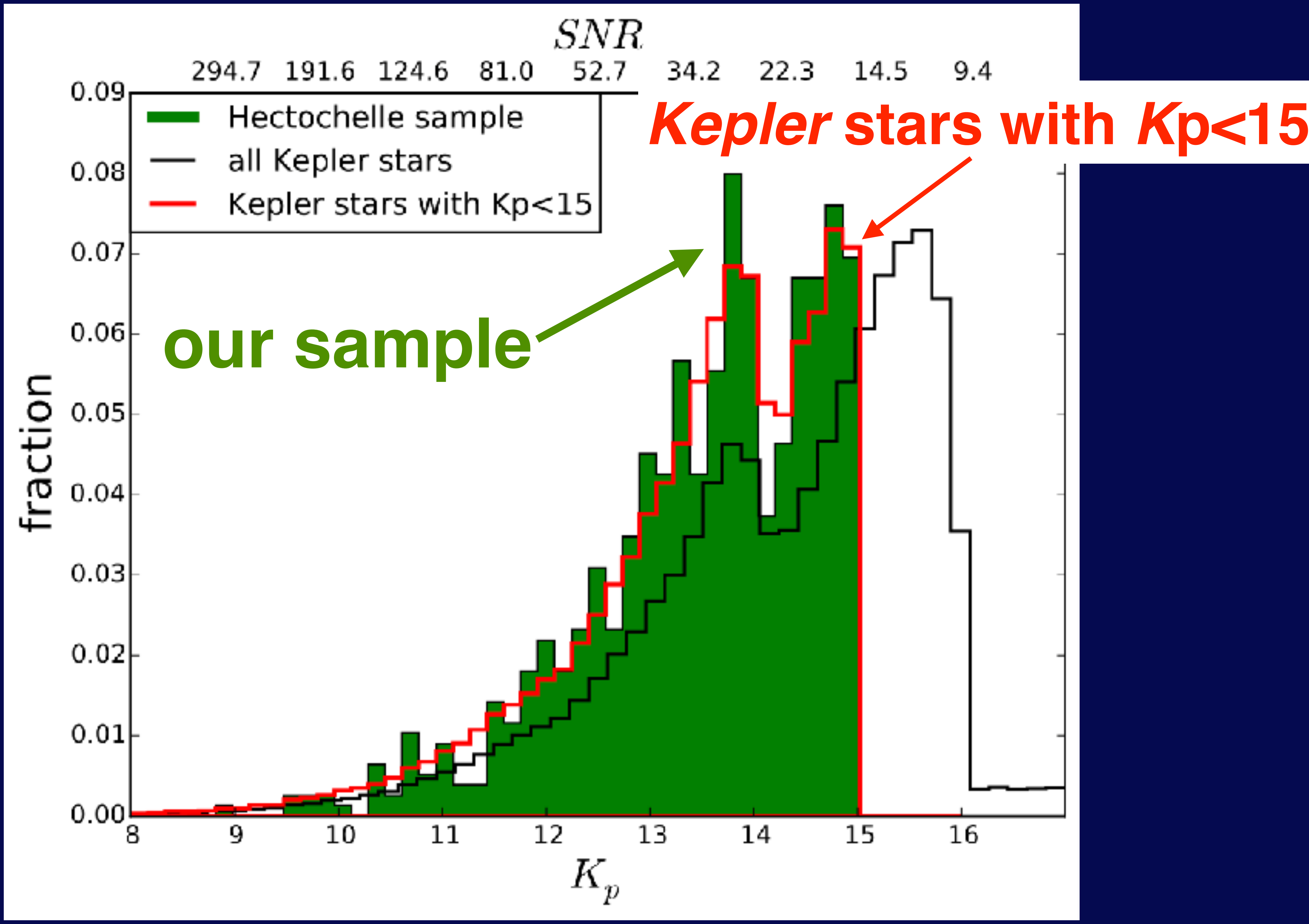
- **Sample**

F/G/K stars, 4000~7000 K

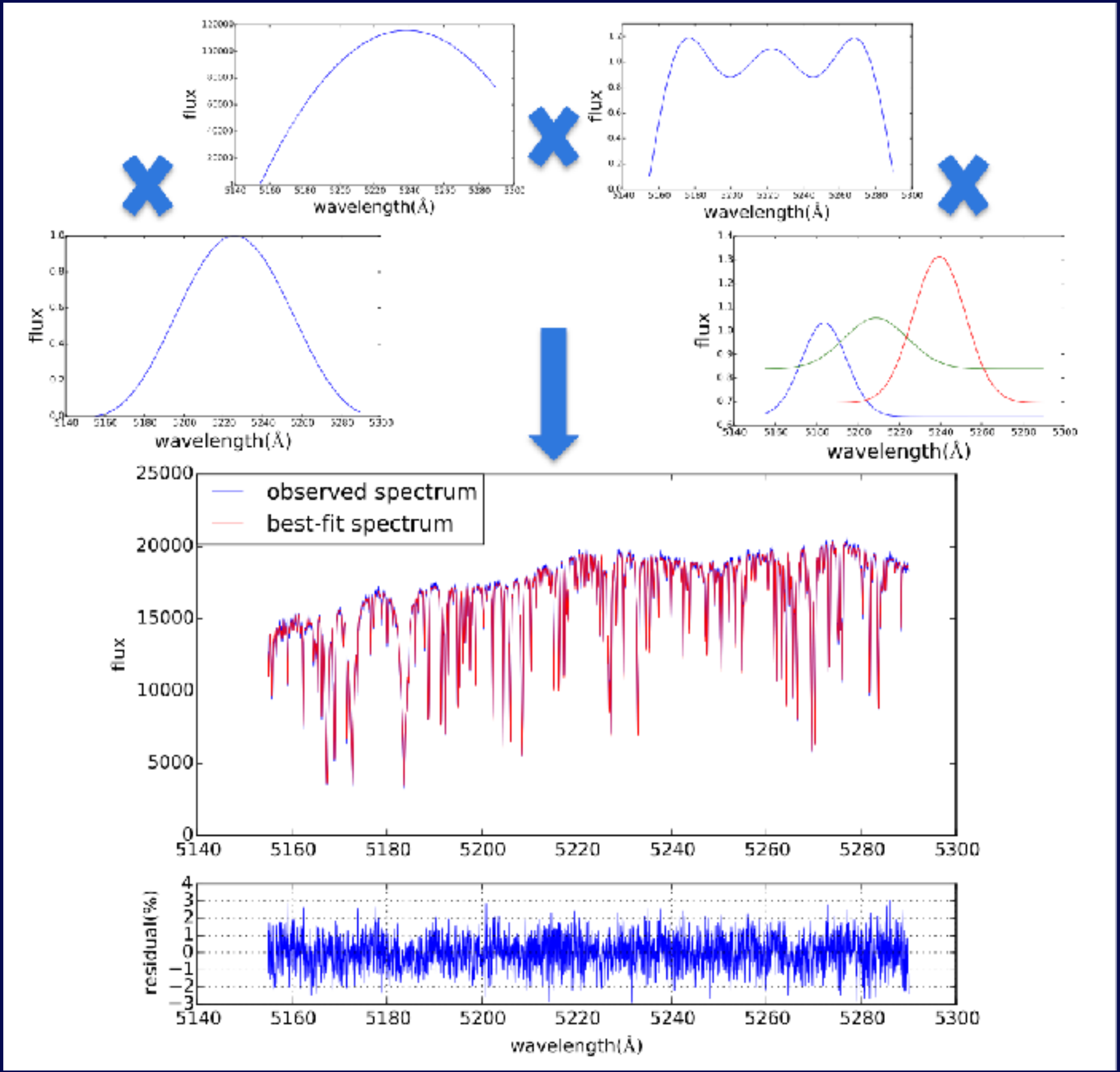


- **Sample**

K_p<15, SNR: 15~80



- **Spectral fitting…**



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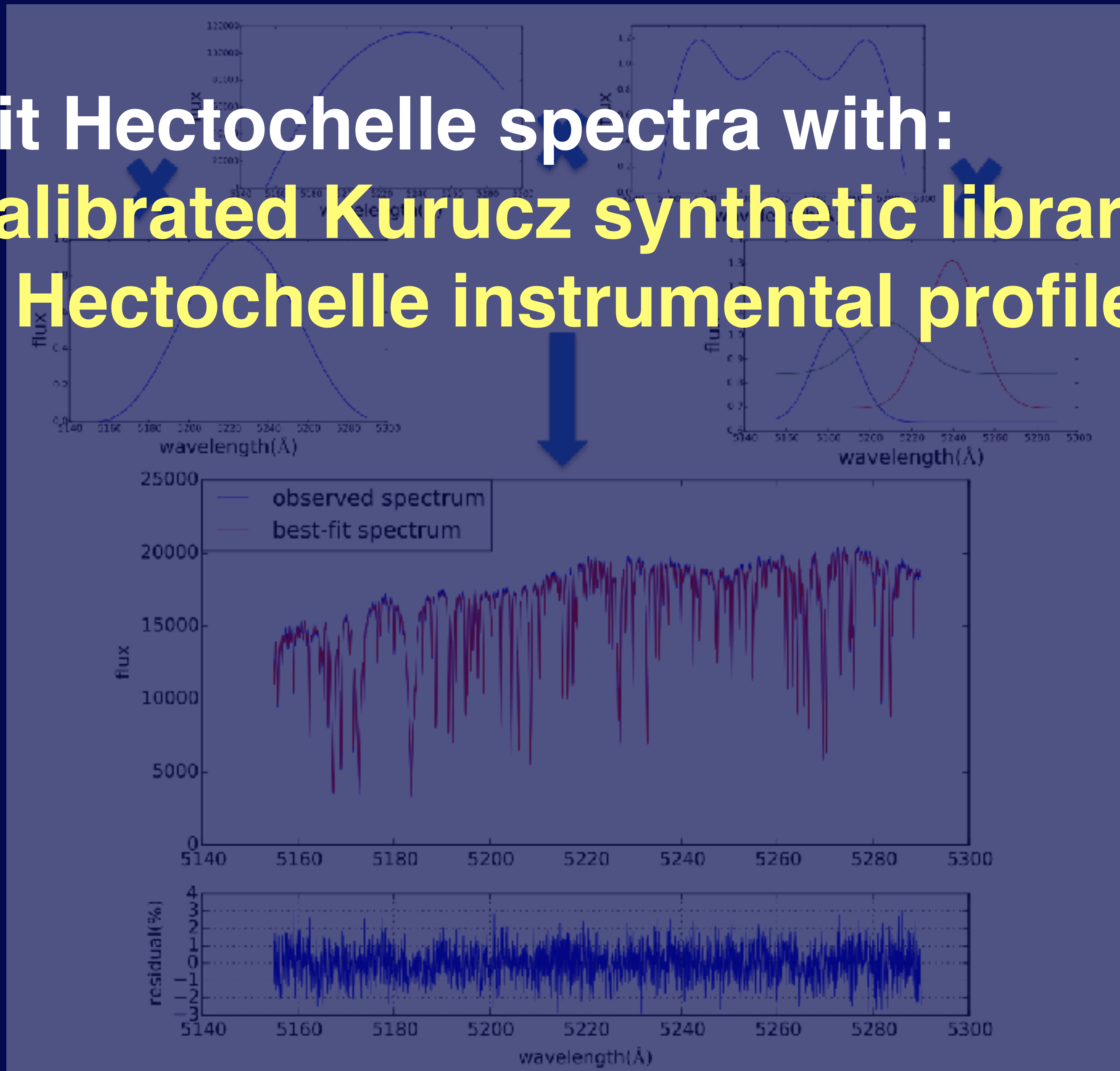
Fit Hectochelle spectra with:
calibrated Kurucz synthetic library
+ Hectochelle instrumental profile



- **Spectral fitting…**

Fit Hectochelle spectra with:

calibrated Kurucz synthetic library

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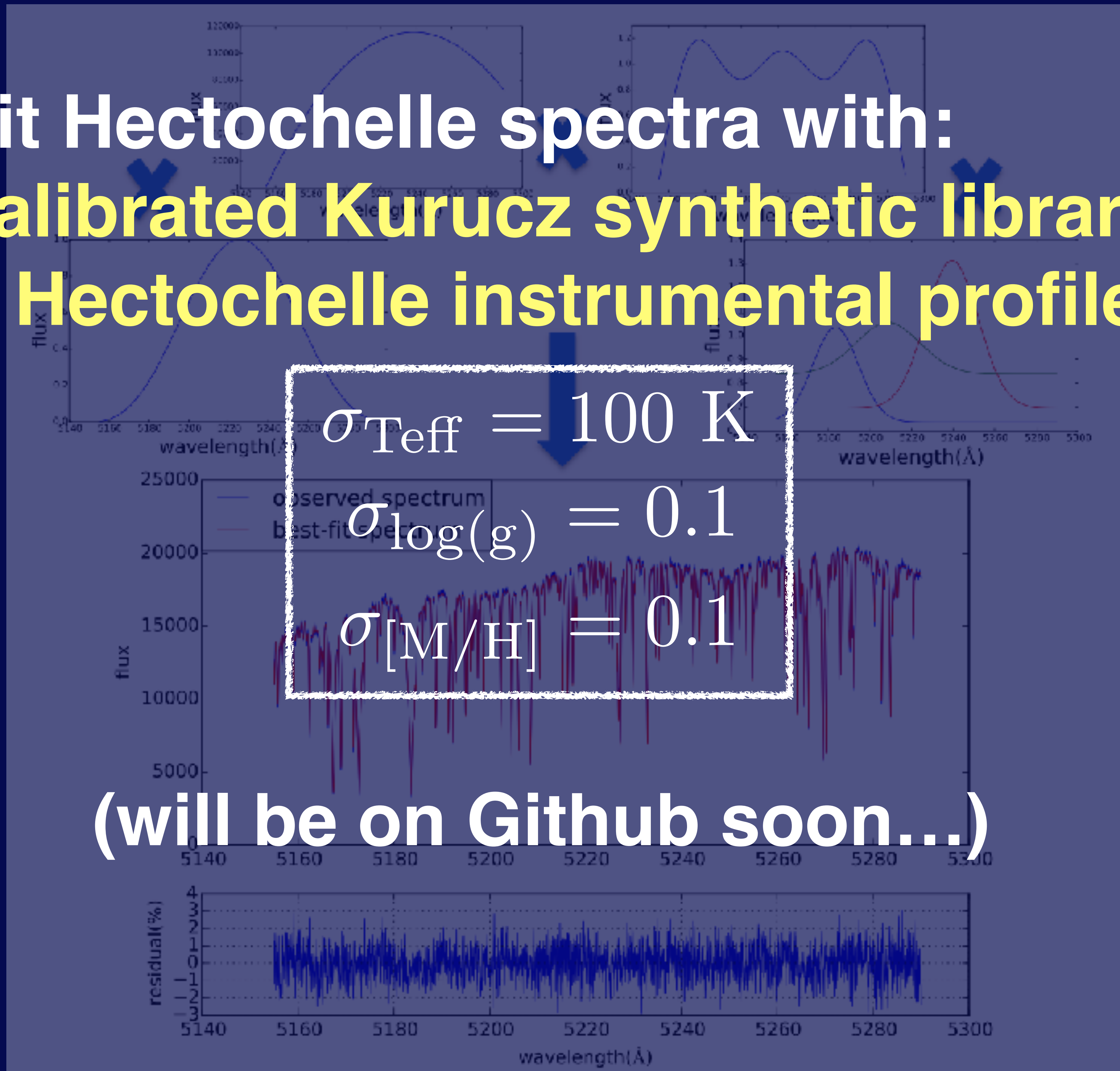
$$\sigma_{\mathrm{Teff}} = 100\ \mathrm{K}$$

$$\sigma_{\log(\mathrm{g})} = 0.1$$

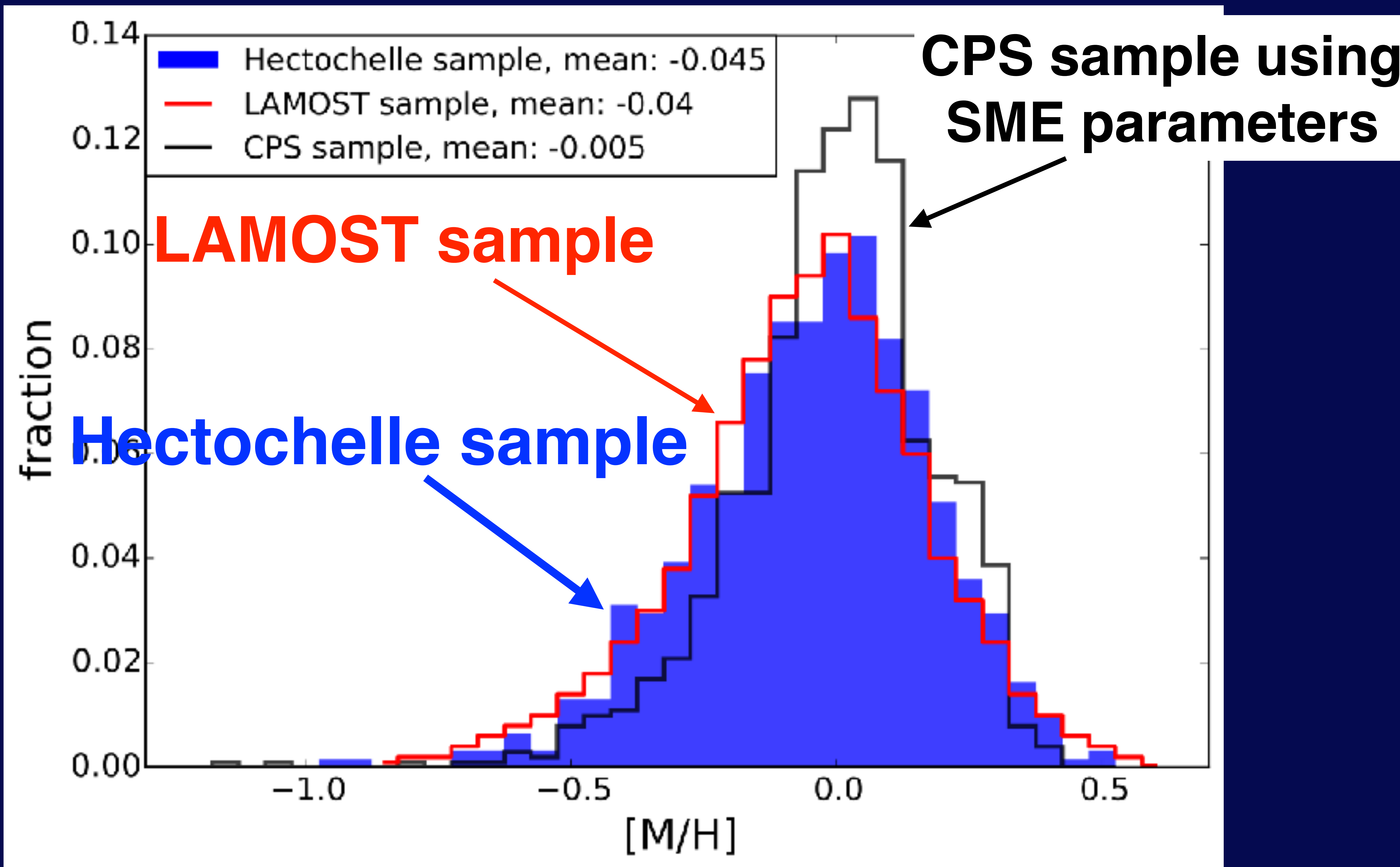
$$\sigma_{[\mathrm{M/H}]} = 0.1$$



(will be on Github soon…)

- **Results**

Metallicity distributions of the two populations are distinct



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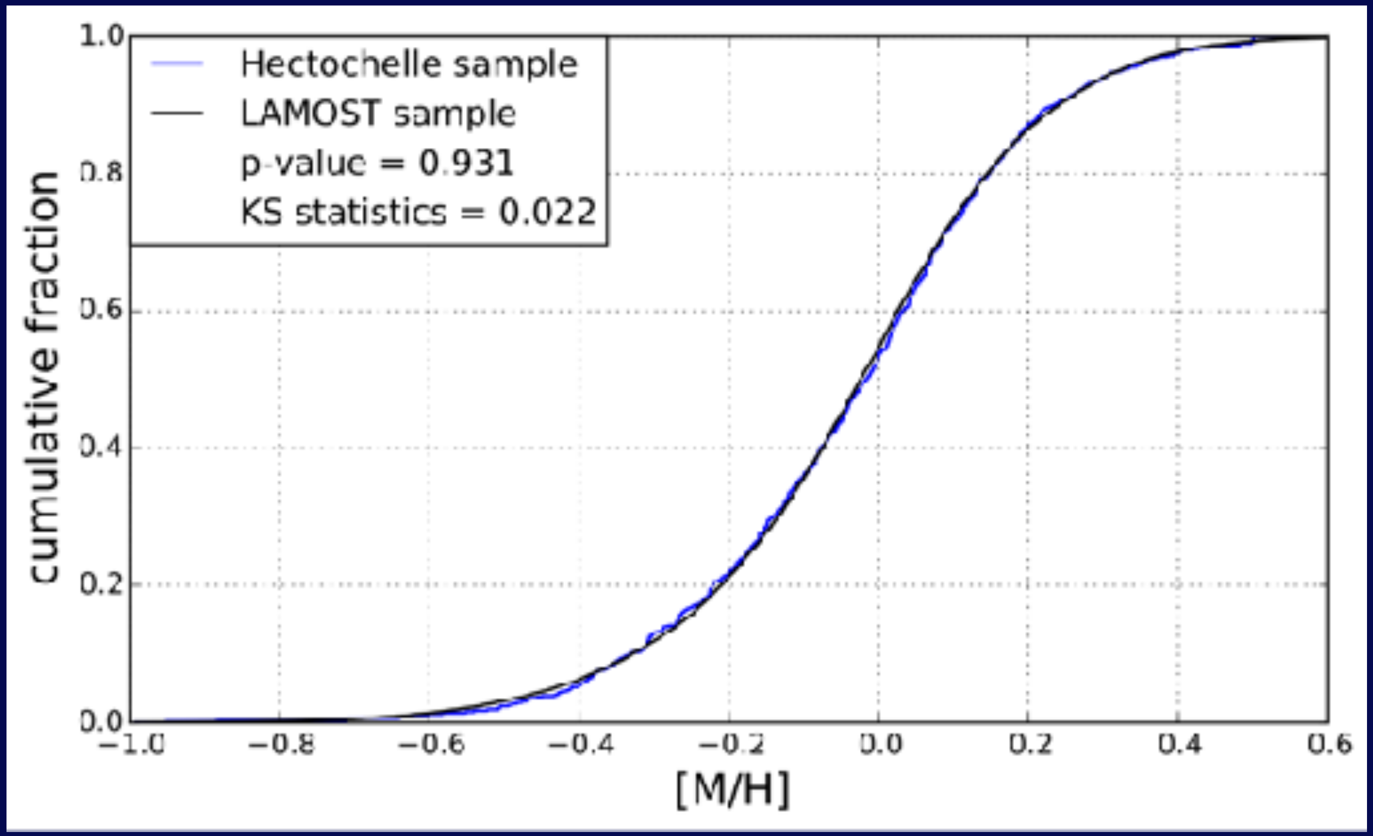

Hectochelle sample vs.
LAMOST sample
p-value = 0.93

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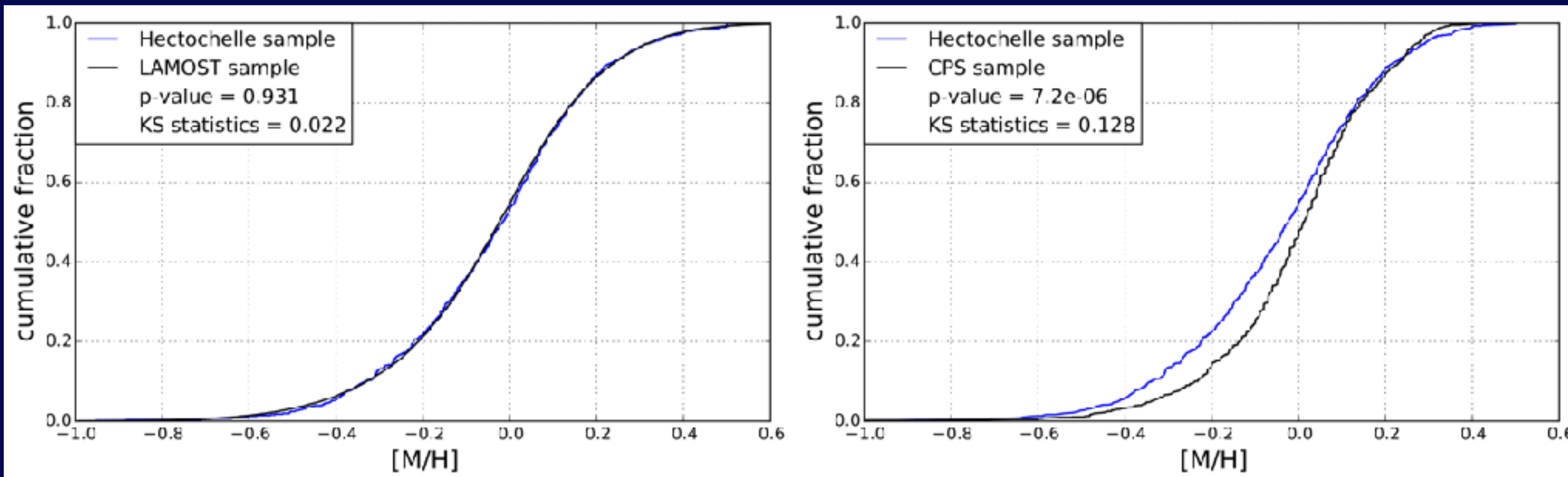

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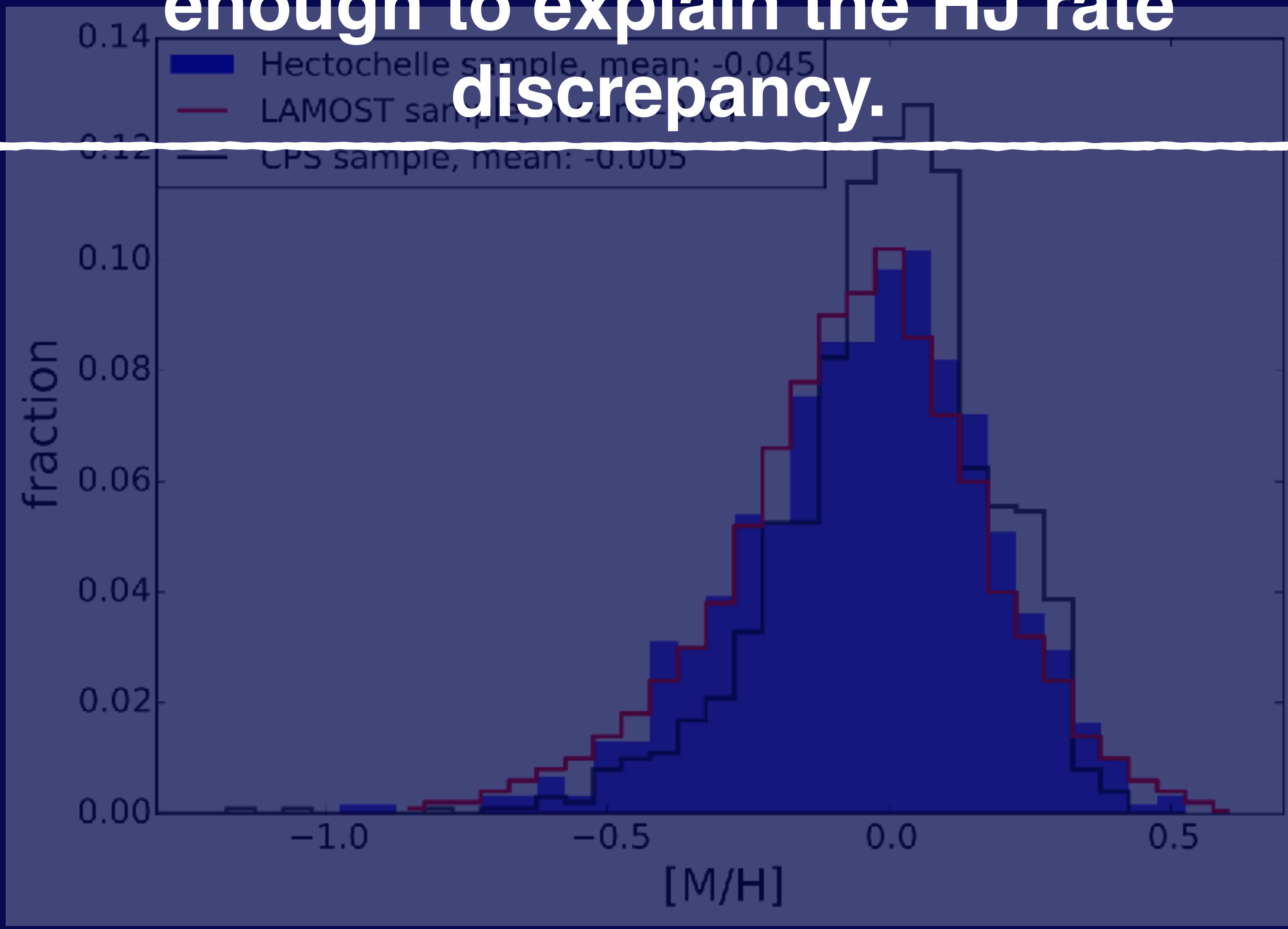
Kepler stars vs.
solar neighborhood stars
p-value = 7.2e-6

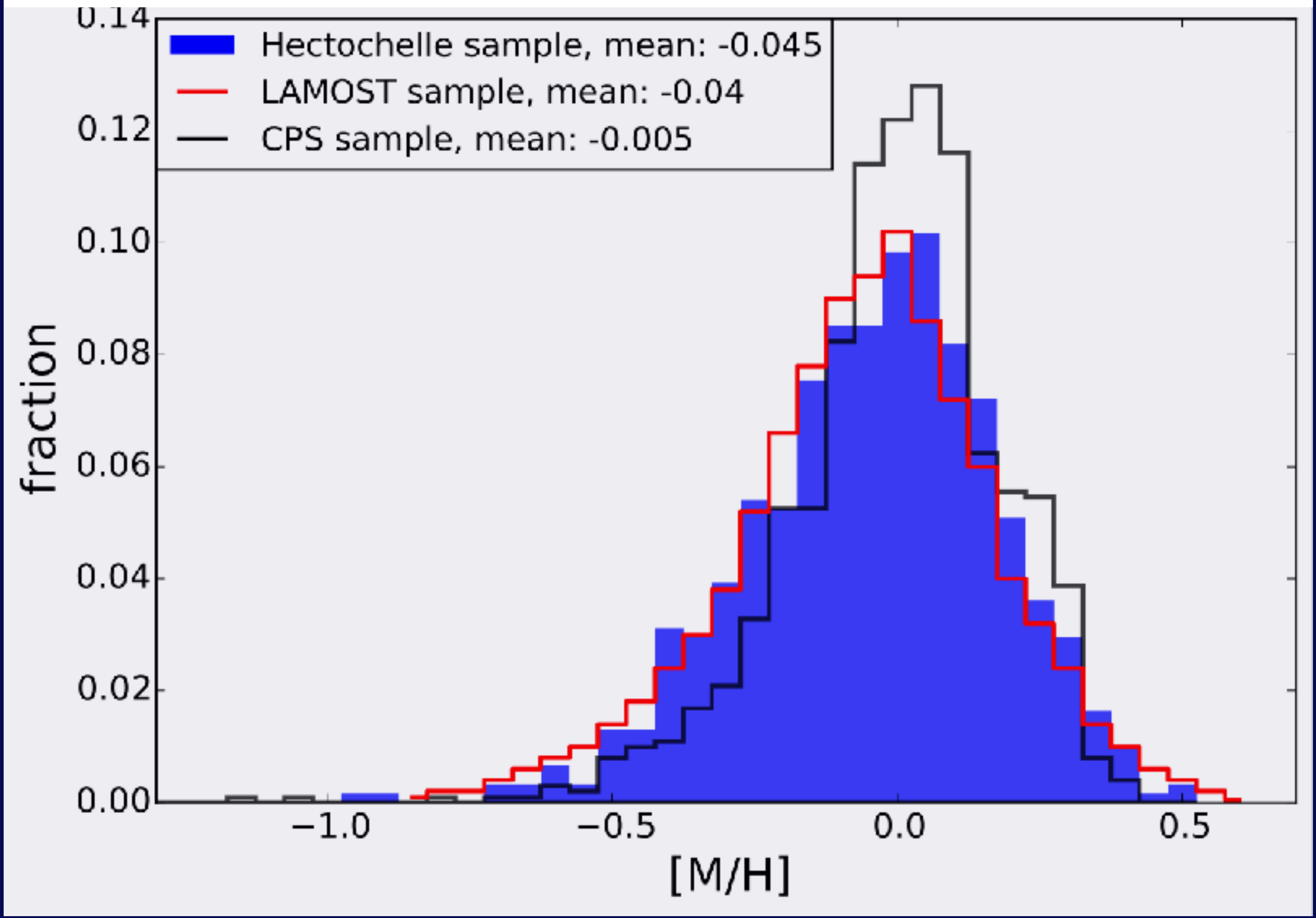
- **Results**

But, the metallicity difference is not big enough to explain the HJ rate discrepancy.



- **Results**

RV sample mean [M/H]: -0.005
Kepler sample mean [M/H]: -0.04



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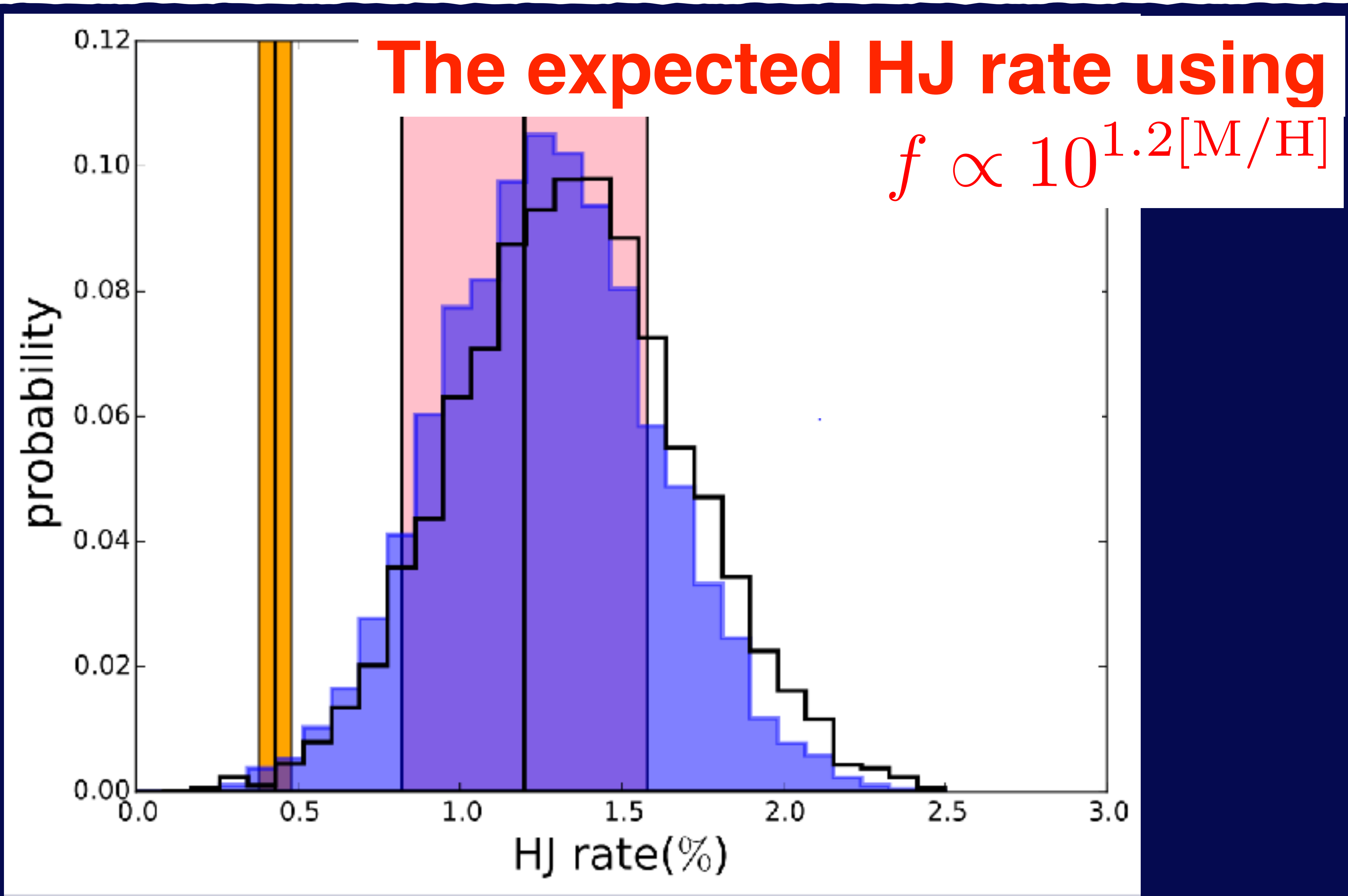

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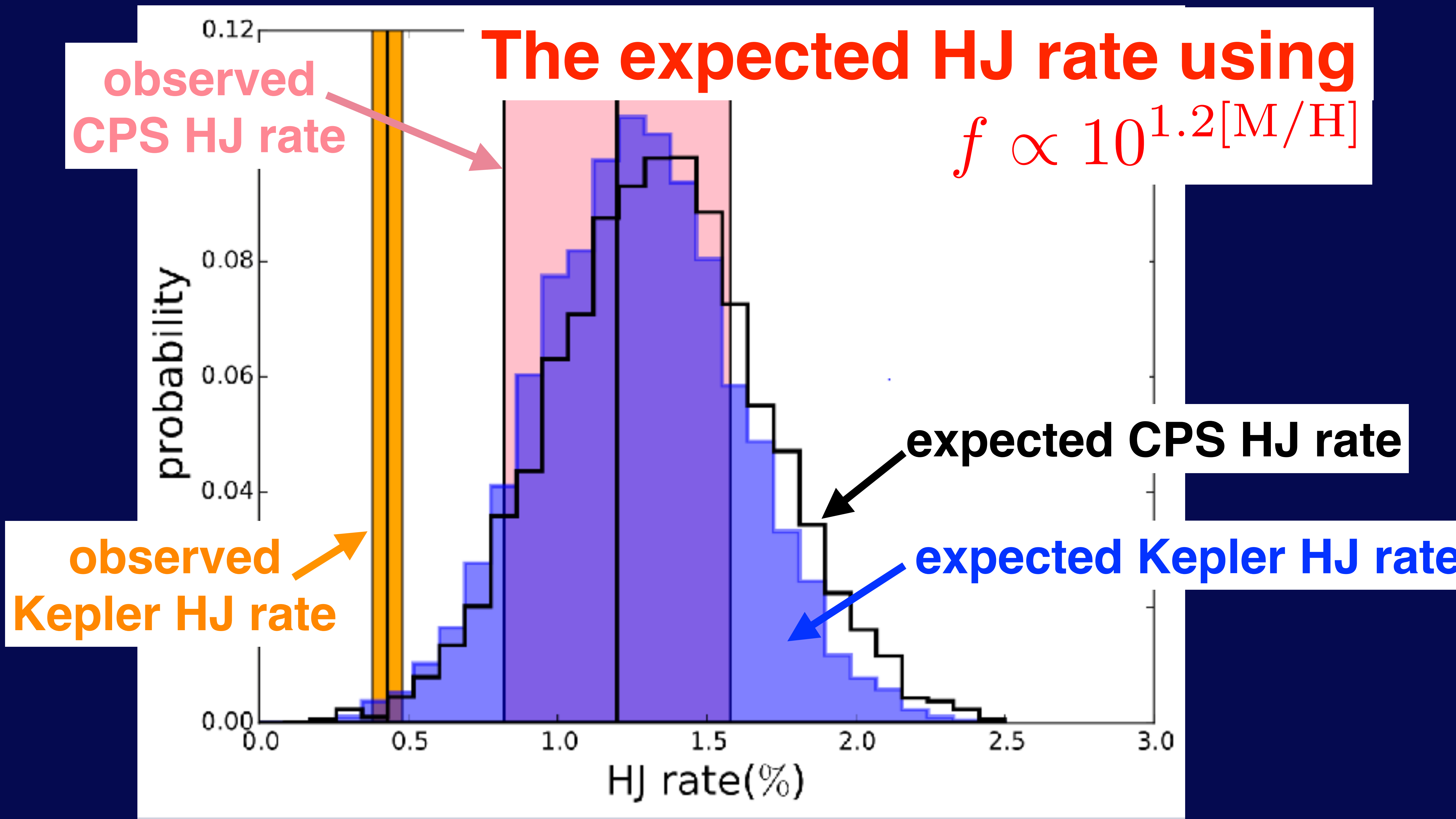

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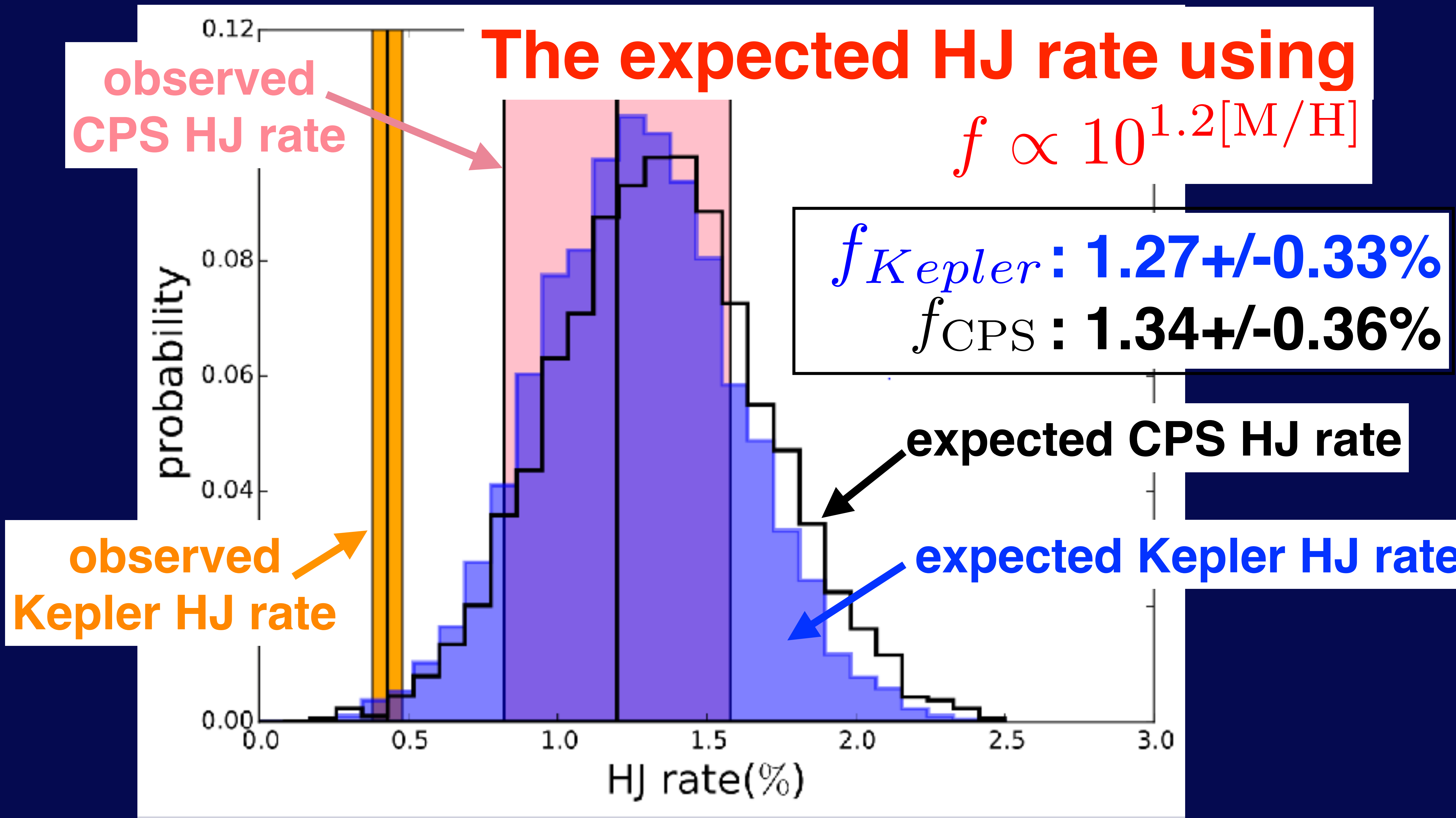

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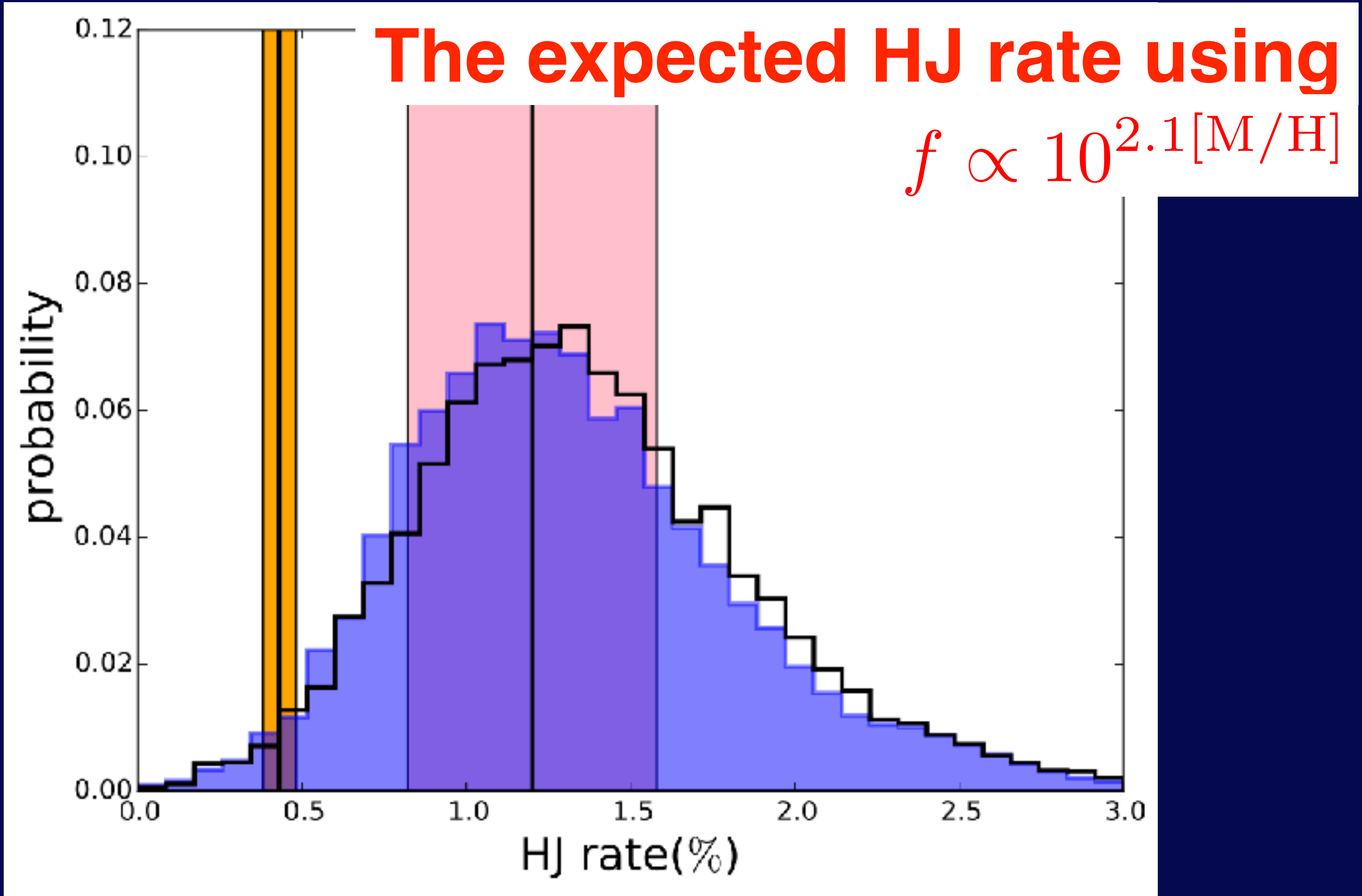

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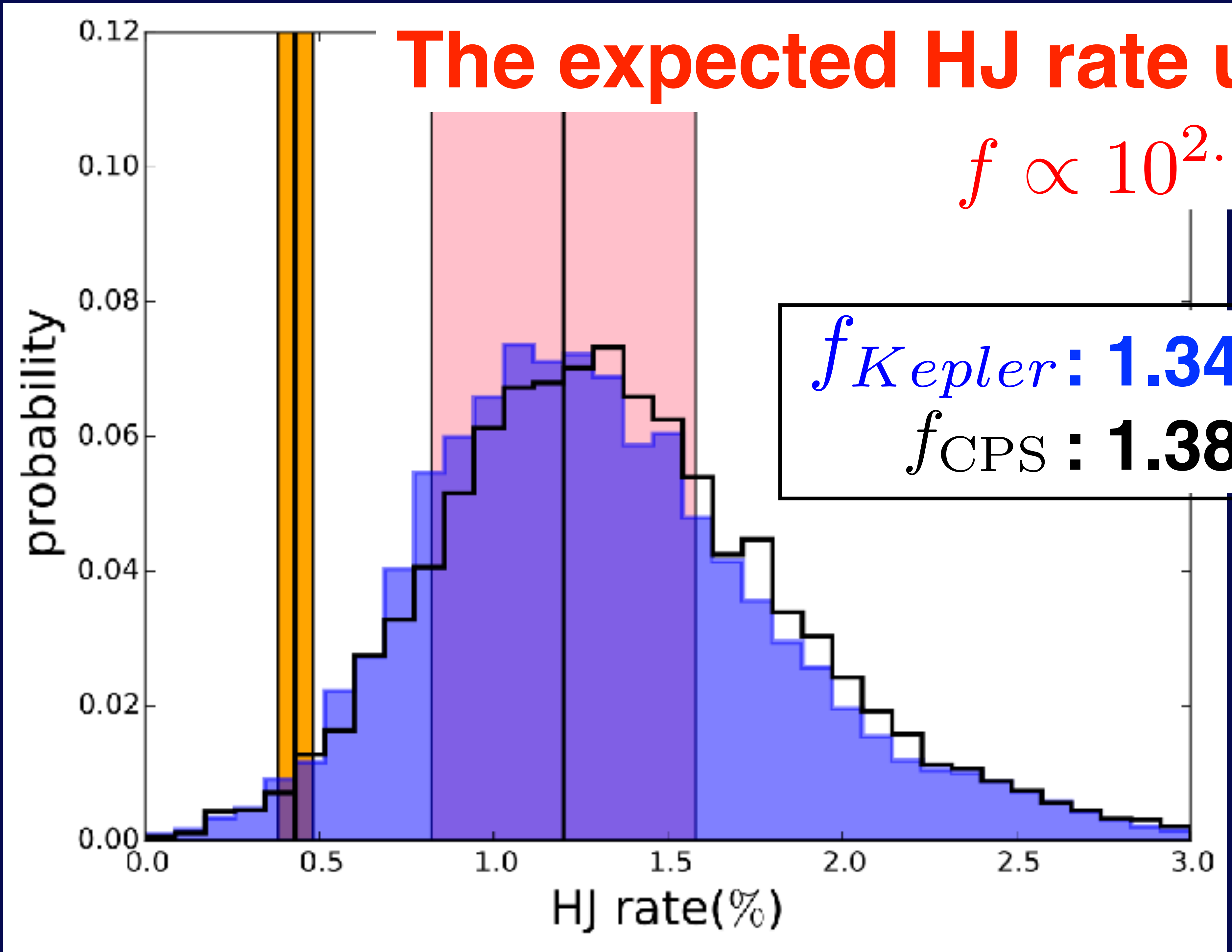

The expected HJ rate using
$f \propto 10^{2.1[M/H]}$

f_{Kepler}: **1.34+/-0.55%**
f_{CPS}: **1.38+/-0.54%**

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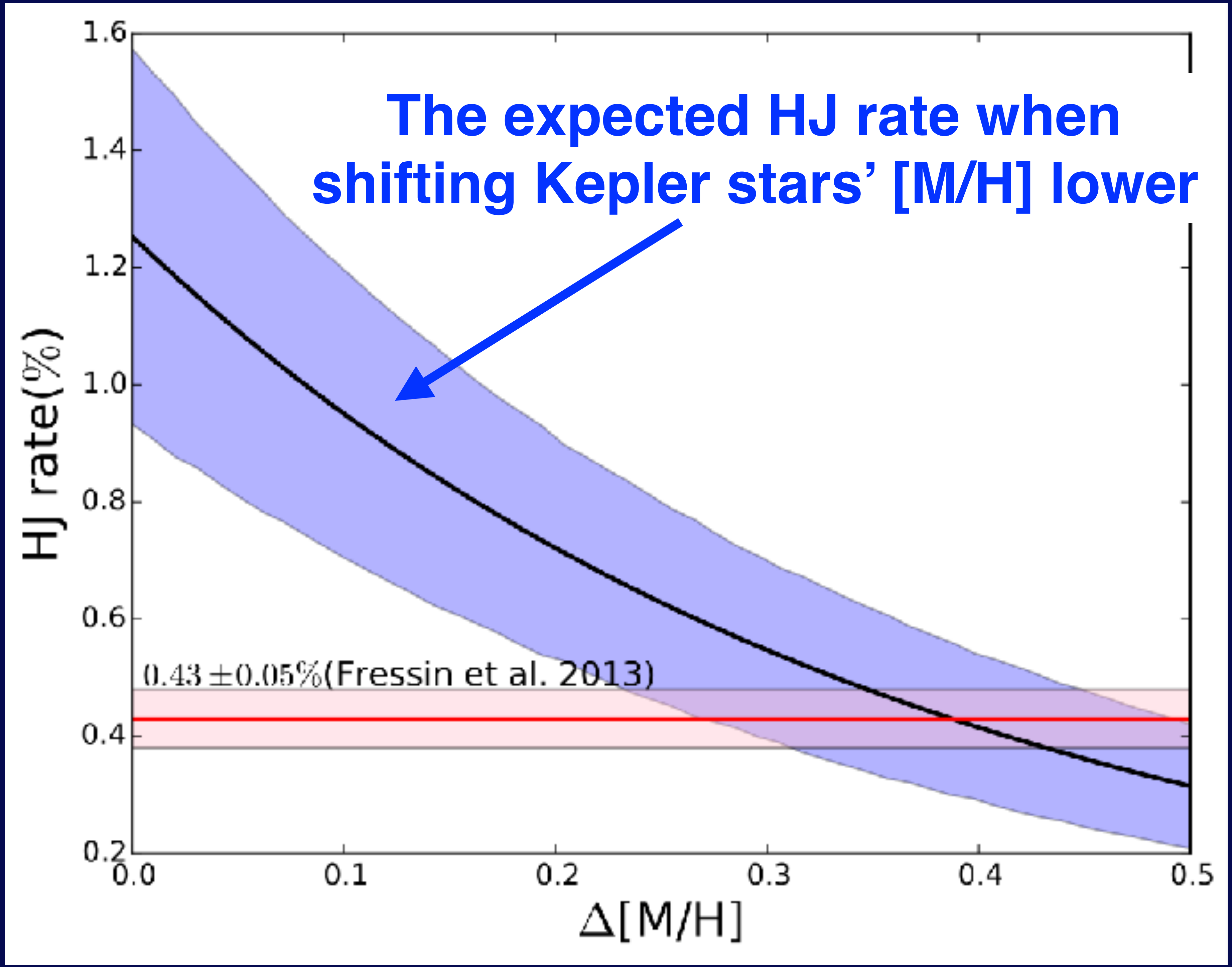

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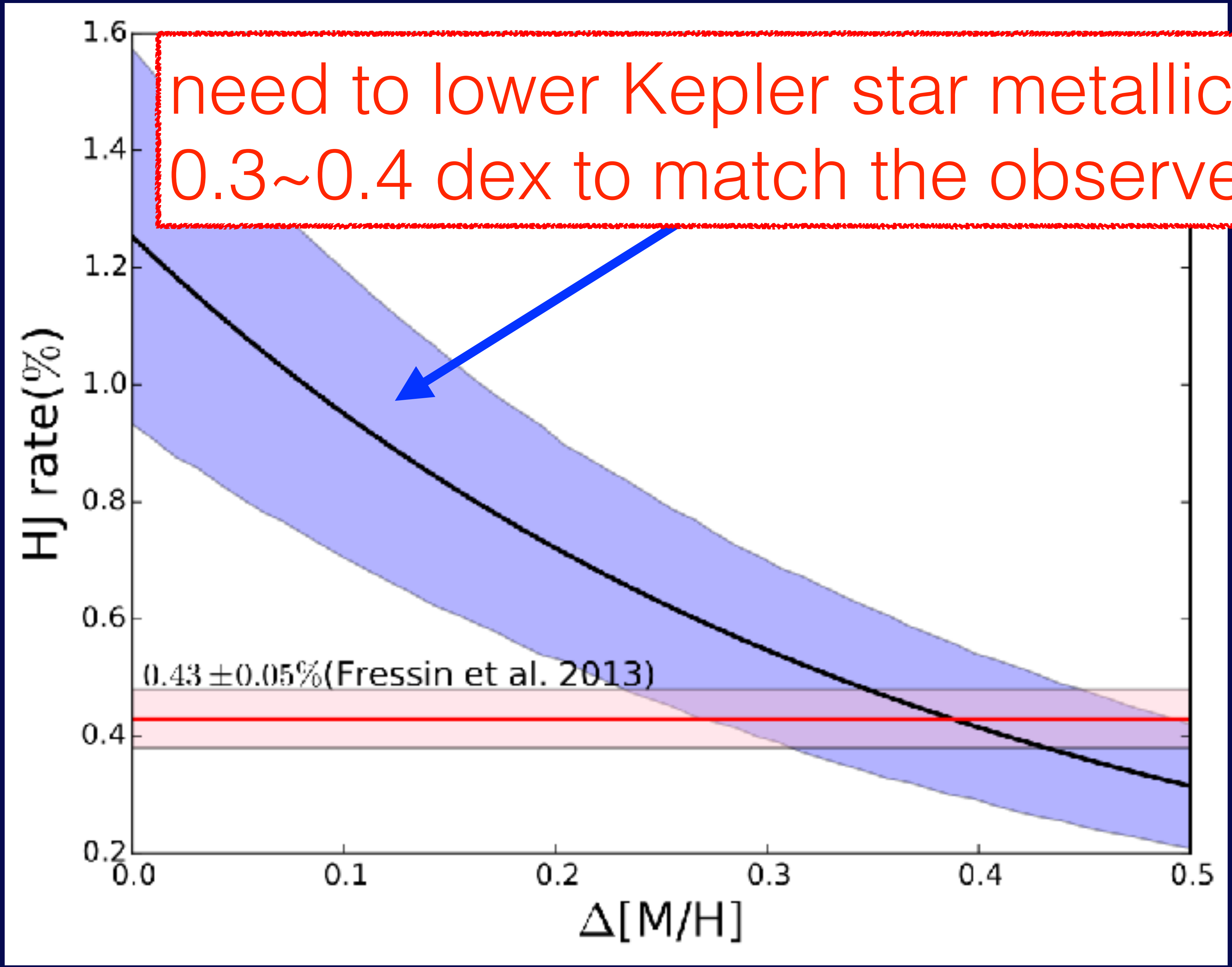

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✳ Inaccurate occurrence rate measurements

— “Inverse detection efficiency” bias occurrence rate estimate, etc.

Check out our paper! (2017APJ, 838, 25G)

The Astrophysical Journal, 838:25 (16pp), 2017 March 20

https://doi.org/10.3847/1538-4357/aa6004

The Metallicity Distribution and Hot Jupiter Rate of the *Kepler* Field: Hectochelle High-resolution Spectroscopy for 776 *Kepler* Target Stars

Xueying Guo[1], John A. Johnson[2], Andrew W. Mann[3,5], Adam L. Kraus[3], Jason L. Curtis[4], and David W. Latham[2]

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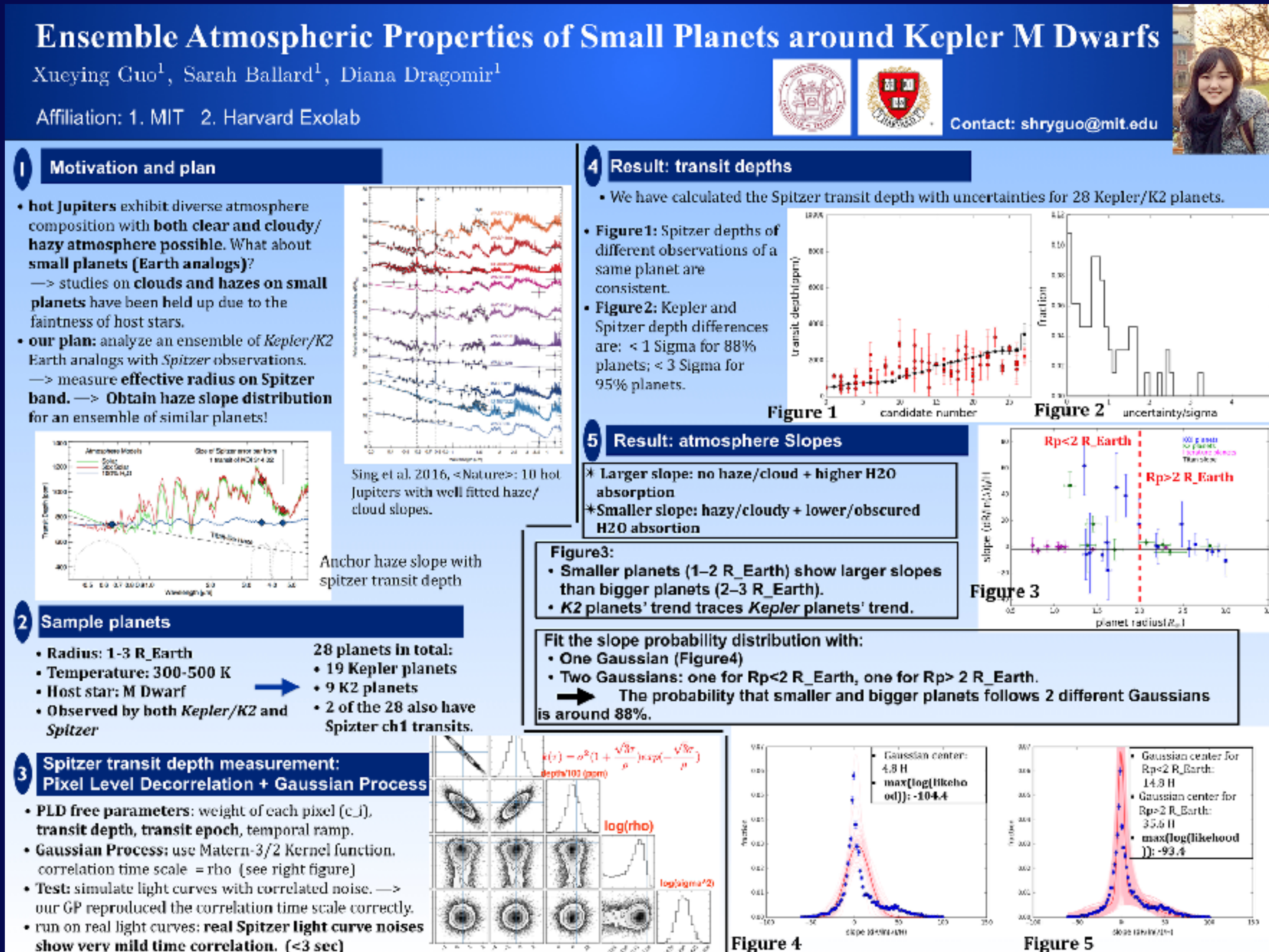
Abstract

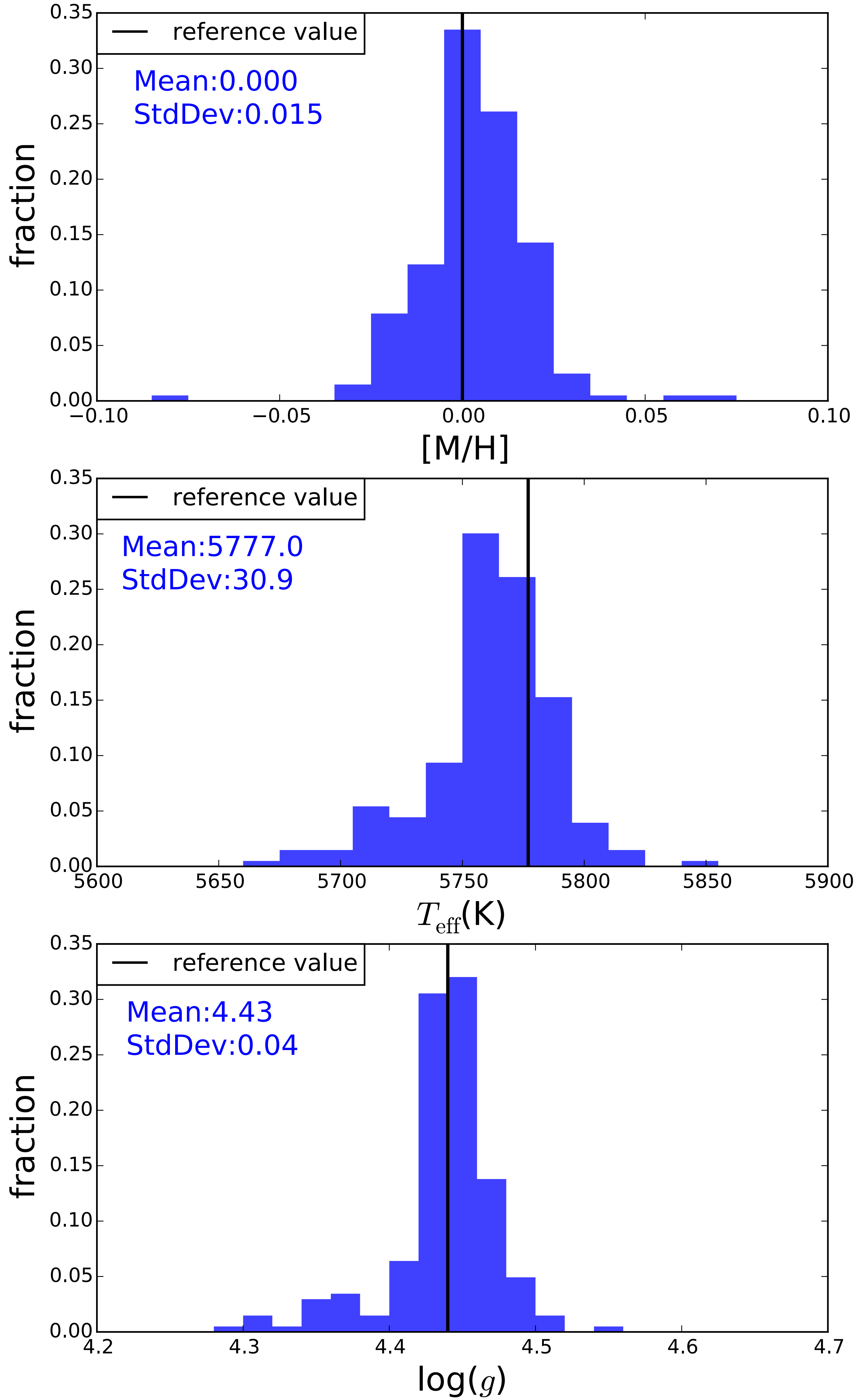
The occurrence rate of hot Jupiters from the *Kepler* transit survey is roughly half that of radial velocity surveys targeting solar neighborhood stars. One hypothesis to explain this difference is that the two surveys target stars with different stellar metallicity distributions. To test this hypothesis, we measure the metallicity distribution of the *Kepler* targets using the Hectochelle multi-fiber, high-resolution spectrograph. Limiting our spectroscopic analysis to 610 dwarf stars in our sample with $\log g > 3.5$, we measure a metallicity distribution characterized by a mean of $[M/H]_{mean} = -0.045 \pm 0.009$, in agreement with previous studies of the *Kepler* field target stars. In comparison, the metallicity distribution of the California Planet Search radial velocity sample has a mean of $[M/H]_{CPS,mean} = -0.005 \pm 0.006$, and the samples come from different parent populations according to a Kolmogorov–Smirnov test. We refit the exponential relation between the fraction of stars hosting a close-in giant planet and the host star metallicity using a sample of dwarf stars from the California Planet Search with updated metallicities. The best-fit relation tells us that the difference in metallicity between the two samples is insufficient to explain the discrepant hot Jupiter occurrence rates; the metallicity difference would need to be $\simeq$0.2–0.3 dex for perfect agreement. We also show that (sub)giant contamination in the *Kepler* sample cannot reconcile the two occurrence calculations. We conclude that other factors, such as binary contamination and imperfect stellar properties, must also be at play.

Key words: catalogs – methods: statistical – planets and satellites: detection – stars: abundances – stars: fundamental parameters – techniques: imaging spectroscopy

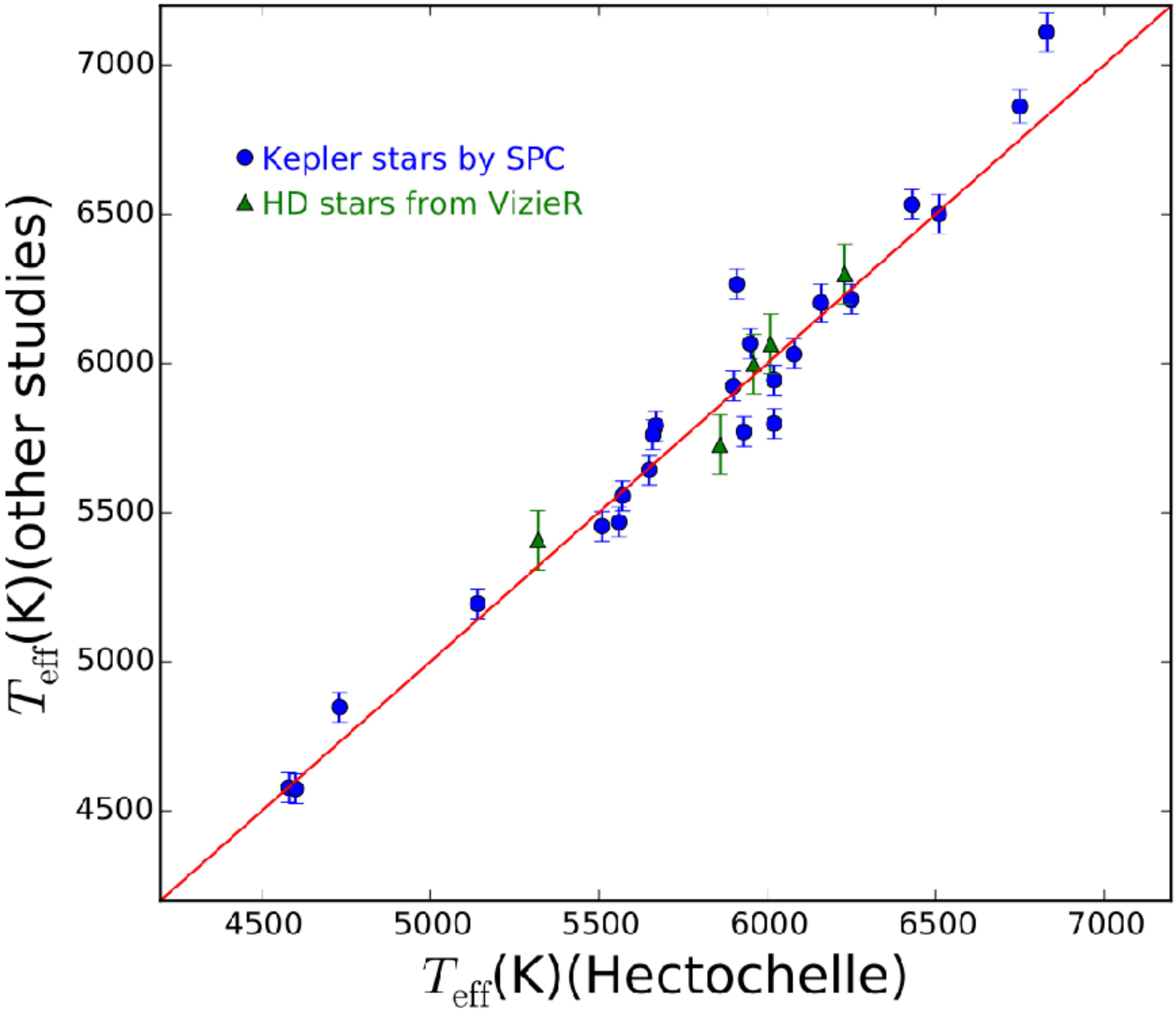
Supporting material: machine-readable table

Poster: *Ensemble Atmospheric Properties of Earth-Analogs around Kepler M Dwarfs*

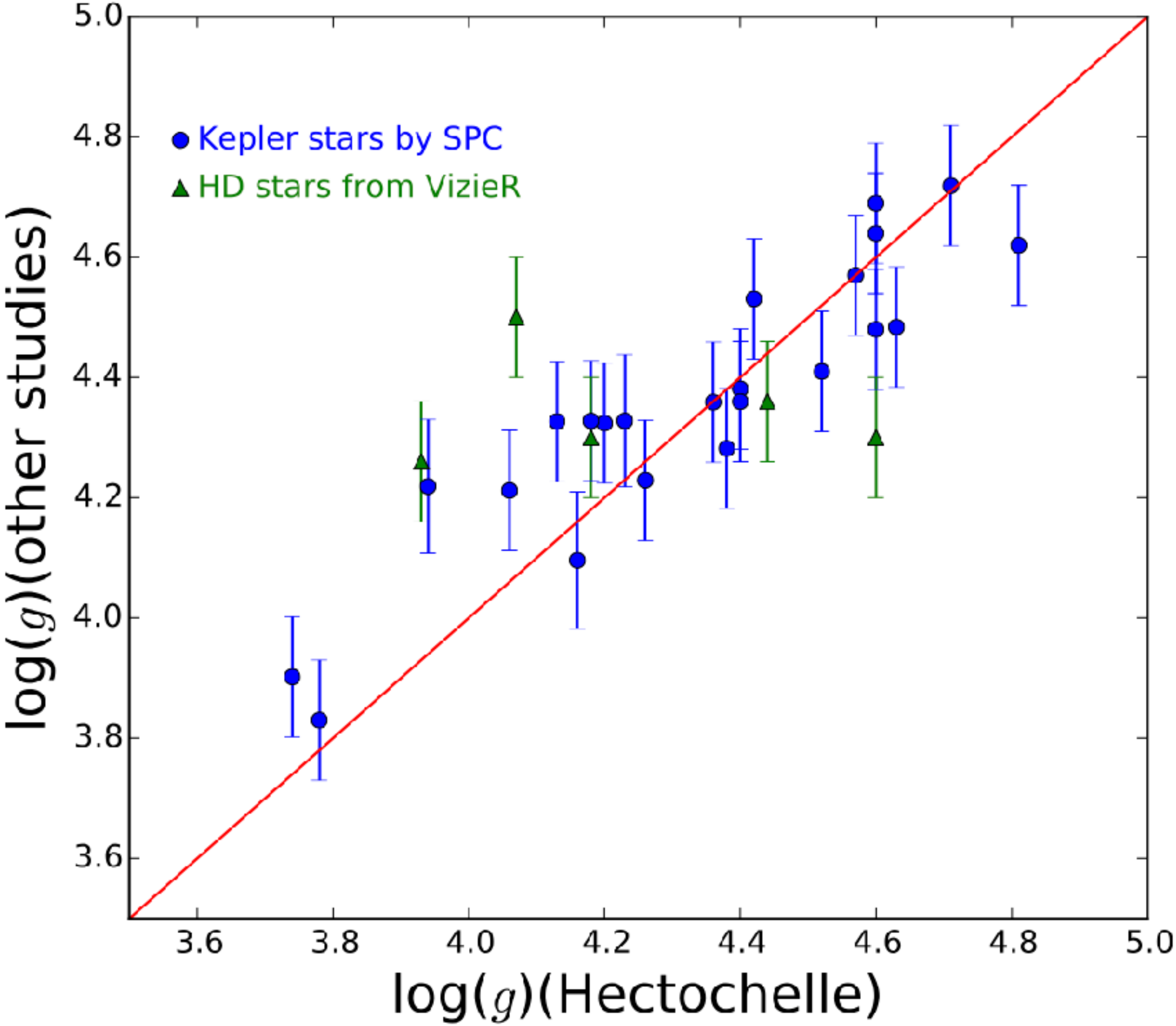


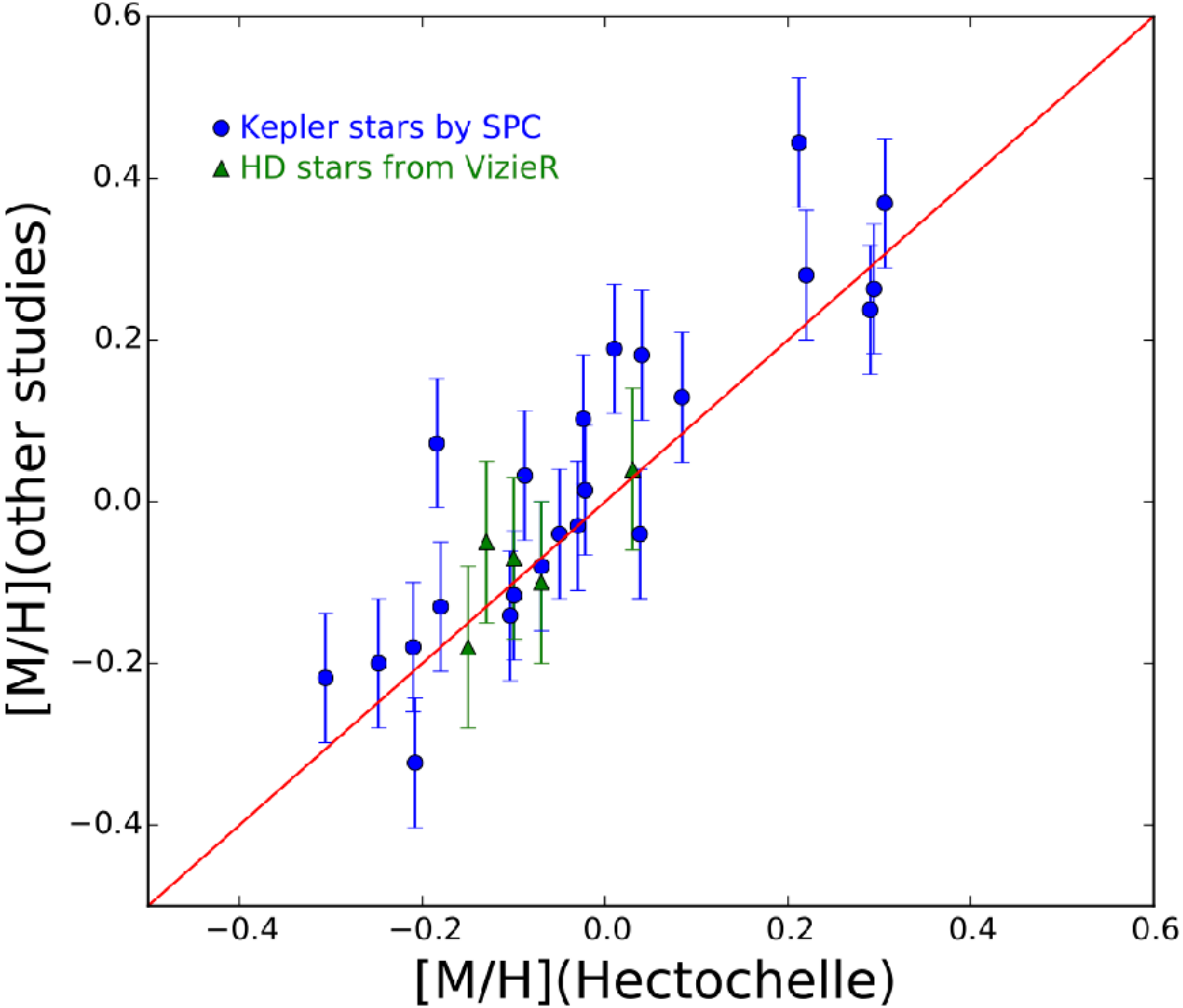


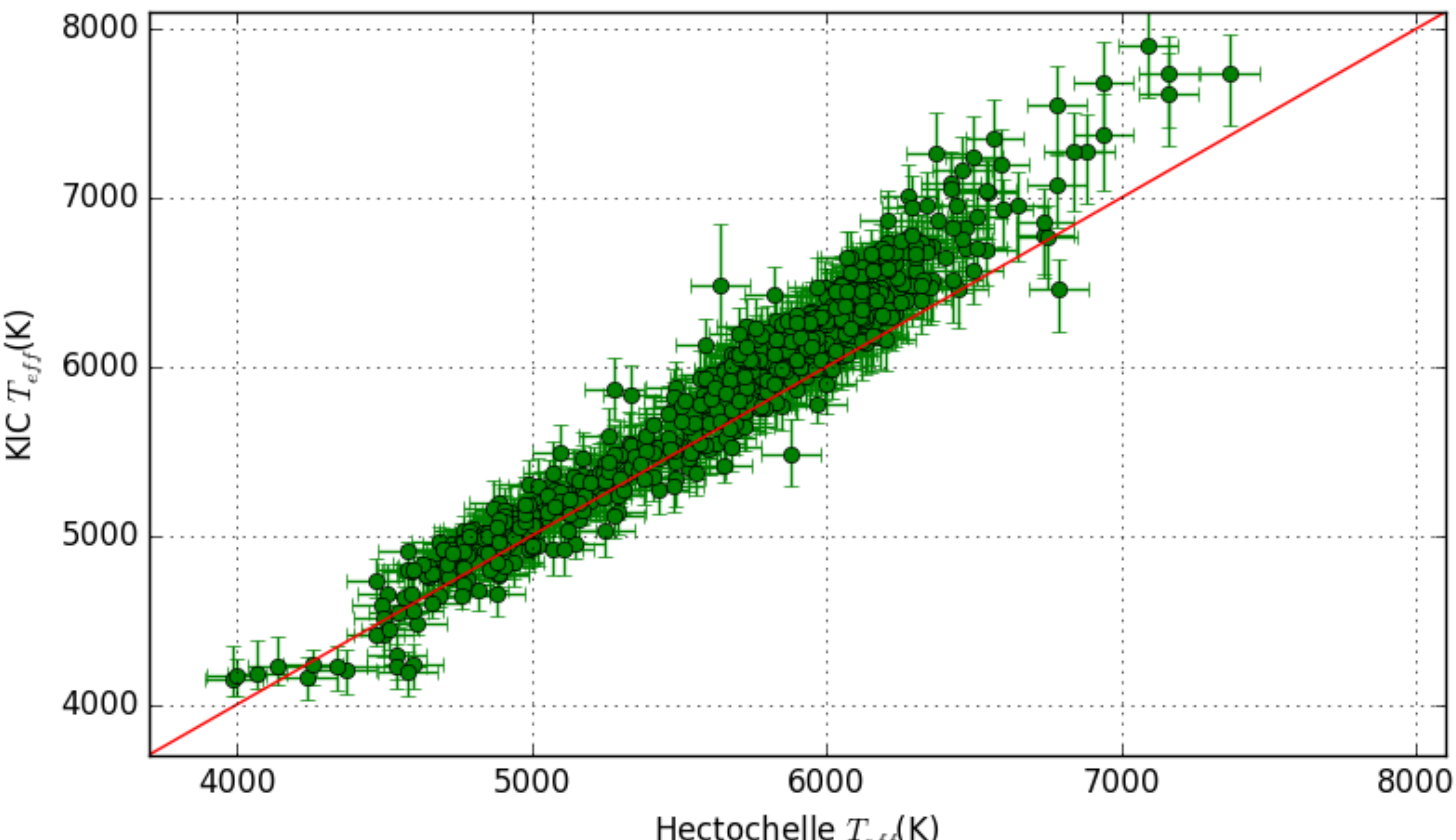
reference value
Mean:0.000
StdDev:0.015
fraction
[M/H]
reference value
Mean:5777.0
StdDev:30.9
fraction
$T_{\rm eff}$(K)
reference value
Mean:4.43
StdDev:0.04
fraction
log(g)



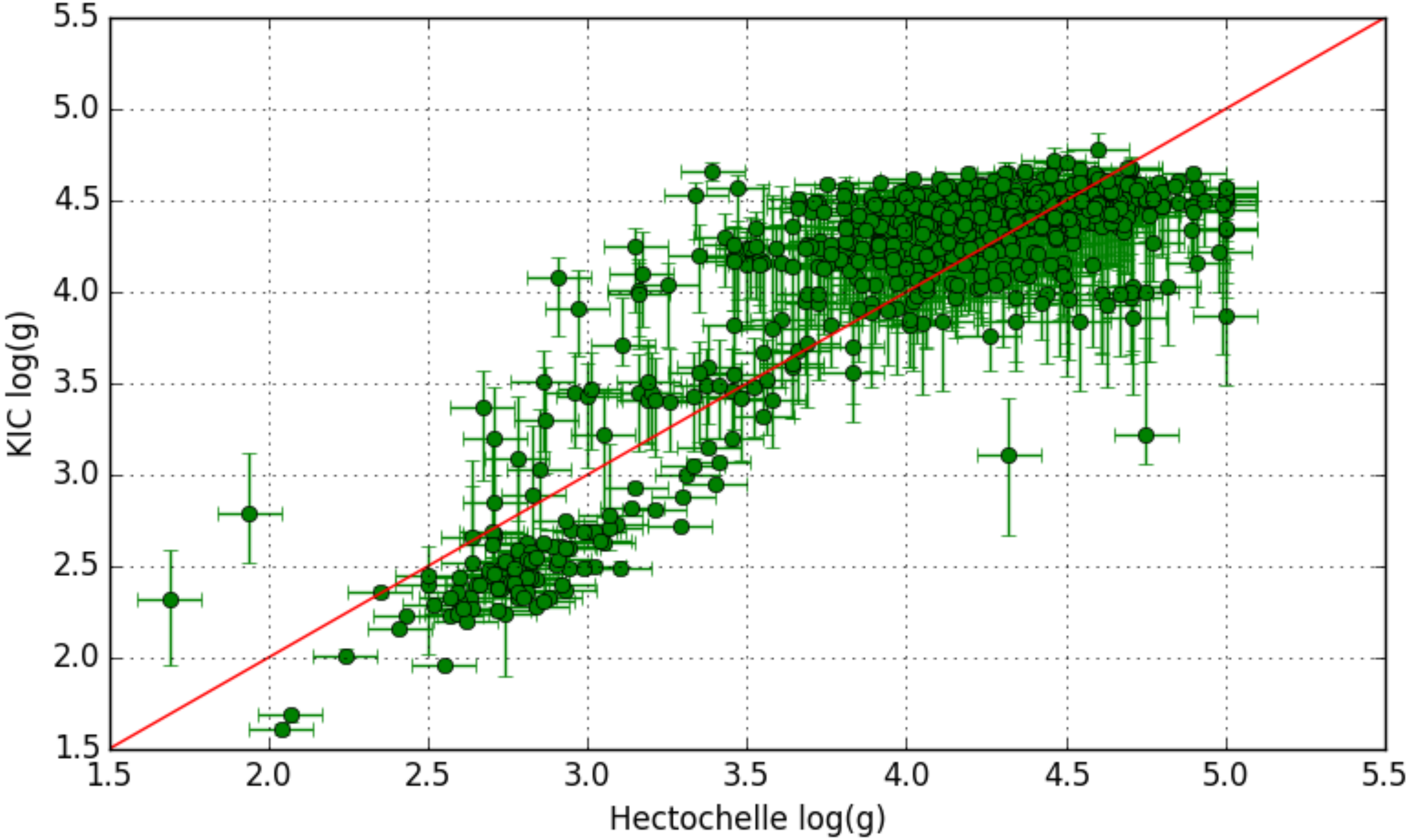
Kepler stars by SPC
HD stars from VizieR
$T_{\rm eff}$(K)(other studies)
$T_{\rm eff}$(K)(Hectochelle)
4500
5000
5500
6000
6500
7000


Kepler stars by SPC
HD stars from VizieR
log(g)(other studies)
log(g)(Hectochelle)
5.0
4.8
4.6
4.4
4.2
4.0
3.8
3.6
3.6
3.8
4.0
4.2
4.4
4.6
4.8
5.0

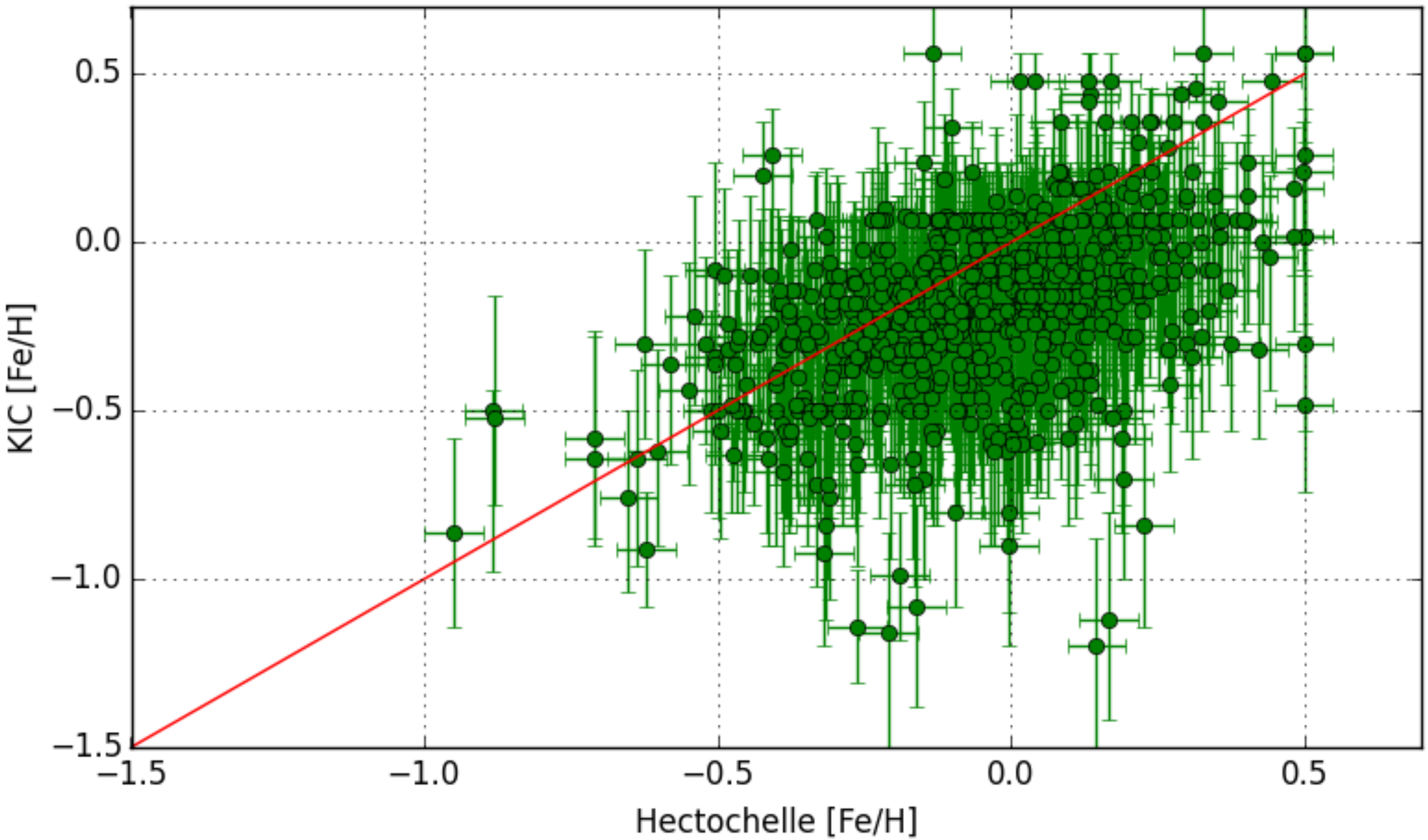

Kepler stars by SPC
HD stars from VizieR
[M/H](other studies)
[M/H](Hectochelle)
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.4
−0.2
0.0
0.2
0.4
0.6



8000
7000
6000
5000
4000
KIC T_{eff}(K)
4000
5000
6000
7000
8000
Hectochelle T_{eff}(K)



KIC log(g)
Hectochelle log(g)
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5


KIC [Fe/H]
Hectochelle [Fe/H]
0.5
0.0
−0.5
−1.0
−1.5
−1.5
−1.0
−0.5
0.0
0.5