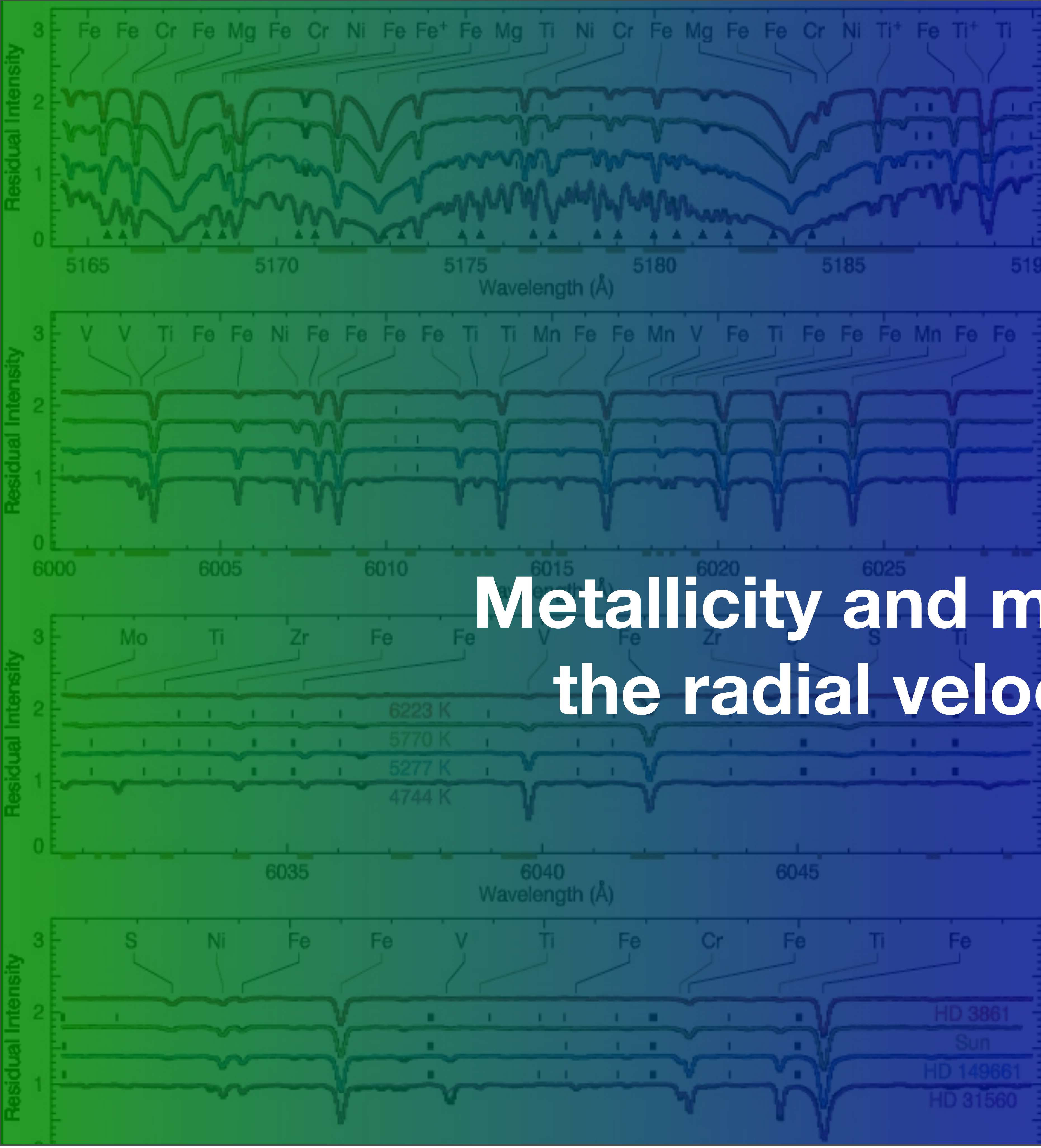
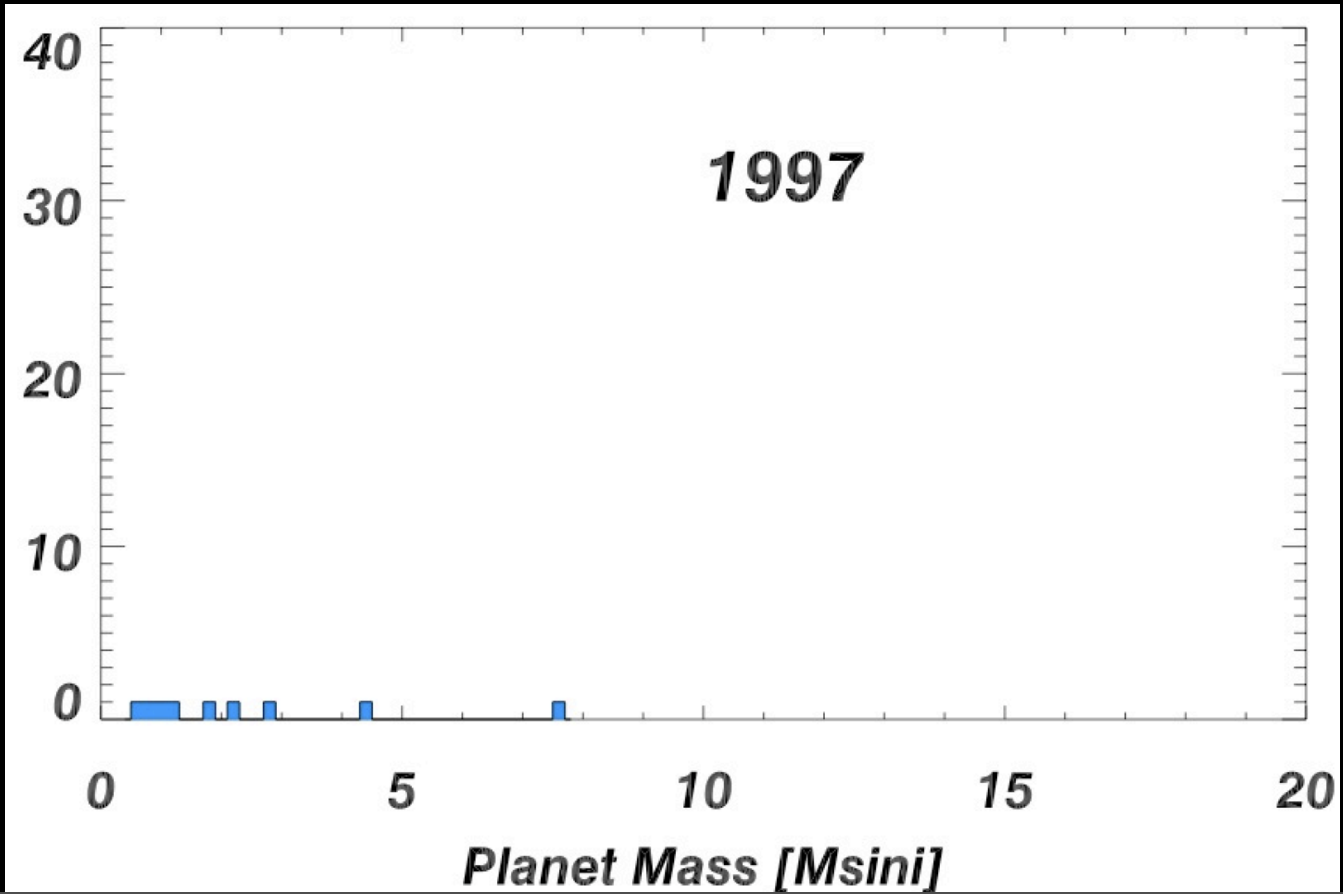


Metallicity and mass trends in the radial velocity database

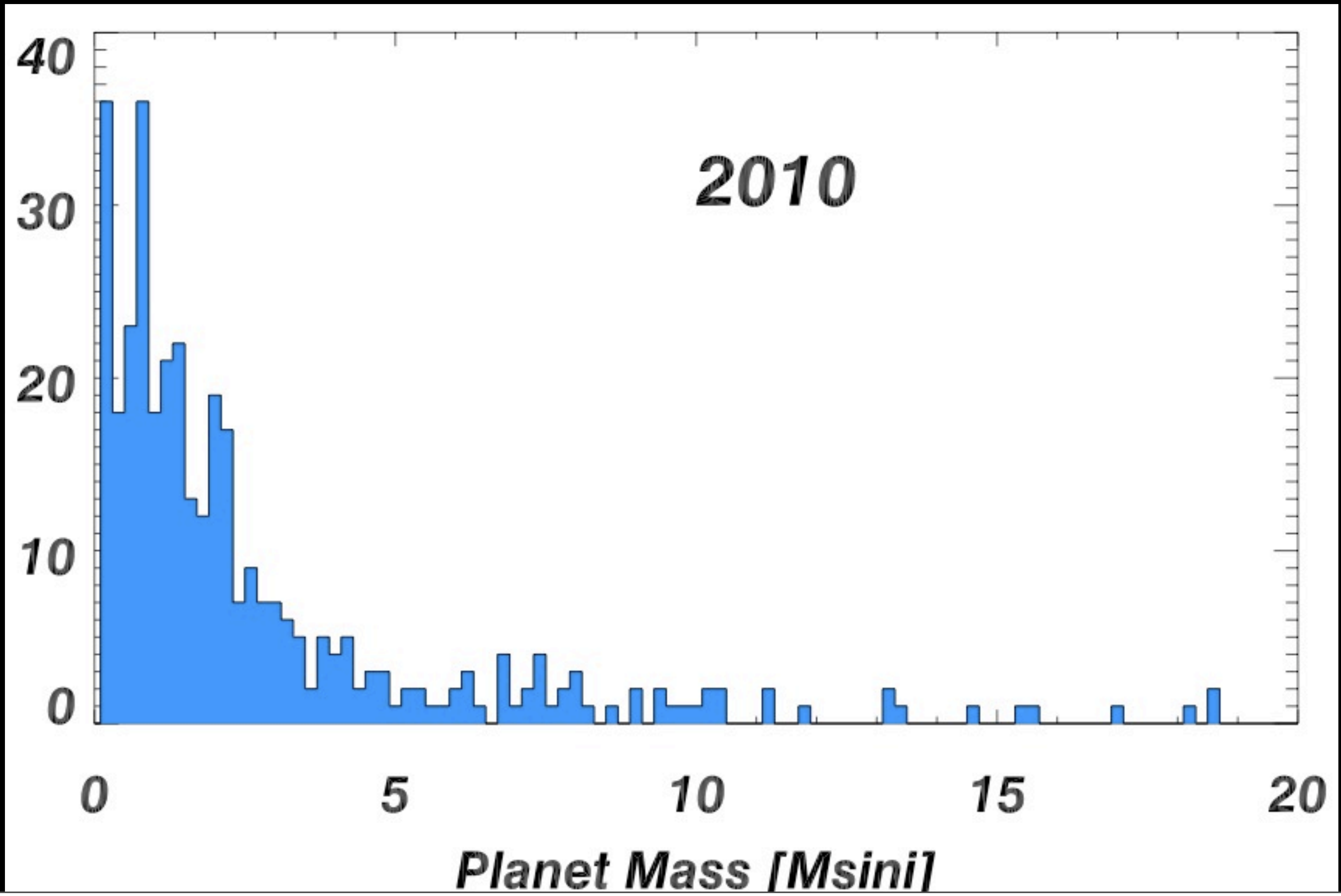
Debra Fischer

Yale UNIVERSITY

Correlations between planet occurrence and stellar properties: metallicity and mass

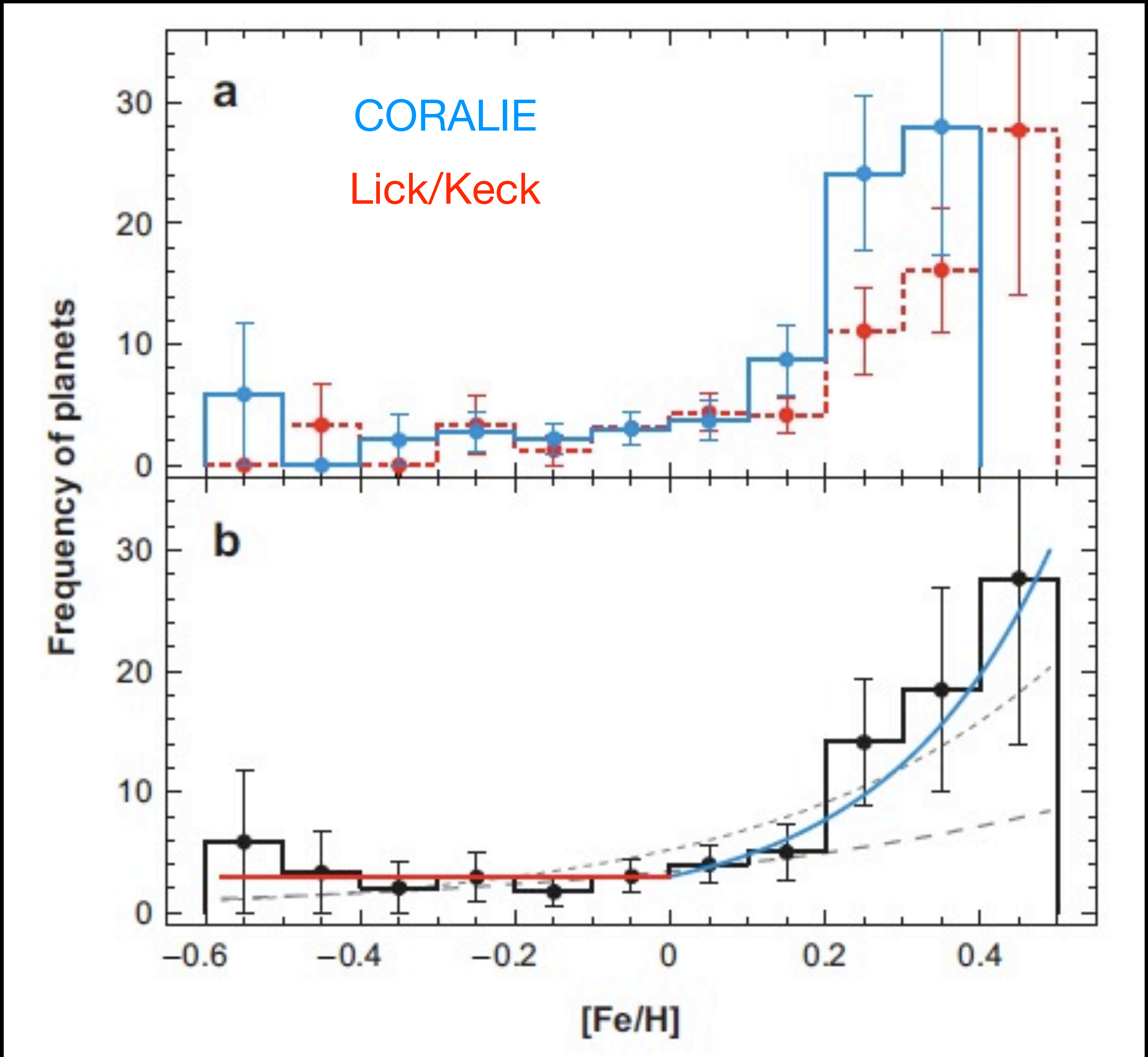


Correlations between planet occurrence and stellar properties: metallicity and mass



Udry & Santos 2007

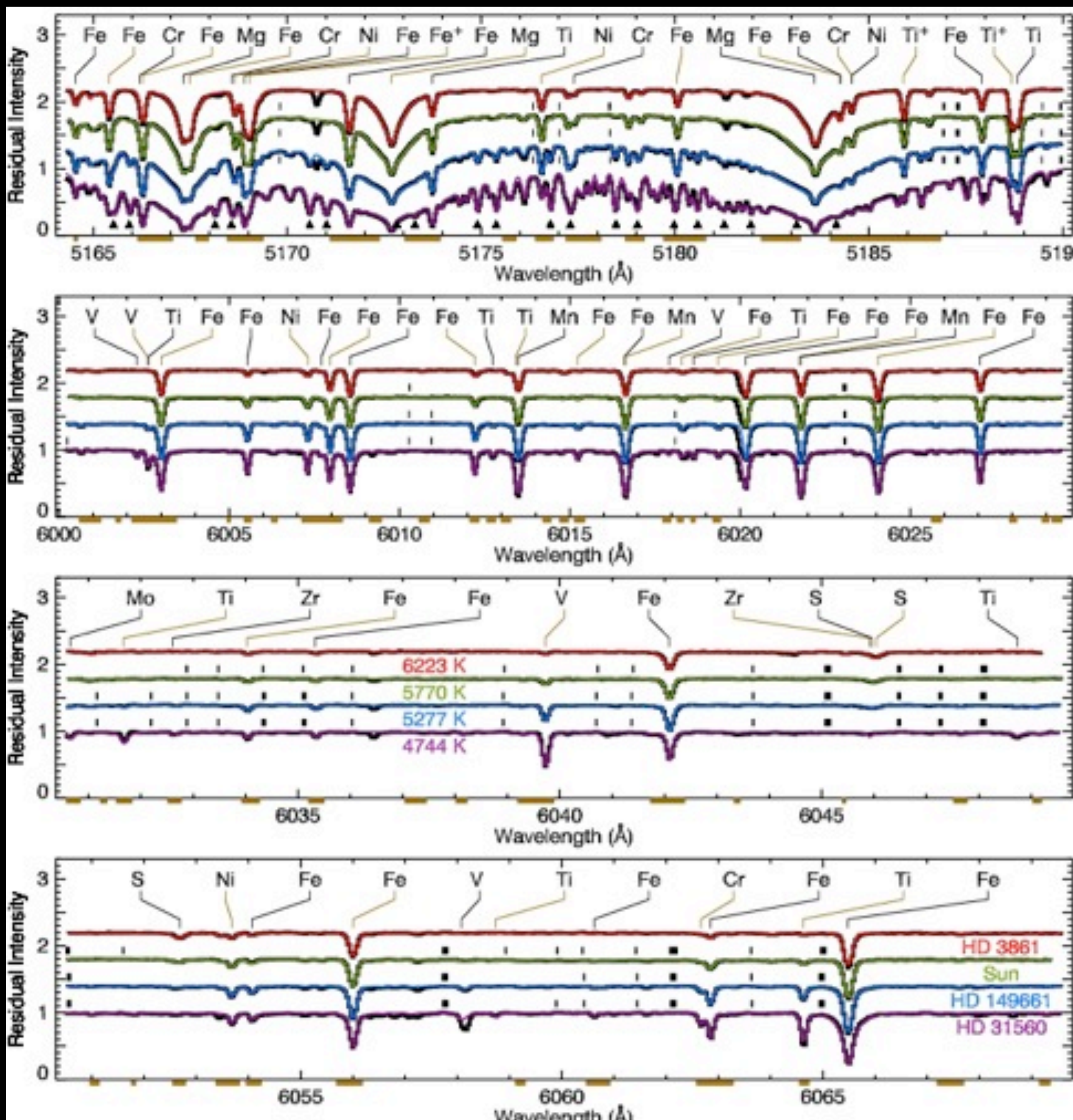
Statistical properties of Exoplanets

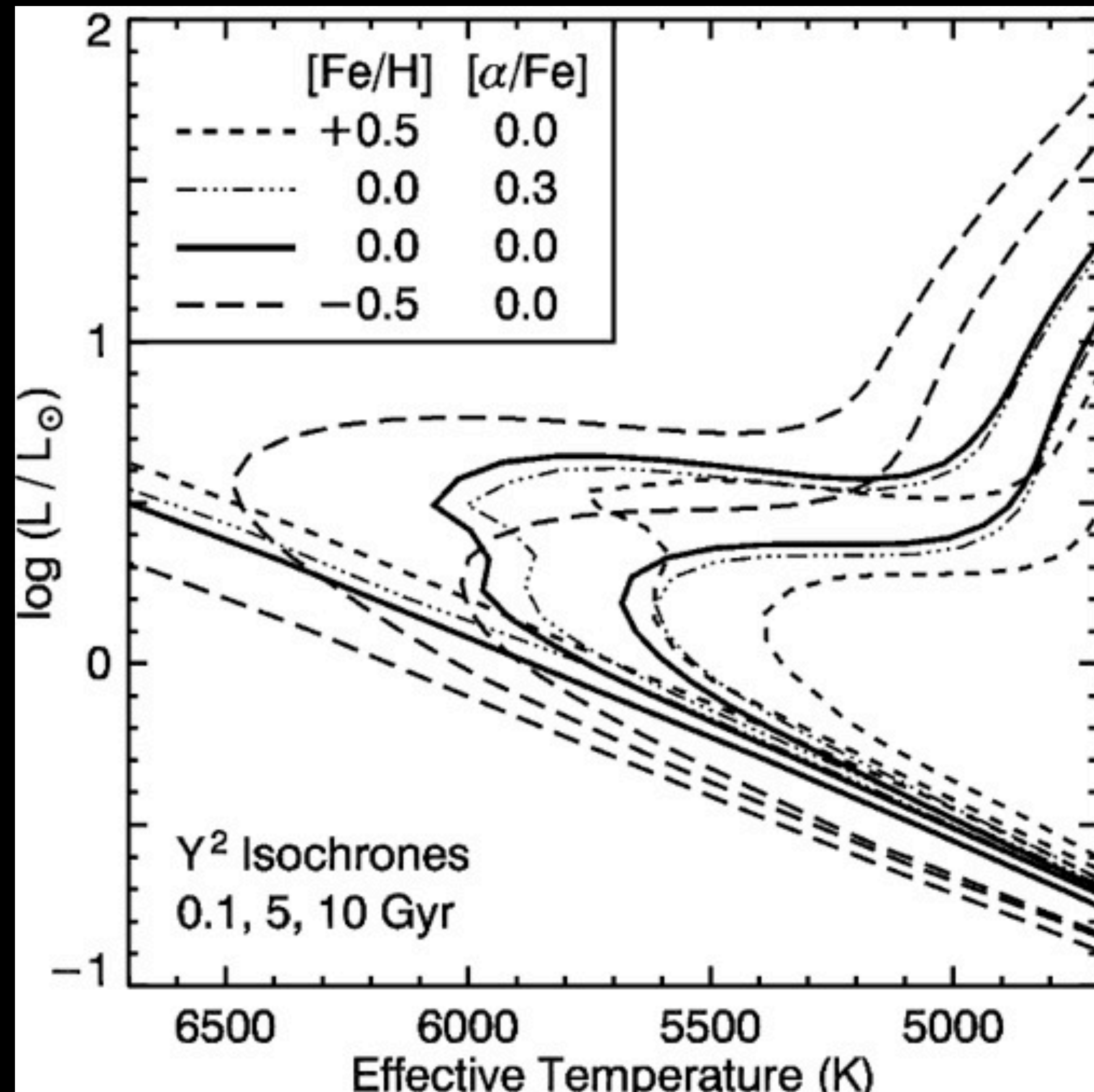


CORALIE data:
Santos, Israelian & Mayor, 2004
- 98 planet hosts and 41 star comparison sample

Lick/Keck data:
Fischer & Valenti 2005
- uniform analysis of 860 stars

SME: spectral synthesis modeling combined with YY isochrone fitting

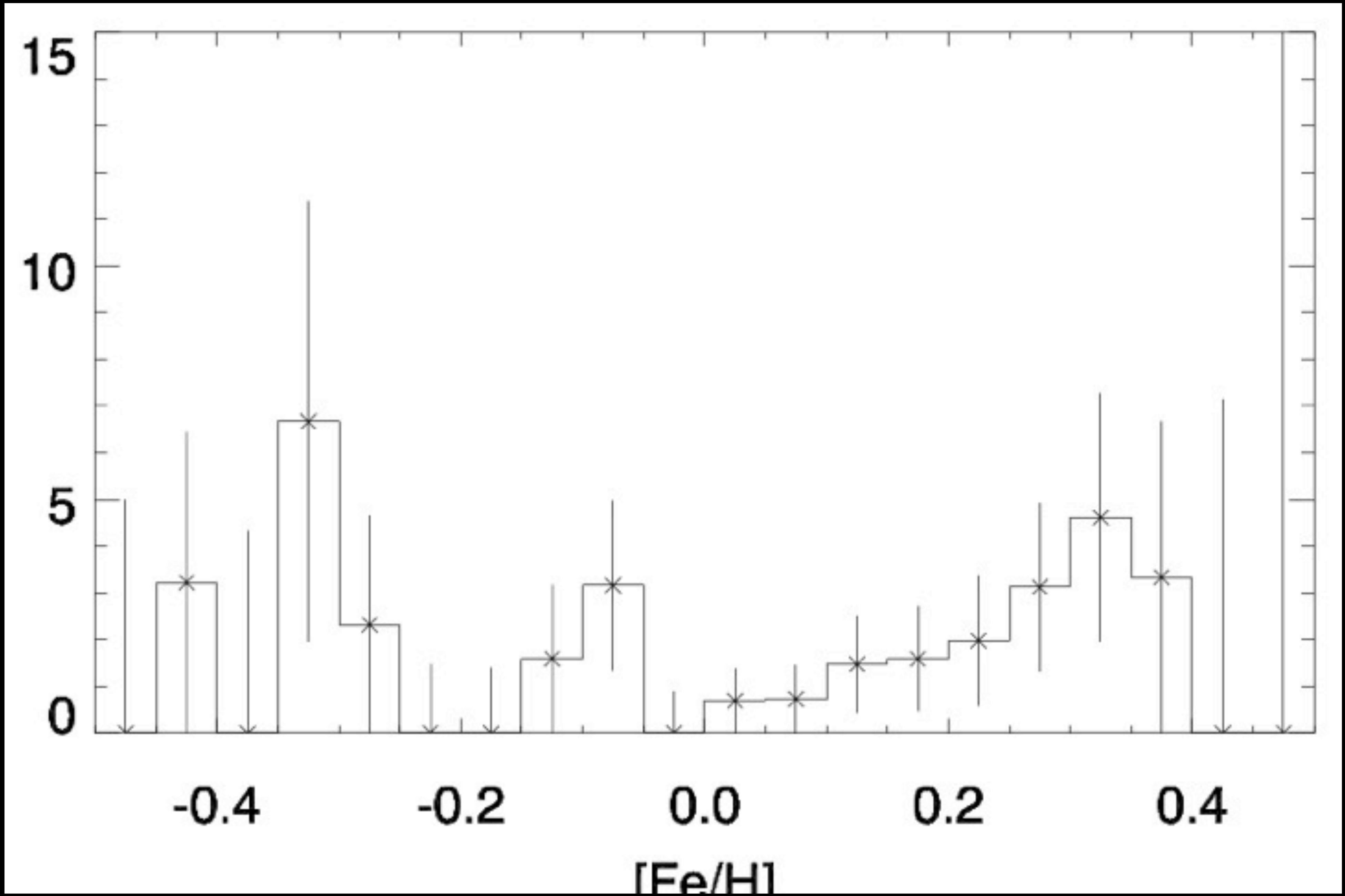




Spectral modeling:
- Teff
- vsini
- abundances
- surface gravity

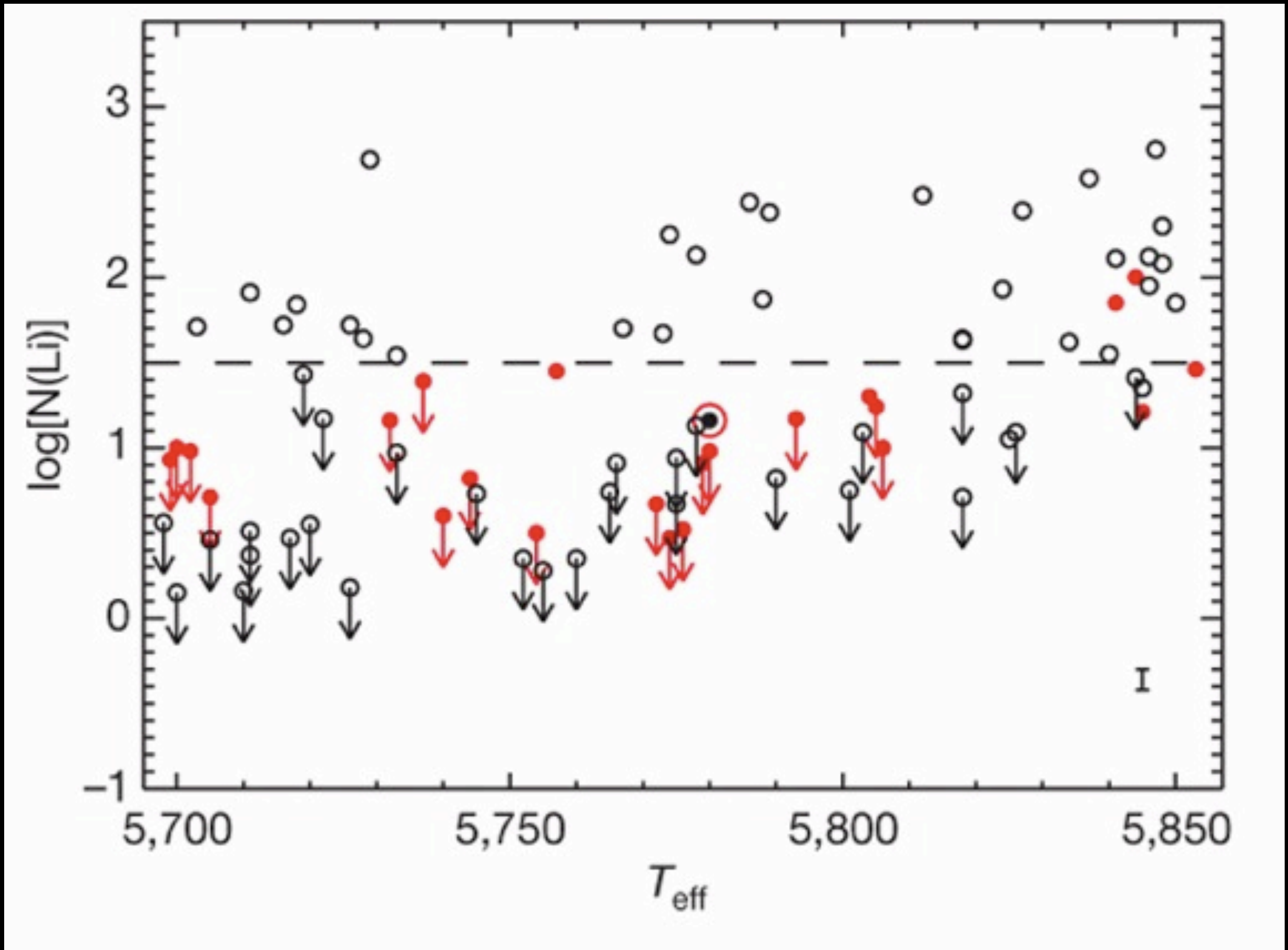
Isochrones:
- stellar masses
- luminosity
- ages
- surface gravity

[Fe/H] for stars with exoplanets Msini < 90 M$_{EARTH}$:
Small number of planets, but distribution is distinctly flatter.



Israelian et al. 2010

Enhanced lithium depletion in sunlike stars with orbiting planets. “The Sun lacks lithium because it has planets.”



Mechanism? planets induce extra mixing?

Note: based on this hypothesis, one would conclude that ~50% of stars do not have planets.

Accretion?

Lin, Bodenheimer & Richardson (1996), Gonzalez (1997/9, 2000)

Laughlin & Adams (1997), Sandquist et al. (1998)

Murray et al. (2001), Fuhrmann, Pfeiffer & Bernkopf (1997/8)

Israelian et al., 2002, Santos et al. (2000, 2003, 2004),

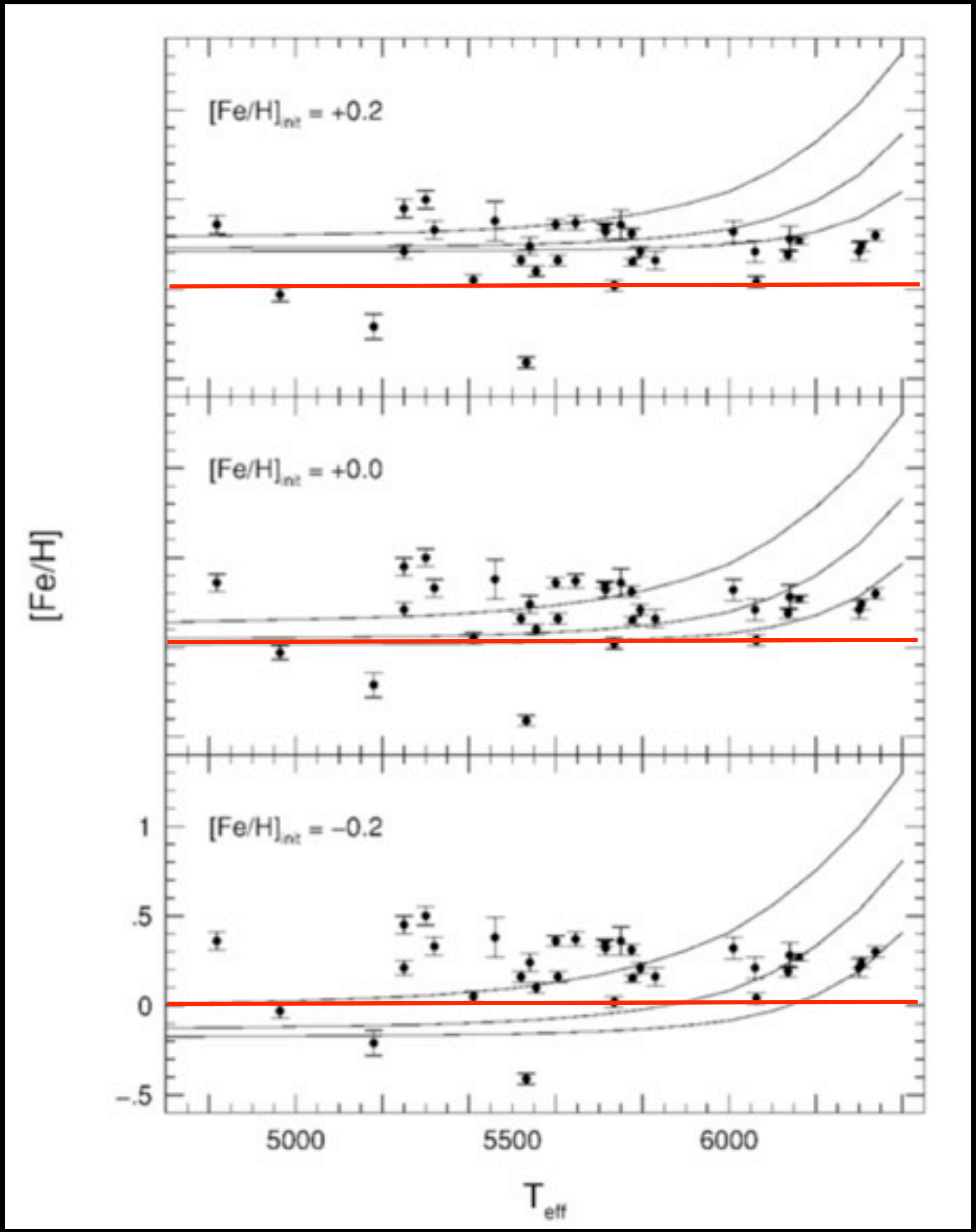
Sadakane et al. (2002), Laws et al. (2003)

Initial Conditions?

Pinsonneault, DePoy, Coffee (2001)

Pinsonneault, DePoy & Coffee 2001

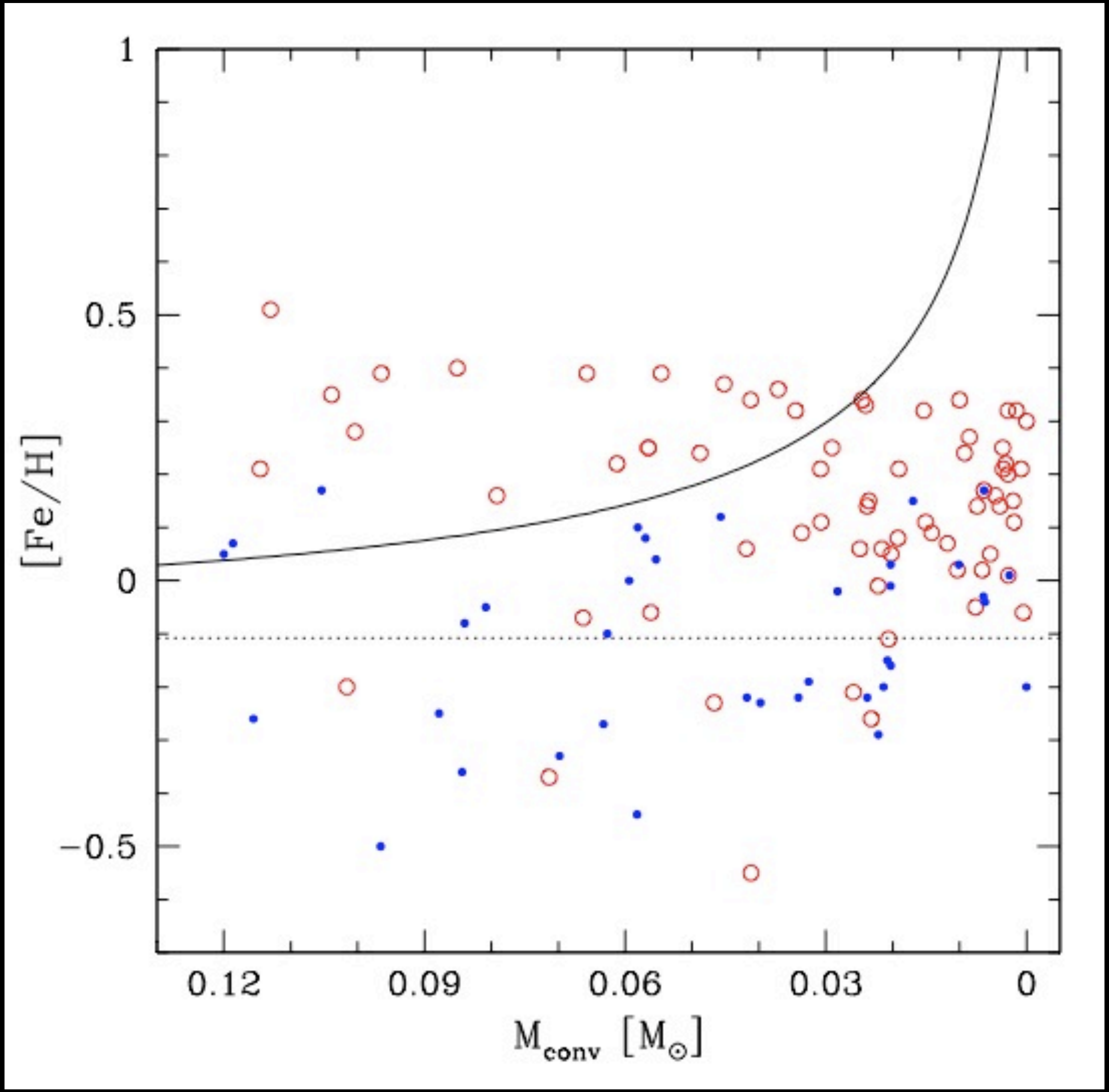
Mass of the CZ in FGK MS stars and the effect of accreted planetary material on apparent metallicity distributions



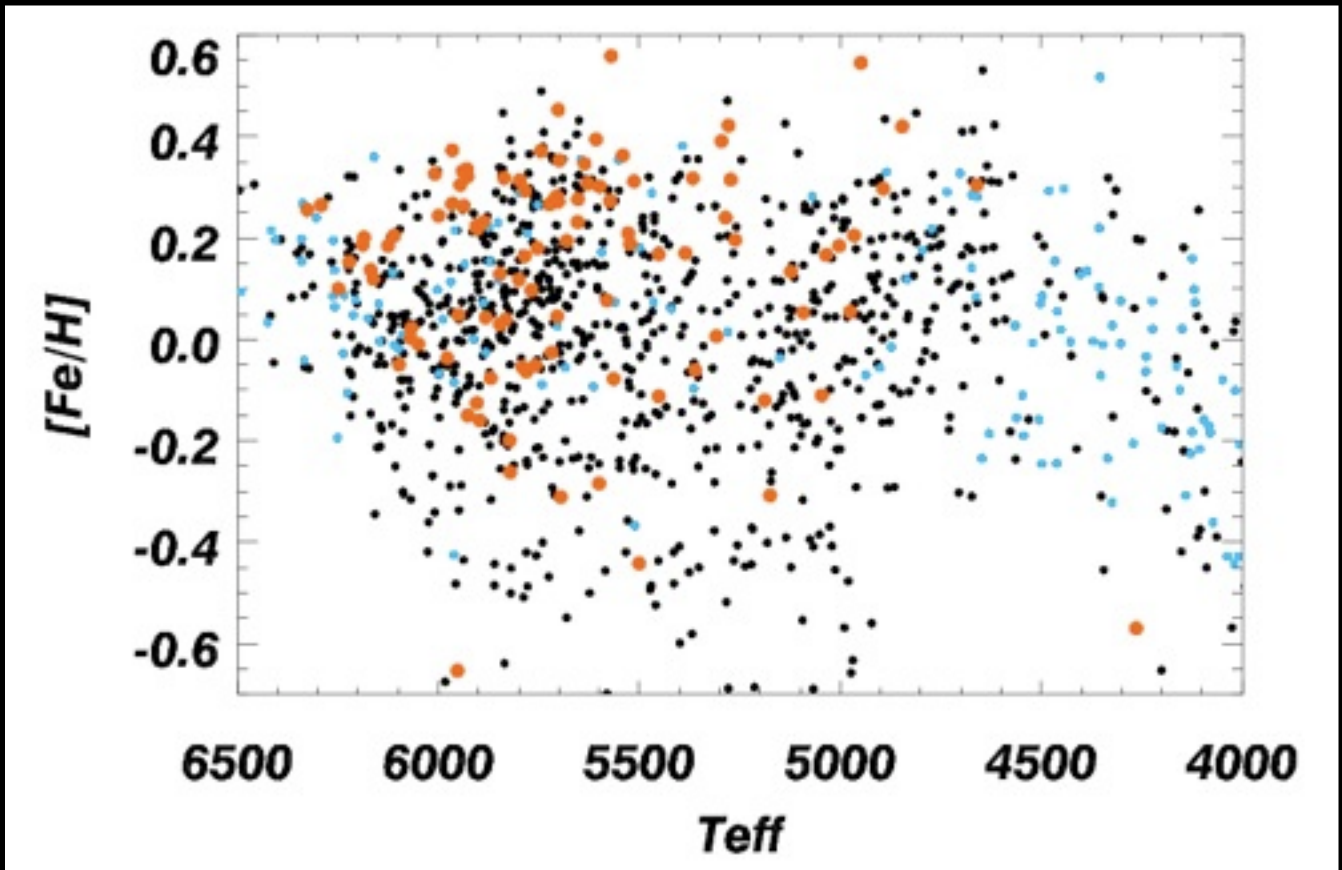
Effect of adding 1, 3, 10 M_{earth} of rocky material to stars with various initial metallicity

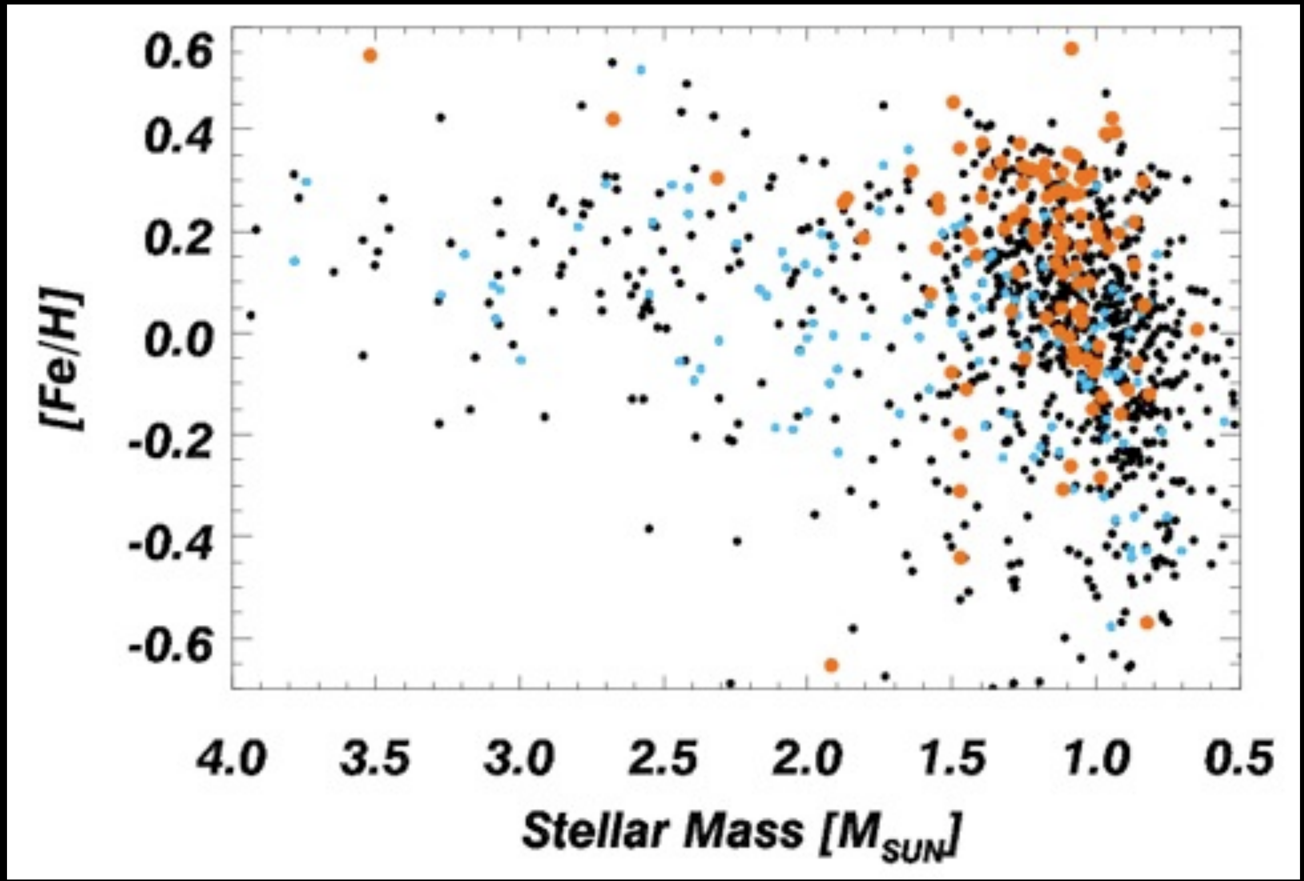
Santos, Israelian & Mayor 2001

The metal-rich nature of stars with planets



No functional dependence of [Fe/H] on Teff or stellar mass





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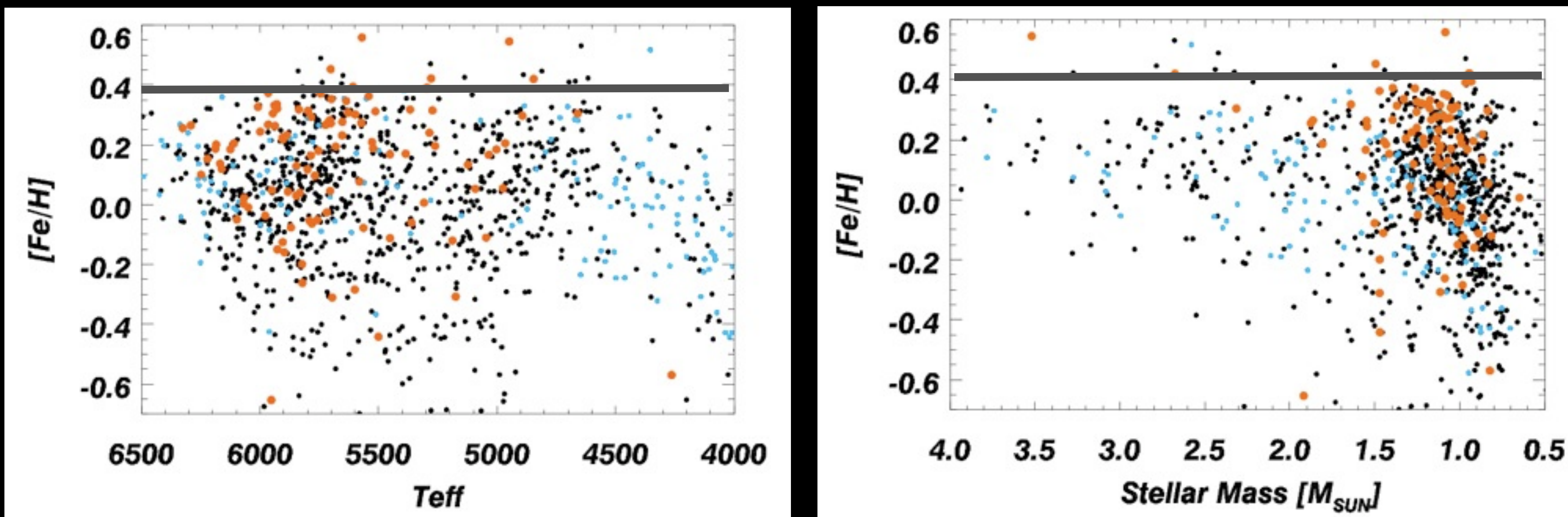
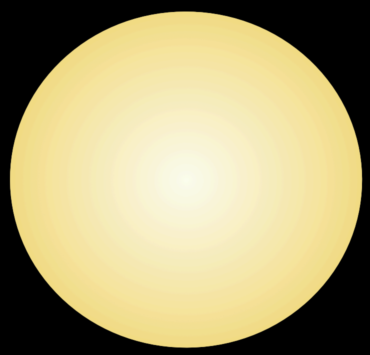


No evidence for accretion in subgiants: planet-metallicity relation observed.
As CZ mass increased, no sign of dilution.

Subgiants without planets have same metallicity distribution as MS stars without planets!

Subgiants with planets have same metallicity distribution as MS stars with planets!



No metallicity gradient across the subgiant branch

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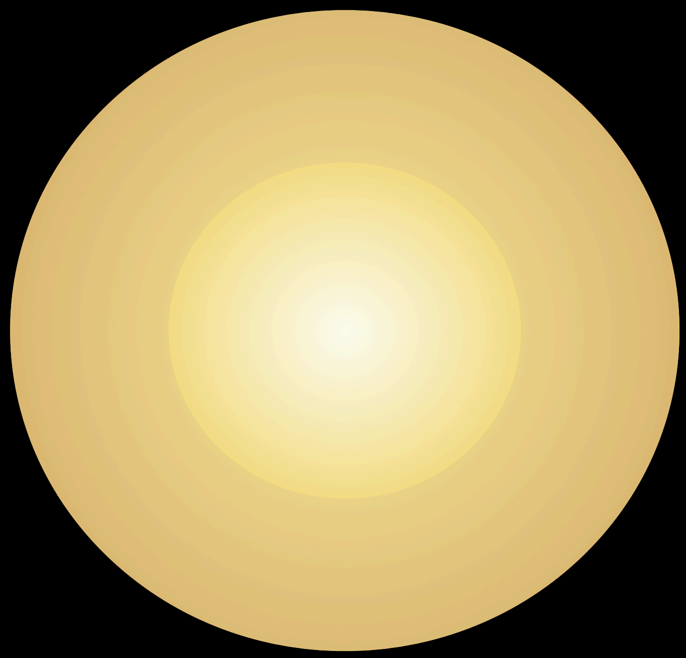

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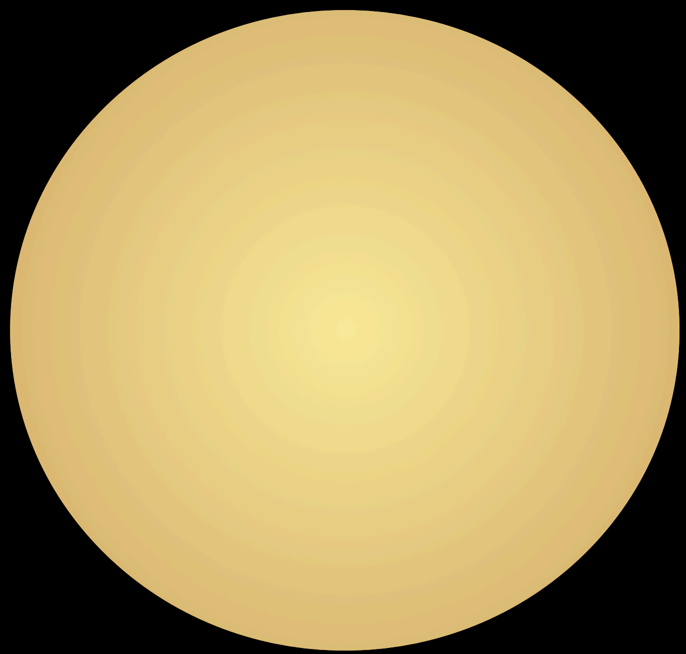
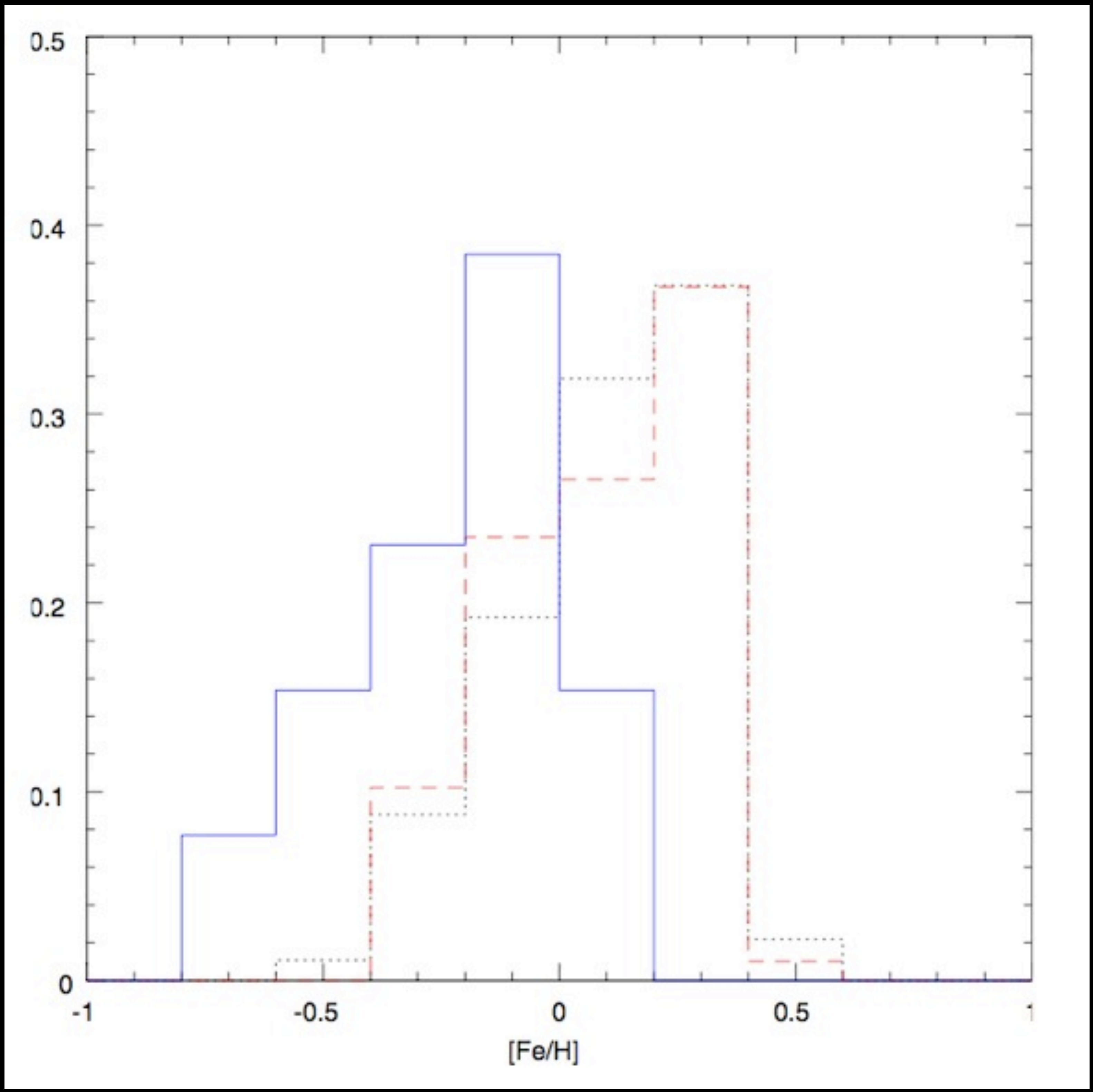


Pasquini et al. 2007

Evolved stars suggest an external origin of the enhanced metallicity in planet-hosting stars



Metallicity distribution for 14 planet-hosting giants

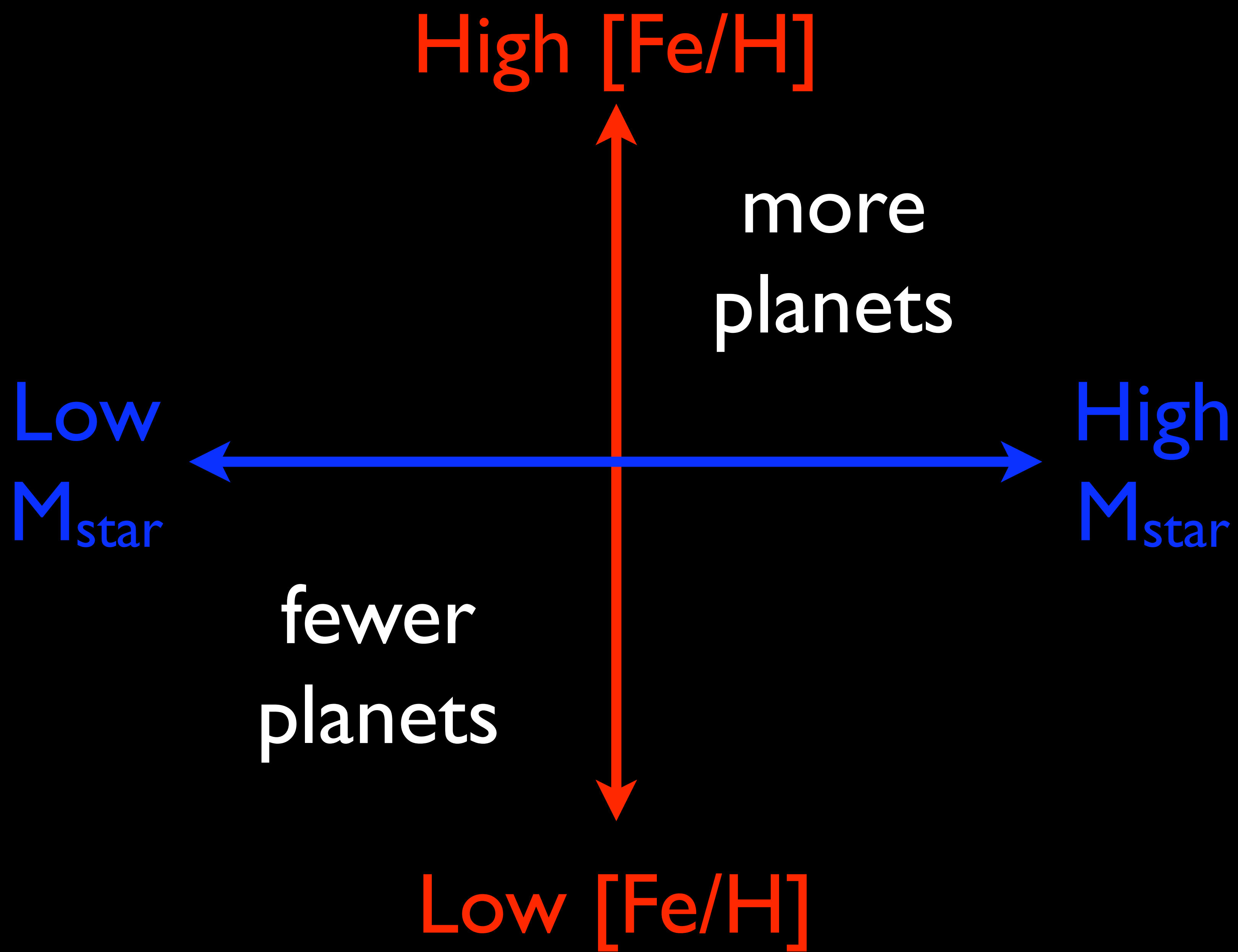
Metallicity distribution for planet-hosting dwarfs (drawn from Schneiders encyclopedia of exoplanets

Conclude: planet-metallicity correlation is caused by accretion and Giants show a shift because of CZ dilution (or ???)

Laughlin 2005

Planet formation depends on metallicity and stellar mass

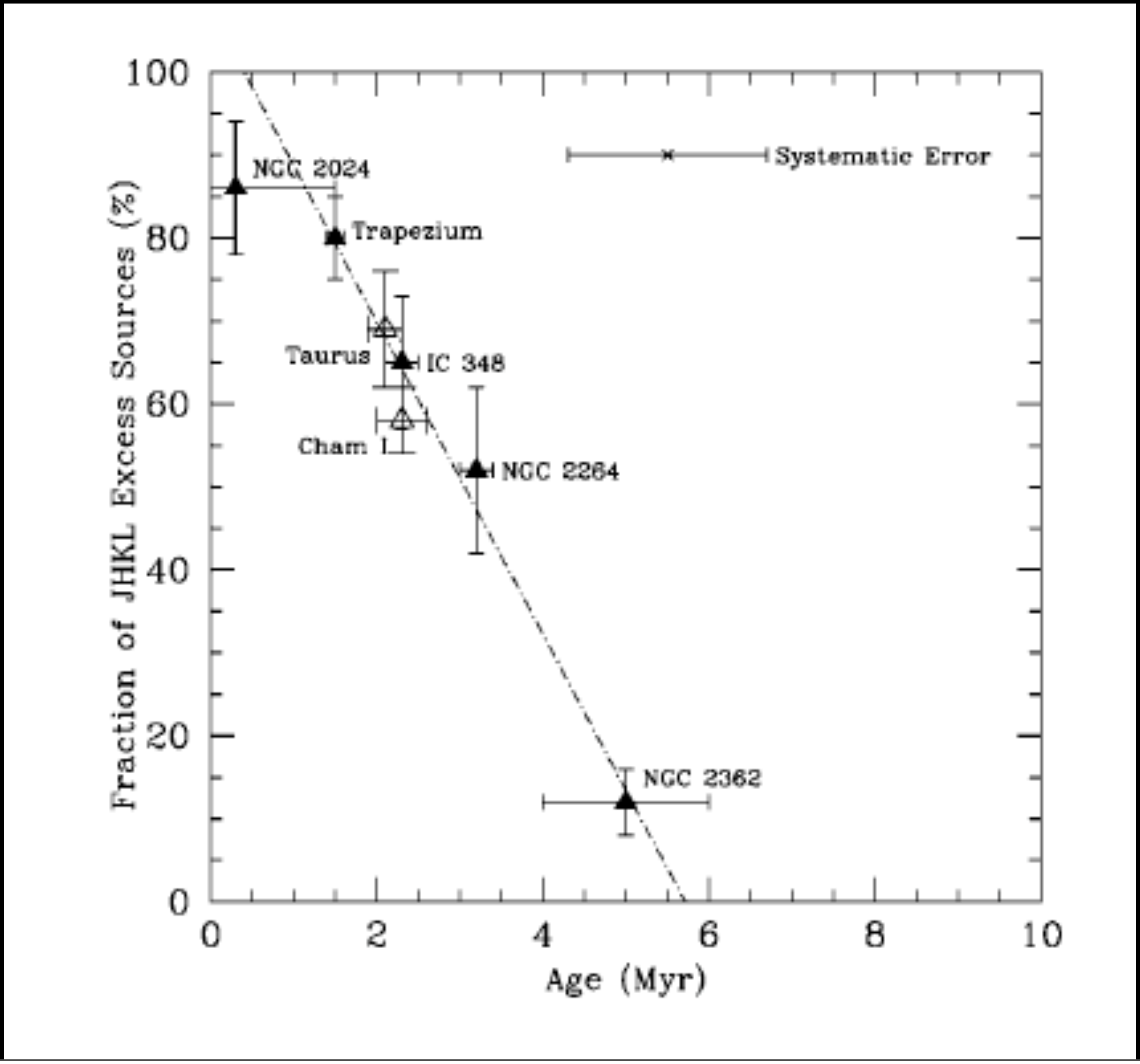
(surface density)

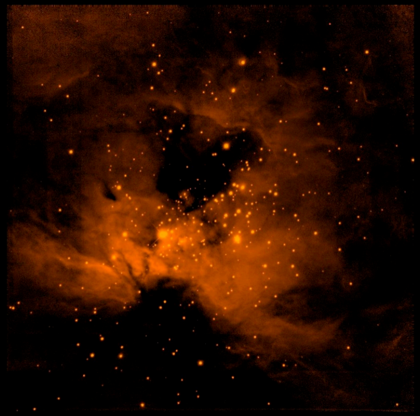


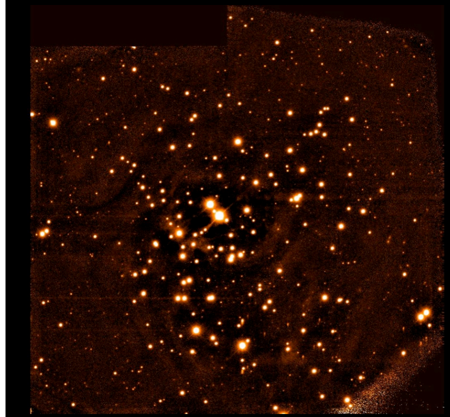
Haisch, Lada & Lada (2001)

Disk frequencies and lifetimes in Young clusters

Though data not adequate to measure disk lifetimes as function of stellar mass



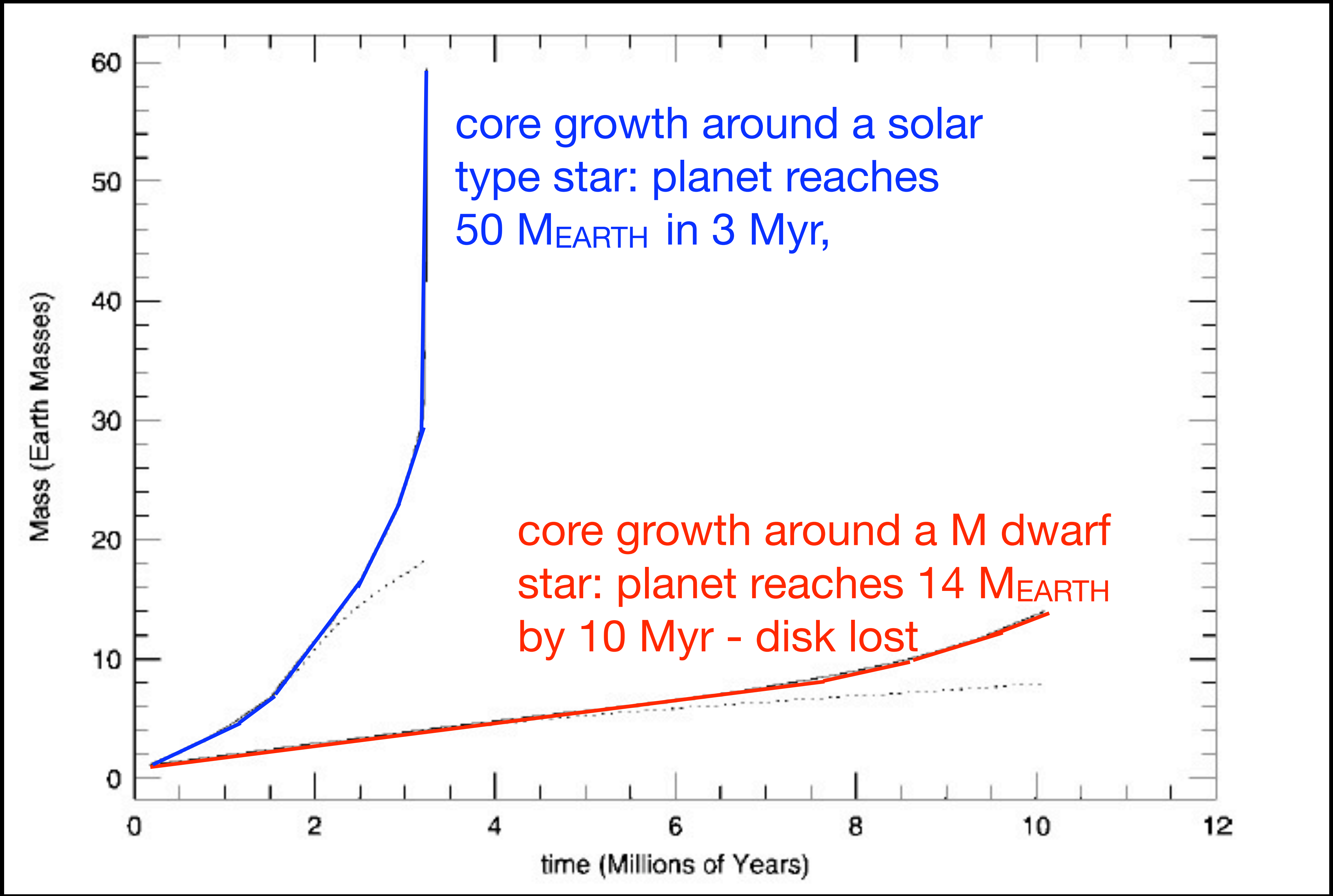




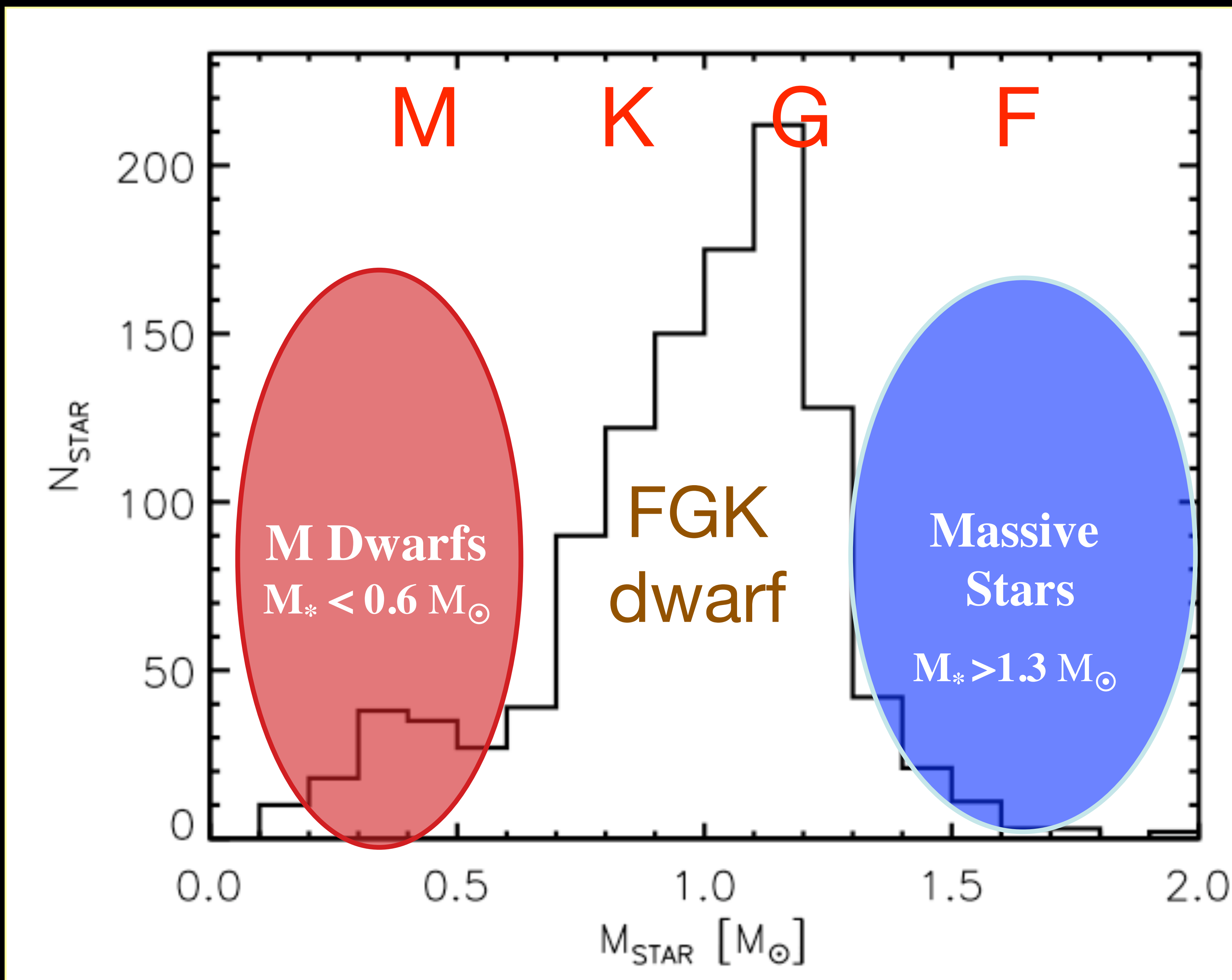
Laughlin, Bodenheimer & Adams (2004)

"Core accretion predicts few Jovian mass planets orbiting Red Dwarfs"

$$\frac{dM\_core}{dt} \quad \text{surface density} \quad \text{Keplerian frequency} \quad \text{Hill radius} \quad \text{core radius}$$



Mass distribution of CPS stars



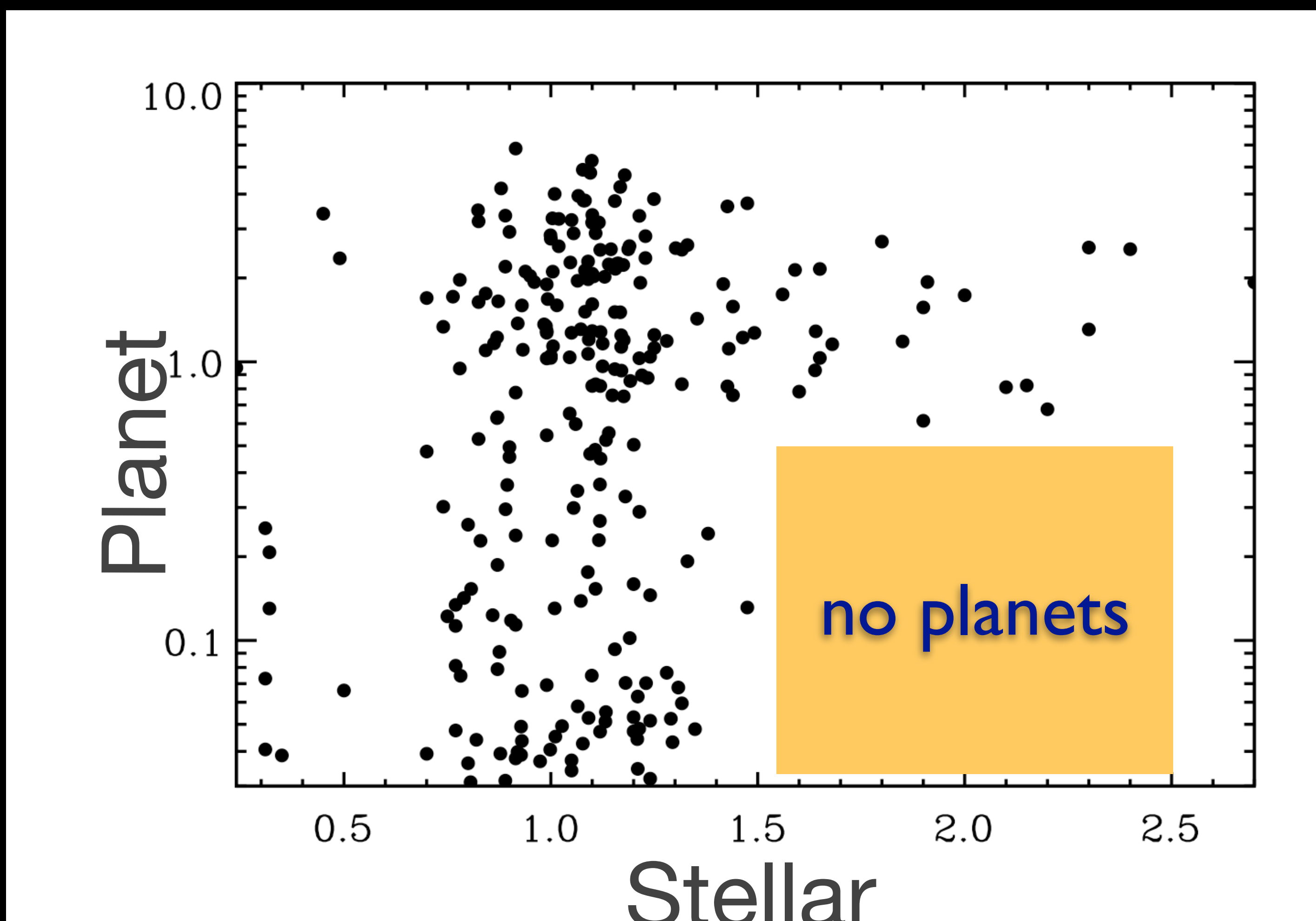
M-to-K (D. Fischer, E. Gaidos, S. Lepine)

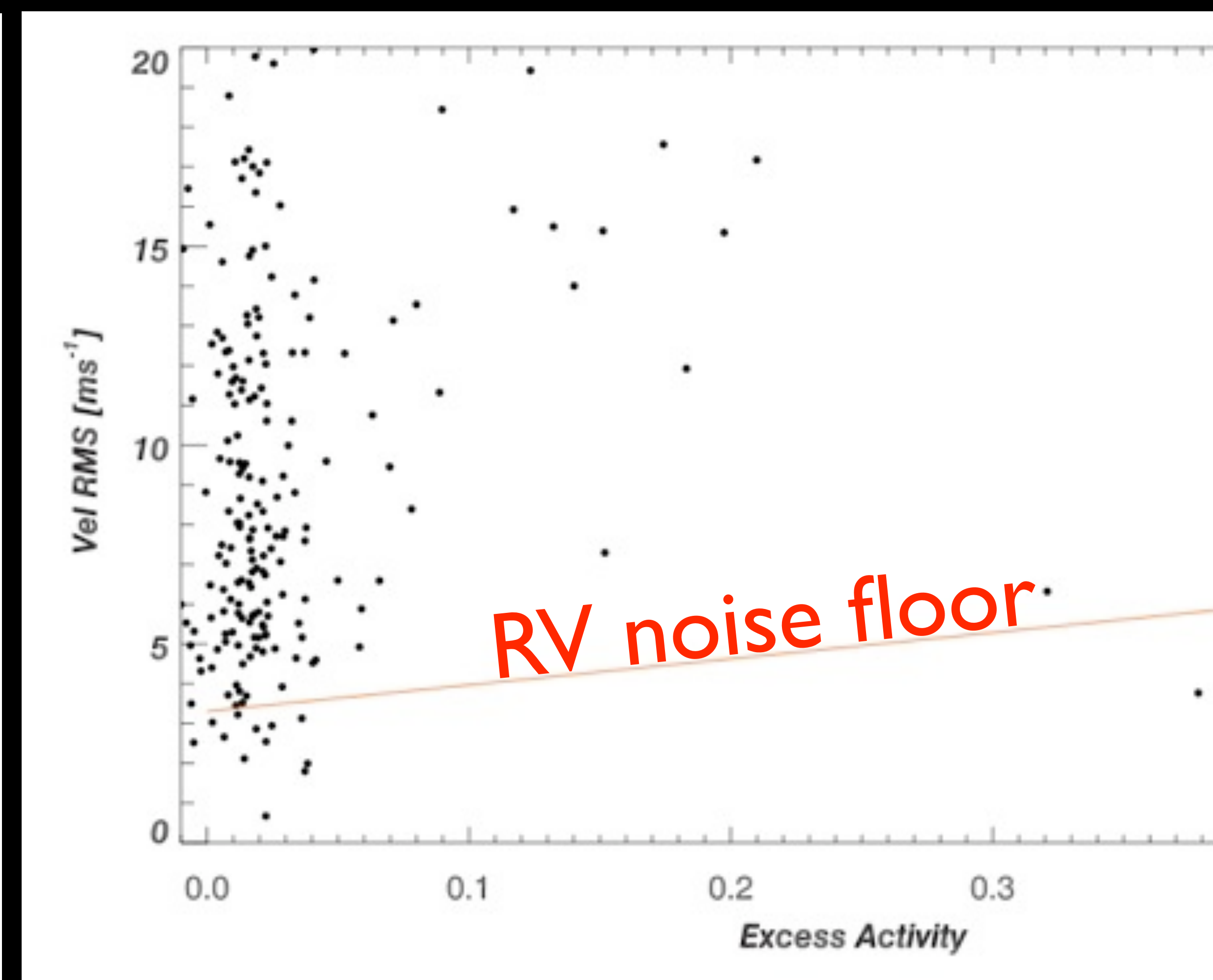
Subgiants: Retired A stars (J. Johnson)

mid-F stars: (K. Clubb, J. Spronck, D. Fischer)

K giants: (S. Reffert, A. Quirrenbach, C. Schwab)

Subgiant stars seem to have more massive planets that reside in wider orbits than MS stars.
(Not a detectability issue, Isaacson & Fischer 2010)

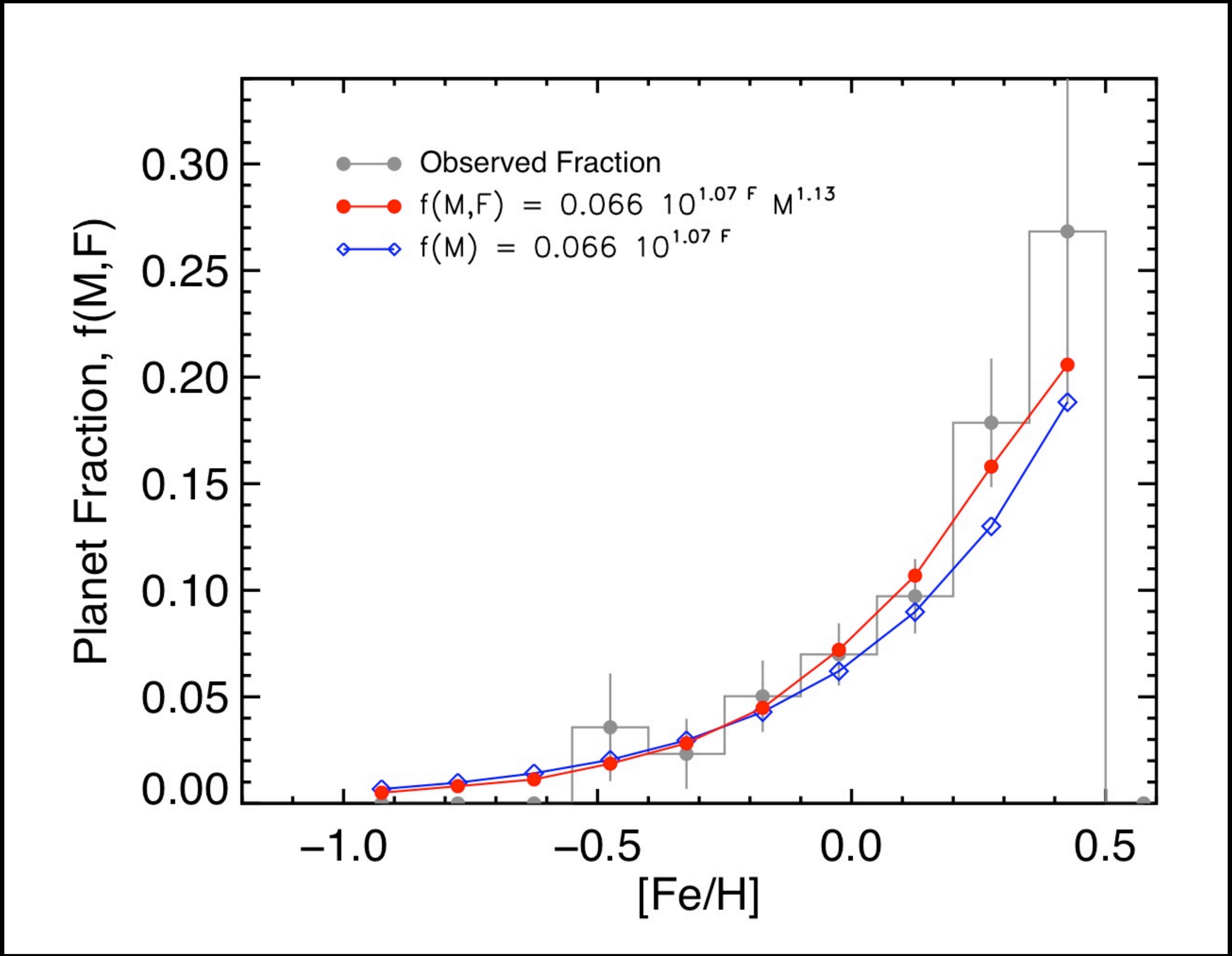




Johnson et al. 2010 (prep)

Giant planet occurrence in the stellar mass-metallicity plane

assumes stellar mass and metallicity are independent parameters



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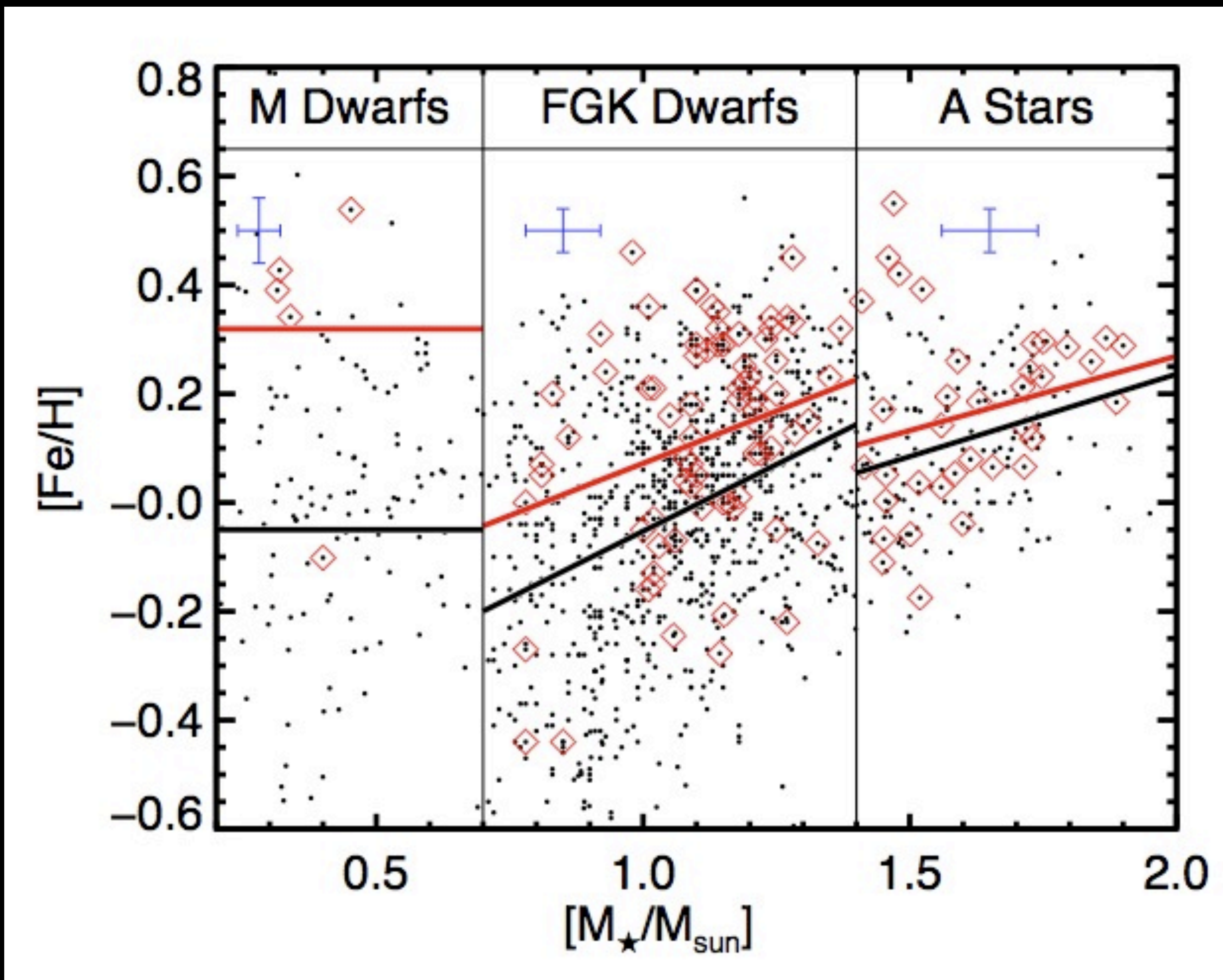

Johnson et al. 2010 (prep)

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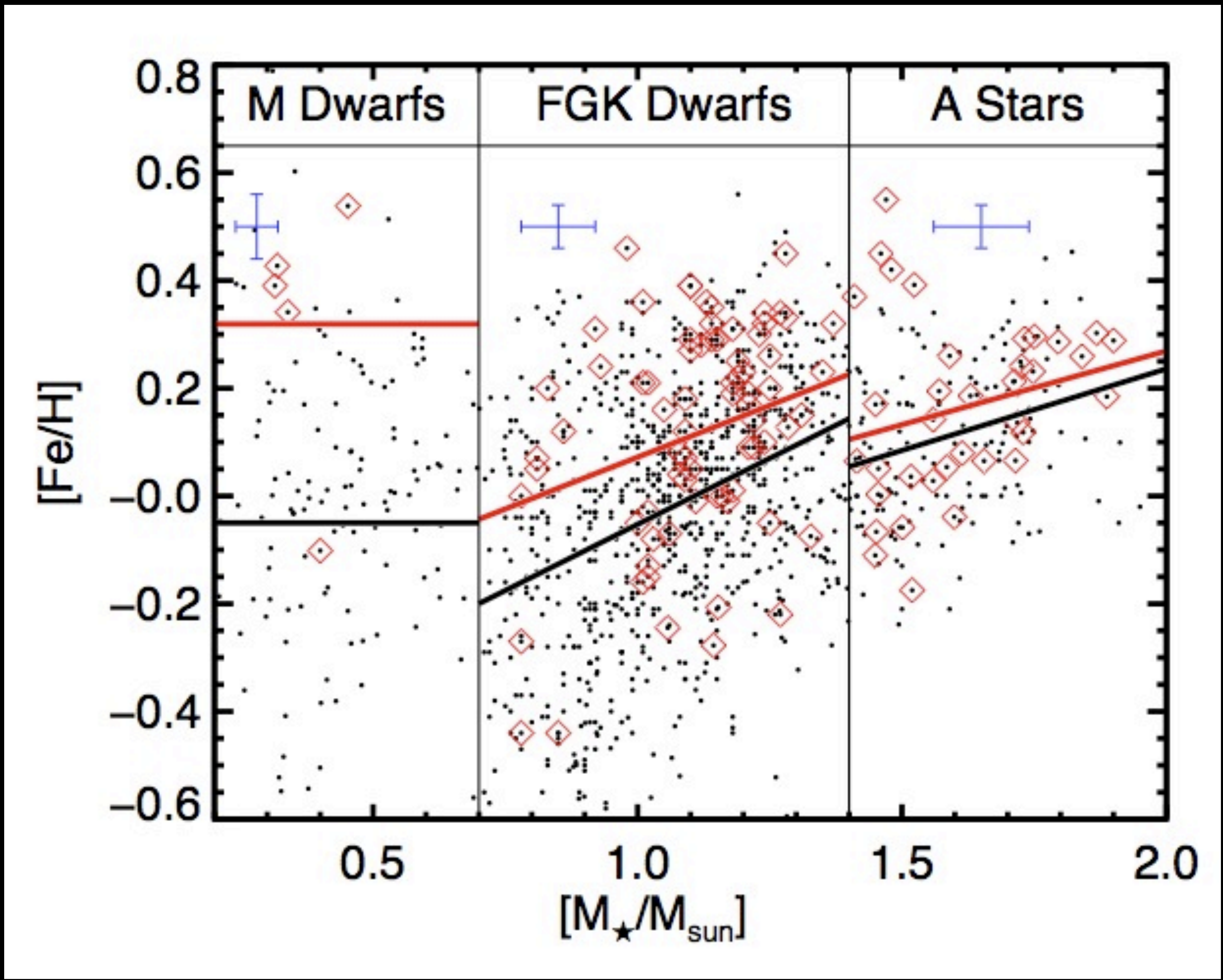

1. Planet-metallicity correlation still holds.

Johnson et al. 2010 (prep)

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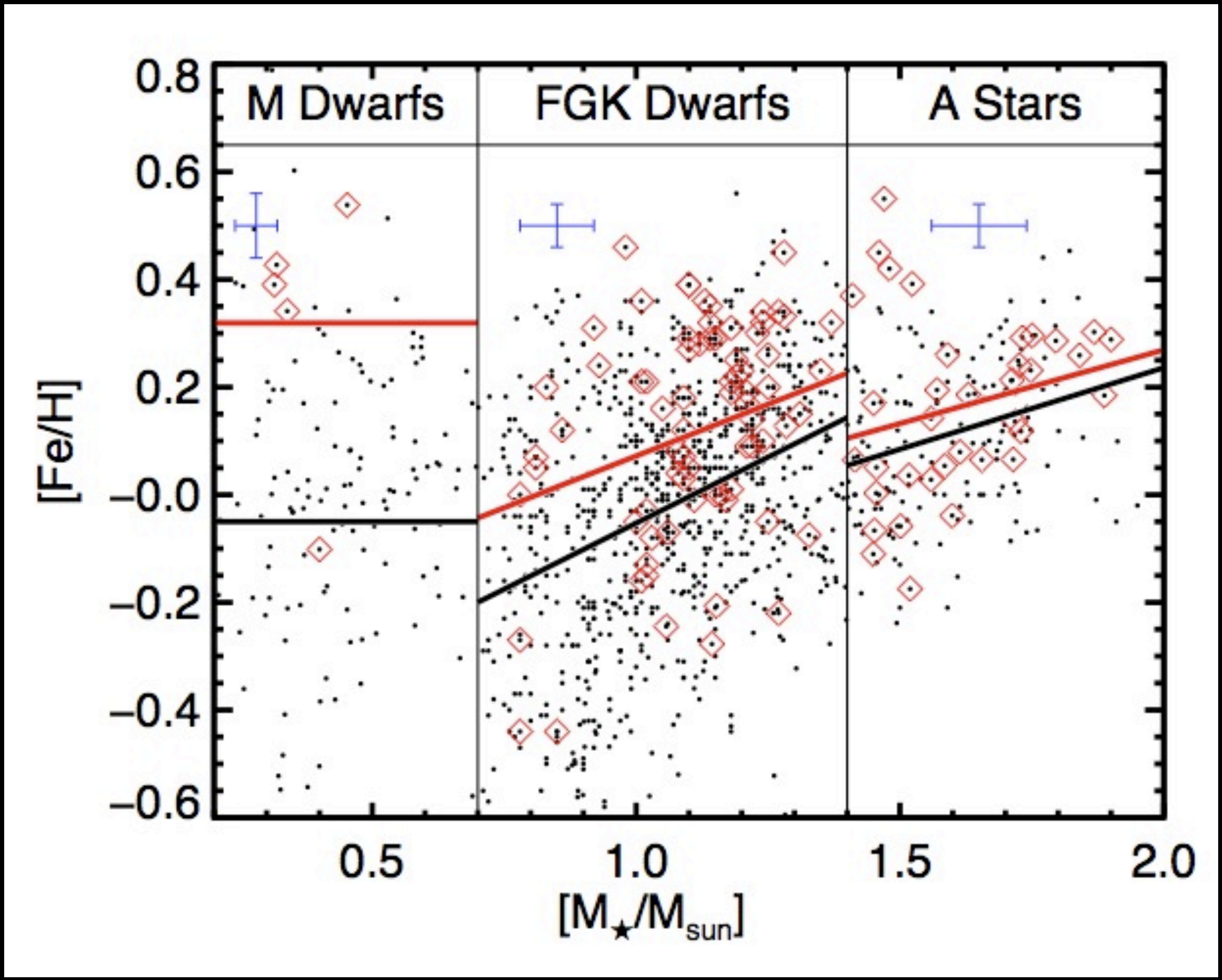
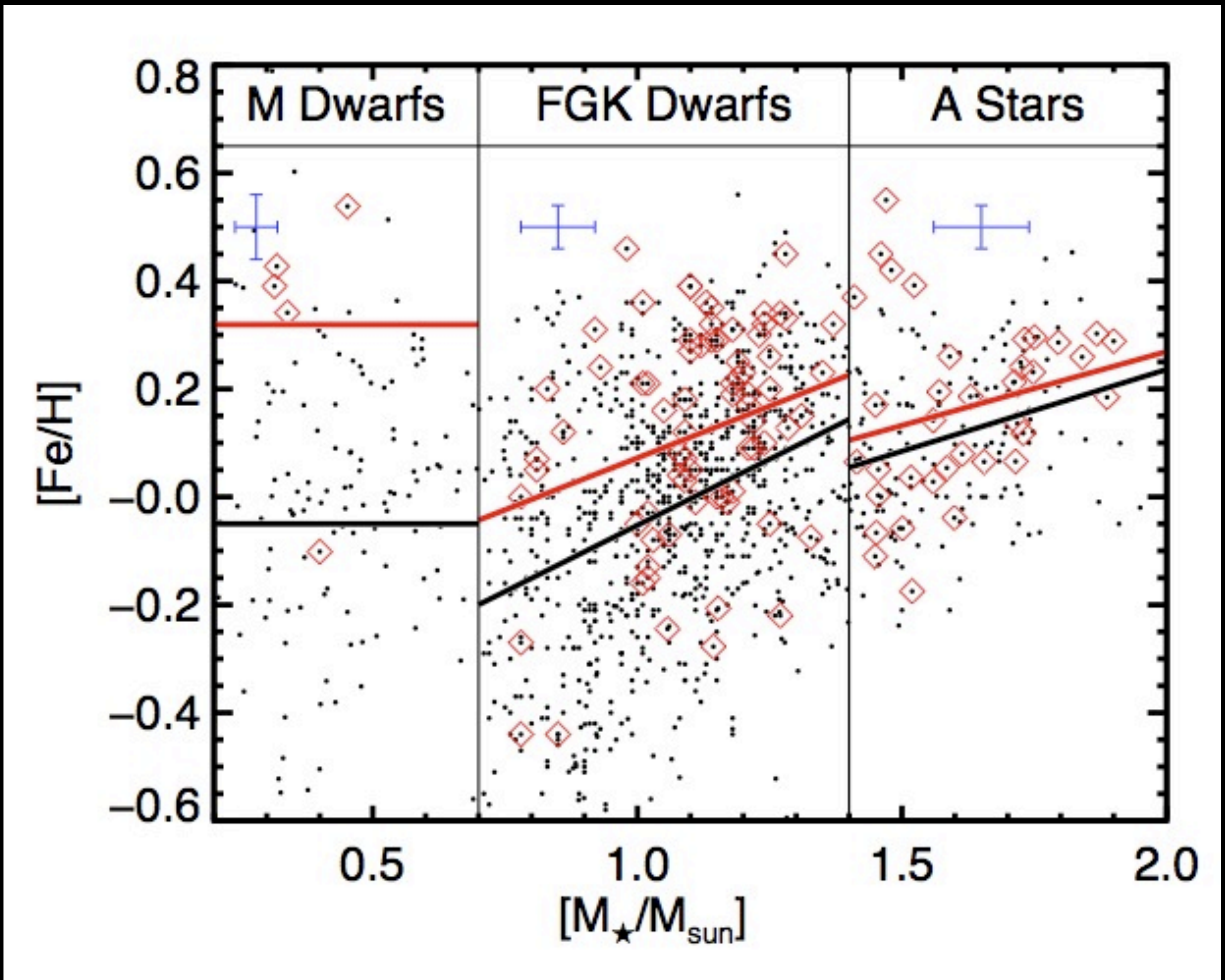


1. Planet-metallicity correlation still holds.

2. Mdwarfs need metals to compensate for low stellar mass; only 4% of Mdwarfs have planets, while 20% of retired A stars have planets, not just CZ pollution!

Johnson et al. 2010 (prep)

Giant planet occurrence in the stellar mass-metallicity plane



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3. The gap between the metallicity for planet hosts relative to non-detections closes as stellar mass increases.

Johnson et al. 2010 (prep)

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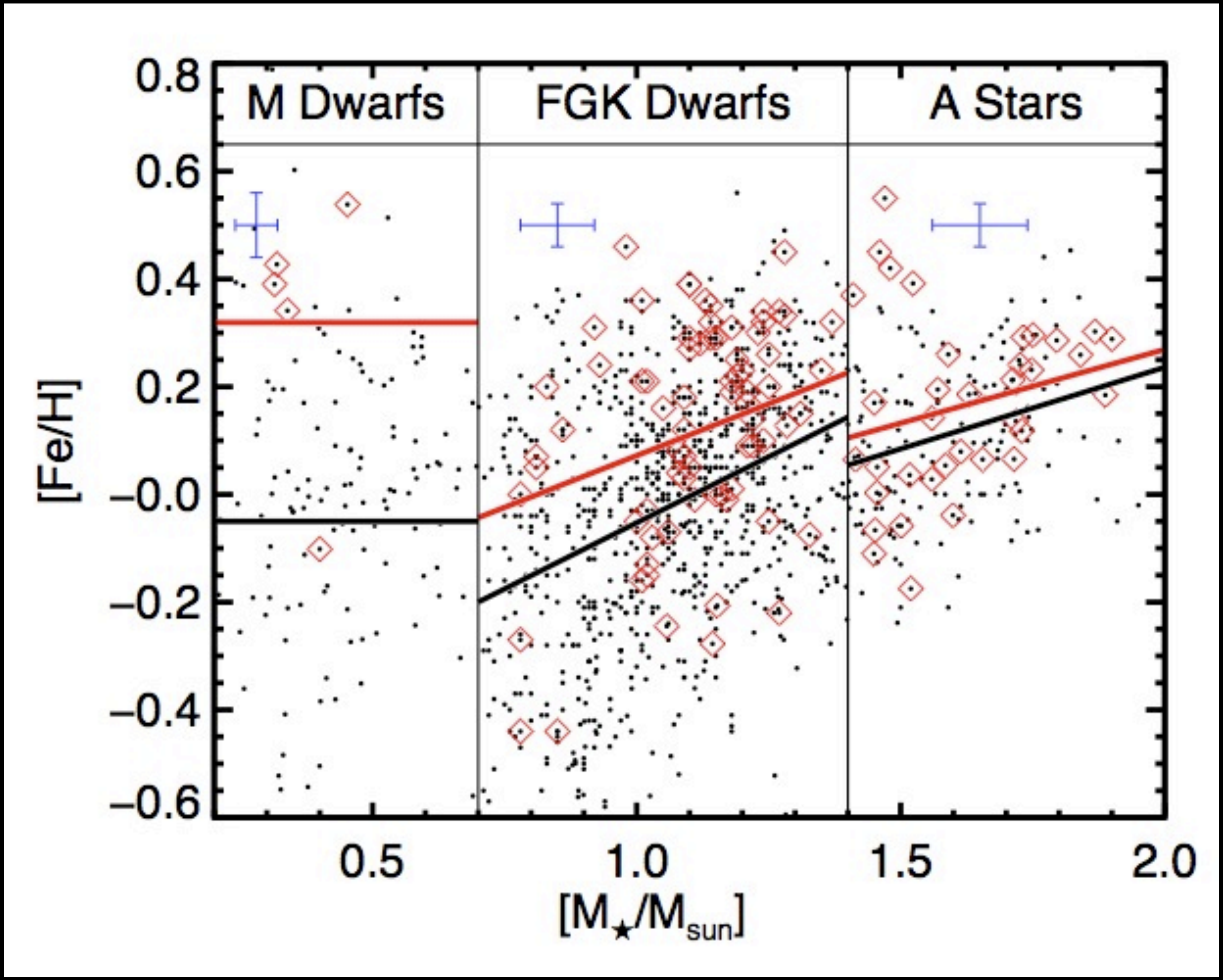

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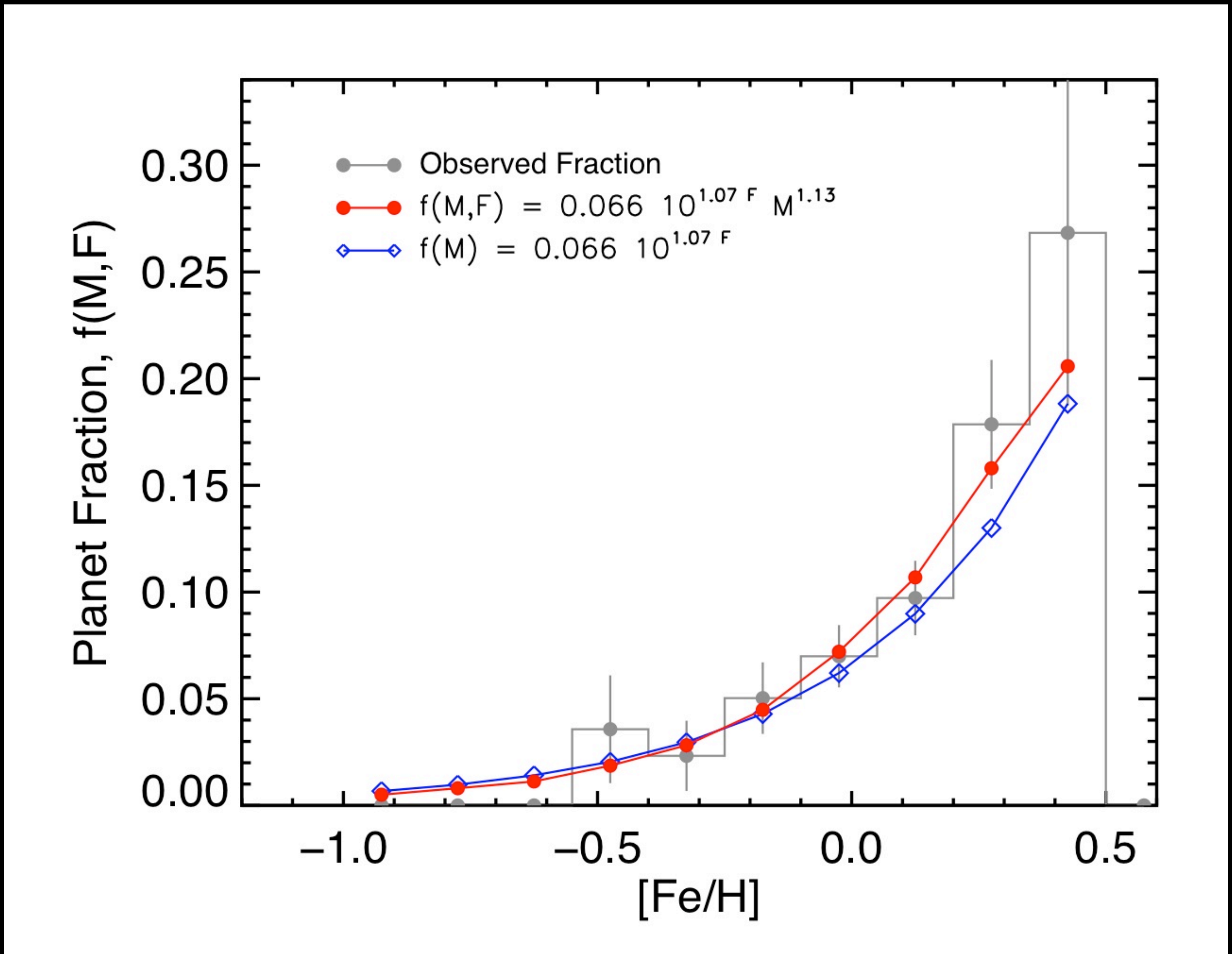
4. Stellar mass and metallicity are correlated

Johnson et al. 2010 (prep)

Giant planet occurrence in the stellar mass-metallicity plane

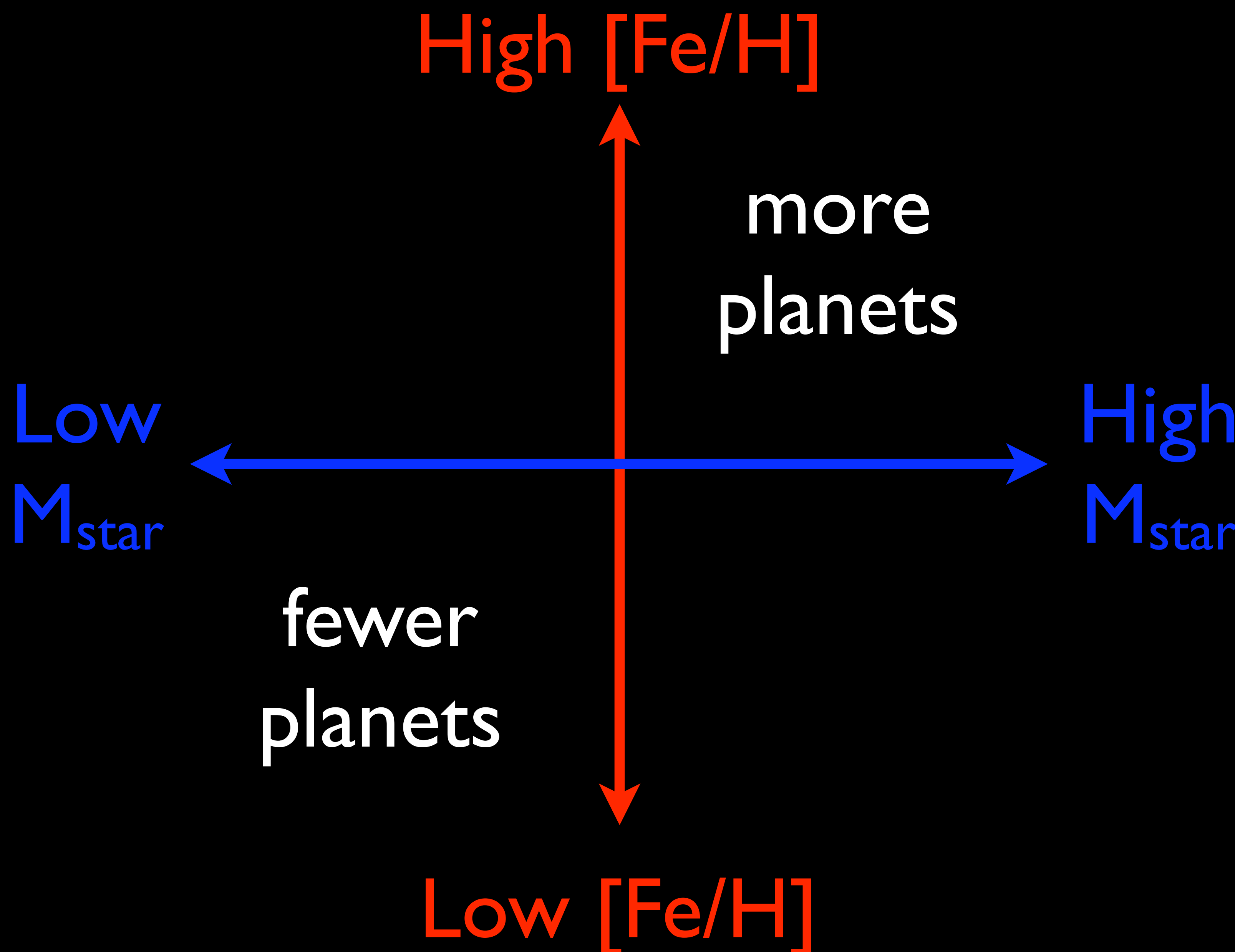


Stellar mass and metallicity may not be independent parameters.

A threshold number of metal atoms or surface density may be the key.

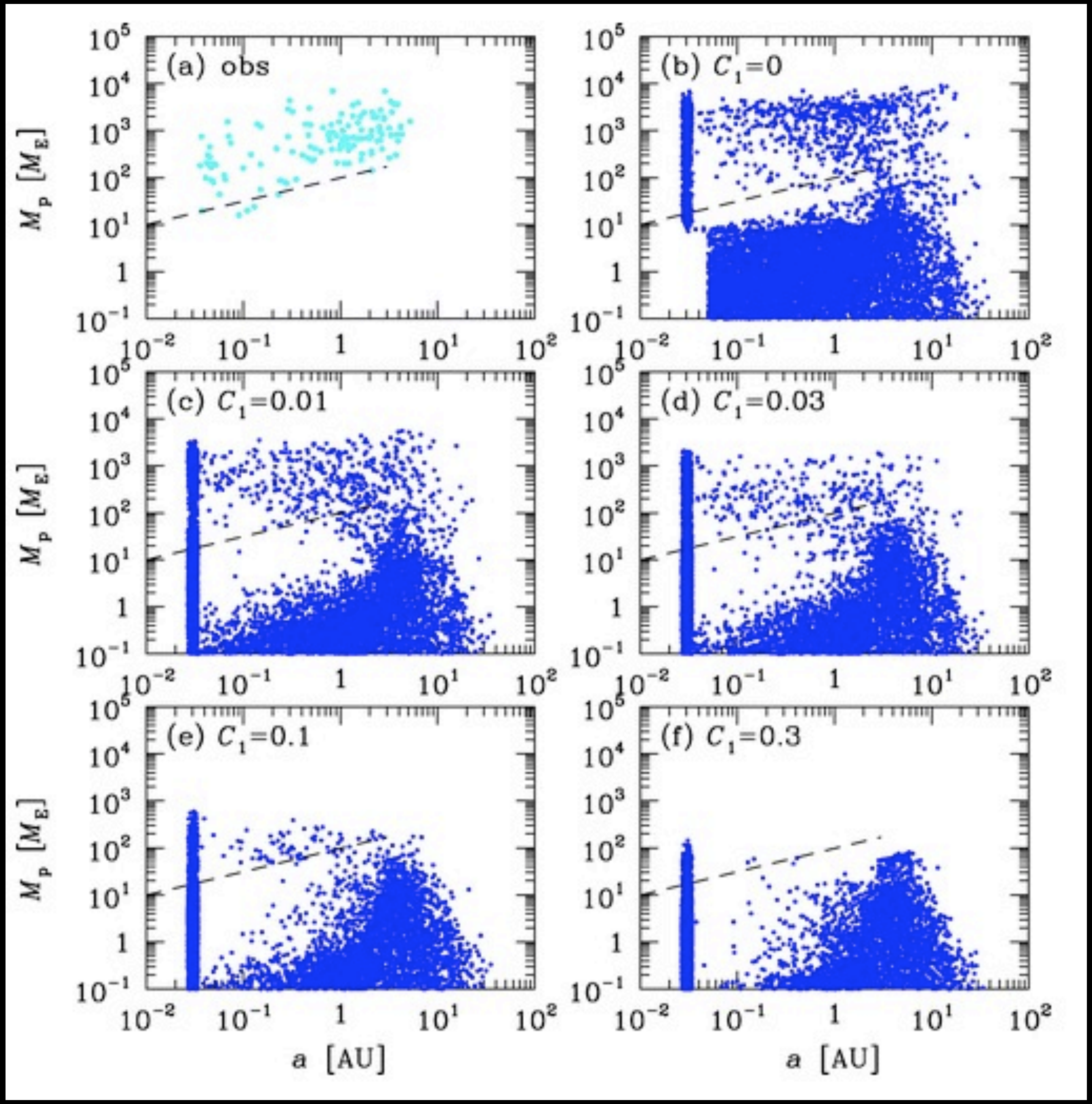
Laughlin 2005

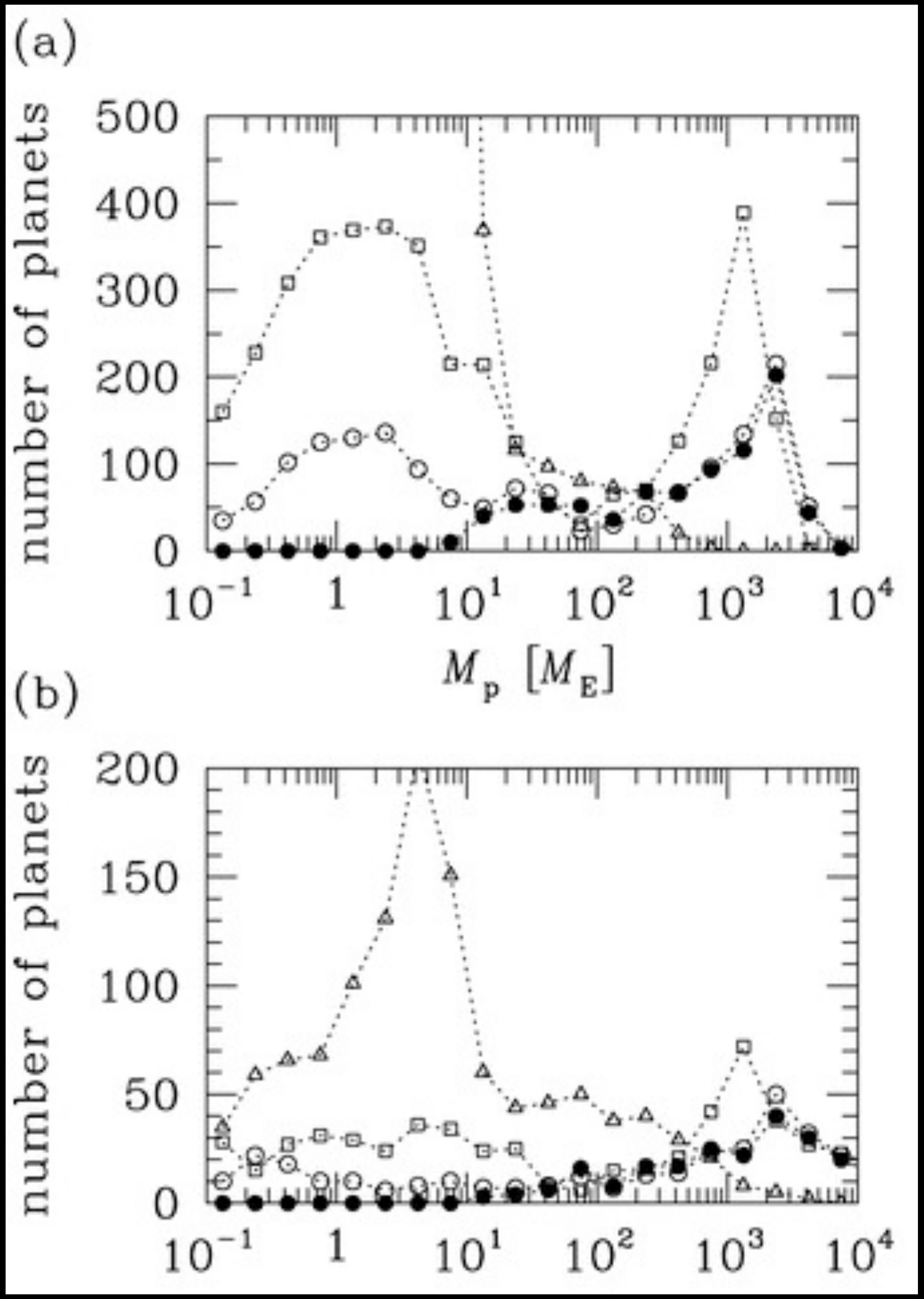
Planet formation depends on metallicity and stellar mass
(surface density)



Ida & Lin 2008

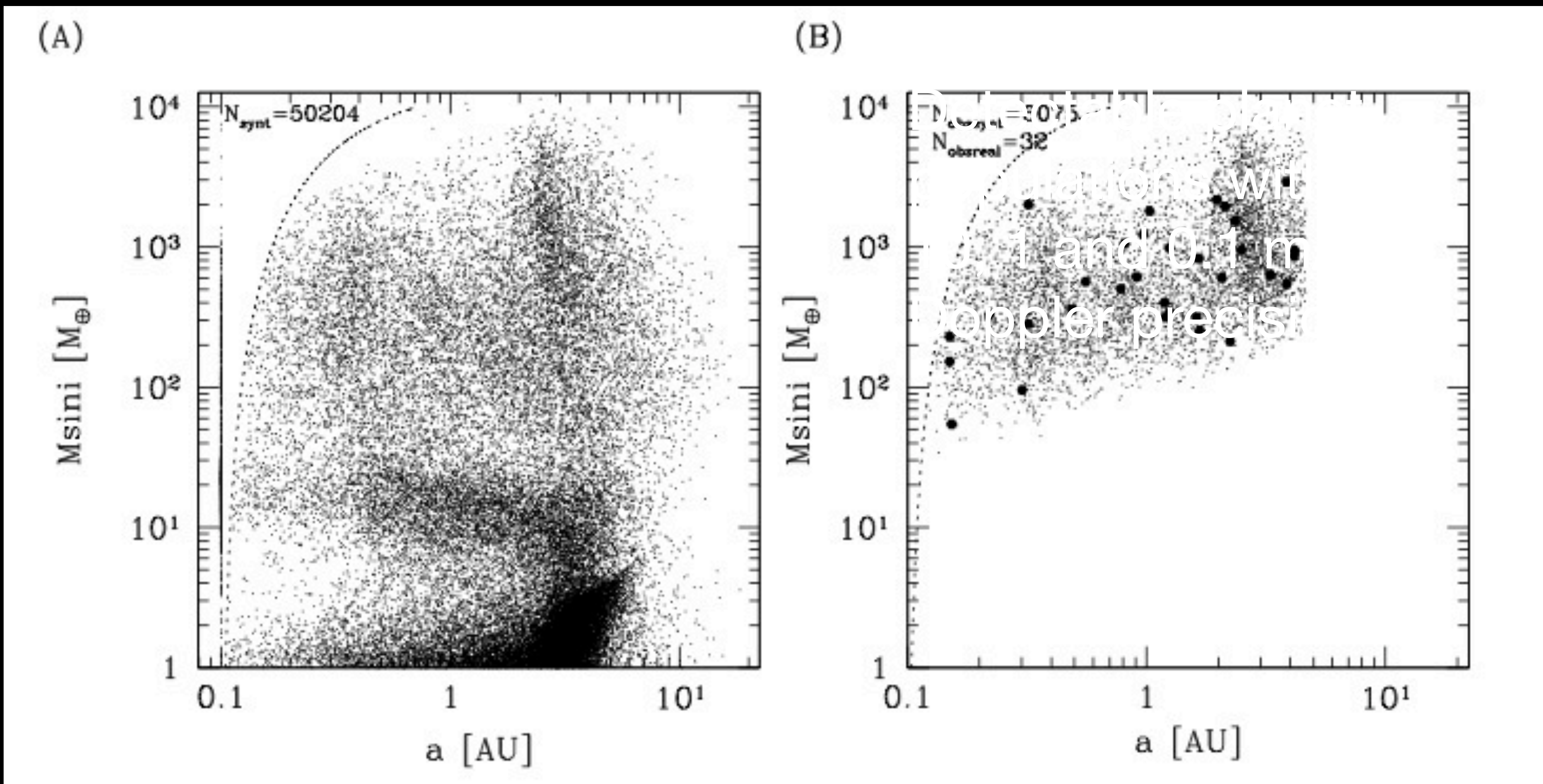
Toward a deterministic model of planet formation IV. Effects of Type I migration





Mordasini et al. 2009

Extrasolar planet population synthesis



Mordasini et al. 2009

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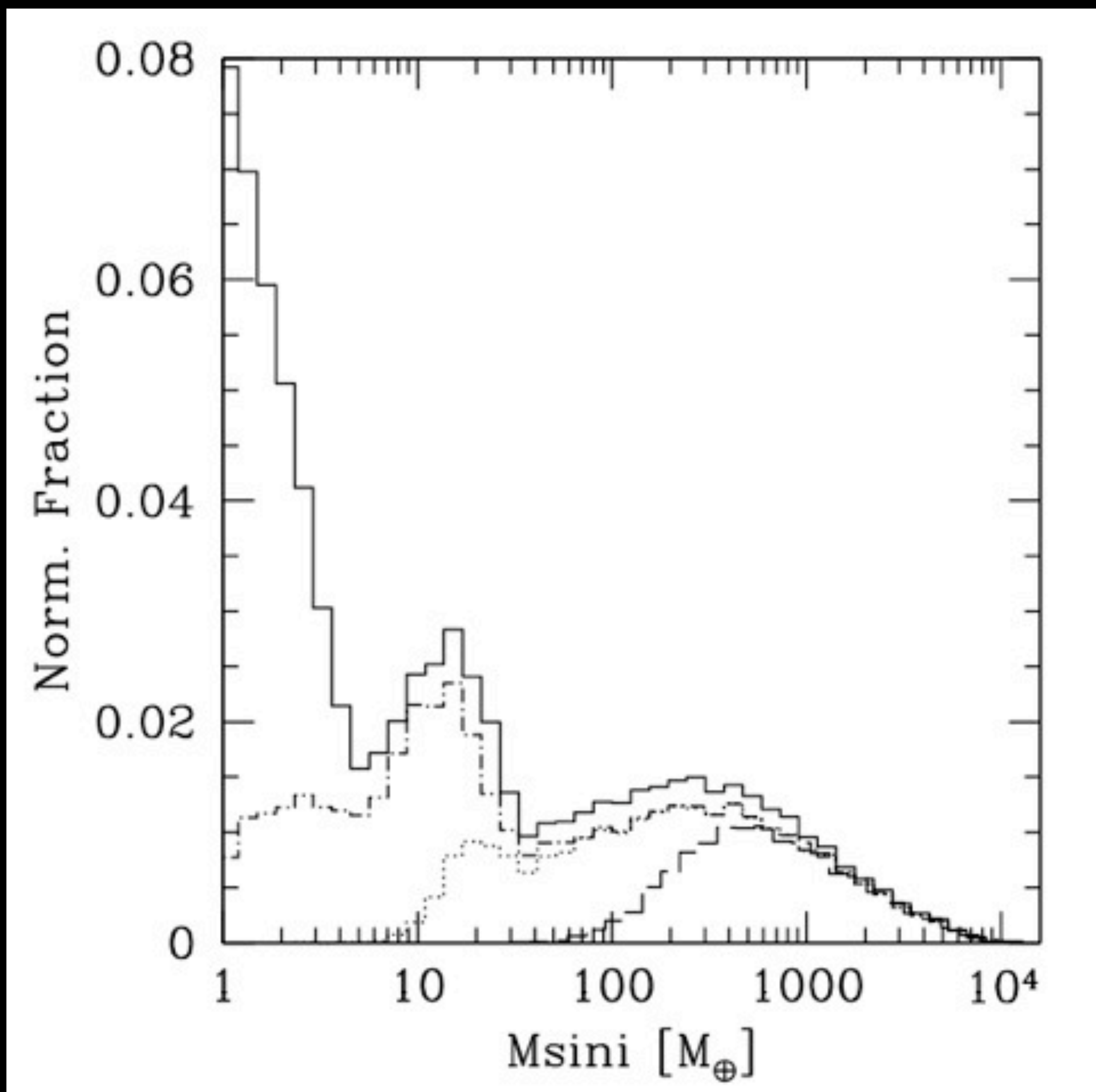
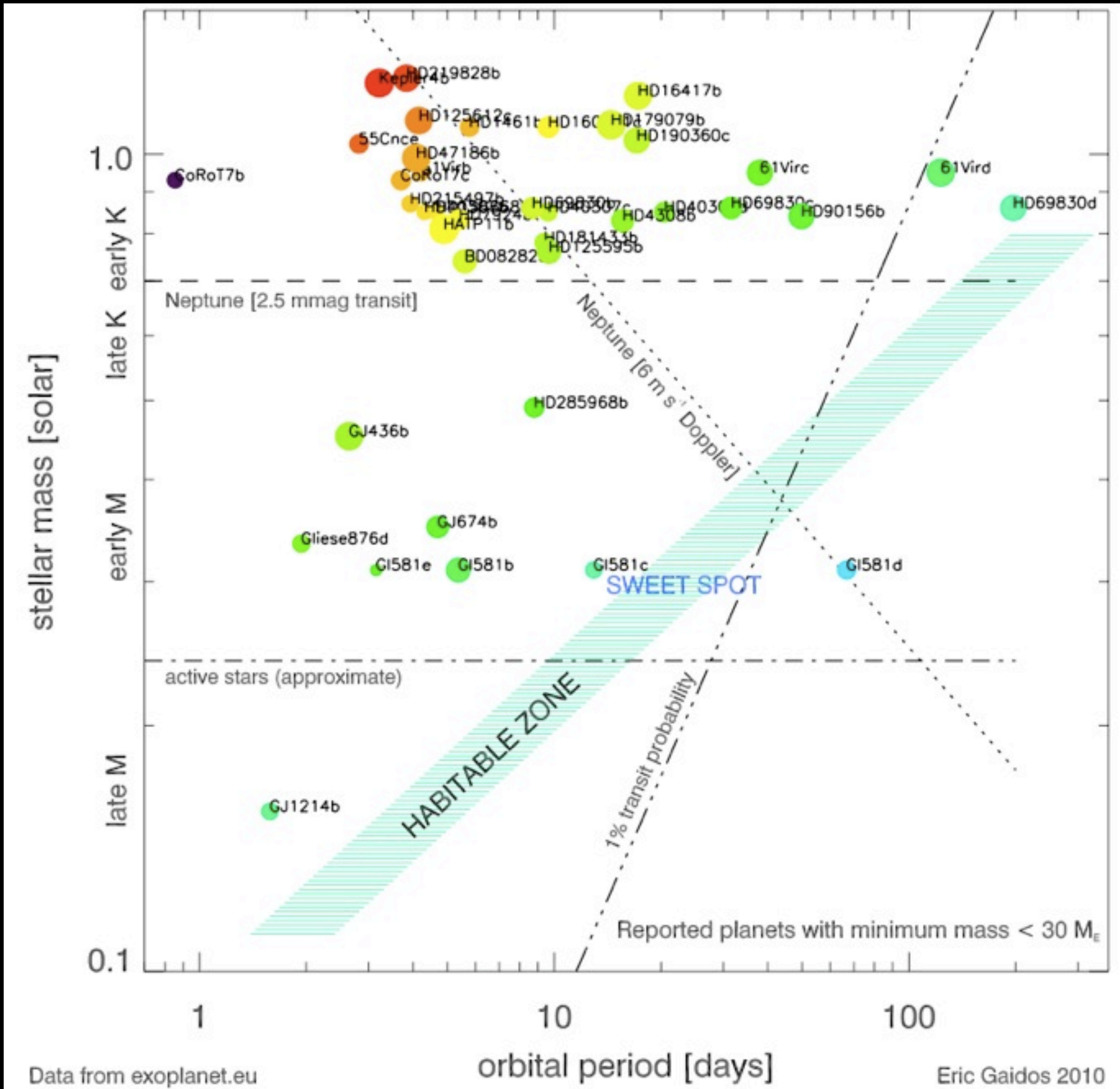


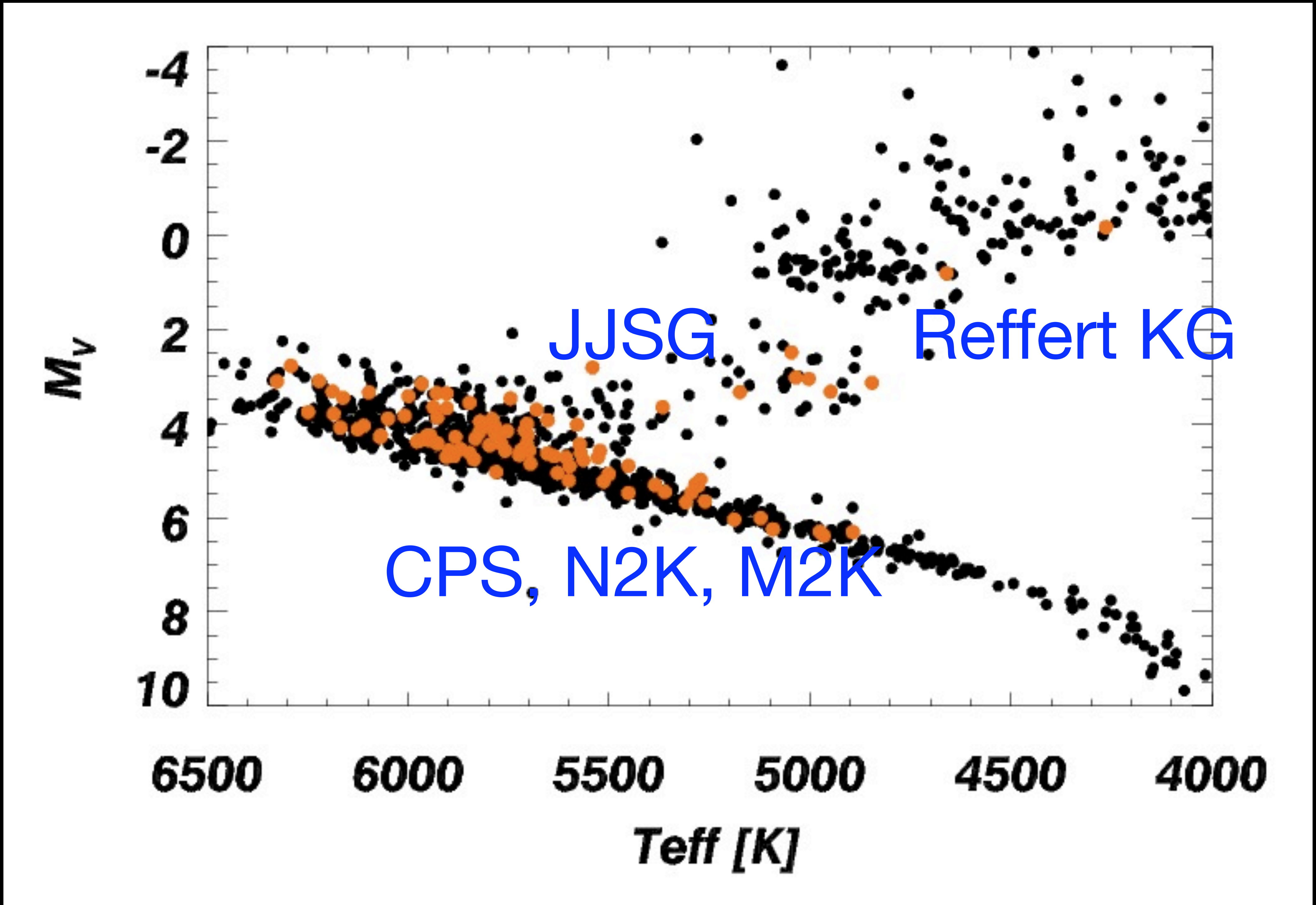
Detectable planet populations with 10, 1 and 0.1 m/s Doppler precision

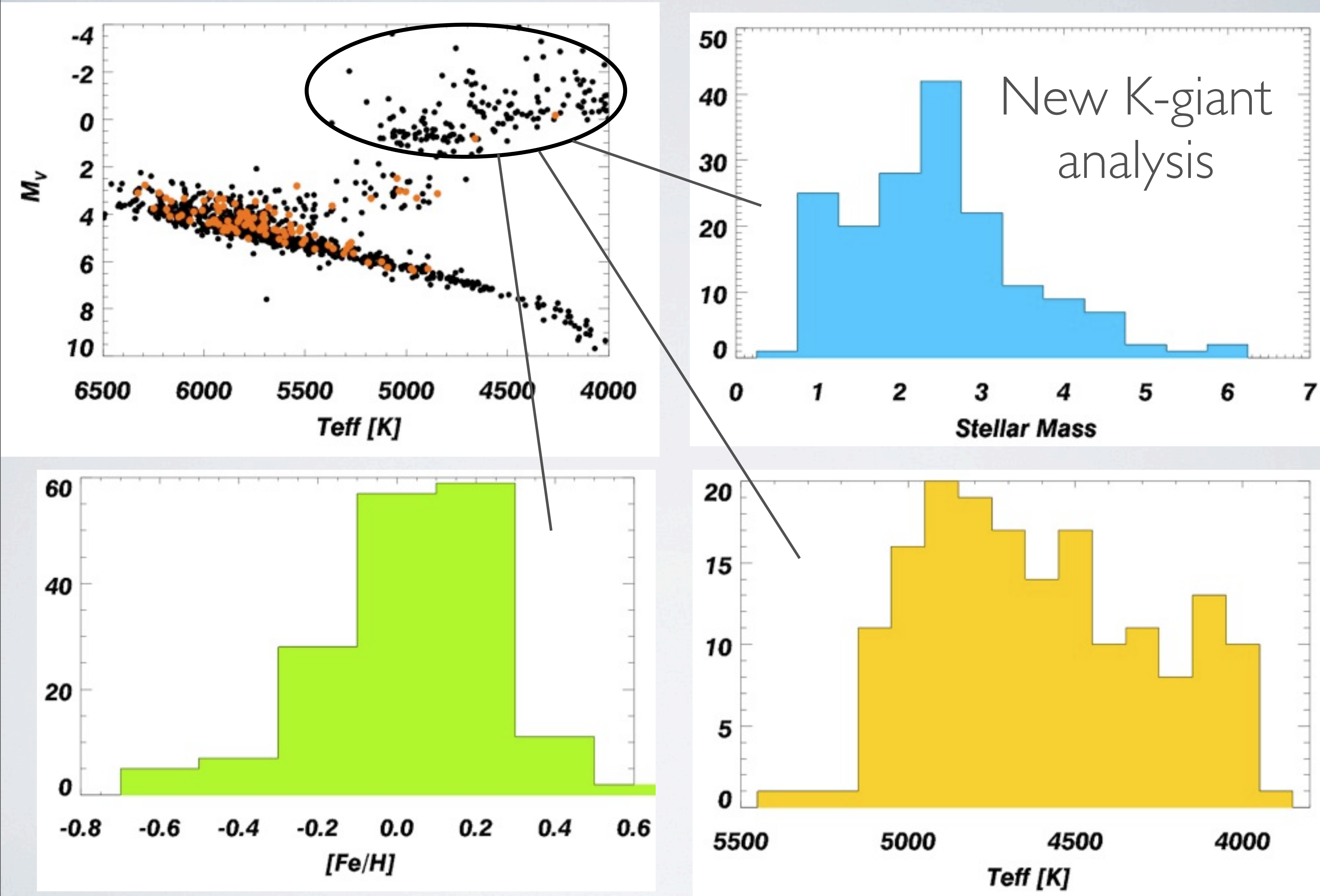
Gaidos 2010

Low mass planet characteristics M < 30 MEARTH



HR diagram of population (red, with planets)




New K-giant analysis
M_V
Teff [K]
Stellar Mass
[Fe/H]
Teff [K]

Dodson-Robinson et al. 2009

Formation Mechanism of Gas Giants on Wide Orbits (gravitational instability wins)