The Transition from Giant Planets to Brown Dwarfs beyond 1 au from the Stellar Metallicity Distribution

Steven Giacalone, Andrew Howard, Greg Gilbert, Judah van Zandt, Erik Petigura, Luke Handley

NSF Astronomy & Astrophysics Postdoctoral Fellow @ Caltech

OHP 2025 — 51 Pegasi b: Cool Giant Planets and their Systems

Giant planets vs brown dwarfs

What are they, anyway?

"As examined in the review, if objects are classified as 'Brown Dwarfs' or 'Giant Planets' on the basis of their formation mechanism, it has now become **clear that their mass domains overlap and that there is no mass limit between these two distinct populations**."

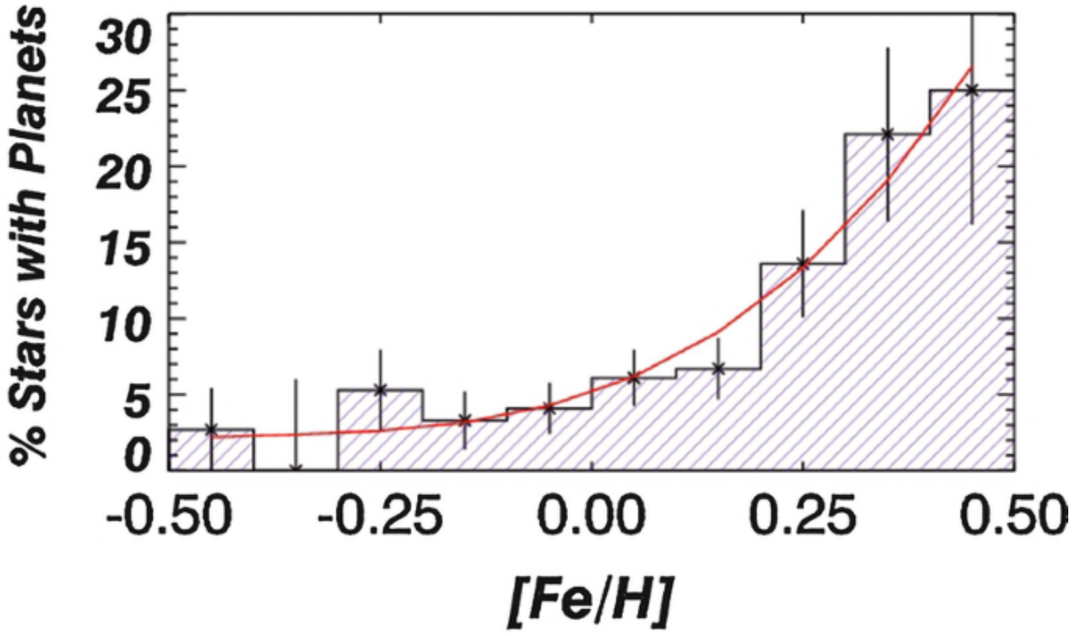
"Deuterium burning (or lack of) plays no role in either brown dwarf or giant planet formation. Consequently, we argue that the IAU definition to distinguish these two populations has no physical justification and brings scientific confusion."

— Chabrier et al. (2014), "Giant planet and brown dwarf formation"

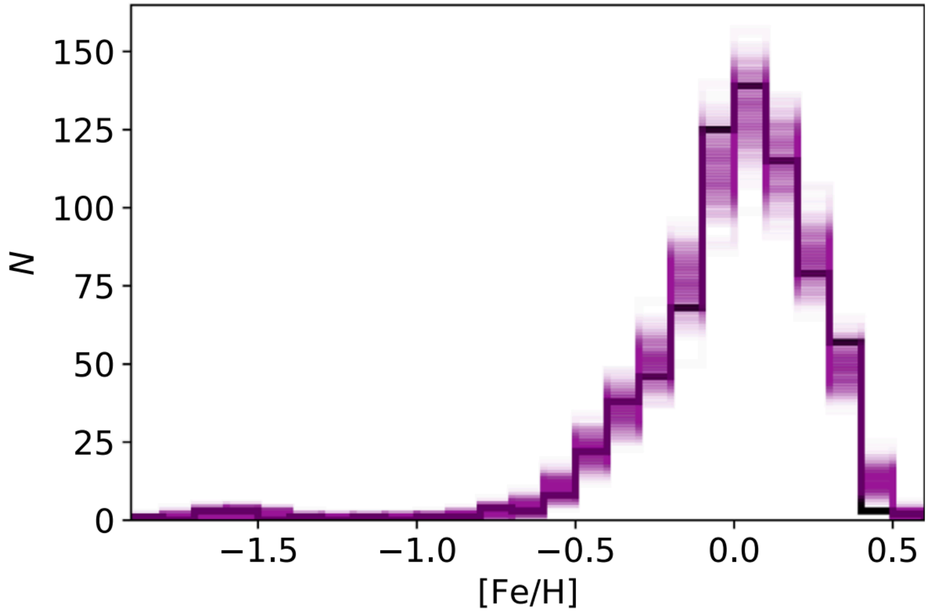
Why stellar metallicity?

Giant planet formation thrives in metal-rich environments

Brown dwarf formation is relatively indifferent



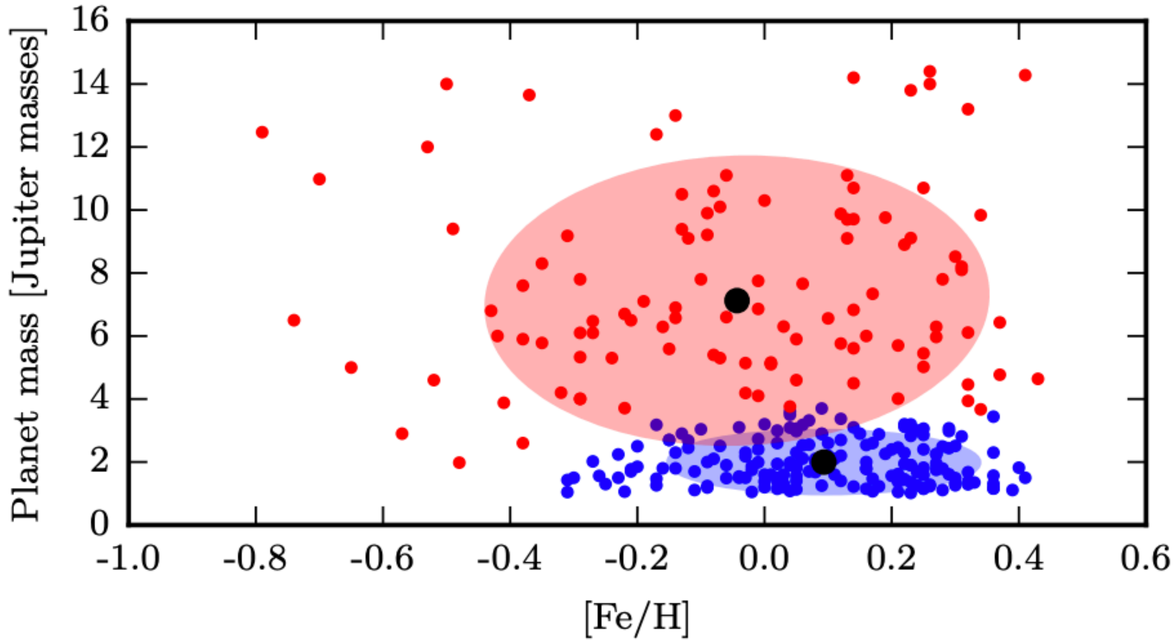
Fischer & Valenti (2005)



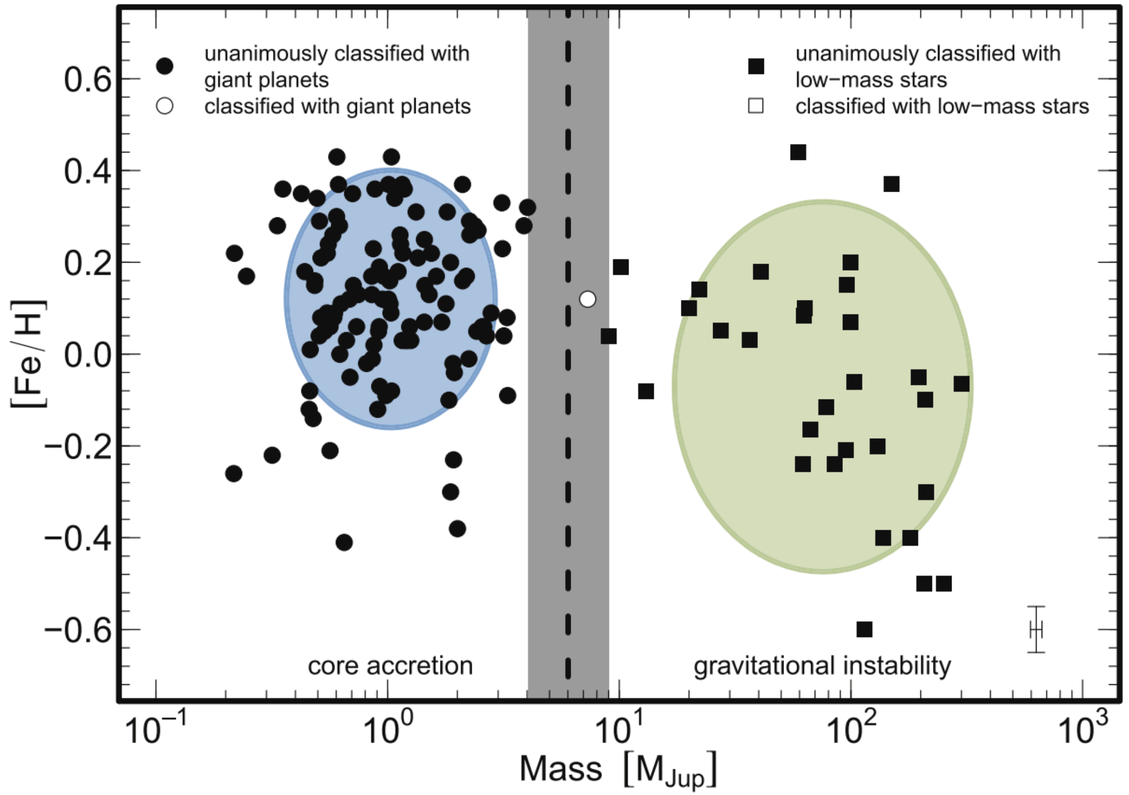
Rosenthal et al. (2021)

What did we already know

Earlier analyses of close-in companions claim a transition at 4-10 M_{Jup}



Santos et al. (2017)
Includes RV and transiting systems

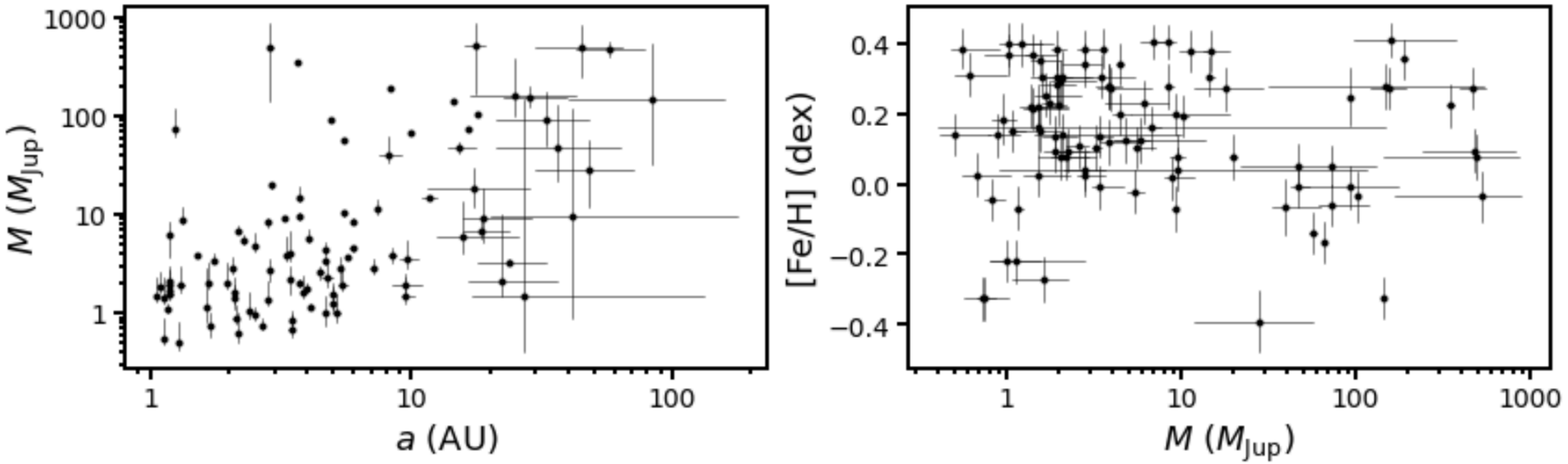


Schlaufman (2018)
Includes only transiting systems

Examining more distant companions with CLS

A uniform sample of orbits, masses, and stellar properties

The California Legacy Survey (CLS) is a decades-long RV survey with ~200 detected companions, all uniformly analyzed (Rosenthal et al. 2021).

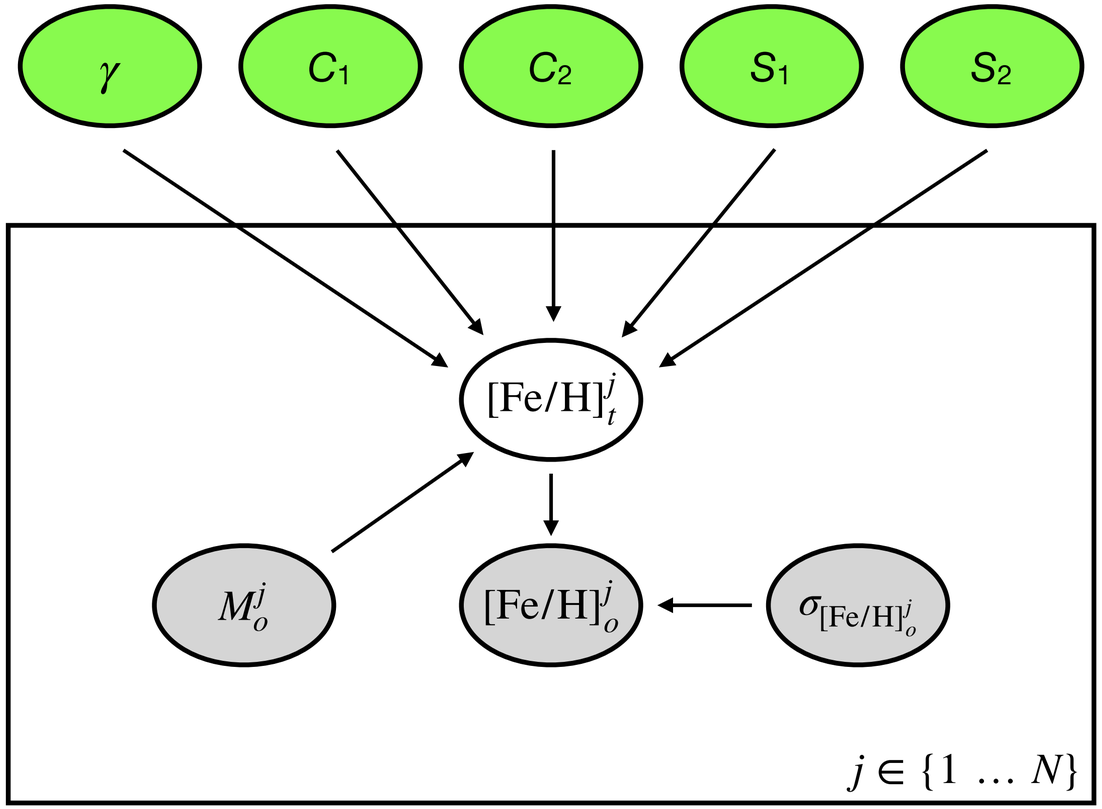


Now with masses determined with Gaia/Hipparcos astrometry (van Zandt et al. submitted).

A hierarchical Bayesian approach

Enables mass posterior sampling and population-level inference

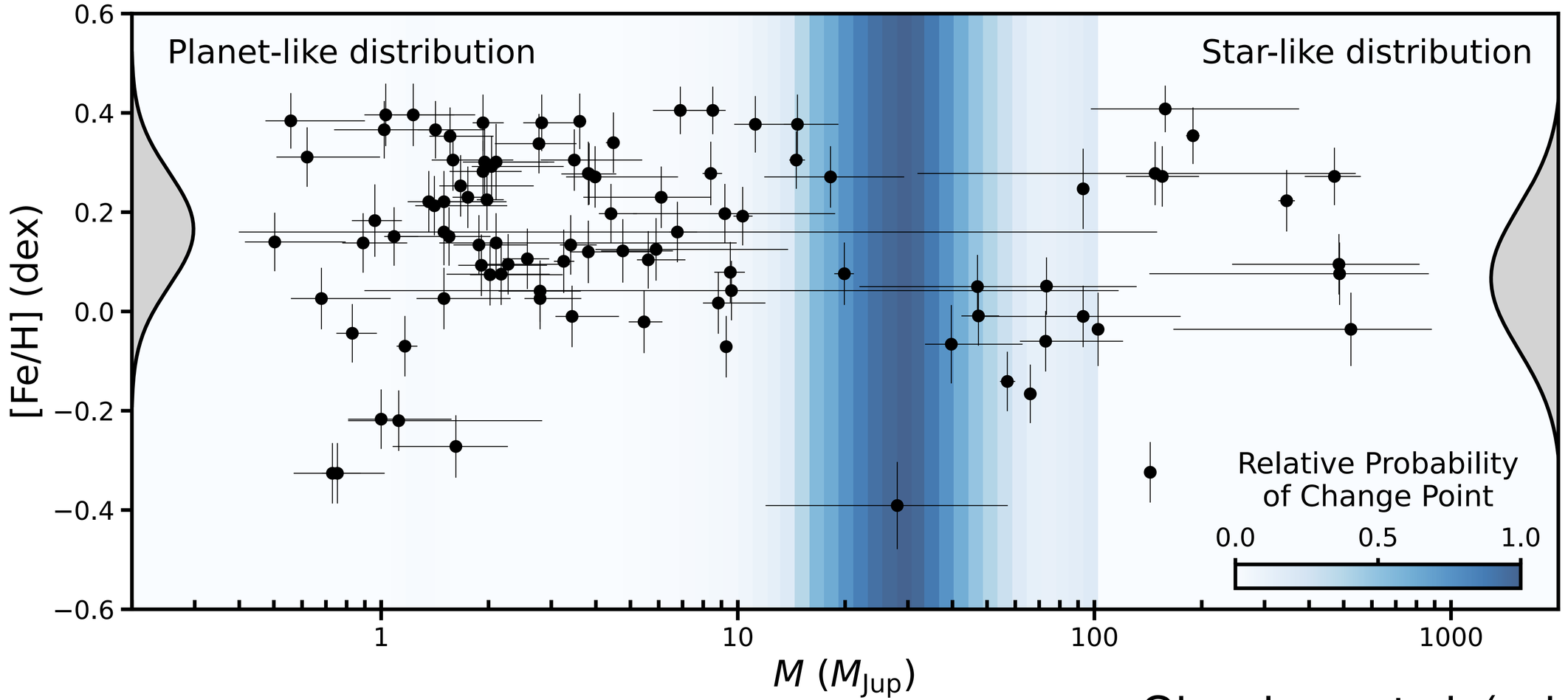
$$[\mathrm{Fe/H}]_t \sim \begin{cases} \mathcal{N}(C_1, S_1) & \text{if } M_t \leq \gamma \\ \mathcal{N}(C_2, S_2) & \text{if } M_t > \gamma \end{cases}$$



Giacalone et al. (submitted)

Results

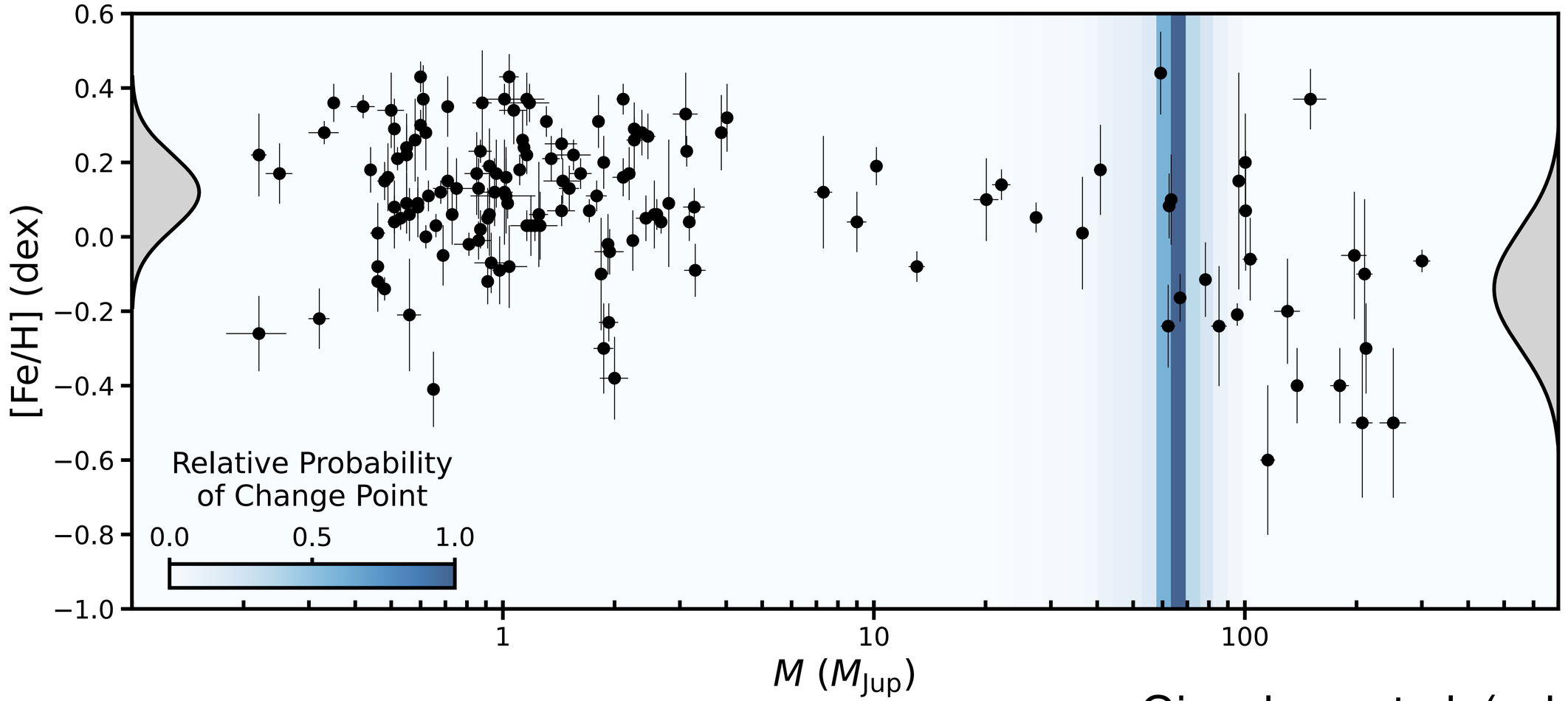
Little evidence (< 2% probability) for a transition at or below 10 M_{Jup}



Giacalone et al. (submitted)

Model applied to close-in companions

Same conclusion: transition most likely above 10 M_{Jup}



Giacalone et al. (submitted)

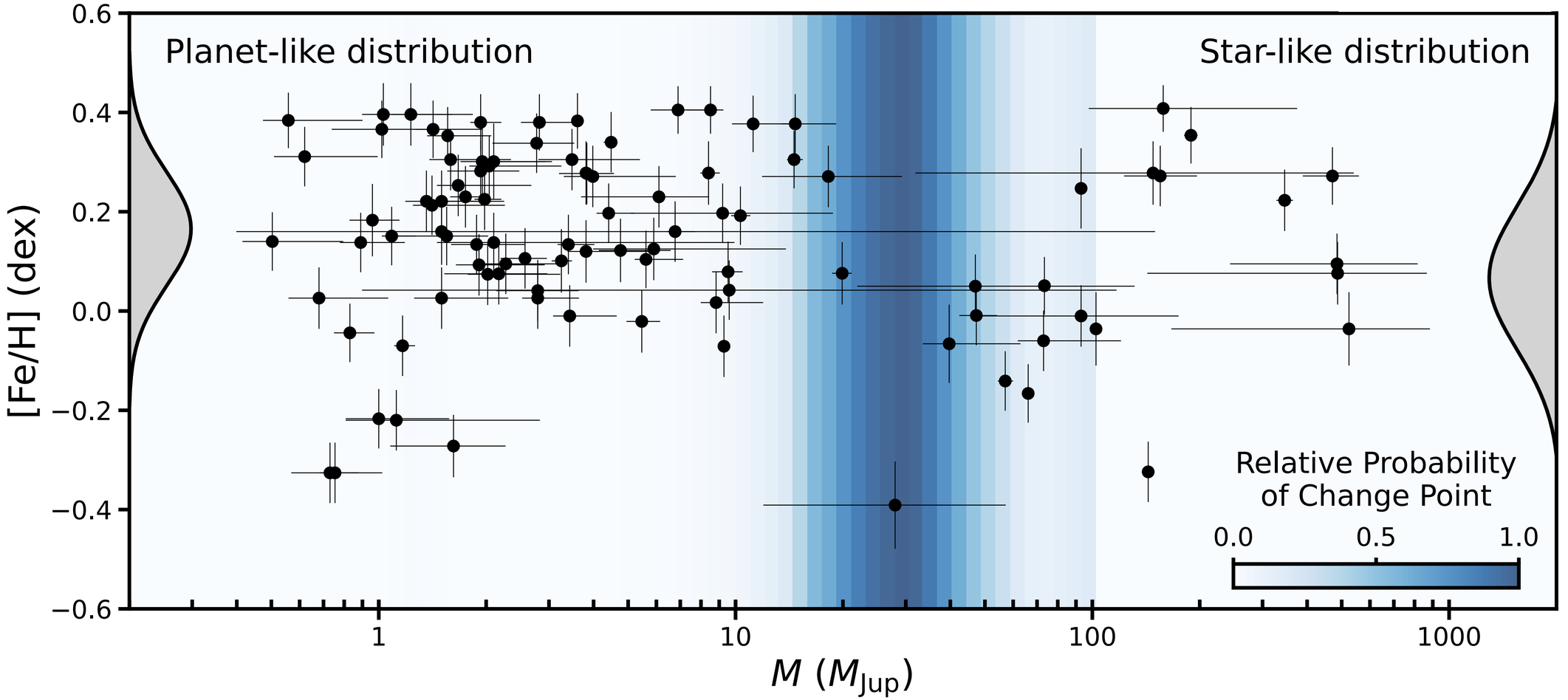
Are there dependences on other parameters?

No strong evidence for “sharp” transitions. Talk to my colleagues to find out more!

For orbital eccentricities:
“Orbital Eccentricities Suggest a Gradual Transition from Giant Planets to Brown Dwarfs”
Greg Gilbert et al. (submitted)

For occurrence rates:
“The Occurrence of Giant Planets and Brown Dwarfs from RVs and Astrometry”
Judah van Zandt et al. (submitted)

Thank you!



Email: giacalone@astro.caltech.edu

Results with no M dwarfs