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KAITLIN KRATTER (U OF A)
MAXWELL MOE (U OF A)

# UNSOLVING EVEN MORE PROBLEMS WITH PLANETS IN BINARIES

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KAITLIN KRATTER (U OF A)
MAXWELL MOE (U OF A)

# UNSOLVING EVEN MORE PROBLEMS WITH PLANETS IN BINARIES

## PLANETS ONLY LIVE WHERE BINARY SYSTEMS ALLOW THEM

Planet occurrence rates that ignore this fact can be misleading (aka “wrong”)

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# UNSOLVING EVEN MORE PROBLEMS WITH PLANETS IN BINARIES

## PLANETS ONLY LIVE WHERE BINARY SYSTEMS ALLOW THEM

Oh, and binaries matter for our understanding of extra-galactic astrophysics, reionization, compact object progenitors,etc…

# OUTLINE

- Where do binaries come from (the 1 minute version)
- What do binaries do to planets (the 2 minute version)
- How binaries might help “unsolve” some solved problems:
  - The planet metallicity correlation: weaker than stated due to binary suppression of planet formation
  - The apparent enhancement of close-in planets around low-mass stars: may be partly explained by binary statistics

# TWO MODES OF BINARY FORMATION

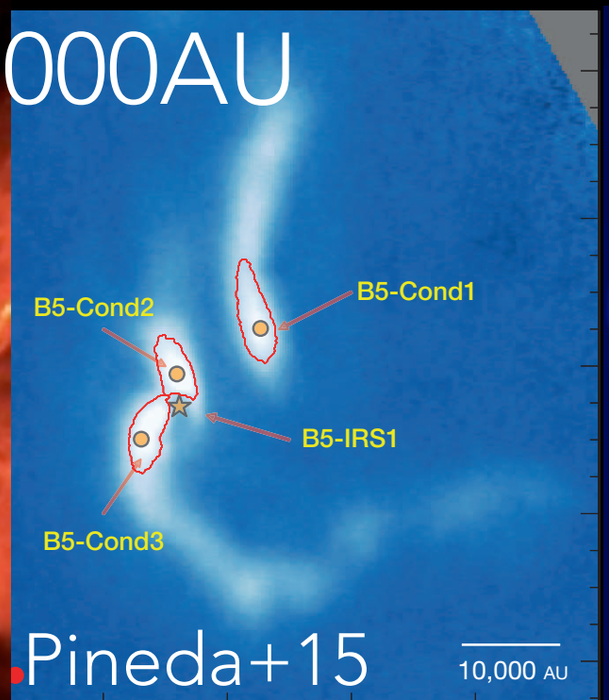
Kratter 2011

- Filament / Core Fragmentation (Bate et al 2003, Fisher 2004, Offner et al 2010, Cunningham+2018, Li+2018)

- Disk Fragmentation (better at high masses…) (Bonnell and Bate 1994, Adams et al 1989, Kratter et al 2008,2010)

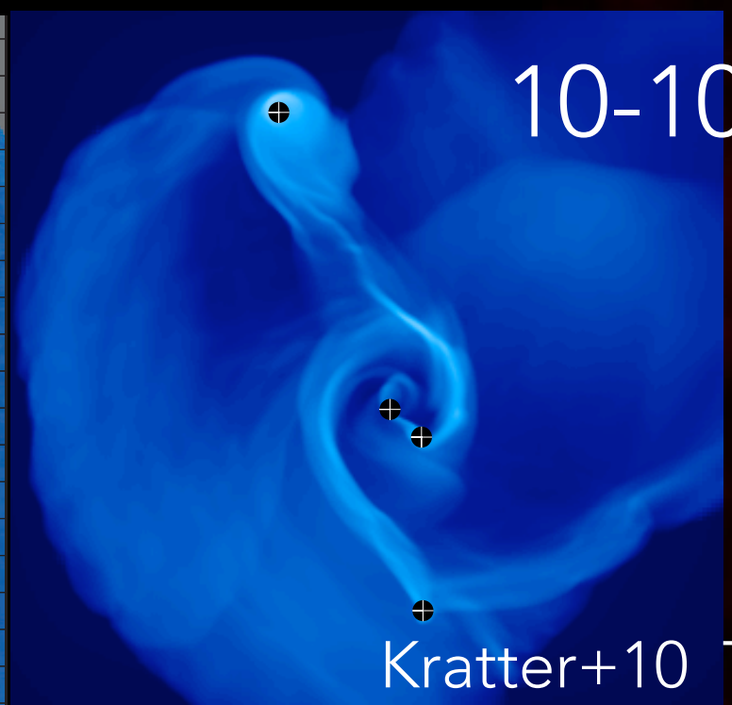
1000-10,000AU

Bate+12

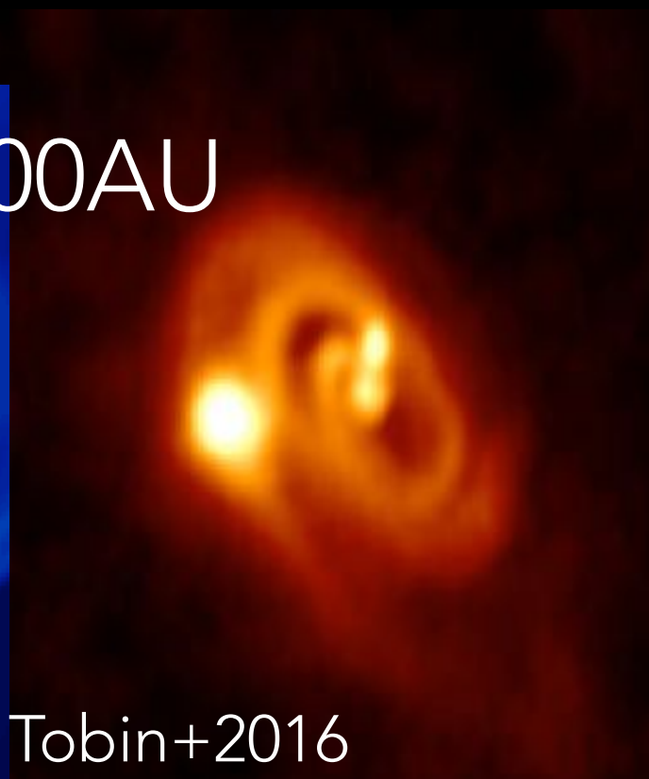



Pineda+15

10-100AU

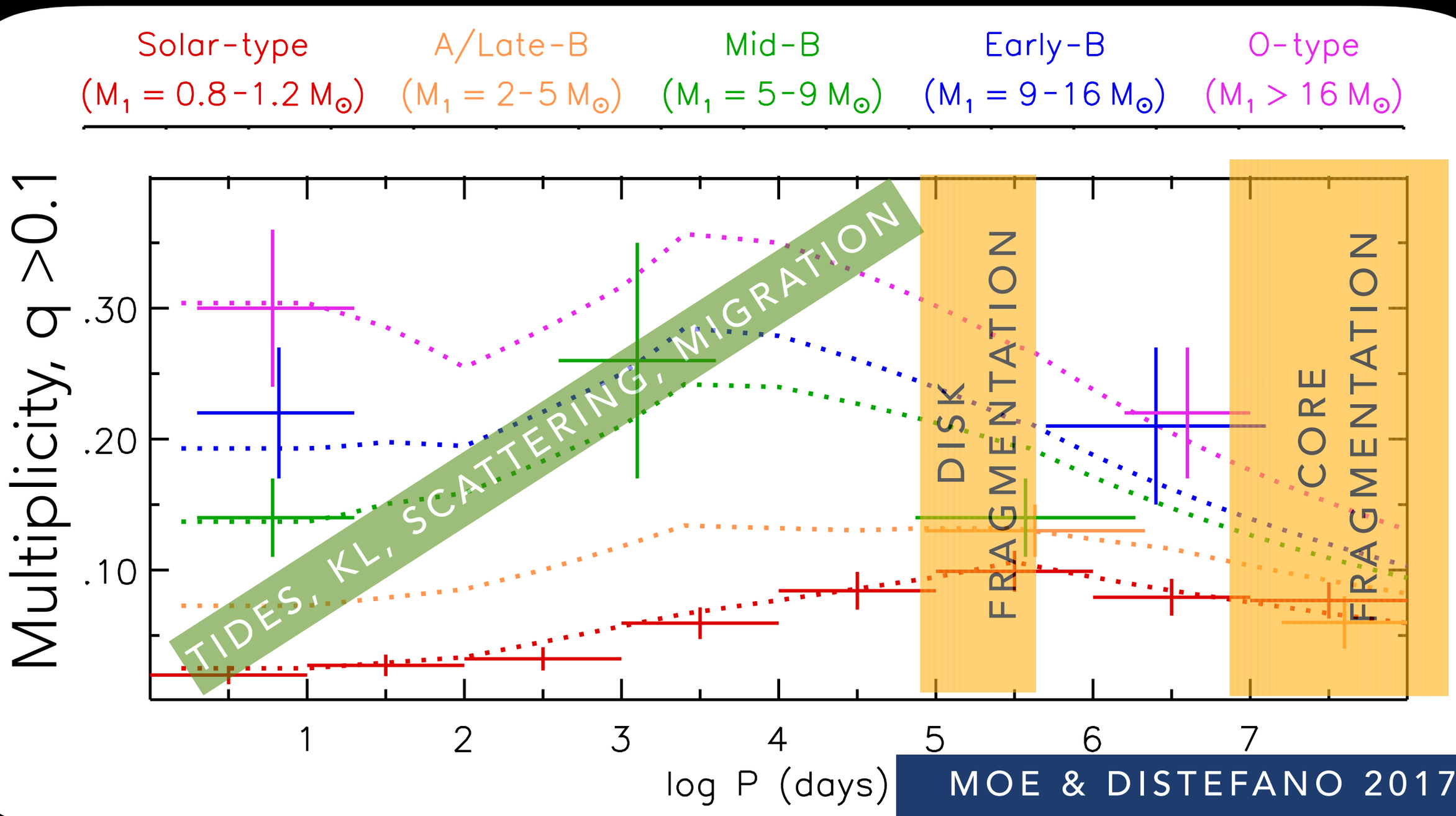


Kratter+10



Tobin+2016

# Binaries form via core and disk fragmentation, and migrate to shorter separations. We expect much of the orbital evolution to occur DURING the Pre-Main Sequence




MOE & DISTEFANO 2017,
MOE & KRATTER 2018

# SO WHERE CAN PLANETS LIVE?

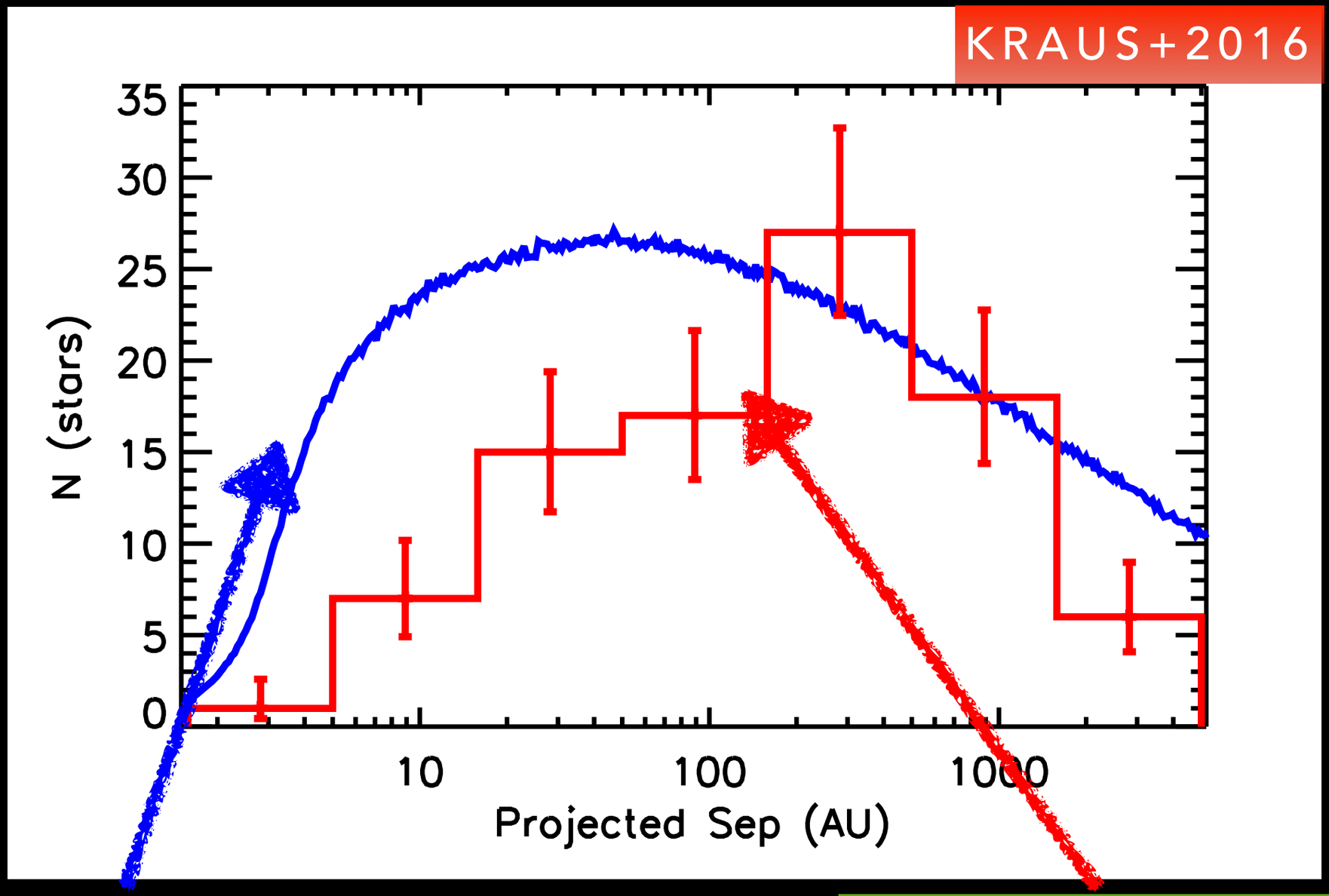
S-TYPE ARE EXPECTED TO BE DISTURBED BY BINARIES <~100 AU

CIRCUMSTELLAR (S-TYPE)

CIRCUMBINARY (P-TYPE)

CBP FORMATION IS ALWAYS IMPACTED BY EVOLUTION OF THE BINARY (DYNAMICALLY, HYDRODYNAMICALLY)

# INDEED, KEPLER SHOWS REDUCTION IN PLANET OCCURRENCE IN CLOSE-ISH BINARIES




how many binaries you should have found, if(!!) planets don't care

how many binaries you find

see also Wang+14,15

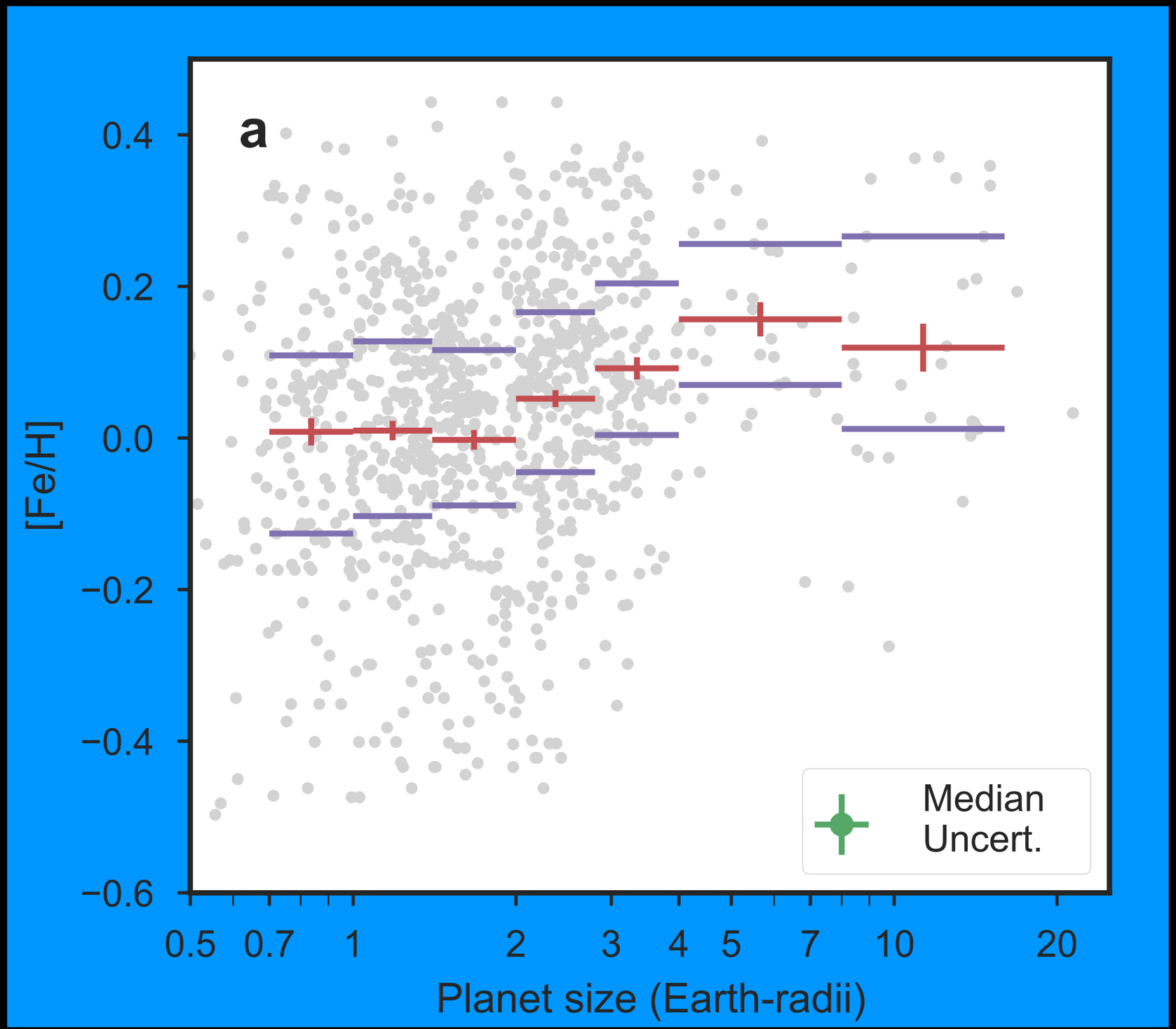
SO WHAT DOES BINARY INDUCED SUPPRESSION MEAN FOR PLANET STATISTICS?

# THE PLANET METALLICITY CORRELATION?

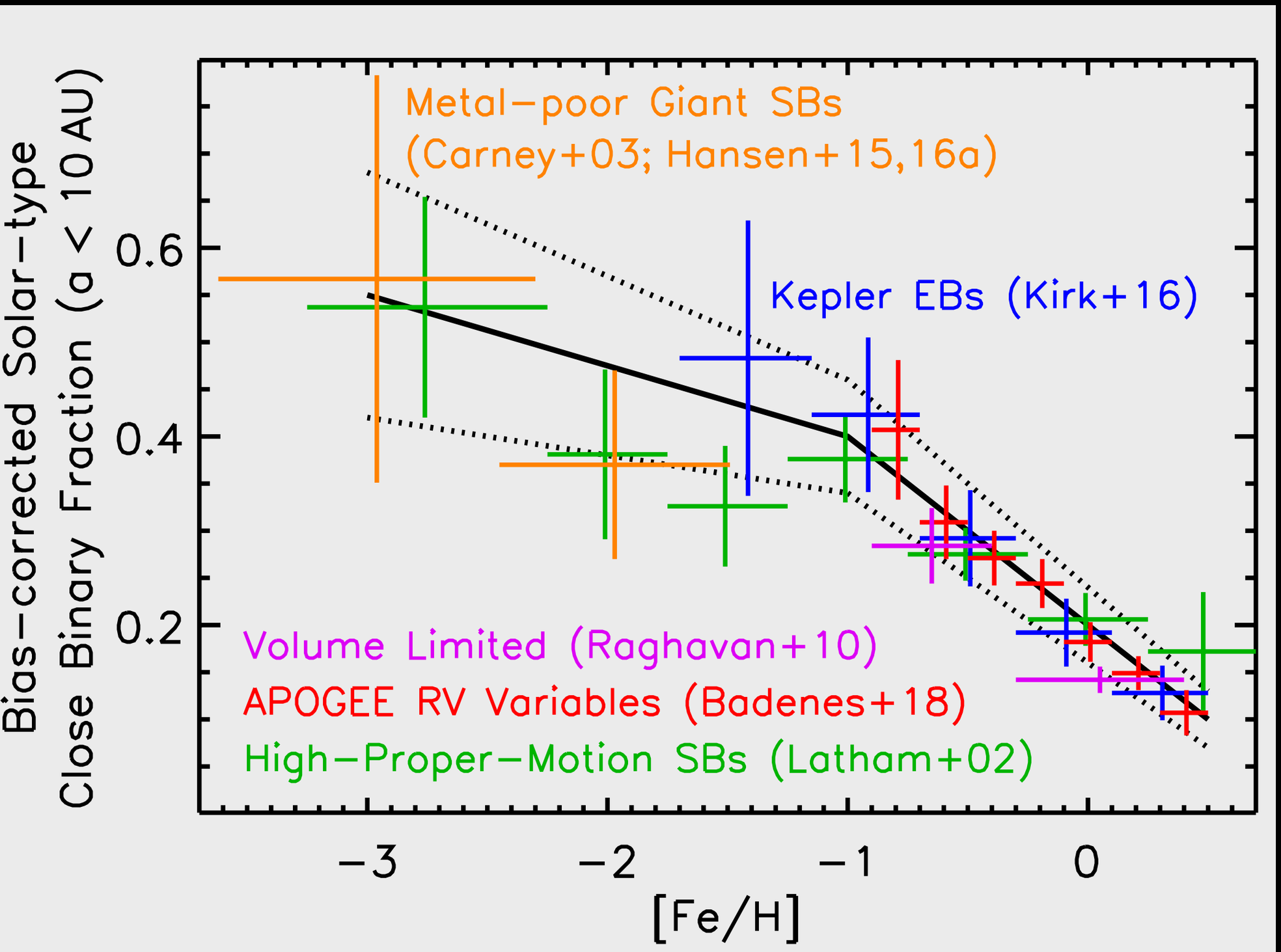
- Starting from the old RV days (Fischer & Valenti 1995), it has been well known that planets seem more common around metal rich stars

- See Andrew's talk for why this might make sense

PETIGURA+2017



# SOME OF THE TREND, ESPECIALLY FOR LOW MASS PLANETS, MAY NOT TELL US MUCH ABOUT PLANET FORMATION AT ALL!

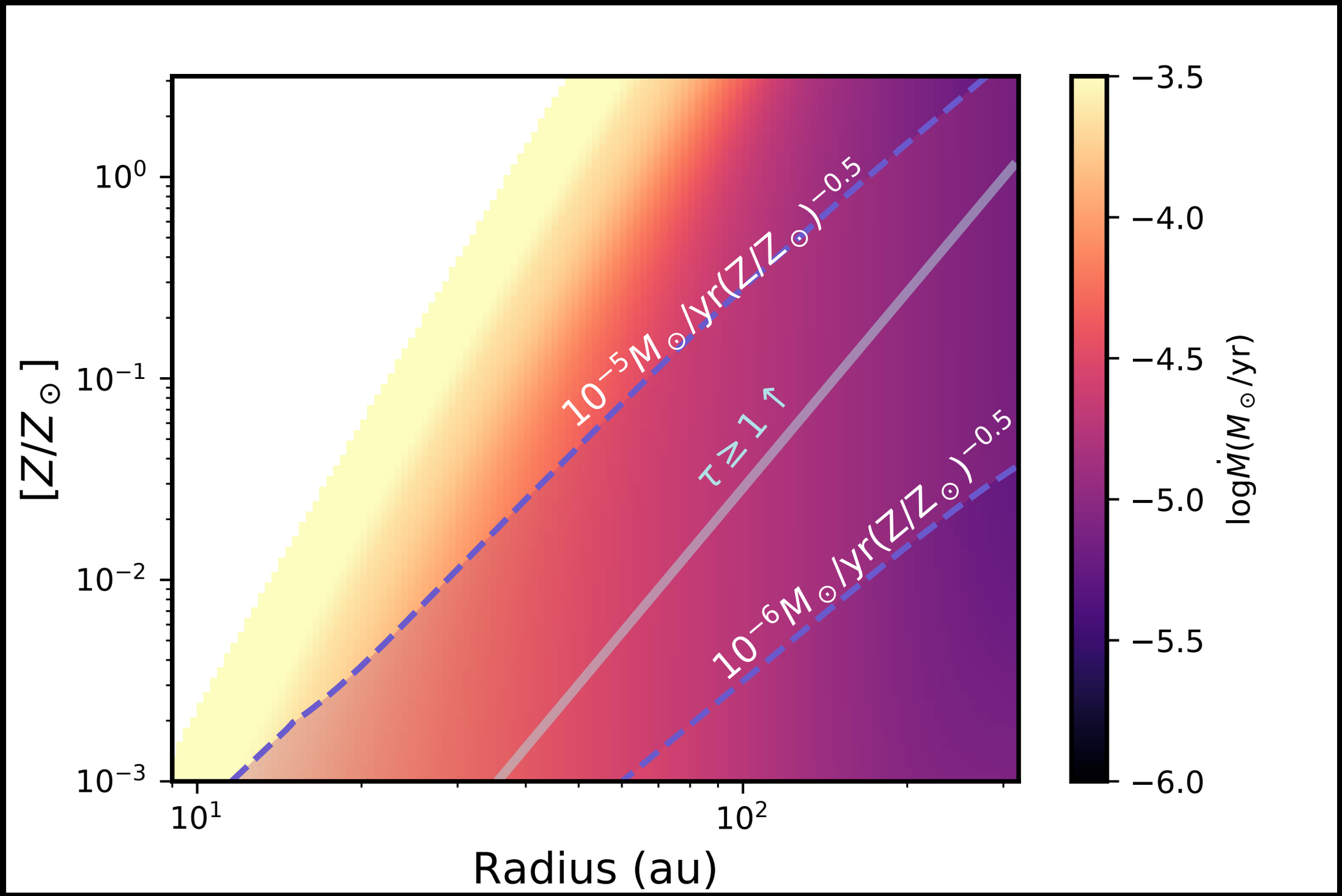



low metallicity stars are much more likely to be found in binaries.

previous results to the contrary did not entirely account for selection biases

MOE, KRATTER, BADENES, 2018 IN PREP

# BINARY ENHANCEMENT DUE TO MORE DISK FRAGMENTATION AT LOW Z




MOE, KRATTER, BADENES, 2018 IN PREP

# CONCLUSIONS

- Where do binaries come from: core and disk fragmentation
- What do binaries do to planets: suppress formation
- How binaries might help "unsolve" some solved problems:
  - The planet metallicity correlation: it may be weaker than expected due to binary suppression of planet formation
  - The apparent enhancement of close-in planets around low-mass stars: may be partly explained by binary statistics