Constraining the influence of stellar mass on planet formation

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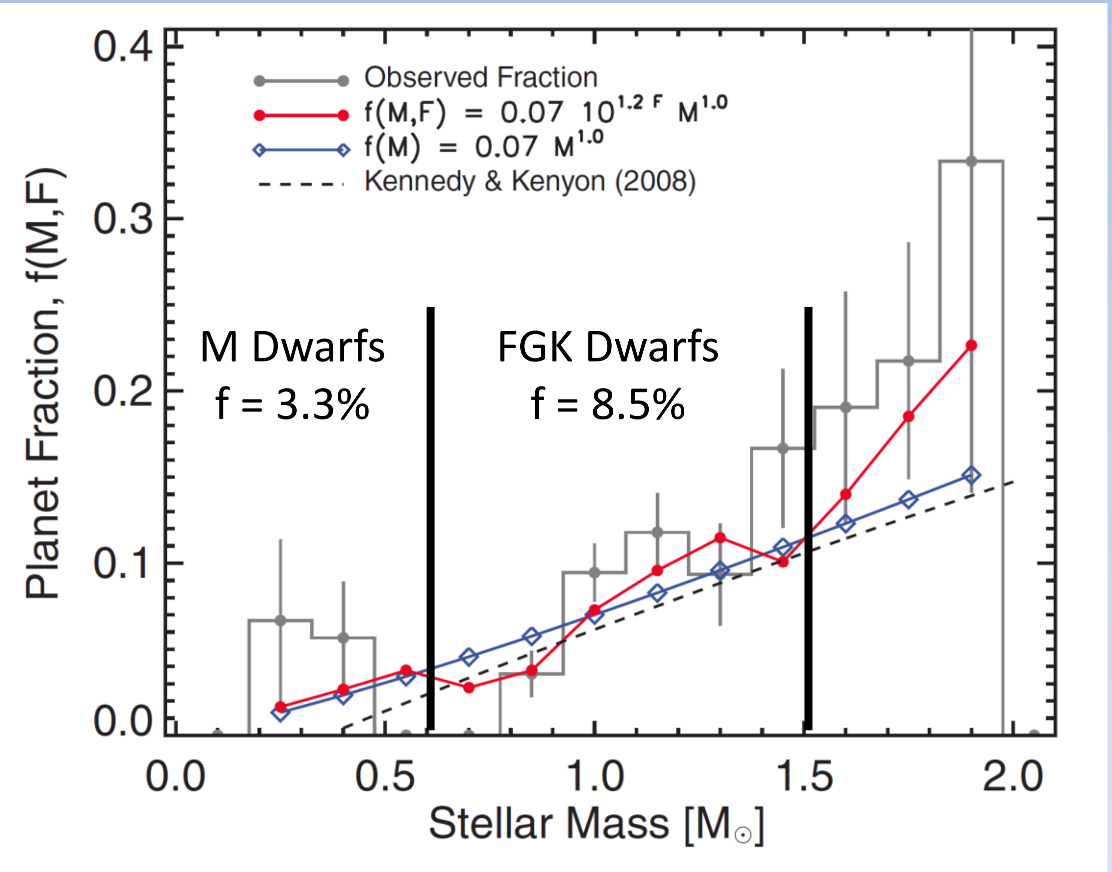
Precision Spectroscopy
IAG/USP
01/08/2017

Occurrence of giant planets appears to increase with stellar mass…



Johnson et al. (2010)

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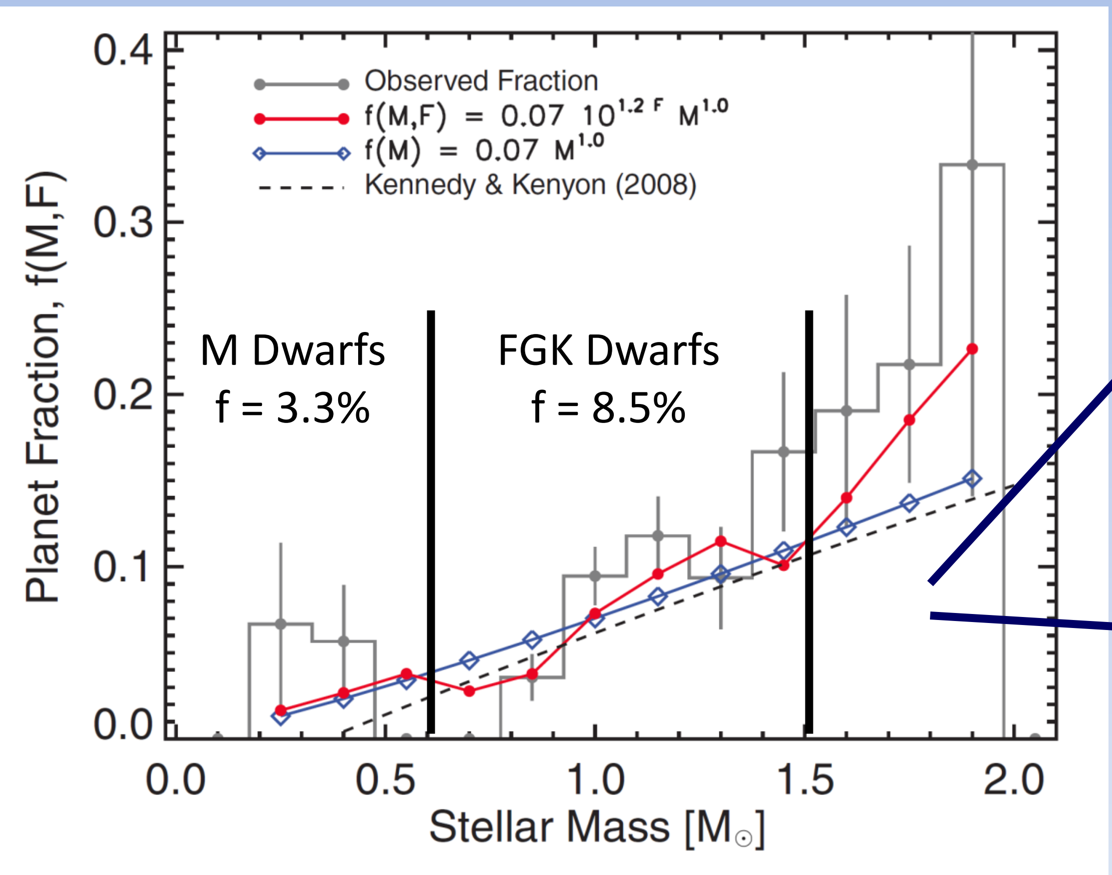
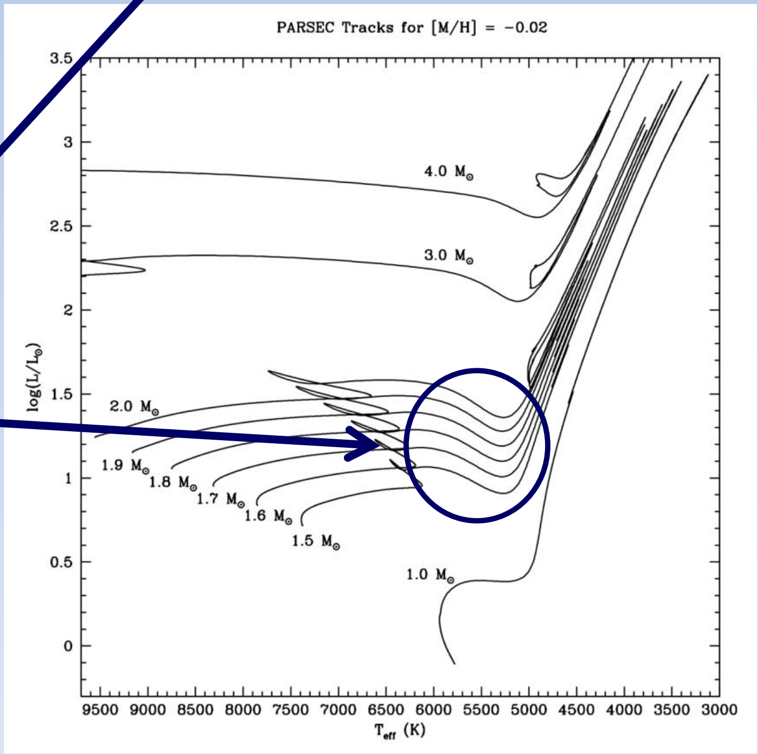


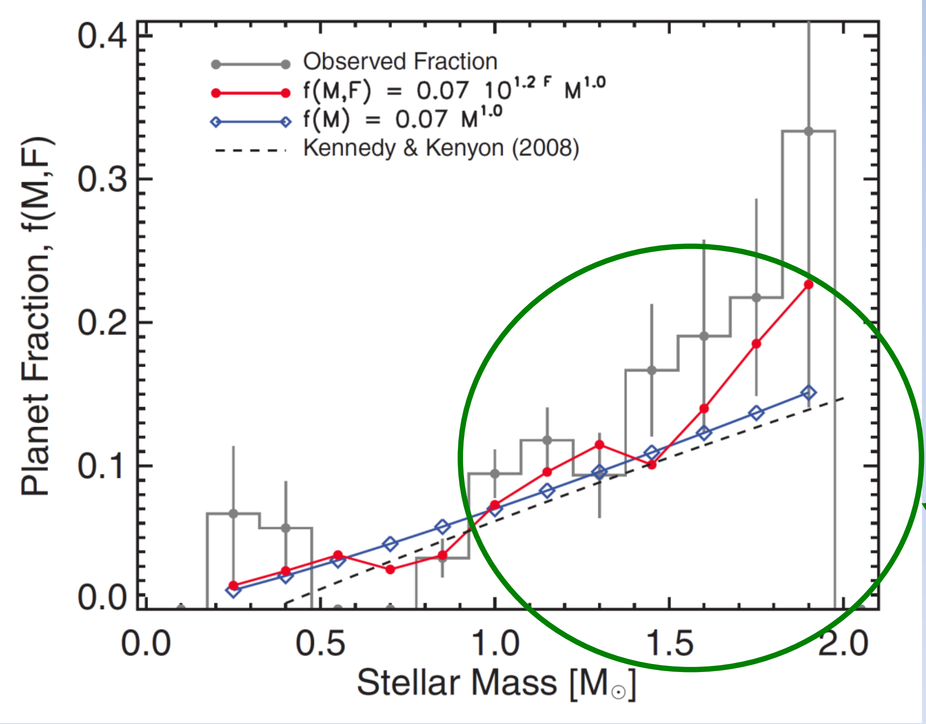
Johnson et al. (2010)

Retired A Stars
f = 14.0%

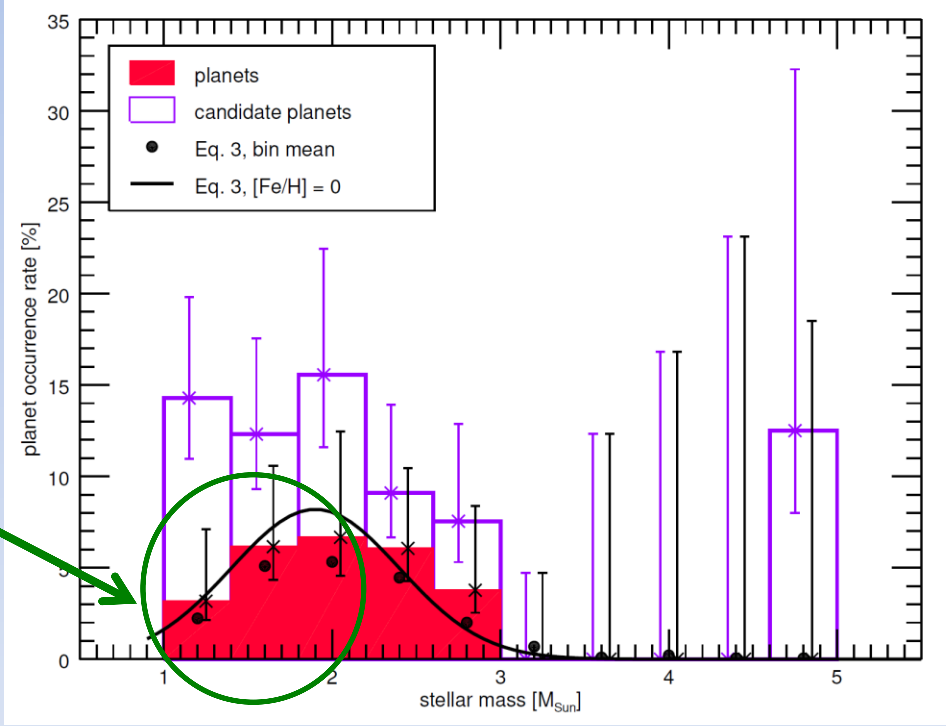


Occurrence of giant planets appears to increase with stellar mass…

Johnson et al. (2010)



Reffert et al. (2015)

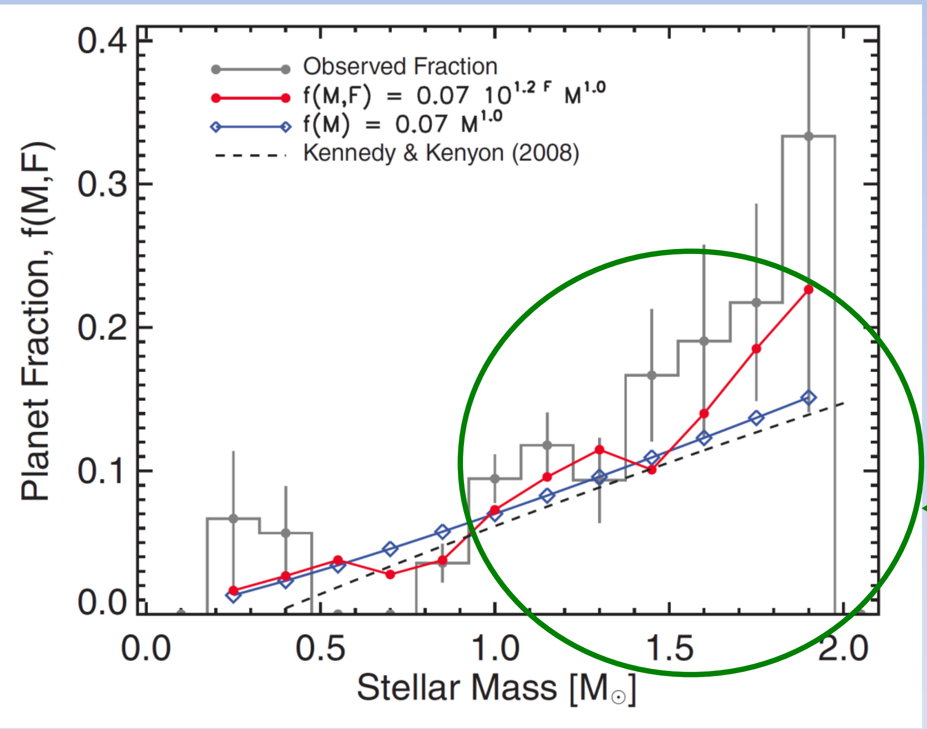


Independent confirmation

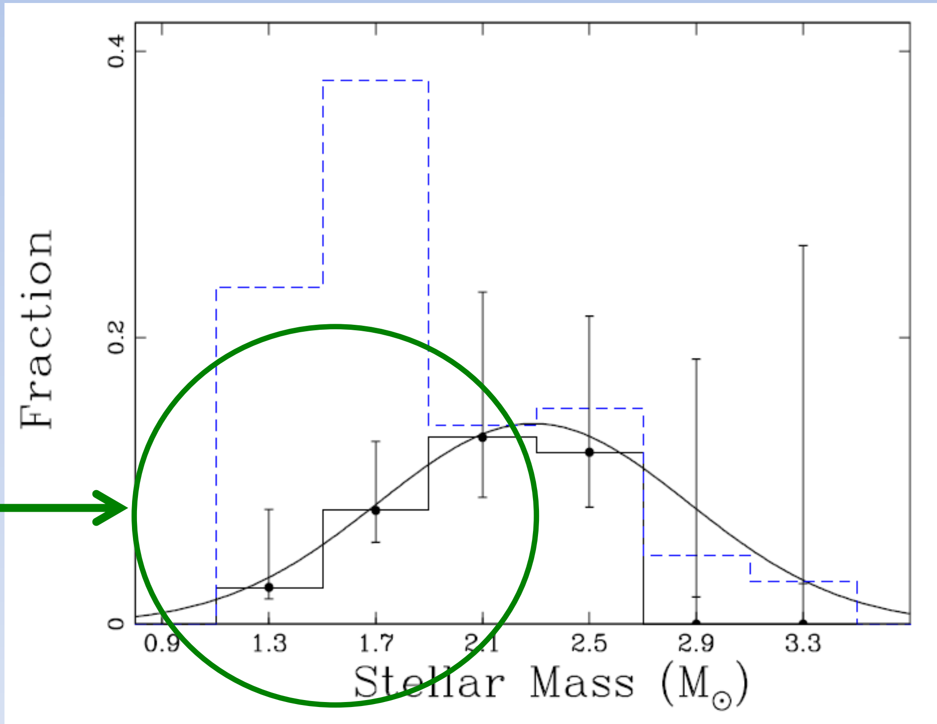
Sample of 373 G-K giants

Occurrence of giant planets appears to increase with stellar mass…

Johnson et al. (2010)



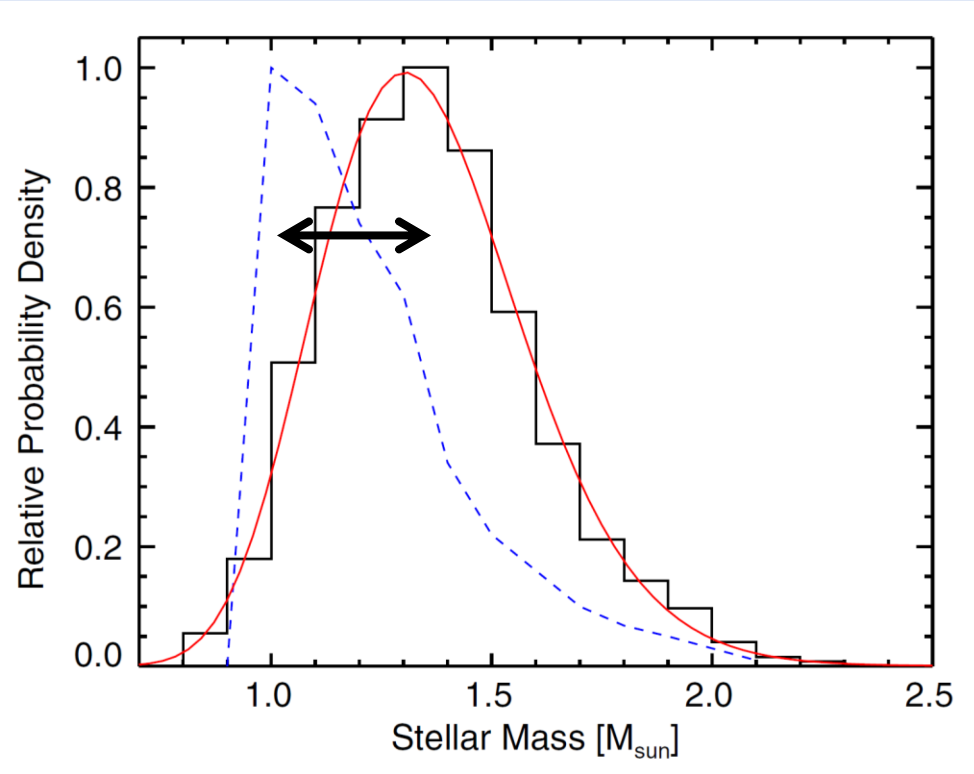
Jones et al. (2016)



Independent confirmation

Sample of 166 giants

…but masses could have been overestimated



Galactic Models

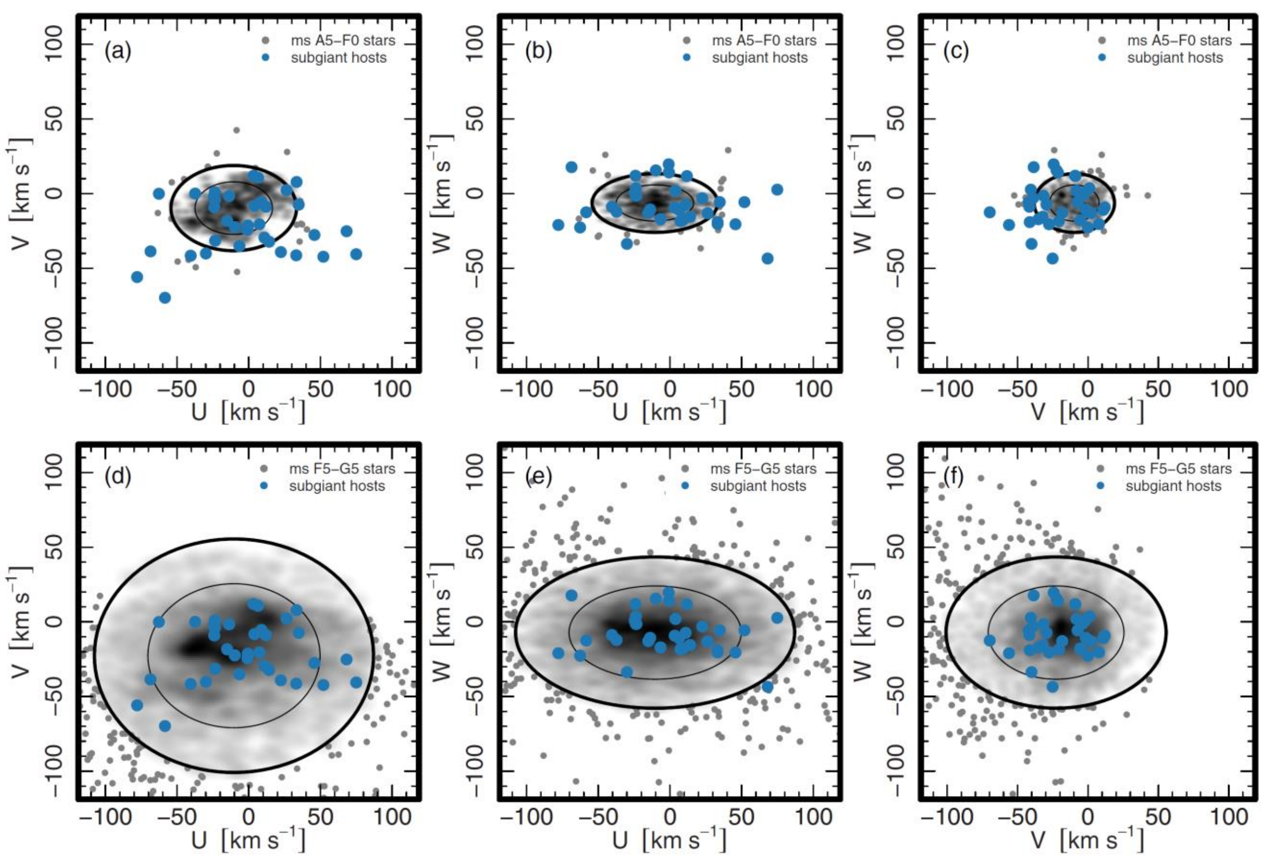
Johnson, Morton & Wright (2013)

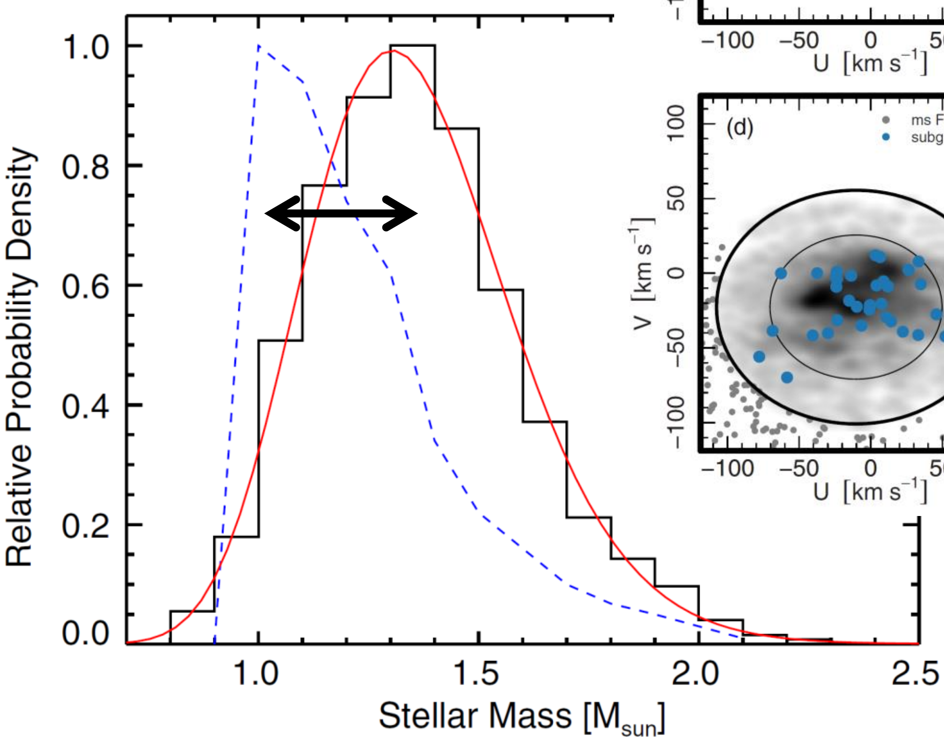
Lloyd (2011,2013)

…but masses could have been overestimated

Kinematics

Schlaufman & Winn (2013)





Galactic Models

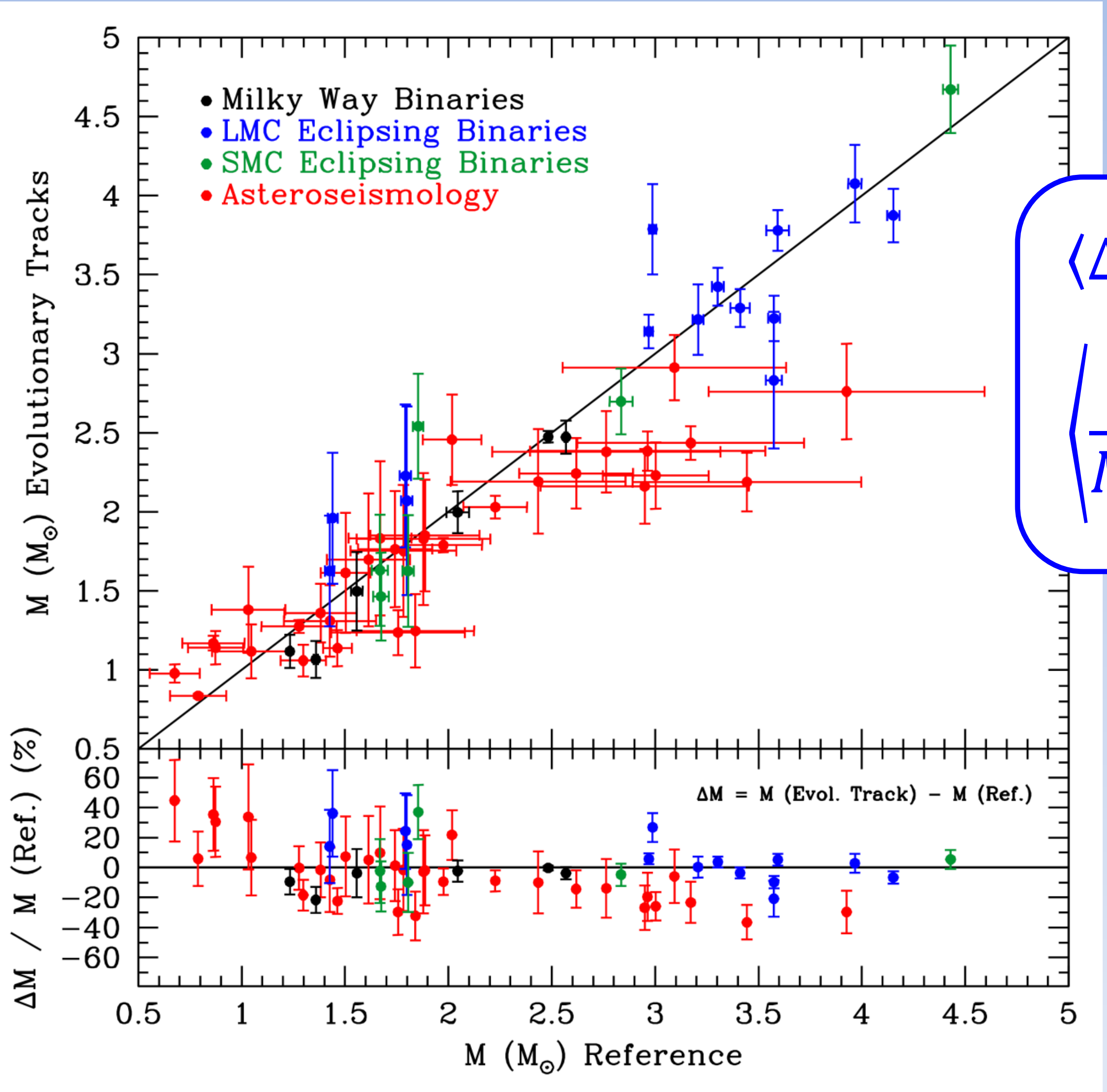
Johnson, Morton & Wright (2013)

Lloyd (2011,2013)

Scientific motivation

- **Does mass influence planet formation?**
- **Can we determine accurate masses for evolved stars?**
- Possible issues:
  - Evolutionary tracks
  - Atmospheric parameters
- Important implications:
  - Planetary formation
  - Stellar evolution
  - Galactic models

Masses are not overestimated by PARSEC tracks



Ghezzi & Johnson (2015)
ApJ, 812, 96

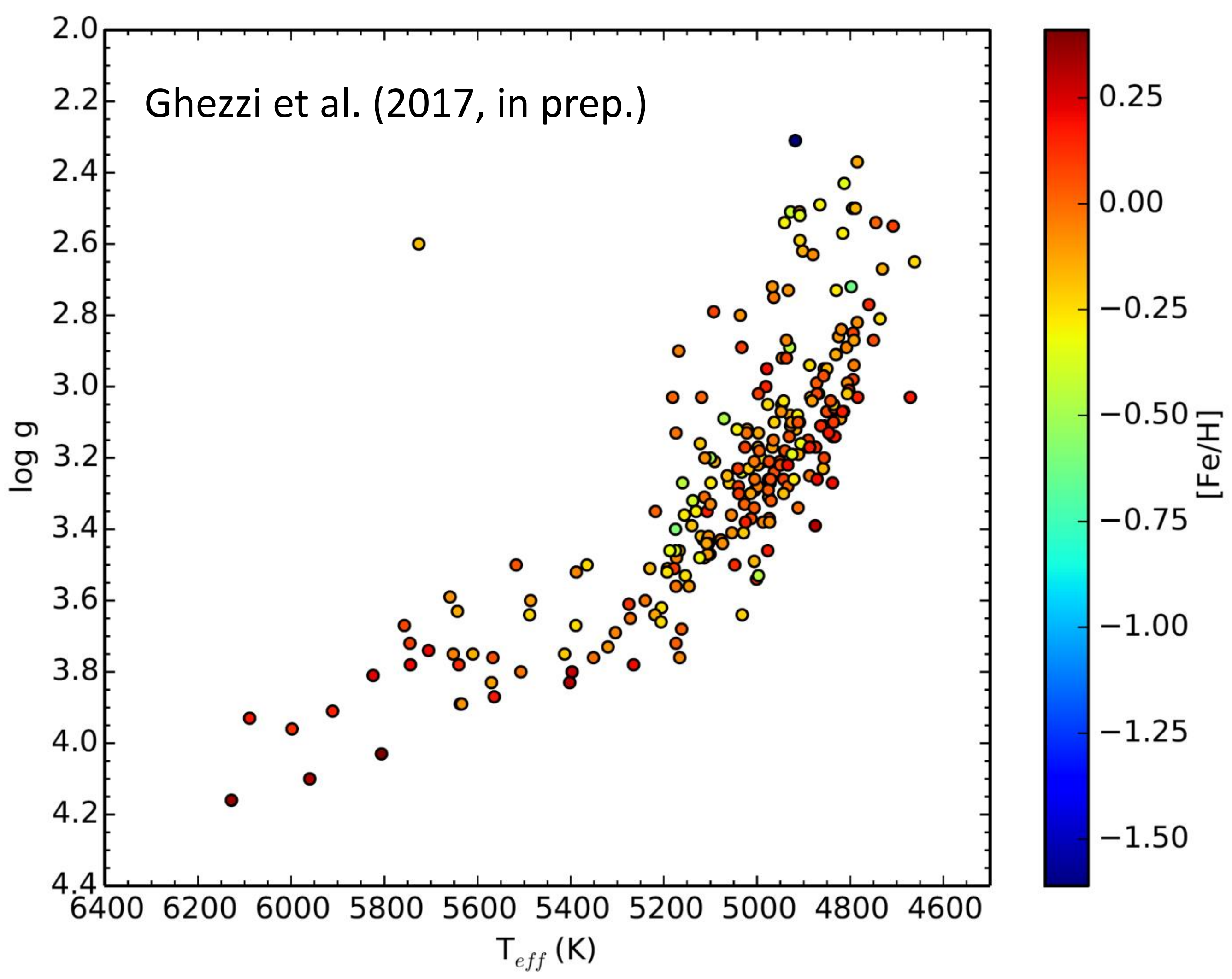
$$\langle \Delta M \rangle = -0.10 \pm 0.05\ M_\odot$$

$$\left\langle \frac{\Delta M}{M_{Ref.}} \right\rangle = -1.30 \pm 2.42\ \%$$

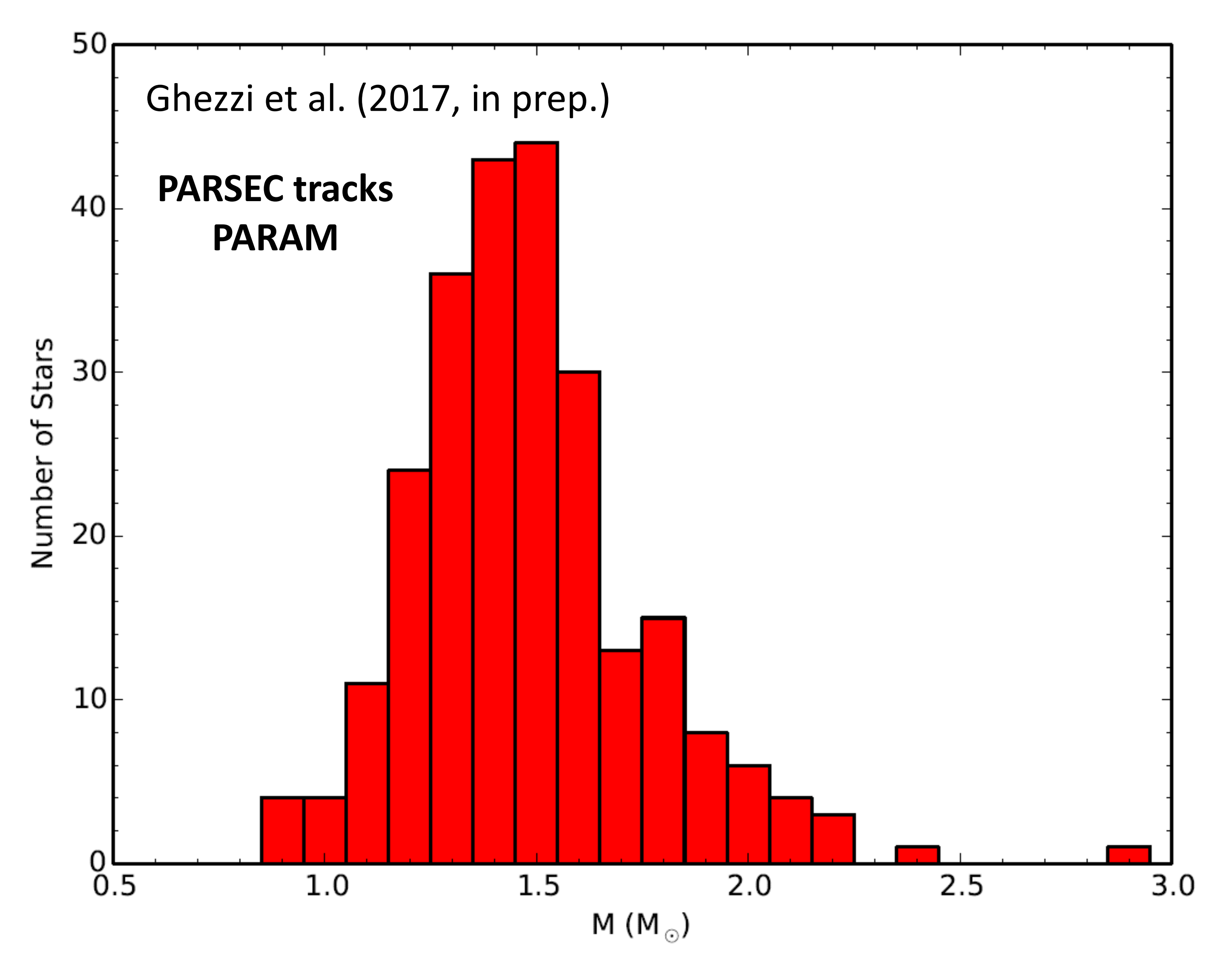
- Stars in binary systems: 26
- Single stars with asteroseismology: 33
- Model-dependent masses calculated with PARAM

Retired A Stars

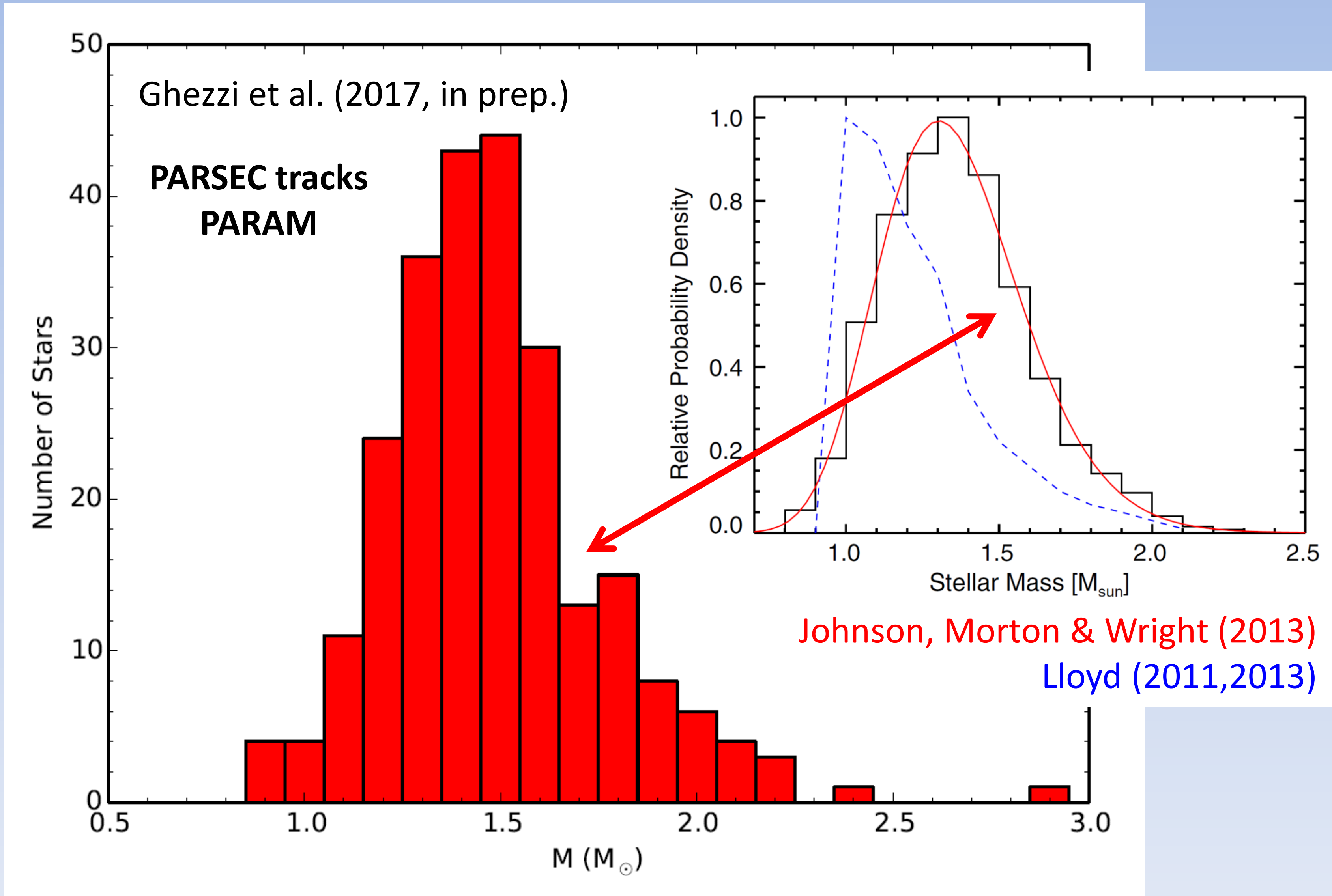
- Sample → 245 stars.
- Not the same as in Johnson et al. (2010)
- Keck/HIRES spectra → R ~ 65,000 and S/N ≥ 100.
- Classical spectroscopic analysis in LTE.



Stellar Masses

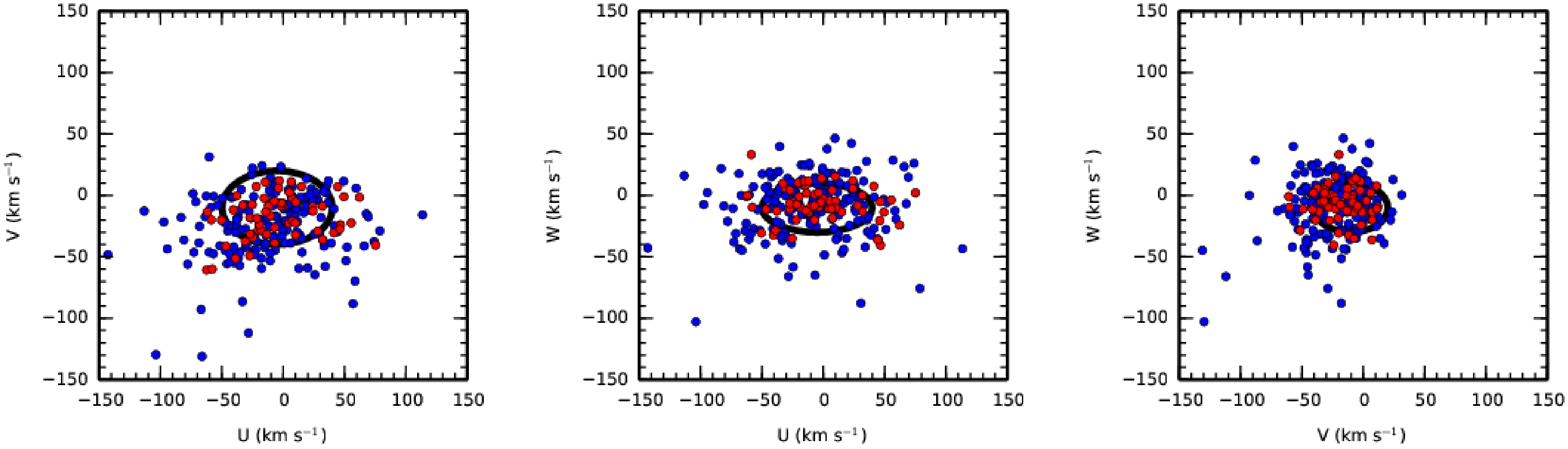


Stellar Masses



Kinematics

Ghezzi et al. (2017, in prep.)



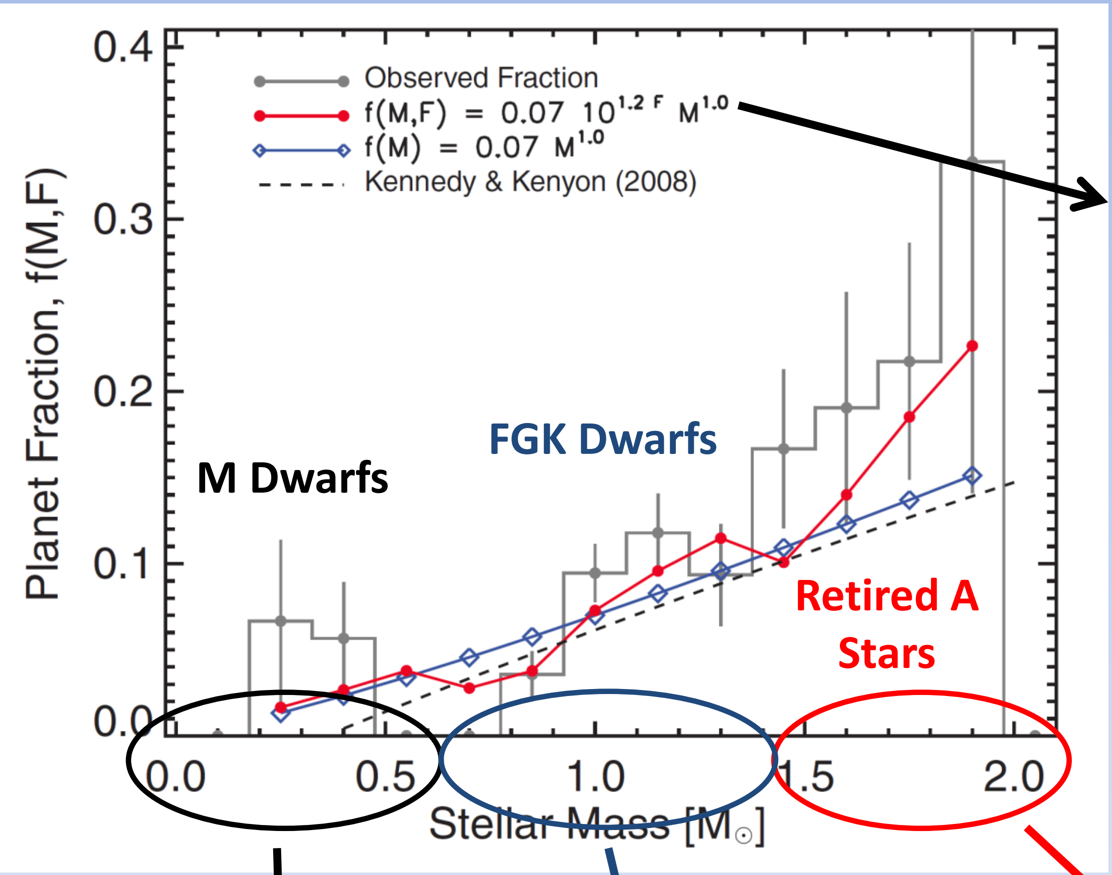
Stars with $M > 1.6\ M_{\odot}$

Stars with $M < 1.6\ M_{\odot}$

95% velocity ellipsoids for MS A5 – F0 stars

Schlaufman & Winn (2013)

Giant Planet Occurrence



$$f = C \times 10^{\beta[Fe/H]} \times M^{\alpha}$$

OR

$$f = C \times (10^{[Fe/H]} \times M)^{\gamma}$$

Bayesian analysis

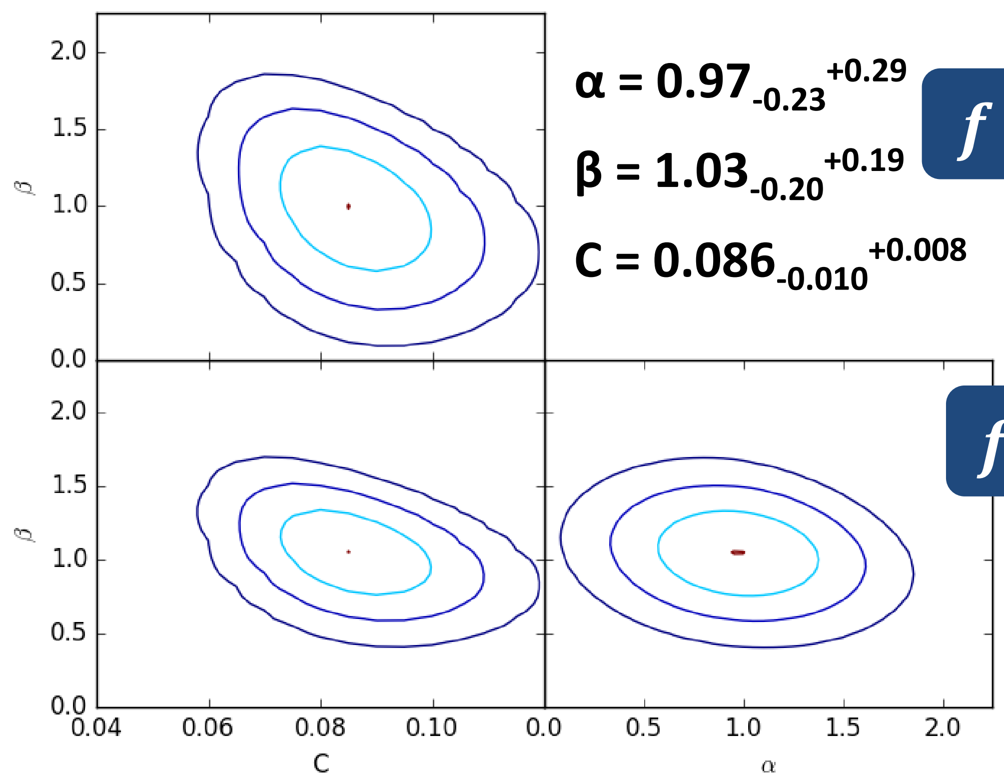
$M_{pl} \sin i \geq 0.5\ M_{Jup}$

Montet et al. (2014)

Johnson et al. (2010)
Brewer et al. (2016)

Ghezzi et al. (2017, in prep.)

Giant Planet Occurrence



$\alpha = 0.97_{-0.23}^{+0.29}$

$\beta = 1.03_{-0.20}^{+0.19}$

$C = 0.086_{-0.010}^{+0.008}$

$$f = 0.086 \times 10^{1.03[Fe/H]} \times M^{0.97}$$

OR

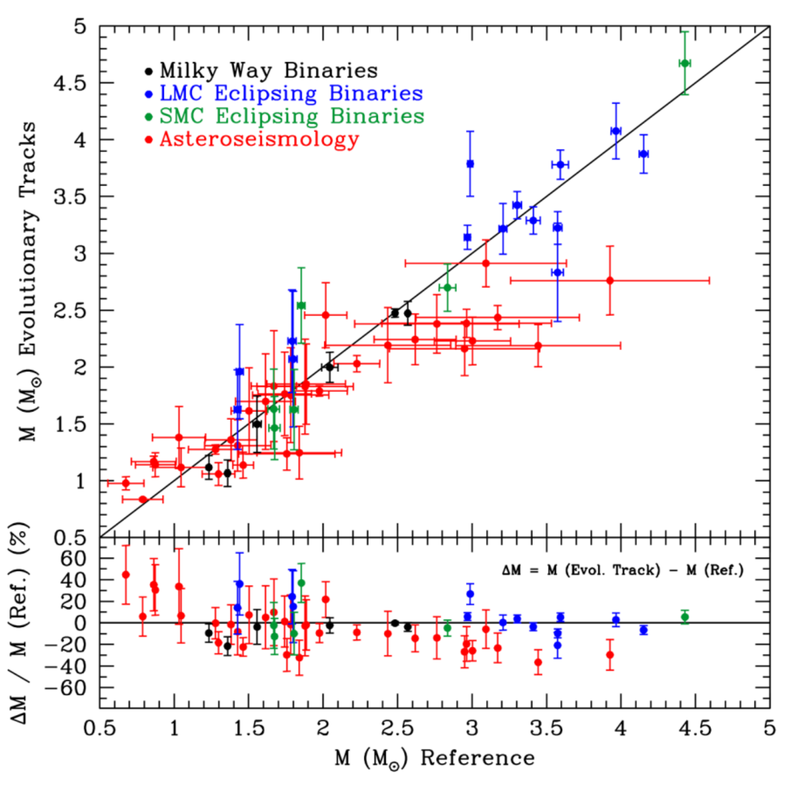
$$f = 0.085 \times (10^{[Fe/H]} \times M)^{1.01}$$

$\gamma = 1.01_{-0.14}^{+0.14}$

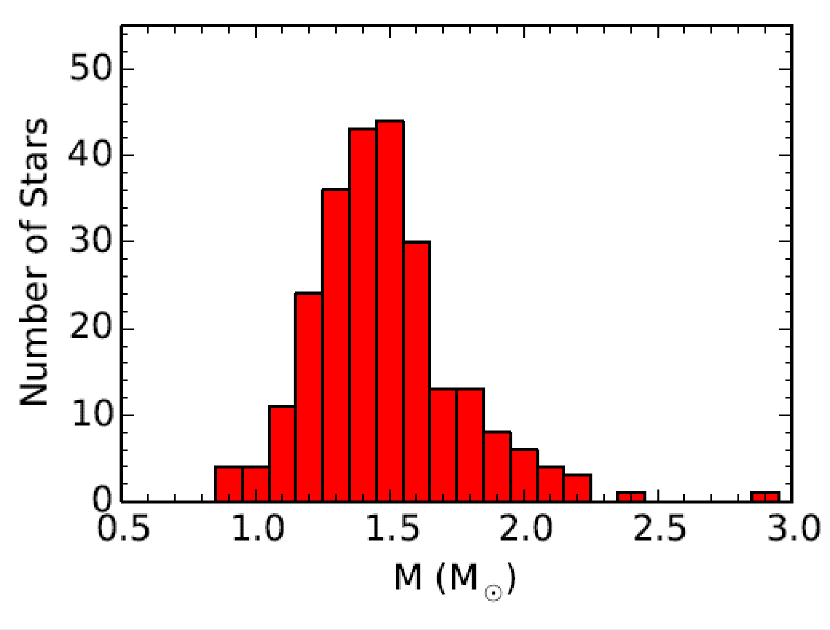
$C = 0.085_{-0.008}^{+0.009}$

Giant planet occurrence could be directly proportional to the overall metal content of the protoplanetary disk

Take Away Messages



Evolutionary tracks (PARSEC + PARAM) provide reliable masses for evolved stars



Retired A stars are indeed massive

(see also Stassun et al. 2017)

Stellar mass – giant planet connection is real

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Thank you!

XXII Ciclo de Cursos Especiais

21 – 24 August 2017

Dr. R. Paul Butler