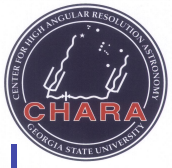


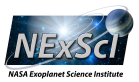

# A complete CHARActerization of the HD189733 and the HD209458 systems

Tabetha Boyajian

Kaspar von Braun, Gregory A. Feiden, Daniel Huber, Sarbani Basu, Pierre Demarque, Debra A. Fischer, Gail Schaefer, Andrew W. Mann, Timothy R. White, Vicente Maestro, John Brewer, C. Brooke Lamell, Federico Spada, Mercedes Lopez-Morales, Michael Ireland, Chris Farrington, Gerard T. van Belle, Stephen R. Kane, Jeremy Jones, Theo A. ten Brummelaar, David R. Ciardi, Harold A. McAlister, Stephen Ridgway, P. J. Goldfinger, Nils H. Turner, Laszlo Sturmann









Full article: Boyajian et al. 2015, MNRAS, 447, 846

# Stellar Diameters and Temperatures VI. High angular resolution measurements of the transiting exoplanet host stars HD 189733 and HD 209458 and implications for models of cool dwarfs

Tabetha Boyajian[1⋆], Kaspar von Braun[2,3,4], Gregory A. Feiden[5], Daniel Huber[6,7], Sarbani Basu[1], Pierre Demarque[1], Debra A. Fischer[1], Gail Schaefer[8], Andrew W. Mann[9,10], Timothy R. White[11], Vicente Maestro[12], John Brewer[1], C. Brooke Lamell[1], Federico Spada[13], Mercedes López-Morales[14], Michael Ireland[15], Chris Farrington[8], Gerard T. van Belle[4], Stephen R. Kane[16], Jeremy Jones[17], Theo A. ten Brummelaar[8], David R. Ciardi[18], Harold A. McAlister[17], Stephen Ridgway[19], P. J. Goldfinger[8], Nils H. Turner[8], and Laszlo Sturmann[8]

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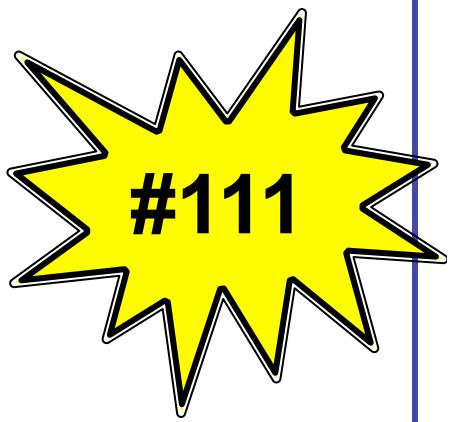
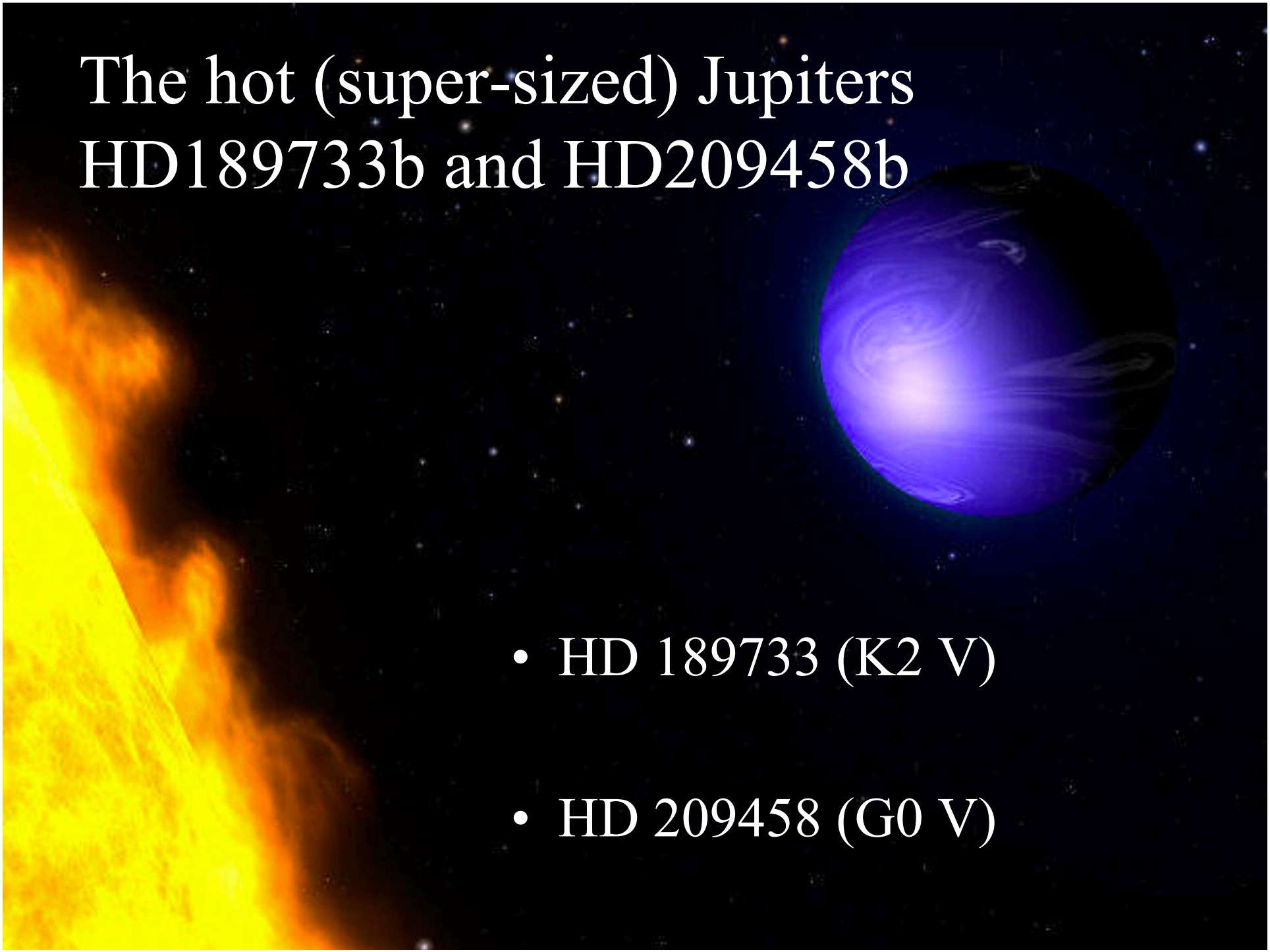
[19] *NOAO, Tucson, AZ, USA*

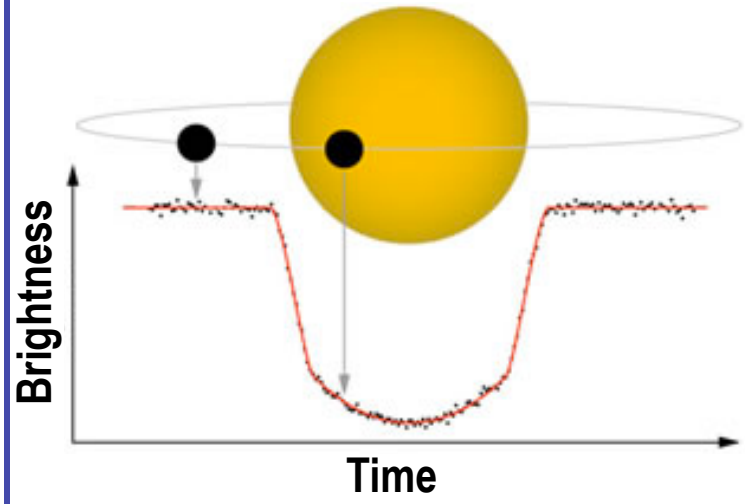


# The hot (super-sized) Jupiters HD189733b and HD209458b



- HD 189733 (K2 V)
- HD 209458 (G0 V)

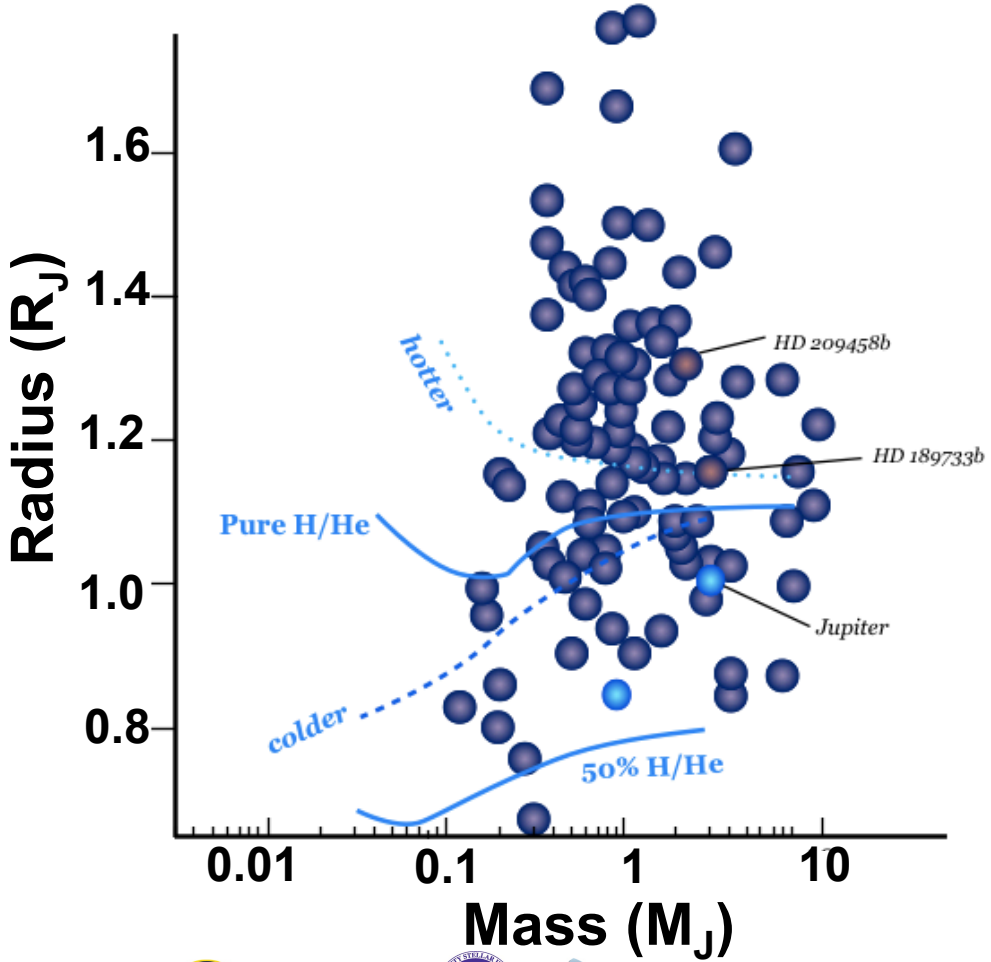
# Planet radii




Depth = $(R_{pl}/R^*)^2$

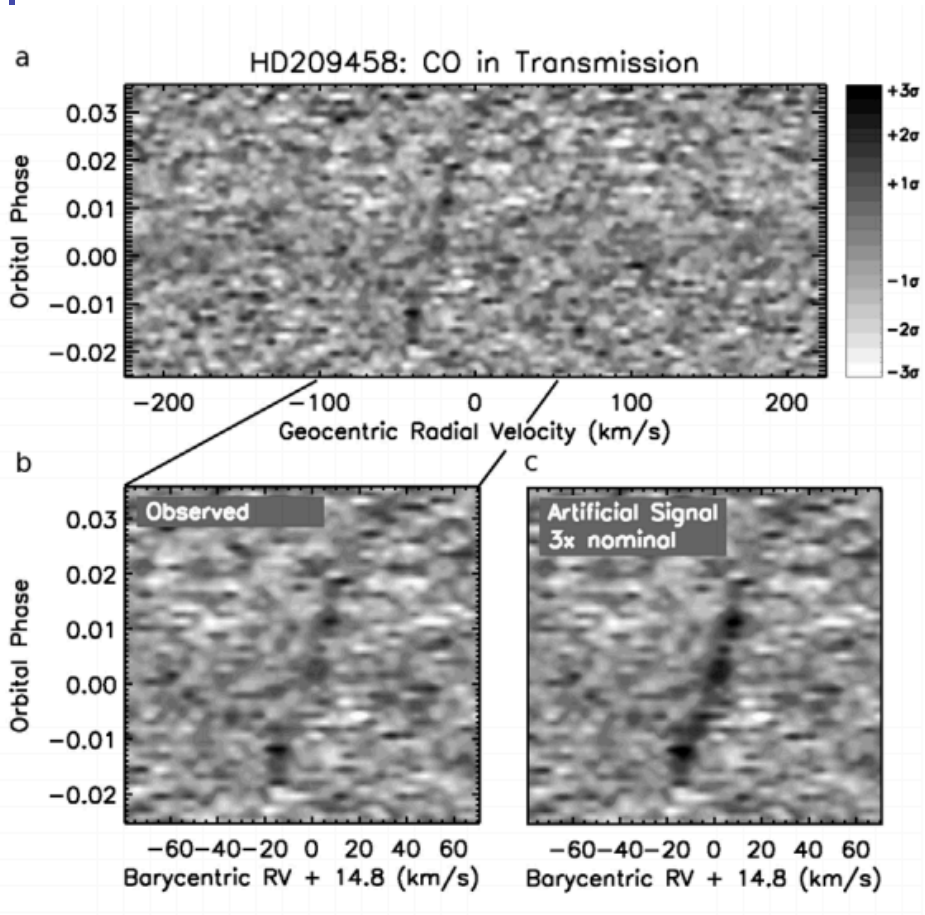
Host star radius must be known!

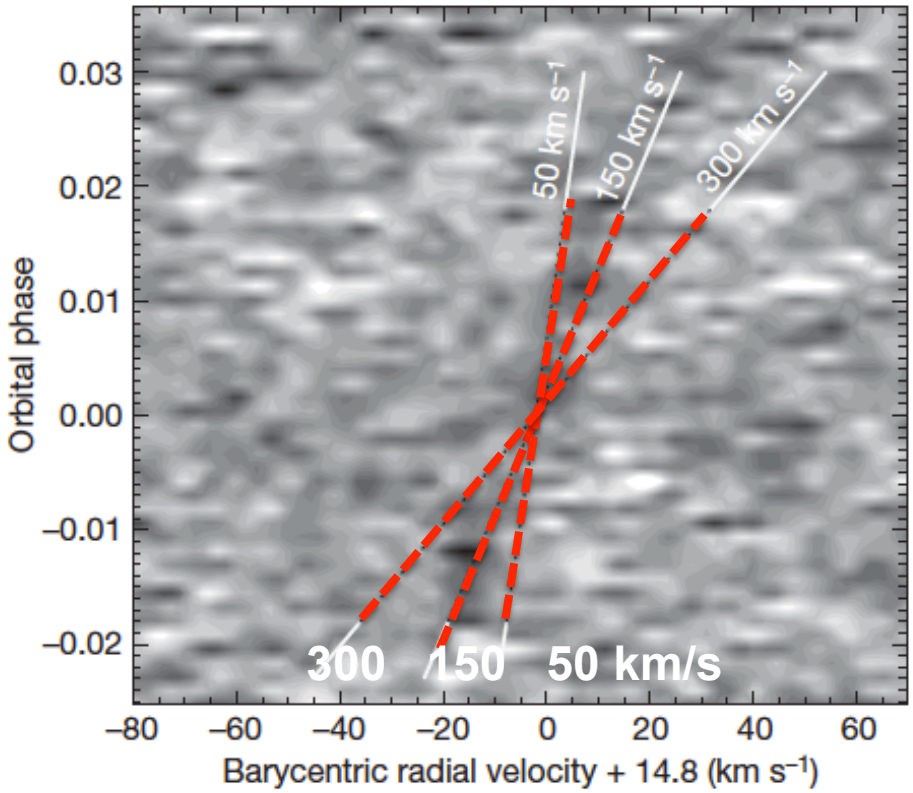
# The "radius anomaly"



# Using the **planet** to learn about the star (special cases)

- The **planet's** RVs are observed for the transiting systems HD 189733 and HD 209458 → measured masses

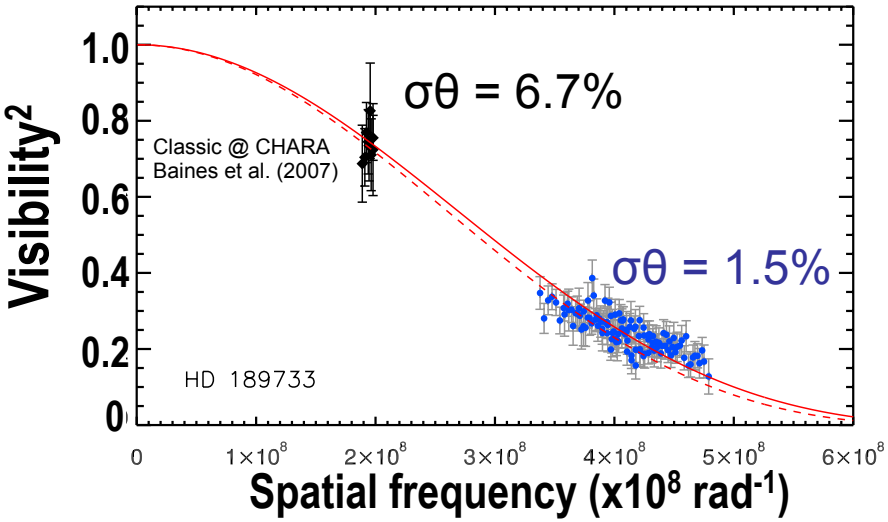


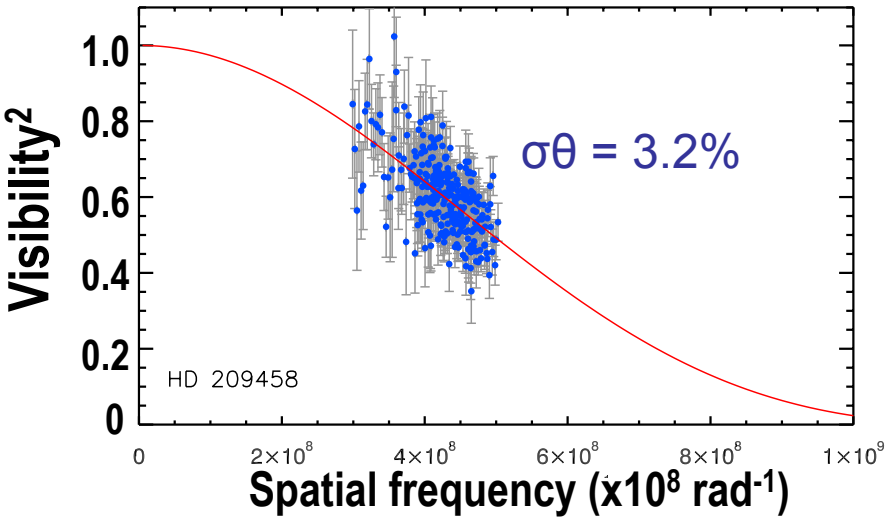



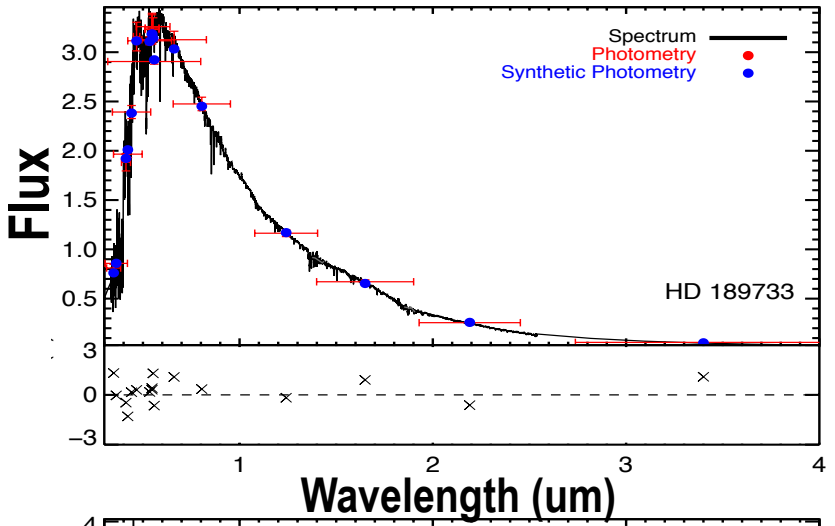

Snellen et al. (2010)

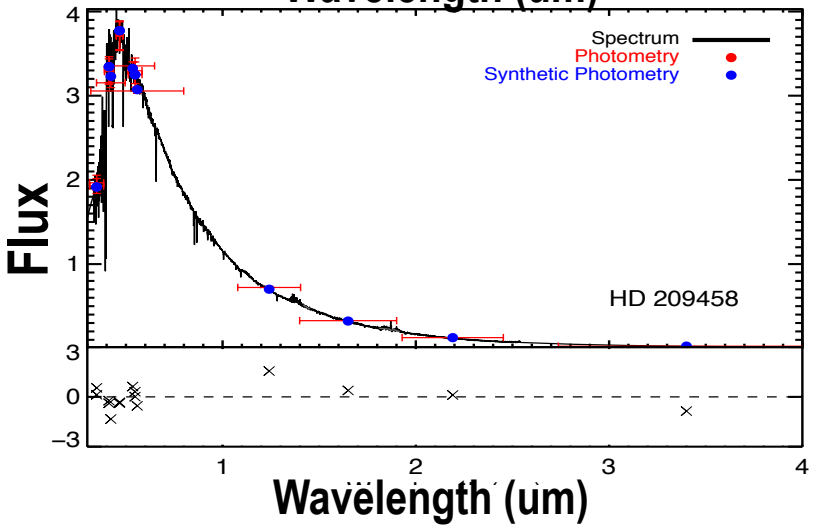
## Interferometry:
PAVO @ CHARA
Baselines > 300m

## Spectrophotometry:
Visible: SNIFS (.32 -.97um; R~1000)
IR: uSpeX (0.7 – 2.5 um; R~400)



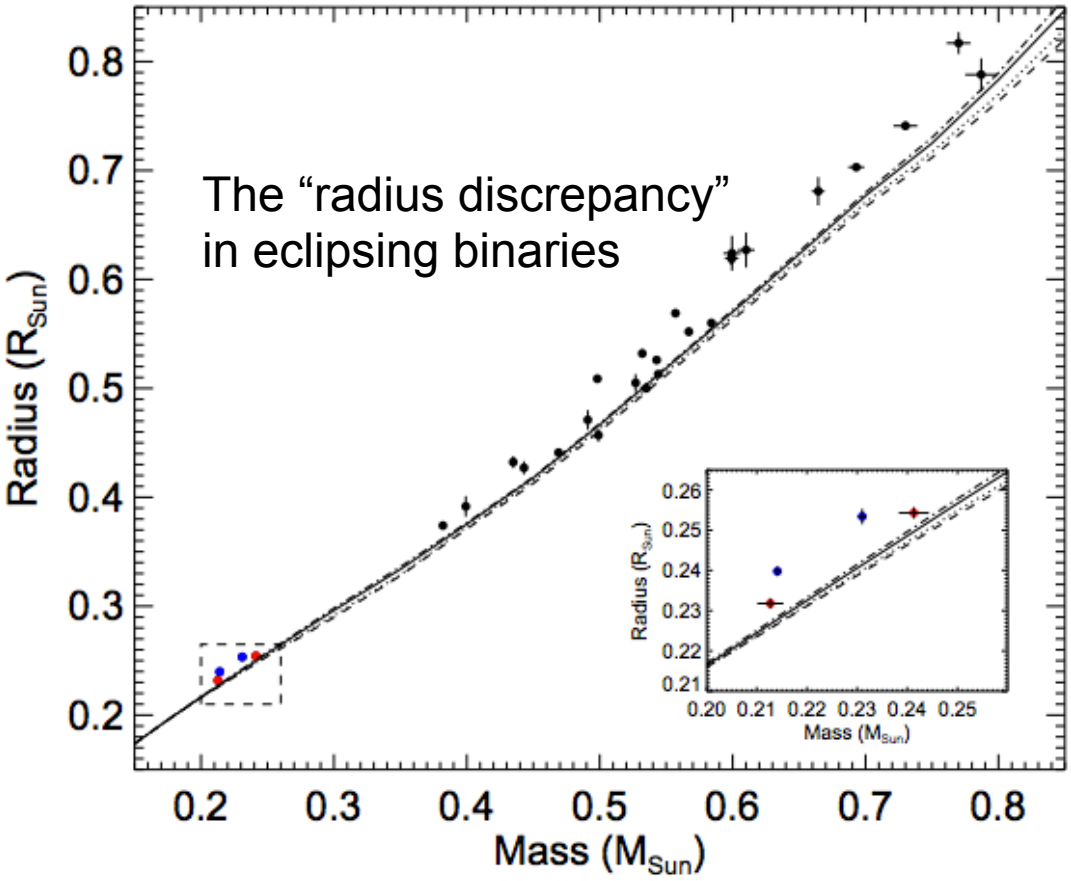



# Model independent properties for both star and planet

| | HD 189733 | | HD 209458 | |
|---|---|---|---|---|
| Property | Value | Reference | Value | Reference |
| $\theta_{\rm LD}$ (mas) | $0.3848 \pm 0.0055$ | this work (§ 2.1) | $0.2254 \pm 0.0072$ | this work (§ 2.1) |
| $F_{\rm Bol}$ ($10^{-8}$ erg s$^{-1}$ cm$^{-2}$) | $2.785 \pm 0.058$ | this work (§ 2.3) | $2.331 \pm 0.051$ | this work (§ 2.3) |
| $L_*$ ($L_\odot$) | $0.328 \pm 0.011$ | this work (§ 3.1) | $1.788 \pm 0.147$ | this work (§ 3.1) |
| $R_*$ ($R_\odot$) | $0.805 \pm 0.016$ | this work (§ 3.1) | $1.203 \pm 0.061$ | this work (§ 3.1) |
| $T_{\rm eff}$ (K) | $4875 \pm 43$ | this work (§ 3.1) | $6092 \pm 103$ | this work (§ 3.1) |
| [Fe/H] (dex) | $-0.03 \pm 0.08$ | Torres et al. (2008) | $0.00 \pm 0.05$ | Torres et al. (2008) |
| $R_{\rm p}/R_*$ | $0.155313 \pm 0.000188$ | Agol et al. (2010) | $0.12403 \pm 0.00043$ | Beaulieu et al. (2010) |
| $R_{\rm p}$ ($R_{\rm Jup}$) | $1.216 \pm 0.024$ | this work (§ 3.2) | $1.451 \pm 0.074$ | this work (§ 3.2) |
| $M_*$ ($M_\odot$) | $0.846 \pm 0.049$ | de Kok et al. (2013) | $1.00 \pm 0.22$ | Snellen et al. (2010) |
| $M_{\rm p}$ ($M_{\rm Jup}$) | $1.162 \pm 0.058$ | de Kok et al. (2013) | $0.64 \pm 0.09$ | Snellen et al. (2010) |
| $\log g_{\rm p}$ | $3.29 \pm 0.02$ | this work (§ 3.2) | $2.88 \pm 0.07$ | this work (§ 3.2) |
| $\log g_*$ | $4.56 \pm 0.03$ | this work (§ 3.2) | $4.28 \pm 0.10$ | this work (§ 3.2) |
| $\rho_{\rm p}$ ($\rho_{\rm Jup}$) | $0.605 \pm 0.029$ | this work (§ 3.2) | $0.196 \pm 0.033$ | this work (§ 3.2) |
| $\rho_*$ ($\rho_\odot$) | $1.62 \pm 0.11$ | this work (§ 3.2) | $0.58 \pm 0.14$ | this work (§ 3.2) |

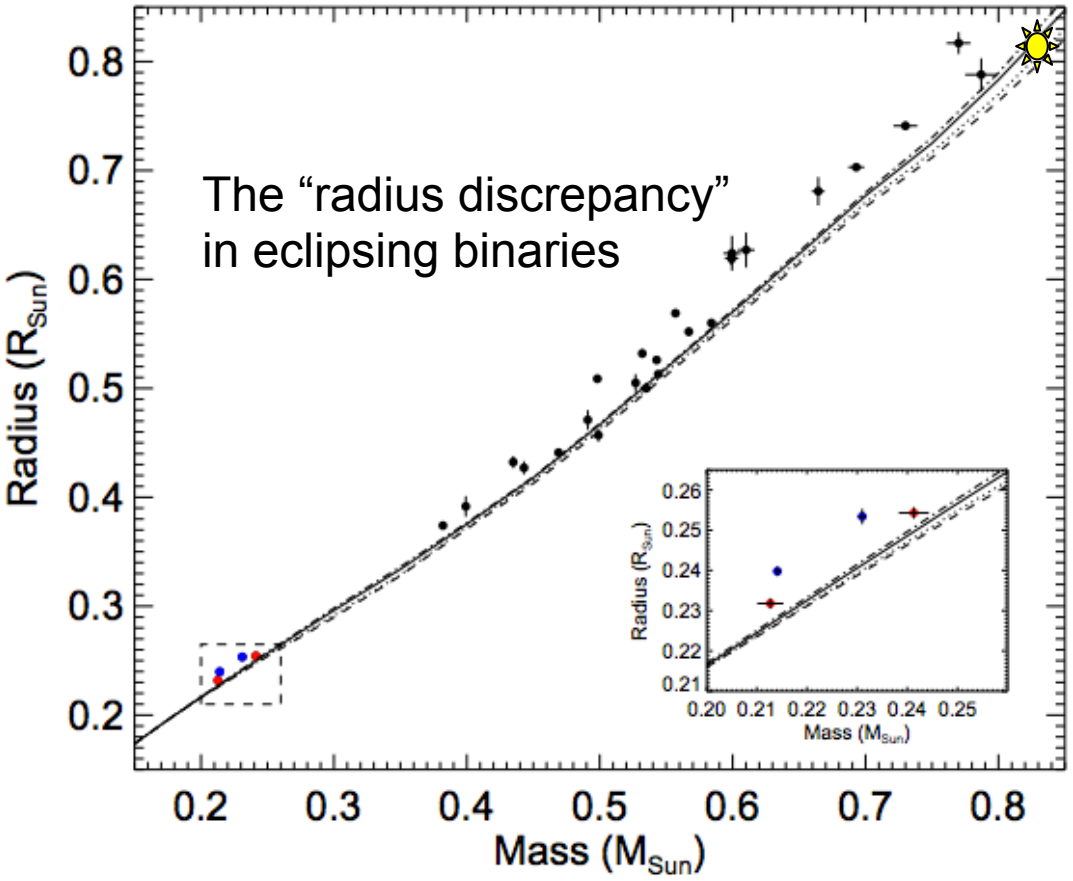
# Stellar mass and radius: Observations versus model predictions




→ Evolutionary models have a hard time reproducing the radius of a star at a given mass.

Figure from Carter et al. (2012)

# Stellar mass and radius: HD189733

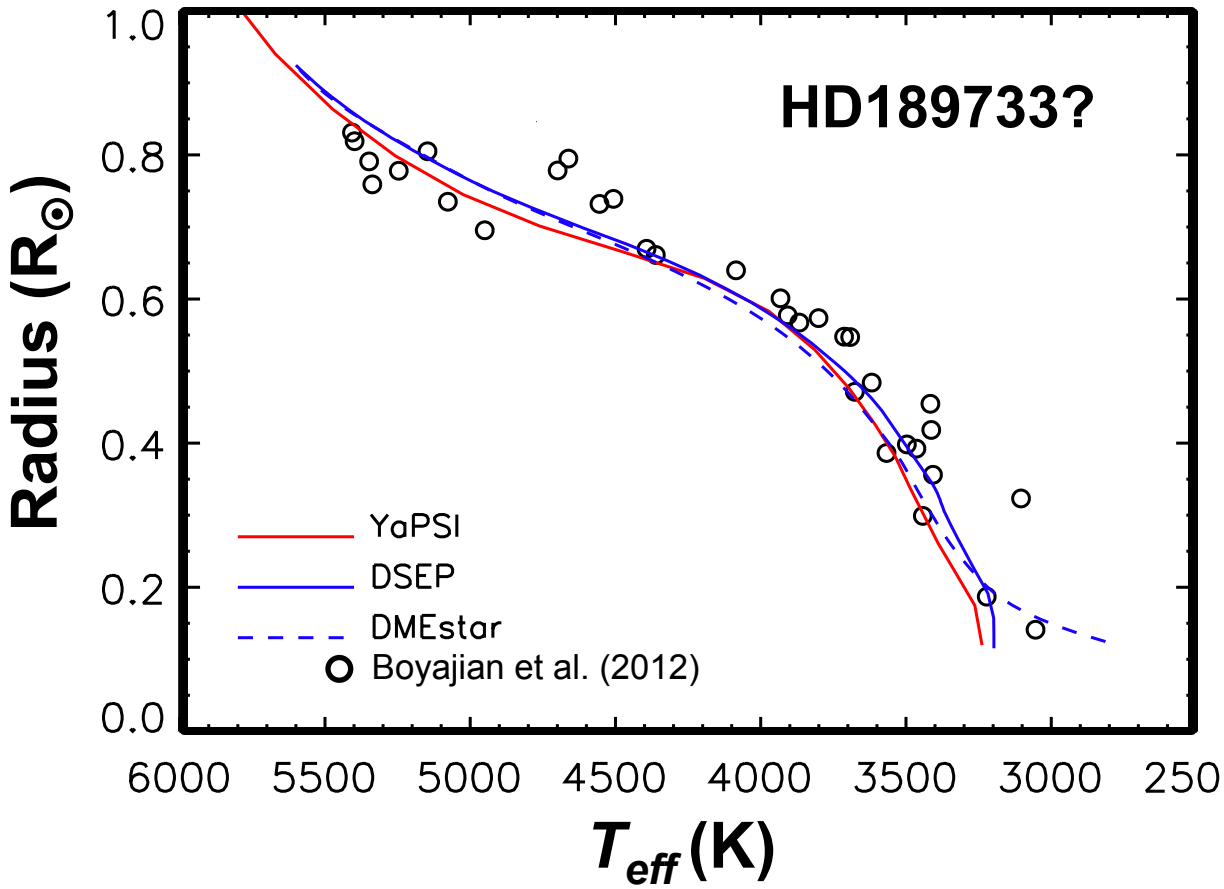



HD 189733

→ **Evolutionary models are in excellent agreement with measured Mass and Radius for HD 189733**

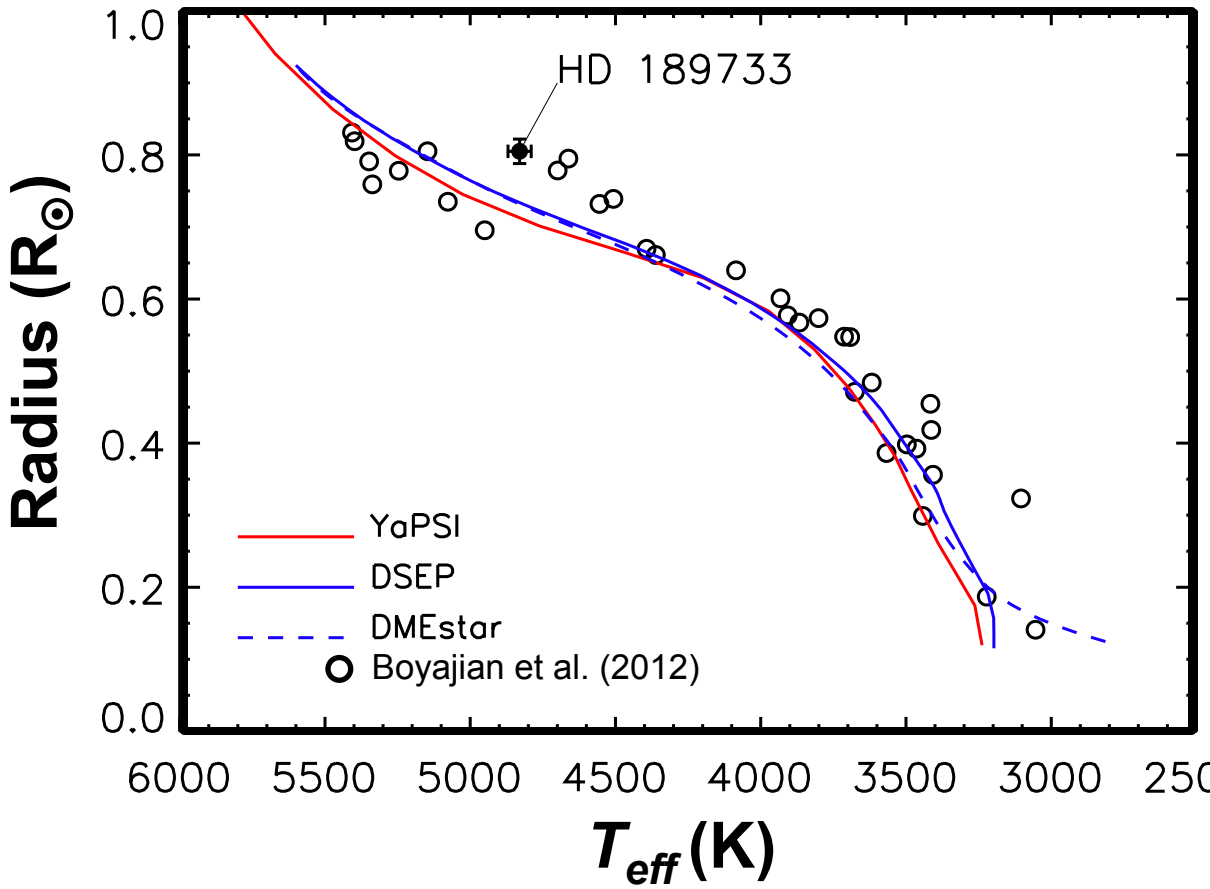
Figure from Carter et al. (2012)

# Stellar $T_{\rm eff}$ and radius: Observations versus model predictions

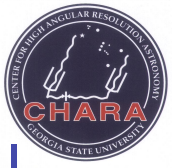



→ **Evolutionary models predict radii too small and $T_{\rm eff}$s too large compared to observations**

# Stellar $T_{\rm eff}$ and radius: HD189733



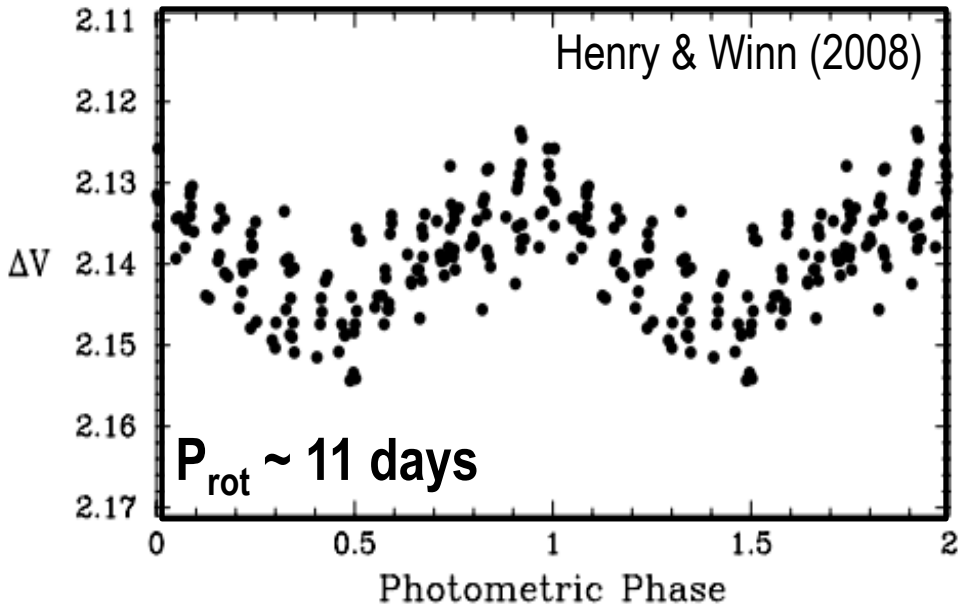

→ **Evolutionary models are NOT in excellent agreement with measured $T_{eff}$ and Radius for HD 189733**

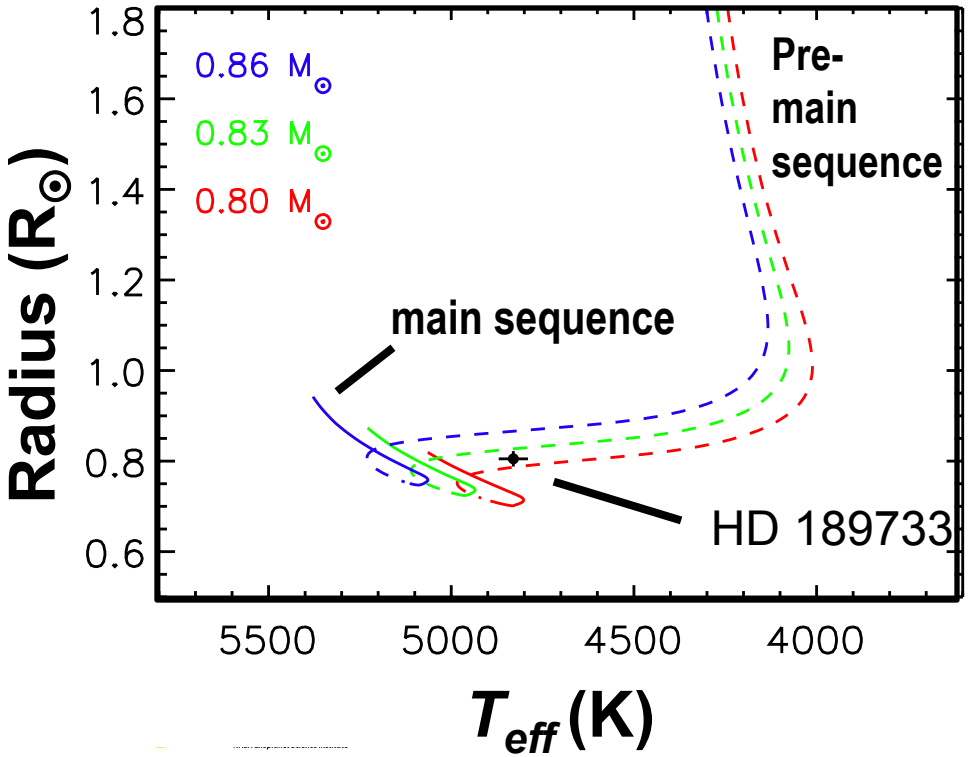



# WHY?

- HD 189733 mass and radius are in agreement, but not the Teff and radius → the luminosity is off by 35%!

- AGE
- COMPOSITION
  - Metallicity
  - α-element enhancement
  - Helium abundance
  - Solar mixture
- CONVECTION
  - Magneto-convection
  - Star spots
  - Reduced mixing length



- AGE
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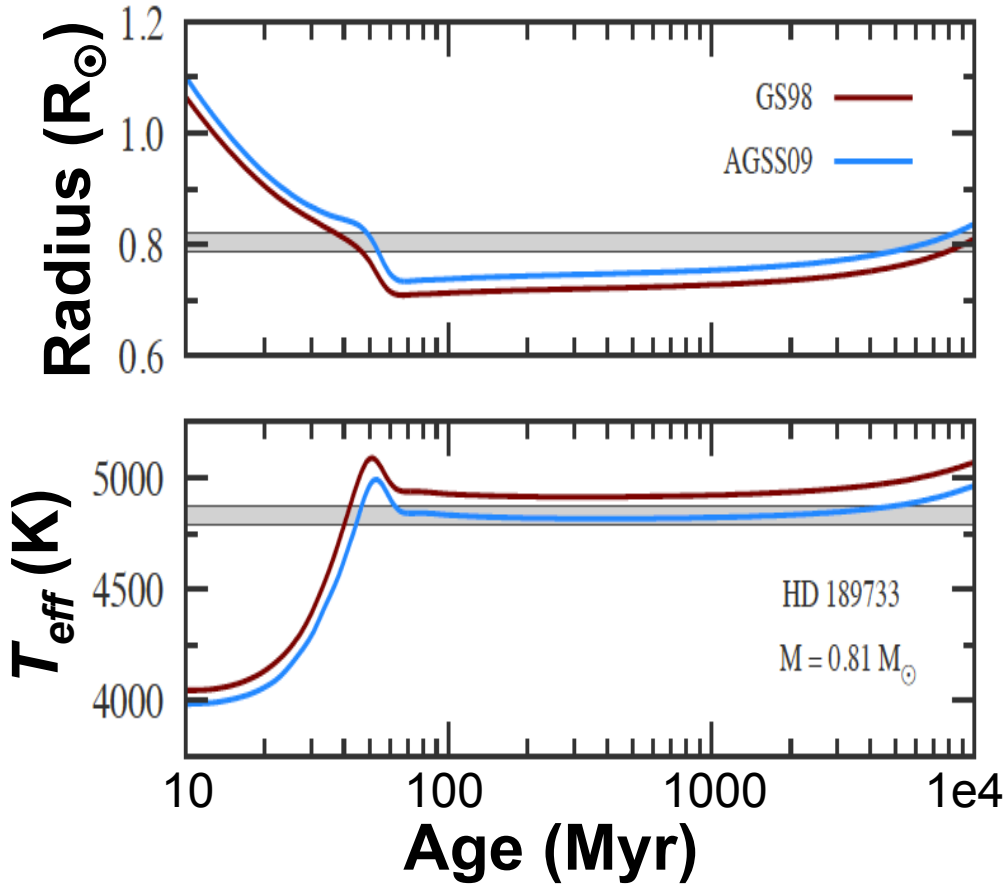
## Example:

**[Fe/H] = - 0.03 +/- 0.08**

(Bouchy et al. 2005; Torres et al. 2008)

**→ Models require [M/H] = + 0.2 (@ 10 Gyr)**



**< B*f* > ~ 40 – 100 G**
**(Moutou et al. 2007; Pillitteri et al. 2014)**

**→ Models require ~1.5kG**

- AGE
- COMPOSITION
  - Metallicity
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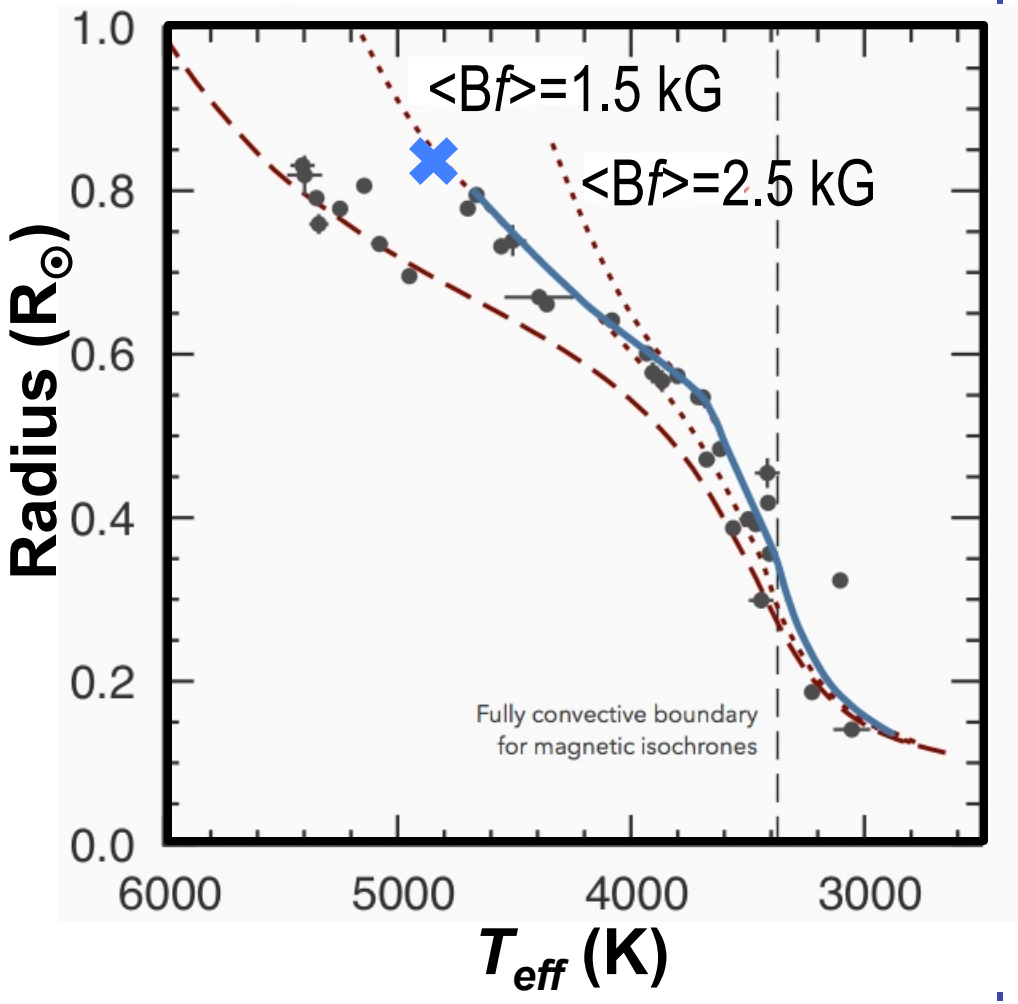


*DMEstar: Feiden & Chaboyer (2012, 2013), as described in Muirhead et al. (2014) and Malo et al. (2014)*

- AGE
- COMPOSITION
  - Metallicity
  - α-element enhancement
  - Helium abundance
  - Solar mixture
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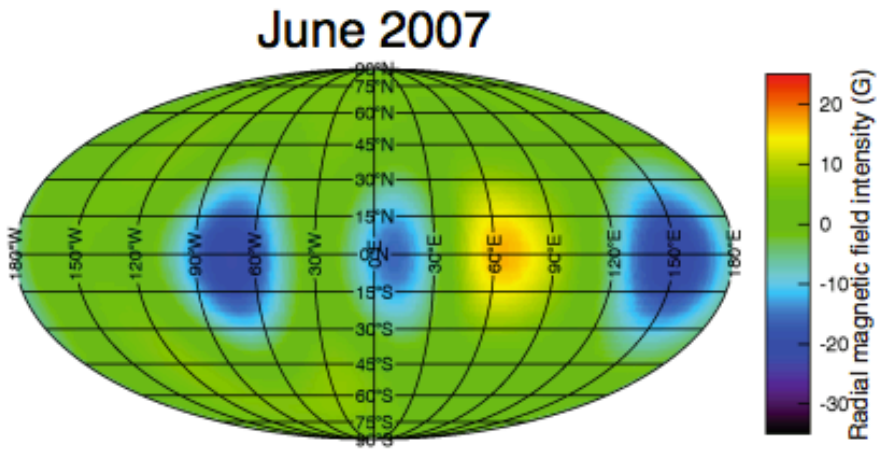
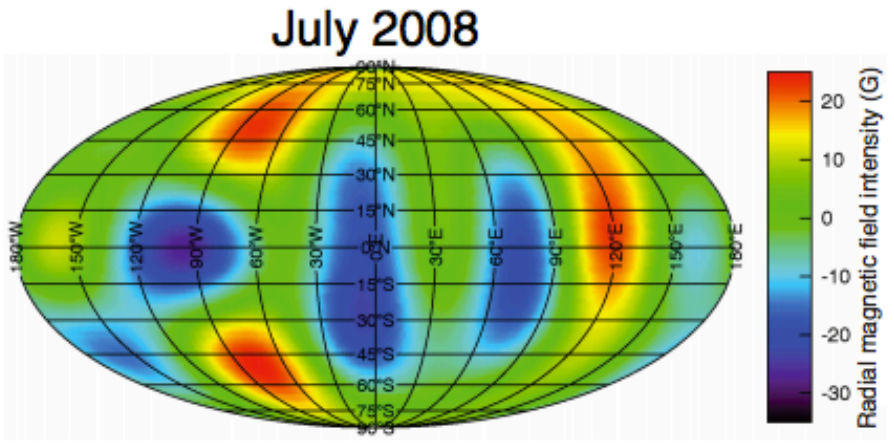
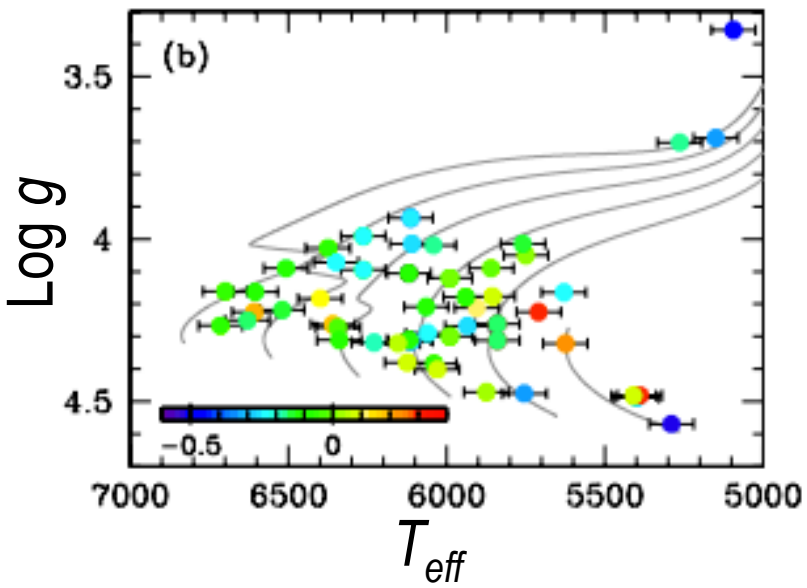
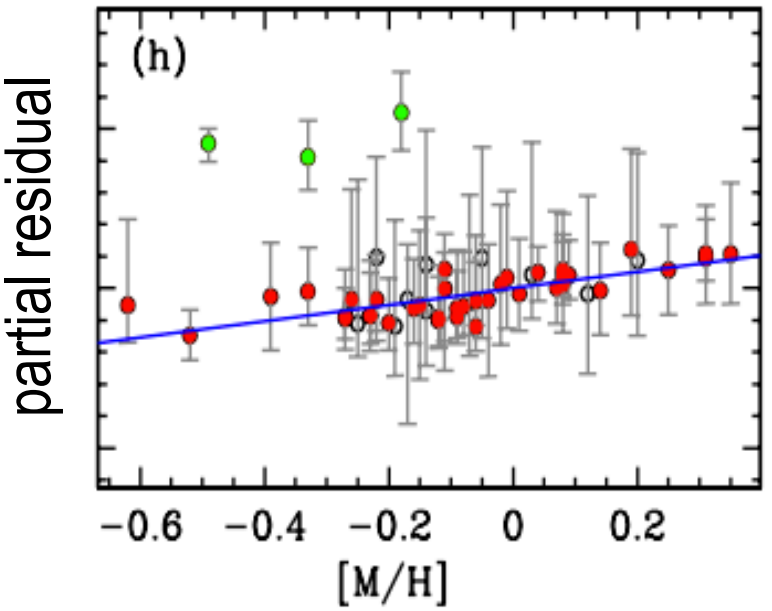



Fares et al. (2010); Llama et al. (2013)

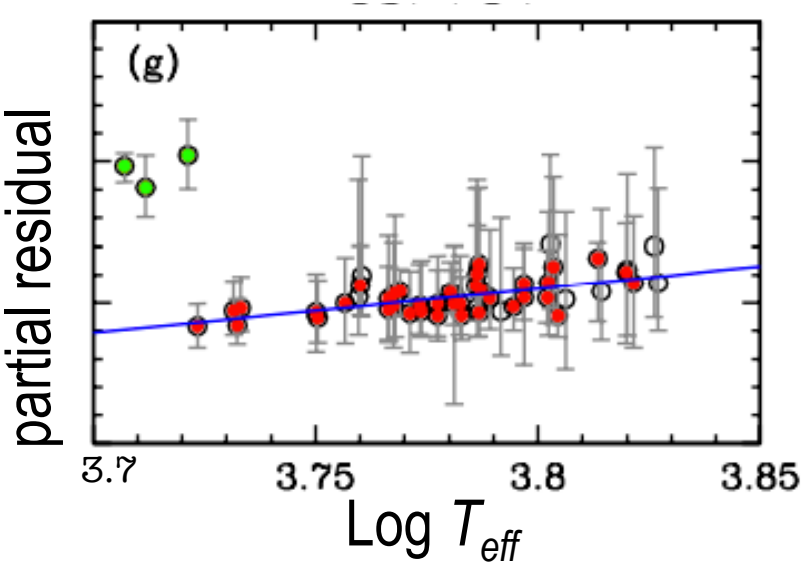
Bonaca et al. (2012)



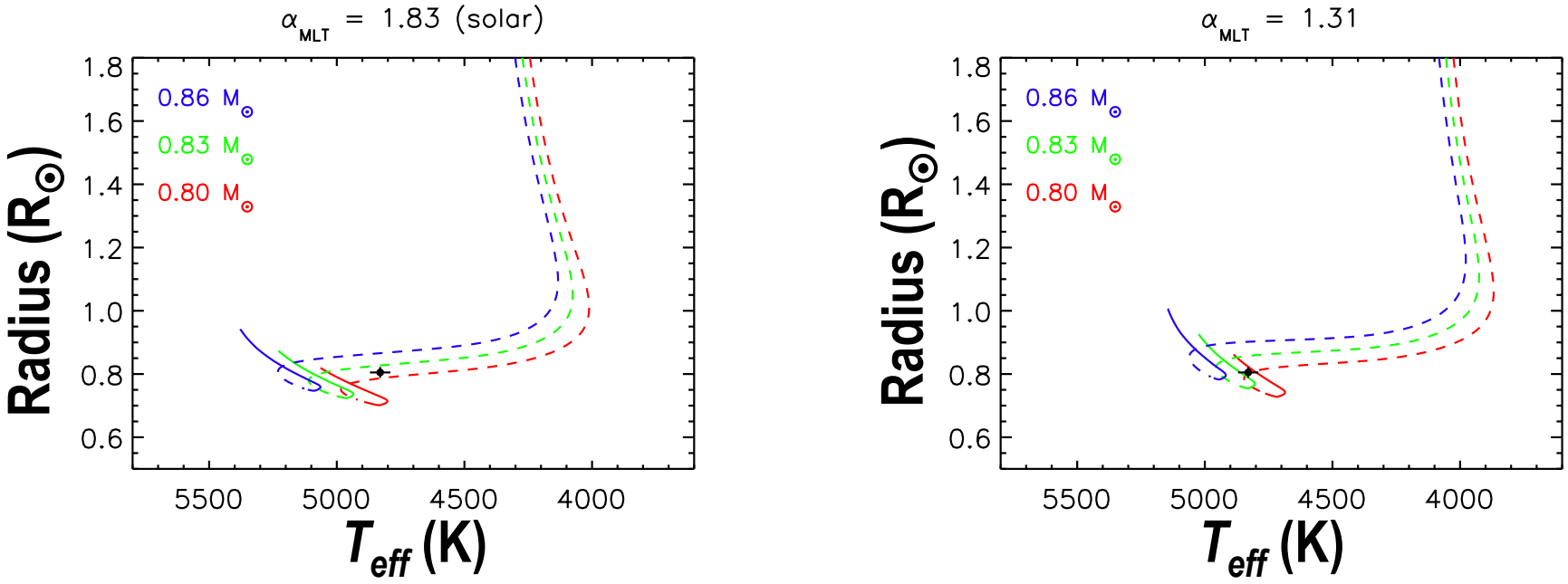




- A
- C
  - M
  - α-
  - Helium abundance
  - Solar mixture

- CONVECTION
  - Magneto-convection
  - Star spots
  - Reduced mixing length



# A physically correct model solution




YREC: MC modeling with mixing length and Helium set free (Helium limited to primordial)

Thank you.