Stellar Multiplicity Meets Stellar Evolution: the APOGEE view

Carles Badenes
University of Pittsburgh / PITT PACC

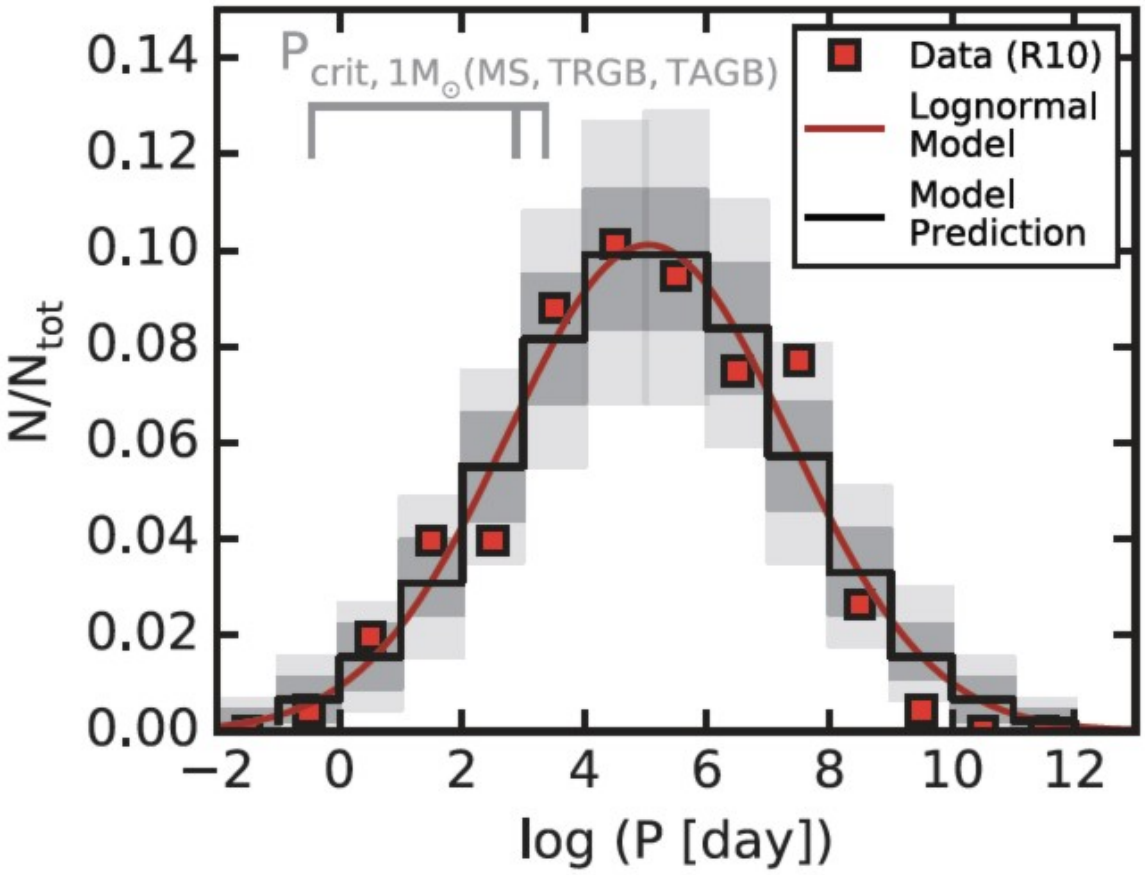
with Peter Freeman (CMU), Todd Thompson (OSU)
Kevin Covey (WWU), and the APOGEE RVVar team

ESO
July 7, 2017

Binaries and Stellar Evolution

Carles Badenes
ESO 07/07/17

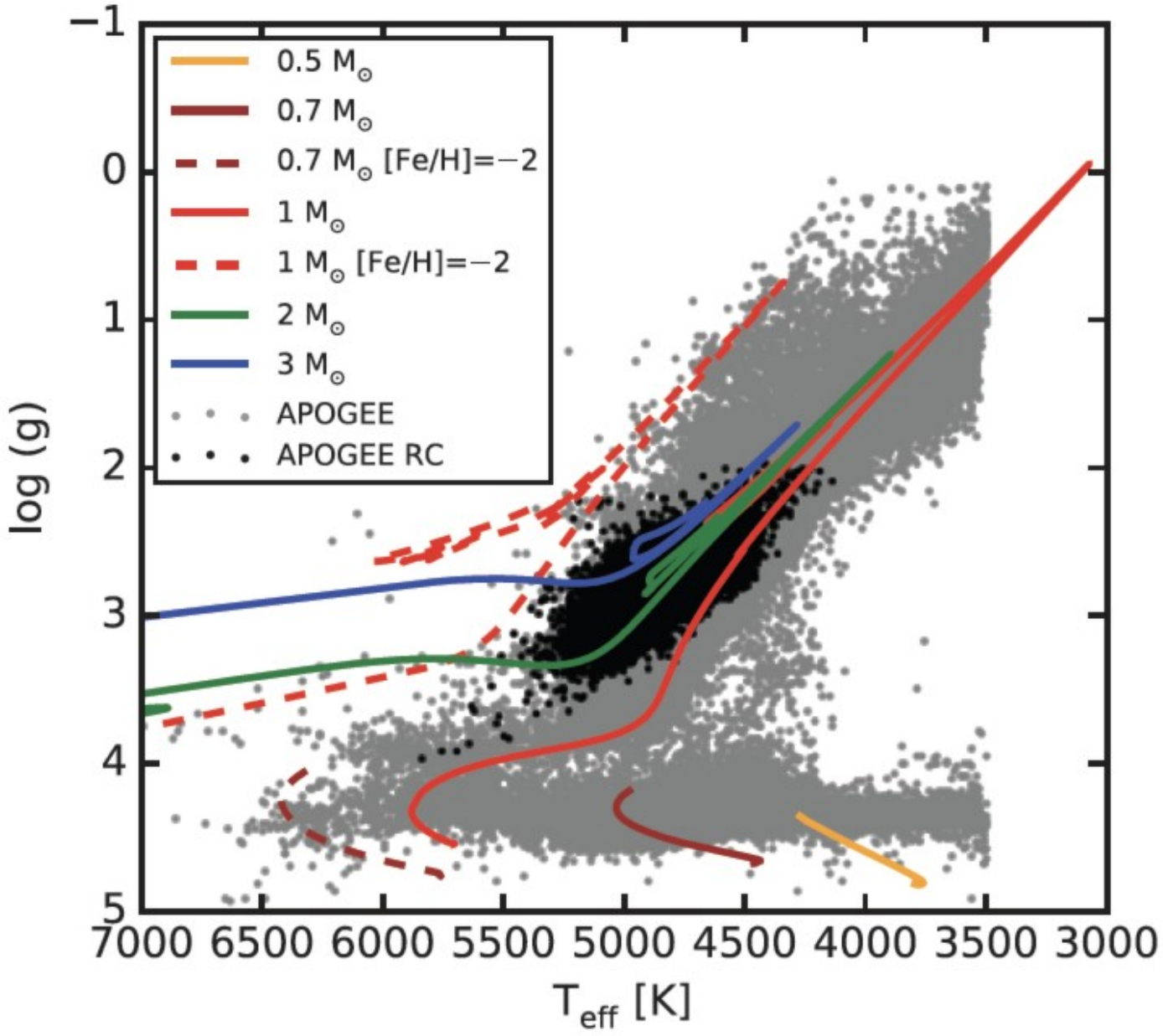
- **Moe talk** ⇒ stellar multiplicity statistics: f_m, P, q, e. Not independent!
- Relatively well known for Sun-like MS stars in the Solar neighborhood [Raghavan+ 10].
- **Pols, Moe talks** ⇒ What happens after the MS? What is the effect of [Fe/H]?
- **APOGEE** [Majewski+ 15] ⇒ Stellar multiplicity from the MS to the RC.



APOGEE

Carles Badenes
ESO 07/07/17

- Galactic evolution: Multi-epoch IR spectra R~20,000, ~10^5 stars, high S/N [Majewski+ 15].
- MS, RG and RC stars, M~1 M_{Sun}, most of MW disk [Zasowski+ 13].
- ASPCAP [Perez+ 16] $\Rightarrow$ T_{eff}, log(g), [Fe/H], **RVs**. RC catalog [Bovy+ 14]. The Cannon [Ness+ 15,16].



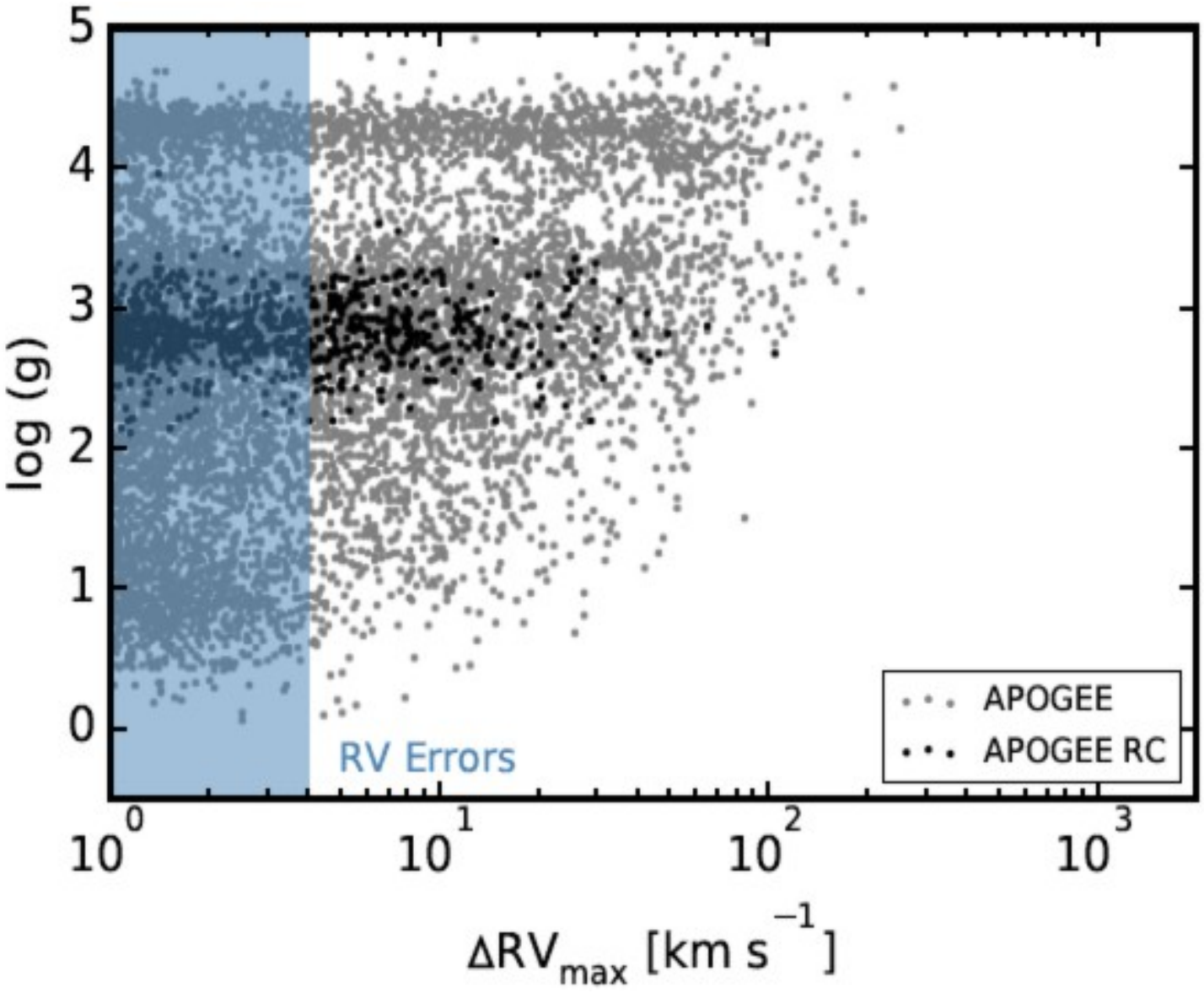
APOGEE: ΔRV_{max} vs. log(g)

Carles Badenes
ESO 07/07/17

- Few RVs/star (median is 3) ⇒ no orbits! [but Troup+ 16]

- Figure of merit: **ΔRV_{max}**. Multiple systems ⇒ $\Delta RV_{max} \gtrsim 4$ km/s (> 3,000).

- Trend of ΔRV_{max} with log(g): stellar multiplicity meets stellar evolution.



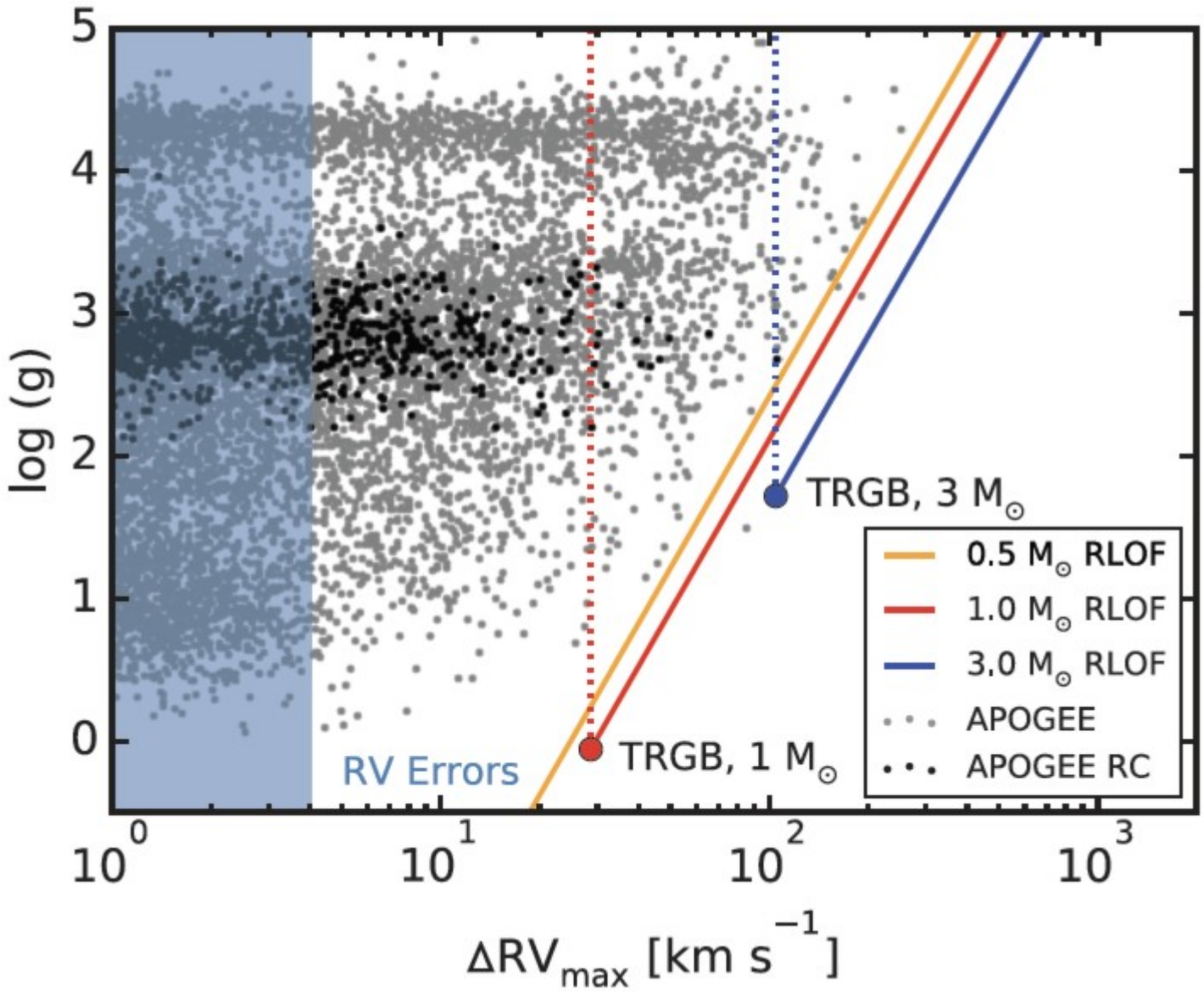
APOGEE: ΔRV_{max} vs. log(g)

Carles Badenes
ESO 07/07/17

- Few RVs/star (median is 3) ⇒ no orbits! [but Troup+ 16]

- Figure of merit: **ΔRV_{max}**. Multiple systems ⇒ $\Delta RV_{max} \gtrsim 4$ km/s (> 3,000).

- Trend of ΔRV_{max} with log(g): stellar multiplicity meets stellar evolution.



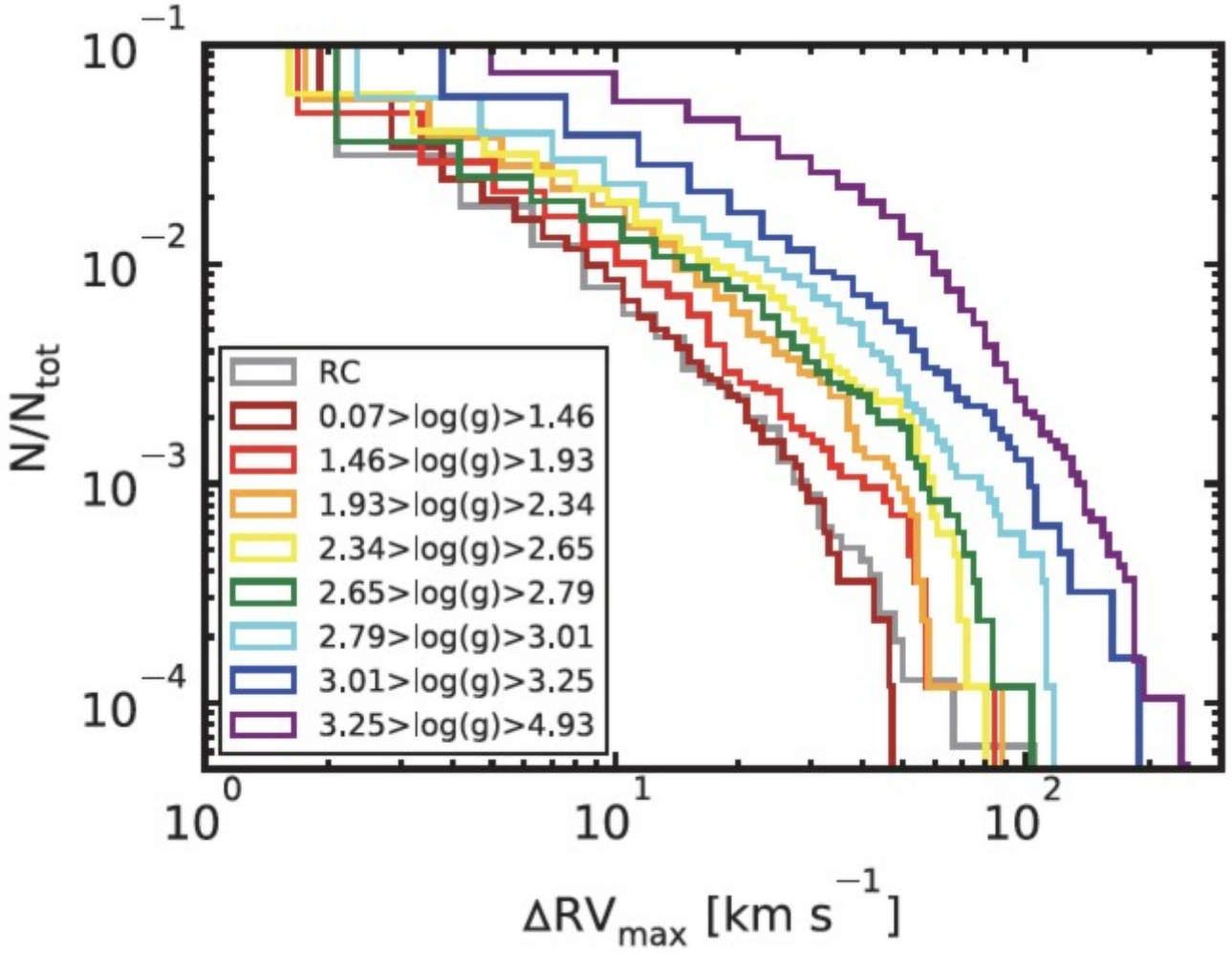
APOGEE: ΔRV_{max} vs. log(g)

Carles Badenes
ESO 07/07/17

- Few RVs/star (median is 3) ⇒ no orbits! [but Troup+ 16]

- Figure of merit: **ΔRV_{max}**. Multiple systems ⇒ $\Delta RV_{max} \gtrsim 4$ km/s (> 3,000).

- Clear trend of ΔRV_{max} with log(g): stellar multiplicity meets stellar evolution.



APOGEE: ΔRV_{max} vs. log(g)

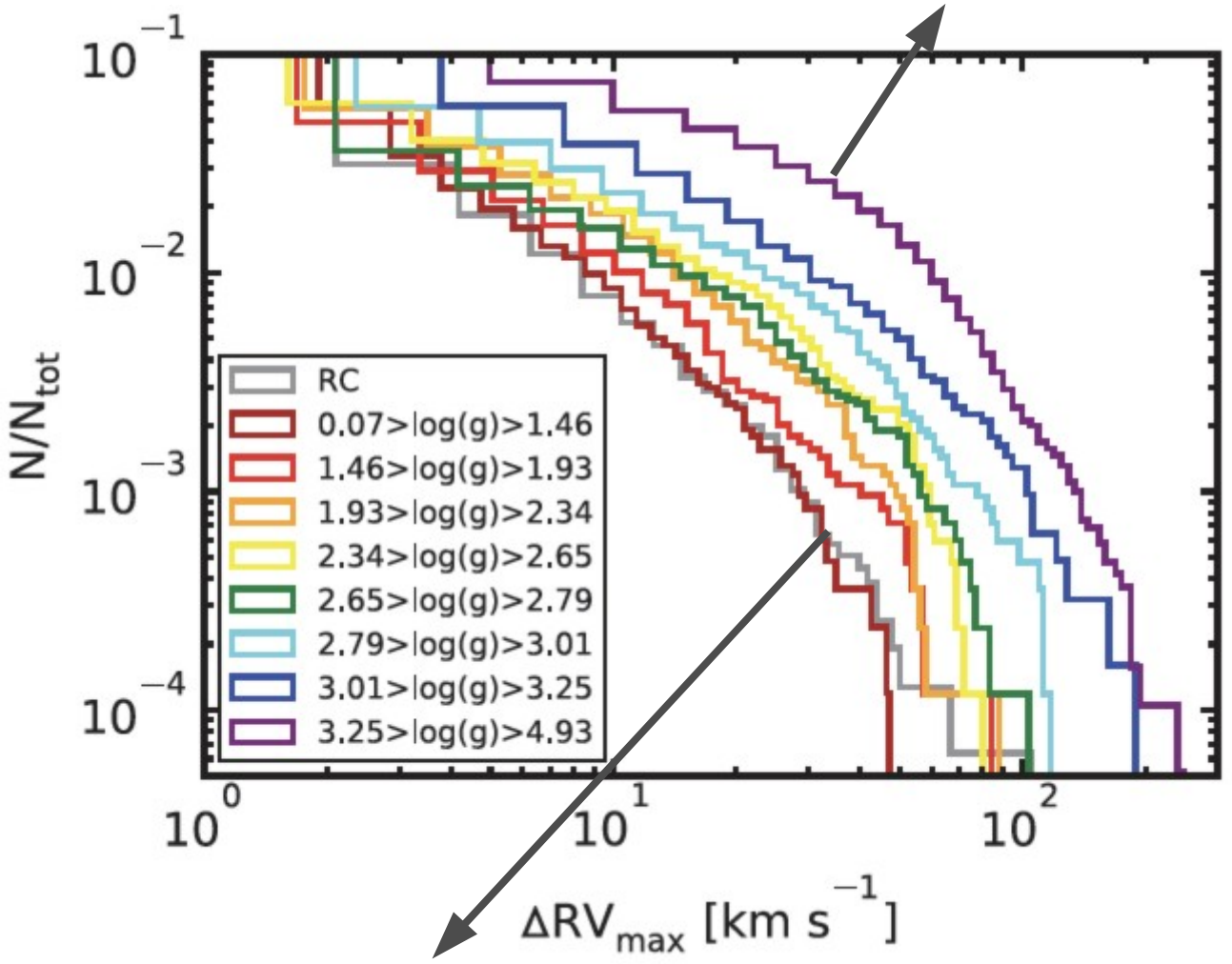
Carles Badenes
ESO 07/07/17

- Few RVs/star (median is 3) ⇒ no orbits! [but Troup+ 16]

- Figure of merit: **ΔRV_{max}**. Multiple systems ⇒ $\Delta RV_{max} \gtrsim 4$ km/s (> 3,000).

- Clear trend of ΔRV_{max} with log(g): stellar multiplicity meets stellar evolution.

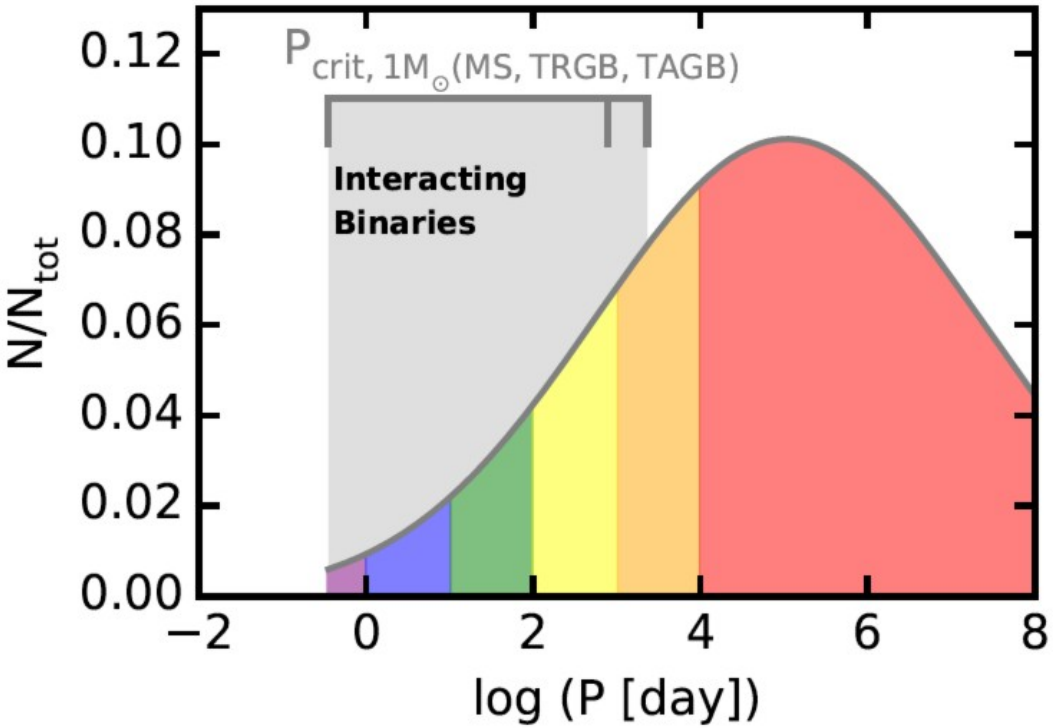
MS & subgiants: higher ΔRV_{max}

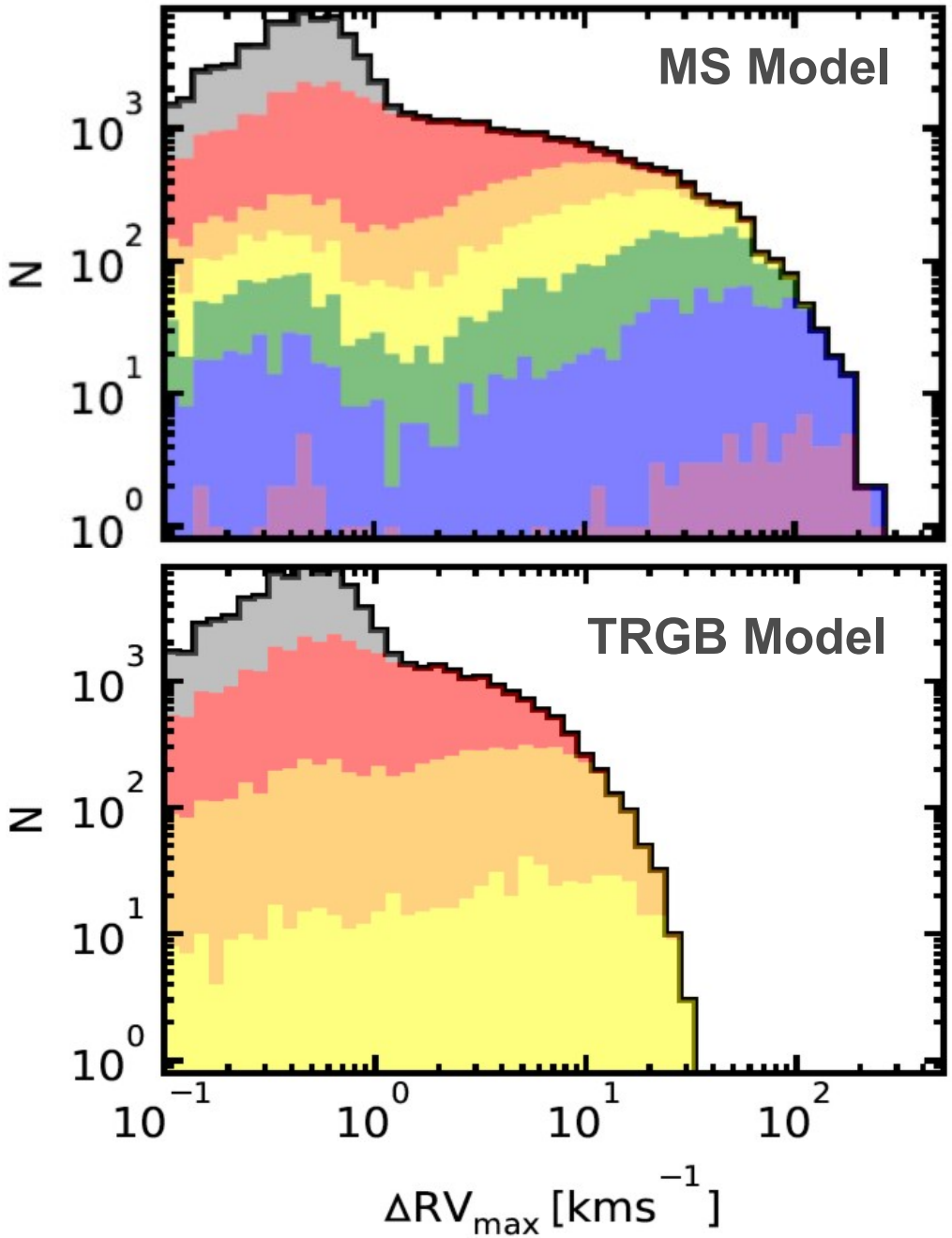


TRGB and RC have similar ΔRV_{max} distributions

APOGEE: Models for ΔRV_{max}

Carles Badenes
ESO 07/07/17





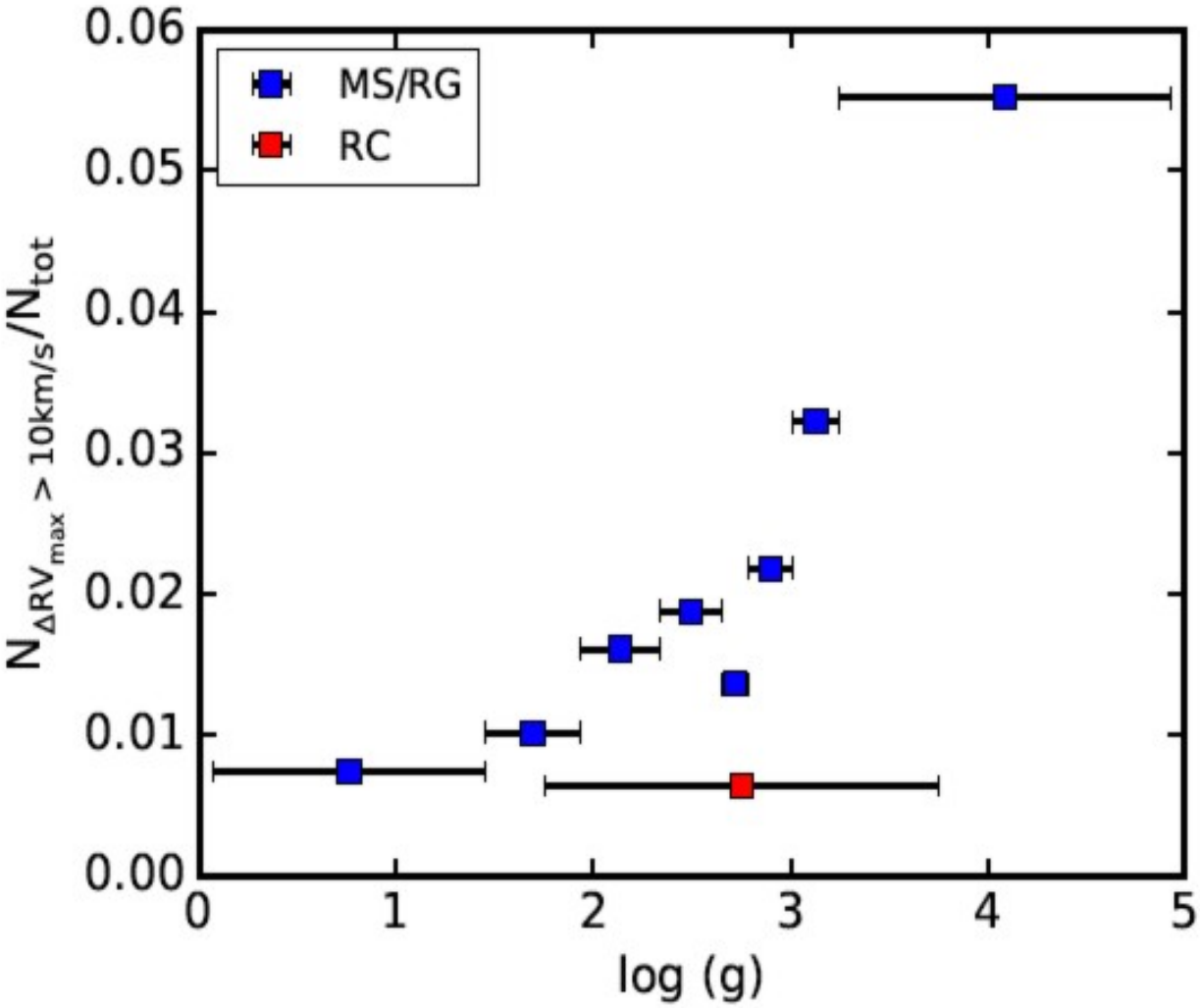
- Multiplicity statistics ⇒ model ΔRV_{max} distribution seen by APOGEE. **Hallakoun talk** [see Badenes & Maoz 12, Maoz+ 12].

- Work in progress!

APOGEE: ΔRV_{max} vs. log(g)

Carles Badenes
ESO 07/07/17

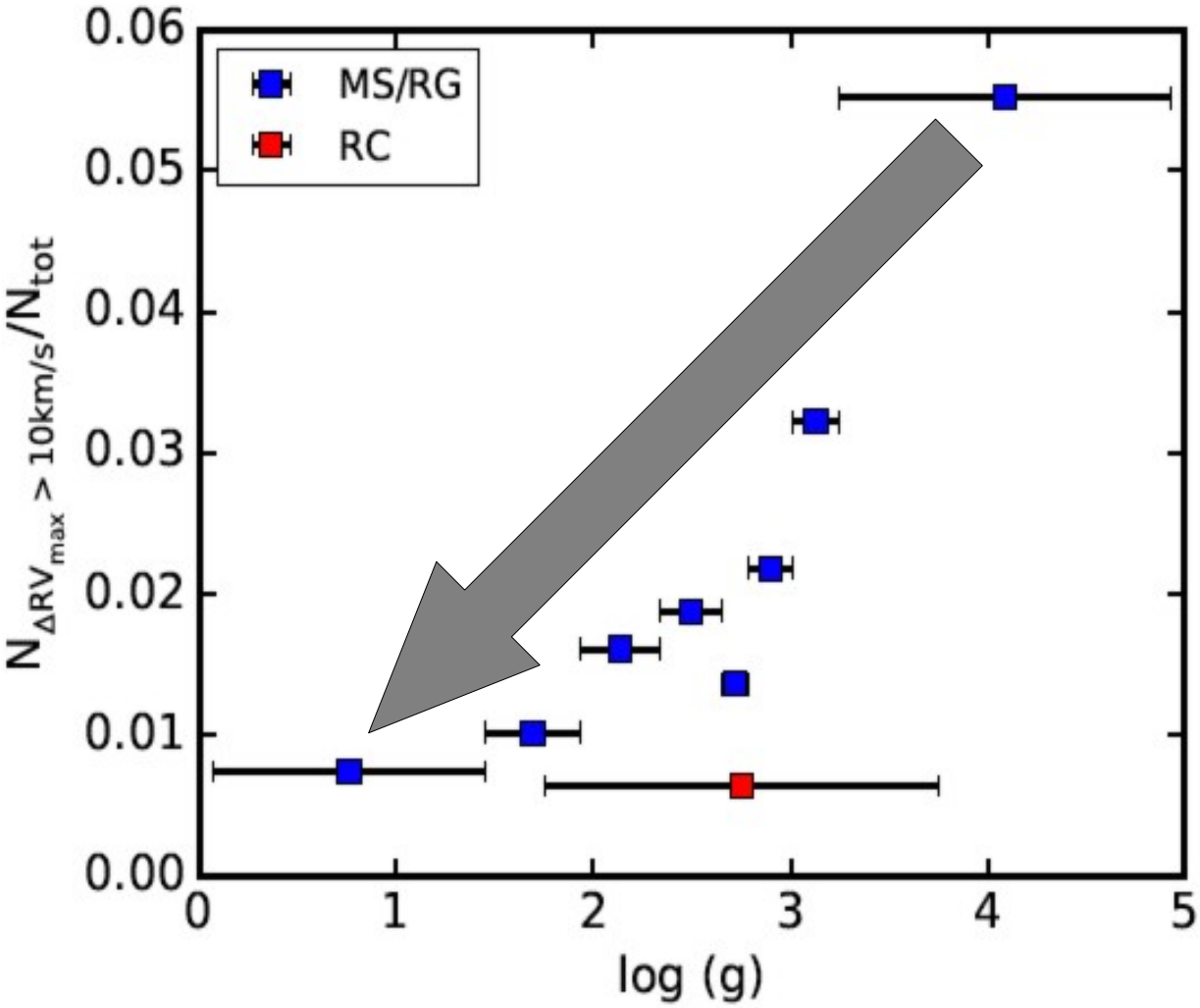
- For simplicity, take ΔRV_{max} > 10 km/s.
- Contamination from RC at log(g)~2.8.
- Attrition of high ΔRV_{max} (short P) systems: 88% of MS systems are gone in the RC.
- Observational constraint on **Case B mass transfer** (CE episodes ⇔ LRNE, **Kaminski, Ohlmann talks** [Ivanova+13, Kochaneck+ 14])



APOGEE: ΔRV_{max} vs. log(g)

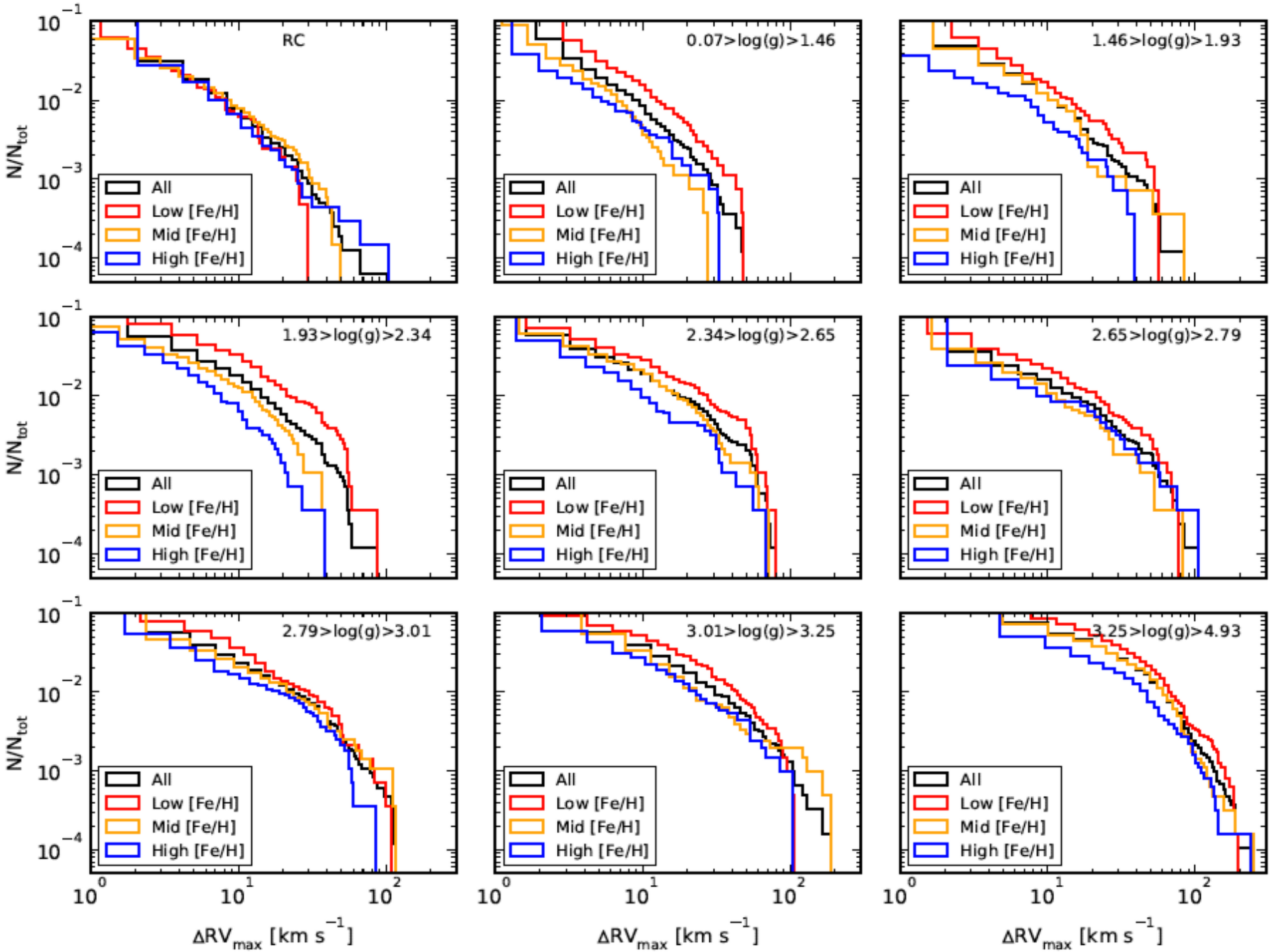
Carles Badenes
ESO 07/07/17

- For simplicity, take ΔRV_{max} > 10 km/s.
- Contamination from RC at log(g)~2.8.
- Attrition of high ΔRV_{max} (short P) systems: 88% of MS systems are gone in the RC.
- Observational constraint on **Case B mass transfer** (CE episodes ⇔ LRNE, **Kaminski, Ohlmann talks** [Ivanova+13, Kochaneck+ 14])



APOGEE: ΔRV_{max} vs. [Fe/H]

Carles Badenes
ESO 07/07/17



Summary

Carles Badenes
ESO 07/07/17

- APOGEE: high resolution, multi-epoch IR spectra of ~100,000 stars (Galactic archeology).

- Unique view of stellar multiplicity, from the MS to the RC. Few-epoch spectra: no orbits $\Rightarrow \Delta RV_{max}$.

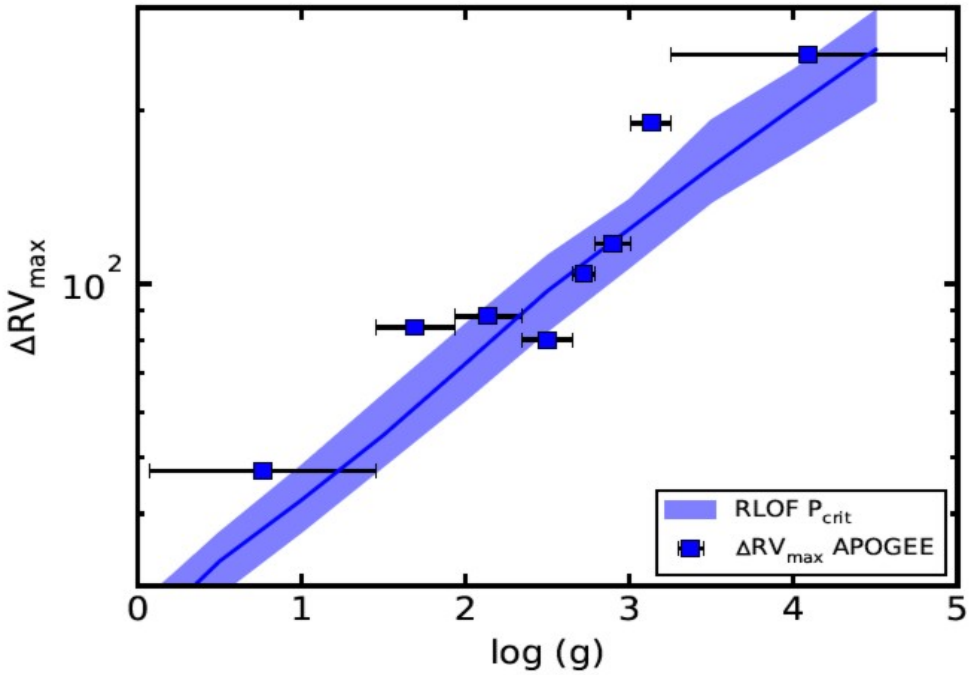
- Attrition of high ΔRV_{max} (short P) systems as stars climb the RGB $\Rightarrow$ 88% of MS systems with ΔRV_{max} > 10 km/s are gone in the RC $\Rightarrow$ Case B mass transfer / rate of CE in the MW.

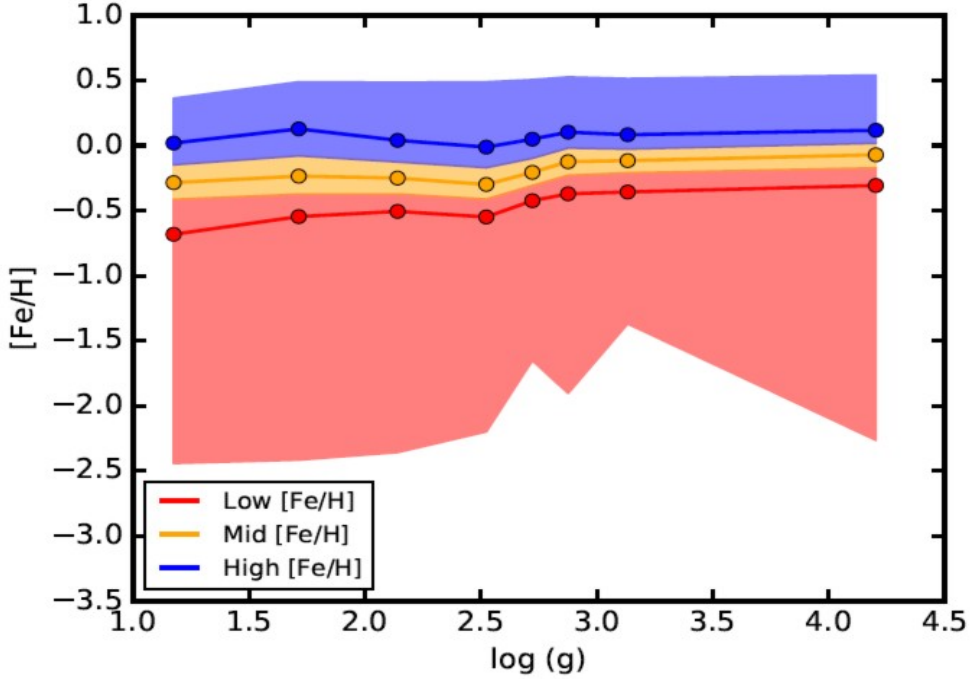
- Clear trend with [Fe/H]: lower [Fe/H] stars have higher ΔRV_{max} distributions $\Rightarrow$ consistent with higher f_m at lower [Fe/H] [Gao+ 14, 17, but Hettinger+ 15].

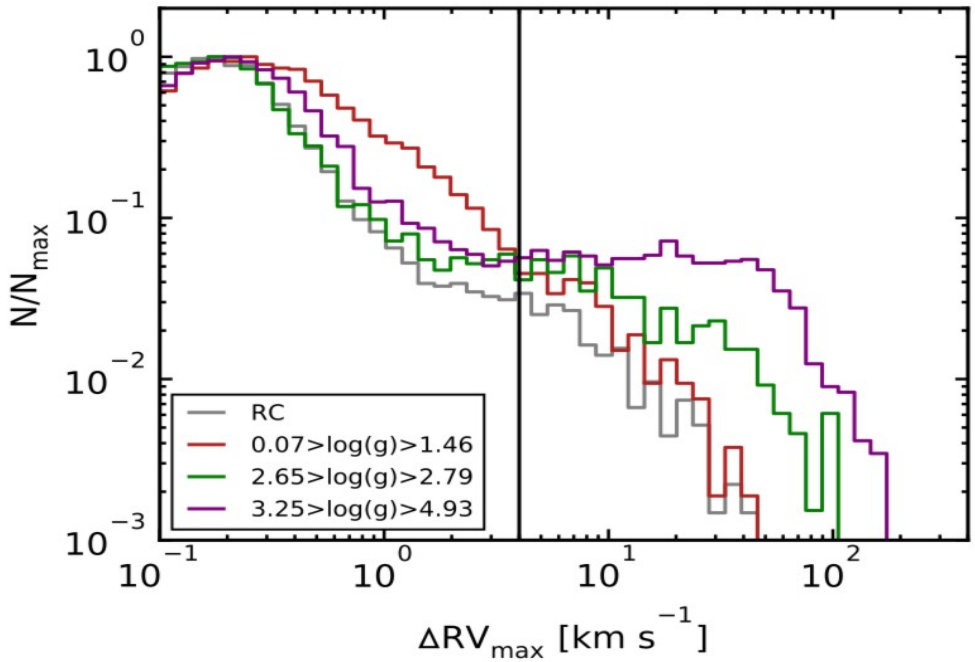
- Future work: Constrain multiplicity statistics, follow-up of interesting systems.

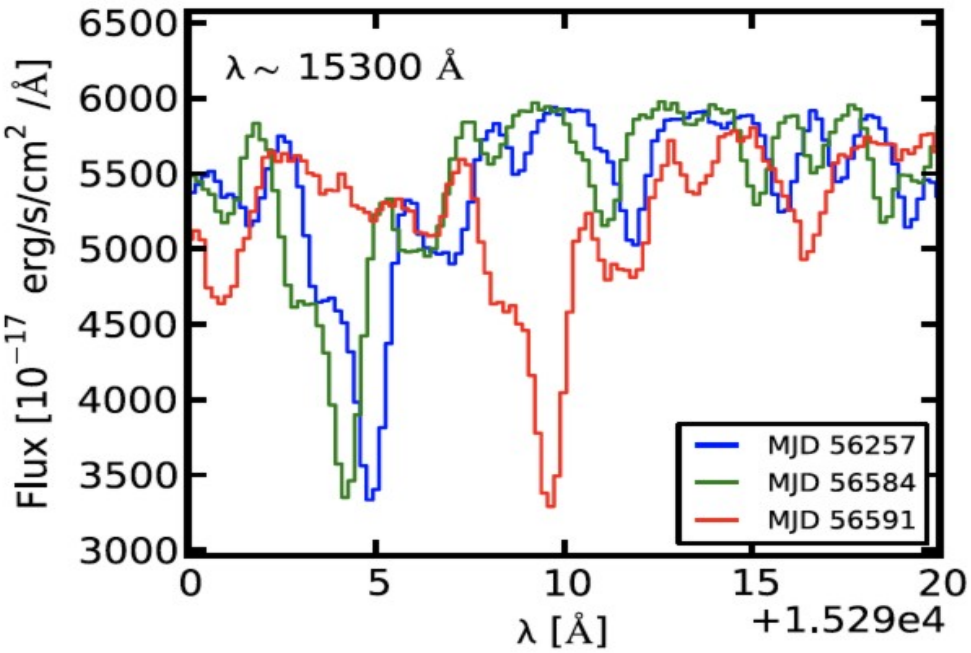
Additional Plots

Carles Badenes
ESO 07/07/17



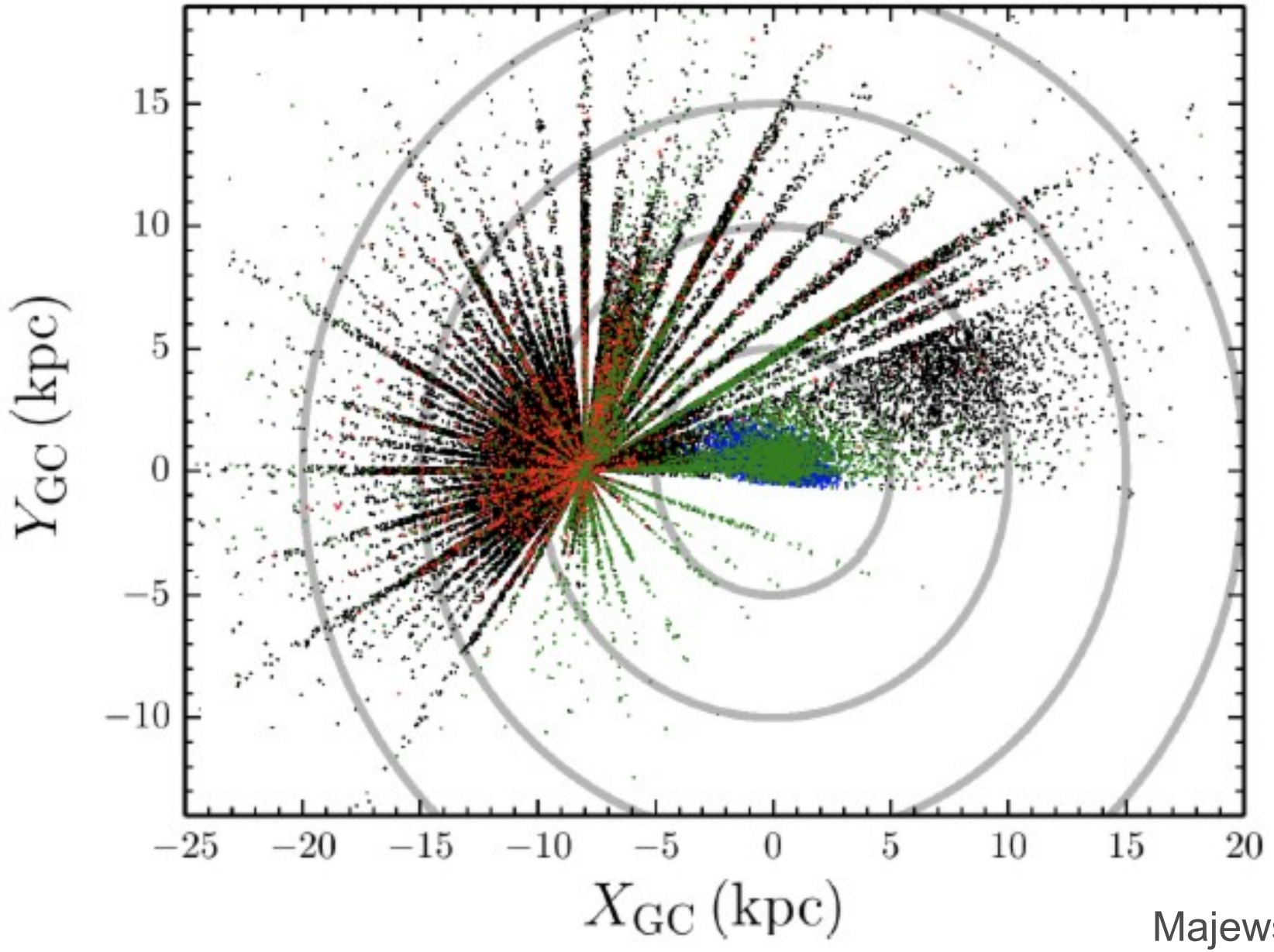






Additional Plots

Carles Badenes
ESO 07/07/17



Majewski+ 15

Additional Plots

Carles Badenes
ESO 07/07/17