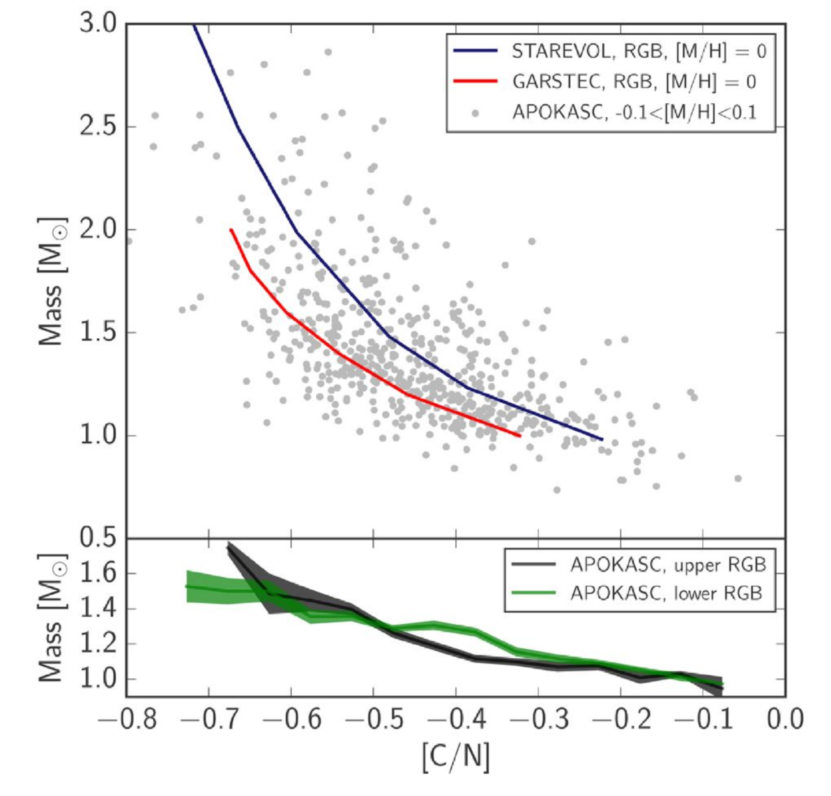
Testing Asteroseismology with APOGEE Star Clusters

Marc Pinsonneault
Ohio State University

The APOKASC Collaboration

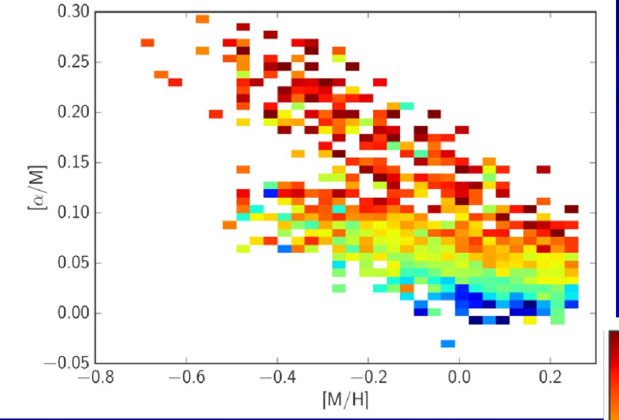
Sample Motivation: Testing the First Dredge-Up and Mixing

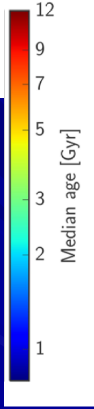


Martig et al. 2016

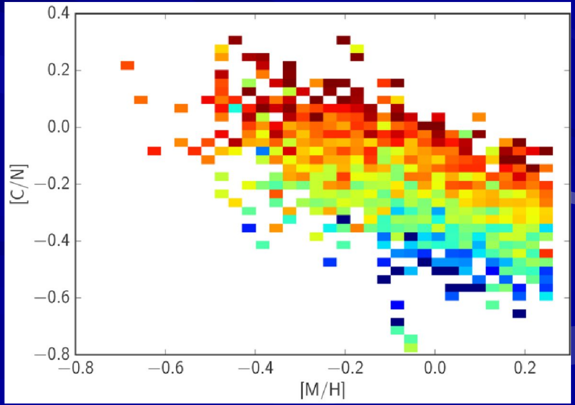
Ness et al. 2016

Lower RGB Similar to Upper RGB; Little mixing

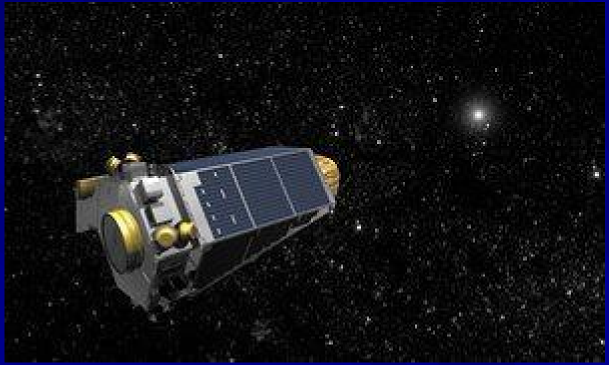




C/N Is a Strong Function of Age



APOKASC



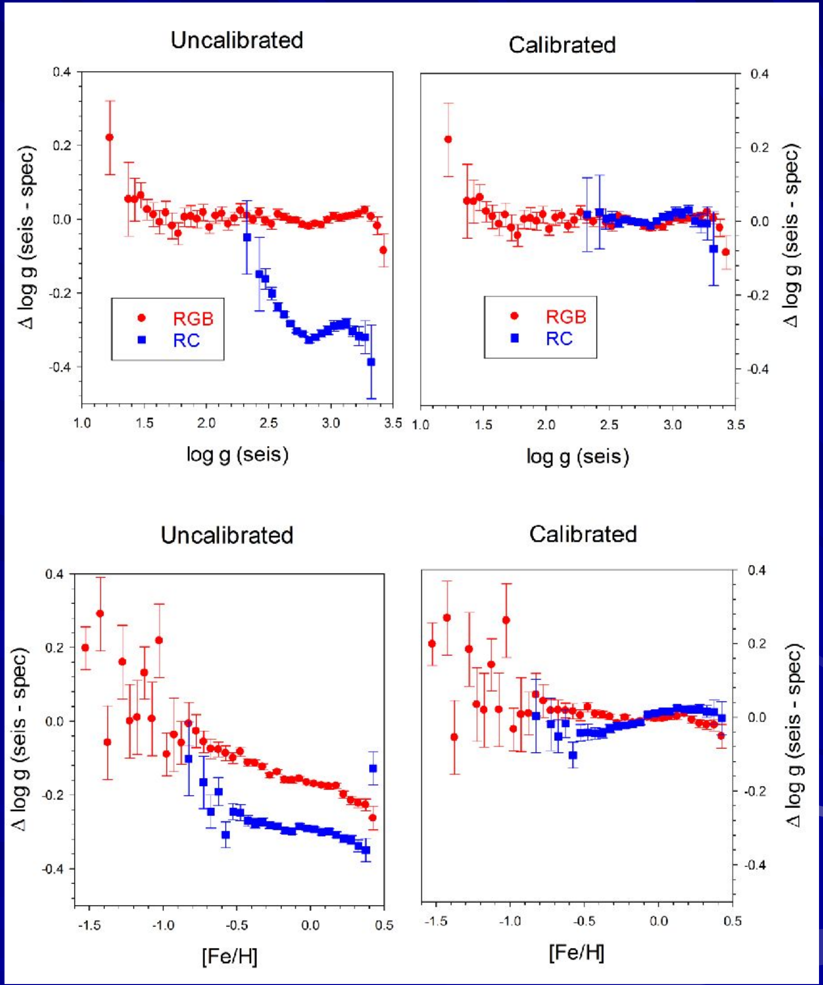
- SDSS-III: More than 10,000 stars in the original Kepler fields with high-resolution H-band spectra
- APOGEE-*Kepler* Asteroseismology Collaboration (APOKASC)
  - DR10: 1,918 giants with spectra and asteroseismic parameters released
  - DR13: 6,700+ giants to be released
- There is also overlap with CoRoT

APOGEE Data Release 13

- Automated fitting algorithm (FERRE) for the entire H band spectrum
- DR13: Numerous improvements
  - 15 element mixture
  - No calibration applied: metallicity, temperature
  - Ex post facto calibration of results against independent measurements
    - Asteroseismic log g
    - Evolutionary state

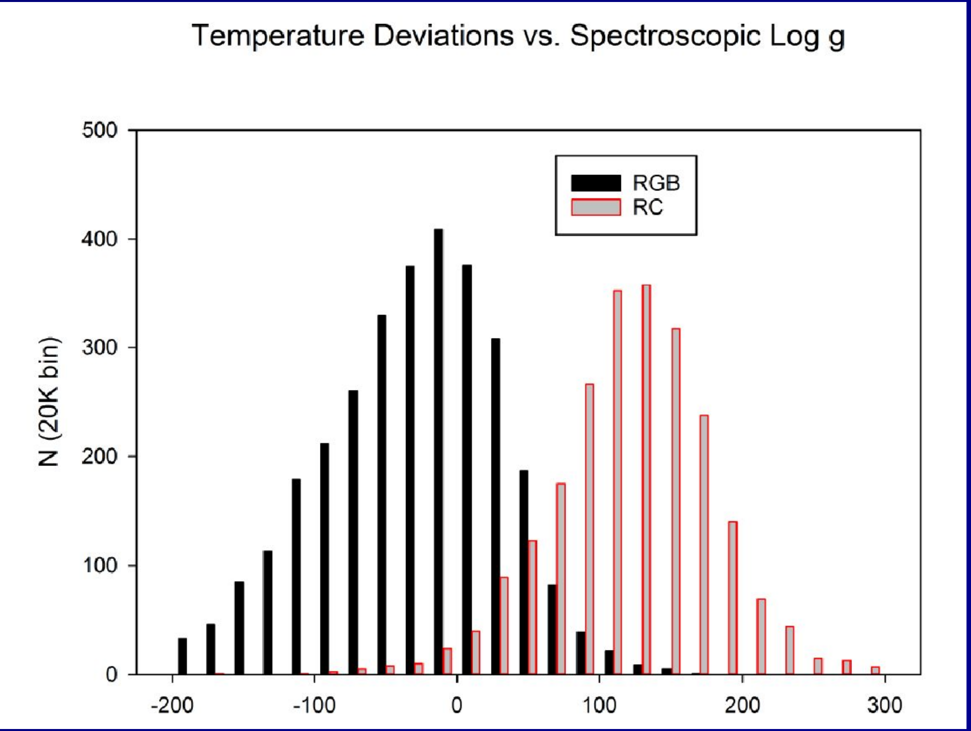
Seismology: Calibrating Spectroscopic Gravities

Asteroseismic Surface Gravities reveal evolutionary state-dependent systematic offsets

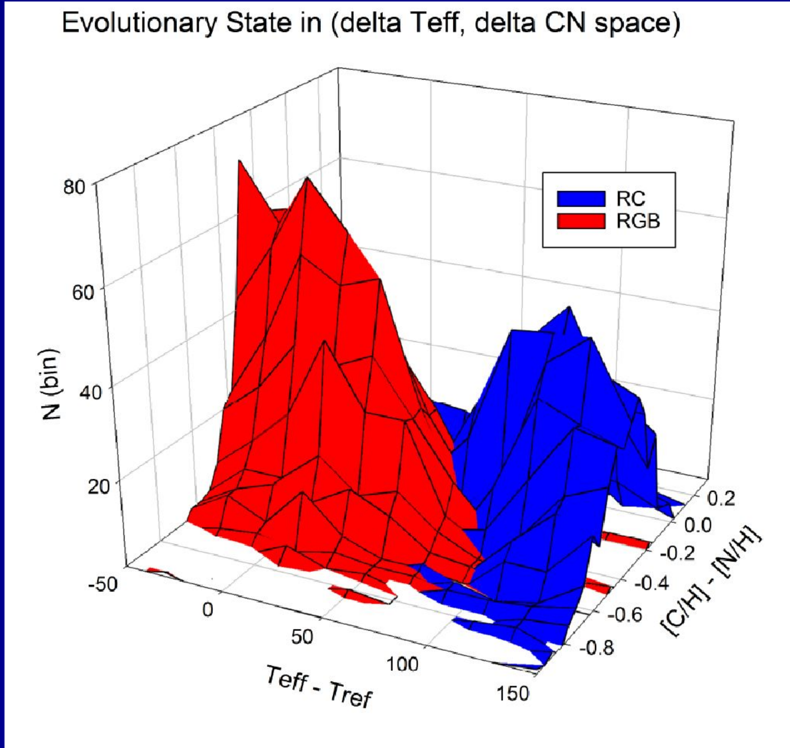


Spectroscopy and Evolutionary State

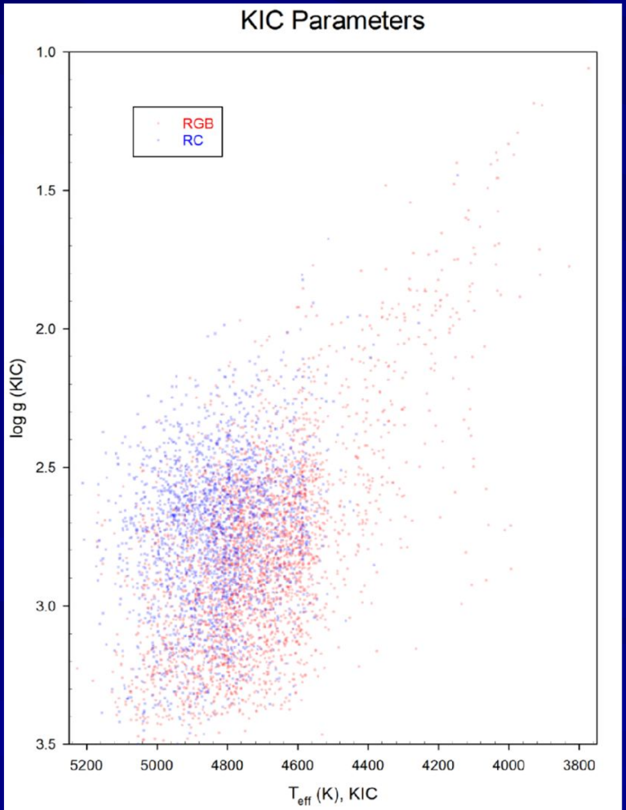
Temperature Offset from Mean RGB ridgeline is a good diagnostic….

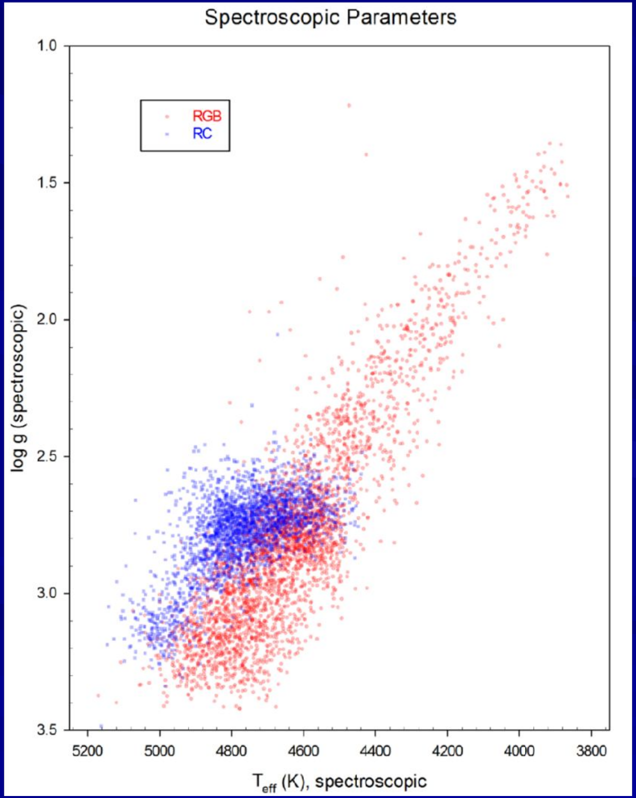


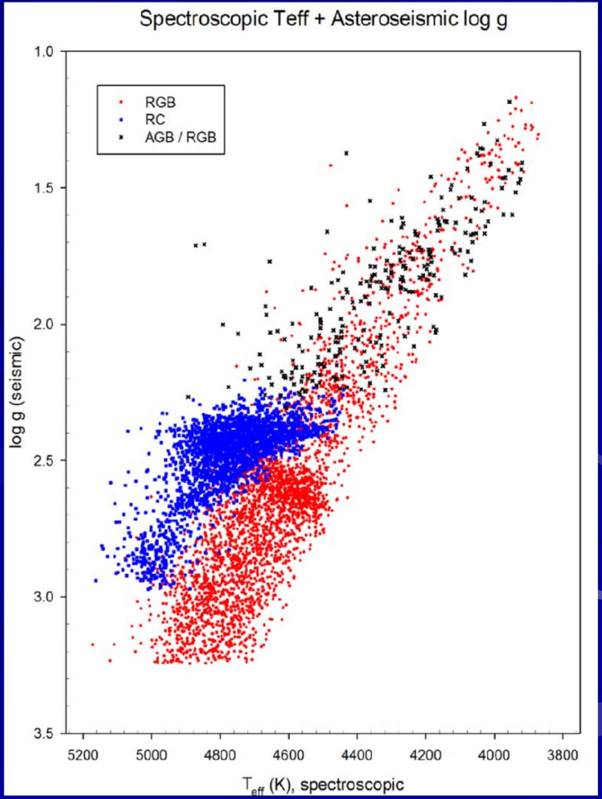
NEW: Overlap Populations are chemically distinct!



The Kepler Giants Revealed

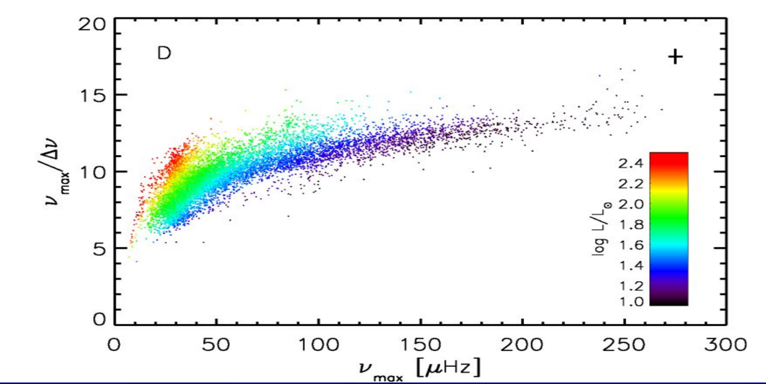






Scaling Relations for Bulk Populations

- Two most basic observables:
  - Frequency of maximum power
  - Mean frequency spacing

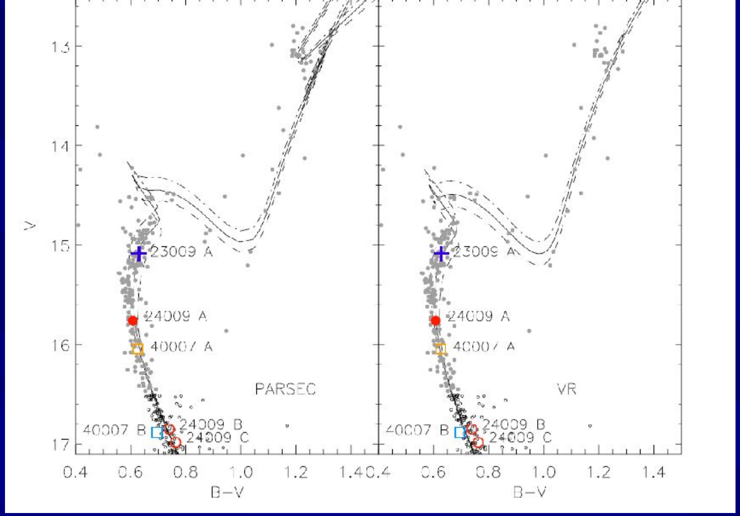


Hekker et al. 2010 data for Kepler giants

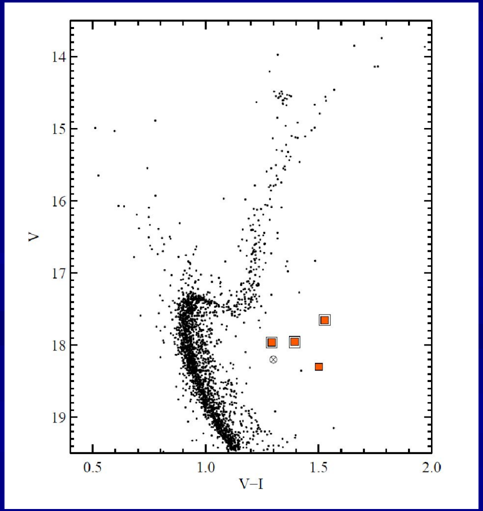
$$\frac{M}{M_\odot} \simeq \left(\frac{\nu_{\max}}{\nu_{\max,\odot}}\right)^3 \left(\frac{\Delta\nu}{\Delta\nu_\odot}\right)^{-4} \left(\frac{T_{\rm eff}}{T_{\rm eff,\odot}}\right)^{3/2}$$

$$\frac{R}{R_\odot} \simeq \left(\frac{\nu_{\max}}{\nu_{\max,\odot}}\right) \left(\frac{\Delta\nu}{\Delta\nu_\odot}\right)^{-2} \left(\frac{T_{\rm eff}}{T_{\rm eff,\odot}}\right)^{1/2}.$$

Open Clusters: Testing Asteroseismology

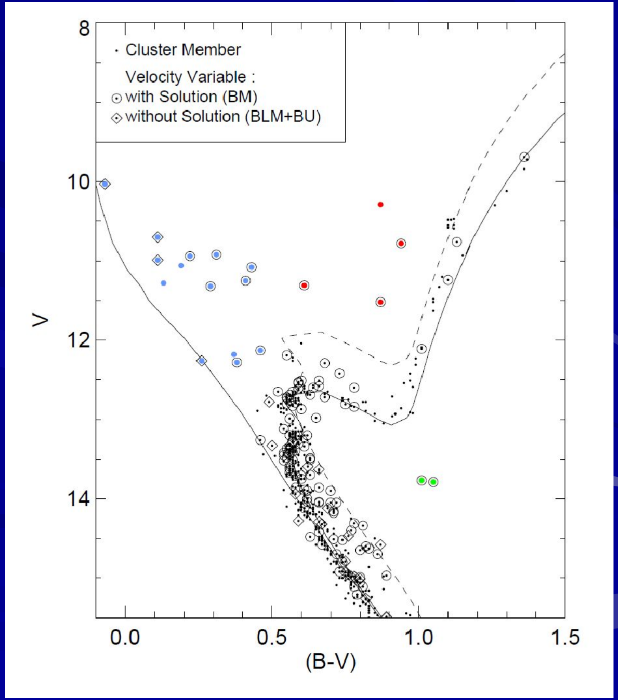


NGC 6819 Brewer et al. 2016



NGC 6791 Milliman et al. 2016

M67 Geller et al. 2015



Prior Work in NGC 6791 (Miglio et al. 2012): Differential Radius Offset, RC vs. RGB

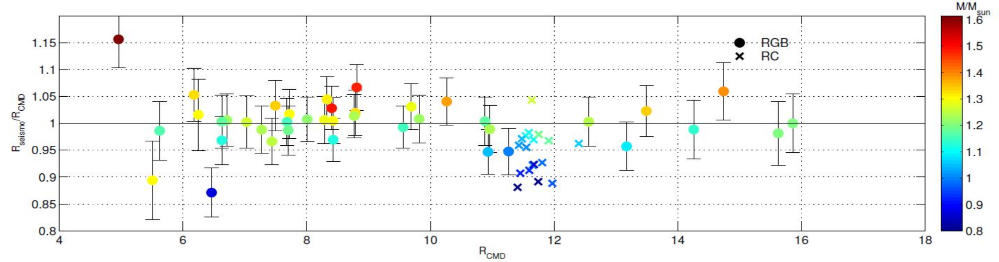
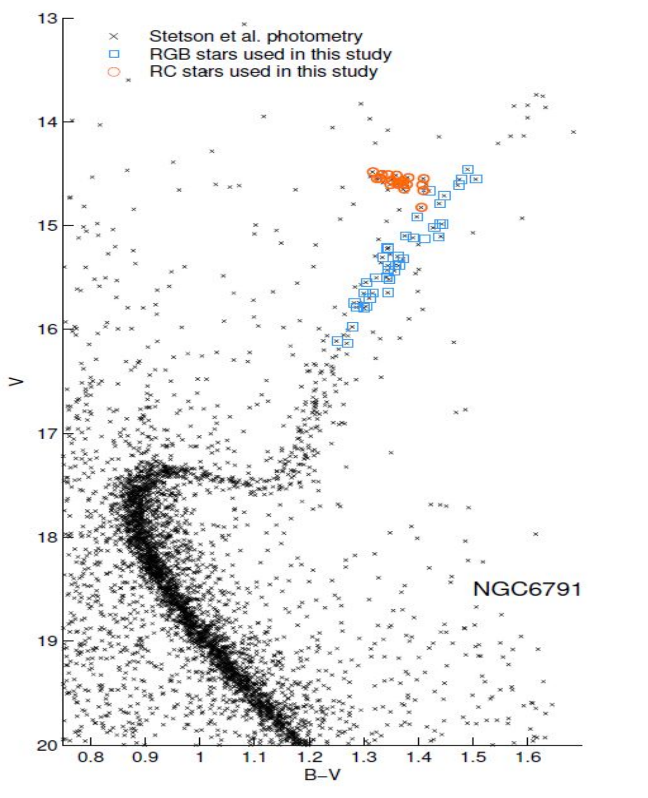


Figure 3. NGC6791: ratio between radii determined using L and $T_{\rm eff}$ ($R_{\rm CMD}$), and those obtained via Eq. 4 ($R_{\rm seismo}$). The mass of each star determined via Eq. 3 is colour coded.



Our Approach

a $(\Delta v/\Delta v_{sun}) = (M/M_{sun})^{0.5}(R/R_{sun})^{-1.5}$

b $(v_{max}/v_{max,sun}) = (M/M_{sun})(R/R_{sun})^{-2}(T/T_{sun})^{-0.5}$

=>Error in M scales as a^3b^{-4}

If you know R (eclipsing binary) or L (cluster):

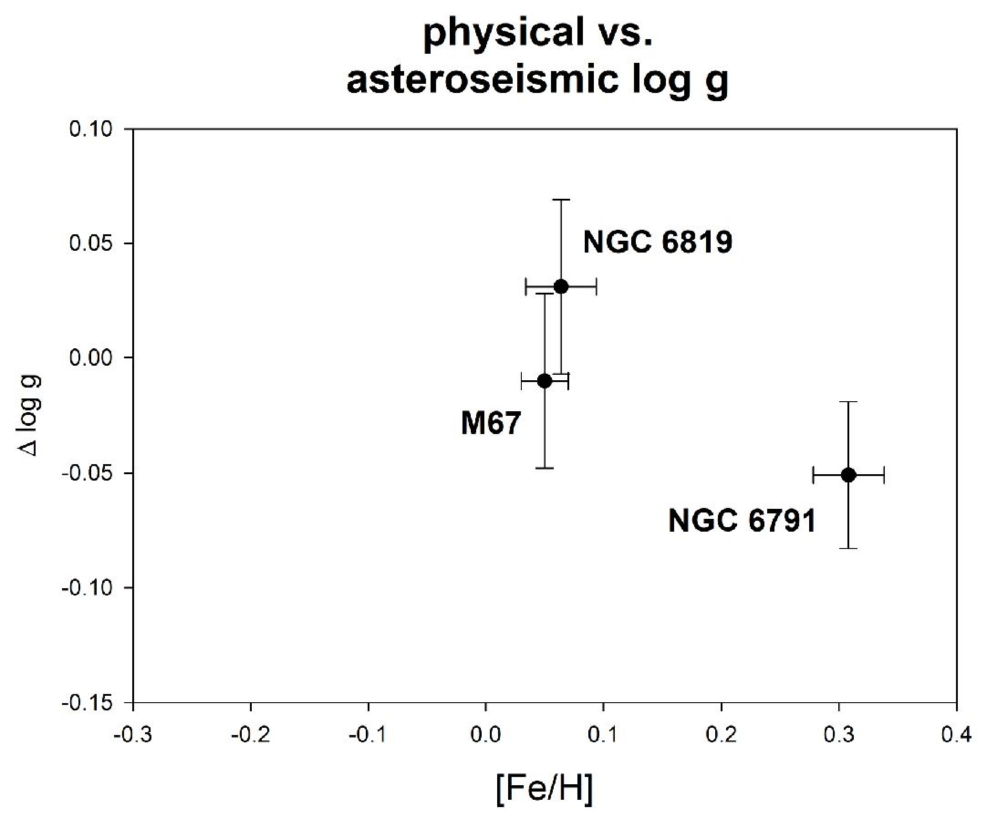
=> Error in M scales as a^2 from Δv

=> Error in M scales as b from v_{max}

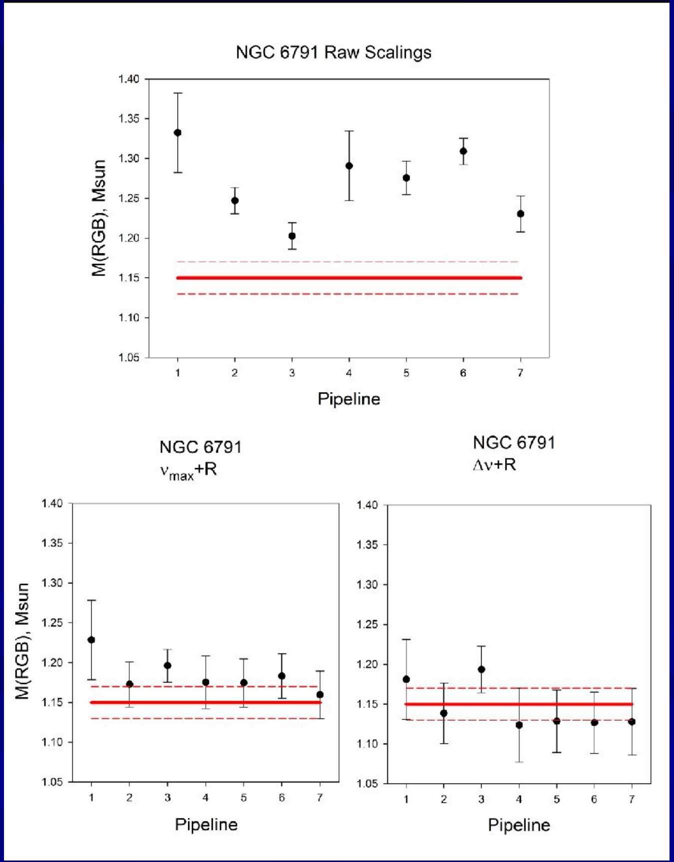
Log g Comparisons

Note:

Systematic Errors Dominate



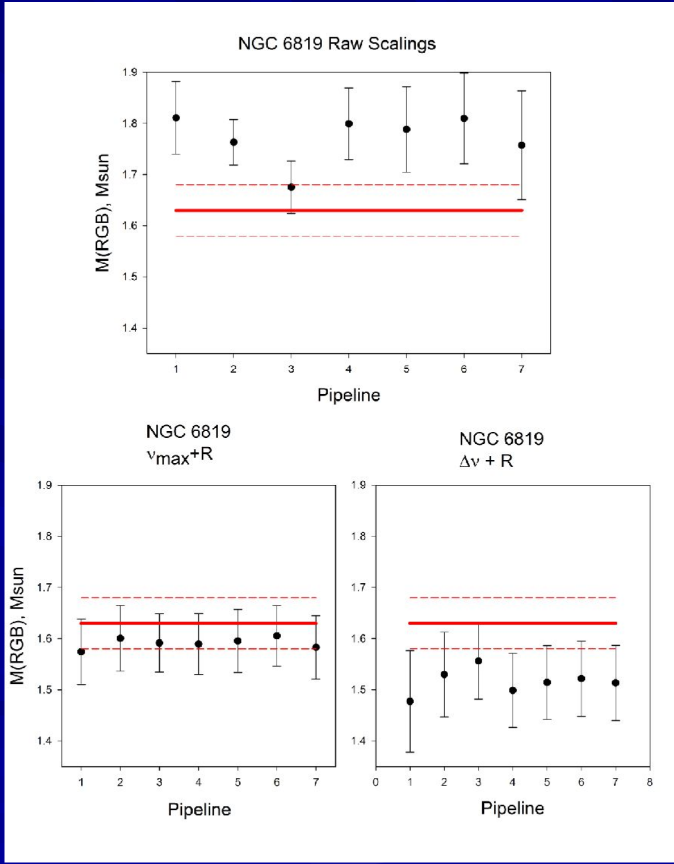
Comparing RGB Mass Scalings



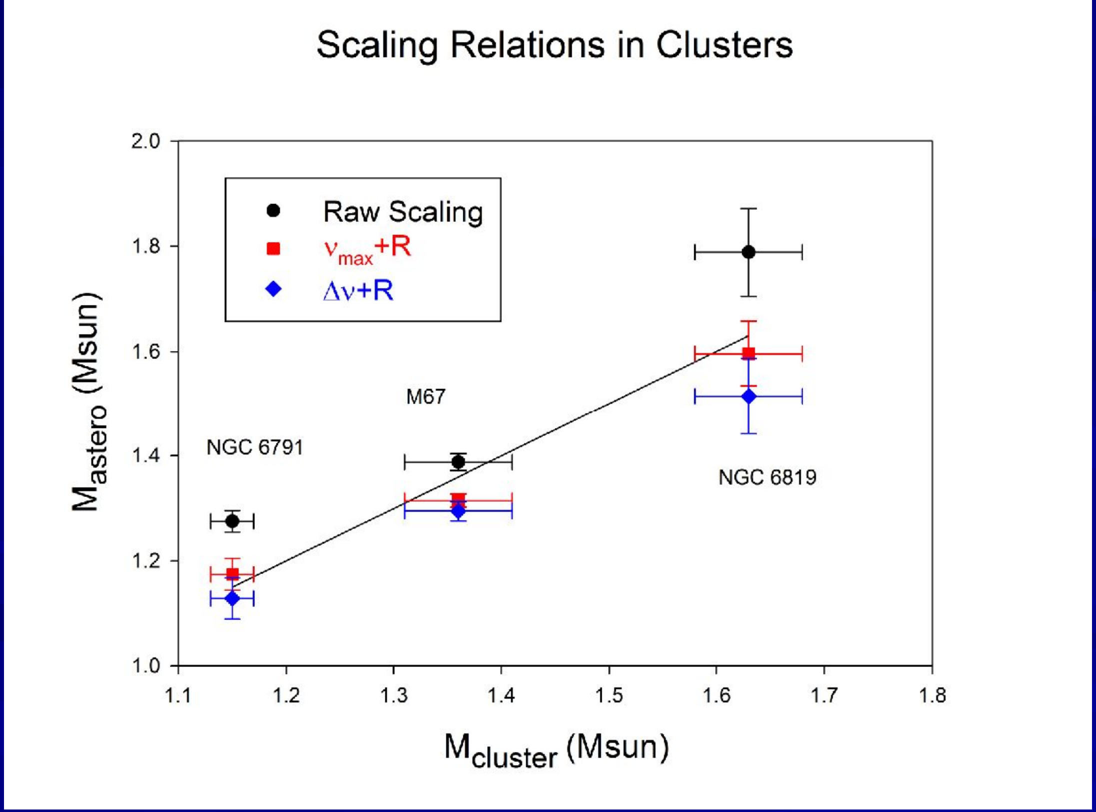
Different answers,
Different reductions

Assuming R:
Closer agreement

$\Delta\nu$ lower than ν_{max}



What is Going On?



Adding a distance makes mass estimation more precise

Δν offset predicted by corrections seen

Caution: zero point of differences sensitive to absolute Teff, distance scales.

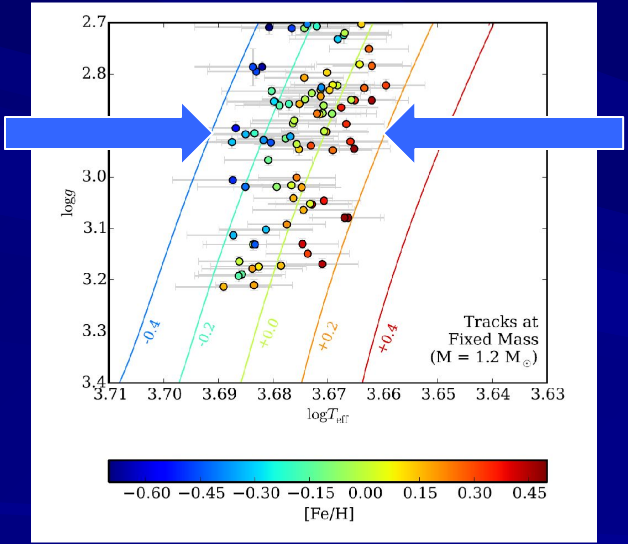
EB vs. OC? Teff systematics? MP vs. AM? Peak-bagging vs. automated analysis?

Conclusions

- Asteroseismic gravities are in good agreement with physical gravities in clusters
- Evolutionary state diagnostics from seismology agree well with spectroscopic ones
- There is a modest but real systematic mass overestimate in red giant stars from raw scalings
- $\Delta\nu$ corrections relative to ν_{max} are present at high significance

Systematic Errors In Red Giant Isochrones

Tayar et al. 2016, in prep



REAL DATA – WEAKER TEFF DEPENDENCE ON FE/H THAN PREDICTED BY SOLAR CALIBRATED MODELS