Binarity, pulsations and peculiarities

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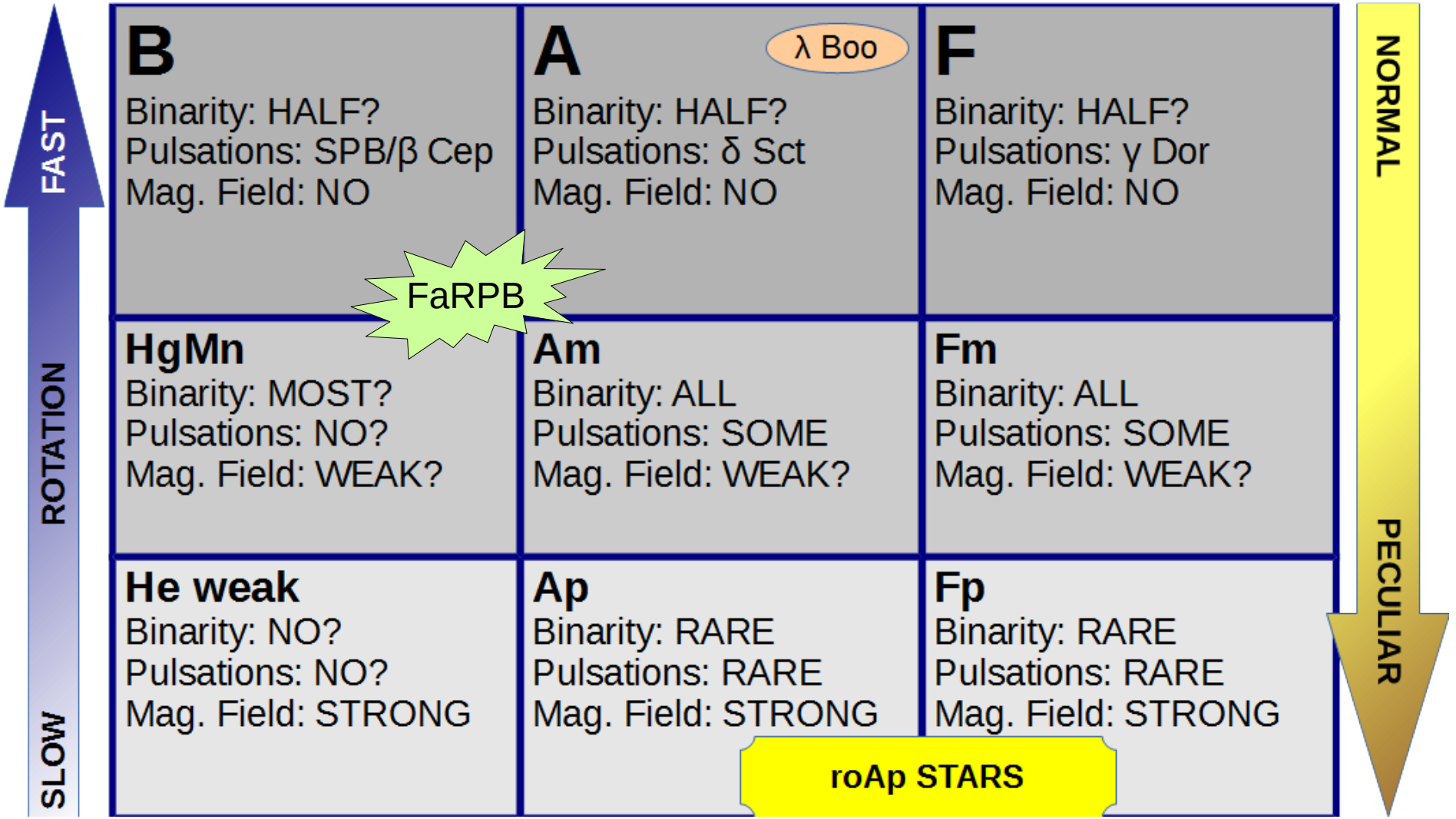
Stars of the Upper Main Sequence



~~Understanding~~ … rotation, pulsations and chemical peculiarities ...

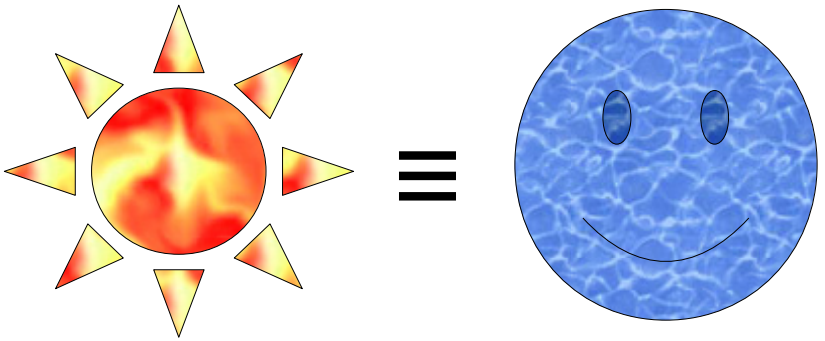
… the roles … in the upper main sequence:

- Normal stars rotate rapidly, might pulsate, might have companions, but no magnetic fields
- Mildly peculiar stars rotate moderately, some pulsate, have companions, but no magnetic fields
- Peculiar stars rotate slowly, rarely pulsate, are mostly alone, but have magnetism

Individual stars will not agree!

"Normal A stars are rather like normal people. If you don't look too hard, there seem to be quite a few of them. After you get to know them well, most seem a little crazy."

Cowley, 1991, IAU Symposium 145, p.183



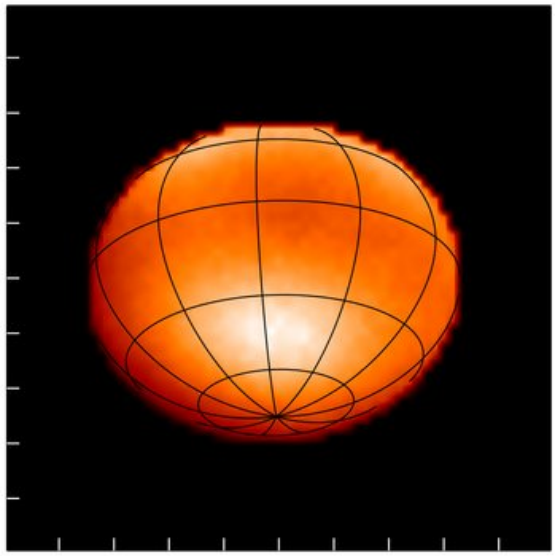
Mostly hydrogen (by number)

How to be normal

Keep moving!

- Rapid rotation
  - Mixing, differential rotation, ...
  - No element segregation
  - Oblate shape
    - Non-uniform surface
- Pulsations

α Cep



M. Zhao et al 2009 ApJ 701 209

Avoid slowing down ...

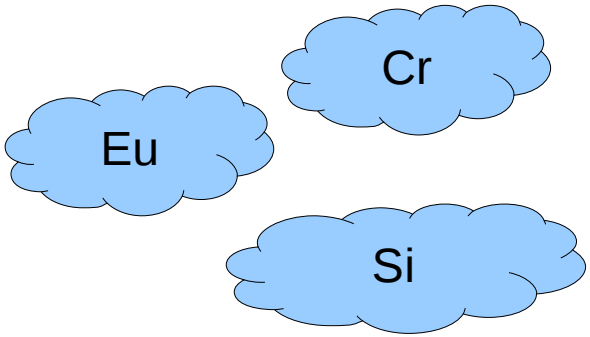
How to slow down

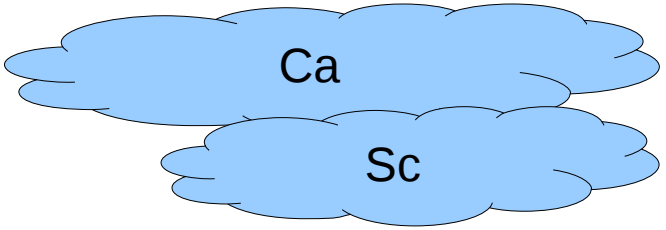
- Magnetic braking?
  - Why not all stars of same initial mass?
  - There are Ap+Am and HgMn+Ap binary systems!
- Tidal braking?
  - requires a [close] companion star
  - an exoplanet is not massive enough
- Hide the rotation inside?
- What about slowly-rotating single normal stars?

Ready to become peculiar...

How to be Peculiar

- Stable envelopes
  - Element separation
    - Enhancements and depletions
- Magnetic fields
  - Surface inhomogeneity
  - Vertical stratification
- Accretion of material?

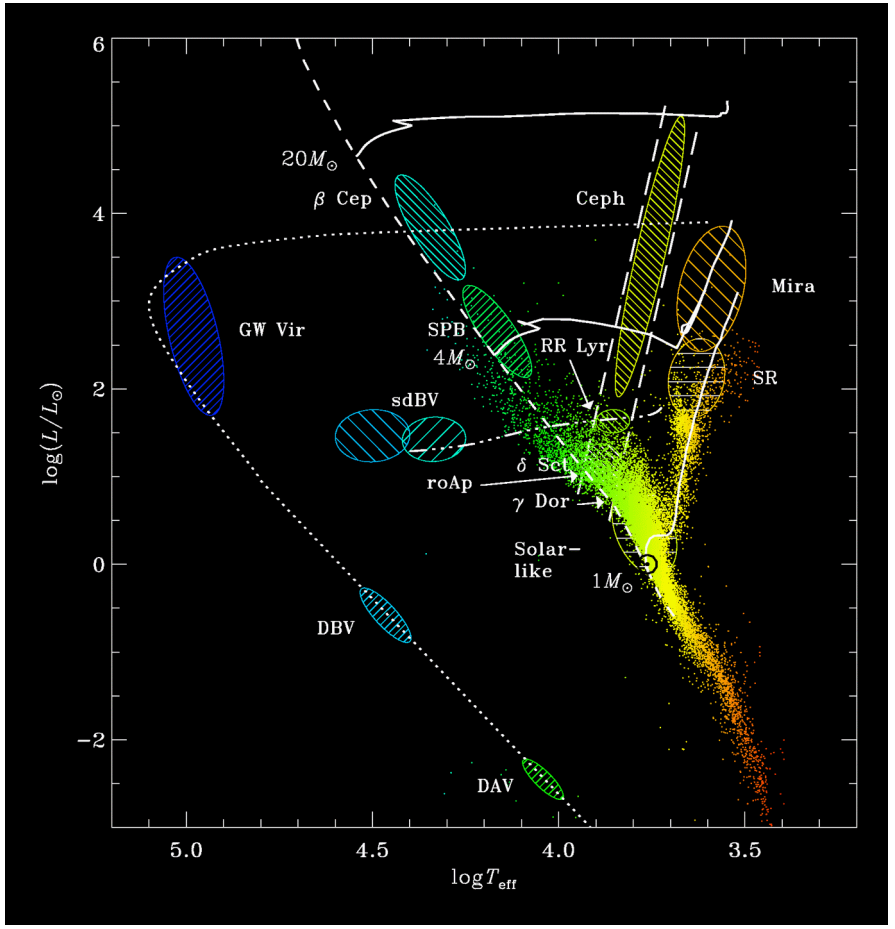




Avoid any instability...

Pulsations are not allowed....

Wide Angle Search for ~~Planets~~ Pulsations!



http://astro.phys.au.dk/~jcd/HELAS/puls_HR/

- 31 million stars
  - Multi-season and multi-site photometry
- Large Database of time-series stellar photometry
  - Statistical studies of variable stars
  - Find “rare” types of pulsators

(i) classical Am stars do not pulsate,
(ii) metallicism and pulsation can coexist among the subgiant and giant A and F stars as in the anomalous-abundance δ Delphini stars, and
(iii) pulsation and metallicism may coexist among the marginal (Am:) metallic-line stars.

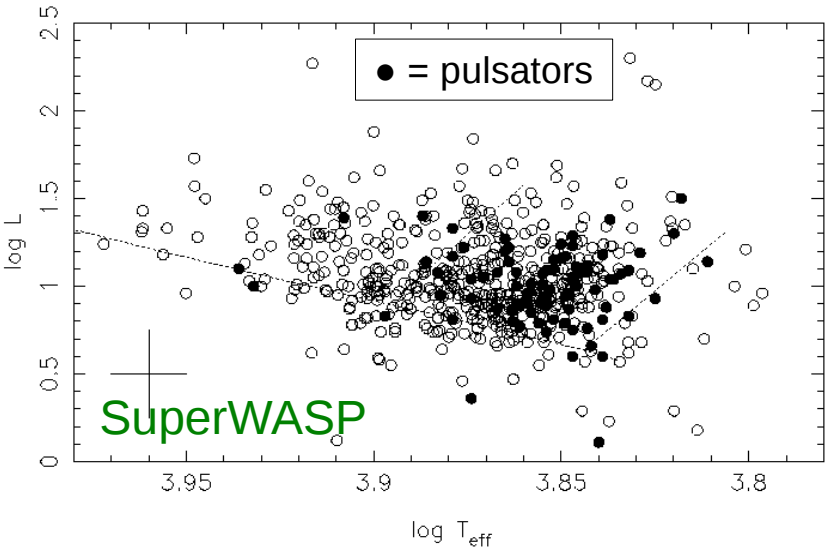
Kurtz, 1976, ApJS, 32, 651

This work was submitted to the University of Texas in partial fulfillment of the requirements of the degree of Doctor of Philosophy.

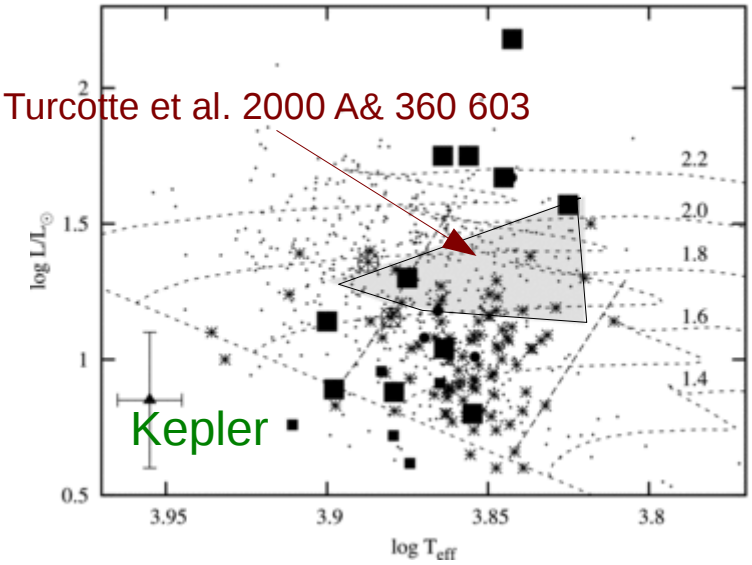
Pulsations in Am stars

- 1620 Am stars with >1000 WASP photometry points
  - excluded eclipsing binaries
- Compute periodograms
  - detailed PERIOD04 analysis
- 227 (14%) found to pulsate

Pulsations in Am stars more common than previously thought, but not where expected!



Smalley et al. 2011 A&A 535 A3



Balona et al. 2011 MNRAS 414 792

Classical Am stars don't pulsate?

- The Renson & Manfroid catalogue is not homogeneous
  - The Am stars found to pulsate might not be classical Am stars
  - Stellar parameters used were not homogeneous
- The presence of pulsating classical Am stars leads to the so-called “helium problem”

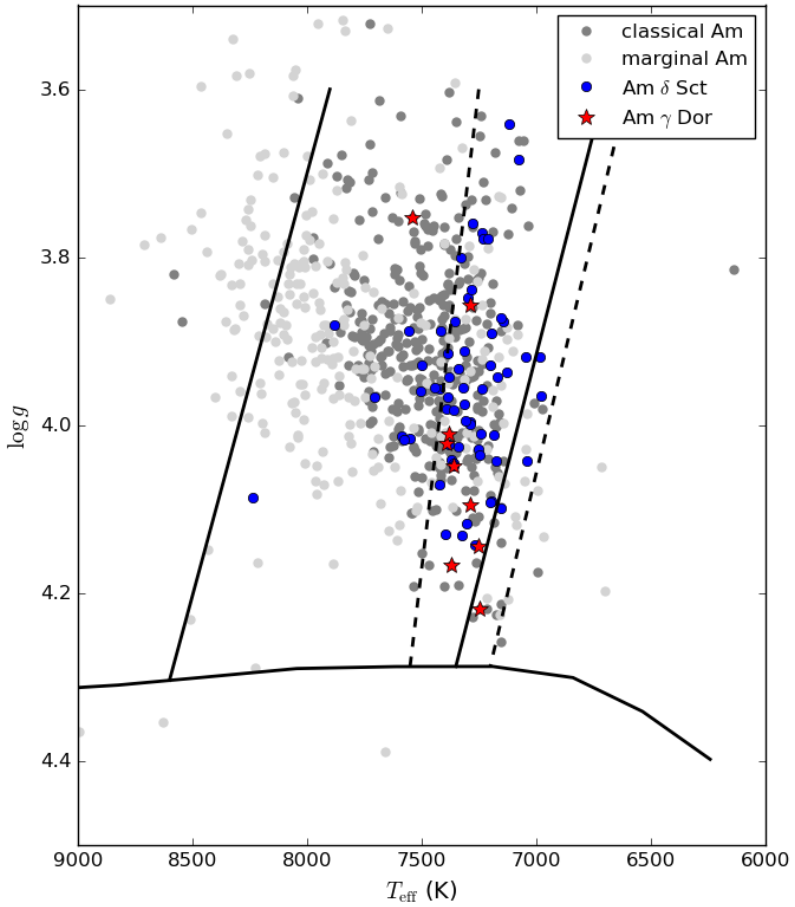
No He, no κ-mechanism

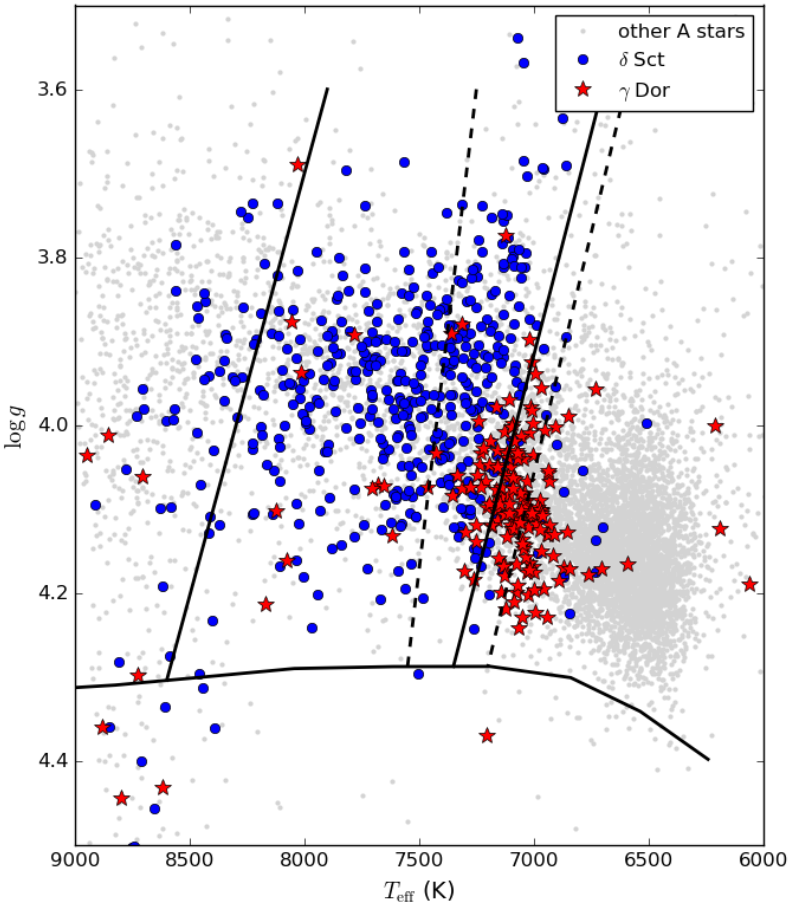
WASP-LAMOST

- LAMOST Am stars
  - Spectral Types
  - T_{eff} and log g
- WASP photometry
  - Am and other A stars

A homogeneous sample of Am and other A stars

Am stars versus other A stars

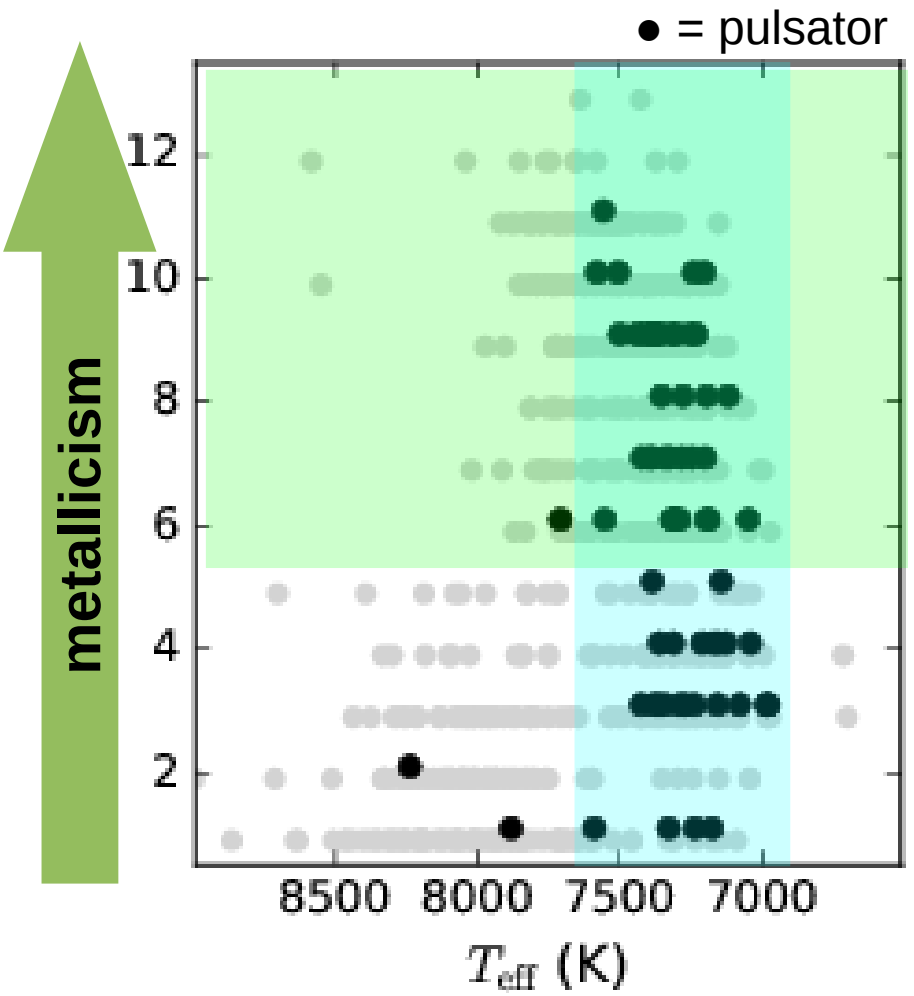




Smalley et al. 2016 MNRAS submitted

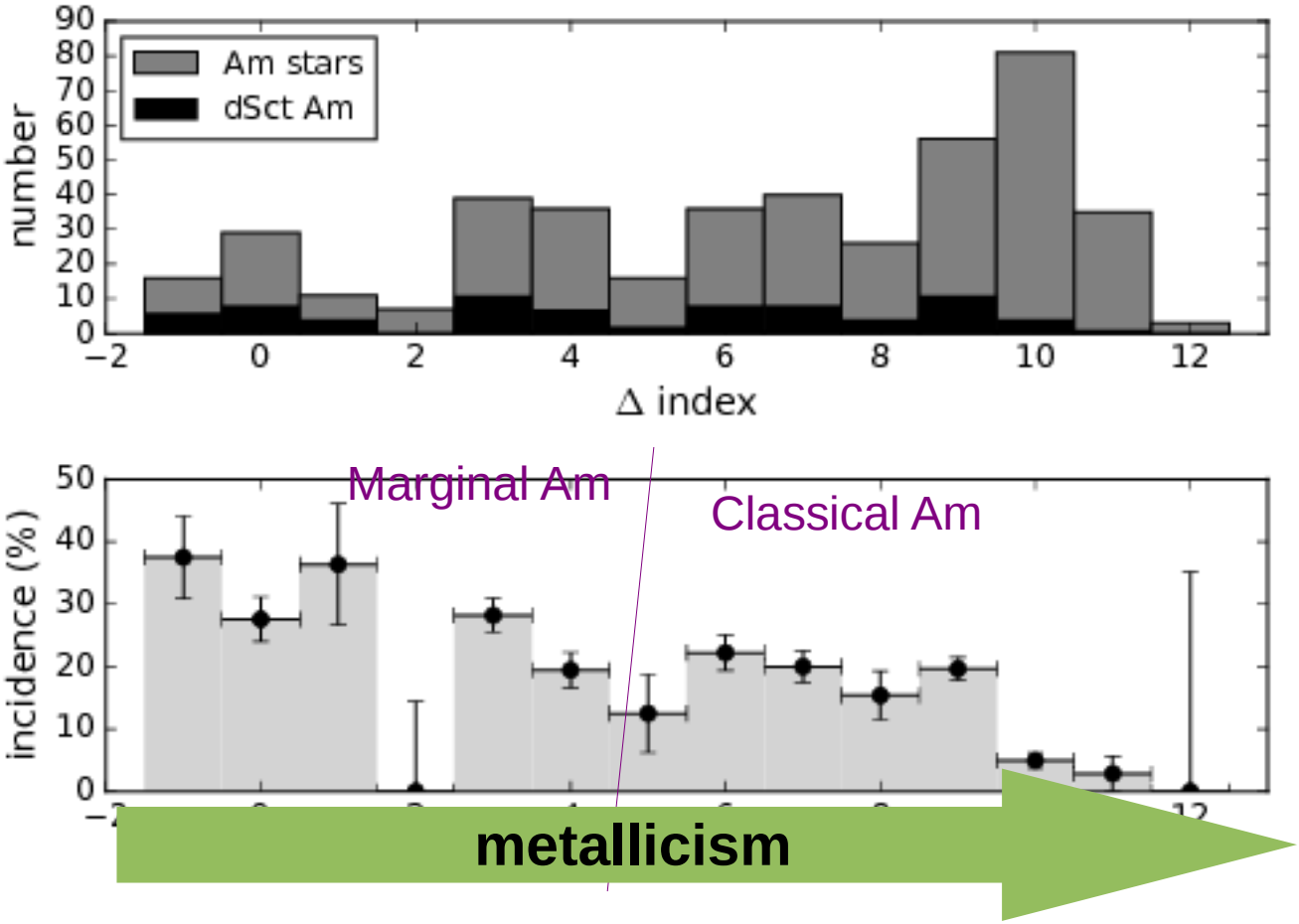
Classical Am Stars **DO** pulsate!

- Am δ Sct pulsations
  - Restricted T_{eff} range
  - Decrease He
    - Blue edge moves redward
  - Driven by turbulent pressure?



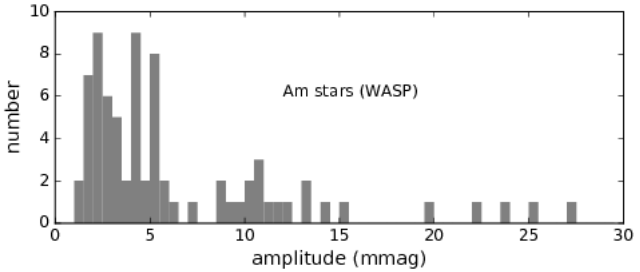
Smalley et al. 2016 MNRAS submitted

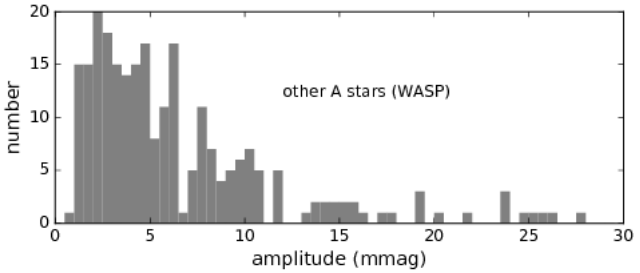
Decreased incidence with metallicity

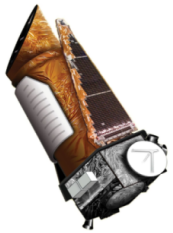


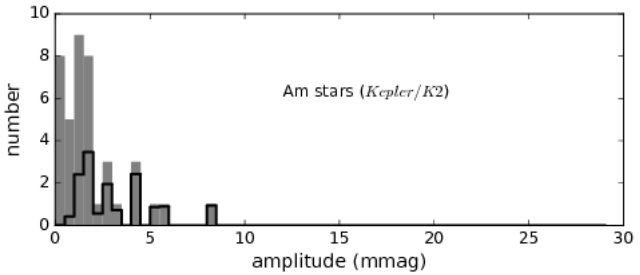
Smalley et al. 2016 MNRAS submitted

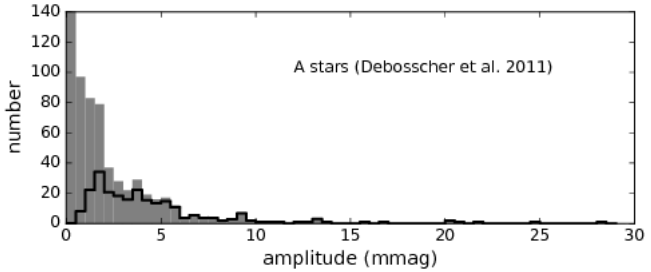
Lower amplitudes in Am stars?

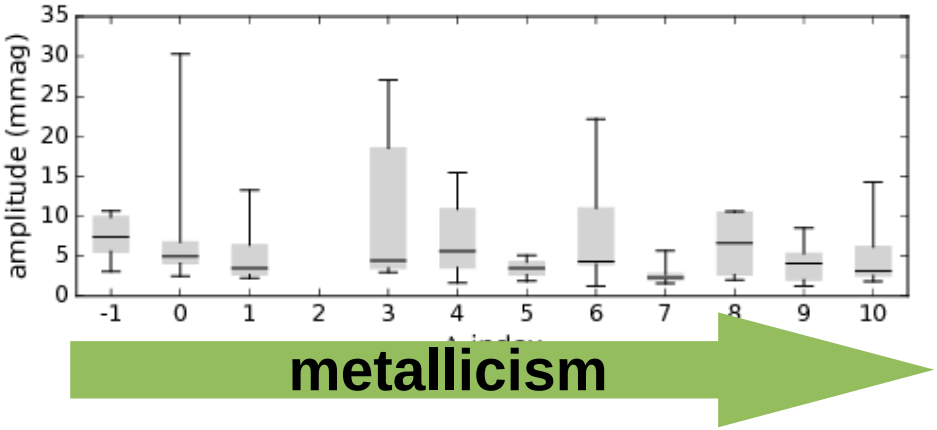










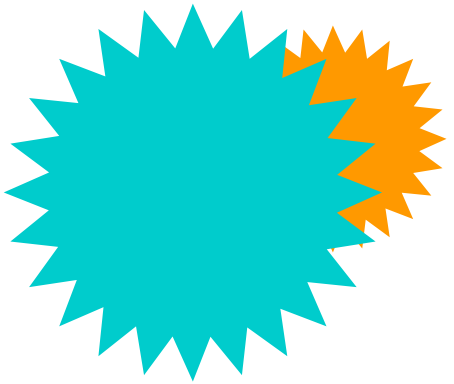


No strong evidence for Am stars having lower amplitude pulsations than normal δ Sct stars.

Smalley et al. 2016 MNRAS submitted

"A curious fact is that among the many Am stars known (all of which are binaries) there should be many eclipsing binaries, but surprisingly very few cases are known."

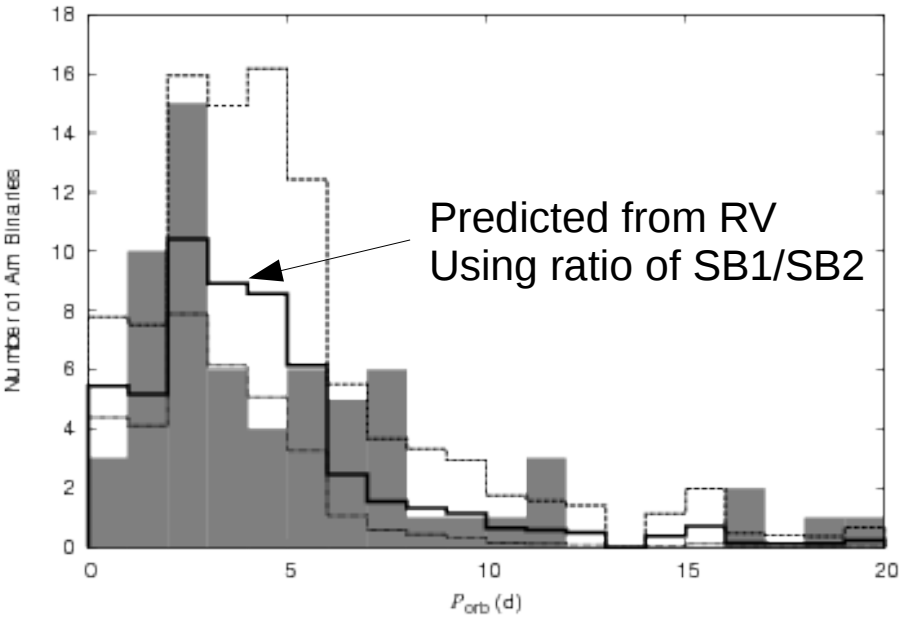
Jaschek, C., & Jaschek, M. 1990, The Classification of Stars



Are all Am stars in binary systems?

- RV surveys
  - 60-70% binary
  - Periods <50days
    - Tidal synchronisation
- Long period systems
    - Born with low rotation?
- Eclipsing systems
  - WASP photometry
  - Consistent with RV

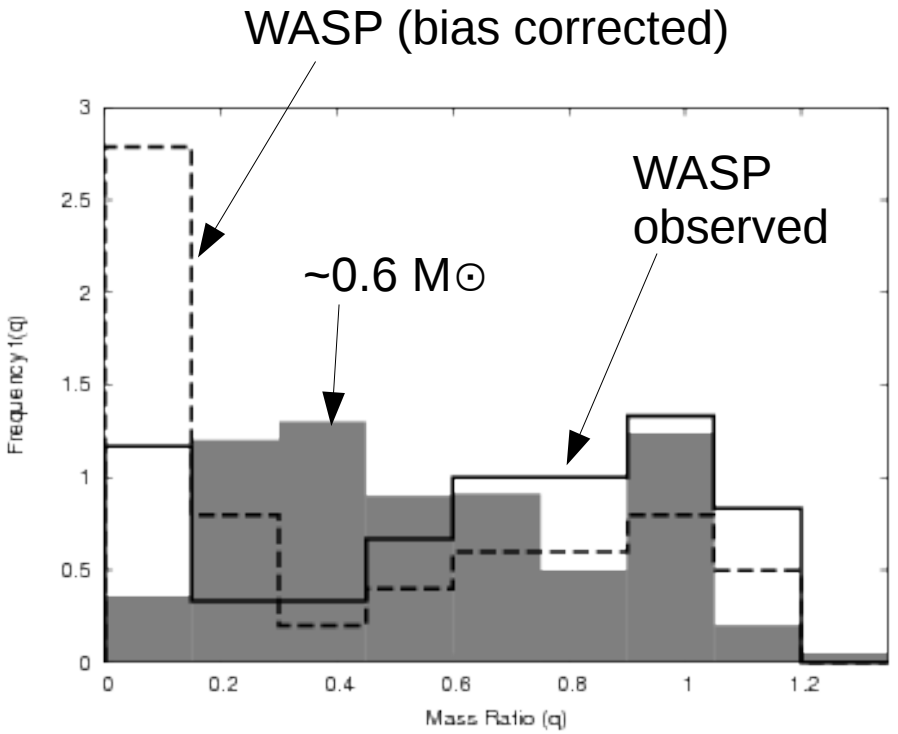
Grey histogram WASP results



Smalley et al 2014 A&A 564 A69

Are 30% of Am stars single?

Mass ratio for Am binaries



Smalley et al 2014 A&A 564 A69

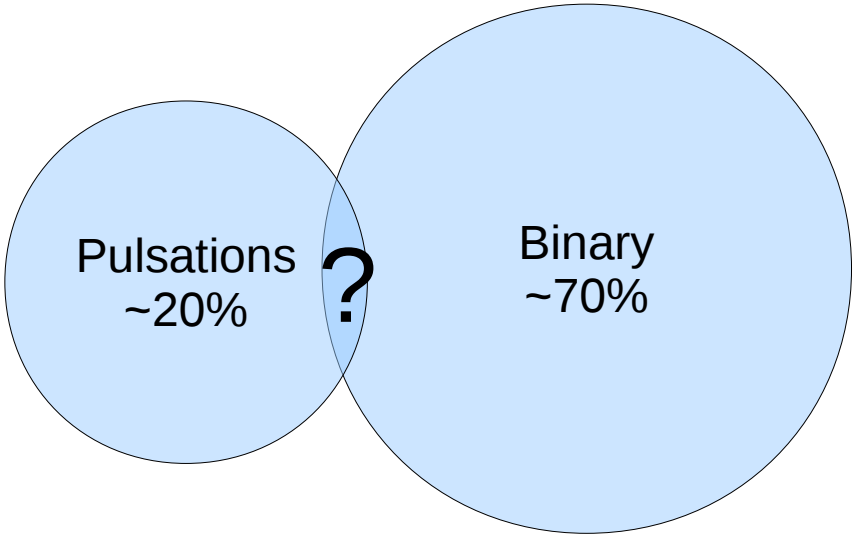
Grey histogram RV results from

Boffin, H. M. J. 2010, A&A, 524, A14

- WASP estimated q
- Types of companion
  - 2 similar stars
  - Am + late-type MS
  - Am + exoplanet
    - e.g. WASP-33
  - Am + white dwarf
    - e.g. IK Peg

Post-CE

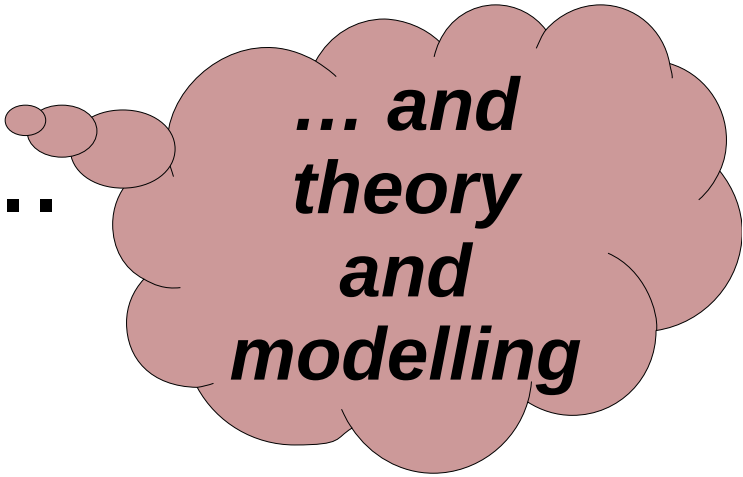
Am Binarity and Pulsations



Tidal interactions reduce pulsations?

- Am pulsators in eclipsing binary systems appear rare
  - 6% in Smalley et al. 2014
  - Would expect more if *ALL* Am stars are binary
  - Single star or “invisible” companion?

The future is much data*...



- Time-series photometry:
  - Space-based: BRITE, K2, TESS, PLATO, …
  - Ground-based: ASAS, exoplanet surveys, ...
- GAIA (results are starting to appear)
  - Distances, radial velocities, binarity, SEDs, ...
- Ground-based spectroscopic surveys
  - RAVE, LAMOST

… more surprises, more mysteries, more understanding

Thank you Don!

Our very own star!