



The magnetic fields of peculiar A and B stars in open clusters

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Magnetic fields – some basic problems

- What is the nature of magnetic fields found in some A and B stars? How are they produced?
 - Long-term stability, simple structure, lack of “activity”, lack of correlation between B and rotation rate suggest that field is a “fossil” left from (at least) PMS
- Why do Ap stars have fields while other A & B’s do not?
 - Not yet understood
- How does the field evolve as the star evolves?
 - If it is a fossil, there is ohmic decay plus distortion and amplification due to stellar structure changes

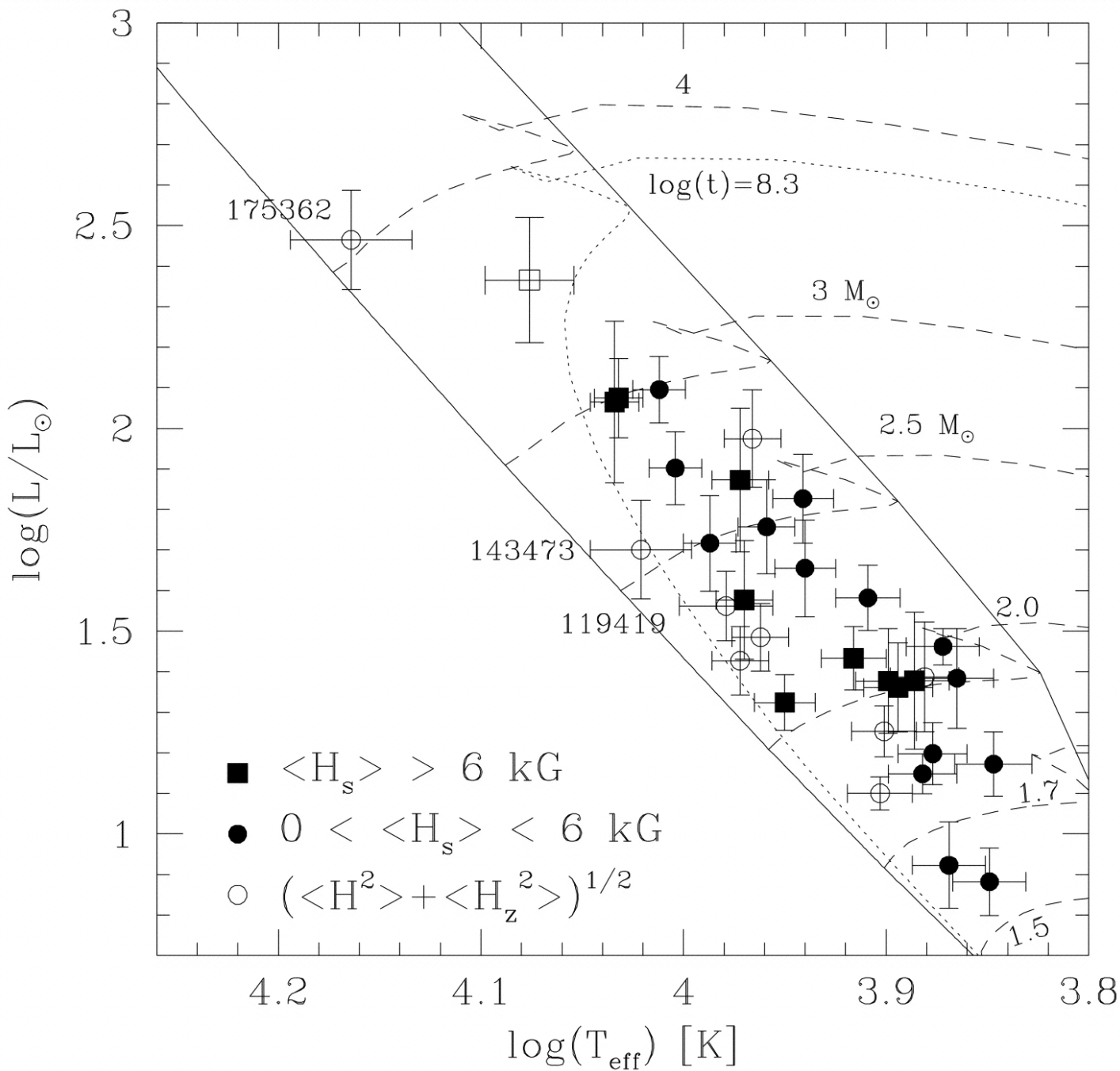
Observational study of Ap evolution

- At present, we know that at *some unknown time* in its main sequence life, a magnetic Ap star can have an observed field structure and surface chemistry
- To make observed characteristics of A stars into far more powerful probes of (M)HD processes, we want to be able to associate a particular field structure and chemistry *with a particular mass and age*, not just say that the observed state happen *sometime*, in a star of unknown age and mass

Observational study of Ap evolution - 2

- We need to determine masses, ages, and fractional ages (= fraction of MS lifetime) for a substantial sample of Ap stars
- The obvious method is to determine T_{eff} and $\log(L/L_{\odot})$ for field stars from parallaxes and photometry, and then compare results with standard evolution models in HR diagram to determine mass and fractional age
- We can then associate a particular observed star with a particular age since the PMS – 10^6 , 10^7 , 10^8 yr, etc
- We can also look for statistical trends in field strength, chemical abundances, rotation periods, etc

- Hubrig et al. sample
- magnetic field
- parallax
- Diagram
- They claim evidence
- first emission
- $3M_{\odot}$ after
- sequence
- Is this related
- rotation



Slow rotation of magnetic Ap stars

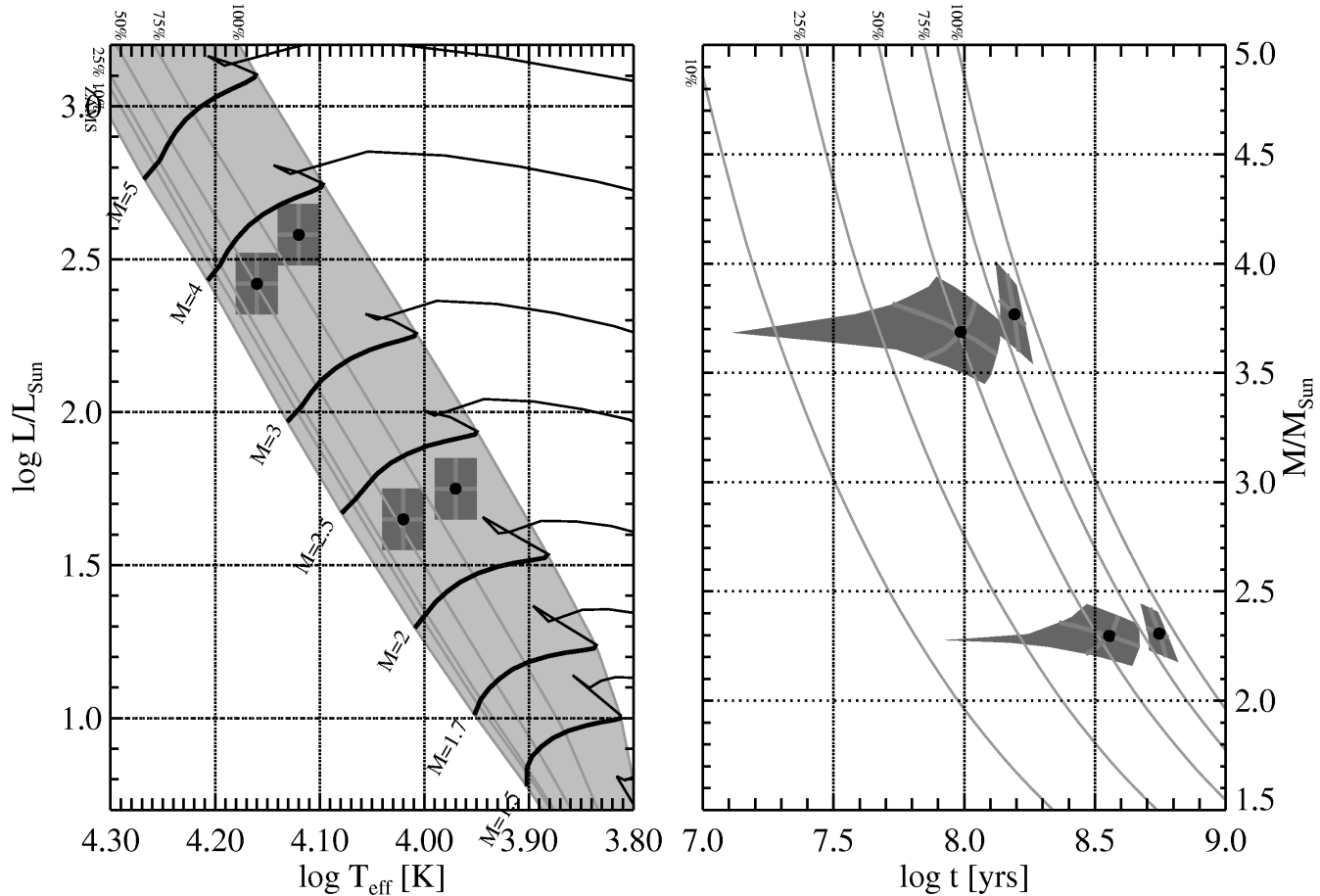
- Slow rotation of Ap stars probably due to magnetic coupling with circumstellar material (accretion disk, stellar wind)
- Even young Ap stars (in clusters, associations) have slow rotation, so loss of angular momentum probably occurs in PMS phase (North)
- Slowest rotators are cooler – lower mass – Ap stars that spend longer in PMS phase (Stepien)
- Hubrig et al result conflicts completely with this picture. If it is right, how do Ap's lose angular momentum without a surface field present to couple to surroundings?

New observational data

- Hubble
- Hipparcos
- (Real-time)
- $\log(L/L_{\text{Sun}})$
- the brightness
- right
- How
- observational
- active

$$\tau = 0.020$$

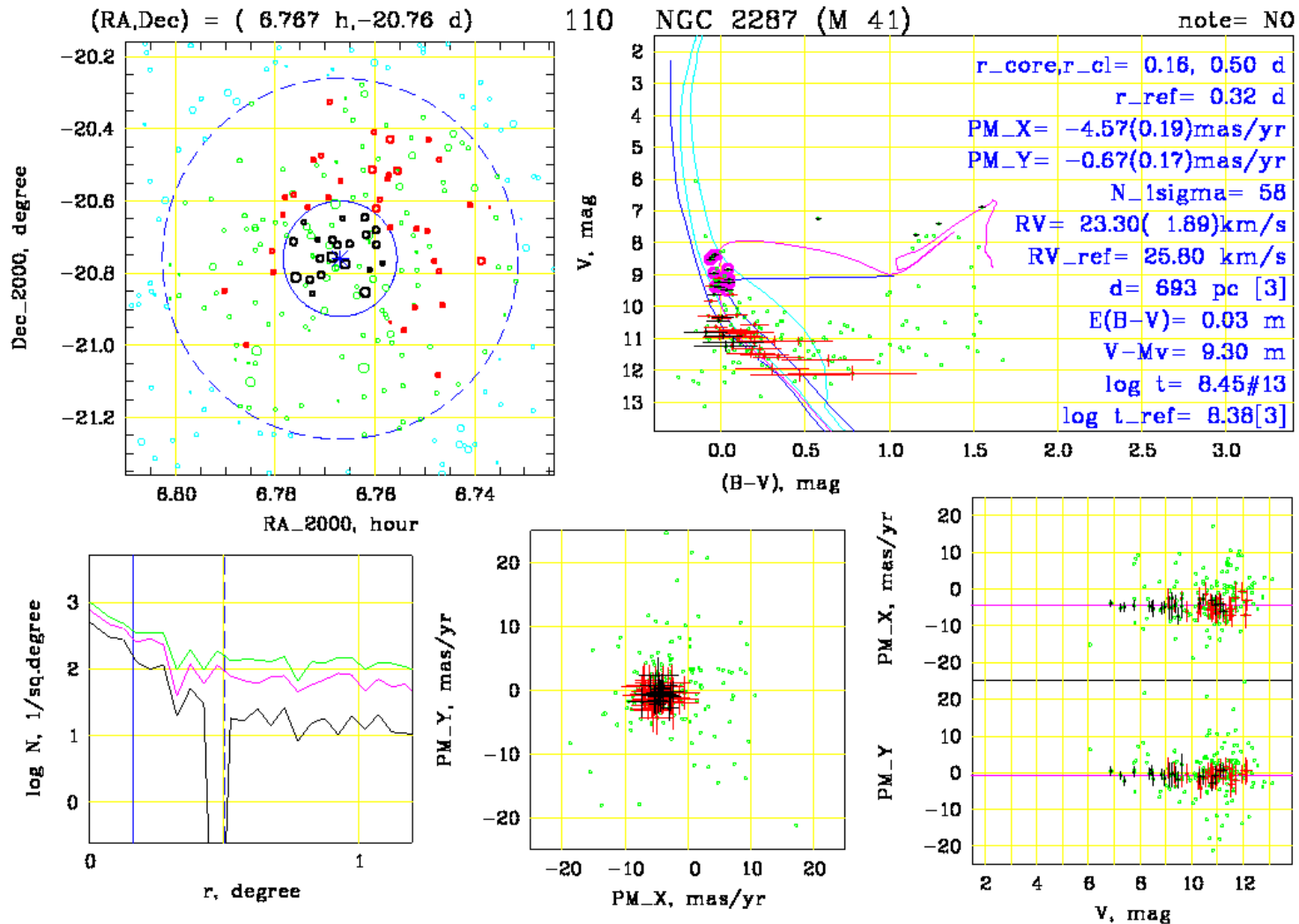
$$Z = 0.008$$



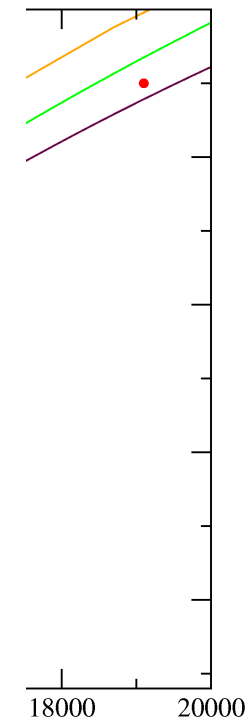
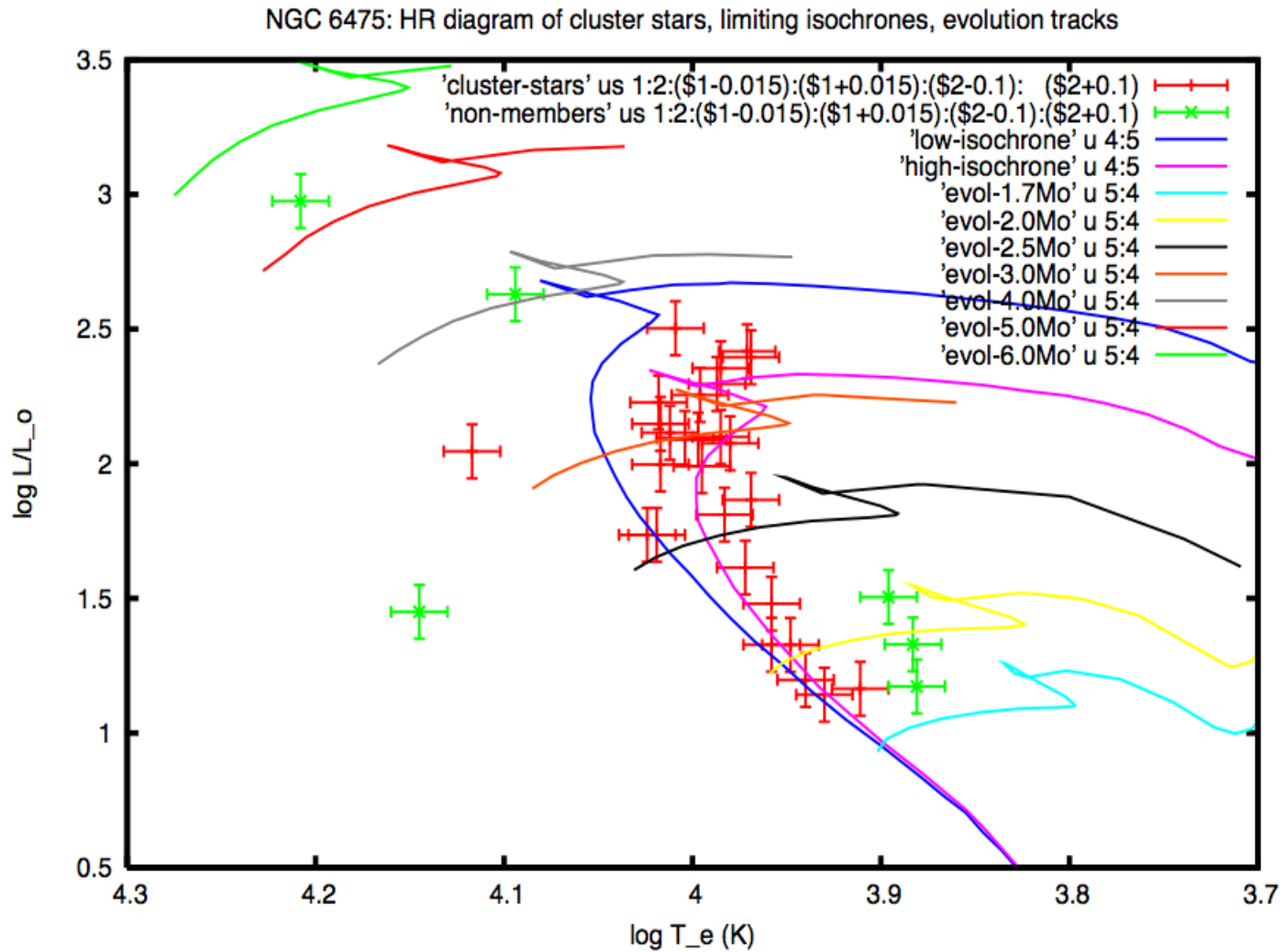
Plot

Plot created on Tue Aug 23 18:53:18 2005 by vincenzo@phoebe with fig_errblob.pro

Cluster magnetic Ap stars



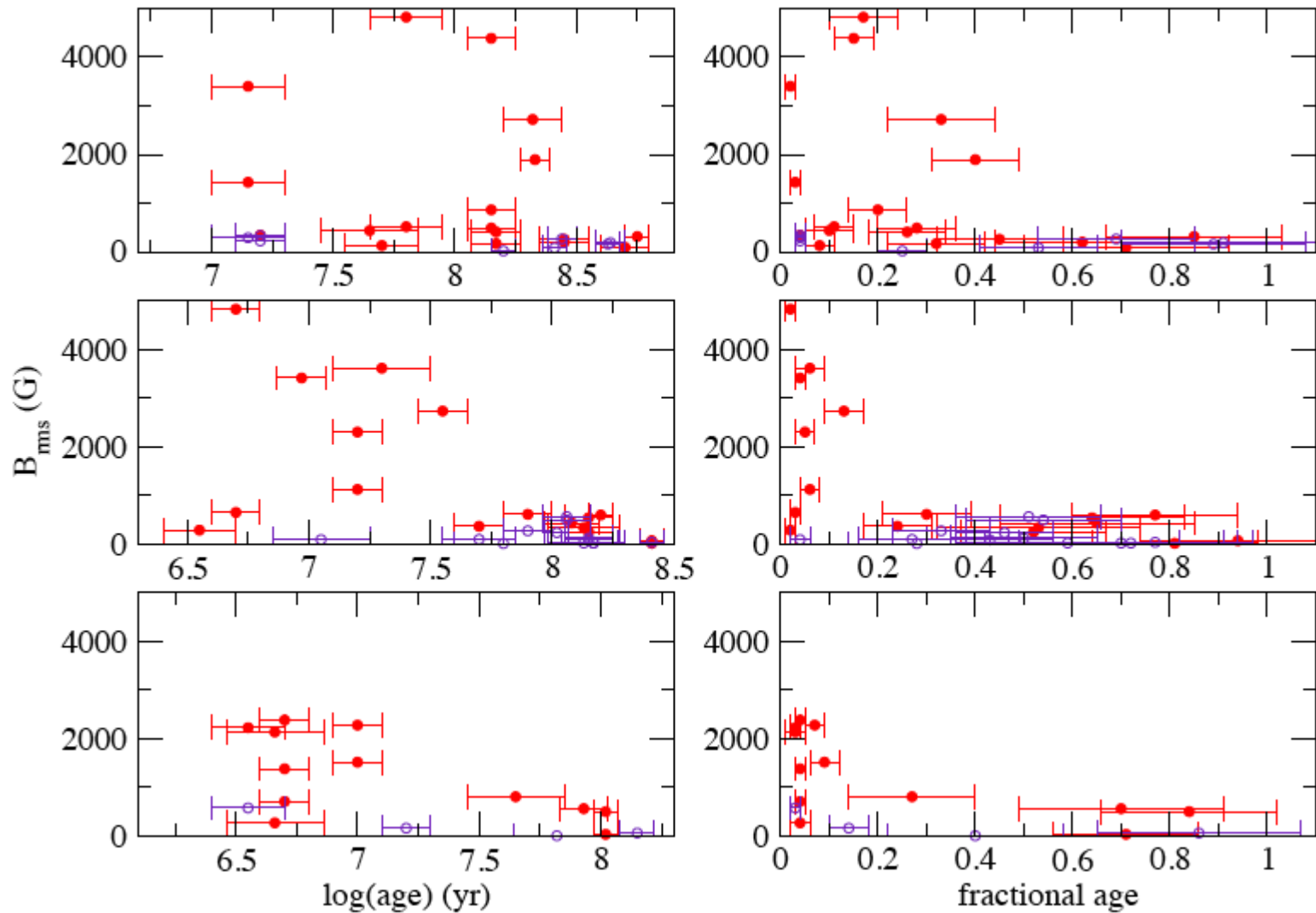
How to use these data?



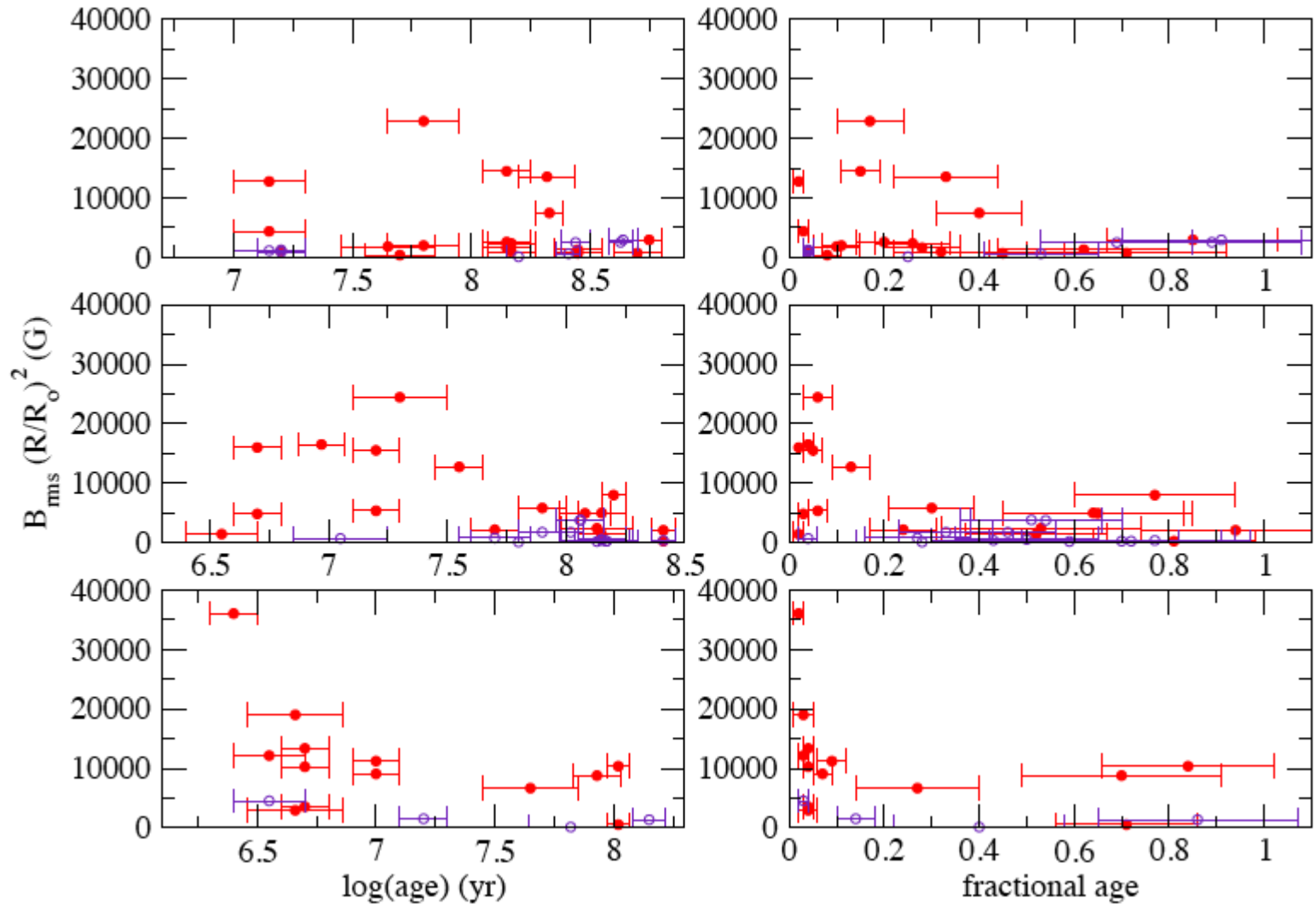
Results so far

- Sample is rich in massive and relatively young stars
- Fractional ages of young cluster magnetic Ap stars are much more precise than those of field stars
- *Fields and fluxes definitely decline with age for all mass ranges between 2 and 5 M_{\odot}*
- This evolution is not in very good agreement with field increase during part of MS lifetime predicted by Brathwaite and collaborators
- Contrary to Hubrig theory, plenty of magnetic fields in young 2 – 3 M_{\odot} stars
- Hardly any stars in sample below 2 M_{\odot} of any age, even though Ap's occur down to 1.6 M_{\odot} among field stars!?

Field strength vs age



Flux vs age



Next?

- The next step is to study how chemistry evolves with stellar age in our sample. We then have a powerful tool for using observed stars to inform theory about how both fields and atmosphere chemistry depend on mass and evolve with time
- This should be very helpful in using observed stellar characteristics to guide and test ideas about the interaction of various stellar hydrodynamic and magneto-hydrodynamic processes, our initial goal