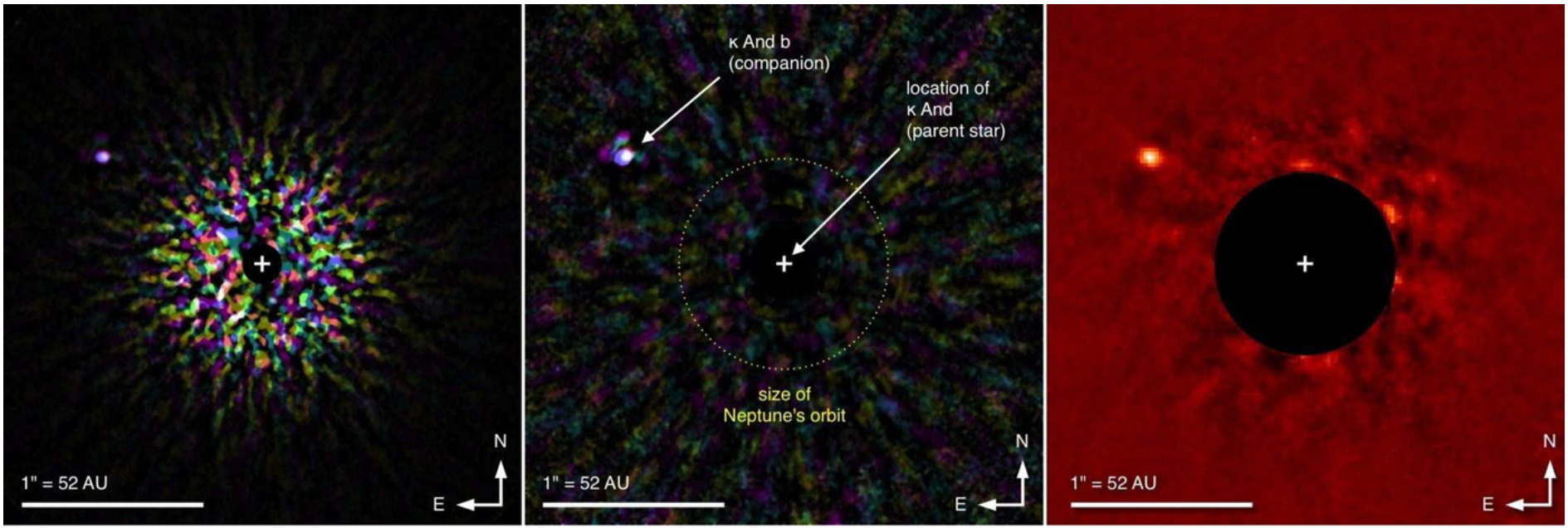
The Ages of Massive Stars and Young Clusters from Rotating Stellar Models

Sagan Symposium

Timothy Brandt
Institute for Advanced Study

7 May 2015

κ And b, companion to B9 star



Carson et al., 2013, ApJL, 763, 32

"Planet:" 13 M_{Jup}? 50 M_{Jup}?

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Star: 30 Myr? 200 Myr?

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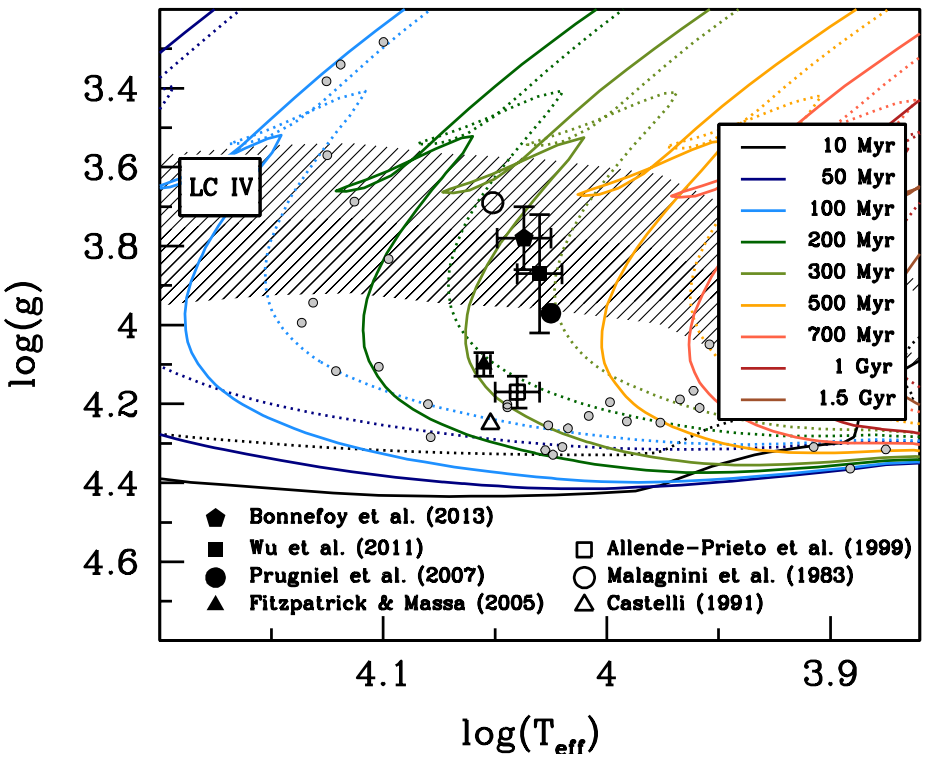
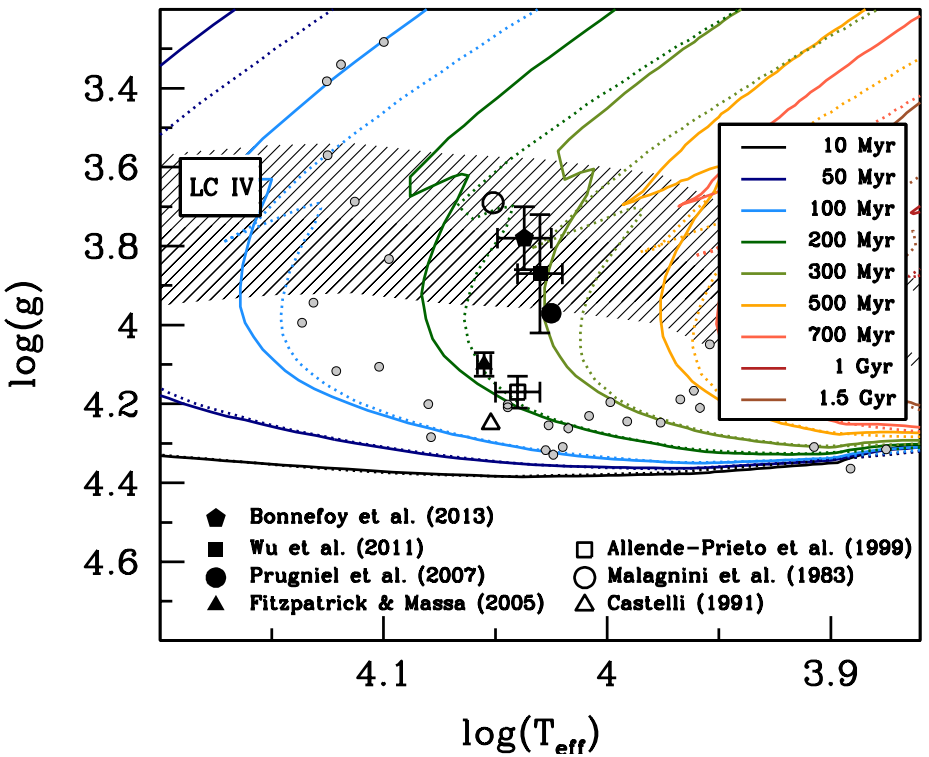
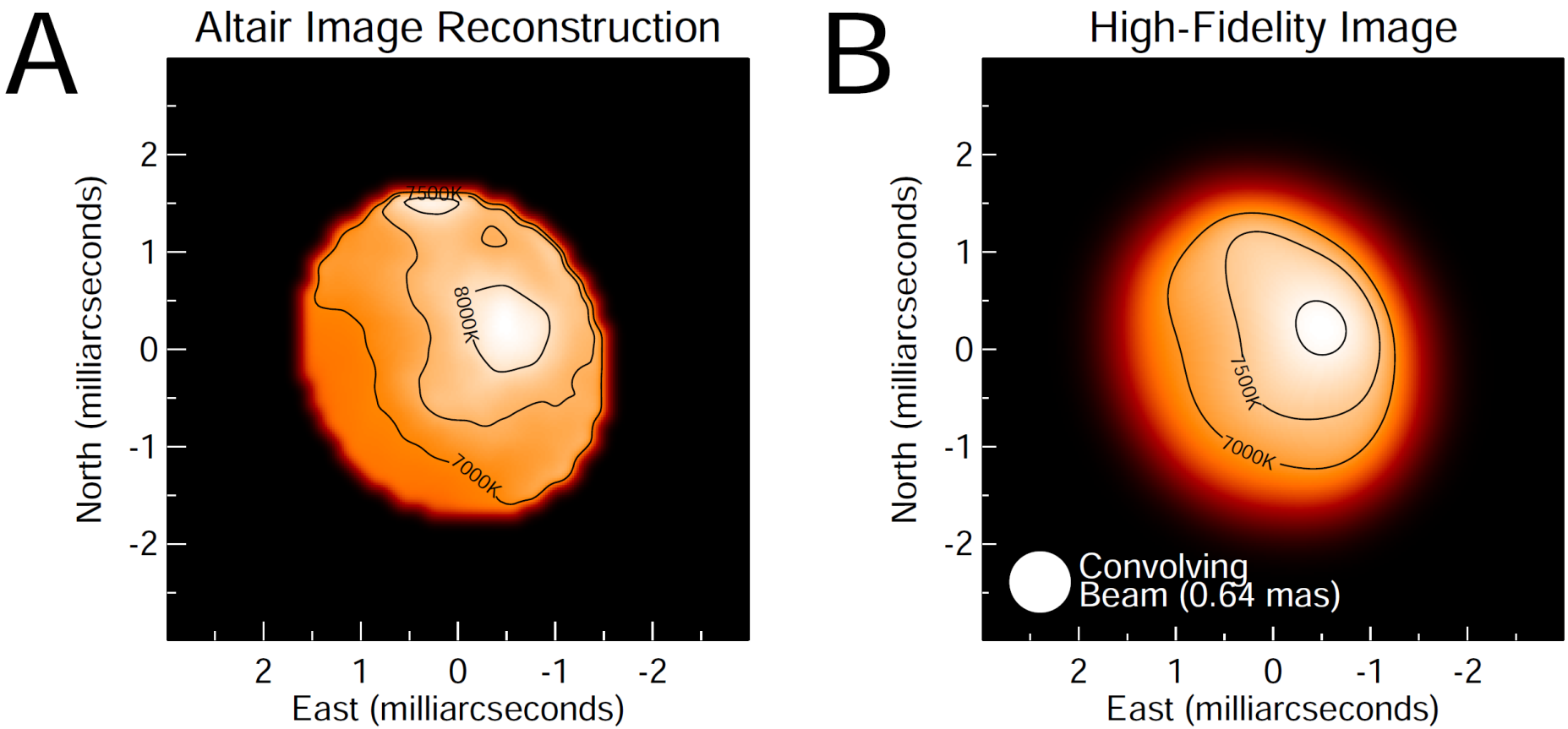
Based on **kinematics**, **H-R diagram placement**





Hinkley et al., 2013, ApJ, 779, 153

Vega and Altair are rotating at ~90% of critical

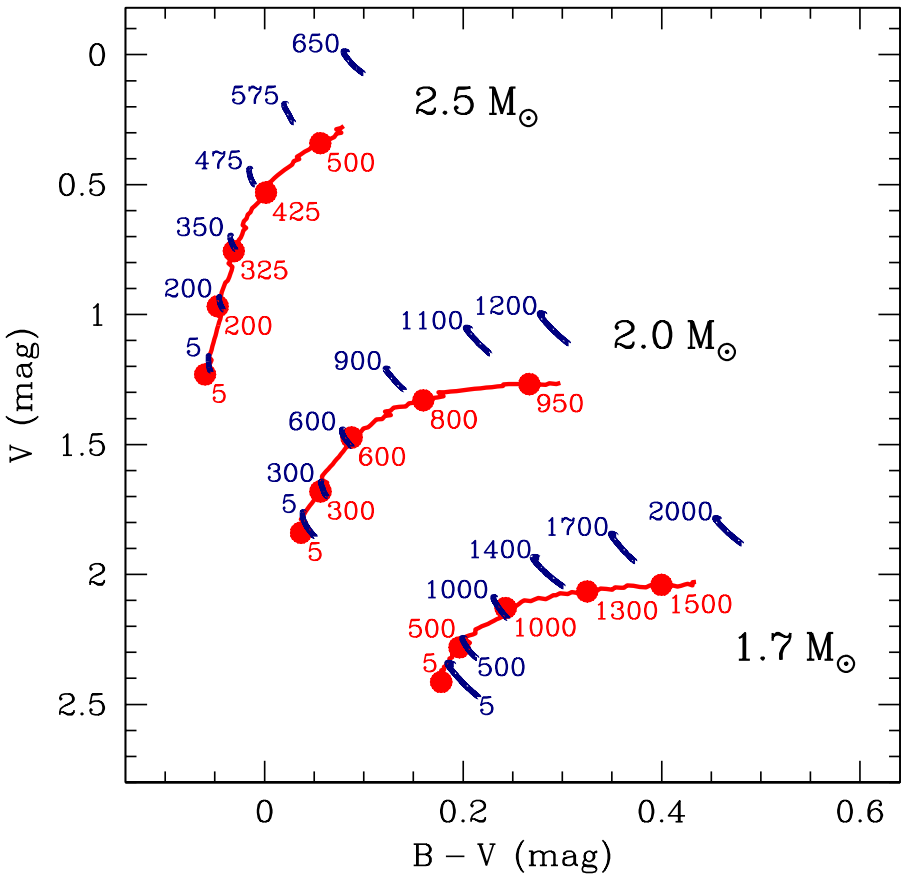


Monnier et al., 2007, Science, 317, 342

Stars $\gtrsim$1.5 $M_\odot$ do not spin down

Rapid rotation:

1. Flattens the star
2. Produces large pole-equator differences in temperature
3. Extends stellar lifetimes
4. Increases stellar luminosity

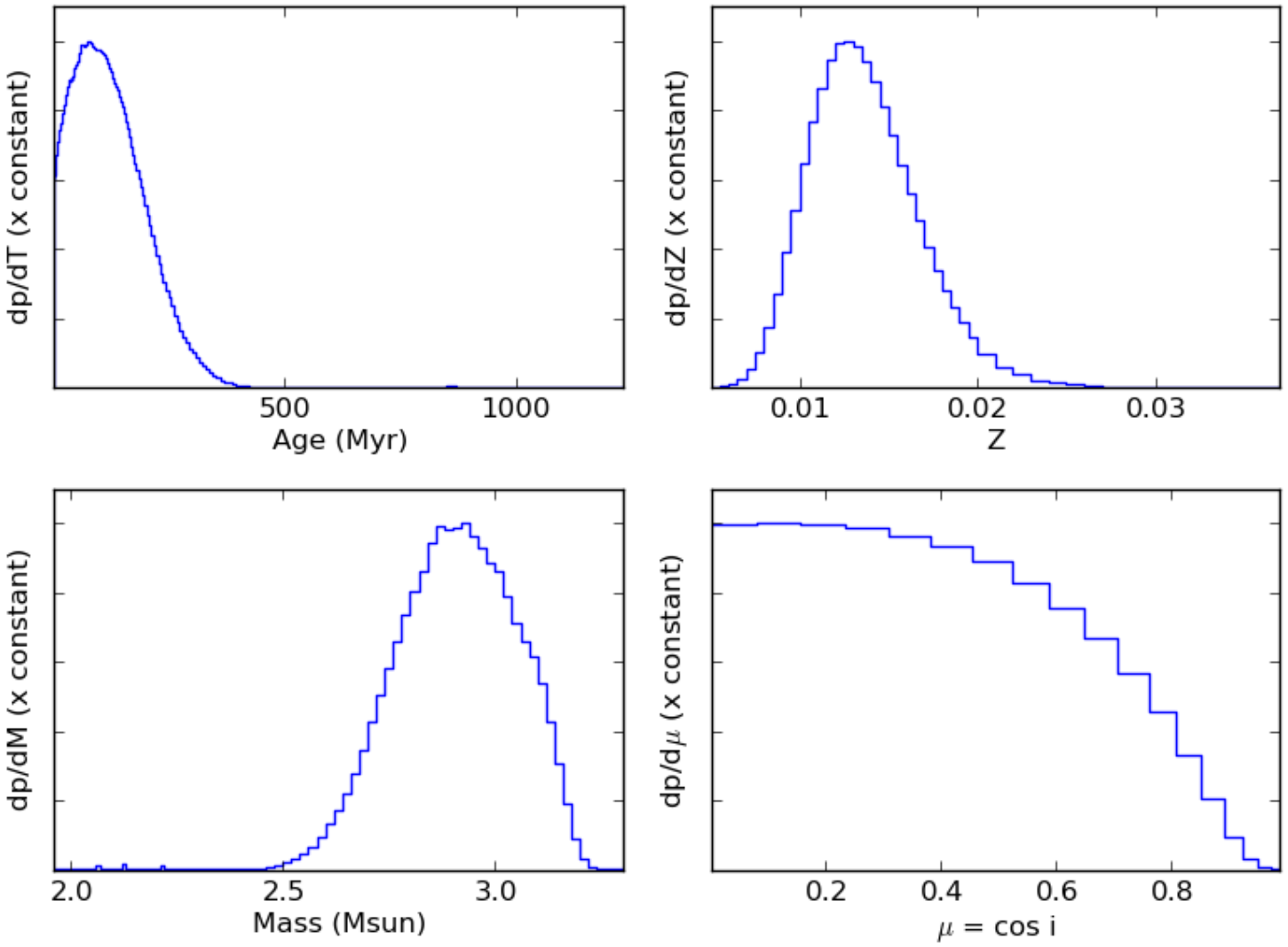


Large rotating evolutionary grids are now available

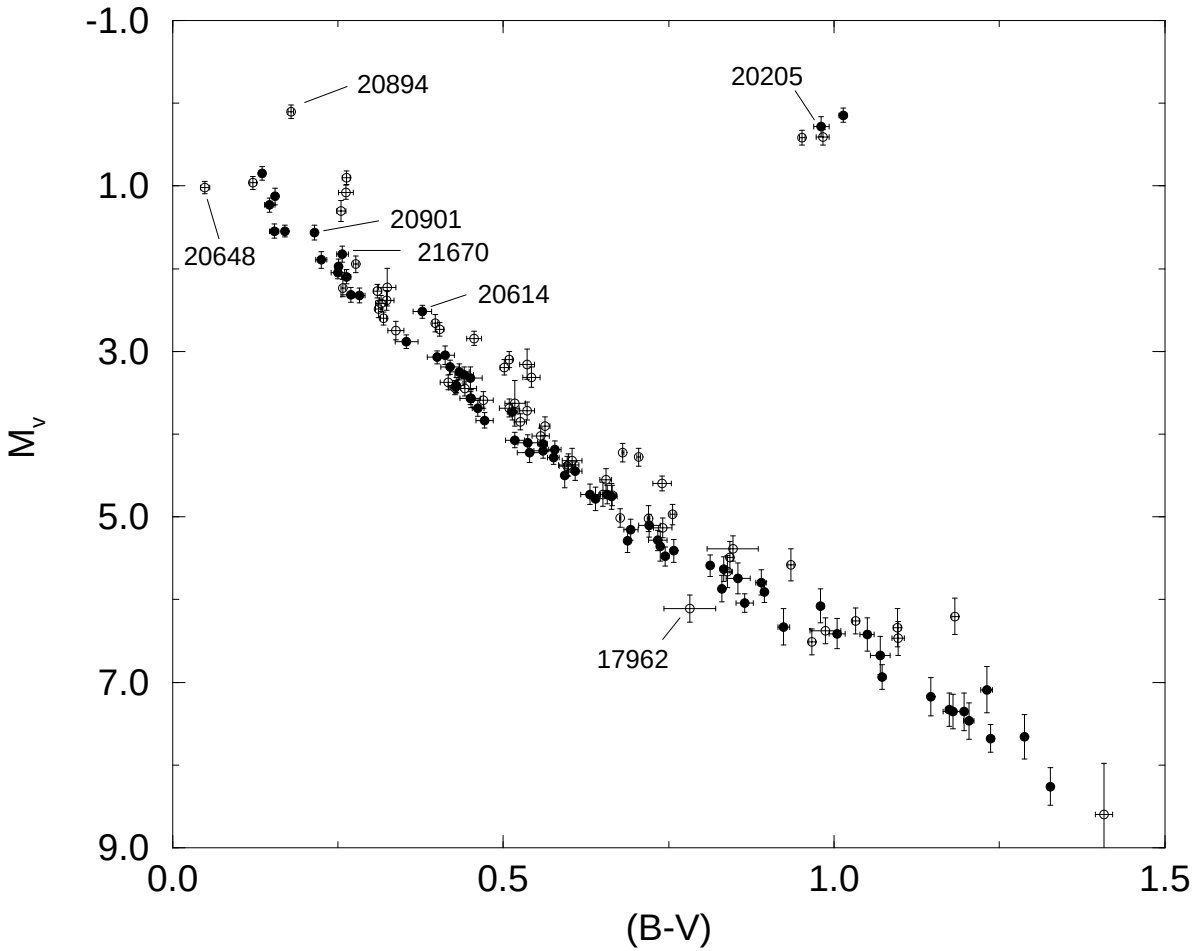
Georgy et al., 2013, A&A, 553, 24

`bayesianstellarparameters.info`

Marginalized posterior probability distributions:



How much does it matter? **Case Study: the Hyades**



Perryman et al., 1998, A&A, 331, 81

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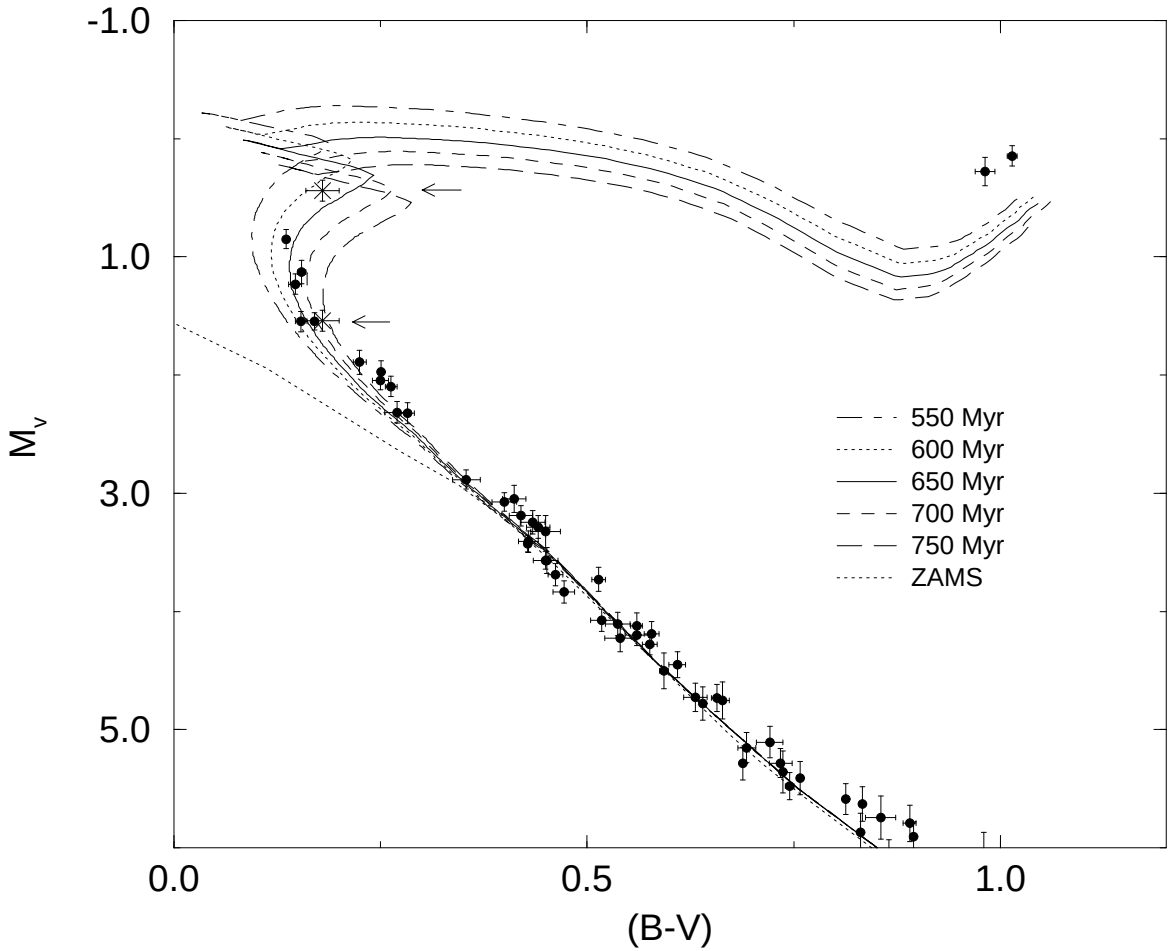

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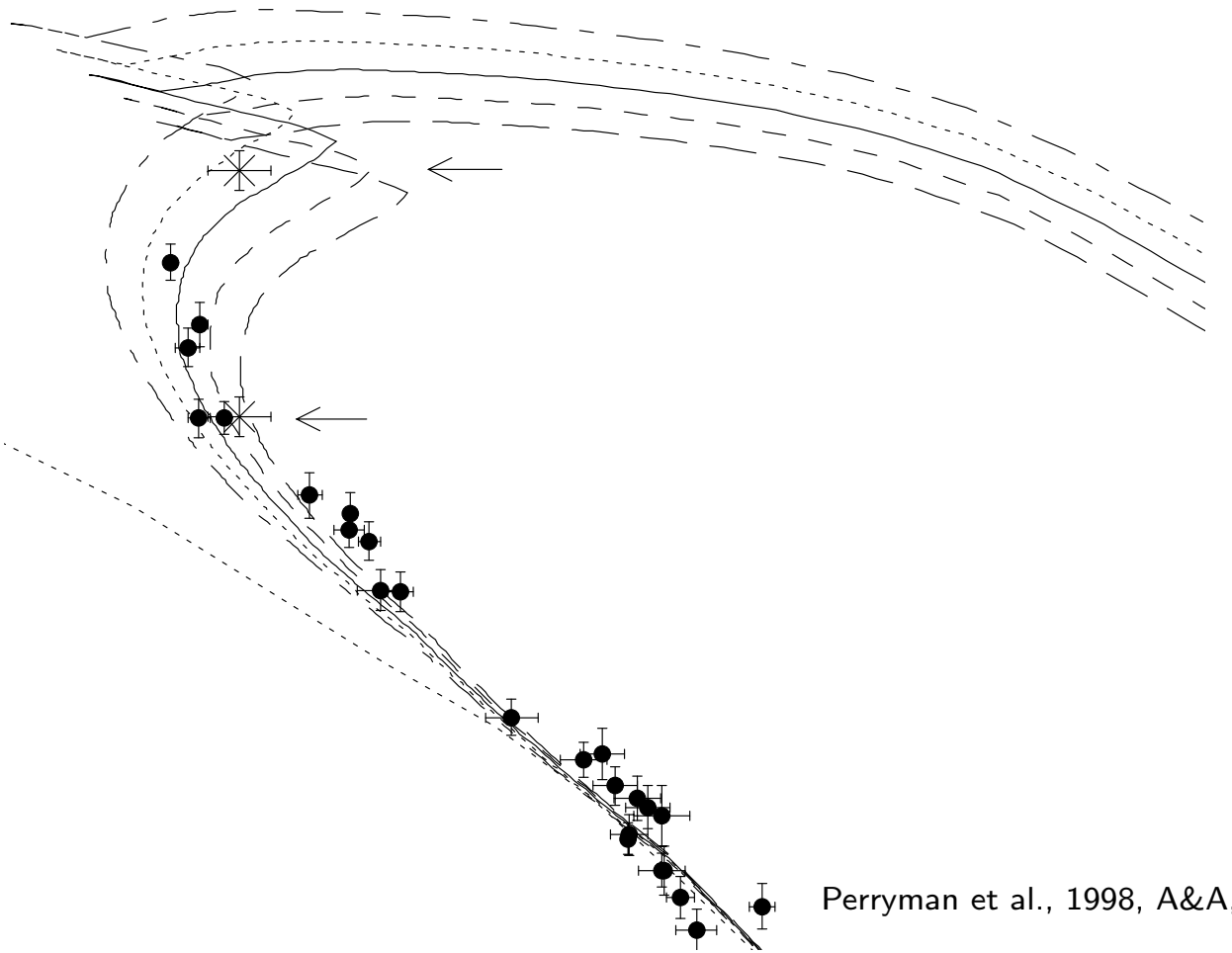

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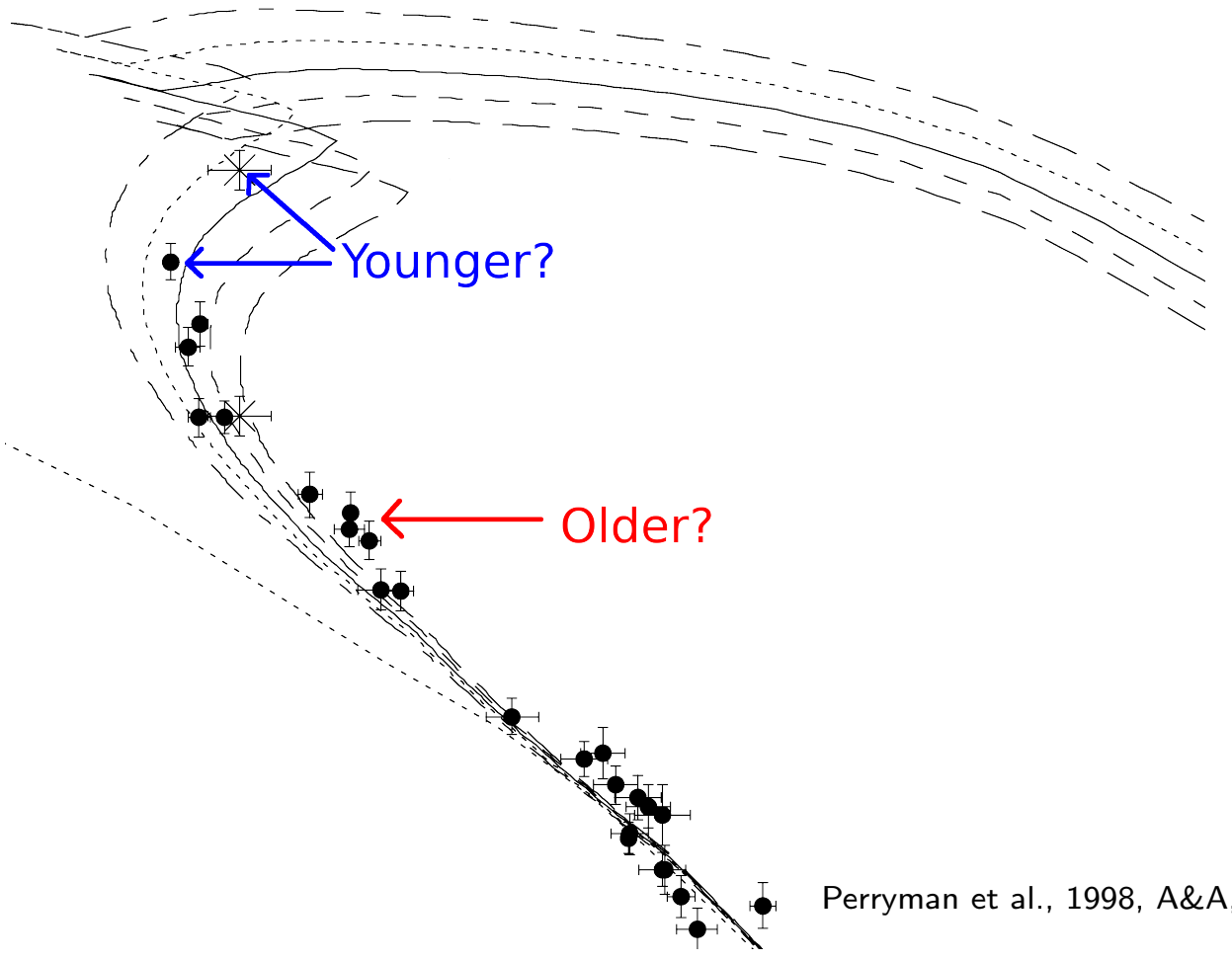

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Now do the Bayesian calculation

$$\text{Each star: } \mathcal{L}_{\text{star}}(M, Z, \tau, i, \Omega \,|\, \text{mags}, v \sin i, \varpi)$$

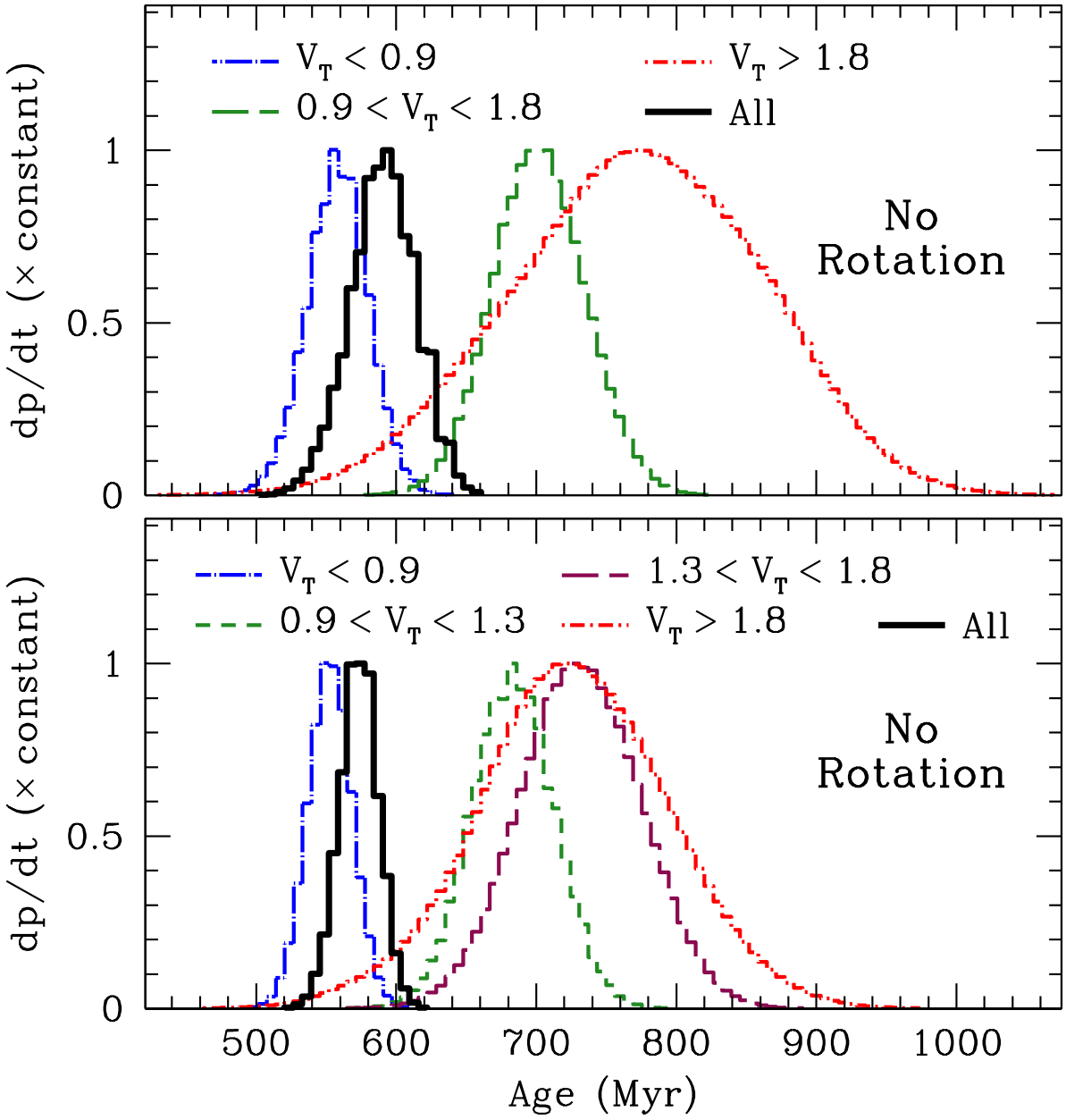
$$\text{Marginalize over } M,\ i,\ \Omega \Rightarrow \mathcal{L}_{\text{star}}(Z, \tau)$$

$$\mathcal{L}_{\text{cluster}}(Z, \tau) = \prod_{\text{stars}} \mathcal{L}_{\text{star}}(Z, \tau)$$

Prior on Z_{cluster} from FGK members $\Rightarrow p(\tau)$

Hyades

Praesepe



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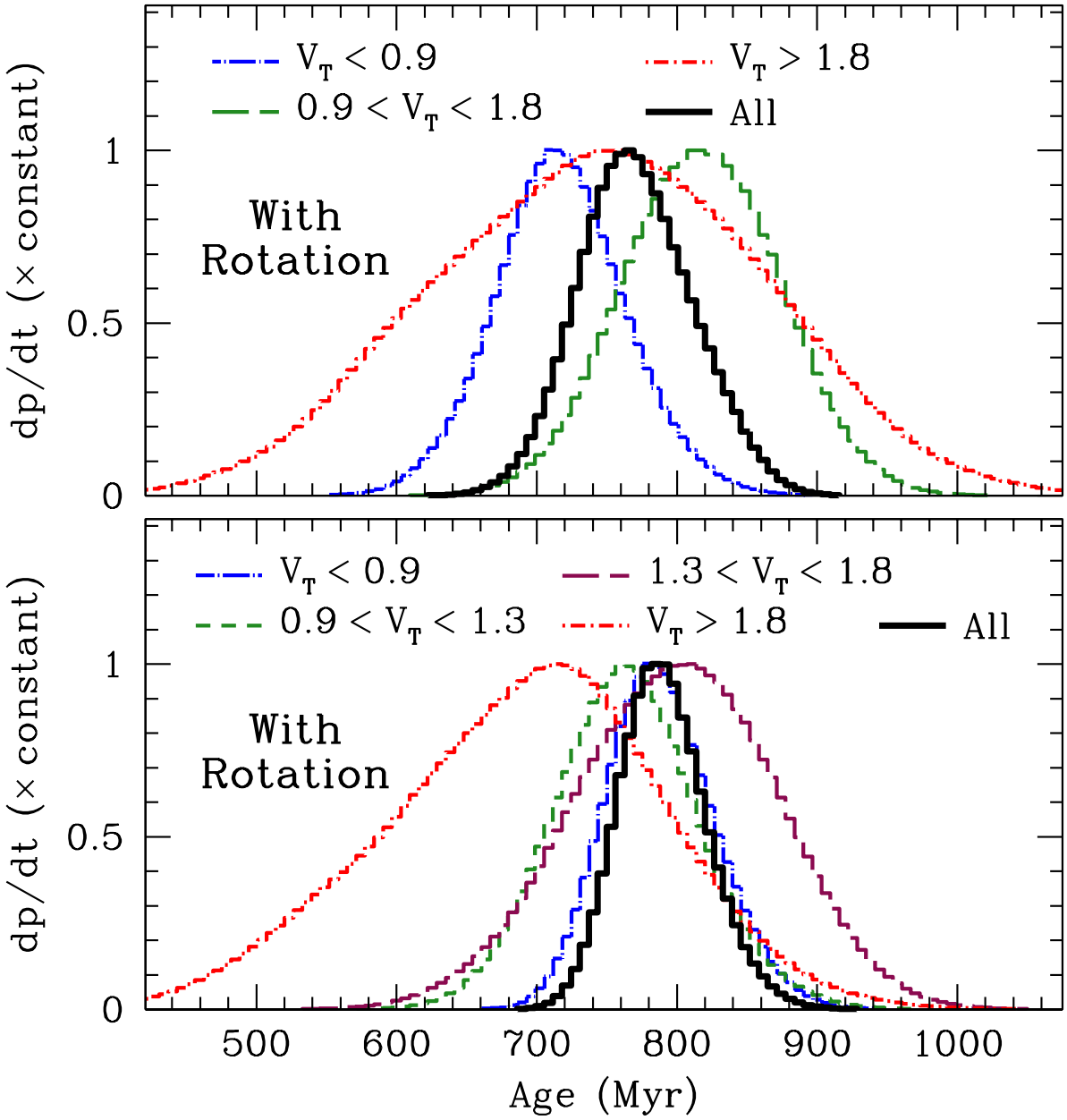
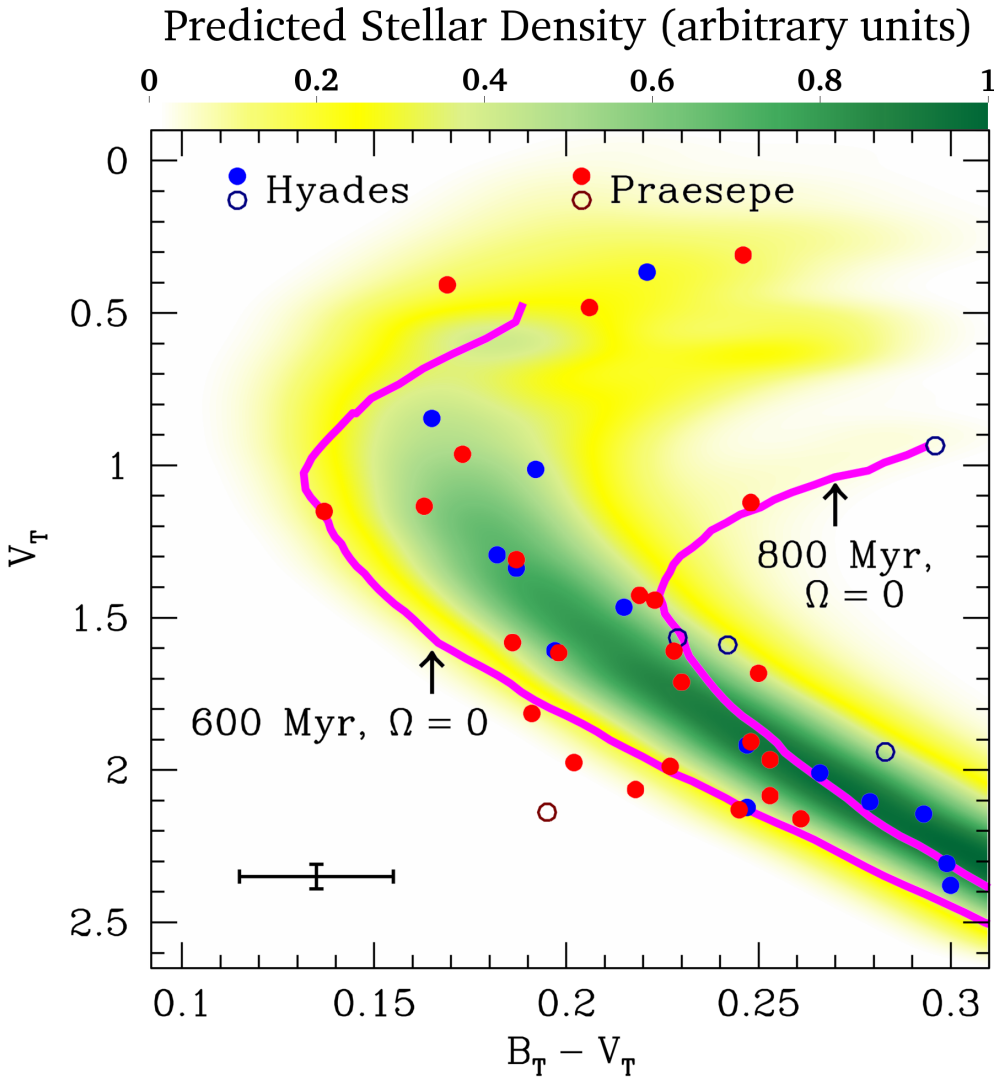


Two Possibilities:

1. The Hyades formed over hundreds of Myr
2. The stellar models are wrong



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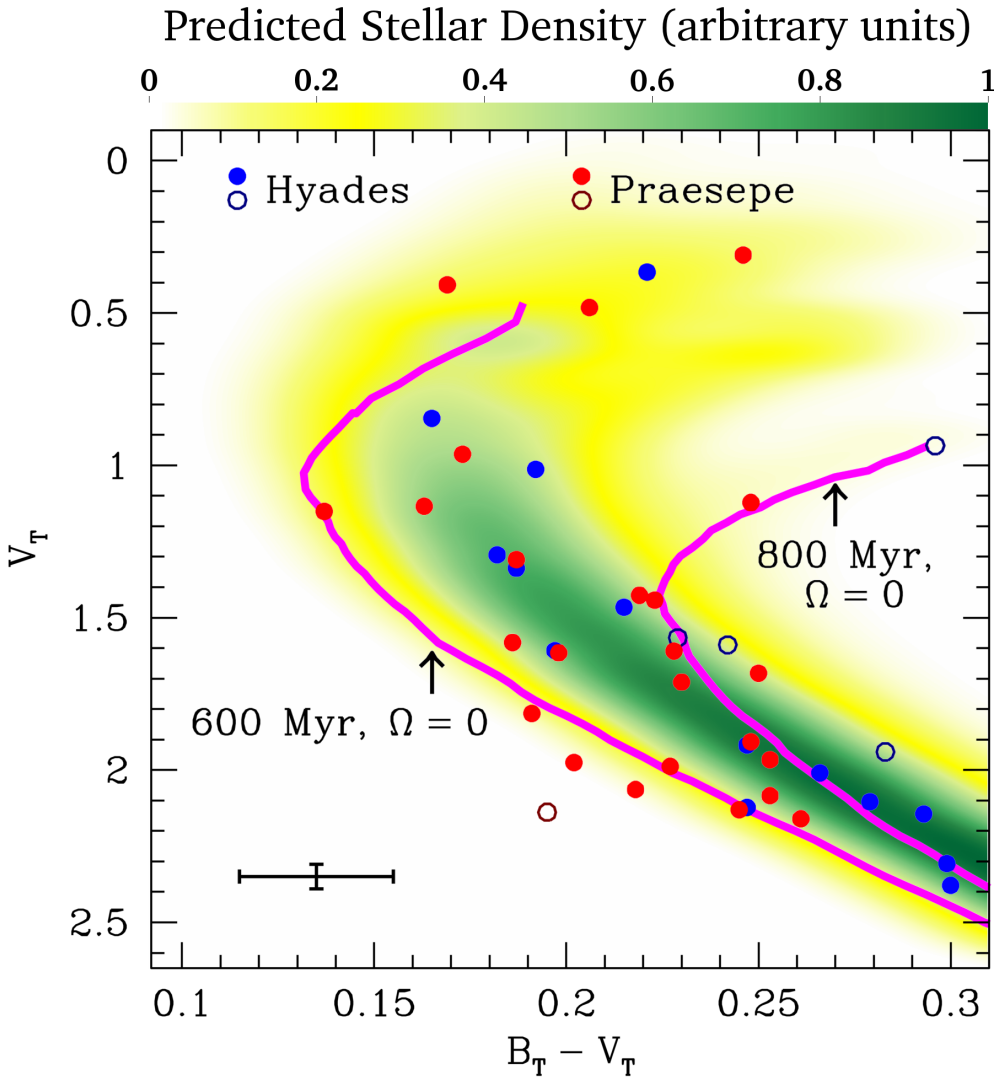
Rotation: a **consistent** picture at an **older** age



NGC 1806: LMC cluster

Doesn't match any isochrone

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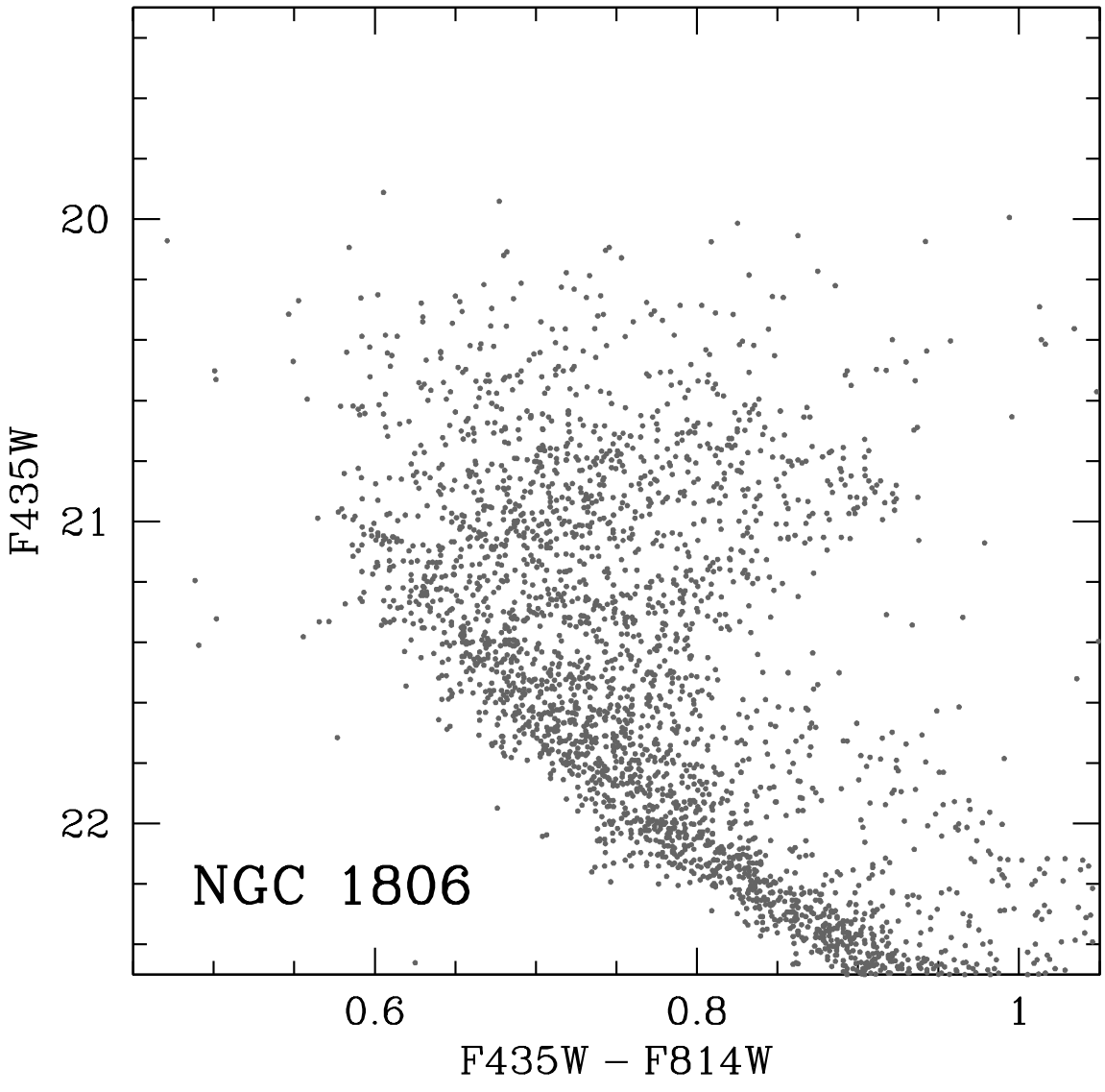

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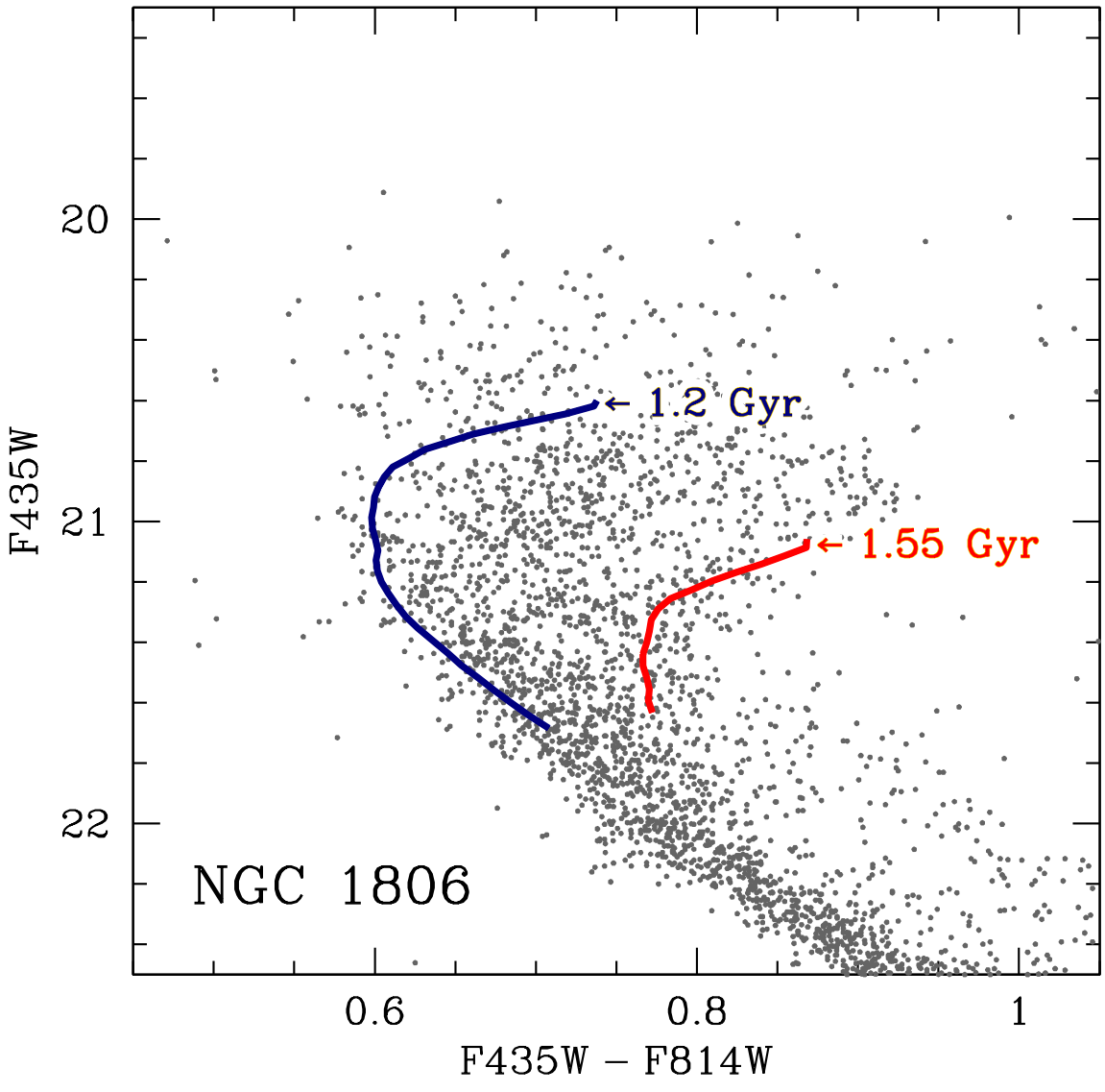

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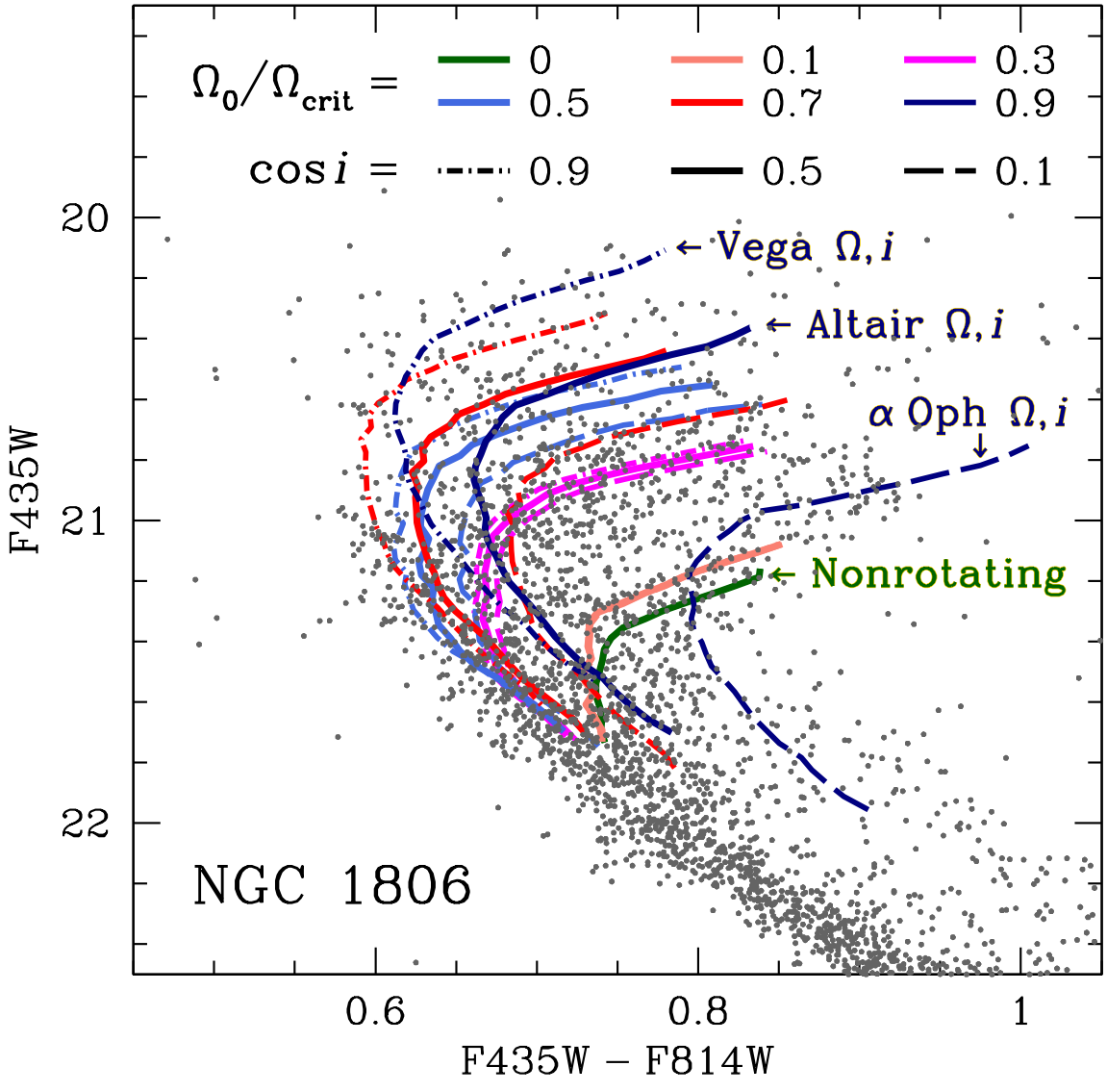

Rotation is crucial for dating massive stars

1. Bayesian ages for your favorite *Hipparcos* A stars
2. Consistent ages in the Hyades, Praesepe
3. No need for age spread in LMC clusters

Stellar evolution still has surprises!

Thank you