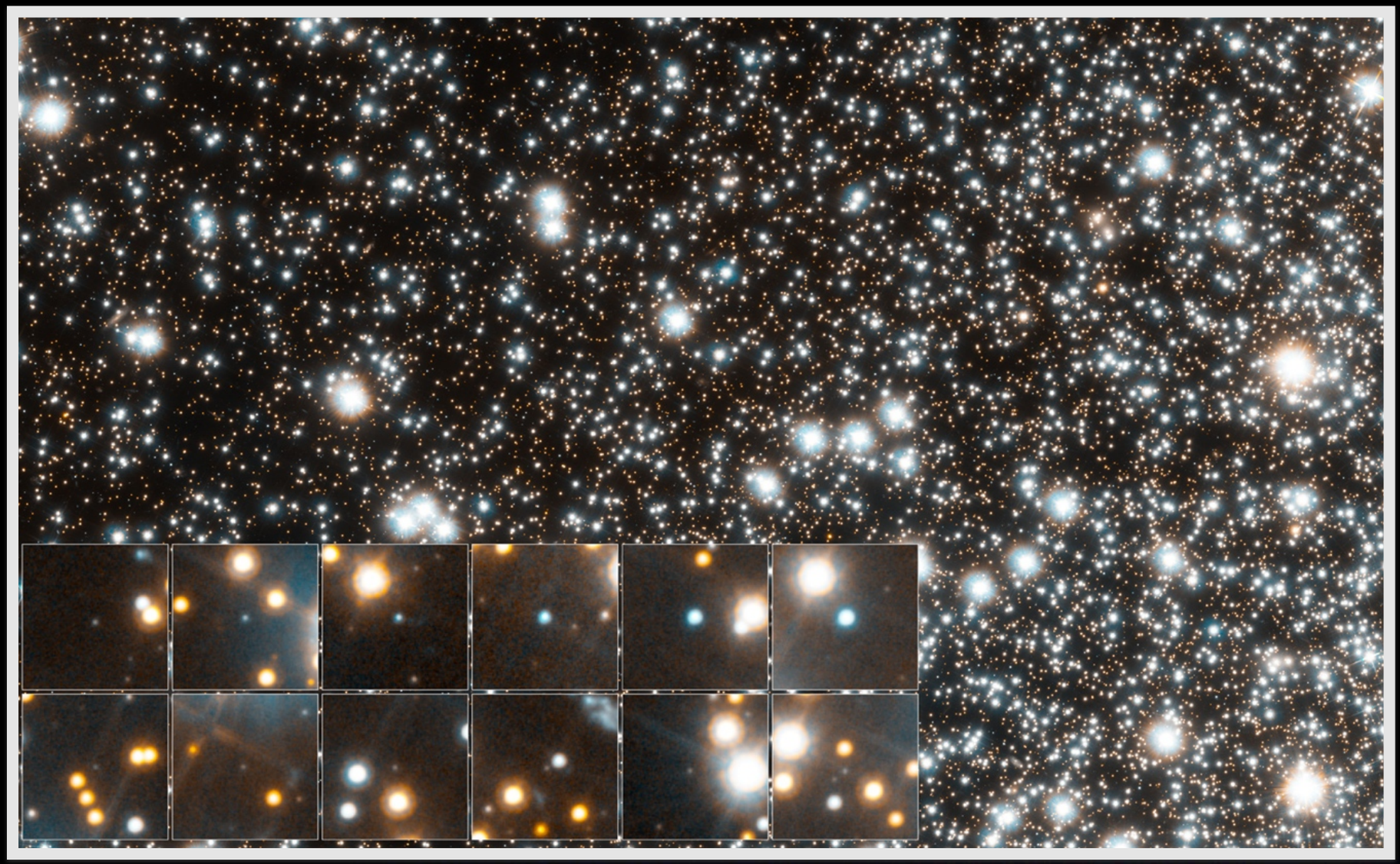
The Initial-Final Mass Relation: 2.0



Jason Kalirai (STScI, JHU)

The Initial-Final Mass Relation: 2.0

Jason Kalirai (STScI, JHU)

Collaborators

Jay Anderson, Pier-Emmanuel Tremblay (STScI)
Pierre Bergeron (UMontreal)
Marcio Catelan (Pontificia - Chile)
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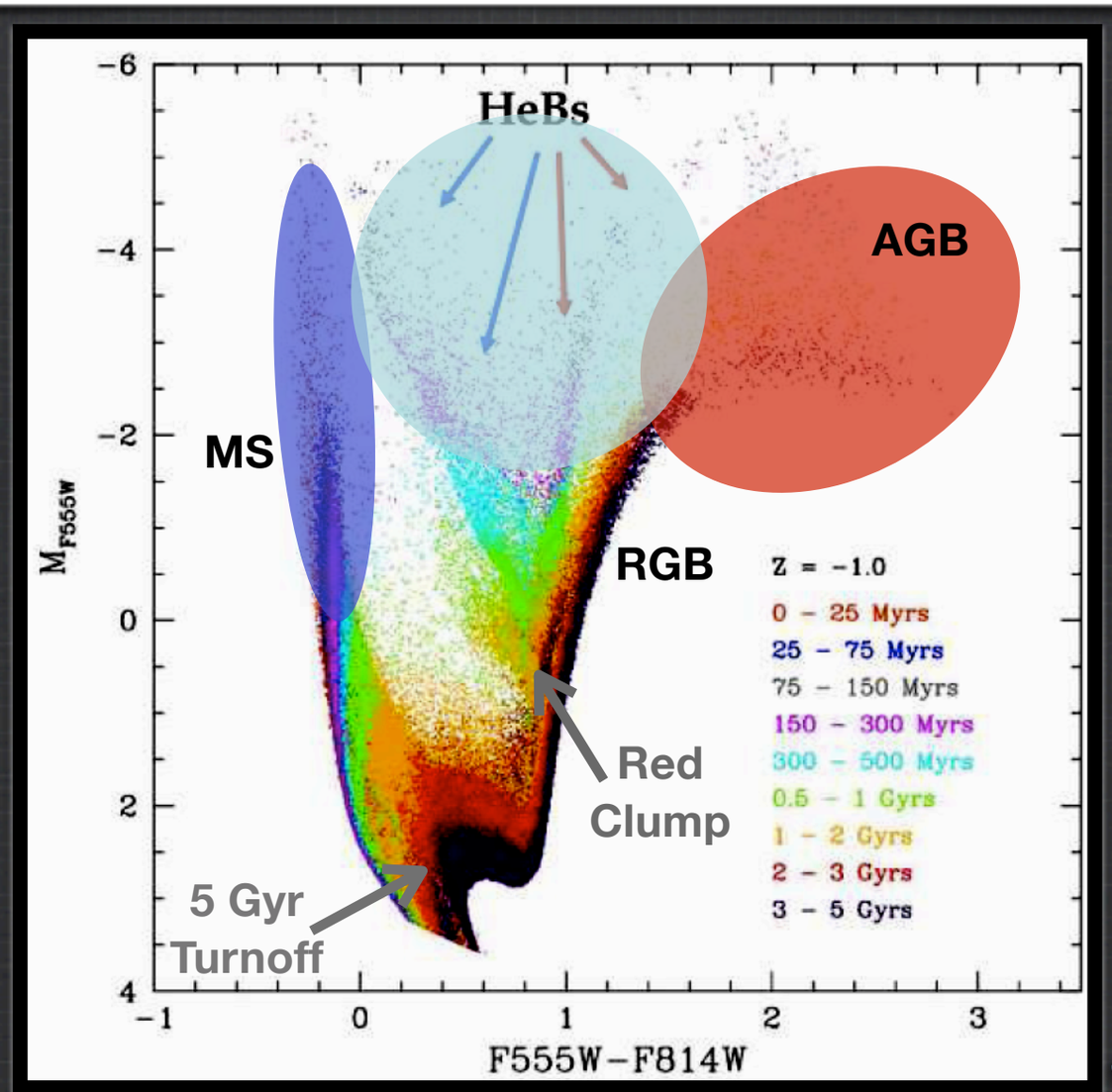
Jeff Cummings (JHU)
Aaron Dotter (ANU)
Greg Fahlman and Peter Stetson (HIA/NRC)
Brad Gibson (Central Lancashire)
Brad Hansen and Mike Rich (UCLA)
Jarrod Hurley (Swinburne)
Daniel Kelson (OCIW)
Ivan King (UW)
Paola Marigo (Padova)
Enrico Ramirez-Ruiz (UCSC)
David Reitzel (Griffith Obs)
Harvey Richer, Saul Davis, Ryan Goldsbury, Jeremy Heyl (UBC)
Mike Shara and David Zurek (AMNH)
Ted von Hippel (Siena College)
Kristen Woodley (UCSC)

A Picture of ~~Galaxies~~ Star light



J. Dalcanton (2010, priv comm.)

The Problem - How Much Mass do Stars Lose?

The Red Giant and Asymptotic Giant Branches

Mass loss affects the brightest phases of stellar evolution:

- ★ Luminosity functions
- ★ Evolutionary time scales
- ★ HB and UV EHB morphologies
- ★ Planetary nebula and white dwarfs

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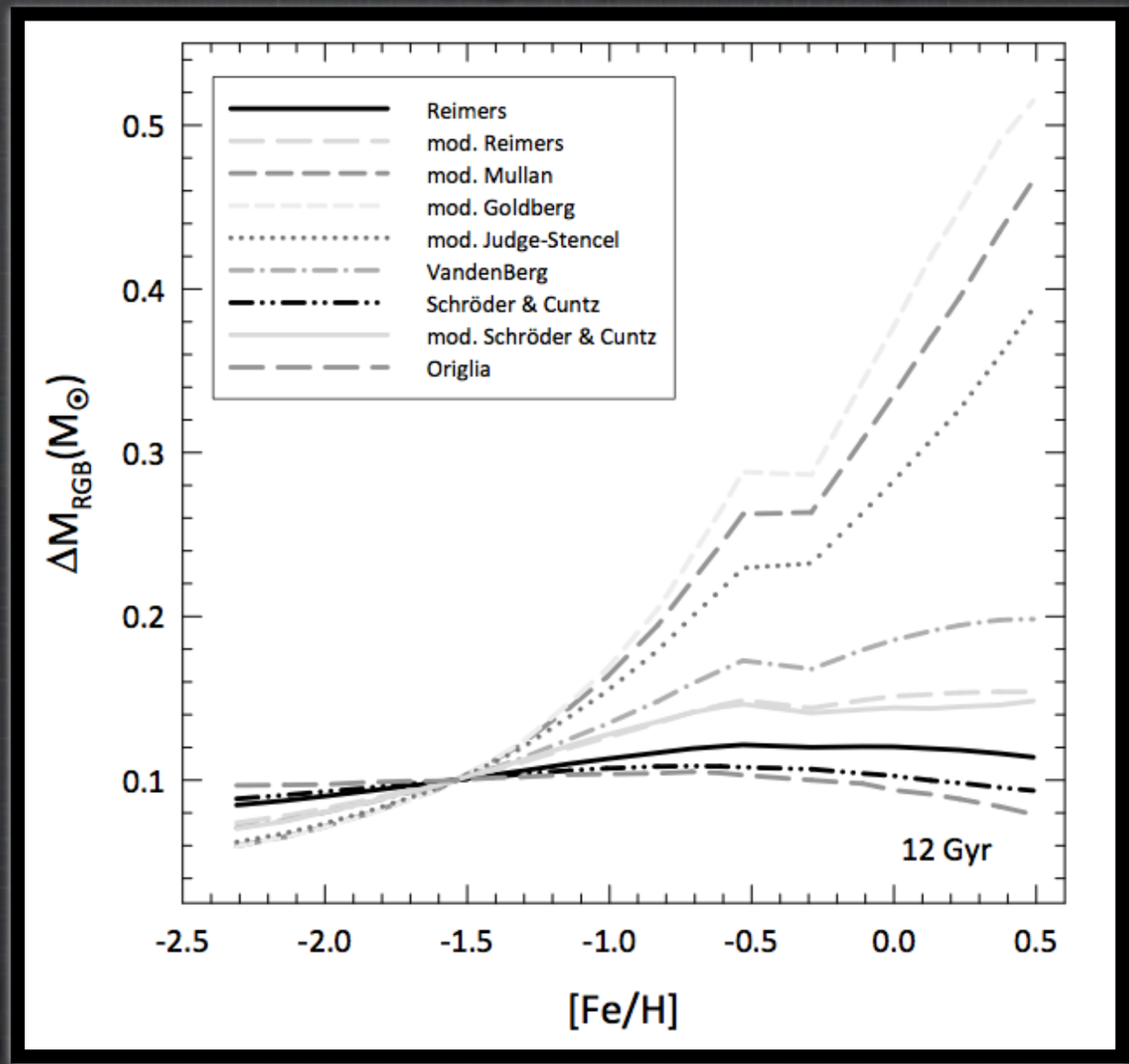
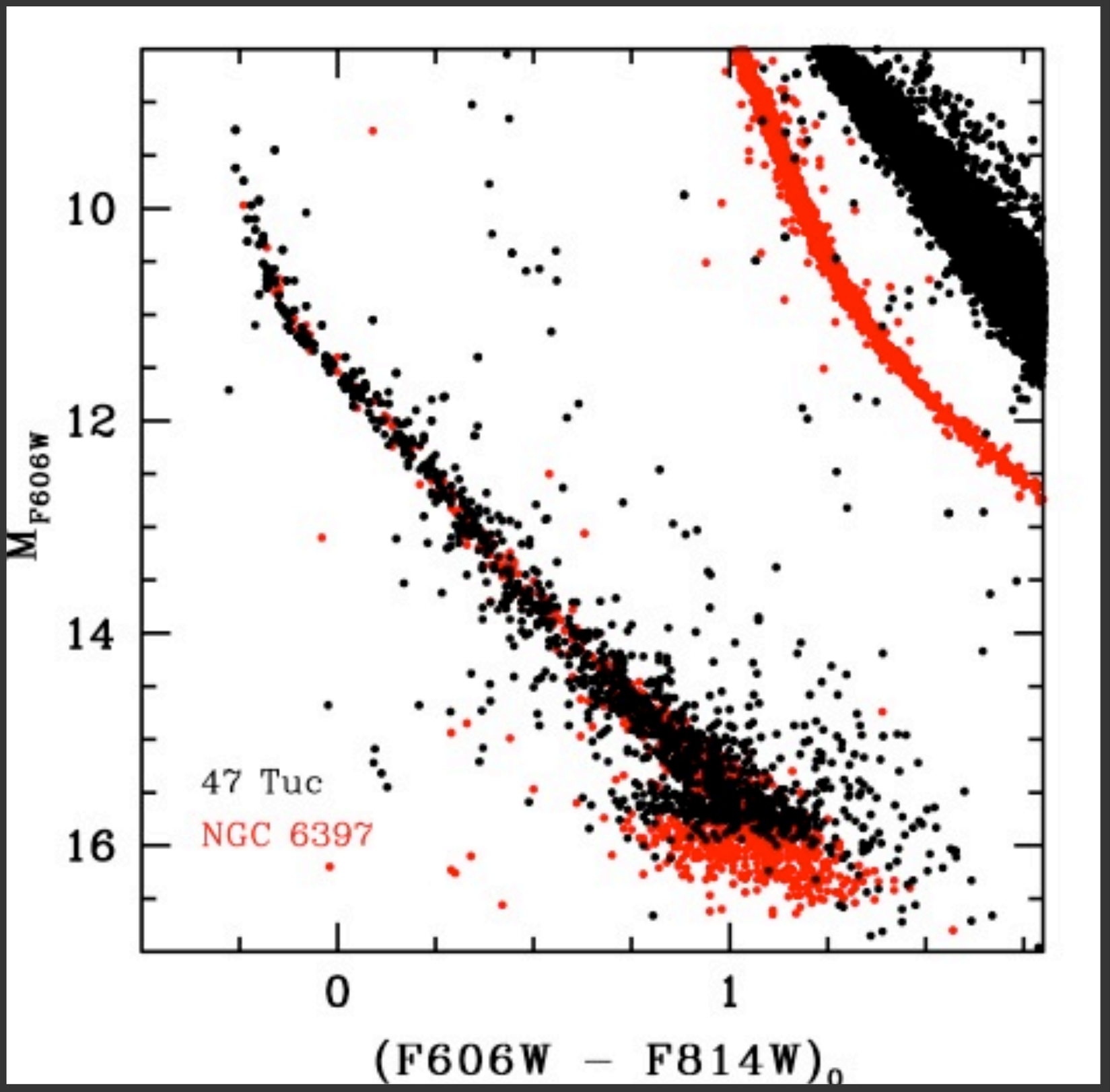


Catelan (2000)
Catelan (2009)

The End Product of Stellar Evolution: SIMPLE stars

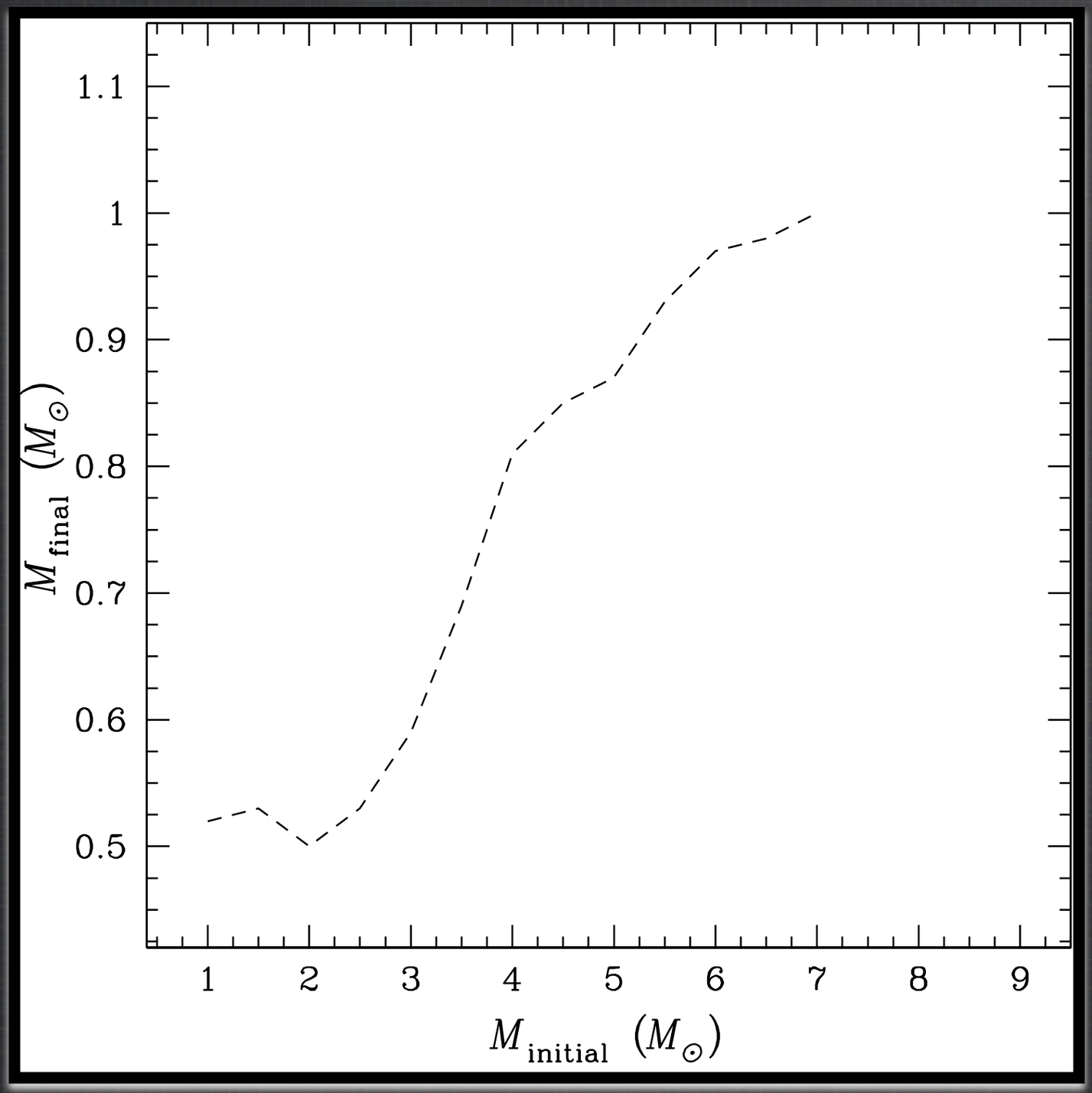


Hansen et al. (2013)

The Problem - How Much Mass do Stars Lose?

The Trick

- ★ Simultaneously measure both the initial and final masses of stars



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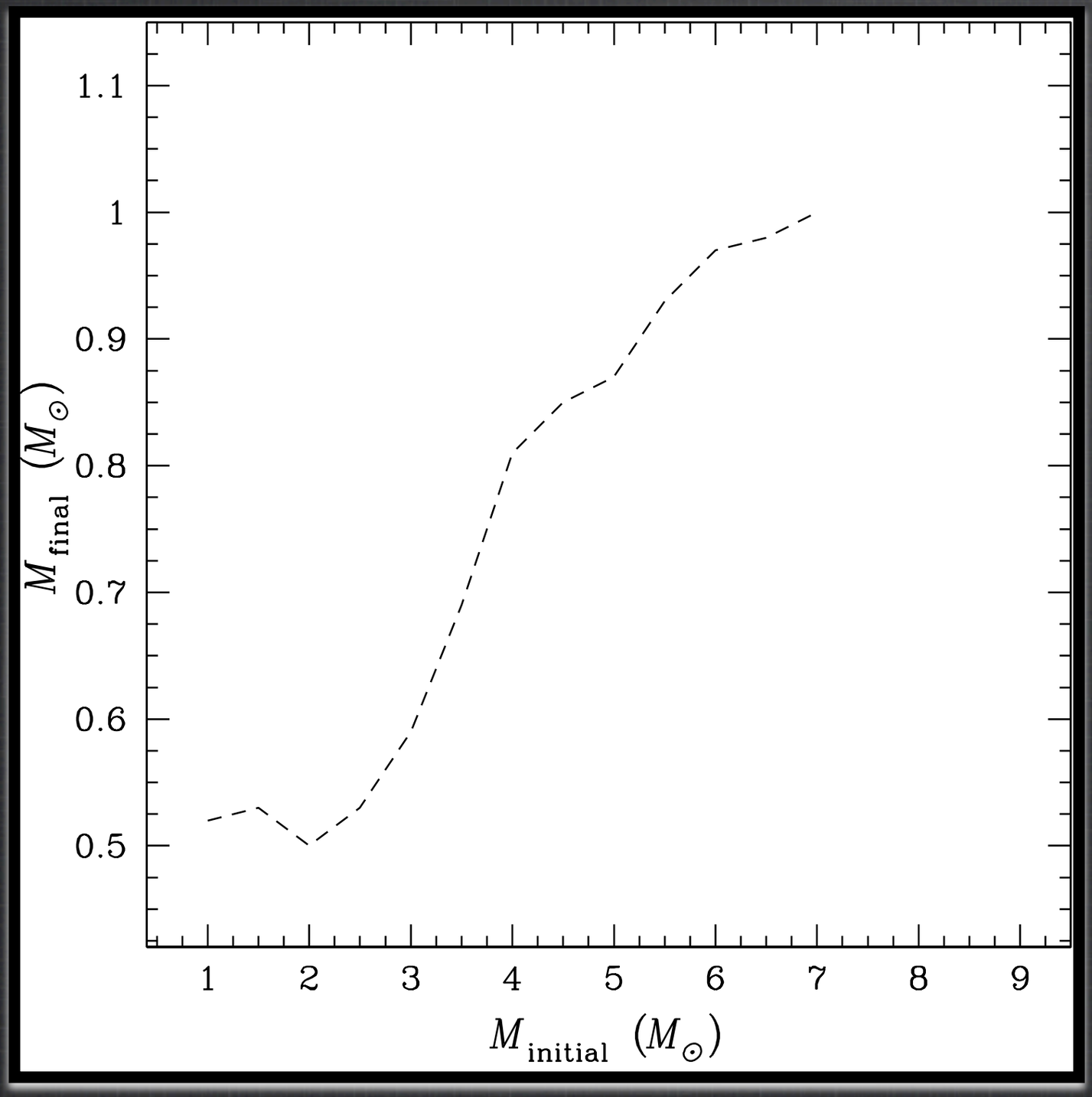

Step 1: The Photometric Survey

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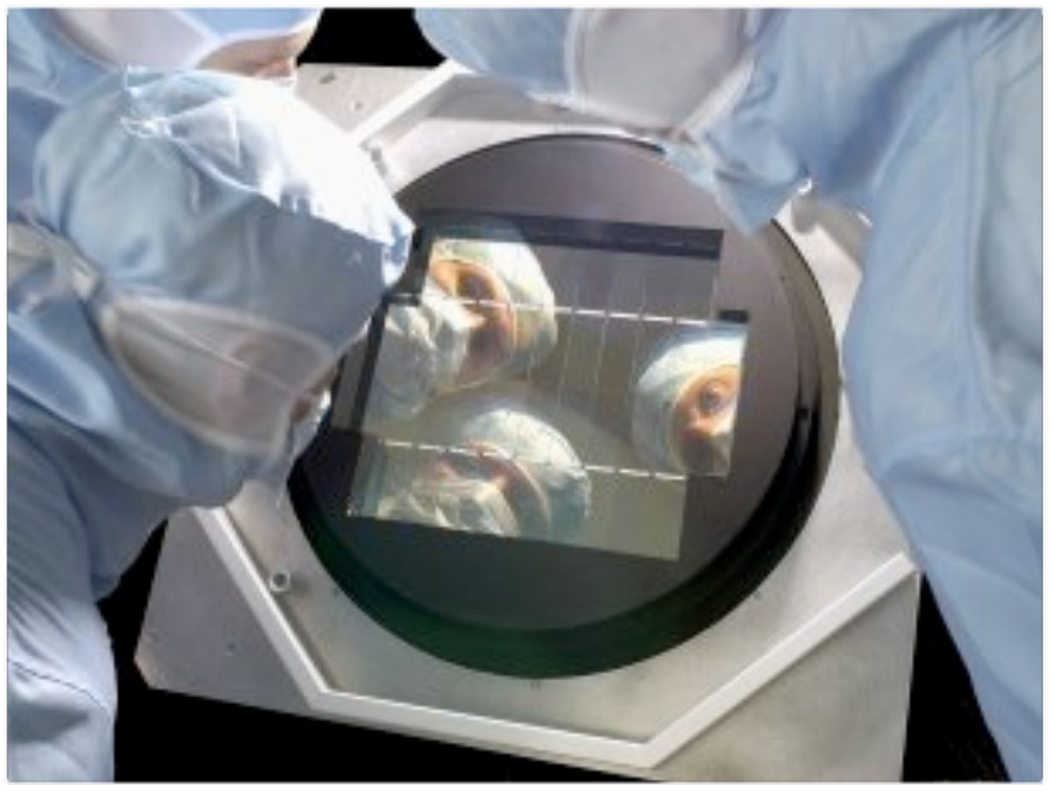
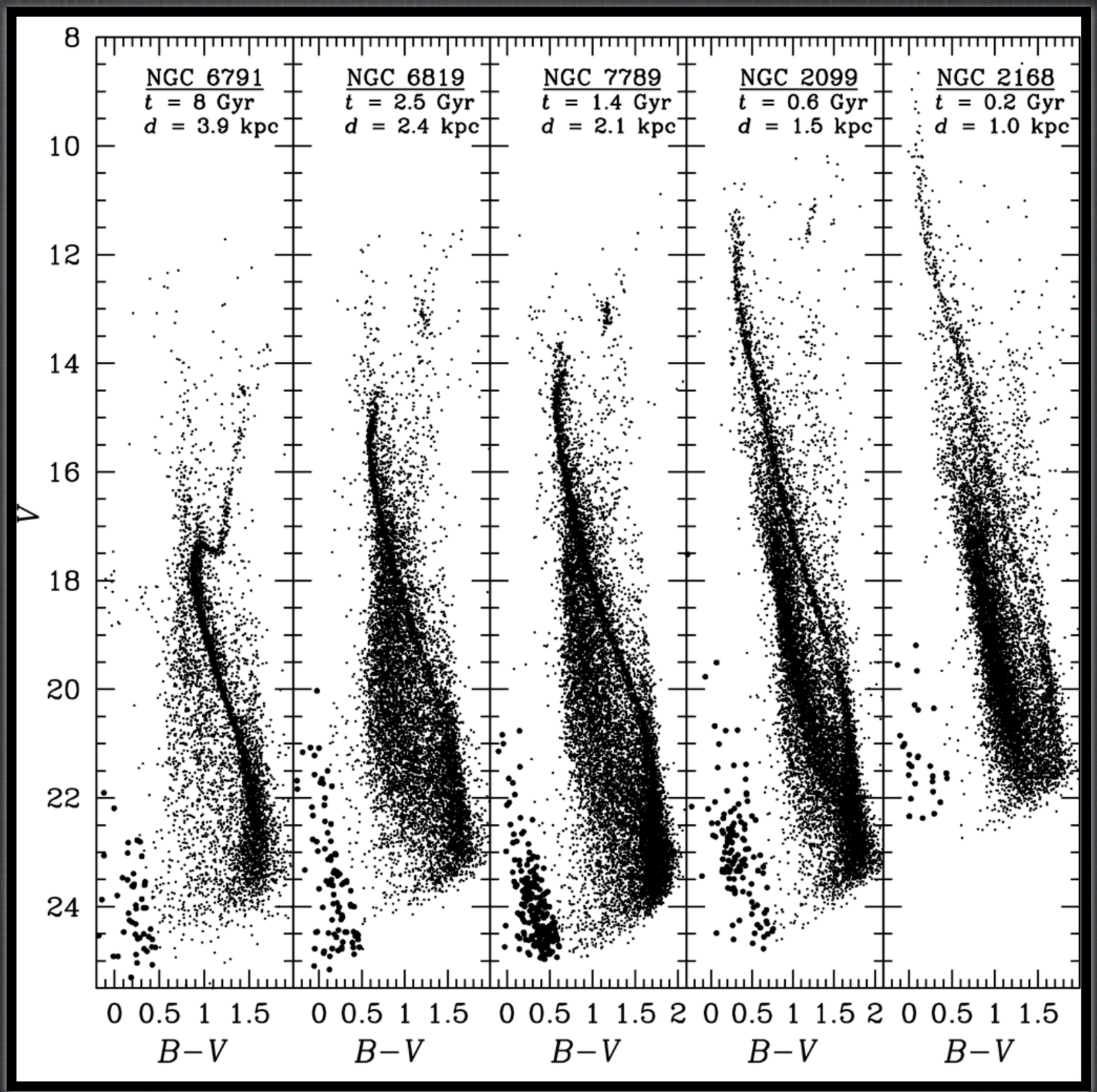


White Dwarfs in Open Clusters



Kalirai et al. (2001a; 2001b; 2001c)
Kalirai et al. (2003)
Kalirai & Tosi (2004)
Kalirai et al. (2007)
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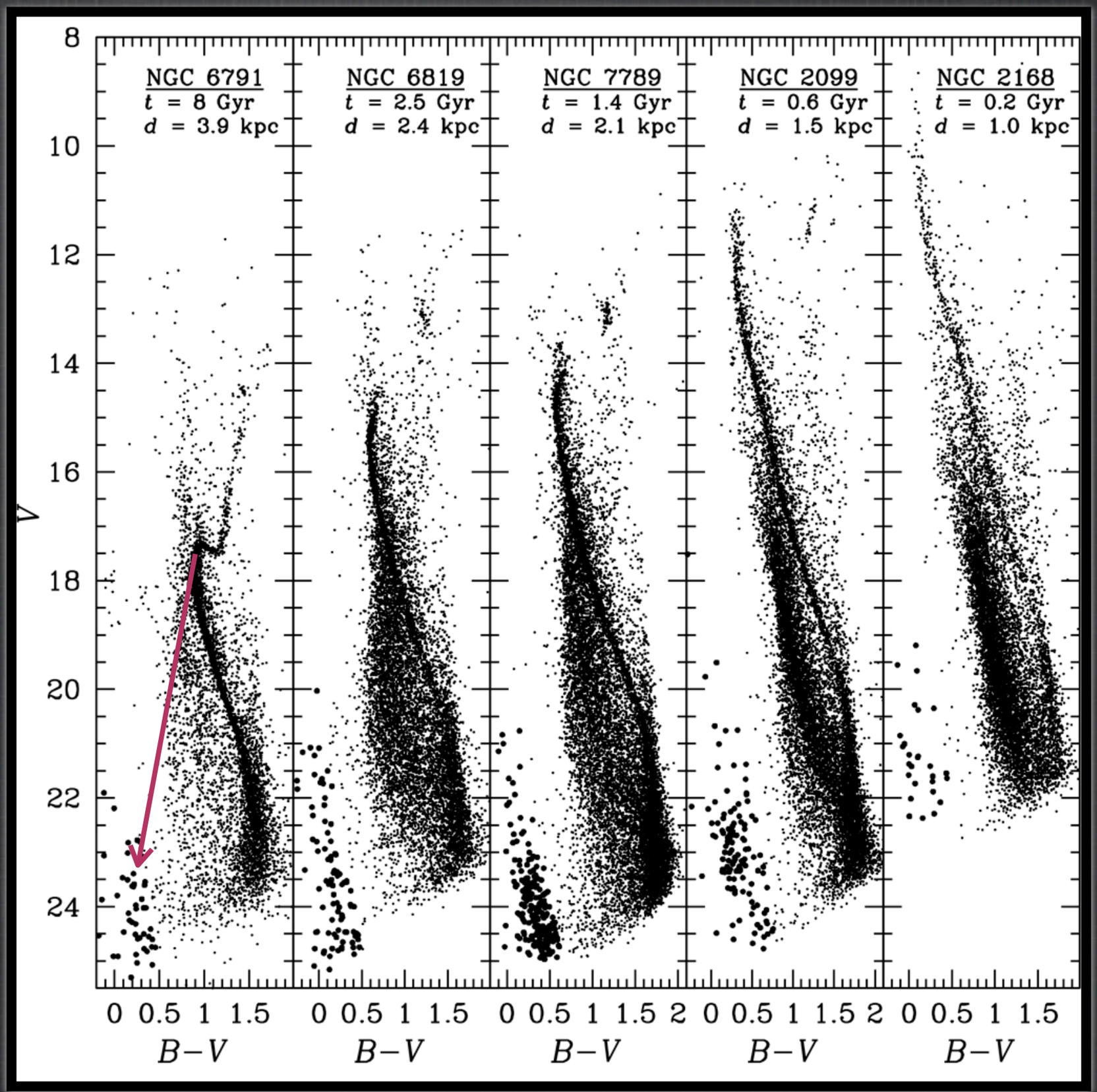

Evolution of 1 M_{SUN} star

Kalirai et al. (2001a; 2001b; 2001c)
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White Dwarfs in Open Clusters

Evolution of 1.6 M_{SUN} star

Evolution of 1 M_{SUN} star

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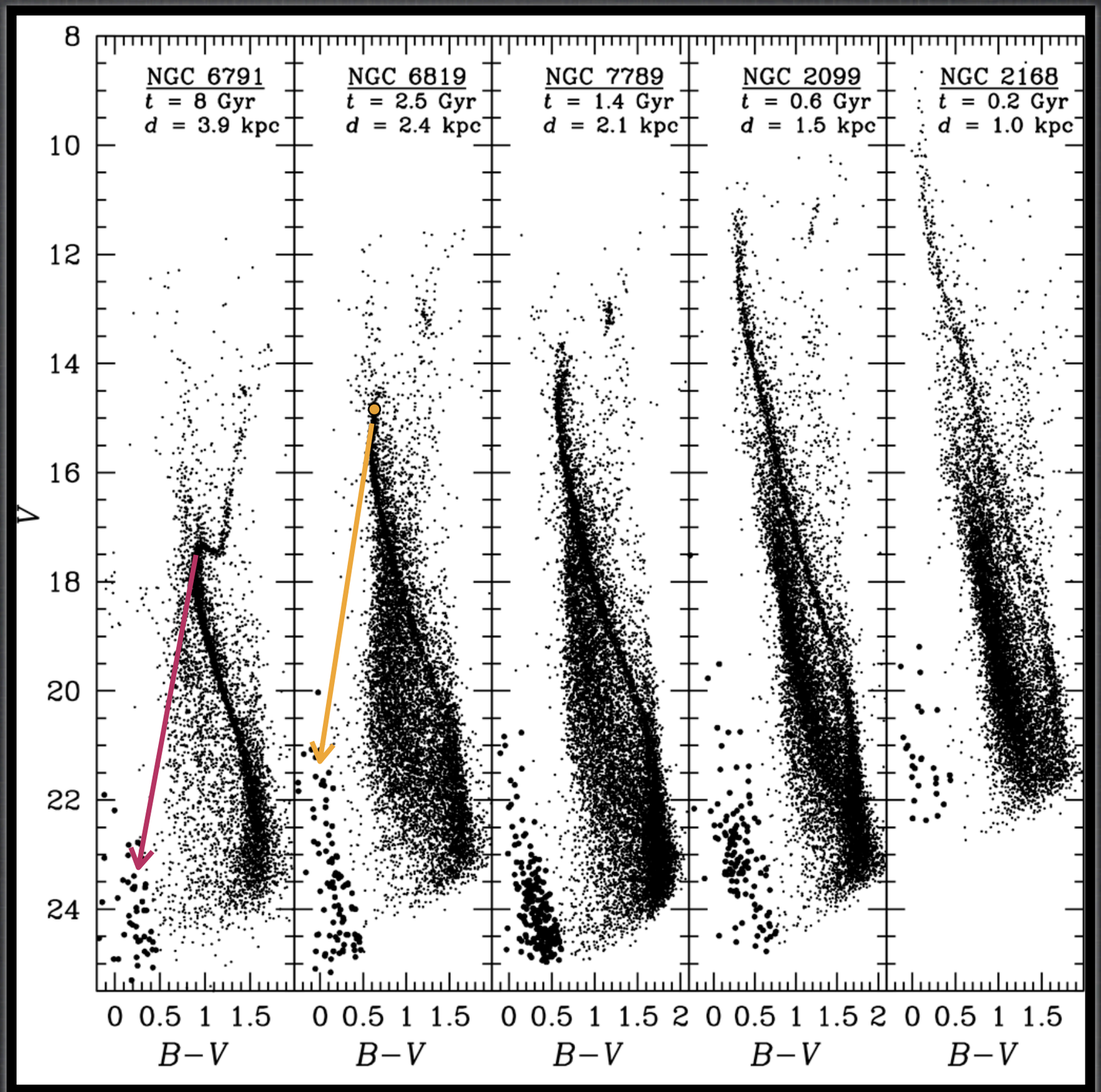


White Dwarfs in Open Clusters

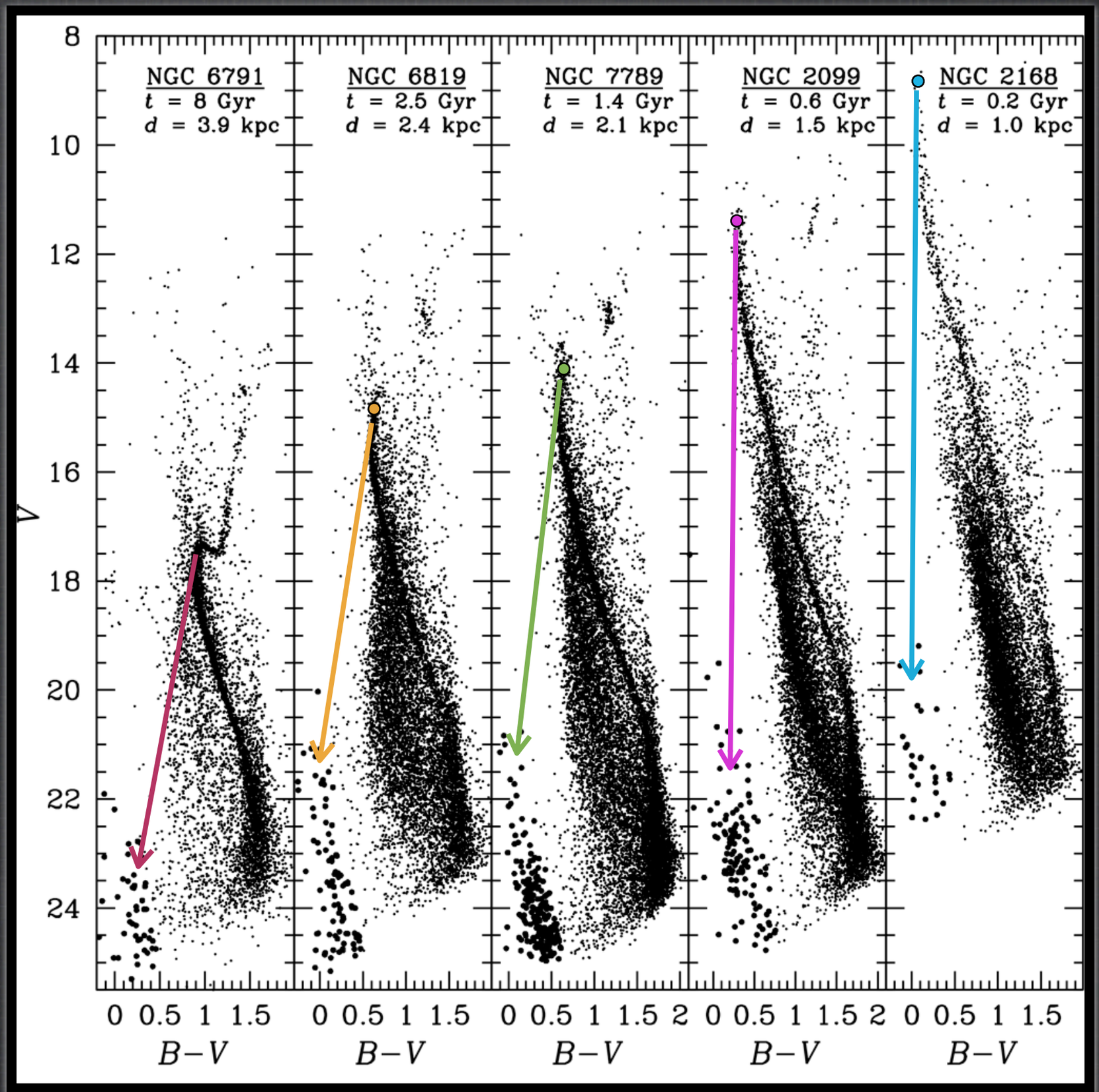
Evolution of 5 M_{SUN} star

Evolution of 2.6 M_{SUN} star

Evolution of 2 M_{SUN} star

Evolution of 1.6 M_{SUN} star

Evolution of 1 M_{SUN} star



Kalirai et al. (2001a; 2001b; 2001c)
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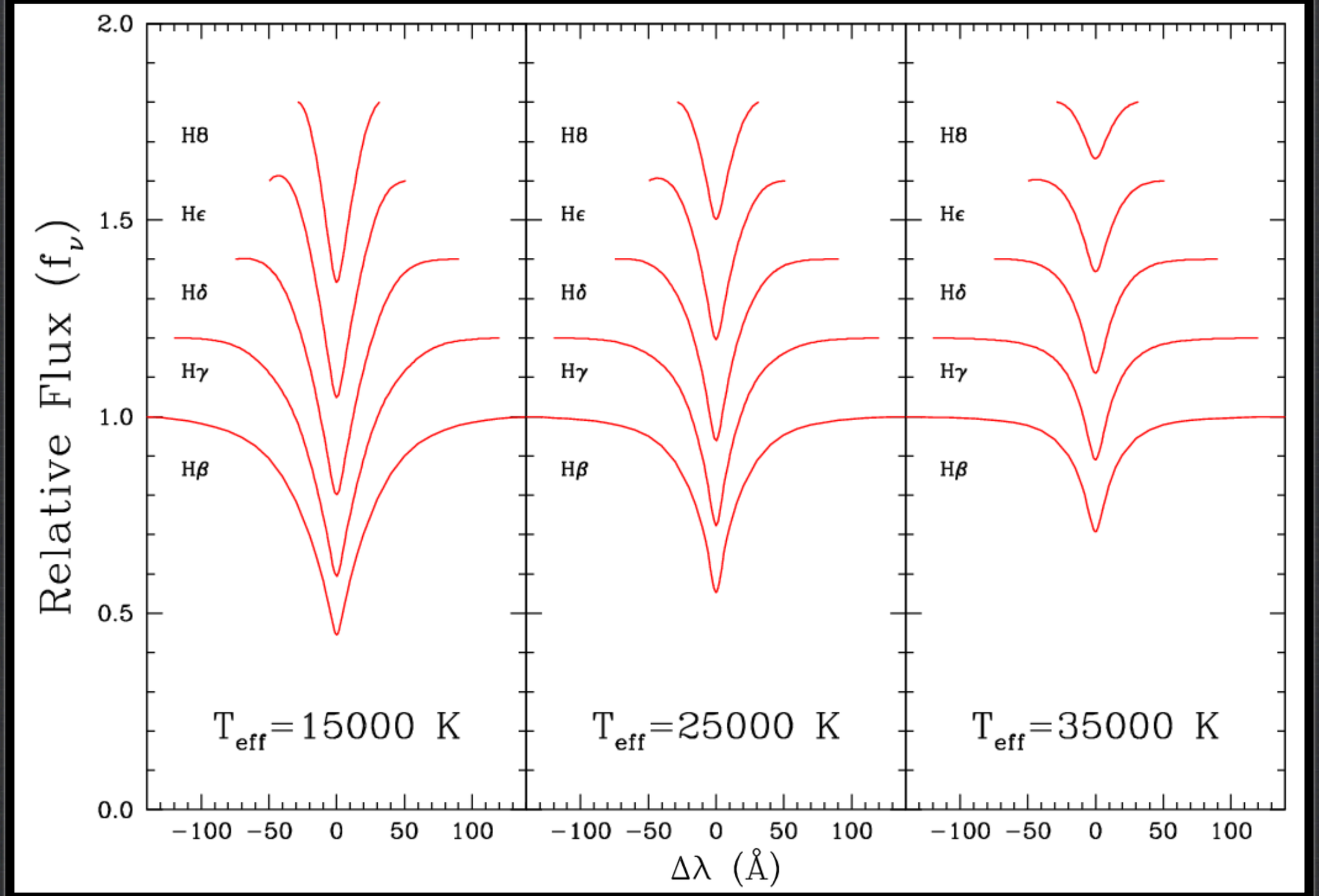
Kalirai et al. (2008)

Step 2: The Spectroscopic Survey

20 nights of Keck I LRIS spectroscopy since 2005 (UCLA, UCSC, NASA)

The Signature of a White Dwarf

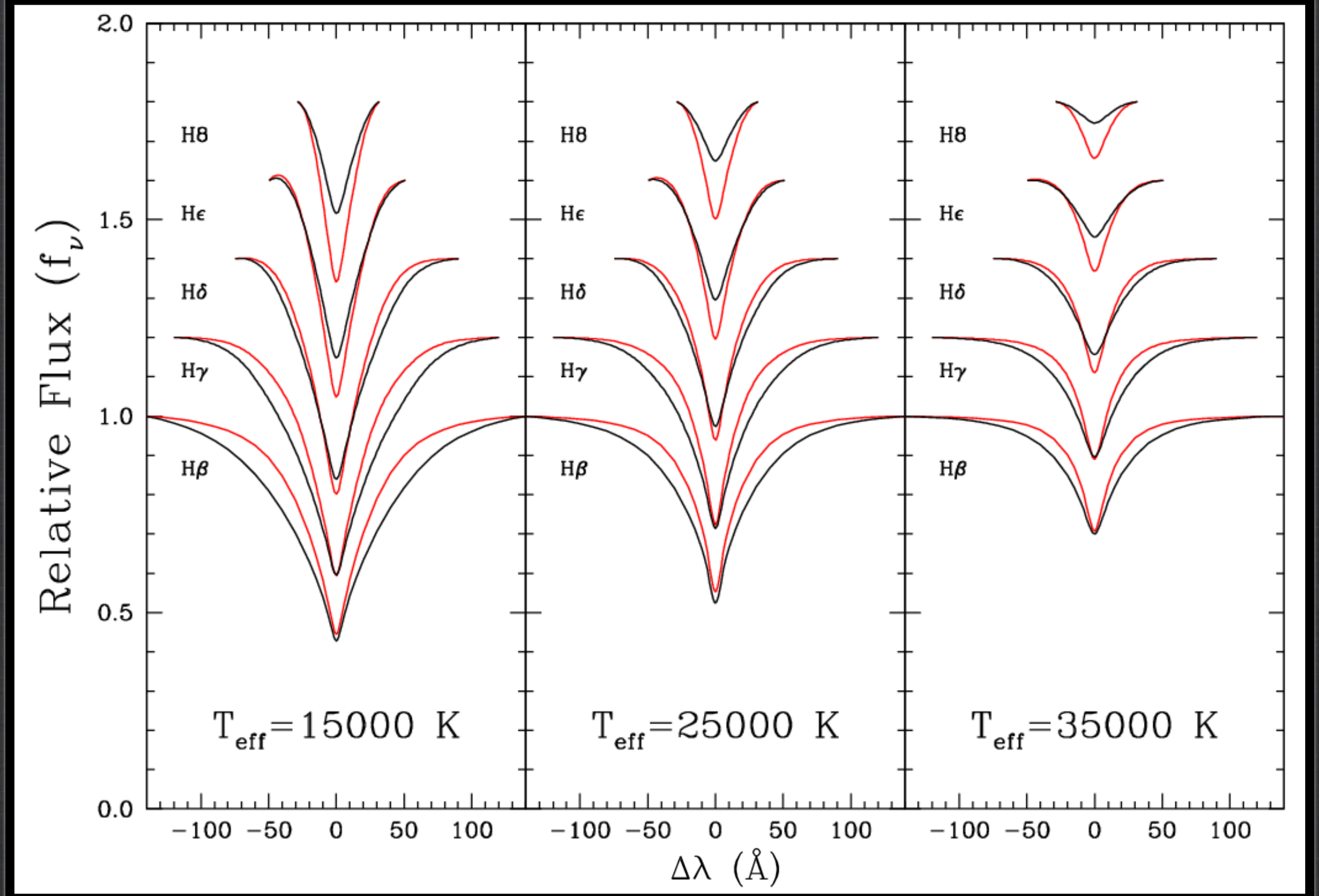
Log(g) = 7.0



P.-E. Tremblay & P. Bergeron, priv comm

The Signature of a White Dwarf

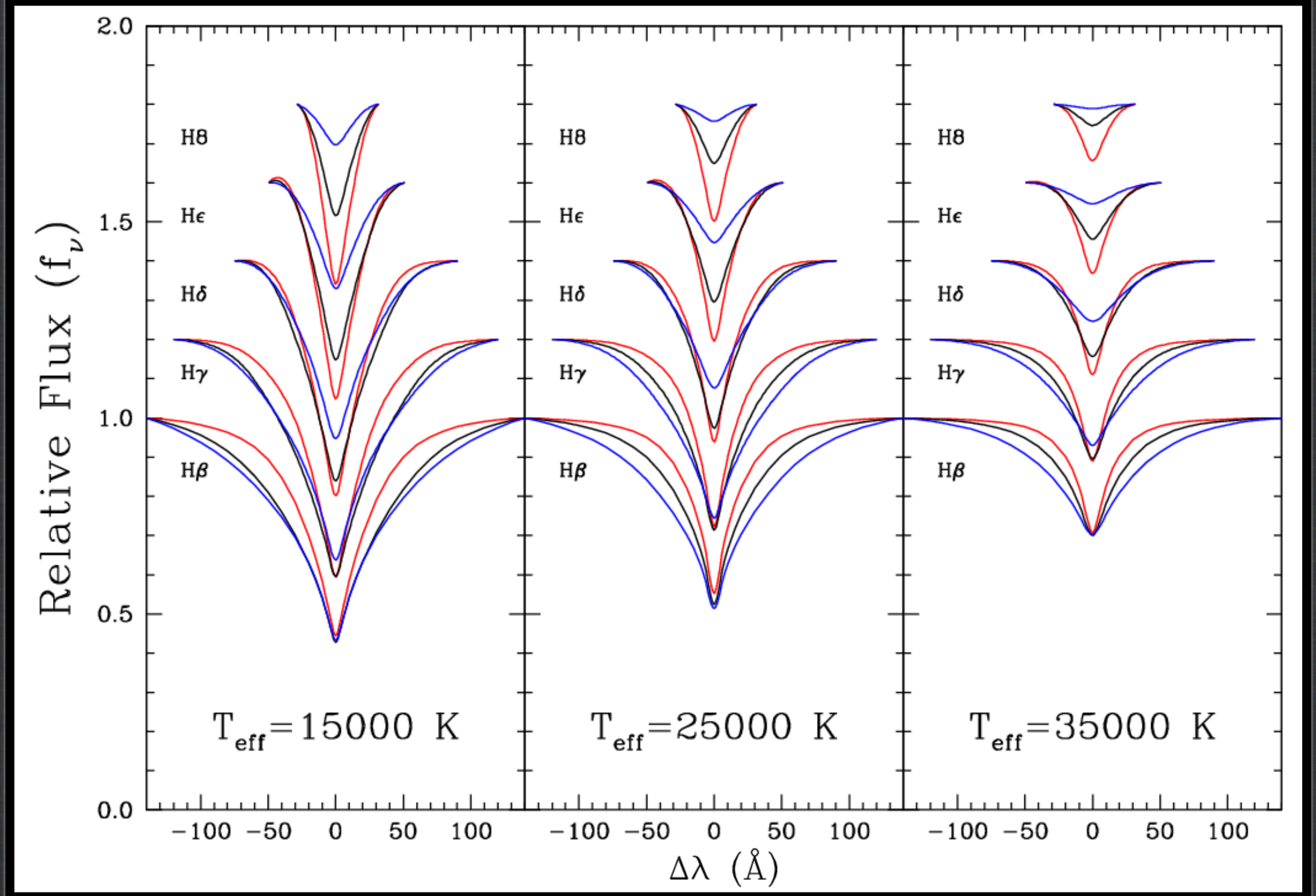
Log(g) = 7.0, 8.0



P.-E. Tremblay & P. Bergeron, priv comm

The Signature of a White Dwarf

Log(g) = 7.0, 8.0, 9.0



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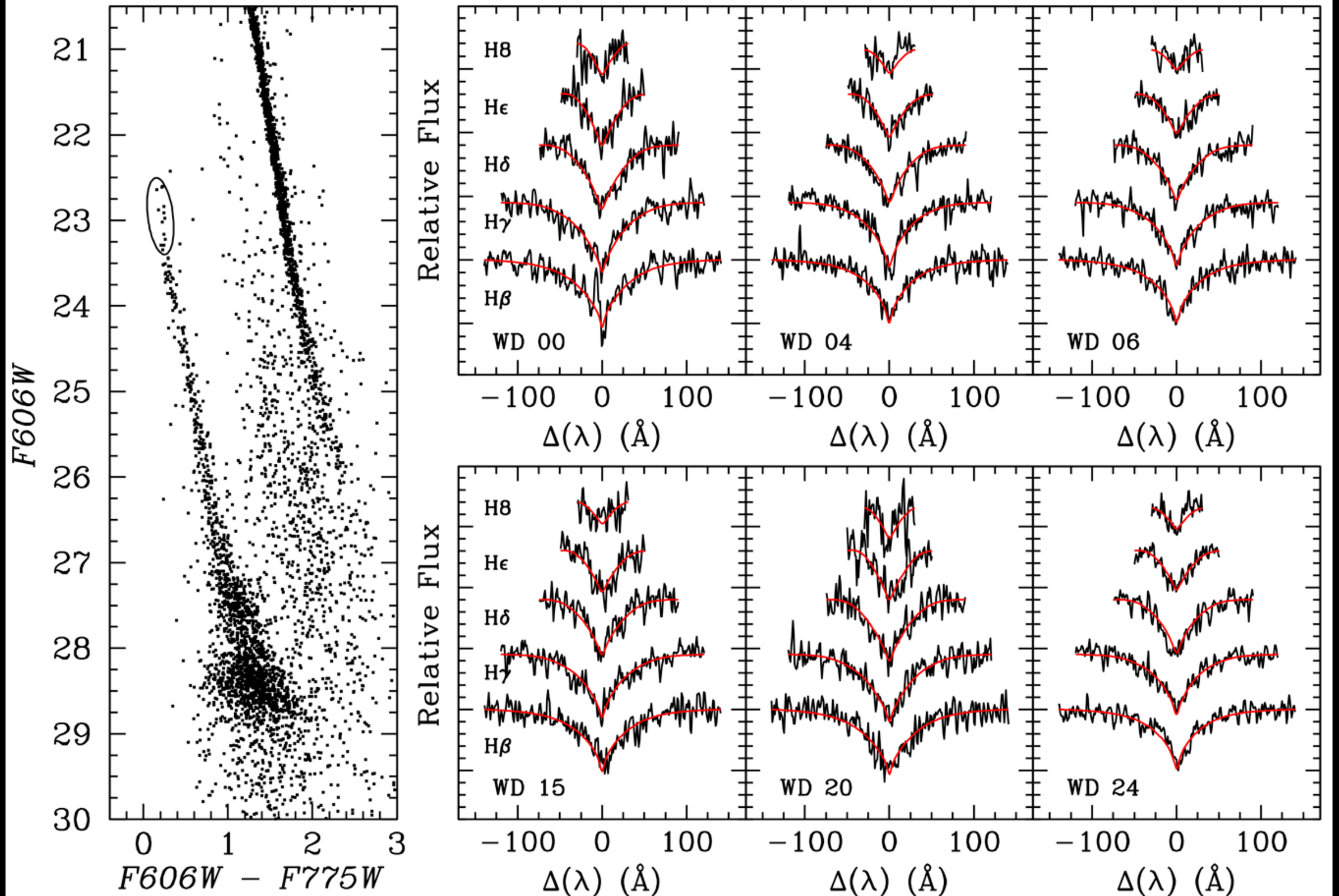
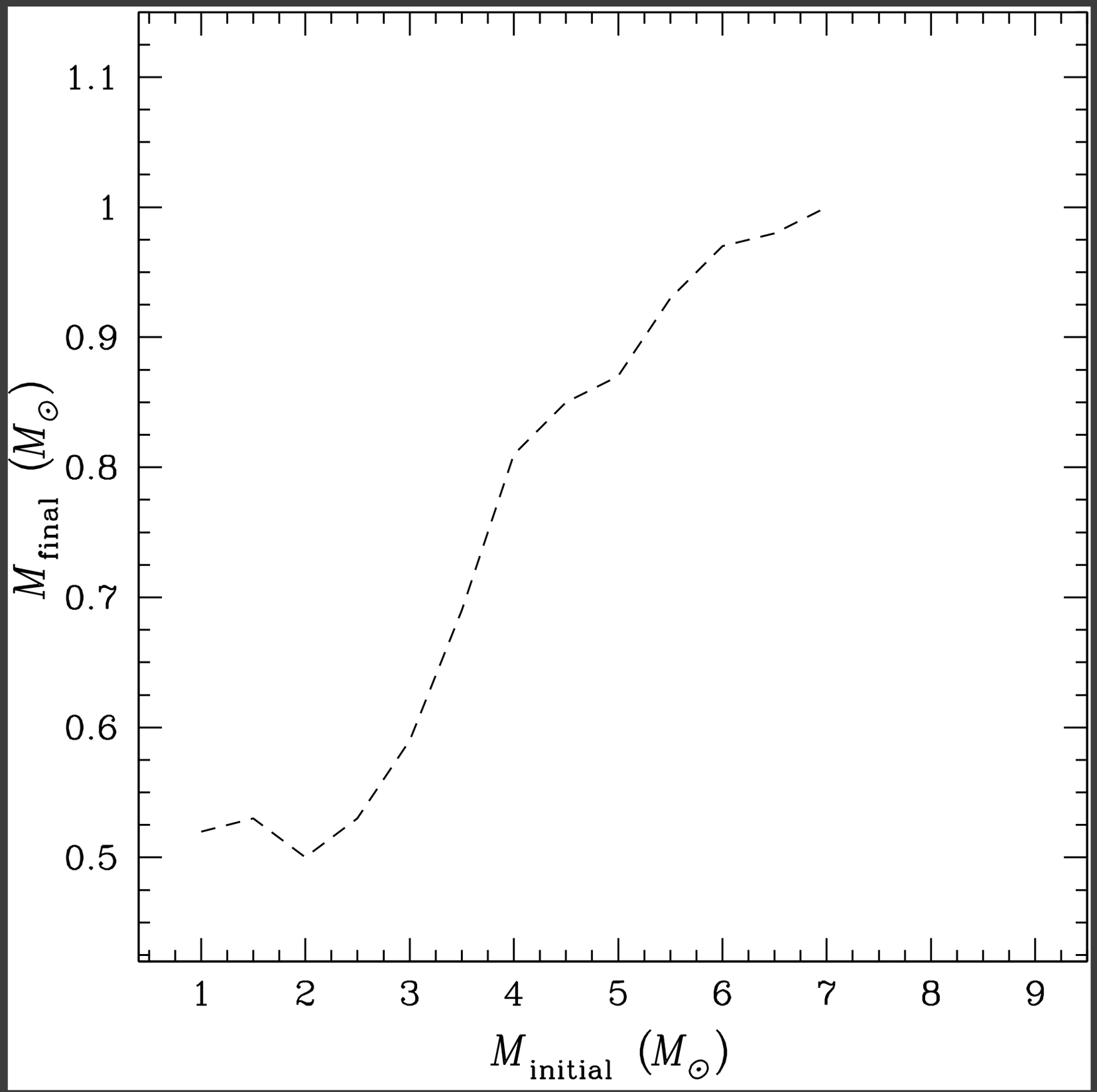
Faint White Dwarfs in the Globular Cluster M4



Kalirai et al. (2009; 2012)

Step 3: The Initial-Final Mass Relation



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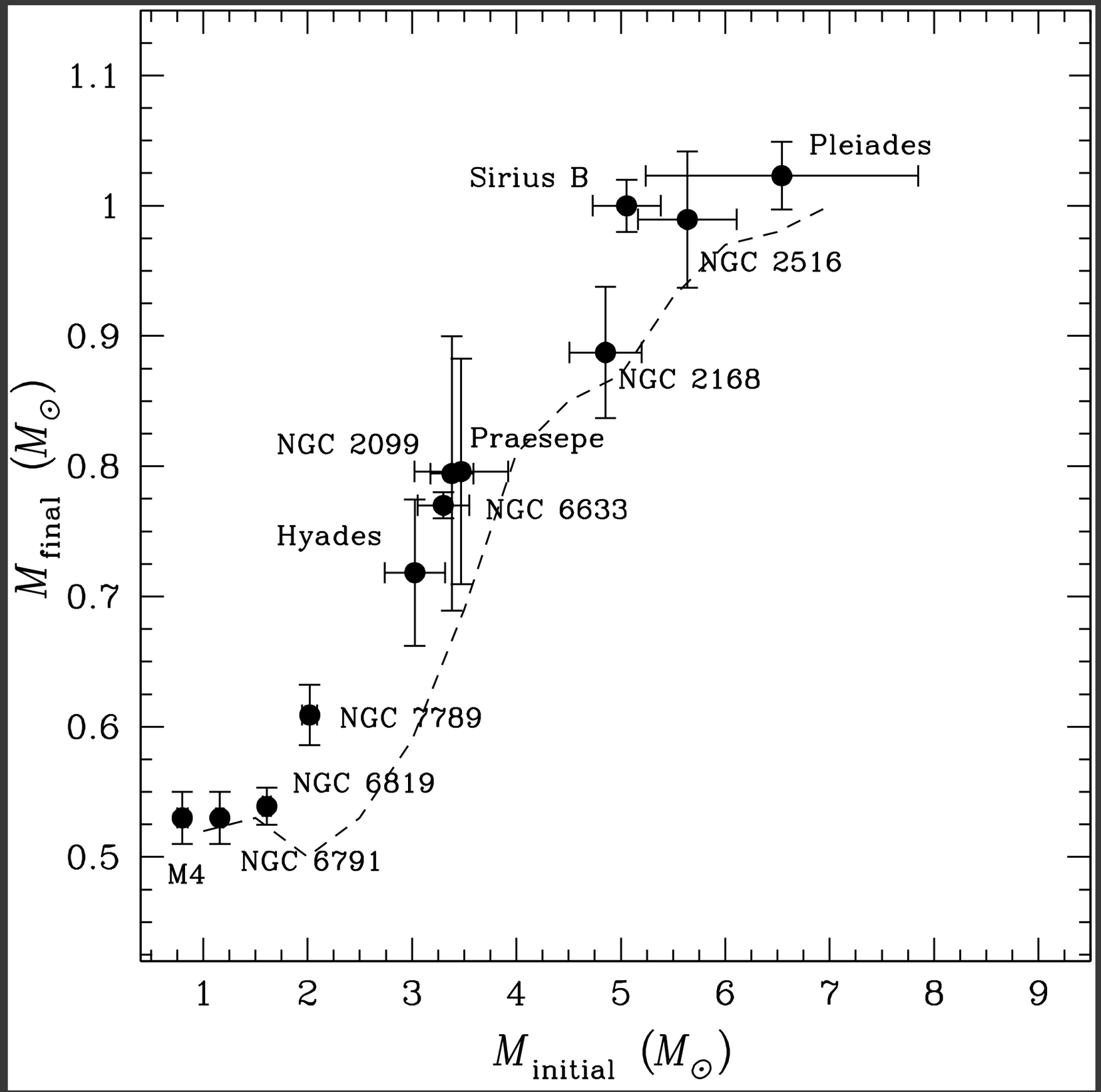

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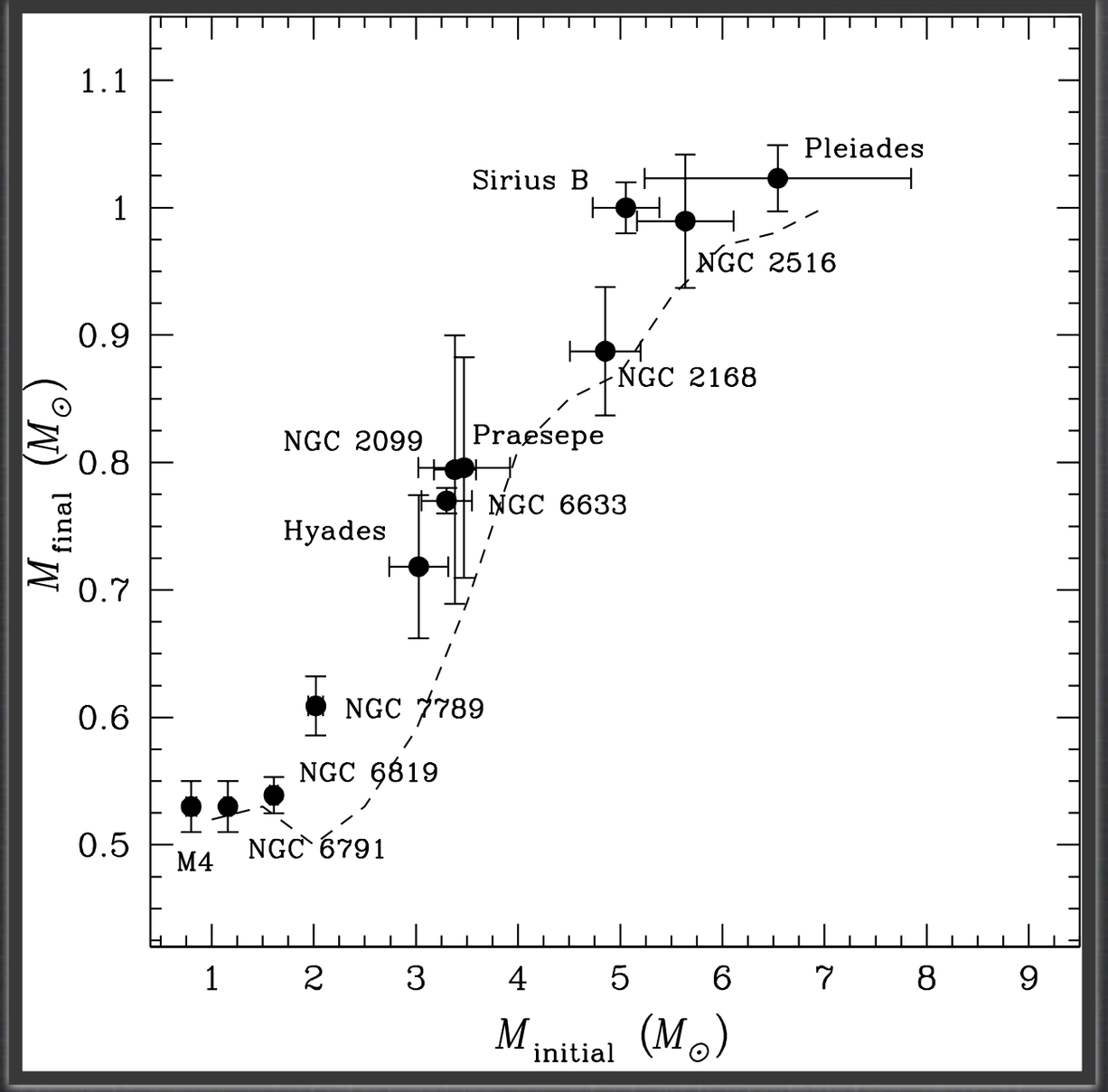

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Summary of Initial-Final Mass Relation

1.) Low mass stars like the Sun will lose 46% of their mass through stellar evolution
2.) Intermediate mass stars with $M_{INITIAL}$ = 2-3 M_{SUN} will lose 70-75% of their mass
3.) Higher mass stars with $M_{INITIAL}$ = 5-6 M_{SUN} will lose 80% of their mass

Step 3: The Initial-Final Mass Relation

$$M_{FINAL} = (0.109 \pm 0.007)\, M_{INITIAL} + 0.428 \pm 0.025\, M_{SUN}$$

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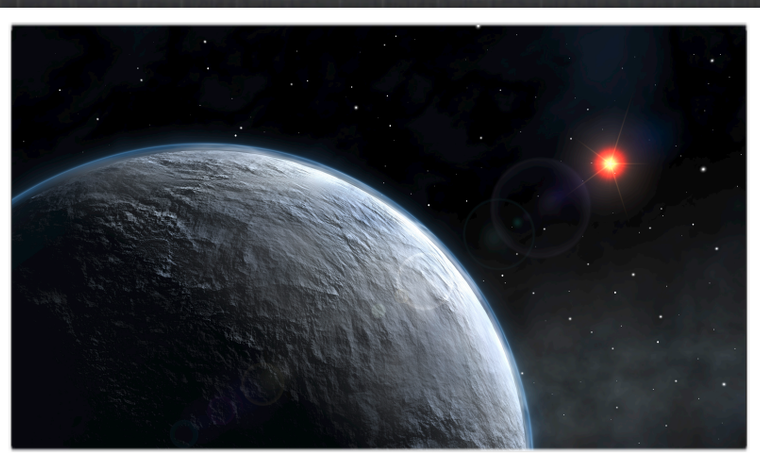
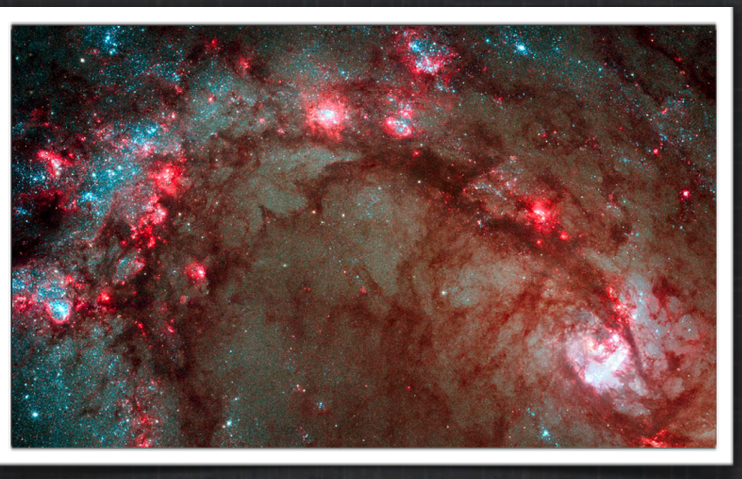
$$M_{FINAL} = (0.109 +/- 0.007) M_{INITIAL} + 0.428 +/- 0.025 M_{SUN}$$

Properties of Planetary Nebulae (Ciardullo 2010)



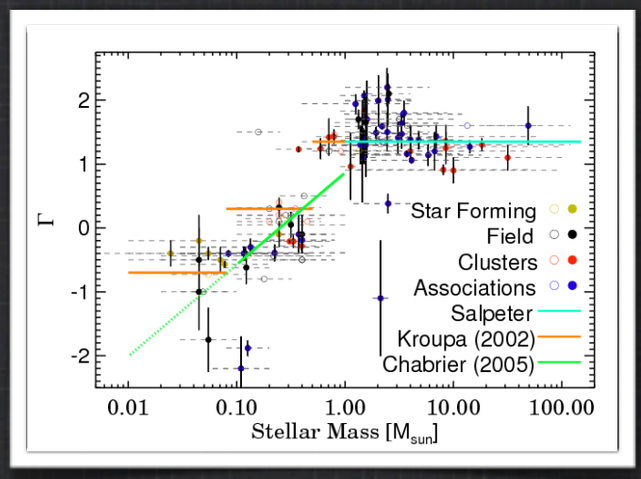
Characterize Exoplanet Hosts (Kilic, Gould, & Koester 2009)

Measure SN Rates, Evolution, and Progenitors (Pritchet et al. 2008; Greggio 2010; Kistler et al. 2011)



Constrain Star Formation Scenarios (Leitner & Kravtsov 2011)

Study Disk Formation in LCDM (Leitner & Kravtsov 2011)



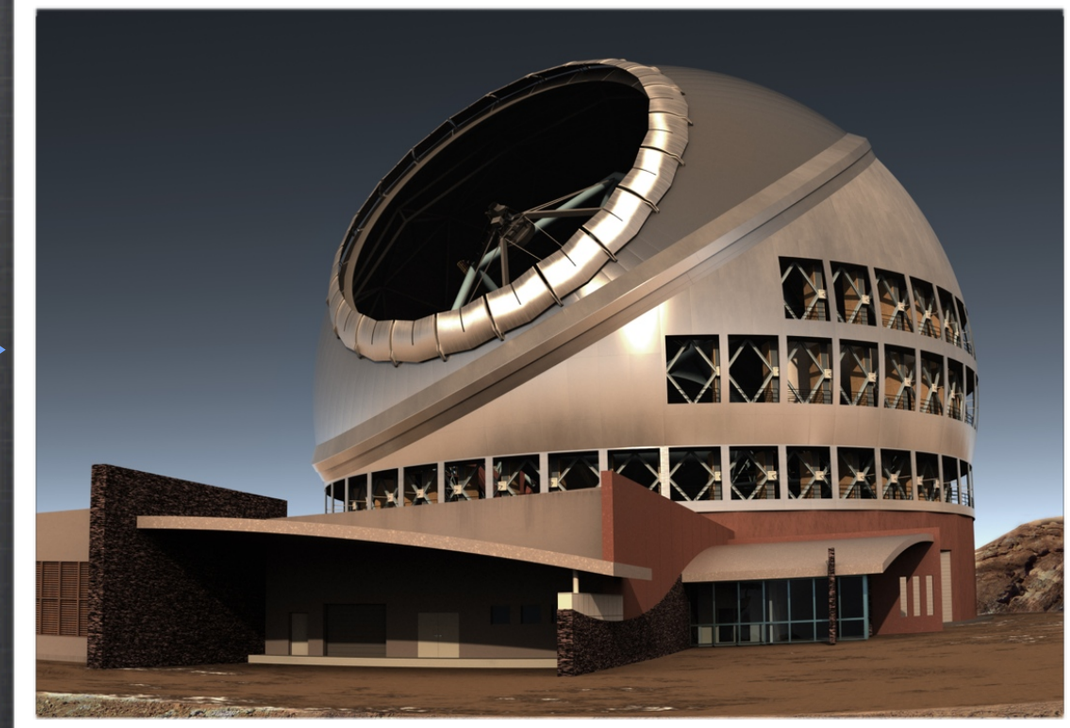
Calculate Stellar IMF (Lockmann, Baumgardt, & Kroupa 2010)

Three New Applications

$$M_{FINAL} = (0.109 +/- 0.007)\ M_{INITIAL} + 0.428 +/- 0.025\ M_{SUN}$$

- ★ The Thermally Pulsing Asymptotic Giant Branch
  Kalirai et al. (2014, ApJ, 782, 17)
- ★ The Formation Time of the Milky Way Halo
  Kalirai et al. (2012, Nature, 477, 684)
- ★ Precise Ages for Globular Clusters
  Hansen, Kalirai et al. (2013, Nature, 500, 51)

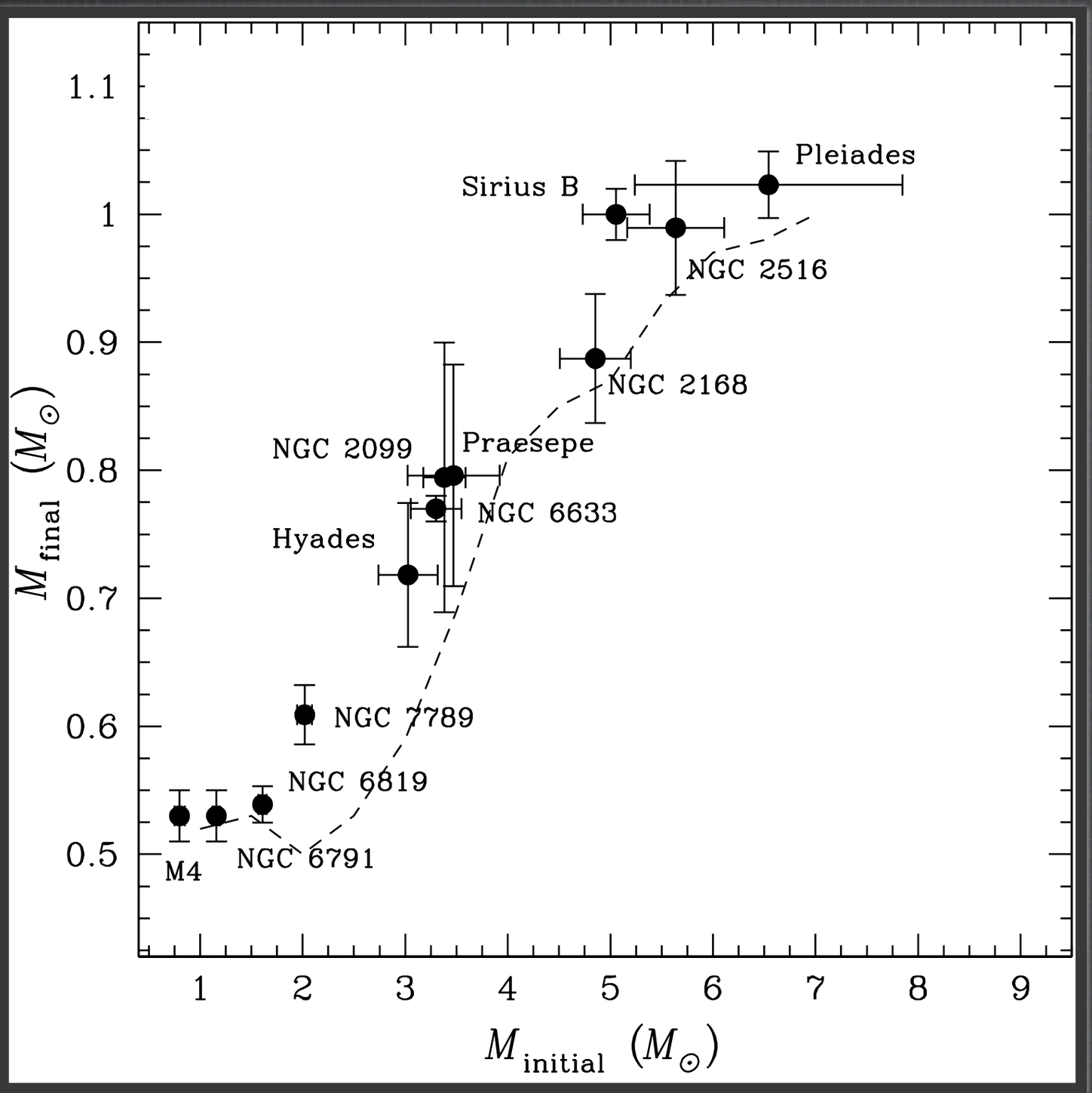
From Keck to TMT: New Opportunities



TMT vastly increases the sample of clusters in which we can characterize stellar remnants

- ★ Measure white dwarfs out to 10 kpc
- ★ Volume would include 36 globular clusters (3 are currently accessible)
- ★ Numerous rich open clusters and systems with odd metallicity and young ages
- ★ Much higher sensitivity to field halo white dwarfs

TMT - The Initial-Final Mass Relation: 2.0



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Future Direction - Adding Two New Dimensions to the Initial-Final Mass Relation

1.) Constraining the upper mass limit to WD formation

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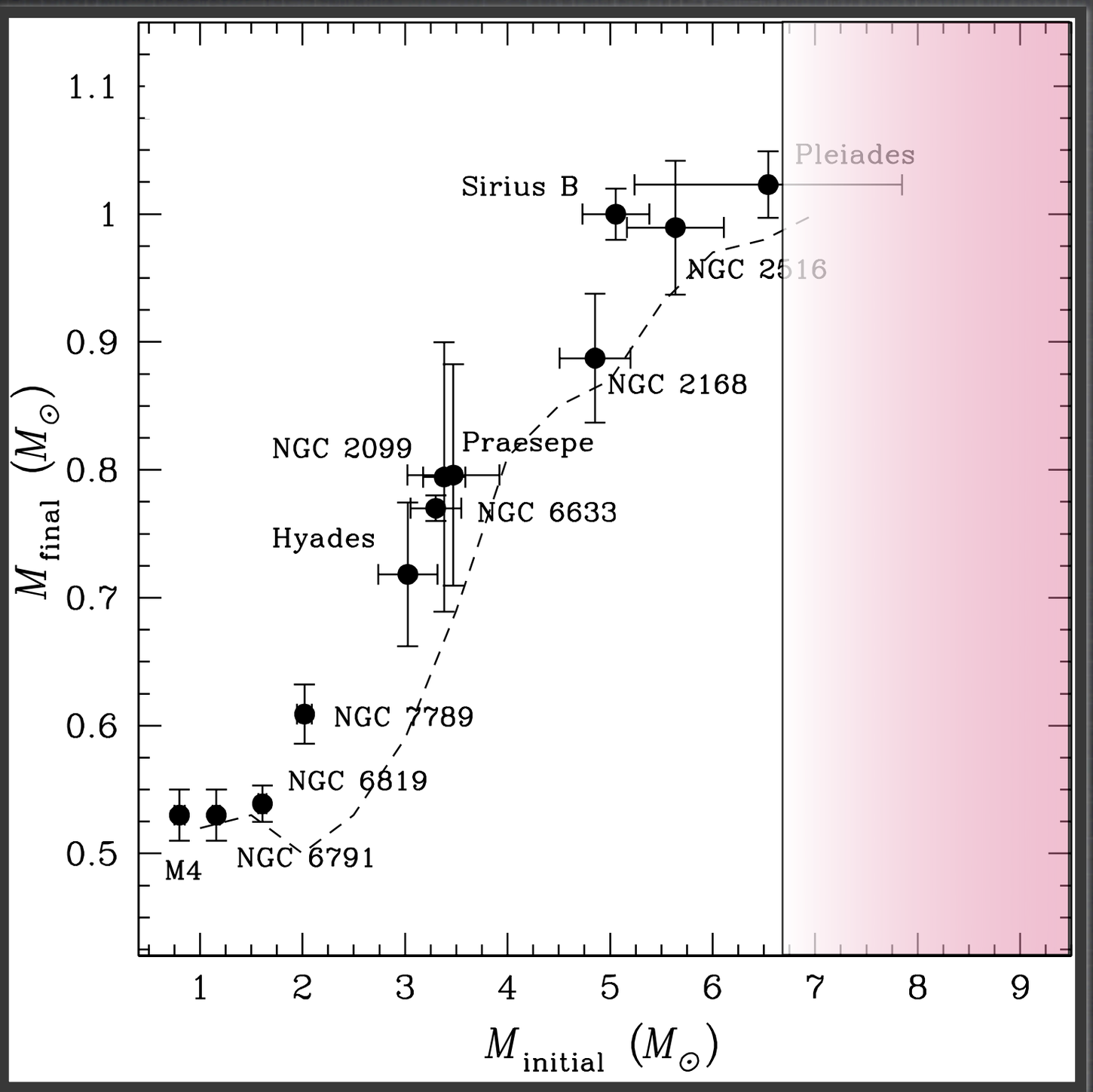

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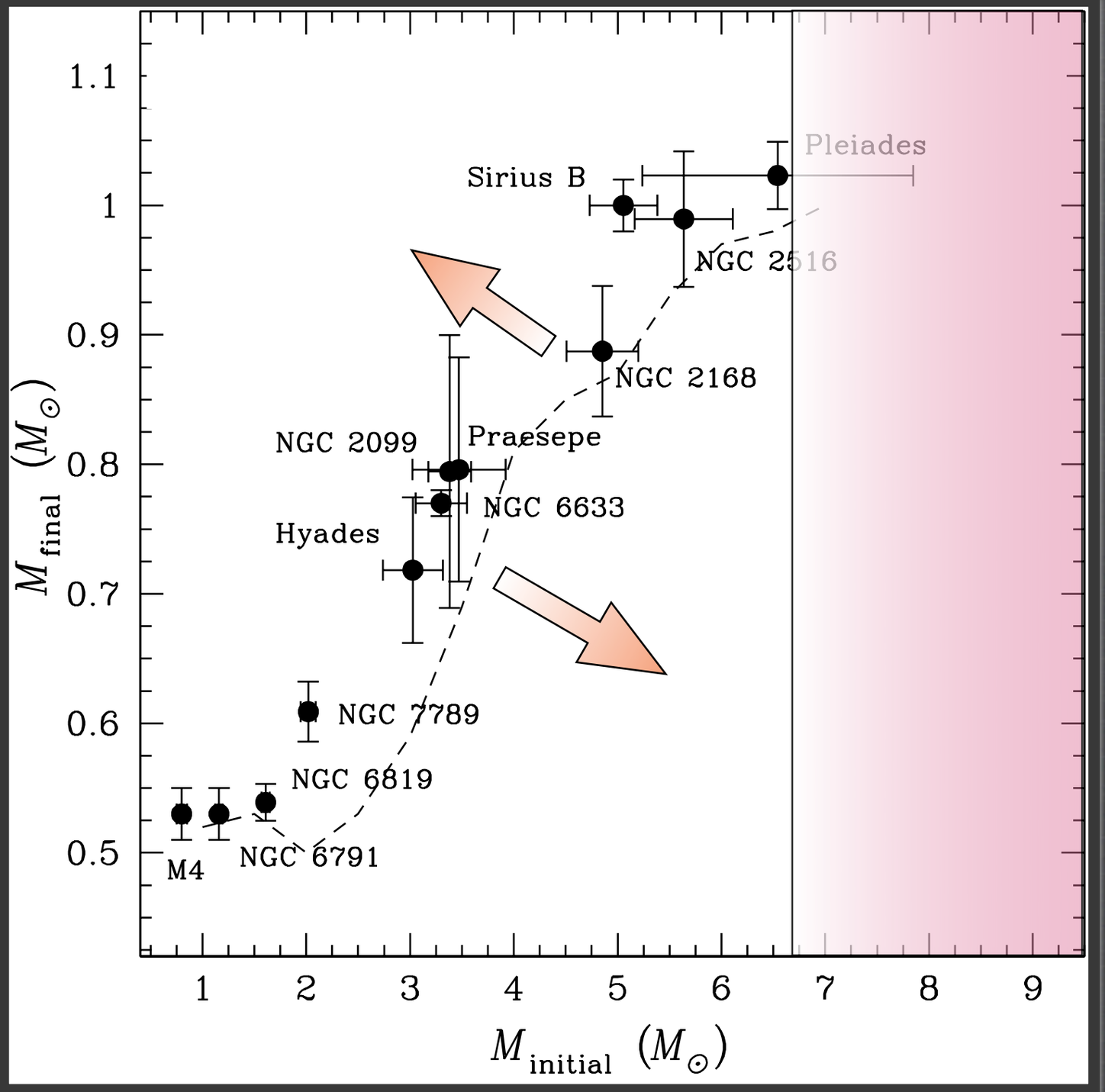

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Future Direction - Adding Two New Dimensions to the Initial-Final Mass Relation

1.) Constraining the upper mass limit to WD formation

2.) Exploring the metallicity dependence of stellar mass loss

Thank You!