



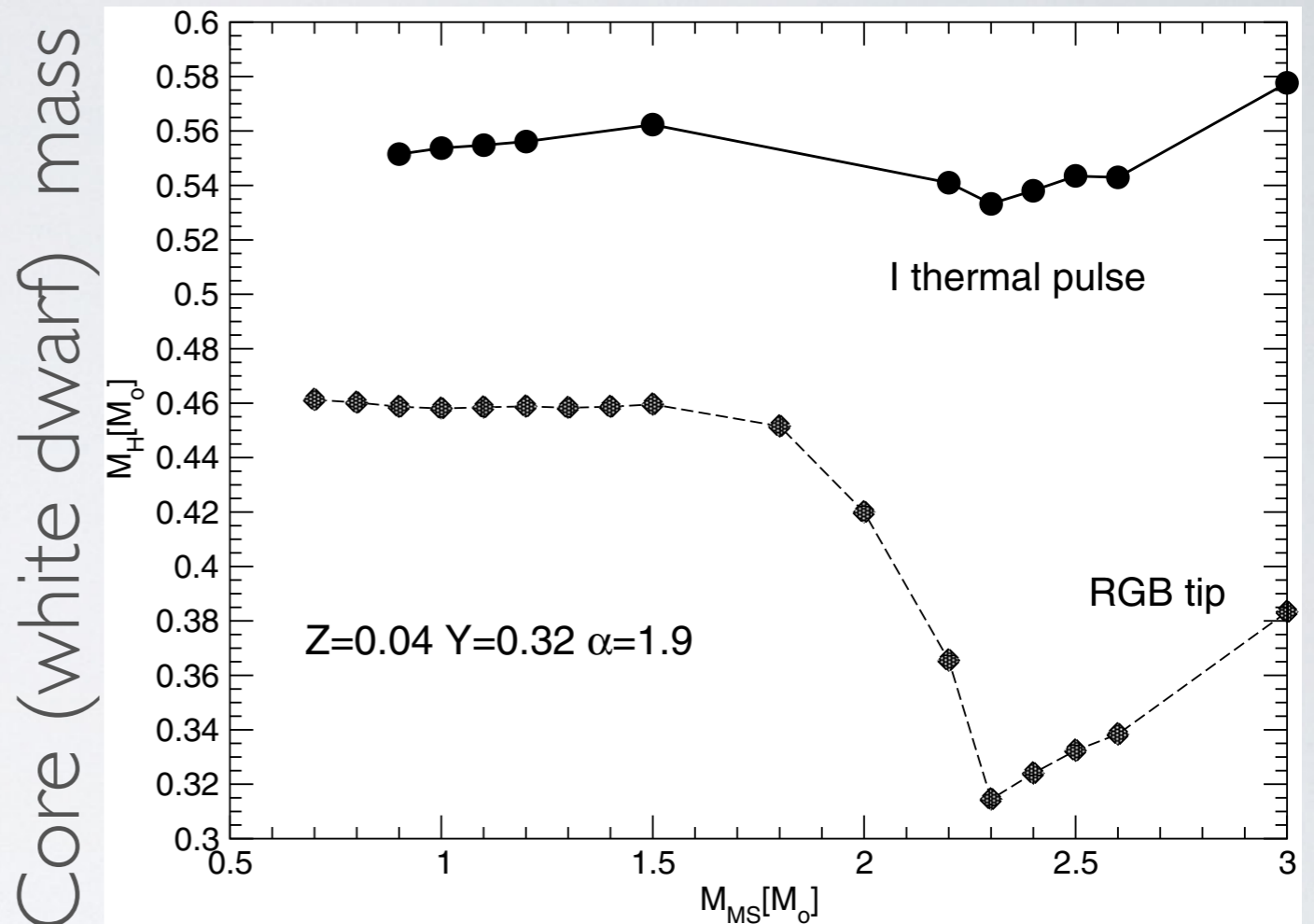
Keele  
University

# Stripped red giant stars

Dr Pierre Maxted, Keele University

# Helium white dwarfs

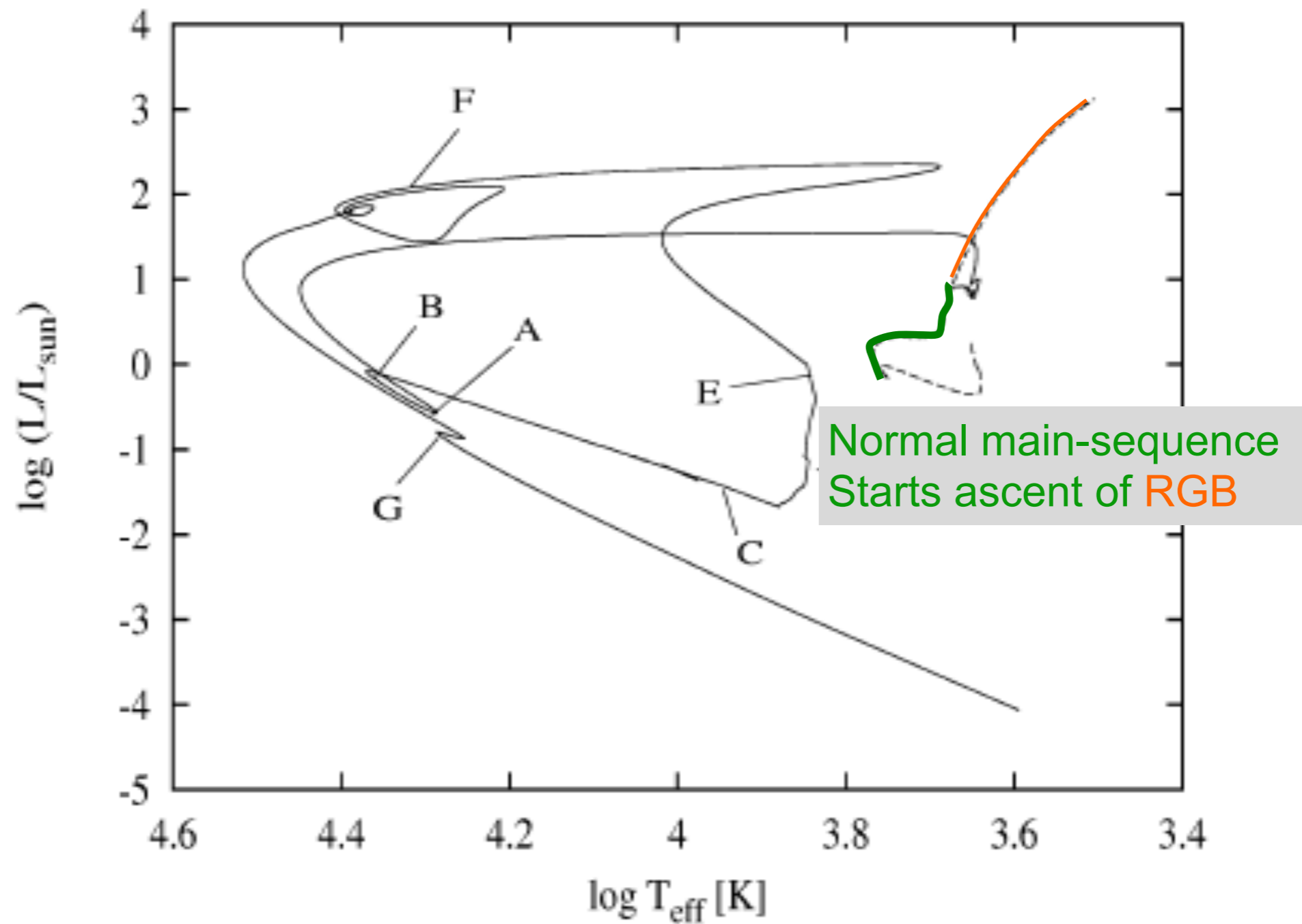
- $M_{\text{WD}} < 0.3 M_{\text{Sun}}$ 
  - *must* be helium core
  - not single star evolution
  - Extremely Low Mass (**ELM**) WD
- $M_{\text{WD}} = 0.3$  to  $0.45 M_{\text{Sun}}$ 
  - probably helium core
  - can be hybrid CO/He
  - often binaries but some singles (metal-rich enhanced wind?)



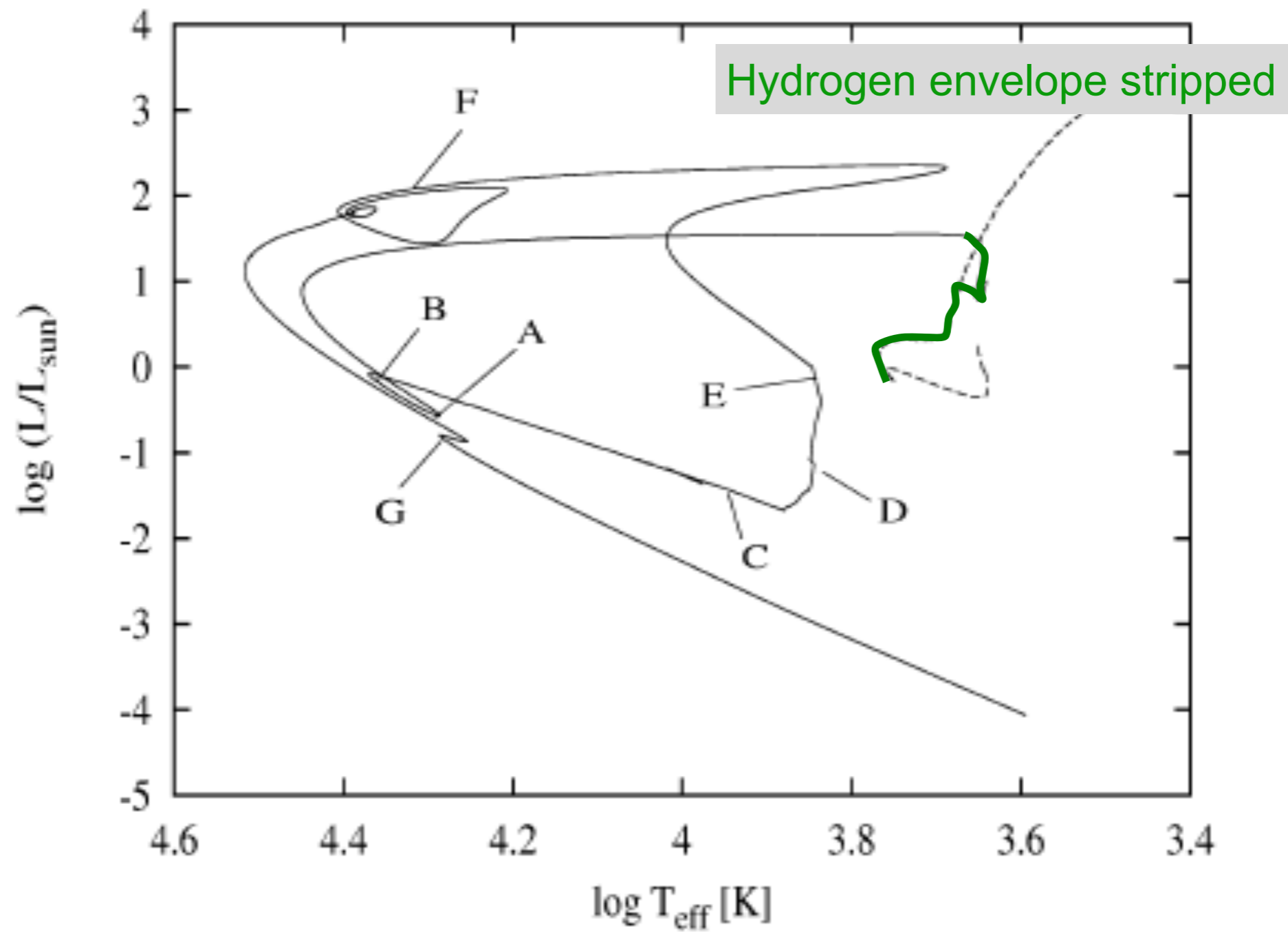
Initial stellar mass

Moroni and O. Straniero, 2009

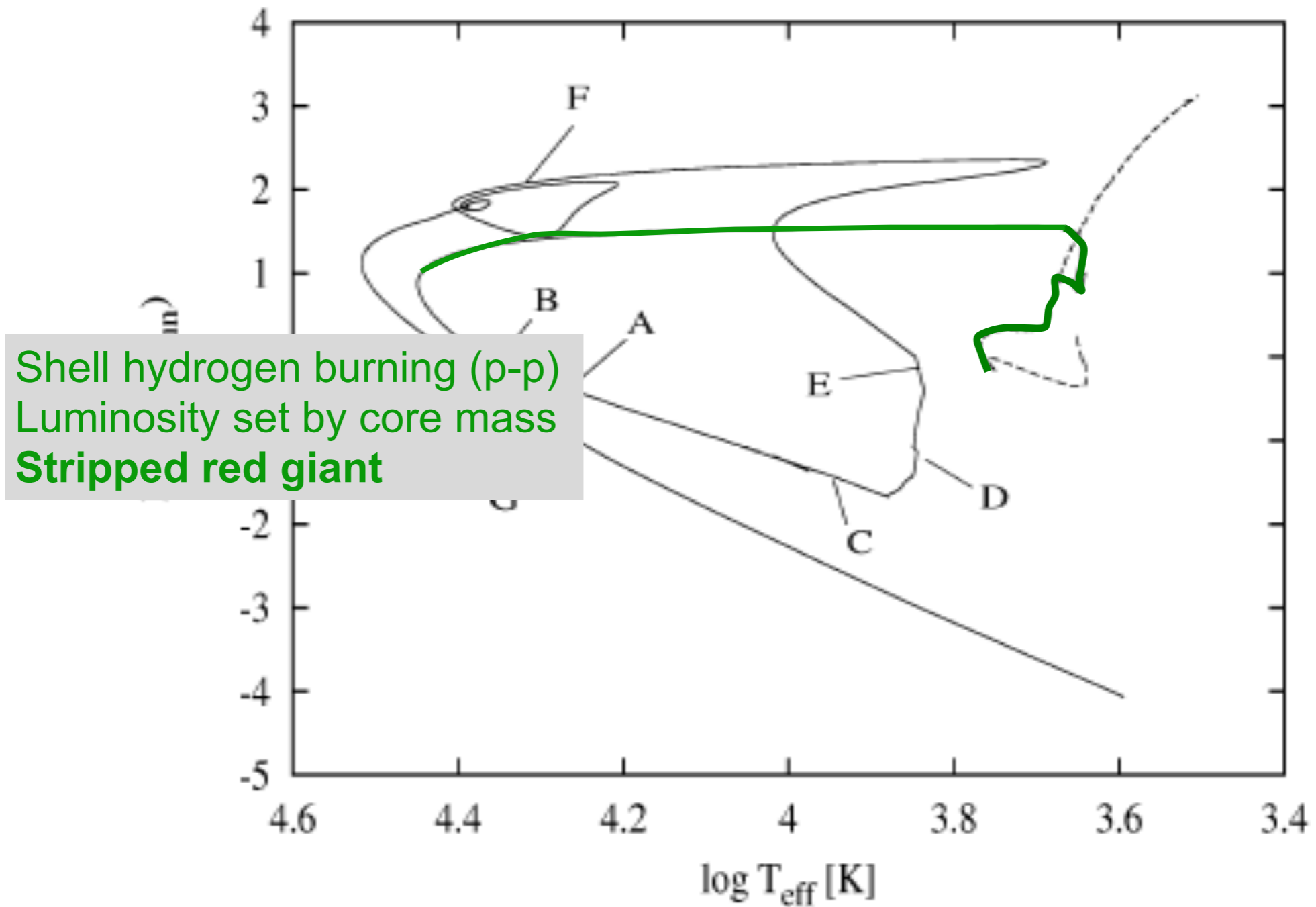
# Pre-He-WD evolution



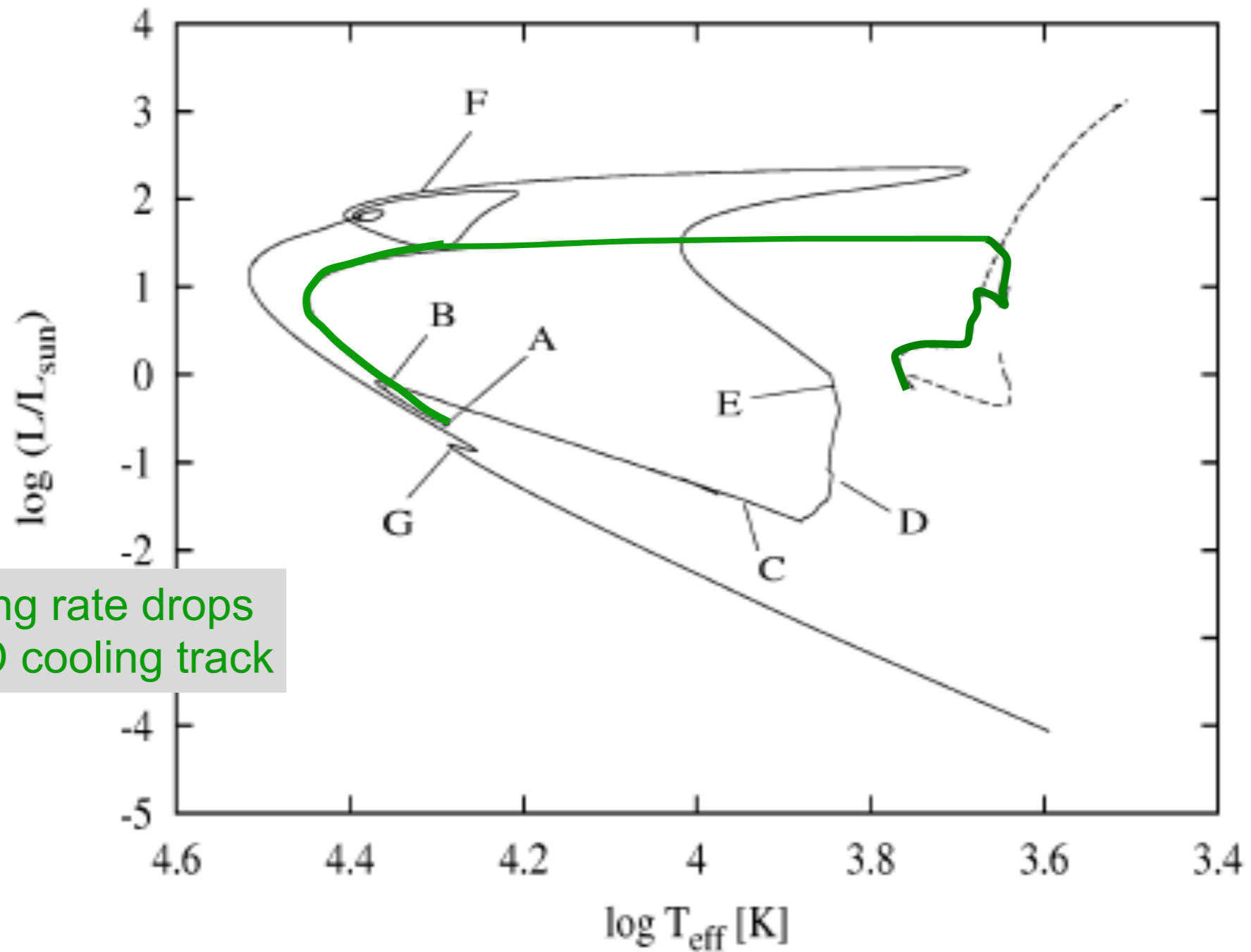
# Pre-He-WD evolution



# Pre-He-WD evolution

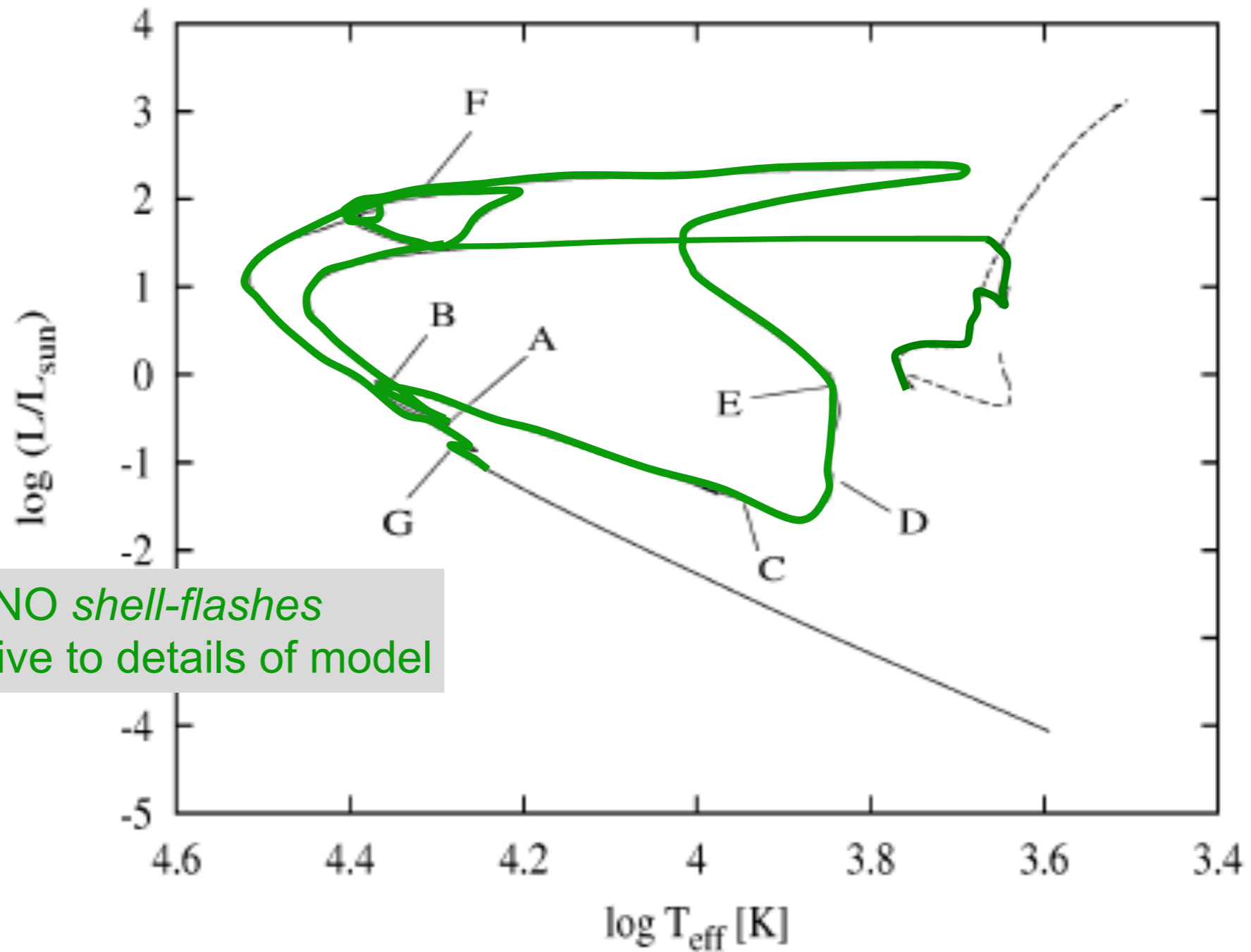


# Pre-He-WD evolution



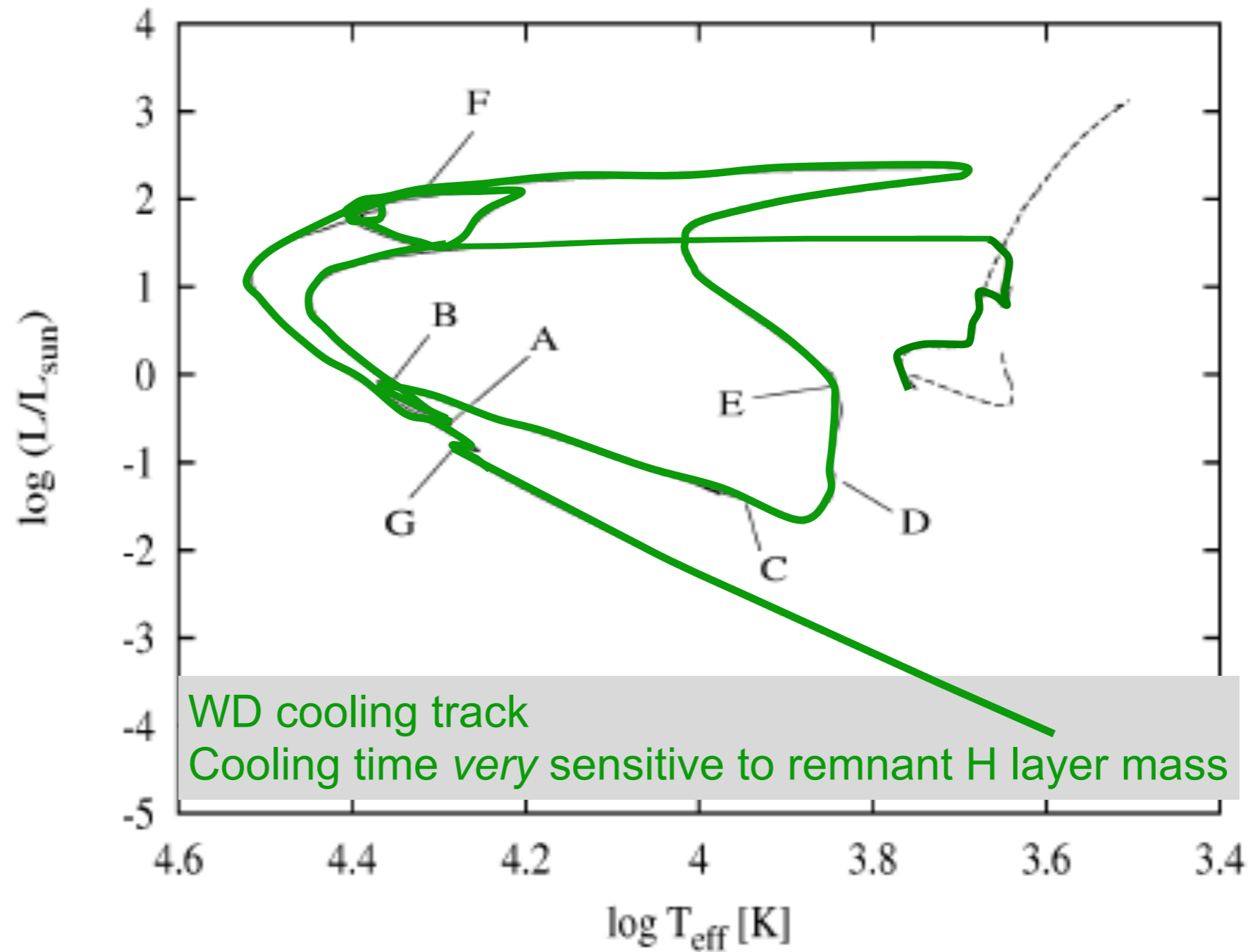
Shell burning rate drops  
Start of WD cooling track

# Pre-He-WD evolution



Possible CNO shell-flashes  
Very sensitive to details of model

# Pre-He-WD evolution





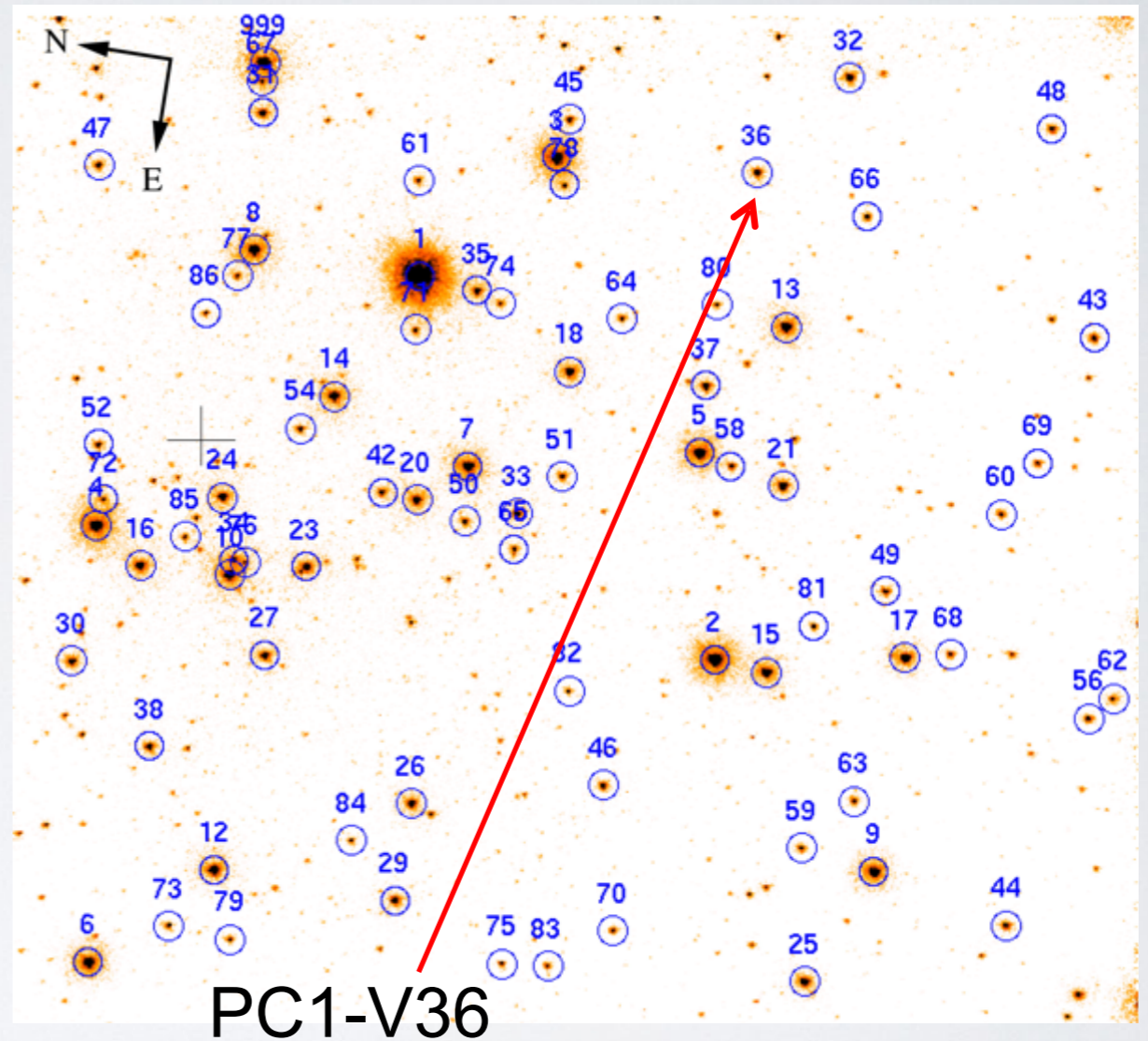
# Predictions from the models

- ELM WD born with thick hydrogen envelopes
  - lower the mass  $\Rightarrow$  thicker the envelope (up to  $\sim 0.05 M_{\text{Sun}}$ )
- For binary systems,  $P_{\text{orb}}$  related to  $M_{\text{WD}}$ 
  - low mass  $\Rightarrow$  short period
  - Also depends on composition
  - observed in WD - NS binaries (milli-second pulsars)
- Lifetime of stripped red giant phase depends on mass
  - lower mass  $\Rightarrow$  longer lifetime (up to 1 Gyr)
- Minimum mass  $\cong 0.15 M_{\text{Sun}}$

# How to strip a red giant

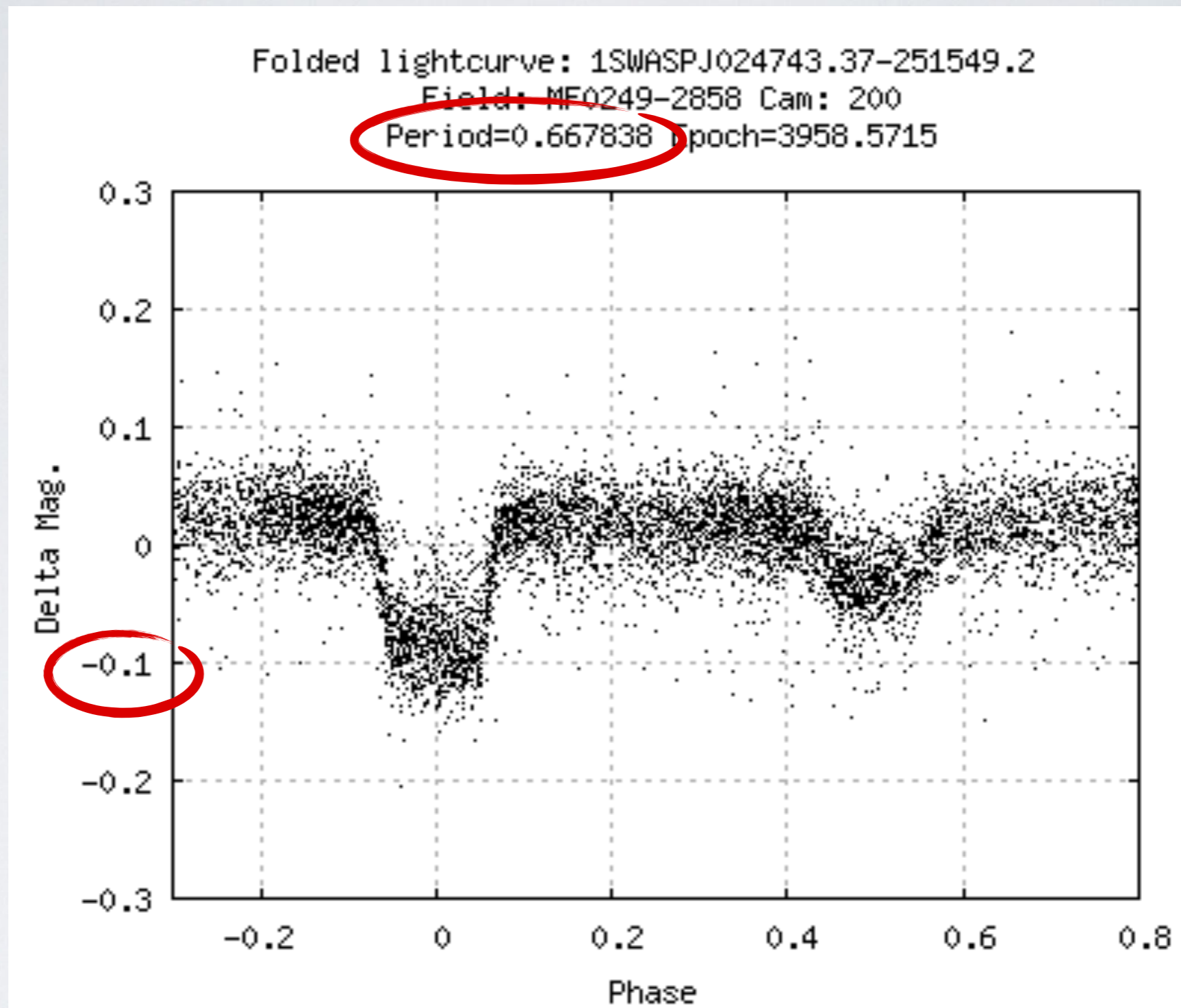
- Binary stars systems
  - Milli-second pulsars
  - Blue stragglers
- Dense stellar systems
  - PCI-V36, 47 Tuc
- Galactic centre/SMBH
  - PS-10jh

Knigge et al., 2008

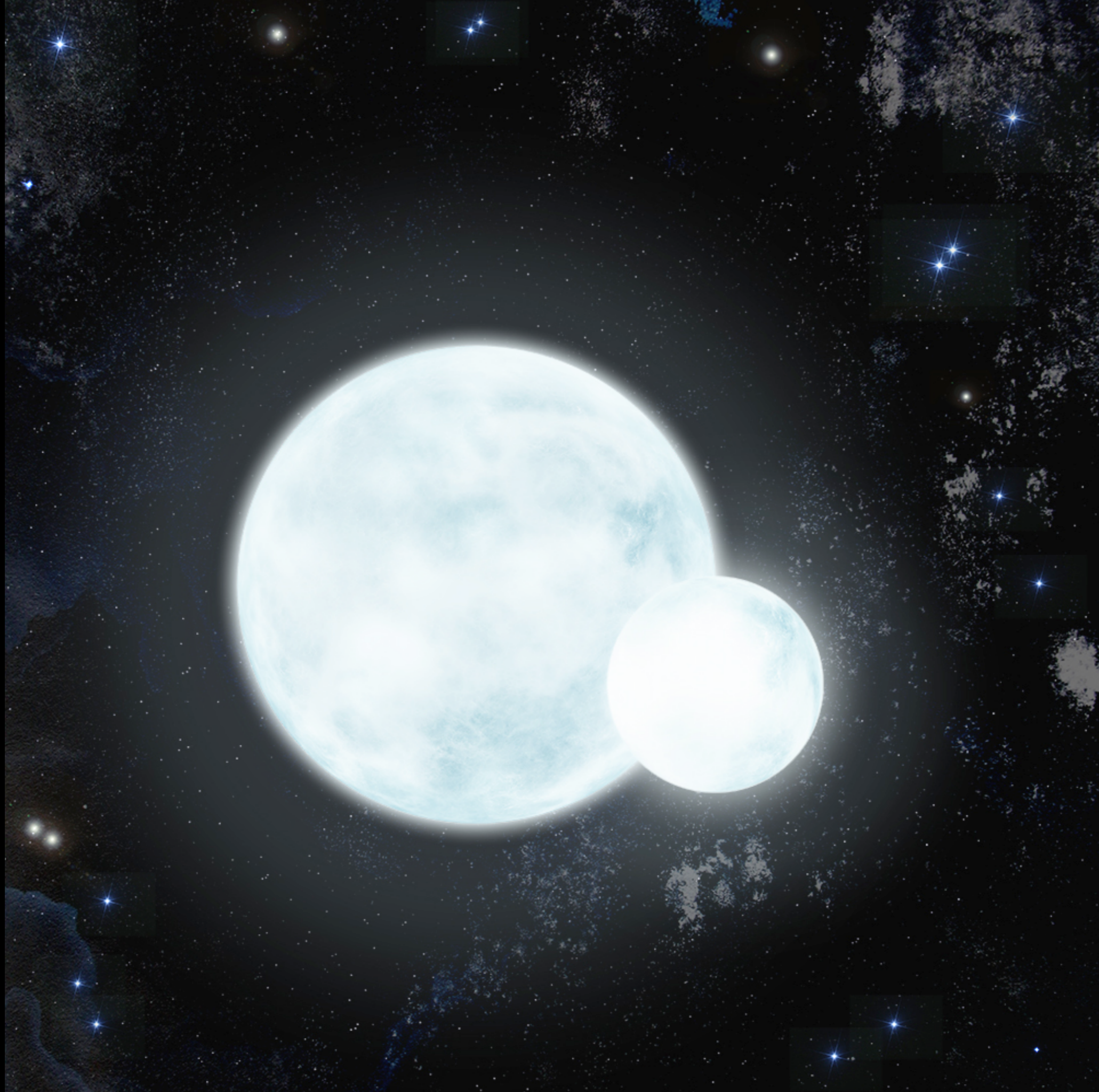


**ELM WD are tracers of extreme environments**

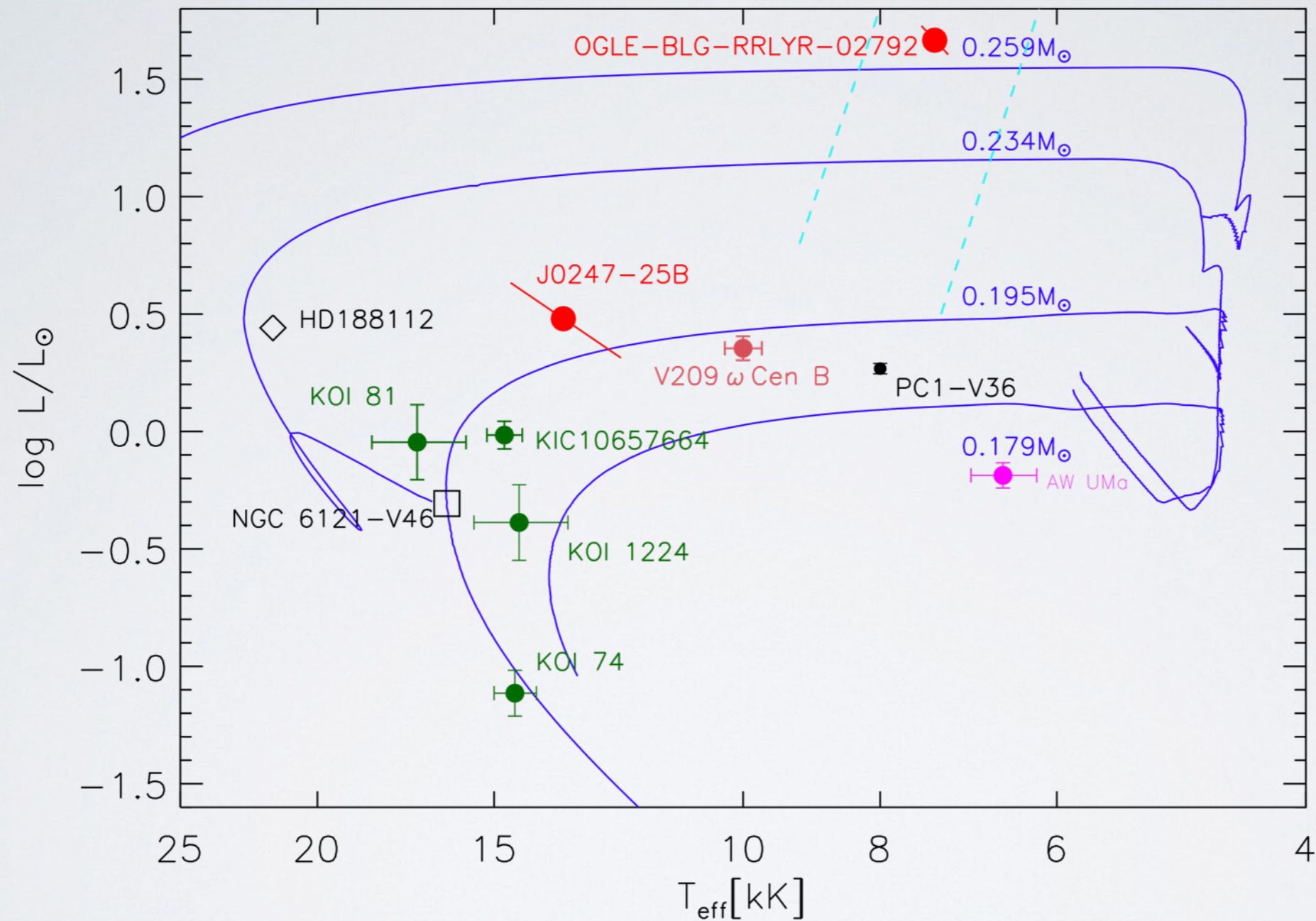
# J0247-25



Total eclipse deeper than secondary eclipse  $\Rightarrow$  Smaller star is hotter  
 $\Rightarrow$  some sort of subdwarf?



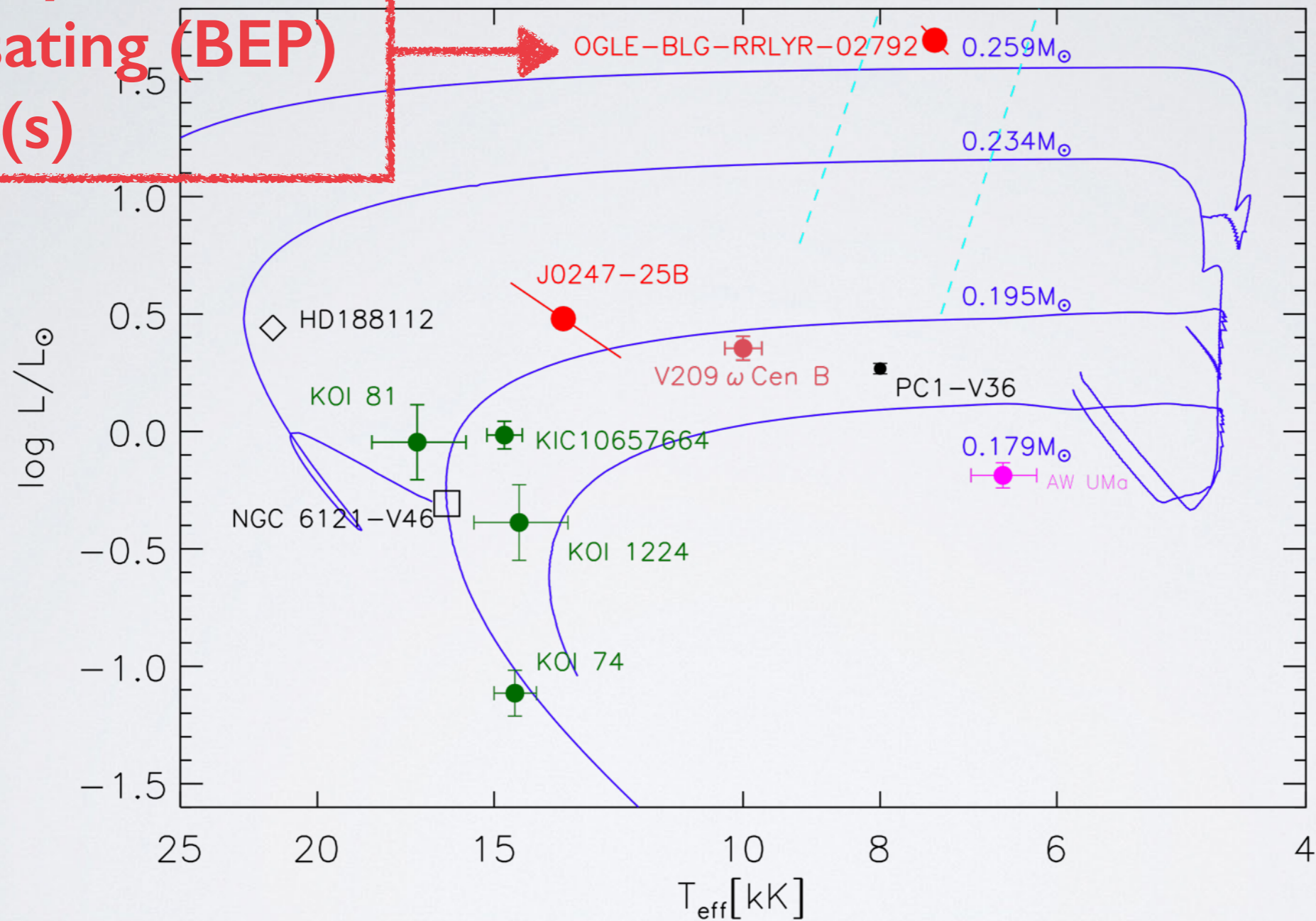
# Known stripped red giants (2011)



**Precursors of helium (ELM) white dwarfs ( $M < 0.3 M_{\text{Sun}}$ )**

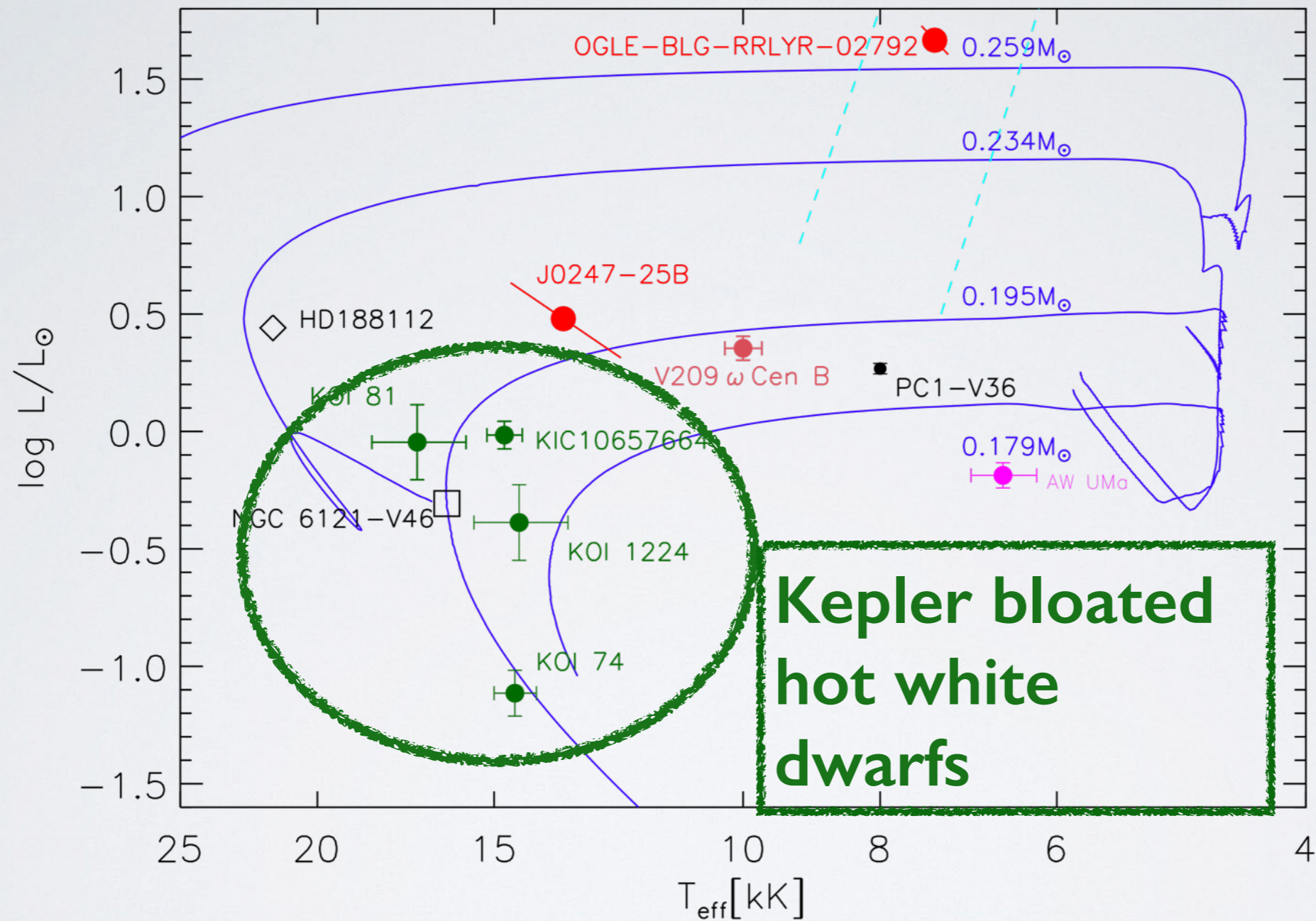
# Known stripped red giants (2011)

Binary evolved  
pulsating (BEP)  
star(s)



Precursors of helium (ELM) white dwarfs ( $M < 0.3 M_{\text{Sun}}$ )

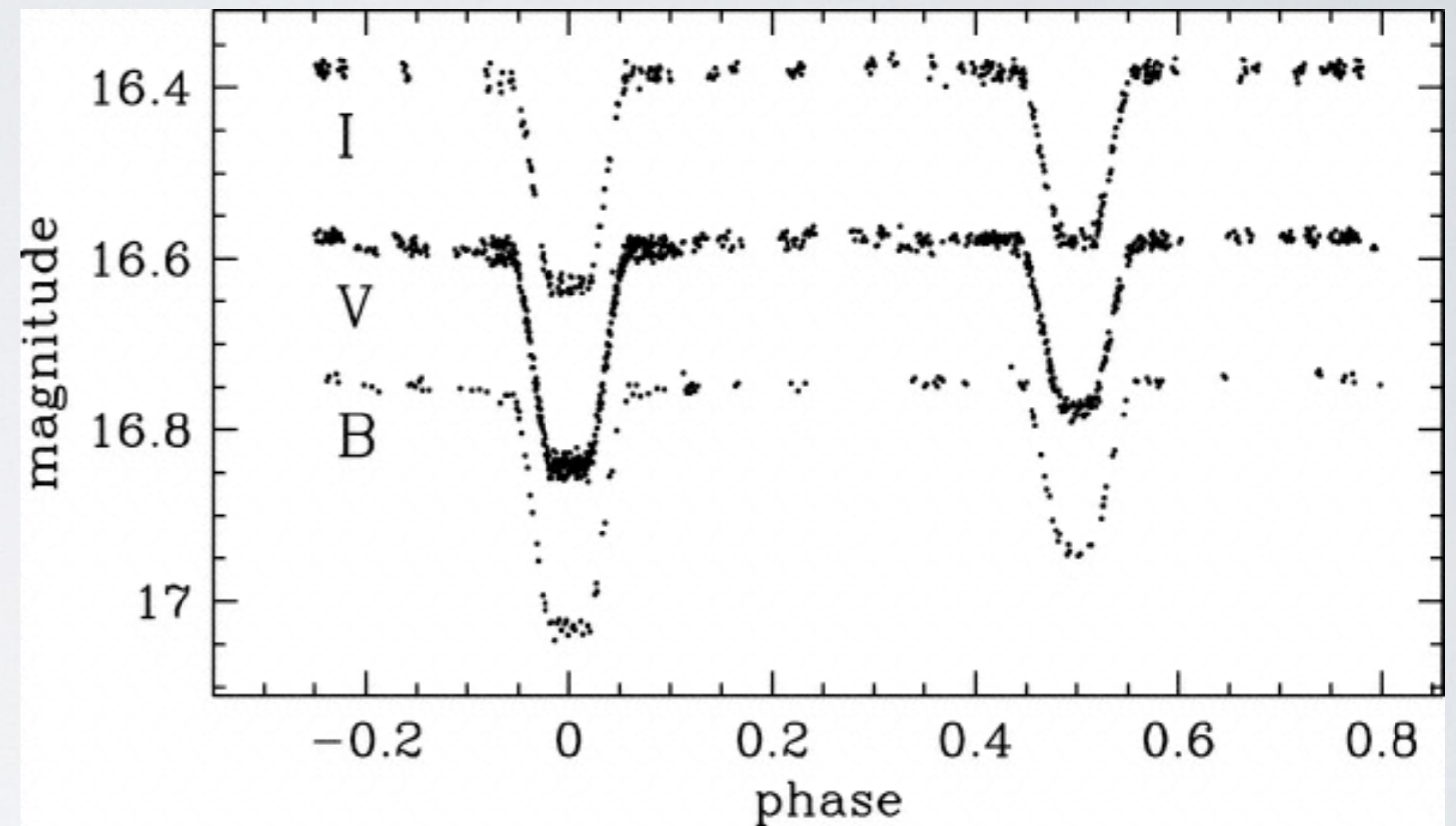
# Known stripped red giants (2011)



Precursors of helium (ELM) white dwarfs ( $M < 0.3 M_{\text{Sun}}$ )

# V209 in $\omega$ Cen

Primary	
Mass	0.95 M
Radius	0.98 R
T	9,400 K
Secondary	
Mass	0.14 M
Radius	0.43 R
T	11,000 K

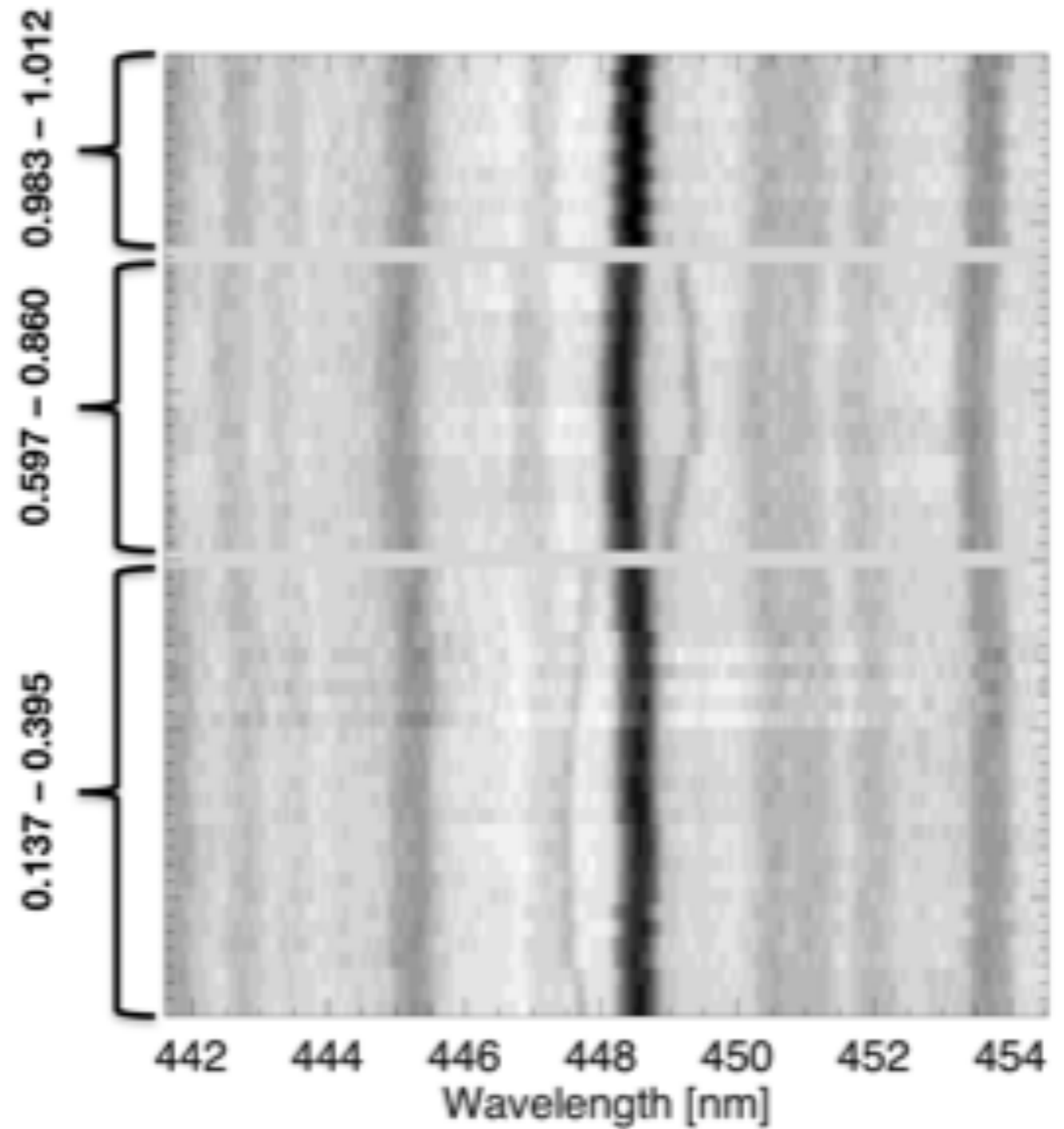


Kaluzny et al., 2007

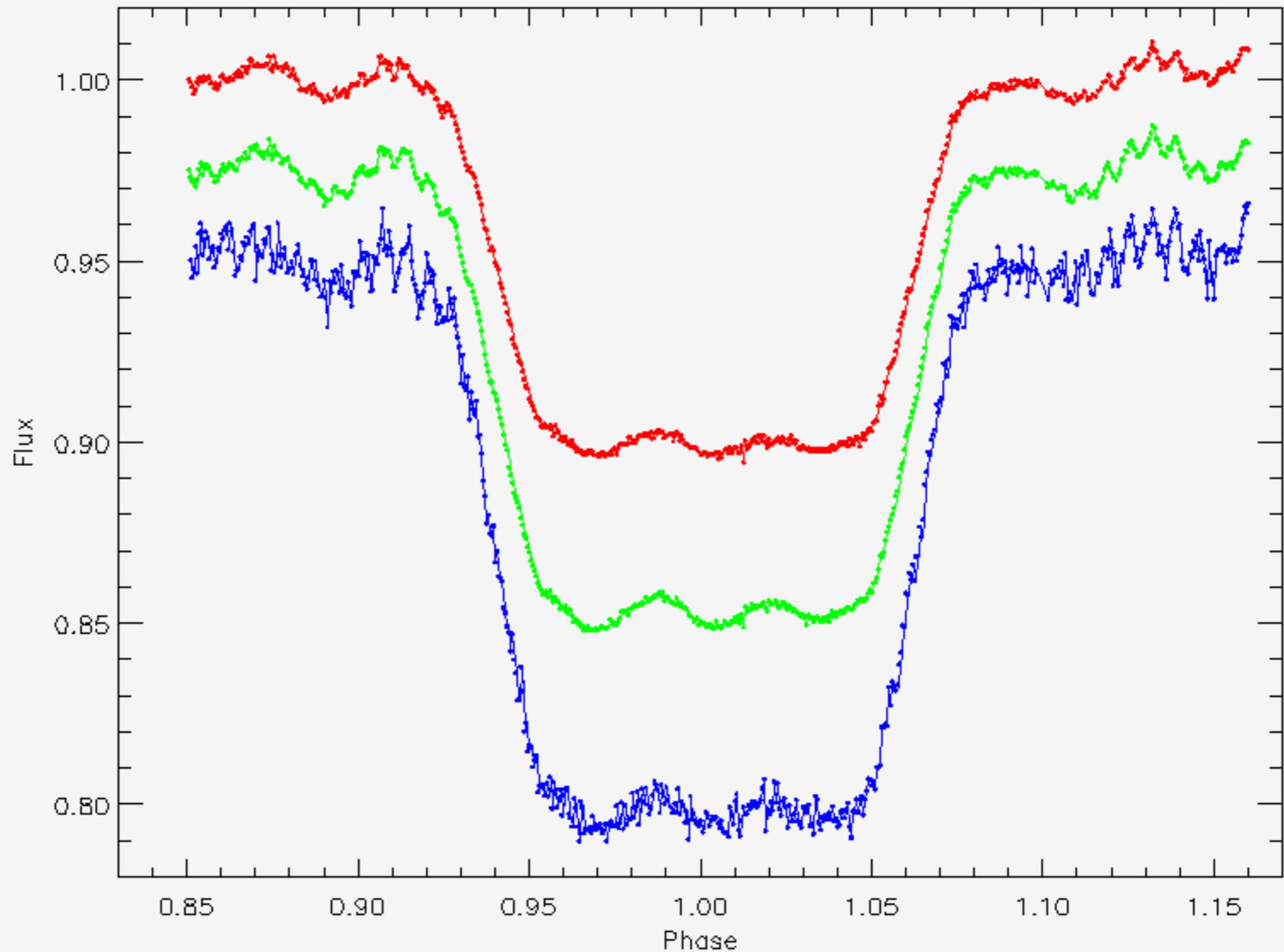


# UVES follow-up of J0247-25

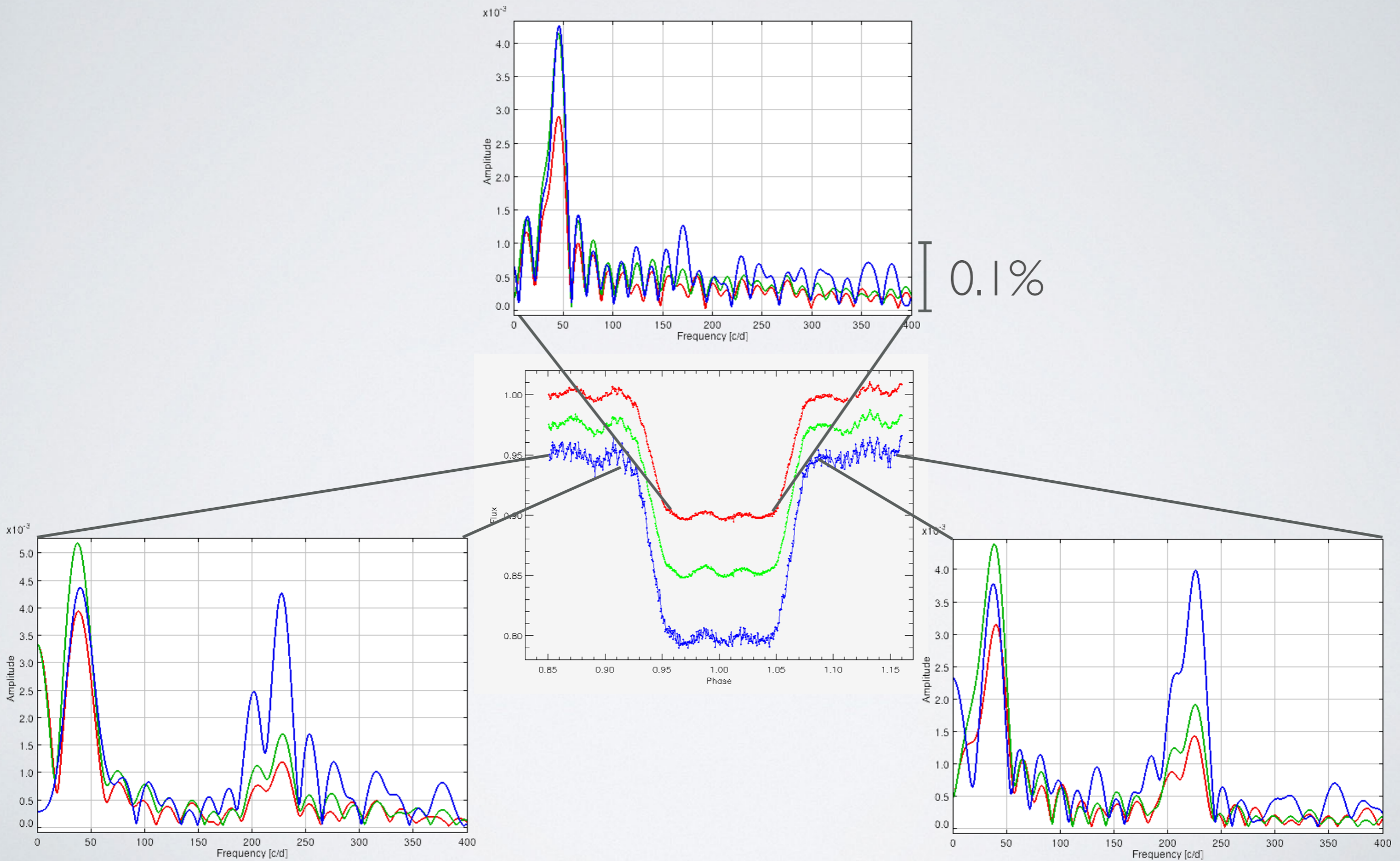
- $M_A = 1.356 \pm 0.007 M_\odot$
- $M_B = 0.186 \pm 0.002 M_\odot$



# Ultracam NTT data



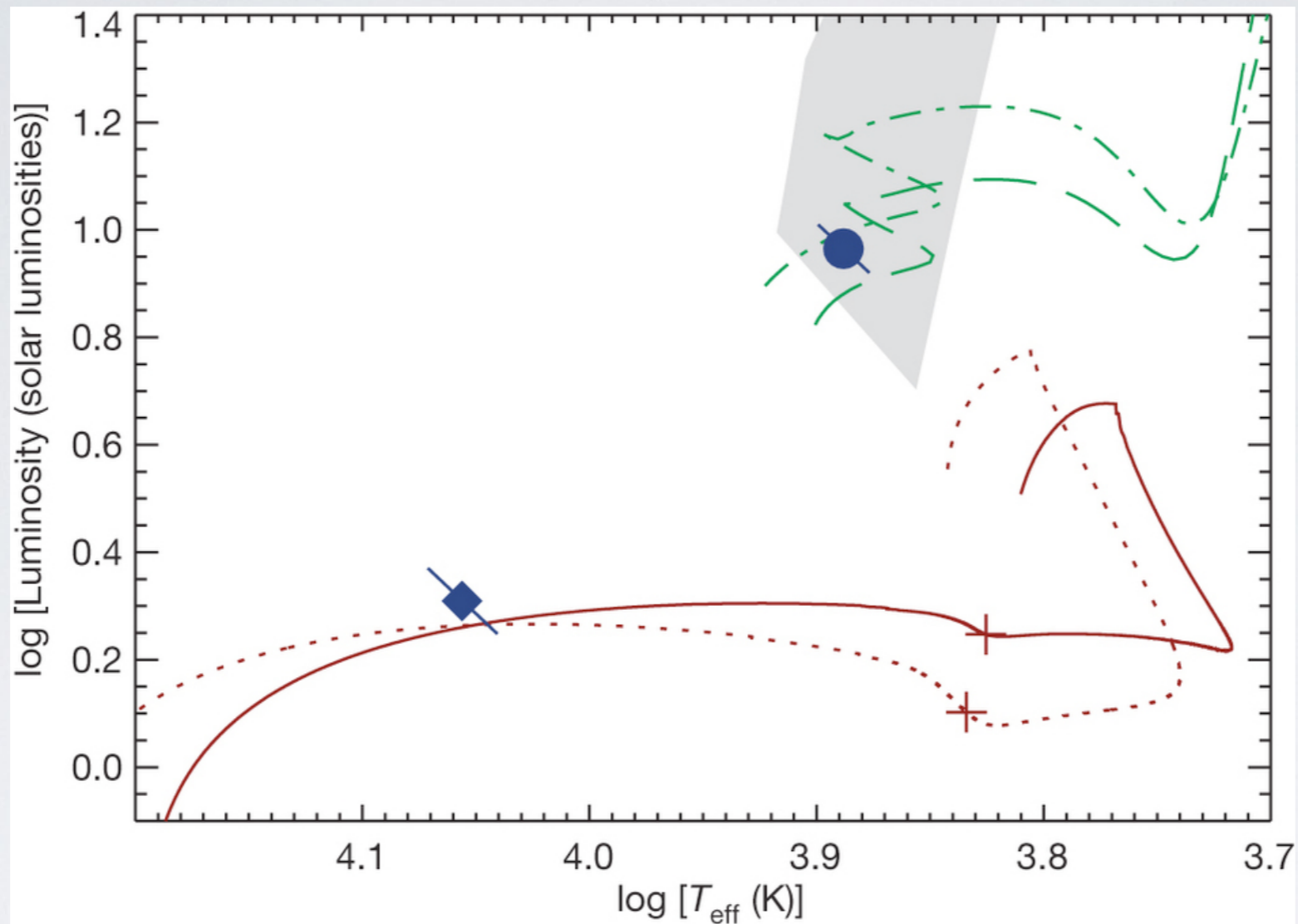
# Pulsations in J0247-25



# Pulsation characteristics

- J0247-25A
  - Metal poor  $\delta$  Scuti star (SX Phe)
  - Non-radial p-modes,  $P \approx 40$  mins
  - Driving from  $\kappa$ -mechanism in He II ionisation zone
- J0247-25B
  - Mixed modes,  $P \approx 6$  mins
    - Envelope – p-modes
    - Core – g-modes
  - Non-radial and radial with  $k \approx 10$
  - Probably similar driving mechanism to SX Phe
  - *Completely new type of pulsating star*
  - Will pulsate again as ZZ Cet when it is an ELM WD

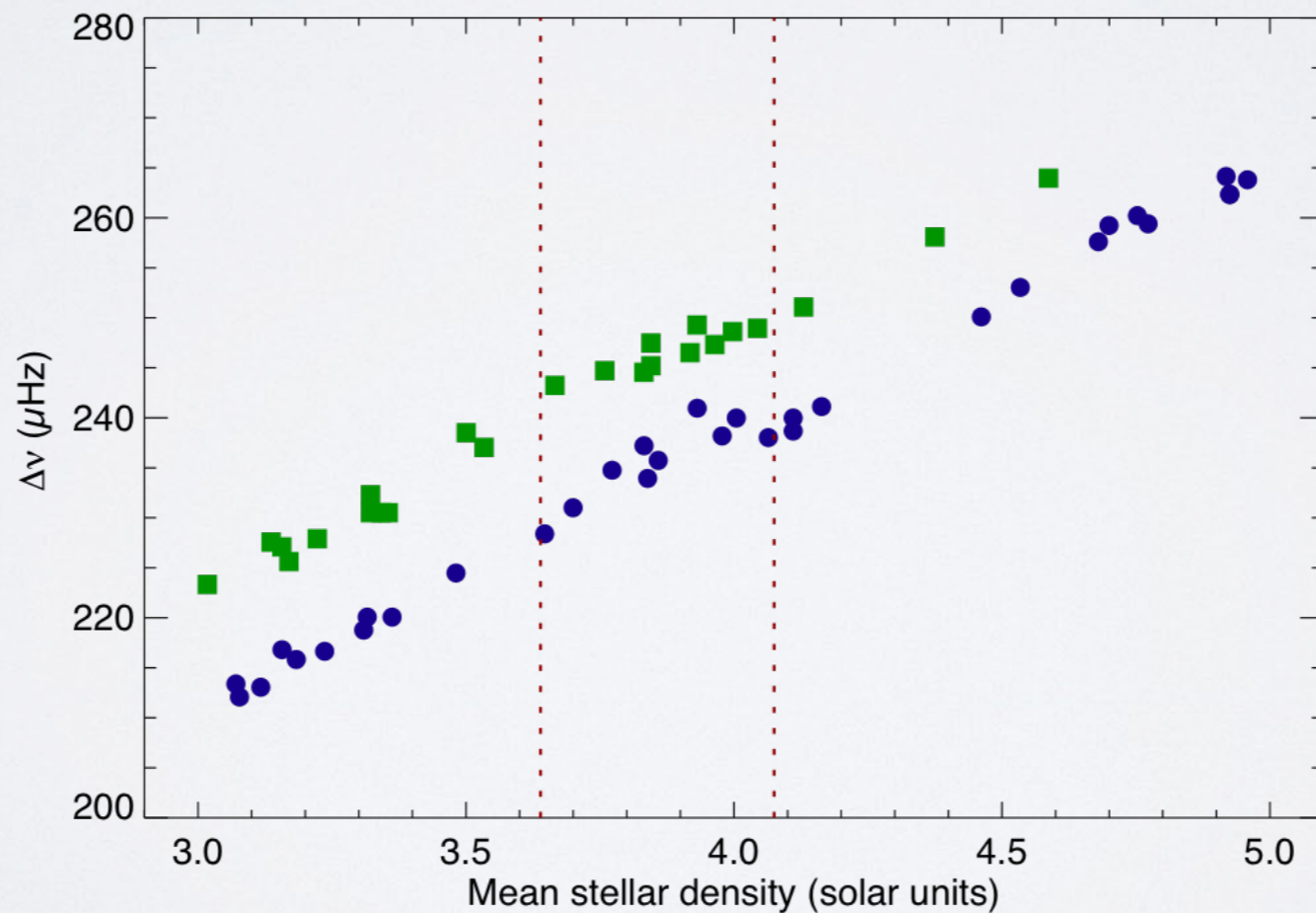
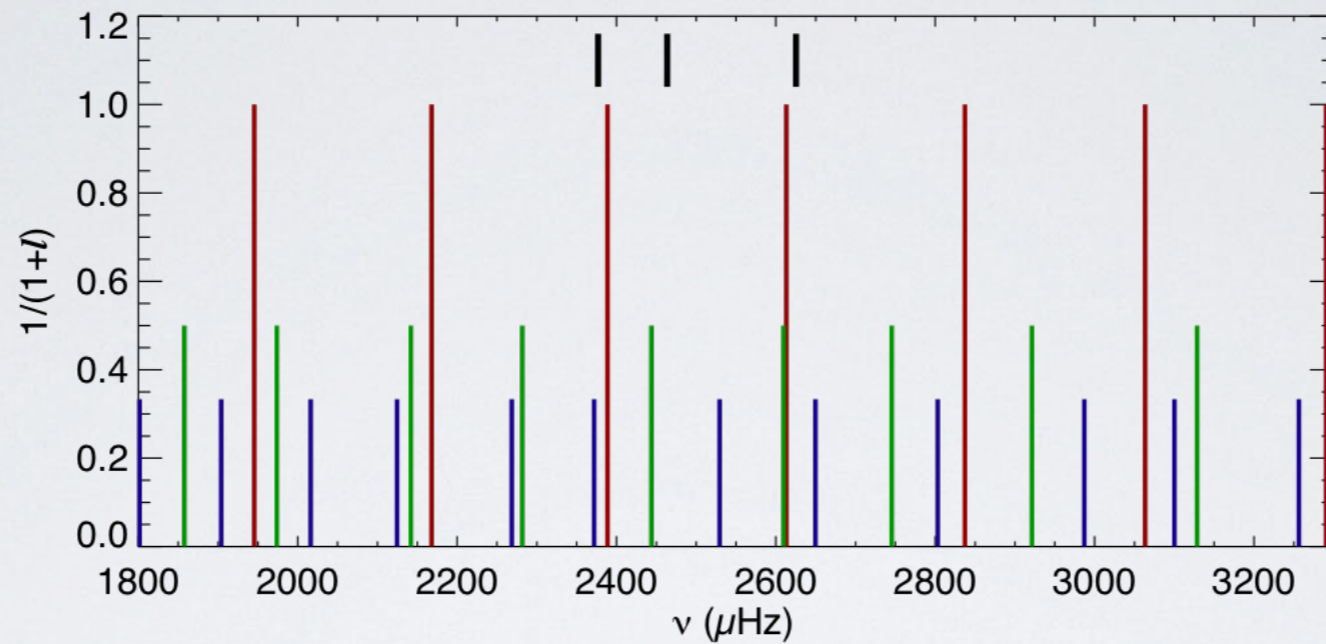
# J0247-25 in the HRD



Maxted et al., Nature 498, 463–465 (2013)

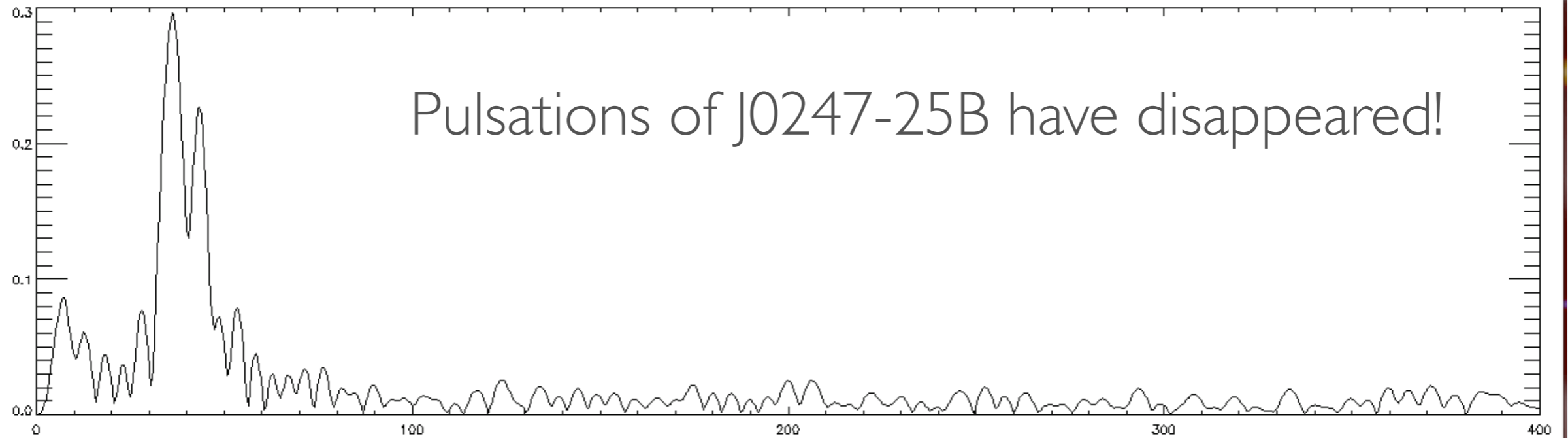
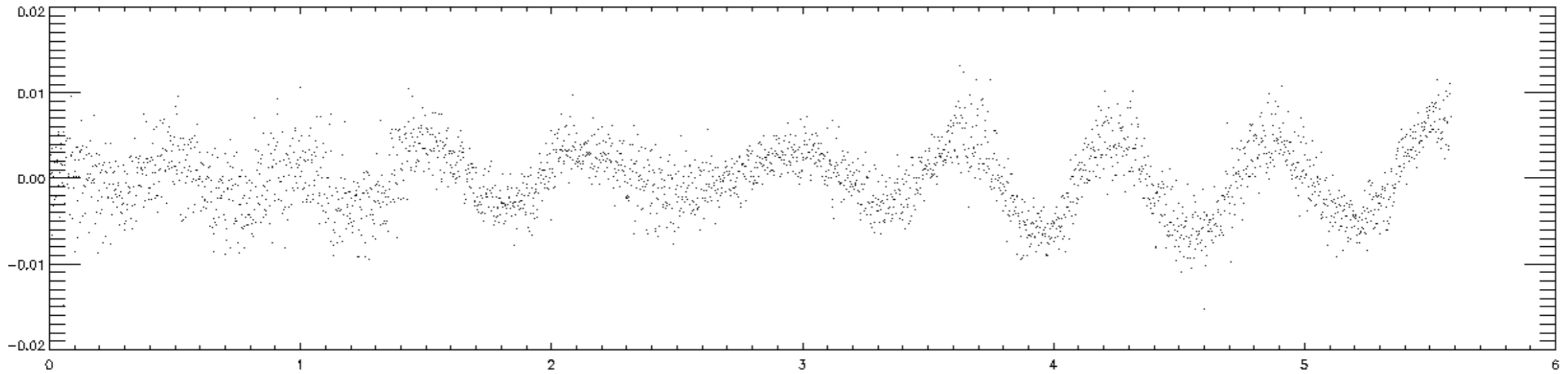
- **J0257-25B** born with a thick hydrogen envelope

# Potential for asteroseismology

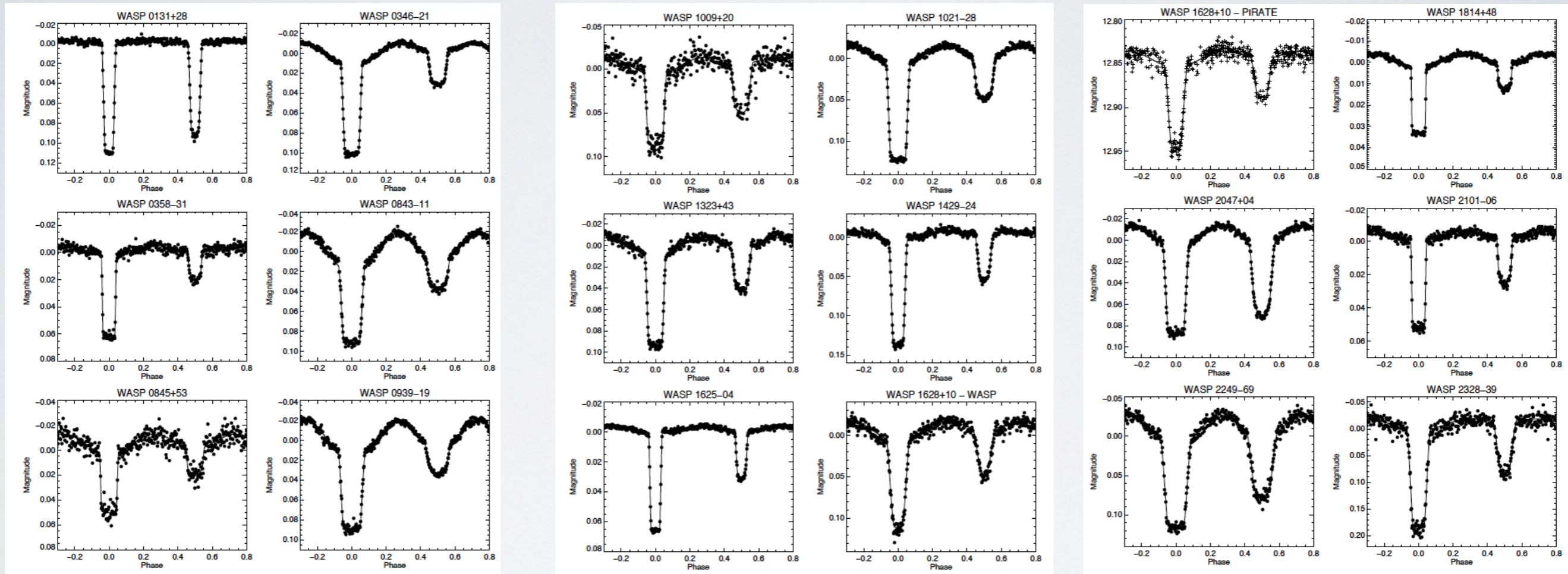


With diffusion  
No diffusion

# SOAR data for J0247-25



# EL CVn-type binaries



17 new eclipsing pre-He-WD from WASP (Maxted et al., MNRAS 2014)



# EL CVn-type binaries

- **EL CVn –**
  - “standard” AIV star,
  - variability found in Hipparcos photometry ( $V=9.4$ )
- **Orbital periods 0.7 – 2.2 days (or longer)**
- **Primary stars A0 – F0 (typically A2)**
- **$T_{\text{eff,B}} = 9,000 – 15,000\text{K}$  (typically, can be a bit hotter)**
- **Companion mass  $\sim 0.2M_{\odot}$**
- **Found in the halo star, thin-disc stars and thick-disk**

# Summary

Name of object depends on how it is discovered / who discovered it

- Kepler (the space craft)
  - bloated hot white dwarf/hot white dwarf
- WASP photometry
  - EL CVn binary
  - stripped red giant star / pre-He-WD
- Spectroscopy
  - ELM WD (if binary period  $\Rightarrow$  not a main-sequence A-star)
- Milli-second pulsar optical counterpart
  - metal-rich low-gravity companion (Kaplan et al., 2013)
- Spectroscopy + parallax (HD188112)
  - helium-core white dwarf progenitor (Heber et al., 2003)