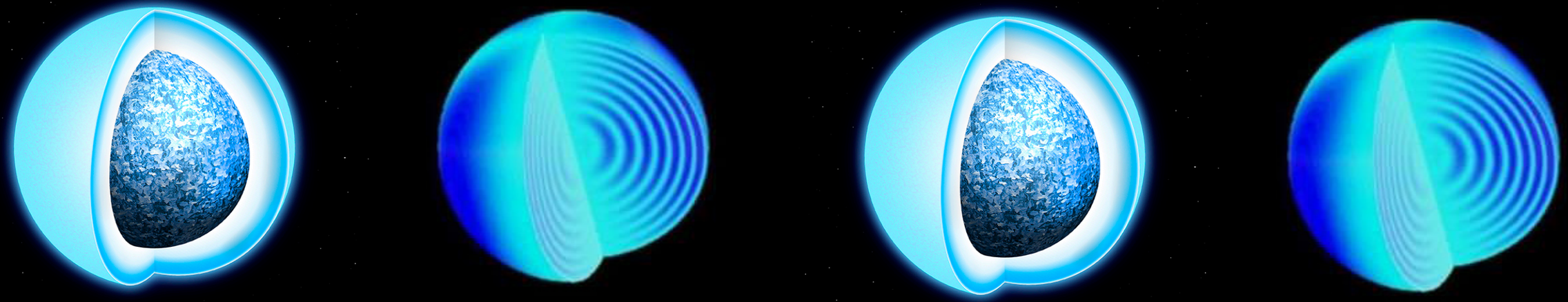
First light on pulsating compact objects with TESS

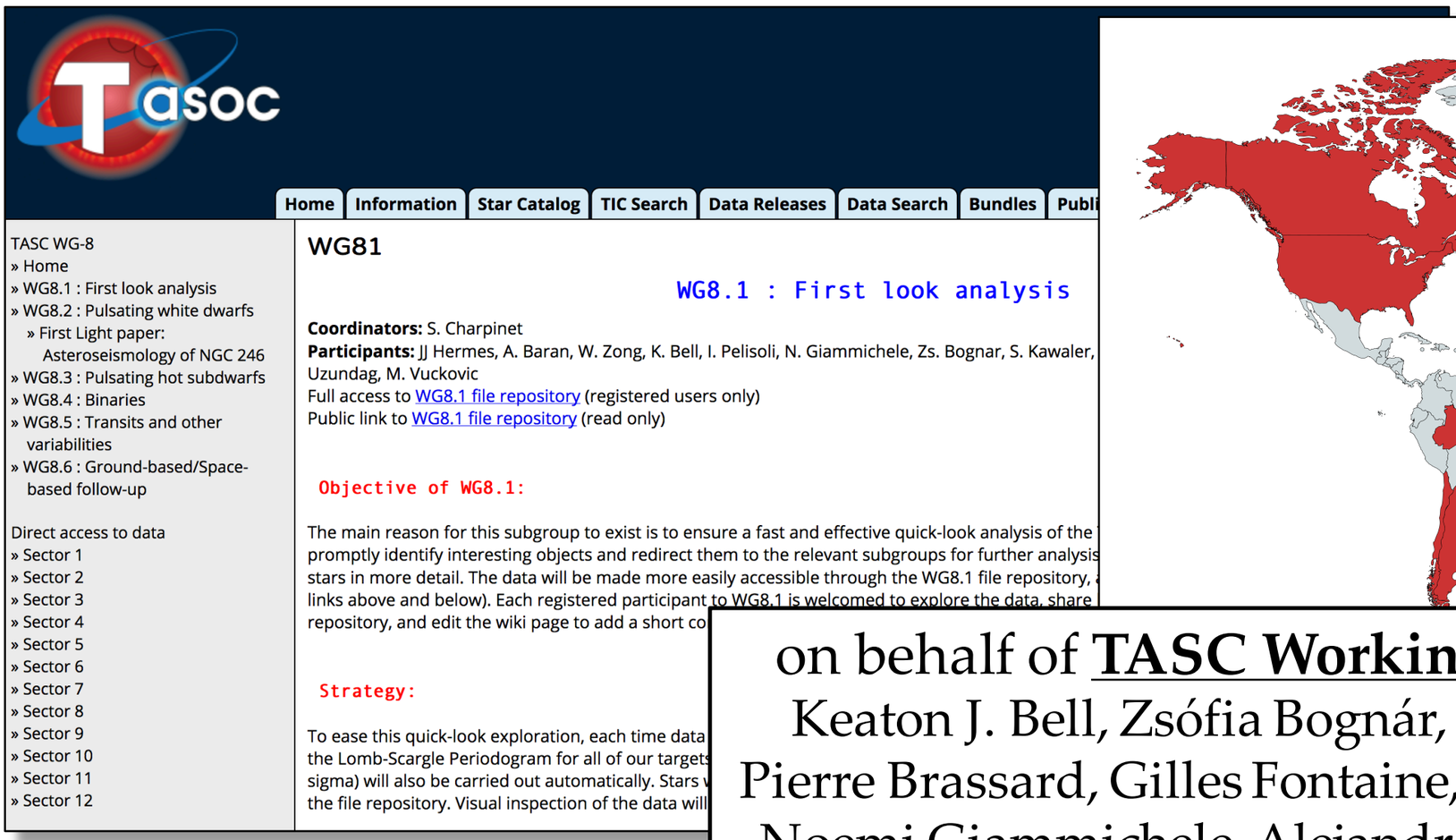


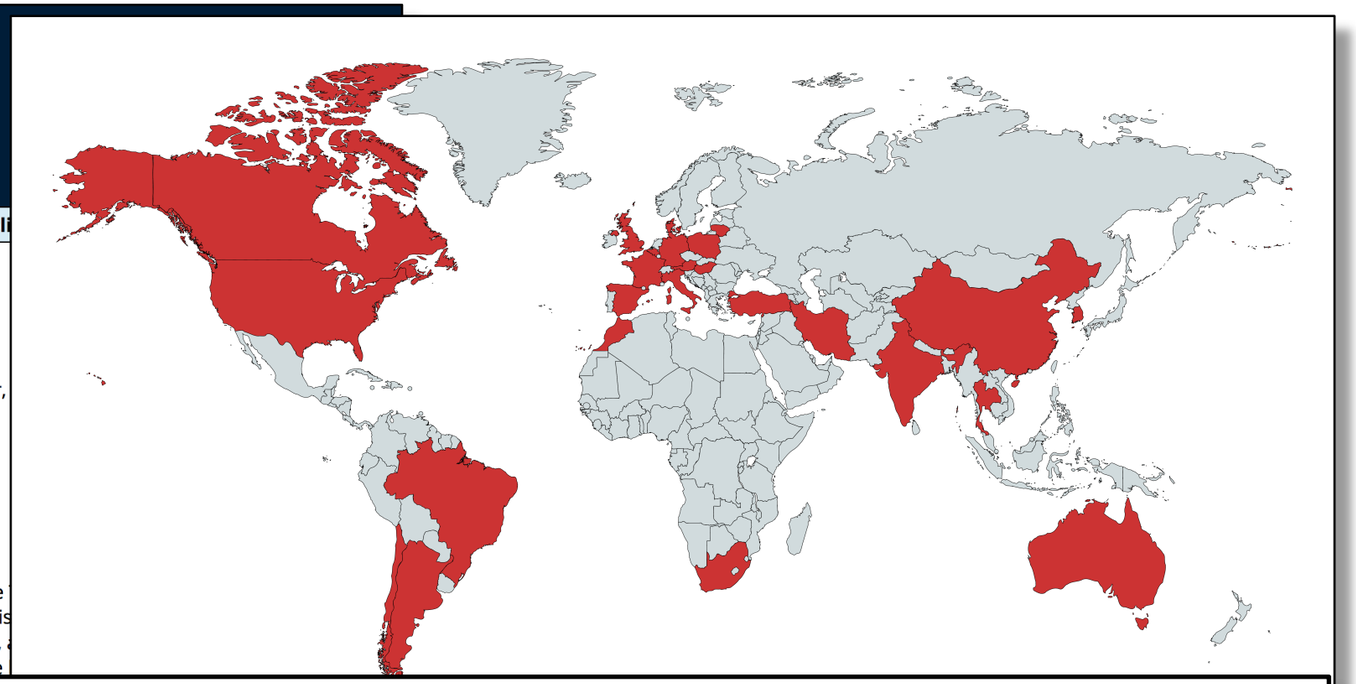
J.J. Hermes

http://jjherm.es
@jotajotahermes

BOSTON UNIVERSITY

on behalf of **TASC Working Group 8**: Stéphane Charpinet, Keaton J. Bell, Zsófia Bognár, Steve Kawaler, Paulina Sowicka, Pierre Brassard, Gilles Fontaine, Valerie Van Grootel, Weikai Zong, Noemi Giammichele, Alejandro H. Córsico, Agnès Bischoff-Kim, Leandro G. Althaus, Paul Bradley, Uli Heber, Stephane Geier, Betsy Green, Dave Kilkenny, Roy Østensen, Ingrid Pelisoli, Roberto Silvotti, John Telting, Maya Vučković, H. L. Worters, Leila M. Calcaferro, Mike Montgomery, Murat Uzundag, Andrzej S. Baran, Hamed Ghasemi, John Debes, Piotr Kołaczek-Szymański, Simon J. Murphy, Andrzej Pigulski, Ádám Sódor, Murat Uzundag, et al.





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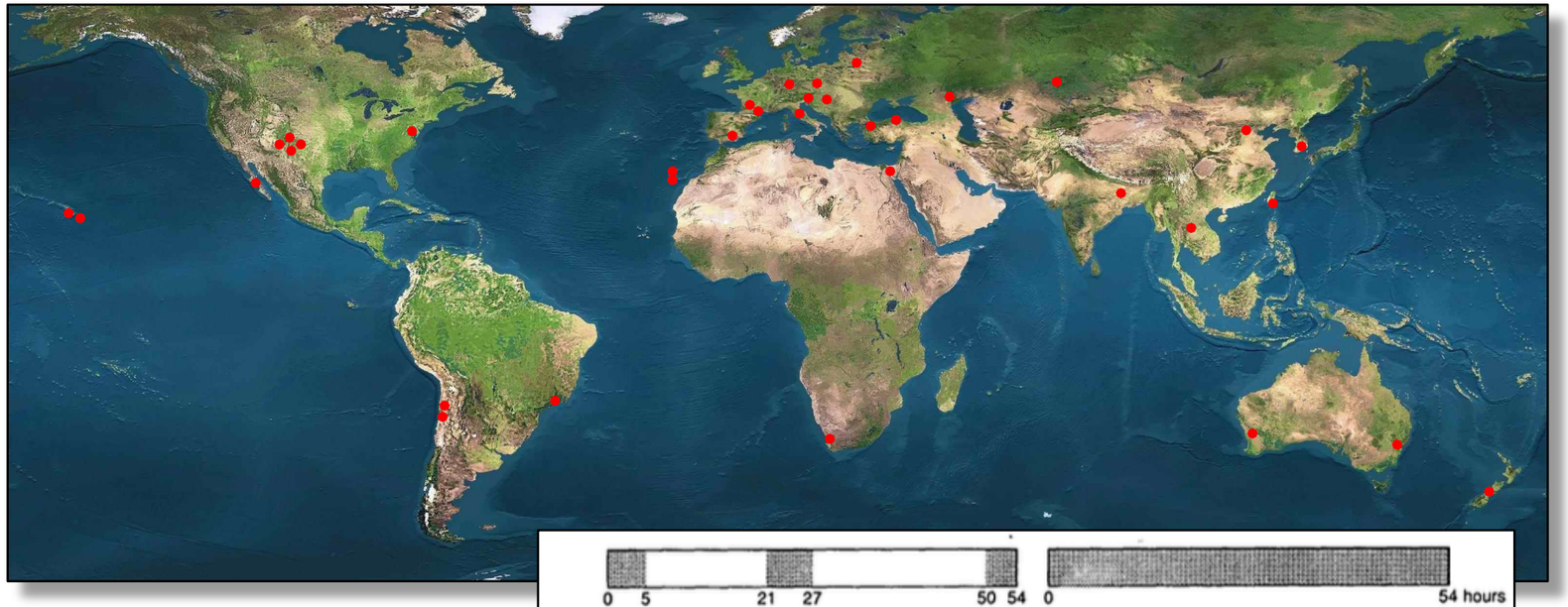
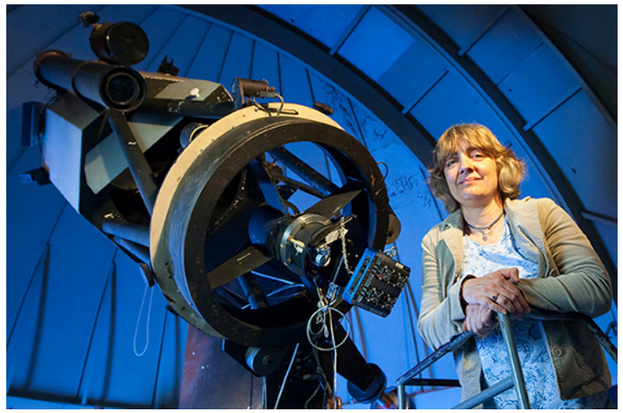
Open to all:
tasoc.dk/wg8



Founder: Ed Nather



Current Director: Judi Provencal

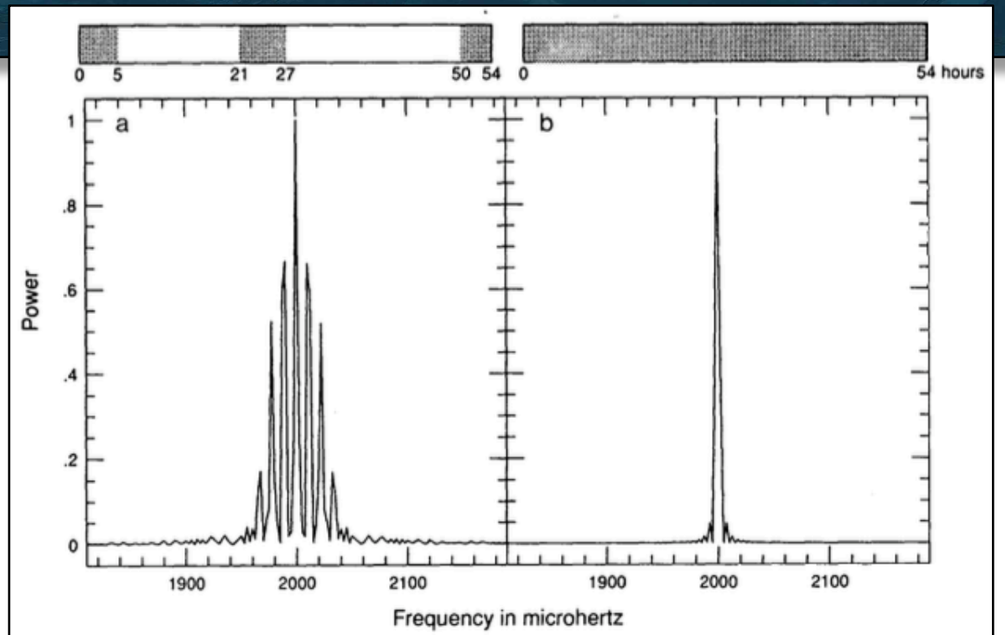
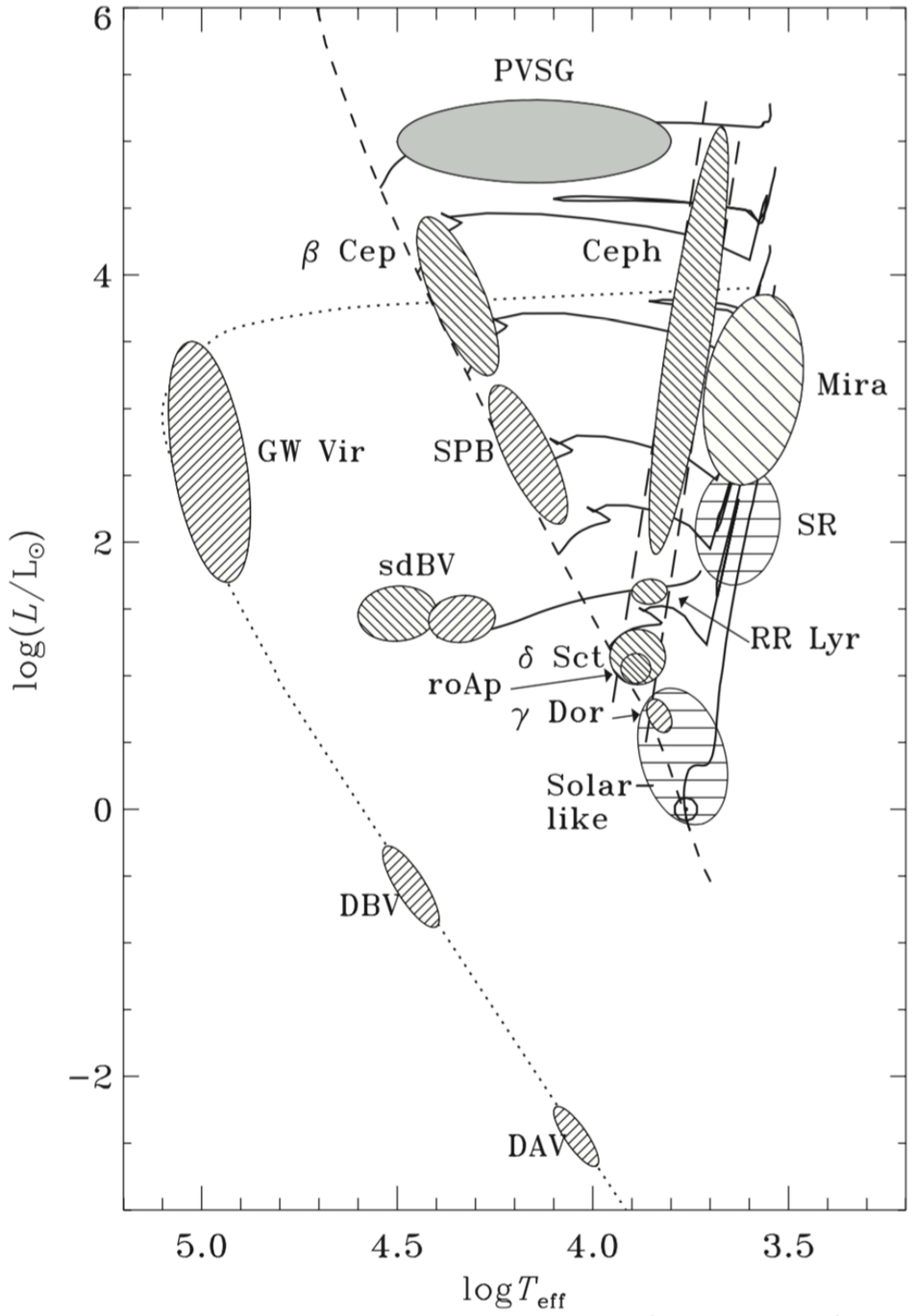


FIG. 1.—Fourier transforms of a single, noise-free, untapered sine wave sampled as indicated at the top of each panel. (*a*) "Alias" pattern typical of time-series data from a single site with daytime gaps. (*b*) Pattern obtained if the daytime gaps are not present.

Nather, Winget, Clemens et al. 1990



HR diagram by
Jørgen Christensen-Dalsgaard

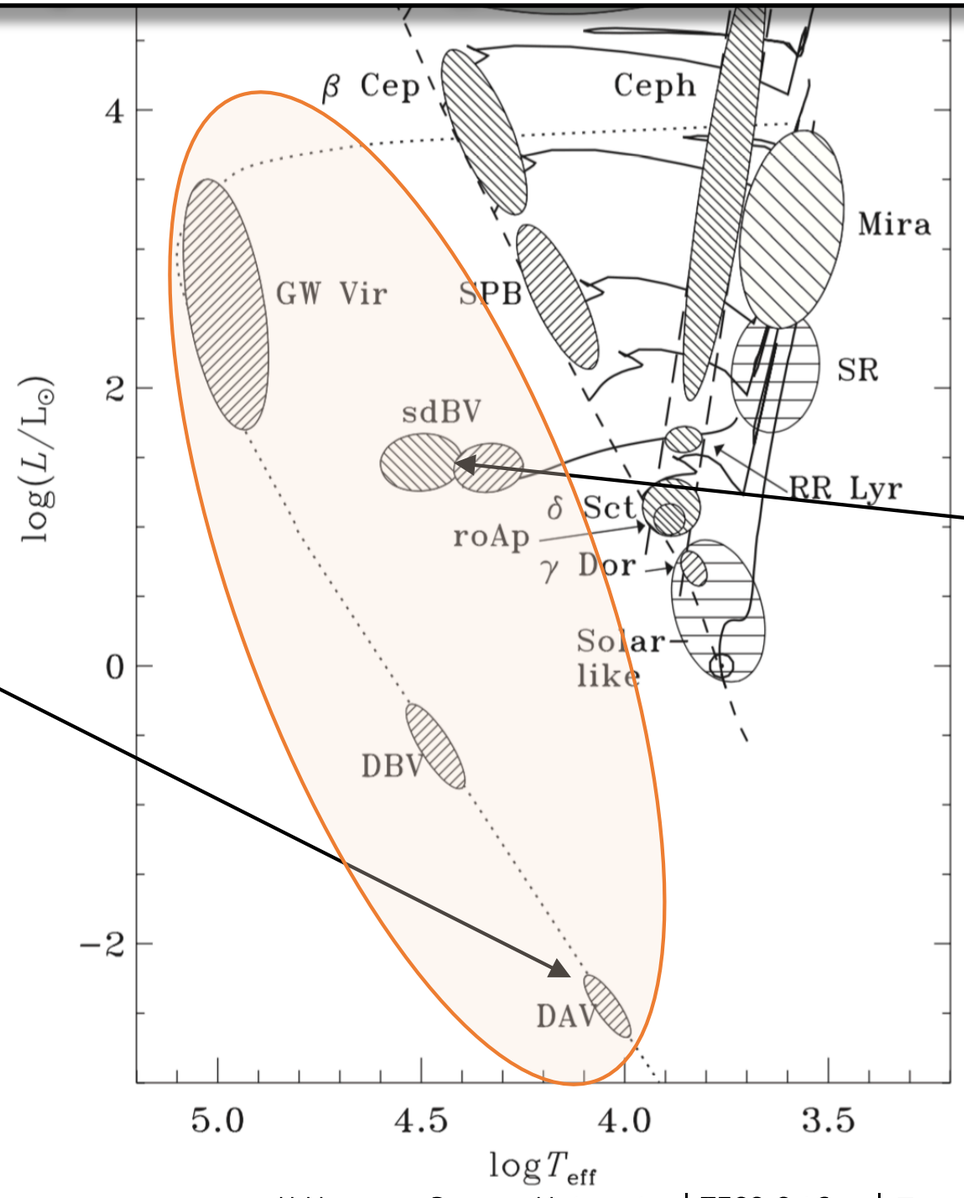
First light on pulsating compact objects with TESS

~0.6 $M_\odot$
~0.01 $R_\odot$

a 'typical'
white dwarf
inert
C/O core

non-degenerate
He layer

non-degenerate
H layer



~0.47 $M_\odot$
~0.2 $R_\odot$

a 'typical'
hot subdwarf (sdB)

core
He burning

non-degenerate
He layer

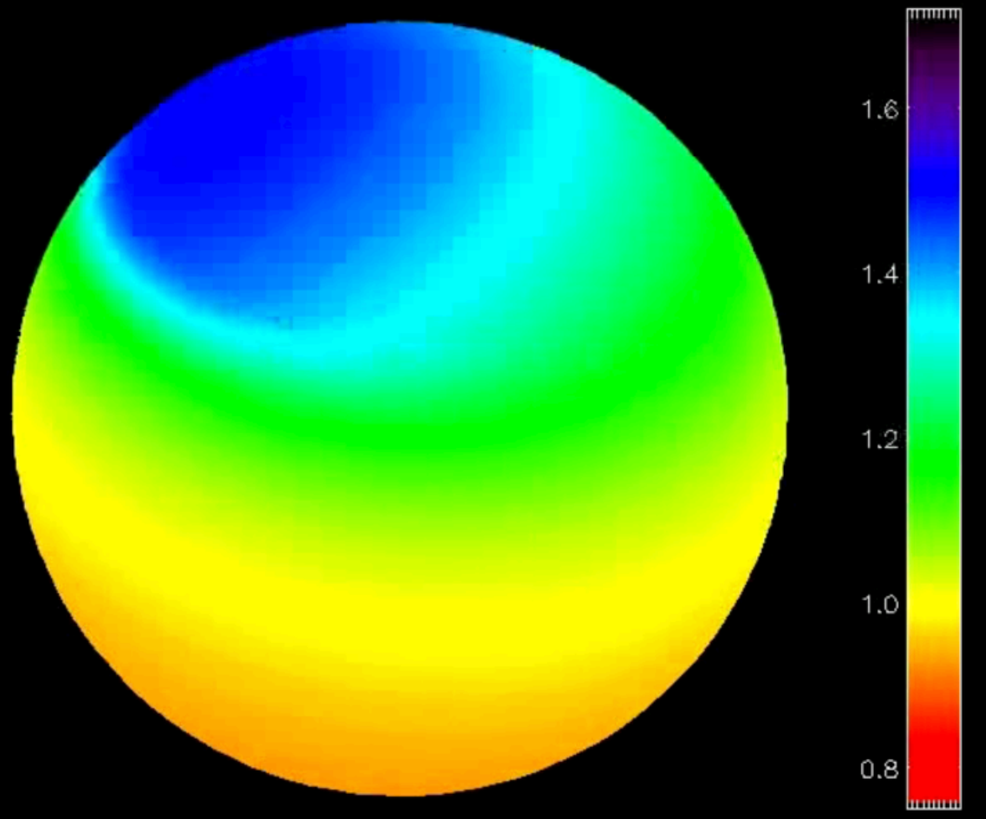
non-degenerate
H layer

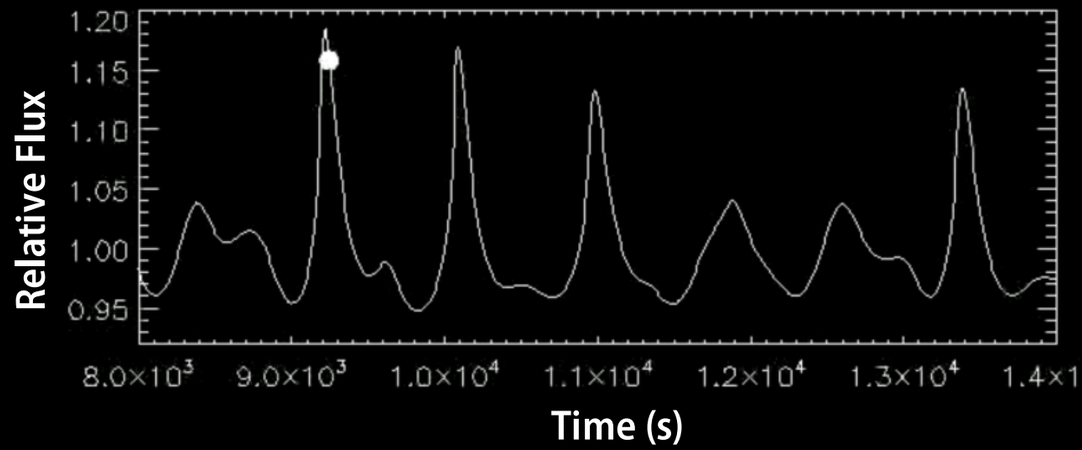
HR diagram by
Jørgen Christensen-Dalsgaard

g-mode pulsations cause surface temperature variations, causing brightness changes

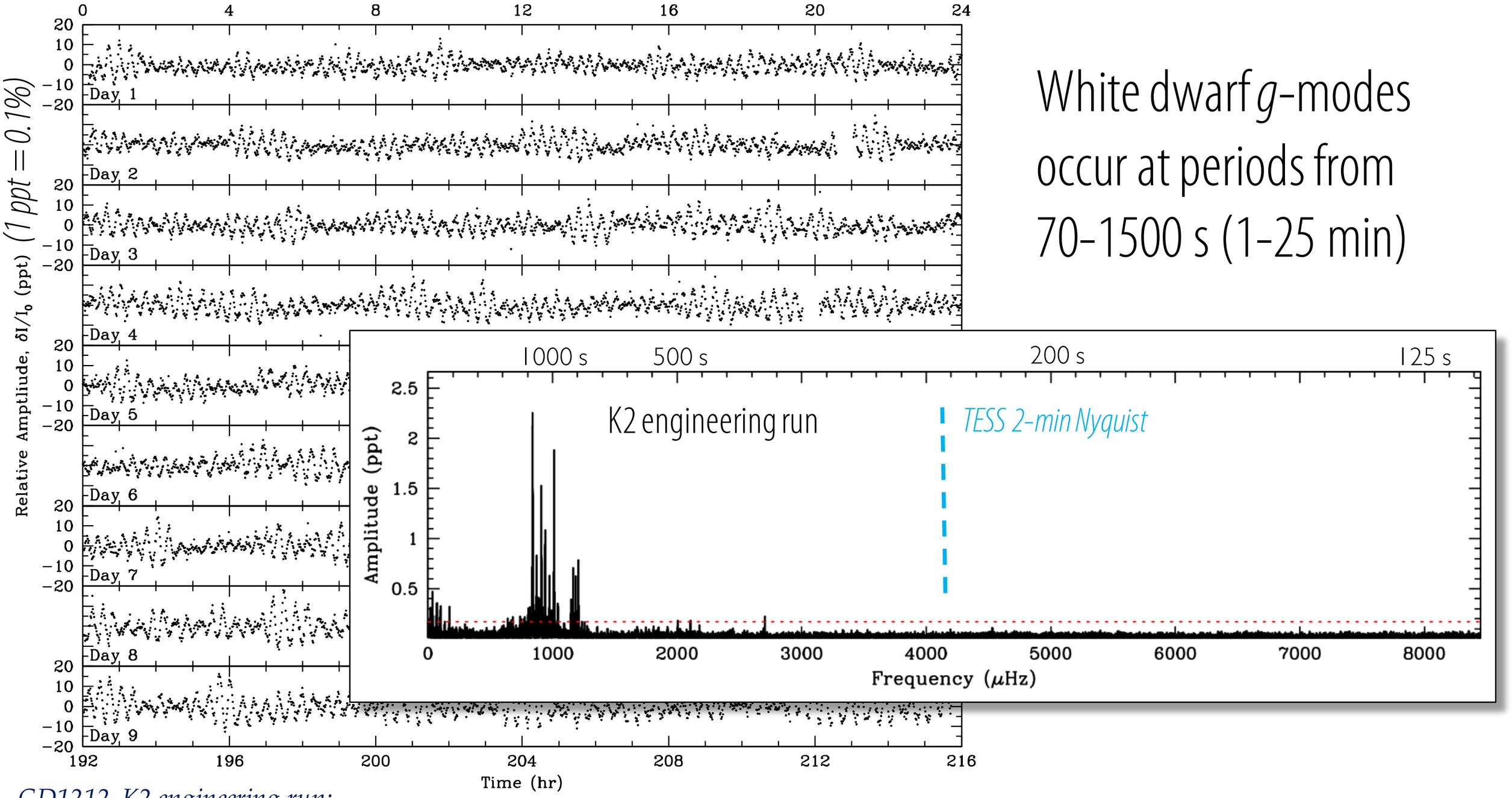
Comparing the observed periods to theoretical models yields **asteroseismology** which can directly constrain

- Remnant core C/O ratio (reaction rates)
- Envelope layer masses (cooling rates)
- (Differential) rotation





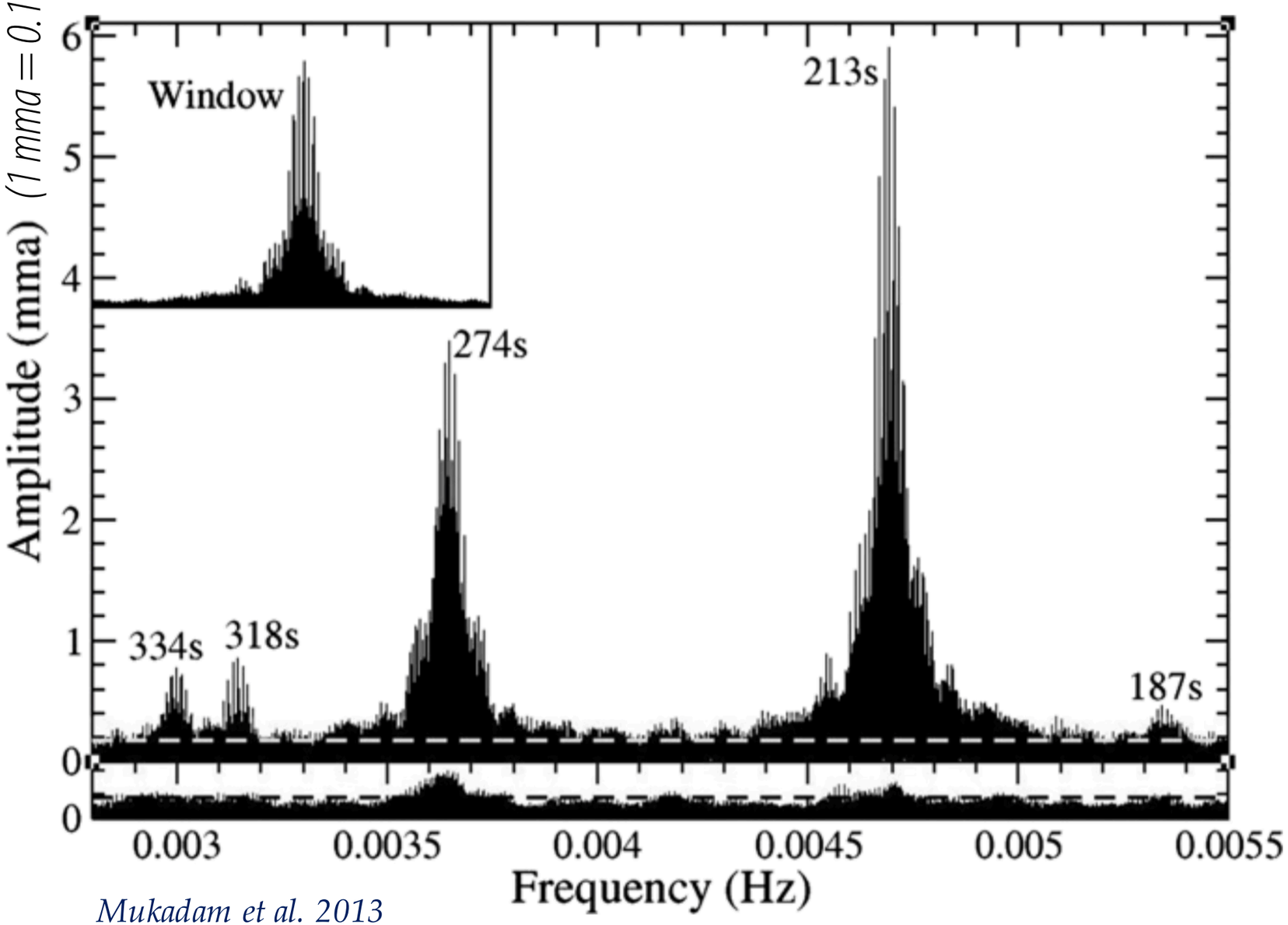
Movie by Mike Montgomery



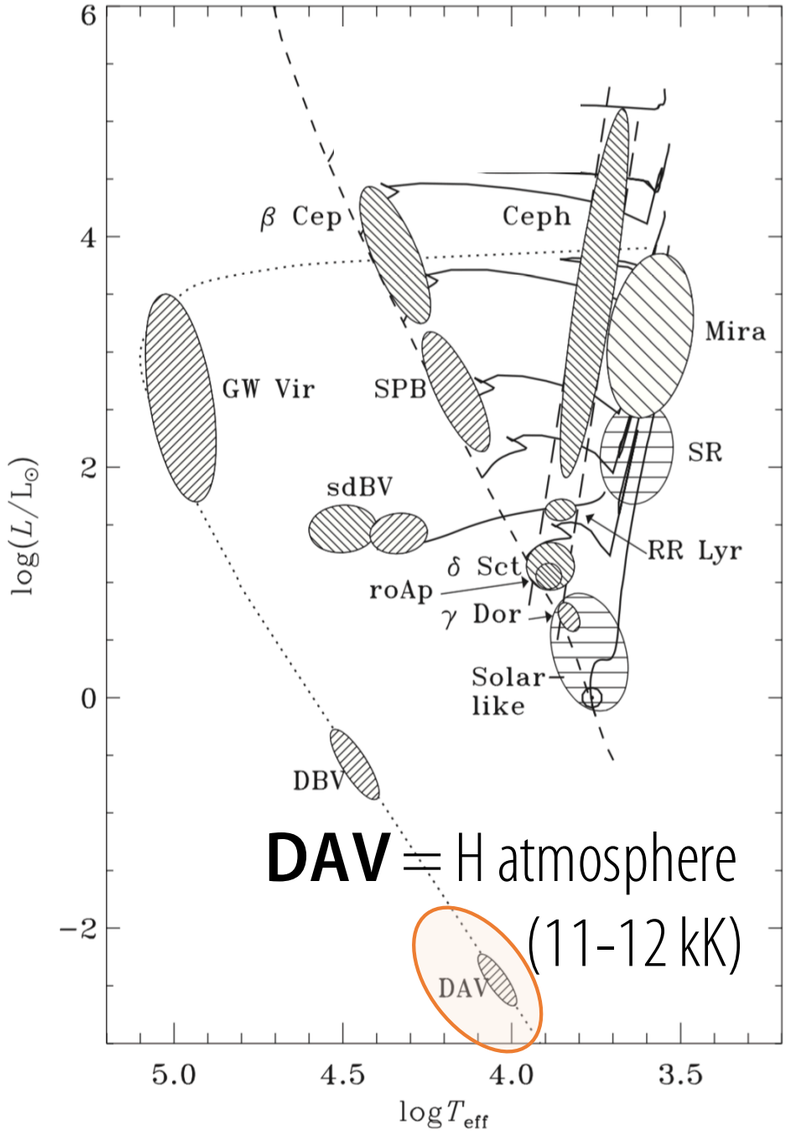
White dwarf *g*-modes occur at periods from 70–1500 s (1–25 min)

GD1212, K2 engineering run: Hermes et al. 2014

R548 (aka ZZ Ceti): T=14.4 mag, 32.8 pc



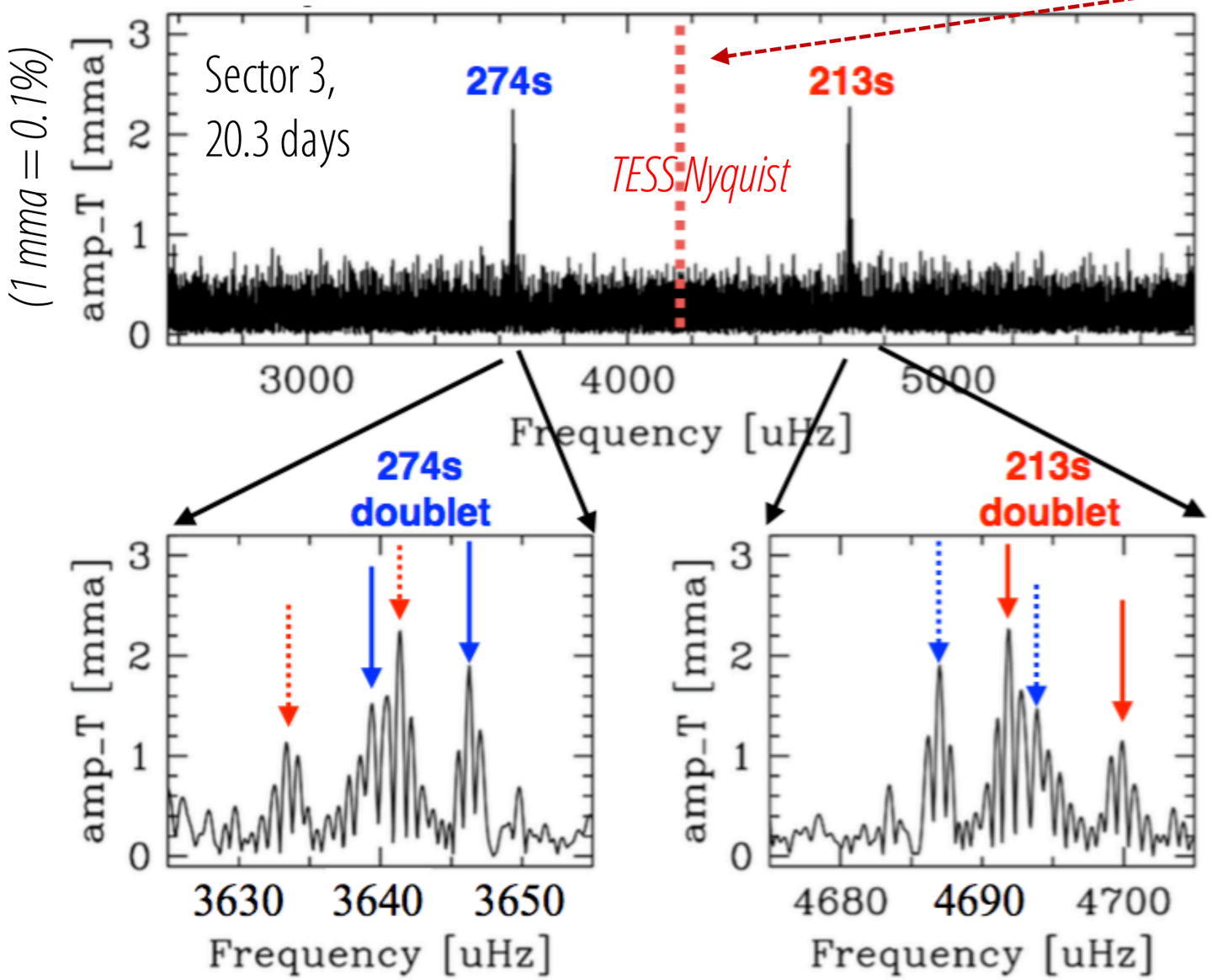
Mukadam et al. 2013

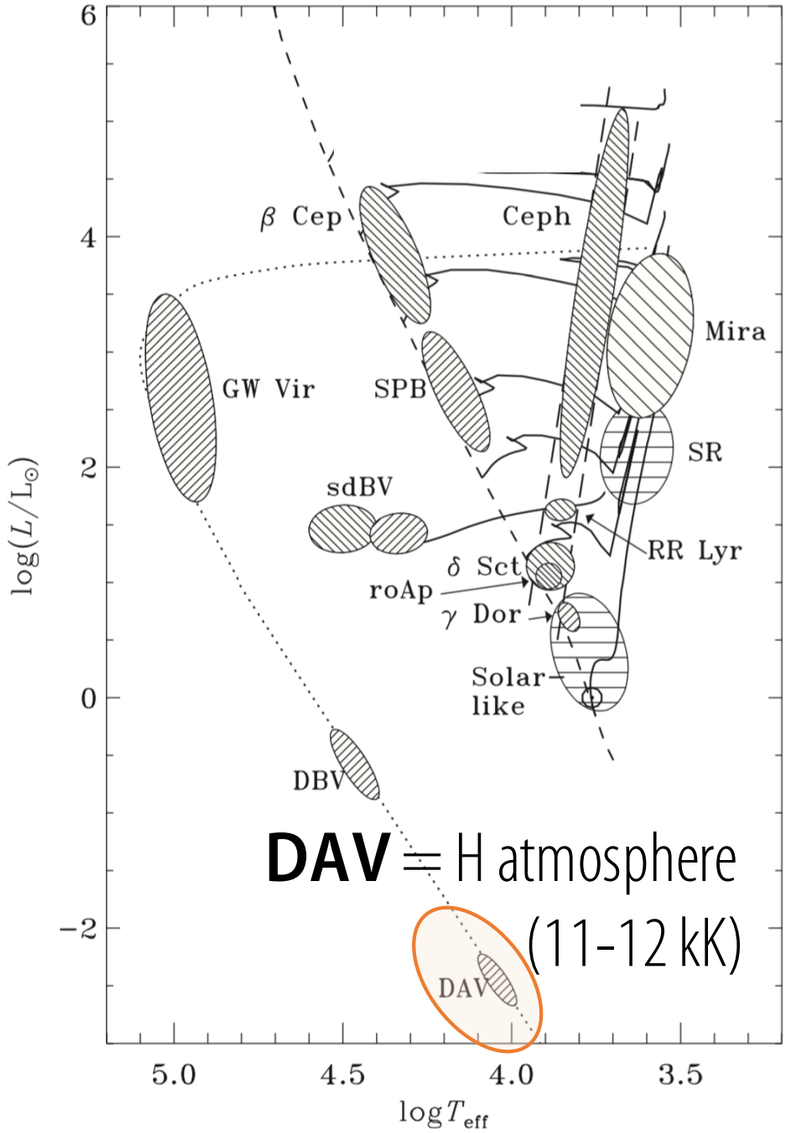


DAV = H atmosphere (11-12 kK)

R548 (aka ZZ Ceti): T=14.4 mag, 32.8 pc

20s cadence needed!

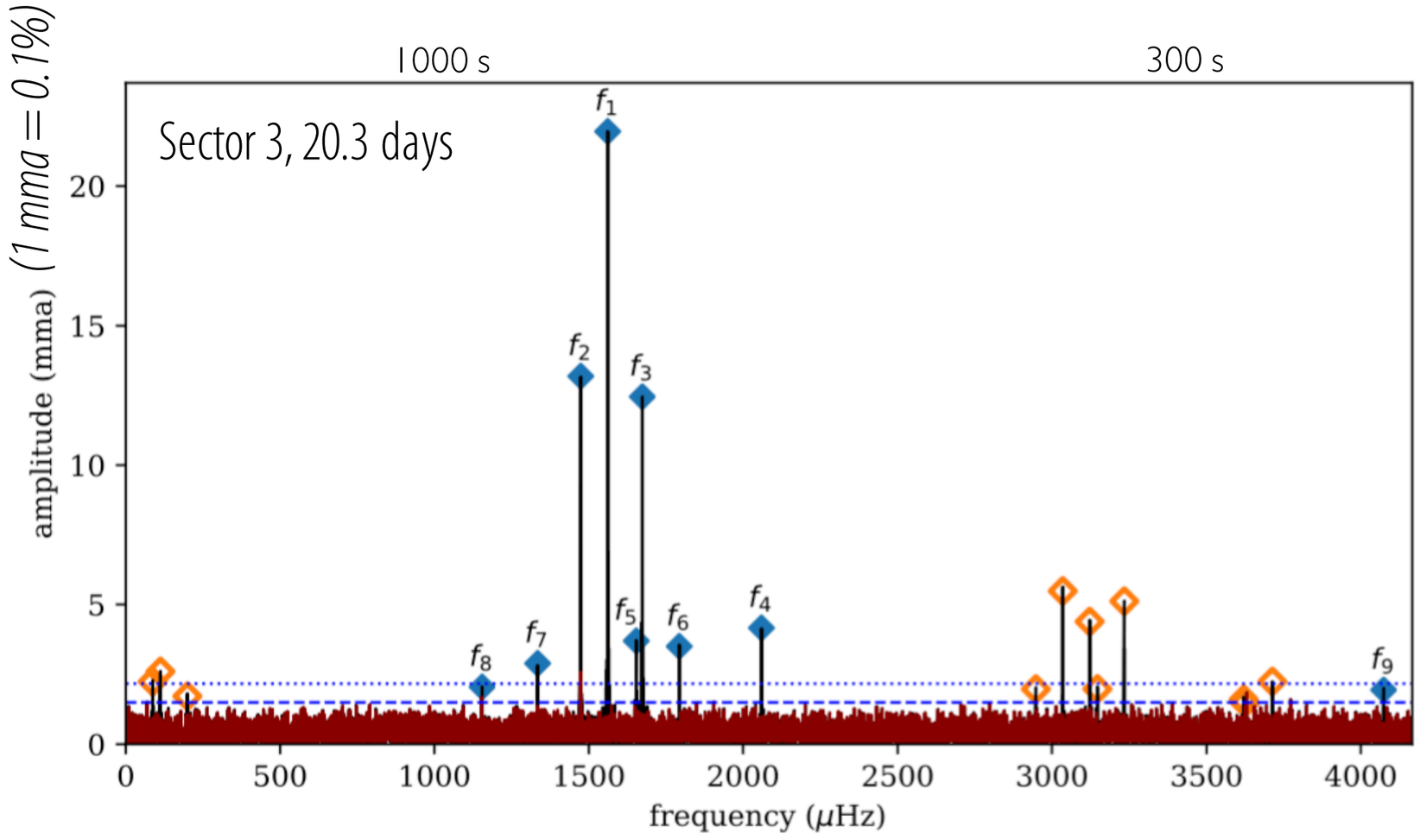


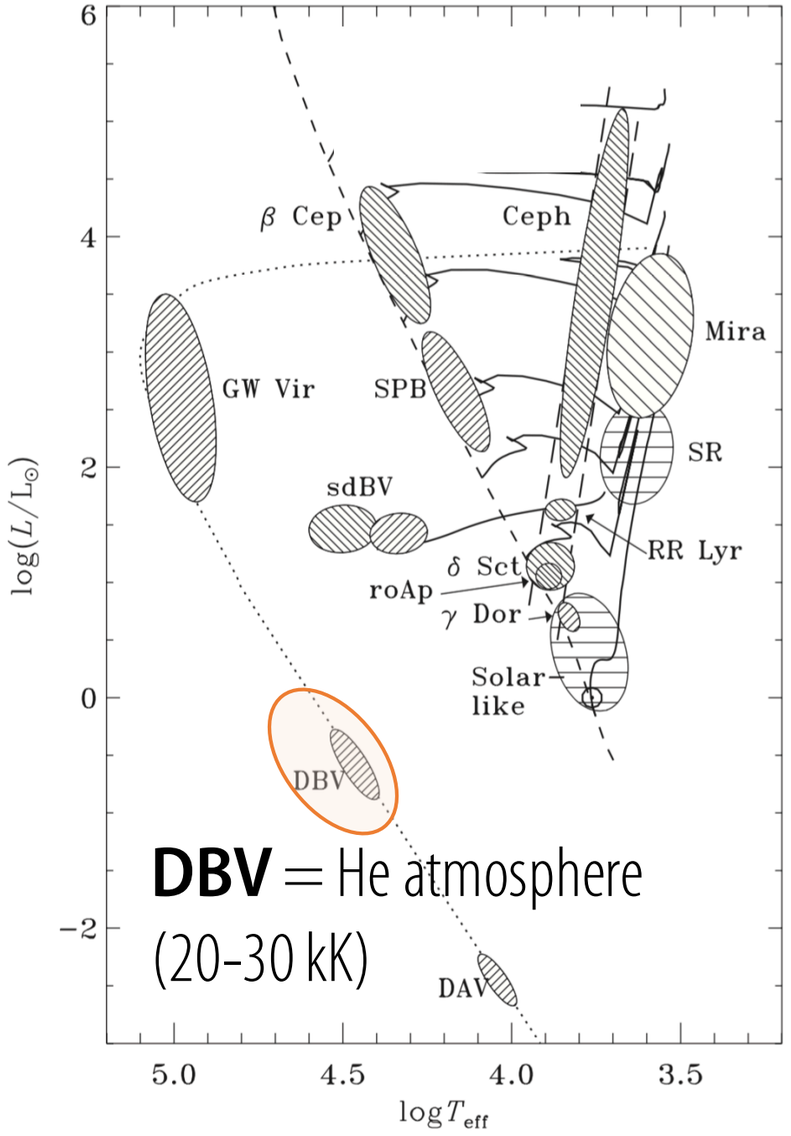


c/o Steve Kawaler
Cory Schrandt, ISU MS thesis 2019

7 TESS DAVs:
Zsófia Bognár et al., in prep.

WD 0158-160 (TIC 257459955): T=14.1 mag, 68.14 pc

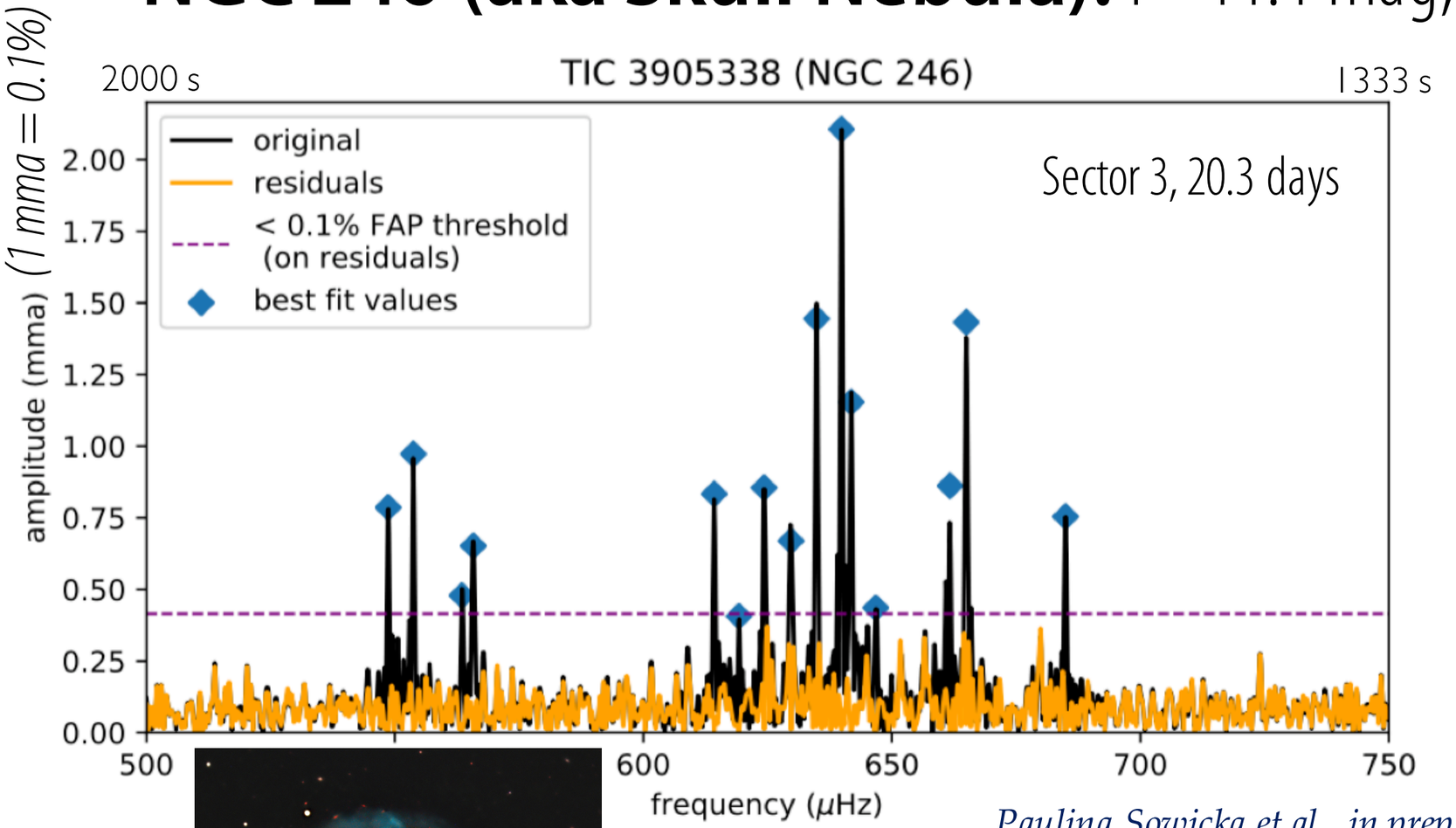




DBV = He atmosphere (20-30 kK)

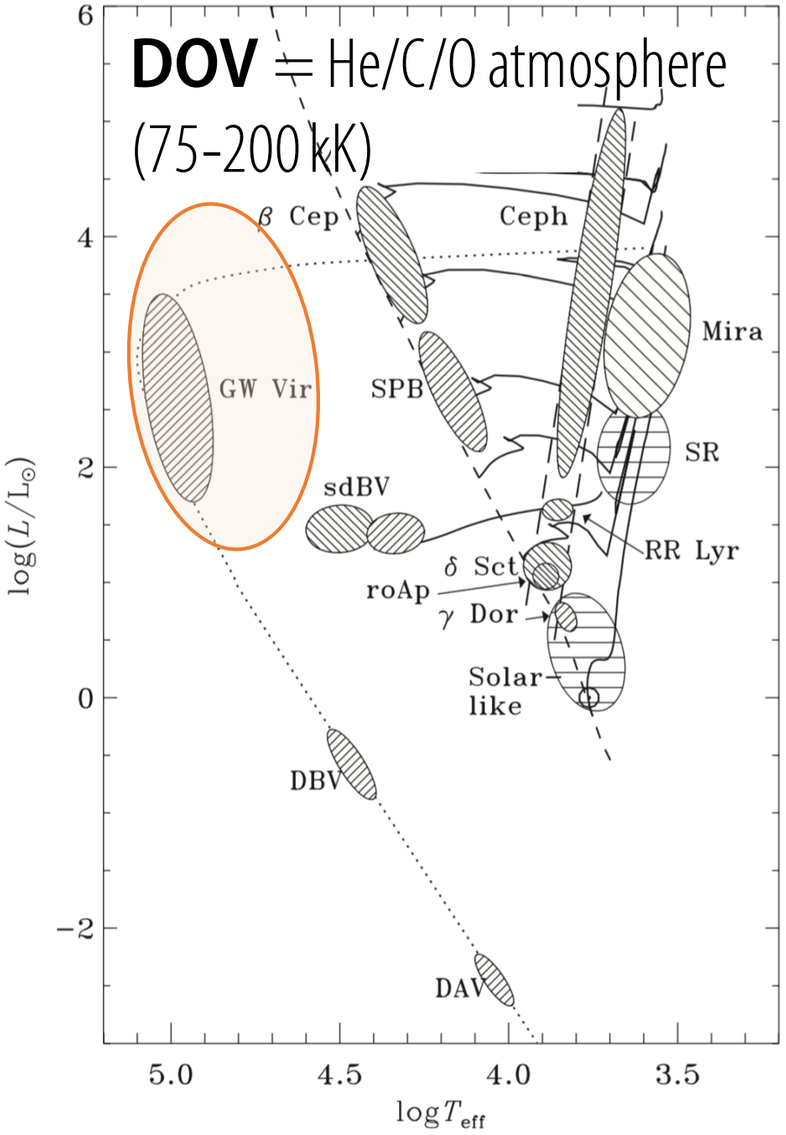
Keaton Bell et al. 2019, submitted

NGC 246 (aka Skull Nebula): T=11.1 mag, 512.3 pc

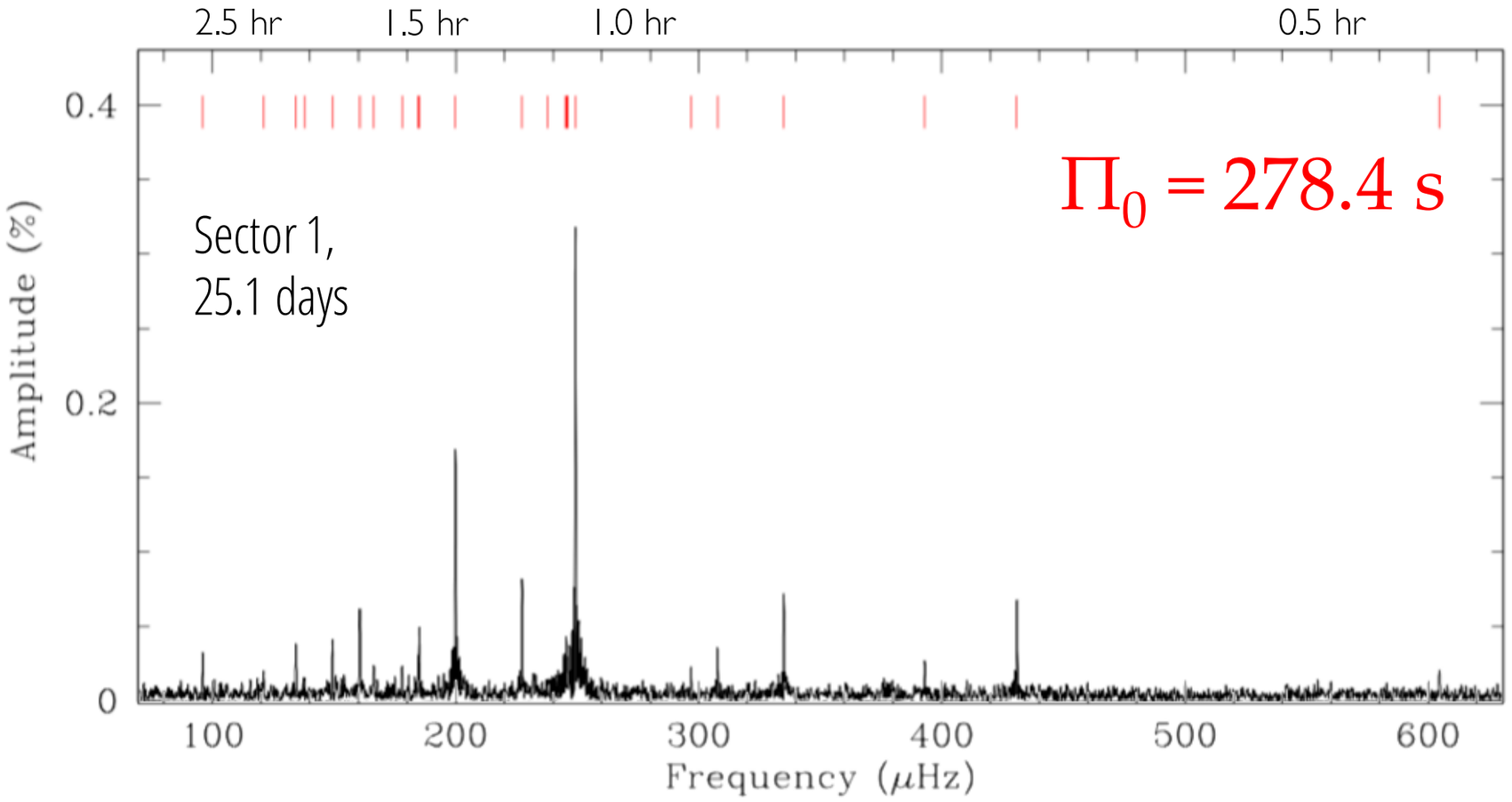


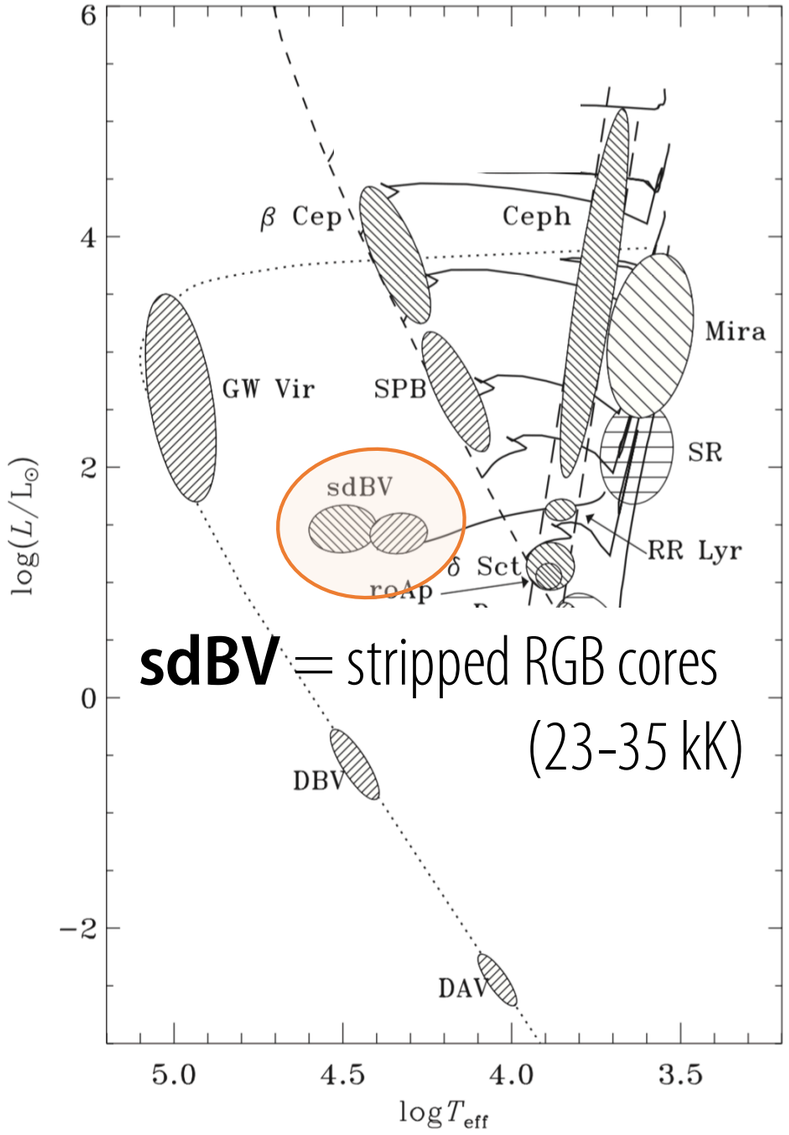
Paulina Sowicka et al., in prep.

Liverpool Telescope image by Göran Nilsson



EC 21494-7018 (aka TIC 278659026): T=11.7 mag, 203.7 pc

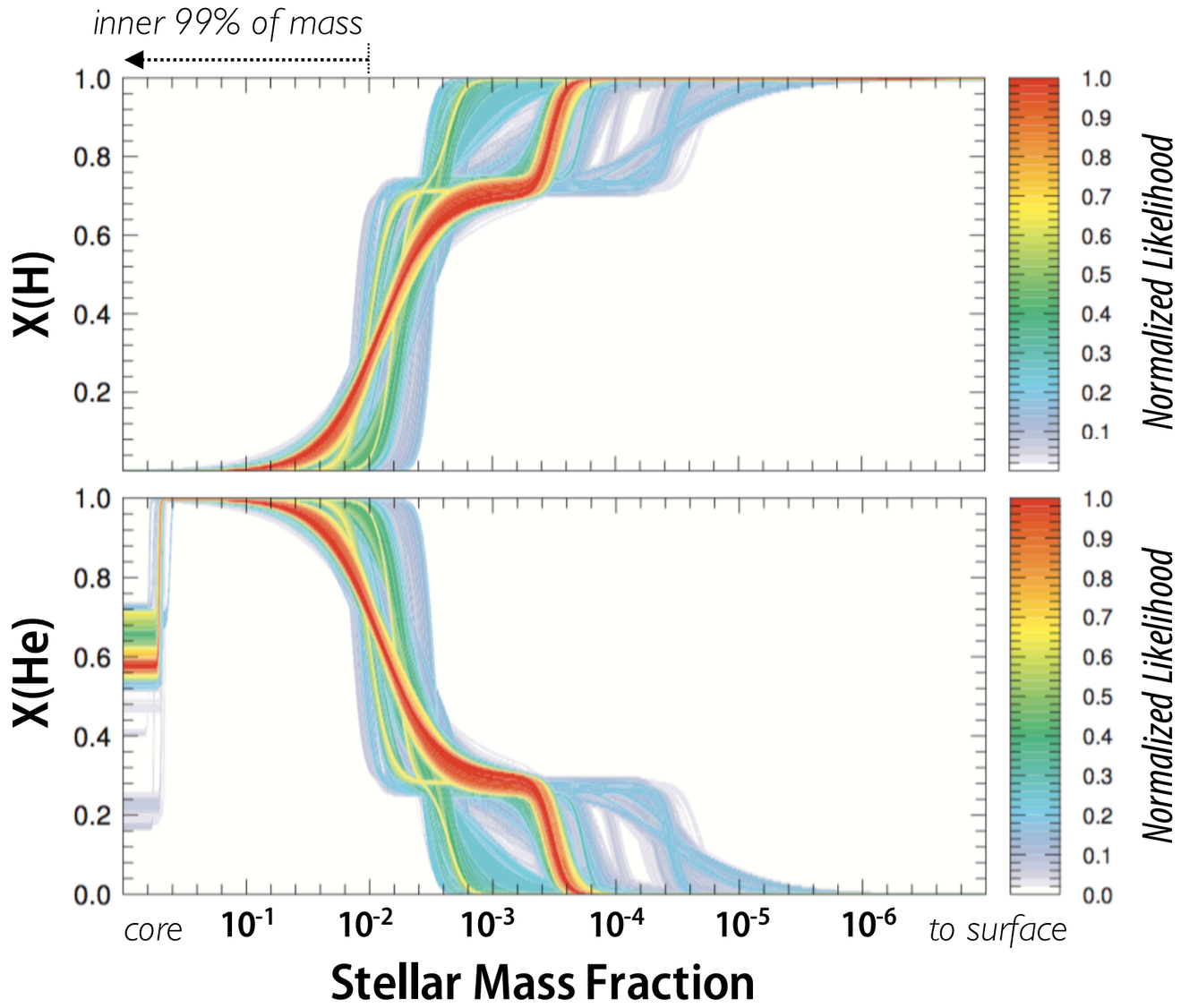


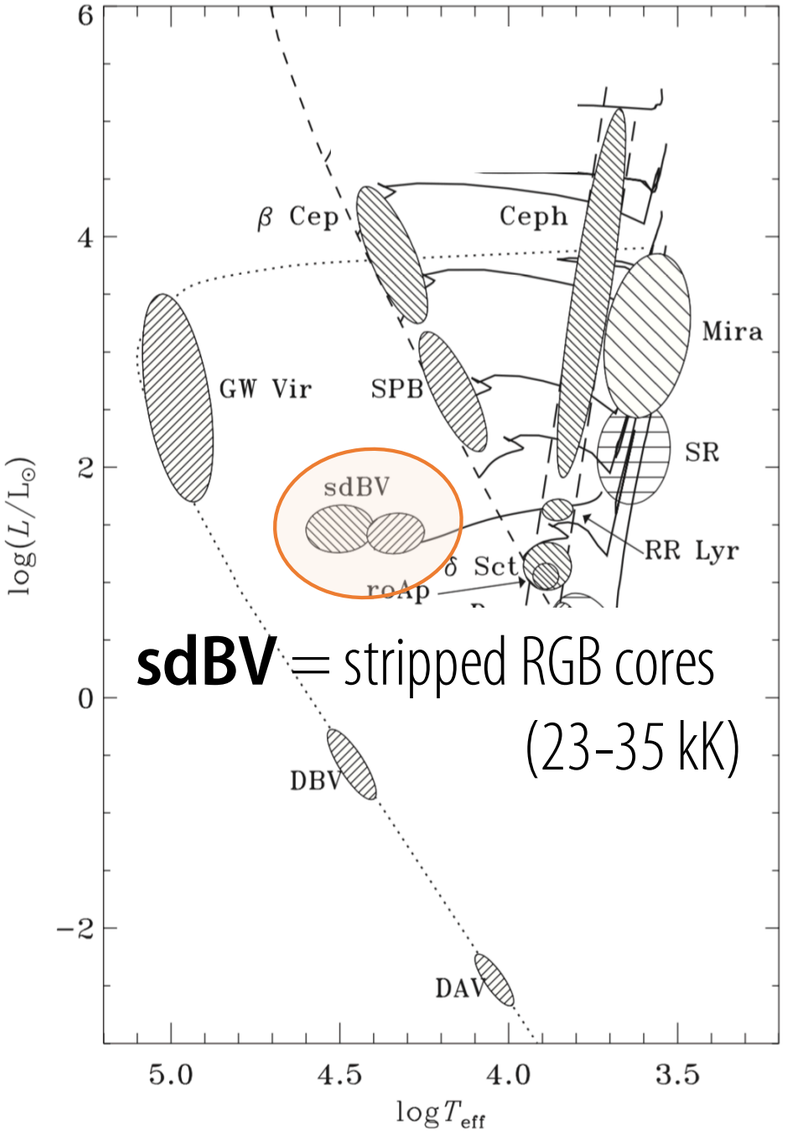


sdBV = stripped RGB cores (23-35 kK)

Stéphane Charpinet et al. 2019, in review

EC 21494-7018 (aka TIC 278659026): T=11.7 mag, 203.7 pc





sdBV = stripped RGB cores (23-35 kK)

Method described in Charpinet et al. 2008; Van Grootel et al. 2013; Giammichele et al. 2017

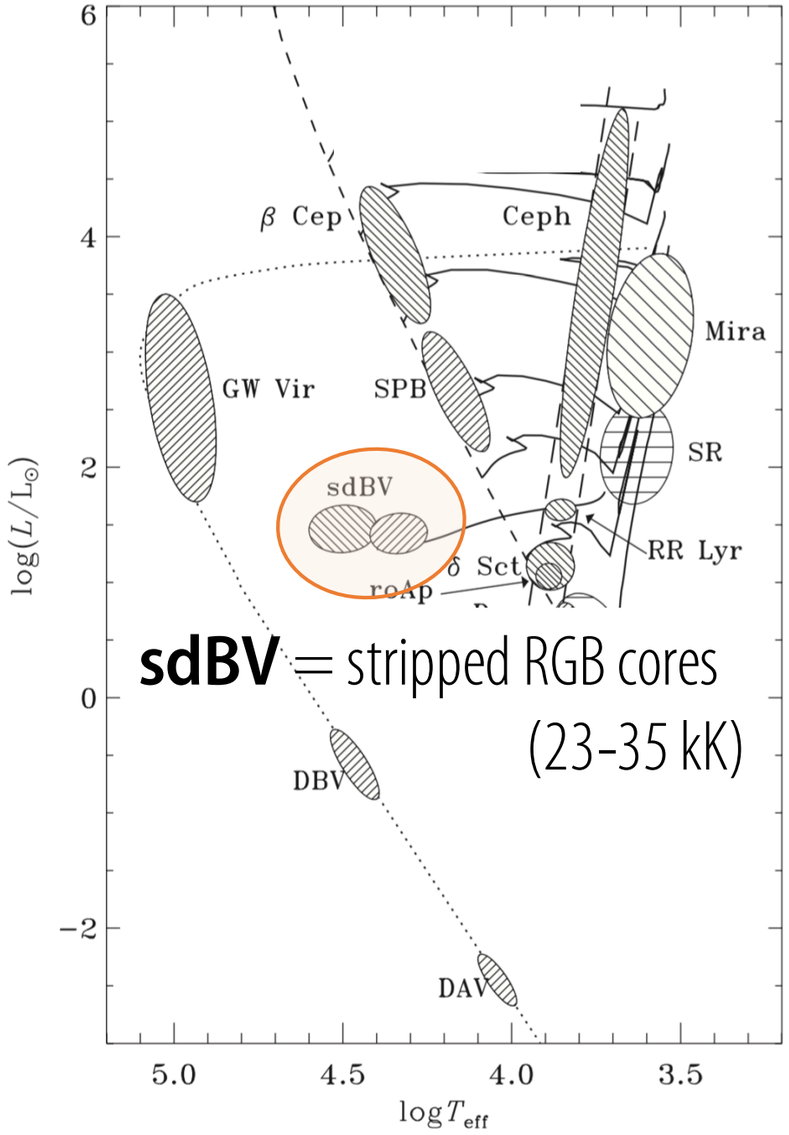
Stéphane Charpinet et al. 2019, in review

EC 21494-7018 (aka TIC 278659026): T=11.7 mag, 203.7 pc

(Unique) seismic solution constrains core:
$42.5^{+6.3}_{-2.7}$ % of He has been burned to C/O

$M_H = 0.0037 \pm 0.0010\ M_\odot$
$R_{sdB} = 0.1694 \pm 0.0081\ R_\odot$
$M_{sdB} = 0.391 \pm 0.009\ M_\odot$

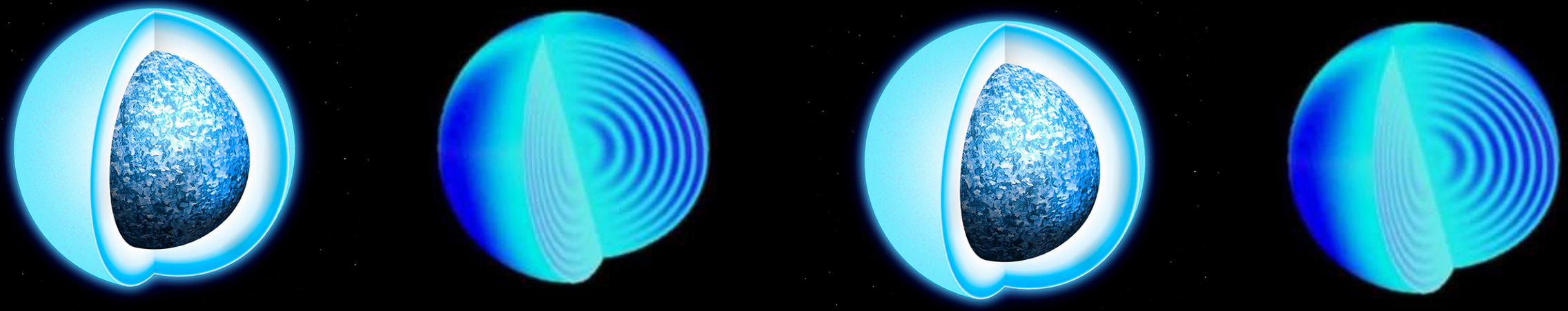
This is a stripped, He-burning core star that did not undergo a He flash! It must have come from a $>2\ M_\odot$ progenitor!



sdBV = stripped RGB cores (23-35 kK)

Stéphane Charpinet et al. 2019, in review

First light on pulsating compact objects with TESS



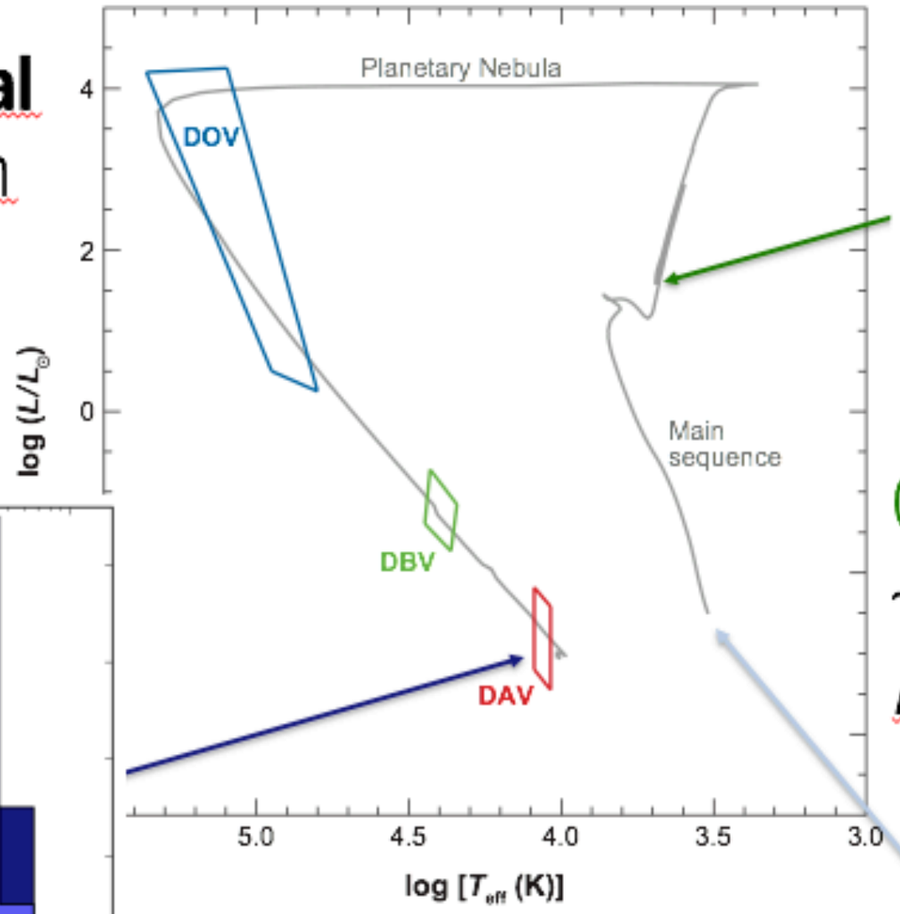
TESS is poised to reveal the internal structure of stellar remnants from asteroseismology

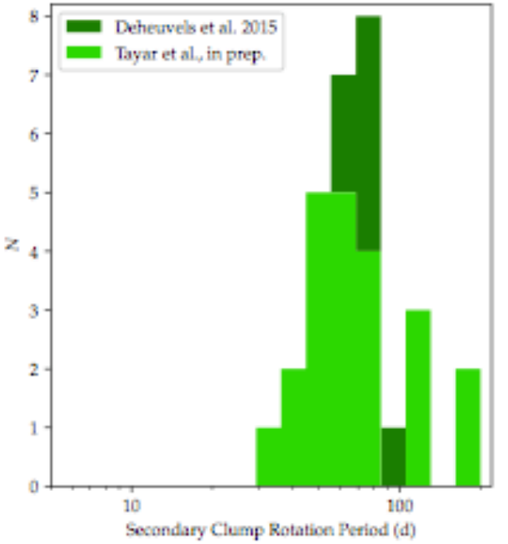
The hottest (>25kK) compact pulsators can be modeled uniquely within just one sector

Excited for the prospect of analyzing rapid pulsations with the future 20-second cadence!

JJ Hermes, Boston University | TESS SciCon

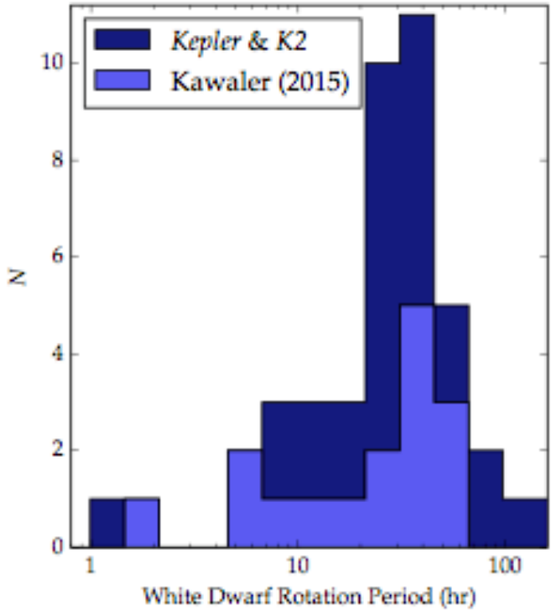
Kepler has mapped **internal** rotation evolution all the way from **MS** to **WD**





Core-He RGB: modes ~0.02-0.10 $R_\odot$

P_{rot}: 30-180 d

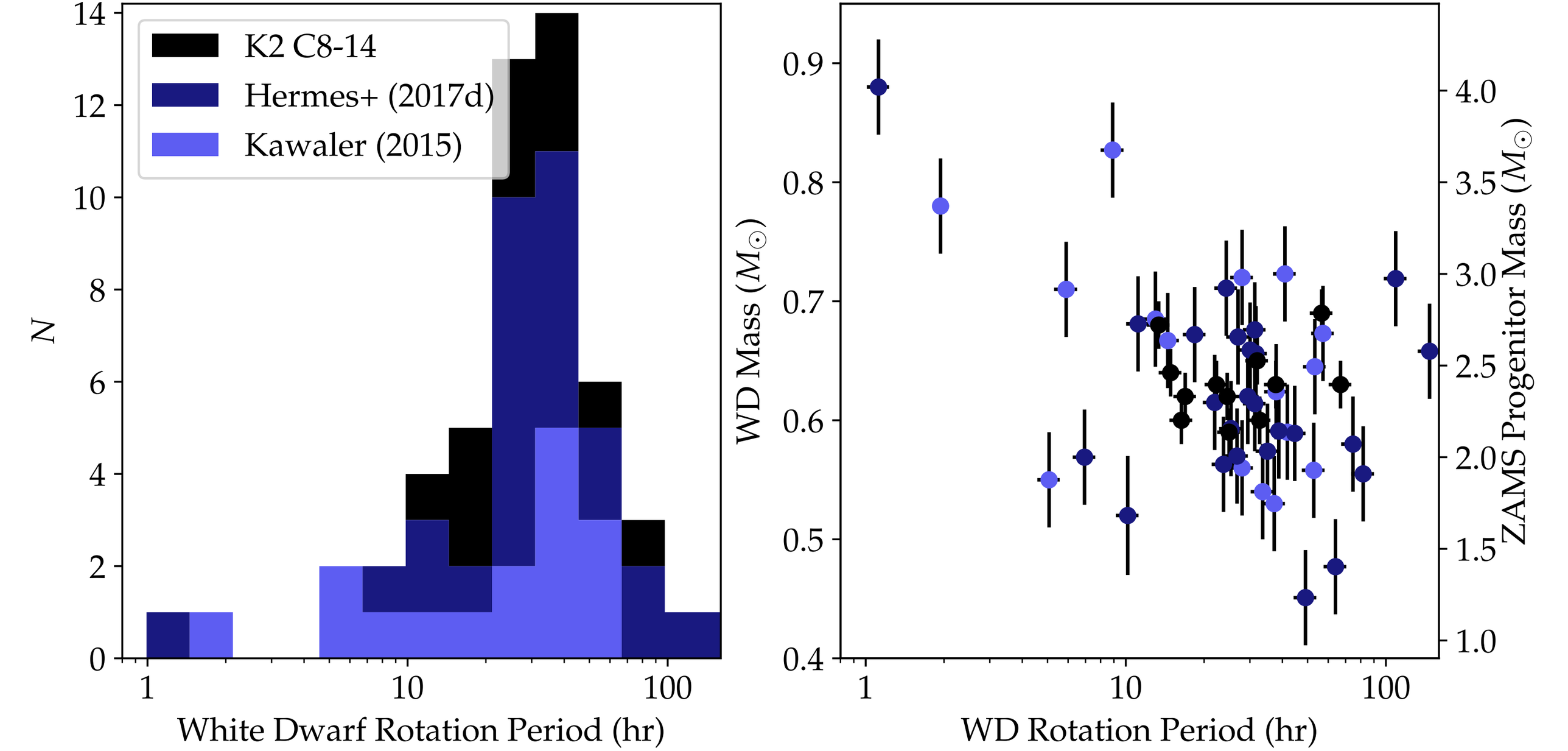


White dwarf: ~0.005-0.013 $R_\odot$

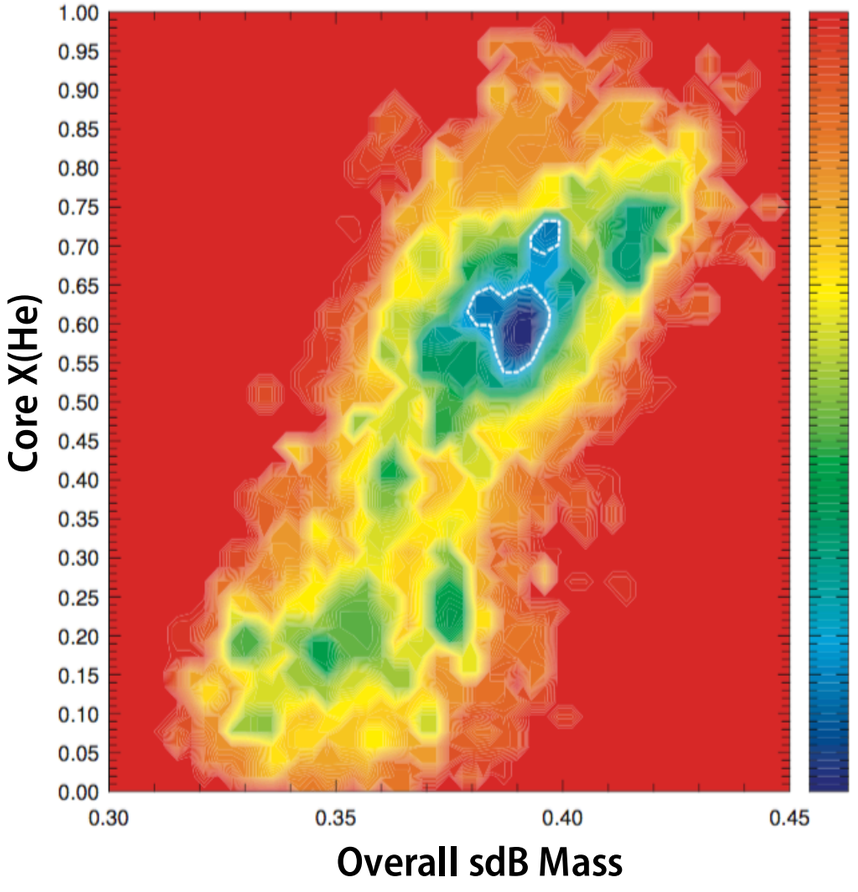
P_{rot}: 0.5-2.2 d

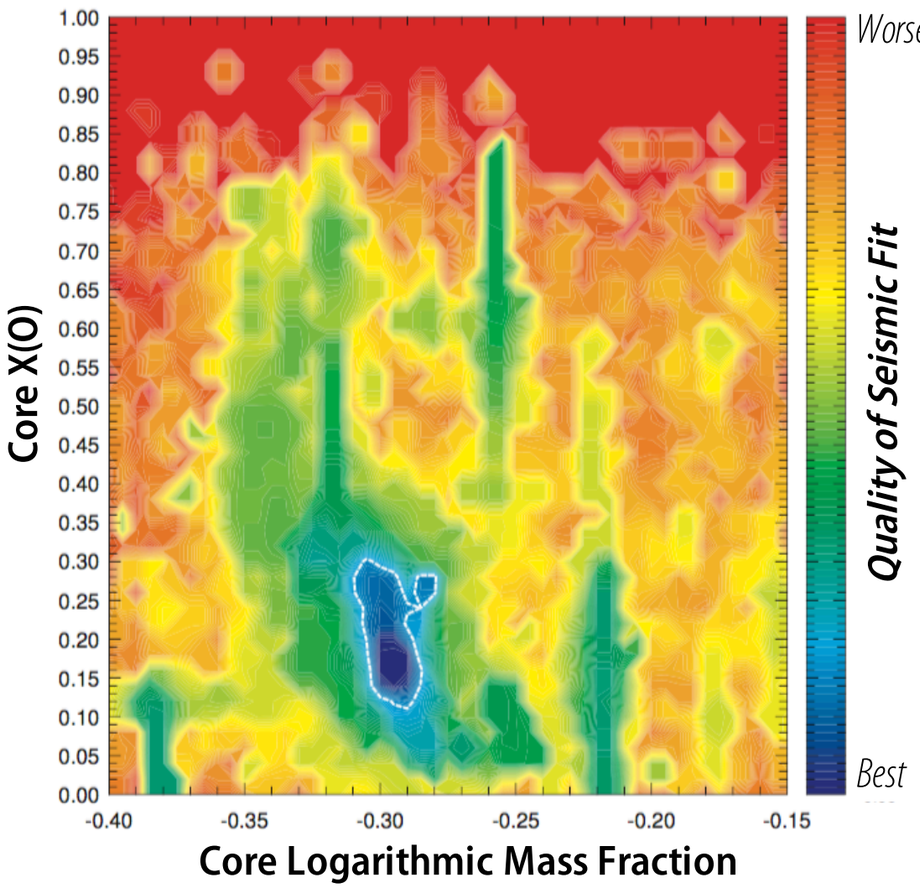
2.5 $M_\odot$ A star:

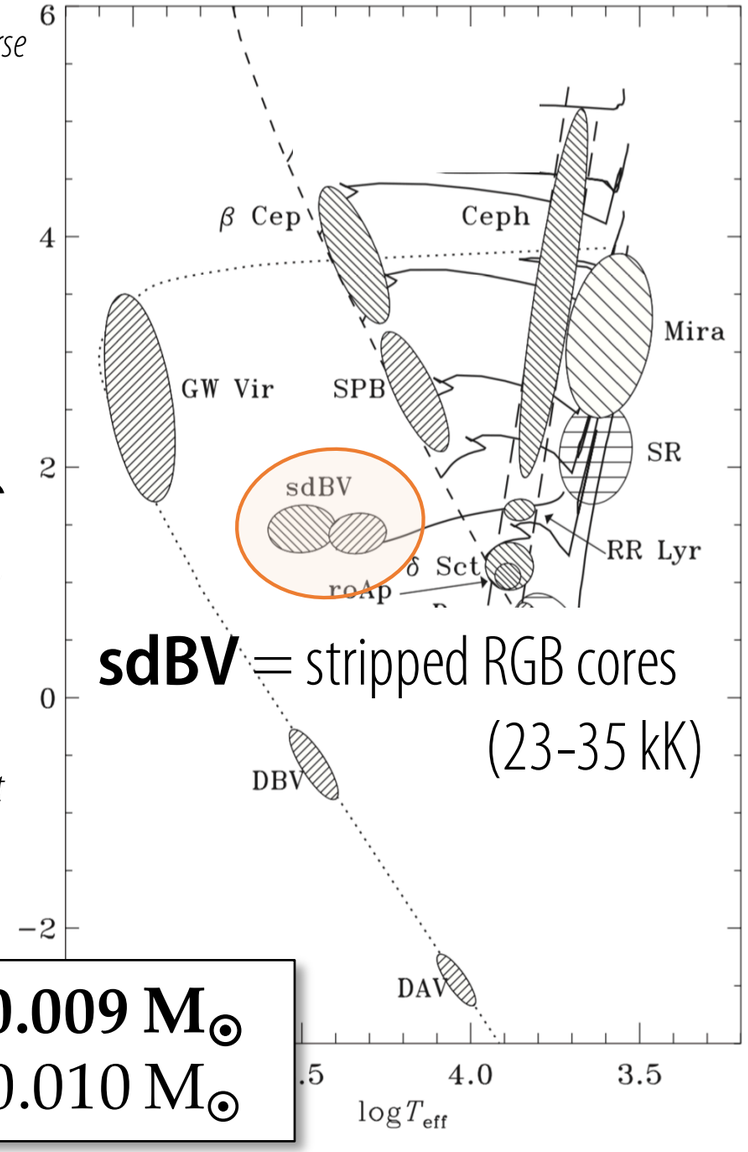
$P_{rot,ZAMS}$ ~ 10 hr


K2 C8-14
Hermes+ (2017d)
Kawaler (2015)
N
White Dwarf Rotation Period (hr)
WD Mass ($M_\odot$)
ZAMS Progenitor Mass ($M_\odot$)
WD Rotation Period (hr)

EC 21494-7018 (aka TIC 278659026): T=11.7 mag, 203.7 pc







sdBV = stripped RGB cores (23-35 kK)

(Unique) seismic solution constrains core:
Roughly 43% of He has been burned to C/O

$\mathbf{M_{sdB} = 0.391 \pm 0.009\ M_\odot}$
$M_{core} = 0.198 \pm 0.010\ M_\odot$

Stéphane Charpinet et al. 2019, in review