Project introduction:
Pulsating white dwarfs in binary systems

Dr. James Munday

Backstory: The Island Life

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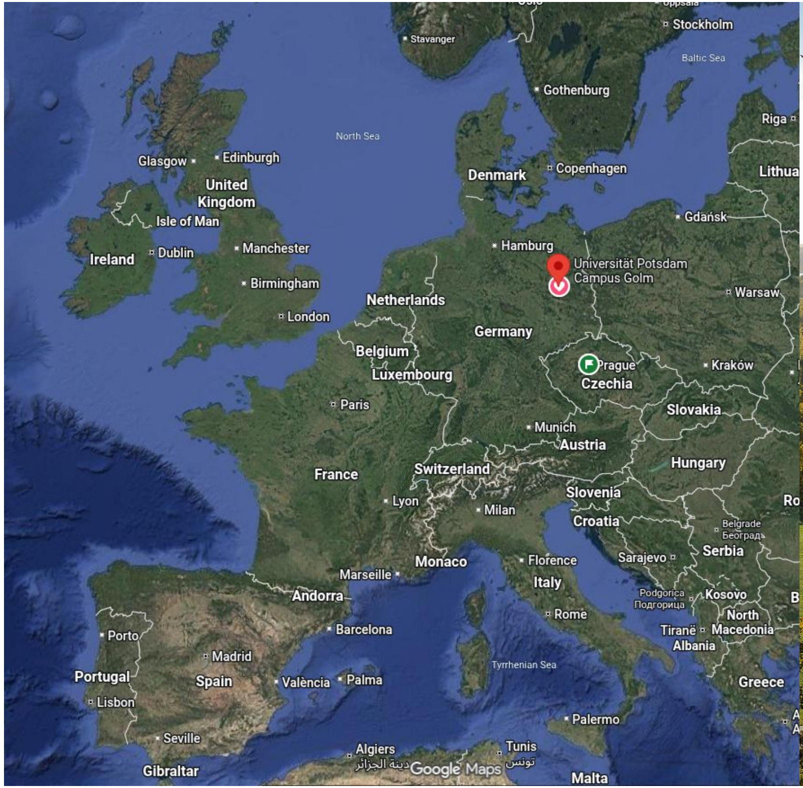
Backstory: (Almost an Island)



James Munday: Career path

Undergraduate (2017–2021) – University of Surrey (UK)

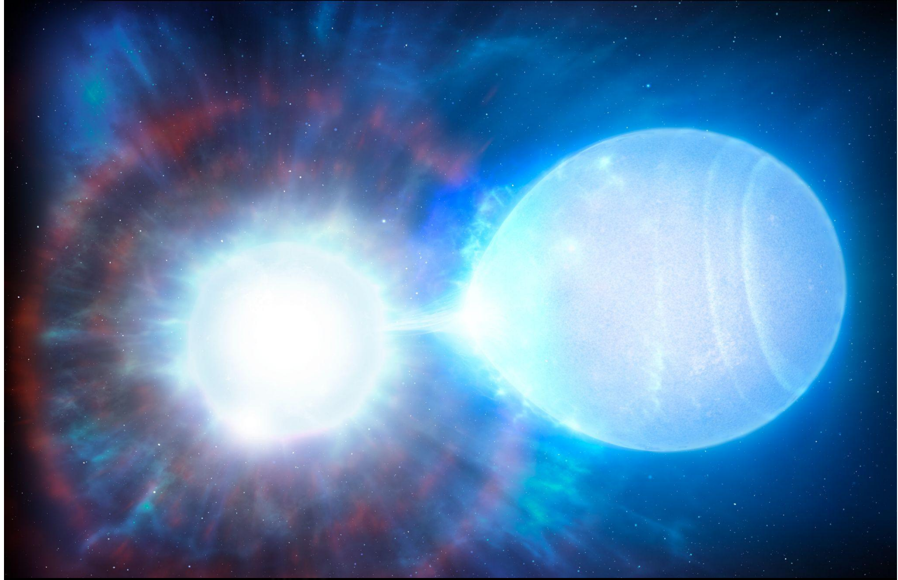
Master's research year (2020–2021) – Instituto de Astrofísica de Canarias (IAC, Spain)
→ Researching binary central stars of planetary nebulae

PhD (2021–2025) – University of Warwick (UK)
→ Research focused around white dwarf binaries
→ Alongside PhD, Isaac Newton Group studentship (Spain)

Postdoc #1 – University of Warwick (UK)→machine learning
Postdoc #2 – Universität Potsdam (Germany)→binary stars

Main research topics

- Evolved binary stars (double white dwarfs, AM CVn, gravitational wave sources)
- Most things related to single white dwarfs
- Type Ia supernovae
- Observations/instrumentation
- Large spectroscopic surveys
- Machine learning
- Transitioning into population modelling



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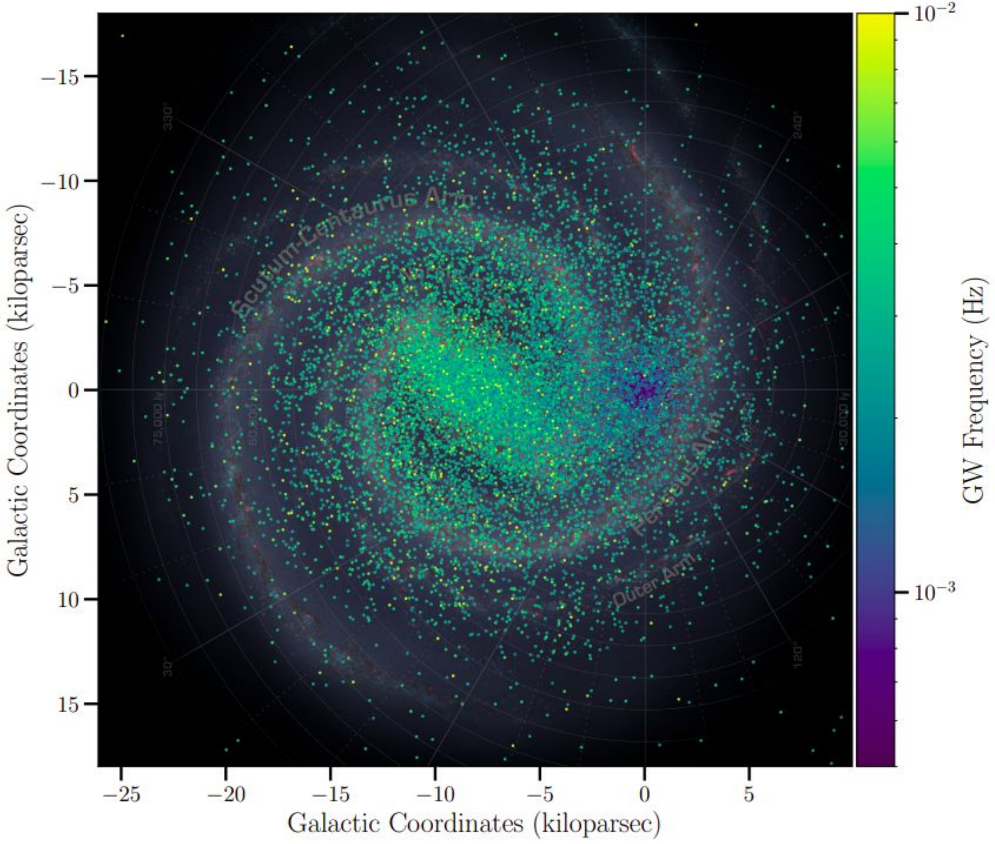

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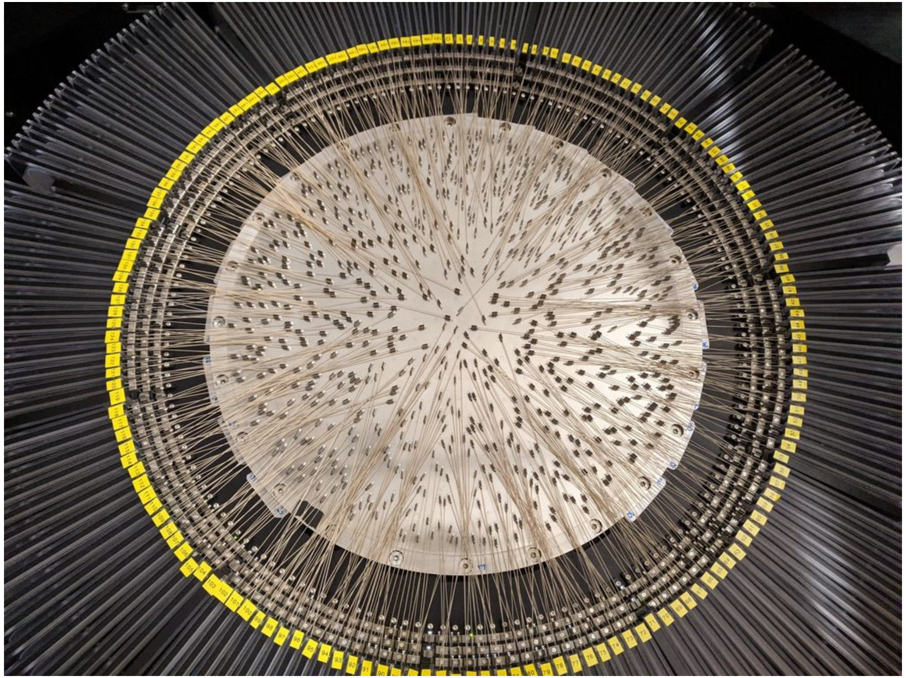
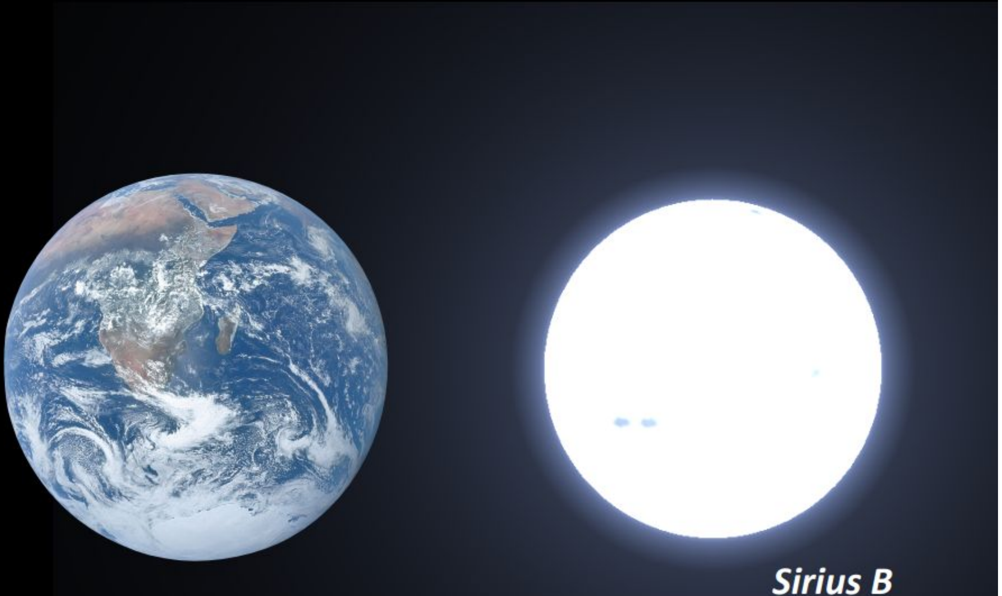


Project 2: Pulsating binary white dwarfs!

Project 2: pulsating binary white dwarfs?



Earth

$0.000003\,M_\odot$

$5.5\,\mathrm{g\,cm^{-3}}$

Apollo 17 „blue marble“

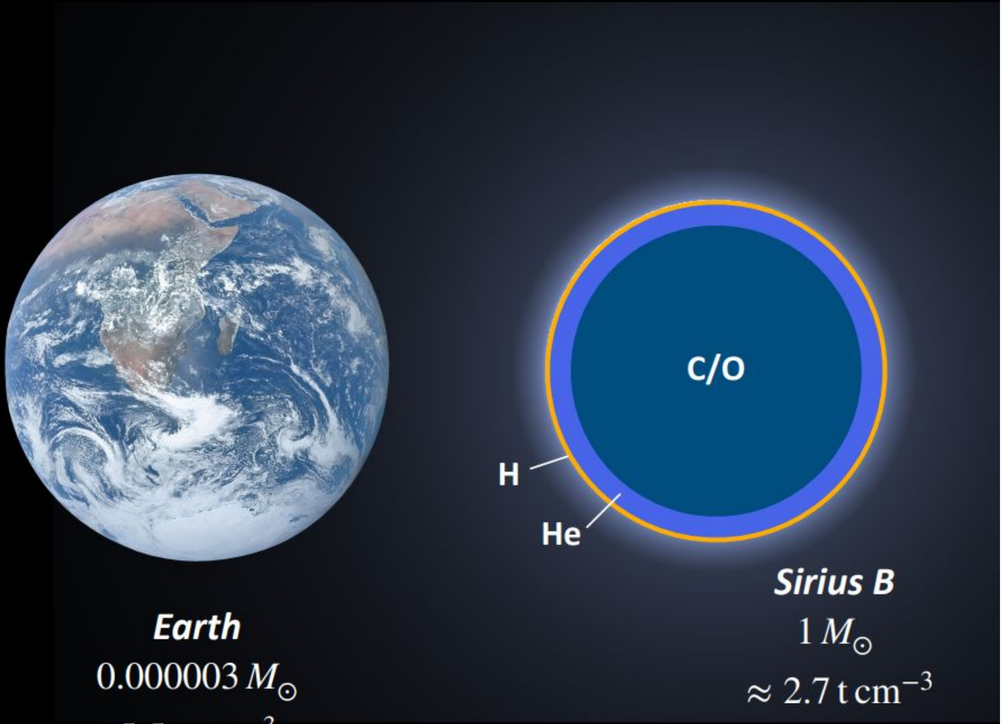
Sirius B

$1\,M_\odot$

$\approx 2.7\,\mathrm{t\,cm^{-3}}$

Celestia / Chris Laurel

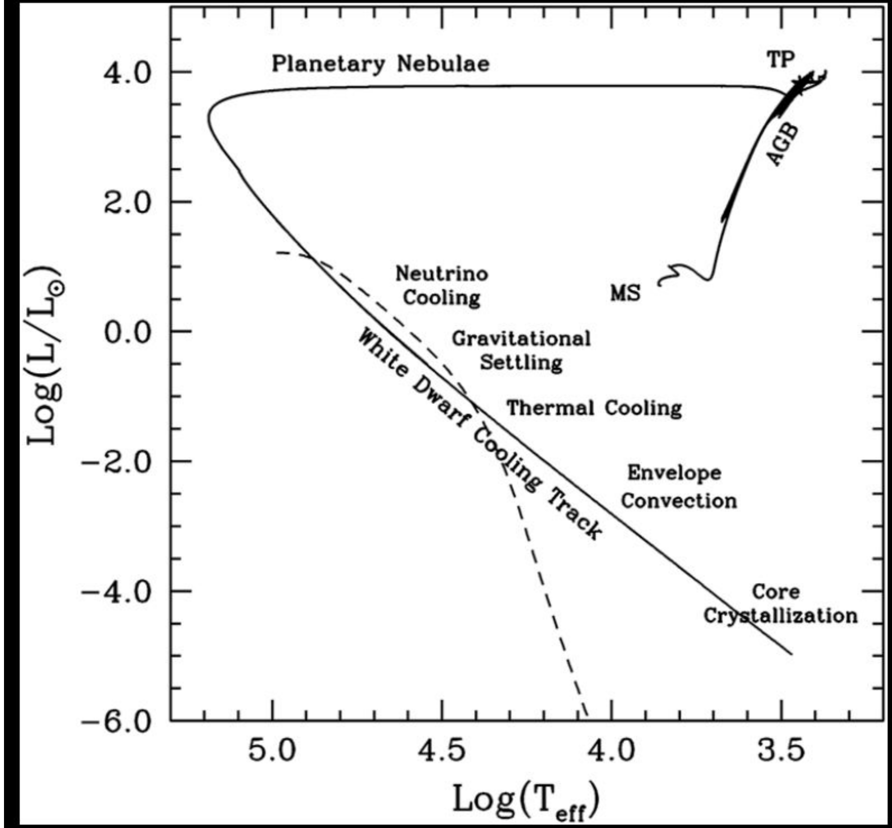
Project 2: pulsating binary white dwarfs?

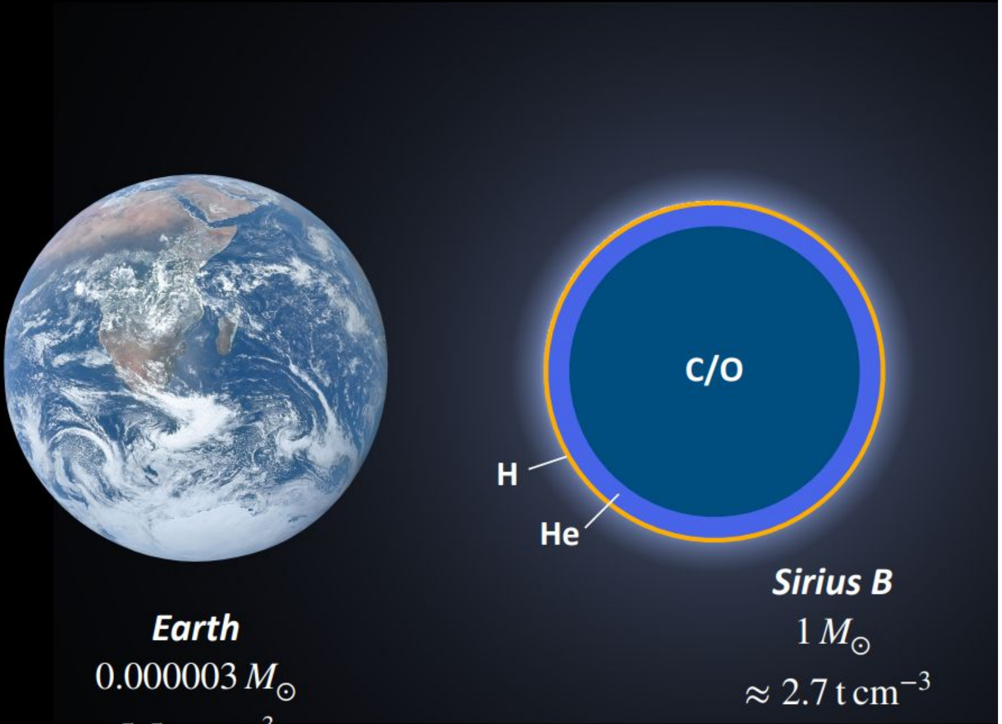


Apollo 17 „blue marble“

Celestia / Chris Laurel

Project 2: pulsating binary white dwarfs?





$5.5\,\mathrm{g\,cm^{-3}}$

Apollo 17 „blue marble“

Celestia / Chris Laurel

White dwarfs can pulsate

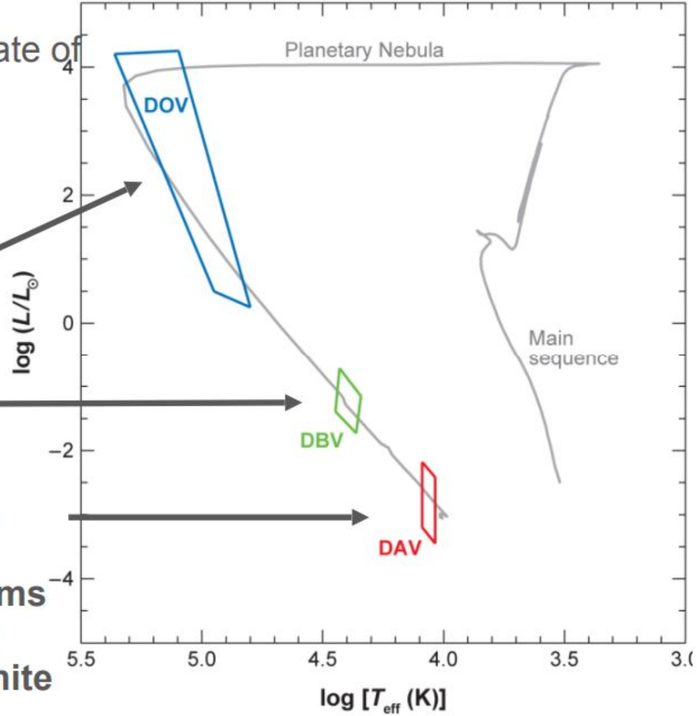
Changes in the state of ionisation zones

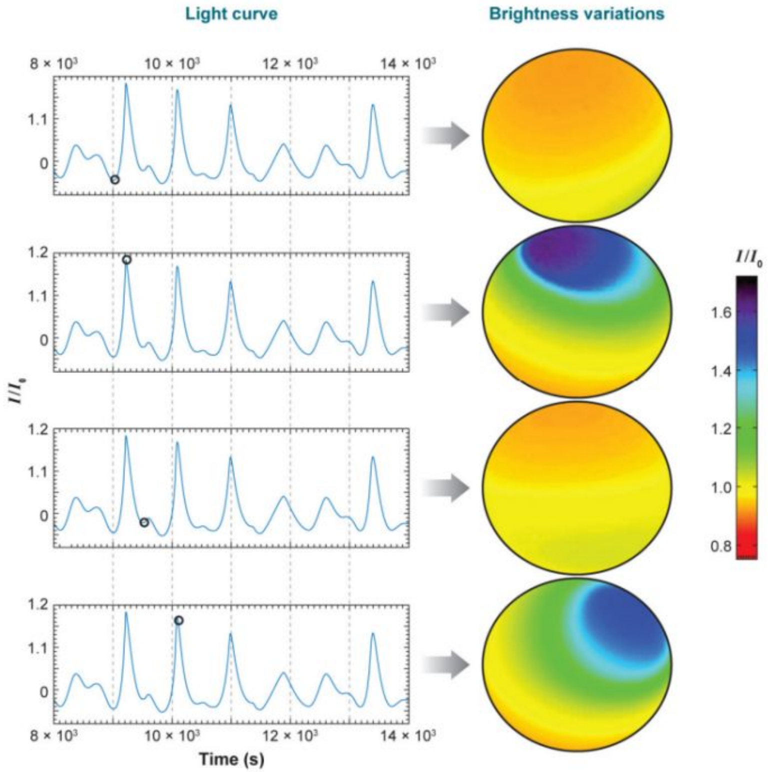
C/O transitions

He III→He II @ ~30,000K

H II→H I @ ~10,000-13,000K

Fully ionised atoms become partially ionised as the white dwarf cools

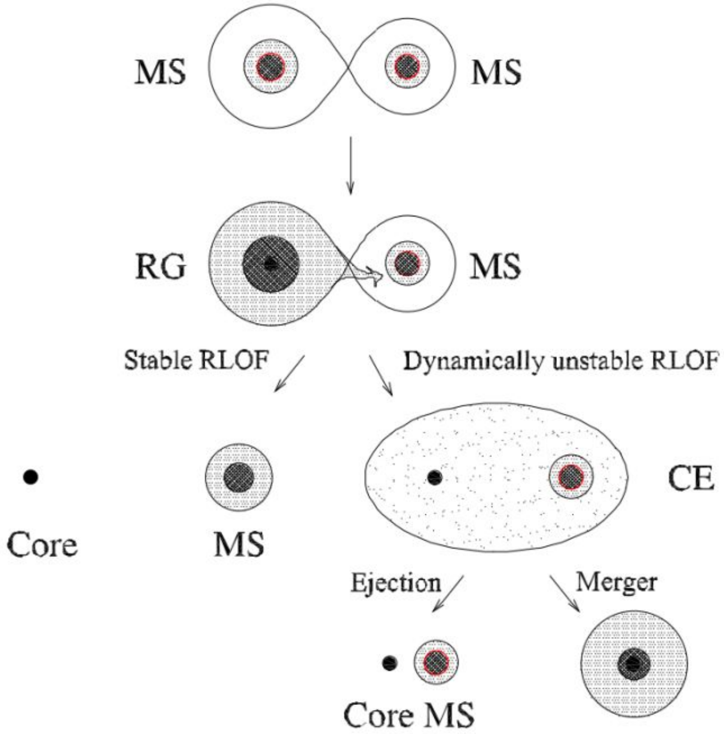




Winget+2008

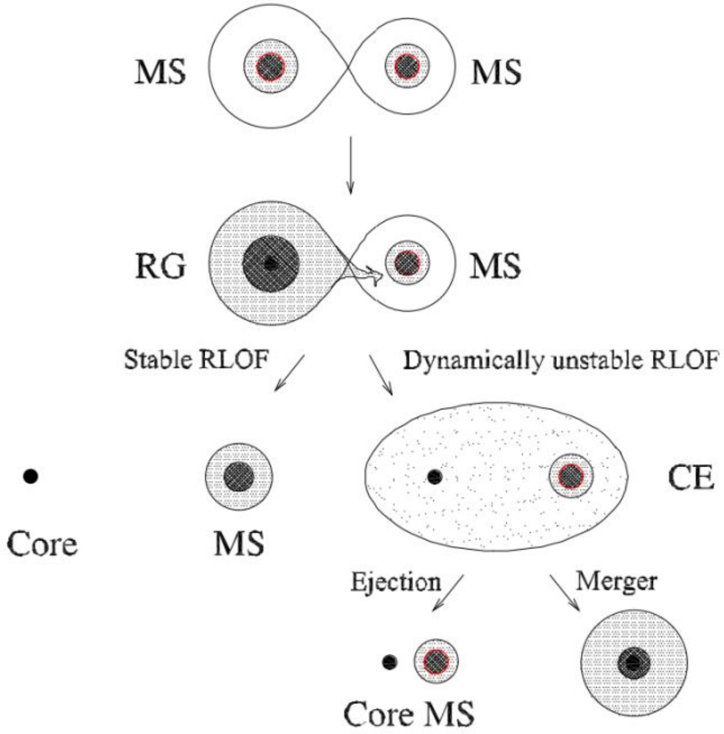
Goes from transparent outer layer to opaque, capturing photons. Initiates strong gravity-mode oscillations → pulsations in light curve

White dwarfs exist in compact binaries too



Han+2020

White dwarfs exist in compact binaries too



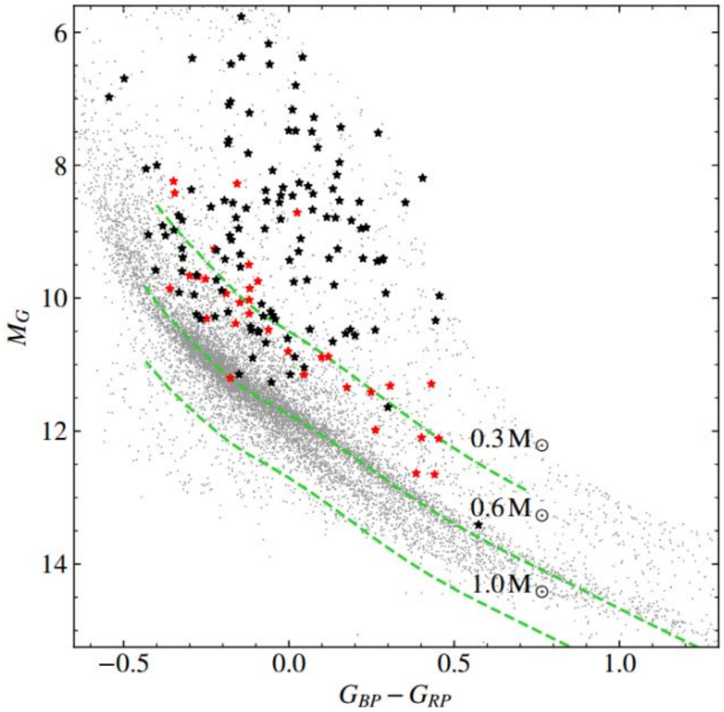
Han+2020

Mass transfer phases accelerate the stars' evolution compared to single star evolutionary tracks

The non-merging cases exist as compact binaries

When stars are stripped to their hot, dense cores, they eventually become white dwarfs and follow the white dwarf cooling sequence

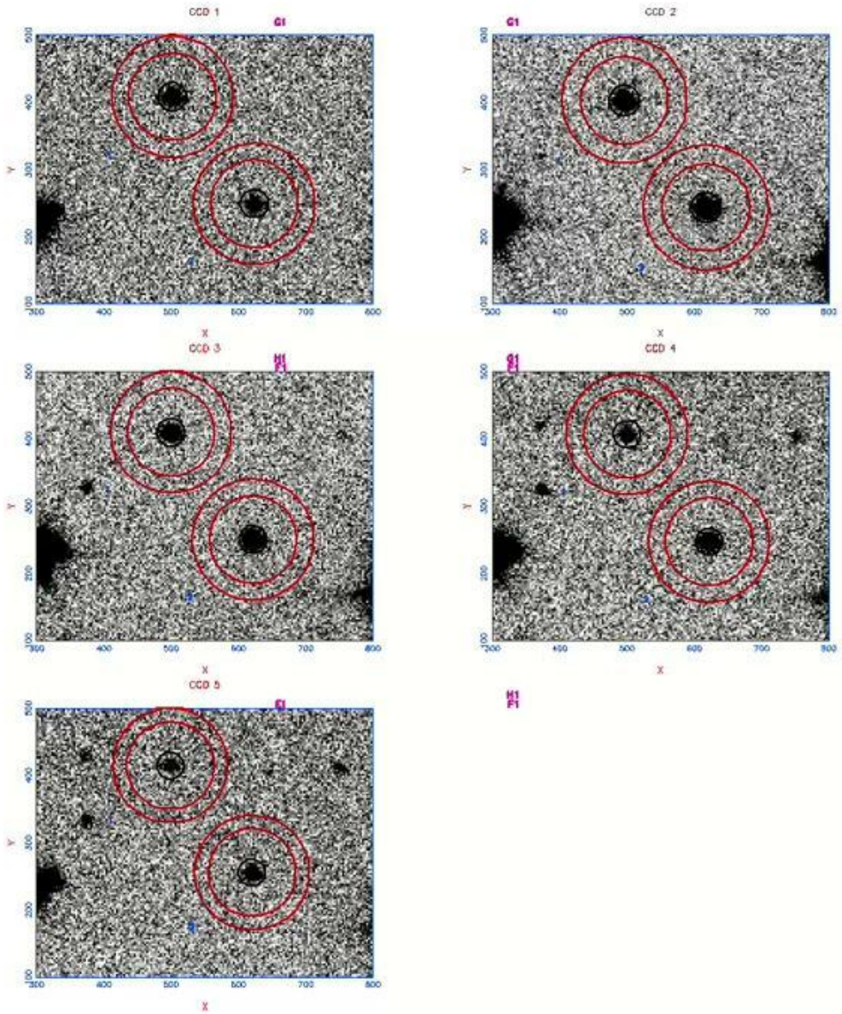
Compact double white dwarfs binaries are born

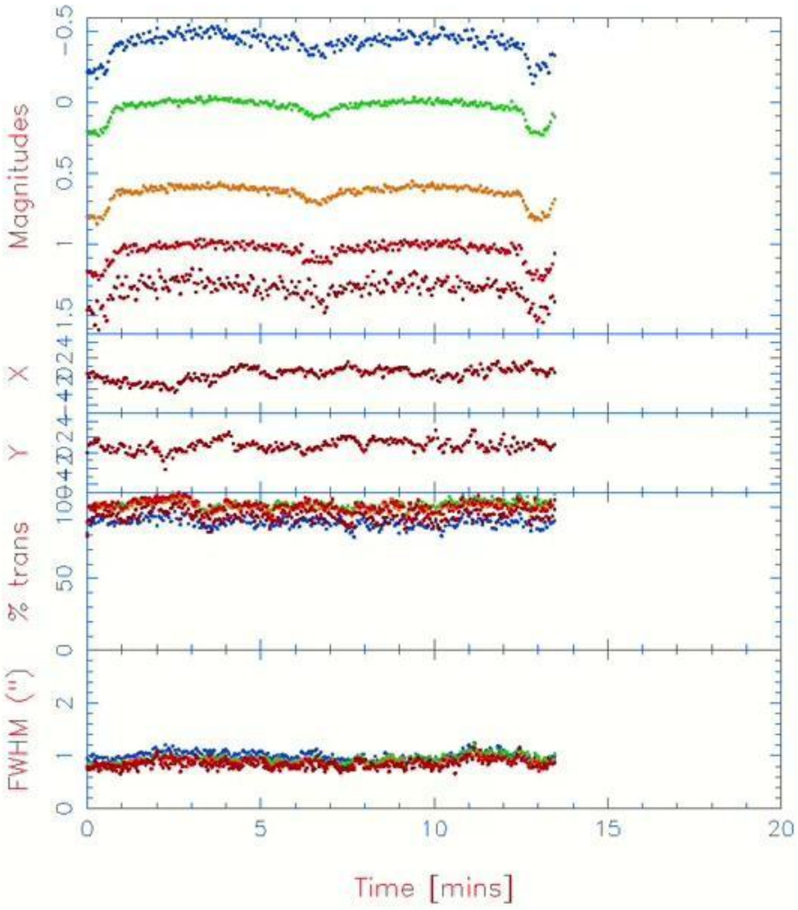


All ~300 confirmed, compact double white dwarf binaries to date

Generally fall above the white dwarf cooling sequence (green lines, traversing from top left to bottom right)

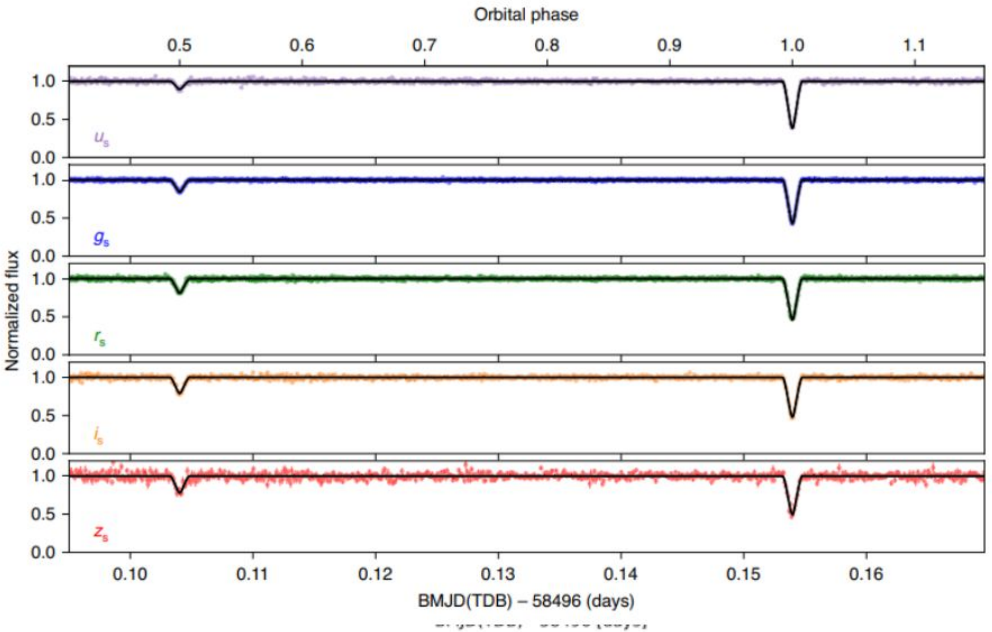
The perfect case to get **precise orbital parameters** is for the star to **1)** be eclipsing **2)** show a unique spectral signature of each star (double lined, SB2)

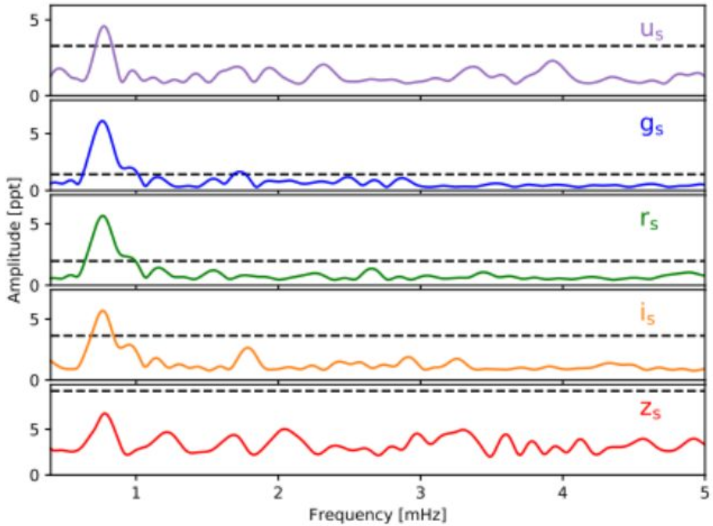

CCD 1
CCD 2
CCD 3
CCD 4
CCD 5


Magnitudes
X
Y
% trans
FWHM (")
Time [mins]

A pulsating white dwarf in an eclipsing binary

Steven G. Parsons[1], Alexander J. Brown[1], Stuart P. Littlefair[1], Vikram S. Dhillon[1,2], Thomas R. Marsh[3], J. J. Hermes[4], Alina G. Istrate[5], Elmé Breedt[6], Martin J. Dyer[1], Matthew J. Green[3] and David I. Sahman[1]





Uncovering the chemical structure of the pulsating low-mass white dwarf SDSS J115219.99+024814.4

A. D. Romero[1]⋆, G. R. Lauffer[1], A. G. Istrate[2] and S. G. Parsons[3]
[1]*Physics Institute, Universidade Federal do Rio Grande do Sul, Av. Bento Goncalves 9500, Porto Alegre 91501-970, RS, Brazil*
[2]*Department of Astrophysics, Radboud University Nijmegen, P.O. Box 9010, NL-6500 GL Nijmegen, the Netherlands*
[3] *Department of Physics and Astronomy, University of Sheffield, Sheffield, S3 7RH, UK*

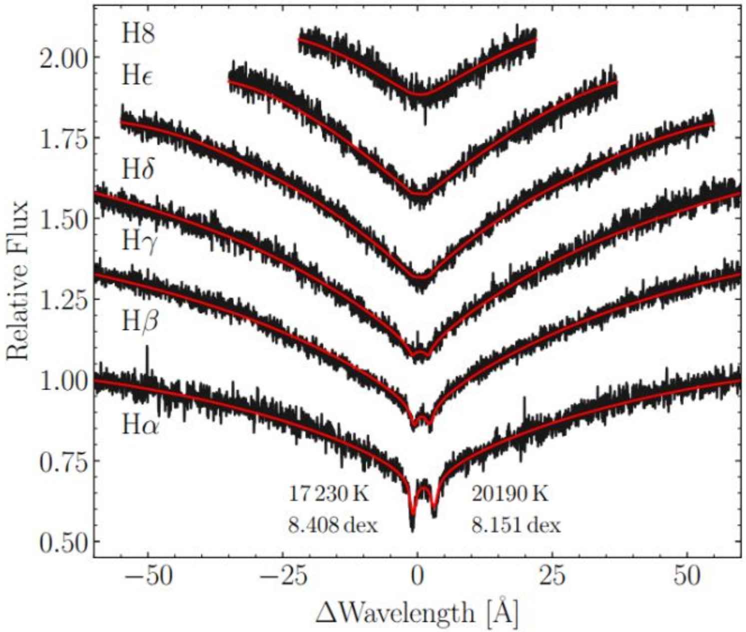
Accepted XXX. Received YYY; in original form ZZZ

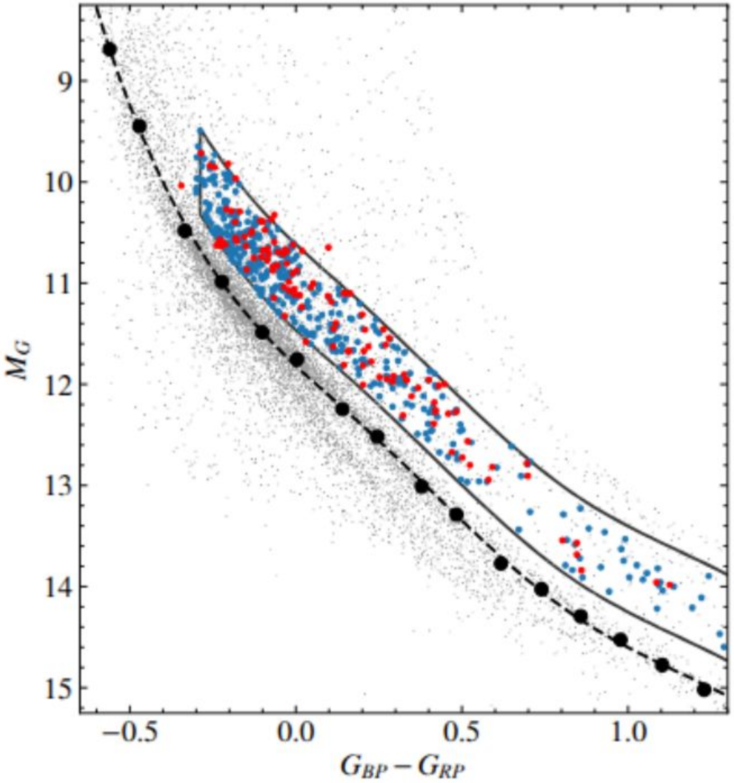
ABSTRACT
Pulsating low-mass white dwarf stars are white dwarfs with stellar masses between 0.30 $M_\odot$ and 0.45 $M_\odot$ that show photometric variability due to gravity-mode pulsations. Within this mass range, they can harbour both a helium- and hybrid-core, depending if the progenitor experienced helium-core burning during the pre-white dwarf evolution. SDSS J115219.99+024814.4 is an eclipsing binary system where both components are low-mass white dwarfs, with stellar masses of 0.362±0.014 $M_\odot$ and 0.325±0.013 $M_\odot$. In particular, the less massive component is a pulsating star, showing at least three pulsation periods of ~1314 s, ~1069 s and ~582.9 s. This opens the way to use asteroseismology as a tool to uncover its inner chemical structure, in combination with the information obtained using the light-curve modelling of the eclipses. To this end, using binary evolutionary models leading to helium- and hybrid-core white dwarfs, we compute adiabatic pulsations for $\ell = 1$ and $\ell = 2$ gravity modes with `Gyre`. We found that the pulsating component of the SDSS J115219.99+024814.4 system must have a hydrogen envelope thinner that the value obtained from binary evolution computations, independently of the inner composition. Finally, from our asteroseismological study, we find a best fit model characterised by $T_{\rm eff}$ = 10 917 K, M=0.338 $M_\odot$, $M_H = 10^{-6}$ $M_\odot$ with the inner composition of a hybrid WD.

Ondrejov: Pulsating white dwarfs in a double-lined binary?

DBL survey (Munday+2024)

Discovered 34 double-lined double white dwarfs.
Many have surface temperatures compatible with pulsators!





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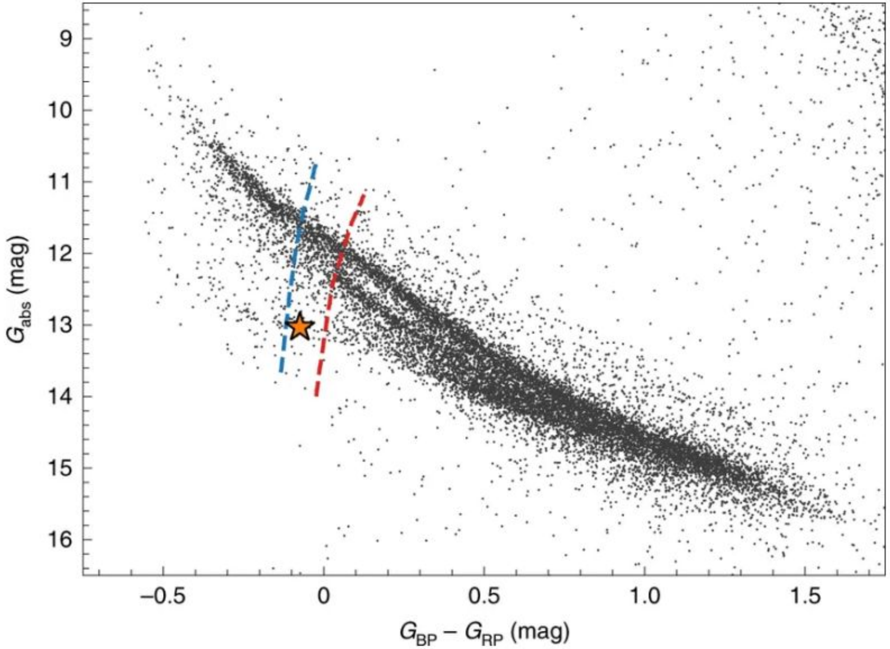
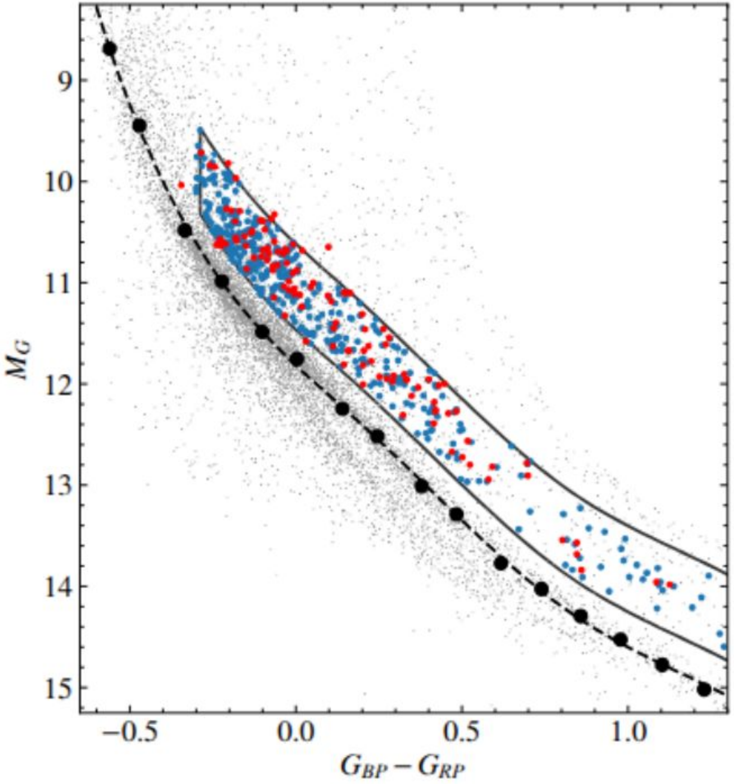
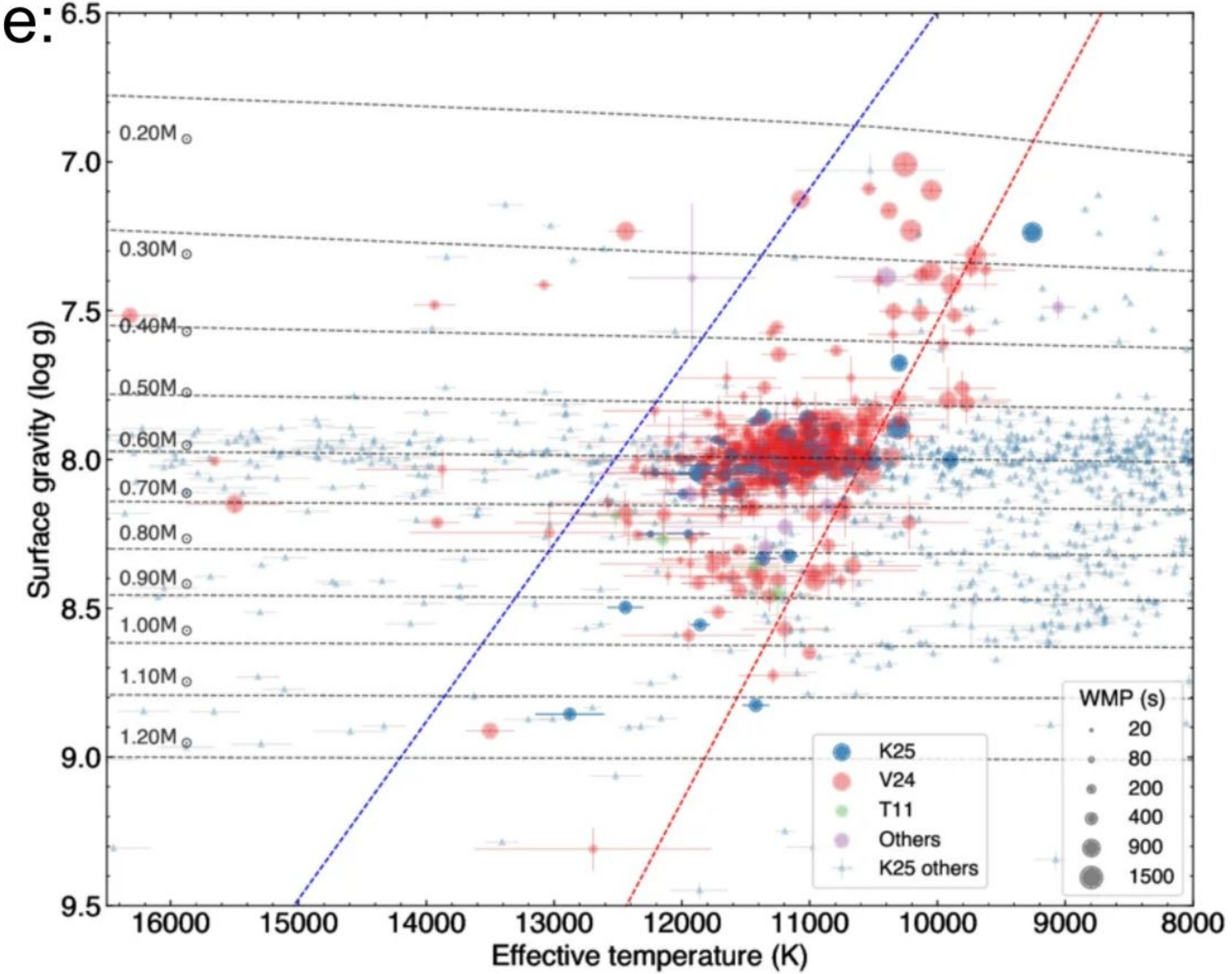




Primary pulsation mode:



Piloting program to test feasibility of project -

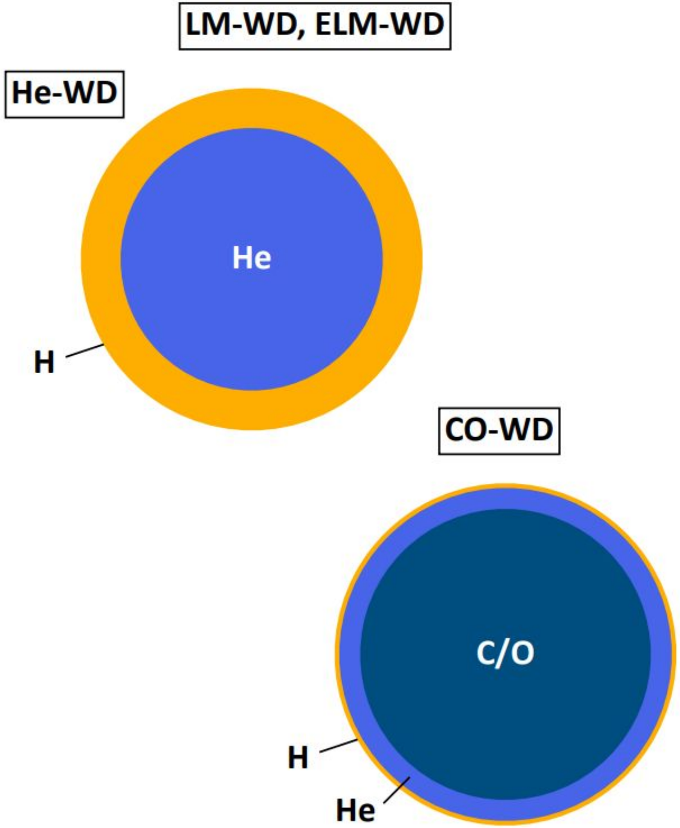
found the first pulsator in a double-lined double white dwarf!!

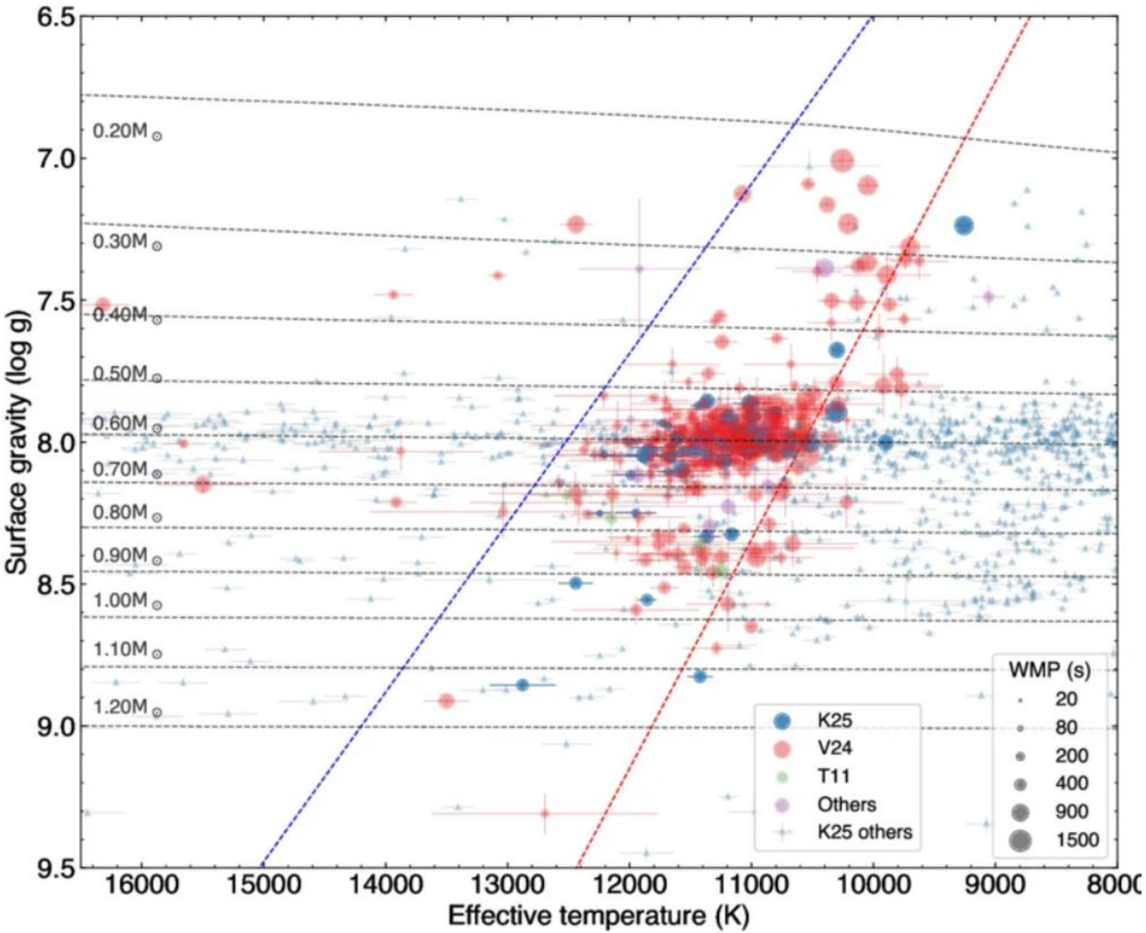
Pulsation period ~ 5min. ~2% amp

Figure: Cang+2025

WMP:
→weighted mean pulsation periods

Pulsation & structure

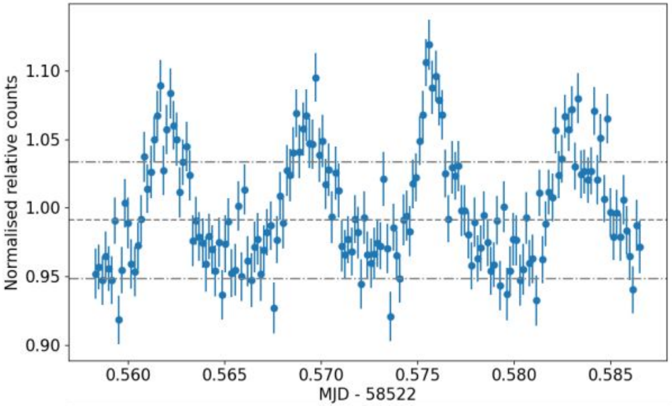


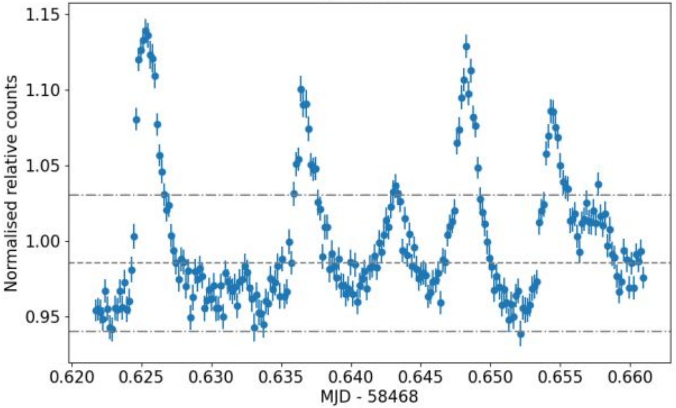


Pulsations

by Ingrid Pelisoli

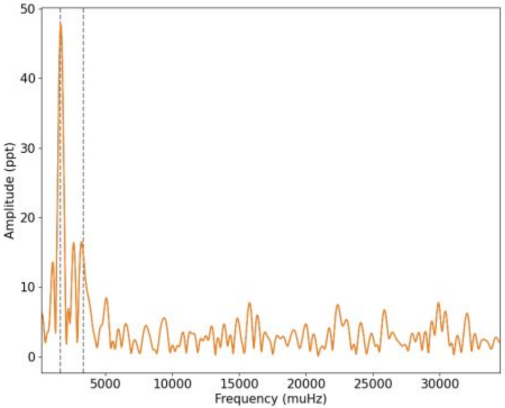
Time-series photometry

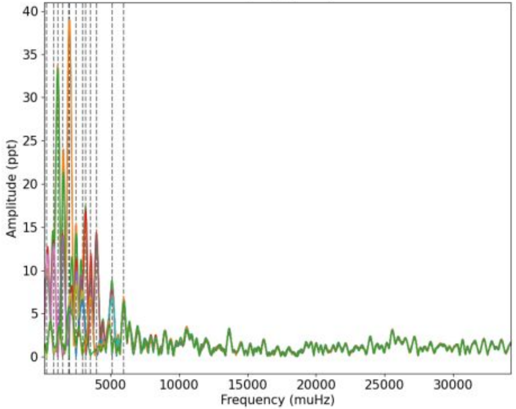




Fourier transform

(actually Generalised Lomb-Scargle Periodogram, see)





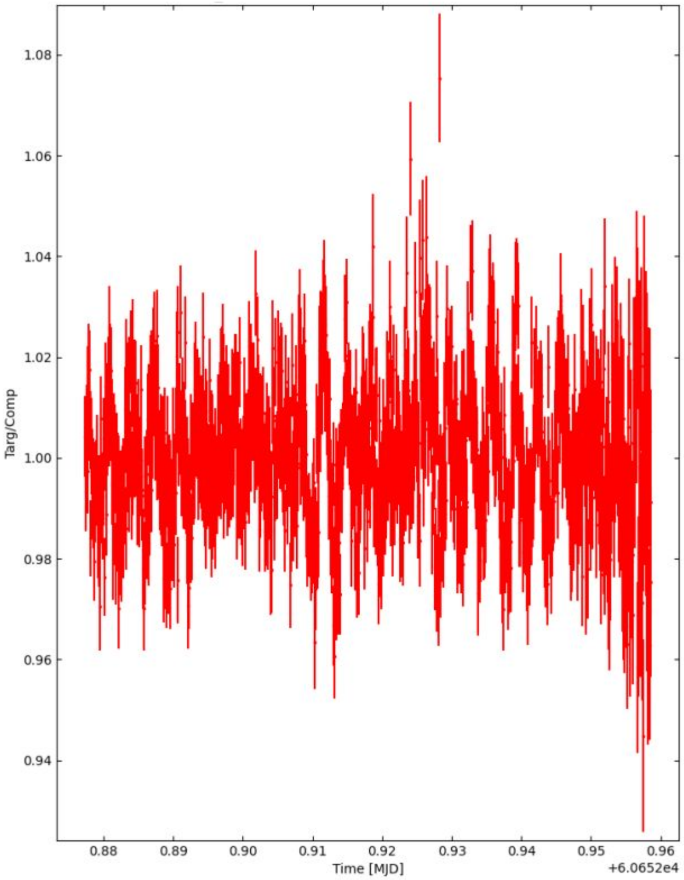
Periods and amplitudes

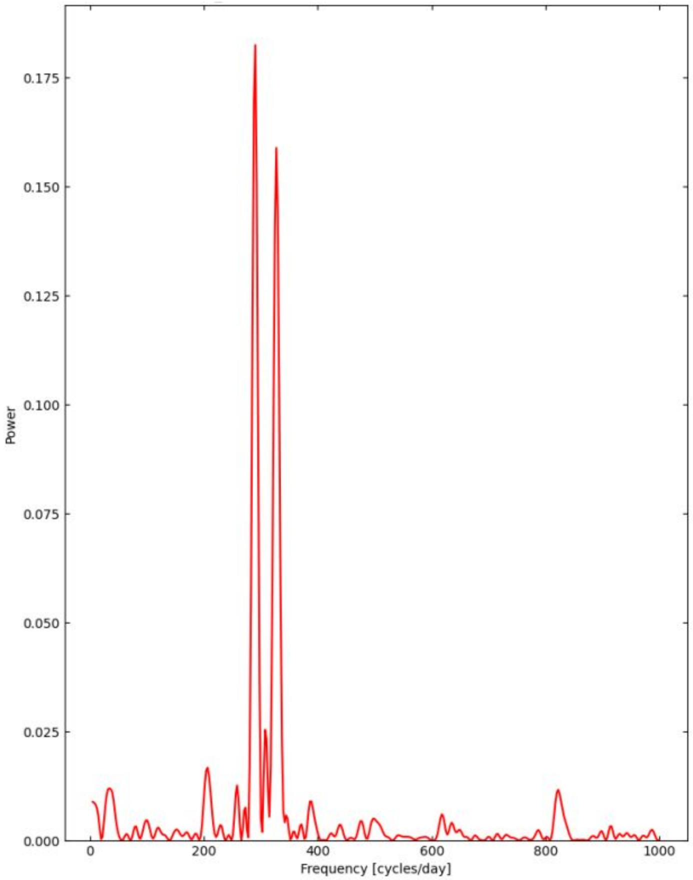
Periods (s)	Amplitude (ppt)
608	47
296	17

Periods (s)	Amplitude (ppt)
505	39
868	33
313	17
663	13
250	14
1167	12
3077	9
403	8
194	6
338	6
282	6
167	6
512	5

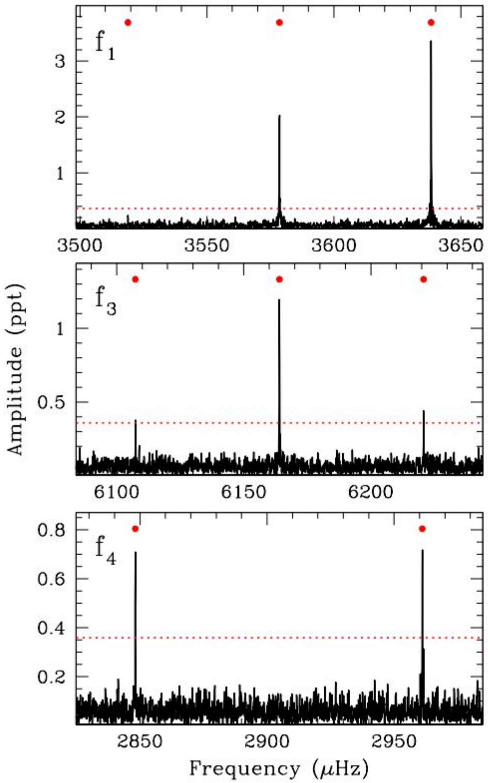
Primary pulsation mode:

You will observe this target! And many that are yet to be observed. We will find >=1 pulsators!





Possible extension:



Hermes+2015

Figure 7. Detailed regions of the Fourier transform of J1136+0409 showing the three different rotationally split pulsation modes, all viewed with the same frequency scale. The triplets are split by roughly 57 μHz, which corresponds to a rotation period of roughly 2.49 hr (see Section 5.3). Our interpretation suggests that the central ($m = 0$) component of f_4 is not observed.