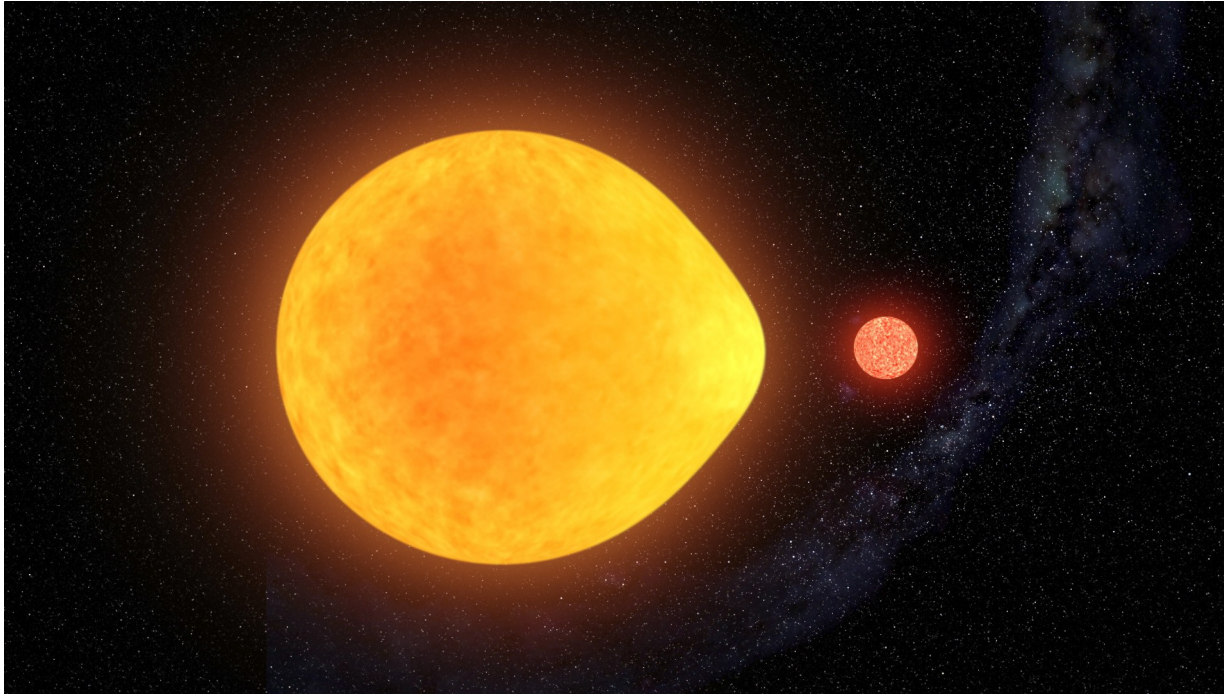


Pulsation in binary stars



Gerald Handler
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NATIONAL SCIENCE CENTRE
POLAND



Synergies and applications

Asteroseismology often requires knowledge about the basic parameters (T_{eff} , L , M , ...) of the stars to be examined to avoid ambiguities – (eclipsing) binary stars can provide that

Some of the quantities asteroseismic and binary star analyses attempt to determine are the same and can be compared and fixed

Some of the astrophysical questions to be resolved are the same, e.g. the “mass discrepancy” (Tkachenko et al. 2020, 2024, Sekaran et al. 2020, Eze & Handler 2024)

Tidal effects on pulsations can significantly influence the evolution of binary systems; the presence of a binary companion can affect the pulsations (Talks by Beck, Fellay, Kołaczek-Szymański)

Fwd: strange LC 355151781



From **Saul A Rappaport**
To **Gerald Handler** , **Olah Katalin**
Date **11-05-2019 19:25**
Priority **Highest**



98 of 298

Hi Katalin and Gerald:

Here is a nifty light curve sent to me by one of the amateurs. There is a 1.58-day (likely) rotational modulation with a set of 4 closely spaced pulsations near 3 hours superimposed.

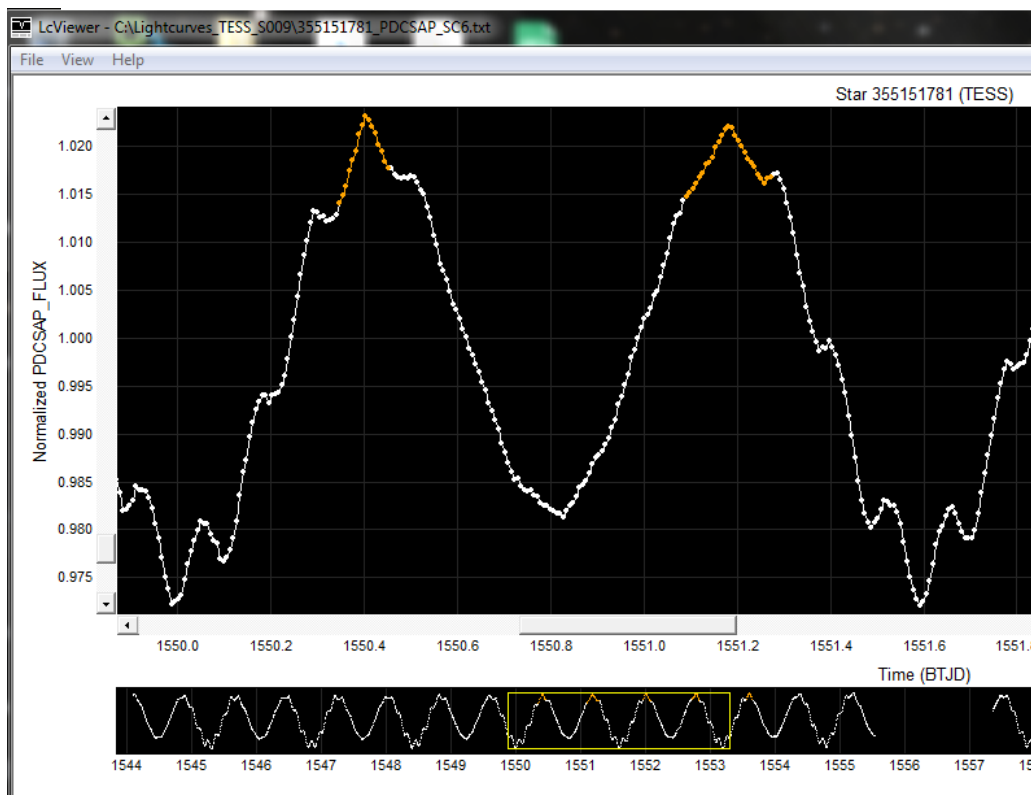
If the 1.58 day modulations are rotational I have no idea what produces them in such a hot star.

I have even less of an idea of whether this is astrophysically interesting or not.

A&A 581, A138 (2015)
DOI: [10.1051/0004-6361/201526424](https://doi.org/10.1051/0004-6361/201526424)
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**Astronomy
&
Astrophysics**

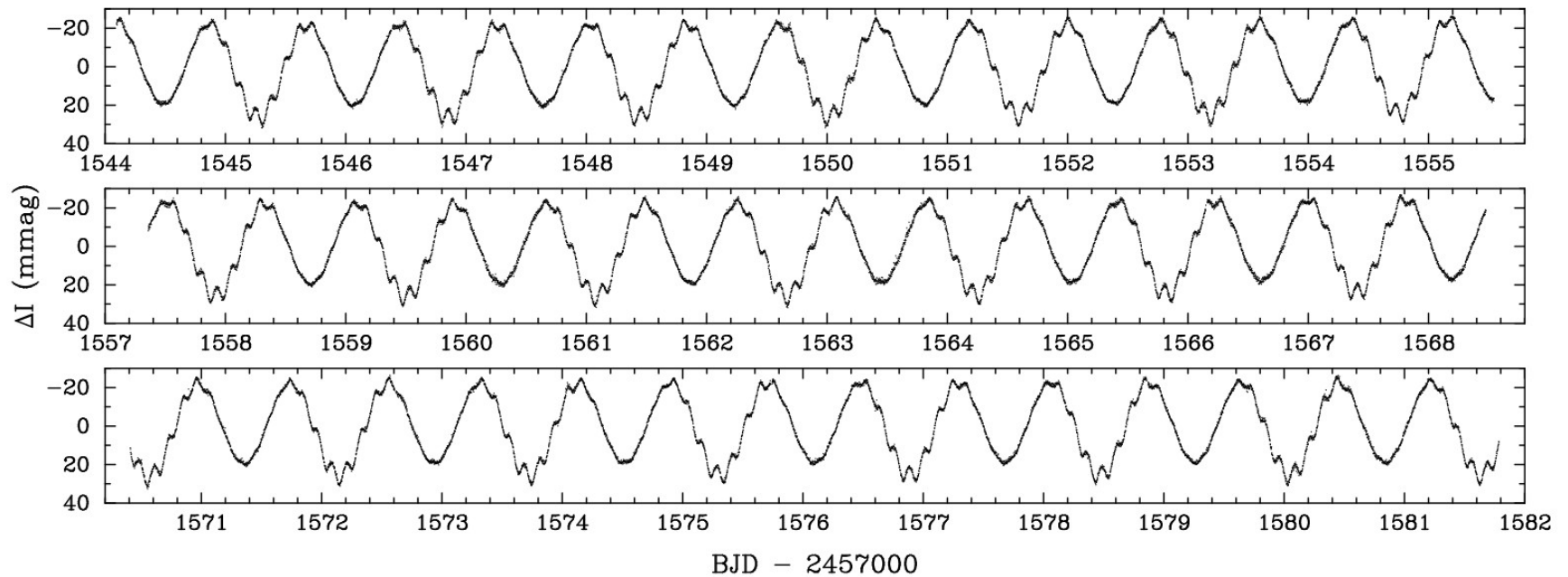
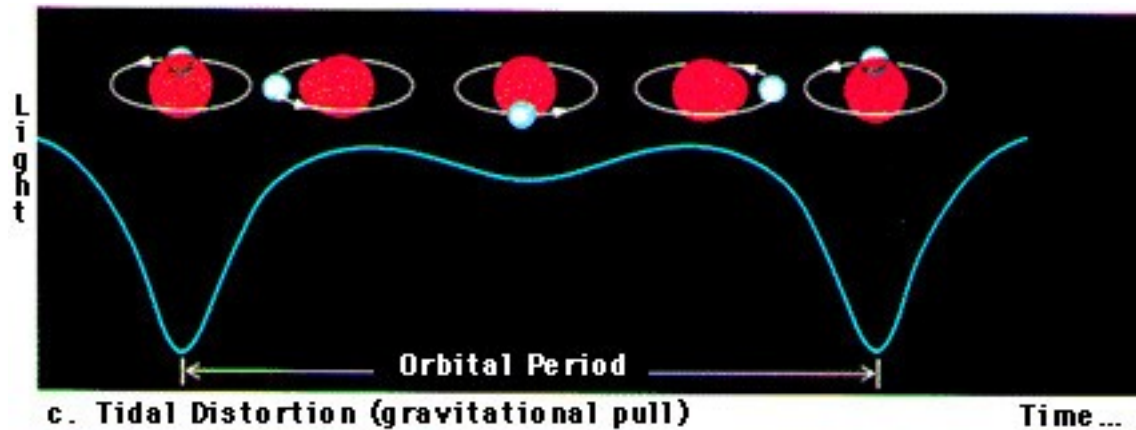
Saul



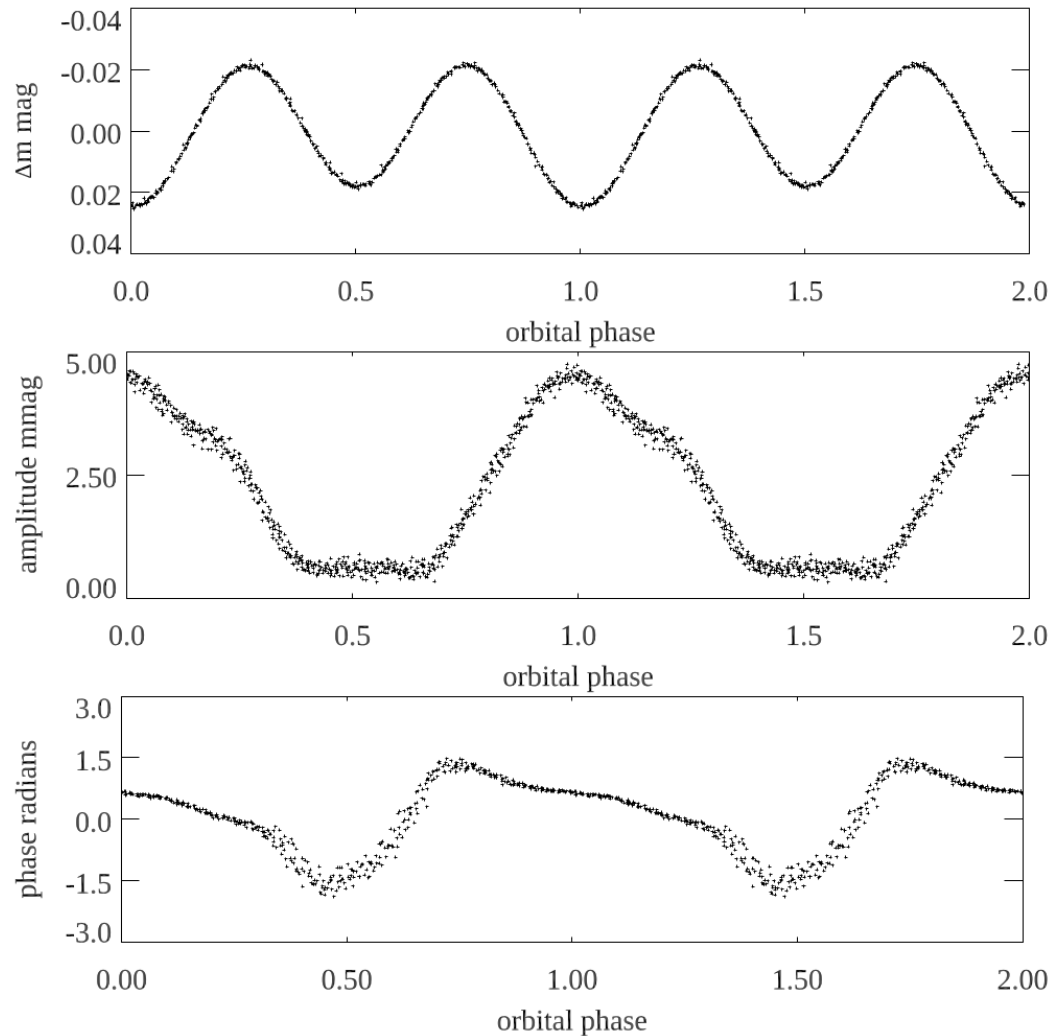
A search for photometric variability in magnetic chemically peculiar stars using ASAS-3 data

K. Bernhard^{1,2}, S. Hümmerich^{1,2}, S. Otero^{2,3}, and E. Paunzen⁴

A pulsating ellipsoidal variable



The pulsation is stronger during the deeper ellipsoidal light minima



Analogy with rapidly oscillating Ap (roAp) stars

Pulsation modes occur in frequency multiplets interpreted as caused by aspect variations of the oscillation – The Oblique Pulsator Model (Kurtz 1982)

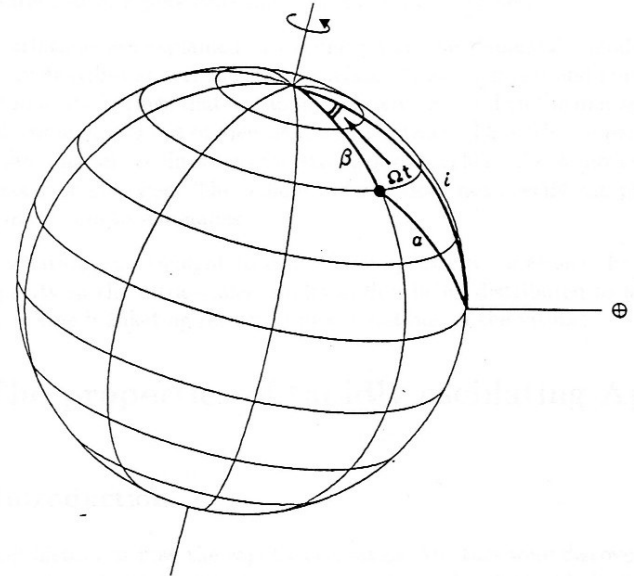
$$\frac{\Delta L}{L} \propto A_0 \cos(\omega t + \phi) + A_1 \cos[(\omega - \Omega)t + \phi] + A_1 \cos[(\omega + \Omega)t + \phi]$$

where

$$A_0 = \cos i \cos \beta$$

and

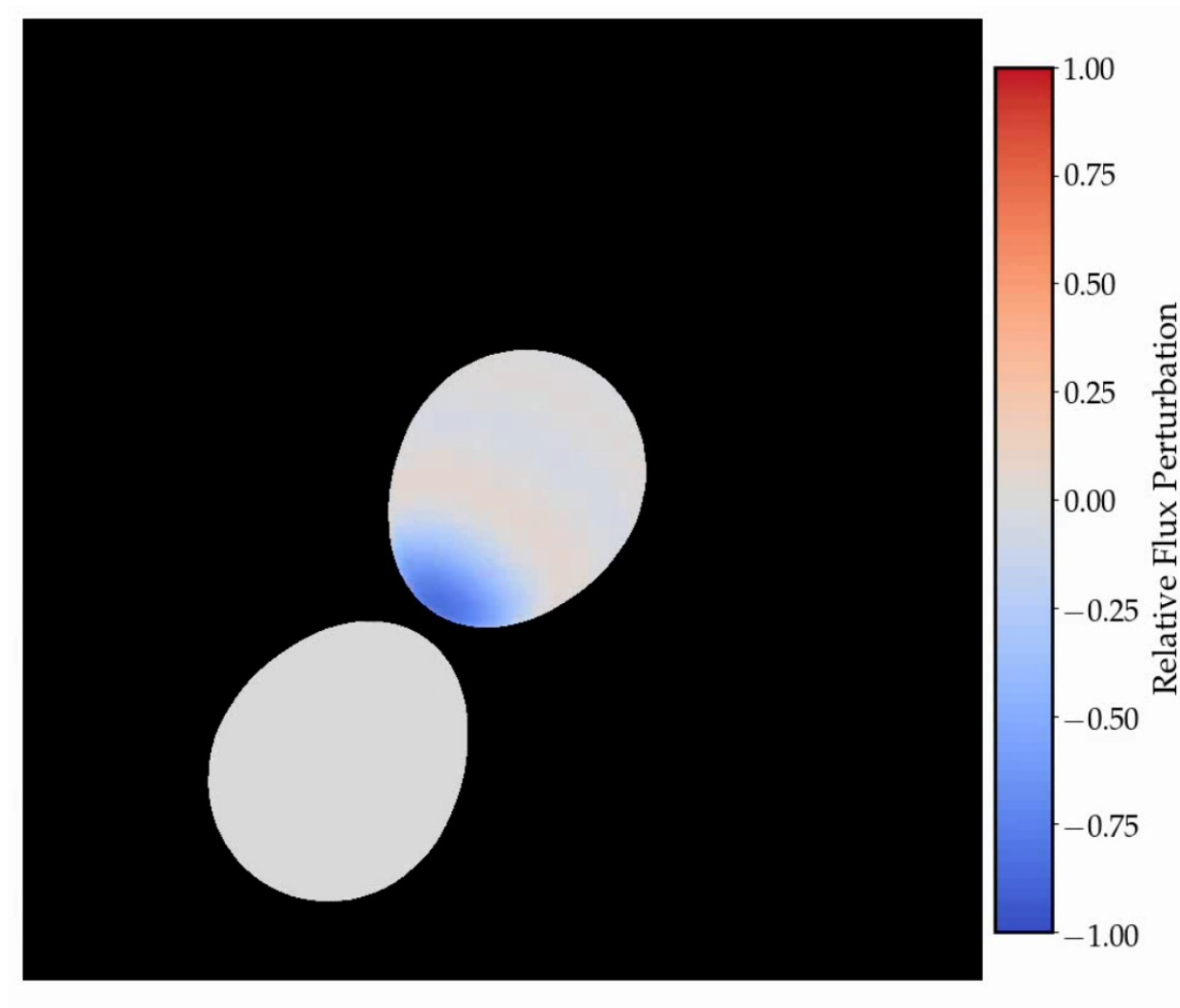
$$A_1 = \frac{1}{2} \sin i \sin \beta.$$



Rotational and pulsational axis are not aligned (oblique)

The oscillations of a tidally tilted pulsator can be mathematically described the same way as roAp pulsations, with β close to 90° .

Schematic of the HD 74423 system



Fuller et al. 2020, MNRAS 498, 5730



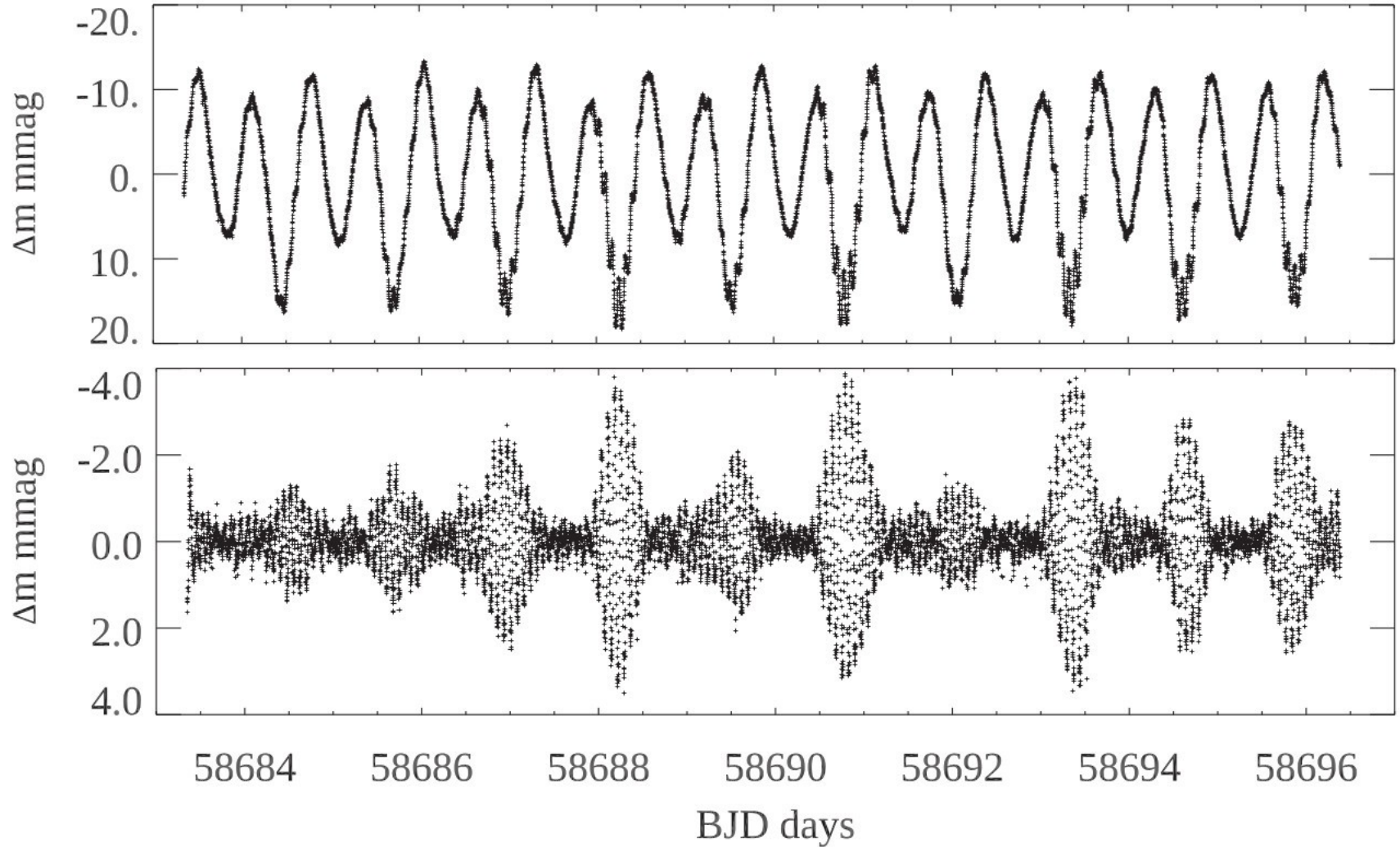
Tidally trapped pulsations in a close binary star system discovered by TESS

G. Handler¹ [✉], D. W. Kurtz², S. A. Rappaport³, H. Saio⁴, J. Fuller⁵, D. Jones^{6,7} , Z. Guo⁸ ,
S. Chowdhury¹, P. Sowicka¹ , F. Kahraman Aliçavuş^{1,9}, M. Streamer¹⁰, S. J. Murphy¹¹ ,
R. Gagliano¹² , T. L. Jacobs¹³ and A. Vanderburg¹⁴

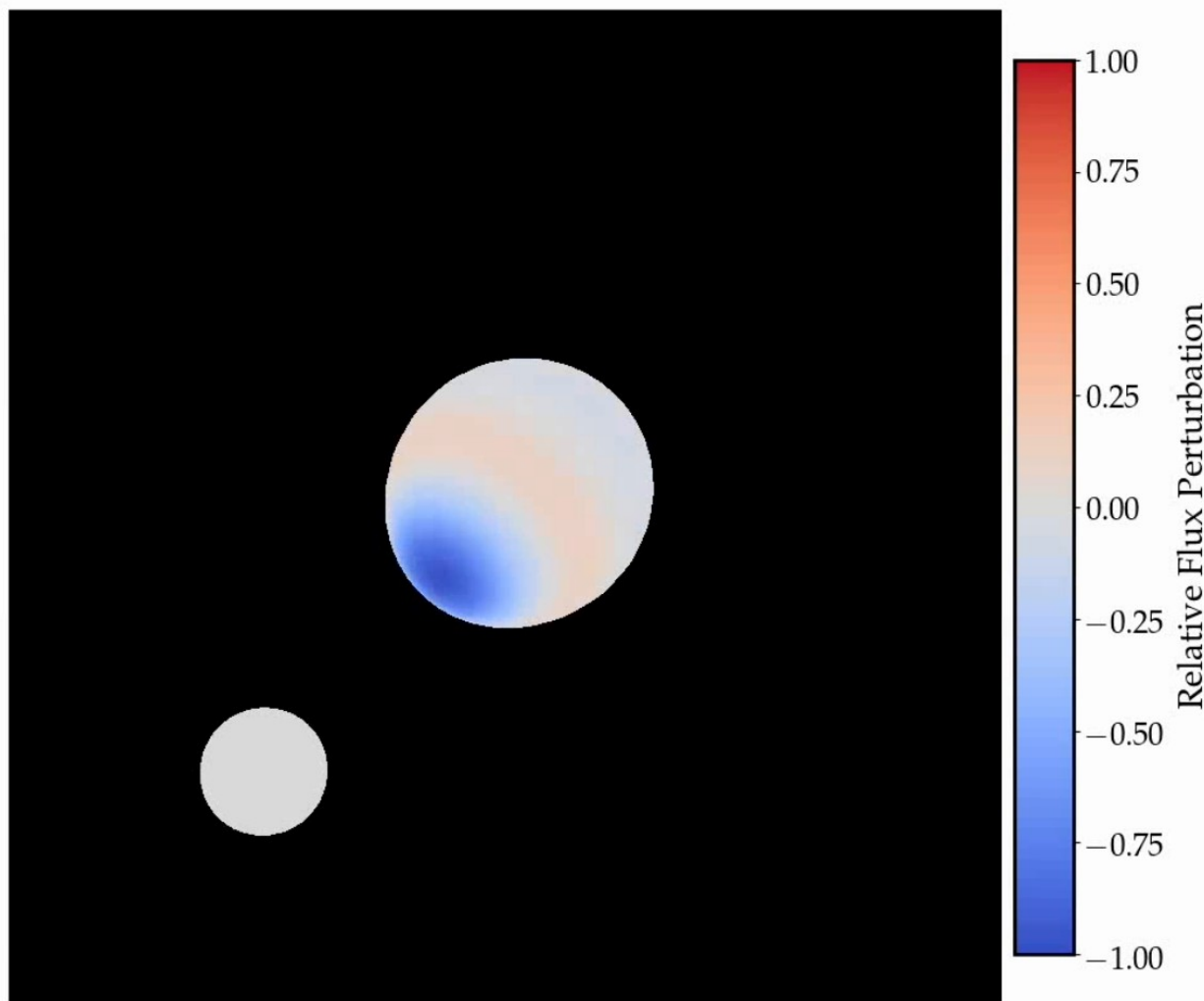
It has long been suspected that tidal forces in close binary stars could modify the orientation of the pulsation axis of the constituent stars. Such stars have been searched for, but until now never detected. Here we report the discovery of tidally trapped pulsations in the ellipsoidal variable HD 74423 in Transiting Exoplanet Survey Satellite (TESS) space photometry data. The system contains a δ Scuti pulsator in a 1.6 d orbit, whose pulsation mode amplitude is strongly modulated at the orbital frequency, which can be explained if the pulsations have a much larger amplitude in one hemisphere of the star. We interpret this as an obliquely pulsating distorted dipole oscillation with a pulsation axis aligned with the tidal axis. This is the first time that oblique pulsation along a tidal axis has been recognized. It is unclear whether the pulsations are trapped in the hemisphere directed towards the companion or in the side facing away from it, but future spectral measurements can provide the solution. In the meantime, the single-sided pulsator HD 74423 stands out as the prototype of a new class of obliquely pulsating stars in which the interactions of stellar pulsations and tidal distortion can be studied.

The single-sided pulsator CO Camelopardalis

D. W. Kurtz^{1,2*}, G. Handler³, S. A. Rappaport⁴, H. Saio⁵, J. Fuller⁶, T. Jacobs⁷,
A. Schmitt⁸, D. Jones^{9,10}, A. Vanderburg¹¹, D. LaCourse¹², L. Nelson¹³,
F. Kahraman Aliçavuş^{3,14} and M. Giarrusso¹⁵



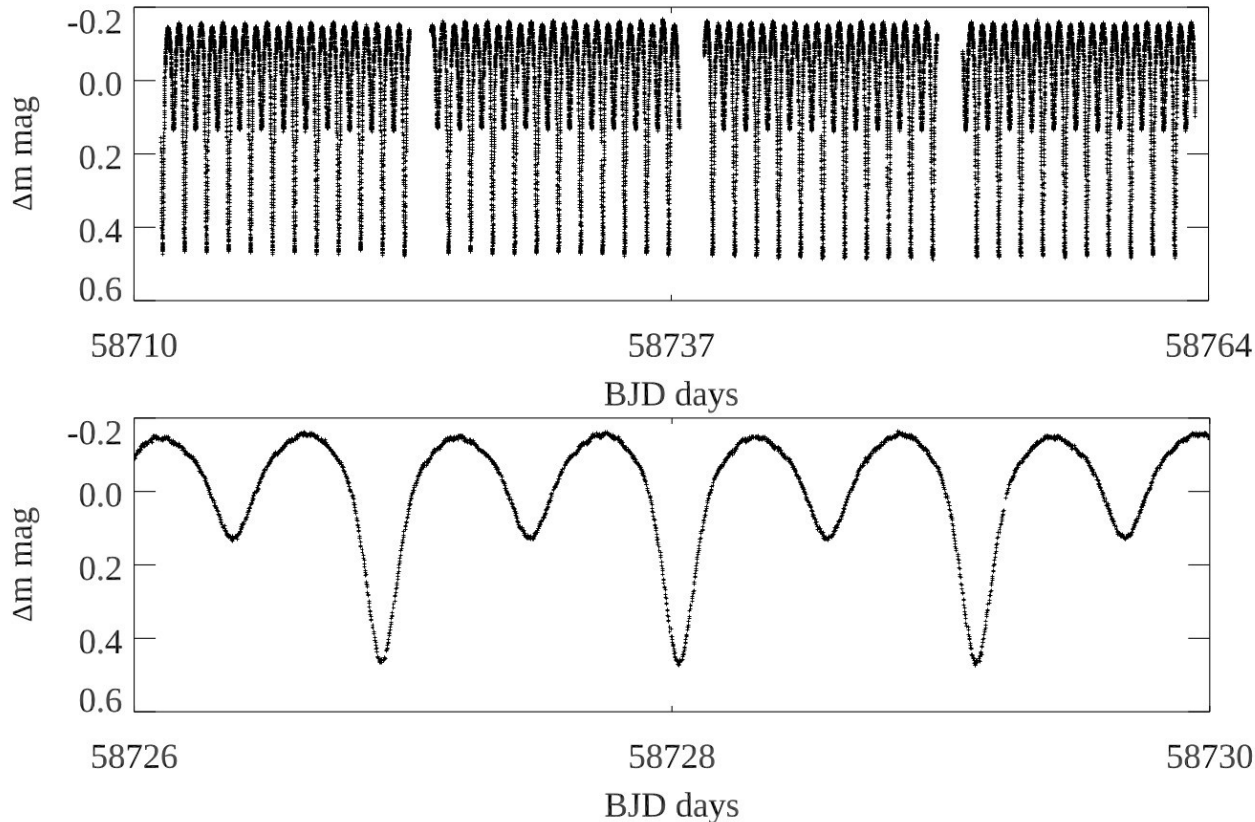
Schematic of the CO Cam system



Fuller et al. 2020, MNRAS 498, 5730

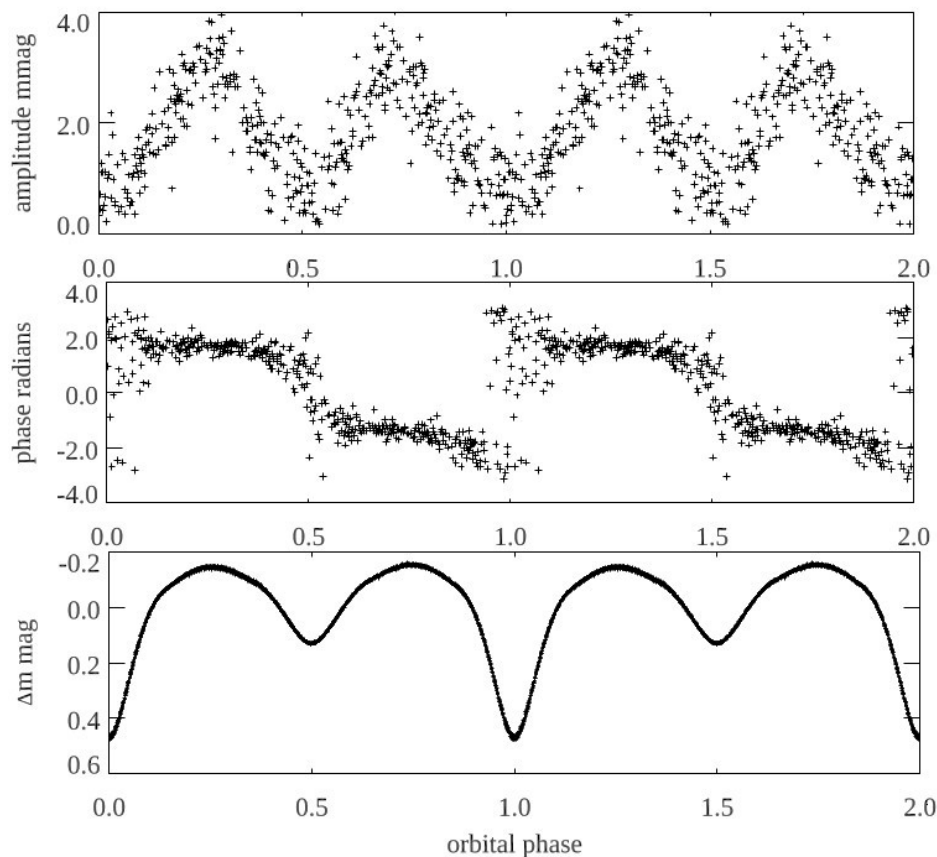
A tidally tilted sectoral dipole pulsation mode in the eclipsing binary TIC 63328020

S. A. Rappaport¹,[★] D. W. Kurtz^{2,3},[★] G. Handler⁴,[★] D. Jones^{5,6}, L. A. Nelson⁷, H. Saio⁸, J. Fuller⁹,
D. L. Holdsworth³, A. Vanderburg¹⁰, J. Žák^{11,12,5}, M. Skarka^{11,13}, J. Aiken⁷, P. F. L. Maxted¹⁴, D.
J. Stevens¹⁵, D. L. Feliz^{16,17} and F. Kahraman Aliçavuş^{18,19}

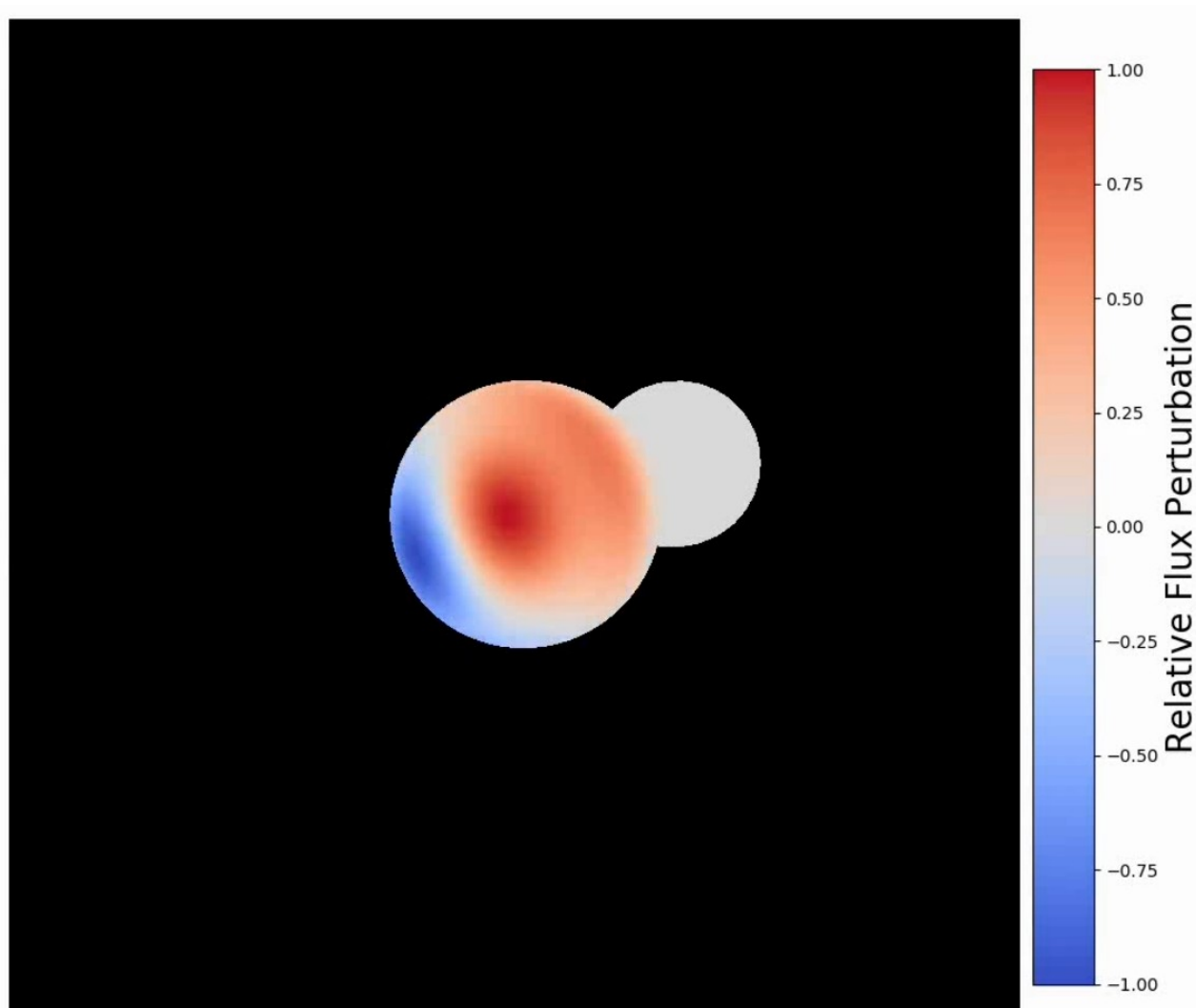


A tidally tilted sectoral dipole pulsation mode in the eclipsing binary TIC 63328020

S. A. Rappaport^{1,★}, D. W. Kurtz^{2,3,★}, G. Handler^{4,★}, D. Jones^{5,6}, L. A. Nelson⁷, H. Saio⁸, J. Fuller⁹,
D. L. Holdsworth³, A. Vanderburg¹⁰, J. Žák^{11,12,5}, M. Skarka^{11,13}, J. Aiken⁷, P. F. L. Maxted¹⁴, D.
J. Stevens¹⁵, D. L. Feliz^{16,17} and F. Kahraman Aliçavuş^{18,19}



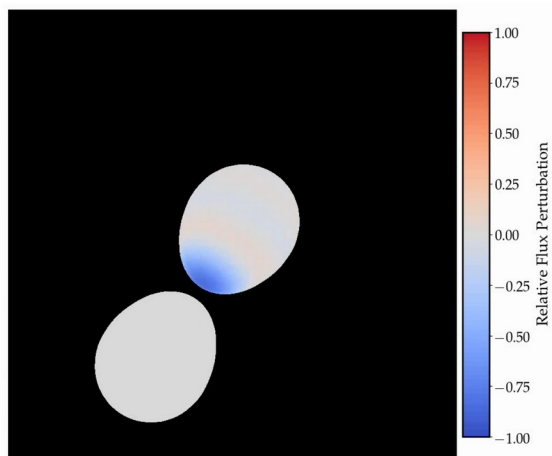
Schematic of the TIC 63328020 system



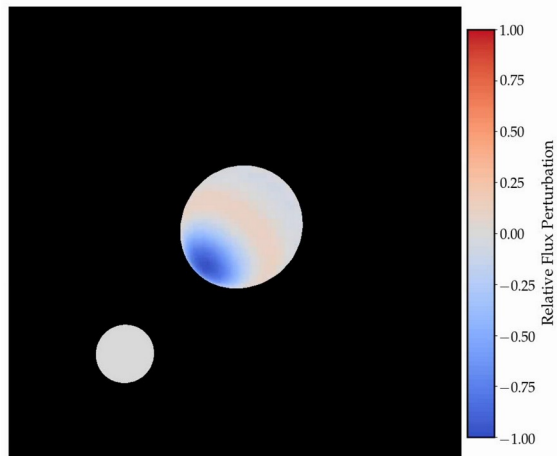
Fuller et al. 2020, MNRAS 498, 5730

The use of Echelle diagrams

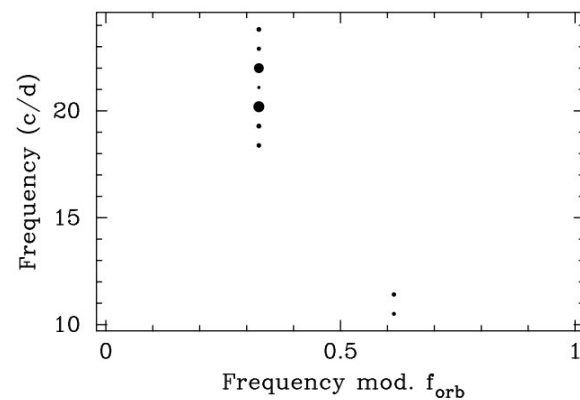
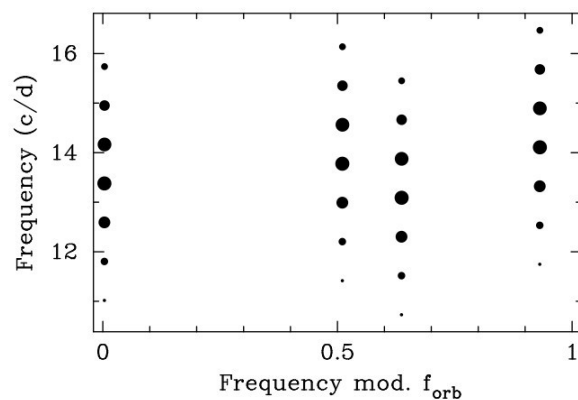
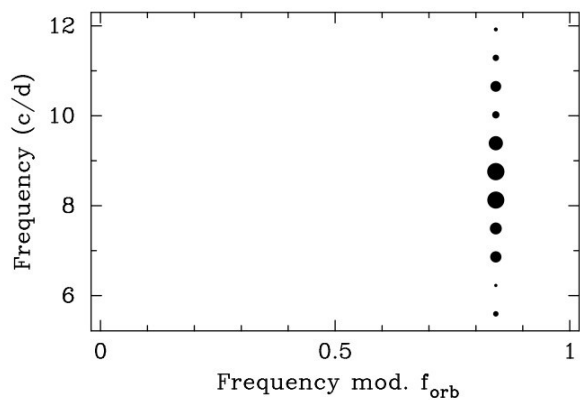
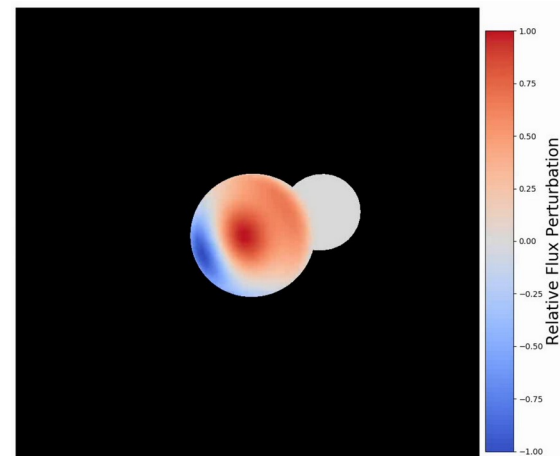
HD 74423



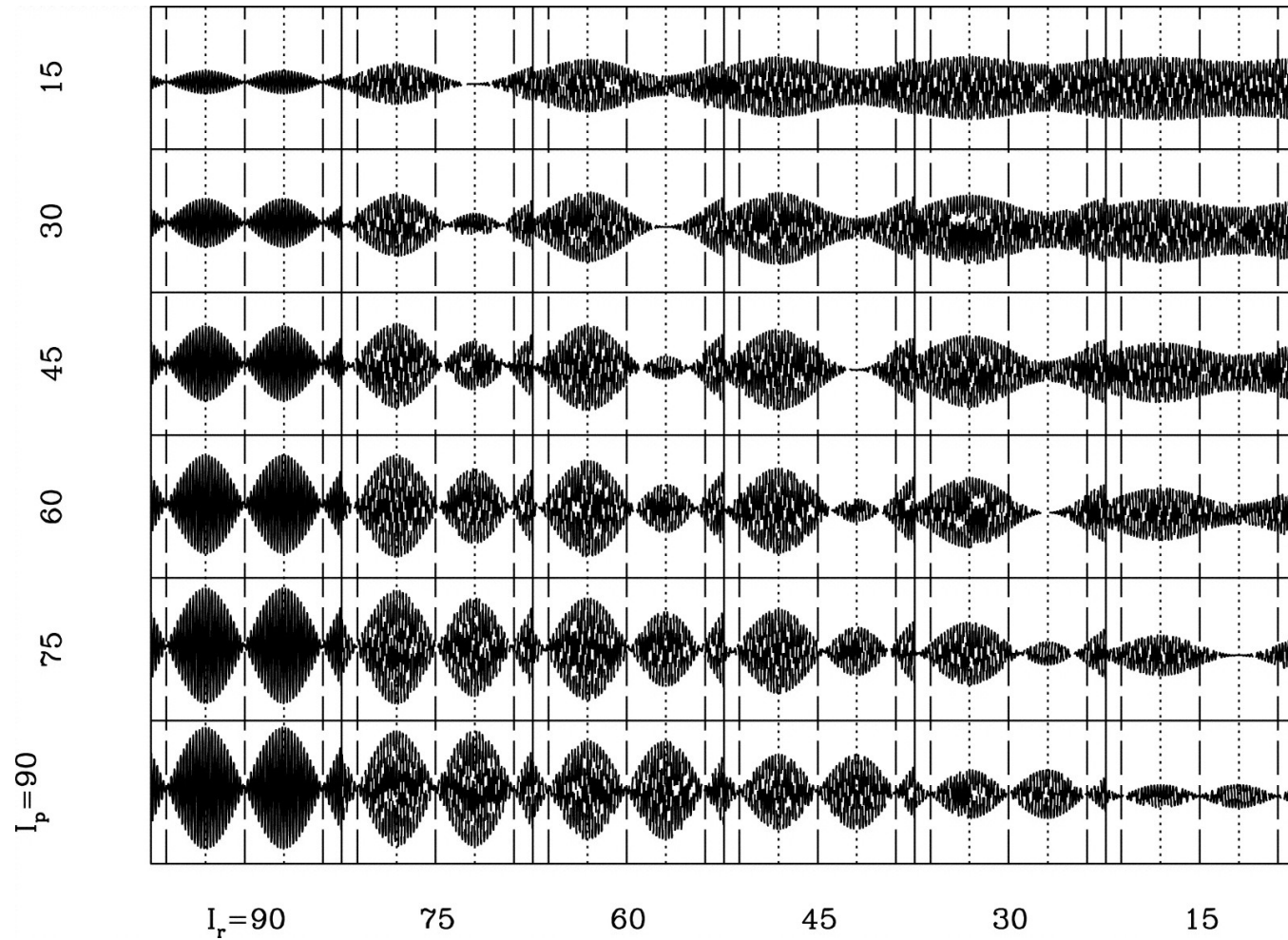
CO Cam



TIC 63328020



Tidally tilted pulsation axis



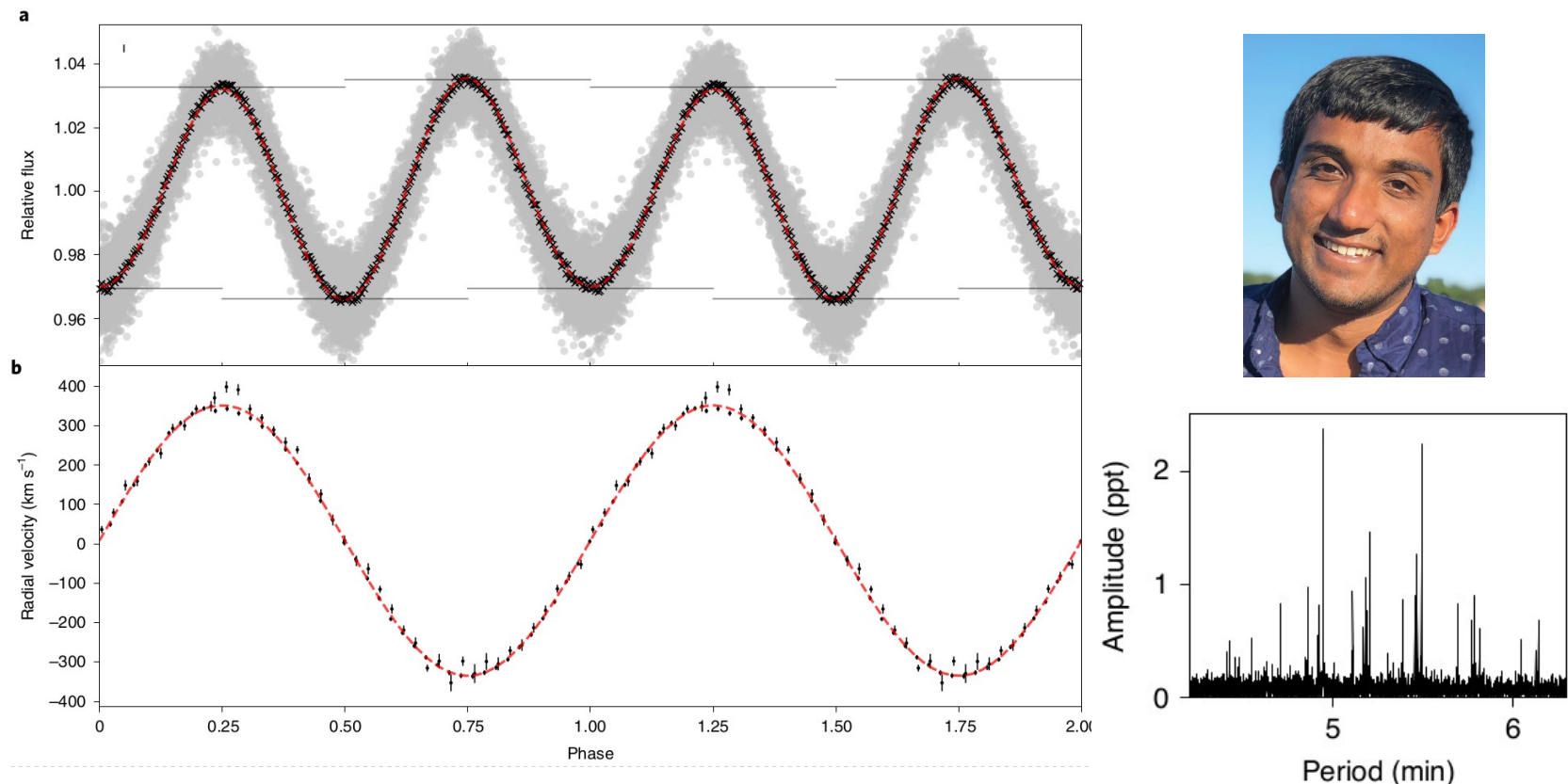
Reed, Brondel & Kawaler 2005,
ApJ 634, 602

$l=1, m=0$

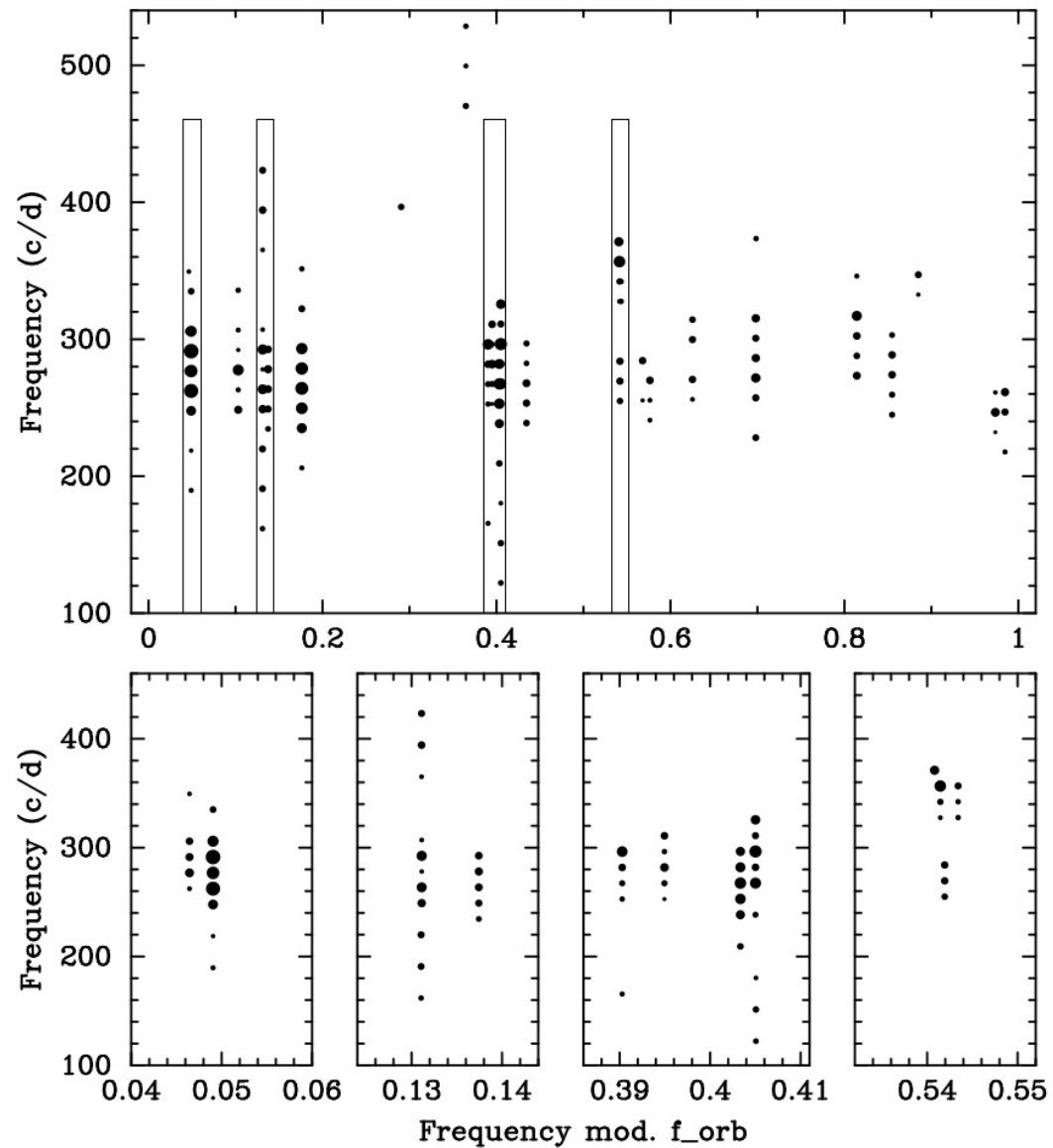


A hot subdwarf–white dwarf super-Chandrasekhar candidate supernova Ia progenitor

Ingrid Pelisoli ^{1,2}✉, P. Neunteufel ³, S. Geier¹, T. Kupfer ^{4,5}, U. Heber⁶, A. Irrgang ⁶, D. Schneider⁶, A. Bastian¹, J. van Roestel⁷, V. Schaffenroth¹ and B. N. Barlow ⁸



Echelle Diagram of the pulsations of HD 265435





Tidally Tilted Pulsations in HD 265435, a Subdwarf B Star with a Close White Dwarf Companion

Rahul Jayaraman¹ , Gerald Handler² , Saul A. Rappaport¹ , Jim Fuller³ , Donald W. Kurtz^{4,5} , Stéphane Charpinet⁶ , and George R. Ricker¹

¹ MIT Department of Physics and MIT Kavli Institute for Astrophysics and Space Research, Cambridge, MA 02139, USA; rjayaram@mit.edu

² Nicolaus Copernicus Astronomical Center of the Polish Academy of Sciences, Bartycka 18, 00-716 Warsaw, Poland

³ TAPIR, Walter Burke Institute for Theoretical Physics, Mailcode 350-17, Caltech, Pasadena, CA 91125, USA

⁴ Centre for Space Research, Physics Department, North West University, Mahikeng 2735, South Africa

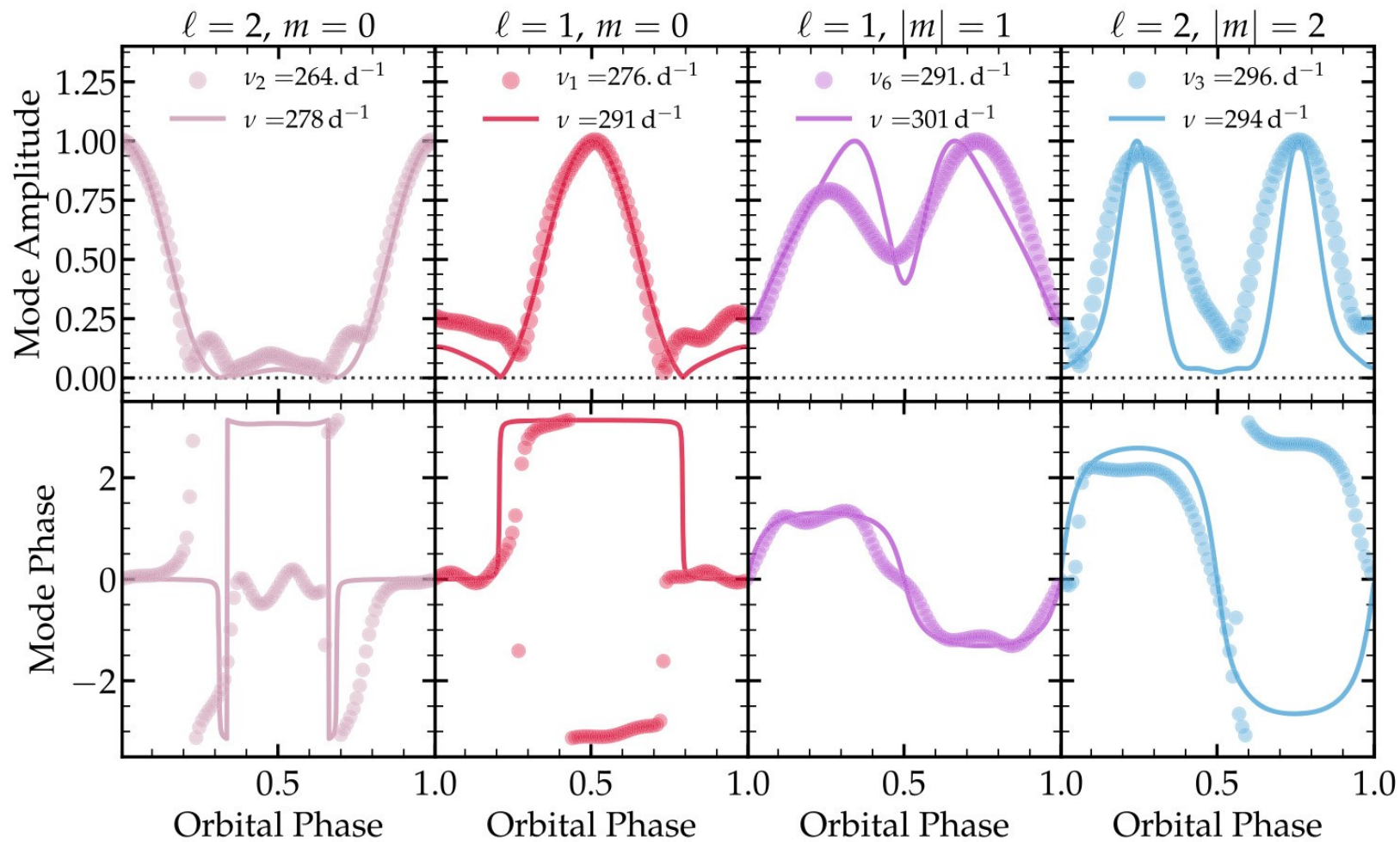
⁵ Jeremiah Horrocks Institute, University of Central Lancashire, Preston PR1 2HE, UK

⁶ Institut de Recherche en Astrophysique et Planétologie, CNRS, Université de Toulouse, CNES, 14 Avenue Edouard Belin, F-31400, Toulouse, France

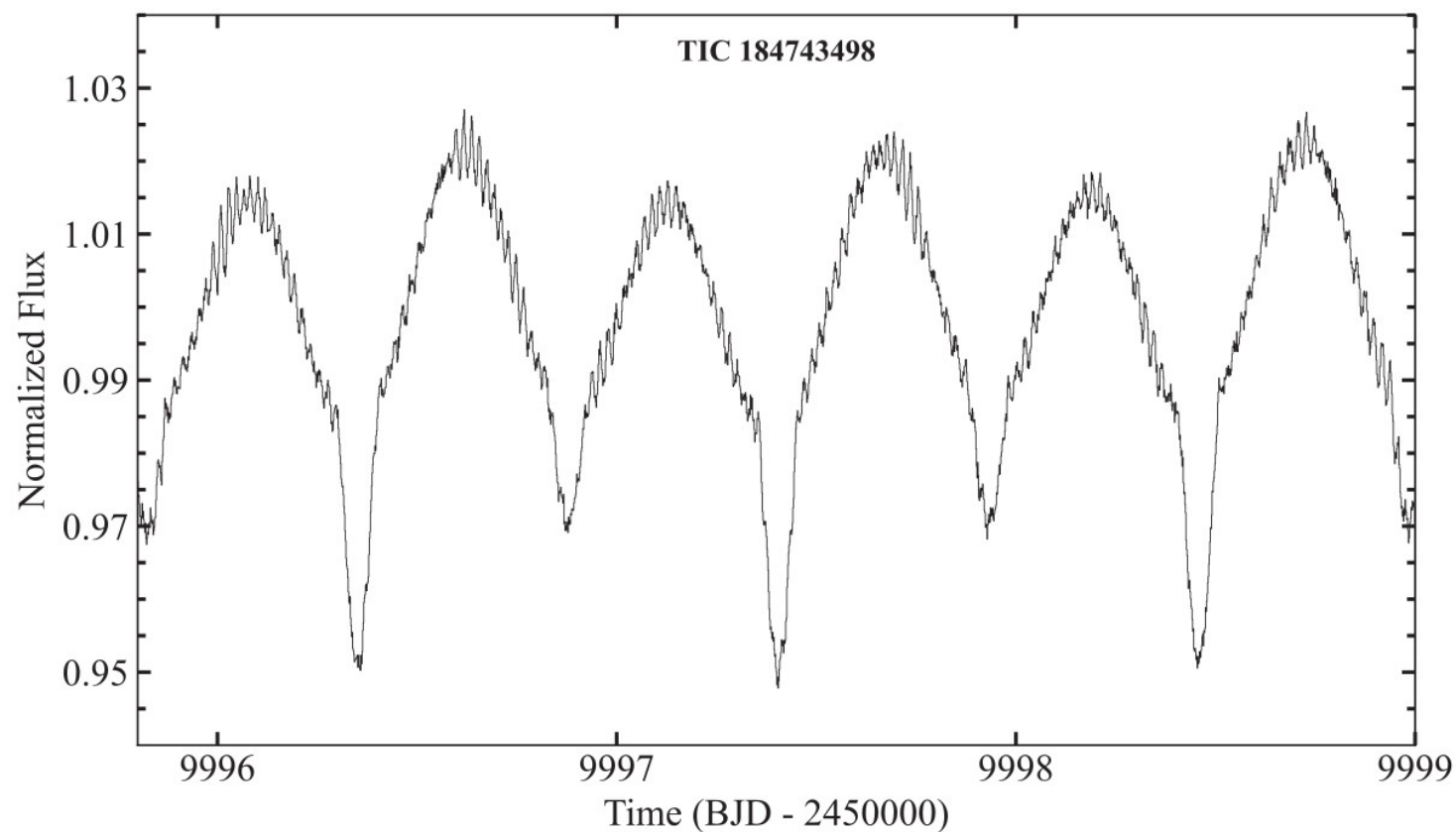
Received 2022 February 9; revised 2022 March 9; accepted 2022 March 9; published 2022 March 30

Abstract

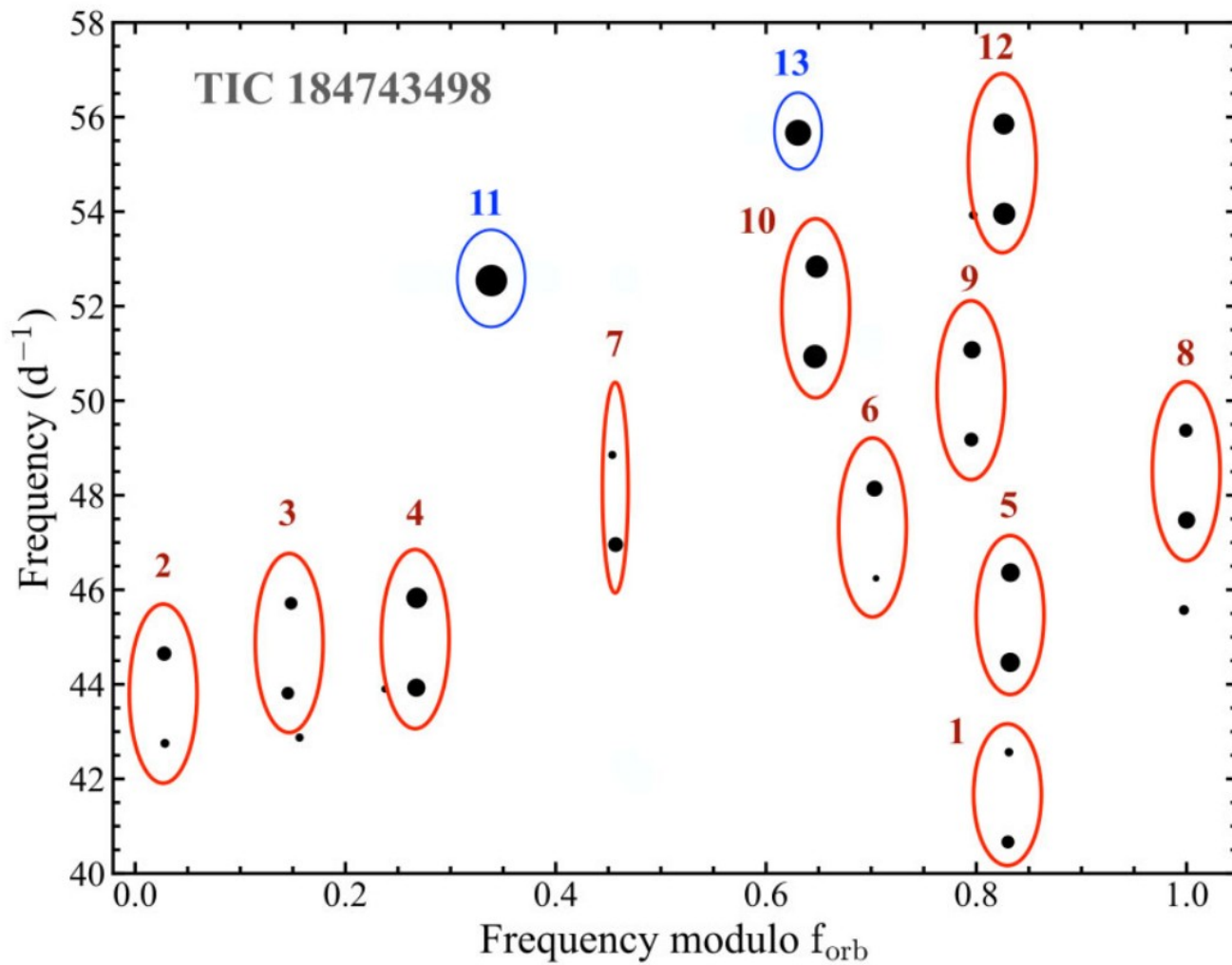
Tidally tilted pulsators (TTPs) are an intriguing new class of oscillating stars in binary systems; in such stars, the pulsation axis coincides with the line of apsides, or tidal axis, of the binary. All three TTPs discovered so far have been δ Scuti stars. In this Letter, we report the first conclusive discovery of tidally tilted pulsations in a subdwarf B (sdB) star. HD 265435 is an sdB–white dwarf binary with a 1.65 hr period that has been identified and characterized as the nearest potential Type Ia supernova progenitor. Using TESS 20 s cadence data from Sectors 44 and 45, we show that the pulsation axis of the sdB star has been tidally tilted into the orbital plane and aligned with the tidal axis of the binary. We identify 31 independent pulsation frequencies, 27 of which have between 1 and 7 sidebands separated by the orbital frequency (ν_{orb}) or multiples thereof. Using the observed amplitude and phase variability due to tidal tilting, we assign ℓ and m values to most of the observed oscillation modes and use these mode identifications to generate preliminary asteroseismic constraints. Our work significantly expands our understanding of TTPs, as we now know that (i) they can be found in stars other than δ Scuti pulsators, especially highly evolved stars that have lost their H-rich envelopes, and (ii) tidally tilted pulsations can be used to probe the interiors of stars in very tight binaries.



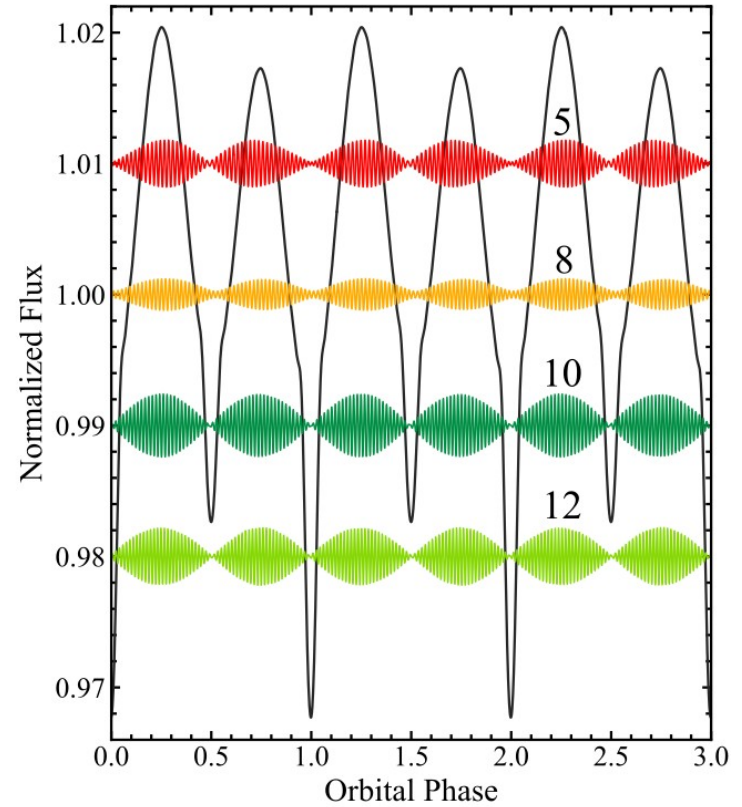
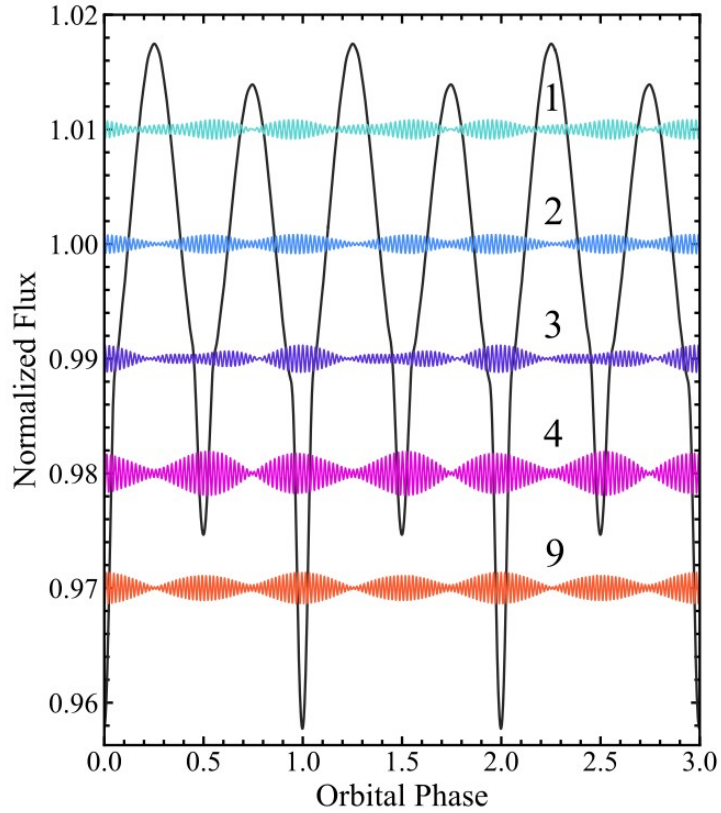
A related kind of beast



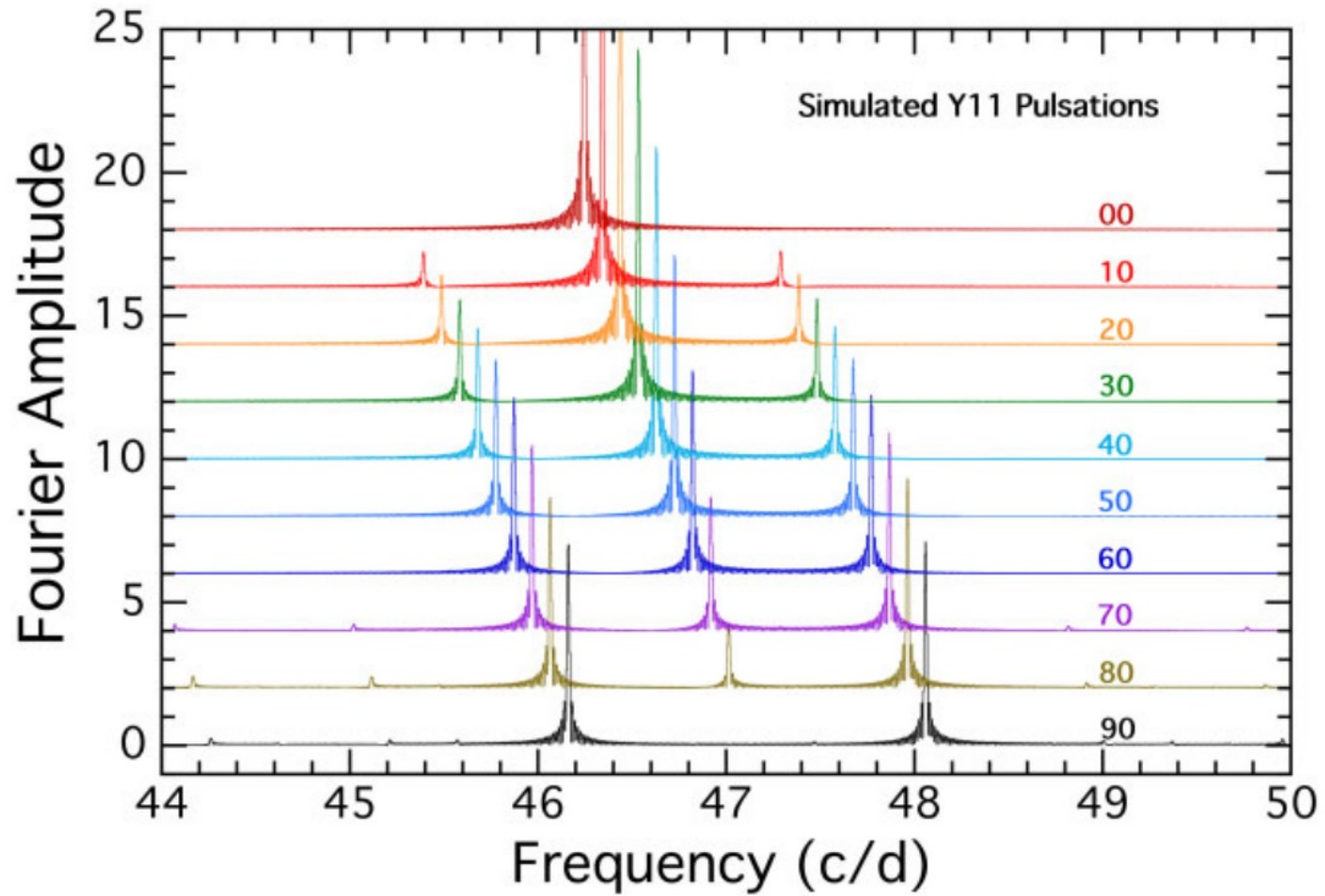
A related kind of beast



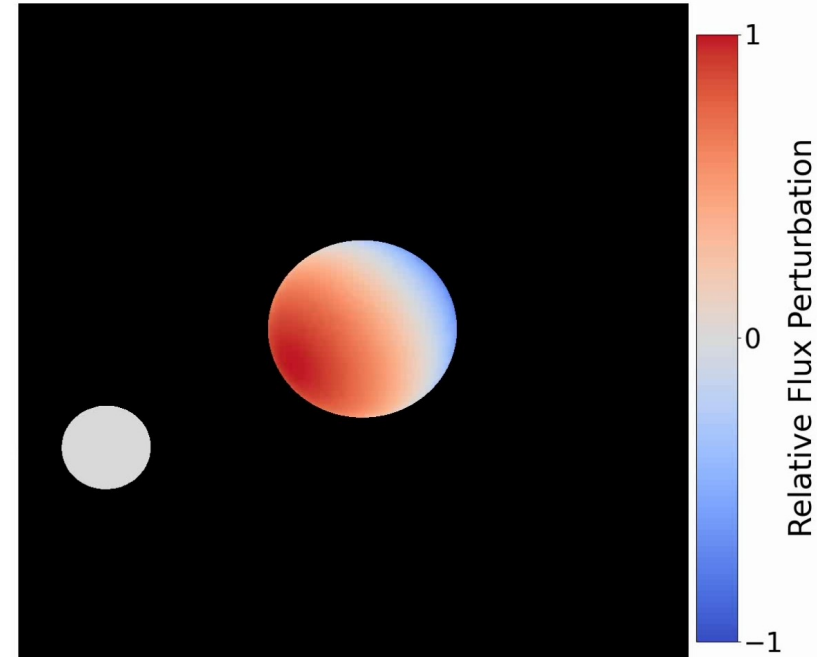
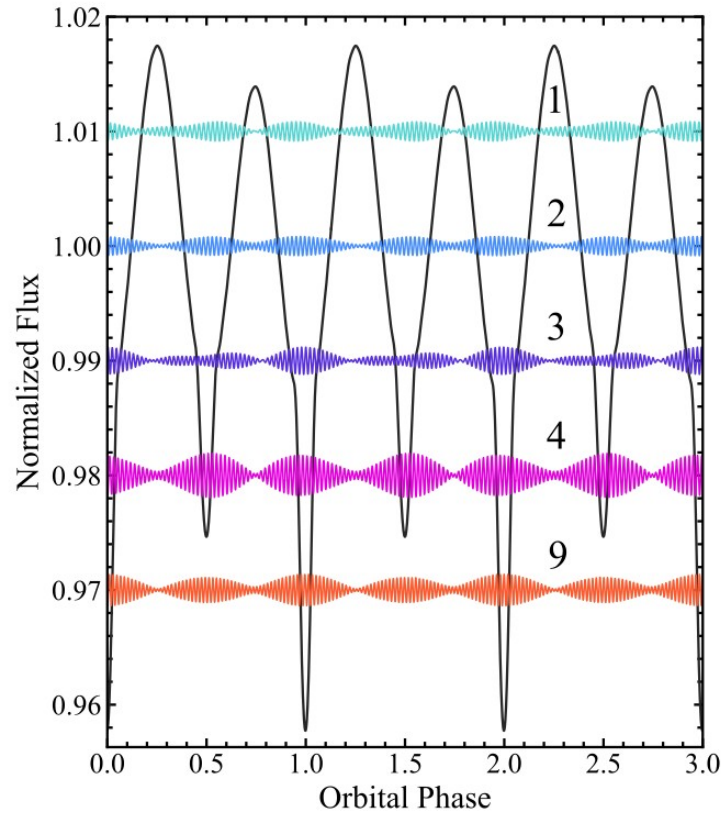
A related kind of beast



A related kind of beast

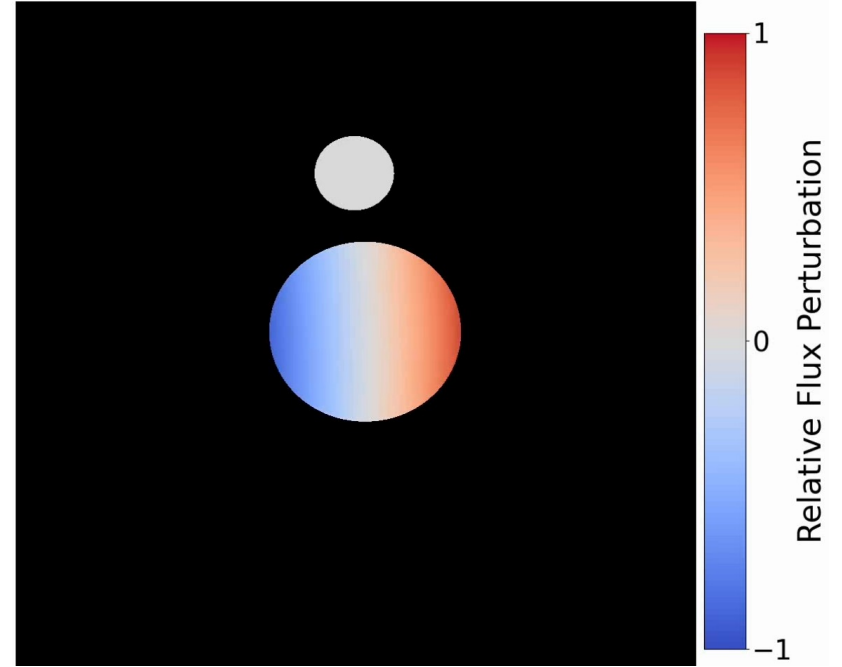
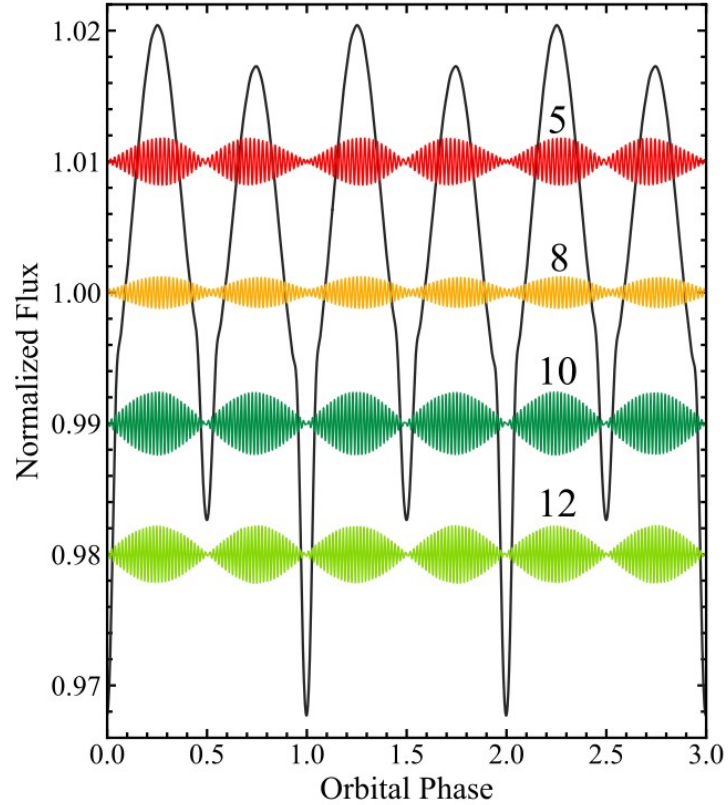


A related kind of beast – triaxial pulsator



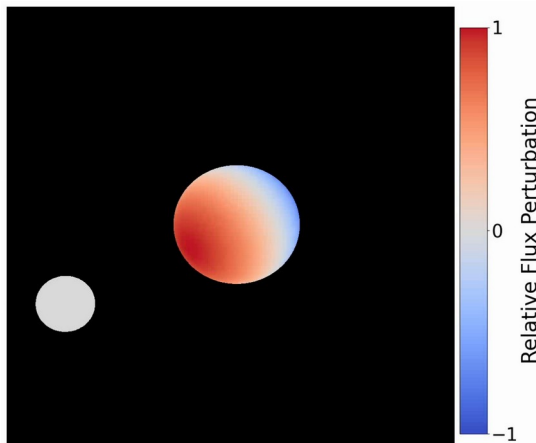
Animation: courtesy Jim Fuller

A related kind of beast – triaxial pulsator

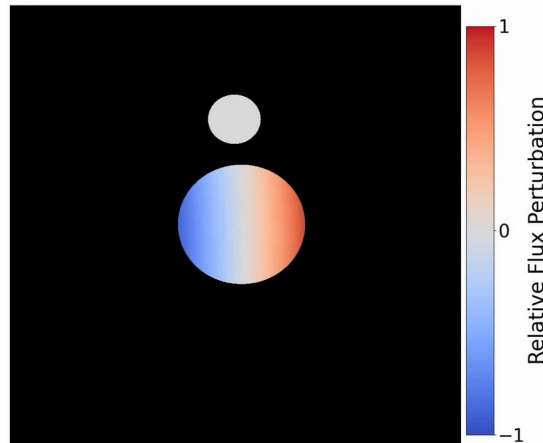


Animation: courtesy Jim Fuller

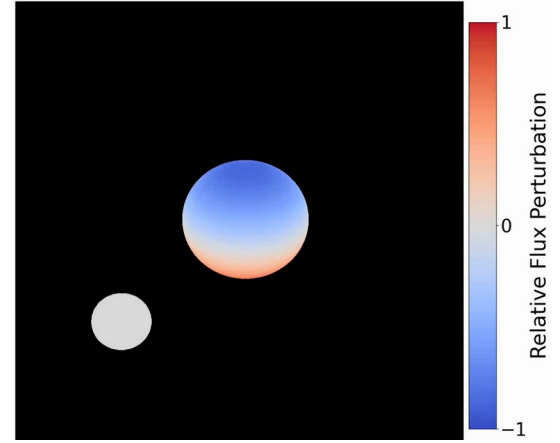
A related kind of beast – triaxial pulsator



x mode



y mode



z mode

Animations: courtesy Jim Fuller

Fuller et al., submitted to ApJ

Coming up next...

TIC 435850195: A Tri-Axial, Tidally Tilted Pulsator

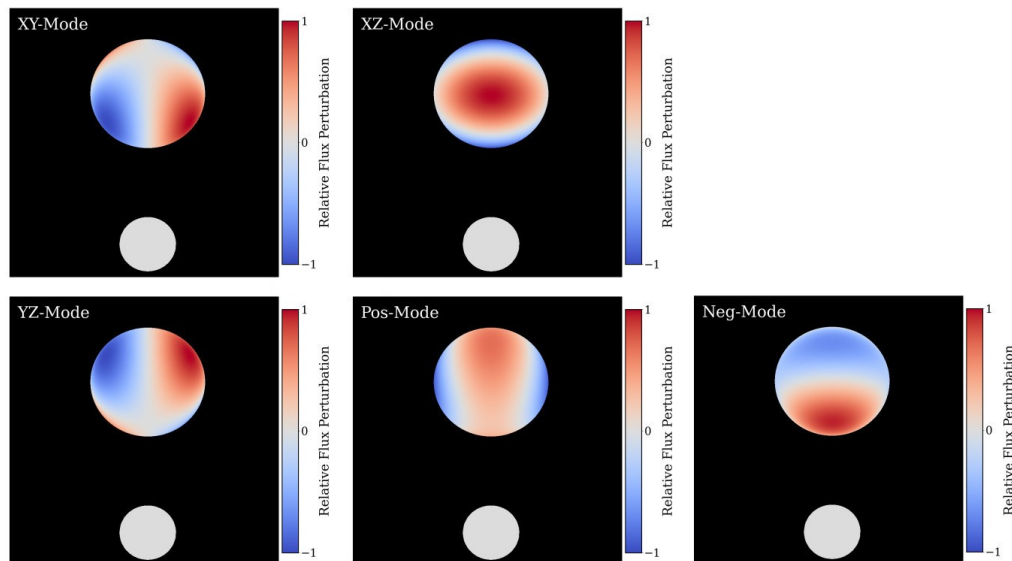
RAHUL JAYARAMAN ¹, SAUL A. RAPPAPORT,¹ BRIAN POWELL,² GERALD HANDLER,³ MARK OMOHUNDRO,⁴
ROBERT GAGLIANO,⁵ VESELIN KOSTOV,^{2,6} JIM FULLER,⁷ DONALD W. KURTZ,^{8,9} VALENCIA ZHANG,¹⁰ AND GEORGE RICKER¹

(ApJ, in press; arXiv: 2409.03815)

Tidally distorted stars are triaxial pulsators

JIM FULLER ,¹ SAUL RAPPAPORT,² RAHUL JAYARAMAN,² DON KURTZ,^{3,4} AND GERALD HANDLER⁵

(submitted to ApJ)



Graphics: courtesy Jim Fuller