Pulsating stars in eclipsing binaries and exoplanets

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Astronomical institute of SAS, April 23, 2025

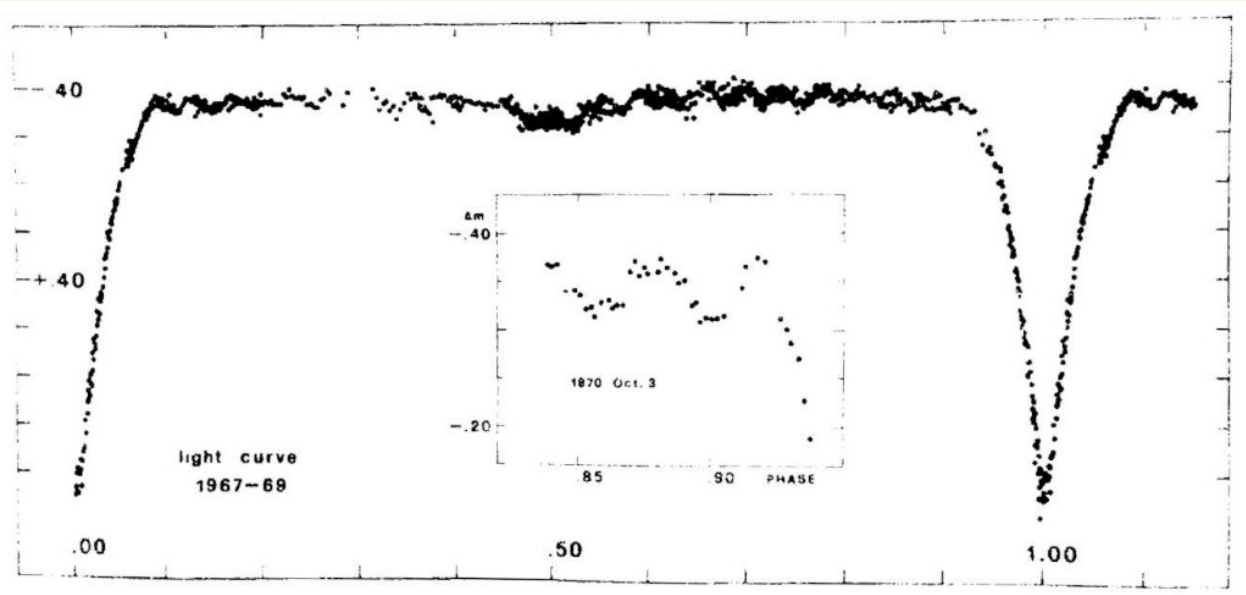
Pulsators in EBs/exoplanets

- One or both components can be pulsating
- Variability: δ Sct, γ Dor, RR Lyr, SPB, ZZ Cet, Mira, solar-type...
- Tidally-induced pulsators in eccentric binary systems (e.g., KIC 3230227, Guo+, 2016), massive exoplanets on eccentric orbits (e.g. HAT-P-2b, de Wit+, 2017)
- Pulsating stars in EBs – reliable absolute parameters – calibration of scaling relations (p-mode solar-type oscillations), calibration of period-luminosity relations
- PB1 and PB2 systems – pulsation can be used to determine orbital parameters – using the light-time effect

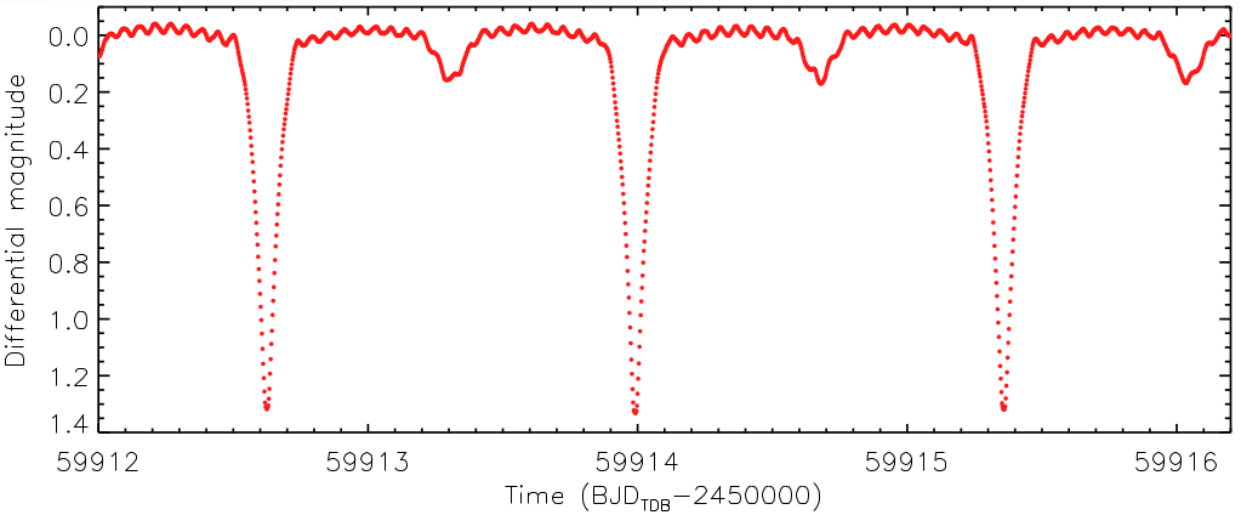
$$\left(\frac{R}{\mathrm{R}_\odot}\right) = \left(\frac{\nu_{\mathrm{max}}}{\nu_{\mathrm{max},\odot}}\right)\left(\frac{\Delta\nu}{\Delta\nu_\odot}\right)^{-2}\left(\frac{T_{\mathrm{eff}}}{\mathrm{T}_{\mathrm{eff},\odot}}\right)^{0.5}$$

$$\left(\frac{M}{\mathrm{M}_\odot}\right) = \left(\frac{\nu_{\mathrm{max}}}{\nu_{\mathrm{max},\odot}}\right)^{3}\left(\frac{\Delta\nu}{\Delta\nu_\odot}\right)^{-4}\left(\frac{T_{\mathrm{eff}}}{\mathrm{T}_{\mathrm{eff},\odot}}\right)^{1.5}$$

AB Cas: ground-based/satellite



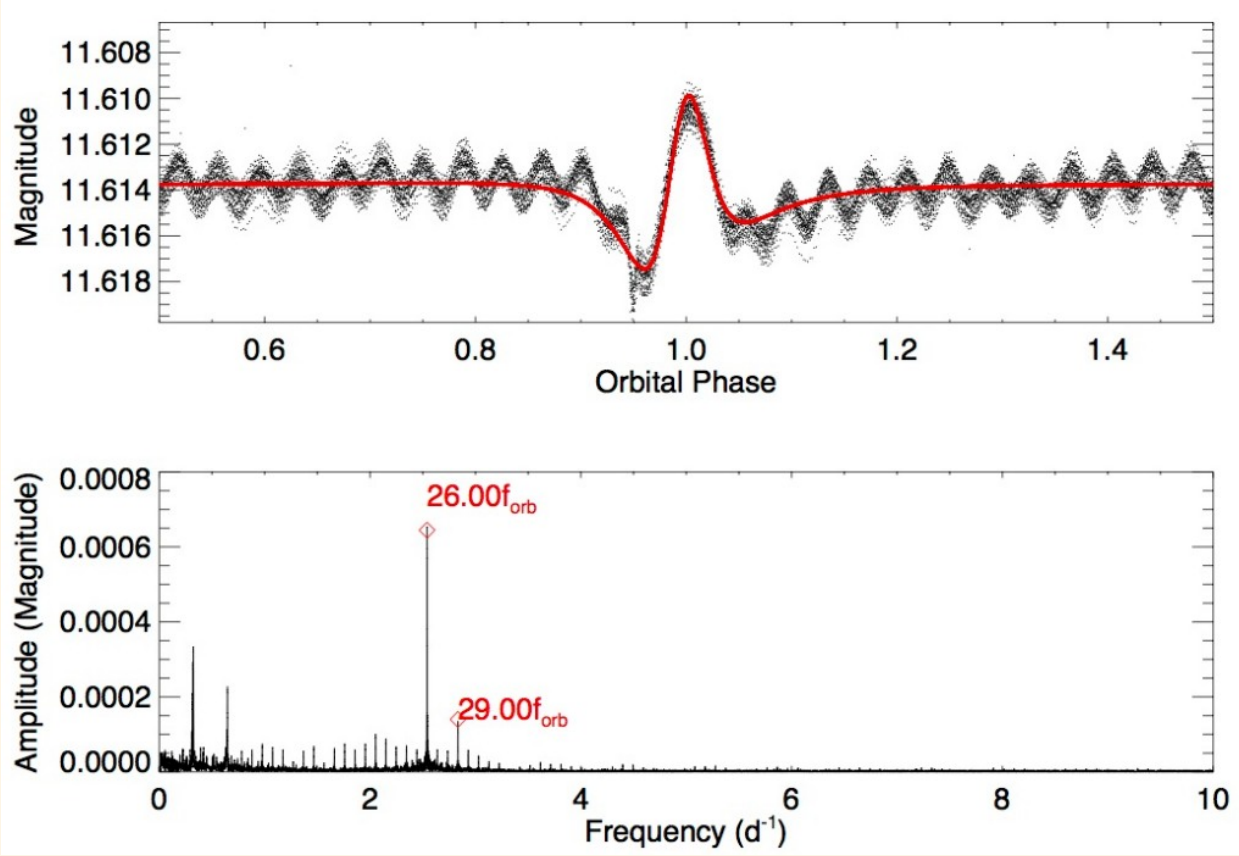
ground-based
photoelectric
(Tempesti, 1971)



TESS CCD
(Miszuda+ 2022)

TEOs

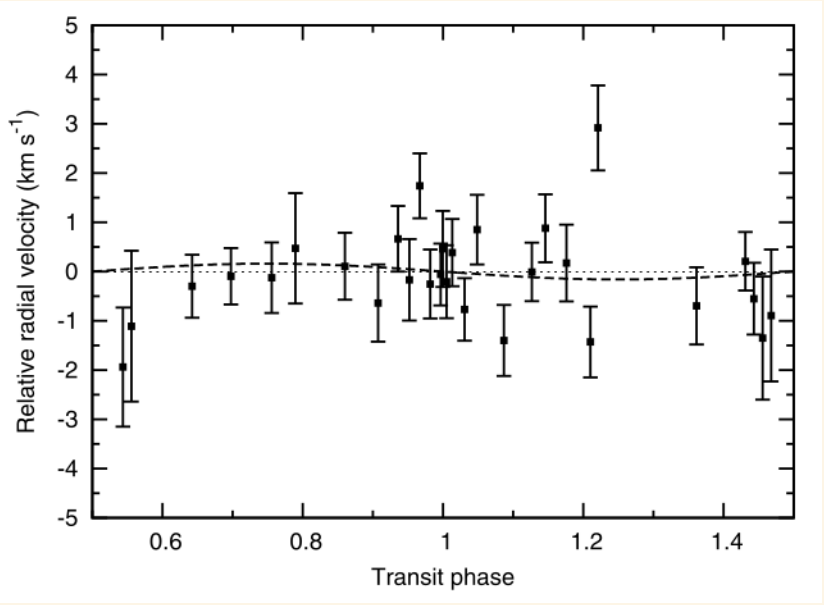
- Tidally-Excited-Oscillations in heartbeat stars (KOI-54, Welsh+, 2011)
- Eccentric close binaries
- Resonances with orbital period
- Sectoral non-radial pulsations
- Amplitude R*/a

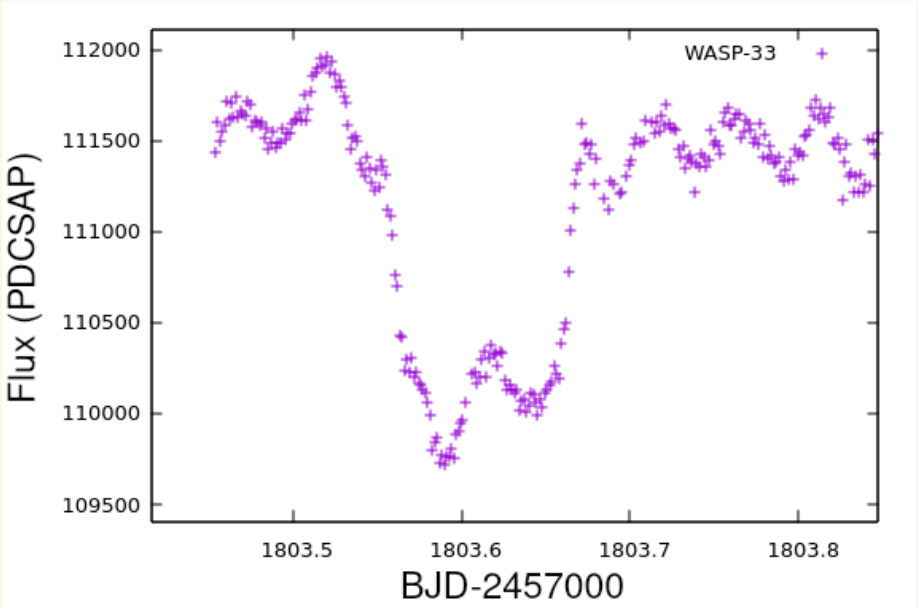


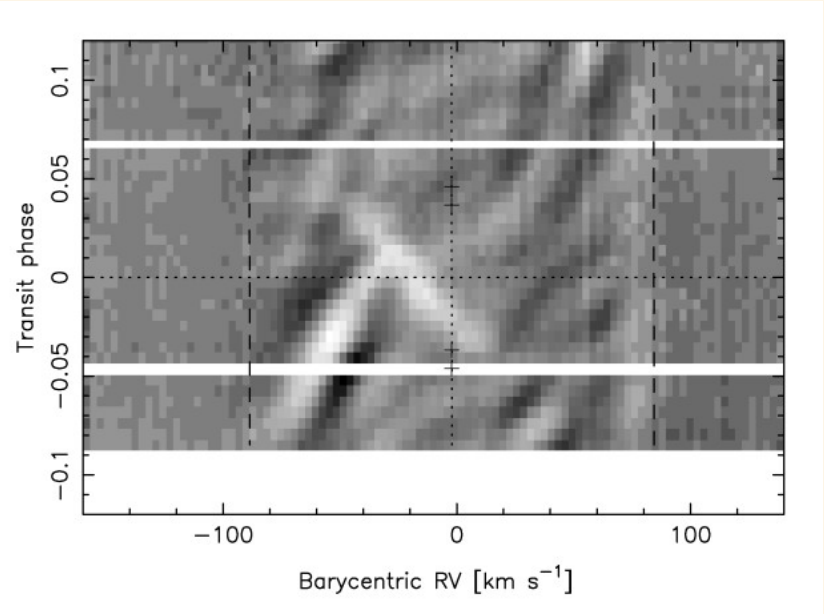
KIC 8719324,
Guo+, 2021

WASP-33b

- WASP-33b: A5V, $v \sin i$ = 86 km/s, V= 8.3, P = 1.22 days
- non-radial pulsations + rapid rotation prevent reliable radial-velocity measurement - σ(RV) ~ 0.8 km/s
- transit LC affected by pulsations
- planet confirmed in LSD profiles



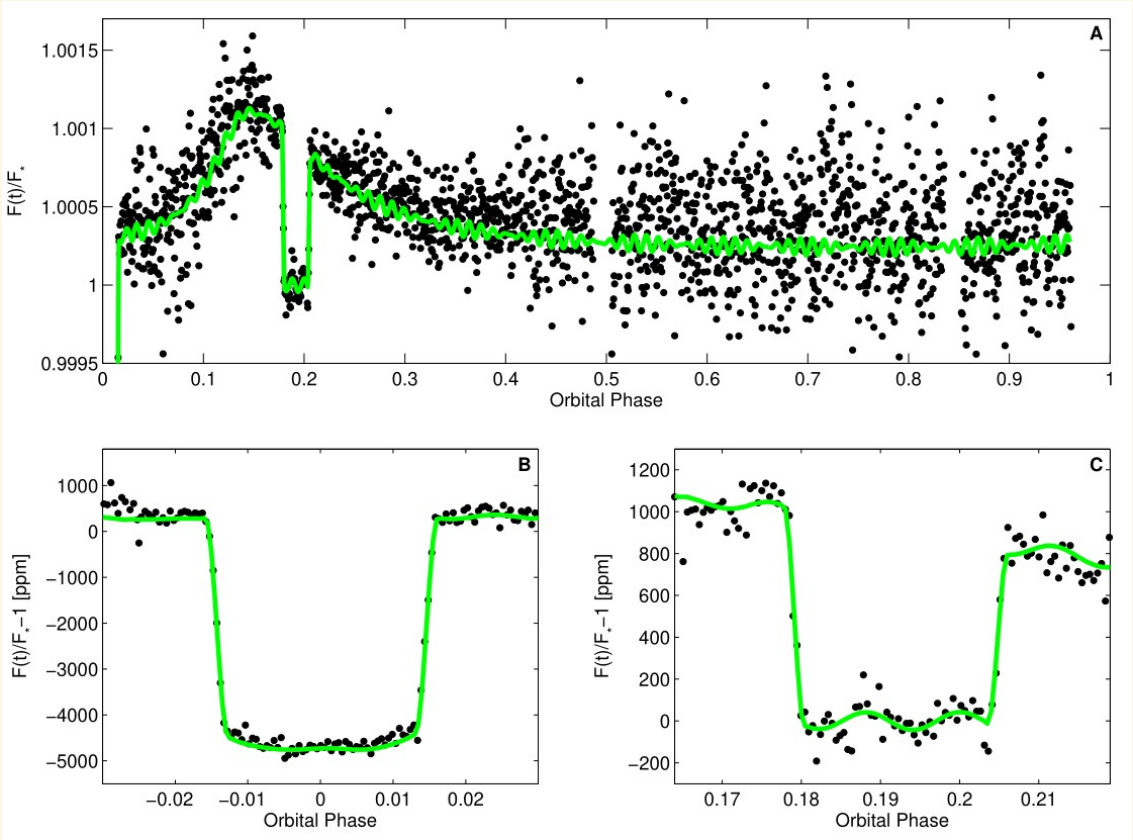




Collier Cameron+, 2010

HAT-P-2b

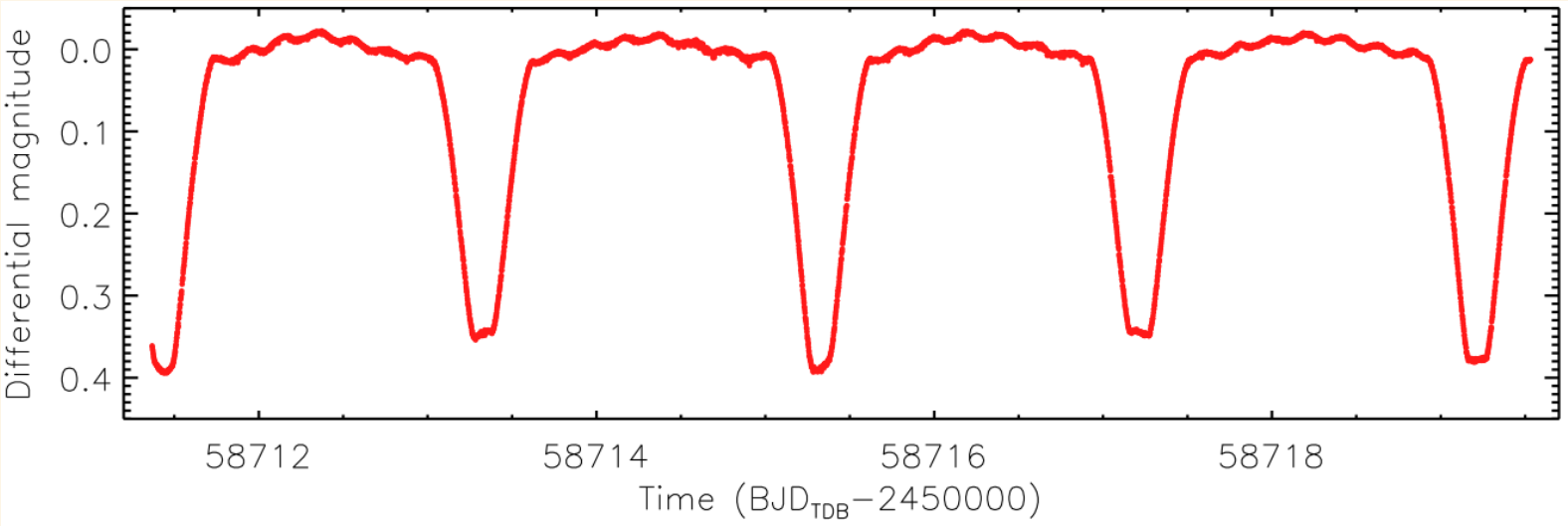
- HAT-P-2b: massive exoplanet with M = 8 Mjup, P = 5.63 days and e = 0.51
- Planet sufficiently massive to induce stellar pulsations, exact harmonics with $79\nu_{orb}$, $90\nu_{orb}$, $91\nu_{orb}$, $95\nu_{orb}$
- Inconsistent with resonant pulsational frequencies predicted by evolutionary and pulsation codes: tidal theories are incomplete!



Spitzer 4.5μm LC
de Wit+, 2017

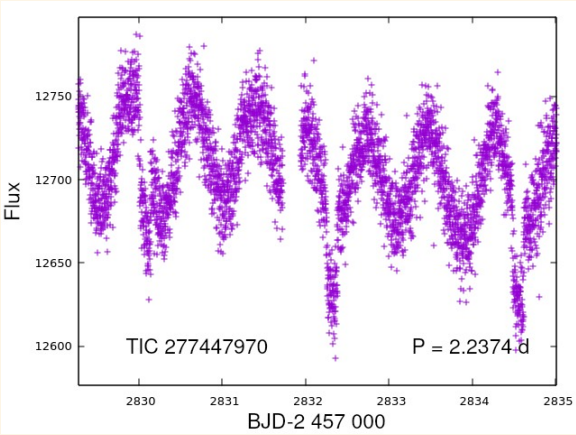
Motivation

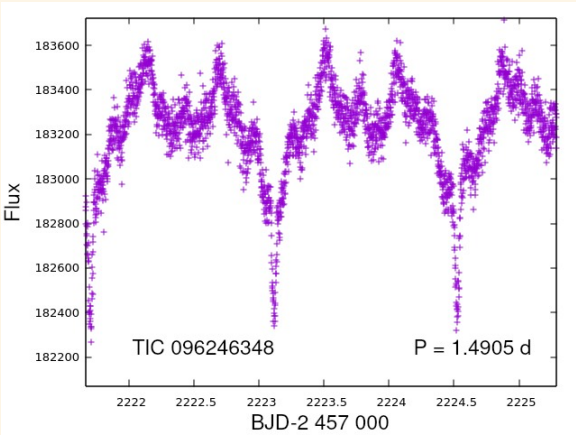
- EBs often contain a pulsating component - cannot be ignored
- EBs with some types of pulsator (e.g. Cepheids, RR Lyrae, β Cep) still rare
- Several transiting exoplanets/EBs with a pulsator were found in the TESS data (by- product of Msc./PhD. thesis of D. Orikhovskyi)

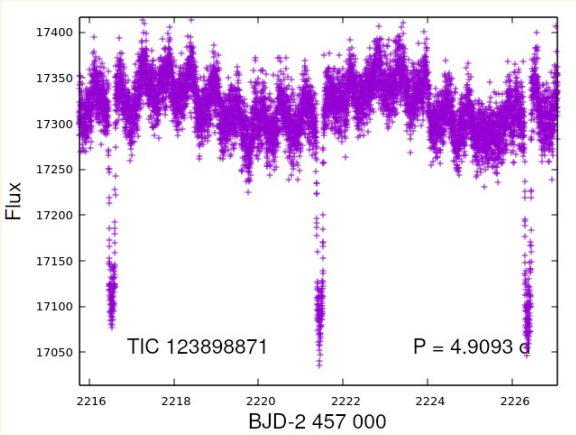


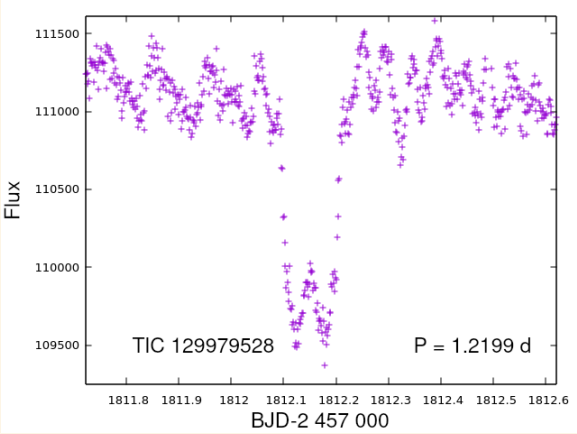
First accurate mass measurement of a β Cep pulsator, Southworth+, 2020

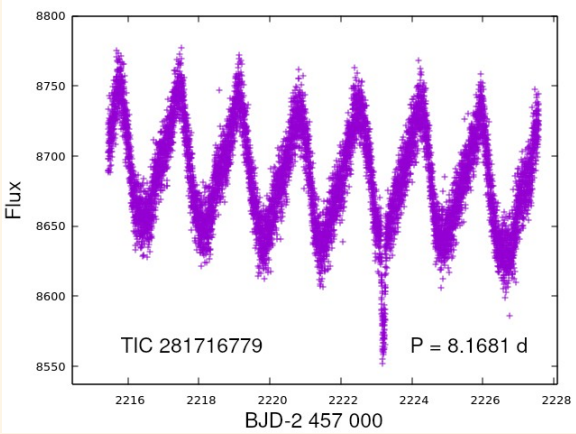
TESS pulsating parent stars

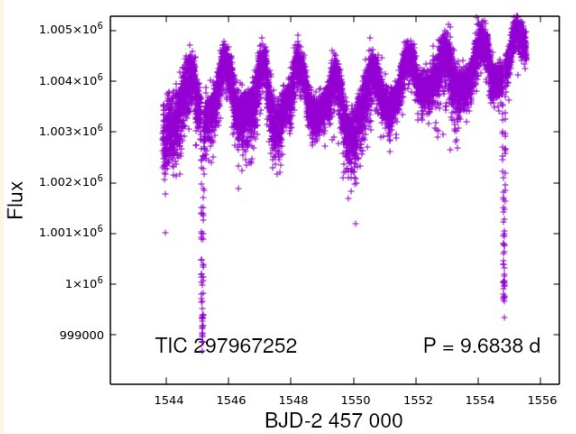








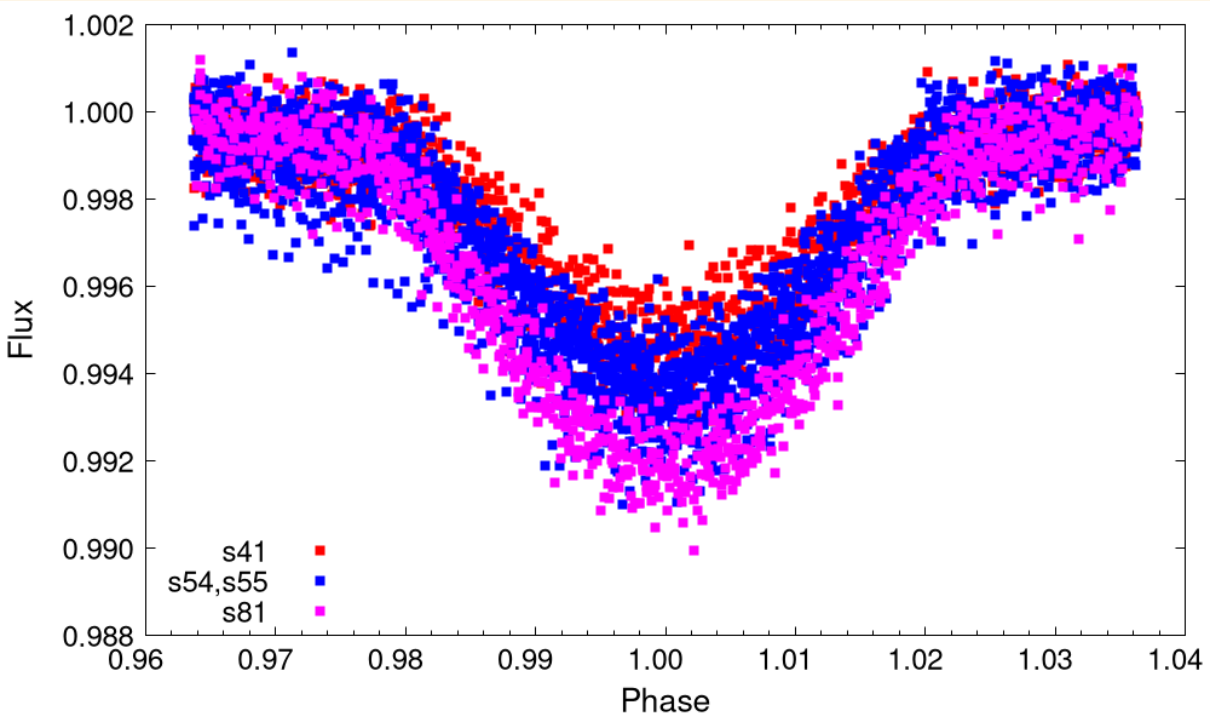




Three case studies

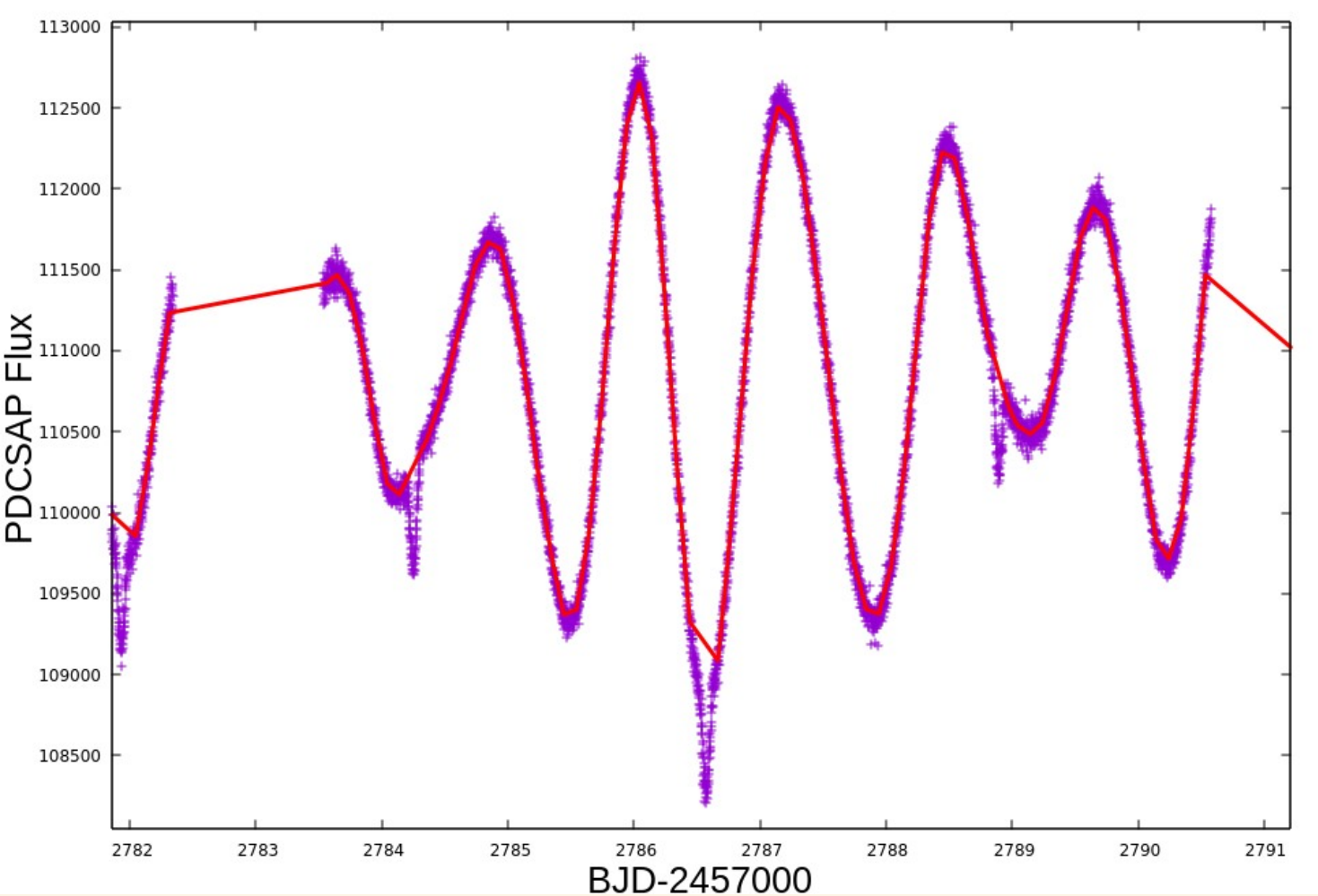
HD190257 - exoplanet candidate

- TIC117789567: B8V, $v \sin i$ = 155 km/s, V= 7.86, P = 2.32 days
- Aerts+ (2023): HD190257 is a slowly-pulsating B-type star (SPB)
- transit LC strongly affected by pulsations
- transit depth is increasing: precession of the orbit
- BD or a planetary mass companion
- tidally induced modes ?



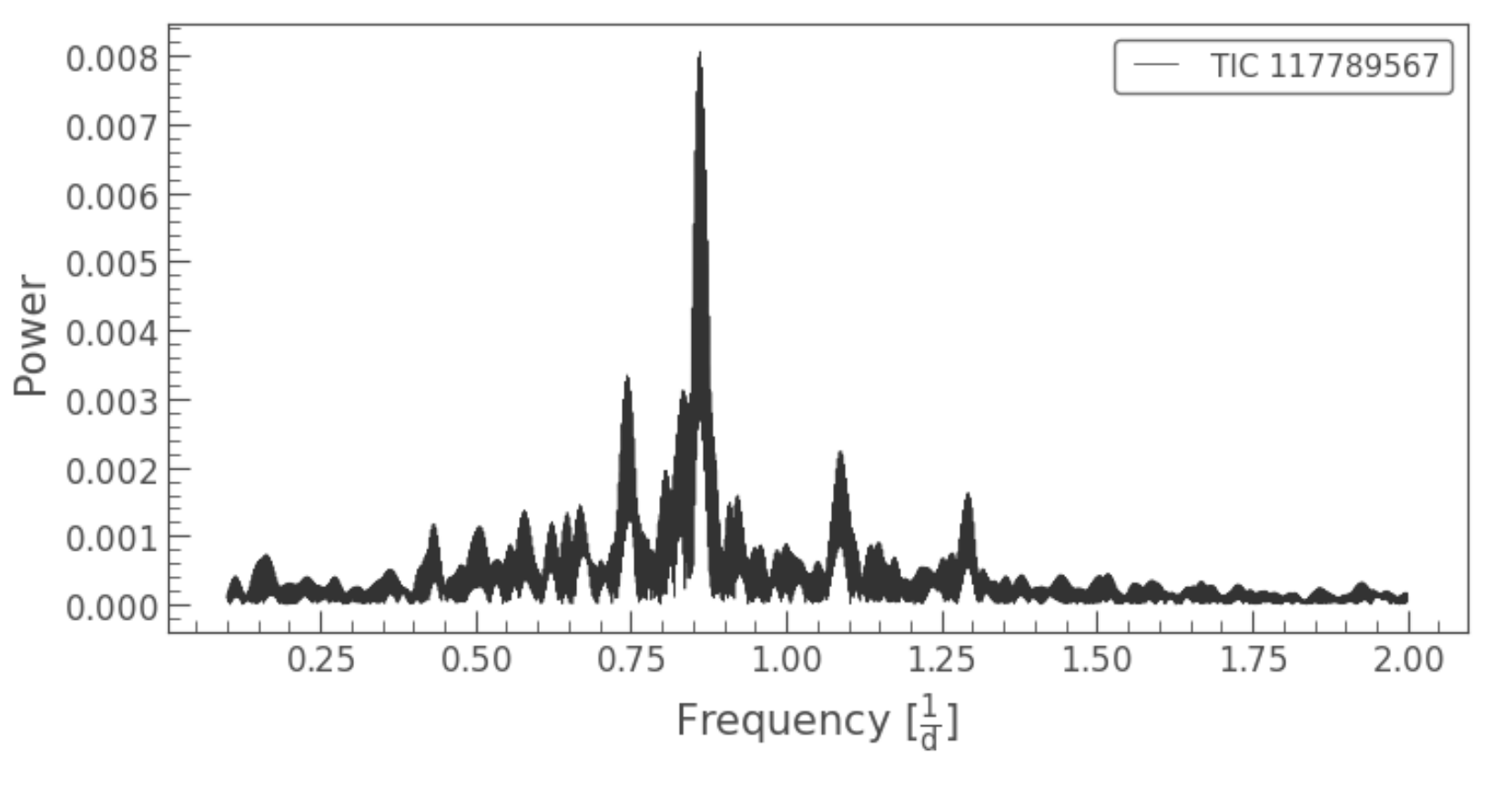
TESS data sectors s41, s54+55, s81, cadence 120 sec

HD190257



SPB oscillations of HD190257, the dominant period is close to the half of the transit orbital period, TESS data sector 54, cadence 120 seconds

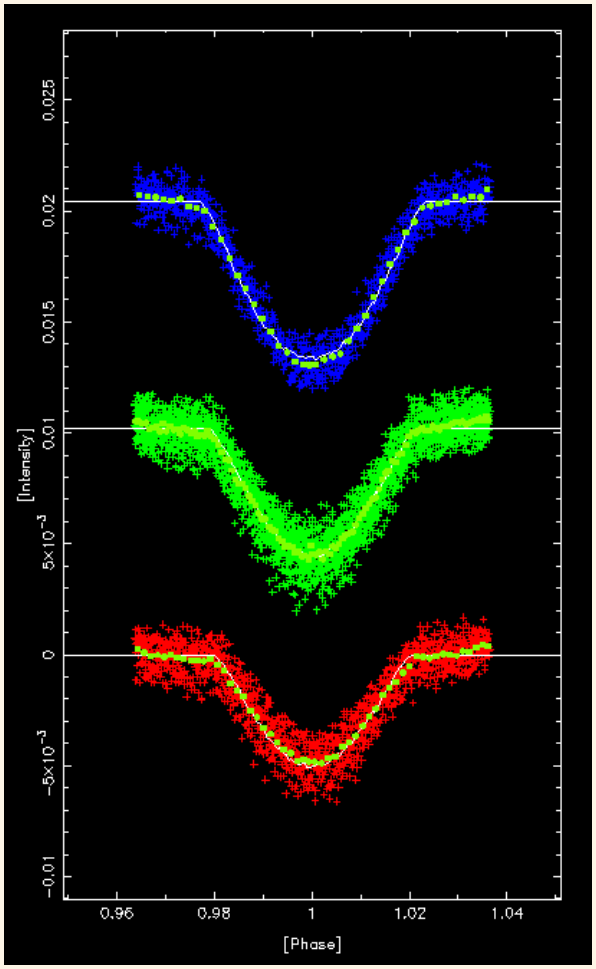
HD190257

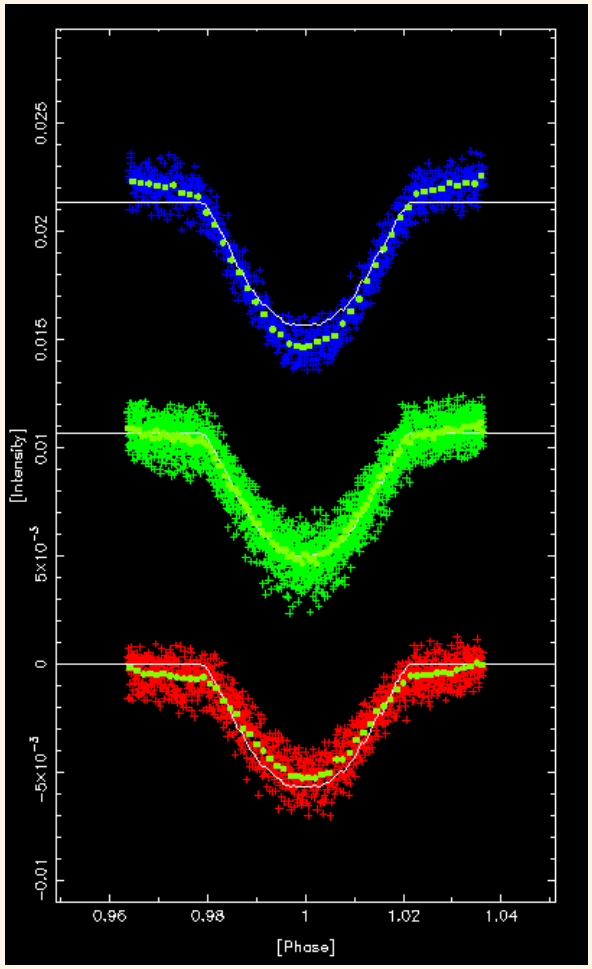


Lomb-Scargle periodogram: maximum power at P_1 = 1.160 days (=half of the orbital period), P_2 = 1.344 days, P_3 = 1.201 days, P_4 = 0.919 days

RMF model

- Grazing transits: big change of the LC but low information content
- RMF model: i = 76.27±0.04 deg, r_p/r_s = 0.0936±0.0006, di/dt = 0.225±0.004 deg/year, parameters affected by de-trending

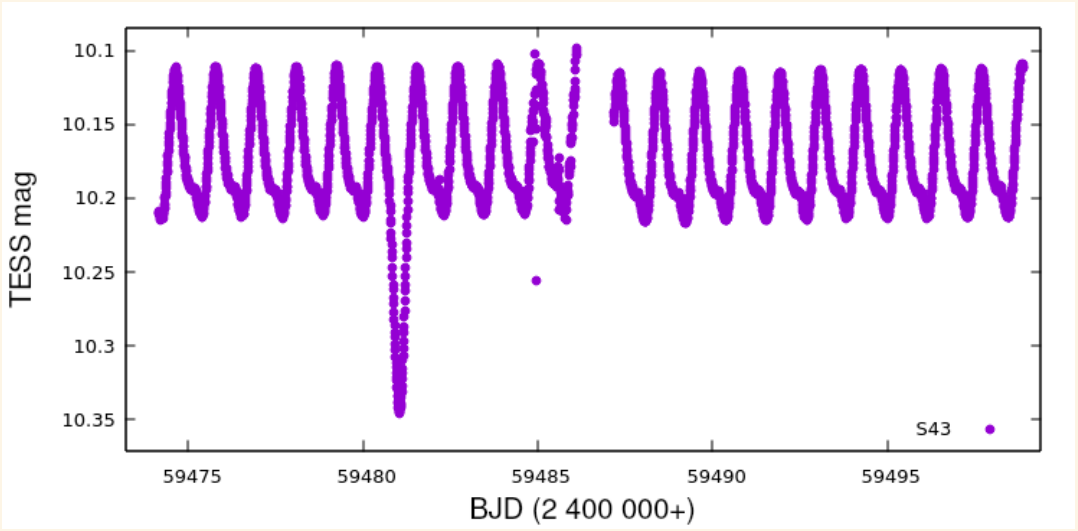


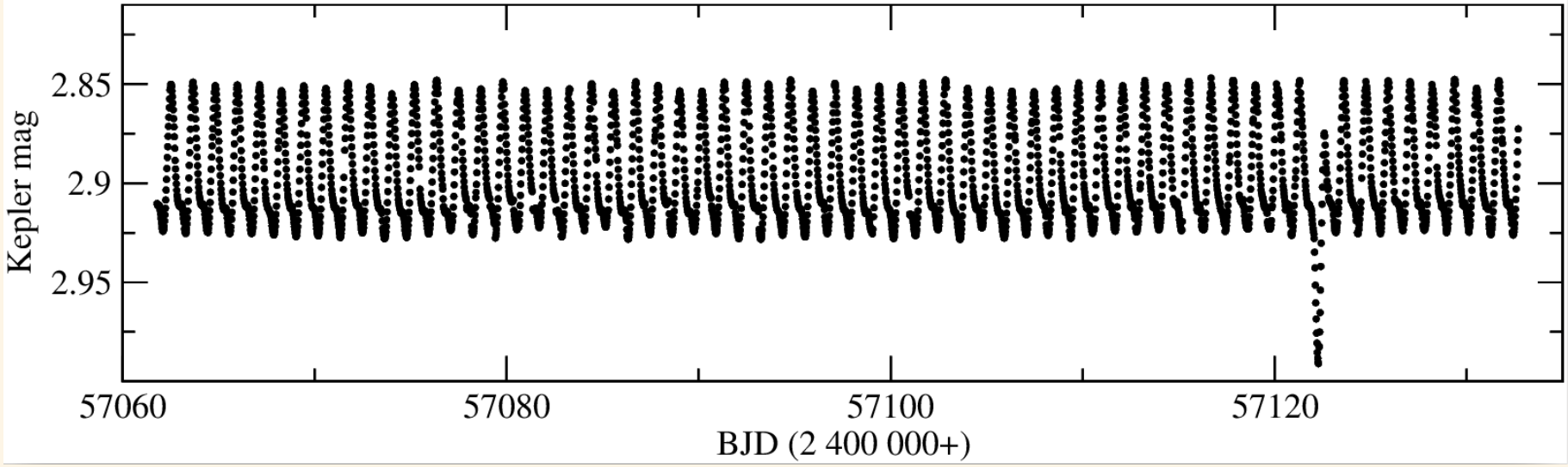


HD284179 - eclipsing binary

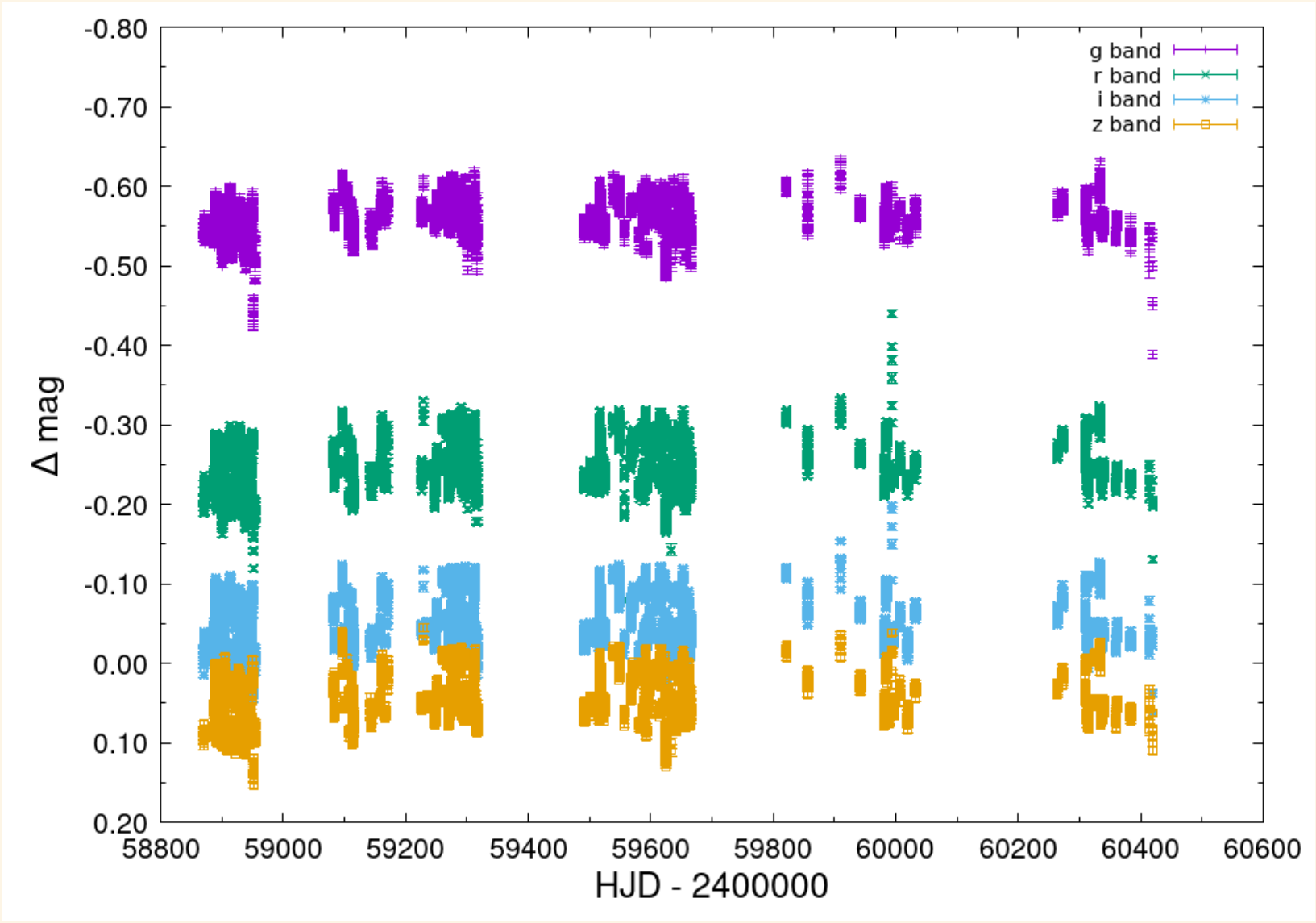
- TIC 15936806: A2V or A0III,
  $v \sin i$ = 96 km/s (APOGEE), V= 10.27, P > 65 days, P <=2360 days
- Jurkovich+ (2023) noticed an eclipse, probably Cepheid II or anomalous Cepheid pulsator
- Gaia: π = 1.371±0.028 mas, RUWE = 1.264, $T_{\rm eff}$ = 12536 K, log g = 4.036, [M/H] = -0.495
- Schmidt+ (2011) give pulsation period P = 1.15247 days, A = 0.07 mag
- Problem: featureless spectrum, poor RVs, lack of good comparison stars

HD284179: TESS/K2

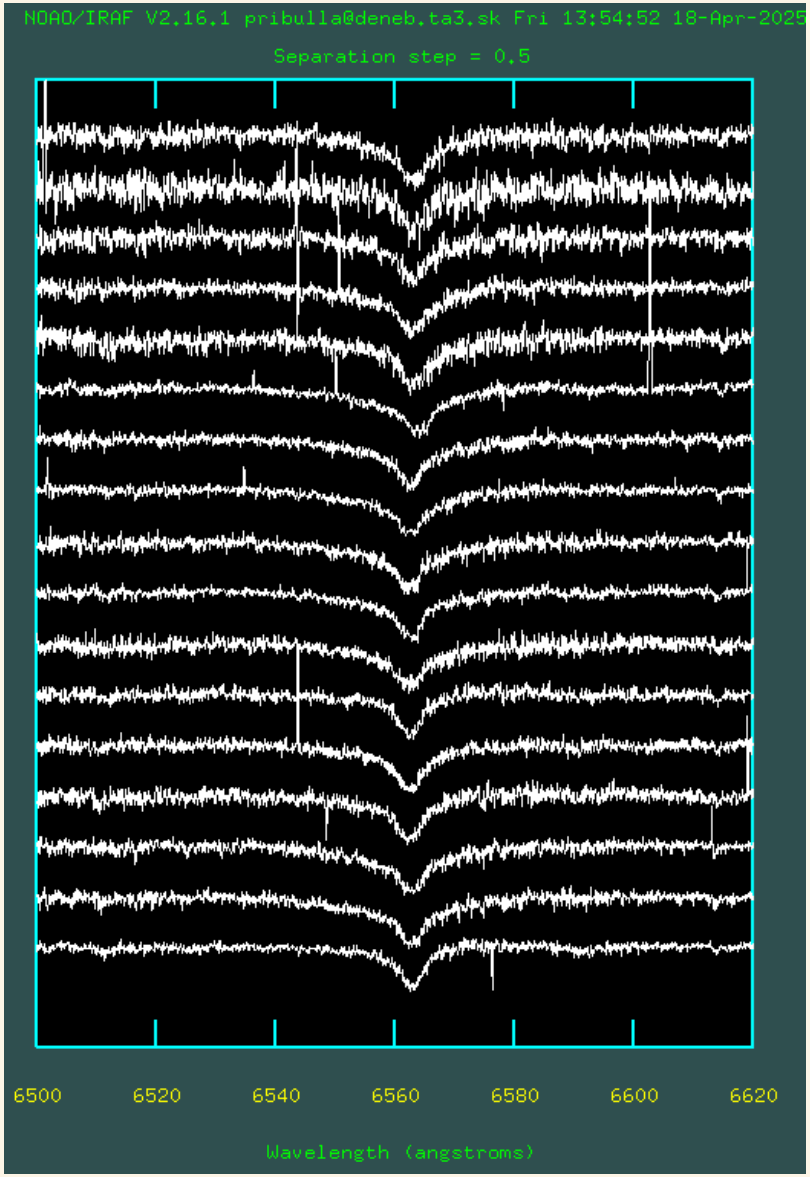




HD284179: GAO 80cm, griz



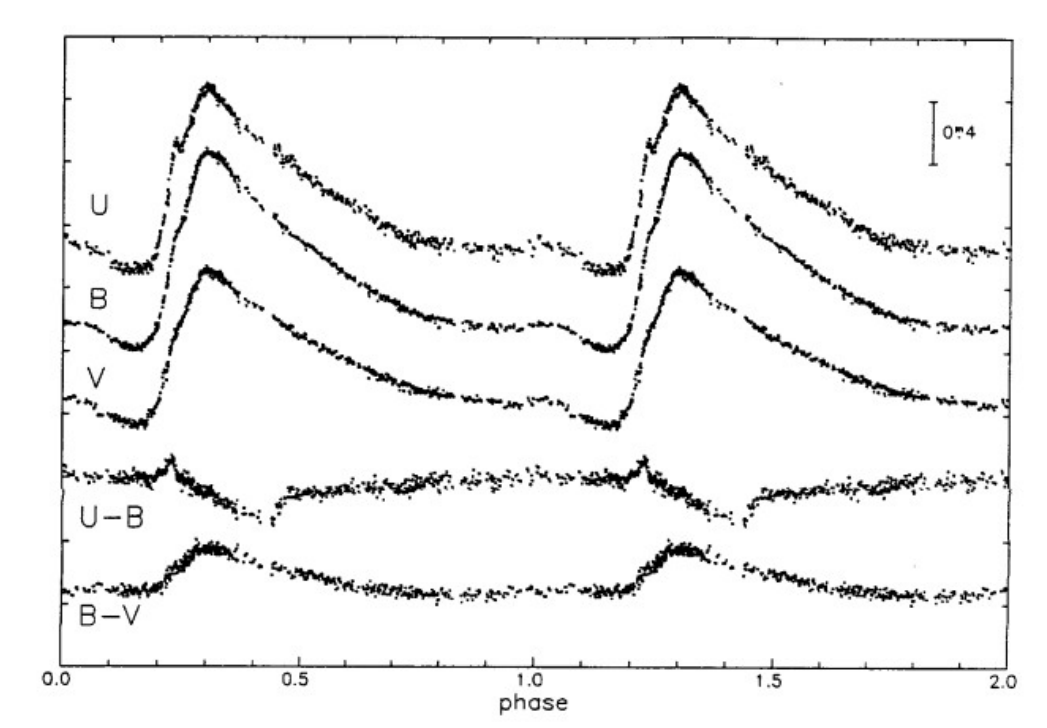
HD284179: MUSICOS@1.3m



- only hydrogen Balmer lines visible
- low metallicity – no metallic lines
- no helium lines
- relatively low SNR 14-41
- RV scatter too large to constrain orbital period
- possibly timing of pulsations ?

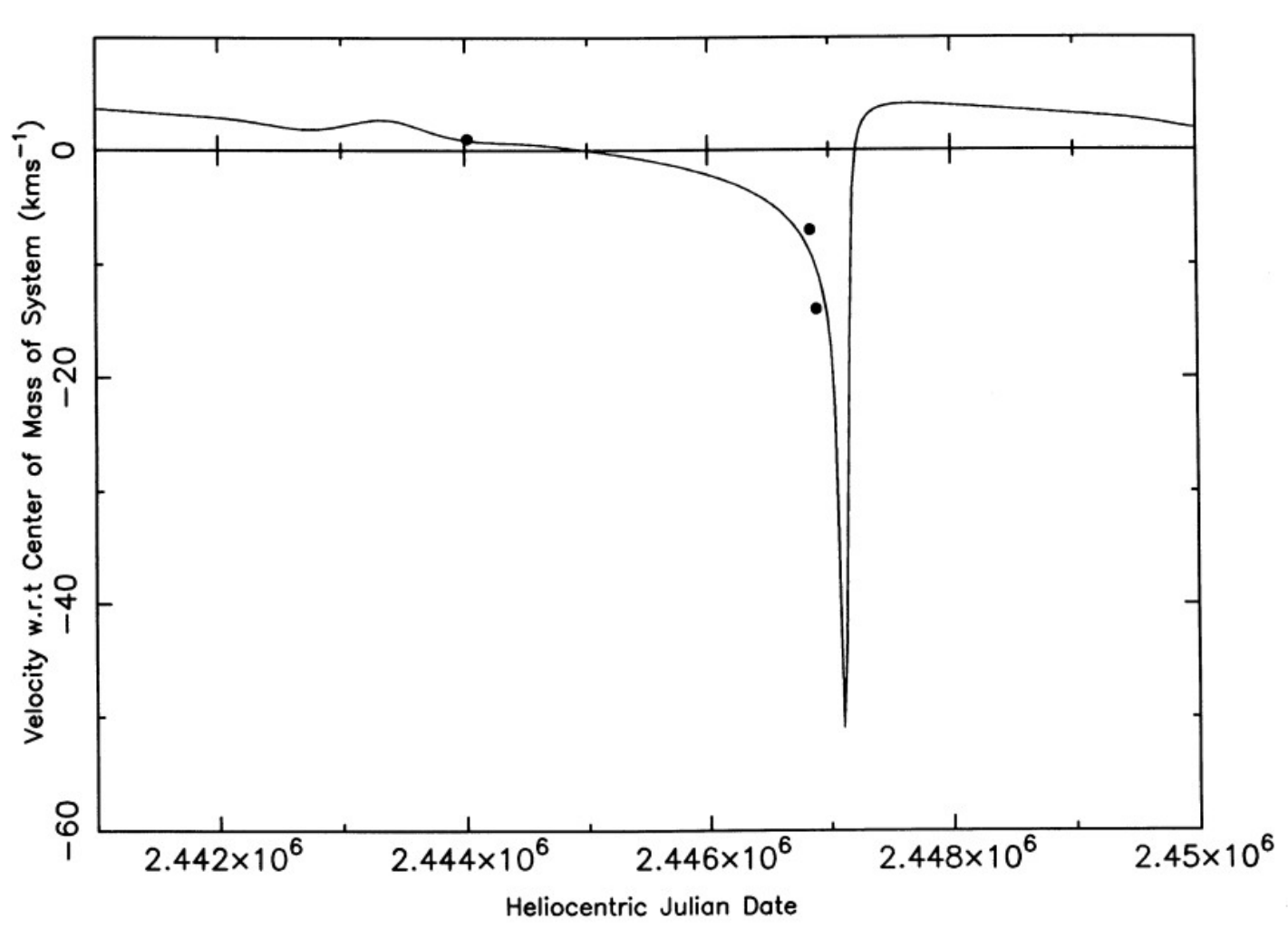
TU UMa - wide non-eclipsing system

- TIC 144376546: A8-F8, V= 9.26-10.24
- Guthnick & Prager (1929): RRab-type variable with P = 0.5577 days (no Blazhko effect)
- Saha & White (1990), extremely eccentric orbit with P_3 = 20.2 years, e=0.97 (RV curve and timing)
- The hypothetical companion invisible in the spectra: WD ?



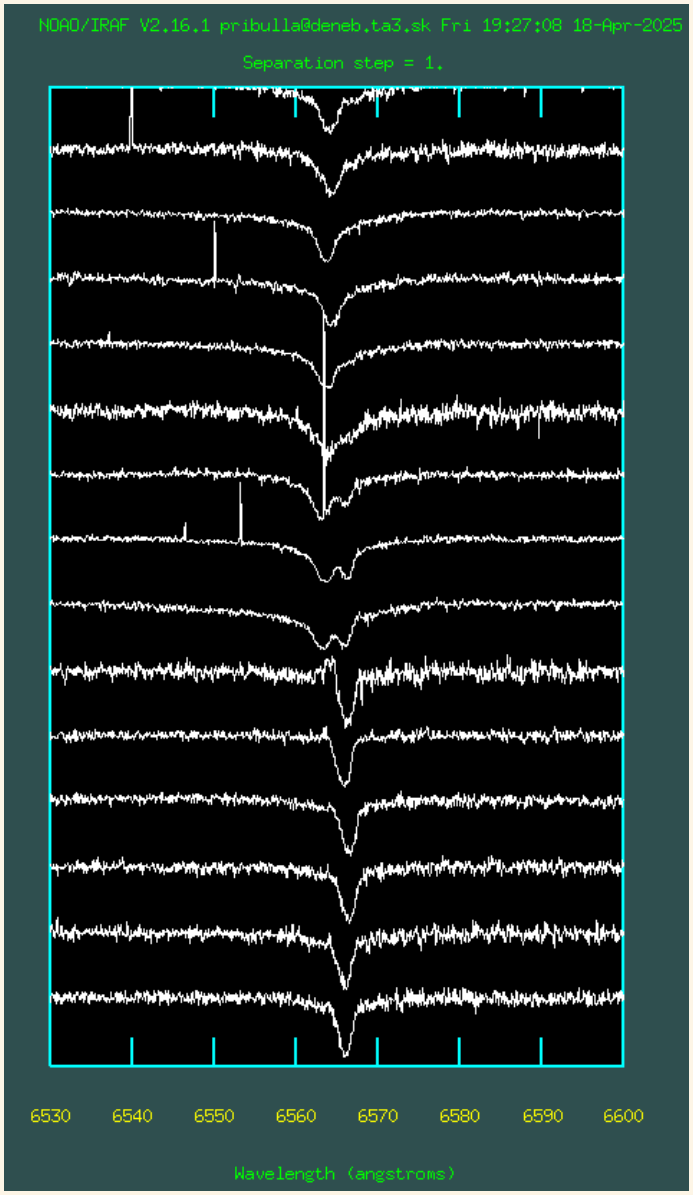
Kiss+ (1995)

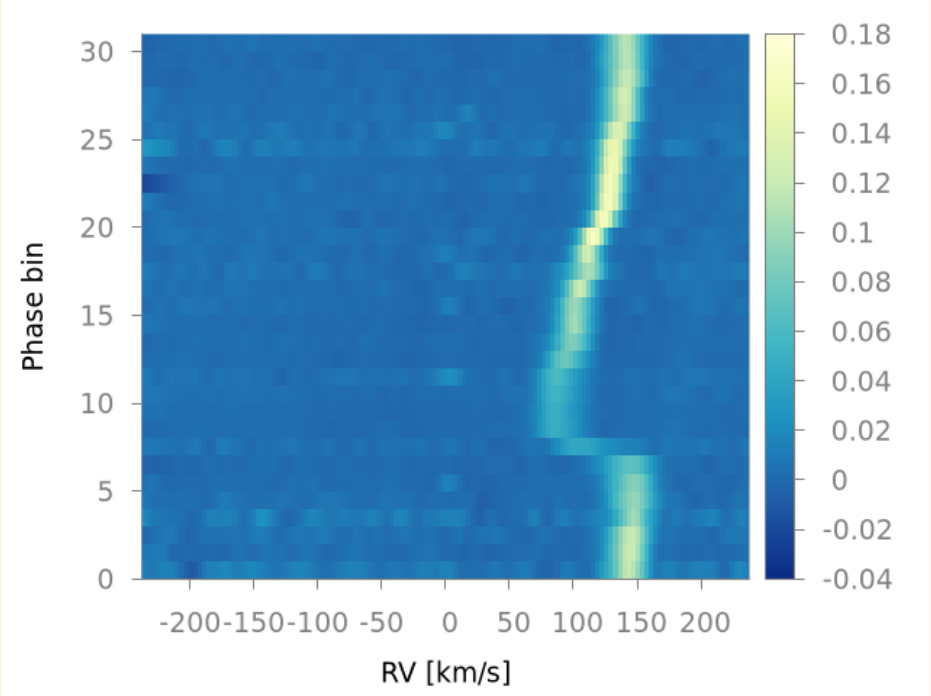
TU UMa



Saha & White (1990), next periastron spike 2027-2028

TU UMa: MUSICOS@1.3m





Trailing spectrum - BF phase change during the pulsation cycle from metallic lines

Hα line profile changes during the pulsation cycle, shocks due to the pulsations

Future plans

- Including radial/non-radial pulsations in the RMF code
- New spectroscopy and timing analysis of three enigmatic pulsators
- Search for resonances between orbital and pulsational frequencies in the TESS sample of hot exoplanet candidates

Thank you !



This work was supported by grants APVV-20-0148, and VEGA 2/0031/22.