

# Adding TESS to CRÉME

## Light curves and masses of 300+ eclipsing binaries

Krzysztof Hełminiak

A. Moharana, T. Pawar, G. Pawar, F. Marcadon

NCAC Toruń

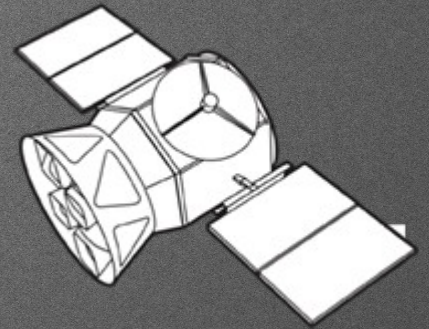
With the contribution from:

**R. Brahm**, J. Coronado, **N. Espinoza**, D. Graczyk, M. Hempel,  
**A. Jordan**, **E. Kambe**, **M. Konacki**, **S. Kozłowski**, **H. Maehara**,  
D. Minniti, E. Niemczura, J. Olszewska,  
B. Pilecki, M. Rabus, **M. Ratajczak**, **P. Sybilski**,  
A. Tajitsu, M. Tamura, A. Tokovinin, **N. Ukita**, L. Vanzi, et al.

Kopal 2024, Litomyśl, 13.09.2024

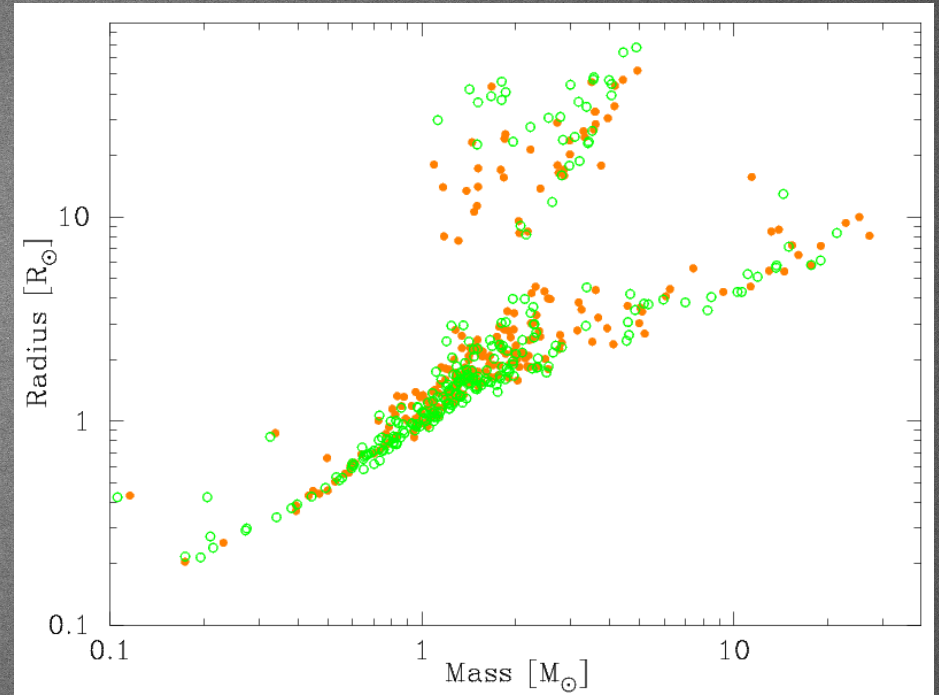
# Outline

- CRÉME – current status
- Satellite photometry – current status
- Highlights of recent (2022 - ...) results
- Next steps and future plans



# Detached Eclipsing Binaries (DEBs)

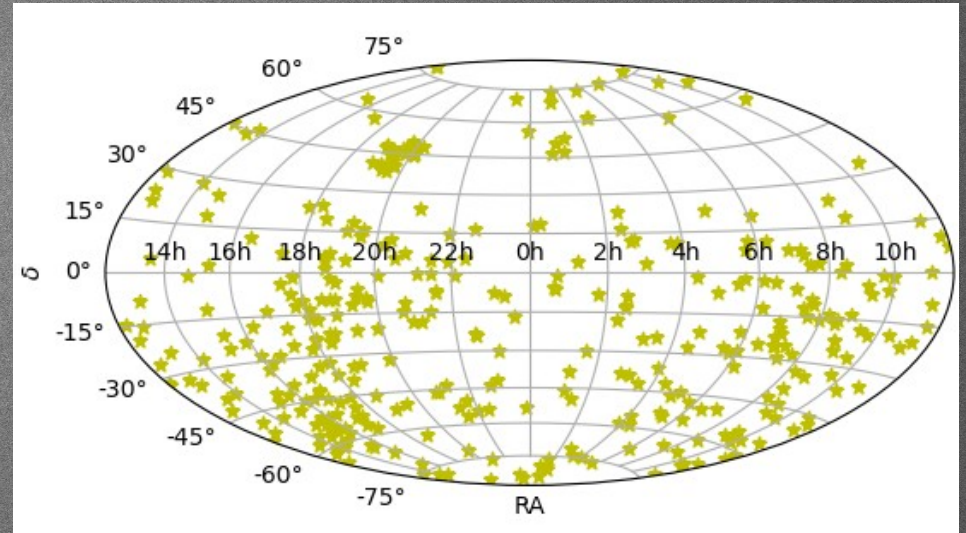
- 337 binaries with very precise ( $< 2\%$ ) parameters
- Large fraction of them has incomplete information (e.g. missing  $[M/H]$ )
- Under-populated regions  
M/R and HR diagrams



Southworth (2015)

# The CRÉME project

- Comprehensive Research with Échelles on the Most interesting Eclipsing binaries
- Identification of new examples of rare, poorly studied or otherwise interesting DEBs
- Precise characterization of the studied systems, including: determination of masses, radii, temperatures, distances, metallicities, and ages of stars
- **High-quality spectroscopic and photometric data needed**



# The CRÉME project statistics

- 386 targets observed (2011 - ...)
- 7000+ high-resolution spectra
- 19 spectrographs, 17 telescopes
- 300+ n of total telescope time



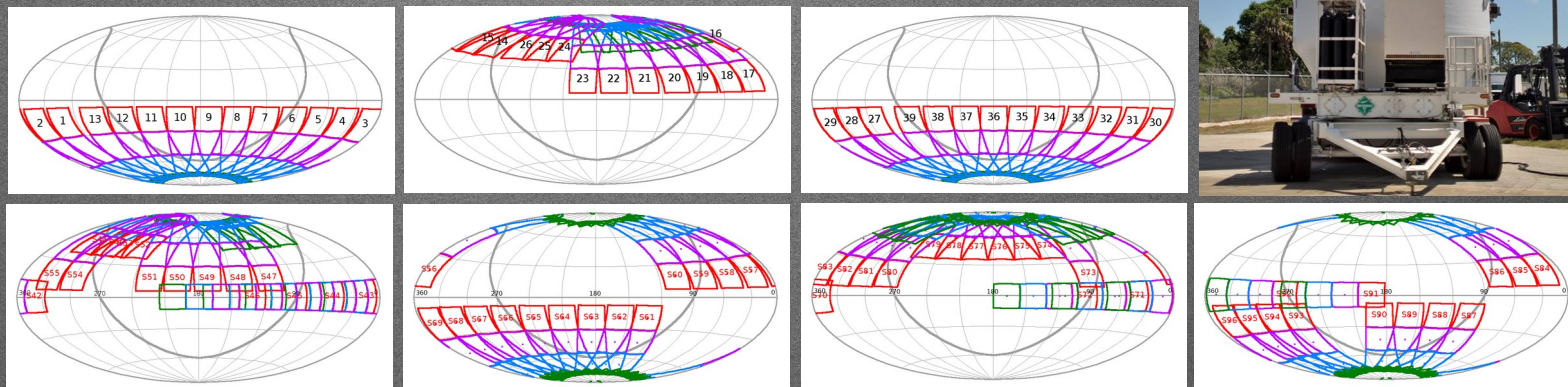
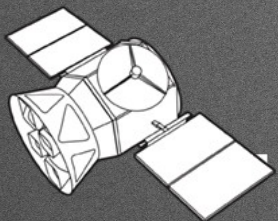
Tel./Spec.	Time	Tel./Spec.	Time	Tel./Spec.	Time
OA0 188cm/HIDES	87.5 n	TNG/HARPS-N	16 n	Magellan-Clay/PSF	4 n
CTIO 1.5m/CHIRON	753 h	SALT/HRS	116 h	NOT/FIES	4 n
Euler/CORALIE	40 n	ESO 3.6m/HARPS	4.5 n	OHP 1.9m/SOPHIE	3 n
MPG 2.2m/FEROS	30 n	Subaru/HDS+IRCS	4.5 n	VLT/UVES	3.5 h

Additionally: Radcliffe/GIRAFFE, AAT/UCLES, OUC-50cm/PUCHEROS, Keck I/HIRES, TNG/SARG, Hamilton/HamSpec

Archives: ESO, SOPHIE, ELODIE, KOA, APOGEE

# TESS operations summary

- Launched 18.04.2018. Observing since 24.07.2018
- Towards 100% with the second extended mission.
- **Currently: sector 83 (Cycle 6)**



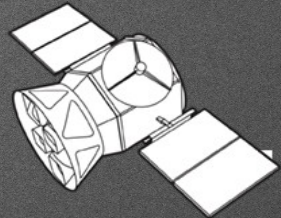
# TESS GI programs of CRÉME targets

- Successful GI applications since Cycle 1
- Current status:

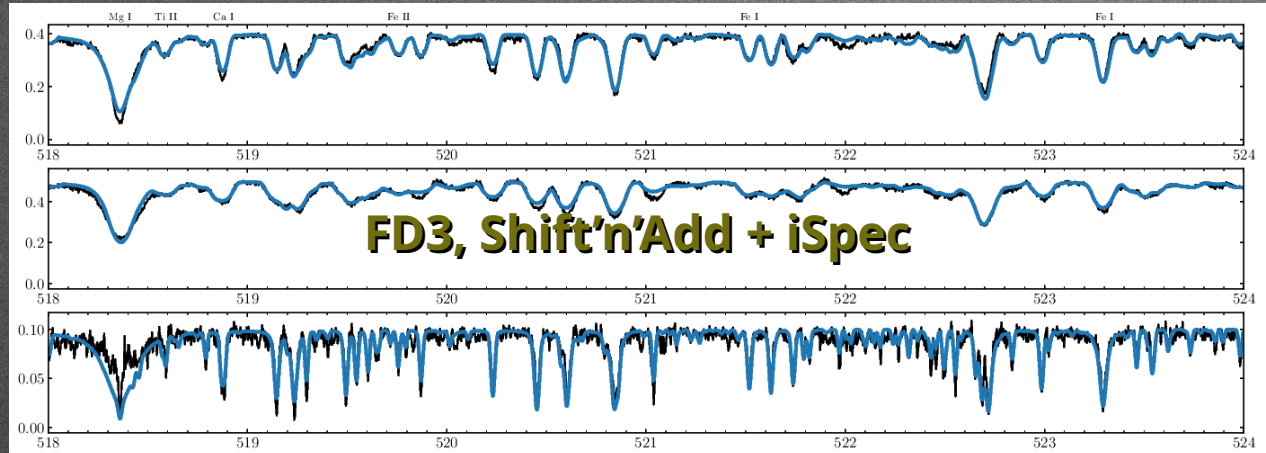
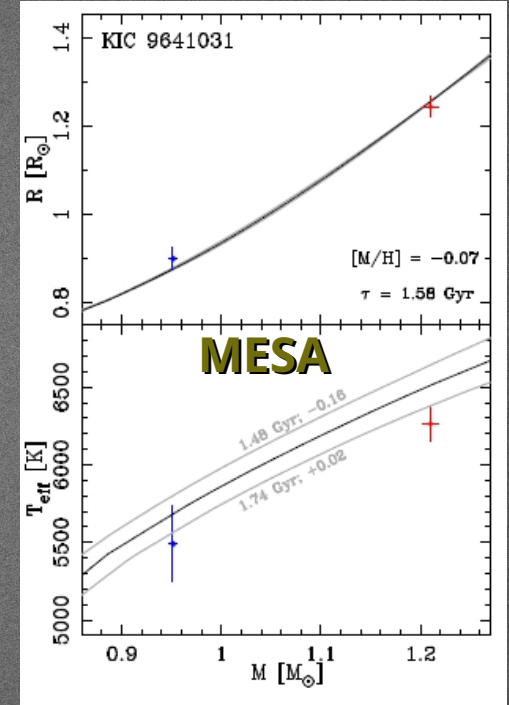
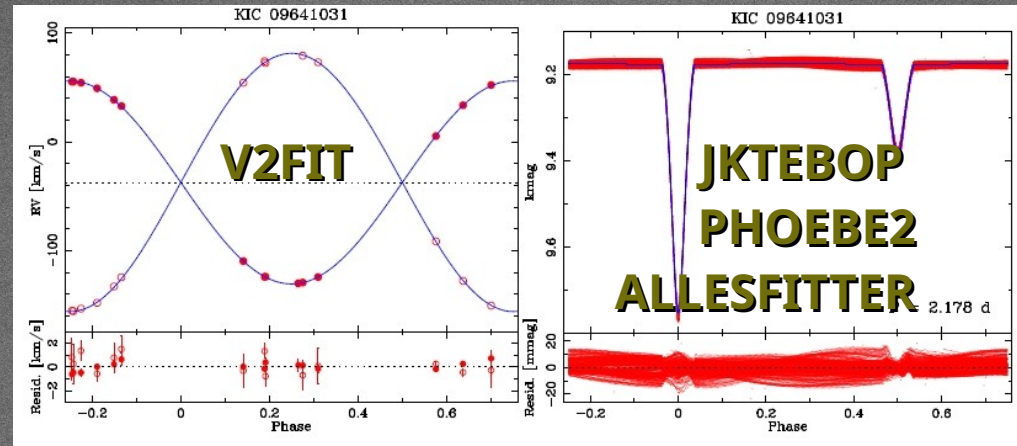
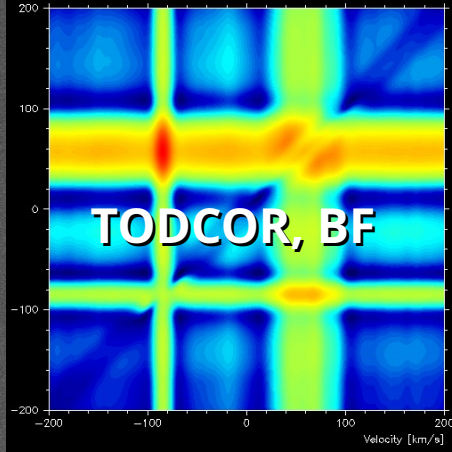
- 1 sector: 66
- 2 sectors: 117
- 3 sectors: 49
- 4 sectors: 34
- 5–13 sectors: 51
- 14-29 sectors: 12

- Additionally: *Kepler* (24) and *K2* (8) observations  
*PLATO* LOPS2 (29)

TOTAL: **329** targets  
(from 83 sectors)  
+ FFI for 6 targets  
+12 more expected in C7



# Methodology

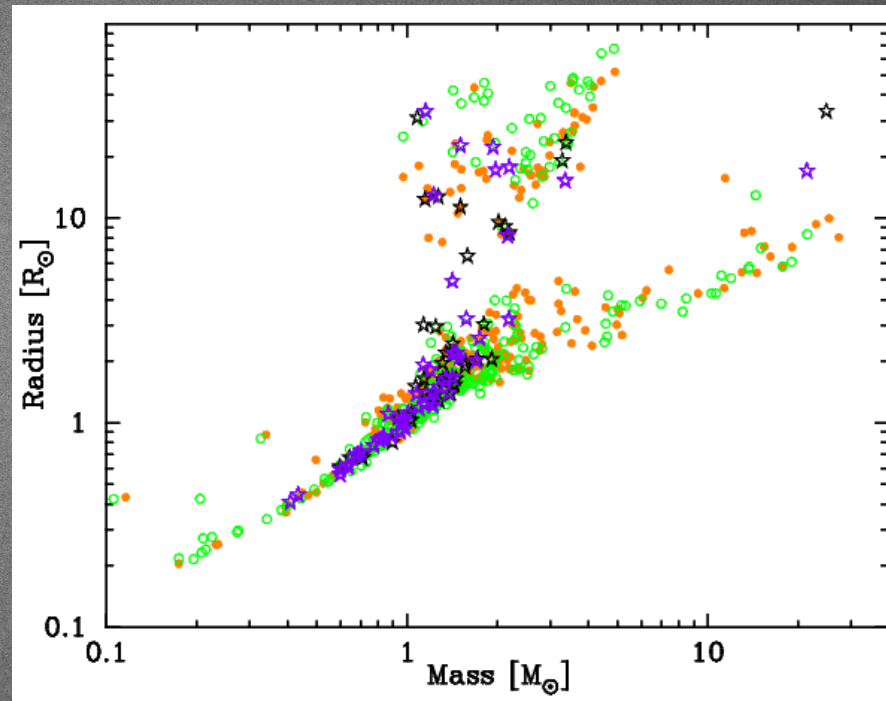


Hełminiak et al. 2021  
Moharana et al. 2023



# Results: summary

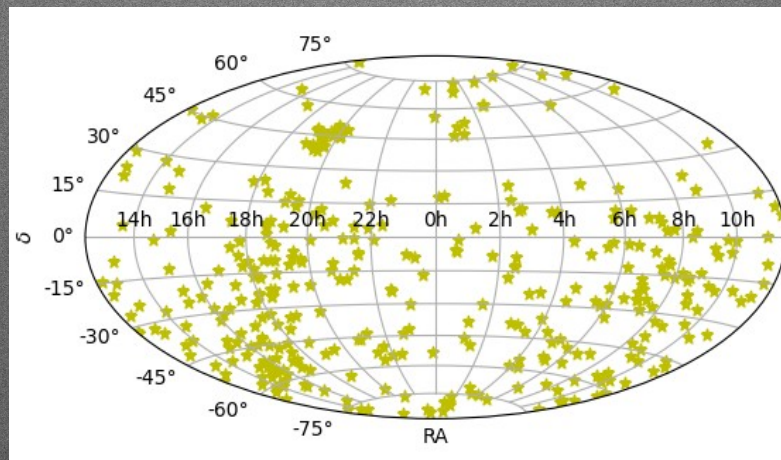
- ~100 models of DEBs with CRÉME data
- 34 published papers
- 28 CRÉME targets in DEBCat
- Examples of results:
  - Low-mass stars
  - Late-type (sub-)giants (M. Ratajczak)
  - Pulsators of various kinds
  - High-order ( $N > 2$ ) multiples
  - Benchmark star candidates
  - High-mass giants
  - Pre-main sequence (PMS)



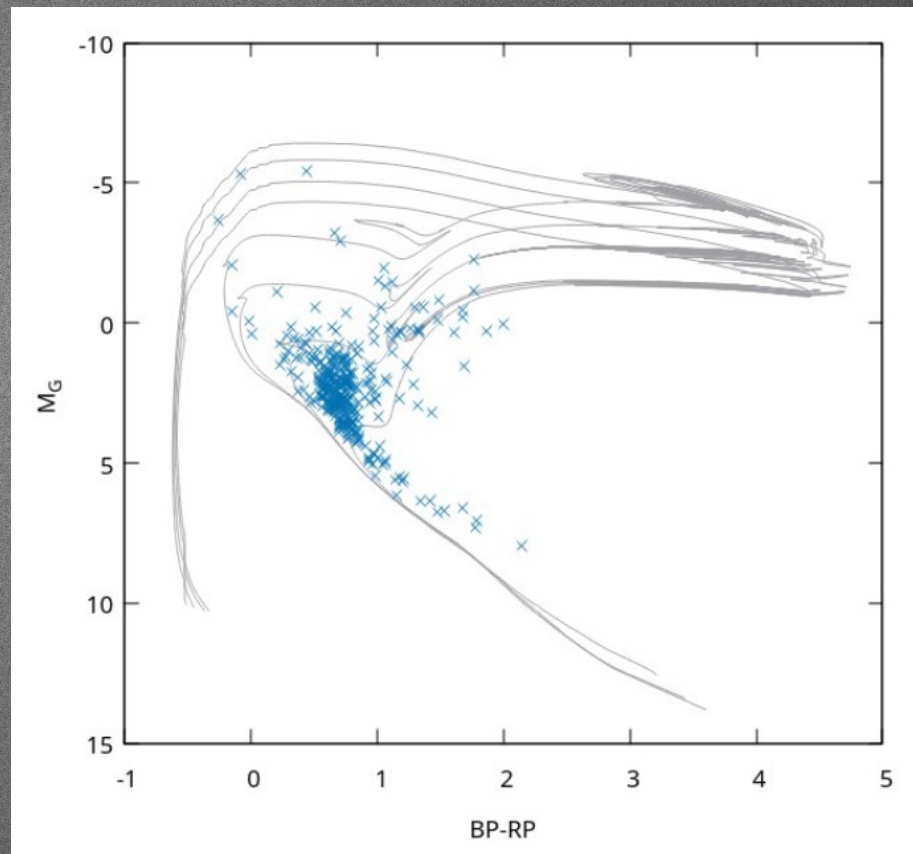
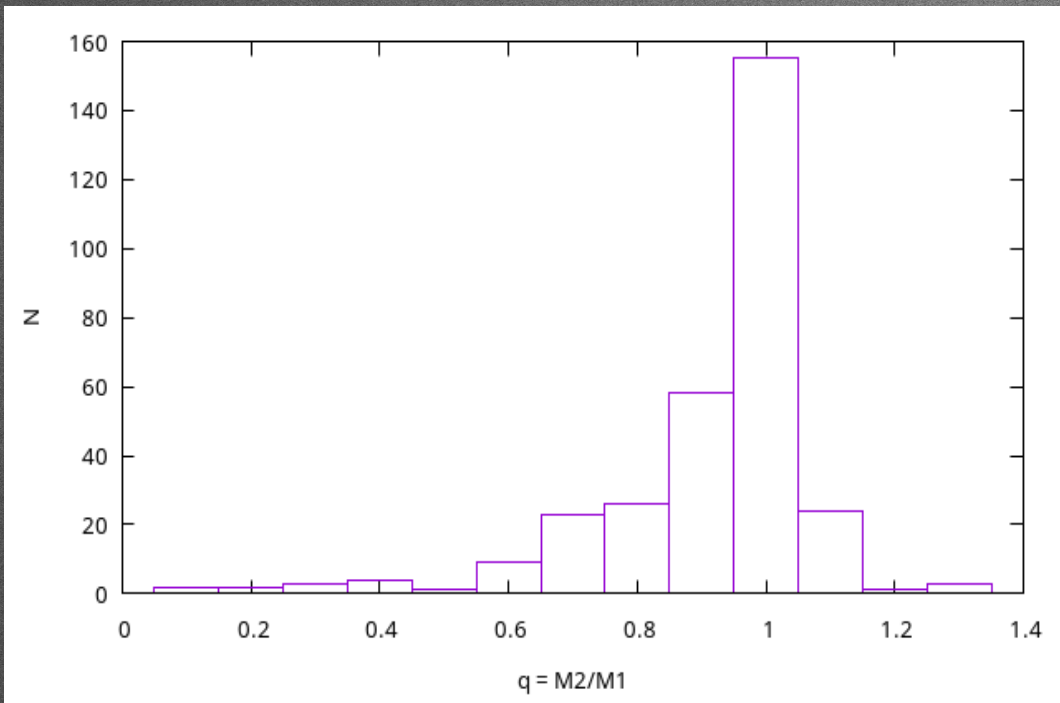
DEBCat vs. CRÉME published

# Results: The 325

- Mass  $M \sin^3(i)$  estimates (not final!) for 650 stars in 325 double-lined CRÉME eclipsing binaries
- 300+ of them with TESS or *Kepler/K2* photometry
- **Masses are enough to identify a lot of interesting cases**

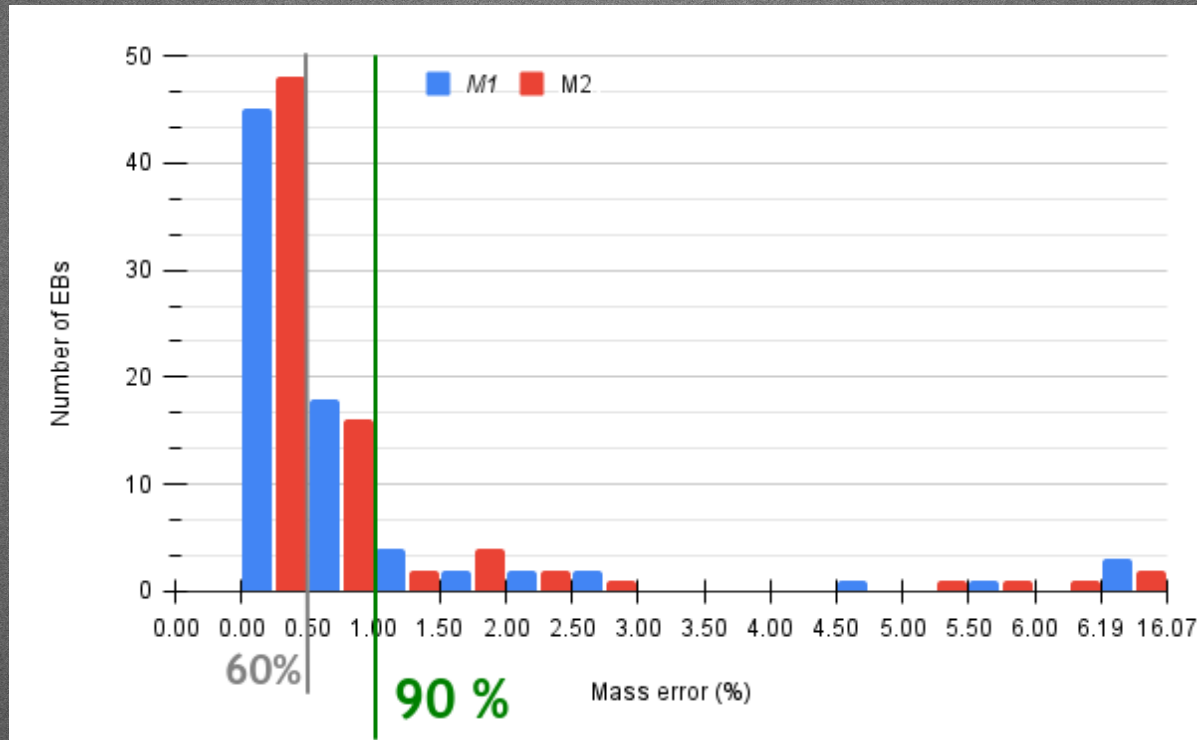


# Results: The 325



# Results: Mass precision

- 78 “long-period” ( $P > 4d$ ) systems with mass error determination

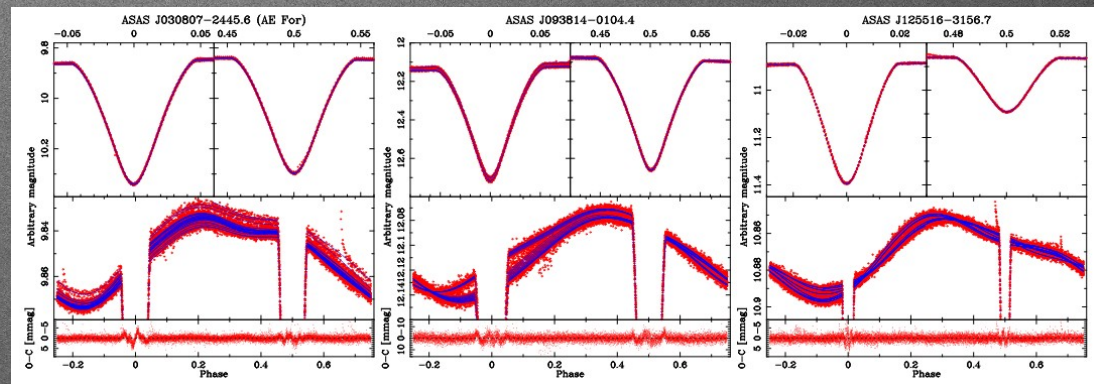
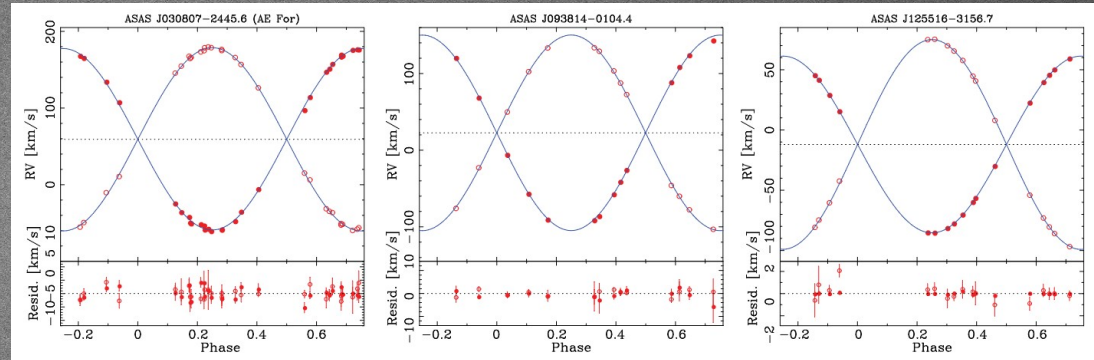


**Best case:  
0.051+0.058%**

# Results: Low-mass stars

- 19 DEBs with two  $M < 0.9 M_{\text{sun}}$  components (work in progress)

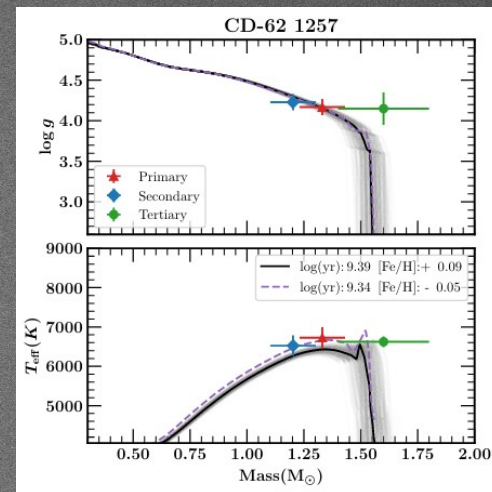
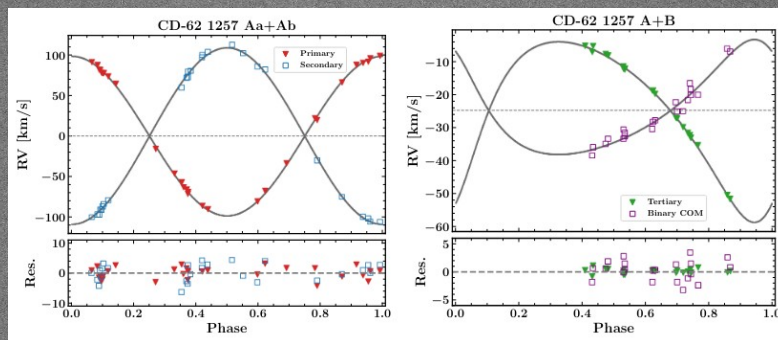
ASAS ID	TIC	RA ( $^{\circ}$ )	DEC ( $^{\circ}$ )	TESS Sectors	V (mag)
011328-3821.1	183596242	18.3679518	-38.3510354	2,3,29,30	11.72
012726-4928.4	158582802	21.8579947	-49.4735722	2	11.45
022311+1630.6	408627978	35.7963686	+16.5099728	42,43	12.09
024013+6144.0	50191648	40.0544455	61.7330474	18,59	10.42
024946-3825.6	215258019	42.4419509	-38.4273681	3,4	11.71
030807-2445.6	88479623	47.0291965	-24.7591243	4,31	10.19
032923-2406.1	144539611	52.3463638	-24.1004384	4	9.36
045304-0700.4	9380768	73.2685086	-7.0066604	5	11.13
050816-4449.1	200363294	77.0643897	-44.8193630	4,6,31,32 <sup>a</sup>	10.15
082552-1622.8	409797166	126.4641538	-16.3797396	34	10.29
093814-0104.4	14307980	144.5561535	-1.0745686	8,35,62	12.31
095039-0530.7	78151317	147.6638052	-5.5120566	8	10.07
112122-4736.1	162585265	170.3406886	-47.6009034	10,63,64	10.39
115632+0717.8	380642488	179.1342228	+7.2974779	46,49	9.53
122408-1914.0	423591132	186.0343834	-19.2325385	37	11.41
125516-3156.7	103683084	193.8187276	-31.9462195	10,64	11.51
174044-0746.2	295936907	265.1824243	-7.7702703	—	10.30
204117-1445.4	327589375	310.3211516	-14.7574544	—	10.65
212954-5620.1	381857817	322.4749409	-56.3348664	1	11.93



# Results: Compact Hierarchical Triples (CHT)

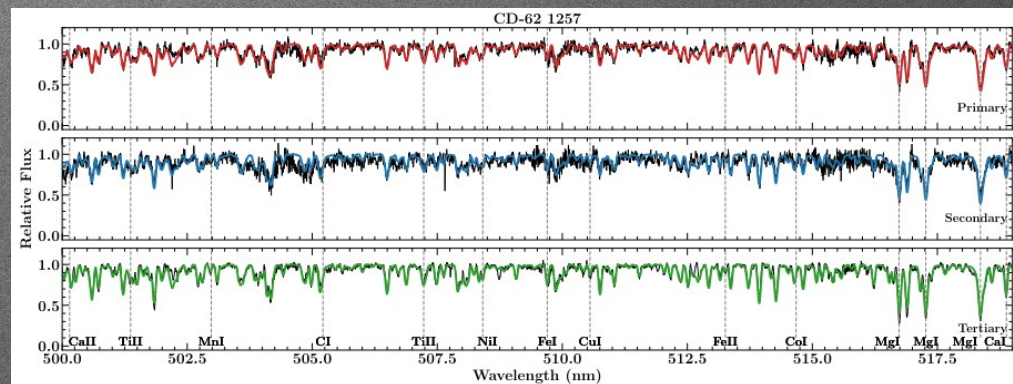
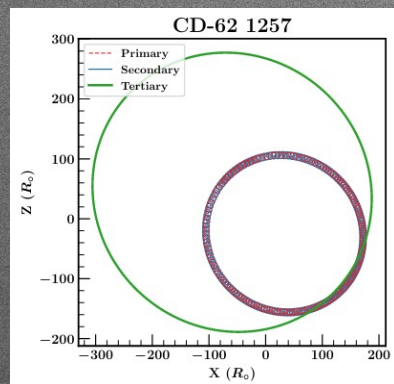
- Short-period DEBs with a third star on a  $P < 1000$  d orbit
- Fundamental parameters of up to 3 components

Talk E12 and poster EP06 by Ayush Moharana



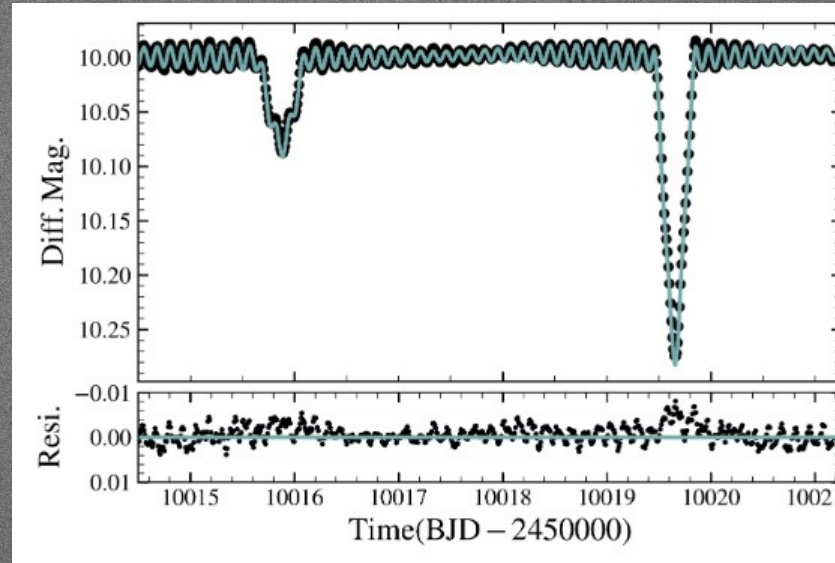
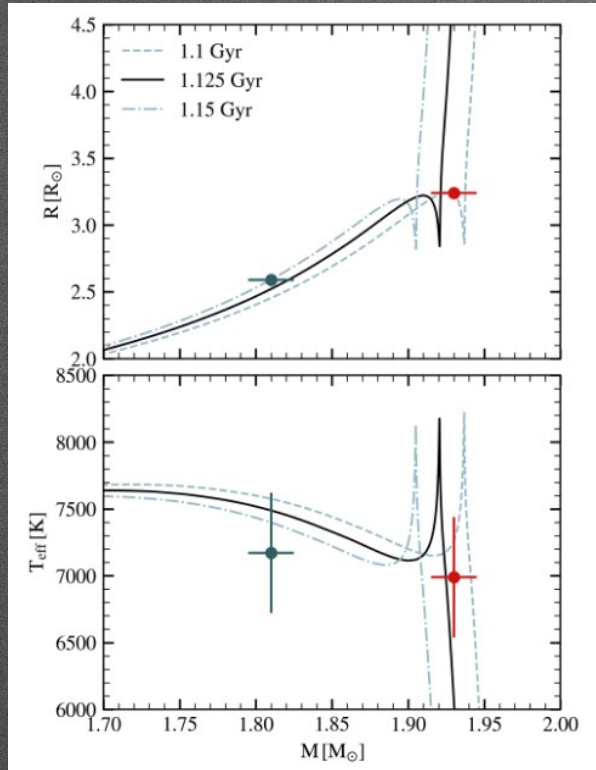
Also:

- Moharana et al. 2023 MNRAS, 521, 1908
- Moharana et al. 2024 arXiv:2405.12136

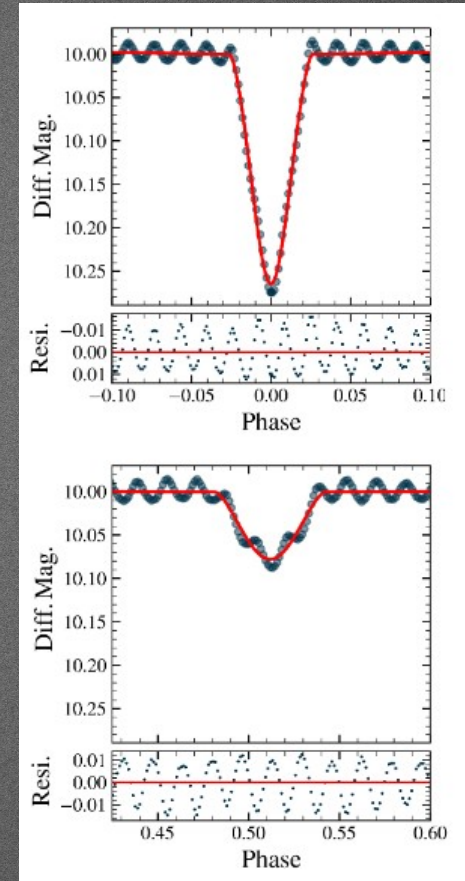


# Results: Pulsating stars in DEBs

- Stellar parameters of 16 new DEBs with  $\delta$ -Sct and  $\gamma$ -Dor pulsators



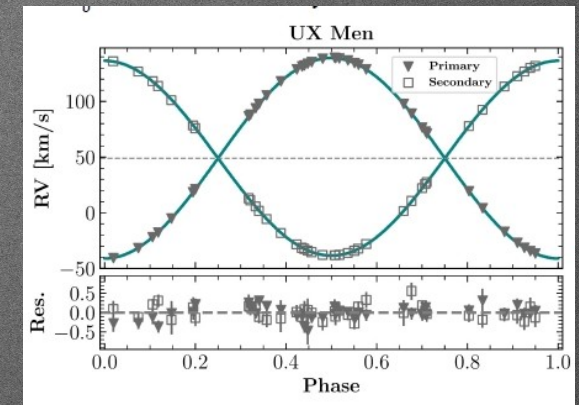
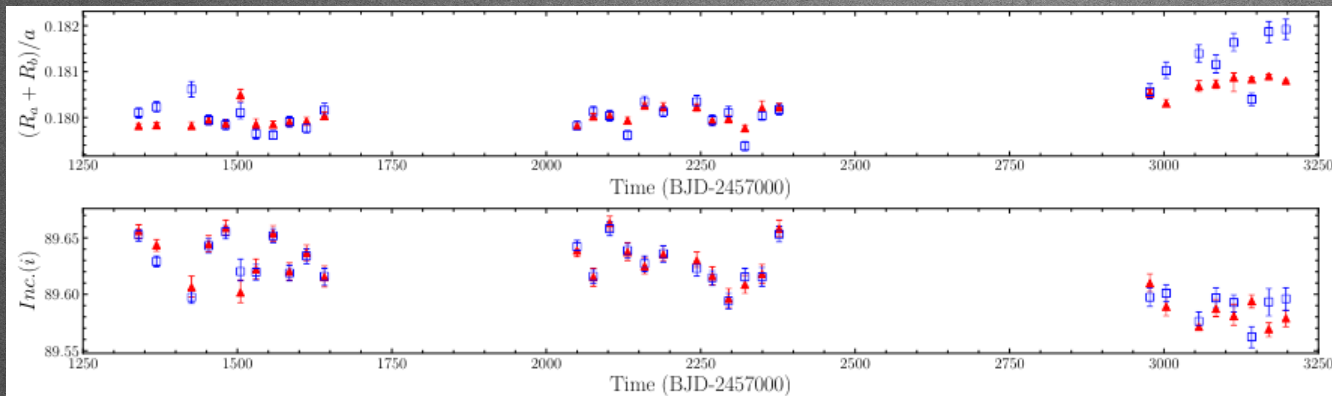
Pawar T. et al. 2024 A&A *accepted*  
Pawar T. et al. 2025a,b *in preparation*



# Results: Benchmarks & long-term stability

- 30 TESS sectors of data analyzed with two different codes
- Four sets of spectroscopic data, 41 spectra
- Variations of results from sector to sector and between spectrographs

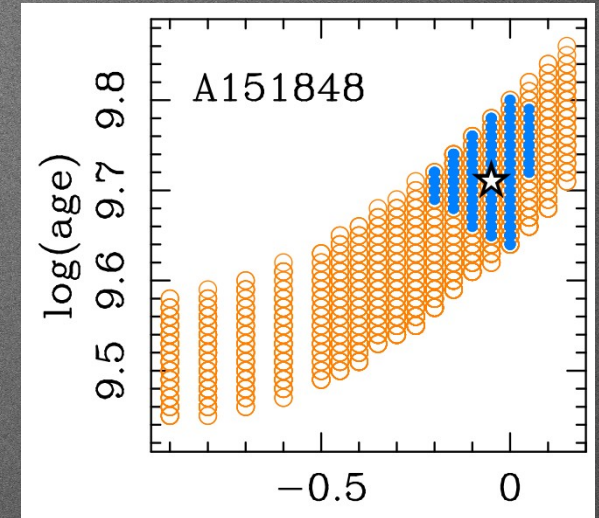
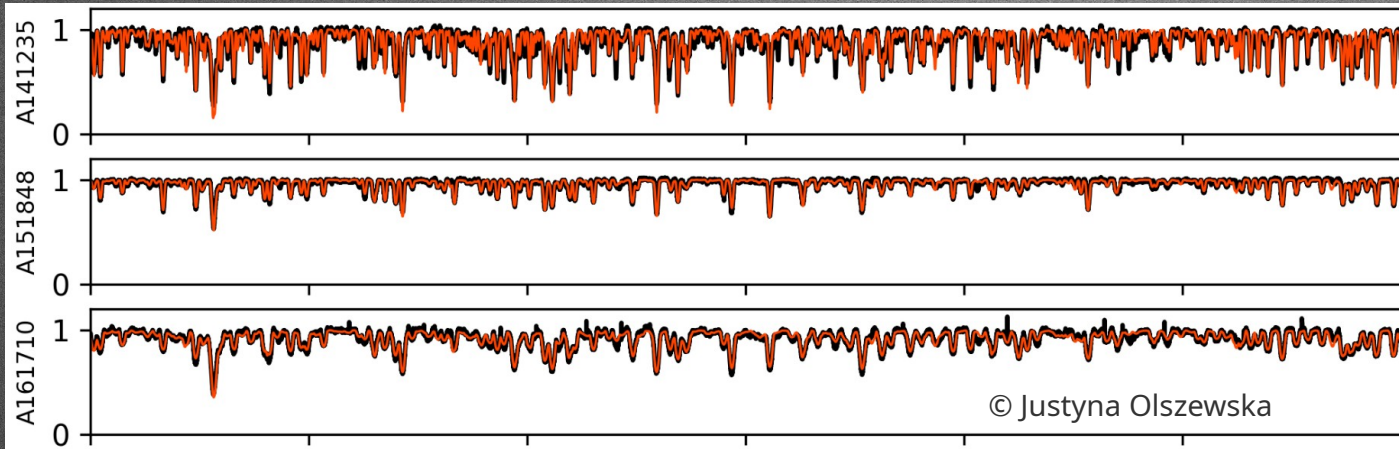
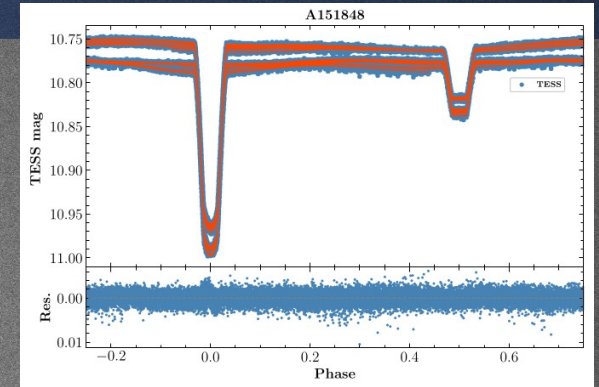
See poster **GP29**  
by **Ganesh Pawar**





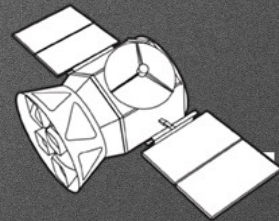
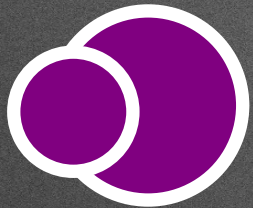
# Results: Total eclipses

- Spectra taken in totality
- Independent estimate of  $T_{\text{eff}}$  and  $[\text{Fe}/\text{H}]$  for better age estimate
- $\delta$ -Sct, low-mass, sub-giants, giants, post-merger candidate



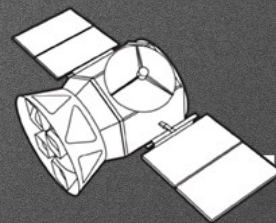
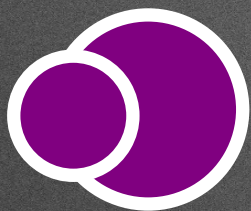
# Future plans and prospects

- Finalize the work on low-mass stars (myself) &  $\delta$ -Sct and  $\gamma$ -Dor pulsators (T. Pawar)
- Extended studies of CHTs (A. Moharana)
- PLATO benchmarks (G. Pawar)
- Improve mass precision in systems with low number of data
- "Filling gaps" in TESS coverage in Cycle 7



# Future plans and prospects

- **New PhD position, from October 2025**
- Other interesting scientific topics:
  - SB+SB quadruples and doubly-eclipsing systems (w/ T. Merle)
  - “Accelerating” stars and planet/BD detection (see the **ADEBBDs** poster **GP06**)
  - High-mass stars
  - Calibration of the  $M-f_{ov}$  relation
  - Testing “abundance clocks”
  - ...



# THANK YOU



eclipsing  
binaries as  
toilet flush  
buttons

