PTA Zjazd 2023
TORUN

Evolution of Compact Hierarchical Triples

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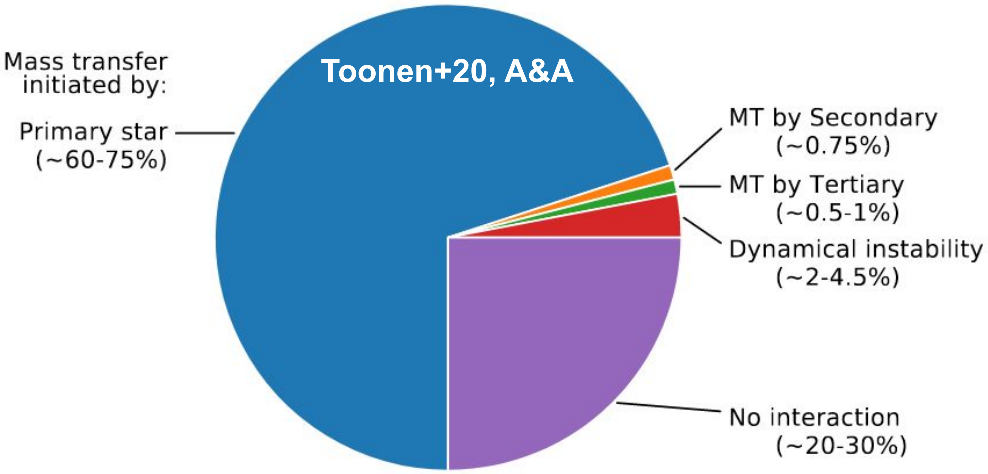
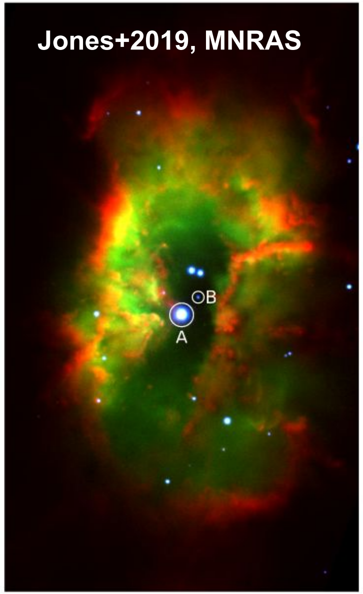
Triples: New binaries ?

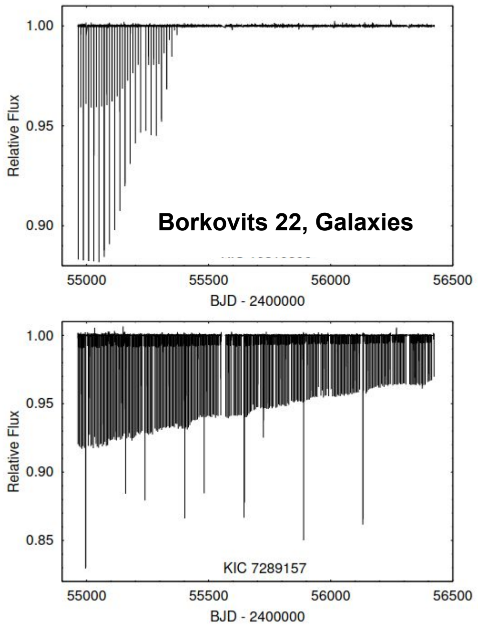


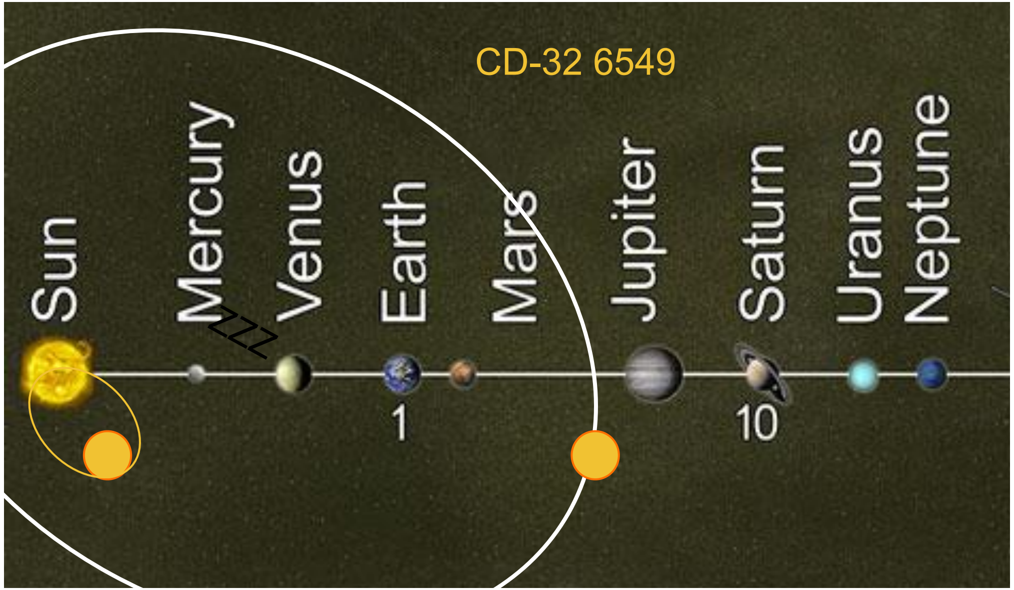
Triples are reactive



Can explain exotic evolutionary phase

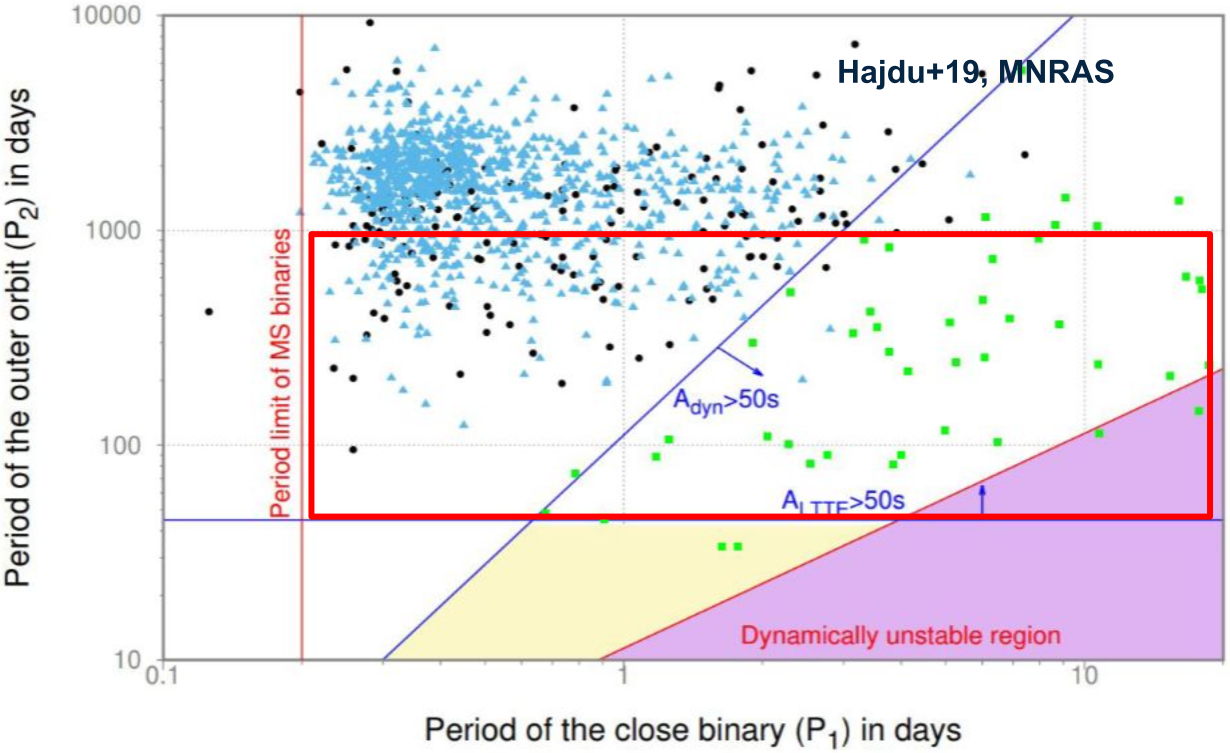
Compact Hierarchical Triples





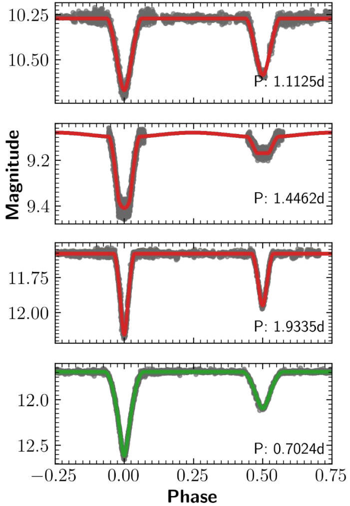
Observable Dynamical Changes

Compact Hierarchical Triples



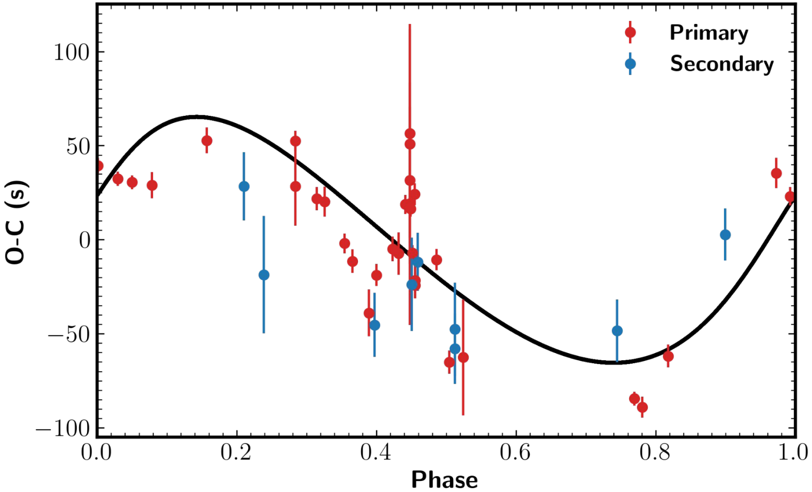
Considered rare, more recent discoveries

The Solaris Survey



Eclipse (Minima) Timing Variations

GSC 00814-01026

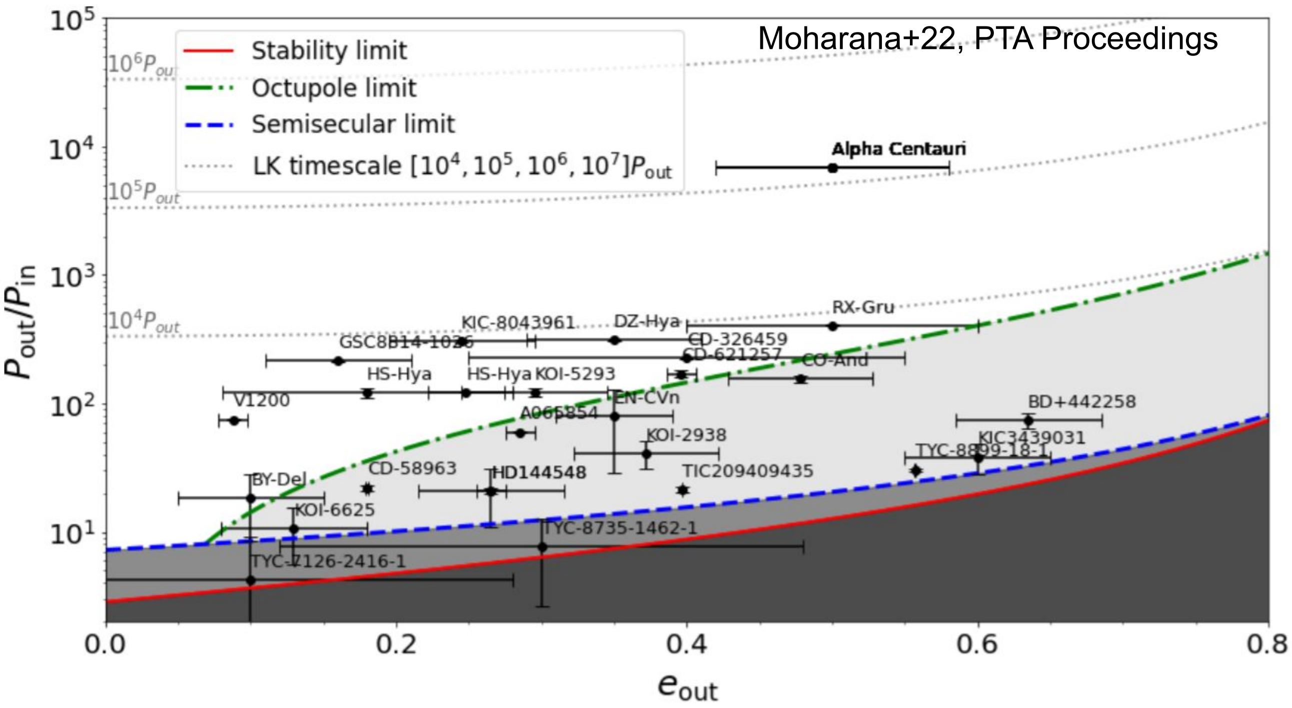


Moharana+23: under-review

Check out the poster for more details

P_{out} = 245.0 ± 0.3 d e_{out} = 0.32 ± 0.04 $M_{tertiary}$ = 0.27 ± 0.01 $M_{\odot}$*

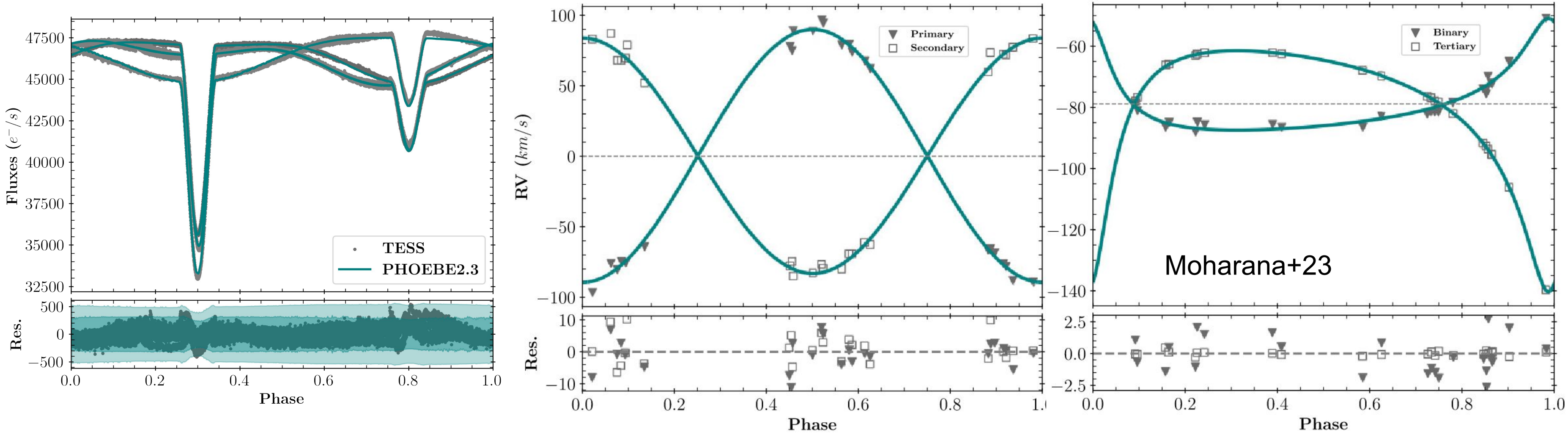
CRÉME Survey and CHTs



PI: K G Hełminiak

Supported by:
2021-2-MLT-006 at HRS-SALT
60h at CHIRON-CTIO via PRELUDIUM
(PI: A Moharana)

Precise Parameters



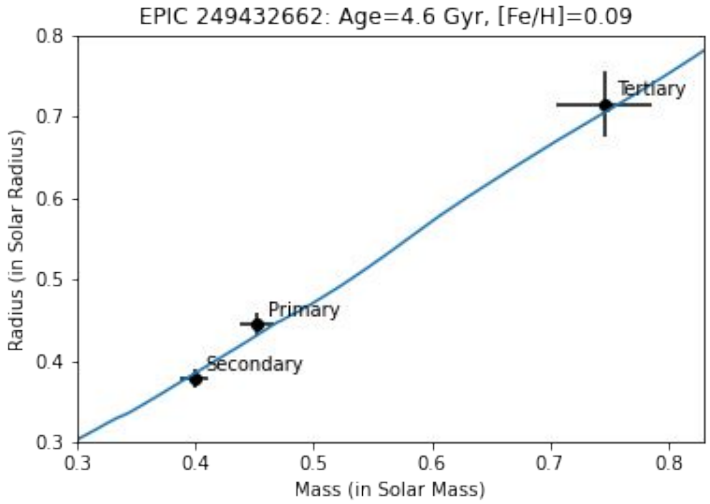
Light curve modelling + **RV Modelling** + **Center-of-Mass RV Modelling**

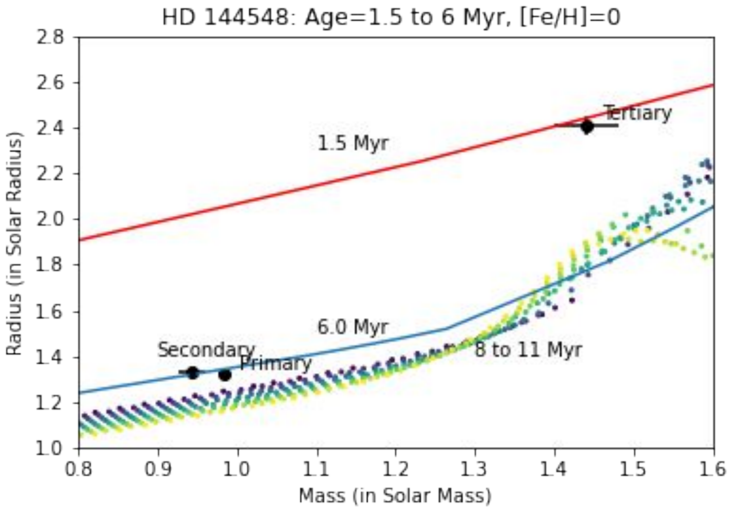
PHOEBE (Prsa,Conroy,Horvat,Jones+)
JKTEBOP (Southworth ‘13)

V2FIT (Konacki+10)
RadVel (Fulton+18)

Need for spectroscopy

- EB and RV modelling give us precise parameters for evolution tests.
- Most triples have been found to be co-evolving
- Need for individual metallicity, temperatures

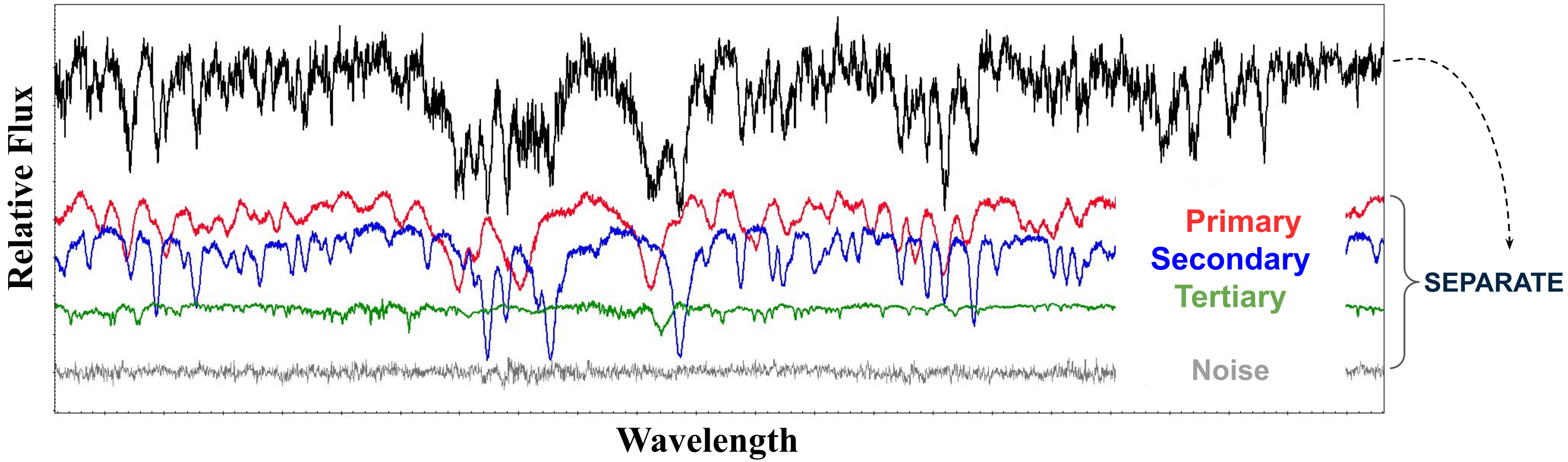




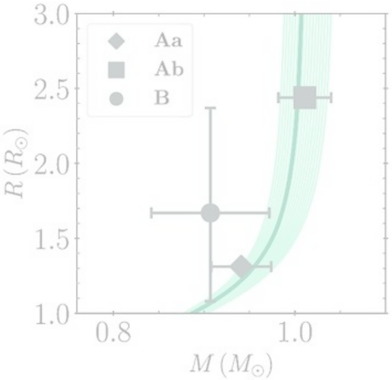
Interacting, evolving or a differently formed triple?

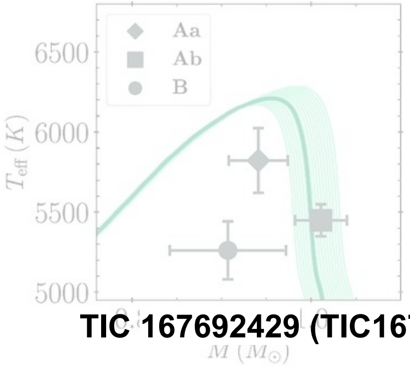
Spectral Disentangling

- **Separate out the component spectra from time-series composite using Fourier decomposition in fd3 (Ilijic+2004). Python wrapper:** github.com/ayushmoharana/fd3_initiator

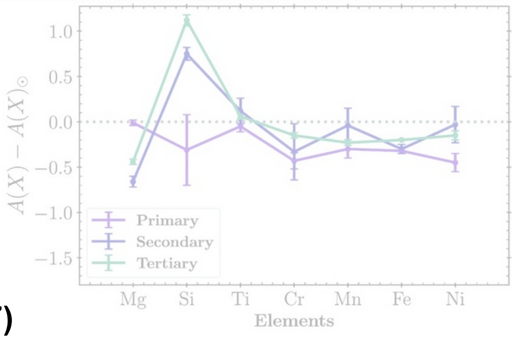


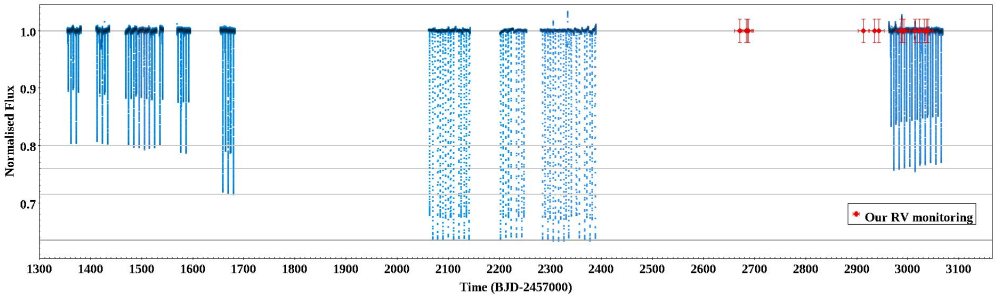
Constraining Evolution

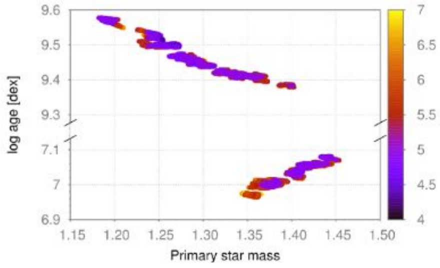




TIC 167692429 (TIC167)





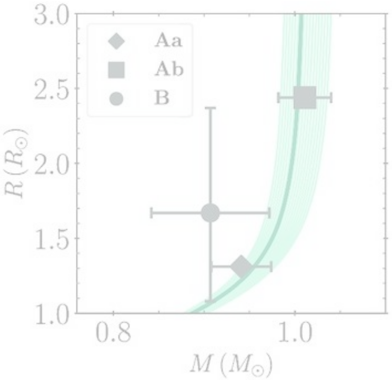


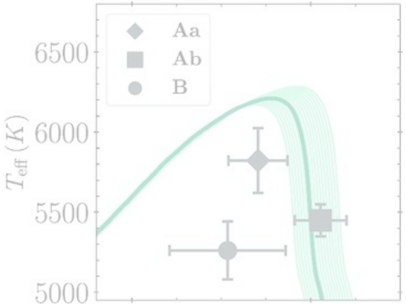
Borkovits+20, MNRAS :

Eclipse depth varying due to third body:

- **ETV+SED +Parsec fitting**
- **Two possible solutions: preMS, postMS**

Constraining Evolution





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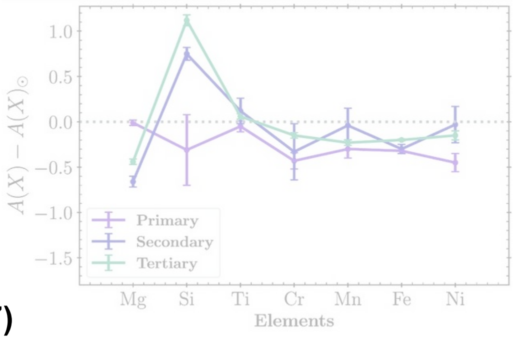
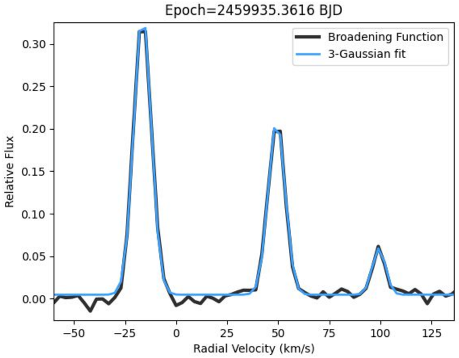


Moharana+in prep :

Broadening Functions (Rucinski 1998), RVs:

- **Resolve degeneracy found in ETV solutions**

Parameters	Post-MS	Pre-MS	SALT HRS
Fractional Flux Primary	**0.5370**	0.4873	**0.5782**
Secondary	**0.4170**	0.4813	**0.3437**
Tertiary	**0.0460**	0.0314	**0.0780**



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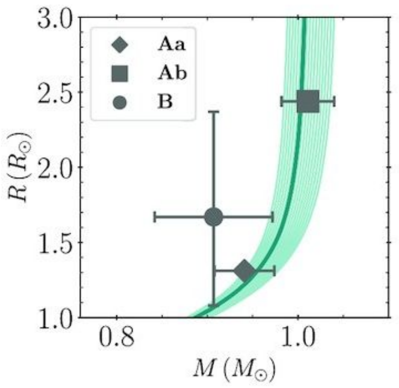
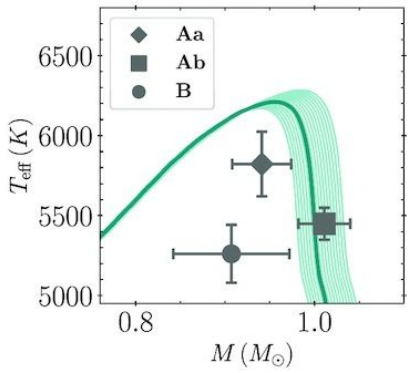
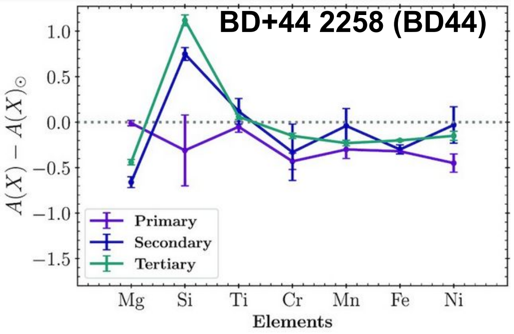
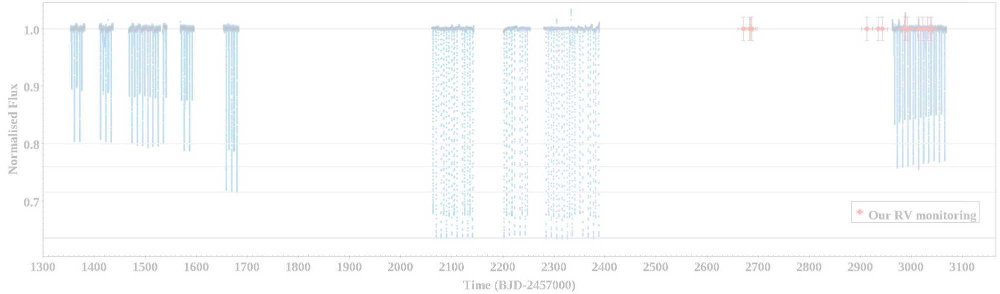






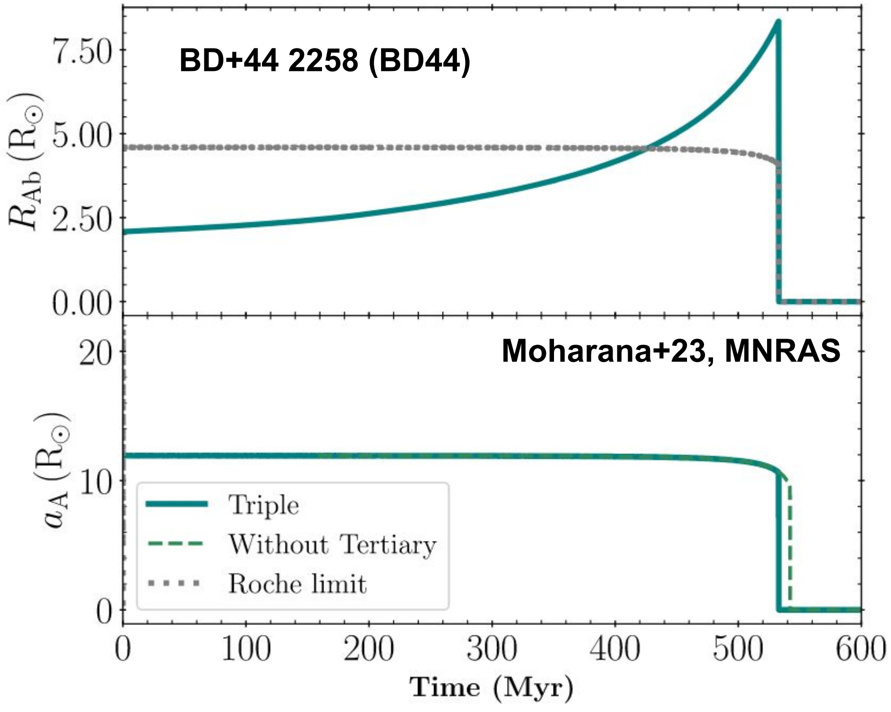
Moharana+23, MNRAS :



Using metallicity, temperatures and abundances:

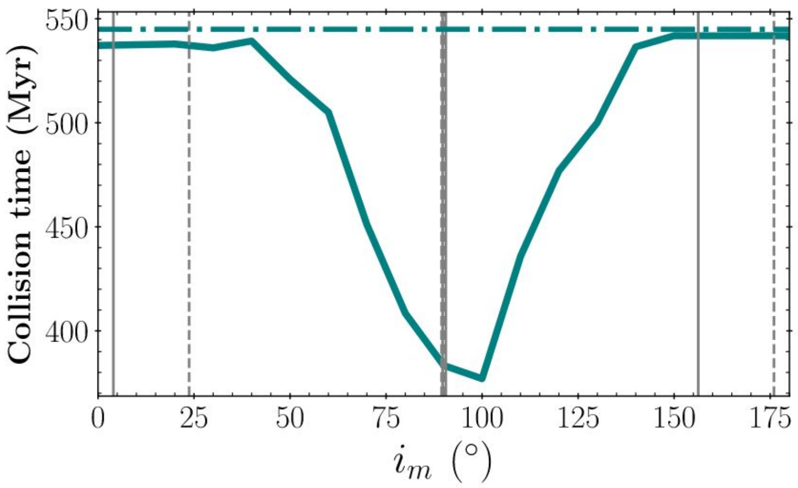
- Precise age estimates
- Distance estimates
- Better constrain on evolutionary phase

Mergers and Collisions

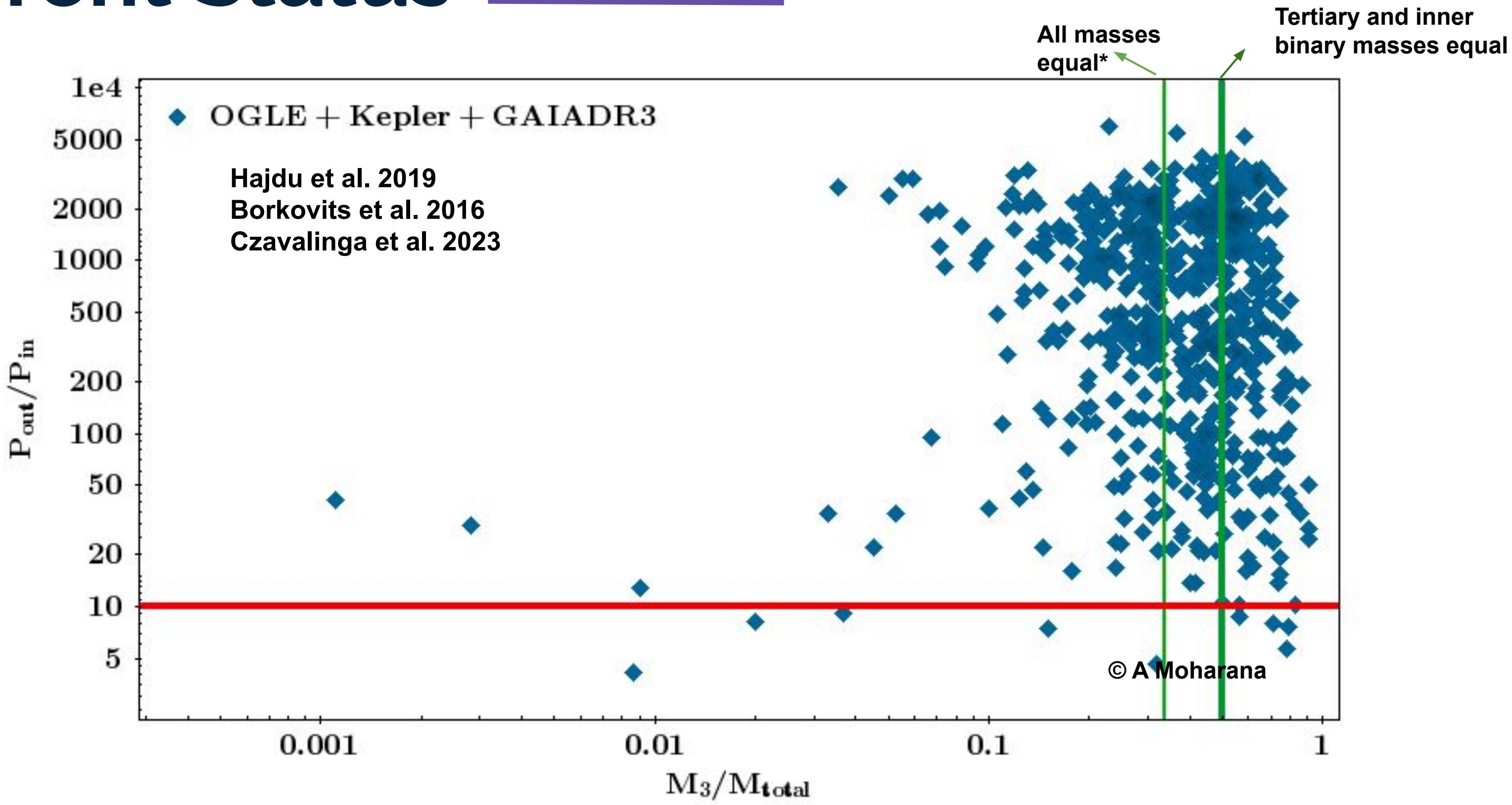


Simulations using REBOUNDx (Rein & Tamayo)

Constraints on i_m show that the system can merge faster than a similar isolated binary



Current Status



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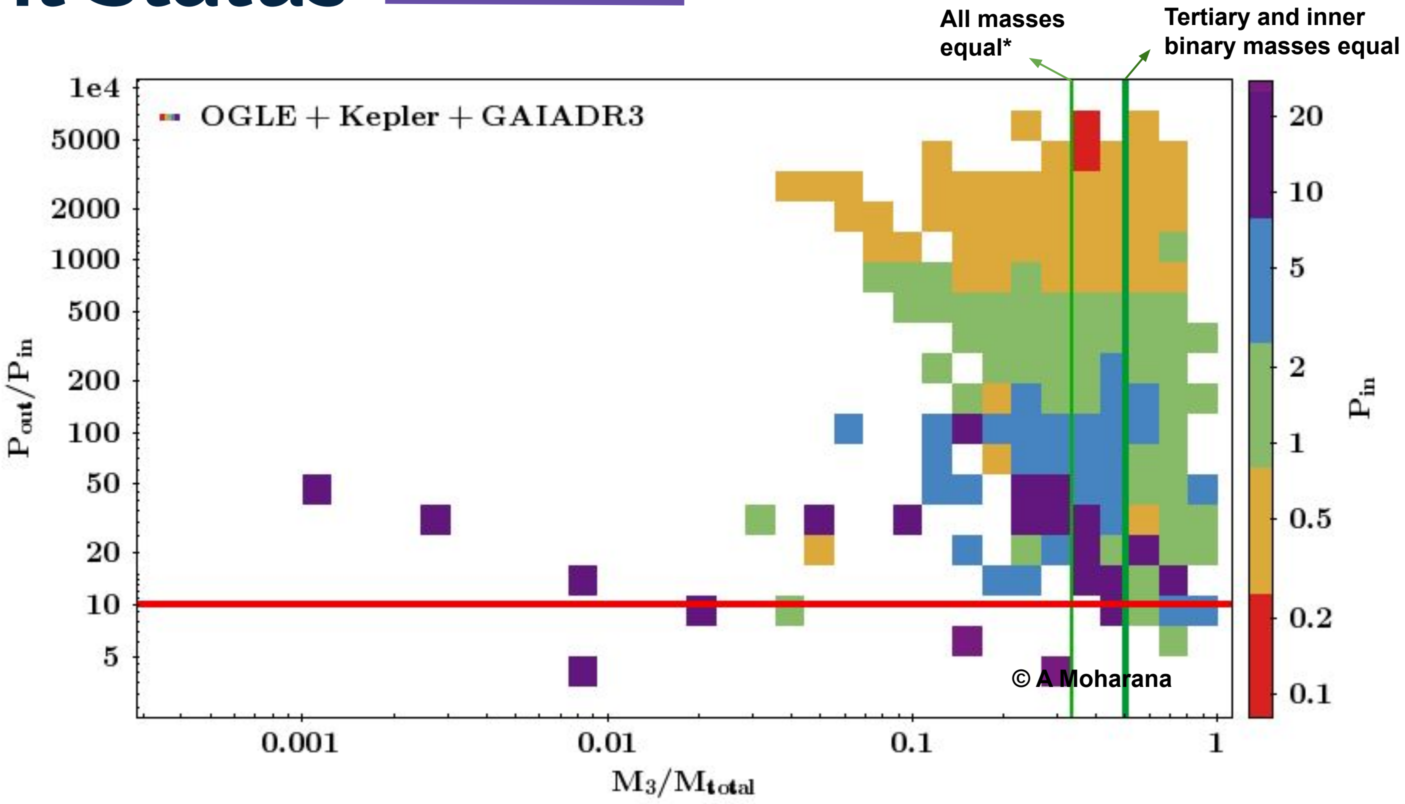

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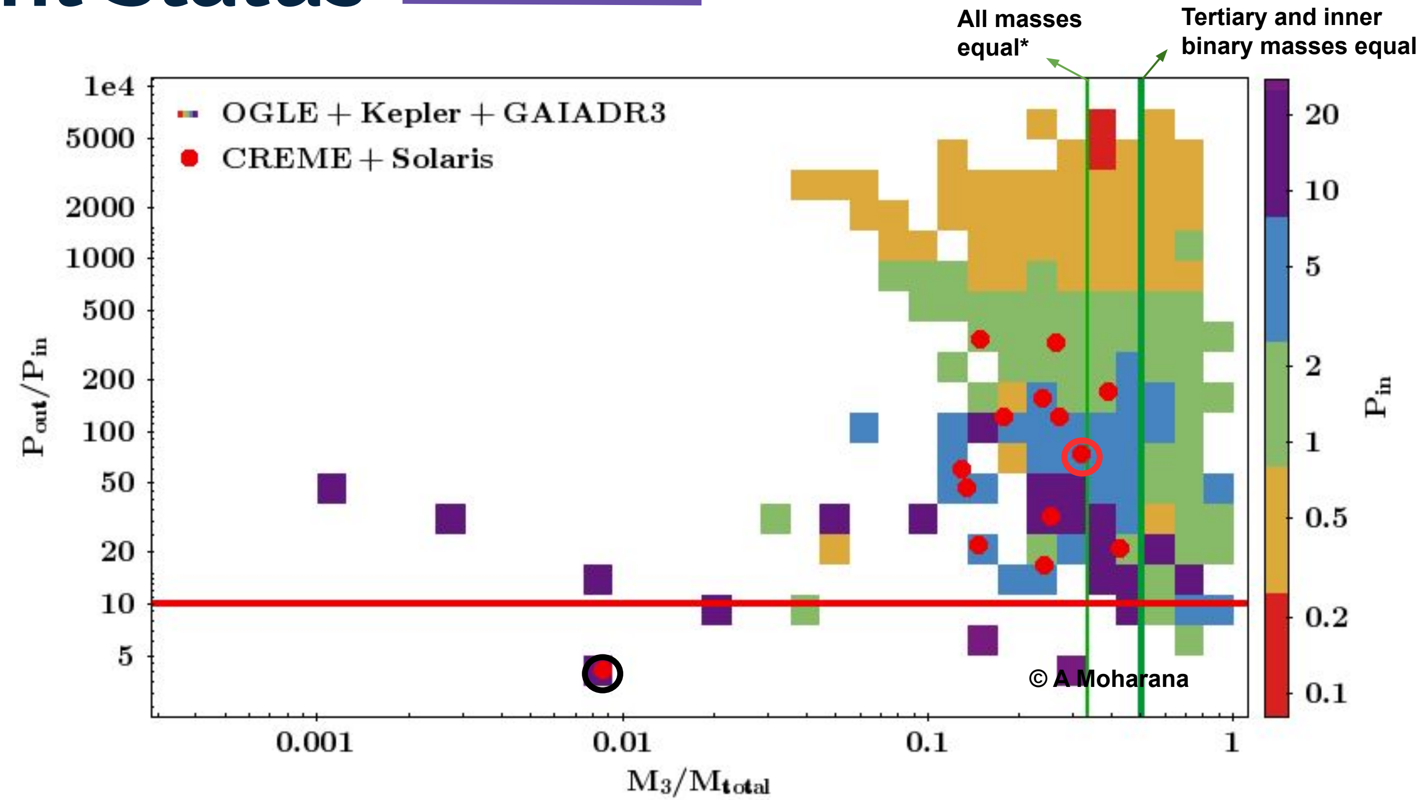

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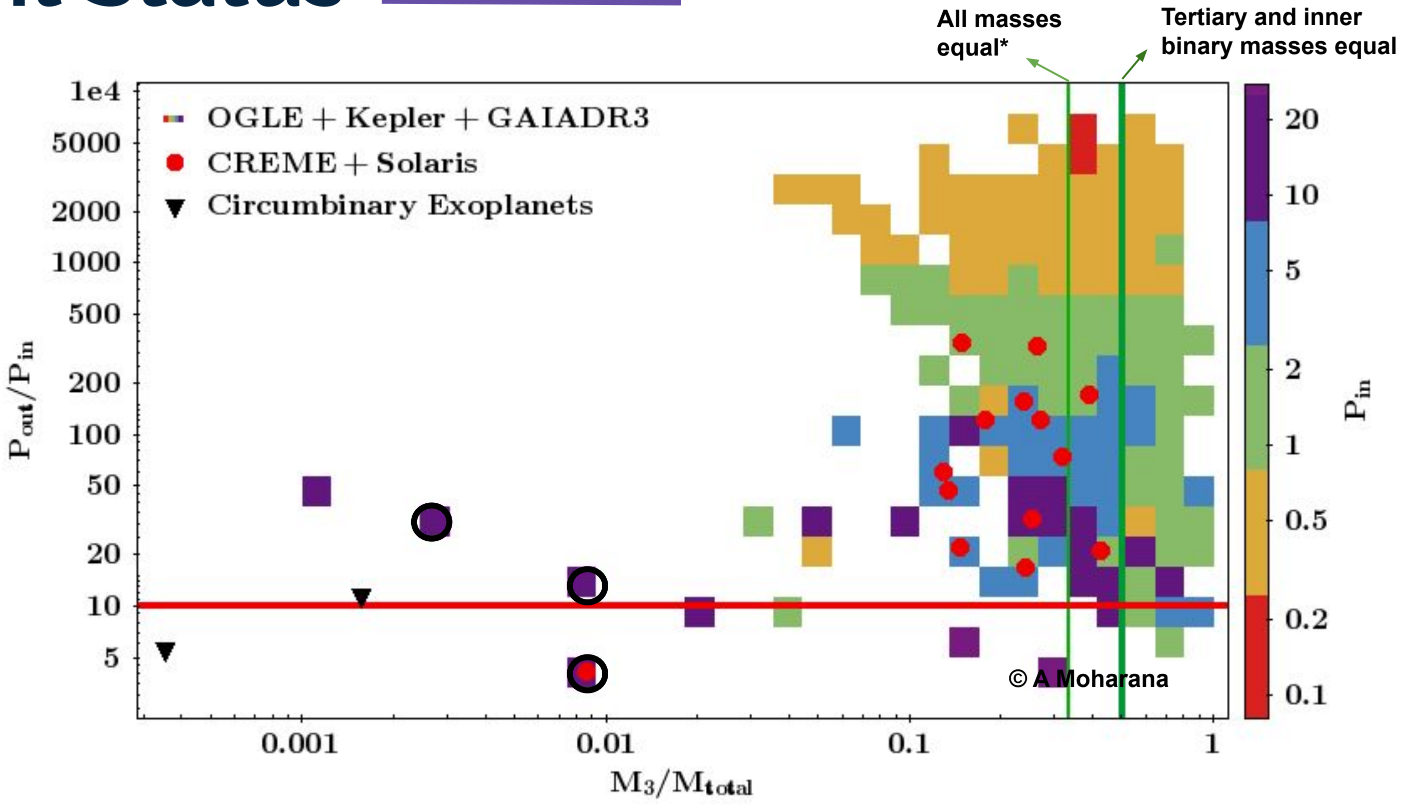
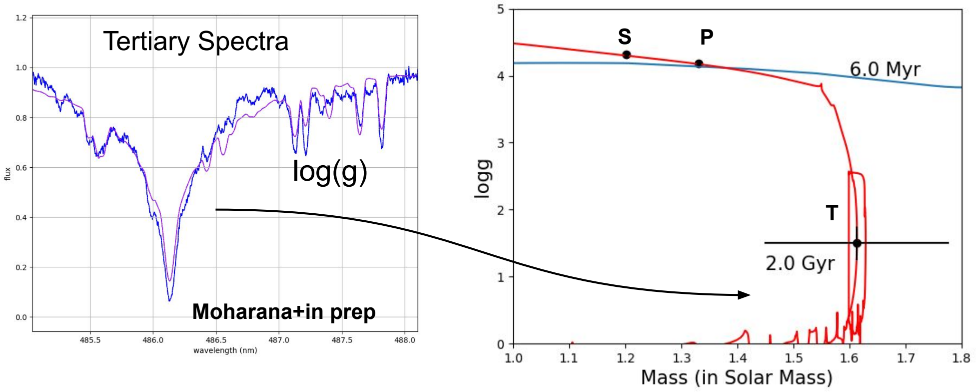


Future

Towards a database of CHT parameters



Constrain formation scenarios

Scenario	Predictions
Sequential disk instability (DI+DI)	Aligned orbits with moderate eccentricity, $q_{in} \geq q_{out}$, moderate period ratios, no 2+2 quadruples.
Sequential core fragmentation (CF+CF, DI+CF)	Non-coplanar eccentric orbits. Wide range of mass ratios.
Late disk instability (CF+DI2)	Small q_{in}, misaligned inner subsystems.
Cloud collisions	Wide 2+2 quadruples, comparable masses

Tokovinin '22, Universe

Summary

- CHT with EB gets us fundamental parameters of all three stars in the system.
- Spectroscopy is important to break degeneracies in stellar evolution.
- Mergers in the inner binary can be dictated by the tertiary.
- CHT with low binary periods have wide tertiaries/ less tight configuration
- Favour 0.33 and 0.5 mass ratio?

Contact:
ayushm@ncac.torun.pl

For details about the techniques, scan the link to paper:

CAMK Torun

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Dziękuję Bardzo.

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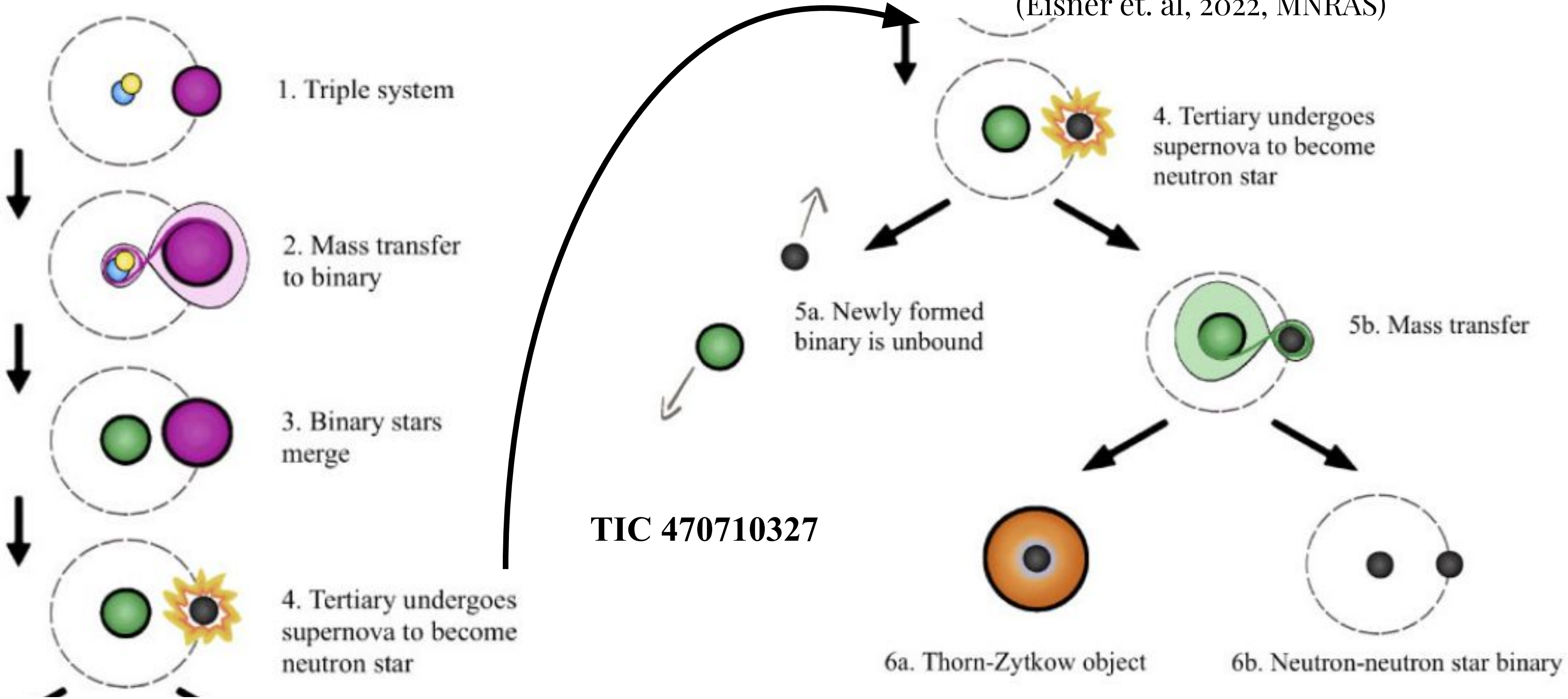
Appendix

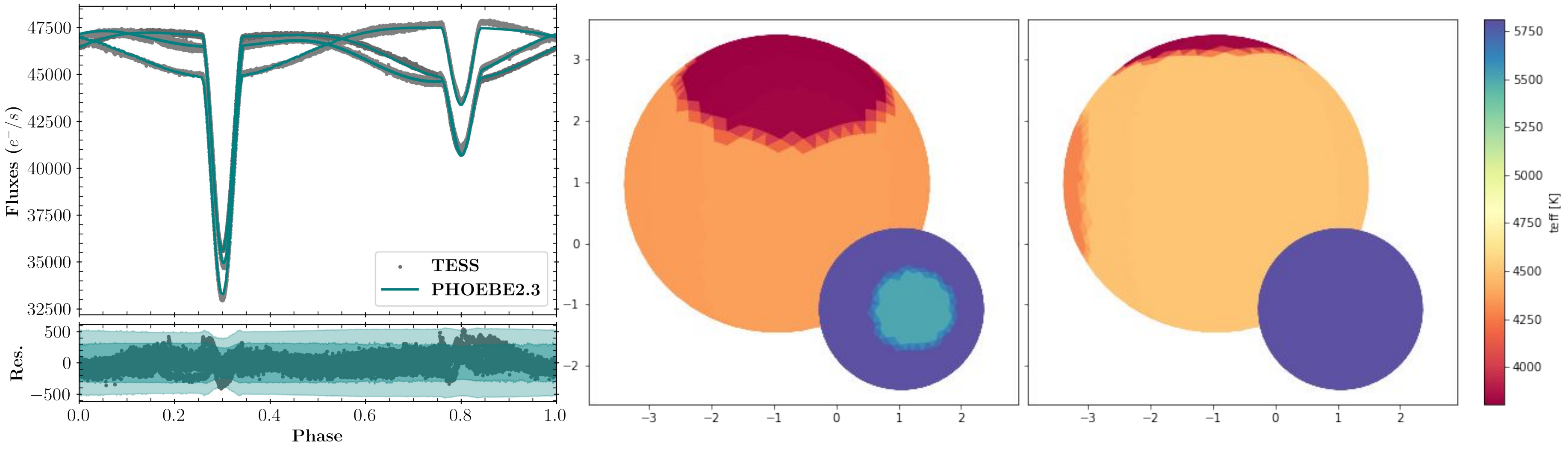
Massive Star CHT

(Eisner et. al, 2022, MNRAS)



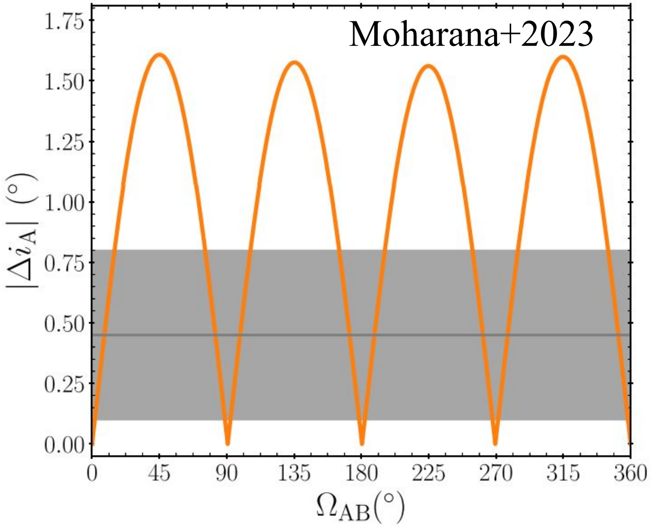
TIC 470710327

Spot Variability



Moharana+23, MNRAS

Mutual Inclination

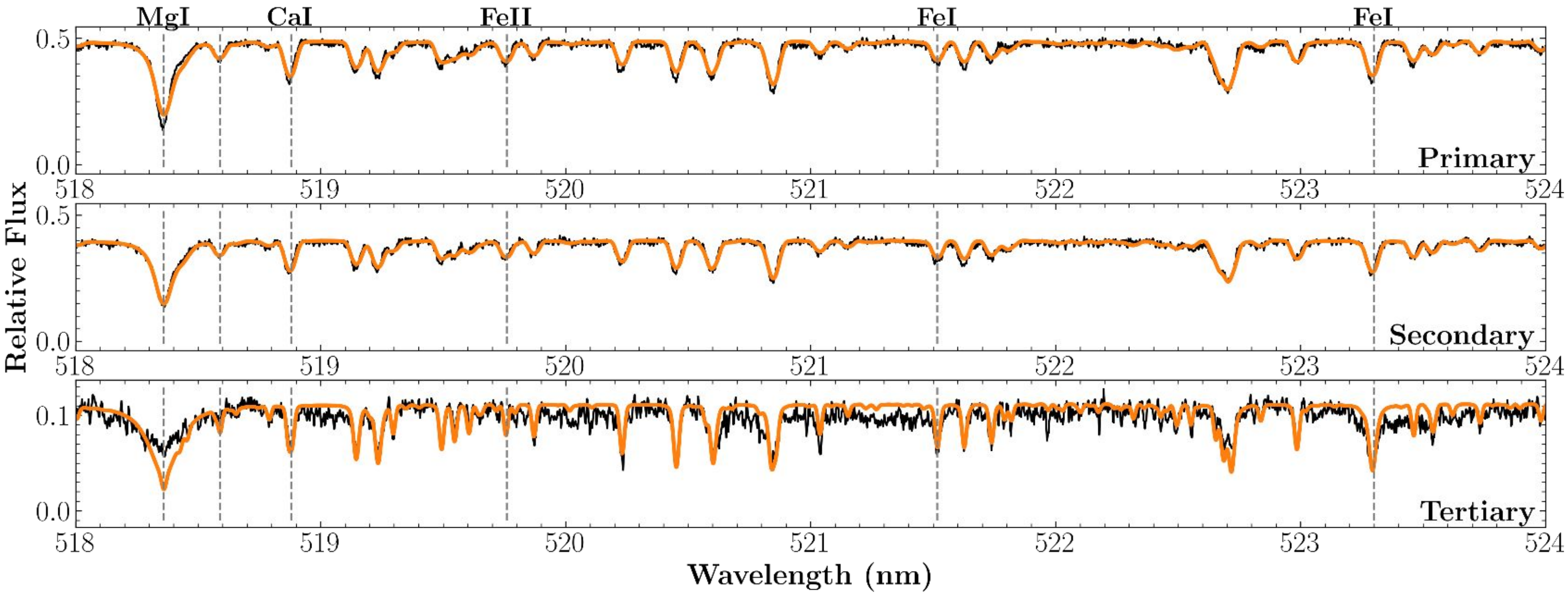


System	Ω_{AB}	i_m	
		Config.A	Config.B
BD44	359.46 ± 0.76	4.03 ± 0.10	175.97 ± 0.01
	266.97 ± 0.79	90.56 ± 0.76	89.45 ± 0.76
	180.23 ± 0.83	156.27 ± 0.01	23.73 ± 0.01
	92.16 ± 0.80	89.71 ± 0.77	90.29 ± 0.77
KIC65	353.80 ± 4.85	6.18 ± 4.83	173.82 ± 4.83
	269.41 ± 11.12	90.09 ± 11.02	89.91 ± 11.02
	180.42 ± 11.18	164.60 ± 0.30	15.40 ± 0.30
	90.67 ± 11.10	90.16 ± 11.00	89.83 ± 11.00
	6.19 ± 4.85	6.17 ± 4.83	173.83 ± 4.83

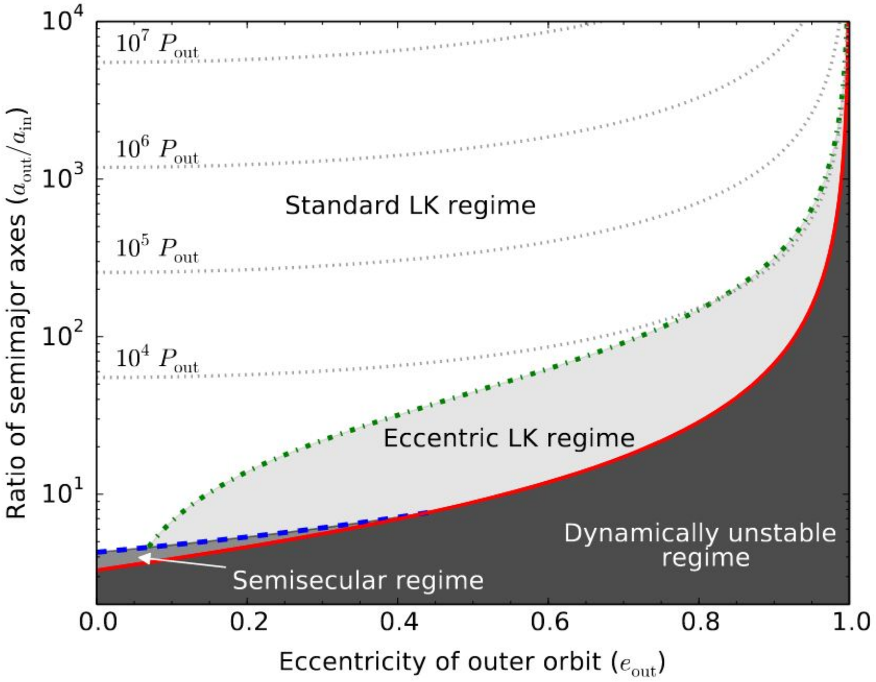
$$\cos i_m = \cos(\Omega_A - \Omega_{AB}) \times \sin i_A \sin i_{AB} + \cos i_A \cos i_{AB}.$$

Gronchi & Tommei (2007)

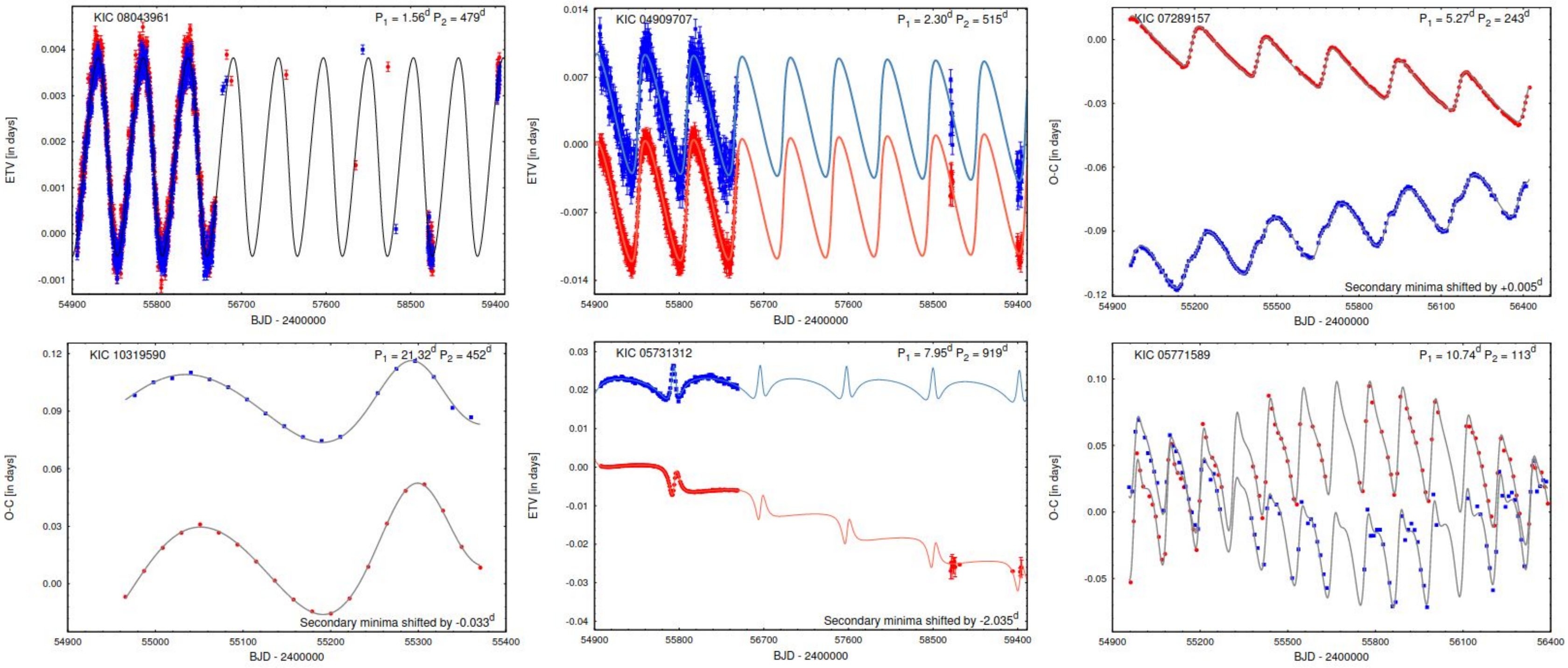
Spectral Modelling



Dynamic regimes



Detections: ETVs



(Borkovits, 2022, Galaxies)

Broadening Functions