NATIONAL KAPODISTRIAN UNIVERSITY OF ATHENS
DEPARTMENT OF PHYSICS
SECTION OF ASTROPHYSICS, ASTRONOMY AND MECHANICS

HELLENIC ASTRONOMICAL SOCIETY

Evolution of Low Mass and Low Temperature Binary Systems close to their period cut-off

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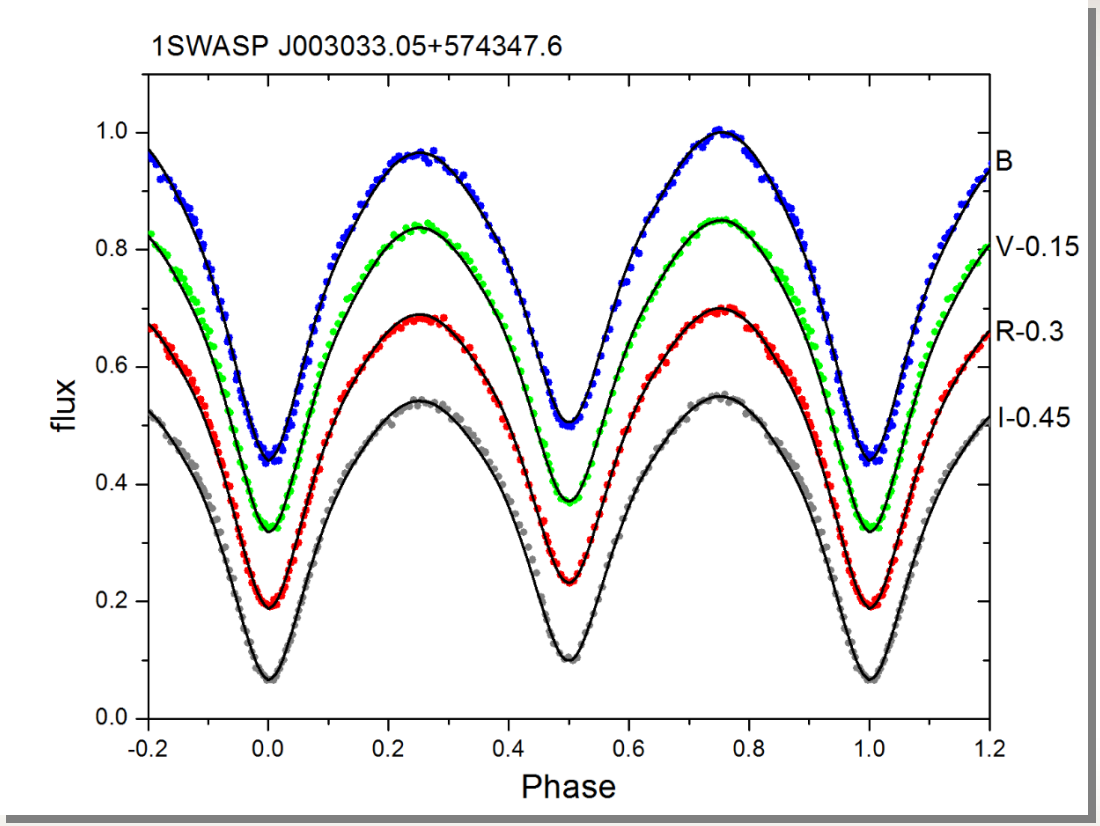
Topics

- Low Mass (and Low Temperature) Contact Binaries (***LMCBs***)
- ***CoBiToM*** project
- Data acquisition & Analysis
- Absolute physical parameters
- Correlation between parameters
- Discussion

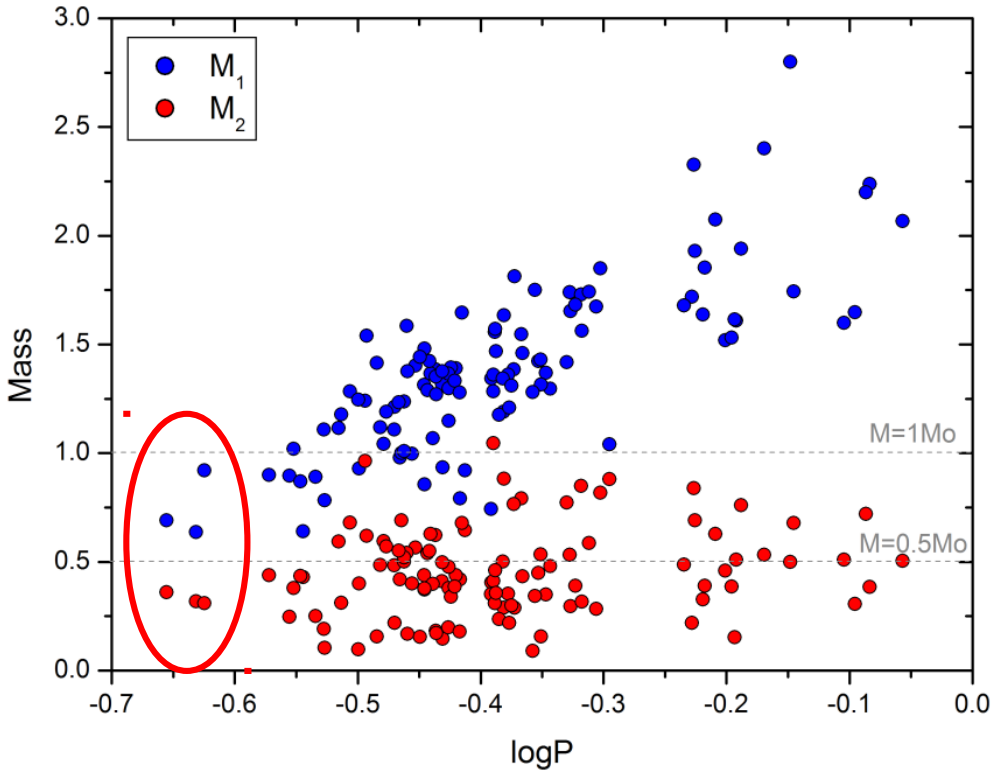
Characteristics of Low Mass CBs

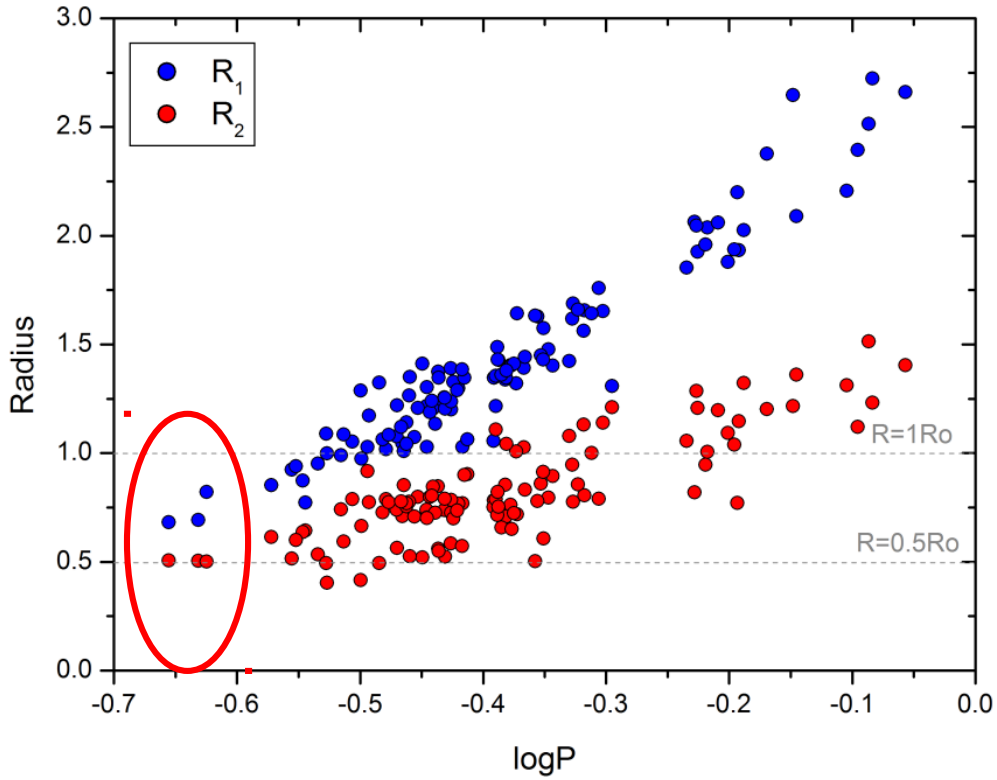
LMCBs are W UMa type systems, which follow certain characteristics:

- Orbital period range 0.2-0.3 days, close to period cut-off (Rucinski 1992)
- Components with similar temperature, due to common envelope (Spectral type: F0-K5)
- Magnetically active (O'Connell effect)
- Continuous variability of total luminosity
- Angular momentum and mass loss, due to stellar wind



Low Mass Contact Binaries (LMCBs)





Gazeas & Niarchos (2006)
Gazeas & Stepien (2008)

Low Mass Contact Binaries (LMCBs)

Evolutionary stage	Age [Gyr]	$M_1 + M_2$ [$M_\odot$]	q	P_{orb} [days]	H_{orb} ($\times 10^{51}$)
Initial (ZAMS)	0	0.9+0.3	3.0	2.50	4.275
Start RLOF	8.64	0.835+0.292	2.86	0.350	2.051
Start contact	8.74	0.355+0.772	0.46	0.230	2.001
Coalescence	9.42	0.251+0.867	0.29	0.219	1.571
Initial (ZAMS)	0	0.9+0.4	2.25	2.50	5.550
Start RLOF	11.40	0.816+0.382	2.14	0.426	2.740
Start contact	12.20	0.390+0.797	0.49	0.287	2.401
Coalescence	13.00	0.210+0.961	0.22	0.286	1.562
Initial (ZAMS)	0	0.9+0.5	1.80	1.50	5.709
Start RLOF	5.46	0.858+0.487	1.76	0.327	3.230
Start contact	5.66	0.557+0.786	0.71	0.245	3.077
Coalescence	6.24	0.440+0.895	0.49	0.207	2.623

- LMCB life starts in detached systems
- Similar evolution with Algol-type systems
- After the mass ratio reversal and the appropriate mass transfer (approx. 0.1 $M_\odot$) a contact configuration is achieved
- Systems with extreme mass ratios present a non-stop mass transfer, where the more massive star absorbs the less massive star
- Small orbital period indicates evolved systems
- This procedure lasts for billions of years, as proper simulations showed

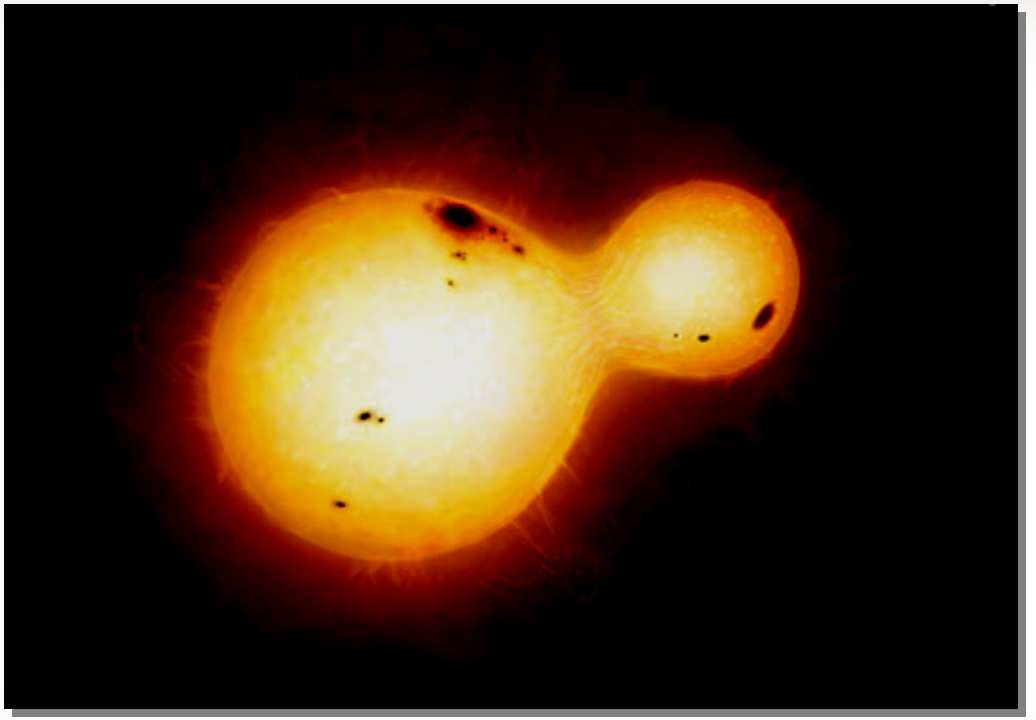
Stepien & Gazeas (2012)

CoBiToM Observing Project

CoBiToM

(***Co***ntact ***Bi***naries ***To***wards ***M***erging)

CoBiToM Project was initiated in 2012 at the University of Athens Observatory. It is focusing in investigating the evolution of contact binaries with very short orbital period and those which are one step before their coalescence.



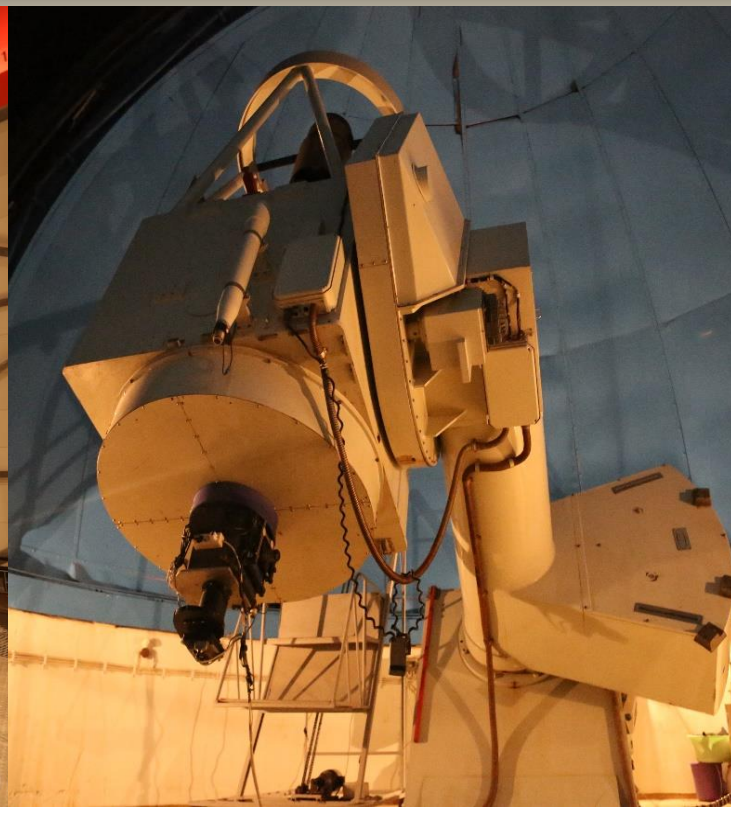
Observatories involved in this project:

- 0.4 m (University of Athens, Greece)
- 1.2 m (Kryoneri Astronomical Station, Greece)
- 1.9 m (Kottamia Observatory, Egypt)
- 2.3 m (Helmos Observatory, Greece)

Telescopes used in CoBiToM

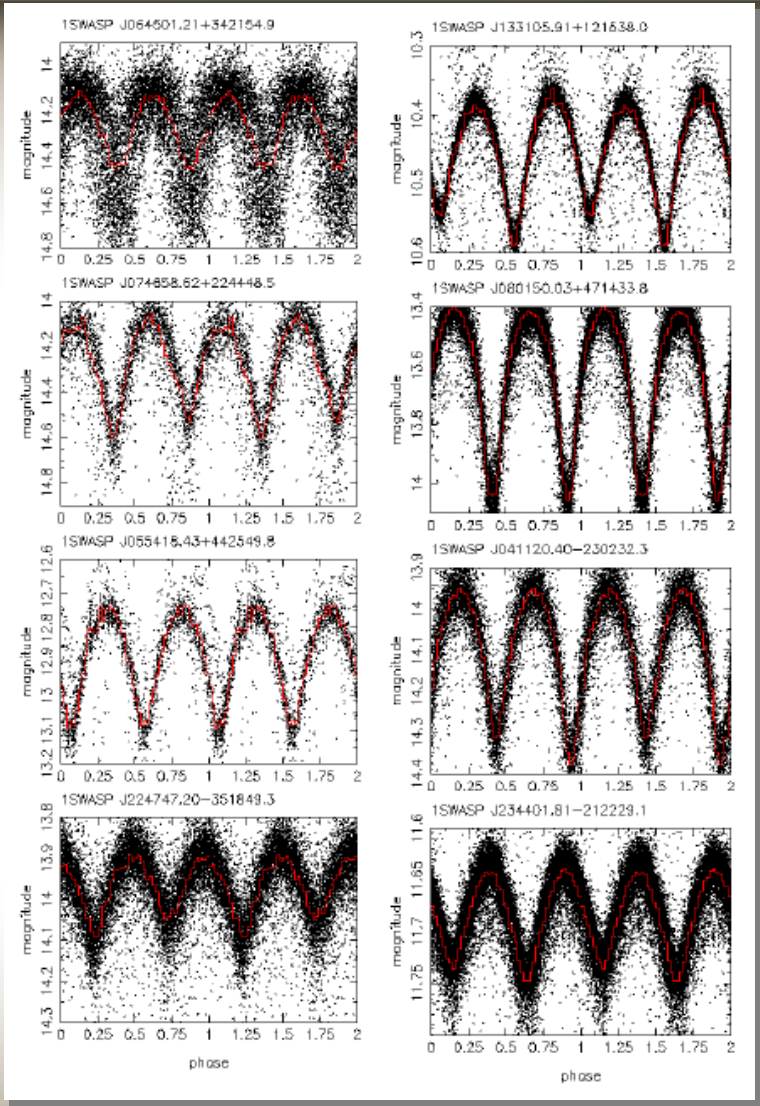
University of Athens Observatory

Helmos Observatory (NOA)



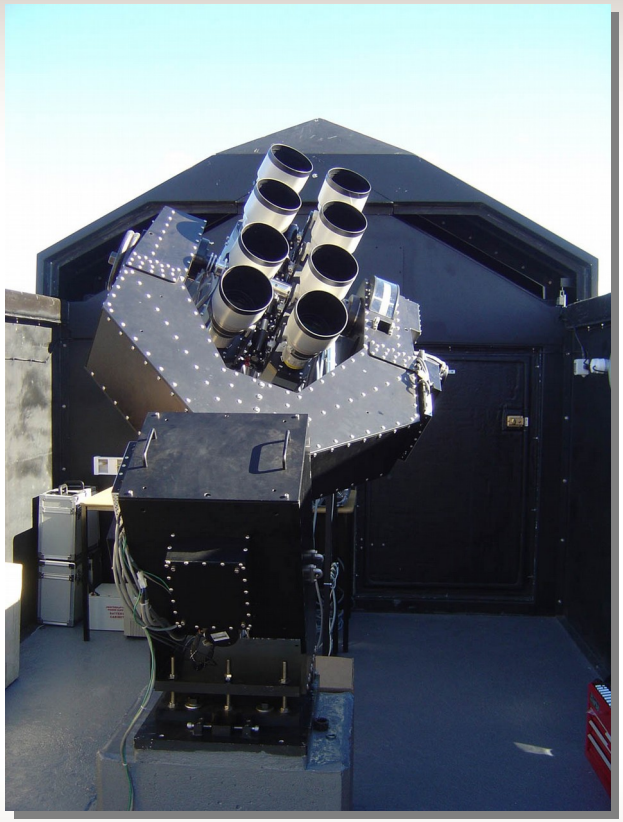
Kryoneri Observatory (NOA)

SuperWASP Project



Sample targets from the SuperWASP Catalog

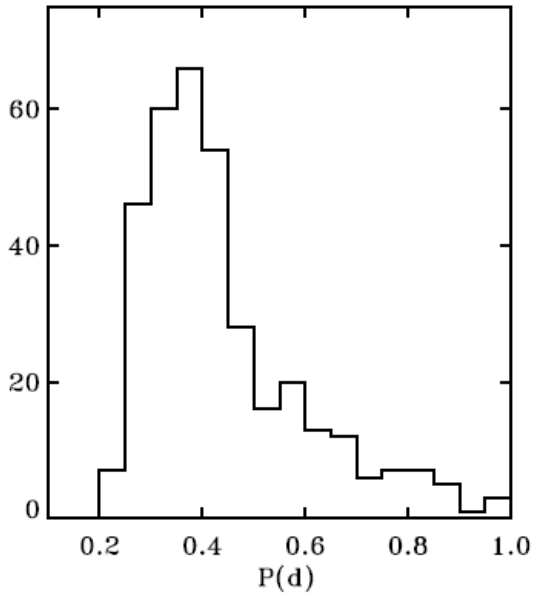
- 2 observatories in both hemispheres (Canary Islands and South Africa)
- Sky survey seeking for transiting exoplanets
- Several variables were found
- Over 50 contact binaries were observed with orbital period close to the period cut-off.

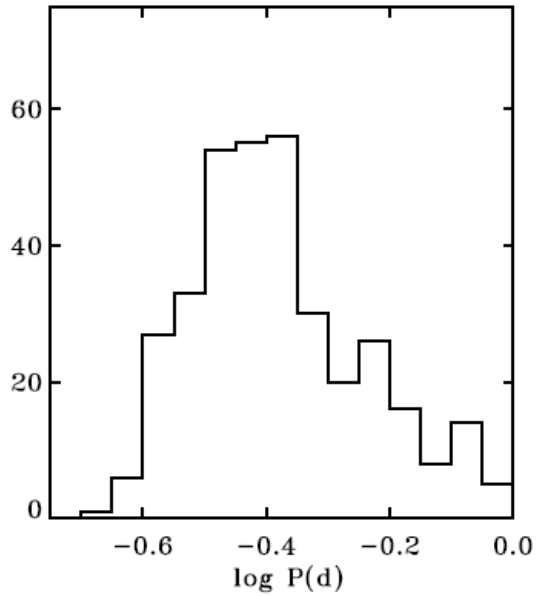


SuperWASP Project
(Pollacco et al. 2006)

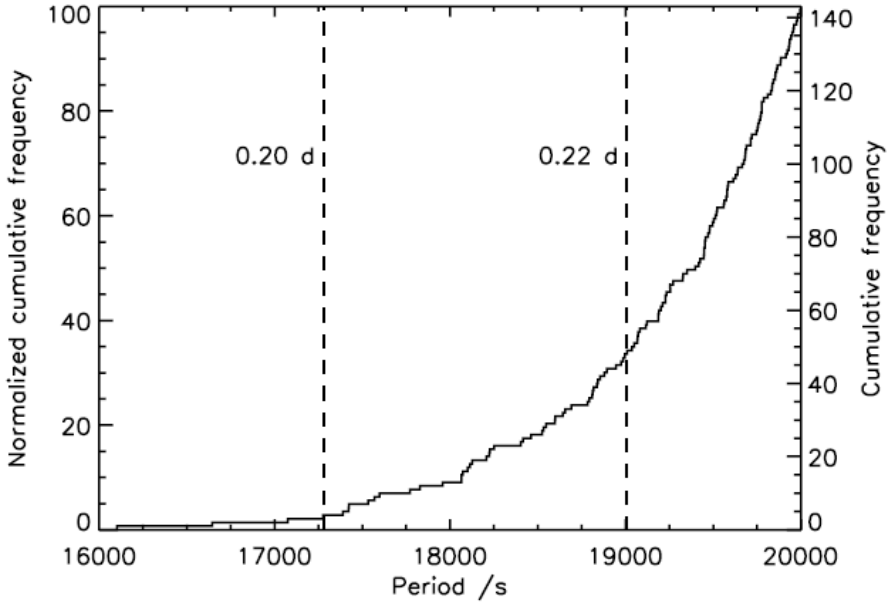
SuperWASP Sample

- Norton et al. (2011) provide 53 eclipsing systems below the period cut-off (0.22 days)
- LMCBs display frequency is very low





(Rucinski 2007)

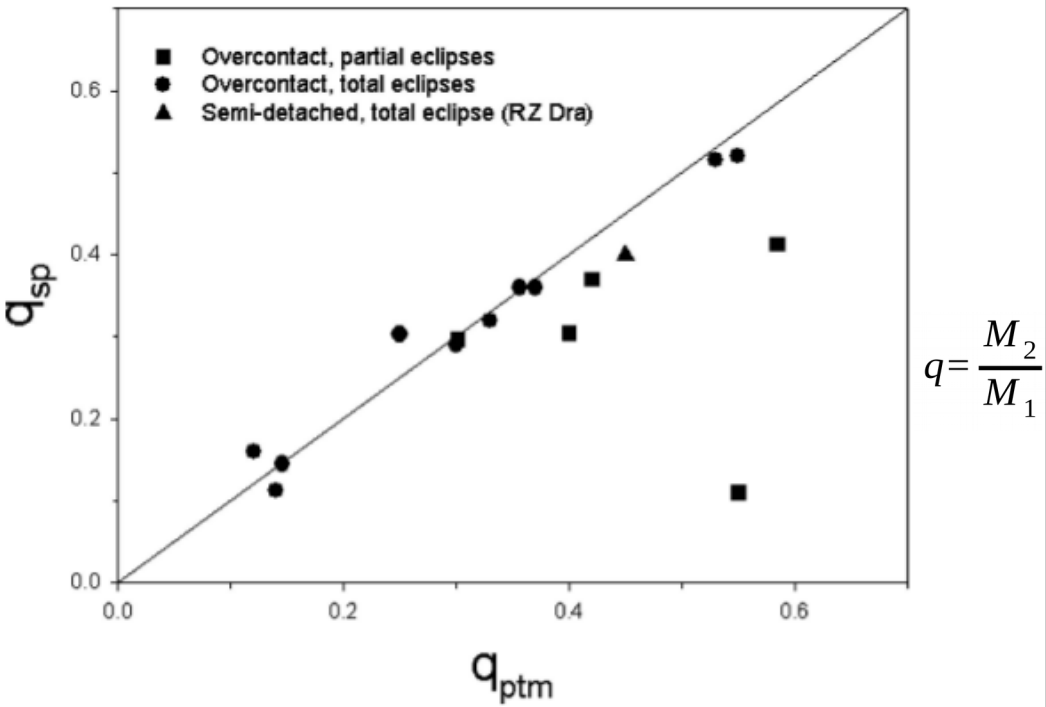


(Lohr & Norton et al. 2013)

Observed Sample

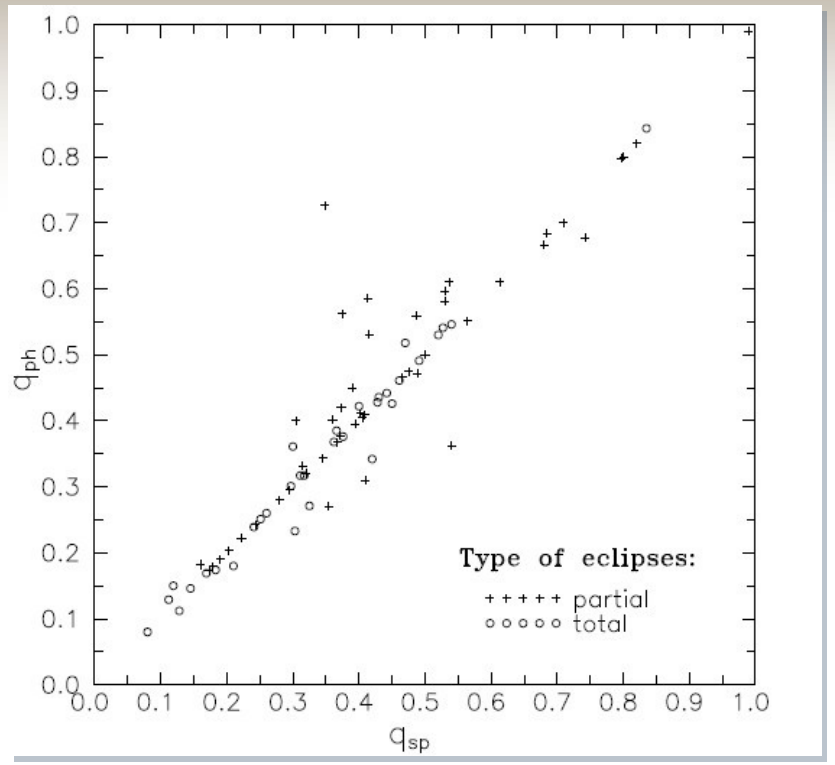
Target	Nights	Observatory	Orbital Period (d)
1SWASP J003033.05+574347.6	2	Helmos	0.2266218(1)
1SWASP J004050.63+071613.9	3	UOAO	0.229273194(5)
1SWASP J052036.84+030402.1	13/5	UOAO/Kryoneri	0.218495417(3)
1SWASP J055418.43+442549.8	7	UOAO	0.217513507(8)
1SWASP J080150.03+471433.8	7	Kryoneri	0.217513507(8)
1SWASP J093012.84+533859.6	14	UOAO	0.22771470(1)
1SWASP J133105.91+121538.0	8	UOAO	0.218013657(5)
1SWASP J150822.80-054236.9	11	UOAO	0.260060347(8)
1SWASP J173003.21+344509.4	4	Kryoneri	0.22371438(1)
1SWASP J174310.98+432709.6	9	Kryoneri	0.25810784(1)
1SWASP J220734.47+265528.6	18/2	UOAO/Helmos	0.23123(1)
1SWASP J234401.81-212229.1	52	UOAO	0.213675822(8)

Data acquisition & Analysis



$$q = \frac{M_2}{M_1}$$

Terrell (2004)

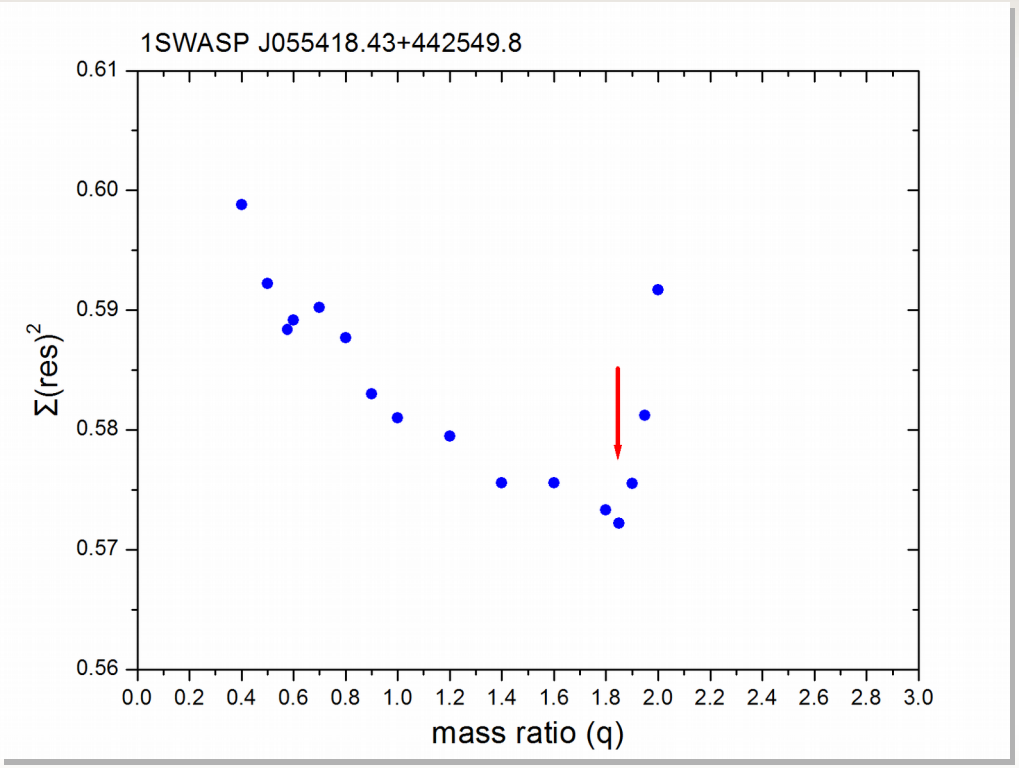


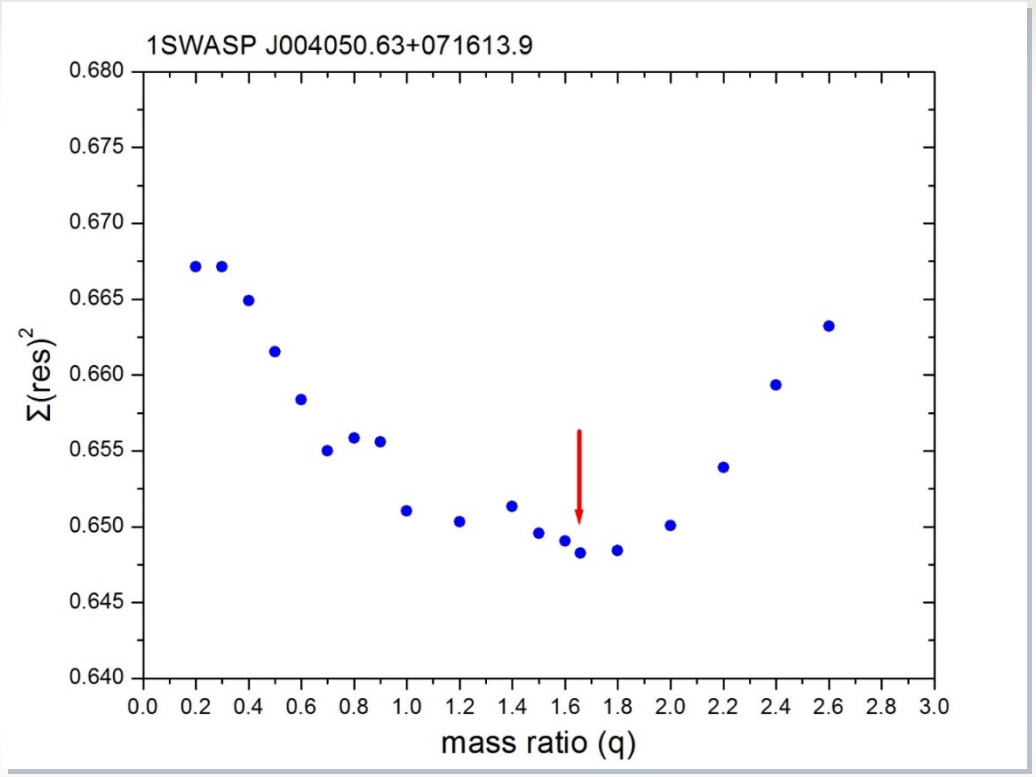
Pribulla et al. (2003)

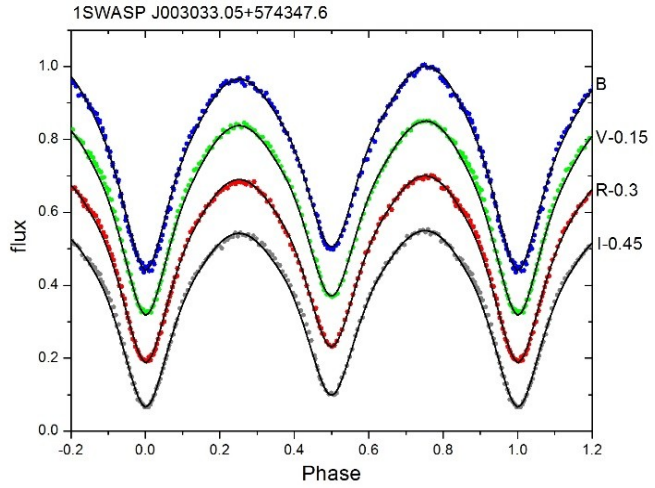
Binary systems with total eclipses result in a 1:1 plot among the spectroscopically and photometrically determined mass ratio, i.e. in such systems we can estimate mass ratio quite accurately just with photometry.

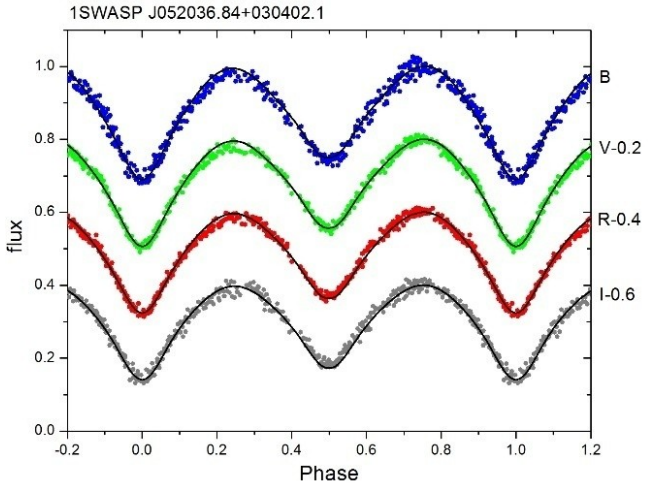
Data acquisition & Analysis

Photometric mass ratio and q-search analysis






1SWASP J003033.05+574347.6
B
V-0.15
R-0.3
I-0.45
flux
Phase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B
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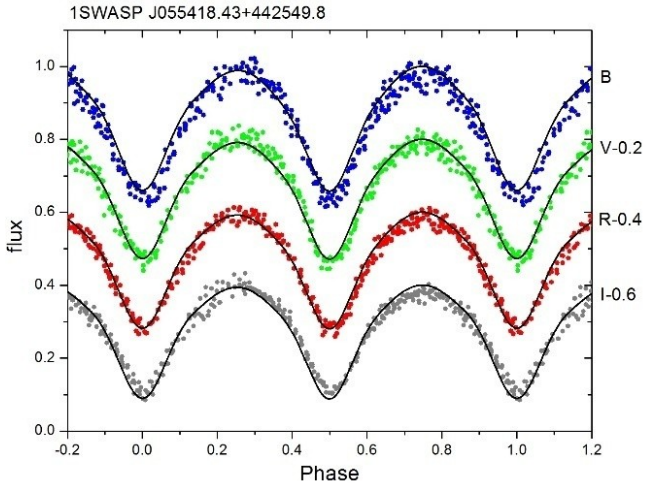
R-0.4
I-0.6
flux
Phase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B
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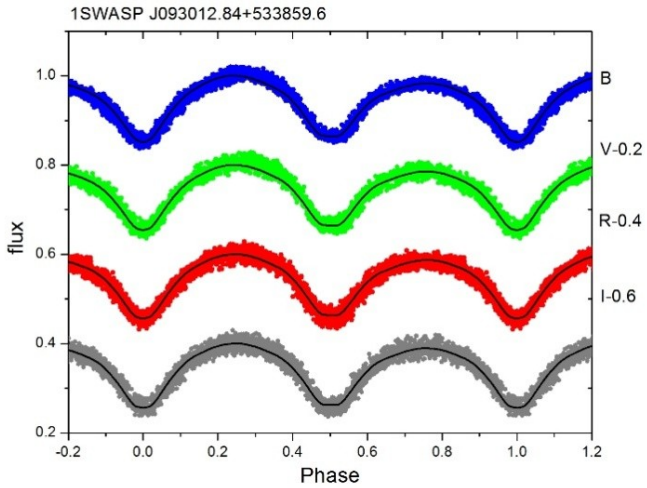
I-0.6
flux
Phase


1SWASP J093012.84+533859.6
B
V-0.2
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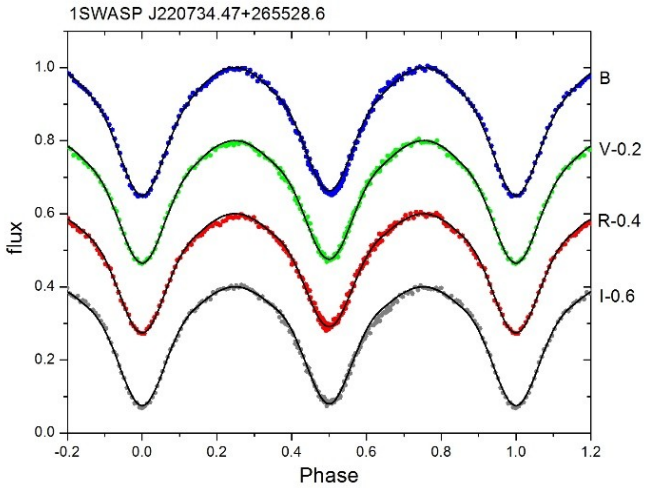
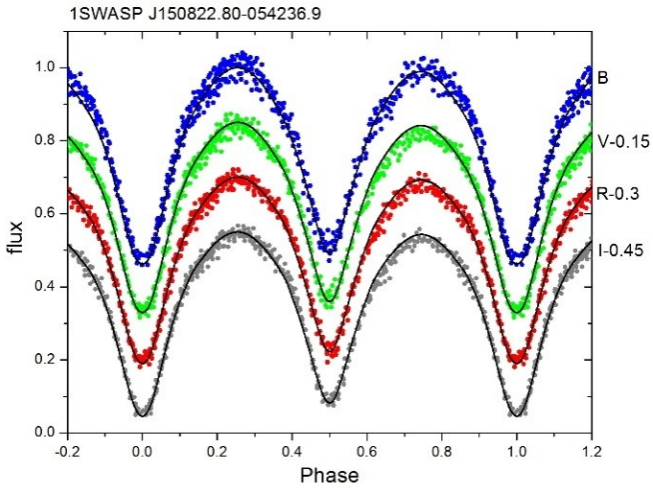
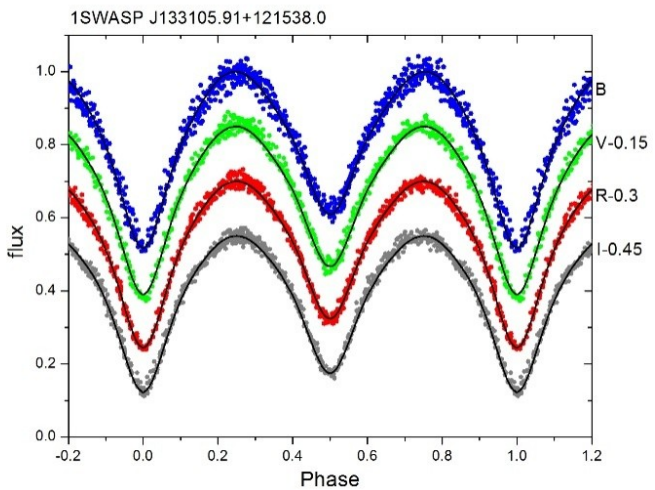
flux
Phase


1SWASP J220734.47+265528.6
B
V-0.2
R-0.4
I-0.6
flux
Phase


1SWASP J150822.80-054236.9
B
V-0.15
R-0.3
I-0.45
flux
Phase


1SWASP J133105.91+121538.0
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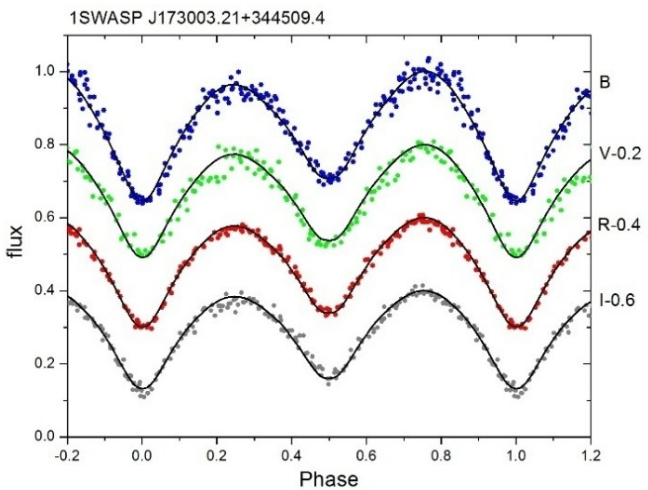
R-0.3
I-0.45
flux
Phase


1SWASP J173003.21+344509.4
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R-0.4
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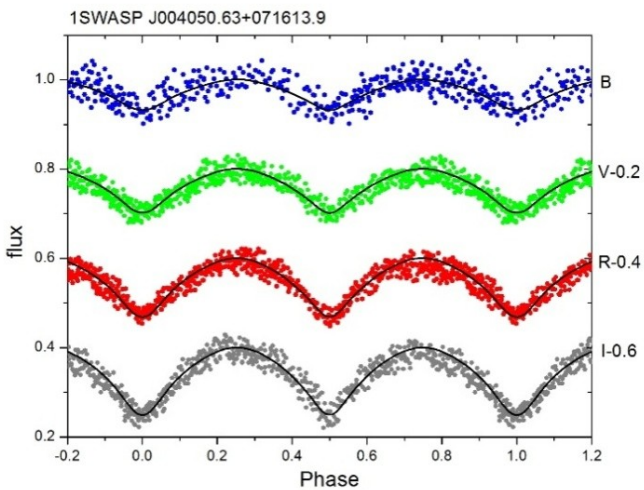
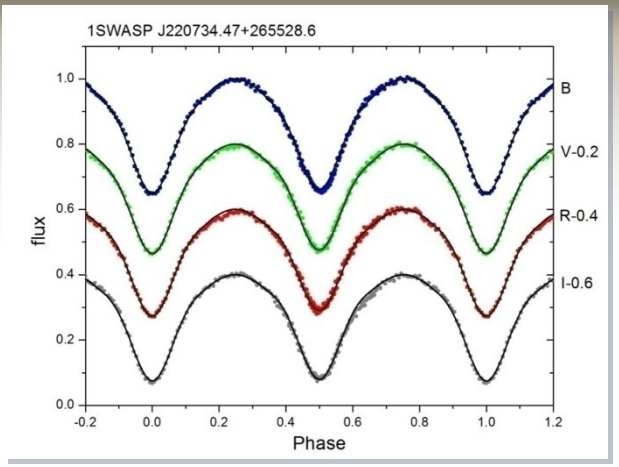
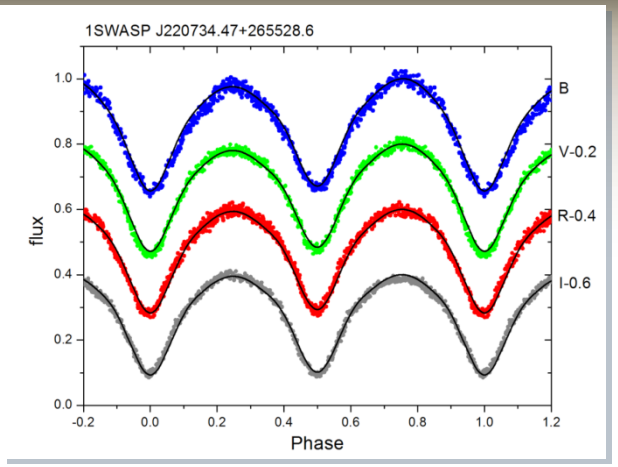
flux
Phase


1SWASP J004050.63+071613.9
B
V-0.2
R-0.4
I-0.6
flux
Phase

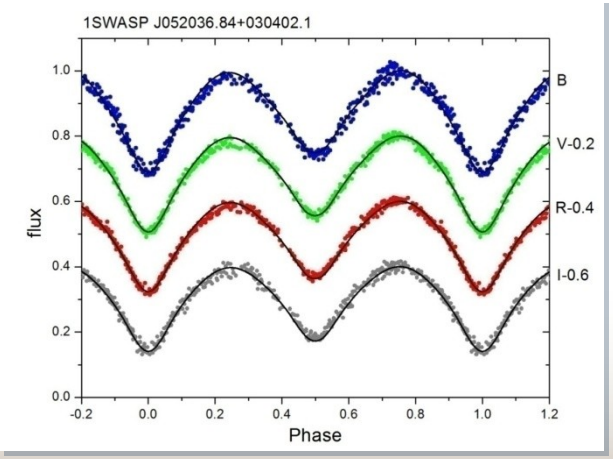
Comparison between observatories



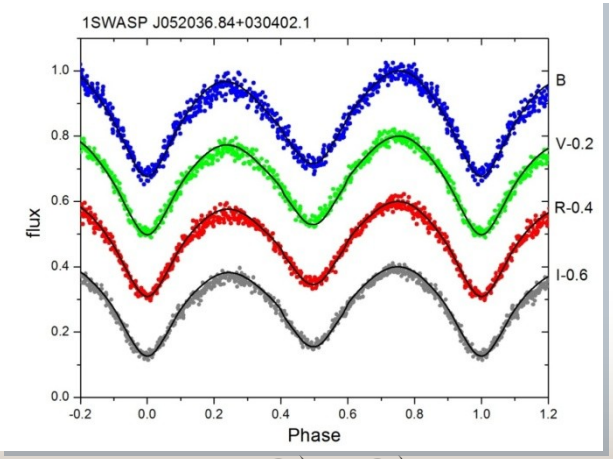
Helmos Observatory



UOA

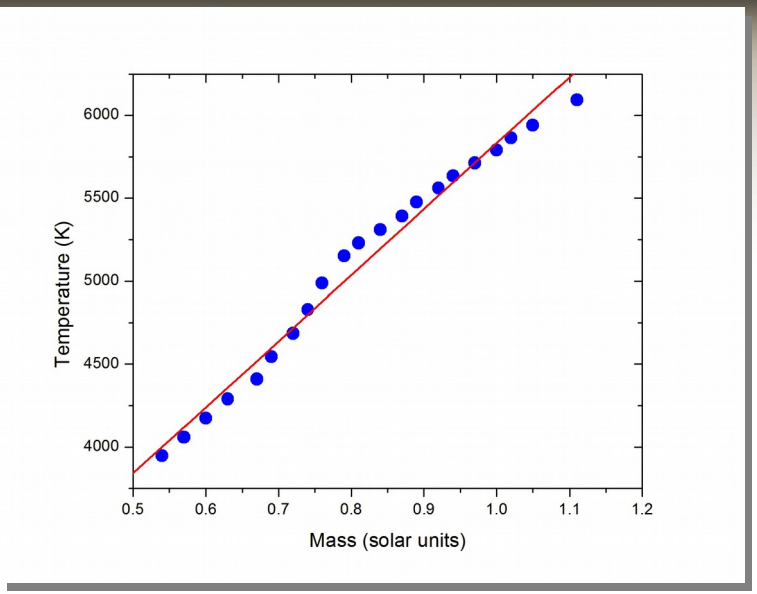


Kryoneri Observatory



UOA

Data mining & Analysis



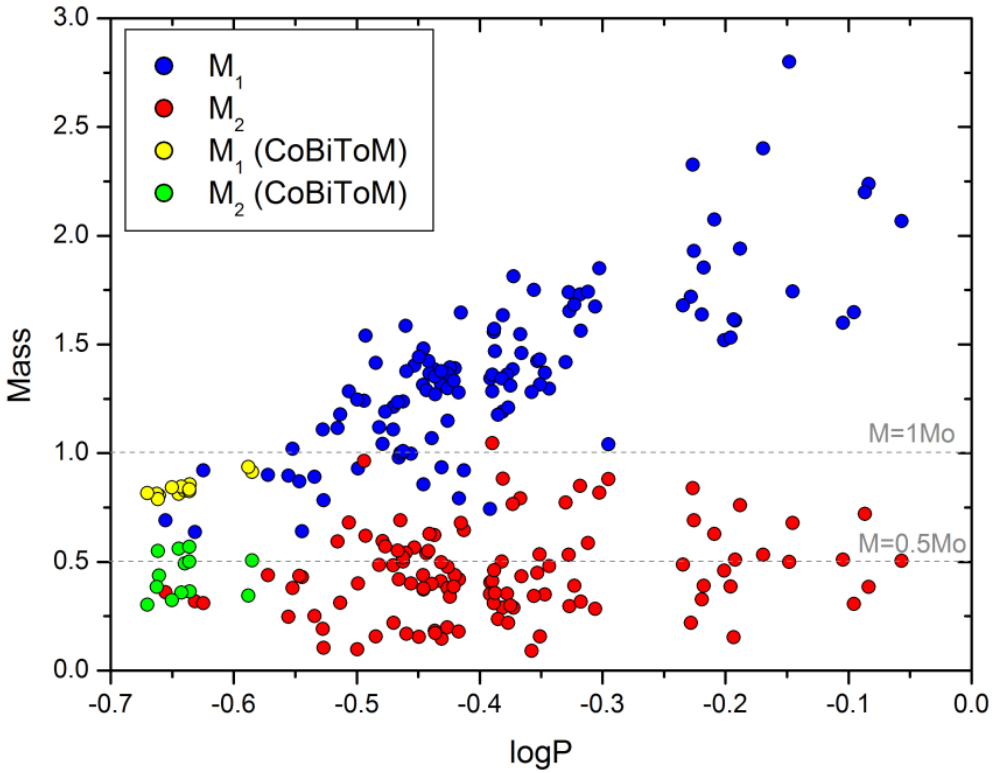
Teff=f(M) Main Sequence Stars (Cox, 2010)

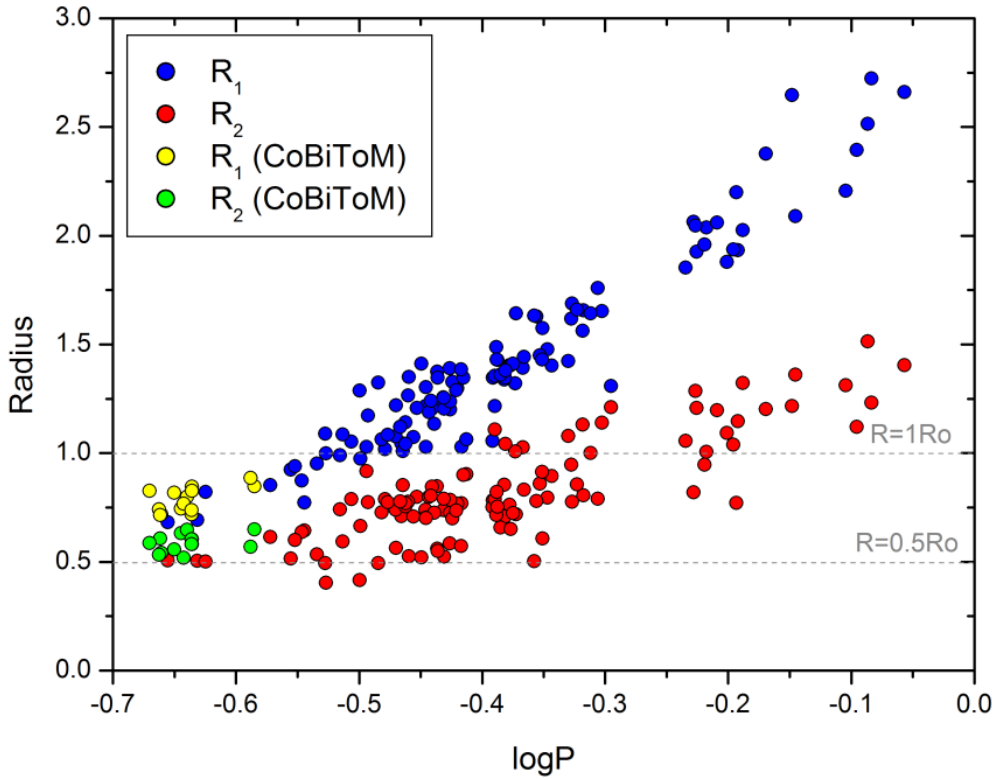
$\log M_1 = 0.725(59) \cdot \log P - 0.076(32) \cdot \log q + 0.365(32)$

Gazeas (2009)

System name	$M_1(M_\odot)$ (Gazeas 2009)	$M_1(M_\odot)$ (M.S.)	$M_1(M_\odot)$ (spectroscopy)
1SWASP J003033.05+574347.6	0.813±0.002	0.639 ± 0.071	
1SWASP J004050.63+071613.9	0.828±0.003	0.894± 0.079	
1SWASP J052036.84+030402.1	0.856±0.012	0.835± 0.077	
1SWASP J055418.43+442549.8	0.806±0.003	0.859± 0.078	
1SWASP J080150.03+471433.8	0.812±0.006	0.760± 0.075	
1SWASP J093012.84+533859.6	0.846±0.012	0.796± 0.075	0.86 (Lohr et al. 2015)
1SWASP J133105.91+121538.0	0.789±0.004	0.806± 0.076	
1SWASP J150822.80-054236.9	0.913±0.012	0.859± 0.078	1.07 (Lohr et al. 2013)
1SWASP J173003.21+344509.4	0.842±0.014	0.722± 0.074	
1SWASP J174310.98+432709.6	0.937±0.024	0.859± 0.078	
1SWASP J220734.47+265528.6	0.824±0.001	0.732± 0.074	
1SWASP J234401.81-212229.2	0.816±0.012	0.644± 0.071	

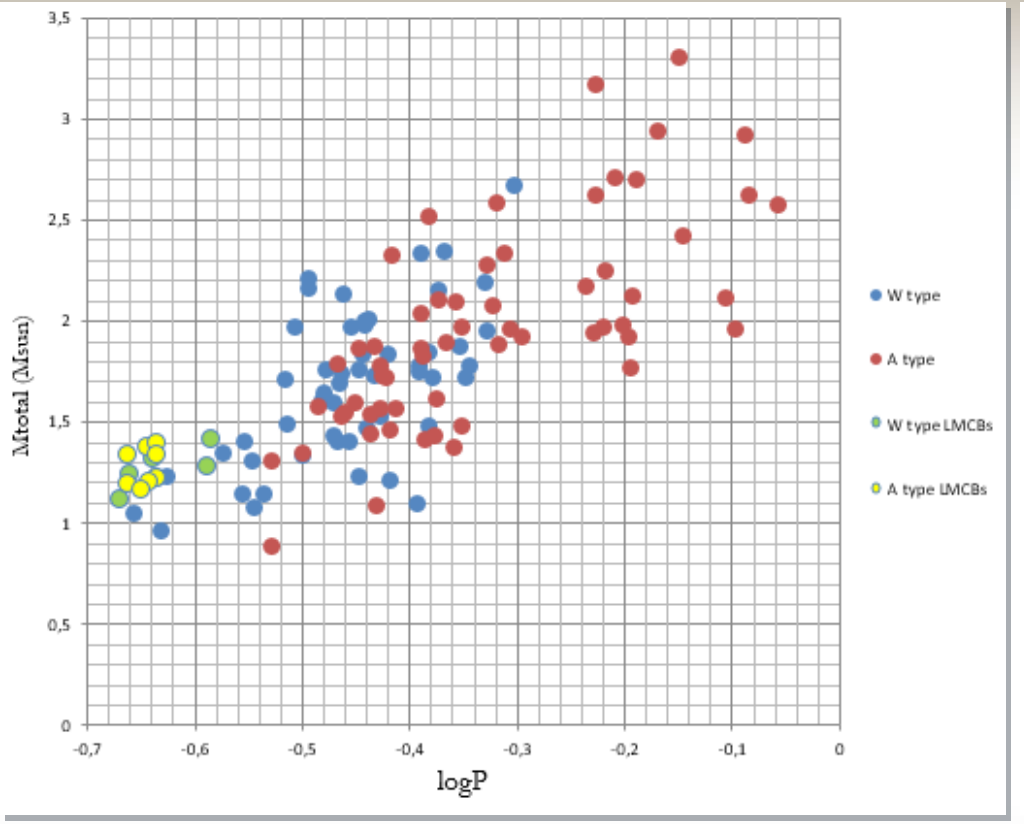
Correlation Diagrams (I)

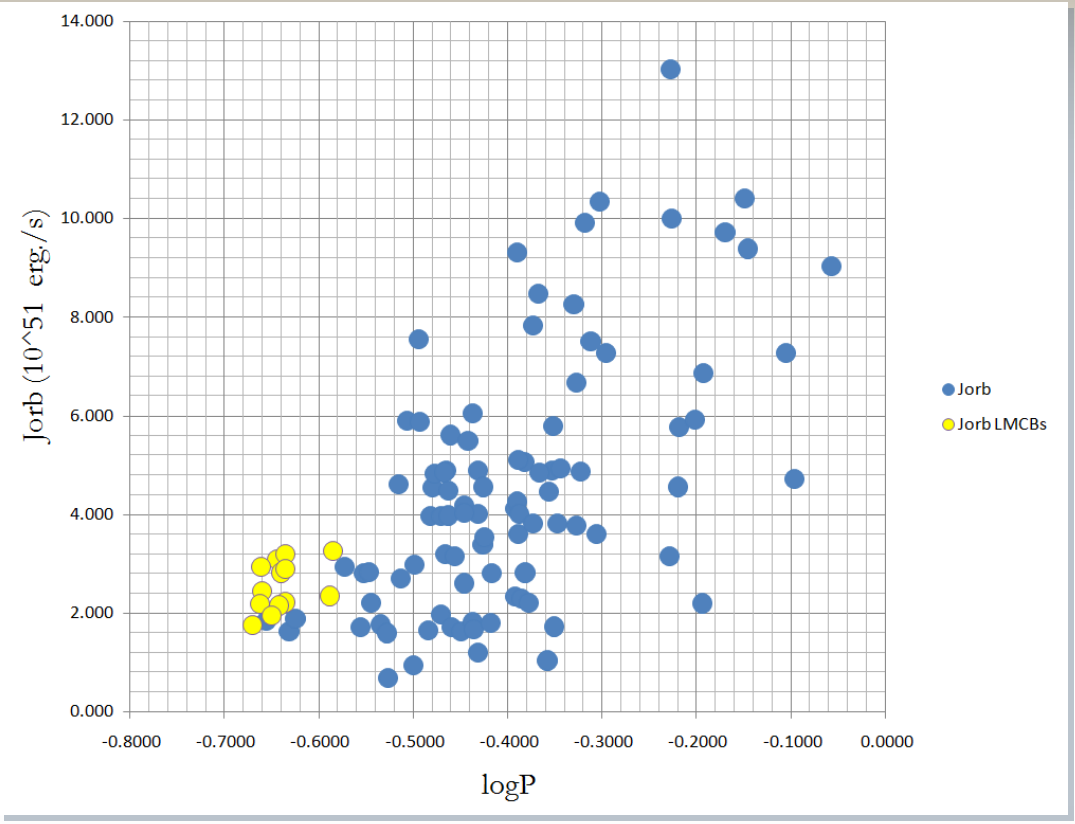




- Increasing the number of objects in the short orbital period range we can improve significantly the evolutionary scenarios and monitor stellar merging processes.

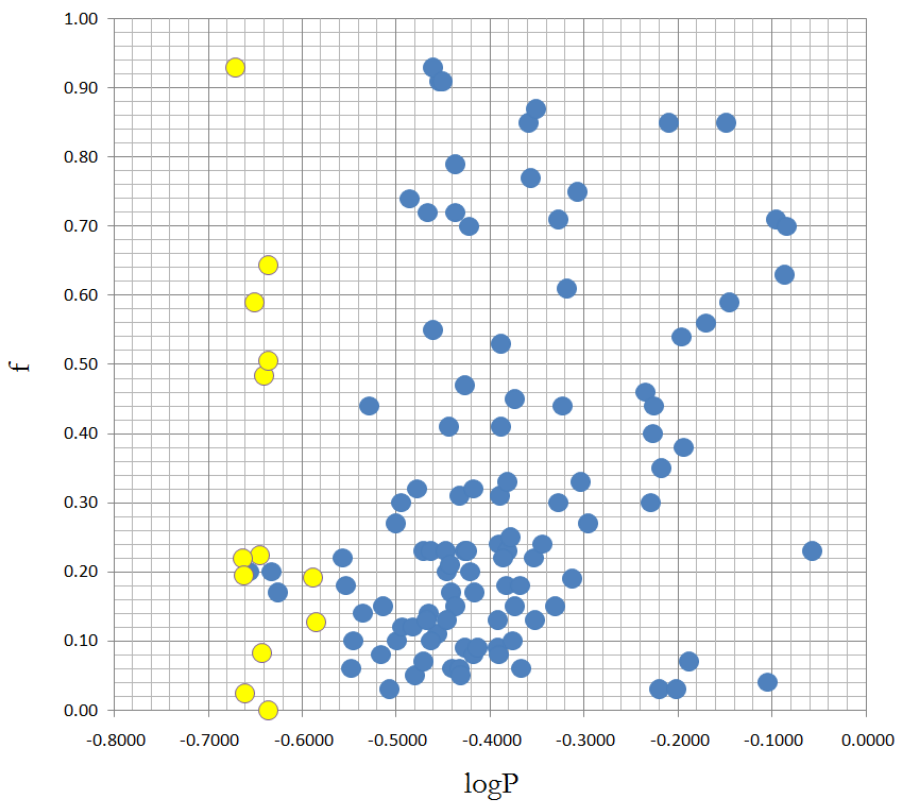
Correlation Diagrams (II)

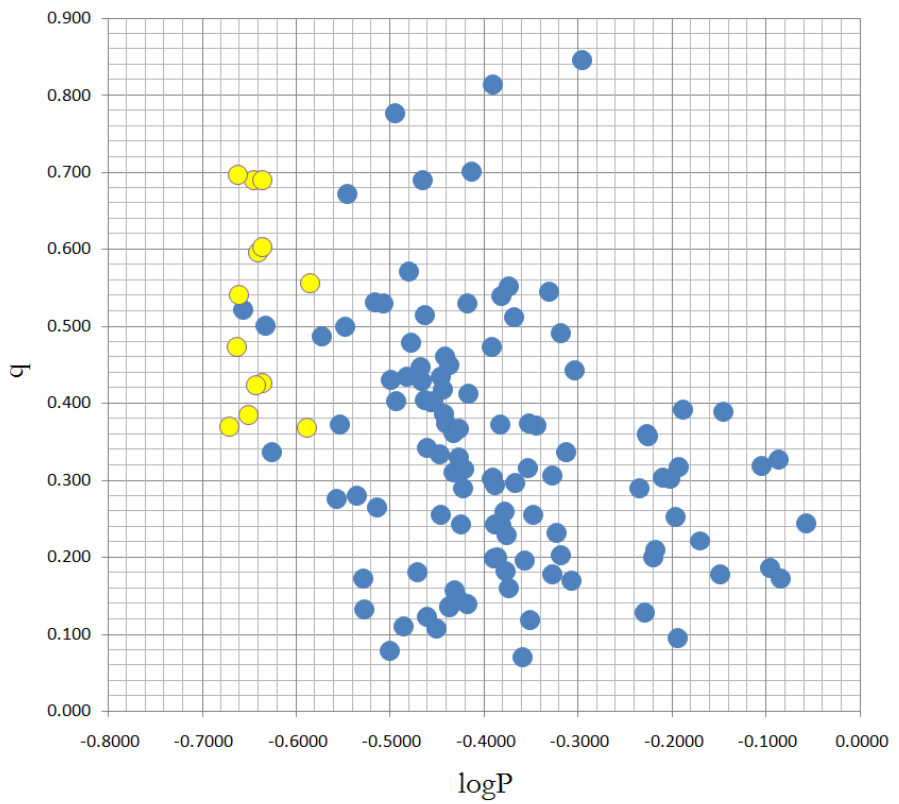




- The systems lose a significant part of their initial mass and angular momentum, as a result of their long evolution process.

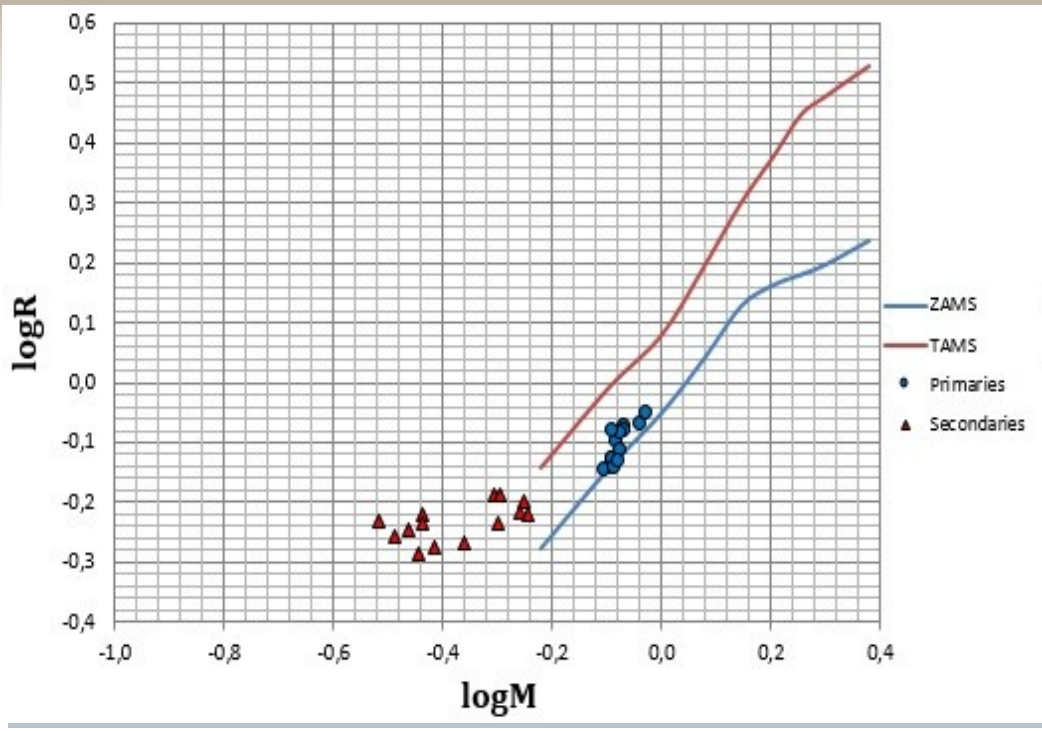
Correlation Diagrams (III)

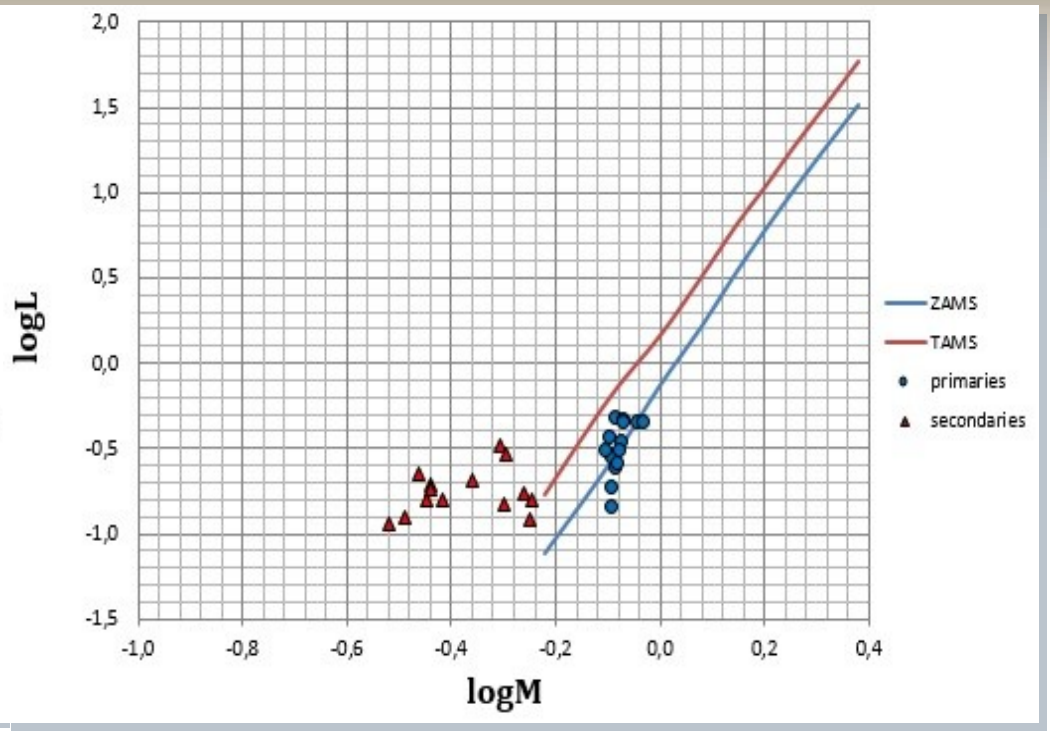




- The majority of LMCBs seem to just enter the contact phase, as they show low fill-out factor (left) and relatively high mass ratio (right).

Correlation Diagrams (IV)





- Secondary components appear over-sized and over-luminous for their MS mass.

(theoretical MS from Padova PARSEC Isochrones, Bressan et al. 2012)

Discussion

- LMCBs are among the most aged W UMa-type systems with significantly evolved MS components
- Light curve analysis from different observatories led to approximately same models and same physical parameters of our sample's light curves
- Over 25 systems have been observed up to date
- ***CoBiToM*** *Project* continues to contribute on the research of stellar merging processes

Future steps

➔ Determine the display frequency of such systems among other CBs

➔ Constrain physical properties of potential stellar mergers

➔ Estimate coalescence time scale in stellar merging candidates


Thank you!