Close Binaries with δ Scuti components:

New discoveries, analysis techniques and recent results

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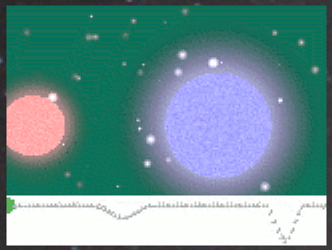
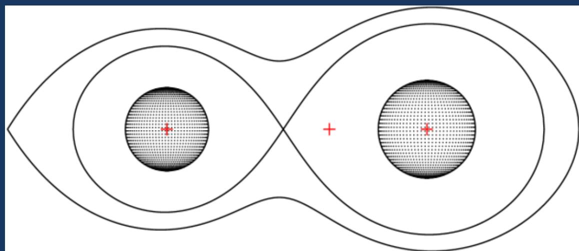


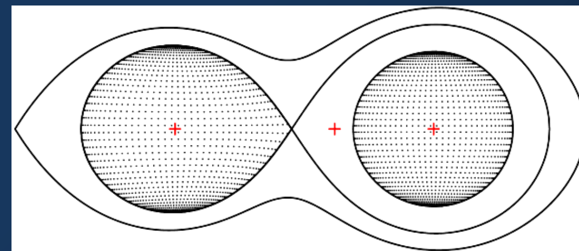
The 10th Hellenic Astronomical Conference, 5-8 September 2011, Ioannina, Hellas

Introduction – Close & eclipsing binaries

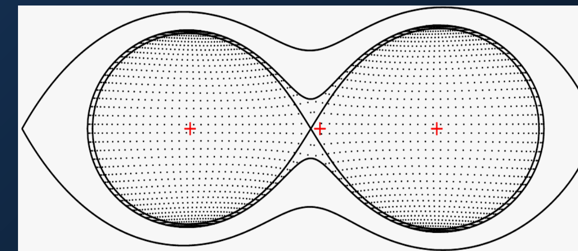
Detached



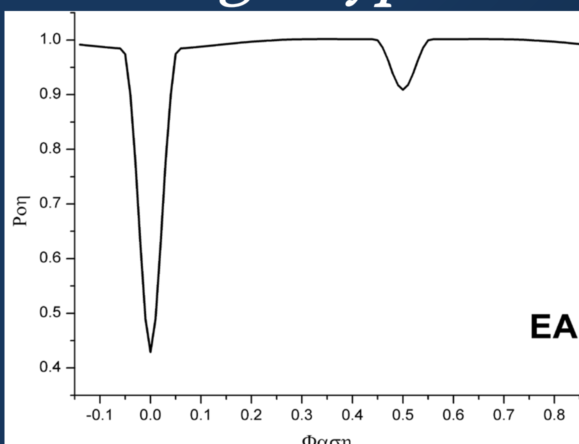
Semidetached



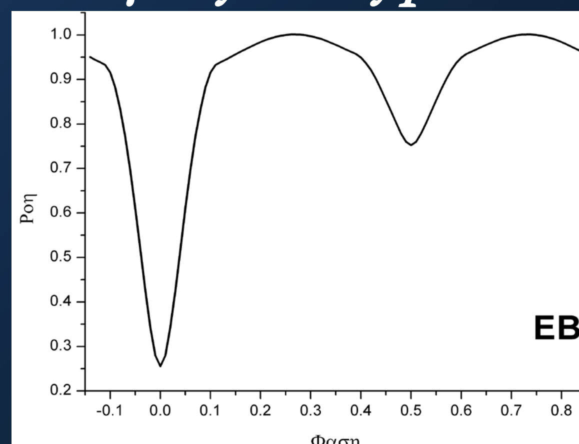
Contact



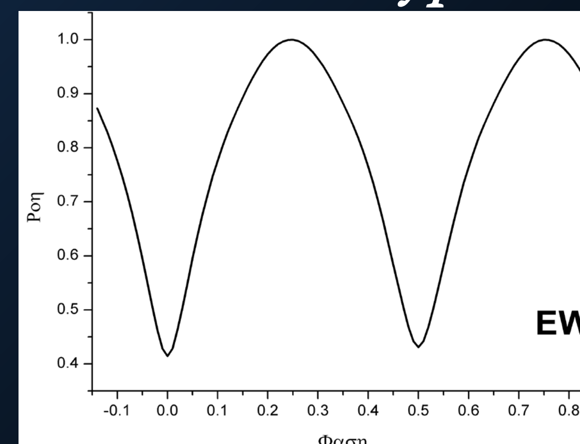
Algol type

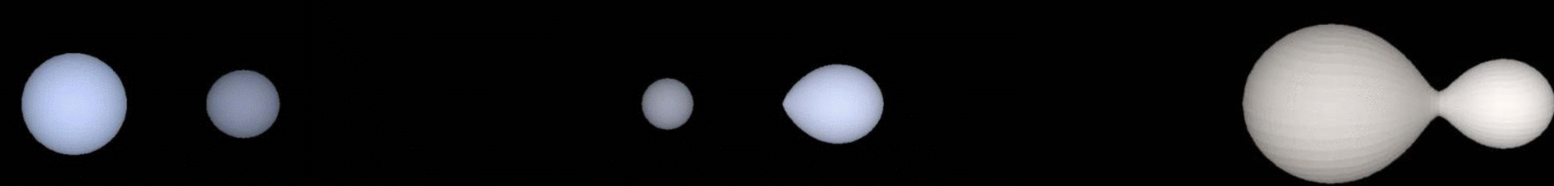


β Lyrae type



W UMa type





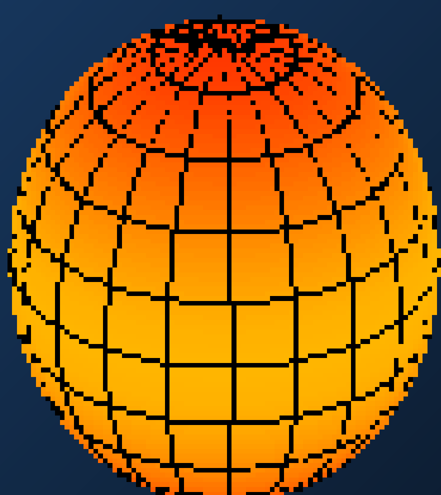
Introduction – Pulsating stars

Internal and surface oscillations $\rightarrow$ $\varkappa$ and γ mechanisms

Pulsation types

Radial

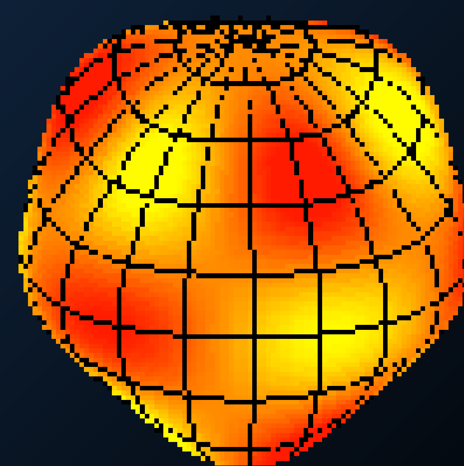
fundamental – **modes**



Non-radial

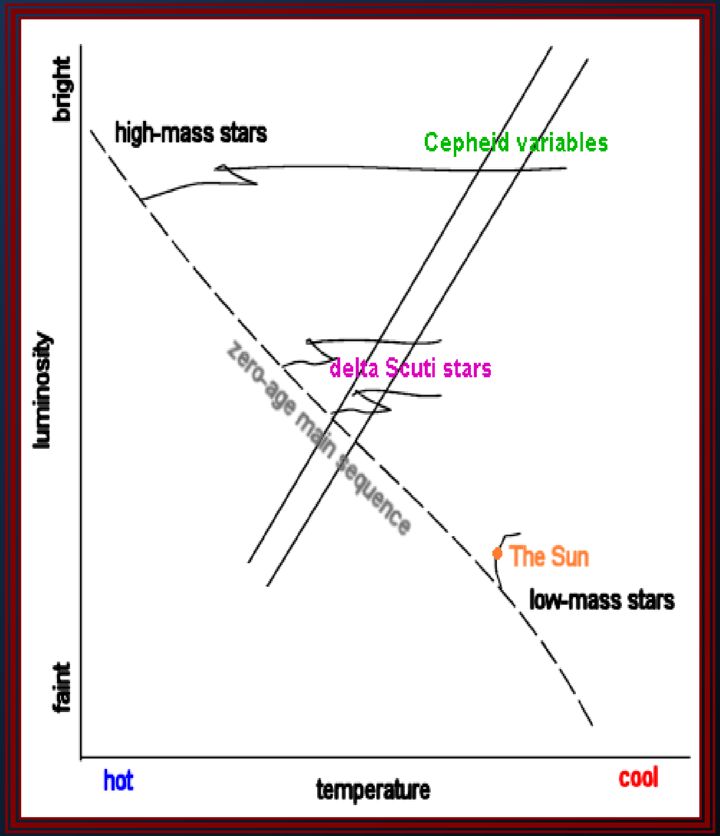
pressure – **modes**

gravity – **modes**



Introduction – δ Scuti pulsators

- A - F spectral classes
- III - V luminosity classes
- 1.5 – 2.5 $M_\odot$
- Pulsation period range: 20 min – 8 hrs



Types

High Amplitude (HADS)

- Subgiants
- Amplitude>0.1 mag
- Radial Pulsations

Low Amplitude (LADS)

- No standard evolutionary stage
- Amplitude<0.1 mag
- Radial & Non-Radial Pulsations

Motivation for studying binaries with pulsators

Pulsating stars → Asteroseismology-Physics of the stellar pulsations

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Binaries → Absolute parameters, evolutionary status and eclipses as spatial filter for better mode identification (Mkrtichian et al. 2004)

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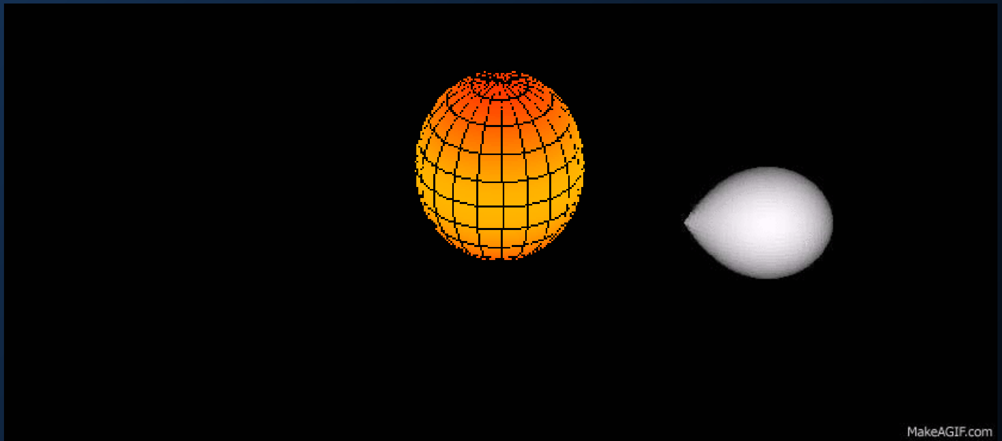
Knowledge about this extraordinary path of stellar lifetime



Brief history

- Mkrtichian et al. (2004) → the oEA (oscillating EA) stars as the (B)A-F spectral type mass-accreting MS pulsators in semi-detached Algol-type eclipsing binaries

- Soydugan et al. (2006a) → connection between pulsation and orbital periods of systems with δ Scuti member with a sample of 20 systems

- Soydugan et al. (2006b) → catalogue with candidate such systems

- Zhou (2010) → catalogue with confirmed systems with a pulsating (in general) member

- Liakos et al. (MNRAS, in prep.) → updated catalogue with 75 confirmed systems with a δ Scuti companion & NEW correlations between fundamental stellar characteristics

Surveys for δ Sct components in EBs

Instrumentation & Sites

Observatory	Location	Telescope	Purpose
Gerostathopoulion	University of Athens	40 cm	Photometry
Gerostathopoulion	University of Athens	25 cm	Photometry
Gerostathopoulion	University of Athens	20 cm	Photometry
Kryonerion	Kyllini Mt., Corinthia	1.2 m	Photometry
Skinakas	Ida Mt., Crete	1.3 m	Spectroscopy

Main Observing Site (Athens)

Advantages

- More than 200 **TOTALLY** clear nights per year
- Plenty of observational time
- Simultaneous observations

Ideal for long term projects

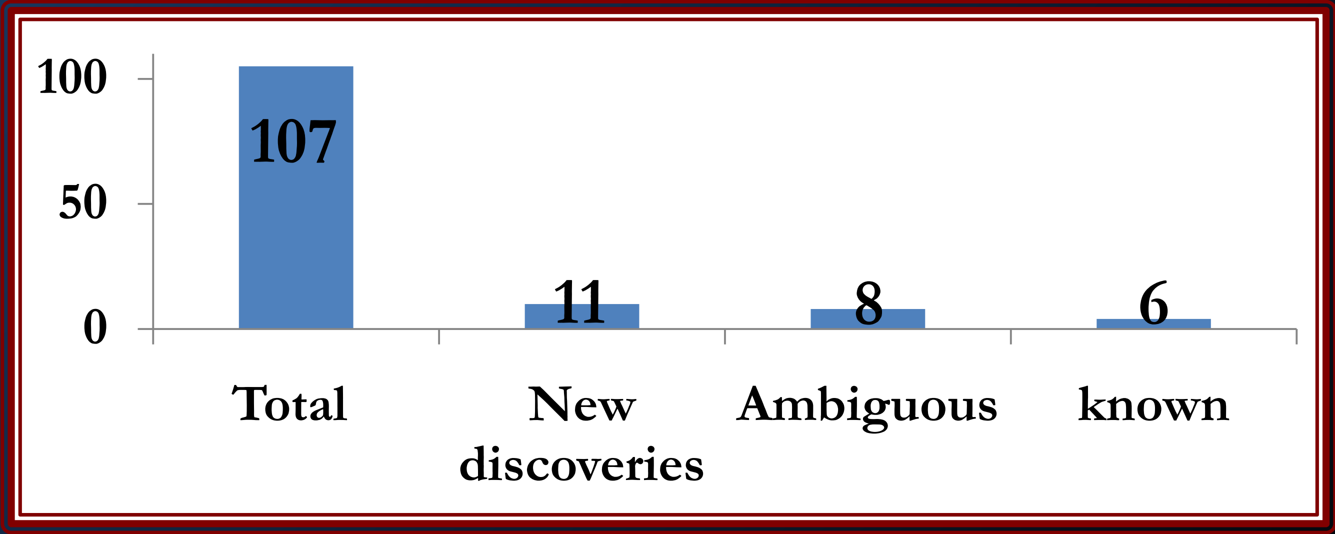
Disadvantages

- Small diameter of the telescopes
- Light pollution

Surveys for δ Sct components in EBs

Log of observations & statistics

Survey No.	Years	Total systems observed	New discoveries	Complete LC of already known
1	2007-2009	30	2	4
2	2009-2011	68	8	1
3	2011- ……	9	1	1
Total nights~500 - Total hours~2100				



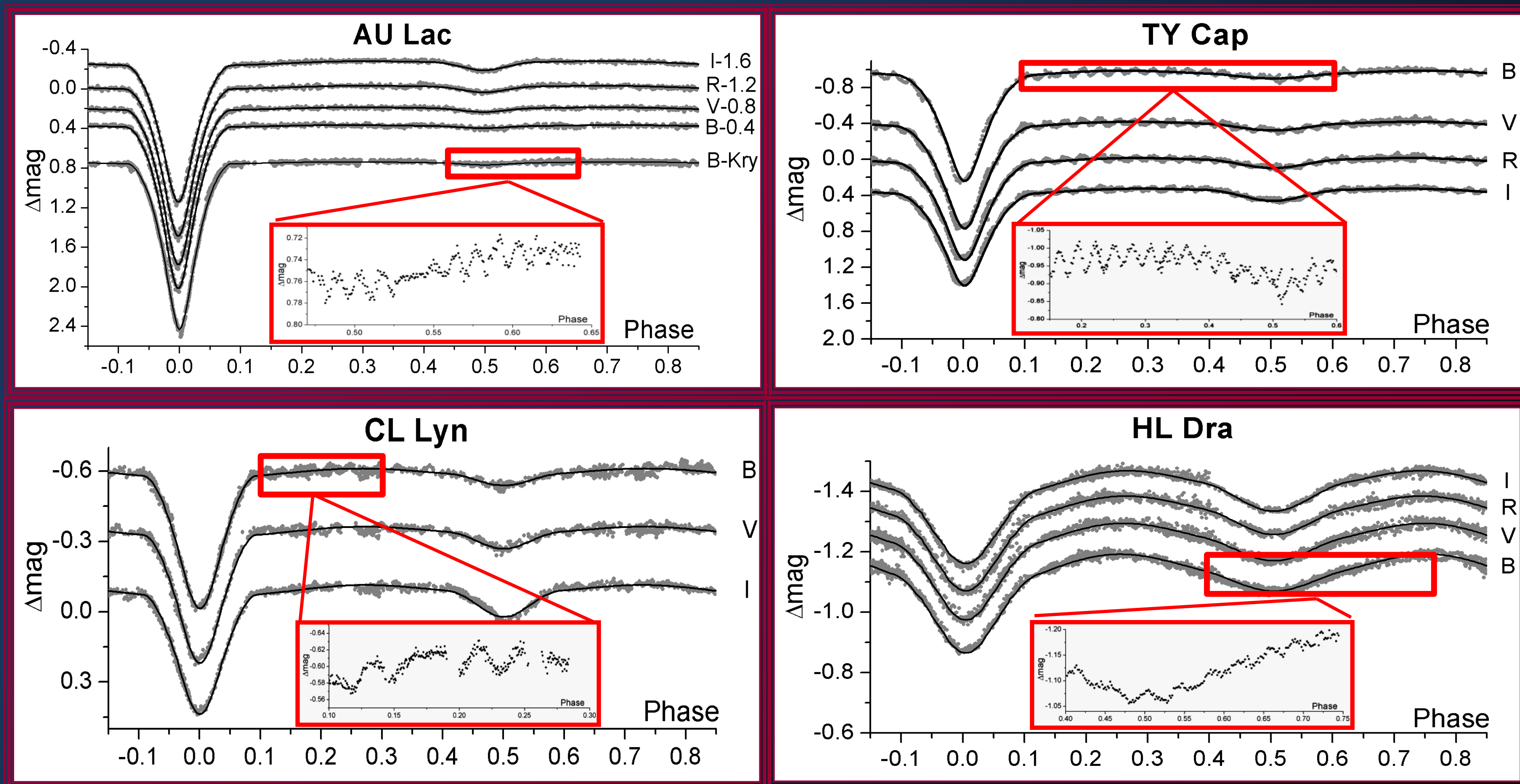
Surveys for δ Sct components in EBs

List of the 17 observed systems with δ Sct component

System	Period [days]	Frequencies found	Total nights	Total hrs	Filters	Comment
Aql QY	7.22954	In prog.	31	200+	BVI	New
Aqr CZ	0.86275	1	10	25+	B	New
Cap TY	1.42346	2	11	35+	BVRI	New
Cet WY	1.93969	1	16	50+	BVRI	New
Cyg UW	3.45080	2	26	90+	BVI	New
Del BW	2.42314	In prog.	In prog.	In prog.	In prog.	New
Dra HL	0.94400	3	17	60+	BVRI	New
Dra HZ	0.77294	1	8	25+	BVRI	New
Dra TZ	0.86603	In prog.	10	25+	BVRI	Known
Eri TZ	2.60610	2	26	80+	BV	Known
Her BO	4.27283	2	25	120+	BVI	Known
Lac AU	1.39243	2	19	80+	BVRI	New
Lyn CL	1.58604	3	12	80+	BVI	New
Peg BG	1.95243	3	15	100+	BVRI	Known
Per IU	0.85703	2	11	40+	BVRI	Known
UMa IO	5.52039	In prog.	47	150+	BVRI	New
UMa VV	0.68738	1	3	15+	BVRI	Known

Surveys for δ Sct components in EBs

Sample of light curves obtained during the surveys

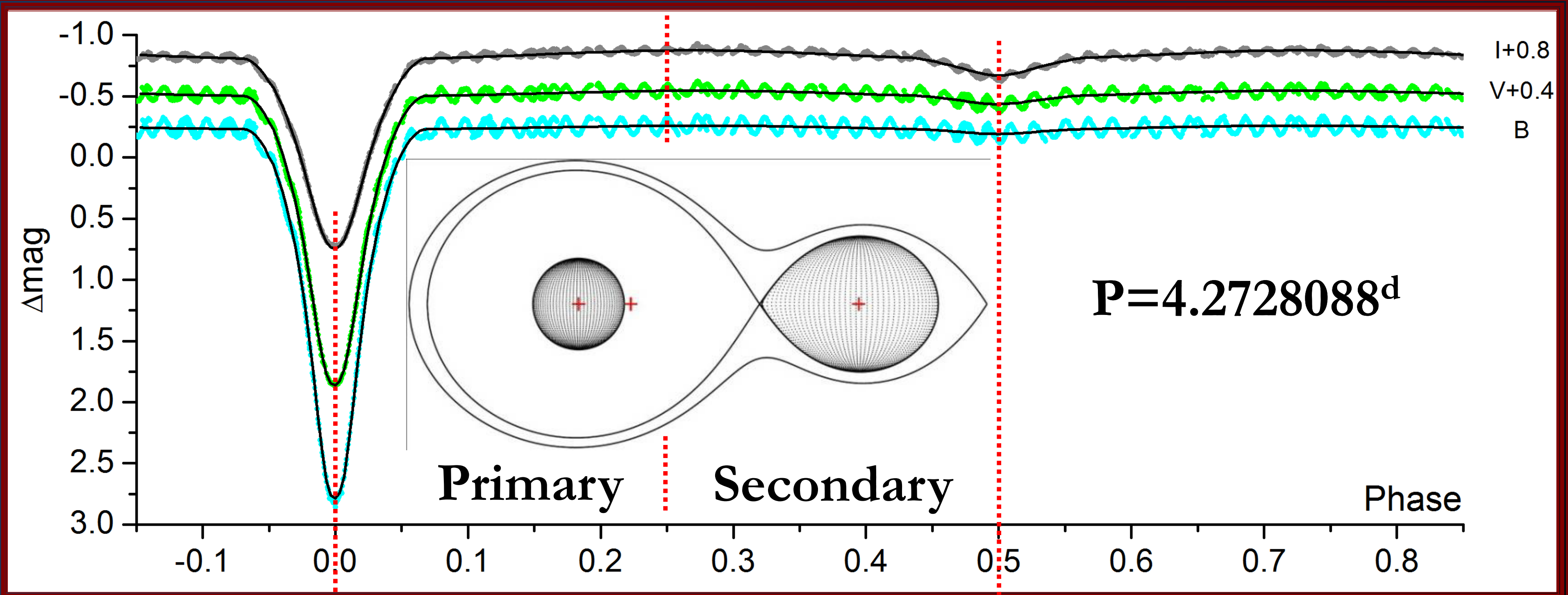


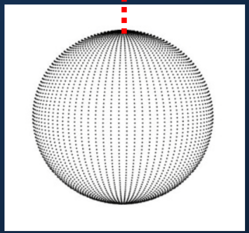
Taken from Liakos et al., MNRAS, in prep.

Data Analysis methods – The case of BO Her

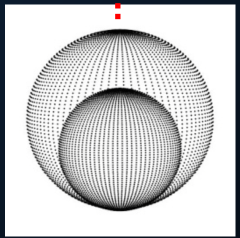
Light curve modelling and 3D simulation

PHOEBE software (Prša & Zwitter 2005) which uses the W-D code





Primary eclipse



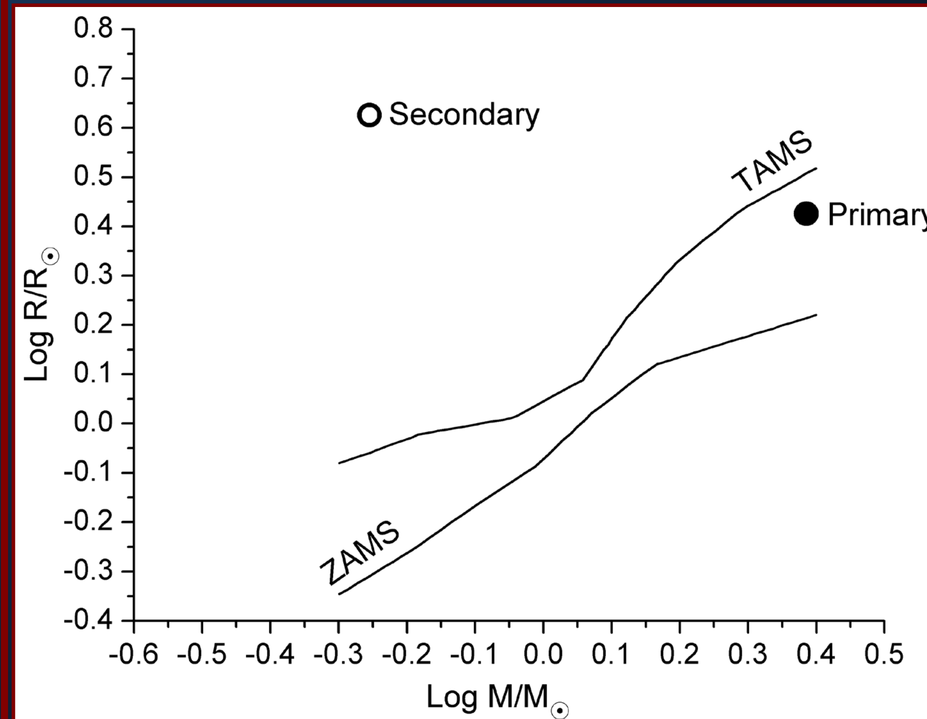
Secondary eclipse

Data Analysis methods – The case of BO Her

Absolute parameters & Evolutionary Status

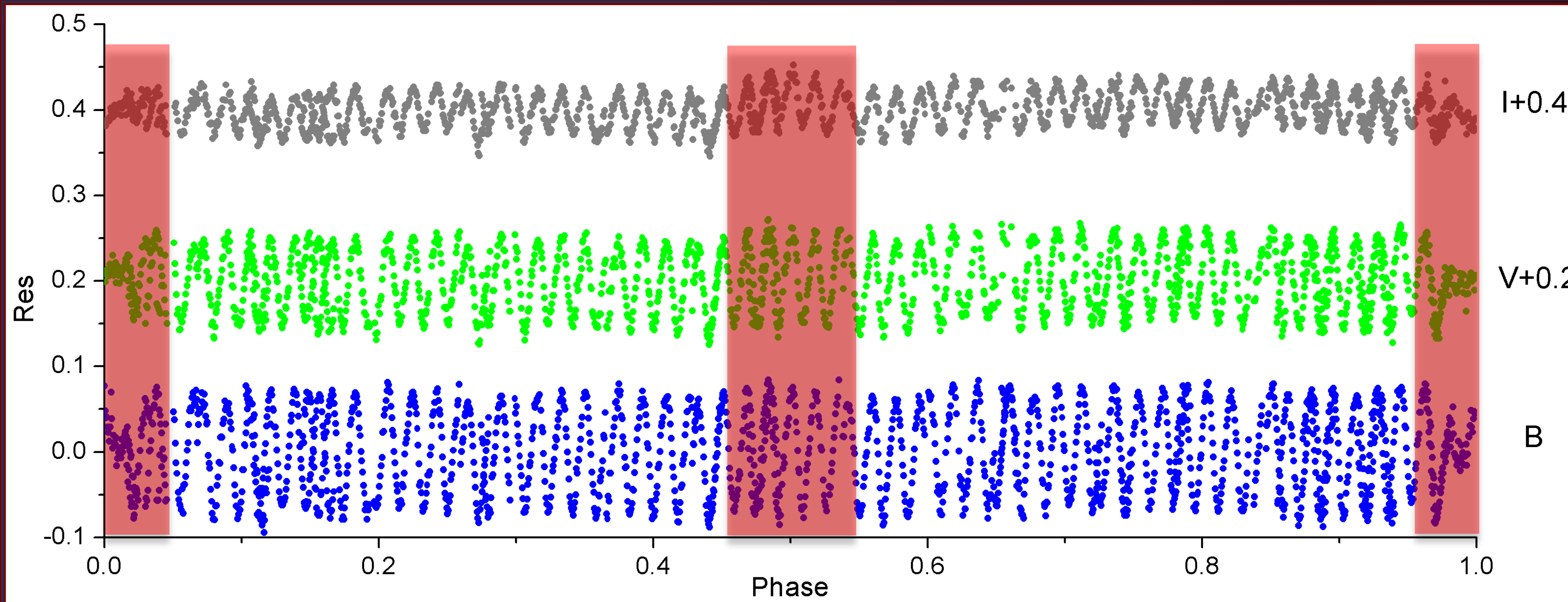
Par.	Primary	Secondary
M [$M_\odot$]	2.43*	0.56 (1)
R [$R_\odot$]	2.7 (1)	4.2 (2)
T [K]	7800*	4380 (50)
L [$L_\odot$]	24 (2)	5.9 (5)
Log g	3.97 (3)	2.93 (3)

*assumed



Data Analysis methods – The case of BO Her

Light curve residuals



- Eclipse and proximity effects are excluded
- Data near the eclipses are not used

Data Analysis methods – The case of BO Her

Frequency analysis

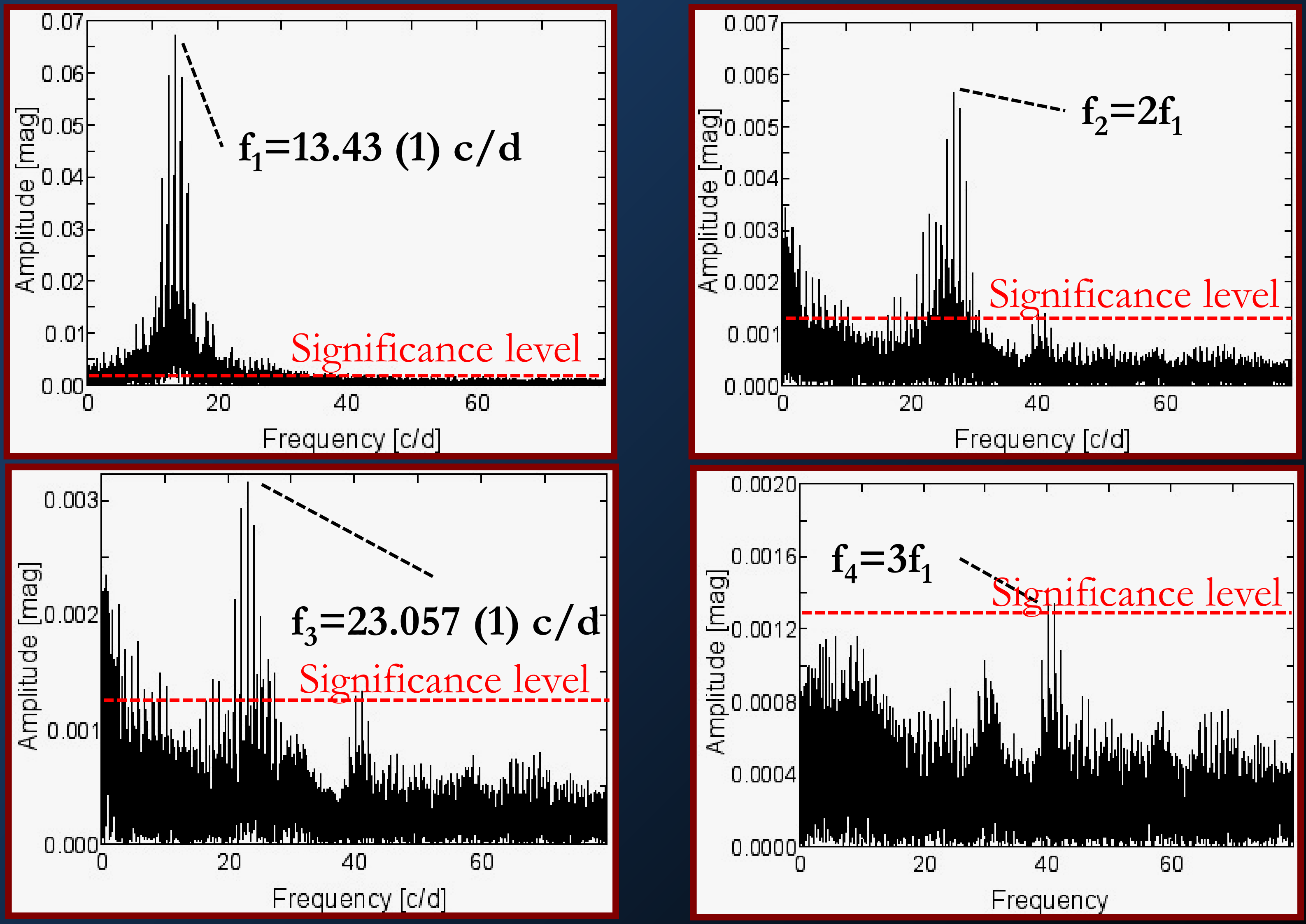
Fourier Analysis with the software Period04 (Lenz & Breger 2005)

$$m = Z + \Sigma A_i \, \mathrm{Sin}\, [2\pi(\omega_i \, t + \Phi_i)]$$

After each frequency computation the residuals are pre-whitened for the next one

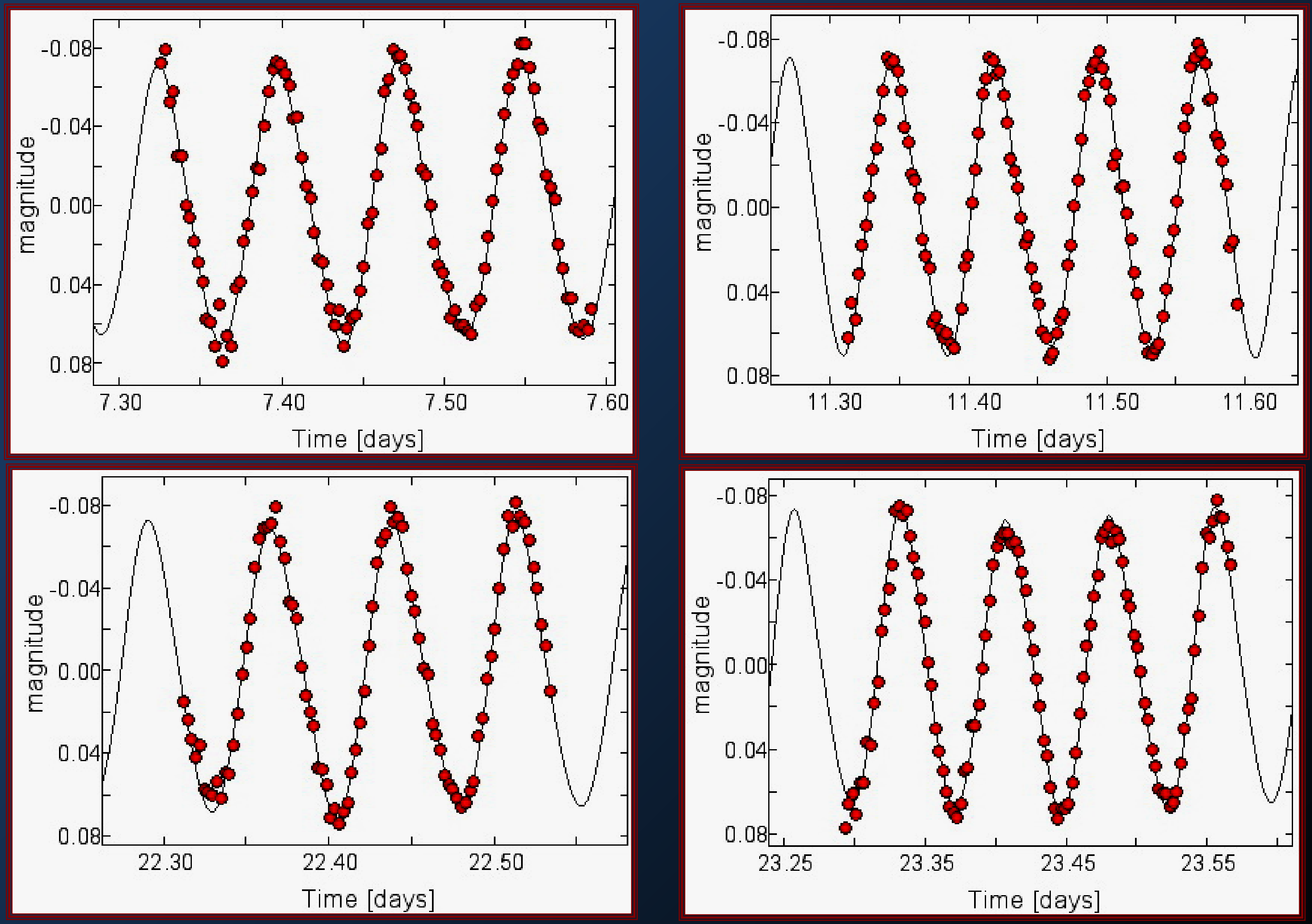
Data Analysis methods – The case of BO Her

Frequency analysis – Fourier Amplitude spectra



Data Analysis methods – The case of BO Her

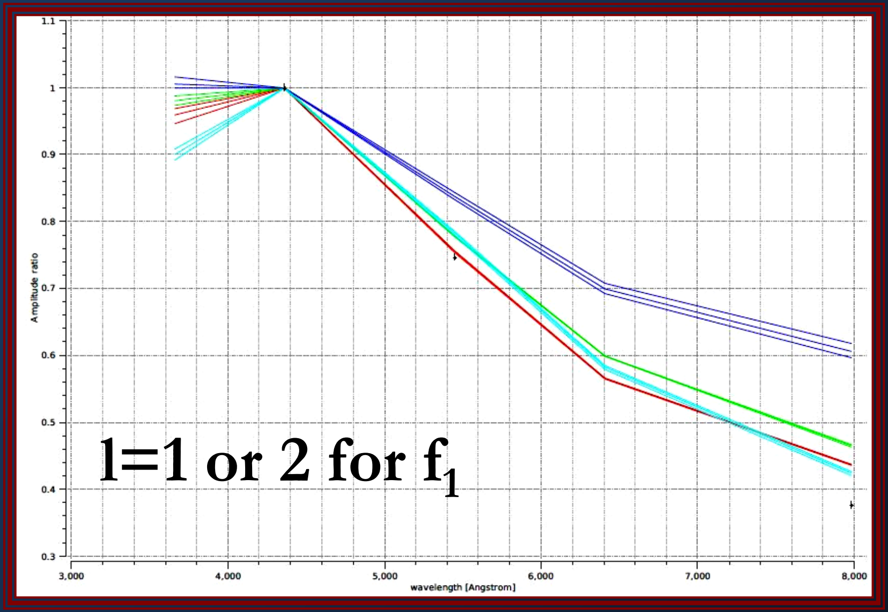
Frequency analysis – Fourier modelling

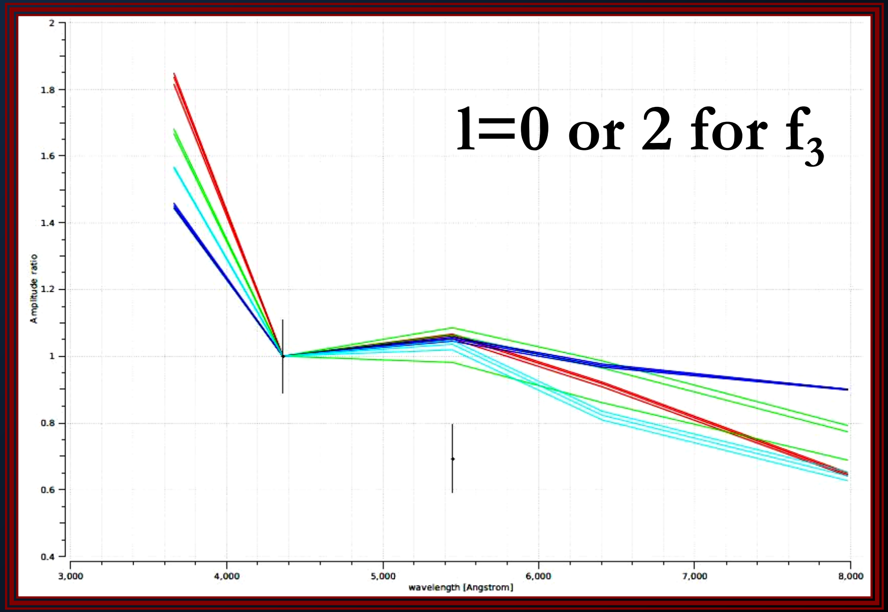


Data Analysis methods – The case of BO Her

Pulsation mode approach

- FAMIAS software (Zima 2008)
- Comparison with δ Sct theoretical models
- Calculation of *l*-degree of spherical harmonics based on static plane-parallel models of stellar atmospheres and on linear non-adiabatic computations of stellar pulsation

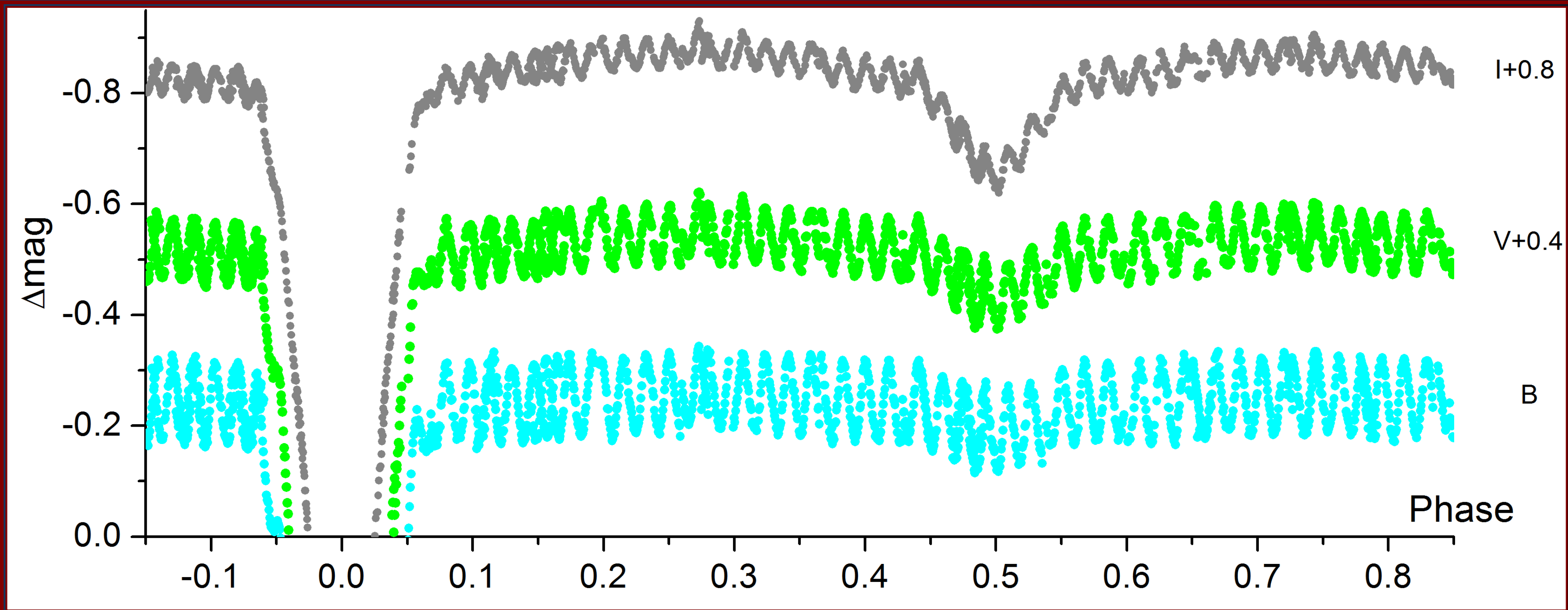




Data Analysis methods – The case of BO Her

Synthetic model

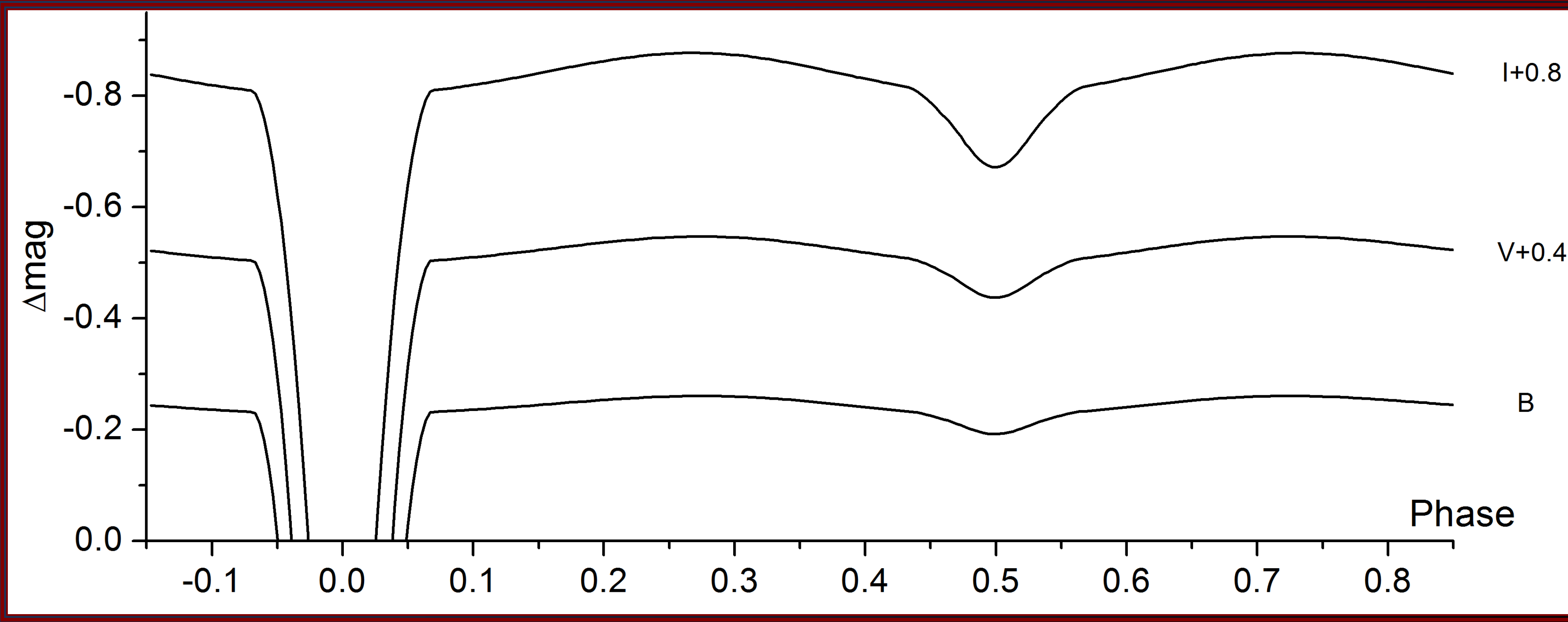
Observations



Data Analysis methods – The case of BO Her

Synthetic model

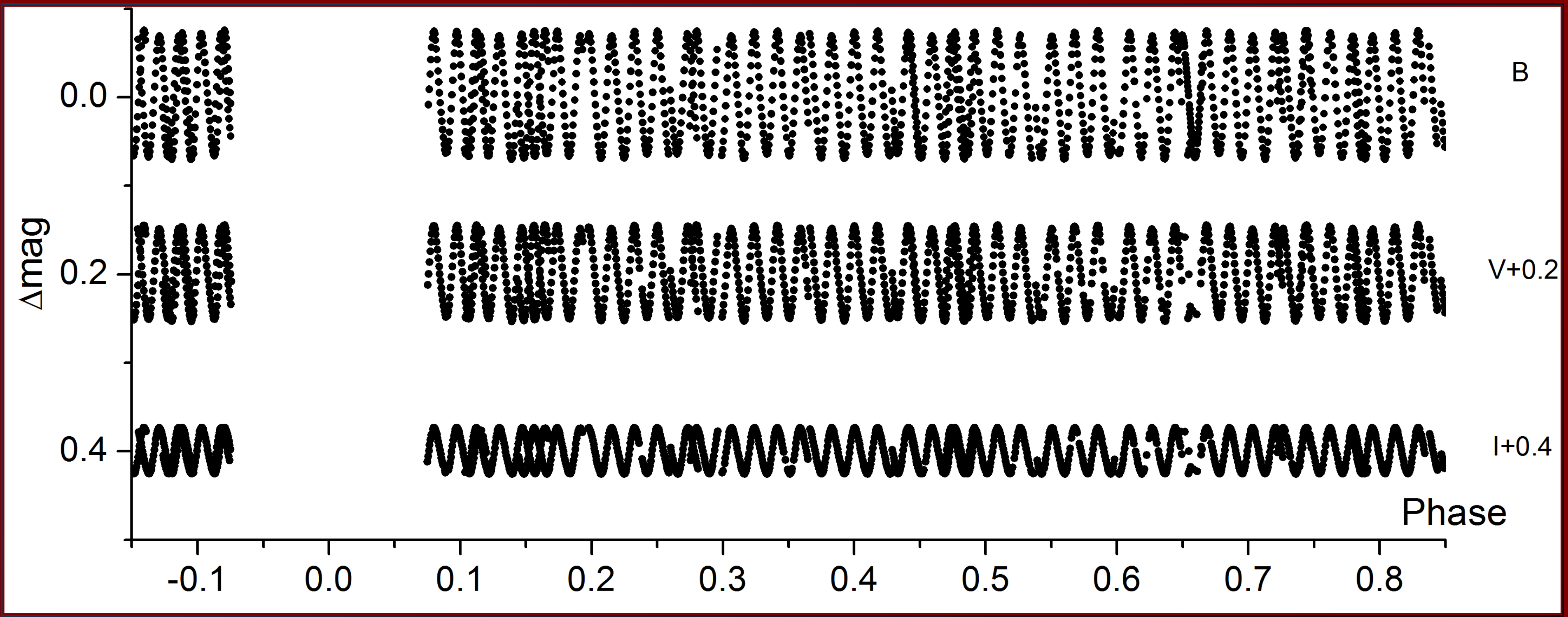
Binary model



Data Analysis methods – The case of BO Her

Synthetic model

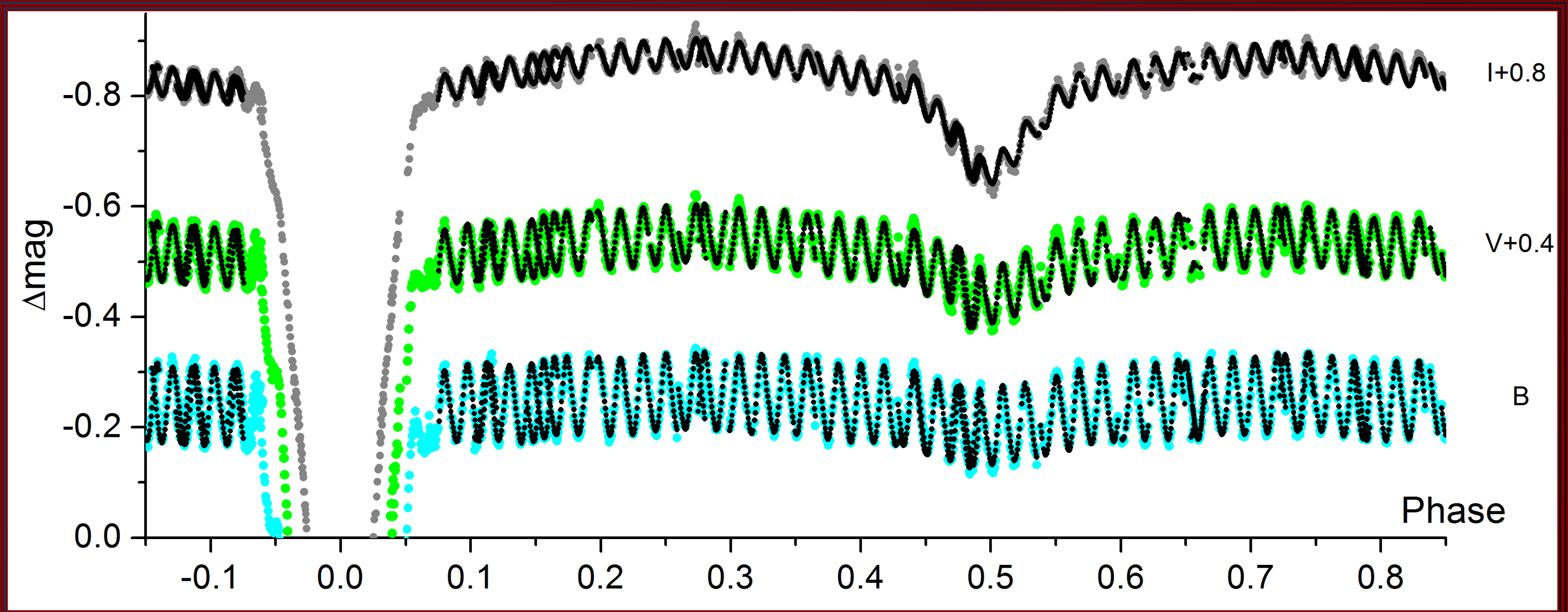
Pulsations model



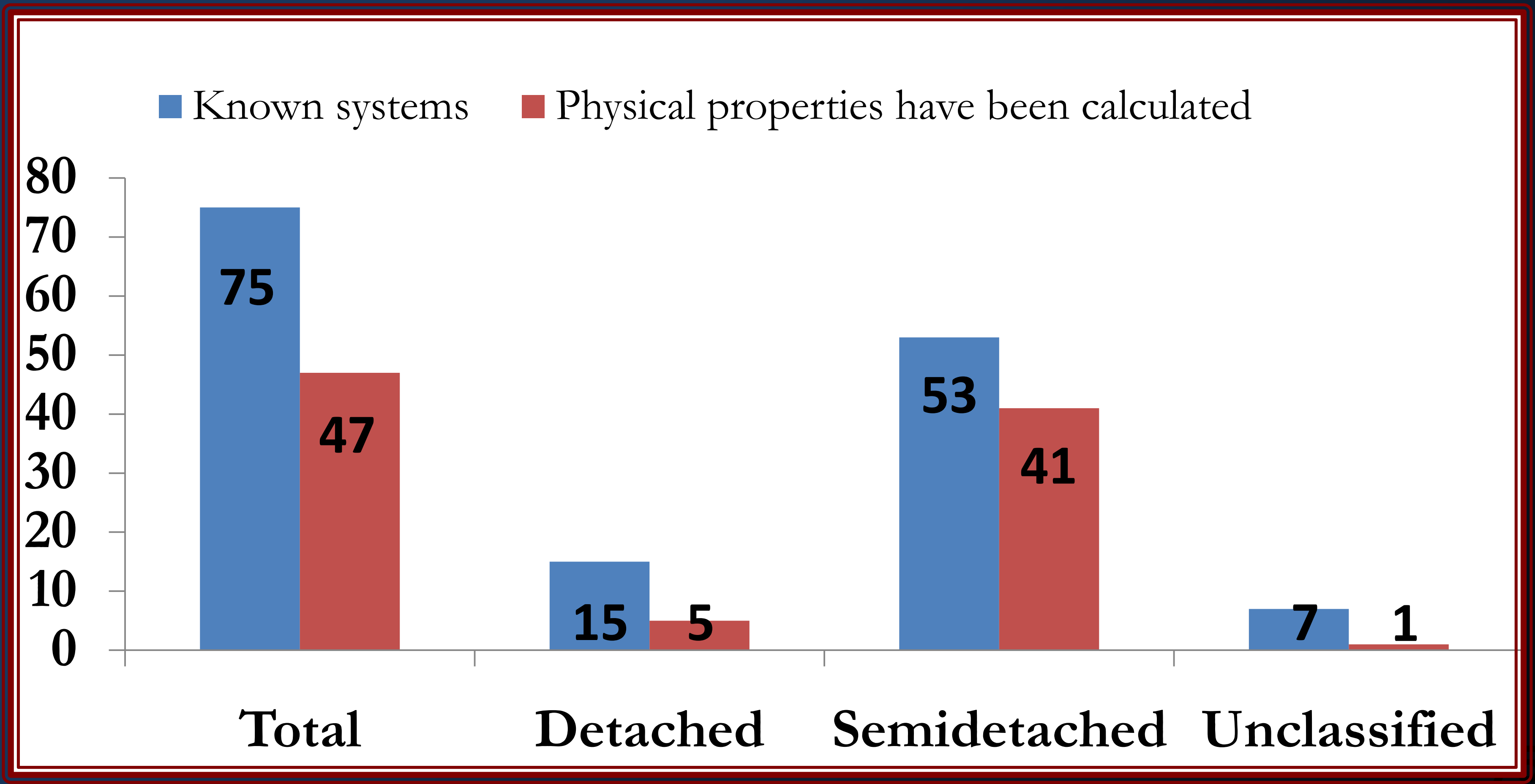
Data Analysis methods – The case of BO Her

Synthetic model

Binary & Pulsation model



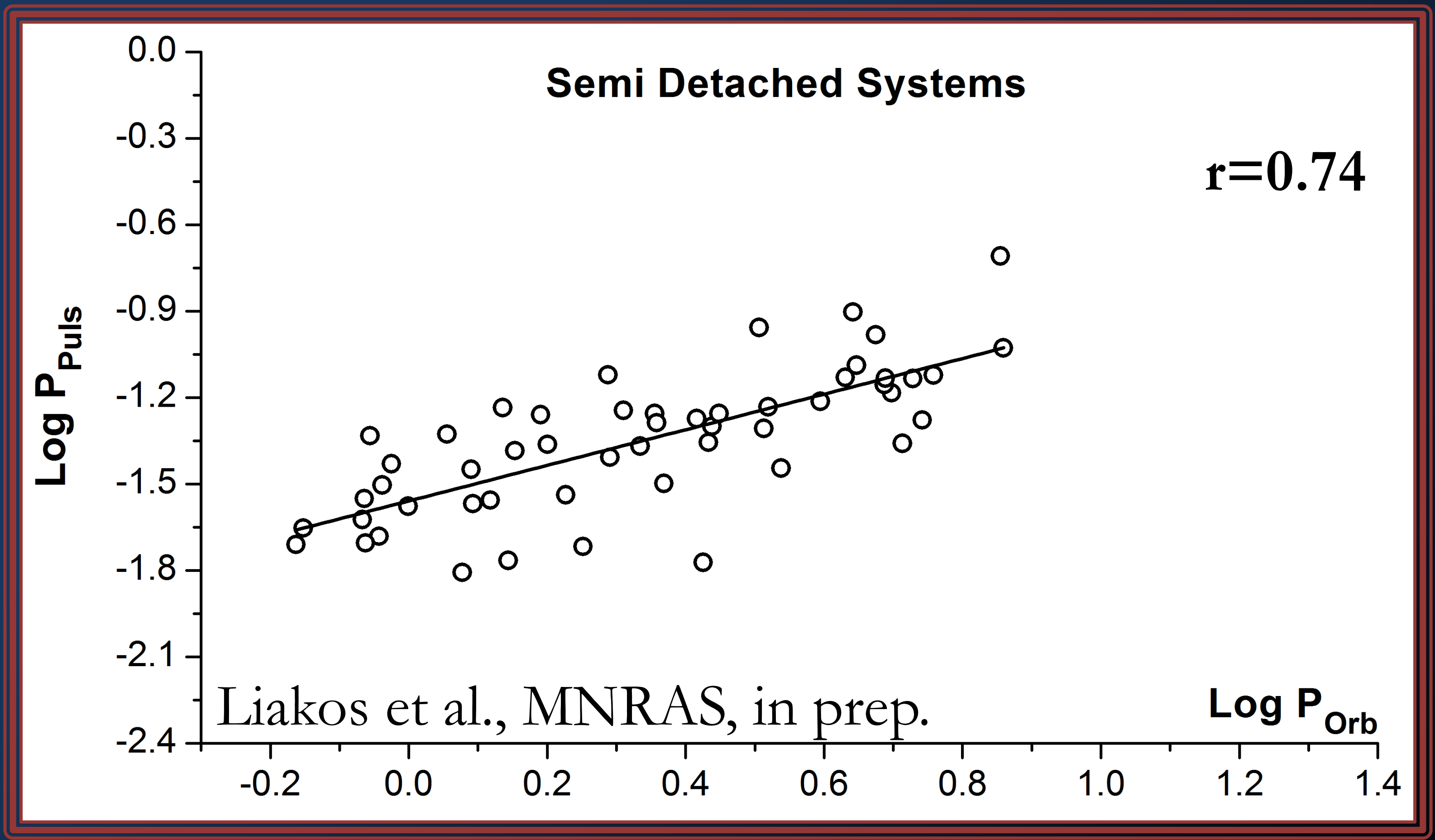
Updated catalogue



11 out of 75 (~15% in total) have been discovered by our surveys

Correlations

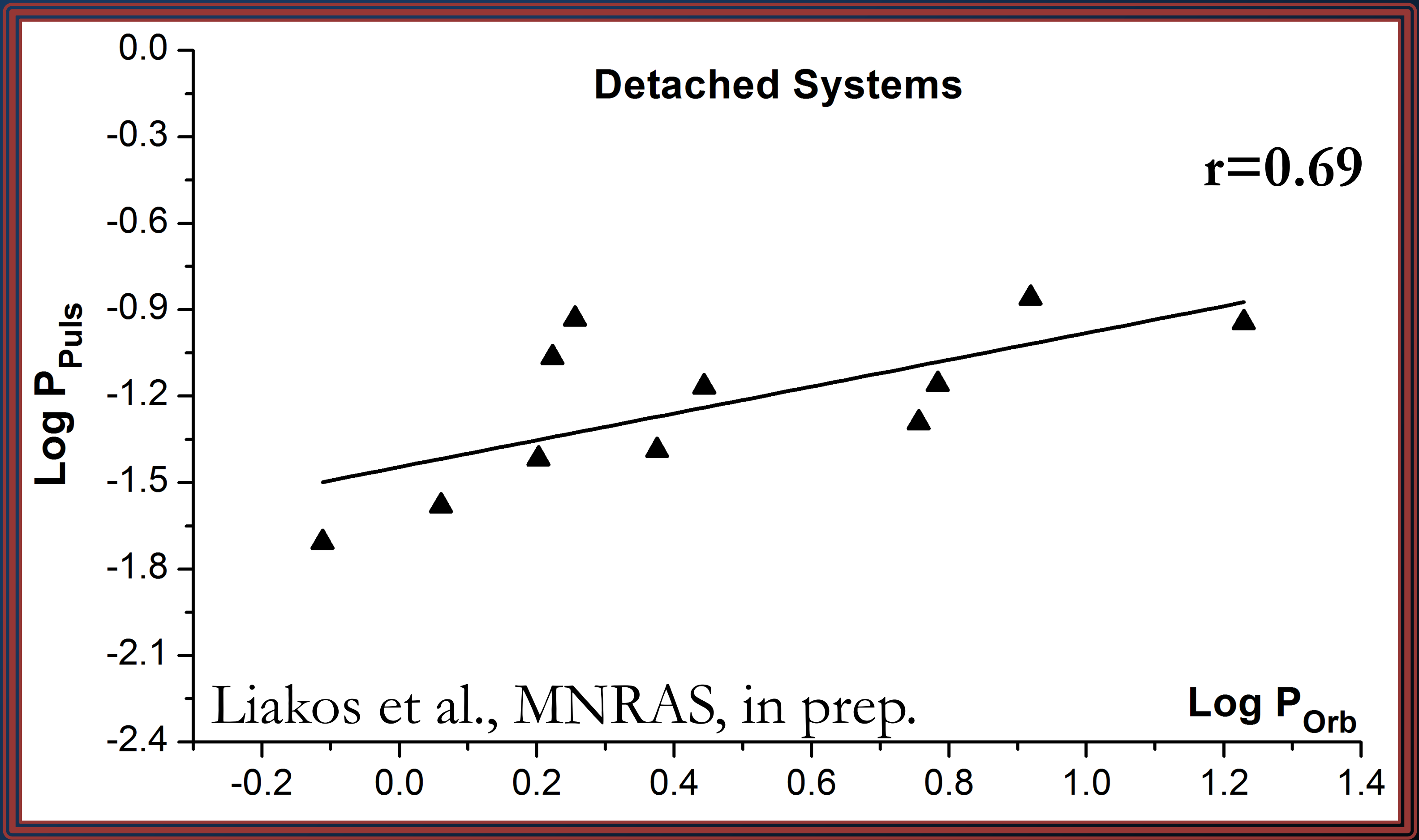
Orbital Period – Dominant Pulsation period



$$\log P_{puls} = -1.56(4) + 0.62(8) \log P_{orb}$$

Correlations

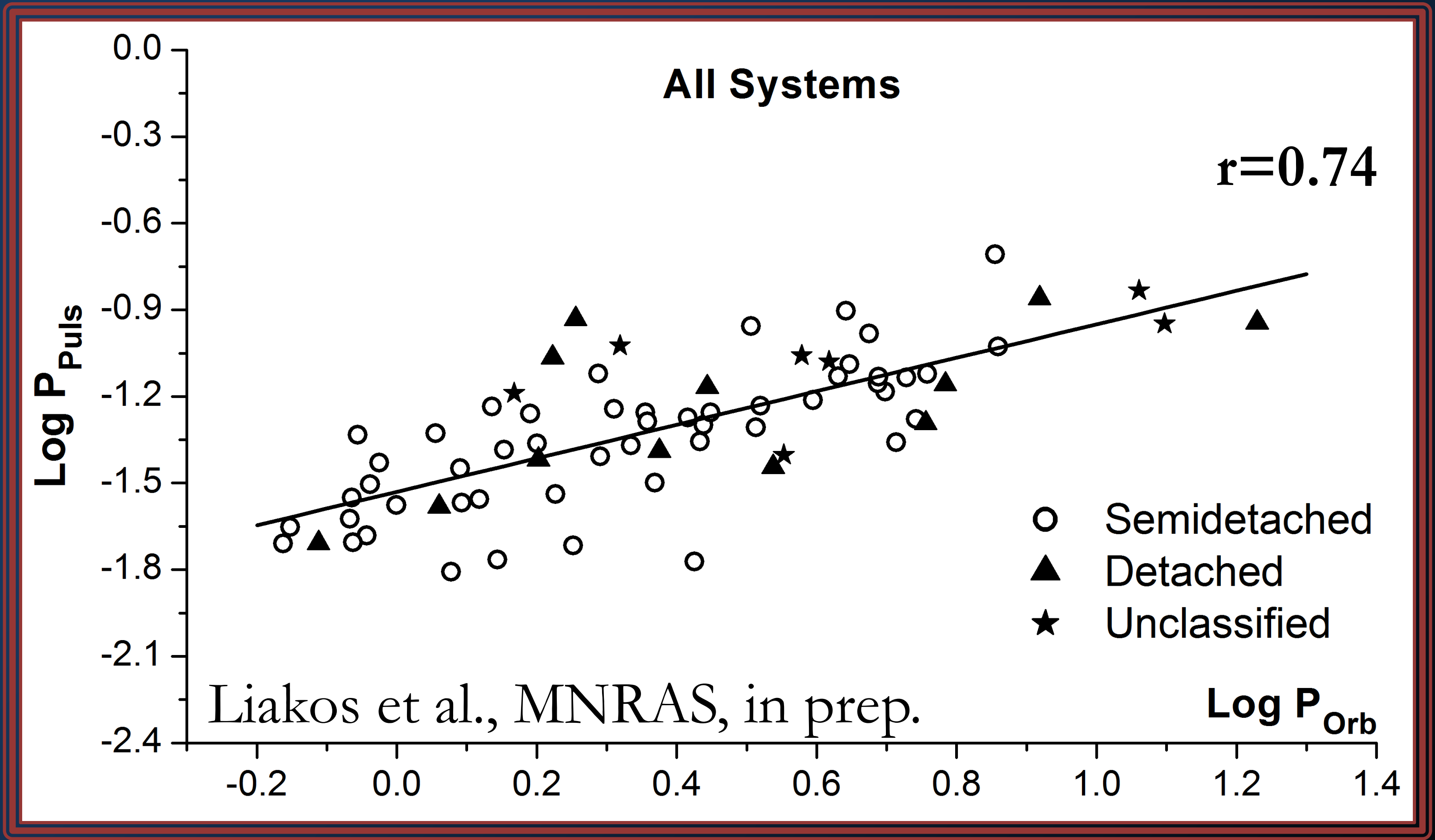
Orbital Period – Dominant Pulsation period



$$\log P_{puls} = -1.4(1) + 0.5(2) \log P_{orb}$$

Correlations

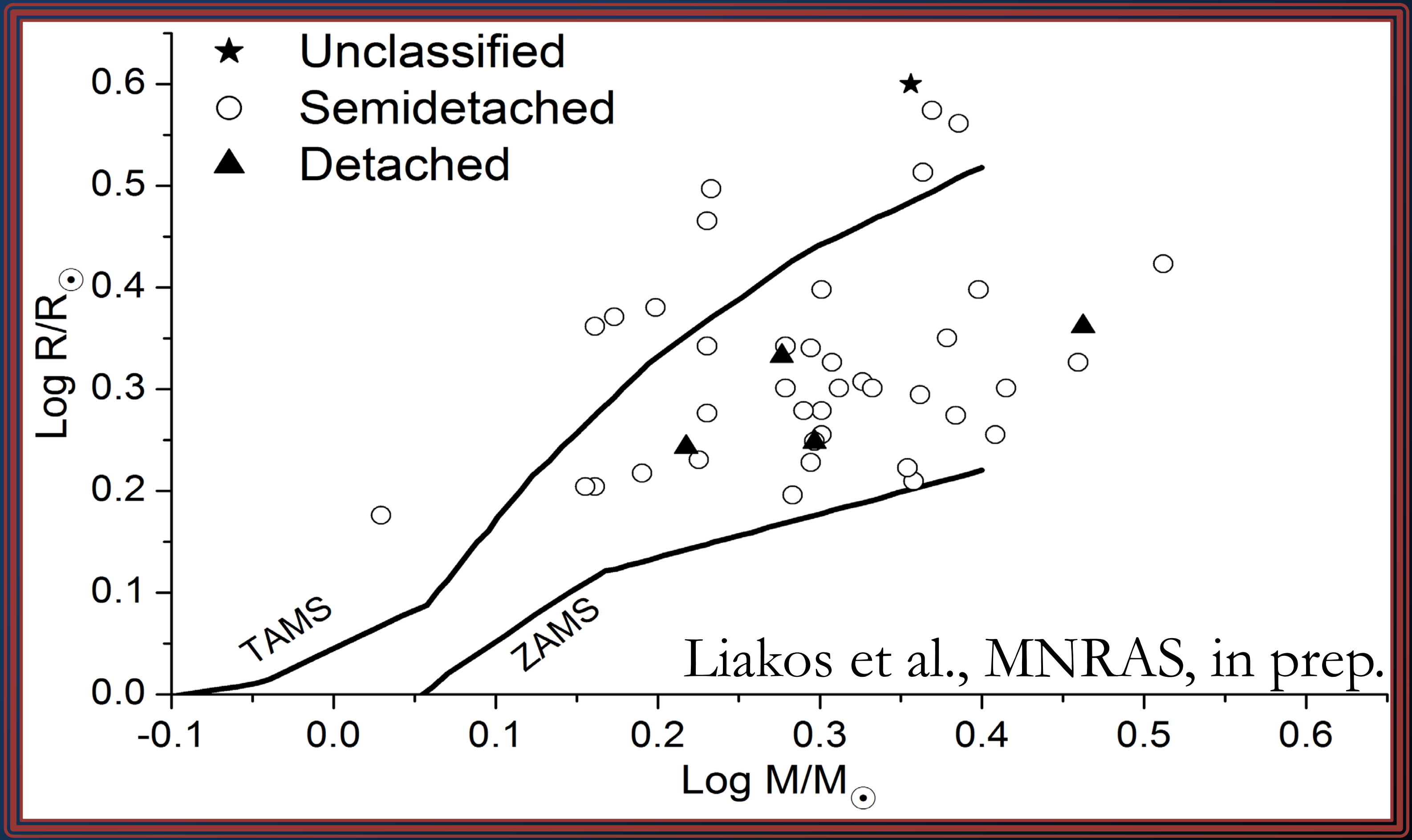
Orbital Period – Dominant Pulsation period



$$\log P_{puls} = -1.53(3) + 0.58(7) \log P_{orb}$$

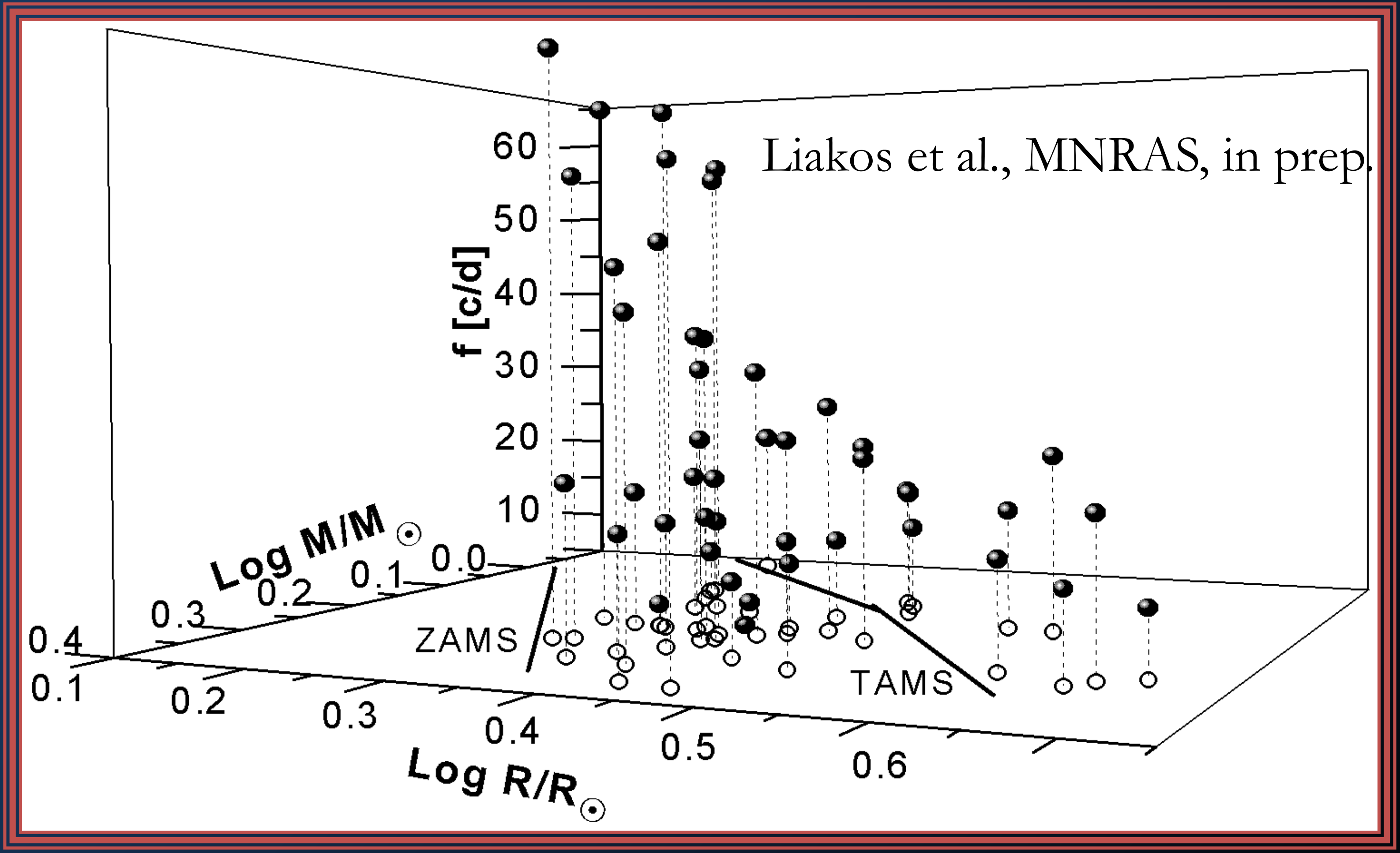
Correlations

Location of the pulsators in the Mass-Radius diagram



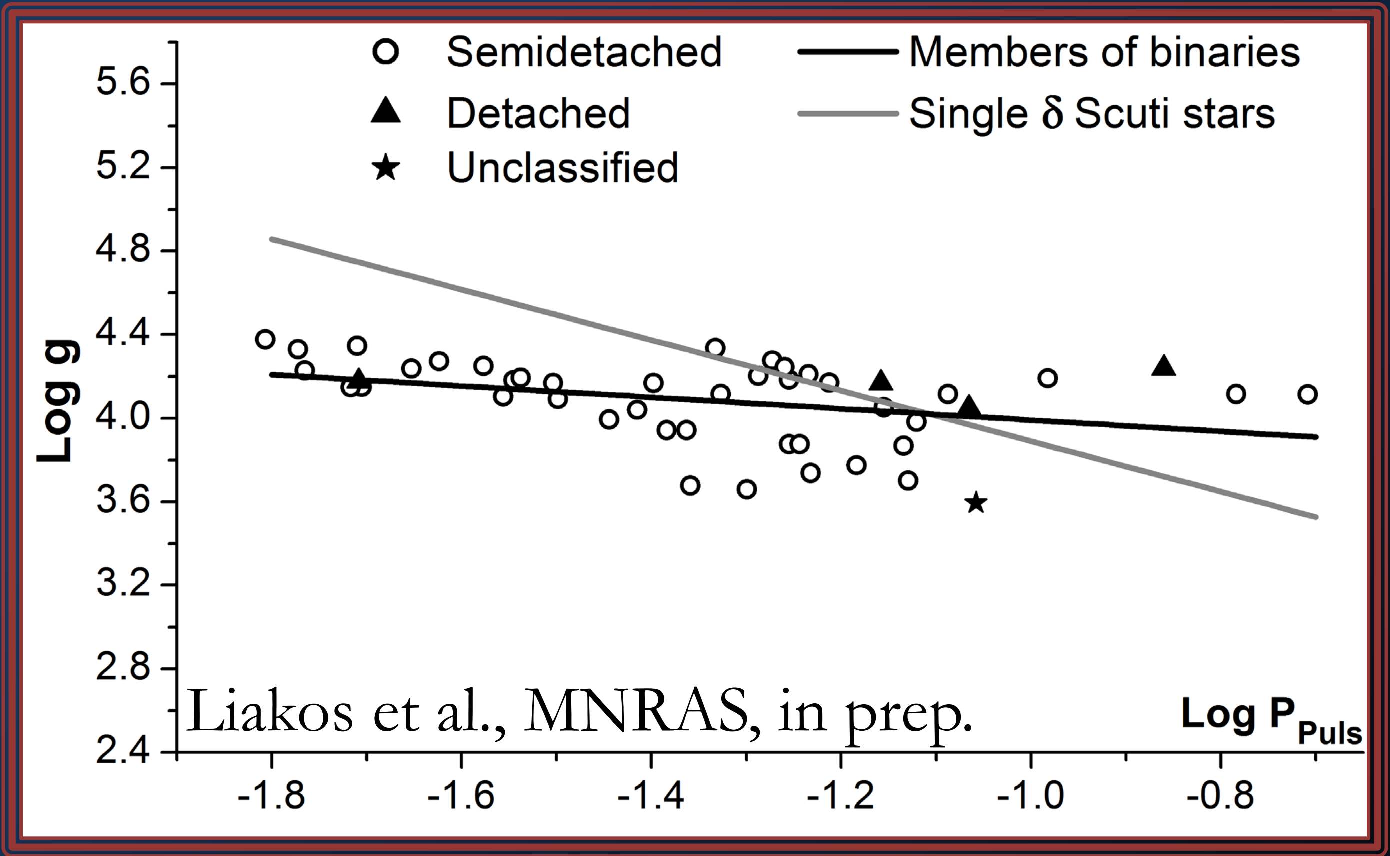
Correlations

Pulsation frequency & Mass-Radius diagram



Correlations

Pulsation frequency vs evolutionary status



$\log g = 3.7(2) - 0.3(1) \log P_{puls}$ → For δ Sct binary-members

$\log g = 2.7(1) - 1.2(1) \log P_{puls}$ → For single δ Sct (Claret et al. 1994)

Summary - conclusions - future prospects

- ✓ Data analysis methods have been presented
- ✓ Our surveys revealed 11 out of 75 (in total) such systems
- ✓ Correlation between pulsation frequencies and fundamental stellar characteristics have been found for δ Sct stars in binaries
- ✓ δ Sct stars in binaries are mostly MS stars
- ✓ Mass gain of the pulsating star is affecting the pulsations
- ✓ The evolution is different for single and binary members δ Sct stars
- ✓ Theoretical establishment for the correlations is needed
- ✓ Surveys for binaries with δ Sct component are highly encouraged for enriching the current sample
- ✓ Monitoring for several decades for cases with rapid mass transfer is proposed

References

Claret, A., Rodríguez, E., Rolland, A., Lopez de Coca, P., 1990, ASPC, 11, 481

Lenz, P., Breger, M. 2005, CoAst, 146, 53

Liakos, A., Niarchos, P., Soydugan, E., Zasche, P., MNRAS, in prep.

Mkrtichian, D.E., Kusakin, A.V., Rodríguez, E., et al., 2004, A&A, 419, 1015

Prša, A., Zwitter, T., 2005, ApJ, 628, 426

Soydugan, E., İbanoğlu, C., Soydugan, F., et al., 2006a, MNRAS, 366, 1289

Soydugan, E., Soydugan, F., Demircan, O., İbanoğlu, C., 2006b, MNRAS, 370, 2013

Zhou, A.-Y. 2010, arXiv:1002.2729v2

Zima, W., 2008, CoAst, 155, 1