Negative Superhumps in Cataclysmic Variables

(Negative superhumps in nova-likes)

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Superhumps

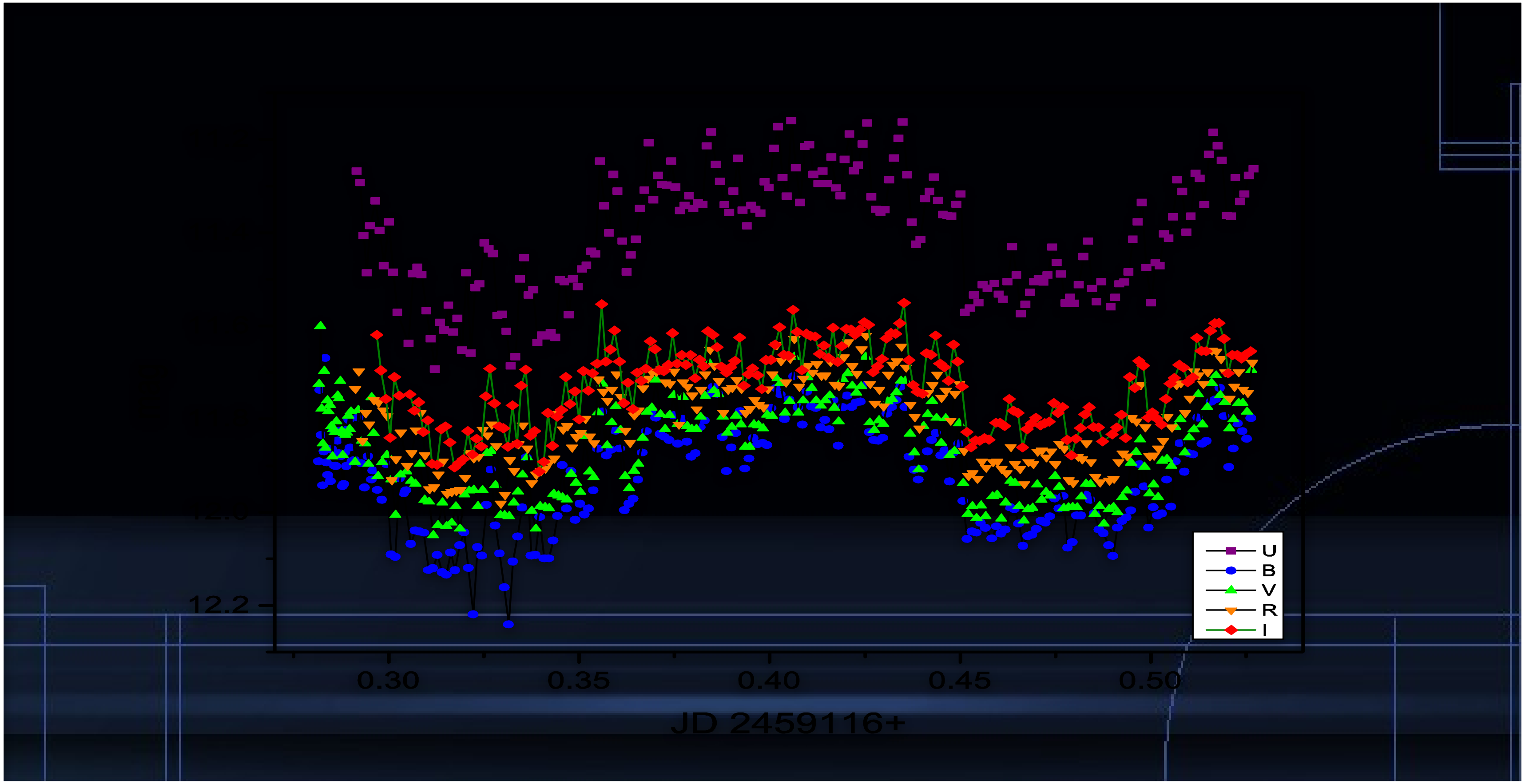
- Periodic changes in brightness with periods close to the orbital period.
- Positive superhumps (P+) - a few percent longer than the orbital period P_{orb}.
- Negative superhumps (P-) - a few percent shorter than the orbital period P_{orb}.

Superhumps in CVs

- Common feature in different types – Dwarf Novae, AM CVn, Old Novae, Nova-likes.
- Evolution of SHs in DN - during superoutbursts and during normal outburst – changes of A and P.
- “Permanent” SHs in NLs – for months, years; switching P+/ P- or simultaneously existing; disappearing.

Example of nSH in BG Tri

- P_{orb}=3:48 h; P-=3:39 h



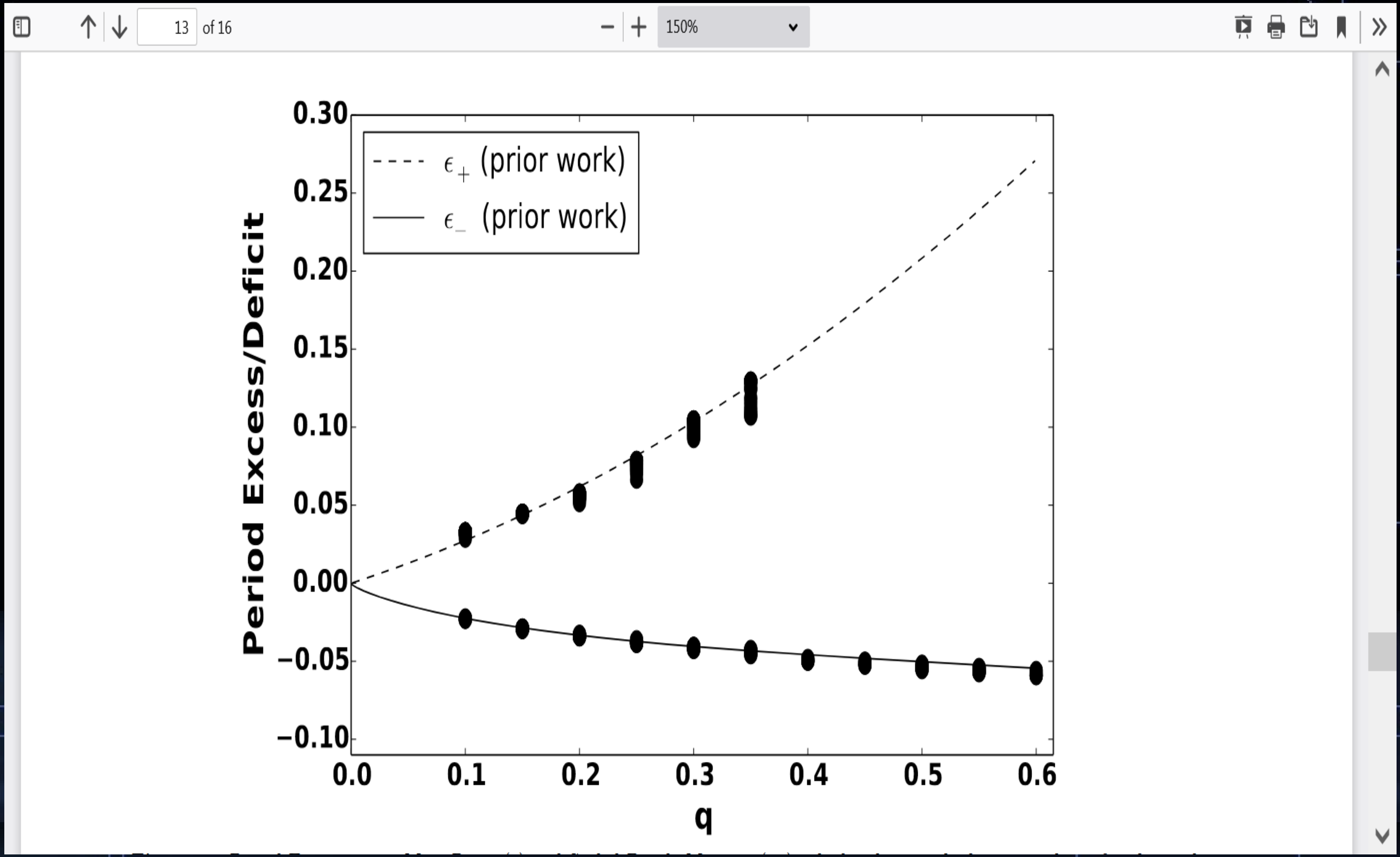
Nature of SHs

- pSHs - due to the prograde apsidal precession of an eccentric accretion disk produced by the tidal instability arising from the 3:1 resonance .
- nSHs - nodal superhumps - probable origin in the retrograde precession of of the line-of-nodes of a tilted disk with respect to the orbital plane.

Formulae

- Beating: $\frac{1}{P_{prec}} = \frac{1}{P-} - \frac{1}{P_{orb}}$
- Mass ratio: $q = \frac{M_2}{M_1}$
- Excess: $\varepsilon = \frac{P_{sh} - P_{orb}}{P_{orb}}$
- Tidal truncation radius: $R_{max} = \frac{0.6}{1+q}$

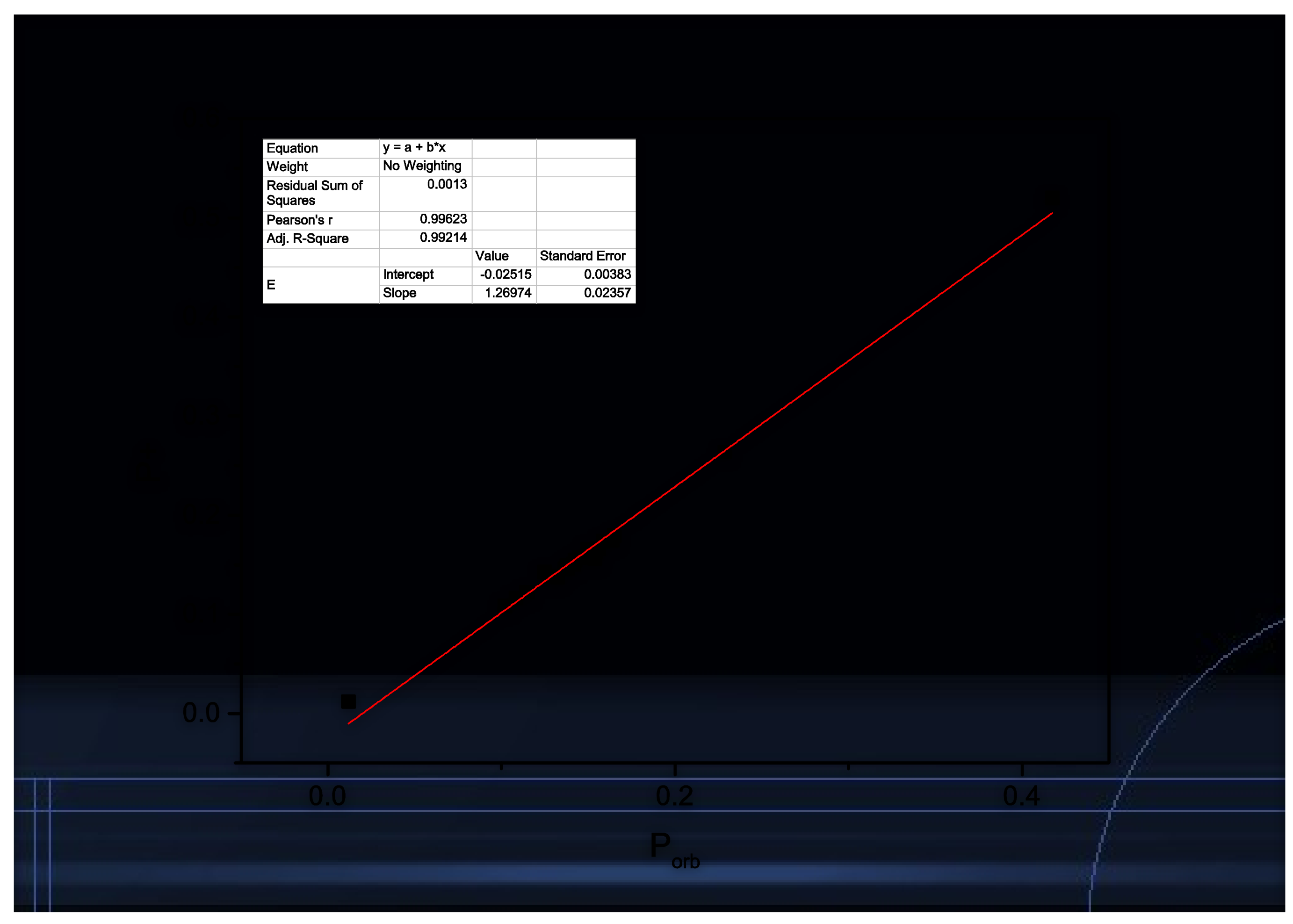
Period Excess versus Mass Ratio (q)



Literature

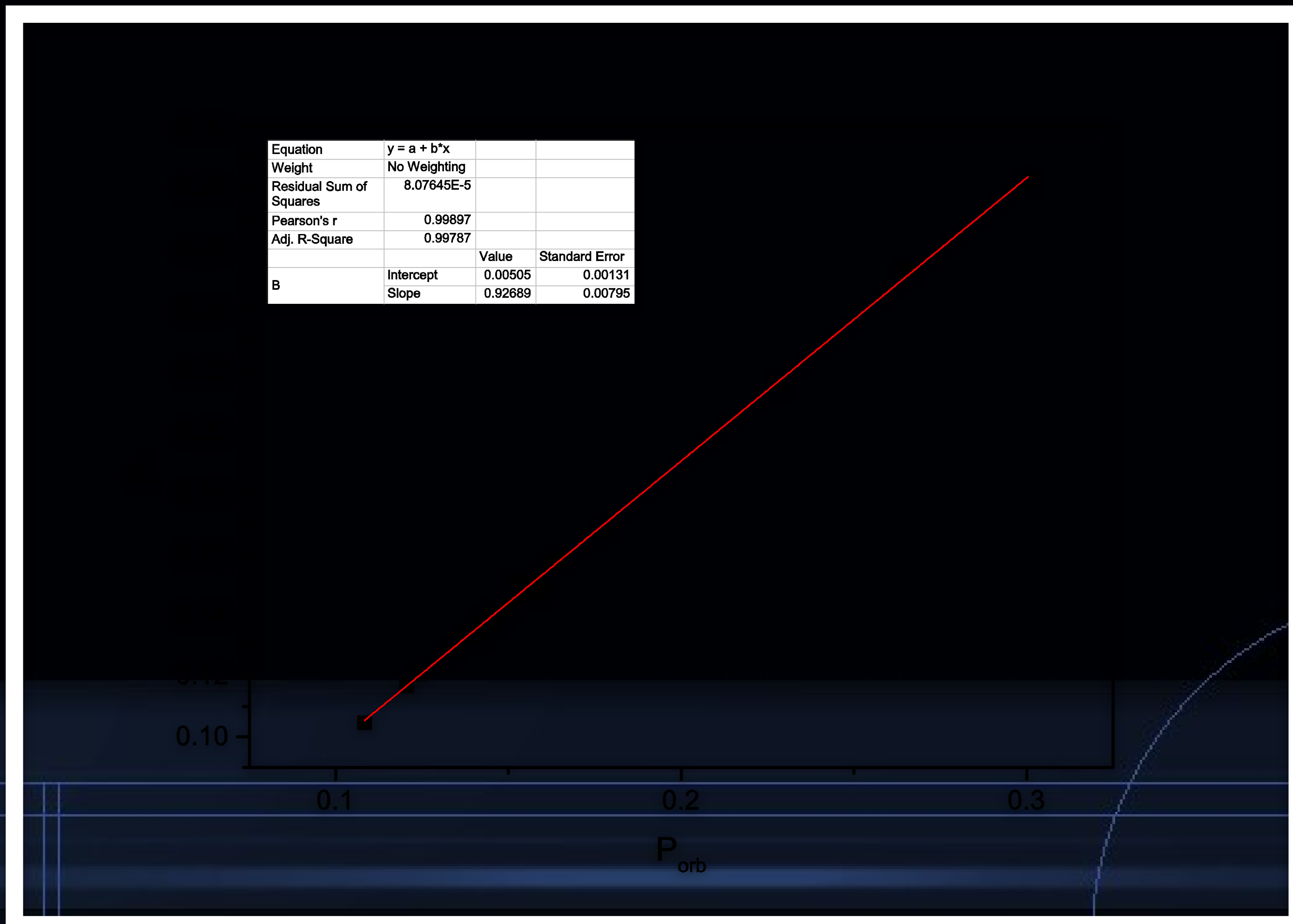
- Stolz B., Schoembs R., 1984, A&A:
  $P_{orb} = a+b\ P_{sh}$
- Fuentes Morales, I. ; Vogt, N. ; Tappert, C. ; Schmidtobreick, L., 2017 – (P_{sh}-P_{orb}) linear fit for 241 stars: 217 DN, 7 old N and 17 NL (for positive SHs).
- We found 24 NL with P+ and 30 with P-.

Linear fit for pSHs



Equation	y = a + b*x		
Weight	No Weighting		
Residual Sum of Squares	0.0013		
Pearson's r	0.99623		
Adj. R-Square	0.99214		
		Value	Standard Error
E	Intercept	-0.02515	0.00383
	Slope	1.26974	0.02357

Linear fit for nSHs



Equation	y = a + b*x		
Weight	No Weighting		
Residual Sum of Squares	8.07645E-5		
Pearson's r	0.99897		
Adj. R-Square	0.99787		
		Value	Standard Error
B	Intercept	0.00505	0.00131
B	Slope	0.92689	0.00795

Larwood, J. 1998, MNRAS

- $$\frac{P_{orb}}{P_{nsh}} = 1 + \frac{3}{7} * \frac{q}{(1+q)^{\frac{1}{2}}} * \cos\theta * \left(\frac{R_d}{a}\right)^{\frac{3}{2}}$$

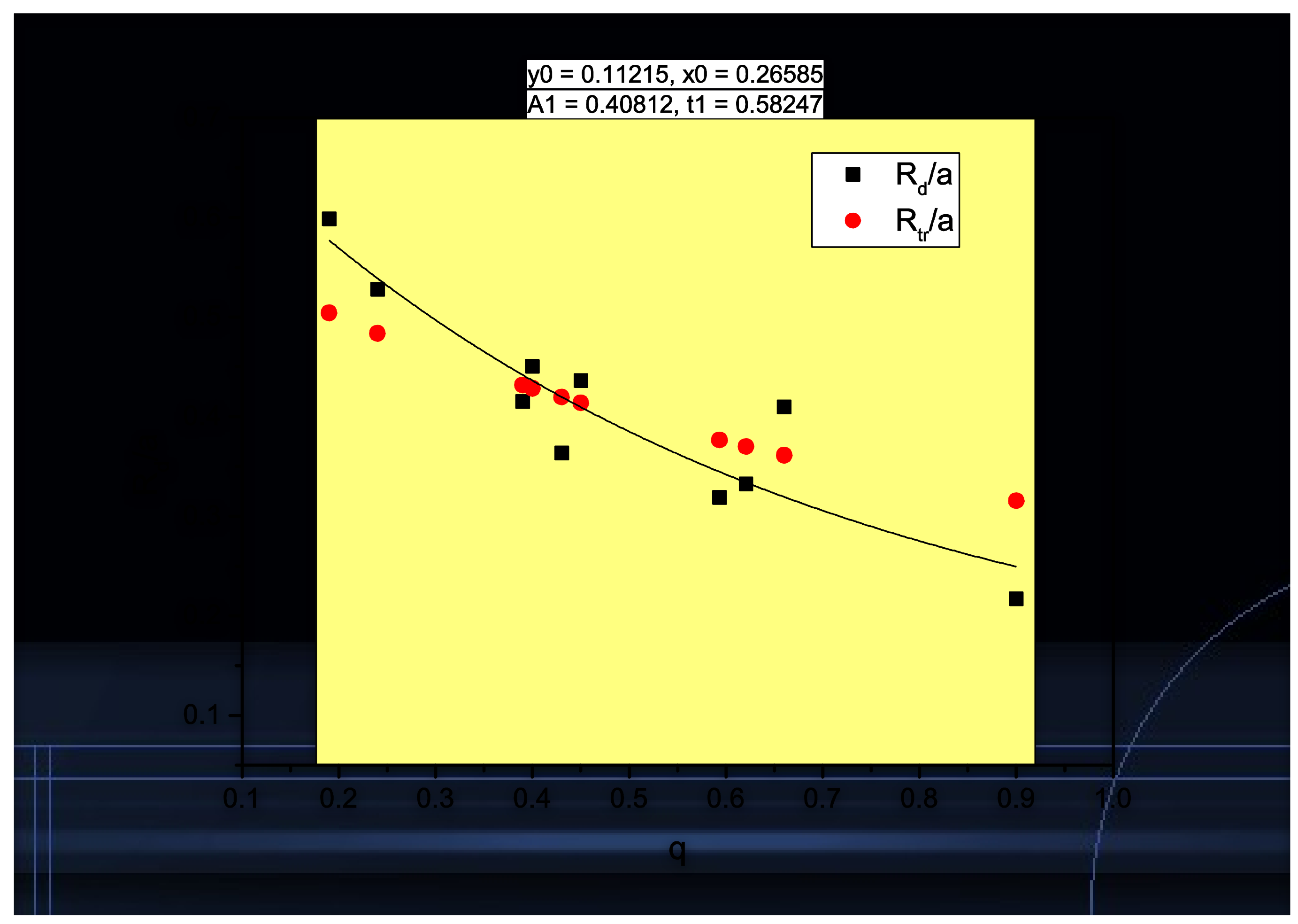
q – mass ratio

θ - tilt angle; ~ 1-5 %; $\cos\theta$ ~ 1

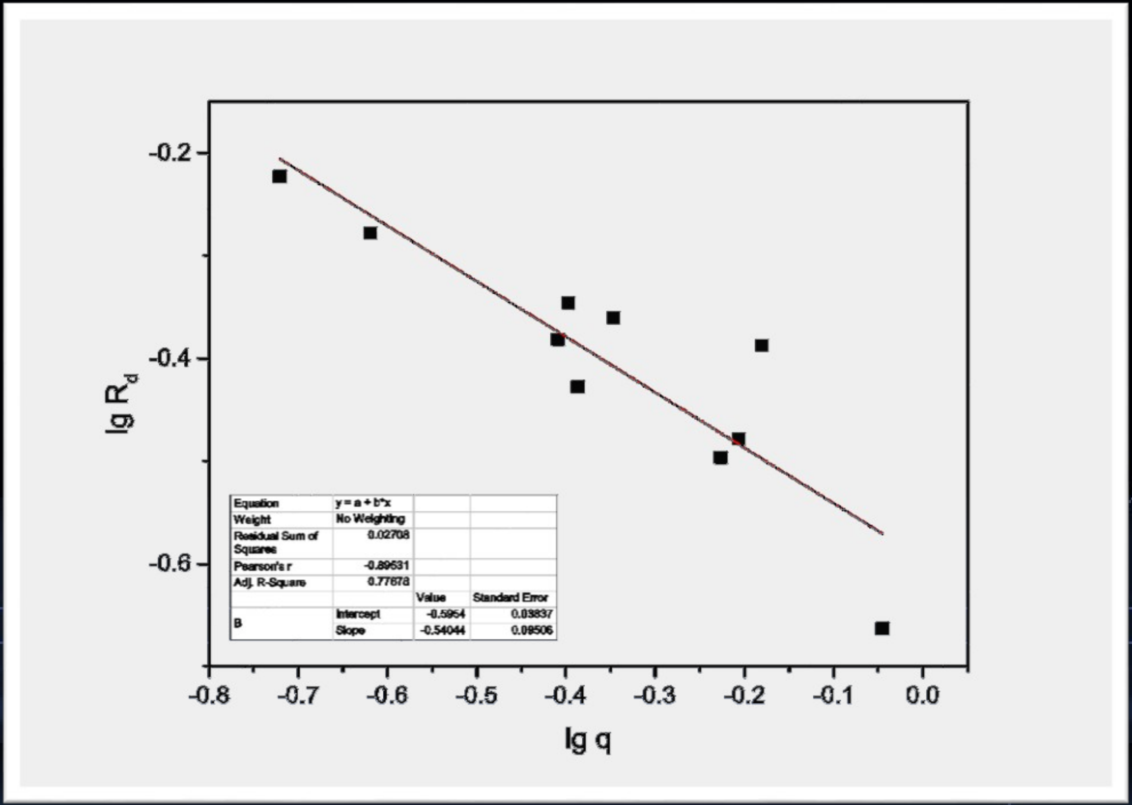
a - orbital separation

R_d - disk radius

Disk radius – mass ratio (for 10 NLs)



Disk radius vs. mass ratio

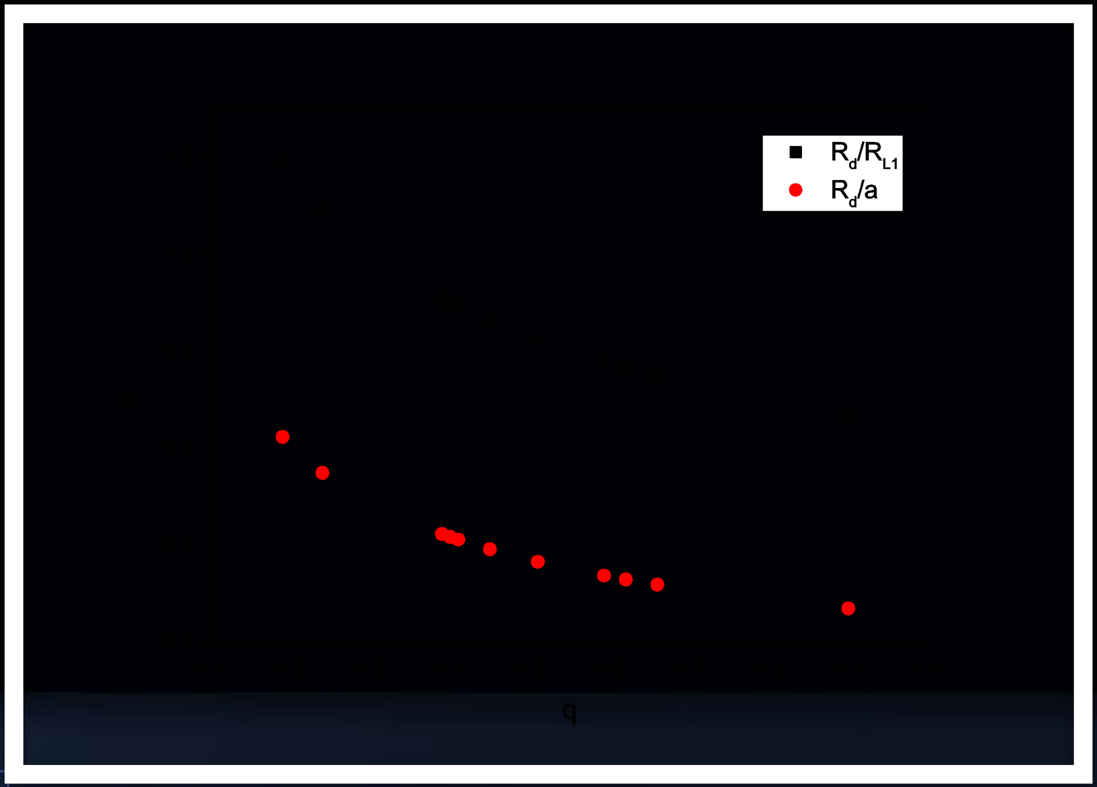


Roche lobe radius of primary and R_d

- $R_{L1} = 0.396 * q^{-\frac{1}{6}}$
- $\frac{R_d}{a} = 0.254 * q^{-0.54}$

- $\frac{R_d}{R_{L1}} = 0.641 * q^{-0.373}$

R_d/R_{L1} and R_d/a vs. q



q ~ 0.2

$R_d > R_{L1}$

Conclusions

- We calculated relation (Psh - Porb) for 24 NLs with pSHs and 30 NLs with nSHs.
- We received dependence between R_{disk} and mass ratio q for nSHs in NLs:

$$\frac{R_d}{a} = 0.254 * q^{-0.54}$$

- We received dependence

$$\frac{R_d}{R_{L1}} = 0.641 * q^{-0.373}$$

Probably nSHs are possible at a strictly defined disk size in each system.

Thank you!

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