

Próby poszukiwania towarzyszy sdB

Adam Blokesz

Kraków, 8 stycznia 2015 r.



Plan

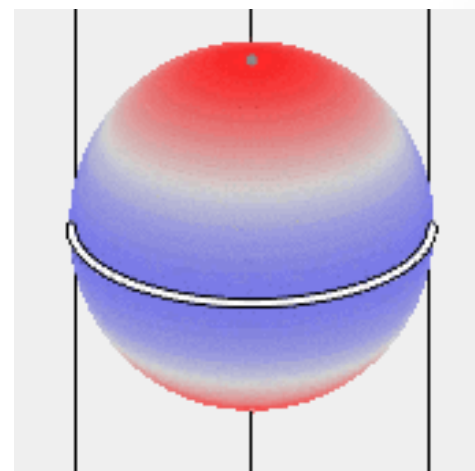
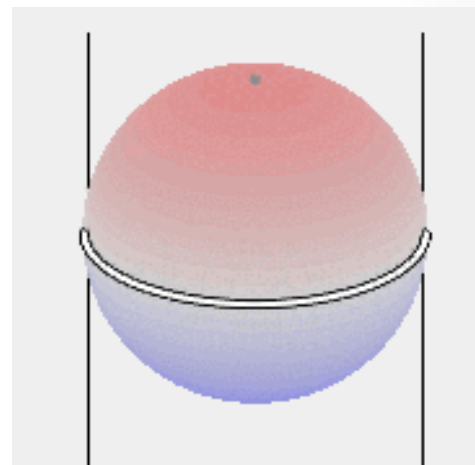
- Pierwsze próby "znalezienia" towarzysza lub wykluczenia jego obecności;
- Inne spojrzenie na gwiazdy pulsujące;
- Kolejny krok.

Pierwsze próby poszukiwania

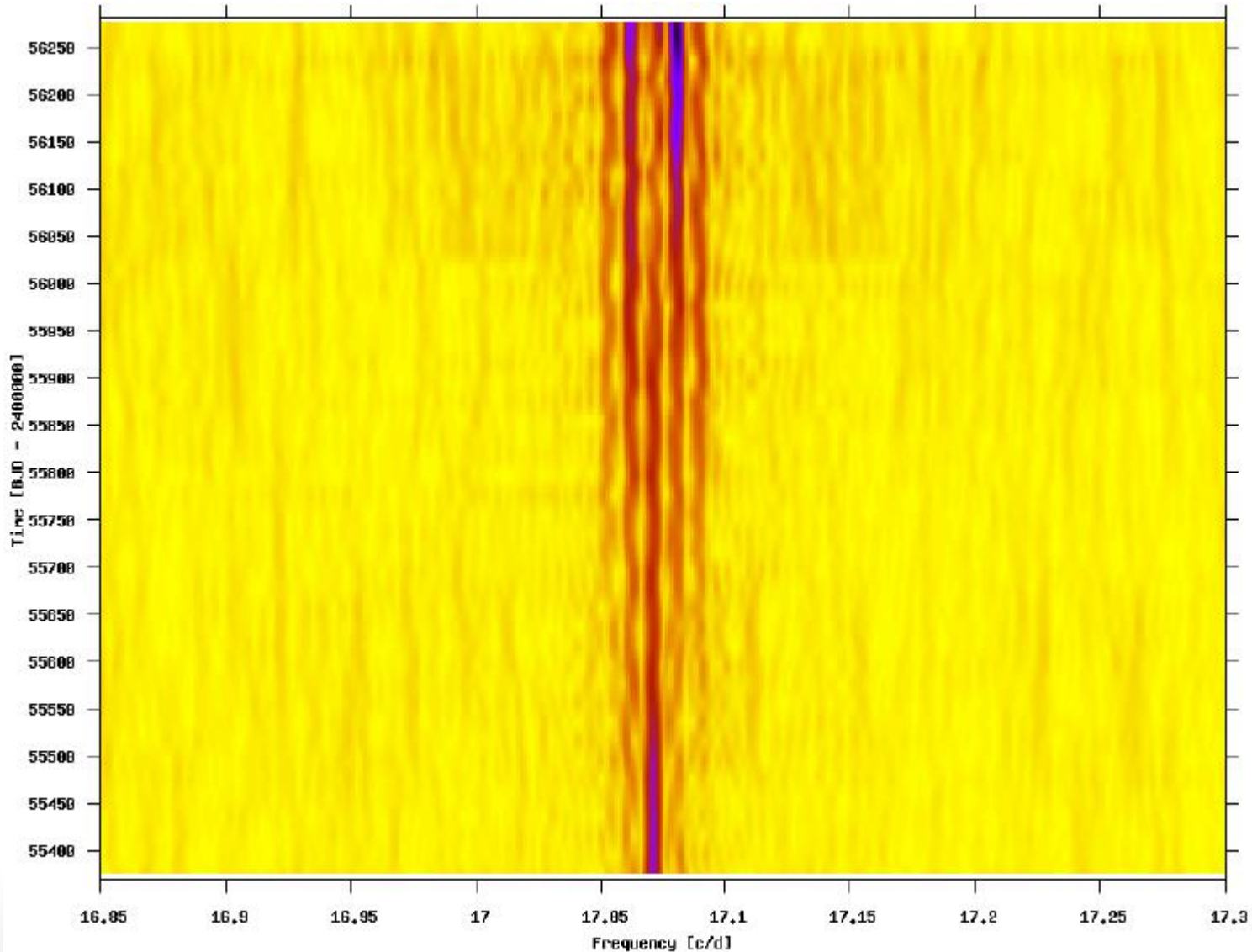
KIC 10670103

Parametry

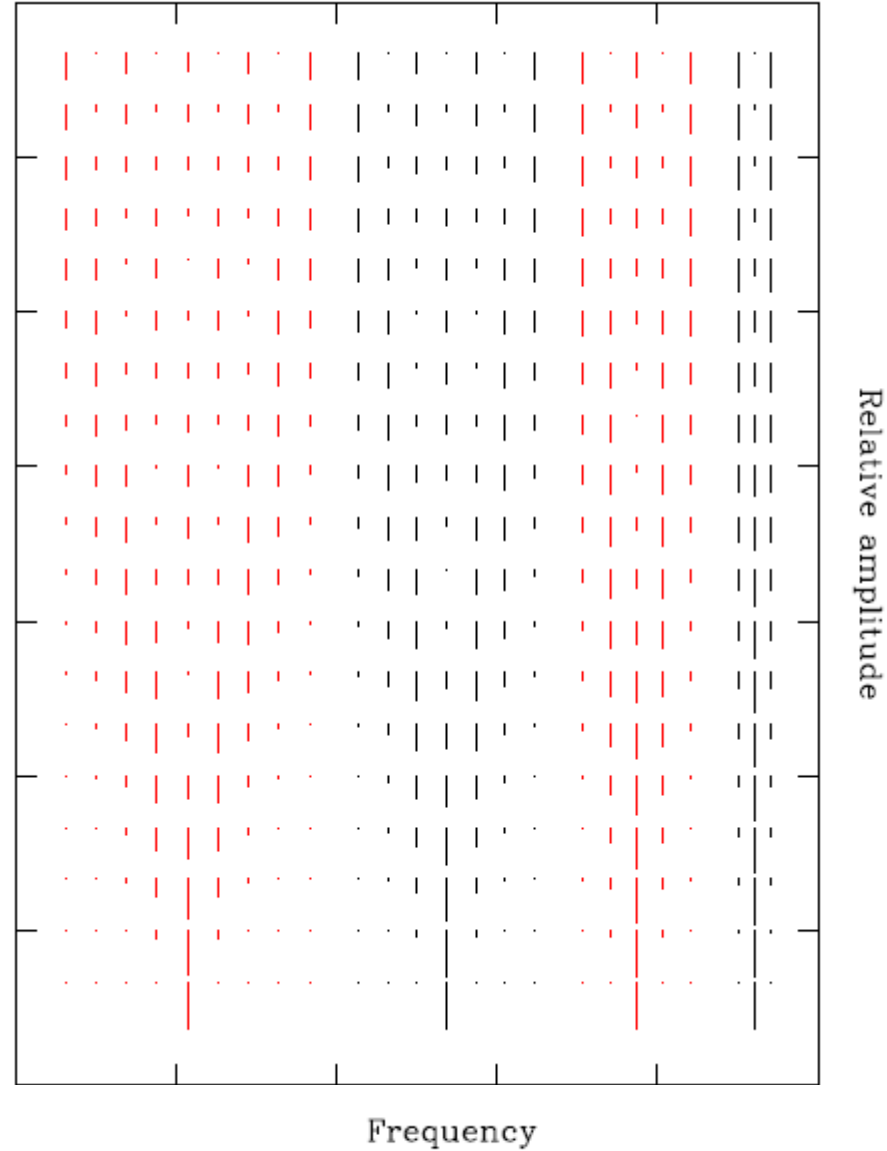
- podkarzeł typu widmowego B;
- masa: $0,5 M_{\text{Słońca}}$;
- promień: $0,31 R_{\text{Słońca}}$;
- temp. efektywna: 20 900 K;
- okres obrotu: 90 dni;



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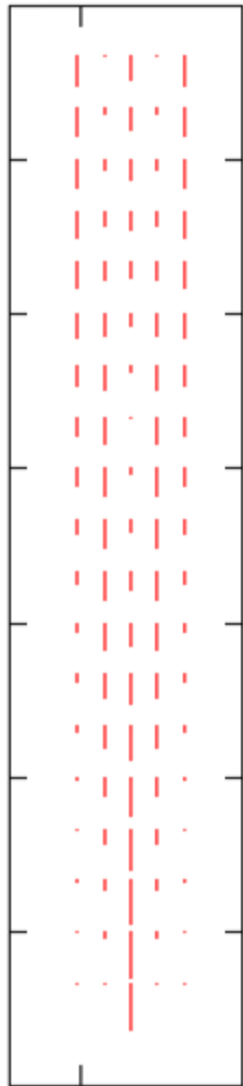


Model teoretyczny - Charpinet

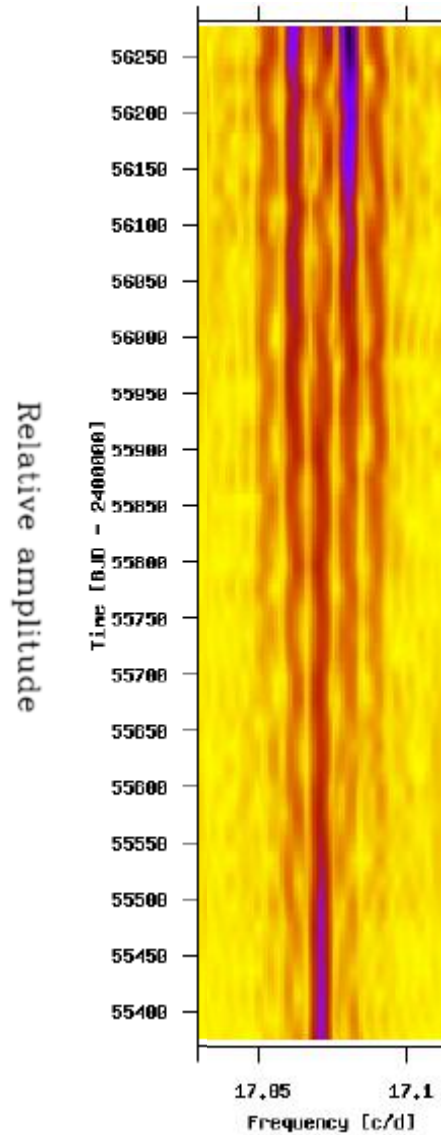


Charpinet, S., et al. 2011, *Nature*, **480**, 496.
Supplementary Information

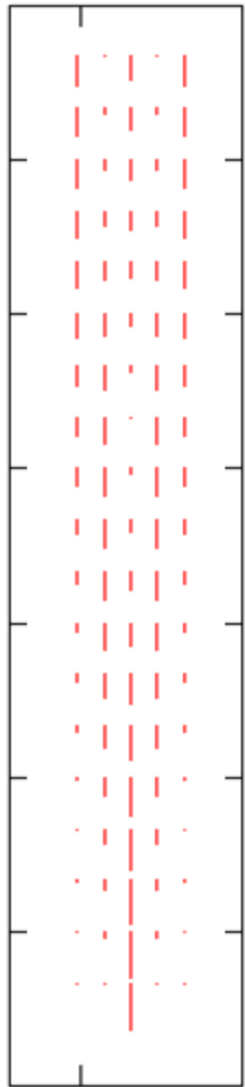
Model teoretyczny
- Charpinet



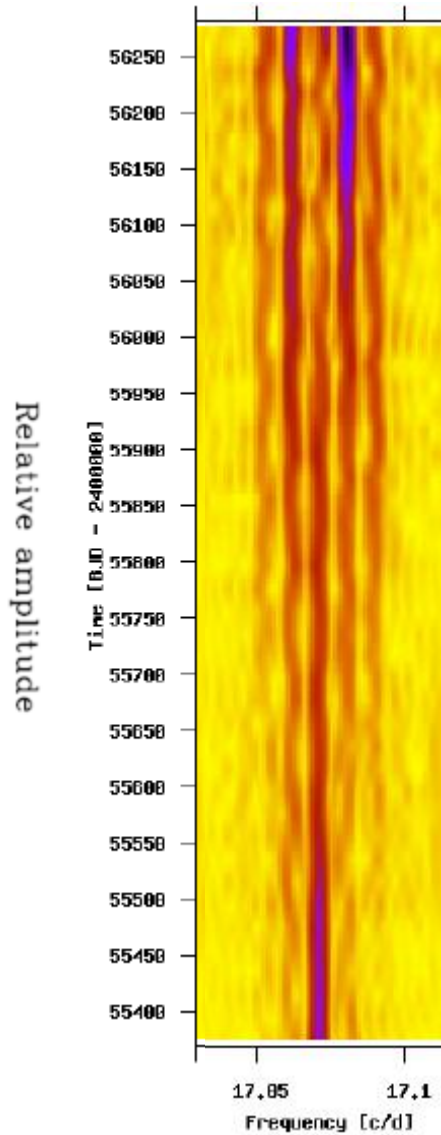
KIC 10670103



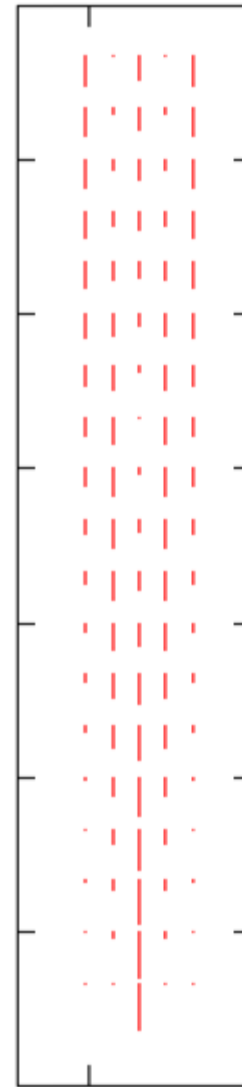
Model teoretyczny
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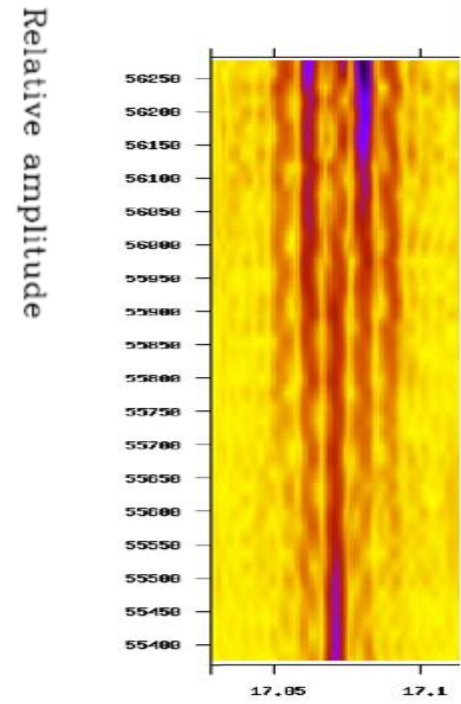
KIC 10670103



Model teoretyczny
- Charpinet



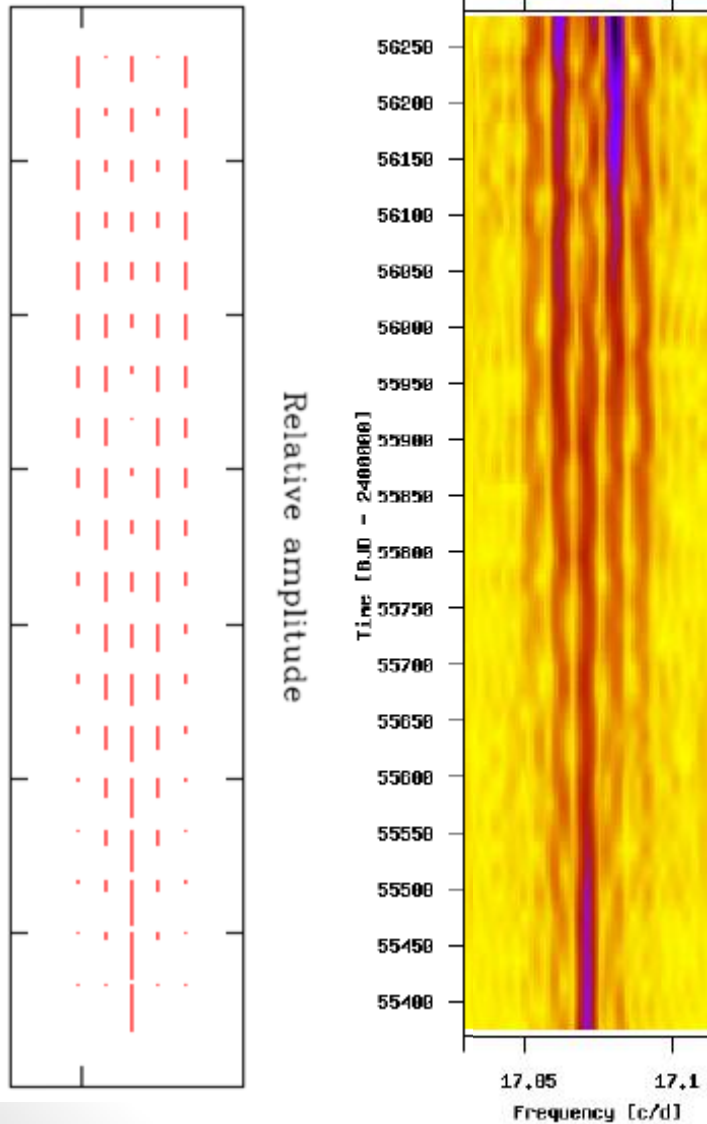
KIC 10670103



Okres precesji – 12 lat

Model teoretyczny
- Charpinet

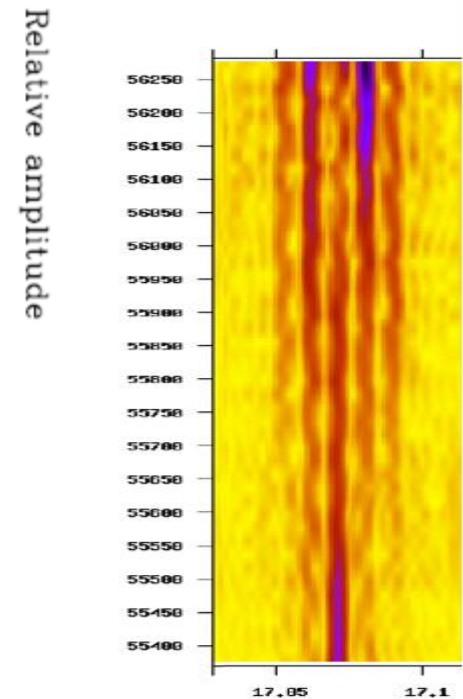
KIC 10670103



Okres precesji – 24 lat

Model teoretyczny
- Charpinet

KIC 10670103



Precesja

$$\omega_p = \frac{3Gm}{2\omega_3 r^3} \frac{(I_3 - I_1)}{I_3} \cos \theta$$

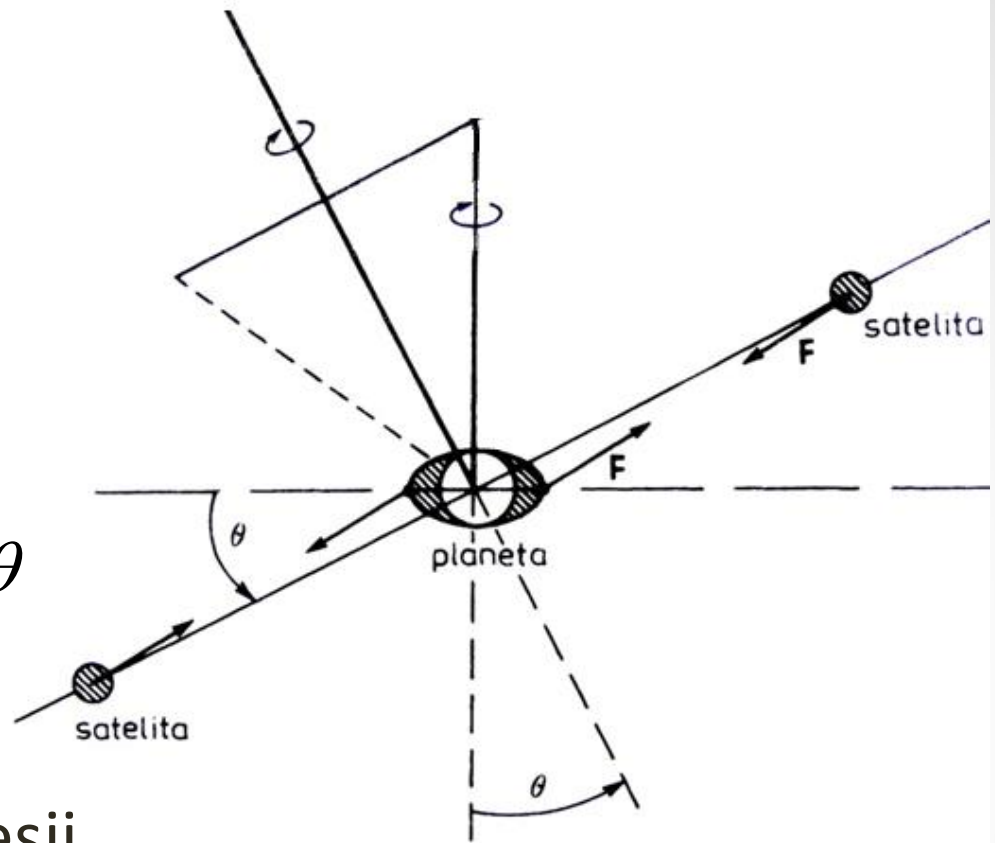
ω_p – częstotliwość precesji

ω_3 – częstotliwość obrotowa planety

r – separacja

m – masa satelity

I – momenty bezwładności planety

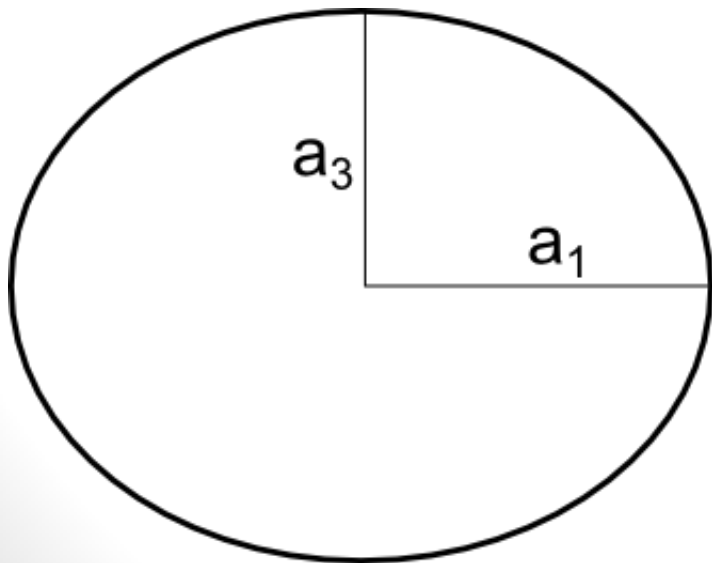


Jak obliczyć momenty bezwładności?

Moment bezwładności elipsoidy obrotowej

$$I_1 = m \frac{a_3^2 + a_1^2}{5}; \quad I_3 = m \frac{2a_1^2}{5} \quad \frac{(I_3 - I_1)}{I_3} = \frac{a_1^2 - a_3^2}{2a_1^2}$$

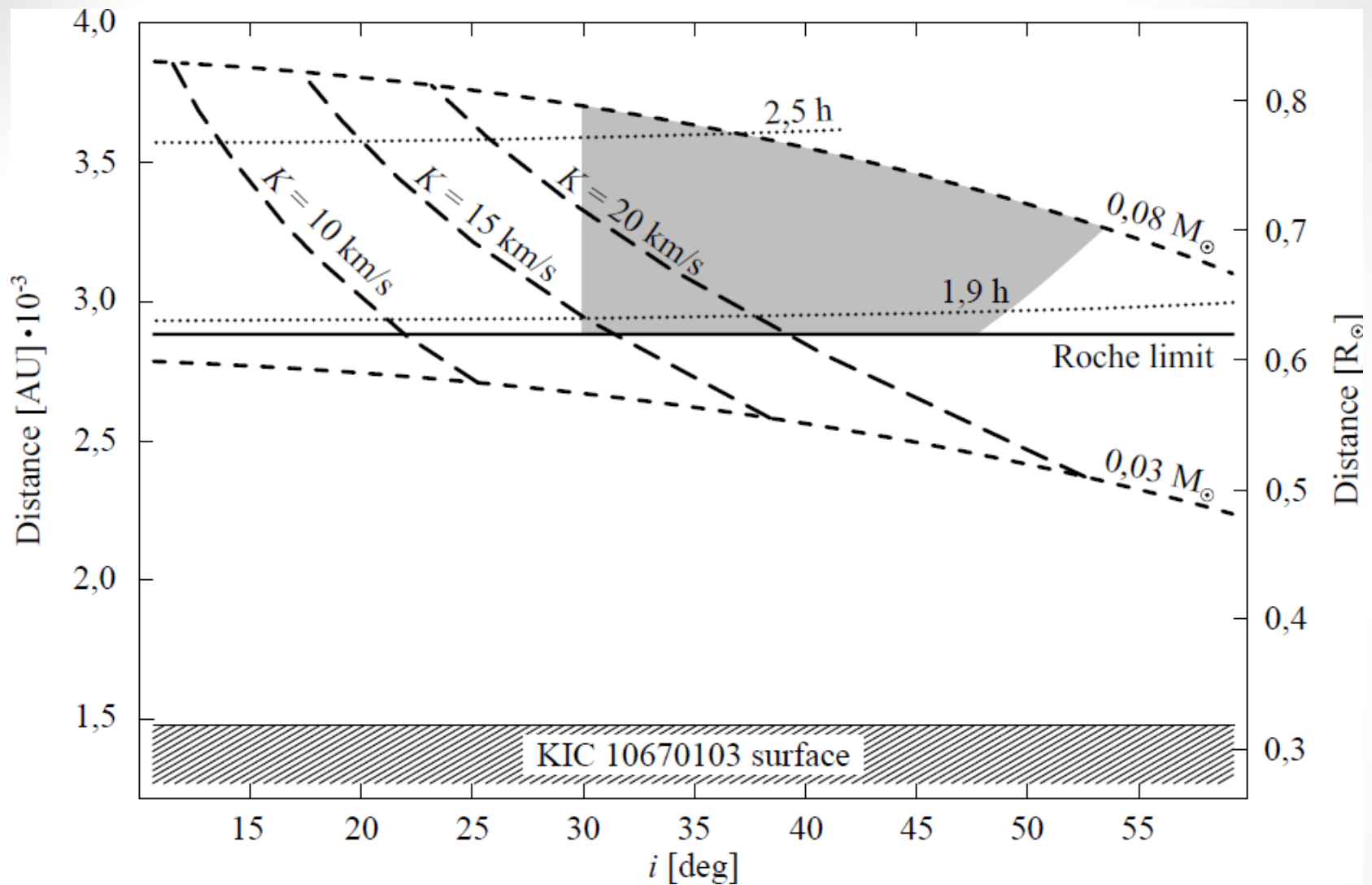
Spłaszczenie



$$\varepsilon = \frac{5 \omega^2 a^3}{4 GM}$$

$$a_1 = a \left(1 + \frac{\varepsilon}{3} \right)$$

$$a_3 = a \left(1 + \frac{2\varepsilon}{3} \right)$$



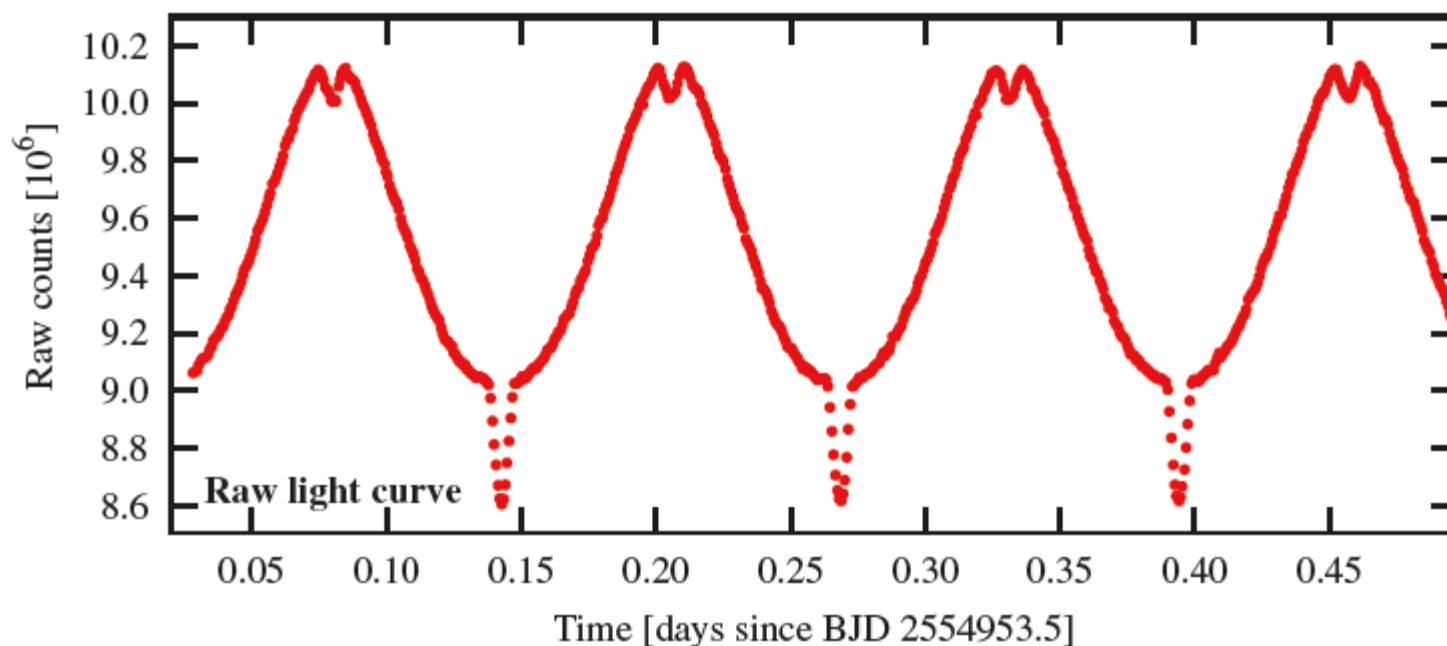
$$r = \left(\frac{3Gm}{2\omega_3\omega} \frac{I_3 - I_1}{I_3} \cos i \right)^{\frac{1}{3}}$$

$$d \approx 2,44 \cdot R \cdot \sqrt[3]{\frac{\rho_M}{\rho_m}}$$

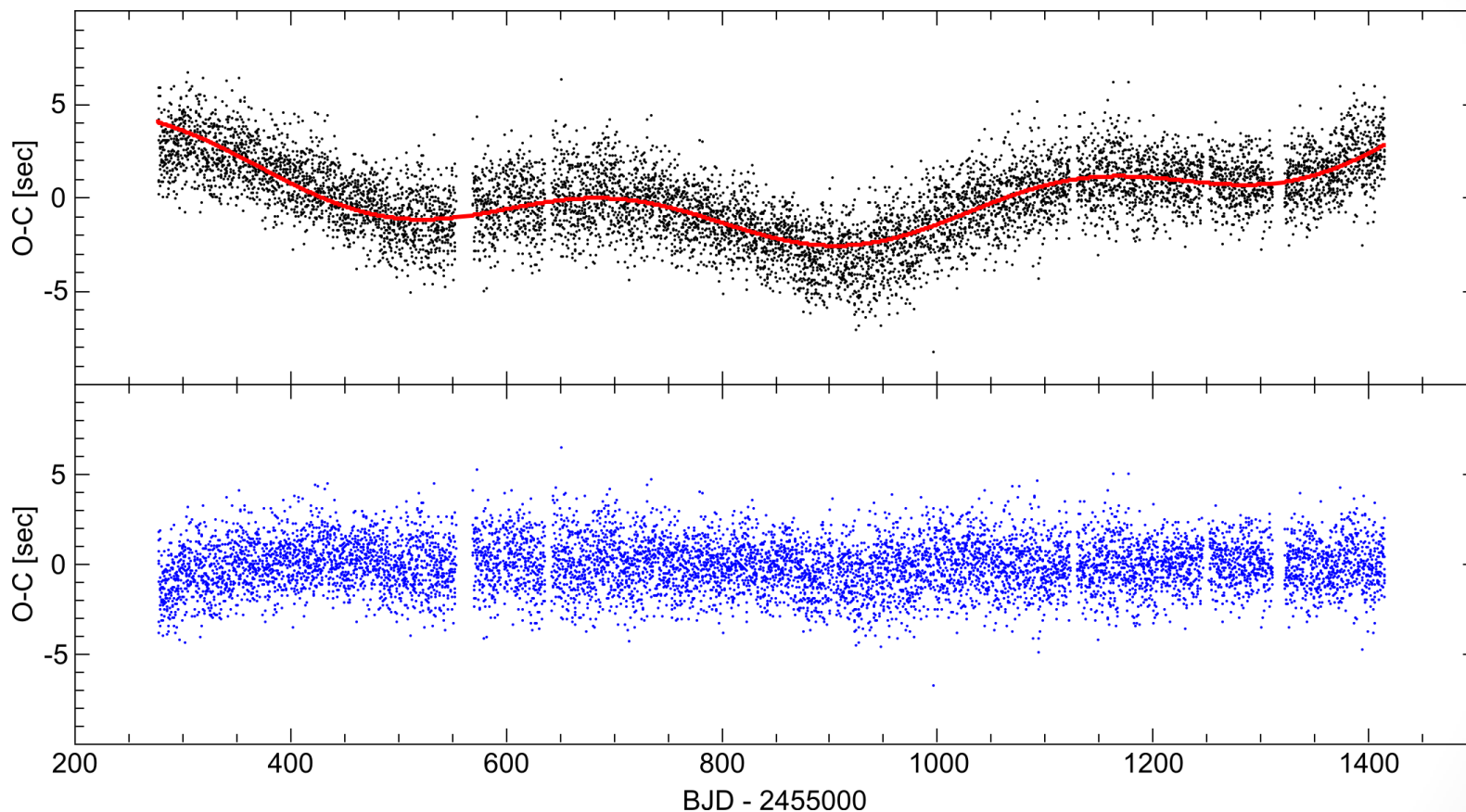
Inne spojrzenie na gwiazdy pulsujące

2M1938+4603 (KIC 9472174)

- Układ podwójny
podkarzeł typu widmowego B + karzeł typu widmowego M

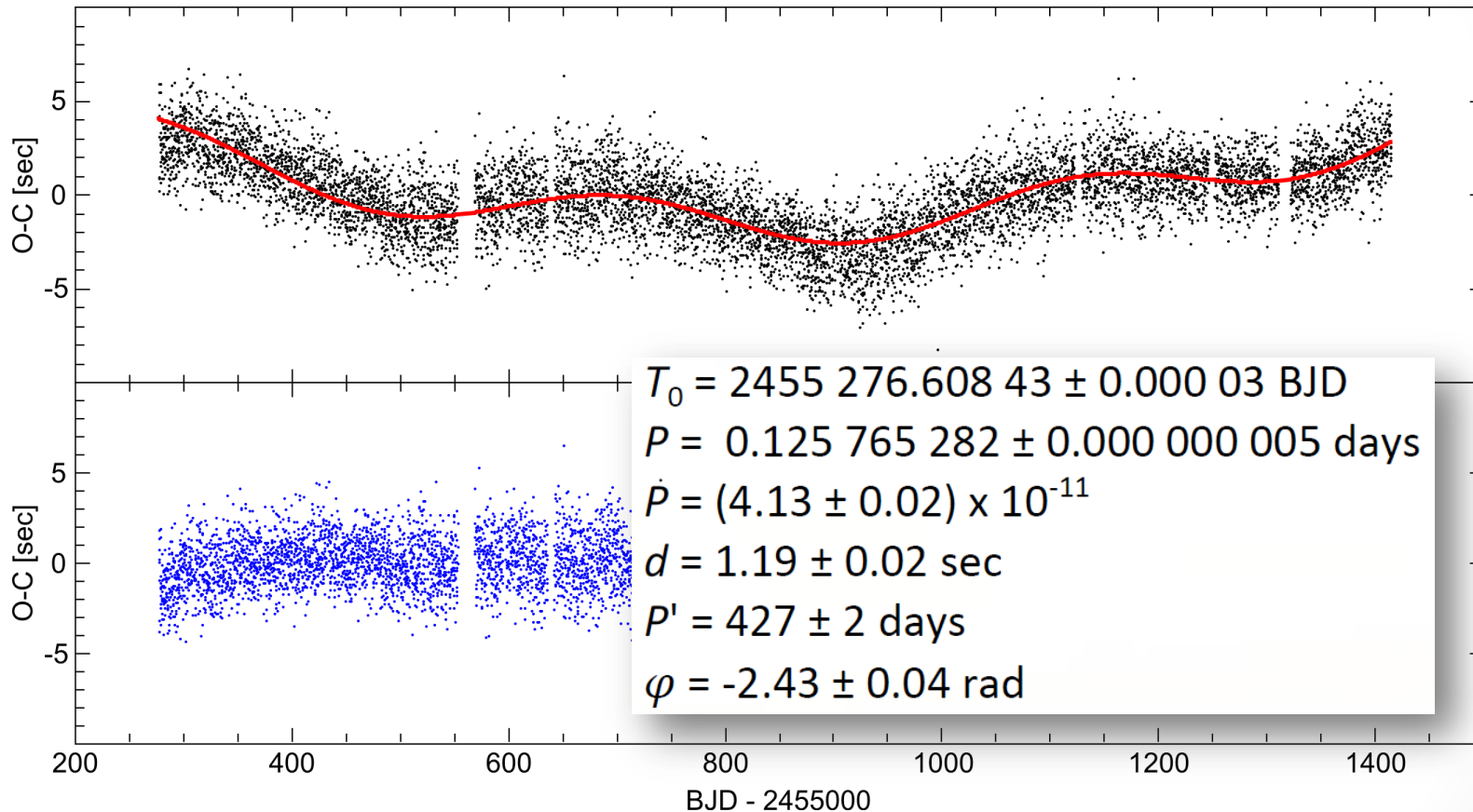


2M1938+4603 (KIC 9472174)



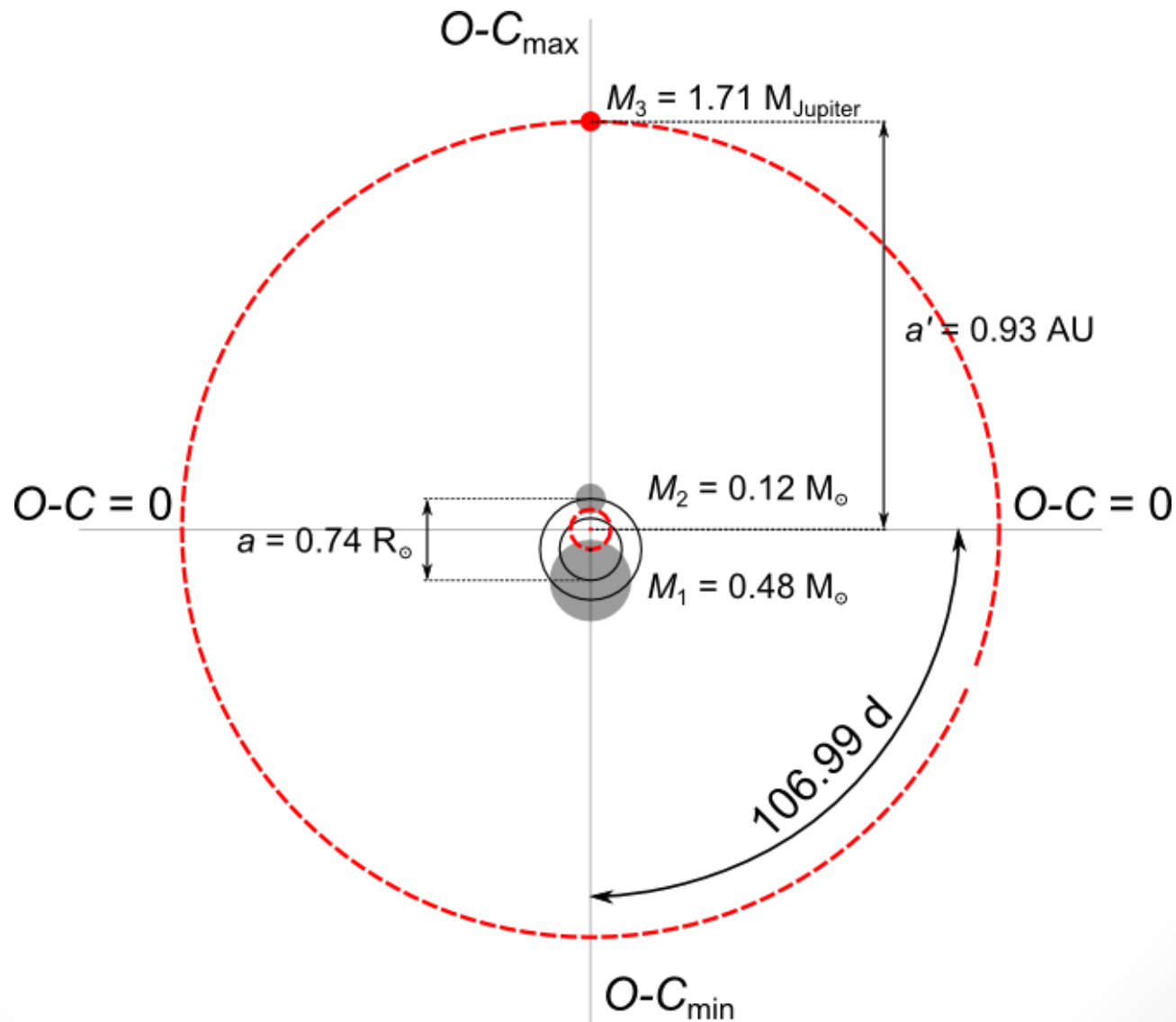
$$C = T_0 + P E + \frac{1}{2} \dot{P} P E^2 + d \sin\left(\frac{2\pi}{P'} P E + \varphi\right)$$

2M1938+4603 (KIC 9472174)



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2M1938+4603 (KIC 9472174)



Kolejne kroki

Binary star detection using the time-delay method: Application to 34 *Kepler* objects of interest.

L. A. Balona

South African Astronomical Observatory, P.O. Box 9, Observatory 7935, Cape Town, South Africa

Założenia:

- dobry zegar
- zmiana odległości

Binarogram

$$z = a \sin i \frac{(1 - e^2) \sin(\nu + \omega)}{1 + e \cos \nu}$$

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$$\Omega = 2\pi / P_{\text{orb}}$$

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$$y = a_1 + \sum_{j=1}^q \{a_{2j} \sin \omega_j(t + \tau) + a_{2j+1} \cos \omega_j(t + \tau)\}$$

$$\omega_j = 2\pi f_j$$

$$y = y(\alpha_1, \alpha_2)$$

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$$\Delta y = y_{obs} - y_{cal}$$

$$\Delta y = \frac{\partial y}{\partial \alpha_1} \Delta \alpha_1 + \frac{\partial y}{\partial \alpha_2} \Delta \alpha_2$$

Model

$$m_1 = 2.0 M_{Sun}$$

$$m_2 = 1.5 M_{Sun}$$

$$m_3 = 1 M_{Sun}$$

$$a_1 = 0.0857 \text{ AU}$$

$$a_2 = 0.22 \text{ AU}$$

$$P_1 = 17.46 \text{ d} = \frac{1}{0.0572} \text{ d}$$

$$P_2 = 172.18 \text{ d} = \frac{1}{0.0057} \text{ d}$$

$$f_1 = 12.76 \text{ d}^{-1}$$

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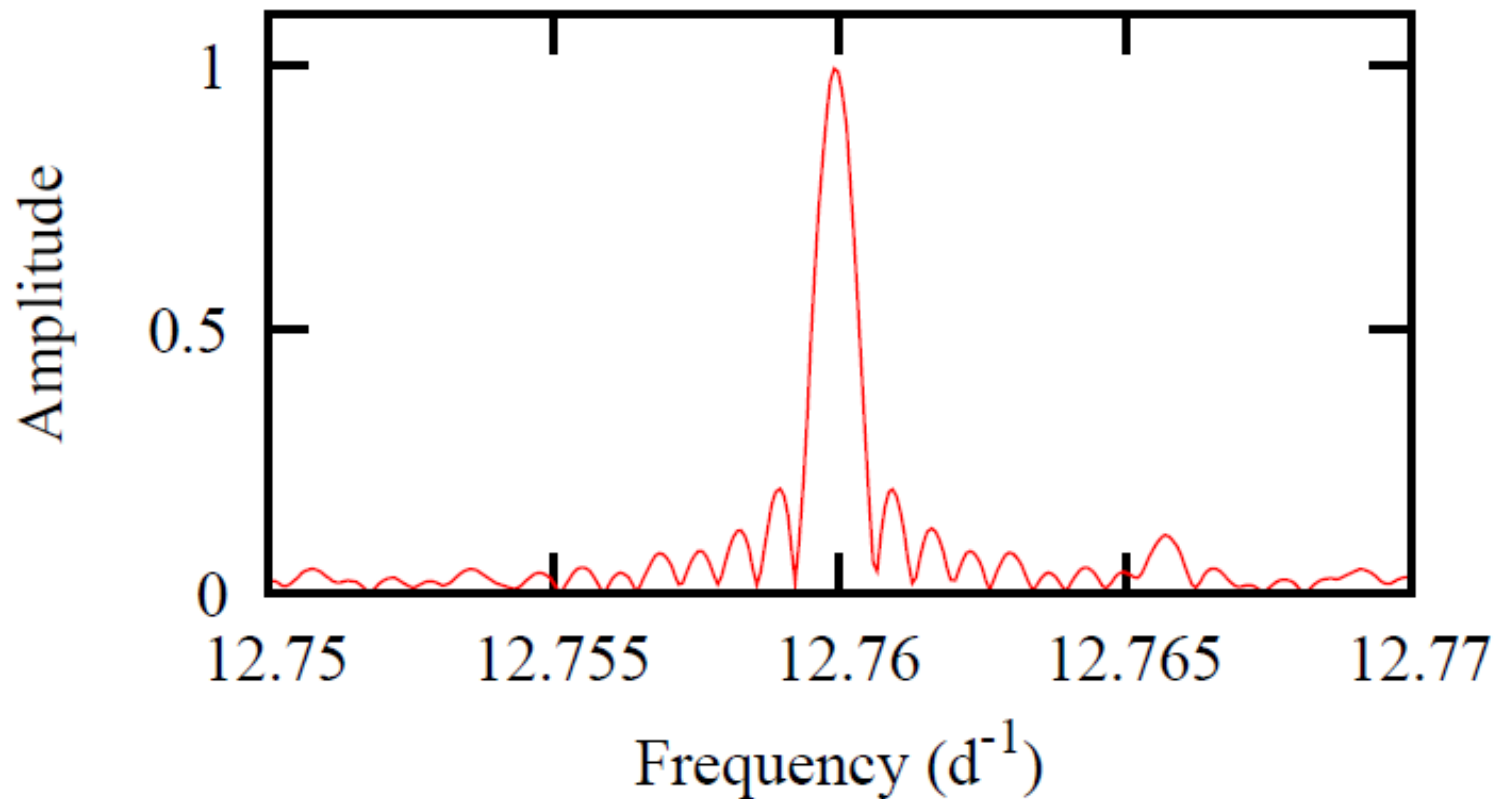
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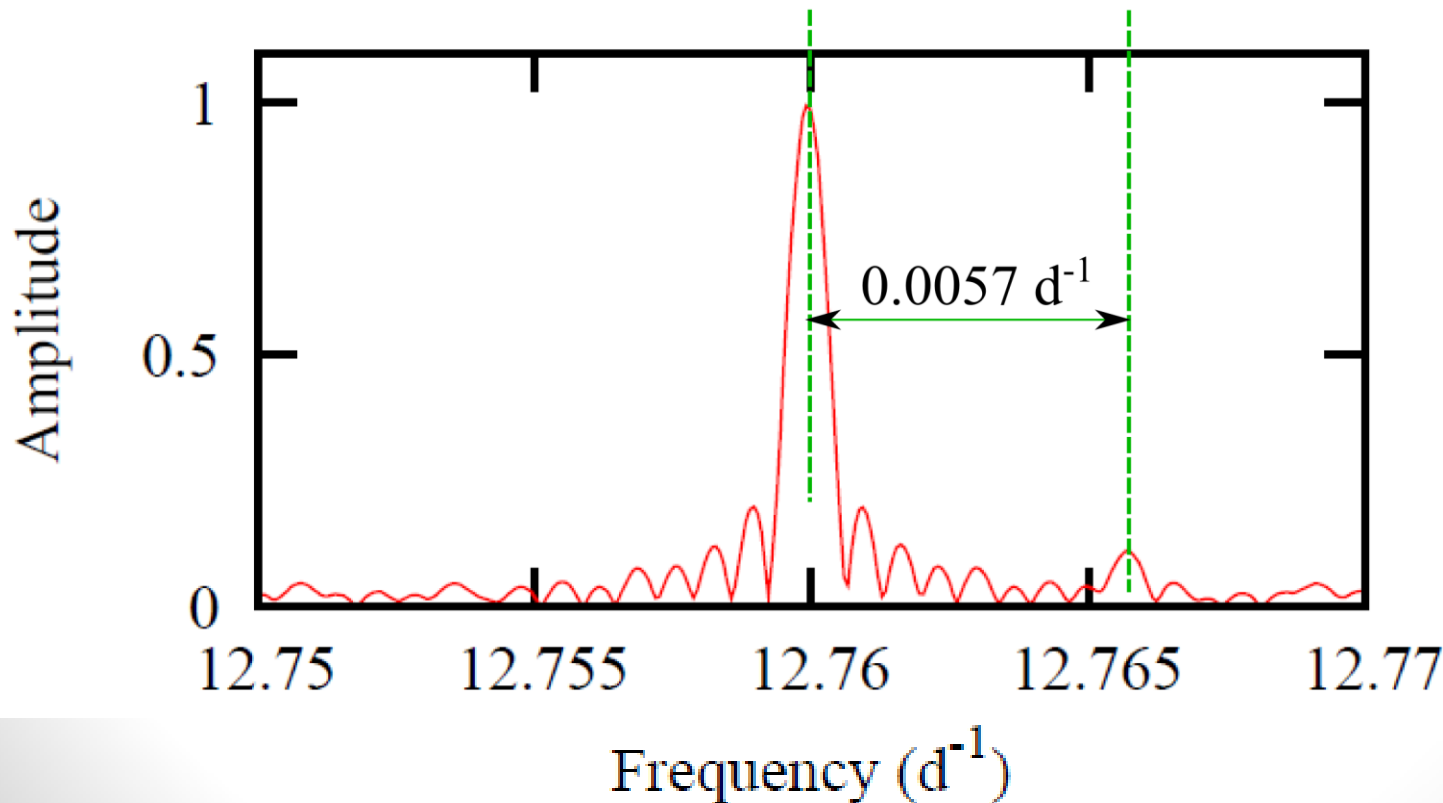
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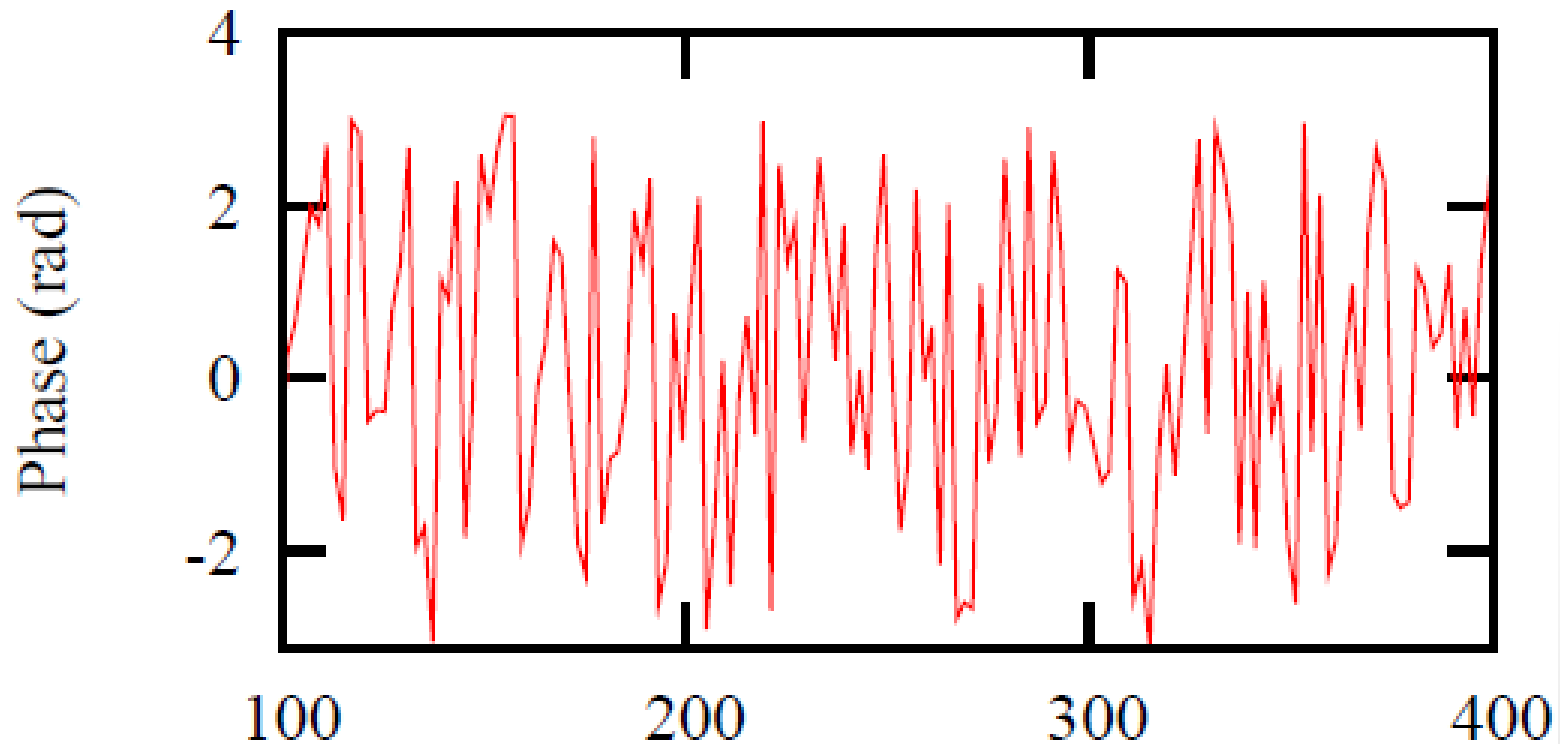
$$f_1 = 12.76 \text{ d}^{-1} \quad 12.7657 \text{ d}^{-1}$$



Model

$$\tau = \frac{a \sin i}{c} \sin(\Omega t + \omega) = \alpha_1 \sin \Omega t + \alpha_2 \cos \Omega t$$

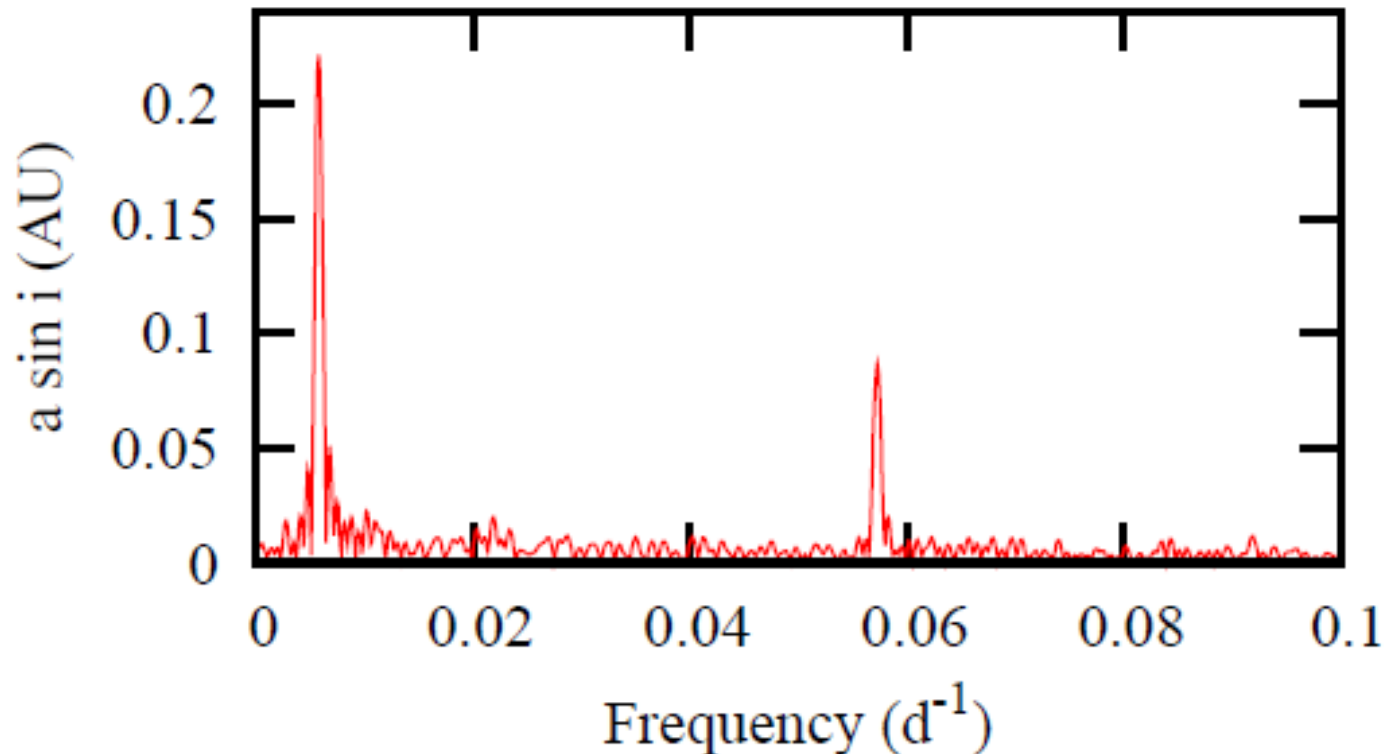
$$y = a_1 + \sum_{j=1}^{\nu} \{a_{2j} \sin \omega_j(t + \tau) + a_{2j+1} \cos \omega_j(t + \tau)\}$$



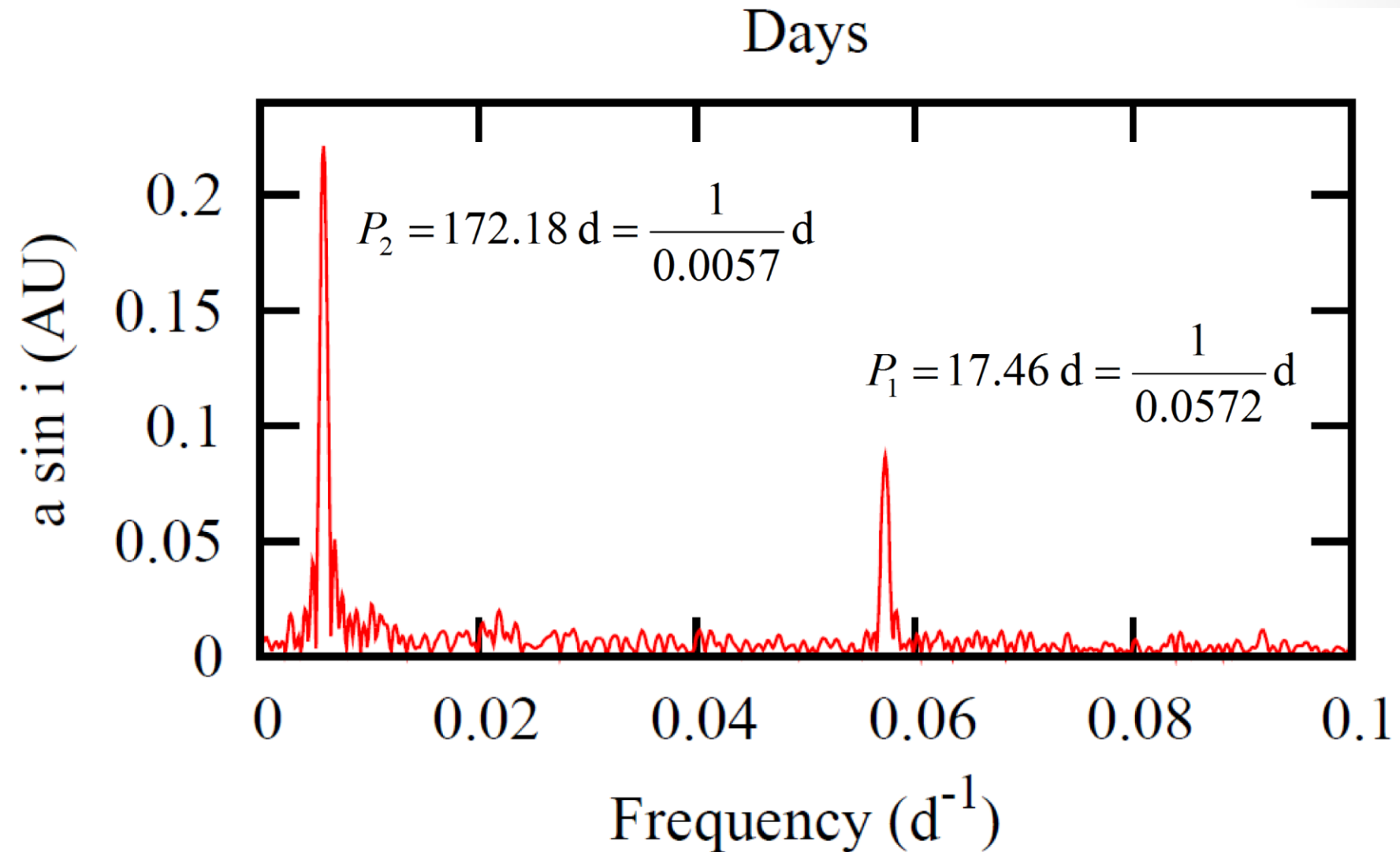
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Binarogram



Binary star detection using the time-delay method: Application to 34 *Kepler* objects of interest.

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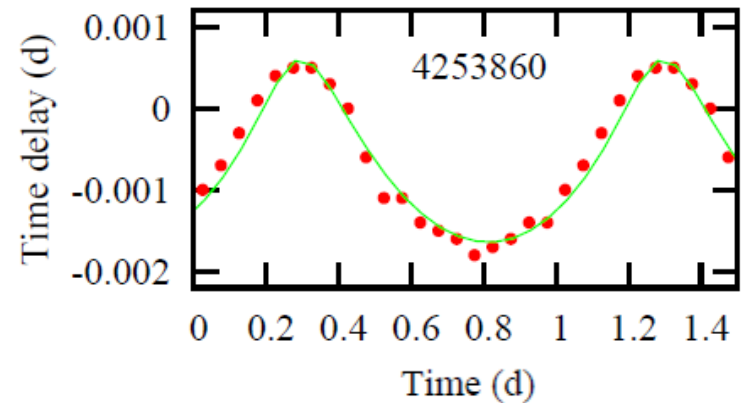
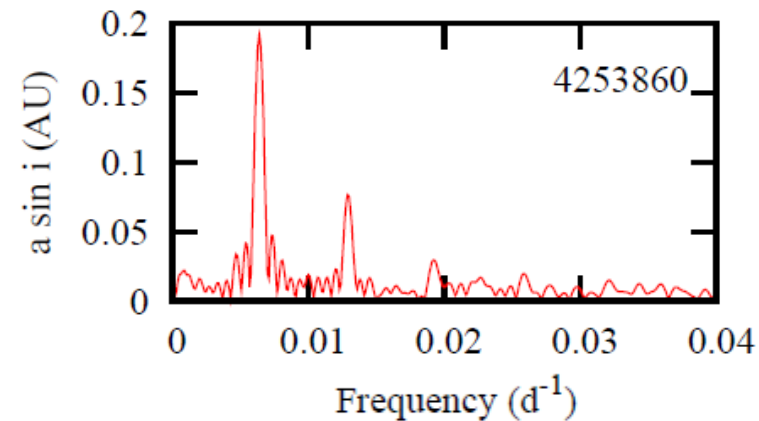
- Model,
- KIC 4150611, KIC 11754974
- 11 000 (KIO) \rightarrow 1250 (12 mag) \rightarrow 34 (δ Sct)

KIC	P d	$a \sin i$ AU
3441784	208.3 ± 0.4	0.271 ± 0.006
4150611	94.3 ± 0.1	0.140 ± 0.001
4253860	155.0 ± 0.6	0.195 ± 0.005
5302006	714.3 ± 0.7	0.263 ± 0.001
9304923	1100 ± 20	0.45 ± 0.02

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$$\tau = \frac{a \sin i (1 - e^2) \sin(\nu + \omega)}{c (1 + e \cos \nu)}$$

Plany

- Sprawdzenie oprogramowania na wynikach L. Balona,
- Sprawdzenie na obiektach typu sdB opisanych w literaturze do których jest spektroskopia (Np. KIC 11558725),
- Badanie obiektów typu sdB, dla którego nie ma spektroskopii lub jest o niskiej zdolności rozdzielczej, a u których podejrzewamy obecność towarzyszy,
- Wybrane obiekty z KOI