Towards new nutation theory

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Goals of work

1) Use the ARIADNA software and the IVS database for calculations of the nutation angles

2) Comparison of them with the predicted ones by the IAU 2000/2006 nutation theory

3) Some ideas to improve the IAU 2000/2006 nutation theory

The IVS database

1) Observations during period 1984 - 2013

2) **Session Earth Orientation Parameter Series (EOP-S)** – duration of each session 24 hours, during of which 3 or more telescopes observed 10-70 radio sources

3) Number of sessions is ~5500

Main stages of reduction of VLBI observations:

1. Theoretical value of *calculated* delay:

$$\tau_c = \frac{1}{c}\vec{B}\cdot\vec{s} + \Delta\tau$$

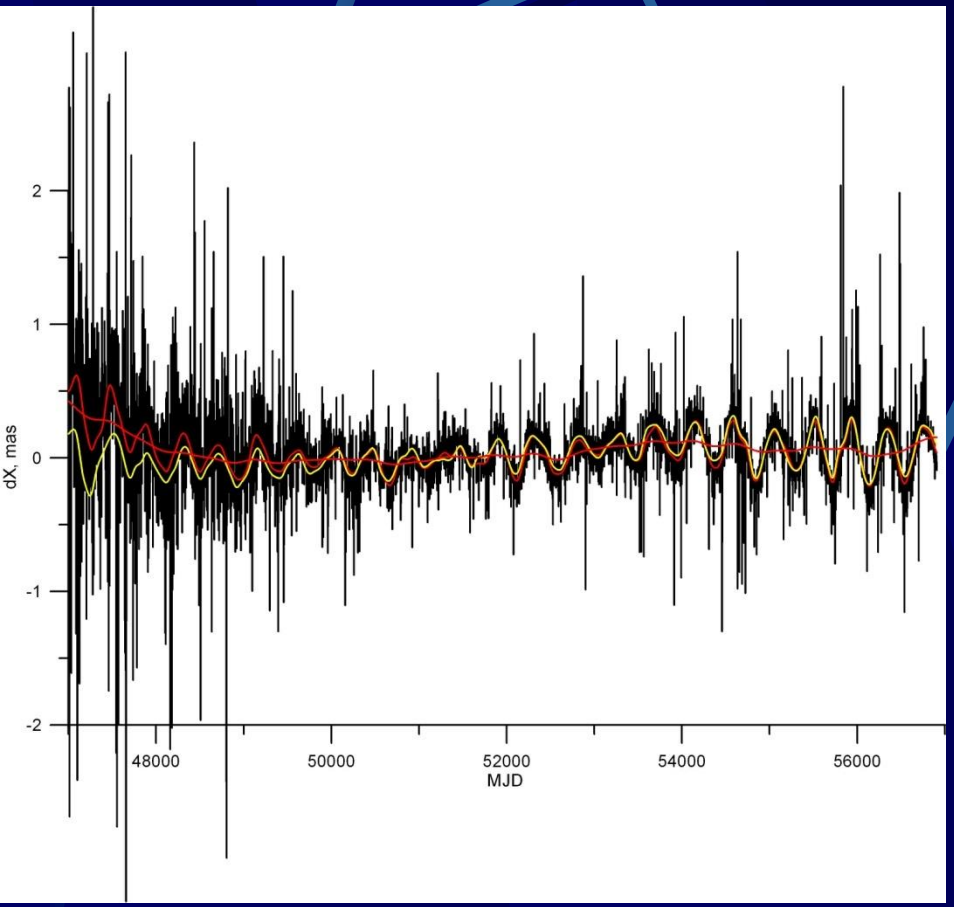
$$\tau_c(t) = F(t, X_i, Y_i, Z_i, \dot{X}_i, \dot{Y}_i, \dot{Z}_i, \Delta X_i, \Delta Y_i, \Delta Z_i,$$
$$\alpha_j, \delta_j, UT1, x_p, y_p, (\Delta\psi, \Delta\varepsilon)(or\ dX, dY), \ldots)$$

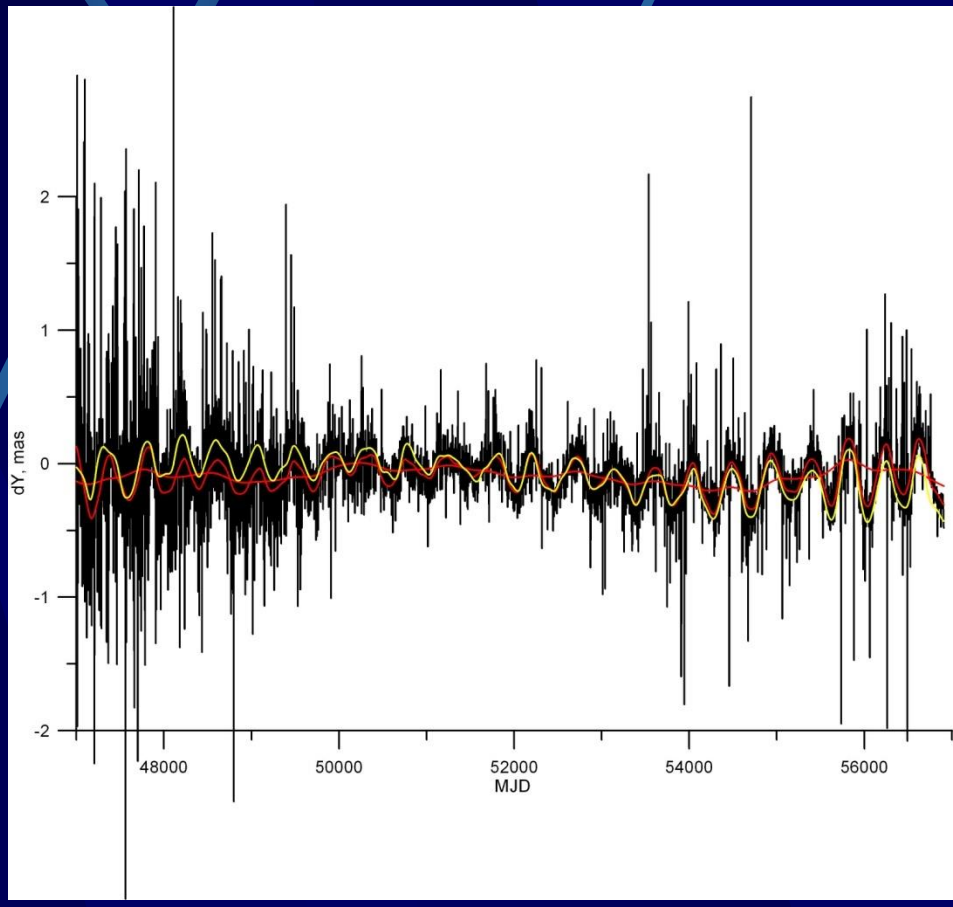
2. Subtraction of it from observed delay and estimation of parameters *Pk* of the linearized model:

$$\tau_o - \tau_c\big|_t = \sum_k \left.\frac{\partial\tau_c}{\partial P_k}\right|_t \Delta P_k(t) + \varepsilon$$

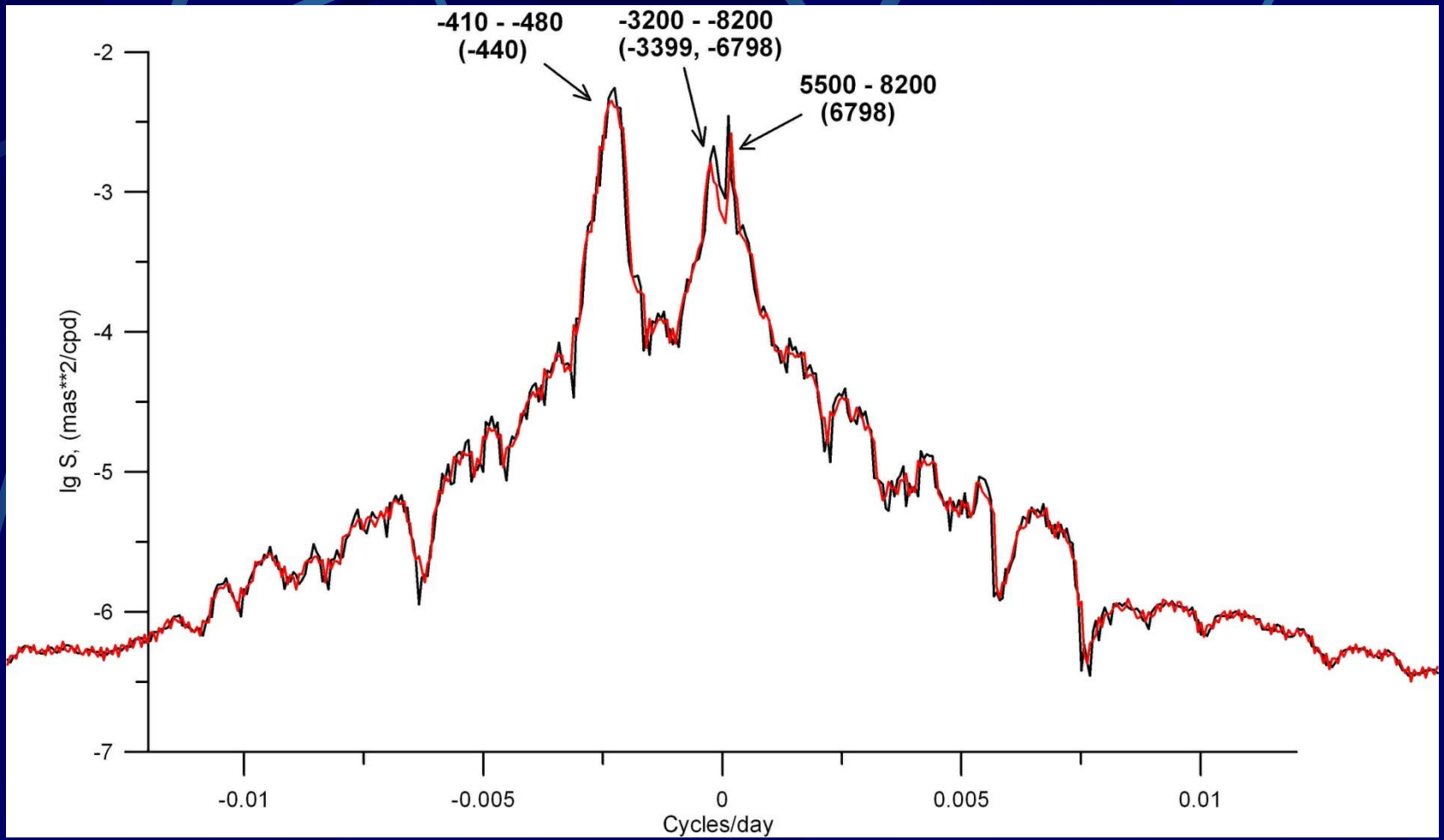
$$\vec{l} = A\vec{x} + \vec{\varepsilon}$$

Corrections for nutation angles





Spectrum of complex residuals



Some questions (1)

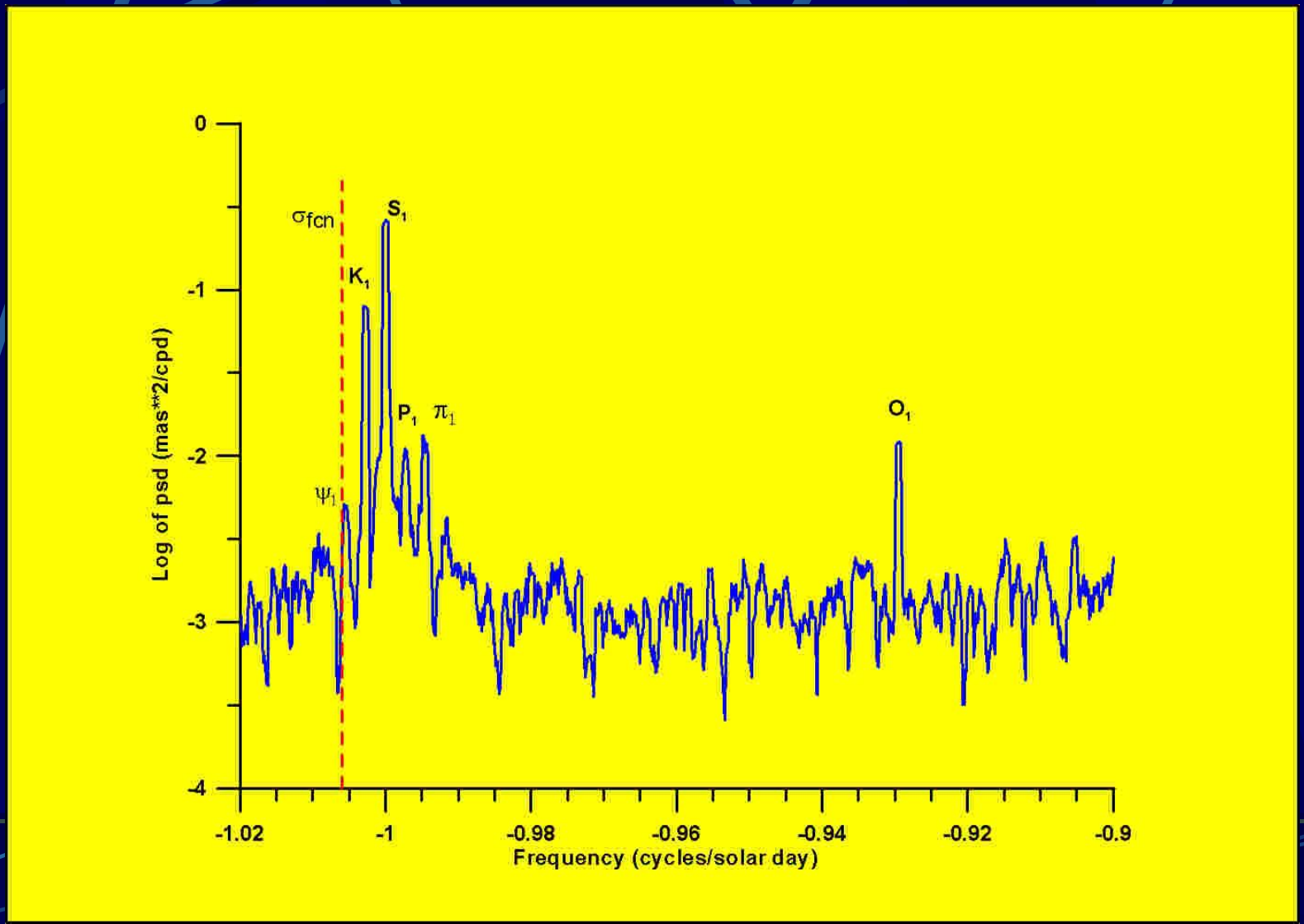
1) Free Core Nutation (FCN) line has significant width. Why?

According theory it is free motion (mode) with
f = -1.002324Ω (P = -430.23 d)

SOFA subroutine (Lambert, 2007) realized a free motion of the CIP in the GCRS with a variable amplitude

a) It is mathematical model
b) What is an excitation process with the FCN frequency?
c) What is physical reason of variability of the FCN amplitude?

Spectral density of atmospheric pressure term around the FCN frequency



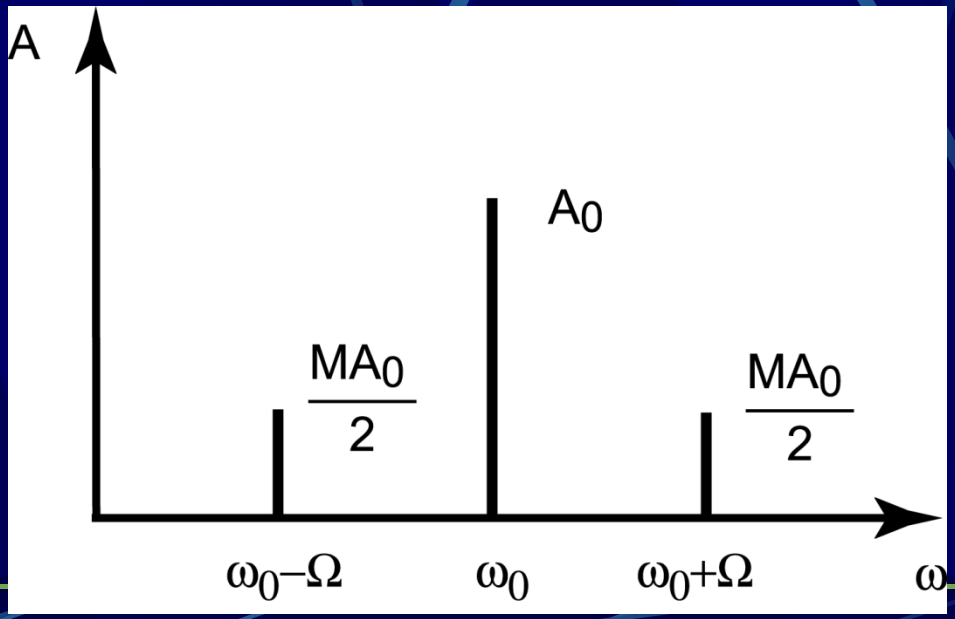
Amplitude modulation of signal

$$a(t) = A(t)\cos(\omega_0 t + \varphi_0)$$

$$A(t) = A_0 + \Delta A\cos(\Omega t + \gamma) = A_0[1 + m\cos(\Omega t + \gamma)]$$

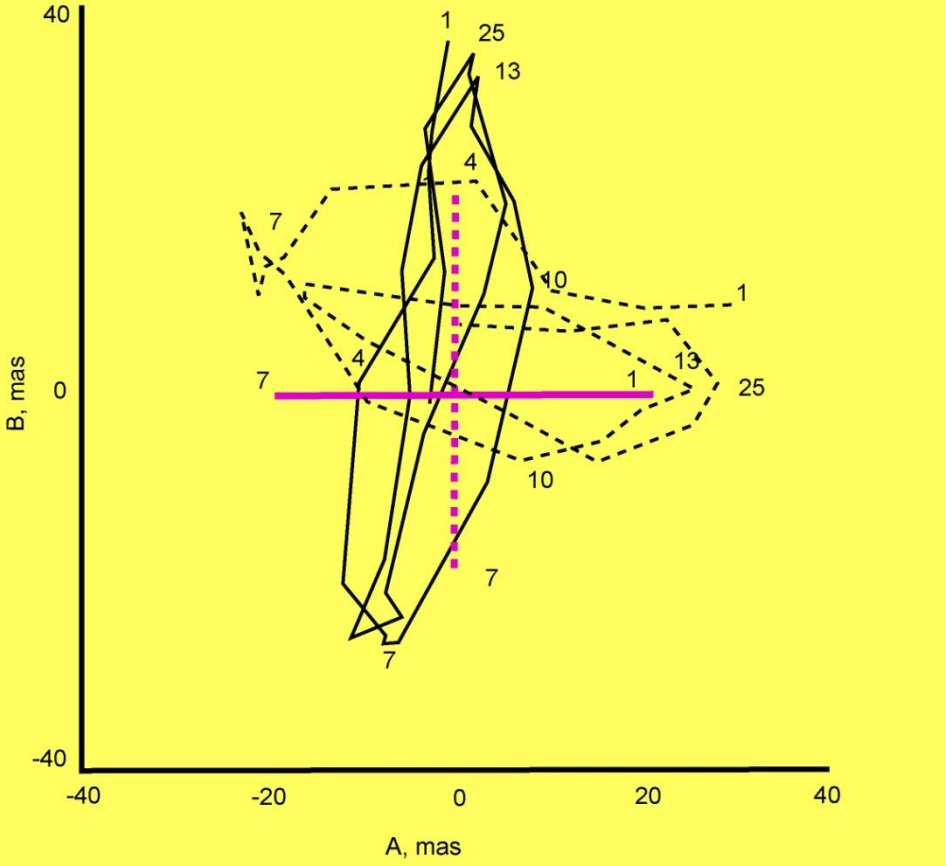
$$a(t) = A_0\cos(\omega_0 t + \varphi_0) + \frac{MA_0}{2}\cos[(\omega_0 + \Omega)t + (\varphi_0 + \gamma)] +$$

$$+ \frac{MA_0}{2}\cos[(\omega_0 - \Omega)t + (\varphi_0 - \gamma)]$$



Annual variation of amplitude of S1 tide ⟹ **K1; P1**

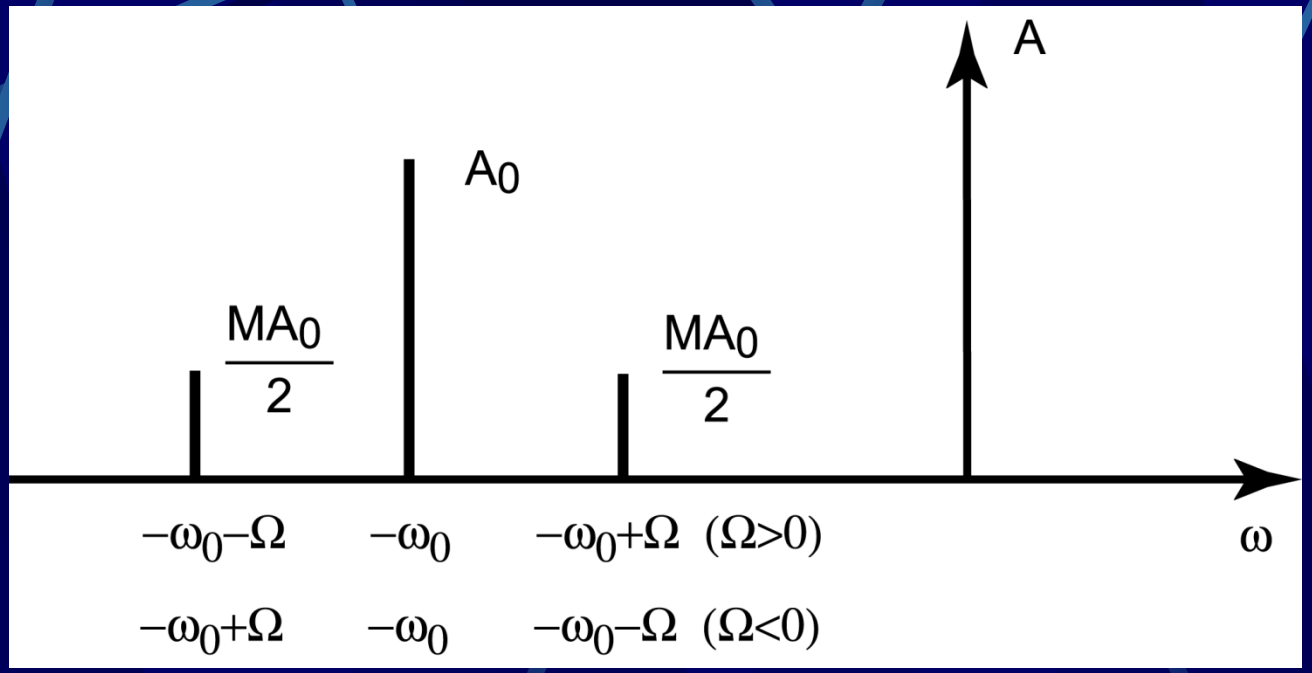
Semiannual variation ⟹ **ψ1; π1**



Annual variation of cosine A and sine B amplitudes of S_1 tide

$$\chi_{S1}(t) = A\cos 2\pi f_{S1}t + B\sin 2\pi f_{S1}t$$

Amplitude modulation of complex signal



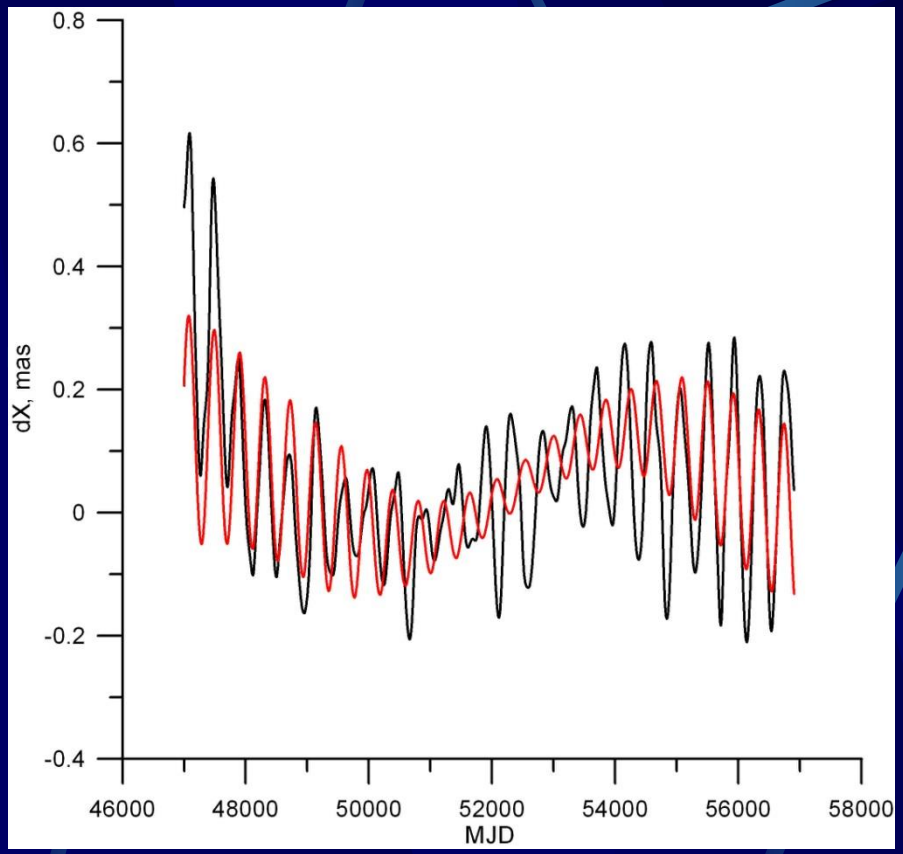
$P = -430 \quad (-410; -480)$

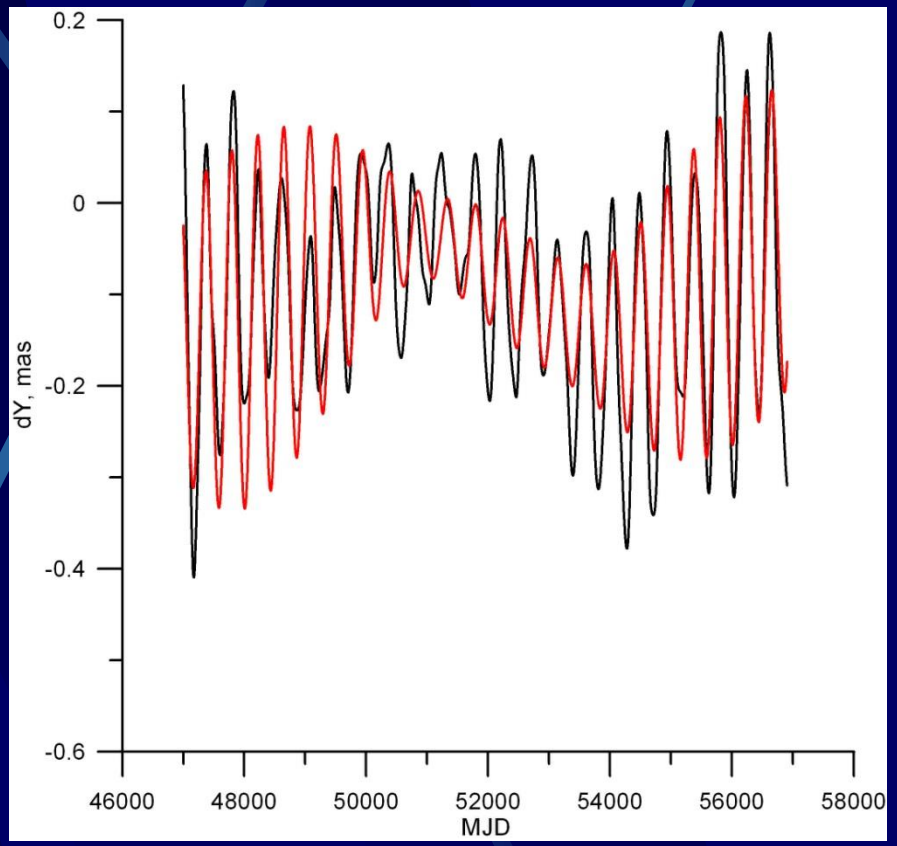
$f = -1.002324 \quad (-1.002439; -1.002083)$

$f_{\text{modulation}} = \pm(0.000115 \cdots 0.000241)$

$P_{\text{modulation}} = \pm(8700 \cdots 6100) \Rightarrow 18.6 \text{ years?}$

Simulation





$$dX(t) = \sum_{i=1}^{4} A_i \cos(2\pi f_i t + \varphi_i) \qquad dY(t) = \sum_{i=1}^{4} B_i \cos(2\pi f_i t + \gamma_i)$$

A	$P = 1/f$	φ	B	$P = 1/f$	γ
0.09	7275.44	2.23	0.06	6838.33	165.60
0.01	493.72	-69.49	0.09	446.43	99.30
0.12	417.26	-91.98	0.09	415.80	-18.87
0.09	406.67	-35.48	0.06	405.37	39.60

Some questions (2)

2) There is significant power in harmonics with periods in range (-3200;-8200 days) that is close to the main retrograde nutation terms -9,3 and -18,6 years and prograde term with period +18.6 years.

Reason is non-perfect modeling of the long nutation terms. What are the Earth structure parameters necessary to correct?

Conclusion

- 30 – years the IVS data base were used for analysis of the nutation angles and comparison with the IAU 2000/2006 nutation series
- Excitation of the FCN is connected with the atmospheric tide ψ_1 that is one of harmonic results from semi-annual modulation of the thermal S_1 tide
- Is the FCN frequency splitting due to modulation by main nutation harmonic with period 18.6 years?
- Modeling of main nutation terms with periods 18.6, 9.3 years is not perfect and has to be improved.

Thank for attention !