Search for Nucleus Decay Parameter variations for Fe-55 and Co-60 Isotopes

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Natural radioactivity - spontaneous decay of metastable nucleus is fundamental quantum effect with no classical analogues

Quantum theory of nucleus α – decay (*Gamow ,1929)*

Radioactive decay law : $N(t) = N_0 \exp(-t / T_d)$

T_d - nucleus life-times are fundamental constants

Content

1. Experiment descriptions

2. Search of decay parameter variations for Fe-55 and Co-60

3. Possible applications

Basic nucleus decays are *α* - ,*β*-, *γ*- decays**,** they are performed via strong, weak and electromagnetic interactions

Examples:

Plutonium α - decay **:** $^{238}\mathrm{Pu} \rightarrow {}^{234}\mathrm{U} + {}^{4}\mathrm{He}$ life-time 87,3 years

Strontium *β* - decay **:** $^{90}\mathrm{Sr} \rightarrow {}^{90}\mathrm{Y} + e^{-} + \bar{\nu}_e$ life-time 50,6 years

Polonium *γ* - decay **:** $^{214}\mathrm{Po}^{*} \rightarrow {}^{214}\mathrm{Po} + \gamma$ life-time 5.7 sec

Exotic (rare) decays:

Inverse *β* – decay, double *β*- decay, etc.

Modern nucleus theory claims that nucleus decay parameters

are independent of nucleus environment and are invariant

in time, hence the deviations from exponential dependence

for any nucleus decay should be negligible ! ?

Experimental tests of nucleus decay parameters stability :

***E. Rutherford, M. Curie,* about 1920**

First hints on nucleus decay low violation were obtained as by-product of applied researches

Methodic : long-time measurement of decay rates for long-living isotopes

D. Alburger, G. Harbottle, E. Norton - Earth. Sci. Lett. 78 , 168 (1986)

β-decay, Isotope - Si-32 , life-time ~ 140 years

$$^{32}\mathrm{Si} \rightarrow {}^{32}\mathrm{P} + e^{-} + \overline{\nu}_e$$

Experimental decay rate beside standard exponent contained small addition of harmonic periodic function.

Oscillation Period: 1 year, oscillation amplitude : 0,054% $\pm$ 0,014%

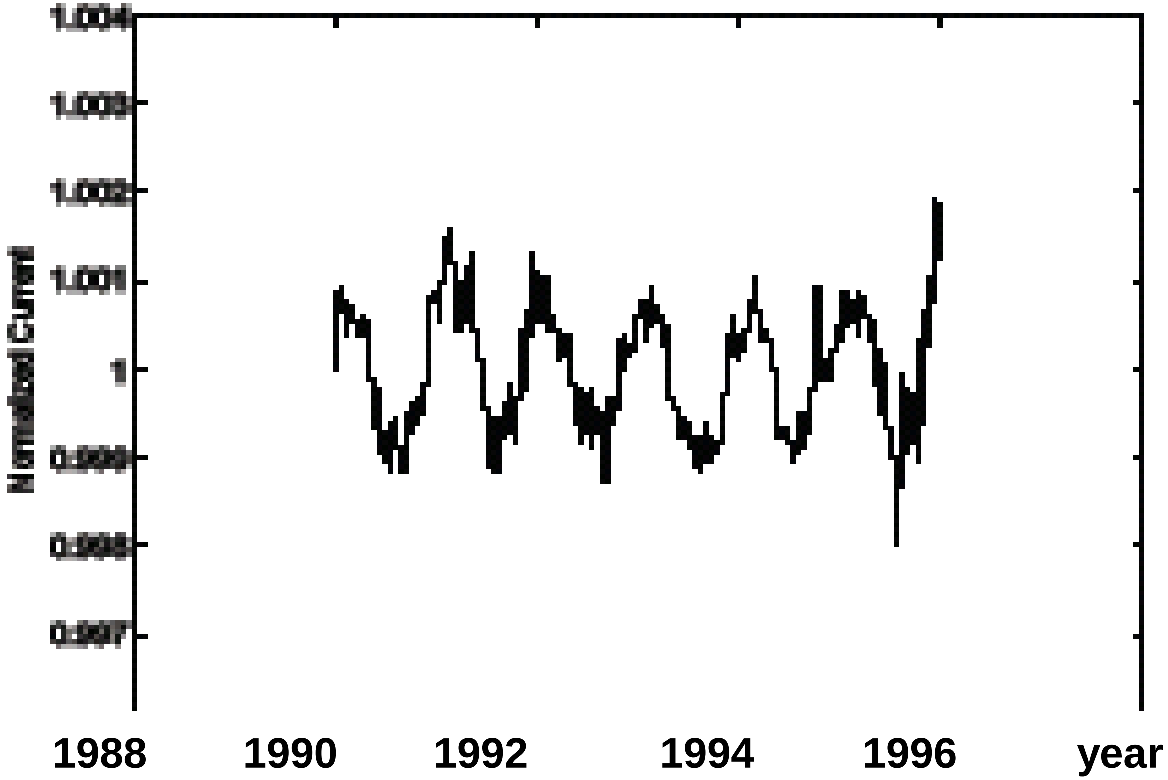
Maximal rate: February 15 $\pm$ 6 days

H. Siegert et al., Appl. Radiat. Isot. 9, 49 (1998)

β-decay, Isotopes - Ag-108, Ba-133, Eu-154, Kr-85, Ra-226, Sr-90

Counting rate versus time for Ag 108

- exponential component subtracted



P. A. Sturrock et al. -   arXiv:1408.3090

Counting rates versus time for Eu154, Kr85, Ra226, Sr90

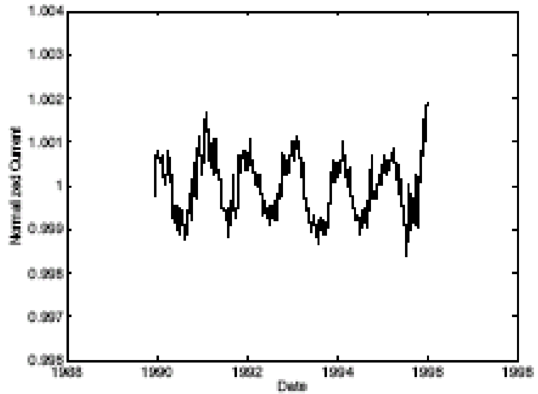


Figure 11. Detrended and normalized relative current measurements versus time for Eu154.

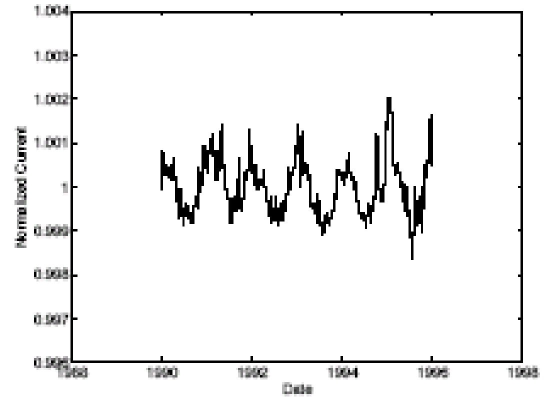


Figure 12. Detrended and normalized relative current measurements versus time for Kr85.

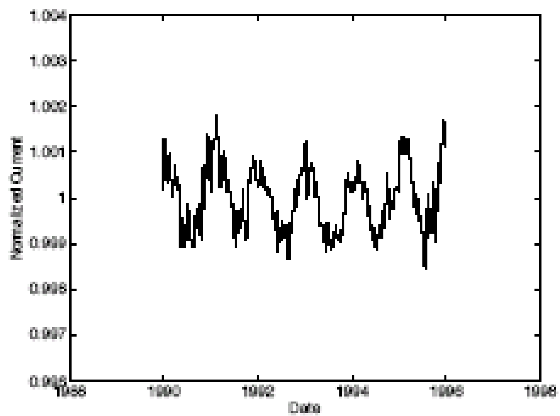


Figure 13. Detrended and normalized relative current measurements versus time for Ra226.

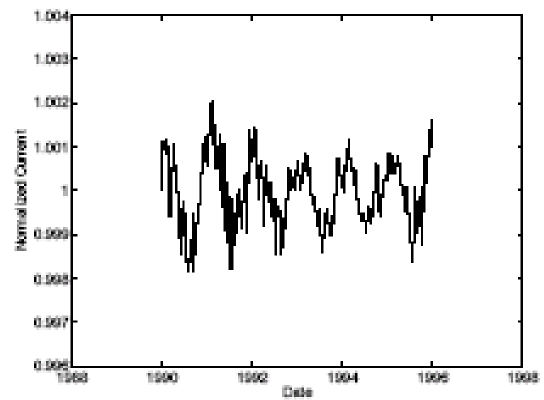


Figure 14. Detrended and normalized relative current measurements versus time for Sr90.

P. A. Sturrock et al. - arXiv:1408.3090

α - decay measurements

K.J. Ellis et al., Phys. Med. Biol. 35, 1079 (1990)

$$^{238}\mathrm{Pu} \rightarrow {}^{234}\mathrm{U} + {}^{4}\mathrm{He}$$

Oscillation Period: 1 year,

oscillation amplitude : 0,08% $\pm$ 0,01**%**

maximal rate : February 20 $\pm$ 10 days

E. Alekseev et al. : arXiv - 1505.01752

$$^{214}\mathrm{Po} \rightarrow {}^{210}\mathrm{Pb} + {}^{4}\mathrm{He}$$

Direct life-time measurement : $T_d = 1.64\ 10^{-4}\ \mathrm{sec}$

Experiment *Tau-2* in Baksan laboratory - *t* Measurement for Po-214

E. Alekseev et al. arXiv : 1505.01752

Decay Scheme of nuclide **226Ra**

$$^{226}Ra\,(T_{1/2}=1600\,y)\xrightarrow[E=4.78\,MeV]{\alpha}{}^{222}Rn\,(T_{1/2}=3.825\,d)\xrightarrow[E=5.49\,MeV]{\alpha}$$

$$^{218}Po\,(T_{1/2}=3.05\,m)\xrightarrow[E=6.0\,MeV]{\alpha}{}^{214}Pb\,(T_{1/2}=26.8\,m)\xrightarrow{\beta}$$

$$^{214}Bi\,(T_{1/2}=19.7\,m)\xrightarrow{\beta}{}^{214}Po\,(T_{1/2}=1.6\cdot 10^{-4}\,s)\xrightarrow[E=7.69\,MeV]{\alpha}$$

$$^{210}Pb\,(T_{1/2}=22.3\,y)\xrightarrow{\beta}{}^{210}Bi\,(T_{1/2}=5.01\,d)\xrightarrow{\beta}$$

$$^{210}Po\,(T_{1/2}=138\,d)\xrightarrow[E=5.3\,MeV]{\alpha}{}^{206}Pb\,(stable)$$

$$^{214}Bi\xrightarrow{e^-}{}^{214}Po^*\xrightarrow{\gamma}{}^{214}Po\xrightarrow{\alpha}$$

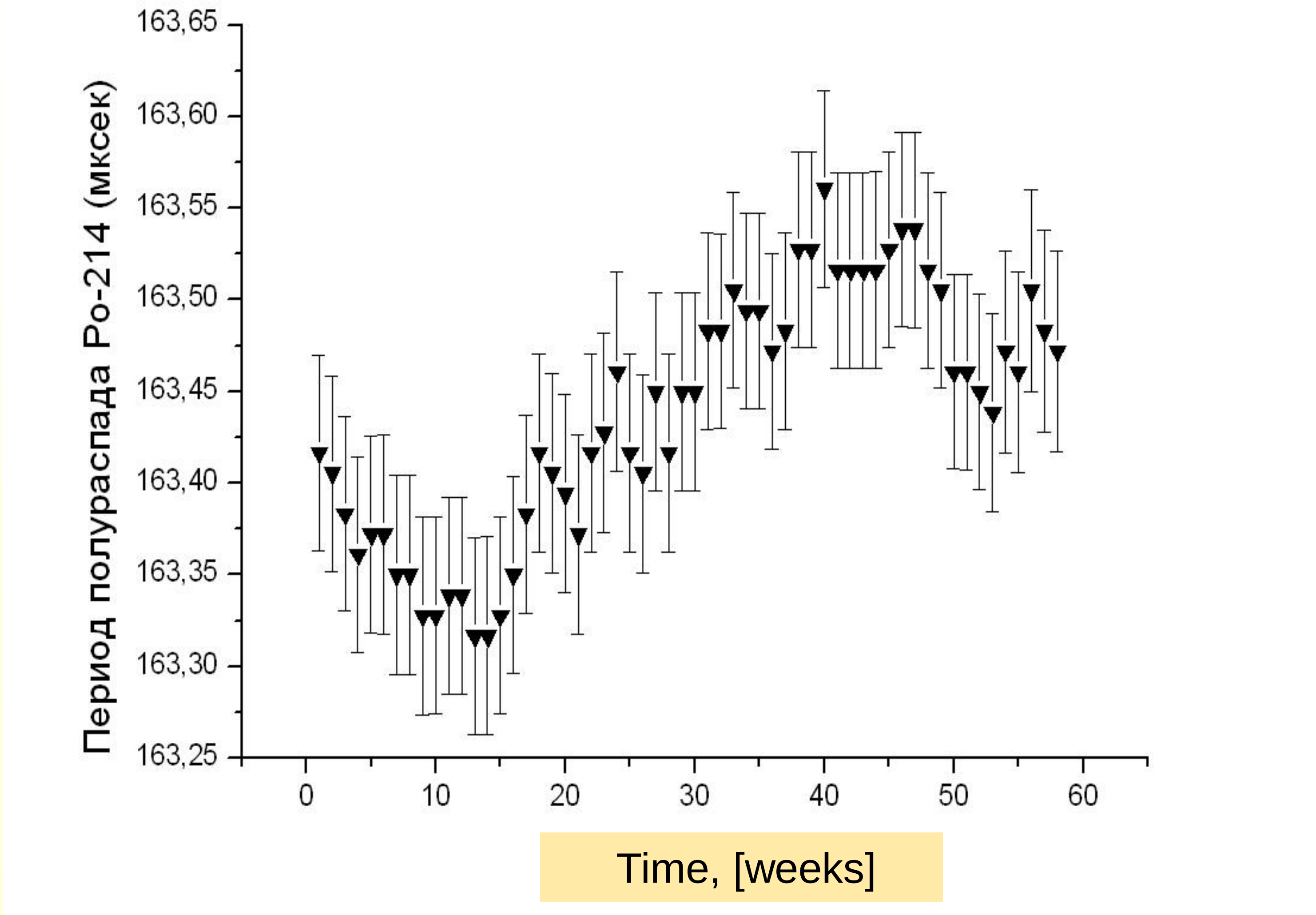
$t = 1.64\cdot 10^{-4}$ sec

214-Po* —> 214-Po + γ ; 214-Po nuclide birth marked by e - , γ emission

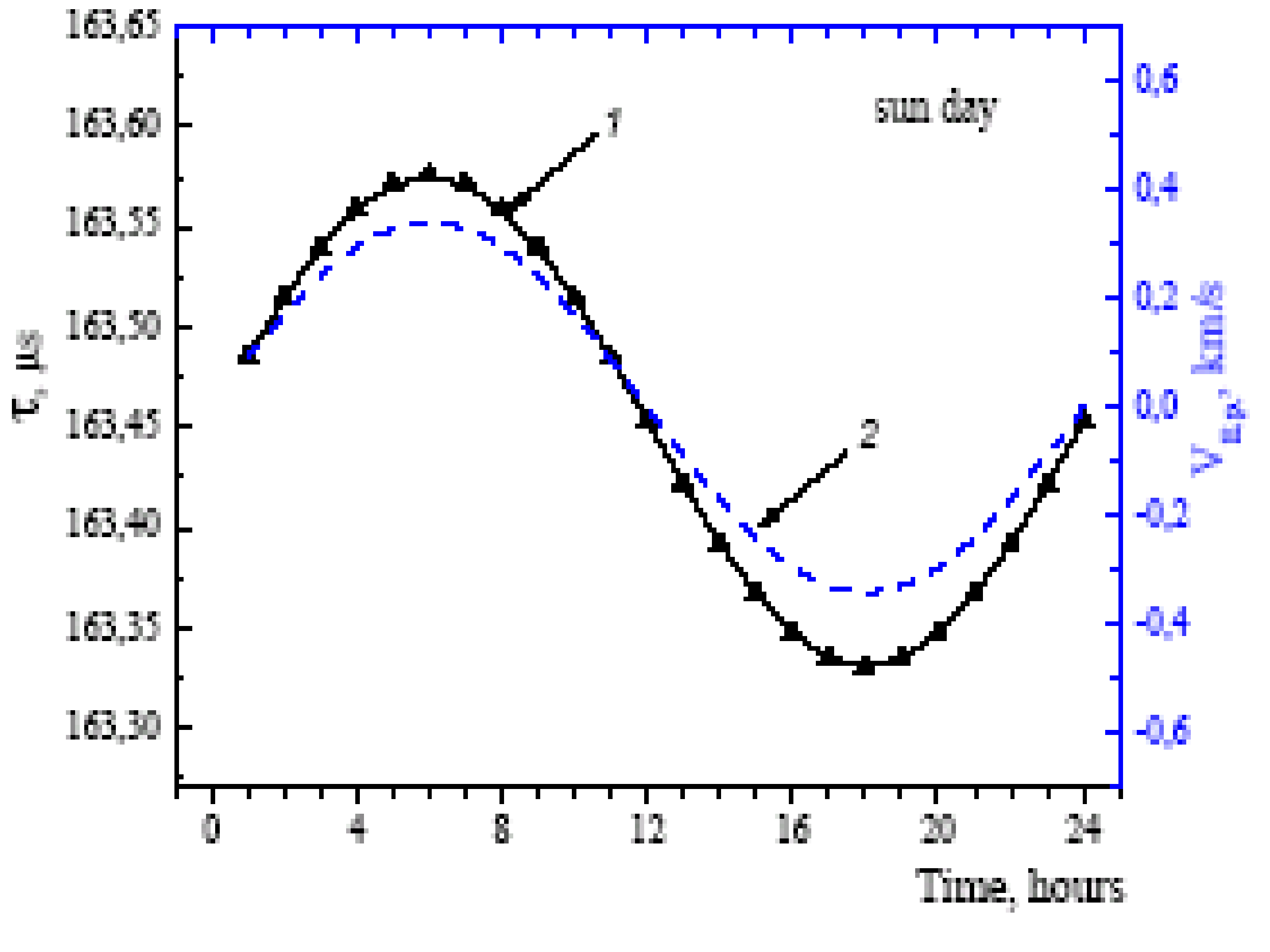
214-Po nuclide decay marked by alpha emission

Po-214 Life - time dependence on year season 2012 - 2016

maximal life-time : September 22 ± 5 day



214 Po life-time sun-day (24 h) oscillations



Daily amplitude: A = $(7.5 \pm 1.2)\ 10^{-4}$

Maximal life-time at : 6 a.m. $\pm$ 20 min.

Experimental results for three Po isotopes

Amplitude of variation				
Variation → Isotope ↓	Solar-daily	Lunar-daily	Sidereal-daily	Annual
^{214}Po (163.46 μs)	$(5.3\pm0.3)\cdot10^{-4}$	$(6.9\pm2.0)\cdot10^{-4}$	$(7.2\pm1.2)\cdot10^{-4}$	$(9.8\pm0.6)\cdot10^{-4}$
^{213}Po (3.705 μs)	$(5.3\pm1.1)\cdot10^{-4}$	$(4.8\pm2.1)\cdot10^{-4}$	$(4.2\pm1.7)\cdot10^{-4}$	$(3.2\pm0.4)\cdot10^{-4}$
^{212}Po (0.2941 ns)	$(7.5\pm4.1)\cdot10^{-4}$			

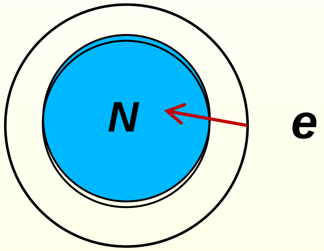
Measurements for Po-214, Po-213, Po-212 :

Isotope life-time changes by 6 orders, but oscillation

parameters practically don't change

Electron capture features and parameters

Electron capture is inverse beta-decay : electron from K-shell captured by nuclide proton, neutron and neutrino are produced. In addition X-ray can be emitted due to transition of electron from upper shell to K-shell



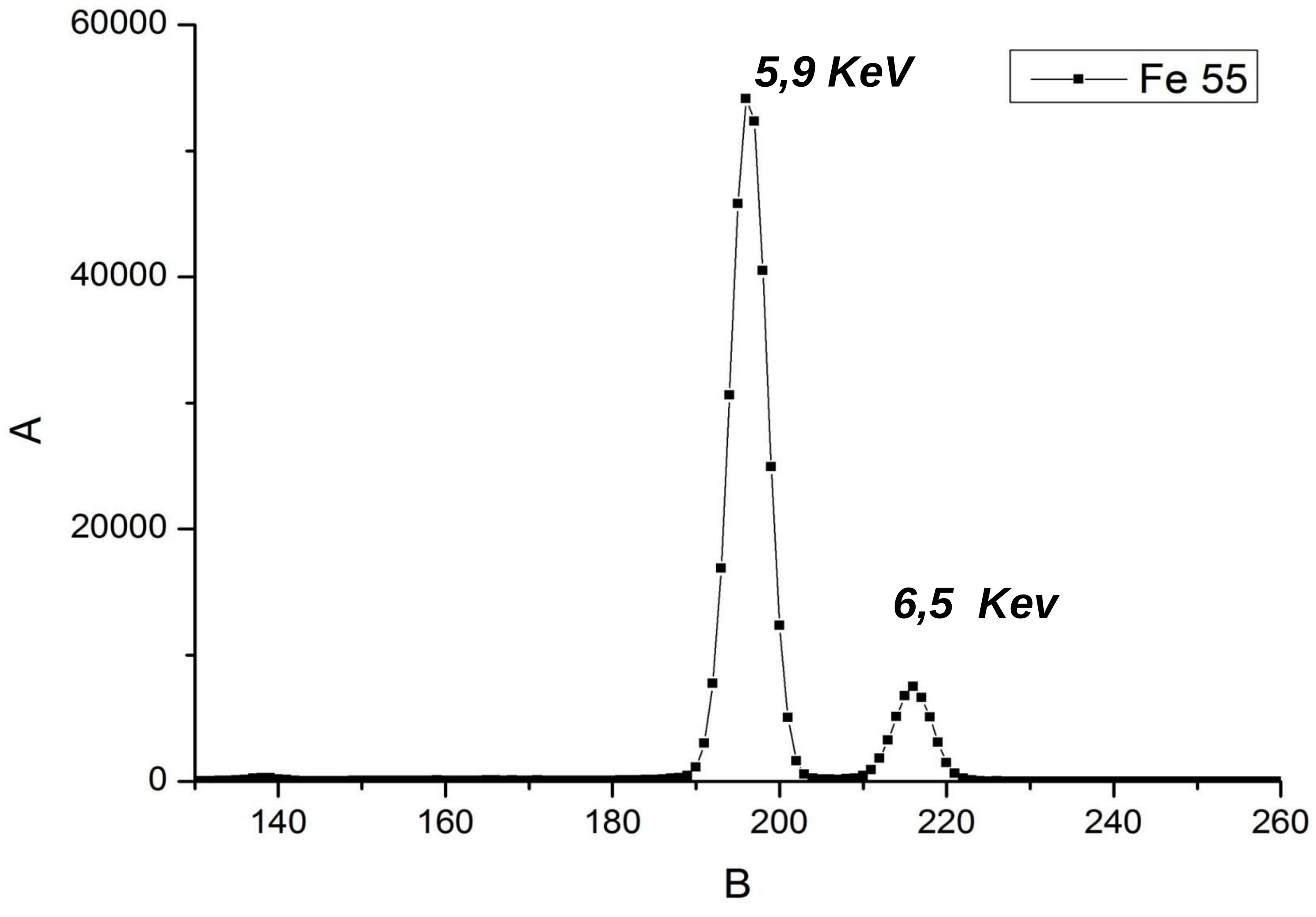
$$e + p \rightarrow n + \nu_e + \gamma$$

Fe-55 : two X-ray lines - α ***: E = 5.9 KeV , P =.87, ΔL= 0***

β : ***E = 6,5 KeV, , P=.13, ΔL= 1***

Life – time : 1004 days

Si Pin detector Fe-55 Amplitude Spectra



Fe-55 Electron Capture Measurement with Si-PIN Detectors

PhIAN - BGU collaboration

Si-PIN X-ray detector - spectrometer

Cooling : *T = - 55 C*

Surface Diameter - 4 mm

Advantages of Fe- 55 measurements:

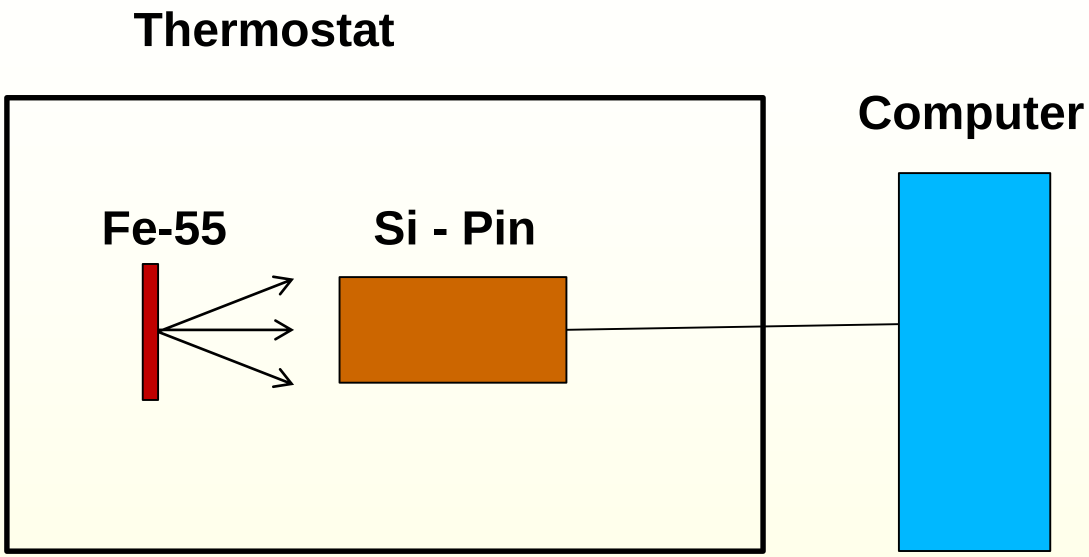
1) New kind of weak process for decay oscillation search

2) Self- calibration via the positions of X-ray spectra peaks , high stability

3) Low background level

Problems : Account of systematic effects: influence of atmospheric pressure, humidity, etc.

Fe-55 Decay Rate Measurement Set - up



Internal thermostat - T = - *55 C*

External thermostat - T = *20 C*

Experimental Test Study of Detector Performance

Fe-55   intensity ~ 300 Kbk

Detector aperture ~ *π* / 8 , Statistics ~ 2*10^7 events per day

daily statistical error *σ* = .03 %

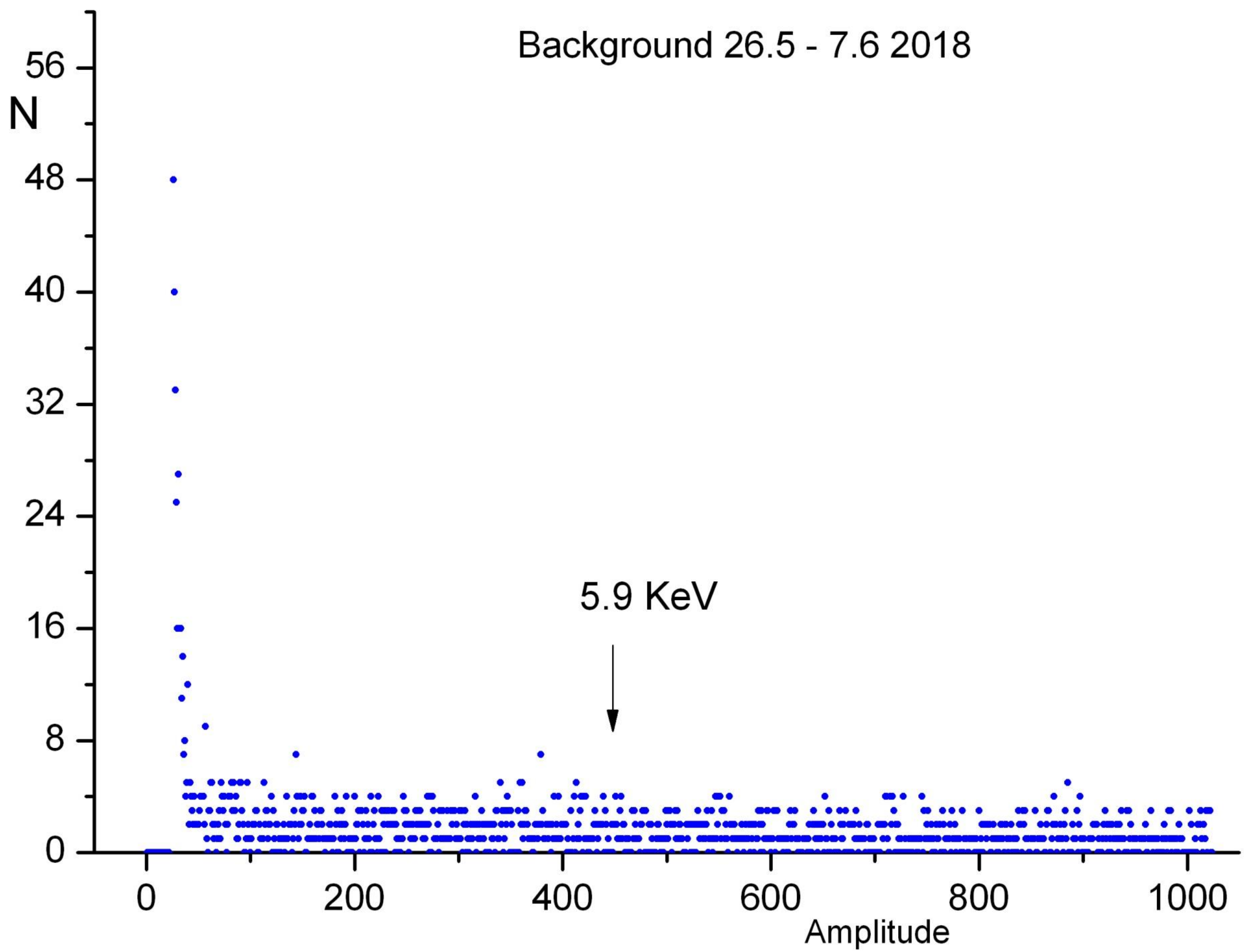
45 months of data storage

Background ~ 35 $\pm$ 7 events/ per day

Background rate corresponds to estimated rate of cosmic ray

Flow

4 years of data acquisition in 2016 - 2020



Background 26.5 - 7.6 2018
N
56
48
40
32
24
16
8
0
5.9 KeV
0
200
400
600
800
1000
Amplitude

Co-60 Decay Rate Measurement

$$n \rightarrow p + e + \nu_e + \gamma$$

Co-60 decay produces two γ lines

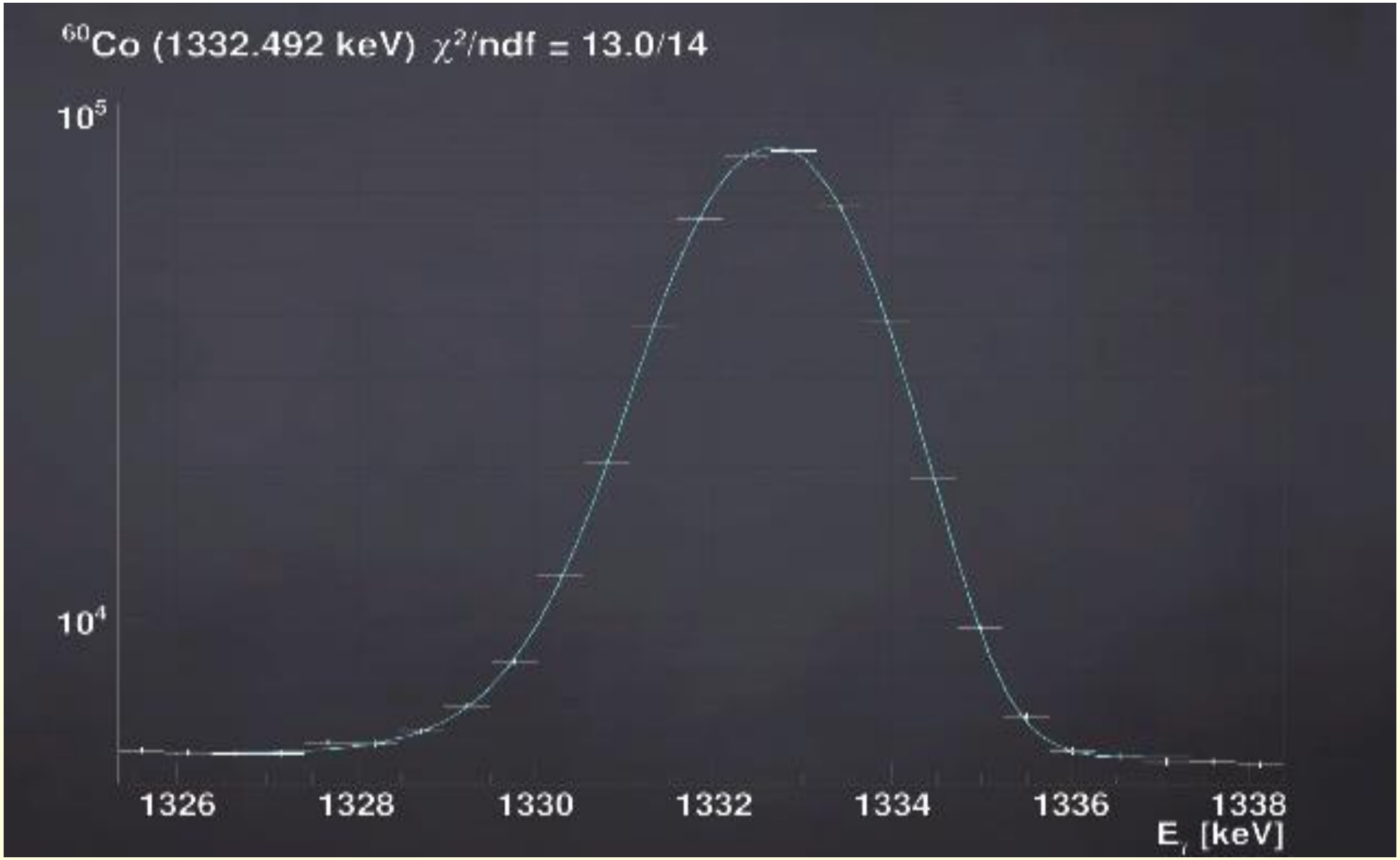
with energies 1173 and 1332 KeV, they are

measured by Coaxial germanium detector

GMX25 – 70A

kept in thermostat at T = 85 K

Co-60 Decay γ-ray amplitude spectra, E=1332,5 KeV

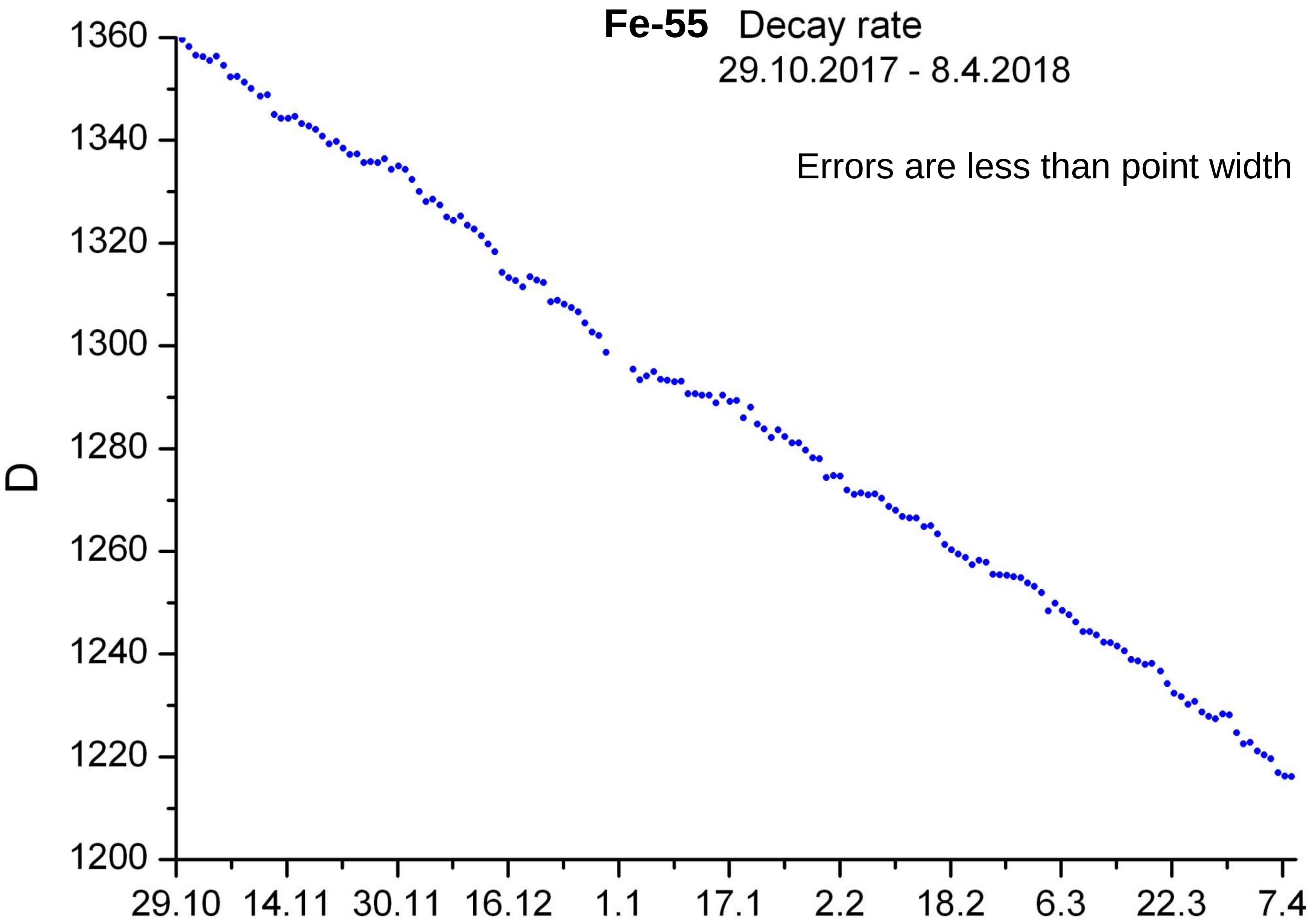


Co-60 decay was used for calibration of experimental set-up on Novosibirsk electron - positron storage rings during experimental runs.

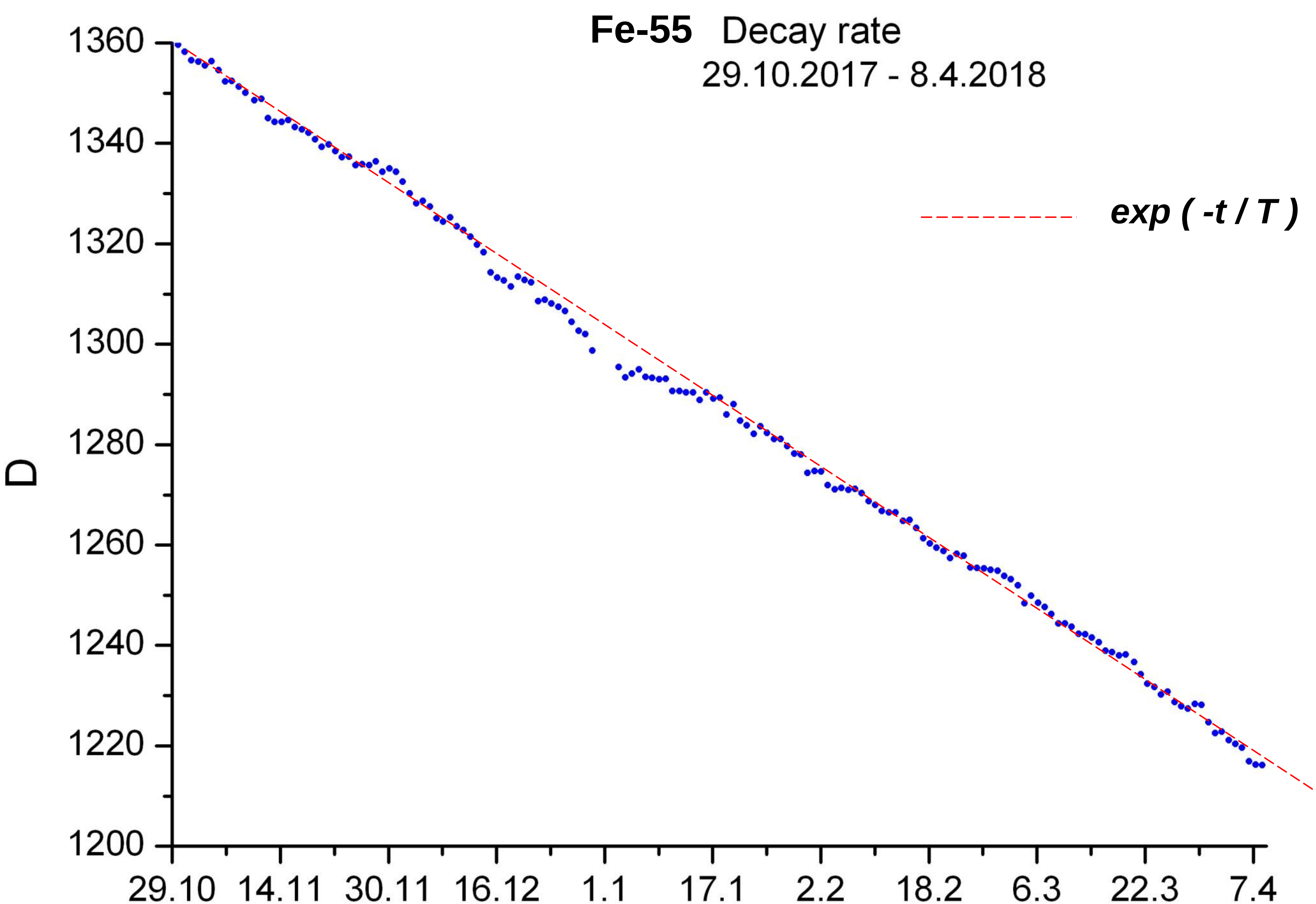
Every day accelerator turned off for 3 hours to compensate liquid Helium loss in superconducting magnets, It permits us to check that accelerator doesn’t influence detector performance.

In sum we have 705 days of data acquisition in 2012 – 2019

Statistics : ~ 1 million events per day



Fe-55 Decay rate
29.10.2017 - 8.4.2018
Errors are less than point width
D
1360
1340
1320
1300
1280
1260
1240
1220
1200
29.10
14.11
30.11
16.12
1.1
17.1
2.2
18.2
6.3
22.3
7.4



Fe-55 Decay rate
29.10.2017 - 8.4.2018
exp (-t / T)
D
1360
1340
1320
1300
1280
1260
1240
1220
1200
29.10
14.11
30.11
16.12
1.1
17.1
2.2
18.2
6.3
22.3
7.4

Nucleus decay rate and Solar activity influence

First evidence of solar activity influence on nucleus decay rate

was obtained for Mn-53 electron capture (*Jenkins et al* 2008, 2009)

Decay rate measured with NaJ crystals , E = 890 KeV

$$e + p \rightarrow n + \nu_e + \gamma$$

Nucleus decay rate and Solar activity influence

Solar activity characterized by 11 years cycle.

It characterized by electromagnetic radiation

and charged particle emission

Sun activity detected by X-ray radiation measurement on satellites.

Active Sun period ~ 7 years, quiet Sun ~ 4 years

Current activity minimum: spring - autumn 2019

X-ray measurement on satellites permits to detect solar bursts

(flares) when X-ray radiation rate rises by 4-5 orders in several

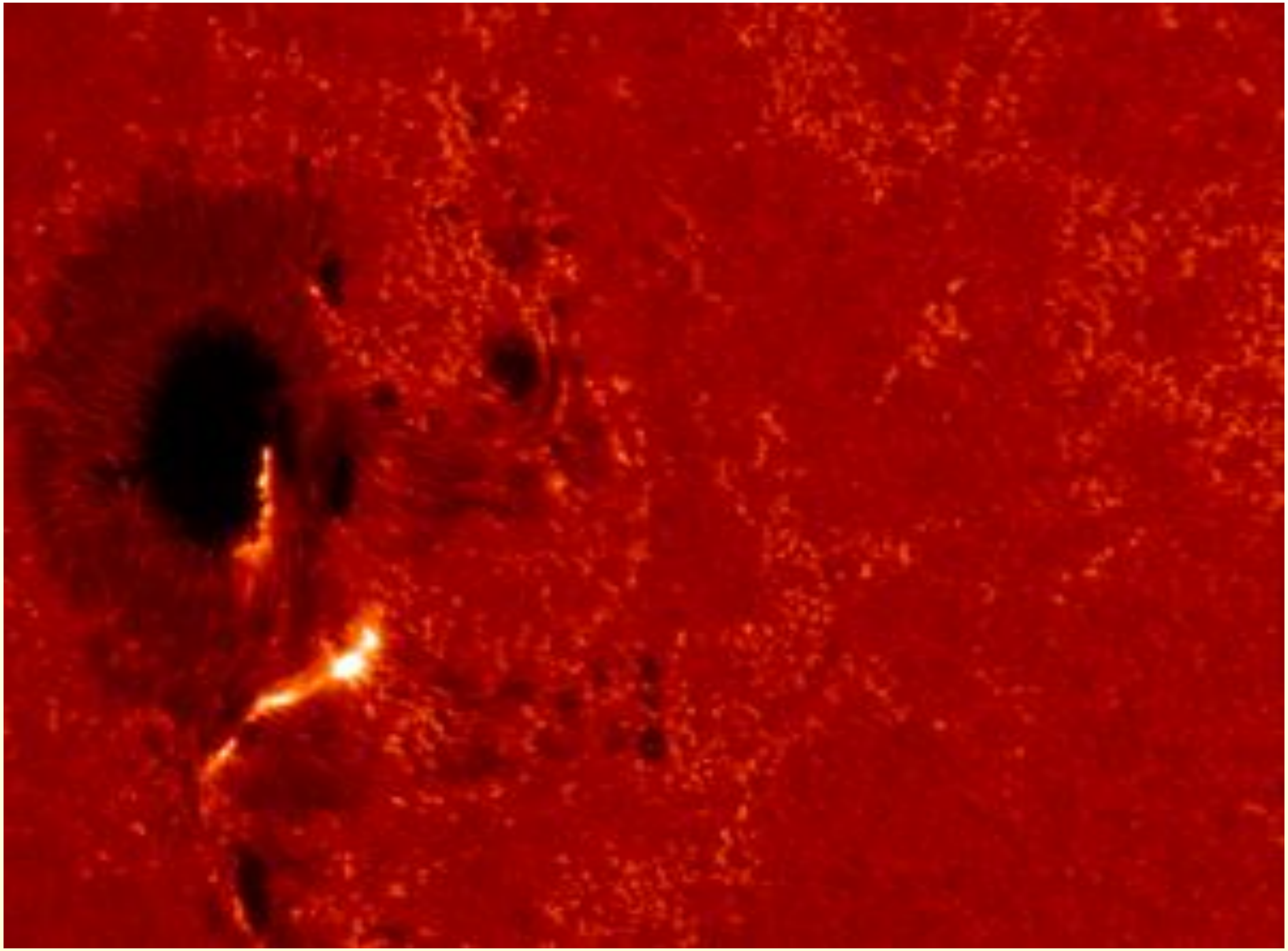
minutes, this maximal rate continues about 15 minutes

Sun burst classification : A < B < C < M < X

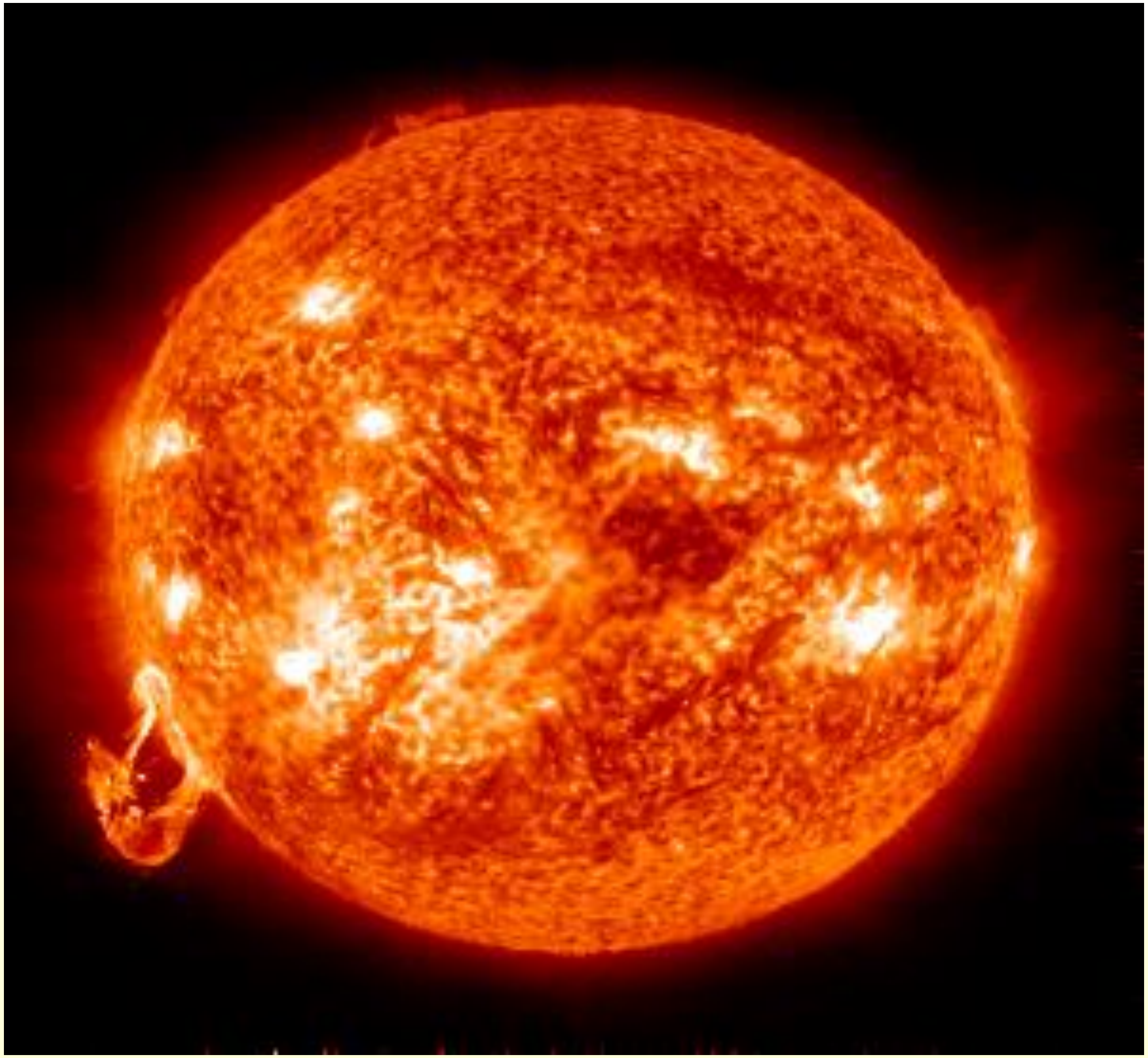
Each class differs by one order of intensity

Solar flares originate from solar dark spots,

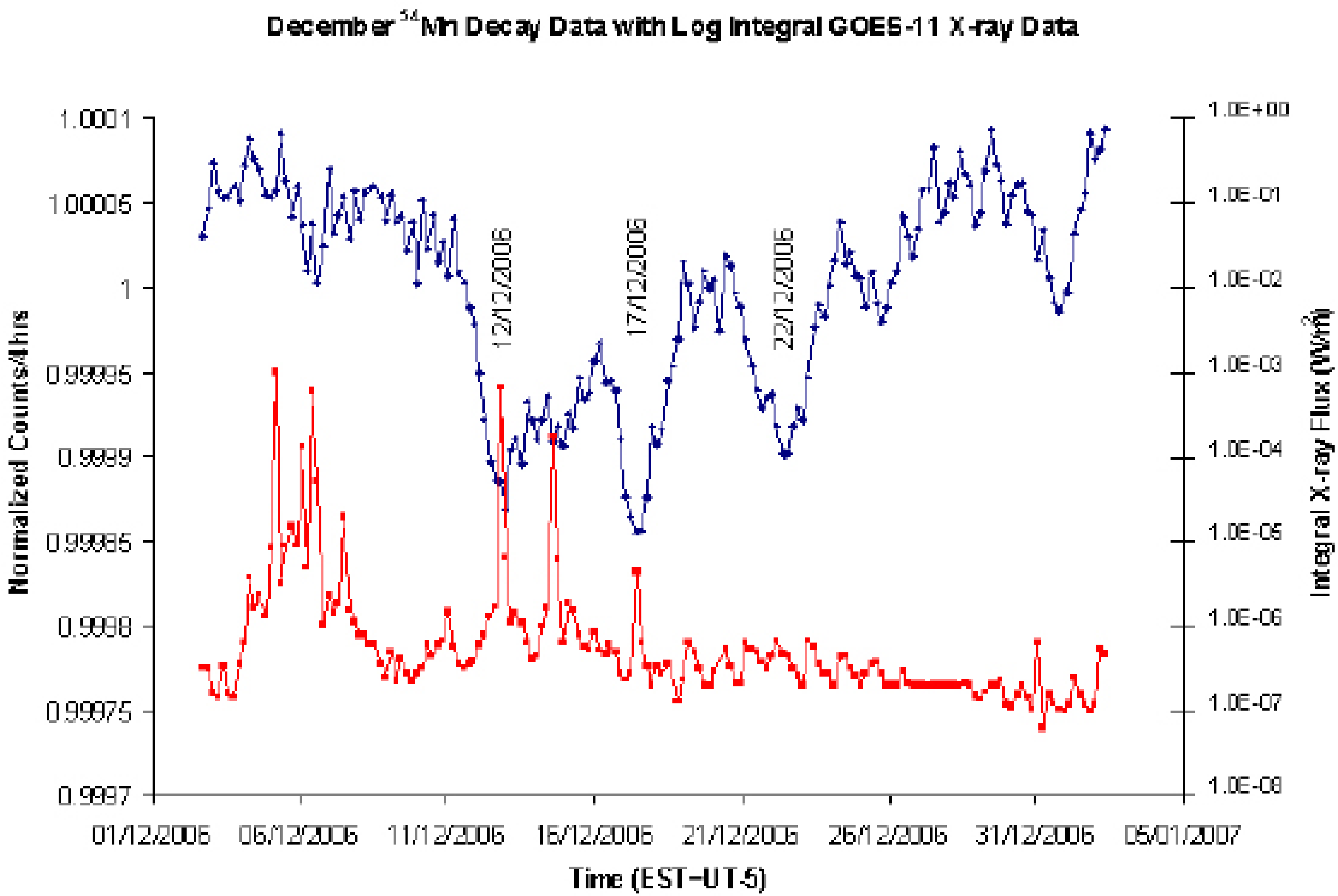
X-ray intensity can rise up to 10 000 times of normal activity



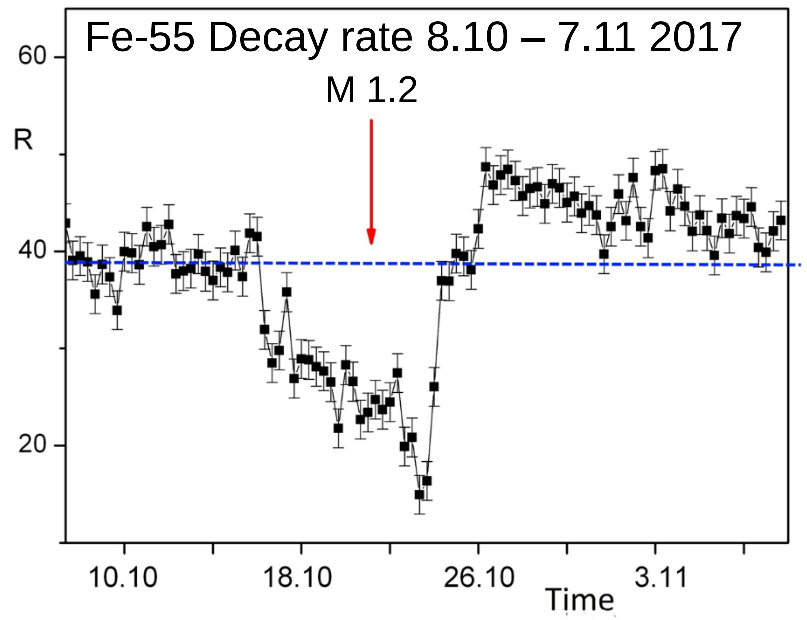
Coronal mass ejection correlate with solar flares, both of them can induce damage to industry and astronautics



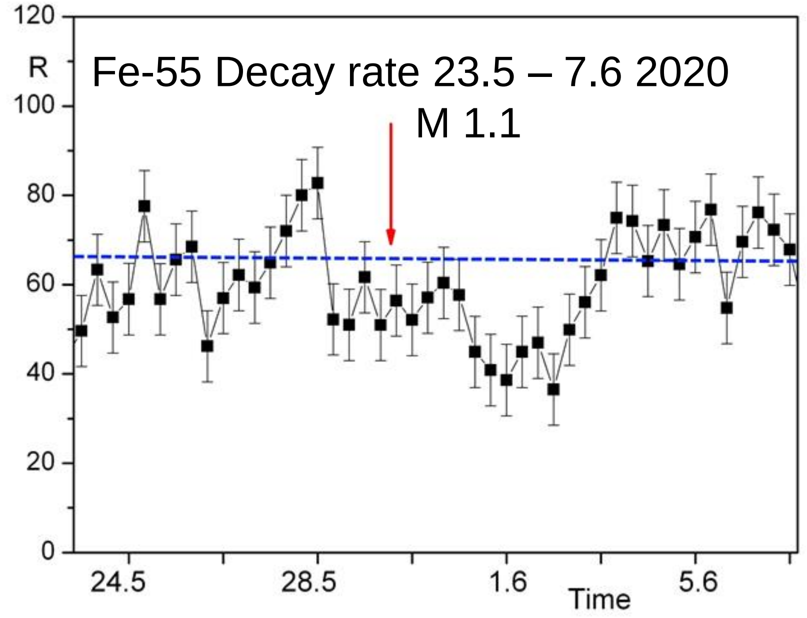
Mn-54 *e*-capture decay rate versus Sun activity ***(Jenkins , 2009)***
December 2006

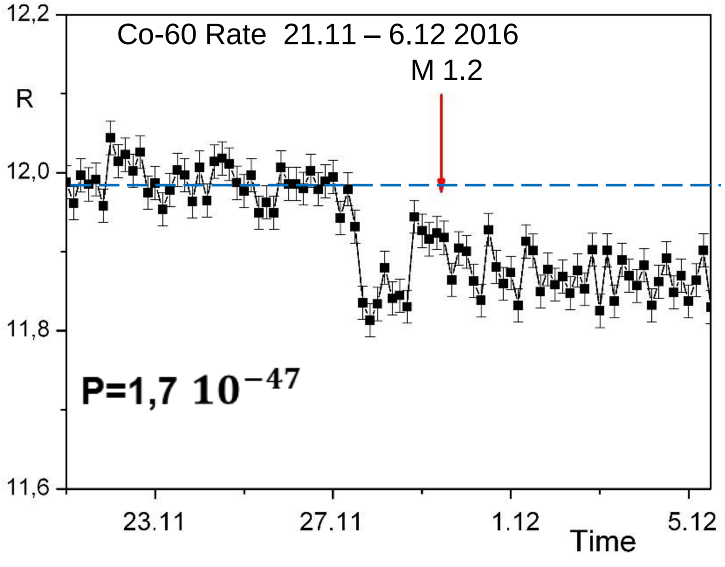


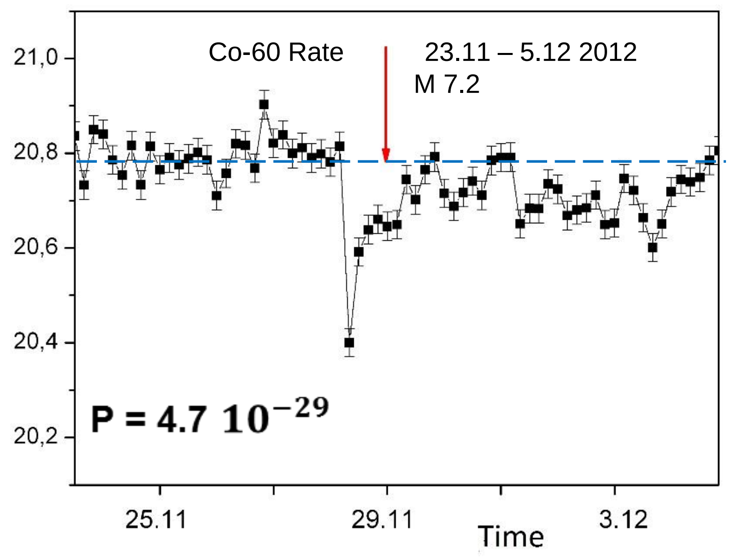
$P=1{,}9*10^{-94}$

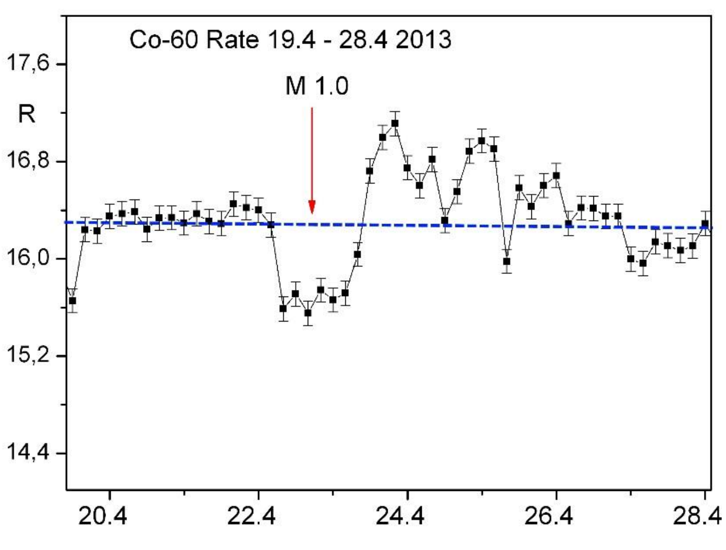


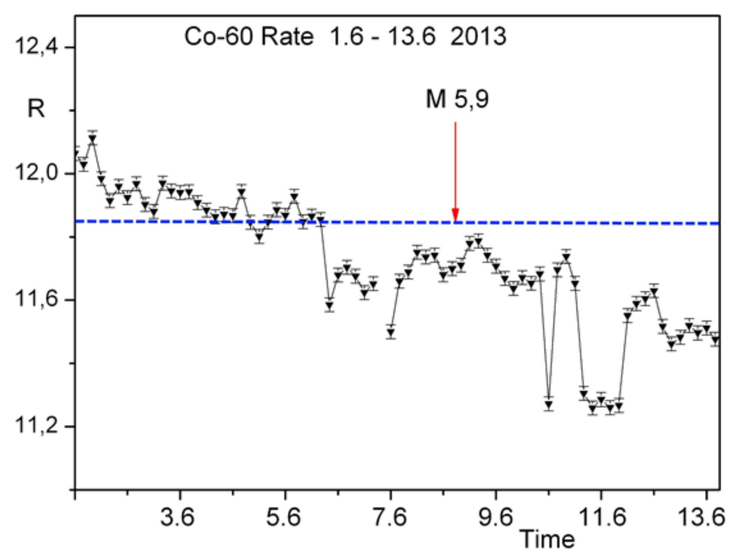
$P = 6.7 * 10^{-34}$

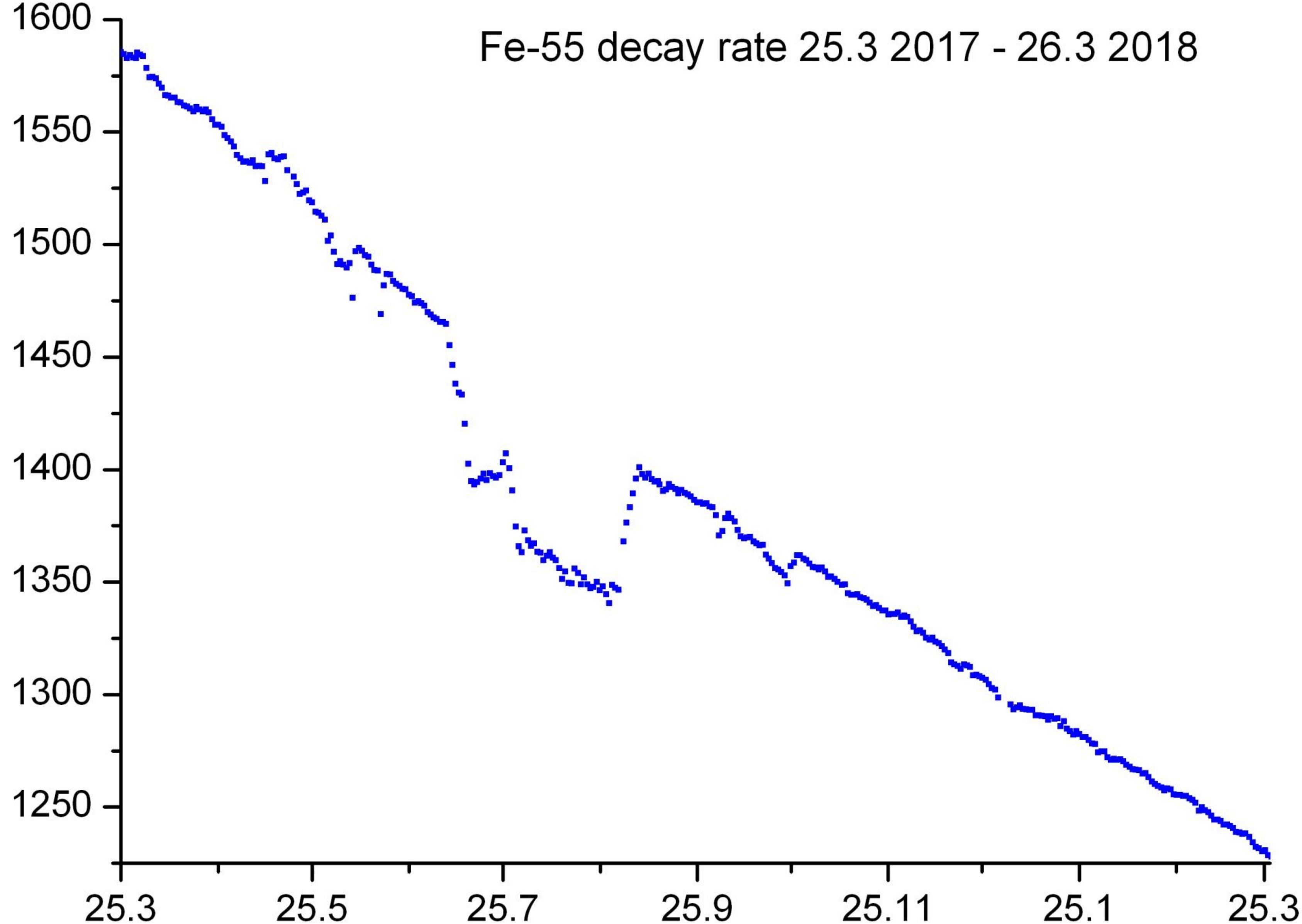


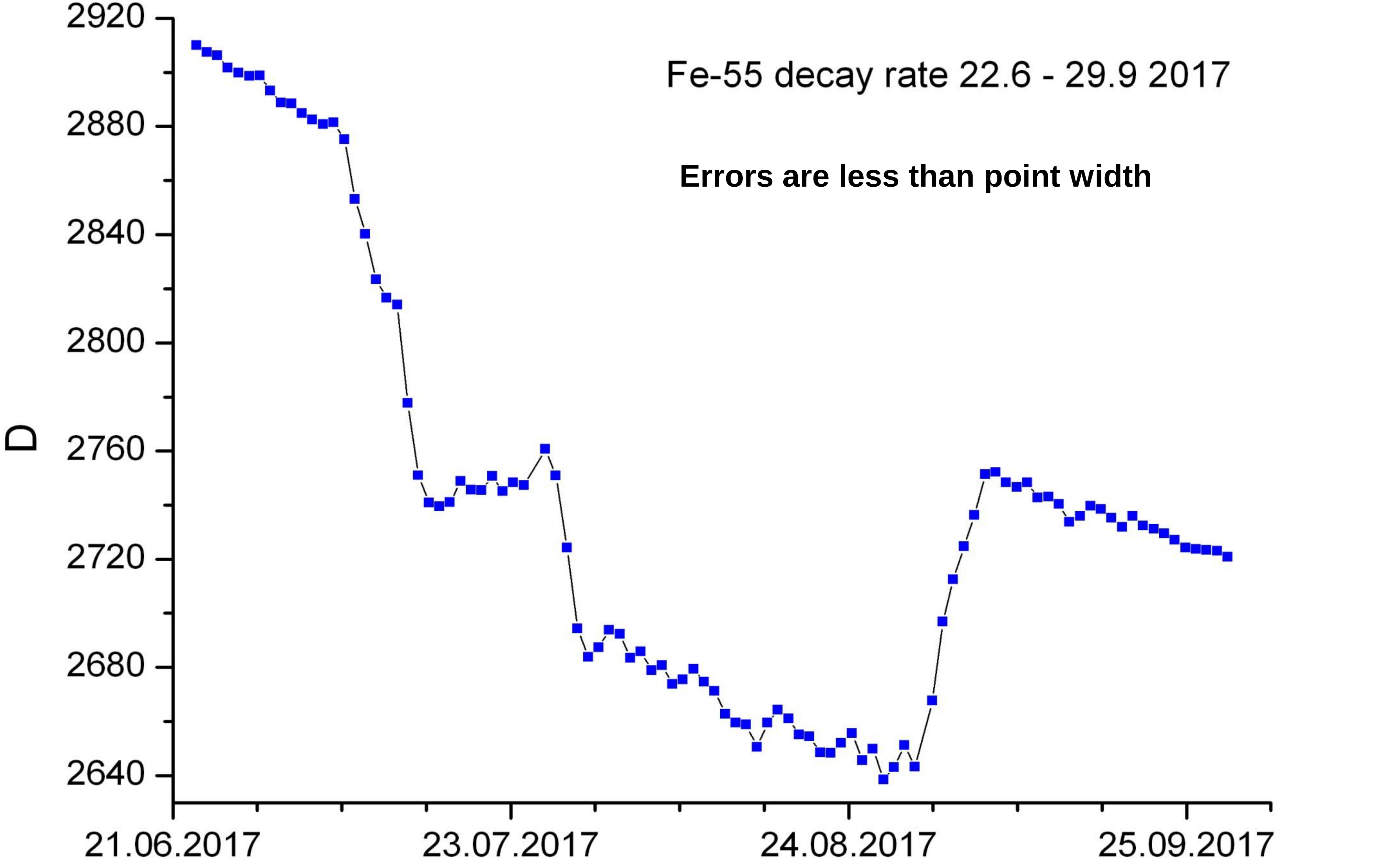

Co-60 Rate 21.11 – 6.12 2016
M 1.2
R
12,2
12,0
11,8
11,6
P=1,7 10^{-47}
23.11
27.11
1.12
5.12
Time

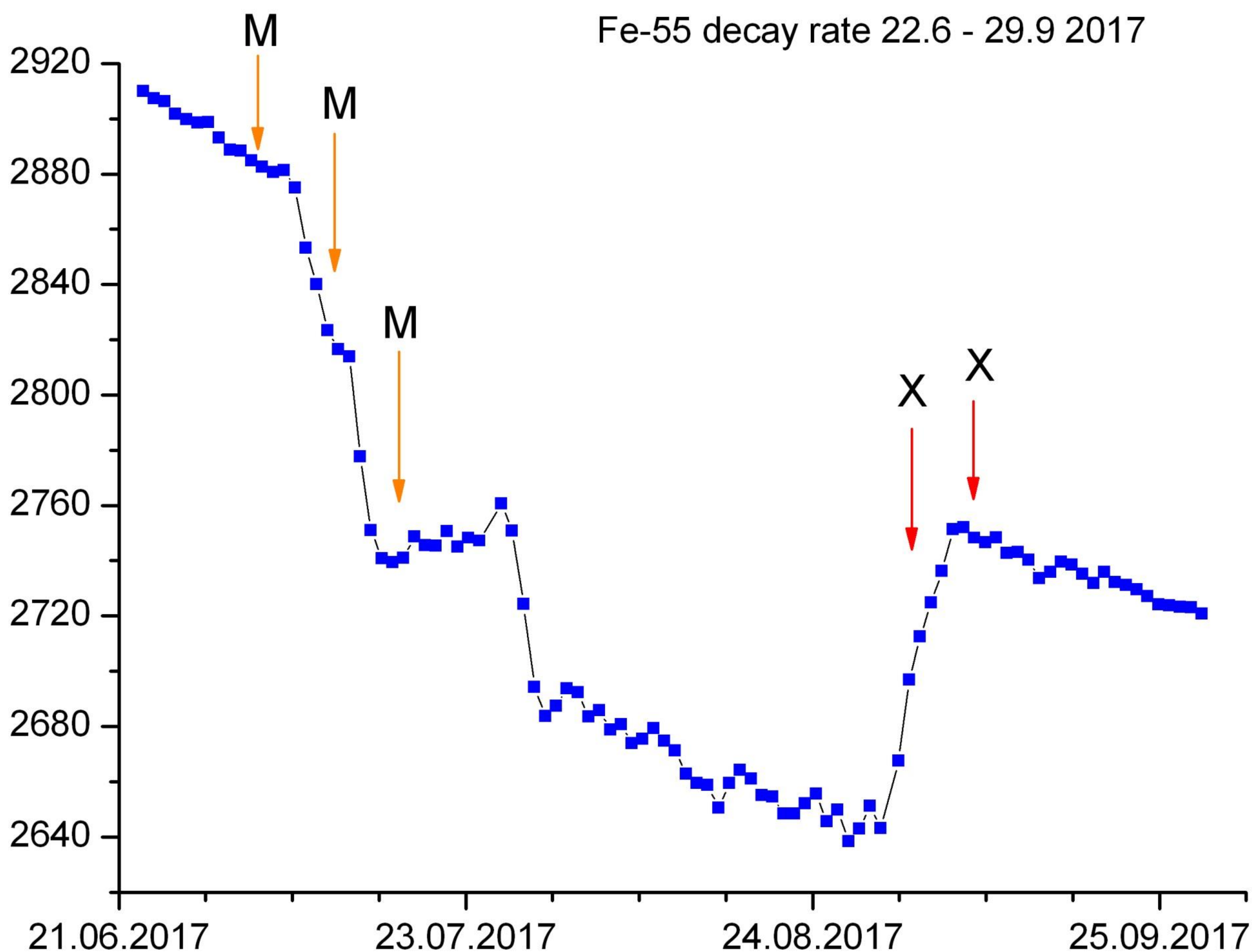

Co-60 Rate
23.11 – 5.12 2012
M 7.2
21,0
20,8
20,6
20,4
20,2
P = 4.7 10^{-29}
25.11
29.11
3.12
Time


Co-60 Rate 19.4 - 28.4 2013
M 1.0
R
17,6
16,8
16,0
15,2
14,4
20.4
22.4
24.4
26.4
28.4

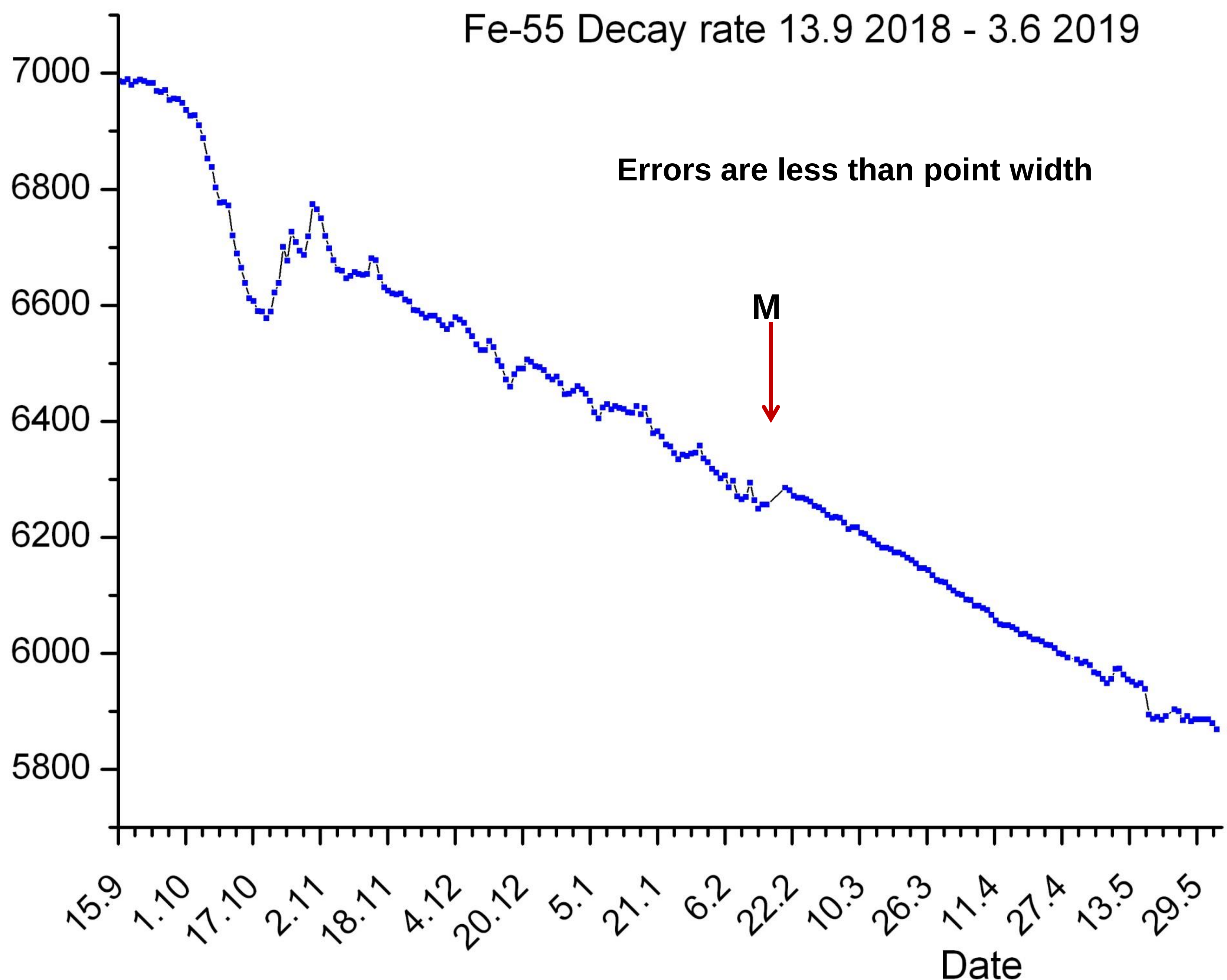

Co-60 Rate 1.6 - 13.6 2013
M 5,9
R
12,4
12,0
11,6
11,2
3.6
5.6
7.6
9.6
11.6
13.6
Time


Fe-55 decay rate 25.3 2017 - 26.3 2018
1600
1550
1500
1450
1400
1350
1300
1250
25.3
25.5
25.7
25.9
25.11
25.1
25.3


Fe-55 decay rate 22.6 - 29.9 2017
Errors are less than point width
D
2920
2880
2840
2800
2760
2720
2680
2640
21.06.2017
23.07.2017
24.08.2017
25.09.2017



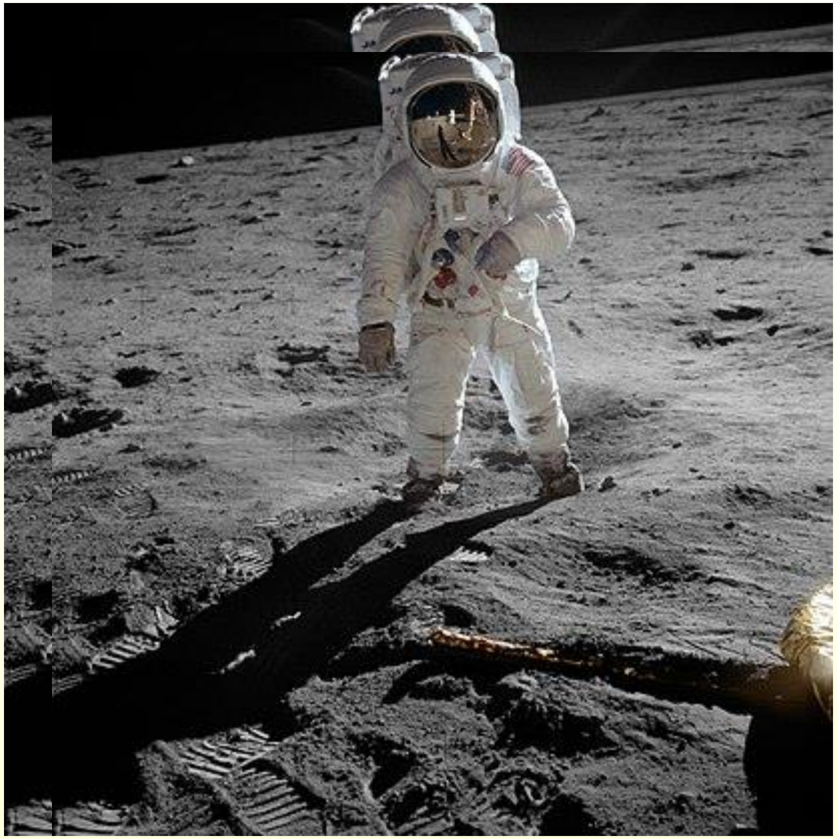
Fe-55 decay rate 22.6 - 29.9 2017
M
M
M
X
X
2920
2880
2840
2800
2760
2720
2680
2640
21.06.2017
23.07.2017
24.08.2017
25.09.2017


Fe-55 Decay rate 13.9 2018 - 3.6 2019
Errors are less than point width
M
7000
6800
6600
6400
6200
6000
5800
15.9
1.10
17.10
2.11
18.11
4.12
20.12
5.1
21.1
6.2
22.2
10.3
26.3
11.4
27.4
13.5
29.5
Date

Solar X-ray activity in form of solar flares and coronal mass ejections and magnetic storms induced by them result in serious damages for satellite equipment, electric and electronic networks

First man on the moon, July 1969,

X- class solar flare can induce lethal radiation dose



It was shown during satellite x-ray monitoring in 1980 - 1994

Solar X-ray activity is essential danger for long term space flight missions to Moon and Mars

On the average, three times per year it occurs Solar flare which radiation is lethal danger for person on Moon surface or in outer space of International space station

Conclusions

1) Multiple experiments on nuclide decay rate measurements

indicate the possible existence of annual and daily variations

at the level about $10^{-3\text{-}4}$

2) Electron capture in Fe- 55 measured by Si detectors and

weak Co-60 decay by Ge detectors

possess high sensitivity to such variations at low background.

3) Measurements performed during 2012 - 2020

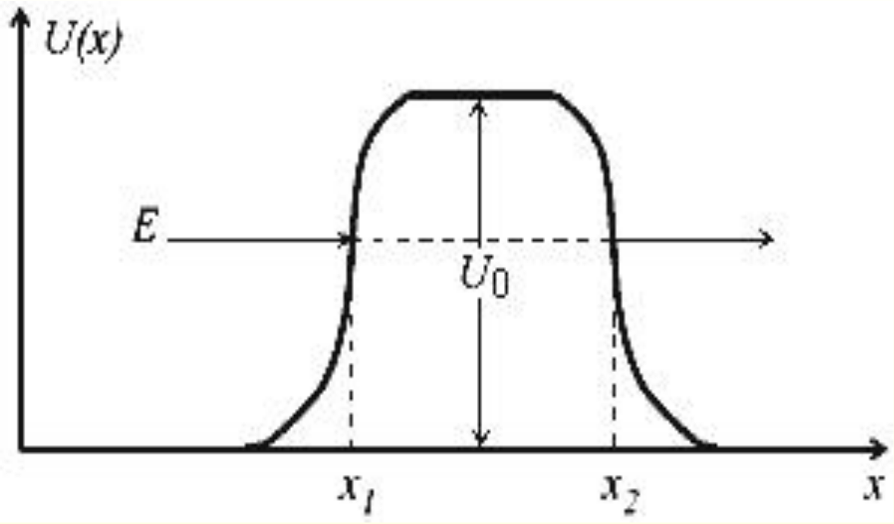
evidence for possible decay rate variation attributed to solar

activity .

Quantum theory of nucleus α-decay

Nucleus α-decay can be described as quantum tunneling of α-particle through the potential barrier constituted by nucleus coulomb potential and nuclear forces on nuclei border

Gamow (1929)



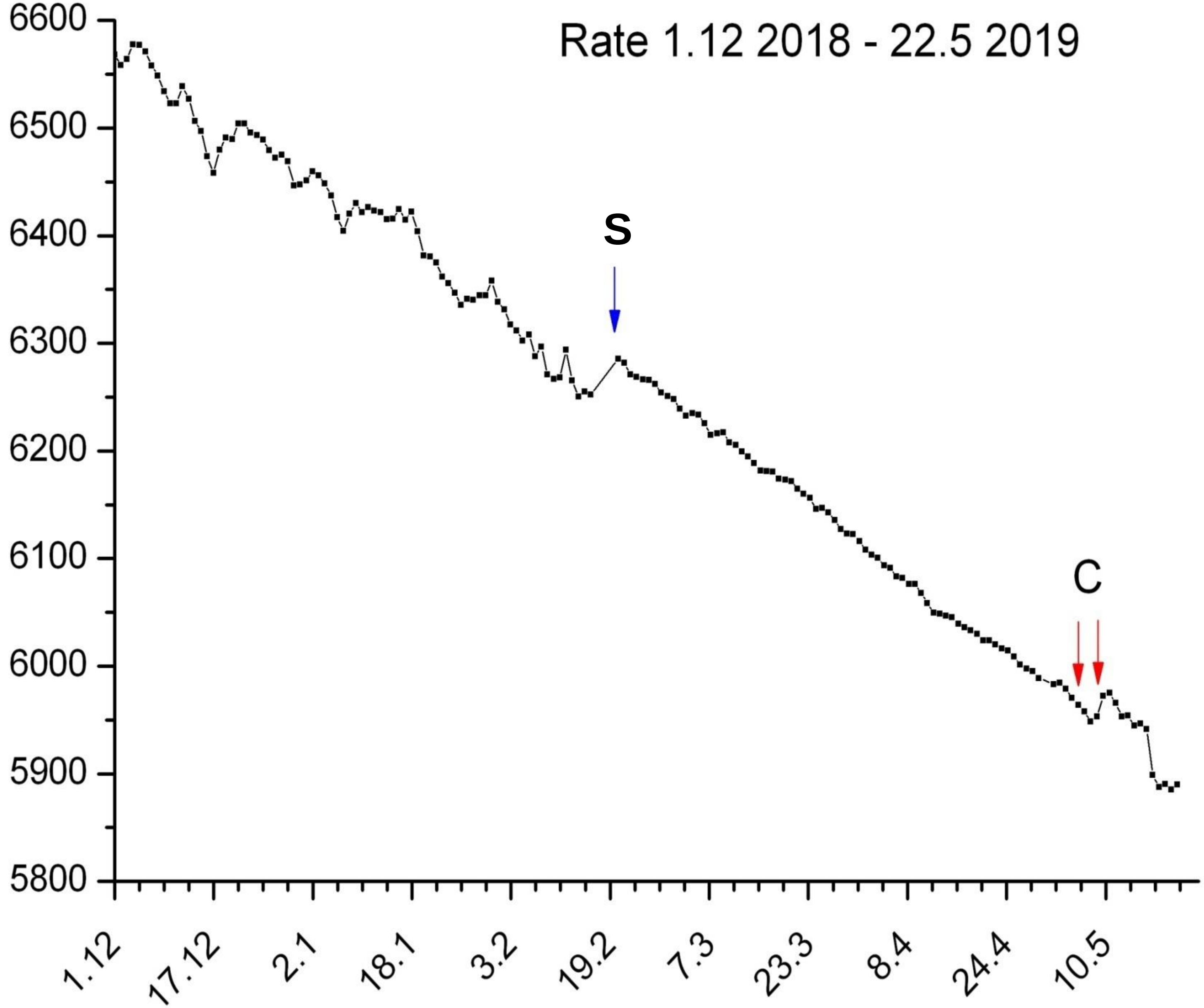
$$E \le U_0$$

particle plane wave spreads from $x = -\infty$

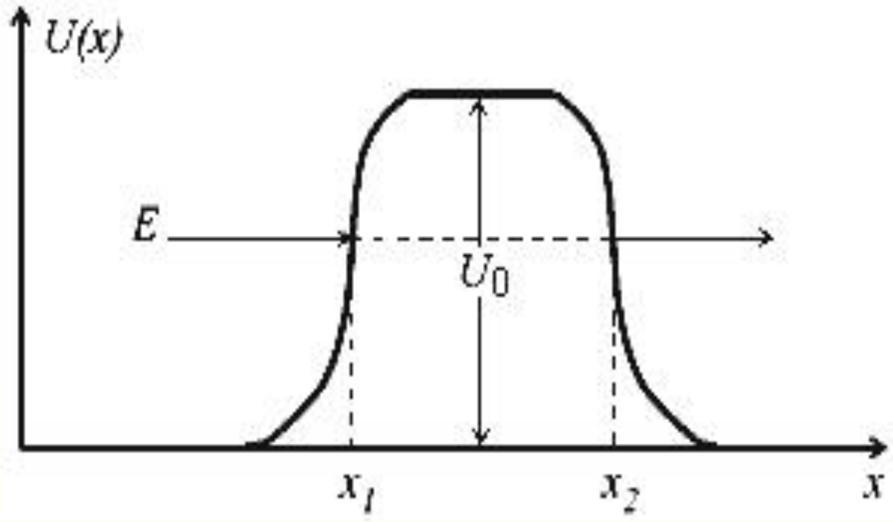
stationary equation

$$i\frac{\partial \psi}{\partial t} = E\psi = -\frac{1}{2m}\nabla^2\psi + U(x)\psi \qquad E = \frac{k^2}{2m}$$

$$-\infty \le x \le x_1 \qquad \psi = \exp(ikx) + A\exp(-ikx)$$


Rate 1.12 2018 - 22.5 2019
S
C
6600
6500
6400
6300
6200
6100
6000
5900
5800
1.12
17.12
2.1
18.1
3.2
19.2
7.3
23.3
8.4
24.4
10.5

1-dimensional particle tunneling through rectangular potential barrier



$$E \le U_0$$

$$E\psi = -\frac{1}{2m}\nabla^2\psi + U_0\psi$$

$$\chi_1 \le \chi \le \chi_2$$

$$\chi_L = \frac{1}{\hbar}[2m(U_0 - E)]^{\frac{1}{2}}$$

$$\psi_0(x) = C\exp[-\chi_L(x - x_1)]$$

$$\psi = \psi_0 + \psi_1$$

$$\psi_1(x) = C_1\exp[\chi_L(x - x_1)]$$

$$|C_1| << |C|$$

$$D \approx \exp[-2\chi_L(x_2 - x_1)]$$

D - transmission coefficient

Gamow theory of nucleus α- decay permits to

calculate nucleus life-time $\tau \sim D^{-1}$,

but it can't explain observed annual and

daily oscillations of Po -214, Po213, Po-212

nucleus life-time

Until now no explanation proposed

Should something be added to quantum formalism

to account Sun gravity influence on life-time ?

Nonlinear Quantum Mechanics

$$i\frac{\partial\psi}{\partial t}=-\frac{1}{2m}\nabla^2\psi+U(\vec{r})\psi$$

- Schroedinger equation *(1928)*

$$\hbar=c=1$$

All fundamental physical theories are nonlinear, quantum mechanics is the only exception. However, there are no arguments, which prove finally and straightforwardly that quantum mechanics must be linear

S. Weinberg

Nonlinear models of quantum mechanics : *Bialanicki- Birula (1976)*
Weinberg (1989)

$$i\frac{\partial\psi}{\partial t}=-\frac{1}{2m}\nabla^2\psi+U(\vec{r})\psi+F(\psi,\overline{\psi})\psi$$

- Nonlinear Schroedinger equation

$F(\psi,\overline{\psi})$ is ψ functional

$$F=k\,|\psi|^2$$

- standard nonlinear Schroedinger equation *(Fermi, 1931)*

Two approaches to Quantum Nonlinearity

i) Nonlinearity is generic and universal for quantum particle dynamics

Bialanicki- Birula (1976)

Weinberg (1989)

Particle free motion described as solitonic or anti-solitonic evolution

ii) Quantum nonlinearity appears only in the particle – field interactions, free particle motion is linear

Kibble (1978)

$$i\frac{\partial\psi}{\partial t} = -\frac{1}{2m}\nabla^2\psi + U(\vec{r})\psi + F(U,\psi,\overline{\psi})\psi$$

Functional *F* depends on *U* field also

High energy nonlinear processes – particle production in gravitaiton field

Kibble (1980), Elze (2008)

Nonlinear Quantum Models

$$i\frac{\partial\psi}{\partial t} = -\frac{1}{2m}\nabla^2\psi + U(\vec{r})\psi + F(U,\psi,\overline{\psi})\psi$$

To find $F(U,\psi,\overline{\psi},)$ existing nonlinear models of universal type should be studied and modified to incorporate interaction with U field consistently

Doebner – Goldin model *(1992)*

$$F(\psi,\overline{\psi}) = \lambda(\nabla^2 + \frac{|\nabla\psi|^2}{|\psi|^2})$$

λ - nonlinearity parameter it can be real or imaginary

This is most popular model of universal type

Properties of Doebner – Goldin model

$$i\frac{\partial\psi}{\partial t} = H_0\psi + F(\psi,\overline{\psi})\psi \qquad F(\psi,\overline{\psi}) = \lambda(\nabla^2 + \frac{|\nabla\psi|^2}{|\psi|^2})$$

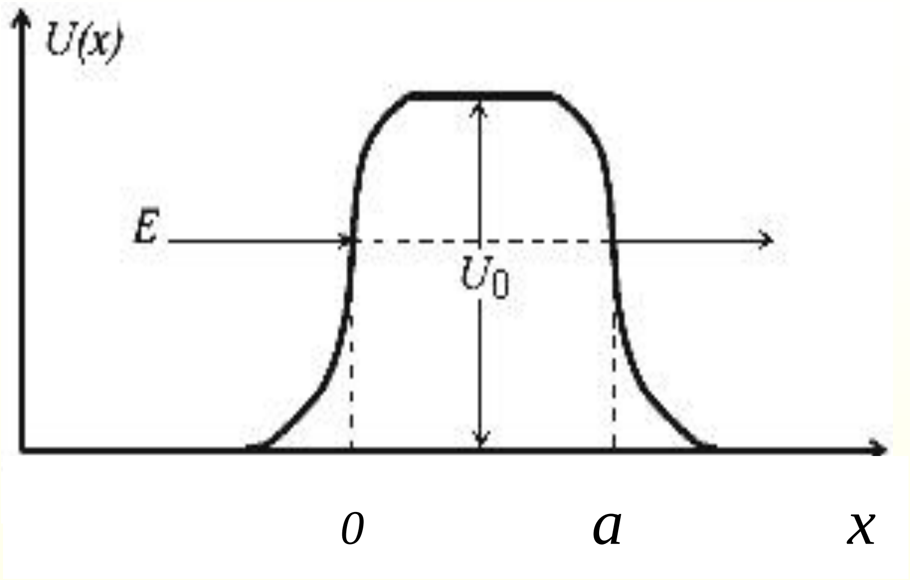
If $\psi_{1,2}$ are solutions, in general $\psi_1+\psi_2$ isn't solution

$<\psi|F|\psi>=0$ $\quad F$ doesn't change particle energy $\overline{E}$

For $U(x)=0$, $\quad \psi = \exp(ikx)$ is solution

Let's consider how F can influence quantum tunneling

Particle tunneling in nonlinear model



For α - decay

$$a \to \infty$$

$$E = \frac{k^2}{2m}$$

We should solve stationary nonlinear equation

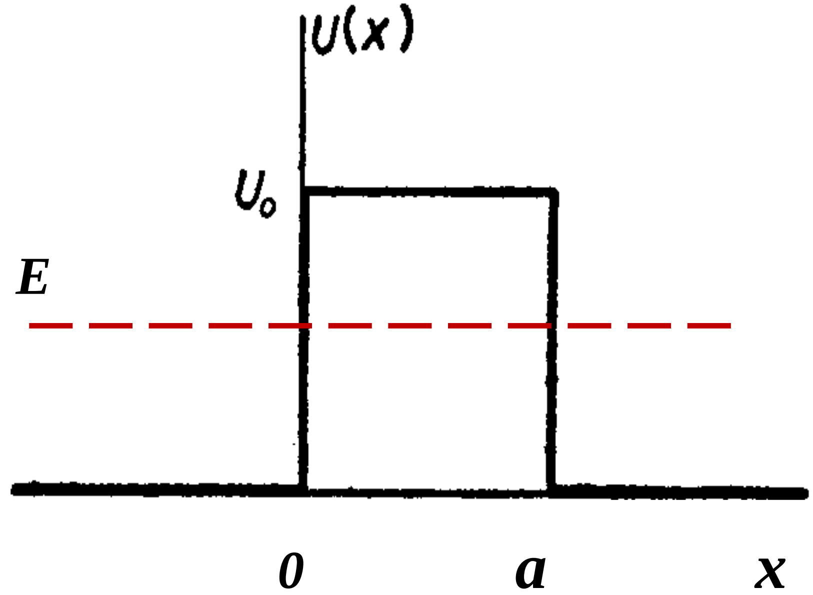
$$E\psi = H_0\psi + F(\psi, \overline{\psi})\psi \qquad F = \lambda(\nabla^2 + \frac{|\nabla\psi|^2}{|\psi|^2})$$

$$E\psi = -(\frac{1}{2m} - \lambda)\nabla^2\psi + \lambda\frac{|\nabla\psi|^2}{|\psi|^2}\psi \qquad -\infty \le x \le 0;$$

$$\psi \approx \exp(ikx) + A\exp(-ikx)$$ For small λ $|A| \to 1$

$E \leq U_0$

$0 \leq x \leq a;$



$$(U_0 - E)\psi = \left(\frac{1}{2m} - \lambda\right)\nabla^2\psi - \lambda\frac{|\nabla\psi|^2}{|\psi|^2}\psi$$

$\psi_0(x) = C_0 \exp(-\chi x)$ - exact solution for main term

$\psi_1(x) = C_1 \exp(\chi x)$ - for secondary term ; $|C_1| << |C_0|$

$$\chi = \sqrt{\frac{2m(U_0 - E)}{1 - 4\lambda m}} \approx \chi_L (1 + 2\lambda m)$$

Tunneling transmission rate

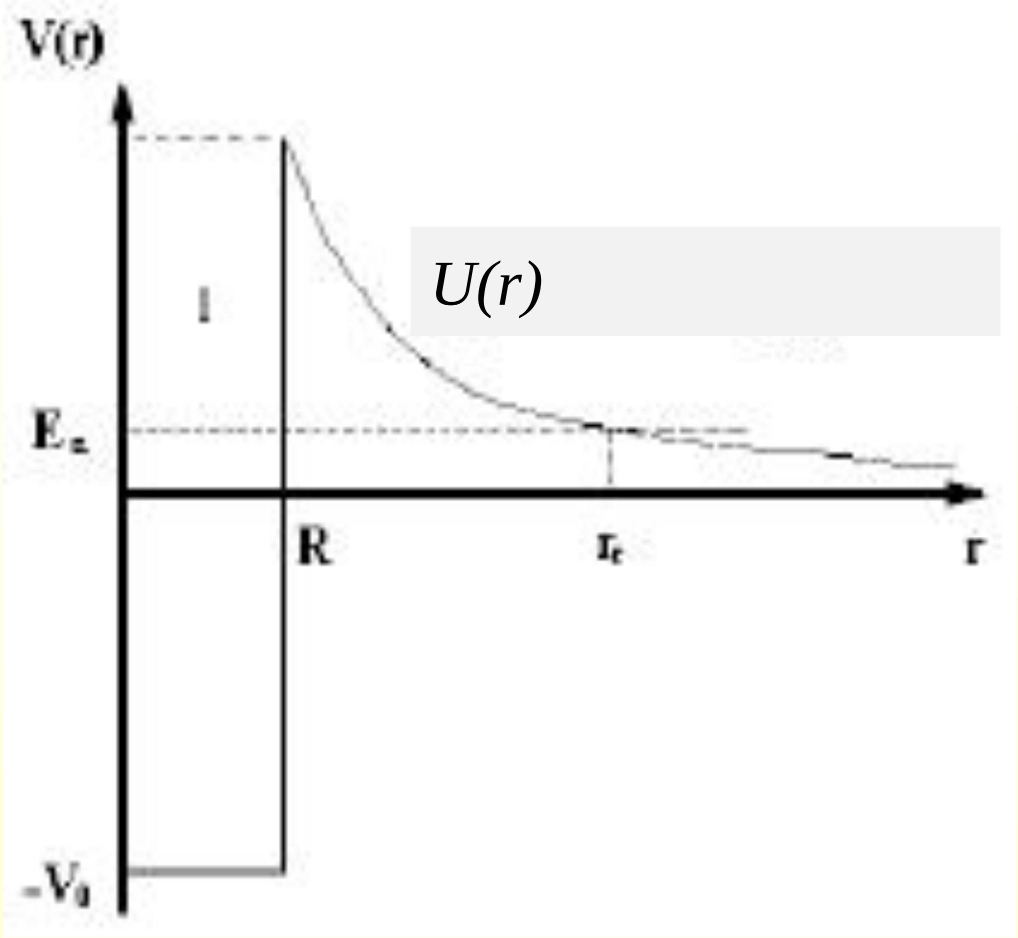
$$D = |C_0|^2 \exp(-2\chi a) \approx D_L \exp(4\chi_L a \cdot m\lambda)$$

$$4\chi_L a \approx 10^2$$ - for nucleus α - decay

$$\chi = \sqrt{\frac{2m(U_0 - E)}{1 - 4\lambda m}} \approx \chi_L (1 + 2\lambda m)$$

as the result D exponentially depends on λ

α- particle tunneling through realistic nucleus potential

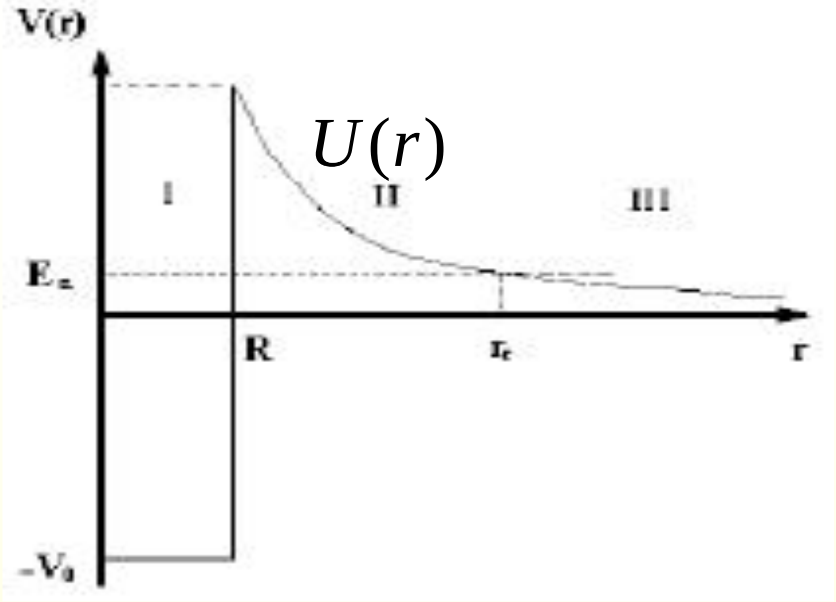


Decay rate calculations – WKB approximation in 3 dimensions

For realistic α – decays, transmission coefficient - $D \approx 10^{-37}$

Transmission coefficient for α- decay in WKB approximation for 3-dimensional model

$$\vec{r} \rightarrow r$$



$$\psi \approx e^{i\alpha(r)}$$

$$[U(x)-E]\psi = (\frac{1}{2m}-\lambda)\nabla^2\psi - \lambda\frac{|\nabla\psi|^2}{|\psi|^2}\psi$$

$$U(x)-E \approx (\frac{1}{2m}-2\lambda)(\frac{\partial\alpha}{\partial x})^2$$

$$D = C\exp[-2\int\alpha(x)dx] \qquad \alpha = \sqrt{\frac{2m[U(x)-E]}{1-4\lambda m}}$$

Nonlinear effects for external field

$$i\frac{\partial\psi}{\partial t} = -\frac{1}{2m}\nabla^2\psi + (U + mV)\psi + F(V,\psi,\overline{\psi})\psi$$

$V(\vec{r},t)$ - gravitation field

$F = \lambda(\nabla^2 + \frac{|\nabla\psi|^2}{|\psi|^2})$ - Doebner – Goldin ansatz

$\lambda = f(V)$ - field dependence of nonlinear term

$f \to 0$ for $V \to 0$

$$\chi = \sqrt{\frac{2m(U_0 - E)}{1 - 4\lambda m}} \approx \chi_L(1 + 2\lambda m) \qquad \lambda = f(V)$$

$$D = |C_0|^2 \exp(-2\chi a) \approx D_L \exp(4\chi_L m\lambda a)$$

Comparison with α – decay experimental results

$V(\vec{x},t)$ - gravitation potential, $V \sim V + c$

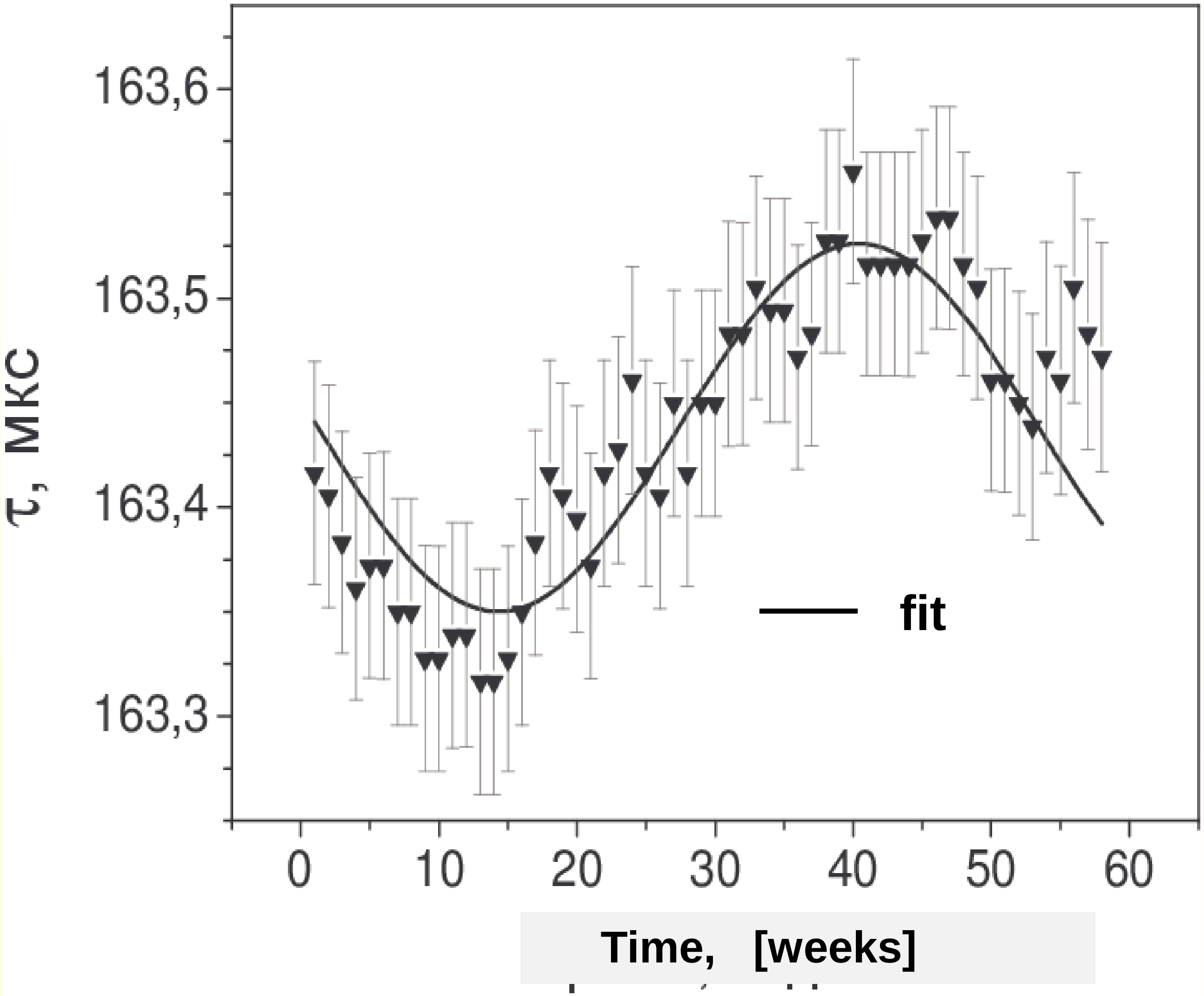
Hence $\lambda = f(V)$ or $\lambda = f(\frac{\partial V}{\partial t}, \frac{\partial V}{\partial \vec{x}}, \ldots)$

Earth orbit is elliptic, so V isn't constant,

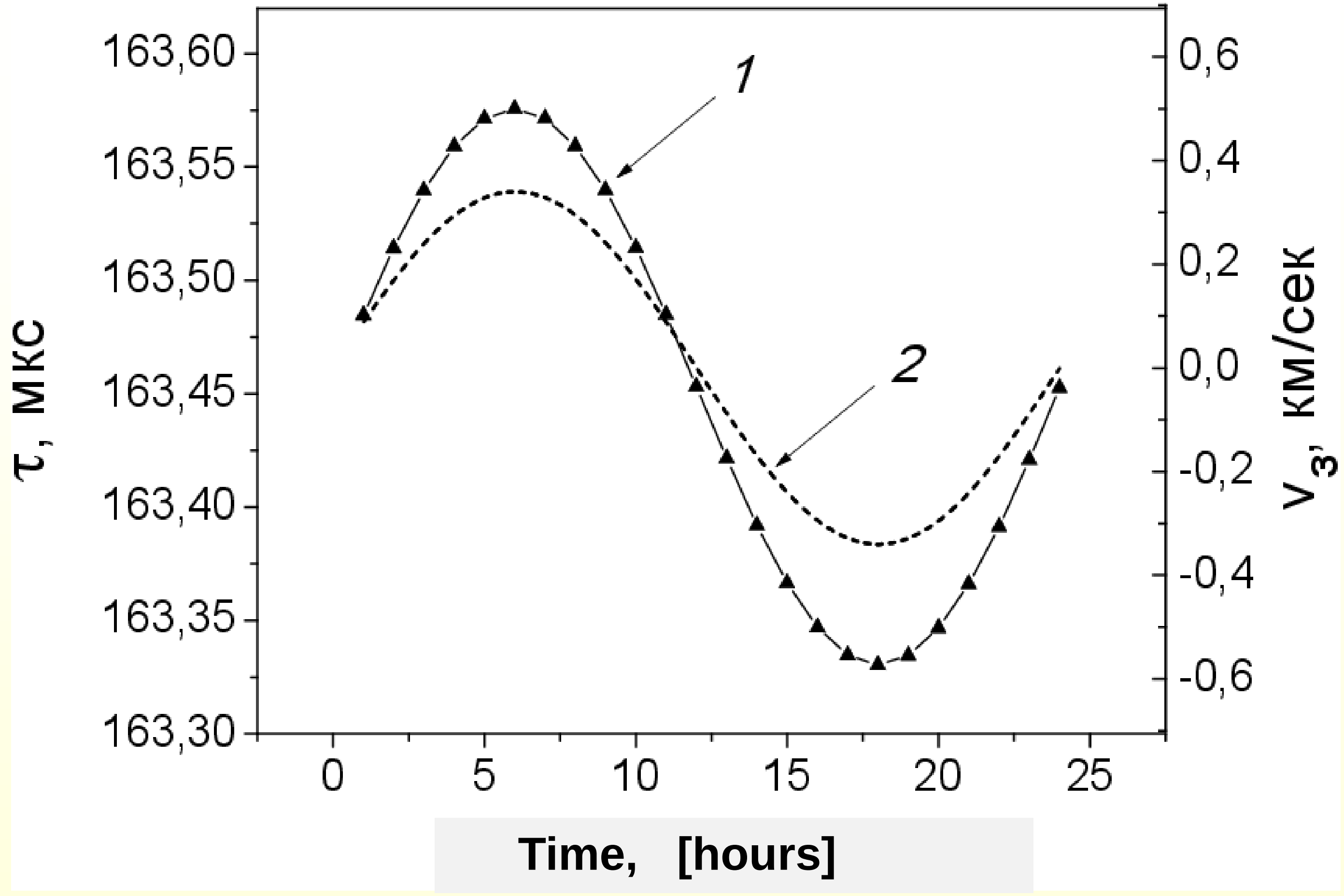
We try to find λ dependence from fitting Po-214 data

Annual V variation : 3% per halve-year ~ .02 % per day

Daily V variation : .01% per 12 hours ~ .02 % per day α– decay life-time annual variation results has best fit: $\lambda = \kappa \dfrac{\partial V}{\partial t}$



α – decay life-time daily variation results versus annual best fit



1 - experimental result

2 – annual parameter fit : $\lambda = \kappa \dfrac{\partial V}{\partial t}$

α – decay life-time variations and nonlinearity parameter

One should find k for data fit : $\lambda = \kappa \frac{\partial V}{\partial t}$

and annual decay variation : $A=(9.8 \pm 0.6)\cdot 10^{-4}$

maximal annual value of $\frac{\partial V}{\partial t} = 1.6 \frac{M^2}{\sec^3}$

it gives: $\kappa = .4 \cdot 10^{-9} \frac{\sec^3}{MeV \cdot M^2}$

It supposes that gravity influence on nucleus can't be reduced just

to standard potential ***V*** action, it should include additional

nonlinear term $\kappa \frac{\partial V}{\partial t}$

Gravity as nonlocal field theory, induced gravity and causality

Classical gravity is emergent theory, i.e. is asymptotic limit of some nonlocal field theory *(Saharov, 1967; Maldacena 1997)*

Nonlocal fields - string theory, AdS+ Holography ,multilocal field, etc., problem – not to violate causality

$\{\Phi_1, \Phi_2, \ldots, \Phi_n\}$ **-** multilocal field $\Phi_j = F(x_1, \ldots, x_j)$

multilocal field is plausible description of such field,

bilocal field is its simplest approximation

Bilocal nonlinear model and influence of Sun activity on decay rates

Sun activity accompanied by significant gas motion

near its surface, so Sun gravity can be variable,

in particular, Sun radiate gravitational waves *(Gibson, 1971)*

$$\lambda = \kappa \frac{\partial V}{\partial t}$$

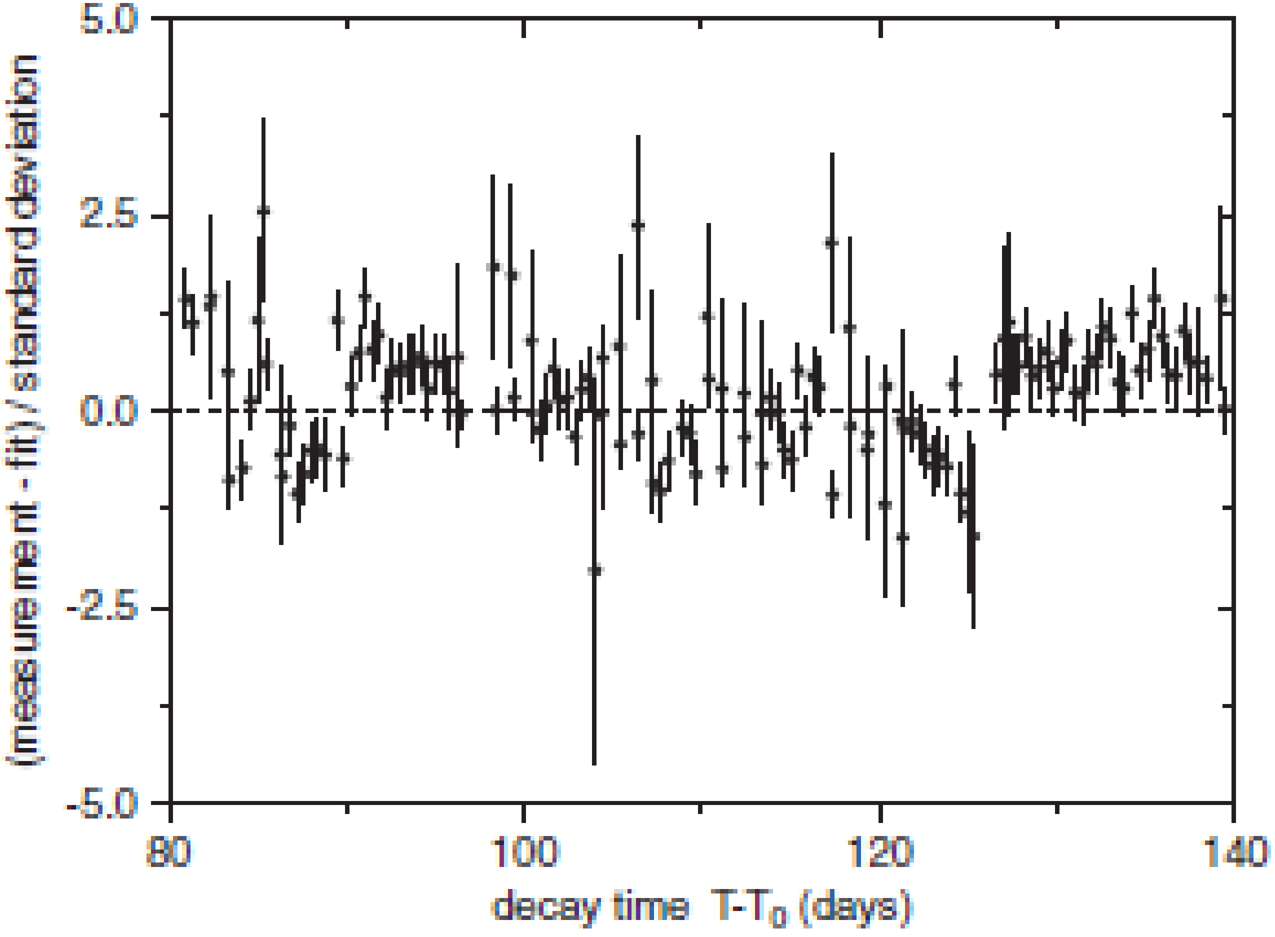


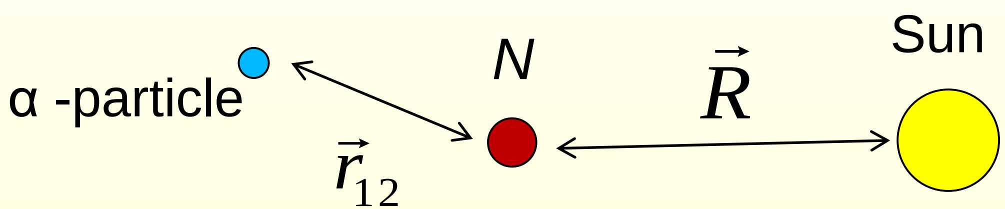
Fig. 2. Residuals from the fit of an exponential decay curve to the data for

α – decay microscopic nonlinear model

$$i\frac{\partial \psi}{\partial t} = -\frac{1}{2m}\nabla^2\psi + U\psi + F(\partial V_t, \psi, \overline{\psi})\psi$$

$\psi(\vec{r}_{12})$ **-** nucleus internal wave function

$\vec{r}_{12} = \vec{R} - \vec{r};$ $\vec{r}, \vec{R}:$ *α* -particle and nucleus centre coordinates relative to Sun centre



$$F = f(\partial V_t)(\nabla^2 + \frac{|\nabla\psi|^2}{|\psi|^2})$$

$$\nabla = \frac{\partial}{\partial \vec{r}_{12}}$$

Gravity derived in bilocal field model *(Diaz, 2017)*

$\Phi_2(x,y)$ **-** scalar bilocal field, it was shown that

it reproduces Einstein gravity in second order

$$g_{\mu\nu}(x) \approx k \frac{\partial^2 \Phi_2(x,y)}{\partial x_\mu \partial y_\nu} + \ldots \quad x \to y$$

$\Phi_2(\vec{r}_1, \vec{r}_2, t) \neq f_1(\vec{r}_1, t) f_2(\vec{r}_2, t)$ **-** nonrelativistic bilocal field

$$\Phi_2(\vec{r}_1, \vec{r}_2) \to \Phi_2(\vec{R}_C, \vec{r}_{12}) \qquad \vec{r}_{12} = \vec{r}_1 - \vec{r}_2$$

Bilocal field model and nucleus decay

Let's suppose that in infrared limit gravity contains two

components $\{\Phi_1, \Phi_2\}$:

$$\Phi_1(x) = g_{\mu\nu}(x)$$ - classical gravity

Φ_2 **-** bilocal field can interact with bilocal matter field operators,

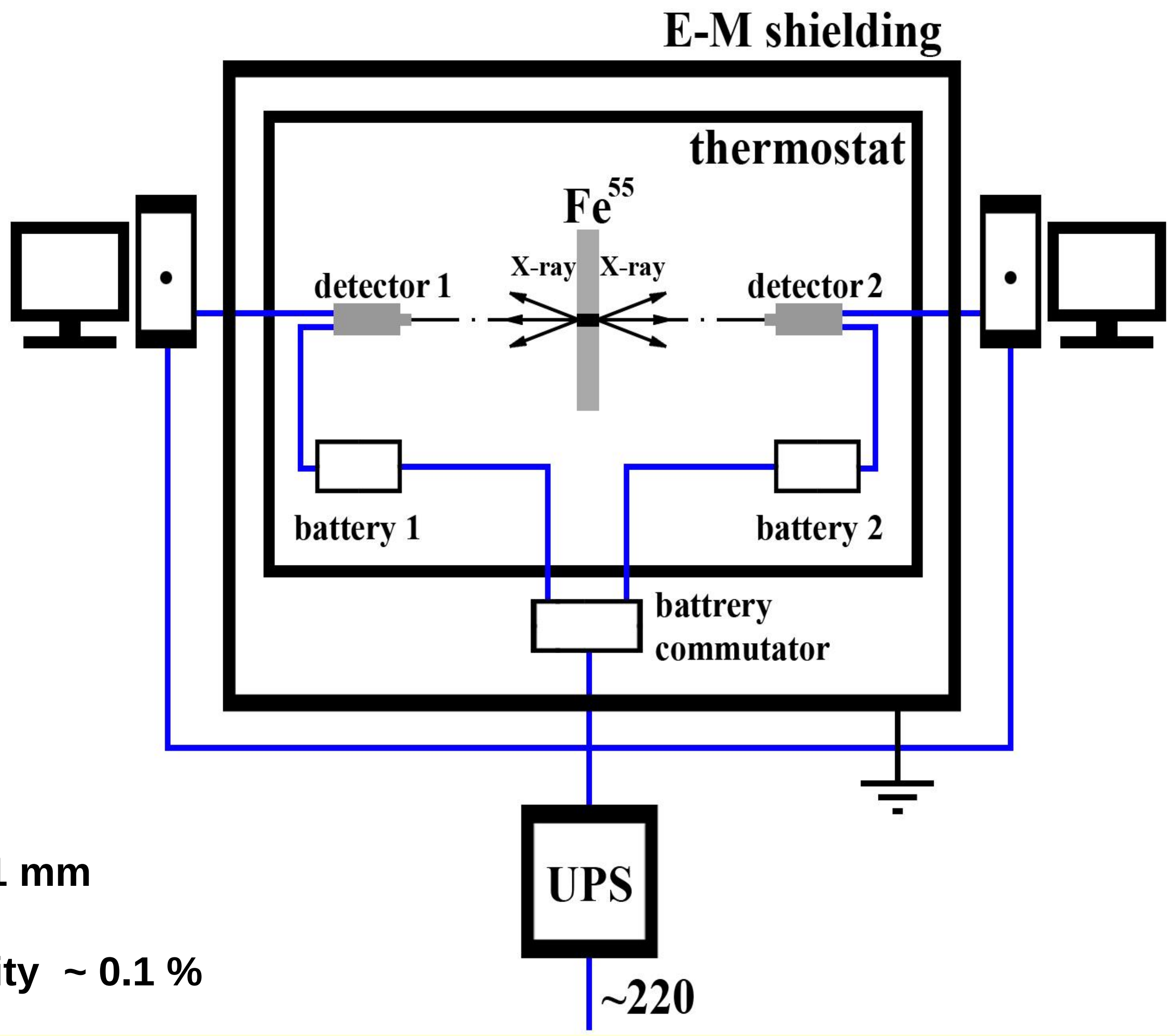
in particular, it can act on bilocal system observables ~ $\vec{r}_{12}$

$$\nabla = \frac{\partial}{\partial \vec{r}_{12}} \qquad F = \Phi_2(\vec{r}_1, \vec{r}_2)(\nabla^2 + \frac{|\nabla \psi|^2}{|\psi|^2})$$

from Po α – decay experiment : $\Phi_2 \approx \partial_t V(\vec{R})$

$\vec{r}_{12}, \quad \frac{\partial}{\partial \vec{r}_{12}}$ don't violate causality at any distance

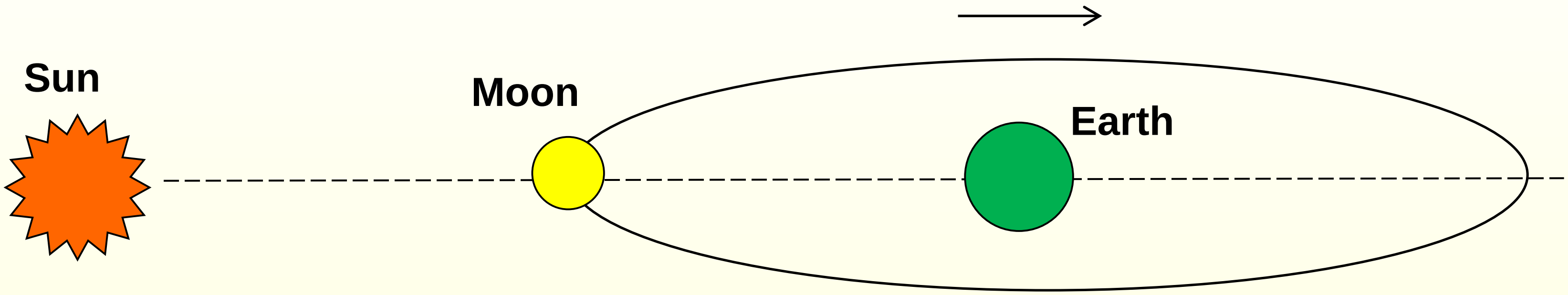
Decay Oscillation Study Project

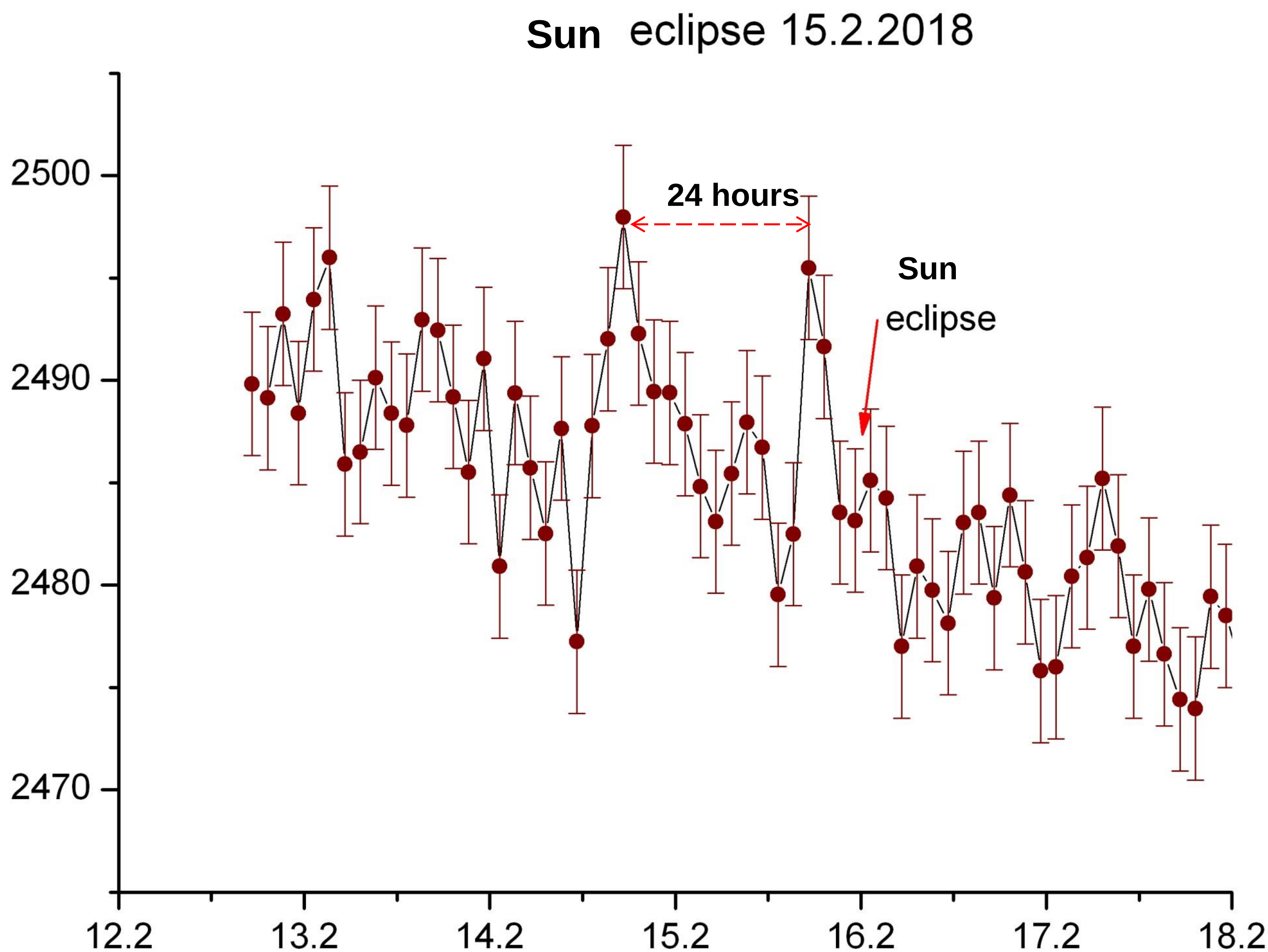


Vacuum ~ .01 mm

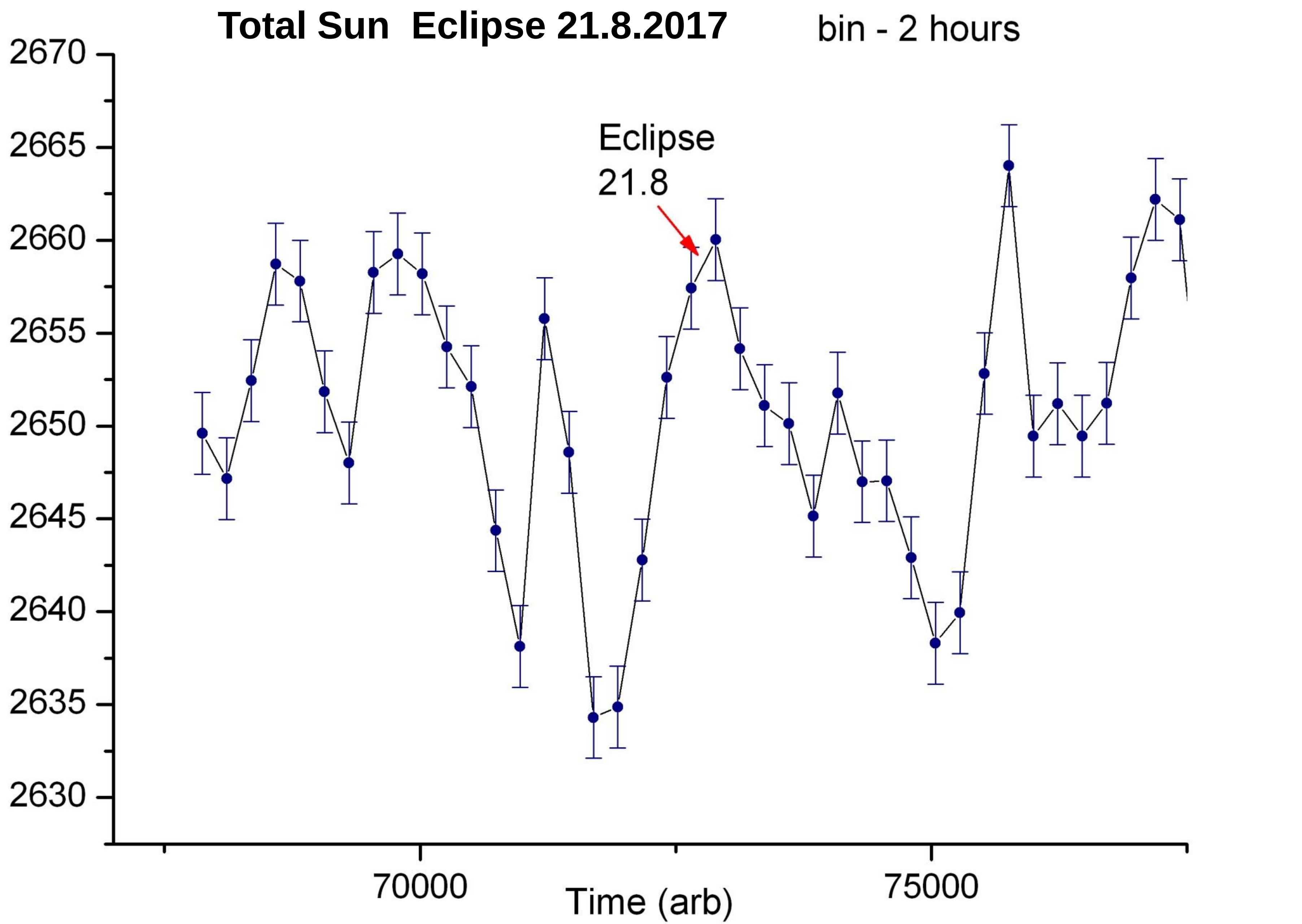
Thermostability ~ 0.1 %

Maximal new Moon is Sun eclipse





Sun eclipse 15.2.2018
24 hours
Sun
eclipse
2500
2490
2480
2470
12.2
13.2
14.2
15.2
16.2
17.2
18.2


Total Sun Eclipse 21.8.2017
bin - 2 hours
Eclipse
21.8
2670
2665
2660
2655
2650
2645
2640
2635
2630
70000
75000
Time (arb)

Nonlinear Field Theory and Nonlinear Quantum Mechanics

Born (*1946)*
Heisenberg *(1948)*

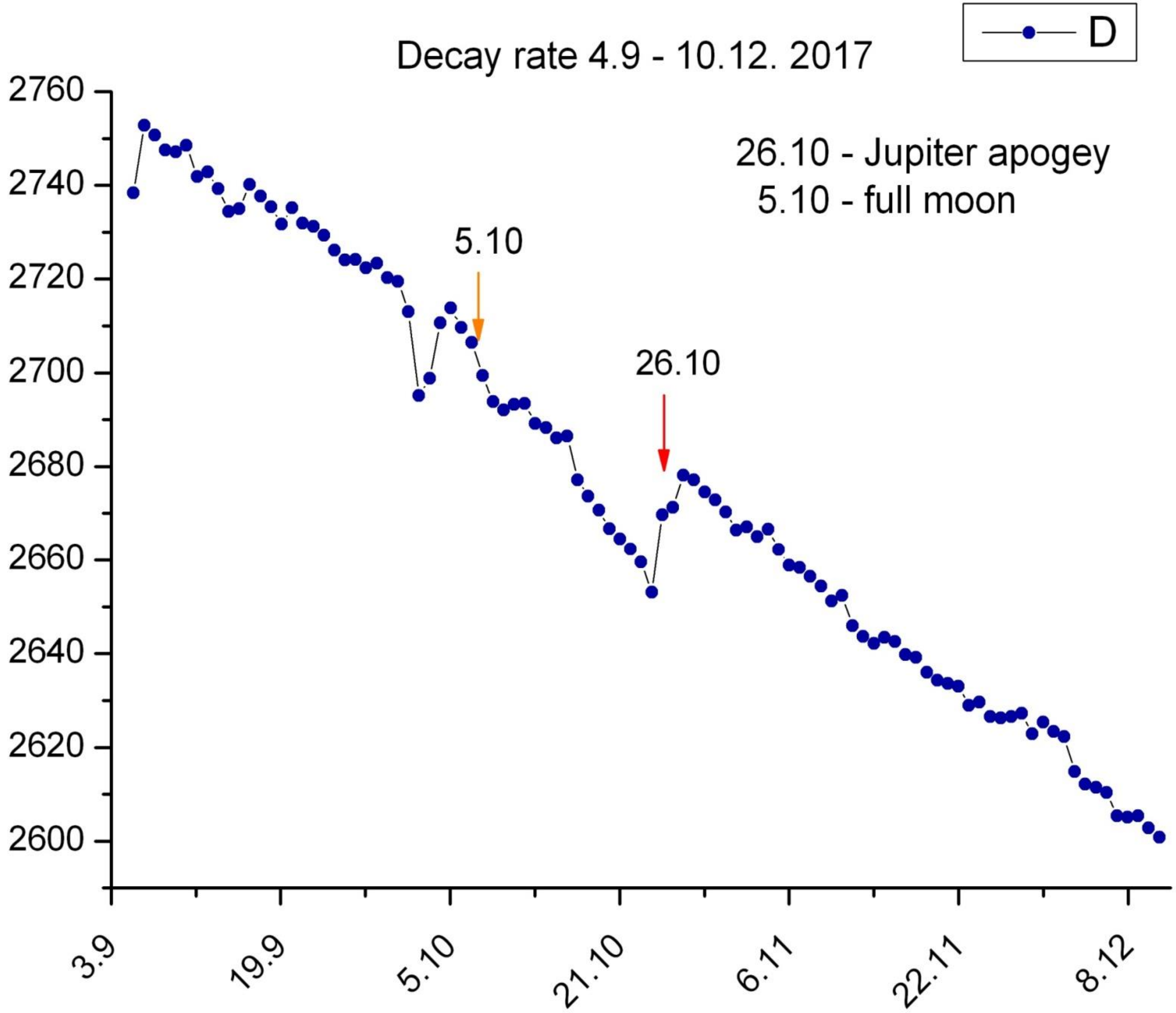
Linearity of Quantum theory is just the hypothesis, and not the axiom
Heisenberg (1949)

Its low energy limit is nonlinear Quantum mechanics

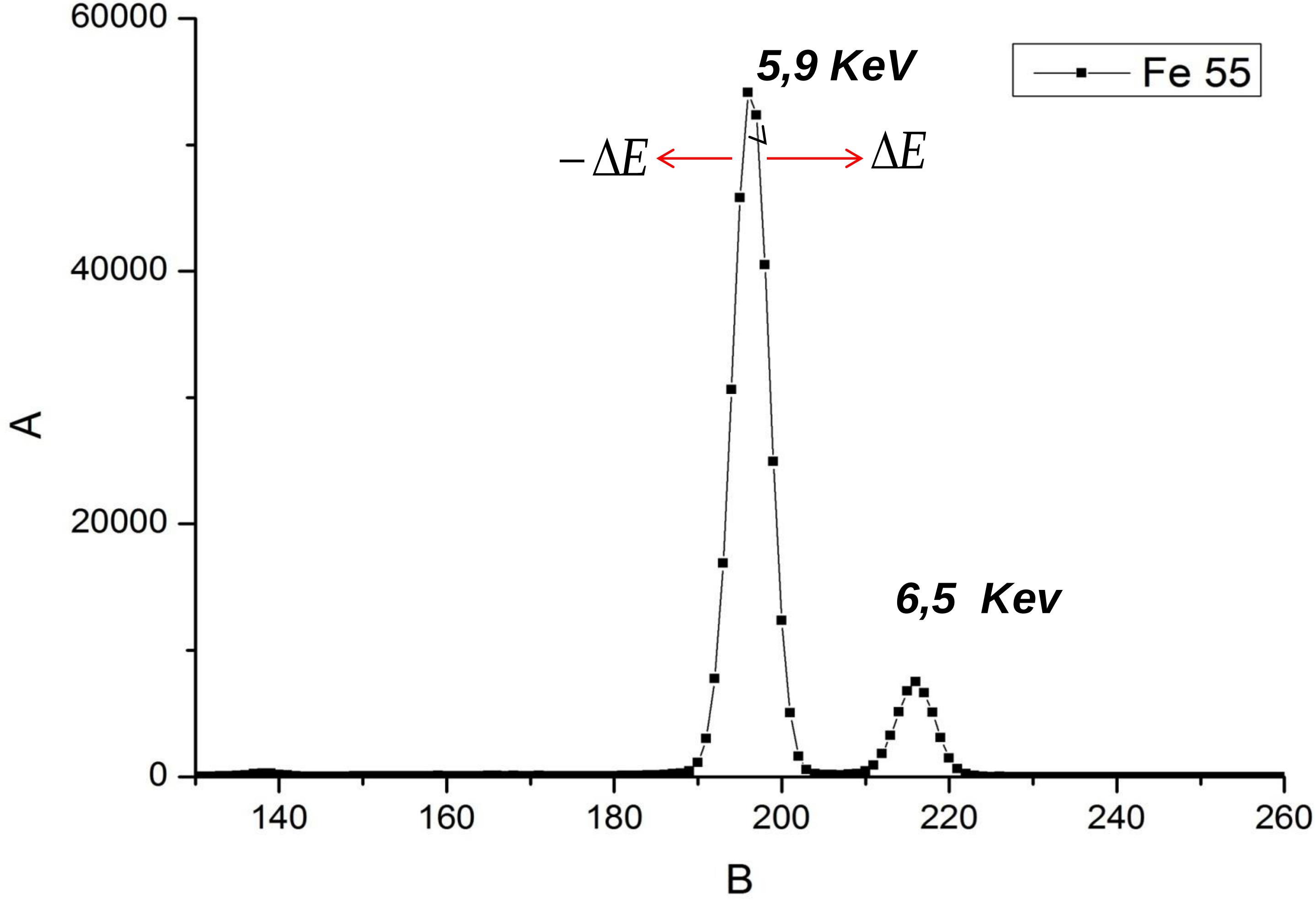
Experimental tests:

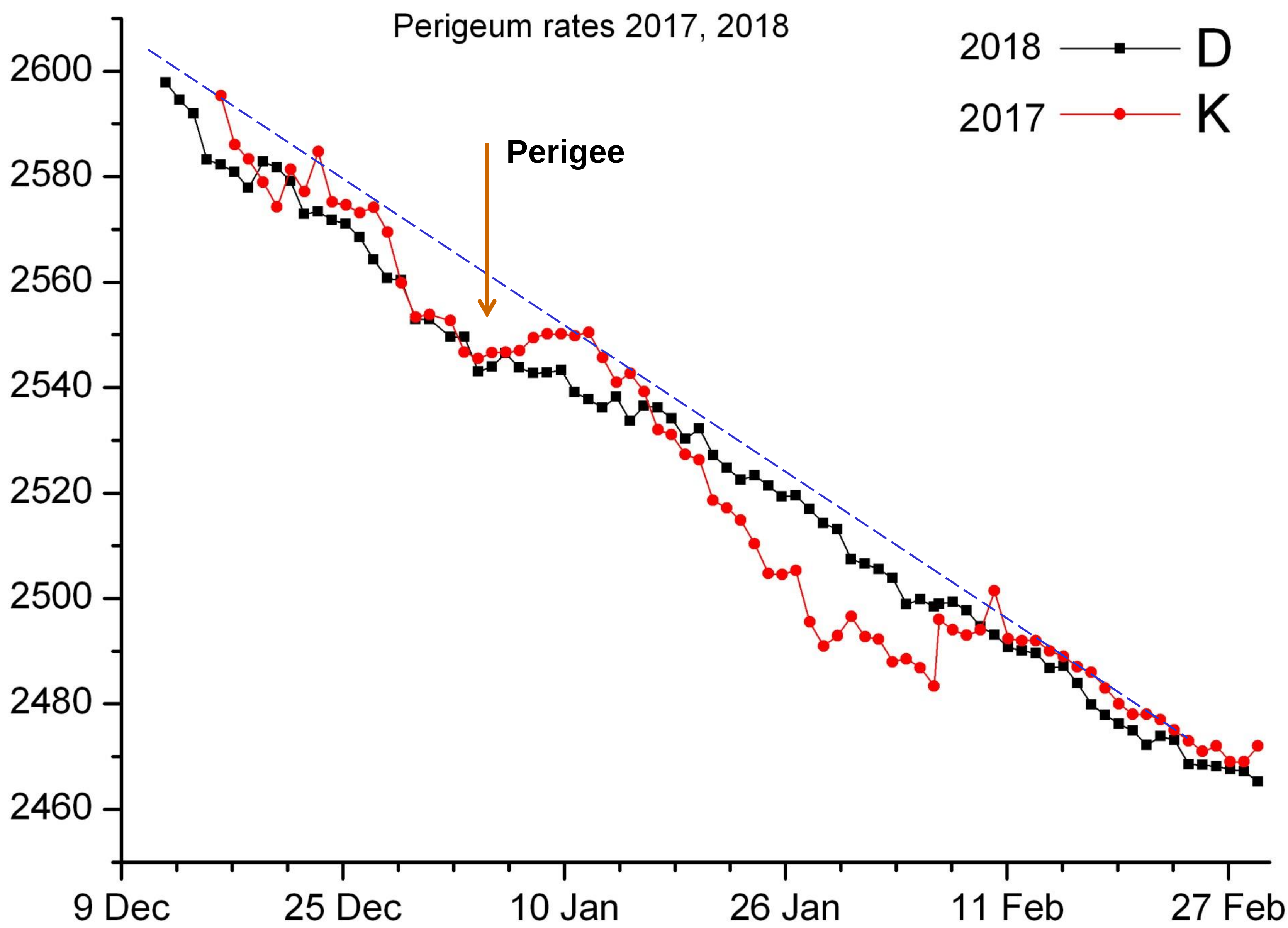
neutron interferometry (1981)

optical level shift in atoms and ions (1990)


D
Decay rate 4.9 - 10.12. 2017
26.10 - Jupiter apogey
5.10 - full moon
5.10
26.10
2760
2740
2720
2700
2680
2660
2640
2620
2600
3.9
19.9
5.10
21.10
6.11
22.11
8.12

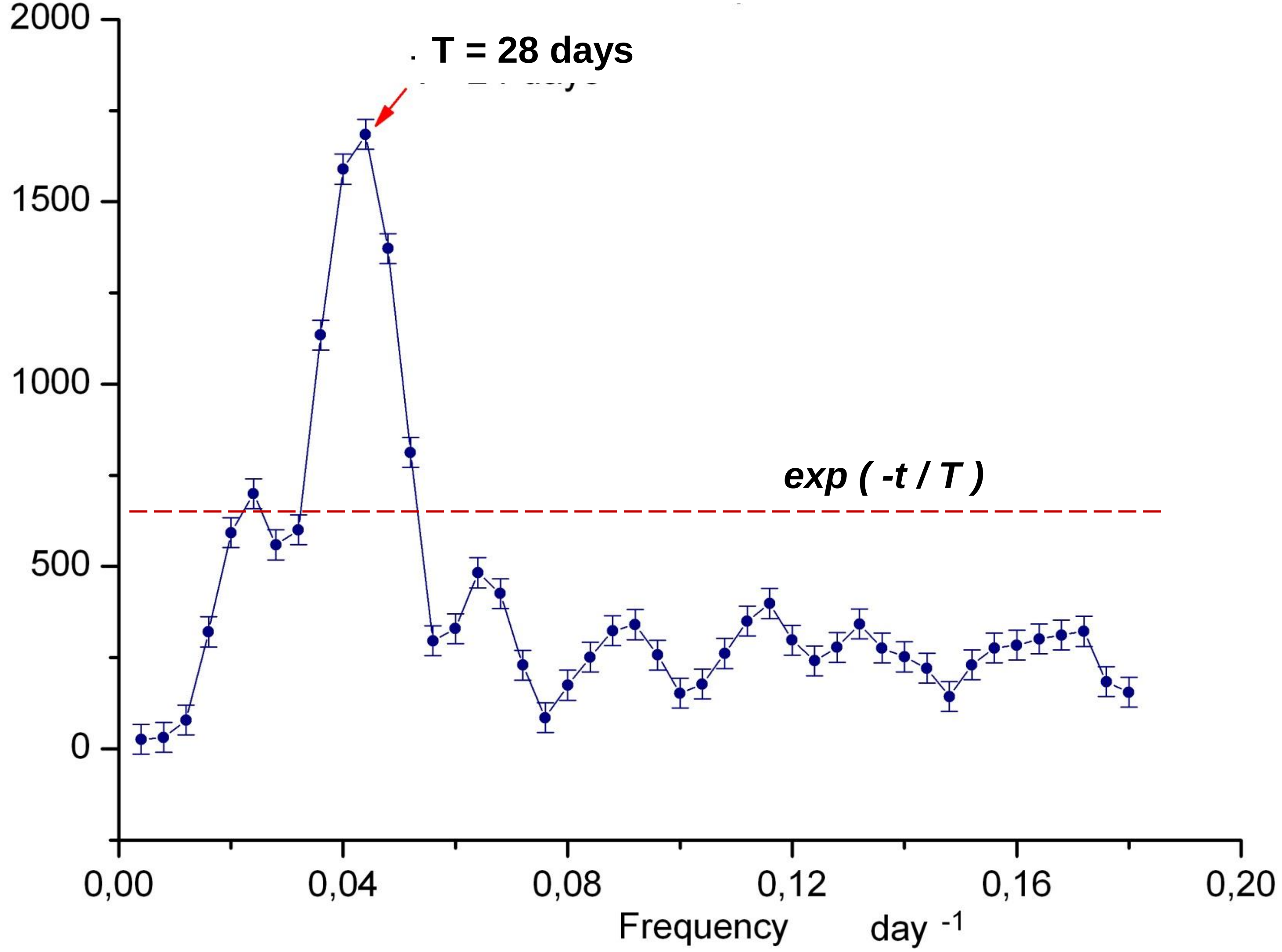
Si-Pin detector stability control performed via measurement of Fe-55 X-ray amplitude peak position



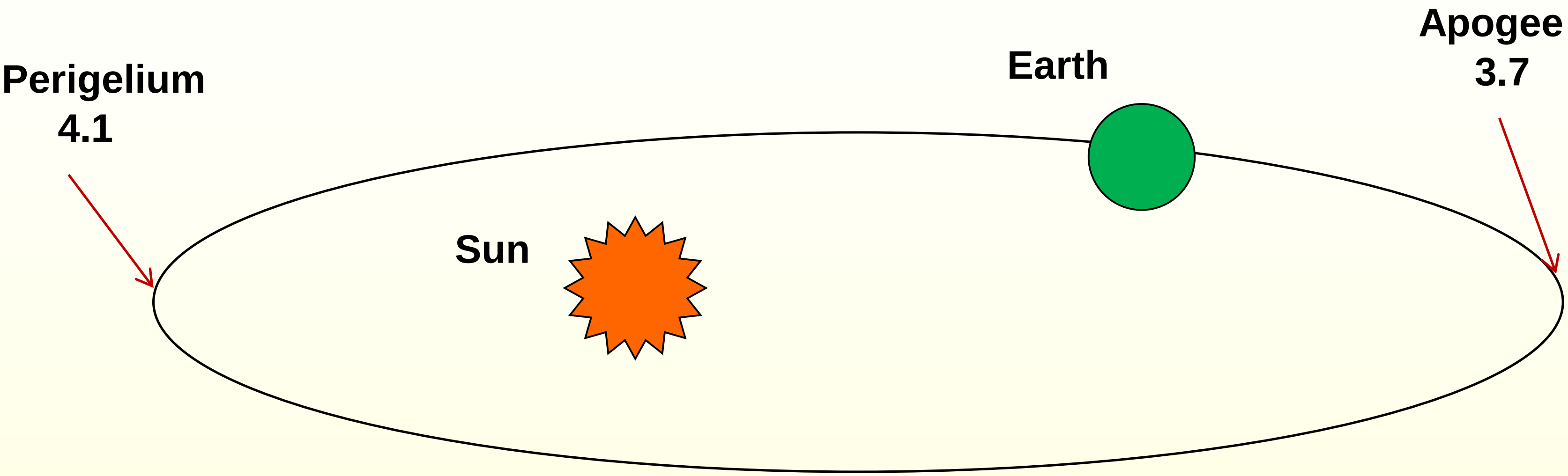


Perigeum rates 2017, 2018
2018 D
2017 K
Perigee
2600
2580
2560
2540
2520
2500
2480
2460
9 Dec
25 Dec
10 Jan
26 Jan
11 Feb
27 Feb

Fourier spectrum 8.3.2017 – 19.12.2017

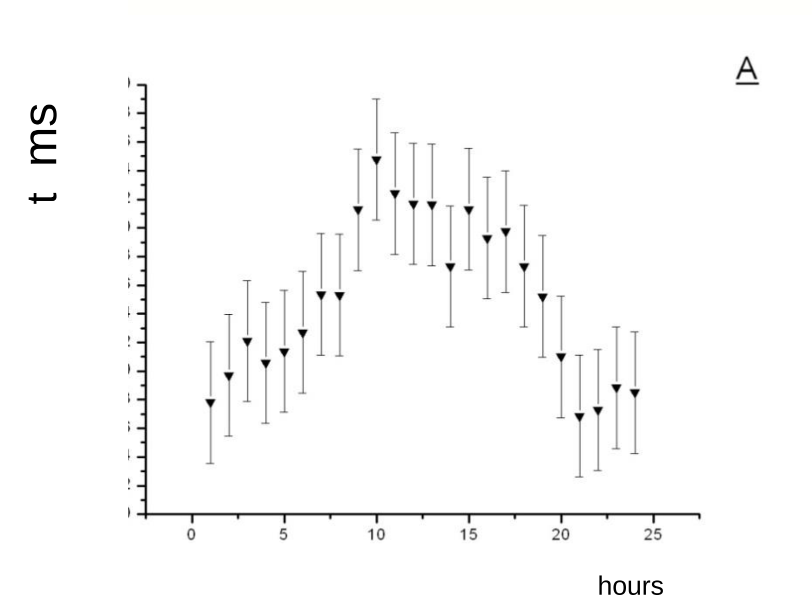


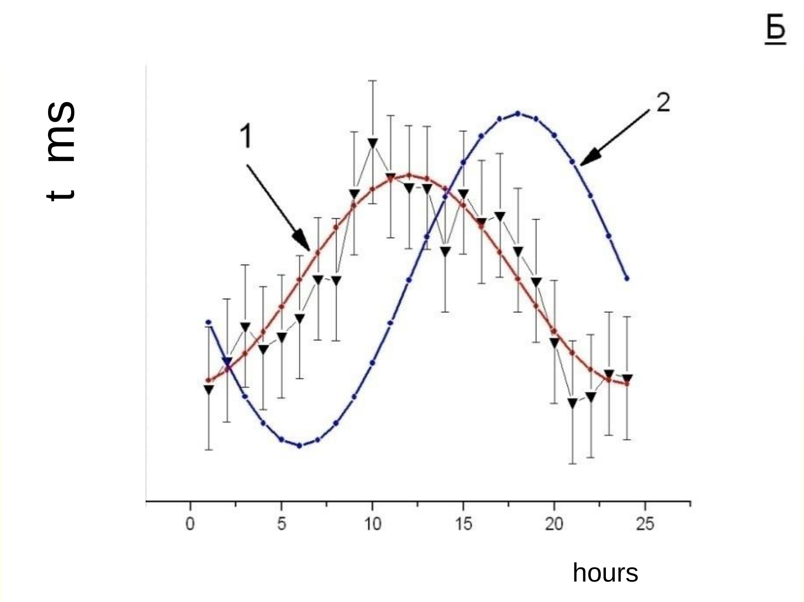
Earth annual motion



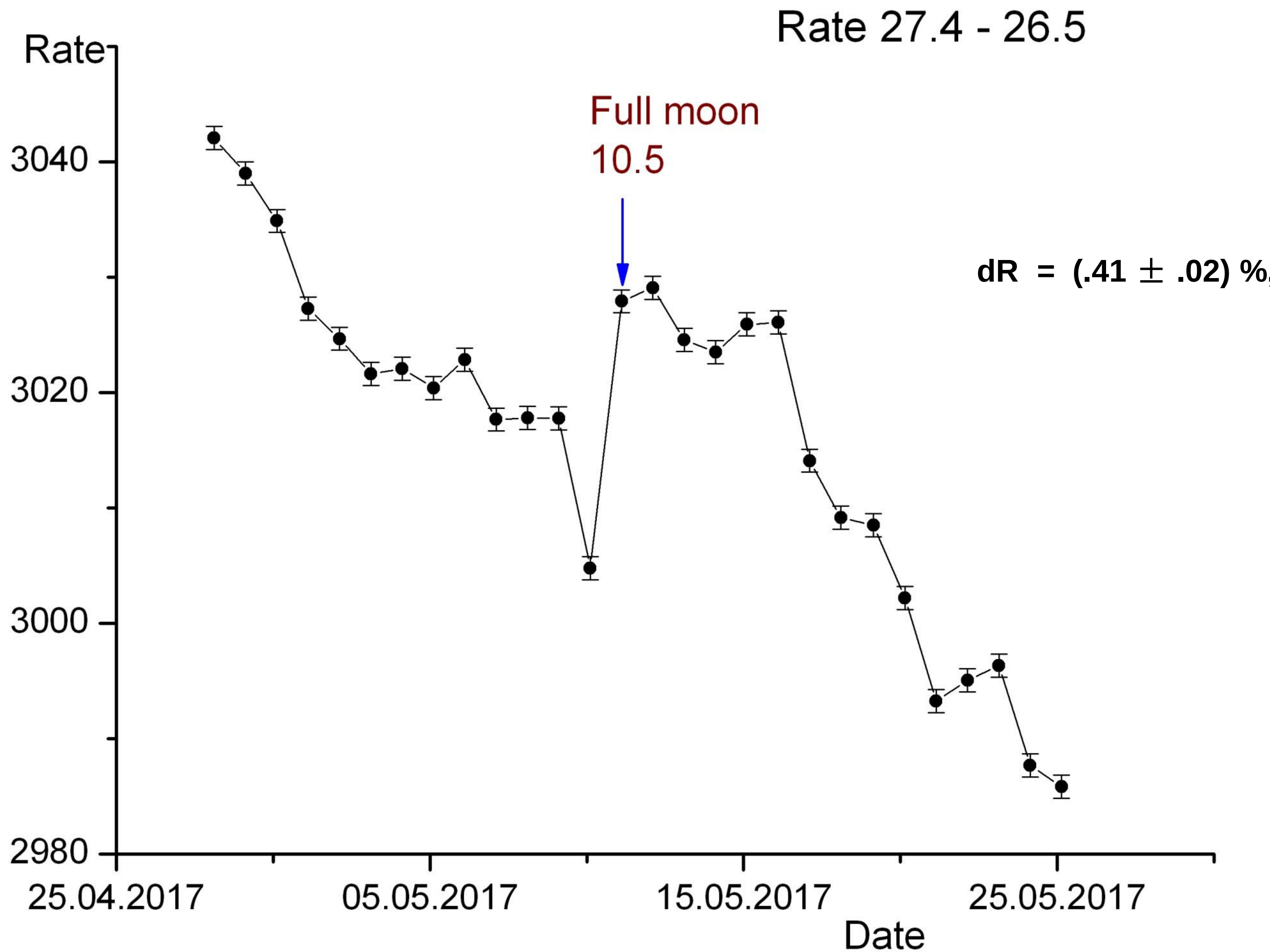
Orbit radius difference $\Delta R = 3\%$

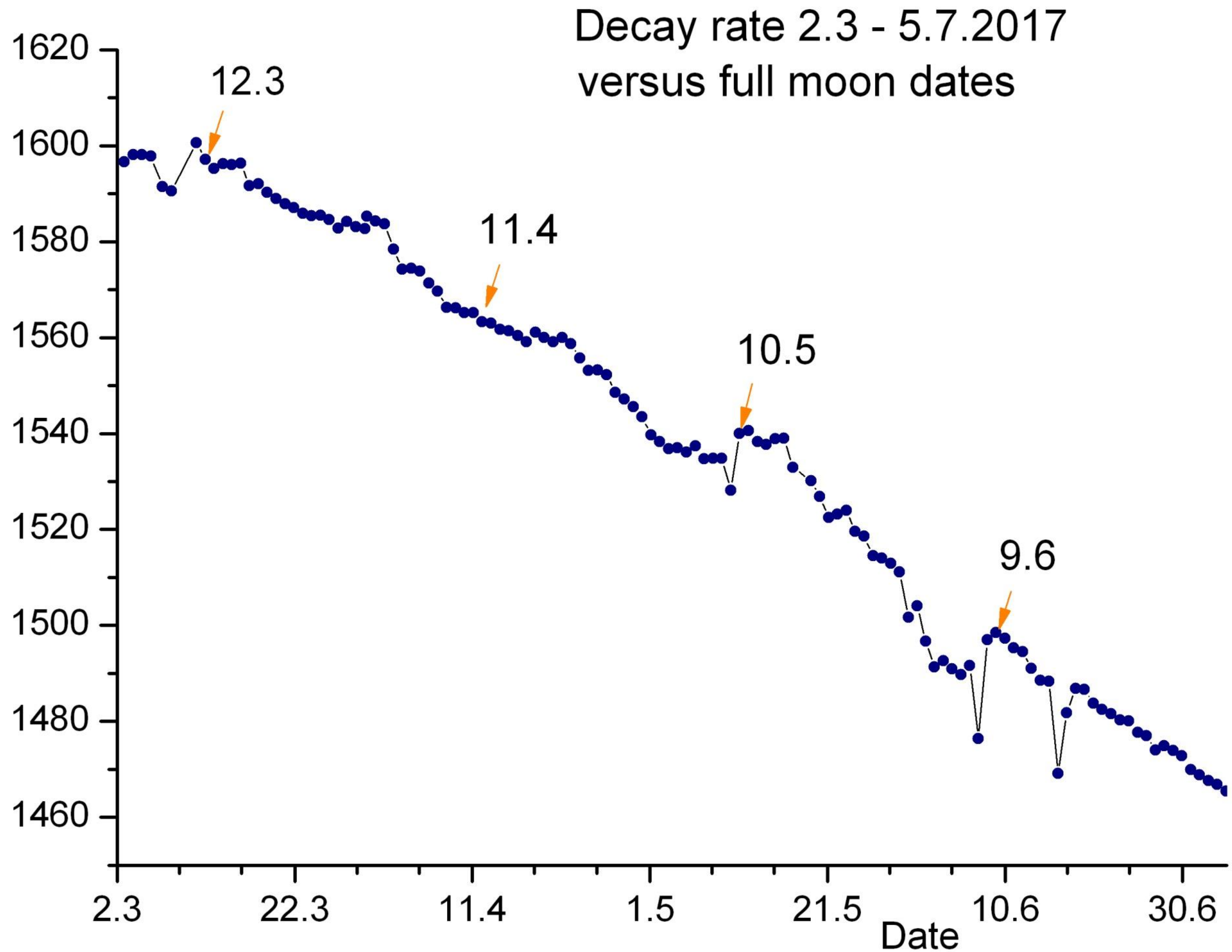
214 Po life-time lunar-day oscillations from moving-average algorithm
(average lunar-day= 24 h 50 мin. 28,2 sec.)





Amplitude $A = (6,9 \pm 2)*10^{-4}$


Rate 27.4 - 26.5
Rate
3040
3020
3000
2980
Full moon
10.5
dR = (.41 ± .02) %,
25.04.2017
05.05.2017
15.05.2017
25.05.2017
Date



Decay rate 2.3 - 5.7.2017
versus full moon dates
12.3
11.4
10.5
9.6
1620
1600
1580
1560
1540
1520
1500
1480
1460
2.3
22.3
11.4
1.5
21.5
10.6
30.6
Date