Radio Observation of Solar-Activity Related mHz Oscillations

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on behalf of VATLY-Hanoi

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VATLY

Vietnam Auger Training LaboratorY

High Energy Cosmic Rays

collaboration with
the Pierre Auger Observatory
in Argentina

Radio-astronomy

- *collaboration with French institutes on the study of data collected in the Plateau de Bure, Nancay, VLA*
- *21 cm observation (SRT) at home*

The choice of radio-astronomy was dictated by a combination of physics motivations (its presence at the forefront of most current explorations in astrophysics) and by arguments of convenience (influence and encouragements of Pr NQ Rieu, presence in Viet Nam of two astrophysicists:

Dinh Van Trung (Hanoi), working at millimeter frequencies on ISM, red giants

Phan Bao Ngoc (Ho Chi Minh city), working on brown dwarfs)

Modern astronomy in Vietnam is just starting now…

The VATLY Radio Telescope

- mobile parabolic dish, 2.6 m in diameter
- observation in the region of the 21 cm hydrogen line
- pointing accuracy of $\sim 0.3^o$ (after applying corrections of $\sim 1^o$)
- The size of the lobe (FWHM) measured to be 5.5 ± 0.3^o

General features

The Sun was observed nearly continuously in the period between mid April and early September 2012.

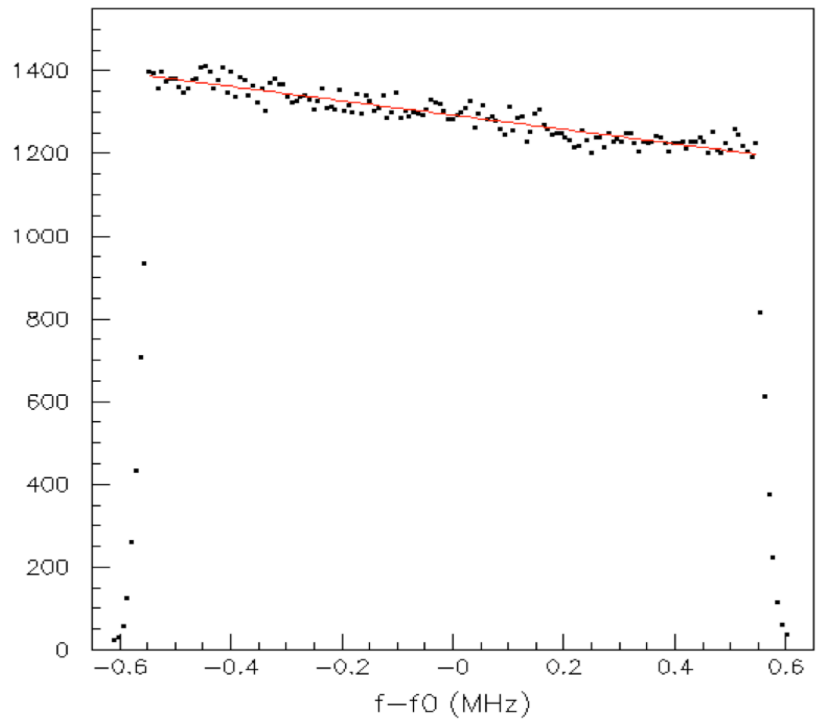
- SRT was operated at a frequency of 1.415 GHz
  (standard data: sequence of measurements of ~7.7 s duration each; frequency histogram covering ~1.2 MHz in 156 bins)

- a calibration run was taken at the beginning of each morning session
  (in some cases, a second one at the beginning of the afternoon)

- pointing corrections were applied every 30 minutes on average
  (implied stopping the telescope movement/data taking ~40 s)

The data are compared with data from the Learmonth observatory taken at the same frequency during the same period.

Hanoi and Learmonth are located at nearby longitudes (105.8°E / 114.1°E) and at nearly opposite latitudes (21.0° N / 22.2° S).



A frequency spectrum is well described by a linear form.

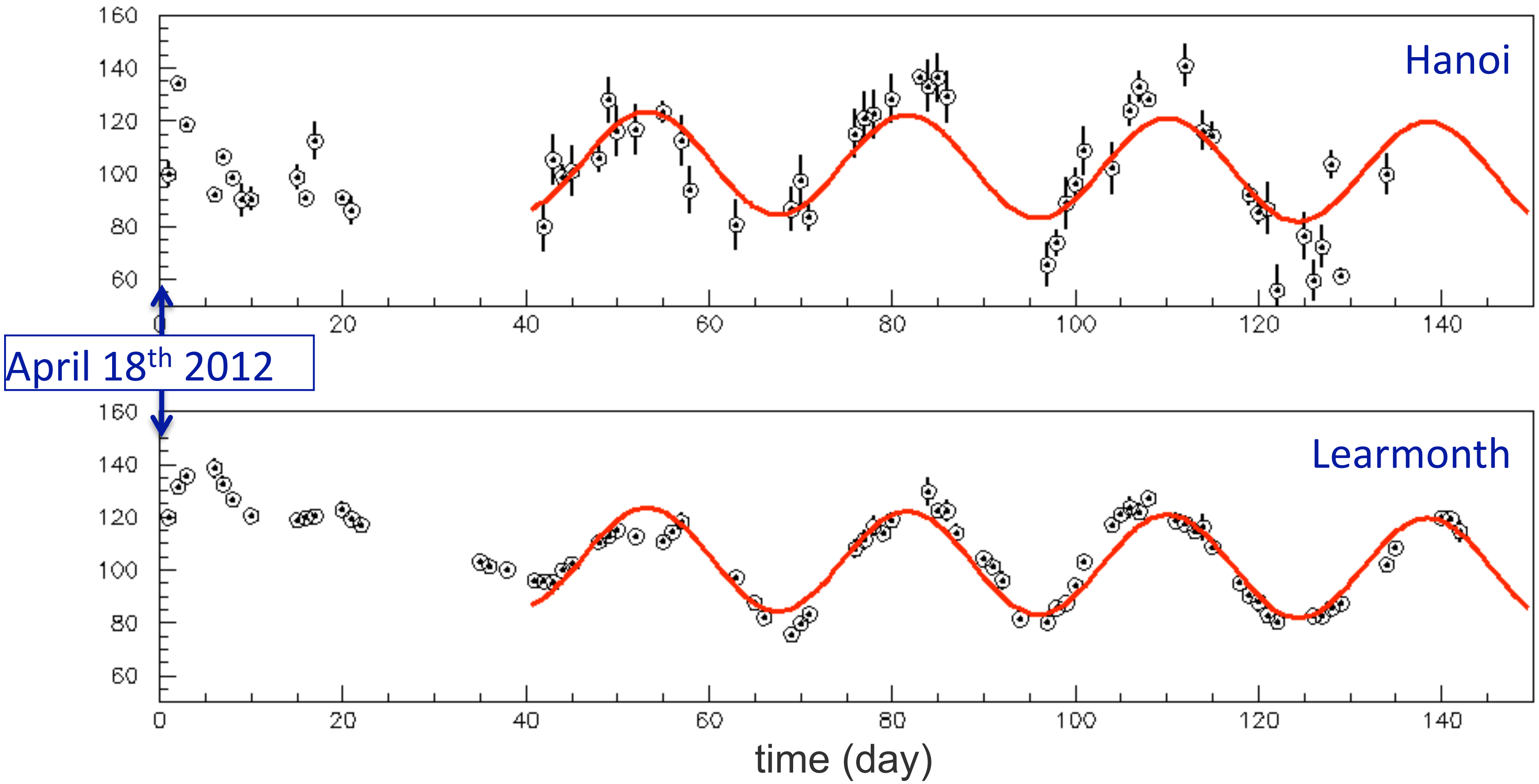
Spectra containing too many bad measurements were eliminated using χ^2.

The mean power density and the slope as a function of frequency:

Gaussian distributed with relative σ of 7.7% and 6.8% respectively.

The slope corresponds to ~13% decrease in power density (effect of the receiver bandpass).

Dependence on calendar time of the daily average signals



28 day rotation period of the Sun has a strong effect on the measured signal: increases ~ 50% between minima and maxima.

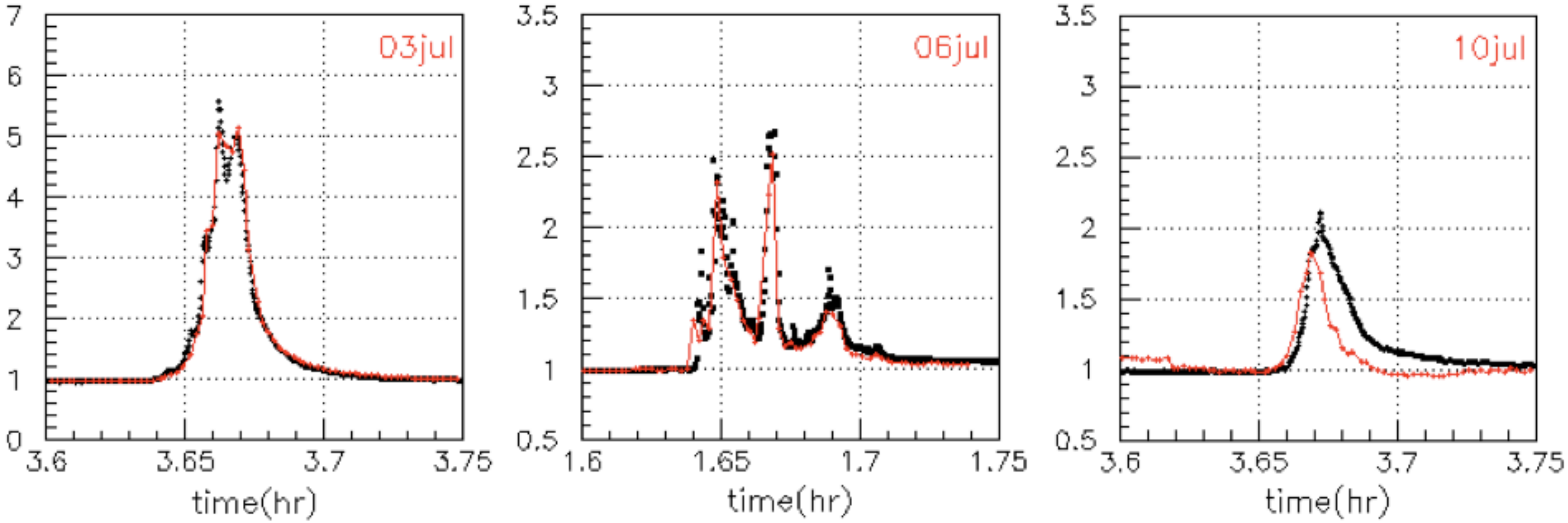
Learmonth and Hanoi data are consistent, the noise in the Learmonth data is typically 1.7 times lower.

Comparing Hanoi data with Learmonth data:

30 flares common to both sets (½ are single flares);

an increase of ~15% with respect to the quiet Sun level;

3 flares exceed 40% (on July 3rd, 6th and 10th)

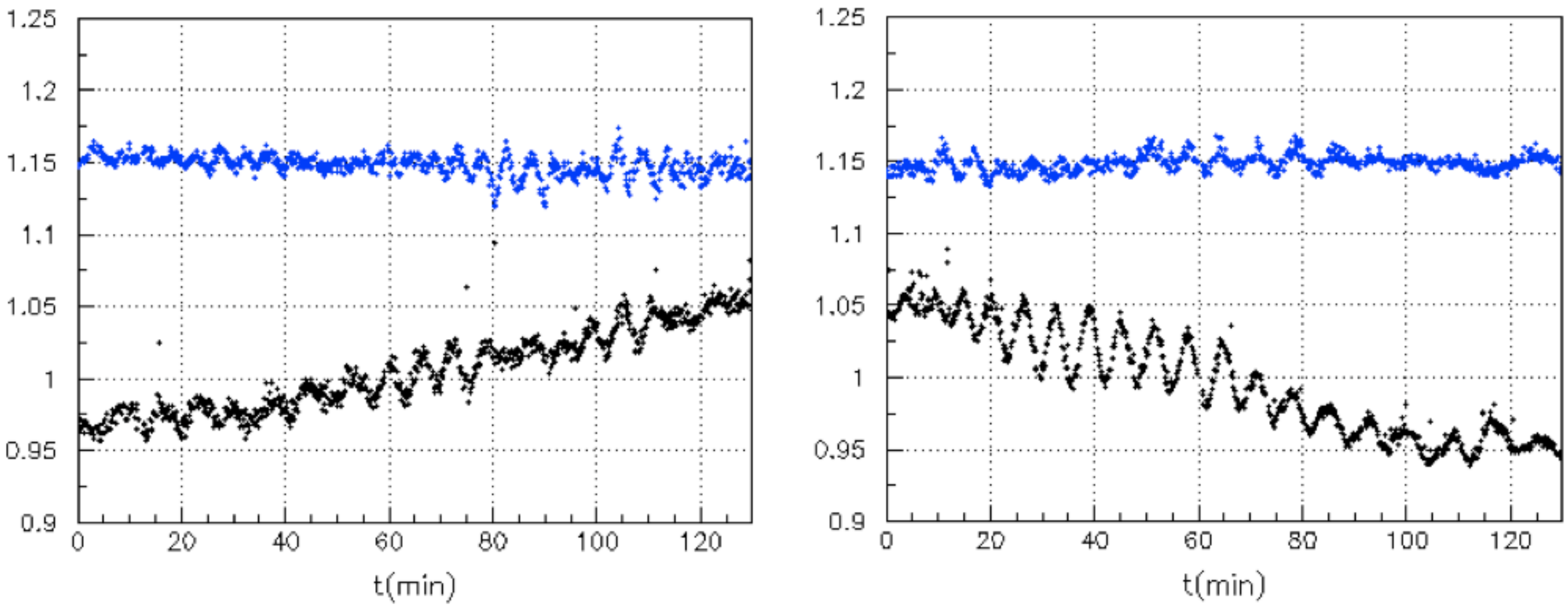


Hanoi

Learmonth

Oscillations: observations

Oscillations at the percent level present in both the Learmonth and Hanoi data, with typical periods of five to seven minutes.



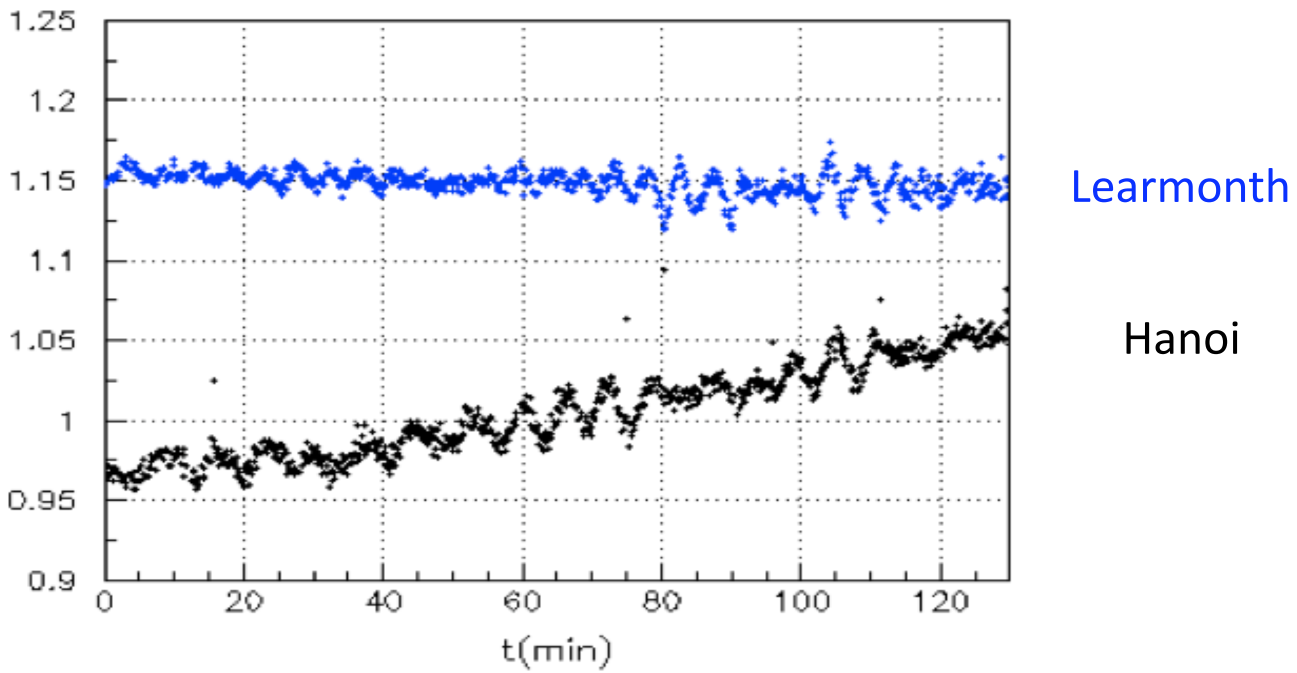
Learmonth and **Hanoi** data normalised to unity
(Learmonth data shifted up by 0.15 for clarity)

Intervals defined as data taking periods lasting more than 25 mn and including no interruption longer than 5 mn,

(*long enough to contain several periods and short enough to be described by a single value of the period.*)

The average duration of an interval is 40 mn.

Data are normalized to unity over the interval.

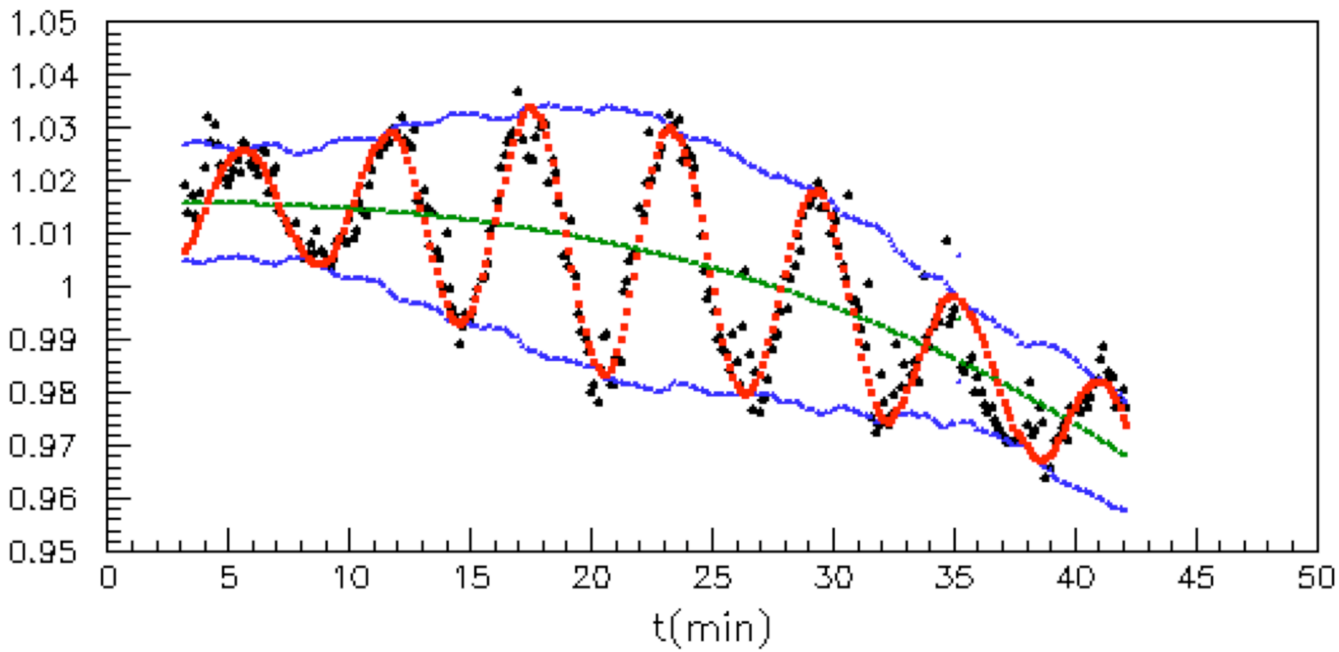


In each interval, the Hanoi and Learmonth data are analysed separately.

Data sets are first fit to a third degree polynomial ***P(t).***

The amplitude ***A(t)*** of the oscillations is evaluated at each point from the deviation of the detected signal, ***S(t)***, with respect to ***P(t)*** in a 6 mn sliding interval centred on the point.

Finally, the data are fit to a form: $S(t) = P(t) + A(t) \sin(2\pi t/T + \varphi)$

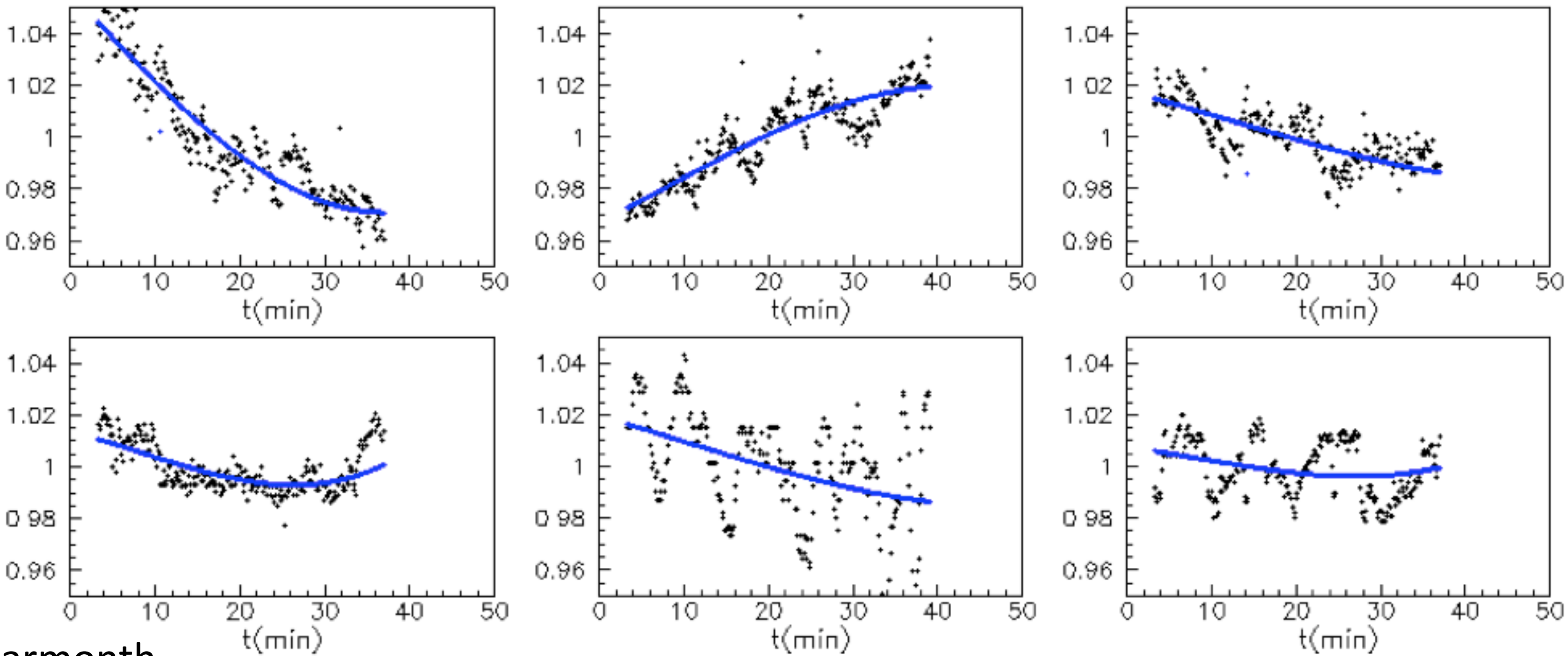


Each of 304 time intervals in the analysis has been assigned to one of three possible categories depending on the adequacy of the fit form to describe the data

Category 0:

when both Hanoi and Learmonth data sets are not properly described by the form: 109 intervals

Hanoi

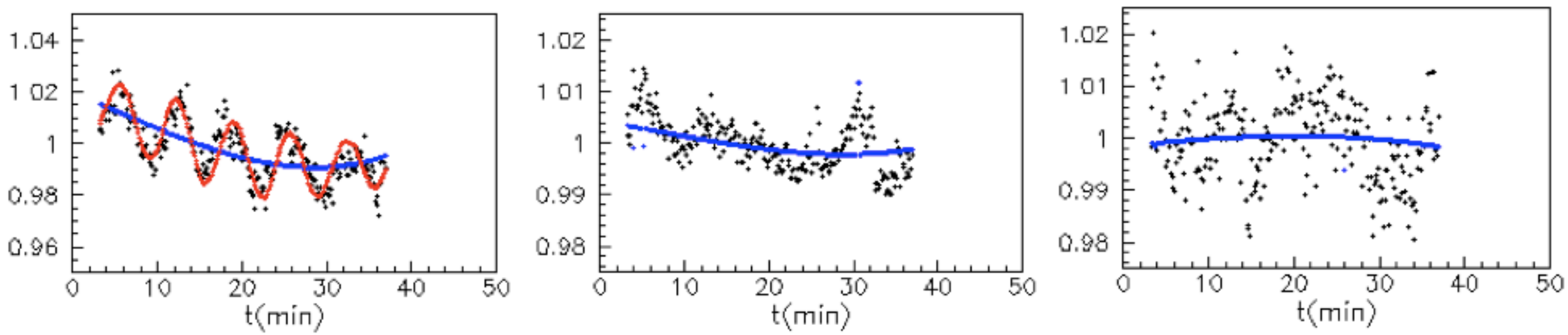


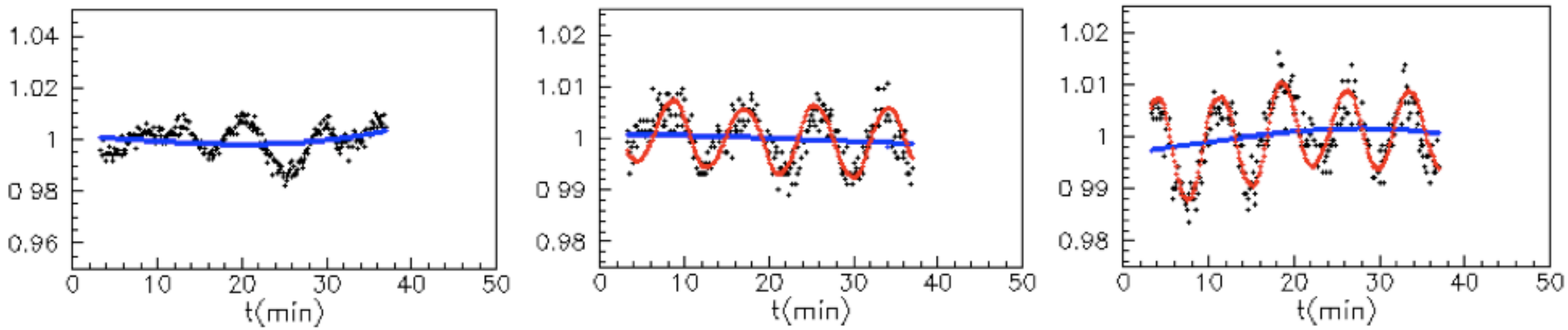
Learmonth

Category 1:

when only one of the Hanoi (19 intervals) and Learmonth (52 intervals) data sets is properly described by the form but not the other.

Hanoi





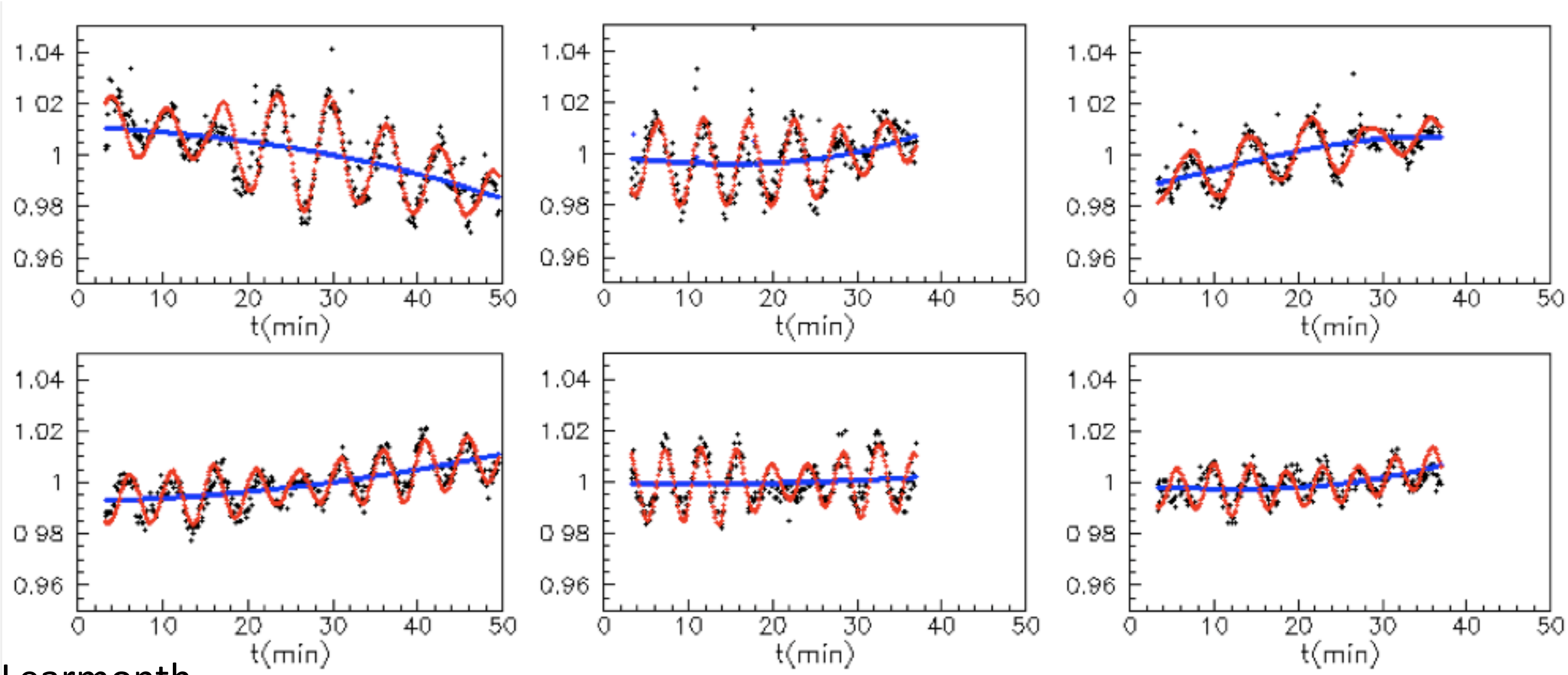
Learmonth

Category 2:

when both Hanoi and Learmonth data are properly described by the form

(124 intervals)

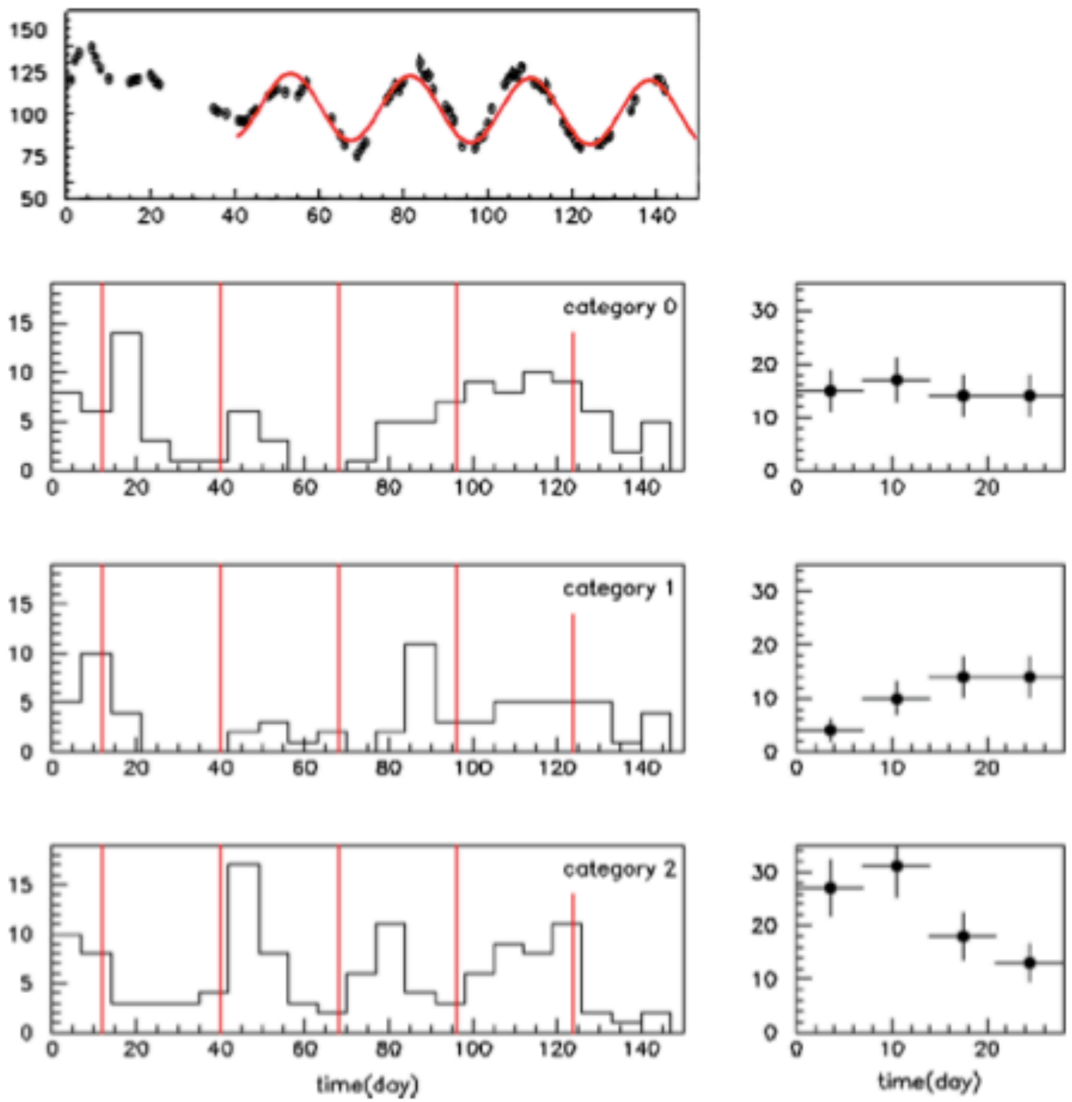
Hanoi



Learmonth

Some oscillations are very clear sine waves; other may be saw-tooth like or may be quickly damped over the interval.

Distribution of the number of intervals over calendar time shows no outstanding feature!



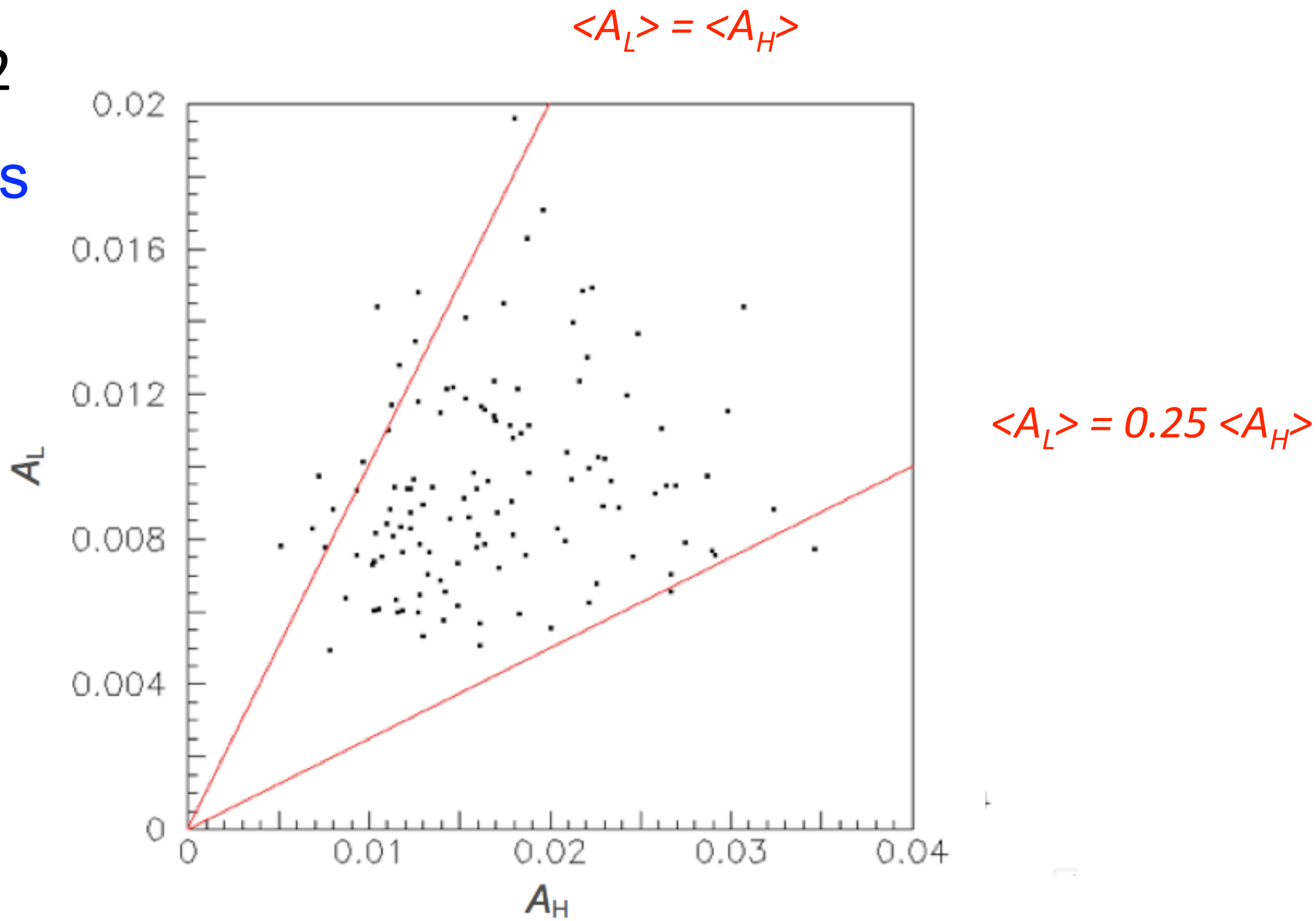
calender time

solar rotation phase

Category 2 intervals are favoured during the periods where solar radio emission is rising, when the more active hemisphere of the Sun is visible from Earth.

Category 2

amplitudes

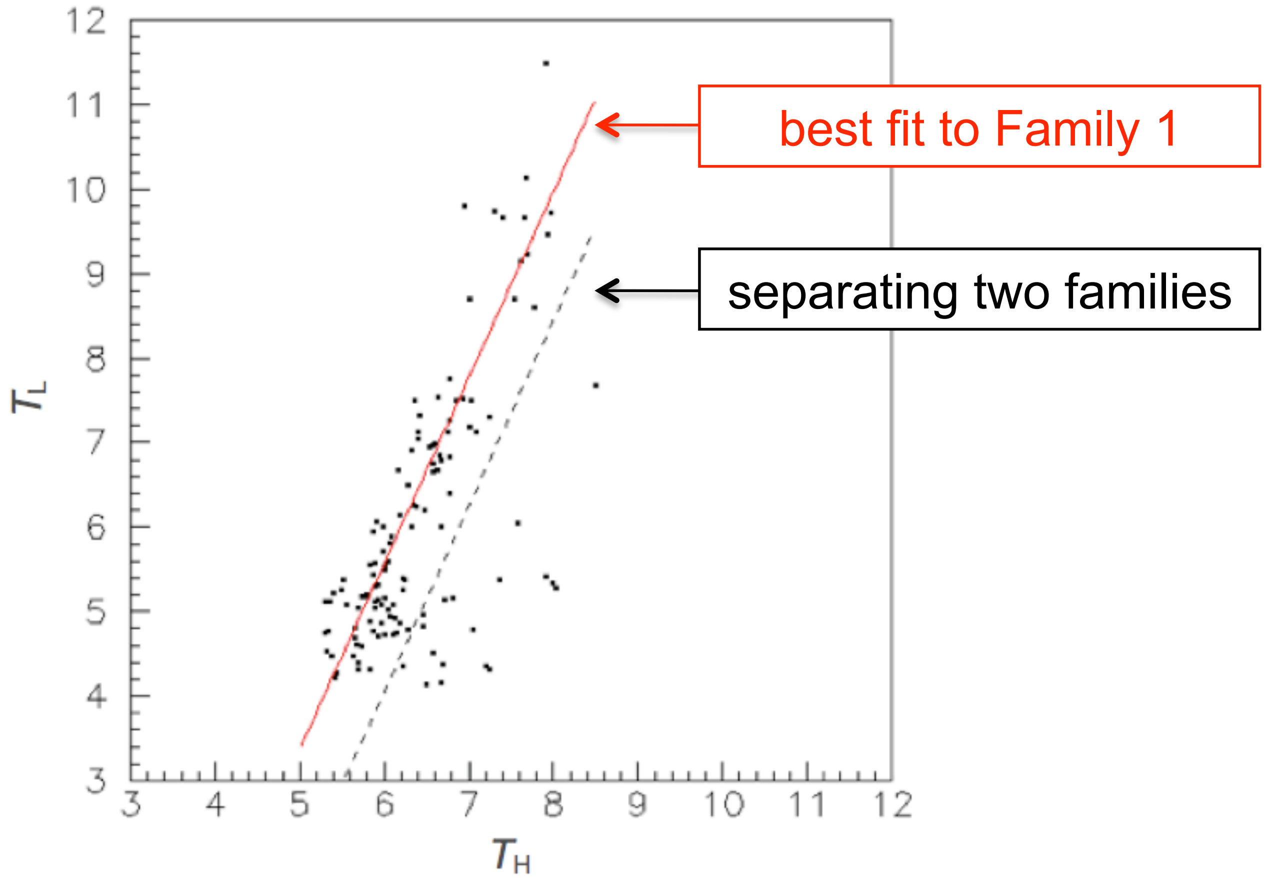


The mean values of $\langle A_H \rangle$ and $\langle A_L \rangle$ for category 2 intervals are 1.68 % and 0.96 % respectively,

→ a factor 1.75 higher in Hanoi than at Learmonth.

Category 2

periods



At variance with amplitudes we observe a strong correlation between Hanoi and Learmonth periods.

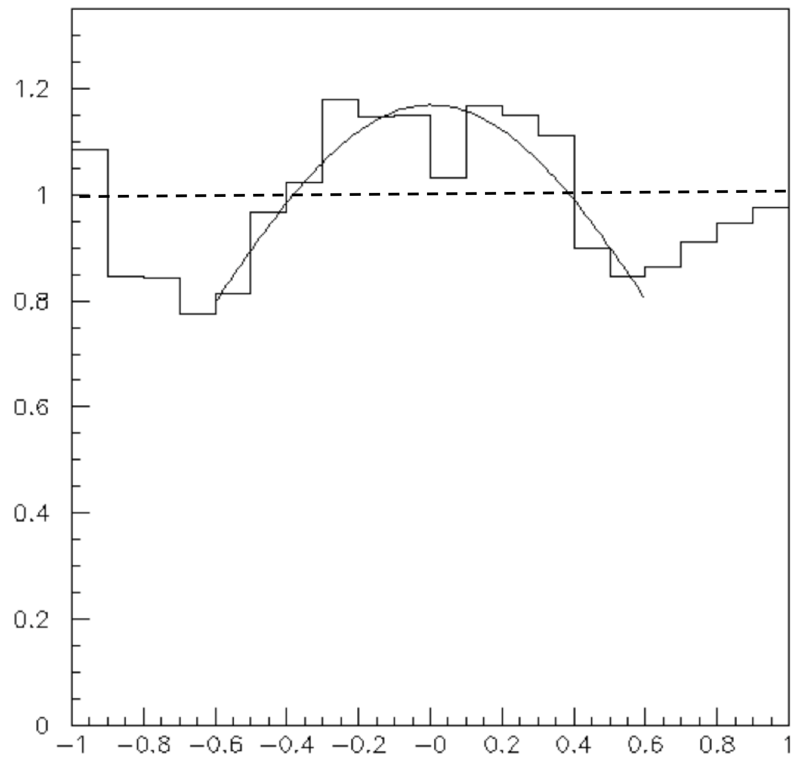
We select family 1 (105 intervals) where the correlation reads

$$T_L = 2.2T_H - 7.6\ mn$$

To reveal new features of the observed oscillations:

Restrict the analysis to Family 1 and select most reliable data by requiring good quality fits and large enough oscillations

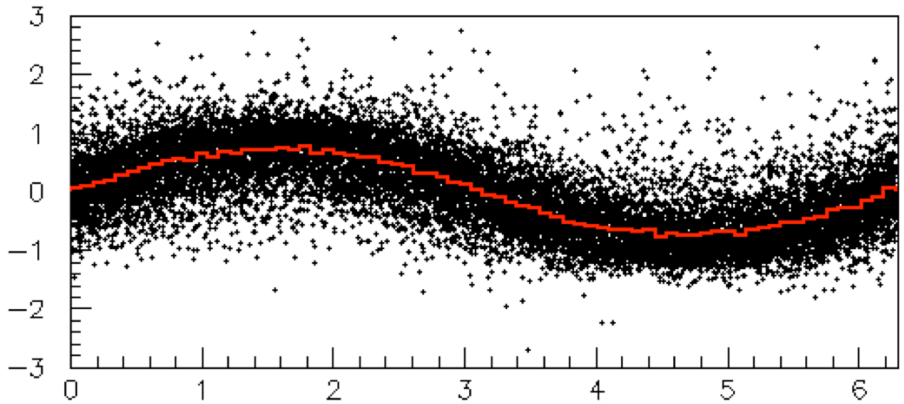
Phase correlation



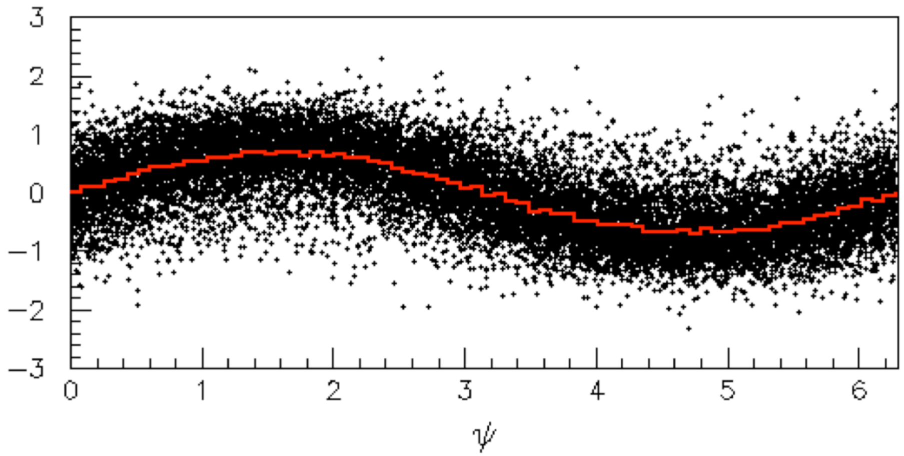
The correlation is seen to reach between 10% and 20%.

Shapes of the observed oscillations

Hanoi



Learmonth



Distribution of *{S(t)–P(t)}/A(t)* over *2πt/T+φ* modulo *(2π)*

Both show, on average, a clear sine wave.

Oscillations: possible instrumental effects

As a check of the solar origin of the observed oscillations, we took data by pointing the telescope 15^o off the Sun; the absence of observed oscillations allows for placing an upper limit of 0.3 % on their possible amplitudes.

The evidence for correlations between the oscillations observed in Hanoi and at Learmonth excludes an interpretation in terms of simple instrumental effects.

However, the similarity between the two instruments implies that they suffer from similar biases or weaknesses.

A possible source of erroneous interpretation is multipathing. Multipathing would be Sun associated and result in different oscillation amplitudes and periods in Ha Noi and at Learmonth.

An important argument against it is the observation of the strong correlation between the periods of the oscillations measured at Learmonth and in Ha Noi.

A crucial test of the multipathing hypothesis excludes an excess of low elevation occurrences (as expected from multipathing involving obstacles on ground), but it displays a significant excess at elevations of the order of 60° for which we have no explanation.

Oscillations: possible physics interpretations

The differences between the precise values of the periods of observed signals (and the weakness of amplitude correlations) is intriguing and calls for an explanation.

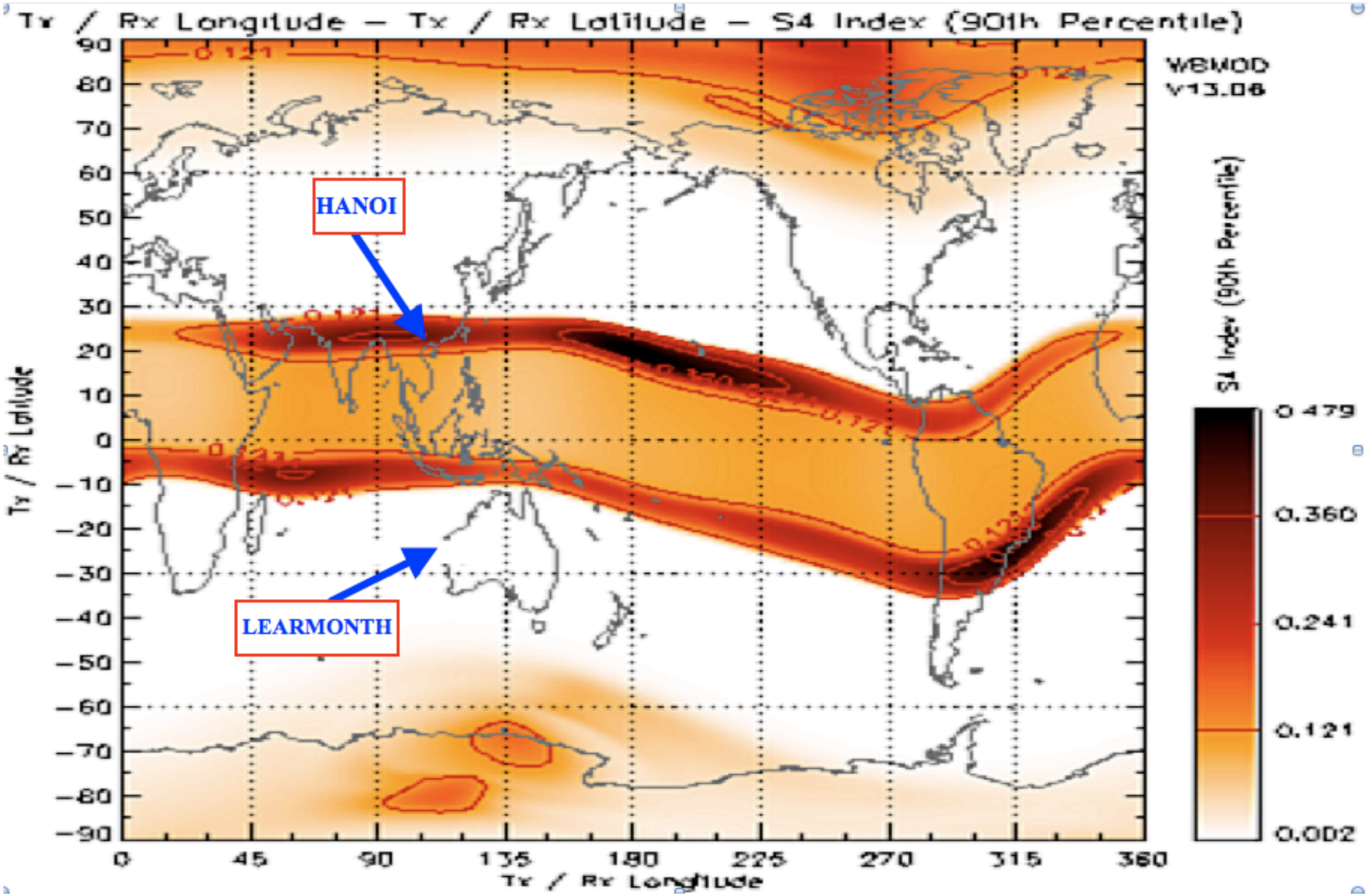
Two natural candidates:

- the effect of the different polarization states detected in Hanoi (circular) and at Learmonth (linear) and

- the effect of different distortions caused by the traversal of the local ionosphere by the solar signal.

The particular position of Hanoi with respect to the geomagnetic equator implies for it a maximal ionospheric scintillation index S4.

Ionospheric scintillation index S4



Summary

The Sun has been observed using the VATLY radio telescope at 1415 MHz between mid April and early September, 2012.

The data have been analysed jointly with Learmonth data. Both sets of data see the same general features. They display frequent oscillations at the percent level and with periods around 6 mn.

On average, the Hanoi and Learmonth oscillations display similar behaviours: they reach together their higher/lower amplitudes; their higher/ lower periods; they tend to be in phase.

However, when looked at interval by interval, they differ significantly, displaying important smearing. Moreover, the average amplitude in Hanoi is larger than in Learmonth (by a factor ~1.75) while the period span in Learmonth is larger than that in Hanoi (by a factor ~2.2).

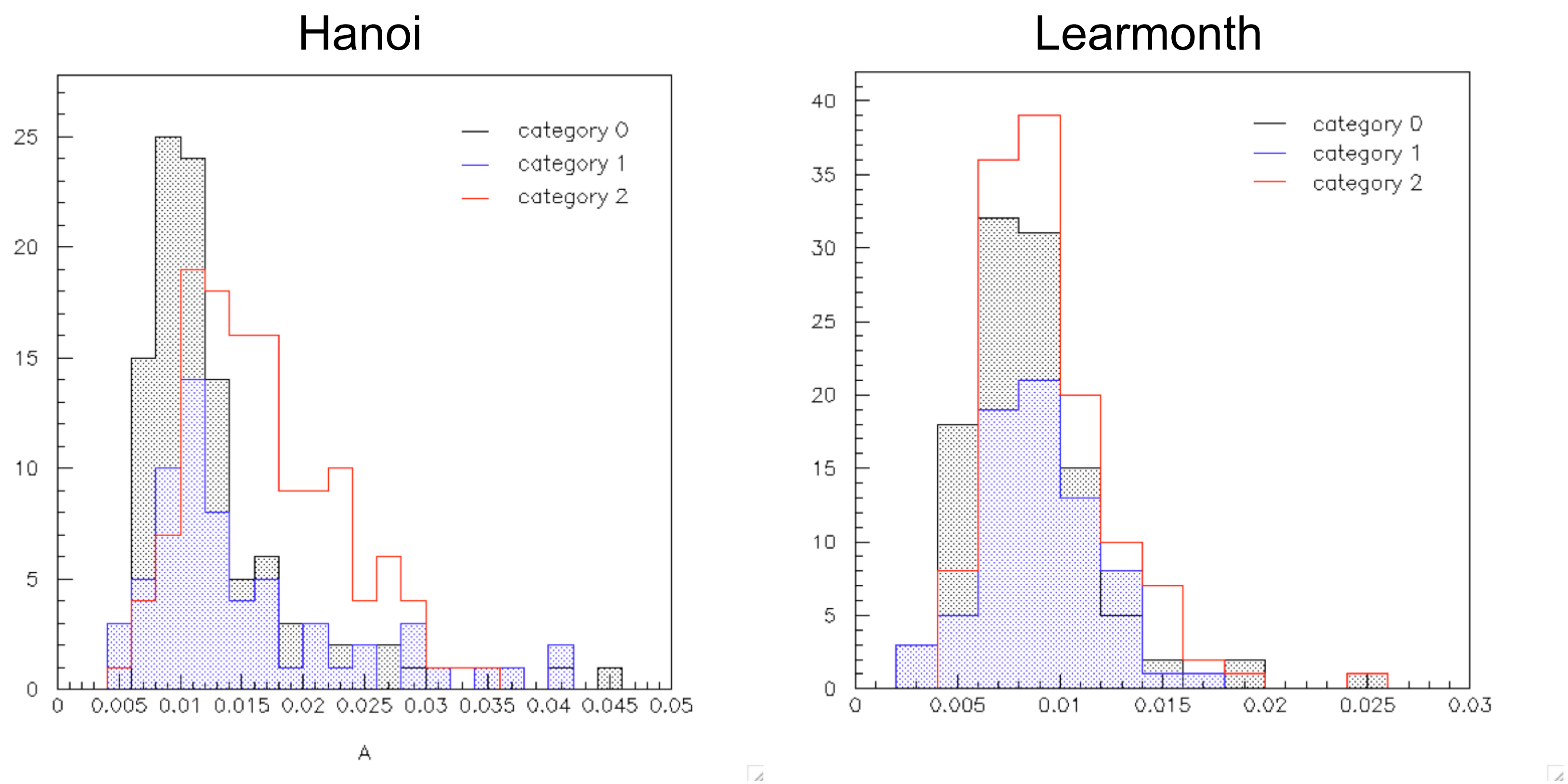
The possible effects that might cause such differences are different polarization states or effects of ionospheric transmission.

We are deeply indebted to the Learmonth Solar Observatory staff, who are making their data available to the public, and particularly to Dr. Owen Giersch for kindly answering many of our questions related to these data.

Financial and/or material support from the Institute for Nuclear Science and Technology, Vietnam National Foundation for Science and Technology Development (NAFOSTED), the World Laboratory and Odon Vallet fellowships is gratefully acknowledged.

Thank you for your attention

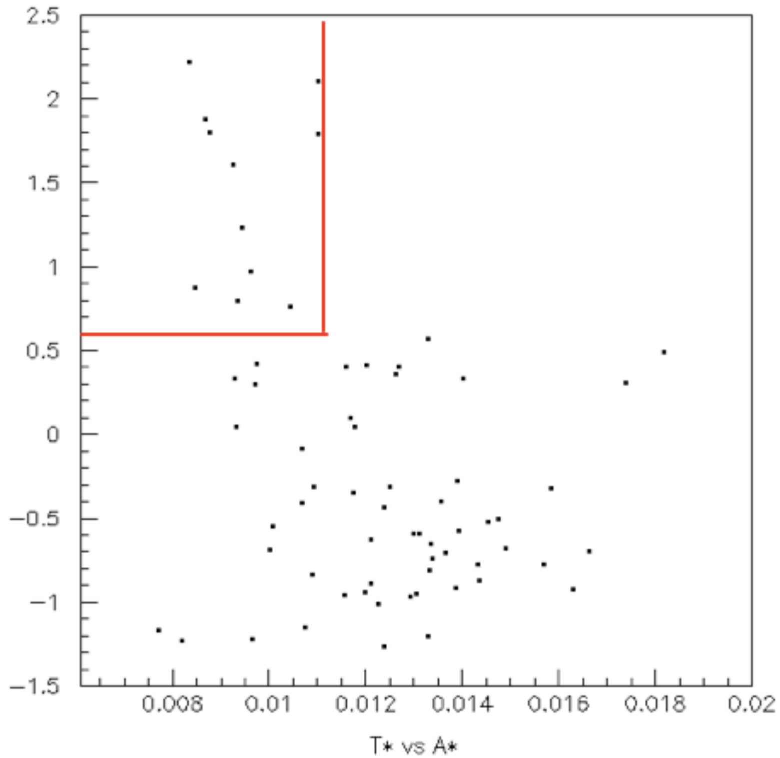
Back up...



Distributions of the average amplitudes *<A(t)>* for each category

A clear tendency for the average amplitudes to increase together with the category index in Hanoi data but not in the Learmonth data.

Period-amplitude correlation



$T^*=\{(T_L-6.3)+2.2^*(T_H-6.3)\}/3.2$ vs $A^*=\{A_H+1.75^*A_L\}/2.75$

all larger *T** intervals (*T*>~0.6mn*) have lower amplitudes (*A*<~1.1%*)