The Finnish Graduate School in Astronomy and Space Physics Summer School 2007:

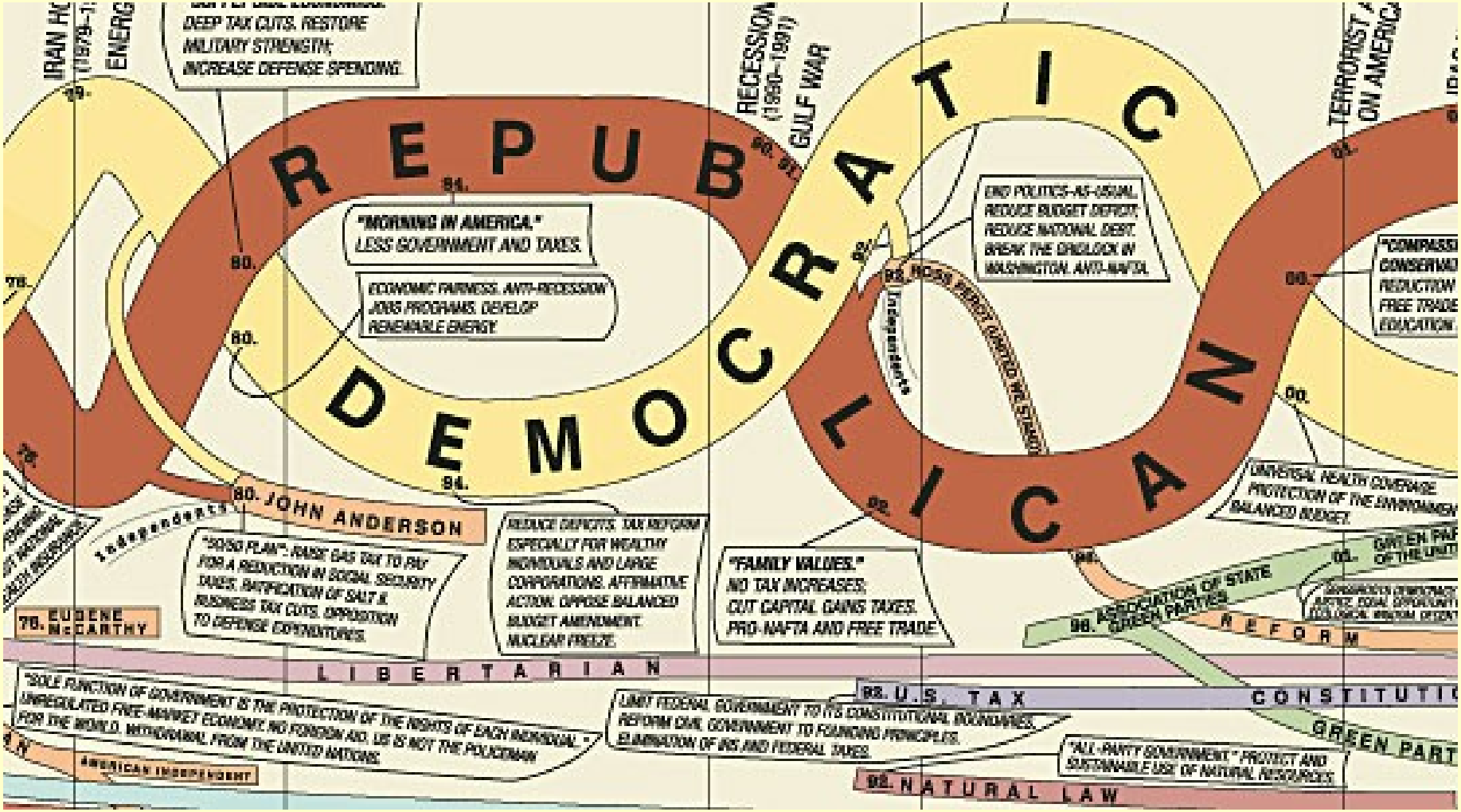
Time Series Analysis

Part I. Motivation

Graphical display of time dependent phenomena

Graphical display of time dependent phenomena

- Historical overview
- Uses
- Problems



From where to start?

- Time
- Phase
- Movement
- Frequency

$$\text{Frequency} = \frac{1}{\text{Period}}$$

$$\text{Period} = \frac{1}{\text{Frequency}}$$

Antikythera

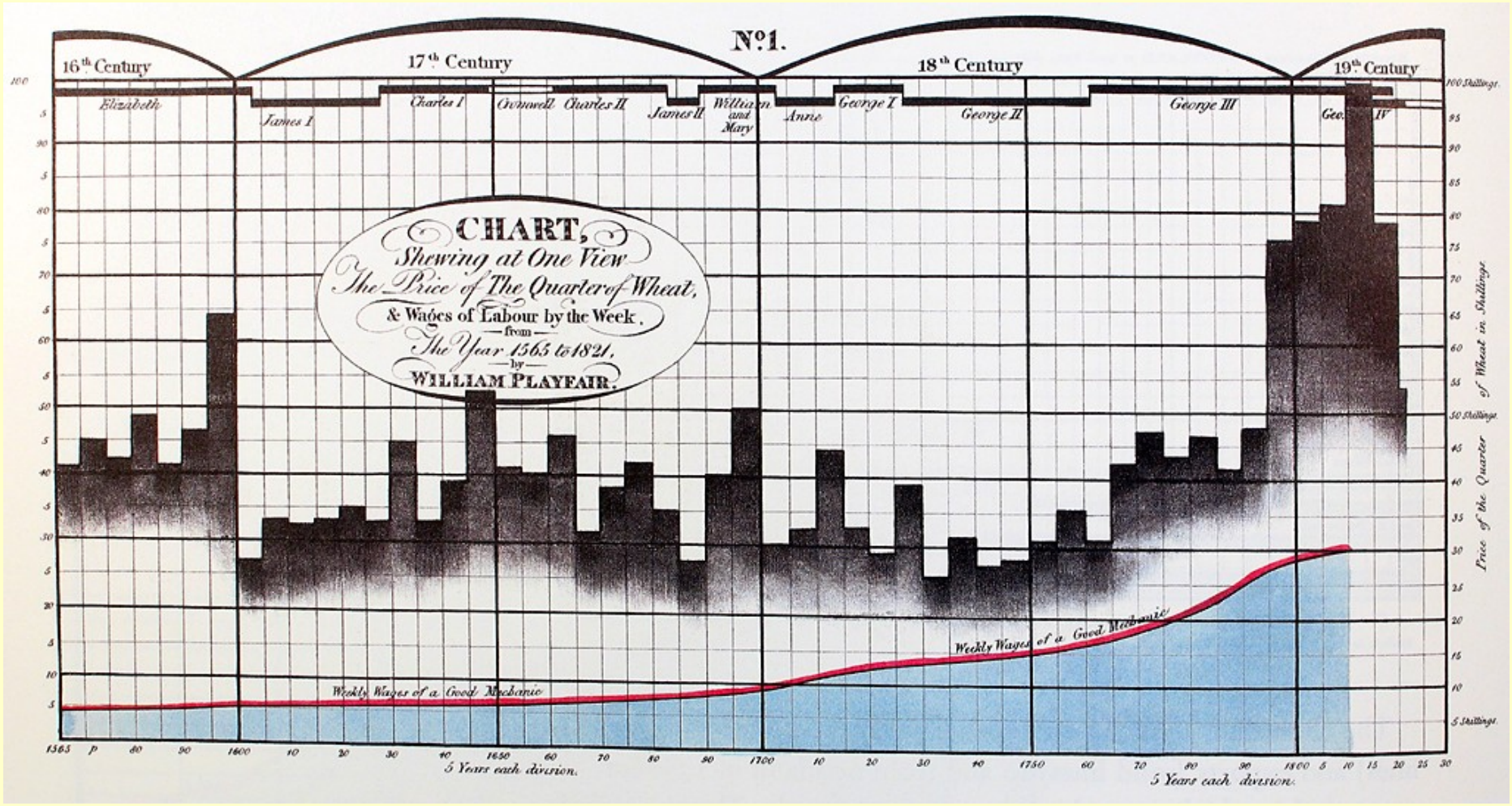
Fourier transforms? Not yet.

$$F(\nu) = \int_{-\infty}^{+\infty} f(t) \mathrm{e}^{-2\pi \mathrm{i} \nu t} \mathrm{d}t$$

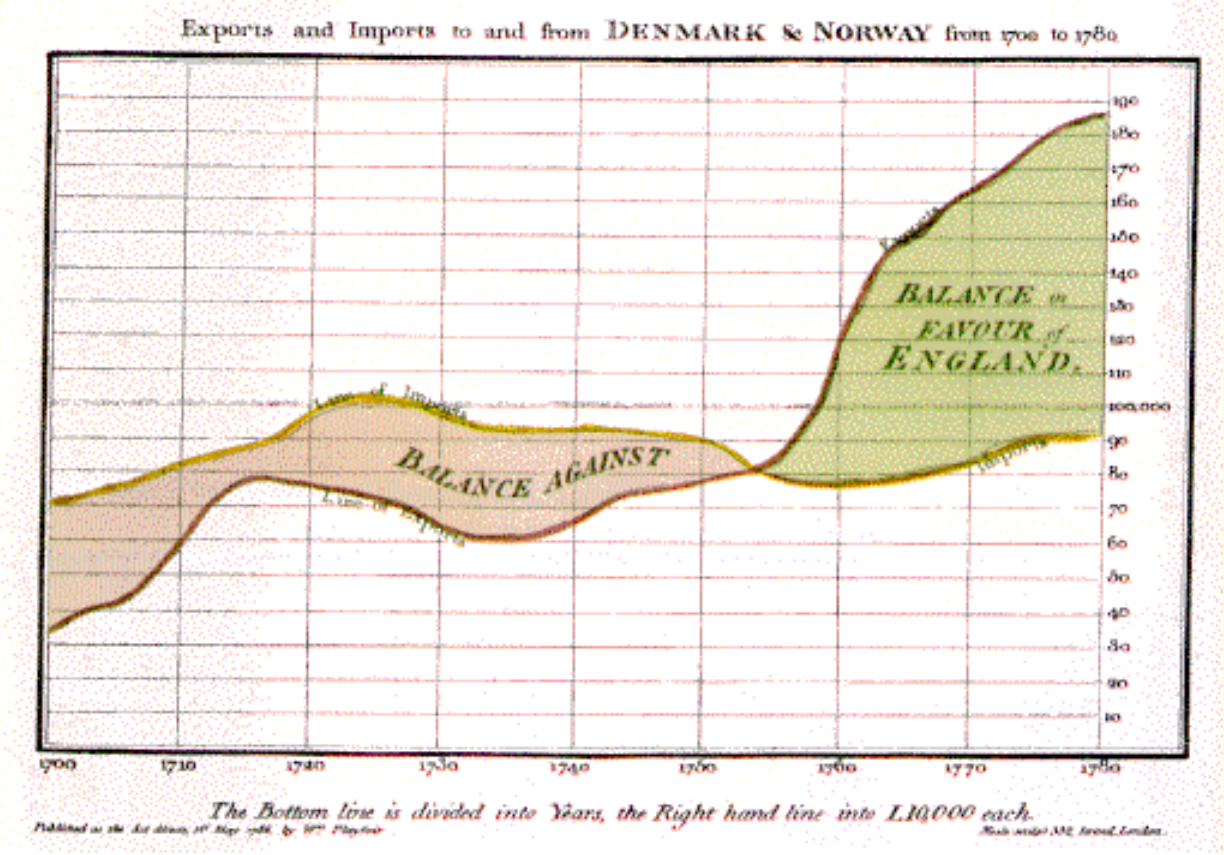
$$f(t) = \int_{-\infty}^{+\infty} F(\nu) \mathrm{e}^{2\pi \mathrm{i} \nu t} \mathrm{d}\nu$$

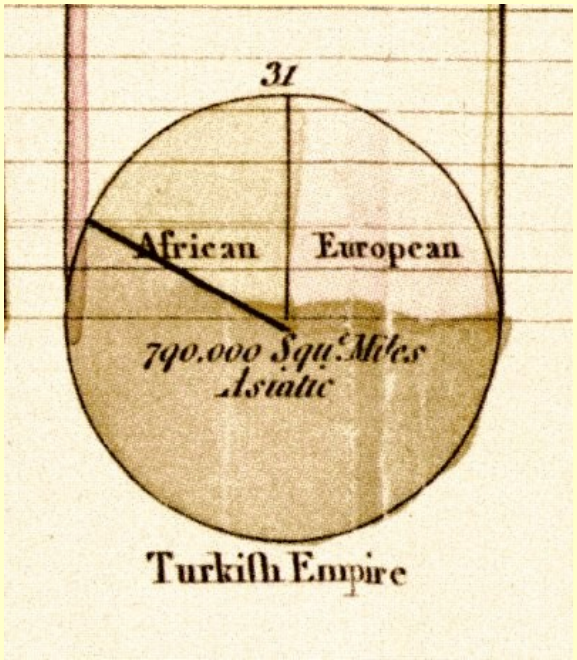
William Playfair

(September 22, 1759 - February 11, 1823)



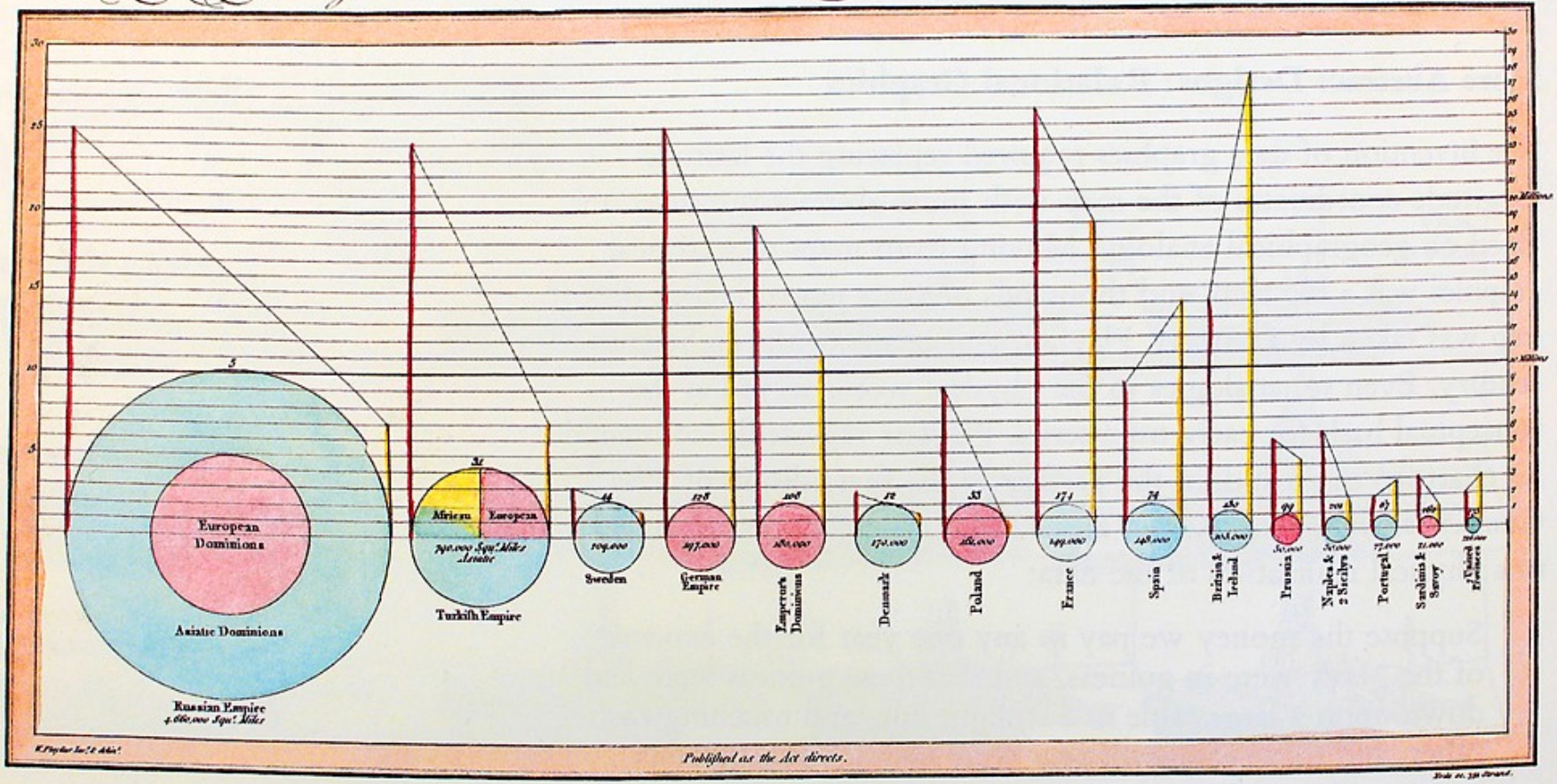
More Playfair





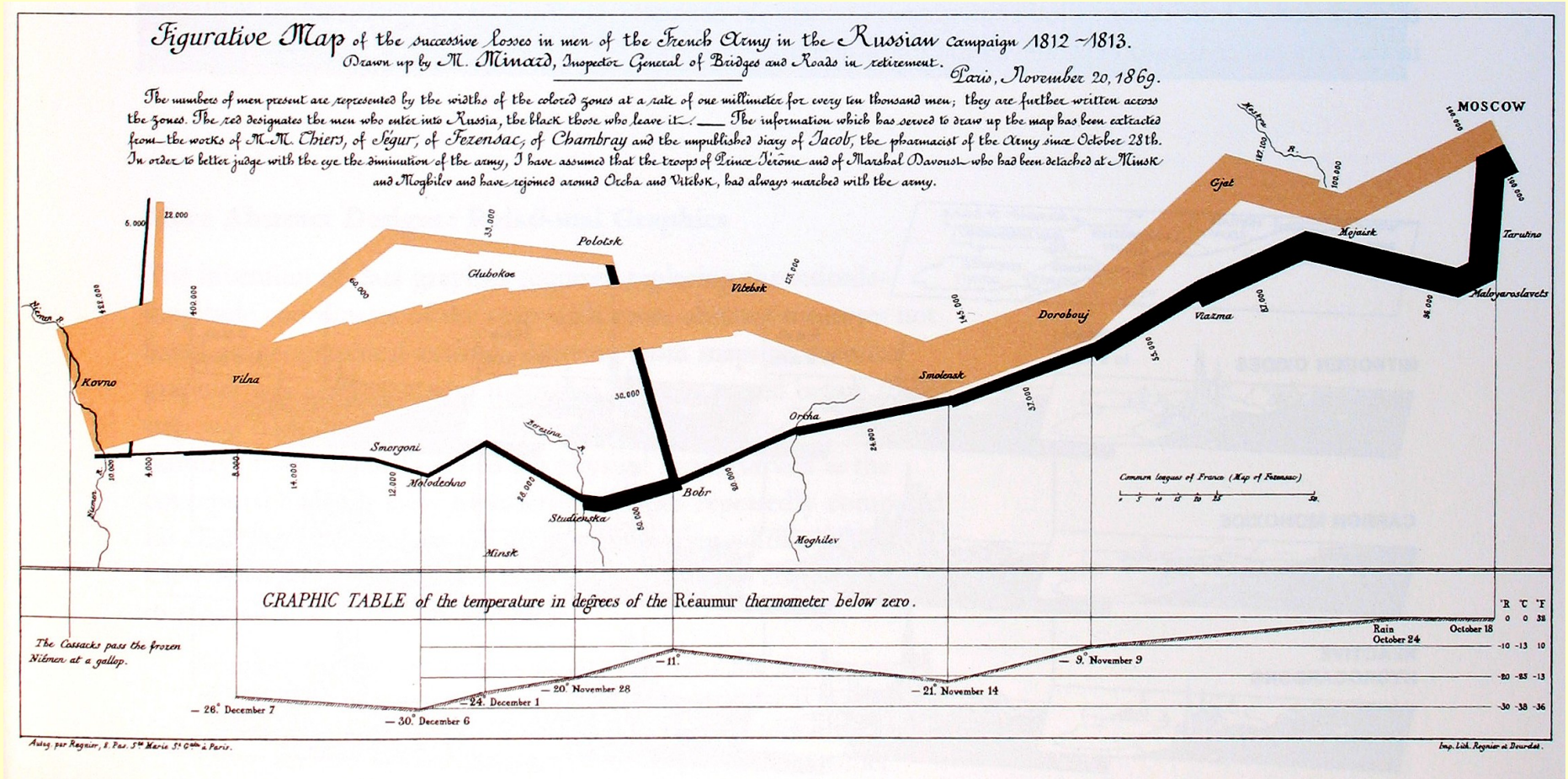
Statistical Chart shewing the Extent the Population & Revenues of the PRINCIPAL NATIONS of EUROPE, in the order of their Magnitude.

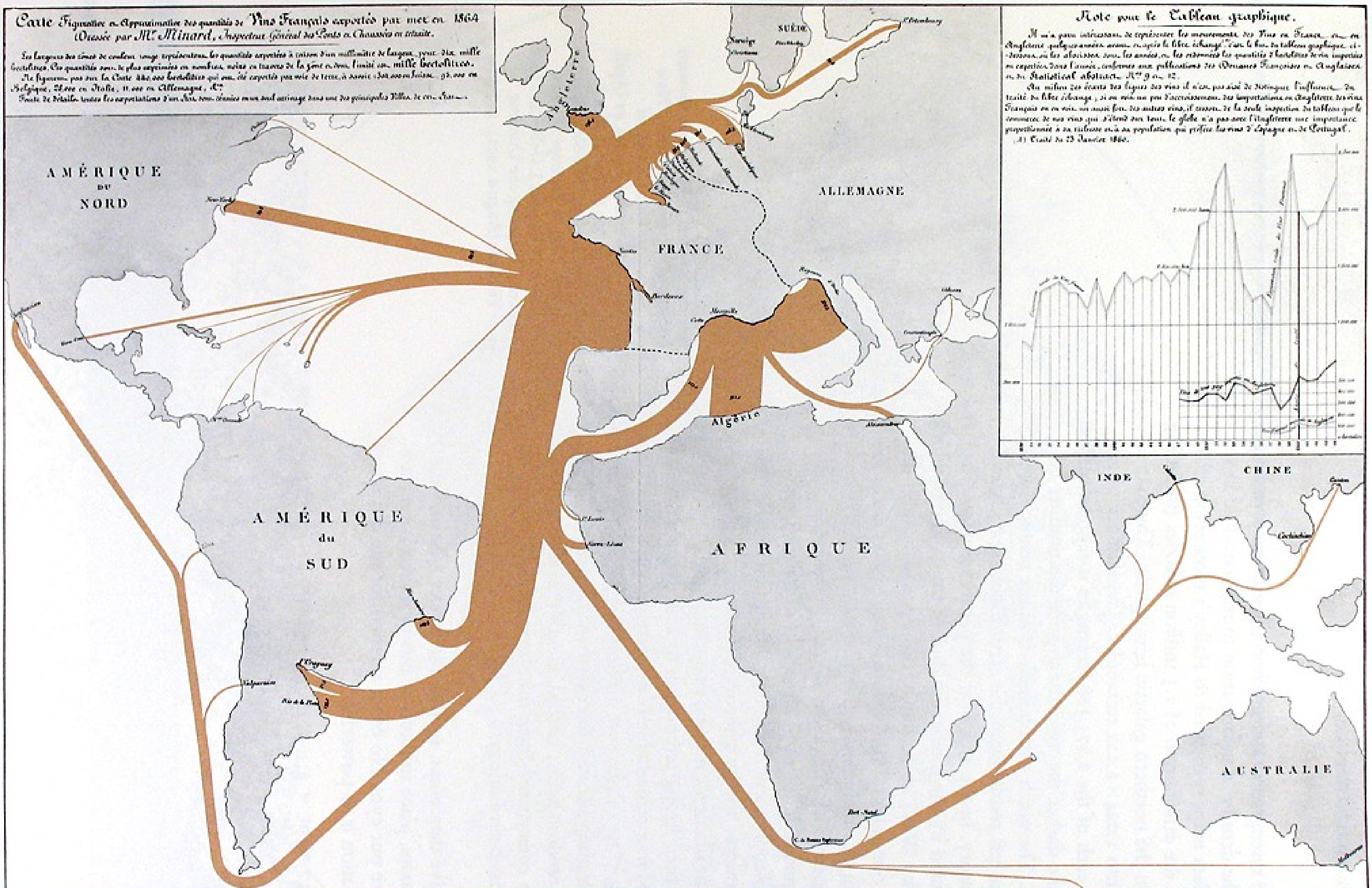
Plate 1st

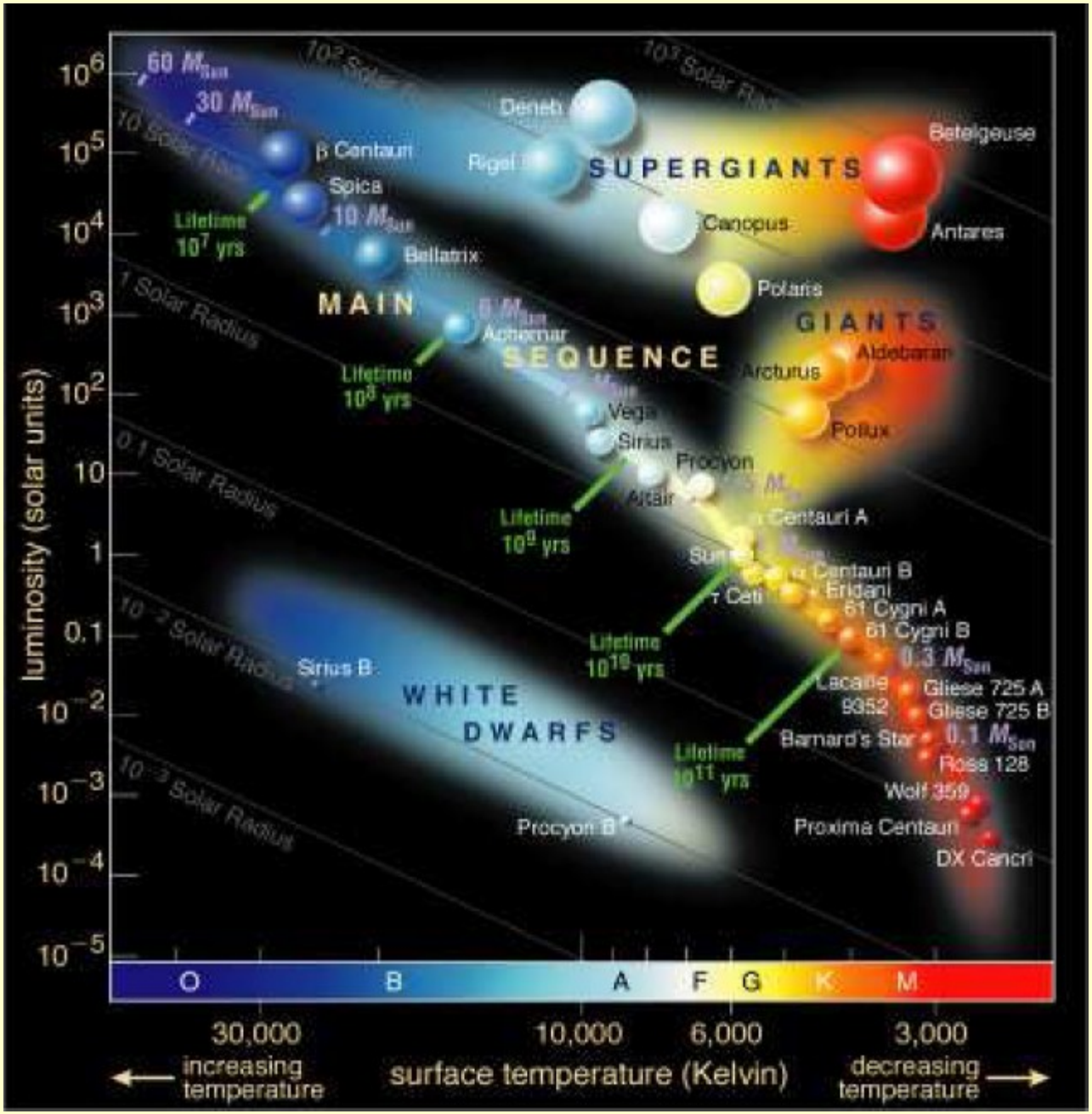


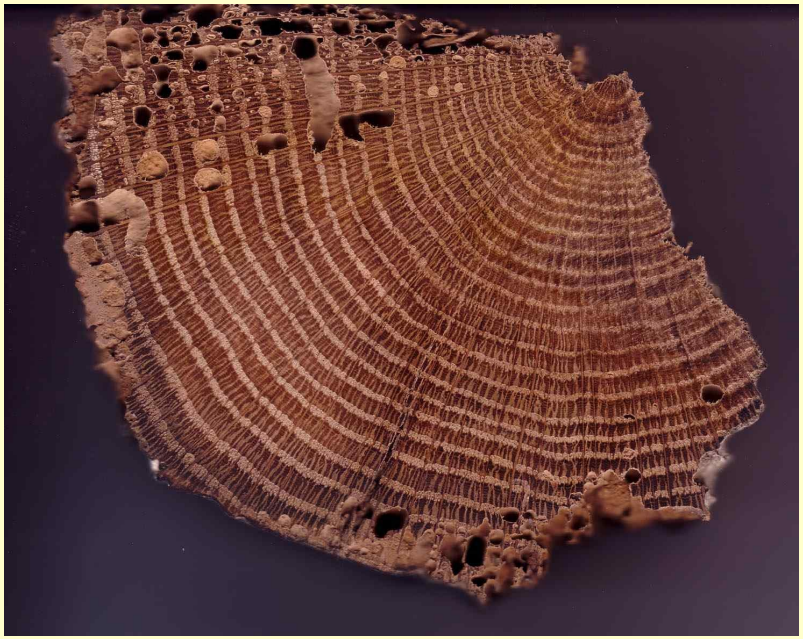
Charles Joseph Minard

March 27, 1781 in Dijon – October 24, 1870 in Bordeaux

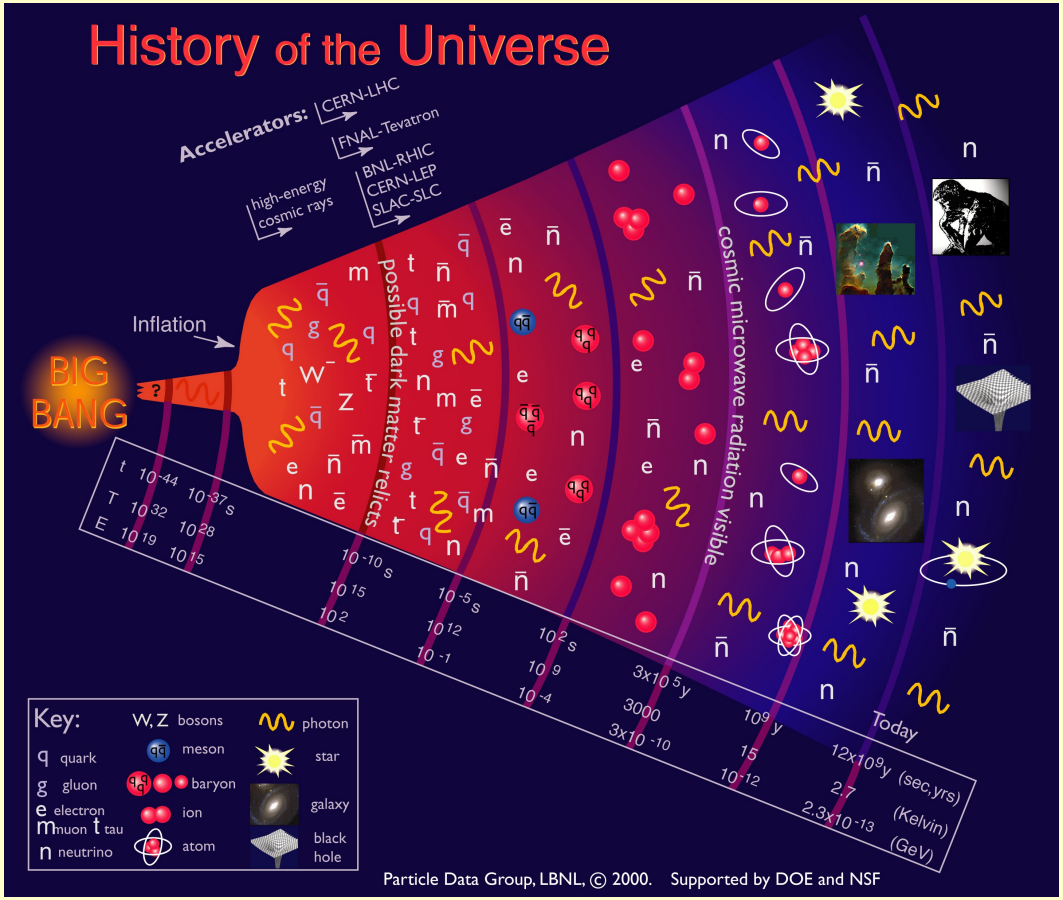


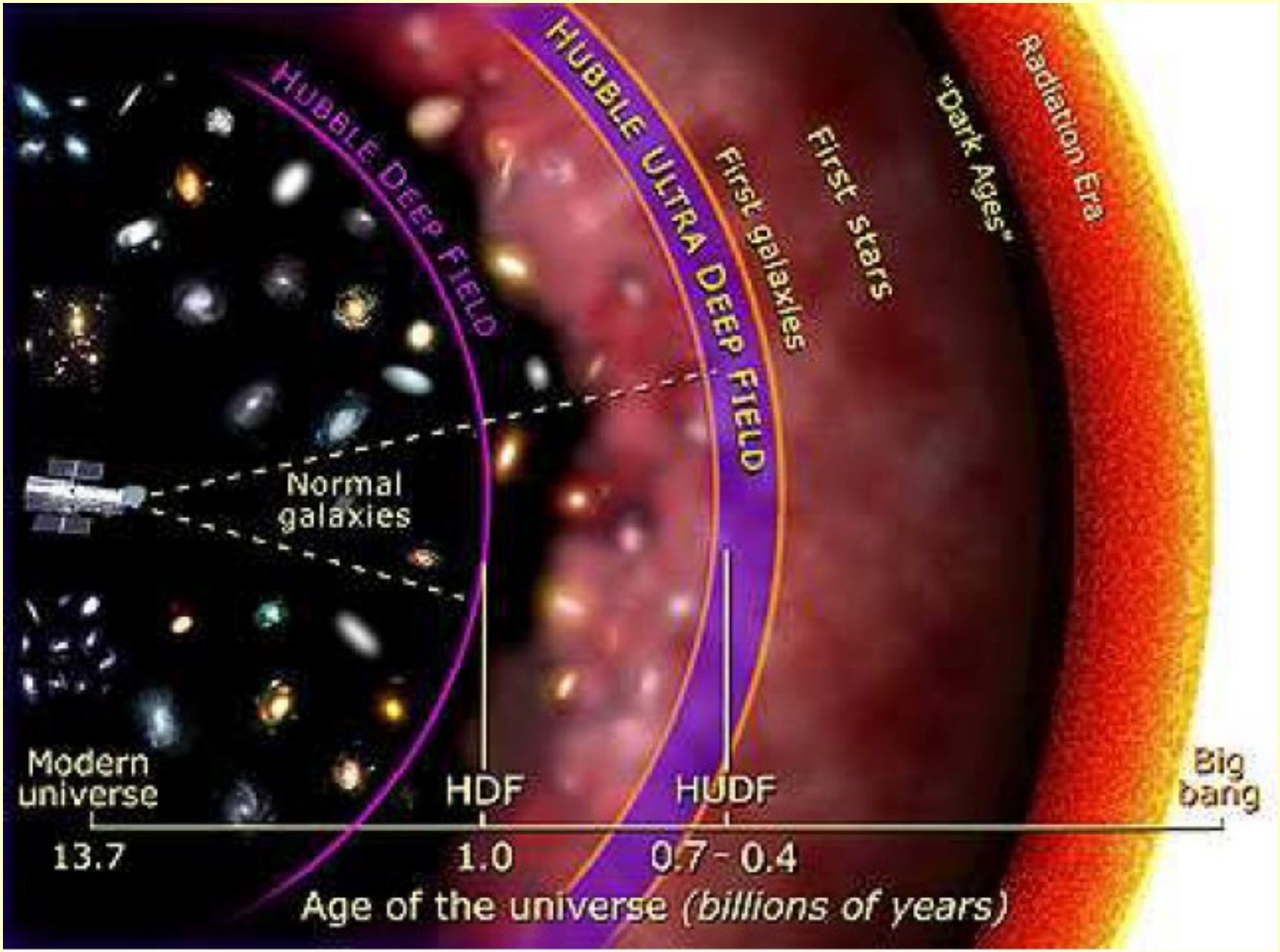

Carte Figurative et Approximative des quantités de Vins Français exportés par mer en 1864
Dressée par Mr. Minard, Inspecteur Général des Ponts et Chaussées en retraite.
Note pour le Tableau graphique.
AMÉRIQUE DU NORD
AMÉRIQUE du SUD
FRANCE
ALLEMAGNE
SUÈDE
AFRIQUE
Algérie
INDE
CHINE
AUSTRALIE
New-York
Bordeaux
Marseille
Rio de Janeiro
Valparaiso
Alexandrie
Cochinchine

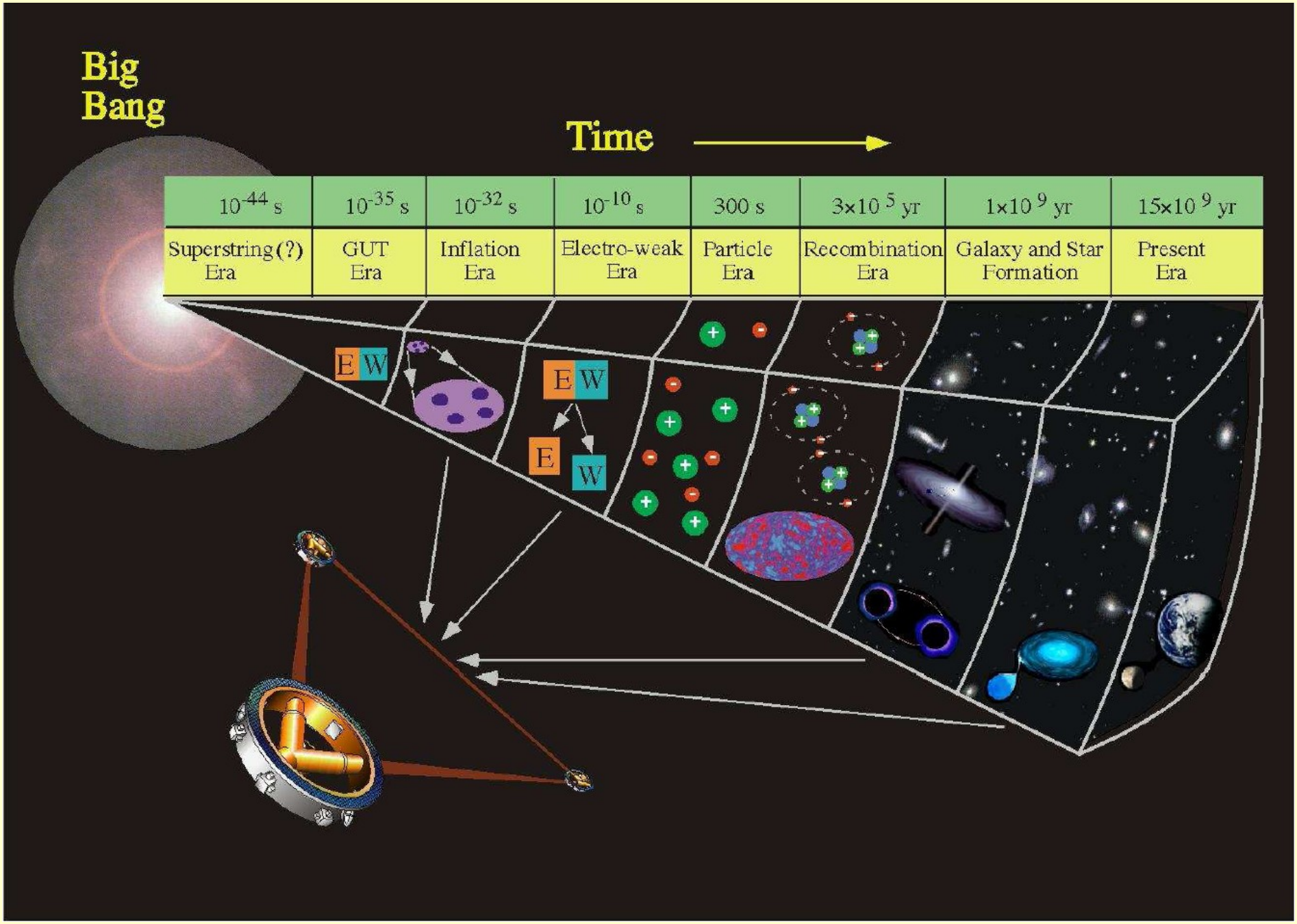

luminosity (solar units)
10^6
10^5
10^4
10^3
10^2
10
1
0.1
10^{-2}
10^{-3}
10^{-4}
10^{-5}
60 M_{Sun}
30 M_{Sun}
10 M_{Sun}
Deneb
Rigel
β Centauri
Spica
Bellatrix
Betelgeuse
Antares
Canopus
Polaris
Aldebaran
Arcturus
Pollux
SUPERGIANTS
GIANTS
MAIN SEQUENCE
Achernar
Vega
Sirius
Procyon
Altair
α Centauri A
α Centauri B
τ Ceti
ε Eridani
61 Cygni A
61 Cygni B
0.3 M_{Sun}
0.1 M_{Sun}
Lacaille 9352
Gliese 725 A
Gliese 725 B
Barnard's Star
Ross 128
Wolf 359
Proxima Centauri
DX Cancri
Sirius B
Procyon B
WHITE DWARFS
Lifetime 10^7 yrs
Lifetime 10^8 yrs
Lifetime 10^9 yrs
Lifetime 10^{10} yrs
Lifetime 10^{11} yrs
1 Solar Radius
0.1 Solar Radius
O
B
A
F
G
K
M
30,000
increasing temperature
10,000
6,000
3,000
decreasing temperature
surface temperature (Kelvin)



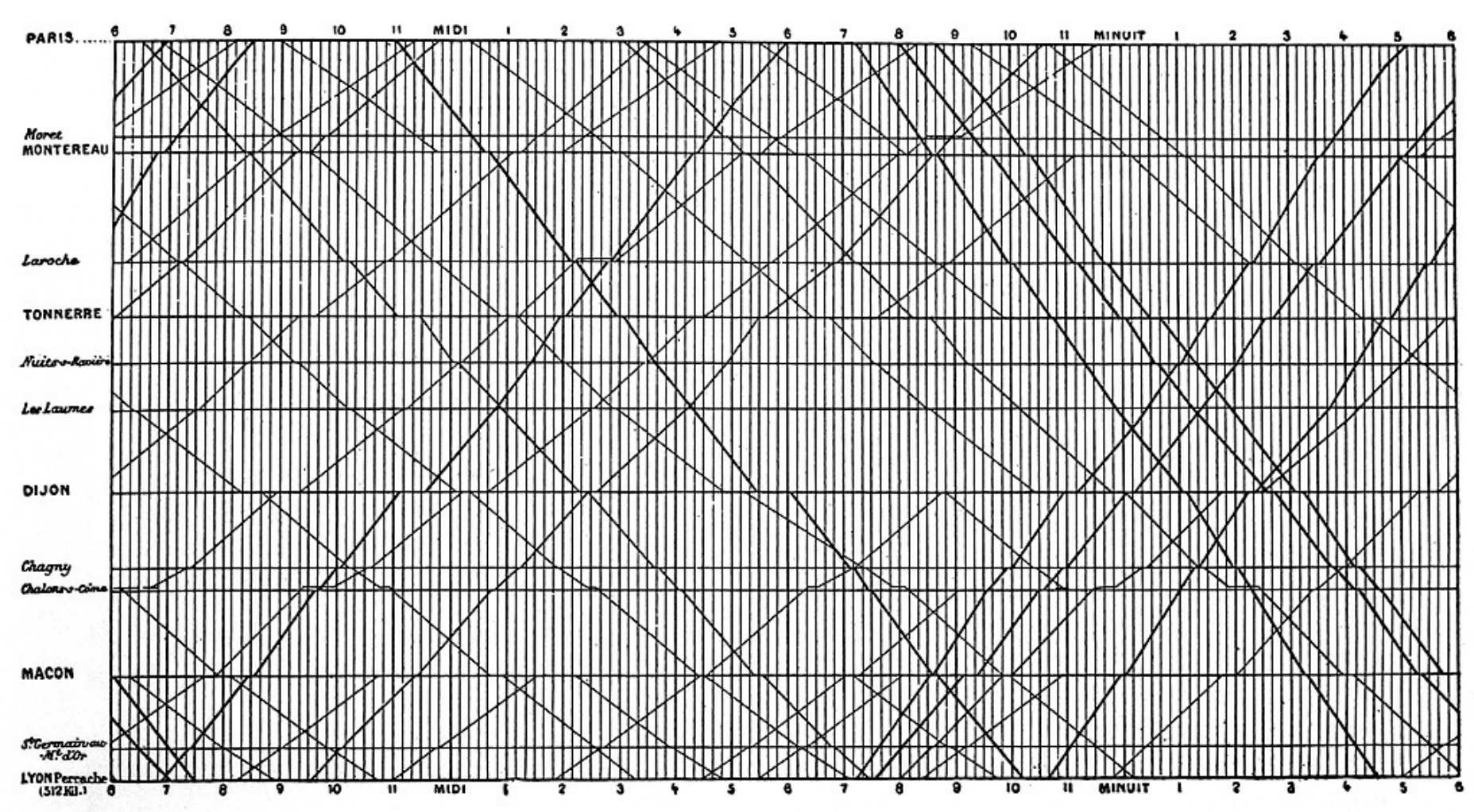
Classical motifs

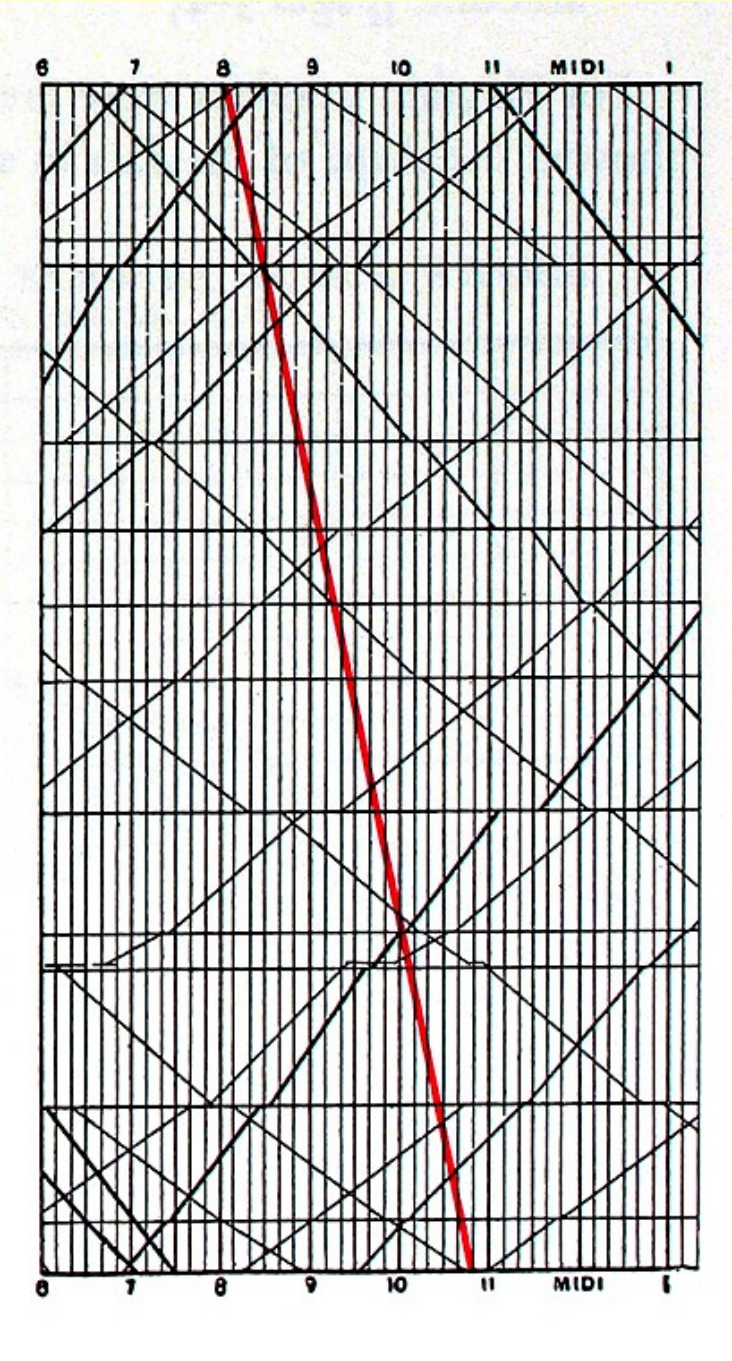



Hubble Deep Field
Hubble Ultra Deep Field
First galaxies
First stars
"Dark Ages"
Radiation Era
Normal galaxies
Modern universe
HDF
HUDF
Big bang
13.7
1.0
0.7 - 0.4
Age of the universe (billions of years)


Big Bang
Time
10^{-44} s
10^{-35} s
10^{-32} s
10^{-10} s
300 s
3×10^{5} yr
1×10^{9} yr
15×10^{9} yr
Superstring (?) Era
GUT Era
Inflation Era
Electro-weak Era
Particle Era
Recombination Era
Galaxy and Star Formation
Present Era
E W
E
W

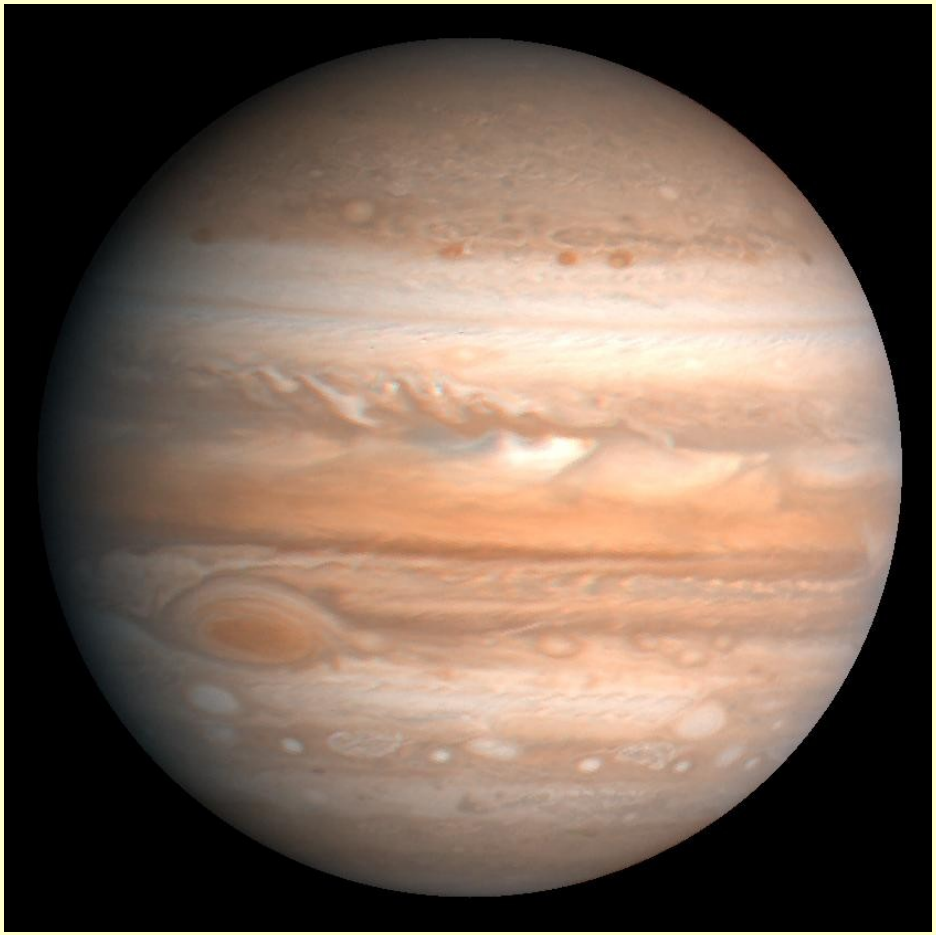
From Paris to Lyon

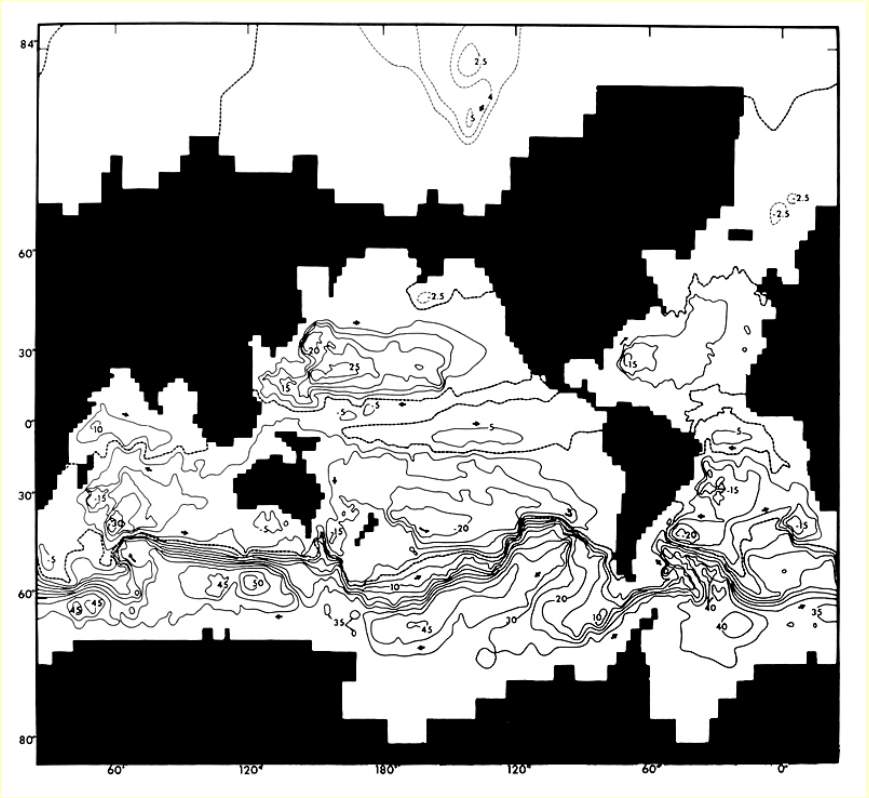




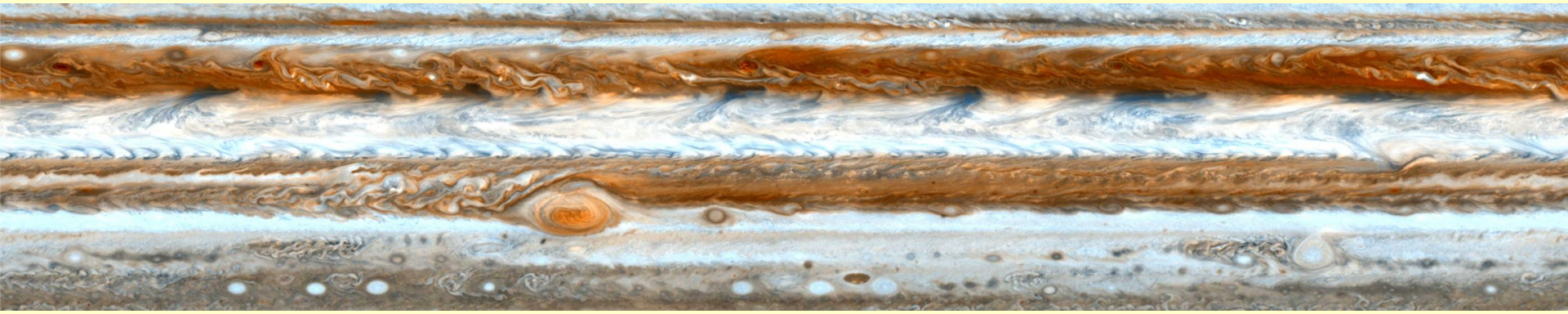
Now they are faster

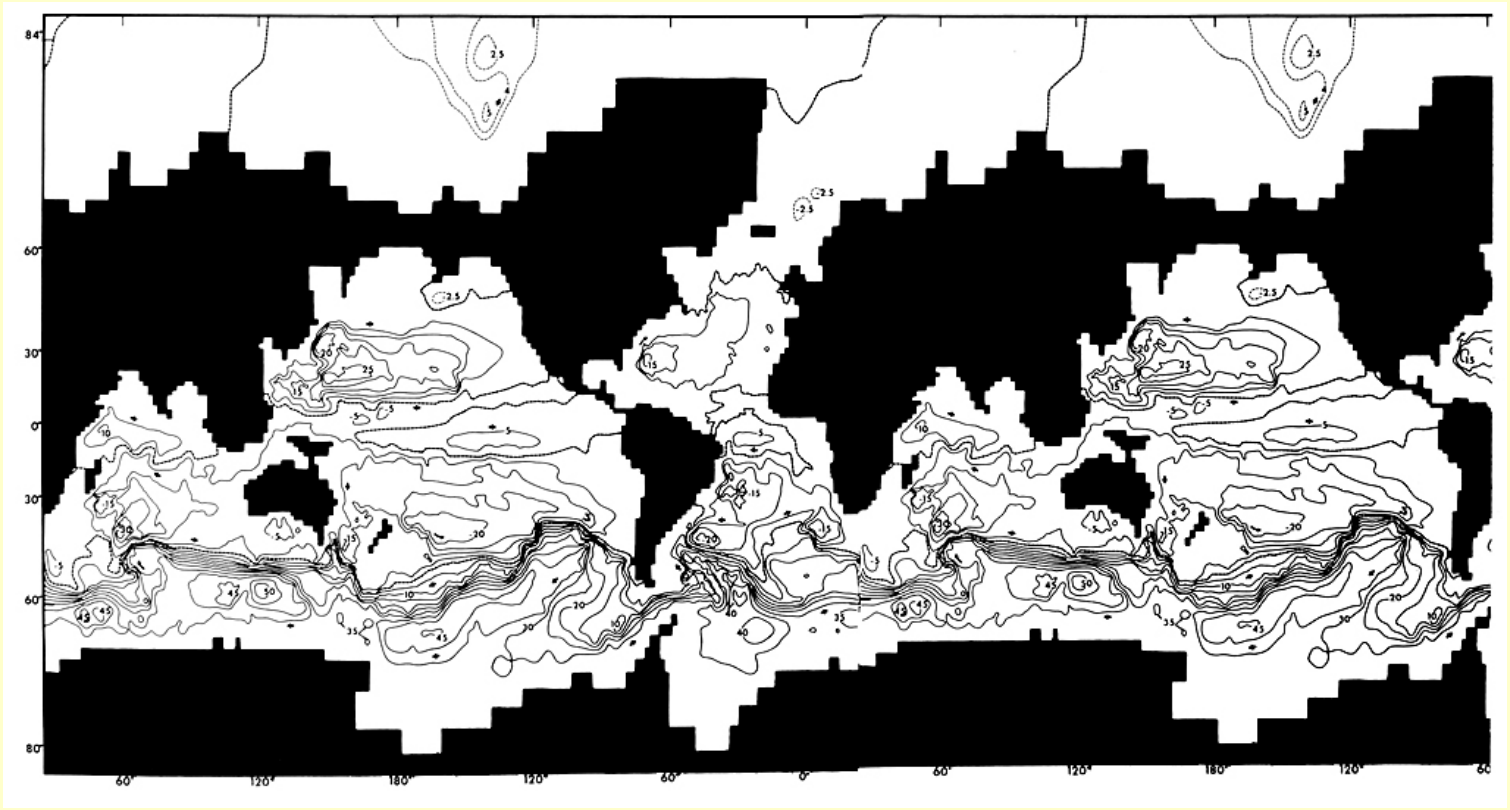
Two planets





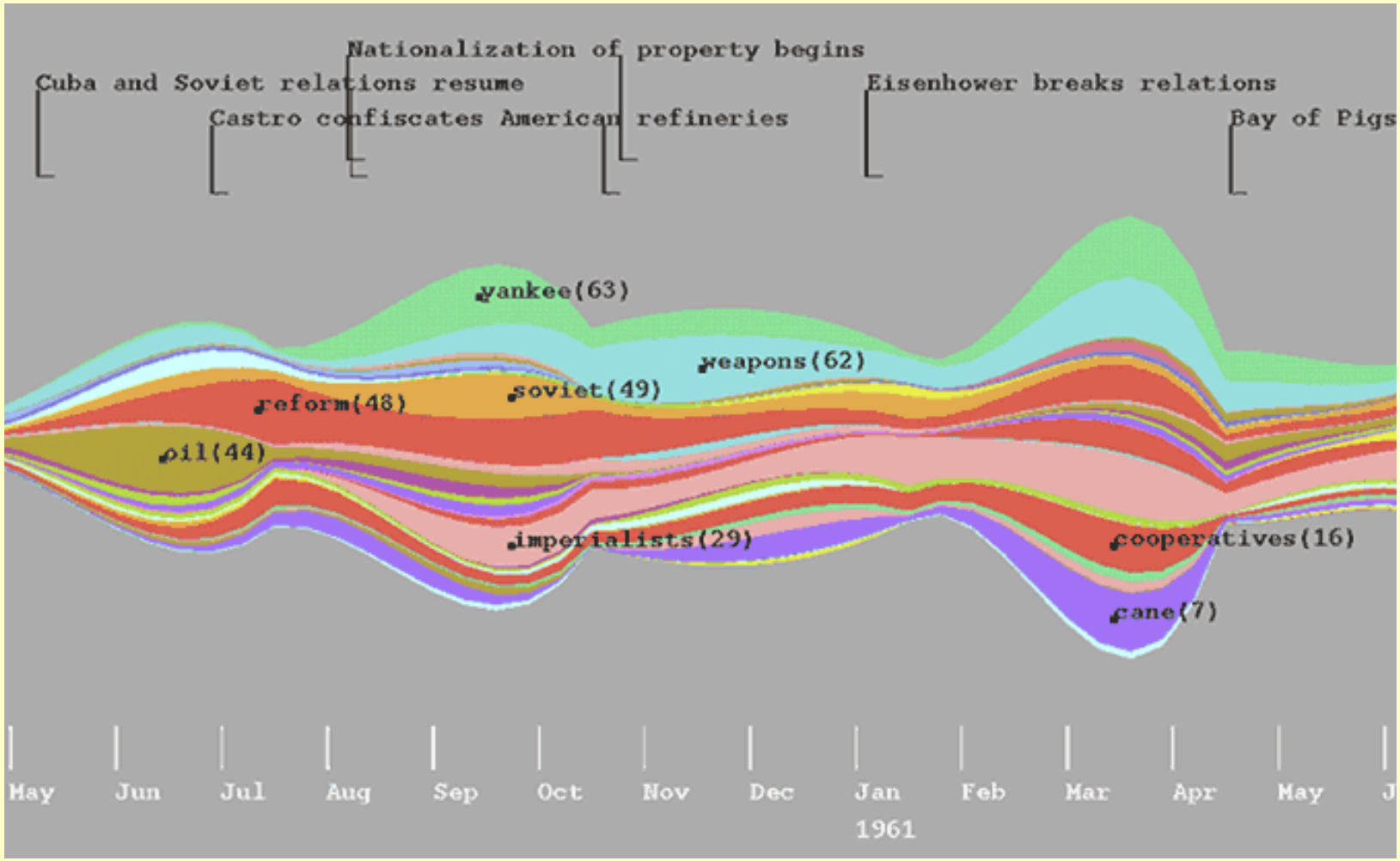
Two planets again





The river flows from left to right through time

Colored currents flowing with the river narrow or widen to depict the strength of individual topics



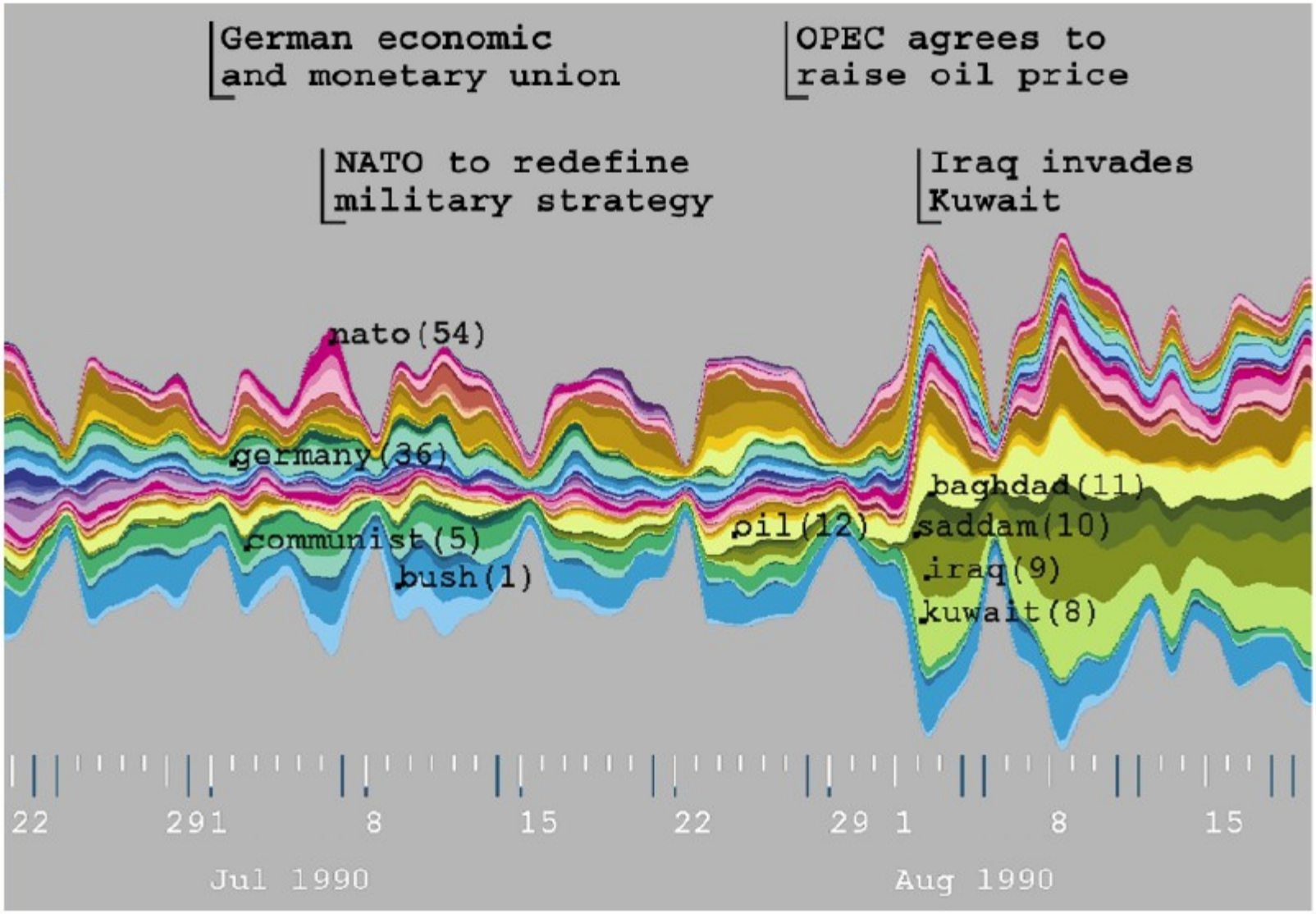
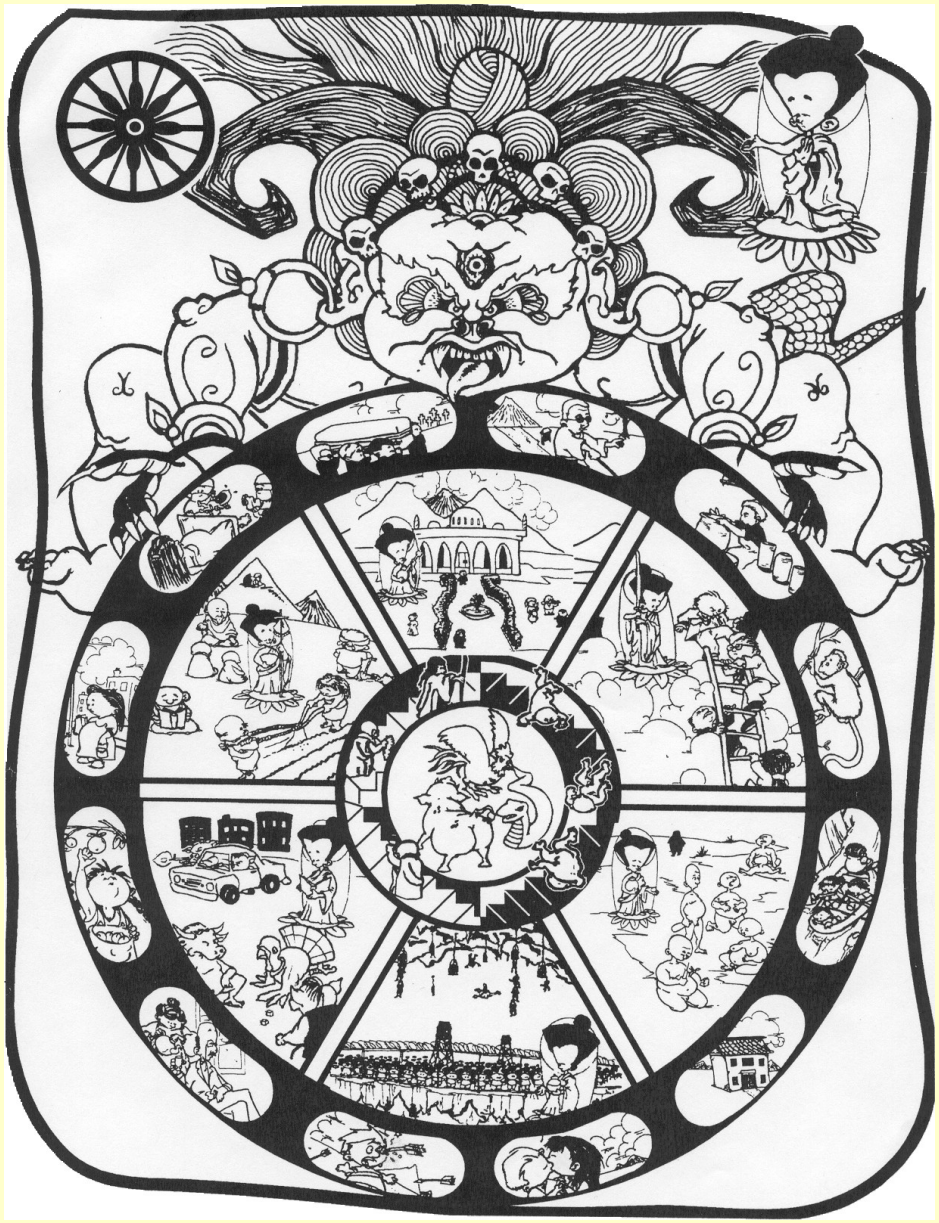
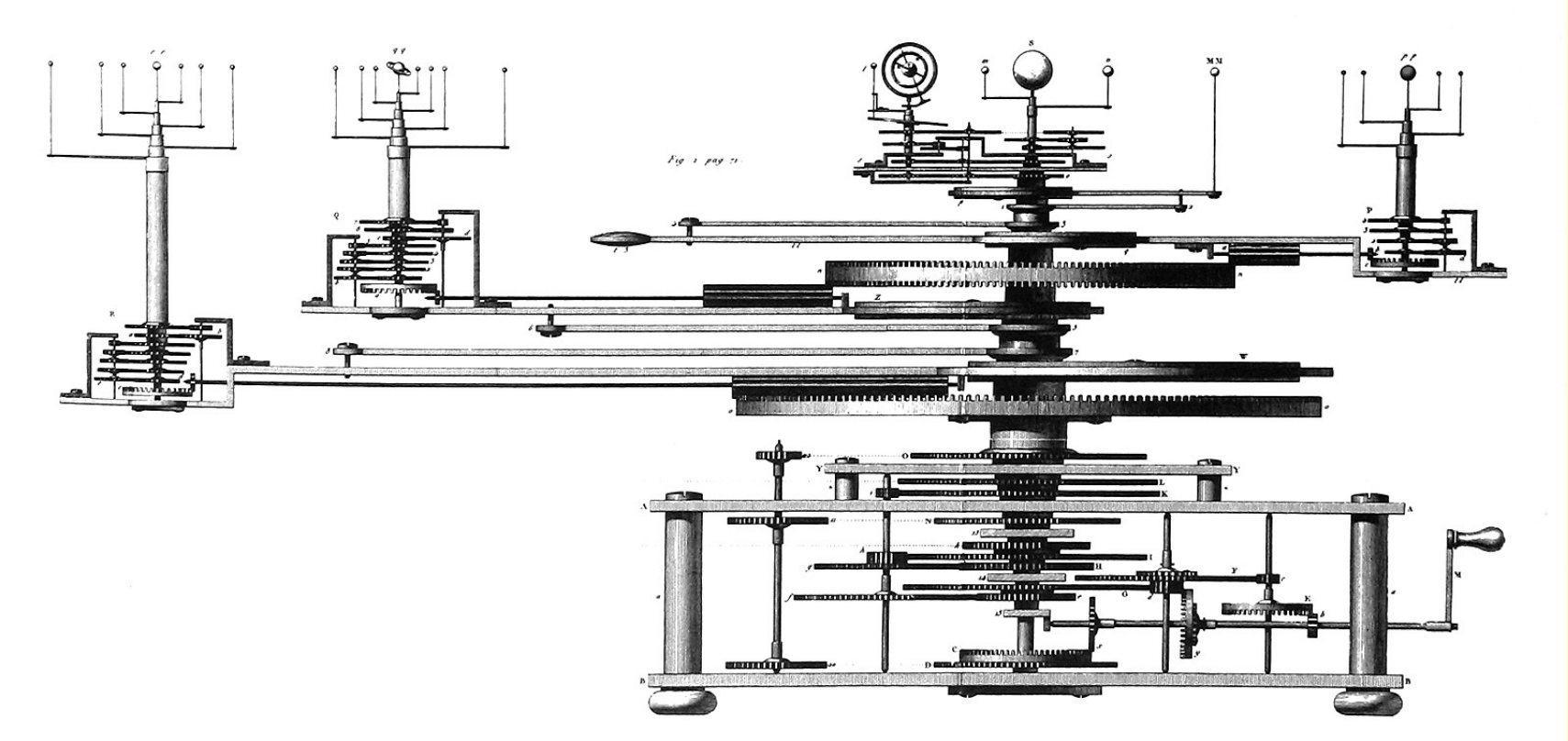


Figure 3: AP data from July - August 1990. A wide current in the river indicates heavy use of a topic, while changes in color distribution correlate to changes in themes.

Phases





Analog computing of phases

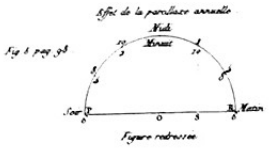


Fig. 4 pag. 98

Fig. 6 pag. 97

pour une lunette qui renverse.

Fig. 3

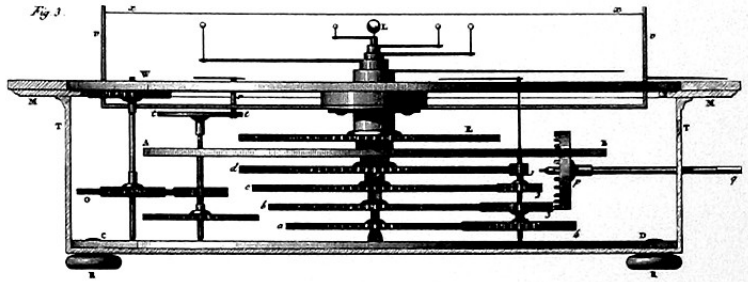
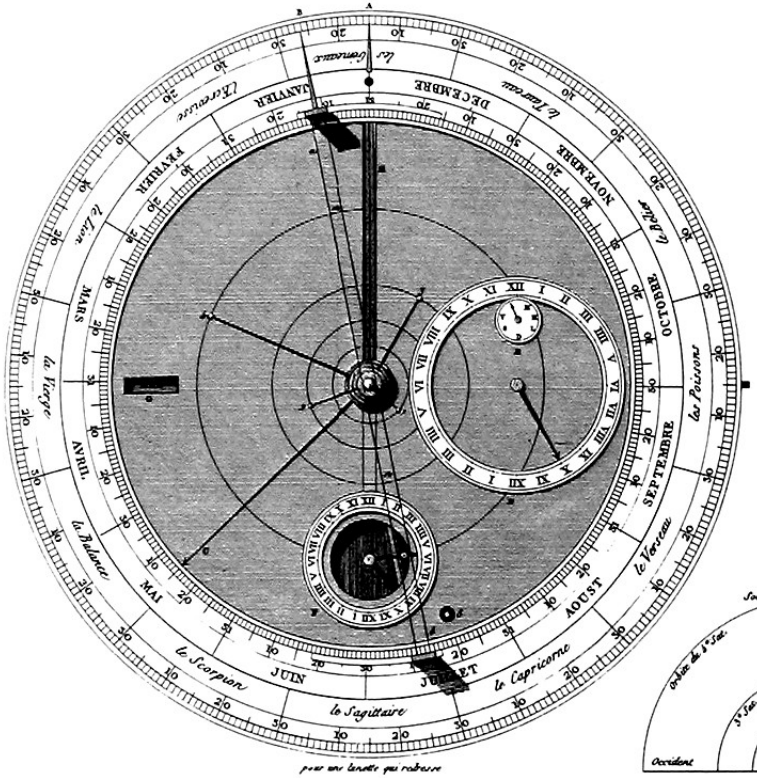


Fig. 1 pag. 94



pour une lunette qui renverse

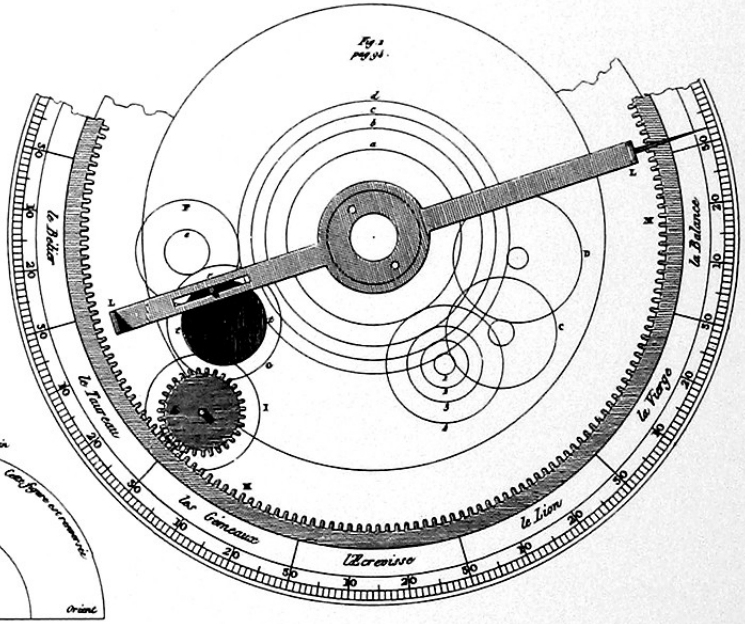
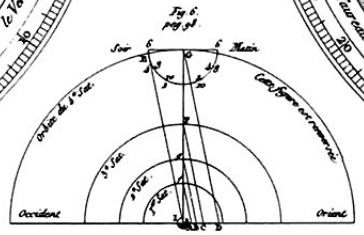
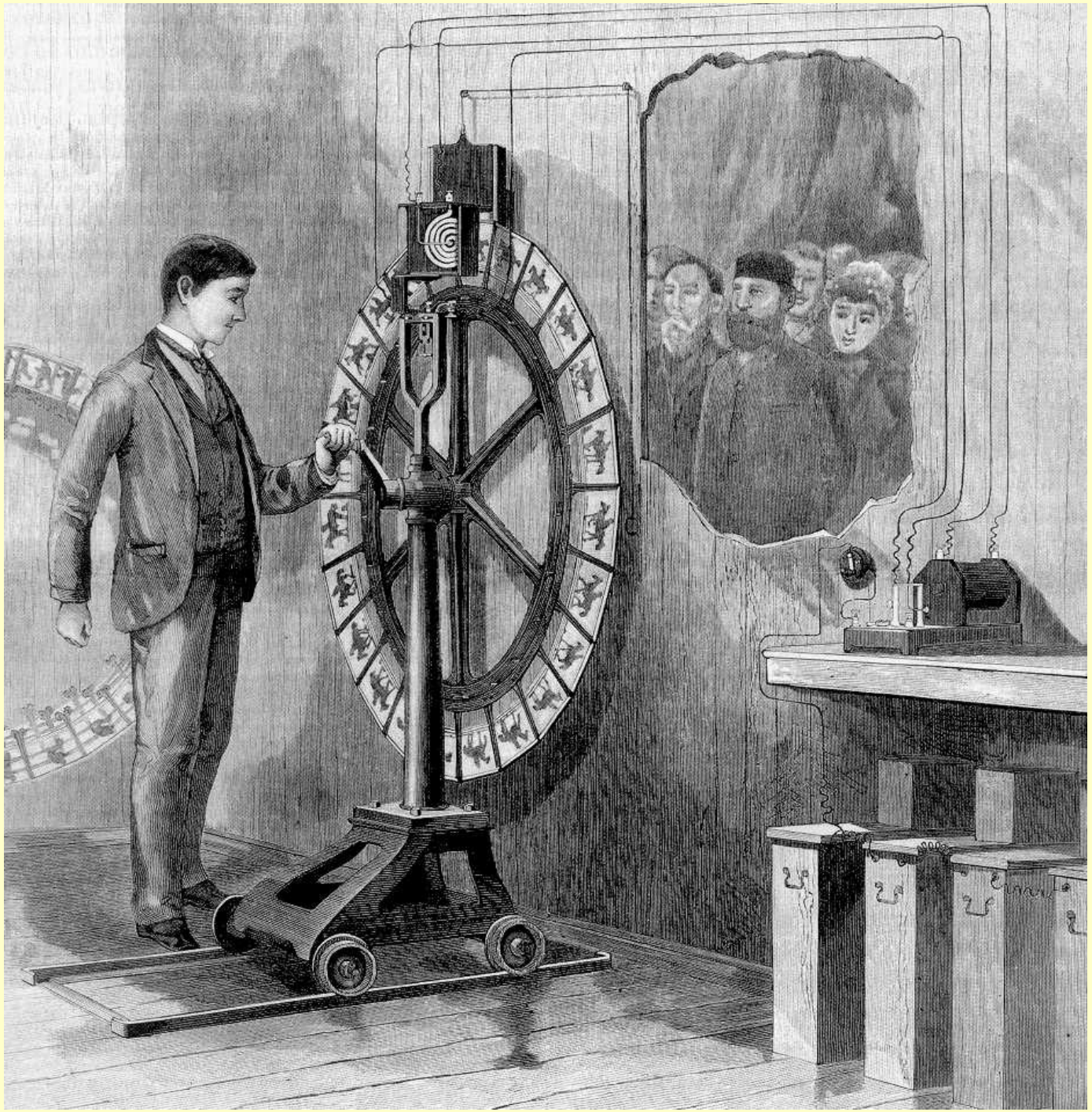


Fig. 1 pag. 94.

Fig. 6 pag. 94.





Tachyscope

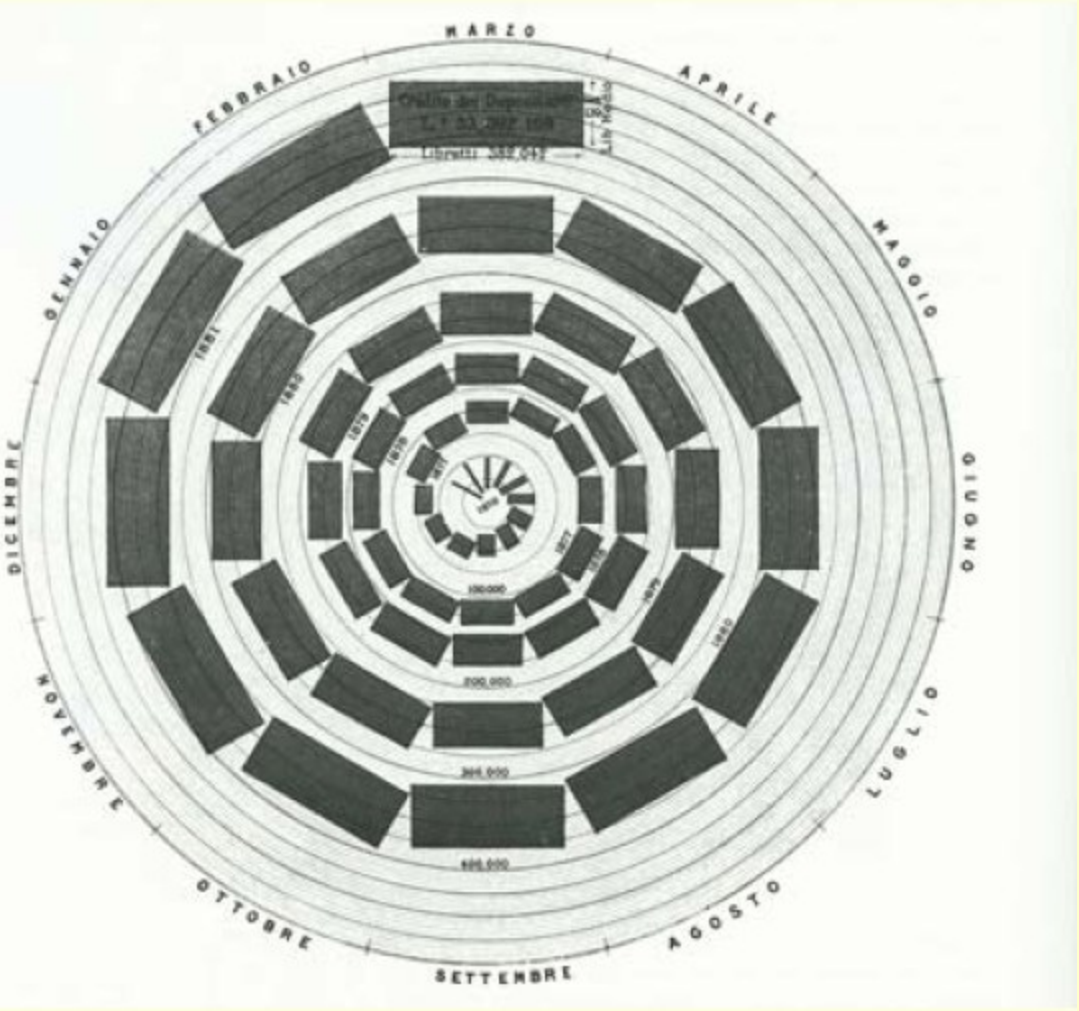
+

Phase computing

=

Peltoscope

Spiral Graphs



History of Italian post office A. Gabaglio, 1888

Spirals
(not galaxies)

Old idea, new data

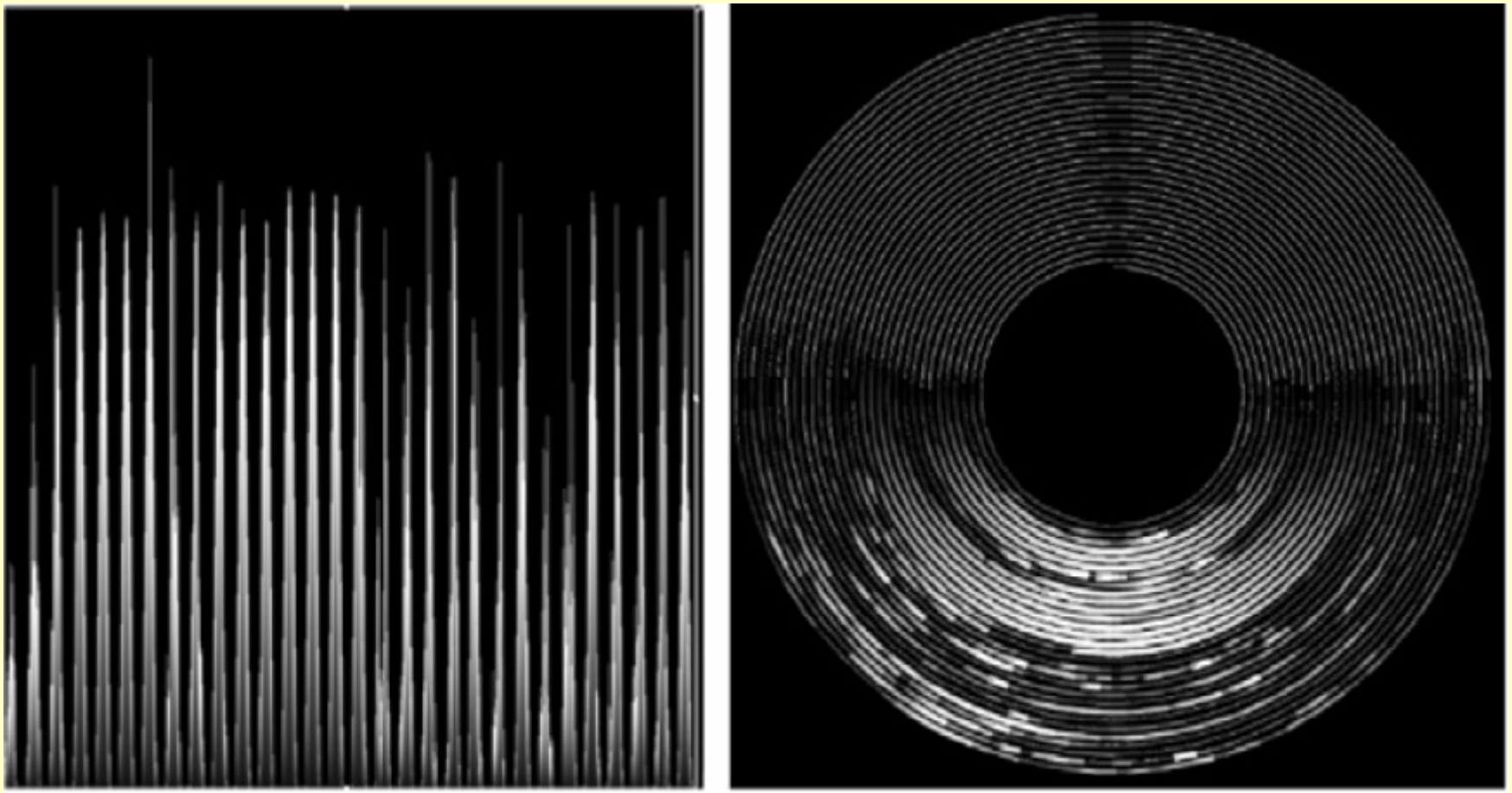


Figure 1:Two visualizations of sunshine intensity using about the same screen real estate and the same color coding scheme. In the spiral visualization it is much easier to compare days, to spot cloudy time periods, or to see events like sunrise and sunset.

Phase

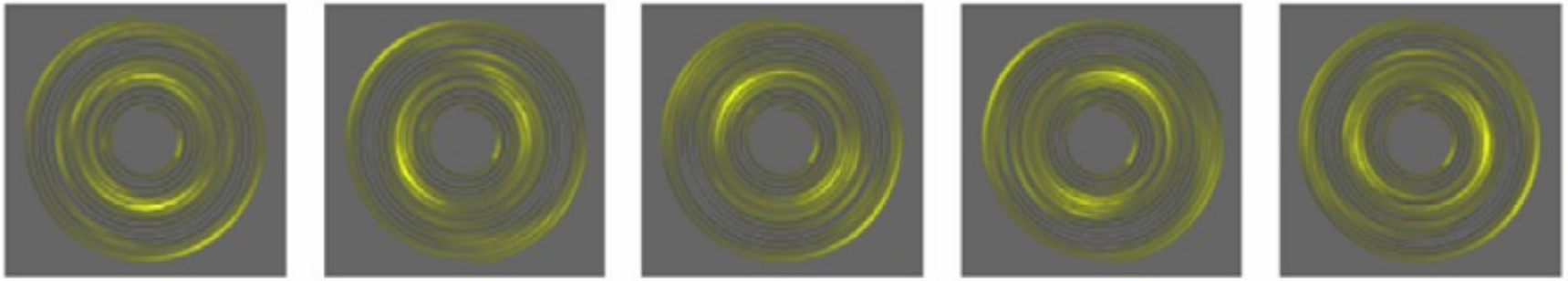


Figure 3:Visualizations of the same data with continously changing cycle length. The period in the data can be found visually, i.e. the visual system is used to detect periodic patterns in the data exploiting the spatial layout on the spiral. In this example, the visual system detects a significant structure in the middle image, which unveils the corresponding periodicity in the data.

$$\varphi_P(t) = tP^{-1} - Int(tP^{-1}) = Frac(tP^{-1})$$

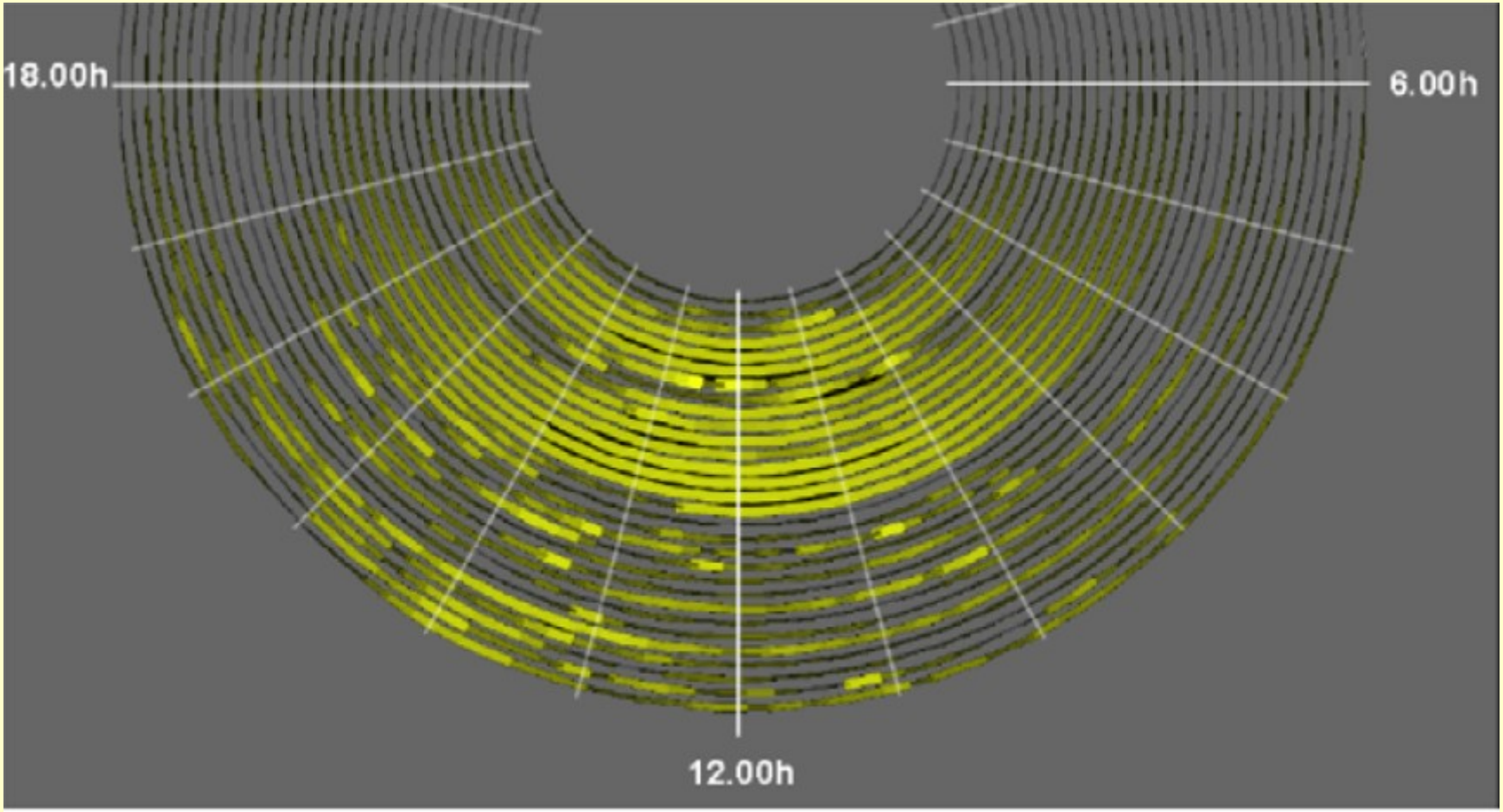


Figure 5:A possible way to add informative scales to the parametric dimensions of a spiral.

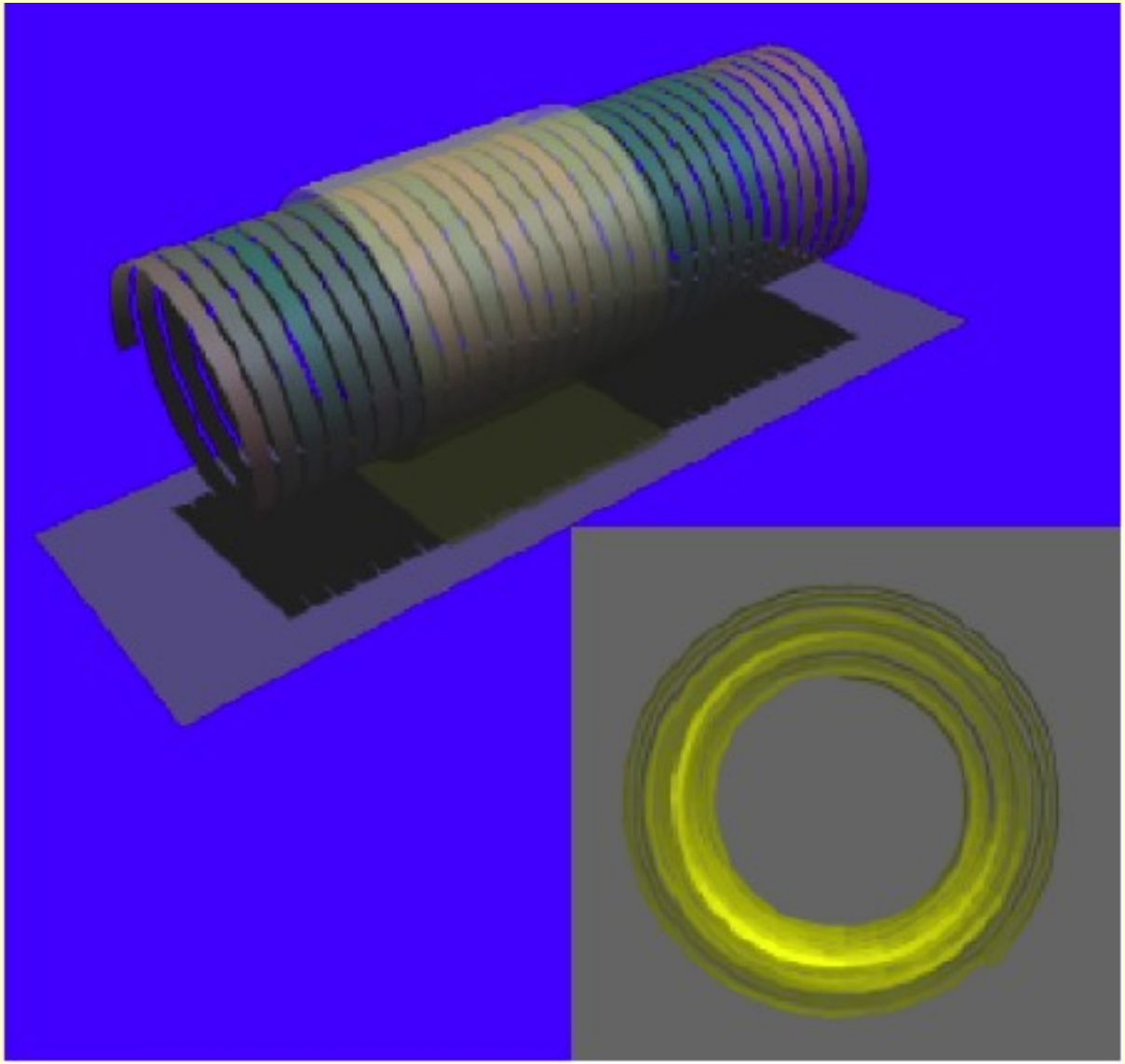
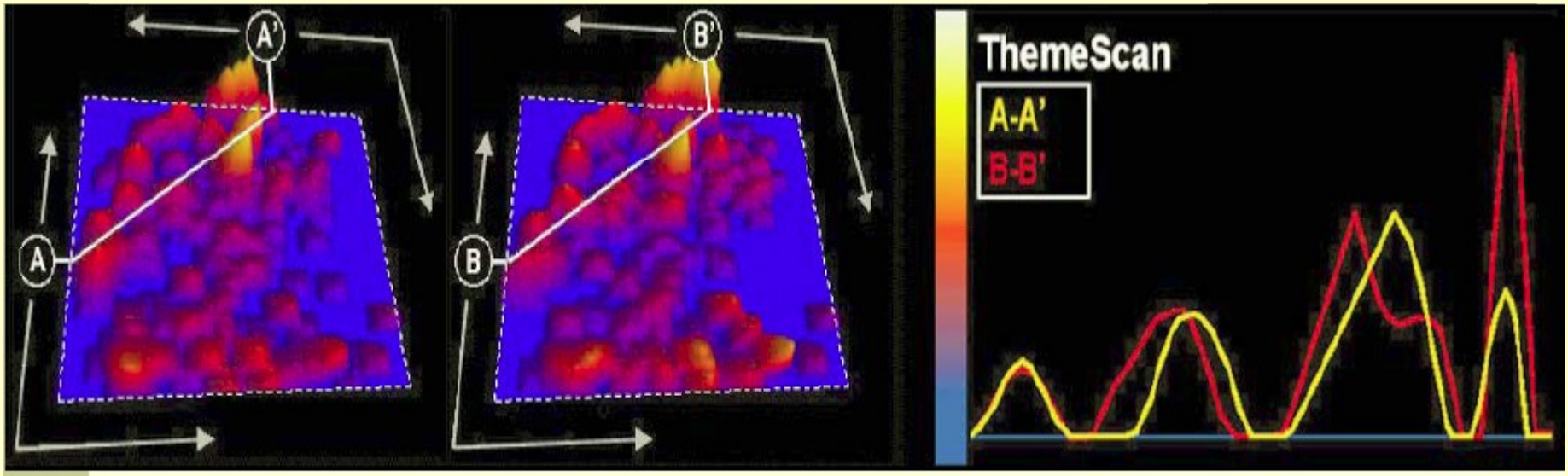
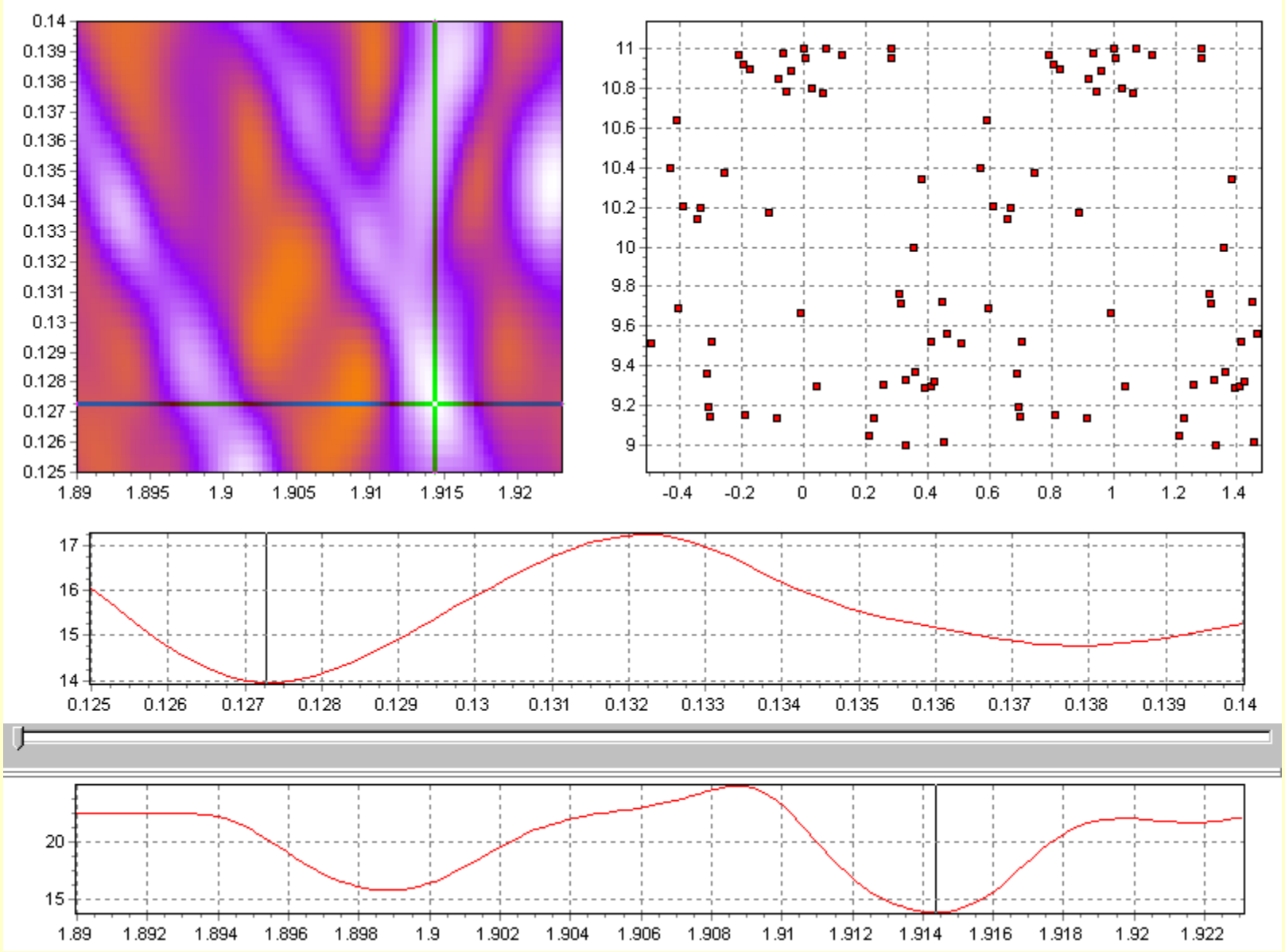


Figure 6:Using a helix in 3D to support intuitive browsing through a large data set.

Scanning

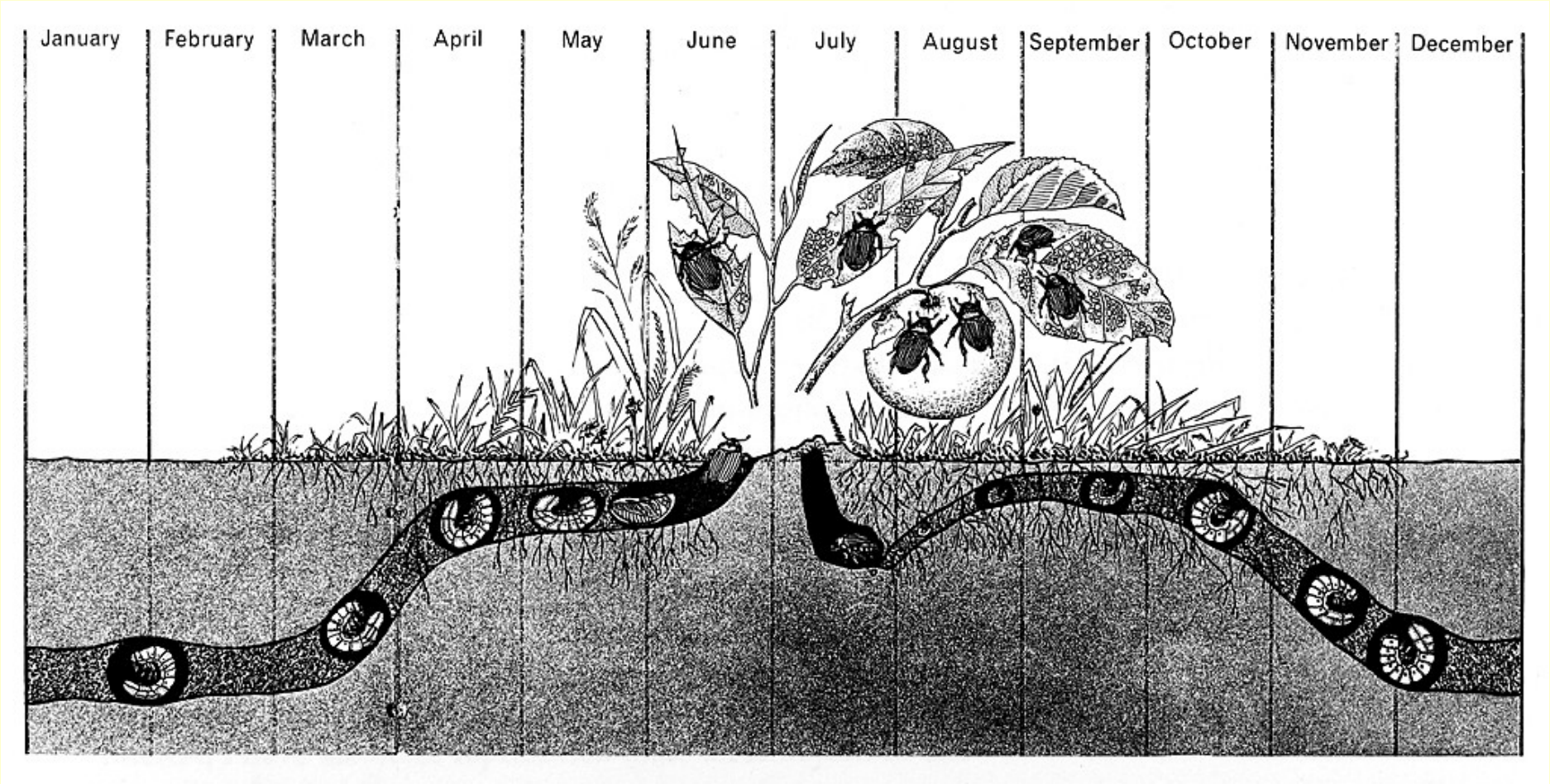


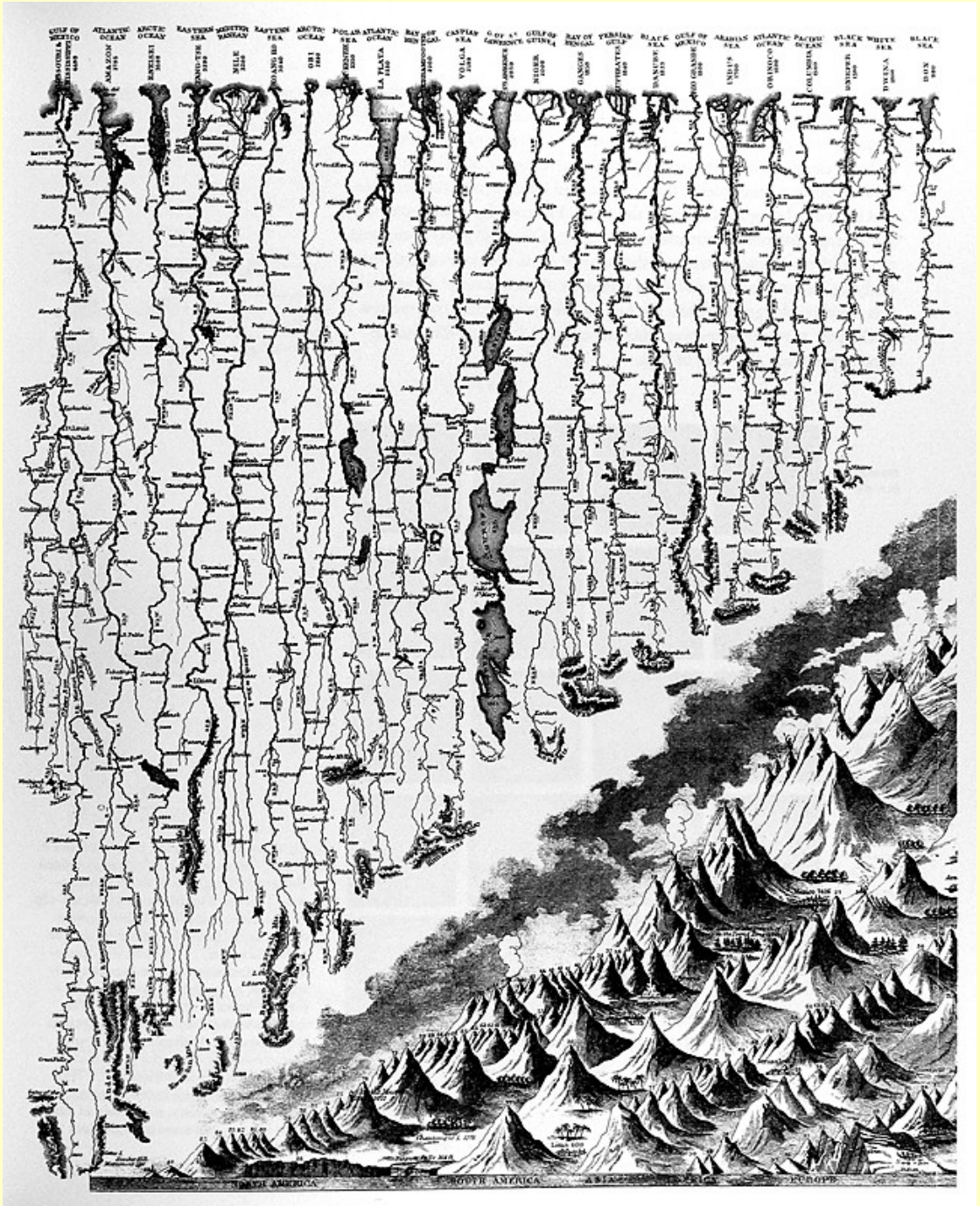
ThemeScan visualization of changes between time slices


0.14
0.139
0.138
0.137
0.136
0.135
0.134
0.133
0.132
0.131
0.13
0.129
0.128
0.127
0.126
0.125
1.89
1.895
1.9
1.905
1.91
1.915
1.92
11
10.8
10.6
10.4
10.2
10
9.8
9.6
9.4
9.2
9
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
1.2
1.4
17
16
15
14
0.125
0.126
0.127
0.128
0.129
0.13
0.131
0.132
0.133
0.134
0.135
0.136
0.137
0.138
0.139
0.14
20
15
1.89
1.892
1.894
1.896
1.898
1.9
1.902
1.904
1.906
1.908
1.91
1.912
1.914
1.916
1.918
1.92
1.922

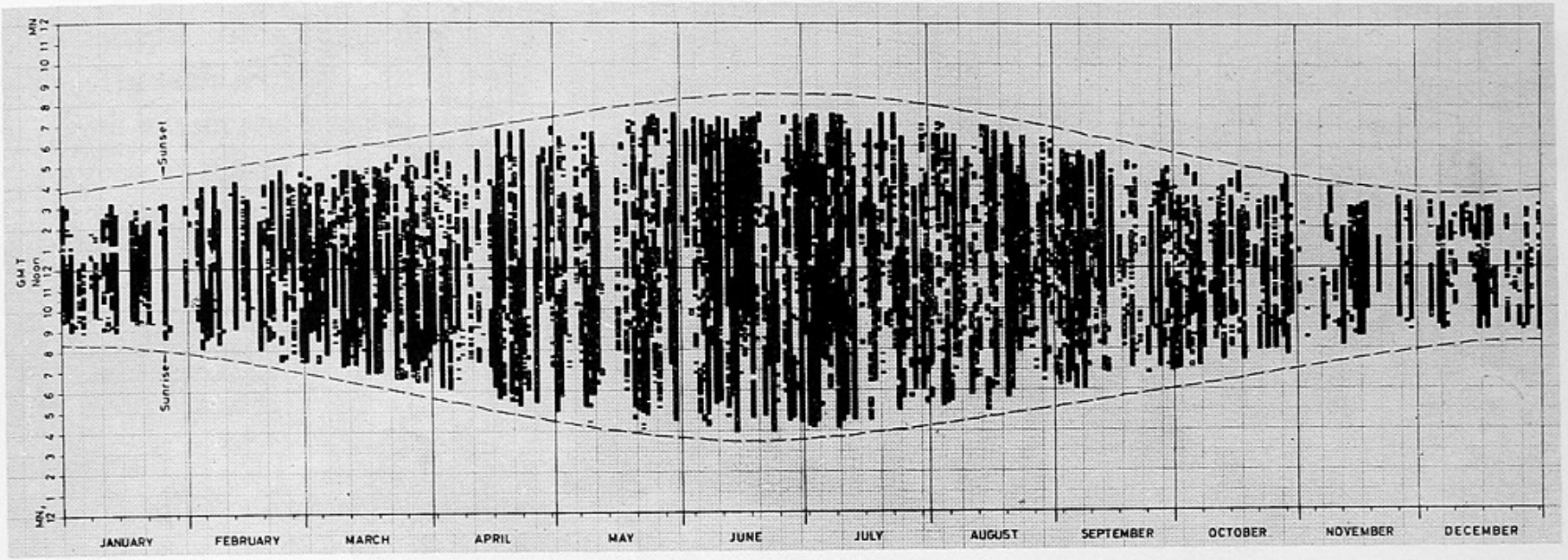
Space and time

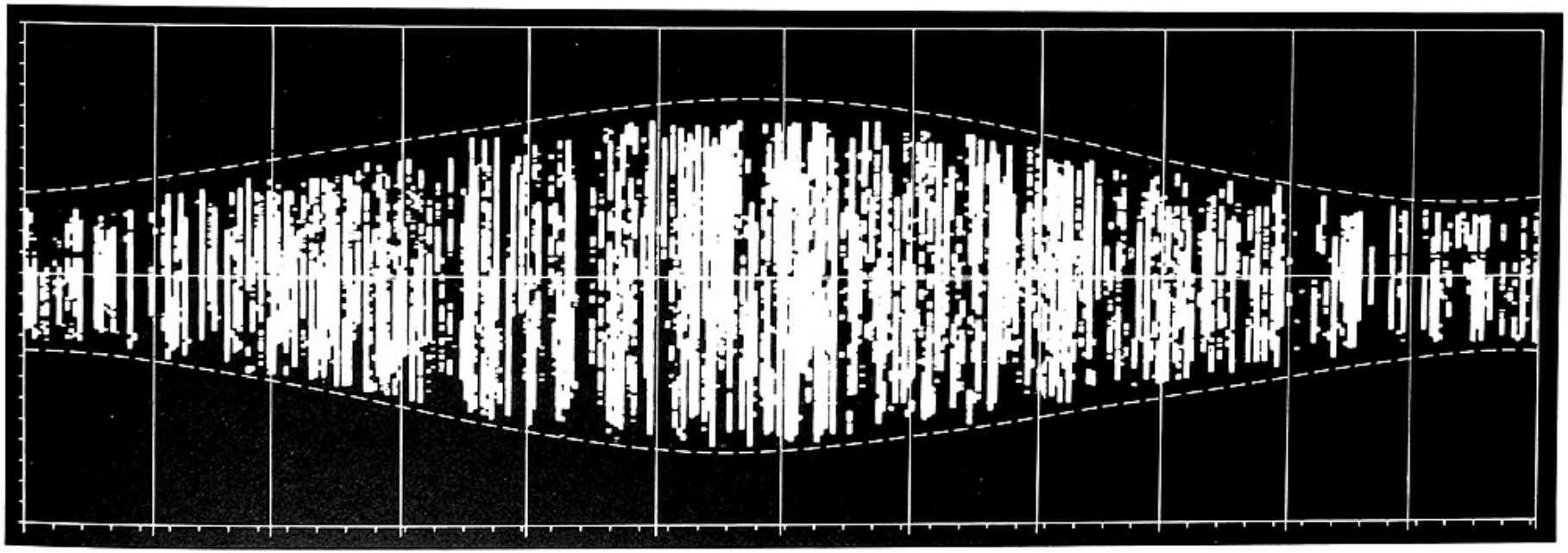
Life circle of Japanese Beetles L. Newman, Man and Insects, 1965



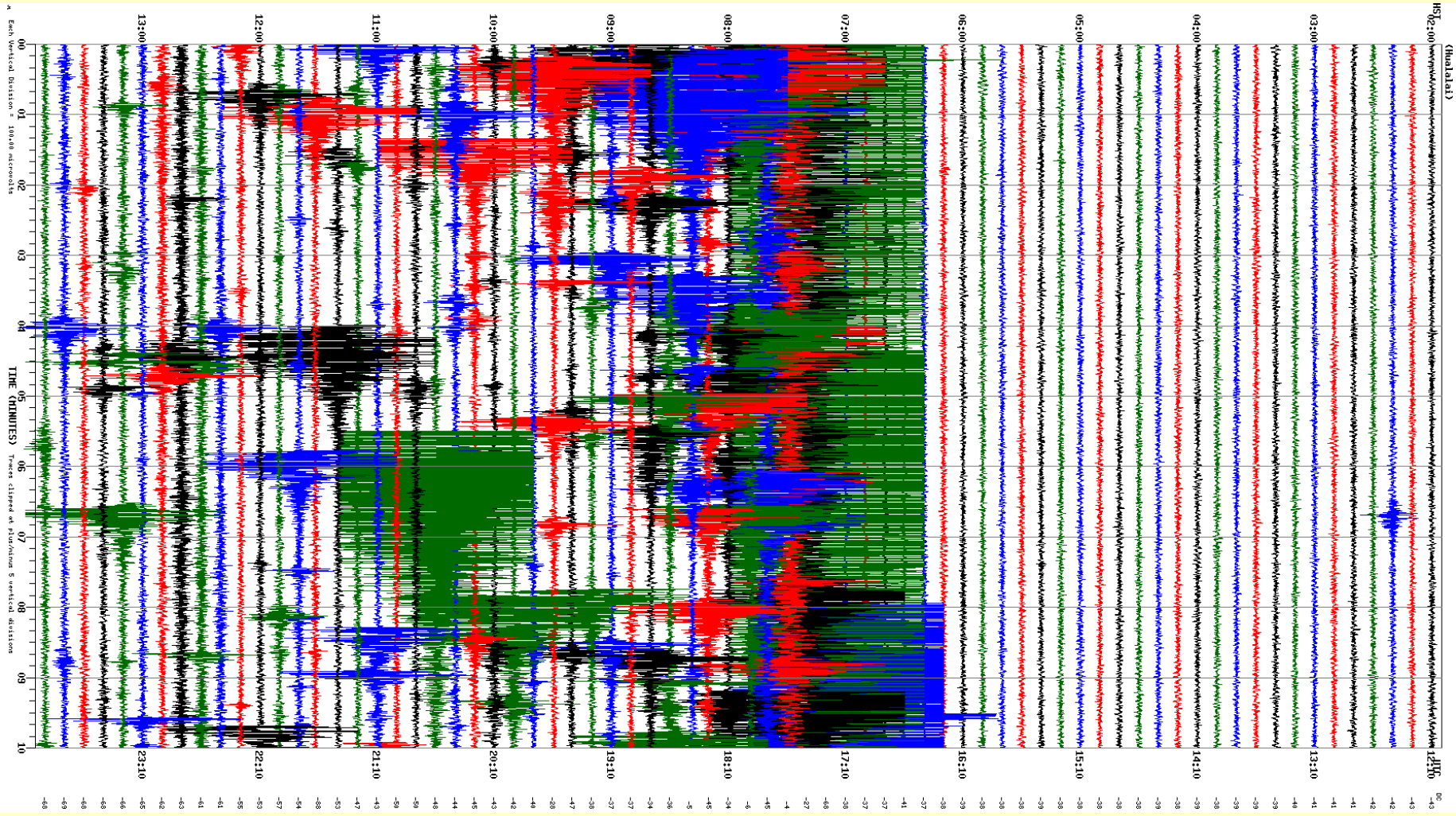


Longest rivers

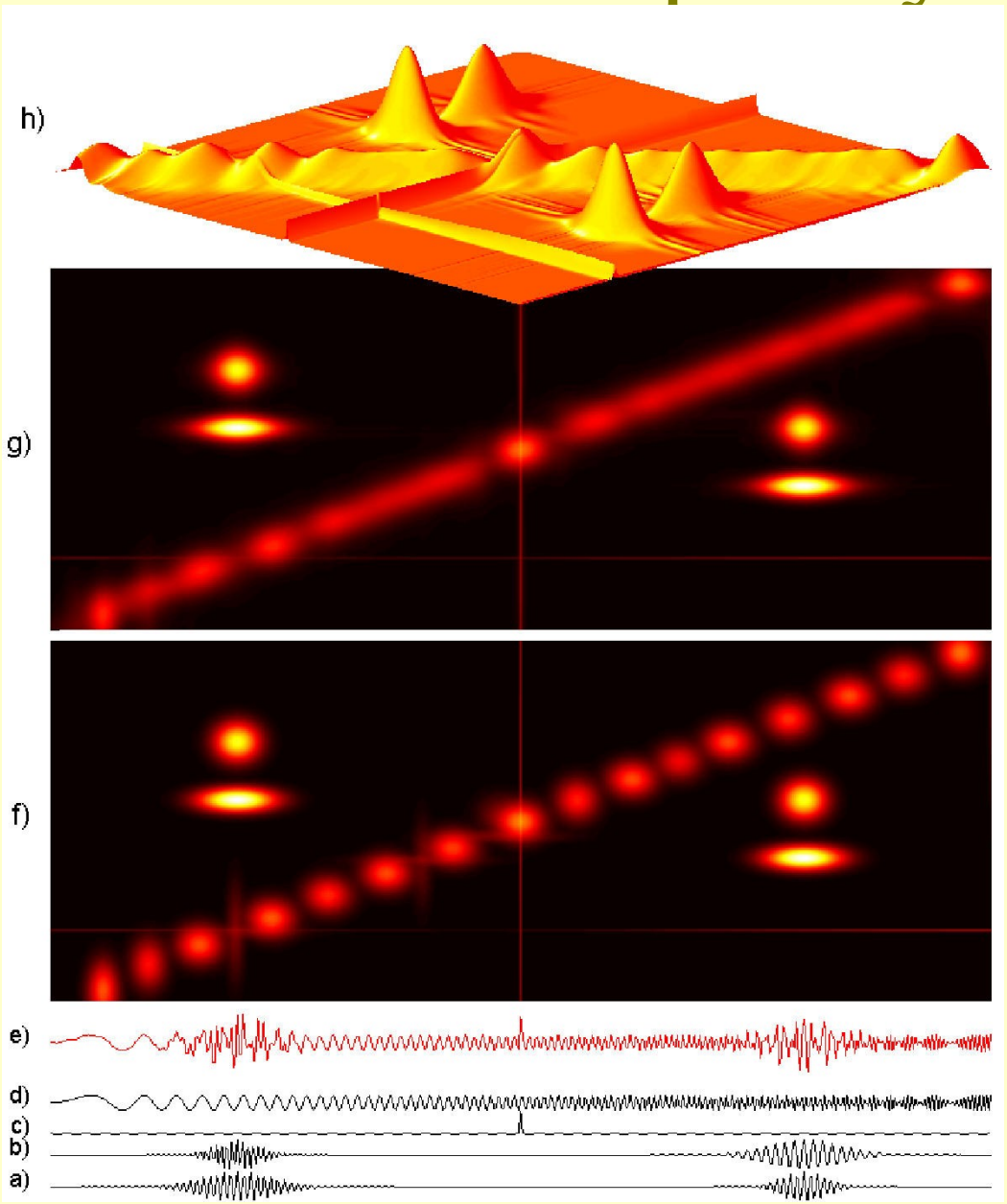

GMT
MN
Noon
Sunset
Sunrise
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER

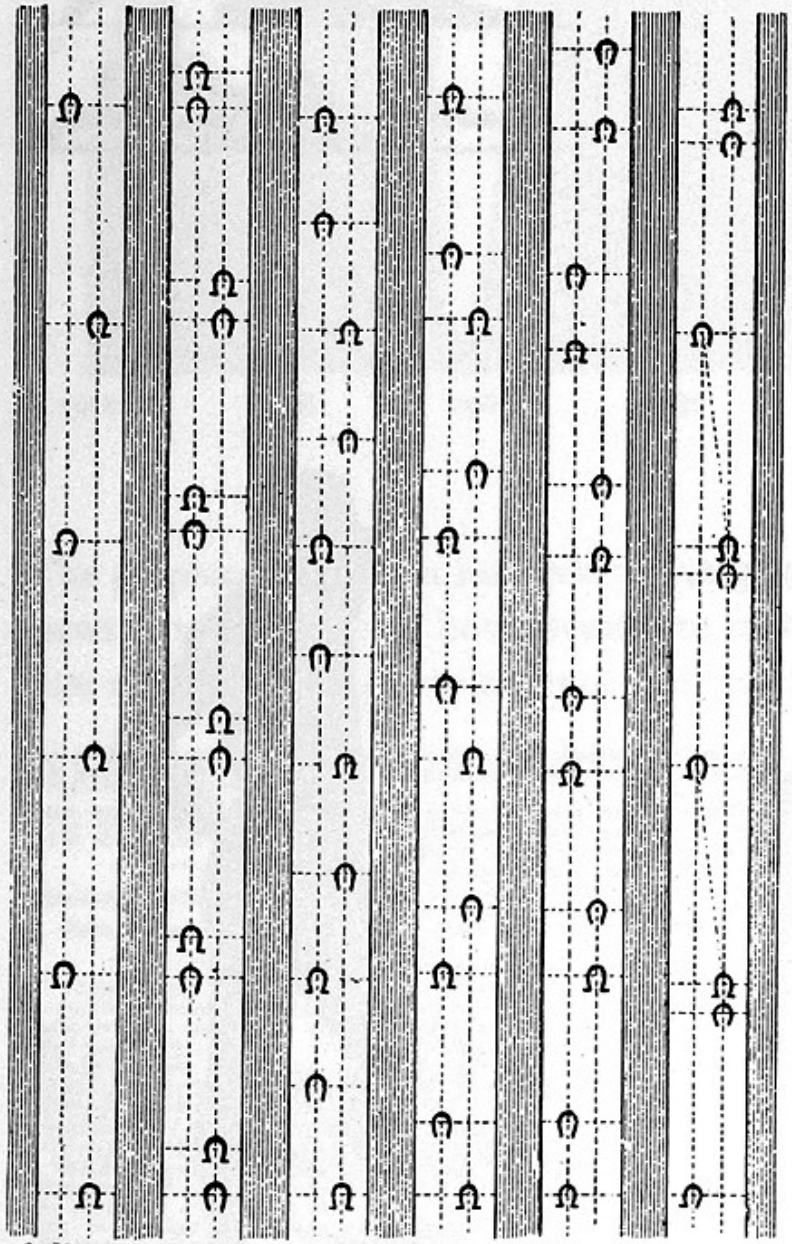


Color coding

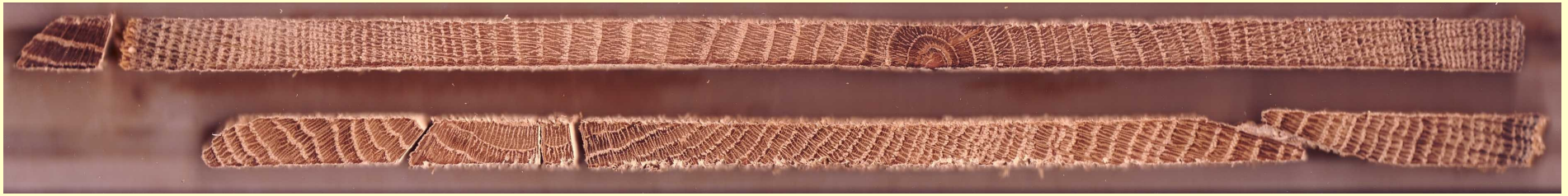


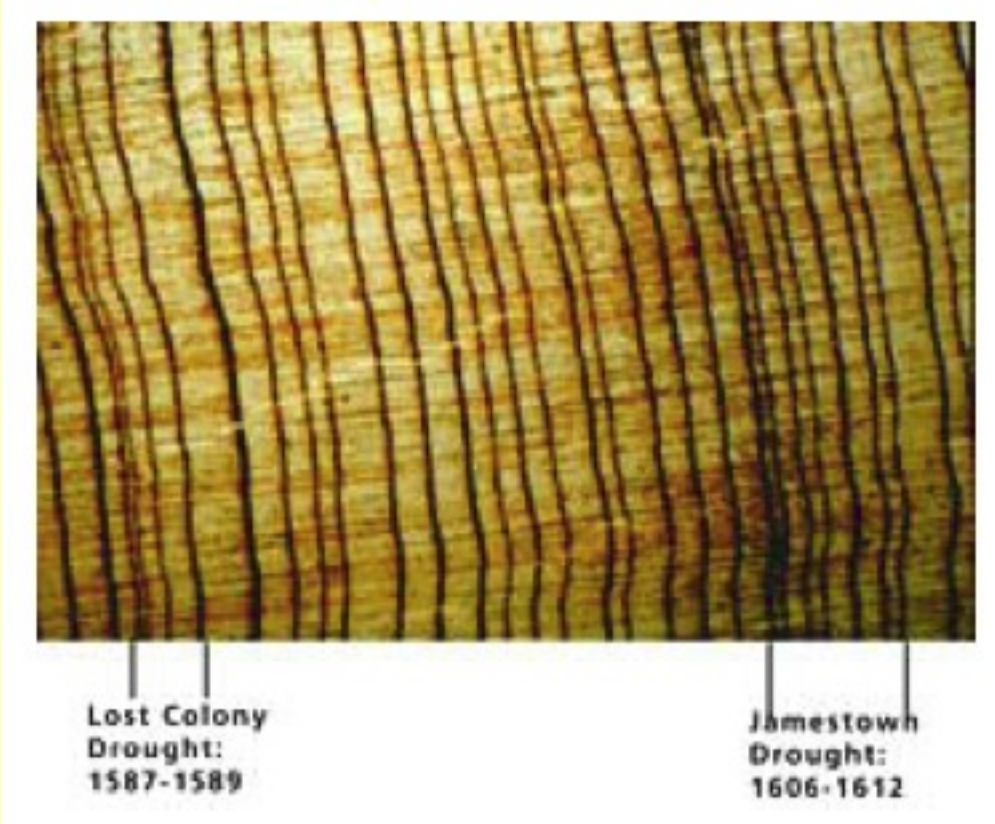
Time and frequency



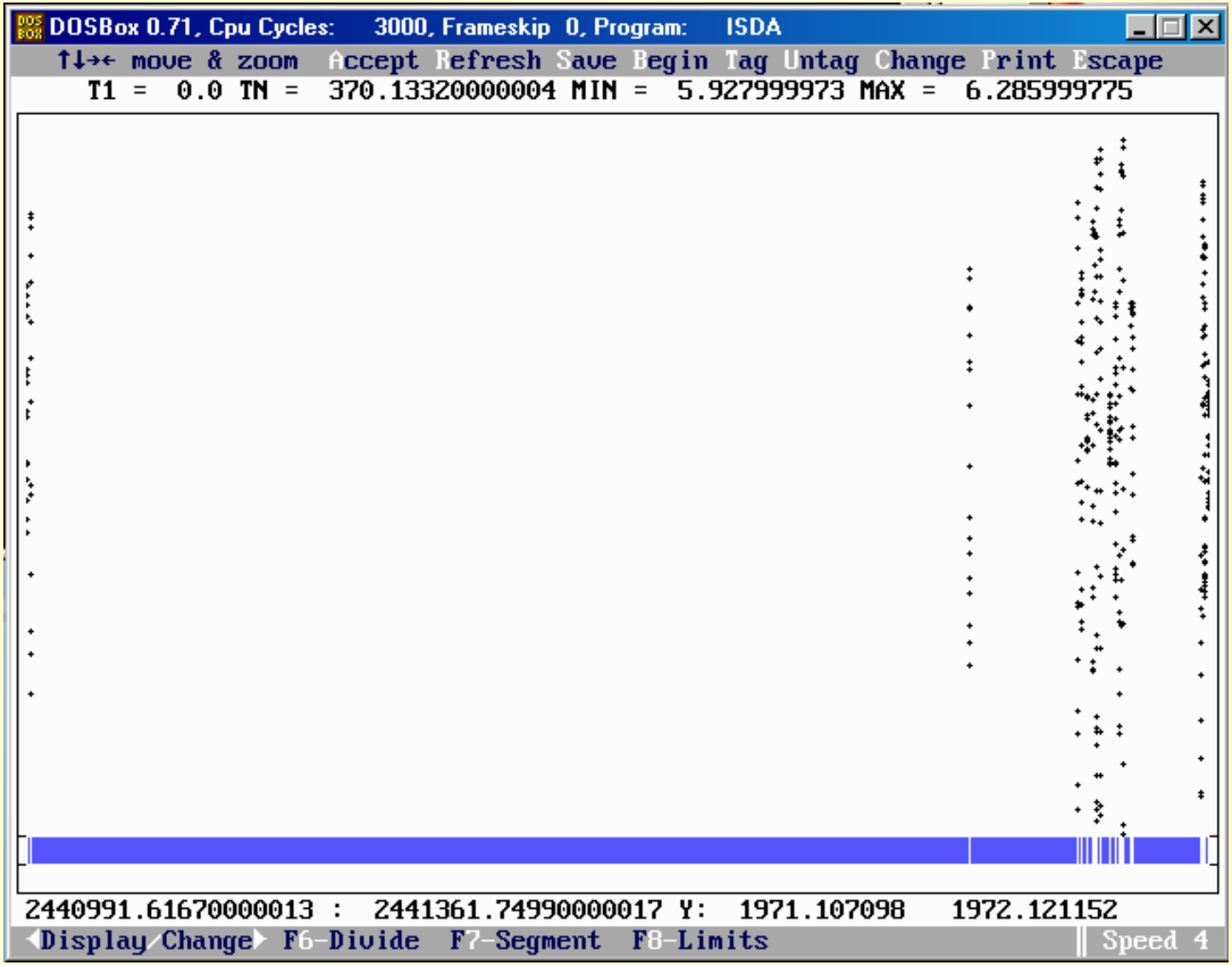

Ordinary walk.
Walk (long stride).
Quick walk.
Amble.
Jog-trot.
Gallop.

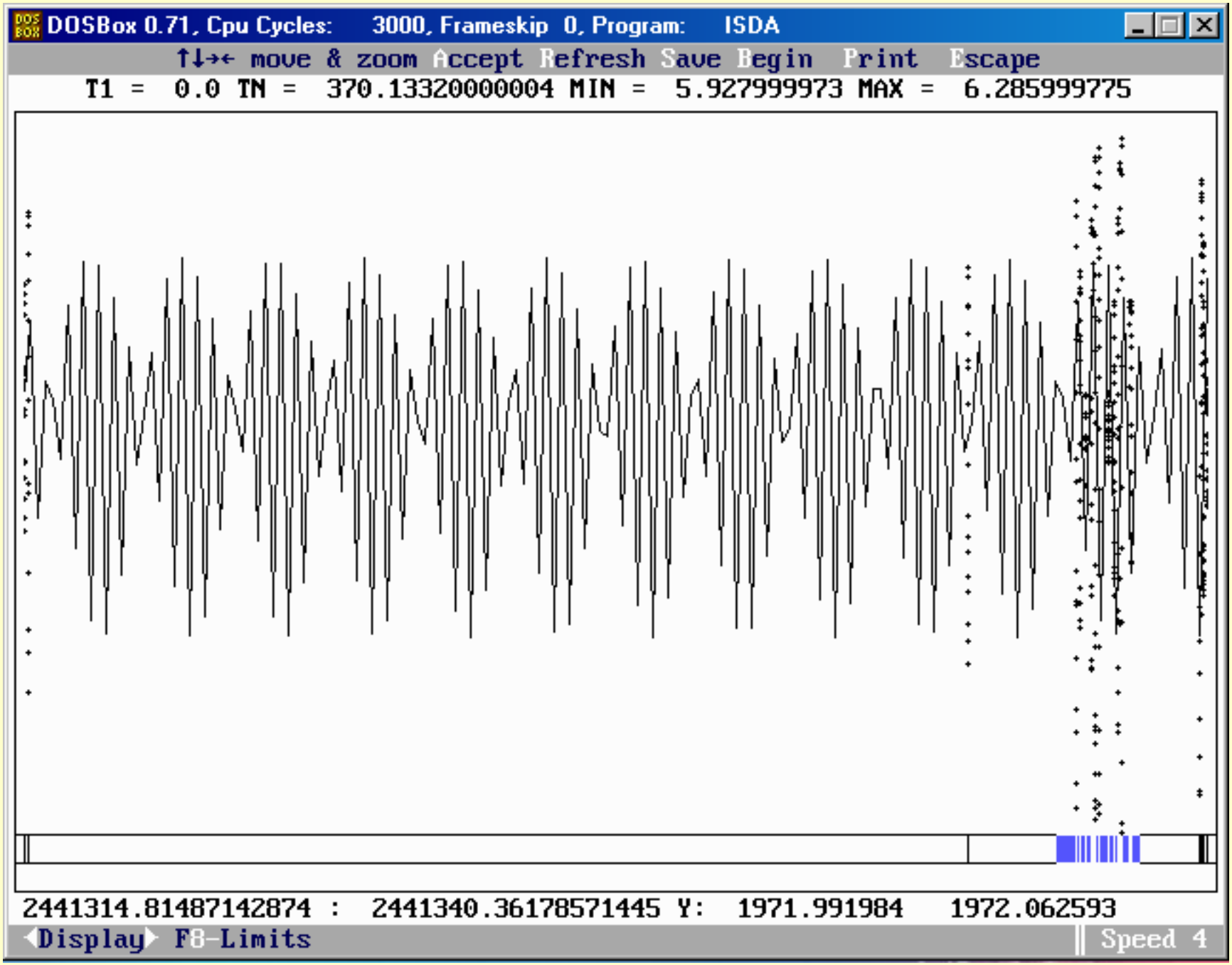
Natural time series





Undersampling

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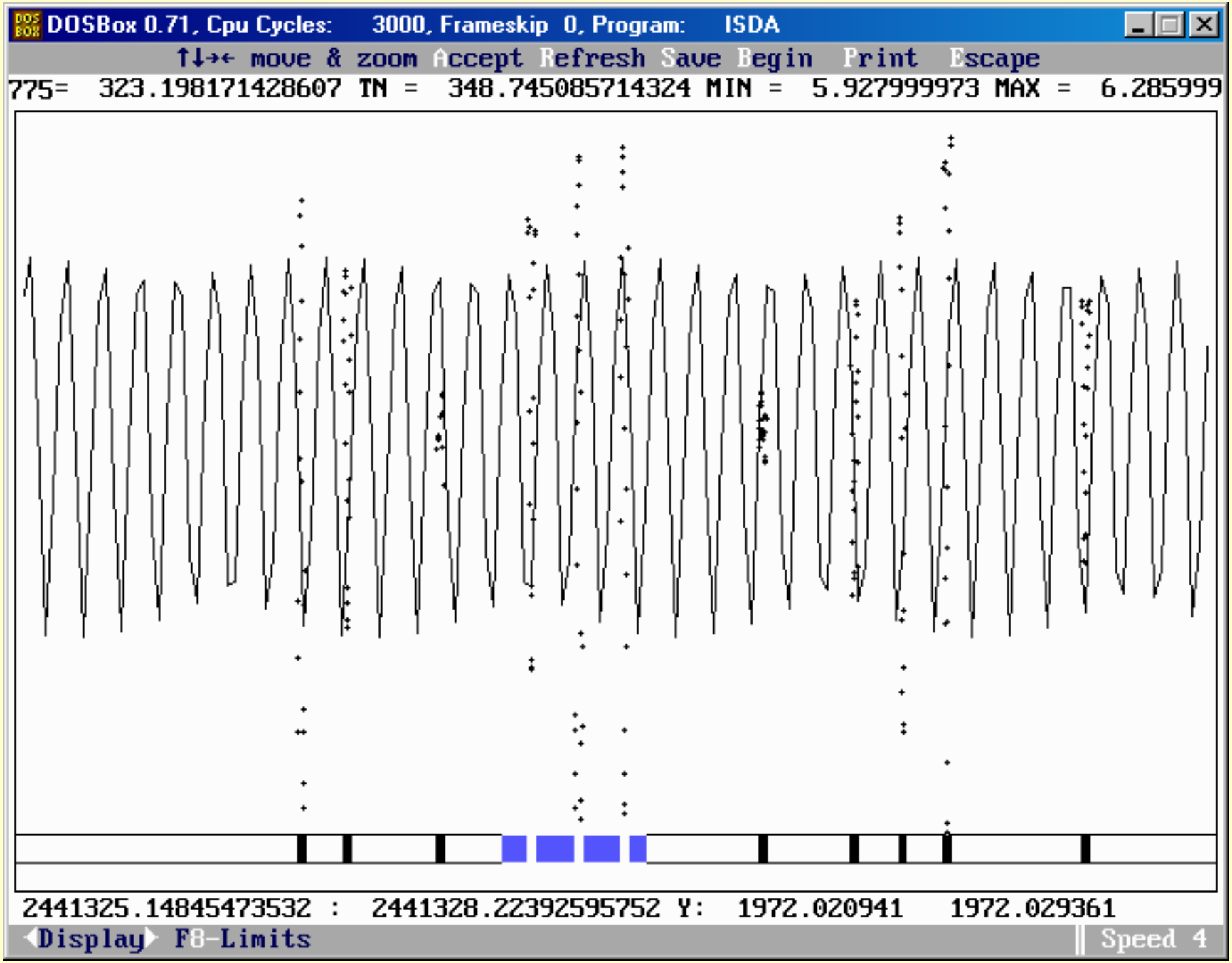
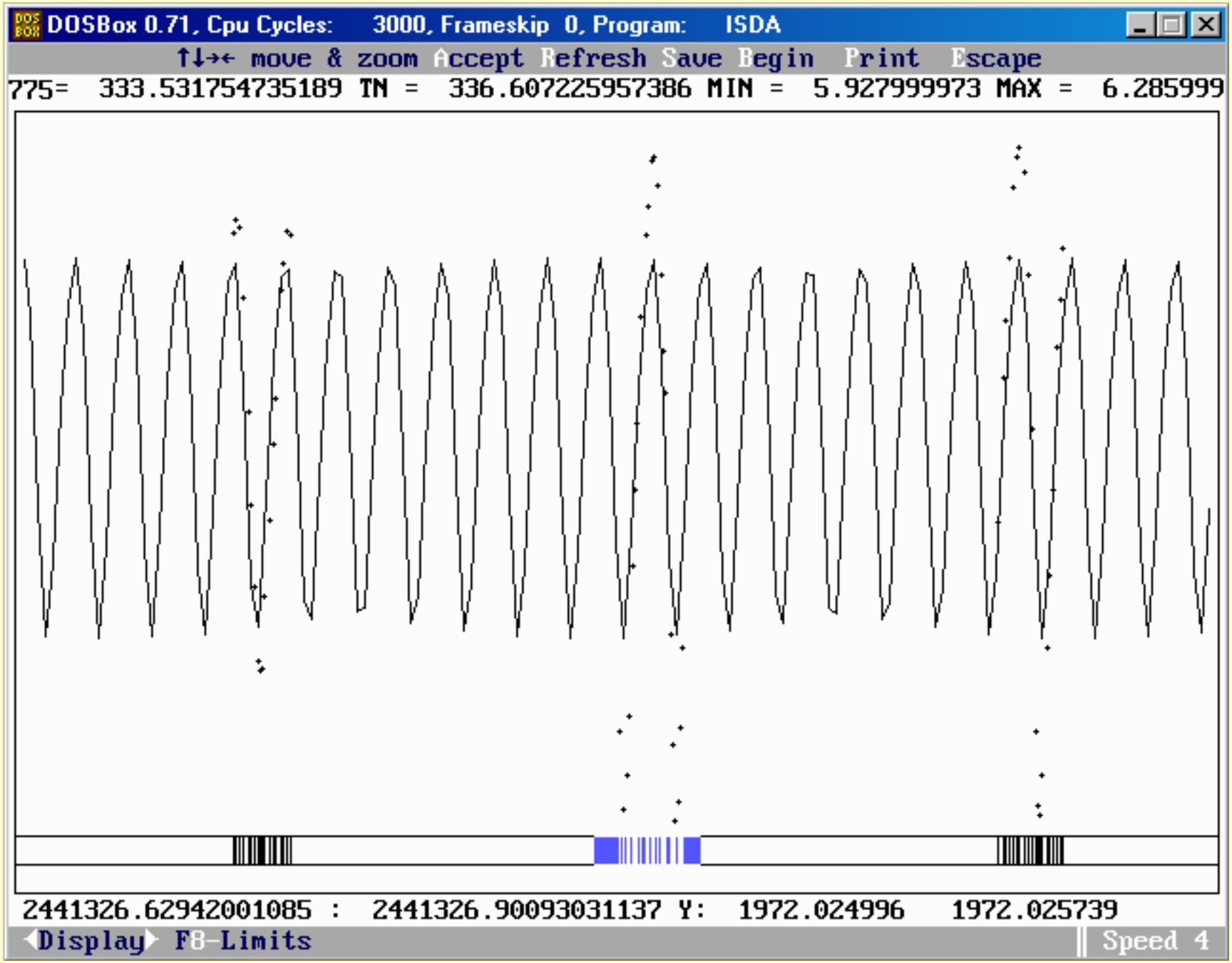
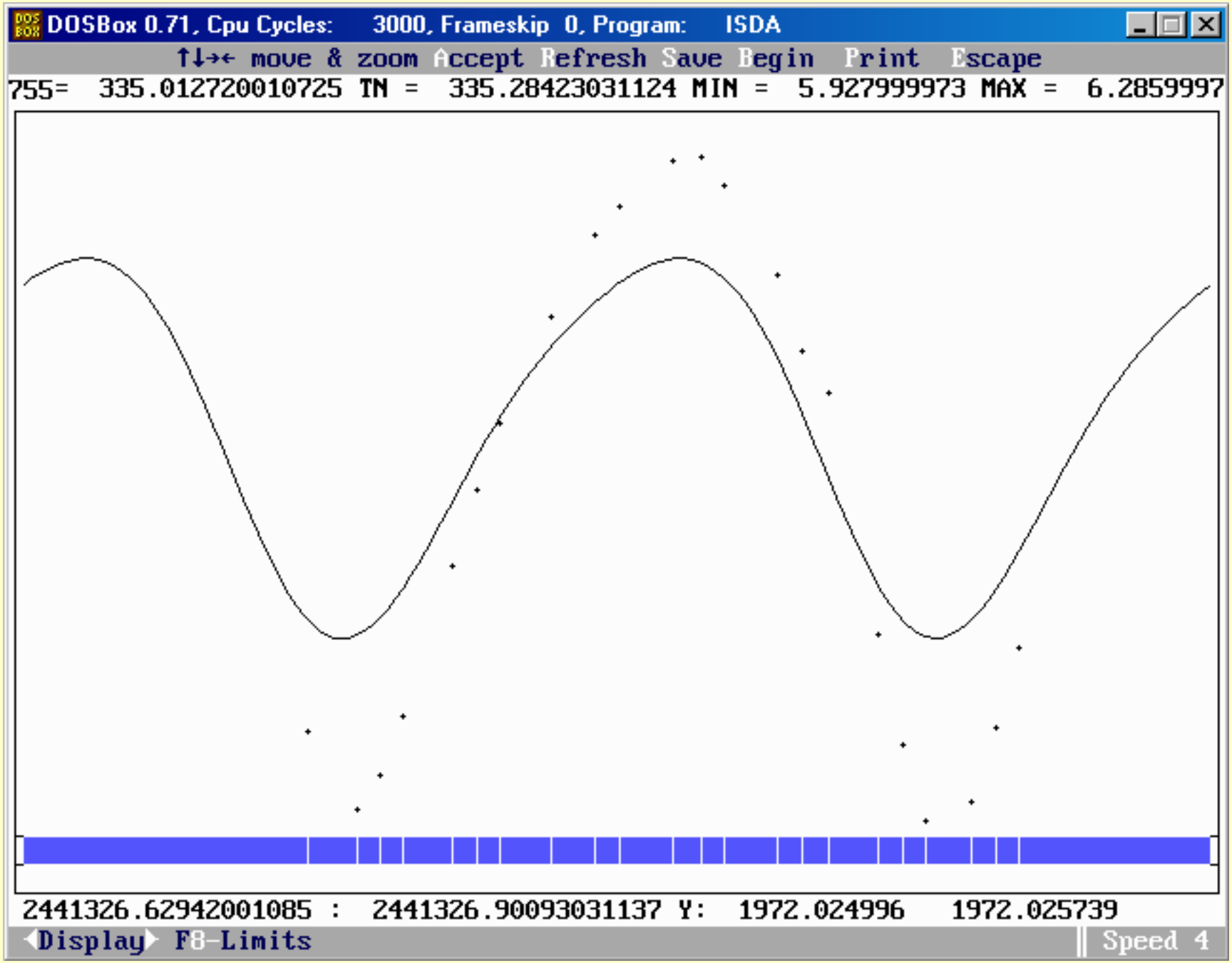
↑↓→← move & zoom Accept Refresh Save Begin Print Escape
T1 = 0.0 TN = 370.13320000004 MIN = 5.927999973 MAX = 6.285999775
2441314.81487142874 : 2441340.36178571445 Y: 1971.991984 1972.062593
Display F8-Limits
Speed 4


DOSBox 0.71, Cpu Cycles: 3000, Frameskip 0, Program: ISDA
↑↓→← move & zoom Accept Refresh Save Begin Print Escape
775= 323.198171428607 TN = 348.745085714324 MIN = 5.927999973 MAX = 6.285999
2441325.14845473532 : 2441328.22392595752 Y: 1972.020941 1972.029361
Display F8-Limits
Speed 4


DOSBox 0.71, Cpu Cycles: 3000, Frameskip 0, Program: ISDA
↑↓→← move & zoom Accept Refresh Save Begin Print Escape
775= 333.531754735189 TN = 336.607225957386 MIN = 5.927999973 MAX = 6.285999
2441326.62942001085 : 2441326.90093031137 Y: 1972.024996 1972.025739
Display F8-Limits
Speed 4


DOSBox 0.71, Cpu Cycles: 3000, Frameskip 0, Program: ISDA
↑↓→← move & zoom Accept Refresh Save Begin Print Escape
755= 335.012720010725 TN = 335.28423031124 MIN = 5.927999973 MAX = 6.2859997
2441326.62942001085 : 2441326.90093031137 Y: 1972.024996 1972.025739
Display F8-Limits
Speed 4

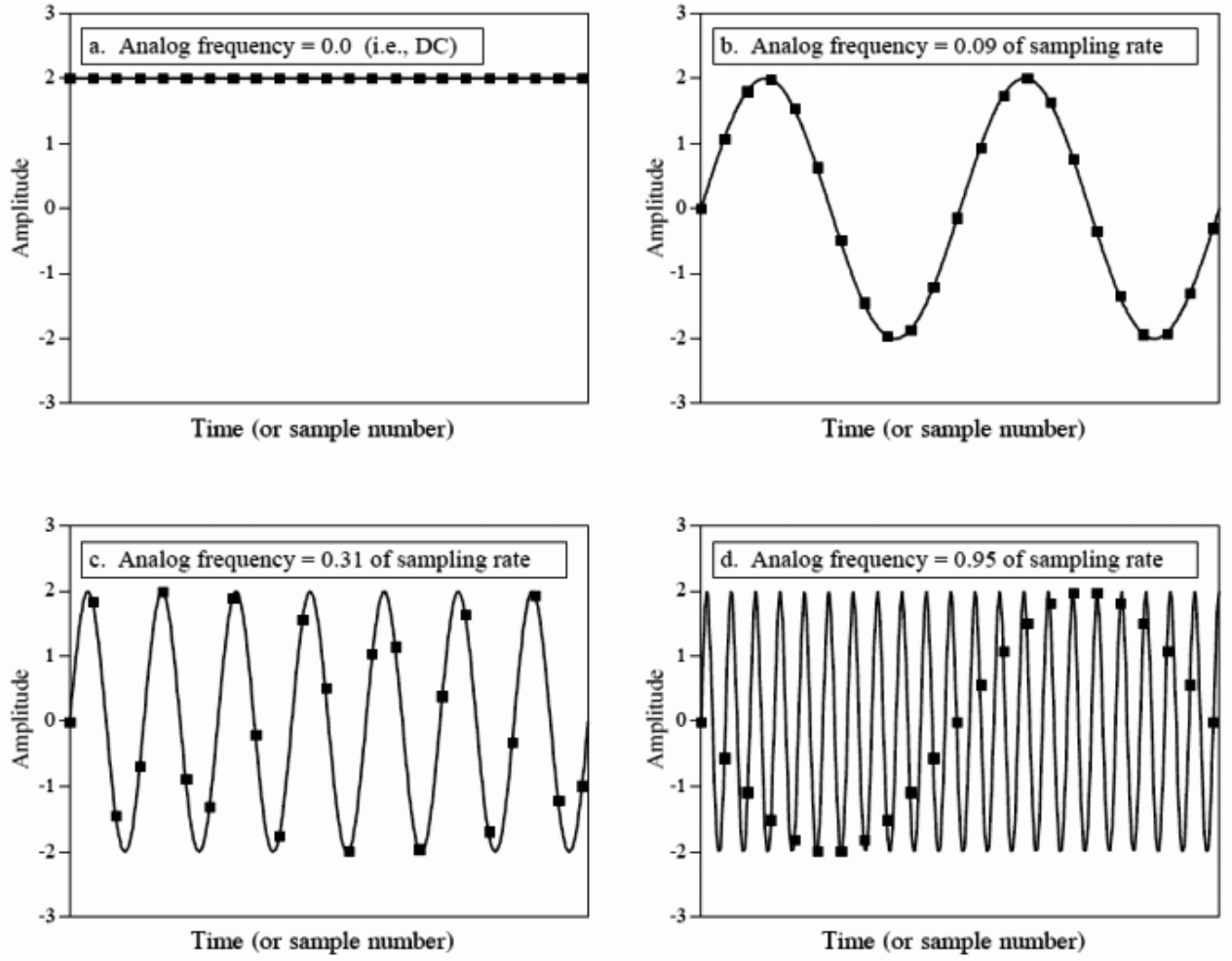
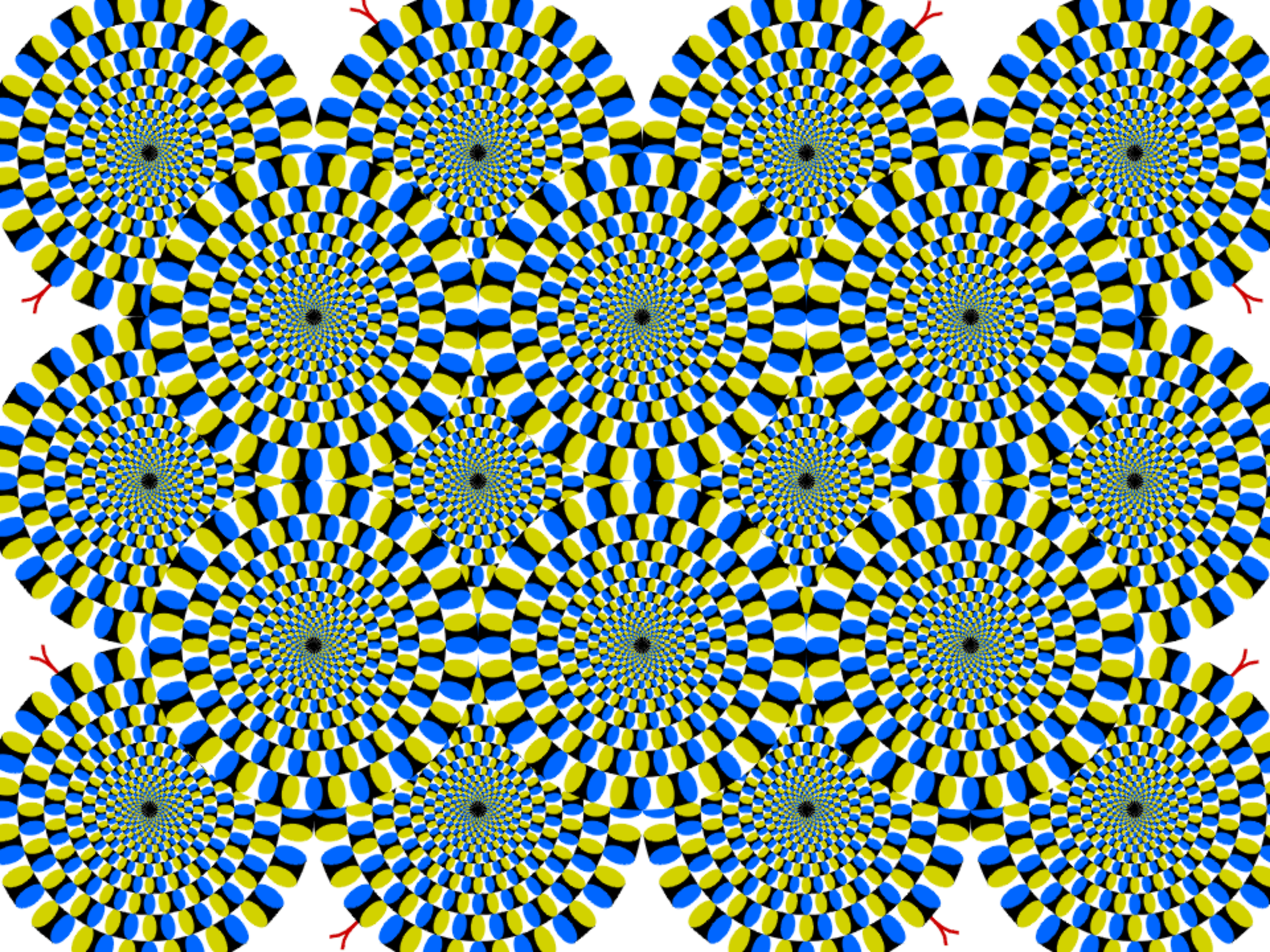


FIGURE 3-3
Illustration of proper and improper sampling. A continuous signal is sampled *properly* if the samples contain all the information needed to recreate the original waveform. Figures (a), (b), and (c) illustrate *proper sampling* of three sinusoidal waves. This is certainly not obvious, since the samples in (c) do not even appear to capture the shape of the waveform. Nevertheless, each of these continuous signals forms a unique one-to-one pair with its pattern of samples. This guarantees that reconstruction can take place. In (d), the frequency of the analog sine wave is greater than the Nyquist frequency (one-half of the sampling rate). This results in *aliasing*, where the frequency of the sampled data is different from the frequency of the continuous signal. Since aliasing has corrupted the information, the original signal cannot be reconstructed from the samples.



Data transformations

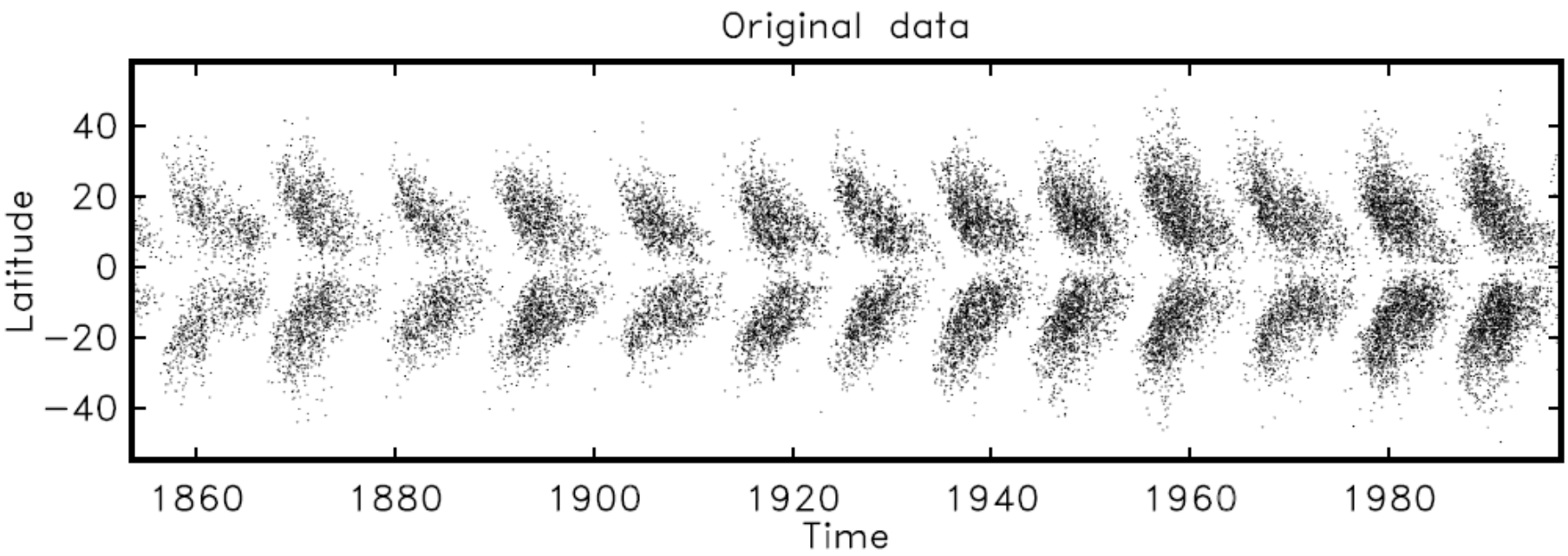
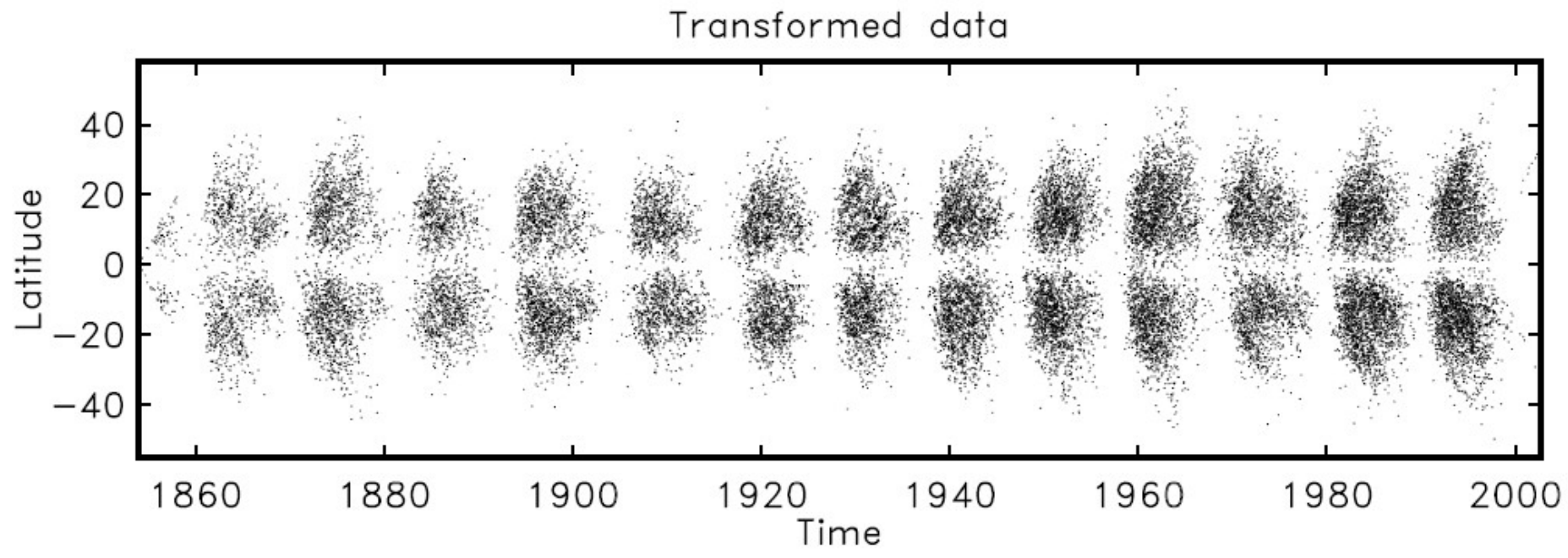
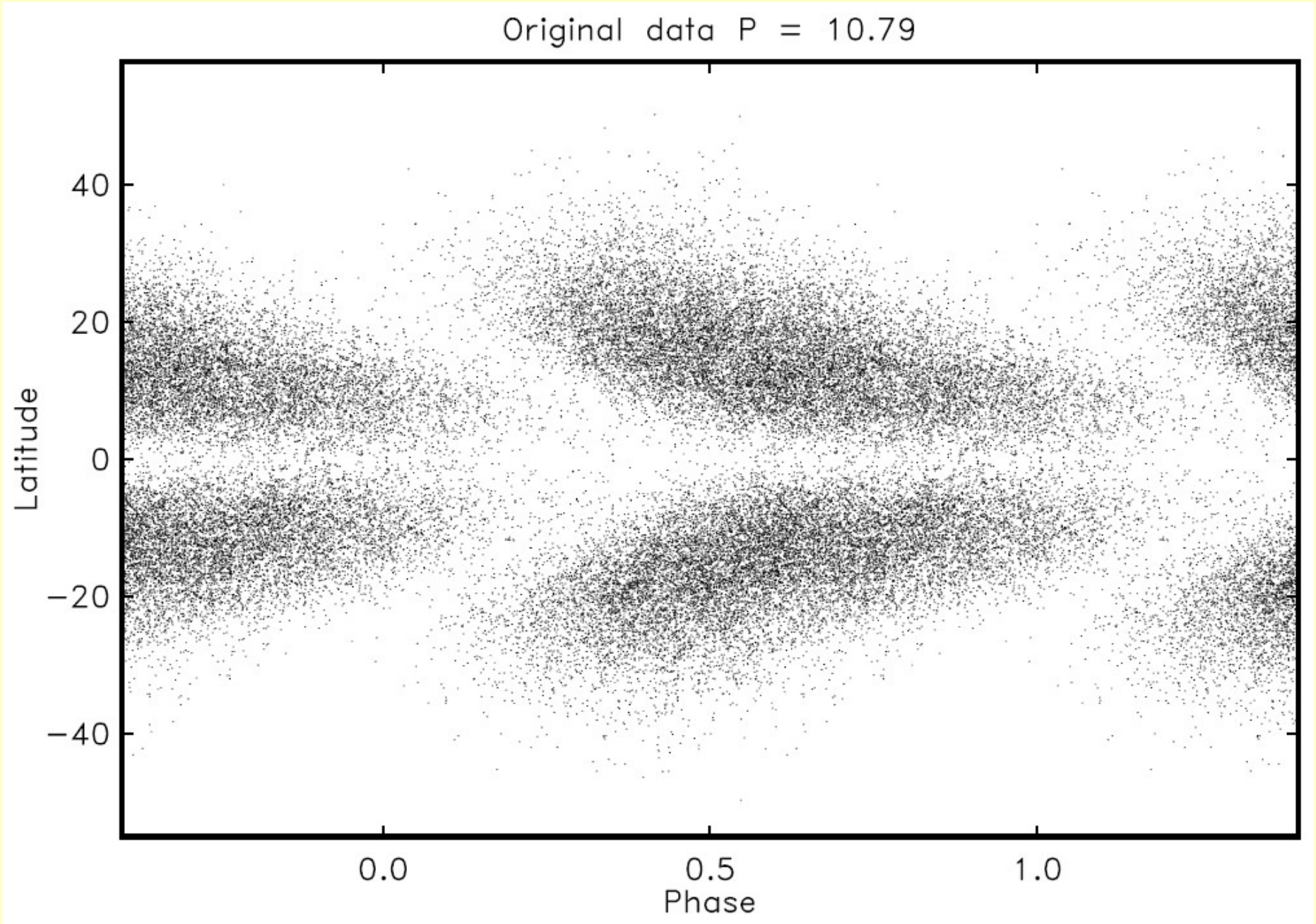
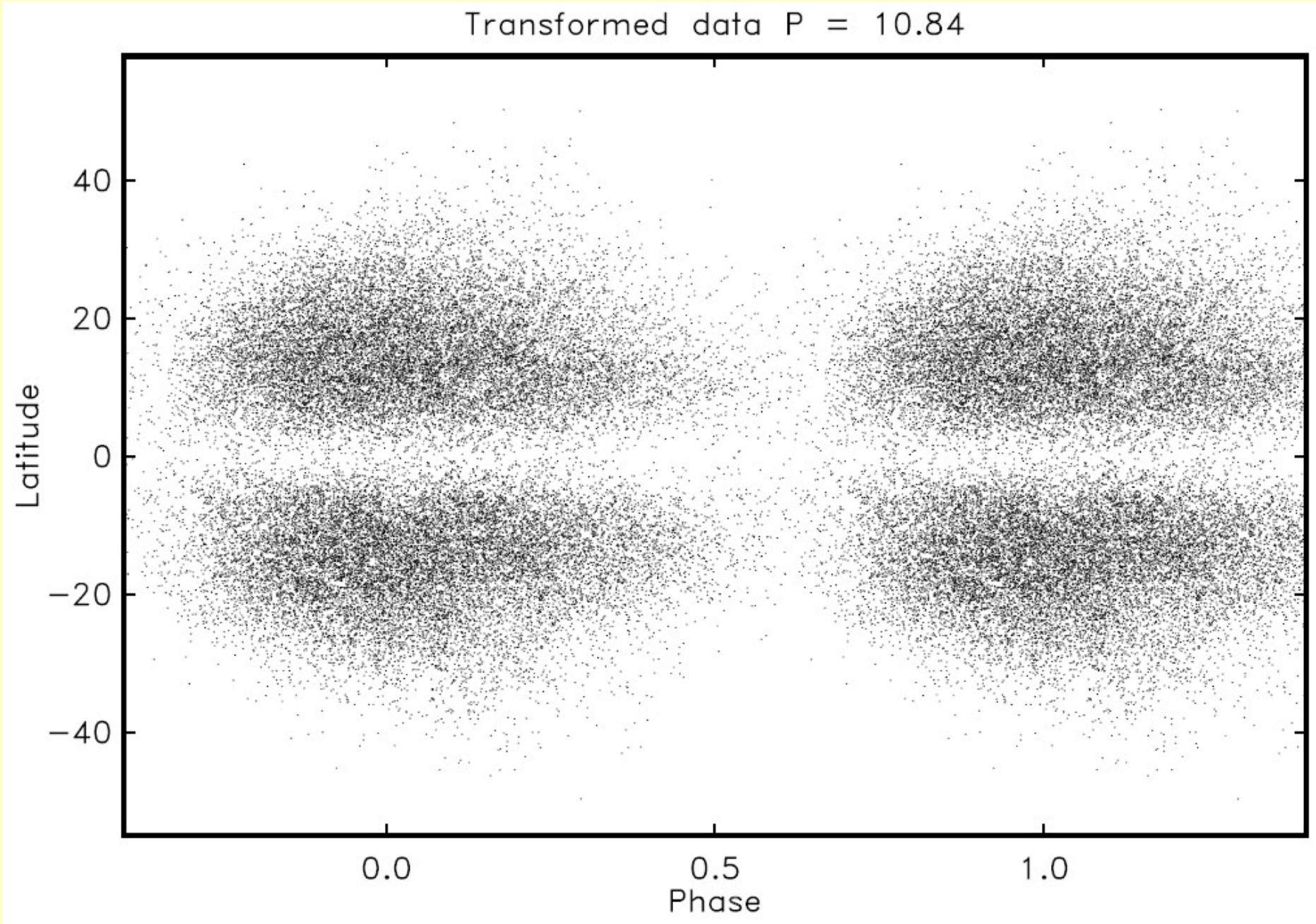


Fig. 2. A butterly diagram showing latitude θ vs time (1853–1996). The cycles are separated by clearly defined gaps.

Transformed data




Original data P = 10.79
40
20
0
−20
−40
Latitude
0.0
0.5
1.0
Phase


Transformed data P = 10.84
40
20
0
−20
−40
Latitude
0.0
0.5
1.0
Phase

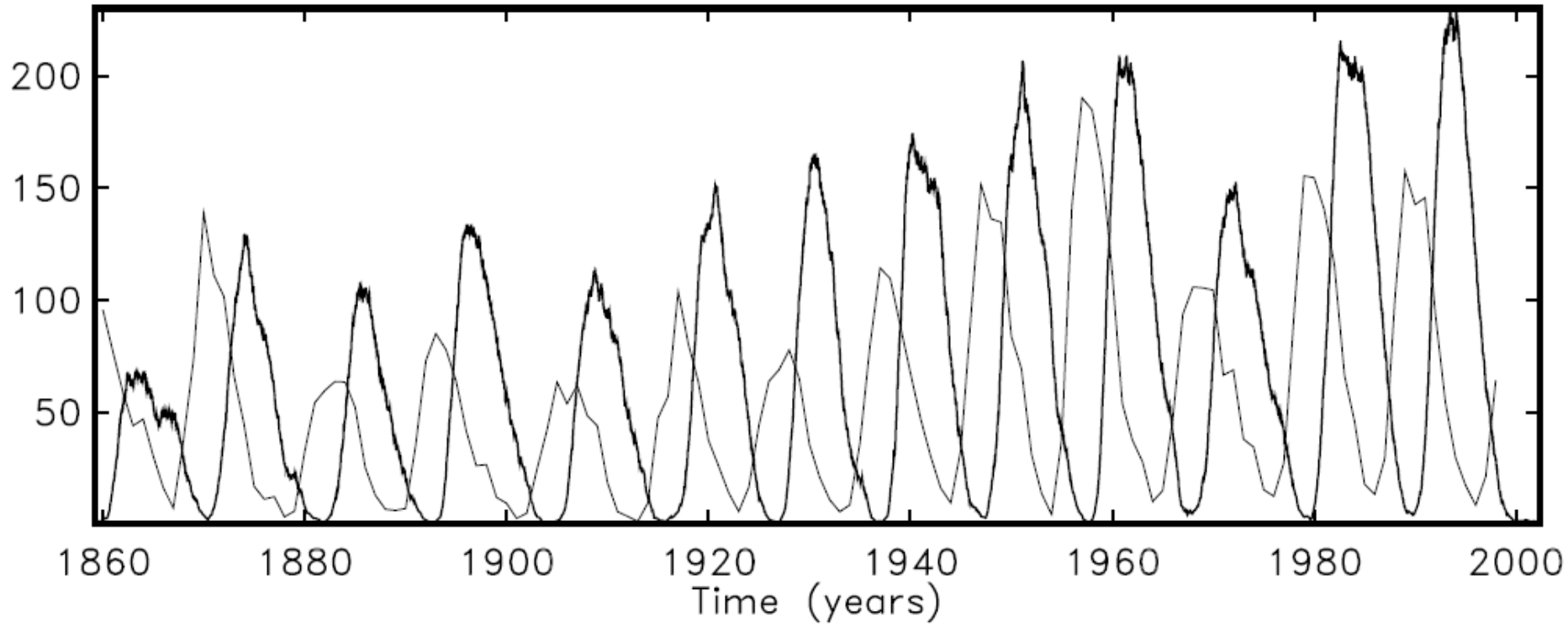
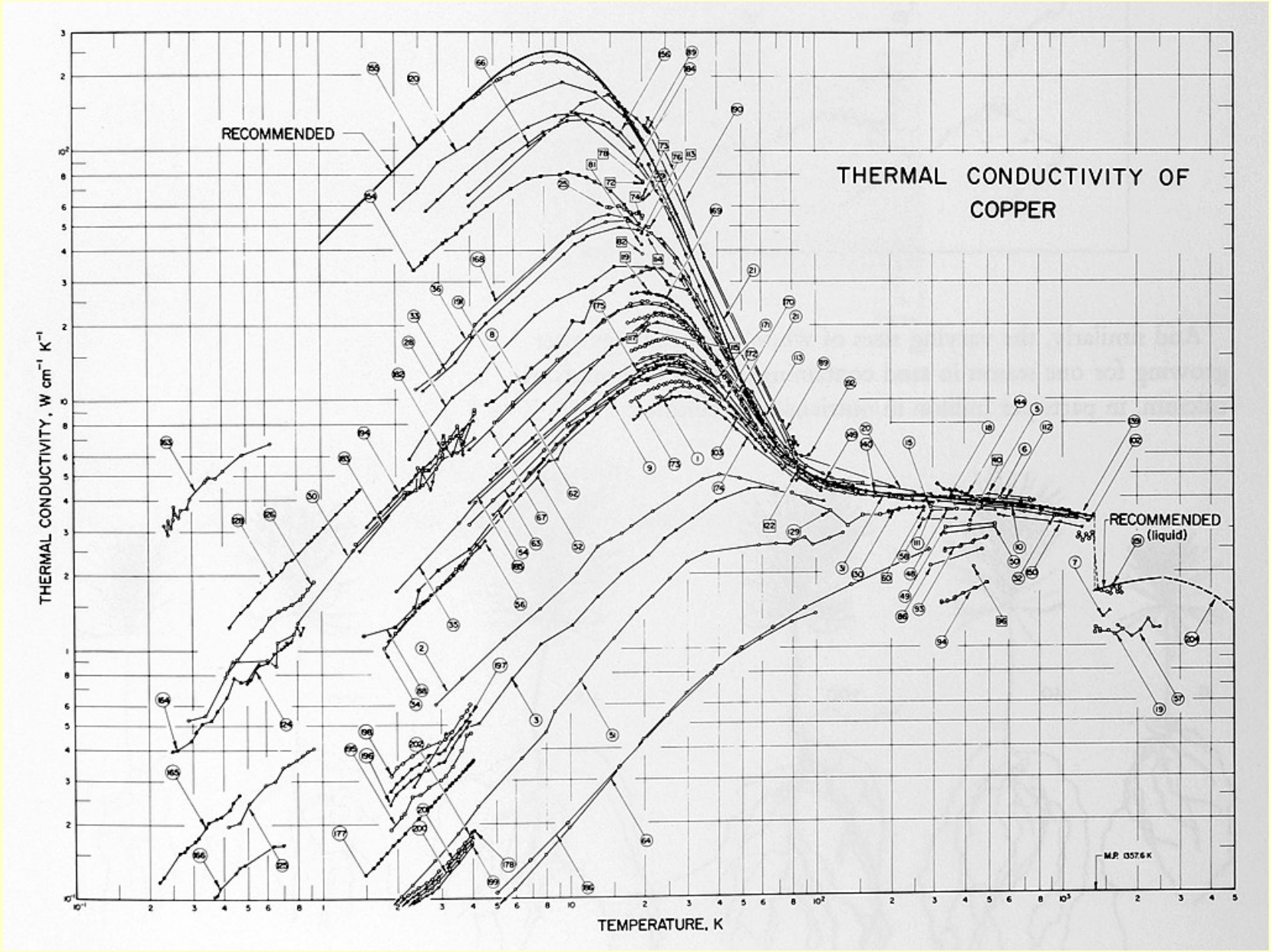
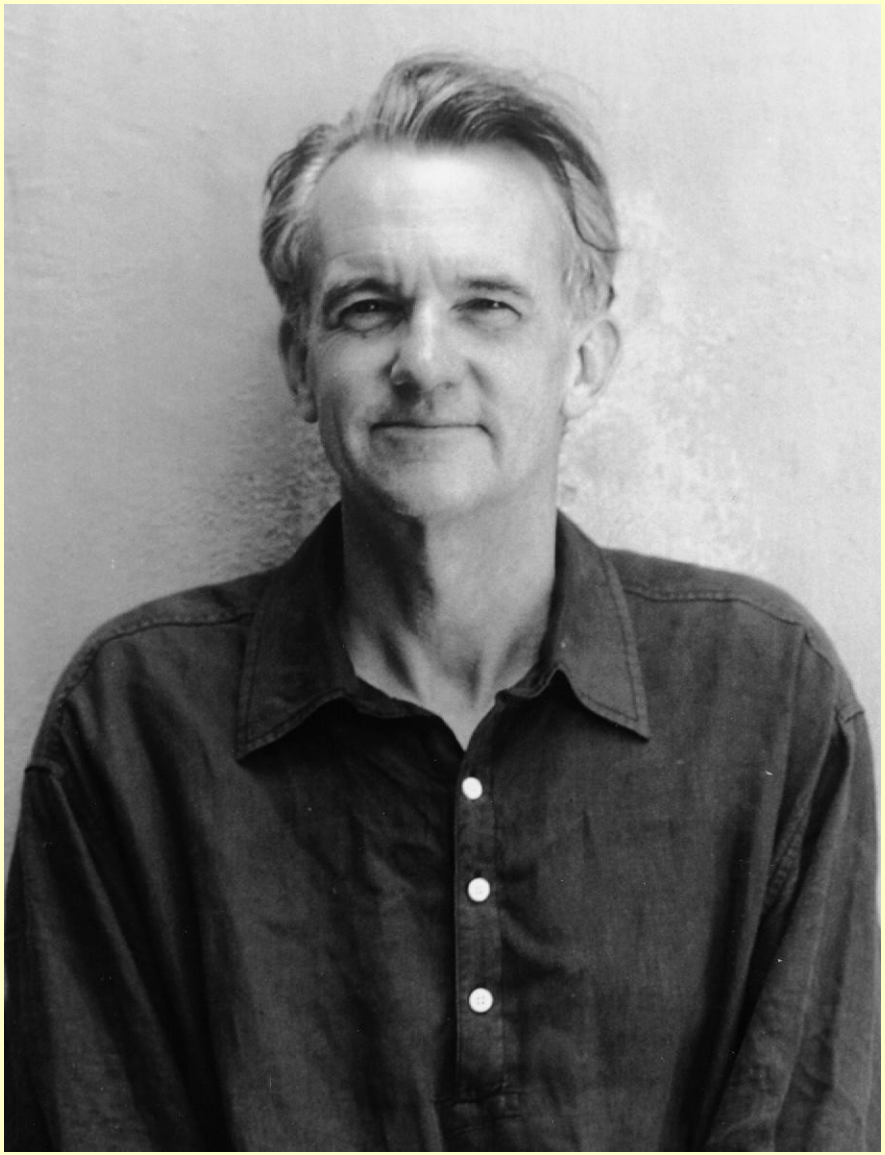


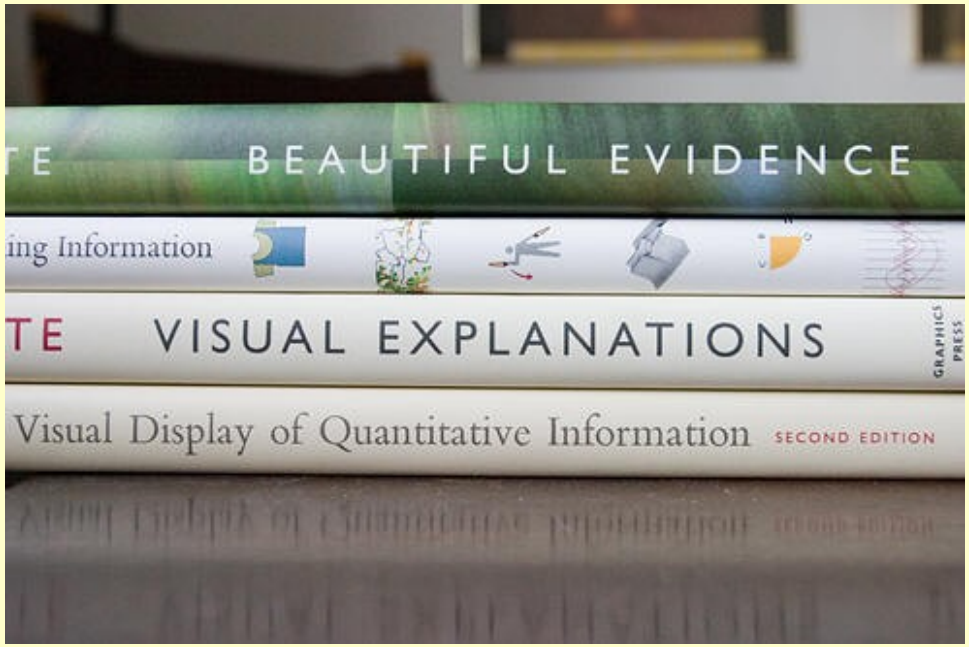
Fig. 7. Yearly mean Wolf numbers compared to the yearly running counts curve for the transformed data. Wolf numbers are depicted with thin line, scaled by 0.3 running counts are depicted by thick line. It can be clearly seen that the minima of the transformed data are much more clearly distinguished and that the cycles show more regular modulation.

Scatter


THERMAL CONDUCTIVITY OF COPPER
RECOMMENDED
RECOMMENDED (liquid)
M.P. 1357.6 K
THERMAL CONDUCTIVITY, W cm⁻¹ K⁻¹
TEMPERATURE, K

Sources





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