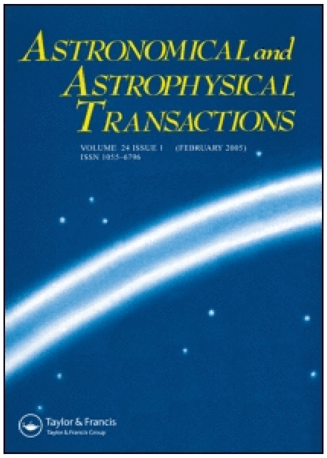


Astronomical & Astrophysical Transactions

The Journal of the Eurasian Astronomical Society

Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713453505

Computer technologies for processing and presenting simulation results and astronomical observational data

Kulikova; Tischenko

Online Publication Date: 01 January 2003
To cite this Article: Kulikova and Tischenko (2003) 'Computer technologies for processing and presenting simulation results and astronomical observational data', Astronomical & Astrophysical Transactions, 22:4, 535 - 541
To link to this article: DOI: 10.1080/10556790310001592790
URL: http://dx.doi.org/10.1080/10556790310001592790

Astronomical and Astrophysical Transactions
Vol. 22, Nos. 4–5, August–October 2003, pp. 535–541

COMPUTER TECHNOLOGIES FOR PROCESSING AND PRESENTING SIMULATION RESULTS AND ASTRONOMICAL OBSERVATIONAL DATA

N. V. KULIKOVA* and V. I. TISCHENKO

Obninsk Institute of Nuclear Power Engineering, Studgorodok 1, Obninsk, 249030 Kaluga Region, Russia

(Received 30 October 2002)

A system of two-dimensional graphic representations of the studied celestial body dynamics is presented. A technology is developed for analysing computer simulation data on disintegration of a particular celestial body within the given time intervals of Keplerian orbits.

Keywords: Computer technology; Computer simulations; Disintegration of celestial bodies

Recent achievements in modern astronomy assume ever greater practical importance. This process, on the one hand, is stimulated by fast development of computer techniques, applied mathematics and computer technologies and, on the other hand, by space exploration and development of long-term missions for practical studies of celestial objects in near and far space. Information on space contamination by small natural bodies, their disintegration products and the evolution of these object trajectories is urgent to determine the best time intervals for laying out mission courses in the safest space regions.

Theoretical studies as well as observational results show the reality of the concept of continuous formation of the interplanetary complex of small bodies. Here mathematical simulation of the dynamics of celestial–mechanical systems, data processing and presentation acquire great significance.

Computer simulation of the Solar System small-body disintegration at any orbital point of a studied object during its long-term existence gives rise to a large body of information which require careful consideration, processing and understanding. When analysing results from various indices, data systematization and transformation with subsequent graphic representation are prominent (Tischenko, 2001).

Universal program packages of the Microsoft Excel type (Koh, 1994) do not provide for processing such bodies of information in reasonable time intervals. Data for plotting are selected manually. This process is strongly influenced by the human factor, which in monotonic operations leads to hardly revealed errors that distort the form of graphs. In visual data processing it is convenient to use several graphs of various parameters, the values of which may

* Corresponding author. E-mail: mna@iate.obninsk.ru

ISSN 1055-6796 print; ISSN 1476-3540 online
DOI: 10.1080/10556790310001592790

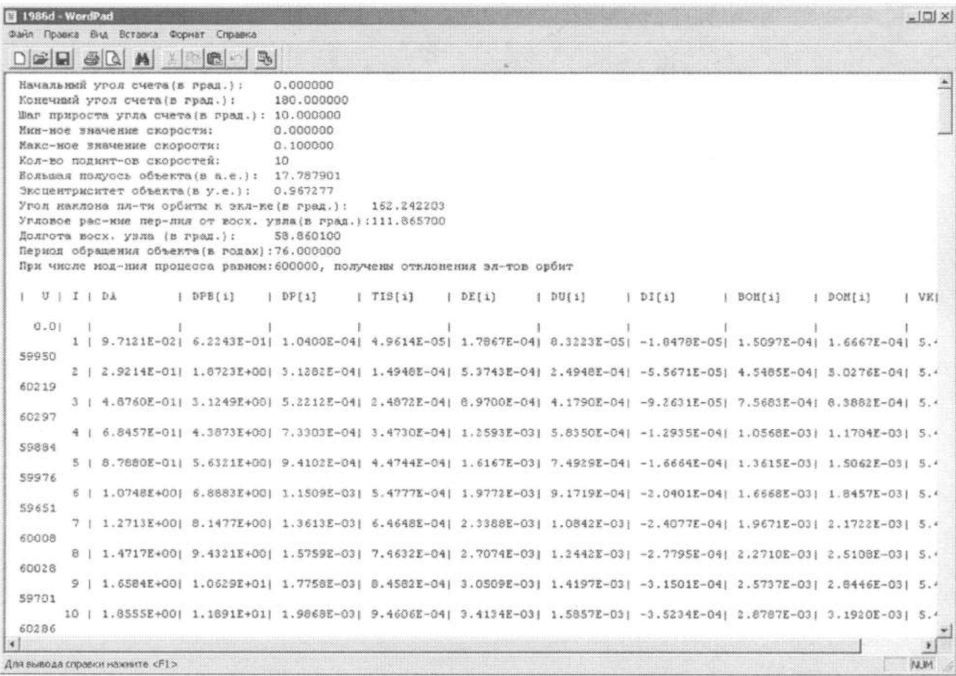
differ by some orders of magnitude. In this case it is desirable to plot on the same axes and to have maximum and minimum numerical parameter values. When using Excel for a particular image form, the scales on the ordinate will be similar for all plots. The values of any parameter are to be scaled manually in order to arrange the curves over the whole plot area.

The possible solution is development of computer technologies together with application of available standard software and its adaptation to the specific requirements of a problem to be solved.

The presented paper describes a system of two-dimensional representation of the studied celestial object dynamics by means of a suitable user interface. The technology has been developed for analysing the results of computer simulation of disintegration of a particular celestial natural object within given time and space intervals presented as tables in text files.

The problem statement, solving algorithm and peculiarities of software realization have been described in detail (Kulikova *et al*., 1993). The paper seeks to establish the fragment scatter in parent-body disintegration and to determine the space regions most contaminated by these fragments. Deviations of the Keplerian orbital elements of ejected fragments from the orbit of a particular small body are taken as the principal output parameters.

Figure 1 shows the simulation input and output data of small-body disintegration. The input and output data are as follows: U is the true anomaly in degrees; i is the number of substance ejection rate subintervals; a, e, i, Ω and ω are the primary orbital parameters; deviations in the fragment orbital elements from the parent body are δa for the orbital semimajor axis a (AU), δe for eccentricity e, δi for the ecliptic inclination angle i (rad), $\delta\Omega$ for the longitude of the



U	I	DA	DPB[i]	DP[i]	TIS[i]	DE[i]	DU[i]	DI[i]	BOM[i]	DOM[i]	VK
0.0											
	1	9.7121E-02	6.2243E-01	1.0400E-04	4.9614E-05	1.7867E-04	8.3223E-05	-1.8478E-05	1.5097E-04	1.6667E-04	5. … 59950
	2	2.9214E-01	1.8723E+00	3.1282E-04	1.4948E-04	5.3743E-04	2.4948E-04	-5.5671E-05	4.5485E-04	5.0276E-04	5. … 60219
	3	4.8760E-01	3.1249E+00	5.2212E-04	2.4872E-04	8.9700E-04	4.1790E-04	-9.2631E-05	7.5683E-04	8.3882E-04	5. … 60297
	4	6.8457E-01	4.3873E+00	7.3303E-04	3.4730E-04	1.2593E-03	5.8350E-04	-1.2935E-04	1.0568E-03	1.1704E-03	5. … 59884
	5	8.7880E-01	5.6321E+00	9.4102E-04	4.4744E-04	1.6167E-03	7.4929E-04	-1.6664E-04	1.3615E-03	1.5062E-03	5. … 59976
	6	1.0748E+00	6.8883E+00	1.1509E-03	5.4777E-04	1.9772E-03	9.1719E-04	-2.0401E-04	1.6668E-03	1.8457E-03	5. … 59651
	7	1.2713E+00	8.1477E+00	1.3613E-03	6.4648E-04	2.3388E-03	1.0842E-03	-2.4077E-04	1.9671E-03	2.1722E-03	5. … 60008
	8	1.4717E+00	9.4321E+00	1.5759E-03	7.4632E-04	2.7074E-03	1.2442E-03	-2.7795E-04	2.2710E-03	2.5108E-03	5. … 60028
	9	1.6584E+00	1.0629E+01	1.7758E-03	8.4582E-04	3.0509E-03	1.4197E-03	-3.1501E-04	2.5737E-03	2.8446E-03	5. … 59701
	10	1.8555E+00	1.1891E+01	1.9868E-03	9.4606E-04	3.4134E-03	1.5857E-03	-3.5234E-04	2.8787E-03	3.1920E-03	5. … 60286

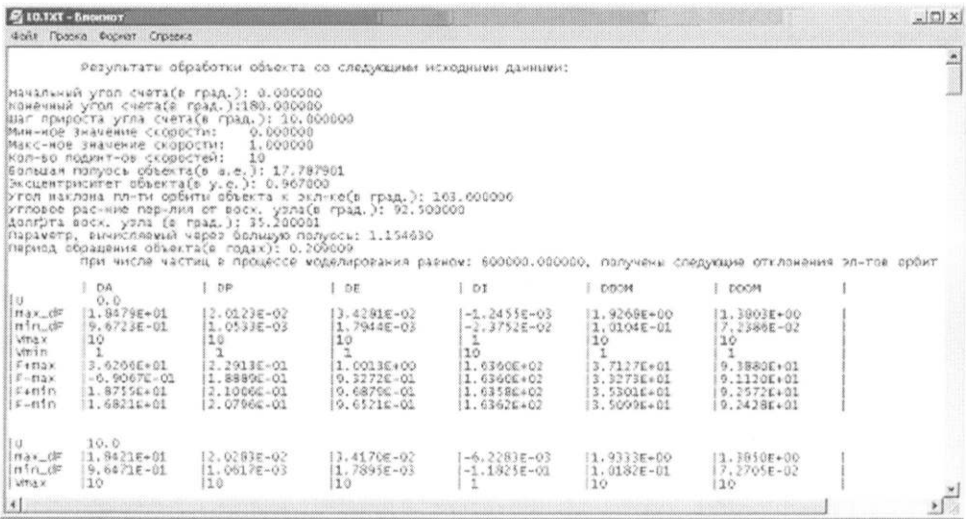
FIGURE 1 Input data and results obtained with the program realizing this algorithm. The symbols on screen correspond to the parameters defined in the text as follows: U, U; I, i; DA, δa; DPB(i), $\delta P(i)$; DP(i), $\delta p(i)$; DE(i), $\delta e(i)$; DU(i), $\delta U(i)$; DI(i), $\delta i(i)$; BOM(i), $g^k\Omega(i)$; DOM(i), $\delta\omega(i)$; VK, V_K.

ascending node (rad) and $\delta\omega$ for the angle distance (rad); δP is the revolution period variation; δp is the orbital parameter variation; V_K is the comet velocity ($\mathrm{km\,s^{-1}}$). When analysing deviations of fragment orbital elements from the corresponding parent-body orbital parameter values, the data samples for maximum and minimum scatter on each orbital element and corresponding values of substance ejection rates have been used. To this end, the 'min–max' utility was developed; the results of its application are presented in Figure 2.

Using the data given in the tables in Figures 1 and 2, it is possible to plot diagrams of the type shown in Figure 3. The dynamic evolution of a celestial body trajectory can be traced from computer simulation; in this case, the plots of each orbital element are compared for the various appearances of a studied object using data samples from a set of files containing information about object disintegration every time that it appears. These analysed data allow us to make definite conclusions on the orbit evolution of a given object within long time intervals.

A visualization system of simulation results allows the necessary data sampling to be made by programming. It is necessary to select the required parameter for a given file and a program will automatically introduce data into a new table, which is later converted to MS Excel where diagrams are plotted on the basis of this table. To complete the table containing data of several files, they are processed in turn and the results obtained are added to the summary table. A program is controlled with the menu shown in Figure 4.

A new table is formed as follows. Initially, the first file corresponding to the required year of object appearance is opened and the line and the column characterizing the parameter are chosen. A button 'Add' is pressed. A line appears in the new table and the year of comet appearance and the range of true anomaly U variations is considered as this line parameter. By repeating these operations for each file, it is possible to obtain a summary table with the required data. When the button 'Export' is pressed, this table is transferred to MS Excel where it can be edited and plotted. The table can be edited within a program; however, here this



```
10.TXT - Блокнот
Файл  Правка  Формат  Справка

        Результаты обработки объекта со следующими исходными данными:

Начальный угол счета(в град.): 0.000000
Конечный угол счета(в град.):180.000000
Шаг прироста угла счета(в град.): 10.000000
Мин-ное значение скорости:    0.000000
Макс-ное значение скорости:   1.000000
Кол-во подинт-ов скоростей:   10
Большая полуось объекта(в а.е.): 17.787901
Эксцентриситет объекта(в у.е.): 0.967000
Угол наклона пл-ти орбиты объекта к экл-ке(в град.): 163.000006
Угловое рас-ние пер-лия от восх. узла(в град.): 92.500000
Долгота восх. узла (в град.): 35.200001
Параметр, вычисляемый через большую полуось: 1.154630
Период обращения объекта(в годах): 0.209009
        при числе частиц в процессе моделирования равном: 600000.000000, получены следующие отклонения эл-тов орбит

         | DA          | DP          | DE          | DI          | DDOM        | DOOM        |
|U         0.0
|max_dF  |1.8479E+01   |2.0123E-02   |3.4281E-02   |-1.2455E-03  |1.9268E+00   |1.3803E+00   |
|min_dF  |9.6723E-01   |1.0533E-03   |1.7944E-03   |-2.3752E-02  |1.0104E-01   |7.2386E-02   |
|Vmax    |10           |10           |10           | 1           |10           |10           |
|Vmin    | 1           | 1           | 1           |10           | 1           | 1           |
|F+max   |3.6266E+01   |2.2913E-01   |1.0013E+00   |1.6360E+02   |3.7127E+01   |9.3880E+01   |
|F-max   |-6.9067E-01  |1.8889E-01   |9.3272E-01   |1.6360E+02   |3.3273E+01   |9.1120E+01   |
|F+min   |1.8755E+01   |2.1006E-01   |9.6879E-01   |1.6358E+02   |3.5301E+01   |9.2572E+01   |
|F-min   |1.6821E+01   |2.0796E-01   |9.6521E-01   |1.6362E+02   |3.5099E+01   |9.2428E+01   |

|U         10.0
|max_dF  |1.8421E+01   |2.0283E-02   |3.4170E-02   |-6.2283E-03  |1.9333E+00   |1.3850E+00   |
|min_dF  |9.6471E-01   |1.0617E-03   |1.7895E-03   |-1.1825E-01  |1.0182E-01   |7.2705E-02   |
|Vmax    |10           |10           |10           | 1           |10           |10           |
```

FIGURE 2 Output file fragment of the 'min–max' utility. The symbols on screen correspond to the parameters defined in the text as follows: DA, δa; DP, δp; DE, δe; DI, δi; DDOM, $\delta\omega$; DBOM, $\delta\Omega$; U, U. Max_dF and min_dF are the maximum and minimum deviation values of the corresponding parameters; Vmax and Vmin are the numbers of ejection velocity subintervals for the maximum and minimum deviation values of the corresponding parameters; F + max and F − max are the orbital element values plus or minus the maximum deviation values for the corresponding parameters; F + min and F − min are the orbital element values plus or minus the minimum deviation values for the corresponding parameters.

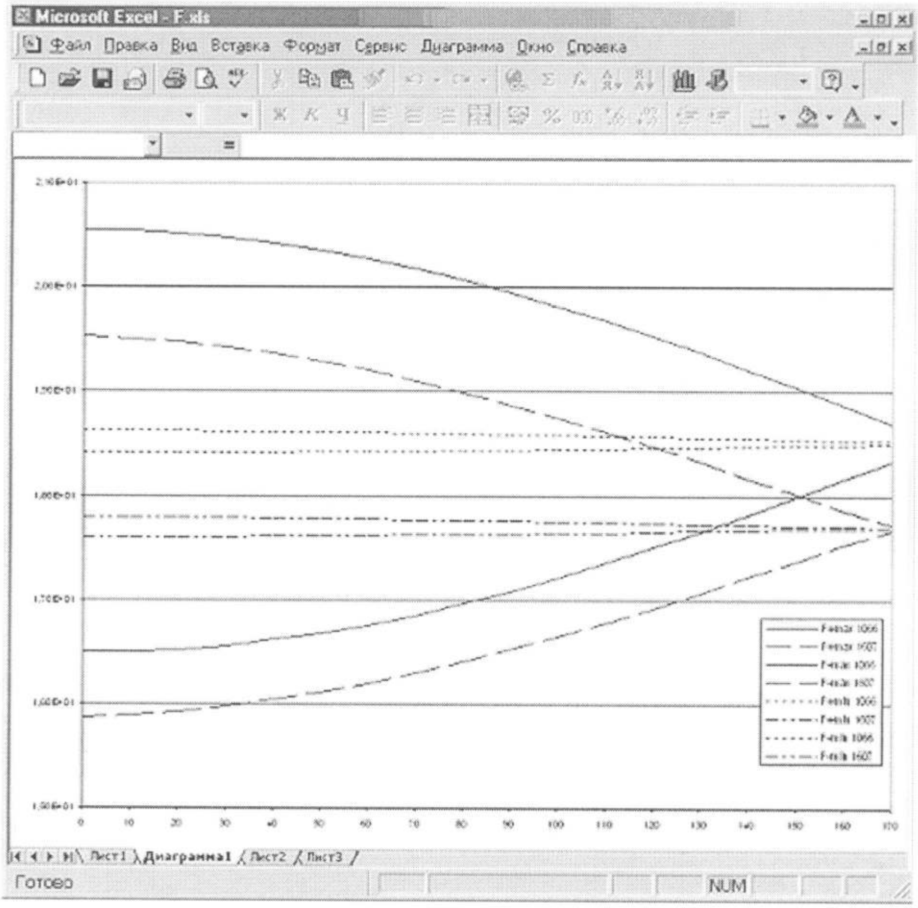


FIGURE 3 Variation range of the semimajor axis and disintegration fragments of Halley's comet in 1007 and 1066.

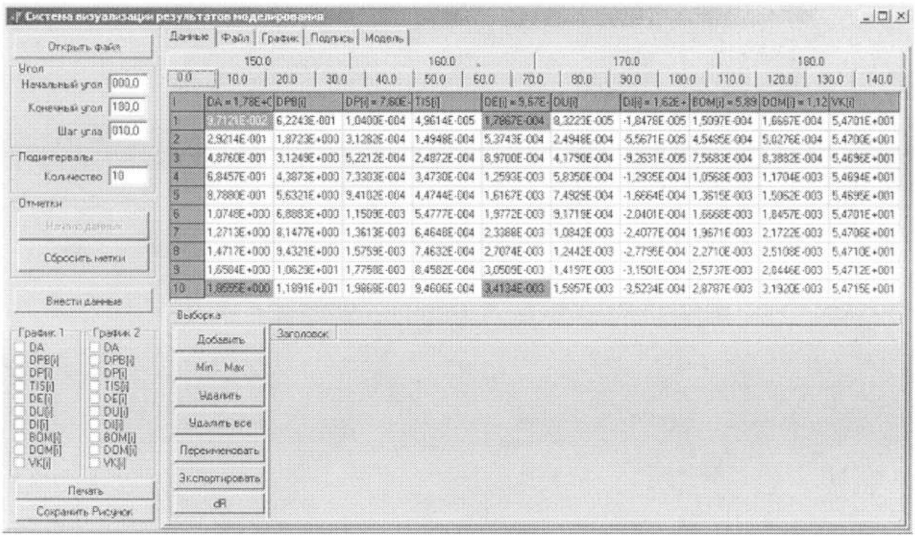


FIGURE 4 A visualization system window of simulation results.

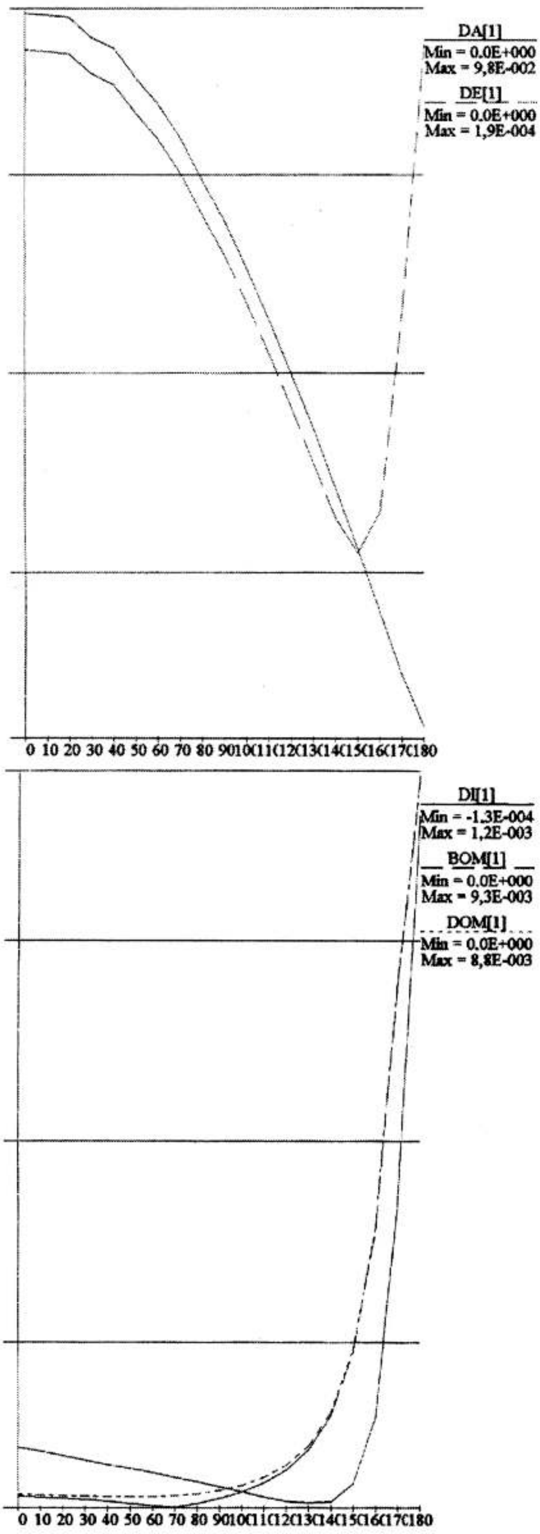


FIGURE 5 An example of twofold plot compression in width.

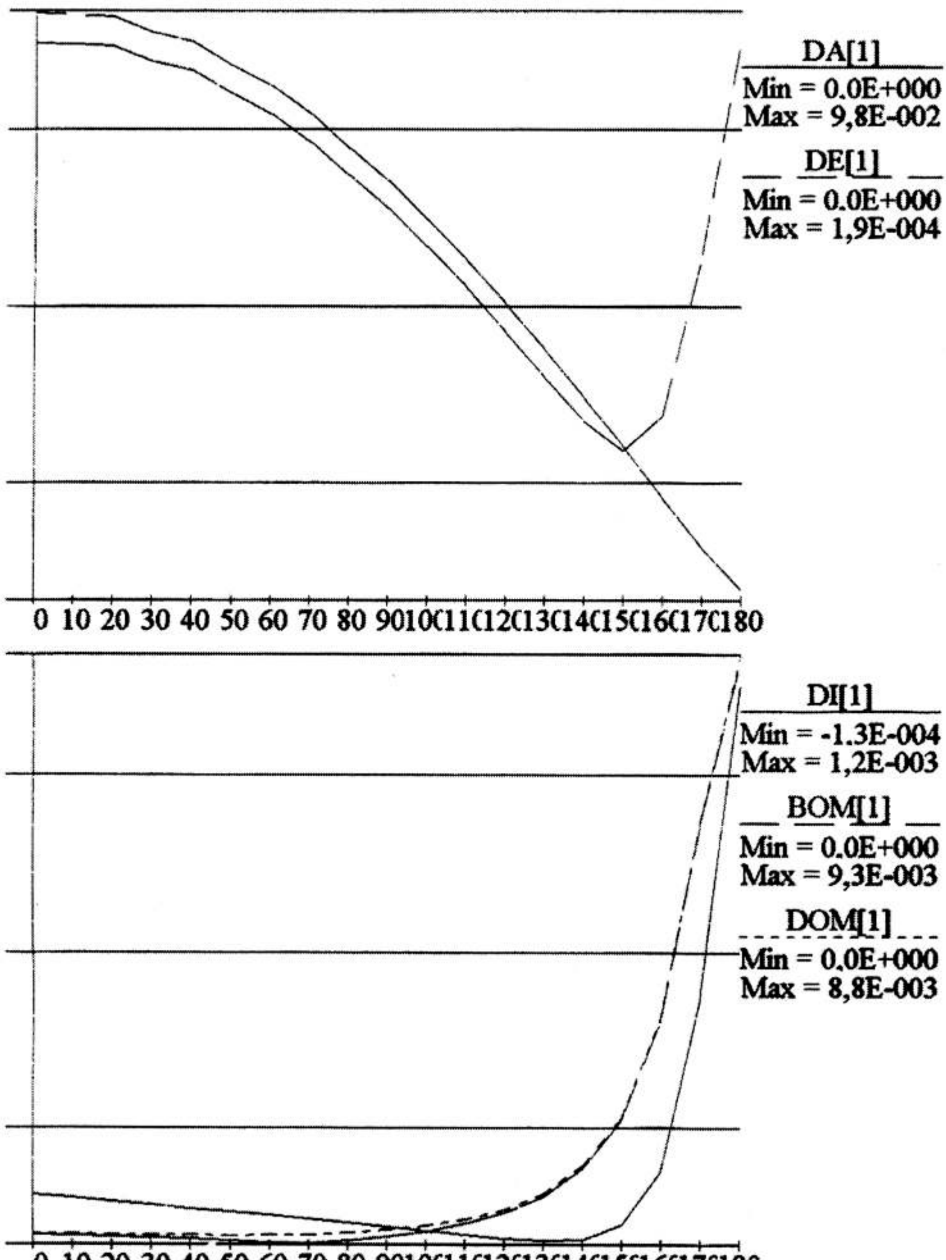


FIGURE 6 An example of twofold plot compression in width and height.

process is limited as initially a visualization system was not intended for it. By editing we mean the following: change in the line name of a new table, deletion of unnecessary lines or clearing the whole table. The *U* range can be viewed with the help of an indicator placed at the bottom of the window. The button ‘Print’ allows us to obtain different plots, that is combined in one sheet on axis compressed, with no scale grid indicated and also to write figure legends. Some plot versions are shown in Figure 5 and 6.

In conclusion, it is worth noting that at this stage the following problems of two-dimensional visualization have been realized:

(i) visual representation of the original table;
(ii) Cartesian system plotting from the chosen screen data without any routine transformation process of text file elements;
(iii) plot overlapping in various combinations (one or two plots are located in a standard sheet with or without superposition using one or several scale grids) with possible axis compression;
(iv) plot presentation for scientific papers and reports.

A complex is realized with the Win32 platform using the Delphi 5.0 medium and can be used for analysing table data with a subsequent plot presentation for reports.

Further development of a technology for three-dimensional visualization of computer simulation results is intended.

References

Koh, O., 1994, *MS Excel 4.0 for Users*, Binom, Moscow, p. 448.
Kulikova, N. V., Myshev, A. V. and Pivnenko, E. A., 1993, *Cosmogony of Small Bodies*, Kosmoinform, Moscow, p. 175.
Tischenko, V. I., 2001, In: Proceedings of the Conference on Near Earth Astronomy of the Twenty First Century, Zvenigorod, Russia, 21–25, May 2001, Geos, Moscow, pp. 216–220.