ON THE PHYSICAL AND DYNAMICAL PROPERTIES OF ASTEROIDS

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Abstract. The paper presents an attempt to study the connection between the physical and the dynamical properties of the asteroids. We have studied a sample consisting of 301 asteroids, taking into account eight physical parameters and three dynamical parameters. The method used is the Principal Components Analysis, with which we have searched clusters of asteroids in the histograms obtained in appropriate plans of the parameter space. We have presented also a first comparison with the Tholen taxonomy and with the Hirayama families.

Key words: asteroids: multivariate analysis; principal components method.

1. THE METHOD

The Principal Components Method (PCM) is used for data processing.

1.1. The Principle of the Method

The PCM permit the data-set analysing through the change of the initial parameters, that can be correlated, by new linear independent parameters. These new variables are called principal components (Rao, 1965). The change of coordinates in the measurements space is done so that the new coordinates are ordered decreasingly in relation to the dispersions on the principal components (Vass, 1980).

If the measurements have the same physical nature, the first principal components will contain, generally, most of the information. The sight of histograms, in the plane of the first two principal components, permits the definition of consistent classes, by reducing the number of dimensions and retaining the maximum of information. If the data are physically nonhomogeneous the problem will be more complicated, especially because of the impossibility of a real weighting. Thus, the hierarchy of principal components may not be useful, because some initial parameters will introduce a great but irrelevant dispersion. It is therefore necessary to analyse more principal components, because it is possible that the "weak" histograms (as absolute dispersion) should express better some classes.

1.2. THE PROGRAMS

The programs, written in FORTRAN for the SPADAM system (Vass, 1980), have been translated for an IBM PC 386 with a VGA display

and completed with the interactive graphic procedures. They permit to calculate the principal components, to raise the histograms by any two components, to cut the chosen clusters and to filter the established classes.

2. DESCRIPTION OF THE CLASSIFICATION

2.1. The Data Used

The set of data we have used comes largely from 'Asteroid Photometric Catalogue' (Lagerkvist et al. 1987). Additionally, we have used other physical data concerning 10 asteroids (Barucci et al., 1991). Dynamical elements have been selected from 'Ephemerides of Minor Planets' (Batrakov et al., 1992). First, we have created a sample of 520 asteroids, but, because of exclusion of asteroids whose data were incomplete, the sample has been reduced to 301 asteroids with 11 parameters: spin, amplitude range, absolute magnitude, slope parameter, diameter, U—B, B—V, albedo, inclination, eccentricity and semimajor axis.

2.2. The Method Testing

The method has been tested on a sample of 301 elements, characterized by 8 physical parameters. We succeeded in separating two classes in the plane of the first and second principal components. After that, each class was divided in two subclasses. The average of the parameters are given in Table 1 for all the four classes.

The composition of the classes are given in Table 2, with respect to the Tholen taxonomy, which uses the same statistical method for analysis. We notice that the division of the two initial classes as obtained by means of the principal components 6 and 7 is dominated by the colours and the albedo.

Table 1

Mean values of the parameters for the 4 classes

No	Class	T/10	A	H	G	D/100	U—B	B—V	Albedo
1	1.1	0.38	0.32	9.30	0.25	0.60	0.27	0.69	0.14
2	1.2	0.48	0.29	8.88	0.25	0.70	0.44	0.85	0.17
3	2.1	0.63	0.18	8.23	0.15	1.44	0.34	0.70	0.05
4	2.2	0.51	0.21	7.97	0.13	1.59	0.31	0.71	0.06

Table 2

Compounds of the classes with respect to Tholen taxonomy

No	Class	Total	S	C	M	X	F	P	B	G	T	D	E	V	A	R
1	1.1	42	—	1	20	6	5	1	5	—	1	—	3	—	—	—
2	1.2	138	128	3	2	1	—	—	1	1	—	—	—	—	1	1
3	2.1	71	—	55	—	4	1	8	2	1	—	1	—	—	—	—
4	2.2	43	3	18	1	3	7	2	—	2	2	2	—	—	—	—

2.3 The Classification Using Physical and Dynamical Parameters

During the test described in 2.2, we found out that the spin, amplitude and slope parameter do not have an effective influence on the class definition. Consequently, only five physical parameters were retained and three dynamical parameters were added.

The sample consisting of 301 asteroids was separated in six classes using the histogram for components 3 and 4. The next step was the analysis of the principal components of these classes.

Thus, the classes 2, 3 and 5 permit each a separation in 2 subclasses : 2.1, 2.2, ... The subclass 5.2 permits a separation in 3 subclasses : 5.2.1

Table 3

Mean values of the parameters

No	Class	H	D/100	U—B	B—V	Albedo	i/10	e	a
1	1	7.86	0.93	0.43	0.85	0.19	0.85	0.17	2.39
2	2.1	8.10	0.81	0.44	0.86	0.18	1.13	0.15	2.81
3	2.2	8.05	0.91	0.26	0.71	0.17	0.96	0.17	2.81
4	3.1	8.46	1.23	0.33	0.71	0.07	1.03	0.17	2.62
5	3.2	9.61	0.62	0.46	0.86	0.17	1.03	0.18	2.47
6	4	11.41	0.28	0.39	0.80	0.09	0.65	0.16	2.33
7	5.1	7.97	1.60	0.33	0.70	0.06	1.09	0.15	3.10
8	5.2.1	10.35	0.32	0.42	0.81	0.13	0.63	0.07	2.94
9	5.2.2	9.95	0.62	0.27	0.71	0.05	1.15	0.17	2.96
10	5.2.3	10.33	0.45	0.34	0.67	0.08	0.53	0.20	3.15
11	6	8.26	2.33	0.33	0.73	0.08	0.99	0.16	3.09

5.2.2, 5.2.3. The averages of the initial parameters for all the 11 classes are presented in Table 3. The number and composition of the classes are given in Table 4 with respect to the Tholen taxonomy.

Table 4

The compounds of classes with respect to Tholen taxonomy

No	Class	Total	S	C	M	X	F	P	B	G	T	D	E	V	A	R
1	1	42	37	1	2	1	—	—	—	—	—	—	1	—	—	—
2	2.1	52	49	—	—	—	—	—	—	1	—	—	—	—	1	1
3	2.2	23	1	2	16	3	—	—	—	—	—	—	1	—	—	—
4	3.1	66	1	38	4	5	5	5	—	2	3	1	1	—	—	—
5	3.2	10	9	1	—	—	—	—	—	—	—	—	—	—	—	—
6	4	15	7	1	—	1	2	1	1	—	1	1	—	—	—	—
7	5.1	40	1	27	1	3	1	5	1	1	—	—	—	—	—	—
8	5.2.1	26	24	1	—	1	—	—	—	—	—	—	—	—	—	—
9	5.2.2	3	—	—	1	1	—	1	—	—	—	—	—	—	—	—
10	5.2.3	11	1	3	—	—	2	—	5	—	—	—	—	—	—	—
11	6	13	2	3	—	—	3	2	1	—	—	1	—	1	—	—

3. THE RESULTS

With respect to the Tholen taxonomy we notice the existence of classes which represent well some taxonomical types (e.g. 1, 2.1, 2.2, 3.2, 5.1, 5.2.1 classes). Some classes (e.g. 3.1 or 6) present a large diversity of taxonomical types, which makes the drawing of any conclusion difficult.

We have expected the following separation of the taxonomical types to be not so good because in Tholen taxonomy there are used 7 colour indices and we had at our disposal only 2 colour indices.

The analysis of the mean-values of the initial parameters for all the 11 classes shows interesting and expected things. For example, the classes 1, 2.1, 3.2 and 5.2.1 have almost the same values for colour indices and albedo (these classes are constituted mostly by the same taxonomical type). So, the separation was made exclusively by the other five parameters.

An inclination-semiaxis diagram for the class 5.2.1 shows two clearly separated groups. The identification of asteroids suggests that this class is disputed between the Coronida and Eos families.

Interesting results were obtained from the class 5.2.3, which contains few asteroids but which represent very well the Themis family. The class 4 contains asteroids from the Flora family : in the class 6 there are the Amor asteroids and the Trojans ones.

4. CONCLUSIONS

Obviously, better results can be obtained with a larger sample and using more parameters. In order to obtain more objective results, we intend to use automated clustering algorithms to separate the subclasses.

Acknowledgements. The author is grateful to Dr. Gheorghe Vass for his assistance in using the programs and for many helpful discussions.

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Received on 10 January, 1993