G-MODE CLASSIFICATION OF TRANS NEPTUNIAN OBJECTS. M. C. De Sanctis[1] , A. Coradini[2] and A. Gavrishin[3], [1] IASF-INAF (ARTOV, 00133 Roma, Italy, mariacristina.desanctis@rm.iasf.cnr.it), [2]IFSI-INAF (ARTOV, 00133 Roma, Italy), [3] Novocherkassk Politechnics, (Novocherkassk, Russia).

Introduction: TNO population show a wide colour diversity. Now is quite widely accepted that the colour diversity is a real characteristics of the outer solar system population and not an observational bias. Colors range from blue to very red but the how is colour distribution of TNOs is under debate. Since the population is characterized by several parameters, reflecting the different phenomena, it is important to use a multivariate statistics in order to understand if different types of objects exist. In what follows we will describe first the characteristic of the population, and then we will describe the strategy needed to tackle this problem.

TNOs Data Sample: We make a statistical analysis using the data of 81 Kuiper Belt objects. We chosen our sample among the KBOs with well known dynamical elements: all the objects have been chosen between those with calculated proper elements (that means two or more oppositions) [1] . The parameters used in our statistical analysis are: colour index B-V and V-R, magnitude H, orbital inclination i, orbital eccentricity e, and semimajor axes a. The colors are taken from different published data.

G-mode: We used the G-mode multivariate statistical approach to analyse this data set The G-mode method was developed by A. Gavrishin and A. Coradini [2]. As a clustering method, the G-mode allows the user to classify a statistical *universe* described by *N* samples, each depending on *M* variables, into homogeneous taxonomic units, considering the instrumental errors, and, if present, to eliminate redundant variables. Another advantage of the method is that different levels of classification can be performed. Once the first quasi-homogeneous groups are found, further analysis can usually subdivide them in homogeneous classes. At this point, it is also possible to recognize the level of similarity and differences between classes.

Results: We applied the G-mode method to our sample the conditions of 99.5% of confidence level. G-mode analysis separates the 81 objects of our sample in five groups, well separated for the dynamical parameters and less separated in colours. Four of the five type, 1, 2, 4, and 5, are well separated in dynamical parameters while type 3 show a wide range of parameters and is superimposed to type 1 and 2 (fig.1). Types 4 and 5 results as the more extreme in terms of semi major axes (average a = 58.3 and a = 89.4 for type 4 and 5 respectively).

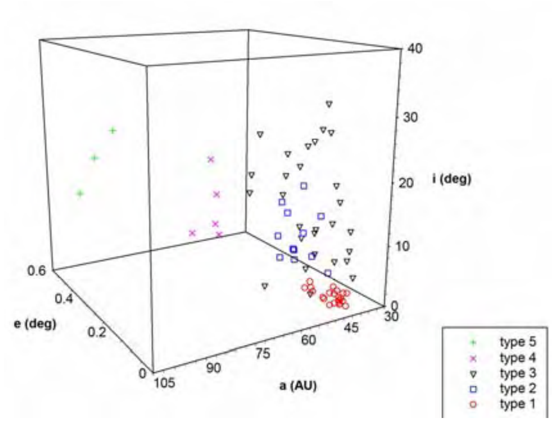

Fig.1: Types distribution, 3-D view of the dynamical parameters

Using only the physical variables the scenario is more complex and the different types seem to be mixed up. However, type 1 is concentrated also in the physical space.

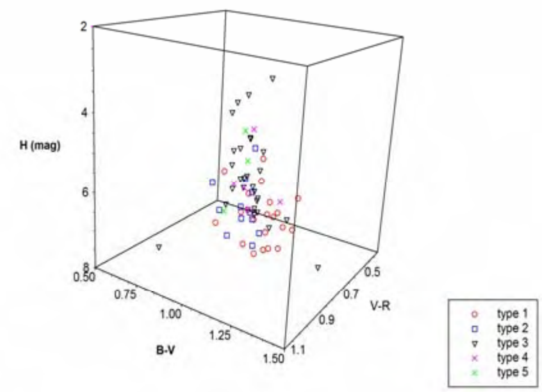

Fig.2: Type distribution: 3-D view of the physical parameters.

Concerning the colours distribution we can say that the types are distributed along a line (colour-colour correlation), except for type 1, that occupies a well defined B-V vs V-R region, in the upper portion of the plot in fig.3. This means that type 1 objects, not only cluster in the dynamical space but also in the colour one. The types identified using G-mode analysis correspond to some dynamical class: in fact all the objects of type 1 are "classical objects", all objects of type 2 are "plutinos", all objects in groups 4 and 5 are "scattered" objects. Only type 3 is a group of dynamical "different" TNOs (scattered and classical objects and 1 plutino).

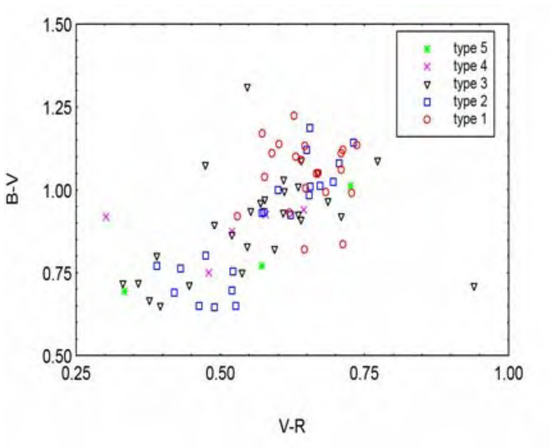

Fig. 3: Colour-colour distribution of the 5 types.

Type 1: This group (22 objects) is very homogeneous. The distribution of all the variables is Gaussian and symmetrical with only strong correlation between semimajor axes and eccentricity. All the objects in this group are "classical" TNOs with very low inclinations (inclination maximum =3.7), semimajor axes between 42.5 and 46.6 AU and maximum eccentricity of 0.132. Also the colours of this type are well defined: mean B-V is 1.05 ± 0.4 and mean V-R is 0.65 ± 0.2. This is a cluster of red objects with very similar orbital characteristics.

Type 2: Type 2 members (21 objects) are the so called "plutinos". We found strong correlation between colour index (rcorr=0.86) and negative correlation between H and B-V. G-mode obtains 4 homogeneous. These classes are well separate in colours but not in orbital parameters. We can observe red and grey objects at low and high inclinations, confirming no correlation with inclination among this group. The colour-colour correlation is evident, but also the fact that this type 2 seems to be separate in two groups of colours: red and blue objects. More specifically we can say that all the blue plutinos are small (H> 6.5) and no blue objects is found among the larger ones.

Type 3: The group is composed by 28 TNOs, mostly "classical objects" (25 objects), 2 scattered objects and 1 plutino (Ixion). This type is very inhomogeneous in dynamical parameters but is more similar in physical parameters. Applying the G-mode method to this group, we obtained 6 classes, with a confidence level of 99.5%, and one object (1999 OY3) is rejected as anomalous. The classes cluster in the dynamical variables and also in the colours space.

Type 4 and type 5: Type 4 is constituted by 5 elements, all scattered objects with semimajor axes between 55 and 65 AU. This group is well separated in semimajor axes and show similar colours. Type 5 is the more extreme group in terms of semimajor axes and eccentricity (83.3 AU<a<94.6 AU). The limited number of elements of these groups does not permit a more sophisticated statistical analyses.

Conclusion: The first evidence that emerge from our analysis is the existence of a very homogeneous subset of data, classified as type 1. All the type 1 objects have perihelia beyond 39.5 AU. We can confirm the presence of a red homogeneous cluster of objects at low inclination.

The second group identified by G-mode analysis consists of 21 "plutinos", that can be, further, separate in 4 classes with different characteristics. Type 2 shows a strong correlation between colour index and negative correlation between size and colours. "Smaller" Plutinos are blue while the red plutinos show a wide range of size. No correlation colour-inclinations found.

The third group identified by G-mode is formed, essentially, by classical objects with inclination above 4 and few scattered bodies and Ixion. The physical characteristics of type 3 are such that the members of this type are not very far from that of type 2, 4 and 5 except for eccentricity and semimajor axes, while are different from that of type 1. The reason of the differences between these two types (1 and 3) that allocate the same a-e space and of the similarities between type 3, 2, 4 and 5 should be understood.

Types 4 and 5 correspond to scattered disk objects located in two different zones. In our classifications, type 4 and 5 show similar colour index, while type 3 and 2 show a larger colour variation.

We have seen that G-mode method is able to classify the KBO population in taxonomic types and classes.

The taxonomic types and classes show different correlations and trends that help us to understand the physical properties of KBOs. The obtained results confirm the existence of dynamical and physical different objects. To understand the reason why there is this strong variegations we must review the observations and the statistical studies in framework of the different formation scenarios, trying to constraint them.

References:

[1] Knezevic and Milani (2003) *A&A*, 403, 1165-1173. [2] Coradini et al.,(1992), *EMP*, 59, 141-152.