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Basaltic asteroids: a howardites - eucrites - diogenites view

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Abstract

We present a compositional classification of 374 V-types selected from the MOVIS catalogue [1]. The classification was made by comparing the V-types colors with those of a sample of 65 HED meteorites from RELAB database. We found that 51 % of the V-type asteroids can be associated with Eucrites, 29 % with Howardites and 20 % with Diogenites. From the collisional family point of view, about 100 (≈27% of the sample) asteroids belongs to (4) Vesta family, 246 asteroids (≈66%) are not assigned to any family of asteroids and the rest 28 (≈ 7%) have been associated with various other families.

1. Introduction

Basaltic asteroids are fragments of primordial bodies that went through the process of differentiation. The differentiated asteroids and igneous meteorites provide important clues to the understanding of the accretion process and the early history of the Solar System. The ≈ 500 km size asteroid (4) Vesta is the representative member of these objects which are classified as V-types.

Most of the V-types are orbiting in the inner part of the Main Belt and have been dynamically linked with Vesta through the Rheasilvia basin [2]. A fraction of the ejected fragments spread around the Main Belt while some of them were sent into near-Earth orbits. The link between the HED meteorites and the V-types has been firmly proved spectroscopically [3]. It is considered that the eucrites were part of the upper layers of the crust, the digionites of the mantle layers while the howardites are a mixture of the two [4].

Recently, new V-type asteroids have been discovered in the middle and outer part of the belt. Since these asteroids cannot be dynamically associated with Vesta it led to the idea that other differentiated parent bodies must have existed.

The aim of this paper is to explore the possibility of using NIR colours provided in MOVIS catalog, to distinguish between the howarditic, eucritic and diogenitic compositions for the asteroids classified as V-types.

1.1. Methodology

We selected the V-type candidates provided in the MOVIS-C catalogue [5]. The following constraints on the color indices errors were applied so that only objects with: $(Y\text{-}J)_{err} \leq 0.118$, $(J\text{-}Ks)_{err} \leq 0.136$, $(H\text{-}K)_{err} \leq 0.146$ were selected, thus resulting in 374 V-type candidates. To classify the asteroids according to HED typologies we used several machine learning methods. The results obtained by KNN(K-Nearest Neighbor, where K is the number of nearest neighbors) proved to be the most reliable for this data set.

As a training set, we used the sample of HED meteorites spectra following the selection of [6]. This contains data for 65 meteorites out of which 13 are Diogenites, 39 Eucrites and 13 Howardites. Their spectra are available in the RELAB database and they are converted to the (Y-J), (J-H), (H-Ks), and (J-Ks) colours corresponding to VISTA filter system. Fitting the training values with the labels of each type of meteorite and iterating through different K values, a label prediction could be established for the basaltic asteroids.

To validate our approach we performed the "leave one out test" for the algorithm. The result is summarized by the confusion matrix shown in Figure 1. The algorithm manages to identify with 53% cases howardites, 92% eucrites and 76 % diogenites. The low percent of howardites identification is due to the fact that compositionally these are a mixture of eucrites and diogenites.

We compared our results with those derived from observed spectra of three objects classified as V types. We found that the compositional type matches for

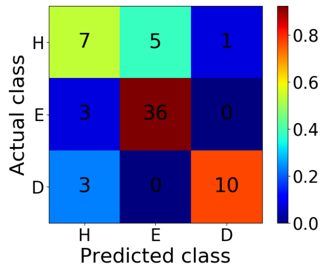

Figure 1: The confusion matrix performed for the HED data set. Probability is indicated by the color gradient

(2763) Jeans and (9064) Johndavies which are eucrites while (5952) Davemonet was classified as howardite and we predicted a diogenite like composition.

We interpreted our results in the context of proper orbital elements provided by [7].

2. Results

The classification algorithm labeled 110 asteroids as being associated to Howardites, 190 as being Eucrites and 74 Diogenites. A clear separation arises between the three groups when a (H-Ks) vs (J-H) plot is considered (Figure 2). About 100 (≈27% of the sample) asteroids belongs to (4) Vesta familly, 246 asteroids (≈66%) are not assigned to any family of asteroids and the rest of 28 (7%) objects belongs to different families including (135) Hertha, (15) Eunomia, (170) Maria, (158) Koronis, and (221) Eos.

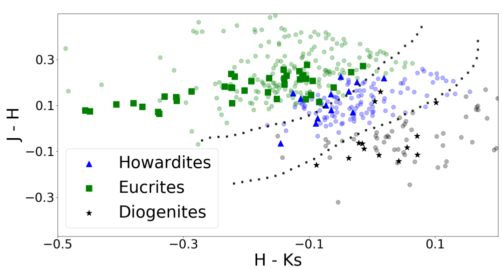

Figure 2: The colors of the asteroids(faded, circles) are correlated with the colors of the HED meteorites.

More than half of the (4) Vesta familly asteroids (53% – 53 out of 100 objects) are compatible with an eucritic composition and about 31 % have a howarditic like surface. Only 16 % of asteroids linked with (4) Vesta are compatible with diogenites, and in the orbital parameter space they are the closest to the familly parent body. Using visible and near-infrared spectra of 12 objects, [8] reported a howarditic composition in most of the vestoids.

The most common type of asteroids found are eucritic in nature regardless if they are vestoids or not while the most rare are associated with a diogenitic composition. In Figure 3 we show the distribution of this asteroid sample in the orbital parameters space. The compositional types are labeled accordingly. We note that most of the diogenites like compositions are found in the inner Main Belt, and only four objects of this type are found in the midlle part and a single diogenite like candidate was found in the outer Main Belt. This distribution does not support the existence of other basaltic families beyond 2.5 A.U.

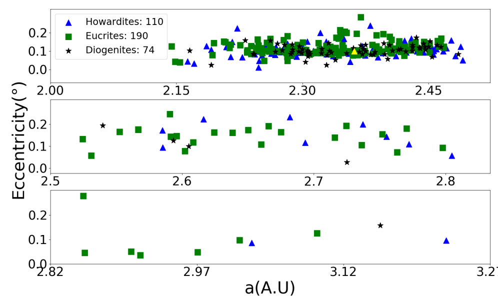

Figure 3: From top to bottom, the subplots show the distribution of the sample of asteroids in the three regions of the asteroid belt: inner, middle and outer belt. Vesta has been designated by a yellow triangle

The diogenitic like objects show slightly smaller diameters than eucritic and howarditic like objects. The vestoids classified here have diameters between ≈ 1 km and ≈ 6 km, with the largest vestoid being classified as an eucrite with a diameter of 6.9 km.

There are several hypotheses proposed to explain the basaltic asteroids in the middle and outer Main Belt. One of these considers the instability of the giant planets during migration which caused the scattering of asteroids in the Solar System. The possibility of transporting V-types due to scattering was confirmed by [9]. We note that most of the V-types in the midlle and outer part of the Main Belt have diameters less than 10 km (28 out of the total of 47 objects). They are more succeptible to be scattered objects due to Yarkovski effect but [10] and [11] deemed it unlikely.

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