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Taxonomic classification of asteroids using future Gaia data

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Abstract

The payload of the Gaia space probe includes detectors (Blue Photometer: BP and Red Photometer: RP) designed to obtain spectro-photometric data from blue to red (from 330 to 1050 nm). Asteroid data obtained by these detectors will be used to derive reflectance spectra for a number of the order of 100,000 objects [3]. Based on this data-base, it will be possible to develop a new asteroid taxonomy. The big advantage of this will be that of including, for the first time after many years, also the blue part of the reflectance spectrum, which has been essentially lost during the last decades in all the most modern ground-based CCD-based asteroid spectroscopic surveys. The blue part of the reflectance spectrum is essential to discriminate among different sub-classes of the big C-complex, including the most primitive asteroids which are known to exist. A particular attention will be devoted to the F taxonomic class, which is characterized by interesting polarimetric properties. In order to prepare the algorithms needed for building the planned Gaia asteroid taxonomy, a campaign of spectroscopic observations covering the same wavelength interval, and obtained at the same phase angles which will characterize Gaia observations, has been carried out at TNG. The state of the art in these activities will be briefly summarized.

1. Introduction

Asteroids are primitive bodies of our Solar System formed around 4.5 billions years ago and very little evolved since then. Thus, the study of these bodies allows us scientists to obtain precious information about the processes of formation and evolution of our planetary system. Numerous asteroid spectra were collected during these last 20-years, in the visible as in the infrared wavelengths.

These spectra allow us to study the composition of asteroids and various classifications were proposed. The first taxonomies proposed by Zellner et al., Chapman et al. and Bowell and al. [3] identified three principal classes: the C class which corresponds to carbonaceous chondrites, the S class to stony-iron meteorites and the M class to metallic-iron-nickel meteorites. Later on, various taxonomies were proposed, built on larger data set and defining more precise classes (Tholen or Bus & Binzel [2]). The payload of Gaia contains two low resolution spectrophotometers which will provide spectroscopic observation of around 100,000 asteroids. The taxonomy of all these asteroids will be produced via an unsupervised classification method.

2. Observations

A spectroscopic campaign using two dedicated runs at the 3.5 m Telescopio Nazionale Galileo (TNG) at La Palma (Canary islands) has been realized. Thirty four asteroids were measured in the same wavelength interval and at the phase angles which will characterize Gaia data. An example of BP-RP relative reflectance derived on the asteroid (720) Bohlinia is shown in Fig.1.

The derived reflectance spectra were cloned using a random noising technique but with some constraints guaranteeing that the cloned spectra still are compatible with asteroid reflectance spectra. Then the low-resolution spectra produced were normalized at the central wavelength of the Johnson V band (550 nm).

3. Taxonomic classification of TNG spectra

The classification of the data set is done via an unsupervised algorithm, which means that no assumptions are made on the data. The goal is to rely on the data itself without making any use of existing taxonomic classifications, which were based on different wavelength intervals and spectral resolution. This ap-

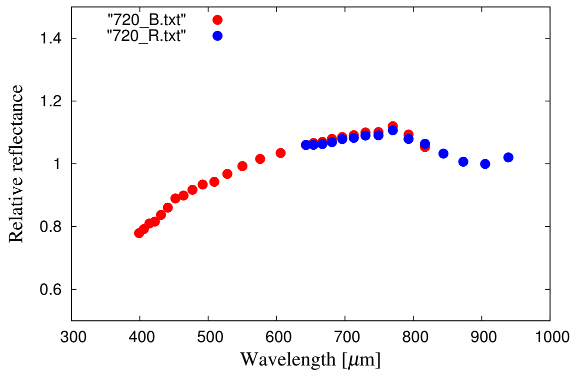

Figure 1: BP / RP Reflectance Spectra of Asteroid (720) Bohlinia

proach has already been tested and validated for asteroids spectra SED by Galluccio et al. [4].

The underlying idea of this method is the use of a metric to quantify the distances between the objects in the space of spectroscopic data. The metric used in the following tests is the Kullback-Leibler divergence, further information can be found in Basseville [1].

The clustering approach is based on the concept of trees, in particular minimal spanning trees (MST), and data partitioning. Based on the MST built on the dataset, a function (referred to as Prim's trajectory) retrieves the distance of the connected vertices of the tree (here asteroid spectra) at each iteration. Then a threshold computed automatically is applied to this function. The sets of spectra below the threshold are considered as clusters used to initialize a K-means-like data partitioning, to obtain the final classification.

The unsupervised classification produced the clusters plotted in Fig.2. These clusters have been assimilated to Bus & Binzel taxonomy to evaluate the quality of the clustering method. The cloning step with noise perturbation leads to some overlaps of Bus classes. The principal classes S and C are however well separated and some minor classes are perfectly recovered (Ld, V, A).

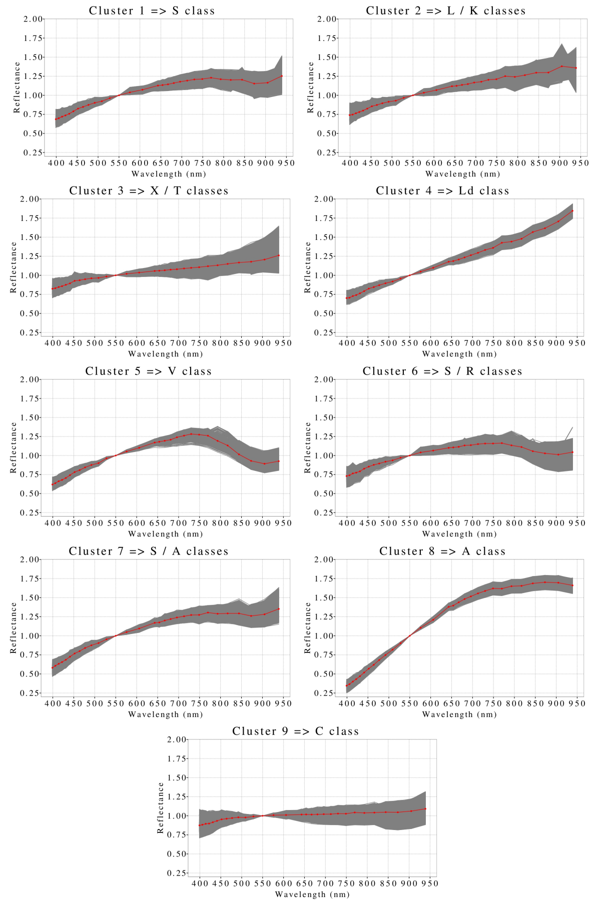

Figure 2: Clusters of spectra obtained: asteroids spectra (grey), mean class spectra (red). Clusters have been compared to Bus & Binzel classes.

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