ANALYSIS OF VISUAL REFLECTANCE SPECTRA OF “HUNGARIA” FAMILY OF ASTEROIDS.

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Introduction: The term “asteroid families” is synonymous with the Japanese researcher “Kiyotsugu Hirayama”, who was the first to use the concept of proper orbital elements to identify groupings of asteroids with nearly identical orbits[4]. Hirayama proposed that the members of asteroid families have a common origin. Hirayama identified 5 distinct asteroid families, today known as Hirayama families: Eos, Themis, Koronis, Flora, and Maria [1]. Elements which are used to classify asteroids into families are Semi major axis (a), proper eccentricities (e) and proper inclination (i) [11]. These families and their membership has greatly increased with subsequent observations.

The present work focuses on the Hungaria family which consists of asteroids located in a swath between 1.78 and 2.06 AU. They are bounded by the v5 and v16 secular resonances, the 4:1 mean motion resonance with Jupiter (4:1 Kirkwood gap), and Mars-crossing orbital space. Its members have relatively high inclinations ($16^{O} < i < 34^{O}$) and eccentricities typically less than 0.18 [10].

Spectroscopic Surveys and other studies has been carried out with respect to Hyngaria family by various authors such as Carvano et al. (2000) [3], Milani et al. (2009) [7], McEachern et al. (2010) [5] and Warner et al. (2009) [10]. But no attempt was made to compare spectral data to comment on the family’s origin. This study intends to achieve this goal using the available visible reflectance spectral data.

Methodology: The experiment was carried out using the available spectral data in the NASA PDS (Planetary data system). The data set “Small solar system objects spectroscopic survey V 1.0” was downloaded form the PDS website. This dataset contains the visible spectra of 820 asteroids obtained between November 1996 and May 2001 at the 1.52 m telescope at the European Southern Observatory (ESO) at La Silla, Chile. The useful spectral range was between approximately 4900 and 9200 Angstroms (0.49 to 0.92 µm). Reflectance values of asteroids are normalized at 5500 Angstroms (0.55 µm). List of the available asteroid spectra in the data set was cross-referenced with Hungaria asteroid catalog provided in the paper “Hungaria group of minor planets” by Cristoper E Spratt,(1989)[9] from which relevant spectral data were extracted. It was possible to acquire spectral data for 28 such asteroids.

Visual inspection of those plots enabled most of the spectra to be sorted in to four categories which are shown in Fig. 1. Type 1 spectra are flat, type 2 show a steady increasing continuum, type 3 are similar to type 2 except that they level off at long wavelengths, and type four show a marked change in slope after reaching a maximum.

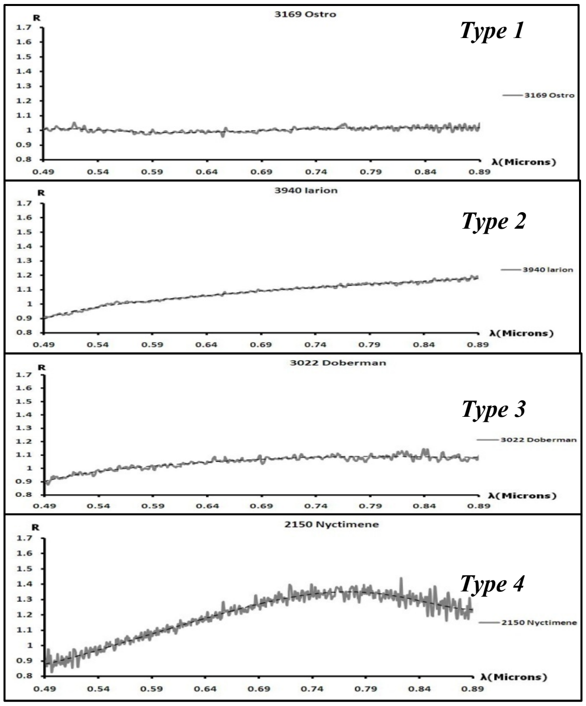

Figure 1. Representative visible spectral types of asteroids.

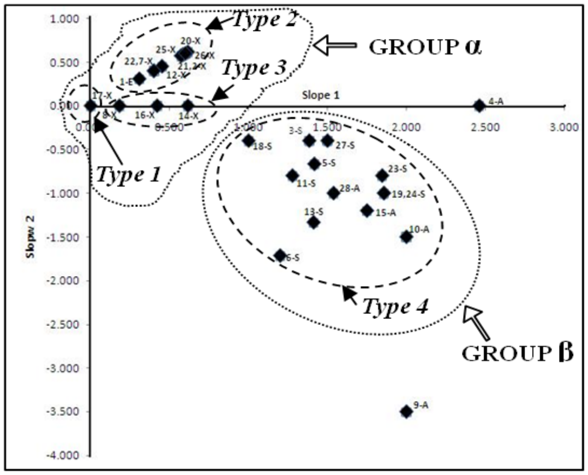

Figure 2. Distribution of asteroids with respect to their spectral characteristics.

In order to quantify the spectra we define two slope parameters. Slope 1 represents the slope of regression line drawn to the spectra 0.49 µm to the wavelength of peak reflectance. Slope 2 represents the slope of regression line drawn from the peak reflectance wavelength to 0.89 µm.

Results: The plot of Slope 1 *vs.* Slope 2 clearly sort the asteroids in to 2 groups that we term ***α*** and ***β*** (Fig. 2). Group ***α*** consists with Type 1, 2, and 3, plots as defined above. These are X type (except 1025 Reima which is an E asteroid) in the Bus et al. taxonomy[2]. Group ***β*** are consist of Type 4 as defined above and they are A and S asteroids according to the Bus taxonomy[2]. A few asteroids in group ***α***, namely 1355 Magoeda, 3400 Aotearoa, 3447 Burckhalter, and 3940 Larion have the very similar spectral features and they plot together or close on the Fig. 2.

Discussion: Our results are in good agreement with the previous studies of Carvano et al. (2000) [3] who identified three spectral types, with the present types 2 and 3 combined, and who pointed out that there are both E/X and A/S asteroids in the Hungaria family.

Despite consisting of three spectrfal types, the ***α*** group are fairly tightly clustered, consistent with a common origin suggested by the dynamic data. The differences in the spectra of the three types could reflect parent body heterogeneity and it is possible that the linear trends shown by the Type 2 asteroids could be a space weathering trend, steeper slopes (reddening) implying greater weathering[8].

Carvano et al. proposed four hypotheses to explain the ***α*** group, (a) fragmentation of a single parent E/X asteroid, (b) independent formation of each asteroid constrained to form in a narrow volume of orbit space by their unusual composition, (c) preferential removal of non E/X asteroids by an unknown dynamic process, and (d) formation over a wide volume of the solar system but concentration in restricted orbit element space. The abundance of E/X asteroids not associated with the Hungaria family led these authors to favor mechanism (d), although not seeing a mechanism for doing this they suggested that perhaps a mixture of mechanisms (a), (b) and (c) could suffice.

Carvano et al. did not discuss the implications of about half the Hungaria family asteroids being S asteroids and we thnk this is critical to understanding formation of the Hungaria dynamic family. In our opinion the coexistence of such chemically diverse material as X/E and A/S asteroids, in the same dynamic family, excludes any hypothesis that invokes composition as a means of constraining formation of the family. Thus we consider hypotheses (b) and (c) as unlikely. We also consider (d) as unlikely, not only because we cannot see a mechanism for this, but also because we now need to find a way of concentrating compositionally diverse material.

We do not share the Carvano et al. discomfort with mechanism (a) because we believe that there are so many X/E asteroids spread throughout asteroid belt, that there must have been many such asteroids originally formed. The problem is why are there so many S asteroids in this dynamic family. We think it unlikely that A/S and E/X asteroids came from the same parent object because of the 2000 or so asteroids for which we have spectra such mixtures are unknown In the solar system.

We suggest that the simplest explanation for the Hungaria family is that one of many A/S asteroids collided with one of many X/E asteroids and that the fragments were thus placed on very similar orbits.[6] One might expect that orbits would be dispersed by such a major impact, but this event occurred in a region of space where orbital resonances with Jupiter and Mars streamed the resulting fragments. The Hungaria family have not been proposed as a source for any major meteorite class, but we do know that the major meteorite classes tend to have peaks in their cosmic ray exposure age histograms suggesting that major break-ups play an important part in asteroid history.

Conclusions

The Hungaria family of Asteroids can be divided in to 2 groups (which we call ***α*** and ***β***), where the Group ***α*** asteroids are E and X asteroids and Group ***β***.are A and S asteroids. Within Group ***α*** there may be subgroups, and in one case trends in their spectra may suggest a space weathering trend. Group ***β*** show some variability in their spectra that may reflection of a number of mechanisms that have been proposed for the orgin of the Hungaria group. We suggest that an impact between one of many X/E asteroids and one of many A/S asteroids is most probable origion for the Hungaria family of asteroids.

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