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Size and Age Dependence of Koronis Family Colors

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Abstract

The ancient and massive Koronis family now has four identified subfamilies (asteroid families made by the breakup of fragments of the ancient collision), with ages running from 5.7 to 290 My. This presents unique opportunities to explore space weathering processes, along with dynamical processes such as collisions and binary formation and destruction.

Analysis of family members with accurate SDSS measurements shows a correlation of average subfamily color with age that for the first time is highly statistically significant. Yet Thomas et al. (2011) report a size dependence of the colors of the ancient family that demands caution when comparing subfamilies with differing size distributions. Reanalyis of the Thomas et al. data show the reported break near asteroid diameter 5 km is not significant. However, analysis of the much more extensive SDSS data set show a significant break past diameter 2.5 km, with smaller objects systematically bluer. The break is not present in the Karin subfamily (the youngest at 5.7 My), but is already fully developed in the Eriphyla subfamily (only 220 My).

The reddening trend with age remains even when comparing only asteroids of similar size, confirming the presence of space weathering phenomena. The meaning of the trend with size is not immediately clear. We consider briefly the strengths and weaknesses of several interpretations of the bluer colors for small objects: 1) those objects receive more jolts from random collisions capable of shaking the regolith and exposing fresh material beneath; 2) those objects receive more jolts from the cycle of fission and recombination driven by YORP; and 3) the lower gravity on those objects retains regolith less well.

1. Introduction

While there are a number of lines of observational evidence for space weathering in main belt and near Earth asteroids, it is generally not possible to isolate the effect of weathering due to varying solar distances, varying chemical compositions, and uncertain surface ages. The Koronis region (between the J5/2 and J7/3 mean motion resonances) provides an opportunity to measure weathering in detail because of a fortuitous combination factors: 1) relatively low density of objects (permitting determination of family membership); 2) the presence of one of the large, ancient familes (providing ample targets for subfamily formation); and 3) a position well away from the dense resonances on the edges of the main belt (that quickly distort family boundaries and history).

Having made a careful search for subfamilies, we found a total of four (including the previously known Karin subfamily) [3]. Table 1 lists the largest object in each family, the number of asteroids identified, the subset of those with high quality SDSS colors, and an estimate of the family age . Figure 1 plots the family average SDSS color a* versus age, together with an empirical estimate of the uncertainties. The data are well fit by a straight line with slope 0.0252±0.0017 mag/decade.

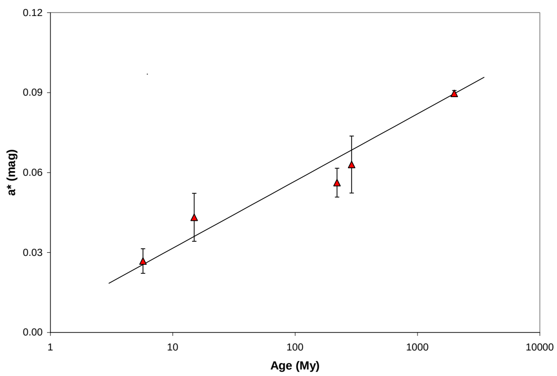
Table 1: Old Koronis family and subfamilies

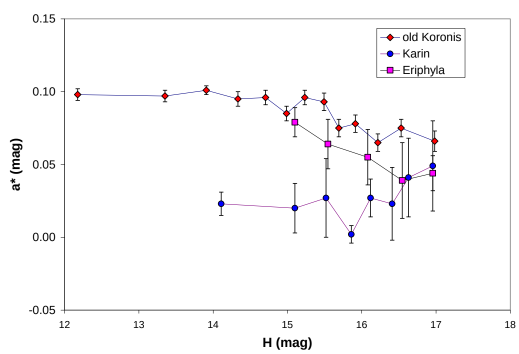
Family	N	N_{SDSS}	t (My)
Old Koronis	5227	1288	2000
158 Koronis	200	30	15
321 Florentina	78	18	290
462 Eriphyla	288	53	220
832 Karin	505	77	5.7

2. Size dependence of color

Thomas et al. [4] measured colors of 89 members of the old Koronis family and reported a trend towards a bluer average for asteroids smaller H around 13.9 mag (2.5 km in diameter assuming an albedo of 0.21). However, averaging their data in independent bins, we find the difference in the values is not highly significant. Further, if those data with large uncertainties are omitted before binning, the difference is not significant at all.

The SDSS data for this family has more than an order of magnitude more measurements and a wider range of asteroid sizes. We bin these data in Figure 2 and confirm the absence of a break at 13.9 mag. However, there is a significant break beginning around 15.3 mag (2.5 km).





Figures 1 and 2.

We explore this further binning the Karin and Eriphyla subfamilies. (The remaining families have too few SDSS measurements to make a significant statement when binned.) The Karin family is consistent with a constant (blue) color independent of size. The 220 My old Eriphyla family has measured values only for asteroids fainter than 15.3 mag. These show the same trend with size as the old Koronis members, although they are systematically bluer than those objects in each bin.

3. Interpretation

Since all families in Figure 2 are made from the same original material, we interpret the differences between them in terms of processes over time. The mechanism that caused the break in the old Koronis data, began after 6 My and was complete by 220 My (though the reddening continued beyond 220 My).

One possibility is collisions with other main belt asteroids that were large enough to shake the regolith and reveal fresh surface, but not large enough to fragment the asteroid. The rate of such collisions depends on the main belt size 10-100 m diameter range, which is not well known. If one extrapolates from the size distribution for small objects found by SDSS [1], the smallest objects should be *less* blue on average. This is due to a distribution so shallow that the increasing number of small projectiles does not even make up for the decreasing target size. This hypothesis can only work with a very different size distribution.

Jacobson and Scheeres [2] show that YORP torques lead many objects to fission and then reaccrete. The reaccretion event may be energetic enough to freshen the regolith. This effect works better for smaller objects as needed, but more work is needed to test the model rigorously.

A third option is that proportionate collisions could have outcomes that differ with size due to varying surface gravity. It is easier to knock the weathered regolith clear of the asteroid altogether for small asteroids.

Acknowledgements

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References

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