# The Sloan Digital Sky Survey Moving Object Catalog

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**Abstract**

Sloan Digital Sky Survey, although optimized for extragalactic science, is significantly contributing to solar system science by producing the largest available database of multi-color photometric measurements for asteroids. This database, SDSS Moving Object Catalog (SDSSMOC), is public[1] and currently contains observations for ∼200,000 moving objects observed prior to June 2004. Of those, ∼68,000 are linked to ∼43,000 unique objects from Bowell's ASTORB file, and their osculating orbital elements are also listed, as well as proper orbital elements from Milani & Knežević. The imminent fourth release of SDSSMOC will include ∼470,000 SDSS observations of moving objects, with a subset of ∼217,000 linked to ∼102,000 unique objects from ASTORB.

The main results derived to date from SDSS observations of asteroids are

1) A measurement of the main-belt asteroid size distribution to a significantly smaller size limit (< 1 km) than possible before. The size distribution resembles a broken power-law, independent of the heliocentric distance (Ivezić et al. 2001; Jurić et al. 2002)

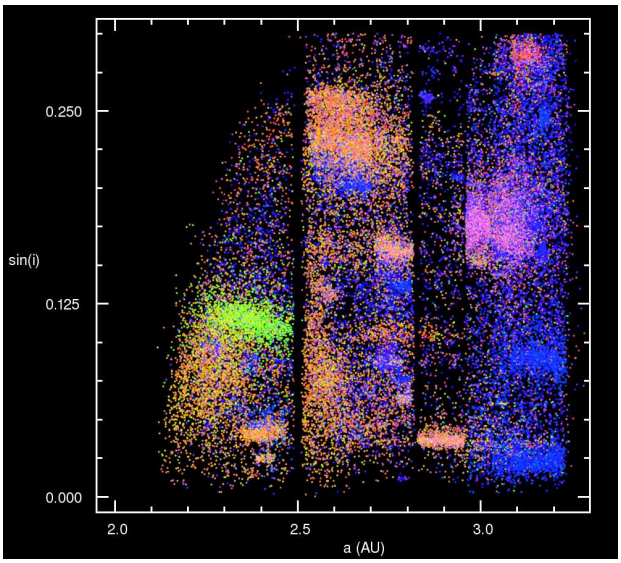
2) A smaller number of asteroids compared to previous work. In particular, the number of asteroids with diameters larger than 1 km is about 750,000 (Ivezić et al. 2001; Jurić et al. 2002)

3) Asteroid dynamical families, defined as clusters in orbital parameter space, also strongly segregate in color space. Their distinctive optical colors support earlier suggestions that asteroids belonging to a particular family have a common origin. SDSS data indicate that about 50 percent of asteroids belong to families (Ivezić et al. 2002; Parker et al. 2007)

4) Asteroid colors depend on their family's age, presumably due to space weathering (Jedicke et al. 2004; Nesvorny et al. 2005)

5) There are significantly more Jovian Trojan asteroids in the leading swarm (L4) than in the trailing swarm, and their color is correlated with their orbital inclination (Szabo et al. 2007)

[1] SDSSMOC is available from http://www.sdss.org/dr6/products/value_added/




**The Colors of Asteroid Families**

The dots in the above Figure show the distribution of ∼45,000 asteroids with available SDSS colors and proper orbital elements in the proper inclination vs. semi-major axis diagram. The proper elements are taken from Milani & Knežević (1992, Icarus, 98, 211), and the sample is complete to $H < 16$ (roughly size limited to objects with $r > 1$ km).

The dots are colored according to their position in the SDSS color-color diagram shown in the middle. The two chosen colors are the principal axes for the asteroid distribution in the SDSS photometric system, with the horizontal axis defined as

$$a^* \equiv 0.89\,(g-r) + 0.45\,(r-i) - 0.57. \qquad (1)$$

The asteroid distribution in this SDSS color-color diagram is highly bimodal, with over 90% of objects found in one of the two clumps that are dominated by rocky S type asteroids ($a^* \sim 0.15$, red and yellow dots), and carbonaceous C type asteroids ($a^* \sim -0.1$, blue dots). Most of the remaining objects have $a^*$ color similar to S type asteroids, and distinctively blue $i^* - z^*$ colors (green dots). They are dominated by Vesta type asteroids. **SDSS colors are a good proxy for asteroid taxonomic classes**.

SDSS data show that asteroid dynamical families, defined as clusters in orbital parameter space, also strongly segregate in color space. The three major asteroid families (Eos, Koronis, and Themis), together with the Vesta family, represent four main asteroid color types. Their distinctive optical colors indicate that the variations in chemical composition within a family are much smaller than the compositional differences between families, and strongly support earlier suggestions that **asteroids belonging to a particular family have a common origin**.

Proper orbital elements are not available for asteroids with large semi-major axis and orbital inclination. In order to examine the color distribution for objects with large semi-major axis, such as Trojans of Jupiter ($a \sim 5.2$) and for objects with large inclination, such as asteroids from the Hungaria family ($a \sim 1.9, \sin(i) \sim 0.38$), we use osculating orbital elements from the ASTORB file compiled by E. Bowell. The middle bottom Figure shows the distribution of ∼101,000 unique known asteroids observed by the SDSS in the space spanned by osculating semi-major axis and the sine of the orbital inclination angle, with the points color-coded according to their position in the SDSS color-color diagram shown in the middle of the poster.

It is remarkable that various families can still be easily recognized due to SDSS color information. This figure vividly demonstrates that **the asteroid population is dominated by objects that belong to numerous asteroid families**.

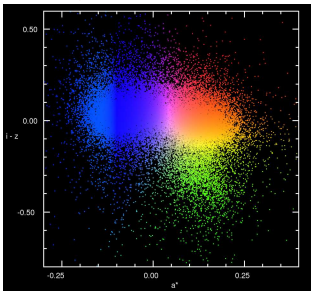
**SDSS Observations of Moving Objects**

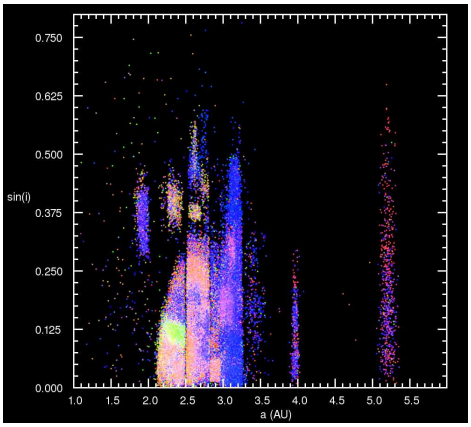
Sloan Digital Sky Survey (SDSS) is a digital photometric and spectroscopic survey which will cover 10,000 deg$^2$ of the Celestial Sphere in the North Galactic cap and produce a smaller (∼ 225 deg$^2$) but much deeper survey in the Southern Galactic hemisphere (for more details see www.sdss.org). The flux densities of detected objects are measured almost simultaneously in five bands ($u$, $g$, $r$, $i$, and $z$, with effective wavelengths ranging from ∼3500Å to ∼9000Å), 95% complete for point sources to limiting magnitudes of 22.0, 22.2, 22.2, 21.3, and 20.5. Astrometric positions are accurate to better than 0.1 arcsec per coordinate (rms) for sources brighter than $20.5^m$, and the morphological information from the images allows robust star-galaxy separation to ∼ $21.5^m$. The survey sky coverage will result in photometric measurements for over 100 million stars and a similar number of galaxies. The imaging part of the Survey will be finished in 2008.

Asteroids observed by SDSS must be explicitly detected to avoid contamination of the samples of extragalactic objects selected for spectroscopy. The basic characteristics of the SDSS moving object survey are:

- Moving objects are detected with a baseline of 5 minutes.
- The sample completeness is 90%, with a contamination of 3%.
- The velocity errors are 2-10%, sufficient for a recovery within a week.
- The five-band photometry is accurate to within 2% for objects brighter than $r \sim 20$.

The third release of SDSS Moving Object Catalog (SDSSMOC) includes all data obtained up to June 2004. The catalog includes data for ∼200,000 unresolved moving objects brighter than $r = 21.5$, with velocity in the range $0.05$ deg/day $< v < 0.25$ deg/day, from 301 observing runs that roughly cover the area included in the SDSS Data Release 5. The SDSSMOC includes various identification parameters, astrometric measurements (position and velocity, with errors), five magnitudes and their errors, and orbital information for previously cataloged asteroids from ASTORB file (compiled by E. Bowell, available from ftp://ftp.lowell.edu/pub/elgb/astorb.html).

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For more information about SDSS results on asteroids please see

Ivezić, Ž., Tabachnik, S., Rafikov, R. *et al.* 2001, *Solar System Objects Observed in the Sloan Digital Sky Survey Commissioning Data*, Astronomical Journal, 122, 2749

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Jedicke, R., Nesvorný, D., Whiteley, R., & et al. 2004, *An age-colour relationship for main-belt S-complex asteroids*, Nature 429, 275

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Nesvorný, D., Jedicke, R., Whiteley, R.J. & Ivezić, Ž. 2005, *Evidence for asteroid space weathering from the Sloan Digital Sky Survey*, Icarus 173, 132

Szabo, Gy., Ivezić, Ž., Jurić, M. & Lupton, R.H. 2007, *The Properties of Jovian Trojan Asteroids Listed in SDSS Moving Object Catalog 3*, MNRAS 377, 1393

and references therein.