Small-body Colors From the UV to the IR
Bringing Together all Space and Ground-based Observations

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Abstract

The main current asteroid taxonomical systems are defined from ground-based observations, limited to 3100-10600 Å (Tholen 1984; Zellner, Tholen, Tedesco 1985), and 4400-9200 Å (SMASS, Bus and Binzel 2002), which do not include several useful regions, such as: 1) the well-known spectral features in the near-IR (20000-50000 Å) that differentiate between common asteroid and meteorite minerals and indicate the presence of volatiles; 2) the far IR, which probes the bodies' emission, thermal inertia and albedo; 3) the UV, where the degree of darkening probes the surface grain properties and space weathering. The few existing studies using multiple instruments from the UV to the IR (ground, Earth-orbit and flyby observations) have been limited to targeted observations of special-interest bodies. We aim to obtain UV to IR colors of a large sample of bodies, to study how they are distributed and how these colors differentiate among bodies with similar spectra on the standard taxonomies. The data are being gathered from archives of multiple space- and ground-based instruments: GALEX, HST, SDSS, 2MASS, Spitzer, WISE and Herschel. Such a combined use of multiple archived observations is commonly done for fixed (non-Solar System) astronomical targets, which can be easily found by their RA and Dec. To obtain such data for Solar System bodies, we are building a database of all archive observations of each known body. We are using their orbits, integrated into the past, to build an index, which will be used to determine whether an observation contains a known body. We present a preliminary analysis, using a small sample of objects identified in multiple instruments. In the future we will expand the database to include more observations (more instruments and more bodies), and the populations we identify will be compared to spacecraft UV to IR spectra of those few bodies observed in close passes and with high resolution spectra. Ultimately, this work will prepare us for the LSST-era.

Moving body observations

Several data archives, particularly those of wide-field, wide-area surveys, contain serendipitous observations of Solar System bodies. But archive queries are usually on the RA/Dec domain. To allow easy collection of data from large numbers of Solar System objects, the archives would need to have databases with the occurrences of Solar System objects within its images, so that queries could be easily done for all moving bodies, or large lists of them.

There are two complementary approaches to populate such databases:

1) Known bodies: For each image in an archive, calculate if there is any known body which should fall on that image. These occurrences can be tagged, and the archive's source catalogs, when available, used to retrieve the corresponding photometry for the object.

2) New body identification: When there are sequences of images, or long exposure images, use them to identify moving bodies. If these do not correspond to any known body, tag them into a moving body database, which can be used for orbit determination, if there are enough observations, or in precovery searches for objects detected in any other images.

We aim to develop both databases, and use them to analyze the colors of all the objects found, matching them in multiple data sources, to obtain colors from the UV to the IR. In this poster, we present the preliminary results of the identification and cross-match of know body observations, for a small sample of bodies and a few archives, which will be expanded in the future.

Identifying know body observations

We integrate into the past the orbits of the known bodies, to obtain their positions as a function of time. For this proof of concept, to reduce the computation time, we used only only the first 10 000 objects. In the future, we will expand the database to include all the known bodies (currently, ~350 thousand numbered, ~250 thousand unnumbered).

The positions were calculated with the SPICE toolkit (Acton 1996), from the Navigation and Ancillary Information Facility (NAIF), from kernel files generated by the JPL HORIZONS system (Giorgini et al. 1996). Since accurate positions have to be calculated for the time and location of each archive exposure, and archives can have several million exposures, the positions are calculated in two steps:

1) A coarse grid is calculated with the position of the bodies into the past, at 1-day time intervals. This precomputed grid is used to filter the number of candidate bodies that have to be considered for each exposure in an archive.

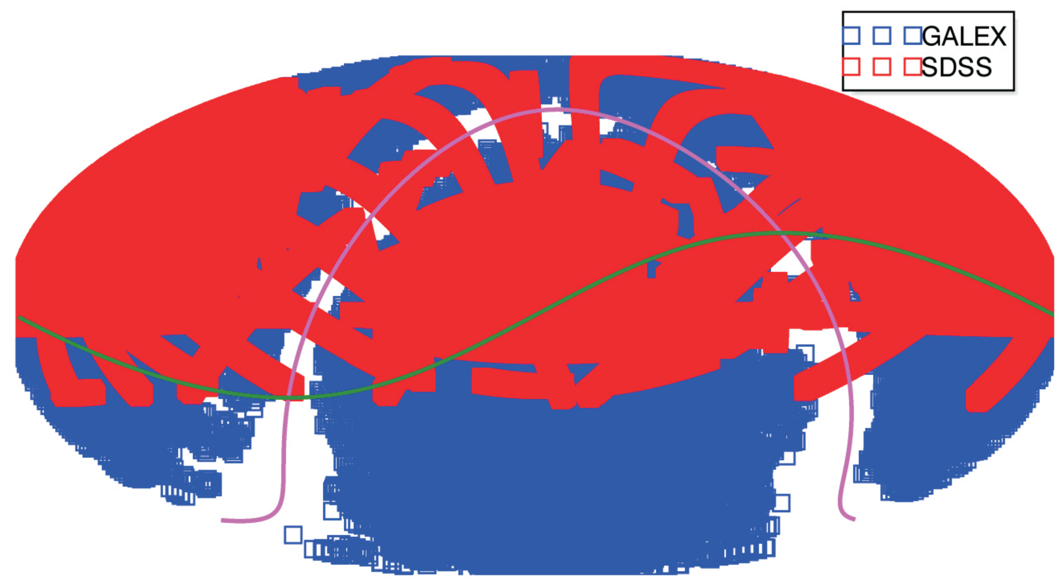
2) The candidates found in (1) have their positions precisely calculated for the time and location of each frame in the archive, to determine if they fall into the field of view.

The resulting matches are stored in a database, indexing all observations of each body.

Observations found

We used the databases of all images from 4 wide-area surveys:

1) GALEX: 2 filters (FUV: 0.15μm, NUV: 0.23μm), 1.2° field of view, 4"/pix <~21 mag
2) SDSS DR10: 5 filters (u: 0.36μm, g: 0.47μm, r: 0.62μm, i: 0.75μm, z: 0.89μm), 9' field of view, 0.4"/pix, < ~22 mag
3) 2MASS: 3 filters (J: 1.25μm, H: 1.65μm, K: 2.17μm), 9' field of view, 1"/pix, < ~ 16 mag, allsky
4) WISE: 4 filters (W1: 3μm, W2: 4.6μm, W3: 12μm, W4: 22μm), 47' field of view, 6"/pix, ~10-17 mag, allsky



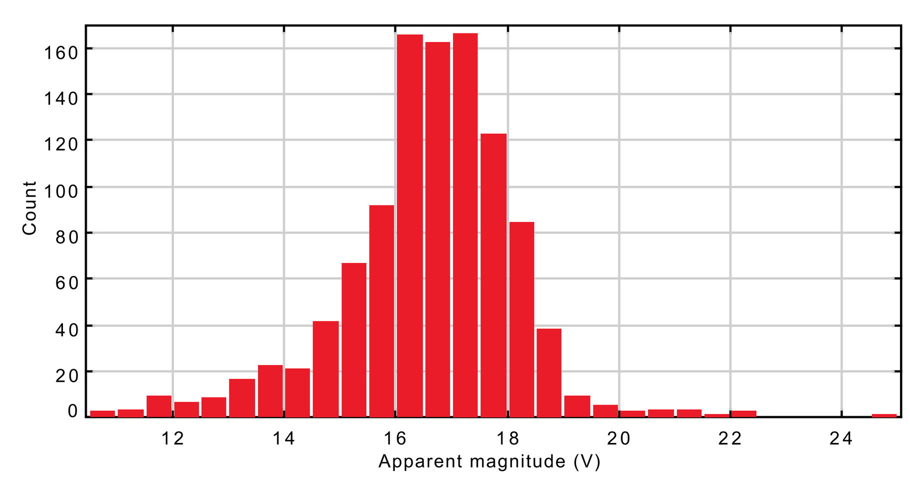
GALEX and SDSS sky coverage (2MASS and WISE are all-sky)

When cross-matching the bodies between different data sources, the number of unique bodies(out of 10 000) we find, by pair, is

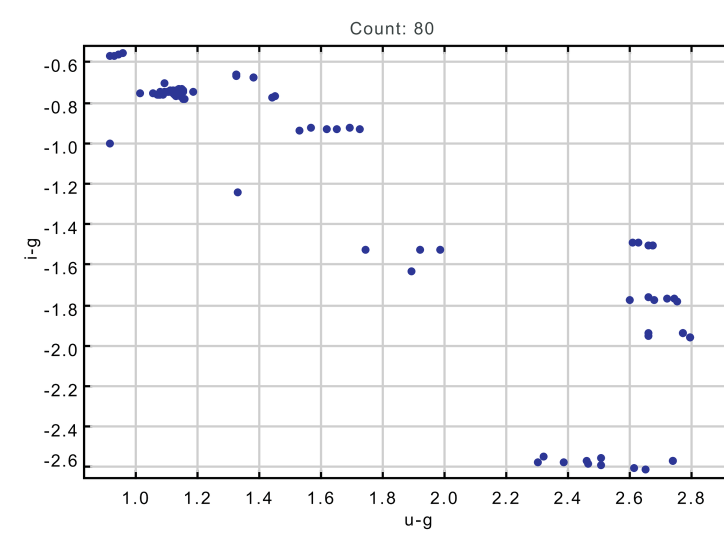
	GALEX	SDSS	2MASS	WISE
GALEX	4036	1255	104	3310
SDSS	1255	2929	85	2394
2MASS	104	85	296	248
WISE	3310	2394	248	8045

1048 matches from 3 data sources (GALEX+SDSS+WISE) and 27 matches from all 4 sources.

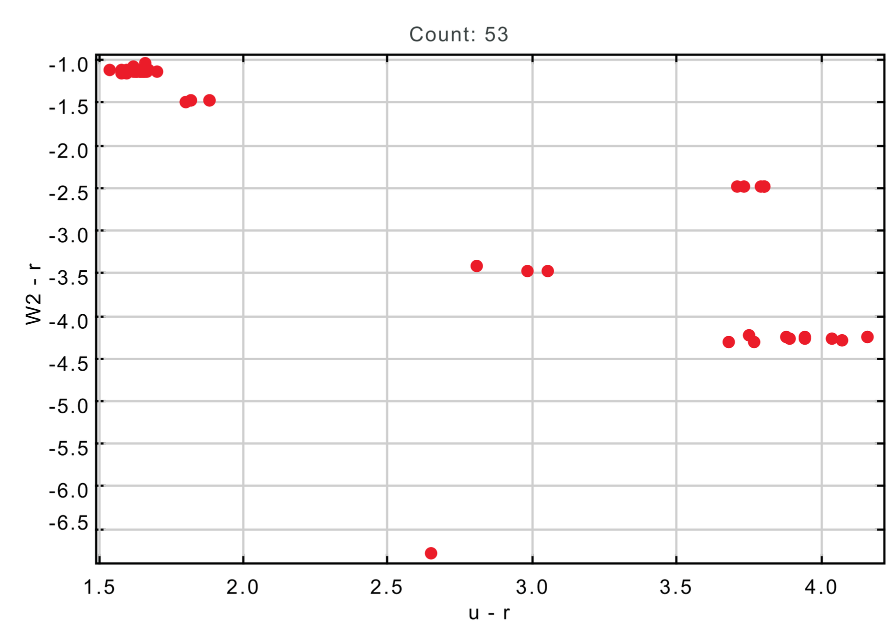
Magnitudes and colors from the sample



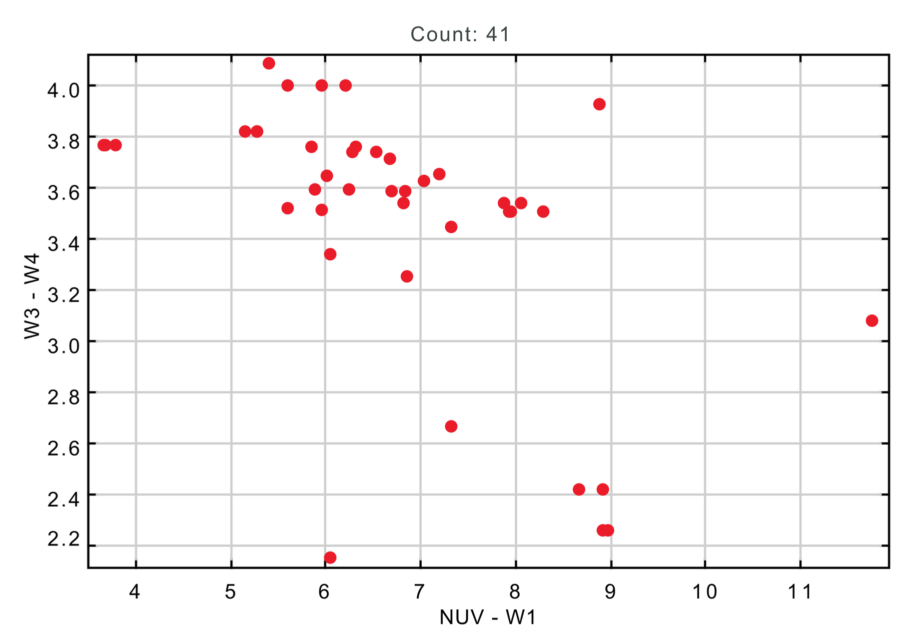
GALEX+SDSS+WISE



SDSS



SDSS+WISE



GALEX+WISE

Conclusions / Future work

An extrapolation from the number of matches suggests 60 000 known bodies could be present among GALEX, SDSS and WISE, and 1 800 from GALEX, SDSS, 2MASS and WISE.

These databases enable systematic color analyses for large numbers of objects, in a wide wavelength range.

More precise matching algorithms to match catalog sources with predicted positions will improve the yield of magnitude retrievals.

Other archives will be processed, to increase the number of available magnitudes.

Images will be processed to identify moving objects and index the observations.

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Poster available at http://www.ppenteado.net/ast/dps2013_pfp.pdf