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Modernizing Lowell Observatory's *astorb* Database

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Abstract

The *astorb* database is an actively currated catalog of orbital elements for all known asteroids in the Solar System. The full catalog is downloadable from Lowell and VizieR. The data in *astorb* are used to support a number of observational planning tools hosted at asteroid.lowell.edu. Since 2016 we have been funded by NASA to modernize both the underlying database infrastructure and the front-end web applications. This effort includes expansion of *astorb* to include physical properties (e.g. albedo, photometric colors, spectral types). We will present an overview of the current *astorb* ecosystem and plans for future development.

1. The *astorb* System

The *astorb* database at Lowell Observatory has been maintained in various forms since the early 1970's. Over this time *astorb* has served as a source of computed orbits for all known asteroids in the Solar System that is independent of similar systems maintained at the Minor Planet Center (MPC), JPL, and the University of Pisa. The user base for *astorb* includes professional astronomers, backyard observers, educators, and developers of widely-used planetaria software.

astorb is updated in real time as new asteroids are designated by the Minor Planet Center. Orbits are originally ingested based on MPC solutions, which serve as a place holder until individual observations for objects are downloaded and the orbits are fit at Lowell. A unique system for estimation of orbit uncertainty and ephemeris errors is employed [1]. The entire catalog along with uncertainties on each orbital element is available for download at Lowell (ftp://ftp.lowell.edu/pub/elgb/astorb.dat.gz) and VizieR (cdsarc.u-strasbg.fr/viz-bin/cat/B/astorb).

One of the most visible use cases of *astorb* has been an associated set of web tools that leverage the database and provide observational planning services. This includes a variety of tools to generate products such as finder charts. Until recently, the code that supported these tools was written in a combination of ADA, IDL, and Fortran. This posed specific problems related to licensing (IDL) and obsolescence (ADA), which impaired our ability to support and troubleshoot problems. In 2016 we were funded by NASA through the Planetary Data Archiving, Restoration, and Tools (PDART) program to overhaul the *astorb* system.

The current funding for *astorb* (renewed in 2019) has enabled modernization of the full system. In general our development has employed mature, open source alternatives to replace much of the heritage code base. Primary development is done in Python3 and PostgreSQL, with additional software packages used for operational support (e.g. SQLAlchemy for interfacing with SQL in Python). We have also employed a number of tools to completely replace (as of early 2019) all of the heritage web applications.

2. Web Applications

A series of *astorb*-supported web apps are accessible at asteroid.lowell.edu. Our general approach is to provide powerful functionality accessible through a streamlined and intuitive interface to inform observational planning or to provide quick results during observing runs. We outline here each of these tools.

AstEph provides an accurate ephemeris for individual objects that is designed to minimize configuration overhead and returns parameters that are of particular relevance to observers, e.g, galactic latitude, uncertainty on sky. Output fields are easily customizable, and can be output to text for external manipulation.

AstObs is designed to assess long-term observability of multiple objects based on default or user prescribed thresholds in V magnitude, galactic latitude, solar elongation, declination, and ephemeris error. These calculations can be run for up to 10 years in the future and are well suited to observational planning purposes. The plots generated by this tool are dynamic and can be manipulated in real time. A variety of out-

put options (both images and data) are available.

AstFinder is a finder chart utility that has two modes: it can generate a finder chart for a given asteroid at a specific time, or it can retrieve all of the asteroids in a field-of-view at a given time and coordinate location. The visualization of these charts employs the Aladin Lite Sky Atlas plugin. The cone search for identifying all objects within a given field employs the Virtual Observatory SkyBoT tool [2]. Several image catalogs are enabled as base layers: DSS for shallow-depth visible images, PanSTARRS DR1 for visible images with a higher limiting magnitude, 2MASS for near-IR imaging, and NEOWISE for thermal-IR imaging. A variety of color maps are available and charts can be output to PNG files.

AstInfo provides a quick-look overview of the data in *astorb* for a given object. This includes designations, orbital parameters, and physical properties that have been ingested. As of early 2019 the collection of physical properties includes a comprehensive set of albedos and diameters, photometric colors, and lightcurve periods and amplitudes.

UpObjects is a filterable list of NEOs that are observable on a given date. Filters can be applied to V magnitude, H magnitude, solar phase angle, solar elongation, and galactic latitude. On the backend this tool leverages a database table of pre-populated ephemerides that range from the current date out to two years in the future. The intent of this tool is to provide easy access to targets of interest that meet certain observability criteria that may be informed by the capabilities of a given telescope. The output fields can be customized and output to a number of file formats.

3. Physical Properties

Aside from the modernization work, the most significant expansion of *astorb* has been the addition of physical properties. Our aim is to actively curate the compilation of physical properties from past and ongoing surveys. Properties of interest include albedo, diameter, photometric colors, spectral taxonomy, mass, lightcurve parameters, binary parameters, and dynamical family membership. These derived properties are compiled across many sources including primary publications, web-based datasets, and NASA's Planetary Data System. We are only focusing on derived physical properties and not on original data. For example, we have ingested lightcurve periods and amplitudes, but will not ingest the original photometric data points used to determine those properties. The compilation of multiple physical properties in a single system will facilitate new investigations into relationships across surveys. In addition, the combination of physical properties with the infrastructure of the orbital elements catalog will enable novel assessments of observability for objects that meet user-defined constraints on physical characteristics.

4. Future Plans

Upgrades to the *astorb* system are ongoing and will involve a number of developments over the next few years. Additional refinements to the existing web applications will continue, and a new GUI interface to the database, nominally called the Asteroid Portal, will be released to the website in the summer of 2019. Starting in mid 2019 we will be transitioning some of the database maintenance routines over to a GPU-based infrastructure. This will leverage the GPU-optimized N-body integrator GENGA [3] and will enable rapid orbit integrations. We also plan to augment the *astorb* system by adding comets to the database. This will provide a single-point interface for observational planning for both comet and asteroid projects. Lastly, we have started development of an application programming interface (API) to enable user queries to the database. This will eventually involve adoption of Virtual Observatory publishing protocols to enhance community access. As a whole the ongoing modernization of *astorb* and the future upgrades will result in a robust, responsive system that will readily adapt to challenges of data curation in the era of Big Data.

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References

[1] Muinonen, K. and Bowell E. Asteroid orbit determination using Bayesian probabilities. Icarus 104, 255-279, 1993.

[2] Berthier, J. and 7 co-authors. SkyBoT, a new VO service to identify Solar System objects. Astronomical Data Analysis Software and Systems XV, 351, 367, 2006.

[3] Grimm, S. and Stadel, J. G. The GENGA Code: Gravitational Encounters in N-body Simulations with GPU Acceleration. ApJ 796, 23, 2014.