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The Steward Observatory Asteroid Relational Database

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ABSTRACT

The Steward Observatory Asteroid Relational Database (SOARD) has been created as a flexible tool for undertaking studies of asteroid populations and sub-populations, to probe the biases intrinsic to asteroid databases, to ascertain the completeness of data pertaining to specific problems, to aid in the development of observational programs, and to develop pedagogical materials. To date SOARD has compiled an extensive list of data available on asteroids and made it accessible through a single menu-driven database program. Users may obtain tailored lists of asteroid properties for any subset of asteroids or output files which are suitable for plotting spectral data on individual asteroids. The program has online help as well as user and programmer documentation manuals. Already SOARD has provided data to fulfill requests by members of the astronomical community. SOARD continues to grow as data is added to the database and new features are added to the program.

INTRODUCTION

Asteroids are characterized by their diversity. We study them using a wide variety of remote sensing techniques in an attempt to determine their composition and physical properties, and relate this information to processes effecting asteroids and other solar system bodies over the age of the solar system. Observations are obtained through groundbased telescopes, spacecraft such as the Infrared Astronomical Satellite (IRAS), and radar, and are focussed on individual objects of particular interest or dedicated surveys. SOARD incorporates the data obtained from these various observations into a single database.

In addition to being objects of scientific investigation, asteroids are potential resources to be utilized in support of the expansion of humans into the solar system. The most accessible of these are the Near Earth Asteroids (NEA's) whose motions around the Sun bring them within reach of low-energy transfer orbits from the Earth. Until recently, the information available on the NEA's has been relatively limited, but with increased rates of discovery and greater numbers of observational programs focussing on these objects, this information is expected to grow rapidly. Since NEA's derive from the main asteroid belt (though some may be extinct comets), knowledge of their source populations provides additional insight into the nature and physical properties of NEA's.

TABLE 1. SOARD DATA SETS

ASTEROIDS II

- Proper Orbital Elements
- Taxonomic Classifications
- Family Designations
- Pole Orientations
- Magnitudes, UBV Colors, Albedos, and Diameters

IRAS

- Radiometric Diameters and Albedos
- Individual IRAS Observations
- Polarimetry file
- Lightcurve file
- UBV Observations
- 8-Color Spectroscopy
- 24 Color Spectroscopy

MISCELLANEOUS

- 52-Color Spectroscopy (J. Bell)
- Osculating Orbital Elements (E. Bowell)
- Preliminary Designations and Discovery Circumstances (MPC)
- Photometric Parameters (MPC)

TABLE 2. DATA SETS IN THE PROCESS OF BEING ADDED

- Families (Zappala, et. al.)
- Proper Elements (Milani and Knezevic)
- Radar Observations (S. Ostro)
- CCD Spectroscopy (L. McFadden, F. Vilas)
- Near-IR Spectra (Lebofsky, Bus, et. al.)

SOARD's goal is to incorporate ALL published asteroid data into one generally accessible database for use in research and in expanding our general and specific understanding of asteroid populations.

SOARD is a menu-driven asteroid database management system which utilizes dBase IV software in a fashion transparent to the user. It allows three basic system outputs at this time: (1) files of designations of asteroids satisfying range criteria for parameters or functions of parameters, (2) subsets of database parameters for subsets of asteroids, and (3) files of multiband photometry or spectroscopy for individual asteroids (for plotting).

SOARD DATA

Table 1 lists the individual data sets which are currently online and accessible through SOARD. It combines ground based observations which were published in ASTEROIDS II, radiometric data collected by IRAS, ancillary IRAS data sets of ground-based polarimetry, lightcurve, and spectroscopic observations, Jeff Bell's 52-color near-IR survey, osculating orbital elements for 16,610 asteroids, and discovery information and photometric parameters published through the Minor Planet Circulars (MPC). As data is incorporated into SOARD, it receives a reference to its source in the literature. This provides online information on the origin of the data and allows maximum understanding of data quality. Data evaluation is critical to its use in an engineering context.

UPDATING THE DATABASE

SOARD is expanding to include the data sets listed in Table 2. Some of the data such as CCD spectroscopy of certain asteroids has been published. Some data is collected and needs to be reduced and published. Monthly updates to SOARD include data available through literature searches, data sent by individual observers, and data obtained from the Minor Planet Circulars (MPC). Ongoing observations and research promise a continually growing body of data which will be added to SOARD.

USING SOARD

When running the SOARD program, the user will view first the main menu shown in Fig. 1. The main menu offers currently three options for system output. Option 1 allows the user to select which asteroid parameters, for any subset of asteroids, to output to a separate file. With Option 2 the user creates files of identification numbers of asteroids which satisfy user-defined range criteria of asteroid parameters. This file can be used as input to either of the other two options to identify the subset of asteroids for which a user selects data. Option 3 creates files of multiband photometry or spectroscopy for individual asteroids.

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Main menu for Asteroid Database selection

     1      Asteroid Parameters/Properties to be Concatenated

     2      Segregate Asteroid numbers by Parameter Ranges

     3      Spectra file for Asteroid Number file

            Press the F1 key for Help on option 1.
            Press the F2 key for Help on option 2.
            Press the F3 key for Help on option 3.

     E      End Current Options & Exit Program
     X      Return to DBase
     Q      Return to DOS

Select Option(s):
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Fig. 1. SOARD main menu.

Under Option 2, SOARD will display the list of parameters within selected data files (e.g. Fig. 2), and the user builds an expression from the parameters (Fig. 3) which specifies the range criteria which the asteroids must satisfy. SOARD prompts the user for the name of the output file. The user may cycle through this process as many times as desired and then take the union or the intersection of any of the created asteroid subsets to write a new subset file.

Option 3 creates individual spectra files for each of the asteroids in the user-specified subset of asteroids. Each spectra file contains four columns: wavelength, reflectance, uncertainty of reflectance, and half width half max.

All output files are dBase format by default and become part of the database which the user can access through SOARD. Output may be written to an ASCII format file as well for access by non-dBase software. Online help is available at various points in the program and can be displayed with a single keystroke.

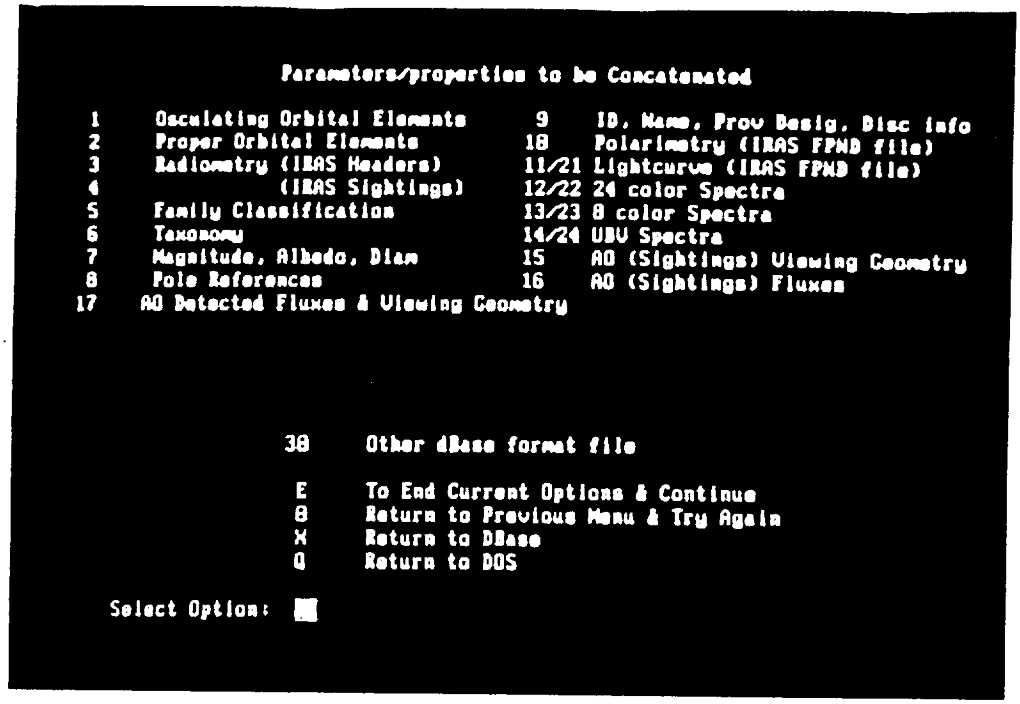

Fig. 2. Second level menu for Option 1. The same choices are available under Option 2.

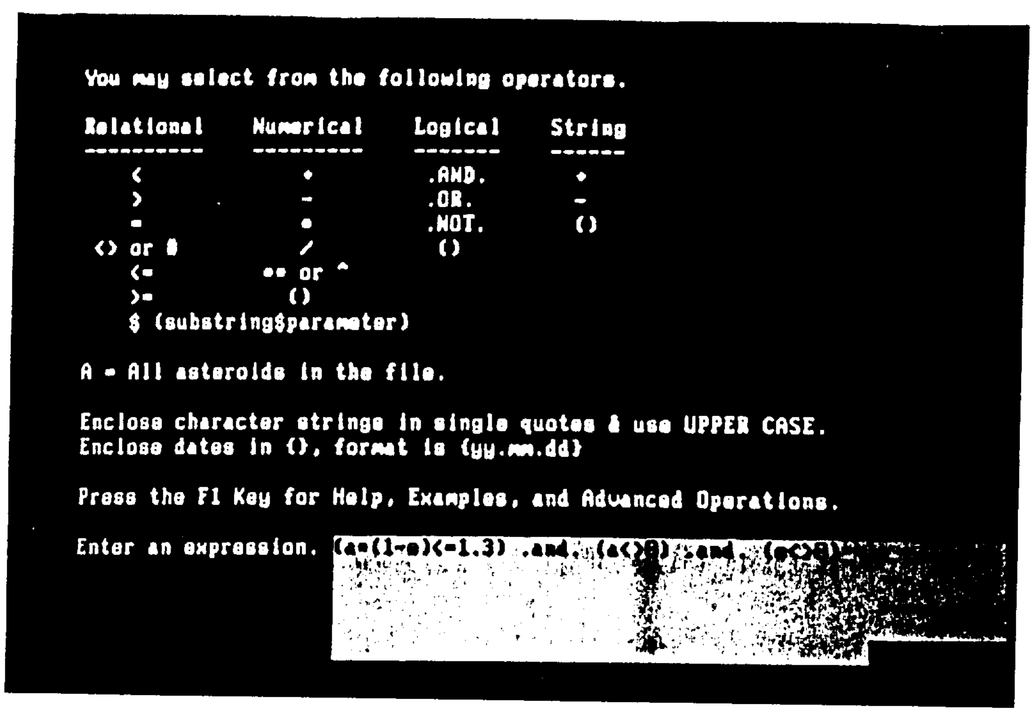

Fig. 3. Sample menu for selecting and building parameter range criteria under Option 2.

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SAMPLE OUTPUT

Graphical and image representations of output files created by SOARD can provide insight into asteroid characteristics and the extent to which they have been explored. In the remaining figures, asteroid populations are shown in semi-major axis/orbital inclination space which is related to their mean physical locations. Figure 4 illustrates the distribution of asteroid geometric albedos determined by IRAS. Geometric albedo clearly decreases with semi-major axis. This has been related to the effects of a heating episode in the early solar system, resulting in greater differentiation of asteroids occurring in the inner belt.

Figure 5 shows the distribution of all 16,610 asteroids in SOARD and identifies the known population of Near Earth Asteroids, which are clustered at low values of semi-major axis. The level of completeness to which these objects have been studied is indicated in Figure 6. Of 140 NEA's in the database, radiometry exists for 5 (from IRAS) and colorimetry (including UBV, 8-, 24-, or 52-color photometry) exists for 31. The sampling of this population is far from exhaustive.

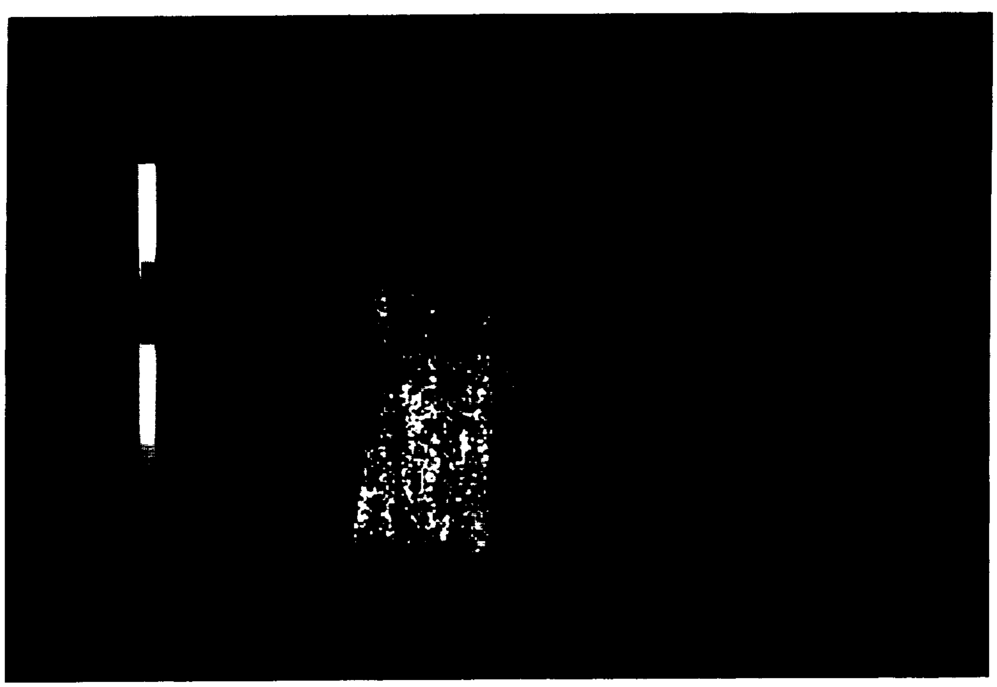

Fig. 4. Distribution of IRAS geometric albedos in the asteroid belt.

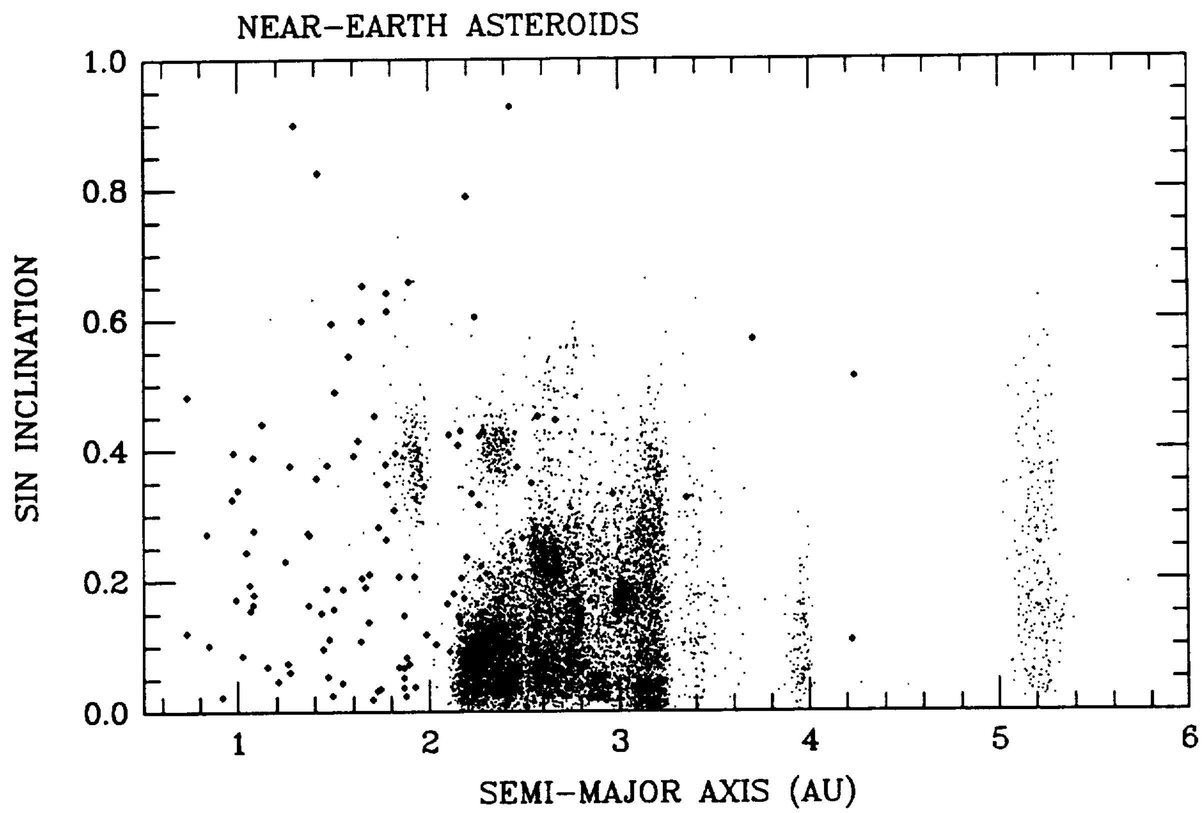

Fig. 5. The distribution of 16,610 asteroids are shown as a function of osculating semi-major axis and the orbital inclination. The Near Earth Asteroids ($q < 1.3$ AU) are displayed as larger points.

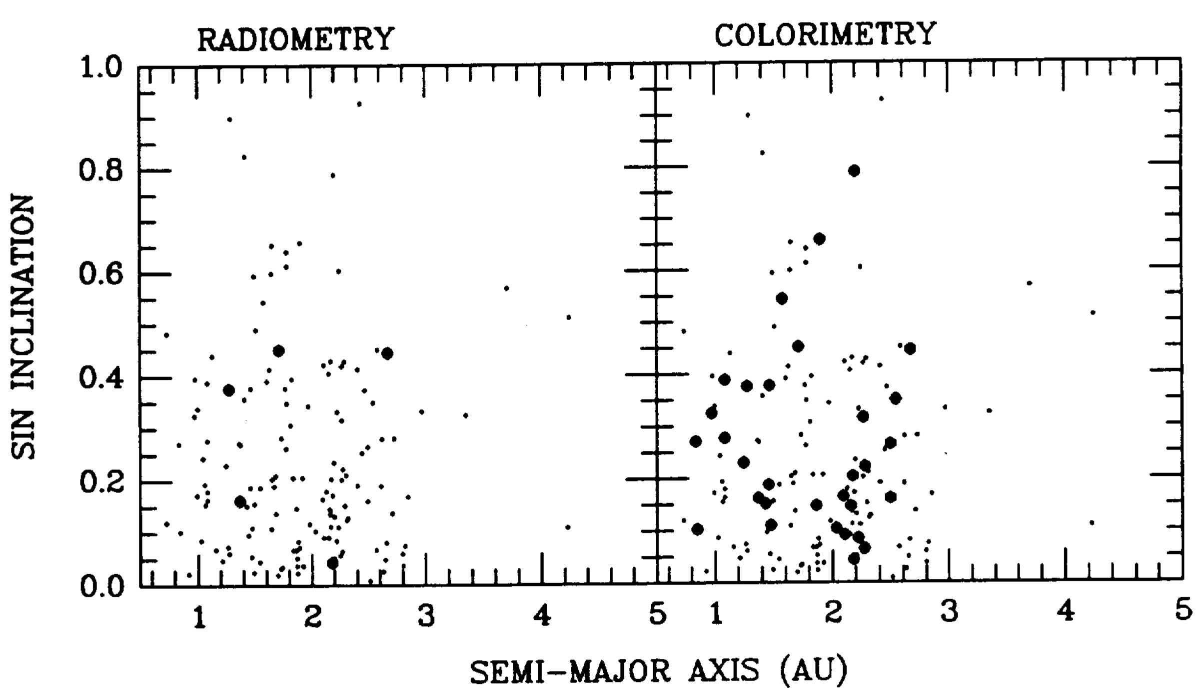

Fig. 6. The distribution of 140 Near Earth Asteroids are shown in both panels. In the left panel, larger points indicate NEA's for which radiometry has been acquired. In the right panel, larger points indicate those for which colorimetry has been acquired.

EXPANDING SOARD

Additional programming will expand the features available through SOARD. A fourth main menu item will allow the user to concatenate functions of asteroid parameters. If a file contains orbital elements such as semi-major axis and eccentricity, the user may calculate the perihelion distance as an output parameter of specific interest. This feature will minimize data which must be distributed with the system while allowing the user maximum choice for customized output of asteroid parameters.

A fifth main menu item will bring a reference search capability online. The user will be able to search a file with more than 11000 literature references. The search may be by author, title, date, publication, some subset of authors or words in a title, or any combination of these parameters.

Another main menu item being investigated is the ability to run external code. Specific programs such as code to generate ephemerides, to run standard thermal models, or to calculate magnitudes would be accessible without leaving the main SOARD program. Files generated through SOARD would be available for direct input into the external code and the output of the external code would be in a form accessable to SOARD.

Because of the desirability of a straightforward graphics display capability for SOARD output, we tested the dBase APPLAUSE II graphics package but found it inadequate for the scientific applications to which we were applying it. At present, results are displayed by writing SOARD output to an ASCII file which serves as input for external graphics packages such as MONGO.

TESTBED ACTIVITIES

SOARD has a testbed site at the California Space Institute in La Jolla, California. This is run by Dr. Lucy-Ann McFadden, who is testing a transportable execution version of the relational database. She has helped identify bugs in the program and has offered many suggestions for improving the SOARD environment. Recently one of Dr. McFadden's students wanted to use SOARD to help him address a research question. He had received no prior tutoring, but with the help of online documentation only, he was able to run the program to extract the subset of data he required. Such successes bode well for a future distributable system.

COMMUNITY SUPPORT

We respond to all moderate requests from the community, and have provided data in support of observing, research, and teaching programs. For instance, the International Space University requested and received information on Near Earth Asteroids. The ISU teaches young professionals from around the world about space activities. The ISU was held in Toronto this year and hosted 130 participants from 30 countries.