Asteroids Dynamic Site - AstDyS

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ABSTRACT

The AstDyS online information service (http://hamilton.dm.unipi.it/astdys/) contains data on numbered and multiopposition asteroids, including orbital elements, their uncertainty, proper elements, ephemerides with uncertainty, and more. AstDyS also provides additional scientific output computed from the raw observational data. This value added currently includes: more accurate orbits computed with advanced dynamical and observational error models; their uncertainty, as expressed by the covariance matrix formalism; ephemerides computed on request for each observer, with uncertainty; mean and proper orbital elements (for this output, AstDyS is the primary source worldwide); statistical quality control, providing a rigorous observational error model. All this is available with a sophisticated web interface, providing multiple search functions and online computations as well as complete orbital and residual files.
There are several ways in which the AstDyS service could be expanded and improved in the next future, like the explicit classification of asteroids into asteroid families, the classification of resonant asteroids, and an updated self-consistent population model (to be used, e.g., for survey simulations).
The IAU Division I endorsed the proposal for AstDyS to become an IAU (Permanent) service, which would include the IAU supervision of the AstDyS system, keeping under control the quality of the work and the continuous update under conditions of scientific competition.

AstDyS: purpose, data sources and computational procedures

The AstDyS online information service is maintained by a consortium including University of Pisa (Italy), the Astronomical Observatory of Belgrade (Serbia), SpaceDyS srl, Cascina (Italy) and sponsored by the European Space Agency; it is accessible at http://hamilton.dm.unipi.it/astdys
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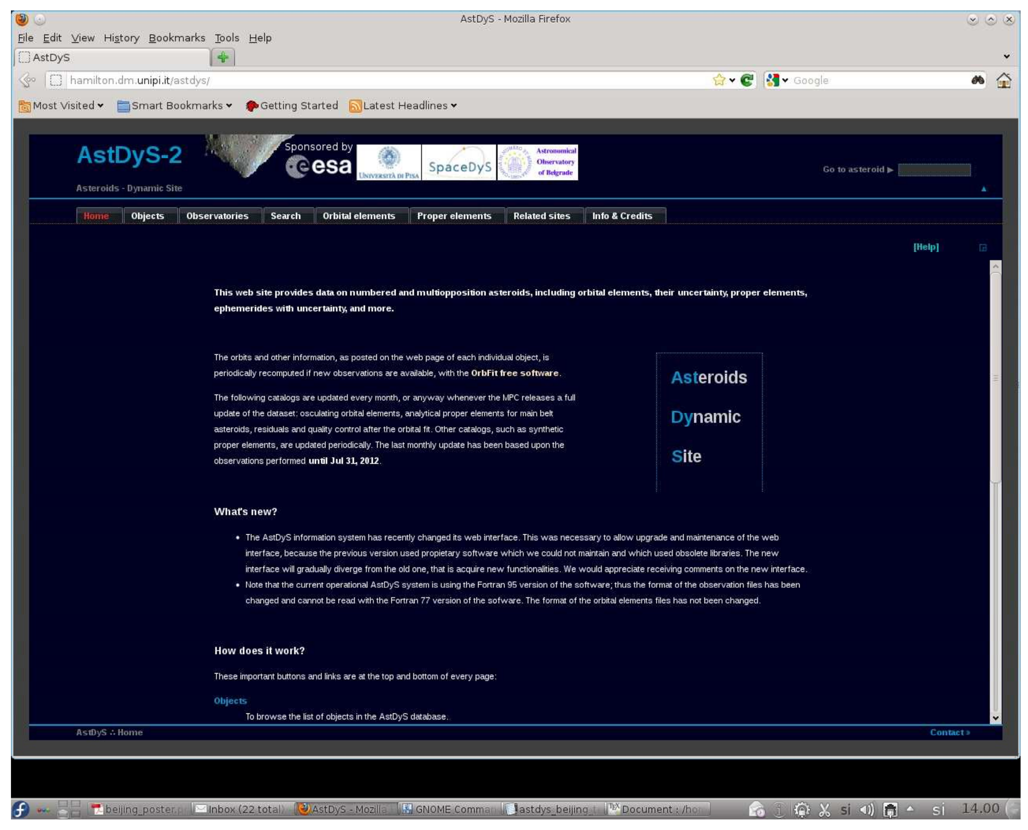
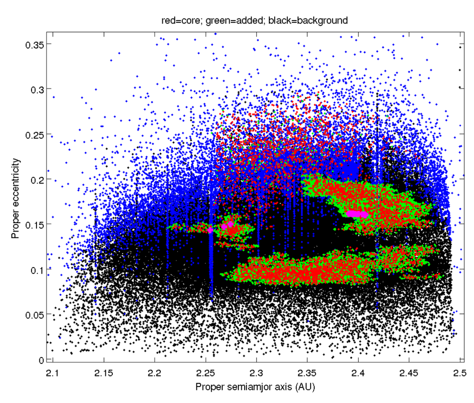
AstDyS main source is the set of astrometric observations of solar system small bodies as maintained and published by the Minor Planet Center (MPC), at CfA, Cambridge, MA (USA). These data are processed to compute the orbits of all the well observed asteroids and Trans-Neptunian objects, with uncertainty as expressed by the covariance matrix. The error model used to debias and weight the observations is based on Baer et al. (2010). The software for orbit determination is based on the free software system OrbFit, available from http://adams.dm.unipi.it/orbfit
The orbits are recomputed regularly (currently every month) to keep up with new discoveries and reobservations of known objects.
The orbits of numbered asteroids are so well constrained that the main limitation to the accuracy of ephemerides is due to imperfections of the error models, also due to star catalogs used in the astrometric reduction. The orbits of multiopposition asteroids are good enough for observational and statistical purposes, but of limited accuracy. Orbits of single opposition asteroids are provided only for the better observed ones.

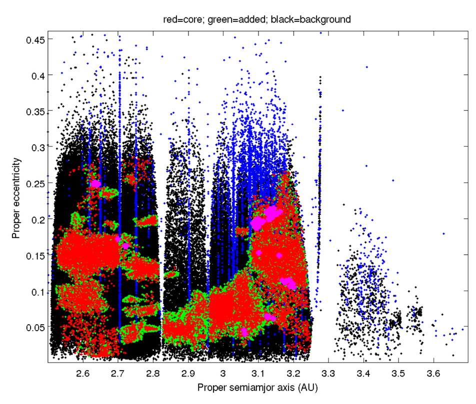
The home page of the AstDyS service



Inner belt



Outer belt



red – families; green – attached members blue – unstable; black – background

Proper elements

The data product for which AstDyS is the primary source worldwide consists of a number of catalogs of proper elements. They provide information on the long term dynamics (many millions of years), on stability versus chaoticity, and on classification into families. In simple terms, proper elements are approximate integrals of motion, taking into account that exact integrals cannot exist. They can be computed with analytic, semianalytic, and synthetic methods.
Currently the most accurate proper elements are computed with a synthetic theory, which is based upon an accurate numerical integration, starting with the orbit as determined from observations, for millions of years. Different synthetic theories are used, e.g., for main belt asteroids, Jupiter's Trojans and Trans Neptunian Objects.
The synthetic method also allows to compute stability parameters allowing to identify stable and/or chaotic orbits.
We have now on AstDyS proper elements for more than 300,000 main belt asteroids, more than 4,000 Trojans, more than 5,000 Hungaria, more than 450 Transneptunians.

Dynamical structures of the small bodies belts

Large proper elements catalogs are powerful tools to assess the dynamical structure of the different regions populated by solar system small bodies. As an example, the main asteroid belt is a region delimited by the sweeping zones of Mars and Jupiter and at moderate eccentricities and inclination; in this region, as a first approximation, the most densely populated portions of the phase space indicate long term stability, gaps indicate sources of instability, such as low order mean motion resonances.
A more detailed look, enabled by the very large data set maintained by AstDyS, shows more complexity, with a web of resonances crossing the entire belt and populated by asteroids injected in the resonances, mostly by non-gravitational perturbations such as the Yarkovsky effect, but also by the outcome of catastrophic collisions.
The availability of parameters such as LCE and uncertainties of proper elements allow to map the ordered and chaotic regions, to study the diffusion processes due to the action of chaos, of non-gravitational perturbation and most often of both acting together.
In the figures of this poster, the blue dots indicate asteroids on unstable orbits, as documented by LCE larger than $1/20000$ yr^{-1} and by RMS instability of the proper semimajor axis larger than 3×10^{-4} AU. The mean motion resonances responsible for these instabilities can be identified in most cases.
There are several ways in which the AstDyS service could be expanded and improved in the next future, and one of them which we expect to implement in the next few months is to provide for each asteroid flags indicating the main resonances, thus incorporating also information on the dynamical structure.

Asteroid families

Another use of the proper elements is the classification of the asteroids in families, which can be interpreted, with some caution, as the outcome of a collision of a smaller impactor on a larger target. Some families can be interpreted as the outcome of a catastrophic fragmentation of a single parent body, some as the outcome of a large cratering event; in many cases the age of the family, that is the epoch of the collision, can be estimated, possibly by using models of the diffusion in the space of proper elements due to chaotic and/or non-gravitational effects.
Another expansion of AstDyS we expect to implement in the next few months is to provide lists of families and family membership. The status of each asteroid as a member of a specific family, if any, shall be provided together with the proper elements.
The procedure to build up these family lists requires several steps, starting from a large proper elements catalog. The most used method is hierarchical clustering, with nearest neighbor distance (Zappalá et al., 1990). However, a more complex procedure is needed when the number density of asteroids in the proper elements space exceeds a critical threshold, which has already been exceeded in the main asteroid belt. In this case we need first to identify a core family with larger asteroids only, then to attach to it smaller objects forming an extended family. In the figures of this poster, the reddots indicate asteroids belonging to core families, the green ones the attached ones; black dots indicate background asteroids, for which a family has not (yet) been identified. The total number of asteroids included in our main belt families exceeds 20% of the total population, but this is only a lower limit to the real fraction asteroids which are family members.

A PERMANENT SERVICE

To make the AstDyS information more visible to the astronomical community and to assist in its long term maintenance and development, the IAU Division I endorsed in 2011 the proposal for AstDyS to become an IAU (Permanent) service. This would imply the IAU supervision of the AstDyS system, keeping under control the quality of the work and the continuous update under conditions of scientific competition.