Astronomical Data Analysis Software and Systems XII
ASP Conference Series, Vol. 295, 2003
H. E. Payne, R. I. Jedrzejewski, and R. N. Hook, eds.

Turning Besançon Observatory On-line Facilities into the VO: Galactic Model Simulation, Binary Star, Molecular Collisional and TNO Databases

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Abstract. For several years, the Besançon Observatory has been developing scientific facilities that are, or will be in the near future, accessible on-line through the World-Wide Web, namely the Besançon model of stellar population synthesis of the Galaxy, and three databases: the BDB Double and Multiple Star database, the BASECOL Molecular Collisional Excitation database and a database of discovery and recovery observations of TNOs. We summarize here the scientific objectives of these facilities and the characteristics of the information exchange protocols implemented so far. Next we describe how we envisage turning these facilities into the Virtual Observatory grid and what are the expectations and needs of VO standards given the specificities of these facilities.

1. Galactic Model of Stellar Population Synthesis

The Besançon model of population synthesis of the Galaxy[1] is based on a semi-empirical approach, where physical constraints and current knowledge of the formation and evolution scenario of the Galaxy are used as a first approximation for the population synthesis. The new revised version (Robin et al. 2002a) includes several important updates of the current knowledge for stellar populations and galactic evolution, such as: (*i*) new parameters for the thin disc, due to significant improvements after Hipparcos: potential, velocity ellipsoid and local luminosity function; (*ii*) the disc is warped and flared in the external part following new constraints from near-infrared star counts; (*iii*) the overall parameters of the thick disc and spheroid (density law, local density and Initial Mass Function) have been adjusted to most recent surveys; and (*iv*) a triaxial outer bulge has been included.

[1] `http://www.obs-besancon.fr/model/`

The model has been accessible over the World-Wide Web since 1996. Parameters for the simulation are passed through web forms and the result is retrieved through ftp. In the framework of the VO, the Galaxy model can be useful to complement observational data to interpolate stellar statistics at new wavelengths or at directions where no data are available yet. We are also implementing a Bayesian classification tool to apply to observational data, based on probabilities computed by the galactic model assuming given observational parameters (Robin et al. 2002b).

2. Double and Multiple Star Database

The BDB database[2] for double and multiple stars has been developed since 1995 to provide the astronomical community through the Internet, with numerical and image data specific to each category of binaries (observational categories at first), raising in particular the difficulties of the identification of the components (Oblak et al. 2002).

To fulfill these goals, the database presents the following functionalities: (*i*) it incorporates catalogues from all observational categories; (*ii*) it is interfaced (or will be in the near future) to other more specialized binary star databases such as Cracow (eclipsing binaries), SIDONIE (visual) and SB9 (spectroscopic); (*iii*) a specific Java tool has been developed to compare numerical data from several catalogues with Digitized Sky Survey and CCD images (from a European Network) of visual binaries; and (*iv*) the database will provide some tools specific to double stars such as ephemeris for eclipsing binaries. The database can be queried through web forms and mail-supplied lists of stars.

3. Ro-Vibrational Collisional Excitation Database

The objective is to build a database concerning molecular ro-vibrational transitions induced by collisions with atoms or molecules, which will provide all or some of the following items: rate coefficients as a function of temperature and fitted functions, total cross sections as a function of energy, potential energy surface used in the calculations, full reference on the PES and on the methods used in the calculations of cross sections, codes to deal with some of the data.

The idea is to have a dynamical database that allows the user to read, transform or create more data (if allowed by the available codes). We are currently calculating the collisional excitation rates of H_2O by H_2; some of the results are already published (Dubernet & Grosjean 2002) and we intend to start the database with our own results on the $H_2O + H_2$ system. The fitted coefficients and functions of the collisional rates will be available as well as the Fortran code used to rebuild the collisional rates. The cross-section (tables and graphs) will be available in order for a user to check the completeness of the data and to complete the data if necessary.

A bibliographic database on ro-vibrational excitation processes has been built. It contains about 400 references from physical and chemical journals,

[2] `http://bdb.obs-besancon.fr/`

with specific keywords added to all references. It gives the possibility to choose the molecules and atoms in collision, the origin of the data (theoretical, experimental), the type of processes (rotational excitation, vibrational excitation, etc.), the type of data (probabilities, cross-sections, collisional rates, etc.) and the usual information (author, year since 1974). The database can be updated automatically via a web page. All the papers providing data relevant to astrophysical use will be linked to files containing the traceability and validation of the data, as well as fits or links of/to the data.

The databases[3] have three main goals: exploitation of observational data, in particular data that will be provided by HERSCHEL/ALMA or existing data from SWAS/ISO, modeling of cometary, planetary and interstellar media, and maximum of information given to theoreticians wishing to do calculations.

4. Trans-Neptunian Object Database

Thanks to our experience in discovery and follow-up of TNOs with the CFH12k (Petit et al. 2001), Besançon Observatory is actively participating in the definition of the strategy of the Ultra-Wide component of the CFHT Legacy Survey, aimed at discovering all TNOs around the ecliptic down to magnitude $m_R = 23.2$. In collaboration with CADC and Department of Physics and Astronomy of the University of British Columbia, we will prepare the observations and data processing and will participate in the additional observations required to determine the orbital parameters of the detected objects.

The outcome of this programme will be an orbital database of more than 1000 TNOs, all discovered in a well characterized survey. In addition, all the TNOs discovered in this survey will be followed to the third opposition, to avoid follow-up bias which is impossible to model. For each discovered TNO, the database will contain: (*i*) the field coordinates and size, with "filling factor" for a mosaic camera, (*ii*) the exposure time, (*iii*) the efficiency curve versus magnitude of discovery observations, together with range of rate of motion of validity, (*iv*) all astrometric measurements, at discovery and recoveries, (*v*) the estimated orbit, and (*vi*) for objects not yet with three oppositions, the full history of recovery attempts, in particular, the failing observations with circumstances.

5. Turning into the VO: Some Considerations

One of the basic concepts of the Virtual Observatory is to use recent technology to enable access to data spread worldwide, keeping them where the relevant scientific expertise resides. In this framework, the Besançon Observatory will make available experimental or simulated data as well as scientific added value to the astronomical community more efficiently through the different facilities described above which have been accessed so far through the World-Wide Web. This makes necessary to broaden the operation methods implemented so far (web pages and forms, HTML or flat files output, http or ftp retrieval); this implies definition of metadata, broader query modes, extraction of large amount of data,

[3] `http://basecol.obs-besancon.fr/`

on-the-fly analysis tools, etc. Some particular milestones of this process have been laid, namely: (*i*) XML formatted output of the data of the BDB database, with interoperability in mind (Debray 2002); while initial developments were done following the Astrores DTD, full final implementation will use the VOTables format (Ochsenbein et al. 2002); (*ii*) planned implementation of the bibcode (Schmitz et al. 1995) within the bibliographic database of the BASECOL facility; it aims mainly at allowing both direct access to the bibliographic services such as ADS, and external retrieval of the keywords added in BASECOL used to classify the compiled references.

To implement VO concepts and standards in the future, we need them to comprehensively account for the scientific and technical requirements of our facilities, for instance, the definition of unambiguous metadata for the description of both services and data. Some requirements are already addressed by present definitions of *Unified Column Descriptors* (UCDs, see Derrière et al. 2002); more specific metadata are however needed for, e.g., the observational log of trans-neptunian objects or the parameters of simulated stellar populations.

On the other hand, our facilities (the Galactic simulation model mainly, but not exclusively) require that emerging protocols properly consider that a request issued by a remote service (web server, remote program) may require a long computing time before the output is sent back; simple http requests do not properly handle this case. Lastly, the VO will likely increase significantly the access rate to our services; replications via mirror sites have to be envisaged.

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