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VOSA: A VO Spectral Energy Distribution Analyzer

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Abstract. VOSA (VO Sed Analyzer)[1] is a public web-tool developed by the Spanish Virtual Observatory[2] and designed to help users to (1) build Spectral Energy Distributions (SEDs) combining private photometric measurements with data available in VO services, (2) obtain relevant properties of these objects (distance, extinction, etc) from VO catalogs, (3) analyze them comparing observed photometry with synthetic photometry from different collections of theoretical models or observational templates, using different techniques (chi-square fit, Bayesian analysis) to estimate physical parameters of the observed objects (teff, logg, metallicity, stellar radius/distance ratio, infrared excess, etc), and use these results to (4) estimate masses and ages via interpolation of collections of isochrones and evolutionary tracks from the VO. In particular, VOSA offers the advantage of deriving physical parameters using all the available photometric information instead of a restricted subset of colors. The results can be downloaded in different formats or sent to other VO tools using SAMP.

We have upgraded VOSA to provide access to Gaia photometry and give a homogeneous estimation of the physical parameters of thousands of objects at a time. This upgrade has required the implementation of a new computation paradigm, including a distributed environment, the capability of submitting and processing jobs in an asynchronous way, the use of parallelized computing to speed up processes (∼ ten times faster) and a new design of the web interface.

1. Introduction

The advent of new and more sensitive surveys providing photometry at many wavelength ranges and covering large sky areas (GAIA, GALEX, SDSS, 2MASS, UKIDSS, AKARI, WISE, VISTA...) has been pushing astronomy towards a change of paradigm where small groups, and not only large consortia, need to analyze large multi-wavelength data sets as part of their everyday work. In this context, the Virtual Observatory

[1]`http://svo2.cab.inta-csic.es/theory/vosa`

[2]`http://svo.cab.inta-csic.es`

(VO),[3] as a common frame to exchange not only observational data but also theoretical models, plays a very important role.

VOSA is in operation since 2008 (Bayo et al. 2008), with more than 500 active users (~7000 files uploaded by users and ~600000 objects analyzed), and more than 70 refereed papers published making use of this tool.

In the next sections we will describe a typical workflow in VOSA and give some details about the new architecture. A more detailed description of the functionalities and capabilities of the tool can be found in the on line documentation.[4]

2. SED building

The first step in the VOSA workflow is uploading a user file with a list of objects to be studied. This can be done using the ad-hoc VOSA format or using VOSA's converter to reformat a coma separated value (csv) or VOtable file. This file can contain different levels of information, from just object names to, optionally, photometry, distances, extinction properties, flags about the detection or upper-limit nature of the values provided, etc.

All this information can be complemented by searching in VO services able to provide name resolution, distance information and extinction properties.

Apart from the photometry included by the user in the input file, VOSA also allows to search in more than 30 VO photometry catalogs so that the user provided SED is complemented by the found data, keeping track of the temporal and quality flags provided by the VO-services.

Once the SED is built, VOSA detects the infrared excess using an algorithm, based on our iterative modification (with outlier rejection approach) of the Lada et al. (2006) parametrization. Photometric points flagged as "excess" will not be taken into account in the fitting process if the models chosen are purely photospheric (after the model that best fits is found, a post-refinement of the infrared detection can be made by comparison of the observed SED and the model photometry).

Then the user has the possibility of visualizing the final SED and fine-tuning each SED manually: changing the automatic infrared detection diagnostic, excluding SED points due to blue/UV excess, deleting points, flagging data-points to be treated as upper-limits, etc. Some of these options can be applied together at once to all the objects in the file if desired.

All the observed (user and VO) photometry must be matched to some filter in the SVO Filter Profile Service[5] to obtain the relevant information needed to properly understand the observed data (zero point, effective wavelength, etc) and to compare it with the adequate synthetic photometry for each theoretical model, calculated using the corresponding filter transmission curve.

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[3] http://www.ivoa.net

[4] http://svo2.cab.inta-csic.es/theory/vosa/help/

[5] http://svo2.cab.inta-csic.es/fps/

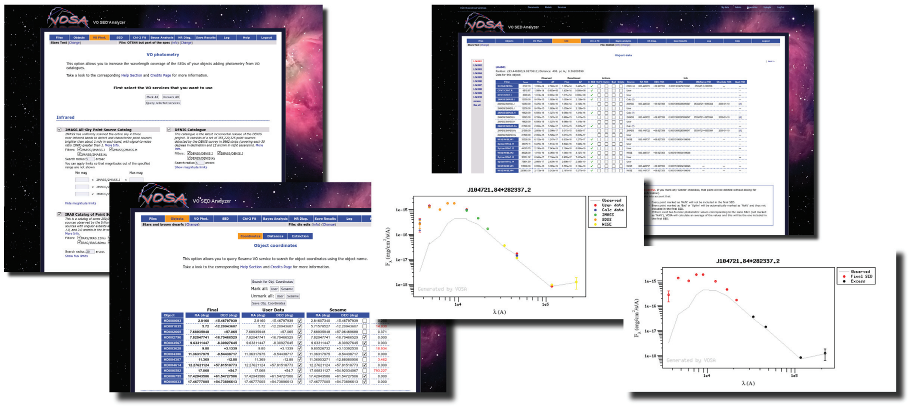

Figure 1. SED building and editing in VOSA.

3. SED analysis

VOSA offers several options to analyze the Spectral Energy Distributions and estimate physical properties for the studied objects.

First, observed photometry is compared to synthetic photometry for different collections of theoretical models in two different ways: brute-force chi-square grid fitting and Bayesian analysis. Chi-square fit provides the best fit model and thus an estimation of the stellar parameters (temperature, gravity, metallicity, ...). It also estimates a bolometric luminosity using the distance to the object and the best fit model. On the other hand, the Bayesian analysis provides the projected probability distribution functions (PDFs) for each parameter of the grid of synthetic spectra. In both methods, users have the option of considering the visual extinction as an additional fit parameter.

Currently, VOSA offers different collections of models for different types of astrophysical objects: from brown dwarfs and planetary mass objects to massive and evolved stars. A suite of stellar population models and six observational libraries covering the parameter space of late-type stars and brown dwarfs are also available.

Once the best fit values for temperature and luminosity have been obtained, it is possible to build an HR diagram using isochrones and evolutionary tracks from VO services and VOSA performs linear interpolations to provide the user with estimates of masses and ages, and their respective confidence intervals.

4. New distributed architecture and asynchronous processes

The need of working with thousands of objects at the same time usually implies long calculation times and a heavy usage of the VOSA server capacities. So we have redesigned VOSA to meet these needs.

Now most of the VOSA calculations are not done in the VOSA web server. VOSA submits them to a different server and waits for the results. This dramatically reduces the load of the VOSA server, that is no longer affected by the number of jobs or the size of user files. In the future this infrastructure could be upgraded so that VOSA can distribute jobs among different servers to balance the load.

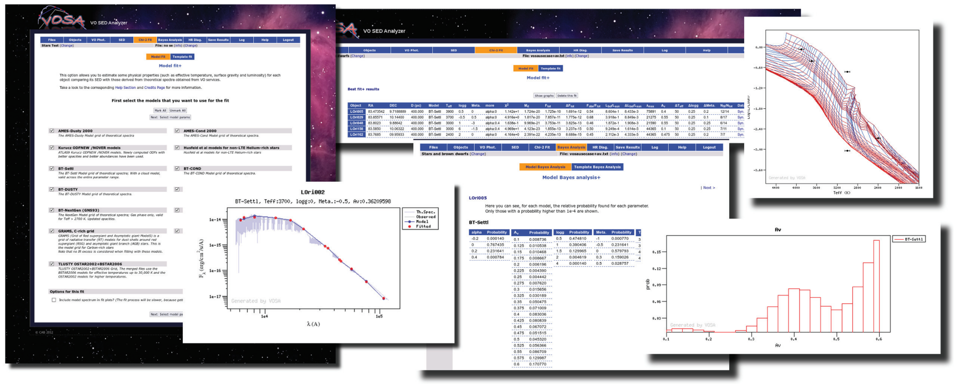

Figure 2. Chi-square fit, Bayesian analysis and HR diagram for stellar objects.

VOSA is designed to work with lists of objects and make mostly the same operations to all of them. We have upgraded VOSA so as to allow computation in a parallelized way, making not necessary to finish an object before starting with the next one. The computation server organizes the jobs so that several of them are carried out simultaneously, and collects the results once all the jobs are finished.

VOSA communicates with the computation server in an asynchronous way. That is, VOSA submits a process and does not wait for it to finish. From time to time, or because a user requests it, VOSA checks the status of the process and, when it is finished, downloads the results, makes the final necessary processing and presents them to the user.

The main advantage of this capability is that the user does not need to wait, with the browser open, to the end of the process. Moreover, long queries are not affected by potential connectivity problems either. Users can start a process, close the computer and come back later to see how it is going. If it is finished, VOSA will show the results. If not, VOSA gives information on the status of the process and provides an estimation of the remaining time. Moreover, processes can be canceled at any time from the VOSA web interface.

References

Bayo, A., et al. 2008, A&A, 492, 277
Lada, C. J., et al. 2006, AJ, 131, 1574