A new VO tool for studying developing planetary systems

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Abstract

The Virtual Observatory (VO) is an international program designed to provide the astronomical community with tools and systems ("Service grid") and data interoperability standards ("Data grid") necessary to explore the digital, multi-wavelength universe resident in astronomical data archives. The project is coordinated by the International Virtual Observatory Alliance (http://www.ivoa.net) to which the Spanish Virtual Observatory (SVO) joined in June 2004. Two are the mayor objectives of the SVO: to adapt the Scientific Data Centre at LAEFF (http://sdc.laeff.esa.es) to the VO standards and requirements and to develop data analysis tools to fully exploit the scientific potential of the VO-compliant astronomical archives.

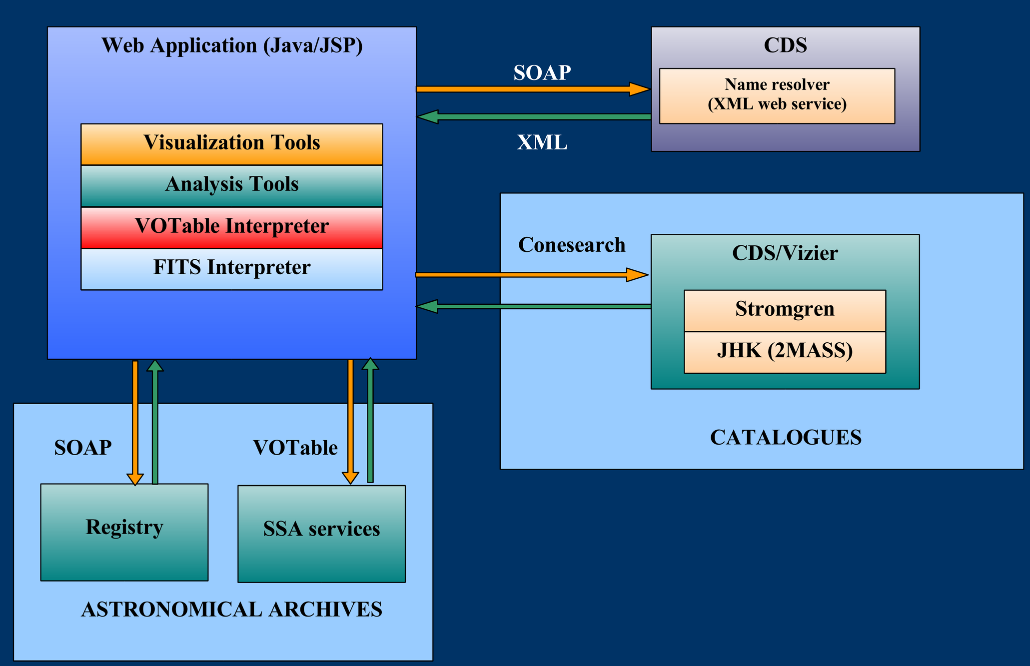
In this context we present here a tool that permits to characterize the protoplanetary disks around young stars by studying their Spectral Energy Distributions (SED). The application will allow the user to gather photometric and spectroscopic information covering the spectral range from the UV to the FIR, trace the SED, fit the photospheric contribution with a stellar model and the IR excess with a self-consistent physical disk model from the catalogue of D'Alessio et al. (2005).

Characterization of circumstellar disks of young pre-main sequence stars
(Solano et al. 2004)

- The transition phase from the optically thick disks around young pre-main sequence phase to the optically thin debris disks around Vega type stars is not well understood and plays an important role in the current theory of planet formation.
- The fitting of a SED with disk models is the best current method for characterizing the disk evolution and its possible connection with planet formation but, if one use physical models, it takes too much computational time to be feasible.
- D'Alessio et al. (2005) developed a grid of physical disk models of accretion disks irradiated by their central stars (http://cfa-www.harvard.edu/youngstars/dalessio) using for that 8000 hours of CPU time in distributed Linux clusters for alleviating that problem.
- In order to increase the efficiency and reliability of SED fitting analyses, the SVO developed a tool to apply a Bayesian Method to select the best fit model or combination of models from the catalogue and give which observables would break the degeneracy in case of multiple possibilities.
- The tool will be extremely useful to analyse the large number of SEDs being currently produced e.g. by *Spitzer* and it will reside at

http://svo.laeff.esa.es/

The tool: conceptual design



Example of the fit of the SED of a Herbig Ae star in a record time of 10 minutes

Step 1: INPUT FORM

- Search driven by Object ID or coordinates
- Registry: SSAP services on-the-fly
- Catalogue info from Vizier

Step 2: DATA GATHERING

Additional data from the user (such as radio continuum fluxes, literature or unpublished photometry) can be added.

The stellar parameters for the star can be provided here for the fit. If they are not provided by the user, the system will compute them from the Strömgren and/or 2MASS photometry.

Step 3: BAYESIAN ANALYSIS

Table 1:

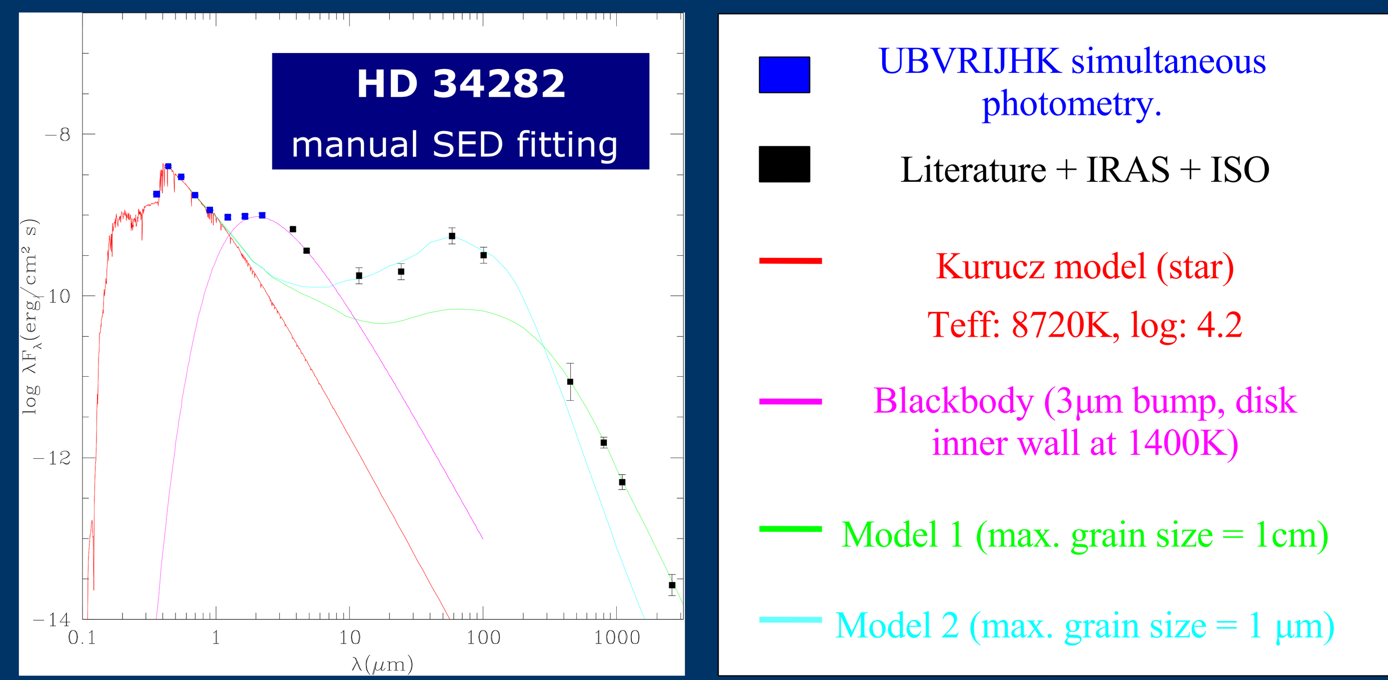
Model Complexity	Evidence
Star + Disk1	0.0
Star + Disk1 + Inner Wall	4.0×10^{-6}
Star + Disk1 + Disk2	1.0E-20
Star + Disk1 + Disk2 + Inner Wall	1.0

The bayesian method tries to fit the observed SED with all synthetic SEDs (star + disk) from the model catalogue and selects the one with higher probability density.

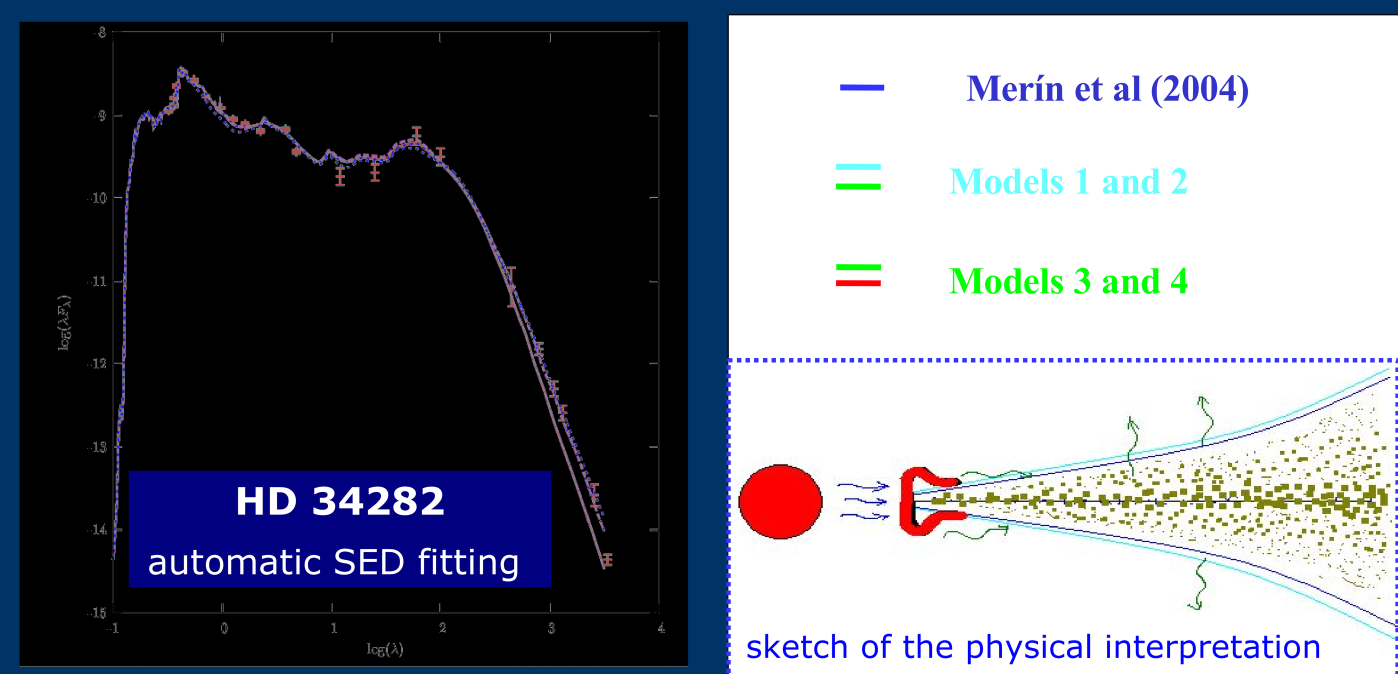
	D	I	S	K	1		+	D	I	S	K	2	
Norm. Probability	Angle	Rext	Rin	Mdot	p	amax		Angle	Rext	Rin	M dot	p	amax
Closest in grid	60	800	44	1,00E-008	3,5	1,00E-006		60	800	49	1,00E-007	2,5	1,00E-002
1,00E+000	60	800	44	1,00E-009	3,5	1,00E-006		60	800	49	1,00E-007	3,5	1,00E-001
6,21E-001	60	800	44	1,00E-009	2,5	1,00E-006		60	800	49	1,00E-007	3,5	1,00E-001
3,46E-001	60	800	44	1,00E-009	3,5	1,00E-006		60	800	44	1,00E-008	3,5	1,00E-003
2,58E-001	60	800	44	1,00E-009	2,5	1,00E-006		60	800	44	1,00E-008	3,5	1,00E-003
2,05E-001	60	800	44	1,00E-009	3,5	1,00E-006		60	300	49	1,00E-007	3,5	1,00E-001
1,37E-001	60	800	44	1,00E-009	2,5	1,00E-006		60	300	49	1,00E-007	3,5	1,00E-001
5,90E-002	60	800	44	1,00E-009	2,5	1,00E-006		60	800	49	1,00E-007	2,5	1,00E-002
5,33E-002	60	800	44	1,00E-009	2,5	1,00E-006		60	300	49	1,00E-007	2,5	1,00E-003
4,97E-002	60	800	44	1,00E-009	3,5	1,00E-006		60	800	44	1,00E-008	3,5	1,00E-002
4,91E-002	60	800	44	1,00E-009	3,5	1,00E-006		60	300	49	1,00E-007	2,5	1,00E-003
4,42E-002	60	800	44	1,00E-009	2,5	1,00E-006		60	800	44	1,00E-008	3,5	1,00E-002
4,32E-002	60	300	44	1,00E-009	2,5	1,00E-006		60	300	49	1,00E-007	3,5	1,00E-001
4,13E-002	60	800	44	1,00E-009	3,5	1,00E-005		60	800	49	1,00E-007	3,5	1,00E-001
3,26E-003	60	800	44	1,00E-009	3,5	1,00E-006		60	800	49	1,00E-007	2,5	1,00E-002
3,08E-002	60	800	44	1,00E-009	3,5	1,00E-004		60	800	49	1,00E-007	3,5	1,00E-001

References
Merín et al. (2004) A&A 419, 301: *Study of the properties and SEDs of the Herbig Ae stars HD 141569 and HD 34282*
D'Alessio et al. (2005), RevMexA&A, 41: *WWW database of models of accretion disks irradiated by the central star* http://cfa-www.harvard.edu/youngstars/dalessio/
Solano et al. (2004), AVO Science Reference Mission Proposal and DEMO: *Characterization of circumstellar disks around pre-main sequence stars.* http://svo.laeff.esa.es/

Step 4: BEST SED FIT and INTERPRETATION



FITTING TIME WITH THE OLD MANUAL METHOD: 2 WEEKS



FITTING TIME IN THE NEW AUTOMATIC METHOD: 10 MINUTES

The SED fit in the upper panel is from Merín et al. (2004) and requires two models with two different grain sizes computed specifically for this case plus a black body for the emission of the disk inner rim. The fit in the plot below was automatically produced by the VO-tool using two already computed models from the catalogue. Both fits are equivalnent: they imply the presence of dust grain growth and settling in this disk with the larger grains in the mid-plane and the smaller ones in the disk surface. Also, both models are truncated at the dust destruction radius.