Classifying the SEDs of Herbig Ae/Be stars

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Abstract

A Herbig Ae/Be star (HAeBe) is a 2-8 Solar mass, pre-main-sequence star (that is, young objects with typical ages of 10Myr) of spectral types A or B. These stars are still embedded in gas-dust envelopes and are sometimes accompanied by circumstellar disks. They are in the gravitational contraction stage and approaching the main sequence (i.e. they are not burning hydrogen in their center). The overall goal of this tutorial is to become familiar with VOspec and SPLAT. For that, we are going to build the Spectral Energy Distribution (SED) of a couple of Herbig Ae/Be stars.

Software: VOspec Version 6.7, SPLAT Version 3.11-1beta

1 Starting out

For this tutorial we need VO spec and SPLAT. If you do not have them already, you can find them here:

VOspec: http://www.sciops.esa.int/index.php?project=SAT&page=vospec

SPLAT: http://www.g-vo.org/pmwiki/About/SPLAT

2 Introduction

Herbig Ae/Be stars show Balmer emission lines in their stellar spectrum and infrared excess due to circumstellar dust. Sometimes Herbig Ae/Be stars show significant brightness variability associated to clumps (protoplanets and planetesimals) in the circumstellar disk.

The SEDs of Herbig Ae/Be stars fall roughly into two groups: Group I sources have a relatively strong far-IR flux, which is energetically comparable

with the flux in the near-IR showing an almost flat spectral energy distribution. Group II sources show a similar near-IR excess as group I sources but their flux falls off strongly towards the far-IR. These were first classified by Meeus et al (2001, AA, 365, 476), see below figure.
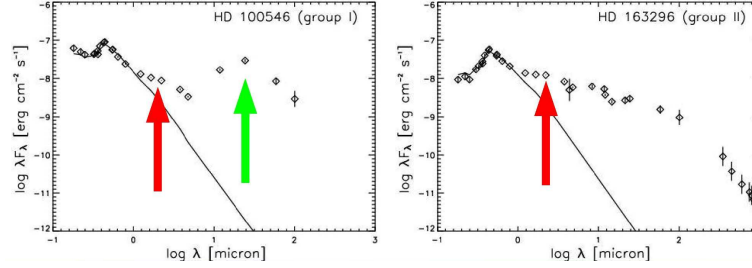
Dullemond and Dominik (2004, AA, 417, 159) provided a physical explanation for this difference: Group II sources have an outer disk which is protected against direct stellar radiation by a puffed-up inner disc. If the outer disc emerges from the inner disc's shadow, i.e. has a large flaring angle, then its SED resembles that of a Group I source.

3   VOspec

▷ **1** *Search for spectra services* – The VO protocol to access spectra is SSAP. We will search SSAP services for spectra of a specific object and then download some. Open VOspec and at **Target** type `HD 100546` and at **Size** enter `0.001`. These are the parameters that define a search around the position of HD 100546. Note that in the background the name of the object is resolved to a position by querying SIMBAD. Click on **Query**. The **Server Selector Window** will open. The Spectra, Photometry and Theoretical Services available in the VO are listed on the left hand side of the window. A click on a branch will open the according list of SSAP services.

▷ **2** *Selecting services* – We want to cover a wider waveband range of observed spectra and where those are missing, select photometry from services providing those from serveys as SDSS or 2MASS. In the branch **Observational Spectra Services** we check

- Far Ultraviolet Spectroscopic Explorer
- The Hubble Space Telescope Spectra
- INES: The IUE Newly Extracted Spectra

- The ISO Data Archive Interoperability System

In **Photometric Services** check CDS Multicatalogue Photometry Service and then click on **Query**. The spectra and photometry are then loaded into the **Spectra List** region of the main VOSpec window.

▷ **3** *Find spectra* – There are two different views in the spectra list. You can toggle between them by clicking the Tree/Table view icon on the top right of the symbol bar. Use the table view to have more information of the spectra displayed. Hint: make use of the features in the table view. Double click on the spectra will give you even more metadata for the spectra. Single click on the column headers will sort the spectra lists.

▷ **4** *Challenge 1: Get metadata of the spectra* – For the FUSE →p2190401... spectra use the **Coverage.Bounds/Start/Stop** columns to get an idea of the covered spectral range. Other important information like the time coverage, the S/N ratio or the resolution can be obtained in a similar way.

▷ **5** *Select spectra* – Select the following spectra:

- FUSE: p219040100000nvo4ttagfcal

- HST: O5C901080, O6GY10010

- INES: LWP16052RL,SWP39712RL

- ISO: SWS0, LWS01

In addition select the following photometric services: 2MASS, AKARI, HIP, IRAS, SDSS, WISE. Then click on **Retrieve**. The selected spectra and photometry are loaded into the main VOSpec window.

▷ **6** *Analysing the spectra* – After the download you see the spectra and photometric data plotted. Change the Y axis from **Jy** to **erg/cm2/s** by clicking on the **Flux Unit** field to the left of the main VOspec window. Look at the spectra and zoom in and out by using the left mouse bottom.

▷ **7** *Challenge 2: Which group does HD100546 belong to ?* – Apply the criteria from the introduction to classify HD100546.

Save the spectra at your local hard drive by going to File →Save as. As data modell use **VO table**. We will need it later.

▷ **8** *Repetition* – Repeat the steps fot the Object `HD 163296`. Select the following spectra:

- FUSE: q219010...

- INES: LWP05471RL

- Hubble: O66Q01010,O66Q01020,O66Q01030.

- ISO: SWS01

Again take photometry from the CDS photometry services.

▷ **9** *Challenge 3: Search metadata* – Sometimes you might want to contact the collegue responsible for this data collection. Find out the contact and Email adress of INES: LWP05471RL.

▷ **10** *Fitting* – Of course spectra analysis is more than looking at downloaded plots. VOspec does provide functions for fitting functions. Next we want to do a Gaussian fit. At first set the spectral flux axis in linear scale. Then zoom into the region with a strong spectroscopic line, e.g. at 2800Å. Go to Select Operations →Fitting Utilities. The **Fitting Window** opens. Select the **Gaussian** tab and click **Generate**. The fitted Gaussian is plotted over the spectrum and the parameters used in the calculation are shown in the **Fitting Window** (where A=amplitude, x0 = central peak, sigma = standard deviation).
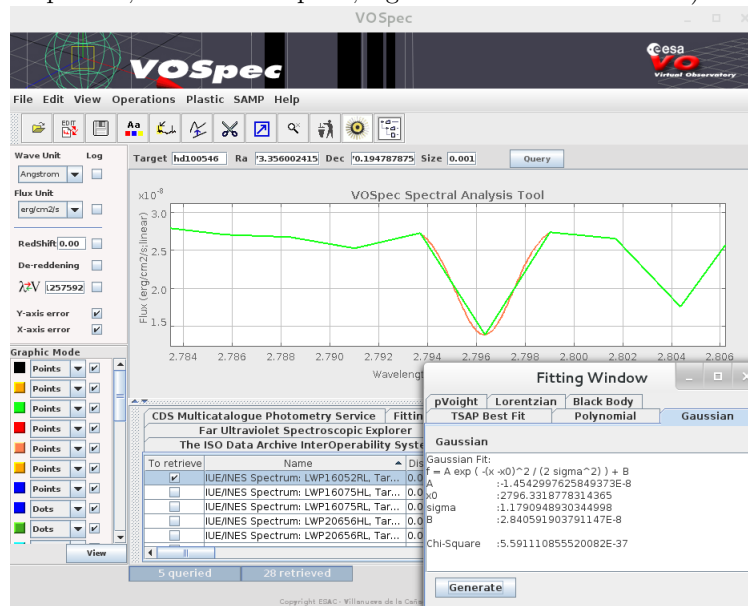

▷ **11** *Filtering* – To apply filtering for a range, we zoom until we fit the range between 2400 and 2800Å. The go to Select Operations →De- Noising →Averaging Filters →Median. Select 10 as **Numbers of points**. Click on **Filter** to generate a filtered spectrum.
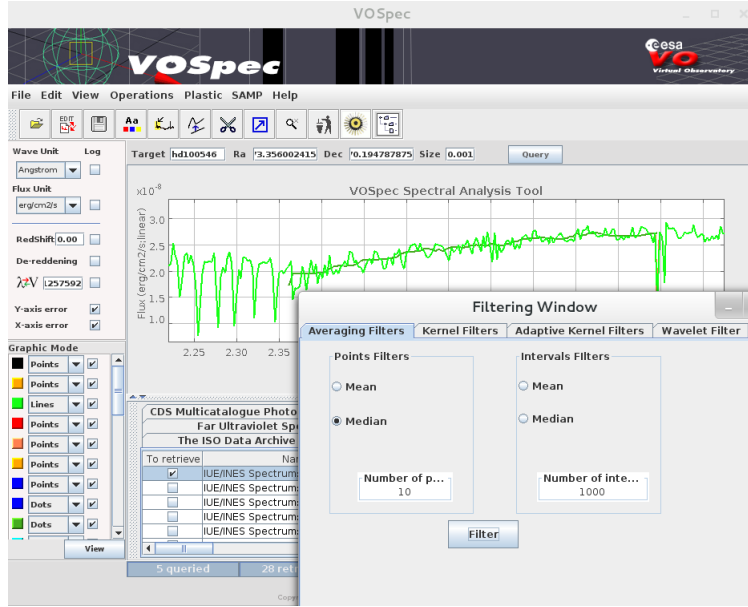
▷ **12** *Identifying lines with SLAP* – The Single Line Access Protocol (SLAP) is used within the VO to retrieve spectral lines from various Spectral Line Data Collections through a uniform interface. We want to use this to identify atomic lines within an area of our spectra. Zoom into the region with the strong spectroscopic line at 2800Å. Then go to Operations →SLAP. Highlight the region across the emission line. The selected region appears yellow and the SLAP Viewer window opens. Within this window open the **SLAP Services tree** and select the NIST atomic spectra service. Then click **select**. A table appears for each service within the **Slap Services Output** field, in our case, only NIST. Go back to the main VOSpec window. By moving the cursor across the yellow region each atomic line that lies closest to the cursor is displayed. One can then identify the most likely atomic or molecular line. Our two lines are the MgII 2795A and MgII 2805A. Click again on Operations →SLAP to deactivate this functionality.

▷ **13** *Model comparison* – Sometimes you want to compare spectra with models. In out case we want to see our observed spectra in the same plot with a Blackbody model spectra. Load the VO table of HD100546 we saved previously by clicking on File →Open spectrum and chose the according *.vot file. Select Operations →Fitting Utilities. The Fitting Window then opens. Select the **Blackbody**, use a **Teff**:12000K and click **Generate**. The blackbody will be overplotted to

the observational SED.
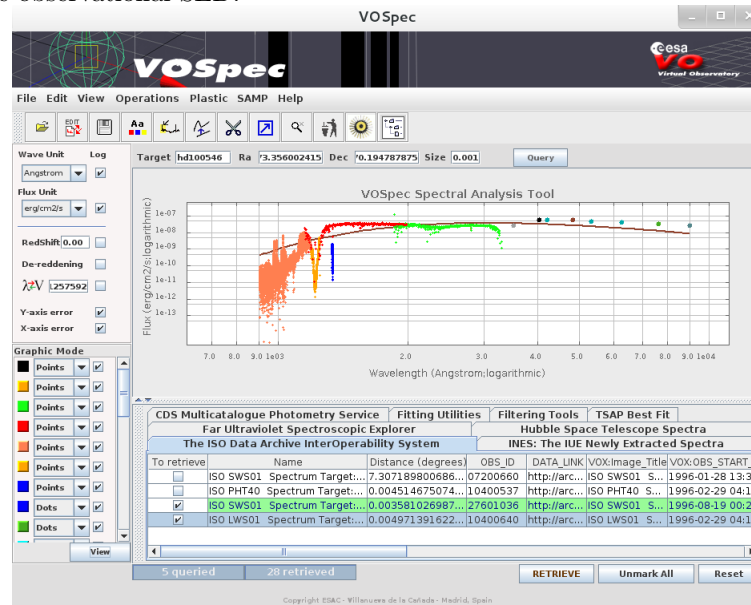
4 SPLAT

Within the VO there is not one single client fitting your needs. Actually there are lots of clients for different data types that 'speak' different protocols to retrieve, export or even send data between two applications. Thus the VO is not about to advice which client to use, but more likely to define standards and protocols so you can chose the client that will fit your demands the best - or just to use your favourite software. SPLAT ist another client for spectra access and analysis which shall be briefly introduced here.

▷ **14** *Searching spectra* – Open splat from command line. The command depends on you OS, on UNIX-alike machines it will be similar to **home**/*bin*/*splat*/*splat*.*GotoFile*→**SSAP**. **The Query VO for Spectra window opens. Type** `Nova Cygni 1992` **into the Object' field, and click Lookup. The coordenates of the object appear in the according fields. Select** `0.1` **arcminutes in the Radius field. Select Query format** `All` **and Wave Band UV. Click on the green Send Query at the right. A new window opens.**

Click on the IUE tab. Select ten lwp spectra. Hint: look for the instrument column label). Click Display selected. The selected

spectra will be loaded into the 'Global list of spectra' on the main SPLAT window and they will be overplotted in the same graphic window. The differences in the MgII 2800 emission line are clearly visible.

▷ **15** *Animate spectra* – In SPLAT main window go to View →Animate spectra. Select several spectra and click Start. New windows open where the selected spectra are displayed one at time, as a movie. Change the X axis range by clicking on Plot configuration window and setting the Lower Y to zero. Click draw. The differences in the MgII 2800 emission line are clearly visible.

5   Solutions

1. The covered waveband range is 900 to 1190 Å, the S/N is 4.17

2. HD100546 is a group I Herbig Ae/Be star

3. Enrique Solano, esm@cab.inta-csic-es

6   References

Acke and van den Ancker (2004, AA, 426, 151)

Dullemond and Dominik (2004, AA, 417, 159)

ESA VO Team (http://esavo.esac.esa.int/VOSpecManual/)

Meeus et al (2001, AA, 365, 476)