ISYA VO Exercise

Classifying the SEDs of Herbig Ae/Be stars

Background:

The Spectral Energy Distribution (SED) 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, A&A, 365, 476). Dullemond and Dominik (2004, A&A, 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.

Purpose: To classify the Spectral Energy Distribution (SED) of a number of Herbig Ae/Be stars (young intermediate mass stars).

Procedure:

Part 1-

1. Open TOPCAT. Download the The et al (1994) Herbig Ae/Be catalogue by doing the following: VO -> Vizier Catalogue Service. Click 'All Rows', select Output Columns as 'standard', select 'By Keyword' and type 'Herbig Ae/Be' in the Keywords box. Click 'Search Catalogues'

2. Select J/A+AS/104/315 - Member of Herbig Ae/Be stellar group (The et al 1994), Output Columns equals standard, and press OK. 8 tables are now downloaded into TOPCAT. To check what each of these tables are open View -> Table Parameters, and check the Description. We want the second table: J.A+AS. 104.315-2, which is Table 1 of The et.al. (1994) and contains the Herbig Ae/Be members and candidate members (108 rows by 9 columns).

3. Gathering IRAS and 2MASS photometry for each source: Select Multiple cone search (VO-> Multicone). In the Keywords field type 'IRAS Point Source' and click 'Submit Query'. Select the IRAS Point Source Catalogue, version 2 (II/125), the input table as J.A+AS.104.315-2, RA column as _RAJ2000, DEC column as _DEJ2000, the search radius column as 10 arcsec, the Output Mode as 'New joined table with best matches', and Error Handling as 'ignore'. The result is a table that contains 64 rows (i.e. 64 cross matches with the IRAS PSC were found), and contains the 9 columns from the The catalogue, 16 columns from the IRAS PSC and a column, called _r, which gives the cross match angular distance or separation in degrees.

4. Create a subset of this cross matched table (note: we are doing this solely for the purpose of the workshop, so that the cross matching with 2MASS-PSC does

not take too long). Select Views -> row subsets and in the Row Subsets window select Subsets -> add sample subset. Choose a subset name and select the best matches, column _r, by typing '$10 < 0.001' into the Expression field. This produces a subset of 29 sources. In the main TOPCAT window chose this subset by selecting the Row Subset field.

5. Select again the VO -> Multicone and this time type '2MASS' in the Keywords field and click 'Submit Query'. Select the 2MASS PSC catalogue (II/246), the input table as the new 29 row subset table, RA column as _RAJ2000, DEC column as _DEJ2000, the search radius column as 5 arcsec, the Output Mode as 'New joined table with best matches', and Error Handling as 'ignore'.

6. We now have the 2MASS JHK values for 26 of the 29 sources. The table contains many columns, therefore, to make the table viewing simpler, open View -> Column Info, and select columns RA, DEC, Name, IRAS flux_12um, flux_25um, flux_60um, J, H, and K magnitudes.

7. Create a new column with the J Flux by doing the following: Click on 'Columns' -> 'New synthetic column'. Input a Name 'Jflux', 'Jy' in the Units field and the expression: pow(10,($33/-2.5))*1614.4526, which represents Flux = $10^{-(j\_m/2.5)}$ x zeropoint (from the SVO filter service where the zeropoint is calculated from the Vega spectrum). Create other columns of the following: Fnu_60 - JFlux and Fnu_12 - Fnu_60.

8. Click on 'Graphics' -> 'Plot' in the main TOPCAT window and plot Fnu_12 - Fnu_60 versus log(Fnu_60 - Jflux). This diagram is an adaptation of figure 5 of Acke and van den Ancker (2004, A&A, 426, 151). The shape of the mid-IR SED of a group I source is 'double-peaked' com pared to the SED of a group II member. The x axis, IRAS Fnu_12 - Fnu_60, provides a quantitative measure for this difference in SED shape, whilst the y axis provides a measure for the differences in flux in the mid- and near-IR. Where do we expect to see Group I and Group II objects in this plot?

Part 2-

1. Now lets take a look at the SEDs of some of following stars. Open VOSPEC from following web page –

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

   Then click on ‘webstart’. It will take a while to start VOSPEC. Be patient!

2. Type 'HD 141569' in the Target field, '0.05' in the Size field and click 'Query'. HD 141569 corresponds to the source in column recno = 67 (i.e row 67 of the The catalogue table 2; IRAS 15473-0346).

3. The Server Selector window opens. Select the Simple Spectral Access (SSA) Services, in the left-hand side of the window in the 'Query by Service' region, by opening up the SSA Services tree. Tick the 'Select all SSA' field and click 'Query'. The spectra are then loaded into the 'Spectra List' region of the main

VOSpec window. This can be viewed also as a table by clicking the 'Tree/Table view' icon on the top right of the main VOSpec window.

4. Select spectra to view from various services, for example ISO, IUE/INES, ESO and FUSE. Check that you are loading spectra for the corr ect object by looking at (right-click on one spectra, and choose Properties), for example, Metadata fields: Target.Name, Distance... Note: ESO data are provided with three different 'Access Formats' for the same spectrum: text, votable and fits. VOSpec only handles votables. Click **Retrieve** to get the data.

5. The spectra you've chosen are loaded into the main VOSpec window. To compare the SED with those in the above figure, 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.

6. Which group would you initially classify the SED of HD 141569 into? Where does HD 141569 (column recno=67) fall in the TOPCAT plot Fnu_12 - Fnu_60 versus log(Fnu_60 - Jflux)?

7. Lets now pick a strong Group I candidate in the plot: the top left point. By clicking on the point in the scatter plot, the corresponding row is highlighted in the table. This object is MWC 1080. Open another VOSpec and type MWC 1080 into the Target field, size '0.05' and click 'Query'. Again tick the 'Select all SSA' field and click 'Query'.

8. Select spectra to view from various services, for example IUE/INES and ISO. Change the y axis from Jy to erg/cm2/s. Does the SED of MWC 1080 look like a Group I SED?