

## **A new tool for Post-AGB SED classification**

Philippe Bendjoya


*Laboratoire Fizeau, Campus Valrose, Cedex 2, 06108 Nice, France*

O. Suarez, L. Gallucio, O. Michel

We present the results of an unsupervised classification method applied on a set of 344 spectral energy distributions (SED) of post-AGB stars extracted from the Toruń catalogue of Galactic post-AGB stars. This method aims to find a new unbiased method for post-AGB star classification based on the information contained in the IR region of the SED (fluxes, IR excess, colours). We used the data from IRAS and MSX satellites, and from the 2MASS survey. We applied a classification method based on the construction of the dataset of a minimal spanning tree (MST) with the Prim's algorithm. In order to build this tree, different metrics have been tested on both flux and color indices. Our method is able to classify the set of 344 post-AGB stars in 9 distinct groups according to their SEDs.

# A New Tool For Post-AGB SED Classification

**Ph Bendjoya<sup>1</sup>, O. Suarez<sup>1,2</sup>, L. Galluccio<sup>1,3</sup>, O. Michel<sup>1</sup>**  
<sup>1</sup>Laboratoire H. Fizeau, Université Nice Sophia Antipolis, Observatoire de la Côte d'Azur, CNRS UMR 8525  
<sup>2</sup>Laboratoire IAS, Université Nice Sophia Antipolis, CNRS UMR 6709  
<sup>3</sup>GIPSA-Lab, Institut Polytechnique de Grenoble, CNRS UMR 5216



### Abstract

We present the results of an unsupervised classification method applied on a set of 344 spectral energy distributions (SED) of post-AGB stars extracted from the Turin catalogue of galactic post-AGB stars. The method aims to find a new unbiased method for post-AGB SED classification. We used the data from the region of the SED (fluxes, IR excess, colours). We used the data from IRAS and MSX satellites, and from the 2MASS survey. We used a clustering method based on the Minimum Spanning Tree (MST) with the Prim's algorithm in order to build the tree and to characterize the dissimilarity between the objects. We used the MST to identify the clusters. Our method is able to classify the set of 344 post-AGB stars in 9 distinct groups according to their SEDs.

### Objectives

- The classification of the SEDs of post-AGB stars has been performed up to now following the classes established by van der Kruit et al. (1993). This classification is based on the aspect of the SED at all wavelengths.
- An ideal SED classification method would establish classes able to separate the objects into different groups according to their theoretical studies as those in van Houw et al. (1997) showed that at least the far IR part of the SED is not univocally related to a specific evolutionary stage.
- AGB star in the IRAS two colour diagram is not a SED classification might not be able to fulfil these ideal conditions.
- The two colour diagrams. Especially the IRAS (12/25 vs 125/60) diagram has been one of the most useful, mainly to identify post-AGB stars and to distinguish between the different evolutionary stages.
- Our approach consists in finding an unsupervised and automatic method to separate the objects into different groups. This method of colour performs with the use of a Minimum Spanning Tree.

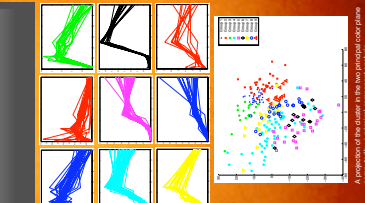
### Method

**STEP 1: PRIMS**  
 - Assumptions: when spectrum (a 10-dimensional vector) is considered as a walk on an undirected graph  $G=(V,E)$  where  $V$  is the set of vertices and  $E$  is the set of edges. The vertices of the graph are the SEDs and the edges are the dissimilarity between two vertices.  
 - Algorithm: construction of a Prim's Minimal Spanning Tree (MST), which connects iteratively the closest non-connected vertex to the graph partially constructed until no vertex remains unconnected.  
 - Data used to build the MST: a normalized full-band color divergence function  $D_{ij}$  defined as  $D_{ij} = \frac{1}{2} \sum_{\lambda} \left( \frac{F_{i,\lambda} - F_{j,\lambda}}{F_{i,\lambda} + F_{j,\lambda}} \right)^2$  where  $F_{i,\lambda}$  is the flux of the  $i$ -th SED at wavelength  $\lambda$ .

Use of the MST: a construction is done of the complete MST (connected with a 1-dimensional function  $D_{ij}$ ).

### Results

Nine groups were found by the previous method. The fluxes corresponding to the post-AGB stars classified in each group are illustrated on the figure on the right. The different groups are represented in the usual color-color space, and on the color-magnitude diagram (CMD). Each group (except roughly) different regions in the diagrams, showing that they represent different characteristics (for the circumstellar envelope of the objects they contain). (legend figure) the same colour-colour diagram for the classification of van der Veen et al. (1989). We see that our method has improved the separation of the objects in the two-colour diagrams, facilitating the identification of a sub-population group but with the position in one of these diagrams.



A projection of the cluster in the two principal colour plane. Comparison a priori for proposed groups.

### Conclusion

We propose for the first time an unsupervised classification population from the SEDs. We used a metric well adapted to evaluate the distance between two spectra (the Kullback-Leibler divergence). The clustering method is based on a Prim's MST computation of 9 groups. Some of these 9 groups show marked differences in their spectral types and their old classifications. They occupy roughly different regions in the two colour diagrams that allow the classification of a source in one of these groups just by its position in the diagram.

### References

van der Veen, H., 1989. Distance measure for signal processing and its application to spectral classification. *IEEE Transactions on Systems, Man, and Cybernetics*, 19(1), 154-159.

van der Veen, H., 1991. Distance measure for signal processing and its application to spectral classification. *IEEE Transactions on Systems, Man, and Cybernetics*, 21(1), 154-159.

Galluccio, L., Bendjoya, P., Suarez, O., Michel, O., 2007. A new method for post-AGB SED classification. *Proceedings of the 13th European Conference on Astronomical Spectroscopy*, 13-15 June 2007, Granada, Spain, pp. 15-18.

Galluccio, L., Bendjoya, P., Suarez, O., Michel, O., 2008. A new method for post-AGB SED classification. *Proceedings of the 14th European Conference on Astronomical Spectroscopy*, 13-15 June 2008, Granada, Spain, pp. 15-18.

Galluccio, L., Bendjoya, P., Suarez, O., Michel, O., 2009. A new method for post-AGB SED classification. *Proceedings of the 15th European Conference on Astronomical Spectroscopy*, 13-15 June 2009, Granada, Spain, pp. 15-18.

Galluccio, L., Bendjoya, P., Suarez, O., Michel, O., 2010. A new method for post-AGB SED classification. *Proceedings of the 16th European Conference on Astronomical Spectroscopy*, 13-15 June 2010, Granada, Spain, pp. 15-18.

Galluccio, L., Bendjoya, P., Suarez, O., Michel, O., 2011. A new method for post-AGB SED classification. *Proceedings of the 17th European Conference on Astronomical Spectroscopy*, 13-15 June 2011, Granada, Spain, pp. 15-18.

Galluccio, L., Bendjoya, P., Suarez, O., Michel, O., 2012. A new method for post-AGB SED classification. *Proceedings of the 18th European Conference on Astronomical Spectroscopy*, 13-15 June 2012, Granada, Spain, pp. 15-18.

Galluccio, L., Bendjoya, P., Suarez, O., Michel, O., 2013. A new method for post-AGB SED classification. *Proceedings of the 19th European Conference on Astronomical Spectroscopy*, 13-15 June 2013, Granada, Spain, pp. 15-18.

Galluccio, L., Bendjoya, P., Suarez, O., Michel, O., 2014. A new method for post-AGB SED classification. *Proceedings of the 20th European Conference on Astronomical Spectroscopy*, 13-15 June 2014, Granada, Spain, pp. 15-18.

Galluccio, L., Bendjoya, P., Suarez, O., Michel, O., 2015. A new method for post-AGB SED classification. *Proceedings of the 21st European Conference on Astronomical Spectroscopy*, 13-15 June 2015, Granada, Spain, pp. 15-18.

Galluccio, L., Bendjoya, P., Suarez, O., Michel, O., 2016. A new method for post-AGB SED classification. *Proceedings of the 22nd European Conference on Astronomical Spectroscopy*, 13-15 June 2016, Granada, Spain, pp. 15-18.

Galluccio, L., Bendjoya, P., Suarez, O., Michel, O., 2017. A new method for post-AGB SED classification. *Proceedings of the 23rd European Conference on Astronomical Spectroscopy*, 13-15 June 2017, Granada, Spain, pp. 15-18.

Galluccio, L., Bendjoya, P., Suarez, O., Michel, O., 2018. A new method for post-AGB SED classification. *Proceedings of the 24th European Conference on Astronomical Spectroscopy*, 13-15 June 2018, Granada, Spain, pp. 15-18.

Galluccio, L., Bendjoya, P., Suarez, O., Michel, O., 2019. A new method for post-AGB SED classification. *Proceedings of the 25th European Conference on Astronomical Spectroscopy*, 13-15 June 2019, Granada, Spain, pp. 15-18.

Galluccio, L., Bendjoya, P., Suarez, O., Michel, O., 2020. A new method for post-AGB SED classification. *Proceedings of the 26th European Conference on Astronomical Spectroscopy*, 13-15 June 2020, Granada, Spain, pp. 15-18.

Galluccio, L., Bendjoya, P., Suarez, O., Michel, O., 2021. A new method for post-AGB SED classification. *Proceedings of the 27th European Conference on Astronomical Spectroscopy*, 13-15 June 2021, Granada, Spain, pp. 15-18.

Galluccio, L., Bendjoya, P., Suarez, O., Michel, O., 2022. A new method for post-AGB SED classification. *Proceedings of the 28th European Conference on Astronomical Spectroscopy*, 13-15 June 2022, Granada, Spain, pp. 15-18.

Galluccio, L., Bendjoya, P., Suarez, O., Michel, O., 2023. A new method for post-AGB SED classification. *Proceedings of the 29th European Conference on Astronomical Spectroscopy*, 13-15 June 2023, Granada, Spain, pp. 15-18.

Galluccio, L., Bendjoya, P., Suarez, O., Michel, O., 2024. A new method for post-AGB SED classification. *Proceedings of the 30th European Conference on Astronomical Spectroscopy*, 13-15 June 2024, Granada, Spain, pp. 15-18.

Figure 1: A projection of the cluster in the two principal colour plane. Comparison a priori for proposed groups.