Statistical studies of spectral variability in blazars

Abstract: Blazars are a subclass of Active Galactic Nuclei whose jets closely point to the Earth, characterized by a strong flux variability. These relativistic jets are the main contribution to their optical emission, however, it is possible that other regions of the source (e.g. the host galaxy or the accretion disk) contribute significantly to the emission in some cases. In such cases, all these components must be taken into account when studying the variability of the source. However, distinguishing among the different parts of the blazar is challenging due to the high dominance of the jet's emission.
The objective of this work is to disentangle the contribution of each component of the blazar, in order to explain the spectral variability of the source and the contribution of each component to this variation. For this purpose, dimensionality reduction techniques, such as Non-negative Matrix Factorization (NMF), are applied to decompose the spectra of the source and identify the different components present in the detected emission.

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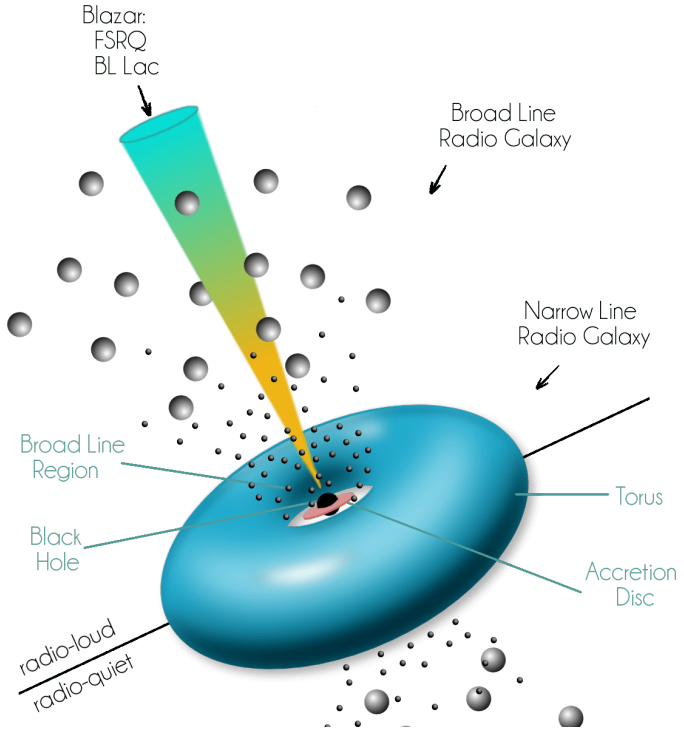
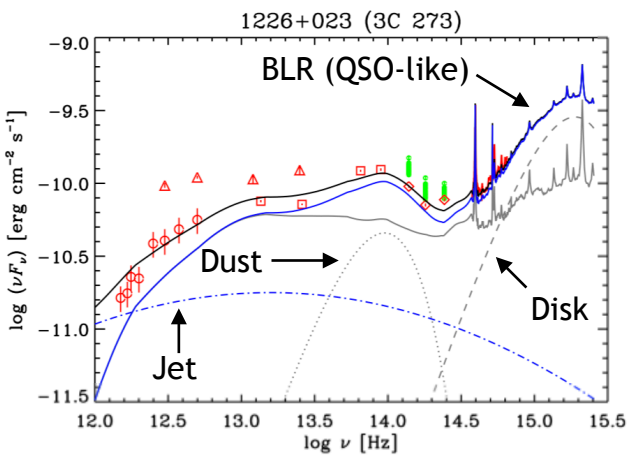
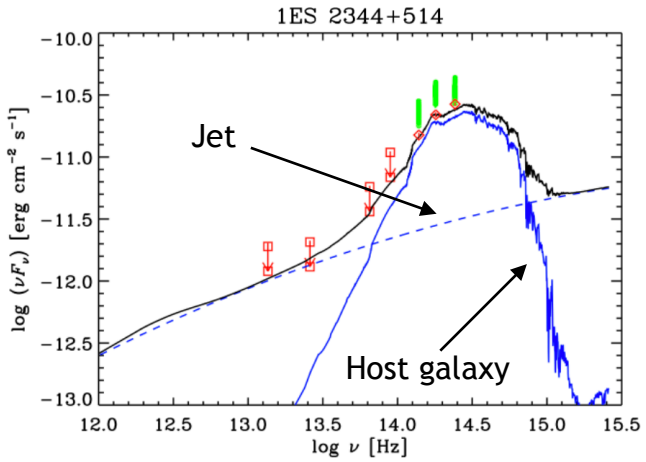
Context

- **Blazars**: radio loud AGNs with jets pointing in the direction of Earth
- Strong **variability** throughout all the electromagnetic spectrum
- **Jet emission** tends to **outshine** other contributions (see figures aside)
    - Host galaxy
    - Accretion disk
    - Broad and narrow line regions (BLR/NLR)
    - Dusty torus
- **Data sample**: optical spectropolarimetry of **~25 blazars** from 2008 to 2018 (Steward Observatory Fermi Support Program)
- **Objectives**:
    - **Disentangle** the **different contributors** to the emission of blazars
    - **Characterize** the **spectral variability** observed in the data sample





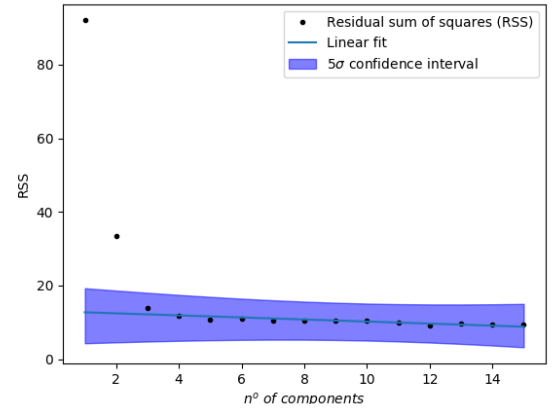


Raiteri et al. 2014

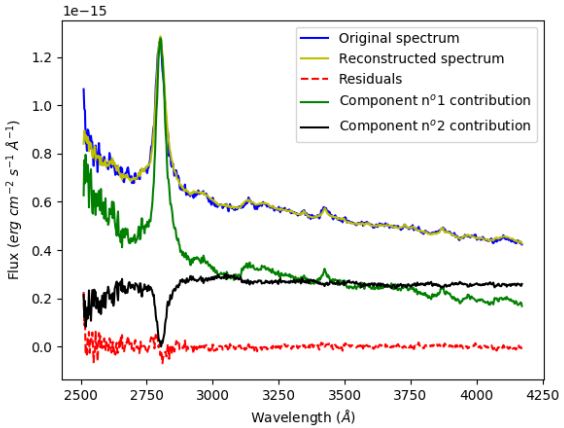
Methodology

Estimation of the minimum number of components to explain the spectral variability.

→ Dimensionality reduction by statistical techniques: Principal Component Analysis (PCA) and Non-negative Matrix Factorization (NMF)



NMF gives minimum # of components explain variance



But resulting components have no physical sense

New strategy →

Reconstruction based on a priori known/expected physical components

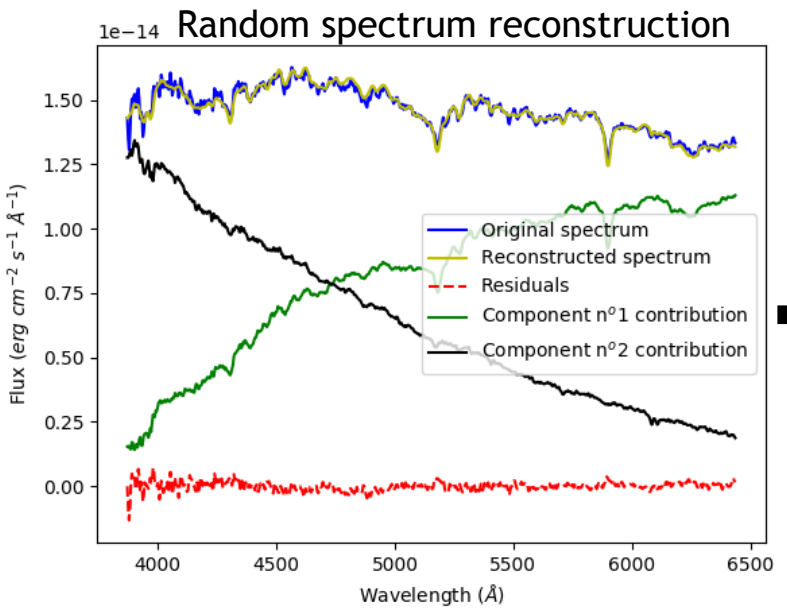
- Galaxy-dominated sources: Galaxy template + power law components
- BL Lac objects: Two power law components
- Flat Spectrum Radio Quasars (FSRQs): QSO template + power law components

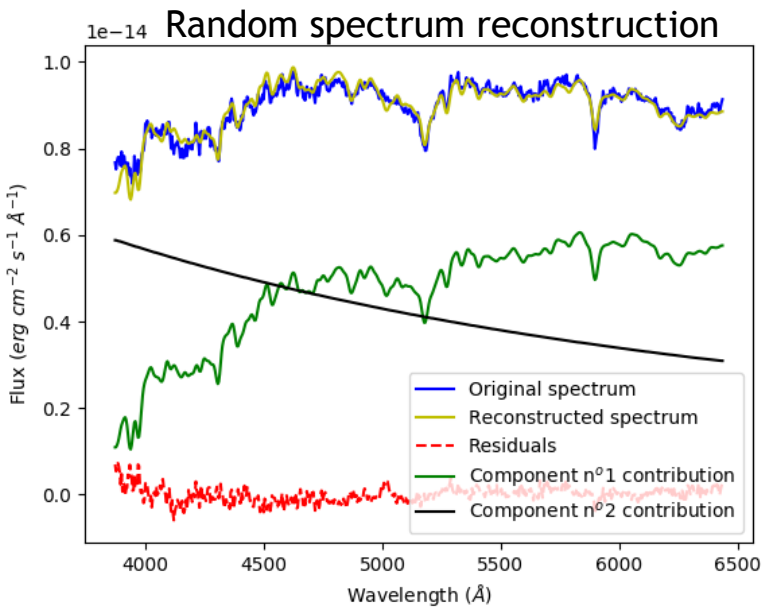
Results

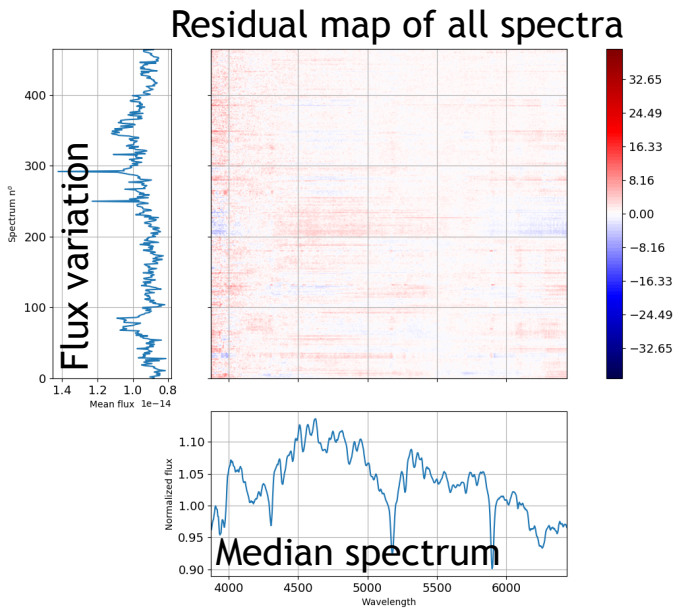
- **Number of components needed** for the reconstruction, as derived from NMF:
  - **Galaxy-dominated sources**: 2 components [Stellar population + power law component]
  - **BL Lac objects**: 2 components [Power law components]
  - **FSRQs**: 3 or more components [QSO emission (BLR) + power law components]
- **“Easy to interpret” reconstruction:** see the following example for Mrk 501

Free components

Physical components

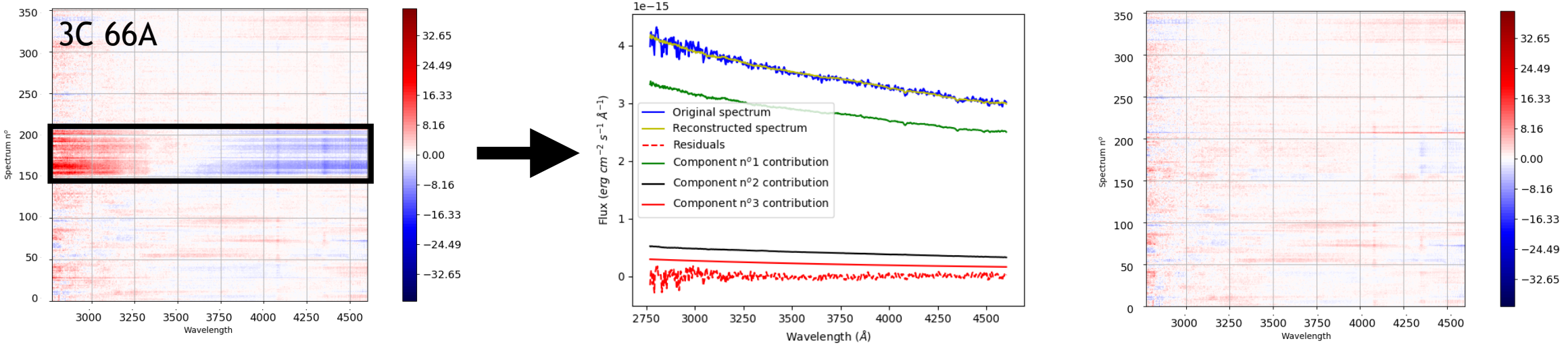






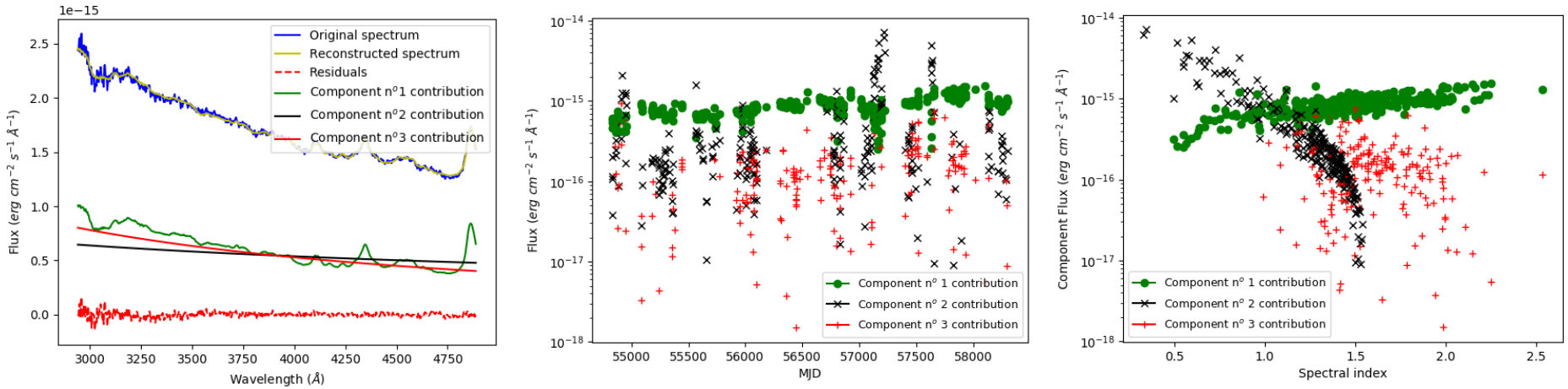
Results

- **Identification of color changes/spectral index changes → extra component**



- **Relation between the flux of the components and MJD/spectral index**

-Comps. 1 and 3 less variable (Middle panel)
-Comp. 3 responsible for the redder-when-brighter behaviour (Right panel)



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Impact & future steps

- With the a priori component methodology we obtain an **accurate reconstruction** of the spectra and the variability, using physical components
- The use of NMF can help to:
  - **Reproduce blazars' spectral variability and help to identify the relevant physical process**
  - Separate the contribution of the host galaxy and the jet
  - Determine the disk and BRL contribution (QSO-like) of the source
  - Detect significant color/spectral index variations
- Future steps:
  - Search for correlations of the components with the polarization
  - Extrapolation of the method to predict ultraviolet (UV) and infrared (IR) flux variability