Applying Hierarchical Clustering to Broad Absorption Line Profiles for Quasar Classification

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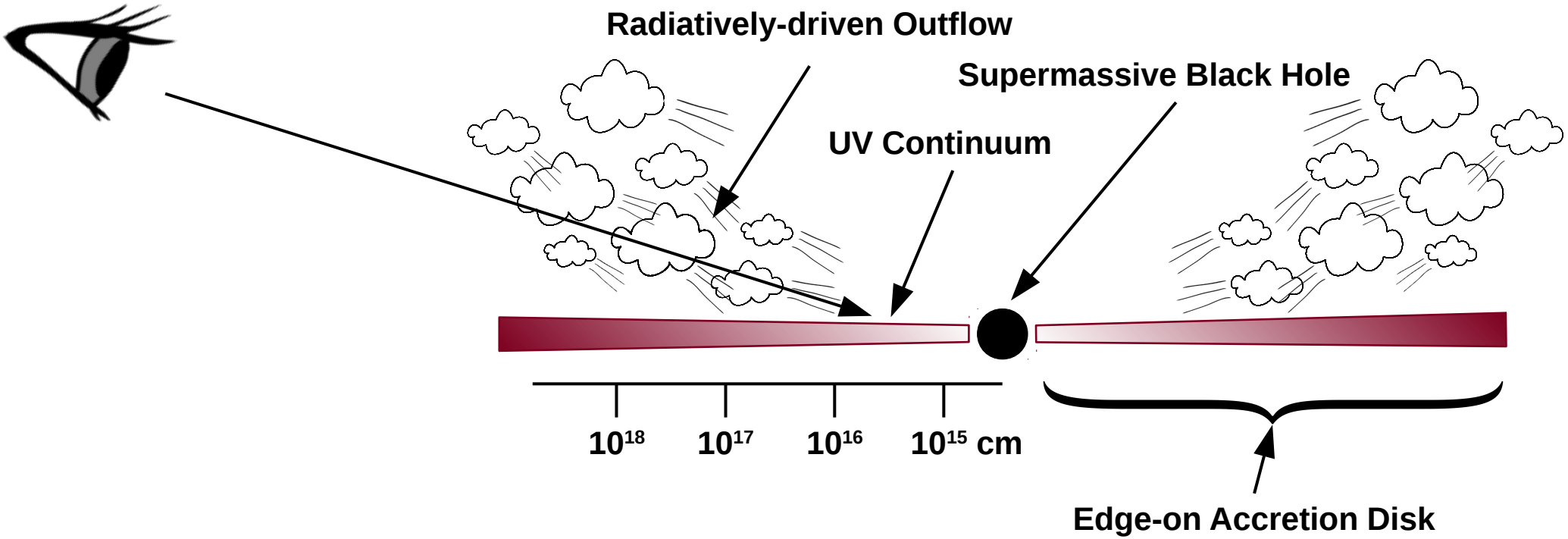
Great Lakes 2016 Quasar Symposium

Western Science

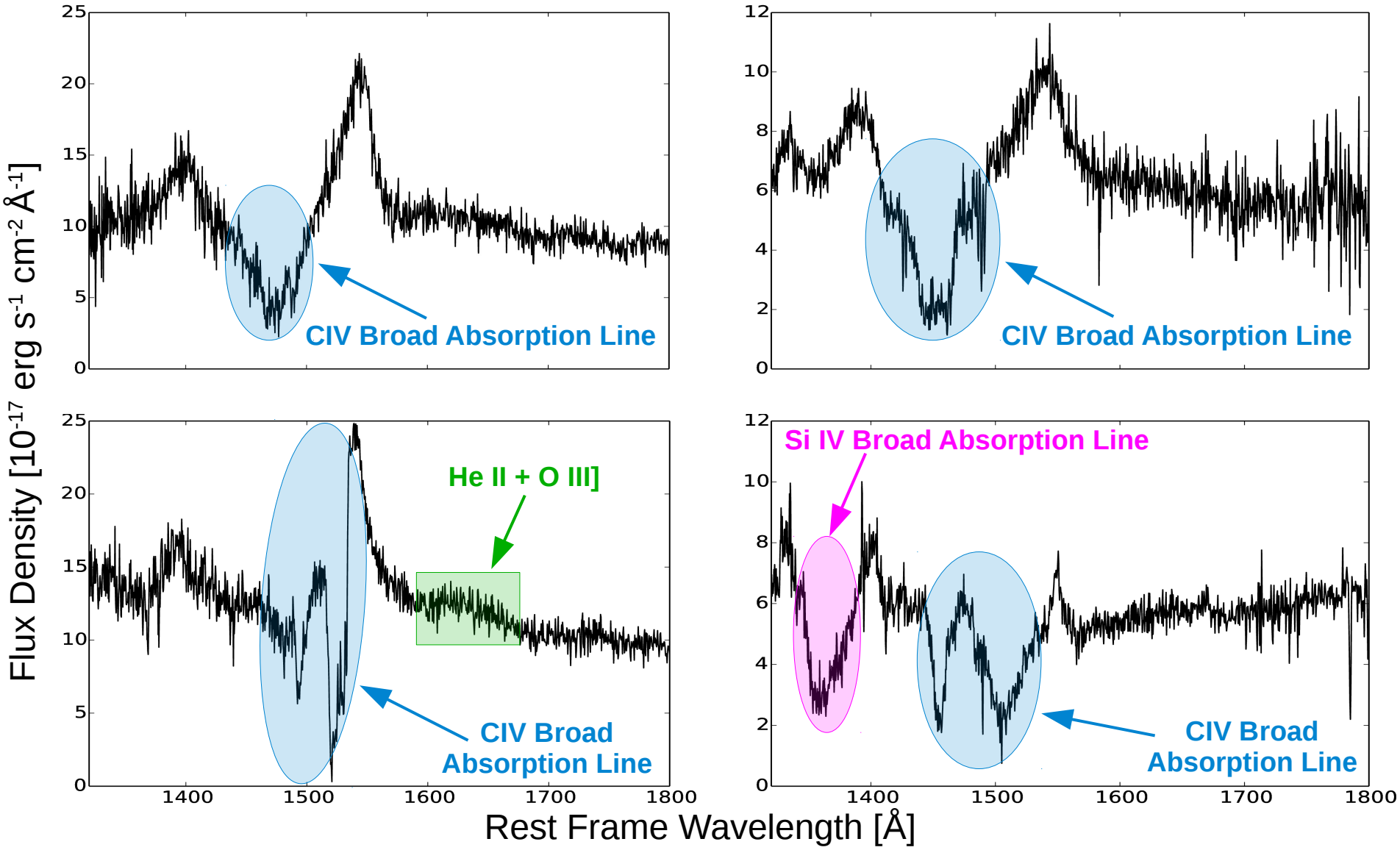
NSERC CRSNG

Image credit: NASA

Broad Absorption Line (BAL) Quasars



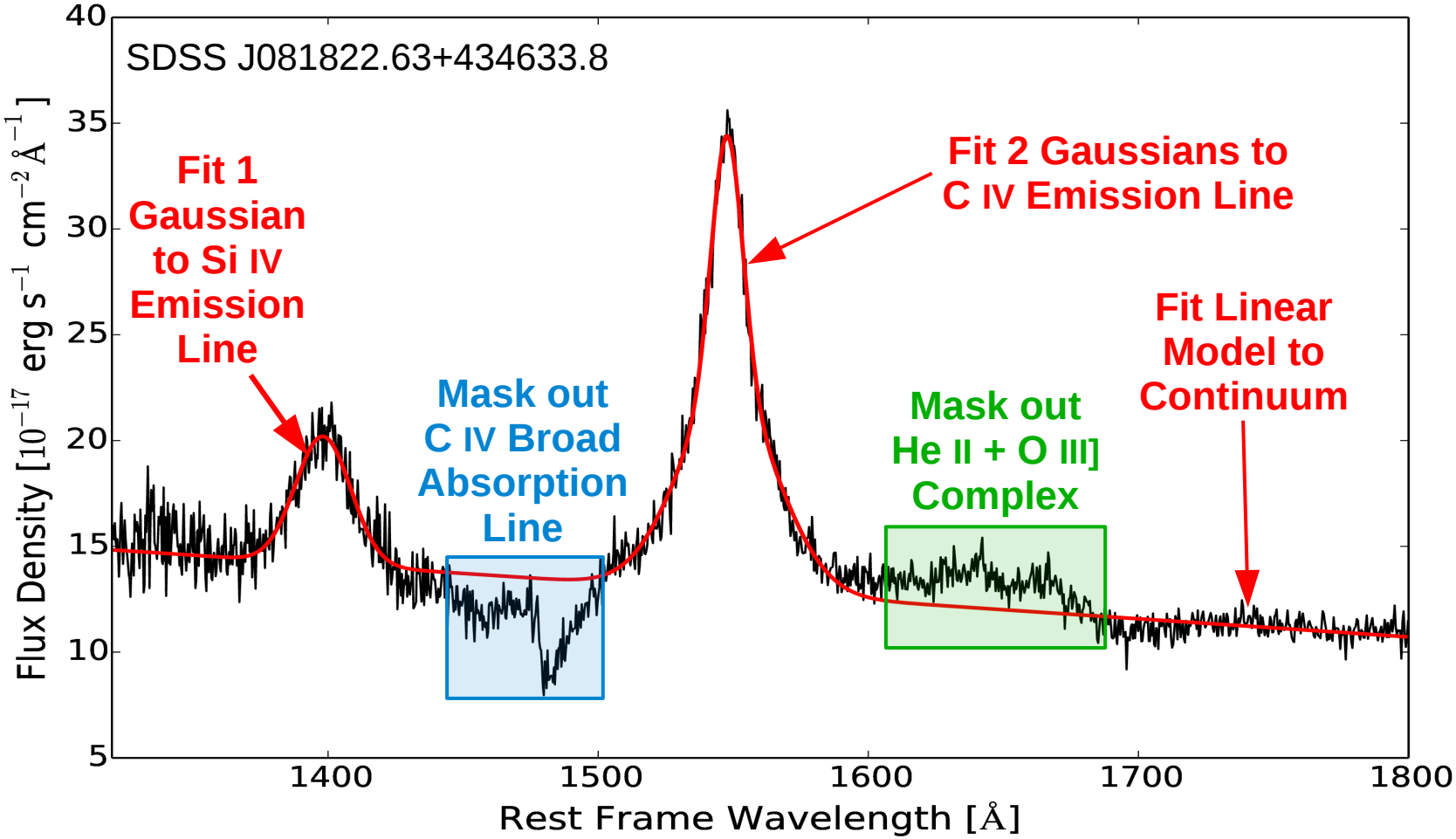
Diversity of C IV BALs



Why are these profiles different?

BAL Quasar Catalog & Data Reduction

- **Sample: 1,084 BAL quasars (1.68 ≤ *z* ≤ 4.93) from SDSS DR5 (Gibson et al., 2009)**
- **Method: (1) fit local continuum and prominent, broad emission lines (1320-1800 Å)**
  (2) normalize and "compare" spectra (1400-1550 Å)



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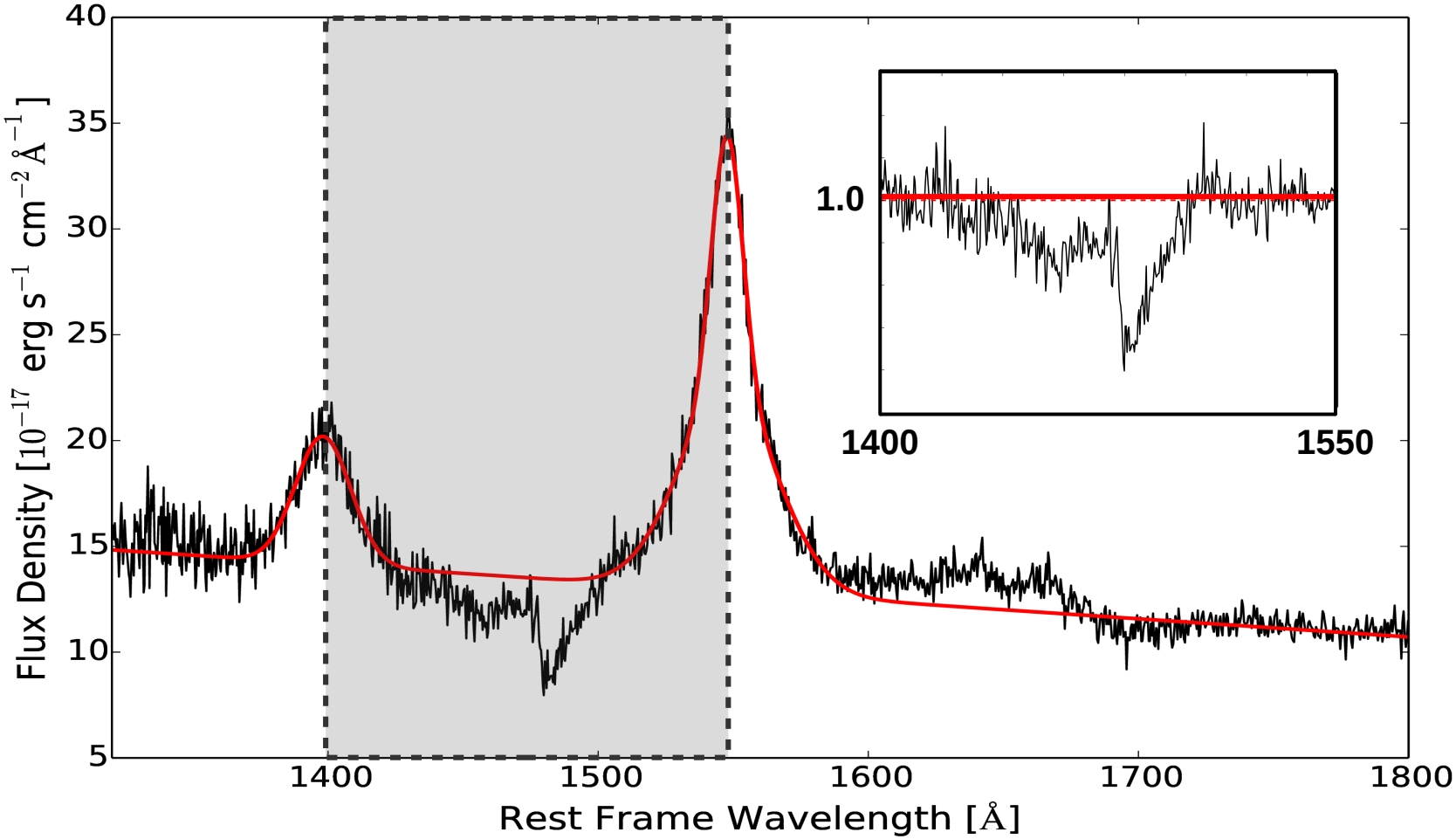
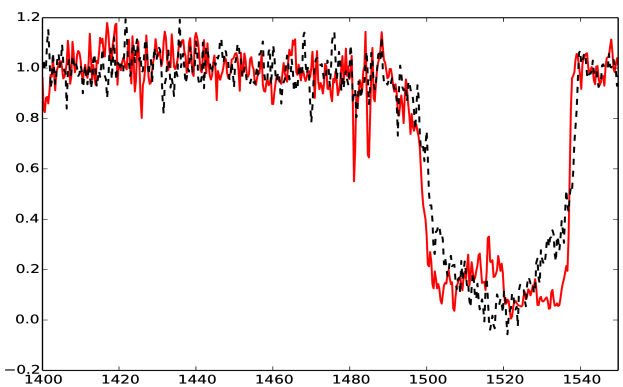
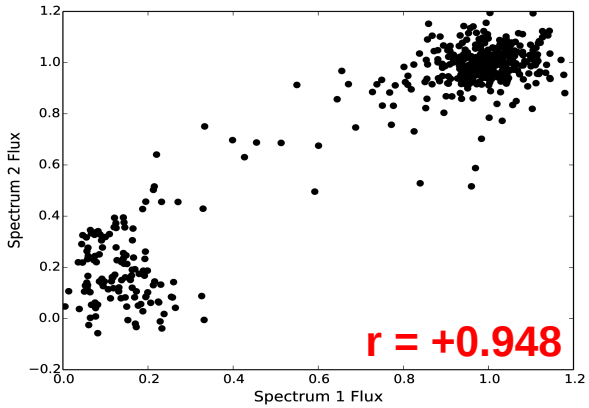


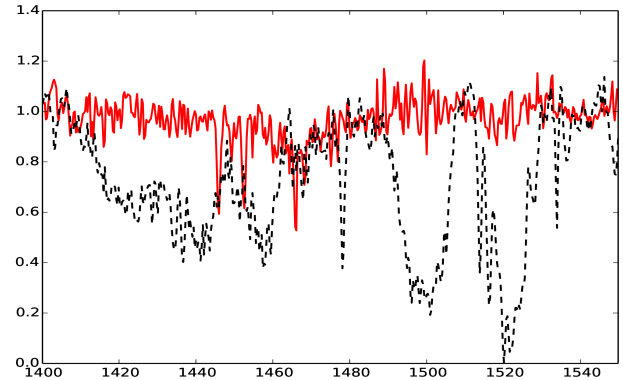
Pearson Product-moment Coefficients

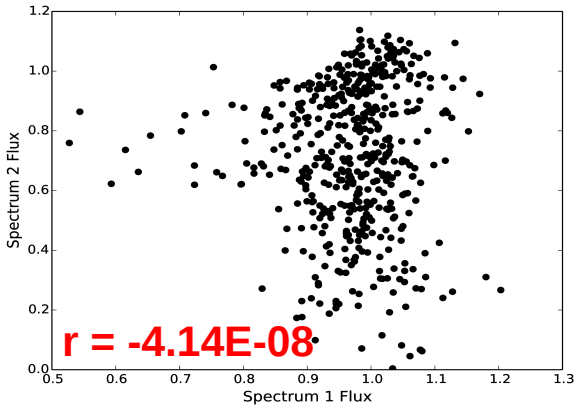
Strong Positive Correlation:



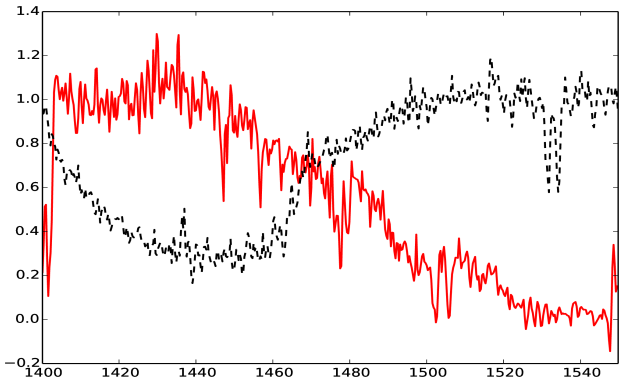


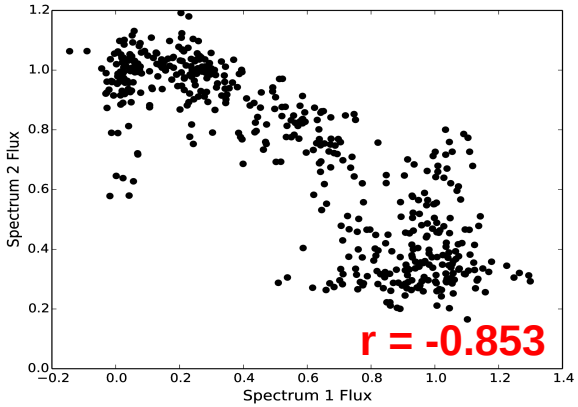
Weak/No Correlation:





Strong Negative Correlation:



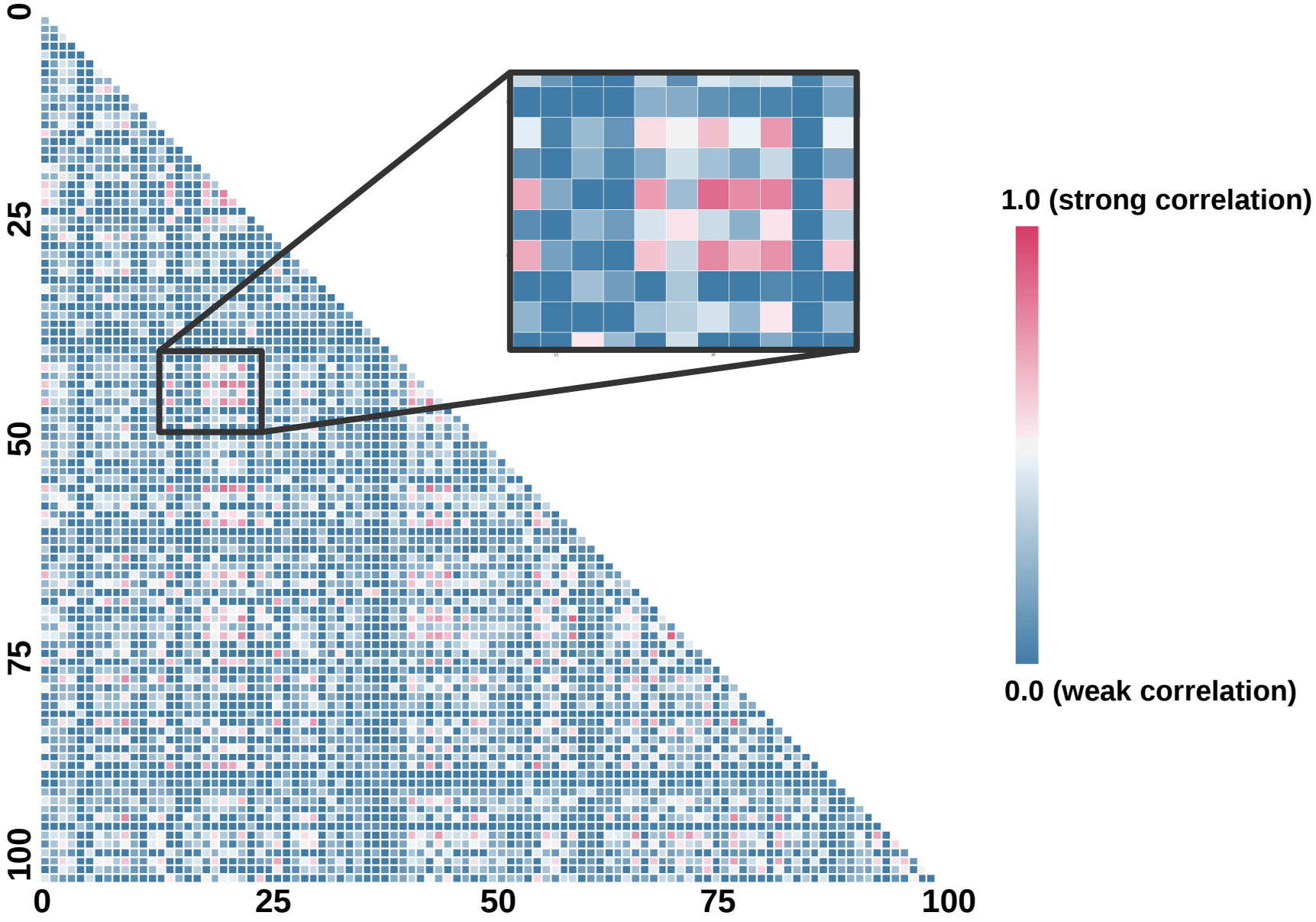


+1.0

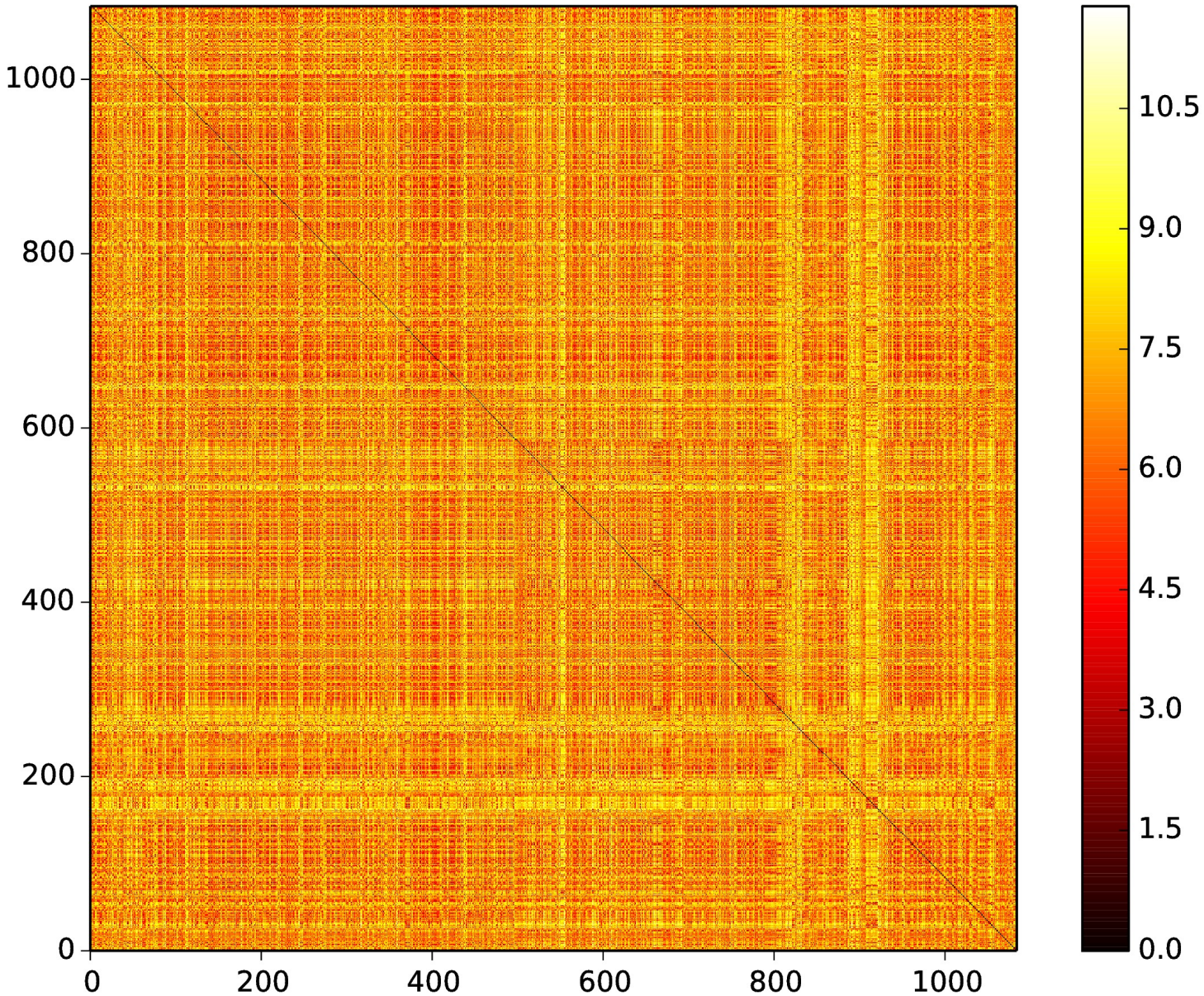
0.0

-1.0

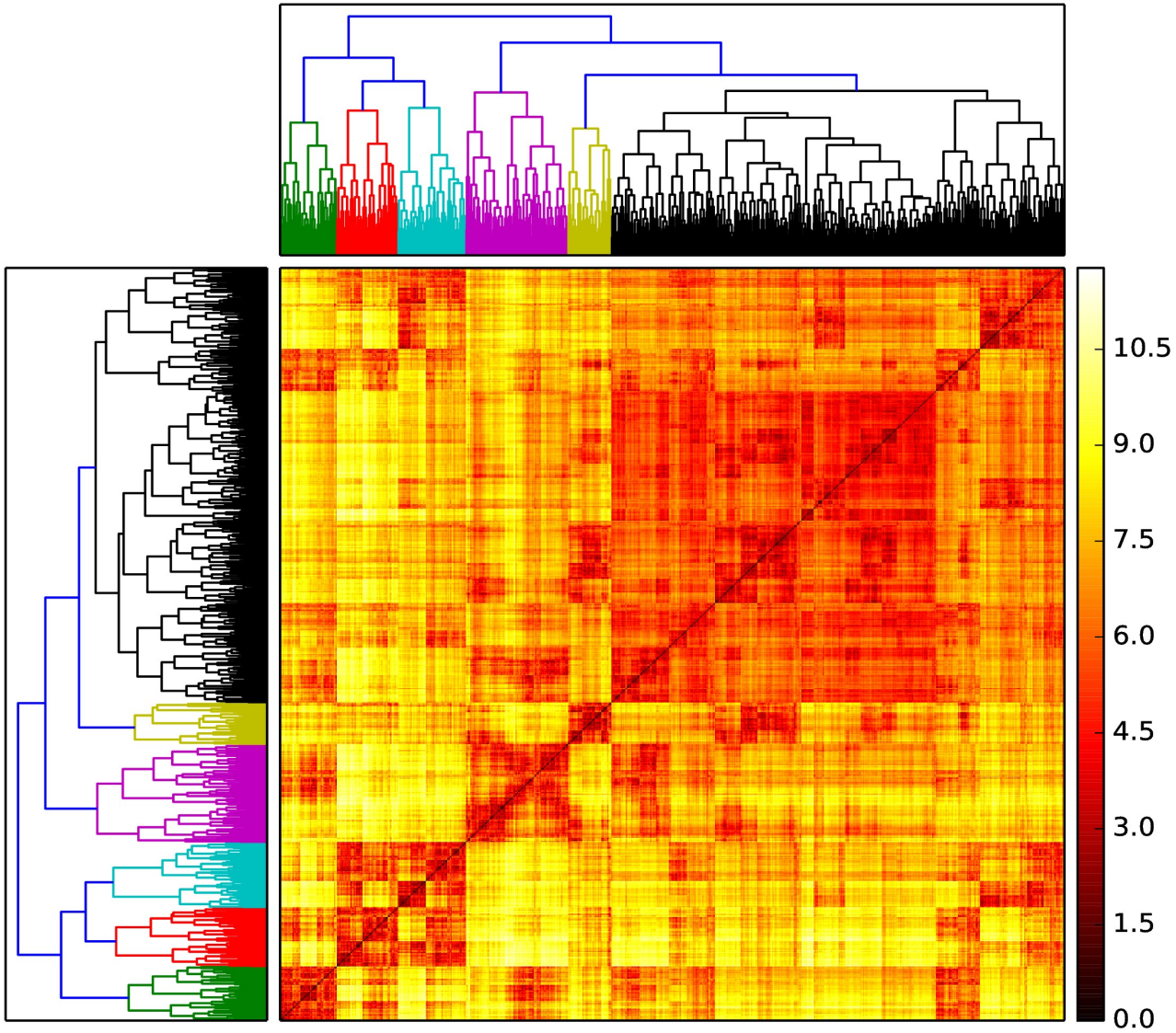
Matrix of Correlation Coefficients



Unclustered Distance Matrix



Results from Hierarchical Clustering



scipy.cluster.hierarchy.linkage
scipy.cluster.hierarchy.dendrogram

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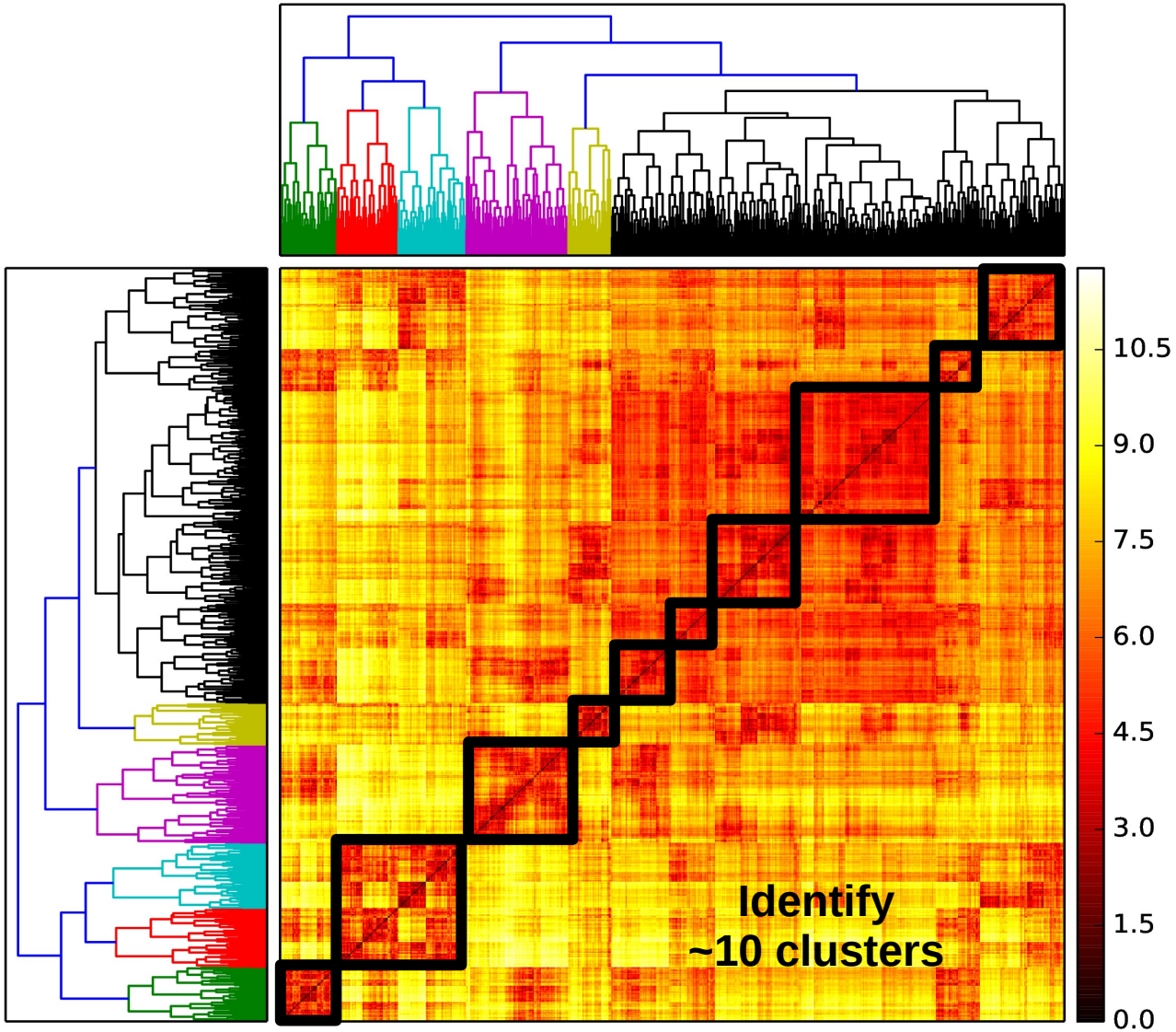

scipy.cluster.hierarchy.linkage
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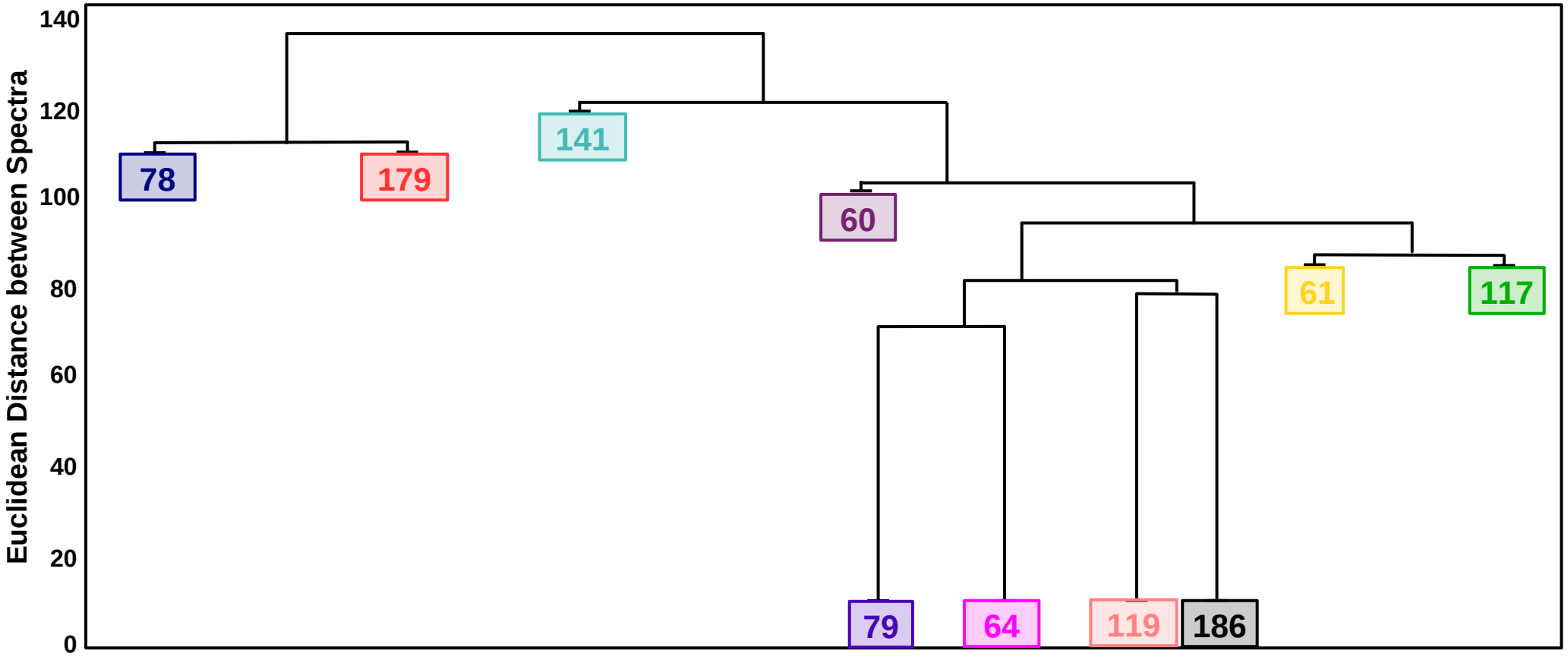
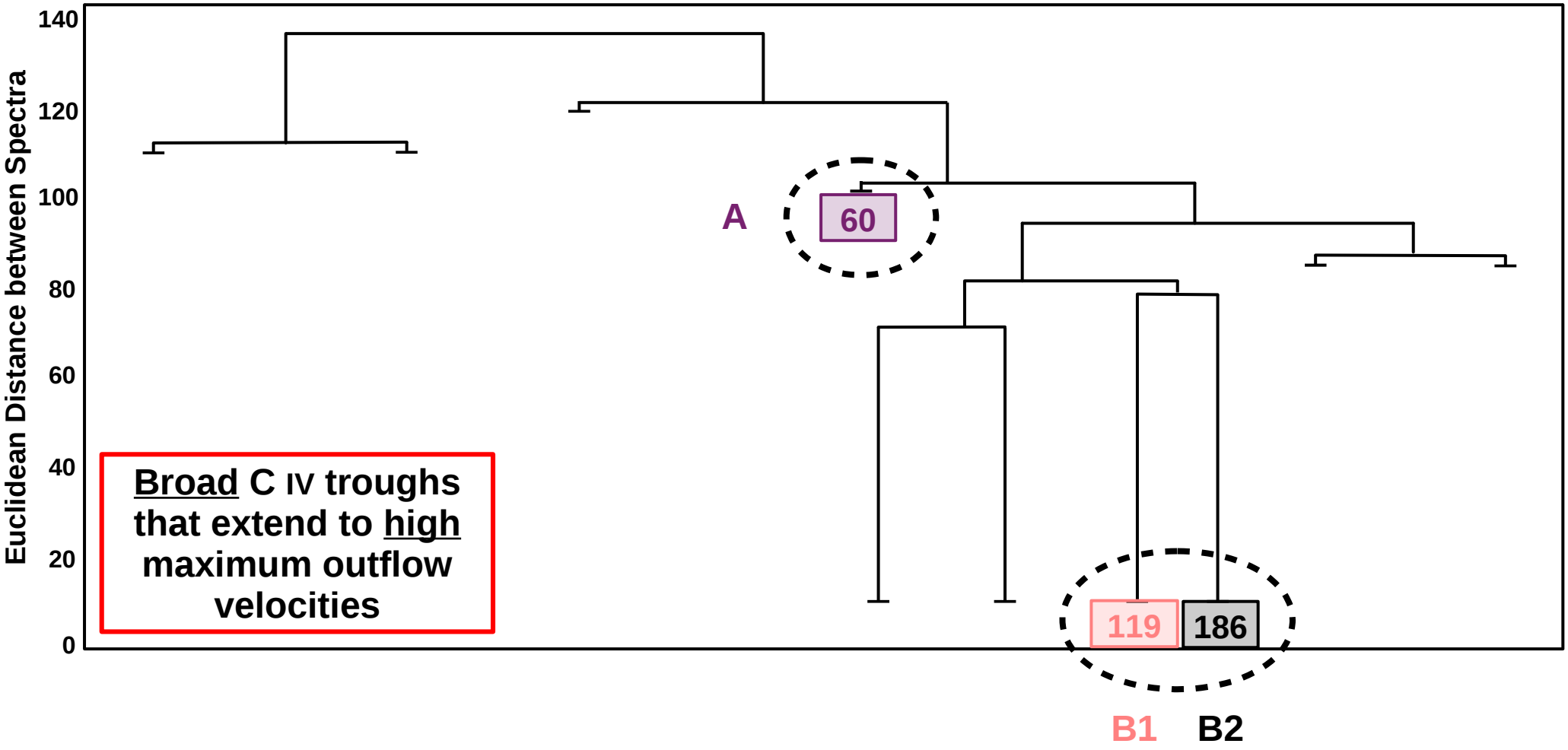
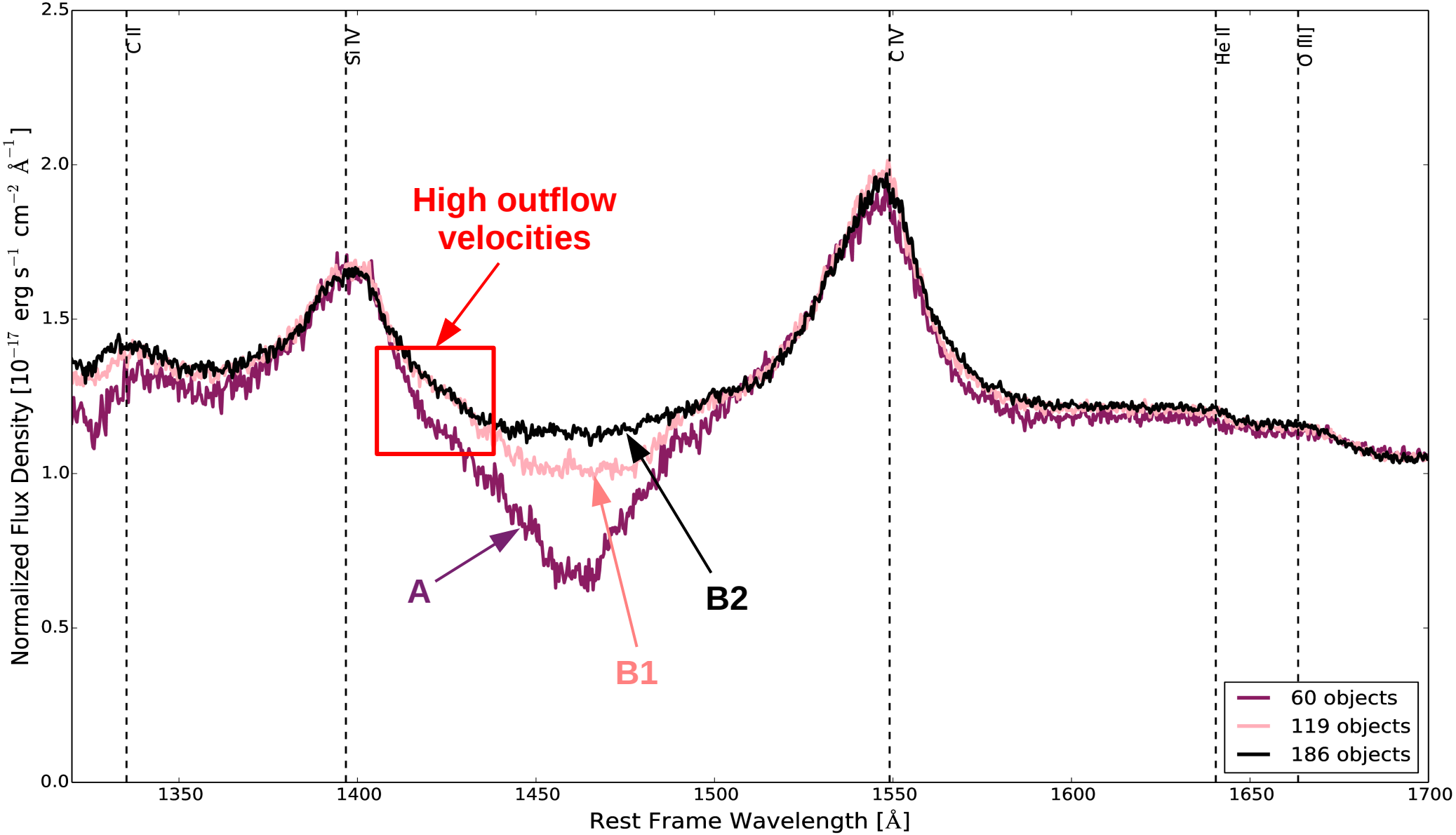
Dendrogram of the Merging Process



Example: Broad, High-velocity C IV Troughs



Broad, High-velocity C IV Troughs



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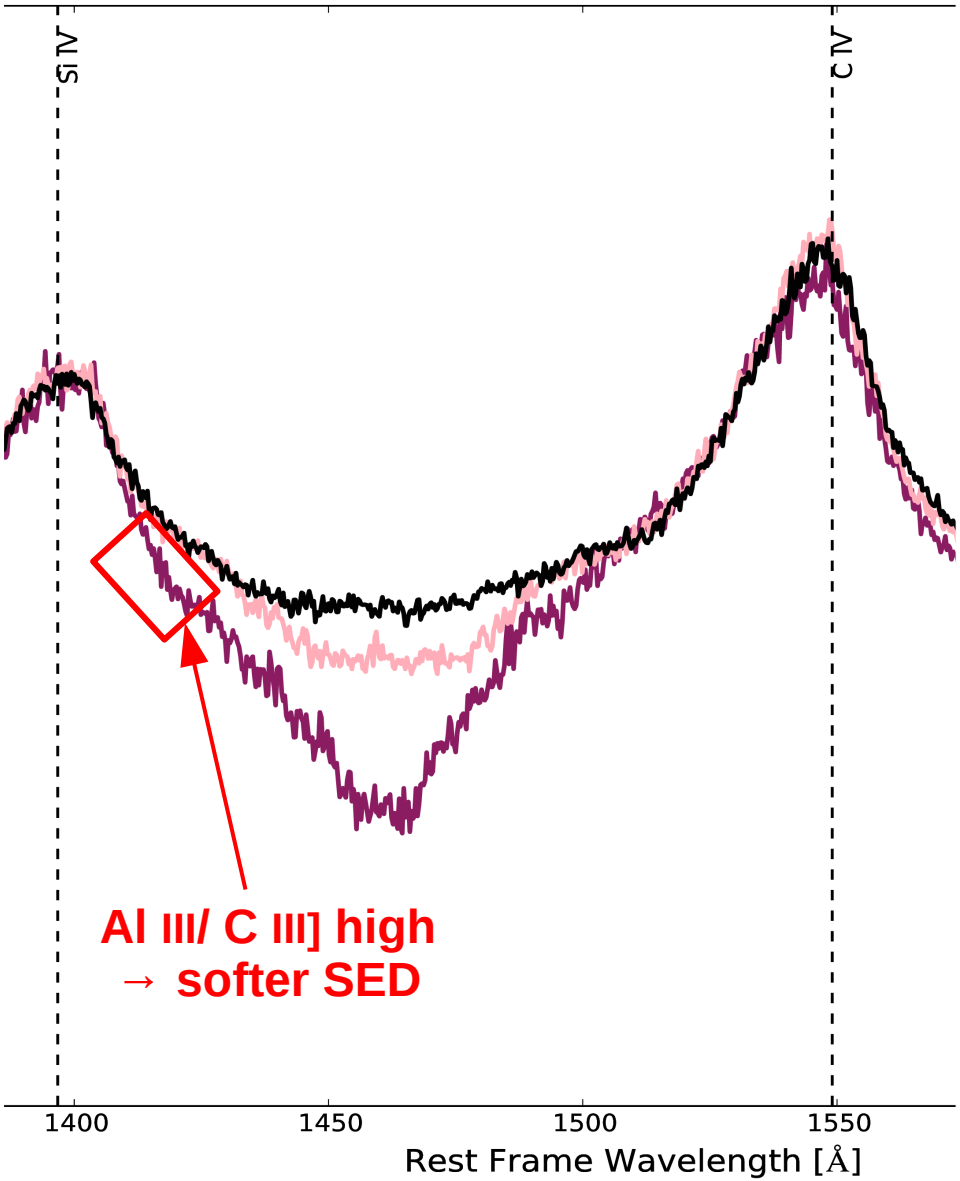
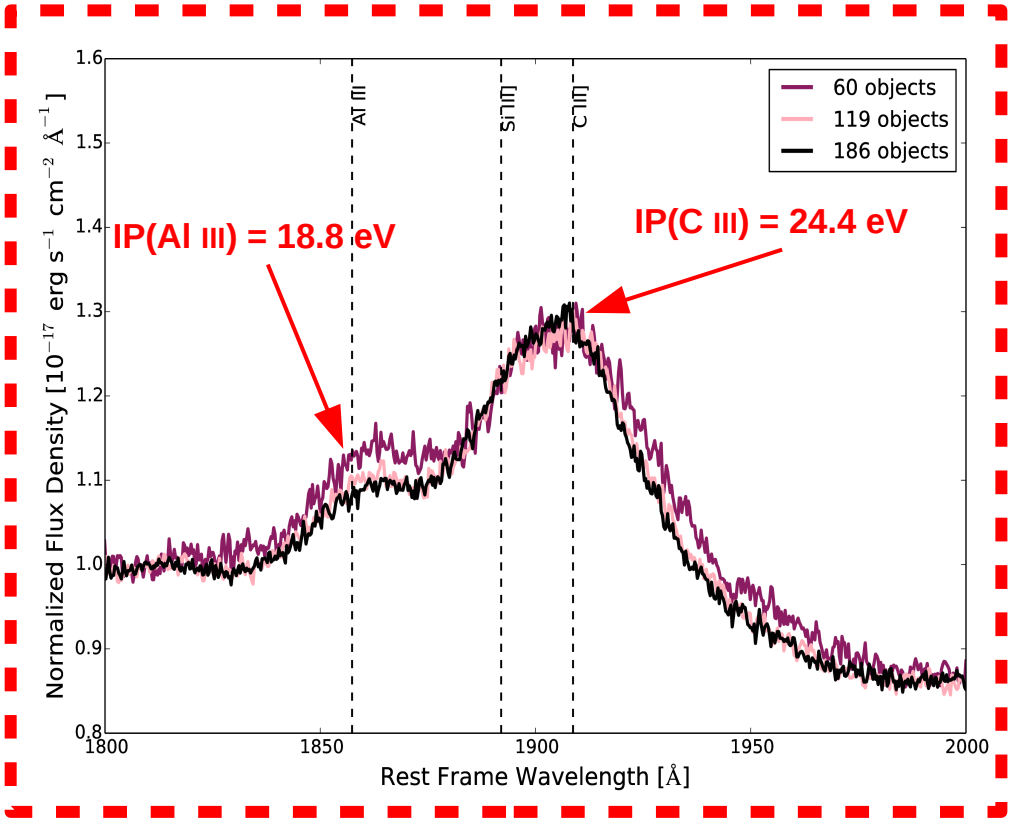
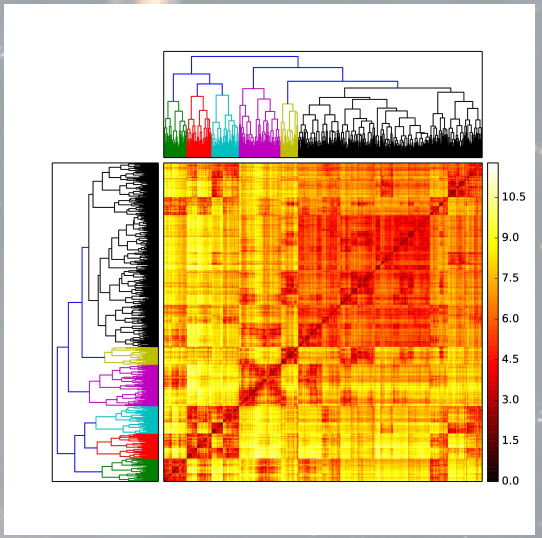


Emission line ratios as a proxy for the hardness of the SED.

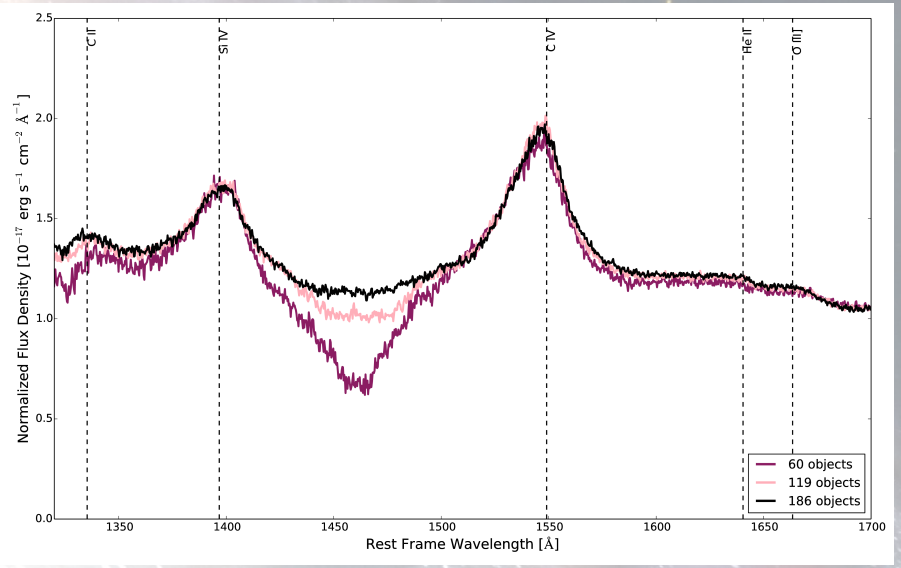


Conclusions/Next Steps

- We apply hierarchical clustering to the C IV troughs of 1,084 BAL quasar spectra. We see at least 10 distinct clusters.

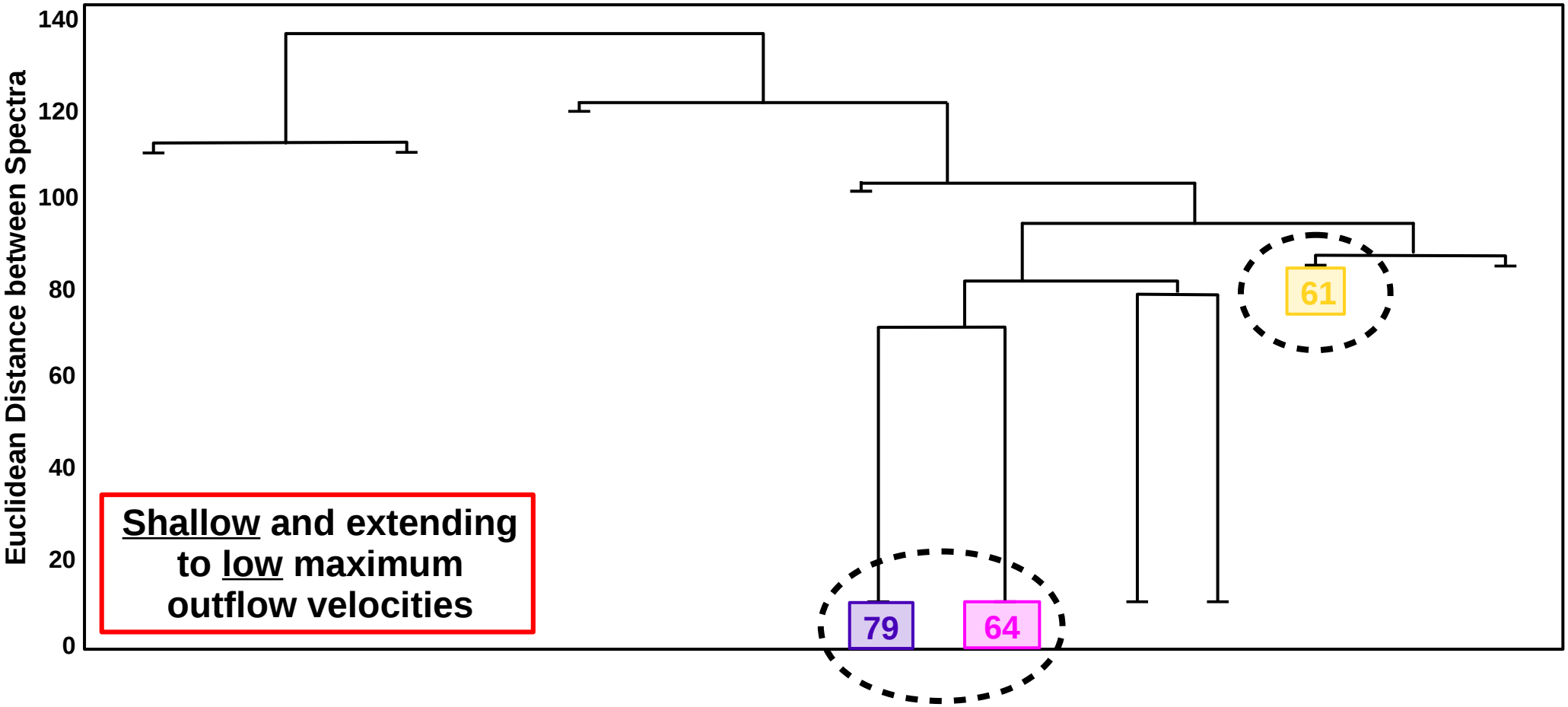


- Certain emission and aborption line properties are seen to group together in distinct categories, which could imply a common cause.



Additional Slides

Example: Shallow, Low-velocity C IV Troughs



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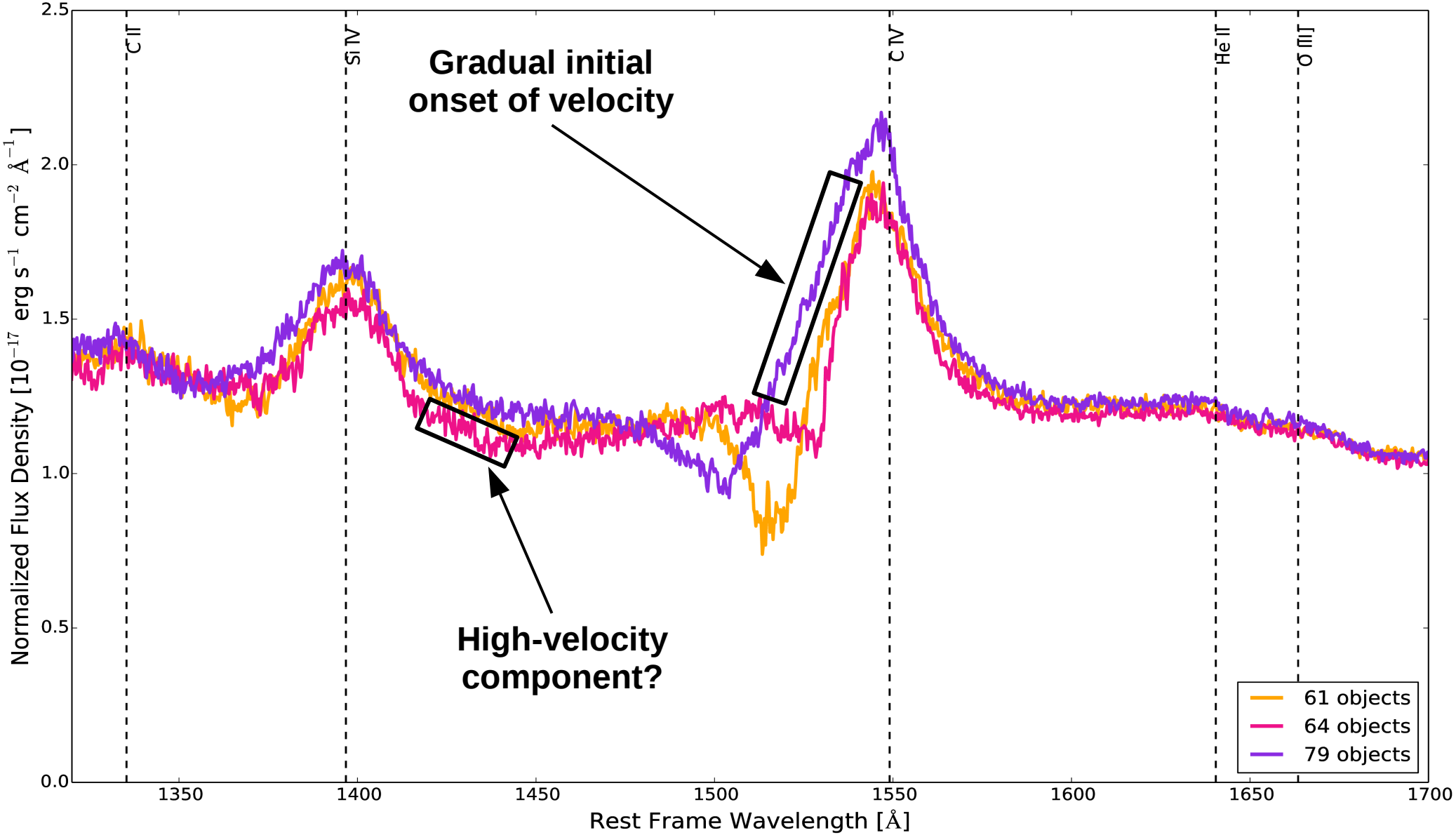

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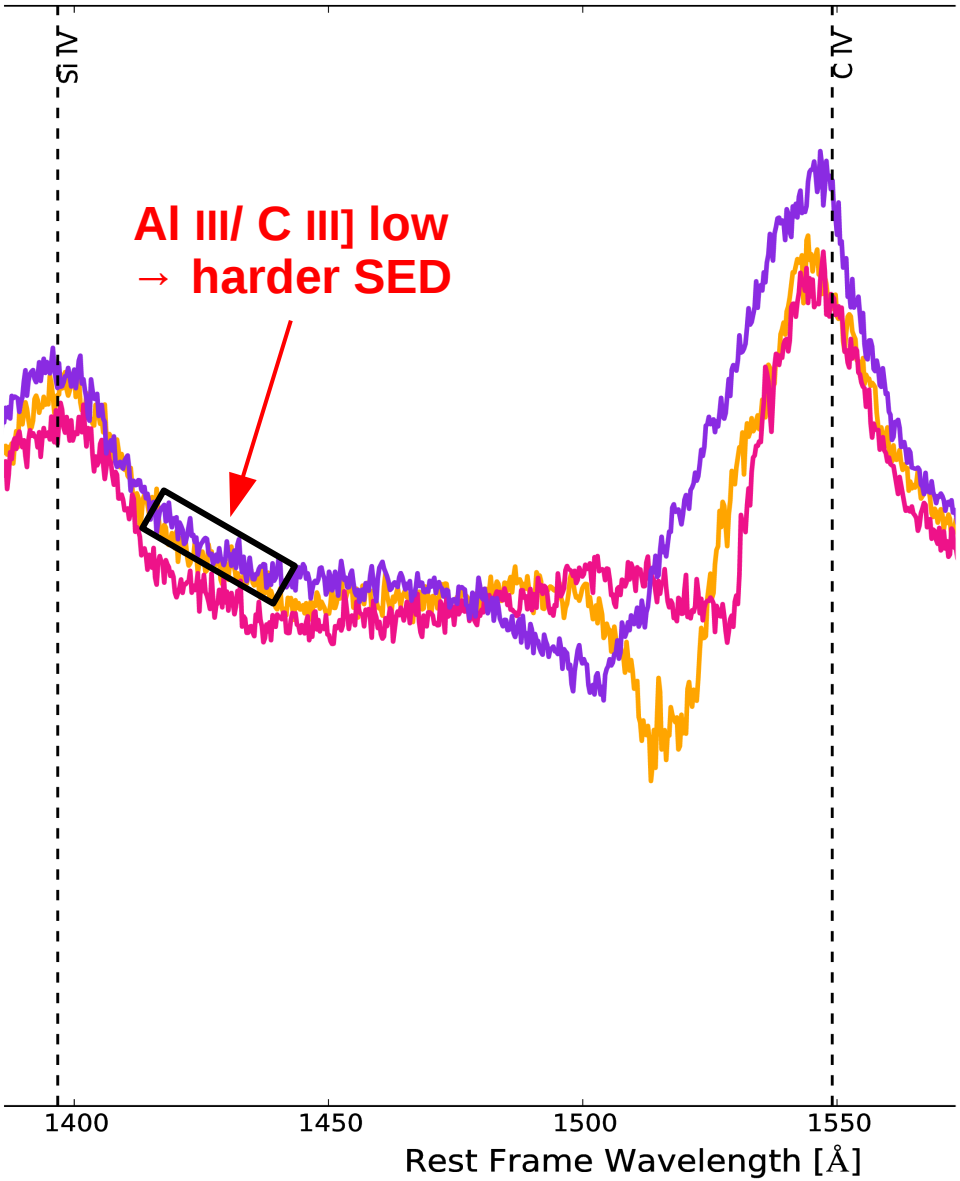

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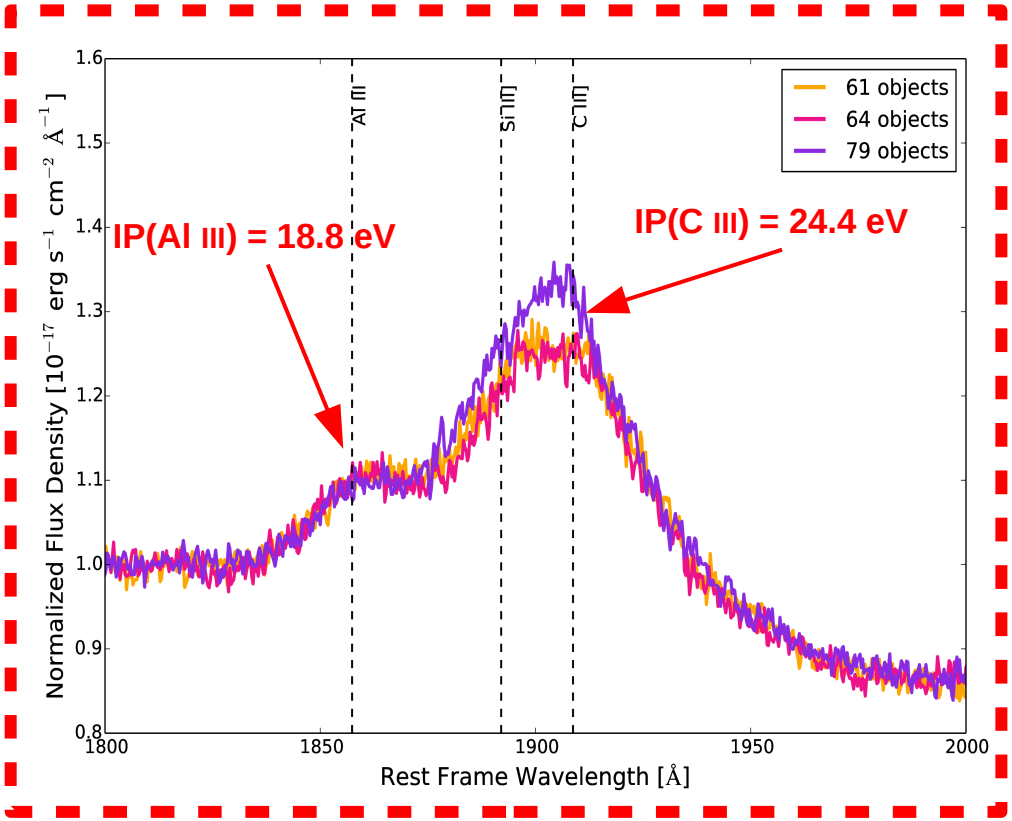
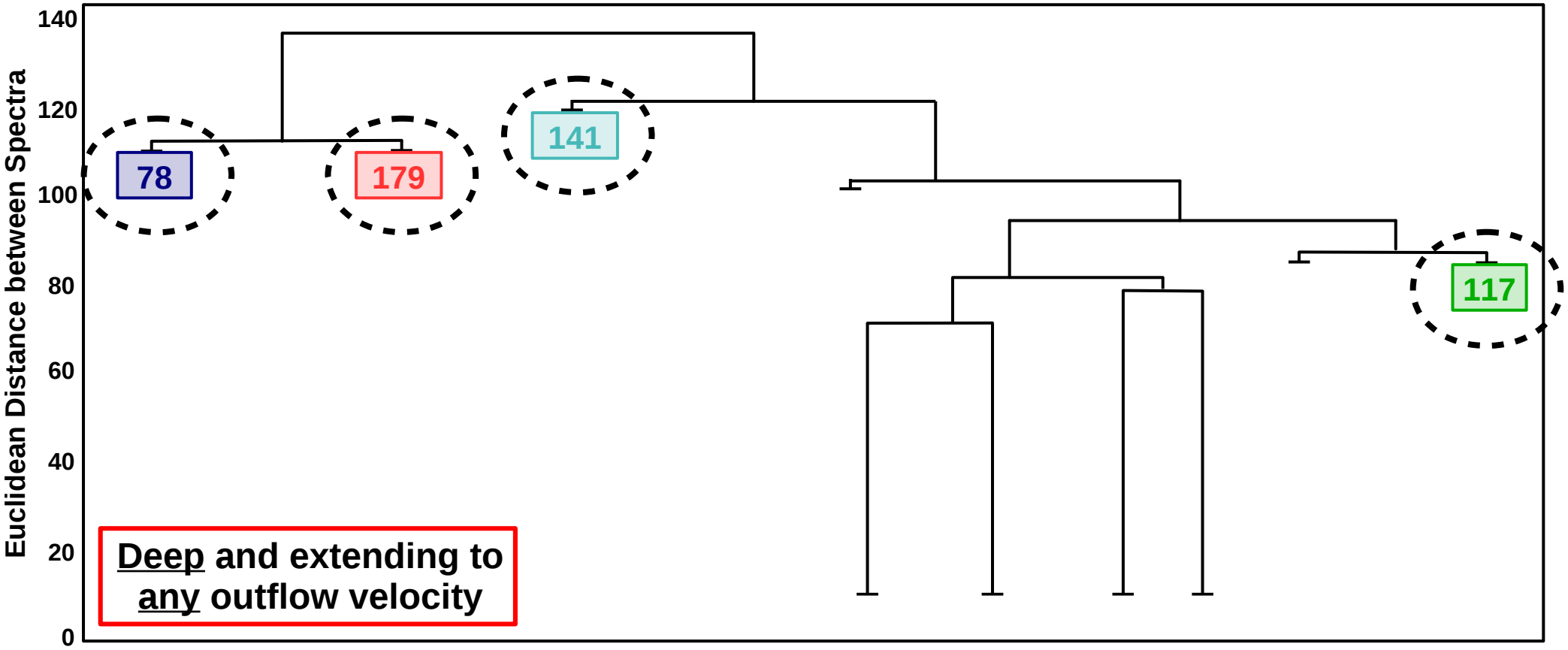


Example: Deep, Any-velocity C IV Troughs



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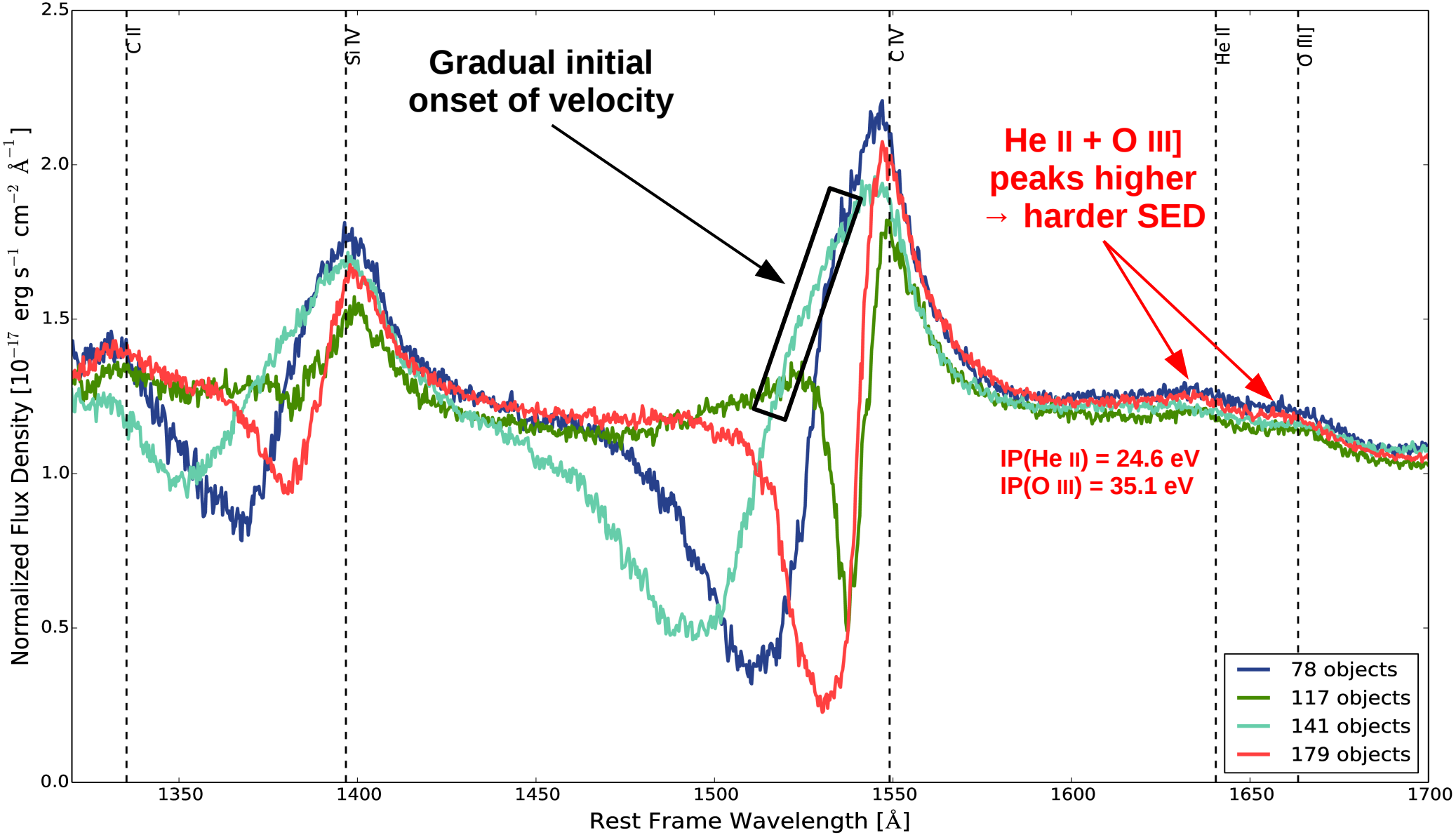

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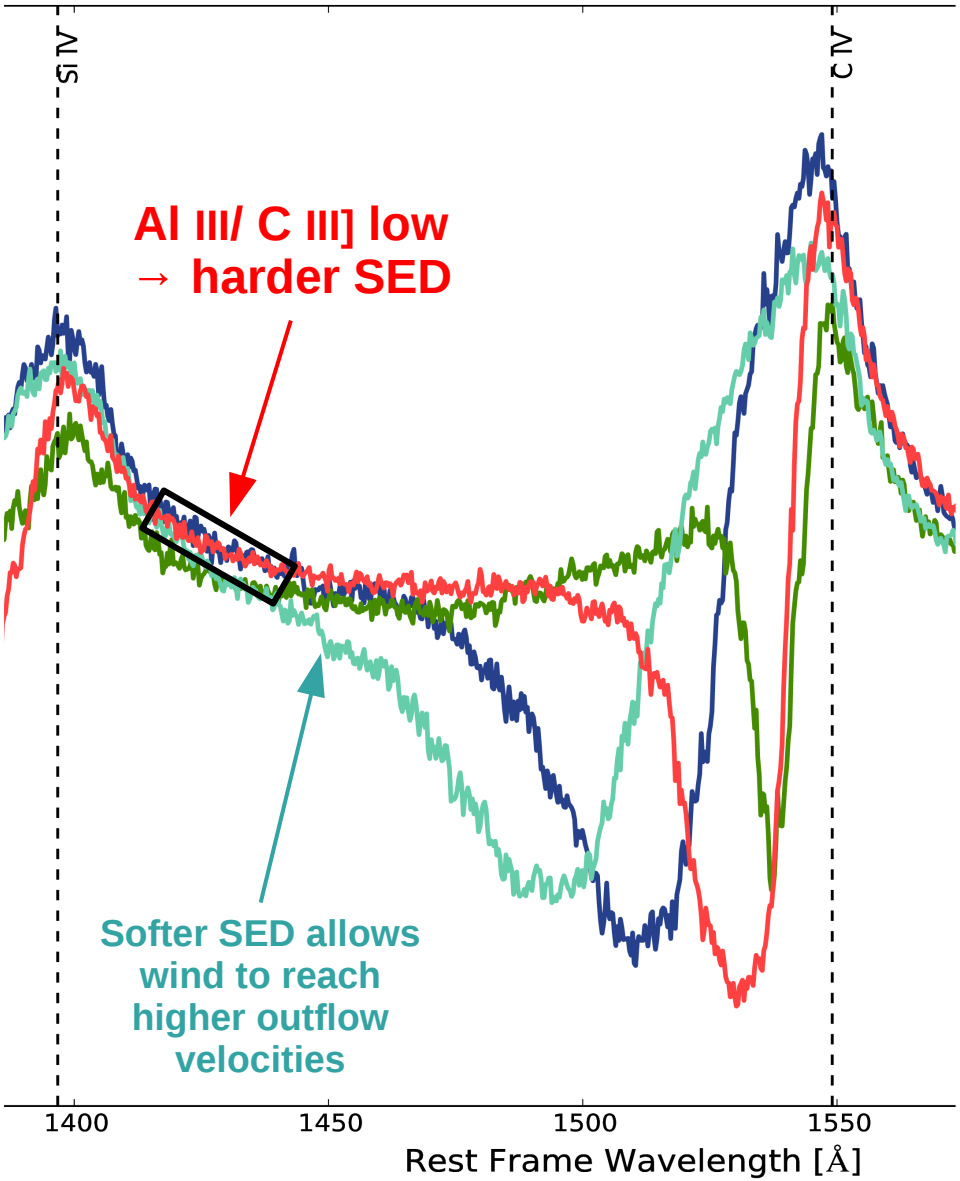

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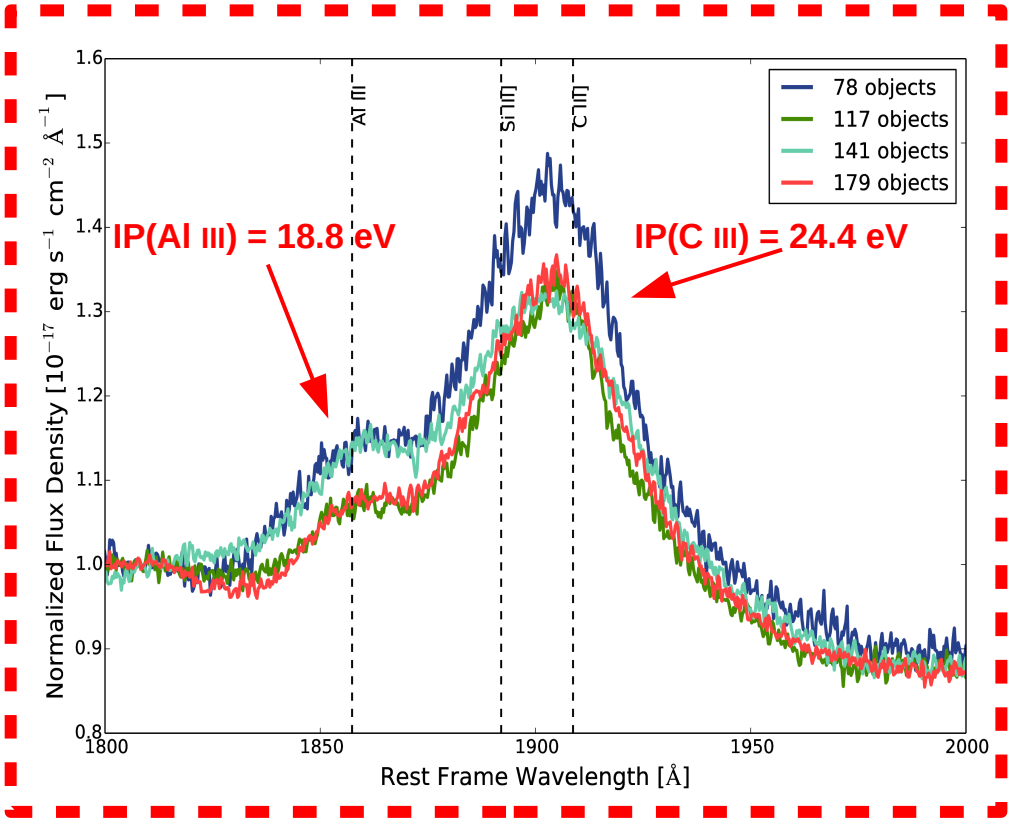
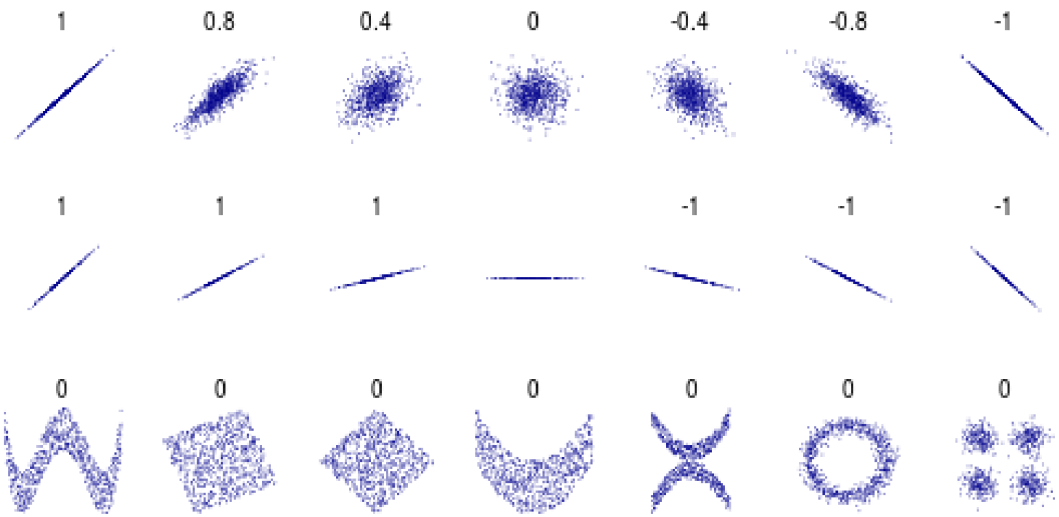


Pearson Correlation Coefficients

- Measures how two sets of data are correlated with one another.

$$r = \frac{\sum_{i=1}^{n}\left(\left(x_i - \bar{x}\right)\left(y_i - \bar{y}\right)\right)}{\sqrt{\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2 \sum_{i=1}^{n}\left(y_i - \bar{y}\right)^2}}$$

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$$

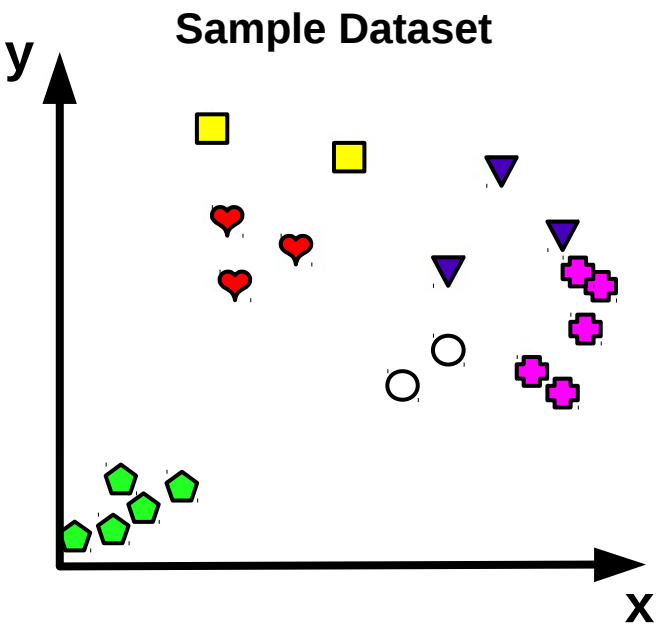


https://en.wikipedia.org/wiki/Pearson_product-moment_correlation_coefficient

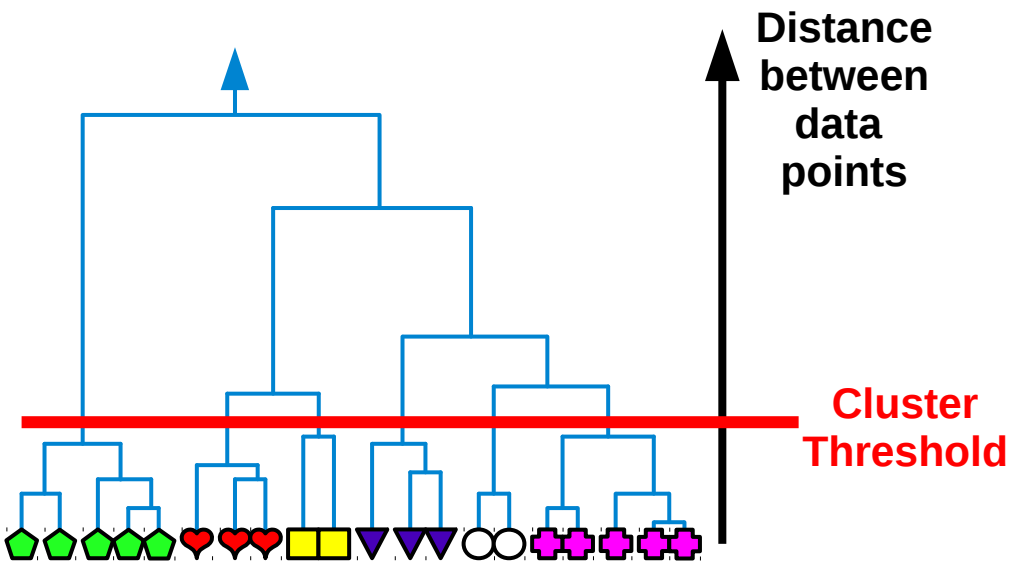
- Simple to compute in Python:

  >>> numpy.corrcoef(...)

Hierarchical Clustering Algorithm



Bovermann et al. (2008)



Dendrogram for Hierarchical Clustering of the Sample Dataset

Generalize to 1084-dimensional space...

Spectrum 1 feature vector: $(0.0, d_{1,2}, d_{1,3}, \ldots, d_{1,1084})$