Dimensionality Reduction

Principal Component Analysis (PCA)

t-Stochastic Neighbor Embedding (t-SNE)

Uniform Manifold Approximation and Projection (UMAP)

Quick review

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What sorts of things are we now good at?

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What should we do if we don't have labels?

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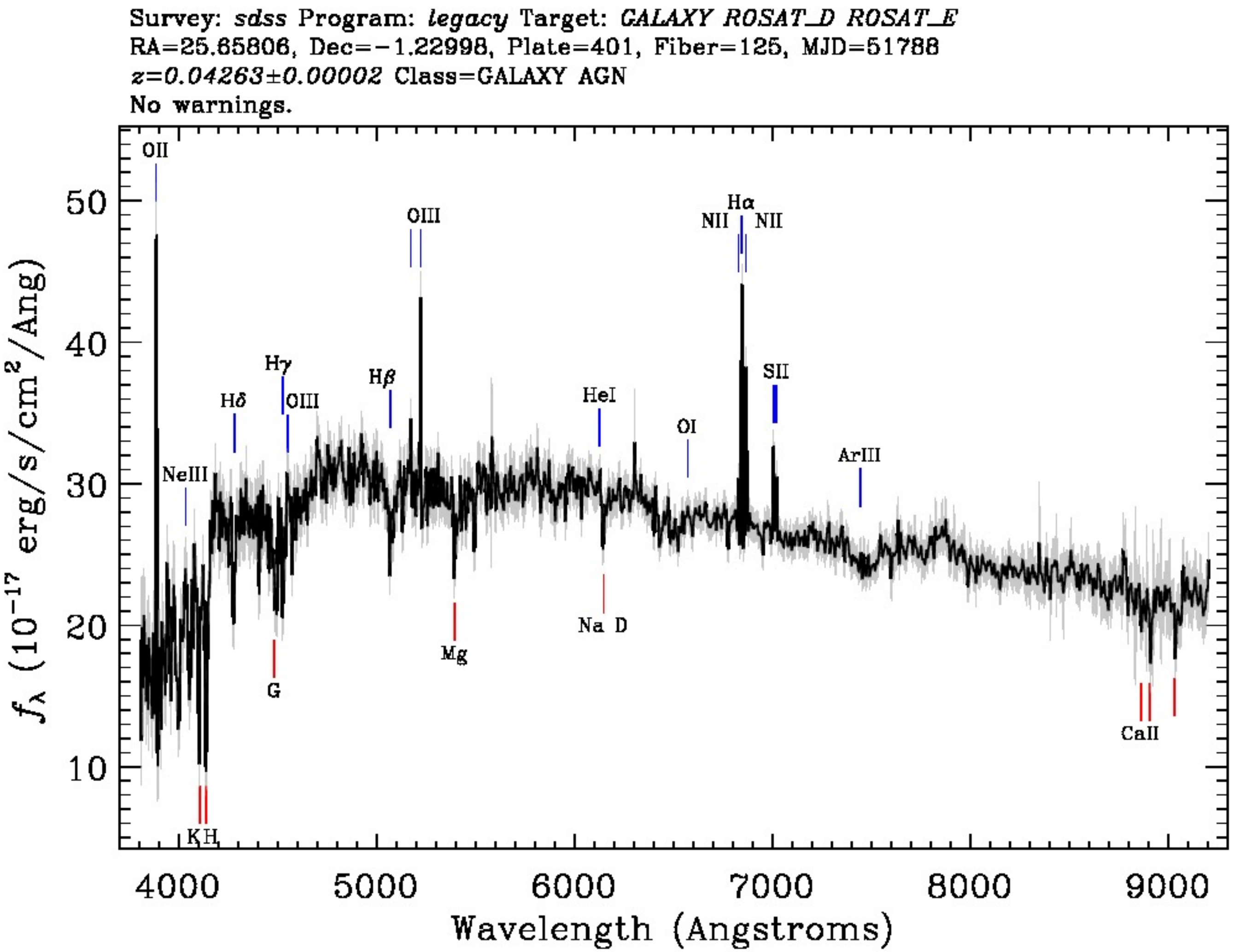
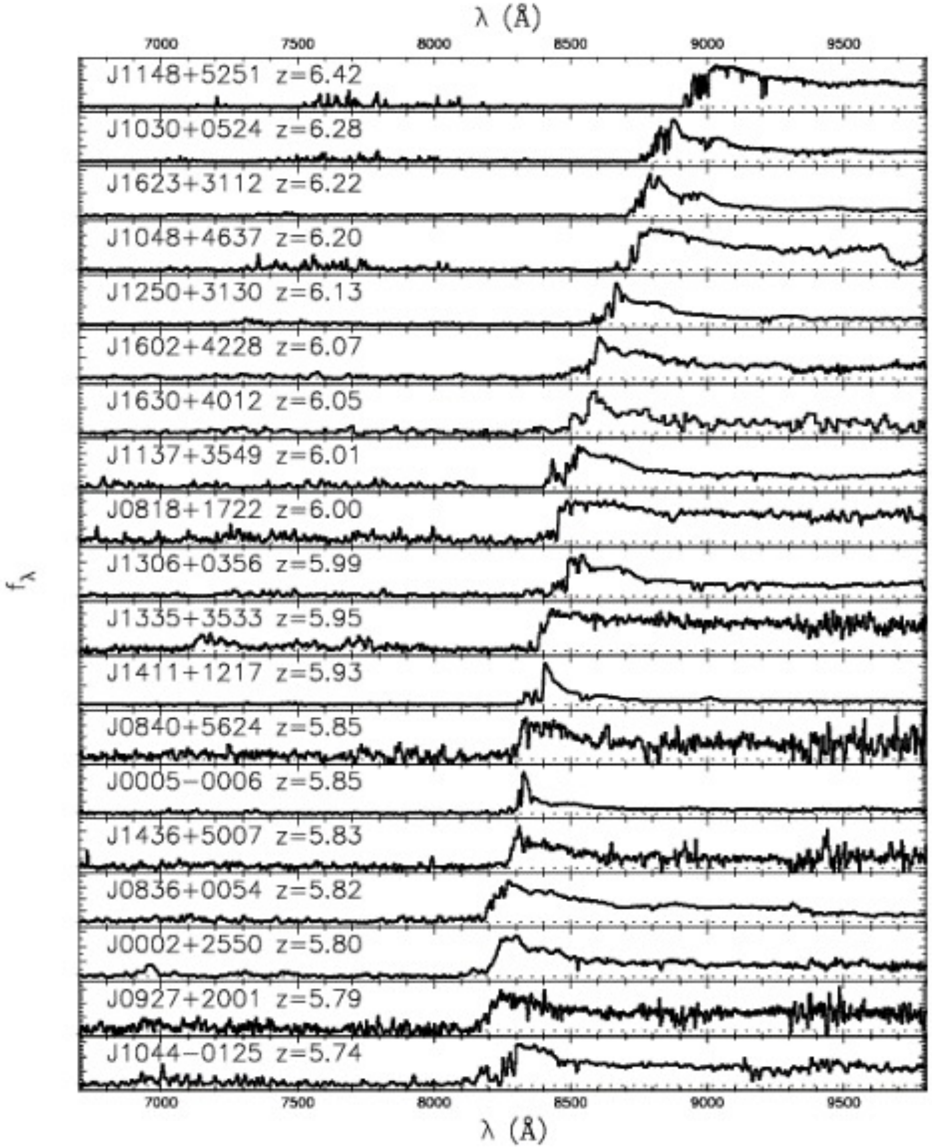
Example: Galaxy spectra

SDSS/Galaxy Zoo



Distant "Lyman Break" Galaxies

Zaroubi et al. 2013



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DAWN

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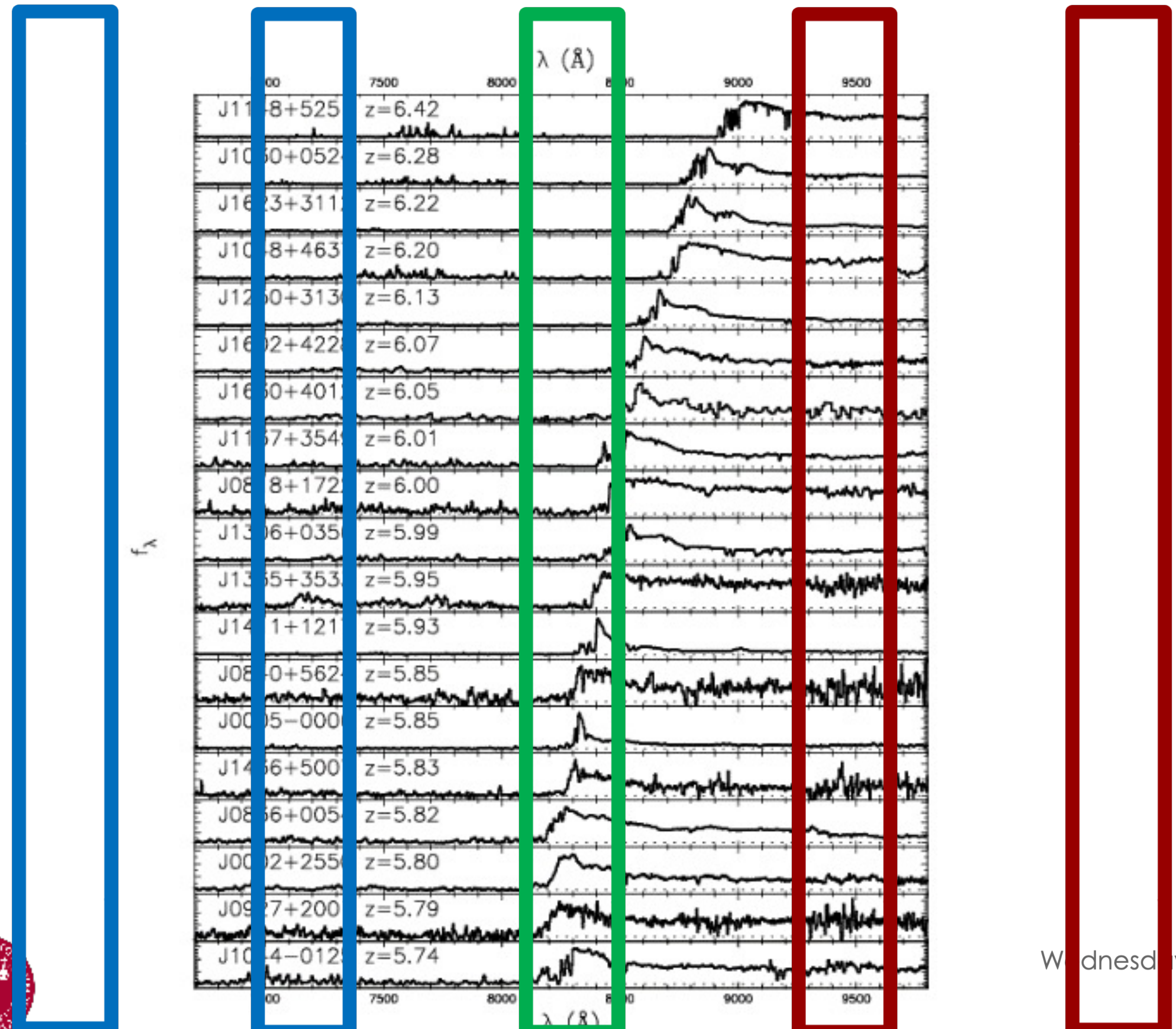

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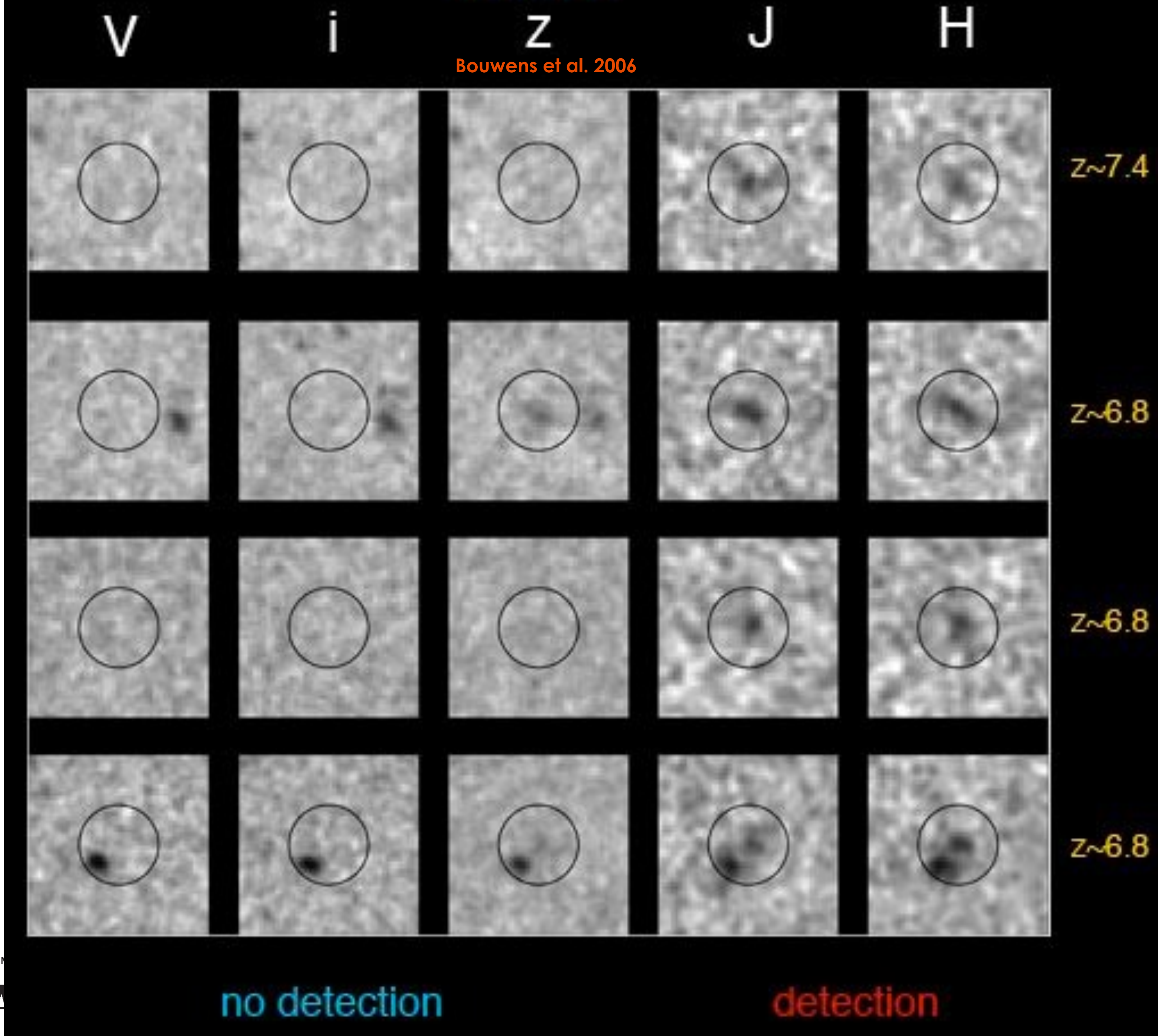

Bouwens et al. 2006

Two Fundamental Assumptions for Photometry

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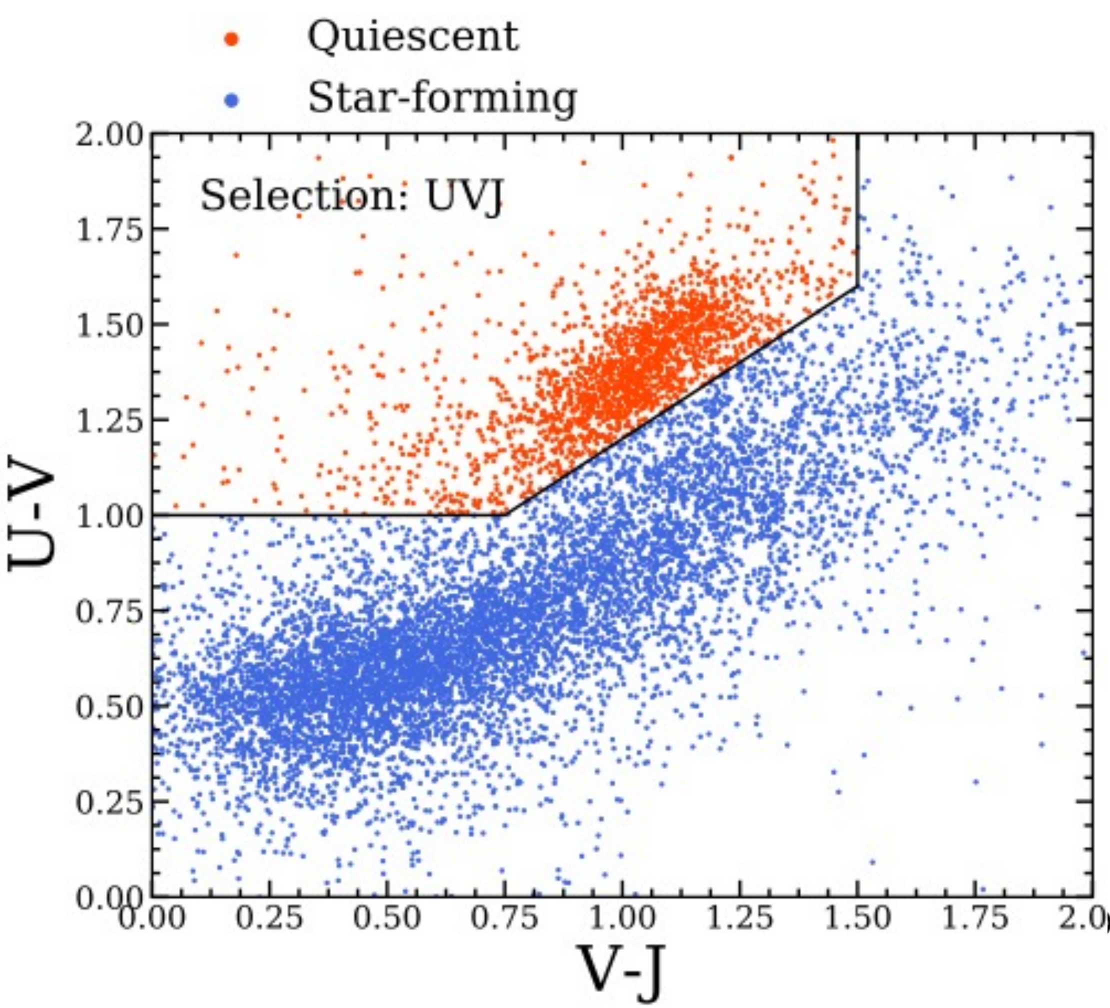
Approach 1: Color space map using two colors (three bands)

COSMOS2015 catalog, objects at z≈1



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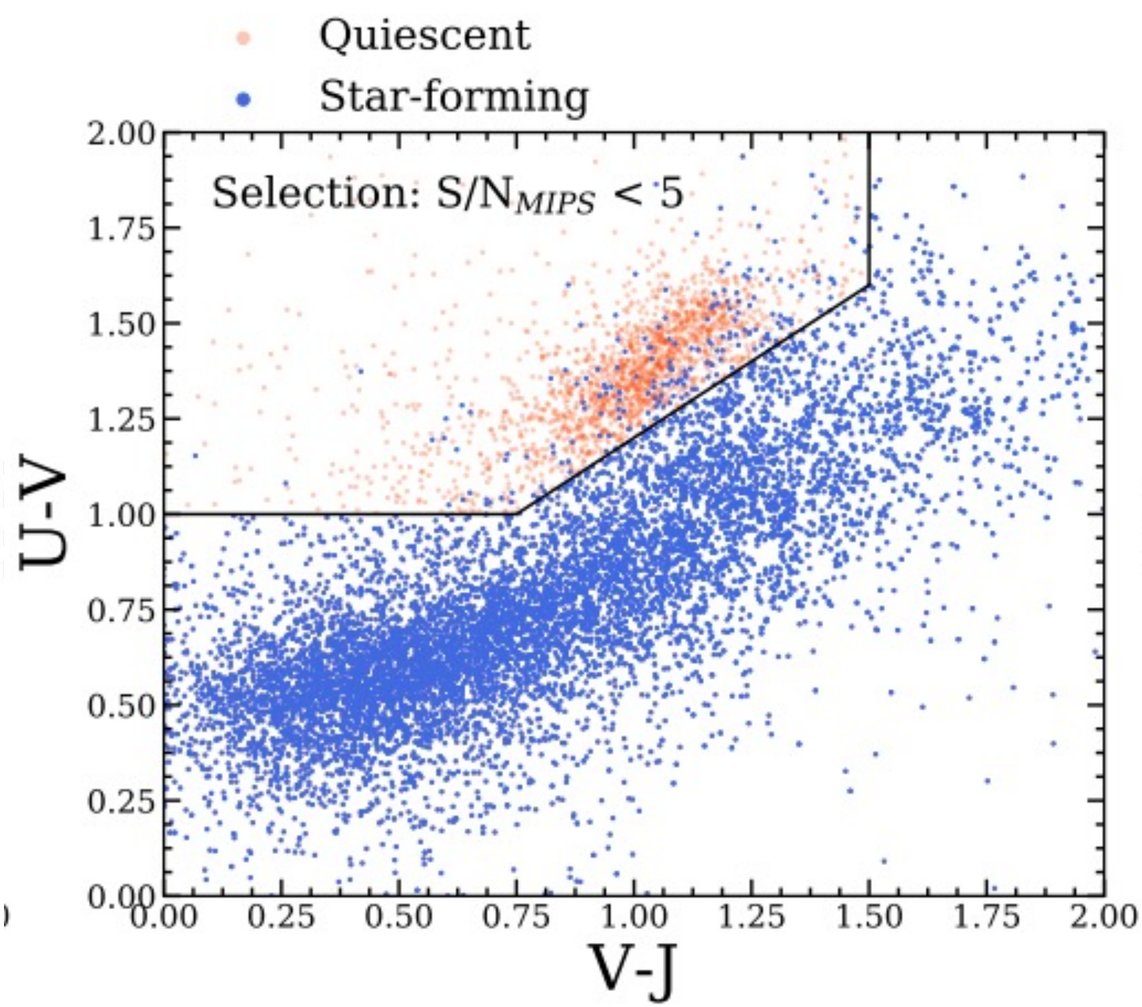
Approach 1: Color space map using two colors (three bands)

COSMOS2015 catalog, objects at z≈1



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Approach 2: Color space map using all bands

~~Two~~ Three Fundamental Assumptions for Photometry

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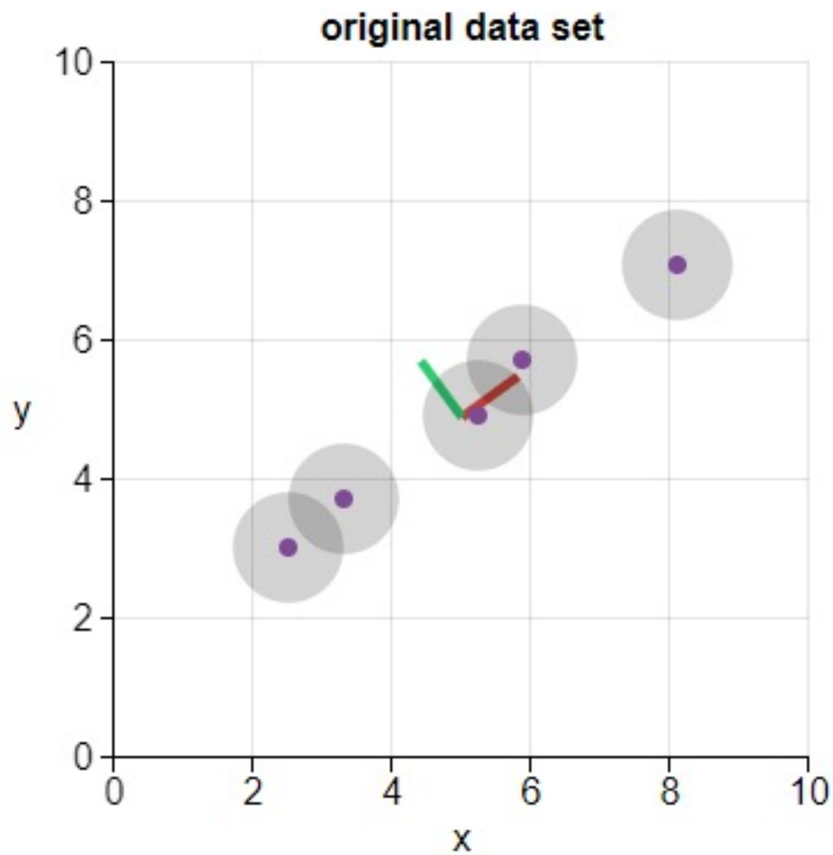
Can we somehow decide what information is "important" even without labels?

Principal Component Analysis (PCA)

https://setosa.io/ev/principal-component-analysis/



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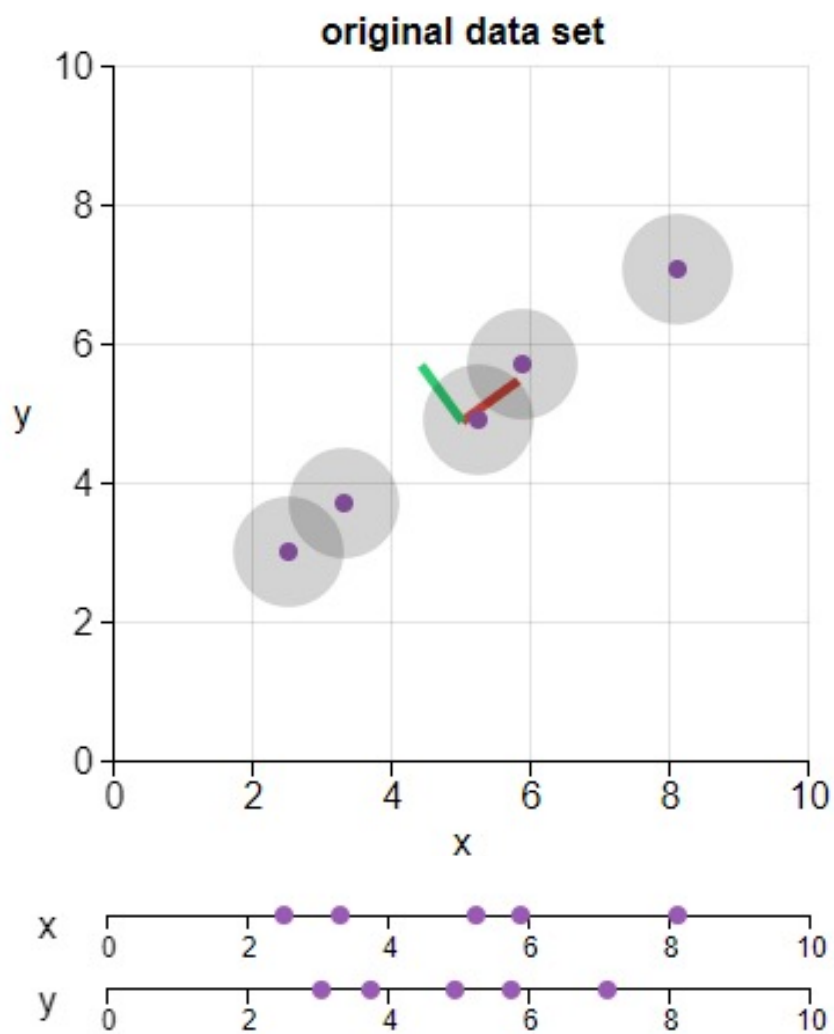

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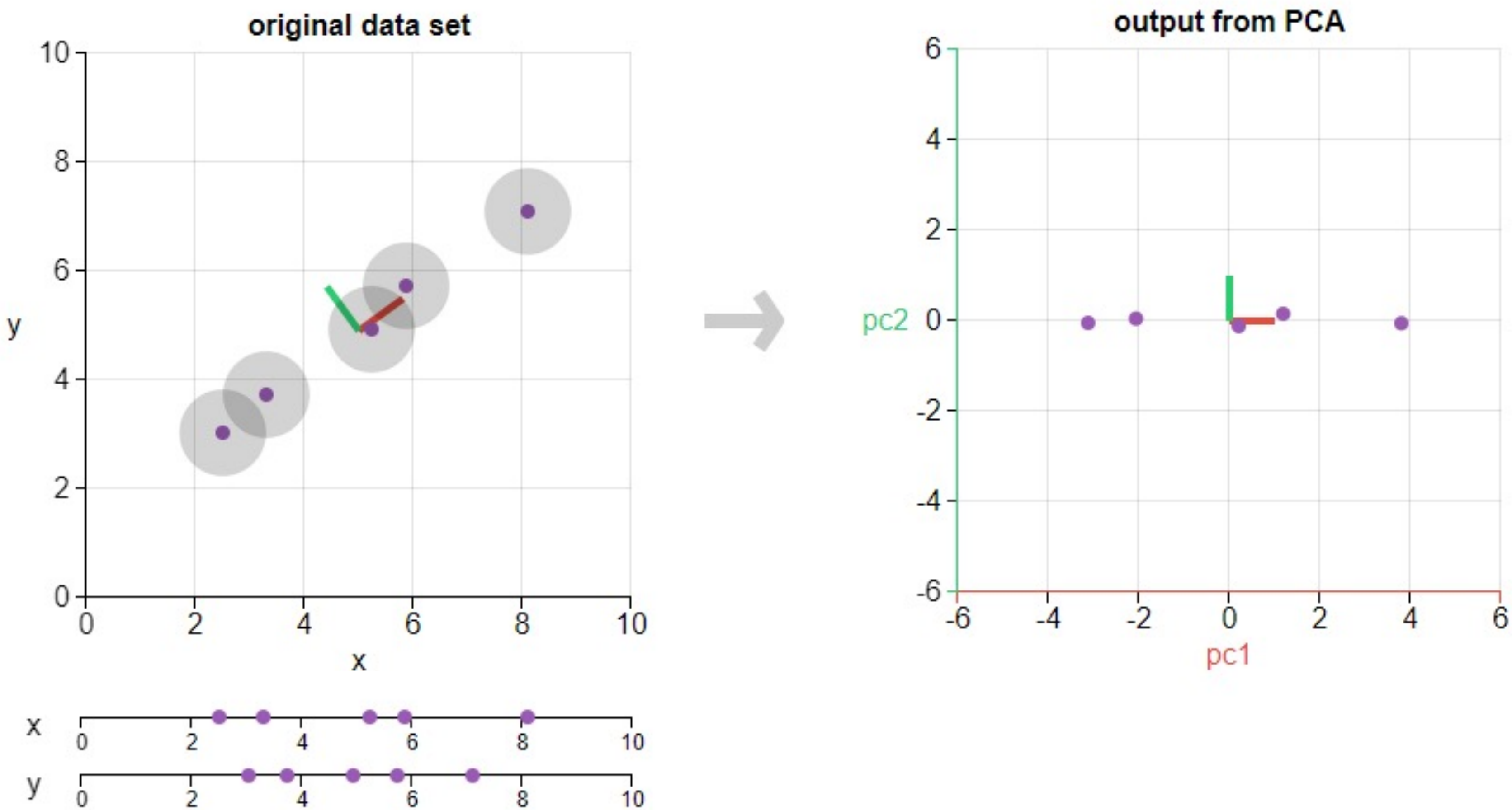

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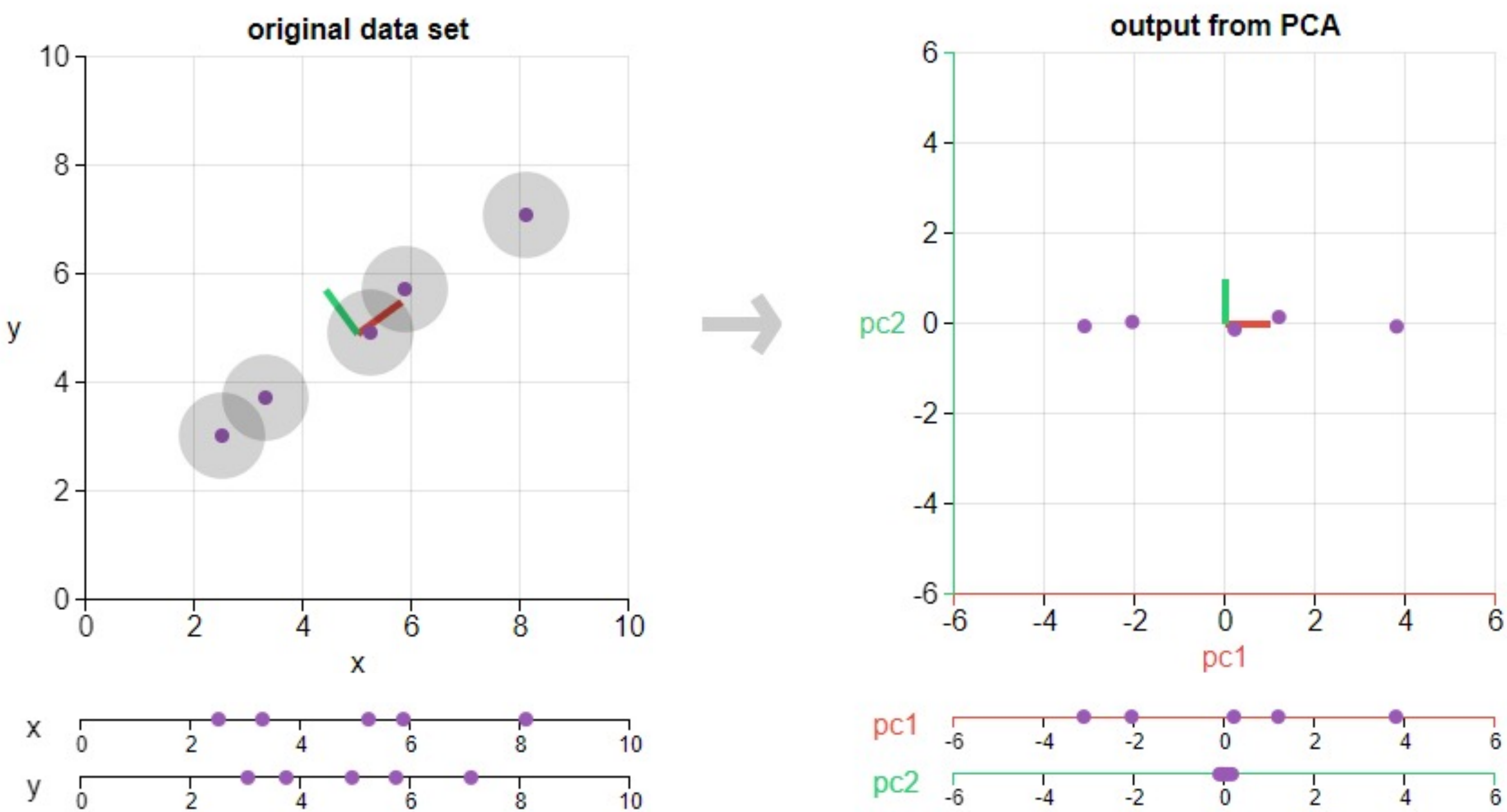
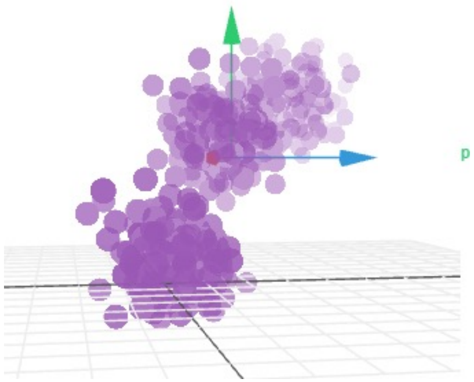


PCA in 3D

https://setosa.io/ev/principal-component-analysis/



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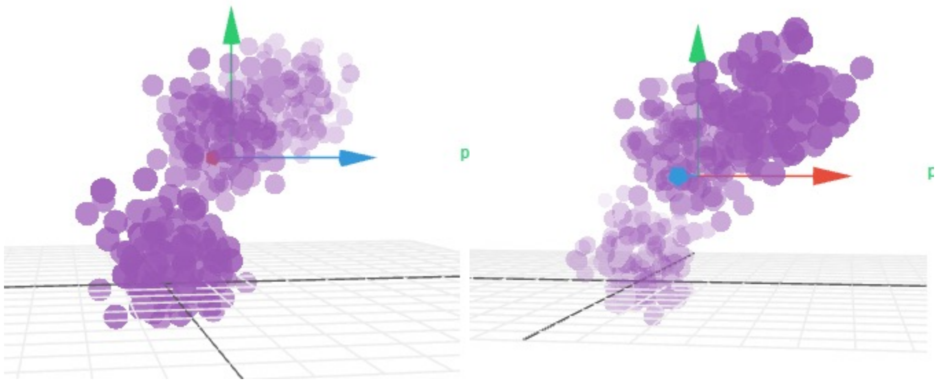

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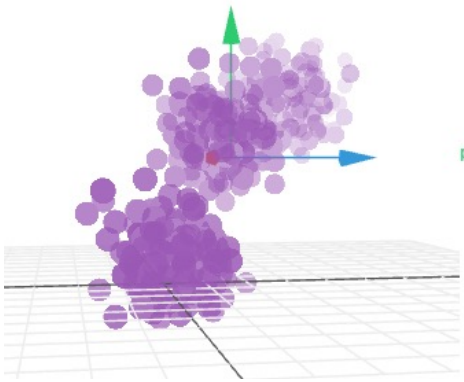

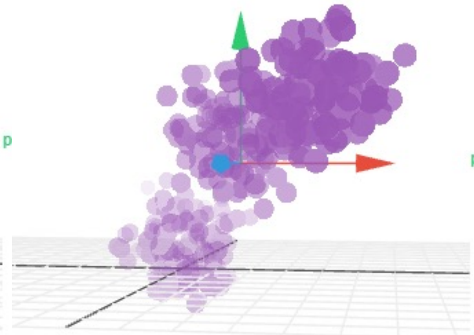

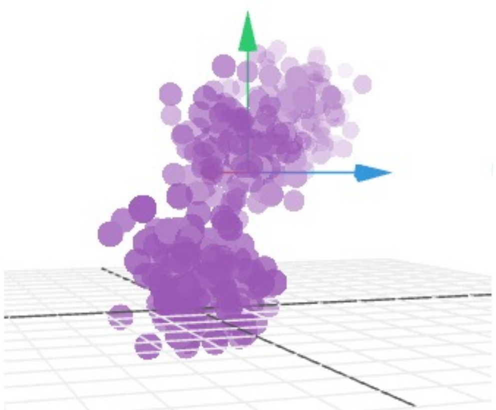

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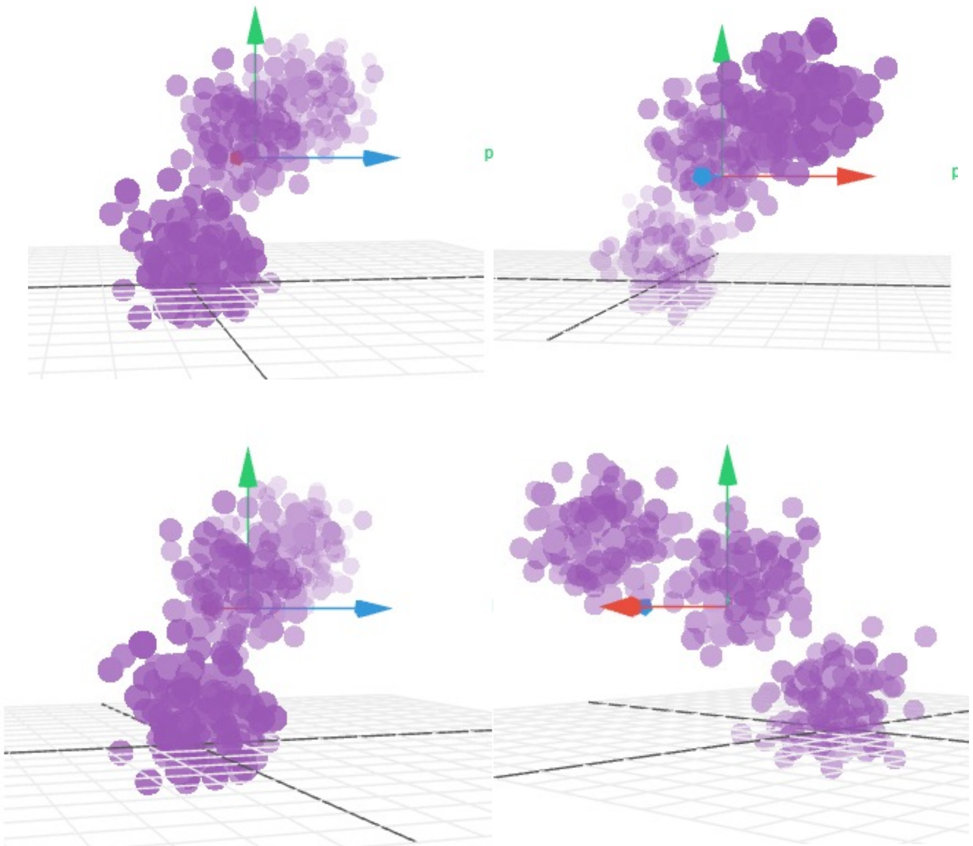

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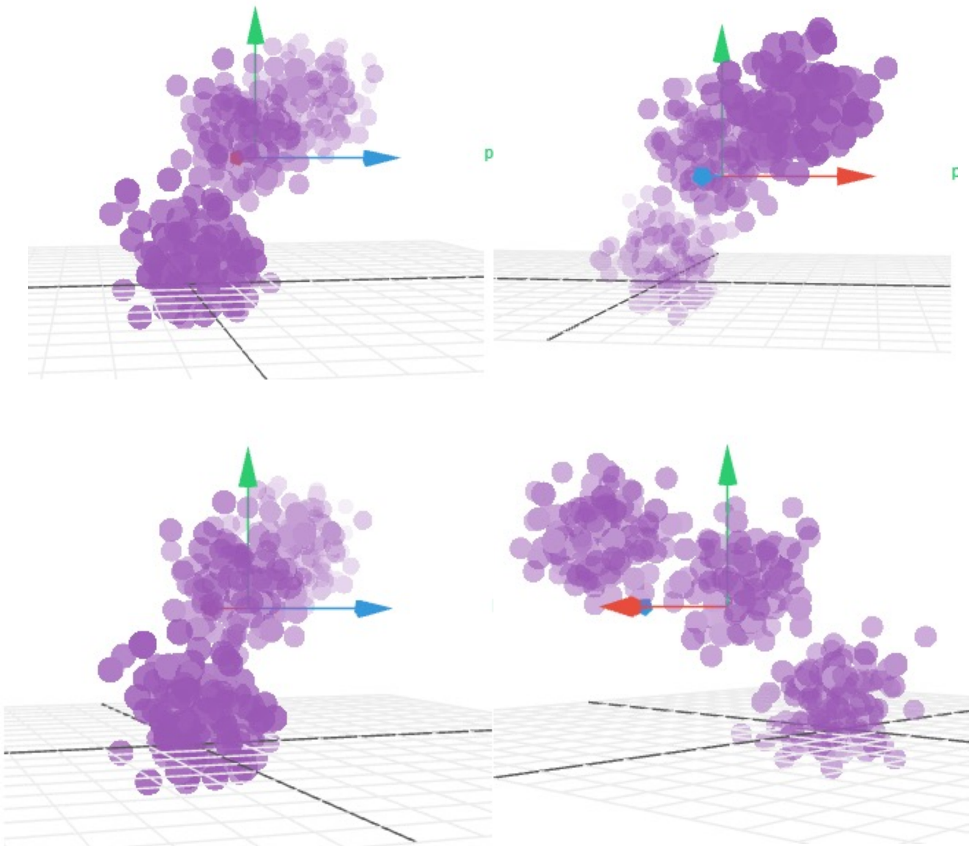

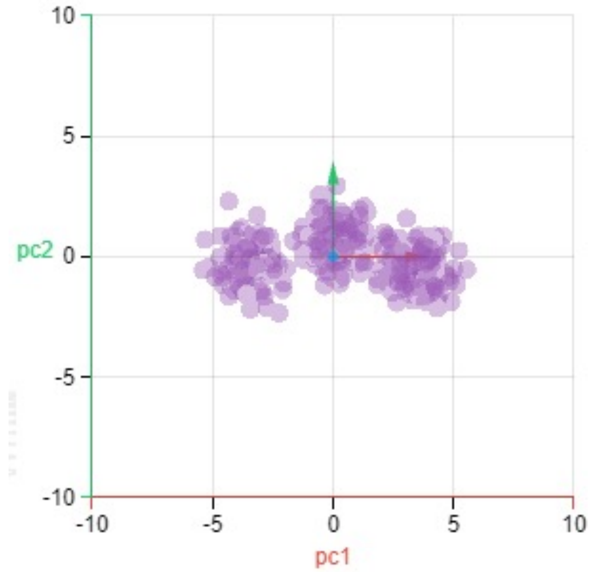

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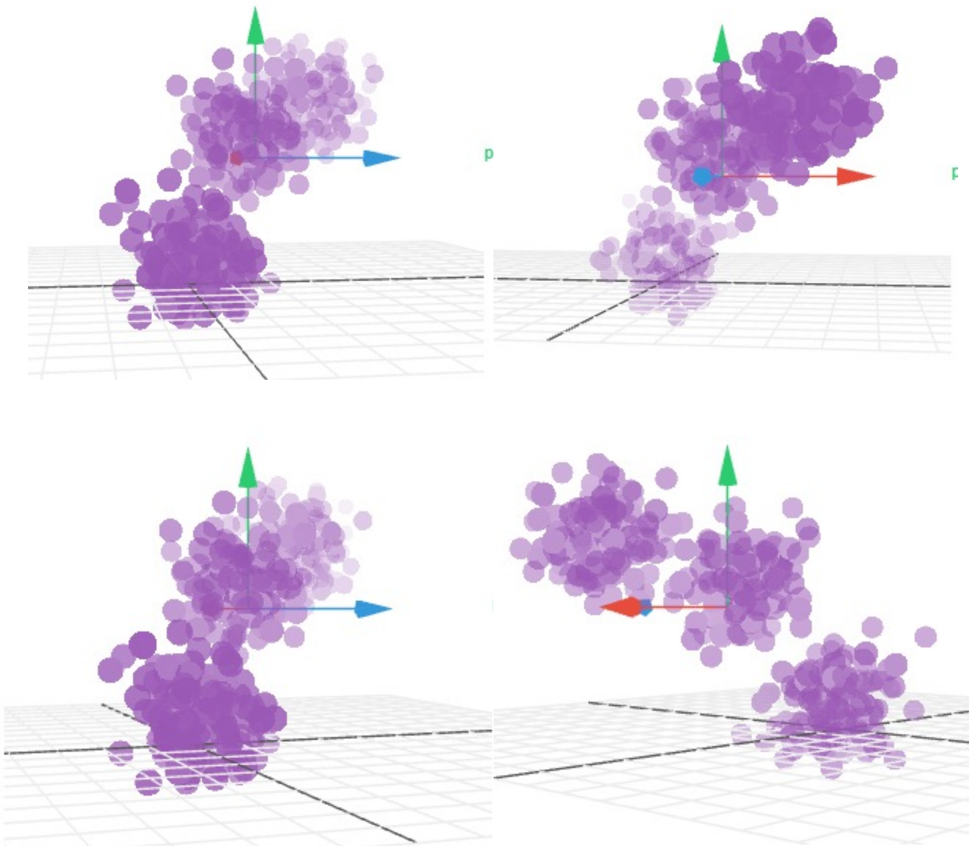

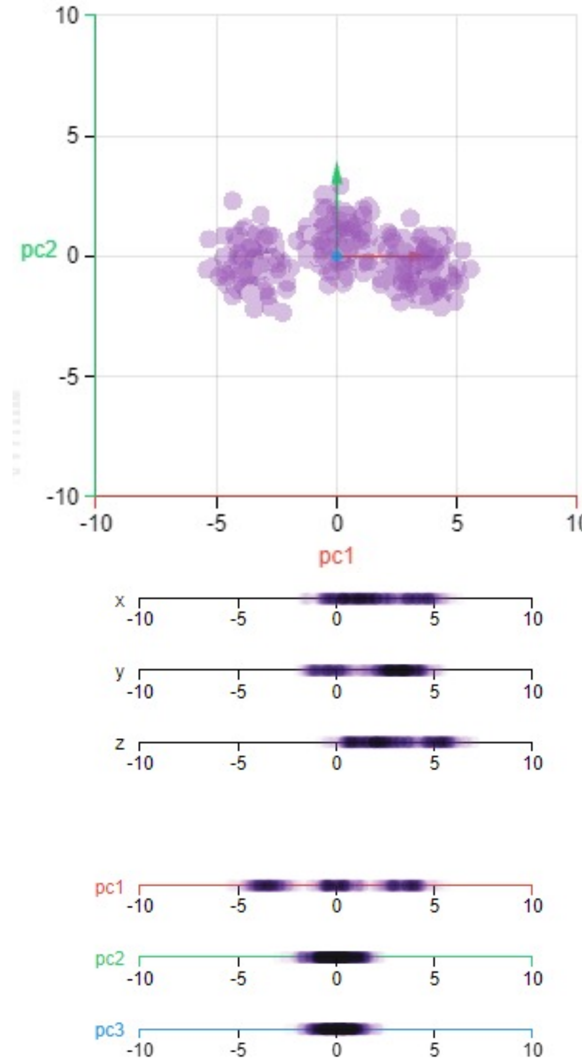

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PCA in 17D

https://setosa.io/ev/principal-component-analysis/

	England	N Ireland	Scotland	Wales
Alcoholic drinks	375	135	458	475
Beverages	57	47	53	73
Carcase meat	245	267	242	227
Cereals	1472	1494	1462	1582
Cheese	105	66	103	103
Confectionery	54	41	62	64
Fats and oils	193	209	184	235
Fish	147	93	122	160
Fresh fruit	1102	674	957	1137
Fresh potatoes	720	1033	566	874
Fresh Veg	253	143	171	265
Other meat	685	586	750	803
Other Veg	488	355	418	570
Processed potatoes	198	187	220	203
Processed Veg	360	334	337	365
Soft drinks	1374	1506	1572	1256
Sugars	156	139	147	175

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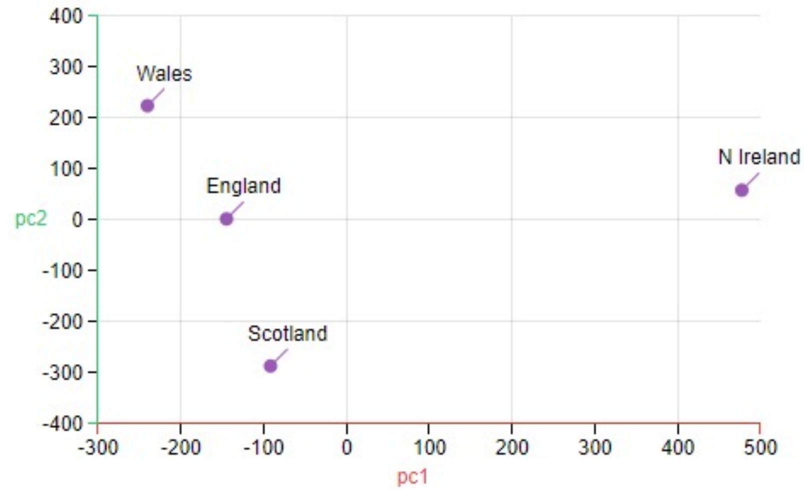

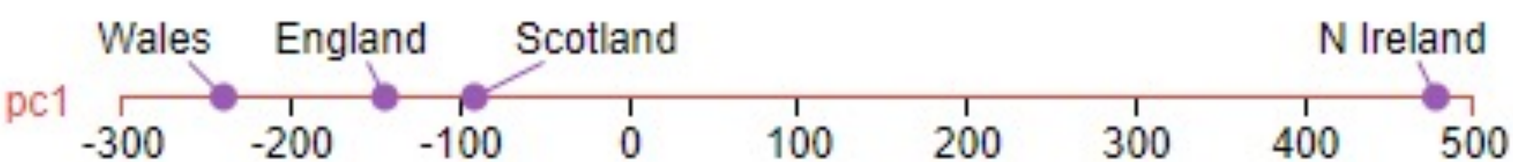

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OK, so how can we find the right basis?

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2. Compute covariance matrix

$$\begin{bmatrix} Cov(x,x) & Cov(x,y) & Cov(x,z) \\ Cov(y,x) & Cov(y,y) & Cov(y,z) \\ Cov(z,x) & Cov(z,y) & Cov(z,z) \end{bmatrix}$$

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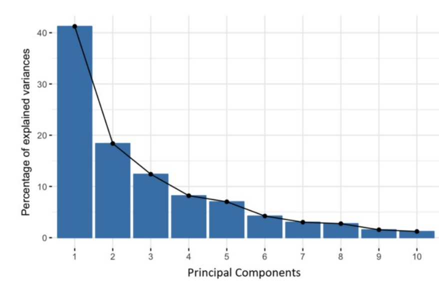
3. Compute eigenvectors and eigenvalues

4. Discard vectors that are not important enough



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Example: Handwritten Digits

MNIST dataset

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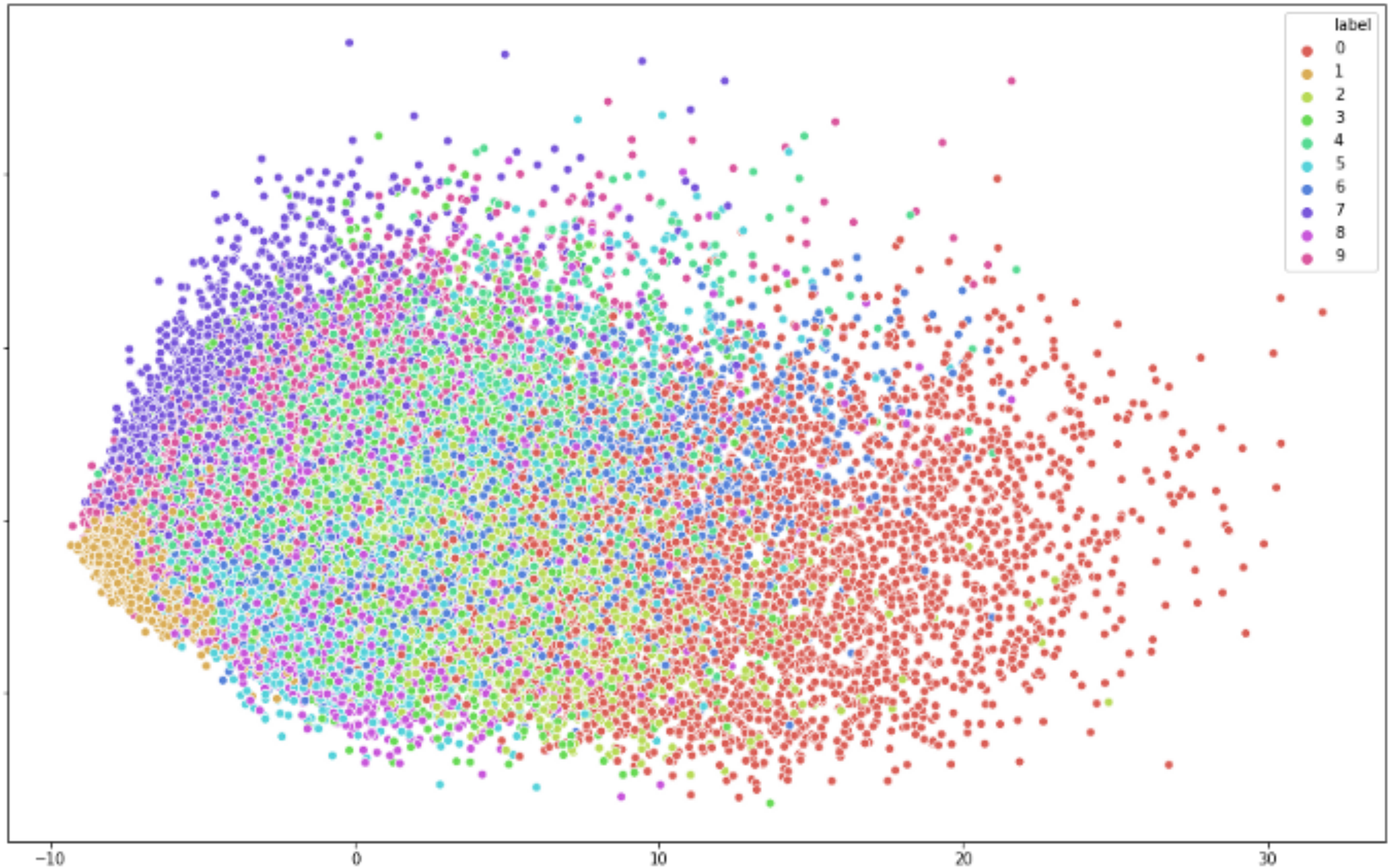
Group "similar" things together

Principal Component Analysis

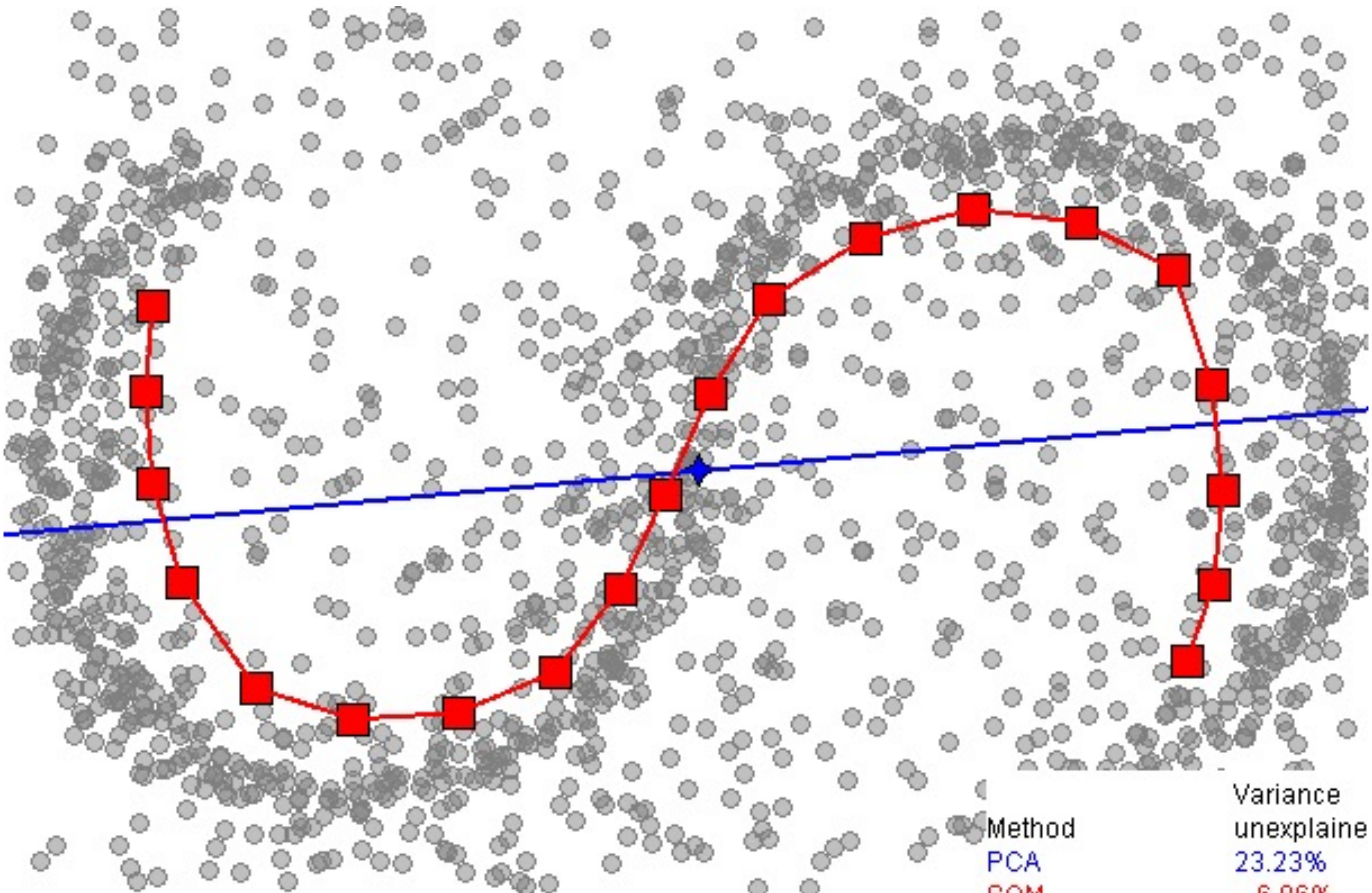


Example: Handwritten Digits

MNIST dataset

Some things aren’t linear!

Wikimedia Commons



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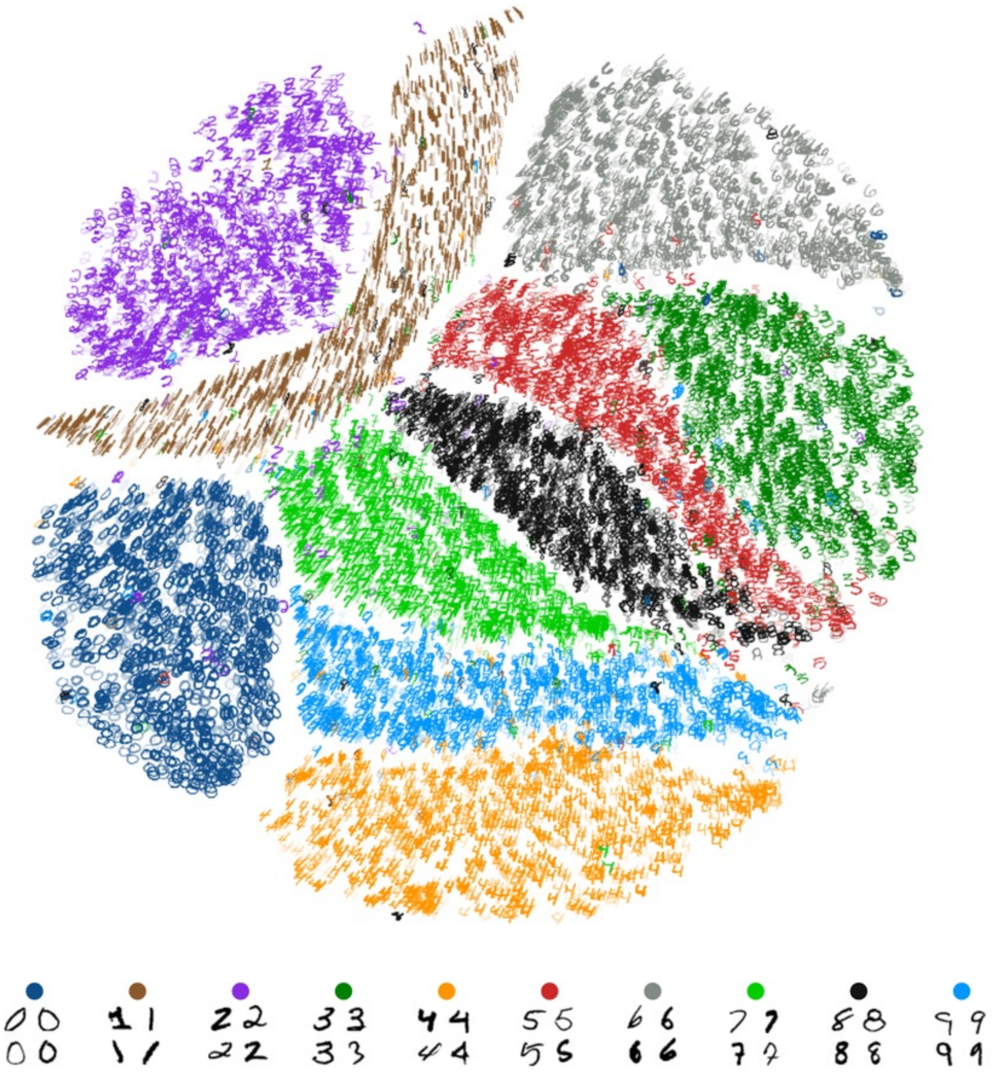
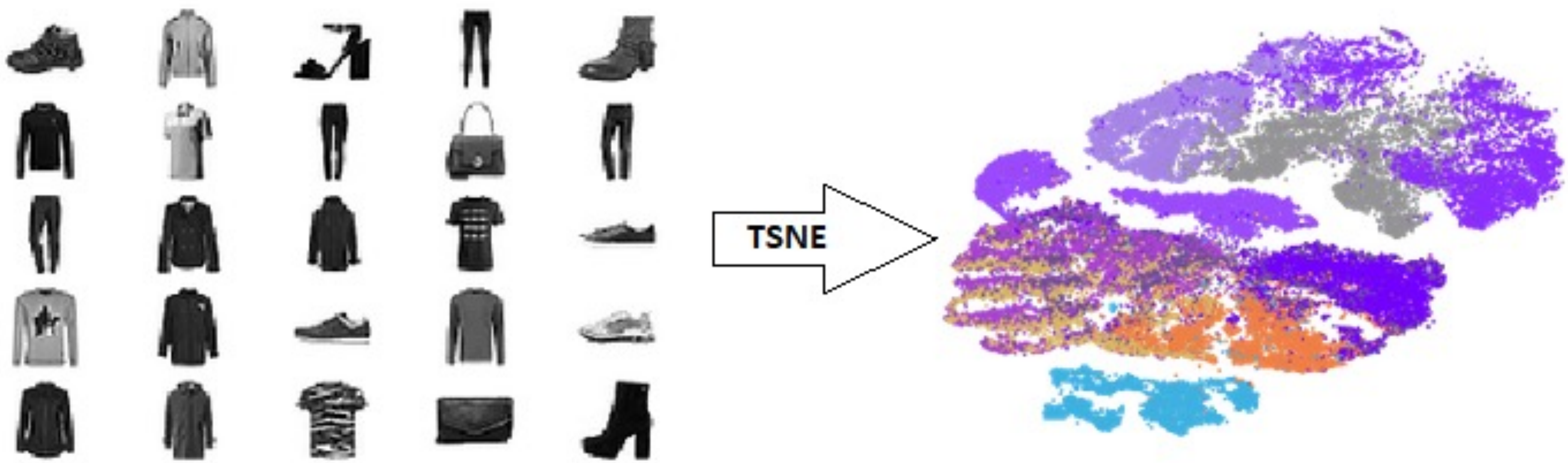
Group “similar” things together

Pezzotti 2019



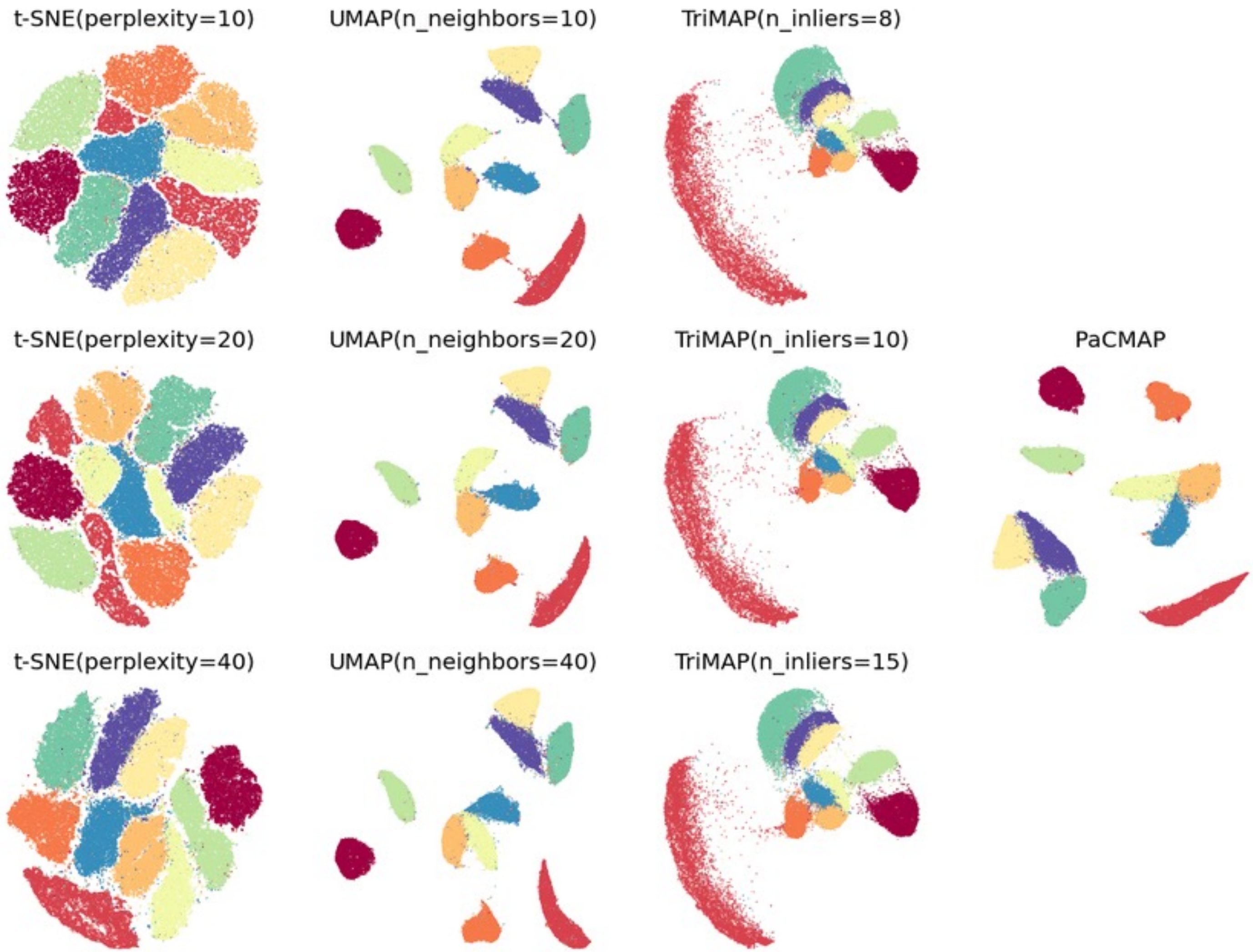
Group “similar” things together

“Fashion MNIST” datasets, t-SNE



Group "similar" things together

Wang et al. 2020



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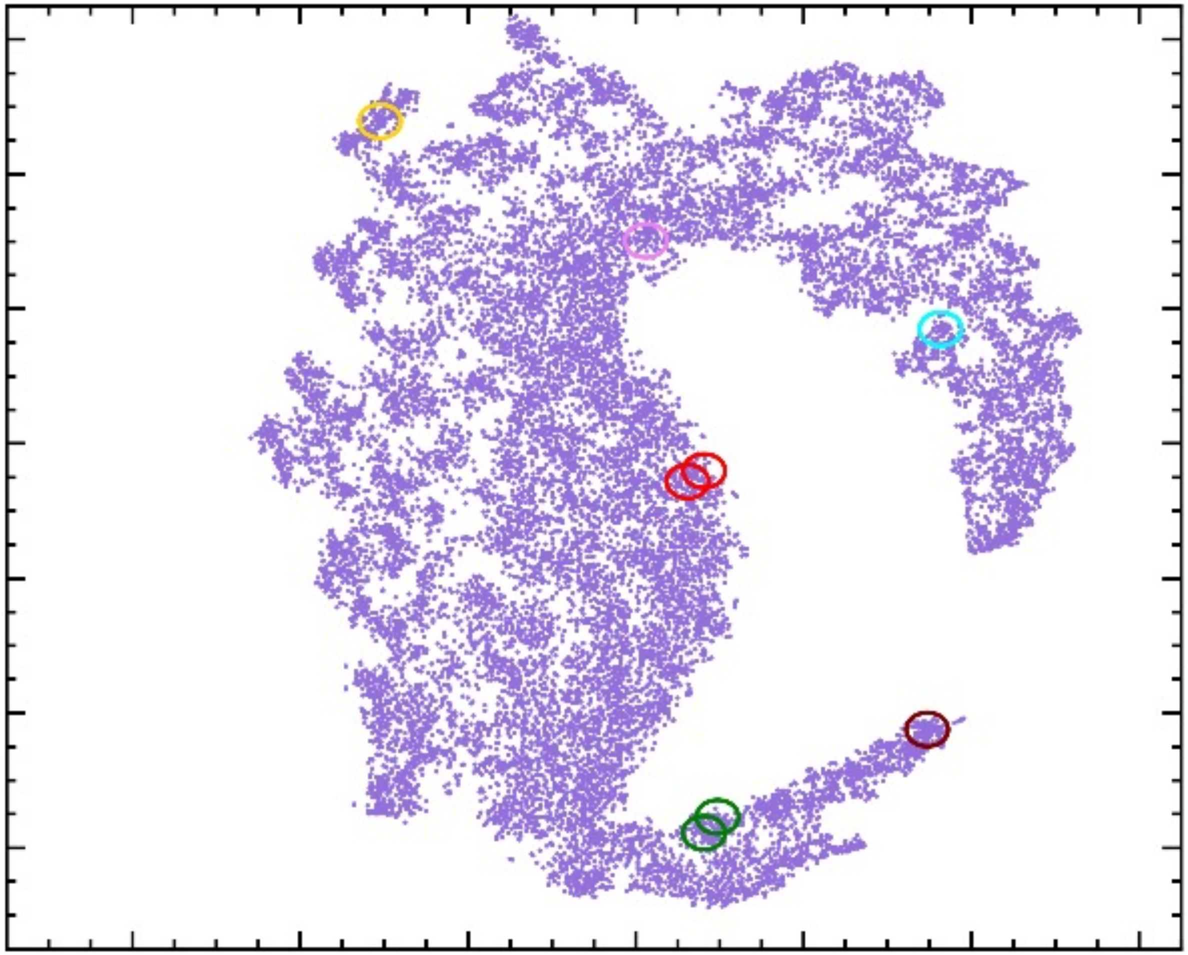
Approach 2: First, make a t-SNE map reducing to two dimensions

COSMOS2015 catalog, objects at z≈1



Approach 2: Similar galaxies are nearby

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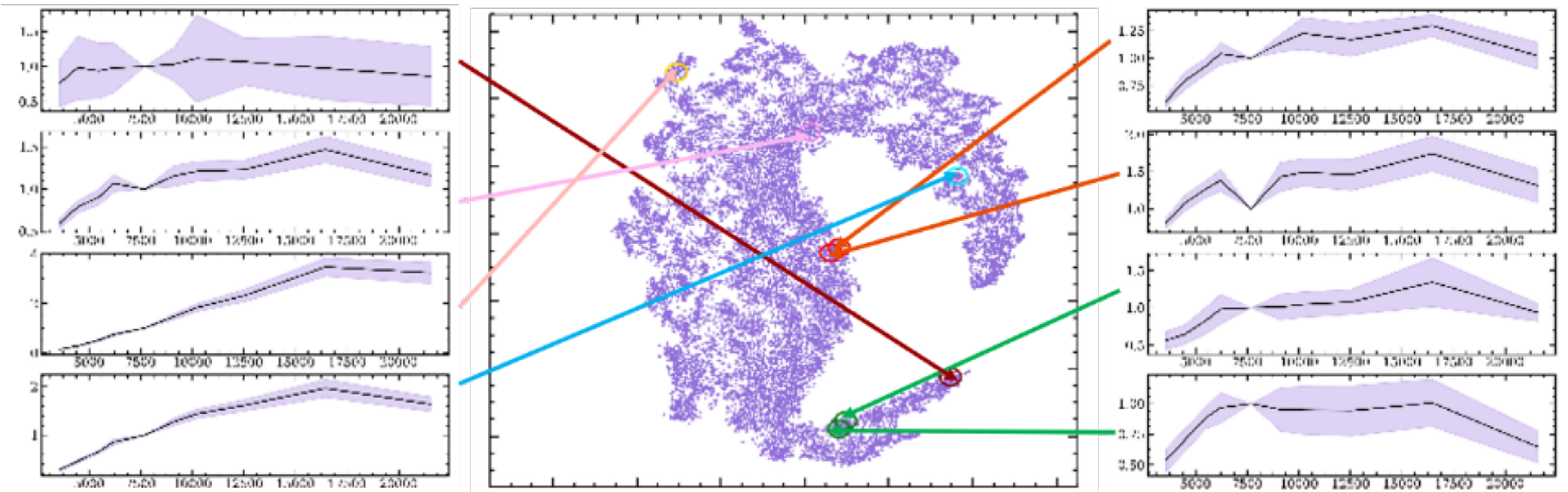
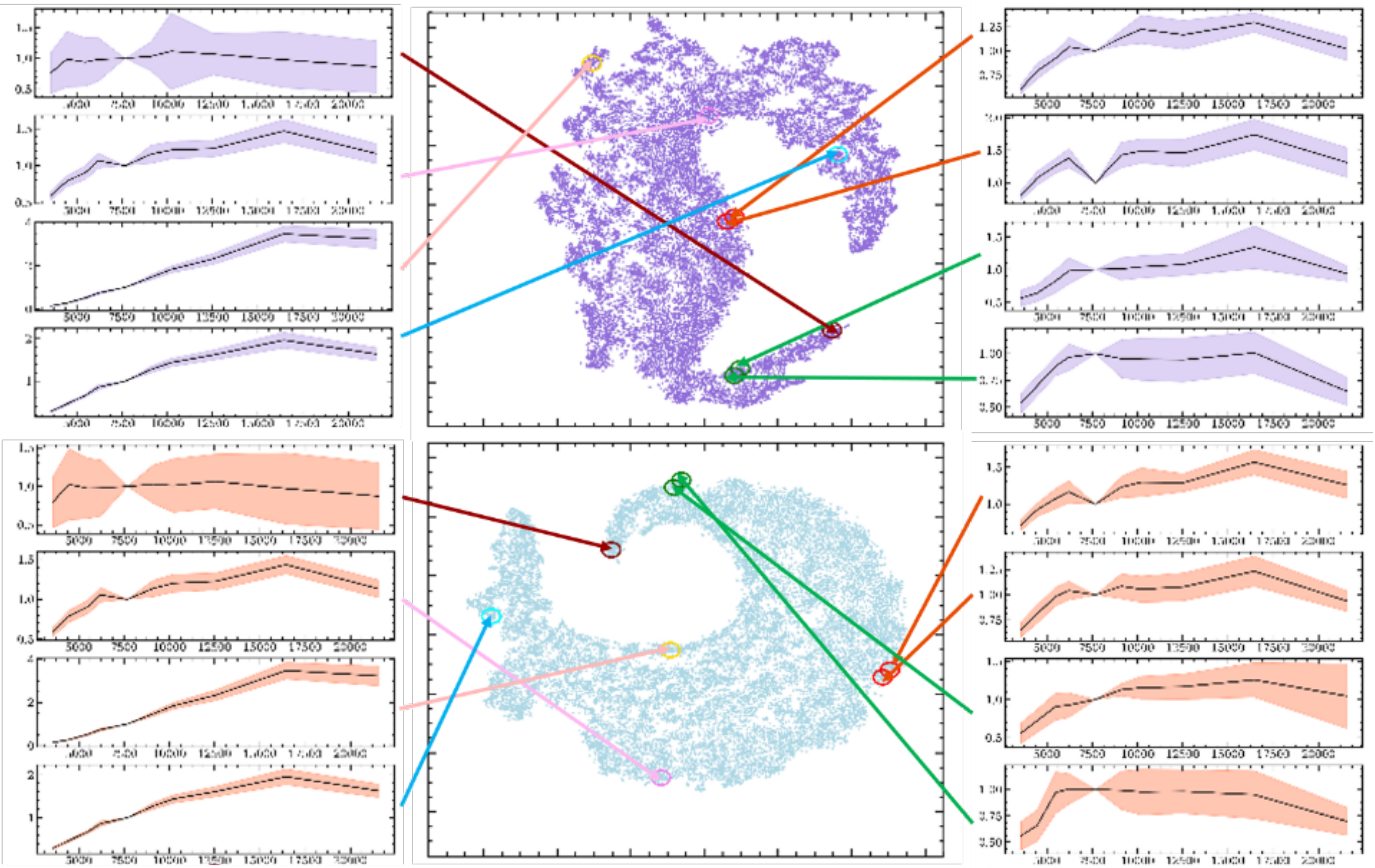


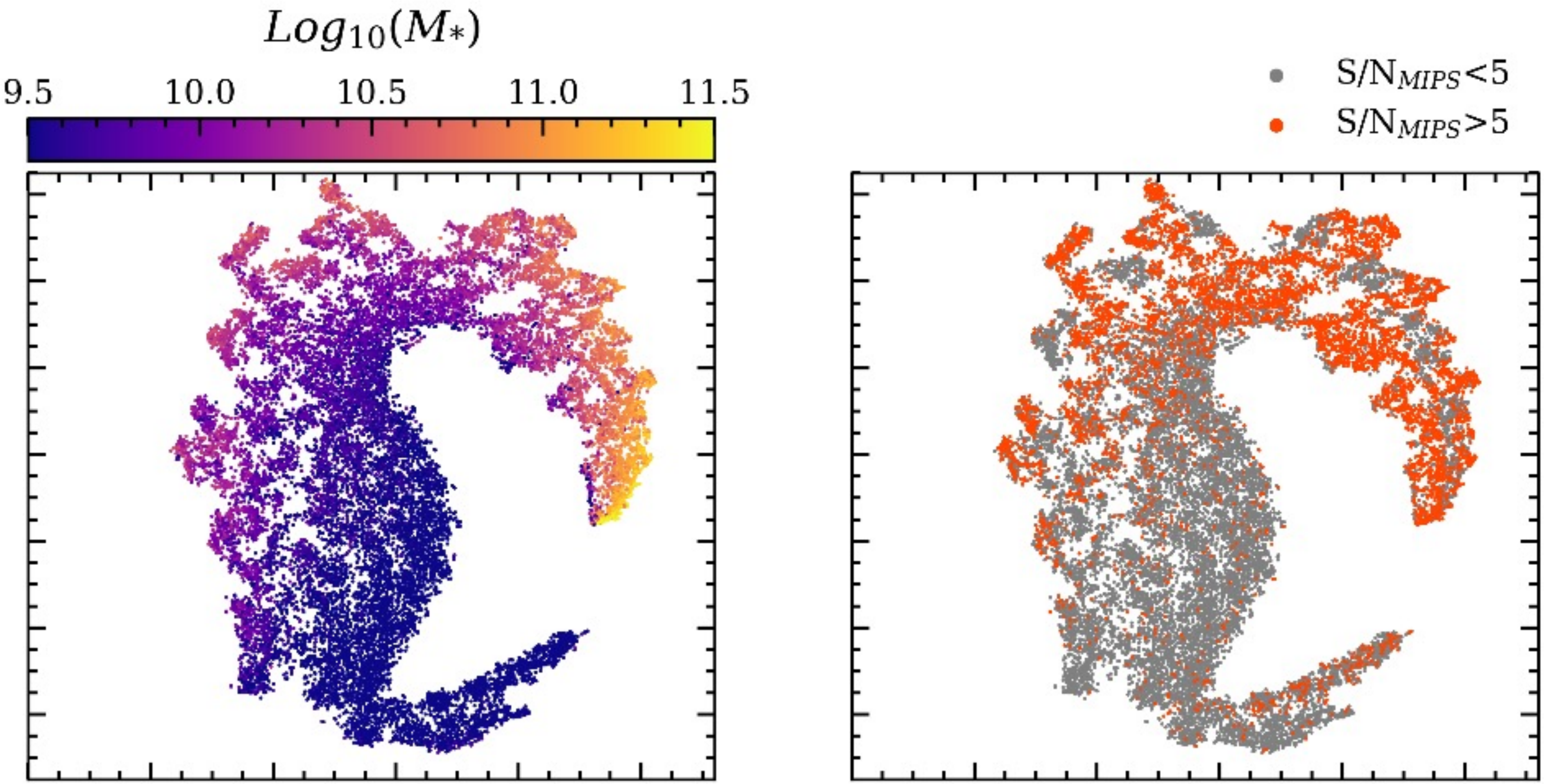
Approach 2: Similar galaxies are nearby

WARNING: positions are neither fixed nor meaningful. Topology is meaningful.



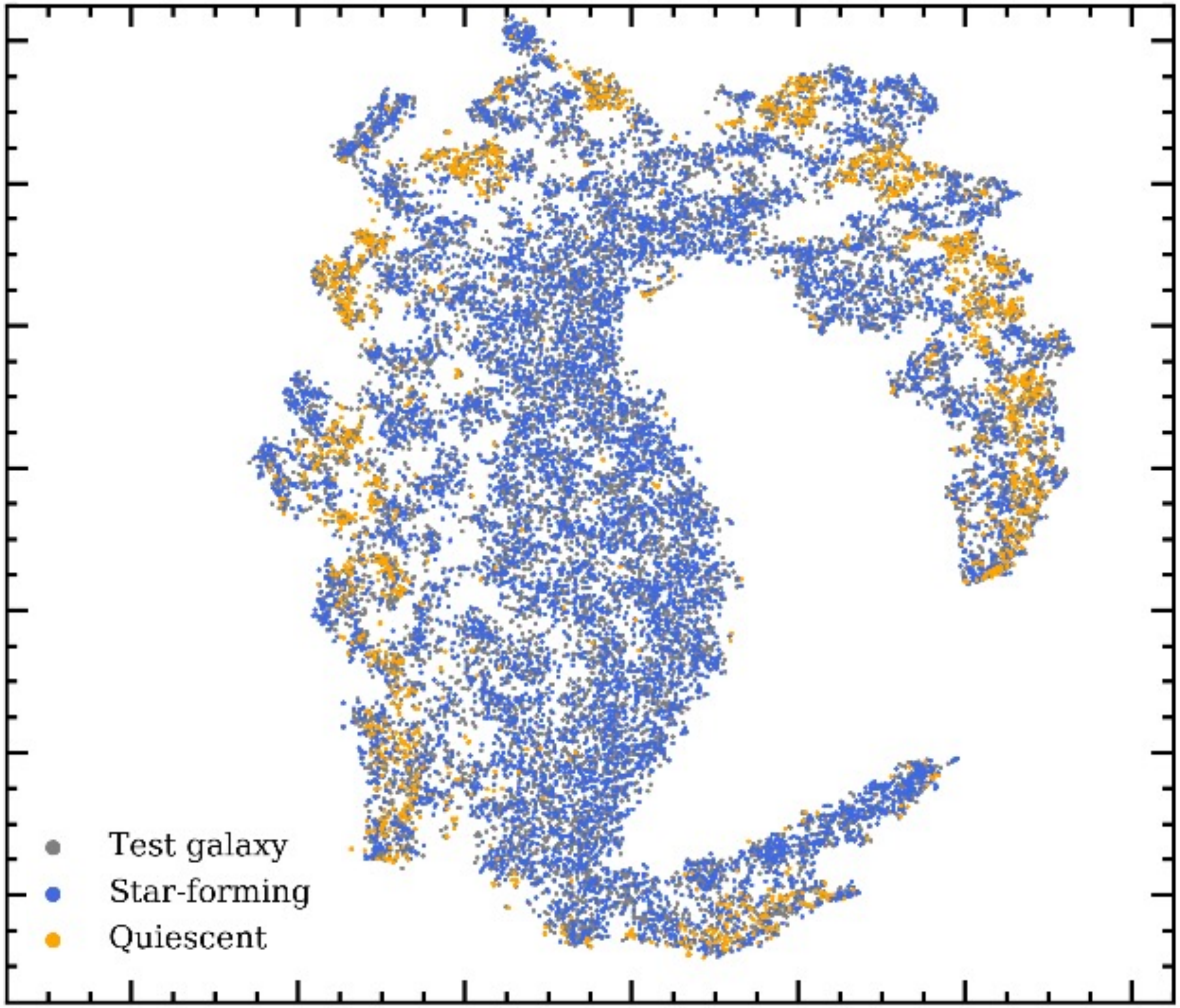
Approach 2: Arranging by photometry also calculates other useful things!

COSMOS2015 catalog, objects at z≈1



Approach 2: Finding "dead" galaxies

COSMOS2015 catalog, objects at z≈1



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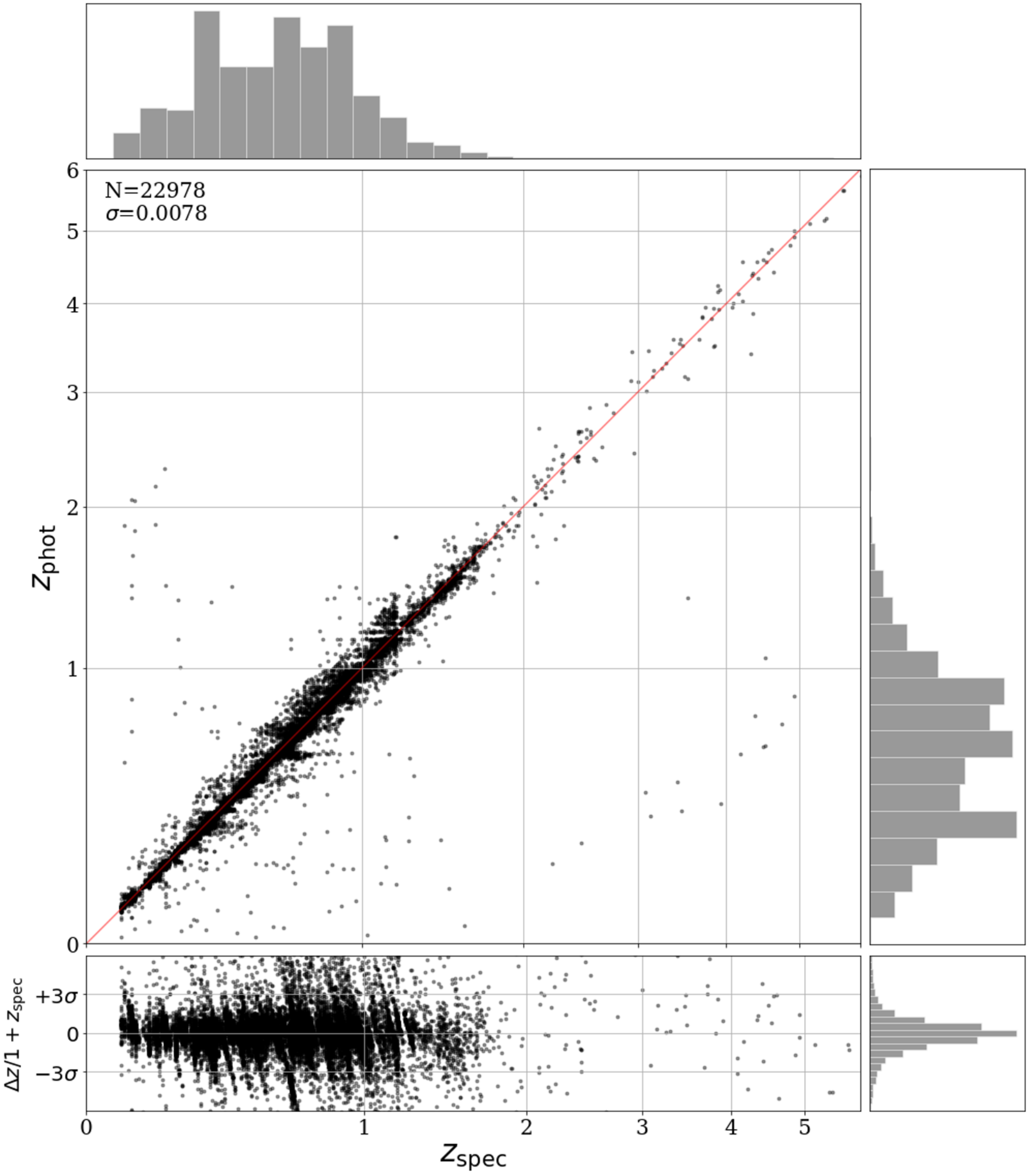
Photometric Redshifts Usually Work…

Hovis-Afflerbach, Steinhardt et al. 2020



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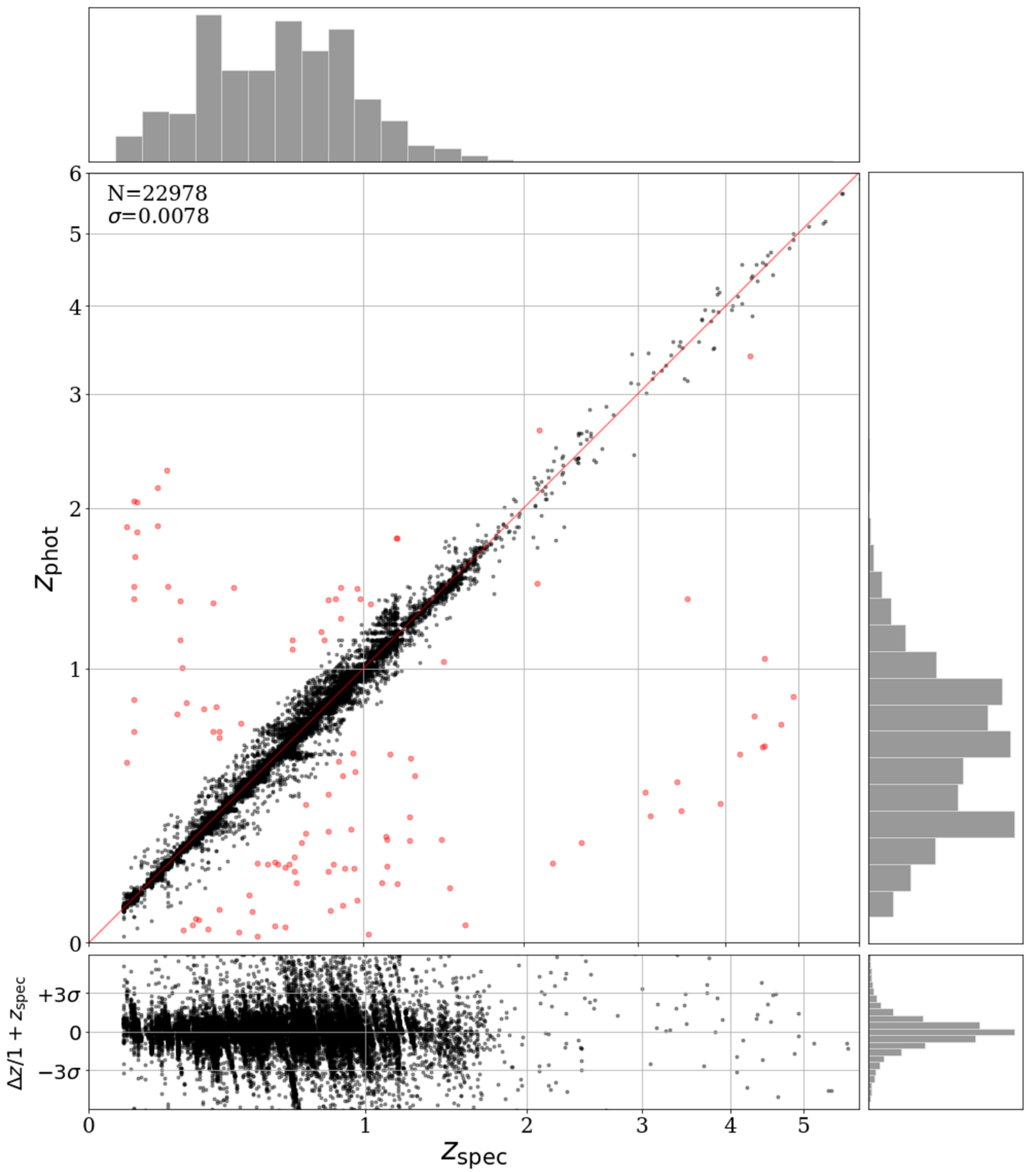

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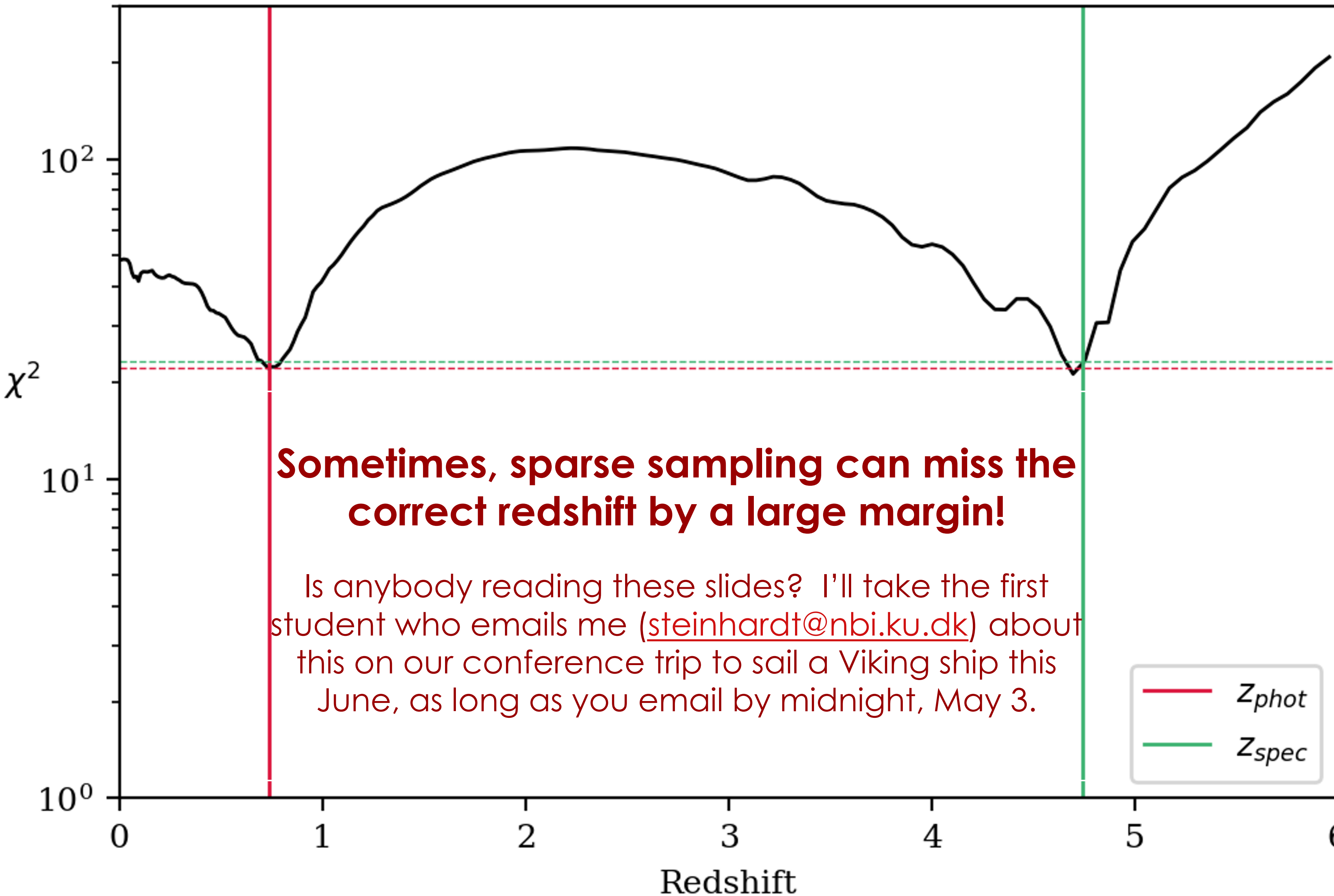

Sometimes, sparse sampling can miss the correct redshift by a large margin!

Is anybody reading these slides? I'll take the first student who emails me (steinhardt@nbi.ku.dk) about this on our conference trip to sail a Viking ship this June, as long as you email by midnight, May 3.

…But Not Always!

About 5% of objects fail template fitting[1]

Can we identify these objects without comparing with spectroscopy?

Can we fix these objects and determine the correct properties?

[1]Hildebrandt et al. 2010:
12 photo-z methods tested on objects with 18 bands, between 4.9% and 29% of objects had dz/(1+z) > 0.15