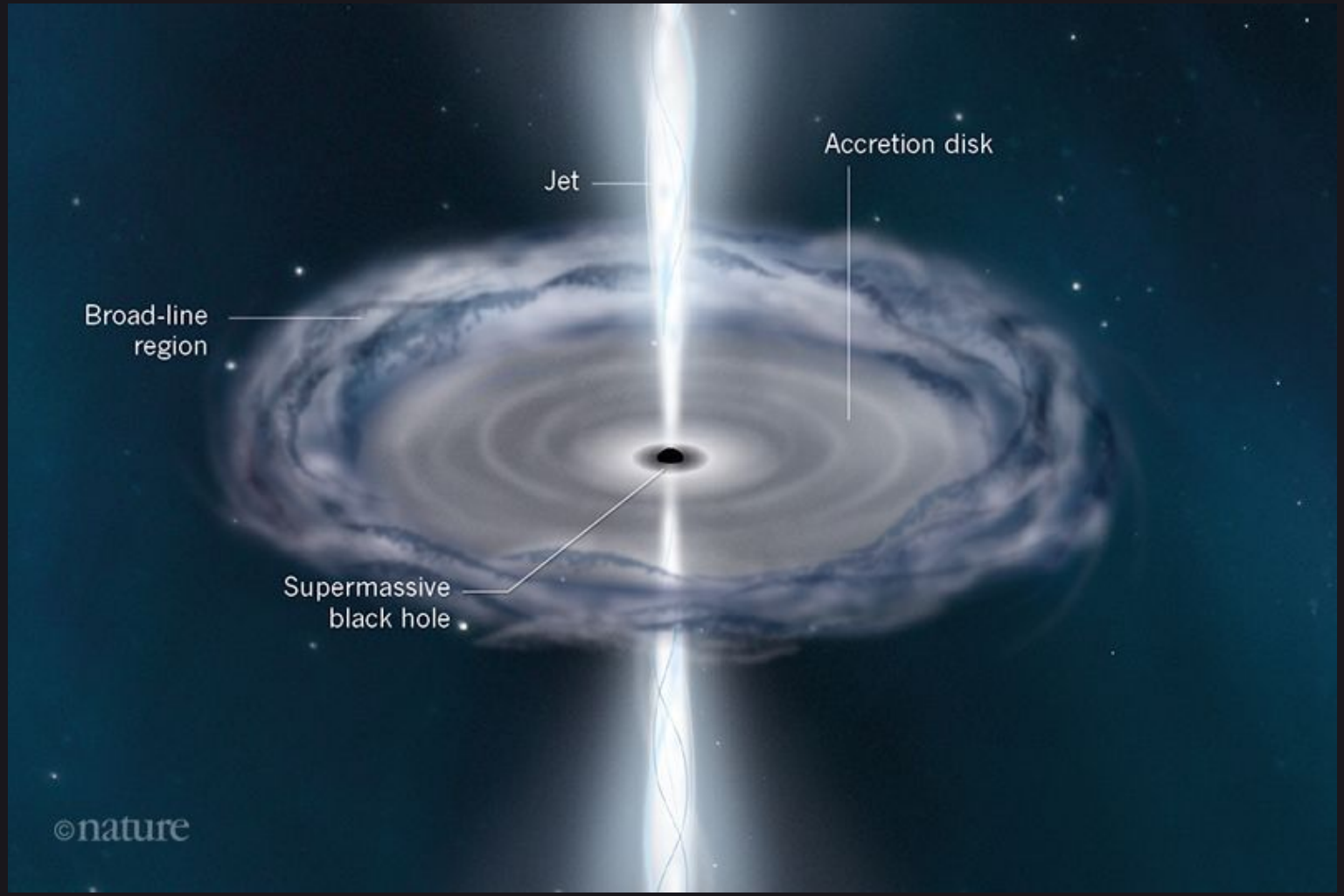
# IGM-Vis

## visualizing the intergalactic medium

David Abramov


Jet
Accretion disk
Broad-line region
Supermassive black hole
©nature

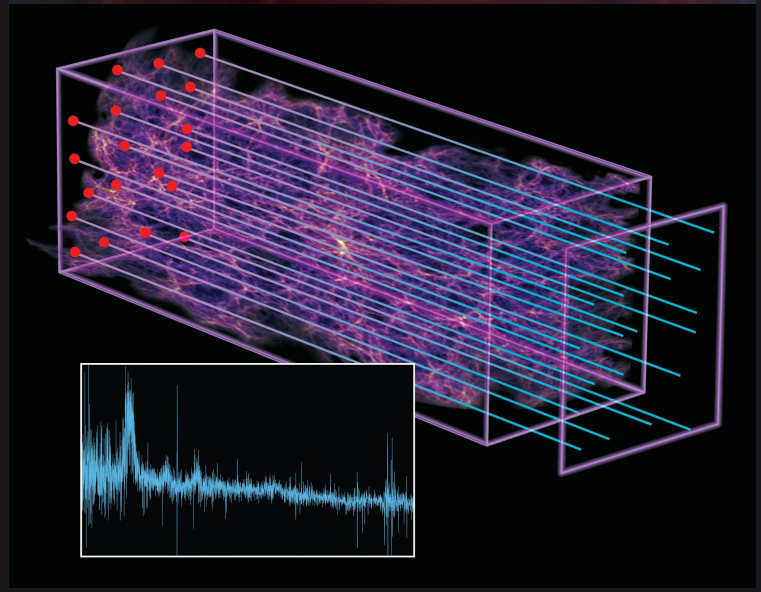
# What is a quasar?

- Quasars are astronomical objects
- Comprised of
  - a supermassive black hole at the center
  - hot gas and dust that is pulled towards the black hole through a structure known as an accretion disk
  - energy is released in the form of light and, sometimes, as a beam of charged particles called a jet.

# What is the data?

~350 Quasar sightlines
- Position (RA, DEC)
- Redshift / Wavelength
- Flux / Absorption Spectra

Since quasars are very bright sources of electromagnetic radiation, their emission spectra can be used to study objects between us and them



# What is the data?

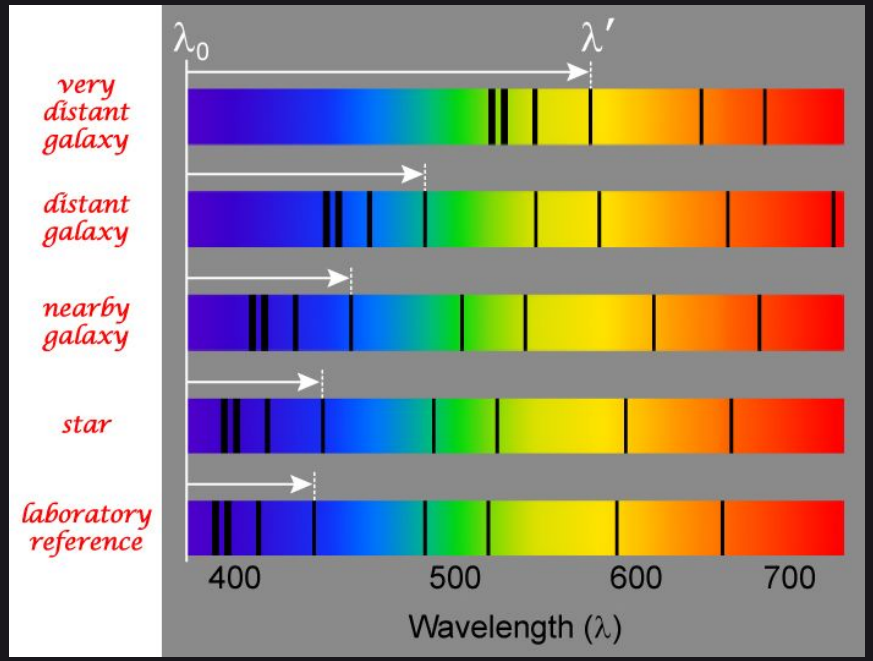
~20,000 Galaxies

- Position (RA, DEC)
- Redshift
- Stellar mass
- Star formation rate
- Virial radius
- Images from Sloan Digital Sky Survey

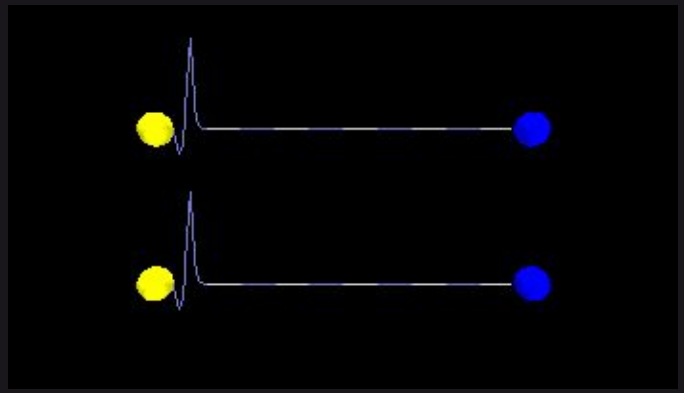
# What is the data?

Quasar emission spectra collected by the Hubble space telescope

- Elemental (ex: hydrogen, carbon) redshift and flux
- Angular Position (right ascension & declination)

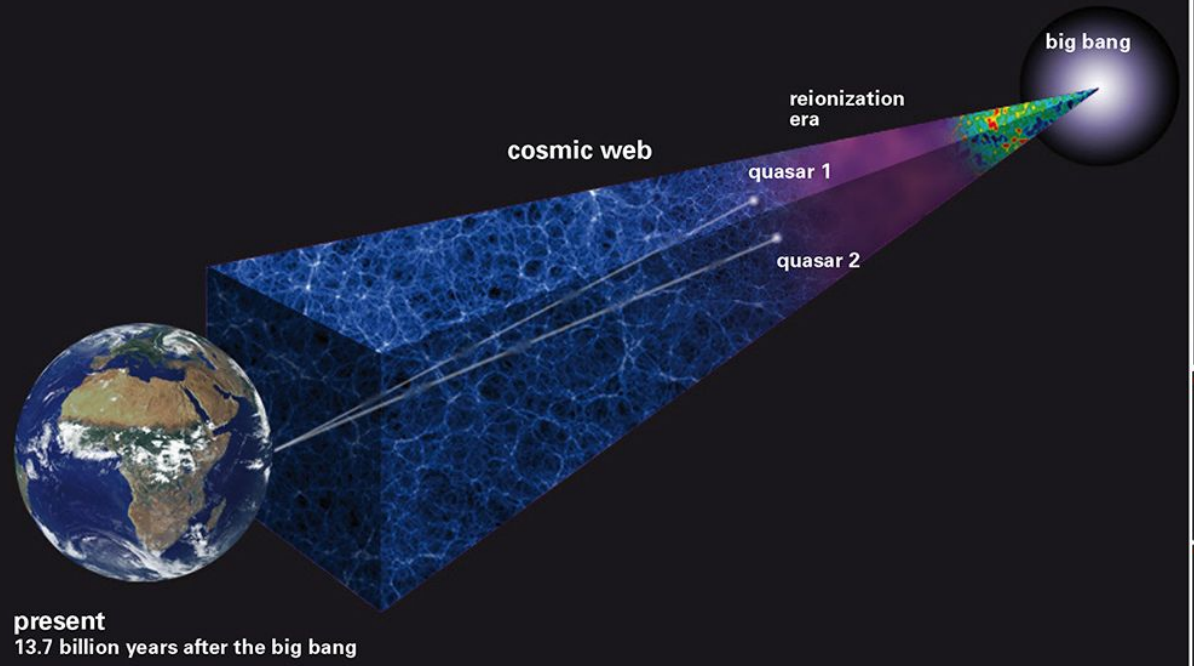


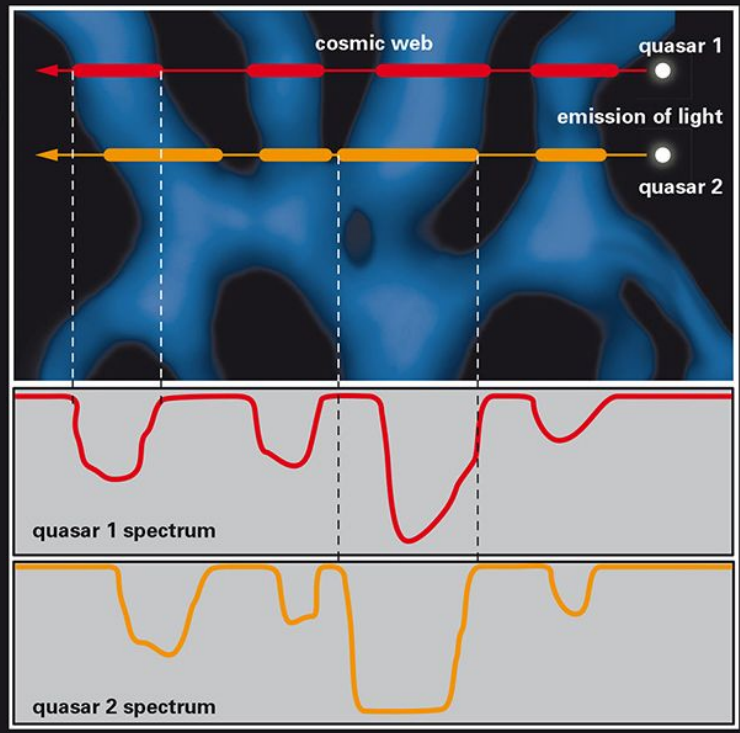

https://phys.org/news/2013-04-textbooks-wrong-astronomers-clash-hubble.html



http://pcmhahn.wixsite.com/foamyether/expanding-universe

# What is the data?

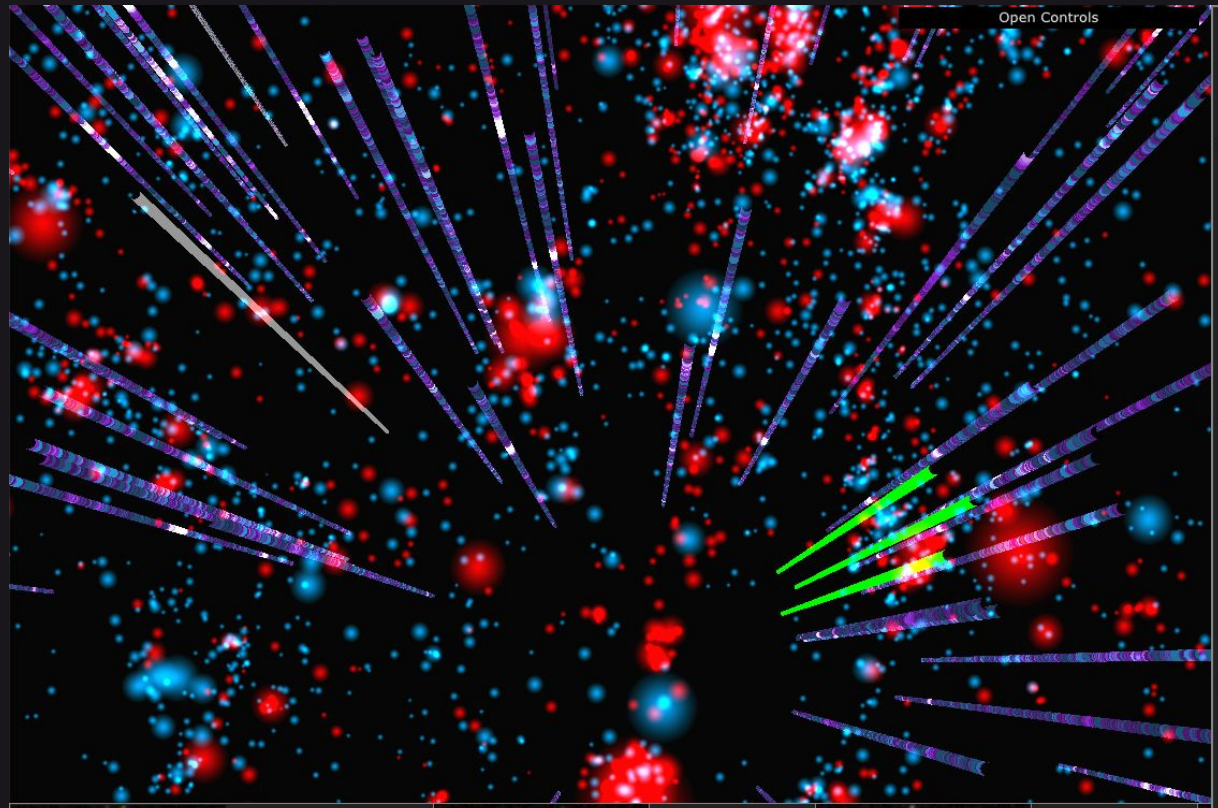



https://news.ucsc.edu/2017/04/cosmic-ripples.html

# What does Joe Burchett want to do with the data?

- Compare the spectra of QSOs (quasi-stellar objects) - “skewers”
- Test the coherence (absorption patterns) between sightlines
- Know the properties any adjacent galaxies
- Test whether a galaxy is responsible for patterns in the spectral data
- Learn about the structure of the universe

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redshift: 0.02433
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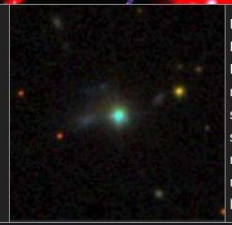
log_sSFR: -10.71



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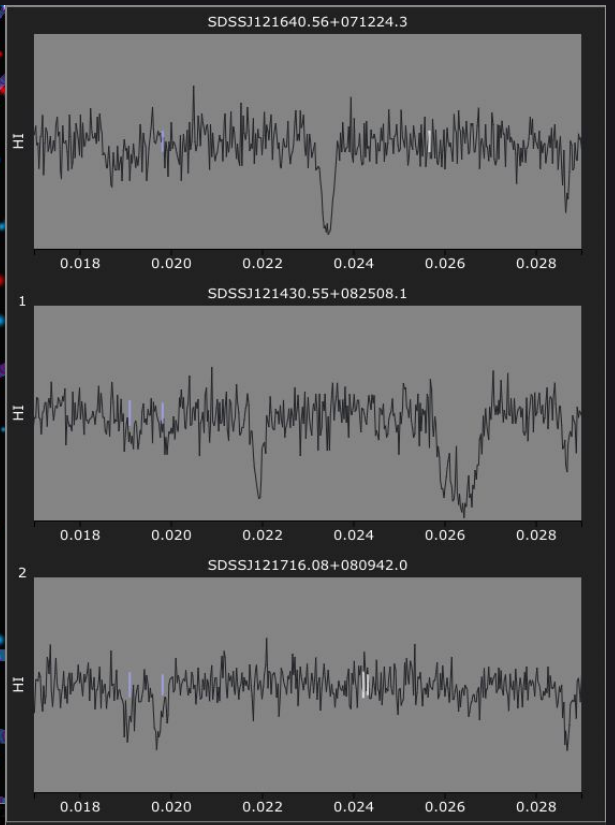



↕ rvir ↔ 1 px

0.018 0.020 0.022 0.024 0.026 0.028

1.308 Mpc

# What analysis tasks are enabled?

Quasar sightline observations can be quickly viewed

Look for coherence (absorption that lines up in redshift) among sightlines

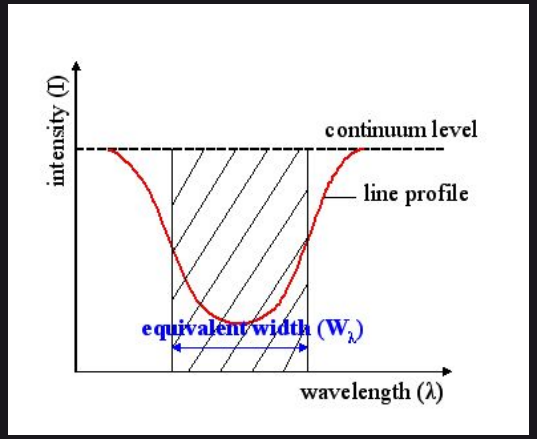
Can easily identify interesting Quasar-galaxy pairs based on proximity and absorption patterns

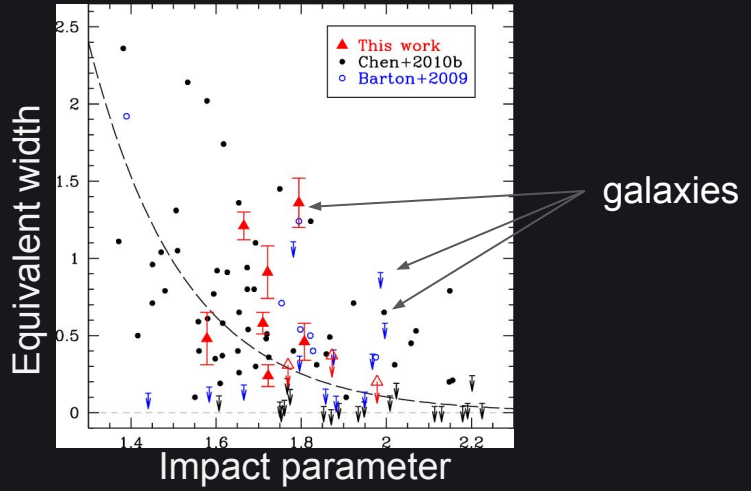
Compare the qualities of galaxies in dense clusters vs in isolation

No need to manually generate plots

# Equivalent Width Plots

- Want to be able to generate equivalent-width plots on demand
- What is an EW plot?

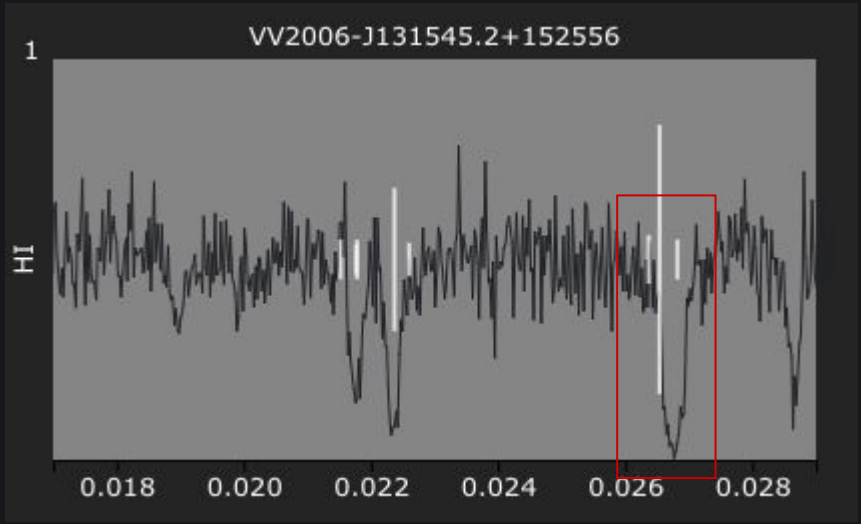


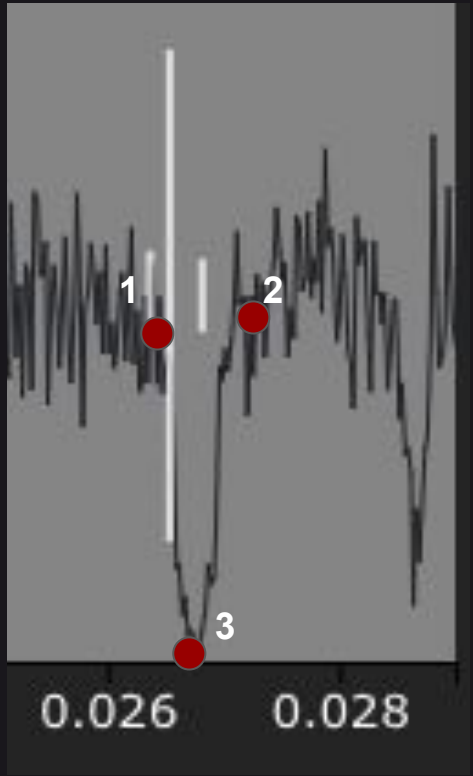




https://www.researchgate.net/figure/Rest-frame-EW-of-Mg-III2796-absorption-line-as-a-function-of-projected-distance-and_fig2_233409354

# Equivalent Width Plots

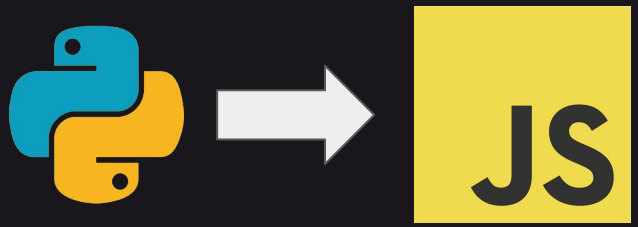
- Want to be able to generate equivalent-width plots on demand
- How does it work in IGM-Vis?



# Equivalent Width Calculation

- And then what?
- I had to convert script that Joe wrote in Python into JS
- Challenging because JS does not natively handle vector math very well
- Used a library called math.js

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10,11,12,13,14,15,16,17,18,19,20,21,22,23

velup: 45.391027974343494 quasar.js:544

veldown: -48.04064452542896 quasar.js:546

dv: 93.43167249977245 quasar.js:548

belowerr: 16 quasar.js:569

0.112 quasar.js:571

EWpix: quasar.js:589
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sigEWf: quasar.js:590
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tauv: quasar.js:591
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EW: 0.6343541475058865 quasar.js:633

N: 12765643495844.37 quasar.js:635

# Equivalent Width Next Step

Generate a plot...

- We can collect and store EW values, the corresponding skewer, and the redshift range
- We can filter galaxies based on its impact parameter (angular distance from the skewer)
- But we still need to filter nearby galaxies that fit within the EW redshift range
- Once we filter down the relevant galaxies, a plot can be generated

# What else could be done?

- Port the 3D visualization into VR (A-Frame)
- Center the camera on a stored galaxy when its image is clicked on
- Sonify the spectral data
- Use machine learning to possibly automate EW plot generation or run statistical analysis based on selected samples
- Visualize holistic details about the dataset
  - EX: histograms for galaxy attributes
- Enable more analysis tasks
- Add an interface to load new datasets within the webpage

# How is the data being visualized?

1. 3D interactive view created using THREE.js
2. 2D spectral line graphs with ticks indicating nearby galaxies, using D3
3. Galaxy images with attribute description

# Why is it visualized this way?

1. The 3D view is an intuitive way to explore the data spatially.
2. 2D line graphs are easy to interpret, and information about the galaxies can be encoded with their height and width.
3. The images tie the visualization back to reality and what can be observed optically, along with its significant features.

# Who will (or could) use this software?

- Astronomers
  - Interact with and explore the cosmological data in a 3D environment before diving into analysis
  - Identify interesting regions of space

- Citizen scientists
  - If specific tasks were isolated, they could be gamified
  - Zooniverse already has a handful of astronomy games that crowdsource discovery

# Is this tool generalizable?

- It could be

- Some of the ranges are hard-coded (i.e. low-redshift domain) to work better with the data, but could be adapted for high-redshift galaxies.

- Other tools directly query sky survey databases. Integrating with existing data pipelines would make this tool more versatile.

- Limited to visual exploration the intergalactic scale