

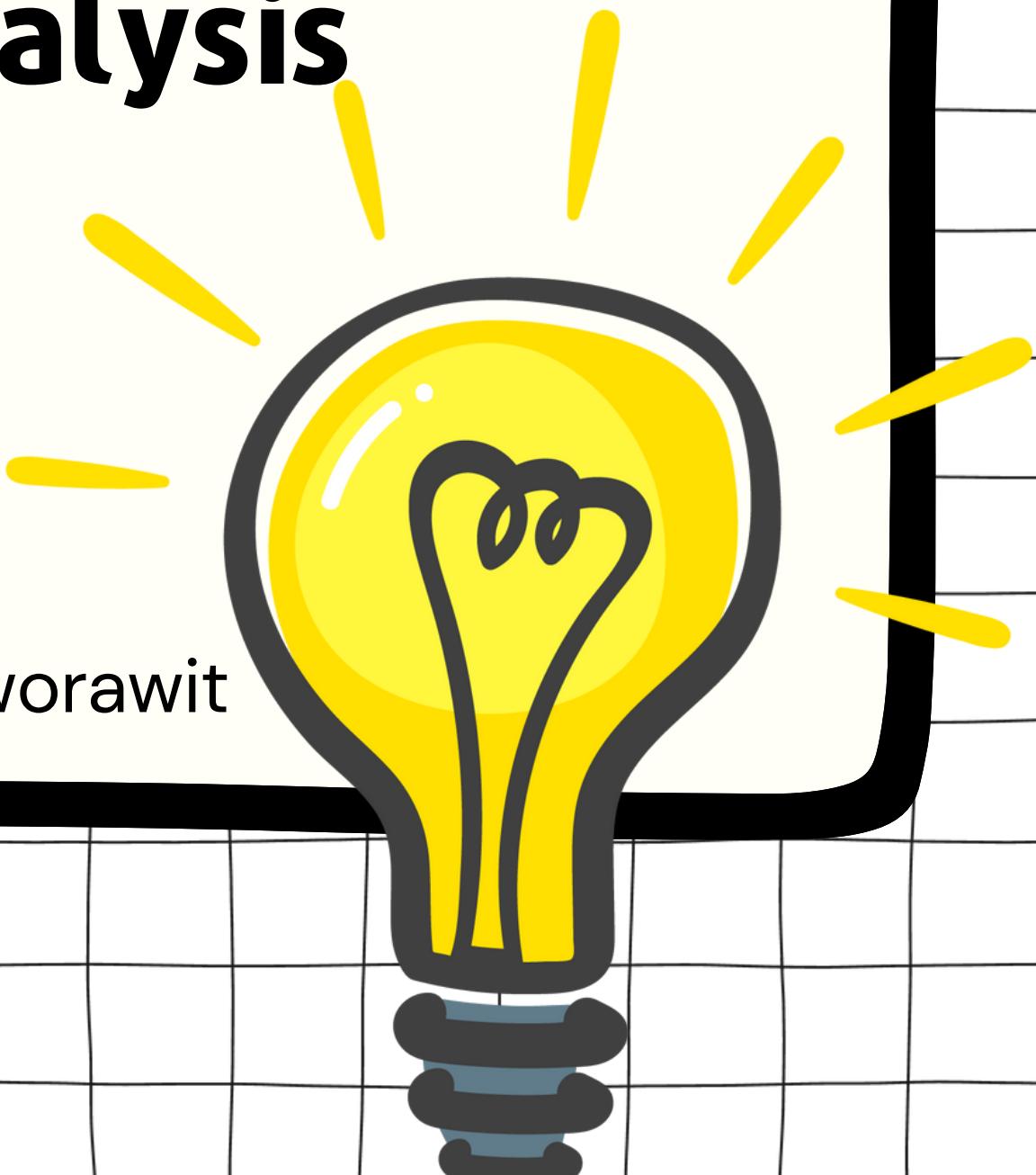


Intro to 1D Spectroscopy Analysis

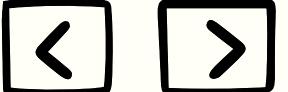
**Line Profile /
Template Fitting/
PCA Decomposition**

ASTRO101: HOW on OAR 2023

Krittapas Chanchaiworawit



Contents



01

Gaussian Profile Fitting

02

Redshift
Determination

03

Line Ratio

04

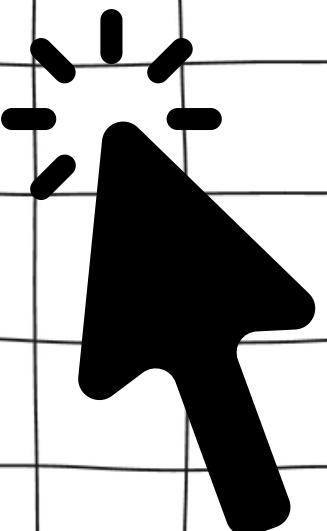
Continuum Slope

05

Spectroscopic
Templates

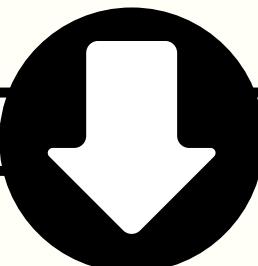
06

PCA
Decomposition

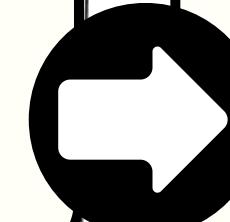
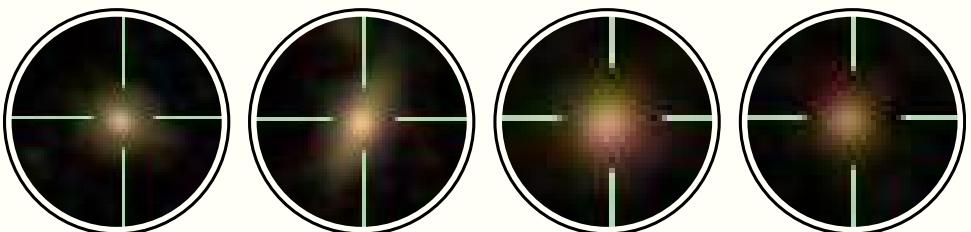


Recap Spectroscopy

- Disperse the light into spectral space
- Gain physical/chemical information on different wavelength ranges



Choose your target

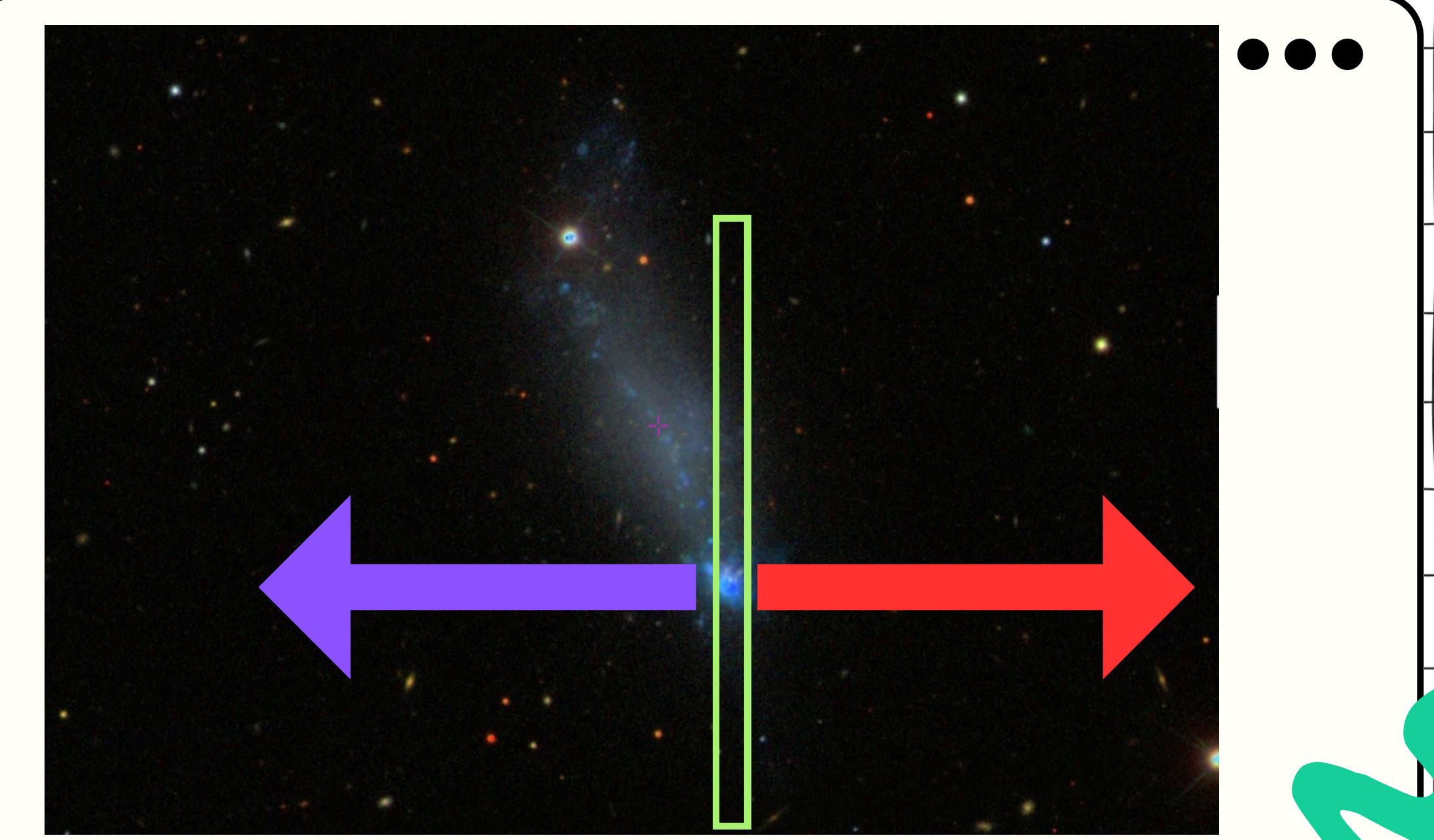


Put a slit on the target

Use prism/grism to disperse light

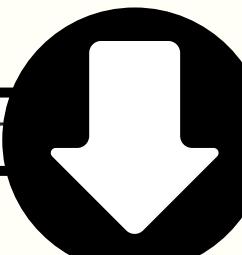
Also gain information from spatial space

What can be improved?

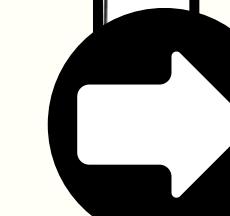
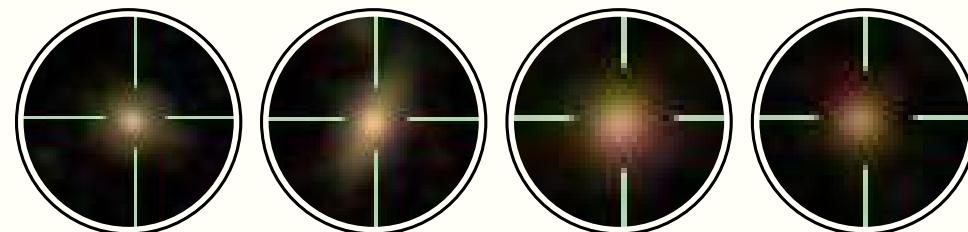


Recap Spectroscopy

- Disperse the light into spectral space
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Choose your target

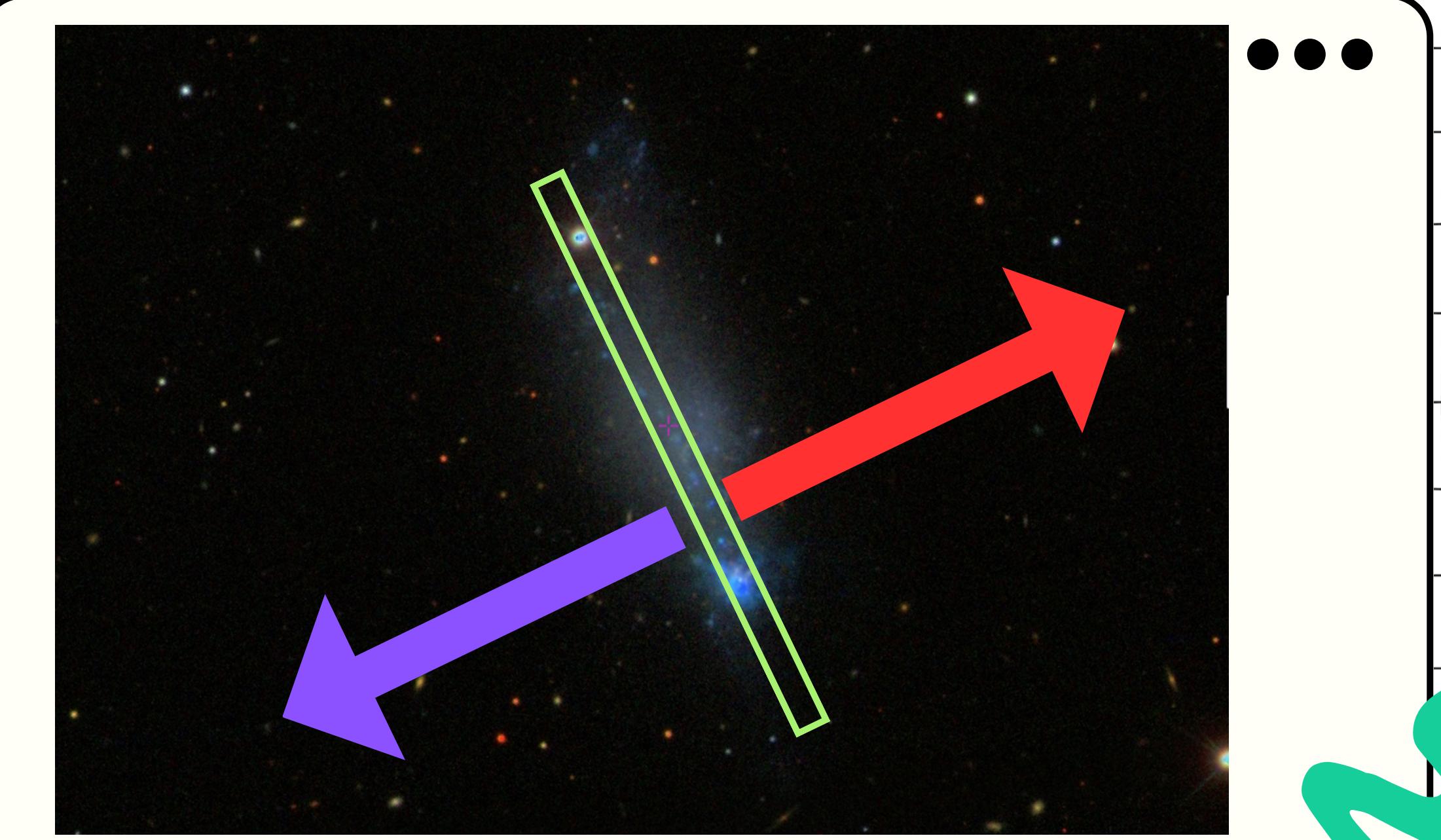


Put a slit on the target

Use prism/grism to disperse light

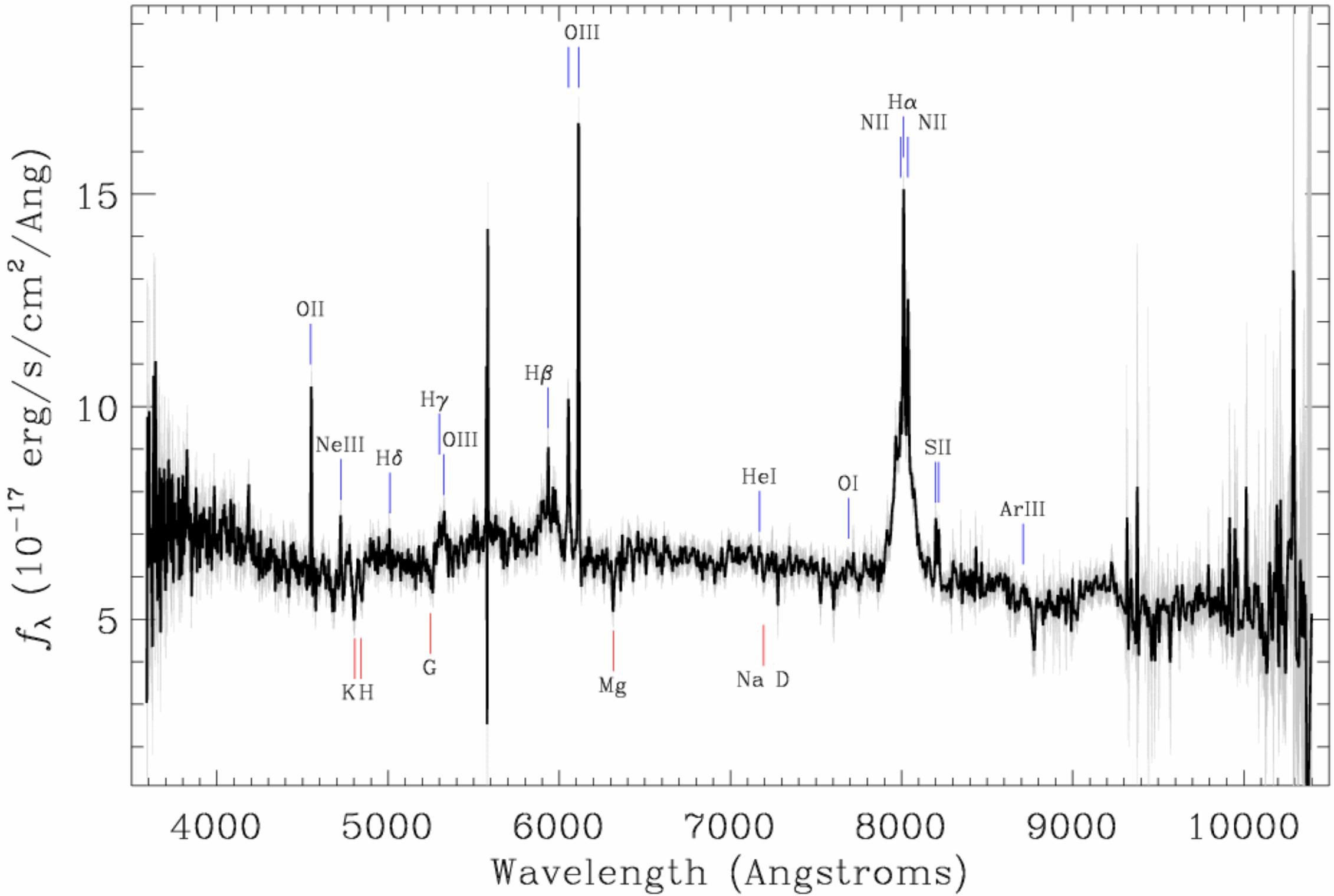
Also gain information from spatial space

What can be improved?



class

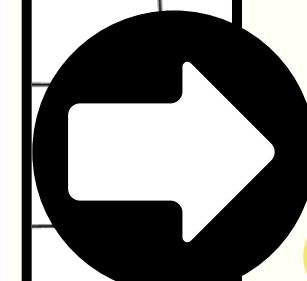
Survey: *boss* Program: *boss* Target: *SN_CAL1*
RA=7.98929, Dec=0.31056, Plate=4220, Fiber=980, MJD=55447
 $z=0.22045 \pm 0.00004$ Class=QSO STARBURST BROADLINE
No warnings.



Features of a spectrum

"Well, at least for galaxies..."

01 Continuum

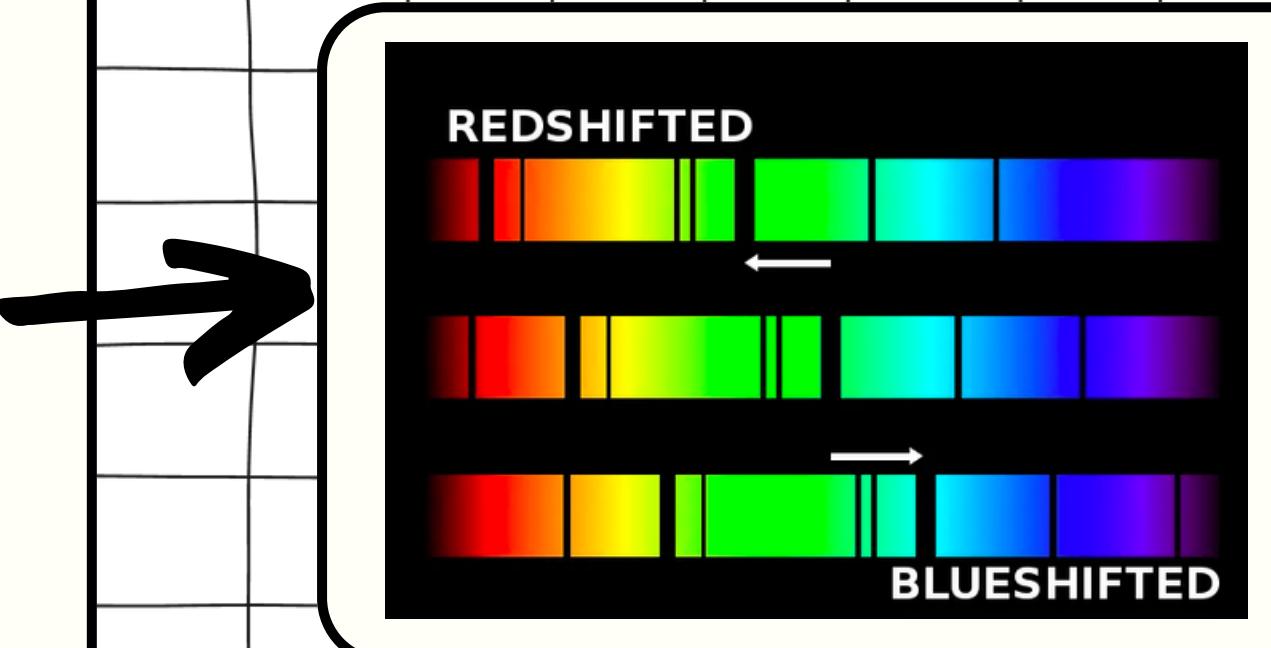


02 Emission lines

03 Absorption lines

What can these wiggle lines tell us?

The spectrum of an object (even for a narrow window of visible light) can give us clues on the physical properties, chemical composition, kinematics, and history of the objects.



What

Unresolved sources can all look like stars, but the shape and features of their spectra can reveal their real identity (i.e., stars, galaxies, quasars, brown dwarfs, etc.).



How

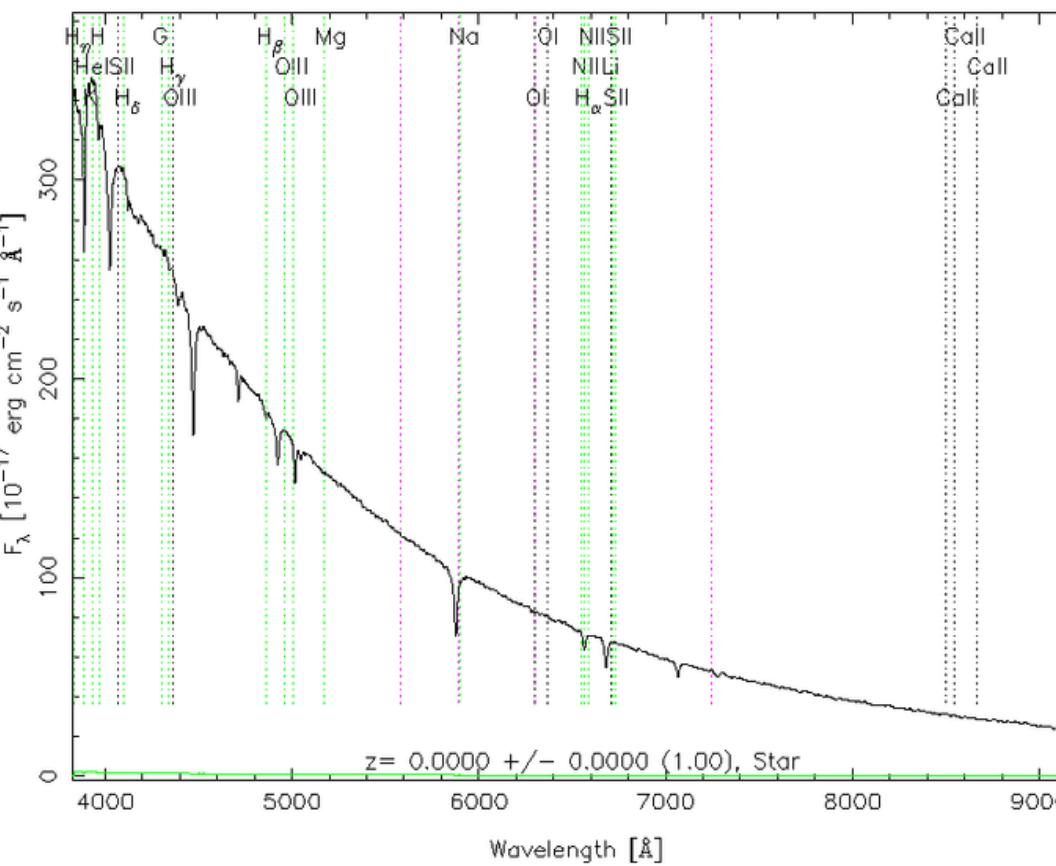
Stellar mass, ages, star-formation rates can help us complete the picture of how these galaxies interact, form stars, and come to be as we see them today.

Where

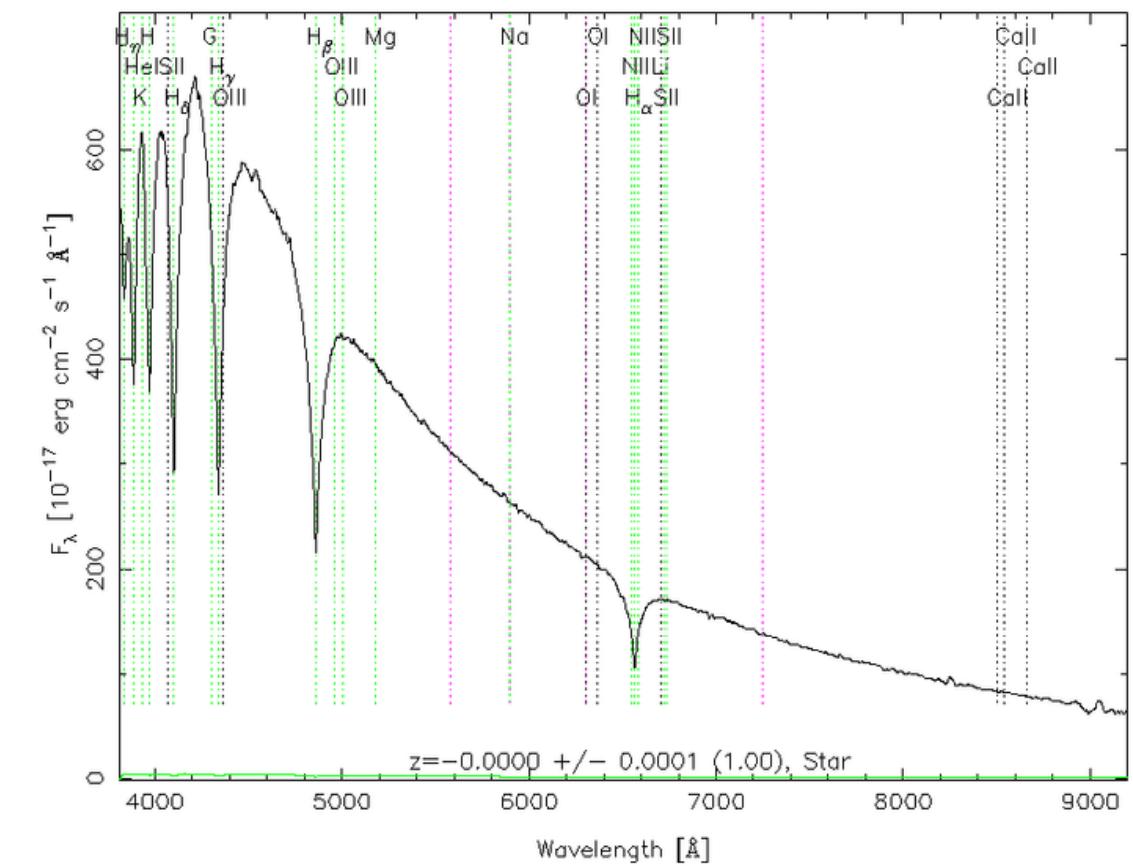
The shifts in the position of key emission (and absorption) features can tell us their redshifts (or regression velocities, which can be mapped to the cosmic flow).

What?

RA=208.88508, DEC= 0.18999, MJD=51942, Plate= 301, Fiber=431

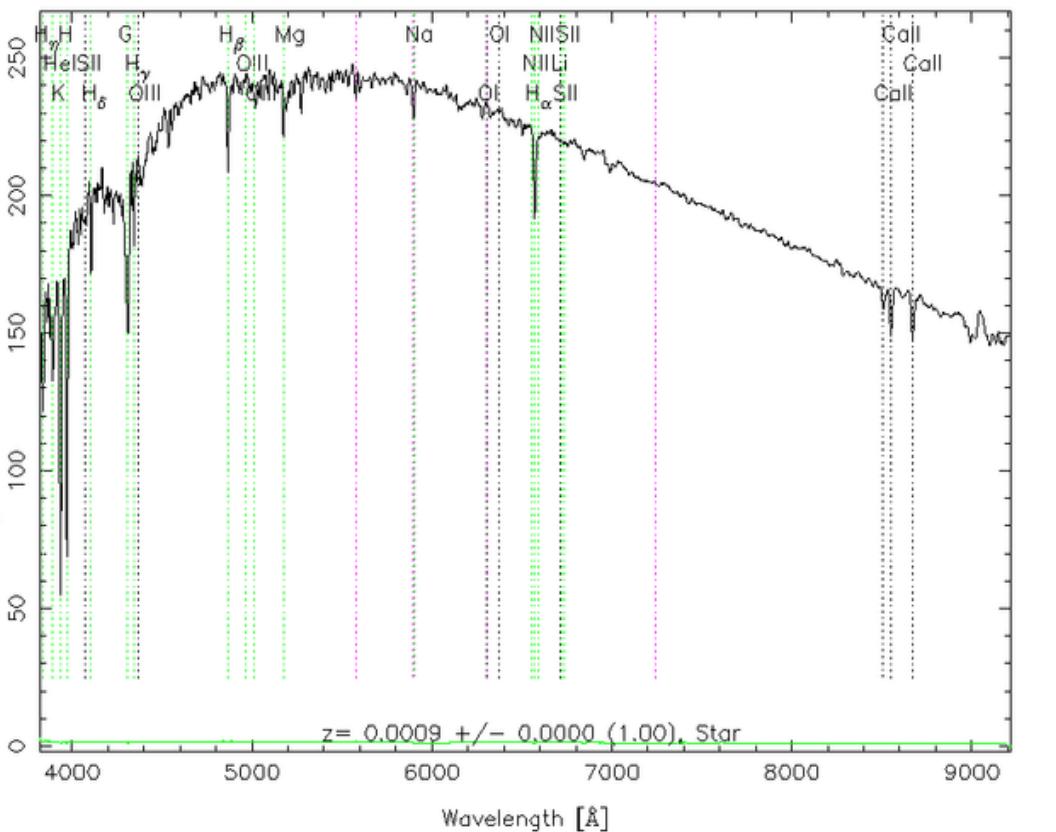


RA=10.09531, DEC=-0.35835, MJD=51793, Plate= 392, Fiber= 63

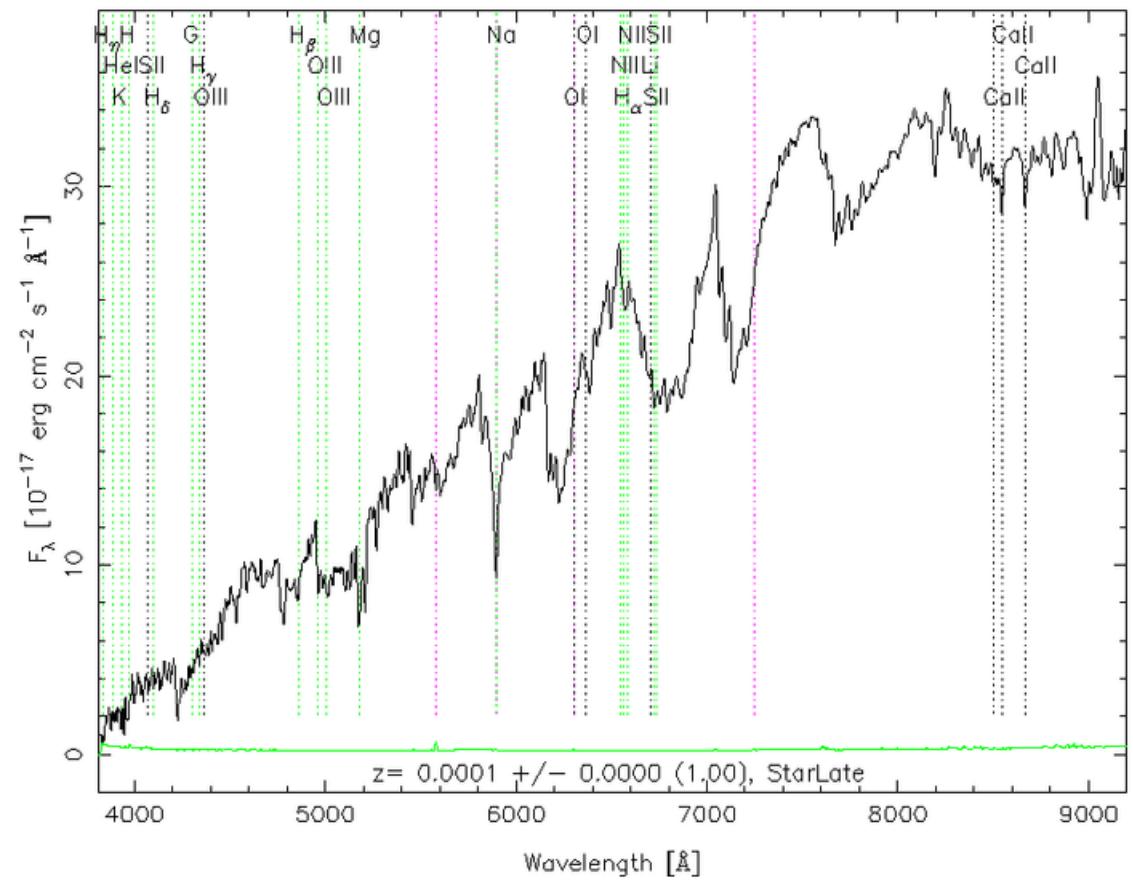


- Purely continuum with some absorption features?
- Peak toward UV, Visible, or IR?
- Contain emission features?
- Broad or narrow features?
- Any sign of stretching or shifting?

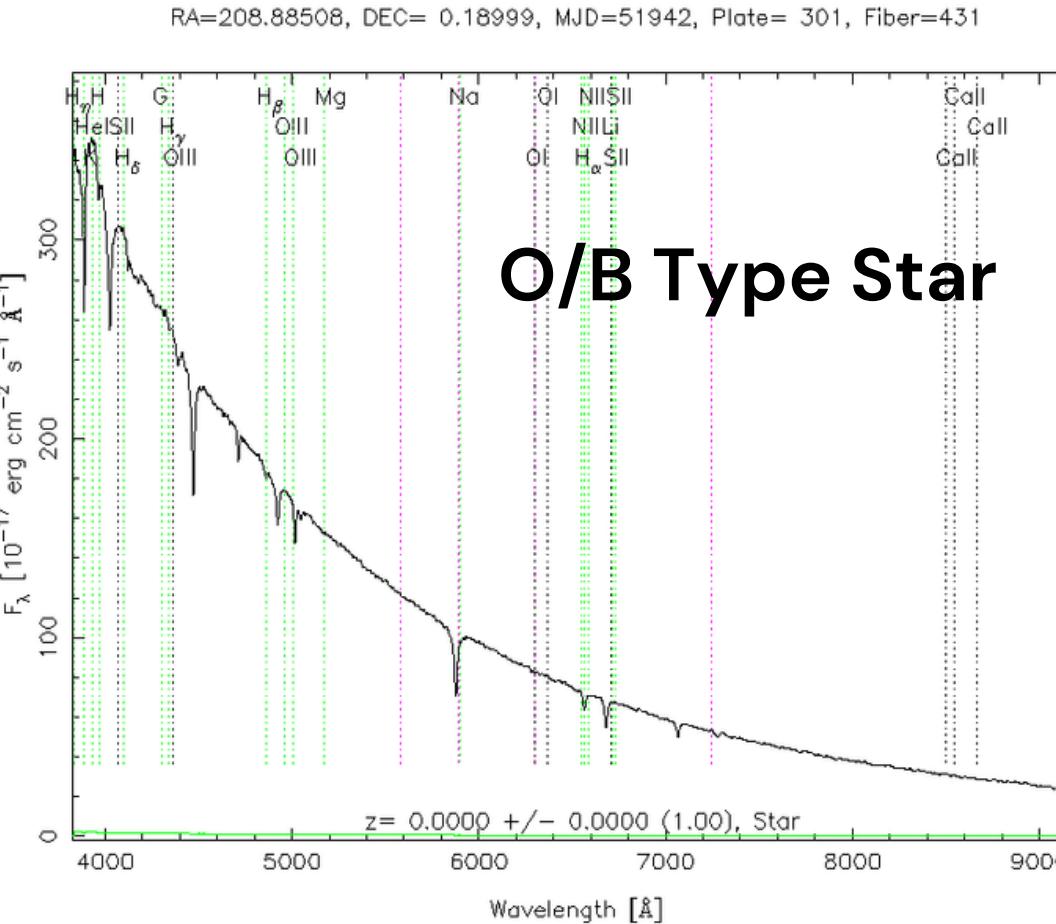
RA=156.85600, DEC=-0.09322, MJD=51957, Plate= 273, Fiber=304



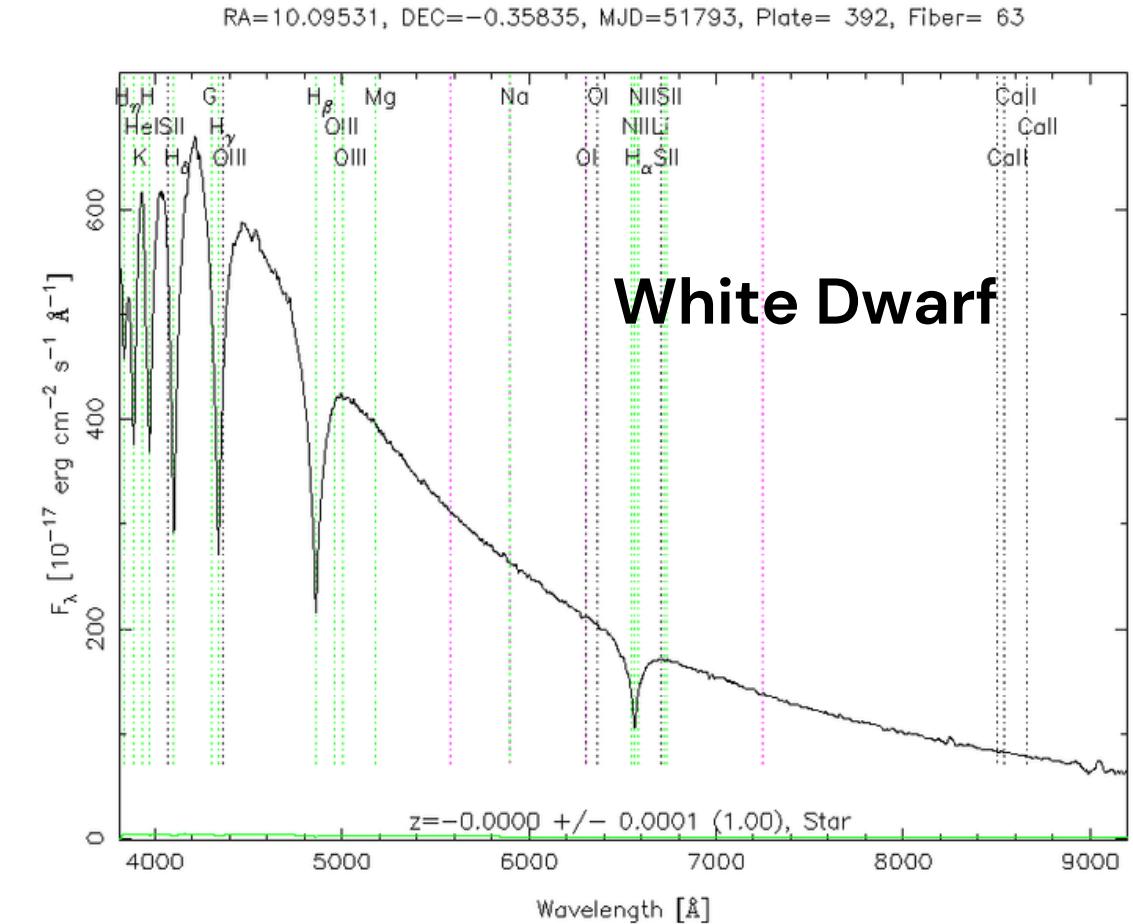
RA=27.66583, DEC=-1.13947, MJD=51793, Plate= 402, Fiber=204



What?

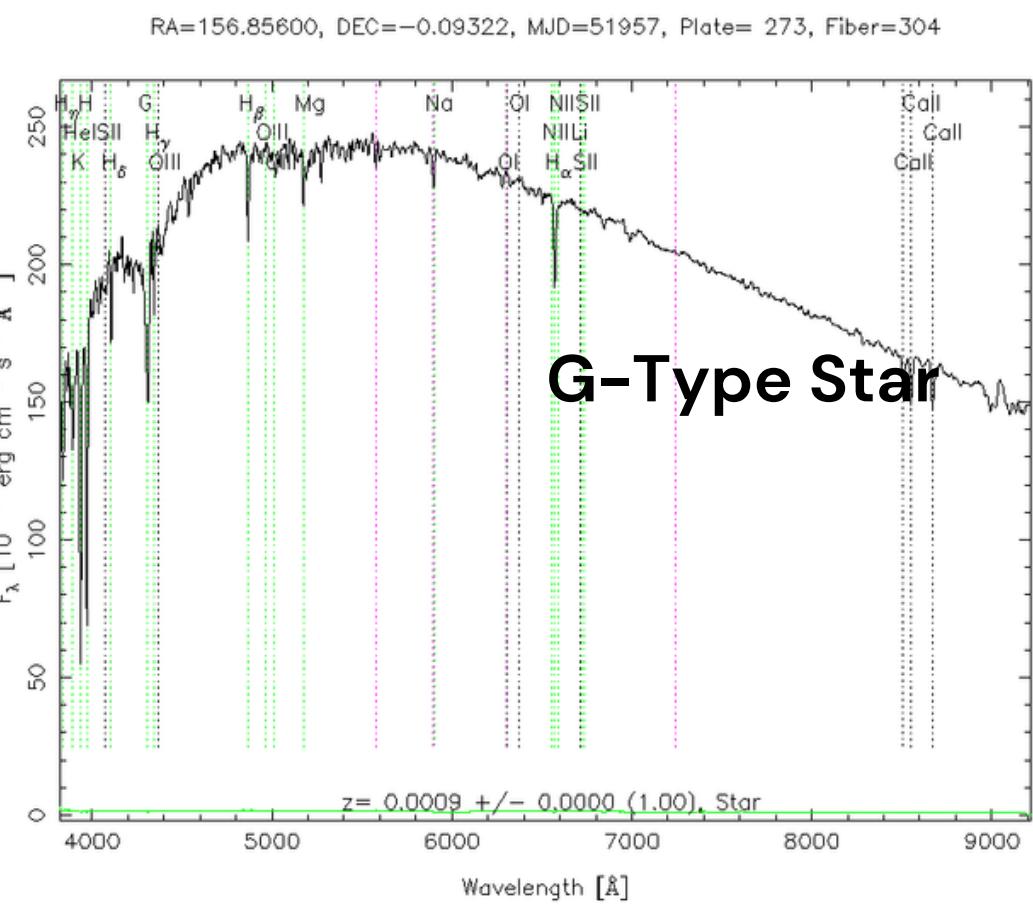


O/B Type Star

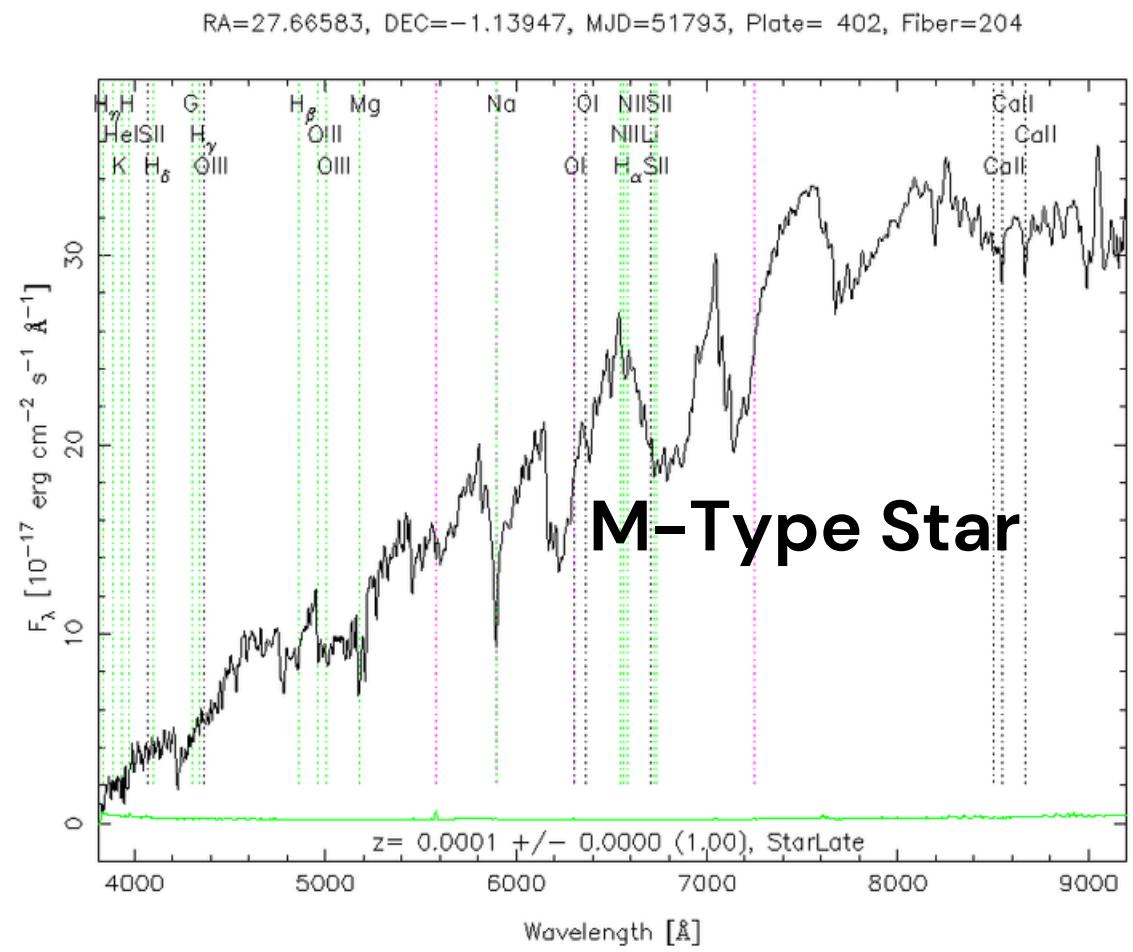


White Dwarf

- Purely continuum with some absorption features?
- Peak toward UV, Visible, or IR?
- Contain emission features?
- Broad or narrow features?
- Any sign of stretching or shifting?



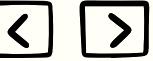
G-Type Star



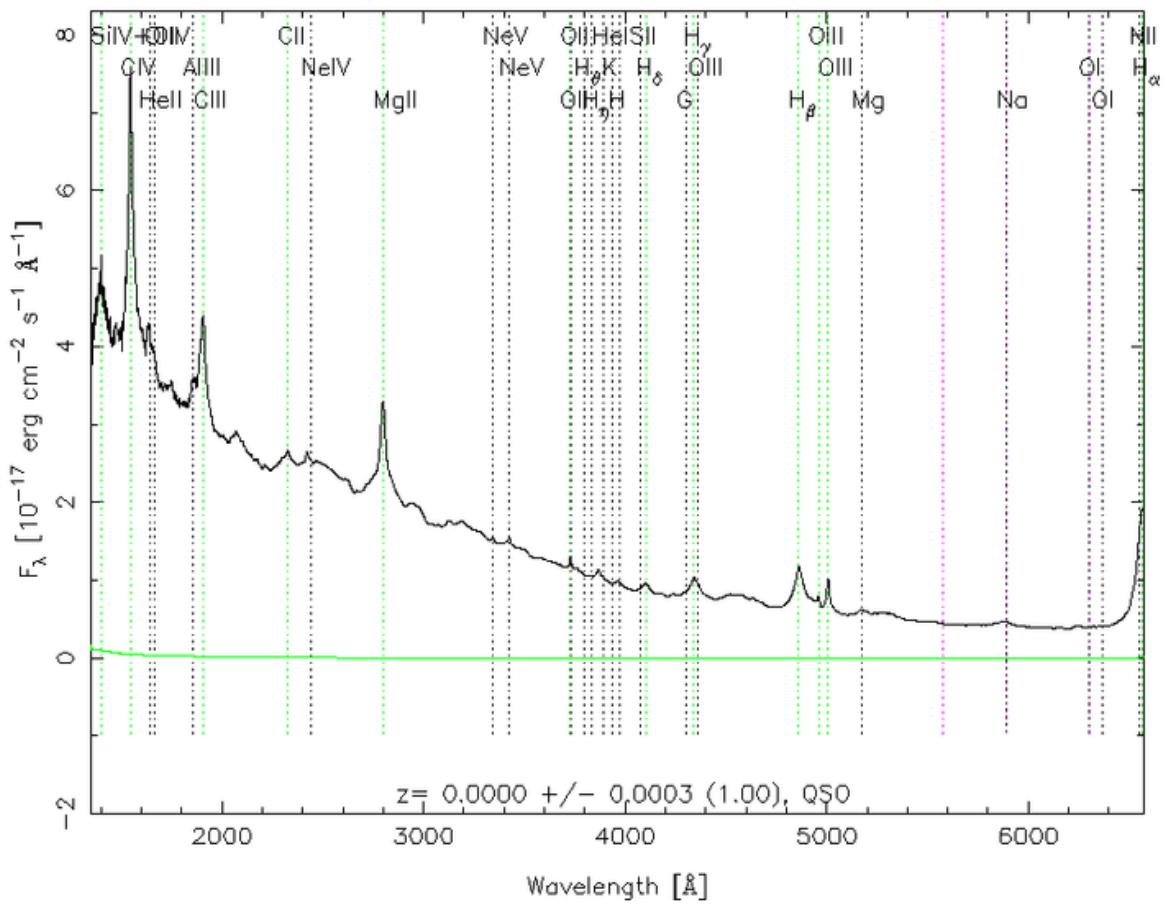
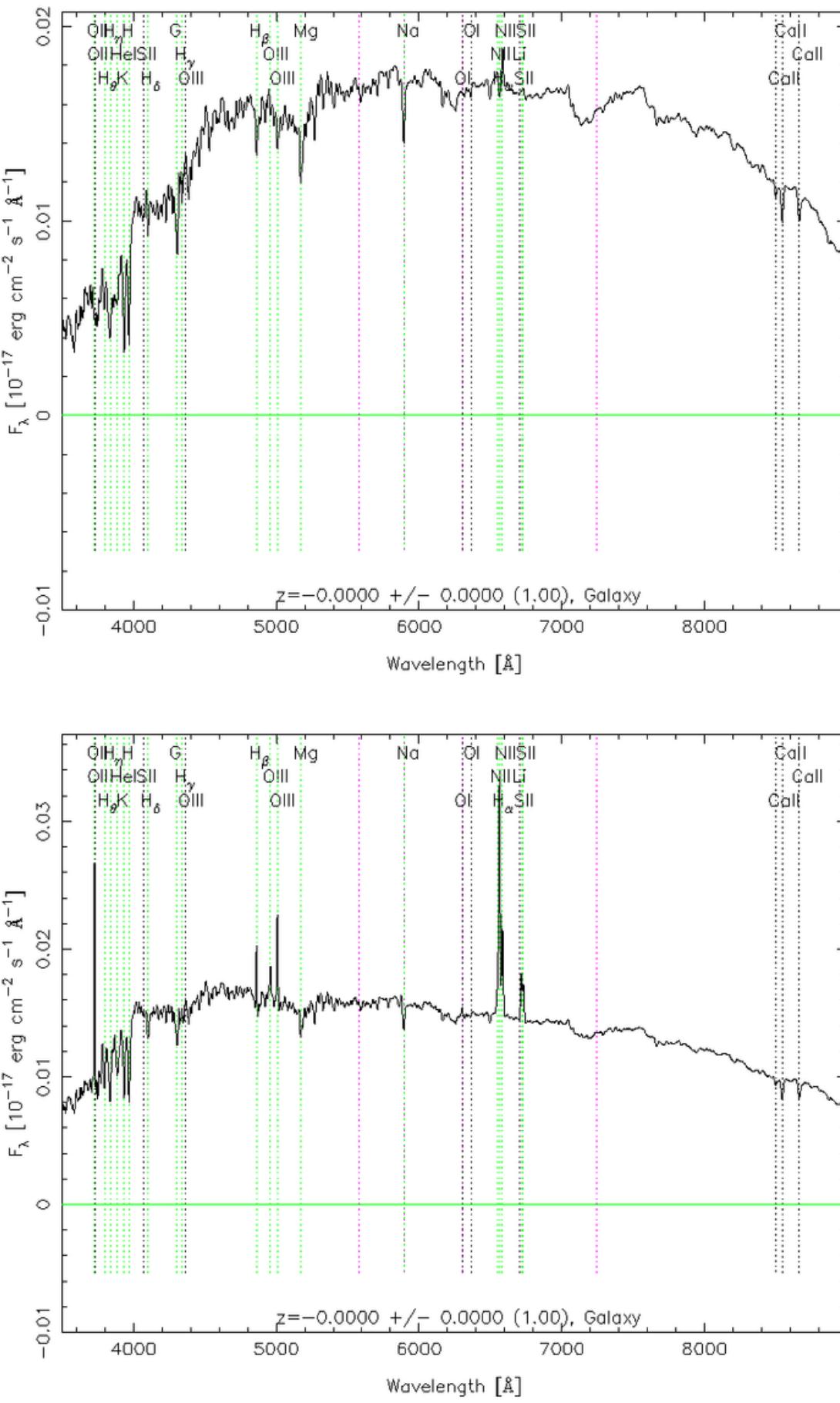
M-Type Star



What?



- Purely continuum with some absorption features?
- Peak toward UV, Visible, or IR?
- Contain emission features?
- Broad or narrow features?
- Any sign of stretching or shifting?



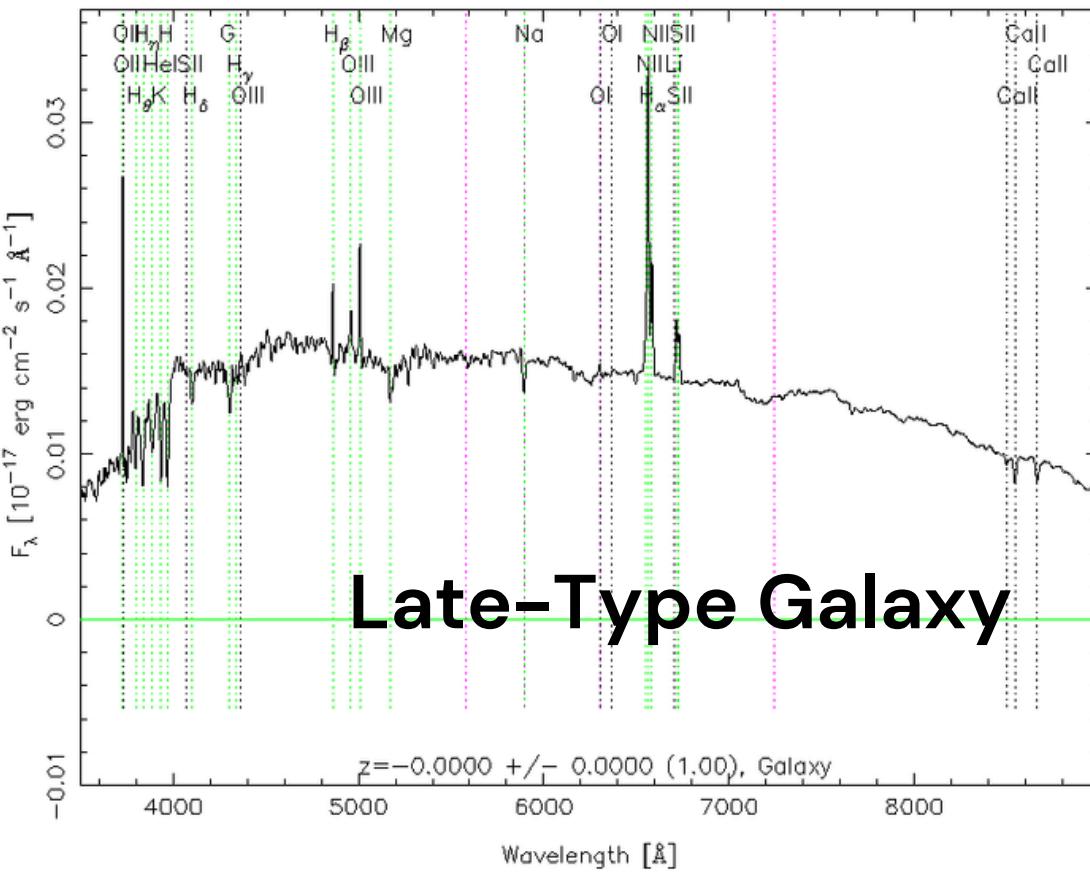
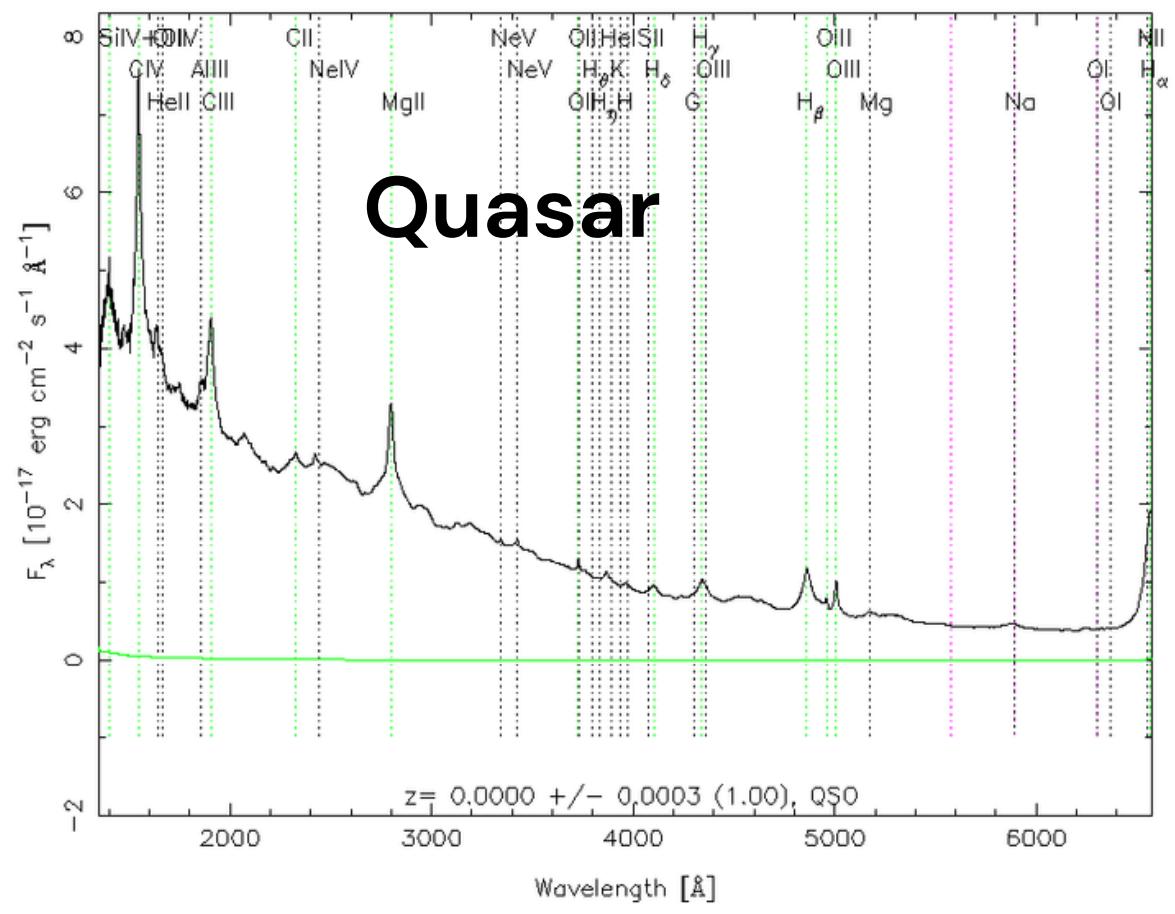
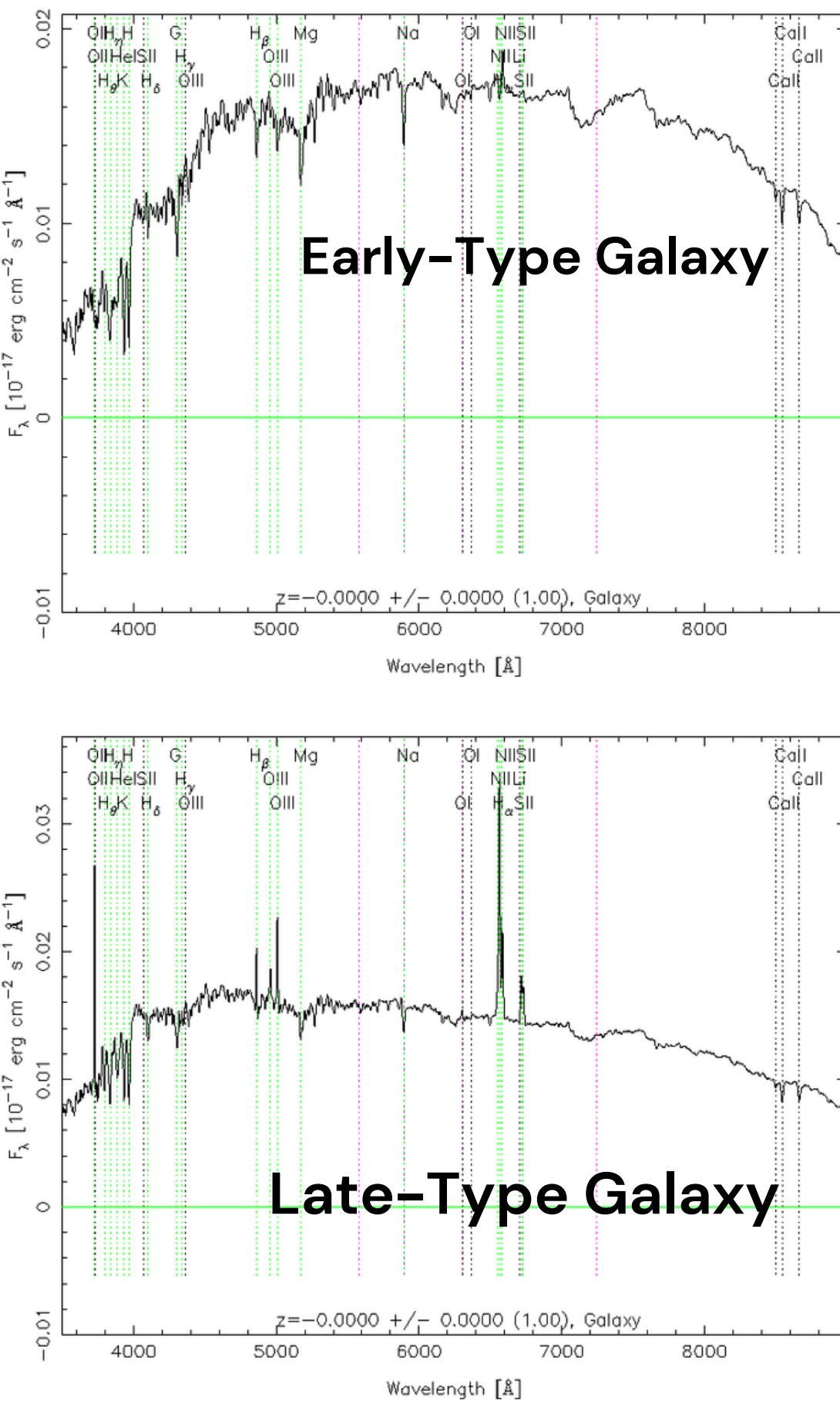
has



what?

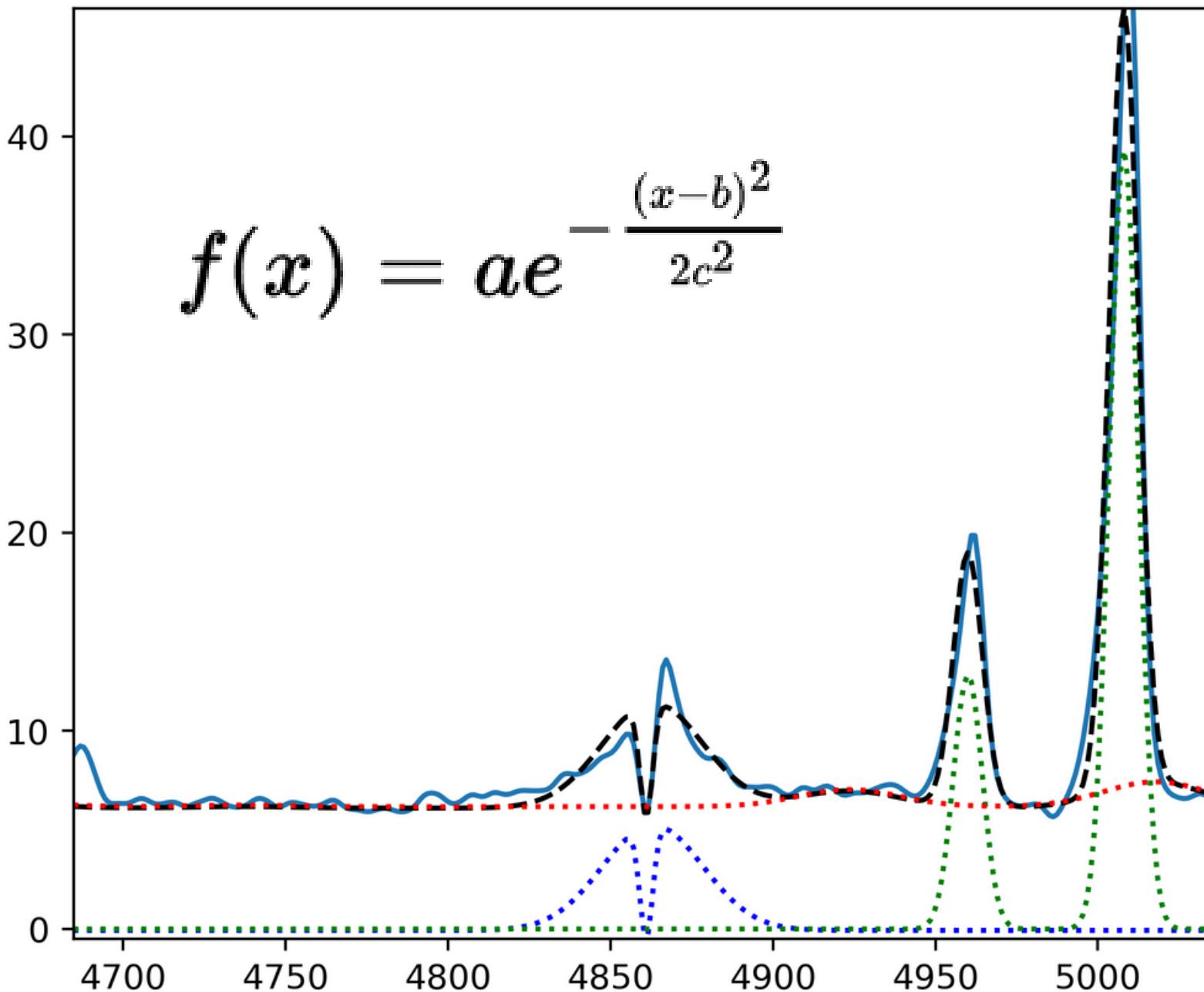
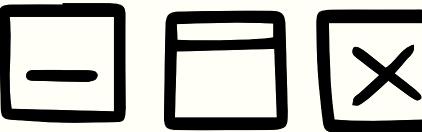


- Purely continuum with some absorption features?
- Peak toward UV, Visible, or IR?
- Contain emission features?
- Broad or narrow features?
- Any sign of stretching or shifting?



has

Gaussian Profile

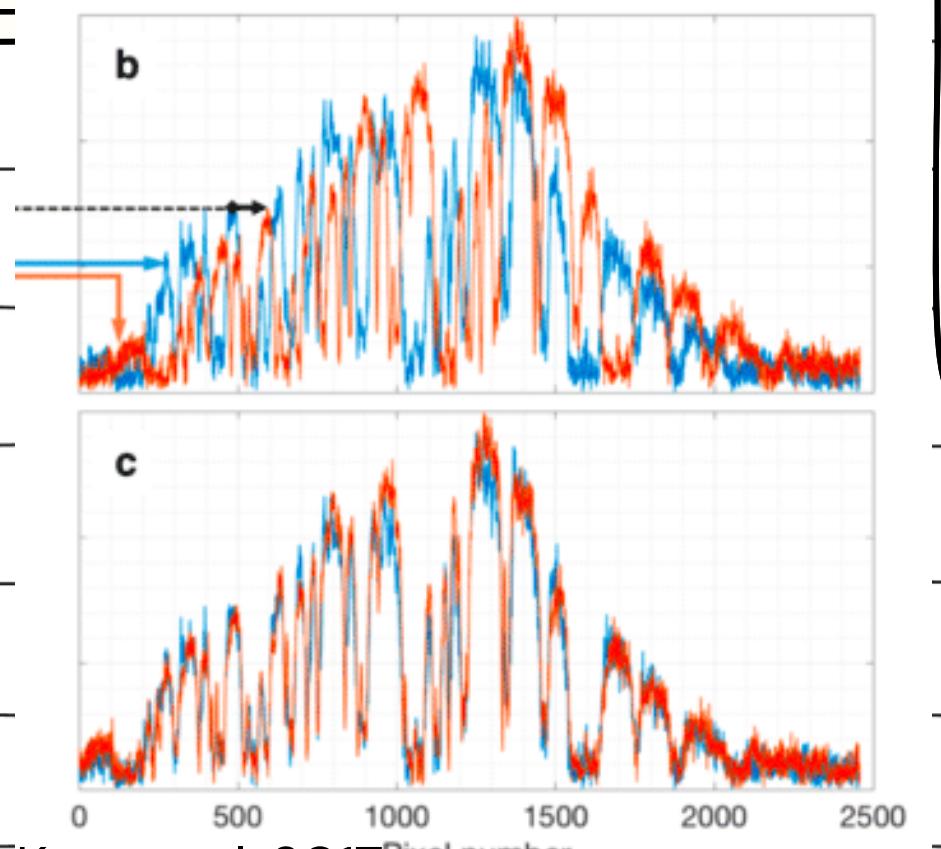


In typical cases, one can assume the emission (or absorption) features to be "Gaussian" in shape, especially if the source is dominated by thermal process (gas, star formation, symmetric stellar winds, etc.).

Redshift Determination

Emission/Absorption lines matching

- Use pure emission line locations (continuum subtracted)
- Match with redshifted locations of prominent (weighted) emission lines.



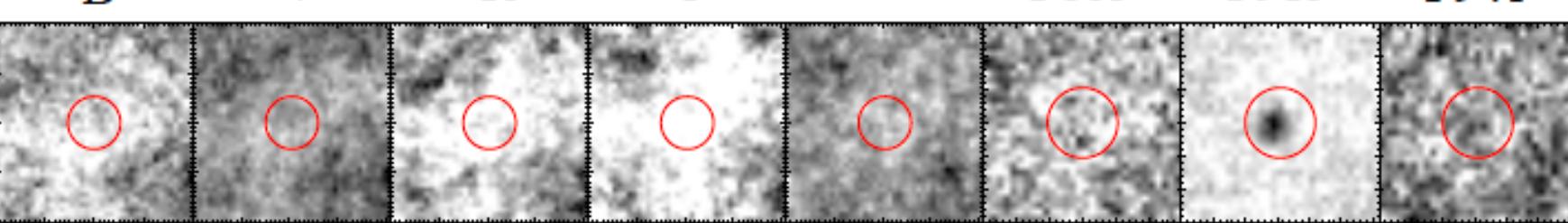
Kara et al. 2017

Template Fitting (Cross-Correlation)

- Stretch and shift "template" across redshift space
- Compute Cross-Correlation Function (CCF)
- Find the peak of CCF

Colors/ Drop Out technique

- Photo-z
- Infer redshift from photometric colors with some priors in the shape of the spectrum
- Specific features that produce dropout in some photometric bands



Line (Flux) Ratio

01

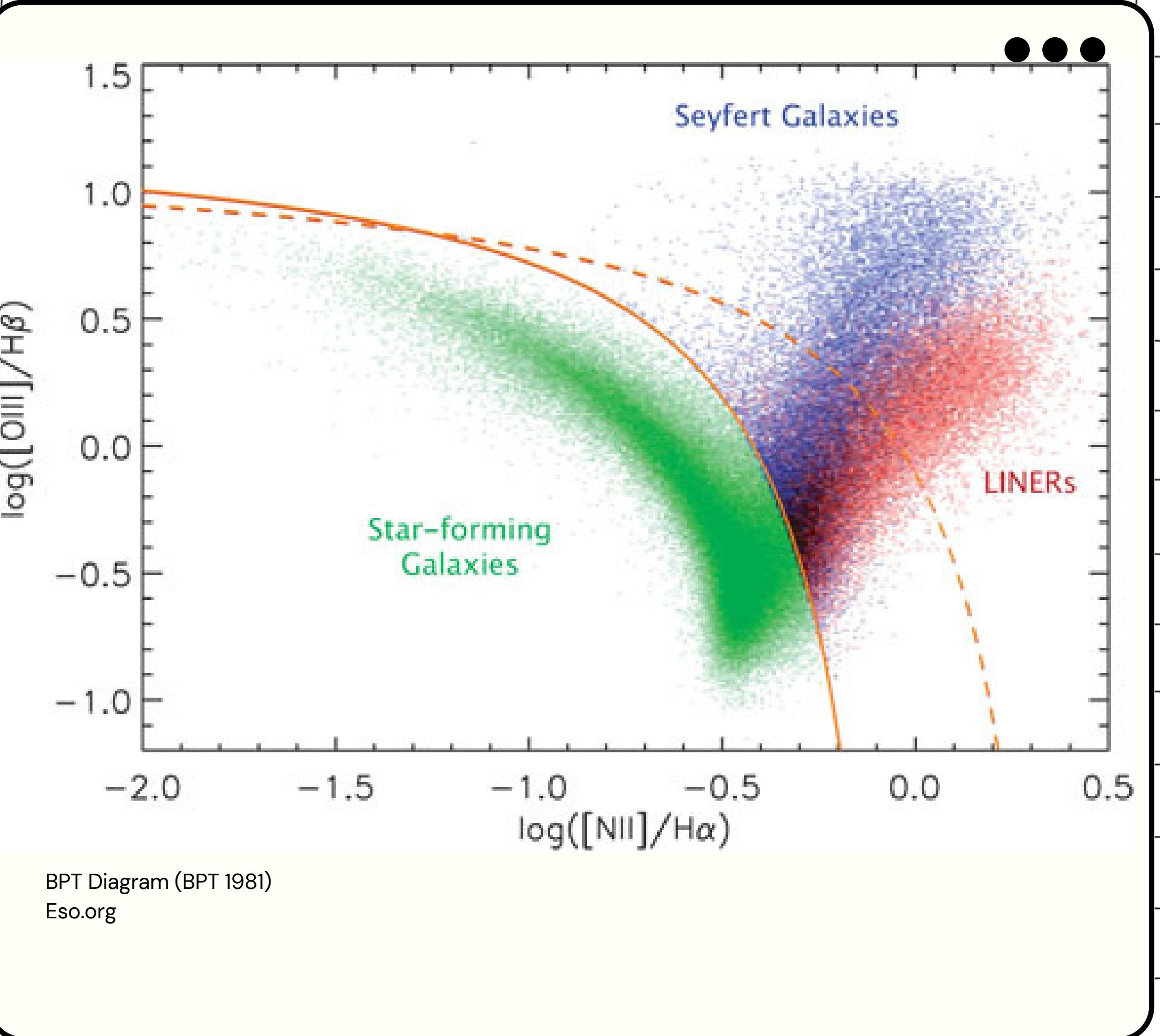
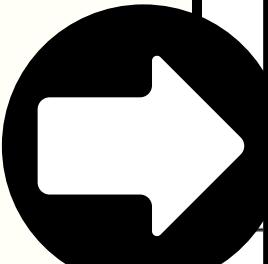
R23 ($\{[OII] + [OIII]\}/H\beta$) can be used for metallicity scaling

02

Extinction from deviation of Balmer decrement ($H\alpha/H\beta$)

03

Indication of excitation states of star-formation-like from AGN activity.



Continuum

Mostly stellar?

01

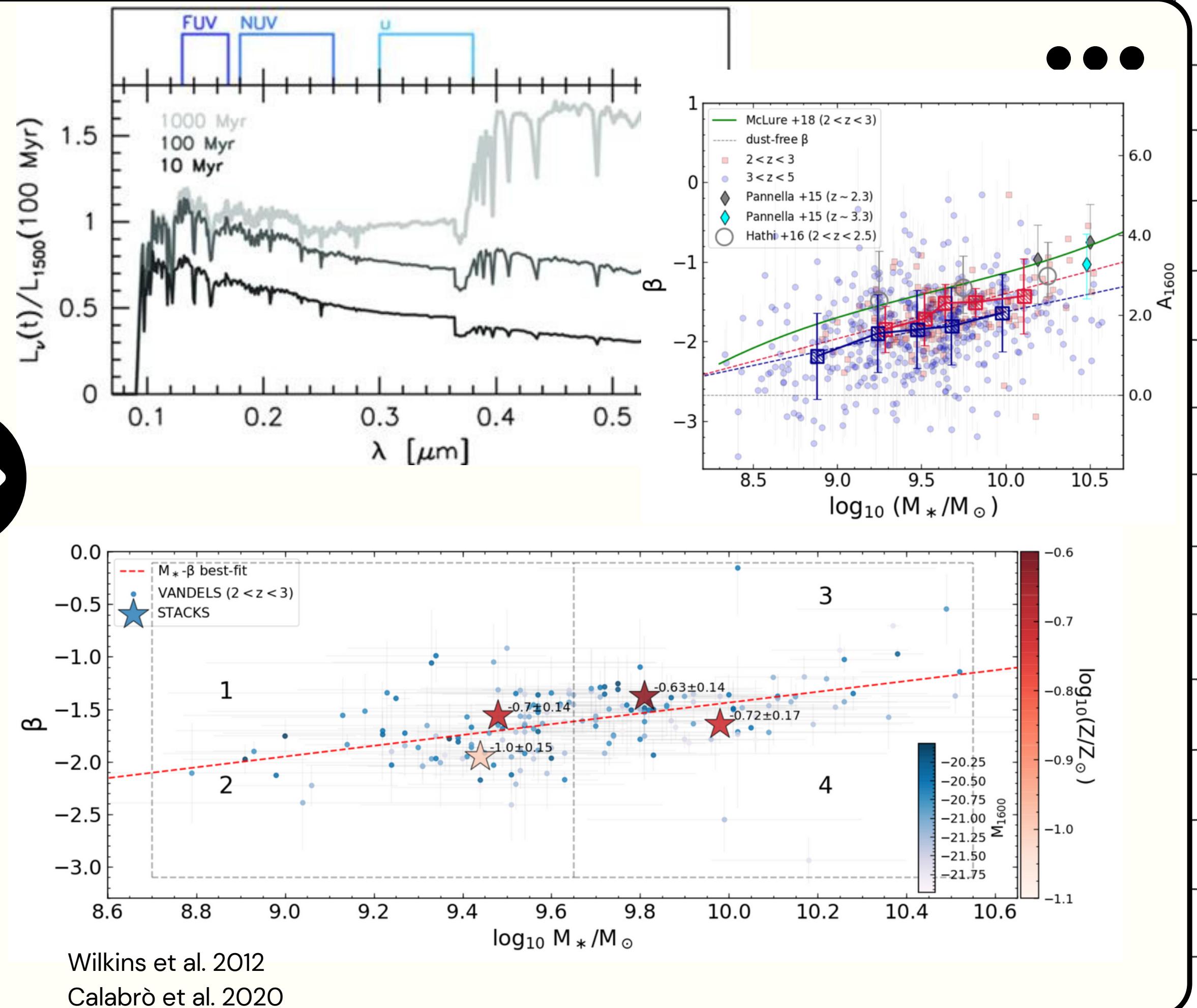
The slope of UV continuum
(Lambda~1250-1750 Angstrom)
infers stellar mass, age, metallicity,
SFR.

01

Dominated by fluxes from young
and massive stars

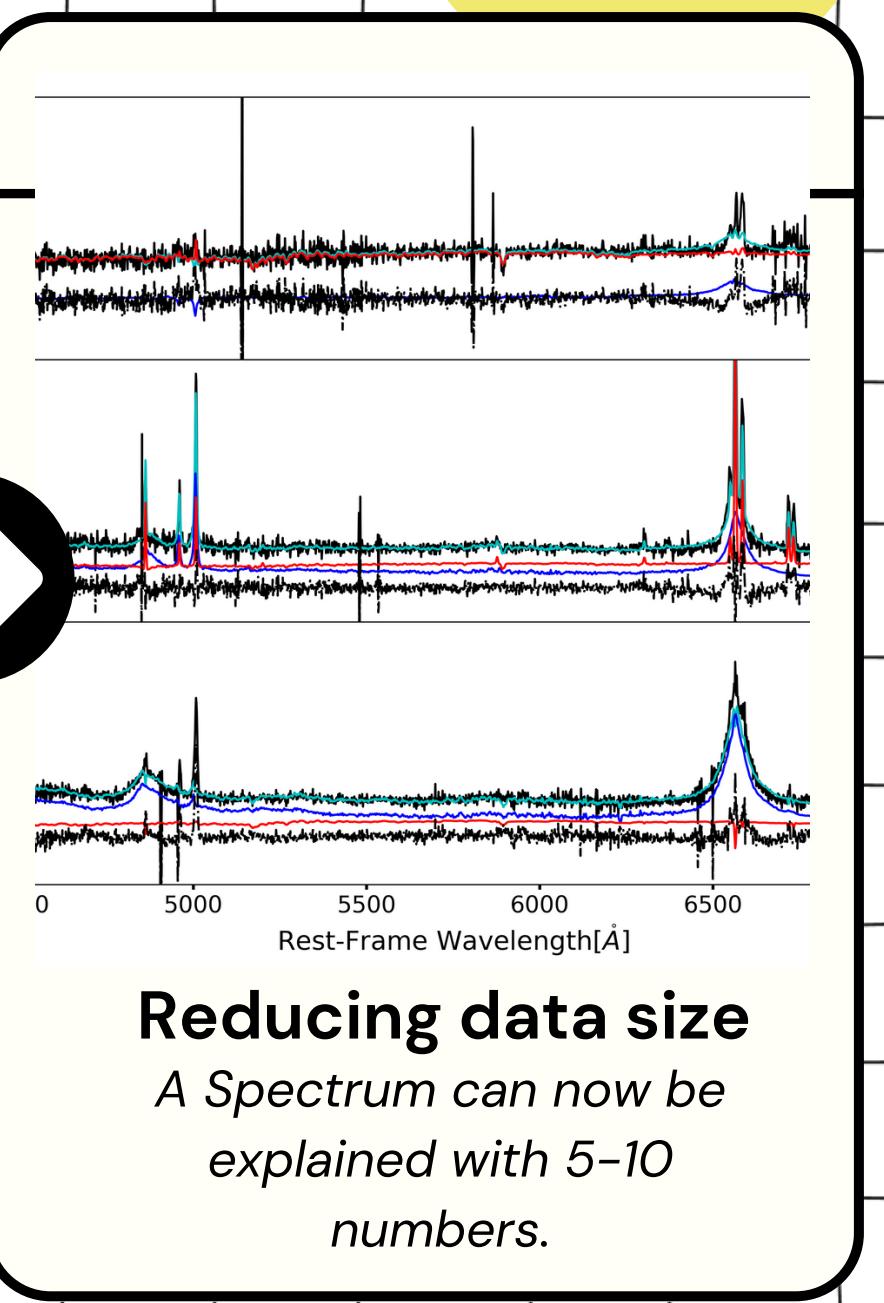
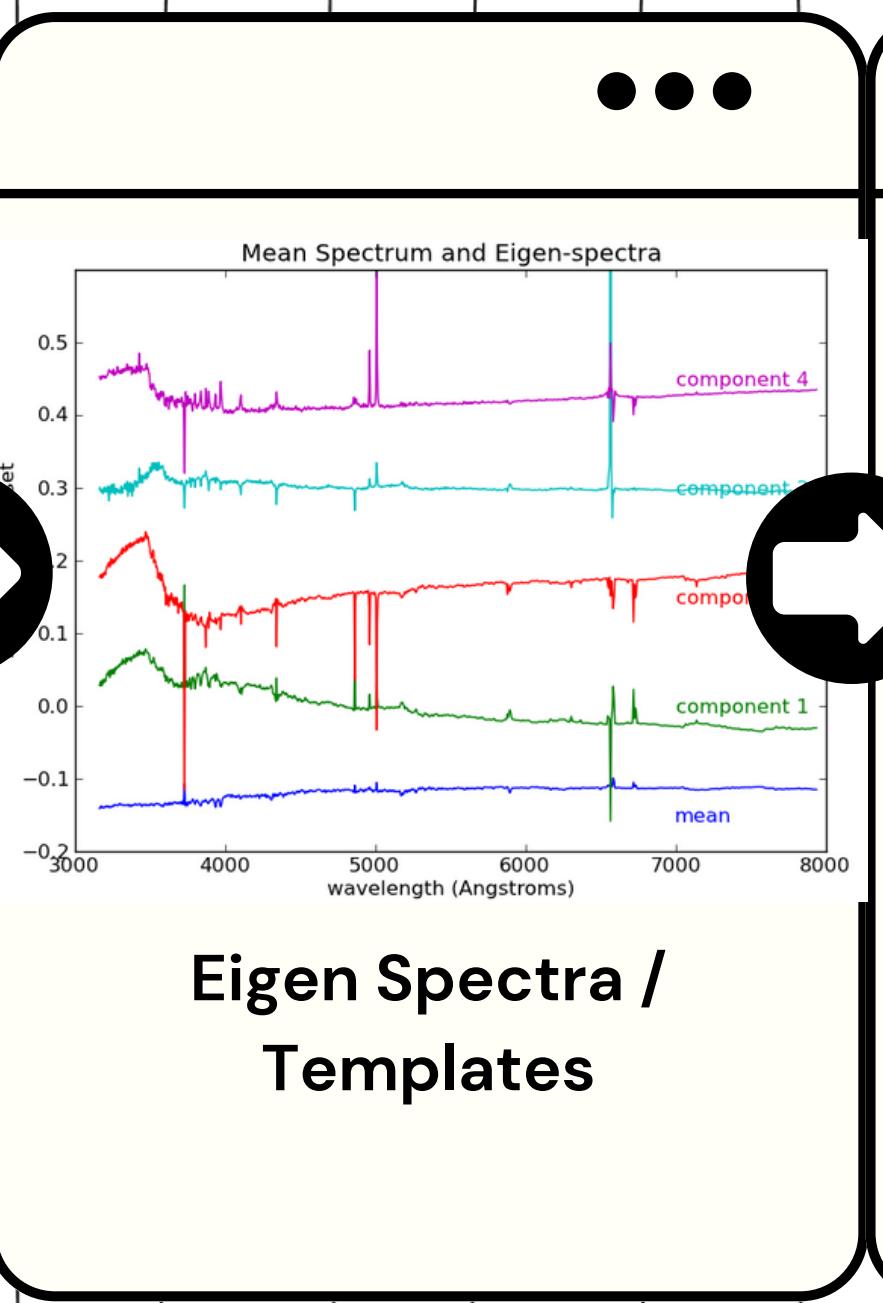
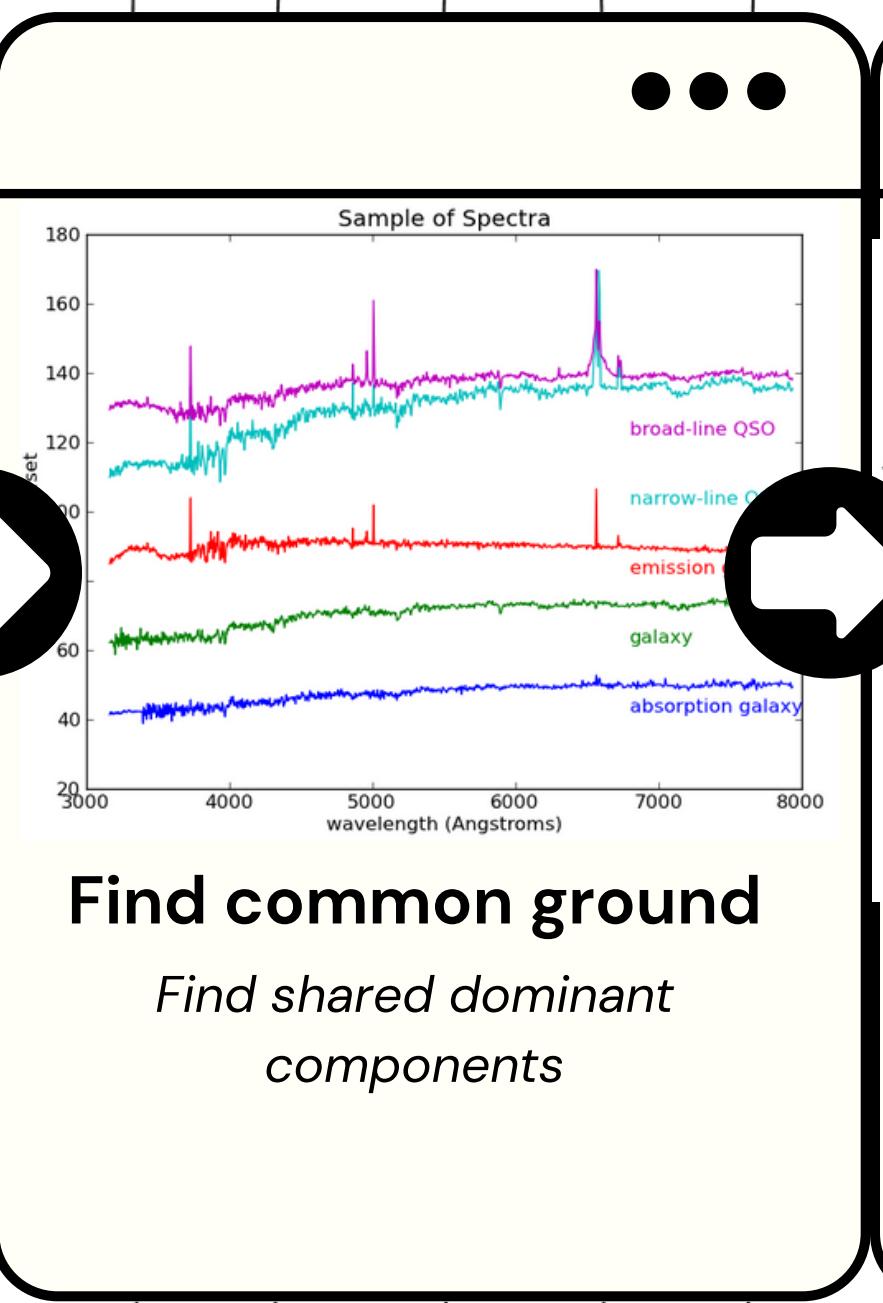
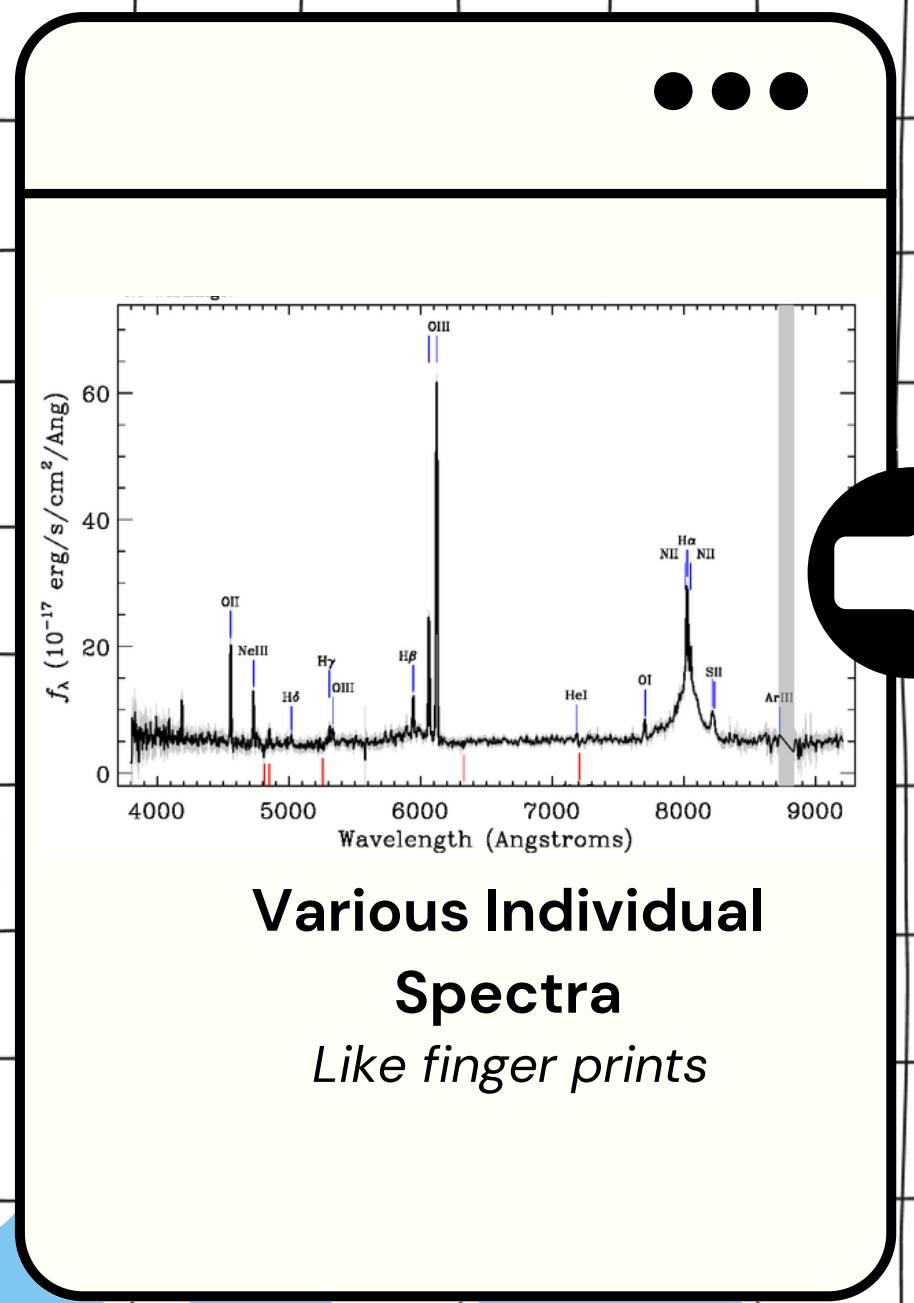
01

Low metallicity environment
tends to produce more massive
stars (top-heavy IMF)



PCA

Principle Component Analysis



Yip et al. 2004
& scikitslearn

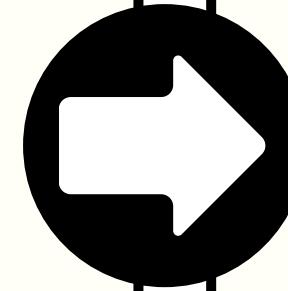
Time to get your hands dirty!

Examples of utilizing template spectra

01 Redshift Determination

02 PCA Decompositions

03 Physical Parameter Extraction



Object:
AGNs +
Galaxies

Features:
Narrow +
Broad
Emission
lines

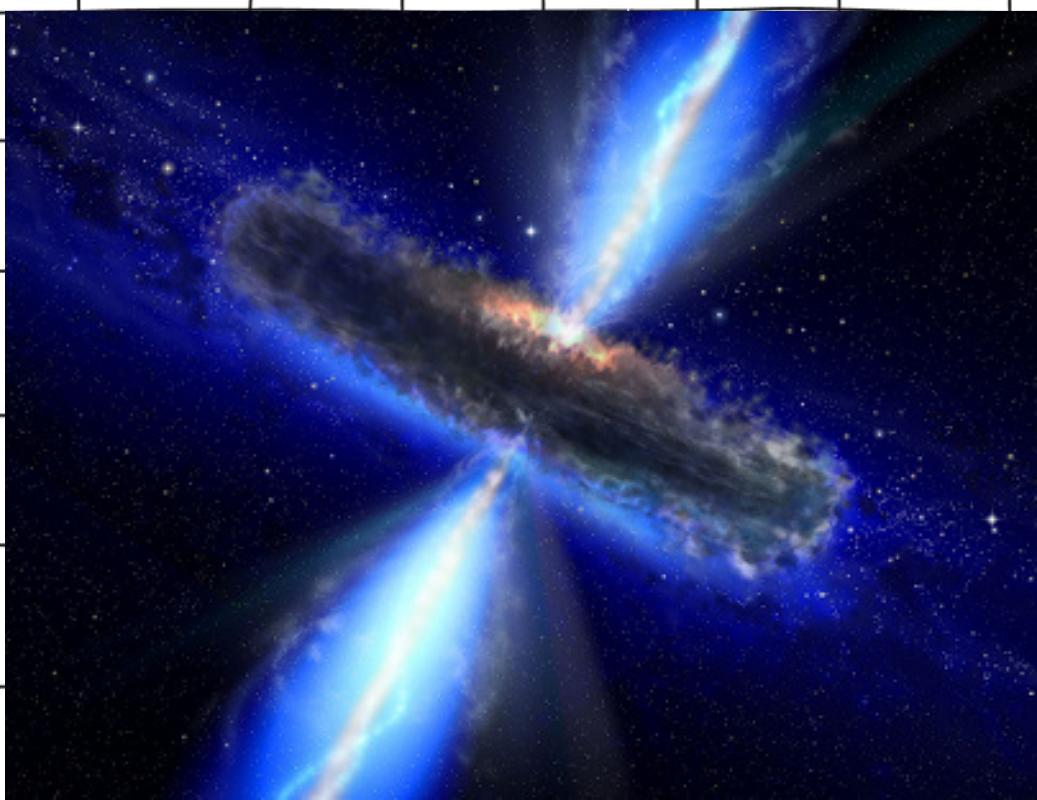
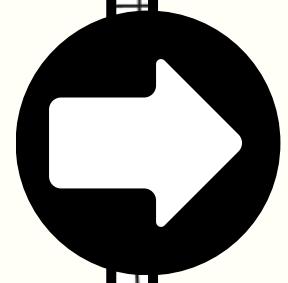
Templates:
Bright QSOs and
star-forming
galaxies

**Physical
Parameters:**
SFR, wind,
stellar mass,
redshift, BH
mass, etc.

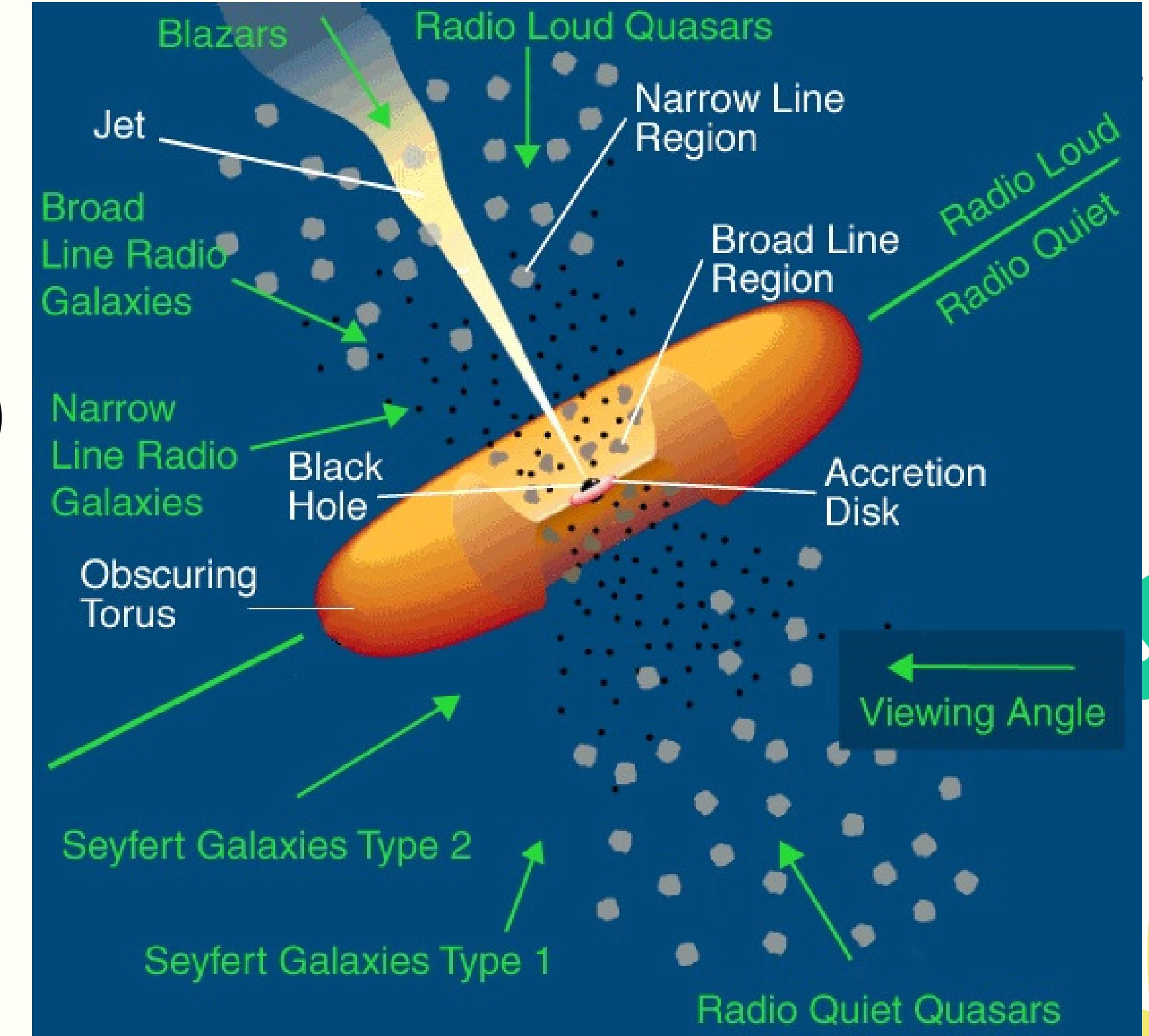


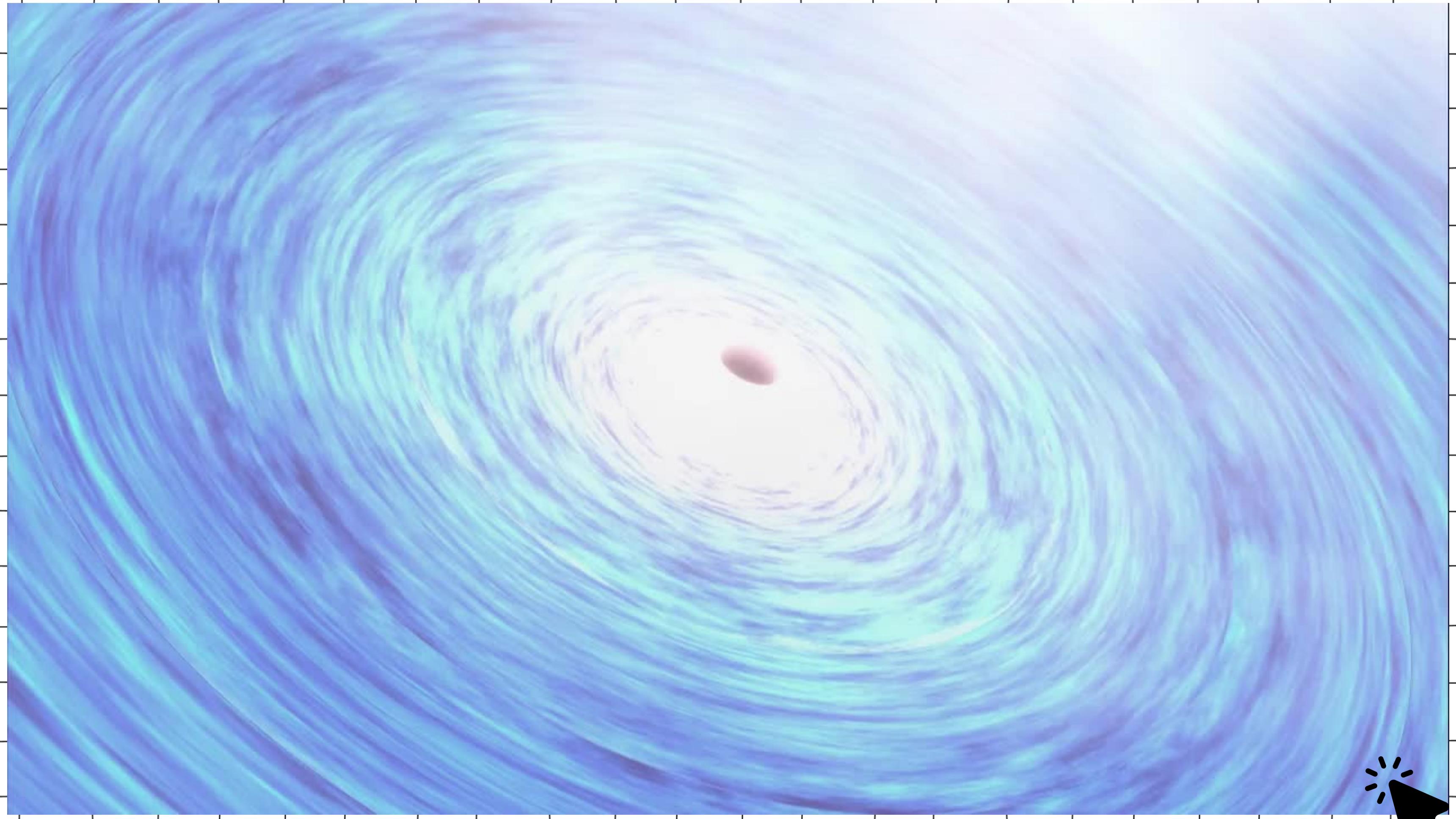
AGN (Active Galactic Nuclei)

Basics and what we thought they
"all" are (or not?)

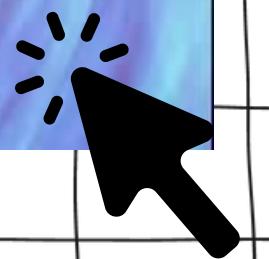


Credits: Pierre Auger Observatory
and sci.esa.int





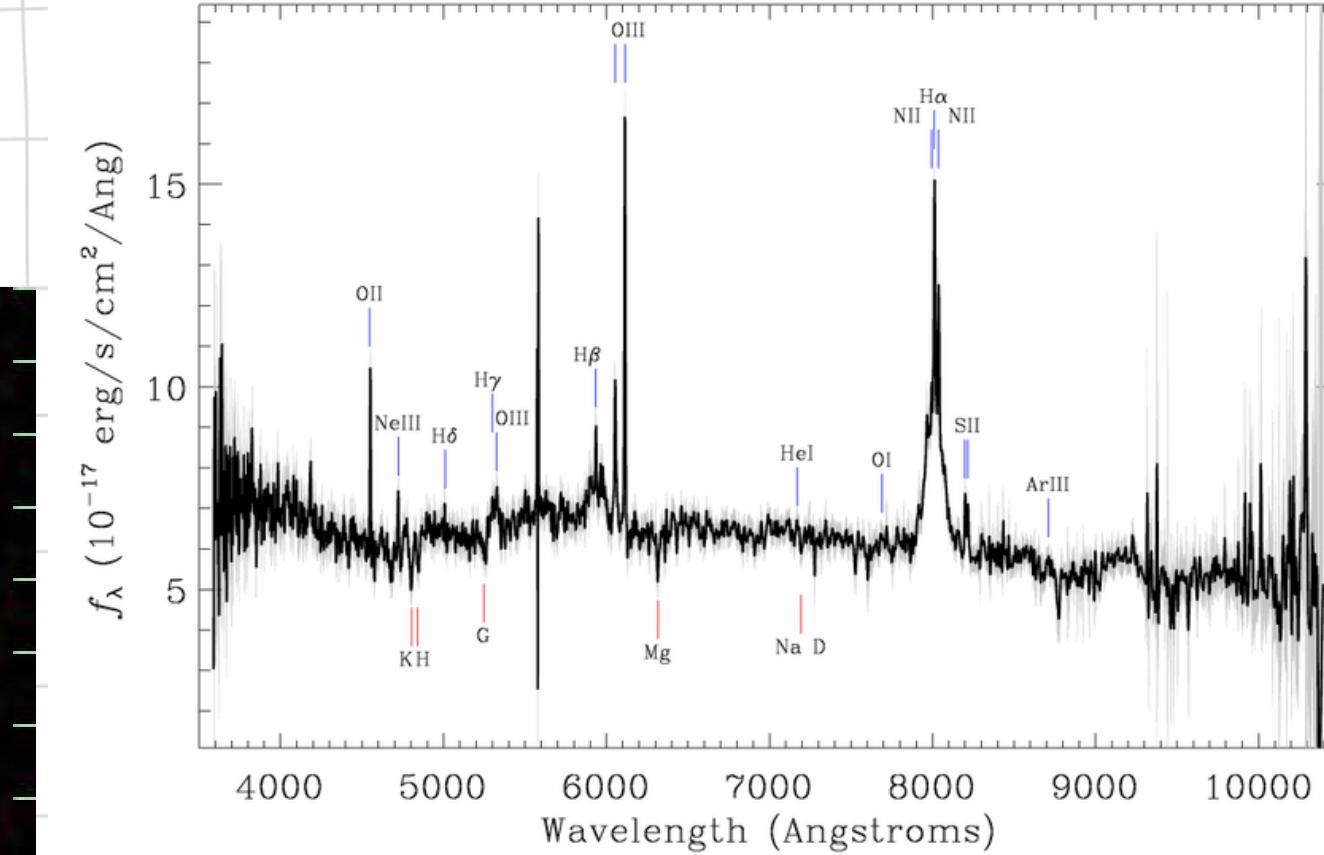
credits: <https://webbtelescope.org>



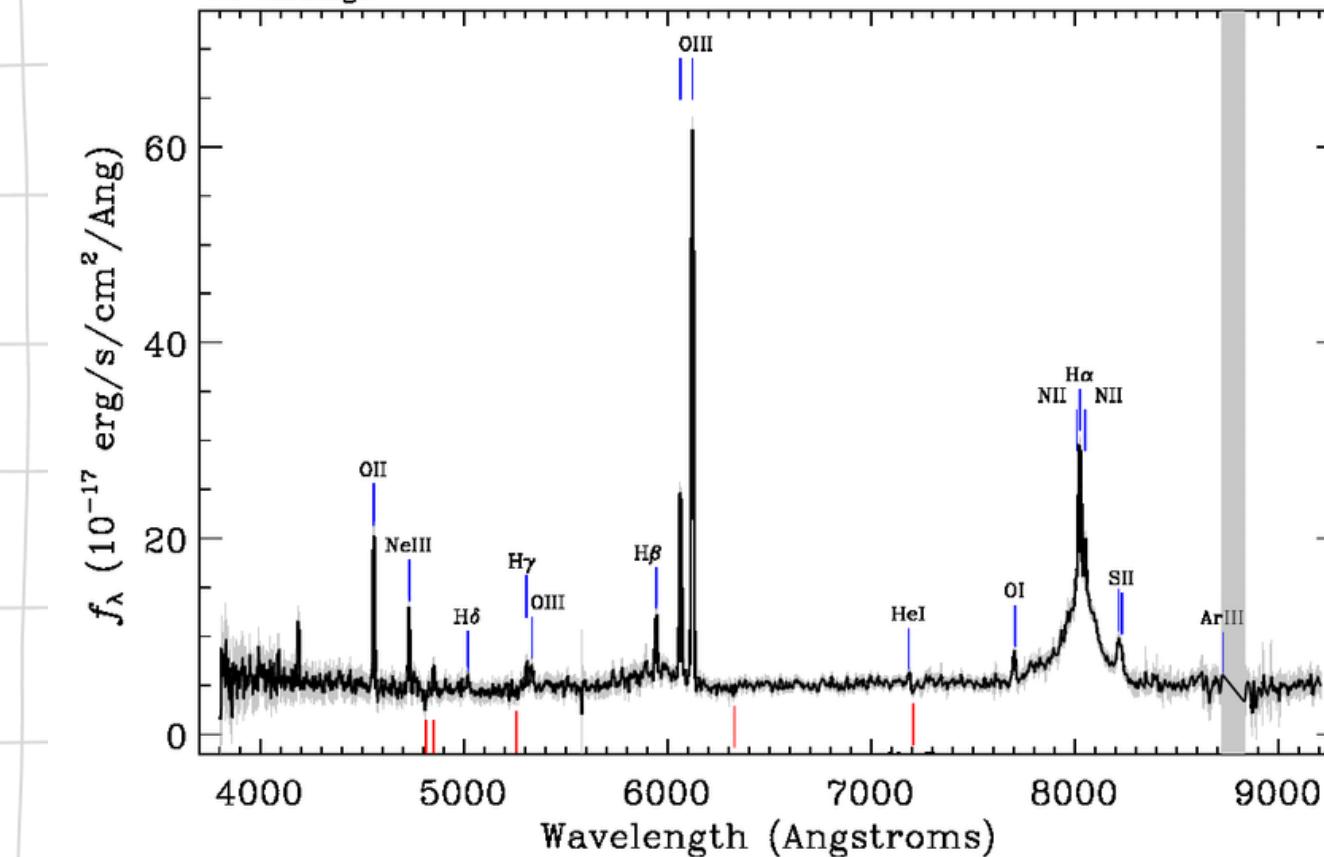
What do they look like?



Survey: *boss* Program: *boss* Target: *SN_CAL1*
RA=7.98929, Dec=0.31056, Plate=4220, Fiber=980, MJD=55447
 $z=0.22045 \pm 0.00004$ Class=QSO STARBURST BROADLINE
No warnings.

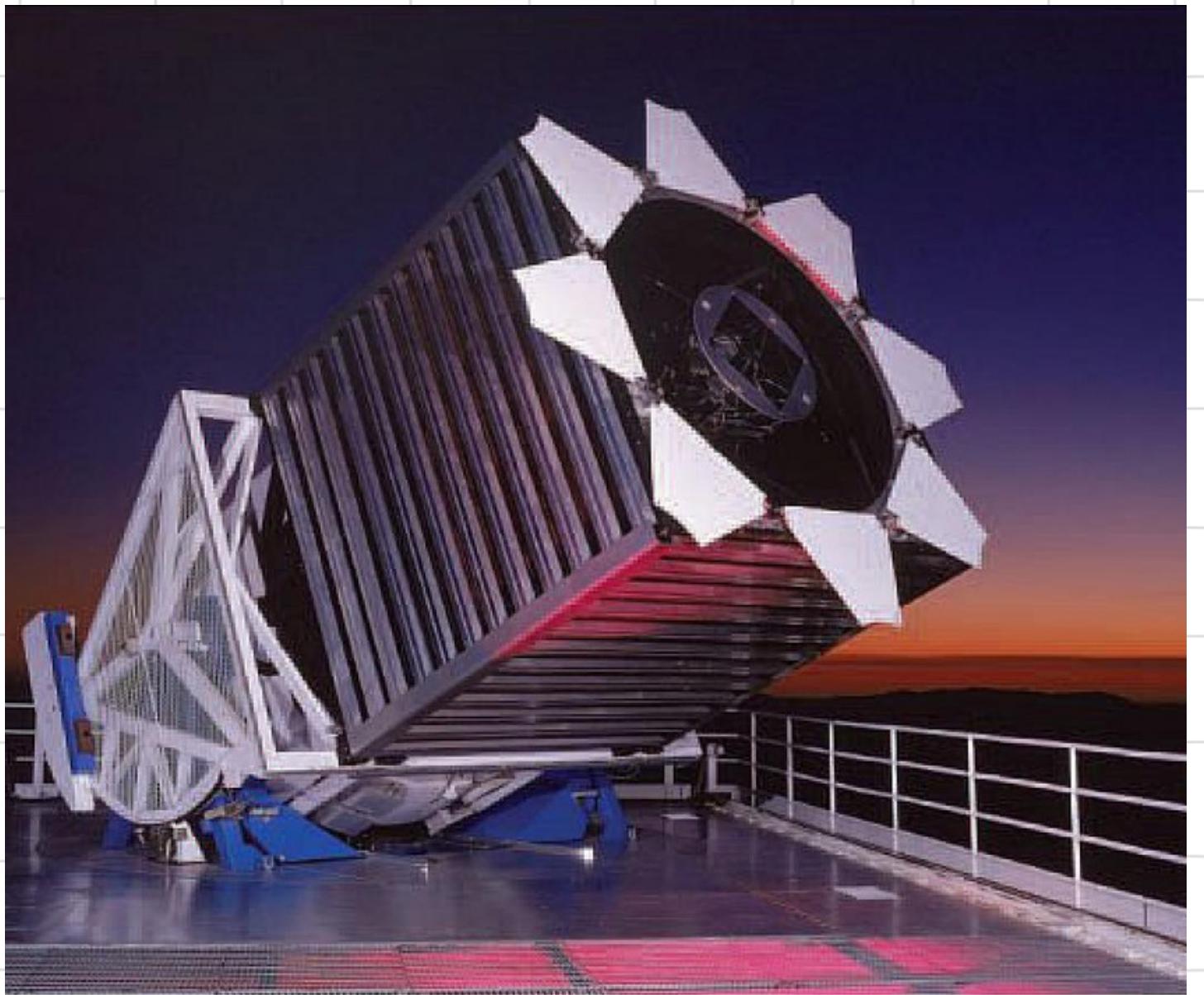


Survey: *sdss* Program: *legacy* Target: *QSO_SKIRT*
RA=139.20589, Dec=0.00877, Plate=472, Fiber=101, MJD=51955
 $z=0.22255 \pm 0.00002$ Class=QSO STARBURST BROADLINE
No warnings.



Data Samples for the Exercises!

Sloan Digital Sky Survey (DR17)



- SDSS-IV Data Release 17 (Abdurro'uf + 2022)
 - 2.5-meter telescope at Apache Point Observatory, New Mexico
 - Imaging covered 14,555 square degrees
 - PSF~1.3" (FWHM)
 - 5-sigma Depth of r~22.2 mag(AB)
 - Spectra (SDSS/BOSS/eBOSS)
 - 1.8 M galaxies
 - 1 M quasars
- Sample of >40,000 low-luminosity AGN from broad-Balmer emission lines (FWHM ~1,000-10,000 km/s) but still show extended features of host galaxies.
- Seyfert-1 Galaxies
- Select just a few (100) Seyfert galaxies with redshift < 0.5

**Just to be clear,
Not this 1D --->**

