Intro To Bagpipes with TAP

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1 Introduction

Welcome to the fascinating world of astronomical research! This document serves as a progress report for our ongoing study in astroinformatics, focusing on the practical applications of the Bagpipes library and the LSST TAP Query system.

As a new student, you may find some of the concepts and techniques discussed here to be complex, but fear not! This report is designed to guide you through the intricacies of galaxy model parametrization and data analysis in a way that is both informative and accessible.

In our research, we delve into the mysteries of galaxies, exploring various aspects such as age, mass, metallicity, and dust content, and how these parameters affect the observable properties of galaxies. By utilizing the Bagpipes library, we create and visualize different galaxy models, offering a hands-on experience in understanding the cosmos.

The LSST's TAP Query, another crucial tool in our arsenal, allows us to access and analyze astronomical data. This gives us an opportunity to apply our theoretical models to actual observations, bridging the gap between theory and practice.

Through this report, you will gain insights into the process of scientific inquiry and data analysis in astronomy. We hope that this journey not only enhances your understanding of the universe but also ignites a passion for exploring the unknown.

So, embark on this journey with an open mind and a curious spirit, and let's unravel the secrets of the universe together!

2 Objective

Work with and understand functionalities of Bagpipes library and LSST's TAP Query.

Sub-objectives

- Visualize effects of galaxy models based on a change of parameters such as age, tau, massformed, metallicity, etc.
- Utilize bagpipes using TAP query data.

3 Activities

Bagpipes Galaxy Model Parametrization

The Base Model

```
# Define the base model parameters
exp = {
    "age": 3.,
    "tau": 0.75,
    "massformed": 9.,
    "metallicity": 0.5
}

dust = {
    "type": "Calzetti",
    "Av": 0.2
}

redshift = 1.0

# Create and plot the base model
base_model = create_model(exp, dust, redshift)
fig = base_model.plot()
fig = base_model.sfh.plot()
```

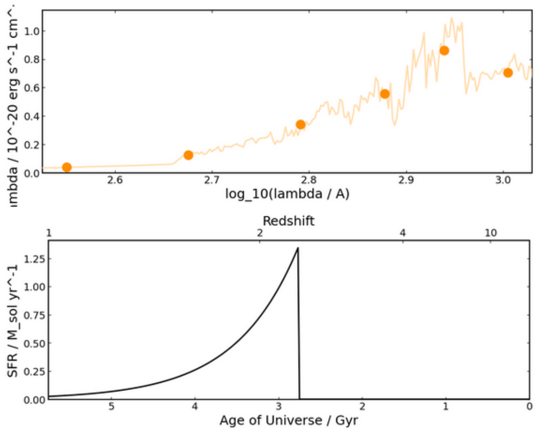

Figure 1: Base Model for Reference

This figure illustrates the base model of a galaxy using the parameters defined in the adjacent code snippet. The graphical representation depicts key characteristics like star formation history and spectral energy distribution, offering a reference point for subsequent model comparisons

Age Parametrization

```
# Young model
exp_young = exp.copy()
exp_young["age"] = 1.
create_model()
young_model.plot()
young_model.sfh.plot()
```

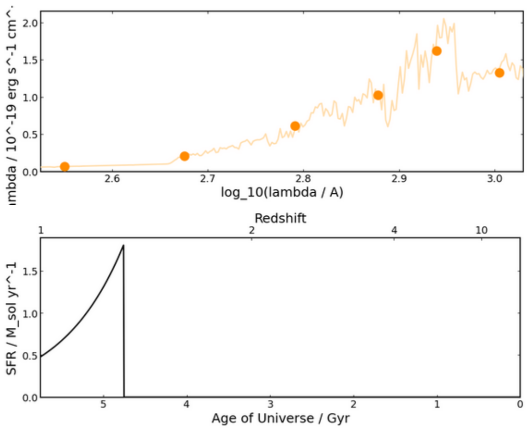

Figure 2: Young Galaxy with Age set to 1 Gyr

This figure shows a galaxy model where the age parameter is set to 1 billion years. It provides a visual comparison against the base model, highlighting how a younger galaxy's characteristics, such as its spectral energy distribution and star formation rate, differ from older models. The young age leads to notable differences in the galaxy's spectrum and SFH, such as potentially more intense star formation activity and distinct spectral characteristics compared to older galaxies.

```
# Old Model
exp_old = exp.copy()
exp_old["age"] = max_age
print(exp_old["age"])
create_model()
try:
    old_model.plot()
    old_model.sfh.plot()
except OverflowError:
    print("Adjust Params")
```

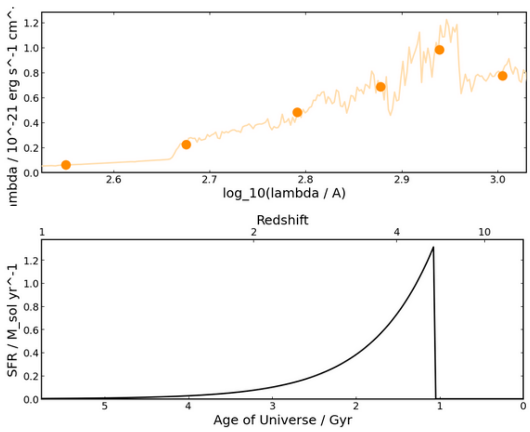

Figure 3: Old Galaxy with Age set to 80% of Universe Age

The figure represents a galaxy model with its age parameter adjusted to 80% of the age of the universe. It visualizes the impact of significant aging on the galaxy's properties, showcasing changes in both its spectral profile and star formation history. The figure shows a subdued star formation history nearing its end and a spectral energy distribution that reflects an older stellar population, possibly with fewer high-energy emissions and more redshift.

Tau Parametrization

```
# Short Tau
exp_short_tau = exp.copy()
exp_short_tau["tau"] = 0.1
create_model()
short_tau_model.plot()
short_tau_model.sfh.plot()
```

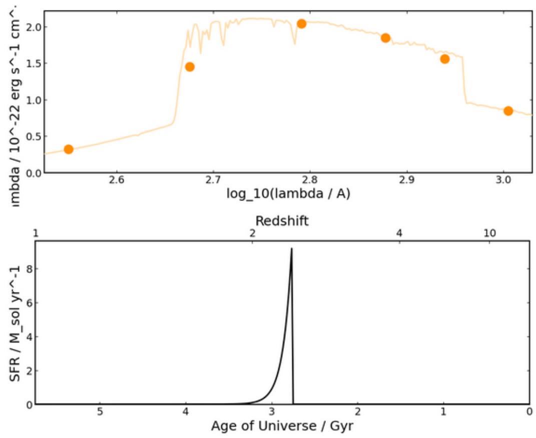

Figure 4: Galaxy with Tau of 0.1

Here, the galaxy model is modified with a short tau value of 0.1. The figure illustrates the effect of this low optical depth on the galaxy's spectrum and star formation history, offering insights into the role of tau in galactic evolution. The low tau value affects the shape of the SFH curve, leading to a steep rise and fall in star formation rates. This parameter setting also influences the galaxy's spectral profile, potentially showing less pronounced long-wavelength emissions.

```
# Long Tau
exp_long_tau = exp.copy()
exp_long_tau["tau"] = 2.
create_model()
long_tau_model.plot()
long_tau_model.sfh.plot()
```

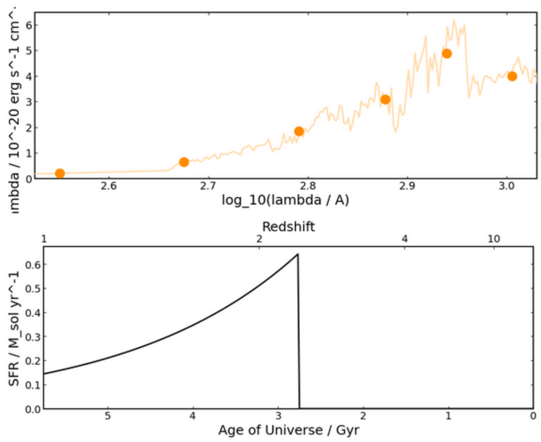

Figure 5: Galaxy with Tau of 2

This figure displays a galaxy model with a long tau value of 2. It contrasts with the short tau model, providing a visual understanding of how higher optical depth influences the galaxy's spectral characteristics and star formation rate. The extended tau results in a more stretched SFH curve with a slower decline in star formation rates.

Mass Parametrization

```
# Low Mass
exp_low_mass = exp.copy()
exp_low_mass["massformed"] =
create_model()
low_mass_model.plot()
low_mass_model.sfh.plot()
```

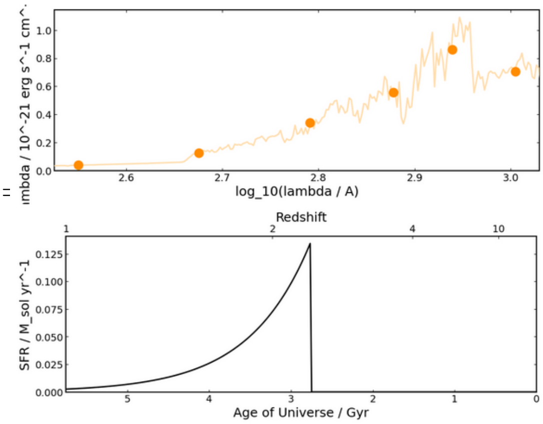

Figure 6: Galaxy with Low Mass

In this figure, the galaxy model is presented with a low mass parameter. It demonstrates how a reduction in galactic mass affects the observable properties of the galaxy, particularly in terms of its spectrum and star formation history. The lower mass could result in a less intense star formation history and a possibly weaker overall spectral output.

```
# High Mass
exp_high_mass = exp.copy()
exp_high_mass["massformed"]
create_model()
high_mass_model.plot()
high_mass_model.sfh.plot()
```

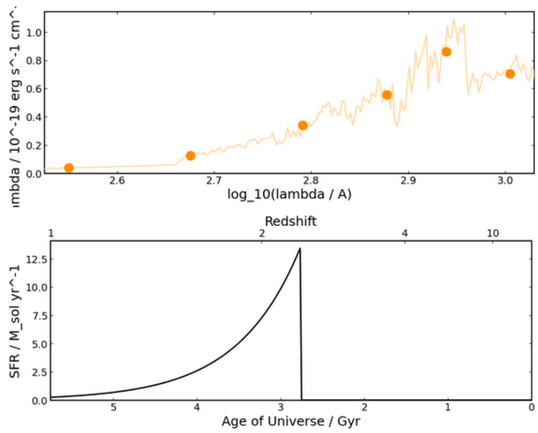

Figure 7: Galaxy with High Mass

This figure portrays a galaxy model with a high mass parameter. It serves as a counterpoint to the low mass model, illustrating the impact of increased mass on the galaxy's spectral energy distribution and star formation rate. The higher mass typically leads to a more robust star formation history.

Metallicity Parametrization

```
# Low Metallicity
exp_low_metal = exp.copy()
exp_low_metal["metallicity"
create_model()
low_metal_model.plot()
low_metal_model.sfh.plot()
```

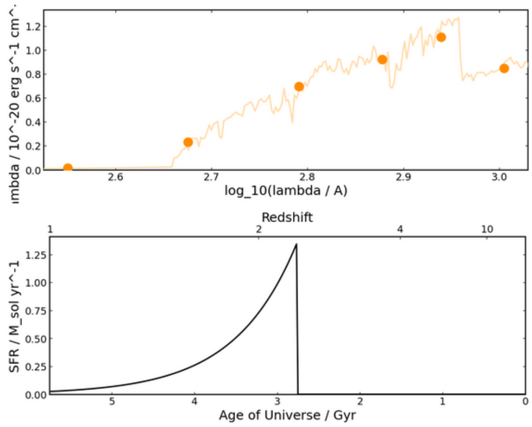

Figure 8: Galaxy with Low Metallicity of 0.1

The figure shows a galaxy model with a low metallicity value of 0.1. It visually explores how metallicity, particularly at lower levels, can influence a galaxy's spectral characteristics and star formation history. This potentially results in a spectral energy distribution that favors shorter wavelengths

```
# High Metallicity
exp_high_metal = exp.copy()
exp_high_metal["metallicity'
create_model()
high_metal_model.plot()
high_metal_model.sfh.plot()
```

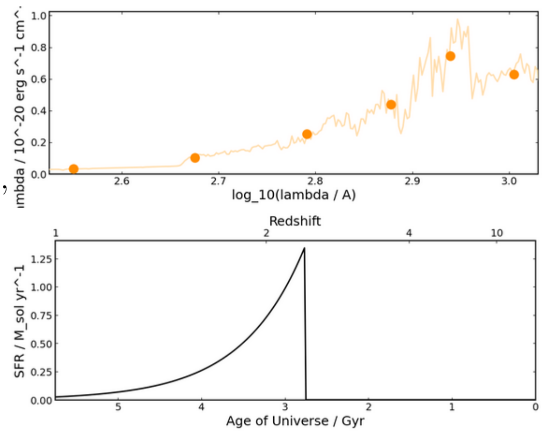

Figure 9: Galaxy with High Metallicity of 1

This figure presents a galaxy model with a high metallicity value of 1. It contrasts with the low metallicity model, offering insights into the effects of higher metallicity on galactic properties like spectrum and star formation. The increased metallicity can lead to more complex light absorption and re-emission processes reducing the prevelance of short wavelengths.

Dust Parametrization

```
# Low Dust
dust_low = dust.copy()
dust_low["Av"] = 0.1
create_model()
low_dust_model.plot()
low_dust_model.sfh.plot()
```

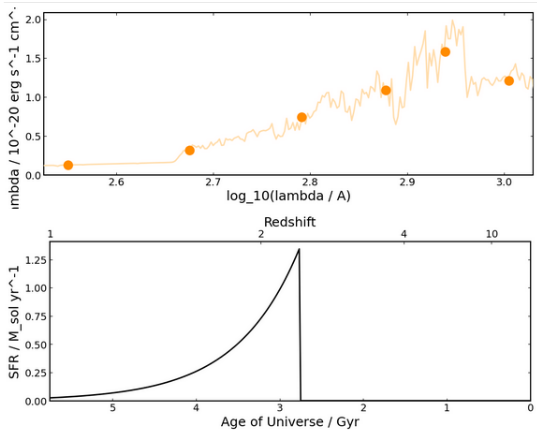

Figure 10: Galaxy with Low Av Dust

In this figure, the galaxy model is altered to have a low dust content. It illustrates the influence of reduced dust on the galaxy's spectrum and star formation, highlighting the role of interstellar dust in galactic evolution. Reduced dust content affects the light absorption and scattering within the galaxy, likely leading to a spectral profile with more pronounced shorter wavelengths as dust obscuration is minimized.

```
# High Dust
dust_high = dust.copy()
dust_high["Av"] = 1.
create_model()
high_dust_model.plot()
high_dust_model.sfh.plot()
```

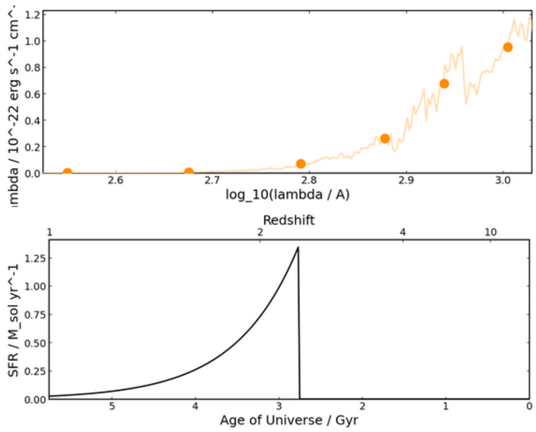

Figure 11: Galaxy with High Av Dust

The figure depicts a galaxy model with high dust content. It contrasts with the low dust model, showcasing how increased dust affects the galaxy's observable properties, such as its spectral energy distribution and star formation history. Increased dust can significantly scatter and absorb light, especially at shorter wavelengths, leading to a spectral profile that might be dominated by longer wavelengths.

There are many kinds of dust, this parametrization focuses on 'Calzetti' Dust.

Redshift Parametrization

```
# Low Redshift
redshift = 0.5
create_model()
low_redshift_model.plot()
low_redshift_model.sfh.plot
```

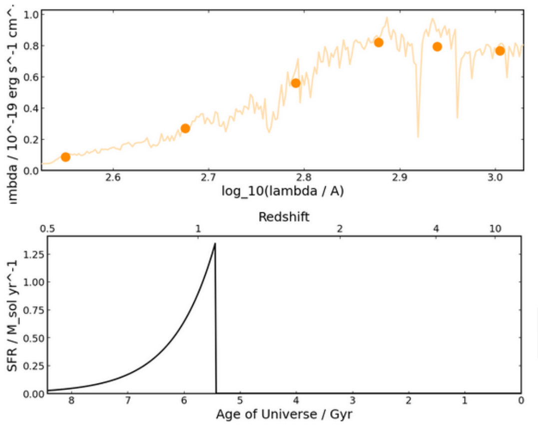

Figure 12: Galaxy with Redshift of 0.5

This figure represents a galaxy model with a redshift value of 0.5. It visualizes the impact of moderate redshift on the galaxy's spectrum and star formation history, elucidating the effects of the universe's expansion on galactic observations. The redshift can shift the spectral lines towards longer wavelengths (redshift effect) and affect the perceived intensity of the galaxy's emissions. Since the redshift is relatively small, the longer wavelengths are not as pronounced.

```
# High Redshift
redshift = 2
create_model()
high_redshift_model.plot()
high_redshift_model.sfh.plot
```

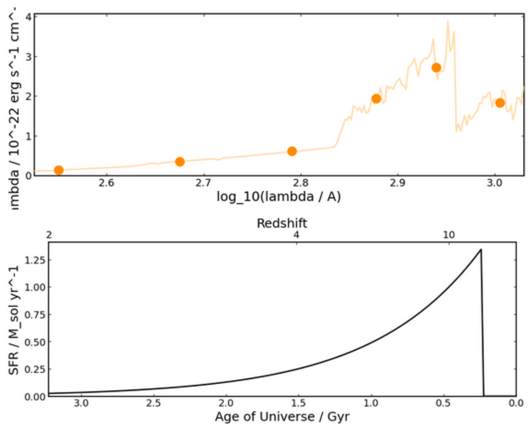

Figure 13: Galaxy with Redshift of 2

Here, the galaxy model is shown with a redshift value of 2. The figure provides a deeper understanding of how higher redshift alters a galaxy's observable characteristics, particularly in terms of its spectral profile and star formation rate. The high redshift dramatically affects the galaxy's observable properties, shifting its spectral lines further towards the red end of the spectrum and altering the apparent magnitude and shape of its emissions.

Tap Query Modeling and Loading

```
def load_dp02_photometry(ID):
    """ Load photometry for a given ID from dataset. """
    # Convert ID to int if it's not already
    ID = int(ID)

    # Find the row in the DataFrame corresponding to this ID
    row = df[df['objectId'] == ID].iloc[0]

    flux_cols = ['g_ap03Flux', 'r_ap03Flux', 'i_ap03Flux',
    'u_ap03Flux', 'y_ap03Flux', 'z_ap03Flux']

    error_cols = ['g_ap03FluxErr', 'r_ap03FluxErr', 'i_ap03FluxErr',
    'u_ap03FluxErr', 'y_ap03FluxErr', 'z_ap03FluxErr']

    # Extract the fluxes and errors
    fluxes = [row[col] for col in flux_cols]
    fluxerrs = [row[col] for col in error_cols]

    # Combine fluxes and errors into a 2D array
    photometry = np.column_stack((fluxes, fluxerrs))

    # Process the photometry data
    # Blow up the errors associated with any missing fluxes
    for i in range(len(photometry)):
        if photometry[i, 0] == 0 or photometry[i, 1] <= 0:
            photometry[i, :] = [0., 9.9 * 10**99.]

    # Enforce a maximum SNR (signal-to-noise ratio)
    for i in range(len(photometry)):
        max_snr = 20.
        if photometry[i, 0] / photometry[i, 1] > max_snr:
            photometry[i, 1] = photometry[i, 0] / max_snr

    return photometry
```

Figure 14: Process object data to produce a photometry using object's flux parameters.

This figure displays the results of photometry analysis on galaxies using LSST filters, based on data obtained from the TAP query. We create a funciton that will take an object with a given ID from the TAP, then obtain their flux values and processes said data to return a photometry for bagpipes to load. It visually represents the light emissions of these galaxies across different wavelengths.

Plotting the photometry data

```
query = "SELECT TOP 20 * FROM dp02_dc2_catalogs.Object
WHERE r_extendedness = 1"

# Execute the query
results = service.search(query)

# Convert the results to a pandas DataFrame
df = results.to_table().to_pandas()

for index, row in df.iterrows():
    ids = (row['objectId'])
    galaxy = pipes.galaxy(str(ids), load_dp02_photometry,
    spectrum_exists=False, filt_list=filt_list)
    fig = galaxy.plot()
```

Figure 15: Querying 20 Glaxy Objects from the DP02 Catalog and plot them.

The filter function we created above was used to plot a graph using pipes.galaxy() and galaxy.plot(). We pass in the object IDs, our filter function, and our filters.

Results of the plotting

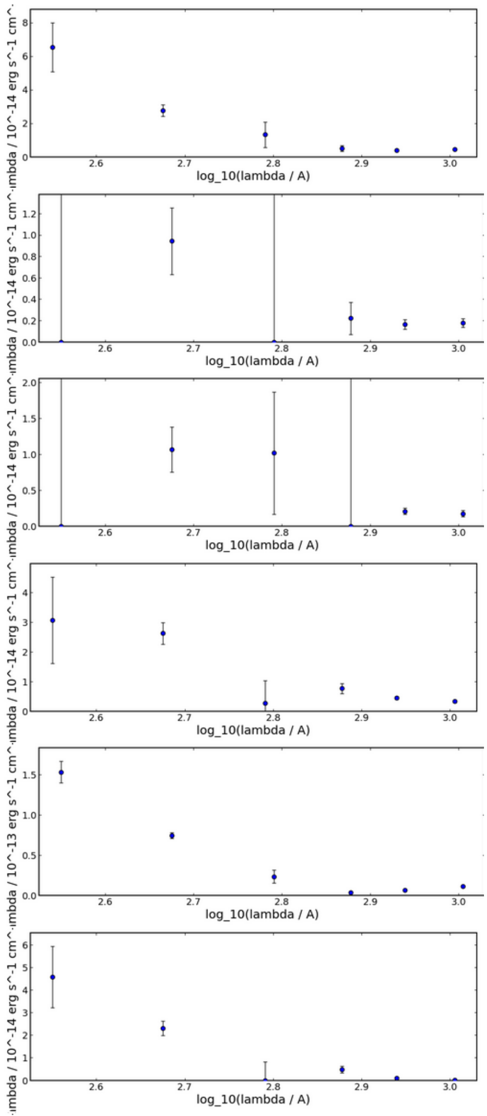

Figure 16: Photometry of TAP Data using LSST Filters

Fitting the Data

Now that we've seen that our loading/filter function works, lets fit the data using pipes.fit().

```
for index, row in df.iterrows():
    ids = (row['objectId'])
    galaxy = pipes.galaxy(str(ids), load_dp02_photometry,
    spectrum_exists=False, filt_list=filt_list)
    fit = pipes.fit(galaxy, fit_instructions)
    fit.fit(verbose=False)
    fig = fit.plot_spectrum_posterior(save=False, show=True)
    fig = fit.plot_sfh_posterior(save=False, show=True)
    fig = fit.plot_corner(save=False, show=True)
```

Figure 17: Fit and Plot spectrum, sfh, and corner.

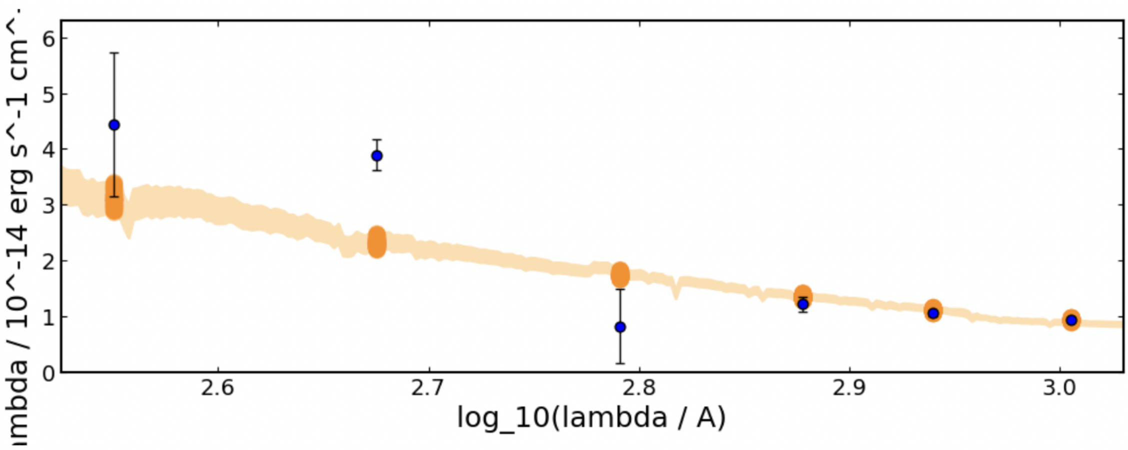

Figure 18: Fitted Spectrum

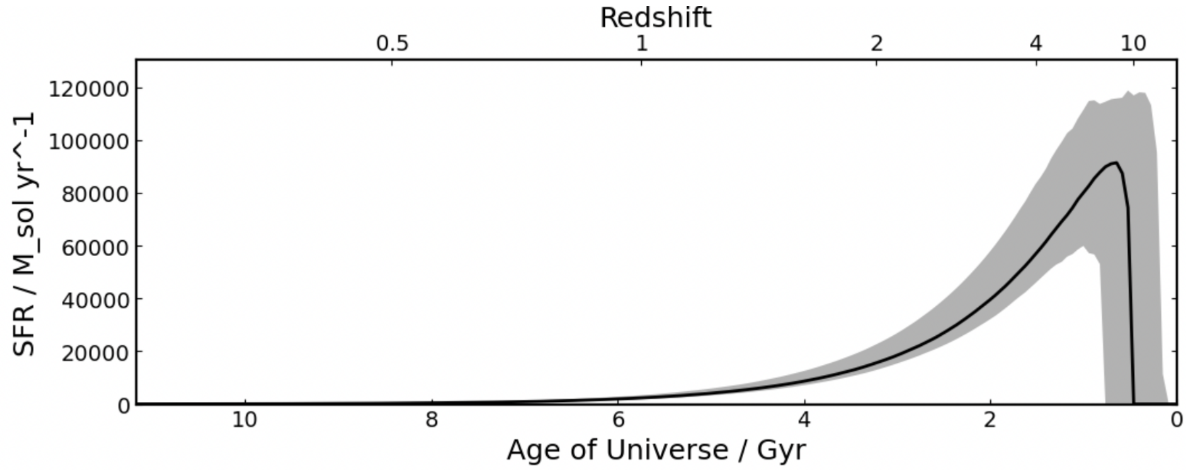

Figure 19: Fitted SFH

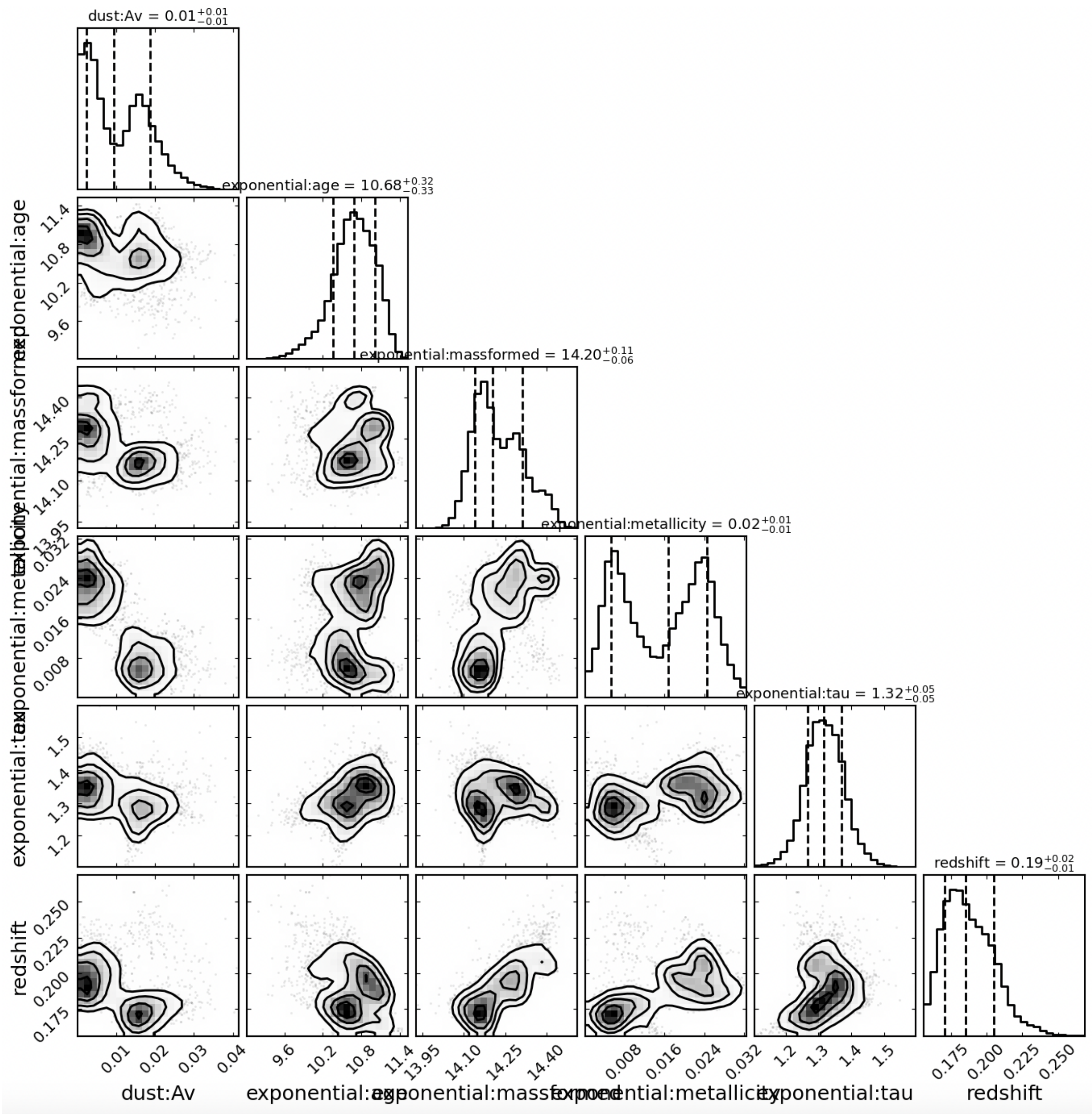

Figure 20: Corner Data

4 Discussion and Analysis

What affects Spectrum Graph?

Galaxy Age

Firstly, I observed that the age of a galaxy has only a slight effect on its spectral properties – mainly the magnitude of the wavelengths. This suggests a degree of spectral stability over time, implying that changes in the stellar composition and luminosity due to aging do not significantly alter the galaxy's overall spectral signature. Though I would believe this is untrue as over time as stars within the galaxy continues to evolve, it will grow redder and dimmer. The graph only shows the latter with it growing dimmer but the composition remains unchanged.

Optical Depth (τ)

More prominently, the optical depth, denoted by τ, emerged as a critical factor. It has a profound impact on the spectral shape, likely due to the attenuation of light caused by the material within the galaxy. A galaxy with lower tau has lower magnitude, but the shape itself becomes more 'averaged' or unified. This is because material is quite transparent and thus leading to less absorption and scattering which could possibly explain the graph shape.

Galactic Mass

Interestingly, the mass of the galaxy appears to have no discernible effect on its spectrum. This challenges the notion of mass as a direct influencer of spectral characteristics, pointing instead towards the composition and internal distribution of matter as more influential factors.

Metallicity

Moreover, my analysis revealed that lower metallicity enhances shorter wavelengths in the spectrum. This attenuation effect is likely a result of the reduced abundance of heavy elements, which typically absorb and re-emit light, thereby influencing the observed spectral energy distribution. Or it could also signify more lighter elements like hydrogen and helium which in turn increase the presence of shorter wavelengths.

Dust Content

The role of dust in shaping galactic spectra is also evident. Increased dust content seems to obscure lower wavelengths, aligning with the understanding of dust's role in scattering and absorbing light, especially at shorter wavelengths.

Redshift

Finally, the redshift of a galaxy significantly alters its spectral profile. In my observations, lower redshifts correlate with a decrease in overall magnitude across all wavelengths but a relative increase in shorter wavelengths, highlighting the impact of the universe's expansion on the observed light from galaxies.

What affects SFH Graph?

Galaxy Age

Younger galaxies have a higher initial magnitude of star formations and their graph have not reached zero yet as to be expected. Old galaxies have expectedly run its course with it showing the gradual drop off to 0.

Optical Depth (τ)

Lower optical depth seems to show a sharper and steeper graph in star formation rates – there seems to be a short period of time when stars were created. Higher tau shows a normal SFM curve in comparison to base model albeit with a lower magnitude.

Galactic Mass

Mass has a high effect on SFH magnitudes. When compared to the low mass model, the high mass shape matched, but the magnitudes differed by a factor of 100.

Metallicity

No visible effects.

Dust Content

No visible effects.

Redshift

No visible effects after modifying graph to match axes.

Tap Query Fitting

By querying top 20 galaxy objects, there were only 6 objects that fit the curve and around 11 being ‘acceptable‘. This can be due to a multitude of factors such as my fit model parameters being inaccurate, not broad enough, or too broad. Further experimentation with fit instructions may return better results.