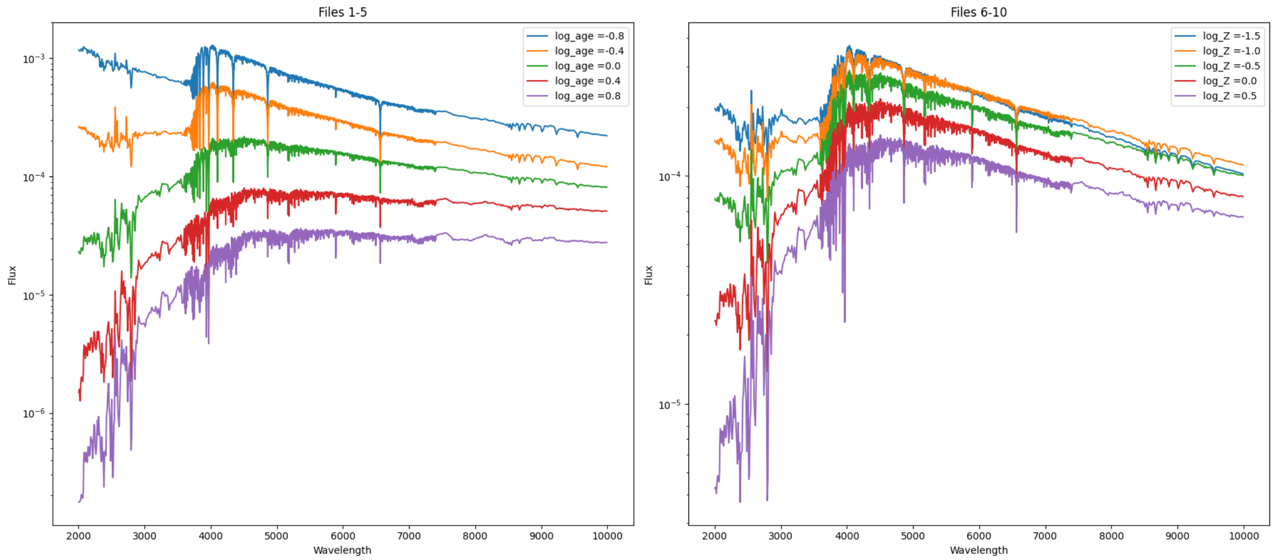
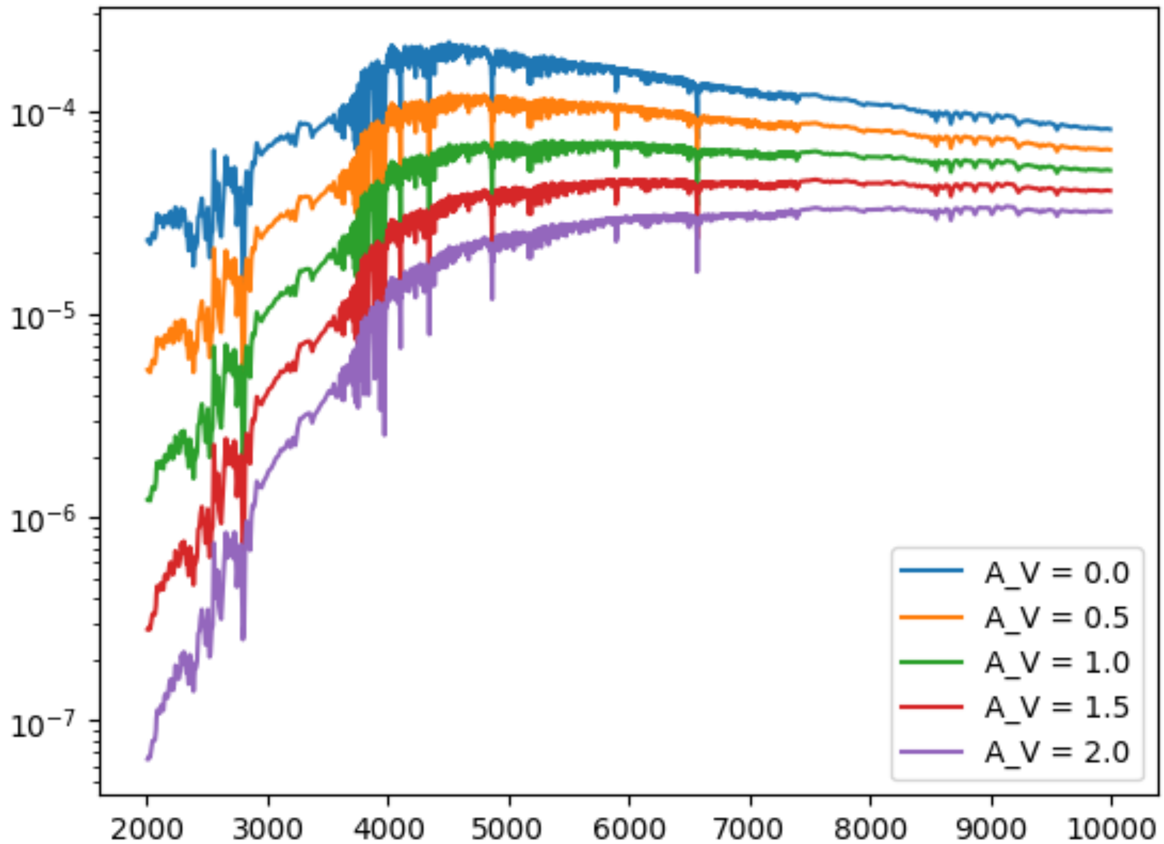
In [147…

```
import numpy as np
from astropy.io import ascii, fits
from matplotlib import pyplot as plt
from astropy import units as u
from astropy import constants as const
from astropy.table import Table
from scipy import stats
#1a
filename1 = 'hw5_files/spec_logage-0p8_Z0.csv'
filename2 = 'hw5_files/spec_logage-0p4_Z0.csv'
filename3 = 'hw5_files/spec_logage0_Z0.csv'
filename4 = 'hw5_files/spec_logage0p4_Z0.csv'
filename5 = 'hw5_files/spec_logage0p8_Z0.csv'
filename6 = 'hw5_files/spec_logage0_Z-1p5.csv'
filename7 = 'hw5_files/spec_logage0_Z-1.csv'
filename8 = 'hw5_files/spec_logage0_Z-0p5.csv'
filename9 = 'hw5_files/spec_logage0_Z0.csv'
filename10 = 'hw5_files/spec_logage0_Z0p5.csv'
files = [filename1, filename2, filename3, filename4, filename5, filename6, f
waves = []
fluxes = []
for filename in files:
    data = ascii.read(filename)
    waves.append(data['wave'])
    fluxes.append(data['flux'])
fig, ax = plt.subplots(1, 2, figsize=(18, 8))
for i in range(5):
    ax[0].plot(waves[i], fluxes[i], label=f'log_age ={0.4*(float(i) - 2.0)}'

for i in range(5, 10):
    ax[1].plot(waves[i], fluxes[i], label=f'log_Z ={0.5 *i - 4}')
ax[0].set_yscale('log')
ax[1].set_yscale('log')
ax[0].legend()
ax[1].legend()

# Add titles and labels
ax[0].set_title('Files 1-5')
ax[1].set_title('Files 6-10')
ax[0].set_xlabel('Wavelength')
ax[0].set_ylabel('Flux')
ax[1].set_xlabel('Wavelength')
ax[1].set_ylabel('Flux')

plt.tight_layout()
plt.show()
```



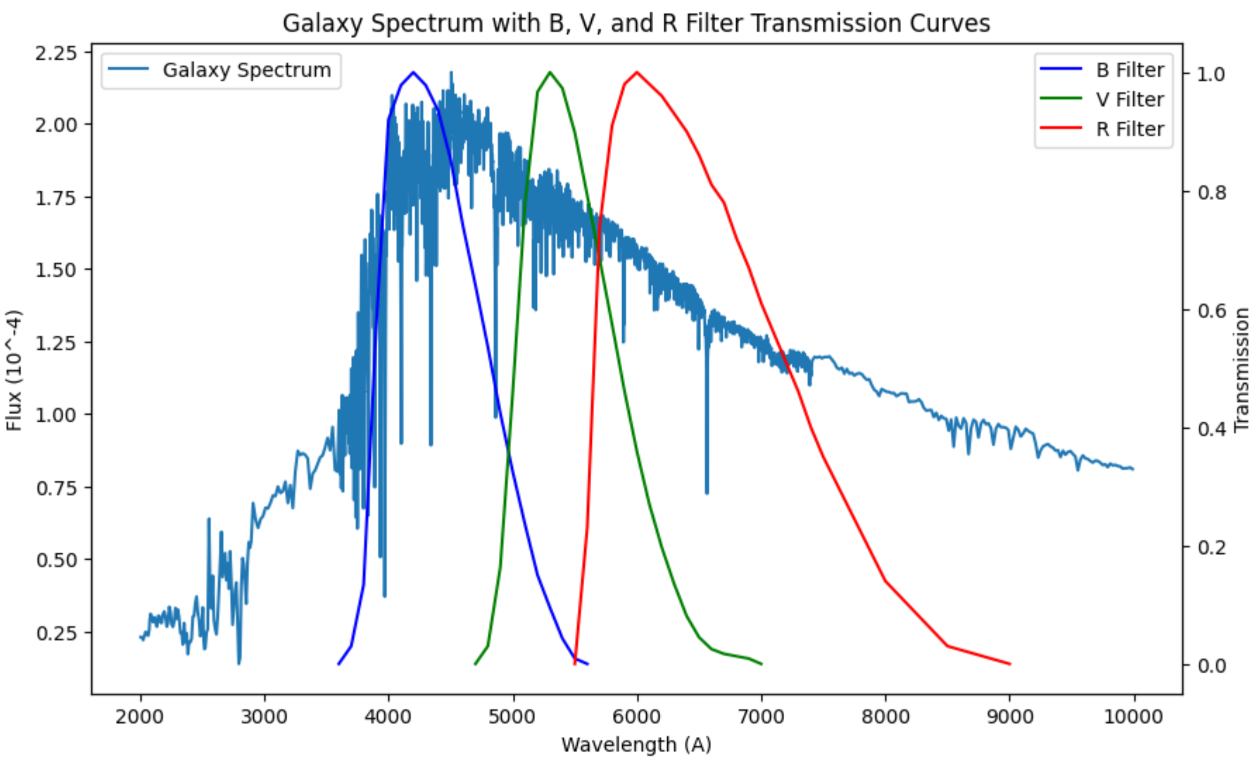
As the age of the population increases, there are less bright blue stars and thus the flux decreases. And the peak wavelength of the flux also shifts to the right since smaller stars have longer peak wavelengths. Metal-rich stars have more elements heavier than helium, which can affect opacities and line blanketing, altering the SED shape, dimming the flux. Higher metallicity can lead to more absorption in certain wavelengths, affecting the overall spectrum.

In [44]:
```
# 1b
data = ascii.read(filename3)
wavelength = data['wave']
flux = data['flux']
Av= [0.0, 0.5, 1.0, 1.5, 2.0]
def calculate_A_lambda(wavelength, A_V, flux):
    # Calculate the attenuation at each wavelength
    A_lambda = A_V * (wavelength / 5500.0) ** -1.15
    final_flux = flux * 10 ** (-0.4 * A_lambda)
    return final_flux
for i in Av:
    final_flux = calculate_A_lambda(wavelength, i, flux)
    plt.plot(wavelength, final_flux, label=f'A_V = {i}')
    plt.yscale('log')
    plt.legend()
```



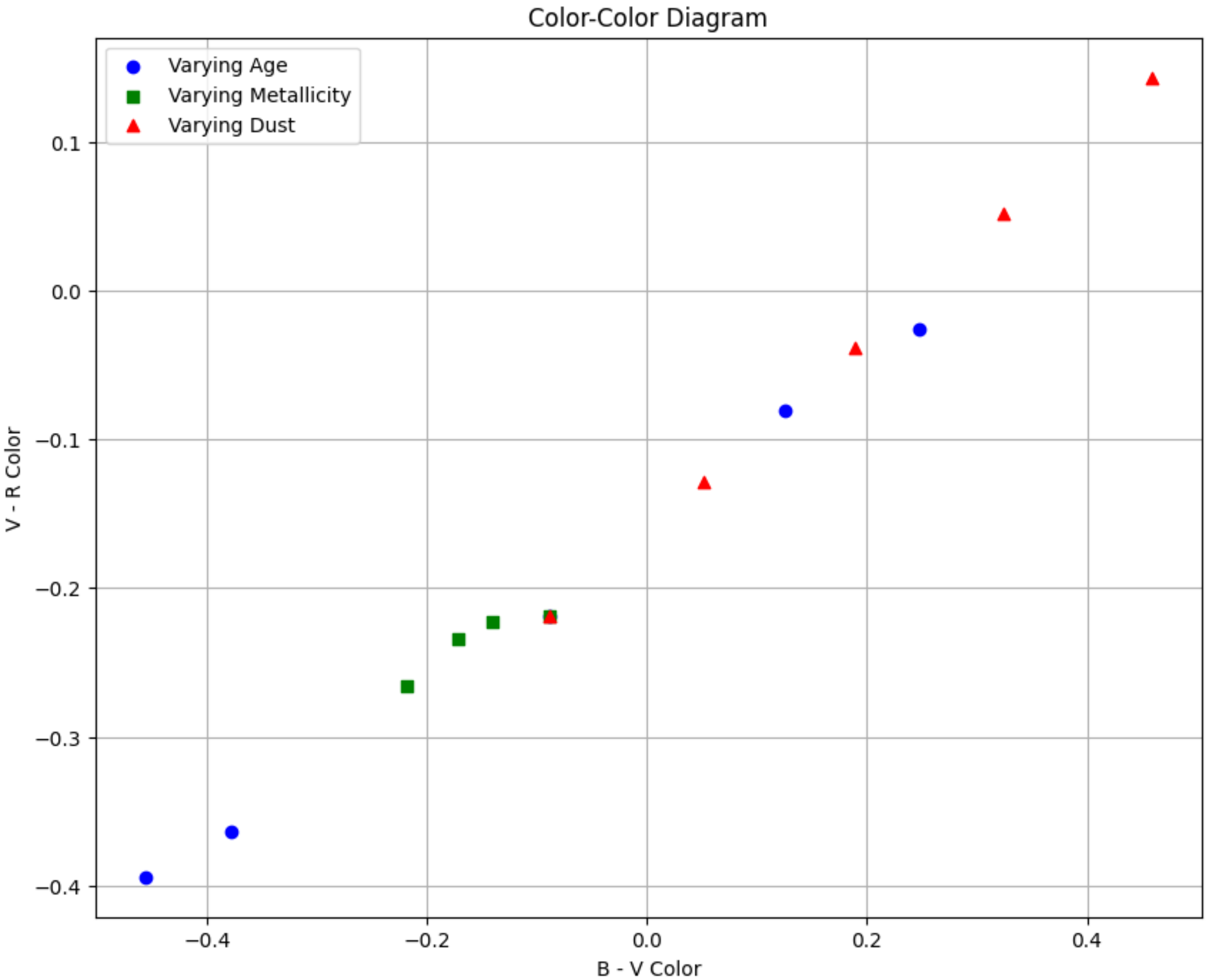
It is clear that as the dust attenuation increases, the flux decreases. It has a similar effect on the flux than the age. Since the dust tends to redden the light emmitted from the stars, which has a similar look with the log_age.

In [63]:
```
#1c
filt1 = ascii.read('hw5_files/bessell_B.dat', names=['wave', 'transm'])
filt2 = ascii.read('hw5_files/bessell_V.dat', names=['wave', 'transm'])
filt3 = ascii.read('hw5_files/bessell_R.dat', names=['wave', 'transm'])
spectrum = ascii.read('hw5_files/spec_logage0_Z0.csv')
wave = spectrum['wave']
flux = spectrum['flux'] * 1e4

fig, ax1 = plt.subplots(figsize=(10, 6))
ax1.plot(wave, flux, label='Galaxy Spectrum')
ax1.set_xlabel('Wavelength (A)')
ax1.set_ylabel('Flux (10^-4)')
ax1.legend(loc='upper left')

ax2 = ax1.twinx()
ax2.plot(filt1['wave'], filt1['transm'], color='blue', label='B Filter')
ax2.plot(filt2['wave'], filt2['transm'], color='green', label='V Filter')
ax2.plot(filt3['wave'], filt3['transm'], color='red', label='R Filter')
ax2.set_ylabel('Transmission')
ax2.legend(loc='upper right')
plt.title('Galaxy Spectrum with B, V, and R Filter Transmission Curves')
plt.show()
```



In [72]:
```
#1d

# Function to compute magnitude
def compute_magnitude(wave, flux, filter_wave, filter_transm):
    filter_interp = np.interp(wave, filter_wave, filter_transm, left=0, righ
    flux_filtered = flux * filter_interp
```

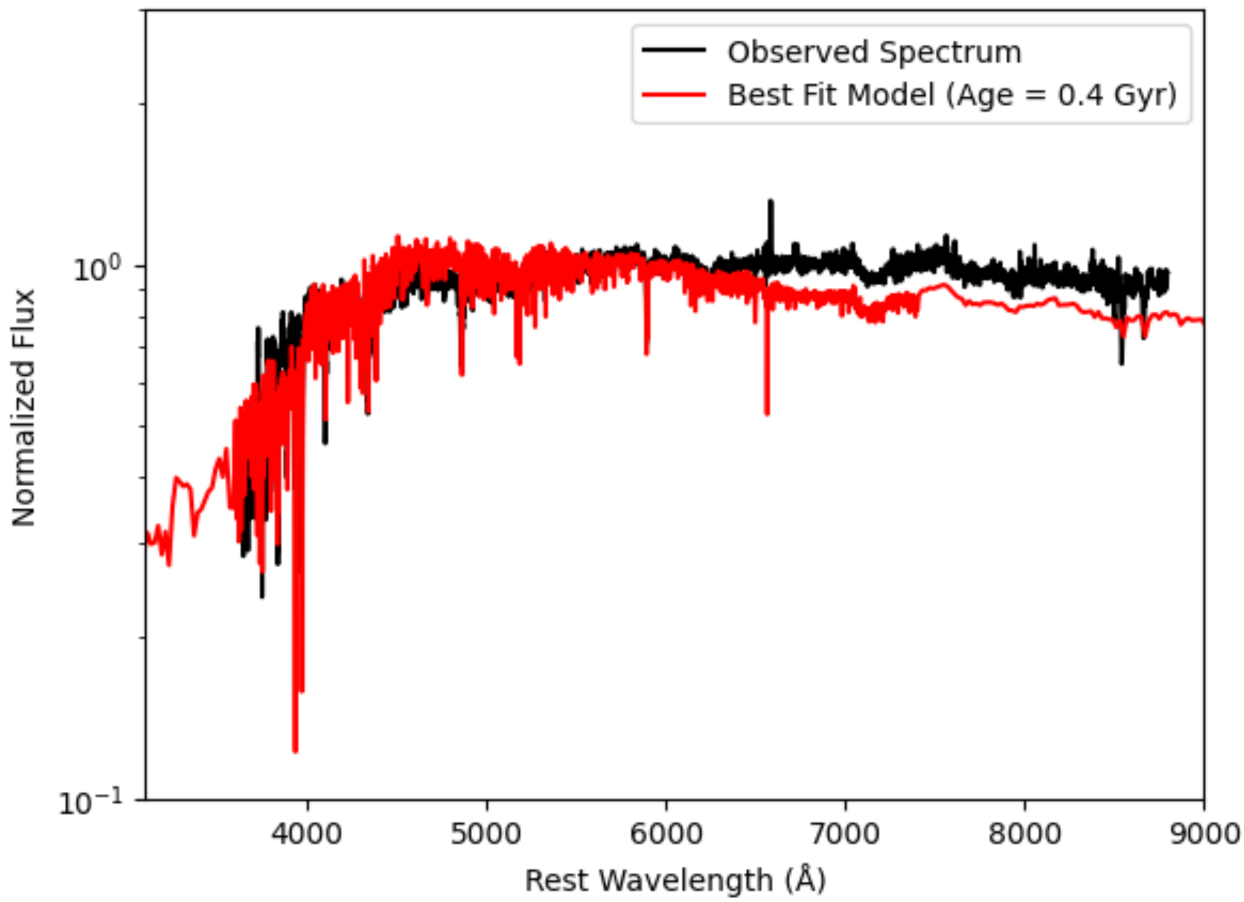
```
    numerator = np.trapz(flux_filtered * wave, wave)
    denominator = np.trapz(filter_interp * wave, wave)
    flux_avg = numerator / denominator
    mag = -2.5 * np.log10(flux_avg)
    return mag

bv_colors_age = []
vr_colors_age = []
for i in range(5):
    wave = waves[i]
    flux = fluxes[i]
    mag_B = compute_magnitude(wave, flux, filt1['wave'], filt1['transm'])
    mag_V = compute_magnitude(wave, flux, filt2['wave'], filt2['transm'])
    mag_R = compute_magnitude(wave, flux, filt3['wave'], filt3['transm'])
    bv_colors_age.append(mag_B - mag_V)
    vr_colors_age.append(mag_V - mag_R)
bv_colors_metallicity = []
vr_colors_metallicity = []
for i in range(5, 9):
    wave = waves[i]
    flux = fluxes[i]
    mag_B = compute_magnitude(wave, flux, filt1['wave'], filt1['transm'])
    mag_V = compute_magnitude(wave, flux, filt2['wave'], filt2['transm'])
    mag_R = compute_magnitude(wave, flux, filt3['wave'], filt3['transm'])
    bv_colors_metallicity.append(mag_B - mag_V)
    vr_colors_metallicity.append(mag_V - mag_R)

spectrum_dust_wave = waves[2]
spectrum_dust_flux = fluxes[2]
bv_colors_dust = []
vr_colors_dust = []

for AV in Av:
    flux_attenuated = calculate_A_lambda(spectrum_dust_wave, AV, spectrum_du
    mag_B = compute_magnitude(spectrum_dust_wave, flux_attenuated, filt1['wa
    mag_V = compute_magnitude(spectrum_dust_wave, flux_attenuated, filt2['wa
    mag_R = compute_magnitude(spectrum_dust_wave, flux_attenuated, filt3['wa
    bv_colors_dust.append(mag_B - mag_V)
    vr_colors_dust.append(mag_V - mag_R)

plt.figure(figsize=(10, 8))
plt.scatter(bv_colors_age, vr_colors_age, color='blue', label='Varying Age',
plt.scatter(bv_colors_metallicity, vr_colors_metallicity, color='green', lab
plt.scatter(bv_colors_dust, vr_colors_dust, color='red', label='Varying Dust

plt.xlabel('B - V Color')
plt.ylabel('V - R Color')
plt.title('Color-Color Diagram')
plt.legend()
plt.grid(True)
plt.show()
```


Color-Color Diagram
Varying Age
Varying Metallicity
Varying Dust
0.1
0.0
−0.1
−0.2
−0.3
−0.4
V - R Color
−0.4
−0.2
0.0
0.2
0.4
B - V Color

In [230…

```
#1e
from scipy.interpolate import interp1d
with fits.open('hw5_files/spec-0570-52266-0537.fits') as hdu:
    galaxy = hdu[1].data
    header = hdu[0].header
zz = 0.047
wv = 10**(galaxy['loglam']) / (zz + 1)
flux = galaxy['flux']
ages = [-0.8, -0.4, 0, 0.4, 0.8]
# Function to normalize the spectrum within the 5500-5700 Å range
def normalize_spectrum(wv, flux, lower_bound=5500, upper_bound=5700):
    mask = (wv >= lower_bound) & (wv <= upper_bound)
    median_flux = np.median(flux[mask])
    normalized_flux = flux / median_flux
    return normalized_flux
# Function to calculate chi-square between model and observed data
def calculate_chi_square(model_wl, model_flux, data_wl, data_flux):
    interp_model = interp1d(model_wl, model_flux, kind='linear', fill_value=
    model_flux_interp = interp_model(data_wl)
    return np.sum((data_flux - model_flux_interp)**2 / model_flux_interp)
normalized_flux = normalize_spectrum(wv, flux)
best_fit_wave_model = None
best_fit_flux_model = None
best_chi_square = np.inf
best_age = None
for i in range(5):
    wave_model = waves[i]
    flux_model = fluxes[i]
    age = ages[i]
    normalized_flux_model = normalize_spectrum(wave_model, flux_model)
    chi_square = calculate_chi_square(wave_model, normalized_flux_model, wv,
    if chi_square < best_chi_square:
        best_chi_square = chi_square
        best_fit_wave_model = wave_model
        best_fit_flux_model = normalized_flux_model
        best_age = age
plt.figure()
plt.plot(wv, normalized_flux, label="Observed Spectrum", color='black')
plt.plot(best_fit_wave_model, best_fit_flux_model, label=f'Best Fit Model (A
plt.yscale('log')
plt.ylim(0.1, 3)
plt.xlim(3100, 9000)
plt.xlabel('Rest Wavelength (Å)')
plt.ylabel('Normalized Flux')
plt.legend()
plt.show()
print(f"Best-fit age: {best_age} Gyr, Chi-square: {best_chi_square}")
```

```
Age: -0.8 Gyr, Chi-square: 1013.9905922611226
Age: -0.4 Gyr, Chi-square: 808.8256525705439
Age: 0 Gyr, Chi-square: 257.41781695427517
Age: 0.4 Gyr, Chi-square: 55.08585282318522
Age: 0.8 Gyr, Chi-square: 88.77539276407234
```

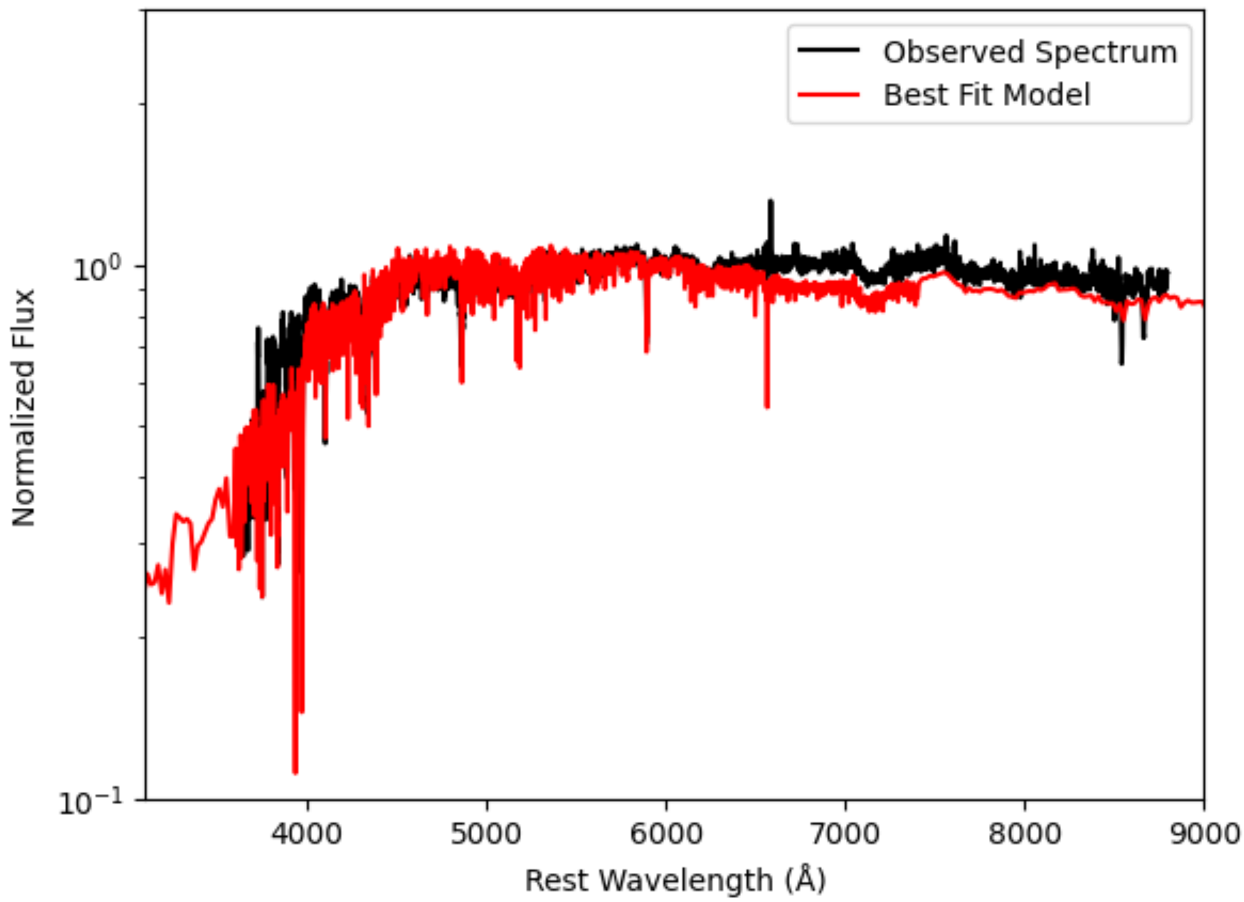



```
Best-fit age: 0.4 Gyr, Chi-square: 55.08585282318522
```

In [294…

```
#1f
best_fit_wave_model = None
best_fit_flux_model = None
best_chi_square = np.inf
data = ascii.read(filename4)
Av = [0.0, 0.1, 0.2, 0.203]  # Ensure Av is defined as a list
wavelength = data['wave']
flux = data['flux']
for i in Av:
    count = 0
    final_flux = calculate_A_lambda(wavelength, i, flux)
    normalized_flux_model = normalize_spectrum(wavelength, final_flux)

    chi_square = calculate_chi_square(wave_model, normalized_flux_model, wv,

    if chi_square < best_chi_square:
        best_chi_square = chi_square
        best_fit_wave_model = wave_model
        best_fit_flux_model = normalized_flux_model
        print(f"Chi-square for Av = {i}: {chi_square}")

plt.figure()
plt.plot(wv, normalized_flux, label="Observed Spectrum", color='black')
plt.plot(best_fit_wave_model, best_fit_flux_model, label=f'Best Fit Model',
plt.yscale('log')
plt.ylim(0.1, 3)
plt.xlim(3100, 9000)
plt.xlabel('Rest Wavelength (Å)')
plt.ylabel('Normalized Flux')
plt.legend()
plt.show()
```

```
Chi-square for Av = 0.0: 55.08585282318522
Chi-square for Av = 0.1: 47.81639055092903
Chi-square for Av = 0.2: 45.02002703826719
Chi-square for Av = 0.203: 45.01707330976184
```



In [ ]:

```
#1g
c = 3.0e10
pc_to_cm = 3.086e18
Mpc_to_cm = pc_to_cm * 1e6
flux_obs = flux * 1e-17
best_model_index = 3
wave_model = waves[best_model_index]
flux_model = fluxes[best_model_index]
interp_model_flux = interp1d(wave_model, flux_model, kind='linear', bounds_e
model_flux_at_obs_wv = interp_model_flux(wv)
D_L = 200 * Mpc_to_cm
flux_model_at_earth = model_flux_at_obs_wv / (4 * np.pi * D_L**2)
mask = (flux_model_at_earth > 0) & (flux_obs > 0)
flux_model_at_earth = flux_model_at_earth[mask]
flux_obs = flux_obs[mask]
M_star_numerator = np.sum(flux_obs * flux_model_at_earth)
M_star_denominator = np.sum(flux_model_at_earth**2)
M_star = M_star_numerator / M_star_denominator

print(f"The stellar mass of the galaxy is: {M_star:.2e} solar masses")
```