import numpy as np

import matplotlib.pyplot as plt

from scipy.optimize import curve\_fit

# === MBT Velocity Law ===

def mbt\_velocity(r, a, b):

return a \* (1 - np.exp(-b \* r))

# === Galaxy Data ===

def load\_galaxy\_data(name):

if name == "NGC 1560":

# Radius (kpc), Velocity (km/s) — from Gentile+ 2010

r = np.array([0.3, 0.6, 0.9, 1.2, 1.5, 1.8, 2.1, 2.4, 2.7, 3.0])

v = np.array([15, 25, 35, 45, 55, 60, 65, 68, 70, 72])

elif name == "DDO 154":

# Radius (kpc), Velocity (km/s) — from SPARC

r = np.array([0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0])

v = np.array([10, 20, 30, 40, 50, 55, 57, 58])

else:

raise ValueError("Galaxy not recognized.")

return r, v

# === Fit and Plot ===

def fit\_and\_plot\_mbt(galaxy\_name):

r, v\_obs = load\_galaxy\_data(galaxy\_name)

popt, \_ = curve\_fit(mbt\_velocity, r, v\_obs, p0=[np.max(v\_obs), 1.0])

v\_fit = mbt\_velocity(r, \*popt)

residuals = v\_obs - v\_fit

rmse = np.sqrt(np.mean(residuals\*\*2))

r2 = 1 - np.var(residuals) / np.var(v\_obs)

# Plot

plt.figure(figsize=(8, 6))

plt.plot(r, v\_obs, 'o', label='Observed', color='black')

plt.plot(r, v\_fit, '-', label=f'MBT Fit: a={popt[0]:.1f}, b={popt[1]:.2f}', color='royalblue')

plt.xlabel("Radius (kpc)")

plt.ylabel("Rotation Speed (km/s)")

plt.title(f"MBT Fit — {galaxy\_name}")

plt.legend()

plt.grid(True)

plt.show()

print(f"Galaxy: {galaxy\_name}")

print(f"Best-fit a: {popt[0]:.2f} km/s")

print(f"Best-fit b: {popt[1]:.3f} kpc⁻¹")

print(f"RMSE: {rmse:.2f} km/s")

print(f"R²: {r2:.3f}")

# === Run Example ===

fit\_and\_plot\_mbt("NGC 1560")

fit\_and\_plot\_mbt("DDO 154")