In [1]:
```
import numpy as np
import os
import matplotlib.pyplot as plt
```

In [2]:
```
os.chdir("C:/Users/Owner/Documents/Classes/F2021/PHYS 512/emacs")
chain = np.loadtxt("planck_chain_tauprior.txt")
chain = np.transpose(chain)
best_pars = [np.mean(lst) for lst in chain]
best_par_errs = [np.std(lst) for lst in chain]
```

In [3]:
```
print(best_pars)
```

```
[68.49463571023382, 0.022419061202794587, 0.1169082294069389, 0.05399870831
269413, 1.897323945010951e-09, 0.9721272751897853]
```

In [4]:
```
print(best_par_errs)
```

```
[0.02376450480204872, 1.4249855004002508e-05, 4.535538423577414e-05, 0.0001
0541637611600632, 3.706920079679145e-13, 0.0002602622230183186]
```

As indicated above, the best-fit parameters are [68.49463571023382, 0.022419061202794587, 0.1169082294069389, 0.05399870831269413, 1.897323945010951e-09, 0.9721272751897853],

and the errors on these parameters are [0.02376450480204872, 1.4249855004002508e-05, 4.535538423577414e-05, 0.00010541637611600632, 3.706920079679145e-13, 0.0002602622230183186].

Seeing as I didn't have time to complete 20,000 iterations in question 3, I opted for 5,000 iterations in question 4.

Again, note that I could not save this as a PDF, so I printed to PDF instead. My apologies if the quality is worse.

In [5]:
```
print(len(chain[0]))
```

```
4999
```

Again, the chain seems to have converged. Indeed, as per the plots below, each parameter seems to oscillate around a given value after some time. Also, it seems as though it converges quicker than the chain in question 3.Perhaps restricting tau is better. However, I had already restricted the other parameters to a 3-sigma spread in question 3, so the difference is only marginal.

In [13]:

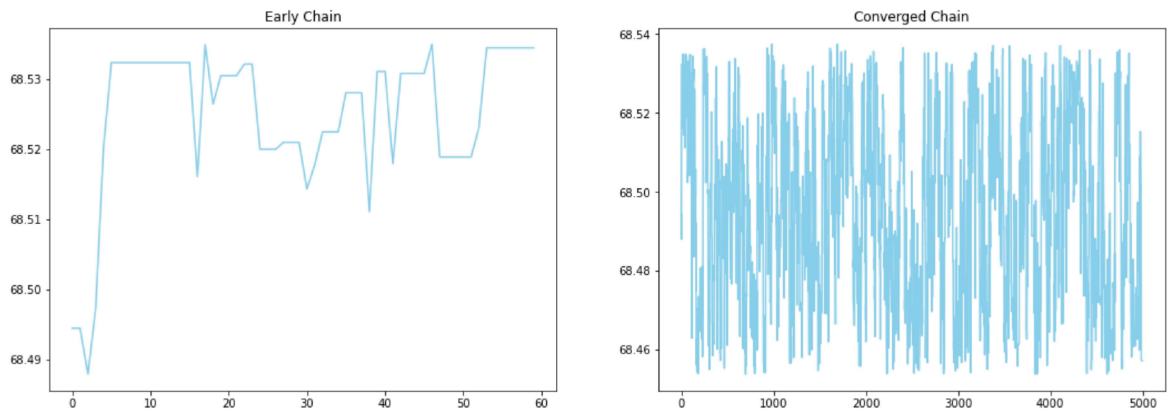
```
n = len(chain[0])
x = range(0, n)

fig, ax = plt.subplots(1, 2, figsize = (18, 6))

ax[0].plot(x[:60], chain[0][:60], c="skyblue")
ax[0].set_title("Early Chain")

ax[1].plot(x, chain[0], c="skyblue")
ax[1].set_title("Converged Chain")

fig.savefig("q3.png")
```



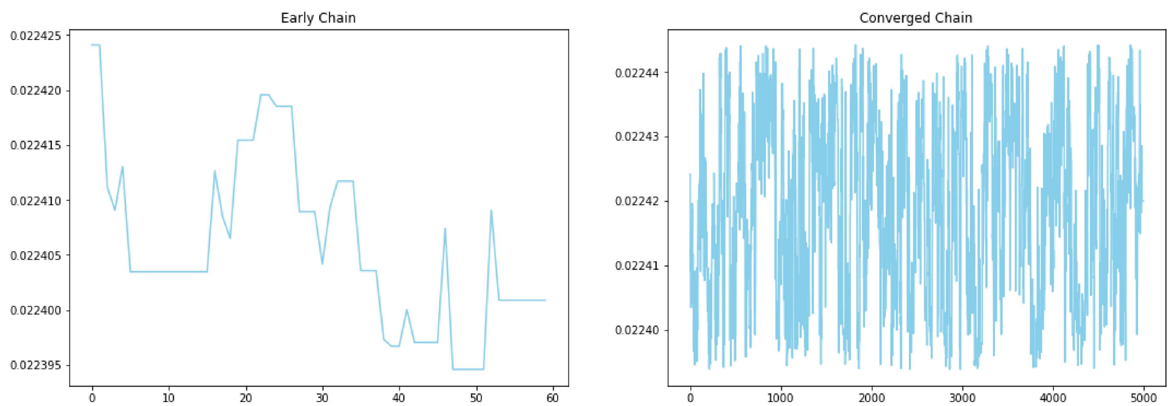
In [7]:

```
fig1, ax1 = plt.subplots(1, 2, figsize = (18, 6))

ax1[0].plot(x[:60], chain[1][:60], c="skyblue")
ax1[0].set_title("Early Chain")

ax1[1].plot(x, chain[1], c="skyblue")
ax1[1].set_title("Converged Chain")
```

Out[7]: Text(0.5, 1.0, 'Converged Chain')



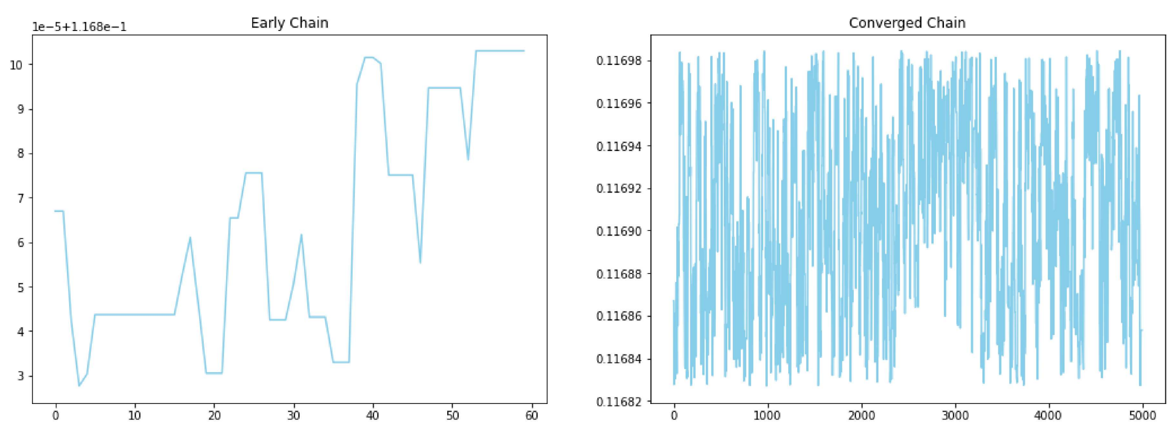
In [8]:

```
fig2, ax2 = plt.subplots(1, 2, figsize = (18, 6))

ax2[0].plot(x[:60], chain[2][:60], c="skyblue")
ax2[0].set_title("Early Chain")

ax2[1].plot(x, chain[2], c="skyblue")
ax2[1].set_title("Converged Chain")
```

Out[8]: Text(0.5, 1.0, 'Converged Chain')

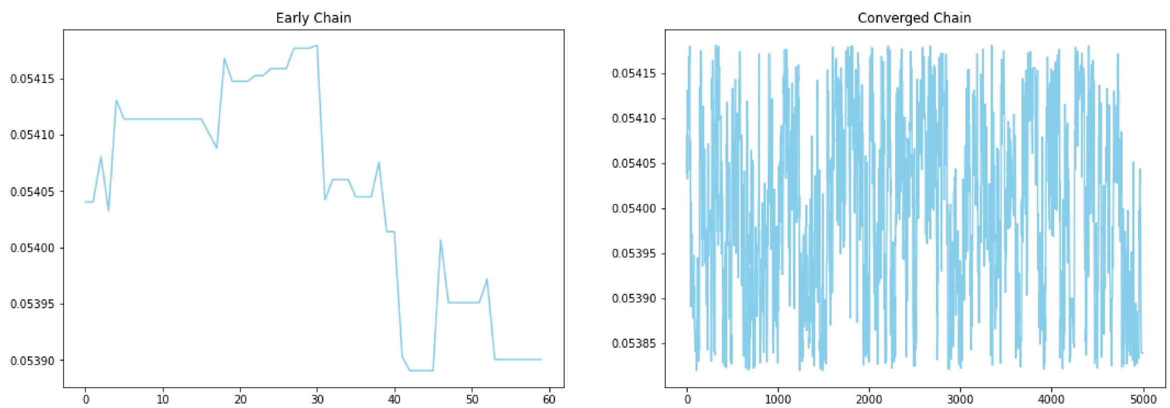


In [9]:
```
fig3, ax3 = plt.subplots(1, 2, figsize = (18, 6))

ax3[0].plot(x[:60], chain[3][:60], c="skyblue")
ax3[0].set_title("Early Chain")

ax3[1].plot(x, chain[3], c="skyblue")
ax3[1].set_title("Converged Chain")
```

Out[9]:
```
Text(0.5, 1.0, 'Converged Chain')
```

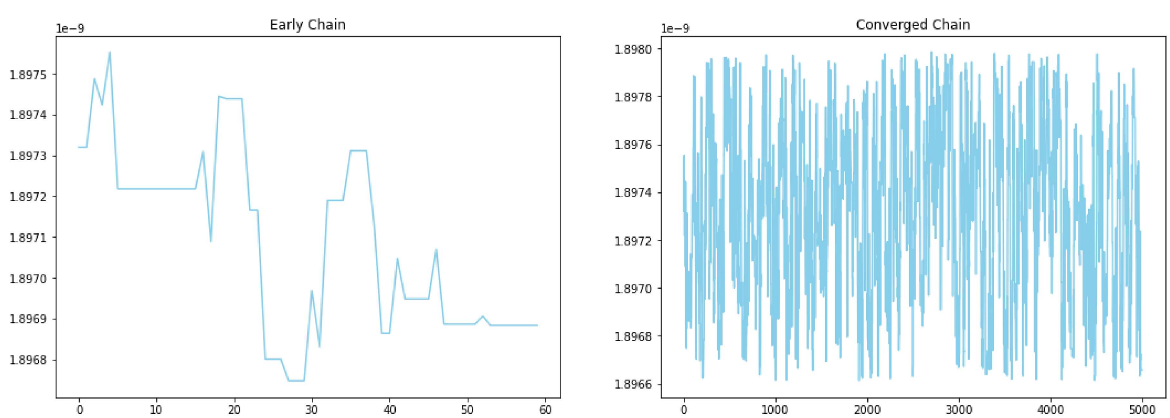


In [10]:
```
fig4, ax4 = plt.subplots(1, 2, figsize = (18, 6))

ax4[0].plot(x[:60], chain[4][:60], c="skyblue")
ax4[0].set_title("Early Chain")

ax4[1].plot(x, chain[4], c="skyblue")
ax4[1].set_title("Converged Chain")
```

Out[10]:
```
Text(0.5, 1.0, 'Converged Chain')
```



In [11]:
```
fig5, ax5 = plt.subplots(1, 2, figsize = (18, 6))

ax5[0].plot(x[:60], chain[5][:60], c="skyblue")
ax5[0].set_title("Early Chain")

ax5[1].plot(x, chain[5], c="skyblue")
ax5[1].set_title("Converged Chain")
```

Out[11]:
```
Text(0.5, 1.0, 'Converged Chain')
```