Dependencies

This notebook requires Python packages listed in the `requirements.txt` file in the repository.
We recommend using a virtual environment to install them:

```
pip install -r requirements.txt
```

In [69]:
```
import bilby
import matplotlib.pyplot as plt
from bilby.core.prior import ConditionalLogUniform, LogUniform, Tru
from bilby.core.prior import PriorDict, Uniform, Constraint,Conditi
import bilby.gw.prior
import numpy as np
from BNSPriorDict_ChirpMassLambda import BNSPriorDict_chirpmass_lam
```

In [70]:
```
# Specify the output directory and the name of the simulation.
outdir = "outdir_nsbh"
# Now we try to sample and see what the error is in generating the
label = "nsbh_example"
bilby.core.utils.setup_logger(outdir=outdir, label=label)

# Set up a random seed for result reproducibility.  This is optiona
np.random.seed(88170235)
```

In [71]:
```
# We are going to inject a GW190425-like system (masses) that is a

#We first establish a dictionary of parameters that includes all of
# parameters, including masses of the two neutron stars (mass_1, ma
# aligned spins of both NSs (chi_1, chi_2), etc.
mass_1_source = 2.4
mass_2_source = 1.15
lambda_1 = 0
lambda_2 = 1346
injection_parameters = dict(
    mass_1_source=mass_1_source,
    mass_2_source=mass_2_source,
    chi_1=0.02,
    chi_2=0.02,
    luminosity_distance=250.0,
    theta_jn=0.4,
    psi=2.659,
    phase=1.3,
    geocent_time=1126259642.413,
    ra=1.375,
    dec=-1.2108,
    lambda_1=lambda_1,
    lambda_2=lambda_2,

)
```

In [72]:
```
def lambda_1_lambda_2_to_lambda_tilde_NSBH(lambda_1, lambda_2, mass
    lambda_tilde = 16./13. * ((12*mass_1 + mass_2)*lambda_2*mass_2*
    return lambda_tilde
```

In [73]:
```
# Calculate lambda_tilde
lambda_tilde = lambda_1_lambda_2_to_lambda_tilde_NSBH(lambda_1, lam
#lambda_tilde = bilby.gw.conversion.lambda_1_lambda_2_to_lambda_til
print(lambda_tilde)
chirp_mass_source = bilby.gw.conversion.component_masses_to_chirp_m
print(chirp_mass_source)
```

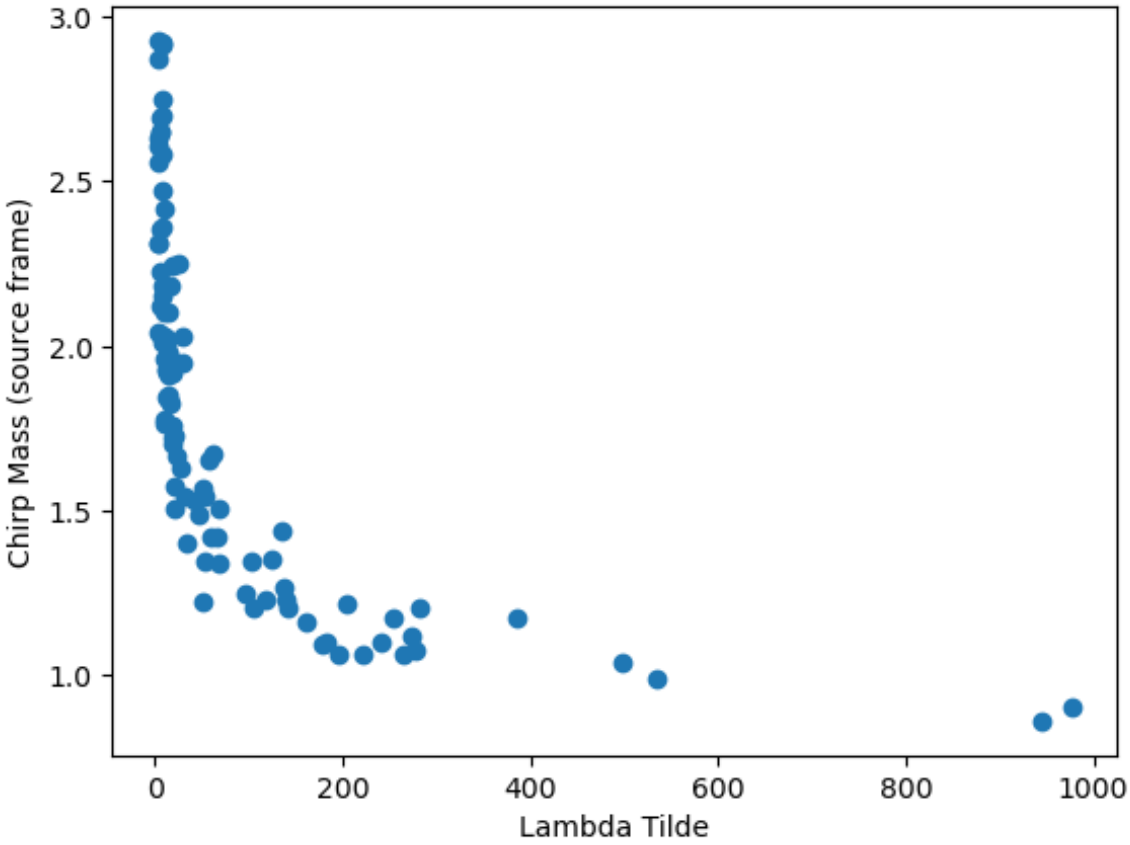
```
153.9104518214027
1.427249102656435
```

In [74]:
```
# We setup the prior dict using the interpolated prior from the fil
priors_gw = BNSPriorDict_chirpmass_lambda_tilde(MCL_filename='./MCL_
# Delta lambda tilde is defined with a uniform prior
#priors_gw['delta_lambda_tilde'] = Uniform(name='delta_lambda_tilde
# Define the other priors for inference
priors_gw['luminosity_distance'] = 250.0 #bilby.gw.prior.UniformSou
# Fix everything to injected values other than Mchirp and lambda_ti
priors_gw['dec'] = - 1.2108 #Cosine(name='dec')
priors_gw['ra'] = 1.375 #Uniform(name='ra', minimum=0, maximum=2 *
priors_gw['theta_jn'] = 0.4 #Sine(name='theta_jn')
priors_gw['psi'] =  2.659 #Uniform(name='psi', minimum=0, maximum=n
priors_gw['phase'] = 1.3 #Uniform(name='phase', minimum=0, maximum=
priors_gw['chi_1'] = 0.02 #bilby.gw.prior.AlignedSpin(name='chi_1',
priors_gw['chi_2'] = 0.02 #bilby.gw.prior.AlignedSpin(name='chi_2',
priors_gw['mass_ratio'] =1.3/1.5 #bilby.gw.prior.UniformInComponent
priors_gw['mass_1'] = Constraint(name='mass_1', minimum=0.5, maximu
priors_gw['mass_2'] = Constraint(name='mass_2', minimum=0.5, maximu
```

```
21:53 bilby INFO    : No prior given, using default BNS priors in /U
sers/smag0001/opt/anaconda3/lib/python3.10/site-packages/bilby/gw/pr
ior_files/aligned_spins_bns_tides_on.prior.
21:53 bilby INFO    : Interpolating chirp_mass_source and lambda_til
de prior from file.
```

In [75]:
```
# Check that the prior is loaded by sampling from it
samples = priors_gw.sample(100)
# Plot the prior samples
plt.scatter(samples['lambda_tilde'], samples['chirp_mass_source'])
plt.xlabel('Lambda Tilde')
plt.ylabel('Chirp Mass (source frame)')
```

Out[75]:
```
Text(0, 0.5, 'Chirp Mass (source frame)')
```



In [76]:
```
# Fix most of the priors to their injected values
for key in [
    "psi",
    "geocent_time",
    "ra",
    "dec",
    "chi_1",
    "chi_2",
    "theta_jn",
    #"luminosity_distance",
    "phase",
]:
    priors_gw[key] = injection_parameters[key]
# We explicitly set the system as a NSBH since we need to use a dif
priors_gw['lambda_1'] = 0.0
```

In [77]:
```
# Set the duration and sampling frequency of the data segment that
# to inject the signal into. For the
# TaylorF2 waveform, we cut the signal close to the isco frequency
duration = 32
minimum_frequency=40
sampling_frequency = 2048
start_time = injection_parameters["geocent_time"] + 2 - duration

# Fixed arguments passed into the source model. The analysis starts
waveform_arguments = dict(
    waveform_approximant="IMRPhenomPv2_NRTidal",
    reference_frequency=50.0,
    minimum_frequency=minimum_frequency,
)
```

In [78]:
```
# Create the waveform_generator using a LAL Binary Neutron Star sou
waveform_generator = bilby.gw.WaveformGenerator(
    duration=duration,
    sampling_frequency=sampling_frequency,
    frequency_domain_source_model=bilby.gw.source.lal_binary_neutro
    parameter_conversion=convert_to_lal_binary_neutron_star_paramet
    waveform_arguments=waveform_arguments,
)
```

```
21:54 bilby INFO    : Waveform generator initiated with
  frequency_domain_source_model: bilby.gw.source.lal_binary_neutron_
star
  time_domain_source_model: None
  parameter_conversion: BNSPriorDict_ChirpMassLambda.convert_to_lal_
binary_neutron_star_parameters_mchirp
```

In [79]:
```
# Set up interferometers.  In this case we'll use three interferome
# (LIGO-Hanford (H1), LIGO-Livingston (L1), and Virgo (V1)).
# These default to their design sensitivity and start at 40 Hz.
interferometers = bilby.gw.detector.InterferometerList(["H1", "L1",
for interferometer in interferometers:
    interferometer.minimum_frequency = 40
interferometers.set_strain_data_from_power_spectral_densities(
    sampling_frequency=sampling_frequency, duration=duration, start
)
interferometers.inject_signal(
    parameters=injection_parameters, waveform_generator=waveform_ge
)
```

```
21:54 bilby INFO    : Injected signal in H1:
21:54 bilby INFO    :   optimal SNR = 8.14
21:54 bilby INFO    :   matched filter SNR = 8.37-0.36j
21:54 bilby INFO    :   mass_1_source = 2.4
21:54 bilby INFO    :   mass_2_source = 1.15
21:54 bilby INFO    :   chi_1 = 0.02
21:54 bilby INFO    :   chi_2 = 0.02
21:54 bilby INFO    :   luminosity_distance = 250.0
21:54 bilby INFO    :   theta_jn = 0.4
21:54 bilby INFO    :   psi = 2.659
21:54 bilby INFO    :   phase = 1.3
21:54 bilby INFO    :   geocent_time = 1126259642.413
21:54 bilby INFO    :   ra = 1.375
21:54 bilby INFO    :   dec = -1.2108
21:54 bilby INFO    :   lambda_1 = 0
21:54 bilby INFO    :   lambda_2 = 1346
21:54 bilby INFO    : Injected signal in L1:
21:54 bilby INFO    :   optimal SNR = 6.59
21:54 bilby INFO    :   matched filter SNR = 7.21-0.41j
21:54 bilby INFO    :   mass_1_source = 2.4
21:54 bilby INFO    :   mass_2_source = 1.15
21:54 bilby INFO    :   chi_1 = 0.02
21:54 bilby INFO    :   chi_2 = 0.02
21:54 bilby INFO    :   luminosity_distance = 250.0
21:54 bilby INFO    :   theta_jn = 0.4
21:54 bilby INFO    :   psi = 2.659
21:54 bilby INFO    :   phase = 1.3
21:54 bilby INFO    :   geocent_time = 1126259642.413
21:54 bilby INFO    :   ra = 1.375
21:54 bilby INFO    :   dec = -1.2108
21:54 bilby INFO    :   lambda_1 = 0
21:54 bilby INFO    :   lambda_2 = 1346
21:54 bilby INFO    : Injected signal in V1:
21:54 bilby INFO    :   optimal SNR = 6.99
21:54 bilby INFO    :   matched filter SNR = 5.57-0.26j
21:54 bilby INFO    :   mass_1_source = 2.4
21:54 bilby INFO    :   mass_2_source = 1.15
21:54 bilby INFO    :   chi_1 = 0.02
21:54 bilby INFO    :   chi_2 = 0.02
21:54 bilby INFO    :   luminosity_distance = 250.0
21:54 bilby INFO    :   theta_jn = 0.4
21:54 bilby INFO    :   psi = 2.659
21:54 bilby INFO    :   phase = 1.3
21:54 bilby INFO    :   geocent_time = 1126259642.413
21:54 bilby INFO    :   ra = 1.375
21:54 bilby INFO    :   dec = -1.2108
21:54 bilby INFO    :   lambda_1 = 0
21:54 bilby INFO    :   lambda_2 = 1346
```

Out[79]:
```
[{'plus': array([ 0.00000000e+00-0.00000000e+00j,  0.00000000e+00-
0.00000000e+00j,
          0.00000000e+00-0.00000000e+00j, ...,
         -9.05485035e-26+2.82680873e-26j, -9.05493881e-26+2.825215
02e-26j,
          0.00000000e+00-0.00000000e+00j]),
  'cross': array([0.00000000e+00+0.00000000e+00j, 0.00000000e+00+
0.00000000e+00j,
         0.00000000e+00+0.00000000e+00j, ...,
         2.81727869e-26+9.02432367e-26j, 2.81569036e-26+9.02441183
e-26j,
         0.00000000e+00+0.00000000e+00j])},
 {'plus': array([ 0.00000000e+00-0.00000000e+00j,  0.00000000e+00-
0.00000000e+00j,
          0.00000000e+00-0.00000000e+00j, ...,
         -9.05485035e-26+2.82680873e-26j, -9.05493881e-26+2.825215
02e-26j,
          0.00000000e+00-0.00000000e+00j]),
  'cross': array([0.00000000e+00+0.00000000e+00j, 0.00000000e+00+
0.00000000e+00j,
         0.00000000e+00+0.00000000e+00j, ...,
         2.81727869e-26+9.02432367e-26j, 2.81569036e-26+9.02441183
e-26j,
         0.00000000e+00+0.00000000e+00j])},
 {'plus': array([ 0.00000000e+00-0.00000000e+00j,  0.00000000e+00-
0.00000000e+00j,
          0.00000000e+00-0.00000000e+00j, ...,
         -9.05485035e-26+2.82680873e-26j, -9.05493881e-26+2.825215
02e-26j,
          0.00000000e+00-0.00000000e+00j]),
  'cross': array([0.00000000e+00+0.00000000e+00j, 0.00000000e+00+
0.00000000e+00j,
         0.00000000e+00+0.00000000e+00j, ...,
         2.81727869e-26+9.02432367e-26j, 2.81569036e-26+9.02441183
e-26j,
         0.00000000e+00+0.00000000e+00j])}]
```

In [80]:
```
# Initialise the likelihood by passing in the interferometer data (
# and the waveform generator
likelihood = bilby.gw.GravitationalWaveTransient(
    interferometers=interferometers,
    waveform_generator=waveform_generator,
)
```

In [ ]:
```
# WHY DOES THIS WORK!!!!!!
priors_gw = dict(priors_gw)
print(priors_gw)

# Run sampler.  In this case we're going to use the `nestle` sample
# For production runs use dynesty
# This will be very slow depending on your chosen signal
result = bilby.run_sampler(
    likelihood=likelihood,
    priors=priors_gw,
    sampler="nestle",
```

```
    nlive=400,
    #injection_parameters=injection_parameters,
    outdir=outdir,
    label=label,
    npool=1,
)
```

```
21:54 bilby INFO    : Running for label 'nsbh_example', output will
be saved to 'outdir_nsbh'
21:54 bilby INFO    : Using lal version 7.3.1
21:54 bilby INFO    : Using lal git version Branch: None;Tag: lalsui
te-v7.19;Id: 84d780c102cf51ea1fdf7a1cbf0a626a5eca0d0a;;Builder: Dunc
an Macleod <duncan.macleod@ligo.org>;Repository status: CLEAN: All m
odifications committed
21:54 bilby INFO    : Using lalsimulation version 5.2.1
21:54 bilby INFO    : Using lalsimulation git version Branch: None;T
ag: lalsuite-v7.19;Id: 84d780c102cf51ea1fdf7a1cbf0a626a5eca0d0a;;Bui
lder: Duncan Macleod <duncan.macleod@ligo.org>;Repository status: CL
EAN: All modifications committed
{'mass_1': Constraint(minimum=0.5, maximum=5, name='mass_1', latex_l
abel='$m_1$', unit=None), 'mass_2': Constraint(minimum=0.5, maximum=
5, name='mass_2', latex_label='$m_2$', unit=None), 'mass_ratio': Del
taFunction(peak=0.8666666666666667, name=None, latex_label=None, uni
t=None), 'luminosity_distance': DeltaFunction(peak=250.0, name=None,
latex_label=None, unit=None), 'dec': -1.2108, 'ra': 1.375, 'theta_j
n': 0.4, 'psi': 2.659, 'phase': 1.3, 'chirp_mass_source': Interped(x
x=array([0.805528  , 0.81658327, 0.82763855, 0.83869382, 0.84974909,
       0.86080436, 0.87185964, 0.88291491, 0.89397018, 0.90502545,
       0.91608073, 0.927136  , 0.93819127, 0.94924655, 0.96030182,
       0.97135709, 0.98241236, 0.99346764, 1.00452291, 1.01557818,
       1.02663345, 1.03768873, 1.048744  , 1.05979927, 1.07085455,
       1.08190982, 1.09296509, 1.10402036, 1.11507564, 1.12613091,
       1.13718618, 1.14824145, 1.15929673, 1.170352  , 1.18140727,
       1.19246255, 1.20351782, 1.21457309, 1.22562836, 1.23668364,
       1.24773891, 1.25879418, 1.26984945, 1.28090473, 1.29196   ,
       1.30301527, 1.31407055, 1.32512582, 1.33618109, 1.34723636,
       1.35829164, 1.36934691, 1.38040218, 1.39145745, 1.40251273,
       1.413568  , 1.42462327, 1.43567855, 1.44673382, 1.45778909,
       1.46884436, 1.47989964, 1.49095491, 1.50201018, 1.51306545,
       1.52412073, 1.535176  , 1.54623127, 1.55728655, 1.56834182,
       1.57939709, 1.59045236, 1.60150764, 1.61256291, 1.62361818,
       1.63467345, 1.64572873, 1.656784  , 1.66783927, 1.67889455,
       1.68994982, 1.70100509, 1.71206036, 1.72311564, 1.73417091,
       1.74522618, 1.75628145, 1.76733673, 1.778392  , 1.78944727,
       1.80050255, 1.81155782, 1.82261309, 1.83366836, 1.84472364,
       1.85577891, 1.86683418, 1.87788945, 1.88894473, 1.9       ,
       1.91105527, 1.92211055, 1.93316582, 1.94422109, 1.95527636,
       1.96633164, 1.97738691, 1.98844218, 1.99949745, 2.01055273,
       2.021608  , 2.03266327, 2.04371855, 2.05477382, 2.06582909,
       2.07688436, 2.08793964, 2.09899491, 2.11005018, 2.12110545,
       2.13216073, 2.143216  , 2.15427127, 2.16532655, 2.17638182,
       2.18743709, 2.19849236, 2.20954764, 2.22060291, 2.23165818,
       2.24271345, 2.25376873, 2.264824  , 2.27587927, 2.28693455,
       2.29798982, 2.30904509, 2.32010036, 2.33115564, 2.34221091,
       2.35326618, 2.36432145, 2.37537673, 2.386432  , 2.39748727,
       2.40854255, 2.41959782, 2.43065309, 2.44170836, 2.45276364,
```

```
       2.46381891, 2.47487418, 2.48592945, 2.49698473, 2.50804   ,
       2.51909527, 2.53015055, 2.54120582, 2.55226109, 2.56331636,
       2.57437164, 2.58542691, 2.59648218, 2.60753745, 2.61859273,
       2.629648  , 2.64070327, 2.65175855, 2.66281382, 2.67386909,
       2.68492436, 2.69597964, 2.70703491, 2.71809018, 2.72914545,
       2.74020073, 2.751256  , 2.76231127, 2.77336655, 2.78442182,
       2.79547709, 2.80653236, 2.81758764, 2.82864291, 2.83969818,
       2.85075345, 2.86180873, 2.872864  , 2.88391927, 2.89497455,
       2.90602982, 2.91708509, 2.92814036, 2.93919564, 2.95025091,
       2.96130618, 2.97236145, 2.98341673, 2.994472  ]), yy=array([
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       6.09104967e-03, 1.20579634e-02, 2.02212850e-02, 3.44741172e-0
2,
       5.49436414e-02, 7.51440589e-02, 9.95500757e-02, 1.23581015e-0
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1,
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1,
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1,
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1,
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1,
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1,
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1,
       6.09700756e-01, 6.01807547e-01, 6.03361186e-01, 6.03858492e-0
```

```
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1,
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1,
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1,
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1,
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21:54 bilby INFO    : mass_2=Constraint(minimum=0.5, maximum=5, name
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21:54 bilby INFO    : luminosity_distance=250.0
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21:54 bilby INFO    : ra=1.375
21:54 bilby INFO    : theta_jn=0.4
21:54 bilby INFO    : psi=2.659
21:54 bilby INFO    : phase=1.3
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21:54 bilby INFO    : chi_2=0.02
21:54 bilby INFO    : geocent_time=1126259642.413
21:54 bilby INFO    : lambda_1=0.0
21:54 bilby INFO    : Analysis likelihood class: <class 'bilby.gw.li
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21:54 bilby INFO    : Analysis likelihood noise evidence: -94025.417
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21:54 bilby INFO    : Single likelihood evaluation took nan s
21:54 bilby INFO    : Using sampler Nestle with kwargs {'method': 'm
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'rstate': None, 'callback': <function print_progress at 0x7f83e2a365
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it=  2346 logz=-35.1332451
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In [57]:
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result.plot_corner()
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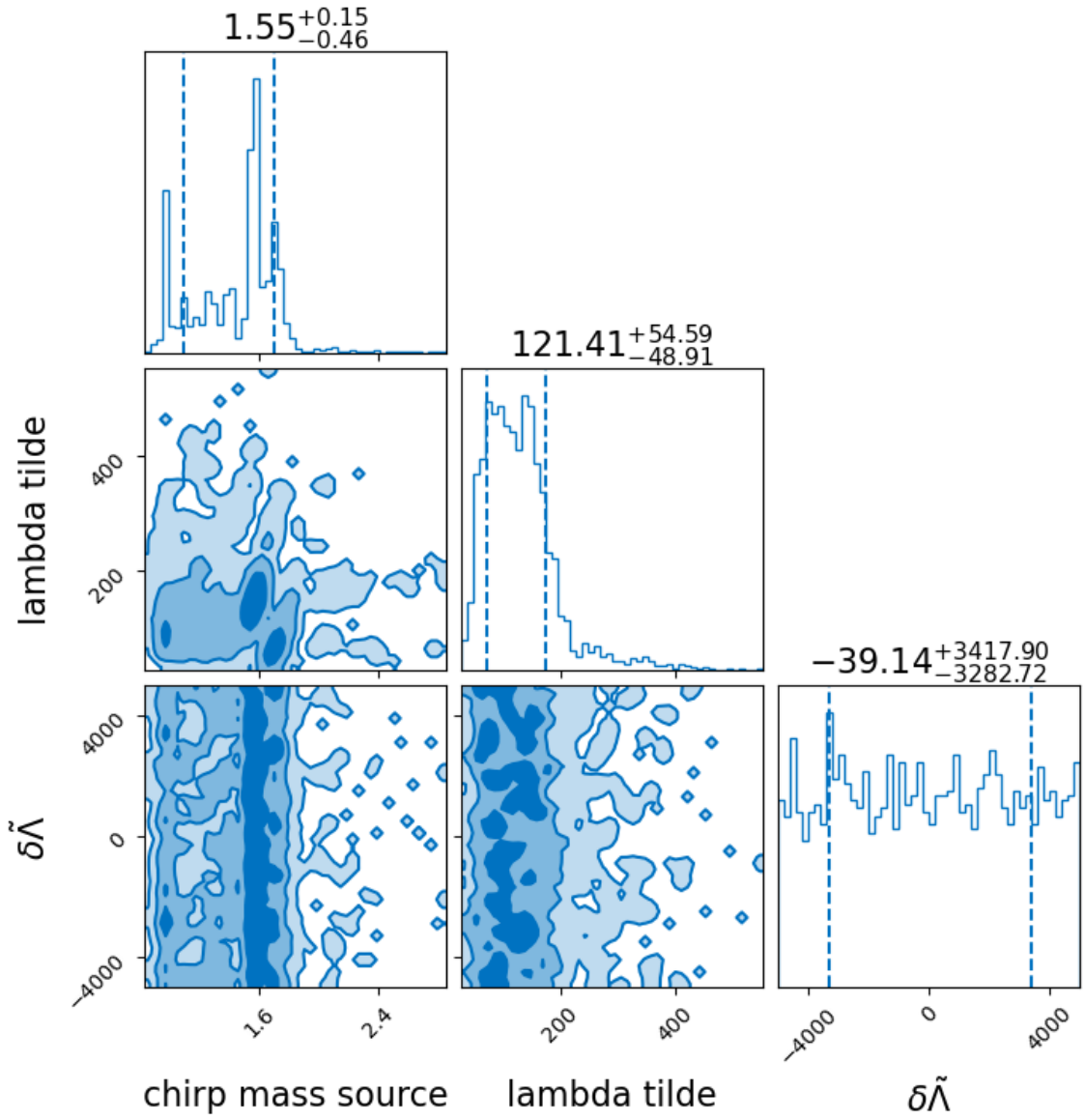
Out[57]:



In [ ]: