

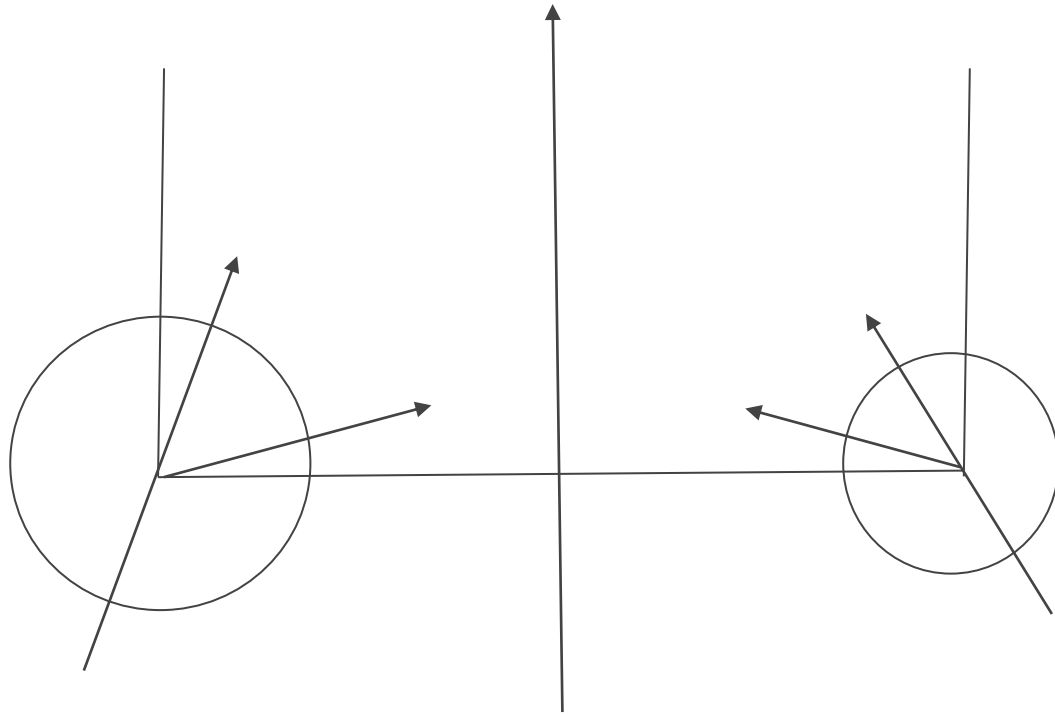


Inferring the properties of parent BHs from the remnant's spin using Deep Learning

Sayan Neogi

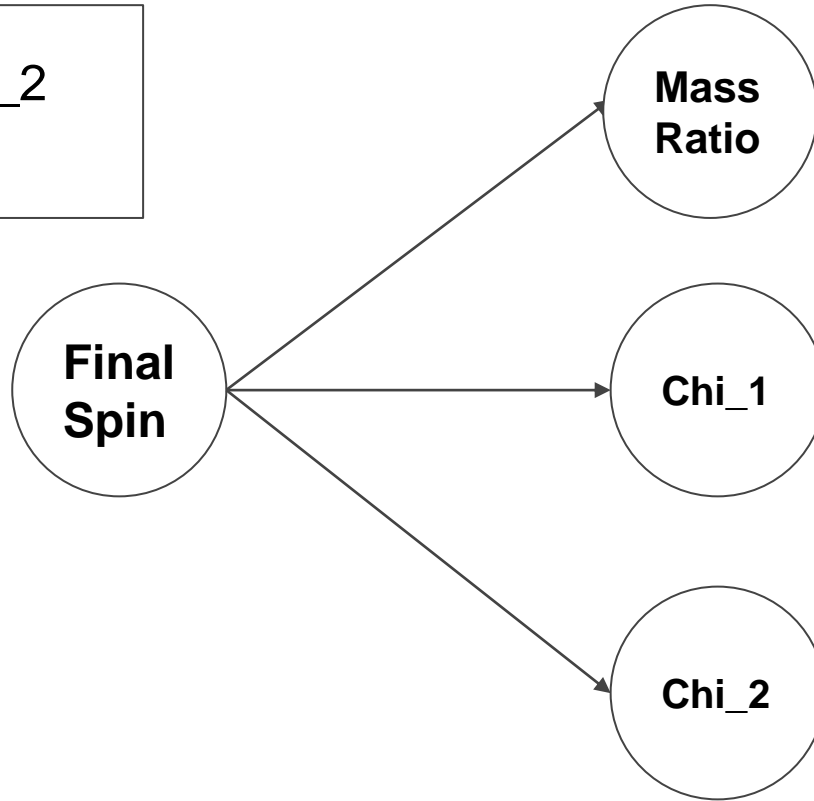
Matthew Mould

Davide Gerosa

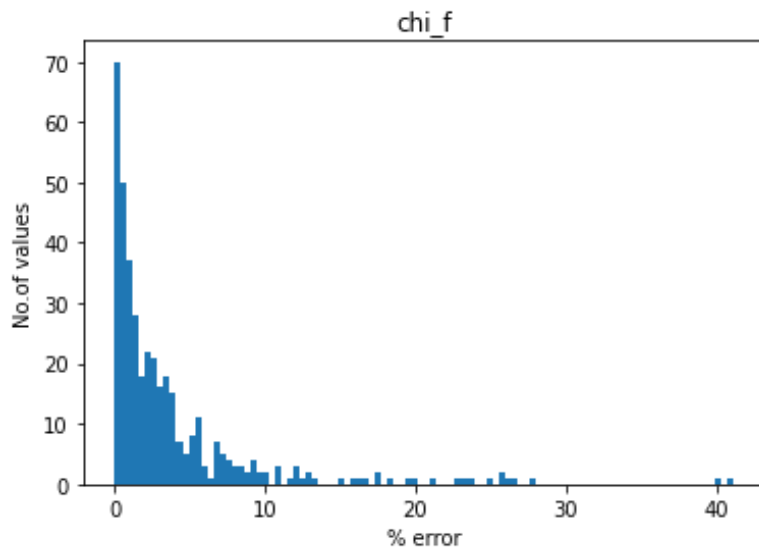
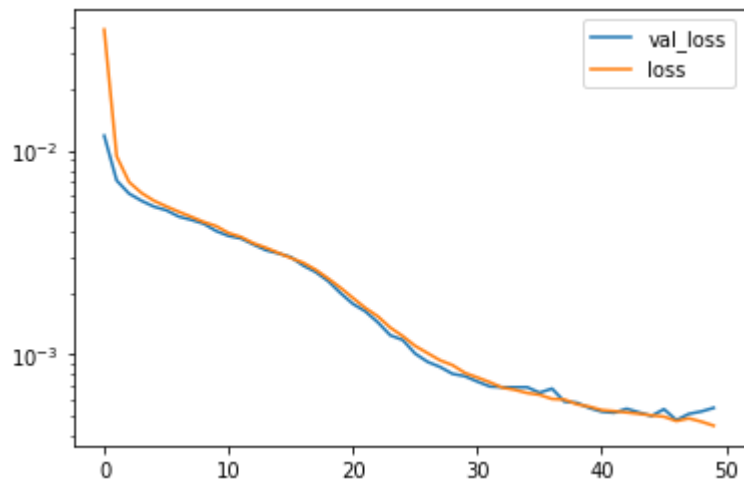


Goal:

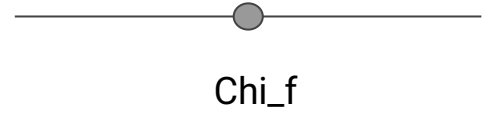
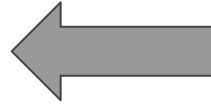
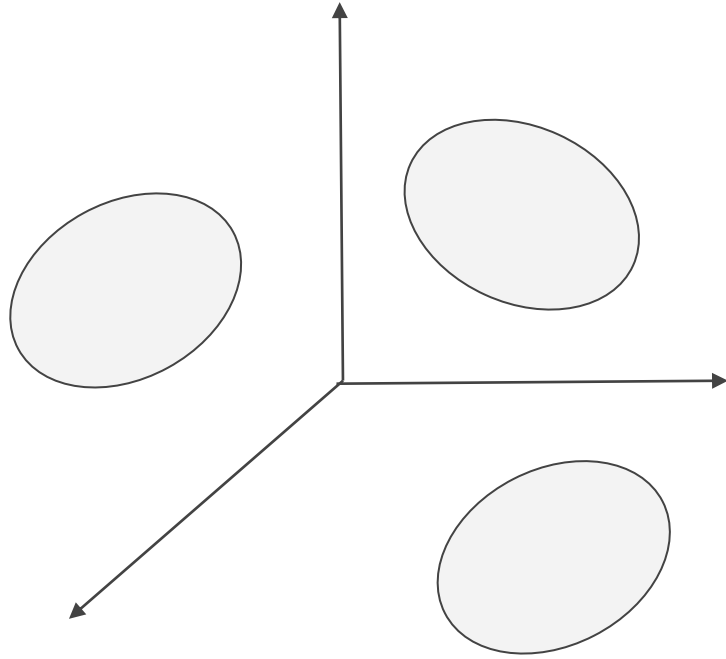
Theta_1, Theta_2
= {0, np.pi}



Simple NN's can learn the Forward model well.



Problem!





Gameplan:

Instead of making point estimates for parent values, output distributions (pdf's) instead.



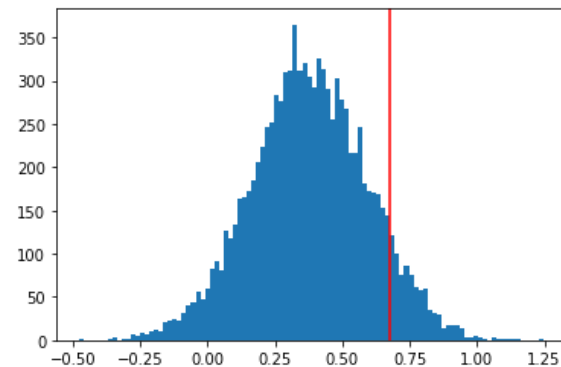
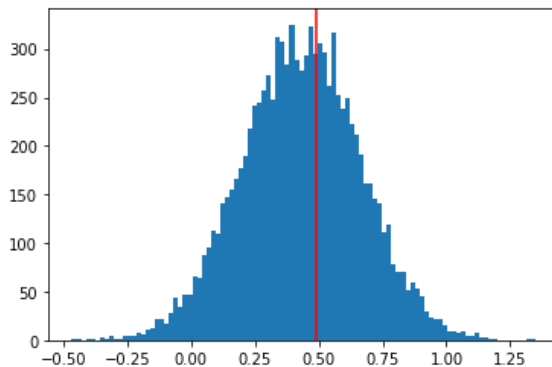
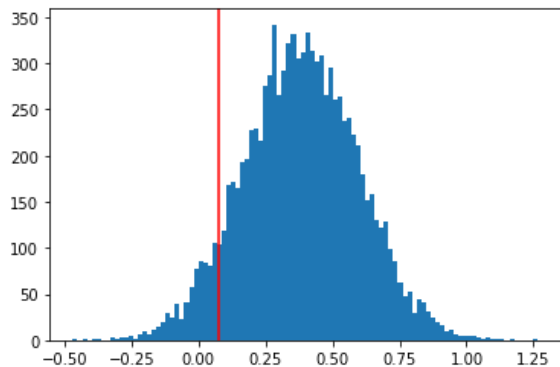
Gameplan:

So given a value of χ_f ,
the network should give us the
probability distribution of q (and χ_1 ,
 χ_2)

Strategies:

1) Use Tensorflow Probability.

a) St. dev of predictions = approx 0.3

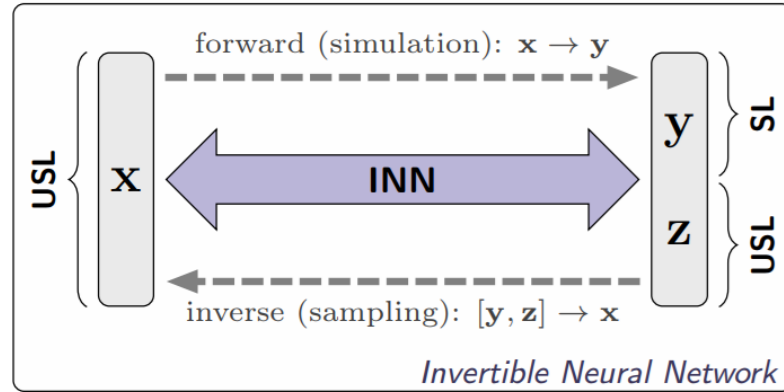
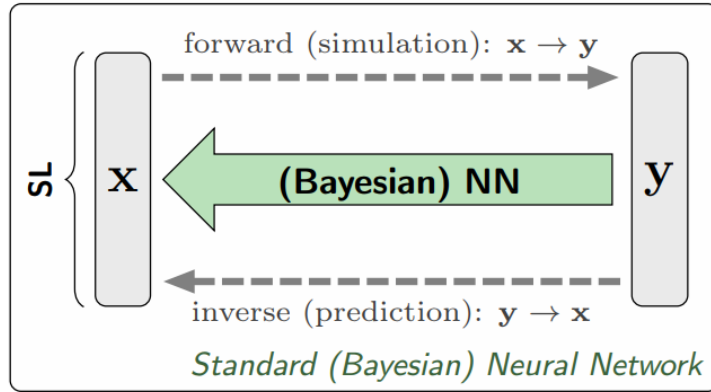


Strategies:

Works poorly with inverse model.

- a) Gaussian is too **simple** to capture the posterior.
- a) Possible Idea (not explored yet): Combine **N** Gaussians with diff. loc and scales
(**N tbd by network**)

2) Use “Invertible Neural Networks”



(Analysing Inverse Problems with INN, Ardizzone et al (2019))

Drawback:

Failed to train it even for simple mappings

3) Use Normalizing Flows

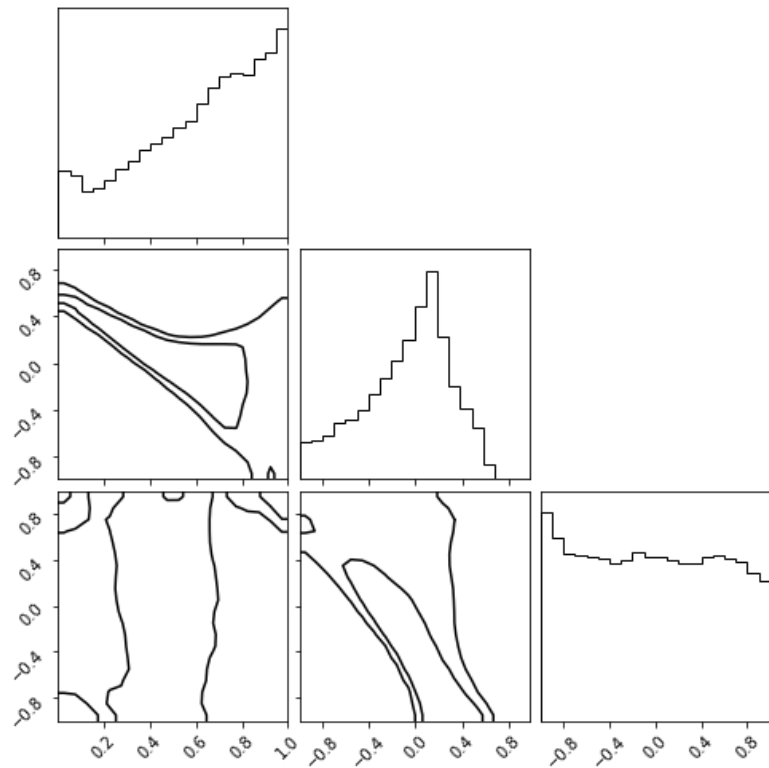
Idea:

Take a normal distribution and apply successive **invertible** transformations to it to better approximate your desired distribution

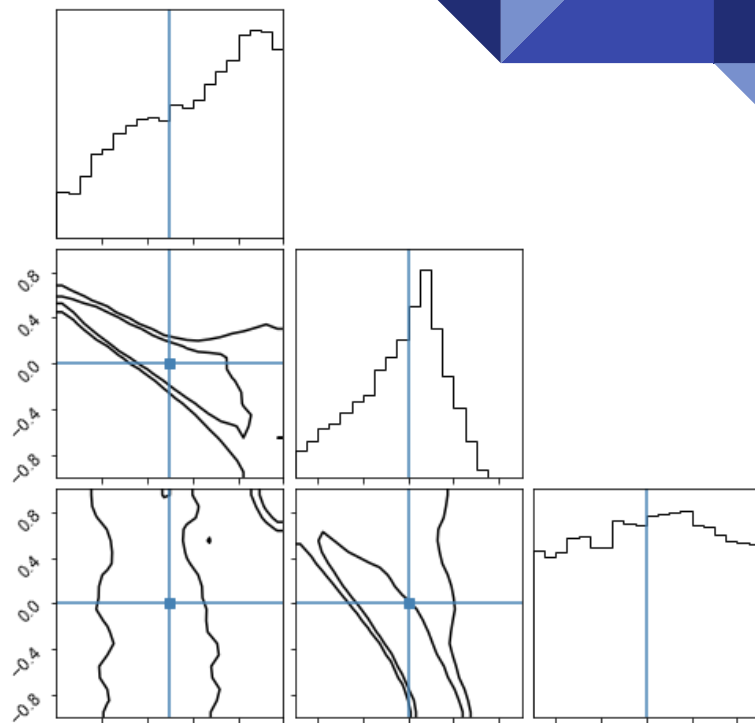
We use **Conditional** Masked Autoregressive Flows.

So for every value of **chi_f**, we get a **different** posterior distribution

Spin-Aligned Case (for $\chi_f=0.62$)

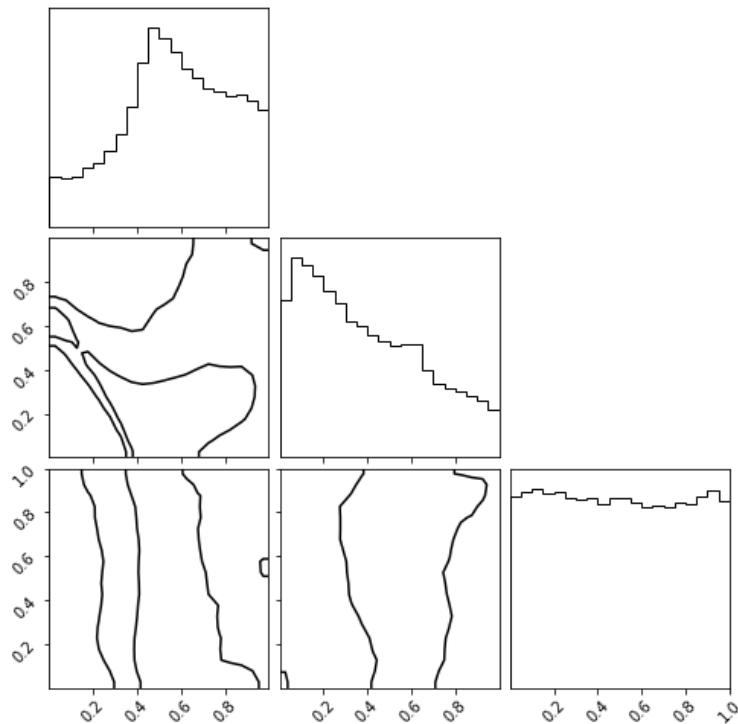


MAFs (Masked
Autoregressive Flow)

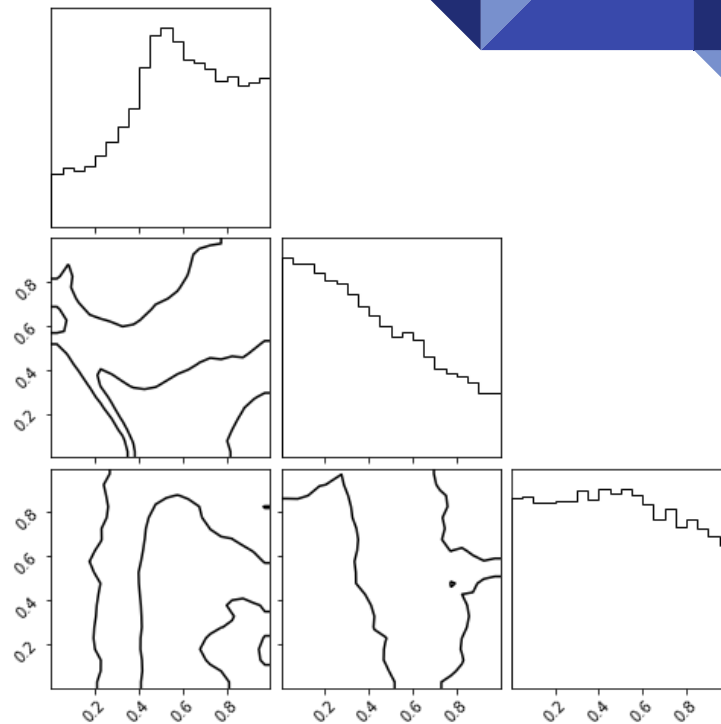


MCMC

(Not) Full Param Space (for $\chi_f=0.62$)

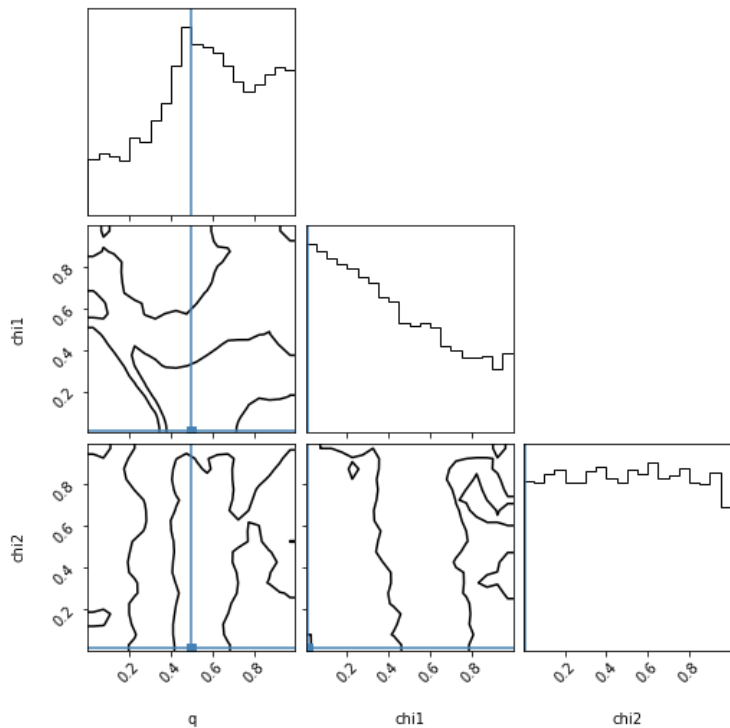


MAFs (Masked
Autoregressive Flow)

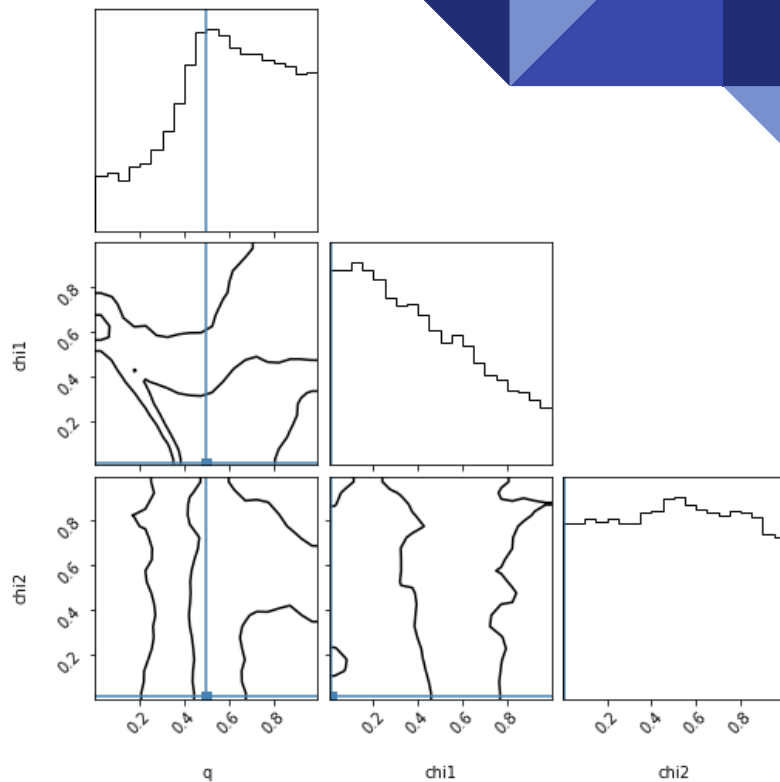


MCMC

Full Param Space (for $\chi_f=0.62$)



MAFs (Masked
Autoregressive Flow)



MCMC

Comparing Distributions

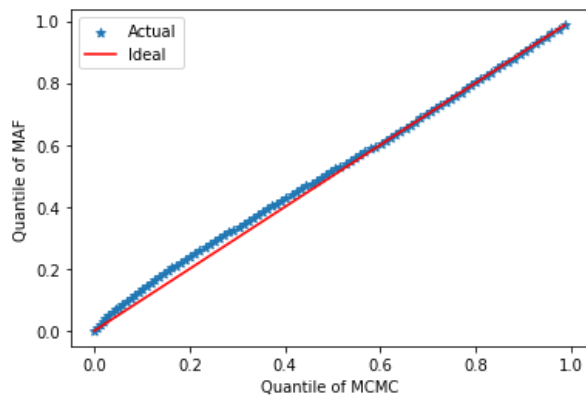
Using the Jensen Shannon Divergence

- a) Modified form of KL
- a) Constrained between $[0,1]$ (0 for identical)
- a) For the full param case, JSD for q dist. is 0.03

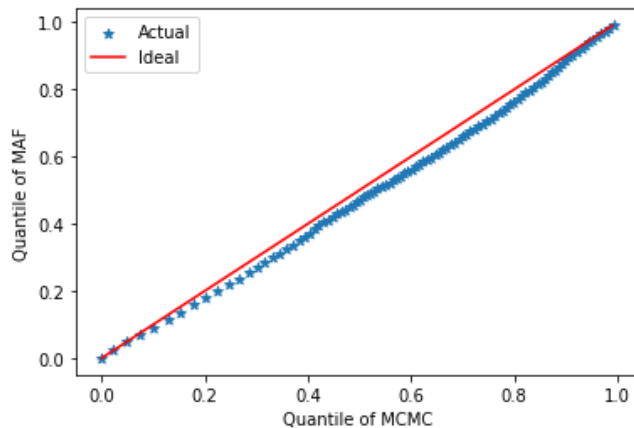
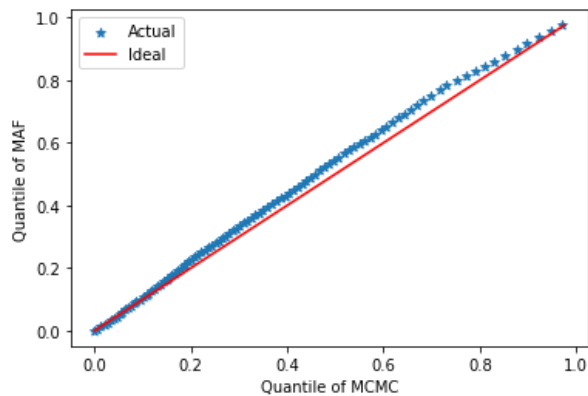
Comparing the MAF and MCMC dist.

Q-Q Plots!

q



chi_1



chi_2

Next Step:

- 1) Robust statistic to compare the MCMC and MAF distributions
 - a) Candidates: KS Test (too sensitive)
 - b) Suggestions?
- 1) Improving the convergence of NN for the full param space.
 - a) Tweaking the architecture
- 1) Using NR data to train the model.
 - a) Training data only about $1e3$
- 1) Investigating the posterior to infer constraints.



Thank You !