

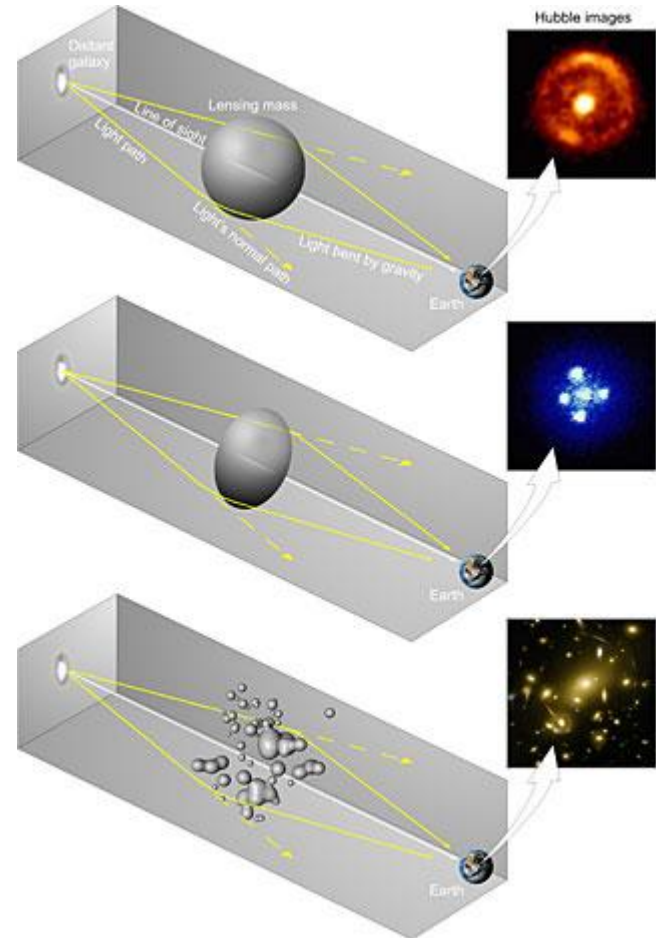


# Normalizing Flows

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# Lentes Gravitacionais

- Trajetória da luz desviada
- Imagens magnificadas e/ou distorcidas





# Motivação

- High red-shift galaxies, dwarf galaxies, star-forming galaxies, etc.
- Distribuição de massa de galáxias e de clusters de galáxias
- Energia e Matéria Escura
- Taxa de expansão do universo



# Problema

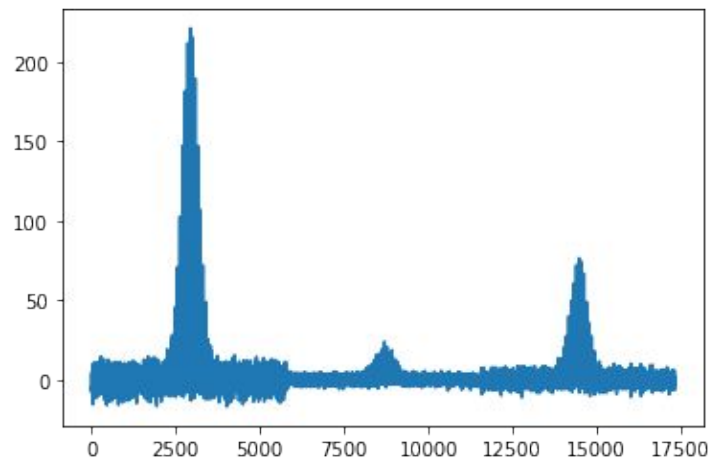
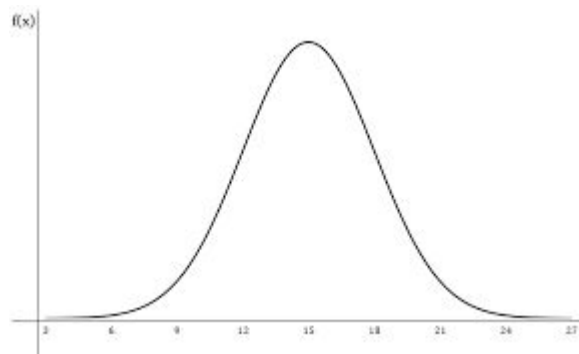
- Imagens demais de telescópios
- Menor resolução das imagens feitas da superfície da Terra

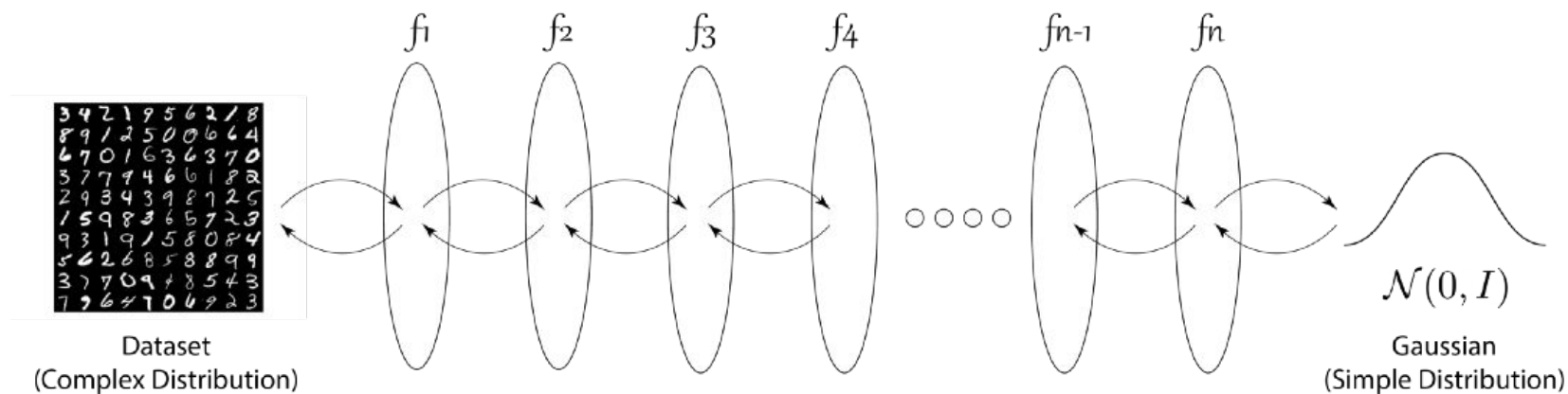
Solução: Modelos automáticos de detecção e regressão de parâmetros importantes

1. *Redshift* da lente
2. *Redshift* da fonte
3. Raio de Einstein (ângulo característico)
4. Dispersão de velocidades da lente

# Normalizing Flows

- Uso de funções reversíveis (bijetoras) e deriváveis
- Convergem mais facilmente do que GANs e VAEs
- Distribuição simples (Gaussiana)  $\leftrightarrow$  Distribuição complexa (Lentes Gravitacionais)





Fonte:

[https://towardsdatascience.com/introduction-to-normalizing-flows-d002af262a4b#:~:text=In%20simple%20words%2C%20normalizing%20flows,the%20function%20can%20be%20calculated.&text=Flow%2Dbased%20models%20are%20trained,z\)%20is%20the%20probability%20function.](https://towardsdatascience.com/introduction-to-normalizing-flows-d002af262a4b#:~:text=In%20simple%20words%2C%20normalizing%20flows,the%20function%20can%20be%20calculated.&text=Flow%2Dbased%20models%20are%20trained,z)%20is%20the%20probability%20function.)



## Network used

- 10x:
  - Random Permutation
  - LU Linear
  - Piecewise Coupling Transformation
- Random Permutation
- LU Linear
- Piecewise Coupling Transformation
- 4 resulting parameter



## Coupling Transformation

$$x \rightarrow x_A, x_B$$

$$\begin{aligned} y_A &= h(x_A, \text{ResNet}(x_B)) & x_A &= h^{-1}(y, \text{ResNet}(x_B)) \\ y_B &= x_B & x_B &= y_B \end{aligned}$$

$h$  é aplicada de forma piecewise para que seu jacobiano seja uma matriz triangular

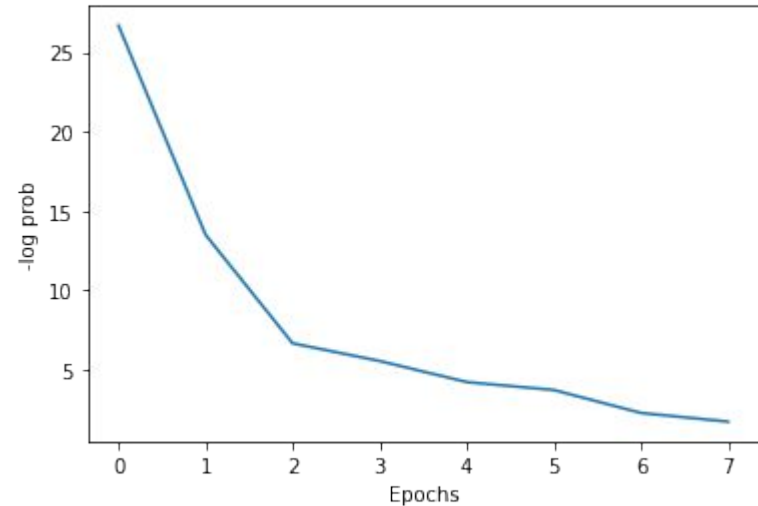
$$h(x^A, \text{ResNet}(x^B)) = (h_1(x_1^A, \text{ResNet}(x_1^B)), \dots, h_n(x_n^A, \text{ResNet}(x_n^B)))$$

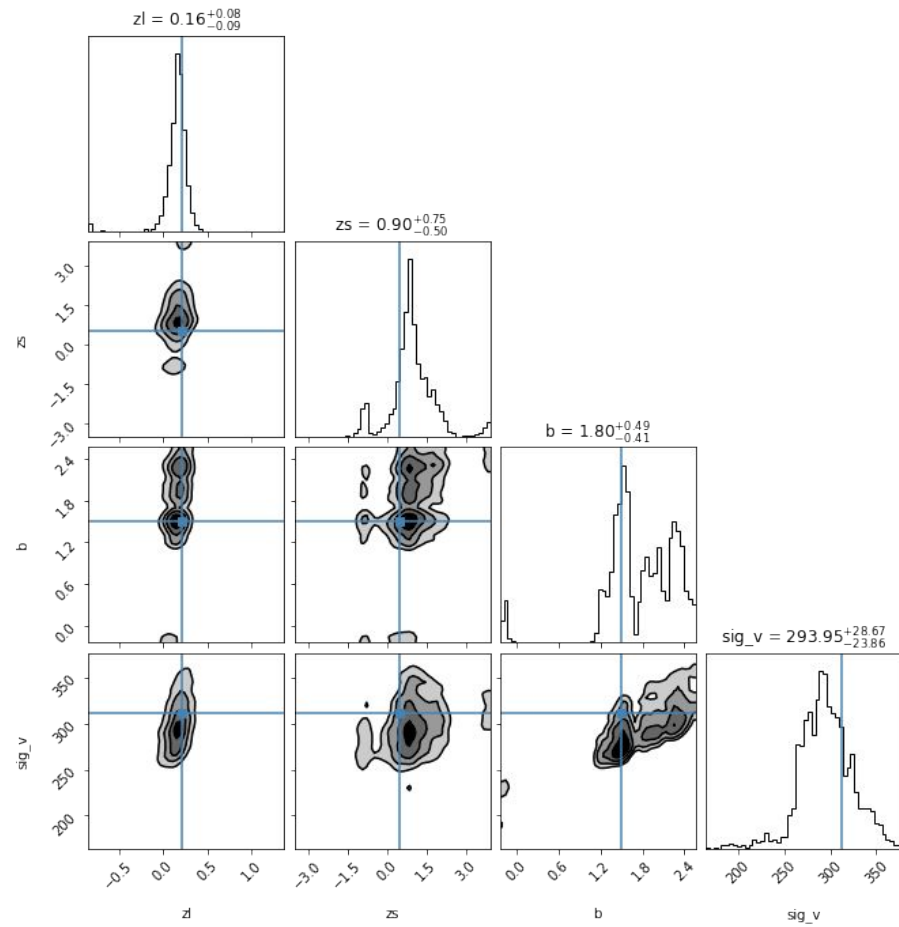
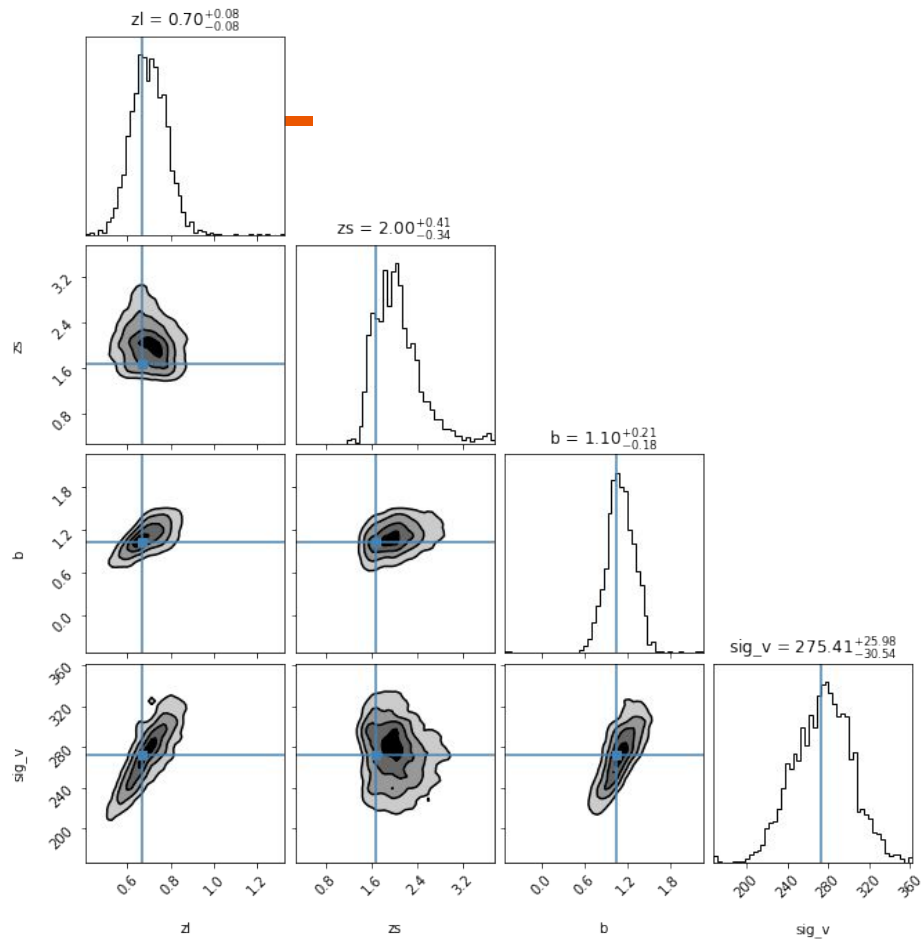


# Resultados

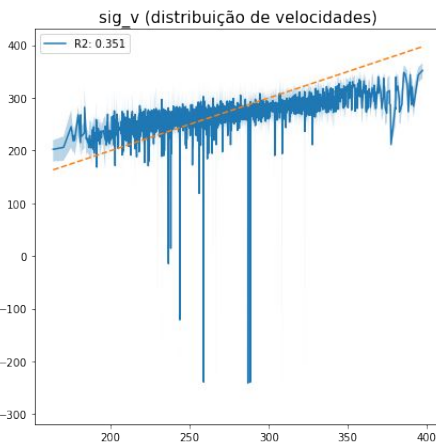
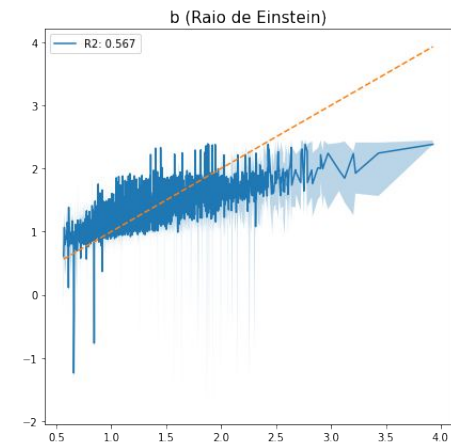
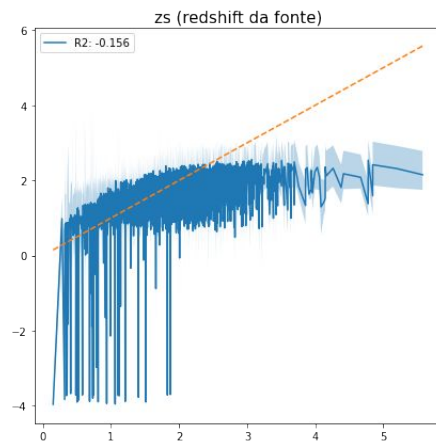
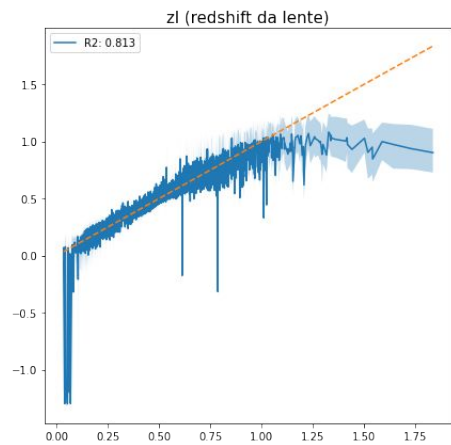
R2 score: métrica sobre a capacidade explicativa das previsões

- Redshift da lente: 0.91 (0.92)
- Redshift da fonte: 0.23 (0.04)
- Raio de Einstein: 0.28 (-0.18 )
- Dispersão de velocidades da lente: 0.67 (-0.28)





## 3 canais



## 1 canal

