Bayesian Stokes inversion

with Normalizing flows

***C. J. Díaz Baso**[1], A. Asensio Ramos[2,3], J. de la Cruz Rodríguez[1]

[1] Institute for Solar Physics, Dept. of Astronomy, Stockholm University, AlbaNova University Centre, SE-10691 Stockholm, Sweden
[2] Instituto de Astrofísica de Canarias, C/Vía Láctea s/n, E-38205 La Laguna, Tenerife, Spain
[3] Departamento de Astrofísica, Universidad de La Laguna, E-38206 La Laguna, Tenerife, Spain

*Email : carlos.diaz@astro.su.se

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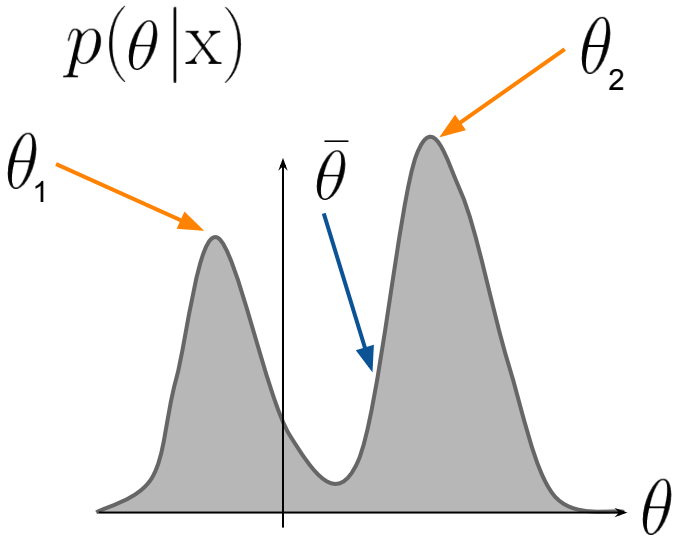
Introduction

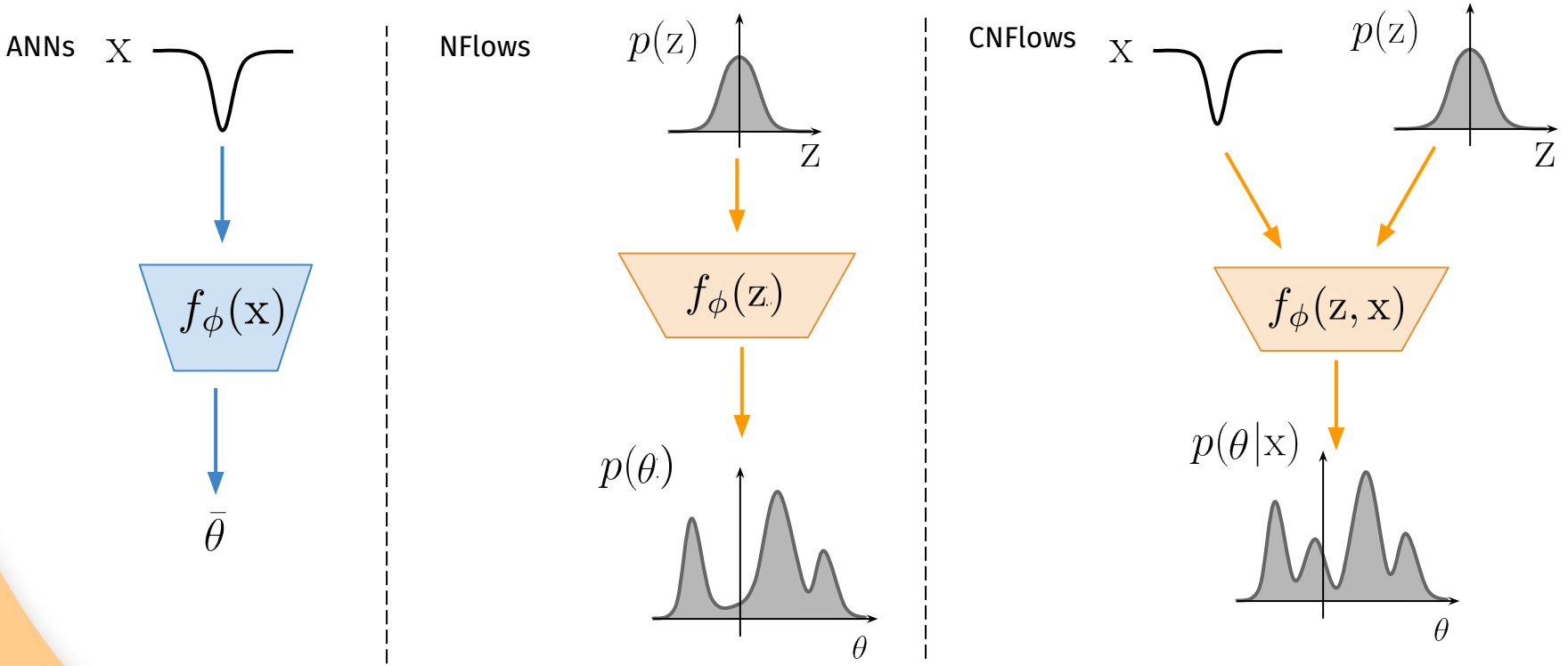
- Inversion codes estimate the **maximum likelihood values (best fit)**.
- Standard neural networks **are much faster but learn the "average" mapping**.
- Bayesian inference give us much more information: **uncertainty**, **correlations**, **multimodality, etc.**
- Bayesian sampling methods are very computationally expensive.



Probability distribution of θ given x.

Is there any way to perform fast Bayesian inference?

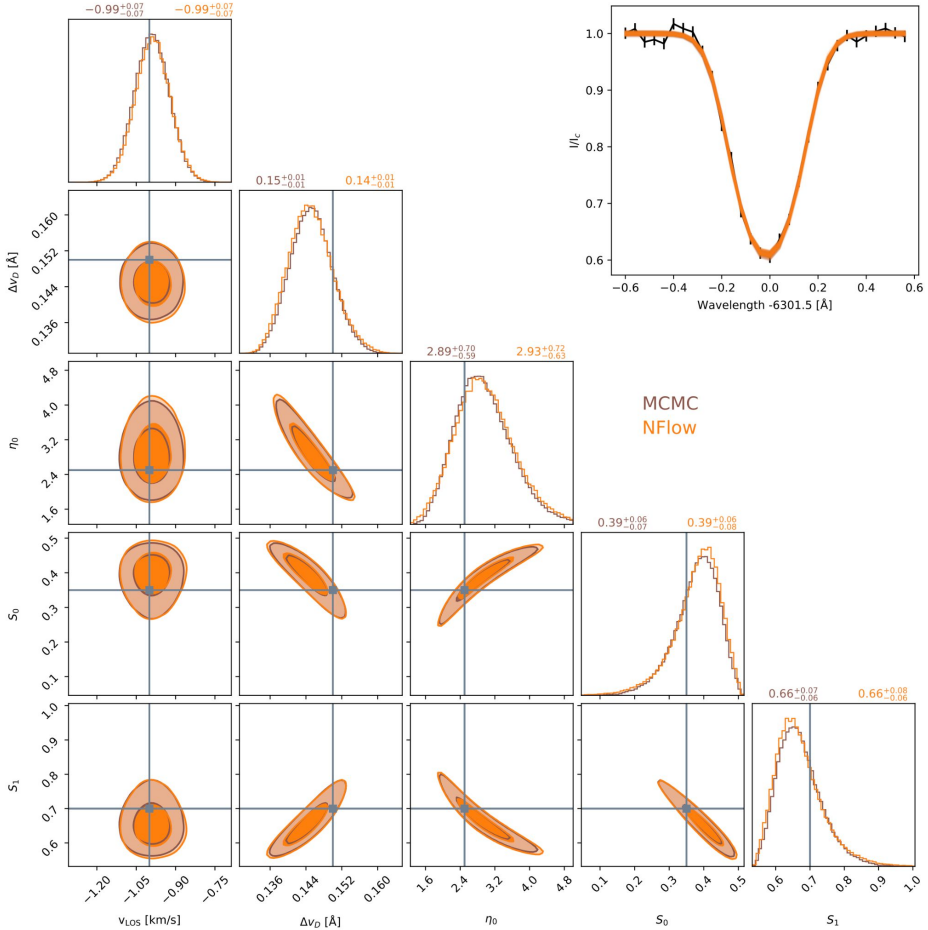
Normalizing flows (Rezende & Mohamed 2015, Dinh et al. 2016)



Normalizing flows transform a simple distribution into an approximation of any other complex distribution.

Milne-Eddington model

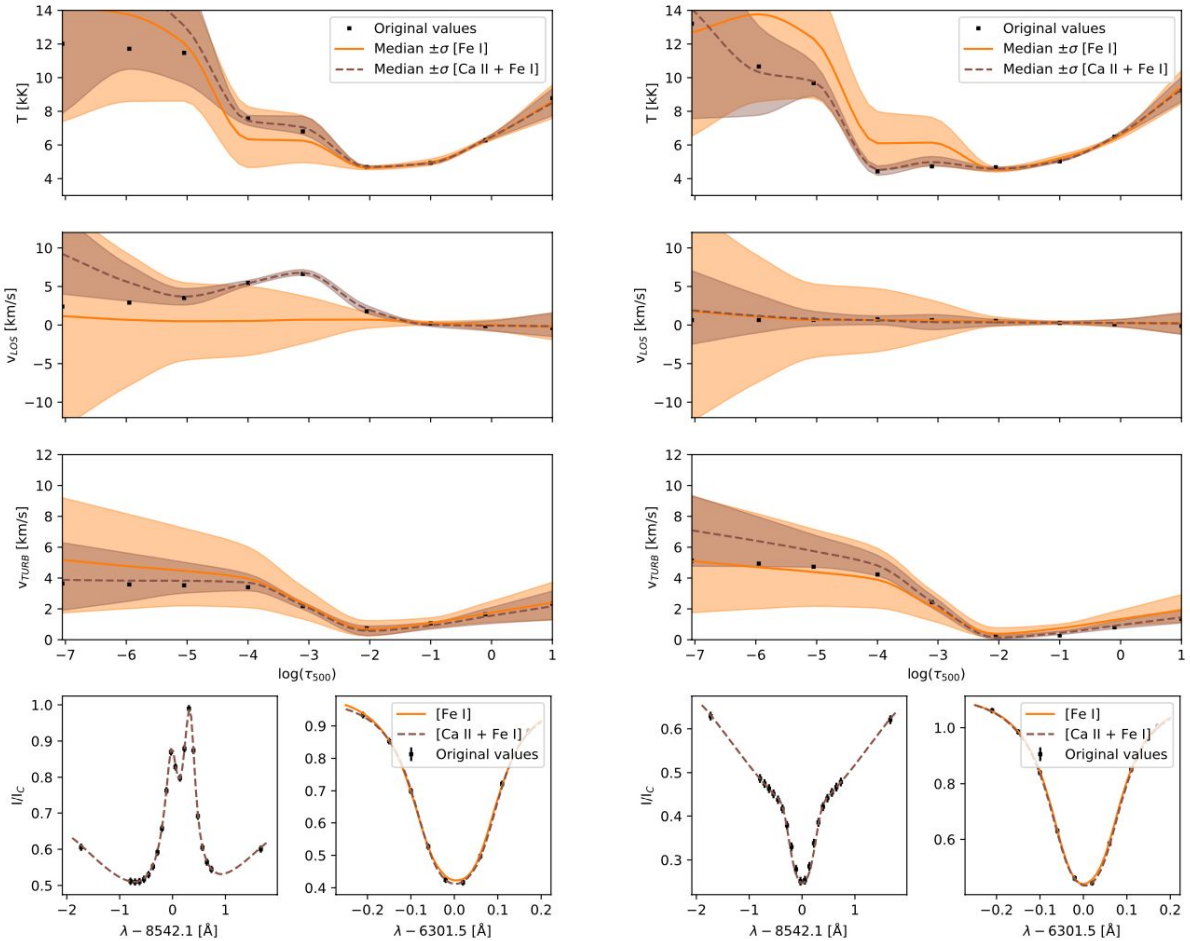
- We have created a database of 10^6 pairs of samples (parameters vs spectra).
- Once trained, **NFlow** can get the distribution for any given observation as accurate as the **MCMC** sampling.



Joint and marginal posterior distributions for the physical parameters involved in the Milne-Eddington model.

N-LTE inversion

- Two flows were trained:
  - → **the orange solution is inferred only using the FeI line**
  - → **the brown solution also uses the CaII profile.**
- Just from the database, the flow learns the range of sensitivity of each line given by width of the solution.
- It takes 1 second (producing 10^4 samples) while an MCMC whould take hours/days.

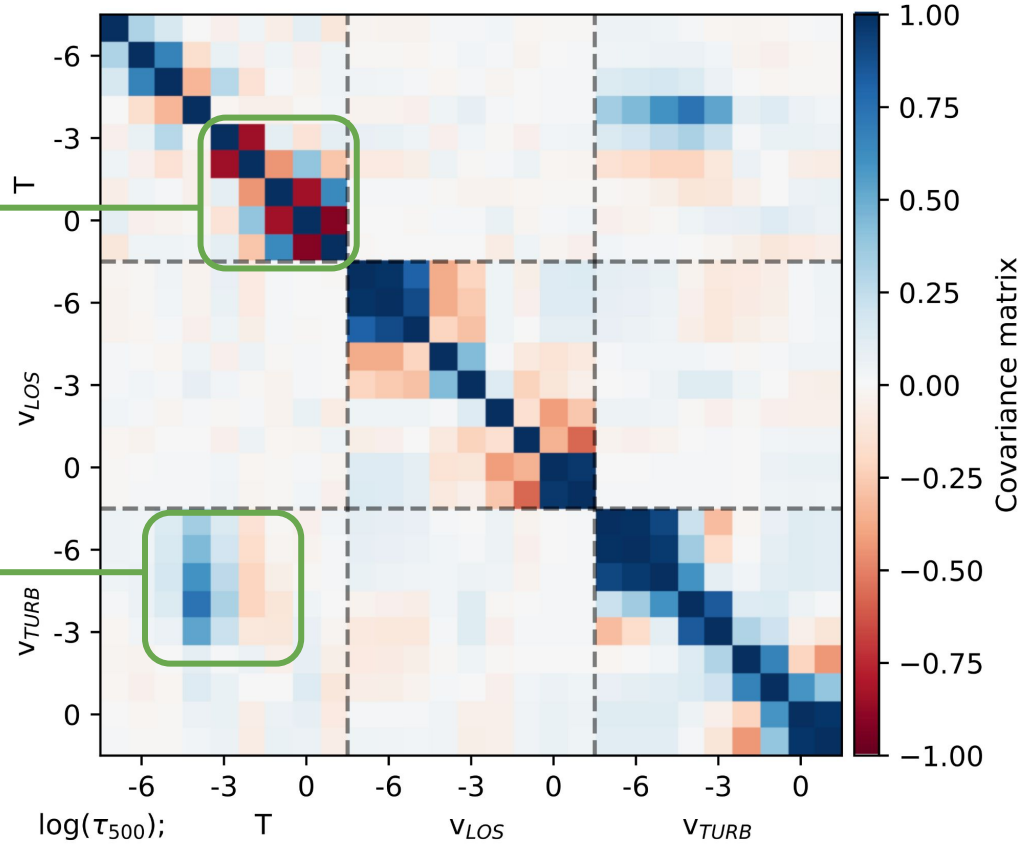


Atmospheric stratification. The colored bands of each curve indicate the standard deviation of each distribution.

N-LTE inversion

- We found checkerboard patterns associated with changes in temperature that can produce a similar fit.

- We found correlations between the broadening of the microturbulent velocity and the temperature.



Correlations between diferent physical quantities and locations along the stratification for a N-LTE inversion.

Summary and perspectives

- A promising approach for inferring the parameter values and uncertainty in spectroscopic inversions.
- Next step is to extend it to magnetic field inference from polarimetric data.
- Given the generality of the technique, it can be applied to other inverse problems.

More details in the manuscript:
https://arxiv.org/abs/2108.07089

The source code is at
https://github.com/cdiazbas/bayesflows

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