

# Using CoFI to experiment with geophysical inversion

*This will be an interactive session where  
participation is encouraged...*

**A Common Framework for Inference**



**AuScope**

**CSIRO**



Australian  
National  
University

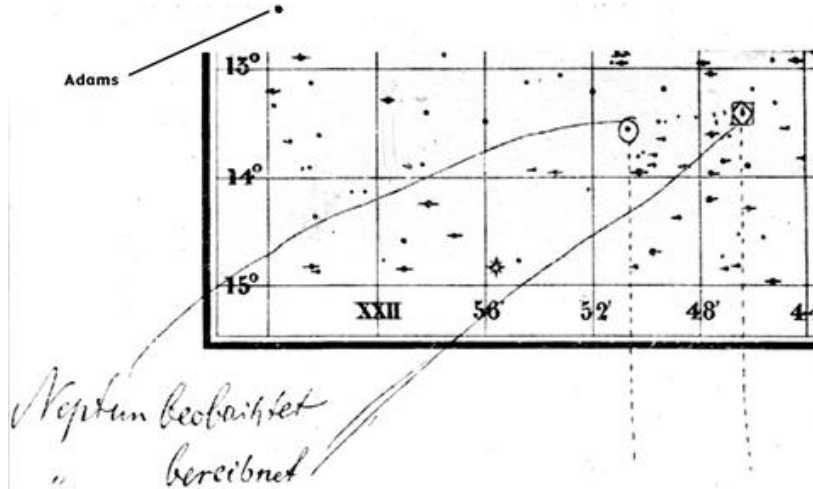


**InLab**

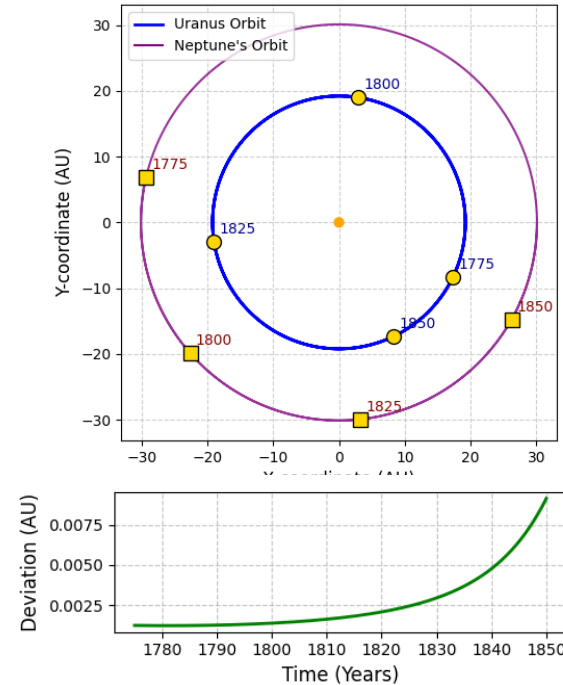
# Discovery of Neptune



*Le Verrier discovered a planet “with the tip of a pen, without any instruments other than the strength of his calculations alone.”...*



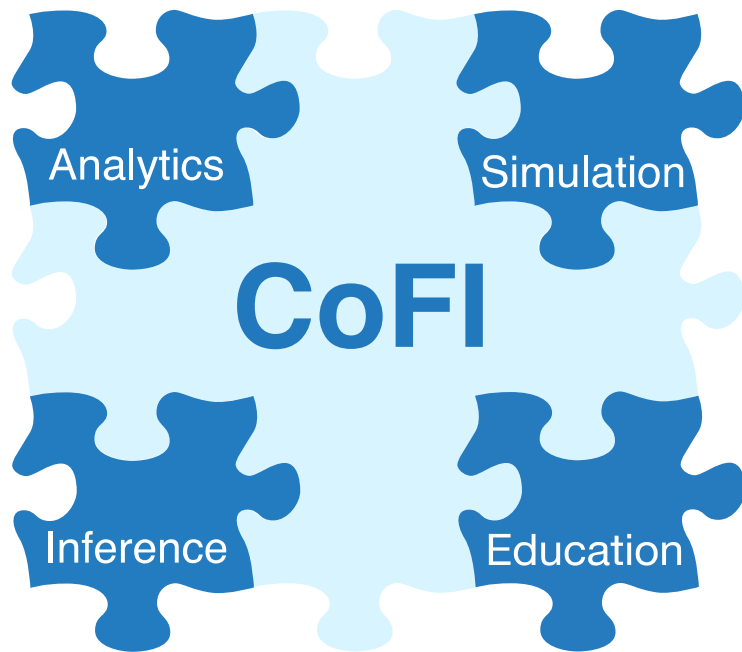
Lequeux, J. (2013). *Le Verrier--magnificent and detestable astronomer*. New York: Springer.



Use the observed data on Uranus and Newton's law of gravitation to deduce the mass, position, and orbit of the perturbing body



# A Common Framework for Inference



## *Vision*

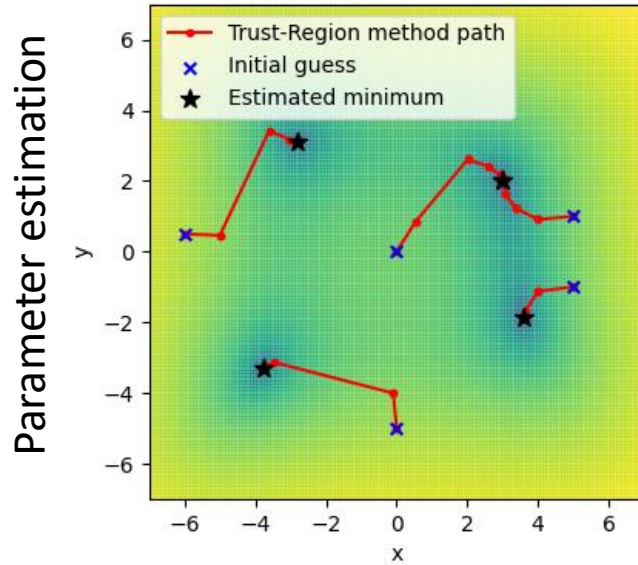
CoFI provides industry, academia and government with a software platform underpinning research, training, and services in the application of inference methods to data.

- *Lower barriers in access to leading edge approaches*
- *Reduce time in application of inference methods to data*
- *Interactive education environment for training in inversion*

*"A good example is the best sermon"*

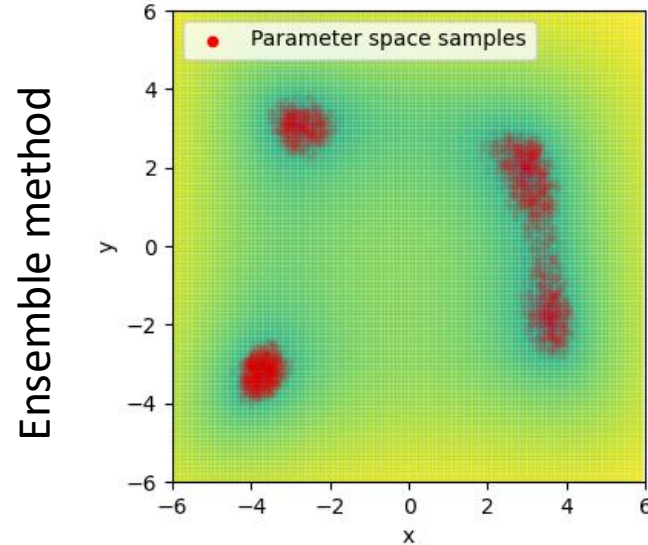
– Benjamin Franklin

# Two approaches to inversion



Optimisation of a misfit function

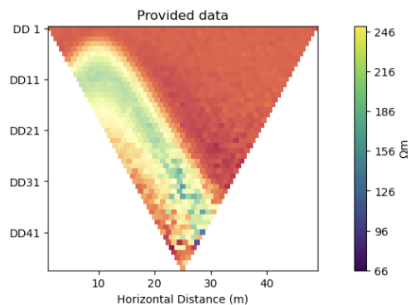
$$\phi(\mathbf{m}) = \|\mathbf{d} - g(\mathbf{m})\|_2^2 + \alpha^2 \|\mathbf{m}\|_2^2$$



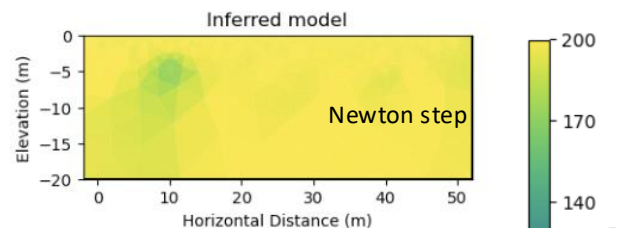
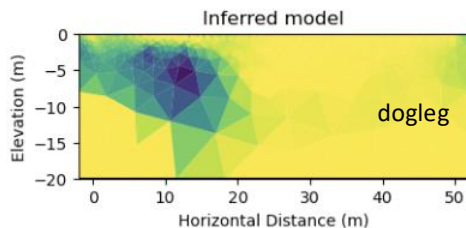
Sample a target pdf

$$p(\mathbf{m}|\mathbf{d}) = k \times p(\mathbf{d}|\mathbf{m}) p(\mathbf{m})$$

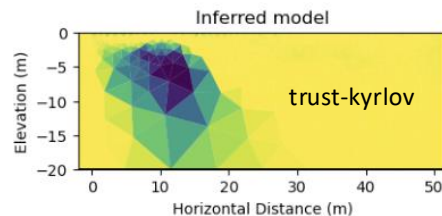
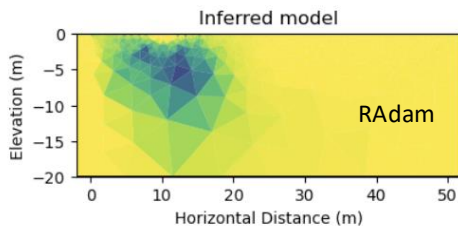
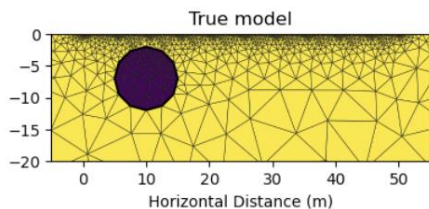
# Exploration is about possibilities



## CoFI - Common Framework for Inference



## Electrical resistivity tomography



and so is finding an inference method using CoFI...

# Momentum based optimizers



Vanilla iterative non-linear optimizers only consider the objective function at the current location

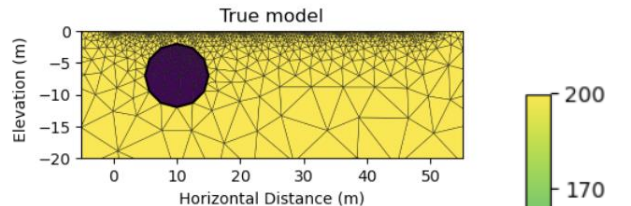
Machine learning methods are frequently applied to noisy data

Build inertia into the search direction to overcome local minima

```
CLASS torch.optim.RAdam(params, lr=0.001, betas=(0.9, 0.999), eps=1e-08, weight_decay=0, decoupled_weight_decay=False, *, foreach=None, differentiable=False) [SOURCE]
```

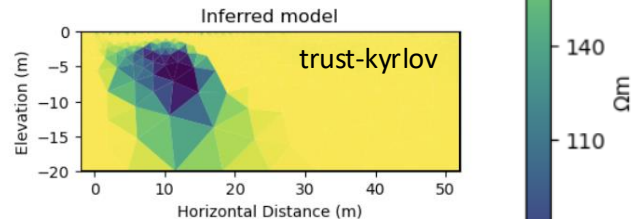
<https://pytorch.org/docs/stable/generated/torch.optim.RAdam.html>

pyGIMLi



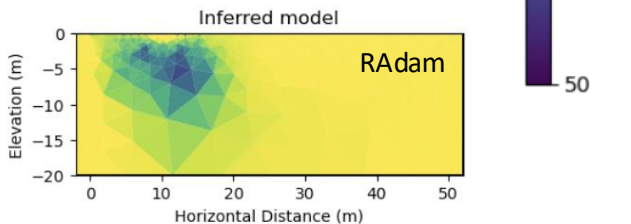
pyGIMLi

SciPy



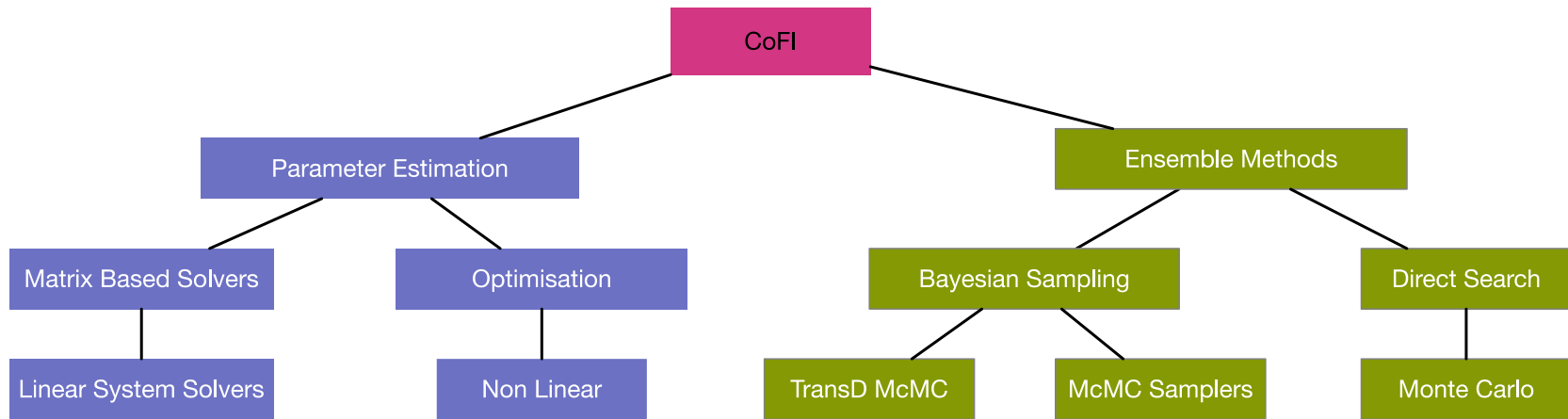
pyGIMLi

PyTorch





# The CoFI explorer



[www.inlab.au/inlab-explorer](http://www.inlab.au/inlab-explorer)

Build on existing and emerging software packages

**Example driven** – we only add a method if there is an example that needs it  
Findable, accessible, interoperable and reusable software



# Capturing an inverse problem

## Base Problem

```
inv_problem = BaseProblem()  
inv_problem.set_objective(DEFINE ME)  
inv_problem.set_jacobian(DEFINE ME)  
inv_problem.set_initial_model(DEFINE ME)
```

Jacobian  
Residuals  
Log Likelihood  
...

## Inversion Options

```
inv_options = InversionOptions()  
inv_options.set_tool("scipy.linalg.lstsq")
```

Proposal Strategy  
Convergence Criteria  
Number of iterations  
...

## Inversion

```
inv = Inversion(inv_problem, inv_options)  
result = inv.run()
```

An inverse method needs to only access a subset of features of a forward problem

Capturing a rich set of examples



# Take home messages...

What we hope you will take home today:

An understanding what CoFI can do.

Some familiarity with the design and philosophy of CoFI

Cognizance of the avenues to engage with CoFI and InLab

What we hope to take away today:

Priorities: Expanding the methods; the examples, building a community, other?

Wish lists: scalability; real data problems; automatic differentiation...



# CoFI – A Common Framework for Inference

The application domain expert says:

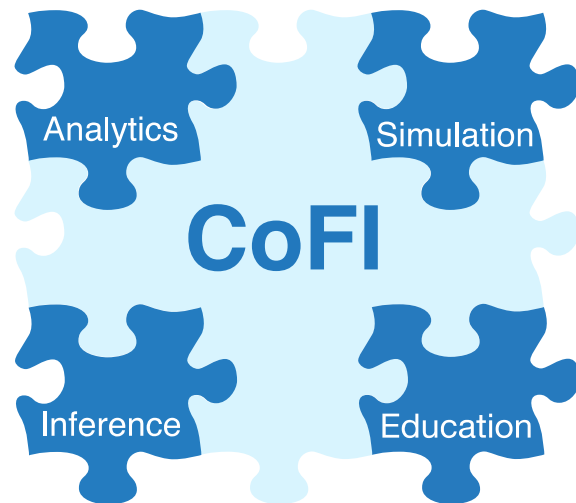
- What inference methods are suited to my data?
- Where can I get access to them? What is required to make them talk to my forward problem/data?
- How much work is that for me?

The research manager says:

- How can my staff learn about state-of-the-art inference methods
- How do we access the expertise?
- Can we keep our design options open?
- How long will it take?

The inference specialist says:

- What other problems can my inference method solve?
- Where can I get access to them?
- How much work is that for me?



[www.inlab.au](http://www.inlab.au)