Data-Optimized Coronal Field Model (DOC-FM)

An HAO-CISL collaboration

Sarah Gibson and Doug Nychka
"Good-morning, madam," said Holmes cheerily. "My name is Sherlock Holmes."
Her features and figure were those of a woman of thirty, but her hair was shot with premature grey, and her expression was weary and haggard.
"We shall soon set matters right, I have no doubt. You have come in by train this morning, I see. ... and yet you had a good drive in a dog-cart, along heavy roads, before you reached the station. ... "
"The left arm of your jacket is spattered with mud in no less than seven places. The marks are perfectly fresh.

There is no vehicle save a dog-cart which throws up mud in that way, and then only when you sit on the left-hand side of the driver."
Holmes’ Calculation

Before meeting Ms. Helen Stoner:

- A PRIOR probability of type of vehicle

Knowledge of vehicles effects:

- LIKELIHOOD of observation given type of vehicle

Combine prior with observation:

- POSTERIOR is a product:
  Likelihood of mud stains given type of vehicle
  \times Probability of type of vehicle

Maximize over vehicle

Holmes’ Conclusion: highest probability - vehicle = dog cart
Space weather alerts: A 21st century necessity

Why did we get this forecast wrong?
We are living in the outer atmosphere of the Sun.

Earth’s magnetic field acts as a shield.
Under certain conditions, the shield can break

Direction of magnetic field matters (southward Bz)

https://archive.org/details/CIL-10059
artist's impression
The bad news: we generally don’t know its magnetic orientation.

The good news: we usually know when something is coming!

http://svs.gsfc.nasa.gov/vis/a010000/a010800/a010809/index.html
Coronal cavities – a space weather source

We would like to be able to deduce their magnetic field
Prior: space weather sources store magnetic energy

Magnetic flux rope – magnetically-energized model
Likelihood: magnetic flux ropes match observations

Data • Model

Morphology

Structure

Data

Model

POS-flow (AIA)

LOS-flow (Doppler)

Data • Model

Flows

Our Conclusion: highest probability -- cavity = flux rope

air • planet • people
Compares well – but how do we translate to a quantified coronal magnetic field distribution?

Pick observations that directly constrain magnetism
Pick parameters that best match observations and prior knowledge

Maximize the posterior
Pick parameters that best match observations and prior knowledge

Maximize the posterior
Data-Optimized Coronal Field Model (DOC-FM)

Model of the solar coronal *physical state* (magnetic field, density, temperature..)
*Use priors!*

Forward operation of magnetically-sensitive *physical processes* on the physical state, resulting in synthetic observations

Maximize posterior

Modify model

Calculation of likelihood comparing synthetic vs. measured observations