Using Deep Learning to Plug an Observational Gap in EUV Irradiance Observations

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Take Home Message

• Measuring Solar Irradiance is important for us as a technological society.

• We lost our capability to measure part of the EUV spectrum.

• We can use neural networks to plug this EUV observational gap.

• Neural networks are not black boxes and can be mined for scientific insight.
MEASURING SOLAR IRRADIANCE IS IMPORTANT FOR US AS A TECHNOLOGICAL SOCIETY
Irradiance is the amount of power per unit area that we receive from the Sun in the form of light.

Why do we care?
Irradiance is the amount of power per unit area that we receive from the Sun in the form of light.

Why do we care?

We are a technological society.
Sunlight without atmospheric absorption
What drives solar EUV variability?
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WE LOST OUR CAPABILITY TO MEASURE PART OF THE EUV SPECTRUM
Helioseismic and Magnetic Imager (HMI):
- Dopplergrams.
- Magnetograms.
- Visible pseudo-continuum.

Atmospheric Imaging Assembly (AIA):
- EUV narrow-band imager.
- 9 EUV channels.
Helioseismic and Magnetic Imager (HMI):
• Dopplergrams.
• Magnetograms.
• Visible pseudo-continuum.

Atmospheric Imaging Assembly (AIA):
• EUV narrow-band imager.
• 9 EUV channels.

EUV Variability Experiment (EVE):
• EUV spectrograph.
• EUV spectral irradiance.
• MEGS-A suffered electrical fault in 2014
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THE EVENGERS

Heliophysics Mentors
Cheung (LM, Stanford)
Jin (SETI)
Munoz-Jaramillo (SWRI)

AI Mentor: David Fouhey
CV / AI Postdoc @ UC Berkeley
(soon Asst Prof at U. Michigan)
SDO/AIA

DEM (temp map inversion)

Physics-based (Forward Model)

SDO EVE emission line spectra

94, 131, 171, 193, 211 & 335 Å

304, 1600 & 1700 Å
The goal is to disentangle the multi-thermal response of the telescopes channels from the inherently multi-thermal nature of the corona. Unfortunately, this is an underdetermined problem.
Use the CHIANTI An Atomic Database to estimate spectral irradiance
We obtain \( \sim 5\% \) median error across MEGS-A emission lines.
Deep Learning (MLP, CNN, etc)

DEM (temp map inversion)

Physics-based (Forward Model)

SDO/AIA

AIA+

SDO EVE emission line spectra

94, 131, 171, 193, 211 & 335 Å

304, 1600 & 1700 Å
WE CAN USE NEURAL NETWORKS TO PLUG THIS EUV OBSERVATIONAL GAP
What is deep learning?

What techies think it is

What advocates think it is

What it really is

What skeptics think it is

What the public thinks it is

A tool that helps us find new things in our data
What is deep learning?*

A class of machine learning algorithms that:

• Use a cascade of multiple layers of nonlinear processing units for feature extraction and transformation.

• Learn multiple levels of representations that correspond to different levels of abstraction (i.e. the levels form a hierarchy of concepts).

* Taken from Wikipedia
What is deep learning?

* Taken from Wikipedia
Why deep learning?
Deep learning has important limitations too.
Deep learning has important limitations too.

Twitter taught Microsoft’s AI chatbot to be a racist asshole in less than a day

by James Vincent | @jvincent | Mar 24, 2016, 6:43am EDT

It took less than 24 hours for Twitter to corrupt an innocent AI chatbot. Yesterday, Microsoft unveiled Tay — a Twitter bot that the company described as an experiment in “conversational understanding.” The more you chat with Tay, said Microsoft, the smarter it gets, learning to engage people through “casual and playful conversation.”
Deep learning has important limitations too.
Deep learning has important limitations too

- Deep learning algorithms are naïve and single-minded in the way they learn.
- Training data selection is absolutely critical for their success.
Deep learning and image data

What the computer sees

image classification

82% cat
15% dog
2% hat
1% mug

cs231n.github.io/classification
Deep learning and image data

EUV Irradiance

3.2x10^{-5} W m^{-2}
Convolutional Neural Networks

Neural networks with layers made of tunable convolution filters
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Several convolutional layers allow the neural network to recognize features of increased complexity
Convolutional Neural Networks

Neural networks with layers made of tunable convolution filters

Several convolutional layers allow the neural network to recognize features of increased complexity
CNNs have revolutionized the way we do image classification.
DEM + Forward model

~5% median error
Linear Model + CNN
~1% median error
NEURAL NETWORKS ARE NOT BLACK BOXES AND CAN BE MINED FOR SCIENTIFIC INSIGHT
Clever ways of setting up your architecture allow you have the CNN construct an image in physical units of irradiance prior to producing an integrated measurement.
What is the neural network paying attention to?
What is the neural network paying attention to?
What comes next?

• We are releasing ML ready AIA and HMI data going from May-2010 to Dec-2017.

• We are plugging the MEGS A emission line observational gap from 2014 onwards.

• We are working on producing a full EUV irradiance spectrum.

• We are looking into turning the now-casting application into the forecasting of EUV irradiance.

• We are looking into the possibility of obtaining spatially resolved maps for the EVE channels.
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