# SWx TREC Deep Learning Laboratory: Advances in Machine Learning for Space Weather

Wendy Carande[1], Allison Liu[1], Cody Feldhaus[1], James Craft[2], and Christopher Pankratz[3]

[1]Laboratory for Atmospheric and Space Physics
[2]University of Colorado, Laboratory for Atmospheric and Space Physics
[3]University of Colorado

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**Abstract**

Space weather events can impact satellite communications, astronaut health, and the electric power grid. It is thus of utmost importance that we develop efficient, reliable tools to determine when space weather events, such as solar flares, will occur and how strong they will be. The SWx TREC Deep Learning Laboratory has developed several state-of-the-art machine learning projects to improve solar flare prediction through the use of deep learning models, generative adversarial network data augmentation, and explainable artificial intelligence techniques. In particular, we compared two generative adversarial networks (GANs) to super-resolve the Solar and Heliospheric Observatory's Michelson Doppler Imager (SOHO/MDI) magnetogram data to match the quality of the Solar Dynamics Observatory's Helioseismic and Magnetic Imager (SDO/HMI) magnetogram data. We find that both GANs are able to preserve key features of the original SOHO/MDI magnetogram data while achieving better resolution to match the SDO/HMI data. In the future, we will use the combined, augmented dataset in a Long Short-Term Memory model for solar flare prediction to see if training on the expanded dataset results in improved predictive power compared to training on the SDO/HMI dataset alone. In addition to data augmentation, we have used Local Interpretable Model-Agnositc Explanations (LIME) on our existing solar flare prediction model to provide more insight into specific predictions. This is an important step in building trust in our model and understanding what features are driving the model's predictions. In this presentation, we will discuss these recent projects as well as future work that the SWx TREC Deep Learning Laboratory will tackle in order to advance the field of machine learning in space weather, including: improved hardware, better visualization capabilities, cutting edge models, software tools, and community resources.

# SWx TREC Deep Learning Laboratory: Advances in Machine Learning for Space Weather

*Space Weather Technology, Research & Education Center*
*University of Colorado at Boulder*

**Wendy Carande**
Allison Liu, Cody Feldhaus,
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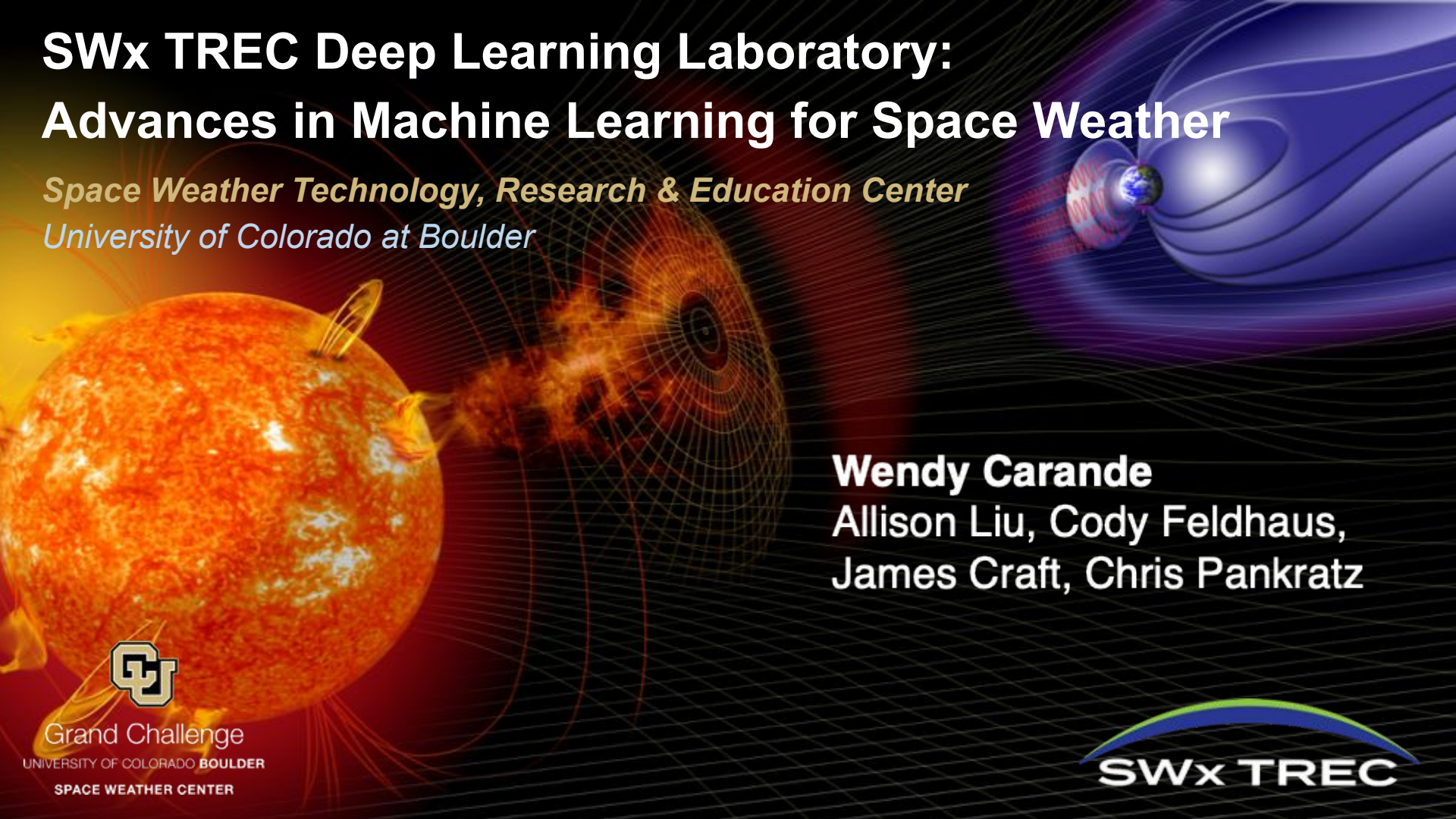


# Who I am...

LASP

SWx TREC

Deep Learning Laboratory

Boulder Solar Alliance

Research Experience for Undergrads

# Deep Learning Lab Updates

Projects:

- Solar flare prediction
- GNSS scintillation prediction

New Hardware! Lambda Hyperplane 8xA100 AMD

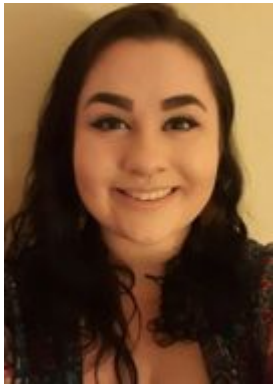
- Processor: 2x AMD EPYC 74F3 (24 cores, 3.2 GHz)
- GPUs: 8x NVIDIA A100 SXM4 Tensor Core GPU (80GB) with NVLink/NVSwitch
- Memory: 2 TB ECC RAM (32x 64GB 3200 MHz - total of 32 slots)
- Extra Storage: 6x 15.36 TB | U.2| NVMe

# The Students

**Current**

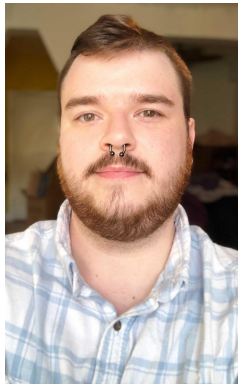
Allison Liu

**Former**



Katy Luttrell

Pranav Subramanian



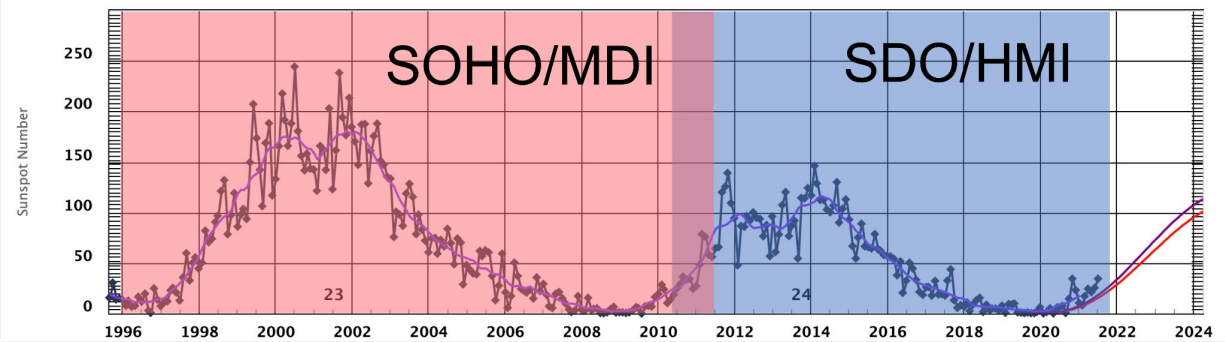
Cody Feldhaus

Kody Newman

Justin Cai

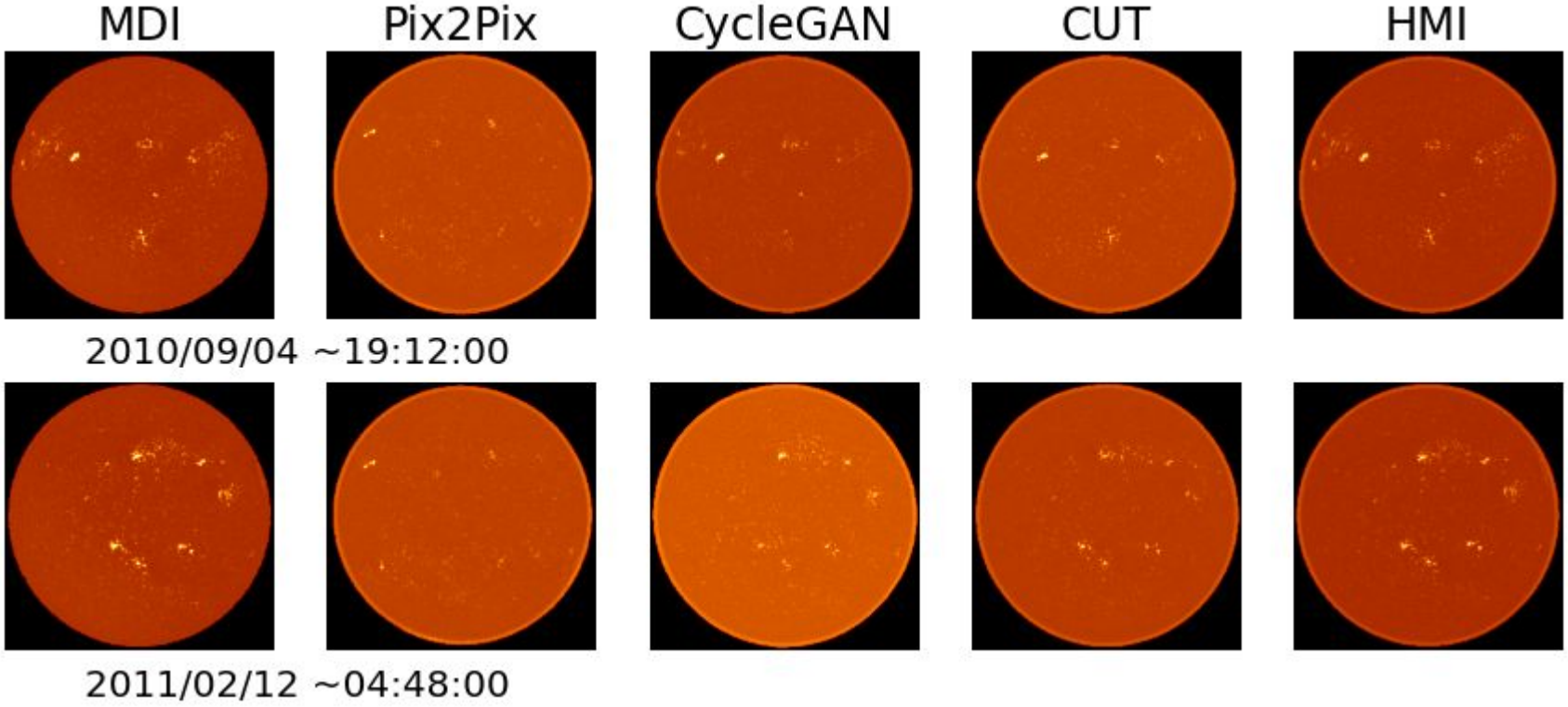
Maxine Hartnett

# Data Augmentation - Generative Adversarial Networks




Courtesy of Allison Liu

# GAN results - see Allison's poster for more info



# Explainable Artificial Intelligence (XAI)

Accountability.

Responsibility.

Transparency.

# XAI (Silly) Example

(a) Original Image (b) Explaining *Electric guitar* (c) Explaining *Acoustic guitar* (d) Explaining *Labrador*

**Figure 4: Explaining an image classification prediction made by Google's Inception network, highlighting positive pixels. The top 3 classes predicted are "Electric Guitar" ($p = 0.32$), "Acoustic guitar" ($p = 0.24$) and "Labrador" ($p = 0.21$)**

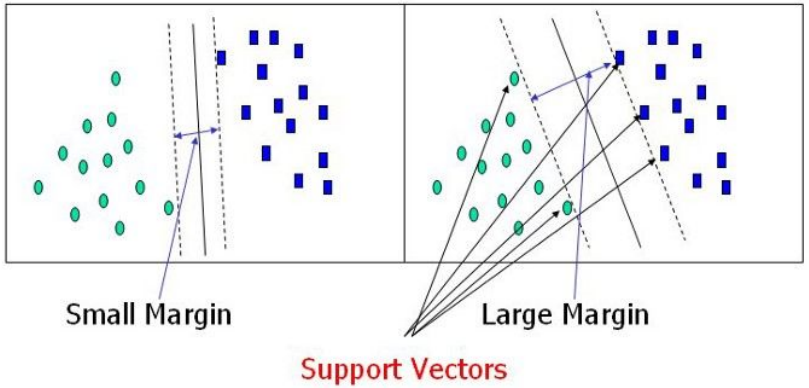
Image credit: https://homes.cs.washington.edu/~marcotcr/blog/lime/

# LIME for Solar Flare Prediction

**Data:** Magnetogram Data, Solar Dynamics Observatory Helioseismic and Magnetic Imager (SDO/HMI)

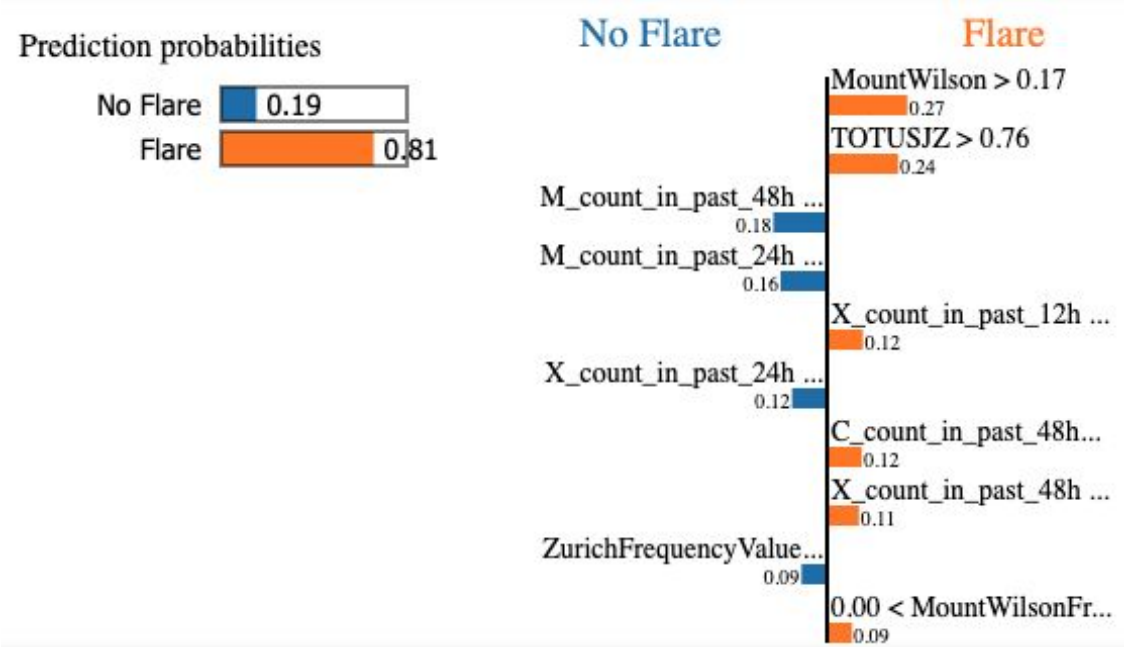
**Features:** SHARP: Space-weather HMI Active Region Patches, Feature Engineering from Past Research

**Model:** SVM: Support Vector Machine




https://towardsdatascience.com/support-vector-machine-introduction-to-machine-learning-algorithms-934a444fca47

# LIME Output




TOTUSJZ: Total unsigned vertical current

Credit: Cody Feldhaus

# Poster Session Info

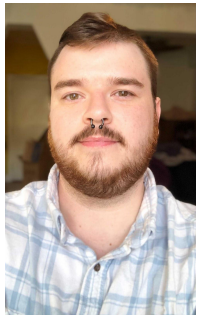
NG45B: Machine Learning in Space Weather V Poster
Thursday, 16 December 2021; 16:00 - 18:00 CST
Convention Center Poster Hall, D-F

**Data Augmentation of Magnetograms for Solar Flare Prediction using Generative Adversarial Networks**

Allison Liu

**Explainable Artificial Intelligence for Solar Flare Prediction**

Cody Feldhaus



**Classification of Solar Flare Magnitudes Using SDO/AIA Movies with 4D Convolutional Neural Networks**

Kiera van der Sande