AI for Space and Aerospace

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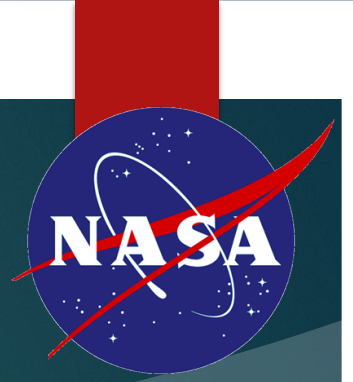
AI CENTER OF EXCELLENCE LEAD,
NASA GODDARD SPACE FLIGHT CENTER

UNIVERSITY OF MAINE ARTIFICIAL INTELLIGENCE WEBINAR SERIES, OCTOBER 7, 2021

Outline

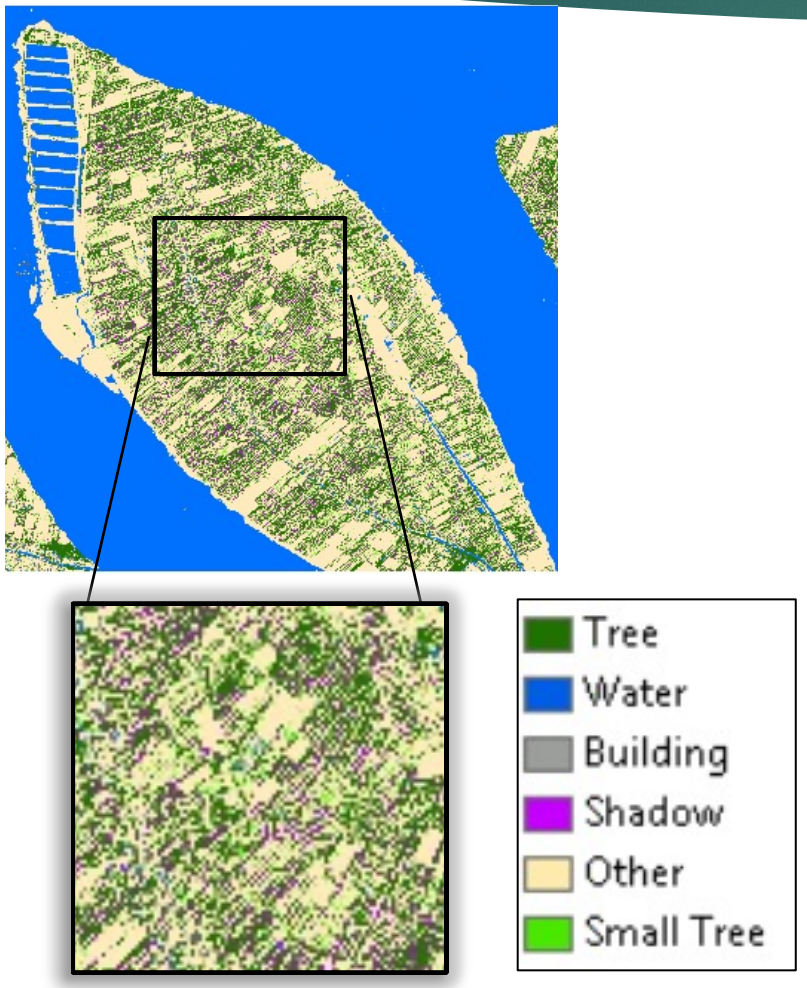


- Applications of AI in Space Sciences
  - Earth Sciences
  - Planetary Sciences
  - Astrophysics
  - Heliophysics
- Applications of AI in Engineering
  - Exploration
  - Navigation and Control
- NASA GSFC AI Center of Excellence
  - Partnerships Opportunities

AI in Earth Sciences

Deep Learning and GPU Image Classification

Mark Carroll, Jordan Caraballo-Vega, Mary Aronne, Chris Neigh, NASA GSFC



With the proliferation of Very High Resolution (VHR) imagery it is possible to map objects as small as individual trees. In this example, Deep Learning has been implemented in the GPU environment to identify agro-forestry in Vietnam. Input data was Maxar WorldView 2 commercial high resolution (<2 m) satellite, and the output presented here is the classification results of a single date imagery.

AI in Earth Sciences

Supporting Aquaculture in the Chesapeake Bay Using AI to Detect Poor Water Quality with Remote Sensing

- Reliable information on water quality is not currently available at the scales required for aquaculture and water resource management needs.
- This project advances the development of new observing strategies using contextual cues from large unstructured datasets to extract patterns; promoting the use of Earth observations and models to monitor aquatic ecosystems.
- Technical approach: develop an analytic center framework (ACF) to harmonize in situ and remotely sensed datasets, then develop an Artificial Intelligence (AI) model to detect patterns of poor water quality from satellite imagery.
- **Reference**: https://ieeexplore.ieee.org/document/9323465 by *Stephanie Schollaert Uz[1], Troy J. Ames[1], Nargess Memarsadeghi[1], Shannon M. McDonnell[2], Neil V. Blough[2], Amita V. Mehta[3,1], John R. McKay[4]*

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3. University of Maryland Baltimore County, Joint Center for Earth Systems Technology, Baltimore, MD,
4. Maryland Department of Environment, Shellfish Monitoring Section, Annapolis, MD

Image Credit: Landsat 8

AI in Planetary Sciences

Search for Life on Mars

- **Smart Instruments for Planetary Exploration**
- **Lots of Data, Little Bandwidth over hundreds of millions kilometers**
- *"trained artificial intelligence systems to analyze hundreds of rock samples and thousands of experimental spectra from the Mars Organic Molecule Analyzer (MOMA), an instrument that will land on Mars within the ExoMars Rosalind Franklin Rover in 2023. "*
- **Goal: Give the instruments the autonomy to make rapid decisions**
  - ***Example.*** **"**"I've got 91% confidence that this sample corresponds to a real-world sample and I'm 87% sure it is phospholipids, similar to a sample tested on July 24th, 2018, and here is what that data looked like." "
- **Reference:** by Dr. Victoria Da Poian and Eric Lyness of NASA Goddard Space Flight Center, https://phys.org/news/2020-06-nasa-life-mars.html

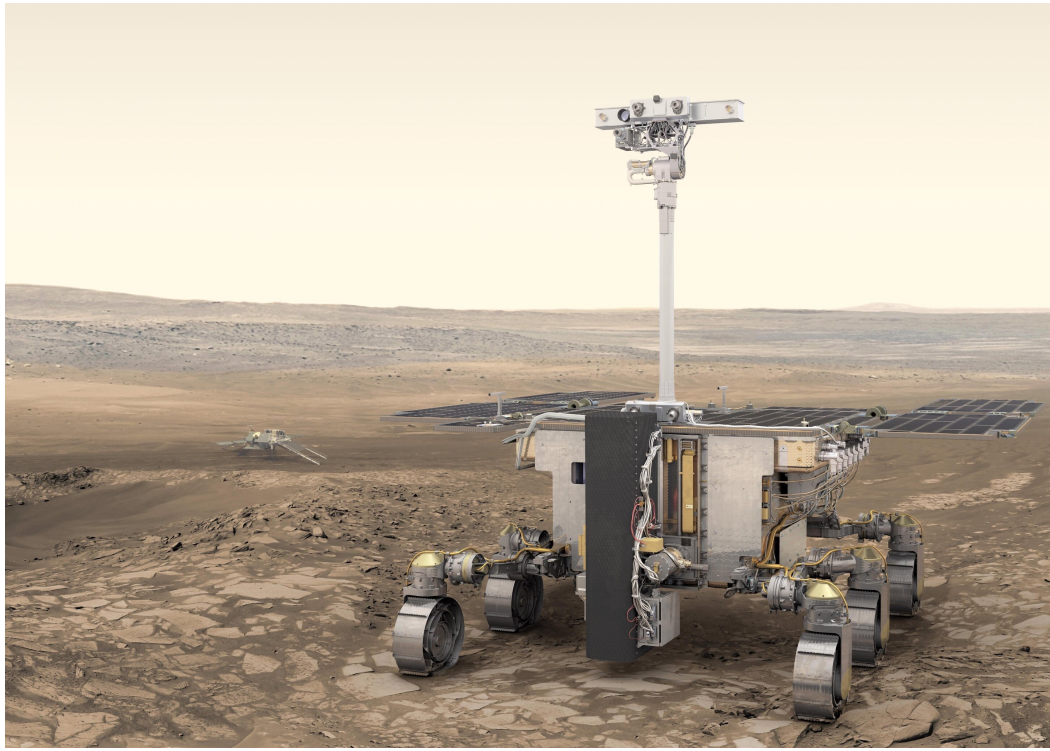


Image Credit: Artist's impression of the Rosalind Franklin Rover on Mars. Credit: ESA/ATG medialab

AI in Planetary Sciences

Automatically Classify the Martian Surface

- **Transverse aeolian ridges (TARs)** were previously **manually located** and studied in some HiRise imagery.
- **Location and spatial distribution of TARs** are now **automatically** classified via Machine Learning applied to HiRise images.
- adaptation of the off-the-shelf neural network RetinaNet that is designed to identify the presence of TARs at a 50-m scale.
- Once trained, the network was able to identify TARs with high precision (92.9%).
- Model also shows promising results for applications to other surficial features like ripples and polygonal terrain.
- Future work includes applying the model more broadly and generating a large database of TAR distributions on Mars.

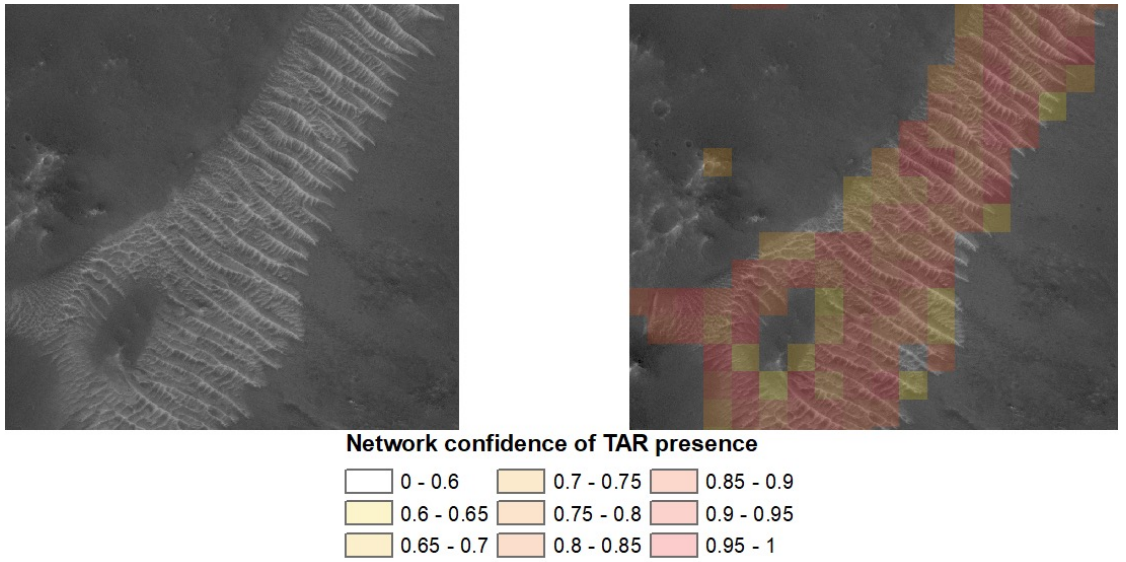


Image Credit: Nagle-McNaughton, T.; McClanahan, T.; Scuderi, L. PlaNet: A Neural Network for Detecting Transverse Aeolian Ridges on Mars. *Remote Sens.* **2020**, *12*, 3607. https://doi.org/10.3390/rs12213607 \

Reference: "PlaNet: A Neural Network for Detecting Transverse Aeolian Ridges on Mars" by T. Nagle-McNaughton (University of New Mexico) and T. McClanahan (NASA Goddard Space Flight Center), https://www.mdpi.com/2072-4292/12/21/3607

AI in Astrophysics

- **"The discovery:** TYC 7037-89-1 is **the first six-star system** ever found where all of the stars participate in eclipses, a discovery made by NASA's Transiting Exoplanet Survey Satellite (TESS). The system is located about 1,900 light-years away in the constellation Eridanus."
- **"The discoverers:** An international team, led by data scientist Brian P. Powell and astrophysicist Veselin Kostov at Goddard, made the discovery using TESS data."
- "They then analyzed the data using autonomous software trained to recognize the tell-tale brightness dips of eclipsing binaries. Among the 450,000 candidates, researchers identified at least 100 with potentially three or more stars, including the new sextuple system"

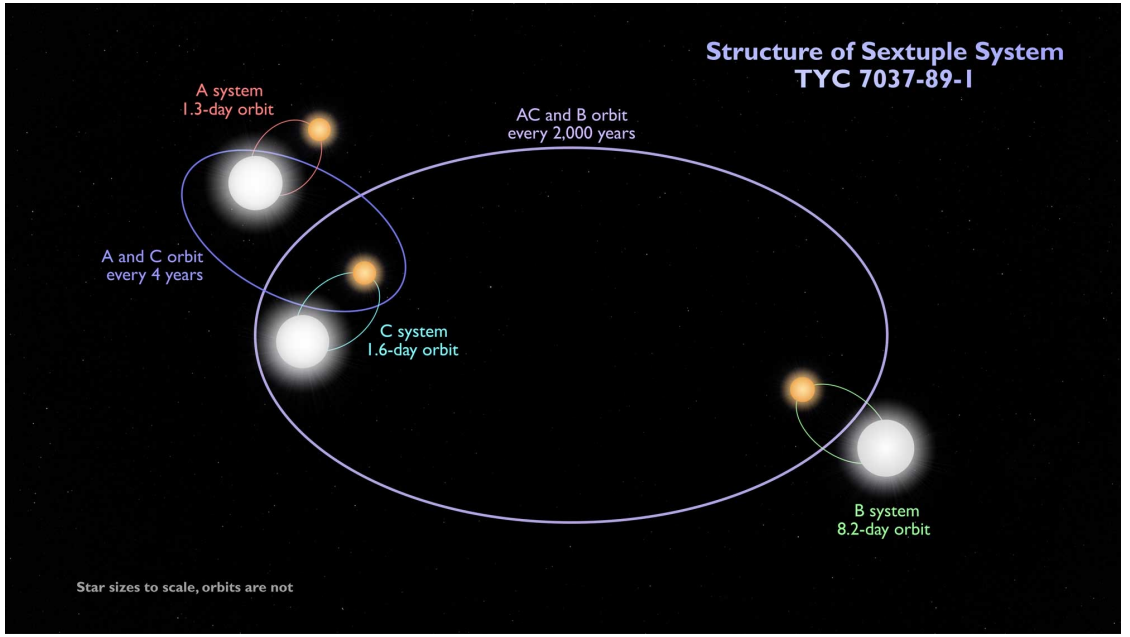
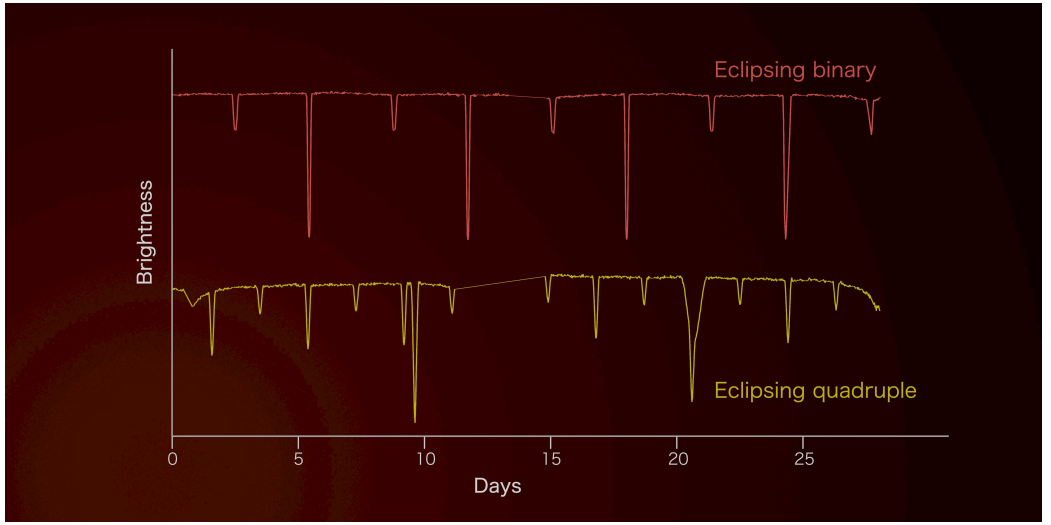


Image Credit: NASA Goddard Space Flight Center,
Reference: "TIC 168789840: A Sextuply-Eclipsing Sextuple Star System," Brian Powel et al, 2021 The Astronomical Journal, 161:162 (20pp)
https://exoplanets.nasa.gov/news/1672/discovery-alert-first-six-star-system-where-all-six-stars-undergo-eclipses

AI in Astrophysics

- **Background:** TESS mission launched in April 2018, "to find new worlds beyond our solar system, or exoplanets, by monitoring brightness changes in nearby stars."
- **Adam Friedman, a 2020 summer intern** at NASA's Goddard Space Flight Center, worked with **Brian Powell, a data scientist** in the High Energy Astrophysics Science Archive Research Center at Goddard.
  - **Initial internship task:** Collecting training data.
- "Astronomers use the data to construct light curves, graphs that show how a star's brightness shifts over time. From the raw TESS data, Powell used the 129,000-core Discover supercomputer at NASA's Center for Climate Simulation (NCCS) at Goddard to build millions of light curves."
- **Goal:** " identify eclipsing binaries, paired stars that alternately pass in front of, or transit, each other every orbit as seen from Earth. "
- **Accomplishment:**
  - Trained a computer system to identify eclipsing binaries
  - Friedman found eight new candidate quadruple star systems.



"This illustration depicts light curves for a representative eclipsing binary (top) and one of the candidate eclipsing quadruple star systems identified by Adam Friedman. The extra dips caused by additional eclipses in the quadruple system result in a more complicated pattern."
Image Credit: NASA's Goddard Space Flight Center
Reference:
https://www.nasa.gov/feature/goddard/2021/nasa-summer-intern-combines-data-science-and-astronomy-with-stellar-results

AI in Heliophysics

Needle in a Haystack: Identifying the Smallest Eruptions in Solar Dynamic Observatory (SDO) , Atmospheric Imaging Assembly (AIA) Images

- **Reframing science into a bigdata framework:**
  - Separates energetic particle hits in CCD images from single-pixel micro events in the solar corona.
  - Only 0.01% of these energetic particles are misclassified and have a solar origin.
  - Because the AIA satellite has recorded over 100 billion discrete events – 10 million misclassified micro eruptions.
  - Uses fast I/O infrastructure paired with GPU-accelerated CUDA data frames.
- **Reference:** *"An Analysis of Spikes in SDO/AIA data", by* Peter R. Young[1,2], Nicholeen M. Viall[1,] Michael S. Kirk[1,3], and Emily I. Mason[1], https://arxiv.org/pdf/2108.02624.pdf
  1. NASA Goddard Space Flight Center, Code 671.
  2. Department of Mathematics, Physics and Electrical Engineering, Northumbria University, U.K.
  3. ASTRA, LLC, Louisville, Colorado, 80027

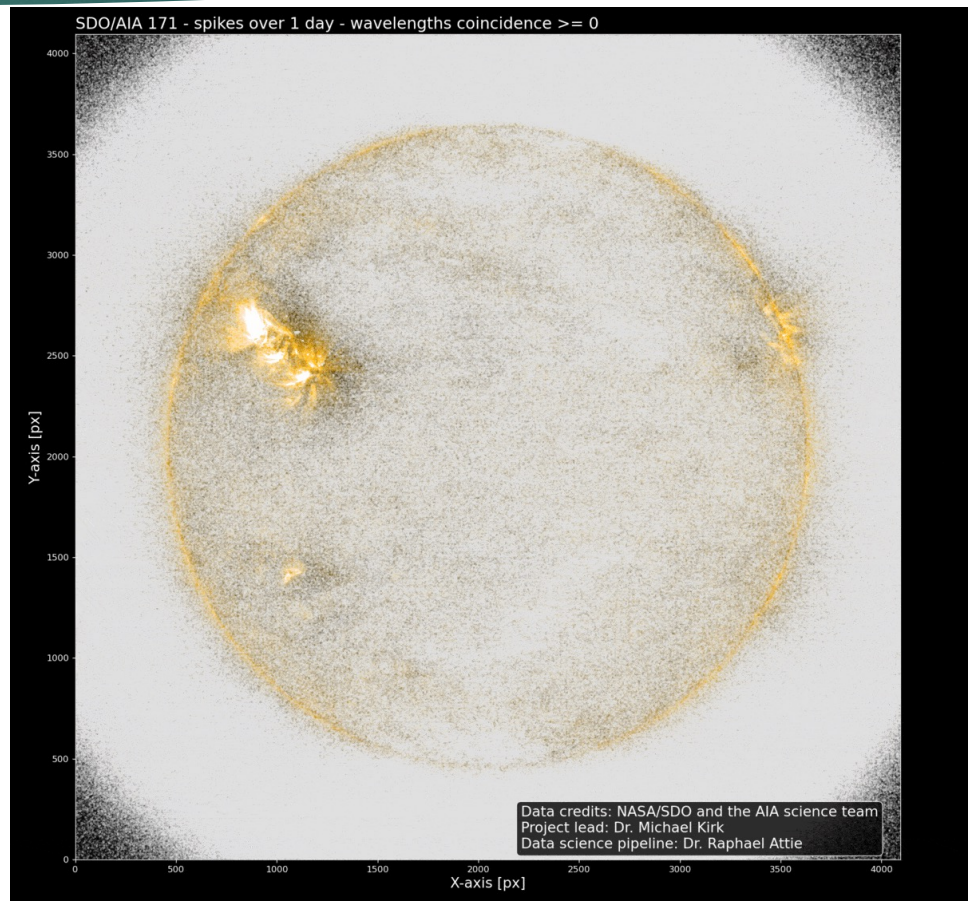


Image Credit: NASA GSFC, ASTRA, GMU, NVIDIA, HP

AI in Heliophysics

GPU-Accelerated Deep Learning for Solar Feature Recognition in NASA Images

- Encoding scientific knowledge into ML to characterize *active regions, coronal holes and sunspots*
- Over 150 million SDO images ~ 6 PB
  - 4K resolution every 1.3 seconds
  - Deep learning for segmentation
  - GPU accelerated
- **Reference:** https://developer.nvidia.com/gtc-dc/2019/video/dc91212-vid by
  - Michael Kirk, NASA GSFC / Catholic University of America
  - James Stockton, Altamira Technologies Corporation

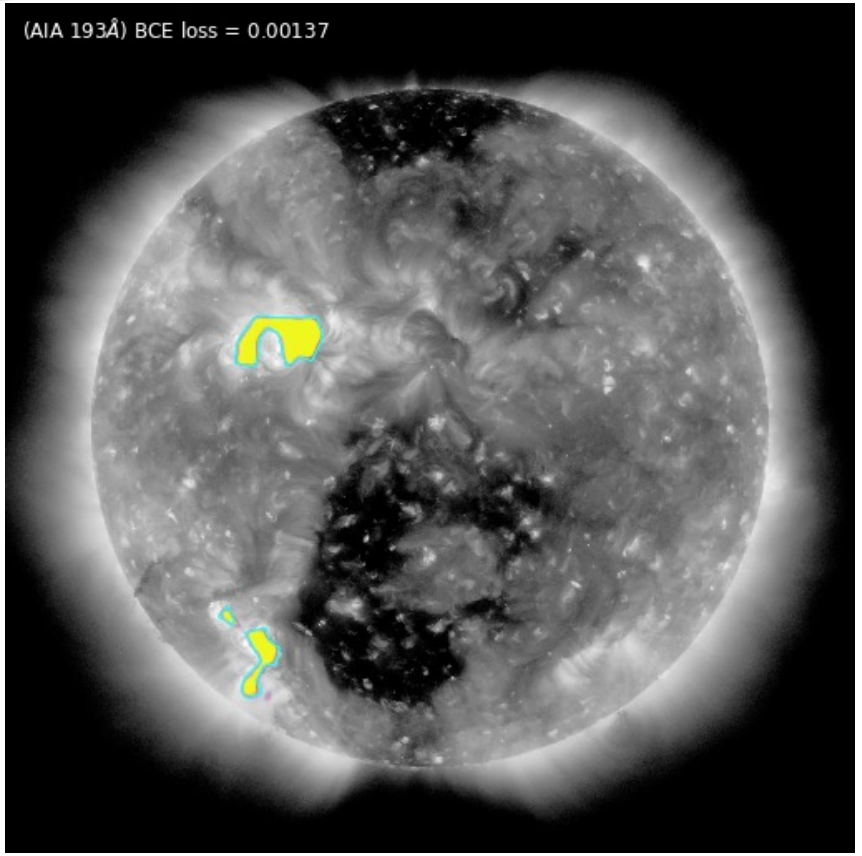


Image Credit: NASA GSFC, ASTRA, GMU, NVIDIA, Altamira

AI in Heliophysics ….

- **NASA's Helio Hackweek, August 20-28, 2020:**
  - https://heliohackweek.github.io/
- **NOAA's MagNet Competition (due 2/12/2021):** Transfer of Energy from solar wind to Earth's Magnetic Field
  - Massive geomagnetic storms
  - GPS systems, satellite communications, electric power transmission, and more.
  - The Disturbance Storm-Time Index (Dst): severity of storms
- **Goals of Competition:** develop Dst forecasting models

"1) push the boundary of predictive performance
2) under operationally viable constraints
3) using specified real-time solar-wind data feeds.

Competitors were tasked with forecasting both the current Dst value (t0), and Dst one hour in the future (t1)."

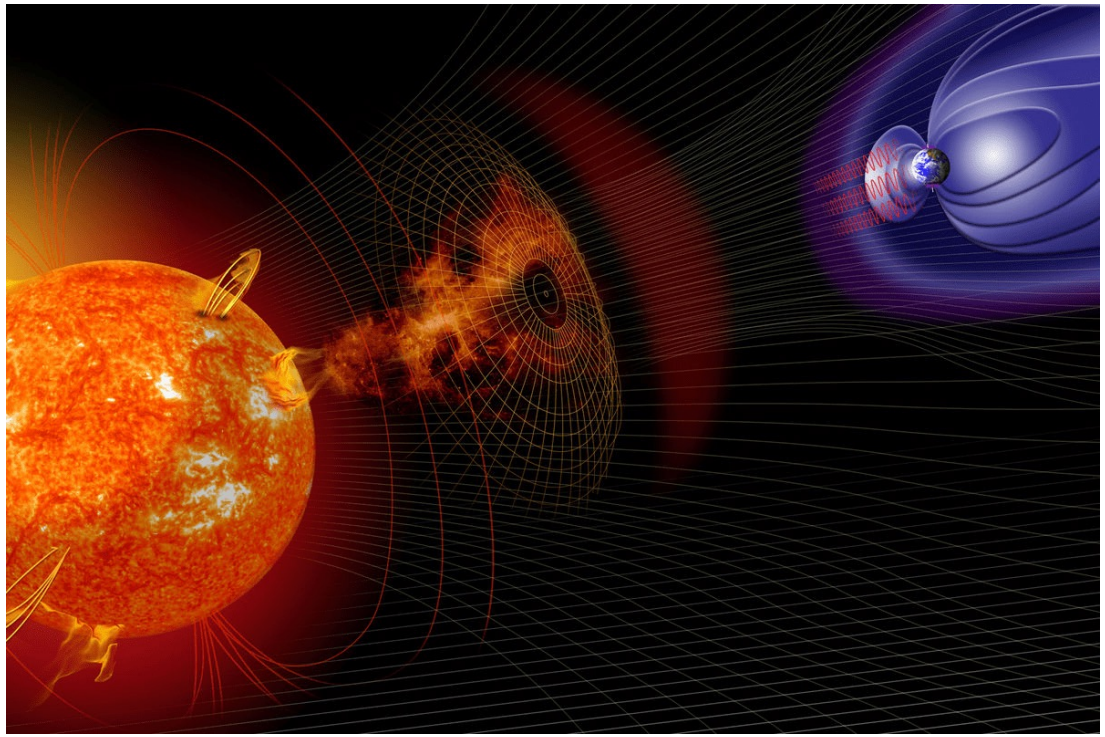
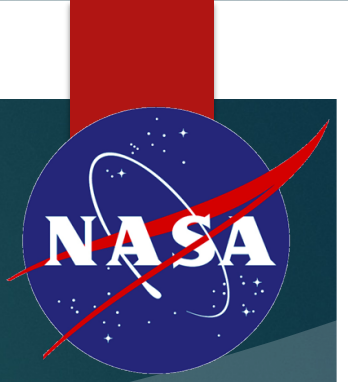


Image Credit: https://github.com/drivendataorg/magnet-geomagnetic-field

Reference and winners' code at:
https://github.com/drivendataorg/magnet-geomagnetic-field

AI in Engineering



- Spacecraft Autonomy
- Enhanced Instrument calibrations
- Real-Time Terrain Mapping and Processing for Hazard avoidance and safe landing
  - Mars 2020
    - Terrain Relative Navigation
    - Matches onboard sensor data to a map of landing area
    - Reference: https://science.nasa.gov/technology/technology-highlights/terrain-relative-navigation-landing-between-the-hazards
  - Perseverance:
    - AutoNav: autonomous driving mode to reach specific coordinates
    - Trained classifier identifies craters and rocks to avoid
    - Reference: https://spacenews.com/nasa-steadily-expands-ai-and-autonomy-for-mars-exploration/

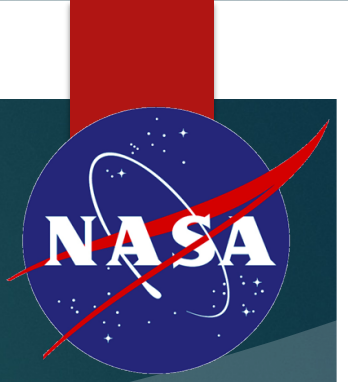
AI Center of Excellence

- **Focal point for serving GSFC AI Community**
  - Communities of Practice (e.g. HelioAnalytics, Cloud Computing, …)
  - Goddard ML Academy
  - Events (seminars, hackathons,..), conferences and workshops
  - Computational Resources (NCCS Scientific Computing, GSFC Cloud Computing program, agency's computational resources)
  - Funding opportunities, proposals
  - Forming partnerships across organizations and with academia and industry
  - Lead: Nargess Memarsadeghi
- **Sponsors:**
  - GSFC Office of Chief Technologist
  - GSFC Computational Information Science and Technology Office (GSFC 606)
  - GSFC Science Task Groups (600)
  - *Inaugurated in Spring 2020*

AI Center of Excellence

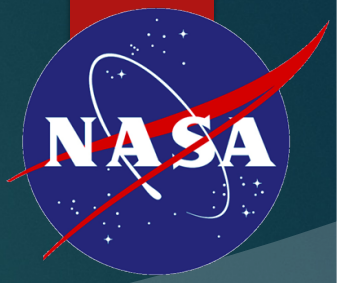
- Monthly Seminars
- Organizing Workshops
  - First NASA AI Workshop, NASA GSFC, November 2018
  - Use of AI/ML in Science Strategic Planning and Prioritization May 12-13, 2020.
  - Second NASA AI Workshop, NASA JPL, February 2021
  - NASA-UMD AI in Earth Sciences: Pathways to a Digital Earth, September 22, 2021
- Forming Partnerships

NASA Partnership Opportunities



- **NASA Internships:** intern.nasa.gov
- **NASA Postdoctoral Program:** https://npp.usra.edu
- **NASA Federal positions, including Pathways Program:** USAjobs.gov
- **Research Grants**: nspires.nasa.gov
- **NASA Space Technology Graduate Research Opportunities (NSTGRO)**
  - https://www.nasa.gov/directorates/spacetech/strg/nstgro
- **NASA Early Career Faculty Grants: https://www.nasa.gov/directorates/spacetech/strg/archives_stro.html**
- **NASA Small Business Innovative Research (SBIR):** https://sbir.nasa.gov
- **Frontiers Development Lab:** https://frontierdevelopmentlab.org
  - See annual projects and reports for many other examples of AI in Aerospace!

Thank You!



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