Project ID: 391

SR - Physics and Astronomy

Rohan Badal
Jai Badal

Color Analysis of Mars Regolith and Estimates of Surface Water on Mars

Mars is similar in size and the distance from the Sun when compared to Earth, so it is fair to assume that the Mars soil is similar to Earth's but lacks organic matter. However, the Mars atmosphere is mostly carbon dioxide and lacks oxygen, so there is a possibility that the red color of Mars soil is not simply due to Iron III Oxide (Fe_2O_3), and that little oxygen on Mars may have combined with iron and the subsurface water and low temperatures may have resulted in minerals other than hematite. We converted ten randomly selected RGB images of mars surface to corresponding hue saturation and value (HSV). Comparing only the hues allows us to ignore effect of shadows or uneven lightning. We developed a method to map these values into Munsell scale. Using portions of image that does not include sky or any part of the rover, we calculated the Munsell number and identified the predominant mineral. We then Identified the physical conditions under which such mineral deposits happen. Using approximate radius of Mars, and distribution of identified mineral on surface, we estimated the amount of water on Mars. From the set of selected images, the representative Munsell color was identified as 7.5YR 6/7. Goethite and akageneite were identified as the most abundant mineral in Mars regolith. Our results suggest that there is surface moisture on Mars as goethite forms in wet cold conditions. It may have up to 0.15 million km3 water bound with iron oxides. This finding is important because it provides supportive evidence for presence of moisture on Mars and estimates its amount.

Project ID: 392

SR - Physics and Astronomy

Cindy Cai

Measuring Sunspot Rotation and Exploring Its Relationship with Solar Eruption

The released energy from solar flares impacts Earth's environment, sometimes causing damage to our communication system. Our hypothesis is that since sunspot rotation is related to solar flares, measuring sunspot rotations could provide data to study the buildup and evolution of magnetic twists in solar eruptions.

I developed and implemented a method by coding a suite of programs that automatically calculates sunspot rotation. This allowed me to process a large sample of data. To calculate sunspot rotation, I first transformed the sunspot images from cartesian coordinates to polar coordinates using the center of gravity as the origin. Then, I applied the cross correlation program to measure the shift. The rotation rate was calculated using the time interval between the images. Assuming sunspots rotate rigidly, I used the standard deviation of a set of calculated rotation rates (of the same sunspot) for the error estimation.

After surveying all active regions from 2009 to 2019 that produced X-class flares and CMEs, upon examining sunspot rotation using the method above, I noticed 82% of the active regions (9 of 11 active regions) contained rotated sunspots producing X-class flares. Additionally, 78% of the rotated sunspots (7 of 9 sunspots) underwent significant rotation, ranging from 20 to 108 degrees.

The results showed that sunspot rotation and X-class flares are strongly correlated. Sunspot rotation can twist the magnetic field, causing buildup of energy that fuels flares.
Future Work: Establishing a model that will calculate how much energy the rotation can generate to fuel flares.

Project ID: 393

SR - Physics and Astronomy

Vikramaditya Sidharth Chandra

Pathfinder: A Novel Convolutional Neural Network for Classifying Photometric Surveys

In this project, I introduce a Convolutional Neural Network (CNN), denoted as Pathfinder, that is specifically engineered to catalog photometric surveys through the utilization of HR diagrams. The primary objective of Pathfinder is to classify objects into various categories with precision and efficiency, with the ultimate aim of identifying novel entities within photometric surveys. The current methods for identifying new objects in photometric surveys are heavily dependent on cross-referencing with databases such as SIMBAD, which can be outdated. To circumvent this limitation, I employed a combination of SIMBAD and GaiaDR3 to construct a comprehensive training dataset comprising of HR diagrams pertaining to three distinct classes: HII Regions (also referred to as the Interstellar Medium), Sets of Stars (including Globular, Open Clusters, and Associated Clusters), and Field Stars (not gravitationally bound or related to each other). The CNN was trained utilizing a combination of data augmentation techniques and optimized hyperparameters, resulting in an accuracy of 97.28%. By systematically scanning the entirety of GaiaDR3 and passing the data through the model, I were able to identify known major structures of the universe. A cross-check with the data points from SIMBAD revealed that the model was able to identify 93.2% of known clusters. Pathfinder represents a significant advancement in the field of photometric survey analysis and is a potent tool that can be employed to classify objects with accuracy and efficiency, with the potential to discover previously undiscovered objects and structures in the universe.

Project ID: 394

SR - Physics and Astronomy

Sven Andersen

Precise Star Temperature and Gravity Measurements Depend on High Spectral Image Signal to Noise Ratios

The characterization of exoplanets that may support life requires accurate determination of the temperature and gravity of the stars they orbit. These properties can be determined through analysis of star spectra. However, the quality of spectra can vary based on the position of the star in the sky, the weather, and the telescope exposure time. Currently optimal approaches to finding precise measurements are not fully established. In this study, I measured how the precision of these measurements correlate with signal-to-noise ratio of their star's spectral images. I found that high signal-to-noise ratios correlate with higher precision in both temperature and gravity values. Therefore it is advisable for scientists to only consider data measured from spectra with high signal-to-noise ratios in order to make accurate judgements about an exoplanet's potential to support life.

Project ID: 395

SR - Physics and Astronomy

Ayush Nayak

Quantum Dot based Quaternion High-Transport Transistor Technology

Transistors themselves have not fundamentally changed in decades, with all advances in the field focused on merely decreasing the size of transistors. This is a problem as soon it will be impossible to continue to shrink transistors further. Transistors have also been exclusively focused on binary, with research into alternative logical systems extremely limited. In this research, a commercially competitive multivalued transistor was created to improve transistors fundamentally and avoid stagnation. A Quantum Dot Field Effect Transistor (QDFET) design was utilized as Quantum Dots (Qdots) promote tunneling through cladding layers, allowing for multiple stability regions, which is conducive to multivalued operation. To design this QDFET, I developed a novel Monte Carlo optimization algorithm to efficiently design molecules with many atomic possibilities. The Monte-Carlo algorithm was coupled with Density Functional Theory (DFT), to simulate many of the molecules. In addition, I devised a Neural Network (NN) model to approximate DFT simulations for certain large-volume calculations. Through the use of the NN and Monte-Carlo algorithm, multiple new QDFET-material designs were discovered for usage as next-generation 4-valued multivalued transistors. 4-valued operation was achieved with a special channel underneath the transistor. A device was then fabricated and the Hall effect across a Qdot matrix was measured. This device was found to have electron mobility over three orders of magnitude ahead of other multivalued options and significantly higher efficiency. With electron mobility on par with mature commercial options and its incredible multivalued logic benefits, this work produces a QDFET with effective performance over one hundred-fold in excess of any conventional transistor, promising a revolution in chip technology and an escape from Moore’s Law, with widespread effects on all of computing.

Project ID: 396

SR - Physics and Astronomy

Demetrios Dresios

Probing for Dark Stars and Drawing Conclusions on Dark Matter Using JWST

This study aims to confirm or deny the existence of dark stars, a theoretical concept that very early stars could be fueled by particle-antiparticle annihilation instead of nuclear fusion. Dark matter has been proposed to be composed of Weakly Interacting Massive Particles (WIMPs), whose existence has not been experimentally confirmed. The James Webb Space Telescope (JWST), with its unprecedented ability to see far into the early universe, opens the door to such experimentation. However, this study expected that, seeing as how Earth-based experiments could not detect the existence of WIMPs in any quantity today, dark stars would not be found.

To test this hypothesis, the procedure involved taking an accumulated spectral dataset of dozens of galaxies from the time before and after dark stars are expected to exist (cutoff at 400 million years after the big bang) Then, these datasets were compared to one another to find if the older galaxies have a more pronounced spectral signal in any wavelength, especially in areas where Dark Stars are expected to emit a signal.

The results show that there was no statistically significant difference between the two spectral sets, with any variation falling within the signal strength variation caused by sensor noise. This experimentally implies (but does not conclusively prove) that dark stars and dark matter are not made of WIMPs.

Using JWST data, this study aimed to investigate the existence of dark stars and found no statistically significant difference between spectral sets. The results suggest that dark matter and dark stars are likely not composed of WIMPs. Further experimentation as more data becomes available from very early galaxies is recommended to further increase certainty.