Project Proposal Report

PROJ 201 Project Proposal Report

Project Title: Astrophysical Image Processing using James Webb Space Telescope Observations

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Month, day, year: 11/04/2022

Abstract

The James Webb Space Telescope (JWST) is a huge progress in the history of astronomy which is an infrared wavelength oriented advanced astronomic space observation tool. With the help of the instruments that James Webb Space Telescope has such as MIRI, NIRCam, NIRISS and NIRSpec, unique data and extraordinary images could be obtained from deep space(NASA, 2022). The project is based on the processing of this unique data which comes in the FITS file format and interpreting this data to display the magnificent images obtained mainly from the James Webb Space Telescope's instruments; NIRcam and MIRI. The main tools data obtained from is MIRI and NIRCam instruments and these instruments shape the main frame of the project.

Through the software environments, such as Jupyter Notebook IDE, have been in the role of facilitation of reading the data and getting the James Webb Space Telescope images. Addition to finding an appropriate coding environment, the proper coding language and library was needed. This project was conducted through the coding language of Python. Python itself would not respond to the needs of processing the data. Therefore, a comprehensive library called Astropy and its subtools and modules are imported to process and extract the data.

The main aim of this project is to compare the data and images obtained from MIRI and NIRCam in terms of their RA and DEC coordinates, World System Coordinates, and amount of pixels in order to determine the hardness ratio of the images. To be able to compare the images, the images must be calibrated by adjusting the pixels and determining the coordinates in order to find the hardness ratio. In the process of calibration, the subtools and submodules of Astropy such as WCS, FITS Tools are used as a result of these modules' sufficiency of processing the data and reforming it. After calibration, the images are aligned; thus, the hardness ratio of these images could be obtained by the comparison of the color energies of images.

Introduction

The James Webb space telescope was launched on 7/12/22. The main mission of James Webb Webb's four instruments, the Near-Infrared Camera (NIRCam), Near-Infrared Spectrograph (NIRSpec), Mid-Infrared Instrument (MIRI), and Fine Guidance Sensor/Near InfraRed Imager and Slitless Spectrograph (FGS/NIRISS), may observe anything from objects in our solar system to the early cosmos (NASA, 2022). Our research is focusing on MIRI and NIRCam instruments and the data they are collecting.

The Mid-Infrared Instrument (MIRI), the first instrument in the project, was created by the MIRI Consortium, a team of scientists and engineers from European nations, a group from the Jet Propulsion Lab in California, and scientists from a number of American universities (NASA, 2022). With a wavelength range of 5 to 28 microns, the mid-infrared portion of the electromagnetic spectrum is visible to MIRI's camera and spectrograph. Its sensitive detectors will let it to identify faint comets, freshly developing stars, and the redshifted light of distant galaxies (NASA, 2022). Wide-field, broadband imaging will be provided by the MIRI camera, and medium-resolution spectroscopy will be made possible by the spectrograph, revealing new physical information about the far-off objects it will view. The MIRI's standard working temperature is 7 K. Webb is equipped with a cutting-edge "cryocooler" for cooling MIRI's detectors. The “cryocooler” is crucial because measurements have a smaller margin of error at lower temperatures. There is a two-step procedure instead: The instrument is cooled to 18K with a pulse tube precooler and to 7K with a Joule-Thomson loop heat exchanger. (NASA, 2022).

Another instrument used in the project is The Near Infrared Camera, created by Lockheed Martin and the University of Arizona, is another important sensor. Webb's main imager, NIRCam, will have a wavelength range of 0.6 to 5 microns. The number of stars in nearby galaxies, young stars, and the earliest stars and galaxies in the process of formation will all be detected by NIRCam. Coronagraphs, which are tools that let astronomers take photographs of extremely faint objects around a center light source, like star systems, are part of NIRCam. By obstructing the light from a brighter object, NIRCam's coronagraphs enable observation of a nearby, dimmer object (NASA, 2022).

Light from the sky is collected by Webb's mirrors and directed at the scientific equipment. Before the light is eventually focused into the detectors, the devices either filter it or spectroscopically disperse it. Every device has a unique detector. In the detectors, photons are taken in and eventually transformed into the electronic voltages that we can measure. Both near-IR HgCdTe and mid-IR Si:As detectors begin the detection process at the same point. A photon that is incident on a semiconductor is absorbed, producing mobile electron hole pairs. These migrate until they arrive at a location where they can be collected under the effect of inherent and added electric fields (Wired, 2022). In order to read a Webb detector's pixels more than once before resetting them, Webb's detectors are utilized. This allows us to average several non-destructive reads instead of just one, which lowers read noise. Another application of Webb is the ability to detect "jumps" in signal level—a telltale sign that a cosmic ray has disrupted a pixel—by utilizing numerous samples of the same pixel.When a cosmic ray has disrupted a pixel, it is possible to apply a correction in ground-based processing to recover a large portion of the scientific value of the afflicted pixel (Wired, 2022).

The JWST actually looks at two ranges of infrared light: the near infrared and mid-infrared. The mid-range infrared is often associated with heat, and that's mostly true. The reason why the JWST looks at infrared light is the Doppler effect. Doppler effect can be observed within the light but since the speed of light is super fast (3 x 108 m/s), the effect isn't noticeable in many situations (Wired, 2022). However, because of the expansion of the universe, just about all of the galaxies that it is seen from Earth are moving away from us. So to us, their light appears to have a longer wavelength. It is called a redshift, meaning the wavelengths are more red because they are longer (Wired, 2022).

Why JWST uses infrared light has another good reason, that is it's difficult to get an unobstructed view of far-away celestial objects thanks to the gas and dust that are the detritus from old stars. These can scatter visible light more easily than they can infrared wavelengths. Essentially, infrared sensors are able to see through these clouds better than visible light telescopes can (Wired, 2022).

Another perspective on this project that could be provided is the using space coordinations which are RA and DEC. Understanding of the positions of the celestial objects is facilitated by these objects RA and DEC values. As longitude and latitude are to the surface of the Earth, RA (right ascension) and DEC (declination) are to the sky. While Dec measures north/south directions, like latitude, RA corresponds to east/west directions (like longitude). In fact, RA is timed in hours, minutes, and seconds (Saintonge, 2022).

How the project team managed to handle understanding the space coordinations was using a module called WCS. Geometric changes between one set of coordinates and another are described by world coordinate systems (WCSs). The mapping of an image's pixels onto the celestial sphere is a typical application. The mapping of pixels to spectrum wavelengths is a further typical use. Furthermore, in the project, the libraries of numpy and matplotlib helped the displaying of the images in the project (Astropy, 2022) .

In this research, our purpose is to find the hardness ratio by comparing two photos taken by MIRI and NIRCam with different wavelengths in the same place via Python and Astropy library.

Purpose

This project aims to collect the different images of the James Webb Space Telescope by Jupyter Notebook, Python language and Python Astropy library. By using these unique images, ascertaining hardness ratio which is usually defined as the ratio of two separate wavebands and frequently employed to approximate spectral characteristics in X-ray photometry is aimed.

Description of Specific Steps

This project is initialized from a curiosity to display the James Webb Space Telescope images. Our endeavors were directed towards finding an appropriate database of James Webb Space Telescope images. The database which is handled by the project team was Mikulski Archive for Space Telescope (MAST). The database that is used by the team suggested by our supervisor Ersin Göğüs. After finding a proper database, the project team tried to find a proper software environment because the project's concept was set to display the James Webb Space Telescope by using the coding language of Python. The IDE of PyCharm is tried to perform as the software environment of the project but this environment was not sufficient to display the images. After that, the IDE of Jupyter Notebook was tried and it succeeded to meet our demands from a software environment. Whereupon, the investigation of Astropy library is conducted. The detailed documentation and tutorials of Astropy library were reached through the internet.

After these steps of the project, the implementation and hands-on chapter was started. The team imported the Astropy library, its submodules and subtools into Jupyter Notebook. The FITS files which were pulled out from the MAST database were read by using Astropy tools. Thereby, the HDUs of the FITS files are obtained and read. The header of each HDU was read and the team displayed every key in the FITS file and its corresponding value. Therefore, we could manage to examine every line in a FITS file's HDU. After that, the data obtained from HDUs is interpreted by using the matplotlib and numpy Python libraries. Later on, the team started to learn about the submodules and subtools, WCS and FITS Tools, which will be used later in the project. By the help of these modules of Astropy, the images will be calibrated, transformed and aligned. As a result, the comparison of the images and obtaining of the hardness ratio will become available. At the end the final report will be written.

Week by Week Schedule

Week 1: Gathering general information about the James Webb Space Telescope.

Week 2: Learning Astropy’s basics which is about processing James Webb‘s raw materials.

Week 3: Learning how to use the Mast database and learning fits files.

Week 4: Printing the files images from the Mast database by using Astropy for both MIRI and NIRCam instruments of James Webb Space Telescope.

Week 5: Writing proposal report.

Week 6: Transforming Images coordinates right ascension and declination coordinates and learning subtools and submodels of astropy, WCS and FITS tools.

Week 7–8: Cropping for both MIRI and NIRCam images and converting FITS file images to .jpg or .png.

Week 9-11: Pixel calibration and synchronization of the images.

Week 12-13: Finding hardness ratio.

Week 14: Writing final report.

Description of Responsibilities of Individual Members

In this project, the team members decide what to do and when to do together in the weekly meetings besides the meetings with attendance of the supervisor. The team members share the weekly tasks equally. Team members contribute to the project while they are fulfilling their responsibilities. The weekly meetings are 3 times a week, one of them is with the supervisor on Tuesday and the other two weekly meetings are on Monday and Friday.

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