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September 13, 2021

Using Python Software to Assess Satellites Impacts on Radio Astronomy

Radio Astronomy faces a growing threat from Radio Frequency Interference (RFI) that might endanger our ability to perform sensitive radio observations from many previously safe locations. The newest threat is from the increase in Low Earth Orbit (LEO) satellite networks that rely on frequencies used by radio astronomers in the K and X band.

For this reason, it is crucial now more than ever to develop software capable of simulating the trajectory, frequency, projected power output of satellites in these networks, and to raise public awareness about how RFI can impact radio observations. My project this summer focused on the testing of a relatively new software package, *pycraf*.

Pycraf is the python package I spent time testing this summer. It can be a valuable aid in the analysis of RFI emitted by satellites in orbit. I also worked on testing a variety of platforms, including Jupyter notebook and Google CoLab, for the use of *pycraf*.

Pycraf, was developed and deployed by Benjamin Winkel with the hope of assisting astronomers in calculating propagations of RFI, and topographic simulations. In testing the package, I relied heavily on the associated GitHub documentation of *Pycraf*, and examples provided there and elsewhere on the

internet. The GitHub documentation's examples of Pycraf were saved as ipynb files and could be run in Jupyter Notebook.

I ran all the examples from the *pycraf* GitHub page to first determine if they were still up to date and the package was still functional. I then transitioned to using Google collaborate (Colab) instead of Jupyter Notebook, in the interest of making these notebooks more widely available. I spent considerable time testing *pycraf* in the new and (previously) untested platform Colab to give feedback on its performance as well.

One of the most useful *pycraf* libraries is explored in the notebook entitled *conversion.ipynb* (01), and the documentation goes over different conversion operations. The ability to convert from and to Decibels is the main point of the file. I used this file first to test how Pycraf does simple conversion of different elements and modified the files as necessary. I also tried to push the methods to their limits to test for any arithmetic errors, runtime errors, or logic errors.

The notebook *A_satellites_plot.ipynb* (04) was the next file to be tested, and this file did not disappoint in term of errors. We jumped from file 01 to 04 because my project was focused on satellites in low earth orbit, and file 04 specifically

addresses simulating satellites in orbit. The first lines of code in the file worked as expected, up until method `_propagate`. The first few lines below that method produced an error. Once run, `vec_propagate` produced an error seconds later indicating the type of input is not what was being expected. This error in `vec_propagate`, prevented parts of the rest of the file from executing, especially the simulations plots, which we were interested to explore.

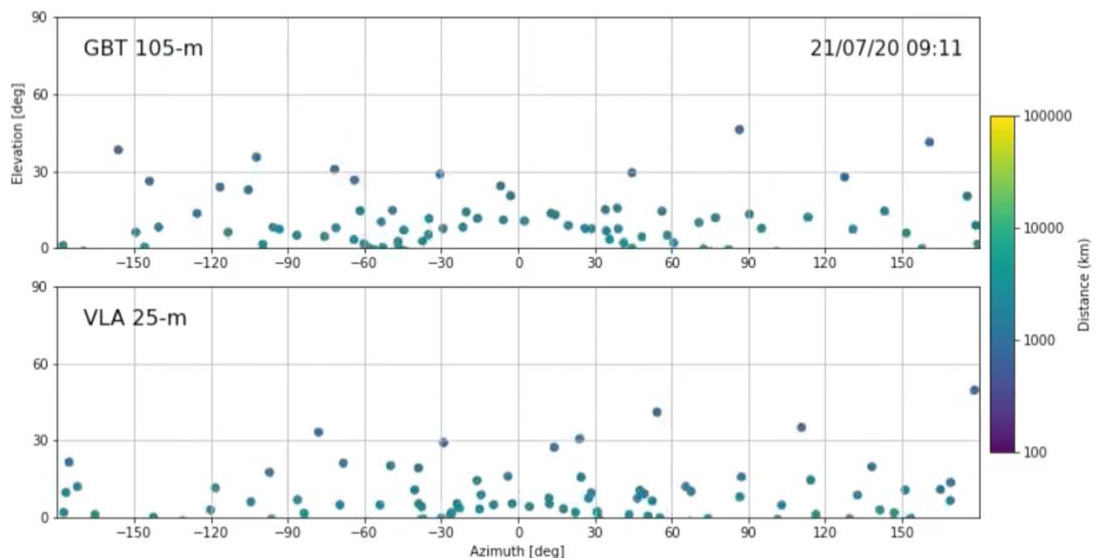
Worked on fixing this issue for few days without any success, I then consulted software developers at NRAO, who concluded that the issue might be an update problem. I contacted Dr. Winkel, who is the main developer of `pycraf`, about the error. After few email exchanges, the author was able to upgrade the sub libraries used by `pycraf` in file 04, and the error was fixed. The code then ran properly, producing animated charts.

The rest of the files were not as relevant to the purpose of the project, but since I was also testing a new platform. I ran them to assess memory allocation of the files, and the run time of each notebook in the platform.

The runtime of these notebooks in this platform (CoLab) was not significantly different from runtimes on the other platform used, Jupyter notebook. But since CoLab is hosted on cloud servers, and it is open source, RAM allocation limits the number of files running at a time, depending on the size of each file.

Most of the files required other types of sub packages, that made it difficult to run all the files completely.

In addition to testing these files, my mentor and I further modified file 04 for various purposes throughout the summer, to get the plots to show the results at the Green Bank Telescope and the Very Large Array.



In conclusion, pycraf proved to be a reliable and useful package for public use. The log of the GitHub page of the package hint that a considerable number of people are using the software, making it likely that other bugs present in the package will be fixed. My summer work was mainly with the Conversion and

Satellites modules, and I can confirm that these modules are reliable in terms of performance and reliability.

As part of the NRAO youth engagement program (Broader Impact), I worked on designing two modules in google Collaboratory (Colab). To help those unfamiliar with radio astronomy to get acquainted with some of it widely used unit, decibel, and built a simple example on how much power output a cellphone produces and how such power output could impact NRAO and other telescopes.

Reference

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