Analytical Comparisons of Cassiopeia A

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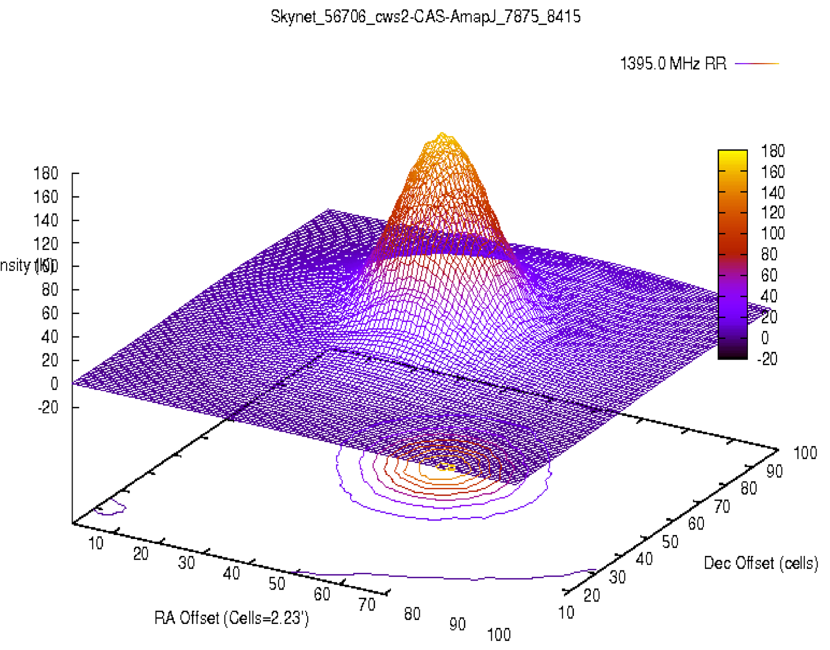
Introduction

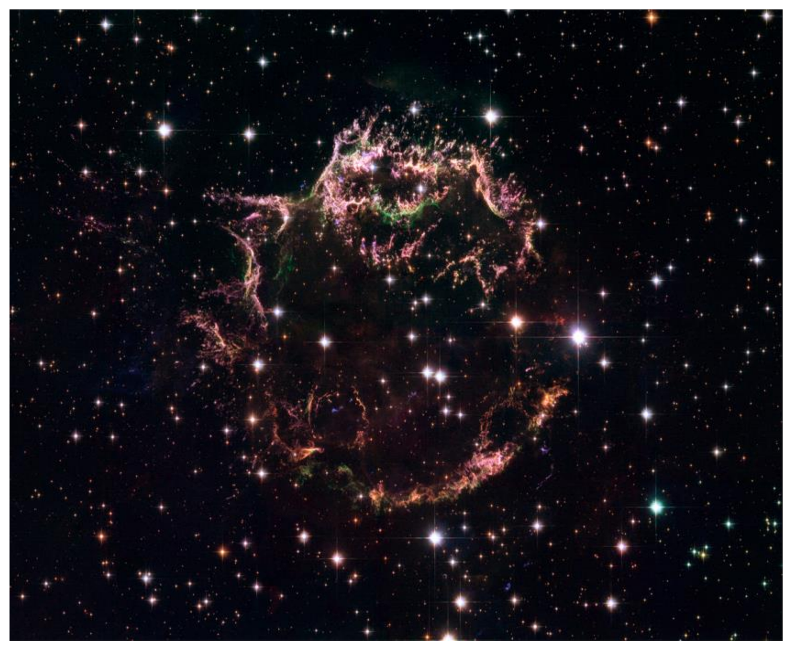
Tasked to investigate the radio universe, our radio astronomy research group journeyed on November 23 to the National Radio Astronomy Observatory (NRAO) in Green Bank, West Virginia. Over the course of three days, we continuously collected preliminary data using the NRAO 40-foot diameter telescope.

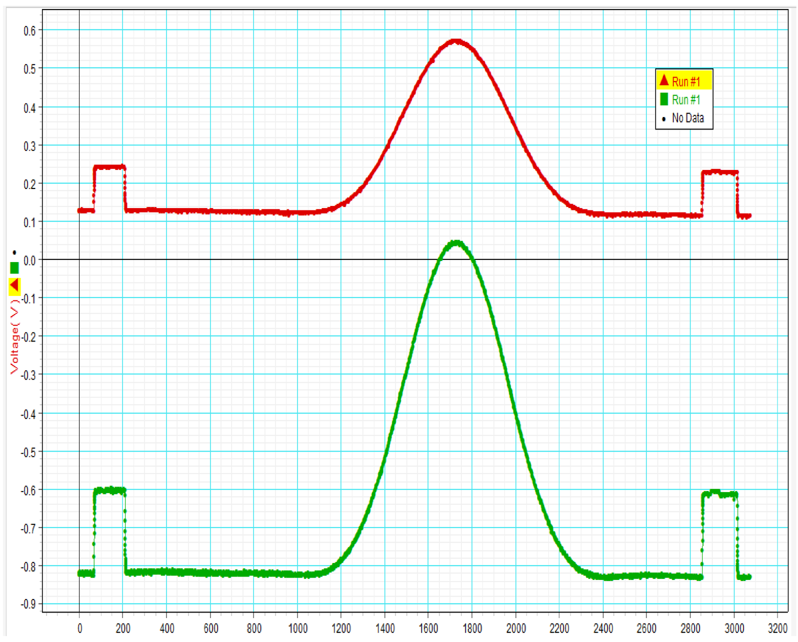
We also utilized the 20-meter Green Bank Telescope. The 20-meter was built in 1994 and was used mainly by the US Navy. The telescope was shut down in 2000 due to a lack of funding. It is now being refurbished and beta tested as a robotic telescope operated via Skynet. Since its recent overhaul, our research team has been benefiting from the final stages of refurbishment.

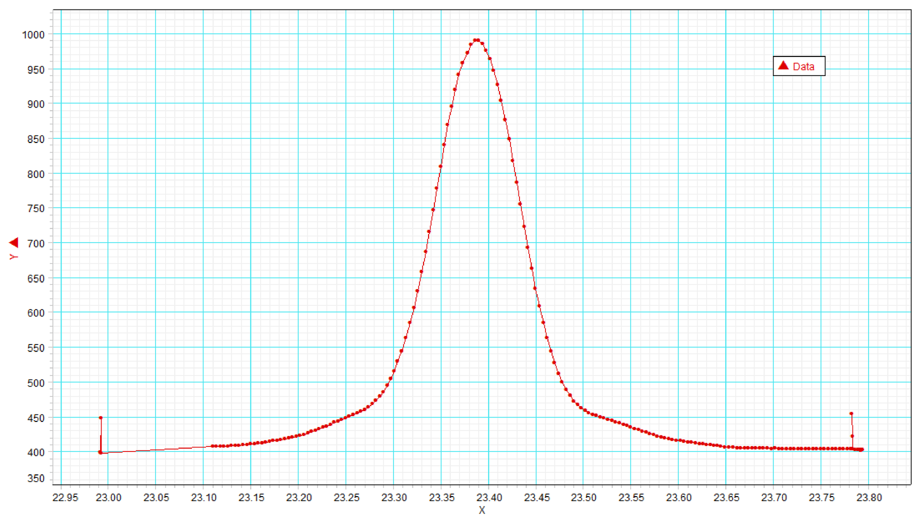
Our main interest of all the celestial objects was Cassiopeia A. There are a few reasons that we are so interested in Cassiopeia A. One of the foremost is the fact that Cassiopeia A is the brightest radio source in the sky. This is because Cassiopeia A is a supernova remnant.

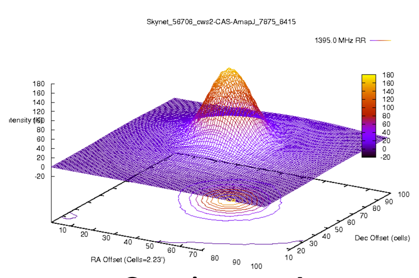
For our specific project, two radio telescopes were utilized to survey the outer space and obtain data on select sources. With that data we compared the two telescopes and compared the percent difference.



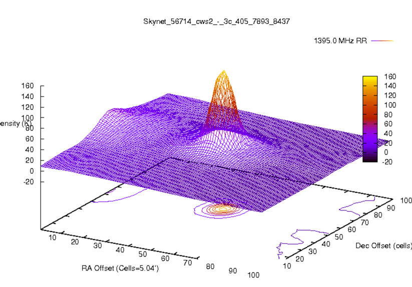




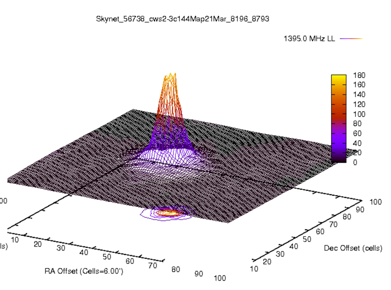




Cassiopeia A
(3c 461)



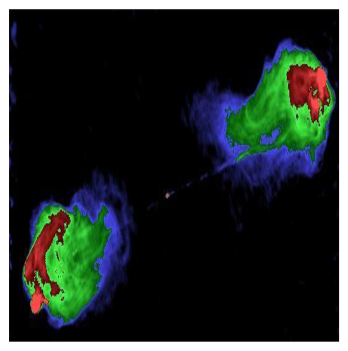
Cygnus
(3C 405)



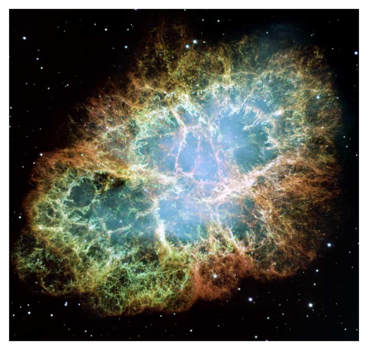
Crab Nebula
(3C 144)

Images From our Data Collection on NRAO's 20m

Cassiopea A



Cygnus



Crab Nebula

Pictures from Hubble Image Gallery & NRAO
http://hubblesite.org/gallery/

Measured Intensities of Radio Sources

Source	Brightness Temperature 40-foot (Kelvin) (Nov 24-26 2013)	Brightness Temperature 20-meter (Kelvin) (Feb-Mar 2014)	Ratio's Percent Difference
Cassiopeia A	29.423	6673.7	0.00%
Cygnus A	23.710	5503.0	2.29%
Crab Nebula	14.288	2660.8	19.7%
3C 400	8.5998	1493.7	26.5%
3C 353	0.87109	164.36	18.4%
3C 274	2.9784	616.74	9.10%
3C 286	0.21238	53.909	11.2%

Ratio of Radio Intensity of Cassiopeia A to Other Bright Radio Sources

Subject	Theoretical Ratio	Experimental (20-meter) Ratio	Ratio's Percent Difference
Cassiopeia A	1.00	1.00	0.00%
Cygnus A	1.24	1.21	2.45%
Crab Nebula	2.83	2.73	3.60%
3C 400	4.30	4.47	3.88%
3C 353	43.5	40.6	6.90%
3C 274	12.5	10.6	16.5%
3C 286	165	124	28.4%

We found through our data that we had a better percent difference, which relates to being more accurate, for data corresponding to brighter sources. This is something that should be expected because the smaller a source is, in terms of brightness, the more likely background radiation is to be picked up, which does not give us a good "zero" to compare the data to.

Methodology

The 40-foot telescope was operated manually and was a transit scope so only one pass of the source was possible every 24 hours. Declination was adjusted and we optimized the adjustment to overcome any slight pointing errors in the slewing mechanism. The chart recorder runs simultaneously with the observation, printing out a graph of intensity in Jansky versus time. We measured the electromagnetic radiation that happens when neutral hydrogen electrons switch from parallel to opposite spin. This process emits a wavelength of 21.1 cm, frequency of 1420.41 MHz.

The procedure for collecting data for celestial bodies, like Cassiopeia, involves getting the 40-foot telescope in position nearly 30 minutes before the run. During this time we made sure we were not hitting any other bodies that would not give us an accurate calibration. After the calibration, we focused the telescope so that we would get maximum Janksy values.

The 20-meter only requires one person to operate. To start the process they must log into Skynet and enter specific information on how to capture the source including: integration time, declination range, right ascension range, type of scan, sweep spacing in arc minutes, and sweep duration.

After we collected all of the data from the two telescopes we set about comparing it. To do this we first had to verify that our data was consistent with the literature (NRAO's intensities). Since the 40-foot telescope does not have the same values of temperature we had to take ratios of Cassiopeia A's intensity to other sources in the sky. These intensities will change from one telescope to another, due to a number of factors, but what will remain the similar are the ratios of the celestial bodies.

The way in which we displayed the data in our charts is a ratio of Cassiopeia A's brightness in Kelvin compared to the named celestial body. (i.e. Cassiopeia A is ≈ 1.2 times larger than Cygnus A) The percent difference equation uses the aforementioned ratios of intensity.

$$\text{Percent Difference} = \left|\frac{2(A-B)}{A+B}\right|$$

Skynet

The 20-meter telescope is part of the distributed network of robotic telescopes operated by students, faculty, and staff at the University of North Carolina. Our radio astronomy research group at Penn State Abington was granted access to Skynet by the National Radio Astronomy Observatory (NRAO) to beta test the recently refurbished 20-meter telescope. Through Skynet, we are fully capable of operating the 20-meter telescope at Green Bank, West Virginia from any internet-capable device.

Skynet is tasked to redirect instructions to the 20-meter telescope to execute a "scan" of a specified radio source. Subsequently, the ASCII (raw data) is then returned and rapidly processed to generate various graphs and results. These results are then posted and accessible for analysis on the NARO server.

Error In Coordinates

Each day the Celestial Sky shifts in galactic right ascension time and declination degrees due to the rotation of the Earth around the galaxy. As you might imagine after a certain amount of time this will accumulate to something significant. About every fifty year this will amount to change in each celestial body that is observable in the sky. This adds up to about a half of a percent error. Therefore, every 50 years the coordinates are updated.

The reason this is relevant to our topic is because of the fact that for the 40-foot telescope we used the B1950 coordinate system to gather data. Once we started using the 20-meter telescope we came to the realization that our sources were now at different galactic coordinates. The galactic coordinates have shifted since the B1950 coordinates were gather to the J2000 coordinates. These newer J2000 coordinates were the utilized by the 20-meter telescope.

The 40-foot telescope only has a one pixel resolution and because of that, a half of a percent error in either declination and right ascension makes a big difference on the data collected. However, after calculating the percent difference between the B1950 coordinates used and the J2000 coordinates we found that the difference in Right Ascension is actually negligible. The percent difference in the declination ranged from 0.141% to 2.86% . Fortunately, due to the method in which we collected data from the 40-foot telescope, which included calibrating and focusing telescope during the scan, we ensured we got the best possible declination. In turn ensuring the best possible data.

[1]Baars, J. W. M., Genzel, R., Pauliny–Toth, I. I. K., Witzel, A. (1977). "The Absolute Spectrum of Cas A; An Accurate Flux Density Scale and a Set of Secondary Calibrators". *Astronomy and Astrophysics* **61**: 99.Bibcode:1977A&A....61...99B.

Percent Difference In Right Ascension

Source	B1950	J2000	%D
Cass A	345.3500	345.39	0.012%
Cygnus A	285.9558	285.9911	0.012%
Crab Nebula	75.5325	75.57556	0.057%
3C 400	285.3419	285.395	0.019%

Percent Difference In Declination

Source	B 1950	J2000	%D
Cass A	58.54639	58.815	0.458%
Cygnus A	40.59611	40.734	0.339%
Crab Nebula	21.98333	22.014	0.141%
3C 400	14.1	14.509	2.860%

%D means Perecent Difference

Conclusion

We decided that the 20-meter data is more accurate than the 40-foot since the percent difference was lower on the 20-meter. What we found in the percent differences is expected as the 40-foot telescope is a very outdated piece of machinery with no regular maintenance. Even though we collected a sizeable amount of data from the 20-meter telescope: encompassing 38 runs, looking at 7 different astronomical objects, and gathering hundreds of thousands of data points: we need to collect more data to make a definite ascertain that the 40-foot telescope is inaccurate. Overall the data we collected is a stepping stone that we hope future Astronomers build upon.