Alpha Centauri A, B & C Imaging using the ALMA Archive

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Abstract

The ALMA archives contain observations of the Alpha Centauri star system. Alpha Centauri is important because it is the closest star system to Earth and may have a planet that is in the habitable zone. This paper provides a basic analysis of some of these observations that were downloaded and reduced by the author.

Introduction

The Atacama Large Millimeter/submillimeter Array (ALMA) maintains archives of observations that are accessible by the general public [1]. Producing images from the raw radio interferometer data requires skill and practice. The author chose the Alpha Centauri system to practice imaging reduction skills due to its proximity and the discovery of planets around Proxima Centauri.

Alpha Centauri is a triple star system located approximately 4.37 light years from Earth. It consists of three stars: Alpha Centauri A (Rigil Kentaurus); Alpha Centauri B (Toliman) and Alpha Centauri C (Proxima Centauri). [2]

Alpha Centauri A is a G type star and Alpha Centauri B is a K type star. A G type star is a main sequence star, which means it is still converting hydrogen to helium. It is between 0.84-1.15 solar masses. A K type star is also a main sequence star with a mass of 0.5-0.8 solar masses and are referred to as Orange dwarfs due their color (Wikipedia). They are a binary star system that appear as single star to the naked eye. Proxima Centauri is a red dwarf M type star that is 4.24 light years from the Sun, which makes it the closest star to Earth. [2] An M type star (red dwarf) is the smallest and coolest of the main sequence stars. IT is usually less that 0.8 solar masses and tend to be long lived (for a star) due to its slow rate of hydrogen burning. (Wikipedia)

Proxima Centauri has one confirmed planet, Proxima b, which has been identified as a rocky planet with a mass of approximately 1.3 x mass of Earth and is in the habitable zone of the star. This means that it is close enough to the star to have liquid water on the planet. [3] A second planet, Proxima c, around Proxima Centauri, has also been identified, though not confirmed. [4] This planet is approximately 5.8 x mass of Earth and 1.5 astronautical units (AU) away from Proxima Centauri. [5]

Processing ALMA Images

The processing of ALMA images requires significant training and practice. NRAO offers imaging and data reduction workshops to assist astronomers. The author attended two of these events in Socorro, New Mexico. (Figures 1 & 2)

These workshops can be found at https://science.nrao.edu/science/meetings/2019/vla-data-reduction/index [6] and https://science.nrao.edu/science/meetings/2018/16th-synthesis-imaging-workshop [7]. The workshops are free, with the exception of travel and hotel costs. Due to the high demand, it is important on signing up 4-5 months ahead of the event. Future workshops are listed on www.science.nrao.edu .

Figure 1: 16th Synthesis Imaging Workshop [6]

Figure 2: 7th Data Reduction Workshop [7]

The workshops describe the process to select and download archived observations of various astronomical objects. The processing of this data requires significant computing power, memory and storage. The author obtained a laptop with 4 CPUs, a 1 TB solid state hard drive, and 16 GB of ram. The operating system was ubuntu with Red Hat Linux 6.

The program that processes the ALMA archive data is the Common Astronomy Software Applications (CASA) program downloaded from the NRAO website (https://casa.nrao.edu/installlinux.shtml). This software requires a working knowledge of UNIX and Python. This experience can be achieved by working through the NRAO tutorials located at: (https://casaguides.nrao.edu/index.php/Main_Page). These tutorials provide practice imaging from multiple different antenna systems.

Obtaining the Alpha Centauri Archive Data

The Alpha Centauri data was obtained from ALMA archive by conducting a search using the ALMA archive interface located at https://almascience.nrao.edu/aq/ . The ALMA query form is shown in figure 3.

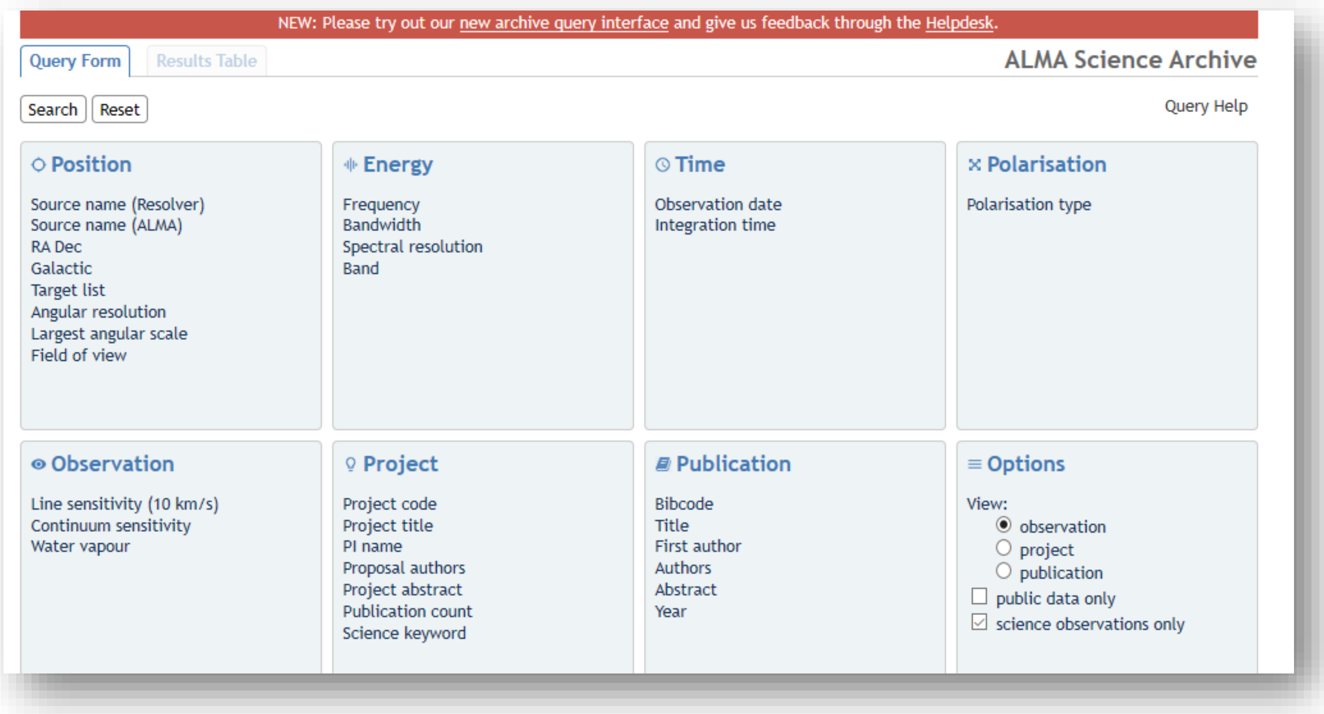

Figure 3: ALMA Archive Interface

The selected archives were identified by project Codes: Alpha Centauri A & B (2013.1.00170.S) and Alpha Centauri C (2016.A.00013.S). The image for Alpha Centauri A & B was reduced by the author and is shown in figure 4.

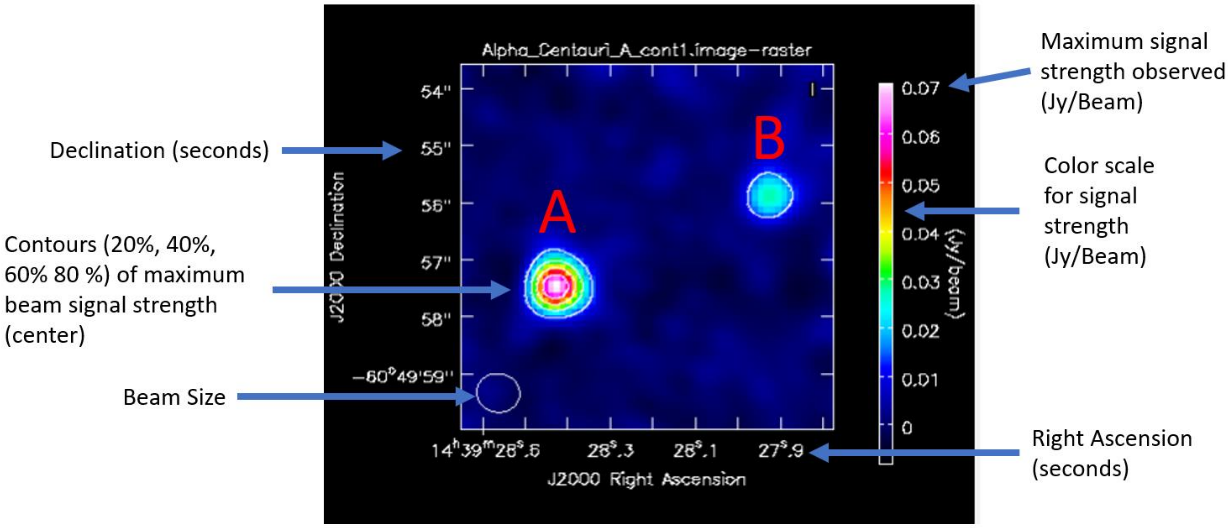

Figure 4: Alpha Centauri A and B reduced from ALMA Archive

Alpha Centauri A and B are approximately 4.37 light years from the Sun and was observed by the ALMA radio telescope at 221-242 GHz on May 2, 2015. They orbit around each other approximately every 80 years [2].

The third star in the system is Proxima Centauri. It revolves around the Alpha Centauri A and B stars approximately every 500,000 years. [8] Proxima Centauri was imaged by ALMA on April 25, 2017 under project code 2016.A.00013.S. The star was observed at 221-242 GHz using: the flux calibrator, J1427-5848; the bandpass calibrator, J1427-4206 and the phase calibrator, J1424-6807. The image in figure 5 was reduced by the author from the ALMA archive.

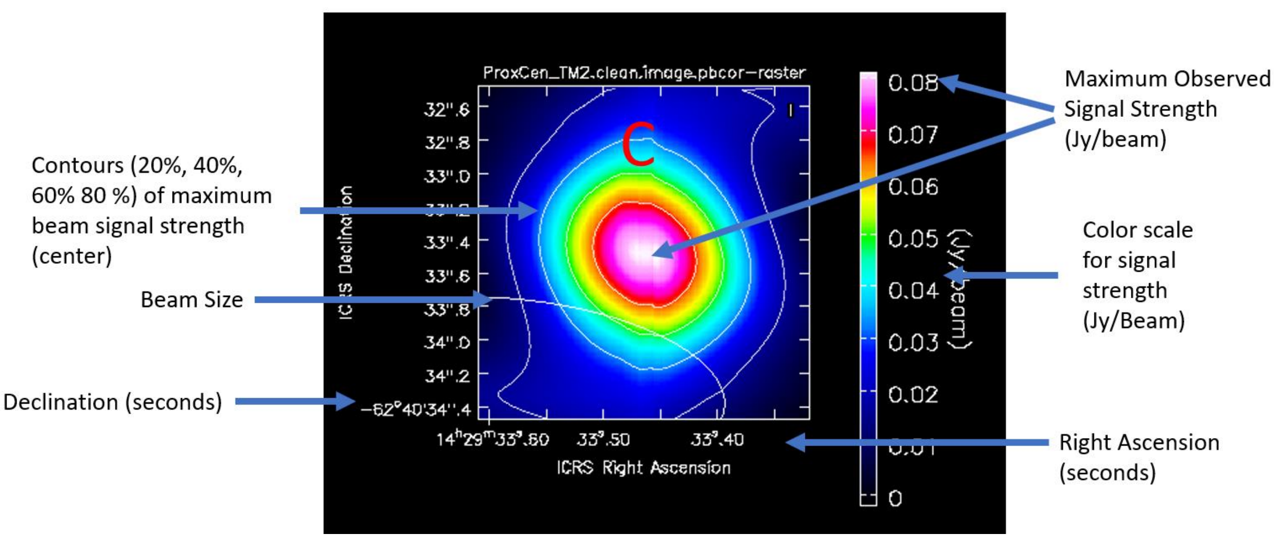

Figure 5:Alpha Centauri C (Proxima Centauri) ALMA Image (note there is no obvious indication of Proxima b in this observation)

Proxima Centauri is a red dwarf and has a confirmed planet discovered in 2016, Proxima b. This planet is 1.3 x the Earth's mass and has a period of 11.2 days at a distance of 0.05 AU from Proxima Centauri [4] [3]. This puts the planet within the habitable zone where liquid water may exist on the planet surface.

The planet, however, is only hot enough for liquid water if it has an atmosphere. The estimate of the planet's surface temperature is 86°F if there is an atmosphere but is only -40°F if there is no atmosphere. [3]

Proxima b may also be tidally locked to the star. This means that the planet will only show one face toward the star. This further complicates the temperature on the planets surface. The star facing side would be much hotter than the dark side of the planet and would have no night.

A second planet around Proxima Centauri has been identified as Proxima c. [5] [4] This candidate planet is approximately 1.5 AU from Proxima Centauri and has a minimum mass of 6 x Earth's mass with a potential surface temperature of -390 °F. [4] It is not habitable and may be closer to our solar systems gas giants such as Jupiter or Neptune.

There is no obvious indication of a planet in figure 5 above. Further research needs to be conducted by the author to determine which radio astronomy frequencies and settings would provide the best opportunity to observe a planet (if possible). Figure 5 does provide the first step by providing excellent detail about a red dwarf and the signal strength pattern around the star.

Next Step in Image Processing Skills

The next step is to obtain archive data of the Alpha Centauri system that contains molecular line observations. These observations may identify the indicators of organic molecules and water which could indicate the existence of life on the Proxima b. This requires the use of different analysis software and an understanding of the molecular chemistry of space and how it relates to solar systems, planets and protostars.

Summary

The ability to utilize the ALMA archives and process the images provides an excellent tool for the amateur radio astronomer. The observations of the Alpha Centauri system are particularly important due to its close location and the identification of a planet that may have liquid water.

The preparation for reducing the ALMA images requires significant training and a very high-end computer, however, is well within the capability of a dedicated enthusiast.

Acknowledgements

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