HU RADIO TELESCOPE

Written by Marlon Smith & Jarrett Goddard

Abstract

This report hereby details Howard University's Portable Radio Telescope contracted and developed by Bison Enterprises. Howard University's Physics Department seeks to build a radio telescope to further their study in dark matter and its affects on the universe. This mysterious substance is hypothesized to be a key ingredient in the universe. As such, further studying the substance could help explain the universe's origin and fate. A great amount of time was dedicated to research and creating conceptual designs for the radio telescope.

Table of Contents

Abstract 2
Introduction & Background 4
Dark Matter 4
Dark Energy 4
Small Radio Telescope (SRT) 5
Problem Statement 5
Design Requirements 5
Solution Approaches and Top Design 6
Project's Spring 2016 Target Goal 6
Project's Final Goal 7
Implementation, Testing and Evaluation 7
Conclusion 7
Recommendation for Future Works 8
References 9
Appendix A 10
Calculation of Angular Resolution 10
Appendix B 12
Appendix C 14
Appendix D 15

Introduction & Background

The **observable universe** — mentioned as *"the universe"*, or *"universe"*, here throughout — is vastly huge with a proper distance of 46 billion light-years between Earth and the edge of the universe. The universe is about 91 billion light-years in diameter at the time of measurement and growing.[1] A team at Cornell University found the speed of expansion to be about 8% faster than that predicted based on Planck data.[2] Physicists believe two invisible substances is to blame for the significant expansion rate. This substance has been dubbed throughout the scientific community as dark matter and dark energy.

Dark Matter

Unlike normal matter, dark matter does not interact electromagnetically with other matter or radiation. This means it does not absorb, reflect or emit light, making it virtually undetectable by normal methods. While invisible to most astronomical instruments, its existence can be inferred from the gravitational effect it seems to have on visible matter.[3] Current research on dark matter could help scientists gain a better understanding of the composition of the universe and, in particular, how galaxies hold together.[3] Such research could, possibly, provide insight into the origin and fate of the universe.

Researchers employ the use of radio telescopes to detect invisible hydrogen gas extending well beyond the visible disks of these galaxies. By clocking that gas, researchers are able to extend the flat rotation curve several times the diameter of the visible galaxy. Large dish radio telescopes help us to infer where dark matter is based on how it affects the visible matter around it. This approach in detecting dark matter stems from a phenomenon known as gravitational lensing. According to the Harvard-Smithsonian, Center for Astrophysics, gravitational lensing occurs when the radiation from a distant source is bent by the gravity of a massive object, like a galaxy, that lies between us and the source.[4] Once a patch of dark matter has been detected, it is measured by subtracting the mass in stars and gas (Hydrogen) from the observed patch.

Dark Energy

Through observations of distant supernovae, two research groups have independently discovered that, rather than decelerating, the expansion of the universe appears to be increasing with time.[5] Researchers hypothesize that this observation is possible due to the presence of some "antigravity" being produced from an unknown substance dubbed dark energy. This substance makes up ~70% of the universe and appears to be associated with the vacuum in space. Dark energy is distributed evenly throughout the universe, not only in space but also in time – in other words, its effect is not diluted as the universe expands.[3] Furthermore, an even distribution implies a global gravitational effect of dark energy on the universe as a whole rather than a local phenomenon. Thus, this effect appears to be the cause of accelerated expansion of the universe.

Small Radio Telescope (SRT)

The Small Radio Telescope (SRT) (Summer 2012) was developed by MIT's Haystack Observatory to serve as an educational tool for universities and colleges teaching astronomy and radio astronomy and radio technology. The telescope is designed to be assembled easily with minimal need for special tools or skills. The necessary components are commercially available with plans, instructions, and software provided by MIT Haystack **(See Appendix C)**.[6] The SRT's antenna is a standard ~2.3 meter satellite television dish mounted on top a fully motorized Az-El mount.

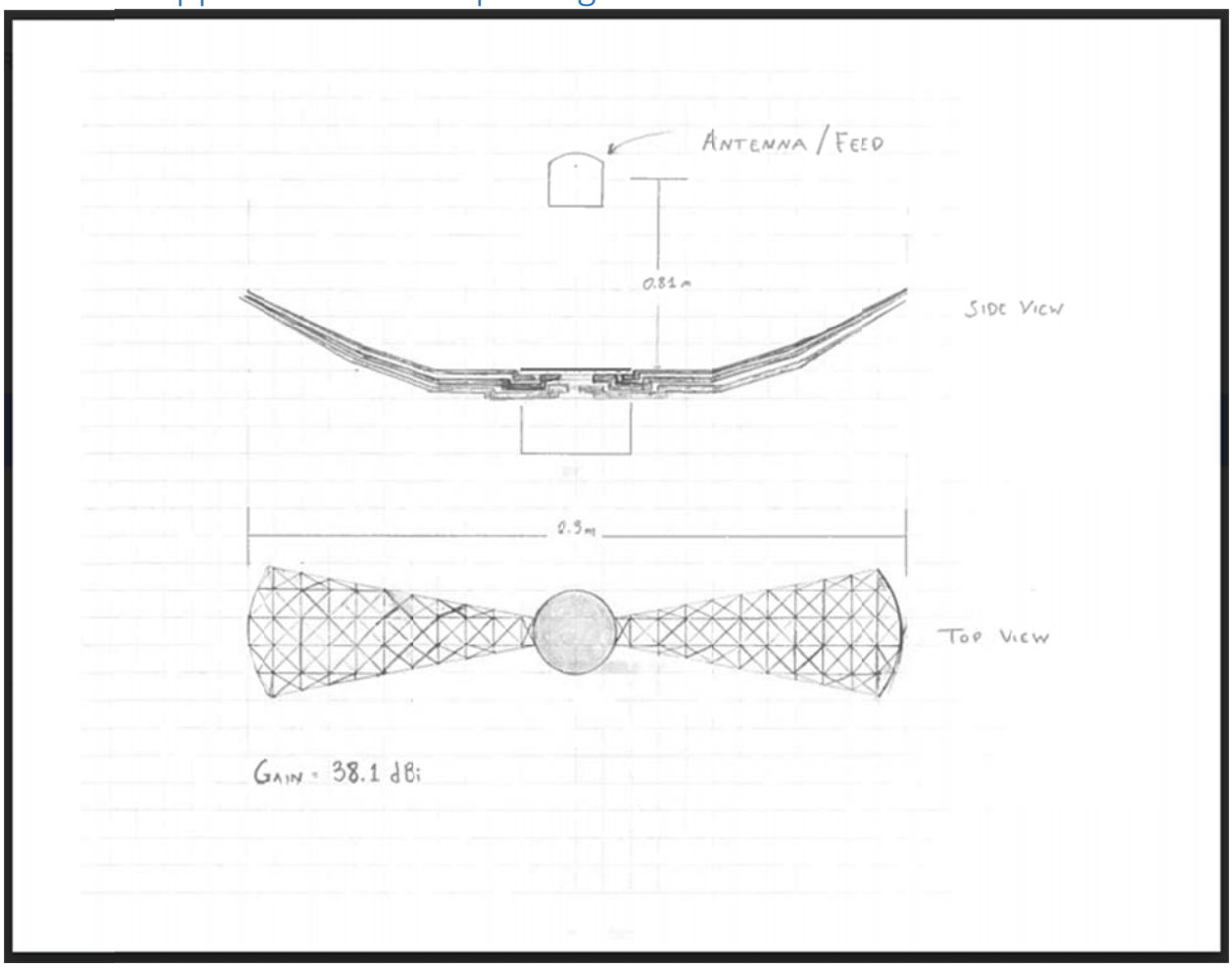
Problem Statement

Howard University's Physics Department is committed to further studying matter and its motion through space and time. As such, the department is currently contributing research to the study of dark matter and its effects on the observable universe. Dark matter is an invisible force undetectable by conventional means. As such, an instrument capable of detecting electromagnetic radiation is required to further the department's research. Thus, a portable radio telescope is to be created based on the MIT Haystack Radio Telescope to detect radio frequencies emitted by hydrogen atoms at the halo of our galaxy.

Design Requirements

Our antenna is to be constructed from C/Ku band mesh supported by a rigid but lightweight aluminum frame. This mesh will serve to reflect all incident microwave energy if the holes in the surface are less than 1/10th of a wavelength.[7] MIT Haystack specifies the use of a 90 inch antenna with an angular resolution of approximately 7.0 degrees **(See Appendix A)**[7].

Solution Approaches and Top Design



There are a variety of radio telescope's currently in operation. These telescopes vary in size and capabilities. Typically, the larger a telescope's antenna, the better the image resolution of the telescope. A trade off of portable telescopes is the loss of resolution in order to save space. As such, our team found the minimal size for our radio telescope antenna and compared it to the average size of an SUV's cargo bay **(See Appendix D)**.

Our top designed antenna unfolds in a circular motion like the blades of a Chinese fan. Each blade locks into place as the unit is unfolded. This method and structure provides an ease of use, quick assembly, and disassembly while save a great amount of space for storage and transportation. The antenna feed is easily attached once the dish has been assembled.

Project's Spring 2016 Target Goal

Bison Enterprises' Spring 2016 target goal is focused on building and testing the Jove radio receiver and central database. Development of the Jove radio antenna will further the team's knowledge of radio astronomy and signal processing; fundamental requirements for

building Howard University's portable radio telescope. Our computer engineers are tasked to create a central database for storing the data collected from the Jove receiver. This database will later be updated to allow storage of data collected from the portable radio telescope as well.

Our client would like to build an online community for scholars to access and contribute their research and data in dark matter. Our team has taken such preference and desire into consideration when designing and building the database. We constructed the Jove antenna based on its specifications as found inside its manual. The antenna is currently unable to detect our target signal due to an incorrect length of copper wire being used on the antenna. Our team has completed a purchase order form for the correct length of wire to be approved and purchased by our client.

Project's Final Goal

The overall goal of this project is to create a portable radio telescope for Howard University's Physics Department. We have completed our preliminary research work in order to increase our knowledge and understanding of radio telescopes including their functionality, and overall operation. We have chosen a final design for our antenna that we must further explore. This exploration includes computer rendering of our design, simulation and computer testing, and final construction of our design.

Implementation, Testing and Evaluation

After the Jove receiver was built, it was necessary to ensure everything was operating accordingly to the manufactures specification. The receiver and antenna is required to work on a short wave frequency centered around 20.1 MHz. The receiver was tested using the suggested operational procedures and guidelines. We must note that our oscilloscope was unable to produce the required output voltage. As such, our team created a voltage divider to obtain the necessary voltage for the receiver.

Our initial test failed due to several faulty components; our team found and removed two defective capacitors. These components were added to our purchase order. Our team will install the components and attempt to complete the testing process once obtain. Several other examinations and evaluation were necessary to ensure that the receiver was built correctly. As such, a power cycle test was performed to ensure there were zero chance of damaging the unit.

Conclusion

Bison Enterprises was contracted to modify and build a portable version of the MIT Haystack Radio Telescope to further the research in dark matter on Howard University's campus. Our team worked exhaustively over the course of six months to design a portable antenna for ease, and efficient, assembly and disassembly. Extensive research was conducted in

order for the team to successfully produce a telescope that was both portable and capable of performing its designated task.

Our team has an extensive amount of research in the area of radio astronomy and signal processing. The project was scaled back in Spring 2016 due to frozen financial accounts and inadequate amount of funding to fill purchase orders for the MIT Haystack components. The Jove radio telescope was introduced as a means of furthering our research and aid in the creation of a central database.

Recommendation for Future Works

Bison Enterprises' believes in longevity, growth and progress. As such, we would like to offer our advice to help future teams complete their objectives, meet their deadlines, and reach their goals. It is recommended that future teams adhere to project guidelines and establish essential business practices **(See Appendix B)**[8]. Your team must be well organized with a team leader and co-leader to track the team's progress, maintain order and enforce the team's policies and guidelines.

The team leader is ideally responsible for setting reasonable deadlines, scheduling regular meetings, tracking the project's progress and providing access to the necessary resources required to complete the project, task, or objective. The co-leader is ideally responsible for overseeing the completion of tasks and objectives. The co-leader should maintain a daily log of containing notable specifics related to the scope of the team's work. A record should be maintained of all tasks performed with deadlines, completion time and signature of completion.

Communication is the number one failing point of any team. Bison Enterprises' advice is to maintain communication both inside and outside of meetings. Engage with your team members on regular and timely basis to complete tasks and overcome challenges. Team members should record specifics on what work was done and how the tasks were completed. Furthermore, maintain an organized Google Drive account with electronic copies of all documentations. Importantly, always strive to sharpen your skills.

References

1. Bars, Itzhak, John Terning, and Farzad Nekoogar. *Extra Dimensions in Space and Time*. New York: Springer, 2010. Web. 16 Apr. 2016. <https://books.google.com/books?id=fFSMatekilIC&pg=PA27#v=onepage&q&f=false>.
2. Castelvecchi, Davide. *"Measurement of Universe's Expansion Rate Creates Cosmological Puzzle."* Nature.com. Nature Publishing Group, 11 Apr. 2016. Web. 16 Apr. 2016. <http://www.nature.com/news/measurement-of-universe-s-expansion-rate-creates-cosmological-puzzle-1.19715?WT.mc_id=TWT_NatureNews#/b1>.
3. *"CERN Accelerating Science."* Dark Matter. CERN, 20 Jan. 2012. Web. 16 Apr. 2016. <http://home.cern/about/physics/dark-matter>.
4. *"Dark Matter in Galaxies."* Www.cfa.harvard.edu/. Harvard-Smithsonian, 10 Dec. 2013. Web. 20 Apr. 2016. <https://www.cfa.harvard.edu/research/rg/dark-matter-galaxies>.
5. Filippini, Jeff. *"The Standard Cosmology."* The Standard Cosmology. UC Berkeley Cosmology Group, Aug. 2005. Web. 16 Apr. 2016. <http://cosmology.berkeley.edu/Education/CosmologyEssays/The_Standard_Cosmology.html>.
6. Leonard, Dan. "*New SRT - SRT Wiki"*. Ed. Heidi N. Johnson. N.p., n.d. Web. 16 Apr. 2016. <https://wikis.mit.edu/confluence/display/SRT/New+SRT>.
7. "Specifications." *MIT Haystack Observatory: Undergraduate Research SRT*. MIT Haystack Observatory, n.d. Web. 16 Apr. 2016. <http://www.haystack.mit.edu/edu/undergrad/srt/antenna/antenna_info.html>.
8. *"What Are the 10 Essential Good Business Practices?"* The Crafts Council of Ireland Enterprise Website. Crafts Council of Ireland, n.d. Web. 19 Apr. 2016. <http://www.ccoienterprise.ie/business/article/10-essential-good-business-practices>.

Appendix A

Antenna Specifications	
Diameter	90" (2.3m)
F/D Ratio	0.375
Focal Length	33.75" (85.7cm)
Gain @ 4.2 GHz	38.1 dBi
Gain @ 1.4 GHz	
Weight with mount	160 lbs
Beam Width	7.0 Degrees (L-band)

MIT Haystack SRT specifies the use of a 90 inch antenna with a beam width of 7.0 degrees. We conducted further research on how to determine the beam width, or angular resolution, of an antenna. The angular resolution (θ) of a telescope defines its ability to distinguish specific details in an image. The smaller value of θ, the better the resolution the telescope will have.

The resolution of a telescope is determined by the following equation, as described by the *Pisgah Astronomical Research Institute (PARI)*:

$$\boldsymbol{\theta = (1.22)(\frac{57.3\lambda}{D})}$$

$\lambda = Wavelength\ in\ meters$
$c = Speed\ of\ Light$
$D = Diameter\ of\ the\ telescope\ antenna\ in\ meters$

Our client provided us with some important details about the purpose and service of our telescope. Our calculation of angular resolution (below) was achieved based solely on the information provided to us by our client. As you can see from our calculations, our result falls within 7.78% accuracy. It is possible that MIT's Haystack specifications were derived from an entirely different equation or actual experiments. If our calculations are indeed accurate, our telescope will have a resolution 7.78% greater than that of MIT's Haystack SRT.

Calculation of Angular Resolution

$f_{Hydrogen} = 1420\ MHz$

$$\lambda = \frac{c}{1420\ MHz} = 21.11\ cm$$

$D = 90" = 2.286\ m$

$$\theta = (1.22)\left(\frac{57.3 * 21.11\ cm}{2.286\ m}\right) = (1.22)(5.291) = 6.455$$

$$Percent\ Error = \left[\frac{(Specified\ \theta) - (Calculated\ \theta)}{(Specified\ \theta)}\right] * 100$$

$$Percent\ Error = \left[\frac{7 - 6.455}{7}\right] * 100 = 7.786\%$$

Appendix B

Ten Essential Business Practices

1. **Assess yourself:** Undertake a personal audit or self-assessment to identify your strengths and weaknesses. Work to your strengths and address your weaknesses – there is a great deal of help and assistance out there if you look. Recognize your reasons for becoming self-employed and be very clear about your objectives and goals.
2. **Surround yourself with a good team:** When you become self-employed, you become responsible for designing, producing, selling, customer care, financing, collecting bad debts, book-keeping, etc. But it is not essential that you undertake all of these tasks unaided. It may be more cost-effective to allow professional and experienced people in particular sectors to assume some 'chores' with which you are not comfortable and thus allow you the time to undertake those with which you are, paying for their work from the increased turnover you are now capable of earning.
3. **Assess your product:** Are you confident that your product is of a high quality in design and production? Are you confident that there is a market for it? Are you confident that your potential customers will pay the price you calculate necessary to meet your costs?
4. **Know your market and competitors:** It is essential that you know your market, as without this knowledge you cannot plan your route to market or the means of promotion you will use to inform your customers of your existence. It is also essential that you have a comprehensive knowledge of your competitors, as this knowledge will allow you to distinguish what the market will stand plus identify the gaps in the market.
5. **The ability to recognize opportunities:** Are you truly an entrepreneur? An entrepreneur will be studying the market and trends etc at all times and may go out on a limb (armed with good information) to seize an opportunity. All decisions should be taken based on information; knowledge is the greatest asset of any business.
6. **Costing and pricing:** This is one of the most difficult tasks you need to address. It is imperative that you know your break-even point: the number of units sold that will cover the costs of your raw materials, your overheads and your production time. Only when you know this figure (plus that of your competitors) will you be comfortable in the knowledge of how high or low your price may go.
7. **Good terms of trade and paperwork:** Everything leaving your 'studio' should be of a quality to promote you in a very positive manner. Your product should have good packaging, branding and promotional materials. Your invoices etc. should be clear and accurate and show concisely your terms of trade – how and when you expect to be paid; carriage – who pays it; breakages – who is responsible; reservation of title, etc.
8. **Keep clear records:** There is no mystery to book-keeping. It is nothing more than a filing system of the day-to-day transactions of your business. If you do not record and understand the transactions, your business will control you rather than you controlling it.
9. **Be tax-compliant:** It is a legal obligation to register for tax with the Revenue Commissioners when you commence self-employment. Registering for tax does not necessarily mean paying tax in the early stages of your business. It may actually result in a repayment – should a number of circumstances be in play – for example, you may be paying PAYE on your employment while making a loss due to the investment in your craft business. Being able to claim the Artists' Exemption on certain products also may be a benefit to registration.

10. **Planning:** The key to a successful business is planning your project from day one. Planning is about making choices which should only be made on the basis of good information.

Tips

- You are a link in the chain of the business; form good relationships with other links.
- Be professional. You are the main asset of the business.
- Indecisiveness wastes time. Gain knowledge and make informed decisions.
- Getting finance is not easy. Acquire it wisely. Spend it wisely.
- You may have an excellent product but, if you are not getting adequately paid for it, you are not in business.
- Undertake market research. Know your competitors.
- Do what you say and say what you do.

Appendix C

Purchase Order for MIT Haystack Small Radio Telescope v2

See Document Entitled
"SRT2 Purchase Orde.xlsx"

Appendix D

Average SUV Cargo Size

See Document Entitled
"17 SUVs That Boast the Most Cargo Space for Under $25k.xlsx"