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QUANTUM COMPUTER IN SPACE EXPLORATION

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INTRODUCTION

The early era of space exploration was mainly focused on the unsaid competition called "space race" between the Soviet Union and the United States. With the launch of first human made object in space i.e., Sputnik 1 by Soviet Union on 4th October 1957 this competition began continuing with the spirit that the United States did the first moon landing Apollo 11 mission on 20 July 1969, these instances are often known as landmarks of this era. The Soviet Union led the way in the firsts whether it was first living being in orbit in 1957, launch of the first space station in 1971, first spacewalk and many more. However, as the focus of the world changed from the "space race" to renewable hardware slowly this competition turned into collaboration and launched the International Space Station.

Data plays an important role in space exploration, faster processing of such data enables the space organization's rovers i.e., Space probes make faster decisions and hence reduce the failure. Now with the new emerging branch of astronomy called Deep space exploration the technology which helps explore distant outer space. With this branch the amount of data produced for processing is increased exponentially for example the recent first ever image of black hole discovered in a distant galaxy which measures 40 billion kilometers across and three million sizes of earth. It took eight telescopes to photograph it, it is 500 trillion kilometers away from us and the size of it is 4.5 petabytes. With a humongous network of sensors and systems positioned across the world and space NASA produced around 12.1 terabytes of data [Wikipedia] for processing every day. NASA rapidly upgrades its spacecraft giving them the ability to process the huge data much faster and also enables them in faster transmission. Noting that some of the space missions could generate as large data as 24 terabytes of data every day. [Wikipedia]To process such data space agencies need faster and more reliable computer processing. The Planetary Data System (PDS) was developed in 90's to give access to data of past 50 years of planetary science missions through distributed topical nodes at 7 research institutes. The data is collected from Astrophysics Great Observatories that includes the Hubble Space Telescope, the Chandra X-Ray Telescope and the Spitzer Infrared Space Telescope. These in turn have become the foundation of Virtual Astronomical Observatory making the better view of digital sky in all wavelength. [NASA]

Around sixty-seven years ago when the first ever transistor was being developed no one would have thought that computers would become a very important part of our society via various applications. The Internet is also not a one-day success. It took almost twenty-four years. With Moore stating the law known as Moore's law that the number of transistors in the IC would double in about two years. Nowadays computers have reached their respective limits leaving very less scope for something.

In order to overcome this limitation scientists are looking for new options, one of such options which is emerging to be a promising candidate in Quantum Computers. Quantum Computers use the laws of quantum mechanics to do the computations. They can solve any given problem way faster than the classical computers. In these qubits which is equal to bits in classical computers for storing the data. Qubits are generated by small particles like protons or electrons that have spins which can be measured by a magnetic field. If we bring it into a magnetic field then it spins in a different direction. The concept of superposition and annealing is used for computation in quantum computers.

LITERATURE REVIEW

The term big data was proposed by Michael Cox and David Ellisworth in a research paper of NASA. For processing this big data NASA uses giving technologies [Micheal Shannon,2019]

- The Quantum Artificial Intelligence Laboratory (QuAIL) and the space agency's quantum computers;
- The agency's Supercomputer- the Pleiades- that performs simulation and modeling;
- Storage of bulk amounts of data on Earth Science and Distributed Active Archive Centers (DAACs);
- Cyber Security of its networks and the NACRA- the Network Activity Cybersecurity Risk Assessment;

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- Expert Medical Care and Exploration of Medical Capabilities (ExMC).

NASA used the Pleiades supercomputer to analyze the data in complicated projects such as space weather, solar flare and many more.

Piyush Mehrotra, [Supporting Big Data] talks about NASA Advanced Supercomputer about its computational power, limitations and community review about it. The potential benefits and the emerging need for quantum computing over the classical computers has been discussed by many authors [Prantosh, Kanamori, Devitt]. Prantosh (2011) has also discussed the benefits of quantum science and its potential scope in a variety of fields, where Aaronson shows implementation of quantum computation in a practical environment and he emphasizes the requirement of absolute zero temperature for measuring the momentum of the atom. He also talks about the limitations of quantum computing. Munro and Devitt (2011) have also implemented a model of quantum computer which is of high performance. In an article D WAVE quantum computer talks about issues and benefits related to D WAVE quantum computers. M.k Bhatia, Chugh.A (2021) proposed a big data query optimization system for customer sentiment analysis of telecom tweets. They suggested a hybrid system that leverages the recurrent neural network, deep learning technique for efficient handling of big data and spider monkey optimization, a metaheuristic technique which helps to train networks faster and enables fast query handling. The comparison is made with deep convolutional networks and models optimized for efficiency and performance for predicting customer churn rate.

[Madan, 2021]There work presents research insights into challenges in big data mining and the privacy concern in big data besides presenting gaps in the research that can be used to plan future research. Suman Madan et.al. (2017) modelled privacy-preserving scheme for big data publishing in the cloud. This method provided high degree of privacy to data. This paper gives insights on overview of big data, associated challenges, privacy and security concerns and the differentiation between privacy & security requirements in big data. The authors also focused on various privacy models which can be stretched to big data domain, analysing the benefits and drawbacks of Data anonymity privacy models.

PROPOSED WORK

IBM Quantum Computer: IBM provides a full-stack approach to bring the best quantum computing services to the community with extensive software tools and cloud computing services which makes it easy for researcher's community. It provides safe, secure and programming tools to access world's best and leading quantum system and simulators via IBM cloud.

Google Colab is short for Colaboratory. It helps various users to write and python program codes. The best part is that in order to do this there is no prior configuration needed. It provides free access to GPU and it can be shared easily. It also helps in combining the executable codes and rich text in one document, also images, HTML and many more. The Colab notebooks are stored in Google Drive account. It is very easily shared with the co-workers or friends and they can also comment on your notebooks or can be edited.

EXPERIMENT

For experiment, we have used IBM Quantum computer platform IBM quantum, in that we have used the IBM Quantum Lab. The data set is picked up from NASA's website, data of exoplanets has been picked up for analysis. For classical computer we have used Google Colab.

For the dataset, we have used NASA's data[Table 1] which is freely available for researchers for analysis and analytical purposes.

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	pl_hostname	pl_letter	pl_name	pl_discmethod	pl_controvflag	pl_pnum
0	HD 180314	b	HD 180314 b	Radial Velocity	0	1
1	HD 180902	b	HD 180902 b	Radial Velocity	0	1
2	HD 181342	b	HD 181342 b	Radial Velocity	0	1
3	HD 181433	b	HD 181433 b	Radial Velocity	0	3
4	HD 181433	c	HD 181433 c	Radial Velocity	0	3

Table 1: Sample Data

For the classical computer and Quantum computer, we used correlation for graphical representation and distribution display for the variation in the attributes in Python Language. We calculated the time taken by Google Collab to do the representation and similarly we noted the time taken by IBM Quantum Computer to make the representation.

Serial Number	Google Collab	IBM Quantum Computer
1.	14.58 Seconds	1 Nano Second*
2.	12 Seconds	1 Nano Second*
3.	11.68 Seconds	1 Nano Second*
4.	11.55 Seconds	1 Nano Second*
5.	11 Seconds	1 Nano Second*

Table 2 Complexity analysis (Reference 10)

Reading for Google Collab	Reading for IBM Quantum Computer
CPU times: user 10.1 s, Sys: 317 ms, total: 10.4 s Wall time: 10.2 s	CPU times: user 7.96 s, sys: 288 ms, total: 8.24 s Wall time: 8.04 s

Table 3 Hardware Reading

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Device 1: Lenovo Laptop Ideapad 310 **RAM: 12GB** **Internet Speed: 50mbps** **SSD: 256 GB** **Intel i5**	**Device 2: Asus vivobook s15** **RAM: 8GB,** **Internet Speed: 6.25 Megabytes per second,** **SSD** **Intel i5-8250U**

Table 4 Hardware used For Experiment

EXPERIMENTAL CODE

The language choose for the experiment is python which is supported by both the platforms. We have used NumPy and Matplotlib packages of Python in order to do the experiment and produce the experiment results.

Google Colab Screenshot 1 to 3 represent the code used in Google Colab to assess the exoplanetary data of NASA in order to produce the images. For quantum computer we used platform of IBM i.e., IBM Quantum Computer so the IBM Quantum Computer Screenshot 1 to 3 represent the code used in IBM Quantum Computer. We have used Numpy, qiskit, qiskit.tool.jupyter, qiskit.visualization, pandas, sklearn.preprocessing, mpl_toolkits.mplot3d. os,Matplotlib.pyplot and ibm_quantum_widgets packages in order to assess the data and produced the image results.

CODE USED IN GOOGLE COLAB

Google Colab Code Screenshot 1

Google Colab Code Screenshot 2

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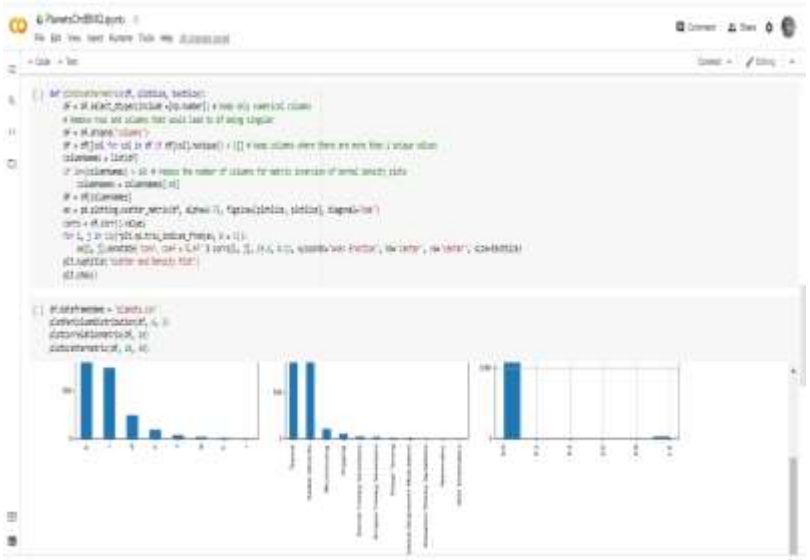

Google Colab Code Screenshot 3

CODE USED IN IBM QUANTUM COMPUTER

IBM Quantum Computer Screenshot 1

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IBM Quantum Computer Screenshot 2

IBM Quantum Computer Screenshot 3

Experimental Results

The image results generated in both the platforms are same however there is a drastic difference in time. The images depict various aspects of the data.

- Per Column distribution1 : This is the distributions of the relevant different variables. The distribution of a variable or dataset as a list of possible values, and some indication to how frequently each value occurs. It also depicts various aspects of the data in how they are occurring.
- Correlation Matrix 2: Table shows correlation coefficients between various variable and each cell of the matrix shows correlation between the two variables of the exoplanetary data used in the experiment. This is a summary of the analysis.
- Scatter Matrix 3: It is the multivariate, the scatter matrix is a statistic matrix of the data it is give us the estimate of the covariance matrix, for the multivariate of the normal distribution.

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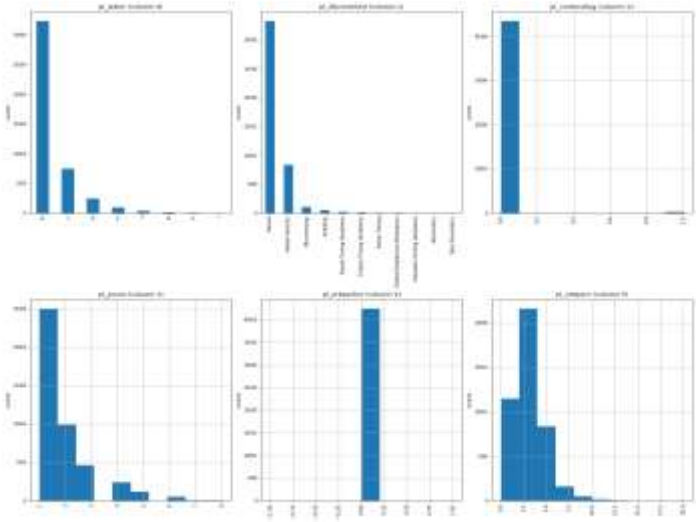
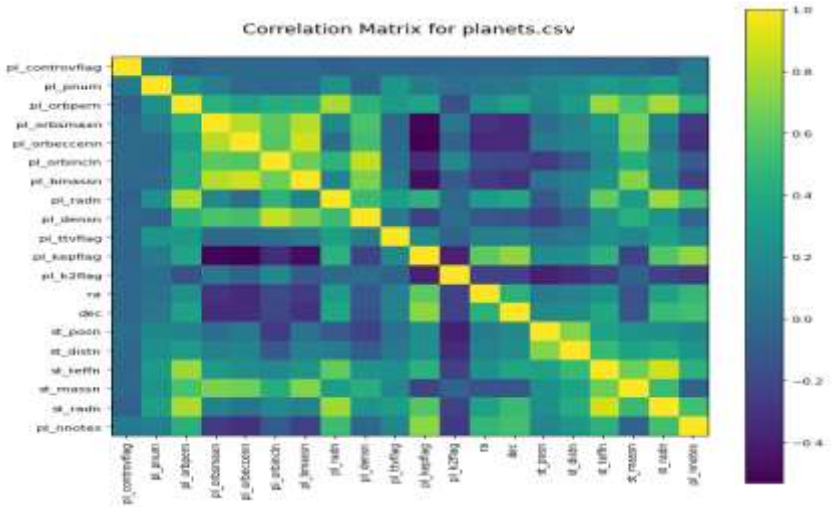
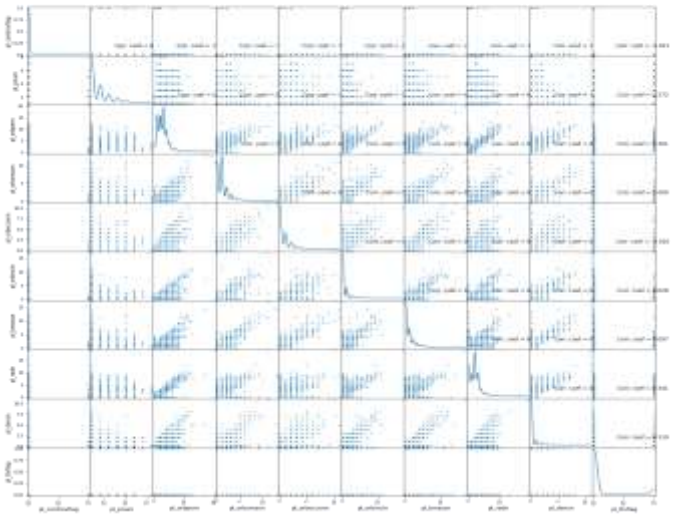


Per Column distribution3



Correlation Matrix 2



Scatter Matrix 4

CONCLUSION

The representation of the correlation of the various attributes of the data on both the computer and seeing the time difference we see a major time difference in the computation power of the quantum computer versus the classical computer. While running the
experiment multiple times and noting down the time and every time we found a major time difference in computation of both the computers. We also acknowledge here that there must be some limitations as we are using Google platform and IBM platform and do not have direct access to any of the servers/computers. The hardware limitations and also the internet speed limitations.

As we have already been talking about the need for speed in computational power in space exploration on big data which is produced in NASA. We have noticed the quantum computer comes out as a suitable potential option for analysis and analytical approaches. The data can be processed in real-time very rapidly with the help of quantum computers. With deep space emerging as one of the most important subjects in the present space exploration and with the wishes of NASA to explore MARS as a potential planet to make it livable, these things directly indicate a lot of future exploratory missions in future. As supercomputers have reached their limits of

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computation it's high time to find the new potential options. As we find in our experiment, the processing speed of the IBM Quantum computer is 1 Nano second as compared to that of a classical computer. We highly recommend it as one of the options for the space exploration missions in the future.

Also considering the limitations of the quantum computers we believe that there is more research needs to be done to overcome the large gap which is there in production of quantum computers that can be overcome in future researches and experimentations.

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