Comparison of Stellar Detectors for Mars, Jupiter, and Sun

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Abstract. Contemporarily, various stellar detectors have been launched to different planets, which offer abundant information for both astrophysics and cosmology. To better illustrate the differences and functions of the detectors, this paper briefly introduces the development of planetary probes and the characteristics of some of the planets and selects three of the most valuable planetary probes for study, comparing their functions, characteristics, and other aspects to investigate the different effects of different planetary characteristics on the function of the probes. The paper focuses on the Mars Rover Curiosity, the Jupiter Rover Galileo, and the Solar Rover Parker. The comparison shows that they all differ in the presentation of the rover form due to the different characteristics of the planet. This study also helps to analyse the future direction of the rovers of these three bodies, e.g., solar probes will continue to face the challenge of becoming more resistant to radiation as well as to heat. These results shed light on guiding further exploration of stellar detectors.

Keywords: Probes; Stellar detectors; Mars; Jupiter; Sun.

1. Introduction

Humanity's never-ending curiosity and exploration of the world is one of the major reasons that sustain it going forward. In addition to the exploration of the Earth, with the development of science and technology, mankind's curiosity about outer space is increasing day by day. In the last and this century, technology has developed at a rapid pace and mankind has gradually acquired the ability to explore outer space, e.g., using astronomical telescopes (dropping celestial probes on other bodies in the solar system). Increased knowledge of outer space will allow mankind to better observe many objects and phenomena, learn from them and extract good resources from them for the benefit of mankind. The earliest exploration of the solar system dates to 1957, when the first artificial satellite was launched again by the Soviet Union. At that time, technology only supported the exploration of satellites around the Earth, followed by the Moon, which is close to the Earth. With the continuous development of science and technology, mankind has now successfully placed different types of probes on several major bodies in the solar system, such as the familiar Moon, Mars, Venus, Jupiter, etc.

There are many different probes in the universe in the past few decades. For instance, the Viking program which organises by NASA, Viking program is published in 1975 and launched in the same year. It is one of the earliest probes which goes into Mars. This one project is generally regarded as a success because it played an integral role in the refinement of knowledge about Mars in the late 1990s and early 2000s [1]. There are a few more projects that are famous, mention the solar system, Moon is a well-known one. Some of the better knowns of these include the Luna 24, one of the early detectors, launched in 1976. The main achievement of Luna 24 was the successful acquisition of a total of 170 g of soil from the lunar Mare Crisium, the first such soil to be obtained by man, and the study of the soil showed that it had a laminated structure [2]. Not only did mankind place a large number of probes in the early days, but in the 21st century, mankind has placed just as many, and more technologically. The Tianwen-1 from China, launched in July 2020, has successfully landed on Mars. Thereby, China has become the second country that successfully reaches Mars in the field of Mars exploration [3].

The purpose of this research is to show the improvement of human technology improvement throughout the years by comparing the probes creates in different decades. Meanwhile, to analyse how the characteristic of a planet affects the design of probes. In the following sections, a brief introduction of Mars, Jupiter and Sun will be shown, also, one of the detectors from each of them will be mentioned and go into detail for analysing. Afterwards, the comparison between those 3 planets will be given. At the end, the limitation of the research and comparison will be demonstrated following by the conclusion.

2. Mars

Mars, the second smallest planet in the solar system, is also the fourth planet from the Sun. It's well known that the atmosphere on Mars is much lesser than the others, for example, on Earth. Mars shared similar surface features with a few planets: the impact craters of the Moon, and some other topographical features on Earth, for example, the volcanoes, valleys, and deserts [4]. Over the years, many probes have been sent to Mars, up to 52 in total, but not all of them were successful. In fact, among those 52 probes, only 5 of them have succeeded and are still working right now. They have been located at different parts of Mars. Three of them are in the Mars orbits, which are the Mars Odyssey, Mars Express, and Mars Reconnaissance Orbiter. The other two are located on the surface of Mars (Mars Exploration Rover Opportunity and the Mars Science Laboratory Curiosity) [4]. Among the five successful rovers launched, the Mars Curiosity Rover is one of the most advanced. The rover, which is part of NASA's Mars Science Laboratory, was launched on 26 November 2011 from Cape Canaveral Air Force Station in Florida and successfully landed on the Moon on 5 August 2012. As a long-lasting detector (with a mission that has exceeded ten years), its composition of it is of high research value [5].

An overview of the Mars Curiosity Rover is shown in Fig. 1. It is mainly composed of thirteen different parts. Each of them plays an important role in making the Mars Curiosity Rover advanced. First, there are three different cameras on it. The Mastcam (Mast Camera), which is located on the top of the Rover, provides very clear panoramas of the view around it by taking colour images and colour videos of the Martian terrain. Meanwhile, this technology allows those images to be spliced and videos to be combined to conduct many valuable studies [6]. The two other cameras on this detector also plays their parts. MAHLI is very similar to the essential tool of the human geologist: the hand lens. It is mounted on the "arm" of this robotic probe, just like a human geographer holding a magnifying glass. This component provides the main method scientists used to discovering and studying the mineral textures and structures in Martian rocks. This lens is small, measuring just 4 cm in diameter, yet can capture colour images down to 12.5 microns. Moreover, it comes with a white light that allows the lenses to function properly with or without the sun's rays [7]. The MARDI, which is located at the base of the rover, provides a good view of the terrain (boulders, cliffs, etc.) and allows the rover to follow a clear and safe path while allowing scientists on Earth to locate the rover more easily [8].

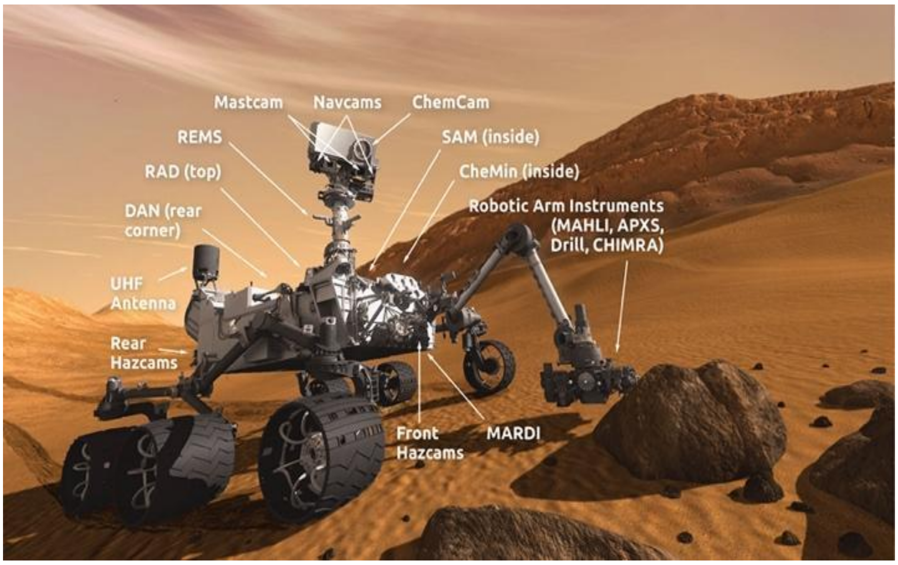

Fig. 1 A sketch of the Mars detectors Mars Curiosity Rover.

Except for these three very useful cameras, there are four spectrometers, two radiation detectors, one environmental sensor and one atmospheric sensor. Most notable are the sample analysis at Mars, and the radiation assessment detector. According to Charles Malespin, SAM is made up of several different parts. Its role is to detect the presence of life signs on Mars. This research is significant because if life exists on Mars, it could indicate that it could very well be a second planet for humans to inhabit in the universe. The radiation assessment detector is also in preparation for future human landings on Mars, it can monitor the surface for harmful radiation, both quantity and quality [8].

3. Jupiter

During the long exploration of Jupiter, scientists have continued to find surprises. It is the largest of all the solar system planets, with a total mass of up to twice that of all the other planets put together, at the same time, it is the fifth farthest planet from the Sun. Its detection dates back to 1610 and it has helped scientists to disprove the old theory that the Earth is the centre of the universe. In other words [9], it was one of the major foundations of human’s exploration of the universe. Over the years, scholars' desire to know more about this giant planet has not been extinguished, but because of the planet's special characteristics, only nine probes have been sent to it, but remarkably, all nine have been successful. The most famous of these is the Galileo probe, named after the great and famous Italian astronomer Galileo. The probe was launched on 18 November 1989 and managed to enter the orbit of Jupiter for a close approach in 1995. Even though the probe crashed into Jupiter's atmosphere on 21 September 2003 to avoid contamination, the research value and results it has brought as the first probe to successfully enter Jupiter's orbit are still immeasurable [10].

Galileo entered the planetary orbit of Jupiter in the form of an artificial satellite. As illustrated in Fig. 2, it has a very complex construction, it is composed of many precision and rigorous components, these parts have helped it to do its job well and have created many valuable discoveries. The most notable of these numerous components was the Galileo Jupiter Atmospheric Probe, which worked only for a short period of time, just one hour after Galileo crashed into the surface of Jupiter. However, in that hour many new discoveries were made.

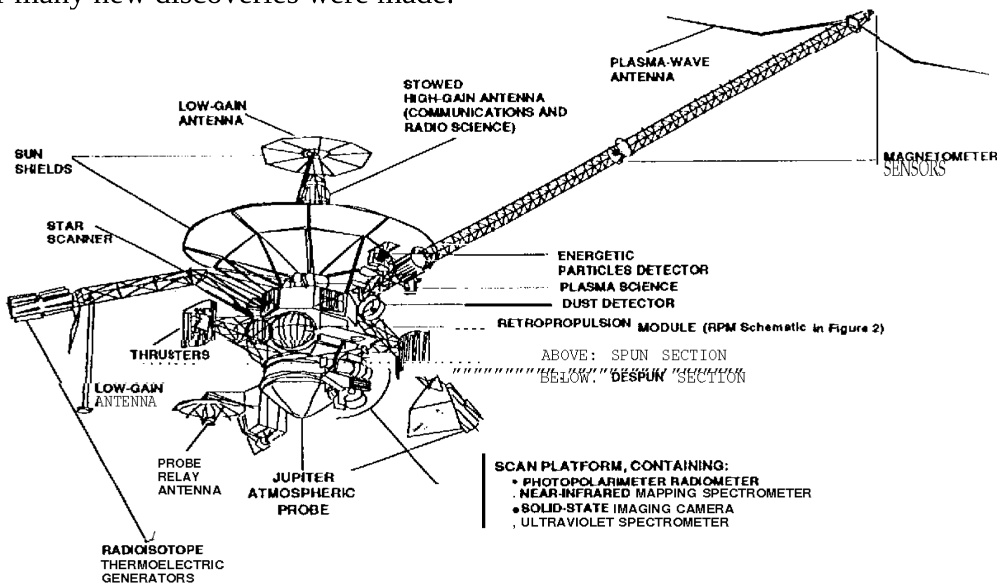

Fig. 2 A sketch of the Galileo.

Since this probe ended its mission a long time ago, there is not enough information about its construction. However, according to information from the Jupiter Exploration Research Office on NASA's official website, it is possible to know that Galileo Jupiter Atmospheric Probe has 6 different parts, which are the Atmospheric Structure Instrument, the Neutral Mass Spectrometer, the Helium Abundance Interferometer, the Net-Flux Radiometer, the Nephelometer, and the Lightning/Radio-Emission Instrument [10].

The data returned by this probe shows that there are very few organic compounds above Jupiter's clouds (about 31,000 miles) and that winds at this location reach 640 m/s. It also breaks some of the initial assumptions scientists had about Jupiter's atmosphere: namely the amount of lightning, water vapour and helium content. The probe brought back results indicating that this set of real data was half as small as had been assumed [10].

4. Sun

The Sun, just one of some 100 billion stars in our galaxy, is the centre of our solar system and is particularly important for life on Earth. It influences the weather and a whole range of things such as photosynthesis. In other words, if the Sun stopped emitting solar energy, life on Earth would cease to exist. Since the Sun is so critical, therefore, human scientists have never stopped exploring it. Due to the peculiarities of the Sun's temperature, even though many probes have been launched towards the Sun over the years, they have remained at a distance from the Sun. It is not until 2021, when the Parker probe, launched by the United States, finally achieved the first probe entry into the Sun's atmosphere [11].

Parker Probe is a probe launched by the USA in 2018, the distance between it and the sun is 7 times closer than other sun probes. It is composed of four main instruments, both four of them have the same characteristic, which has been able to afford the extremely high temperature and radiation; they are fields, WISPR, SWEAP, and ISΘIS. Fields are the ones who observe the forces, catching the changes in the magnetic and electric fields in the solar atmosphere at different moments. The relevant magnetic fields in the Sun are understood by measuring the waves inside the heliosphere. Parker Probe’s field is made by five antennas, and the measurements of the electric field around it is done by these five antennas, as depicted in Fig. 3. Four of these five antennas have demonstrated an impressive heat resistance that can support their normal operation at 2500 degrees Fahrenheit outside the probe's heat shield. These four antennas measure the properties of the solar wind. The rest of the antenna extends vertically in the shadow of the heat shield, helping to produce a three-dimensional image of the electric field under the higher frequencies. In addition, there are three magnetometers on the field, which are used to measure the variation of the magnetic field under time, as well as to measure the large-scale coronal magnetic field. They are advanced and can sample the magnetic field at a rapid rate of two million times per second in a hot environment like the Sun [12].

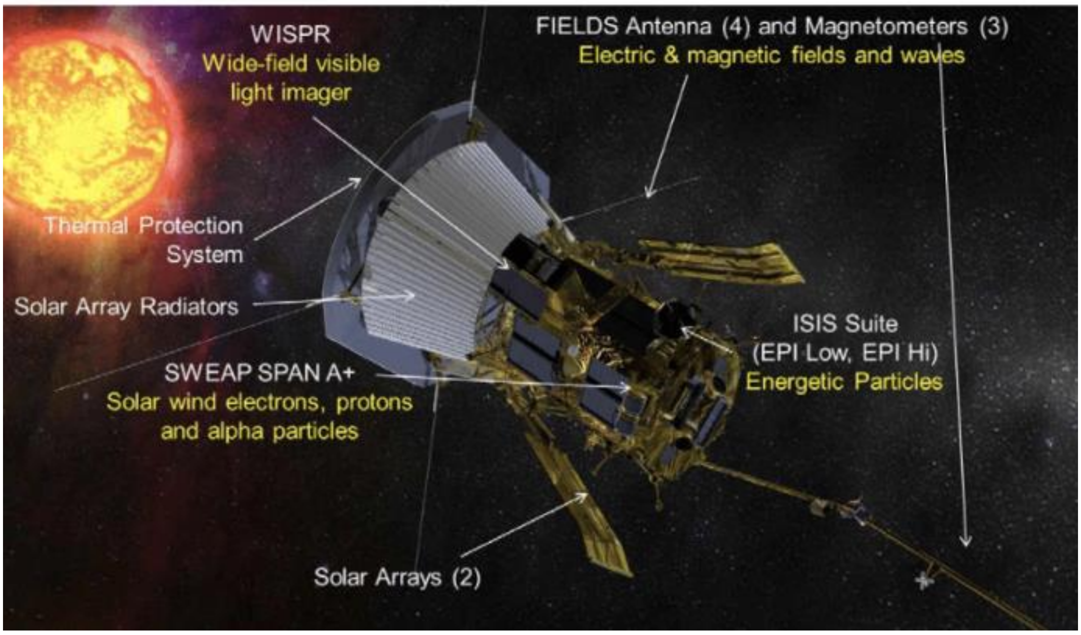

Fig. 3 A sketch of Parker Probe

In Parker Probe (seen from Fig. 3), WISPR is the only instrument which can take images, the size of it is about the size of a shoebox. It has been of great value at different times of the voyage. Before the probe flew through the corona and the solar wind, it took on the responsibility of observing the general structure of the corona. The structure of the various ejecta from the Sun was recorded by WISPR [13]. SWEAP is a composition of the Solar Wind Electrons Alphas and Protons investigation. Their main role is to detect particles in the solar wind, such as helium ions, electrons and protons. It is also responsible for measuring such properties as density, velocity, and temperature. With the information it brings, scientists have gained a better understanding of solar wind plasma [13]. ISΘIS work as a historical Inquirer, as human historians, explore the past of mankind, ISΘIS explores the past of particles. By exploring, the entire life cycle of particles is brought to the attention of scientists. It allows scientists to understand where these particles originated from, what kind of acceleration they have undergone and other important information [13].

5. Comparison, limitation & prospects

By comparison, the most obvious thing that can be seen throughout the 3 different detectors is their detection types due to the characteristics of the planets. To be specific, the Curiosity Rover on Mars is performing as a detection vehicle, which means it arrived on the surface of Mars. Differently, the Galileo on Jupiter is like an artificial satellite, which is launched into the orbits around Jupiter. The Parker probes is also working around the orbits and working on getting closer. It also contributes to the difference in the research value they bring. Apparently, the research value of each detector is profoundly important. The main research output of the Mars Curiosity rover lies in the study of minerals on the Martian surface, e.g., the texture and structure of Martian rocks. The Galileo rover on Jupiter, on the other hand, will mainly produce observations of Jupiter as a whole, as well as the content of organic compounds in its atmosphere, wind speeds, etc. As for the Sun, research has been focused for many years on how to get close to it due to the irresistible heat factor, and Parker has managed to achieve this by successfully approaching and entering the solar corona, allowing the study of the different components in the corona.

One major limitation of the above comparison should be noted that the large difference between the years of manufacture of the three probes. Galileo on Jupiter were built in the last century, which is much earlier than Curiosity and Parker (built in this century). It is likely that the advances in scientific development in this century (especially in the years when Parker was produced) were much better than it in the last century, which may also account for the differences between the probes.

Even with the rapid development of science today, there are still some shortcomings in the detectors. For example, Galileo encountered a problem while in orbit around Jupiter: an imminent collision with Io. To avoid the event, it had to crash into the surface of Jupiter and destroy it. If the problem of collision can be circumvented, then it should be possible to obtain more valuable information from longer-term observations. Parker is by far one of the most remarkable probes in terms of solar exploration. It achieved the feat of making the first entry into the solar corona. However, if the probe's heat and radiation resistance can continue to be upgraded closer to the Sun's atmosphere, the research value will be even more immeasurable.

Therefore, future research on solar probes should continue in greater depth on how to be more resistant to radiation and high temperatures. Mars rovers can already successfully land on Mars and can focus more on the study of imaging equipment to restore the original Martian landscape more deeply and to detect all the resources on Mars. For Jupiter, it is time to continue exploring how to get inside the atmosphere of Jupiter for long periods of time, rather than being destroyed after only one day of operation, as was the case with the probe carried by Galileo.

6. Conclusion

In summary, this paper investigates the differences between Mars-, Jupiter- and Sun-based probes. Specifically, the paper compares the Curiosity rover, Galileo and Parker, one of which landed on the planet's surface and two of which orbited of the planets. Galileo has ceased operations and the other two are still in normal operation. According to the analysis, this study discusses the different qualities of the different planets, e.g., the influence of factors like temperature on the class of probes, and the limits to detection. Nevertheless, the impressions outlined above may stem from a difference in science and technology at different times. In the future, one should continue to upgrade detectors according to the properties of the planets, e.g., the way to make the Sun's detectors more resistant to radiation and to heat. Overall, these results provide a guide to the future direction of detectors.

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