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The Application of Gamma Rays in the Observation of Moon

Manho Yeung

Xinyuan International School，　Jiangxi nanchang 330000

***ABSTRACT*：** *Gamma ray is a penetrating form of electromagnet radiation arising from the radioactive decay of atomic nuclei. It consists of the shortest wavelength electromagnetic waves and so imparts the highest photon energy. In this paper, the primary goal is to study the application of gamma radiation to the lunar observation. Firstly, The paper illustrates the history of discovery of gamma rays and condition that causes the occurrence of them. And then the thesis also demonstrates how scientists employed Fermi space telescope to detect these gamma rays and the source of them. Finally, there exist some potential problems in the regular exploration of the Moon and how scientists to overcome them. These insights can provide a view toward the the current application of gamma rays and its future prospects.*

***KEY WORDS*：** *gamma rays，history of discovery, lunar observation, Fermi Space Telescope, shielding problems, the application of gamma rays*

1.The History of Discovery of Gamma Rays

The gamma ray was firstly discovered by Paul Villard, a French chemist and physicist. In 1900, Paul Villard discovered the first gamma ray source, one type of radioactive decay process, called gamma decay. In this type of decay, a gamma ray is emitted by an excited nucleus almost upon formation. Paul Villard discovered gamma radiation while studying radiation emitted from radium. Villard knew that his described radiation was more powerful than previously described types of rays from radium, which included bats rays, first noted as “radioactivity” by Henri Becquerel in 1896, and alpha rays, described as a less penetrating form of radiation by Rutherford, in 1899. Nonetheless the gamma rays were not considered as a different fundamental type. Later, in 1903, Villard’s radiation was identified as being of a fundamentally different from previously named rays by Rutherford, who named Villard’s rays “gamma rays”by analogy with the beta and alpha rays that Rutherford had differentiated in 1899. The “rays” emitted by radioactive element were named in order of their power to penetrate various materials, using the first three letters of the Greek alphabet: alpha rays as the least penetrating, followed by

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beta rays, follower by gamma rays as the most penetrating. Gamma rays were also observed by Rutherford that they were not deflected(or at least, not easily deflected) by a magnetic field, another property making them unlike alpha and beta rays.

Gamma rays were first thought to be particles with mass, like alpha and beta rays. Rutherford initially believed that they might be extremely fast beta particles, but their failure to be deflected by a magnetic field indicated that they had no charge(different from beta particles). In 1914, gamma rays were observed to be reflected from crystal surfaces, proving that they were electromagnetic radiation. Rutherford and his co-worker Edward Andrade measured the wavelengths and higher frequency. This was eventually recognized as giving them, more energy per photon, as soon as the latter term became generally accepted. A gamma decay was the then understood to usually emit a gamma photon. [1]

2.The Principle of Gamma Rays

Gamma rays are produced primarily by four different nuclear reaction: fission, fusion, alpha decay and gamma decay. In nuclear fission, an unstable atom splits into two or more smaller pieces that are more stable, and releases extra neutrons, which can then split additional atoms, resulting in a chain reaction that releases a lot of energy. Such as when one neutron hits the Uranium atom, and then the atom splits into one Barium atom, one Krypton and 2 neurons. In nuclear fusion, it is a nuclear process, where energy is produced by smashing together light atoms. It is the opposite reaction of fission, where heavy isotopes are split apart. Fusion is the process by which the sun and other stars generate light and heat. Generally, fusion occurs when atom with small mass like deuterium, under certain conditions, only at high temperatures and pressures can let the bondage of extra nuclear electron out of the nucleus, let two nuclei can be attracted to each other and collision together, nucleus polymerization with each other , to generate new quality heavier nuclei, such as helium, neutron while quality is bigger, but the neutron has no charge, so they can escape from the bondage of the nucleus in the process of the collision and release. Alpha decay occurs when a heavy nucleus gives off a helium-4 nucleus, reducing its atomic number by 2 and its atomic weight by 4. This process can leave the nucleus with excess energy, which is emitted in the form of a gamma ray. Gamma decay occurs when there is too much energy in the nucleus of an atom, causing it to emit a gamma ray without changing its charge or mass composition.

Gamma-ray astronomy is the astronomical observation of gamma rays, the most energetic form of electromagnetic radiation, with photon energy above 100 keV. The wavelength and frequency of gamma ray that are ten to the minus tenth meters and ten to the eighteenths to ten to the twenty-two Herz, which allow gamma rays to have a strong penetrability to go through the objects or particles in a long distance in space.

Gamma rays represent the strongest form of energy in the universe for light, and they are usually produced by throwing off sources of matters high speed, such as giant black holes. What’s special about short bursts of gamma rays is that they

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confirm Einstein's idea that radio waves, infrared, visible light, X-rays, and gamma rays all travel at the same speed through space. According to the theory established by scientists, space-time is a dynamic "bubble" structure on a very small physical scale, trillions of times smaller than an electron. The model predicted that bubble space-time would produce high-energy gamma rays, slower than lower-energy photons—a prediction that has also been validated by observations from space telescopes. [2]

3.The phenomenon in the detection of the Moon

Fermi Space Telescope is the observatory designed to see the most extreme places in the universe. Observing each object that these gamma rays come from is to explore places in the space with the most extreme environment. The kind of objects Fermi observe is pulsars, neutron stars, black holes as well as dark matter. The main challenge detecting gamma rays is that the earth atmosphere will block some of those gamma rays, so scientists will use the satellites in space to measure gamma rays. Fermi does not have lens and mirrors, because gamma rays will just go straight through them. The main instrument on Fermi Large Area Telescope(LAT), which detect gamma rays by converting them into electron-positron pair, those are charge particles, so fundamentally, Fermi is designed to measure the track of those charge particles moving through and from that, figure out where gamma ray came from. The problem is that in the environment lower orbit, there are a large number of charge particles, ten thousand charge particles are coming through Fermi, so scientists have to distinguish that gamma ray from ten thousand charge particles. Often, large number of energy and stuffs splash up in order of all directions and end up with extra hits in the tracking part of detectors that are not actually from the original electron-positron but rather from energy that is kicked up when they interact further in the Fermi. So to analyze these events, scientists have written a long and complex program that basically uses all information that was recorded by the instrument and figure out what is the direction of gamma rays, its energy and whether it is a real gamma ray. So the software is also important to Fermi. The software to analyze the lab data has gone through many revisions, but PASS 8 is the first revision of the software that scientists took it to account from the experience gained from operating the lab and its orbital environment. PASS 8 gives telescope a completely hardware upgrading, but on the ground. Scientists increased the sensitivity of Fermi by 40%, which refers launching another lab instrument help operating it as well as for 7 years. So apparently, the upgrade of software obviously improve the performance of Fermi. [3]

The Sun, obviously, is the brightest source of light in space. However, that depends on how "lights" are defined. Recently, NASA used Fermi Space Telescope to detect gamma rays from the Sun and the Moon. To our amaze, the Moon is actually brighter than the Sun. As we all know, gamma rays are only produced by extremely high-energy events such as fission, fusion, alpha decay and gamma decay, though, in astronomically, like exploding stars and black holes gobbling down matter, and places where there are extremely strong magnetic fields, but, obviously,

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the Moon does not have such circumstance. The answer is cosmic rays. Cosmic rays are high-energy photons and atomic nuclei which move through space at nearly the speed of light. They originate from the sun, from outside of the solar system, and from distant galaxies. In this case, a big source were subatomic particles slammed around by shock waves from an exploding star or gas blasted from galaxy nuclei; as they bounce back and forth they gain incredible energies and shoot away at near light speed. These travel across the galaxy and then slam into the Moon's surface. So much energy is deposited by this that the nuclei in the atoms on the Moon's surface get energized, and relieve that excitement by sending out gamma rays. That is what Fermi is detecting. As scientists expose fermi on the radiation, the images presented in the computer became more clear(higher resolution).At short exposures, it is hard to even see the Moon's shape at all, but by adding together more and more gamma ray observations(essentially creating a longer exposure after the fact) it becomes more clear.

By the way, if Fermi detects higher energy gamma rays, like above a billion GeV, the Sun once again dominates the Moon. The source is the same: Extremely energetic cosmic rays hitting the solar atmosphere. The sun has a decent magnetic field which protects it from some cosmic rays, but ones with really higher energy get through—that's why Fermi detects much higher energy gamma rays from the Sun. From the Earth, at least, the Sun tended to win contests like this. So in my opinion, in certain range of energy, gamma rays from the Moon is stronger than that from the Sun, but in much higher energy, the Sun once again exceeds the Moon. [4]

4.The problem faced in observing Moon and the possible solution.

Exposure to the radiation is one of the main barriers to space travel and long-term space mission. Earth's magnetosphere and atmosphere are both aviation shields. Gamma rays coming from the Moon, generated by cosmic rays, both pose a threat to astronauts because both are ionizing radiation with great penetrating power. It costs tons of shielding to prevent them from striking astronauts. However, for lower energy gamma rays, the risk to astronauts is due to exposure over time. Think of an X-ray technician vs. an X-ray patient. A patient's lifetime exposure to X- ray is not very high, so a patient accepts the risk. For technician, however, things are different. They are exposed each workday, so they leave the room and are shielded from the x-rays by certain materials. It's similar for astronauts. The more time they spend on the Moon in a gamma ray/cosmic ray environment, the more they need to limit their exposure. Not only by shielding, but by timing. even in Low-Earth Orbit, astronauts risk exposure to greater radiation. In addition, scientists need to understand the radiation environment on the Moon. NASA has been looking into the lunar radiation environment as far back as 2005 in the anticipation o fa human outpost on the Moon. They launched the Lunar Reconnaissance Orbiter(LRO) in 2009 that contained an instrument called the Comic Ray Telescope for the effects of Radiation(CRaTER)， whose job is to characterize the Moon's Radiation environment and the biological impact it have on astronauts. It utilizes the plastics to mimic human tissue an placed them behind different shielding materials. Finally, scientists found that materials

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with high atomic numbers and high density are effective shields, such as lead(atomic number 82) is a good shield because it is also very dense has a cheap cost. [5]

5.The assumption and prediction about the use of Gamma Rays in the future.

In gamma-ray astronomy, gamma rays bursts are extremely energetic explosions that have been observed in distant galaxies. They are the brightest and most energetic electromagnetic events known to occur in the universe. Bursts can last from ten milliseconds to several hours. Scientists still cannot find out the source and cause of these bursts. However, with further study and observation by Sophisticated space telescope, scientists perhaps can locate the direction of those gamma bursts and figure out the mystery ultimately.

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