What are the bright spots on Ceres?

SHIGABUTDINOVA Dinara
Cliffside Park High School

Introduction

Ceres is the biggest asteroid in the asteroid belt that was declared to be a protoplane. Ceres is more similar to terrestrial planets than other asteroids in the asteroids belt due to its rocky core, icy mantle and a thin crust. When the Dawn mission spacecraft was sent to study Ceres in spring 2015, a new shocking discovery was made - the bright spots. Everyone was surprised to see this strange feature because this discovery was not expected. Ceres' bright spots are unique and extraordinary and now more studies will be done to figure out what the bright spots actually are. There are however some possibilities of what the bright spots might be, based on observations, data collected, and previous studies. This long term research project was guided by the question, What are the bright spots on Ceres?

Methods

- Used secondary data predominantly, such as interpreted topographic maps, information on composition.
- Identified various apparatuses used for studying Ceres.
- Examined already existing images and data of Ceres from NASA's website.
- Compared and contrasted information on various asteroids and meteorites with data on Ceres.
- Distinguished between other large bodies in our Solar System and Ceres.
- Studied the geography of the Solar System and the location of Ceres.
- Researched the distribution of volatiles and various elements in our Solar System.
- Interpreted information on reflectance and albedo and created syntheses and analyses of data.
- Created diagrams, graphs, and tables using data from various secondary and credible sources.
- Data and diagrams are used to support various hypotheses shown in the results that follows.

Results

Possibility #1

The bright spots might be ice

- Ceres is located before the snow line.
  - Volatiles can condense into frozen grains.
  - Planets located before 5AU (snow line) can sustain ice (figure 3).
- Comets carrying water collided with Ceres.
  - Impact by a comet resulted in the Occator crater revealing the bright spots (figure 1).
  - Hydrogen volatiles evaporate due to vacuum but get replenished due to abundant supply of ice.
  - Water vapor is evident that is supported by the findings of Herschel Space Observatory.

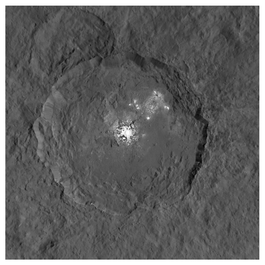

Figure 1. This image shows bright spots located inside the Occator crater
Image credit: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA

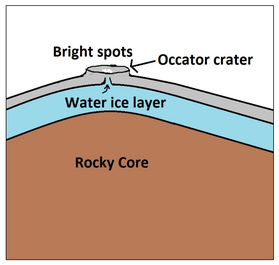

Figure 2. This diagram shows the abundant supply of water ice in the water ice layer and how it refill the evaporating ice through the dent located in the Occator crater.

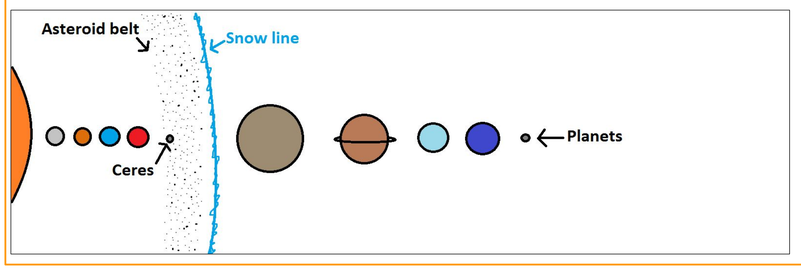

Figure 3. This diagram shows that Ceres is located between the snow line and the protostar where volatiles such as hydrogen can condense. This explains why hydrogen and oxygen could condense on Ceres.

Possibility #2

The bright spots are not pure ice.

- Reflectance spectra of ice is 1.0 and reflectance spectra of bright spots is 0.4 (figure 5)
  - Reflectance of dirty glaciers is 0.15 that brings up a possibility that volatiles are mixed with rocks or dirt which results in not pure ice (figure 4).
  - Bright spots look pure white from space but might be mixed with rocks once observed from a closer distance.
  - Closer observations need to be made or ground data collected.

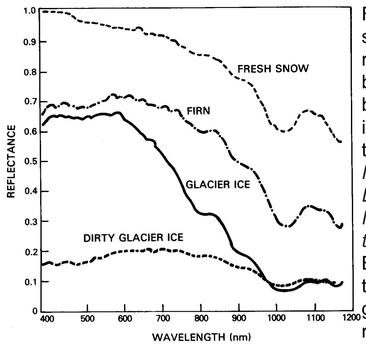

Figure 4. This diagram shows the comparison in reflectance spectra between ice and the the bright spots. The information used to create this graph was taken from *Now Appearing At a Dwarf Planet Near You: NASA's Dawn Mission to the Asteroid Belt.*
By this graph, one can tell that the bright spots differ greatly from ice just by reflectance spectra. The reflectance for ice is 1.0 and the reflectance for the bright spots on Ceres is 0.4.

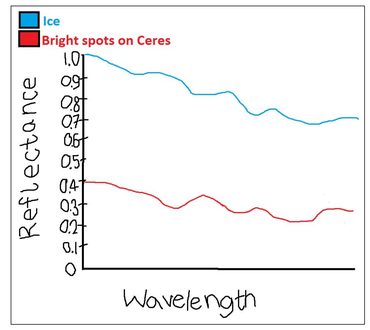

Figure 5. This graph shows reflectance spectra for ice in its different forms. This figure can be used to identify the reflectance spectra for pure snow that is 1.0 and how it reflectance spectra changes a as it ages through time and gets contaminated with dirt/rocks.
Image credit: Hall et al., 1985

Possibility #3

The bright spots might be a volcanic activity or geyser:

- Heat might be provided by the sun.
- Water vapor is evident when Ceres is closest to Sun on it's orbit and water vapor is happening on Ceres in two darkest regions because dark material can hold more heat.
  - Water vapor is present on the sunny side
  - The temperatures during the day go up to 235 Kelvin.
  - With the discovery of OH, Water vapor was theorized to be present by the Herschel Space Observatory.
  - Water vapor will be present if there is a source such as volcanic activity or geyser.
  - With water vapor, atmosphere can exist trapping more heat.
- Heat might be provided from the interior of Ceres.
  - If heat is provided independently by Ceres, volcanic activity and geysers can occur.
- Solar radiation evaporates the ice before it reaches the surface.
- Hypothesis can be checked by angling the camera in a way that the white spots are located on the horizon and the sun is located right in the back of it (figure 7).
  - Heat waves will be present if the hypothesis is true (figure 7).

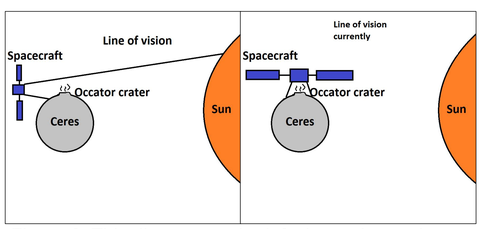

Figure 6. This diagram on the left shows the angle and position at which the spacecraft has to be to test the hypothesis. The diagram on the right shows how the spacecraft is usually positioned orbiting Ceres.

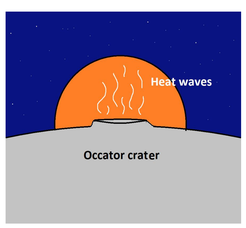

Figure 7. This diagram shows how what the images would come out like if the spacecraft is positioned correctly and the hypothesis comes out to be true.

Possibility #4

The bright spots might not be volcanic activity or geysers:

- Source of heat is needed in order for geysers and volcanic activity to occur.
  - Two ways are possible
    - Radioactive decay. Radioactive decay on Earth only supplies half of the heat for Earth. Since Ceres is 13.5 times smaller than Earth, it won't be needing as much radionuclides to produce its heat.
    - Friction: by two planets on opposite side spaced out linearly (figure 8) such as Mars and Jupiter in this case.
      - Ceres is located 1.14 AU from Mars and 2.66 AU from Jupiter. The distance is too great for the bodies to exchange momentum. The bodies need to be as close as Earth and the Moon to influence each other in any way.
      - Earth is 0.69 AU away from Venus and 0.38 AU away from Mars and the bodies still have no influence over each others heat. This distance is greater than the one Ceres has to it's closest planetary bodies therefore Jupiter and Mars can't cause friction inside Ceres.
- There is no trace of radionuclides being produced on Ceres (table 1) and Ceres is not located close enough to other planetary bodies, which makes Ceres unlikely to be able to produce it's own heat.

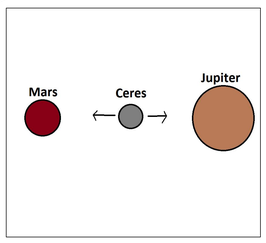

Figure 8. This diagram shows one of the ways Ceres could've had heat by being positioned between two planetary objects. This position would have caused Ceres to be pulled by the two planets in two different directions and therefore cause friction that would produce heat.

Table 1. This table shows the list of elements that are known to be present on Ceres today. This list does not include radionuclides - one of the two factors that could have provided heat for Ceres.

Known elements present on Ceres today.
• Iron rich clay minerals (cronstedtite) • Carbonate minerals (dolomite and siderite) • Magnesium sulfate hexahydrite • Ammonia-rich clays • Sodium silicate

Possibility #5

The bright spots might be minerals and salts:

- Ceres is composed mainly of silicates.
  - There are four possibilities of what could be silicates: Na, Fe, Mg and Ca
- The Solar Institute in Germany hypothesized that the bright spots are a type of magnesium sulfate called hexahydrite (table 1).
  - There's a suggestion that these salt rich areas were actually left behind after water-ice converted in the past and asteroid with its collision would have undug the mixture of ice and salt.
- To verify this possibility, a framing camera (figure 9) can be used to identify the composition of the bright spots.
- The possibility can be tested spectroscopically or ground data.

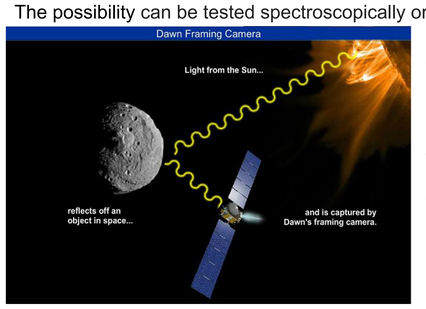

Figure 9. This diagram shows how the framing camera works. Framing camera provides information on Ceres' surface through Ceres' reflectance spectra characteristics that is directly influenced by the sun because the light helps determine the reflectance spectra.
Image source: NASA.gov

Conclusion

With the explorations made by the Dawn mission, it is still unknown what the bright spots on Ceres are. It is important to knowing what the bright spots are because it might be the missing piece to the puzzle that might help us understand the formation of our solar system better. The bright spots cannot be pure ice because the bright spots and ice reflectance spectra do not align. It cannot be geysers or volcanic activity because Ceres' only source of heat seems to be the sun and this provides heat only when Ceres is located closest to the sun. This means there is no continuous flow of the water vapor. The bright spots are most likely to be minerals and salts.Ceres is known to consist majority of silicates, therefore there is a high chance the bright spots might be that the magnesium sulfate hexahydrite was undug in result of a collision. To further confirm if this hypothesis is valid, closer observations using better technologies should be made, or ground data collected.

Reference

Asteroids and meteorites. Retrieved from http://ase.tufts.edu/cosmos/print_images.asp?id=15

Bode's Law. Retrieved from http://www.astro.cornell.edu/academics/courses/astro201/bodes_law.htm

Bonello G., Berthet P., d'Hendecourt L. (2005). Identification of Magnesium Sulfate Hydration State Derived from Nir Reflectance Spectroscopy. Retrieved from http://www.lpi.usra.edu/meetings/lpsc2005/pdf/1996.pdf.

Burbine T. H., McCoy T. J., Meibom A., Gladman B., Keil K. Meteoritic Parent Bodies: Their Number and Identification. Retrieved from http://www.mtholyoke.edu/~tburbine/Burbine.asteroidsIII.20002.pdf.

Hussmann H., Sohl F. , Spohn T. (2006). Subsurface oceans and deep interiors of medium-sized outer planet satellites and large trans-neptunian objects. Retrieved from https://www.researchgate.net/profile/Tilman_Spohn/publication/225019299_Subsurface_Oceans_and_Deep_Interiors_of_Medium-Sized_Outer_Planet_Satellites_and_Large_Trans-Neptunian_Objects/links/55018a3a0cf24cee39f7b952.pdf.

Lunine J. I. Origin of Water Ice in the Solar System. Retrieved from http://www.esalq.usp.br/lepse/imgs/conteudo_thumb/Origin-of-Water-Ice-in-the-Solar-System-1.pdf

McCord T. B., McFadden L. A., Russell C. T., Sotin C., Thomas P. T. (2006). Ceres,Vesta, and Pallas: Protoplanets, Not Asteroids. Eos, 87, 10. Retrieved from http://www-ssc.igpp.ucla.edu/personnel/russell/papers/CeresVesta.pdf

Mitton J. (2002). Asteroid Rendezvous: NEAR Shoemaker's Adventures at Eros. Retrieved from https://books.google.com/books?id=efCy2YC7u3IC&pg=PA104&lpg=PA104&dq=why+are+c+type+asteroids+dark?&source=bl&ots=AXb3bVOQPq&sig=3kfwb3VoSYuBHdEUccX1hfsqOZY&hl=en&sa=X&ved=0ahUKEwjngMTxnsvKAhWixlMKHTtGBY4Q6AEIRDAG#v=onepage&q=why%20are%20c%20type%20asteroids%20dark%3F&f=false.

Morbidelli A. W. F. Bottke Jr., Ch. Froeschlé, Michel P. Origin and Evolution of Near-Earth Objects. Retrieved from http://www.boulder.swri.edu/~bottke/Reprints/Morbidelli-etal_2002_AstIII_NEOs.pdf.

Ostro S. J.,Benner L. A. M.,Nolan M. C., Margir C., Giorgini J. D., Scheeres D. J., Broschart S. B., Kaasalainen M., Vokrouhlicky D., Steven Chesley S. R., Margot J., Jurgens R. F.,Rose R., Yeomans D. K., Suzuki S., De Jong E. M. (2004). Radar observations of asteroid 25143

Itokawa (1998 SF36). Meteoritics & Planetary Science, 39 (3) 407-424. Retrieved from http://echo.jpl.nasa.gov/asteroids/Itokawa/ostro.etal.2004.itokawa.pdf.

Preusker F., Scholten F., Matz K. D., Roatsch T., Jaumann J., Raymond C. A., Russell C. T., (2014). Vesta in the Light of Dawn: First Exploration of a Protoplanet in the Asteroid Belt. Retrieved from http://www.hou.usra.edu/meetings/vesta2014/pdf/2027.pdf.

Qi C.,Oberg K., Wilner D., d'Alessio P., Bergin E., Andrews S. M., Blake G. A., Hogerheijde M., van Dishoeck E. V. (2013). Planets and the Snow Line. Retrieved from https://www.cfa.harvard.edu/news/su201326#sthash.YulWKjGp.dpuf

Rivkin A. S., Volquardsen E. L., Clark B. E. (2006). The surface composition of Ceres: Discovery of carbonates and iron-rich clays, 182, 563–567. Retrieved from http://irtfweb.ifa.hawaii.edu/~elv/icarus185.563.pdf.

Russell C. T., Raymond C. A., Nathues P., Gutierrez-Marquez P., DeSanctis M. C., Ammannito E., Prettyman T. H., Konopliv A., Park R., McSween H. Y., Jaumann R., Joy S., Polanskey C. A., Rayman M. D., and the Dawn Science Team (2015). Dawn Explores Ceres: Results from the Survey Orbit. Retrieved from http://nesf2015.arc.nasa.gov/sites/default/files/downloads/pdf/05.pdf.

Thomas P. C., Parker J. W., McFadden L. A., Russell C. T., Stern S. A., Sykes M. V., Young E. F. (2005). Differentiation of the asteroid Ceres as revealed by its shape. *Nature, 437*. Retrieved from http://hubblesite.org/pubinfo/pdf/2005/27/pdf.pdf

Thompson M. (2015). Fatberg, The Albedo Effect. Retrieved from http://fatberg.nl/the-albedo-effect/.

Wiegert P., Balam D., Moss A., Connors M., Shelton I. (2007). Evidence for a Color Dependence in the Size Distribution of Main-belt Asteroids. 133, 1609Y1614. Retrieved from http://astro.uwo.ca/~wiegert/papers/2007AJ.133.1609.pdf

Zolotov M. Y. (2016). Formation of Sulfate on Parent Bodies of Carbonaceous Chondrites, Ceres, Europa and other Icy Bodies. Retrieved from http://www.hou.usra.edu/meetings/lpsc2016/pdf/1778.pdf.

Acknowledgments: Special thanks to Dr. Catherine Quinlan my mentor and Dr. Dean Eppler my scientist advisor. I could have not done this without them.