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Education

◆Bachelor of engineering, Nihon Univercity, Chiba, Japan, 2019~current
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◆ CATIA　V5R18　Part Design Specialist, 2016
◆ Driver's License, 2016

Research Keyword

Starshade, Occulter, High-contrast exoplanet imaging, Optimization

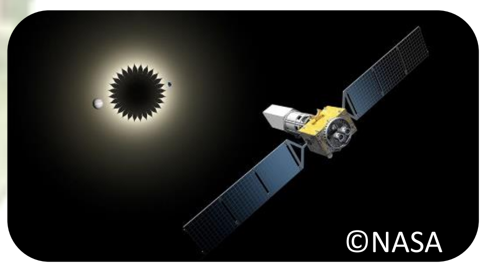
Research Overview

"Derivation of Optimal Apodization Function in Starshade System"

1. Starshade Project

Most of exoplanet observations have been performed by the indirect method. However, it is necessary to observe the planets directly in order to obtain information on the planet's surface and atmosphere necessary for characterizing the planets.

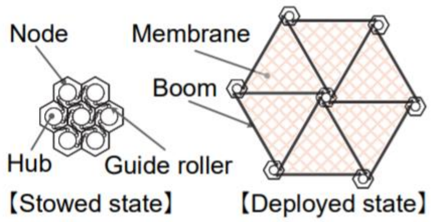
The biggest problem when directly observing planets is that the light intensity difference between stars and planets is too large to capture planetary light. A Starshade system consisting of a space telescope and an occulter solves this problem.



【Starshade】

In addition to the space telescope, a Starshade places a structure of several tens of meters, called an occulter, between the telescope and the star, which enables direct observation of the planet by blocking the light from the star.

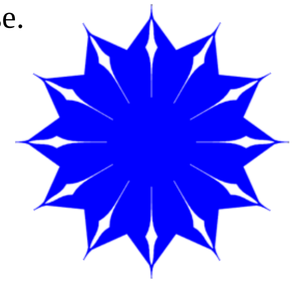
2. Starshade Using SDMT and Polygonal Shape Occulter



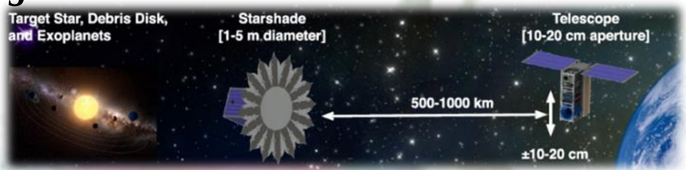
【SDMT】

The problems of the Starshade system include the improvement of detector technology, the high-precision formation flight of telescope satellites and occulter satellites, and the maintenance of shape accuracy and rigidity required for occulters. Since the petal-shaped occulters currently proposed have a curved outer shape that is unsuitable for the deployment structure, so that they have a very complicated deployment style, and it is difficult to guarantee reliable deployment and the cost is expected to increase.

Therefore, we are planning to apply Self-Deployable-Membrane Truss(SDMT) as an approach to the occulter structure of the Starshade, If this is possible, the technical issues of the structure will be greatly reduced compared with the currently proposed method, and the feasibility including cost will be further enhanced. Because SDMT members extend in a straight line, it is desirable that the outer surface of the occulter be a straight line. Therefore, we proposed a polygonal occulter with an outer shape that looks like a polygonal line and a hole inside the petal.


【 polygonal occulter 】

3. *Space Demonstration of Starshade Using SDMT*

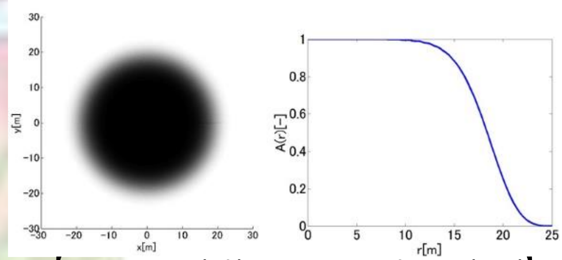


【Miniaturized Distributed Occulter/Telescope (mDOT);An example of a small star shade demo machine.Reference; Adam W. Koenig,∗ Bruce Macintosh,† and Simone D'Amico‡ Stanford University, Stanford, California 94305," Formation Design of Distributed Telescopes in Earth Orbit for Astrophysics Applications," JOURNAL OF SPACECRAFT AND ROCKETS, STANFORD UNIVERSITY on June 16, 2019,pp.3,】

We would like to design a 10m class small occulter using SDMT for this polygonal line shape, and perform a Starshade demonstration experiment that has not yet been realized in space.

If a demonstration experiment is conducted and it is proved that the performance as expected is achieved with a small occulter, it will lead to observation with a larger star shade and contribute to the development of exoplanet observation. The object of observation in the demonstration experiment is dust light surrounding the star (Exozodiacal light / disk). The reason why the star disk is the target of observation is that if the star disk that disturbs the planet is observed in advance, the risk in the future direct observation mission of the habitable planet can be reduced. In addition, clarifying the mineralogical properties of dust in the disk is a valuable clue for exploring planetary material and the formation process of planets, and we believe that the scientific results of this survey are significant. This is because the exploration of planetary materials and the formation process of planets reveals the mineralogical properties of dust in the disk as valuable clues, and the scientific results of this survey are considered to be significant. We believe that observing Exozodiacal light in this way not only reduces the risk of future direct observation missions for habitable planets, but also has scientific results in itself and is the best observation target for demonstration experiments.

4. *Optimized Apodization Function*

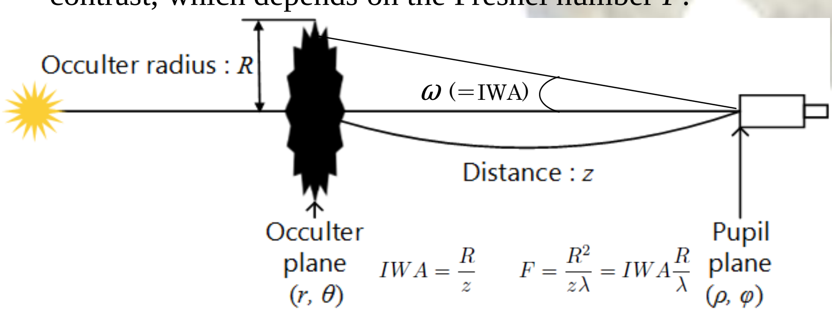


【apodized mask(left) and apodization function(right)】

Occluter's shape design requires that the target contrast be achieved at the location of the star-planet contrast telescope.

If the occulter shape is a simple geometric shape, sufficient contrast cannot be obtained at the position of the telescope due to light diffraction. The proposed occulter shape is an apodized mask that reduces the light transmittance of the occulter film to the edge of the circle in a circular occulter. Decreasing the opacity at the edge of the circle and weakening the diffracted light is called apodization, and this is called the apodization function.The occulter geometry is defined by an apodization function. In order to achieve sufficient contrast on the pupil plane, it is necessary to find the optimal apodization function. However, the optimal setting of each parameter has not been determined in the Starshade design for 10m class occulters.

So, from theory, we set a simple range for the size of the occulter, the space between spacecrafts, and the size of the required shadow. Starshade performance depends on the Inner Working Angle (IWA) and contrast, which depends on the Fresnel number F.



【Each parameter of the star shade system and its relational expression】

R is the star radius, z is the distance between the star and the telescope, and λ is the wavelength. From previous studies, the F required to achieve enough contrast to image a planet like Earth is around 10.

As a result, in order to enable the development of small-scale Starshade formation in Earth's orbit,

it is necessary to minimize R and z as much as possible while minimizing the effect on F. As is apparent from the equation, F is proportional to IWA and inversely proportional to λ. Therefore, I found that by using the smallest possible wavelength and the largest possible IWA, the size of the Starshade and the space between spacecrafts can be minimized.

5. *Current Research and Research Goals*

The goal is to enumerate all the possible combinations within the theoretical range for each parameter in the optimization problem, and find the optimal apodization function that achieves the target contrast in the required design. For this purpose, we are trying to derive the optimal apodization function and build an evaluation method for 10m class occulters by collecting statistical data and defining the optimal evaluation method for the apodization function.