Investigation of the Triangular Earth-Moon Libration Point L_5 Using Non-Variable Starlight

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1. Introduction

Kordylewski clouds have been investigated and disputed since Kordylewski reported their existence in 1961[3], and there are equal amounts of information to support Kordylewski's discovering them, and refute it. The dynamics of any existence of said clouds has also been extensively studied and has resulted in predicted areas or orbit shapes that would be most stable [2]. If these clouds do in fact exist at the Earth-Moon libration points then in turn it can be inferred that a small but noticeable effect on starlight passing through these locations would occur. Starlight has been used as a means to study interplanetary dust before and if there is enough of a collection of dust grains in the Earth-Moon libration points there should be a measurable effect on starlight passing through the regions. Using what is known about extinction due to dust clouds and possible locations of the Kordylewski clouds reported, an investigation was launched into attempting to determine if there is in fact any kind of reddening of starlight passing through the L_5 area.

1.1. Background

It was reported by Kordylewski that the clouds located at the libration points would have an apparent brightness slightly less than that of the Gegenschein [3], which itself is quite hard to view except on very dark night conditions. It has been hypothesized that if the libration clouds were viewed when near or at the anti-solar point that it could be an interference of the Gegenshcein[7]. When Roosen investigated the L_5 area himself on a night when it was at least 5 degrees away from the anti-solar point and reported no evidence of a cloud at all[8]. Many have reported that there was in fact a noticeable cloud formation at the L_5 point when images were taken from a high altitude plane and determined that these clouds would only be visible at small phase angles [11]. Many questions still remain as to whether the clouds are merely stable in their position or if they possibly orbit in a predicted area or pattern. Numerical models developed by Mignard determine that the shape and size if orbits near the triangular libration points can be anywhere from an elliptical shape to a more kidney bean shaped orbit[6]. Mignard outlined that for any particles to be able to maintain a position in these libration points, they needed to be more than micron-sized[6].

2. Theory

In researching possible dust clouds at the triangular Lagrange points, numerous different approaches can be made. Many have used programs to model the behavior or predicted paths, orbits of these clouds, while some have attempted to photograph or image the glow of the clouds directly. Attempting to photograph the clouds themselves can be extremely difficult to achieve, and there are many alternative possible night time glows that could cause much interference. This would explain why so many of the investigations who attempted to merely photograph the locations often reported near zero glow in the predicted positions of the Lagrange points. [8, 9]. The approach taken in this research was to observe non-variable starlight when both passing through these Lagrange points and when outside them. If there is any cloud of significant density at these locations, a reddening of the starlight observed would occur.

3. Method

The observational techniques used were based on the following three assumptions: (1)the Lagrange points would be localized around the 60 degree angle location from the Earth and Moon, (2) the clouds, if existent, would likely have a relatively elliptical to kidney bean shaped range therein, and (3) the most accurate viewing time would be when the moon is full and below the horizon. General fields of view (FOV) were located 60 degrees and 45 degrees of angular distance on the moons orbit and following the it's in the sky for the L_5 region. The images were taken over a course of 3 days between July 12 and July 14 2010. The images were taken when the moon was below the horizon but the L_5 point was between 15 to 30 degrees above the horizon as was recommended by Vanysek [11]. Used to image the locations was a VersArray:1300B digital camera system with a cooled CCD having 1340x1300 image array, 20x20-micron pixels, as well as an FOV of 17.87x17.33 arc minutes. This camera was attached to a 24 inch Ritchey Chretien Each star field was exposed through a red, blue, and visible filter for telescope on an equatorial mount. Each star field was exposed through a red, blue, and visible filter for every imaging occasion. The exposure time depended on the intensity of the stars being imaged but included 30, 35, 50, and 100 second exposures and flats were taken through each filter as well at the respective times.

The data was processed three ways, eliminating: dark noise, variation in sensitivity across the CCD, and sky glow. The procedures are thoroughly overviewed in Snyder et al [10]. The intensity of each star on both days was recorded and compared for determination of reddening. The standard color excess equation was used during data analysis as well as a magnitude change equation subtracting the magnitude outside the Lagrange point area from the inside value.

$$M_B\text{-}M_V = 2.5 * \log B/V \tag{1}$$

$$(M_{B,L5} - M_{V,L5}) - (M_{B,O} - M_{V,O}) \tag{2}$$

$$2.5 \log [(V_O * B_{L5})/(B_O * V_{L5})] \tag{3}$$

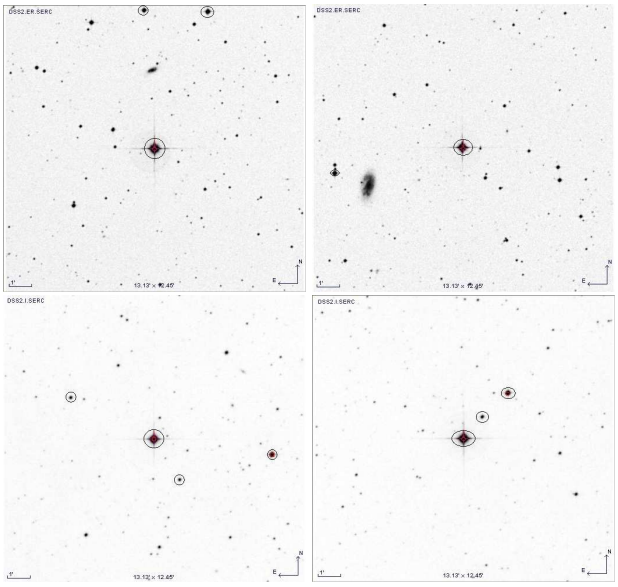

Figure 1: Star fields included in the data collection were HIP 64403, 64905, 70118, 70535; respectively. The stars studied in each field are circled. The stars in the FOV of HIP 64403 and HIP 64905 were located behind the Lagrange point on 7/13 and outside of it on 7/14. The stars in the FOV of the stars HIP 70118 and HIP 70535 were outside of the Lagrange point location on 7/13 and behind it on 7/14.

In equation 2, $M_{B,\ L5}$ is the magnitude of the blue light when the star is located behind the Lagrange point location and$M_{V,L5}$ is the magnitude through the visible filter when behind the Lagrange point location. The way the equations were derived a positive color excess value indicates reddening of the starlight while a negitive value suggests otherwise.

4. Results and Discussion

The results of the study are shown in figure 2 and figure 3 with each point representing a different star observed. The color excess for both in the cloud and out of the cloud are relatively similar if not the same in both cases. When there is a change in the color excess from one environment to the other it is no larger than .2 and no more than .28 for the magnitude change. There is of course no trend due to the fact that the stars could be rearranged in any order, but the outliers are very curious targets for further investigation. The three outliers near the end of the color excess change graph of Figure 2 are all from the same FOV of HIP 70535. The results of the color excess and magnitude change on the starlight show a small measurable effect although not necessarily reddening.

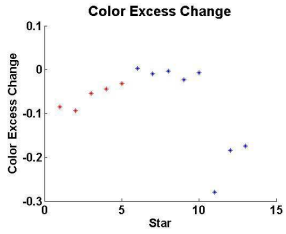

Figure 2: The color excess change in all the observed stars is shown with the dots in blue pertaining to the stars that were located behind the Lagrange point on 7/13 and outside the location on 7/14. The red dots pertain to the stars that were located outside the Lagrange point on 7/13 and behind it on 7/14. The 3 outliers on the end belong to the FOV of HIP 70535 which was farther away from the L_5 point location and lower in declination than HIP 70118.

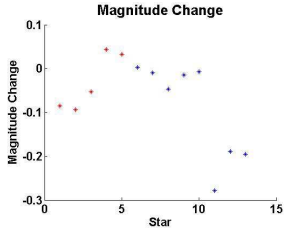

Figure 3: The Magnitude changes of stars observed is plotted in no specific order. The last two outliers are located in the FOV of HIP 70535 which was located behind the Lagrange point location on 7/14 and outside the area on 7/13.

In the graph of Figure 3, the outliers on the end are again the stars in the FOV of HIP 70535 and the resulting magnitude change may be ebough to result in a visible,

and measurable, effect. The remaining of the stars sampled, although had an overall change in values, yet the change recorded was on a scale small enough to not definitely produce any visible effect on the starlight. The results show a general non-reddening trend, and for the small sample that may have had a change of some kind, it is still undetermined of what the range of implications could be involved in the change itself. Although the stars chosen were noted to be of non-variable status, it is likely that there could still be small scale fluctuations of which the influences are not yet known.

5. Conclusions

The case was presented that if the reports of dust clouds located at the triangular libration points of the Earth-Moon system (Lagrange points) were in fact accurate, and the clouds were of measurable size to be visible by the human eye or photographs, then a visible reddening of background starlight should be perceivable by imaging sources. In light of the overwhelming star candidates that did not show a change in excess color large enough to determine a reddening of the starlight passing through the Lagrange point, any change of the amounts recorded can be said to be small enough to impose no noticeable effect on the apparent magnitude of the stars observed. The change in magnitude is seen to be no more than a fraction of a magnitude which is small enough to argue that there was no effect on the starlight passing through the Lagrange point L_5 during the nights of observations. This result is in direct argument against earlier claims made by Kordylewski and others [3, 11] and although the results are not a definite refutation of the possibility of Kordylewski clouds, it is highly likely there are no discernable dust clouds of reasonable size located in the Lagrange point of L_5 in the Earth-Moon system at the time of observations.

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