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Implementation of AstroCamp Data with *Besselian Elements* Towards Solar Eclipse Hisab

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ABSTRACT

Ephemeris is the main reference calculation for the Falak science in solar eclipses calculation, the data can be obtained from various sources, one of which is from the AstroCamp program by Muhammad Faqih Taufiq. There are several eclipse calculation methods using *Ephemeris* data, ranging from low-accuracy to high-accuracy calculations. The *Ephemeris* are used continuously to find Bessel Elements in the solar eclipse calculation. Currently, the calculation of solar eclipses using *Besselian Elements* data is considered the most powerful calculation method regarding eclipse prediction. This study aims to determine the accuracy of *Ephemeris data* from AstroCamp which is processed into Bessel elements in the solar eclipses calculation. To determine the accuracy of these calculations, researchers conducted qualitative research on the Hybrid Solar Eclipse on April 20, 2023, with a comparative approach to analyze the accuracy of the calculations. The result shows that the solar eclipse estimate obtained from calculations utilizing the Bessel Element of the *AstroCamp Ephemeris* has a significant difference between NASA predictions and the reality of the eclipse.

I. Introduction

The solar eclipse is one of the celestial phenomena that is also discussed in science, because it can be seen from the many studies that discuss solar eclipses in falak literature from time to time. The study includes the understanding of the Solar Eclipse, the position of the solar eclipse in a religious view, the priorities that can be done during the eclipse, the view of the solar eclipse from an astronomical perspective, and the calculation of the solar eclipse itself.

Even often the object of study, until now the calculation of solar eclipses has many varieties that are scattered in circulation. Even though astronomical data has been used to calculate solar eclipses, each calculation has pros and cons and yields a unique result.

Leaving aside the *Human Error* aspect, the different results of solar eclipse calculations can be caused by two factors. That is the use of astronomical data and the calculation methods used. Until now, while utilizing astronomical data, the author found three types of calculations. First, the use of astronomic data and calculation methods prepared by the author in the same book or book. Second, calculate the astronomical data that will be used and the solar eclipse that will occur. Third, the use of astronomical data in other literature outside the calculation method is to be used.

Of the three types of calculations that the author found, the third type of calculation allows the author to combine one calculation method by utilizing certain astronomical data, which in general *ephemeris data* will be obtained from the Ministry of Religious Affairs of the Republic of Indonesia (KEMENAG) through his book published throughout the year, namely the book "*Ephemeris Hisab Rukyat*" and *ephemeris* data accessed through the Winhisab application.

However, a unique case occurred when the author found a computer-based software program called AstroCamp by Muhammad Faqih Taufiq, one of which contained *Ephemeris* data, and found that it was possible to use the data for solar eclipse calculations.

Many solar eclipse calculation methods use *ephemeris* data from the Sun and Moon, both calculations with low *accuracy* and high accuracy. Some techniques that are considered to have high accuracy in the determination of eclipse prediction are the Bessel method [1]. Astronomical organizations frequently employ this method to forecast eclipses; NASA is well known for its accuracy in this regard.

So far calculations with this method using ready-made Bessel Elements, Bessel numbers can be known from the book *Elements of Solar Eclipses 1951 – 2000* by Jean Meuss [2]. It can also be seen in Kitab *Al-Dūrru Al-Anīq* by KH. Ahmad Ghazali Muhammad Fathullah and can be found in books by other falak experts [3]. Based on the search that the researchers carried out, the researcher just found a study that discusses in detail how to get the values of the Bessel Element, namely the research conducted by Alfan Maghfuri in his thesis entitled *Reformulation of the Solar Eclipse Hisab Algorithm Using Hisab Rukyat Ephemeris Data which was* later made into a book entitled "*Eclipse Algorithm (Study of Solar Eclipse Calculation with Ephemeris Hisab Rukyat Data)*". In the thesis or book, it is explained how to find the values of the Bessel Element by utilizing the data of *Ephemeris* Hisab Rukyat and its calculations about the approximate contact time of the solar eclipse.

By looking at the problems that have been described, the researcher wants to study more deeply and conduct research on the eclipse of the Sun using the *Besselian Elements* method, where the value of the Bessel Element is obtained from the calculation output using *ephemeris* data in the AstroCamp application, with the title: "Implementation of AstroCamp Data with *Besselian Elements* Against the Hisab of Solar Eclipse (Case Study of Hybrid Solar Eclipse April 20, 2023)".

According to the description of the background of the problem above, it can be stated the core problem that the author wants to make the focus of research, namely: "How is the

accuracy of calculating solar eclipses using AstroCamp data with *the Besselian Elements* method?".

This study aims to determine how accurate the calculation of solar eclipses using AstroCamp data with the Besselian Elements method is. In addition to the above objectives, this research is expected to present theoretical and practical benefits. Theoretically, it can provide in-depth information and knowledge about the method of calculating solar eclipses using *Besselian Elements* and the accuracy of the calculation results using these methods. Practically, it is expected to make it easier for students and students to learn the calculation of solar eclipses using *Besselian Elements*.

II. Method

The research uses a type of qualitative methodology with a comparative approach [4]. The study presents the calculation of the solar eclipse using *AstroCamp's Ephemeris* data with *the Besselian Elements method*, followed by an assessment of the accuracy of the calculated results. To assess the accuracy of solar eclipse calculations using *AstroCamp's Ephemeris* data using *the Besselian Elements* method, researchers compared these results with eclipse estimates made by an international agency known for its accuracy, NASA [5]. This research involves field research activities [6], where these writing researchers made observations at the time of the hybrid solar eclipse which will take place on April 20, 2023, in Indonesia, Australia, and Papua New Guinea [7].

Data collection techniques include observation, interviews, and documentation. Regarding this, the author interviewed directly the creators of the AstroCamp program, direct observations of the partial eclipse that will occur in the Jepara area and observations of the hybrid solar eclipse of April 20, 2023, as well as documentation on the timing of the early eclipse, middle eclipse and end of the eclipse. The type of data used is primary data in the form of *the book Eclipse Algorithm (Study of Solar Eclipse Calculation with Hisab Rukyat Ephemeris Data)* by Alfan Maghfuri and an interview with the maker of the AstroCamp application, Muhammad Faqih Taufik, while secondary data is taken from several past studies that are still related to this study. The researchers' data analysis involved comparative analysis data, to demonstrate the process of calculating solar eclipses using AstroCamp *Ephemeris* data with *the Besselian Elements* process. In that phase, data is used to obtain accurate information that is used to answer the research questions asked in this study.

III. Results and Discussion

From research on *Besselian Elements* calculations using *AstroCamp Ephemeris* data, the author found several things, namely as follows:

A. AstroCamp

AstroCamp is a software program or application based on a Windows PC that contains data on astronomical objects better known as *Ephemeris*. This application was designed and formed by a student of Ma'had Aly TBS Kudus named Muhammad Faqih Taufiq.

Muhammad Faqih Taufik more familiarly called Faqih was born in Lau Village, Dawe District, Kudus Regency on January 8, 2001. Faqih began his formal education at

MI NU Al-Munawwaroh, then continued his education at MTs NU TBS and MA NU TBS while staying at the Al-Maimuniyyah Langgardalem Kudus Islamic Boarding School. Starting to know Falak since studying at MTs, after graduating from the aliyah bench then continued his education at the S1 level by taking the Takhassus Ilmu Falak program at Ma'had Aly TBS Kudus.

Since entering the world of lectures, Faqih himself often participates in webinars about science that he feels are interesting to him. One of them was a webinar held in Ramadan in mid-2020 which was held by LF PBNU at that time. In the webinar, one of the speakers was Dr. Ing. Khafid and his participants received the Mawaqit program and received permission to change the program [8].

From there, Faqih took the initiative to create an application containing *Ephemeris* data which was later named AstroCamp, to make it easier to find Sun and Moon data so that it could be used for all versions of Windows [8]. In making AstroCamp, the creator only grafted calculations from the Mawaqit program and spoke them in a visual basic language based on Visual Studio 2019. The calculation algorithm used in AstroCamp refers to the VSOP87 algorithm and the ELP2000 which are both algorithms used in the Mawaqit program.

The main features of the AstroCamp application are divided into three following the appearance of the menu, namely:

1. Home

   This menu is the *default* display when you first open AstroCamp, this menu contains Sun and Moon data which is presented in real referring to *Universal Time*, even on the menu Faqih also affixes the state of the moon, such as the position of the moon according to its distance to the Earth, according to the constellation of stars, and according to the field of seasons *(Solstice)*.

2. Ephemeris

   The display of *ephemeris* data in this menu seems the same as the display in the Winhisab application, this makes it easy for users to understand and this menu is also embedded with a print feature that can allow users to export *the desired* ephemeris data.

3. Prayer Time

   In the Prayer Time menu, Faqih designed the appearance of this menu like the Imsakiyah schedule (in one month) covering five prayer times, Imsyak, sunrise, Dluha, midnight, and the last third of the night.

   Users can choose a place based on the coordinate name and date based on the Gregorian calendar system, this is what causes the output of prayer times produced not in a month of the Hijri calendar, but a month in the Miladi calendar.

Because one of the discussions in this study is AstroCamp *ephemeris*, the following are the steps for taking *ephemeris data* on the AstroCamp application:

1. Open AstroCamp, then click the Ephemeris menu.

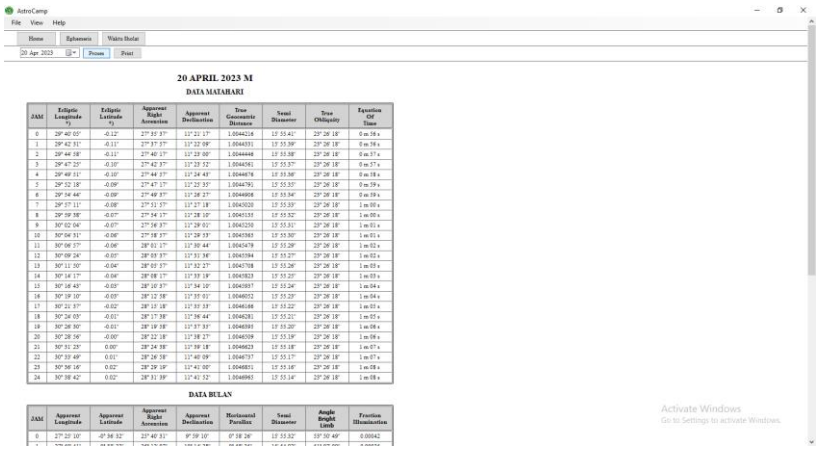

Figure 1. AstroCamp App start menu

2. Set the date

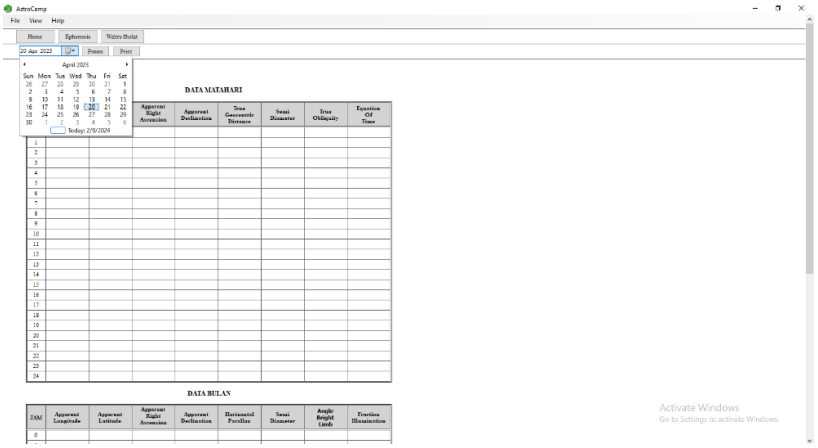

Figure 2. Display on the Ephemeris menu (the author is determining the date searched)

3. Click process, to display the *ephemeris data* you're looking for.

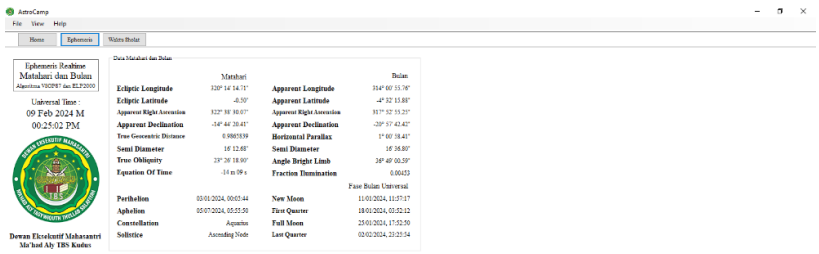

Figure 3. *Display on the Ephemeris menu (the application is processing data)*

4. Data *Ephemeris* AstroCamp

20 APRIL 2023 M

DATA MATAHARI

JAM	Ecliptic Longitude *)	Ecliptic Latitude *)	Apparent Right Ascension	Apparent Declination	True Geocentric Distance	Semi Diameter	True Obliquity	Equation Of Time
0	29° 40' 05"	-0.12"	27° 35' 37"	11° 21' 17"	1.0044216	15' 55.41"	23° 26' 18"	0 m 56 s
1	29° 42' 31"	-0.11"	27° 37' 57"	11° 22' 09"	1.0044331	15' 55.39"	23° 26' 18"	0 m 56 s
2	29° 44' 58"	-0.11"	27° 40' 17"	11° 23' 00"	1.0044446	15' 55.38"	23° 26' 18"	0 m 57 s
3	29° 47' 25"	-0.10"	27° 42' 37"	11° 23' 52"	1.0044561	15' 55.37"	23° 26' 18"	0 m 57 s
4	29° 49' 51"	-0.10"	27° 44' 57"	11° 24' 43"	1.0044676	15' 55.36"	23° 26' 18"	0 m 58 s
5	29° 52' 18"	-0.09"	27° 47' 17"	11° 25' 35"	1.0044791	15' 55.35"	23° 26' 18"	0 m 59 s
6	29° 54' 44"	-0.09"	27° 49' 37"	11° 26' 27"	1.0044906	15' 55.34"	23° 26' 18"	0 m 59 s
7	29° 57' 11"	-0.08"	27° 51' 57"	11° 27' 18"	1.0045020	15' 55.33"	23° 26' 18"	1 m 00 s
8	29° 59' 38"	-0.07"	27° 54' 17"	11° 28' 10"	1.0045135	15' 55.32"	23° 26' 18"	1 m 00 s
9	30° 02' 04"	-0.07"	27° 56' 37"	11° 29' 01"	1.0045250	15' 55.31"	23° 26' 18"	1 m 01 s
10	30° 04' 31"	-0.06"	27° 58' 57"	11° 29' 53"	1.0045365	15' 55.30"	23° 26' 18"	1 m 01 s
11	30° 06' 57"	-0.06"	28° 01' 17"	11° 30' 44"	1.0045479	15' 55.29"	23° 26' 18"	1 m 02 s
12	30° 09' 24"	-0.05"	28° 03' 37"	11° 31' 36"	1.0045594	15' 55.27"	23° 26' 18"	1 m 02 s
13	30° 11' 50"	-0.04"	28° 05' 57"	11° 32' 27"	1.0045708	15' 55.26"	23° 26' 18"	1 m 03 s
14	30° 14' 17"	-0.04"	28° 08' 17"	11° 33' 19"	1.0045823	15' 55.25"	23° 26' 18"	1 m 03 s
15	30° 16' 43"	-0.03"	28° 10' 37"	11° 34' 10"	1.0045937	15' 55.24"	23° 26' 18"	1 m 04 s
16	30° 19' 10"	-0.03"	28° 12' 58"	11° 35' 01"	1.0046052	15' 55.23"	23° 26' 18"	1 m 04 s
17	30° 21' 37"	-0.02"	28° 15' 18"	11° 35' 53"	1.0046166	15' 55.22"	23° 26' 18"	1 m 05 s
18	30° 24' 03"	-0.01"	28° 17' 38"	11° 36' 44"	1.0046281	15' 55.21"	23° 26' 18"	1 m 05 s
19	30° 26' 30"	-0.01"	28° 19' 58"	11° 37' 35"	1.0046395	15' 55.20"	23° 26' 18"	1 m 06 s
20	30° 28' 56"	-0.00"	28° 22' 18"	11° 38' 27"	1.0046509	15' 55.19"	23° 26' 18"	1 m 06 s
21	30° 31' 23"	0.00"	28° 24' 38"	11° 39' 18"	1.0046623	15' 55.18"	23° 26' 18"	1 m 07 s
22	30° 33' 49"	0.01"	28° 26' 58"	11° 40' 09"	1.0046737	15' 55.17"	23° 26' 18"	1 m 07 s
23	30° 36' 16"	0.02"	28° 29' 19"	11° 41' 00"	1.0046851	15' 55.16"	23° 26' 18"	1 m 08 s
24	30° 38' 42"	0.02"	28° 31' 39"	11° 41' 52"	1.0046965	15' 55.14"	23° 26' 18"	1 m 08 s

DATA BULAN

JAM	Apparent Longitude	Apparent Latitude	Apparent Right Ascension	Apparent Declination	Horizontal Parallax	Semi Diameter	Angle Bright Limb	Fraction Illumination
0	27° 25' 10"	-0° 36' 32"	25° 40' 31"	9° 59' 10"	0° 58' 26"	15' 55.32"	53° 50' 49"	0.00042
1	27° 59' 41"	-0° 33' 22"	26° 12' 07"	10° 14' 28"	0° 58' 25"	15' 54.92"	51° 07' 09"	0.00025
2	28° 34' 10"	-0° 30' 12"	26° 43' 43"	10° 29' 43"	0° 58' 23"	15' 54.52"	46° 05' 30"	0.00013
3	29° 08' 38"	-0° 27' 02"	27° 15' 22"	10° 44' 53"	0° 58' 22"	15' 54.12"	34° 25' 04"	0.00005
4	29° 43' 03"	-0° 23' 52"	27° 47' 02"	11° 00' 00"	0° 58' 20"	15' 53.71"	355° 18' 09"	0.00001
5	30° 17' 27"	-0° 20' 42"	28° 18' 43"	11° 15' 02"	0° 58' 19"	15' 53.30"	288° 56' 54"	0.00002
6	30° 51' 49"	-0° 17' 32"	28° 50' 26"	11° 30' 00"	0° 58' 17"	15' 52.89"	266° 40' 46"	0.00008
7	31° 26' 09"	-0° 14' 22"	29° 22' 11"	11° 44' 55"	0° 58' 16"	15' 52.48"	258° 53' 11"	0.00017
8	32° 00' 28"	-0° 11' 12"	29° 53' 58"	11° 59' 44"	0° 58' 14"	15' 52.06"	255° 07' 18"	0.00031
9	32° 34' 44"	-0° 08' 02"	30° 25' 46"	12° 14' 30"	0° 58' 13"	15' 51.64"	252° 57' 10"	0.00050
10	33° 08' 59"	-0° 04' 53"	30° 57' 36"	12° 29' 11"	0° 58' 11"	15' 51.21"	251° 34' 07"	0.00072
11	33° 43' 12"	-0° 01' 43"	31° 29' 28"	12° 43' 47"	0° 58' 10"	15' 50.79"	250° 37' 37"	0.00099
12	34° 17' 23"	0° 01' 26"	32° 01' 23"	12° 58' 19"	0° 58' 08"	15' 50.36"	249° 57' 33"	0.00131
13	34° 51' 32"	0° 04' 36"	32° 33' 19"	13° 12' 47"	0° 58' 06"	15' 49.93"	249° 28' 21"	0.00166
14	35° 25' 40"	0° 07' 45"	33° 05' 17"	13° 27' 09"	0° 58' 05"	15' 49.49"	249° 06' 45"	0.00206
15	35° 59' 45"	0° 10' 53"	33° 37' 17"	13° 41' 27"	0° 58' 03"	15' 49.06"	248° 50' 41"	0.00250
16	36° 33' 48"	0° 14' 02"	34° 09' 19"	13° 55' 39"	0° 58' 02"	15' 48.62"	248° 38' 45"	0.00299
17	37° 07' 50"	0° 17' 10"	34° 41' 23"	14° 09' 47"	0° 58' 00"	15' 48.17"	248° 30' 02"	0.00351
18	37° 41' 50"	0° 20' 18"	35° 13' 29"	14° 23' 50"	0° 57' 58"	15' 47.73"	248° 23' 50"	0.00408
19	38° 15' 47"	0° 23' 26"	35° 45' 38"	14° 37' 47"	0° 57' 57"	15' 47.28"	248° 19' 42"	0.00469
20	38° 49' 43"	0° 26' 33"	36° 17' 49"	14° 51' 39"	0° 57' 55"	15' 46.83"	248° 17' 15"	0.00534
21	39° 23' 37"	0° 29' 40"	36° 50' 02"	15° 05' 26"	0° 57' 53"	15' 46.38"	248° 16' 13"	0.00603
22	39° 57' 29"	0° 32' 47"	37° 22' 17"	15° 19' 08"	0° 57' 52"	15' 45.93"	248° 16' 21"	0.00676
23	40° 31' 18"	0° 35' 53"	37° 54' 35"	15° 32' 44"	0° 57' 50"	15' 45.48"	248° 17' 31"	0.00754
24	41° 05' 06"	0° 38' 59"	38° 26' 55"	15° 46' 15"	0° 57' 48"	15' 45.02"	248° 19' 35"	0.00835

Figure 4. AstroCamp Sun and Moon (Ephemeris) data dated April 20, 2023

The author used the AstroCamp tool to obtain Ephemeris data, which was then used to calculate Besselian Elements.

B. Besselian Elements *Calculation Results* Using AstroCamp *Ephemeris* Data

The following are the results of the calculation of Bessel elements using AstroCamp *Ephemeris* Data on April 20, 2023:

Table 1. *Besselian Elements calculation results using AstroCamp Ephemeris*

X0	*Y0*	*d0*	*M0*	*L10*	*L20*	Tan *f1*
X1	*Y1*	*d1*	*M1*	*L11*	*L21*	Tan *f2*
0.033297	-0.421855	11.41161	240.2411	0.54680	0.0007	0.00465
0.49503	0.2441388	0.01374	15.00342	0.00011	0.00011	0.00463

To see how far the difference in the calculation results of *the Besselian Elements* Calculation Using *AstroCamp Ephemeris* Data, the author compared the results of the calculation of the Bessel elements above with the results of the calculation of NASA's Bessel elements. Here are *Nasa's* Besselian Elements [9]:

Table 2. *NASA's Besselian Elements calculation*

	X	*Y*	*d*	*M*	*L1*	*L2*	Tan *f*
0	0.0268500	-0.427366	11.411789	240.243	0.5468040	0.0006630	0.00466
1	0.4950182	0.2441992	0.013741	15.0034	0.0001216	0.0001210	0.00463
2	0.0000135	-0.0000494	-0.000003	0.00000	-0.0000116	-0.0000115	0.00000
3	-0.0000071	-0.0000037	0.000000	0.00000	0.000000	0.000000	0.00000

Judging from the two tables above, there is a difference between the value *of Besselian Elements* from AstroCamp calculations and *Besselian Elements* used by NASA, with a

significant difference in *Besselian Elements* X0 which has a difference of 0.006447. In addition to this difference, the *Besselian Elements* displayed by NASA have values up to four different orders from the *Besselian Elements calculations* carried out by researchers, which only display two orders of elements. Of course, these differences will give birth to different results later in determining the contact time of the eclipse.

C. Solar Eclipse Testing Using AstroCamp Data with *Besselian Elements Method*

To see this difference, researchers made a comparison between eclipse calculations using the Bessel Element from AstroCamp and eclipse predictions from NASA with the fact of eclipse time contact from direct observations or observations. The eclipse on April 23, 2023, is a hybrid solar eclipse. This type of eclipse is a combination of a total solar eclipse with a ring solar eclipse [10]. For the Indonesian region, almost all regions can see the eclipse, especially the eastern part of Indonesia through which this ring eclipse passes. The following presents several data comparisons from observations of the hybrid eclipse phenomenon on April 20, 2023.

Here the author will divide the testing based on the eclipse that occurs, namely::

1. Partial Eclipse

First, researchers made direct observations during the eclipse. Only a partial solar eclipse, which happened in the Jepara region, was observed by the researchers. This observation was made by researchers together with the Al-Aqrob Falak Community located in Tigajuru, Mayong District, Jepara Regency. When viewed from Google Earth, the location is located at coordinates -06 45' 09'' S and 110 44' 34'' E, at an altitude of 8 masl. Estimates predicted by NASA regarding the coordinates show that the eclipse will occur at 09:29:33 WIB and end at 12:18:38 WIB, with the middle of the eclipse occurring at 10:51:31 WIB [11].

While the calculation data using the Bessel Element through AstroCamp data obtained the eclipse began at 09:28:15 WIB and ended at 12:17:04 WIB, while the middle of the eclipse occurred at 10:50:03 WIB.

Table 3. *Partial Solar Eclipse between Besselian Elements using Ephemeris AstroCamp, NASA's Besselian Elements, and the observations*

Contact	Result	Besselian AstroCamp	Besselian AstroCamp Difference	Besselian NASA	Besselian NASA Difference
Beginning Eclipse	--:--:--	09:28:16 WIB	-----	09:29:33 WIB	-----
Middle of the Eclipse	--:--:--	10:50:05 WIB	-----	10:51:31WIB	-----
End of Eclipse	12:18:11 WIB	12:17:07 WIB	01 Minutes 04 seconds	12:18:38 WIB	27 seconds

However, due to the lack of preparation during the observations, researchers could not get an initial contact image of the eclipse. In addition to the initial contact of the eclipse, in the middle of the eclipse, also give No. results. To get the middle of the eclipse when observations are obtained from the end of the eclipse minus the beginning of the eclipse then divided by two. These results are then added to the beginning of the eclipse, it will be obtained in the middle of the eclipse. The observations during the eclipse using the method of capturing images from the eclipse contact, No. image from the beginning before the occurrence of the eclipse to the end of the eclipse takes place.

Second, to see the contacts of a partial solar eclipse from beginning to end, researchers used other data to examine eclipse contacts in real-time observations. The data was taken from a real-time observation video uploaded by the TBS KUDUS TV channel [12], where the video shows the documentation of the Falakiyyah Ma'had Aly Team of TBS Kudus along with live observation time. The observation was made on the Rooftop of TBS Multipurpose Building in Kudus which is located at coordinates -06 48' 03'' LS and 110 50' 09'' BT, with an altitude of 25 meters above sea level.

Estimates predicted by NASA regarding the coordinates show that the eclipse occurred at 09:29:29 WIB and finished at 12:18:52 WIB, with the eclipse taking place at 10:51:35 WIB [11]. While the calculation data using the Bessel Element and AstroCamp data obtained the eclipse began at 09:28:10 WIB and ended at 12:17:18 WIB, while the middle of the eclipse occurred at 10:50:08 WIB.

Table 3. *Calculation comparison of the Partial Solar Eclipse between Besselian Elements using Ephemeris AstroCamp, NASA's Besselian Elements, and the observation video Ma'had Aly TBS Kudus*

Eclipse Contact	Observation Video	Besselian AstroCamp	Besselian AstroCamp	Besselian NASA	Besselian NASA Different
Eclipse Start	09:29:50 WIB	09:28:12 WIB	01 menit 38 seconds	09:29:29 WIB	21 seconds
Mid Eclipse	10:54:18 WIB	10:50:10 WIB	04 menit 08 seconds	10:51:35 WIB	02 Minutes 43 seconds
Eclipse End	12:18:46 WIB	12:17:20 WIB	01 menit 26 seconds	12:18:52 WIB	06 seconds
Eclipse Duration	02:48:56	02:49:08	12 seconds	02:49:23	27 seconds

From the table above shows calculations using the Bessel Element from AstroCamp culminating results that are quite significant with the fact of eclipse contact, which is with an average difference of 1 minute 32 seconds while the middle of the eclipse has a difference of 4 minutes 8 seconds. For predictions, NASA has an

average difference of 13.5 seconds, while in the middle of the eclipse there is a difference of 2 minutes 43 seconds from the reality of the middle of the eclipse.

2. Ghybrid Eclipse

In addition to the partial solar eclipse contact that researchers have described above, on April 20, 2023, there will also be a total solar eclipse. Some of the areas through which the total eclipse passes are Exmouth City, Westren Australia. Researchers then searched the data and found a video of observations made by Perth Observatory uploaded by the TimeAndDate channel [13]. The video shows live coverage of the process of a total solar eclipse and at the beginning of the video the situation around the observation site has been shown. Researchers traced the location using the Google Earth application, and thought the Perth Observatory carried out eclipse observations in a field around the city of Exmouth, namely at coordinates -21 57' 31'' LS and 114 07' 55'' E with an altitude of 5 meters above sea level.

Estimates predicted by NASA regarding the coordinates show that the eclipse occurred since 10:04:25 WITA and ended at 13:02:25 WITA, the total phase began at 11:29:41 WITA and finished at 11:30:38 WITA. As for the middle of the eclipse occurred at 11:30:09 WITA [11]. While the calculation results using the Bessel Element with AstroCamp data found that the eclipse began at 10:03:09 WITA and ended at 13:00:59 WITA, the total phase began at 11:28:21 WITA and finished at 11:29:13 WITA. As for the middle of the eclipse occurred at 11:28:47 WITA.

Table 4. *Comparison of the results of the calculation of the March 20, 2023 Partial Solar Eclipse between Besselian Elements using Ephemeris AstroCamp, NASA's Besselian Elements, and video observations made by the Perth Observatory*

Eclipse Contact	Exmouth	AstroCamp	Difference	Predictions	Different from NASA
Eclipse Start	10:04:27 WITA	10:03:09 WITA	01 Minutes 18 seconds	10:04:25 WITA	2 seconds
Total Start	11:29:28 WITA	11:28:21 WITA	01 Minutes 07 seconds	11:29:41 WITA	13 seconds
Mid Eclipse	11:29:57 WITA	11:28:47 WITA	01 Minutes 10 seconds	11:30:09 WITA	12 seconds
Total End	11:30:26 WITA	11:29:13 WITA	01 Minutes 13 seconds	11:30:38 WITA	12 seconds
Total Duration	58 seconds	52 seconds	6 seconds	57 seconds	1 seconds
Eclipse Duration	02:57:47	02:57:50	3 seconds	02:58:00	13 seconds

From the table above, the evidence shows that the results shown from calculations using the Bessel Element from AstroCamp have an average difference of 1 minute 12.6 seconds while from NASA's prediction the average difference is 10 seconds from the reality of the eclipse time. From the results of the data analysis that the researchers have described above, there is a significant difference in the calculation of the Bessel Element from AstroCamp, which is up to 1 minute more. Whereas usually in calculations using Bessel Elements only bring up the difference in seconds, besides the significant difference there is also a component of elements that are not in the Bessel algorithm in *Alfan Maghfuri's* Eclipse Algorithm Book.

To see if the results of the Bessel Element component with two orders have an effect on the eclipse contact results, the author attempts to make a comparison using the Bessel Element in the Book of *Al-Dūrru Al-Anīq* by KH. Ahmad Ghazali Muhammad Fathullah. This attempt was made to prove the influence of the order on the results of the eclipse calculation.

Table 5. *The Value of Bessel Elements in Kitab Al-Dūrru Al-Anīq dated April 20, 2023*

X0	*Y0*	*d0*	*M0*	*L10*	*L20*	Tan *f1*
X1	*Y1*	*d1*	*M1*	*L11*	*L21*	Tan *f2*
0.02699	-0.42732	11.41178	240.24296	0.54681	0.00067	0.00465
0.49495	0.24417	0.01374	15.00342	0.00011	0.00011	0.00463

Then the author made calculations using the Bessel Element from Kitab *Al-Dūrru Al-Anīq* and carried out a comparison with the total eclipse observation data in the City of Exmouth.

Eclipse Contact	Eclipse Start	Total Start	Mid Eclipse	Total End	Eclipse End
Exmouth Observation Video	10:04:27 WITA	11:29:28 WITA	11:29:57 WITA	11:30:26 WITA	13:02:14 WITA
Al-Durru Al-Anīq	10:04:22 WITA	11:29:39 WITA	11:30:08 WITA	11:30:36 WITA	13:02:24 WITA
Different	5 seconds	11 seconds	11 seconds	10 seconds	10 seconds

From the above comparison, it can be seen that although the Bessel Element component of Kitab *Al-Dūrru Al-Anīq* contains only two orders, the results obtained

have a difference of seconds not up to minutes and the difference shown is also close to NASA's prediction data.

IV. Conclusion

Solar eclipse calculations using AstroCamp data with the Besselian Elements method are included in contemporary manifold calculations. Based on the analysis that the researchers have done, the application of AstroCamp data with Bessel elements resulted in a difference from the observational reality of about 1 minute 4 seconds to 4 minutes 8 seconds. Although the calculation of the Bessel element with AstroCamp has a difference in the order of minutes, it is still very accurate, considering that only with *data can Ephemeris* approach the calculation results with NASA-level algorithms.

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