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Re-Distribution of the Regions of 100 Comets Using a Statistical Method

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Abstract

In this study, the comets have distributions regarding their heliocentric distances where they appear in two regions, Kuiper belt (short period) and Oort cloud (long period). Details here give new information about the entire regions of these comets; the research shows that 54% of comets are nearby asteroid belt, but only 11% are in Kuiper belts and 35 % are from Oort cloud. The research focuses on comets with a nucleus's radius larger than 1 km. The comets with a nuclear radius of 1-10 km have high percentage 51%.

From the results, the maximum comets' radius is found in comet 29P/Schwassmann -Wachmann as roughly 87 km, and also in comet C/2018 N2 (ASASSN) which has radius 88 km. All comets, that have been distributed concerning heliocentric, depend on statistical results to divide new comets' regions versus their radiuses. The results reveal new details of comets' distances from the sun. The distances of 100 comets are shown in Figure (2).
The results show that there is a third comets' region: region (A) found between Mars and Saturn and between Oort cloud and Kuiper belt.

There is one comet like(C/2019 L3 (ATLAS)) that is farther than Alpha Centauri star. Therefore, the comet is restricted by a couple of gravity systems.

Keywords: Kuiper belt; Oort cloud; Comets nuclei radius.

أعادة توزيع مناطق 100 مذنب باستخدام طريقة إحصائية

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الخلاصة

في هذه الدراسة ، للمذنبات توزيعات تتعلق بمسافة مركزية الشمس حيث تظهر في منطقتين ، حزام كويبر (ذات فترات قصيرة) وسحابة أورت (ذات فترات طويلة). تقدم التفاصيل هنا معلومات جديدة حول مناطق هذه المذنبات بأكملها ؛ يُظهر البحث أن 54٪ من المذنبات هي عبارة عن أحزمة كويكبات قريبة ، لكن 11٪ فقط تقع في أحزمة كويبر و 35٪ من سحابة أورت. ركز البحث على المذنبات التي يبلغ نصف قطر نواتها أكثر من كيلومتر واحد . تم اهمال المسافات البعيدة من الشمس وحساب النسب المئوية الحالية للمذنبات التي يبلغ نصف قطرها النووي من 1–10 كيلومتر بنسبة عالية 51٪.

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اظهرت النتائج ان اقصى حجم لنصف قطر المذنب 29P/ Schwassmann–Wachmann الذي تم العثور عليه هو 87 كم والمذنب C / 2018 N2 (ASASSN) الذي يبلغ نصف قطره 88 كم .

جميع المذنبات التي تم توزيعها بخصوص مركزية الشمس ، اعتمادًا على النتائج الإحصائية لتقسيم مناطق المذنبات الجديدة مقابل نصف قطرها ؛ كشفت النتائج تفاصيل جديدة لمسافات المذنبات من مركزية الشمس. مسافات 100 مذنب كما هو موضح في الشكل(2)
كما اظهرت النتائج وجود ثلاث مناطق للمذنبات : المنطقة (A) توجد ما بين المريخ وزحل، وكذلك ما بين سحابة اورت وحزام كويبر، هناك مذنب مثل ((C/2019 L3 (ATLAS) ابعد من مسافة نجمة الفا سنتوري.
لذلك فان المذنب مقيد من قبل زوجين من الانظمة.

1. Introduction

Comets are made of ice and refractory dust grains [1]. It is a relic from the early solar nebula's creation of planets beyond the frost line[2]. A comet comprises an apparent nucleus of ice and rock surrounded by a murky atmosphere known as the coma[3]. It is rich in organic and inorganic species, and measurements of their chemical composition are crucial for reconstructing the conditions of planet formation in our solar system [4]. Our understanding of astronomical objects, particularly comets, is based on the information obtained from line emission detected via interactions such as visible light emission. This provides us with limited knowledge on comets and, as a result, a limited view of our cosmos [5]. The physical features of the solar wind are reflected in comet spectra[6]. Comets are ice entities that heat up as they approach the sun, sublimating volatile material from their nuclei to form a hazy gas around them [7].

The solar wind has a significant impact on the comet's ion tail [8],[9]. There are two large groupings of comets with orbits ranging from 2 to 5 AU. They are thought to come from two icy reservoirs beyond Neptune's orbit: the Kuiper belt and the Oort cloud. Long-period comets (those taking more than 200 years to complete an orbit around the sun) come from the Oort cloud, while short-period comets (those taking less than 200 years to complete an orbit around the sun) come from the Kuiper Belt [10]. Jan Oort, a Danish astronomer theorized that comets live in a massive cloud in the solar systems beyond reaches. The Oort cloud is the name given to this phenomenon. According to estimates, it might include a trillion comets and make up a considerable portion of the solar system's mass. However, we have no direct evidence of the Oort cloud's existence [11]. Khalaf demonstrated in 2006 that the interaction around the nucleus of the comet is primarily influenced by the addition of a new ion to the plasma of the solar wind [12].

The coma vapors are made up of molecules released from the nucleus due to solar heating and relative sublimation. These molecules in the coma are exposed to direct solar radiation once they leave the nucleus and can be destroyed in various ways due to the combined effect of these processes[9]. The Kuiper Belt is a disk-shaped region beyond Neptune's orbit that extends from 30 to 50 AU from the sun and contains numerous tiny icy bodies. It is now thought to be the origin of short-period comets, while some sources place the Kuiper belt between 30 and 100 AU from the sun[13].The distance between the sun and the Oort cloud is so great that Pluto's eccentric orbit takes it as close as 30 AU and as far as 50 AU from the sun. The Oort cloud's inner boundary, on the other hand, is estimated to be between 2,000 and 5,000 AU from the sun. The outside edge could be 10,000 or perhaps 100,000 AU away from the sun, which is roughly one-quarter to halfway between the sun and the closest nearby star [14]. The asteroids belt, generally positioned between the orbits of Mars and Jupiter around

2.2 to 3.2 AU from the sun, is where the vast majority of asteroids, also known as minor planets, are discovered. Some asteroids orbit in near-Earth space, while others are forced out of the asteroids belt and into the outer solar system by the gravitational effects of stars[15] .
Three Regions' distances of the comets concerning the sun with their references are shown in Table 1.

Table 1: Regions' distances concerning the sun

	Asteroids belt	Kuiper belt	Oort cloud
Distance from the Sun AU	2.2 – 3.2 AU [6]	30 – 50 AU [4]	2000 – 100,000 AU [16]

2. Mathematical nuclei' relations.

The derived equation of estimated radius to comets nucleus is given by the following relation[17] :

$$\text{p}.\Phi(\alpha).\ R_h^2 = 2.238 \text{ x } 10^{22}\ r_h^2\ \Delta^2\ 10^{0.4(ms-H)} \quad (1)$$

The term Δ is the geocentric distance, r_h is the heliocentric distance, both in AU units, and H is the absolute magnitude of the comet, m_s is the apparent magnitude of the sun (-26.74) [18], p is a geometric albedo (0.04) [19], $\phi(\alpha)$ is a [phase angle or phase function of the nucleus as follows[20] :

$$-2.5\ (\alpha) = \alpha\ \text{p} \quad (2)$$

α : represents the angle of Sun-comet-Earth, which can be extracted by easy trigonometric methods from knowing the distances as shown in Figure 1.

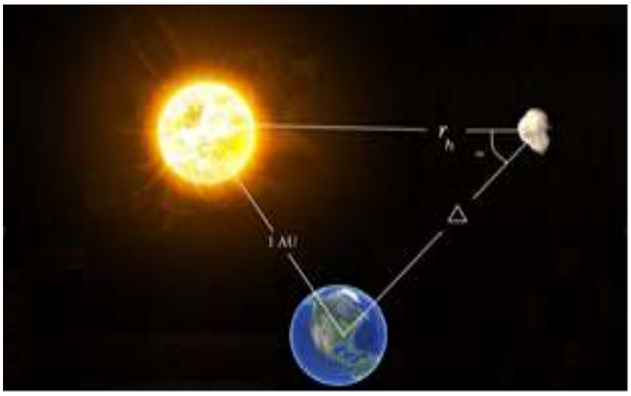

Figure 1: Phase angle of Sun-comet-Earth [21].

The following equation has given the absolute magnitude (Hc) of the comet:

$$H_c = m - 5 \log (r_h\ \ \Delta) - \alpha\ B \quad (3)$$

Where m is the comet's apparent magnitude, Δ is Earth-comet distance, r_h is a Sun-comet distance, and B is the phase coefficient equal to 0.04.

3. Results and Discussion

From equation (1), the radius of the comet's nucleus can be estimated. The nuclei have wide ranges in their sizes and also in their heliocentric distances. They begin from roughly a few hundreds of meters to the thousands of kilometers. In this research, the maximum comets' radius is found in comet 29P/Schwassmann -Wachmann as roughly 87 km, that is from Oort cloud and also in comet C/2018 N2 (ASASSN) which has radius 88 km.

Here are 100 comets that have been distributed concerning heliocentric, depending on statistical results to new comets' regions division versus their radiuses. Results reveal new details of comets distances from the sun. The distances of 100 comets are represented in Figure 2**.**

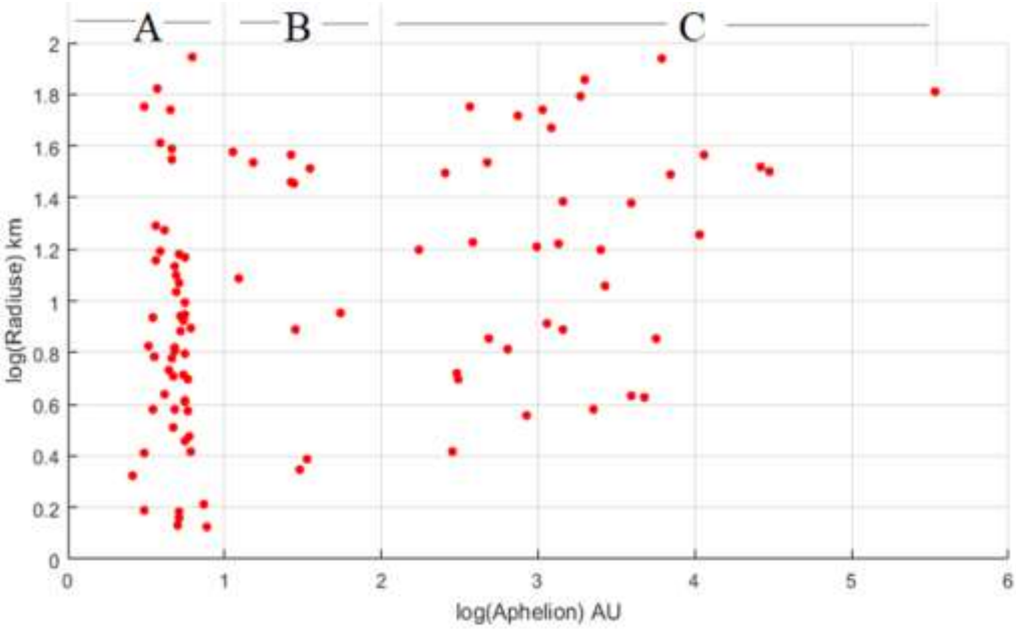

Figure 2: Comets' regions: Region (A), Kuiper belt (B) and Oort cloud(C).

Notation: Required information of comets' orbit elements to calculate their radiuses can be found in the appendix, Table A.

Table 2: Heliocentric range of three comets' regions and nuclei' masses

	Region A	**Kuiper belt B**	**Oort Cloud C**
Heliocentric range	2.5 - 7.7 AU	11.2 - 54.6 AU	174 - 338844 AU
Radius of nucleus	1.3 - 88 km	2.2 - 38.0 km	2.6 - 87 km
Percent of comets	54 %	11 %	35 %

Region (A) has a contrast distance compared to asteroid belt where (A) orbits have a wider range of about 2.5 – 7.7 AU, while asteroids belt has a range of 2.2 – 3.2 AU. Differences in both regions can be found in Figure 3.

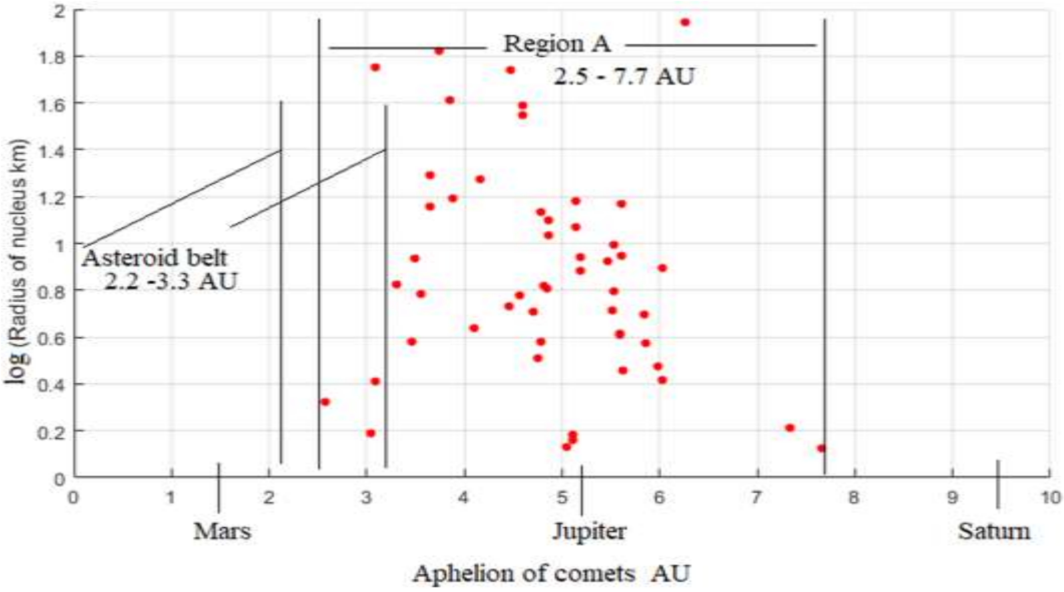

Figure 3: Clear differences in both ranges (region A and asteroid belt) and their orbits separated by wide distance from Kuiper belt.

The asteroid belt also has a small percentage of observed comets: it has only 4% of all the comets, as shown in the above figure. Many of the current asteroids were fundamentally comets, but their volatile matter has been exhausted since a long time ago. 4% of these objects have ejected some matter from their surface since a few billion years ago (4.5 billion years). This indicates that these objects had large sizes in the early age of the solar system creation, and over time they became smaller and fainted sources.

There are some differences when dividing comets with more details. Figure 4 reveals a new important region (A) which is the closest to the Kuiper belt (the short period), as shown in Figure 4. Oort cloud in global references with range 2000-5000 AU, while the farthest limit might be 10,000 AU or 100,000 AU from the sun; that is one-quarter to halfway between the sun and the nearest neighboring star [20], but studies revealed some different distances, where Oort cloud is about 174 - 340,000 AU, Table 2, which refers to the distance behind Alpha Centauri star that is at a distance of roughly 275,182 AU, see Figure 4.

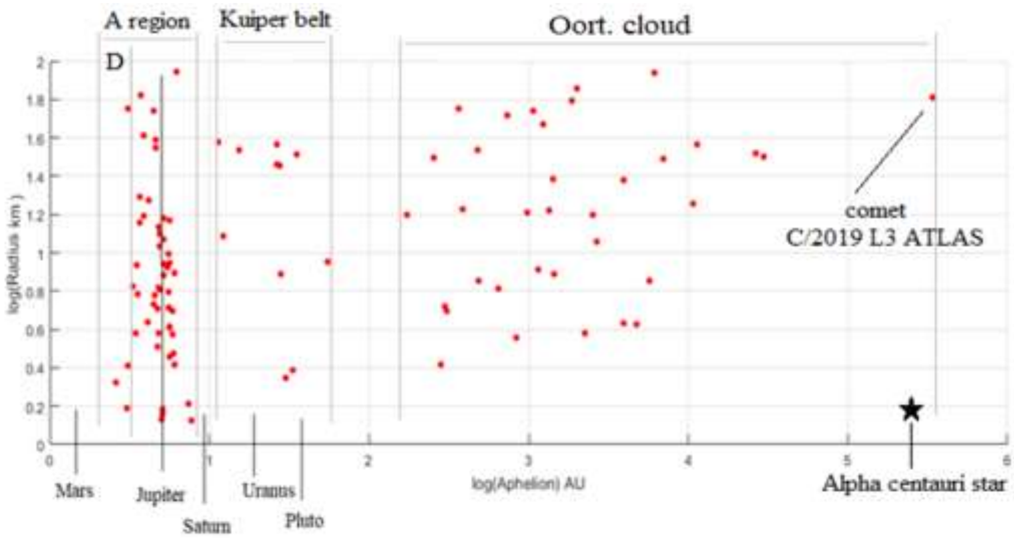

Figure 4: The shortest periods and the highest percent of the comets in the region (A), around 2.5 – 7.7 AU, which include region D (asteroids belt) at range 2.2 – 3.2 AU.

Region (A) contains 54% of the total observed comets containing asteroid regions (D). In region A, there is a high percentage of the comets; they concentrate at Jupiter orbit, which is why the Jupiter planet has many moons and (more than Saturn's moons). Some of Jupiter's moons have irregular shapes (just rocks, have no uniform shape); they were basically comets in the early solar system, which exhausted most of their matter over time because they are close to the sun. This is a normal state where comets that have small periods will have many rotations around the sun; therefore, they will exhaust their matter faster than the distant comets that we see as moons around Jupiter planet.

The distance of comet C/2019 L3 (ATLAS) (comet no.15 in the appendix's table) has a stupendous aphelion distance of about 377,000 AU. This means that the comet goes to the region behind Alpha Centauri star and returns to the solar system. In this case, there are two probabilities, either this estimated value (comet's aphelion) is not actual (because it is only valued among these comets), or that both our sun and the nearest star (Alpha Centauri) share one bound gravitation system. Thus, the stellar clusters have been formed.

There are 1% of the comets in some regions of the Oort cloud that follow a double gravity system, which contains 1 billion comets (10^9 comets), that is 0.01 of $10^9/360^o$ of the common comets between two stars. This is similar to atoms bonding to form the molecules.
The sizes of comets nucleus have also been extracted (See Table 2). Another set of comets conform to their sizes and percentages within a specific range, as proven in Table 3.

Table 3: The Sizes of cometary nuclei versus their percent

Radius of nucleus	Percent	Radius of nucleus	Percent
1 - 10 km	51 %	50 - 60 km	5 %
10-20 km	18 %	60 - 70 km	3%
20-30 km	4 %	70 - 80 km	1%
30-40 km	12 %	80 - 90 km	2 %
40-50 km	2 %	< 90 km	1 %

4. Empty triangle problem.

The Data of 100 comets in the appendix table gives aphelion and perihelion distance to the sun; when the rate (aphelion/ perihelion) represents the comets radius, a space appears. Currently, this area has no clear explanation as it requires extended studies. The case is shown in Figure 5.

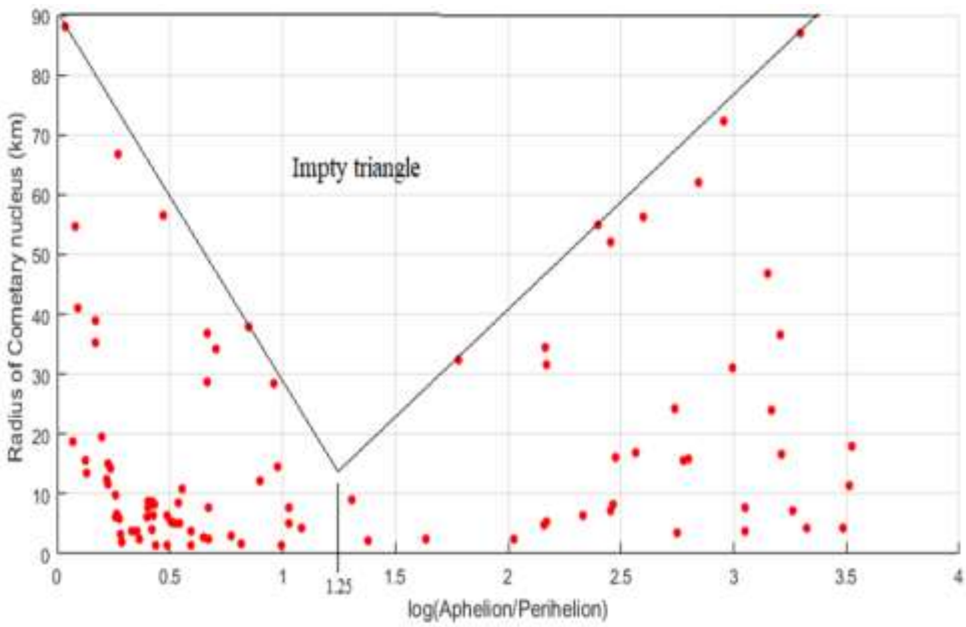

Figure 5: The empty triangle has unknown relation between comets radiuses and the ratio (aphelion/perihelion) distances.

As shown in the above figure, the radius of the nucleus decreases when the ratio (Aphelion/Perihelion) increases to reach 1.25 value (less radius value), then the radius increases linearly with increasing the ratio of (Aphelion/Perihelion). Some results are expected from this triangle, e.g., if the ratio log (Aphelion/Perihelion) was 1unit, the nucleus's radius must be > 30 km, see Figure 5, and if this ratio was 1.5 unit, the radius of the nucleus will take values >23 km and so on. The reason for this behavior is unknown yet.

5. Conclusions

1- The study shows some essential points which indicate the distributions of comets' heliocentric distances and sizes, where there are three comets' regions instead of two (short and long periods), and the third region is near the Asteroid belt which has a distance between the (2.5 to 7.7) AU, whereas Asteroid belt has distance from (2.2 to 3.3)AU as investigated in Figures 2 and 4.

2- All comets are shown in the appendix. The figures above give a clear evidence about three regions (region A (Asteroid belt), Kuiper belt and Oort cloud), where region A contains some of the asteroid belt and its extended distance to include more space farther than the region of the asteroid belt in Figure 3. The research shows that region A has 54% of the observed comets, 4 % of the comets in the asteroid belt, see Figure 3, and 50% of the comets exist from roughly half the distance between Mars and Jupiter planets to extend behind Jupiter planet, where they concentrate exactly around Jupiter orbit. This explains why Jupiter planet has a larger number of moons.

3- The Kuiper belt is a short period for comets, but region A has comets shorter than the Kuiper belt. It is the region closest to the Sun as shown in Figure 4, and the Kuiper belt has only 11% of the comets observed, while region A has 54%. The Oort cloud is a very large area, extending from 174 to 300,000 AU, where Pluto is at a distance of 39.5 AU. There is one comet like (C/2019 L3 (ATLAS)) that is farther than Alpha Centauri star distance; thus, the comet is restricted by a couple of gravity systems. Therefore, these comets are constrained by their pairwise gravitational systems. They have varying angles of inclination that make them shaped like a ball.

4- The results reveal an empty area that does not contain comets and it needs to be studied and explained in the future as shown in Figure 5 and it is called empty triangle.

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The Appendix

Table A: Orbital elements' data of 100 comets [22]

Comet name	Apparent magnitude	Heliocentric Distance r_h Million km	Geocentric distance Δ Million km	Aphelion AU	Perihelion AU	No.
Wirtanen 46p	11.64	166.670	241.30	3.0920	1.050	1
64P/Swift-Gehrels	15.75	238.310	119.89	4.4540	1.393	2
38P/Stephan-Oterma	11.18	261.330	121.39	11.270	1.585	3
C/2020 F3 (NEOWISE)	15.1	231.702	241.70	173.15	0.289	4
C/2016 N6, PANSTAR.	13.61	481.360	362.11	1867.3	2.670	5
78P/Gehrels 2	13.05	318.480	368.48	3.7350	2.010	6
C/2016 M1, PANSTAR.	13.74	418.050	455.77	2000.4	2.210	7
C/2018 L2 (ATLAS)	14.16	265.970	352.33	253.25	1.710	8
C/2018 N2 (ASASSN)	14.81	637.090	657.39	6170.7	3.124	9
C/2018 A3 (ATLAS)	15.18	490.240	389.97	478.40	3.270	10
C/2019 N1 (ATLAS)	15.70	472.370	389.97	26311	1.704	11
C/2016 R2, PANSTAR	15.26	540.930	542.42	736.41	2.602	12
92P/ Sanguin	31.75	1304.37	1280.7	8.891	1.820	13
P/2010 H2 (Vales)	16.73	652.101	728.19	4.5931	3.108	14
C/2019 L3 (ATLAS)	17.09	954.232	1054.5	337722	3.551	15
21P/Giacobini-Zinner	15.71	277.150	171.61	3.4970	1.010	16
C/2015 O1, PANSTAR.	15.72	699.070	605.47	4.4641	3.730	17
C/2017 K6 (Jacques)	24.21	1243.82	1247.8	2249.9	2.003	18
P/2010 H2 (Vales)	15.82	543.750	688.06	3.8500	3.110	19
C/2018 A6 (Gibbs)	15.86	513.710	485.32	15.335	3.010	20
48P/Johnson	15.88	345.600	363.32	3.6445	2.305	21
P/2014 L2 (Neowise)	31.51	1476.22	1504.36	10.417	2.234	22
240P/NEAT	16.36	414.25	312.49	3.6445	2.125	23
74P/Smirnova-Chernyk	17.72	558.03	623.00	4.1679	3.554	24
C/2017 T3 (ATLAS)	17.04	422.30	512.44	1334.9	0.825	25
C/2019 T4 (ATLAS)	17.97	1103.6	1142.7	1067.0	4.241	26
12P/Pons-Brooks	26.6	1816.6	1745.6	33.468	0.774	27
65P/Gunn	17.97	534.22	591.61	3.8849	2.911	28
C/2017 O1 (ASASSN1	24.46	1374.1	1261.8	836.65	1.499	29
20D/Westphal	30.11	3981.8	3862.3	30.030	1.254	30
C/2016 T3, PANSTAR.	24.79	1311.4	1168.6	282.07	2.649	31
C/2018 R3 (Lemmon)	18.23	368.50	475.21	1440.5	1.291	32
49P/Arend-Rigaux	18.28	343.45	333.89	3.5580	1.420	33
C/1995 O1 (Hale-Bopp)	25.29	6511.0	6480.6	363.19	0.917	34
Comet 333P/LINEAR	25.33	1093.5	1025.1	7.33.18	1.115	35
C/2018 E1 (ATLAS)	18.66	536.71	461.64	54.534	2.705	36
66P/du Toit	18.70	448.84	452.49	6.0211	1.285	37
117P/Helin-Roman-Alu.	19.01	756.20	613.71	5.1360	3.045	38
C/2014 F3 Sheppard-	19.40	1109.2	1244.1	26.42	5.721	39
56P/Slaughter-Burnham	25.4	1047.12	929.672	7.666	2.505	40
C/2013 YG46	19.69	650.34	520.99	3.3051	1.804	41
C/2017 K4 (ATLAS)	20.05	654.66	637.44	28.110	2.648	42
C/2015 ER61, PAN.	19.89	1049.7	929.28	383.18	1.042	43
C/2016 Q2, PANSTAR.	19.98	1330.5	1453.7	6985.0	7.080	44

37P/Forbes	19.99	408.51	424.85	3.4550	1.608	45
C/2017 Y2 ,PANSTAR.	20.03	932.68	982.86	2502.9	3.956	46
17P/Holmes	20.09	689.39	711.59	5.1826	2.053	47
25D/Neujmin 2	20.15	375.75	319.91	3.0890	1.338	48
C/2018 E2 (Barros)	20.21	761.59	667.82	1143.9	3.922	49
26P/Grigg-Skjellerup	20.22	247.45	387.10	3.0434	1.117	50
123P/West-Hartley	20.62	516.16	528.52	5.5949	2.126	51
294P/LINEAR	20.55	253.38	298.65	5.1030	1.297	52
C/2019 Y1 (ATLAS)	11.47	135.83	240.46	1224.4	0.863	53
88P/Howell	15.90	358.53	230.54	4.8590	1.358	54
210P/Christensen	15.46	123.97	269.32	5.8422	0.545	55
Halley (1P/Halley)	25.57	5228.0	5240.8	35.082	0.585	56
29P/Schwassman.	16.03	866.38	984.64	6.2614	5.724	57
C/2018 A6 (Gibbs)	16.76	547.10	660.28	27.6818	3.0179	58
P/2010 H2 (Vales)	16.83	643.29	781.67	4.5930	3.1076	59
114P/Wiseman-Skiff	17.26	250.11	200.45	5.5102	1.5793	60
P/2019 Y2 (Fuls)	17.49	320.37	186.96	4.7832	2.1247	61
78P/Gehrels 2	17.81	477.61	349.51	5.4614	2.0104	62
Comet 117P/Helin-Rom.	17.97	676.90	536.02	5.1361	3.0562	63
C/2014 F3, Sheppard	18.20	929.23	1019.4	26.428	5.7216	64
297P/Beshore	18.23	488.00	318.98	4.5590	2.4080	65
28P/Neujmin 1	18.44	601.13	523.58	12.280	1.5520	66
Encke (2P/Encke)	18.50	285.00	419.83	4.0940	0.3360	67
C/2019 T3 ATLAS	18.60	965.64	990.76	29533	5.9470	68
249P/LINEAR	18.70	284.25	140.52	5.0446	0.5104	69
74P/Smirnova-Chernykh	18.89	636.29	683.53	4.7812	3.5519	70
10P/Tempel	18.90	501.23	360.99	4.7115	1.4220	71
17P/Holmes	18.96	474.73	481.93	5.1826	2.0566	72
C/2016 Q2, PANSTAR.	18.99	1136.3	1202.1	11359	7.0871	73
C/2016 N6, PANSTAR.	19.10	934.68	962.91	3942.5	2.6691	74
C/2018 A3 (ATLAS)	19.18	753.13	868.83	985.36	3.2760	75
C/2016 R2, PANSTAR.	19.23	1011.6	969.08	2.6023	1426.3	76
C/2019 V1 (Borisov)	19.23	499.34	489.50	5673.5	3.0966	77
65P/Gunn	19.25	663.12	745.40	4.8562	2.9103	78
260P/McNaught	19.31	350.11	329.61	5.8612	1.4922	79
240P/NEAT	19.36	668.53	557.72	5.6083	2.1286	80
C/2018 X2 Fitzsimmon	19.79	519.22	437.86	307.91	2.1250	81
5D/Brorsen	19.89	858.32	943.59	5.6124	0.5898	82
C/2018 R3 (Lemmon)	20.33	572.14	467.98	3939.7	1.2906	83
C/2019 K5 (Young)	20.31	537.31	576.50	299.93	2.0350	84
354P/LINEAR	20.38	300.98	349.04	2.5758	1.3381	85
22P/Kopff	20.45	716.66	617.78	4.8401	1.5760	86
25D/Neujmin 2	20.50	364.76	409.62	6.0211	1.2854	87
C/2016 N4 (MASTER)	20.38	1239.4	1101.3	1101.3	3.1991	88
C/2013 YG46	20.55	711.85	644.87	4.8058	1.8044	89
123P/West-Hartley	20.64	520.29	518.48	5.5949	2.1261	90
294P/LINEAR	20.71	259.79	295.19	5.1031	1.2977	91

C/2019 K4	20.92	553.35	679.75	4739.6	2.2594	92
119P/Parker-Hartley	21.08	726.35	780.68	5.5287	3.0387	93
C/2018 F1 (Grauer)	21.20	774.57	912.43	641.87	2.9930	94
C/2018 L2 (ATLAS)	21.21	807.09	877.23	486.81	1.7117	95
C/2017 T3	21.03	1064.3	1004.0	2686.6	0.8250	96
119P/Parker-Hartley	20.08	726.33	781.54	5.5287	3.0386	97
7P/Pons-Winnecke	21.48	591.02	507.08	5.6150	1.2563	98
110P/Hartley 3	21.57	574.62	716.37	4.7482	2.4753	99
21P/Giacobini-Zinner	21.68	700.89	562.38	5.9874	1.0135	100