This memorandum presents the small-body perturber file SB441-N373, which is available for use with JPL planetary ephemeris DE441. The file includes the ephemerides of the 373 small-body perturbers used by Park et al. (2021) for DE440 and DE441. A second file SB441-N16 is also available and contains the same ephemerides restricted to the 16 most massive perturbers in the main asteroid belt.

We generated the small-body ephemeris (SBE) perturber file (Chamberlin 1998) SB441-N373 containing the mutually perturbed ephemerides of the 373 small bodies used for JPL planetary ephemerides DE440 and DE441 (Park et al. 2021). Table 1 provides the corresponding list of perturbers and their masses, which are set according to the DE441 planetary ephemeris solution. In addition to the 343 small-body perturbers already considered for DE431 (Folkner et al. 2014, Farnocchia 2017), this perturber set also includes 30 Kuiper Belt objects. The reduced file SB431-N16 contains the same ephemerides but only for the 16 most massive bodies in the main asteroid belt. The two SBE files cover the time interval from 8001 BC-12-21 TDB (JD -1200525.5) to 9000-01-01 TDB (JD 5008242.5).

We generated SB441-N373 and SB441-N16 with the same iterative procedure used to create the previous SB431-N16 and SB431-N343 small-body perturber files (Farnocchia 2017). The orbit of each perturber was integrated relative to the solar system barycenter using DE441 as a reference planetary ephemeris. At each iteration the orbit of each perturber was estimated based on the following dataset:

1) All available optical astrometry from the Minor Planet Center (https://minorplanetcenter.net) from January 1950 to March 2021. Earlier observations have the potential for larger, non-random errors and were therefore ignored. We corrected the astrometry for star catalog systematic errors using the Eggl et al. (2020) debiasing scheme and weighted the data according to Veres et al. (2017). Outliers were rejected based on the Carpino et al. (2003) scheme with $\chi_{rej} = 3$.
2) High-accuracy astrometry from the second data release of Gaia (Gaia Collaboration 2018).
3) Asteroid radar delay and Doppler measurements (Ostro et al. 2002, https://ssd.jpl.nasa.gov/?radar).
4) Pseudo-range points for Ceres and Vesta from the Dawn mission (Konopliv et al. 2014, 2018).

Figure 1 shows the position differences between consecutive iterations as a function of time for (1) Ceres. While the Ceres position is well constrained at the time of the observations included in the orbital fit, position differences tend to increase toward the ends of the time interval, i.e., from year 8001 BC to year 9000. This behavior is expected and common to all the 373 asteroids considered in the analysis.

For a more comprehensive assessment, Figure 2 shows the cumulative distribution of the position differences between consecutive iterations for all 373 perturbers. The procedure converges in terms of minimizing the differences between iterations after six iterations. The final trajectory differences can be as large as 1000 km as we approach the ends of the considered time interval, where the fidelity of the ephemeris necessarily degrades. However, as shown by Figure 3, the vast majority of these differences are within 1 km from year 1500 to 2500. These position differences are a mere measure of convergence and should not be interpreted as a measure of the ephemeris uncertainty.
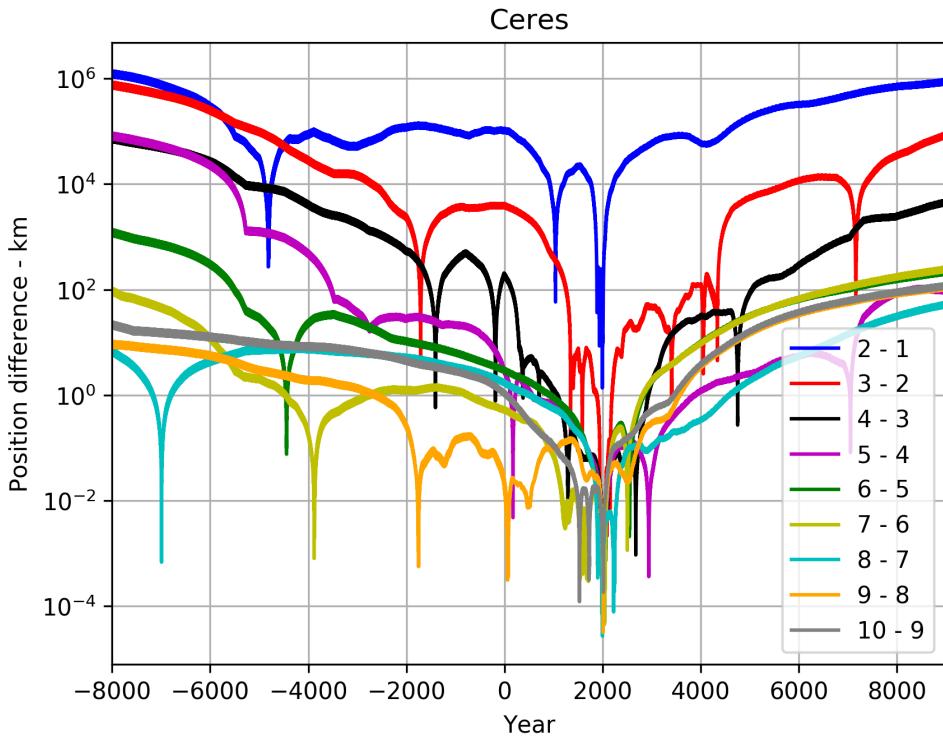
Figure 1. Position differences between consecutive iterations as a function of time for Ceres.
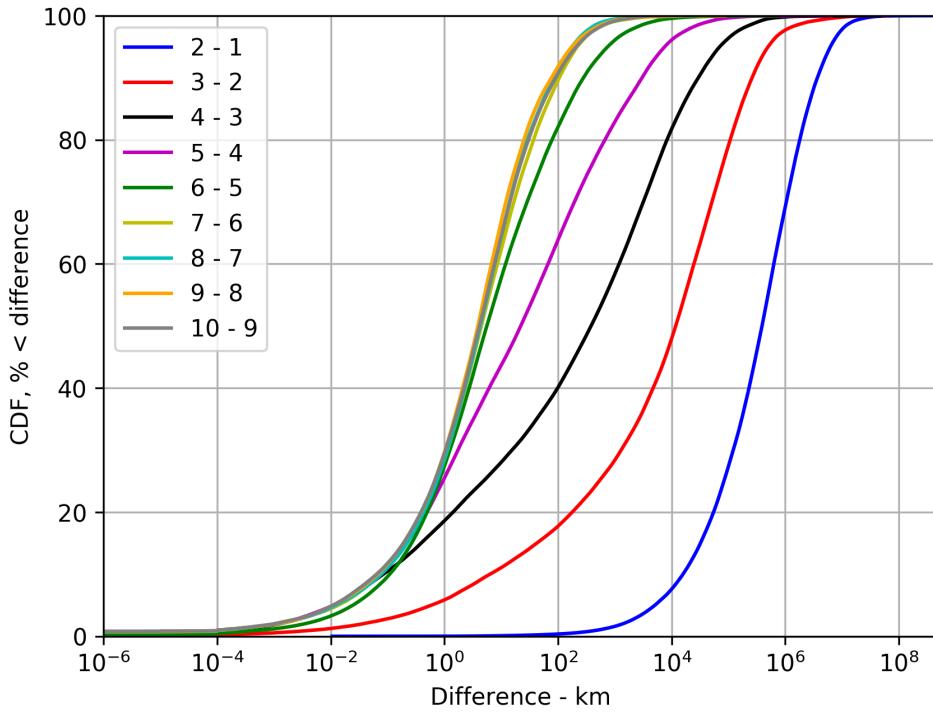
Figure 2. Cumulative density function of the position differences between consecutive iterations for all 373 perturbers. The time interval is from year -8001 to year +9000.
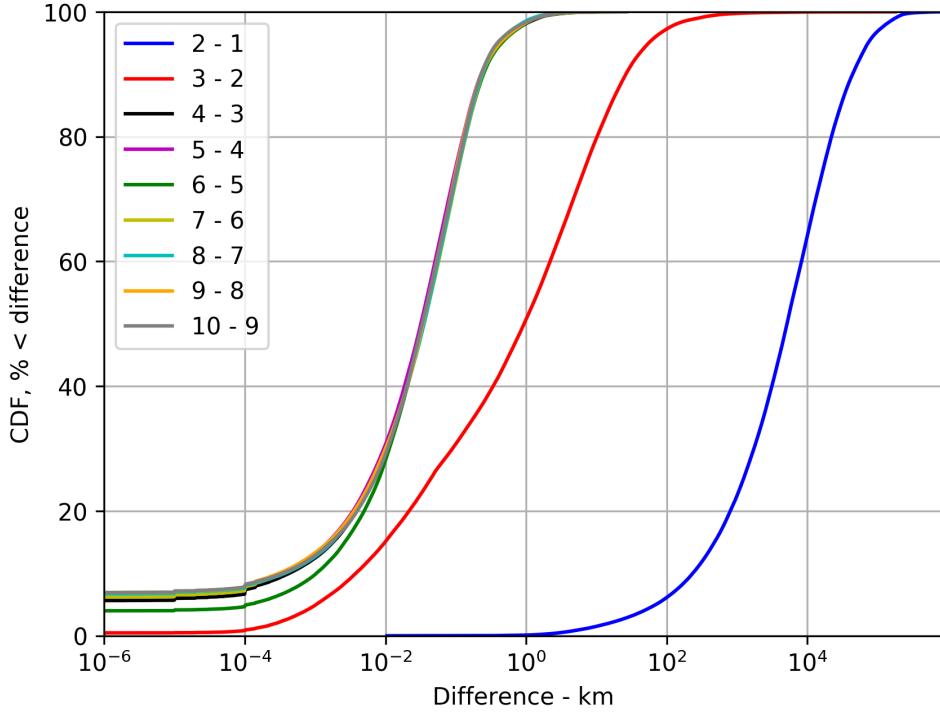
Figure 3. Cumulative density function of the position differences between consecutive iterations for all 373 perturbers. The time interval is from year 1500 to year 2500.

The new SBE files correspond to the sixth iteration and are available on nexus at the following path:

nexus:/home/dfarnocc/data/sb441-n373.nio   (NAVIO native format)
nexus:/home/dfarnocc/data/sb441-n16.nio   (NAVIO native format)

ACKNOLEDGEMENTS

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Table 1. Name (or provisional designation for unnamed asteroids), number (if available), SPICE ID, and GM of 373 perturbers. The GM values match the ones used for DE441 (Park et al., 2021) and they are reported in full precision even though not all digits are significant.

Name/Provisional designation	Number	Spice ID	GM - au^3/d^2
Ceres	1	2000001	1.3964518123081070e-13
Vesta	4	2000004	3.8548000225257904e-14
Pallas	2	2000002	3.0471146330043200e-14
Hygiea	10	2000010	1.2542530761640810e-14
Davida	511	2000511	8.6836253492286545e-15
Interamnia	704	2000704	6.3110343420878887e-15
Europa	52	2000052	5.9824315264869841e-15
Sylvia	87	2000087	4.8345606546105521e-15
Eunomia	15	2000015	4.5107799051436795e-15
Juno	3	2000003	4.2823439677995011e-15
Psyche	16	2000016	3.5445002842488978e-15
Camilla	107	2000107	3.2191392075878588e-15
Thisbe	88	2000088	2.6529436610356353e-15
Iris	7	2000007	2.5416014973471498e-15
Euphrosyne	31	2000031	2.4067012218937576e-15
Cybele	65	2000065	2.0917175955133682e-15
Dido	209	2000209	1.9511008134506610e-15
Aurora	94	2000094	1.9476499609659456e-15
Doris	48	2000048	1.9085161956485640e-15
Bertha	154	2000154	1.9062882233624486e-15
Amphitrite	29	2000029	1.7788759570378772e-15
Ursula	375	2000375	1.7716875294908651e-15
Herculina	532	2000532	1.7651295651126369e-15
Stereoskopia	566	2000566	1.7007818925283807e-15
Siegena	386	2000386	1.6744520343182799e-15

Alauda	702	2000702	1.6730262398441171e-15
Laetitia	39	2000039	1.6238080168284406e-15
Metis	9	2000009	1.4490138025867273e-15
Hebe	6	2000006	1.4423591761343029e-15
Bamberga	324	2000324	1.3808681586222395e-15
Elektra	130	2000130	1.3272835717079433e-15
Themis	24	2000024	1.3109170444249925e-15
Patientia	451	2000451	1.2973797046097596e-15
Fortuna	19	2000019	1.2396175182794244e-15
Palma	372	2000372	1.2340564359220072e-15
Daphne	41	2000041	1.2055616051144469e-15
Irene	14	2000014	1.1863795139948057e-15
Diotima	423	2000423	1.1511452195400677e-15
Egeria	13	2000013	1.1389436761809467e-15
Hesperia	69	2000069	1.1215489958719225e-15
Parthenope	11	2000011	1.0258530487431674e-15
Papagena	471	2000471	1.0154946317000345e-15
Lachesis	120	2000120	1.0049283867977807e-15
Aglaja	47	2000047	9.5484521825652372e-16
Aegle	96	2000096	9.4294212130582306e-16
Hedwig	476	2000476	9.3290849487079058e-16
Aspasia	409	2000409	9.3071301802989339e-16
Juewa	139	2000139	9.2595552169711510e-16
Winchester	747	2000747	8.9162160614799751e-16
Kalliope	22	2000022	8.8054945035882155e-16
Lomia	117	2000117	8.7956326624912993e-16
Scheila	596	2000596	8.7503854623745788e-16
Nemesis	128	2000128	8.5847861311410371e-16
Io	85	2000085	8.4105681134479927e-16
Hestia	46	2000046	8.2924109896839845e-16
Sibylla	168	2000168	8.2862151230975531e-16
Germania	241	2000241	8.2578918855189583e-16
Eugenia	45	2000045	8.0375351695515079e-16
Pales	49	2000049	8.0309019561585371e-16
Kreusa	488	2000488	7.9522883193510027e-16
Dembowska	349	2000349	7.7770392072089233e-16
Lucina	146	2000146	7.4145517820883541e-16
Eukrate	247	2000247	7.2166473124525787e-16
Freia	76	2000076	7.1965348672034277e-16
Philomela	196	2000196	7.1883691717843153e-16
Lamberta	187	2000187	6.9988762217142864e-16
Eleonora	354	2000354	6.9799427588689871e-16
Berbericia	776	2000776	6.9144773619266927e-16
Elpis	59	2000059	6.1242440038278814e-16
Minerva	93	2000093	5.8909323687573915e-16
Flora	8	2000008	5.7402666475018234e-16
Massalia	20	2000020	5.7134184386435100e-16
Julia	89	2000089	5.6998032445109094e-16
Armenia	780	2000780	5.6837732628121214e-16

Nemausa	51	2000051	5.5966052085629955e-16
Philosophia	227	2000227	5.2949727893225519e-16
Pompeja	203	2000203	5.1804790437901480e-16
Eucharis	181	2000181	5.1233398977263506e-16
Pretoria	790	2000790	5.0431481947350735e-16
Atalante	36	2000036	5.0135973834869766e-16
Gudrun	328	2000328	4.9982468308633827e-16
Melpomene	18	2000018	4.8181149848174751e-16
Bettina	250	2000250	4.6944966247935396e-16
Arethusa	95	2000095	4.6026462068512803e-16
Aletheia	259	2000259	4.5251089435001250e-16
Myrrha	381	2000381	4.4933216634745898e-16
Medea	212	2000212	4.4605106892003544e-16
Klymene	104	2000104	4.4137261924065115e-16
Melete	56	2000056	4.3334389285268117e-16
Gyptis	444	2000444	4.2471030993597299e-16
Kleopatra	216	2000216	4.1427288444080811e-16
Pulcova	762	2000762	4.1146229595421110e-16
Vibilia	144	2000144	4.0738380707775932e-16
Erminia	705	2000705	3.9116752395114746e-16
Adorea	268	2000268	3.8623042613708653e-16
Emma	283	2000283	3.8354815246046577e-16
Harmonia	40	2000040	3.7393826630015266e-16
Argentina	469	2000469	3.6478450110028057e-16
Ino	173	2000173	3.4944452970189009e-16
Aquitania	387	2000387	3.4383044497176679e-16
Bellona	28	2000028	3.4043931236013436e-16
Lampetia	393	2000393	3.3572279402433382e-16
Siwa	140	2000140	3.3451752752267848e-16
Victoria	12	2000012	3.2843482824404967e-16
Hippo	426	2000426	3.2507694999797983e-16
Astraea	5	2000005	3.2161933241855116e-16
Ianthe	98	2000098	3.1864312654754617e-16
Chloris	410	2000410	3.1527319370312520e-16
Circe	34	2000034	3.1392144602052048e-16
Adeona	145	2000145	3.1319493503427420e-16
Ophelia	171	2000171	3.0262531306199368e-16
Hermione	121	2000121	3.0027755581135258e-16
Comacina	489	2000489	2.8775529812775966e-16
Ninina	357	2000357	2.8721263188047396e-16
Ausonia	63	2000063	2.8598833773736982e-16
Thia	405	2000405	2.8343442027590178e-16
Xanthippe	156	2000156	2.7907996428036474e-16
Ornamenta	350	2000350	2.7857999144799436e-16
Thalia	23	2000023	2.7673067211701877e-16
Gallia	148	2000148	2.7635117872432285e-16
Merapi	536	2000536	2.7333272315776016e-16
Nuwa	150	2000150	2.6906654264657009e-16
Charybdis	388	2000388	2.6866209145075665e-16

Eva	164	2000164	2.6856363262058272e-16
Athamantis	230	2000230	2.6546896309806863e-16
Loreley	165	2000165	2.6454299615525259e-16
Antiope	90	2000090	2.6428816005892839e-16
Meliboea	137	2000137	2.6291667570900683e-16
Princetonia	508	2000508	2.6003747033565168e-16
Wratislavia	690	2000690	2.5859089556681753e-16
Euterpe	27	2000027	2.5613865804152161e-16
Alexandra	54	2000054	2.5613643856735632e-16
Hispania	804	2000804	2.5527830470049859e-16
Elfriede	618	2000618	2.5193204889207218e-16
Liguria	356	2000356	2.5189815204630036e-16
Adria	143	2000143	2.4983185526188601e-16
Kassandra	114	2000114	2.4884067006540889e-16
Protogeneia	147	2000147	2.4858578423681320e-16
Johanna	127	2000127	2.4754901346706772e-16
Prokne	194	2000194	2.4561528144043314e-16
Fides	37	2000037	2.4281305508271871e-16
Chicago	334	2000334	2.4136220339629290e-16
Aurelia	419	2000419	2.3773578209205859e-16
Bertholda	420	2000420	2.3670178521081795e-16
Marianna	602	2000602	2.2809674909014779e-16
Polyxena	595	2000595	2.2465030240169206e-16
Padua	363	2000363	2.2392126408313992e-16
Hypatia	238	2000238	2.2188561497353161e-16
Lumen	141	2000141	2.1889333845457843e-16
Polyxo	308	2000308	2.1647804370959252e-16
Ani	791	2000791	2.1076085204803308e-16
Roberta	335	2000335	2.0843132667000589e-16
Carlova	360	2000360	2.0487987640827176e-16
Diana	78	2000078	2.0368097558802117e-16
Undina	92	2000092	2.0222499285918262e-16
Asterope	233	2000233	1.9979624331073550e-16
Adelheid	276	2000276	1.9922195146137866e-16
Lutetia	21	2000021	1.9760028913855683e-16
Gerlinde	663	2000663	1.9725537729863713e-16
Bredichina	786	2000786	1.9534428745516884e-16
Messalina	545	2000545	1.9519850083243681e-16
Aemilia	159	2000159	1.9236219019969684e-16
Marion	506	2000506	1.9069839846057659e-16
Galatea	74	2000074	1.9011716936752780e-16
Helio	895	2000895	1.8942493318435747e-16
Armida	514	2000514	1.8861295755338590e-16
Isis	42	2000042	1.8735257964754667e-16
Beatrix	83	2000083	1.8459902693767395e-16
Zelinda	654	2000654	1.8271153845028229e-16
Concordia	58	2000058	1.8012505811829385e-16
Proserpina	26	2000026	1.7812616814154862e-16
Hohensteina	788	2000788	1.7711871549942670e-16

Edith	517	2000517	1.7655929611836170e-16
Hersilia	206	2000206	1.7485910807435368e-16
Tanete	772	2000772	1.7365447581348131e-16
Denise	667	2000667	1.7174750596131368e-16
Penelope	201	2000201	1.6663045771433504e-16
Aline	266	2000266	1.6594282580293835e-16
Vaticana	416	2000416	1.6511852151088483e-16
Tokio	498	2000498	1.6166164033700236e-16
Arsinoe	404	2000404	1.6144760474032773e-16
Peraga	554	2000554	1.5935521711557882e-16
Tercidina	345	2000345	1.5891479446112133e-16
Iduna	176	2000176	1.5731944639940773e-16
Brixia	521	2000521	1.5584113647898650e-16
Faina	751	2000751	1.5375064738104504e-16
Erato	62	2000062	1.5213428223941847e-16
Feronia	72	2000072	1.5086969937360234e-16
Dynamene	200	2000200	1.5063743226656710e-16
Christa	1015	2001015	1.4774018524534620e-16
Eunike	185	2000185	1.4541092712549263e-16
Eos	221	2000221	1.4535063882245356e-16
Hertha	135	2000135	1.4516053346827936e-16
Semele	86	2000086	1.4367577023452309e-16
Veritas	490	2000490	1.4268068051088923e-16
Emita	481	2000481	1.4232478918230183e-16
Aegina	91	2000091	1.4195955177021533e-16
Alkeste	124	2000124	1.4082516742158776e-16
Artemis	105	2000105	1.4049343696798120e-16
Nephele	431	2000431	1.3981336733485380e-16
Freda	1093	2001093	1.3774121589661637e-16
Antigone	129	2000129	1.3694441284769087e-16
Erigone	163	2000163	1.3501425119063151e-16
Thetis	17	2000017	1.3398683097840782e-16
Desiderata	344	2000344	1.3166985822586556e-16
Niobe	71	2000071	1.3120783938467559e-16
Rusthawelia	1171	2001171	1.3076632020262883e-16
Lictoria	1107	2001107	1.2924733629447915e-16
Melusina	373	2000373	1.2907423434479045e-16
Hera	103	2000103	1.2873552745693193e-16
Ate	111	2000111	1.2685989278560462e-16
Ariadne	43	2000043	1.2683502962561622e-16
Terpsichore	81	2000081	1.2659277966238143e-16
Boliviana	712	2000712	1.2600845433723963e-16
Elisabetha	412	2000412	1.2572594904492957e-16
Sapientia	275	2000275	1.2560415636174639e-16
Tatjana	769	2000769	1.2538556013158105e-16
Josephina	303	2000303	1.2250630736040161e-16
Panopaea	70	2000070	1.2210133021360091e-16
Arachne	407	2000407	1.2159649691849770e-16
Sophrosyne	134	2000134	1.2041493785248888e-16

Lanzia	683	2000683	$1.2001846940536772 \times 10^{-16}$
Fringilla	709	2000709	$1.1932045854274149 \times 10^{-16}$
Mandeville	739	2000739	$1.1895704235209679 \times 10^{-16}$
Leto	68	2000068	$1.1706570191254942 \times 10^{-16}$
Cantabia	740	2000740	$1.1508271223874676 \times 10^{-16}$
Irmintraud	773	2000773	$1.1496018031508255 \times 10^{-16}$
Bruchsalia	455	2000455	$1.1481333345022554 \times 10^{-16}$
Cava	505	2000505	$1.1434524745954757 \times 10^{-16}$
Hamburga	449	2000449	$1.1381715328316359 \times 10^{-16}$
Havnia	362	2000362	$1.1276722765420132 \times 10^{-16}$
Lydia	110	2000110	$1.1273277623952921 \times 10^{-16}$
Luscinia	713	2000713	$1.1149155704508719 \times 10^{-16}$
Gratia	424	2000424	$1.1020156825676931 \times 10^{-16}$
Hermentaria	346	2000346	$1.0985328629139597 \times 10^{-16}$
Vundtia	635	2000635	$1.0924383869373906 \times 10^{-16}$
Ludmilla	675	2000675	$1.0490232752479031 \times 10^{-16}$
Klotho	97	2000097	$1.0268048353591737 \times 10^{-16}$
Luisa	599	2000599	$1.0123777316180206 \times 10^{-16}$
Ilmatar	385	2000385	$9.9761856285164428 \times 10^{-17}$
Rachele	674	2000674	$9.9353572574888636 \times 10^{-17}$
Laurentia	162	2000162	$9.9012689165513785 \times 10^{-17}$
Apollonia	358	2000358	$9.6707984008514061 \times 10^{-17}$
Mashona	1467	2001467	$9.5394755694739102 \times 10^{-17}$
Ara	849	2000849	$9.5120755198622806 \times 10^{-17}$
Campania	377	2000377	$9.3034159609754771 \times 10^{-17}$
Kolga	191	2000191	$9.2700509595298383 \times 10^{-17}$
Vanadis	240	2000240	$9.2554952801502296 \times 10^{-17}$
Octavia	598	2000598	$9.2033836661599851 \times 10^{-17}$
Virginia	50	2000050	$9.0658136009410138 \times 10^{-17}$
Carina	491	2000491	$9.0327213999208335 \times 10^{-17}$
Eurykleia	195	2000195	$8.8316977379090735 \times 10^{-17}$
Felicitas	109	2000109	$8.7342926229301395 \times 10^{-17}$
Hekate	100	2000100	$8.5508621409348064 \times 10^{-17}$
Edna	445	2000445	$8.5315615035236235 \times 10^{-17}$
Corduba	365	2000365	$8.4396008586097327 \times 10^{-17}$
Aeria	369	2000369	$8.3367824102254174 \times 10^{-17}$
Leukothea	35	2000035	$8.2709231678802929 \times 10^{-17}$
Evelyn	503	2000503	$8.2076751772281633 \times 10^{-17}$
Leda	38	2000038	$8.1662072211026138 \times 10^{-17}$
Genoveva	680	2000680	$8.1500190613822256 \times 10^{-17}$
Nausikaa	192	2000192	$8.1421291402953426 \times 10^{-17}$
Nysa	44	2000044	$8.1199988686104986 \times 10^{-17}$
Phaeo	322	2000322	$8.0728377277727621 \times 10^{-17}$
Palatia	415	2000415	$8.0573077475670552 \times 10^{-17}$
Flammario	1021	2001021	$8.0204286497228632 \times 10^{-17}$
Olga	304	2000304	$8.0059632073324802 \times 10^{-17}$
Industria	389	2000389	$8.0059339257419884 \times 10^{-17}$
Vincentina	366	2000366	$7.9789468325426613 \times 10^{-17}$
Cheruskia	568	2000568	$7.9746650958283244 \times 10^{-17}$

Pomona	32	2000032	7.8745071666519418e-17
Kalypso	53	2000053	7.7095685025651228e-17
Isabella	210	2000210	7.6634863234092905e-17
Marghanna	735	2000735	7.5655501926340450e-17
Isolda	211	2000211	7.5601798507442215e-17
Tisiphone	466	2000466	7.5283506550204848e-17
Klio	84	2000084	7.4956976014309418e-17
Mnemosyne	57	2000057	7.4726412893591611e-17
Andromache	175	2000175	7.3124241595549987e-17
Devosa	337	2000337	7.3103127682005358e-17
Lilaea	213	2000213	7.2814102101785253e-17
Miriam	102	2000102	7.2712620981242410e-17
Chaldaea	313	2000313	7.1875707986893794e-17
Notburga	626	2000626	7.0220769064283794e-17
Thyra	115	2000115	6.9735406024392451e-17
Tamara	326	2000326	6.8326580922414544e-17
Massinga	760	2000760	6.8050136041110561e-17
Leonora	696	2000696	6.7737156689916036e-17
Mathesis	454	2000454	6.6798192418293831e-17
Una	160	2000160	6.5142513315502267e-17
Anacostia	980	2000980	6.3470276384468785e-17
Honoria	236	2000236	6.2517263026028503e-17
Henrietta	225	2000225	6.1488489136531271e-17
Montague	535	2000535	6.0506637862539676e-17
Dione	106	2000106	5.9339850700917689e-17
Megaira	464	2000464	5.8233026402841637e-17
Eurydike	75	2000075	5.8027456297983493e-17
Tauris	814	2000814	5.7450720854270621e-17
Urania	30	2000030	5.7057263757897529e-17
Amherstia	516	2000516	5.6630276385517128e-17
Sappho	80	2000080	5.6471154275060233e-17
Misa	569	2000569	5.5692610319519898e-17
Rosa	223	2000223	5.5210833825561731e-17
Sulamitis	752	2000752	5.5029875850101036e-17
Pickeringia	784	2000784	5.3189337421443262e-17
Frigga	77	2000077	5.2724601168331567e-17
Martha	205	2000205	5.2364312133805402e-17
Alekto	465	2000465	5.1867195285102107e-17
Lehigh	691	2000691	5.1209748534841818e-17
Nephthys	287	2000287	5.1065425768005637e-17
Ekard	694	2000694	5.1009798048889617e-17
Svea	329	2000329	5.0225799203206768e-17
Dike	99	2000099	5.0146072111900431e-17
Eurynome	79	2000079	4.8242269181746132e-17
Baucis	172	2000172	4.6588271221088771e-17
Tekmessa	604	2000604	4.6458511951546986e-17
Oceana	224	2000224	4.6384503227747140e-17
Genua	485	2000485	4.5881147721288083e-17
Palisana	914	2000914	4.4492831201915857e-17

Titania	593	2000593	4.3152660225791144e-17
Ulla	909	2000909	3.9646932614462939e-17
Semiramis	584	2000584	3.8849243156686706e-17
Alkmene	82	2000082	3.8285657667248552e-17
Eichsfeldia	442	2000442	3.7681035098461244e-17
Ampella	198	2000198	3.4690964938059876e-17
Praxedis	547	2000547	3.2890148523379750e-17
Phocaea	25	2000025	3.2560800200694920e-17
Irma	177	2000177	3.1948857613518979e-17
Amalthea	113	2000113	3.0819925205610637e-17
Iphigenia	112	2000112	3.0519626458450430e-17
Budrosa	338	2000338	2.8649827091745162e-17
Pariana	347	2000347	2.4842140182945907e-17
Ganymed	1036	2001036	2.1127616210185089e-17
Theobalda	778	2000778	2.0592519759347046e-17
Aethra	132	2000132	1.7504352843147015e-17
Irmgard	591	2000591	1.5650082930549903e-17
Echo	60	2000060	1.4826078565237201e-17
Lacadiera	336	2000336	1.4252117646877083e-17
Pythia	432	2000432	1.3601888558172924e-17
Peitho	118	2000118	1.3157171164548998e-17
Chimaera	623	2000623	1.0120911587092832e-17
Bilkis	585	2000585	9.5027260308642622e-18
Eros	433	2000433	9.9506001554648484e-19
Orcus	90482	2090482	9.4096246431561093e-14
2002 MS4	307261	2307261	7.6535017490671978e-14
2006 QH181		3361580	6.9916025897378817e-14
Salacia	120347	2120347	6.5117020793631265e-14
2003 UZ413	455502	2455502	6.4838580755817233e-14
2003 AZ84	208996	2208996	6.0821235283947692e-14
2002 AW197	55565	2055565	6.0247324245997600e-14
Haumea	136108	2136108	5.9616300545042843e-13
Varuna	20000	2020000	5.4950752234118650e-14
Ixion	28978	2028978	4.5176656225097590e-14
Varda	174567	2174567	3.9657768869641912e-14
2004 GV9	90568	2090568	3.7193502373824432e-14
2004 XA192	230965	2230965	3.6450226020091094e-15
2005 RN43	145452	2145452	3.6285479917789626e-14
Makemake	136472	2136472	3.4318555006292089e-13
2010 KZ39		3525142	2.9579875156960054e-14
2004 XR190		3308265	2.9040995181884837e-14
2001 UR163	42301	2042301	2.7251938920337723e-14
2007 JJ43	278361	2278361	2.6769158975337699e-14
Gonggong	225088	2225088	2.5856788277090390e-13
2010 FX86		3515022	2.5710342570810209e-14
Chaos	19521	2019521	2.5383796456297310e-14
Eris	136199	2136199	2.4854480302873160e-12
2002 TC302	84522	2084522	2.2819963431204538e-13
2008 ST291	528381	2528381	2.1338903510045792e-14

2010 RE64	523639	2523639	1.9128866968694360e-14
2002 UX25	55637	2055637	1.8603512445448687e-14
2010 RF43		3545742	1.7561425934907343e-14
Quaoar	50000	2050000	1.5294877459751145e-13
Sedna	90377	2090377	1.4934867884244863e-13