# Orbit assessment of DAMPE satellite

**Liang Chang [1, 2], Hu Jiang [1, 2, *] and Jiji Cai [1, 2]**

[1] Innovation Academy for Microsatellites, Chinese Academy of Sciences, Shanghai, 201304, China
[2] Shanghai Engineering Center for Microsatellites, Shanghai, 201304, China

[*] Corresponding author's e-mail: jiangh@microsate.com

**Abstract:** Dark Matter Particle Explorer (short for DAMPE) is one of the space missions innovated by the Chinese Academy of Sciences. Its scientific goals are to discover dark matter particles, study the characteristics of dark matter particles and their laws of space deployment, detect gamma rays, and find out the source's cosmic rays. The attainment of such goals will lead to great leaps in the frontiers of modern physics and astronomy. Based on precision orbit elements of DAMPE newly available, some main orbit elements were simulated. Further, with the help of SOCRATES Plus software, the close approach of DAMPE to the space objects was computed. The objects are singled out that may endanger the wholesomeness of the DAMPE.

## 1. Introduction

DAMPE is a famous spacecraft from China, launched into its working orbit by the end of the year 2015 [1]. The DAMPE aims at discovering dark matter particles, studying the characteristics of dark matter particles and their laws of space deployment, detecting Gamma rays, and finding out the sources of cosmic rays. There are four various detectors equipped in the satellite's main body, including a neutron detector, a silicon-tungsten tracker, a plastic scintillator array, and BGO calorimeter. Both payloads attached to DAMPE and the subsystems of the platform were turned out to be wholesome three years after its launch[2-4]. DAMPE has brought about many more fruitful results [5-7]. All scientific goals have been fully attained as of today [5, 8, 9, 10]. It might as well accumulate much more dataset before the scientists make more discoveries of the dark matter particles. To some degree, orbit stability is one of the focuses that might bring about even more fruitful achievements. The particular inertial pointing attitude of DAMPE makes its long stay in space. But it seems to have been decaying in orbit in recent years due to the maximal solar activities. To make sure when DAMPE will be destroyed by the Earth's dense atmosphere, it is necessary to grasp information on the precision orbit altitude. Herein, the problem of orbit decaying is put forward. To provide effective constraints for DAMPE's reentry decision-making, the orbit element changing and orbital safety for DAMPE are simulated in details.

## 2. Orbital changing and its safety

### *2.1. Orbit changes*

To grasp the orbital changing characteristics of DAMPE, by means of open access web resources [11], the three orbital parameters are derived，which include the orbital altitude, orbital eccentricity, and the orbit inclination.

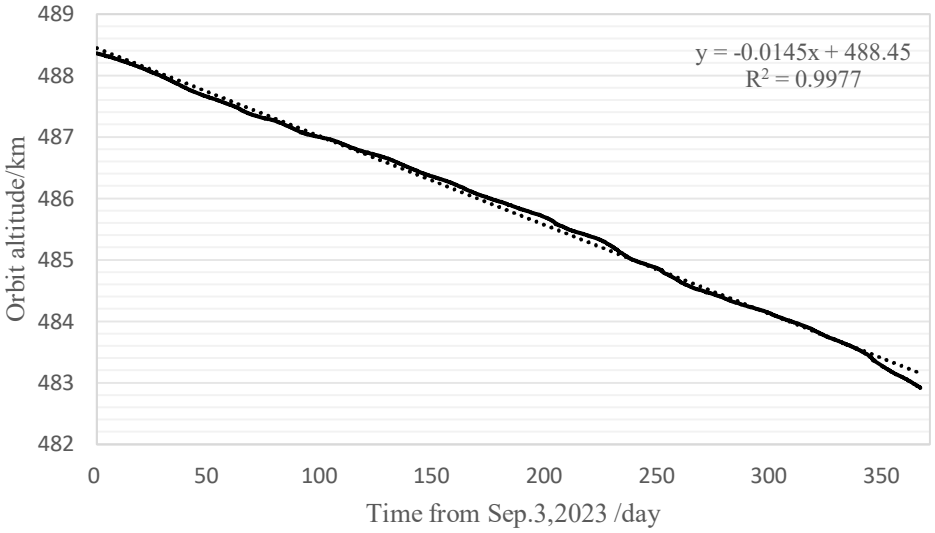


**Figure 1.** Orbital altitude changing from Sep. 3, 2023.

From Figure 1, it has shown that during the recent year from Sep. 03, 2023, to Sep. 02, 2024, the altitude for satellite DAMPE dropped from 488.4 km to 482.9 km. Orbital altitude changing rate is nearly -5.5 km per year. Orbit changing is mainly attributed to air drag and solar pressure perturbation. The recent years belong to maximal solar cycle years, which could have caused sharp changes in orbit altitude. The dotted line in Figure 1 is a fitted straight line for the orbit altitude changes during the recent year. It shows there is a rate of -0.0145 km/day for the orbit altitude change.

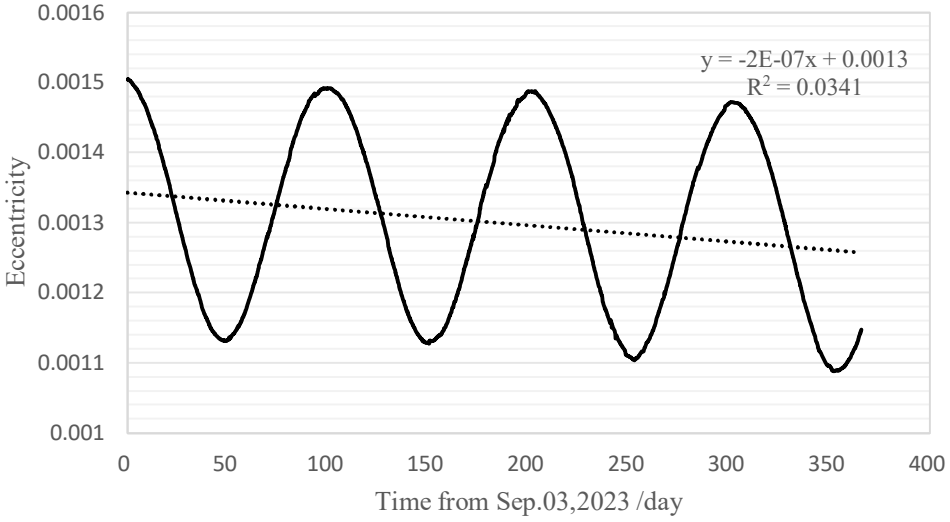


**Figure 2.** Orbital eccentricity changing since Sep. 03, 2023.

In Figure 2, it has shown eccentricity changing for satellite DAMPE has an apparent periodicity. The slope for eccentricity changing is about $-2\times10^{-7}$ per day. The eccentricity at the epoch Sep. 03, 2023, 02:12:32 UTC is about 0.0015.

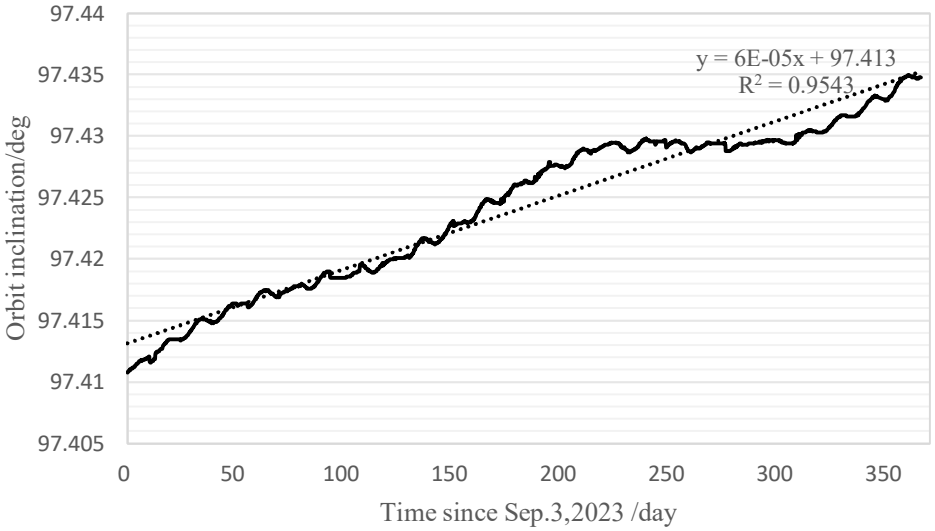


**Figure 3.** Orbital inclination changing since Sep. 03, 2023.

From Figure 3, it has shown that there is a secular uphill trend in inclination. The slope for the fitted straight line is $6\times10^{-5}$. The inclination is about 97.41 deg at the epoch of Sep. 03, 2023 02:12:32 UTC.

*2.2. Orbital safety assessment*

Among the computation [9], it is assumed that the computation interval ranges from 2024 Sep.03 16:00:00 UTC to 2024 Sep. 10 16:00:00 UTC. The computation threshold for the allowed separation between DAMPE and the other objects is 5.0 km. During the computation, the data set was then updated as of 2024 Sep. 03 16:05:35 UTC. During the computation, about 70, 000 conjunctions are considered. In each conjunction, position and velocity can be predicted in J2000 reference system for both DAMPE satellite and the opposite object; and the minimum range could be derived by $\mathrm{Min}(\sqrt{(x_j - x_D)^2 + (y_j - y_D)^2 + (z_j - z_D)^2})$, where $(x_j, y_j, z_j)$ are the coordinates for the object j and $(x_D, y_D, z_D)$ are the coordinates of the DAMPE. The detailed results are presented in Table 1.

**Table 1.** Space conjunctions between DAMPE and other objects.

| NORAD catalog number | Object name [Ops status] | Time of closest approach /UTC | Minimum range/Km | Maximum probability | Relative speed (km/s) |
|---|---|---|---|---|---|
| 56851 | OBJECT F [+] | 2024-09-08 11:29:40.353 | 0.201 | 8.875E-05 | 9.376 |
| 56847 | OBJECT B [+] | 2024-09-07 22:55:04.696 | 0.742 | 6.509E-06 | 9.440 |
| 58552 | STARLINK-31046 [+] | 2024-09-04 04:21:35.308 | 1.217 | 4.640E-05 | 13.861 |
| 48916 | ICEYE-X13 [+] | 2024-09-06 09:53:19.146 | 1.563 | 7.858E-07 | 14.548 |
| 43236 | LKW-4 [+] | 2024-09-10 12:10:01.268 | 1.740 | 6.994E-07 | 14.187 |
| 46126 | STARLINK-1619 [P] | 2024-09-10 | 1.890 | 3.465E-05 | 6.080 |

| | | | | | |
|---|---|---|---|---|---|
| | | 02:30:26.139 | | | |
| 48964 | SPARTAN [+] | 2024-09-09 00:45:13.441 | 2.473 | 3.000E-07 | 14.691 |
| 59269 | STARLINK-31609 [+] | 2024-09-09 16:23:39.598 | 2.586 | 1.728E-05 | 8.088 |
| 43887 | LEMUR-2-NATALIEMURRAY [+] | 2024-09-10 07:33:49.116 | 3.021 | 3.902E-07 | 9.561 |
| 58797 | STARLINK-31193 [+] | 2024-09-04 20:32:22.600 | 3.423 | 5.763E-06 | 13.938 |
| 59768 | STARLINK-31826 [+] | 2024-09-06 03:17:30.352 | 3.634 | 4.159E-06 | 14.754 |
| 60104 | STARLINK-32009 [+] | 2024-09-09 14:32:58.553 | 3.792 | 3.910E-06 | 14.683 |
| 58798 | STARLINK-31168 [+] | 2024-09-06 13:23:06.833 | 3.839 | 4.888E-06 | 13.600 |
| 57845 | STARLINK-30419 [+] | 2024-09-05 17:40:46.665 | 4.049 | 6.771E-06 | 8.990 |
| 57938 | STARLINK-30710 [+] | 2024-09-06 07:56:44.777 | 4.525 | 2.750E-06 | 14.674 |
| 59267 | STARLINK-31579 [+] | 2024-09-07 04:37:16.754 | 4.529 | 5.852E-06 | 7.089 |
| 57937 | STARLINK-30400 [+] | 2024-09-05 22:33:50.731 | 4.622 | 2.576E-06 | 14.747 |
| 59014 | STARLINK-31454 [+] | 2024-09-06 16:06:00.963 | 4.671 | 3.181E-06 | 13.809 |
| 58031 | STARLINK-30556 [+] | 2024-09-06 03:32:28.028 | 4.742 | 3.386E-06 | 13.274 |
| 60104 | STARLINK-32009 [+] | 2024-09-09 12:58:46.208 | 4.845 | 2.392E-06 | 14.688 |
| 43521 | CZ-2C R/B [-] | 2024-09-10 13:19:04.048 | 4.934 | 1.497E-07 | 9.103 |

Table 1 shows that there are 21 space objects, which may approach to satellite DAMPE within a 5 km distance. The upper probability is 8.875E-05, which takes place at 2024-09-08 11:29:40.353 between DAMPE and OBJECT F [+]; and the least probability is 1.497E-07, which happens at 2024-09-10 13:19:04.048 between DAMPE and CZ-2C R/B [-]. The nearest conjunction of DAMPE with another space object happened at 2024-09-08 11:29:40.353, and the opposite object is OBJECT F [+]; the probability is 8.875E-05 or so.

## 3. Conclusions

According to the orbital changing characteristics and orbital safety assessment, authors come to some conclusions as followings. The altitude for DAMPE has decreased by 5.5 km in the past year. The orbital altitude changing rate is -5.5 km per year or so. Orbital changing is mainly attributed to solar pressure and air drag effects. The eccentricity changing rate is about $-2\times10^{-7}$ per day. The inclination changing slope for the fitted straight line is $6\times10^{-5}$. There are 21 space objects, which approach to DAMPE within a 5 km separation. More frequent monitoring of space objects is quite necessary and impending so as to prevent DAMPE from collision in space.

## Acknowledgments

The task for this research are fulfilled with the help of the online software SOCRATES Plus. We are sincerely grateful to Kelso T.S. for his online data sets.

## References

[1] Gibney E., Biever C. and Castelvecchi D. (2015). China's dark-matter satellite launches era of space science. Nature 528, 443-444. https://doi.org/10.1038/nature.2015.19059.
[2] Jiang W., Li X., Duan K. K., et al. (2020). The boresight alignment of the DArk Matter Particle Explorer Res. Astron. Astrophys. 20, 092. https://doi.org/10.1088/1674-4527/20/6/92.
[3] Wang S. X., Zang J. J., Jiang W., et al. (2022). A Study on Monte Carlo Simulation of the Radiation Environment above GeV at the DAMPE Orbit, Res. Astron. Astrophys. 22, 045011. https://doi.org/10.1088/1674-4527/ac550e.
[4] Huang Y. Y., Ma T., Yue C., et al. (2020). Calibration and performance of the neutron detector onboard of the DAMPE mission, Res. Astron. Astrophys. 20, 153. https://doi.org/10.1088/1674-4527/20/9/153.
[5] Ambrosi G., An Q., Asfandiyarov R., et al. (2017). Direct detection of a break in the teraelectronvolt cosmic-ray spectrum of electrons and positrons. Nature 552, 63-66. https://doi.org/10.1038/nature24475.
[6] Alemanno F., An Q., Azzarello P., et al. (2021). Observations of Forbush Decreases of Cosmic-Ray Electrons and Positrons with the Dark Matter Particle Explorer ApJL 920 L43. https://doi.org/10.3847/2041-8213/ac2de6.
[7] Zhang P. P., He X. Y., Liu W., et al. (2023). Evidence of fresh cosmic ray in galactic plane based on DAMPE measurement of B/C and B/O ratios, JCAP02 007. https://doi.org/10.1088/1475-7516/2023/02/007.
[8] Parenti A. On behalf of the DAMPE collaboration (2023). Galactic cosmic rays: latest results from the DAMPE mission, J. Phys.: Conf. Ser. 2429 012003. https://doi.org/10.1088/1742-6596/2429/1/012003.
[9] Fang K., Bi X. J. and Yin P. F. (2020). DAMPE Proton Spectrum Indicates a Slow-diffusion Zone in the nearby ISM, APJ 903 69. https://doi.org/10.3847/1538-4357/abb8d7.
[10] Chang J. (2024). Recent Progress of the DAMPE Mission. Chinese Journal of Space Science, 44 (4): 633-642. https://doi.org/10.11728/cjss2024.04. 2024-yg11.
[11] Kelso T. S. (2024). SOCRATES Plus Search Form. https://celestrak.org/SOCRATES/search.php.