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An Update on the Future Flyby of Gliese 710 to the Solar System Using *Gaia* DR3: Flyby Parameters Reproduced, Uncertainties Reduced

Raúl de la Fuente Marcos [1] and Carlos de la Fuente Marcos [2]

[1] *AEGORA Research Group*
Facultad de Ciencias Matemáticas
Universidad Complutense de Madrid
Ciudad Universitaria, E-28040 Madrid, Spain
[2] *Universidad Complutense de Madrid*
Ciudad Universitaria, E-28040 Madrid, Spain

ABSTRACT

Charting the near-future motion of known stars through the Galaxy, none will pass closer to the Sun than Gliese 710. Here, we present an updated analysis of this upcoming flyby using *Gaia* DR3 data as well as the latest planetary ephemerides. Our new estimate reproduces the nominal values of those already published, but with reduced associated uncertainties. The distribution of distances of closest approach has a median value of 0.052 pc with a 90% probability of coming within 0.048–0.056 pc of the Sun; the associated time of perihelion passage is determined to be between 1.26–1.33 Myr with 90% confidence, with a most likely value of 1.29 Myr.

Keywords: Stellar kinematics, Solar neighborhood, Solar system

The outskirts of the solar system might be disturbed by future stellar encounters with the Sun, but only if they result in close-enough passages. Such flybys may send small bodies hurtling towards the inner regions of the solar system (see e.g. Dybczyński & Królikowska 2022). Out of all the future encounters between known stars and the solar system, none will be closer than that of Gliese 710 (also known as GJ 710 or HD 168442), a K7V star located 19 pc from the Sun in the constellation of Serpens Cauda (Gray et al. 2006). This upcoming flyby was first noticed more than two decades ago by García-Sánchez et al. (1999) and confirmed later by several independent studies (Matese & Lissauer 2002; Bobylev 2010; Feng & Bailer-Jones 2015) prior to the release of the first *Gaia* data. Berski & Dybczyński (2016) gave the first estimate of the parameters of this encounter using *Gaia* DR1 data, followed by Bailer-Jones (2018). More satisfactory results based on *Gaia* DR2 were obtained by Bailer-Jones et al. (2018), de la Fuente Marcos & de la Fuente Marcos (2018), Bobylev & Bajkova (2020), and Jiménez-Torres (2020). The release of *Gaia* EDR3 led to further improvements in the predicted values of the timing and depth of this encounter (de la Fuente Marcos & de la Fuente Marcos 2020; Bobylev & Bajkova 2021; Dybczyński & Królikowska 2022).

Gaia DR3 (Gaia Collaboration et al. 2016, 2022) provides, among other data, right ascension and declination, absolute stellar parallax, proper motions in right ascension and declination (all referred to epoch 2016.0 or 2457388.5 TDB), spectroscopic radial velocity, and their respective standard errors for over 3.38×10^7 sources. Out of these data, only radial velocities represent an improvement with respect to those in *Gaia* EDR3 as their uncertainties have often been reduced (Katz et al. 2022). Here, we have used input data from *Gaia* DR3 and barycentric Cartesian state vectors for the solar system —provided by Jet Propulsion Laboratory's HORIZONS[1] and based on the new DE440/441 planetary ephemeris (Park et al. 2021), and retrieved using resources from the Python package Astroquery (Ginsburg et al. 2019)— to revisit the topic of the future flyby of Gliese 710 to the solar system. Gliese 710 is designated *Gaia* DR3 4270814637616488064 and has parallax of 52.3963±0.0171 mas (*Gaia* DR2's was

Corresponding author: Raúl de la Fuente Marcos
rauldelafuentemarcos@ucm.es

[1] https://ssd.jpl.nasa.gov/?horizons

52.5185±0.0478 mas), proper motions in right ascension of −0.414±0.019 mas/yr (−0.460±0.084 mas/yr) and declination of −0.108±0.017 mas/yr (−0.028±0.073 mas/yr), and radial velocity of −14.42±0.26 km/s (−14.53±0.44 km/s).

In order to improve our understanding of this upcoming flyby, we have carried out N-body simulations using the integration tools already applied to research this topic by de la Fuente Marcos & de la Fuente Marcos (2018, 2020), namely software developed by Aarseth (2003)[2] that implements the Hermite integration scheme described by Makino (1991). Details of this software used within the context of studying the long-term dynamical evolution of the solar system can be found in de la Fuente Marcos & de la Fuente Marcos (2012). The physical model considers the perturbations from the Sun, the four most massive planets, the barycenter of the Pluto-Charon system, and Gliese 710 (with an assumed mass of 0.6 $M_{\odot}$).

Figure 1 shows the results of 10^4 integrations of control orbits of Gliese 710 generated using data from *Gaia* DR3. We focus on providing an estimate of the value of the distance of closest approach and its associated time of perihelion passage. The distribution of times is shown in the top-left panel, the mean and standard deviation are 1.29±0.02 Myr; the median value is 1.29 Myr and 1.26–1.33 Myr is the 90% confidence interval. The distribution of distances of closest approach in the top-right panel has a mean and standard deviation of 0.052±0.002 pc (or 10 635±500 au, median of 10 633 au) with a 90% probability of coming within 0.048–0.056 pc (<0.057 pc, 99%) that places Gliese 710 inside the inner Oort cloud (see e.g. Hills 1981). Figure 1, bottom panels, shows that faster approaches tend to produce earlier and closer flybys. However, the effects of the flyby on the orbit of the Pluto-Charon system (and therefore, on the classical trans-Neptunian belt) are still negligible.

Our results are remarkably similar to those obtained by Dybczyński & Królikowska (2022) although these authors consider the Galactic tidal field. The neglect of the Galactic potential may not have significant effects on our results as they are based on integrations forward in time for 1.5 Myr while the Sun takes ∼220 Myr to complete one revolution around the center of the Galaxy. Our new estimate is consistent with the nominal values of those previously published but reducing the associated uncertainties.

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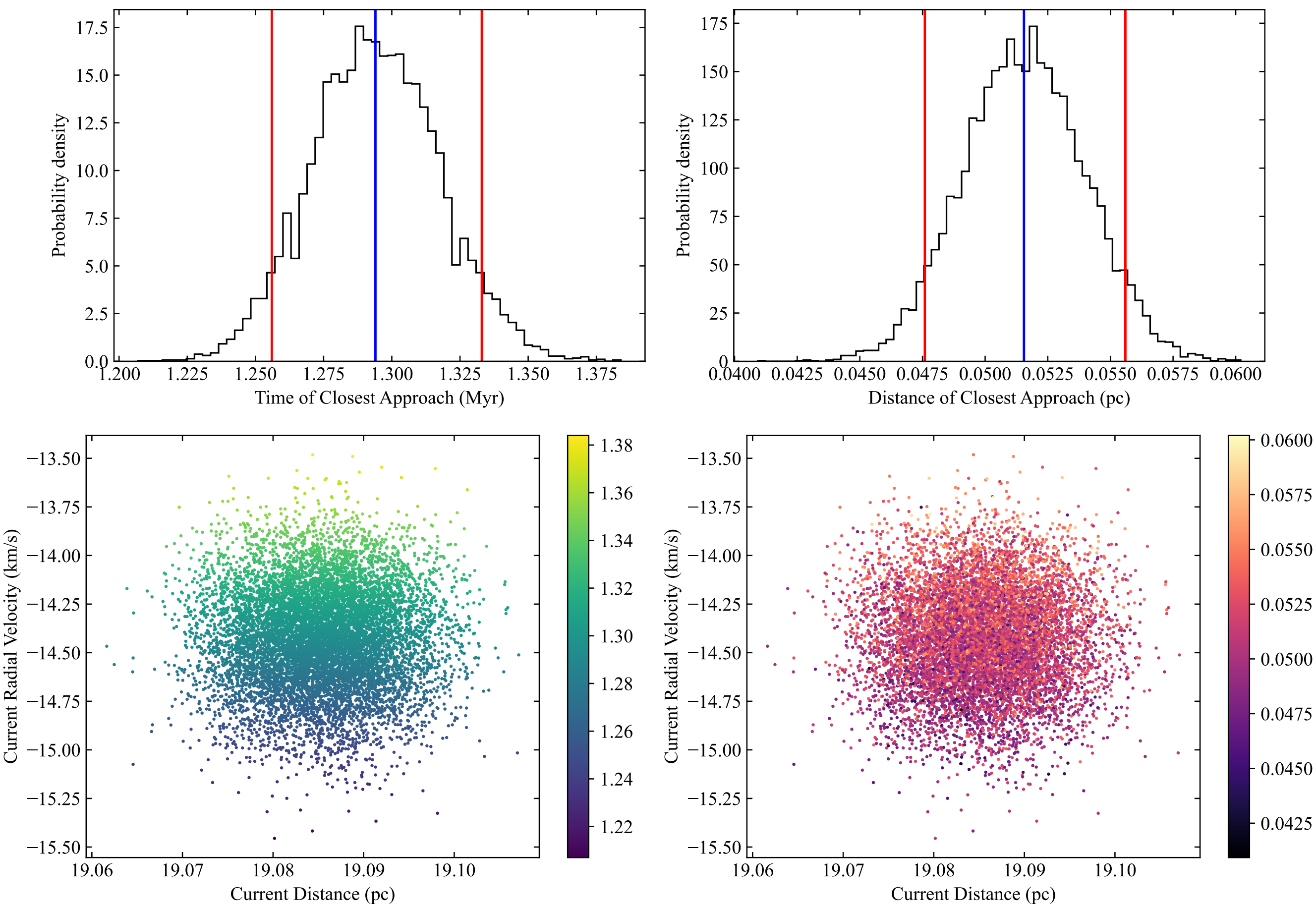

Figure 1. Future perihelion passage of Gliese 710 as estimated from *Gaia* DR3 input data and the N-body simulations discussed in the text. The distribution of times of perihelion passage is shown in the top-left panel and perihelion distances in the top-right one. The blue vertical lines mark the median values, the red ones show the 5th and 95th percentiles. The bottom panels show the times of perihelion passage (bottom-left) and the distance of closest approach (bottom–right) as a function of the observed values of the radial velocity of Gliese 710 and its distance (randomly generated using the mean values and standard deviations from *Gaia* DR3), both as color coded scatter plots of the distribution in the associated top panel. Histograms have been produced using the Matplotlib library (Hunter 2007) with sets of bins computed using Numpy (Harris et al. 2020) by applying the Freedman and Diaconis rule; instead of considering frequency-based histograms, we used counts to form a probability density so the area under the histogram will sum to one. The colormap scatter plot has also been produced using Matplotlib.

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