Matching the activity of comet 67P/Churyumov-Gerasimenko with long-term ground-based astrometry

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50 years of astrometric data for comet 67P/C-G (orbital period about 6.45 years) provides a unique opportunity to benchmark non-gravitational acceleration models to the in situ measurements of the volatile release performed from the Rosetta rendezvous mission (2014-2016). Taken together, the Earth-bound and in-situ data yields lower fit errors and serves as a test-case for our ability to deduce thermo-physical quantities of cometary nuclei from the Earth-bound observations.

Introduction

The long-term monitoring of orbital changes of periodic comets provides limits on the non-gravitational forces arising from the sublimation of icy volatiles on cometary nuclei. For comet 67P/C-G various orbit reconstructions have been published [1], the ESOC/Flight Dynamics (FD) data [2,3], and the combined radar-ranging ground-based astrometry fit to MPEC data [4,5].

Here, we consider a model for the non-gravitational accelerations (NGA) for comet 67P/C-G including the available MPEC observations from 1969 up to the year 2018. For the duration of the Rosetta mission around comet 67P/C-G (2014-2016), the NGA can be compared to the observed outgassing as probed by the in situ Rosetta COPS/DFMS instruments [6,7,8]. We retrieve several thermophysical properties of the nucleus from the NGA analysis, including the diurnal thermal lag angle and the seasonal progression of the sub-solar latitude.

During the Rosetta mission comet 67P/C-G displayed remarkable repetitive diurnal and seasonal variations for dust and gas emission, which resulted in a highly predictable near-nucleus dust-coma [9,10]. While around perihelion several outbursts have been observed [11] from nucleus locations with a higher volatile content [6,7], the overall activity of comet 67P/C-G is largely regular and follows the seasonal illumination patterns [8]. The known orientation of the rotation axis of comet 67P/C-G and the minor orientation changes induced by the outgassing [12,13] allow one to extrapolate the derived NGA from 2014-2016 [1] back several decades up to the first observations in 1969 and to predict the orbit for the upcoming apparition.
Rotating jet model

Here, we propose a refined set of rotating jet parameters compared to [5], which more closely follows the NGA extracted by [1] and covers all observed 7 revolutions of 67P/C-G. We provide a prediction for the upcoming 2021/22 apparition. The accurate orbit analysis of comet 67P/C-G serves as a reference case for description of NGA acting on cometary nuclei [14].

The favorable Earth-comet geometry of the 1982/82 apparition (left panel, Fig. 1) provides strong constraints on the NGA, where trajectory errors of about 30000 km perpendicular to the line-of-sight result in astrometric errors in the order of 100 arcsec. A similar viewing geometry occurs in 2021/22 and allows us to test the performance of activity models based on thermophysical properties of the nucleus.

Conclusion

The case of comet 67P/C-G shows the achievable precision of the orbit reconstruction by connecting space-craft observations and long-term Earth based astrometry. We expect that also for other comets with known rotation-axis the RJM provides a good tool to constrain the water production and to improve the models upon the standard Marsden parameters. A promising example is comet 46P/Wirtanen, where the rotational state is well known [15], in addition to the shape information from radar observations. The (dis)similarities of the two RJM discussed here shows the maximum accuracy to be expected from such parametrizations. In general additional fit parameters tend to yield better agreement between models and observations. For comet 67P/C-G we find improved volatile production based on thermo-physical models compared to the asymmetric g(r) Marsden model.

Acknowledgments

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References

[1] T. Kramer and M Läuter. Outgassing-induced acceleration of comet 67P/Churyumov-


