EPSC Abstracts
Vol. 11, EPSC2017-877, 2017
European Planetary Science Congress 2017

A dynamical study on extrasolar comets

B. Loibnegger (1) and R. Dvorak (1)
(1) Department of Astrophysics, University of Vienna, Vienna, Austria (birgit.loibnegger@univie.ac.at)

Abstract

Since the detection of absorption features in spectra of β Pictoris varying on short timescales it is known that comets exist in other stellar systems ([1]). In our work we assume the existence of an Oort Cloud like structure around other stars with planetary systems. Collisions of the comets with the planets, close encounters and captures can occur. The different architecture of the systems plays an important role in the outcome of the scattering process, which is why we chose two differently build systems, namely HD 10180 and HIP 14810 for our investigations. We show the influence of the most massive planet on the orbit of captured comets respectively on the collision frequency with the planets and statistics of stable orbits of comets and find that the orbital properties of the most massive planet in the system indeed have an influence on the interaction with the small bodies.

1. Introduction

Evidence for cometary activity in other planetary systems was first found in the analysis of spectra of β Pictoris (e.g.,[1, 6]). They found a large number of metallic absorption lines varying on short time scales which were interpreted as clouds of gas and dust obscuring the light of the star produced by so called falling evaporating bodies. Observations of other star systems yielded the same absorption features, as for example HD 21620, HD 42111, HD 110411, and HD 145964. These transient absorption features were discovered around mainly young ($\sim$ 5 Myr) A-type stars during a campaign by Welsh and Montgomery ([9]) and showed radial velocities in the range of $\pm$ $100\mathrm{km\,s^{-1}}$. Nilsson et al. (2010) observed 22 exo-Kuiper-belt candidates in five exo-systems and they argue that leftover planetesimal belts are common since dust has a limited lifetime, and observations which proof its existence lead to the assumption that there are larger asteroidal and/or cometary bodies that continuously renew the amount of dust and form dusty debris disks through collisions ([7]).

The study of exocomets is also closely related to the possible habitability of terrestrial planets in extrasolar systems, as comets are able to deliver both liquid water and basic organic substances from regions beyond the snowline to the inner parts of planetary systems (see for example observational results for the Solar System comet 67P/Churyumov-Gerasimenko based on Rosetta (e.g., [8]).)

2. Method and Setup

In order to answer questions about the dynamics of comets in extrasolar systems we did massive n-body calculations with induced thousands of massless cometary bodies dispersed in a sphere around the planetary systems. The n-body calculations have been done with the Lie-Integrator [5] with the planets treated as point masses and the ability of treating close encounters of the comets with the planets with very high accuracy due to the adaptive step-size control. The used systems HD 10180 and HIP 14810 were chosen from *http:// exoplanet.eu/* because of their differences in architecture. HD 10180 is a Sun-like star with 1.06 $\pm$ 0.05 M_{Sun} and has 6 confirmed planets with the most massive one, HD 10180 h, orbiting outside of all the others. HD 10180 h has a mass of 0.21 $M_{Jupiter}$ and semi-major axis of 3.4 AU. HIP 14810 has m = 0.99 $\pm$ 0.04 M_{Sun}. Its planetary system is built the other way round: the most massive planet HIP 14810 b (m = 3.88 $M_{Jupiter}$) at $\sim$ 0.07 AU, with the less massive two other planets orbiting outside of it. The comets stemming from an Oort Cloud like structure around the systems are assumed to have been disturbed by a passing star long time ago and are on their way inward towards the central star on nearly hyperbolic orbits [3, 4]. The comets are started evenly distributed in a spherical structure extending from 90 to 150 AU in the system of HD 10180 and semi-major axis of initially between 30 to 80 AU for HIP 14810 with an eccentricity between 0.91 and 0.99. Integrations of the systems were carried out for a total time of 1 Myr.

3. Results

Due to interactions with the planets comets could either be ejected from the system or stay in the system ("capture"). We show the number of comets ending up in close in stable orbits after the 1 Myr of computations for the two systems according to the initial inclination (see fig1). One can observe that for the system of HD 10180, where in general the planets are farther away from the star, the capture on orbits with low values of eccen- tricity and semi-major axis is only possible for comets with low inclination with respect to the orbital plane of the system. For HIP 14810 captures happen for all inclinations of the comets.

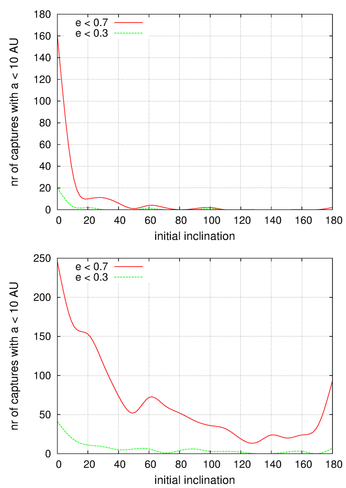

Figure 1: The upper panel shows the number of comets captured on orbits with low eccentricity and semi-major axis for the system HD 10180 ($a_{inital,comet}$= 90AU). The lower panel shows the same for HIP 14810 ($a_{inital,comet}$= 50AU). In the system of HIP 14810 captures are possible for all initial inclinations of the comets.

4. Summary and Conclusions

We can conclude, that the architecture of the system has an influence on the interaction of the planets with the comets. The main influence on the encounter and capture frequency is the value of the semi-major axis of the planets. The closer in a planets orbits, the faster it is and thus the more close encounters with comets it suffers. With collisions it seems to be the other way round. The outer a planet orbits from the star, the more collisions with comets it experiences. This is the same for both systems shown in this study. Nevertheless collisions and encounters are more probable to happen with comets with low initial inclination. For planets farther out this is even more important, as we could observe, that for the closely packed system of HIP 14810 captures of comets is possible for almost all initial inclinations.

Acknowledgements

B.L. and R.D. wish to acknowledge support by the FWF Austrian Science Fund project S11603-N16.

References

[1] Beust, H., Vidal-Madjar, A., Ferlet, R., & Lagrange-Henri, A.-M.: The inner part of the protoplanetary disk around Beta Pictoris, ESA Special Publication, p315, 1990.

[2] Dones, L., Brasser, R., Kaib, N., & Rickman, H.: Origin and Evolution of the Cometary Reservoirs, Space Science Reviews, Volume 197, Issue 1-4, pp. 191-269, 2015.

[3] Duncan, M. J., Brasser, R., Dones, L., & Levison, H. F.: The Role of the Galaxy in the Dynamical Evolution of Transneptunian Objects, The Solar System Beyond Neptune, p.315-331, 2008.

[4] Fouchard, M., Froeschlé, C., Rickman, H., & Valsecchi, G. B.: The key role of massive stars in Oort cloud comet dynamics, Icarus, Volume 214, Issue 1, p. 334-347, 2011.

[5] Hanslmeier, A., & Dvorak, R.: Numerical Integration with Lie Series, Astronomy and Astrophysics, Vol. 132, p. 203, 1984.

[6] Kiefer, F., Lecavelier des Etangs, A., & Vidal-Madjar, A.: Exocomets in the disk of two young A-type stars, SF2A-2014: Proceedings of the Annual meeting of the French Society of Astronomy and Astrophysics, p. 39-43, 2014.

[7] Nilsson, R., Liseau, R., Brandeker, A., et al.: Kuiper belts around nearby stars, Astronomy and Astrophysics, Volume 518, 15 pp, id.A40, 2010.

[8] Rickman, H., Marchi, S., A'Hearn, M. F., et al.: Comet 67P/Churyumov-Gerasimenko: Constraints on its origin from OSIRIS observations, Astronomy & Astrophysics, Vol. 583, id.A44, 8 pp, 2015.

[9] Welsh, B., & Montgomery, S. L.: Exo-comet Detection in Debris Disks Around Young A-type Stars, American Astronomical Society Meeting Abstracts #221, id. 109.03, 2013.