



Universiteit
Leiden
The Netherlands

Dynamics of the Oort cloud and formation of interstellar comets

Torres Rodriguez, S.

Citation

Torres Rodriguez, S. (2020, April 30). *Dynamics of the Oort cloud and formation of interstellar comets*. Retrieved from <https://hdl.handle.net/1887/87515>

Version: Publisher's Version

License: [Licence agreement concerning inclusion of doctoral thesis in the Institutional Repository of the University of Leiden](#)

Downloaded from: <https://hdl.handle.net/1887/87515>

Note: To cite this publication please use the final published version (if applicable).

Cover Page



Universiteit Leiden



The handle <http://hdl.handle.net/1887/87515> holds various files of this Leiden University dissertation.

Author: Torres Rodriguez, S.

Title: Dynamics of the Oort cloud and formation of interstellar comets

Issue Date: 2020-04-30

Cover:

-Design: Santiago Torres Rodríguez

-Advisor: Christian Chávez López

-Image credit: NASA, ESO, ESA, Science Photo Library

ISBN: 978-94-028-2033-1

Dynamics of the Oort Cloud and Formation of Interstellar Comets

Proefschrift

ter verkrijging van
de graad van Doctor aan de Universiteit Leiden,
op gezag van Rector Magnificus prof.mr.C.J.J.M. Stolker,
volgens besluit van het College voor Promoties
te verdedigen op donderdag 30 april 2020
klokke 13:45 uur

door

Santiago Torres Rodríguez
geboren te Mexico City
in 1987

Promotor:	Prof. dr. Simon Portegies Zwart	(Sterrewacht Leiden)
Co-promotor:	Dr. Anthony Brown	(Sterrewacht Leiden)

Promotiecommissie:	Prof. dr. H.J.A. Rottgering	(Sterrewacht Leiden)
	Prof. dr. I.A.G. Snellen	(Sterrewacht Leiden)
	Prof. dr. M.R. Hogerheijde	(Sterrewacht Leiden/UvA)
	Dr. R.A. Capuzzo Dolcetta	(Sapienza University of Rome)
	Dr. J. Zuluaga	(University of Antioquia)

To Bárbara

L'ordre est le plaisir de la raison, mais le désordre est le délice de l'imagination.
—Paul Claudel, 1929.

Contents

1	Introduction	1
1.1	Comets	5
1.1.1	Short period comets	5
1.1.2	Long period comets	6
1.1.3	Interstellar comets	10
1.2	Methods and data	12
1.2.1	Gaia	12
1.2.2	AMUSE	13
1.3	Thesis	17
2	The origin of interstellar asteroidal objects like 1I/2017 U1 'Oumuamua	23
2.1	Introduction	25
2.2	'Oumuamua as a rare object	26
2.2.1	Observational constraints	26
2.2.2	Dynamical ejection from the Sun's Oort cloud	27
2.2.3	Origin from the Oort cloud of another star	28
2.2.4	Origin from the debris disc of another star	29
2.3	Where did 'Oumuamua come from	30
2.3.1	An origin from the solar neighbourhood	30
2.3.2	An origin from beyond the solar neighbourhood	31
2.4	Discussion and conclusions	36
3	Galactic tide and local stellar perturbations on the Oort cloud: creation of interstellar comets	39
3.1	Introduction	41
3.2	Model for stellar encounters	44
3.2.1	Analytic model	44
3.2.2	Perturbations on the Oort cloud	46
3.3	Close encounters with the solar system	48
3.3.1	Observational model	49
3.3.2	Stellar encounters with the Solar System	53
3.3.3	The case of GJ 710/HIP 89825	58

Contents

3.4	Dynamical evolution of the Oort cloud	61
3.4.1	Numerical model	61
3.4.2	Galactic tide and Gaia star perturbation	63
3.5	Summary and Conclusions	70
4	Dynamical evolution of the solar system debris disk in its birth cluster	75
4.1	Introduction	77
4.2	Numerical implementation	79
4.3	Effect of stellar encounters on the early solar system	82
4.3.1	Extended models	82
4.3.2	Compact models	97
4.3.3	Extended vs compact models and the Oort cloud	110
4.4	Interstellar objects	111
4.5	Summary and Conclusions	114
5	Dynamical evolution of exo-Oort clouds around the Sun's closest neighbour stars due to local stellar perturbations and the Galactic tidal field	117
5.1	Introduction	119
5.2	Close stellar encounters experienced by the Sun's nearest neighbours	121
5.3	Dynamical evolution of exo-Oort clouds of the Sun's neighbour stars	132
5.3.1	TICs/ISOs in the solar neighbourhood	141
5.4	Summary and Conclusions	142
	Bibliography	147
	Summary	157
	Resumen	163
	Samenvatting	169
	List of publications	175
	Curriculum Vitae	179
	Acknowledgements	183

