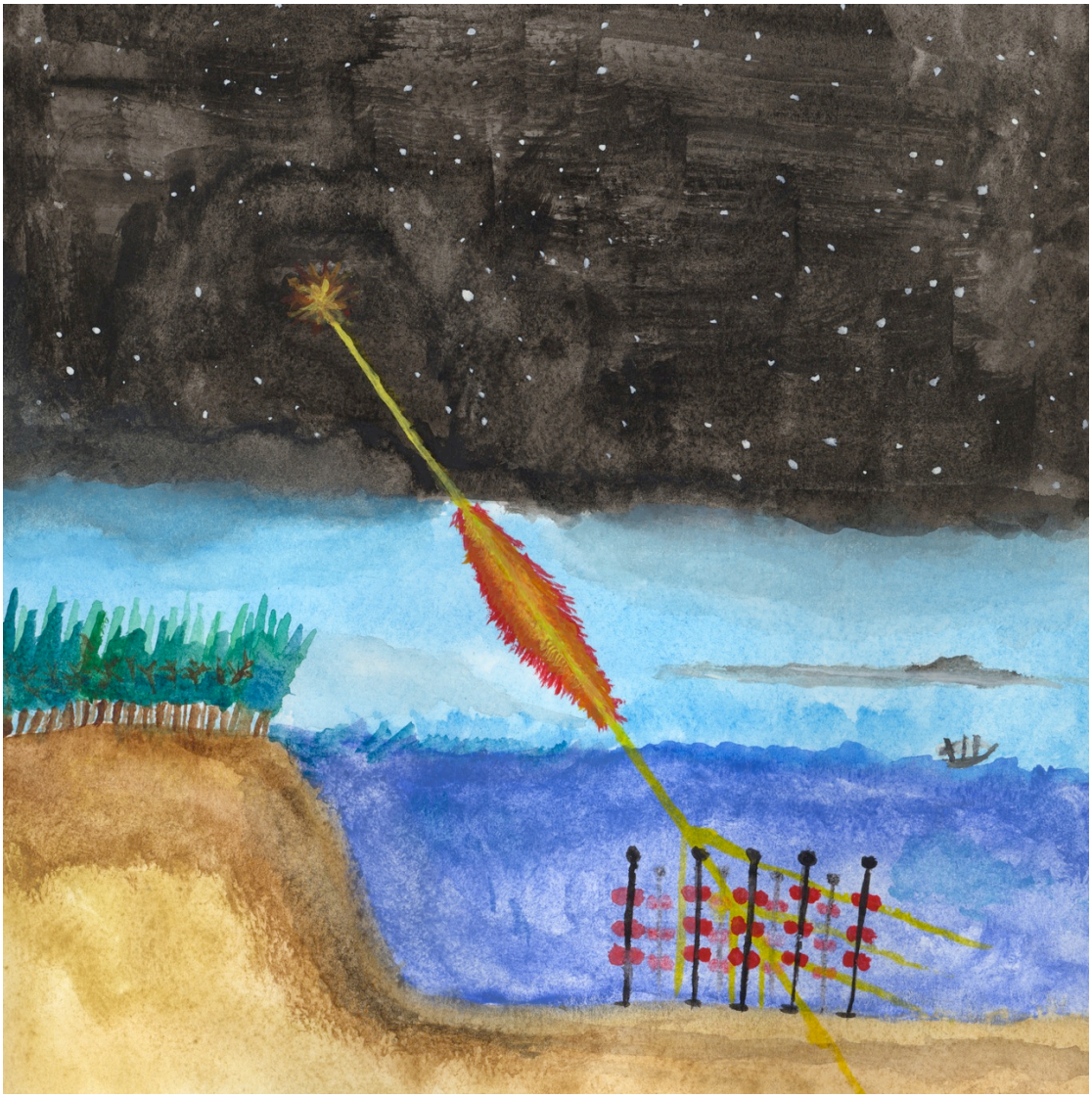
Starlight beneath the waves : in search of TeV photon emission from Gamma-Ray Bursts with the ANTARES Neutrino Telescope

Laksmana-Astraatmadja, T.

Starlight beneath the waves



Frontispiece: An illlustration of the physical processes described in this dissertation. A Gamma-Ray Burst (GRB) emits high-energy γ-rays towards the Earth. Depending on the distance to the GRB and the energy of the γ-ray, some of them will get annihilated by the cosmic infrared background. Those that survive will initiate electromagnetic showers in the atmosphere, producing some amount of muons. The muons then penetrate the sea, losing their energy along the way. As the muons traverse the sea, electromagnetic shock-waves will be generated in the form of Čerenkov photons. These photons will then be detected as signals by the array of photomultiplier tubes that comprise ANTARES. Illustration by the author.

Starlight beneath the waves

In search of TeV photon emission from Gamma-Ray Bursts with the ANTARES Neutrino Telescope

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 dinsdag 26 maart 2013
klokke 11.15 uur

door

Tri Laksmana Astraatmadja
geboren te Djakarta, Indonesië
in 1981

Promotiecommissie

Promotor:	Prof. dr. M. de Jong
Overige leden:	Prof. dr. A. Achúcarro
	Prof. dr. ing. J. F. J. van den Brand (Vrije Universiteit Amsterdam)
	Prof. dr. E. R. Eliel
	Prof. dr. P. M. Kooijman (Universiteit van Amsterdam)
	Dr. A. Kouchner (Université Paris Diderot – Paris VII, Parijs)
	Prof. dr. K. H. Kuijken
	Dr. K. E. Schalm
	Prof. dr. R. A. M. J. Wijers (Universiteit van Amsterdam)

Casimir PhD series, Delft-Leiden 2012-33
ISBN 978-90-8593-146-1
First published in print format 2013

Cover image: An artist's impression of a Gamma-Ray Burst (GRB), by A. Roquette (ESO)
Cover design by Fitorio Leksono

Typeset by the author using the Tufte-LaTeX class developed by Kevin Godby
`http://tufte-latex.googlecode.com`

Printed in The Netherlands by Ipskamp Drukkers B.V., Enschede

Dit is zeker echt niets nieuws
dit smalle pad is al vaak betreden
alleen deze keer
is het om de weg uit te stippelen.

Aarde der Mensen
Pramoedya Ananta Toer

Dedicated to the next generation
Putri Mahalia
and
Aria Widiadana Astraatmadja

Contents

Preface

This booklet is a doctoral dissertation which came out as a result of four years of research conducted at the National Institute for Subatomic Physics (Nikhef) in Amsterdam, The Netherlands. Some of the text written in this dissertation is based on the following material:

- Astraatmadja T. L. 2011. *On the detection of TeV γ-rays from GRB with km^3 neutrino telescopes — I. Muon event rate from single GRBs*. **MNRAS**, **418**: 1774–1786 (Sections 1.5, 2.2–2.3, 3.1–3.6, Chapter 4)

- Astraatmadja T. L., 2012a, *On the detection of TeV γ-rays from GRB with km^3 neutrino telescopes: ANTARES's responses to downgoing muons*. Technical Report ANTARES-PHYS-2012-005 (Section 3.7, Chapters 7–10)

- Astraatmadja T. L., 2012b, *On the detection of TeV γ-rays from GRB with km^3 neutrino telescopes: Simulation and optimization of three selected GRBs*. Technical Report ANTARES-PHYS-2012-006 (Chapter 11)

The offer to do this research project came from Maarten de Jong. I attended his class on astroparticle astrophysics in 2007, during my master studies at the Leiden Observatory. He was later appointed as a professor at Leiden University and offered me a PhD position. I was interested and quite enthusiastic, but was unsure to undertake a project in such an unfamiliar topic. During my visit to Nikhef for the job interview, the then leader of the ANTARES group at Nikhef (to which I was later attached), Gerard van der Steenhoven, assured me that somebody with my background and capabilities could be a useful addition to the group. I was convinced. I would like to thank Gerard for his confidence and for telling me that there is a place for an astronomer like me in astroparticle physics.

The ANTARES group at Nikhef is akin to a close-knit family. The bond that developed over the years helped me ease the

stress of doing research. Claudio Bogazzi, Giada Carminati, Akis Gkaitatzis, Claudio Kopper, Gordon Lim, Tino Michael, Dimitris Palioselitis, Jelena Petrovic, Eleonora Presani, Corey Reed, Stephan Schulte, Erwin Visser, Guus Wijnker, thank you all for your suggestions and comments, for giving me the most awesome time at Nikhef, and for showing me how to survive at ANTARES. Thank you Ana Carolina Assis Jesus, Ching-Cheng Hsu, and Jeroen Snijdewint for your patience in sharing an office with me. Special thanks to Erwin for all those Dutch translations, and thank you Maria Tselengidou for making working in Nikhef at weekends much less dreary. You guys are a constant reminder that I was never alone in working on this project.

My research is greatly aided by Mieke Bouwhuis, Aart Heijboer, and Dorothea Samtleben. Thank you for helping me in matters of the GCN alert messages, track reconstruction, and L0 data analysis. The dissertation would not be the same without your help. I want to thank also Antoine Kouchner and Clancy James for their suggestions and for refereeing my work towards data unblinding. Additional thanks should also be given to Aart and Clancy for presenting my results on my behalf respectively in Moscow and Bologna. I thank also Yuri Cavecchi, Samia Drappeau, and Peter Polko from the Anton Pannekoek Astronomical Institute for sharing their knowledge of high-energy astrophysics.

Thank you Ralph Wijers for reading the manuscript of my first paper. Without your suggestions and constant assurance that the paper is worth publishing, it would never have ended up the way it is.

Finally, I would like to thank Maarten de Jong for supervising my research and for his support and belief in this work. Without his constant push in the right direction and encouragement, this dissertation would have run out of steam and would never have been completed.

Tri L. Astraatmadja