

University of Groningen

Sulphur, zinc and carbon in the Sculptor dwarf spheroidal galaxy

Skúladóttir, Ása

IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.

Document Version

Publisher's PDF, also known as Version of record

Publication date:

2016

[Link to publication in University of Groningen/UMCG research database](#)

Citation for published version (APA):

Skúladóttir, Á. (2016). *Sulphur, zinc and carbon in the Sculptor dwarf spheroidal galaxy*. Rijksuniversiteit Groningen.

Copyright

Other than for strictly personal use, it is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license (like Creative Commons).

The publication may also be distributed here under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license. More information can be found on the University of Groningen website: <https://www.rug.nl/library/open-access/self-archiving-pure/taverne-amendment>.

Take-down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Downloaded from the University of Groningen/UMCG research database (Pure): <http://www.rug.nl/research/portal>. For technical reasons the number of authors shown on this cover page is limited to 10 maximum.



rijksuniversiteit
groningen

Sulphur, Zinc and Carbon in the Sculptor Dwarf Spheroidal Galaxy

Proefschrift

ter verkrijging van de graad van doctor aan de
Rijksuniversiteit Groningen
op gezag van de
rector magnificus prof. dr. E. Sterken
en volgens besluit van het College voor Promoties.

De openbare verdediging zal plaatsvinden op

maandag 18 april 2016 om 12.45 uur

door

Ása Skúladóttir

geboren op 14 november 1982
te Reykjavik, IJsland

Promotor

Prof. E. Tolstoy

Copromotor

Dr. S. Salvadori

Beoordelingscommissie

Prof. P.C. van der Kruit

Prof. T.C. Beers

Prof. J.E. Norris

Cover: Ines Sigel
Printed by: Ipskamp Drukkers, Enschede

ISBN: 978-90-367-8736-6 (printed version)
ISBN: 978-90-367-8736-9 (electronic version)

Contents

1	Introduction	1
1.1	The Local Group	1
1.1.1	Sculptor	3
1.2	Stellar archaeology	5
1.3	Carbon-enhanced metal-poor (CEMP) stars	9
1.4	This thesis	11
2	Technical background	13
2.1	Stellar spectroscopy	13
2.1.1	Data reduction	14
2.2	Stellar atmosphere models	16
2.2.1	Effective temperature, T_{eff}	16
2.2.2	Surface gravity, $\log g$	17
2.2.3	Microturbulence velocity, v_t	18
2.2.4	Metallicity, $[\text{Fe}/\text{H}]$	18
2.3	Abundance determination	18
2.3.1	EW vs synthetic spectra method	18
2.3.2	Line list	19
2.3.3	Corrections	20
3	Sulphur abundances in theSculptor dwarf spheroidal galaxy	21
3.1	Introduction	22
3.2	Observations and data reduction	23
3.2.1	Observations	23
3.2.2	Data reduction	24
3.3	Stellar parameters and model atmospheres	25
3.4	Abundance measurements	25
3.4.1	Errors	27
3.5	NLTE corrections	29
3.6	Results and discussion	32

3.6.1	Possible outliers	32
3.6.2	The trend of [S/Fe] with [Fe/H]	35
3.6.3	Comparison of [S/Fe] and [S/Mg]	36
3.7	Conclusions	39
3.8	Appendix	39
4	Zinc abundances in the Sculptor dwarf spheroidal galaxy	47
4.1	Introduction	48
4.2	Observations and data reduction	50
4.3	Velocity measurements	51
4.4	Abundance analysis	53
4.4.1	Stellar parameters	54
4.4.2	New targets	56
4.4.3	Titanium	59
4.4.4	Neodymium	59
4.4.5	Zinc	60
4.4.6	Errors	63
4.5	Results and discussion	64
4.5.1	Titanium	64
4.5.2	Neodymium	66
4.5.3	Zinc in Sculptor	66
4.5.4	Zinc in the Local Group and beyond	70
4.6	Conclusions	72
4.7	Appendix	79
5	The first carbon-enhanced metal-poor star in Sculptor	79
5.1	Introduction	80
5.2	Observations and data reduction	82
5.2.1	Data reduction	83
5.2.2	Continuum normalization	83
5.3	Stellar parameters	84
5.4	Abundance measurements	85
5.4.1	Iron	87
5.4.2	Oxygen, carbon, and nitrogen	89
5.4.3	Indicators of mixing, $^{12}\text{C}/^{13}\text{C}$ ratio and Li	90
5.4.4	Alpha elements	92
5.4.5	Odd-Z elements	93
5.4.6	Iron-peak elements	93
5.4.7	Heavy elements	93
5.5	Error analysis	94
5.6	Results	96
5.6.1	Carbon in Sculptor	96
5.6.2	The general abundance pattern	98

5.7	Origin of the abundance pattern	100
5.7.1	Alpha and iron-peak elements	100
5.7.2	Carbon-enhancement	100
5.7.3	The lighter n -capture elements	103
5.8	Possible formation scenario	105
5.9	The CEMP-no fraction in Sculptor	107
5.10	Conclusions	108
5.11	Appendix	109
6	Carbon-enhanced metal-poor stars in dwarf galaxies	117
6.1	Introduction	118
6.2	Observations of carbon-rich stars	120
6.3	Cosmological merger-tree model	123
6.4	Results: the global picture	127
6.4.1	Star formation histories	131
6.5	Data comparison	132
6.5.1	Carbon-enhanced stars in Sculptor	133
6.5.2	Carbon-enhanced stars in ultra-faint dwarfs	135
6.6	The low-[Fe/H] tail of Sculptor	137
6.7	Summary and discussion	138
	Bibliography	143
	English summary	157
	Nederlandse Samenvatting	165
	Íslensk samantekt	173
	Acknowledgements	181

