

10 Billion Years of Massive Galaxies

10 Billion Years of Massive Galaxies

Proefschrift

ter verkrijging van
de graad van Doctor aan de Universiteit Leiden,
op gezag van Rector Magnificus prof. dr. P. F. van der Heijden,
volgens besluit van het College voor Promoties
te verdedigen op woensdag 15 december 2009
te klokke 17.15 uur

door

Edward Nairne Cunningham Taylor

geboren te Baltimore (VS)
in 1980

Promotiecommissie

Promotores: Prof. dr. M. Franx
Prof. dr. P. G. van Dokkum (Yale University)

Overige leden: Prof. dr. E. F. Bell (University of Michigan)
Prof. dr. K. H. Kuijken
Prof. dr. G. K. Miley
Prof. dr. H. Röttgering
Prof. dr. S. C. Trager (Rijksuniversiteit Groningen)

for my mum and dad — i think you're cool, too.

Here's to Cisco and Sonny and Leadbelly, too,
and all the good people that travelled with you;
here's to the hearts and the hands of the men
that come with the dust, and are gone with the wind.

— Bob Dylan, *Song to Woody* (1962)

Table of Contents

I	Introduction and Summary	1
1	Statement of the Problem	1
2	The Basic Requirements of a Modern Lookback Survey	2
3	Galaxy Formation and Evolution – What we have learned	7
4	This Thesis	12
5	Outlook	16
II	The MUSYC NIR-Selected Catalog of the ECDFS	23
1	Introduction	24
2	Data	26
3	Data Combination and Cross-Calibration	32
4	Detection, Completeness, Photometry, and Photometric Errors	36
5	Additional Checks on the MUSYC Calibration	47
6	Number Counts	54
7	Photometric Redshifts	55
8	Interpolating Restframe Photometry — Introducing InterRest	62
9	Summary	66
A	Public Spectroscopic Redshifts for the ECDFS	68
III	The Rise of Massive Red Galaxies	75
1	Introduction	76
2	Data	79
3	Photometric Redshifts and Restframe Properties	82
4	Constructing a Stellar Mass Selected Sample	88
5	The Color–Magnitude and Color–Mass Diagrams for $z_{\text{phot}} \lesssim 2$	90
6	The Color Distribution of Massive Galaxies for $z_{\text{phot}} < 2$	94
7	The Color Evolution of Massive Red Galaxies	97
8	The Rise of Red Galaxies Over $z_{\text{phot}} \lesssim 2$	100
9	Quantifying Potential Systematic Errors	105
10	Quantifying the Rise of Red Galaxies Without Redshifts	116
11	Summary and Conclusions	122
A	The $z = 0$ Comparison Point	123
B	A Detailed Comparison with COMBO-17	126
IV	On the Dearth of Compact Galaxies in the Local Universe	135
1	Introduction	136
2	Basic Data and Analysis	138
3	Searching for Massive, Compact, Early-Type Galaxies	142

4	The Importance of Selection Effects for Compact Galaxies	150
5	Discussion	156
6	Summary and Conclusions	161
A	Looking for Compact Galaxies in the Photometric Sample	164
V	On the Masses of Galaxies in the Local Universe	173
1	Introduction	174
2	Data	177
3	Comparing M_* and \tilde{M}_d Assuming Dynamical Homology	181
4	Comparing M_* and $M_{d,n}$ Accounting for Non-Homology	186
5	Exploring Potential Biases in $M_*/M_{d,n}$	190
6	Discussion	197
7	Summary	201
A	Validating the SDSS DR7 Velocity Dispersions	202
B	Repeating our Analysis for a General Galaxy Sample	204
VI	Nederlandse Samenvatting	211
1	Achtergrond	211
2	Terugkijken in de Tijd	212
3	De Opkomst van de Rode Sterrenstelsels	213
4	De Groei van Passieve Sterrenstelsels	214
5	Stellaire Massa's van Sterrenstelsels	215
6	Conclusies	216
	Curriculum vitae	219
	Acknowledgments	221

List of Figures

II	The MUSYC NIR-Selected Catalog of the ECDFS	23
1	MUSYC in the ECDFS	25
2	Astrometric registration of the $Iz'JH$ images	34
3	Curves of growth for point-sources after PSF matching	35
4	Completeness for synthetic $R^{1/4}$ -law sources	38
5	Completeness as a function of position	39
6	Completeness and reliability via comparison to FIREWORKS	40
7	Validating our total flux measurements	43
8	Validating our flux error estimates	46
9	Validating the MUSYC ECDFS astrometric calibration	48
10	Photometric comparison between GOODS and MUSYC	50
11	Photometric comparison between COMBO-17 and MUSYC	51
12	K band apparent magnitude number counts	54
13	Stellar identification using $Bz'K$ colors	56
14	Validating the MUSYC ECDFS photometric redshifts	60
15	Interpolating restframe fluxes: illustrating the InterRest algorithm	63
16	Interpolating restframe fluxes: validating the InterRest algorithm	64
A.1	The $z_{\text{phot}}-z_{\text{spec}}$ diagram for different z_{spec} samples/quality flags .	71
III	The Rise of Massive Red Galaxies	75
1	Validating the MUSYC catalog photometric redshift determinations	83
2	z_{phot} errors, and their effect on other derived quantities	87
3	Empirically determining our mass completeness limit	89
4	The color–magnitude diagram for $z_{\text{phot}} \lesssim 2$	91
5	The color–stellar mass diagram for $z_{\text{phot}} \lesssim 2$	93
6	Color distributions for $M_* > 10^{11} M_{\odot}$ galaxies at $z \lesssim 2$	95
7	Testing our ability to recover a single-color (red) galaxy population	96
8	The color evolution of massive galaxies for $z \lesssim 2$	98
9	Comparing the data to passively evolving stellar population models	99
10	The rise of massive, red galaxies over cosmic time	101
11	Comparison with other works	104
12	The effect of different photometric redshift analyses on our results	112
13	Observed colors for a passively evolving stellar population	119
14	Quantifying the evolution of red galaxies without redshifts	121
A.1	The ‘low- z ’ NYU VAGC comparison sample	124
B.1	Reanalysis of the MUSYC data adopting COMBO-17 redshifts	127
B.2	MUSYC analysis of the COMBO-17 photometry	129
B.3	MUSYC analysis of the COMBO-17 photometry, recalibrated	131

IV	On the Dearth of Compact Galaxies in the Local Universe	135
1	The relation between M_*/L and color	141
2	The size–mass relation for massive, red sequence galaxies, showing the SDSS spectroscopic selection criteria	143
3	Illustrative examples of the galaxies we consider	144
4	Comparison between SDSS model and NYU VAGC Sérsic radii	147
5	Using σ as a consistency check on M_* and R_e	149
6	The red sequence galaxy M_* – R_e relation at low- and high- z	153
7	Red galaxy sizes at $z \sim 0.1, 1.6,$ and 2.3	155
8	The stellar populations of our compact galaxy candidates	157
A.1	Selecting $z \lesssim 0.1$ galaxies based on color alone	164
A.2	The M_* – R_e diagram for the spec. and phot. samples	166
A.3	The size distribution of $0.066 < z < 0.12$ red galaxies	168
V	On the Masses of Galaxies in the Local Universe	173
1	M_* vs. \tilde{M}_d : assuming homology	182
2	M_*/\tilde{M}_d as a function of global properties	183
3	Mass- and structure-dependence of M_*/\tilde{M}_d	185
4	M_* vs. $M_{d,n}$: accounting for non-homology	187
5	$M_*/M_{d,n}$ as a function of global properties	188
6	Does $M_*/M_{d,n}$ vary with mass, structure, or both?	189
7	Looking for possible observational biases	191
8	Looking for possible sample selection effects	193
9	Looking for possible biases in the M_*/L estimates	195
A.1	Validating the SDSS DR7 velocity dispersion measurements	203
B.1	M_* vs. $M_{d,n}$ for a general galaxy sample	205
B.2	M_* vs. $M_{d,n}$ derived using the SDSS/NYU catalogs	206
B.3	Stellar and dynamical masses for different states of activity	207
B.4	Mass- and structure-dependence of $M_*/M_{d,n}$	208

