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Eric Rohr
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Jellyfish Galaxies and the Multiphase Nature of Gas Around Galaxies

Referees: Dr. Annalisa Pillepich

Prof. Dr. Cornelis Dullemond

Abstract

Gas is everywhere throughout the Universe, from the gas between galaxies, the intergalactic medium (IGM), to the gas surrounding a galaxy, the circumgalactic medium (CGM), to the gas within a galaxy, the interstellar medium (ISM). According to the standard paradigm, galaxies form at the centers of dark matter halos out of gas that cools from the otherwise hot gaseous atmospheres around them. In turn, the latter are influenced by accreting material from the IGM, by outflowing gas due to feedback, and by infalling satellite galaxies.

In this thesis, I investigate the complex relationship between satellite galaxies and the multiphase host halo gas using the cosmological magneto-hydrodynamical simulations TNG-Cluster and TNG50, the highest-resolution simulation from the IllustrisTNG suite. These simulations provide an unparalleled combination of resolution and sample size, coupled with a well-validated galaxy formation model, enabling several novel insights.

First, in TNG-Cluster, I affirm that massive cluster satellites, with masses similar to or larger than the Milky Way, are capable of retaining their own hot, X-ray-emitting gaseous atmospheres. These atmospheres should be statistically detectable with current and upcoming X-ray surveys and instruments. In contrast, for less massive satellites in smaller groups and clusters, I demonstrate that the ram pressure tails observed in TNG50 "jellyfish" galaxies originate from the satellite's interstellar medium. As this cool, metal-enriched gas is stripped from the jellyfish galaxies, it is deposited into the host halo. Consequently, satellites contribute more cool gas to galaxy groups and clusters than is present in them today.

Furthermore, I demonstrate that across cosmic time, the mass of the cool intracluster medium in cluster progenitors correlates with the number of gaseous satellites, affirming that satellites are a legitimate source of cool halo gas, according to TNG. Moreover, I illustrate the complex evolution of the cool intracluster medium, considering interconnected processes such as gas accretion from the intergalactic medium, gas heating and cooling, satellite stripping, star formation, and, most importantly, feedback from the central supermassive black hole. In TNG-Cluster, the total mass of the cool-phase intracluster medium unambiguously decreases since H 2 4, over the past 10 12 billion years, just after the onset of strong, kinetic-mode feedback from the central supermassive black hole.

These novel results challenge long-standing ideas about the evolution of both satellite and central galaxies, offering fresh insights into the role of environmental effects and feedback processes. I propose specific observational tests to validate these simulation predictions, providing a clear path for future empirical investigations. Comparing these simulation outcomes with data from current and upcoming surveys will sharpen our understanding of galaxy formation and evolution, ultimately guiding the development of more sophisticated galaxy formation models for next-generation cosmological simulations.

Zusammenfassung

Gas ist überall im Universum vorhanden, vom Gas zwischen den Galaxien, dem intergalaktischen Medium (IGM), über das Gas, das eine Galaxie umgibt, dem zirkumgalaktischen Medium (CGM), bis hin zum Gas innerhalb einer Galaxie, dem interstellaren Medium (ISM). Nach dem Standardparadigma bilden sich Galaxien, in den Zentren von Halos aus dunkler Materie, aus Gas, das sich von den ansonsten heißen Gasatmosphären um sie herum abkühlt. Letztere werden wiederum durch akkretierendes Material aus dem IGM, ausströmendes Gas aufgrund von Rückkopplungen und einfallende Satellitengalaxien beeinflusst.

In dieser Arbeit untersuche ich die komplexe Beziehung zwischen Satellitengalaxien und dem mehrphasigen Gas des Wirtshalos mithilfe der kosmologischen magneto-hydrodynamischen Simulationen TNG-Cluster und TNG50, der hochauflösendsten Simulation aus der IllustrisTNG-Suite. Diese Simulationen bieten eine beispiellose Kombination aus Auflösung und Stichprobengröße, gekoppelt mit einem gut validierten Galaxienentstehungsmodell, das mehrere neue Erkenntnisse ermöglicht.

Erstens zeige ich, dass in massereiche Haufensatelliten in TNG-Cluster, die eine ähnliche oder größere Masse als die Milchstraße haben, in der Lage sind, ihre eigenen heißen, Röntgenstrahlen emittierenden Gasatmosphären zu behalten. Diese Atmosphären sollten mit aktuellen und zukünftigen Röntgendurchmusterungen und Instrumenten statistisch nachweisbar sein. Im Gegensatz dazu zeige ich für weniger massereiche Satelliten in kleineren Gruppen und Haufen, dass die in TNG50-Quallengalaxien beobachteten Staudruckschweife aus dem interstellaren Medium der Satelliten stammen. Wenn dieses kühle, metallangereicherte Gas aus den Quallengalaxien entfernt wird, lagert es sich im Wirtshalo ab. Folglich tragen die Satelliten mehr kühles Gas zu den Galaxiengruppen und -haufen bei, als heute in ihnen vorhanden ist.

Zweitens zeige ich, dass über die kosmische Zeit hinweg die Masse des kühlen Intraclustermediums in den Vorläufern von Sternhaufen mit der Anzahl der Gassatelliten korreliert, was bestätigt, dass Satelliten gemäß TNG eine legitime Quelle für kühles Halo-Gas sind. Darüber hinaus veranschauliche ich die komplexe Entwicklung des kühlen Haufenmediums, indem ich miteinander verbundene Prozesse wie Gasakkretion aus dem intergalaktischen Medium, Gaserwärmung und -abkühlung, Satellitenstripping, Sternentstehung und vor allem die Rückkopplung durch das zentrale supermassereiche Schwarze Loch berücksichtige. In TNG-Cluster nimmt die Gesamtmasse des Intraclustermediums in der kühlen Phase seit H 2 4 eindeutig ab, und zwar über die letzten 10 12 Milliarden Jahre, unmittelbar nach dem Beginn der starken kinetischen Rückkopplung durch das zentrale supermassereiche Schwarze Loch.

Diese neuen Ergebnisse stellen langjährige Vorstellungen über die Entwicklung von Satelliten- und Zentralgalaxien in Frage und bieten neue Erkenntnisse über die Rolle von Umwelteinflüs-

sen und Rückkopplungsprozessen. Ich schlage spezifische Beobachtungstests vor, um diese Simulationsvorhersagen zu validieren und einen klaren Weg für zukünftige empirische Untersuchungen aufzuzeigen. Der Vergleich dieser Simulationsergebnisse mit Daten aus aktuellen und zukünftigen Durchmusterungen wird unser Verständnis von Galaxienentstehung und -entwicklung schärfen und letztlich die Entwicklung anspruchsvollerer Galaxienentstehungsmodelle für kosmologische Simulationen der nächsten Generation anleiten.

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)LJXUH ãÐî ûæÆ · • ÜK•ÆJÜÐM LQ LQWHUVWHOODU PHGLXP ,60
JDODFWLF PHGLXP &*0 JDOD[LHV FDQ FKDQJH SKDVH DQG V
RXWÚRZV FDXVHG E\ VWHOODU DQG VXSHUPDVVLYH EODFN K
H[WUDJDODFWLF DFFUHWLRQ DQG VDWHOOLWH DFFUHW
ODUJHU JDOD[\ RQ WKH OHIW 7KH HÎHFWV RI WKH &*0 IURP
DQG YLFH YHUVD LV WKH PDLQ WRSLF RI WKLV WKHVLV ,
,UHWXUQ WR ODWHU WKH DYHUDJH WHPSHUDWXUH RI W
GHQRWHG E\ WKH UHGGHU FRORU WKH VPDOOHU JDOD[\ KD
SKDVH PRUH OLJKW EOXH FORXGV DQG WKH ODUJHU JDO
VKRZQ ZKLOH WKH VPDOOHU JDOD[\ KDV RQOY WWR ODU IHH
+RUL]RQ 7HOHVFRSH &RPSODE\ &RPSODE\ &RPSODE\

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G U R P H G D Q H E X O D W U \ L Q J W R G H F L G H L I E H O R Q J H G W R R X U
X Q L Y H U V H ~ Z K D W O D W H U E H F D P H N Q R Z Q D V D J D O D [\ : L W K
R W K H U J D O D [L H V G R L Q I D F W H [L V W W K H D V W U R Q R P H U V Q R W
J D O D [L H V W K H \ D U H D O O P R Y L Q J D Z D \ I U R P (D U W K 8 V L Q J & H
Z L W K D N Q R Z Q S H U L R G O K E L Q W W L W 3 L F N G W R W R Q V X K L H W K H L U
G L V W D Q F H V L W E H F D P H F O H D U W K D W W K H I D U W K H U D Z D \ J D
+ X E E O H / H P D W U D W L R Q E Z E ì O H ô

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Z K H D U H W K H U H F H 3 V L W L R Q H Y H O R W D Q F H L W R W K H X E E O H \ F R Q W D Q
7 K H 8 Q L Y H U V H L V H [S D Q G L Q J 7 K L V G L V F R Y H U \ L V W K H E D V L V I
H [S D Q V L R Q Z D V F R Q V L V W H Q W Z L W K W K H D W W K H W L P H U H F H

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Z K H U H L V W K H (L Q V W H L Q 6_a W H L Q W K H R H V R U L F W K H Q V R U H V ¥ H Q H U J \ W H Q
c •2 L V W K H (L Q V W H L Q J U D Y L W D W L R Q D O F R Q V W D Q W Z K H U H
F R Q V W D Q W D Q G V P H H G R I L G H W K W F R N V R O R W L F D O F R Q V W D Q W
D V D Q H J D W L Y H P D V V R U H Q H U J \ R I H P S W \ V S D F H W R F R X Q W H
W K H J U D Y L W D W L R Q D O F R Q V W D Q W D Q G V S H H G R I O L J K W (L Q V W H L Q
L V R W U R S L F 8 Q L Y H U V H D W O H D V W R Q O D U J H V F D O H V R E H \ V
v : D O N H U P H W U L F

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ZKH9UGHHVFULEHV WKH VSDWLDO FXUYDWXUH RI WKH 8QLYHUVH &RUUHVSRQGLQJ WR WKH
WKHUHLV QHJDWLYH QXO¹B³ &RUUHVSRQGLQJ WR WKH 8QLYHUVH &RUUHVSRQGLQJ WR W
WKHH[SDQVLRQ RIWKH8QLYHUVH &RUUHVSRQGLQJ WR W
H)UHHGPDQQ7KH VFDOH IDFWRU LV GHVFULEHG &XUHVGXXKLW &DWWKW
VFDOH 01B³&RUUHVSRQGLQJ WR WKH VFDOH IDFWRU &RUUHVSRQGLQ UHO
FRPRYLQJ3&G LVWKHGQLFVW DQFH WKDW UHPDLQV FRQVWDQW ZL
E &³ &RUUHVSRQGLQ WRGD\ &RUUHVSRQGLQ WRGD\ 7KH VROXWLRQ WR GHWHUP
KLVWRU\ RI 01B8QLYHUVH &RUUHVSRQGLQ WKH VHW RI)UHHGPDQQ HTXDWL

$$\Omega(t) = \frac{a(t)}{a(t_0)} = \frac{c\,d}{a(t_0)} = \frac{92}{a(t_0)} = \frac{2}{} \qquad (1)$$

$$\frac{a(t)}{a(t_0)} = \frac{c}{} \; d = \frac{>}{2} = \frac{2}{} \qquad (2)$$

ZKHUH &³ &RUUHVSRQGLQJ WR WKH +XEEOH &RQVWDQW &RUUHVSRQGLQ WR WKH
&RUUHVSRQGLQ WR WKH [LVWV &RUUHVSRQGLQ WR WKH 8QLYHUVH &RUUHVSRQGLQ WR WKH
(TQ ï

$$d_{curvature} = \frac{\Omega(t)}{c} \qquad (3)$$

,W LV WKHQ FRQYHQLHQW &RUUHVSRQGLQ WR WKH [SUHVVLRQ &RUUHVSRQGLQ WR WKH
PHQWLRQHG &RUUHVSRQGLQ WR WKH &XXP GHQVLW &RUUHVSRQGLQ WR WKH &RUUHVSRQGLQ WR WKH &RUUHVSRQGLQ WR WKH

WKH SUHëV>HQFHBÖR;ïR1UïGDUN PDWWHU 4XLFNO\ WKHUHDIWHU
UROWDWLRQ FXUYH LQ $QGURPHGD DQG RWKHU VSLUDO JDOD
WKH JDODFW%LDEERXWXRUUXWWHVZKLFK ZRXOG OHWHU EH FRQ×UP
LPSURYHG REVHUYDWLRQDO &RQVWUDLQWV &RQVLGHUDWLRQ RI
ìôòï $GGLWLRQDO DUJXPHQWV IRU WKH H[LVWHQFH RI GDUN
DQG JOREXODU FOXVWHU YHORFLW&DOOXOD&RQVWDQW&RQ&RQ&RQ

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7DEOH &XUUHQWO&DFSEHSWHUV ZKLFK DUH HPSOR\HG WKUF
JLYHQ EO&QFN &RODEUDWLRQ DW WKH DVVXPHV D ÚDW

3DUDPHWHUV	9DOXH	'HVFULSWLRQ
	“ NPV0SF	+XEEOH &RQVWDQW
EDU	ë ëïóñ	EDU\RQ GHQVLW\
GP	ë îëóô	GDUN PDWWHU GHQVLW\
W”		UHODWLYLVWLF SDUWLFOH GHQVLW
”	ë ñôìì	GDUN HQHUJ\ GHQVLW\
<A	ë ôññò	VSHFWUDO VFDODU LQGH[
f	ë óìðô	DPSOLWXGH RI WKH OLQHDU SRZHU V VFDOH RI ó 0SF

,Q WKLV WKHVLV , IRFXV DOPRVW HQWLUHO\ RQ EDU\RQ
QDWXUDOO\ WDNLQJ WKH JUDYLWDWLRQDO HÎHFWV RI FRO
GDUN HQHUJ\ LQWR DFFRXQW 7RGD\ WKHUH LV DOVR D PLQ
WKH 8QLYHUVH IURP UHODWLYLVWLF SDUWLFOHV OLNH SKR
ZKLFK DUH PRVWO\ SKRW &RQVHTXHQW&H WKHVH SKRWR
SHUKDSV WKH PRVW LPSRUWDQW LQJUHGLHQW IRU DVWU
WKRVH RULJLQDWLQJ IURP DVWURSK\VLFDO VRXUFHV VR
ZRXOG EH D PXFK PRUH GLÑFXOW VFLHQFH LI LW ZRXOG HY
7DNLQJ WKH SUHVHQW GD\ YDOXH IRU WKH +XEEOH SDU
+XEEOH FRQVWDQW WRGD\ WKH FULWLFDO GHQVLW\ RI WK

d FULW c J FP 0 NSF FP í ó

ZKHUH WKH ODWWHU LV WKH HTXLYDOHQW K\GURJHQ QXP
FRPSRQHQWV RI WKH 8QLYHUVH WR FRQVWLWXWH &RVPLF
GHQVLW\“ EDU\RQLF PDWWHU GHQVLW\ &RVPLF
W” IRU D WRWDO HQHUJ\ GHQVLW\
7KHVH SDUDPHWHUV WKH PDVV HQHUJ\ GHQVLWLHV DQG
RQ WKH JOREDO KRPRJHQHRXV VFDOHV 2QVPDOOHU VFD
KRPRJHQHRXV 7KLV VKRXOG FRPH DV QR VXUSULVH VLQF
SHRSOH DUH LQ QR ZD\ KRPRJHQHRXV DQG DW WKH VH
LQKRPRJHQHLWLHV FDQ EH SDUDP<LZKLE]KGHV WKLHV VKRZ

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GHQVLW\ÚXFWXDWLRQV YDU\ZLfWRKWFKHOOHLQHQJWSKRZHQGWSKHFD
RQ VFDOHV RZKHUH• NPV0SF 7DEÍOH XPPDUL]HV WKHVH YDOXH
IURP &0% PHDVXUHPHQWV &RVOODERUDWLRQ HW DO

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,Q WKH EHJLQQLQJ WKHUH ZDV QRWKLQJ EXW WKHUH ZDV DO
IRU WKH H[LVWHQFH RI RXU 8QLYHUVH GHWDLOV WKDW WKH %
WLRQ LQ DQ XQGHUO\LQJ TXDQWXP ×HOG DQG WKHVH LQLWLD
8QLYHUVH ,Q WKHVH QDWDO PRPHQWV WKH 8QLYHUVH ZDV
VWDQGDUG FRVPROJLFDO PRGHO SUHGLFWV D SHULRG RI H[S
VXSSRUWHG E\ D FRVPRORJLFDO FRQVWDQW ZLWK VXÑFLHQW
*XWLÓOLQÓ6WDUÈÓÓQ WKLV FRQWH[W SDUWV RI WKH 8QL
FDXVDOO\ FRQQHFWHG SUH LQÚDWLRQ EHFDPH GLVFRQQHFWH
WRZDUGV ÚDWQHVV $Q\LQLWLDO PLFURVFRSLF SHUWXUED
VFDOH 6SHFL×FDOO\ LQÚDWLRQ SUHGLFWV WKDW D *DXVVL
GHQVLW\ÚXFWXDWLRQV DQG WKDW WKH LQLWLDO SRZHU VSH
EHQ¢RZ 7KHVH GHQVLW\SHUWXUEDWLRQV KDYH REVHUYDEOH
$IWHU WKH LQÚDWLRQDU\SHULRG WKH 8QLYHUVH ZDV UDG
H[SDQGHG DGLDEDWLFDOO\ LW FRROHG $IWHU D IHZ PLQXW
IRUP DWRPLF QXFOHL FDOOHG ELJEDQJ QXFOHRV\QWKHVLV Z
UDWLR RI +HOLXP WR $OGUHQ&RUUHOD DQ DHOX WHV XQWLO
” \HDUV WKH UDGLDWLRQ GRPLQDWHG 8QLYHUVH ZDV VW
$W UHGVKLIW WKH 8QLYHUVH WUDQVLWLRQHG WR EHFRPLQJ PDW
DW D GHFHOHUDWLQJ UDWH DOEHLW QRZ GHFHOHUDWLQJ V
$W UHGVKLIW D FRVPLF WLP\HIRU IUHH HOHFWURQV DQG QX
×QDOO\ IRUP QHXWUDO +\GURJHQ DQG +HOLXP LQ WKH SRRUO
3KRWRQV FRXOG VWLOO VFDWWHU RÎ WKH VWLOO IUHH HOHFW
ODVW VFDWWHULQJ RÎ D IUHH HOHFWURQ WKH %LJ %DQJ SKR
8QLYHUVH ZDV QRZ WUDQVSDUHQW DQG ZH FDQ GLUHFWO\ R
VFDWWHULQJ 7KH WHPSHUDW XEXWRKDWKQHRSZKERHWHQQUVHZGWK LW
D WHPSHUDWXUH RI DWLQJ WKH &0% %HFDXVH WKH EDU\RQL
ZHUH FRXSOHG DQG LQ HTXLOLEULXP WKH SUHGLFWHG &0% V
SHUWXUEDWLRQV DULVLQJ IURP PDWWHU GHQVLW\ DQLVRWUR

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, QRZ WUDQVLWLRQ IURP WKHRU\ WR WKH DFWXDO REVHUYD

3ODQFN &RROD ÍEñUKDWH RQHEWDQG DERXW WKH 8QLYHUVH I

7KH WHPSHUDWXUH RI WKH QHDUO\ SHUIHFW EODFNERG\ PHQW RI WKH WRWDO SKRWRQ HQHUJ\ &0% SKRWRQV GRPLQDWH WKH DVVXPLQJ WKDW WKH &0% LV DW DQ DYHUDJH WHPSHUDWXUH RI 7KH &0% H[LVWV LQ DOO GLUHFWLRQV RI WKH VN\ %HFDXVH WKH WHPSHUDWXUH SHUWXUEDWLRQV FDQ EH GH VRPH QRQ *DXVVLDQ IHDWXUHV PD\ H[LVW DOO VWDWLVW SRZHU VSHFWUXP 7KH ODUJH VFDOH LVRWURS\ VXSSRUW RQ WKH VN\ VHSDUDWH GHVFULSWLRQV RI WKH LQÚDWLRQDU\ SHULRG &®Q WKH EDVXQ DQG WR PRWLRQV LQ WKH SKRWRQ EDU\RQ ÚXLG 7KH GLVWUL EDU\RQLF DQLVRWURSLHV DW WKH WLPH RI ODVW VFDWWH %HIRUH UHFRPELQDWLRQ WKH EDU\RQ SURWRQ ÚXLG SU WKH JUDYLWDWLRQDOO\ SXOO RI GDUN PDWWHU RQ VXE K WKH EDU\RQV IROORZHG WKH DOUHDG\ GHFRXSOHG GDUN P ZLWK WLPH :KLOH WKH EDU\RQV ZHUH JUDYLWDWLRQDOO SUHVVXUH IURP WKH EDU\RQ SURWRQ ÚXLG OHG WR WKH E SKRWRQ EDU\RQ ÚXLG ZDV FRPSUHVVLQJ DQG H[SDQGLQJ D KRWWHU DQG YLFH YHUVD 7KH DQJXODU SRZHU VSHFWU SUR[LPDWHO\ WKH VRXQG KRUL]RQ VLW RI WKLV SHDN GH FXUYDWXUH LQ WKH 8QLYHUVH ZKLFK FDQ EH FRQVWUDLQ ZLWK D WRWDO PDVV HQ7KH HGHQW LVW DSH RI WKLV SHDN GHS WRWDO PDWWHU GHQVLW\ EDU ZKRW H FRQVWUDLQWV UHTXLUH WKH S &RPS W 7KH VHFRQG GDQG WKLUG SHDNV DW VPDOOHU D PDWWHU DQG EDU\RQLF GHQVLWLHV 7KH &0% LV DEOH W LQ WKH HDUO\ 8QLYHUVH LQGHSHQGHQWO\ FKHFNLQJ WK 8QLYHUVH H[SODLQHG DERYH 7KH FRVPRORJLFDO SDUDPH 8QLYHUVH DJUHH UHPDUNDEO\ ZHOO &&0 DVORXQHRXW WKH V VRPH PLQRU GLVFUH SDUDPHWHUV &RPSDUVLVW

&RPSDULVRQ

$IWHU WKH WLPH RI ODVW VFDWWHULQJ WKH 8QLYHUVH KDG UHFHQ IURP UDGLDWLRQ WR PDWWHU GRPLQDWHG WKH 8QLYH 7KH EDU\RQV ZHUH GHFRXSOHG IURP WKH SKRWRQV DQG FR PDWWHU ZKLFK KDG EHHQ FRQWLQXRXVO\ JURZLQJ WKHL QRZ WXUQ WR WKH IRUPDWLRQ RI GDUN PDWWHU KDORV DQ

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,Q D VWDWLF 8QLYHUVH DQ\ GHQVLW\ SHUWXUEDWLRQ LQ D
LQÚXHQFH RI JUDYLW\ ZRXOG FRQWLQXH WR JURZ ,Q DQ H[SD
VRPH UHVWRULQJ SUHVVXUH v HLWKHU UDGLDWLRQ RU PDJQH
GHQVLW\ SHUWXUEDWLRQV LV OHVV VWUDLJKWIRUZDUG %HFD
DQG K\GURG\QDPLFDO HÎHFWV WKH SUHVVXUH IUHH DSSUR[LP
WKH 8QLYHUVH FDQQRW EH LJQRUHG 6ROYLQJ WKH HYROXWLR
FRRUGLQDWHV \LHOGV D WZR PRGH VROXWLRQ ZKHUH WKH JUR
RI VWUXFWXUH)XUWKHU D YHORFLW\ SHUWXUEDWLRQ FDQ DO
LQZDUGV WRZDUGV WKH SHUWXUEDWLRQ IXUWKHU LQFUHDV
GHQVLW\ DQG YHORFLW&'SHQ WXUEDWLRQ ZRZXW WK WLPH
7KH OLQHDU SHUWXUEDWLRQ WKHRU\ LV D JRRG DSSUR[LPD
RUGHU RI RU OHVV WKDQ WKH EHJLQQLQJ RI WKH 8QLYHU
WXUEDWLRQV OHDG WR UXQDZD\ FROODSVH WKH OLQHDU DSSU
WKH XVH RI 1 ERG\ QXPHULFDO VLPXODWLRQV WR IROORZ WKH
KDOR FROODSVH &RPSXWHU VLPXODWLRQV FRQILUP DQDO\WLF
FROODSVH RI GHQVLW\ SHUWXUEDWLRQV LQ DQ H[SDQGLQJ E
VSKHULFDO RYHUGHQVLW\ WKH VSKHUXQ DQ*RRWOD SVH GXH W
,Q WKH PRUH UHDOLVWLF VFHQDULR RI D QRQ SHUIHFWO\ XQLI
SHULRG RI YLROHQW UHOD[DWLRQ ZKHUH WKH KDOR YLULDOL
JUDYLWDWLRQOO\ ERXQG GHVSLWH WKH XQLYHUVDO H[SDQ
LQ WKH 8QLYHUVH $V WKH KDORV FRQWLQXH DFFUHWLQJ GD
ERXQGDU\ GHPDUFDWLQJ WKH HQG RI WKH KDOR ,W LV FRPP
UDGLXV DV W¥KDHWUZDKGLFXKWW K DYHUDJH WRWDO HQFORVHG GHQ
GHQVLW\ RI WKH 8QLYH¨UVH¤LVDWQKGHWWKRHWKDOOPRDFVDWWKHQ FORVHG E\
GDUN PDWWHU VWUXFWXUH ZLWKLQ D KDOR LV VXUSULVLQJO\
ZKHQ QRUPDOL]LQJ E\ W(KLQ KDORV RYLUQ TUXOOD DU GUXV HW DO
ìôôñ 'HVSLWH WKLV UHODWLYHO\ DUELWUDU\ KDOR VL]H GH×QL
LQGHHG H[WHQG EH\RQG WKH VRYLGHLW DLUDGLXV VHH 6HFWLRQ

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,Q WK&HO 8QLYHUVH VPDOO REMHFWV IRUP ×UVW ZKLFK JURZ
EHFRPH ODUJHU REMHFWV WKDW H[LVW WRGD\ )RU DOO KDOR
ZKLFK LV VHW E\ WKH VWUHDPLQJ OHQJWK RI WKH GDUN PDW
FROG GDUN PDWWHU VPDOOHU KDORV &RXOG &RXOG EH RUH PD