Roediger et al. 2012, ApJ (in print)
arXiv:1201.6361

Stellar migrations and more in cluster disk galaxies

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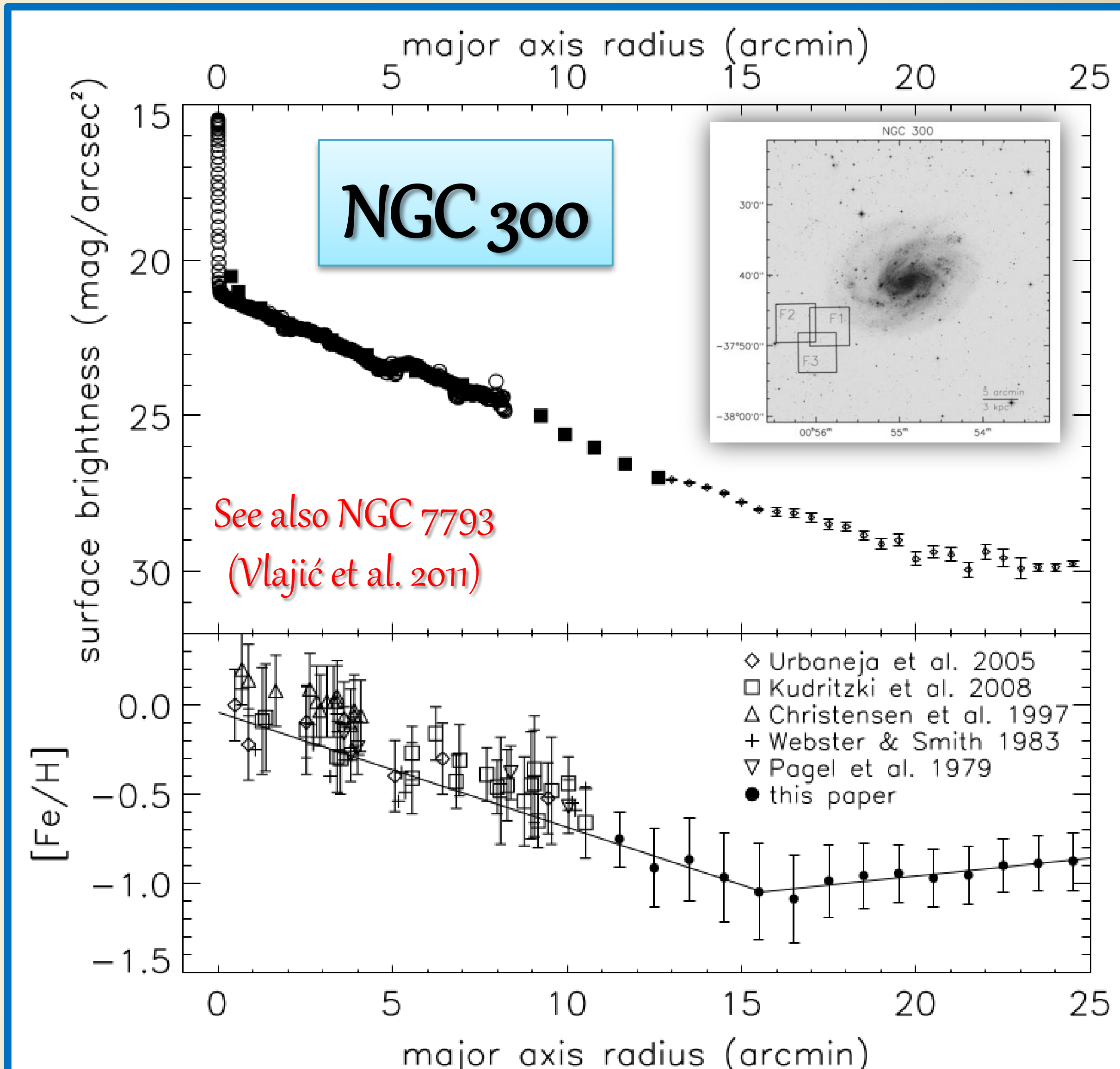
Disk galaxies come in many Types (I)

Bland-Hawthorn et al. (2005); Vlajić et al. (2009)

Type	I
Surface brightness profile	Exponential (> 5 R_d)
Fraction of field disk population (Gutierrez et al. 2011)	20%
Formation scenario	Inside-out

Type I's should have **negative** stellar age and metallicity gradients

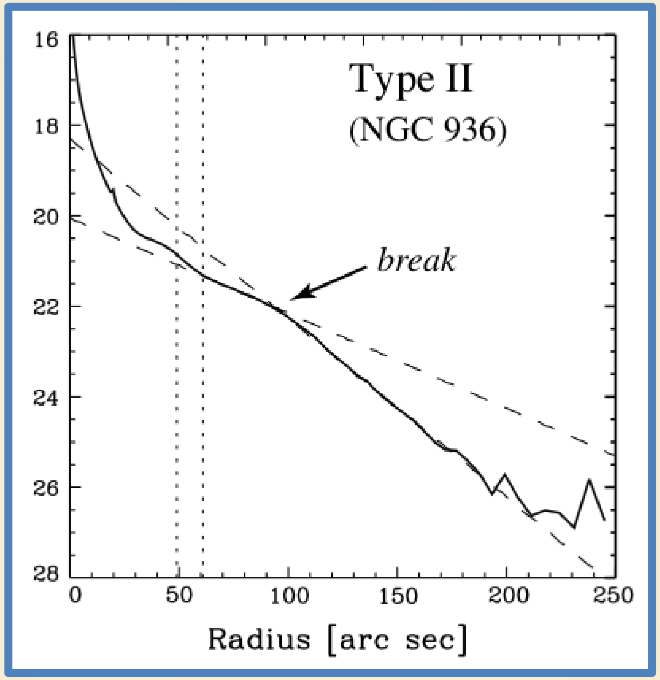
(Ferguson & Clarke 2001; Mollá & Diaz 2005; Naab & Ostriker 2006)



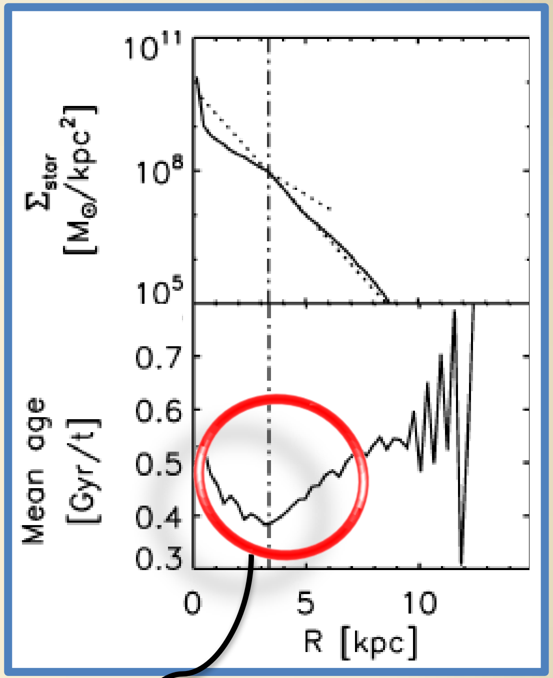
Disk galaxies come in many Types (II)

Type	II
Surface brightness profile	Down-bending double exponential
Fraction of field disk population (Gutierrez et al. 2011)	50%
Formation scenario	Inside-out + stellar migrations

Erwin et al. (2008)



Roškar et al. (2008)



Stellar ages should **increase** beyond break in Type II's

(Roškar et al. 2008; Sánchez-Blázquez et al. 2009; Martínez-Serrano et al. 2009)

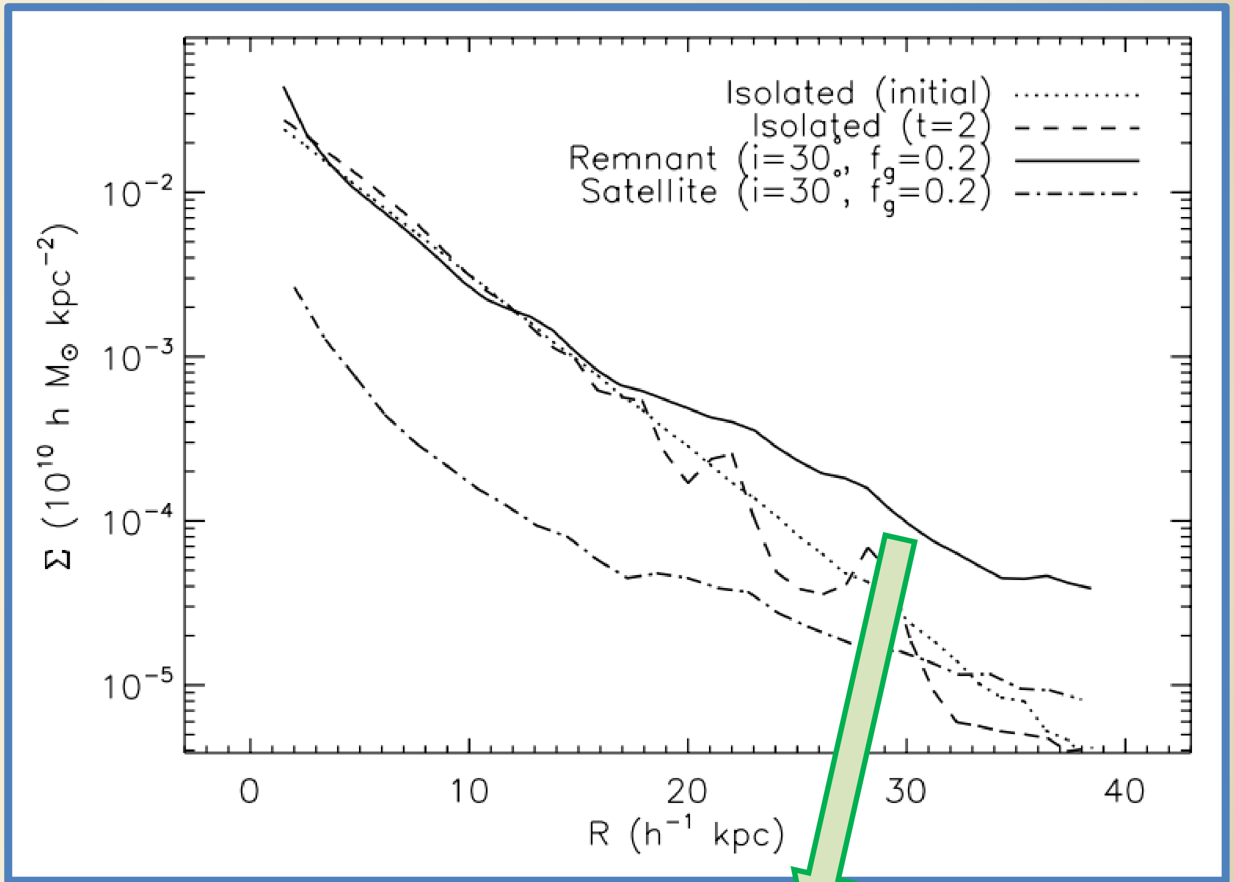
Field Type II's exhibit upturns in their age gradients

(de Jong et al. 2007; Barker et al. 2011; Yoachim et al. 2012; Radburn-Smith et al. 2012)

Disk galaxies come in many Types (III)

Younger et al. (2007)

Type	III
Surface brightness profile	Up-bending double exponential
Fraction of field disk population (Gutierrez et al. 2011)	30%
Formation scenario	Minor merger(s)



Type III's might also harbour **upturns** in their age gradients

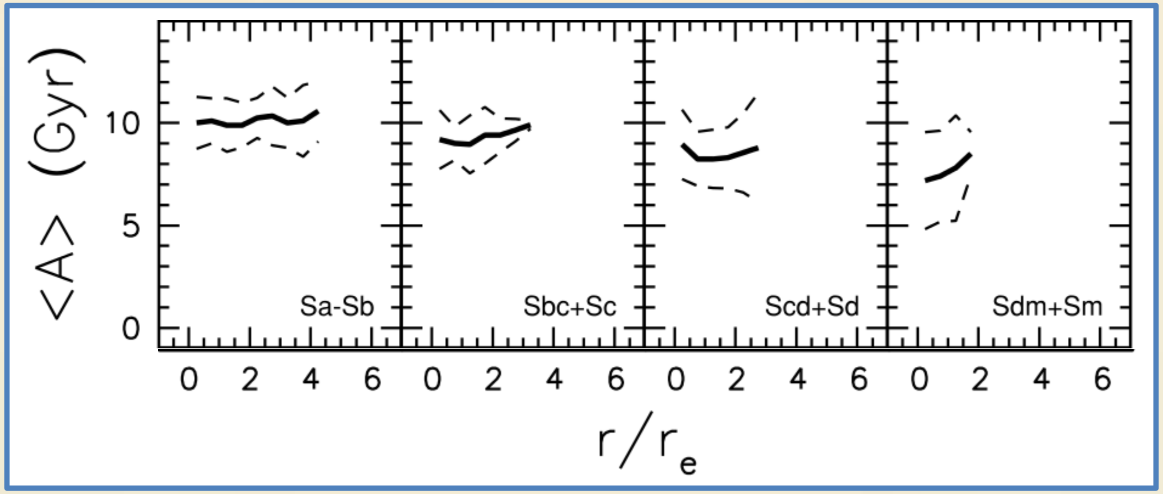
Outer disk built up from **inner disk stars**, akin to stellar migrations (Younger et al. 2007)

What about cluster disks?

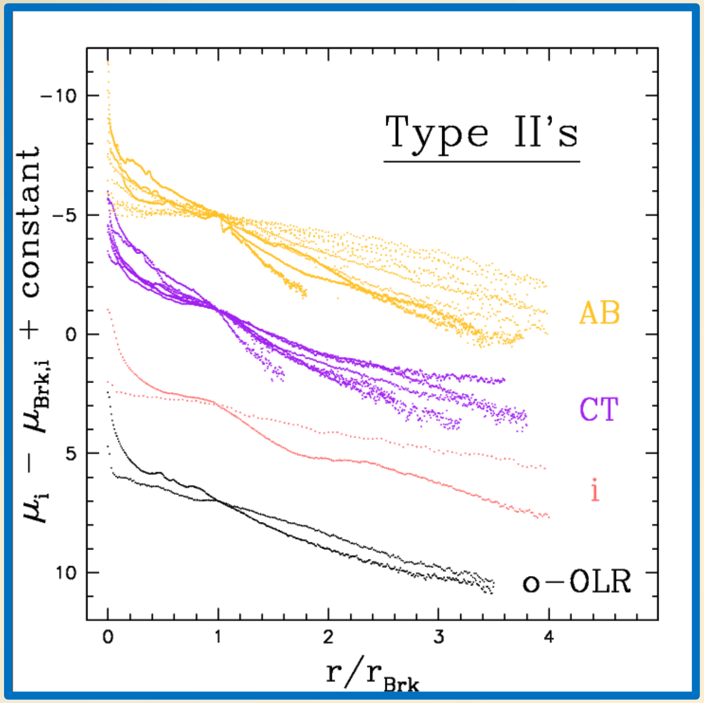
McDonald et al. (2011) – *g, r, i, z & H surface photometry for 286 Virgo galaxies*

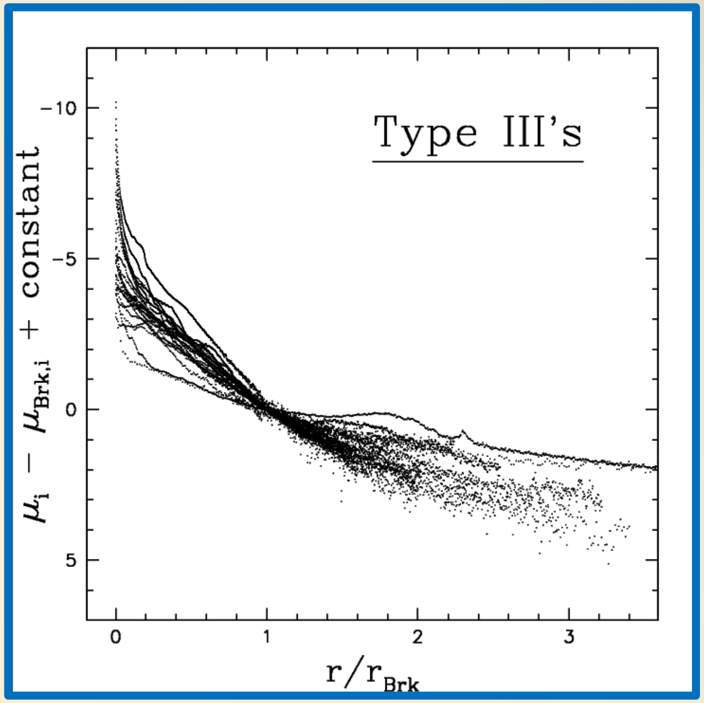
Morphology	N	B/T_i	Luminosity (M_i)	Surface brightness ($\mu_{e,i}$)	Size ($r_{e,i}$)
Sa-Sm	44	0 – 0.24	-17.4 – -21.0 mag	21.3 – 23.3 mag arcsec^{-2}	1.9 – 5.5 kpc

Roediger et al. (2011a,b) – *colour/stellar population analysis of McDonald et al. data*



Outer disk structure depends on enrivonment





Environment	Morphologies	Type composition		
		I	II	III
Virgo[a]	Sa – Im	0.32	0.36	0.32
Field[b]	S0 – Sm	0.20	0.50	0.30

[a] analysis of deeper imaging (< 28 mag arcsec^{-2}) may alter these numbers

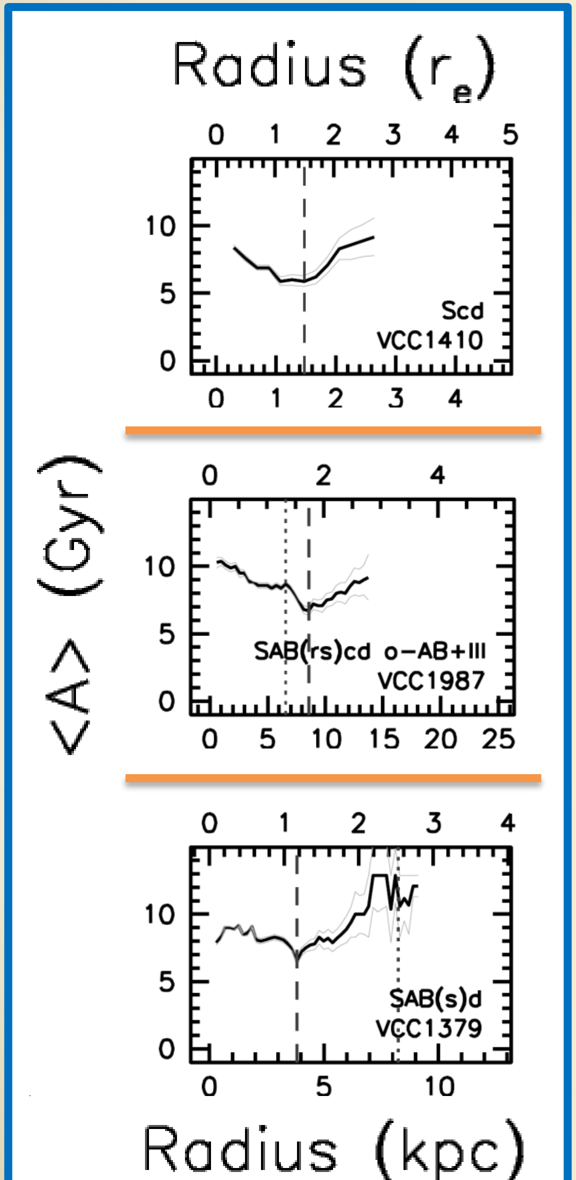
[b] values from Gutierrez et al. (2011)

Age upturns are found in all disk Types …

I

II

III



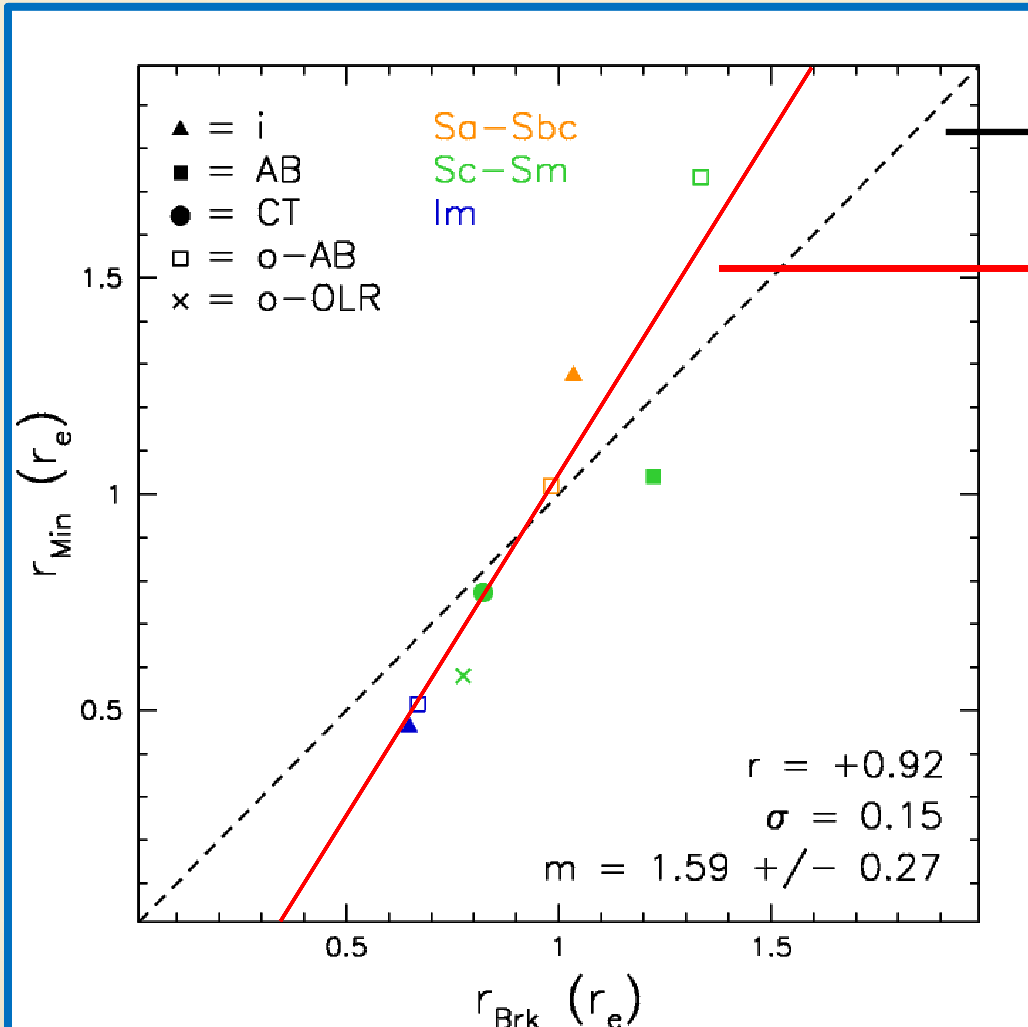
VCC ID (1)	$d\langle A\rangle/dr_i$ (Gyr kpc^{-1}) (2)	$d\langle A\rangle/dr_o$ (Gyr kpc^{-1}) (3)
	Type I	
0583	-5.70	+1.78 ± 0.51
1410	-2.13 ± 0.40	+3.05 ± 0.38
1566	-6.88 ± 1.80	+0.56 ± 0.30
	Type II	
0596	-0.32 ± 0.02	+0.05 ± 0.02
0849	-3.61 ± 0.72	+1.25 ± 0.42
0865	-0.19 ± 0.04	+0.56 ± 0.02
1021	-2.04	+1.29 ± 0.29
1654	-1.09	+4.72 ± 0.95
1929	-0.58 ± 0.18	+0.54 ± 0.07
1943	-0.59 ± 0.16	+0.35 ± 0.11
1987	-0.40 ± 0.03	+0.48 ± 0.02
	Type III	
0692	-2.04 ± 0.78	+0.88 ± 0.30
0912	-0.78 ± 0.34	+0.31 ± 0.04
1379	-0.60 ± 0.11	+1.10 ± 0.11
1686	-1.82 ± 0.37	+2.26 ± 1.18
1811	-1.67 ± 0.46	+0.54 ± 0.23
2012	-0.28 ± 0.08	+0.42 ± 0.35

Bootstrap linear fits to inner and outer gradients of upturning age profiles

Large range in upturn strength!

… and those upturns correlate with the breaks in Virgo Type II's …

(as predicted by simulations; Roškar et al. 2008, Sánchez-Blázquez et al. 2009; Martínez-Serrano et al. 2009)



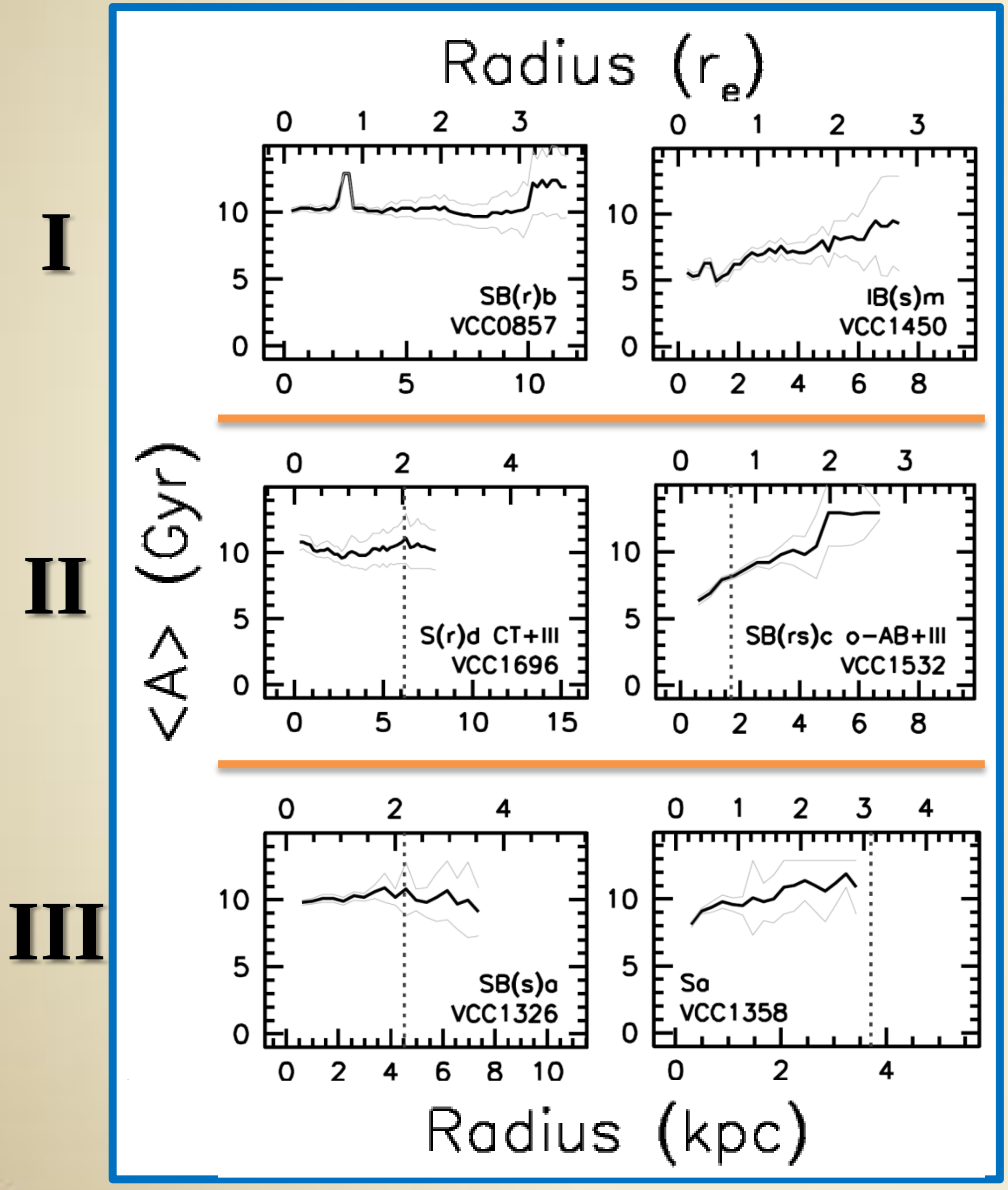
Theory

Virgo

Upturns also offset from breaks in **field Type IIs**

(Yoachim et al. 2012)

… but upturns are not that common overall



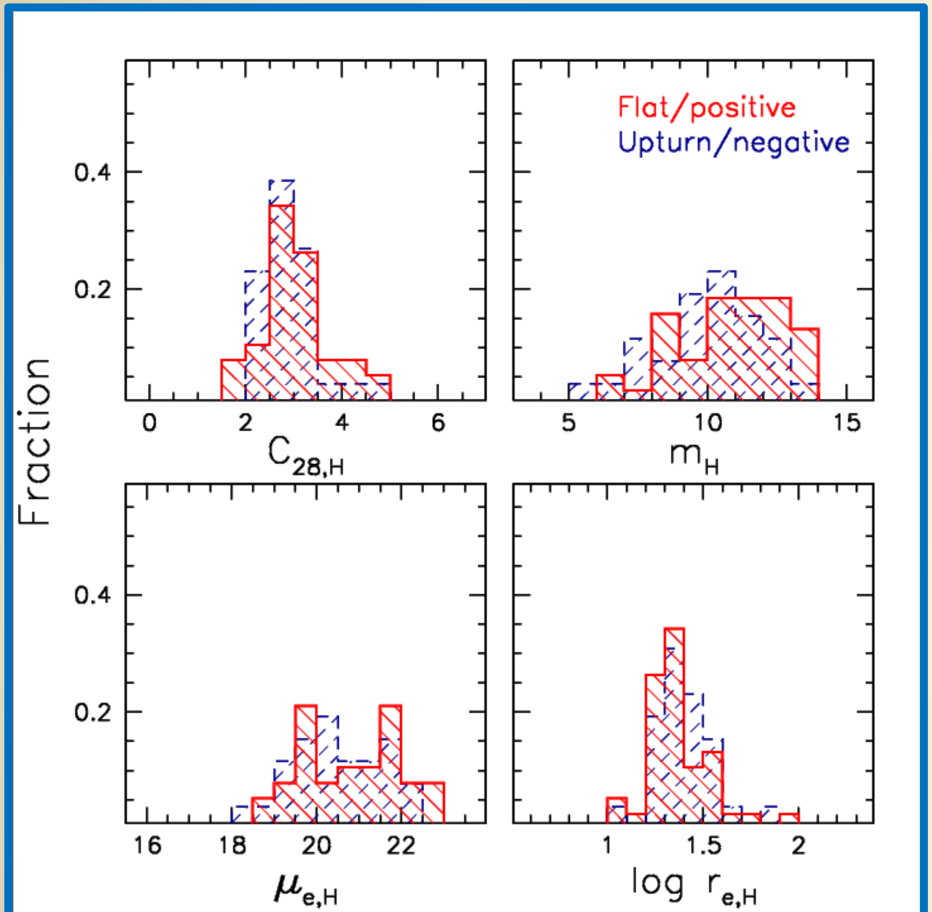
Virgo

Type	Positive	Flat	Negative	Upturn
I	7	8	2	3
II	8	3	3	8
III	7	5	2	6

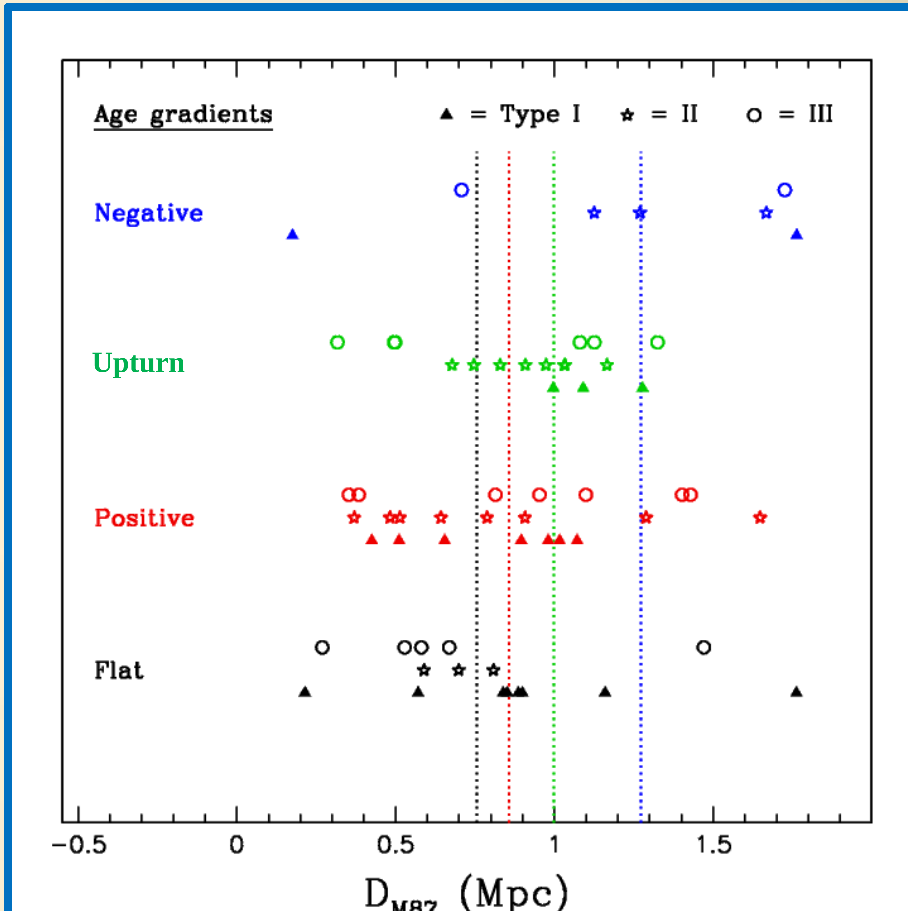
Models

Type	Positive	Flat	Negative	Upturn
I			✓	
II				✓
III				✓

Why do cluster and field disks differ?



Age gradients within Virgo disks **do not correlate** with their structure



Flat and positive age gradients are found most often **near cluster core**

Summary

1. **Type II disks are rarer in clusters than in the field**
   - *outer structure of disks sensitive to repeated tidal forcing*
2. **Age upturn phenomenon found amongst all disk Types in Virgo**
   - *stellar migrations a generic aspect of disk galaxy evolution?*
3. **Flat and positive age gradients dominate amongst Virgo disks**
   - *tides and ram pressure stripping mix and quench outer disks*

Future work

For observers:

Analyse deeper imaging (< 28 *r*-mag arcsec^{-2}) for cluster disks to produce unmatched description of outer disk structure in dense environments (e.g., NGVS).

For theorists:

Produce high-res hydrodynamic simulations of cluster galaxies, including ram pressure stripping and harassment.

See Roediger et al. (2012), arXiv:1201.6361