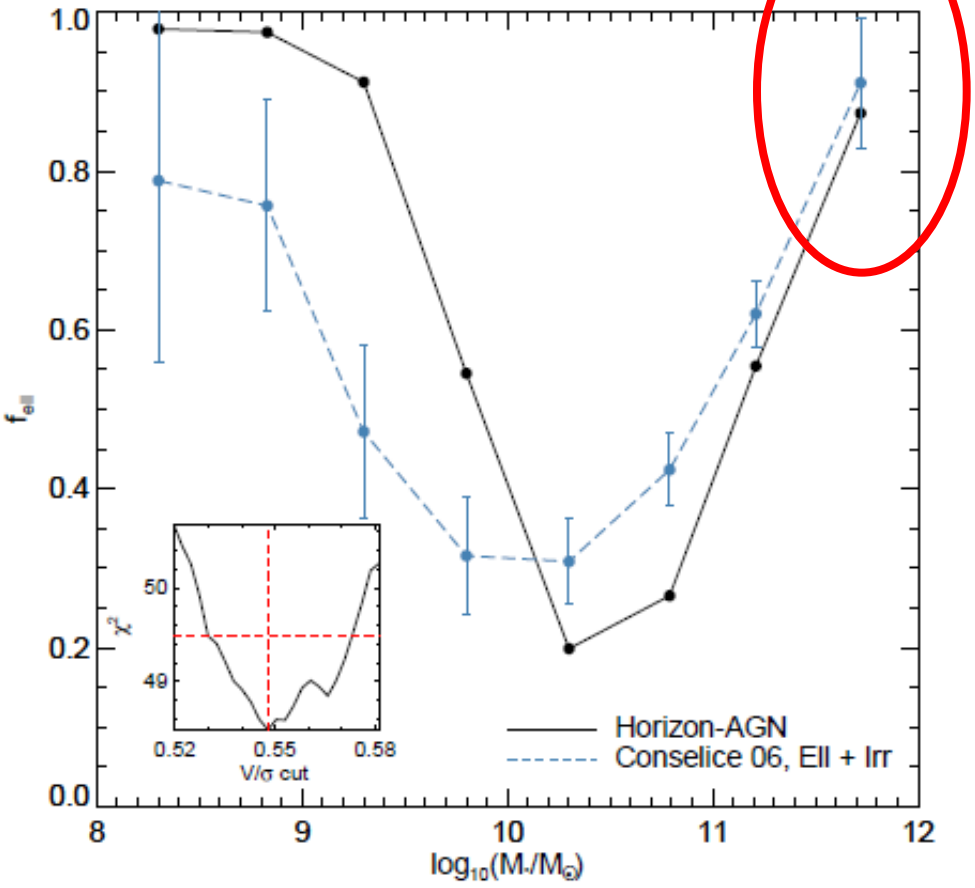
Why do extremely massive disk galaxies exist?

Sugata Kaviraj, Ryan Jackson, Garreth Martin

RUM 2018

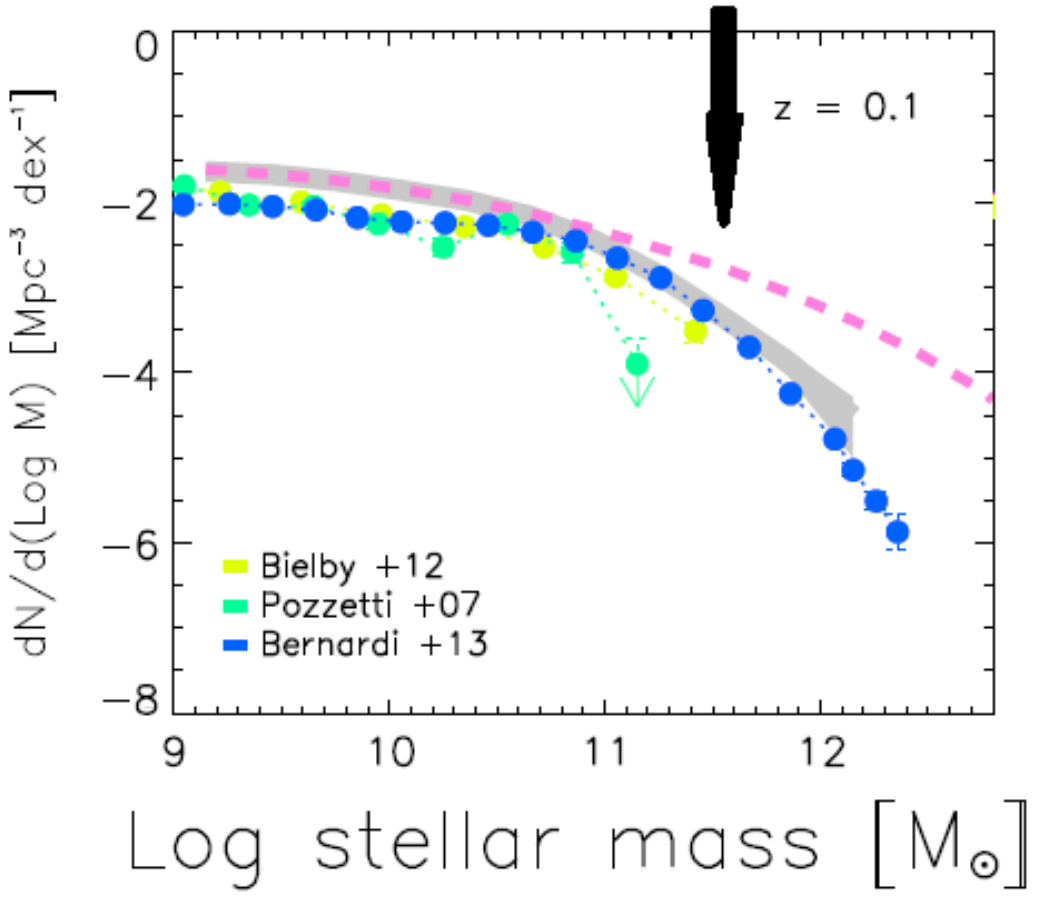
Why do massive disks exist today?



- Around 10% of massive galaxies ($M > 10^{11.5}$ MSun) are disks

Martin +18, MN, 474, 3140

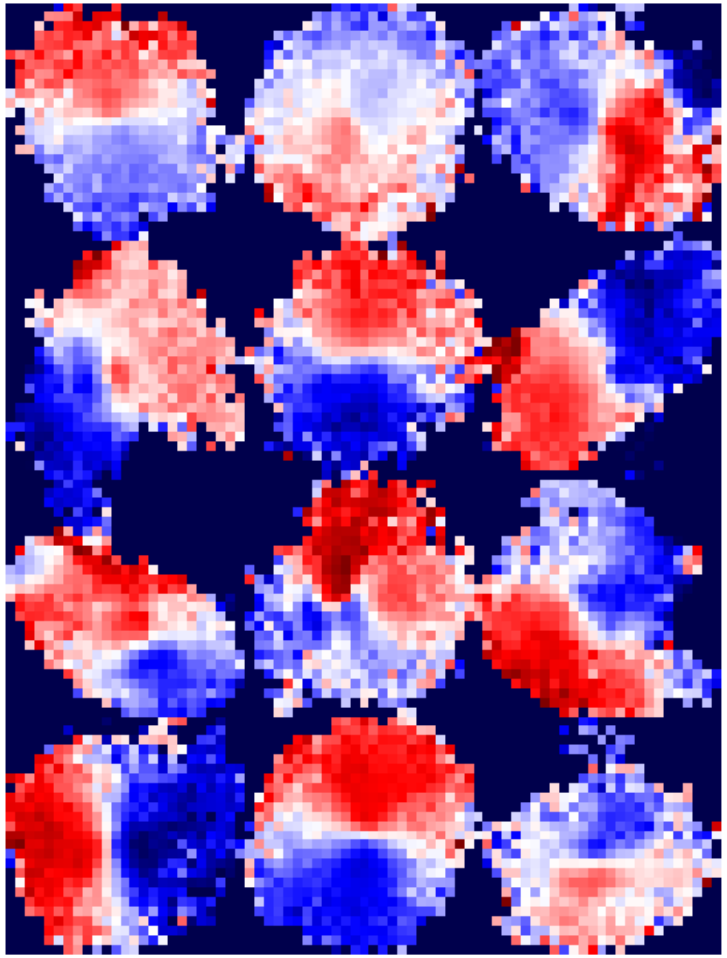
Why do massive disks exist today?



- Around 10% of massive galaxies ($M > 10^{11.5}$ MSun) are disks

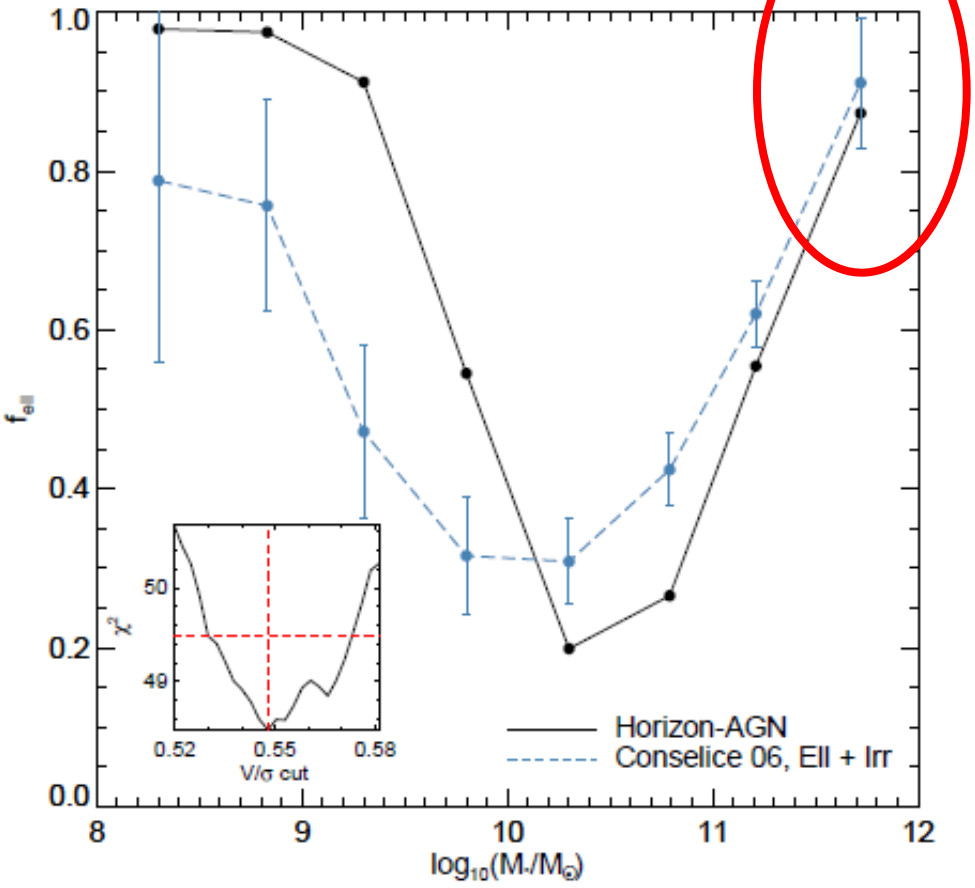
Kaviraj +17, MN, 467, 4739

Why do massive disks exist today?



- Around 10% of massive galaxies ($M > 10^{11.5}$ MSun) are disks
- Velocity fields show clear rotation

Why do massive disks exist today?

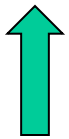


- Around 10% of massive galaxies ($M > 10^{11.5}$ MSun) are disks
- Velocity fields show clear rotation
- But massive galaxies have rich merger histories
- And mergers destroy disks and create spheroids…

Martin +18, MN, 474, 3140

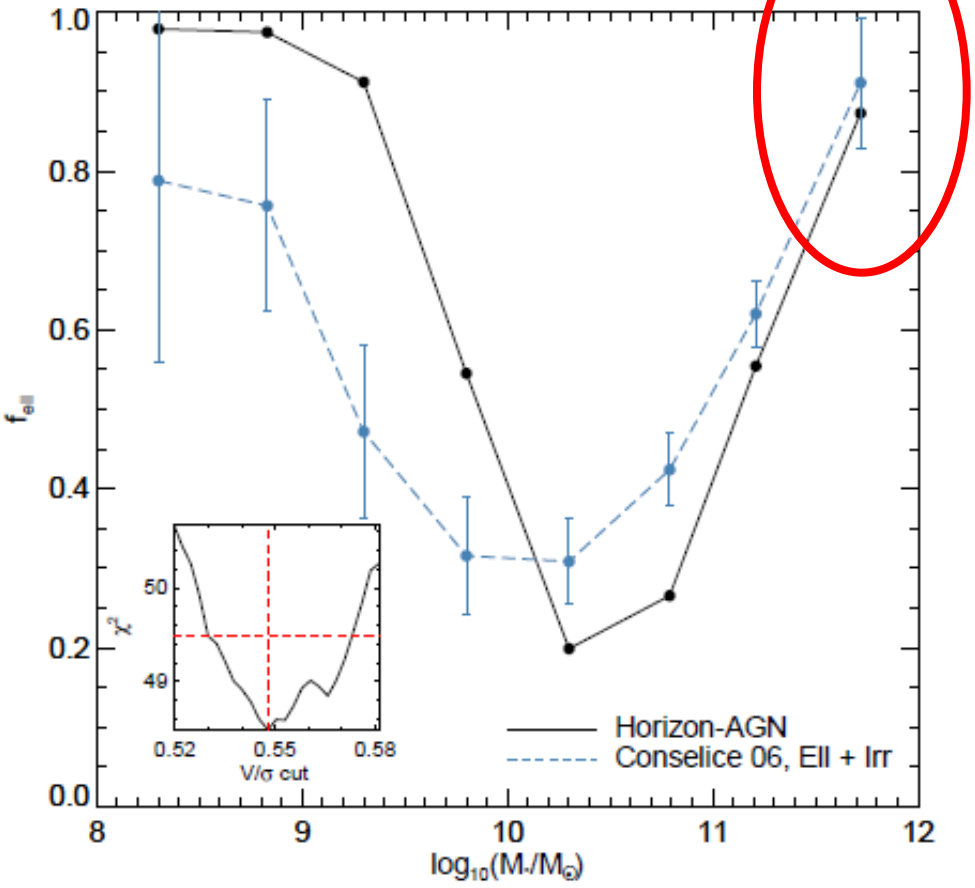
Why do massive disks exist today?

$\log_{10}(M_\star/M_\odot)$	z of largest (i)	ratio of largest (ii)	# major (iii)	# minor (iv)	ex situ mass (v)
10.5–11.0	$1.224(1.092)^{+0.509}_{-0.341}$	$2.864(2.485)^{+0.996}_{-0.238}$	1.178 ± 0.921	1.118 ± 1.063	$0.412(0.401)^{+0.089}_{-0.070}$
	$1.169(1.027)^{+0.614}_{-0.396}$	$3.249(2.719)^{+1.413}_{-0.444}$	0.726 ± 0.803	0.816 ± 0.872	$0.201(0.176)^{+0.091}_{-0.050}$
11.0–11.5	$1.203(1.027)^{+0.488}_{-0.322}$	$2.815(2.367)^{+0.978}_{-0.284}$	1.355 ± 1.032	1.504 ± 1.185	$0.542(0.533)^{+0.078}_{-0.061}$
	$1.121(0.968)^{+0.601}_{-0.364}$	$3.244(2.679)^{+1.291}_{-0.419}$	0.946 ± 0.981	1.150 ± 1.052	$0.336(0.321)^{+0.093}_{-0.059}$
11.5–12.0	$1.235(1.092)^{+0.520}_{-0.369}$	$3.076(2.523)^{+1.141}_{-0.282}$	1.217 ± 1.114	1.548 ± 1.246	$0.609(0.597)^{+0.081}_{-0.067}$
	$0.901(0.632)^{+0.573}_{-0.538}$	$2.210(2.099)^{+0.538}_{-0.128}$	1.238 ± 0.921	1.714 ± 1.201	$0.536(0.555)^{+0.070}_{-0.119}$



Massive disks and spheroids share similar merger histories (Martin +18 , MN, 480, 2266)

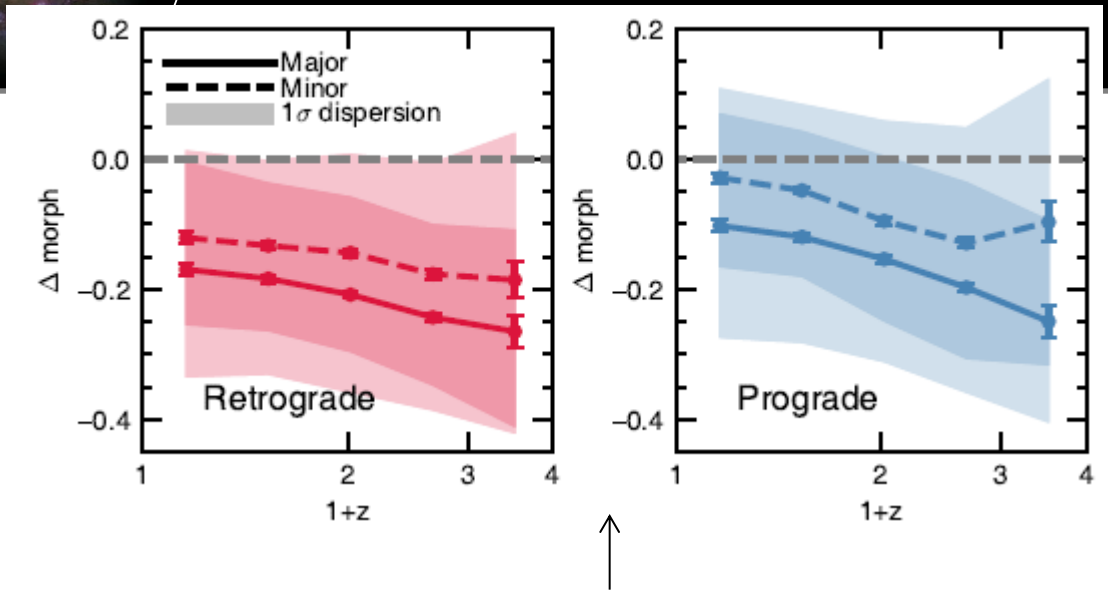
Why do massive disks exist today?



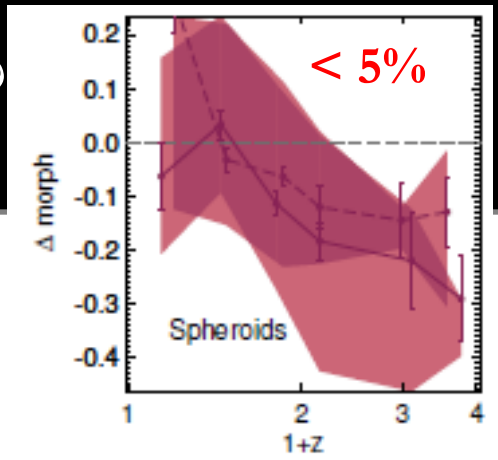
Martin +18, MN, 474, 3140

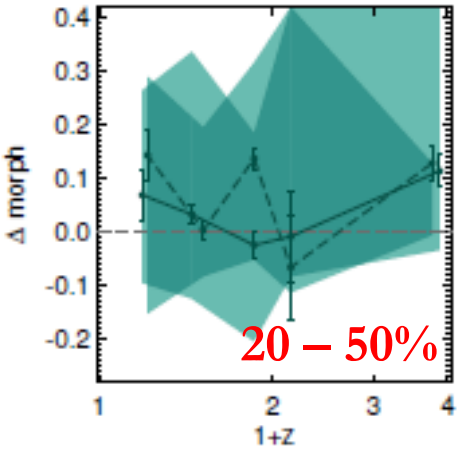
- Around 10% of massive galaxies ($M > 10^{11.5}$ MSun) are disks
- Velocity fields show clear rotation
- But massive galaxies have rich merger histories
- And mergers typically destroy disks and create spheroids…
- **So why do such massive disks exist today?**

Why do massive disks exist today?

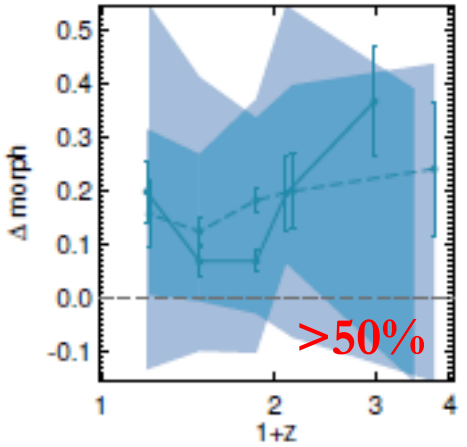


Effect of orbital configuration





Effect of gas fraction on mergers involving spheroids →

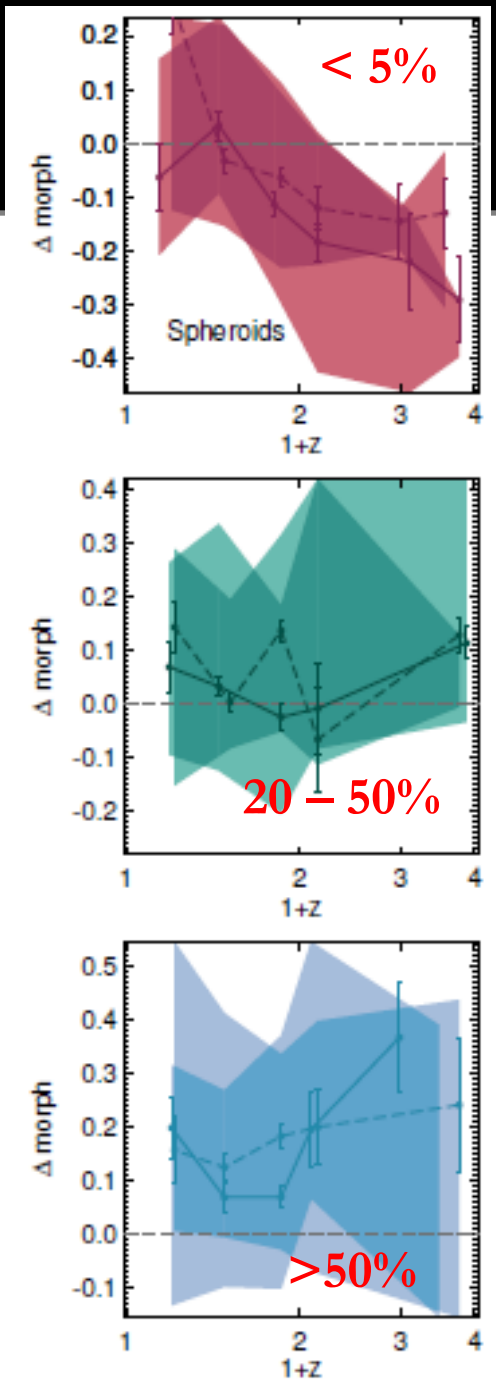


Martin +18, MN, 480, 2266

Why do massive disks exist today?

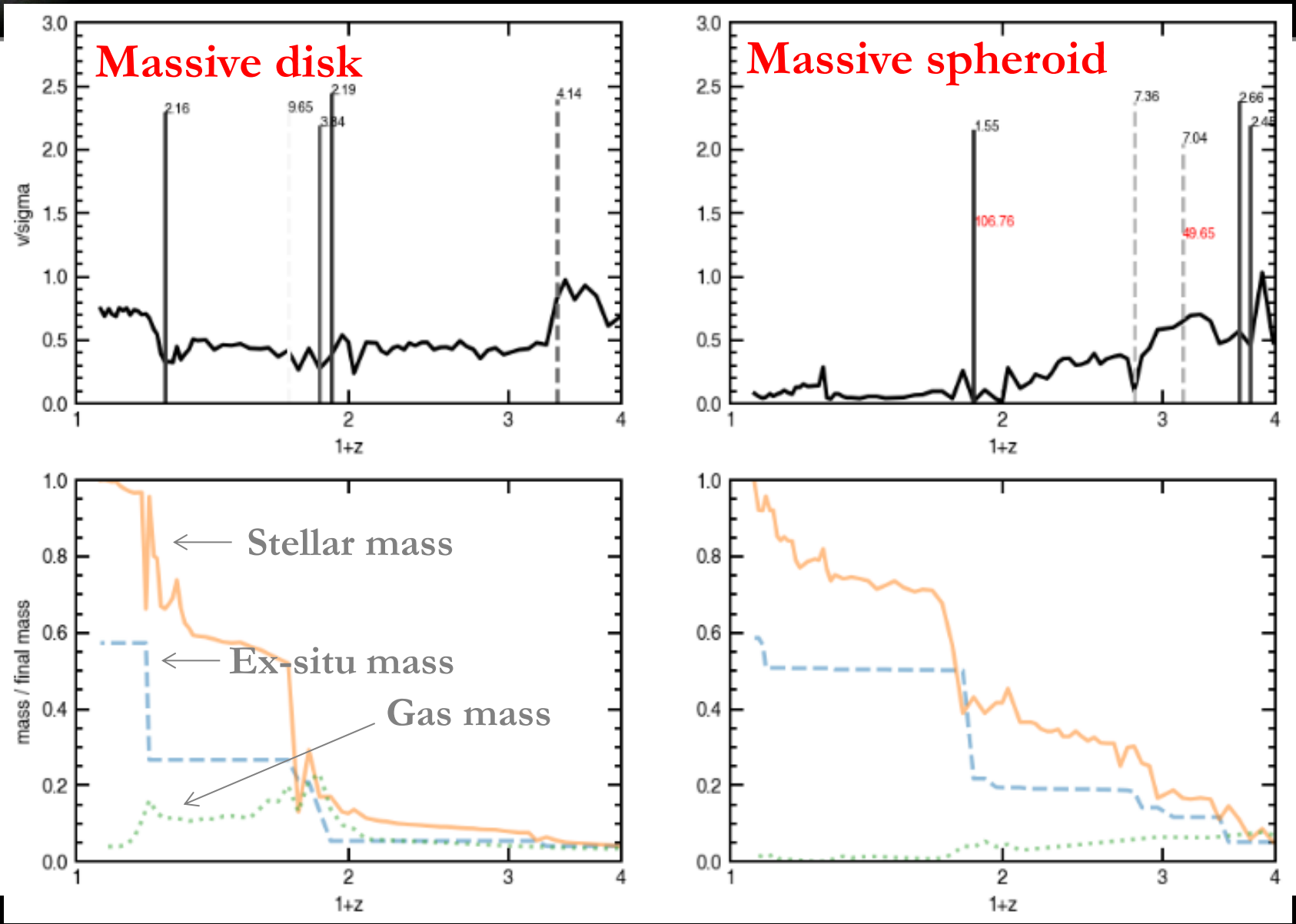
- Gas-rich mergers tend to produce fast-rotating remnants **(e.g. Springel +05, Font +17, Martin +18 and others)**

- Could gas be responsible for the existence of today's massive disks?



Martin +18, MN, 480, 2266

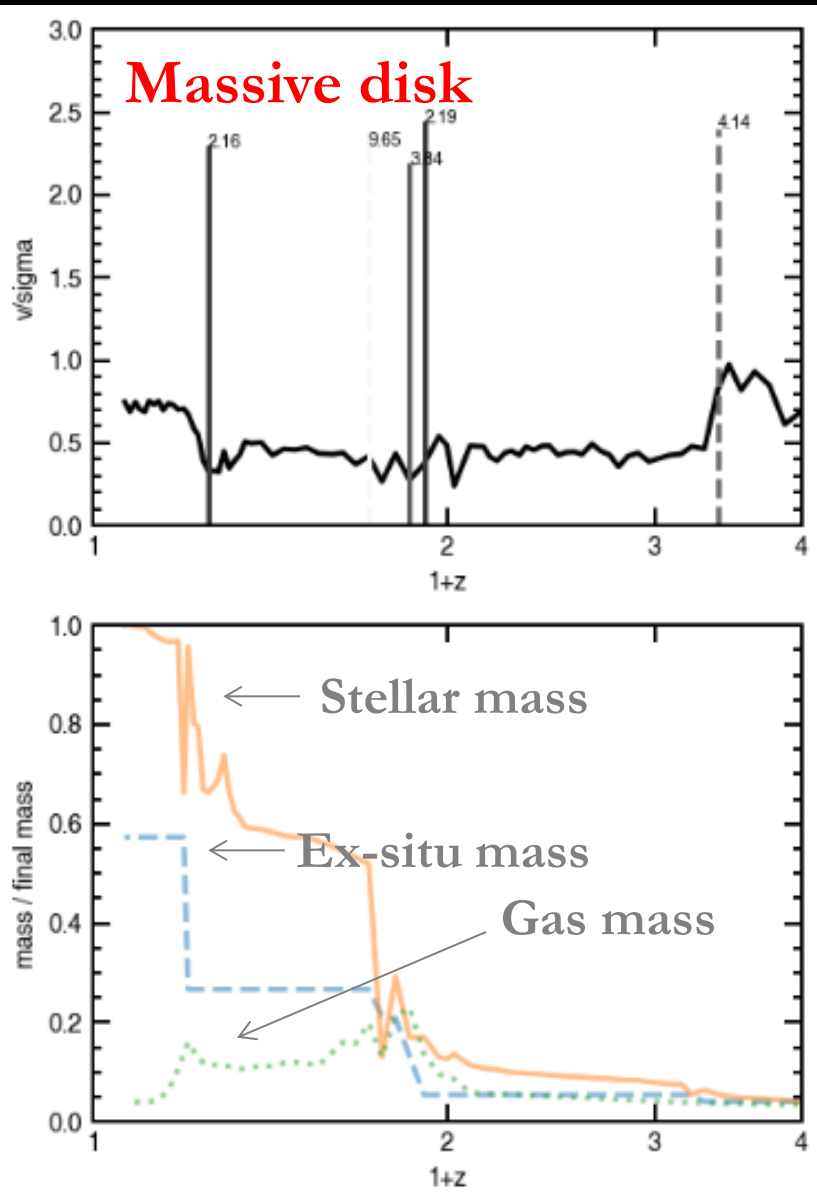
Why do massive disks exist today?



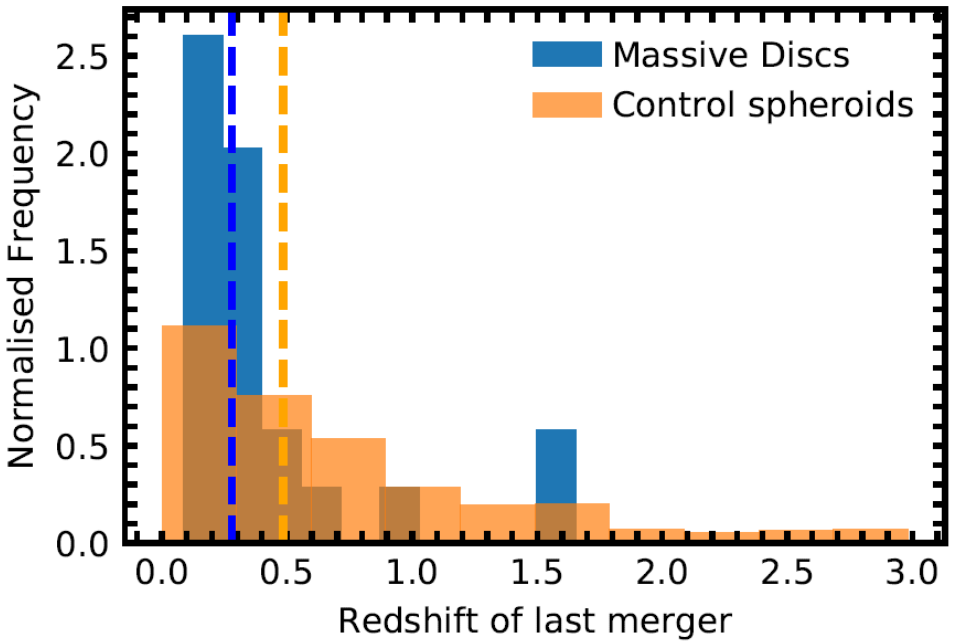
Why do massive disks exist today?

- **Every** massive disk shows a recent uptick in v/sigma coincident with a gas-rich merger

- Compare the properties of the last mergers in massive disks to a control sample of last mergers in massive spheroids…

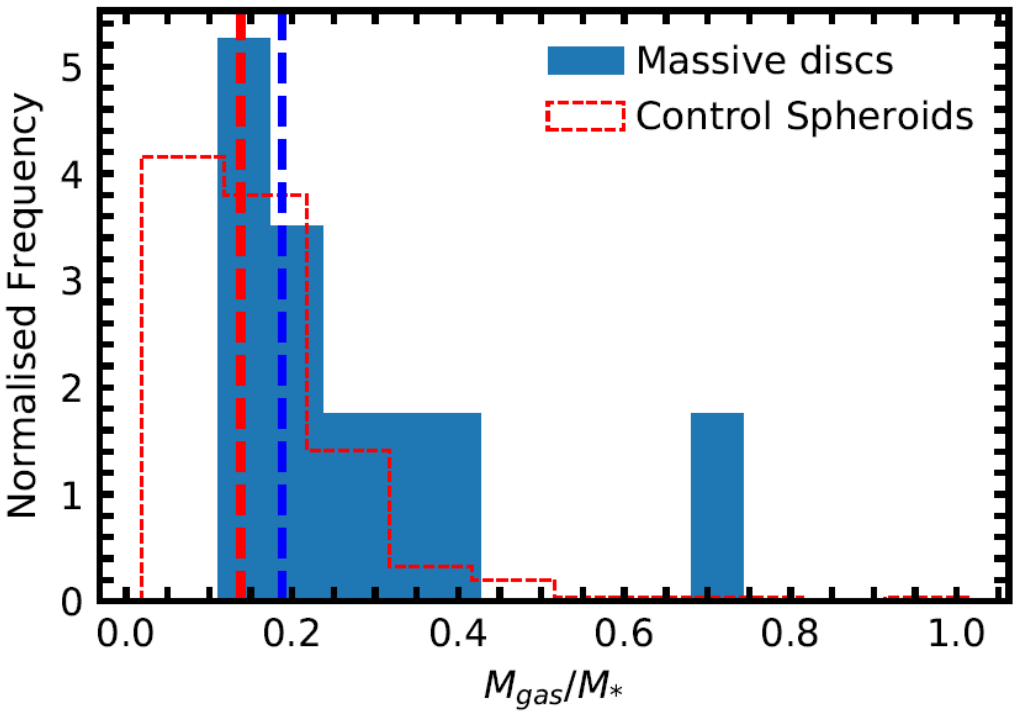


Why do massive disks exist today?



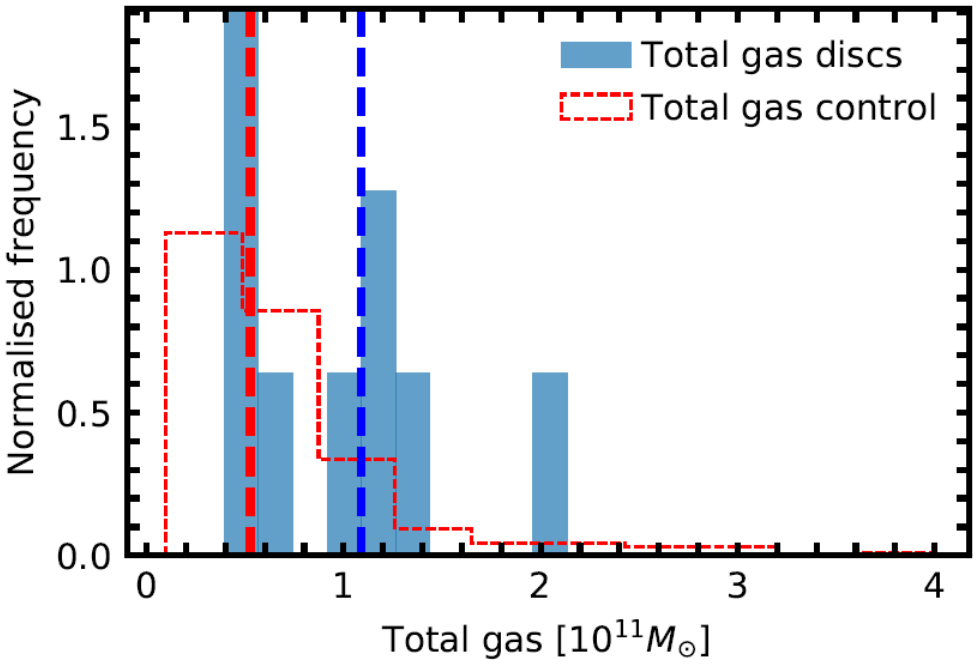
- Last mergers in massive disks:
  - Are more recent

Why do massive disks exist today?



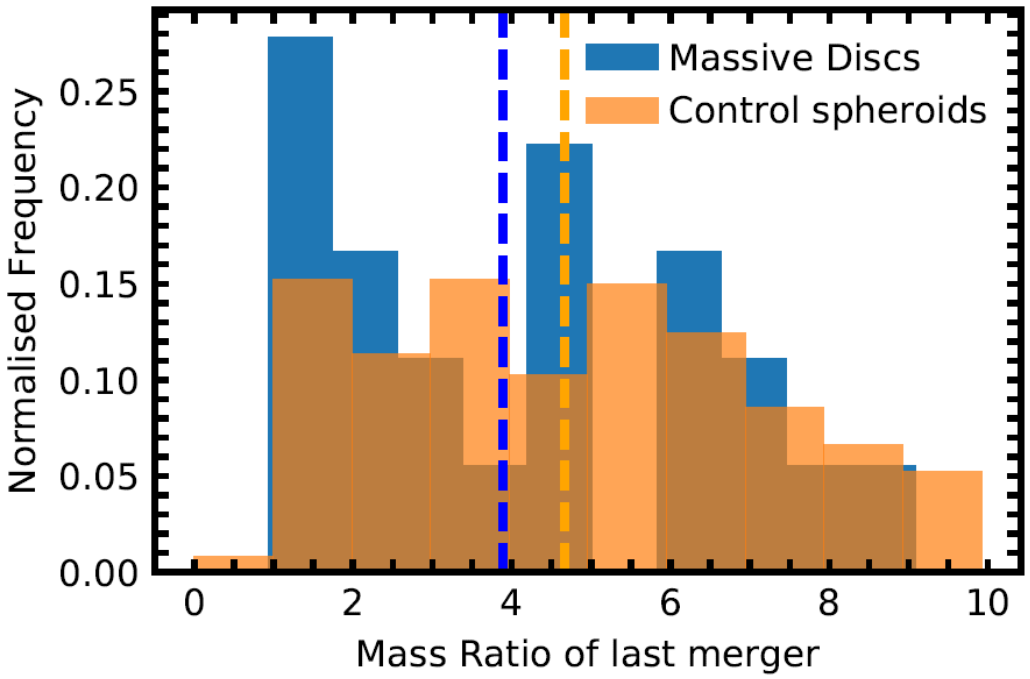
- Last mergers in massive disks:
  - Are more recent
  - Have higher gas fractions

Why do massive disks exist today?



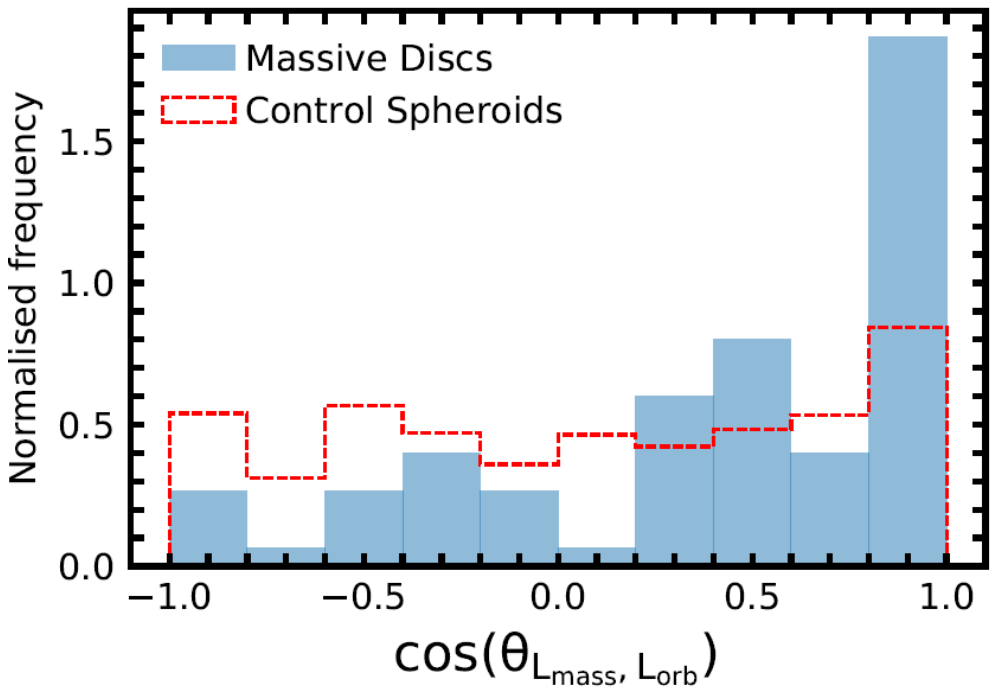
- Last mergers in massive disks:
  - Are more recent
  - Have higher gas fractions
  - Bring in a higher absolute mass of gas

Why do massive disks exist today?



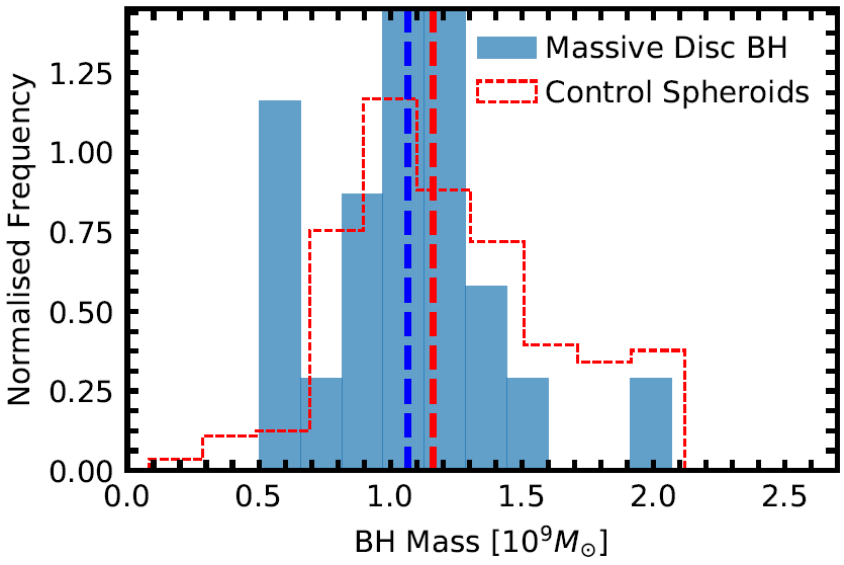
- Last mergers in massive disks:
  - Are more recent
  - Have higher gas fractions
  - Bring in a higher absolute mass of gas
  - Have slightly higher mass ratios

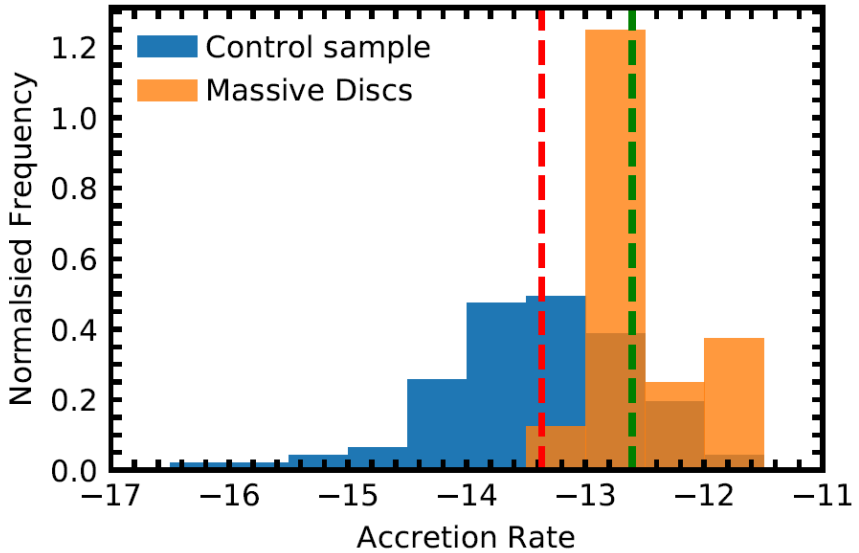
Why do massive disks exist today?



- Last mergers in massive disks:
  - Are more recent
  - Have higher gas fractions
  - Bring in a higher absolute mass of gas
  - Have slightly higher mass ratios
  - Show a slight preference for prograde coplanar orbits

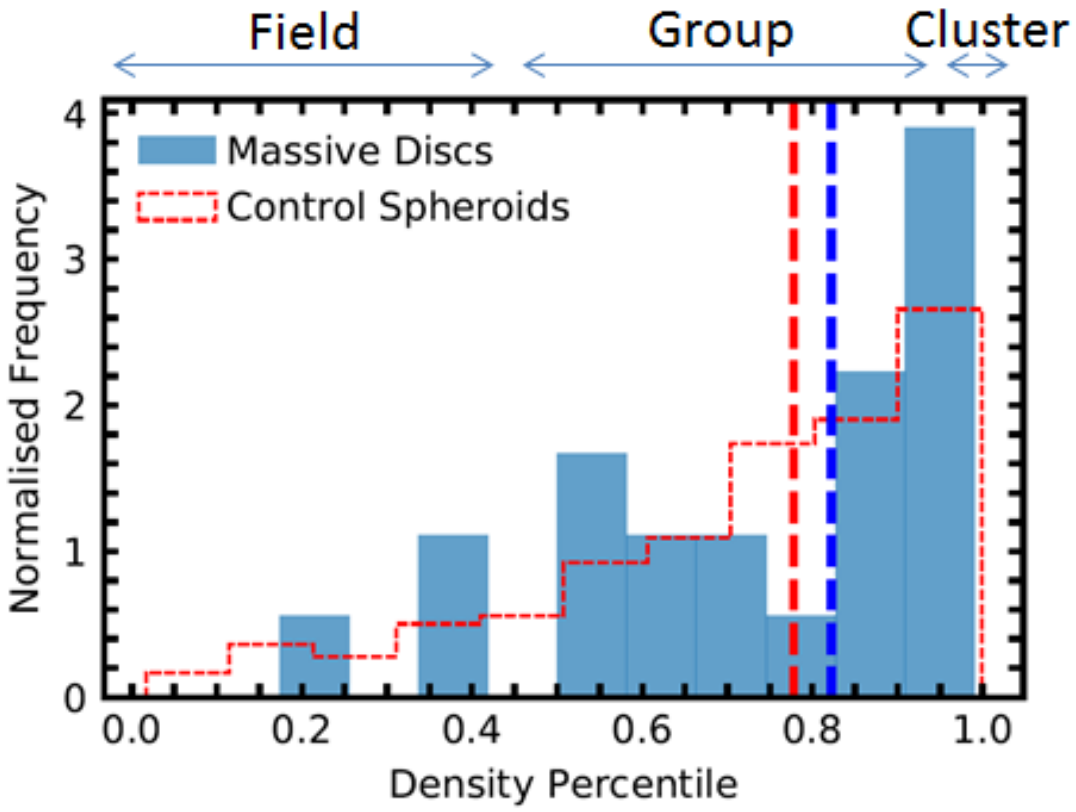
Why do massive disks exist today?





- Massive disks shows similar BH masses to massive spheroids – not surprising since they are rejuvenated spheroids
- They show elevated AGN activity

Why do massive disks exist today?



- Massive discs shows similar BH masses to massive spheroids – not surprising since they are rejuvenated spheroids
- They show elevated AGN activity
- …and many inhabit dense environments
- Could they explain observed massive disc galaxies that host double lobed AGN?

Why do massive disks exist today?

Object	Redshift	$L_{1.4GHz}$	Optical	Radio	Ref
NGC612	0.0298	2×10^{25}	NLRG	FRII	1
0313-192	0.0671	1×10^{24}	NLRG	FRI/DD?	2,3
J0832+0532	0.099	1.5×10^{24}	NLRG	FRII	4
3C223.1	0.107	5.4×10^{25}	NLRG	FRII	5,6
J1159+5820	0.054	2.3×10^{24}	WLRG	FRII/DD	7,4
3C236	0.1007	1.0×10^{26}	NLRG	FRII/DD	8
3C293	0.0450	2×10^{25}	WLRG	FRII?/DD	9,4
3C305	0.0416	1.2×10^{25}	NLRG	CSS	10, 11
Speca	0.1378	7×10^{24}	WLRG	FRII?/DD	12
J1649+26	0.055	1×10^{24}	WLRG	FRII	14,4
PKS1814-637	0.0641	1.2×10^{26}	NLRG	CSS	13
J23345-0449	0.0755	3×10^{24}	WLRG	FRII/DD	15

Table 4 Radio AGN showing clear disk and/or spiral morphologies in optical images. Reference key: 1. Emonts et al. (2008); 2. Ledlow et al. (2001); 3. Keel et al. (2006); 4. Singh et al. (2015); 5. de Koff et al. (2000); 6. Madrid et al. (2006); 7. Kozieł-Wierzbowska et al. (2012); 8. O'Dea et al. (2001); 9. van Breugel et al. (1984); 10. Sandage (1966); 11. Heckman et al. (1982); 12. Hota et al. (2011); 13. Morganti et al. (2011); 14. Mao et al. (2015); 15. Bagchi et al. (2014). The radio luminosities in column 3 are in units of W Hz^{-1}. Columns 4 and 5 give the optical spectroscopic and radio morphological classification respectively, with uncertain classifications indicated by a question mark; a DD designation in column 5 indicates a double-double source.

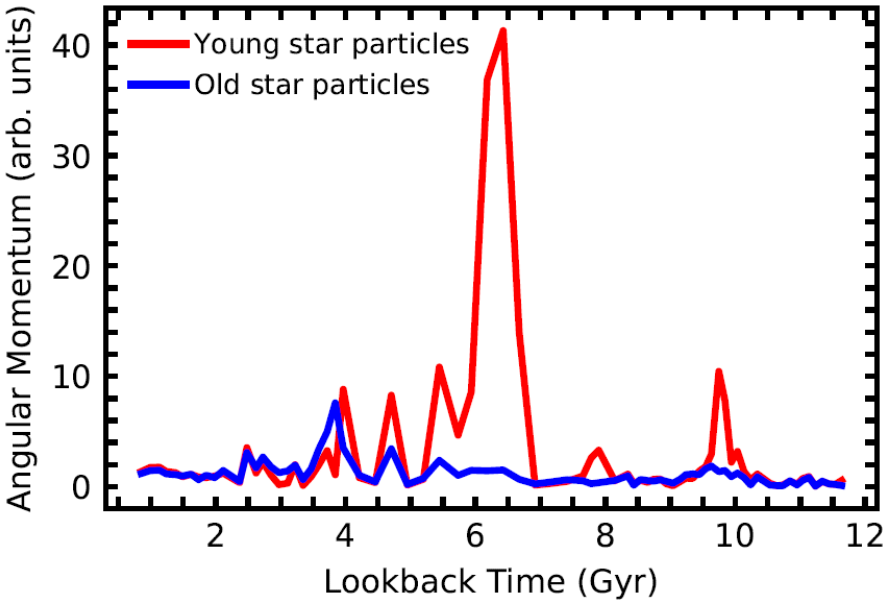
Tadhunter 2016

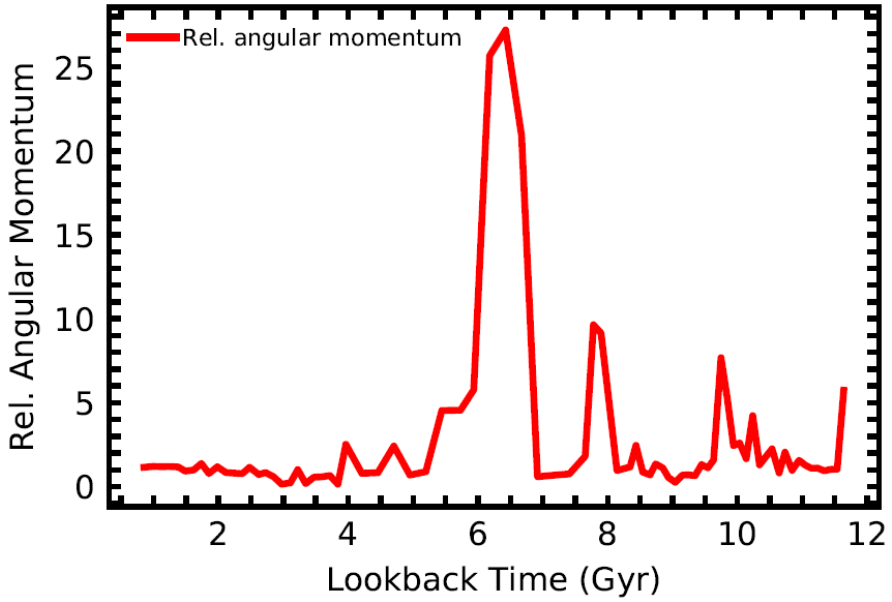
Why do massive disks exist today?

Other questions we are exploring now:

- Do the mergers spin up the whole system or create a new fast-rotating component?

Why do massive disks exist today?





Why do massive disks exist today?

Other questions we are exploring now:

- Do the mergers spin up the whole system or create a new fast-rotating component?

- Does the frequency of extremely massive disks correlate with gas fraction of the Universe?

Summary

Ryan Jackson, Garreth Martin et al. in prep.

- Around 10% of extremely massive galaxies host significant disc components
- These galaxies are initially spheroids
- …but have recent gas-rich mergers -> disc rejuvenation
- Many inhabit dense environments (large groups and clusters)
- Explains powerful double-lobed AGN in disc galaxies reported in the observational literature?
- **Gas-rich mergers regulate the morphological mix of the Universe at the highest stellar masses**