Morphology and Size Evolution of Massive and Compact Galaxies

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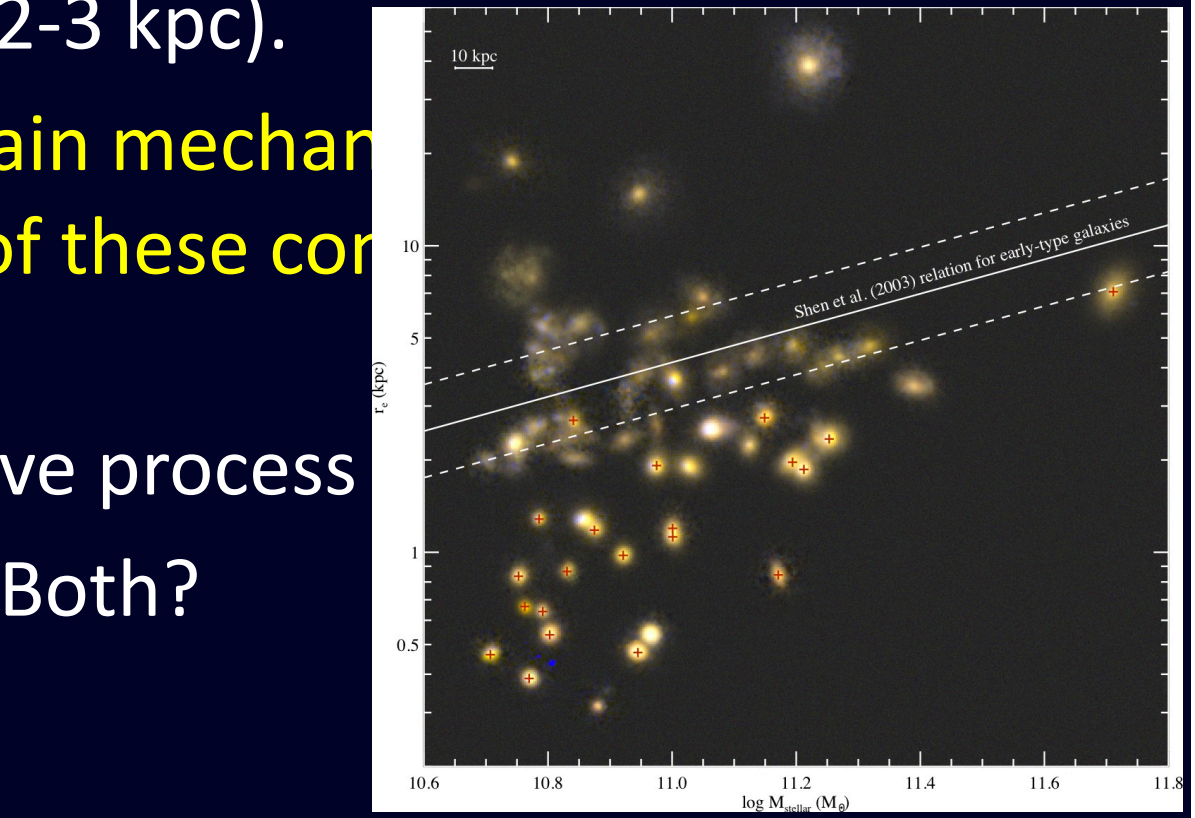
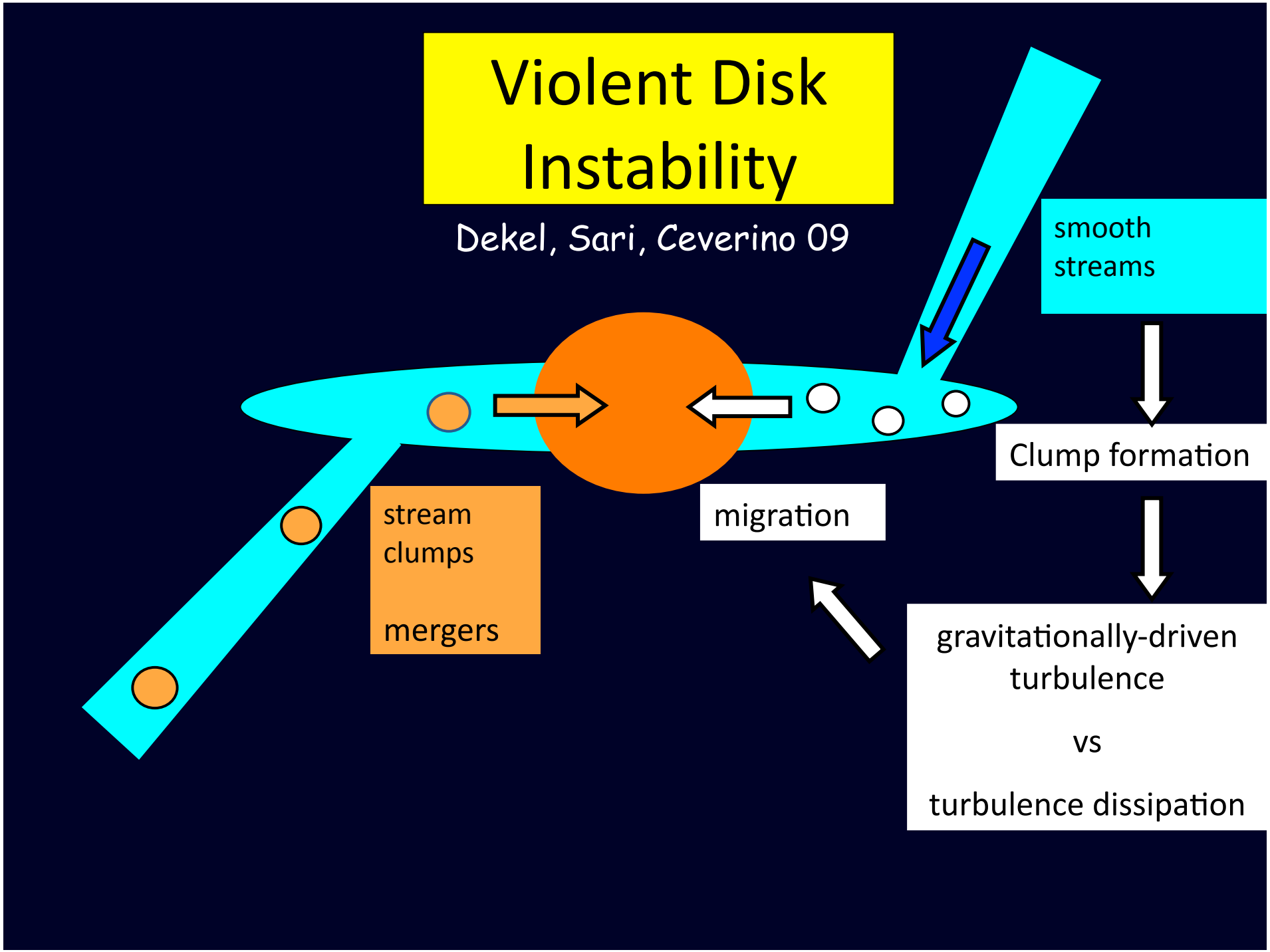
Santa Cruz, 2012

Structure of massive galaxies at high-z

- Massive, $M_s \approx 10^{11}\ M_{sun}$, spheroids or nuggets
- Compact (Re < 2-3 kpc).
- Which is the main mechan
  the formation of these cor
  galaxies?
- A Very dissipative process
- Mergers? VDI? Both?



Szomoru, Franx, van Dokkum 2011


Violent Disk Instability
Dekel, Sari, Ceverino 09
smooth streams
Clump formation
gravitationally-driven turbulence
vs
turbulence dissipation
migration
stream clumps
mergers

Galaxy formation simulations done with ART

- AMR code: HYDRO-ART (Kravtsov et al 1997, Kravtsov 2003)
- Gas Cooling, Star Formation, Stellar Feedback (Ceverino & Klypin 2009; Ceverino, Dekel and Bournaud 2010)
  - Cooling below 10^4 K (minimum temperature of 300 K).
  - Thermal feedback + runaway stars.
  - Things that we are NOT doing (although it is tempting): Shutdown cooling, shutdown of hydrodynamical forces.
- Sample of **30** halos with a virial mass between 10^{12} -10^{13} $M_\odot$ h^{-1} at z=1
- Maximum resolution of 30-70 pc

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.1

85

5

2
ensity
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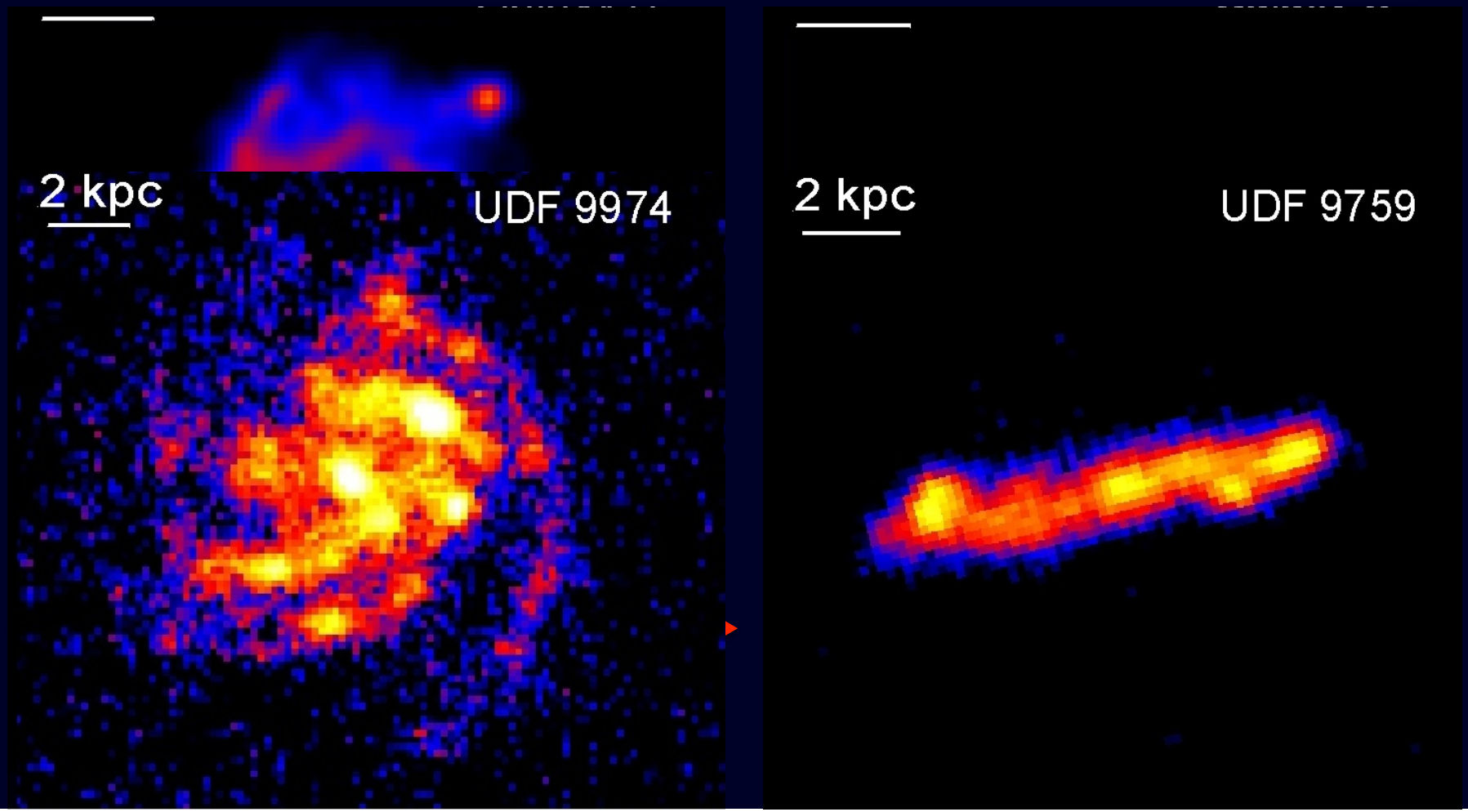
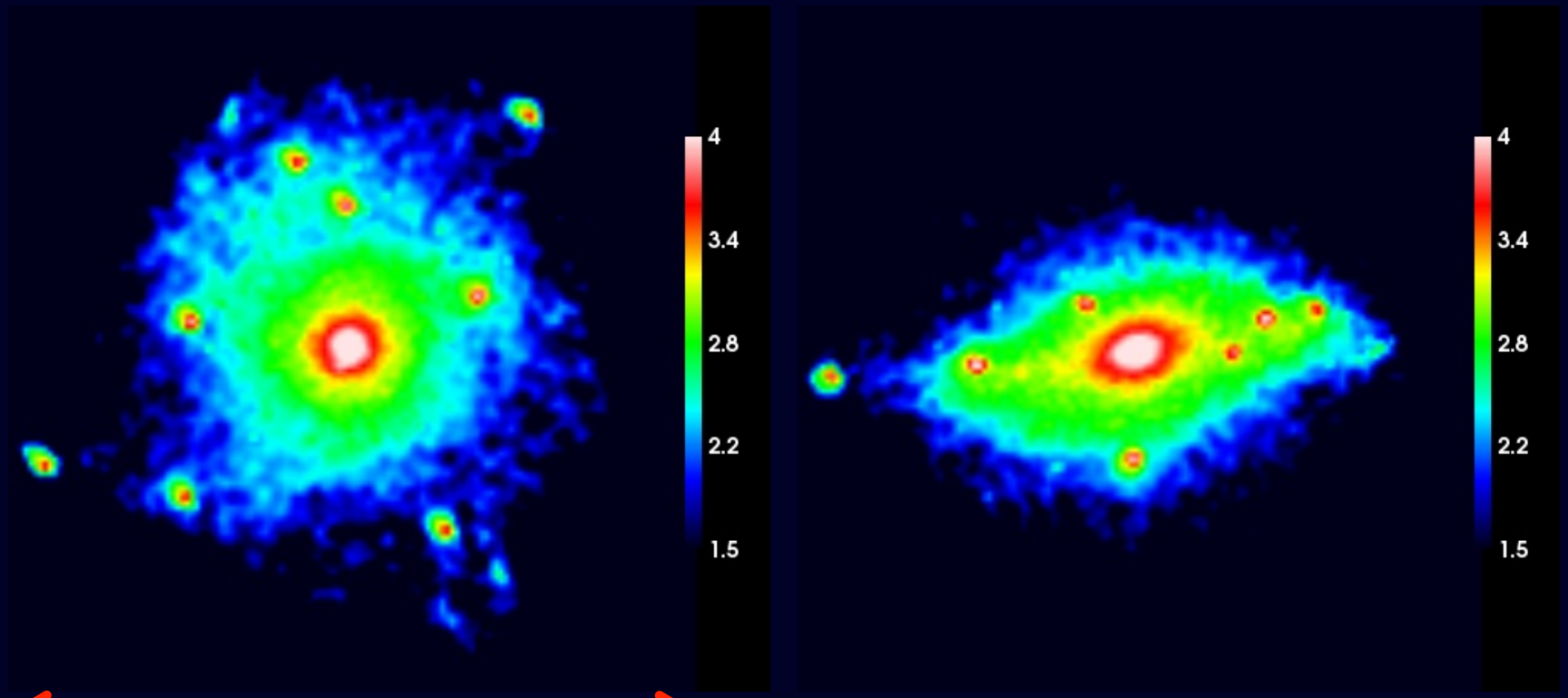
Young stellar disc

Ceverino, Dekel & Bournaud 2010



A Massive Bulge

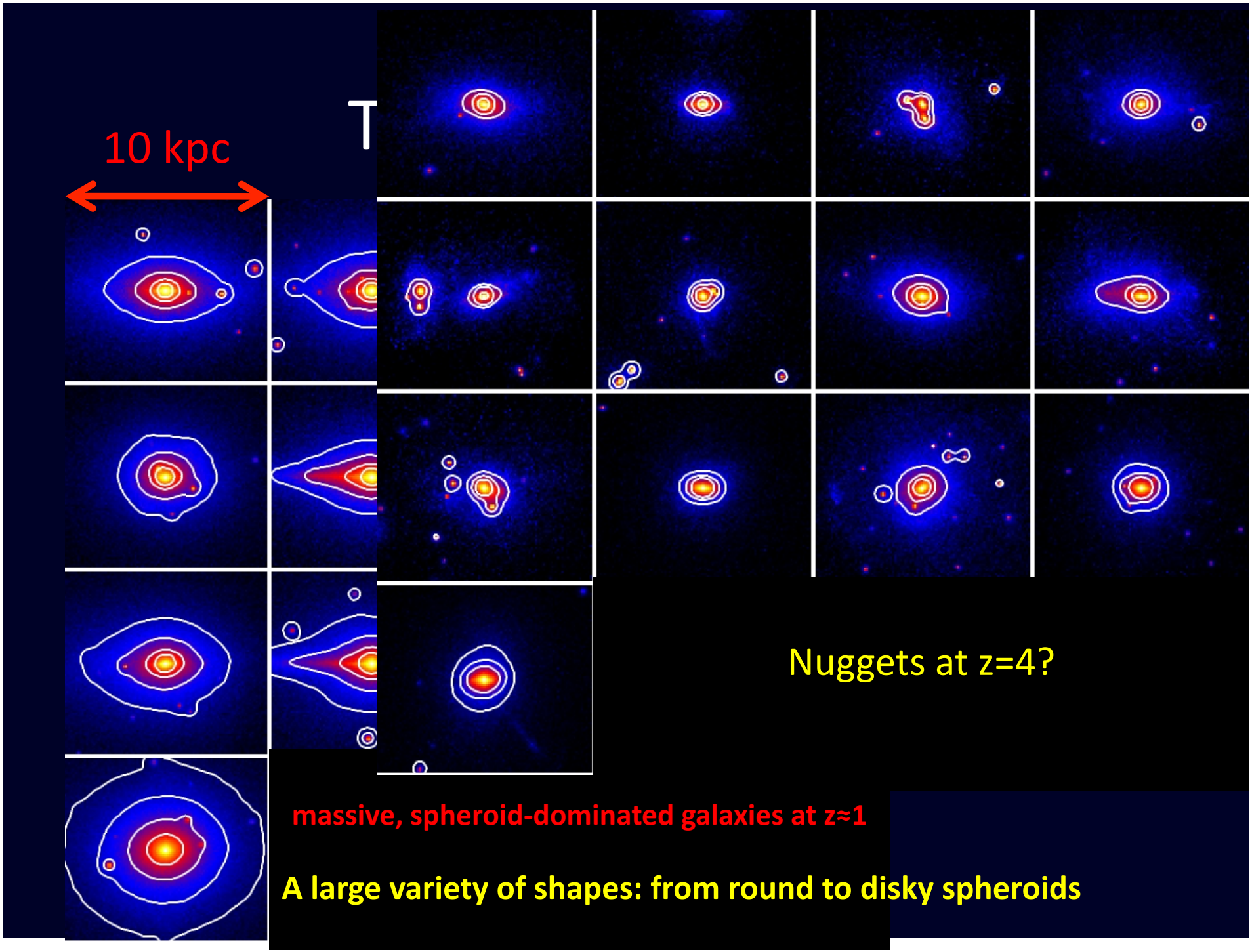
Stellar Surface Density



10 kpc

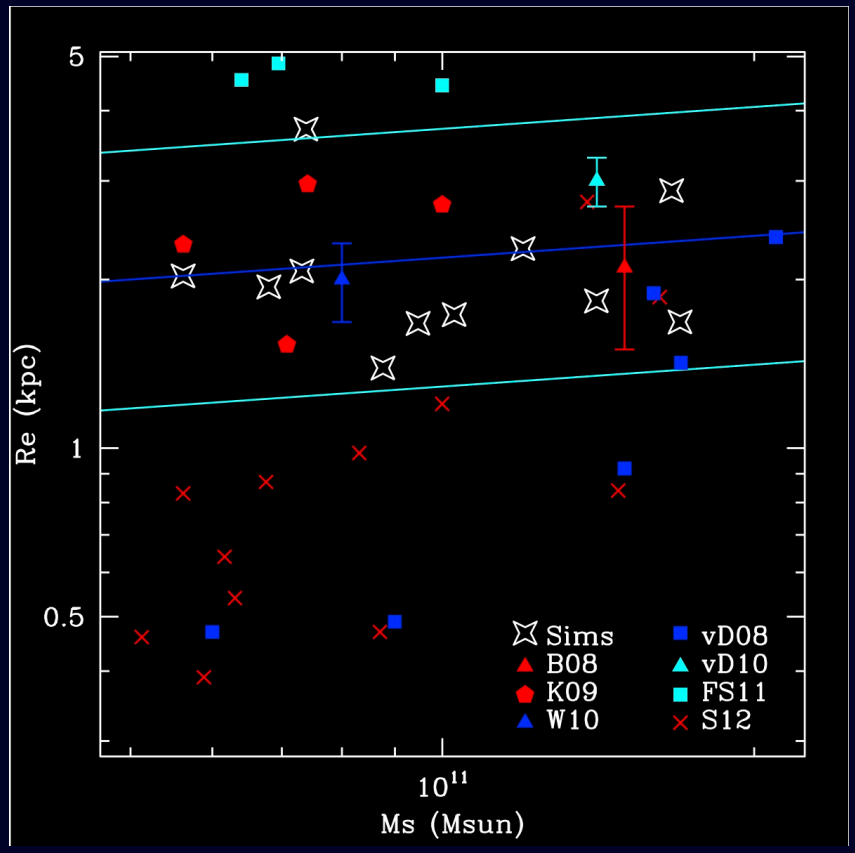
Face-on view

Edge-on view

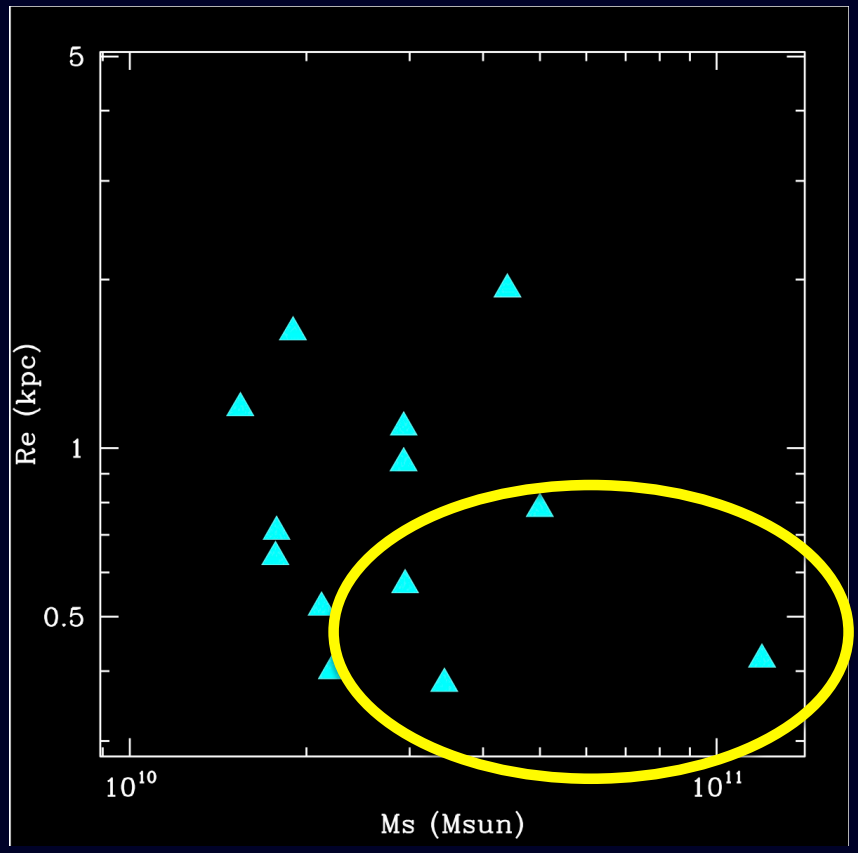

10 kpc
T
Nuggets at z=4?
massive, spheroid-dominated galaxies at z≈1
A large variety of shapes: from round to disky spheroids

Mass-size relation

z≈2

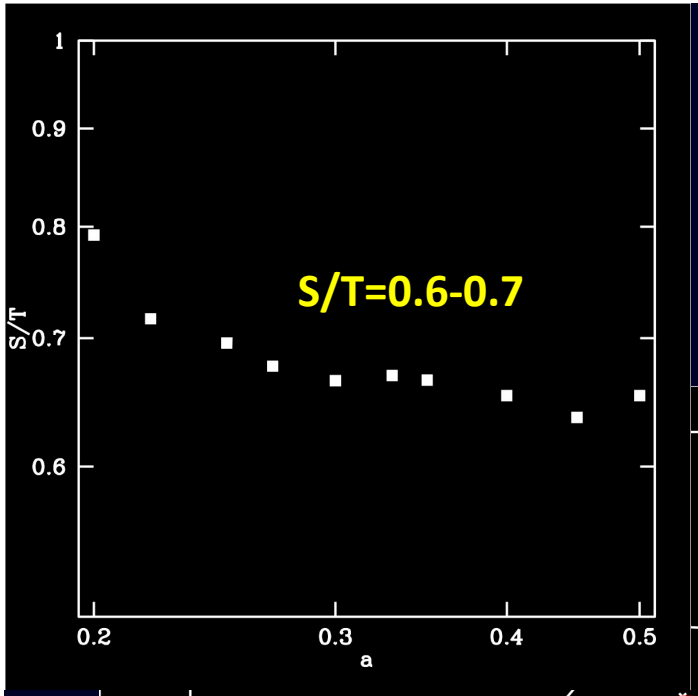


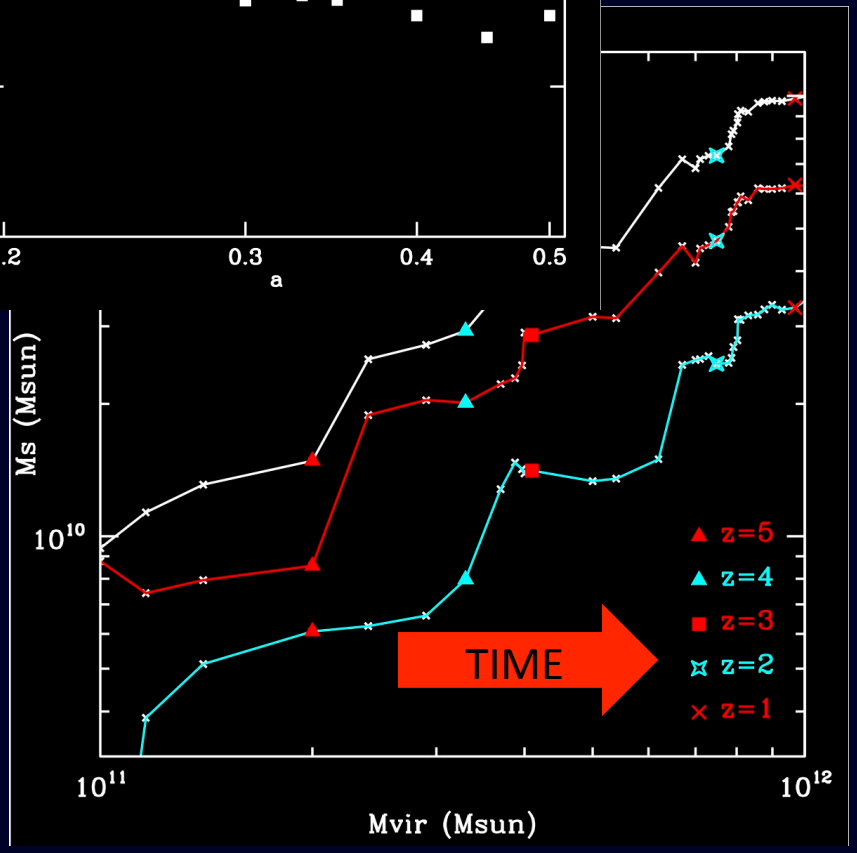
z≈4



Nuggets?
R_e< 1 kpc

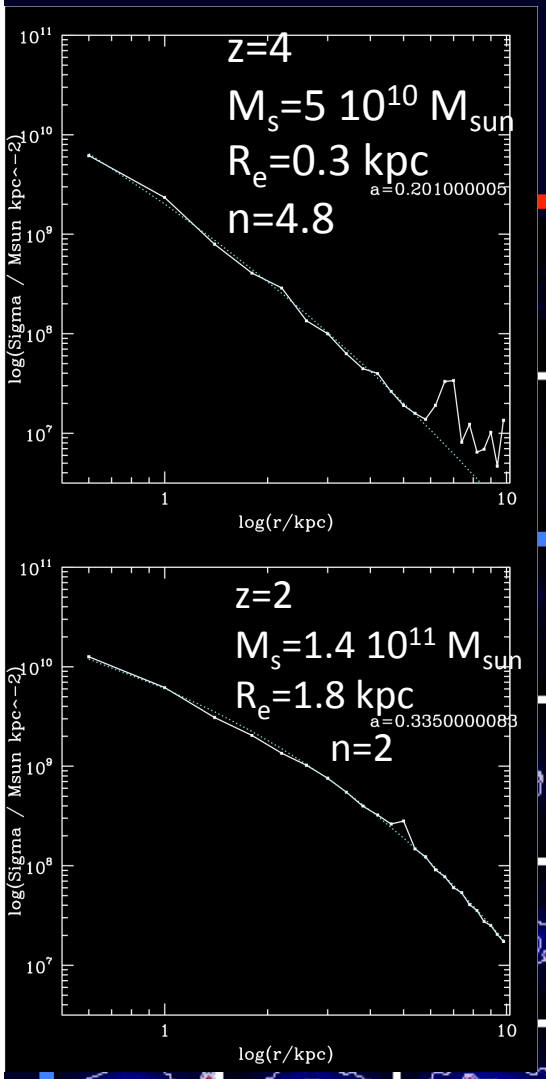
bulge and disc growth





- Continuous disc growth fuels by gas accretion
- Continuous bulge growth due to VDI
- Major mergers only produces discrete and rare jumps in the stellar growth.
- $M_s/M_{vir} \approx 0.5\ \Omega_b/\Omega_m$

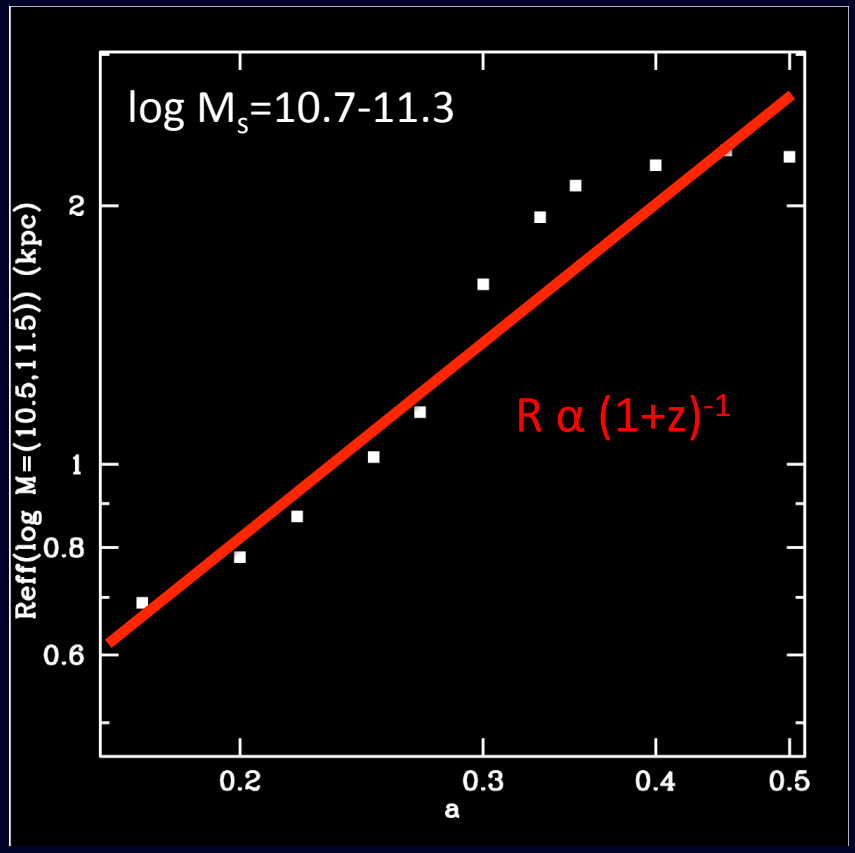
One example:



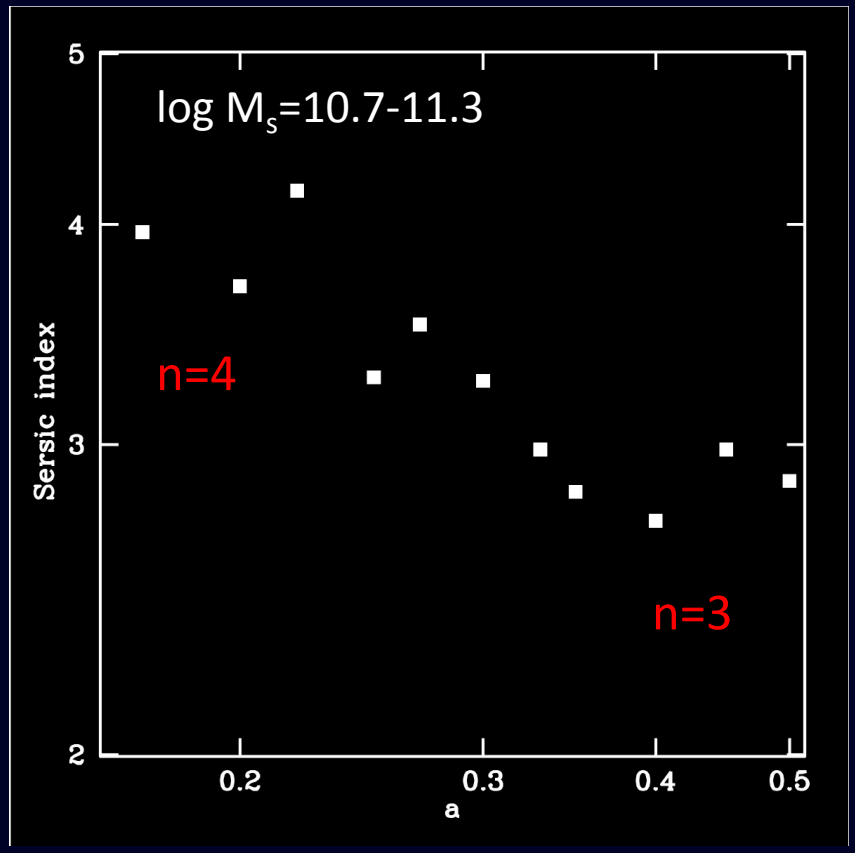
- Period of frequent wet major mergers
- Period of strong gas accretion, disc growth and disk instabilities (VDI)

Size and morphology evolution

z=4 z=1

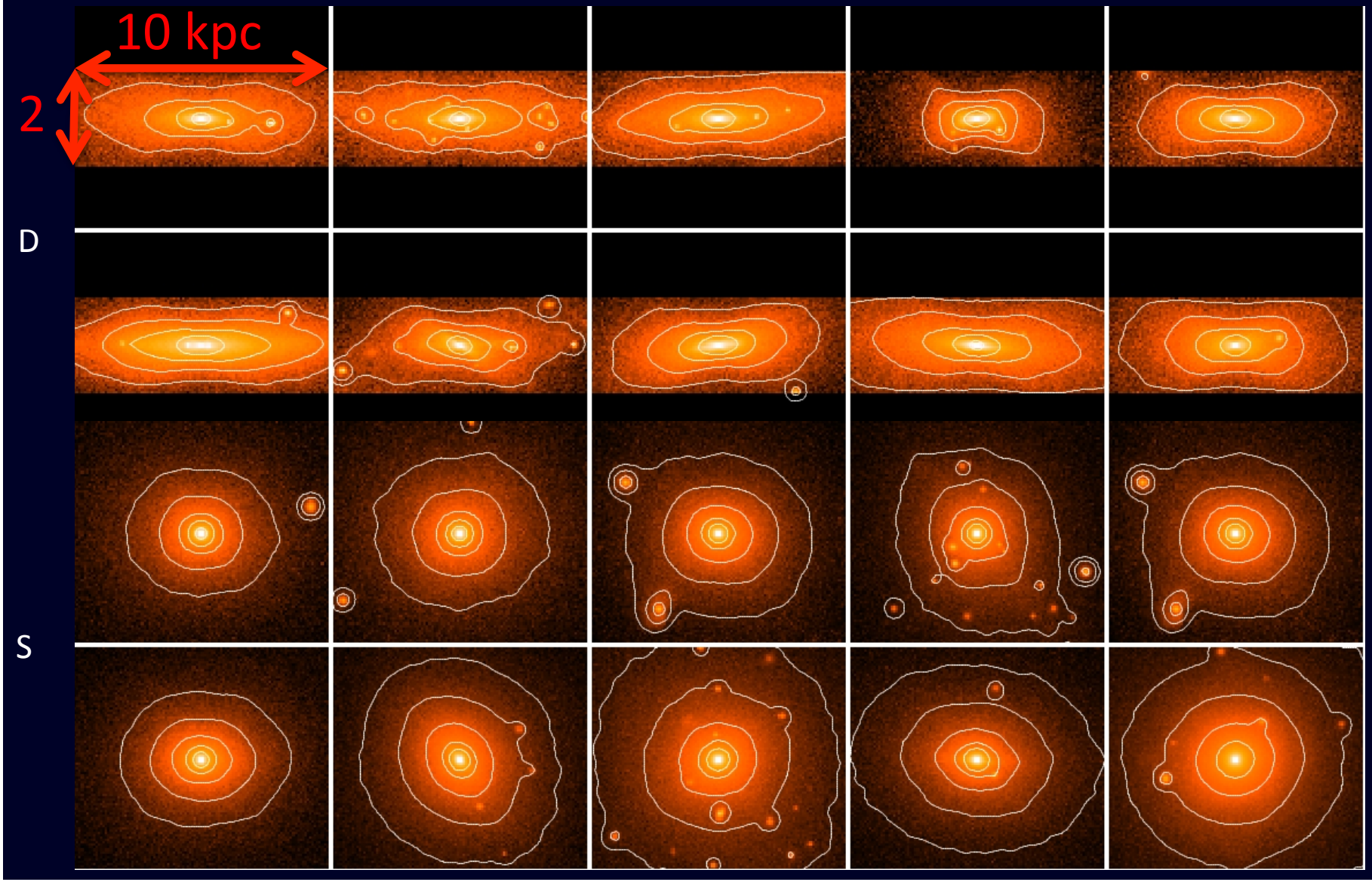


Consistent with observations



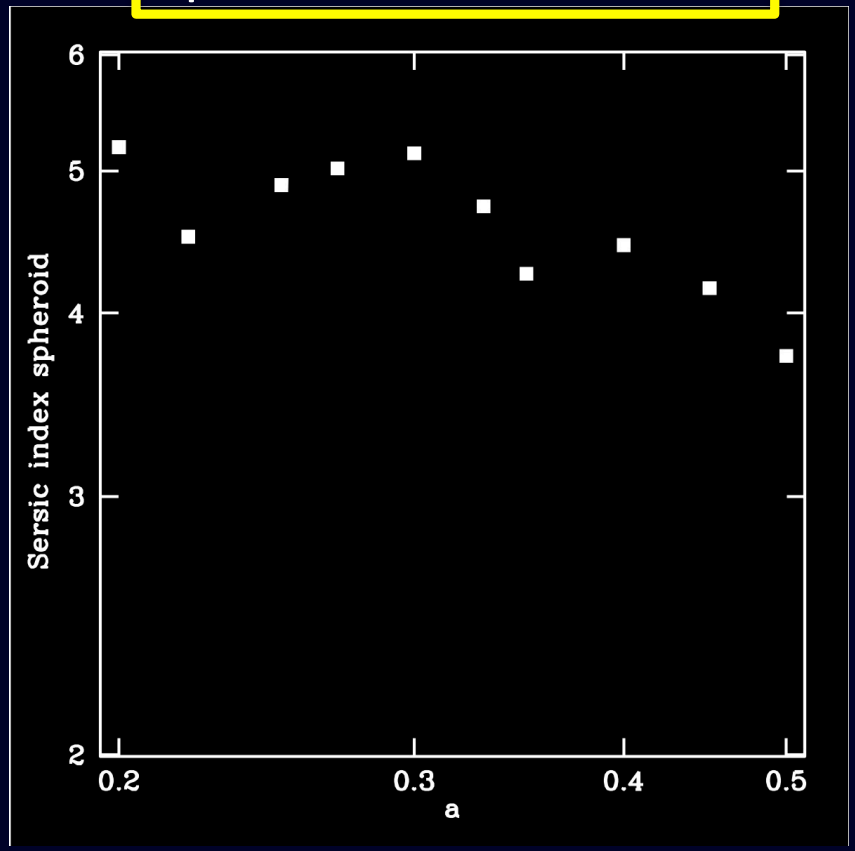
Classical spheroids

Spheroid and disk components

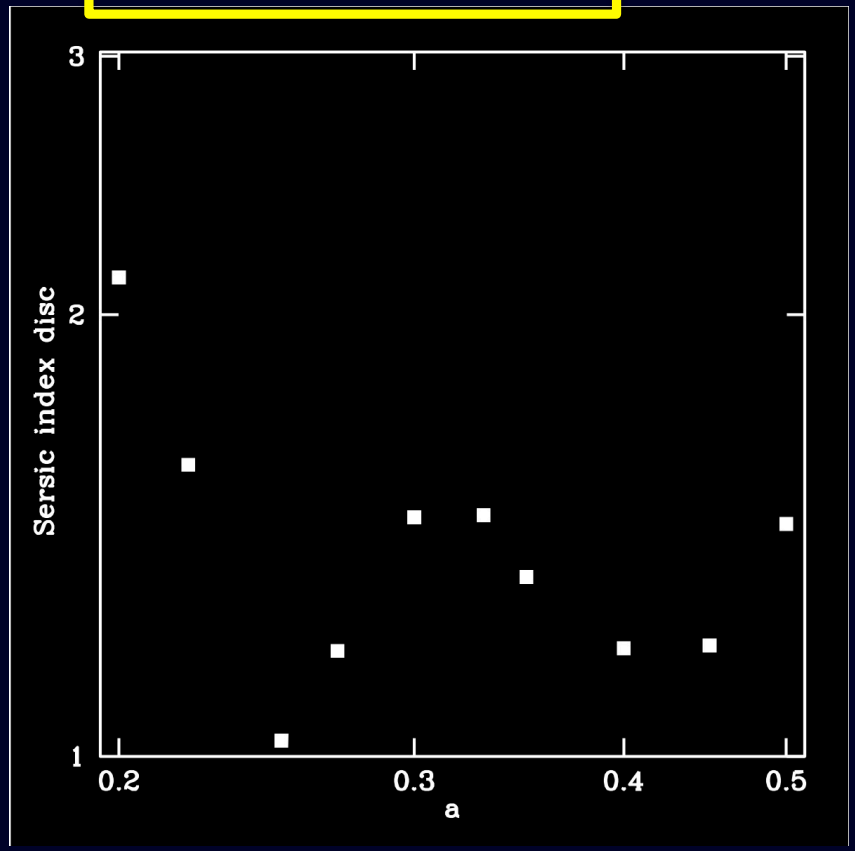


Classical spheroids plus exponential discs

Spheroid: <n>=4.3 ±1.4



Disc: <n>=1.5 ± 0.6

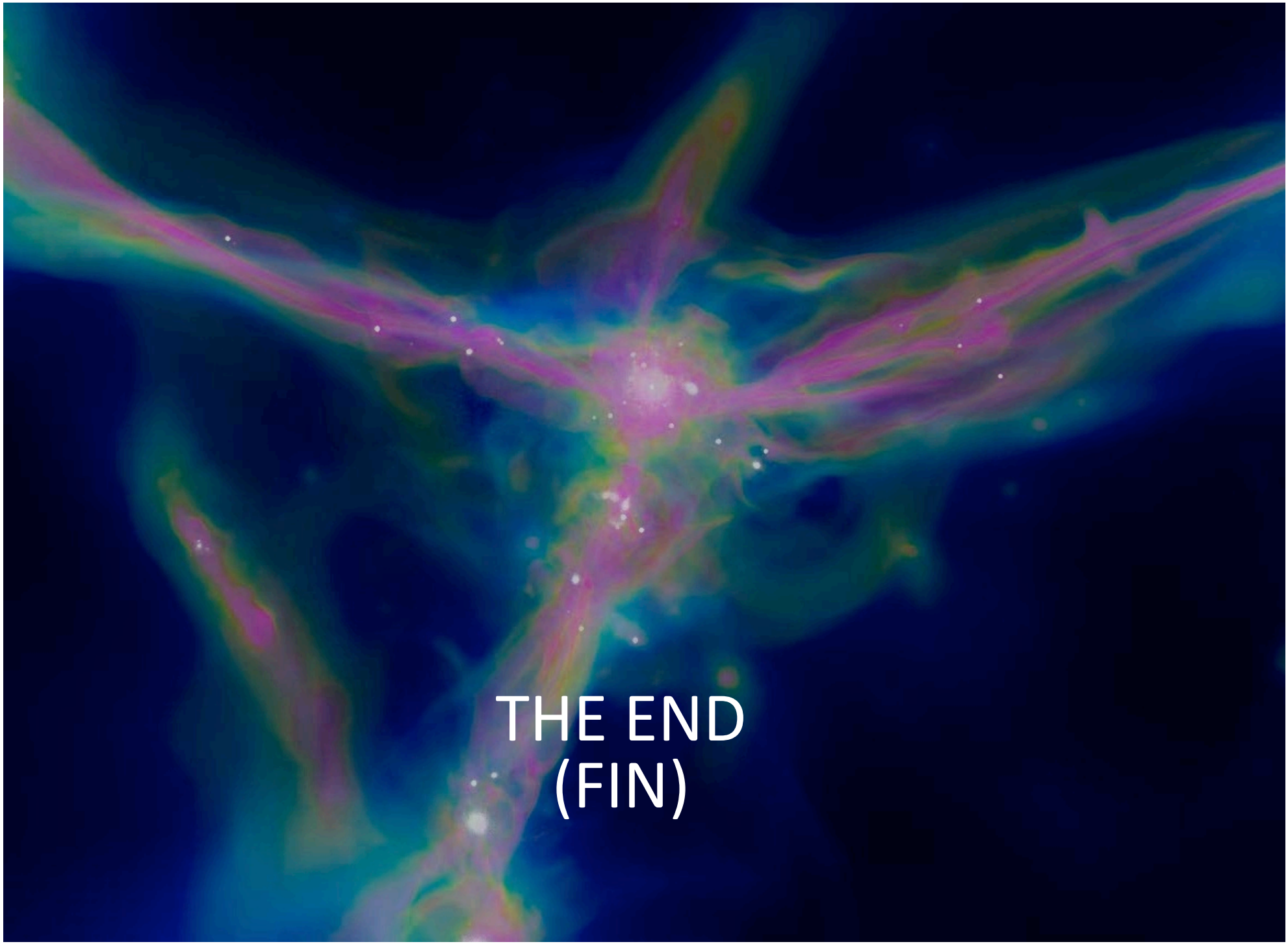


Classical bulges

Exponential discs

Conclusions

- Final products of violent disk instability (VDI) are compact (R_e=2-4 kpc), classical ($2<n_{sersic}<5$), spheroids or S0s with S/T≈0.6-0.7
- Disc and bulge grow and evolve together mostly by smooth gas accretion and VDI
- The effective radius of typical, $M_s=10^{11}$ M_{sun}, galaxies at z=1 has grown by a factor 2.5 between z=4 and z=1.
- Spheroids grow during an early phase of frequent wet mergers (z>3) plus a second, more extended phase of disc and bulge growth by VDI.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