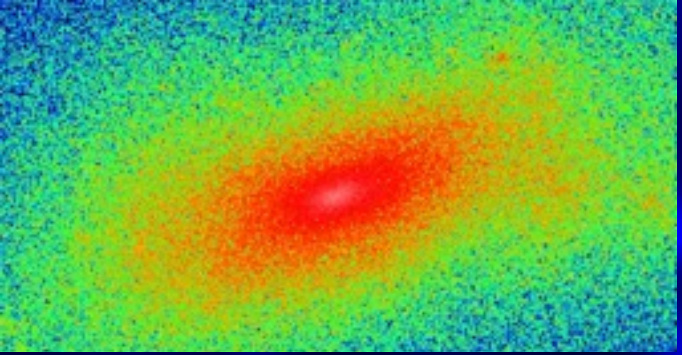
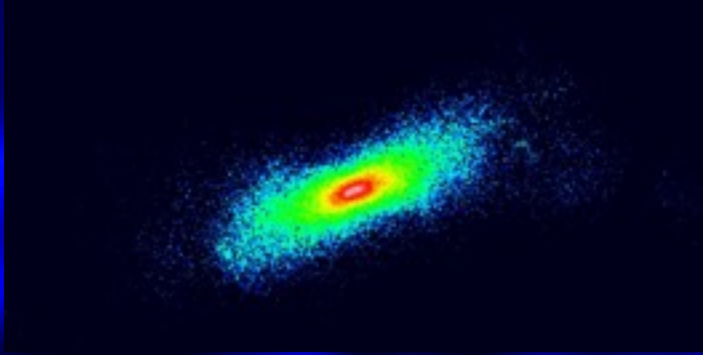




The Rise and Fall of Elongated Galaxies in the VELA simulations

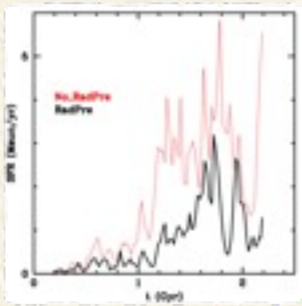
Daniel Ceverino
(Heidelberg Uni.)

Joel Primack (UCSC)
Anatoly Klypin, (NMSU); Avishai Dekel (HUJI); Nir Mandelker (Yale); Dylan Tweed (SJTU)

CANDELS meeting, 2017

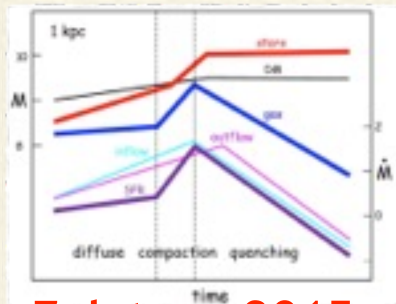
VELA simulations

Radiative Feedback



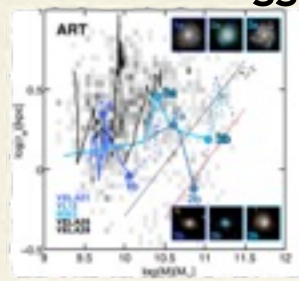
Ceverino+ 2014

Compaction & Quenching



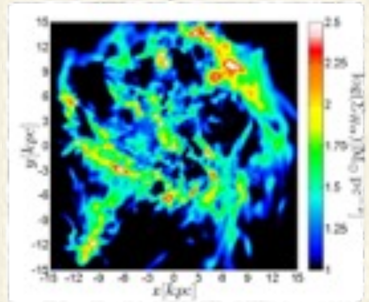
Zolotov+ 2015

Blue & Red Nuggets



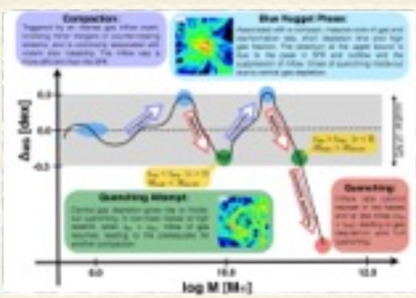
Barro+ 2014

Violent Disk Instability



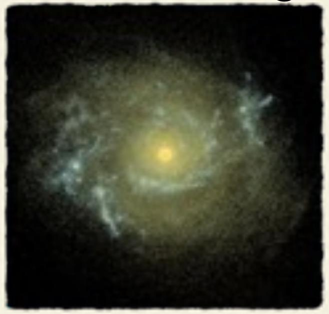
Mandelker+ 2017

Main Sequence



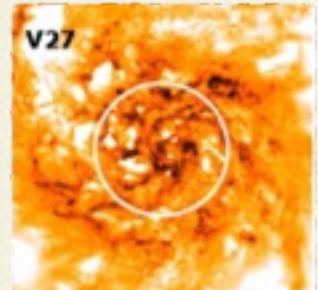
Tacchella+ 2016

Mock HST images



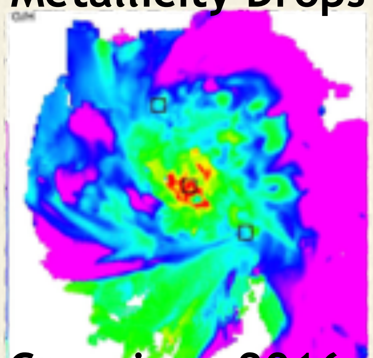
Snyder+ 2015

Outflows in Hα



Ceverino+ 2016b

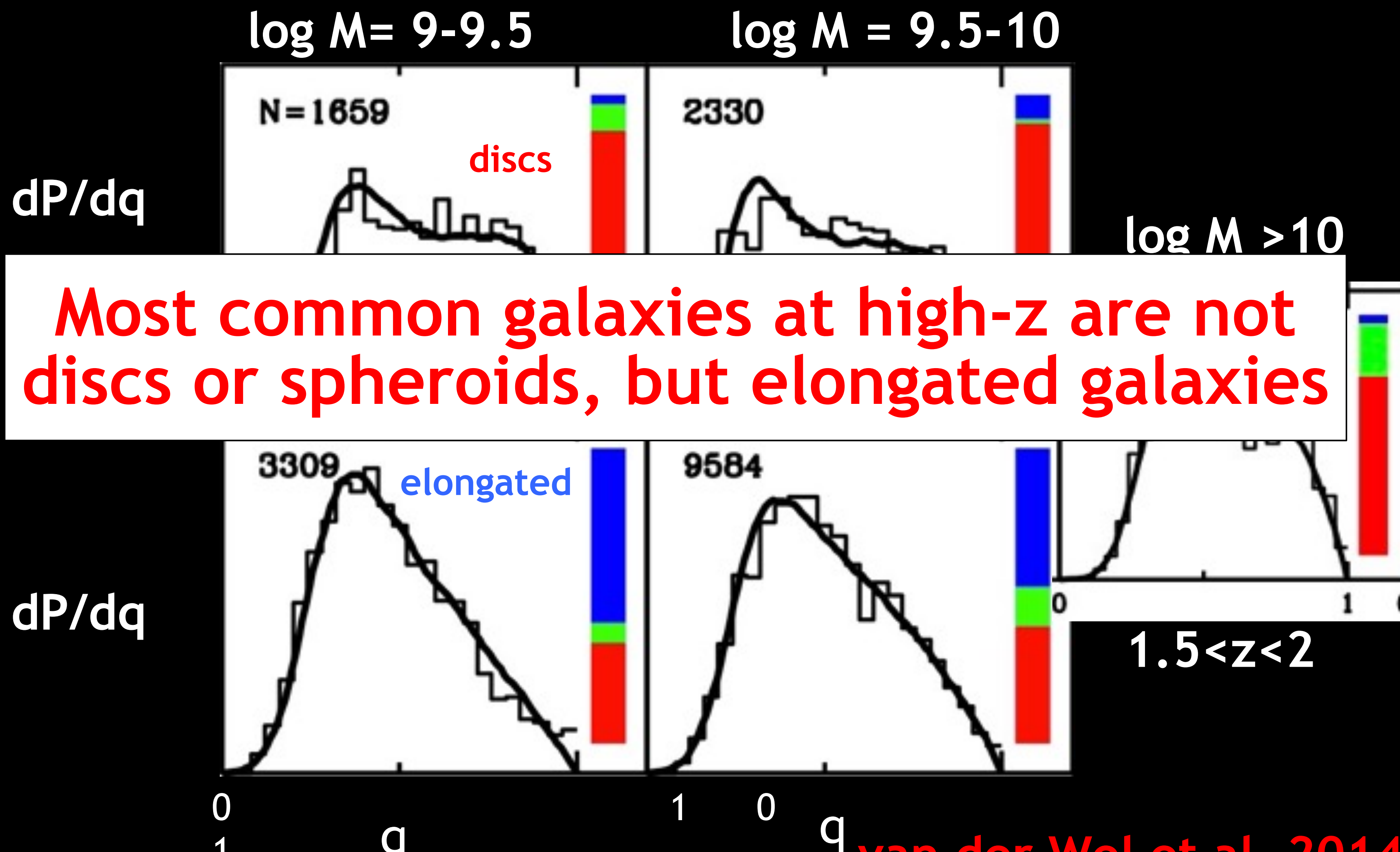
Metallicity Drops



Ceverino+ 2016a

Moody+ 2014, Barro+ 2014b, Ceverino+ 2015b, Barro+ 2015, Tacchella+ 2016b,
Inoue+ 2016, Tomassetti+ 2016, Barro+ 2017

Distribution of projected axis ratio

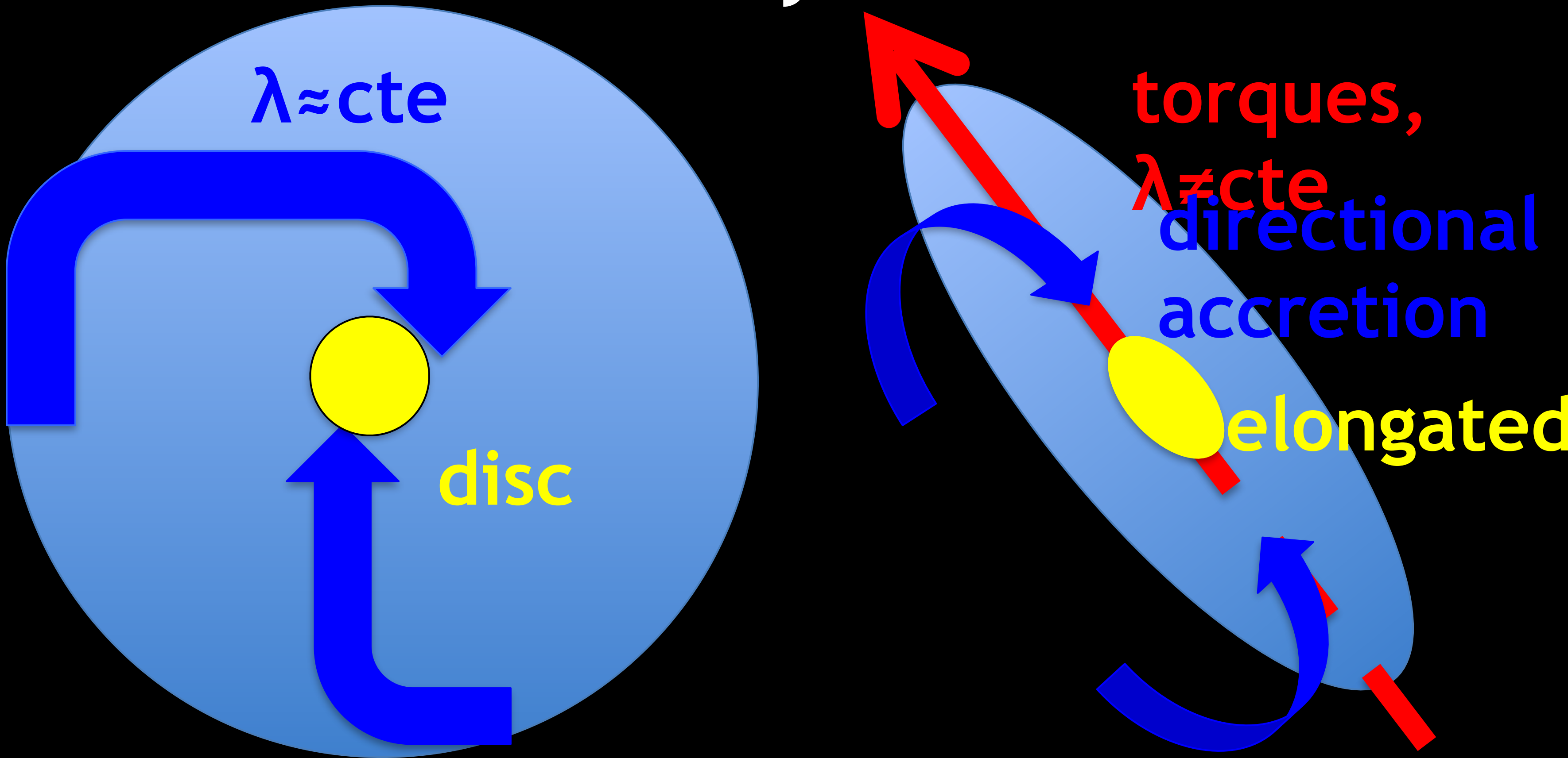


Most common galaxies at high-z are not discs or spheroids, but elongated galaxies

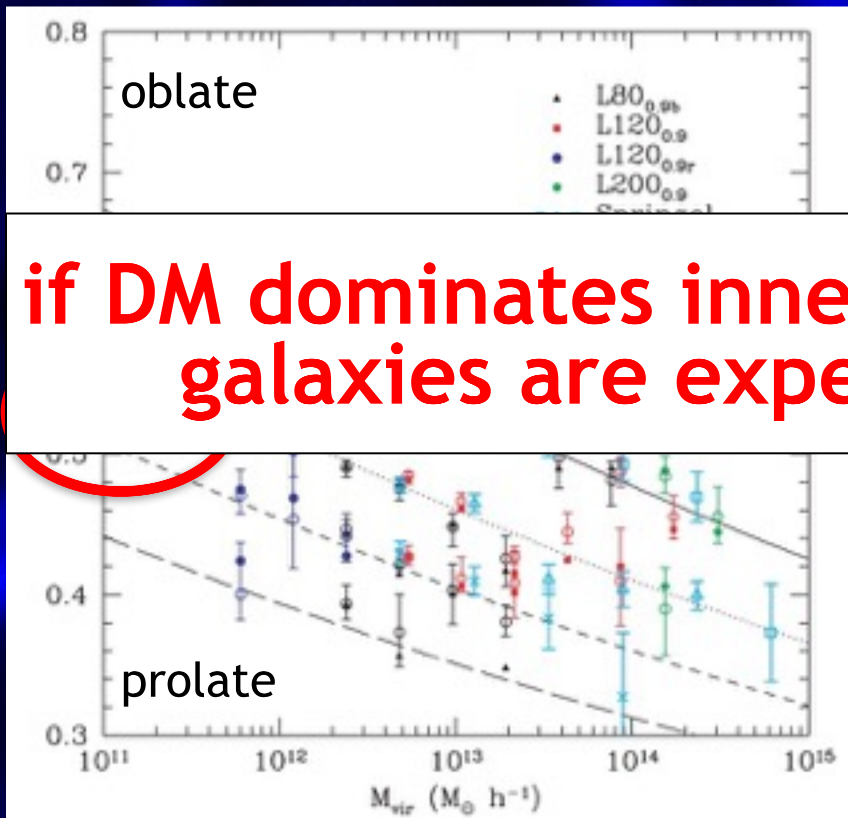
van der Wel et al. 2014

How do elongated galaxies form in ΛCDM?

The effect of a prolate halo on baryons



Small halos at high-z are highly prolate



Allgood et al. 2006:

- Halos of a given mass are more prolate at

$M_{vir} \approx 10^{11} M_\odot$ at z=2

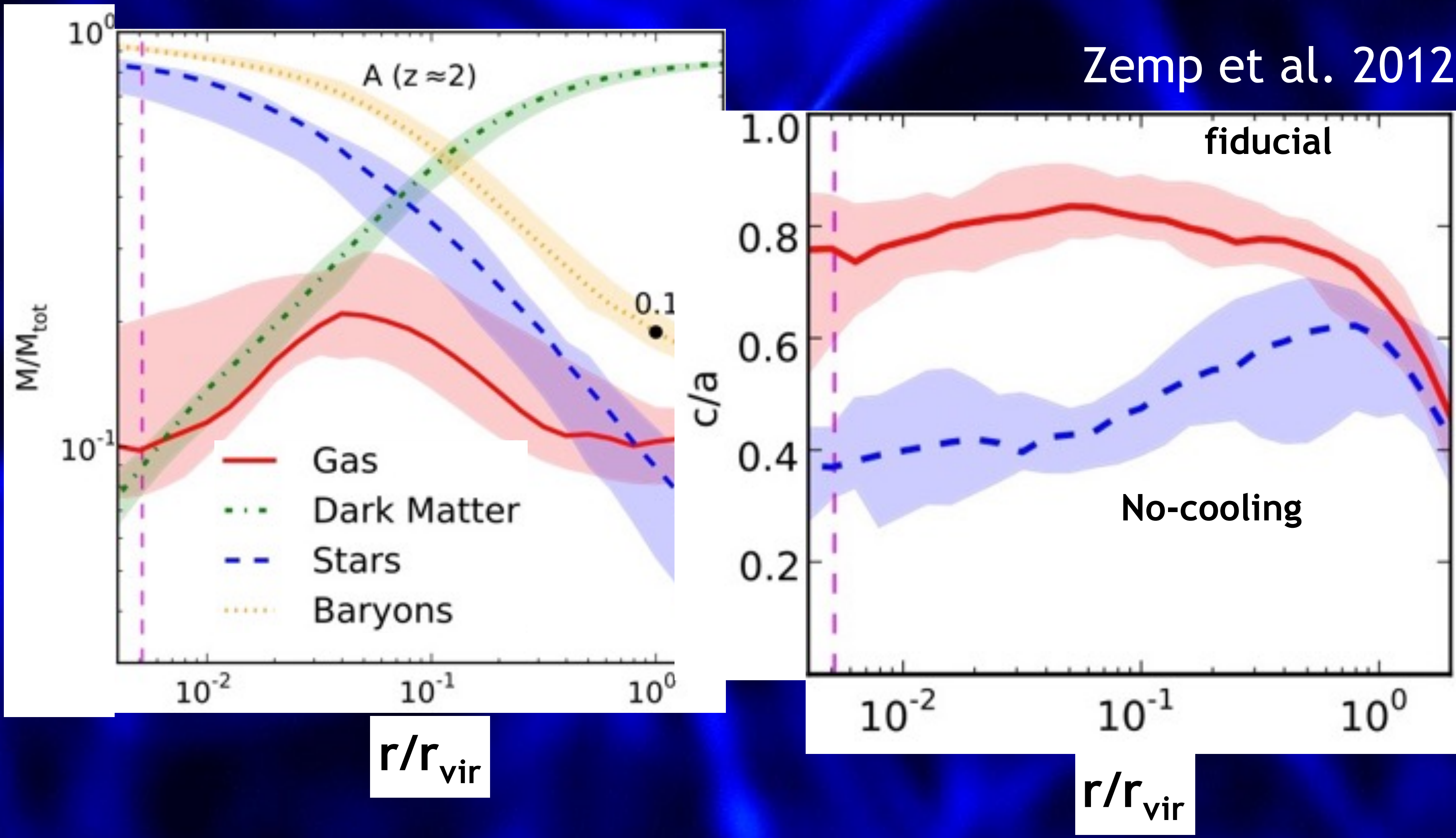
are as prolate as today's clusters.

- Halos are increasingly elongated at lower radii

if DM dominates inner potential, elongated galaxies are expected within λCDM

If baryons dominates inner potential, halos get rounder

Zemp et al. 2012

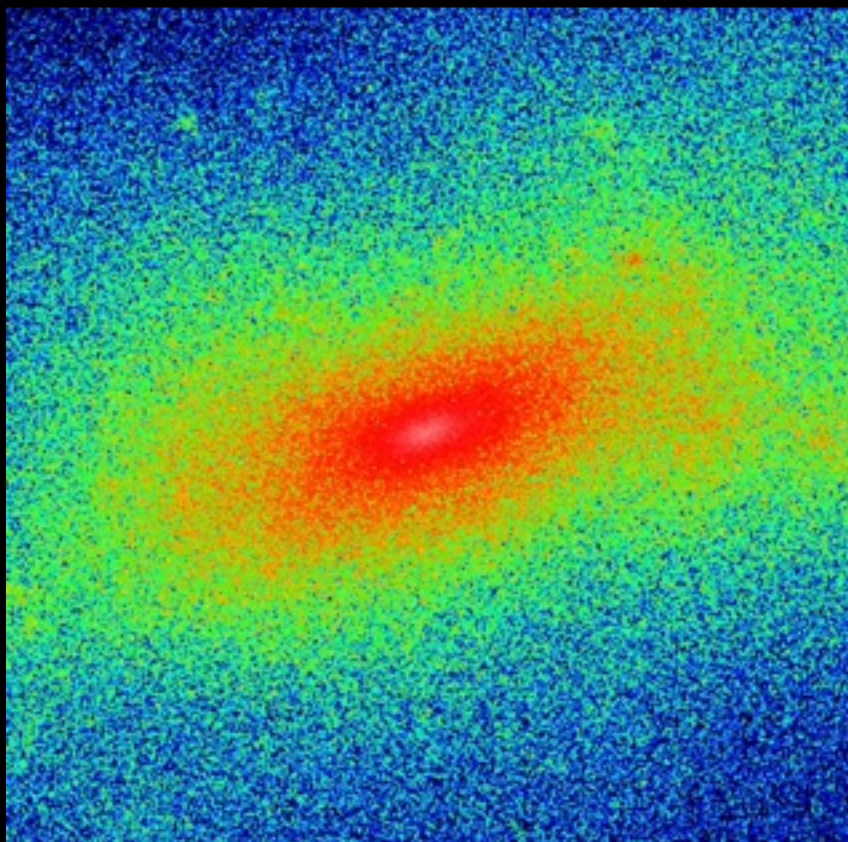


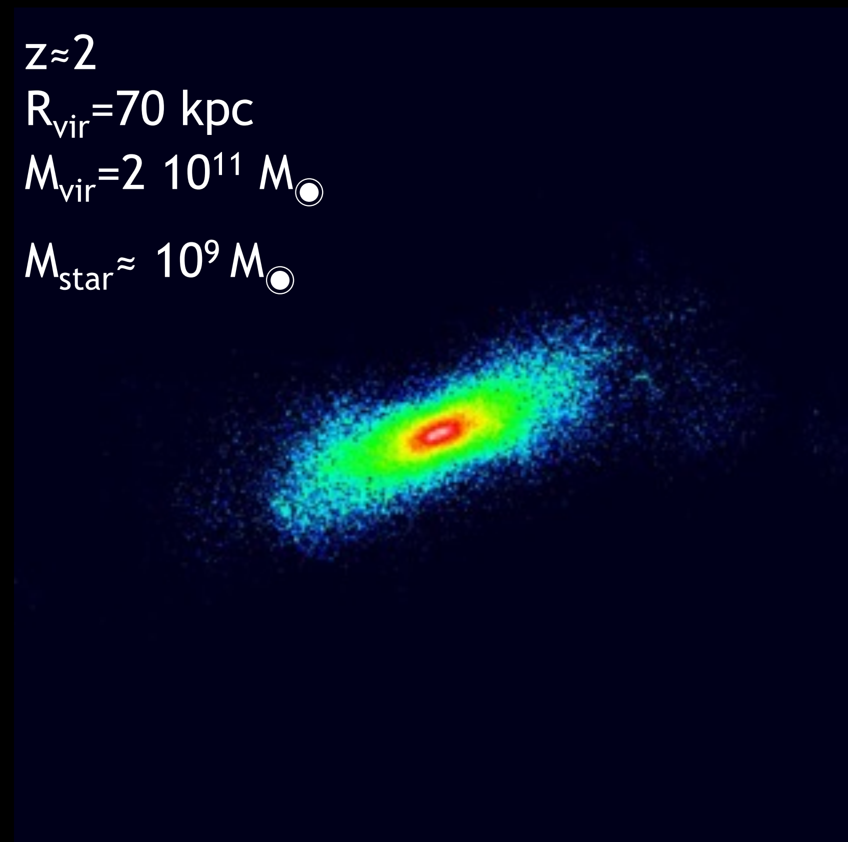
VELAs

- 35 zoom-in simulations
- AMR code: ART (Kravtsov et al 1997, Kravtsov 2003)
- Gas Cooling, Star Formation, Stellar Feedback (thermal)(Ceverino & Klypin 2009; Ceverino, Dekel and Bournaud 2010)
- Radiative Feedback (Ceverino et al. 2014)
- halos with a virial mass between $10^{11}\ M_{\odot}$ - $2 \times 10^{12}\ M_{\odot}$ at $z \approx 1$
- Maximum resolution of 15-30 pc, $M_{DM}=8\ 10^4\ M_{\odot}$

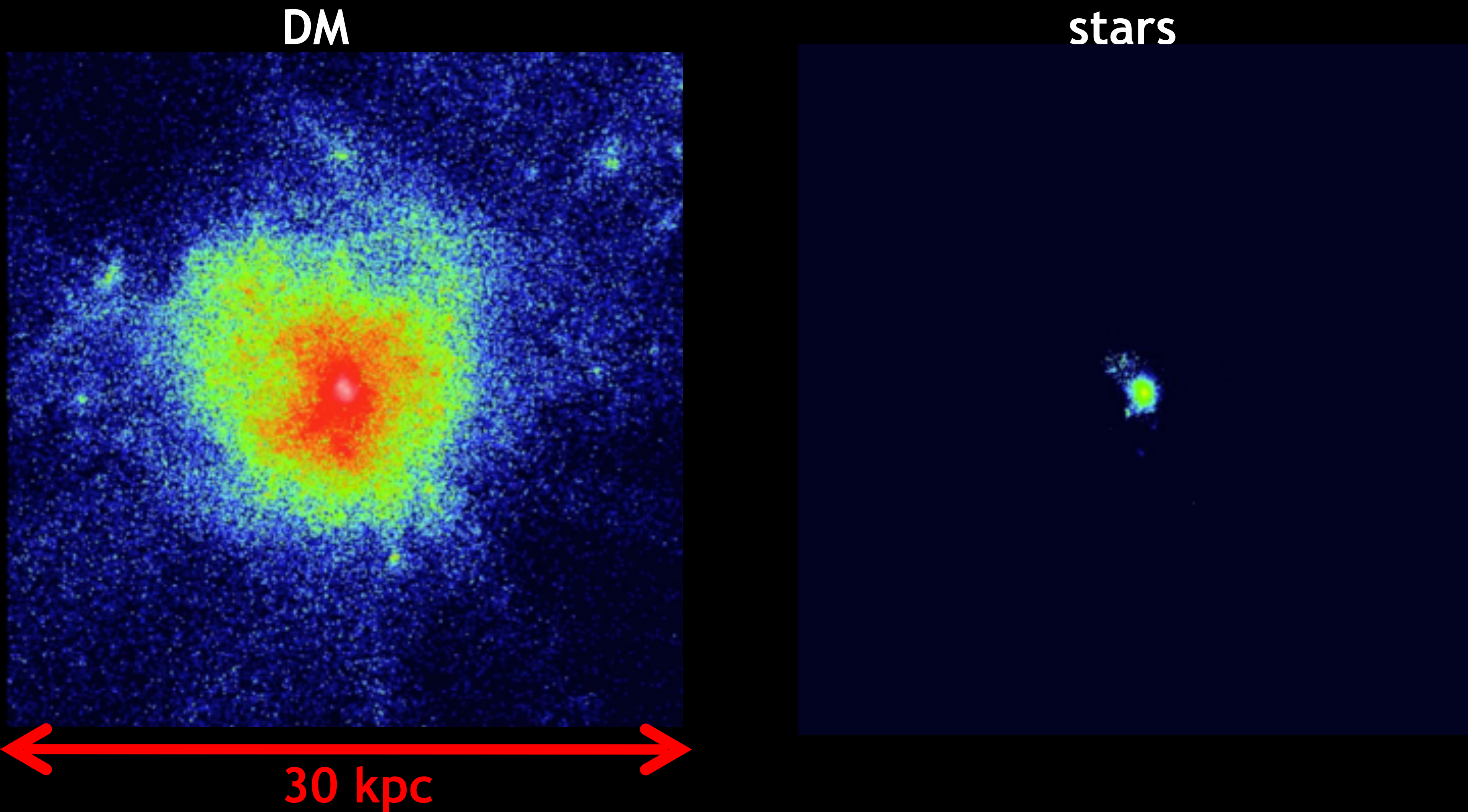
Prolate DM halo → elongated galaxy

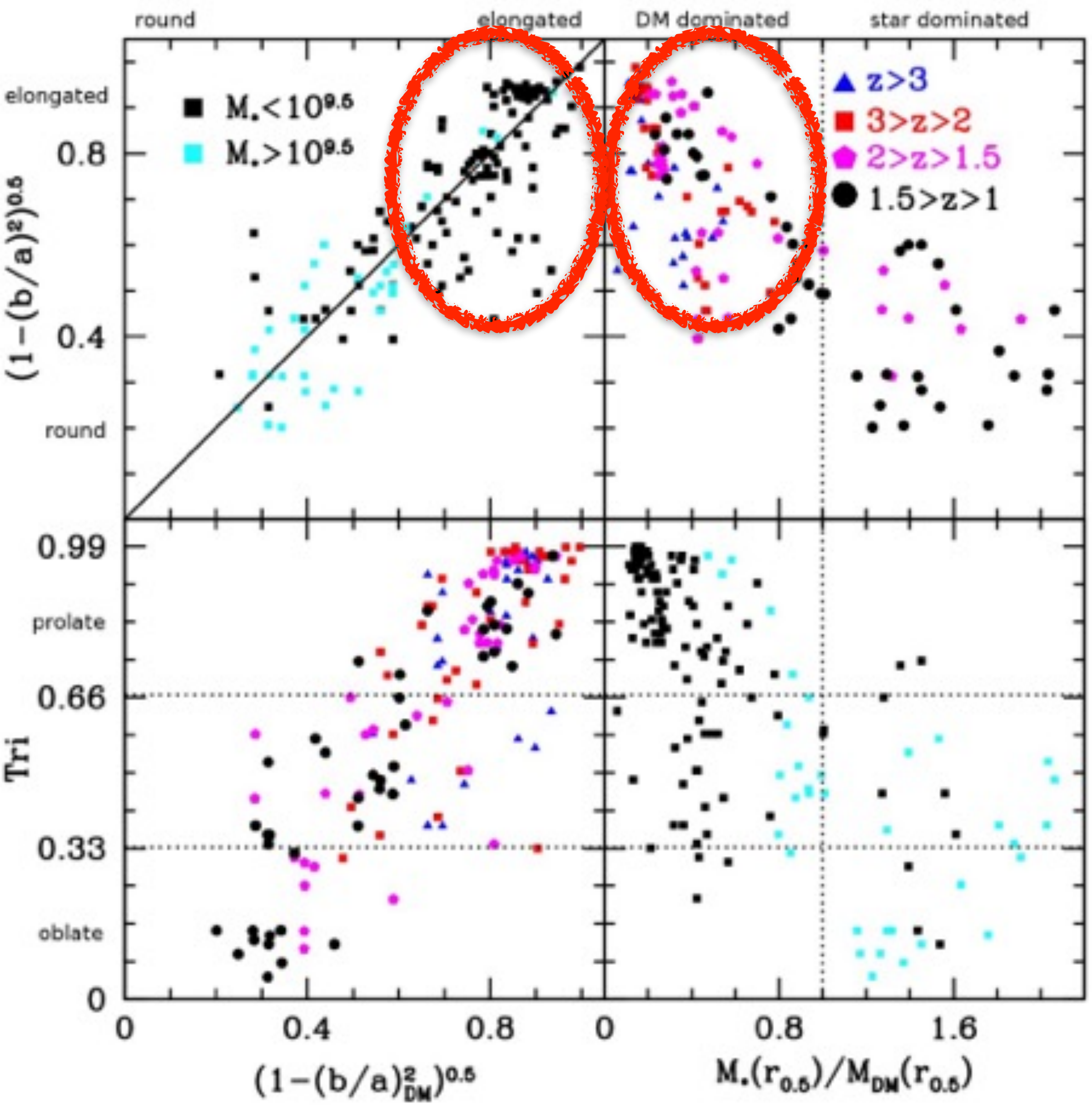
DM **VELA28** **stars**





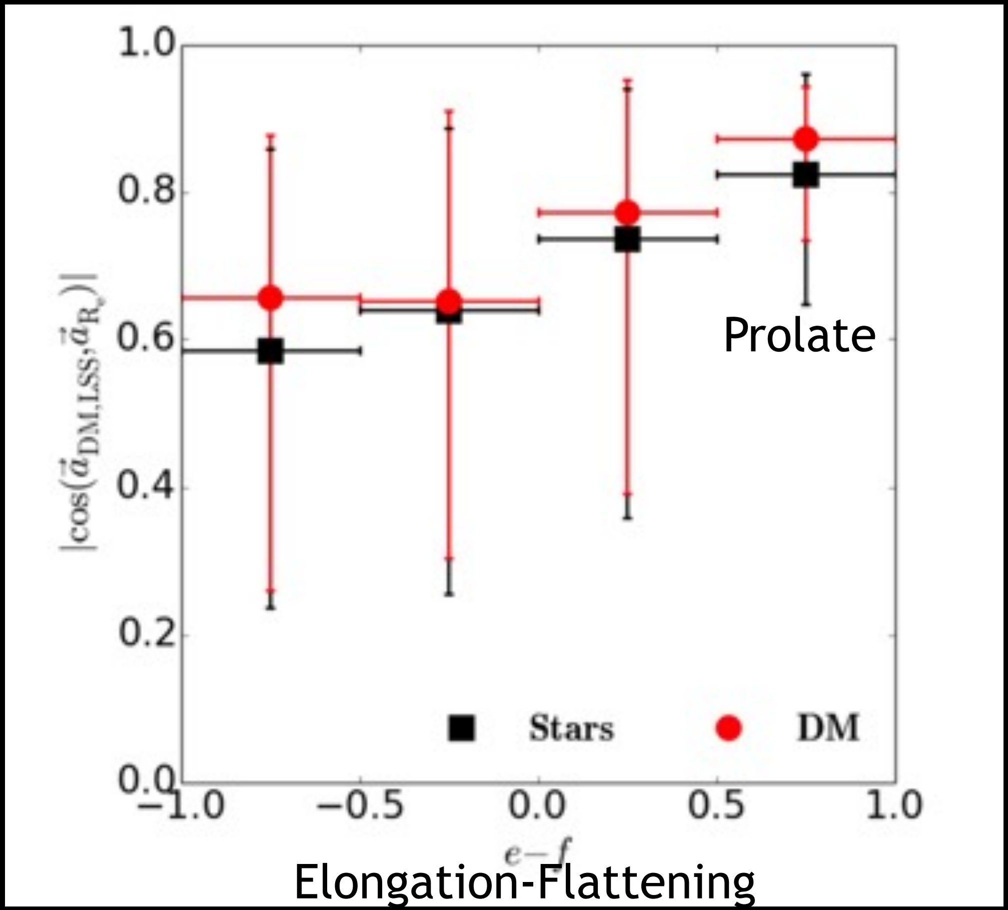
30 kpc

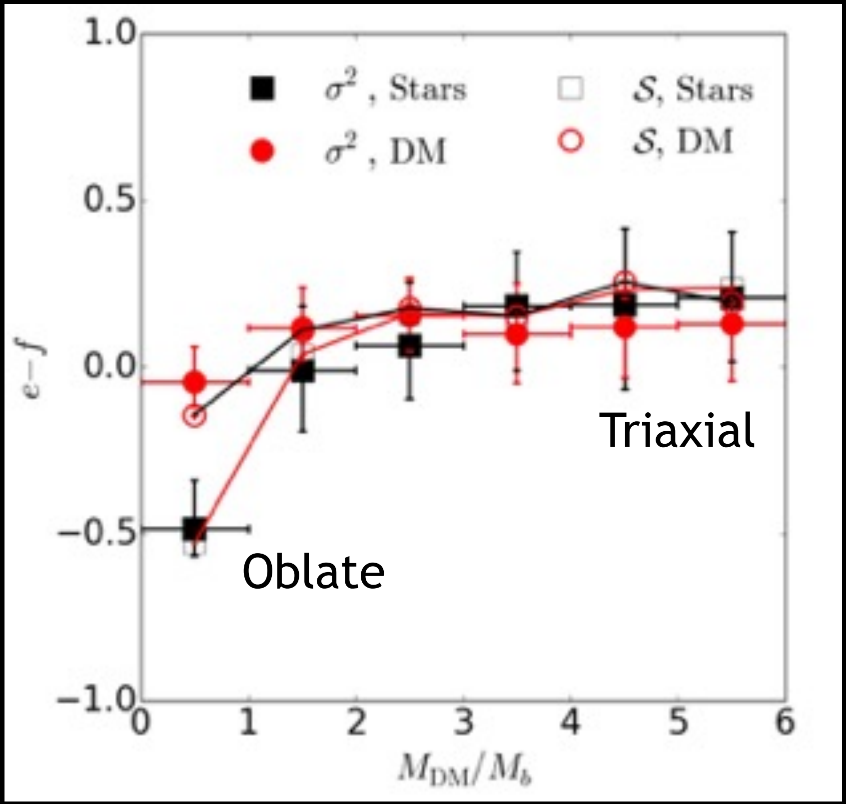

DM
stars
30 kpc



Ceverino, Primack & Dekel 2015

Torques by the halo induce stellar elongation and its alignment with the streams



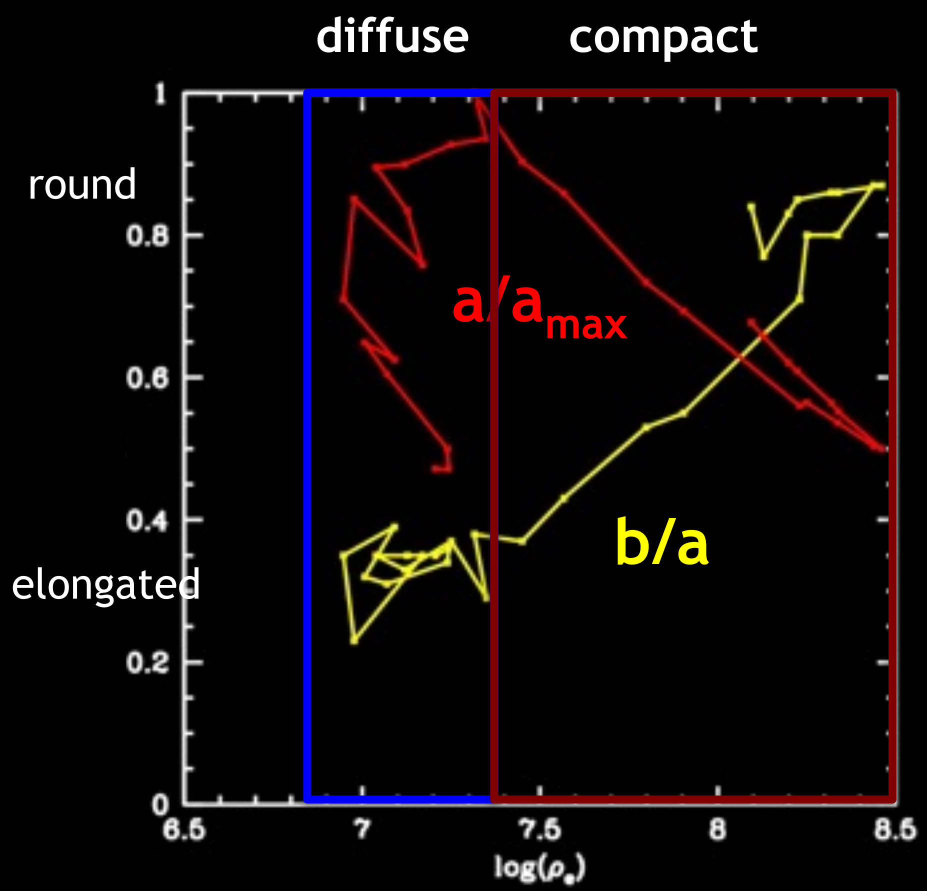


Tomassetti+ 2016

elongation is supported by anisotropic velocity dispersion

Smearing elongation

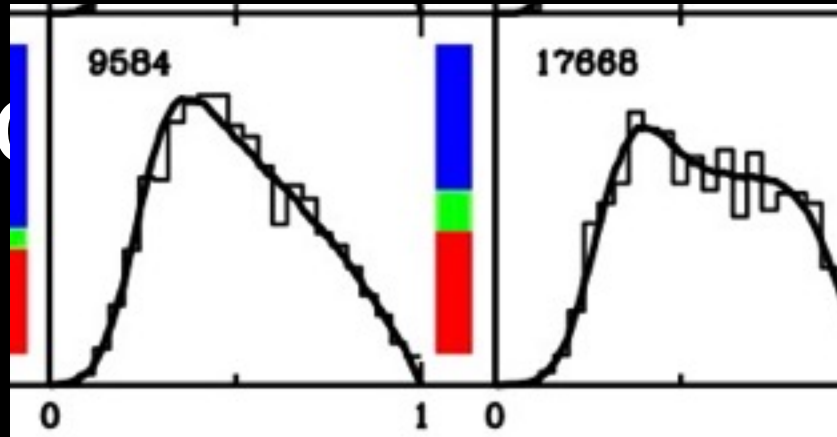
smearing elongation

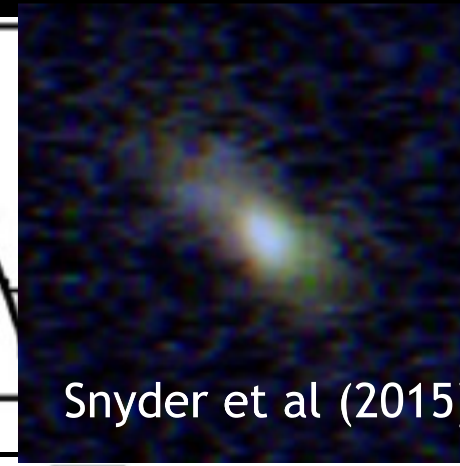


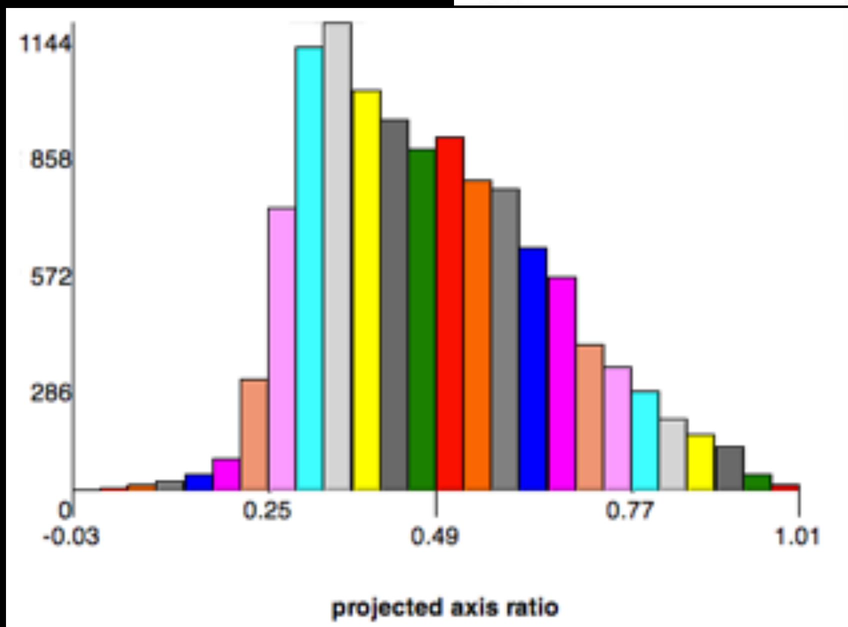
- Growth of an elongated galaxy
- During the compaction phase stellar density increases
- Disruption of stellar orbits with high eccentricity.
- Rounder nugget

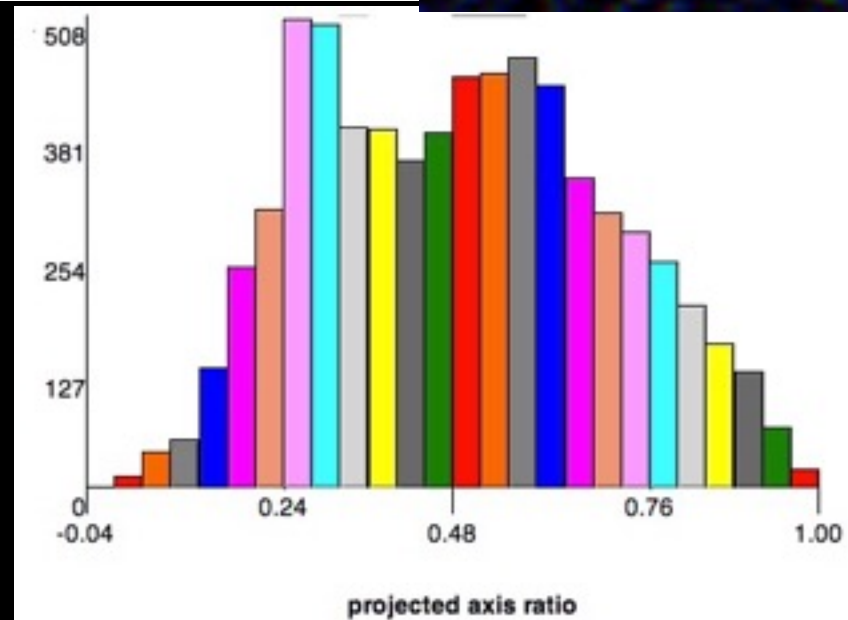
Pr

log M









The transition mass at log M~9.4 when $V_{cir,eff}$~100 km/s

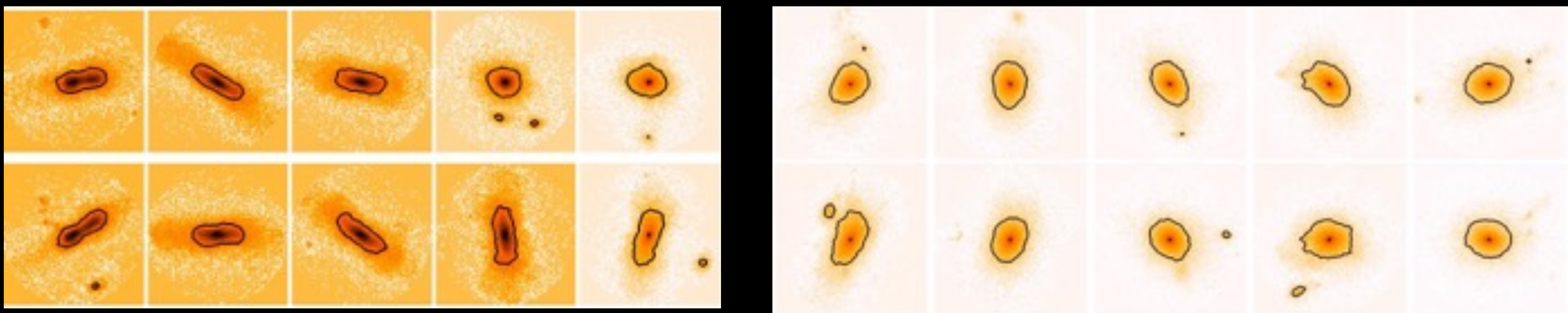
Summary

Formation of elongated Galaxies
- DM dominates inner potential
- prolate inner halo
- directional accretion along major axis

Smearing elongation
- if baryonic density increases
- high-eccentric orbits are deflected

The End

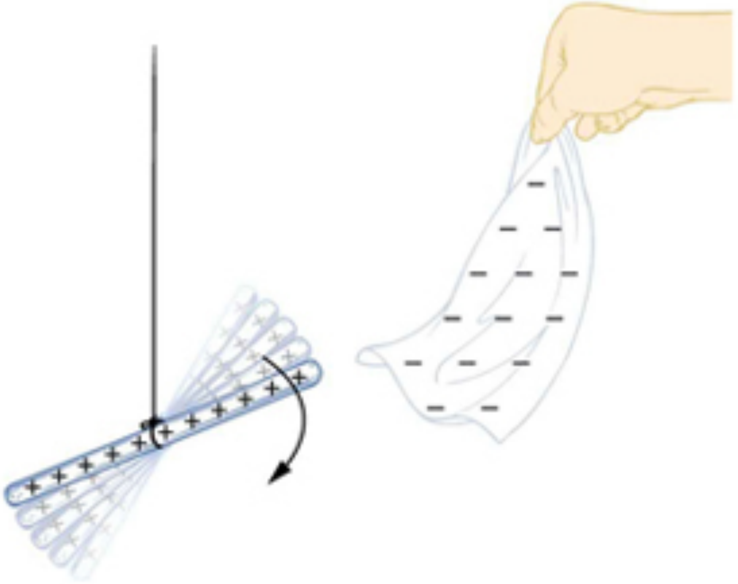
from elongated galaxies to nuggets

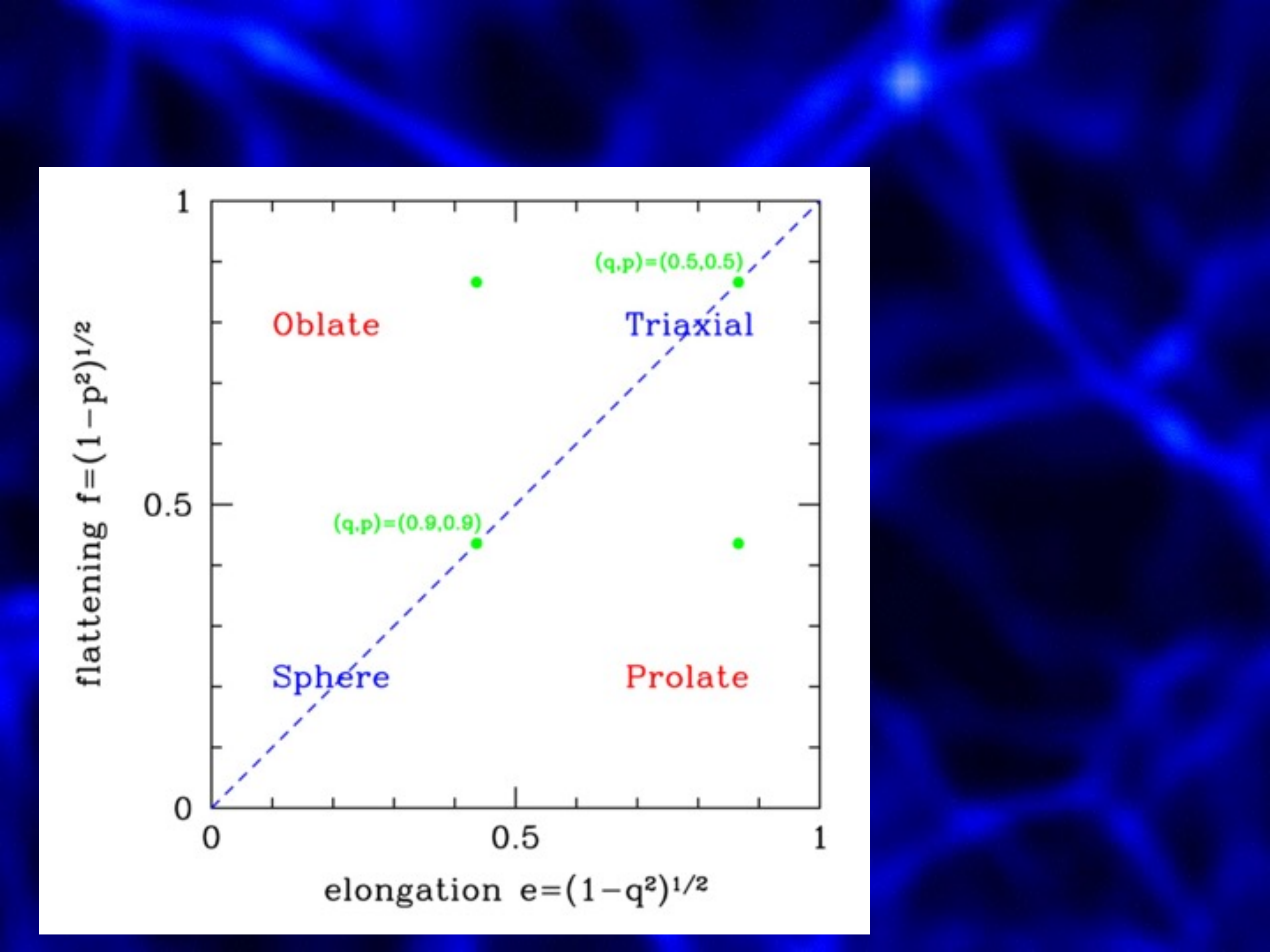


X

Z

z = 2.3 2 1.9 1.8 1.6


(a)



Oblate
Triaxial
Sphere
Prolate
(q,p)=(0.5,0.5)
(q,p)=(0.9,0.9)
flattening f=(1−p²)^1/2
elongation e=(1−q²)^1/2
0
0.5
1