Understanding the origin of the golden mass across cosmic history

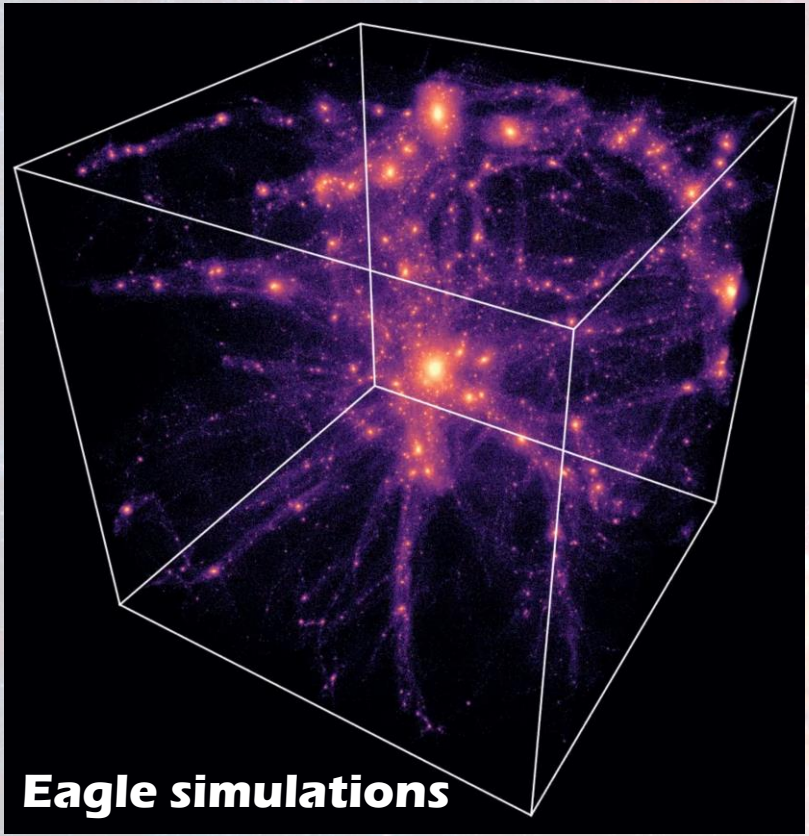
INAF
OSSERVATORIO ASTRONOMICO
DI CAPODIMONTE

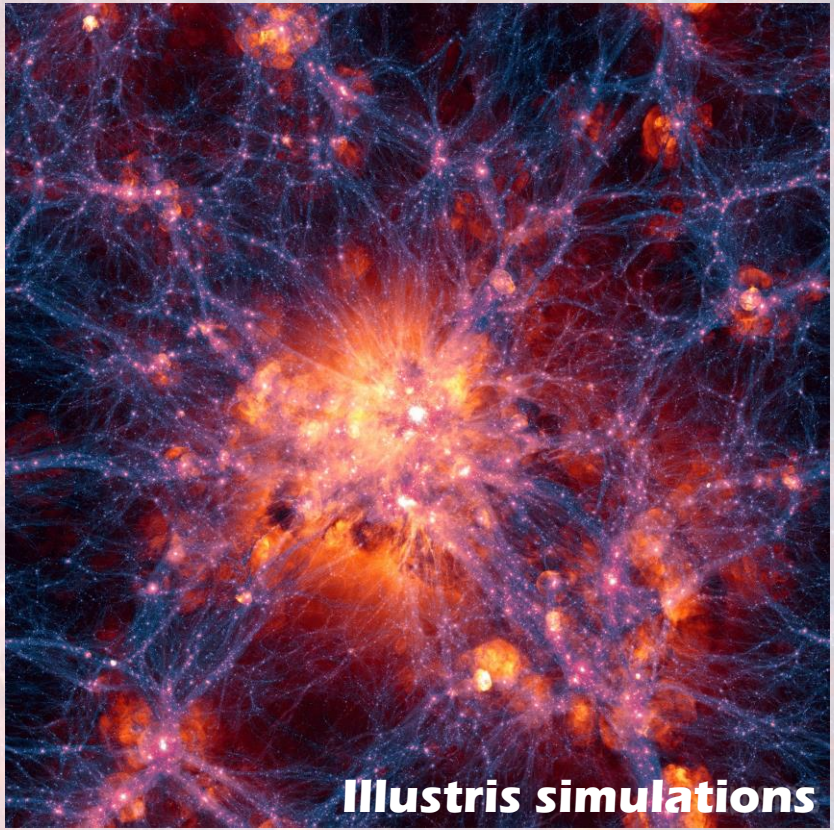
Crescenzo Tortora

INAF - OACN

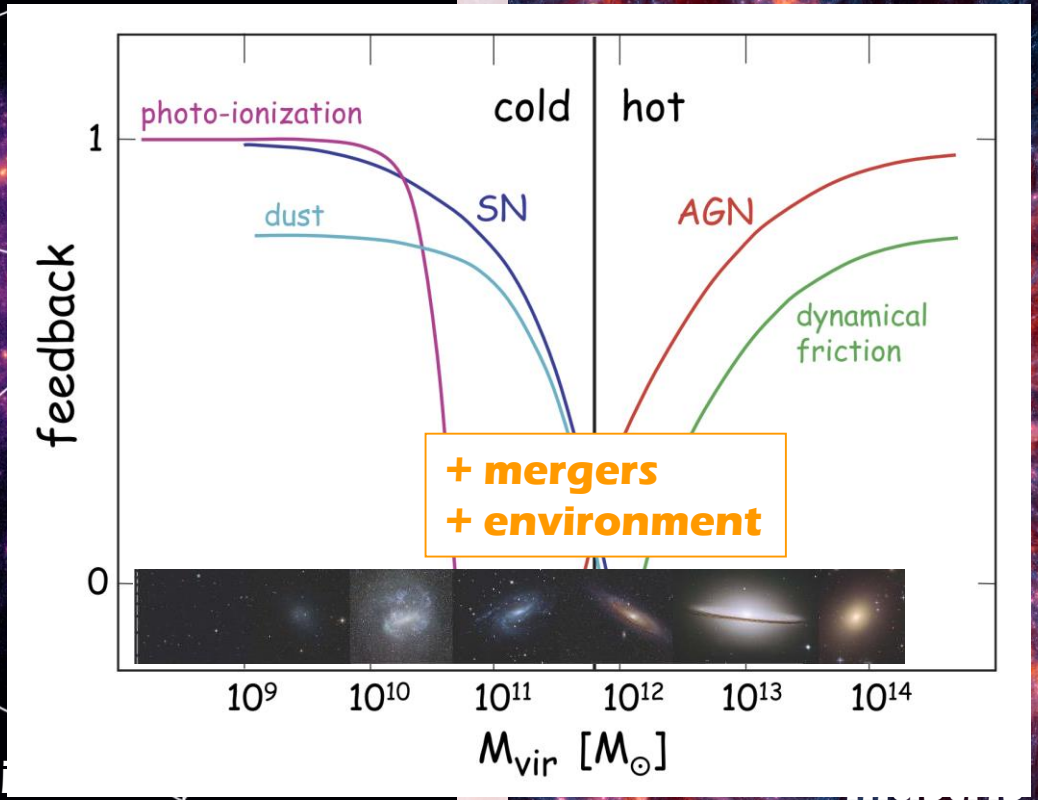
General framework and golden mass

The state of the art of galaxy formation and evolution



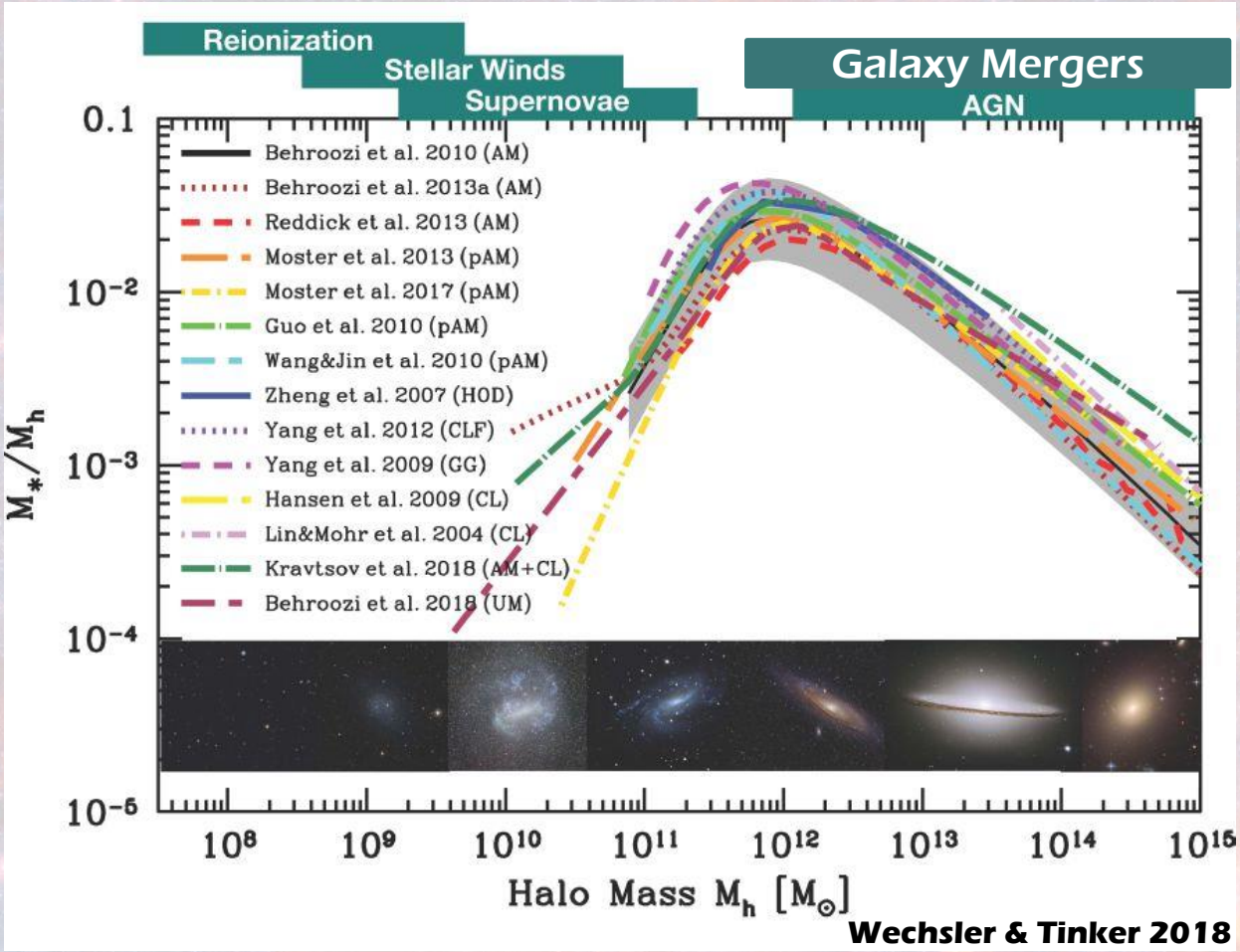


The state of the art of galaxy formation and evolution



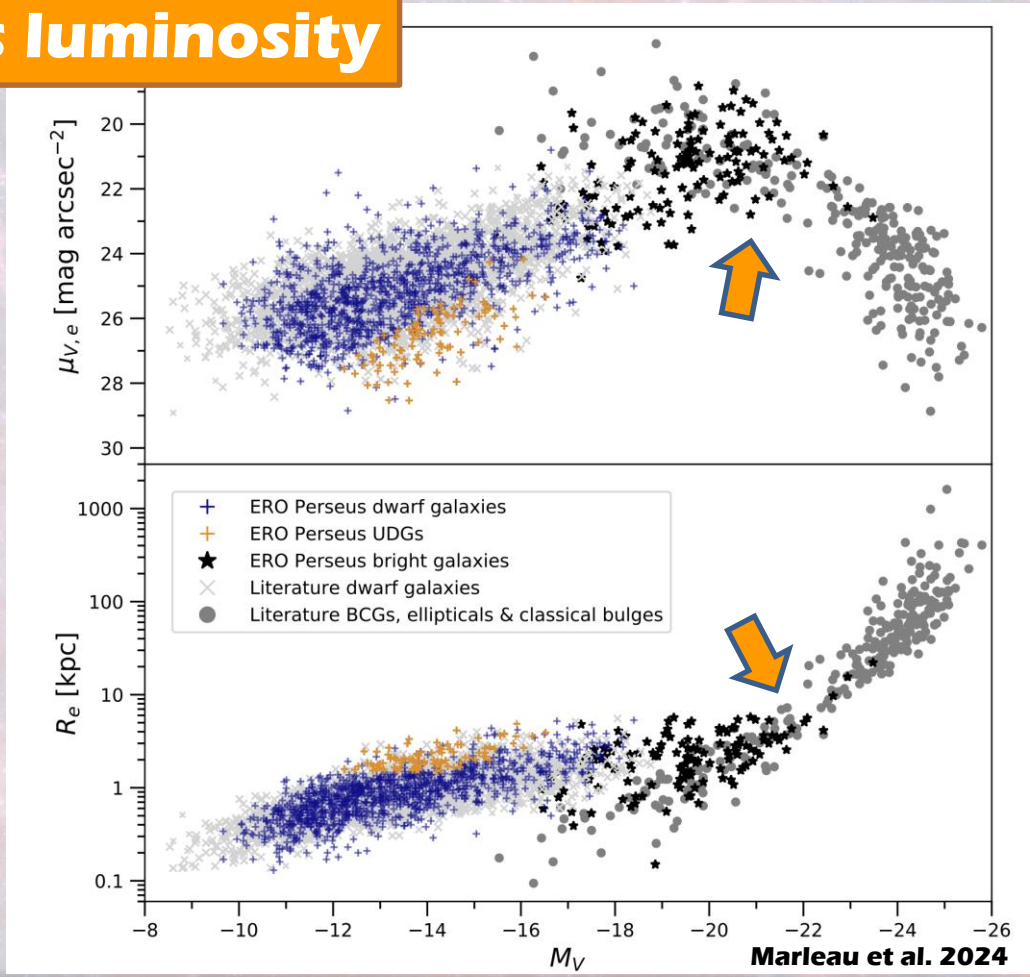
Eagle simulati

simulations

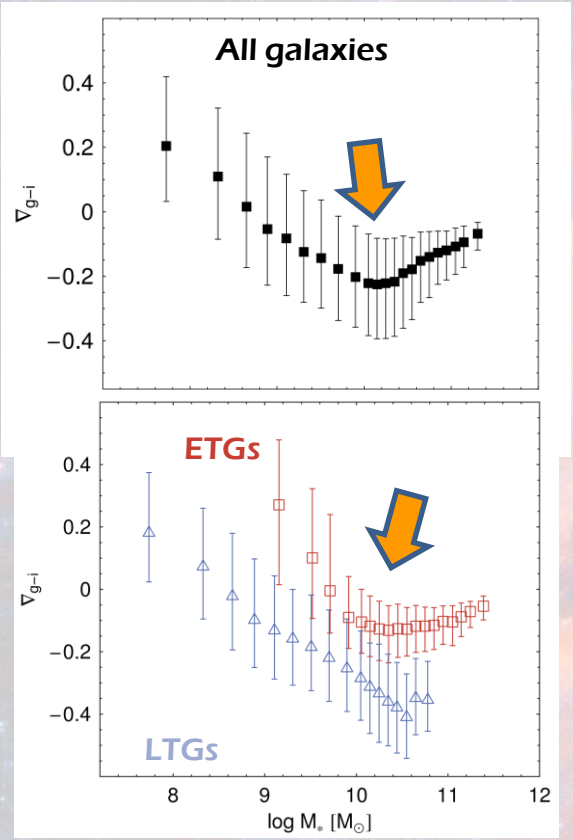


Wechsler & Tinker 2018

SB_e and R_e vs luminosity

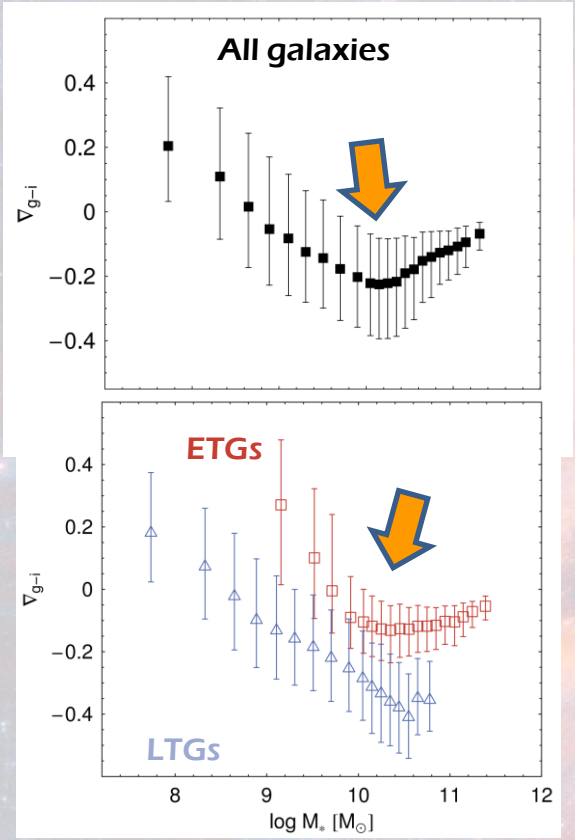


Colour and stellar population gradients

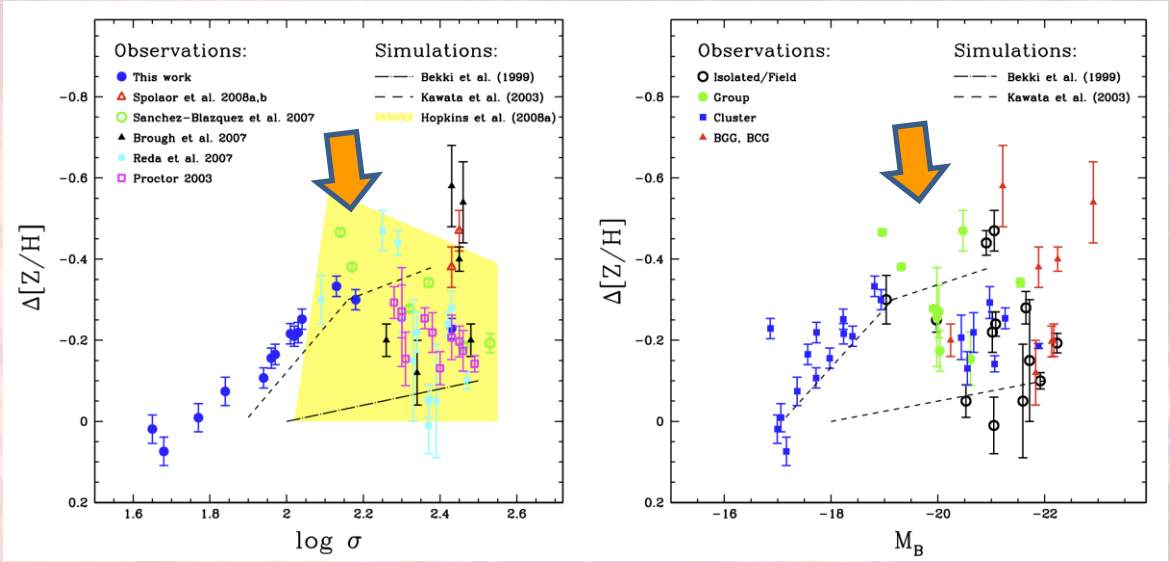


Tortora et al. 2010

Colour and stellar population gradients

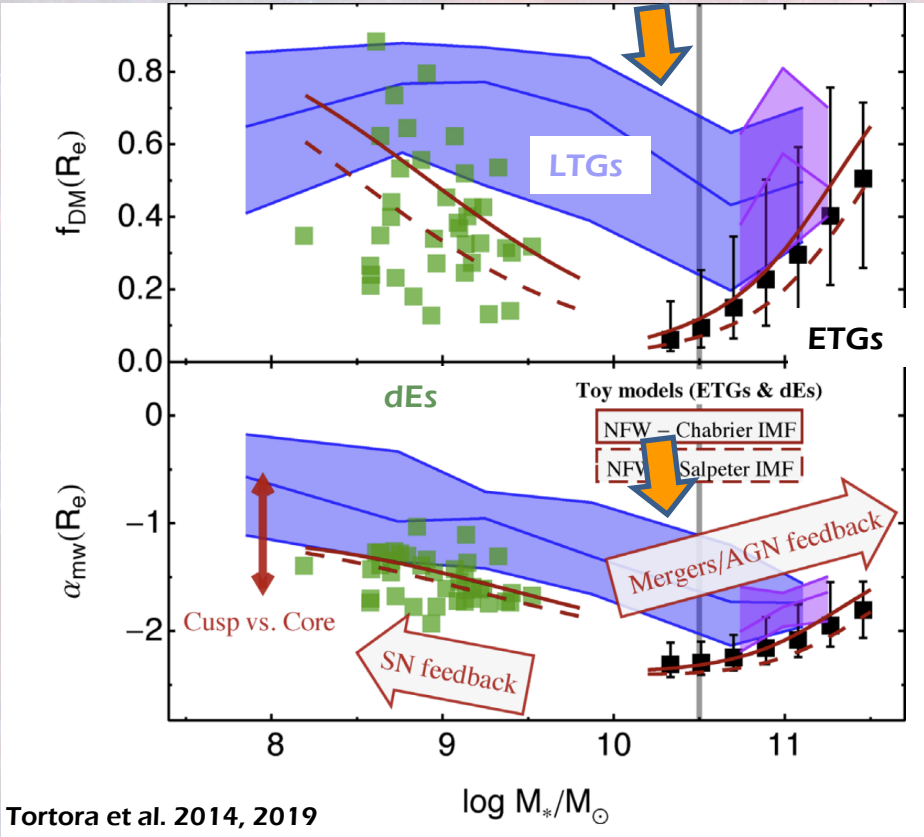


Tortora et al. 2010



Spolaor et al. 2009

Central DM fraction and total mass density slope



Tortora et al. 2014, 2019

DM fraction within R_e

Total mass density slope within R_e

Size and SB vs M_*

M_{halo} vs M_*

DM fraction vs M_*

Golden mass
(or bimodality mass)

Colour and stellar population gradients vs M_*

Mass density slope vs M_*

Since there is a causality between physical processes and scaling relations

Since there is a causality between physical processes and scaling relations

It is natural to expect that there is a causality between physical processes and emergence of the golden mass

Since there is a causality between physical processes and scaling relations

It is natural to expect that there is a causality between physical processes and emergence of the golden mass

Questions arise

What physical processes contribute to the formation scenarios?

Under what physical conditions are galaxies formed?

How does galaxy mass assemble?

What is the origin of the golden mass?

Since there is a causality between physical processes and scaling relations

It is natural to expect that there is a causality between physical processes and emergence of the golden mass

Questions arise

What physical processes contribute to the formation scenarios?

Under what physical conditions are galaxies formed?

How does galaxy mass assemble?

What is the origin of the golden mass?

Galaxies across a wide mass and redshift range (with unresolved and resolved data) are needed!

Analyzing the golden mass through simulations

Comparing simulations and observations

CASCO: Cosmological and AStrophysical parameters from Cosmological simulations and Observations

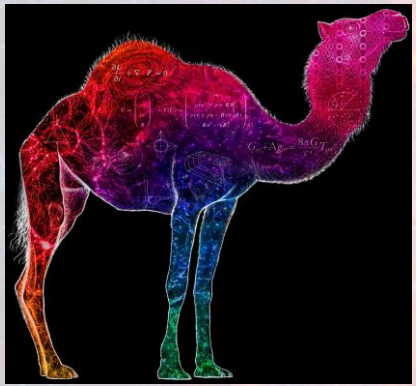
CAMELS, DREAMS, TNG, etc.

Busillo et al. 2023, Busillo et al. 2024, submitted to A&A, Tortora et al. 2024 in prep.

Comparing simulations and observations

CASCO: Cosmological and AStrophysical parameters from Cosmological simulations and Observations

CAMELS, DREAMS, TNG, etc.



CAMELS simulations

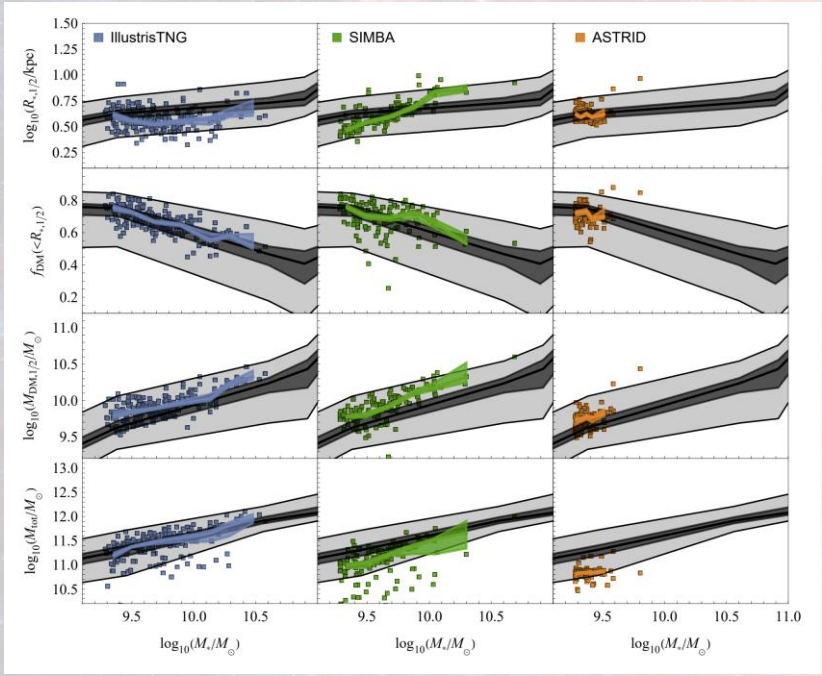
Several thousand cosmological simulations, using different subgrid models, mass resolution, volume, and variations in astrophysical (SN and AGN feedback) and cosmological parameters (Villaescusa-Navarro et al. 2021, ...).

Busillo et al. 2023, Busillo et al. 2024, submitted to A&A, Tortora et al. 2024 in prep.

Comparing simulations and observations

CASCO: Cosmological and AStrophysical parameters from Cosmological simulations and Observations

CAMELS, DREAMS, TNG, etc.

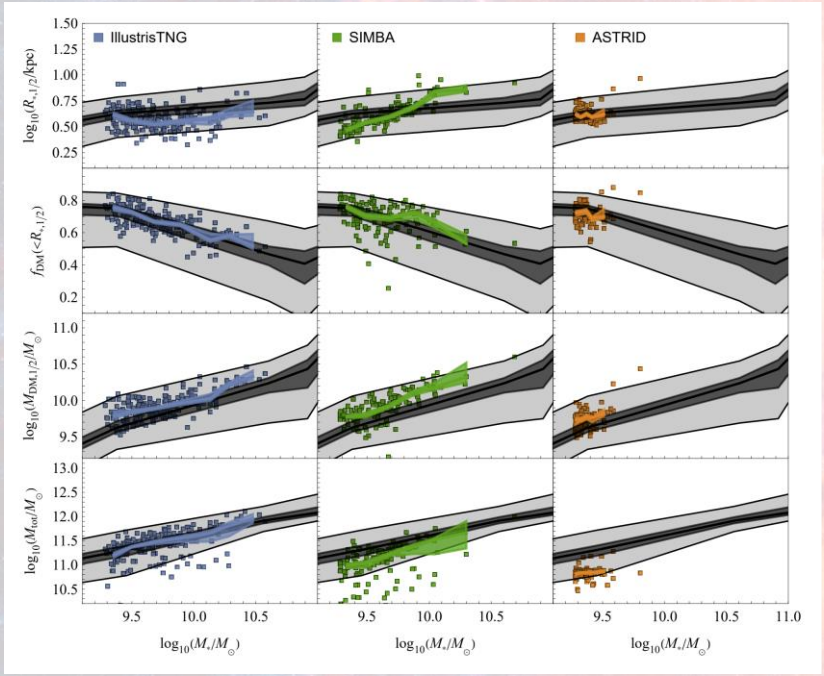


Busillo et al. 2023, Busillo et al. 2024, submitted to A&A, Tortora et al. 2024 in prep.

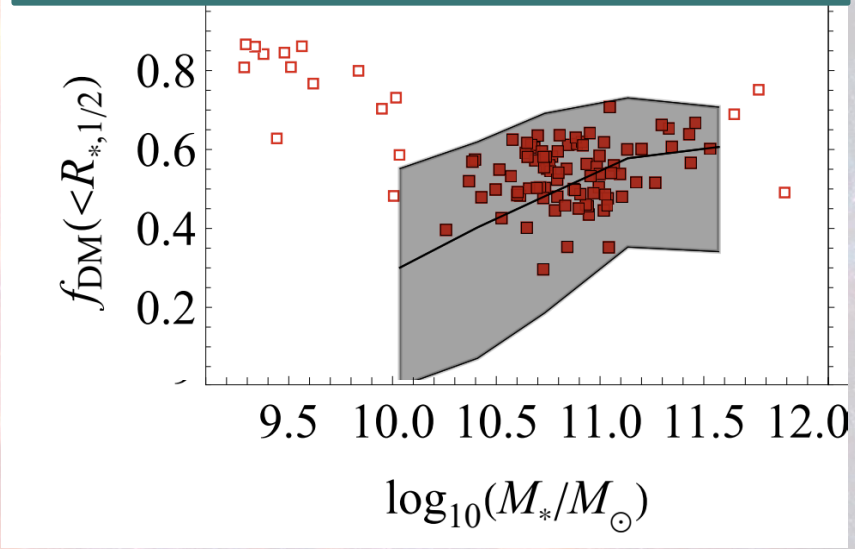
Comparing simulations and observations

CASCO: Cosmological and AStrophysical parameters from Cosmological simulations and Observations

CAMELS, DREAMS, TNG, etc.

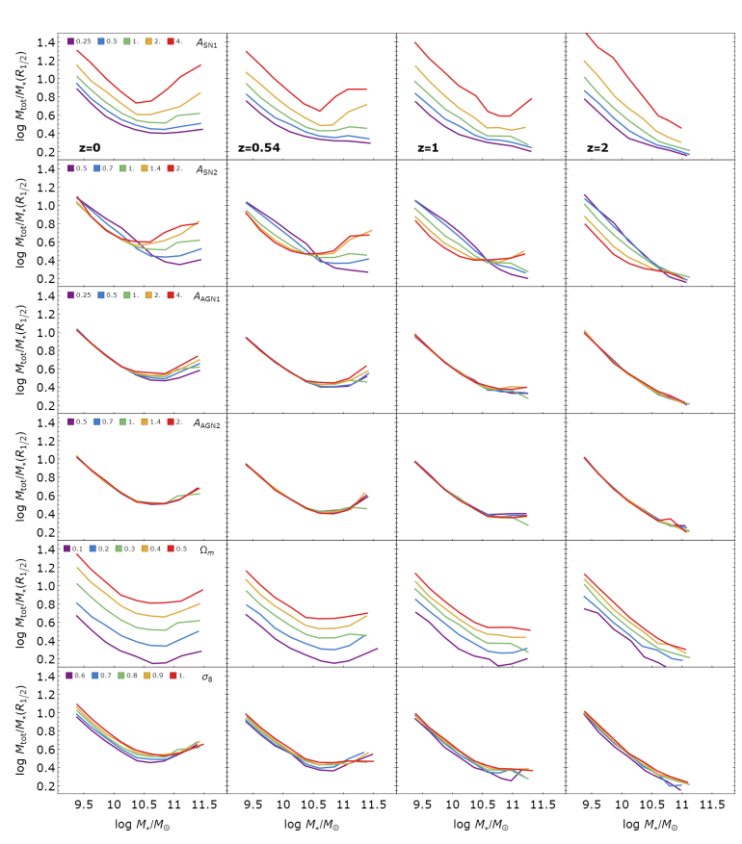


Data vs CAMELS simulations



Busillo et al. 2023, Busillo et al. 2024, submitted to A&A, Tortora et al. 2024 in prep.

The golden mass in CAMELS simulations



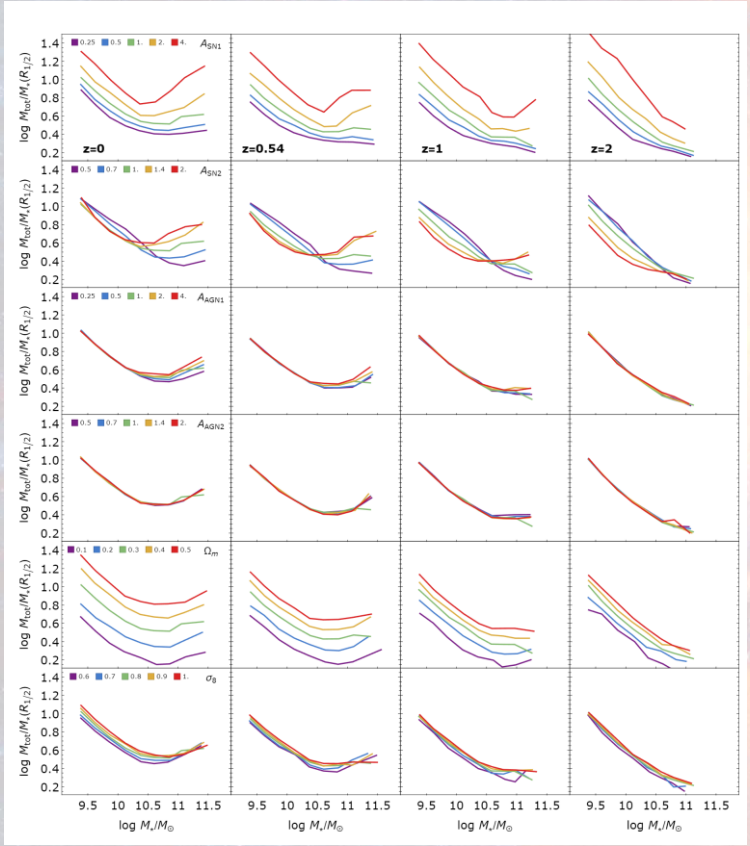
SN wind strength

AGN feedback strength

Cosmological parameters

Tortora et al. 2024, in prep.

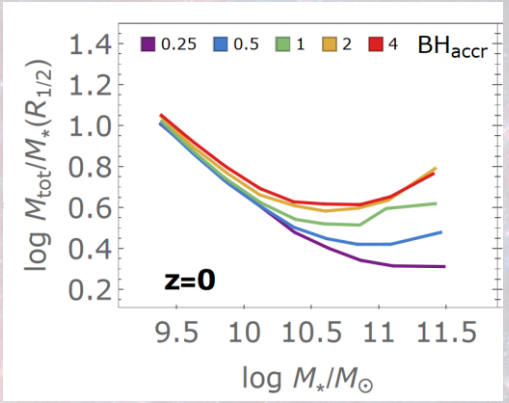
The golden mass in CAMELS simulations



SN wind strength

AGN feedback strength

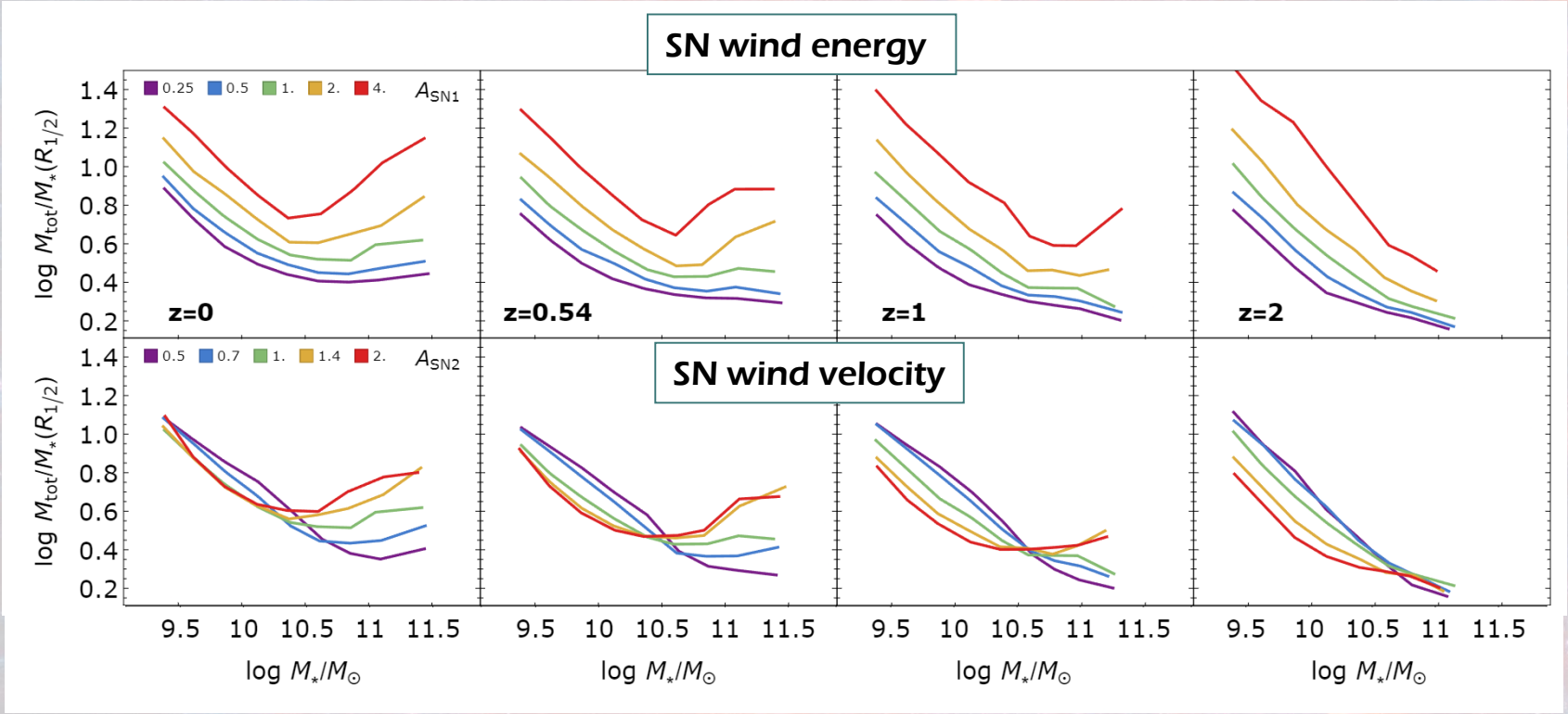
Cosmological parameters



...and more free parameters in the latest releases

Tortora et al. 2024, in prep.

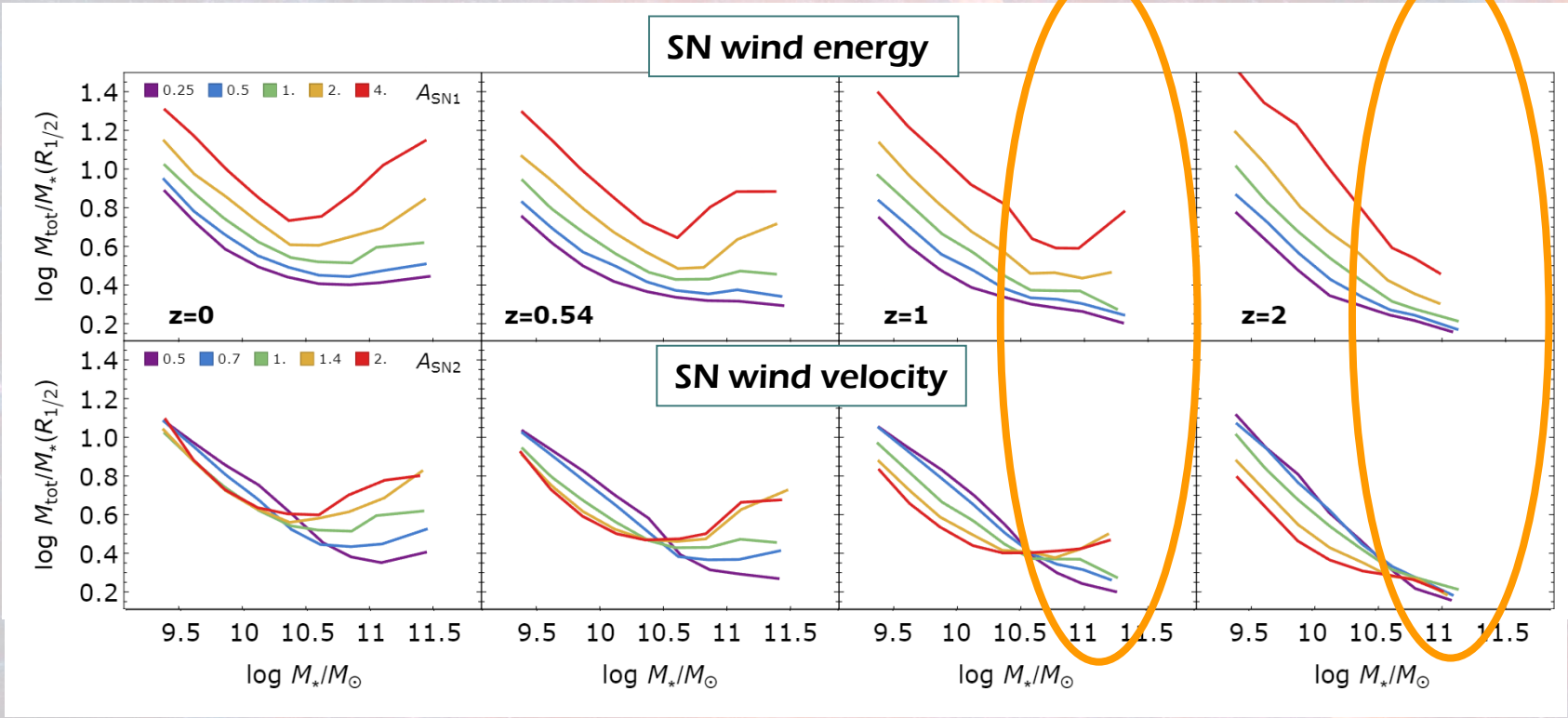
The golden mass in CAMELS simulations



Tortora et al. 2024, in prep.

The golden mass in CAMELS simulations

When does the golden mass emerge?

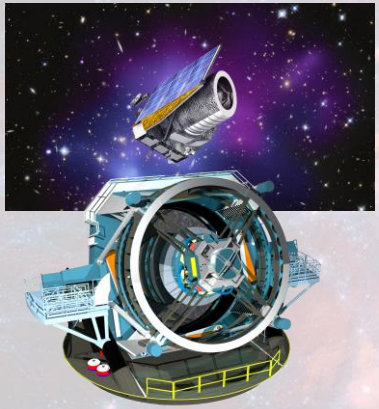


Tortora et al. 2024, in prep.

What about (new) observations?

Data in the next 5 years

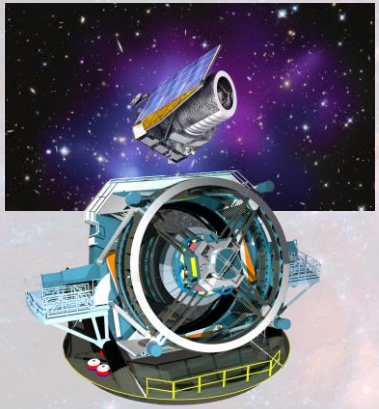
Euclid and Rubin



Billions of galaxies with integrated and 'resolved' photometry at $z < 3$ (10-100,000 in the local universe):

- Colours, stellar populations, stellar masses;
- Colour and stellar populations gradients;
- Structural parameters;
- Spec. Follow-up using GC populations for dynamical analysis;
- etc.

Euclid and Rubin

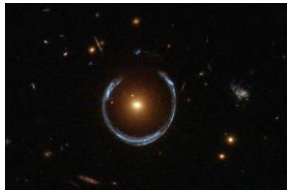


Billions of galaxies with integrated and 'resolved' photometry at z < 3 (10-100,000 in the local universe):

- Colours, stellar populations, stellar masses;
- Colour and stellar populations gradients;
- Structural parameters;
- Spec. Follow-up using GC populations for dynamical analysis;
- etc.

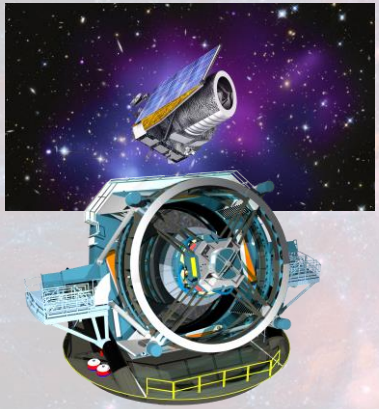
~100,000 strong lenses (5-10,000 with dynamics) up to z=2:

- mass,
- dark matter fraction,
- total and DM mass profiles,
- Initial Mass function,
- etc.



Euclid and Rubin + (StePS)-WEAVE and 4MOST

Precise velocity dispersions and stellar population parameters at z < 1

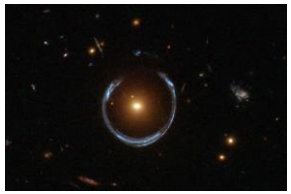


Billions of galaxies with integrated and 'resolved' photometry at z < 3 (10-100,000 in the local universe):

- Colours, stellar populations, stellar masses;
- Colour and stellar populations gradients;
- Structural parameters;
- Spec. Follow-up using GC populations for dynamical analysis;
- etc.

~100,000 strong lenses (5-10,000 with dynamics) up to z=2:

- mass,
- dark matter fraction,
- total and DM mass profiles,
- Initial Mass function,
- etc.



Data in the next 10 years

with ELT and SHARP?

SHARP

NEXUS

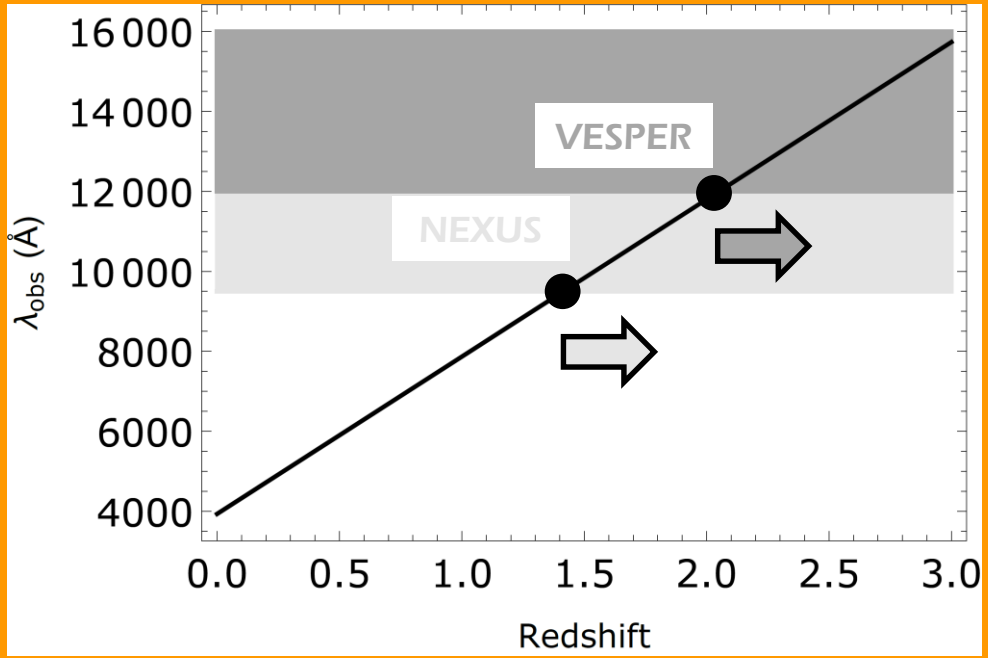
Scaling relations of integrated quantities

VESPER

Scaling relations of 'spatially-resolved' quantities

Specifics	Motivations/Comments	NEXUS	VESPER

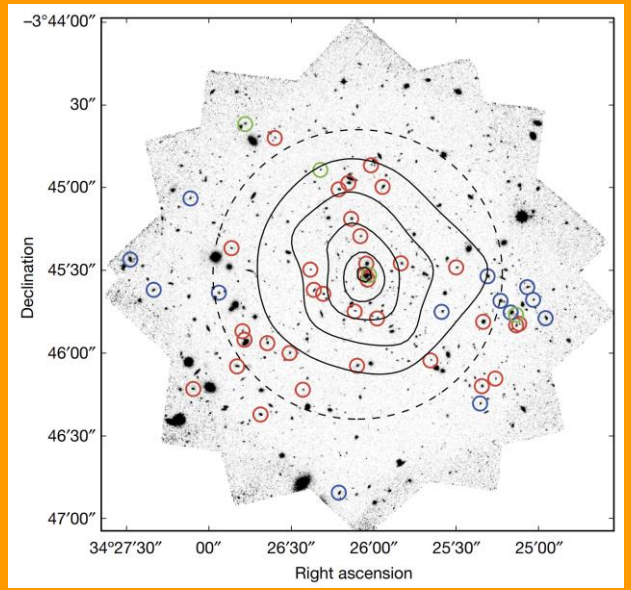
Specifics	Motivations/Comments	NEXUS	VESPER
Redshift coverage	*Most optical abs. lines in (down to Ca H&K)*	z > 1.5	z > 2

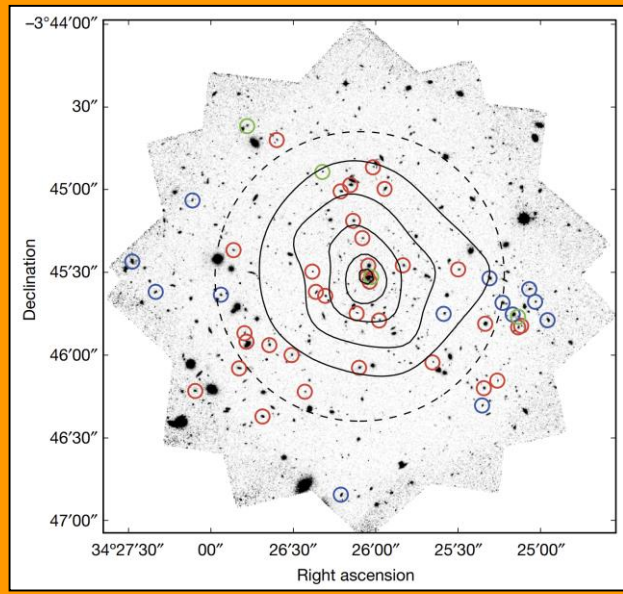


Specifics	Motivations/Comments	NEXUS	VESPER
Redshift coverage	*Most optical abs. lines in (down to Ca H&K)*	z > 1.5	z > 2
Spec. resolution	*Recovering st. pop. and* σ	2000/6000	3000

Specifics	Motivations/Comments	NEXUS	VESPER
Redshift coverage	*Most optical abs. lines in (down to Ca H&K)*	z > 1.5	z > 2
Spec. resolution	*Recovering st. pop. and σ*	2000/6000	3000
FOV	*Observe enough galaxies in a single pointing*	~30 galaxies in 72″×72″ ~0.6×0.6 Mpc²	~12 galaxies in 24″×72″ ~0.25×0.6 Mpc²

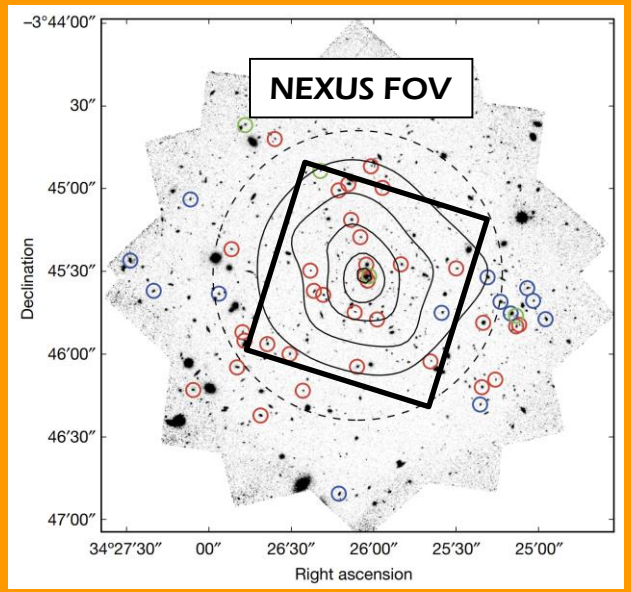
Willis et al. 2020,
XLSSC 122, z ~2

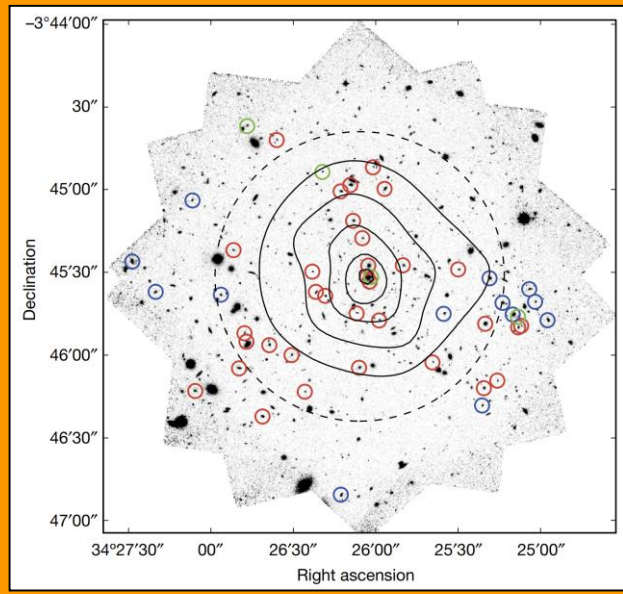




Specifics	Motivations/Comments	NEXUS	VESPER
Redshift coverage	*Most optical abs. lines in (down to Ca H&K)*	z > 1.5	z > 2
Spec. resolution	*Recovering st. pop. and σ*	2000/6000	3000
FOV	*Observe enough galaxies in a single pointing*	~30 galaxies in 72″×72″ ~0.6×0.6 Mpc²	~12 galaxies in 24″×72″ ~0.25×0.6 Mpc²

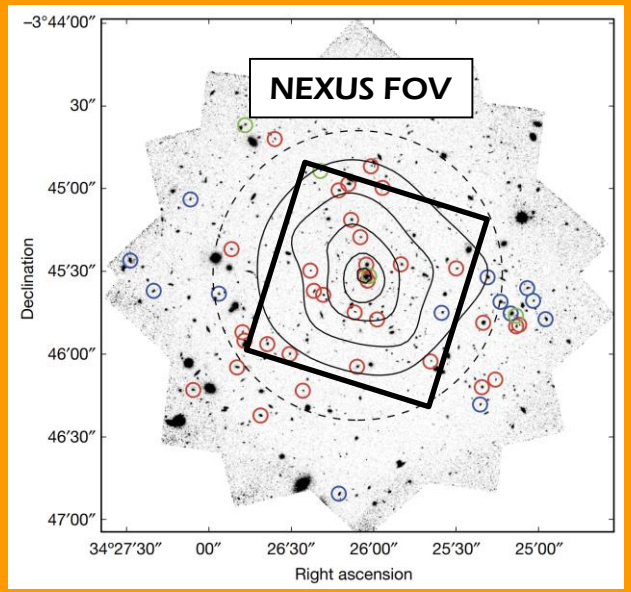
Willis et al. 2020,
XLSSC 122, z ~2

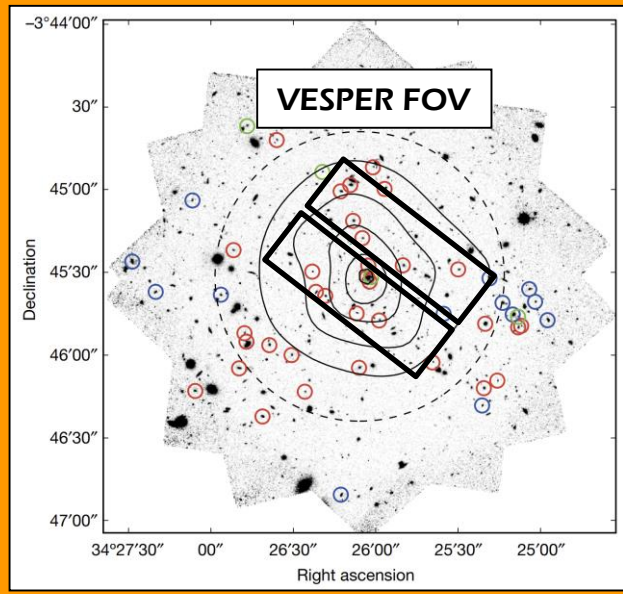




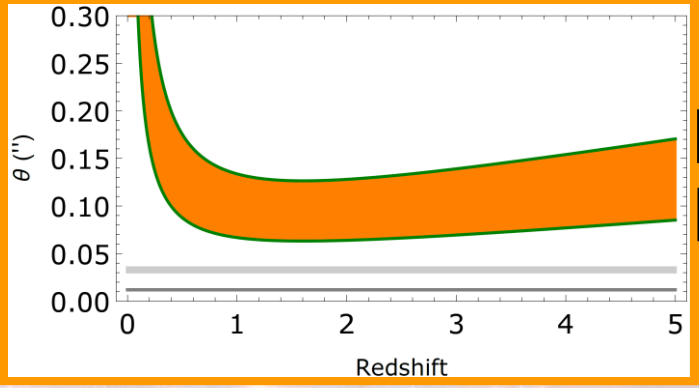
Specifics	Motivations/Comments	NEXUS	VESPER
Redshift coverage	*Most optical abs. lines in (down to Ca H&K)*	z > 1.5	z > 2
Spec. resolution	*Recovering st. pop. and σ*	2000/6000	3000
FOV	*Observe enough galaxies in a single pointing*	~30 galaxies in 72″×72″ ~0.6×0.6 Mpc²	~12 galaxies in 24″×72″ ~0.25×0.6 Mpc²

Willis et al. 2020,
XLSSC 122, z ~2



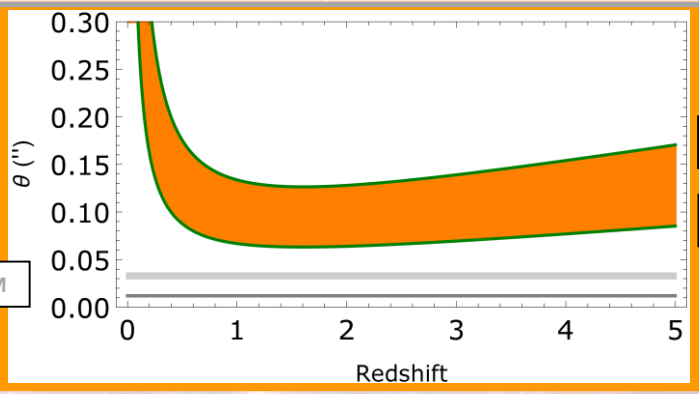


Specifics	Motivations/Comments	NEXUS	VESPER
Redshift coverage	*Most optical abs. lines in (down to Ca H&K)*	z > 1.5	z > 2
Spec. resolution	*Recovering st. pop. and σ*	2000/6000	3000
FOV	*Observe enough galaxies in a single pointing*	~30 galaxies in 72″×72″ ~0.6×0.6 Mpc²	~12 galaxies in 24″×72″ ~0.25×0.6 Mpc²
Spatial resolution	*R_e = 0.5-1 kpc is around 0.1″*	Half of the light in the slit width of 0.2″	Within the FOV of 1.7 × 1.5″, we can map the spectra up to some Re



Specifics	Motivations/Comments	NEXUS	VESPER
Redshift coverage	*Most optical abs. lines in (down to Ca H&K)*	z > 1.5	z > 2
Spec. resolution	*Recovering st. pop. and σ*	2000/6000	3000
FOV	*Observe enough galaxies in a single pointing*	~30 galaxies in 72″×72″ ~0.6×0.6 Mpc²	~12 galaxies in 24″×72″ ~0.25×0.6 Mpc²
Spatial resolution	*R_e = 0.5-1 kpc is around 0.1″*	Half of the light in the slit width of 0.2″	Within the FOV of 1.7 × 1.5″, we can map the spectra up to some Re
Pix. Scale - PSF FWHM	*Important for VESPER*	0.035″/pix – 0.012″	0.031″/sp – 0.012″ (R_e ~ 3 × spaxel size)

Pixel/spaxel scale and PSF FWHM



Specifics	Motivations/Comments	NEXUS	VESPER
Redshift coverage	*Most optical abs. lines in (down to Ca H&K)*	z > 1.5	z > 2
Spec. resolution	*Recovering st. pop. and* σ	2000/6000	3000
FOV	*Observe enough galaxies in a single pointing*	~30 galaxies in 72″×72″ ~0.6×0.6 Mpc^2	~12 galaxies in 24″×72″ ~0.25×0.6 Mpc^2
Spatial resolution	*R_e = 0.5-1 kpc is around 0.1″*	Half of the light in the slit width of 0.2″	Within the FOV of 1.7 × 1.5″, we can map the spectra up to some Re
Pix. Scale - PSF FWHM	*Important for VESPER*	0.035″/pix – 0.012″	0.031″/sp – 0.012″ (R_e ~ 3 × spaxel size)
S/N and exp. time	R=2000 (NEXUS) or 3000 (VESPER), exp. time: 1h	Width=200 mas S/N = 20-100 (K=20, K_{Re} = 20.75) S/N = 5-30 (K=22, K_{Re} = 22.75)	Diameter=200mas (K = 20) S/N = 20-100 (μ_K(Re)=18) S/N = 5-25 (μ_K(2Re)=19.7) S/N=1-8 (μ_K(3Re)=20.95)

Specifics	Motivations/Comments	NEXUS	VESPER
Redshift coverage	*Most optical abs. lines in (down to Ca H&K)*	z > 1.5	z > 2
Spec. resolution	*Recovering st. pop. and σ*	2000/6000	3000
FOV	*Observe enough galaxies in a single pointing*	~30 galaxies in 72″×72″ ~0.6×0.6 Mpc²	~12 galaxies in 24″×72″ ~0.25×0.6 Mpc²
Spatial resolution	*R_e = 0.5-1 kpc is around 0.1″*	Half of the light in the slit width of 0.2″	Within the FOV of 1.7 × 1.5″, we can map the spectra up to some Re
Pix. Scale - PSF FWHM	*Important for VESPER*	0.035″/pix – 0.012″	0.031″/sp – 0.012″ (R_e ~ 3 × spaxel size)
S/N and exp. time	R=2000 (NEXUS) or 3000 (VESPER), exp. time: 1h	Width=200 mas S/N = 20-100 (K=20, K_{Re} = 20.75) S/N = 5-30 (K=22, K_{Re} = 22.75)	Diameter=200mas (K = 20) S/N = 20-100 (μ_K(Re)=18) S/N = 5-25 (μ_K(2Re)=19.7) S/N=1-8 (μ_K(3Re)=20.95)
Observables	-	Integrated st. pop. and σ	St. pop. gradients and σ profile

Specifics	Motivations/Comments	NEXUS	VESPER
Redshift coverage	*Most optical abs. lines in (down to Ca H&K)*	z > 1.5	z > 2
Spec. resolution	*Recovering st. pop. and σ*	2000/6000	3000
FOV	*Observe enough galaxies in a single pointing*	~30 galaxies in 72″×72″ ~0.6×0.6 Mpc²	~12 galaxies in 24″×72″ ~0.25×0.6 Mpc²
Spatial resolution	*R_e = 0.5-1 kpc is around 0.1″*	Half of the light in the slit width of 0.2″	Within the FOV of 1.7 × 1.5″, we can map the spectra up to some Re
Pix. Scale - PSF FWHM	*Important for VESPER*	0.035″/pix – 0.012″	0.031″/sp – 0.012″ (R_e ~ 3 × spaxel size)
S/N and exp. time	R=2000 (NEXUS) or 3000 (VESPER), exp. time: 1h	Width=200 mas S/N = 20-100 (K=20, K_{Re} = 20.75) S/N = 5-30 (K=22, K_{Re} = 22.75)	Diameter=200mas (K = 20) S/N = 20-100 (μ_K(Re)=18) S/N = 5-25 (μ_K(2Re)=19.7) S/N=1-8 (μ_K(3Re)=20.95)
Observables	-	Integrated st. pop. and σ	St. pop. gradients and σ profile

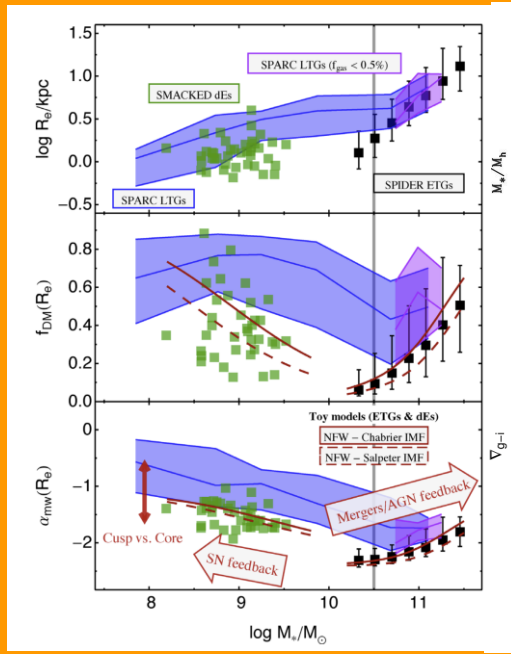
Exp. Time of 100 hours | **3000 galaxies** | **1200 galaxies**

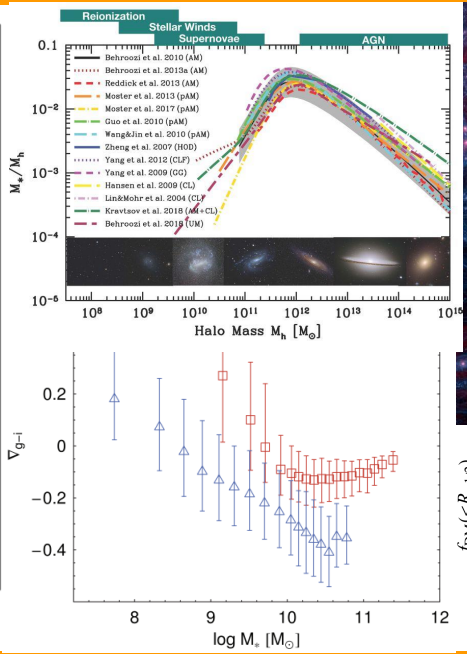
Specifics	Motivations/Comments	NEXUS	VESPER
Observables	-	Integrated st. pop. and σ	St. pop. gradients and σ profile
Final products	-	Scaling relations (St. pop., σ, DM fraction vs. mass and z)	Scaling relations (St. pop. gradients, DM fraction, mass density slope vs. mass and z)

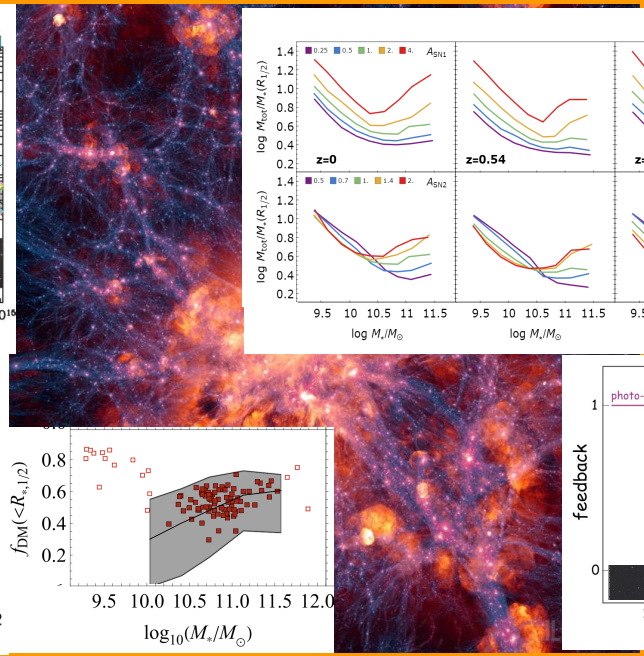
Specifics	Motivations/Comments	NEXUS	VESPER

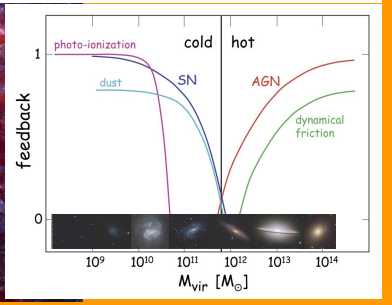
SHARP can help to understand the origin of the golden mass across cosmic history

Observables	-	Integrated st. pop. and σ	St. pop. gradients and σ profile
Final products	-	Scaling relations (St. pop., σ, DM fraction vs. mass and z)	Scaling relations (St. pop. gradients, DM fraction, mass density slope vs. mass and z)









Wish you a "SHARP" future