ICRAR

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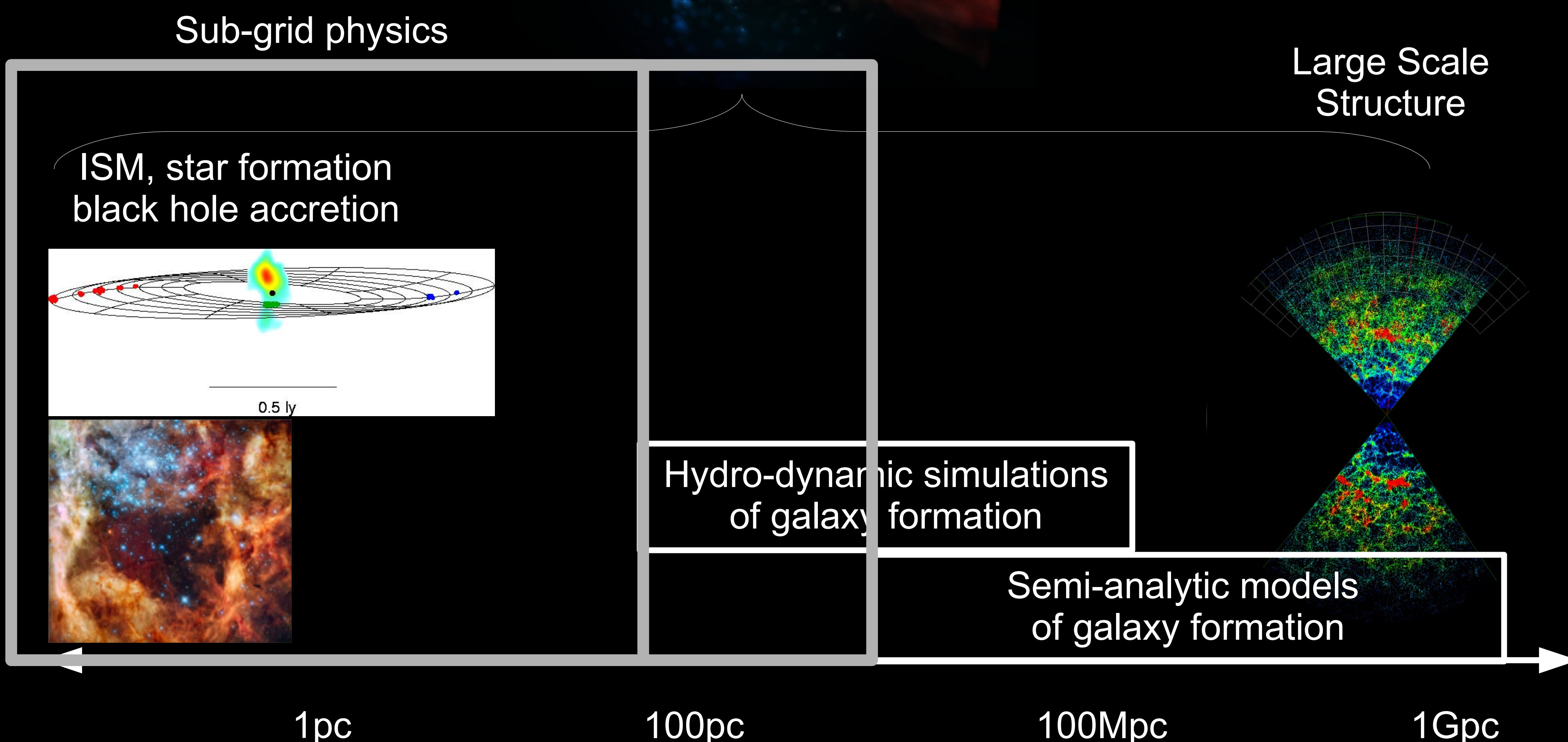
SHARK

Introducing a new, open source, free and flexible semi-analytic model

Claudia Lagos (ICRAR, DECRA fellow)

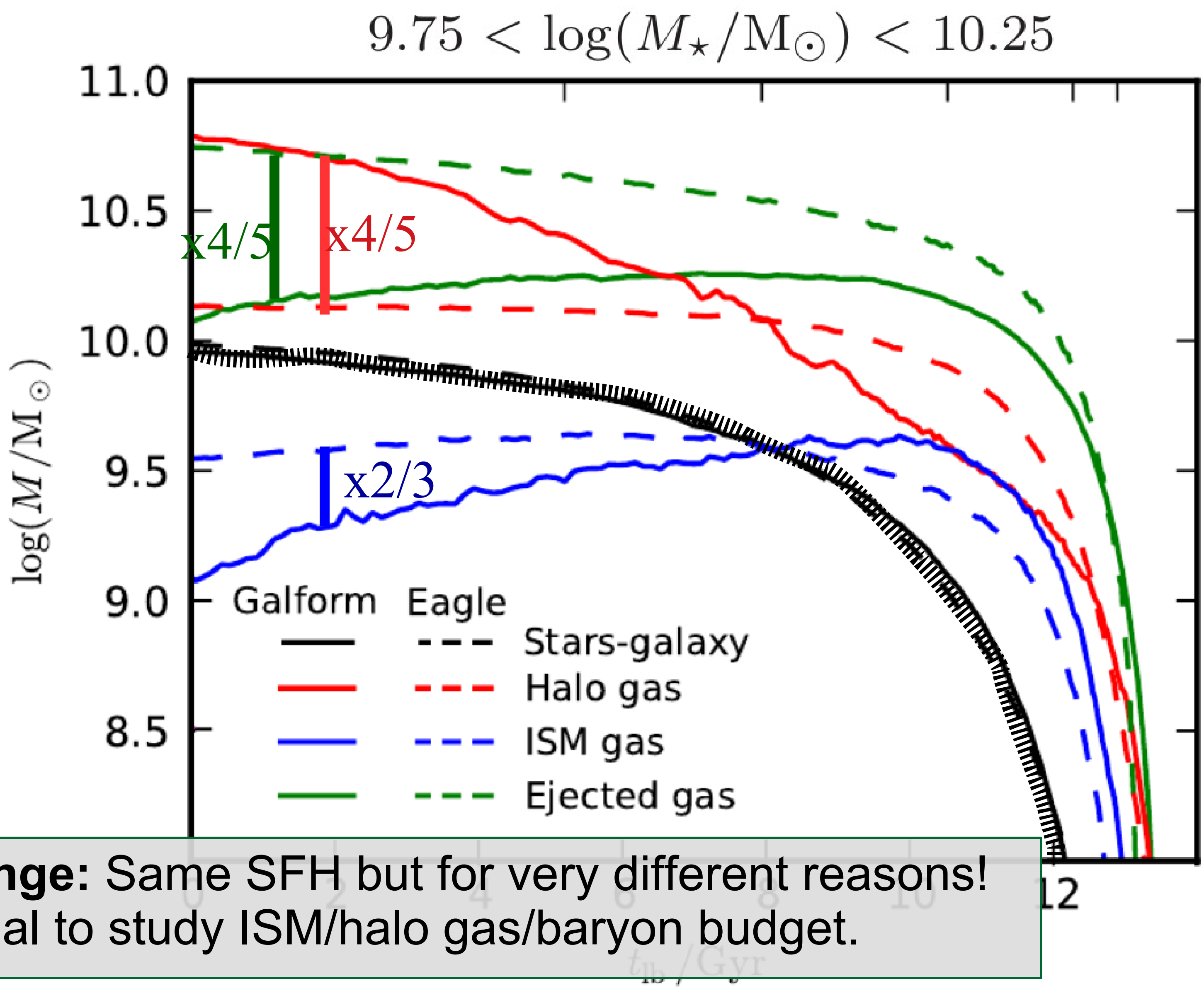
Why do we still need SAMs?

I) Connection to LSS
II) Flexibility to test physical models/systematic study of physics



The need for systematic studies

Mitchell, Lacey, Lagos et al. (2017): a one-to-one comparison between EAGLE and GALFORM

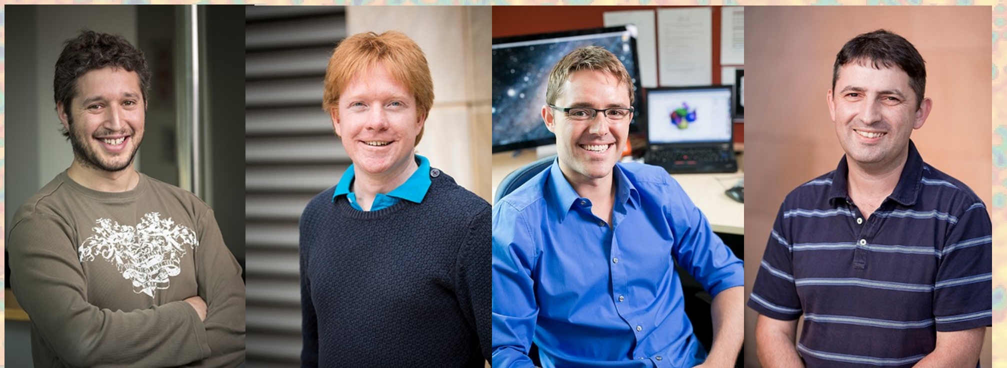


Challenge: Same SFH but for very different reasons! Essential to study ISM/halo gas/baryon budget.

Explore and understand the effects of our model assumptions (specially regarding feedback, ISM). Aim at predictions of what would distinguish different feasible models – **SAMs best suited**

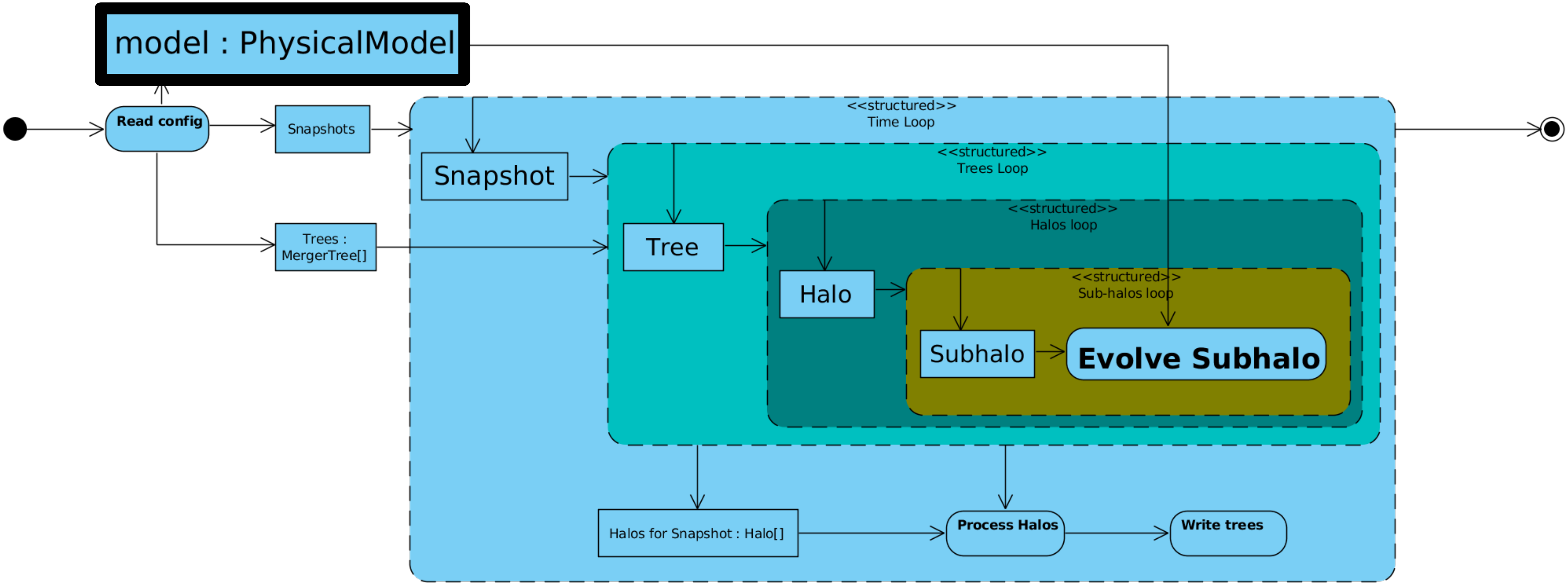
Requires a flexible, modular SAM where to easily test different physical models and assumptions

SHARK: Multidisciplinary team



SHARK Design

Led by Claudia Lagos, in collaboration with computer and data intensive scientists and computational astrophysicists at ICRAR (started April 2017) (c++, GSL libraries, cmake, python)



- **STATUS**: version 1.0-dev of the code finished
- **Introductory paper** in preparation (Lagos et al., in prep.)
- Science papers coming soon: led by Lagos, Chahuan (PhD), and Poulton (PhD)

Physical processes in SHARK

- Motivation: include a wide range of models for every one physical process

Parameter	suggested value range	variable/equation
halo properties		
halo_profile	nfw/einasto (nfw)	Eq. 1
lambda_random	0 (Eq. 2) or 1 (random distribution) (1)	
gas cooling		
rcore	$0 - 0.1$ (0)	$r_{\rm c}$ in Eq. 4
lambdamodel	cloudy or sutherland (cloudy)	Λ in Eq. 5
model	Croton06 or Benson10 (Croton06)	Described in § 3.4.1
stellar feedback		
model	FIRE, LAGOS13, LAGOS13Trunc, GALFORM or LGALAXIES	(LAGOS13) § 3.4.3
v_sn	$50 - 500\,{\rm km\,s^{-1}}$ ($150\,{\rm km\,s^{-1}}$)	$v_{\rm hot}$ in Eqs. 18-21
beta_disk	$0.5 - 5$ (3.8)	α in Eqs. 18-21
redshift_power	-0.5 to 1.5 (0.13)	β in Eqs. 20 and 22
eps_halo	$0.1 - 10$ (2)	$\epsilon_{\rm halo}$ in Eq. 16
eps_disk	$1 - 10$ (1)	$\epsilon_{\rm disk}$ in Eq. 19
star formation		
SFprescription	BR06, GD14 or KMT09 (BR06)	in § 3.4.2
nu_sf	$0.25 - 1.25\,{\rm Gyr^{-1}}$ ($0.5\,{\rm Gyr^{-1}}$)	$1/\tau_{\rm H_2}$ in Eq. 8
boost_starburst	$1 - 4$ (3)	η_{burst} in § 3.4.2
sigma_HI_crit	$0.01 - 0.1\,{\rm M_\odot\,pc^{-2}}$ ($0.1\,{\rm M_\odot\,pc^{-2}}$)	$\Sigma_{\rm thresh}$ in § 3.4.2
Po	$10,000 - 30,000\,{\rm K\,cm^{-3}}$ ($10,000,\,{\rm K\,cm^{-3}}$)	P_0 in Eq. 9; only relevant for BR06
beta_press	$0.7 - 1$ (0.8)	$\alpha_{\rm P}$ in Eq. 9; only relevant for BR06
gas_velocity_dispersion	$7 - 10\,{\rm km\,s^{-1}}$ ($10\,{\rm km\,s^{-1}}$)	$\sigma_{\rm gas}$ in Eq. 10; only relevant for BR06
clump_factor_KMT09	$1 - 10$ (5)	only relevant for KMT09

Physical processes in SHARK

- Motivation: include a wide range of models for every one physical process

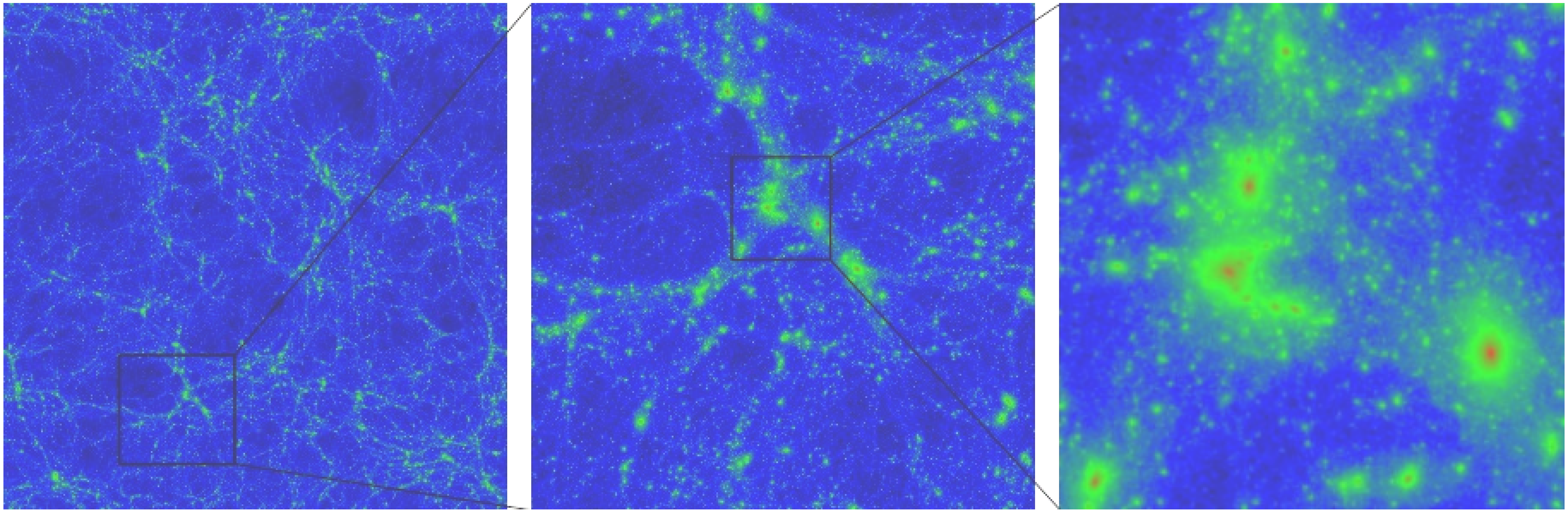
reionisation		
model	GALFORM or Sobacchi (GALFORM)	in § 3.4.8
vcut	$7 - 11$ (10)	in § 3.4.8
zcut	$30 - 50\,\mathrm{km\,s^{-1}}$ ($35\,\mathrm{km\,s^{-1}}$)	in § 3.4.8
alpha_v	-1 to 0 (-0.2)	only relevant for Sobacchi model, Eq. 29
AGN feedback & BH growth		
model	GALFORM or Croton16 (Croton16)	AGN feedback model § 3.4.9
mseed	$0 - 10^5\,\mathrm{M_\odot/h}$ ($10^4\,\mathrm{M_\odot/h}$)	$m_{\rm seed}$ in § 3.4.9
mhalo_seed	$0 - 10^{11}\,\mathrm{M_\odot/h}$ ($10^{10}\,\mathrm{M_\odot/h}$	$m_{\rm halo,seed}$ in § 3.4.9
f_smbh	$10^{-5} - 10^{-2}$ (4×10^{-4})	$f_{\rm smbh}$ in Eq. 30
v_smbh	$100 - 300\,\mathrm{km\,s^{-1}}$ ($200\,\mathrm{km\,s^{-1}}$)	$v_{\rm smbh}$ in Eq. 30
tau_fold	$0.5 - 10$ (1)	$e_{\rm sb}$ in § 3.4.9
accretion_eff_cooling	$0.07 - 0.4$ (0.1)	η in § 3.4.9; only relevant for Croton16
kappa_agn	$10^{-3} - 10$ (1)	$\kappa_{\rm r}$ in Eq. 33; only relevant for Croton16
mass_thresh	$10^{11.5} - 10^{12.5}\,\mathrm{M_\odot}$ ($10^{12}\,\mathrm{M_\odot}$)	$m_{\rm thresh}$ in § 3.4.9; only relevant for Croton16
alpha_cool	$0.3 - 3$ (1)	§ 3.4.9; only relevant for GALFORM
f_edd	$0.0001 - 0.1$ (0.01)	§ 3.4.9; only relevant for GALFORM

Model also includes: disk instabilities, galaxy mergers

SHARK's backbone: SURFS

SURFS (Synthetic UniveRses for Future Surveys): Elahi et al. (2018a,b)

Name	Box size $L_{\rm box}$ [h^{-1}Mpc]	Number of Particles N_p	Particle Mass m_p [h^{-1}M$_\odot$]	Softening Length ϵ [h^{-1}ckpc]	Comments
L40N512	40	512^3	4.13×10^7	2.6	Small volume, high resolution test
L210N512	210	512^3	5.97×10^9	13.7	Moderate volume, low resolution test
L210N1024	210	1024^3	7.47×10^8	6.8	Moderate volume, moderate resolution
L210N1024NR	210	2×1024^3	6.29×10^8	6.8	Nonradiative (adiabatic gas, no star formation or feedback) analogue
			1.17×10^8		to L210N1024.
L210N1536	210	1536^3	2.21×10^8	4.5	Moderate volume, current high resolution.
L900N2048	900	2048^3	7.35×10^9	14.6	Large volume, low resolution, low cadence for HODs

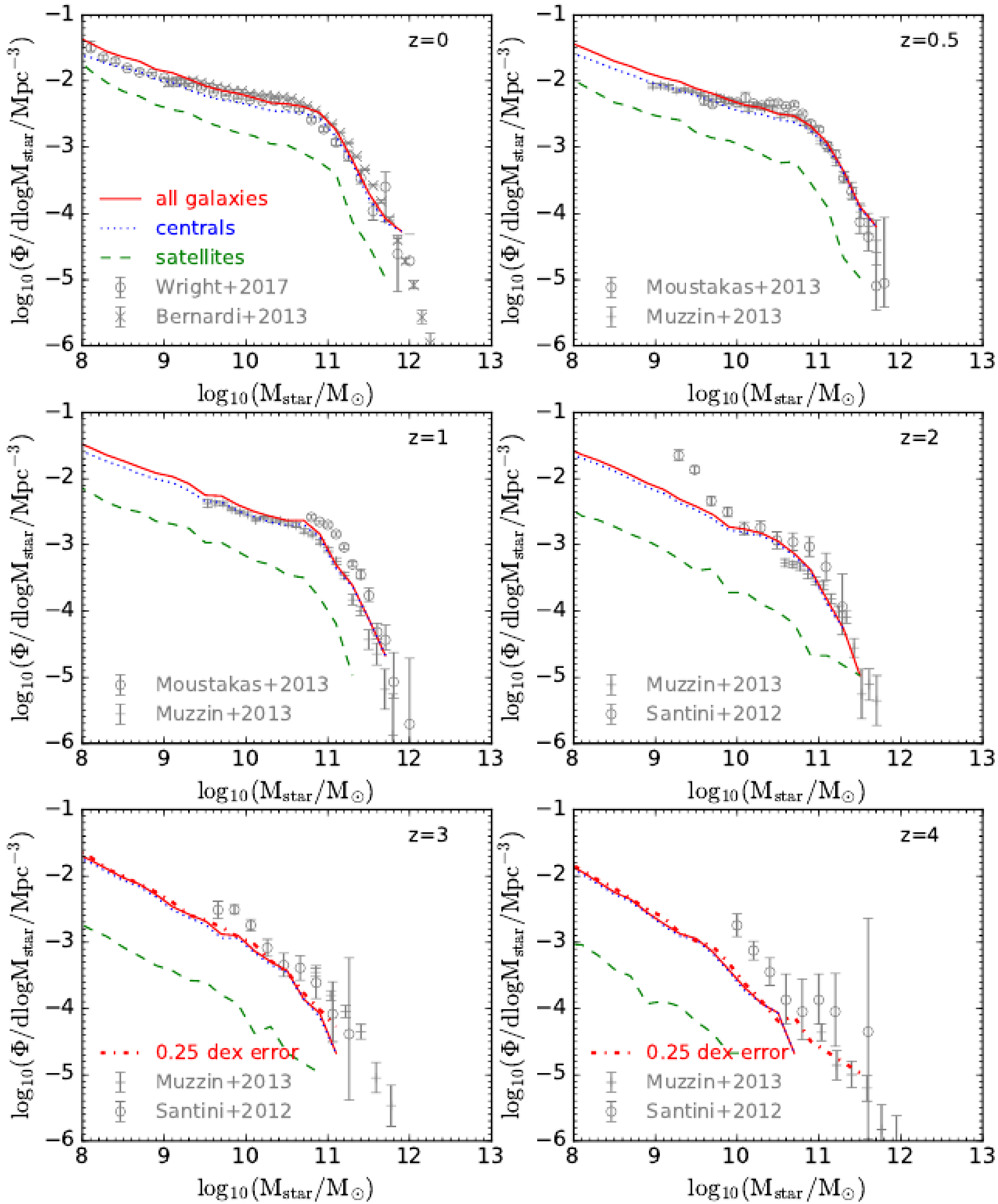


Preliminary results

Lagos et al. in prep.

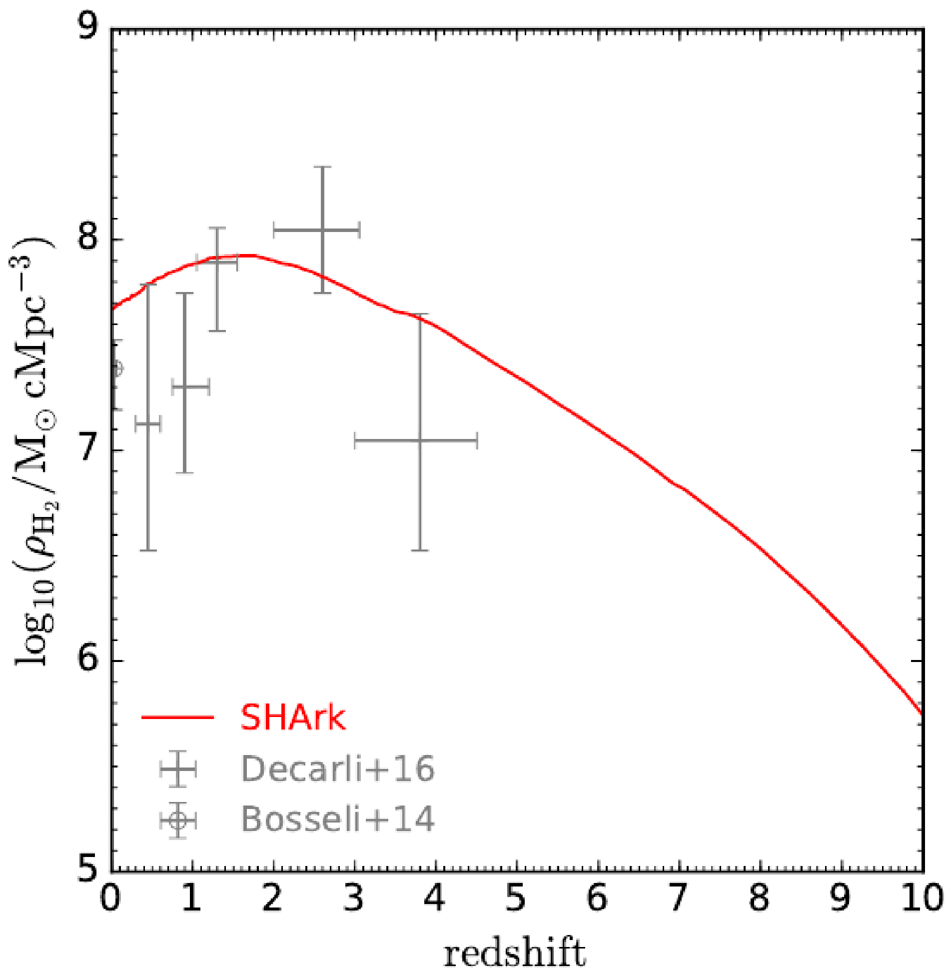
→ good agreement with the SMF (primary constrain)

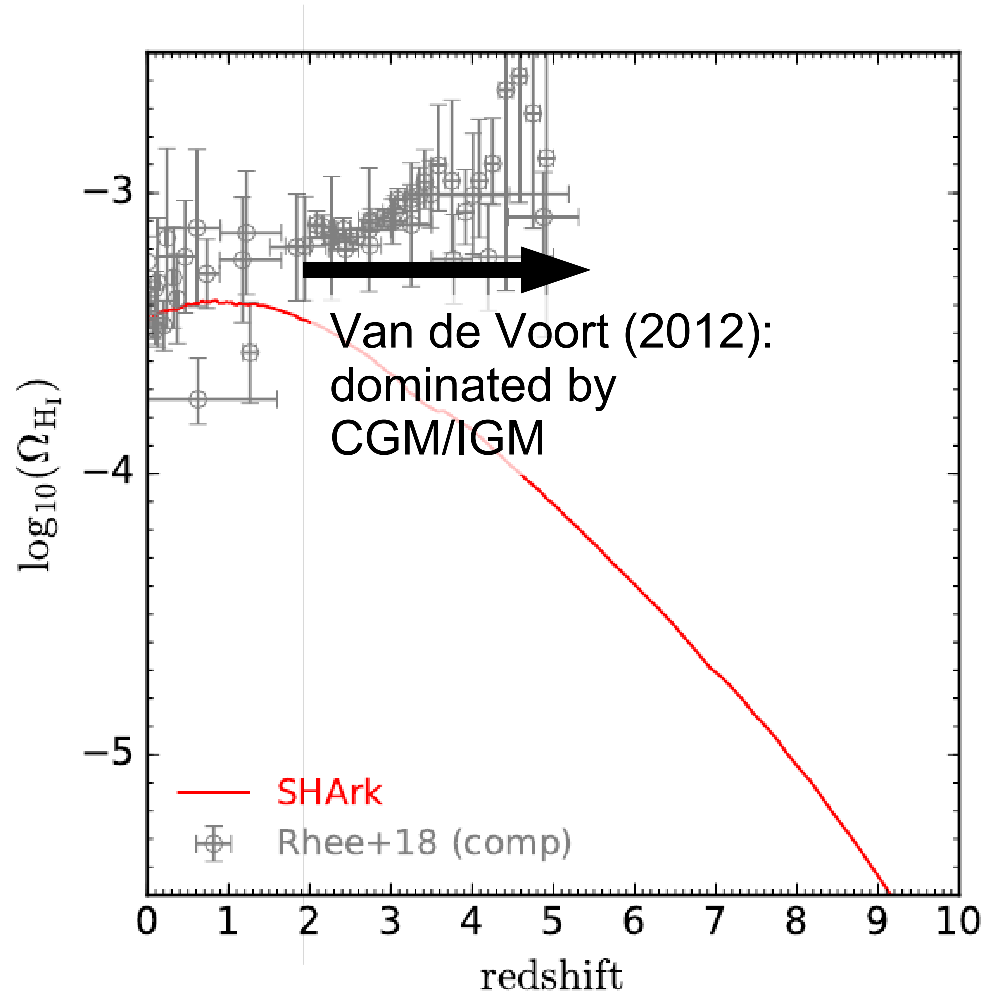
→ tunning was done using "sensible" parameters



Global history of the universe: stars

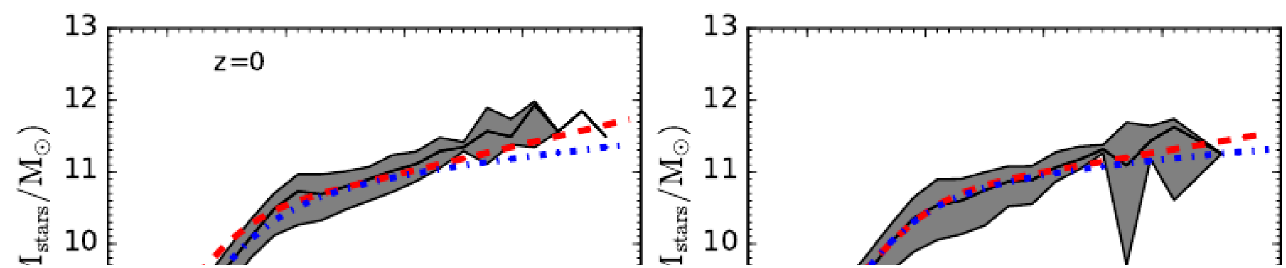
SFR/stellar mass (primary constraints) and ISM abundances agree reasonable well with observations.
New observations produce consistent SFR-stellar mass (Driver et al. 2018)





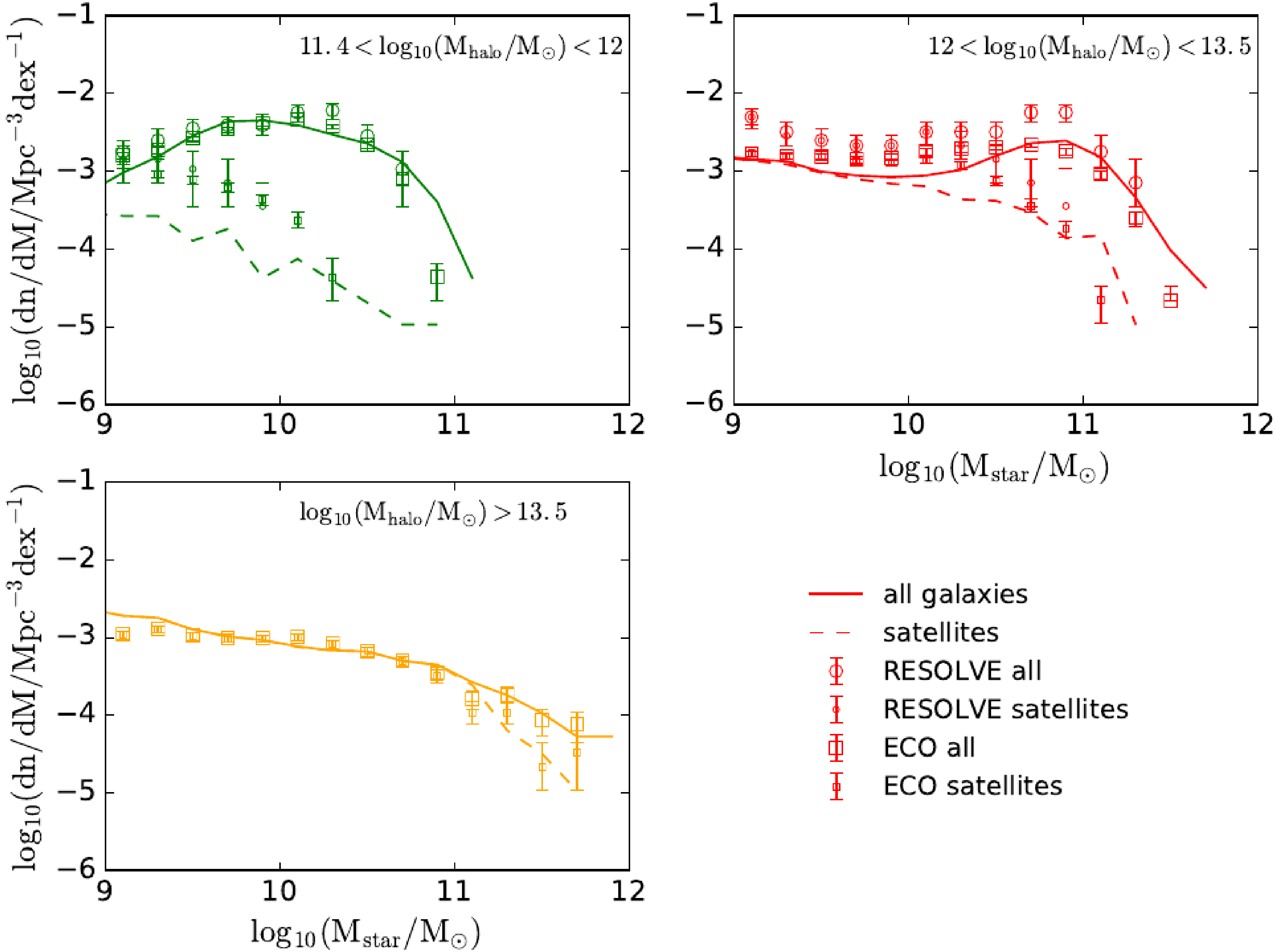
Lagos et al. (in prep.)

Stellar-halo relation

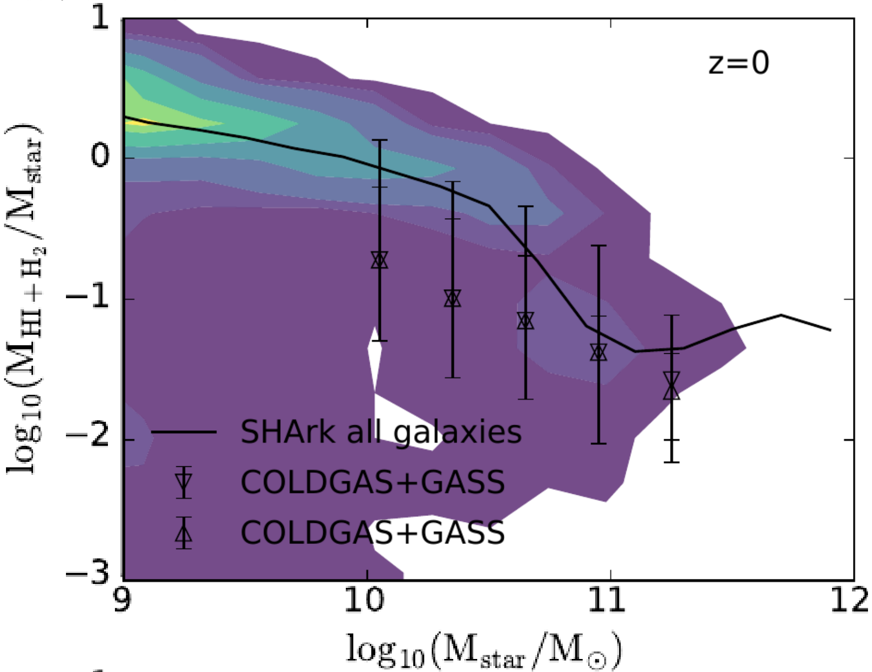


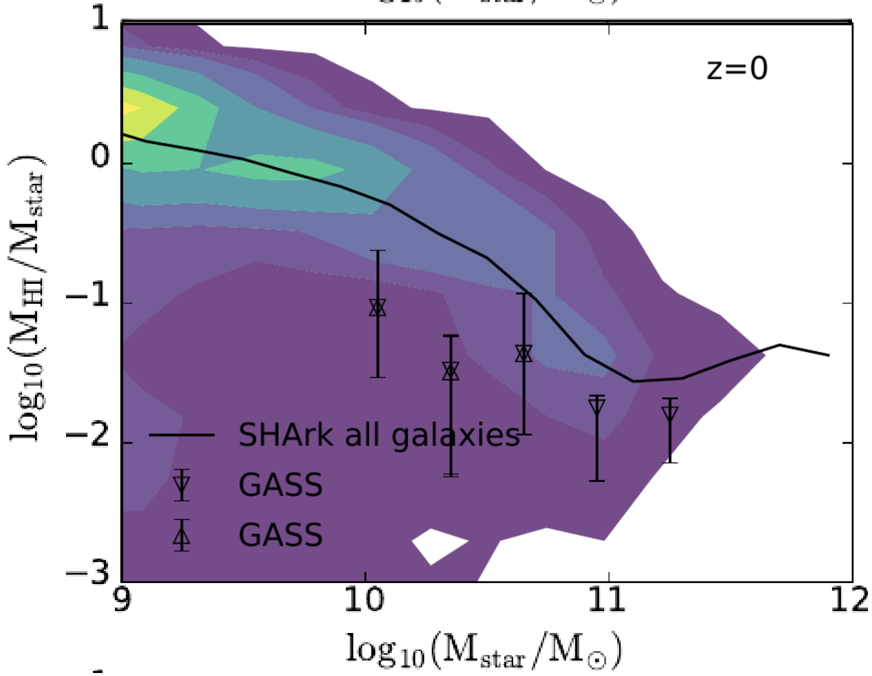
Lagos et al. (in

We **do not tur**
halo mass rela



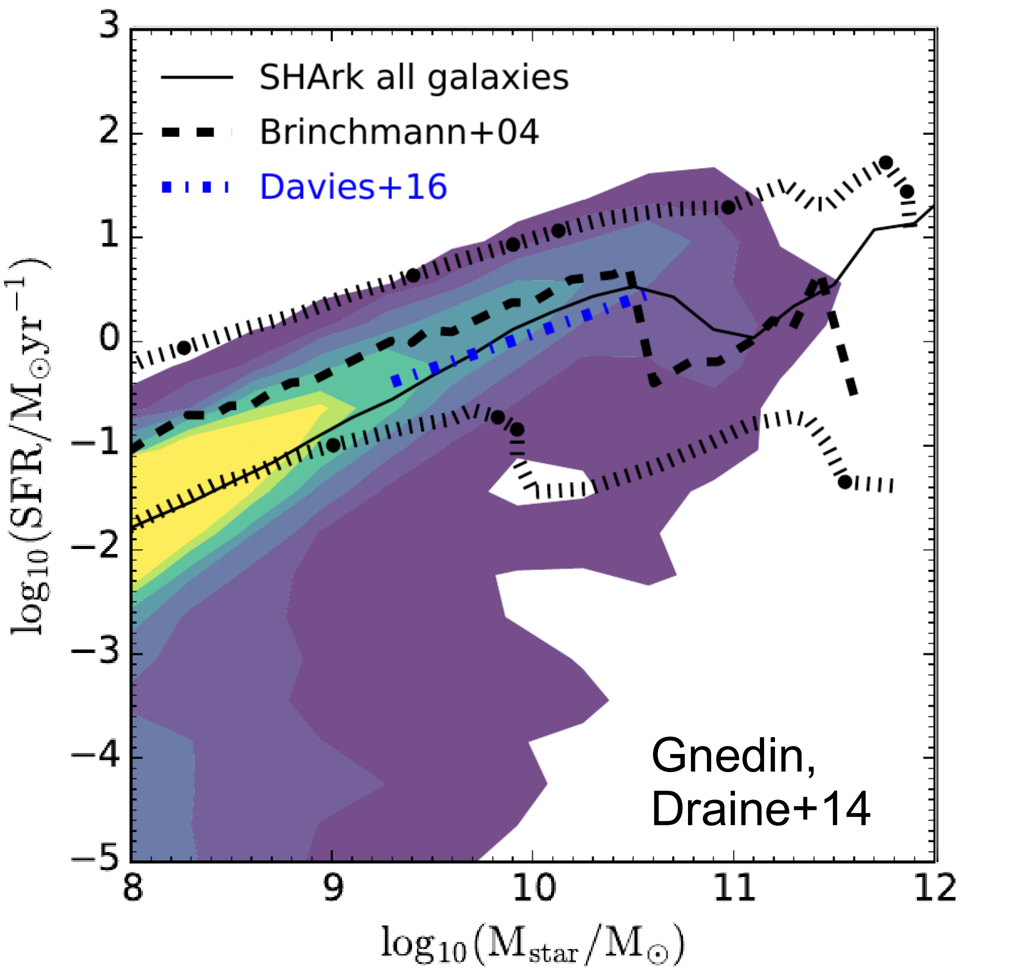
Testing the physics: star formation





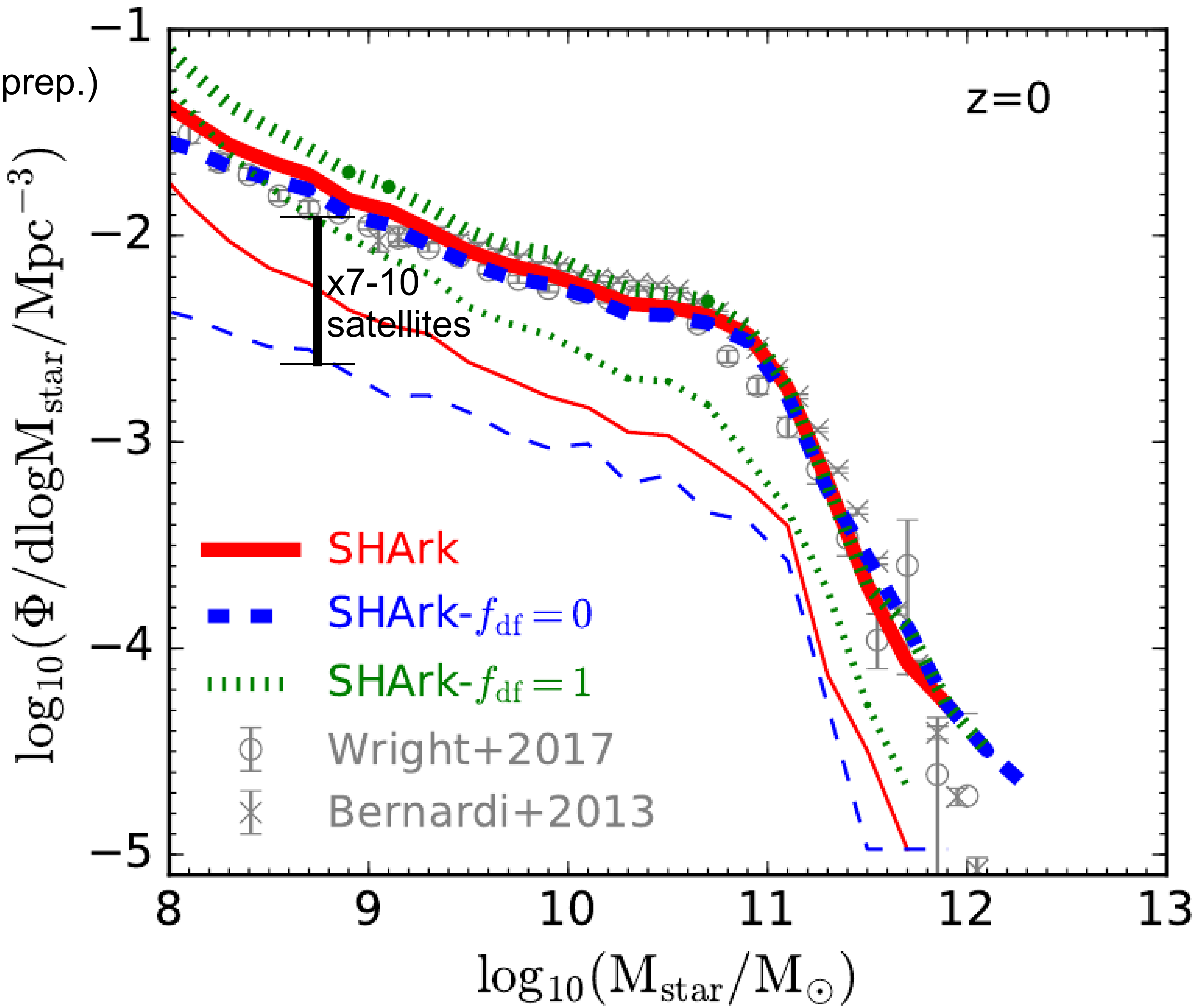
Lagos et al. (in prep.): SF law and SB/normal SF galaxies and effect on gas content/SF

$$\Sigma_{SFR} = \frac{\tau_{H_2}}{\eta_{burst}} \Sigma_{mol}$$



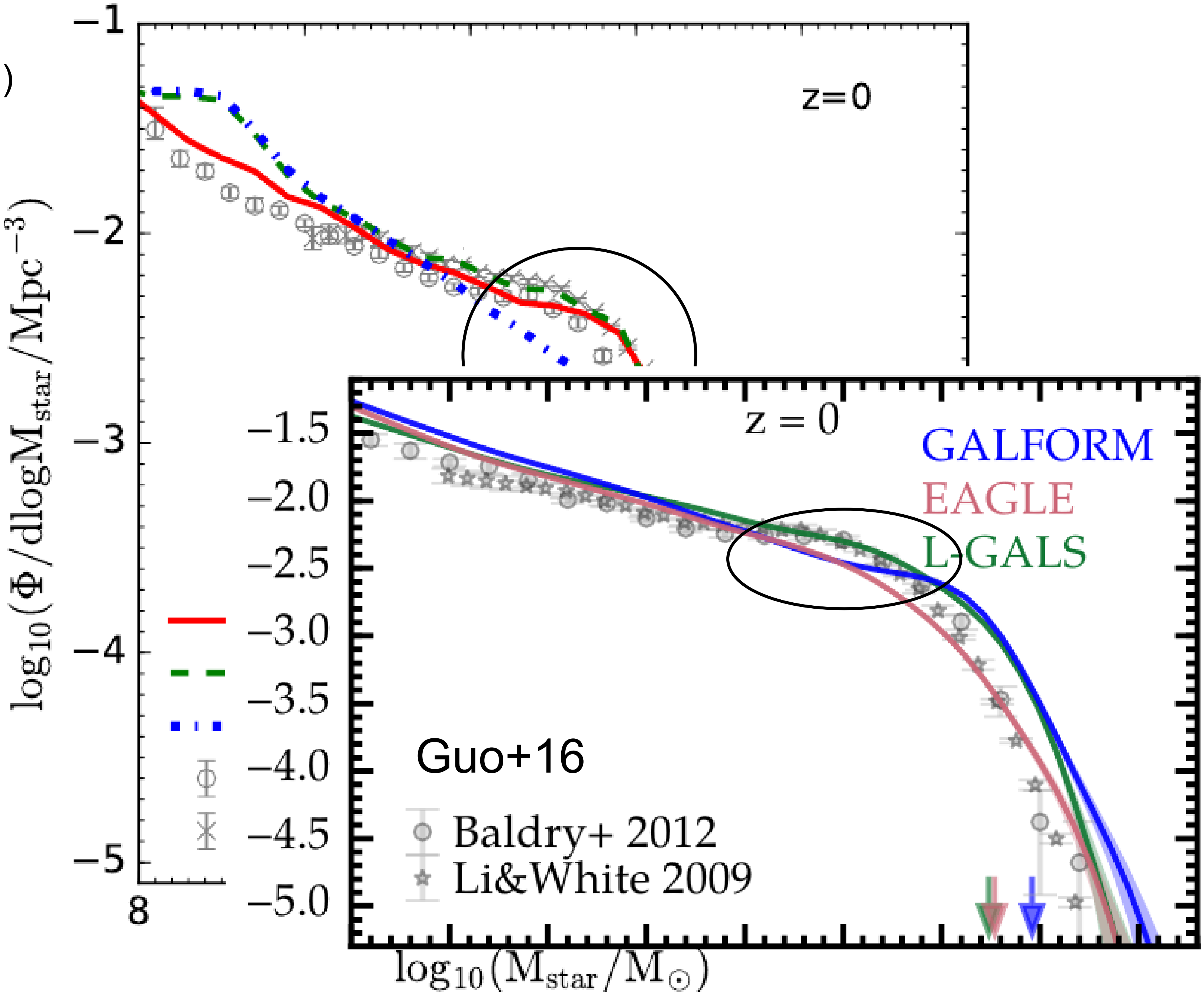
Testing the physics: dynamical friction

Lagos et al. (in prep.)



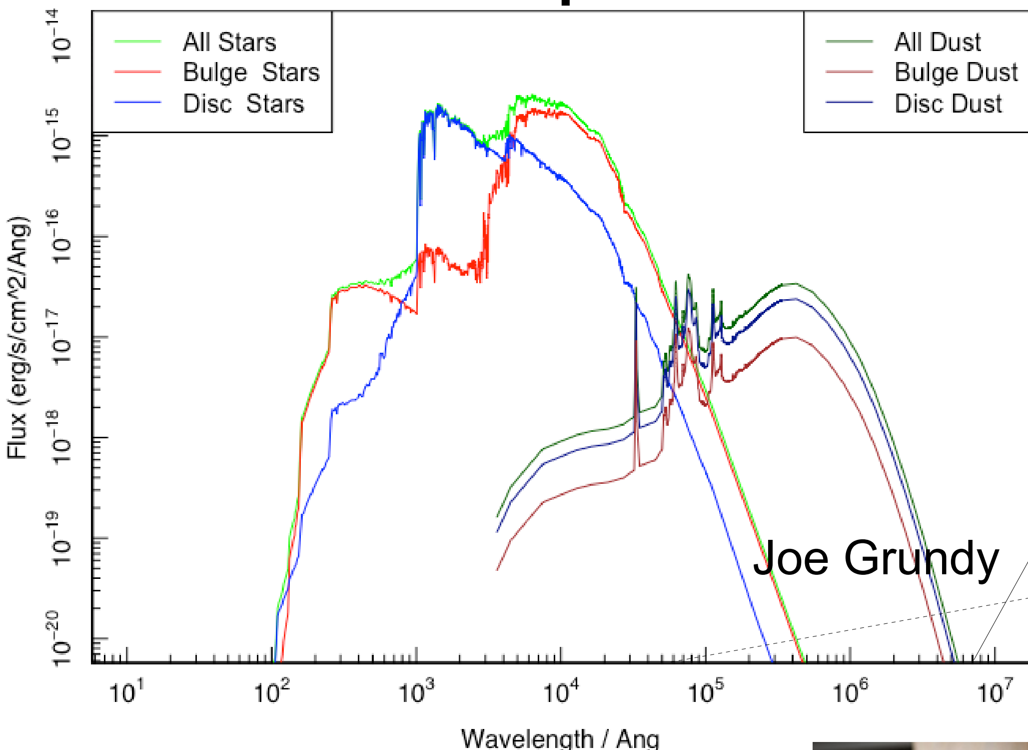
Testing the physics: gas cooling and AGN

Lagos et al. (in prep.)



SEDs and lightconing

ProSpect



Joe Grundy

STATUS: in beta testing

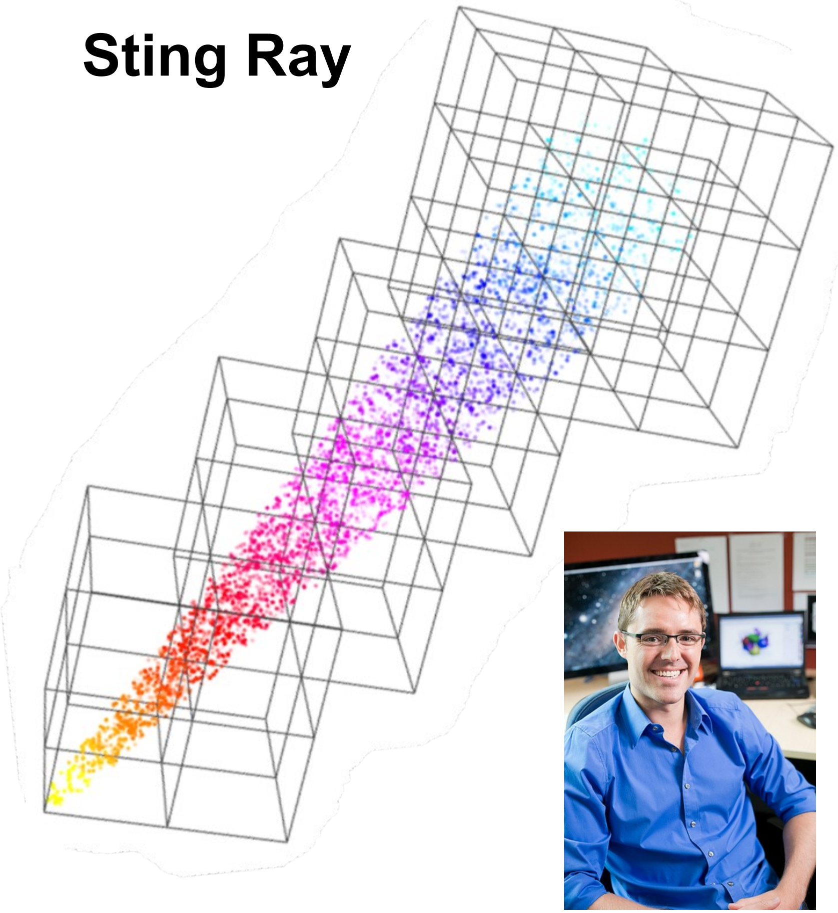
Cool features:

- Dust extinction model based on EAGLE work (Trayford+17, and in prep.)

Features:

- BC03
- Dale+14 IR templates
- Energy balance (ala MAGPHYS)

Sting Ray

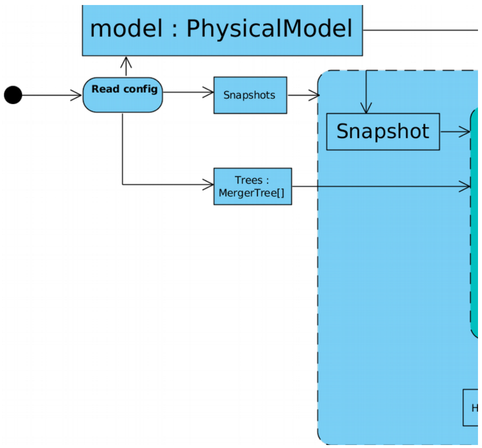


STATUS: In beta testing

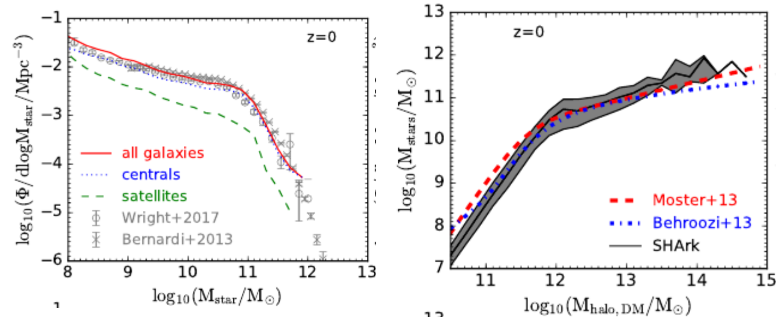
Cool features:

- Lensing (mostly for HI, but generic feature)
- Possible to do halo/subhalo lightcones
- Outputs observed SEDs

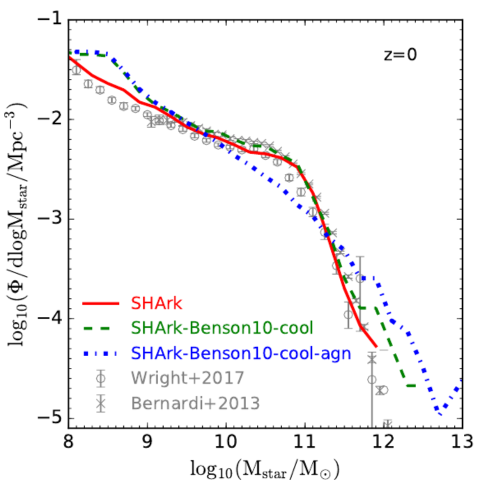
Conclusions and Prospects



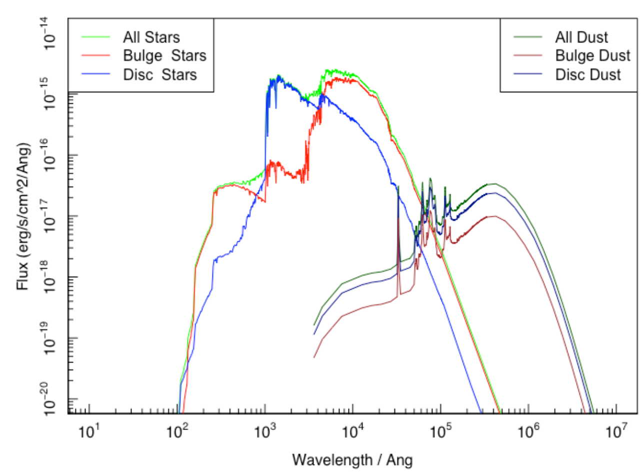
(1) New open source, free semi-analytic model SHARK. Motivation is to provide a **wide range of models/physics** to allow for easy systematic testing of models of all relevant baryonic processes



(2) Very promising preliminary results of optimal models. **Public release of code planned for mid/late 2019.**



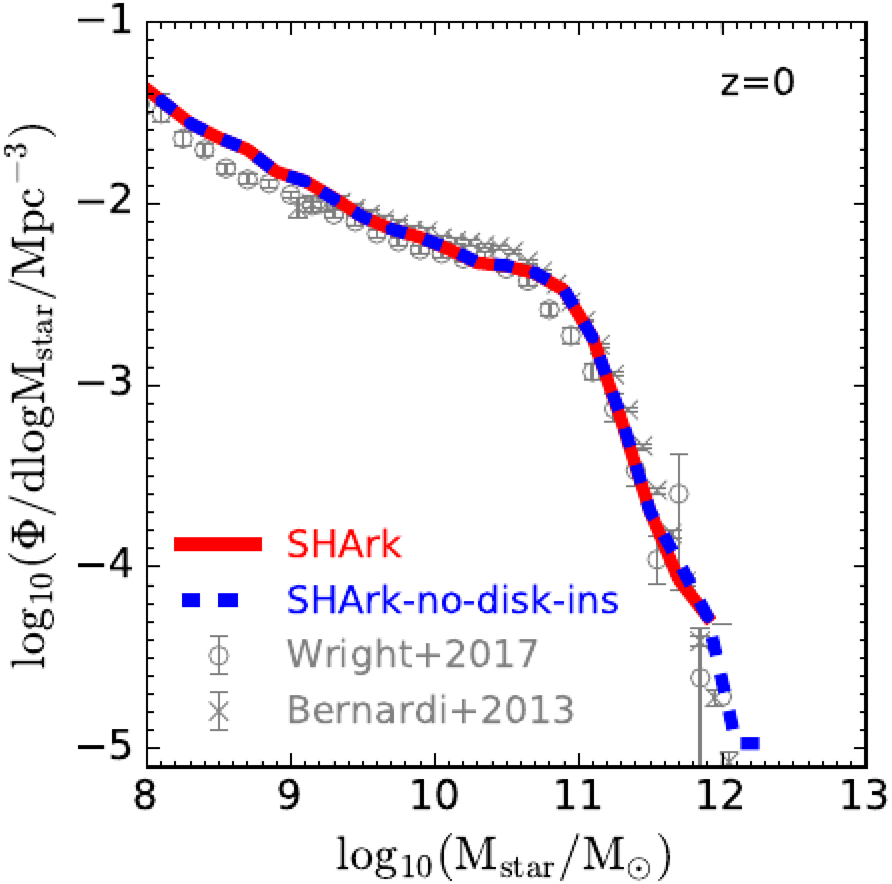
(3) Proven to be very useful for easy testing of key physical processes. This is enabled due to the **numerical integration of all equations**, which allow for arbitrary complexity.

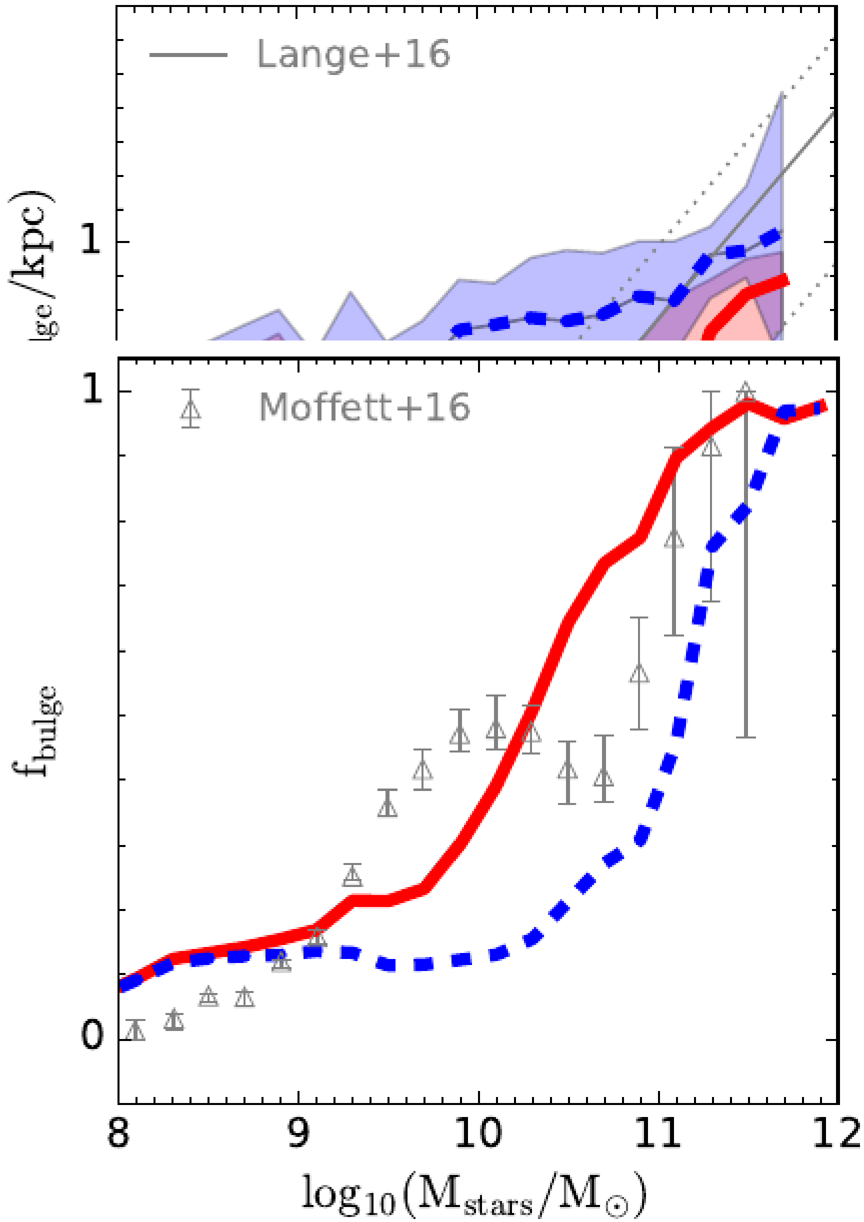


(4) Future: full SEDs and **lightcones for specific surveys** will be constructed (planned: Taipan, DEVILS, WAVES, ASKAP, etc.)

Testing the physics: disk instabilities

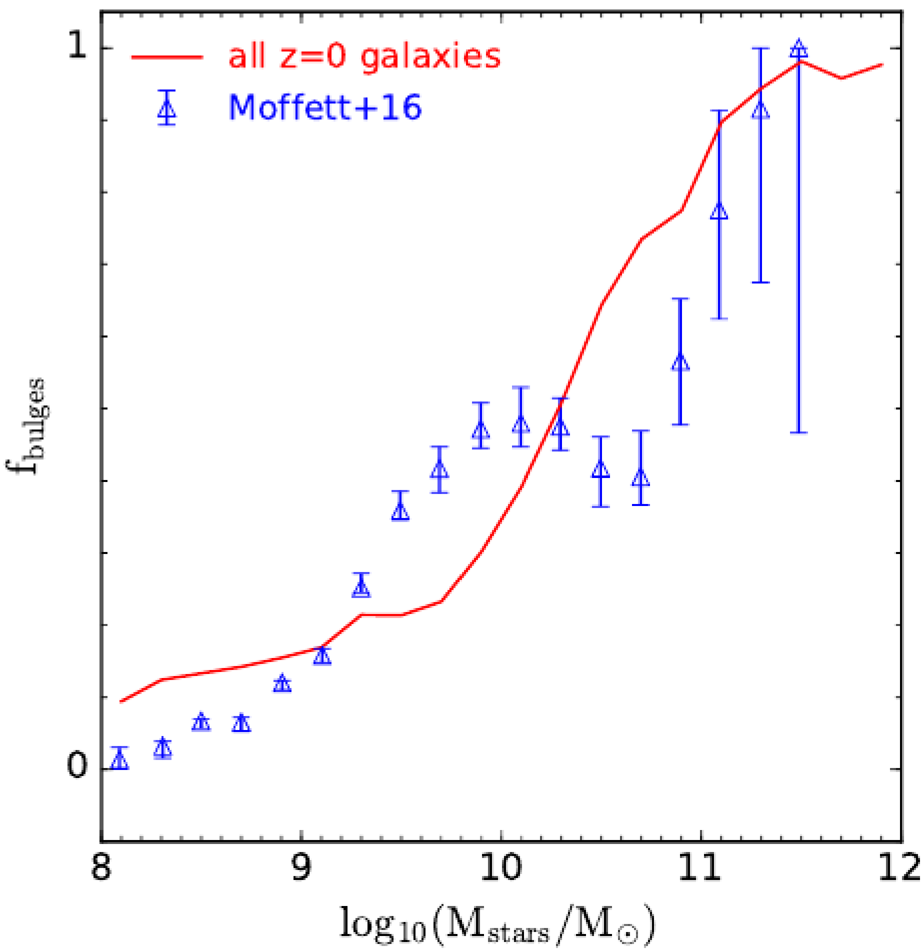
Strongly linked to assumptions in BH seeding and AGN feedback

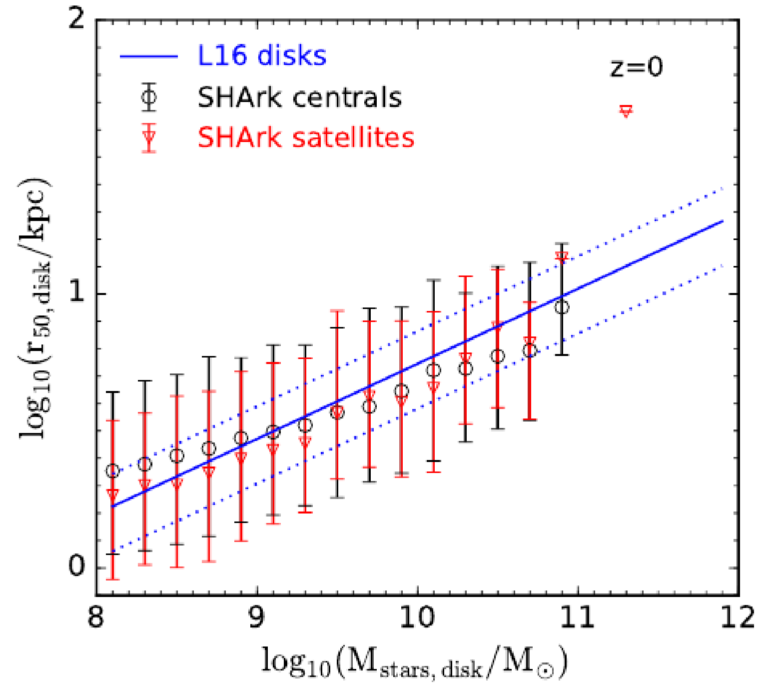


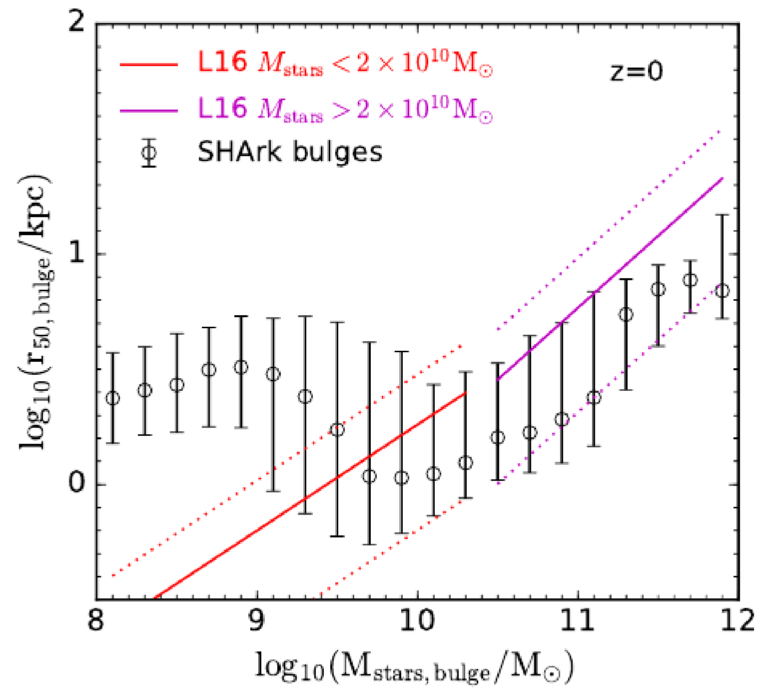


Sizes and bulge-to-total ratios

Lagos et al. (in prep.)

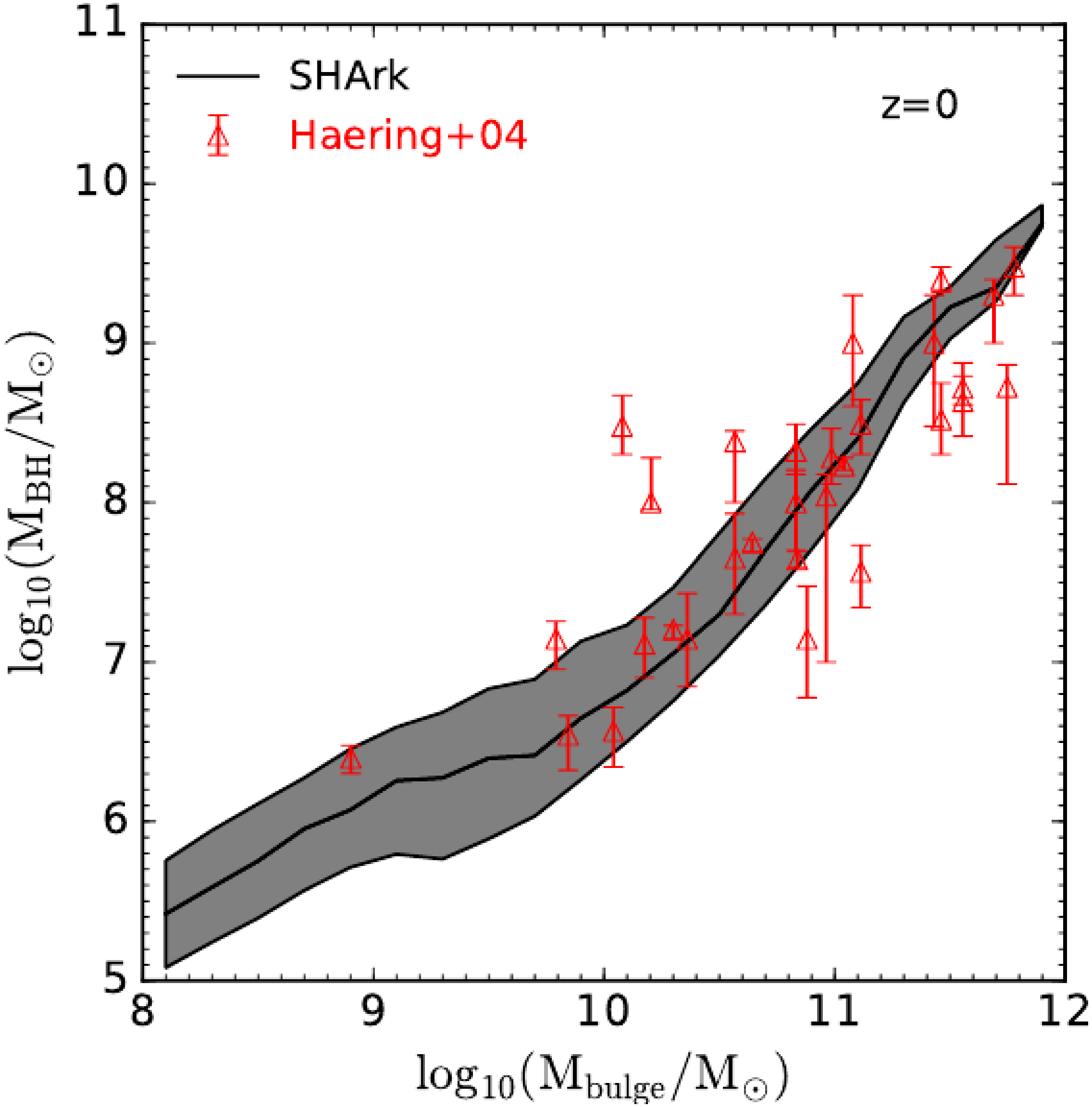






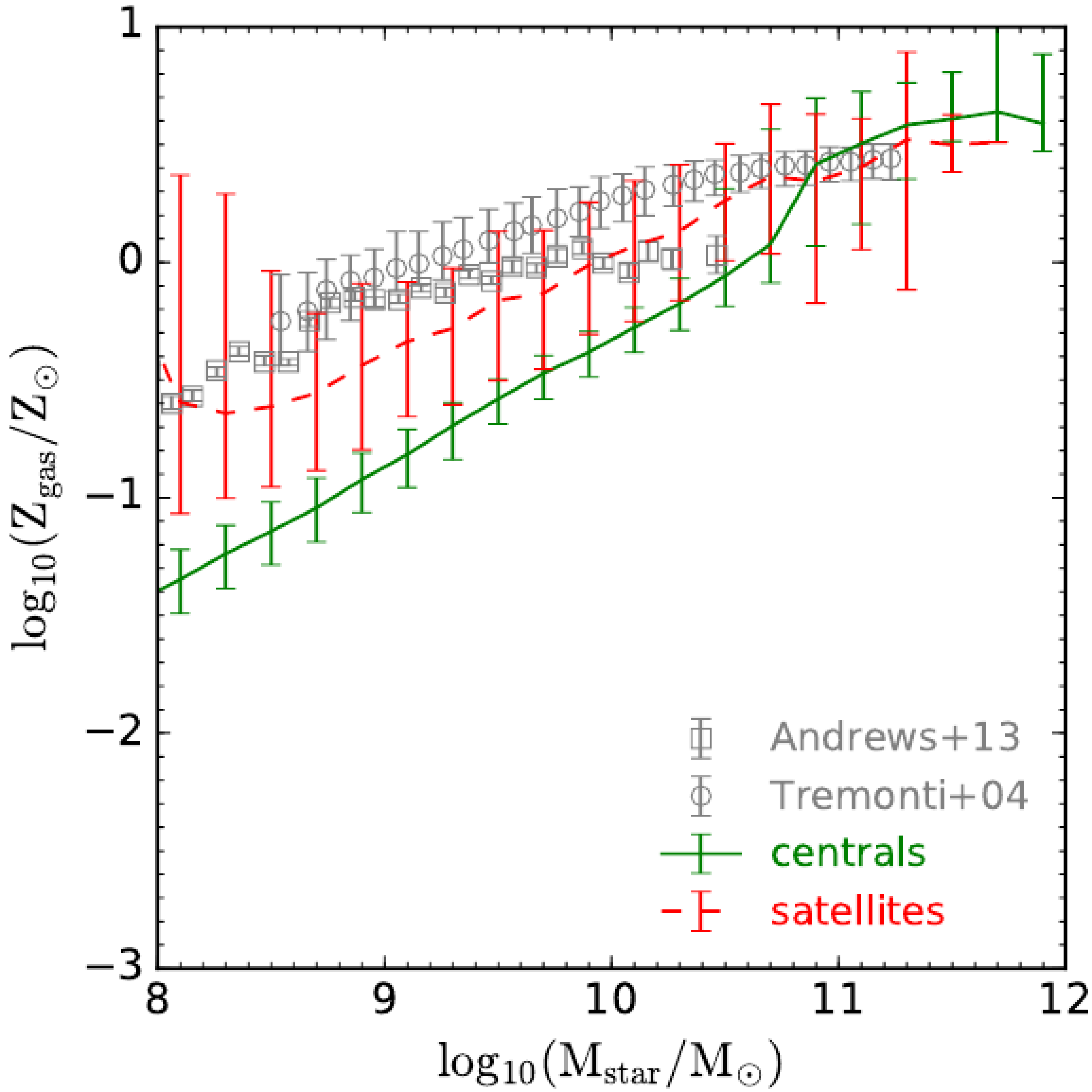
Black holes in SHARK

Lagos et al. (in prep.)



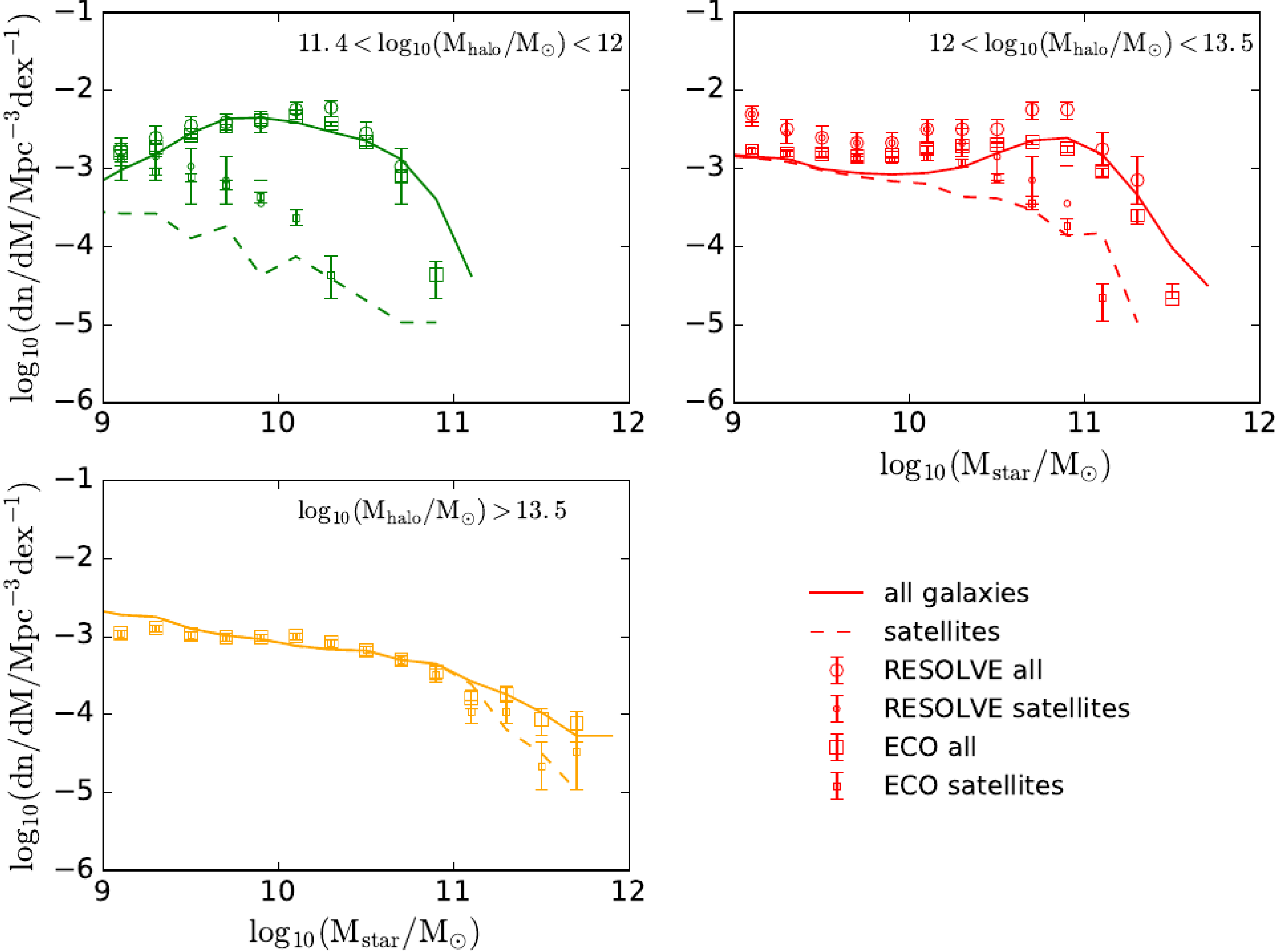
Mass-gas metallicity relation

Lagos et al. (in prep.)



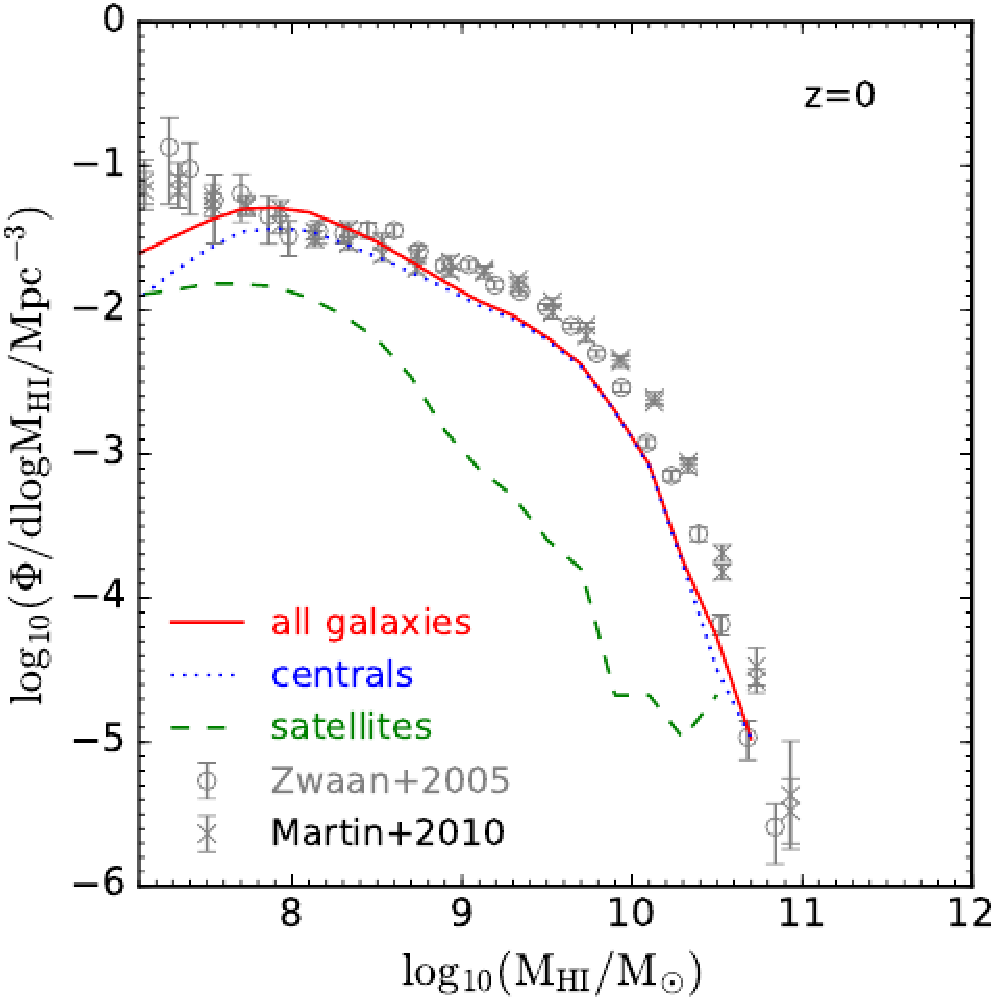
SMF in different environments

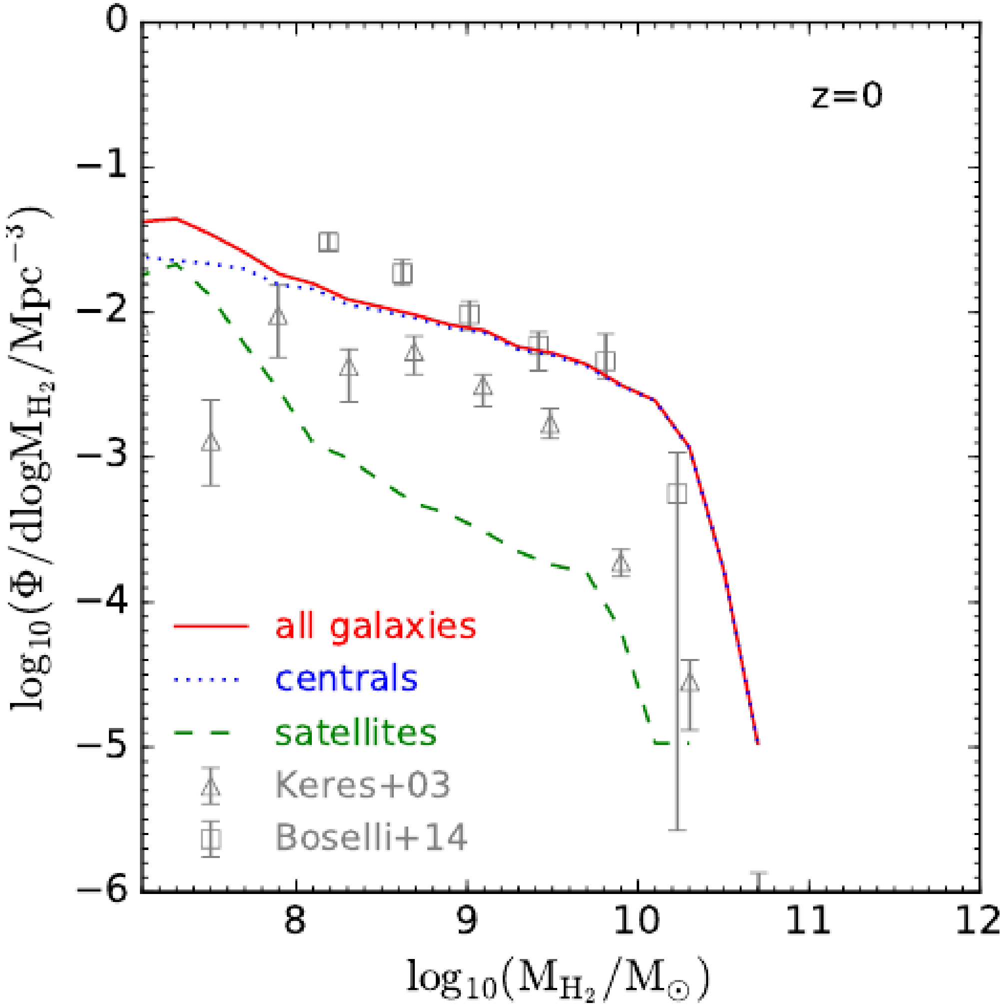
Lagos et al. (in prep.)



Mass functions of ISM content

Lagos et al. (in prep.)





Importance of ISM properties

Collacchioni, Cora, Lagos (submitted to MNRAS): gas metallicity is an important tracer of feedback