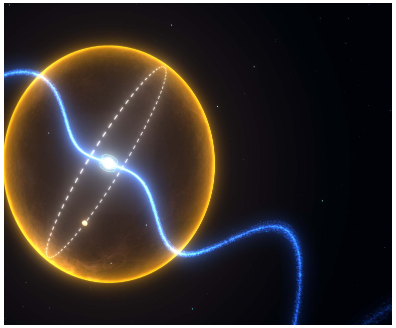
CAASTRO
ARC CENTRE OF EXCELLENCE FOR ALL-SKY ASTROPHYSICS

THE UNIVERSITY OF MELBOURNE

Properties of simulated galaxies at *z*~4-7

Edoardo Tescari

University of Melbourne / CAASTRO
www.caastro.org



CAASTRO
ARC CENTRE OF EXCELLENCE FOR ALL-SKY ASTROPHYSICS

THE ANGUS PROJECT

Project Title: The interplay between galaxies and intergalactic gas at high redshift

Term of Allocation: (e.g. Dec 2012, Jun 2013, etc.): May 2013

Lead Investigator (must be a CAASTRO investigator/staff/student/affiliate):

Name: Edoardo Tescari - CAASTRO postdoctoral fellow in Theoretical Cosmology - School of Physics, The University of Melbourne, Parkville, VIC 3010

Email: edoardo.tescari@unimelb.edu.au

Assigned: **~4M** CPU hours at the NCI Facilities in Canberra

Other investigators in proposal (may be drawn from outside CAASTRO): Antonios Katsianis[1,9], Akila Jeeson-Daniel[1,9], Alan Duffy[1,9], Stuart Wyithe[1,9], Emma Ryan-Weber[2,9], Chris Power[3,9], Ragini Singh[4,9], Brian Schmidt[4,9], James Bolton[5,9], Matteo Viel[6], Paramita Barai[6], Giuseppe Murante[6], Luca Tornatore[6,7], Stefano Borgani[6,7], Alexandro Saro[8], Klaus Dolag[8]

Angus = ***A**ustraliaN **G**ADGET-3 early **U**niverse **S**imulations*

OUR GADGET-3 = P-GADGET3(XXL)

- **Stellar Evolution** & **Chemical Enrichment** modules (extension of the original G3 star formation module)

- Several **supernova driven galactic wind feedback prescriptions** (Barai, Viel, Borgani, Tescari et al. 2013)

- **Improved AGN feedback scheme** (extension of the original Springel et al. 2005 model)

- **Metal line cooling**

- **Low Temperature** (molecular) **cooling**

- **Friends-of-Friends** & **SubFind** on the fly tools

CAASTRO
ARC CENTRE OF EXCELLENCE FOR ALL-SKY ASTROPHYSICS

PUBLICATIONS

Simulated star formation rate functions at $z \sim 4-7$, and the role of feedback in high-z galaxies

E. Tescari[1,6⋆], A. Katsianis[1,6], J. S. B. Wyithe[1,6], K. Dolag[2], L. Tornatore[3,4], P. Barai[3], M. Viel[3,5] and S. Borgani[3,4,5]

MNRAS submitted

+

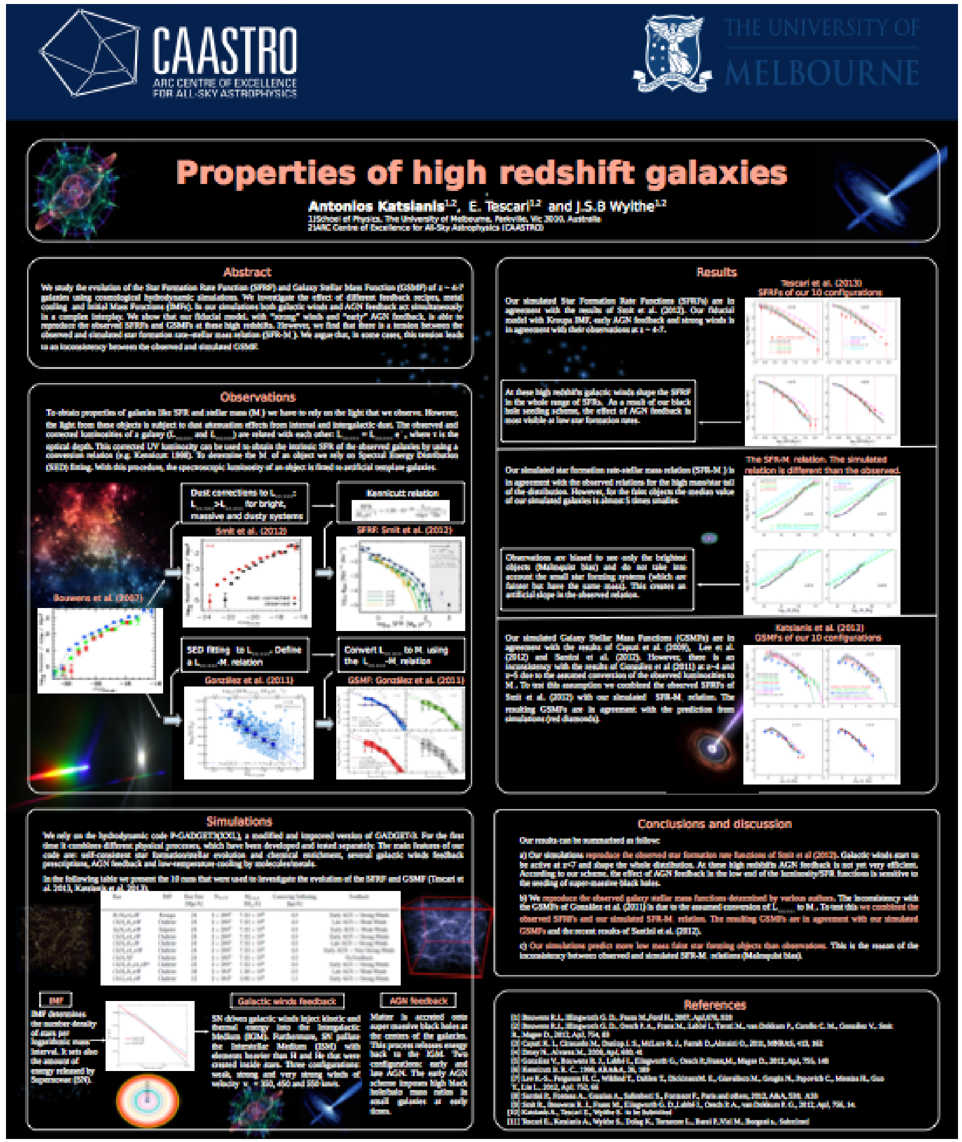
Simulated high-z galaxies: stellar mass function and star formation rate−stellar mass relation at $z \sim 4-7$

A. Katsianis[1,2⋆], E. Tescari[1,2] and J. S. B. Wyithe[1,2]

To be submitted...

CAASTRO
ARC CENTRE OF EXCELLENCE FOR ALL-SKY ASTROPHYSICS

POSTER #7



SET OF SIMULATIONS

Run	IMF	Box Size [Mpc/h]	N_{TOT}	M_{GAS} [$M_{\odot}/h$]	Comoving Softening [kpc/h]	Feedback
Kr24_eA_sW	Kroupa	24	2×288^3	7.32×10^6	4.0	Early AGN + Strong Winds
Ch24_lA_wW	Chabrier	24	2×288^3	7.32×10^6	4.0	Late AGN + Weak Winds
Sa24_eA_wW	Salpeter	24	2×288^3	7.32×10^6	4.0	Early AGN + Weak Winds
Ch24_eA_sW	Chabrier	24	2×288^3	7.32×10^6	4.0	Early AGN + Strong Winds
Ch24_lA_sW	Chabrier	24	2×288^3	7.32×10^6	4.0	Late AGN + Strong Winds
Ch24_eA_vsW	Chabrier	24	2×288^3	7.32×10^6	4.0	Early AGN + Very Strong Winds
Ch24_NF	Chabrier	24	2×288^3	7.32×10^6	4.0	No Feedback
Ch24_Zc_eA_sW[a]	Chabrier	24	2×288^3	7.32×10^6	4.0	Early AGN + Strong Winds
Ch18_lA_wW	Chabrier	18	2×384^3	1.30×10^6	2.0	Late AGN + Weak Winds
Ch12_eA_sW	Chabrier	12	2×384^3	3.86×10^5	1.5	Early AGN + Strong Winds

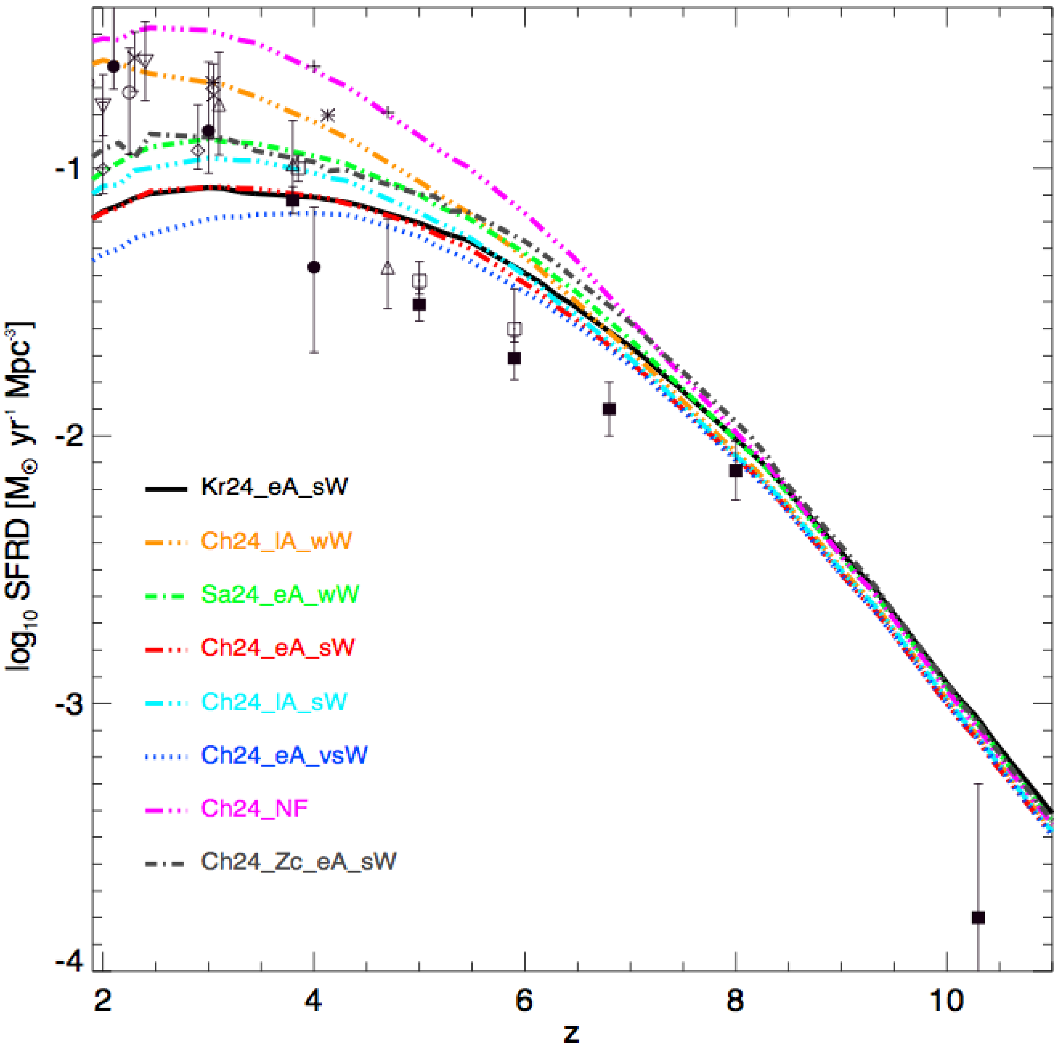
Table 2. Summary of the different runs used in this work. Column 1, run name; column 2, Initial Mass Function (IMF) chosen; column 3, box size in comoving Mpc/h; column 4, total number of particles ($N_{TOT} = N_{GAS} + N_{DM}$); column 5, initial mass of the gas particles; column 6, comoving softening length; column 7, type of feedback implemented. See Section 2.4 for more details on the parameters used for the different feedback recipes. (a): in this simulation the effect of metal cooling is included (see Section 2.2).

Wind velocity = 350 km/s (wW), 450 km/s (sW) and 550 km/s (vsW)

AGN feedback in two configurations = BHs seeded ± aggressively ("eA" and "lA")

Tescari et al. (2013) + Katsianis, Tescari & Wyithe (2013)

COSMIC SFRD: SIMS Vs OBS



Box Size = 24 Mpc/h (com)

Number of part. = 2×288^3

Spatial res = 4 kpc/h (com)

$M_{GAS} = 7.32 \times 10^6 M_{sun}/h$

Wind velocity = 350 km/s (wW), 450 km/s (sW) and 550 km/s (vsW)

AGN feedback in two configurations = BHs seeded ± aggressively ("eA" and "lA")

3 IMFs (Chabrier, Kroupa and Salpeter) & Metal cooling

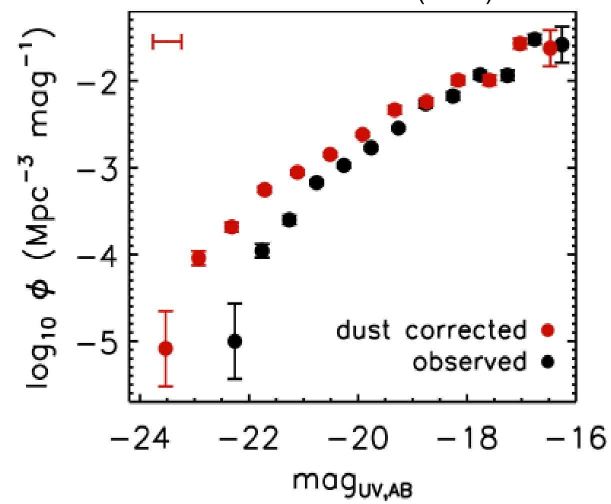
Tescari et al. (2013)

SFR FUNCTIONS: OBS

Smit, Bouwens et al. (2012):

1) Stepwise conversion: $\frac{\mathrm{SFR}}{M_\odot \mathrm{yr}^{-1}} = 1.25 \cdot 10^{-28} \frac{L_{\mathrm{UV,corr}}}{\mathrm{erg\,s^{-1}Hz^{-1}}}.$

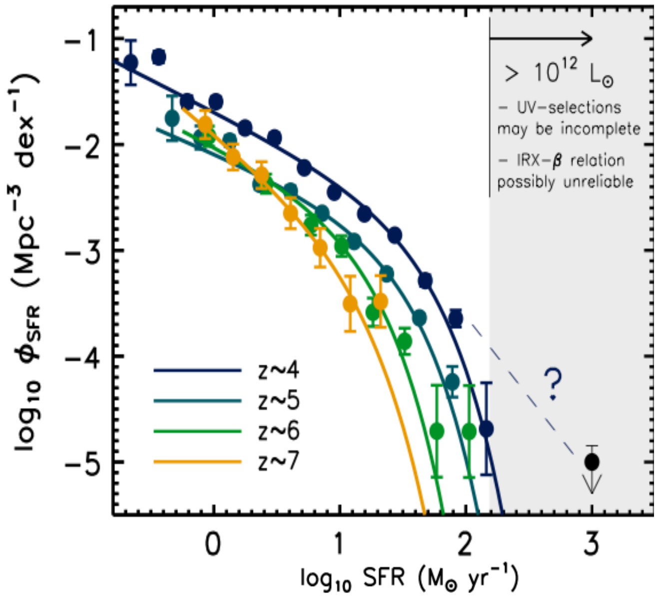
2) Schechter LF: $\phi(L)\,dL = \phi^* \left(\frac{L}{L^*}\right)^\alpha \exp\left(-\frac{L}{L^*}\right) \frac{dL}{L^*}.$



$$\phi(\mathrm{SFR})\,d\mathrm{SFR} = \frac{\phi^*}{1 - C_1 \frac{d\beta}{dM}} \left(\frac{\mathrm{SFR}}{\mathrm{SFR}^*}\right)^{\frac{\alpha + C_1 \frac{d\beta}{dM}}{1 - C_1 \frac{d\beta}{dM}}} \times \exp\left(-\frac{\mathrm{SFR}}{\mathrm{SFR}^*}\right) \frac{d\mathrm{SFR}}{\mathrm{SFR}^*}.$$

$$\alpha_{\mathrm{SFR}} = \frac{\alpha_{\mathrm{UV,uncorr}} + C_1 \frac{d\beta}{dM}}{1 - C_1 \frac{d\beta}{dM}}$$

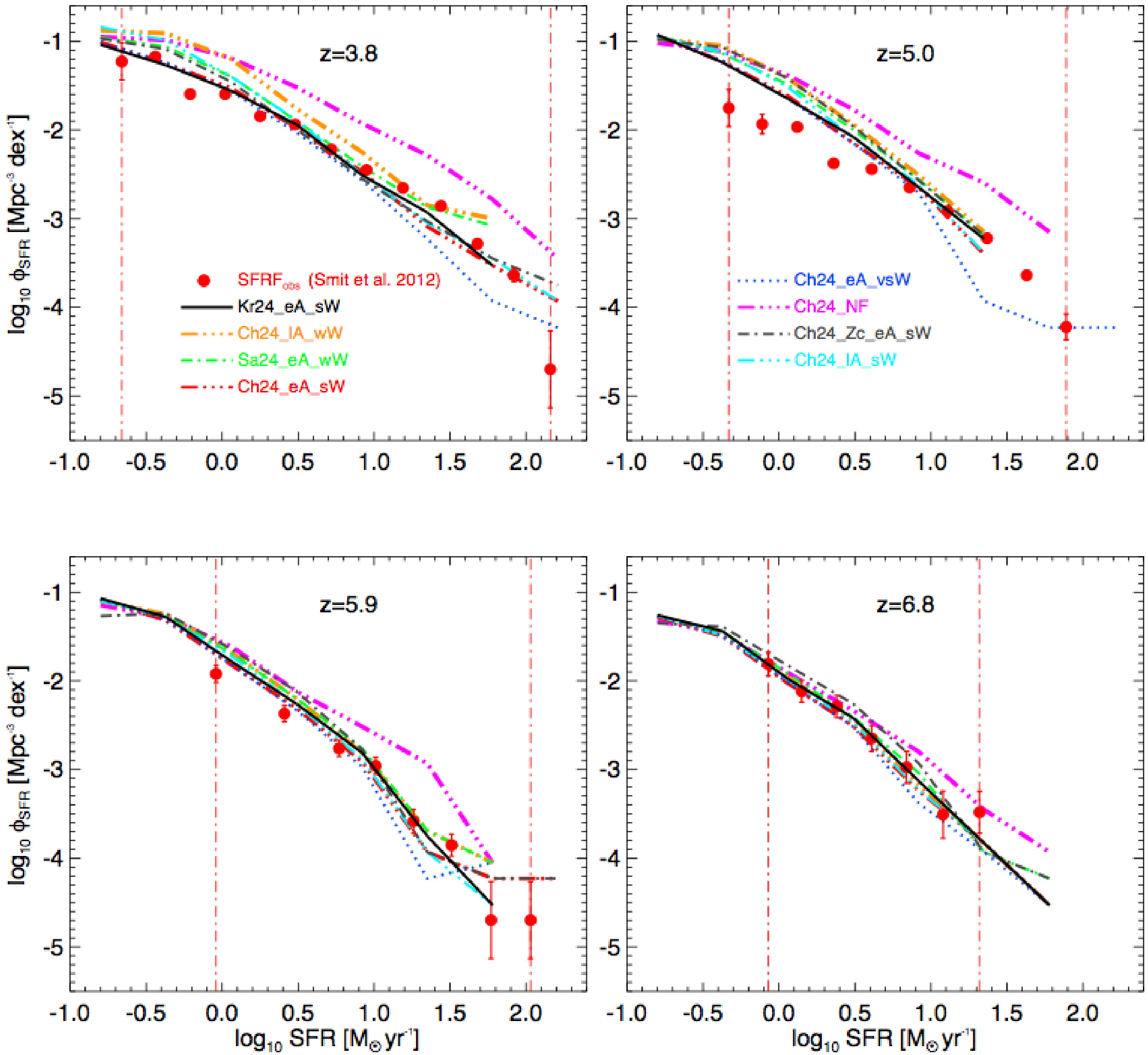
$$\phi^*_{\mathrm{SFR}} = \frac{\phi^*_{\mathrm{UV,uncorr}}}{1 - C_1 \frac{d\beta}{dM}}.$$



SFR FUNCTIONS: SIMS

Observations:

Smit et al. (2012)

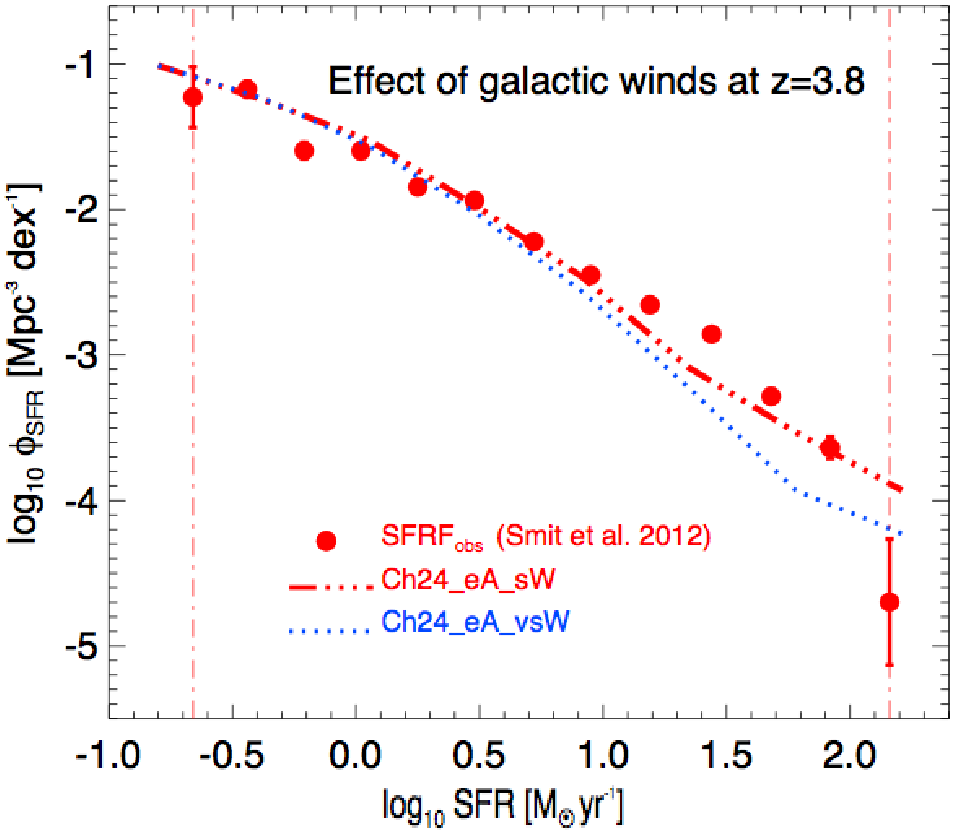


Tescari et al. (2013)

SFR FUNCTIONS: SIMS

Observations:

Smit et al. (2012)

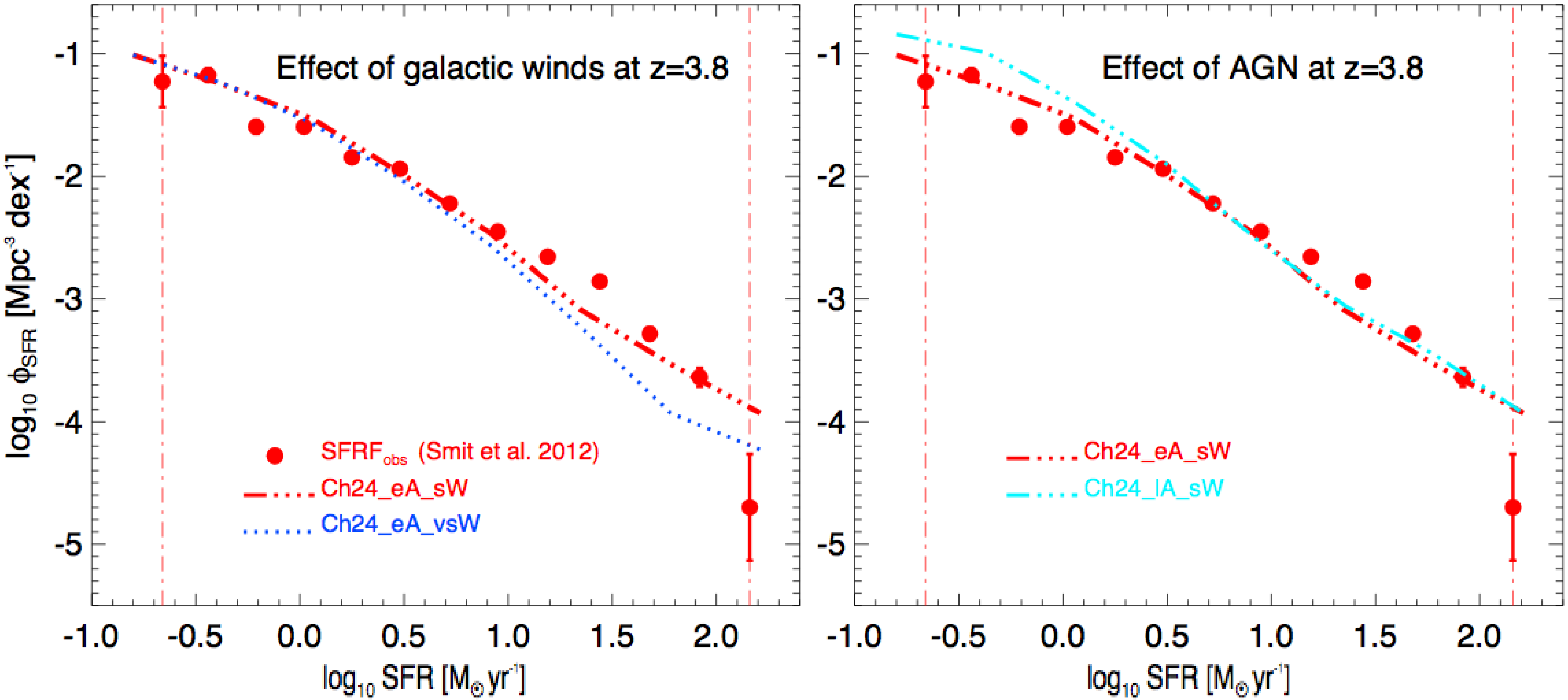


Tescari et al. (2013)

SFR FUNCTIONS: SIMS

Observations:

Smit et al. (2012)



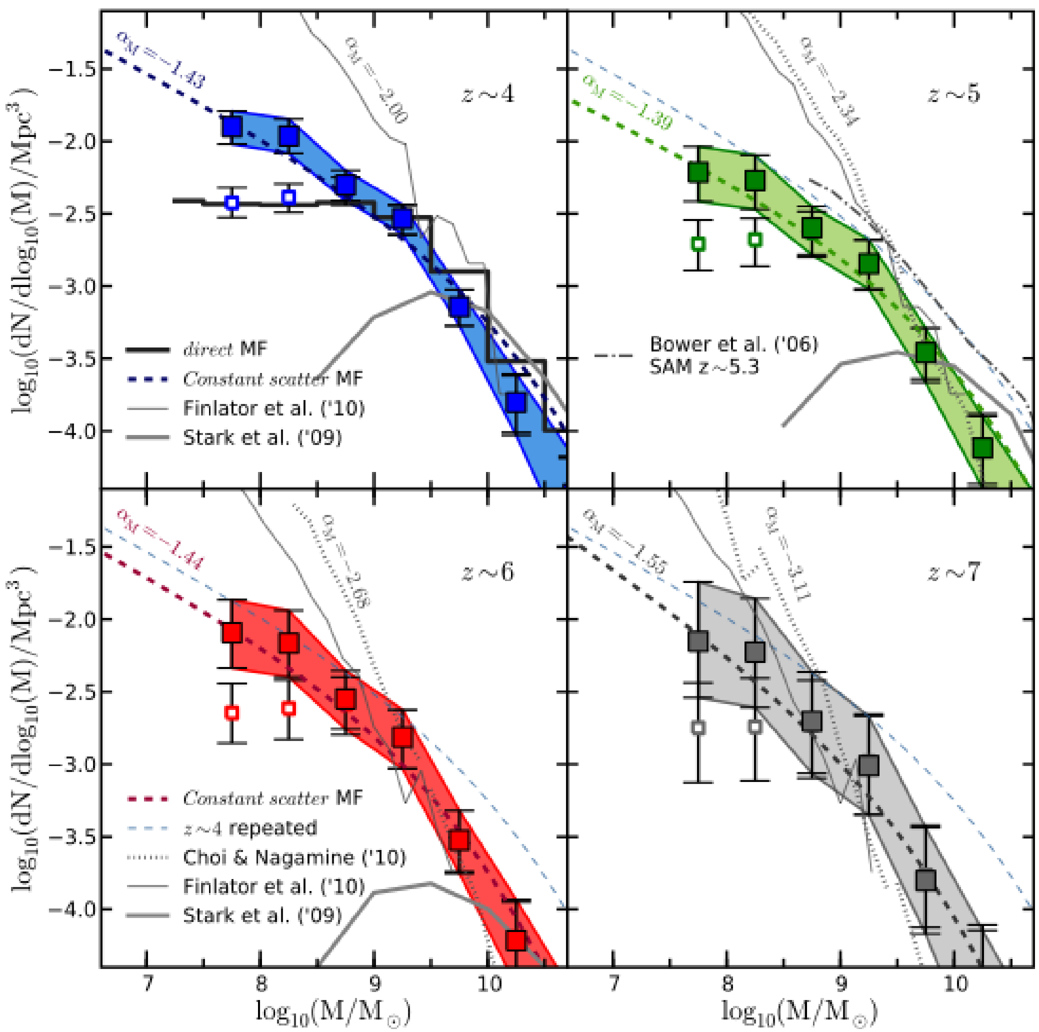
Tescari et al. (2013)

STELLAR MASS FUNCTIONS

Observations:

UV

González et al. (2011)

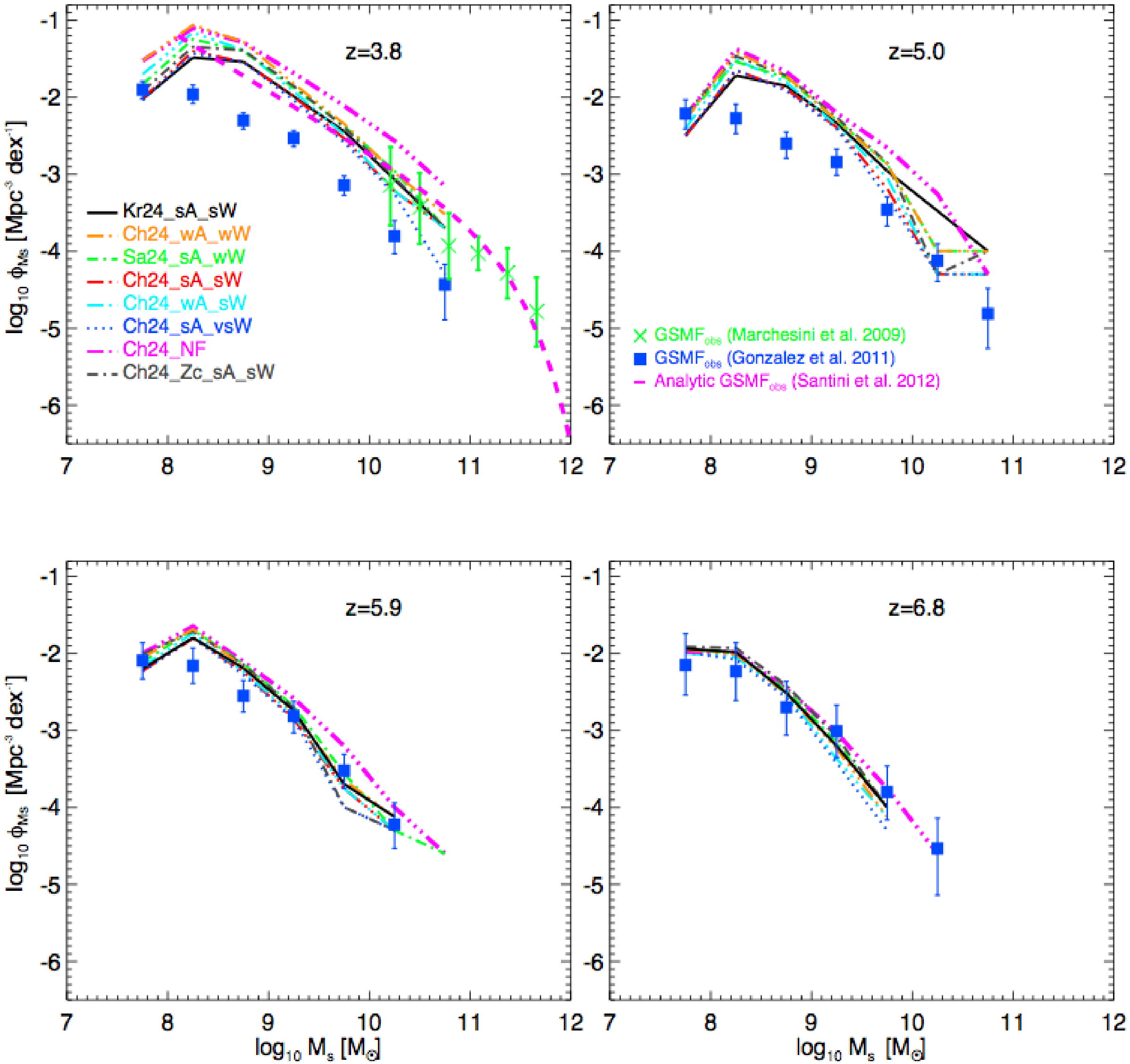


STELLAR MASS FUNCTIONS

Observations:

UV
González et al. (2011)

IR
Santini et al. (2012)
Marchesini et al. (2009)



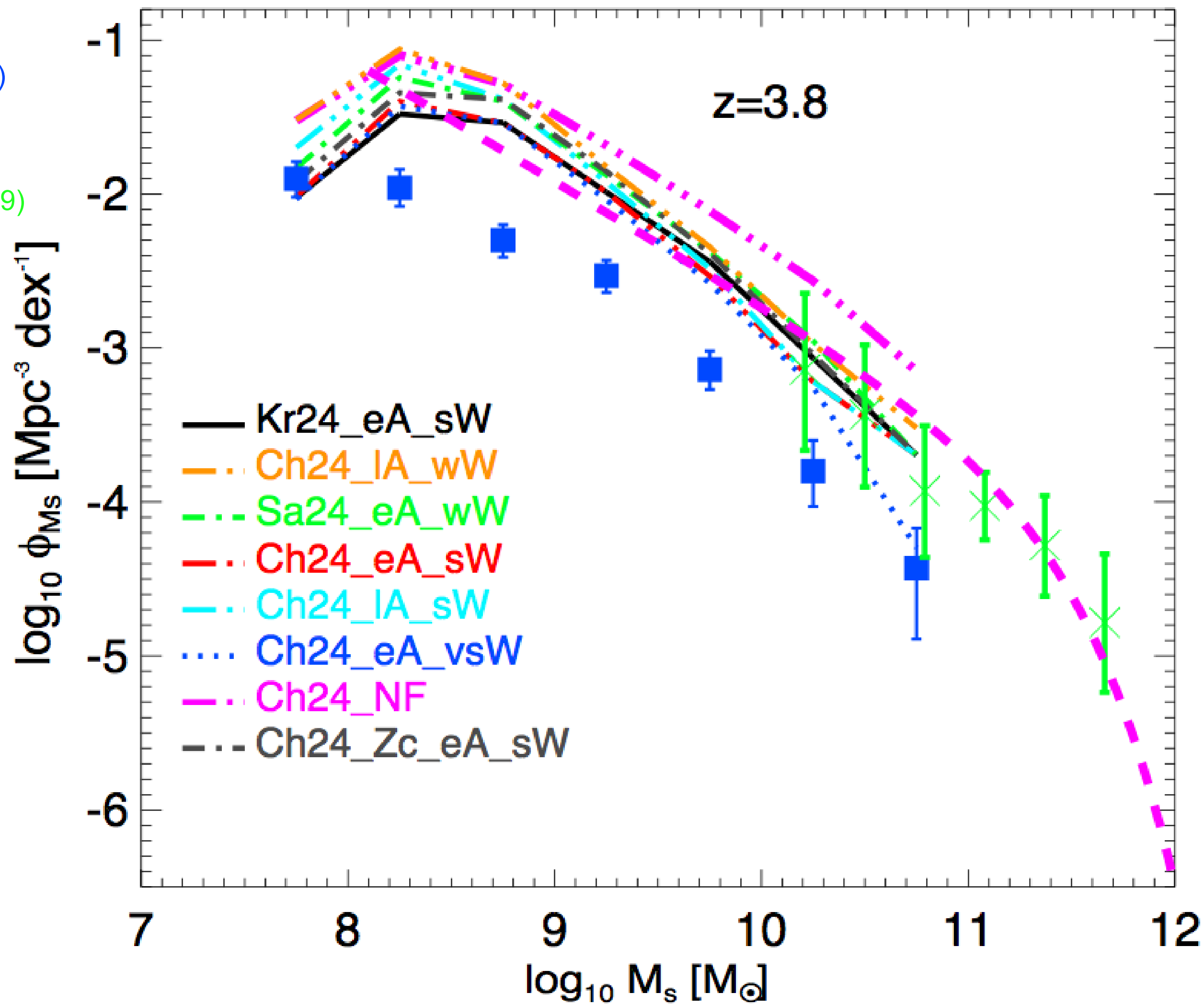
Katsianis, Tescari & Wyithe (2013)

STELLAR MASS FUNCTIONS

Observations:

UV
González et al. (2011)

IR
Santini et al. (2012)
Marchesini et al. (2009)



Katsianis, Tescari & Wyithe (2013)

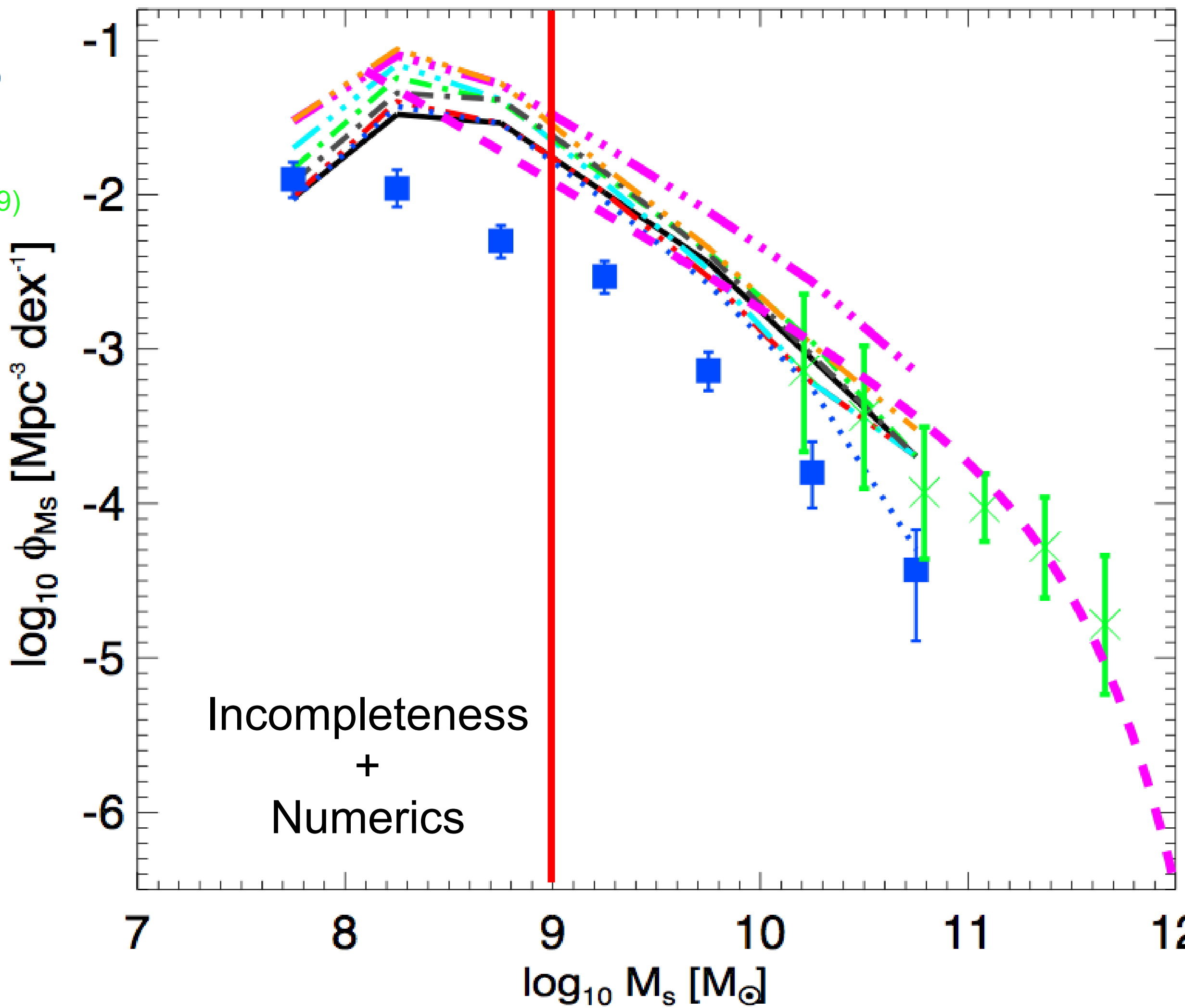
STELLAR MASS FUNCTIONS

CAASTRO
ARC CENTRE OF EXCELLENCE FOR ALL-SKY ASTROPHYSICS

Observations:

UV
González et al. (2011)

IR
Santini et al. (2012)
Marchesini et al. (2009)



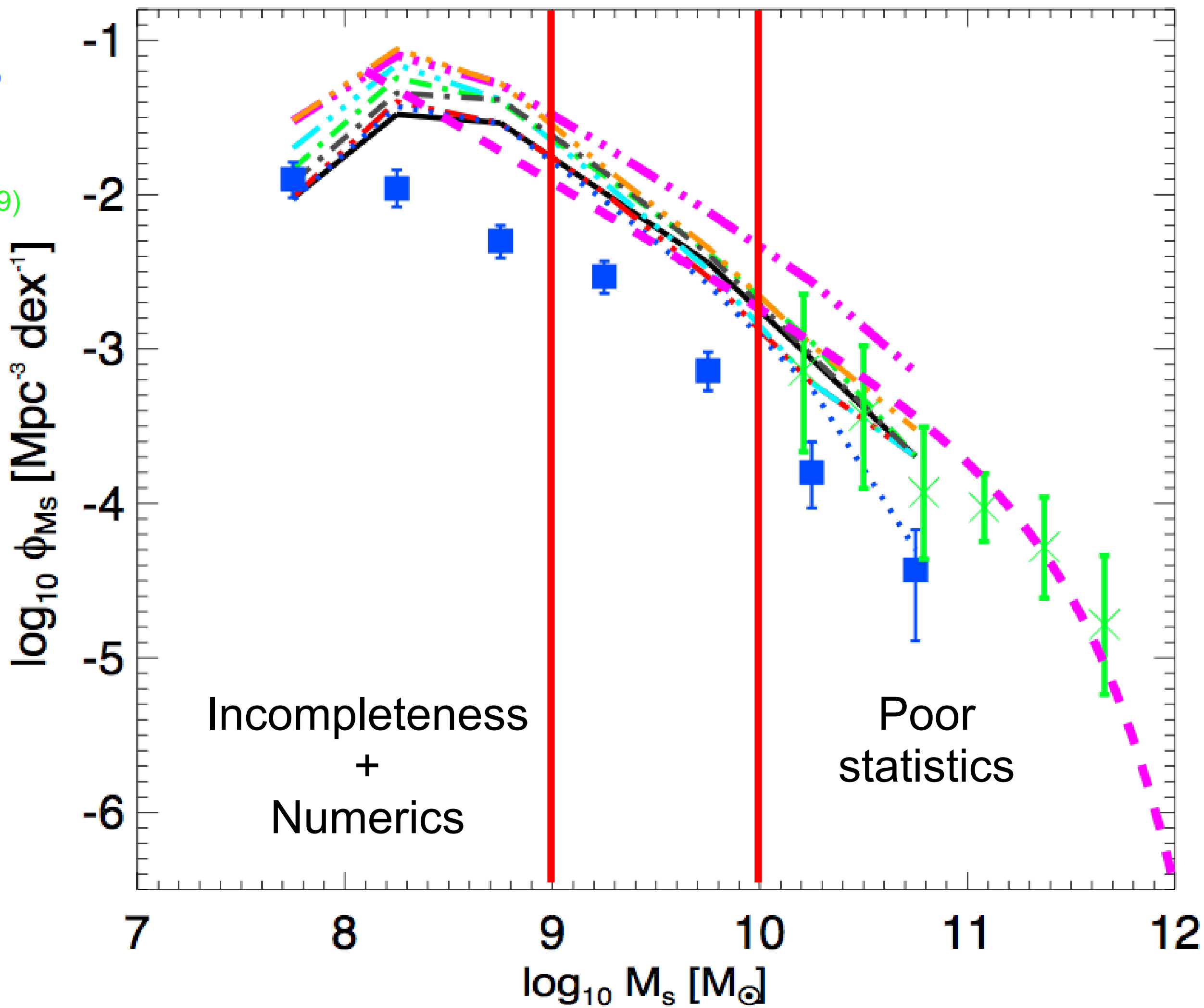
Katsianis, Tescari & Wyithe (2013)

STELLAR MASS FUNCTIONS

Observations:

UV
González et al. (2011)

IR
Santini et al. (2012)
Marchesini et al. (2009)



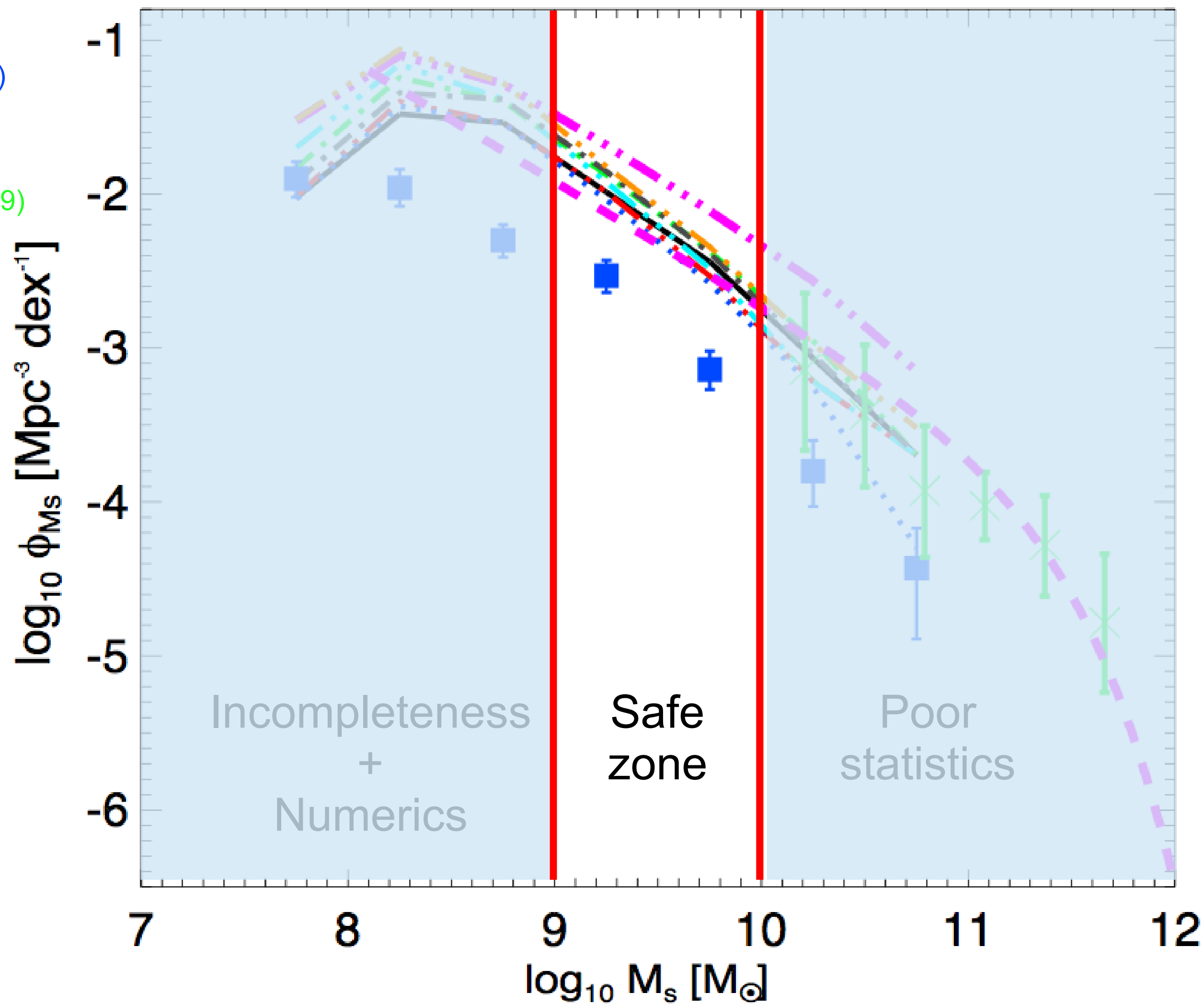
Katsianis, Tescari & Wyithe (2013)

STELLAR MASS FUNCTIONS

Observations:

UV
González et al. (2011)

IR
Santini et al. (2012)
Marchesini et al. (2009)



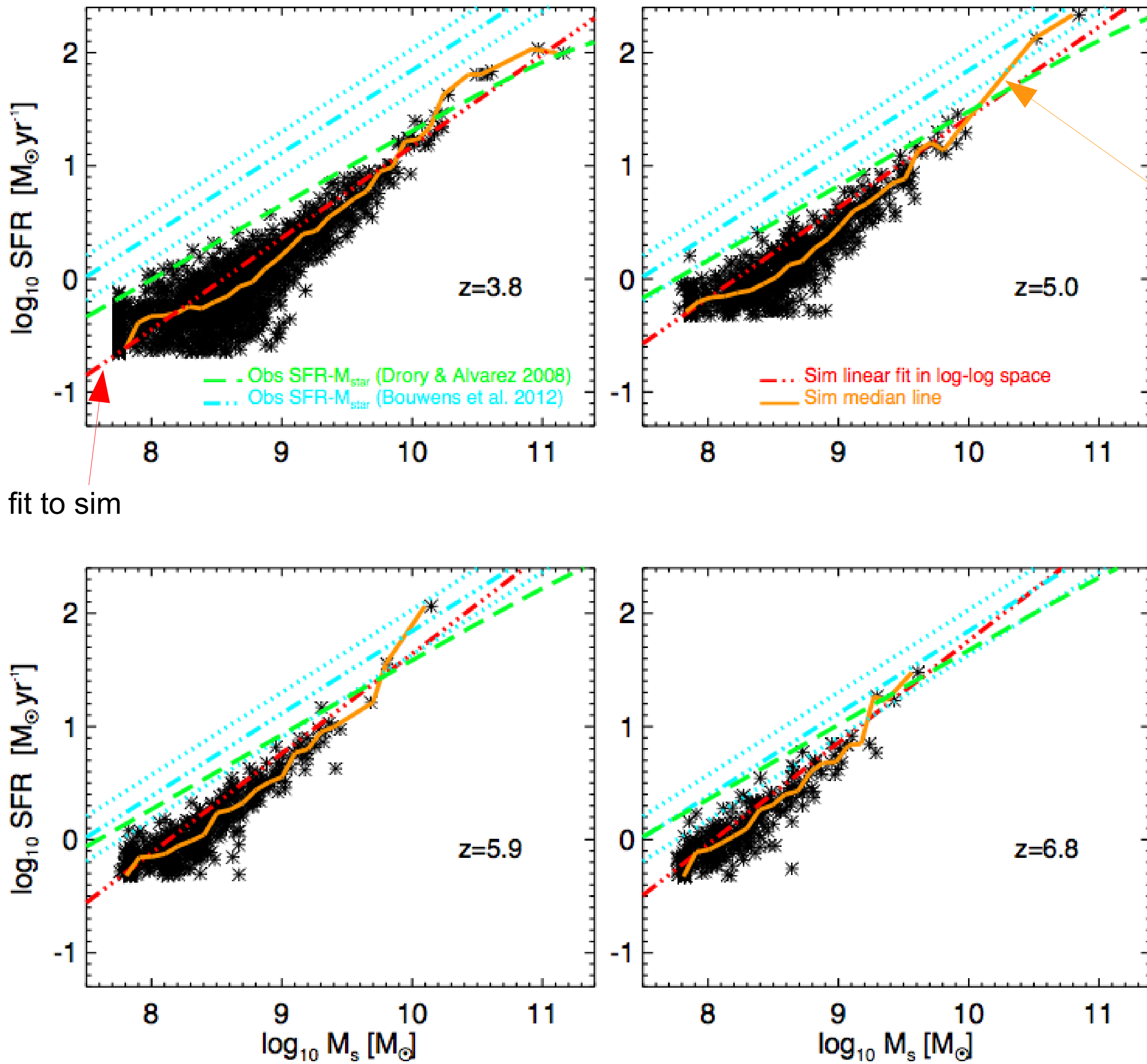
Katsianis, Tescari & Wyithe (2013)

SFR-STELLAR MASS RELATION

Observations:

UV
Bouwens et al. (2012)

IR
Drory & Alvarez (2008)



Sim median value

Linear (log-log) fit to sim

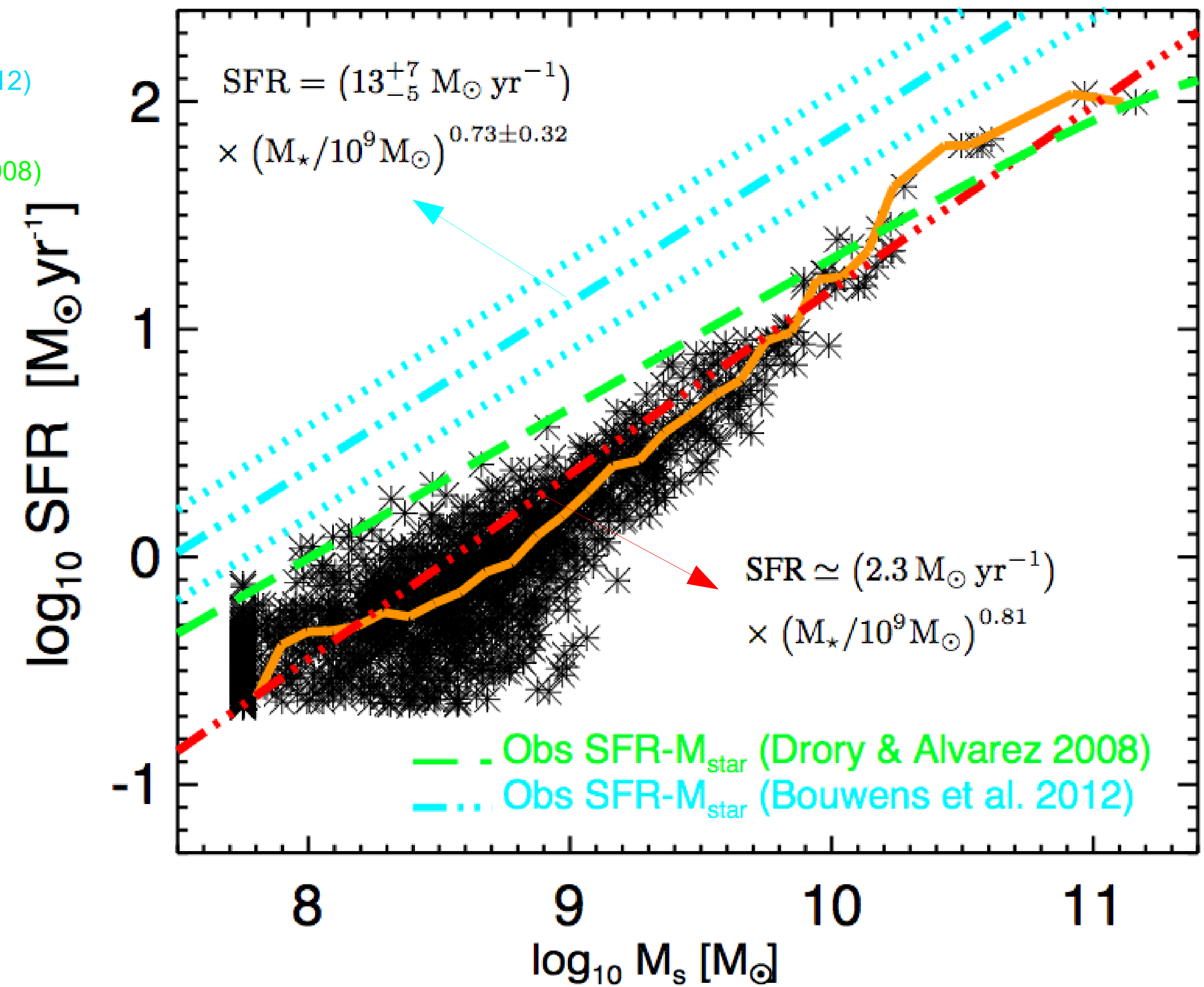
Katsianis, Tescari & Wyithe (2013)

SFR-STELLAR MASS RELATION

Observations:

UV
Bouwens et al. (2012)

IR
Drory & Alvarez (2008)



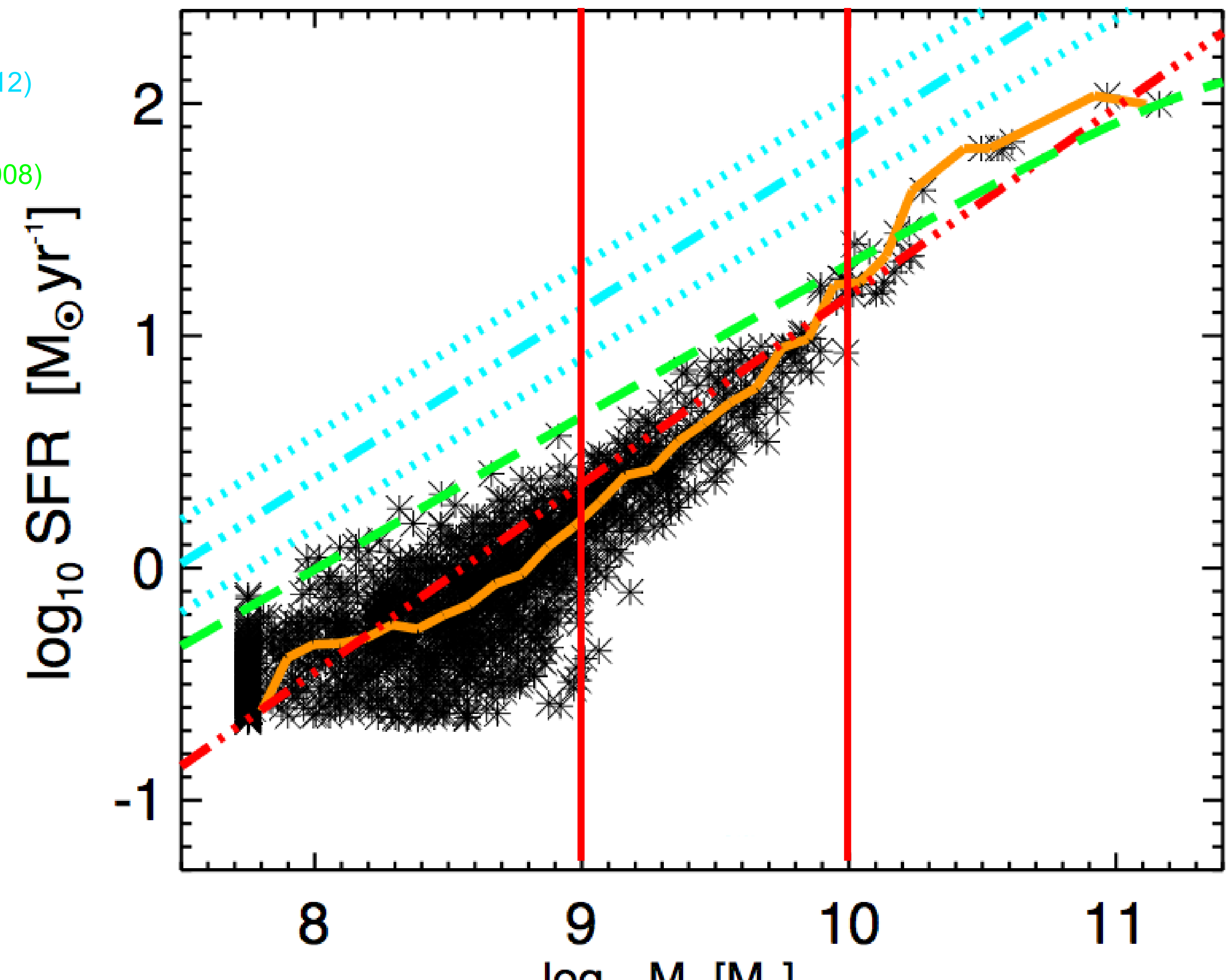
Katsianis, Tescari & Wyithe (2013)

SFR-STELLAR MASS RELATION

Observations:

UV
Bouwens et al. (2012)

IR
Drory & Alvarez (2008)



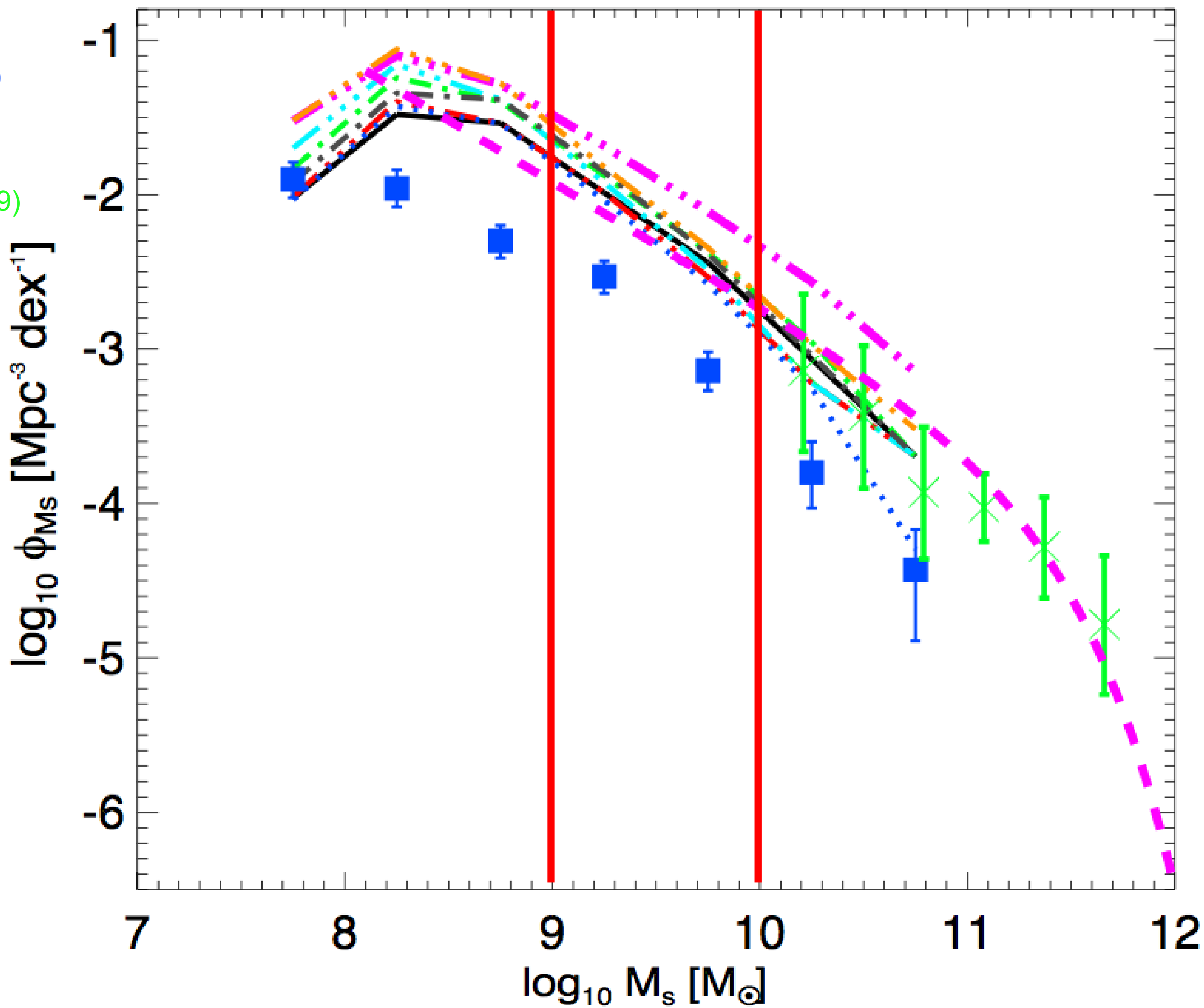
Katsianis, Tescari & Wyithe (2013)

STELLAR MASS FUNCTIONS

Observations:

UV
González et al. (2011)

IR
Santini et al. (2012)
Marchesini et al. (2009)



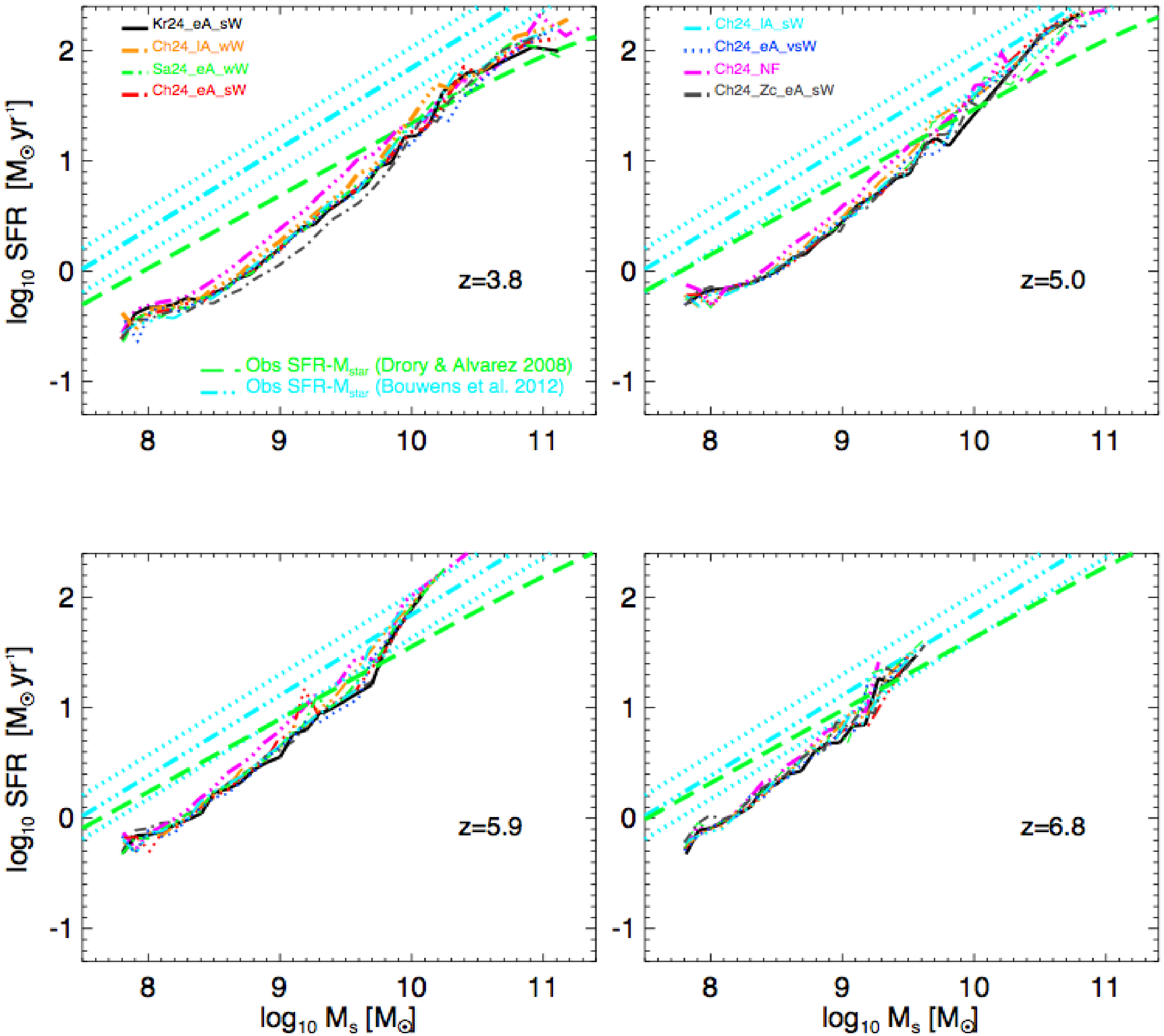
Katsianis, Tescari & Wyithe (2013)

SFR-STELLAR MASS RELATION

Observations:

UV
Bouwens et al. (2012)

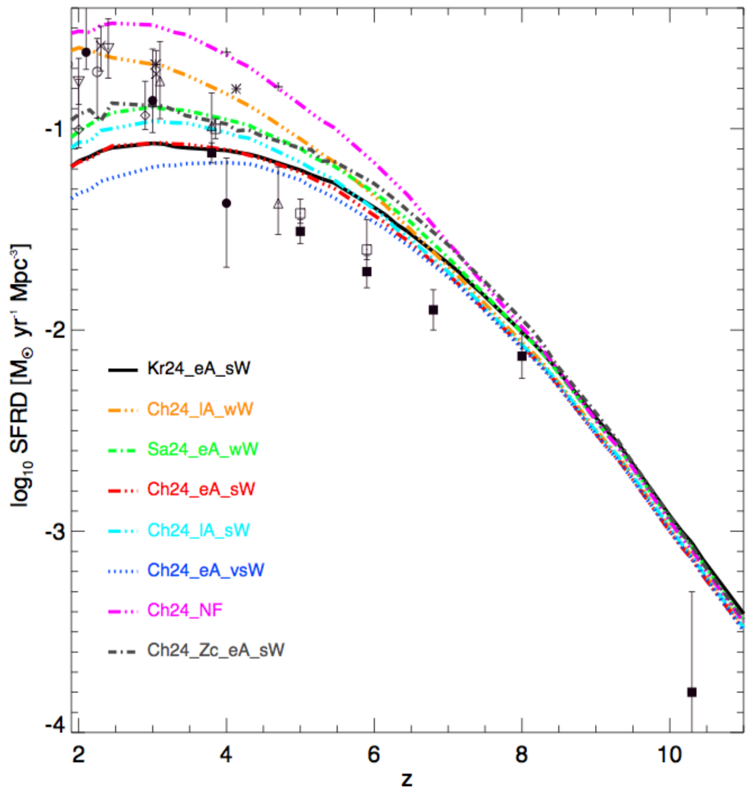
IR
Drory & Alvarez (2008)



Katsianis, Tescari & Wyithe (2013)

SUMMARY

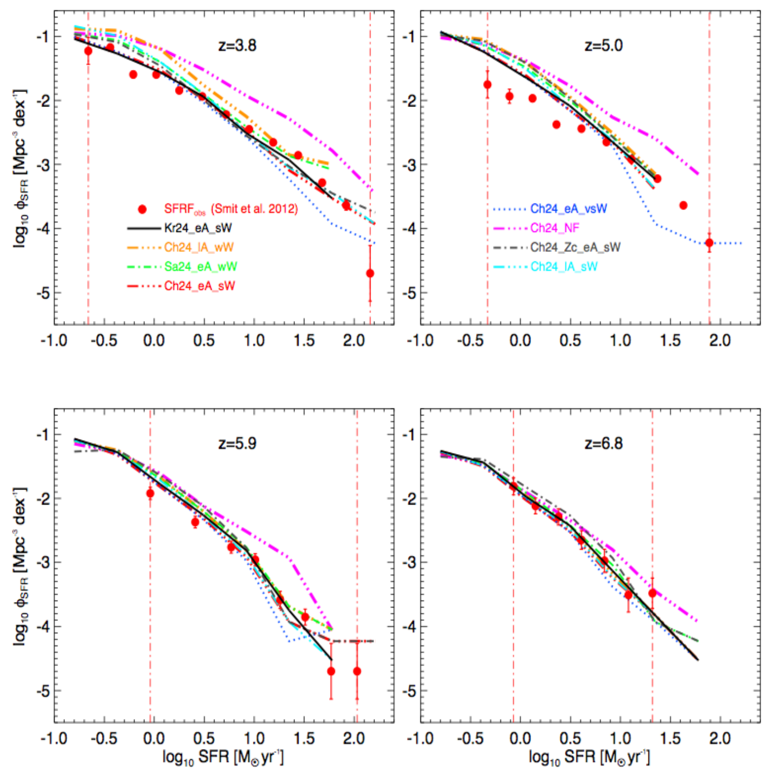
- We reproduce the evolution of the total SFRD.



CAASTRO
ARC CENTRE OF EXCELLENCE FOR ALL-SKY ASTROPHYSICS

SUMMARY

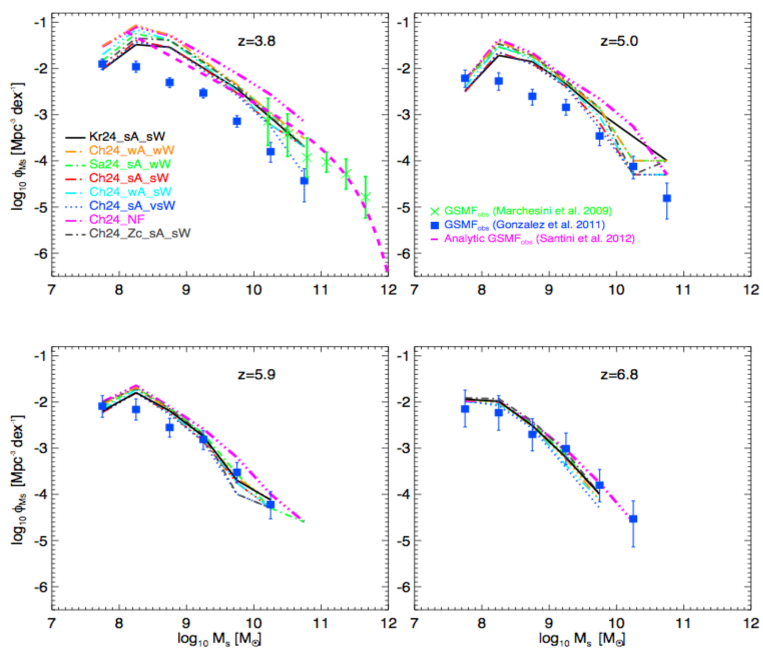
- We reproduce the evolution of the total SFRD.
- We reproduce the evolution of SFRFs.



CAASTRO
ARC CENTRE OF EXCELLENCE FOR ALL-SKY ASTROPHYSICS

SUMMARY

- We reproduce the evolution of the total SFRD.
- We reproduce the evolution of SFRFs.
- We overproduce the UV GSMFs at $z < 5$.

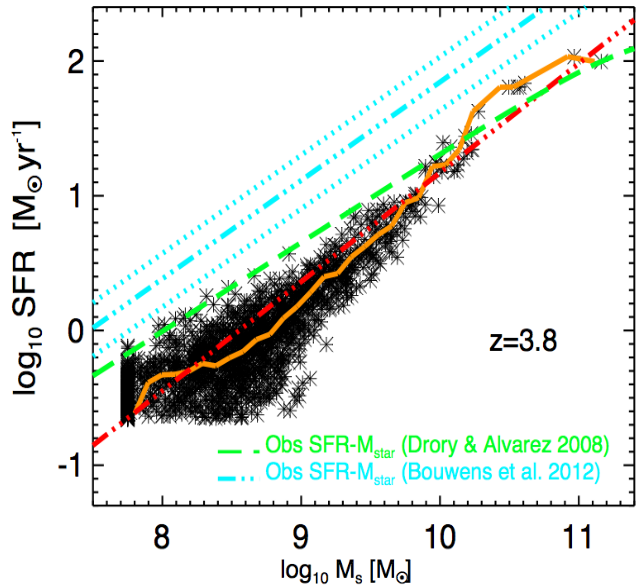


SUMMARY

- We reproduce the evolution of the total SFRD.
- We reproduce the evolution of SFRFs.
- We overproduce the UV GSMFs at $z < 5$.

Tension between simulated and observed GSMFs
→ **different SFR-stellar mass relations**

SUMMARY



Tension between simulated and observed GSMFs
→ different SFR-stellar mass relations

Sims predict a whole population of faint galaxies not seen by current obs

CONCLUSIONS AND…

- Feedback effects (SN driven winds) in place at $z\sim7$.

- Efficient feedback (strong galactic winds + early AGN) needed to reproduce observed SFRFs at high redshift (and especially at $z\sim4$).

- IMF has a minor impact on the SFRFs and GSMFs.

- Metal cooling increases the number of objects with low and intermediate SFRs.

...FUTURE

- Extension to lower redshift to test further the interplay between galactic winds & AGN feedback.
- LAEs at z ~ 3: ANGUS + CRASHα, in collaboration with Akila Jeeson-Daniel (UoM).
- Quasar transverse proximity effect: produced ~270 CLOUDY tables + high res sims.
- CIV absorption systems at z > 4. Clustering of metals Vs LBGs (with Emma Ryan-Weber).