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ARC CENTRE OF EXCELLENCE
FOR ALL-SKY ASTROPHYSICS

THE UNIVERSITY OF
MELBOURNE

Cosmological Simulations with GADGET-3: Update

Edoardo Tescari

University of Melbourne / CAASTRO

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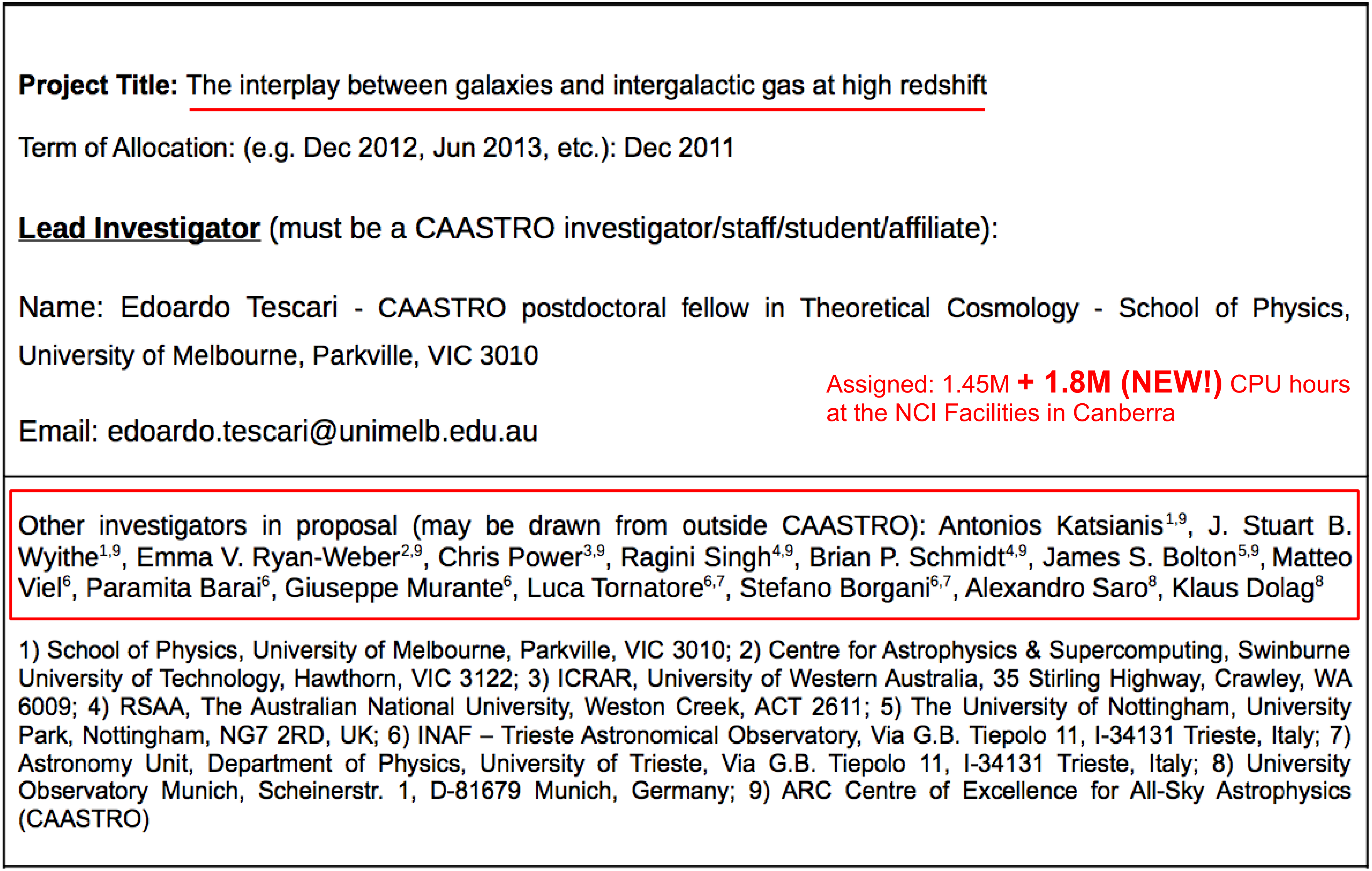
THE ANGUS PROJECT



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

Term of Allocation: (e.g. Dec 2012, Jun 2013, etc.): Dec 2011

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

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

Assigned: 1.45M **+ 1.8M (NEW!)** CPU hours at the NCI Facilities in Canberra

Email: edoardo.tescari@unimelb.edu.au

Other investigators in proposal (may be drawn from outside CAASTRO): Antonios Katsianis[1,9], J. Stuart B. Wyithe[1,9], Emma V. Ryan-Weber[2,9], Chris Power[3,9], Ragini Singh[4,9], Brian P. Schmidt[4,9], James S. 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]

1) School of Physics, University of Melbourne, Parkville, VIC 3010; 2) Centre for Astrophysics & Supercomputing, Swinburne University of Technology, Hawthorn, VIC 3122; 3) ICRAR, University of Western Australia, 35 Stirling Highway, Crawley, WA 6009; 4) RSAA, The Australian National University, Weston Creek, ACT 2611; 5) The University of Nottingham, University Park, Nottingham, NG7 2RD, UK; 6) INAF – Trieste Astronomical Observatory, Via G.B. Tiepolo 11, I-34131 Trieste, Italy; 7) Astronomy Unit, Department of Physics, University of Trieste, Via G.B. Tiepolo 11, I-34131 Trieste, Italy; 8) University Observatory Munich, Scheinerstr. 1, D-81679 Munich, Germany; 9) ARC Centre of Excellence for All-Sky Astrophysics (CAASTRO)

OUR GADGET-3 = P-GADGET3(XXL)

- **Stellar Evolution** & **Chemical Enrichment** modules (extension of the original “star formation” module by Luca Tornatore)

- **Low Temperature** (molecular) cooling (by Umberto Maio)

- **Improved AGN feedback scheme** (extensions by Luca Tornatore, Dunja Fabjan and Klaus Dolag)

- **Magnetic Field** model (by Klaus Dolag and Federico Stasyszyn)

- **Friends-of-Friends** & **SubFind** on the fly post-processing tools (by Volker Springel and Klaus Dolag)

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SFR FUNCTIONS: OBS

Smit, Bouwens et al. (2012):

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

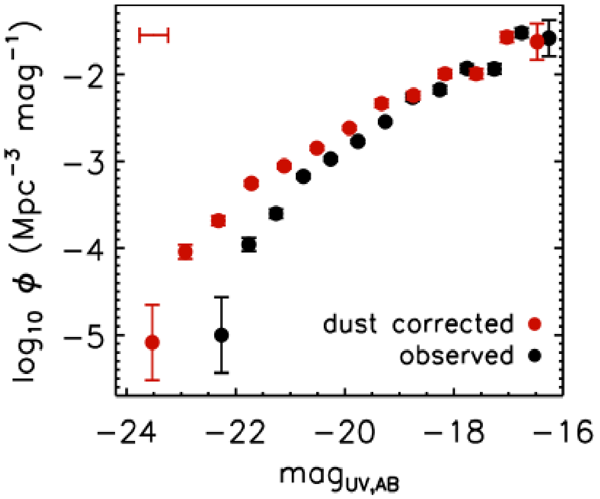
2) Schechter LF: $$\phi(L)\,dL = \phi^* \left(\frac{L}{L^*}\right)^{\alpha} \exp\left(-\frac{L}{L^*}\right) \frac{dL}{L^*}.$$

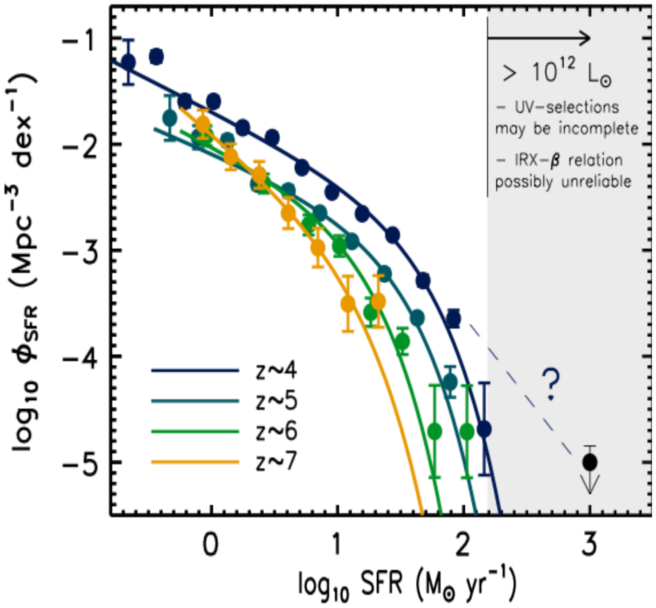
$$\phi(\mathrm{SFR})\,d\mathrm{SFR} = \frac{\phi^*}{1 - C_1 \frac{d\beta}{dM}} \left(\frac{\mathrm{SFR}}{\mathrm{SFR}^*}\right)^{\frac{\alpha + C_1 \frac{d\beta}{dM}}{1 - C_1 \frac{d\beta}{dM}}} \times \exp\left(-\frac{\mathrm{SFR}}{\mathrm{SFR}^*}\right) \frac{d\mathrm{SFR}}{\mathrm{SFR}^*}.$$

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

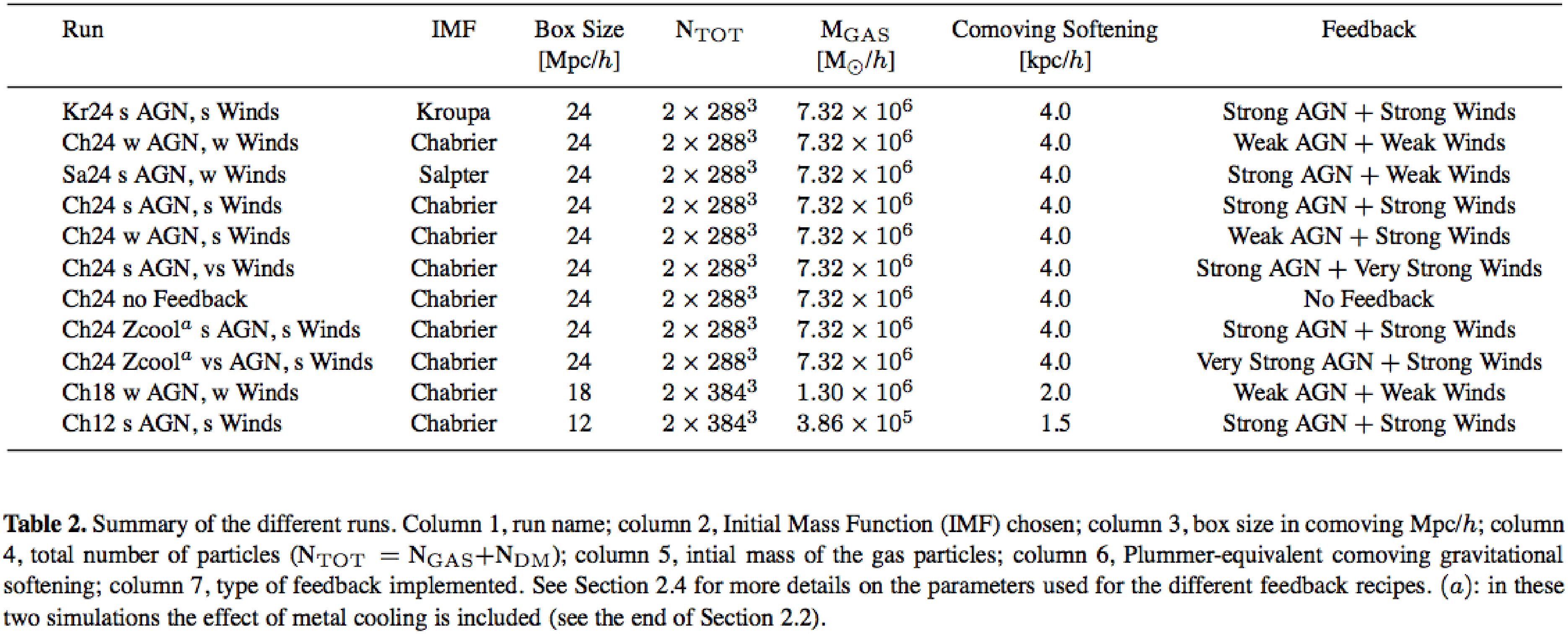
$$\phi^*_{\mathrm{SFR}} = \frac{\phi^*_{\mathrm{UV,uncorr}}}{1 - C_1 \frac{d\beta}{dM}}.$$

$z \sim 4$ UV LF from Bouwens et al. (2007)





SET OF SIMULATIONS



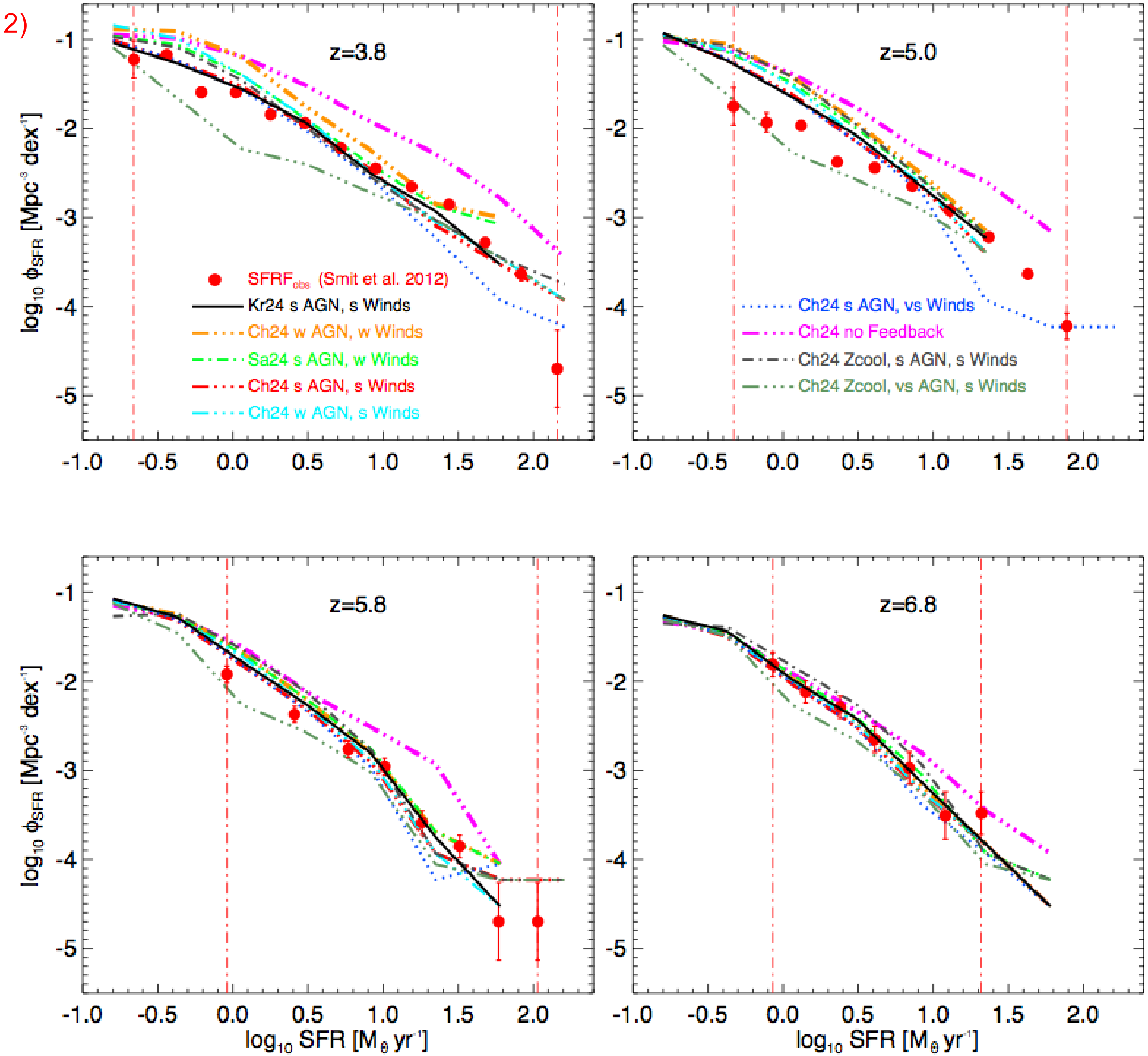
Run	IMF	Box Size [Mpc/h]	N_{TOT}	M_{GAS} [$M_\odot/h$]	Comoving Softening [kpc/h]	Feedback
Kr24 s AGN, s Winds	Kroupa	24	2×288^3	7.32×10^6	4.0	Strong AGN + Strong Winds
Ch24 w AGN, w Winds	Chabrier	24	2×288^3	7.32×10^6	4.0	Weak AGN + Weak Winds
Sa24 s AGN, w Winds	Salpter	24	2×288^3	7.32×10^6	4.0	Strong AGN + Weak Winds
Ch24 s AGN, s Winds	Chabrier	24	2×288^3	7.32×10^6	4.0	Strong AGN + Strong Winds
Ch24 w AGN, s Winds	Chabrier	24	2×288^3	7.32×10^6	4.0	Weak AGN + Strong Winds
Ch24 s AGN, vs Winds	Chabrier	24	2×288^3	7.32×10^6	4.0	Strong AGN + Very Strong Winds
Ch24 no Feedback	Chabrier	24	2×288^3	7.32×10^6	4.0	No Feedback
Ch24 Zcool^a s AGN, s Winds	Chabrier	24	2×288^3	7.32×10^6	4.0	Strong AGN + Strong Winds
Ch24 Zcool^a vs AGN, s Winds	Chabrier	24	2×288^3	7.32×10^6	4.0	Very Strong AGN + Strong Winds
Ch18 w AGN, w Winds	Chabrier	18	2×384^3	1.30×10^6	2.0	Weak AGN + Weak Winds
Ch12 s AGN, s Winds	Chabrier	12	2×384^3	3.86×10^5	1.5	Strong AGN + Strong Winds

Table 2. Summary of the different runs. 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, intial mass of the gas particles; column 6, Plummer-equivalent comoving gravitational softening; column 7, type of feedback implemented. See Section 2.4 for more details on the parameters used for the different feedback recipes. (a): in these two simulations the effect of metal cooling is included (see the end of Section 2.2).

Tescari et al.
(2013)

SFR FUNCTIONS: SIMS

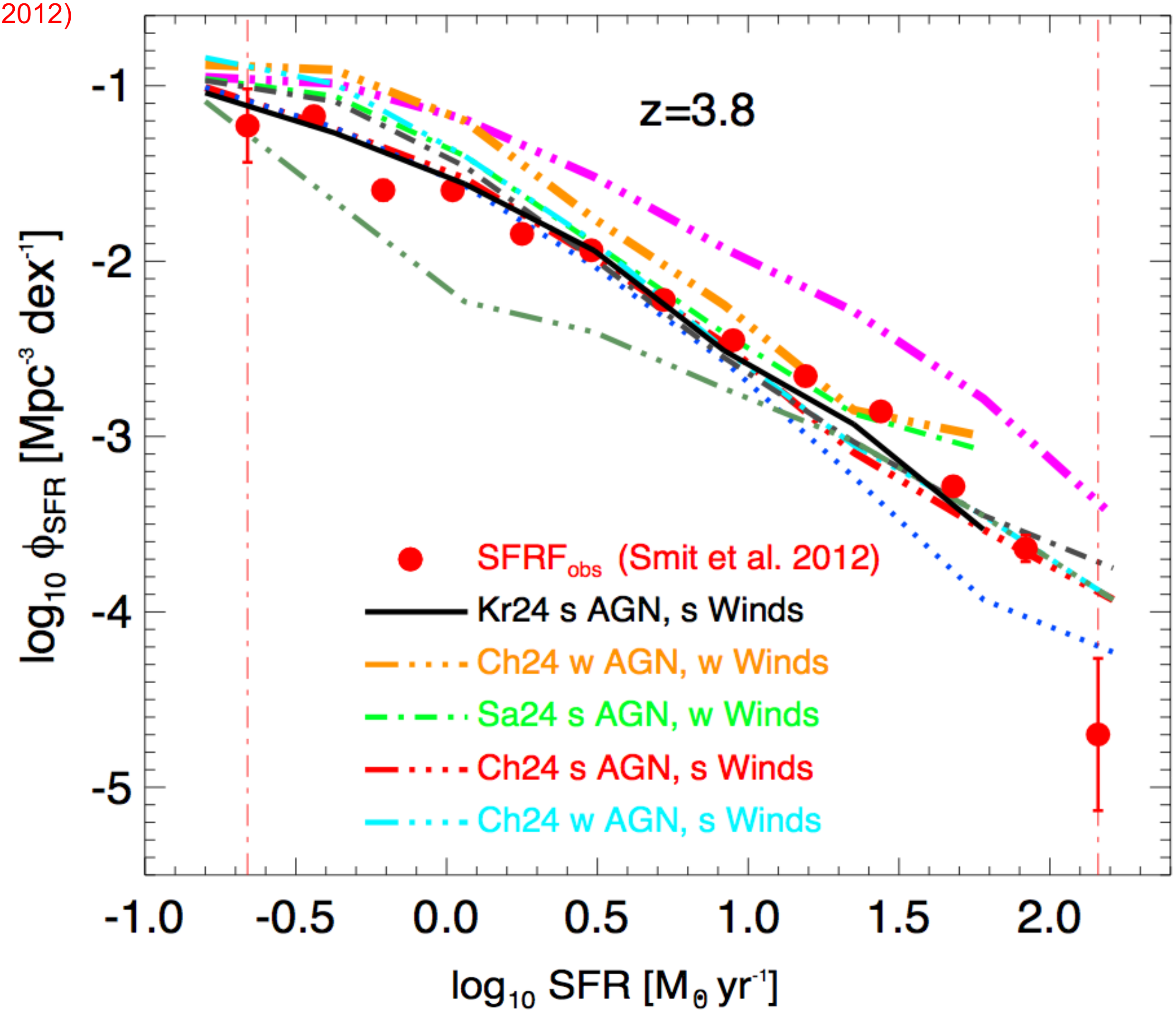
Obs from Smit et al. (2012)



Tescari et al. (2013)

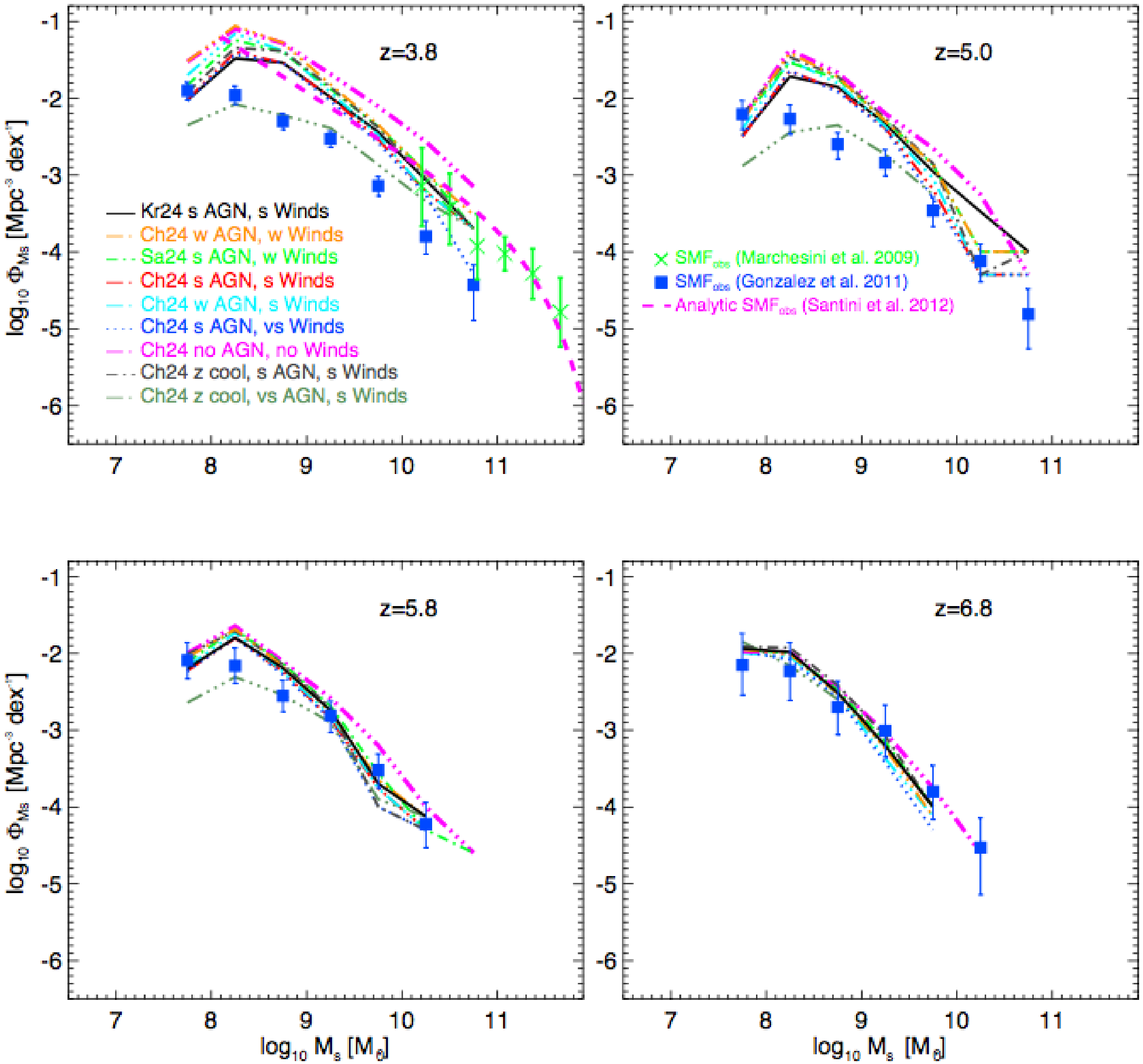
SFR FUNCTIONS: SIMS

Obs from Smit et al. (2012)



Tescari et al. (2013)

STELLAR MASS FUNCTIONS



Observations from:

González et al. (2011)
Santini et al. (2012)
Marchesini et al. (2009)

Katsianis et al. (2013)

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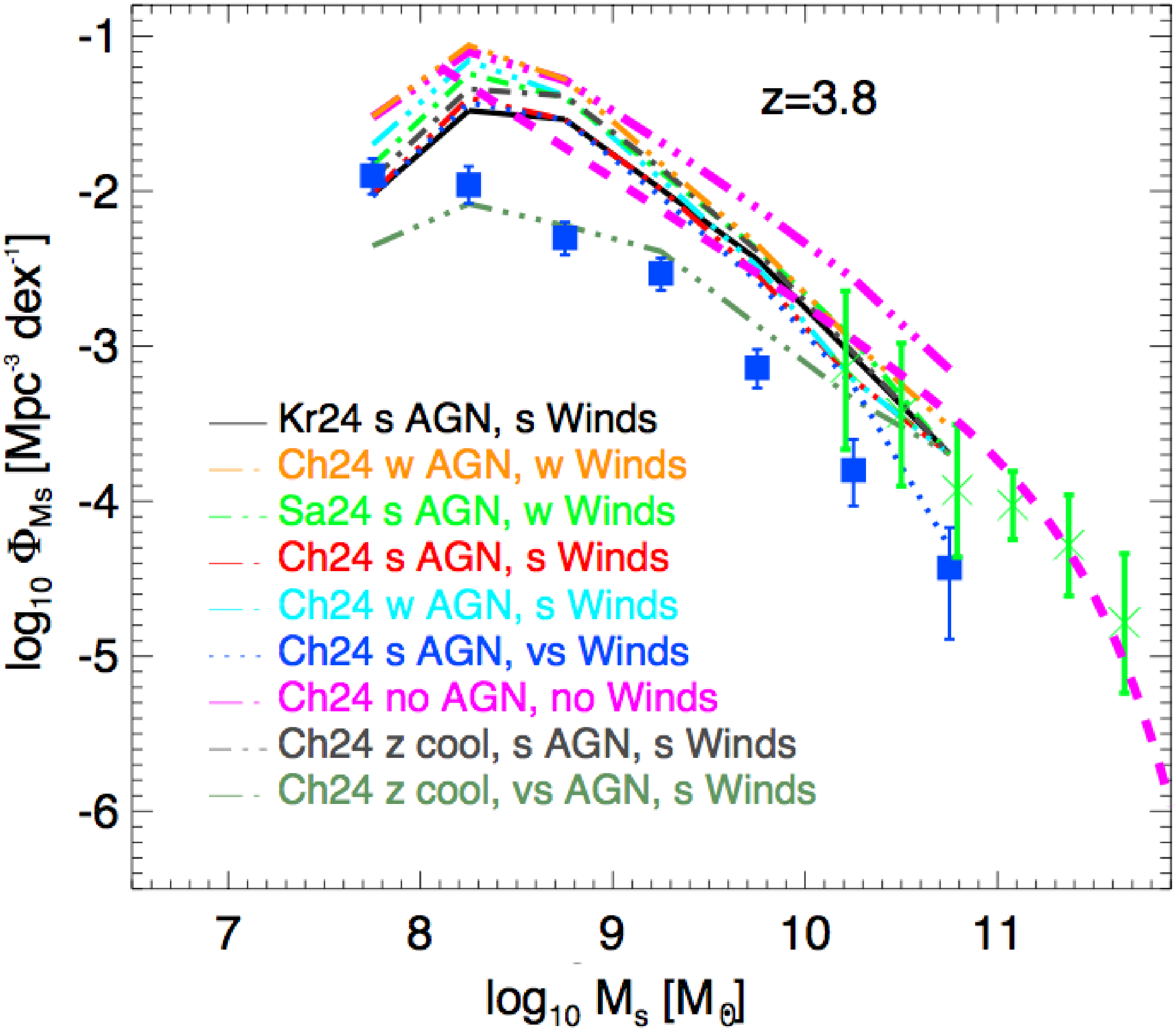
STELLAR MASS FUNCTIONS



Observations from:

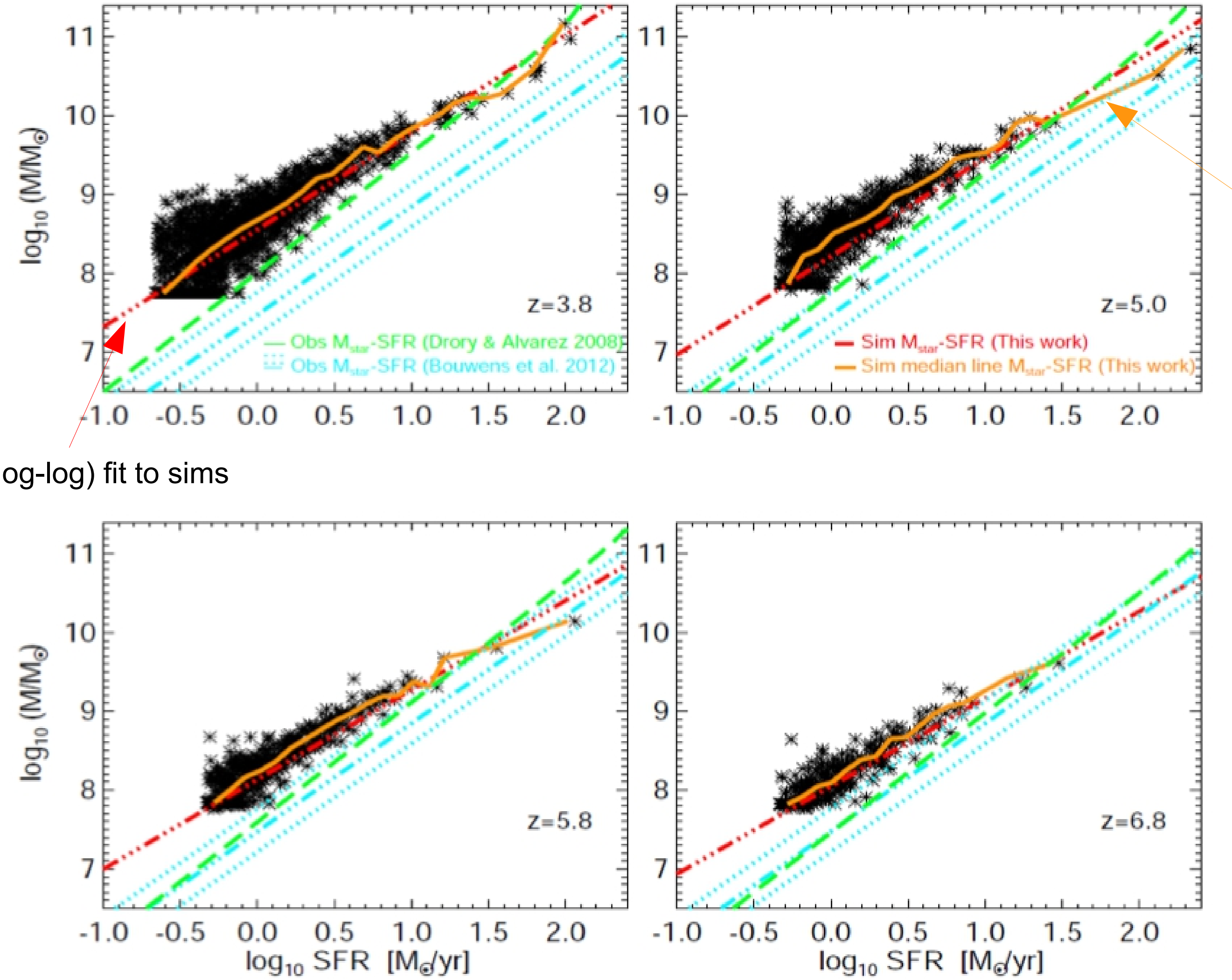
González et al. (2011)
Santini et al. (2012)
Marchesini et al. (2009)

Katsianis et al. (2013)

STELLAR MASS-SFR RELATION

Observations from:

Bouwens et al. (2012)
Drory & Alvarez (2008)

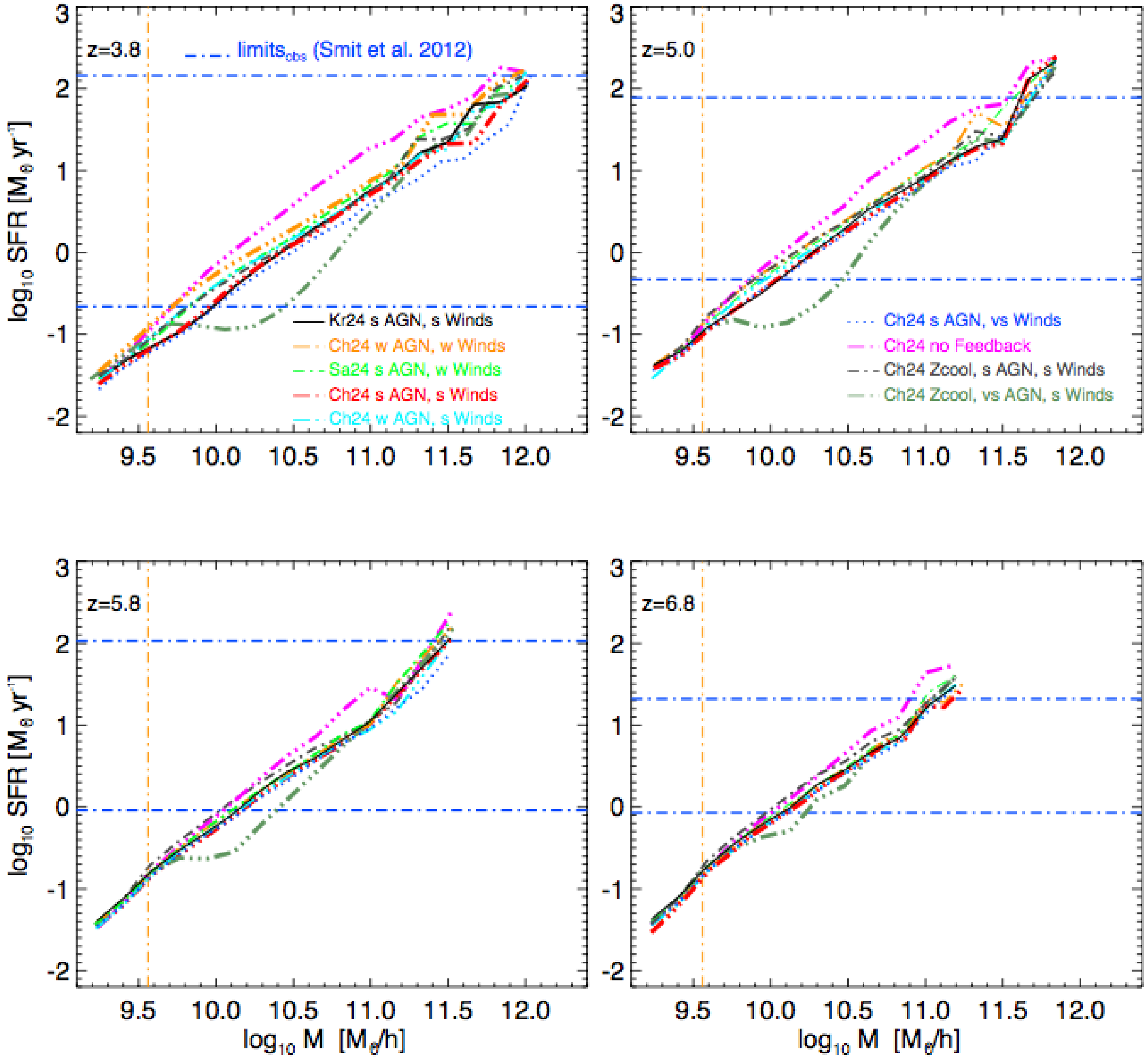


Sims median value

Linear (log-log) fit to sims

Katsianis et al. (2013)

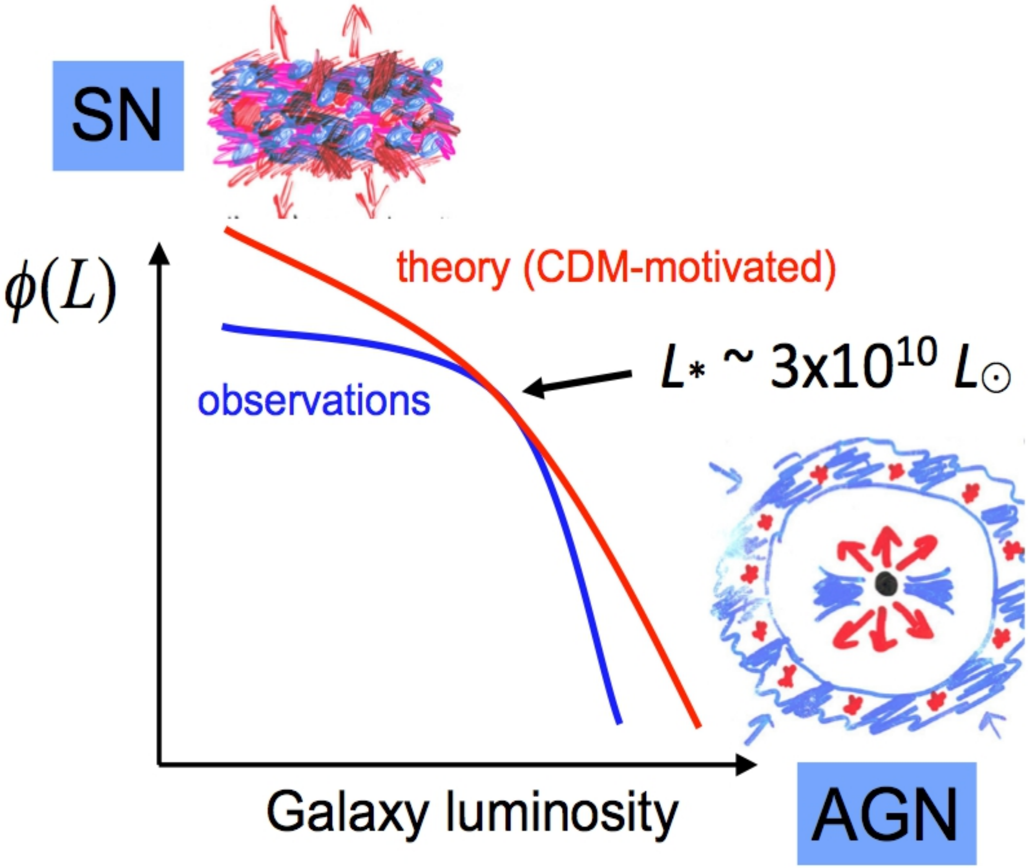
SFR-HALO MASS RELATION



Katsianis et al. (2013)

AGN Vs GALACTIC WINDS

LOW REDSHIFT



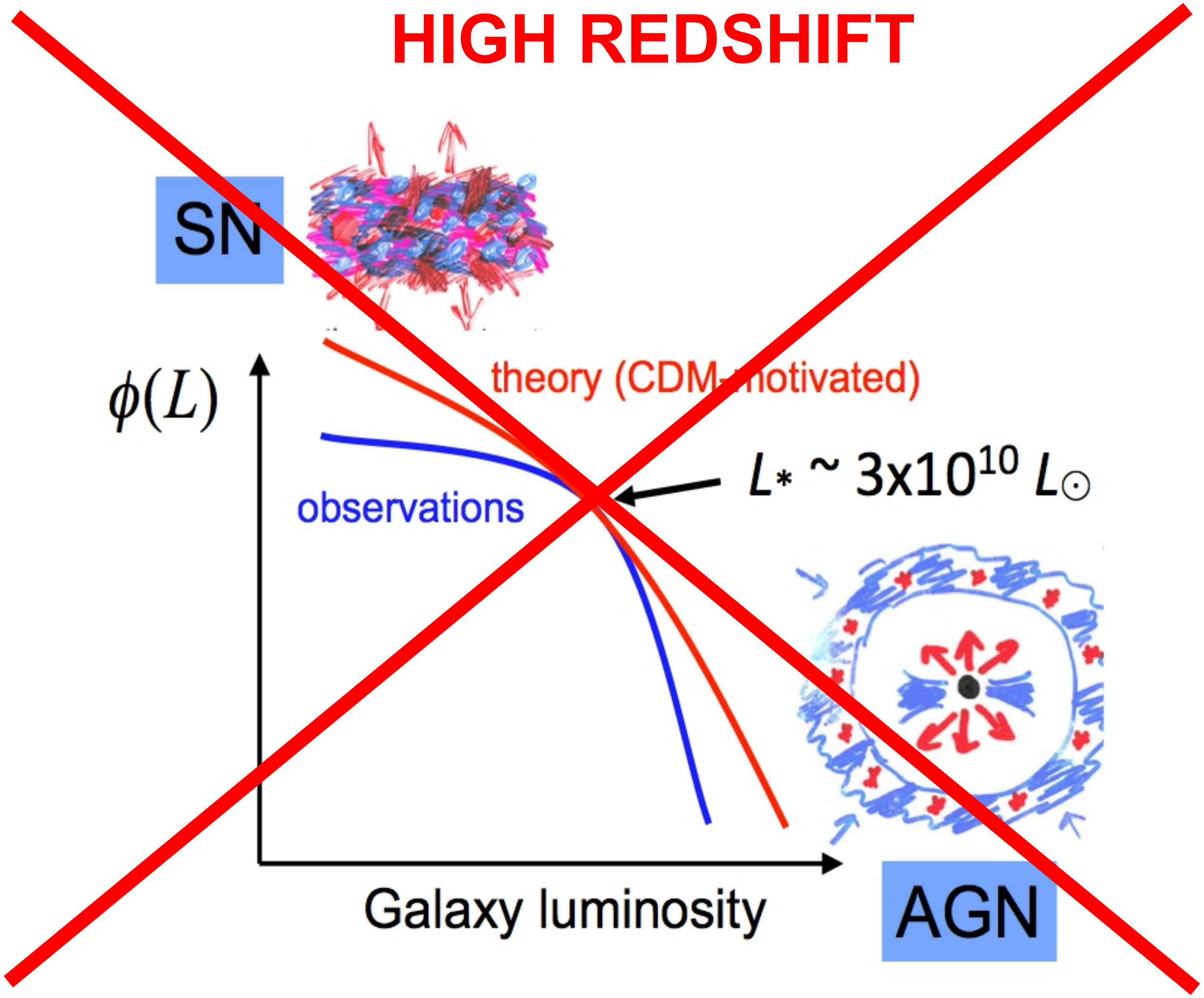
SAMs:
Croton et al. (2006)
Bower et al. (2006)

&

SIMS:
Puchwein &
Springel (2013)

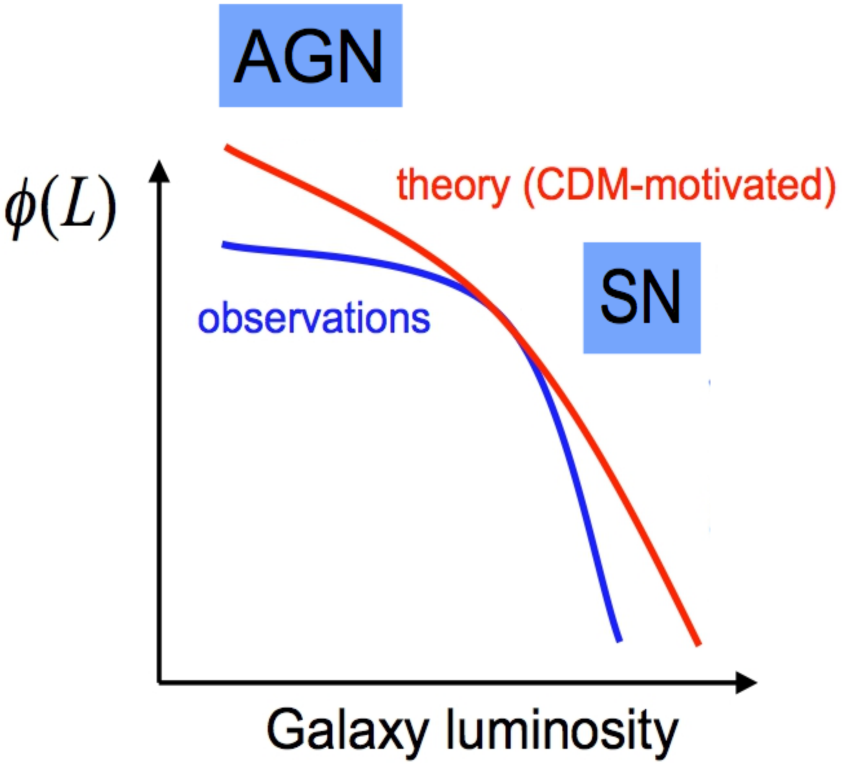
AGN Vs GALACTIC WINDS

HIGH REDSHIFT



AGN Vs GALACTIC WINDS

HIGH REDSHIFT



CONCLUSIONS

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

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

- AGN feedback important in shaping the low end of the star formation rate/stellar mass functions.

- Evolutionary scenario for the AGN feedback?

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

CONCLUSIONS

AustraliaN GADGET-3 early Universe Simulations

Angus

Angus Young
from

AC/DC