Constant vs. variable winds: effect on high-z galaxies

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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):

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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 Jeesson-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\(^6,7\), Alejandro Saro\(^6\), Klaus Dolag\(^8\)

Angus = AustraliaN GADGET-3 early Universe Simulations
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, Puchwein & Springel 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
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 in press

The stellar mass function and star formation rate–stellar mass relation of galaxies at $z \sim 4 - 7$

A. Katsianis$^{1,2*}$, E. Tescari$^{1,2}$ and J. S. B. Wyithe$^{1,2}$

MNRAS submitted
Wind velocity = 350 km/s \((wW)\), 450 km/s \((sW)\) and 550 km/s \((vsW)\) + momentum-driven winds \((MDW)\)

AGN feedback in two configurations = BHs seeded ± aggressively \(\text{("eA" and "IA")}\)

Tescari et al. (2014) + Katsianis, Tescari & Wyithe (2013)
Box Size = 24 cMpc/h

Number of part. = 2 x 288³

Spatial res = 4 kpc/h (com)

\( M_{\text{GAS}} = 7.32 \times 10^6 \, M_{\odot}/h \)

Winds = constant \( v \) (ref 450 km/s) & variable \( v \) (momentum driven)

AGN feedback in two configurations = BHs seeded ± aggressively (“eA” and “IA”)

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

Tescari et al. (2014)
Smit, Bouwens et al. (2012):

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

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

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

\[
\alpha_{\text{SFR}} = \frac{\alpha_{\text{UV,uncorr}} + C_1 \frac{d\beta}{dM}}{1 - C_1 \frac{d\beta}{dM}}.
\]

\[
\phi^*_{\text{SFR}} = \frac{\phi^*_{\text{UV,uncorr}}}{1 - C_1 \frac{d\beta}{dM}}.
\]
Observations:
Smit et al. (2012)
Observations:
Smit et al. (2012)

Tescari et al. (2014)
**CONST vs. VARIABLE WINDS**

**Observations:**
Smit et al. (2012)

**MDW**

\[ v_w = 450 \text{ km s}^{-1} \]
\[ \eta = 2 \]

**CONST**

\[ v_w = 2 \times v_{\text{circ}} \]
\[ \eta = 2 \times \frac{450 \text{ km s}^{-1}}{v_w} \]

Tescari et al. (2014)
**CONST vs. VARIABLE WINDS**

**Observations:**
Smit et al. (2012)

**CONST**

\[ v_w = 450 \text{ km s}^{-1} \]
\[ \eta = 2 \]

**EDW**

\[ v_w = 2 \times v_{\text{circ}} \]
\[ \eta = 2 \times \left( \frac{450 \text{ km s}^{-1}}{v_w} \right)^2 \]

**MDW**

\[ v_w = 2 \times v_{\text{circ}} \]
\[ \eta = 2 \times \frac{450 \text{ km s}^{-1}}{v_w} \]

**MDW_DVS**

\[ v_w = v_{\text{circ}} \]
\[ \eta = 2 \times \frac{450 \text{ km s}^{-1}}{v_w} \]

Tescari et al. (2014)
● Feedback effects (SN driven winds) in place at $z \sim 7$.

● Efficient feedback (strong galactic winds + early AGN) needed to reproduce observed SFRFs at high redshift (and especially at $z \sim 4$).

● IMF & metal cooling have a minor impact on the SFRFs.

● A non-aggressive variable wind scaling is needed, otherwise the amount of objects with low SFRs is greatly suppressed and at the same time winds are not effective in the most massive systems.
- **Extension to lower redshift** to test further the interplay between galactic winds & AGN feedback.

- LAEs at $z \sim 3$: **ANGUS + CRASHα**, in collaboration with Akila Jeeson-Daniel (UoM).

- Quasar transverse proximity effect: produced $\sim 270$ **CLOUDY tables + high res sims**.

- **CIV** absorption systems at $z > 4$. Clustering of metals Vs LBGs (with Emma Ryan-Weber).
Observations:

UV
González et al. (2011)
Observations:

UV
González et al. (2011)

IR
Santini et al. (2012)
Marchesini et al. (2009)
Katsianis, Tescari & Wyithe (2013)
Observations:

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- **UV**
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  - Santini et al. (2012)
  - Marchesini et al. (2009)
Observations:

UV
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Katsianis, Tescari & Wyithe (2013)
Observations:

- **UV**
  - González et al. (2011)

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

Katsianis, Tescari & Wyithe (2013)
Observations:
- UV
  Bouwens et al. (2012)
- IR
  Drory & Alvarez (2008)

Linear (log-log) fit to sim

Sim median value

Katsianis, Tescari & Wyithe (2013)
SFR-STELLAR MASS RELATION

Observations:

- UV
  Bouwens et al. (2012)

- IR
  Drory & Alvarez (2008)

\[
\text{SFR} = (13^{+7}_{-5} \, M_\odot \, \text{yr}^{-1}) \times (M_\star/10^9 M_\odot)^{0.73 \pm 0.32}
\]

\[
\text{SFR} \approx (2.3 M_\odot \, \text{yr}^{-1}) \times (M_\star/10^9 M_\odot)^{0.81}
\]

Katsianis, Tescari & Wyithe (2013)
SFR-STEellar Mass Relation

Observations:
- UV
  Bouwens et al. (2012)
- IR
  Drory & Alvarez (2008)

Katsianis, Tescari & Wyithe (2013)
Observations:

- UV
  González et al. (2011)

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SFR-STELELLAR MASS RELATION

Observations:

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Katsianis, Tescari & Wyithe (2013)
• We reproduce the evolution of the total SFRD.
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• We reproduce the evolution of SFRFs.
• We overproduce the UV GSMFs at $z < 5$. 
SUMMARY

- We reproduce the evolution of the total SFRD.
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Tension between simulated and observed GSMFs → different SFR-stellar mass relations
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

Sims predict a whole population of faint galaxies not seen by current obs.
ALL the IMFs are normalized to 1

Tescari et al. (2014)
“Stars” evolve and give back, in addition to H and He, the following elements to the surrounding medium:

- C
- Ca
- O
- N
- Ne
- Mg
- S
- Si
- Fe

**Chemical Enrichment**

*Extending* star-formation model for a more detailed description of the evolution of the stellar population.

(Tornatore et al. 2004/2007):

- Model rate of SN Ia (e.g. binary systems $0.8 - 8M_\odot$).
- Adopt lifetime function $\tau(m)$
  (Padovani & Matteucci 1993, Maeder & Maynet 1989, ...).
- Adopt yields $p_{Z_i}(m, Z)$
  (Hoek & Groenewegen 1997, Thielemann et al. 2003, Woosley & Weaver 1995, ...).
- The IMF fixes the number of stars at given mass
  (Salpeter 1955, Arimoto & Yoshii 1987, Kroupa 2001, ...).

$\Rightarrow$ Explicitly follow the evolution of rates for SN Ia, SN II and AGB stars along with their respective metal production.
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