Quasar feedback in the early Universe: SDSS J1148+5251

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OUTLINE

- A model for the formation and evolution of high-z quasars: *GAMETE/QSO$_{DUST}$*
- A pilot study: SDSS J1148 at z=6.4
- Model results: chemical evolution of J1148
- Implications for Quasar feedback

GAMETE/QSOdust

A semi-analytical hierchical model for the formation & evolution of high-z quasars

RV, Schneider, Salvadori, Bianchi 2011

extensive parameter space exploration →

Investigation of several QSO evolutionary scenarios:

- several **merger histories** of the given host dark matter halo
- different plausible **SFHs**: star formation in quiescent and/or merger-driven bursts
- different properties of the stellar populations (**IMFs**): standard and/or "top-heavy"
- **BH growth** via gas accretion and mergers
- **BH feedback** → Energy driven galactic scale wind
- chemical enrichment (**metals and dust**) on the stellar characteristic timescales
- **dust** formation in both the main stellar dust sources: **AGB stars & SNe**

  (RV, Schneider,Bianchi,Andersen 2009)
- **dust destruction** by SN shocks and **grain growth** in molecular clouds

Quasar & SN driven gas outflow

Valiante et al. 2011, 2012

Energy-driven galaxy scale winds

Gas outflow rate

↓

Quasar feedback

&

Supernova feedback

$$dM_{ej}(t)/dt = dM_{ej,SN}(t)/dt + dM_{ej,AGN}(t)/dt,$$

$$\frac{dM_{\rm ej,AGN}}{dt} = 2\epsilon_{\rm w,AGN}\,\epsilon_{\rm r}\left(\frac{c}{v_{\rm e}}\right)^2 \dot{M}_{\rm accr}$$

$$\frac{dM_{\rm ej,SN}}{dt} = \frac{2\epsilon_w E_{\rm SN}}{v_{\rm e}^2} R_{\rm SN}(t),$$

A pilot study: SDSS J1148 at z=6.4

The model can be contrained using the properties observed or inferred from observations:

- BH mass $M_{BH} = (2 - 6)\times10^{9}\ M_{sun}$ *(Willot et al. 2003; Barth et al. 2003)*
- Gas mass $M_{H2} = 1.6\times10^{10}\ M_{sun}$ *(Walter et al. 2004)*
- Dynamical mass $M_{dyn} \sim 5.5\times10^{10}\ M_{sun}$ *(Walter et al. 2004)*
- Stellar mass $M_{star} = M_{dyn} - M_{H2} \sim 3.9\times10^{10}\ M_{sun}$ *(Walter et al. 2004)*
- Metallicity $Z/Z_{sun} = 1.32^{+1.57}_{-1.10}$ *(Matsuoka et al. 2009)*
- Dust mass $M_{dust} = (2 - 5)\times10^{8}\ M_{sun}$ *(Bertoldi et al. 2003; Beelen et al. 2006; Valiante et al. 2011)*
- SFR $\sim (180 - 3\times 10^{3}) M_{\odot}/yr$ *(Bertoldi et al. 2003; Maiolino et al. 2005,Dwek et al. 2007, Li et al. 2007)*

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- Dust mass $M_{dust} = (2– 5)\times10^8 M_{sun}$ *(Bertoldi et al. 2003; Beelen et al. 2006; Valiante et al. 2011)*
- SFR ~ $(180 - 3\times 10^3) M_\odot$/yr *(Bertoldi et al. 2003; Maiolino et al. 2005,Dwek et al. 2007, Li et al. 2007)*

Fundamental free parameters:

- star formation efficiency
- BH Bondi accretion efficiency
- BH feedback efficiency

} Control the shape of the SFH

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J1148: testing different scenarios

- SFH → $SFR(z) = f_* M_{gas}(z)$ $f_* = (\varepsilon_q + \varepsilon_b) / \tau_{dyn}$ ***quiescent*** vs ***bursted*** ($\varepsilon_b = 0$) ($\varepsilon_b > 0$)

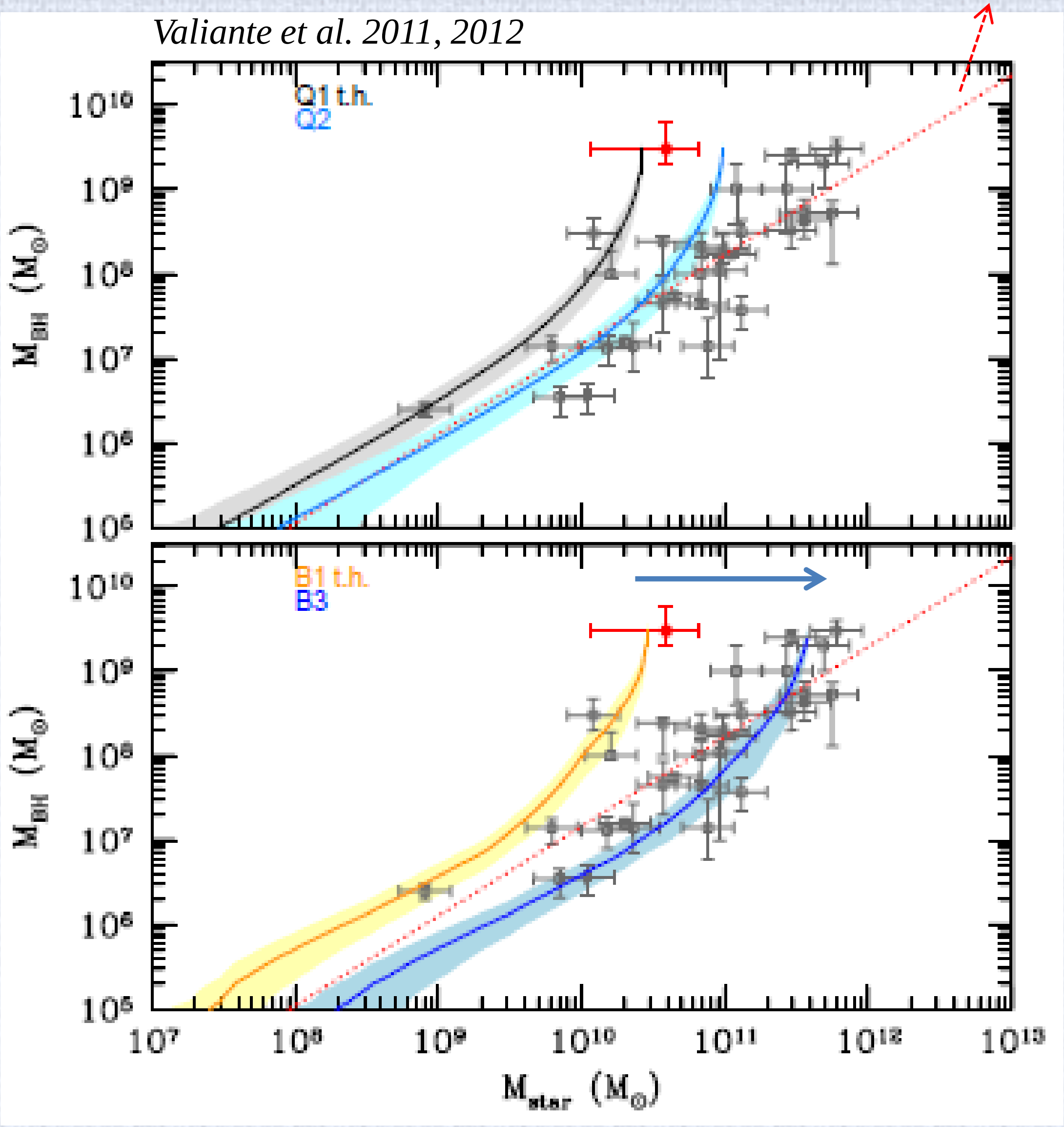
- Increasing SF eff. : *low-*f_* → *intermediate-*f_* → *high-*f_*

- IMF → $\varphi(m) \propto m^{-1.35} \exp(-m_{ch}/m)$ ***standard*** vs ***top-heavy*** (m_{ch} = 0.35 M_{sun}) (m_{ch} = 5.0 M_{sun})

Results: *The M_{BH} – M_{star} relation*

The M_{BH} – M_{star} relation

Marconi & Hunt 2003



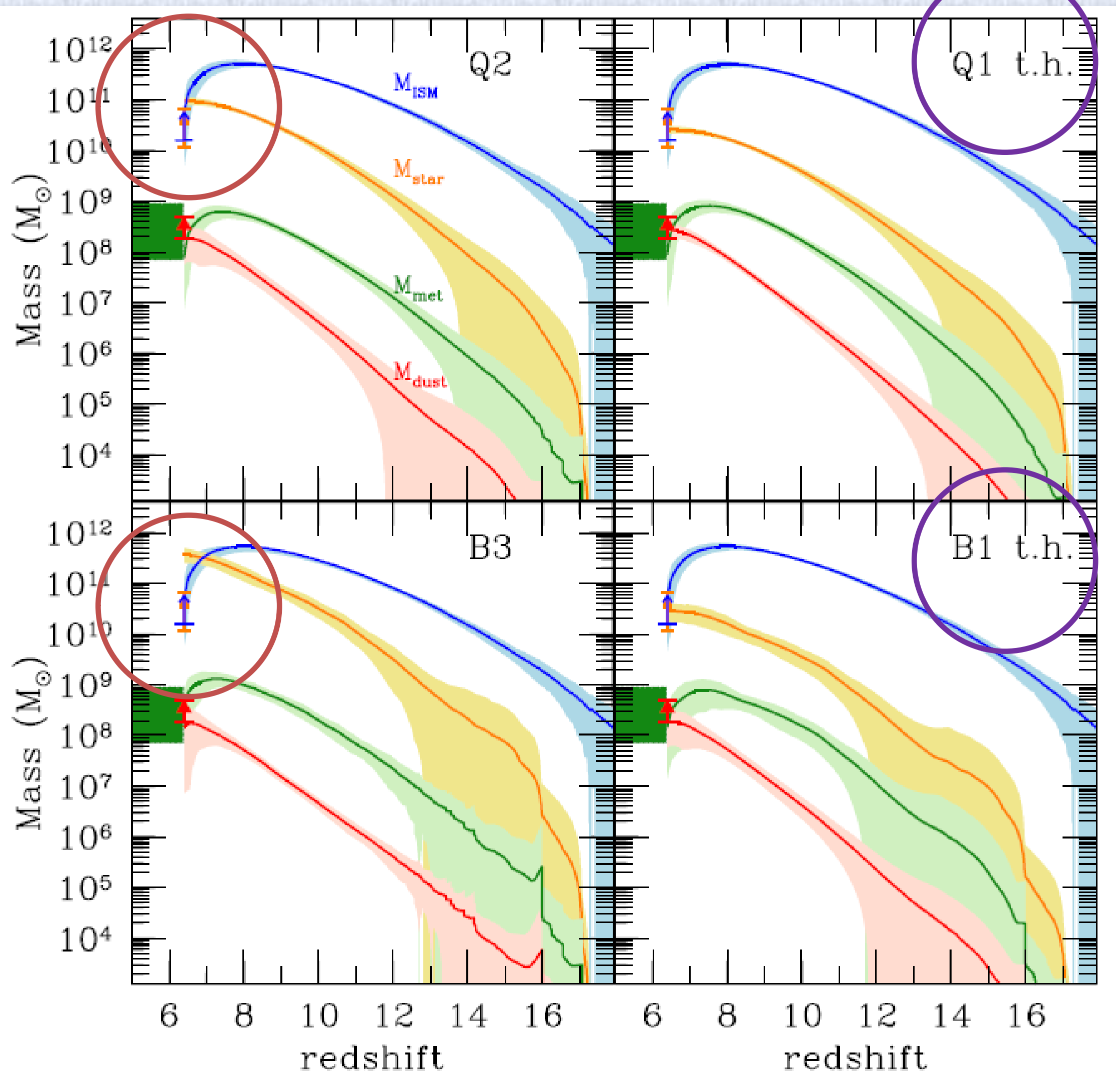
<u>*Quiescent SFH models*</u>

Q1 → low-f_* (top-heavy IMF)
Q2 → intermediate-f_*

<u>*Bursted SFH models*</u>

B1 → low-f_* (top-heavy IMF)
B3 → high-f_*

RESULTS: *The chemical evolution*

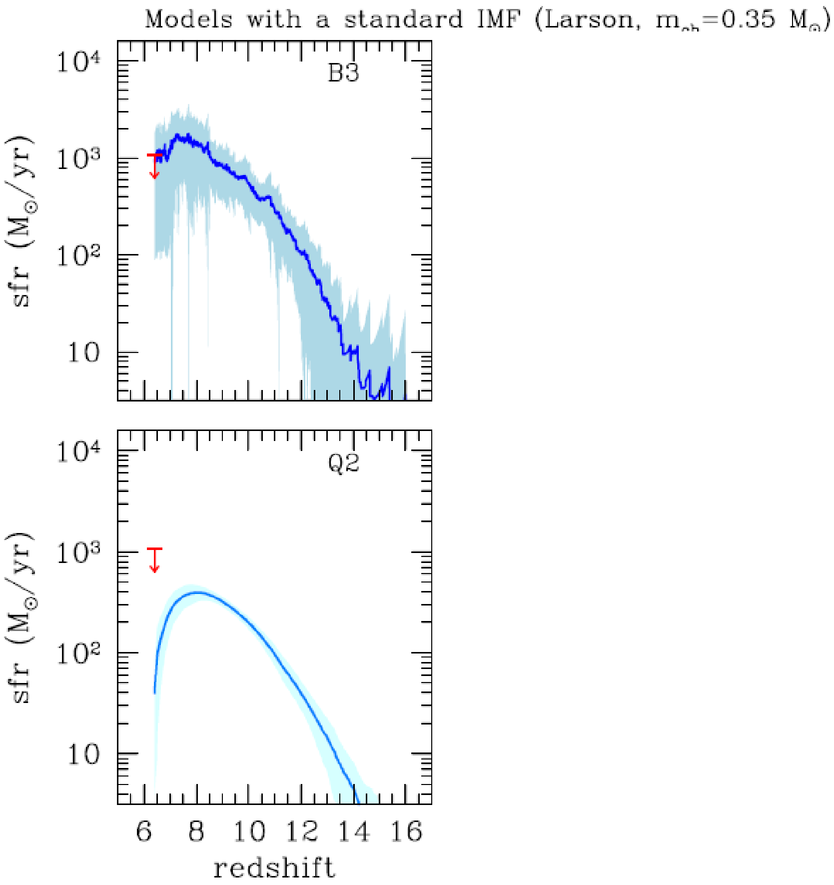


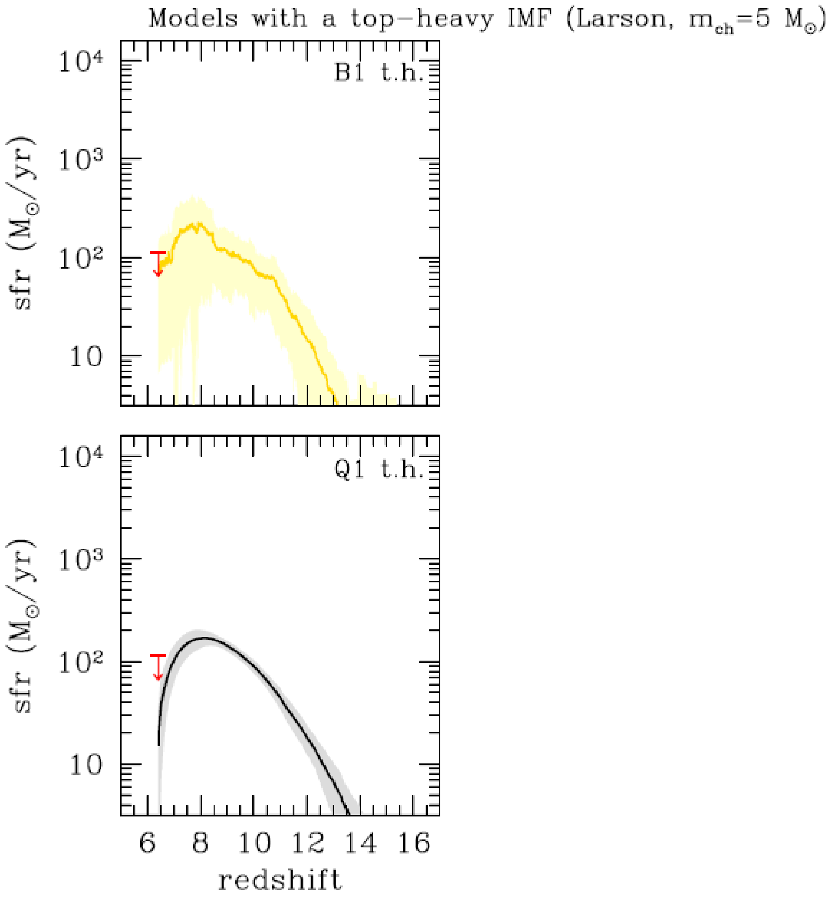
Quiescent (Bursted) SFHs with a standard IMF reproduce the observed dust mass if **a factor of ~ 3 (10) larger stellar mass** is produced

Quiescent and bursted low-f_* models reproduce the mass of metals and dust ONLY with a ***top-heavy IMF*** (m_{ch} = 5 M_{sun})

J1148: Quasar-driven *gas outflow at z>6*

RV, Schneider, Maiolino, Salvadori, Bianchi 2012

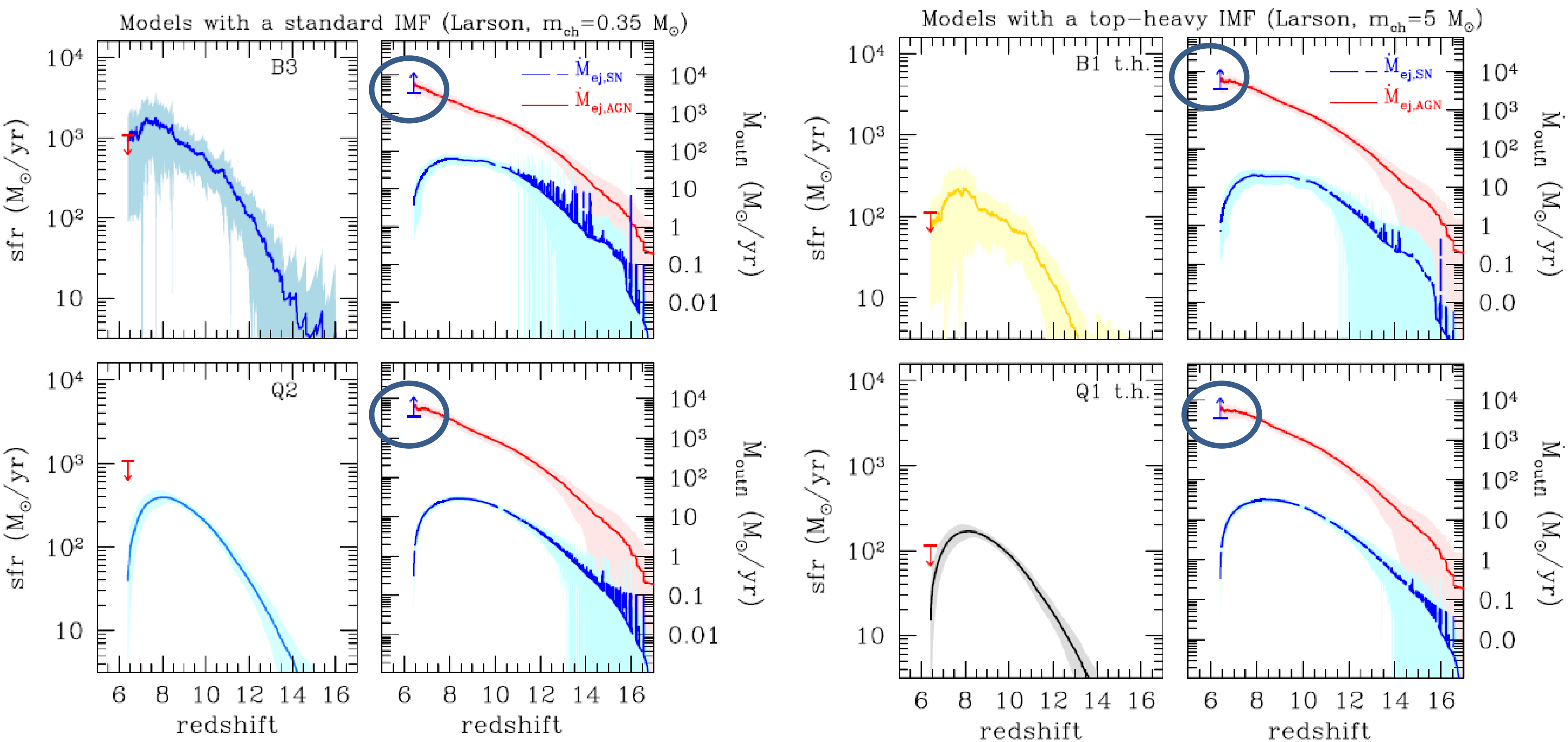




J1148: Quasar-driven *gas outflow at z>6*

RV, Schneider, Maiolino, Salvadori, Bianchi 2012

Massive outflow rate > 3500 M_{sun}/yr in J1148 ***(Maiolino et al 2012)***



Quasar-dominated gas outflow

Conclusions

Models aimed at interpreting the observed dynamical (M_{BH}, M_{star}) and chemical (M_{met}, M_{dust}) properties of QSOs at z>6 predict that:

- Large outflows are launched during the latest ~ (100 − 200) Myr of the evolution independently of the SF efficiency and IMF
- The gas outflow rate is in good agreement with the > 3500 M_{sun}/yr rate inferred for J1148 by Maiolino et al. (2012)
- The gas outflow is dominated by QSO feedback leading to a down-turn in the star formation rate at $z < 7 - 8$
- Supernova explosions give a negligible contribution to the observed winds at $z = 6.4$


THANK YOU!