The origin of dust in high redshift QSOs:

SDSS J1148+5251

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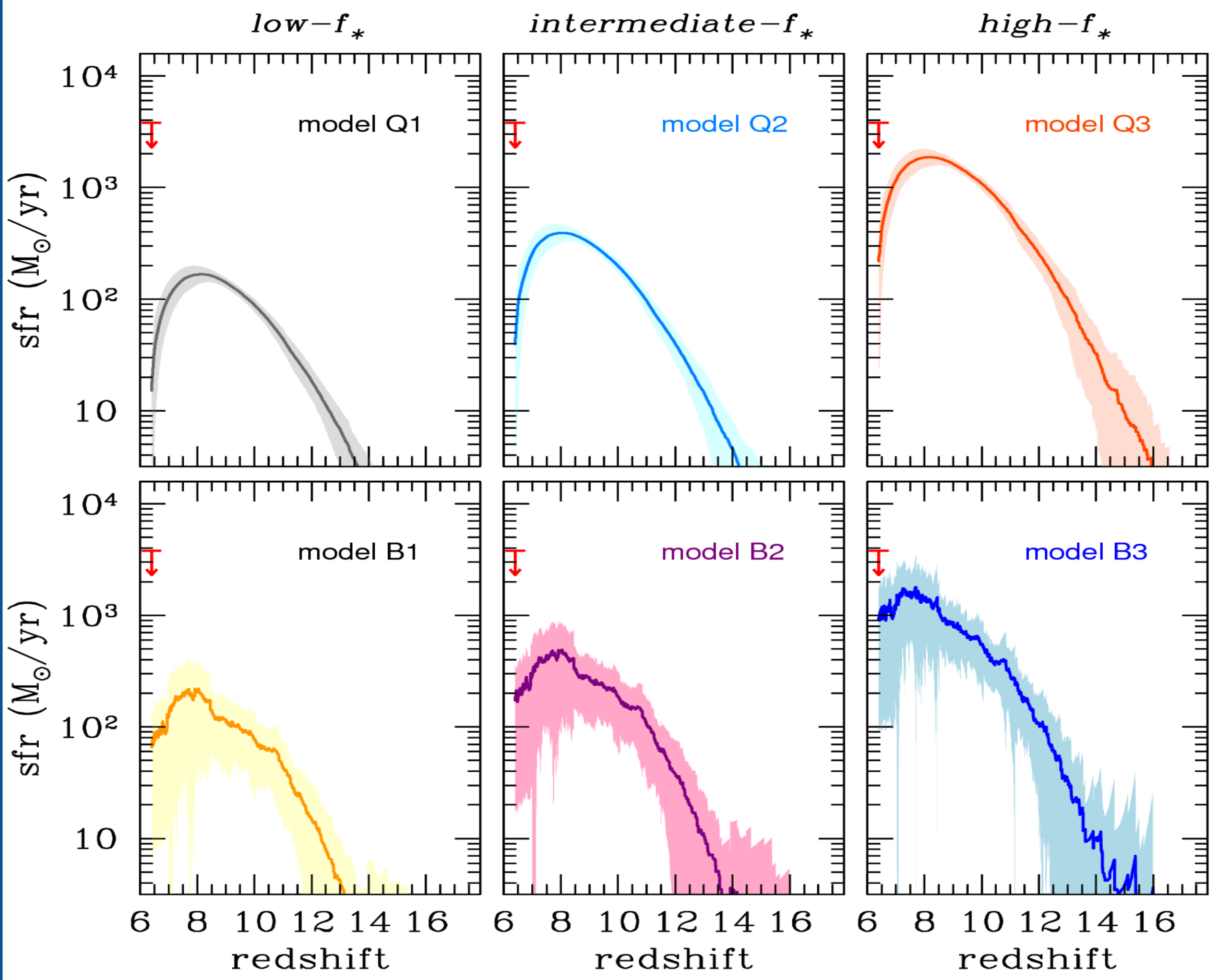
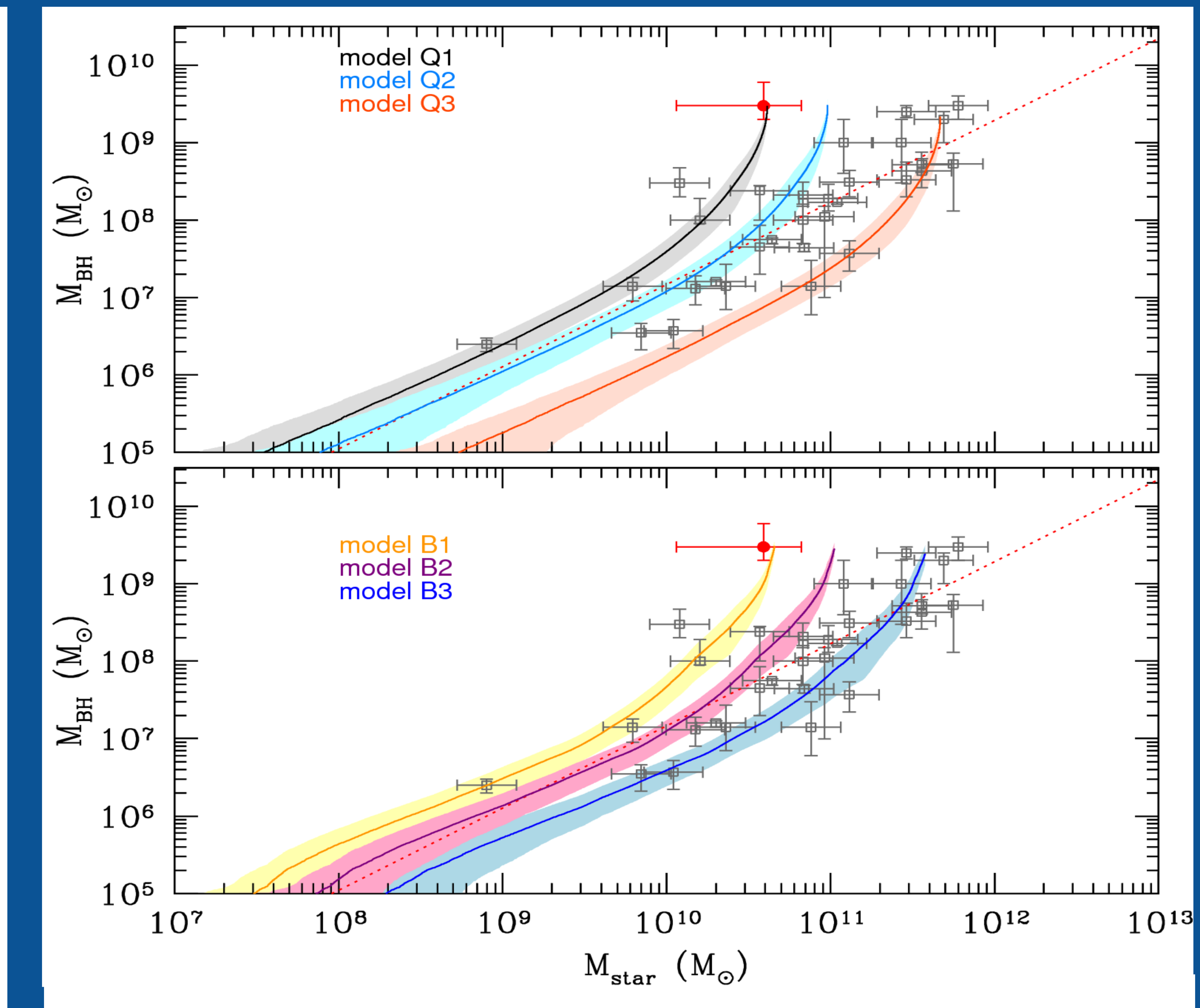
Abstract

We present a hierarchical semi-analytical model for the formation and evolution of the high redshift (z = 6.4) quasar SDSS J1148+5251. Our code, GAMETE/QSODUST, allows us to reconstruct a set of hierarchical merger histories of a 10^{13} $M_\odot$ dark matter halo and model the evolution of the corresponding galaxy and its central super massive black hole.



1. The SFHs of J1148 host galaxy

"Quiescent" (upper panels) and "bursted" (lower panels) SFH models[1]. Curves represent the averages over 50 different hierarchical merger histories, with the corresponding 1σ dispersion.



2. The M_{BH}-M_{star} relation

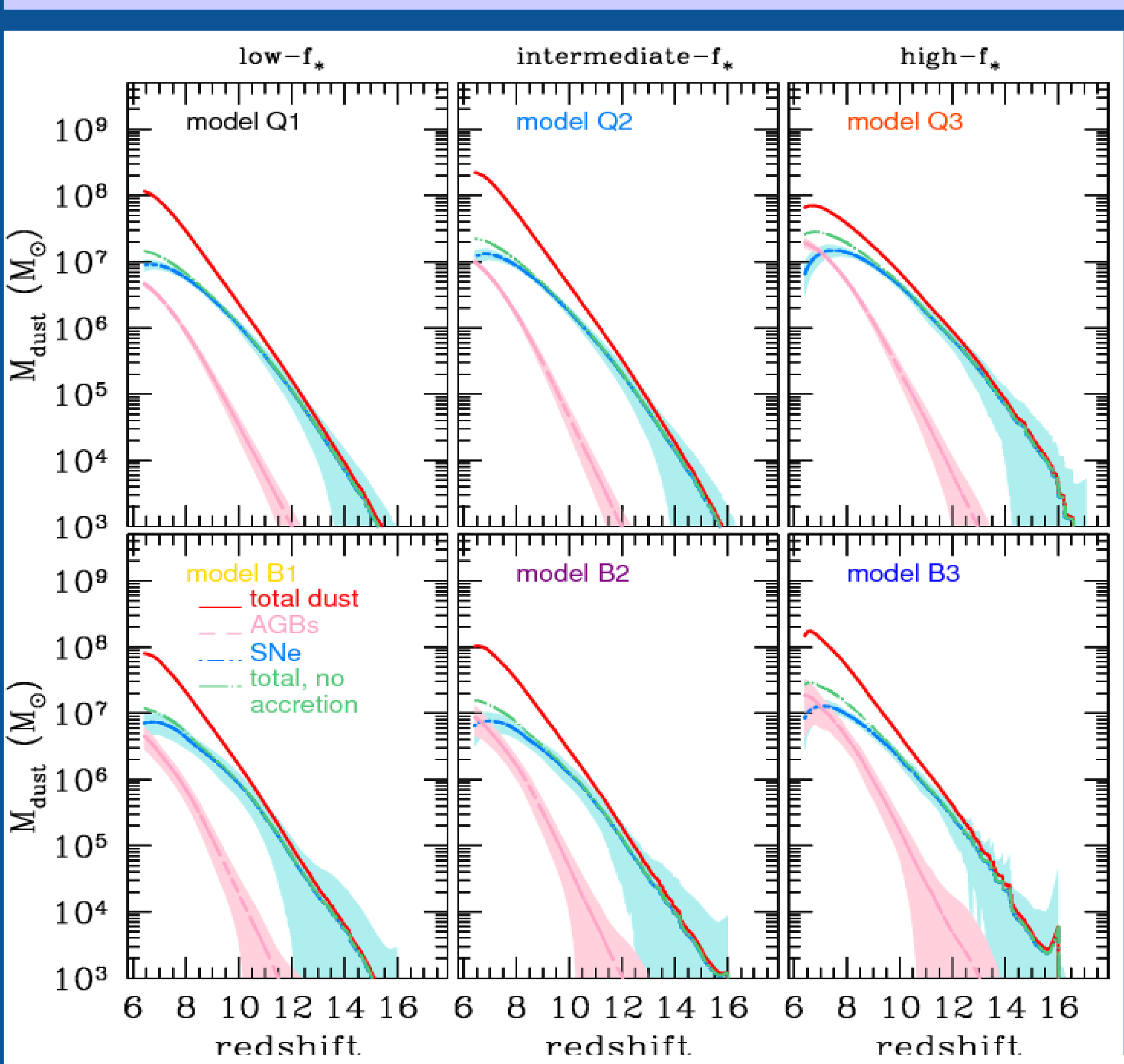
Predicted M_{BH}-M_{star} relations[1]. Red circle shows the J1148 position[2,3]. Grey data points and red dotted line are the observations in the local Universe and the empirical fit M_{BH}/M_{star}~0.002, respectively[4].

Method

We model different possible SFHs for J1148 (fig. 1) and explore their impact on the chemical properties of the QSO host. We follow: the BH assembly via both coalescence with other BHs and gas accretion (fig. 2) ; the build up and SFH of the QSO host galaxy driven by binary mergers and mass accretion; the evolution of gas, stars and metals in the ISM accounting for mass exchanges with the external medium; dust formation in SN ejecta and AGB stars, dust destruction by interstellar shocks and grain growth in MCs; the AGN feedback which powers a galactic scale wind, self-regulating the BH growth and eventually halting star formation[1].

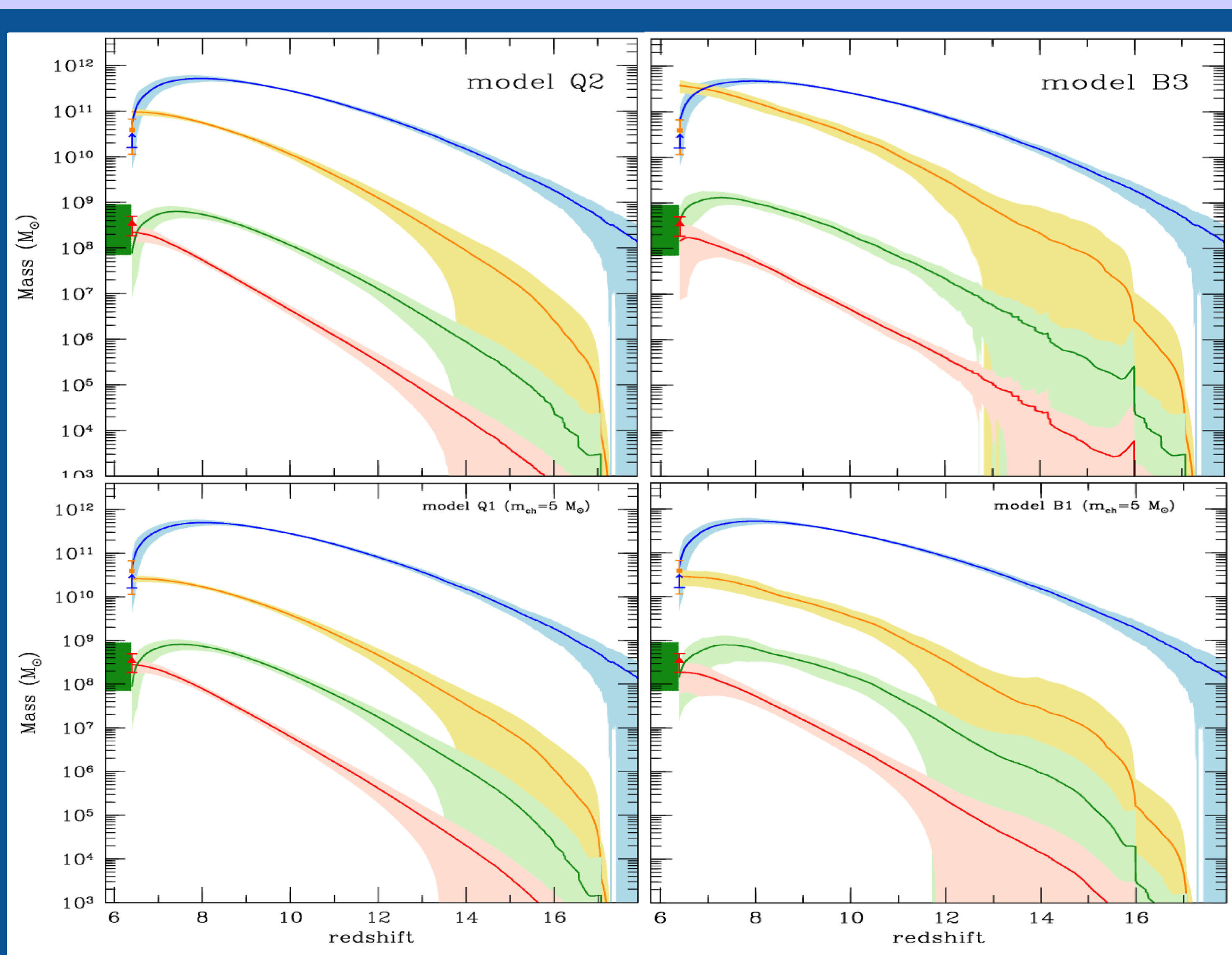
Main results *(Valiante et al. 2011)*

- The observed dust mass, M_{dust} = (2 - 6)×10^8 $M_\odot$, can be reproduced only if grain growth in molecular clouds is considered (fig. 3).
- SNe dominate the early dust enrichment while AGB stars contribute at z < (8 – 10)[5]. This latter contribution depends on the shape of the SFH and on the adopted IMF (fig 3).
- If Pop II/I stars form with a standard IMF (m_{ch}=0.35 $M_\odot$) a final stellar mass of (1–5)×$10^{11}$$M_\odot$, which is a factor 3-10 larger than that inferred for J1148, is required to reproduce the observed dust mass and gas metallicity of this quasar (fig 4, upper panels).
- If Pop II/I stars form with a top-heavy IMF (m_{ch}=5 $M_\odot$) the observed chemical properties can be reconciled with the inferred stellar mass of J1148 (fig 4, lower panels).



3. The evolution of the dust

The total dust mass (red ilnes) compared with (i) the dust mass computed without the MC-grown dust (green lines), (ii) the SN dust (cyan lilnes) and (iii) the AGB dust (pink lines) components [1].



4. The ISM chemical evolution

Redshift evolution of the average mass of gas (blue), stars (yellow), metals (green) and dust (red) for models which succesfully reproduce the dust and metals mass of J1148 (Valiante et al. 2011). The blue arrow is the lower limit to the gas mass inferred by observations. The yellow circle indicates the final stellar mass with error bars accounting for the uncertainties on the dynamical mass. The red triangle shows the expected average dust mass with error bars accounting for the uncertainties given in the literature. The filled green rectangle represent the range of metal masses estimated adopting the observed metallicity of high-z NLRs.

Discussion

- We show that MC-grown dust is the dominant component even at z>6, while stellar sources, SNe and AGB stars, can not account for the total amount of dust observed in J1148. This result differs from what was inferred in Valiante et al. 2009 for two main reasons: the peculiar SFH and the close-box approximation made in that work.
- Our results show the importance of a statistical analysis, were a sufficiently larger sample of SFHs and merger histories can be investigated.
- The higher stellar mass required to reproduce chemical properties of J1148 in models which adopt a standar IMF would shift the data of J1148 on the BH-stellar mass relation much closer to the observed local correlation.
- All the observed properties, including the stellar mass, of J1148 can be reproduced assuming a top-heavy IMF. Indeed, physical conditions in the ISM of high-z galaxies may favour a shift in the fragmentation mass scale and hence in the IMF characteristic mass[6].

References

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