Horizon-AGN: evolution of galaxy properties over cosmic time

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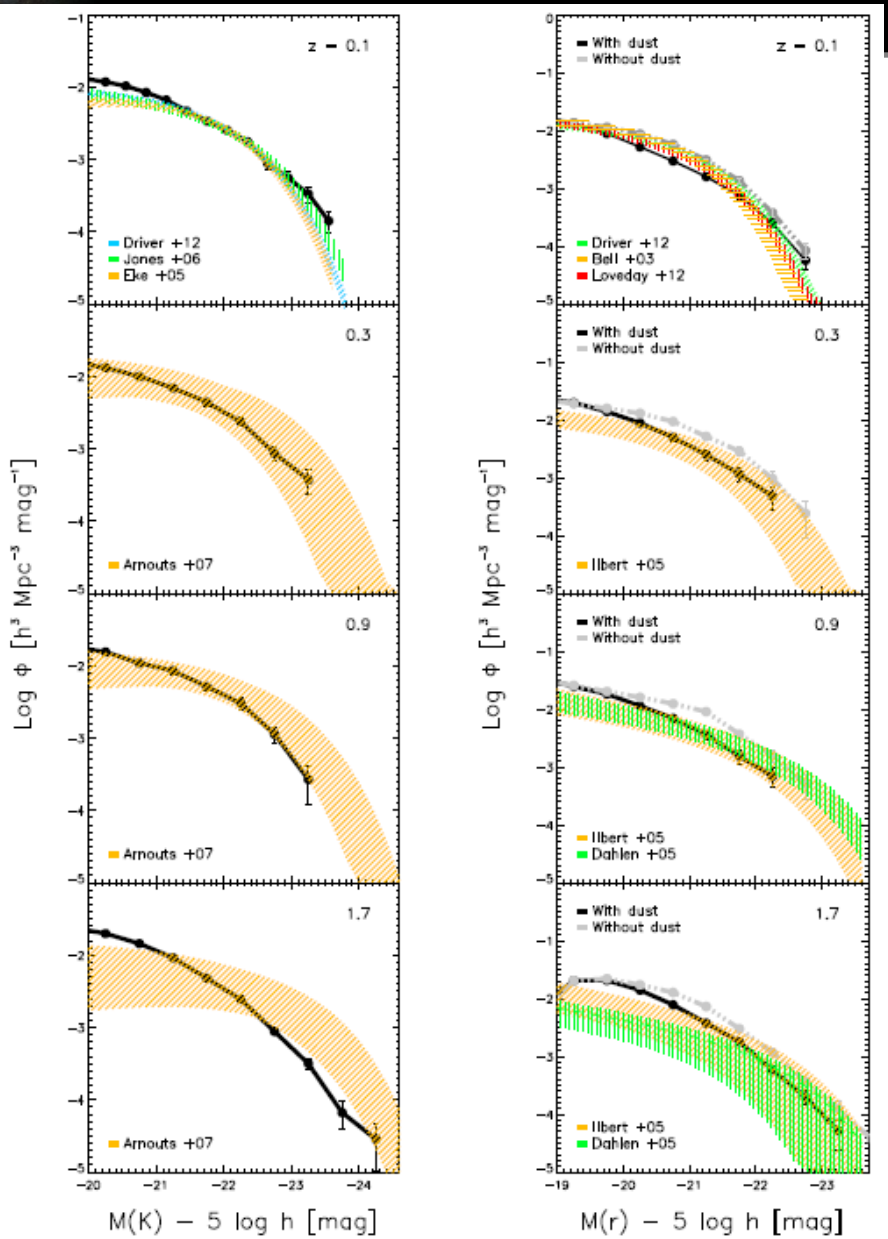
The Horizon-AGN simulation

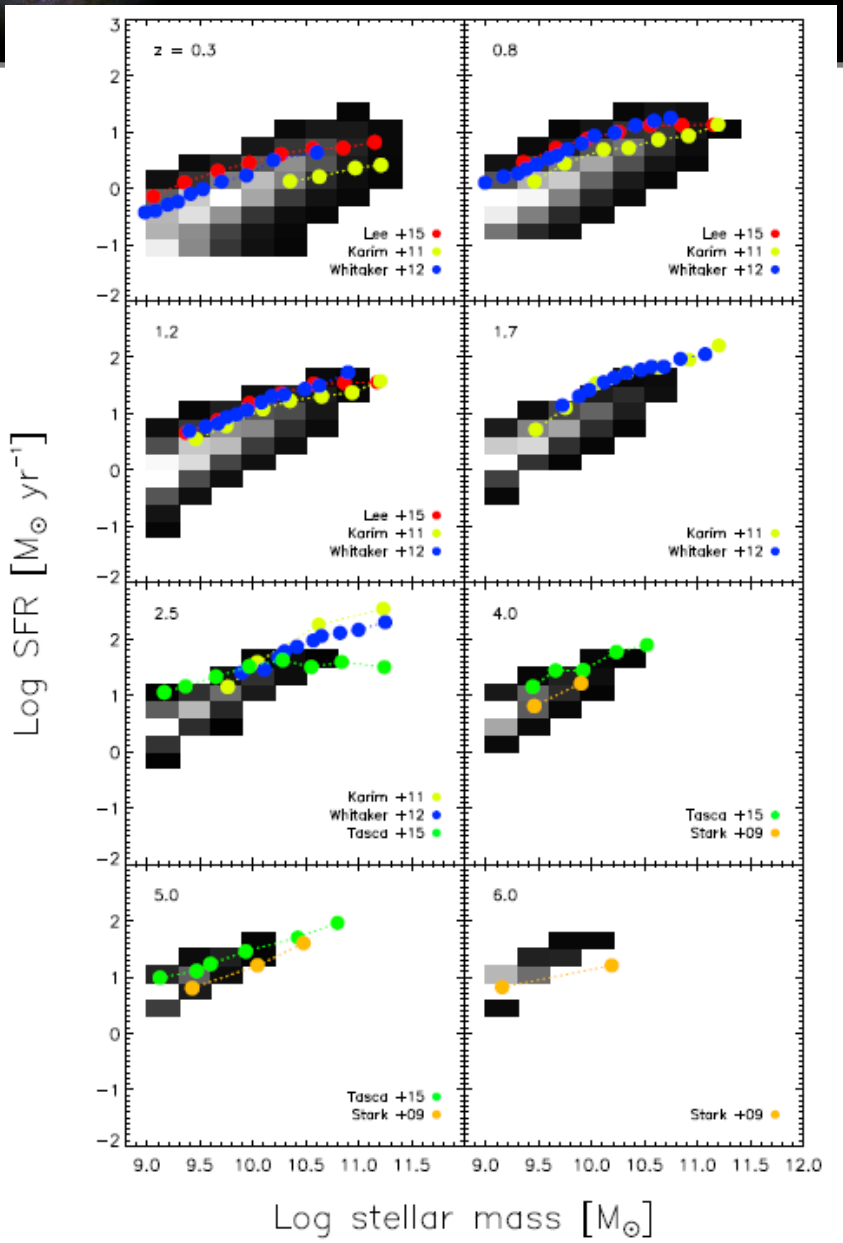
- Cosmological hydro simulation using RAMSES (Dubois +14)
- 100 h^{-1} Mpc, 1024^3 particles
- DM resolution 8×10^7 Msun
- SN (Kimm, PhD thesis) and AGN feedback (Dubois +12)
- Not tuned to local Universe, except for AGN feedback parameters

Rest-frame luminosity functions



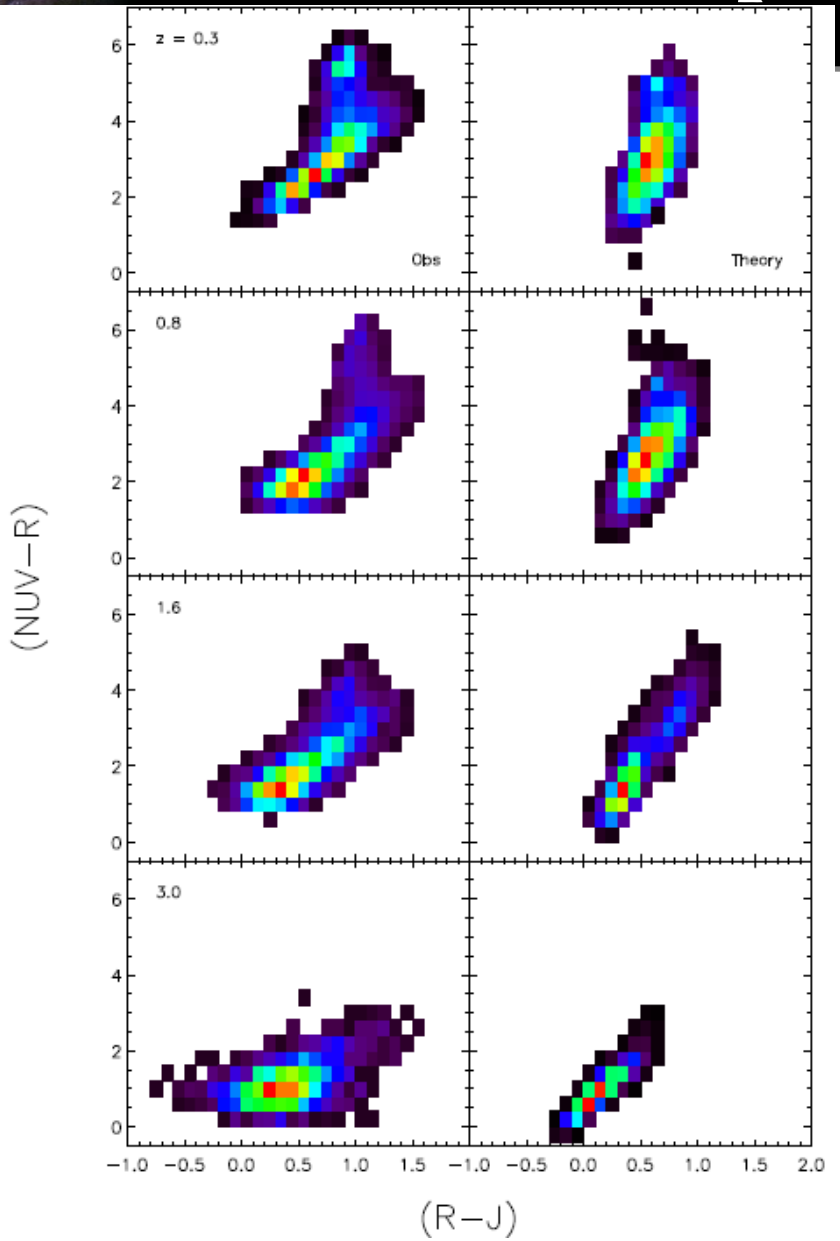
- Good reproduction of K-band and r-band luminosity functions
- K-band traces underlying stellar mass (at least at low z)
- r-band is more sensitive to the star formation history
- Good reproduction of both LFs at $0.1 < z < 1.7$ simulation successfully captures stellar mass buildup
- Systematic overproduction of low mass galaxies – SN feedback not strong enough

The star formation ‘main sequence’



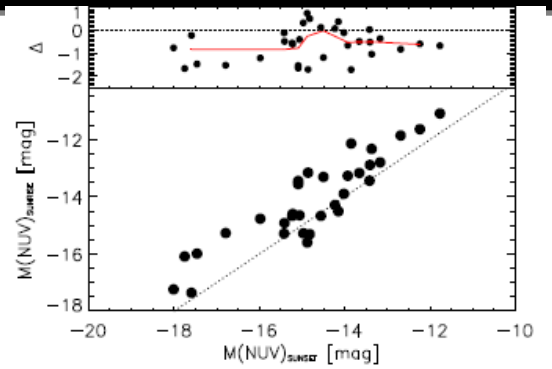
- SF main sequence derived by various authors using a variety of techniques
- Good reproduction within spread of observational data
- Around z=2.5 massive end undershoots observations – unclear why
- Predictions undershoot data regardless of stellar mass at z~6 (will come to this later)

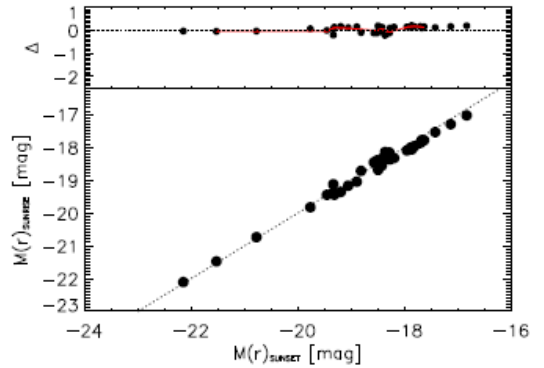
Rest-frame UV-optical-NIR colours

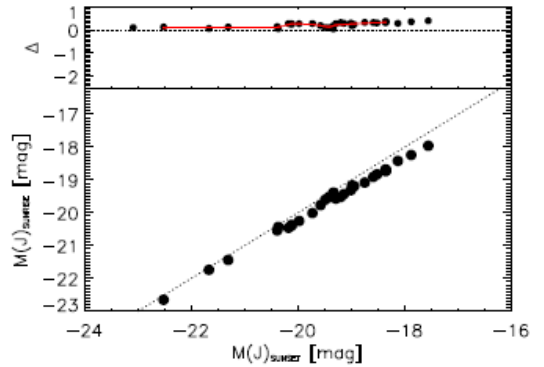


- NUV-optical-NIR colours are strong constraints on SFH (e.g. Yi +05)
- Compare Hz-AGN to colours from COSMOS2015 (Laigle +16)
- Main locus of predicted colours consistent with observations
- Predicted bimodality is too weak – quenching of star formation inadequate (especially at low z)
- But…colours are problematic, largely due to how we treat the dust

Rest-frame UV-optical-NIR colours

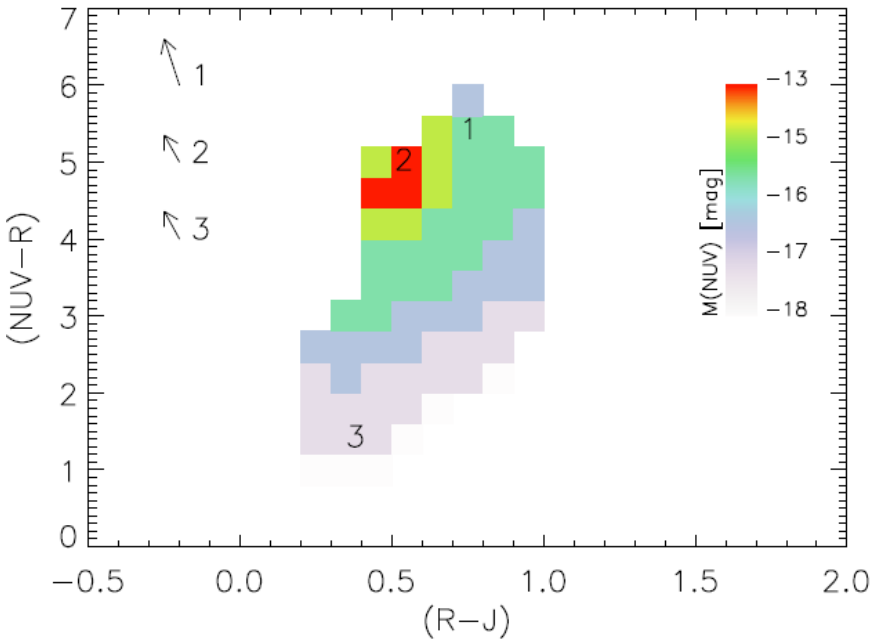






- Dust calculated using SUNSET – dust screen placed in front of every star particle
- How does this compare to a more accurate treatment with RT (using SUNRISE)
- Long wavelengths well approcimated by SUNSET
- Offsets present in NUV magnitudes

Rest-frame UV-optical-NIR colours



- Is bimodality better predicted using SUNRISE? Not really - bimodality still too weak in Hz-AGN
- Feedback recipes likely to blame – star formation quenching is not complete (in massive galaxies), only apparent when we use UV filters

Rest-frame UV-optical-NIR colours

More potential problems with dust:

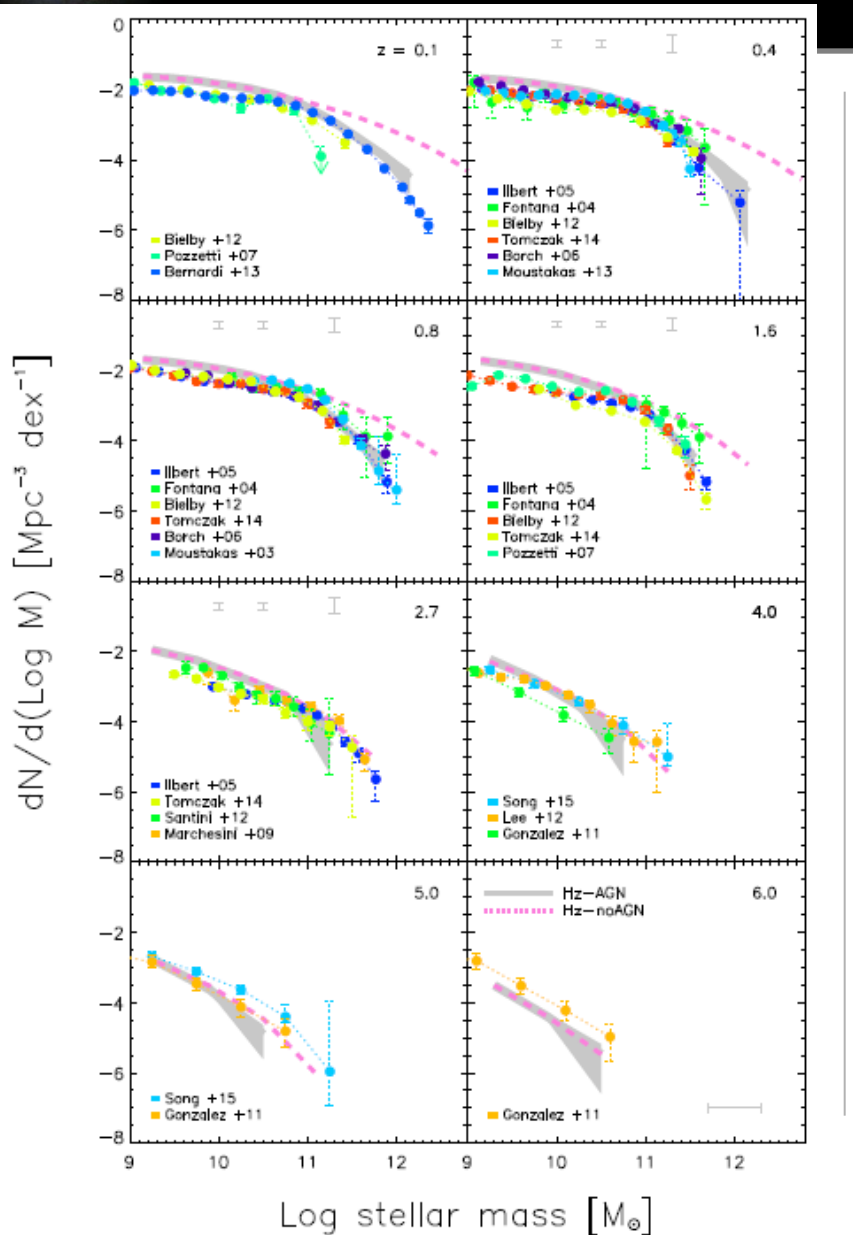
- Dust-to-metal ratio may not be a fixed (Milky-Way-like) value, likely to vary with both metallicity/metal column density (Vladilo +04, Fisher +14)

- Extinction law may be a function of age and metallicity (Buat +12)

- Lack of high redshift dust data – not clear that we can extrapolate local dust properties to high redshift

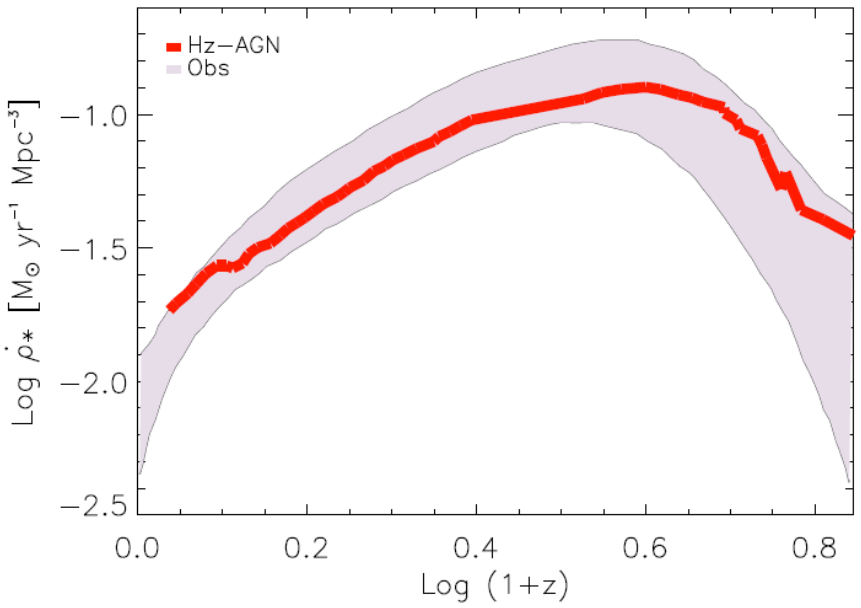
Colours (especially those involving short wavelength filters) not a good test of the accuracy of models at any redshift

Stellar mass functions



- Predictions match observations below the knee of the MF
- Overproduction of galaxies at the low mass end
  - More realistic treatments of clumpy ISM to drive stronger outflows (Kimm +15)?
  - Use SF efficiency at level observed in star clusters (10% per free fall time, Agertz +15)…clustered SF drives stronger outflows
- Predictions undershoots data at z~5
  - Mass/spatial resolution important (Kimm +12). Higher resolution -> resolve smaller haloes earlier -> earlier star formation -> order of magnitude SF enhancement (e.g. Kimm +12, Rasera & Teyssier +06)

Cosmic star formation history



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Summary

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- Hz-AGN reproduces key observables that trace the aggregate stellar-mass growth of galaxies over cosmic time

- Two main points of tension
  - Overproduction of low-mass galaxies
  - Galaxies not massive enough at z~5

  (Solvable via better SN feedback recipes and higher resolution simulation?)

- Hz-AGN is an excellent tool for studying galaxy evolution to z~5 and making predictions for future surveys . Already many papers: galaxy alignments (Welker + 15, Chisari +16), morphology (Dubois +16), impact of merging (SK + 15), evolution of BHs (Volonteri +16, Beckmann + 16)