What would we like to learn about galaxy formation from SPICA?

(a theorist's perspective)

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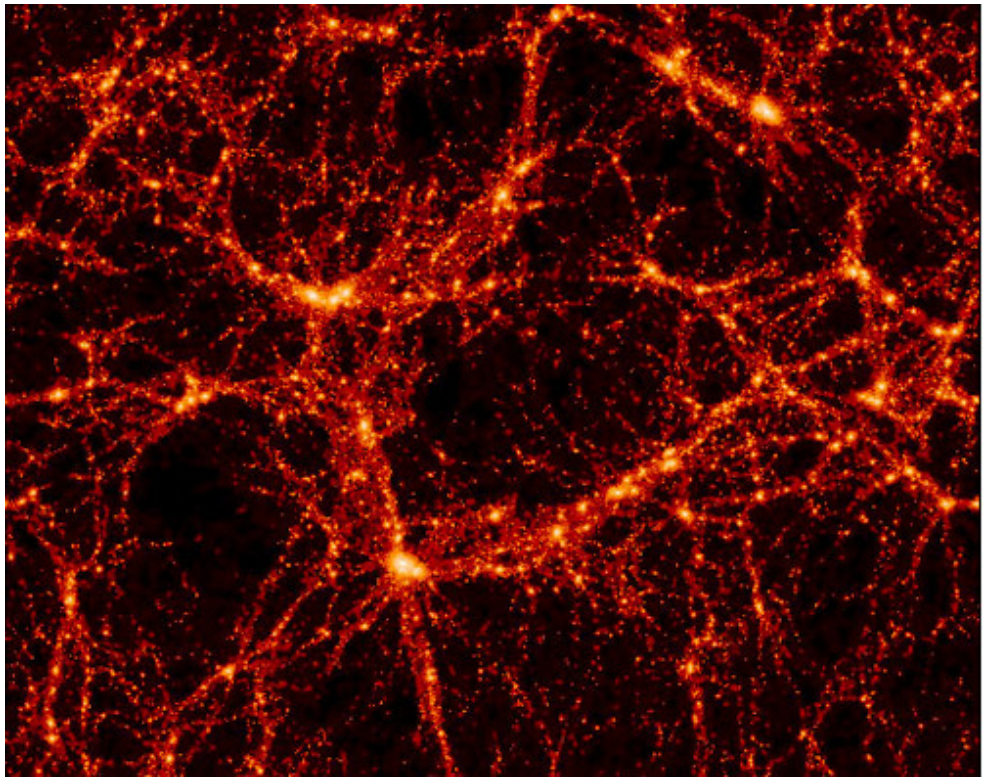
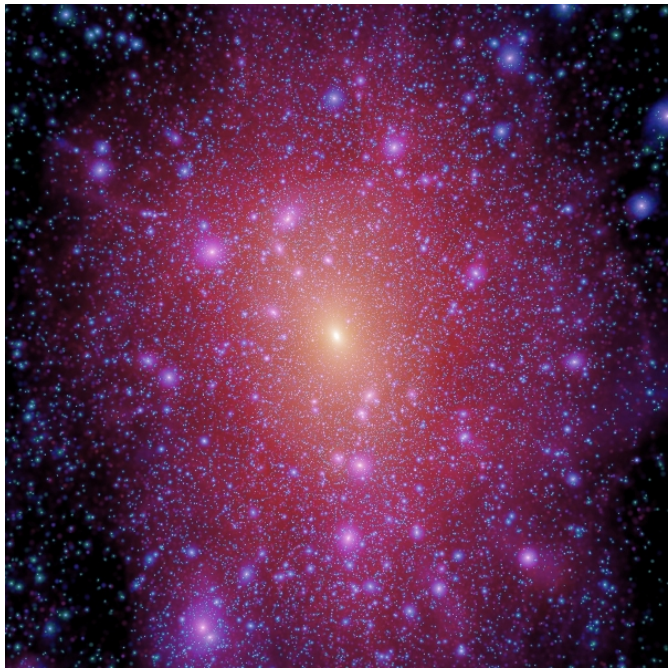
Physical processes in galaxy formation

- hierarchical formation of structure in dark matter
- collapse & cooling of gas in dark matter halos
- star formation
- stellar feedback
  - photoionization
  - supernova (SN) explosions
- chemical enrichment
- galaxy mergers & instabilities
- assembly of supermassive black holes
- AGN feedback

Evolution of dark matter





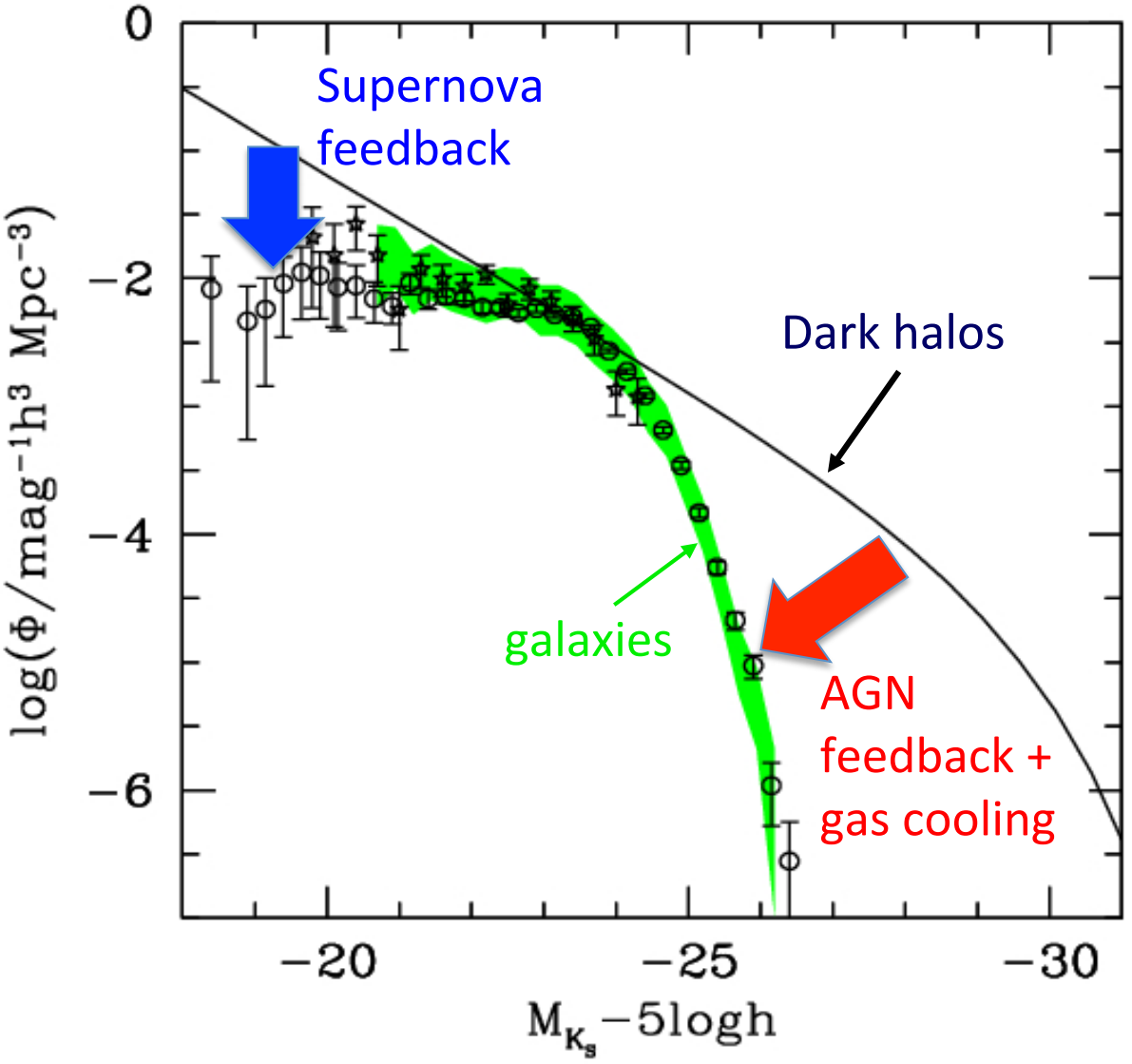
- Well understood in standard ΛCDM model

Explaining the galaxy luminosity function

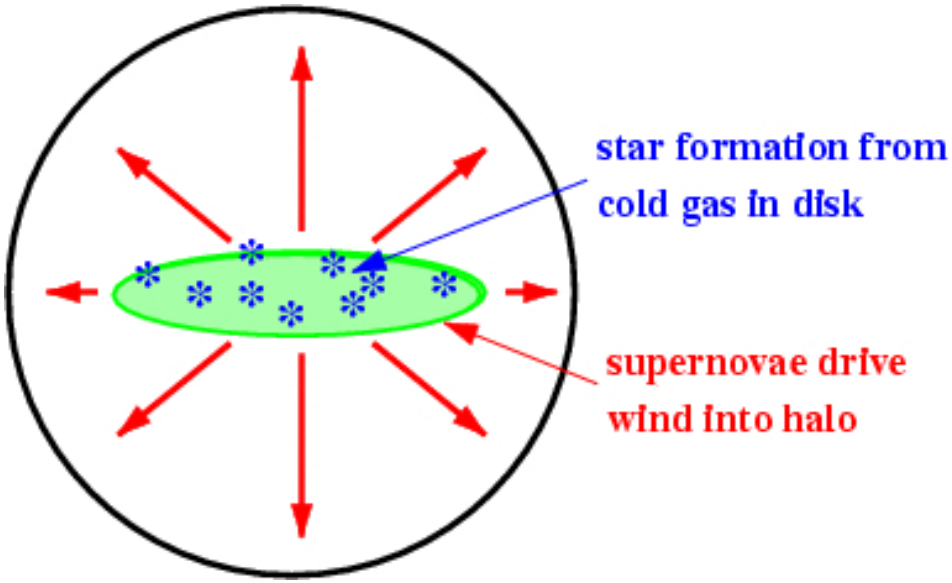
Halo mass function & galaxy luminosity function have different shapes

⇨

Strong effects on galaxy formation from stellar & AGN feedback

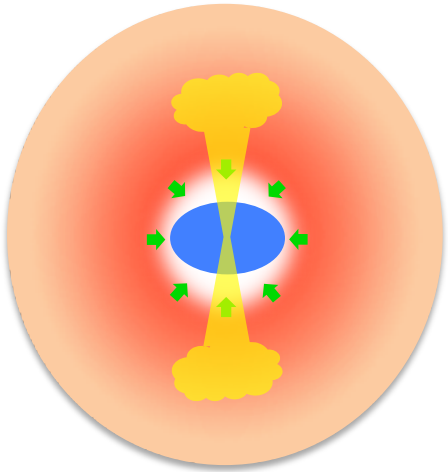


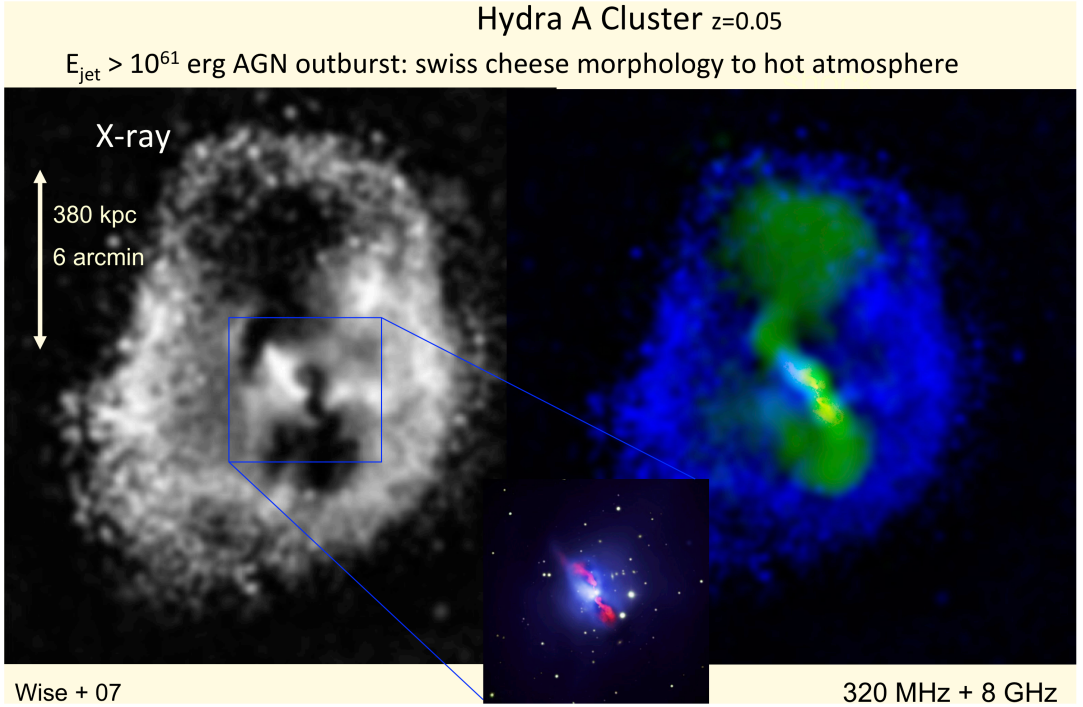
Supernova feedback



- Energy from SN drives galactic winds
- Very effective in low-mass halos

AGN feedback





- Relativistic jets heat halo gas & prevent further cooling
- QSO-driven winds may also be important at higher z
- AGN feedback mainly effective in higher-mass halos

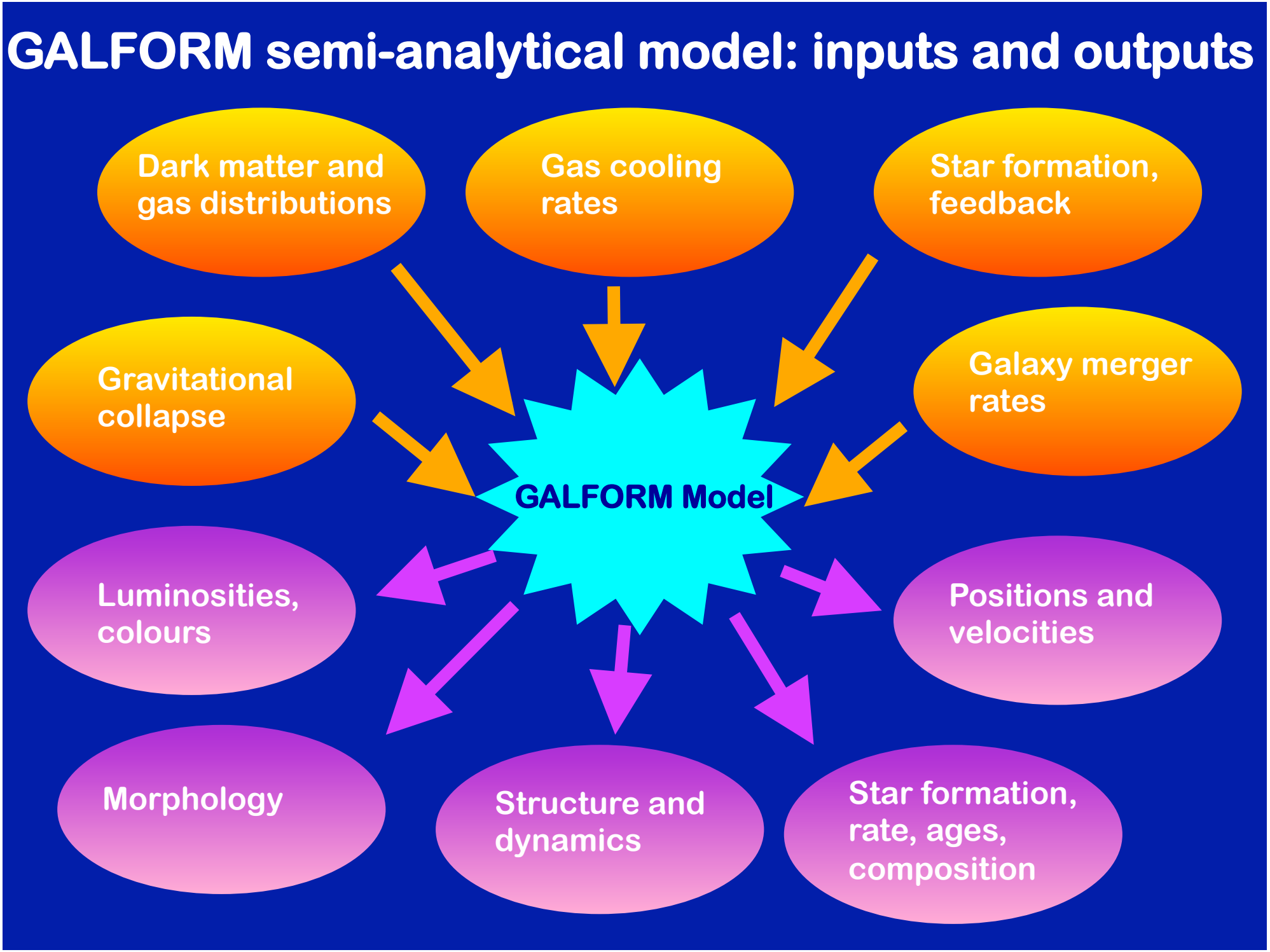
Star formation triggering: quiescent vs. starburst

Quiescent star forming disk

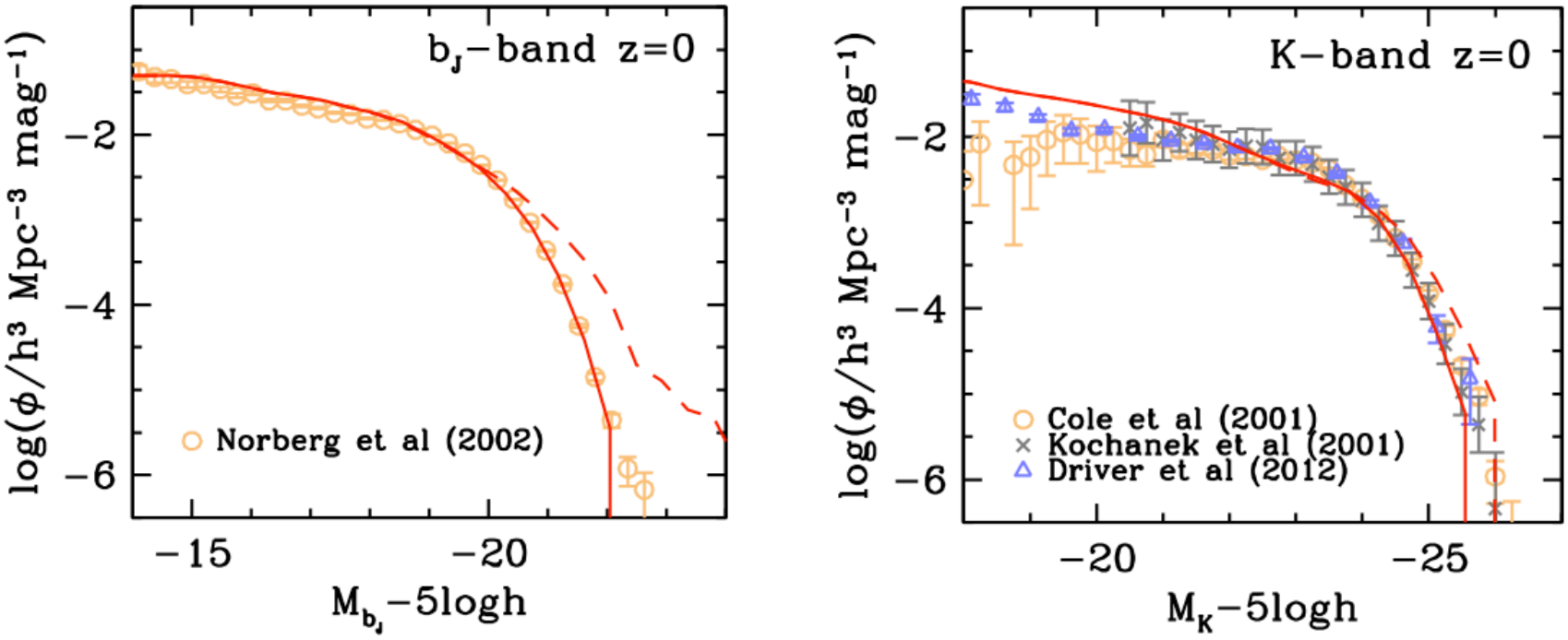
Galaxy merger

Disk instability

GALFORM semi-analytical model: inputs and outputs



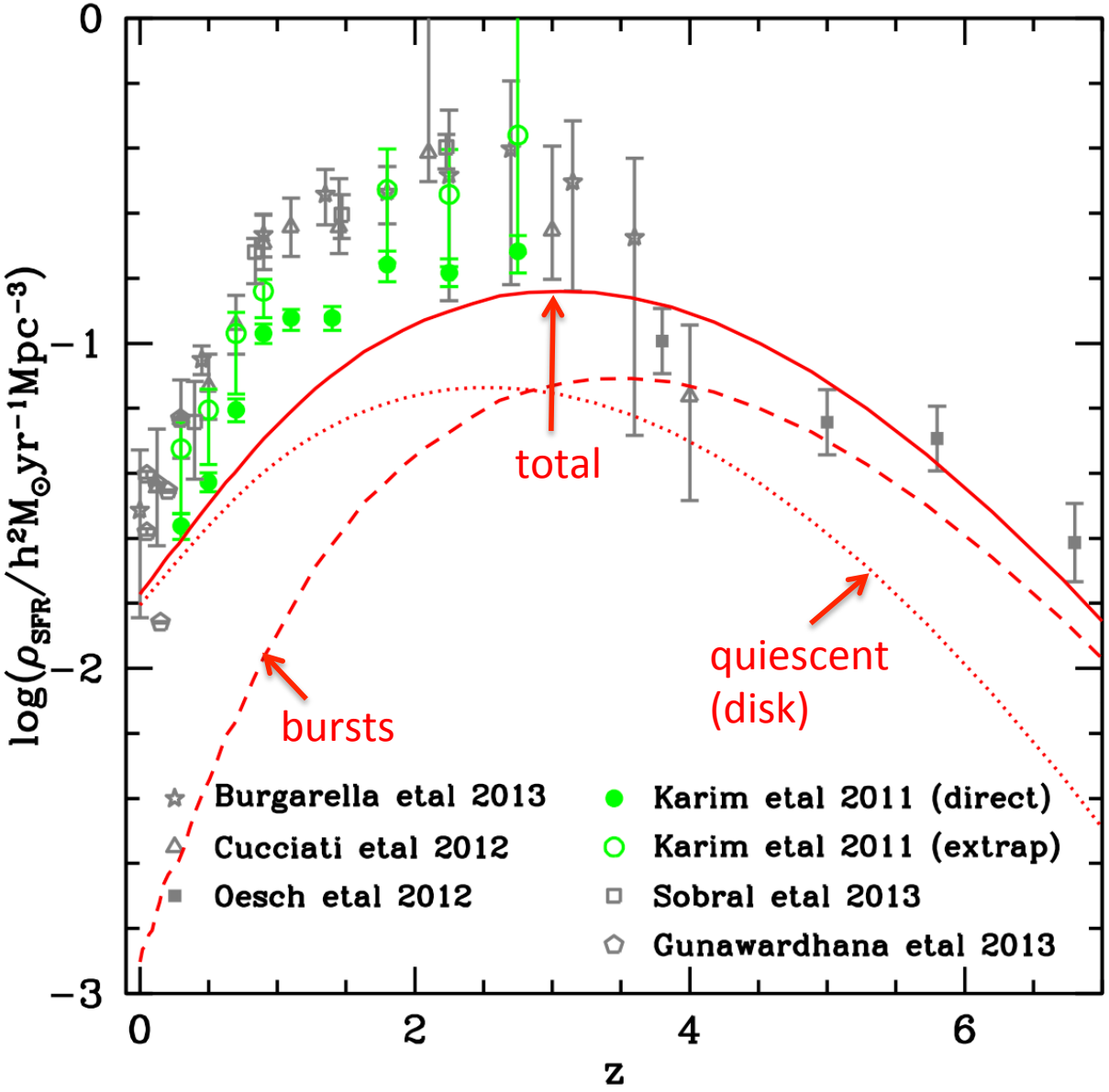
Galaxy formation models



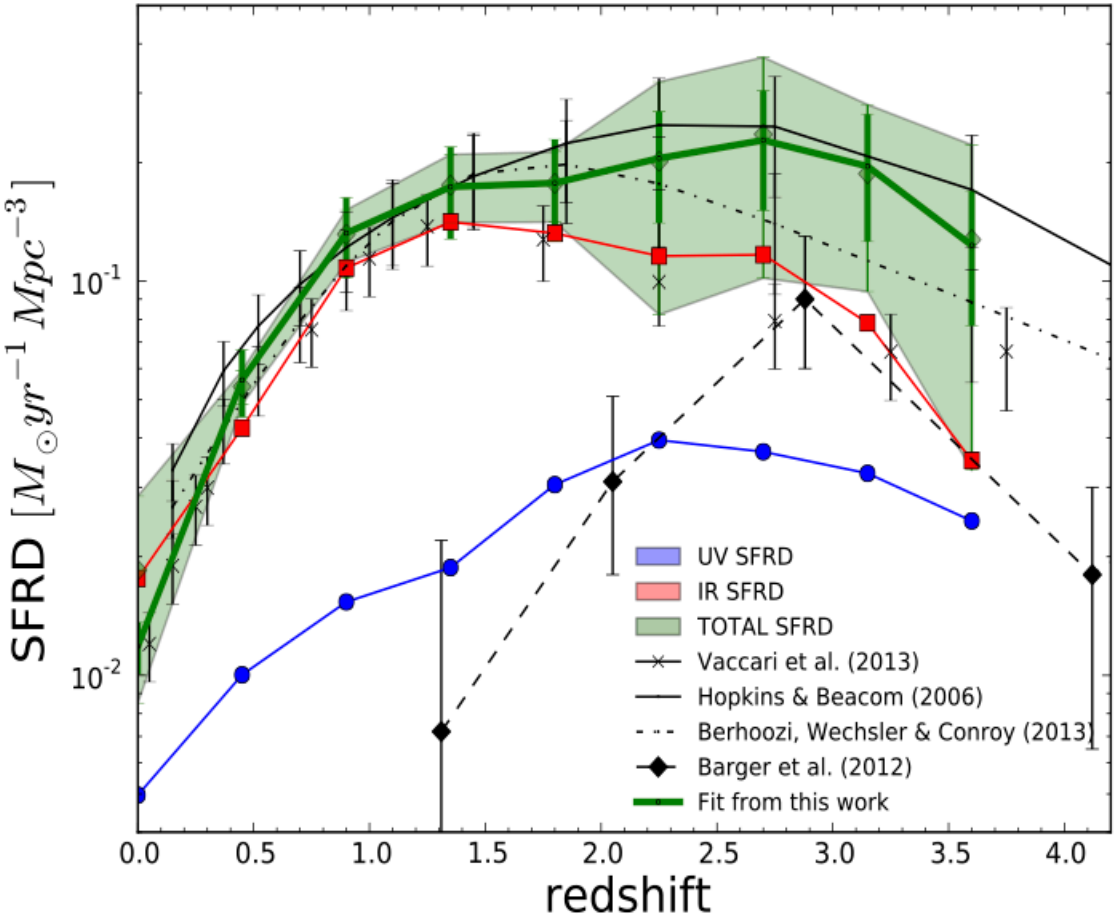
Lacey et al 2015

- galaxy formation models contain parameters for SN & AGN feedback & SF
- calibrate models on z=0 observations e.g. galaxy luminosity functions

Cosmic star formation history in Lacey15 model



Observed cosmic star formation history

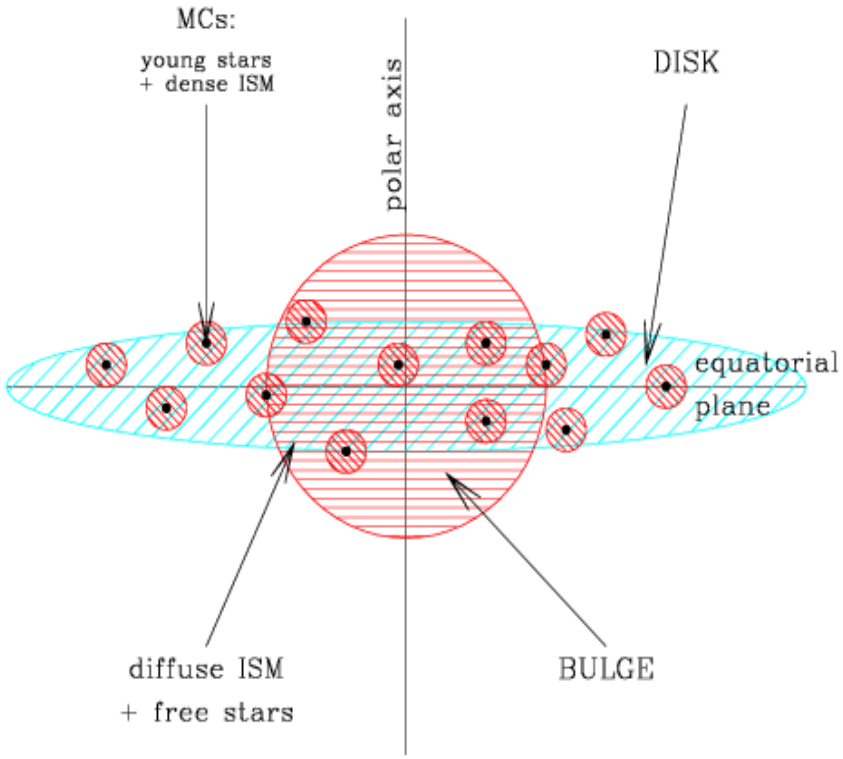


Burgarella+13

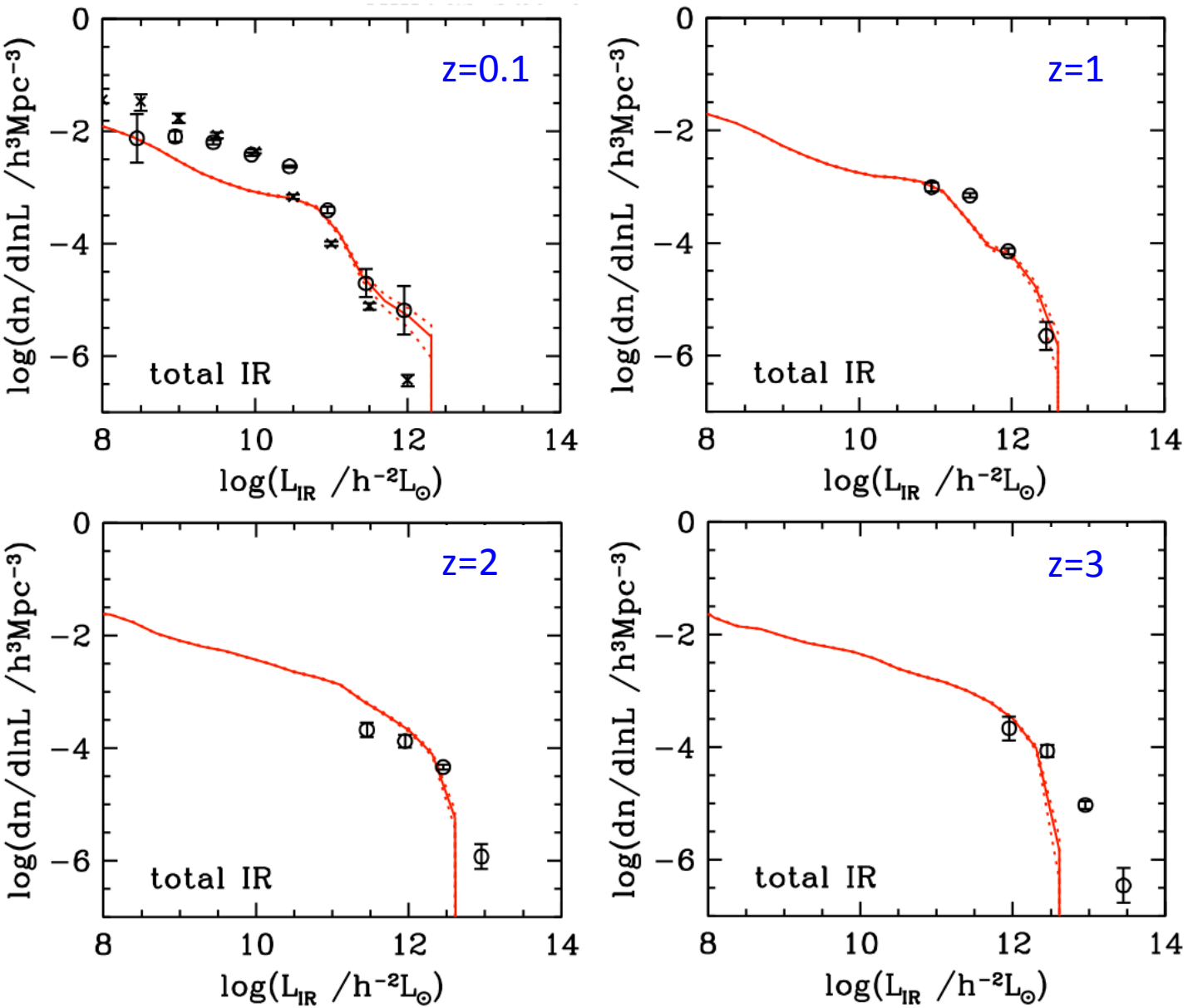
- Dominated by dust-obscured star formation at least up to z ~ 3 - 4

Modelling galaxy SEDS with dust

- dust in diffuse medium and molecular clouds
- stars form in clouds and leak out
- Stellar luminosity from pop synthesis
- radiative transfer of starlight through dust
- physical dust grain model
- heating/cooling of dust grains
  -> dust temperature
  -> IR/sub-mm emission



total IR luminosity function evolution



Model:
Lacey+15

Obs:
Gruppioni+13

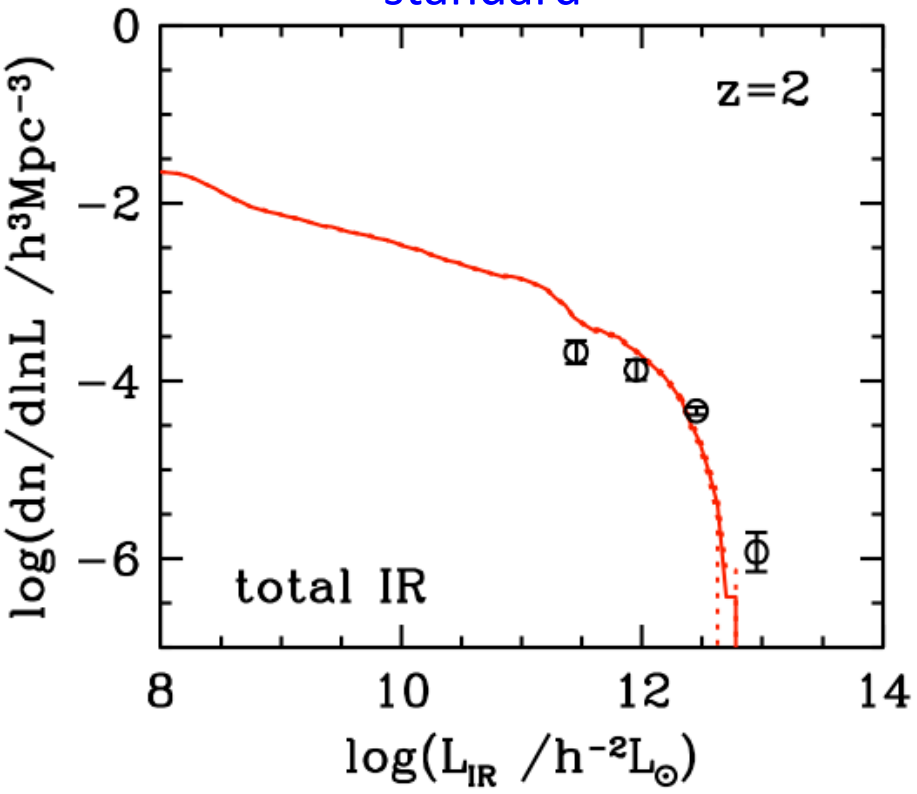
Uncertainties in galaxy formation models

- May have correct processes included in models, but detailed physics of star formation, SMBH assembly, SN & AGN feedback processes complex and still uncertain

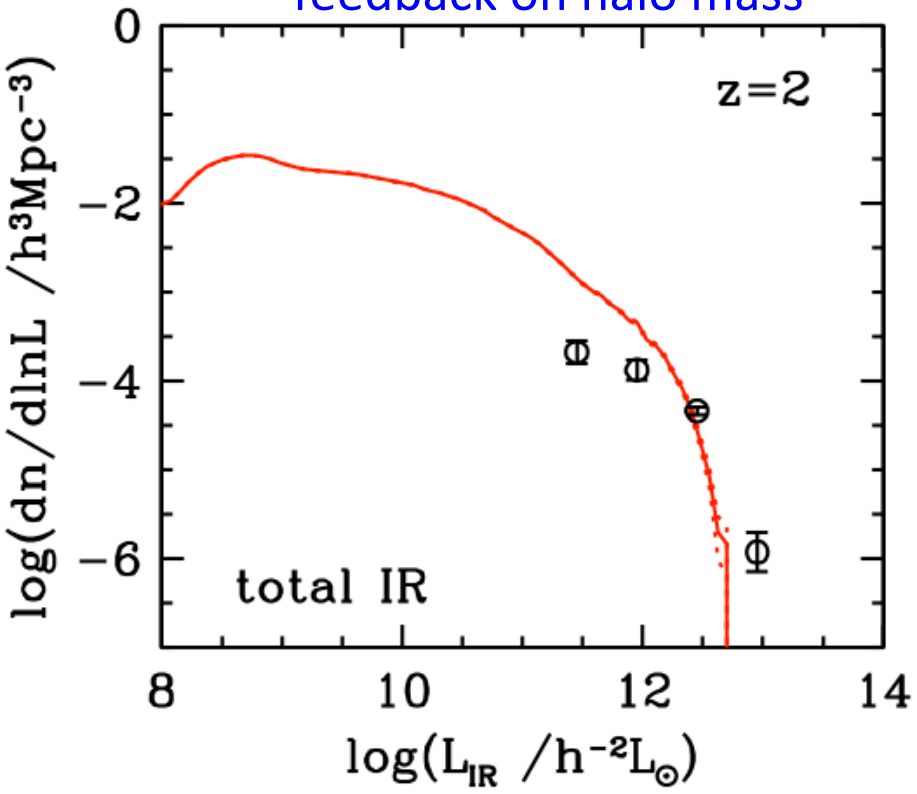
=> need high-redshift observations to test physics in models

Effects of varying SN feedback on IR LF

standard



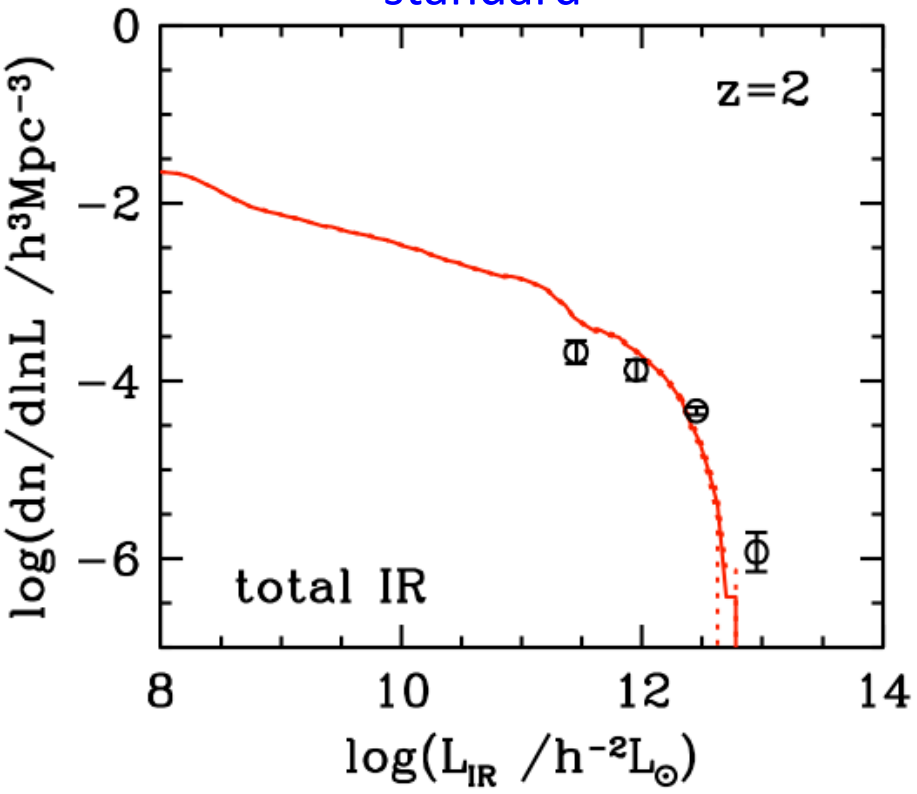
weaker dependence of SN feedback on halo mass



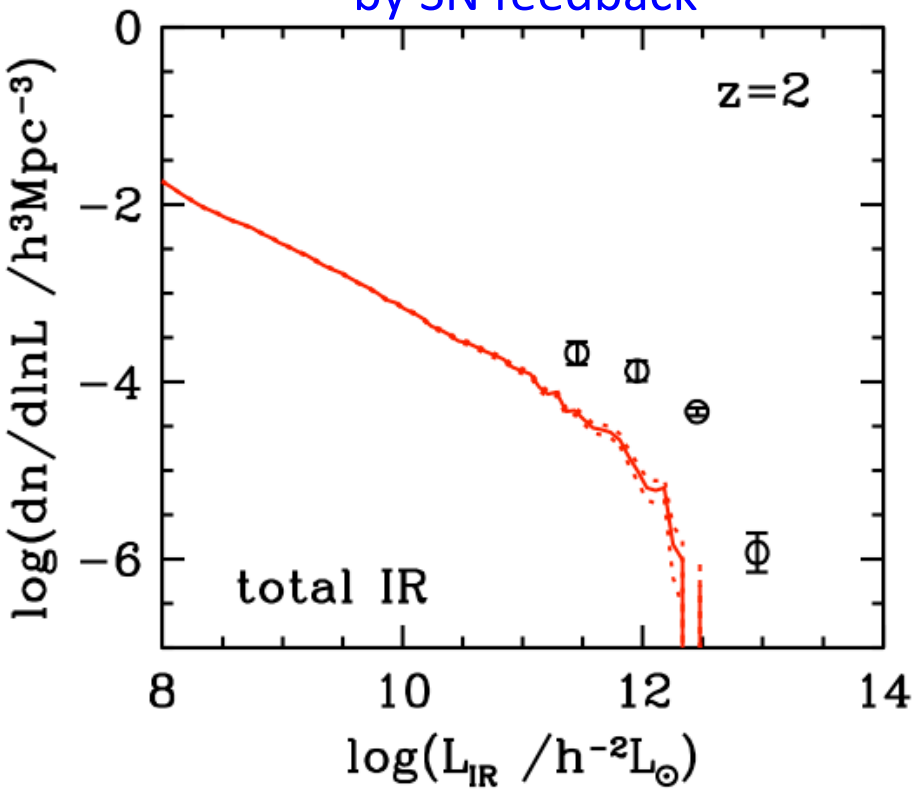
$$\dot{M}_{\rm eject} = \beta(V_c)\psi = \left(\frac{V_c}{V_{\rm SN}}\right)^{-\gamma_{\rm SN}} \psi$$

Effects of varying SN feedback on IR LF

standard



slower return of gas ejected by SN feedback

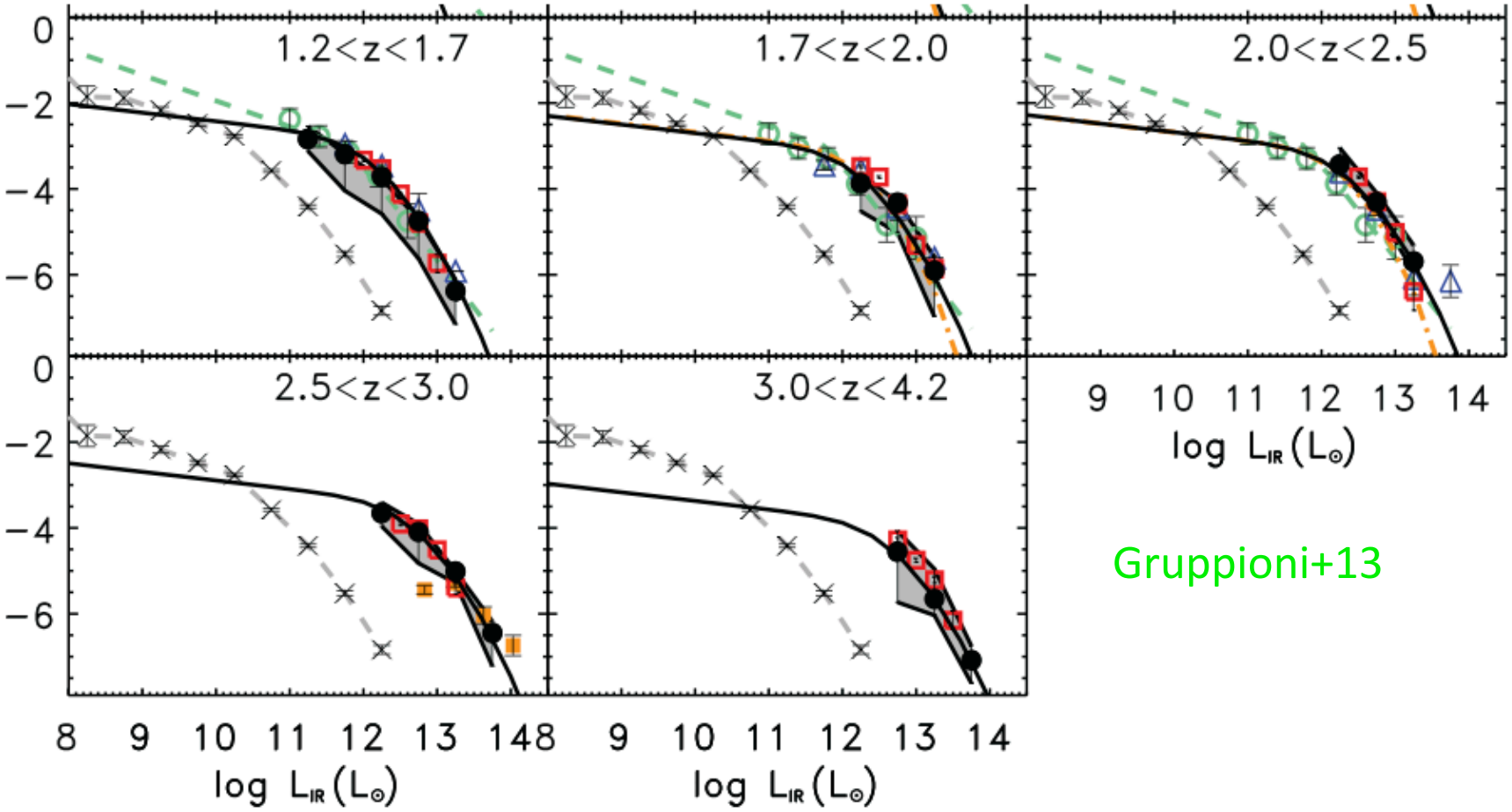


$$\dot{M}_{\rm return} = -\alpha_{\rm ret}\frac{M_{\rm res}}{\tau_{\rm dyn,halo}}$$

What might SPICA tells us about high-z galaxies?

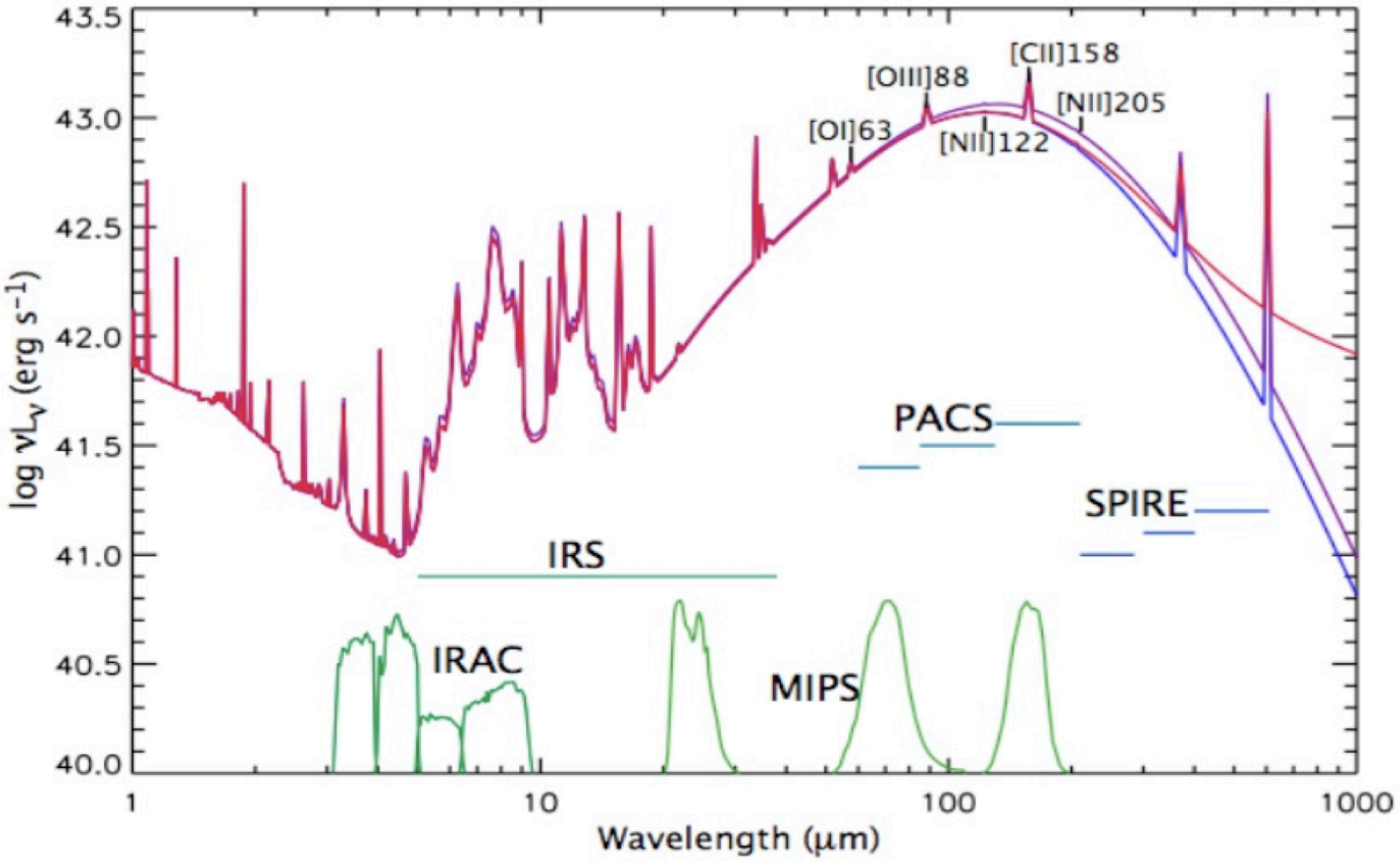
- SFRs
- Gas masses + metallicities
- ISM conditions -> clues to SF triggering
- dust
- AGN -> SMBH assembly & feedback
- Outflows -> feedback

Herschel observations of far-IR LF



Gruppioni+13

- Herschel limited by CONFUSION
- FIR LF at lower L_{IR} not constrained at high-z by Herschel data
- => no direct measurement at high-z of SFRs & dust obscuration for lower-mass galaxies, nor of total SFRD



- Herschel limited by confusion in far-IR
- SPICA will be even more confused for FIR continuum

=> Need to use FIR lines or MIR to circumvent confusion