The Herschel ATLAS and Galaxy Evolution

Steve Eales and the H-ATLAS consortium (with help from the GAMA team)

Basic Parameters:

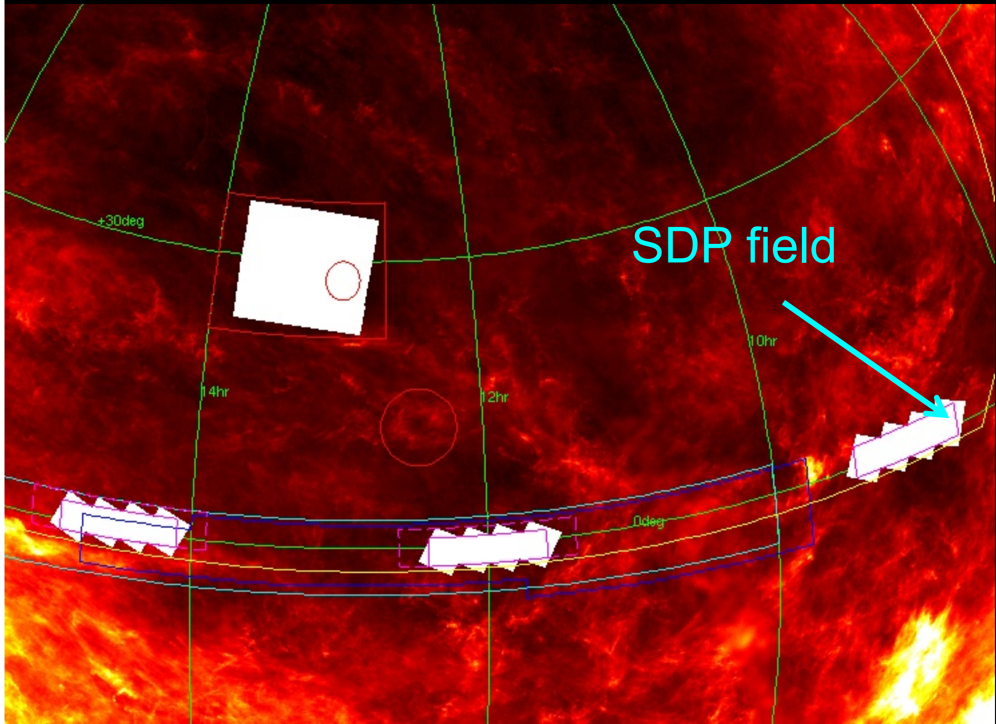
• survey of 550 square degrees in five bands from 100-500 μm
• team of 140 astronomers from 14 countries
• detected ≈500,000 sources at >5σ

Key Science Themes:

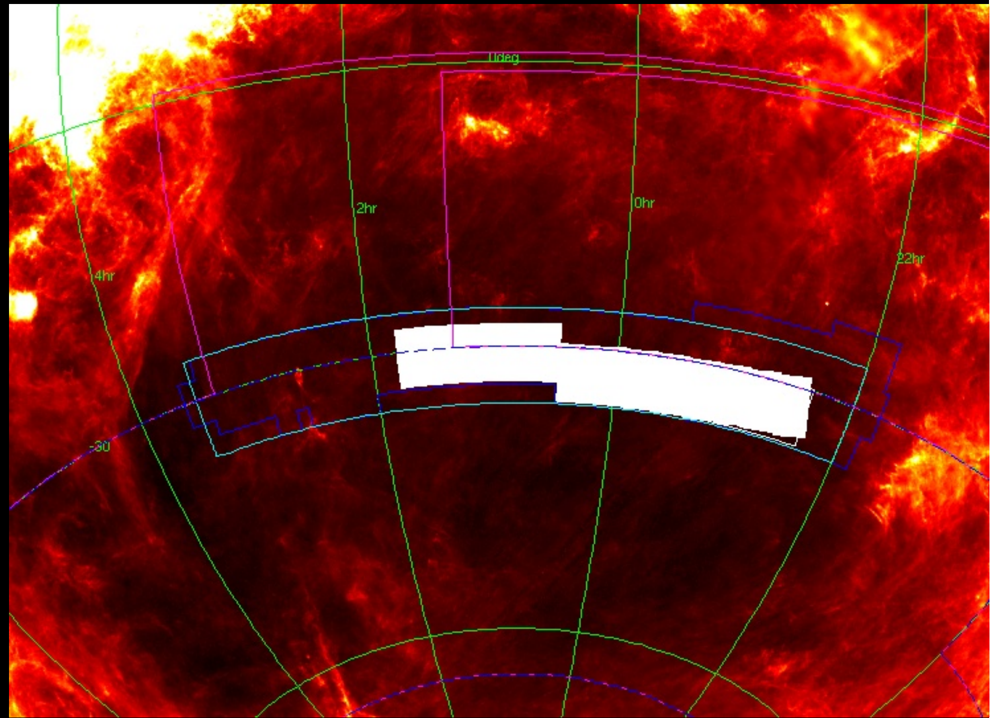
1. Local Universe Survey
2. Synergies with Planck
3. The Herschel Lens Survey
4. AGN and rare objects
5. Large scale structure and High-z galaxies
6. Galactic star and planet formation

See talks by Clark and Negrello, poster by Rowlands, Ibar, Dannerbauer, Gonzalez-Nuevo, Omont

NGP and Equatorial



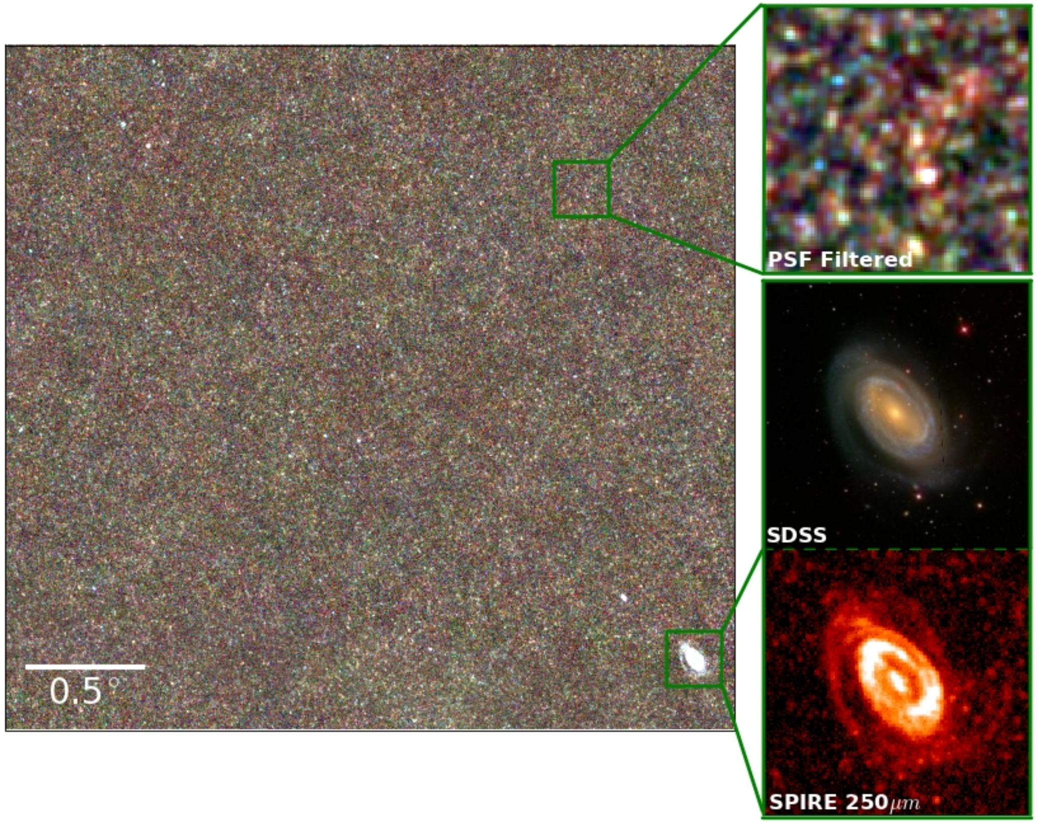
SGP



Fields chosen to allow maximum overlap with existing and planned surveys
GALEX, 2dF, SDSS, GAMA, UKIDSS, KIDS, VIKING, PanSTARRS, DES, SPT, SASSy

and to be accessible to new facilities which will be valuable for follow-up
ALMA, SKA and prototypes, SCUBA2, LOFAR, e-MERLIN

Survey Status



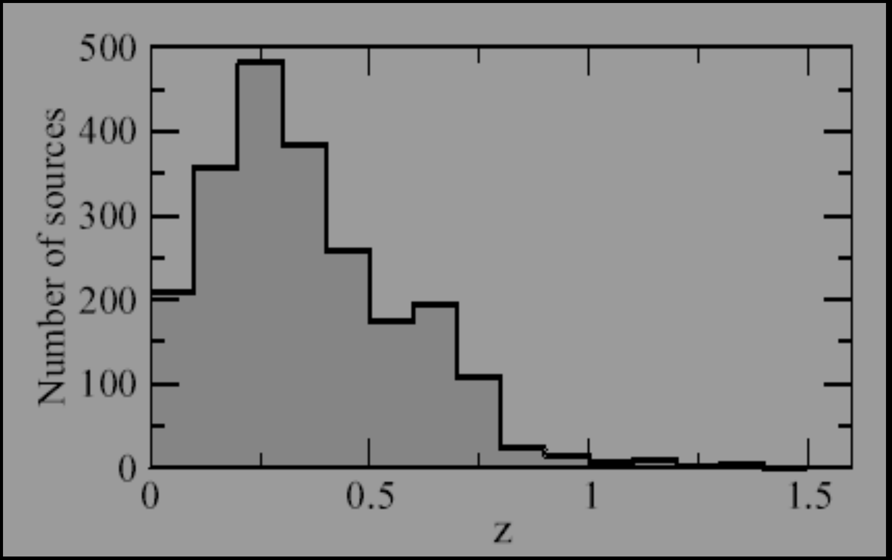
False-colour image made from the three SPIRE images (red-500 μm; green-250 μm; blue – 250 μm) of one sixteenth of the NGP field, which includes the Coma Cluster.

- Data from Science Demonstration Field (7000 sources + optical/IR counterparts) publicly released (h-atlas.org)
- H-ATLAS: internal data release for equatorial fields; worldwide data release planned for 2014
- SGP and NGP maps – all finished by summer 2013; world-wide data release of maps and catalogues planned for 2014

The Counterparts and their Redshifts

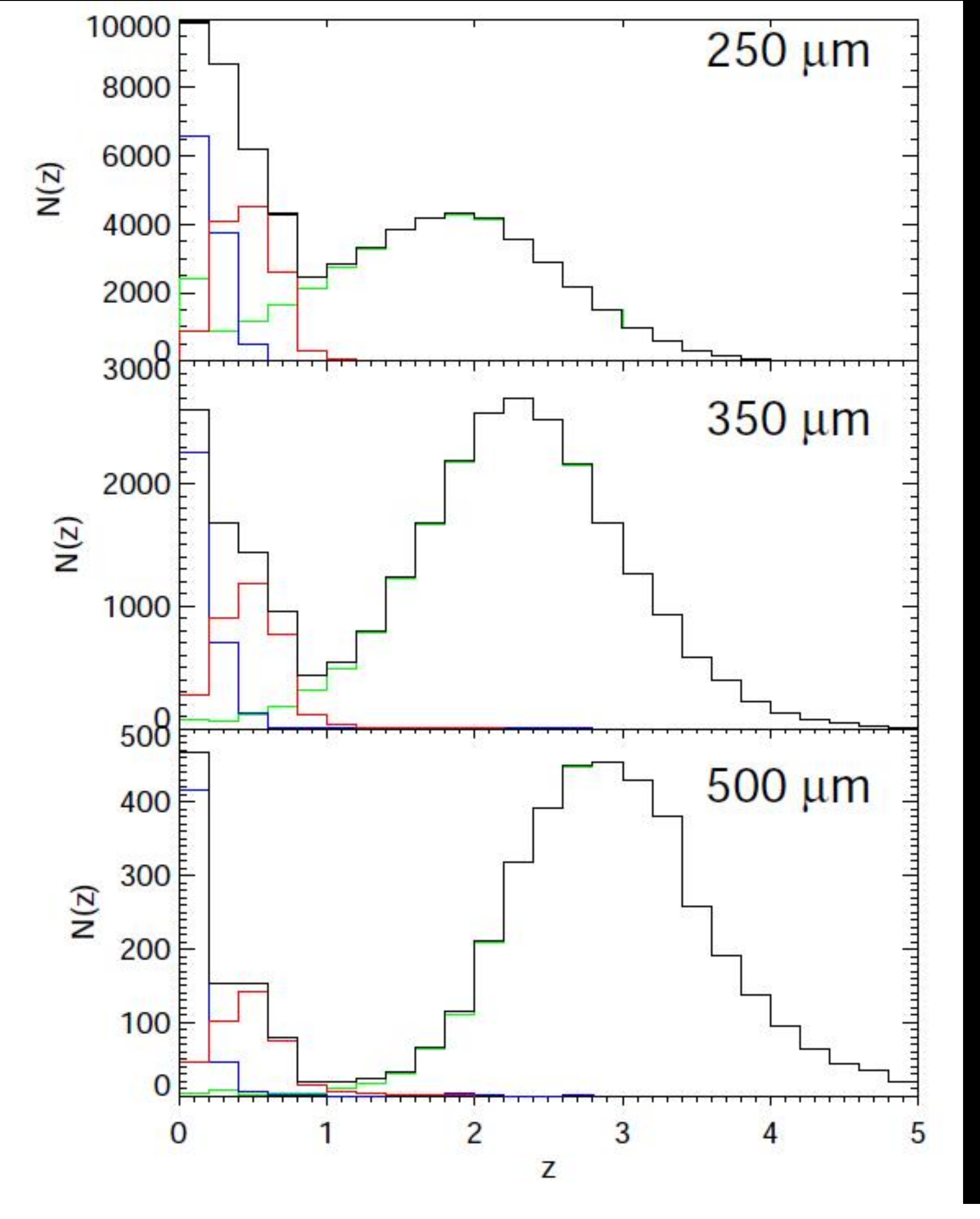
At low redshift we can find the counterparts directly -

We can find the counterparts to 1/3 of the sources using a Bayesian technique to match the Herschel sources directly to galaxies on the SDSS – *effectively complete upto z=0.5*



At high redshift we can use the Herschel colours

Redshifts from the Herschel Colours

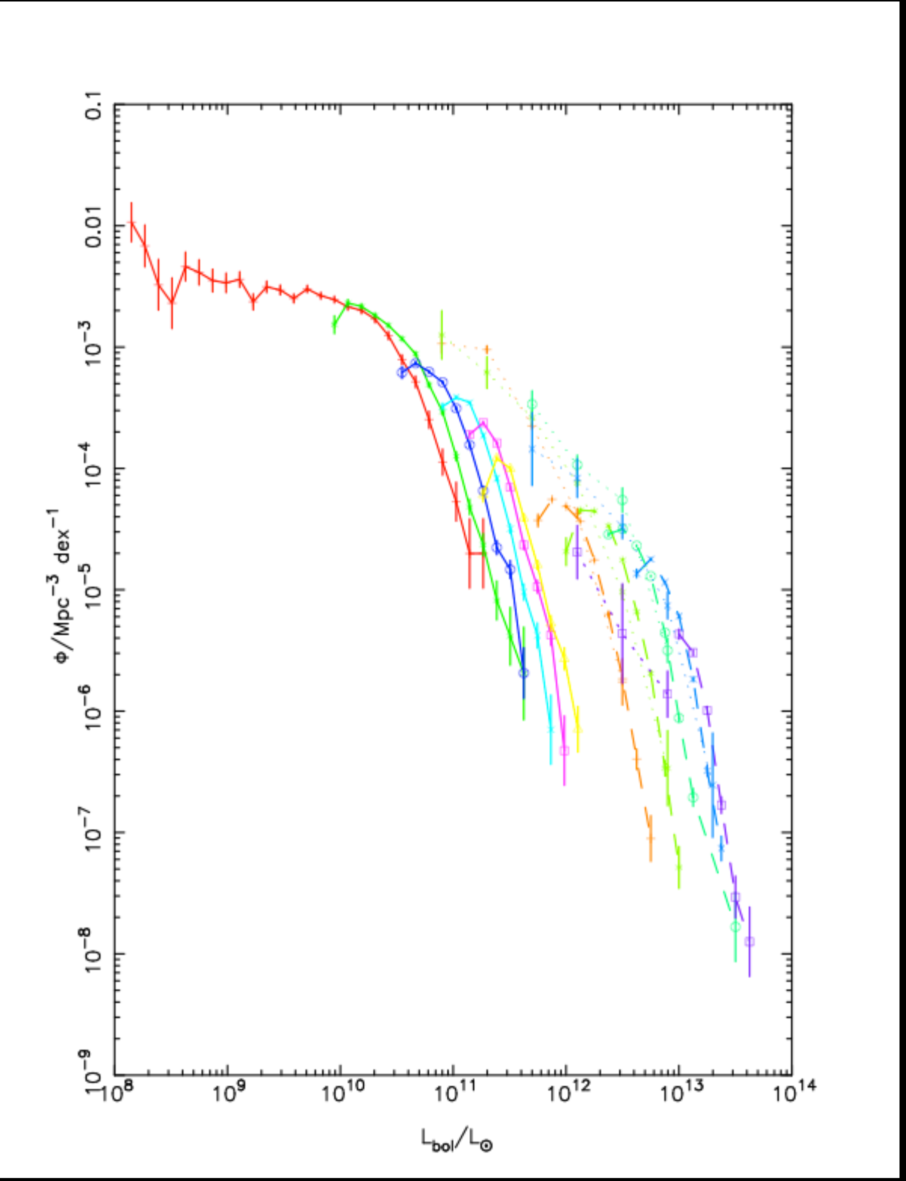


- Average template derived from the Herschel fluxes for 30 H-ATLAS galaxies with CO redshifts at 1 < z < 4.2 (Pearson et al. 2013, MN in press, astroph)

- Bimodel redshift distribution at 250μm suggests two population of sources. Lapi et al. (2011, ApJ, 742, 24) show that the high-redshift peak can be fit by a model in which the high-z sources are ellipticals being forced in single bursts of star formation – ***not necessarily unique model***

The luminosity function from z=0 to z=4.5

- Evolution seen at low redshift
- Consistency with Hermes results (Gruppioni et al. 2013)
- Steady evolution out to z=4.5
- Eales et al. in prep.

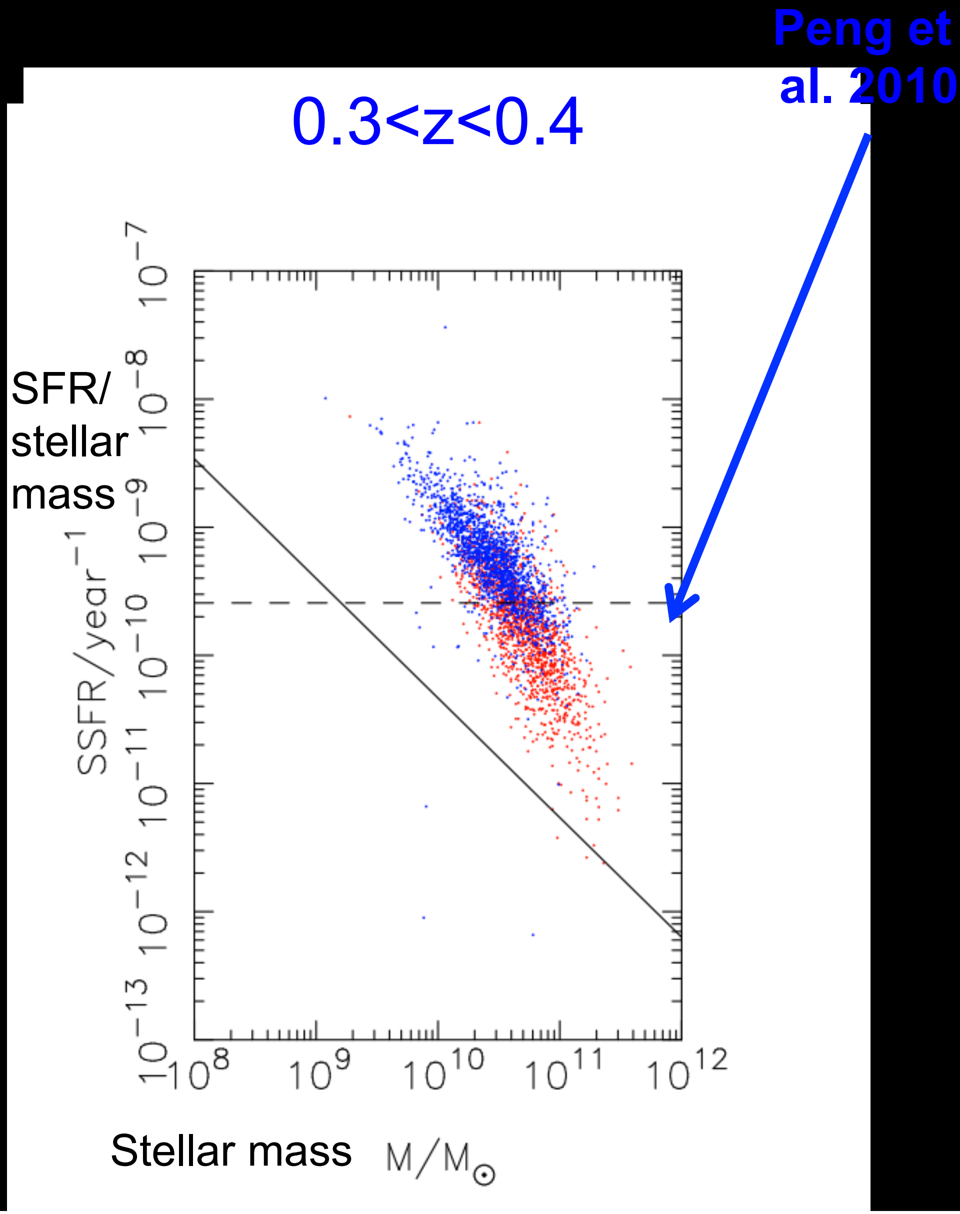


The galaxy main sequence

Stellar masses and star-formation rates derived from UV, optical, near-IR and Herschel photometry using MAGPHYS (Da Cunha et al. 2008)

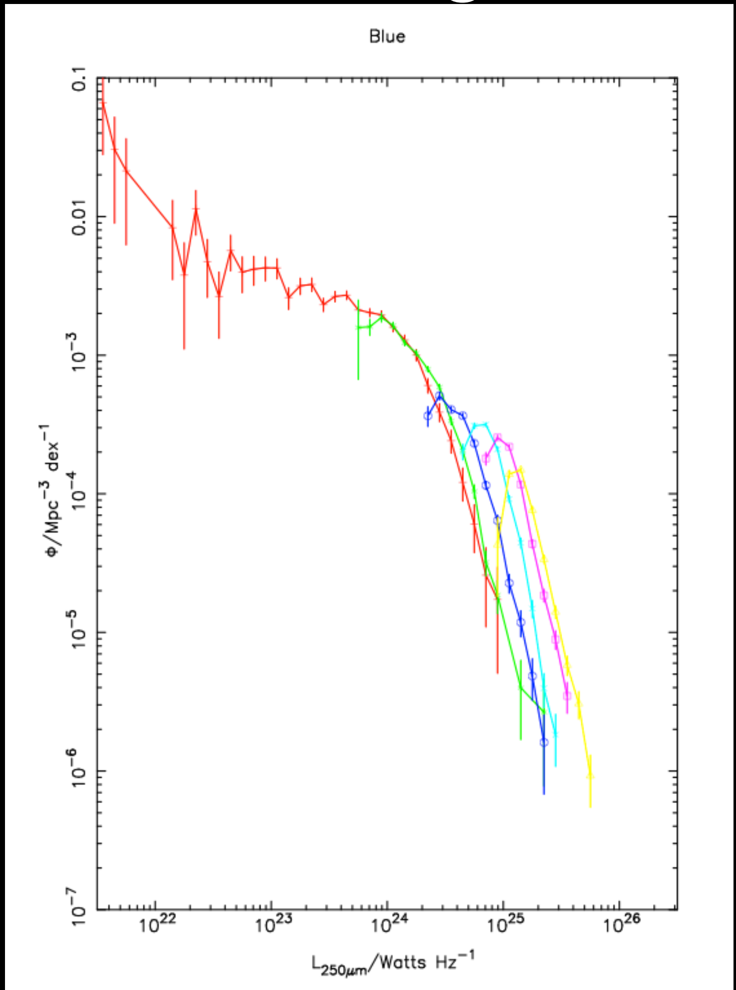
Division into blue and red galaxies using the criterion of Baldry et al. (2012)

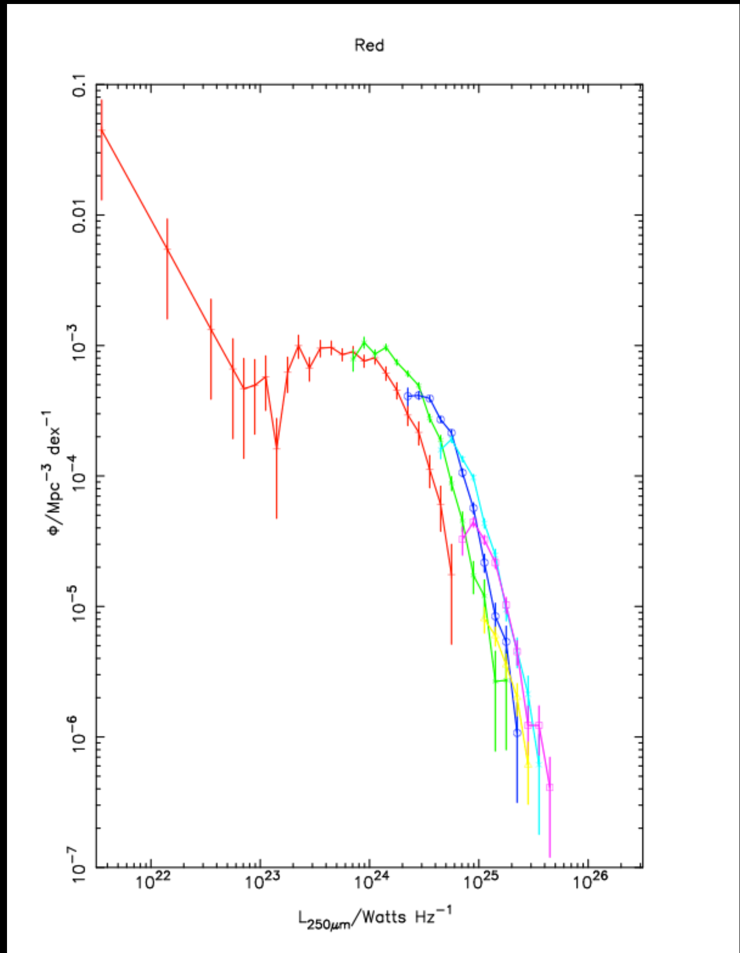
A similar steep GMS has recently found by the GAMA team (Bauer et al. 20130 at low redshift using a different method and by Whittaker et al. (2012) at high redshift



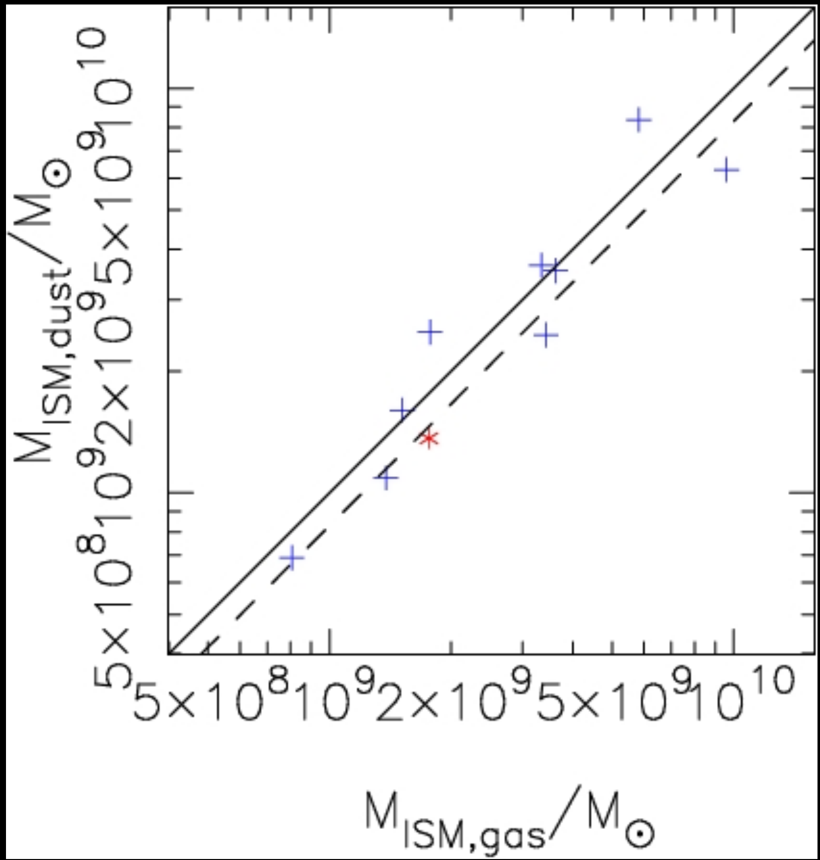
What are the red galaxies?

They show as strong cosmic evolution as the blue galaxies out to z=0.3





Can we use Herschel to measure the ISM masses in hundreds of thousands of galaxies?

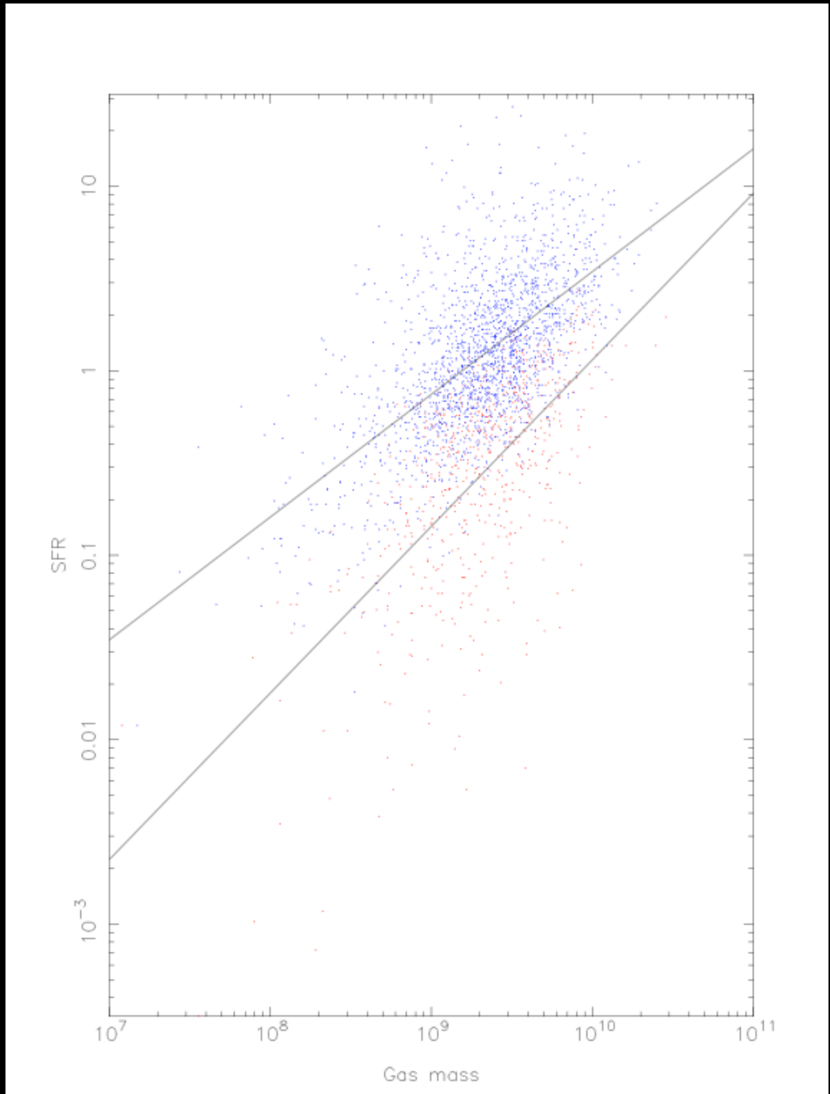


- Gas masses estimated from the dust and CO/HI for nine galaxies in Virgo and M31 (asterisk)
- CO X-factor determined by minimising the dispersion between the estimates (X≈2)
- Calibration agrees with that from Planck for the Milky Way (dashed line)
- rms discrepancy between estimates is 30% - ***includes all observational errors and the systematic errors in the two methods***

Eales et al. 2012, ApJ, 761, 168

The evolution of the overall luminosity function from z=0.4 to z=0 can be explained by the gradual reduction of the mass of the ISM in galaxies – Dunne et al. 2011.

The Schmidt-Kennicutt Law for red and blue galaxies



The red galaxies contain a large mass of gas but stars are forming more slowly per mass of ISM than in the blue galaxies.

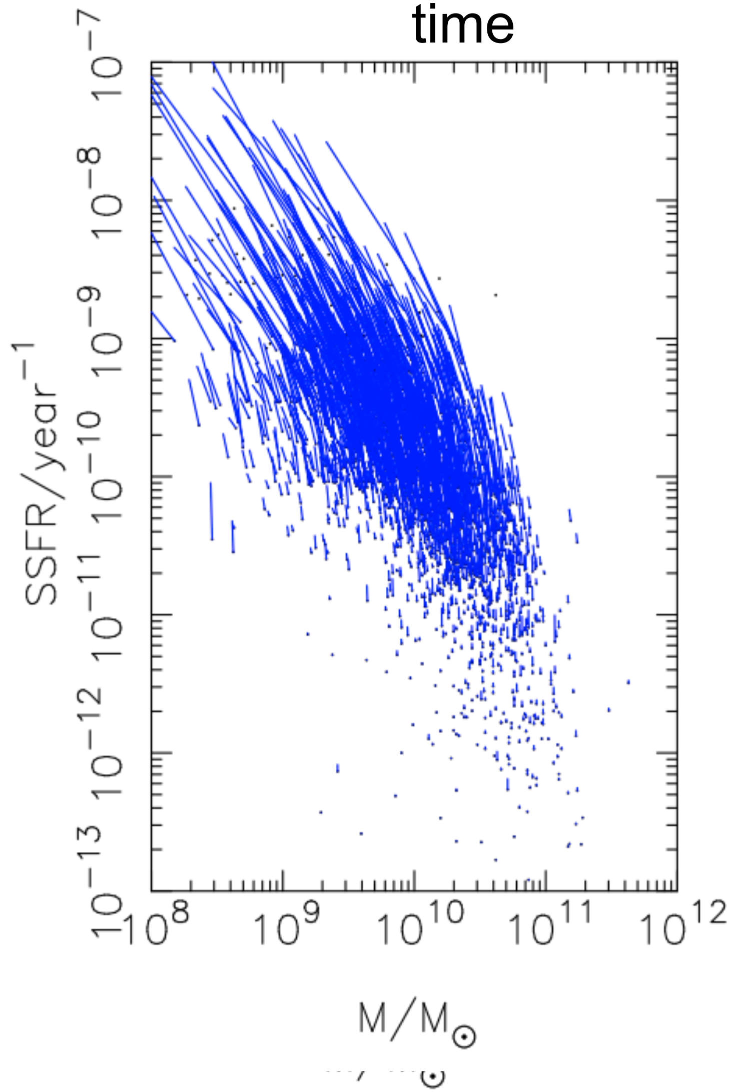
The galaxies might be dominated by atomic gas but measurement of the molecular gas in a similar sample of massive early-type galaxies (Saintonge et al. 2012) suggest that the star-formation rate per mass of molecular gas is indeed lower.

A simple model for evolution on the main sequence

- Use the dust mass as the instantaneous measure of the gas reservoir
- Assume no gas supply to galaxy

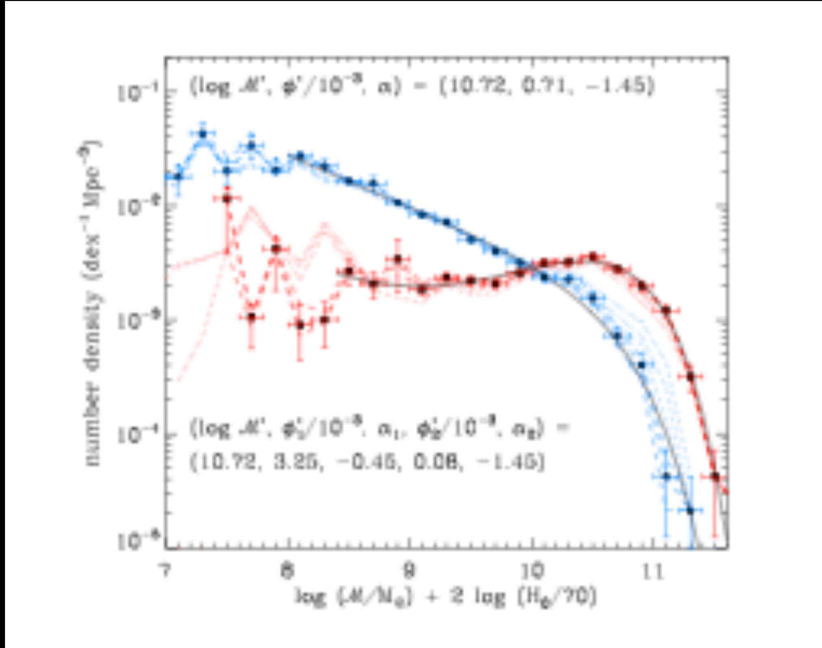
The red galaxies are evolving very slowly ('zombie galaxies'; low-mass galaxies are evolving too quickly

0.5 Gyr backwards in time



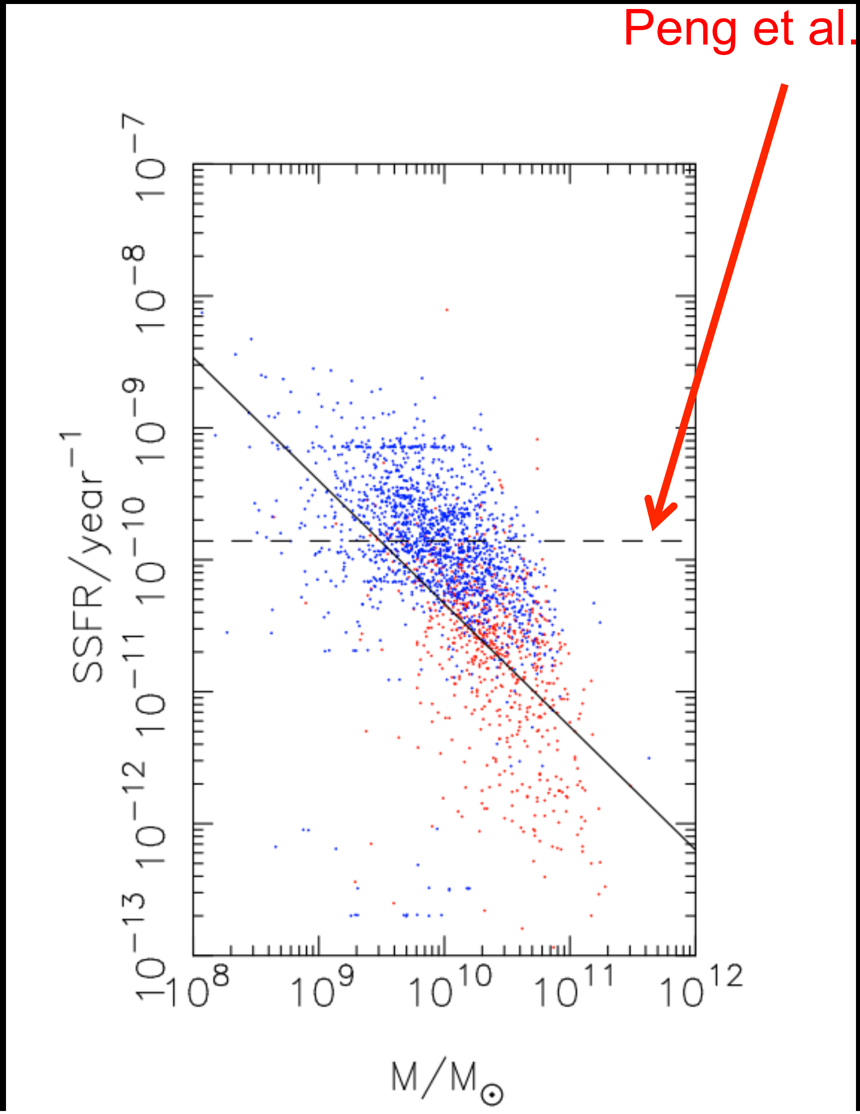
Disagreement with the paradigm?

- Removal of gas is the commonly accepted way of ‘quenching’ the star formation in a star-forming galaxy to turn it into a red dead galaxy
- Peng et al. (2010) find star-formation rate (SFR) divided by stellar mass (M*) is a constant
- They show that a ‘quenching rate’ that is proportional to SFR can explain the shape and constancy of the stellar mass function for blue star-forming galaxies
- They also show that this quenching relation one can explain the stellar mass function of red galaxies



Two types of quenching?

- We could still explain the shape relative shapes of the stellar mass functions for blue star-forming and red galaxies with a quenching rate proportional to stellar mass
- The red galaxies are not galaxies in transition between star-forming galaxies and red and dead ellipticals – they are evolving too slowly
- Is there a second type of less catastrophic quenching that occurs at low redshift and reduces the star-formation efficiency?



Conclusions

1) We find that a significant proportion (1/4 to 1/3) of the H-ATLAS galaxies at $z < 0.4$ have red optical colours
2) This population shows as a strong cosmic evolution as the blue galaxies
3) The Schmidt-Kennicutt law is offset by a factor of ≈6 between the two populations
4) The red galaxies are now individually evolving very slowly and are not transition objects between the ‘main sequence’ and red and dead galaxies devoid of gas
5) There must be a second evolutionary channel between the star-forming main sequence and red galaxies.
6) The overall evolution at $z < 0.4$ can be explained by a general decrease in the ISM reservoirs in galaxies (Dunne et al. 2011)