WG2: High-redshift universe, galaxies and galaxy evolution

Key science:

1. When (and where) do stars form and galaxies assemble?

i.e. Transformation of gas to stars, and evolution of galaxies, over cosmic time from the Dark Ages to the present day. Role of mergers, chemical evolution of galaxies and the IGM

2. Co-evolution of galaxies and their central black holes

3. Evolution of large-scale structure as traced by gas and galaxies ('cosmic web')

WG2: High-redshift universe, galaxies and galaxy evolution

Focus of our discussion

- This community is already multi-wavelength in its approach, studies of galaxy evolution are identified as 'key science' for many of the next-generation facilities discussed at this meeting.

- Our main aim was therefore to identify 'gaps and missing links' together with issues needing further work.

- We also recognize the importance of reconciling the 'fossil record' in the local universe with direct observations at high redshift, and note that there is still important work to be done on nearby galaxies.

WG2: High-redshift universe, galaxies and galaxy evolution

Stars and gas in the local universe

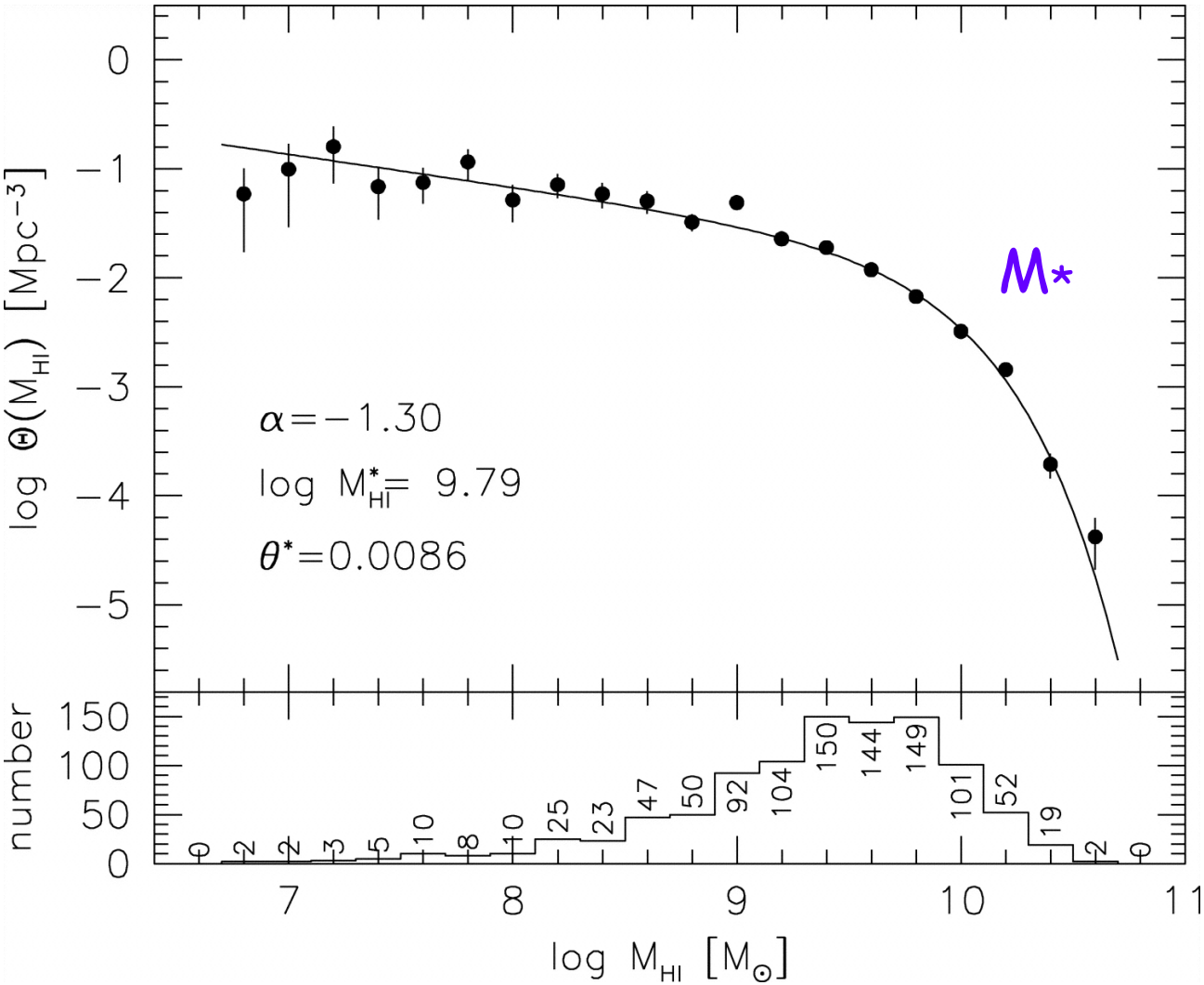
- The census of galaxies, gas and star formation in the local universe is essentially complete, largely thanks to recent large-area surveys (SDSS, 2dFGRS, HIPASS...)

- Local HI mass function well-determined, 'dark galaxies' without an optical counterpart are extremely rare

- Star formation occurs in a wide range of environments, SF rates cover at least five orders of magnitude (0.01 to 1000 Msun/year)

- Still need spatially-resolved information of high-quality in a carefully sampled way using SDSS/2dF to define sample – i.e. a galaxy GAIA project?

The local HI mass function (HIPASS, Zwaan et al. 2003)

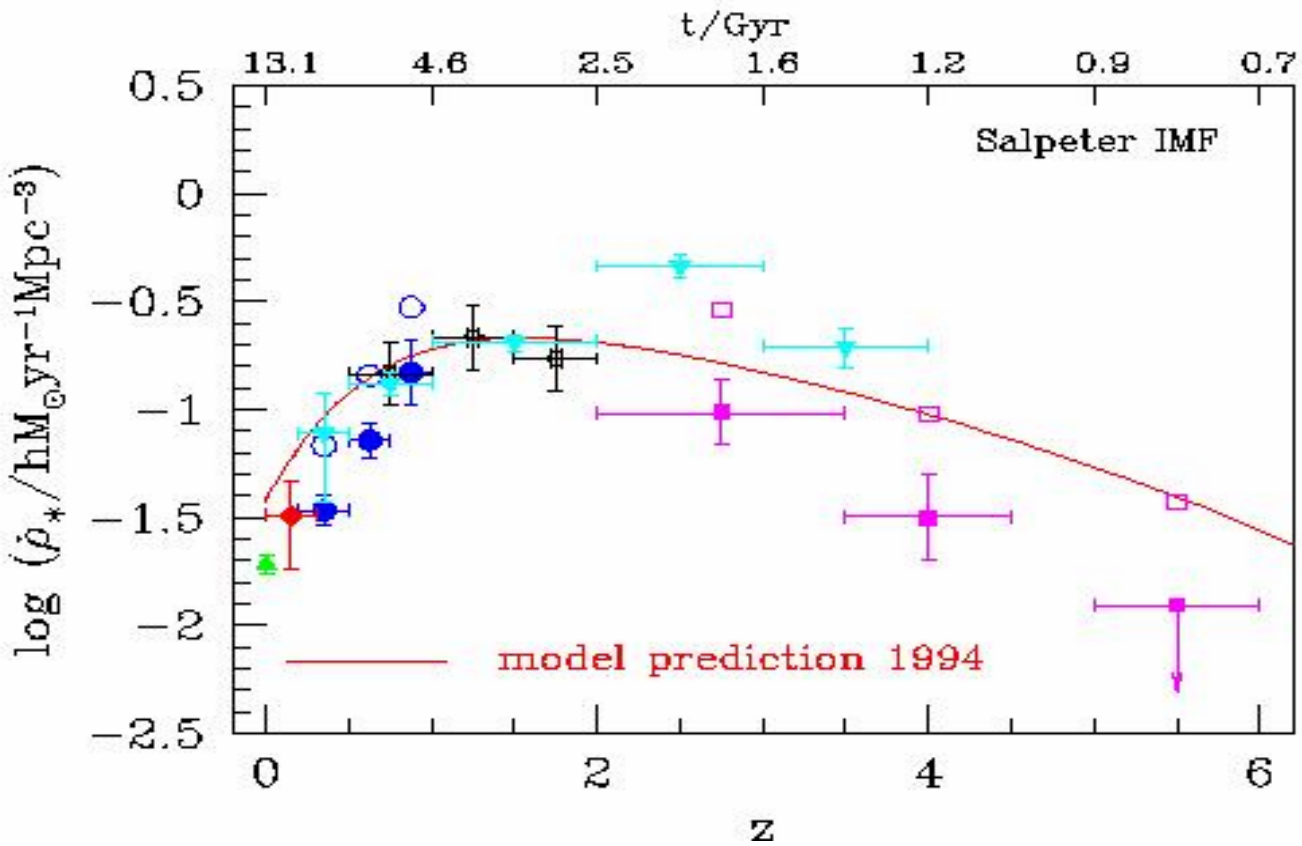


Almost nothing is known about the evolution of the HI mass function beyond the local Universe (z<0.1).

Measurement of HIMF (z) should allow us to trace 'assembly' of galaxies?

Needs SKA.

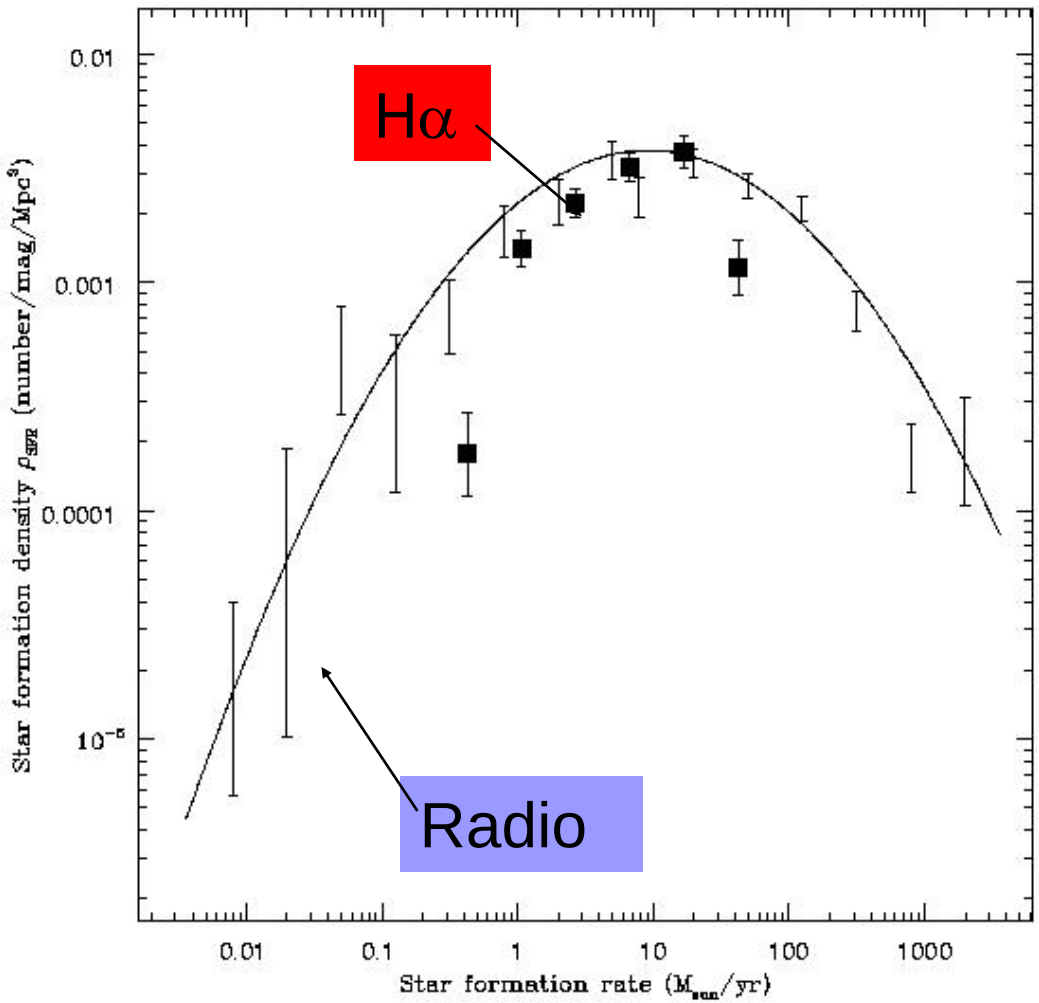
Star formation history of the Universe



(Baugh et al. 1998)

Integrated SF history of the universe already largely mapped out, but “not very constraining” for models (M. Lehnert). Need ‘differential’ information.

Local star-formation density ("*where* do stars form?")



Integral under this plot = zero-point of the Madau diagram in $M_{sun}/yr/Mpc^3$.

Hα and radio/FIR agree reasonably well – there is a *wide* range in SFR (> 5 orders of magnitude) in the local universe.

Star-forming environments in the high-z universe may be just as diverse?

WG2: High-redshift universe, galaxies and galaxy evolution

Where and when do stars form?

- Intrinsically a multi-wavelength problem, important contributions from ALMA, JWST, SKA, optical, X-ray....

- A major challenge is to find the first stars, since such objects will be rare. GRBs very important as tracers of first light and probes of Epoch of Reionization, require co-ordinated strategies for detection and follow-up since rapid response needed. Fast-moving field, with much progress likely in next 5-10 years.

- CDM theory successfully predicts large-scale structure, but several nagging problems remain (e.g. numbers of dwarf galaxies, formation time for massive galaxies, angular momentum), which likely have solutions in galaxy formation details. How can we attack these? Needs theorists, more detailed simulations of galaxy evolution including e.g. instabilities in gas disks.

WG2: High-redshift universe, galaxies and galaxy evolution

Some gaps and missing links

- Science planning needs to include follow-up of high-z SZ clusters.

- Fluorescence studies of the IGM may have potential as a new probe of structure and dynamics (perhaps out to EoR?)

- More work needed on the extent to which PopIII stars and newly-forming globular clusters will be observable at high redshift.

- "Star-formation remains the big unknown". Still no theory for local SF, and extra complications (few or no metals, unknown IMF) for the first generation of stars. Can only be guided by observations.

WG2: High-redshift universe, galaxies and galaxy evolution

Coevolution of galaxies and supermassive BHs

- Does bulge-BH relation persist to high redshift? Fields of AGN and galaxy evolution now closely linked in ways which are not yet understood.

- **Problem:** Even with next-generation facilities, impossible to make direct measurements of BH mass in galaxies beyond the (very) local universe? Limit is resolution, not sensitivity.

- Thus BH mass measurements will not progress much without significantly better resolution for dynamical studies. Space VLBI will help somewhat, but we could also search for new higher-frequency (200-350 GHz?) maser lines to allow higher-resolution observations than 22 GHz H_2O.

WG2: High-redshift universe, galaxies and galaxy evolution

Collaboration and complementarity

- Studies of both galaxy evolution and large-scale structure require large samples of objects. Past progress has come from telescopes with wide fields of view and large multi-object spectrographs/focal-plane arrays.

- For next-generation facilities, we see the field-of-view mismatch at differerent wavelengths (and in particular the small FoVs of ALMA and 30-100m optical telescopes) as a potentially serious problem.

Telescope	Frequency	Field of View (deg)
SKA (at HI)	0.1 – 1 GHz	~50
ALMA	84 – 720 GHz	0.003
ELTs	opt-IR	0.001

WG2: High-redshift universe, galaxies and galaxy evolution

Next-generation wide-field telescopes?

- Many of the future facilities we heard about this week will have very small fields and this is a major limitation for some of the key science, particularly in the optical.

- Could we use ´fly-eye' techniques to achieve a large field with high resolution? Or add a spectroscopic capability to a wide-field telescope like LSST?

- Should we plan for separate point-source and resolved-source telescopes?

- What about wide-field upgrades to 8-10m telescope instrumentation? Do we still need these as a complement to 30m telescopes or as specialist instruments, as has already happened for 4m telescopes in the 8m era.