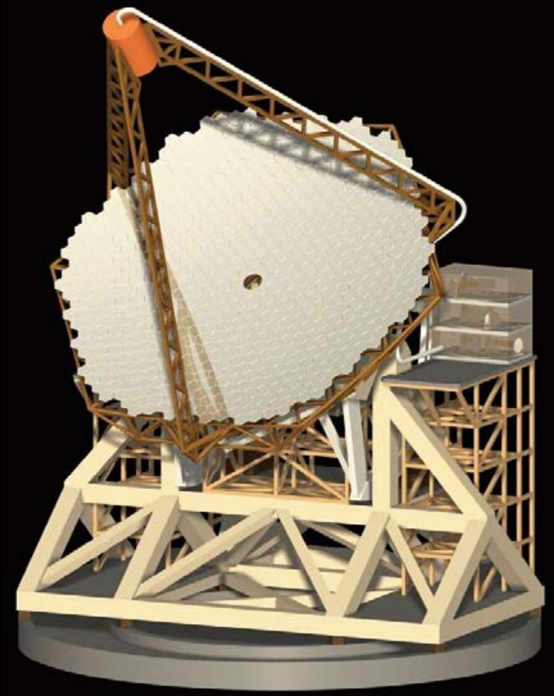
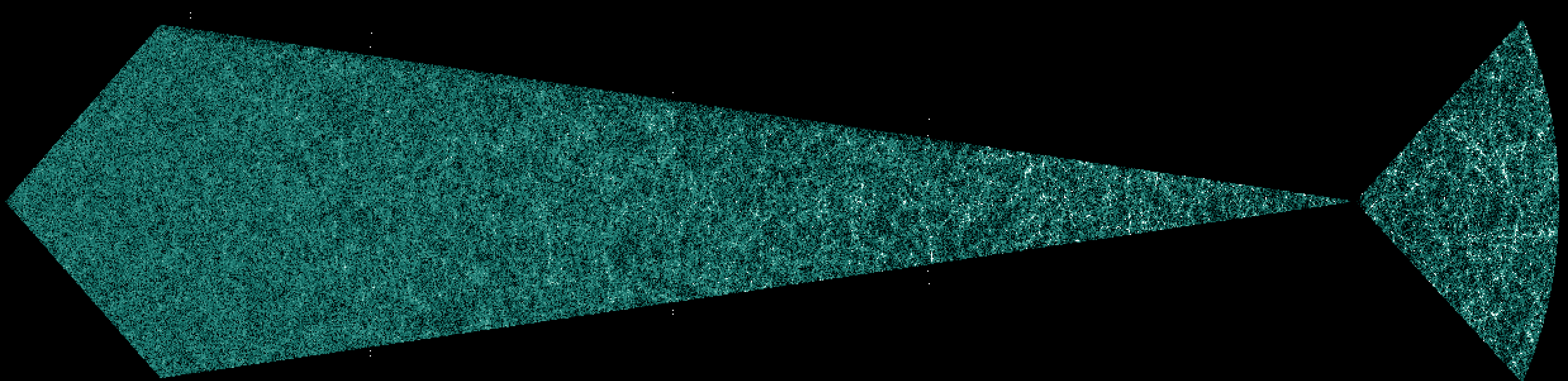
Towards a GSMT Science Case

Large Scale Structure and Cosmology

Matthew Colless, 11 September 2002



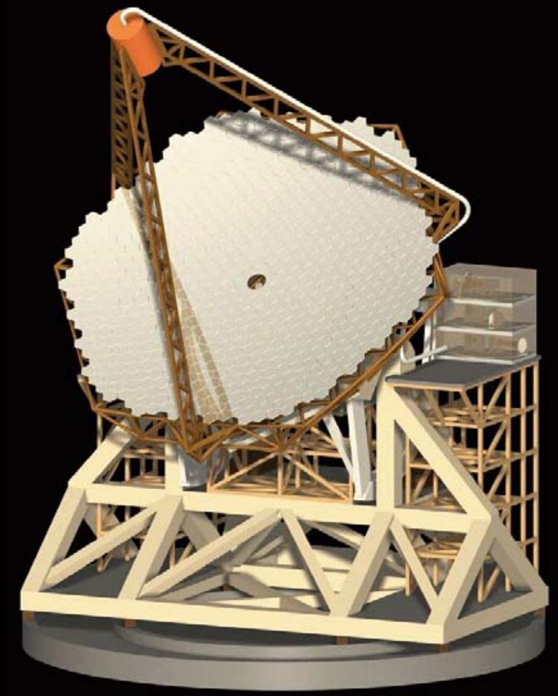


Left - light cone from Hubble volume simulation, showing evolution of LSS.

Right - redshift slice through present day structures.

A 3-D baryon map at $z \approx 3$

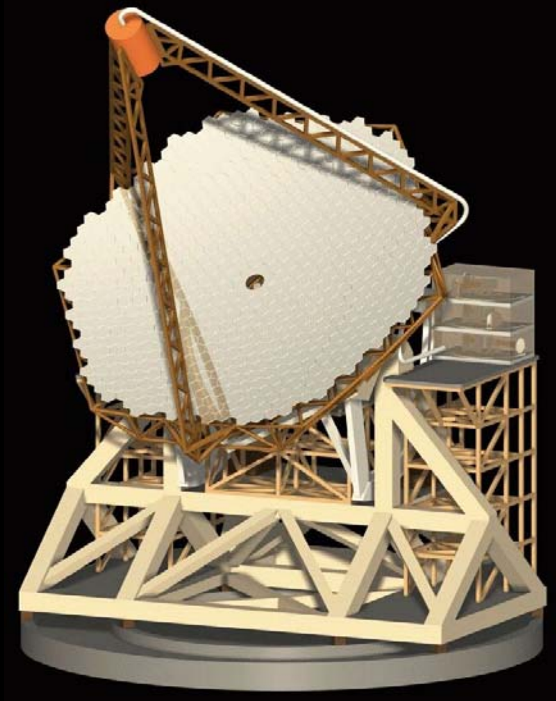
Galaxy z-survey and IGM tomography



- Goal: to extend detailed 8m studies of galaxies and IGM at $z \approx 0$-1 to $z \approx 2$-3.5; obtain 3-D map of mass and metals and measure clustering statistics for galaxies and Ly α forest (also proto-clusters, QSOs).
- Galaxies: redshift survey down to densities equivalent to L* densities today (crucial link to present-day galaxy population, now absent).
- Tomography of IGM: use multiple sight lines to trace LSS on scales >1 Mpc (since Ly α forest traces regions within $10^{\pm 1}$ of mean density, and HI optical depth should be a monotonic function of line-of-sight mass density).
- LSS and galaxy formation: the relative distributions of the IGM and the galaxies give the mass distribution and biases, and together with the locations of metals, strongly constrain galaxy formation models.

A 3-D baryon map at $z \approx 3$

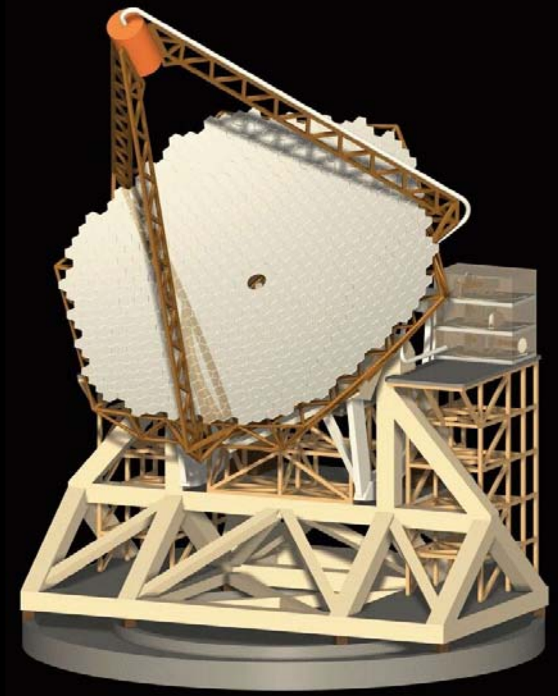
Baseline program and requirements



- Baseline program: an SDSS-like survey at $z \approx 2$-3.5
  - z-range because optical z's relatively easy, HI Ly α available, pre-select from optical imaging;
  - 10 sq.deg. gives few 10^7 Mpc^3 and 5×10^5 galaxies.
- Telescope/instrument requirements:
  - Adaptive optics: 'super-natural' seeing only (0.3 arcsec sufficient)
  - Multi-fiber spectrograph for IGM: 400-500 fiber MOS can do all available $R < 24$ IGM probes over 20′ FoV; with 10 hours/pointing can do all 5x104 IGM probes over 10 sq.deg. in 125 nights.
  - Multi-slit spectrograph for galaxies: low-resolution ($R \approx 500$) imaging slit spectrograph doing 500 galaxies over 20′ FoV; 2 hours gives 80% completeness to $R \approx 26.5$; 5×10^5 galaxies over 10 sq.deg. in 250 nights

The emergence of LSS

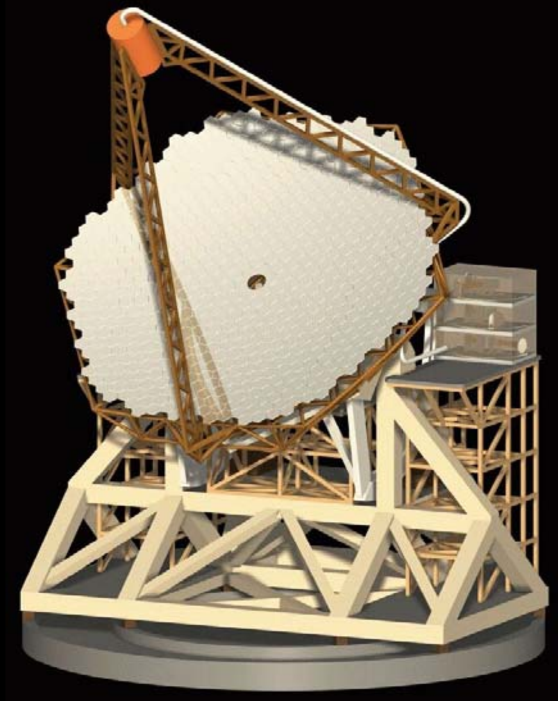
Studies of proto-clusters



- Step 1 - find proto-clusters (not with GSMT):
  - Sunyaev-Zeldovich detections from ground and satellites (Planck will detect 1 cluster/sq.deg.).
  - Clustering from Ly-break sample or z-survey.
  - Search around beacons (QSOs, ultra-steep spectrum radio galaxies).
- Step 2 - measure properties of clusters (and members):
  - multi-object spectroscopy to determine membership and structure
  - scale of clusters probably from 1-10 Mpc (i.e. 2-20 arcmin)
  - number of bright cluster members probably 10-100 (highly uncertain)
- Telescope/instrument requirements:
  - wide-field MOS with relatively modest multiplex

Evolutionary cosmology

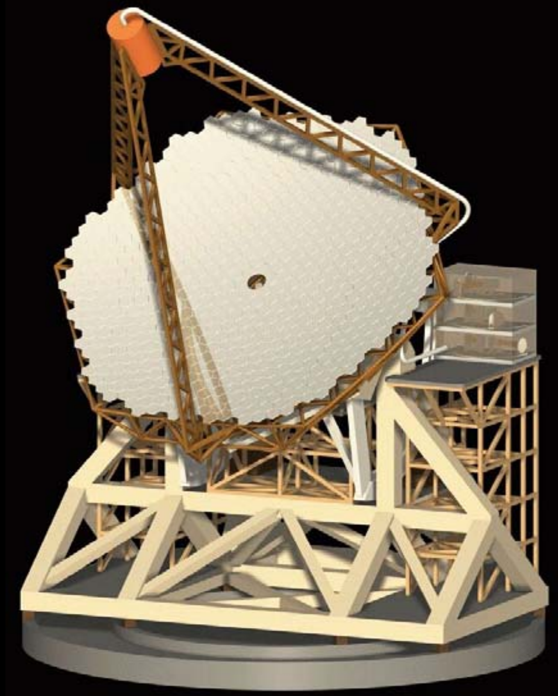
The change in the equation of state



- What is the equation of state for the dark energy?
  - For cosmological constant, $w \equiv p/\rho = -1$ is constant
  - For quintessence models, w evolves with redshift
- Method 1 - classical tests with high precision at high z:
  - Best option is SNe distances at $z \approx 0.5$-2 (cf. SNAP satellite).
  - Needs wide-field photometry & single-object spectra to $J \approx 24$-25.
- Method 2 - LSS measurements at high z:
  - Can measure w(z) from galaxy power spectrum, the growth factor (via cluster mass function), or from redshift distortion of LSS;
  - Requires very large (10^5-10^6) samples of galaxies at $z \approx 1$, and hence widest possible FoV and highest multiplex (8m rather than 30m?)
- What about evolution of fundamental constants (e.g. α) with redshift?

LSS and Cosmology

Wide-field science with 30^{+}m telescopes



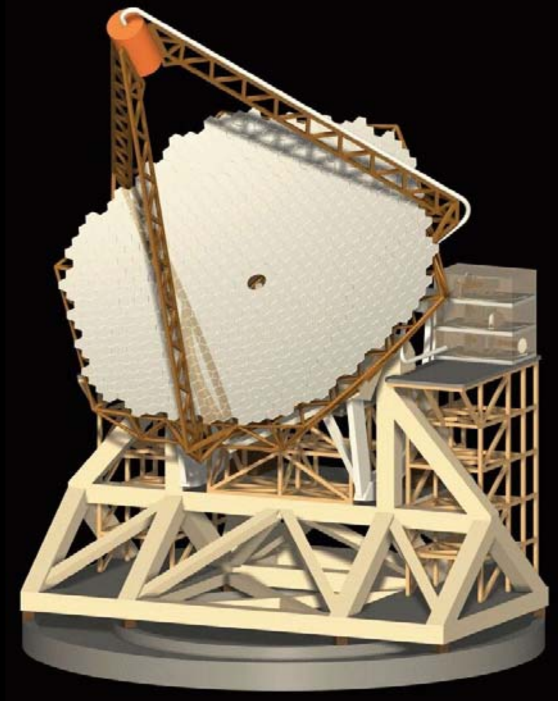
- Basic requirements: LSS/cosmology case basically requires a wide-field light-bucket with moderate adaptive-optics enhancement of natural seeing.

- Why a 30m telescope?: essentially the 10x higher throughput (i.e. aperture) - can not only look at objects 10x fainter, but sources are 100x more numerous (e.g. background sources for IGM).

- Instrumentation: essentially considering optical spectroscopy (low background) at low to medium dispersion over a 10-20′ FoV - this FOV is the main instrumentational challenge. Adaptive optics are only required to achieve 'super-natural' seeing (0.3 arcsec) over this FoV.

Synergies with other facilities

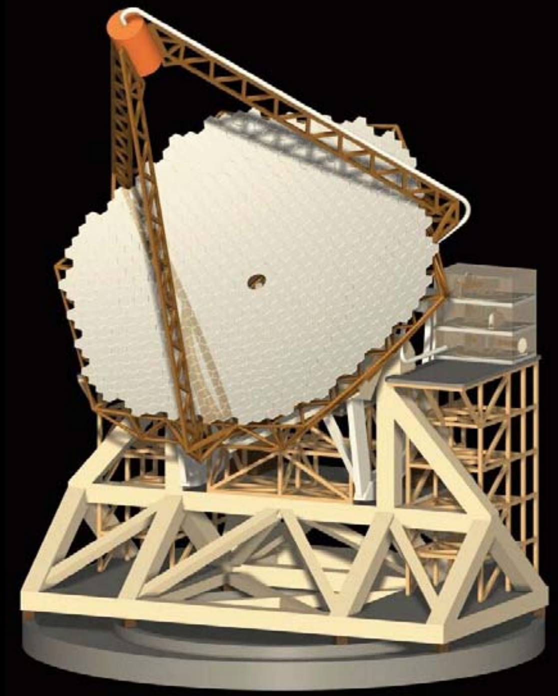
Links to NGST/ALMA/SKA science



- Major new facilities (NGST, ALMA, SKA and many others) will provide new types of targets for which follow-up optical/IR imaging and spectroscopy will be highly desirable.
- The existing 30^+m telescope LSS and cosmology science cases do not give much consideration to this (although some limited consideration is given to competition from NGST).
- Likewise, the science cases for these other facilities give relatively little consideration to 30^+m optical/IR telescopes (of course, NGST and ALMA should precede the availability of 30^+m telescopes, while much of the SKA case is related to the 'dark ages').

Status Summary

30^{+}m telescope LSS/cosmology drivers



- The current LSS and cosmology science case for a 30^{+}m telescope is surprisingly poorly developed and needs considerable work. The net needs to be cast more widely, and the best cases fully developed.
- The strongest and best-developed case is for a very large survey (the 'baryon map'), which will require years of telescope time.
- The science with potentially the most far-reaching impact (the 'equation of state of the universe') might be done by SNAP or an 8m wide-field MOS.
- The lack of synergy with other major new facilities needs to be addressed.
- Telescope requirements: undemanding - aperture + 'super-natural' seeing
- Instrument requirements: clear - wide-field optical(+NIR?) multi-object spectroscopy (the wide FoV is the major challenge).