



# AAO Wide-Field Spectroscopy Facilities and Programs

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Anglo-Australian Observatory

JENAM, University of Hertford, 20 April 2009

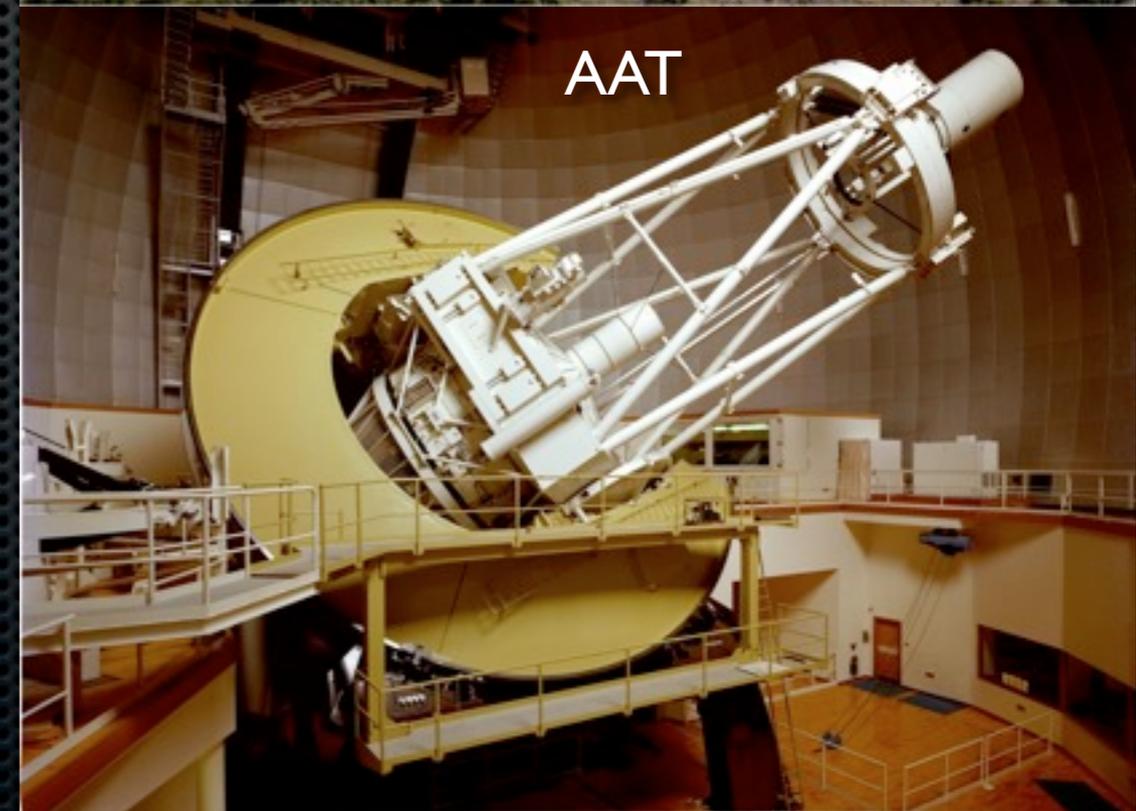
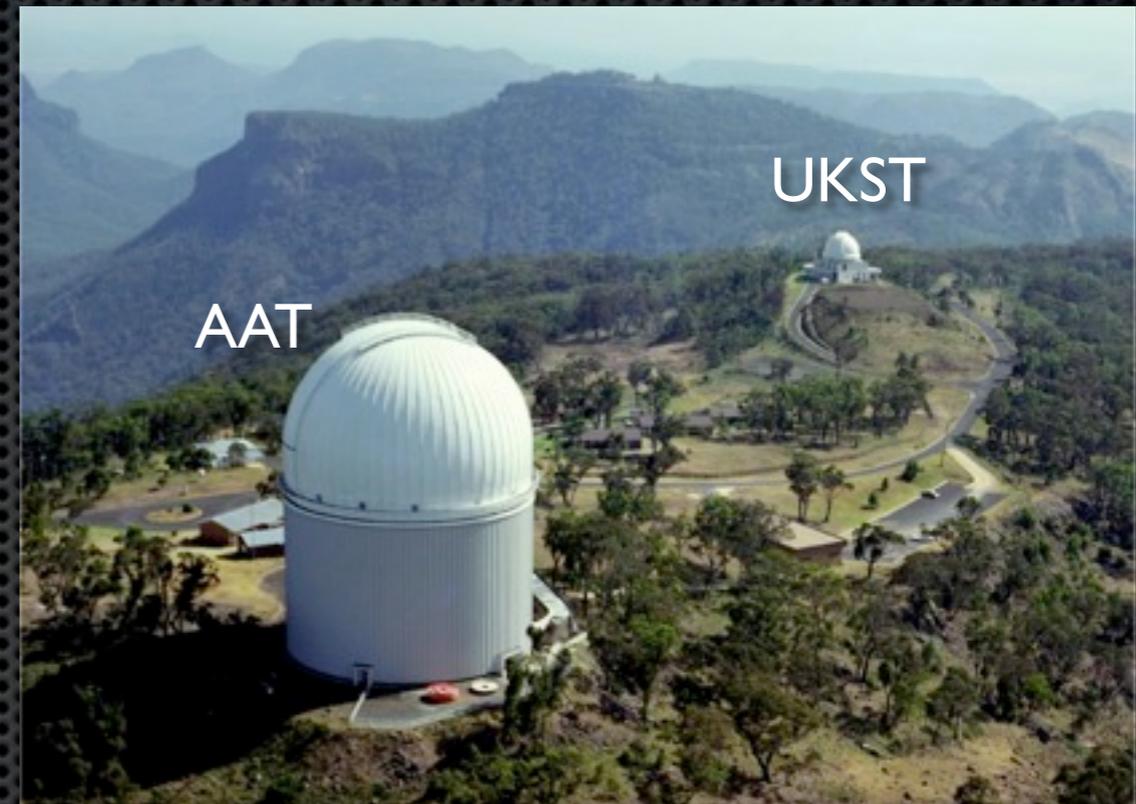
# Talk outline

- **The Anglo-Australian Observatory**
  - Current status, instrumentation strategy and track record
- **AAT facilities and programs**
  - AAOmega, <HERMES> and <<NGI dF>>
  - The WiggleZ Survey - baryon acoustic oscillations & dark energy
  - GAMA - the assembly of stars and mass into galaxies
  - HERMES - Chemical fingerprinting and Galactic Archeology
- **UKST facilities and programs**
  - The 6dF Galaxy Survey - mass and motions in the local universe
  - The RAVE Survey - a dynamical survey of Galactic structure
  - Announcement of Opportunity and future programs

# Anglo-Australian Observatory

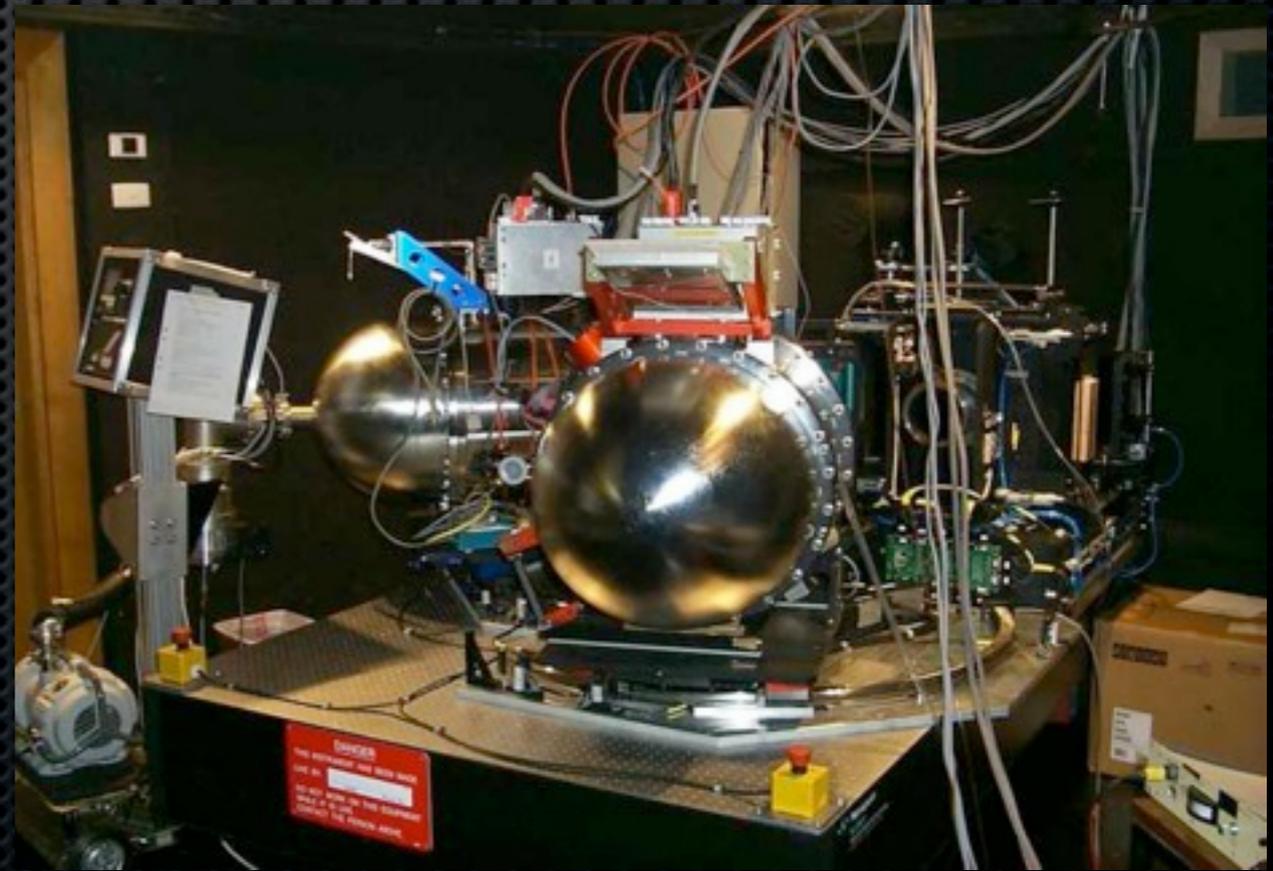
- **The AAT and the UKST...**
  - The AAT is a 4m on a moderate site competing with 8m's on the best sites
  - UKST is 1.2m Schmidt with 6° FoV
- **AAO's strategy...**
  - ...exploit AAT and UKST capabilities for wide-field survey spectroscopy
  - ...exploit AAO's world-class program in astronomical instrumentation
  - ...actively seek out new science opportunities and quickly exploit them with large time allocations
- **High productivity & impact...**
  - AAT is #1 4m for papers & citations
  - AAT is #5-ranked optical telescope of any size for both papers & citations

*Trimble & Ceja 2008, Astron.Nachr., 329, 632*

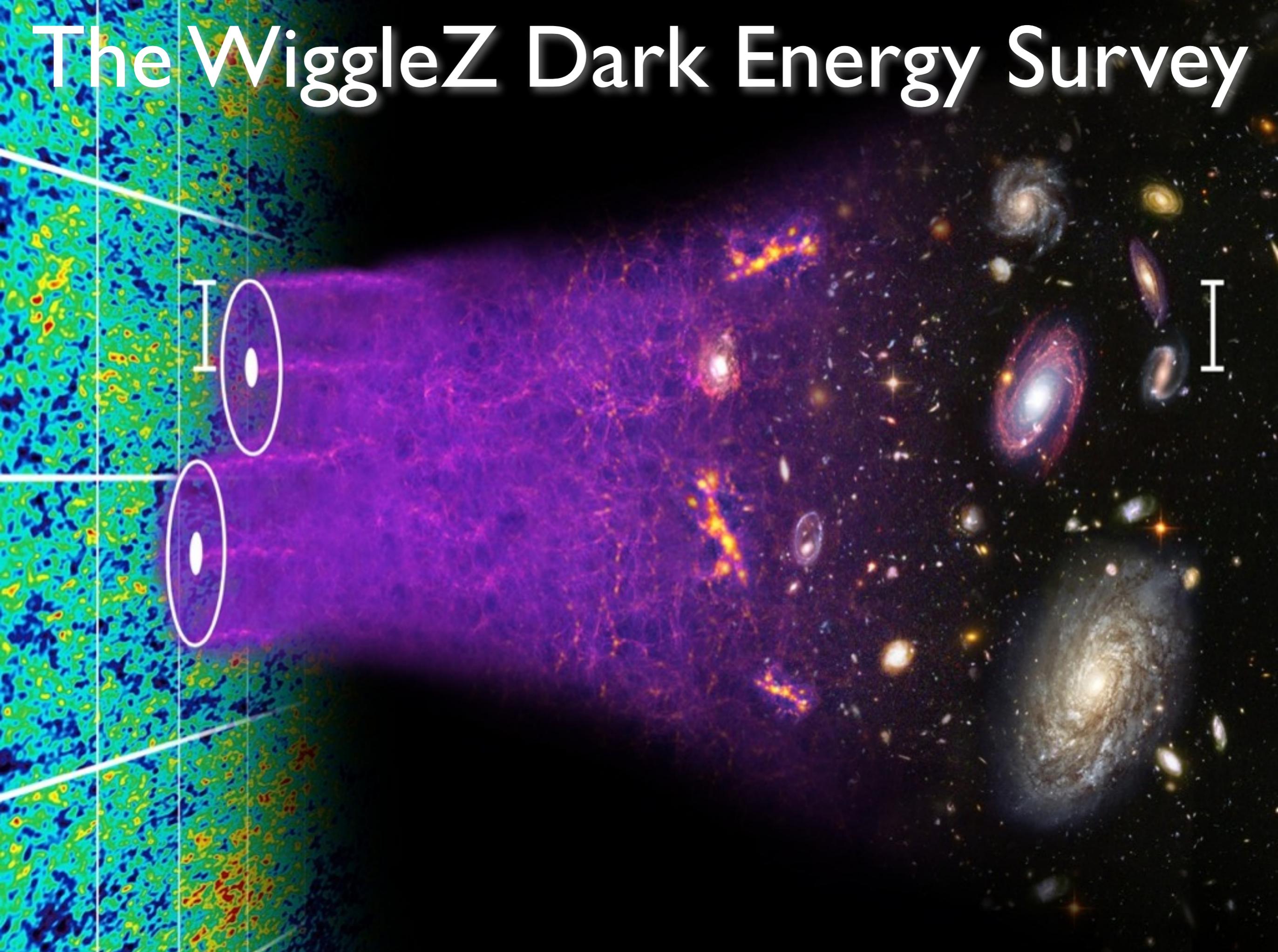


# AAOmega spectrograph

- **AAT + 2dF + AAOmega**
  - >\$15M investment over 10 years
  - AAOmega peak thruput 21%
  - Emission-line galaxies at  $z \sim 1$  in 1 hr



# The WiggleZ Dark Energy Survey



# The WiggleZ survey

- **Project goals:**

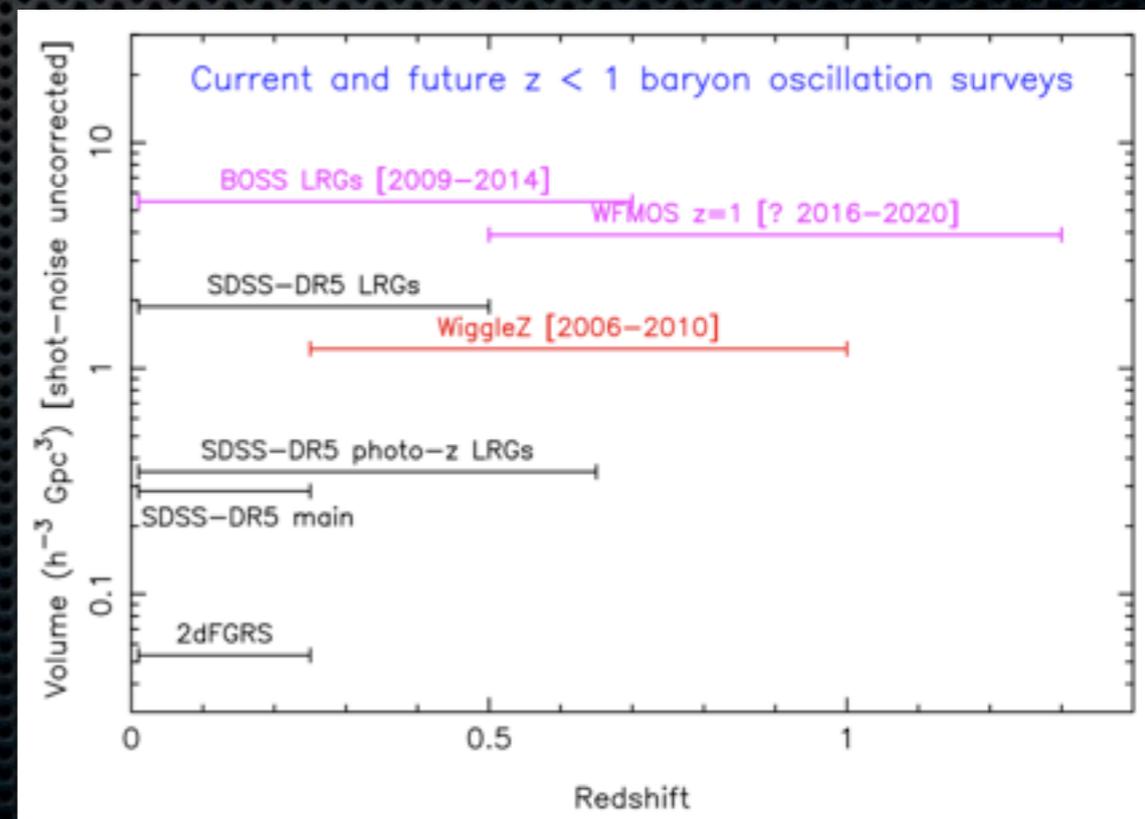
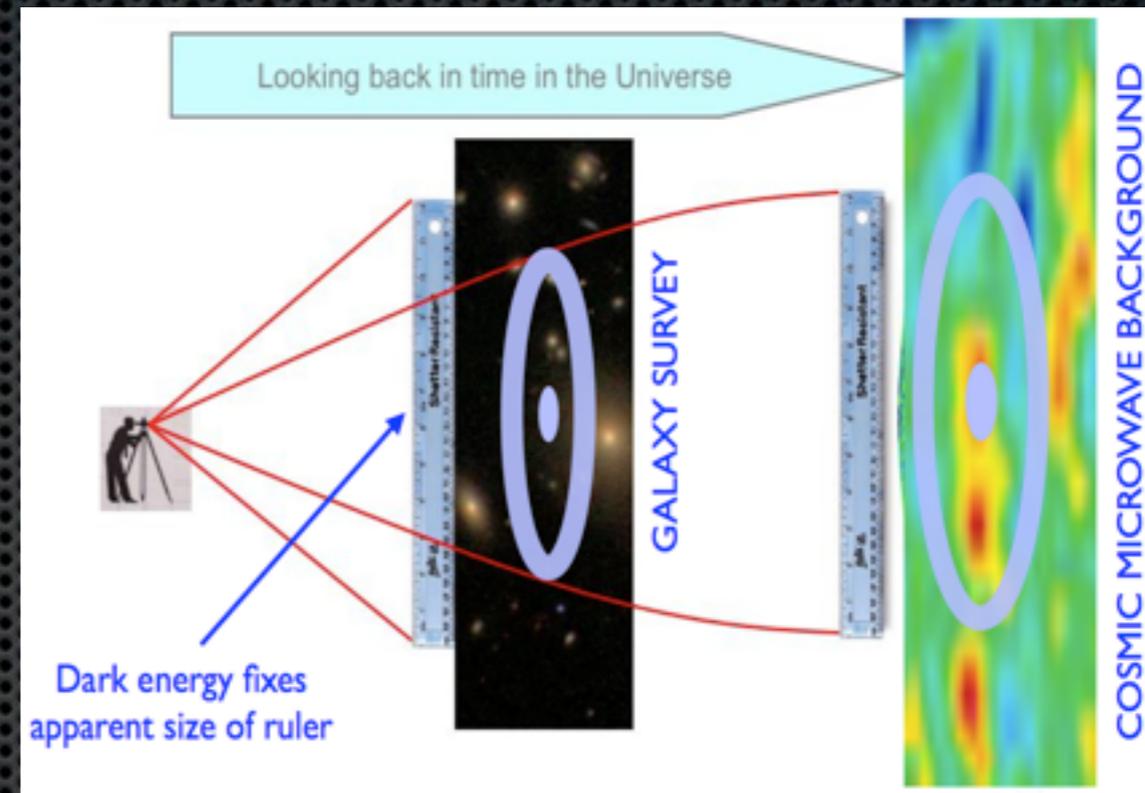
- first BAO measure of  $w(z)$  at  $z > 0.5$
- map 240,000 galaxies at  $0.3 < z < 1.0$
- measure BAO scale to 2% and test  $w_0 = -1$  over  $z \sim 0.3 - 1.0$

- **Survey observations and sample:**

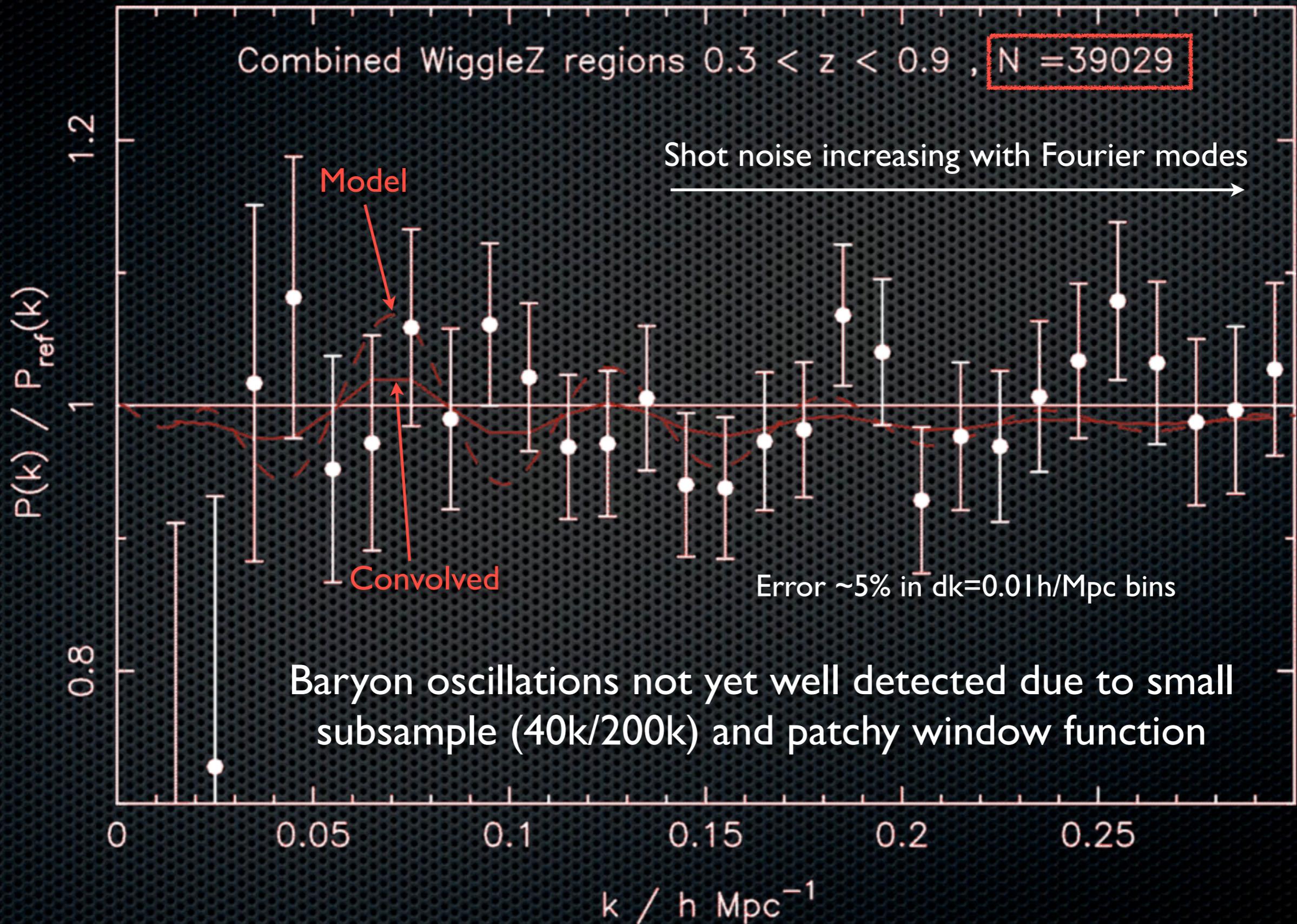
- Star-forming galaxies at  $z > 0.5$  from GALEX (UV) and SDSS/RCS2 (opt)
- Sample covers 1000 deg<sup>2</sup> on sky and a volume of  $\sim 1$  Gpc<sup>3</sup>

- **Status and results:**

- About 2/3 complete; finish in 2010
- Measured small-scale clustering and preliminary power spectrum



# Acoustic oscillations

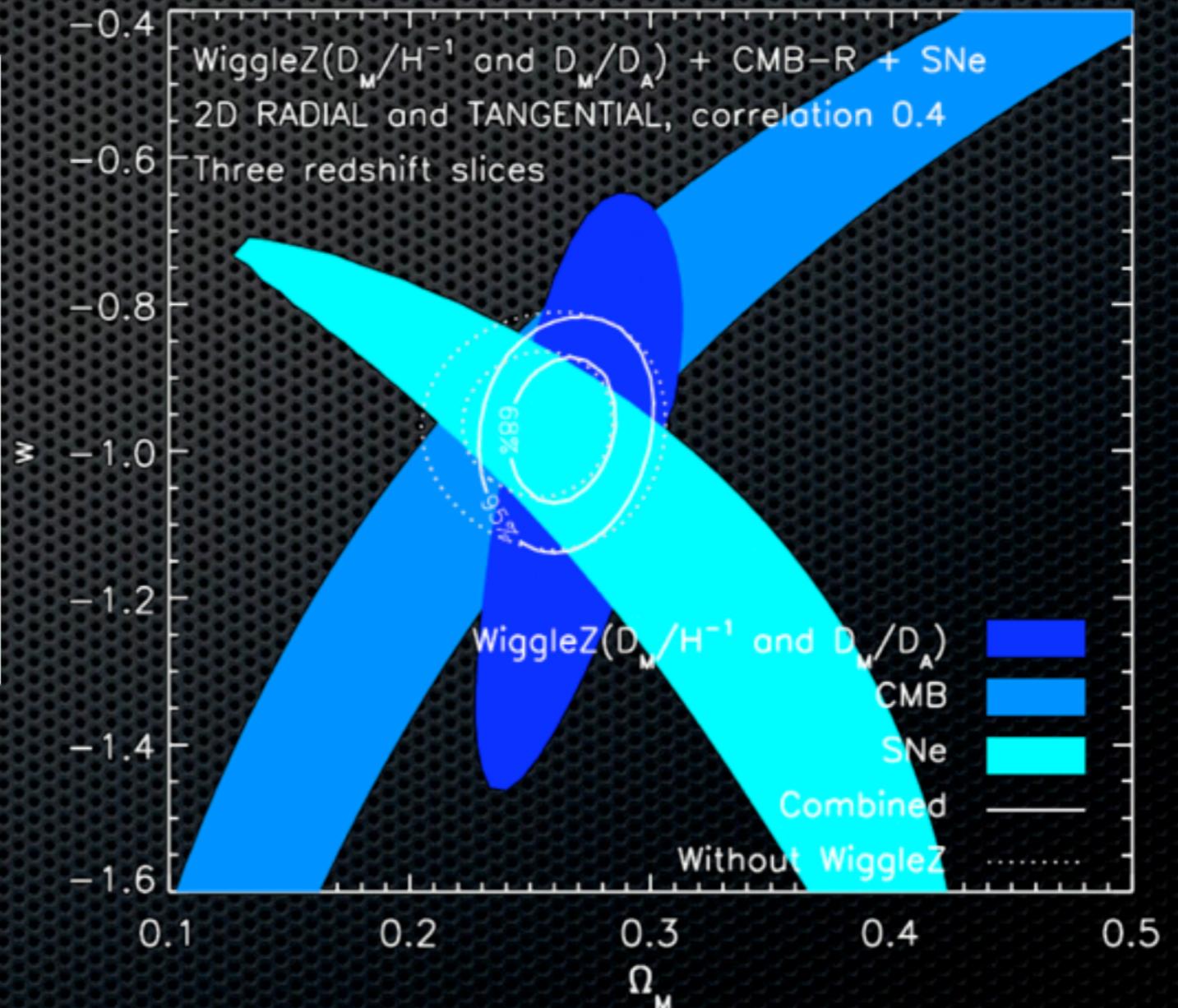


# Survey forecasts

- Predicted measurement precision of completed survey:
  - 2.5% precision on measurement of overall BAO scale...
  - ...or 5.7%, 3.4% and 4.6% in 3 redshift intervals



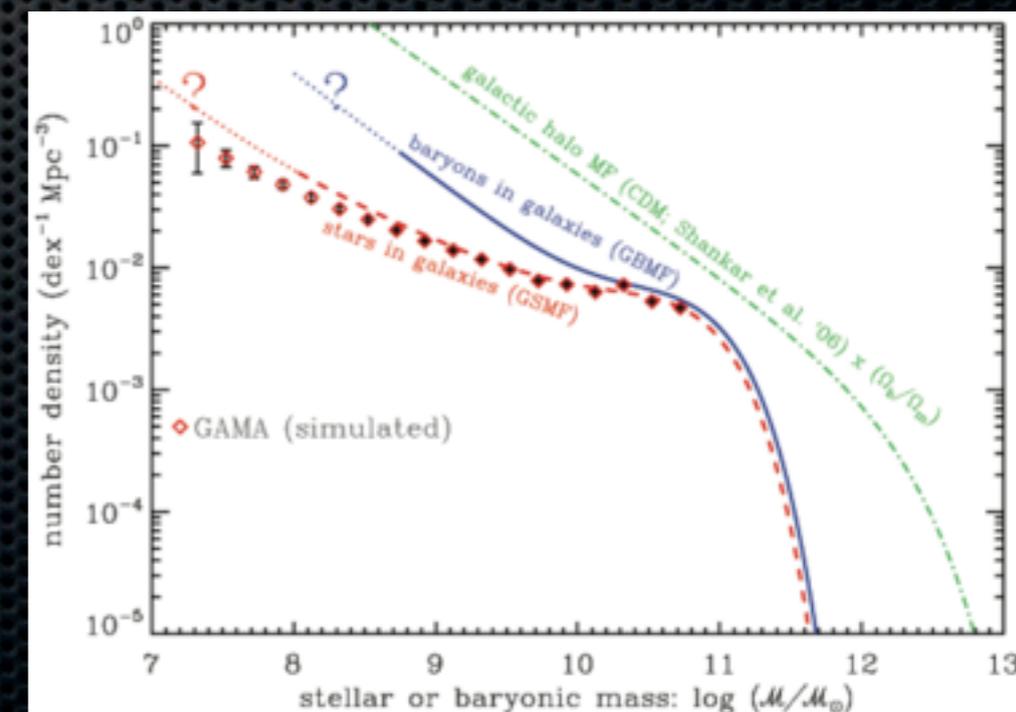
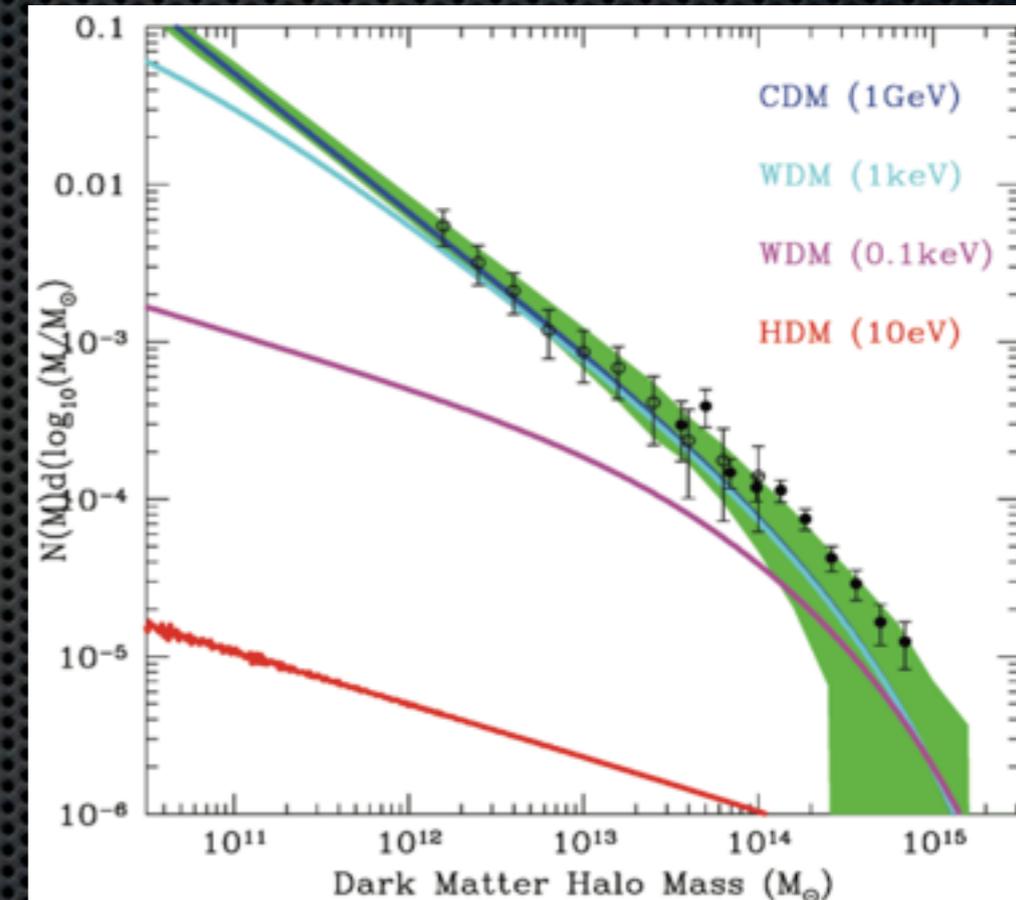
$\Rightarrow \sigma(\Omega_m) = 0.02, \sigma(w_0) = 0.07$





# Science goals of GAMA

- **Measure the halo mass function** via galaxy group velocity dispersions to directly test the predictions of dark matter models (CDM, WDM, etc.) down to Local Group masses
- **Measure the dynamic, baryonic, HI & stellar mass functions** down to LMC masses, and their dependence on redshift, environment, galaxy type & structural component
- **Measure the recent merger and star formation rates** as functions of galaxy type, mass and environment



# HERMES & Galactic Archeology

- **HERMES is a new instrument for the AAT** - effectively a high spectral resolution channel for 2dF/AAOmega
- **RAVE (R=7500)** measures stellar motions & properties (T, g, Fe/H) and probes kinematics & SFH of the Galaxy
- **HERMES (R=30,000)** will measure higher precision stellar motions & properties, incl. precise chemical abundances
- **Approach:** use this chemical 'fingerprint' as well as the phase-space information to uniquely identify the common original associations in which groups of stars were formed
- **Galactic archeology with HERMES:**
  - identify the building blocks (proto-galaxies or stellar associations) from which the disk, bulge & halo of the Milky Way assembled
  - uncover the assembly sequence and the underlying processes
  - determine the importance of mergers and accretion events

# Galactic Archeology survey

- **Performance:** in 1-2 hours HERMES will reach  $S/N=100$  for  $V=14-15$  stars, which have sky density of 80-140  $\text{deg}^{-2}$  at poles, i.e. 250-440 per 2dF field
- **Survey plan:**  $10^6$  stars over 10,000  $\text{deg}^2$  to  $V=14$  at 5 fields/night (incl. weather) will take 660 bright nights (4 years at 50% allocation)

- **Access to the Galaxy's various stellar components:**

- Old disk dwarfs can be seen to about 1 kpc, disk giants to 5 kpc  
halo giants to 15 kpc

Component	Dwarfs	Giants
Thin disk	58%	20%
Thick disk	10%	7%
Halo	2%	3%

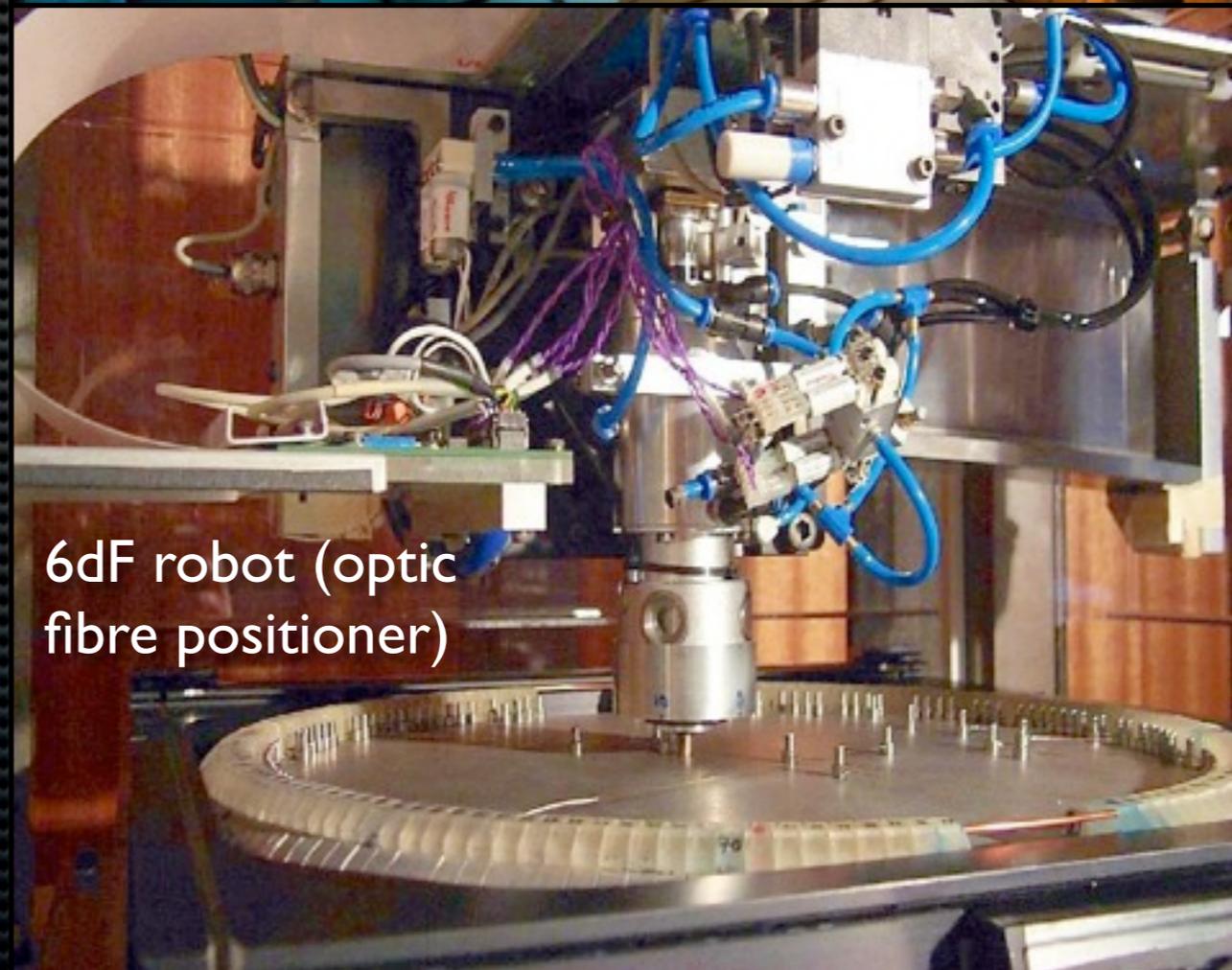
- About 9% of thick disk stars and 14% of thin disk stars pass through survey's 1 kpc dwarf horizon
- All star-formation sites come within survey due to azimuthal mixing
- **Thus a survey of  $10^6$  stars with  $V<14$  will yield:**
  - ~20 thick disk dwarfs from each of ~4500 star-formation sites
  - ~10 thin disk dwarfs from each of ~35000 star-formation sites

# HERMES and GAIA

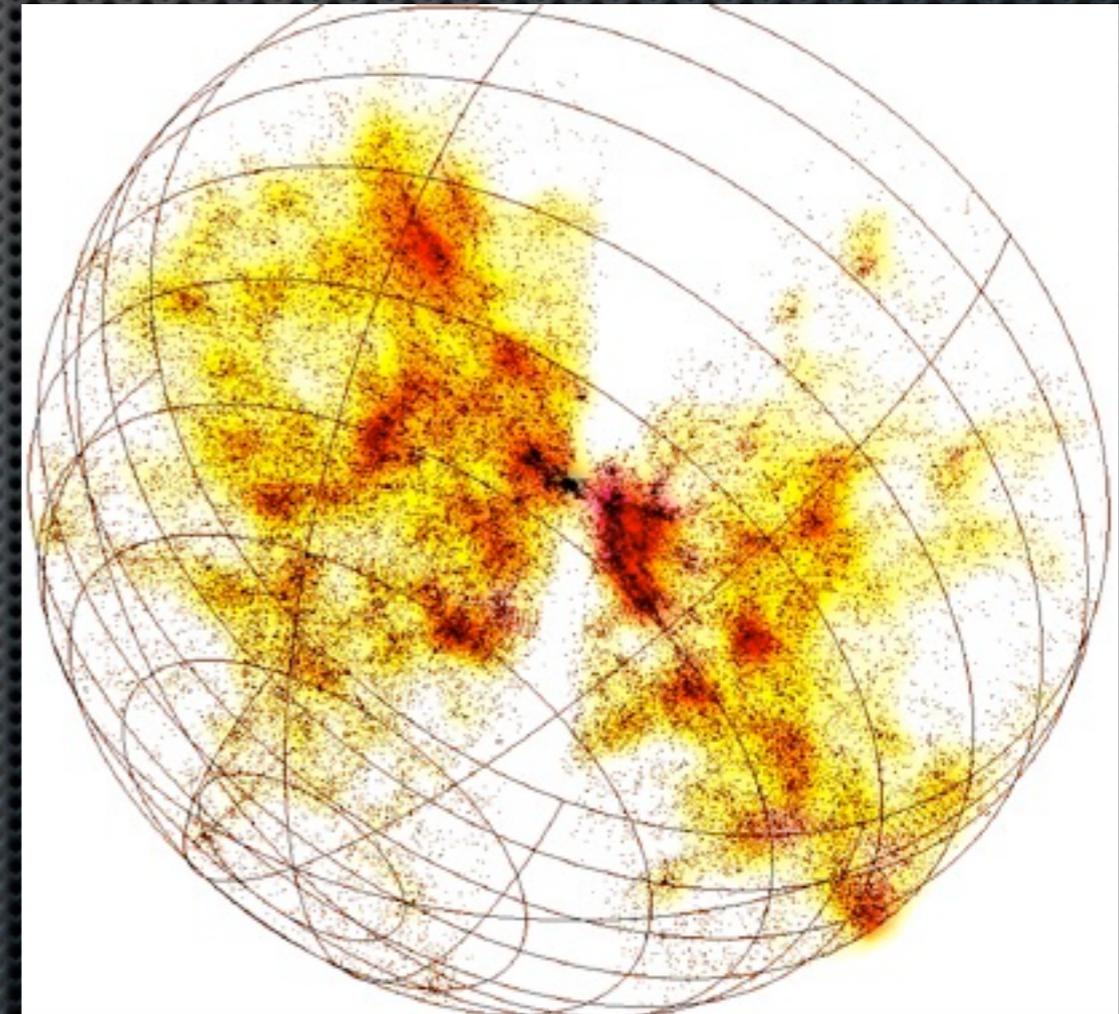
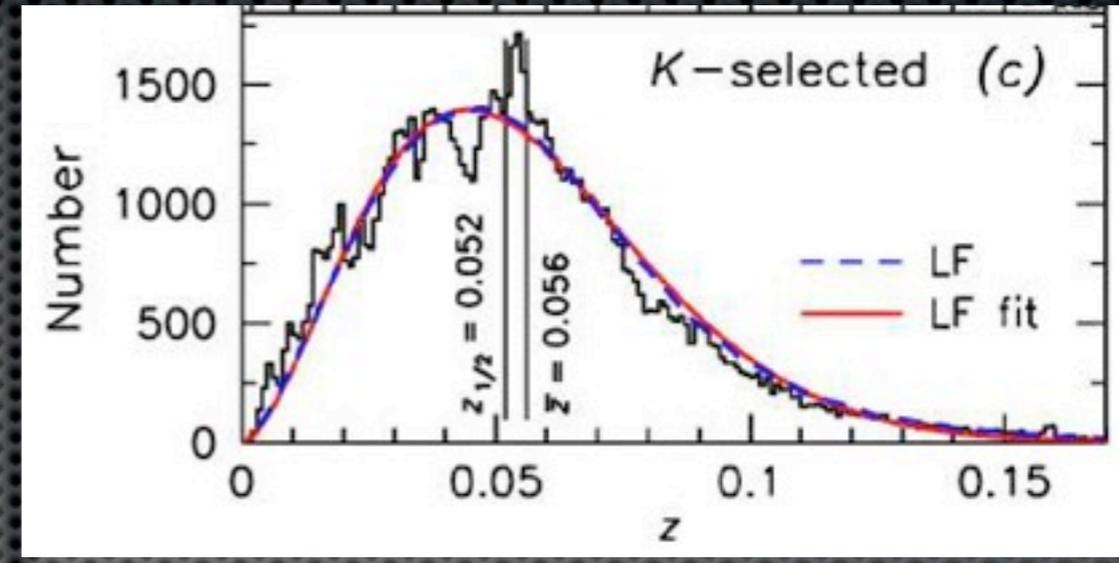
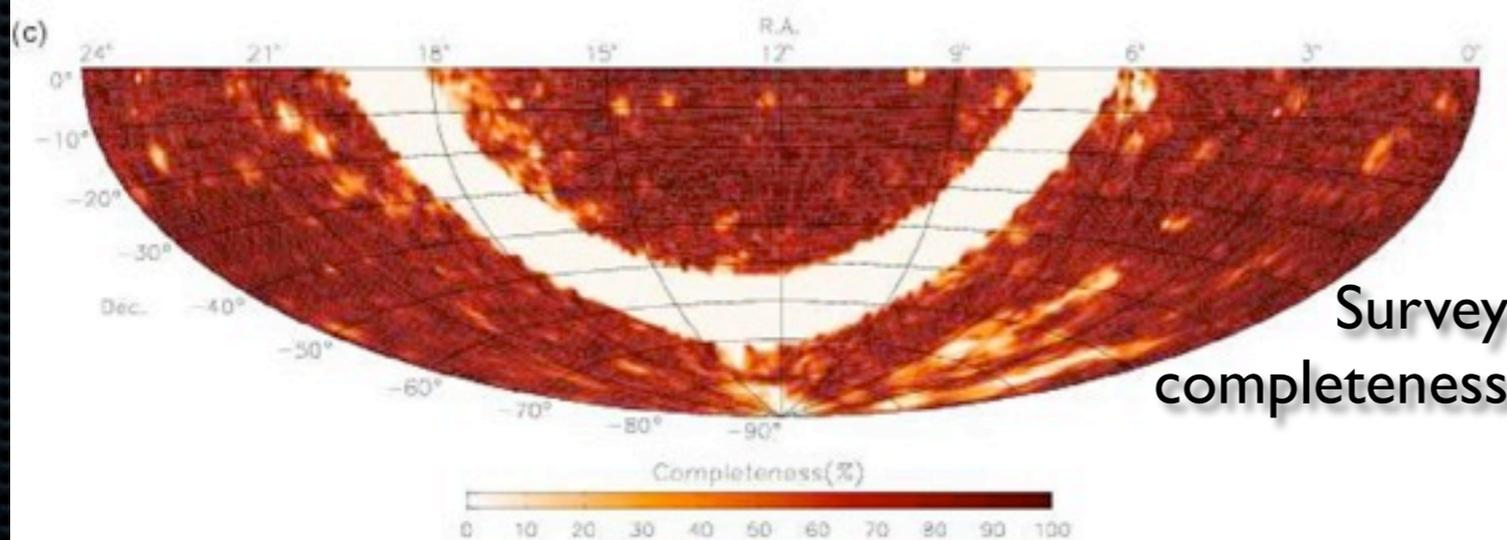
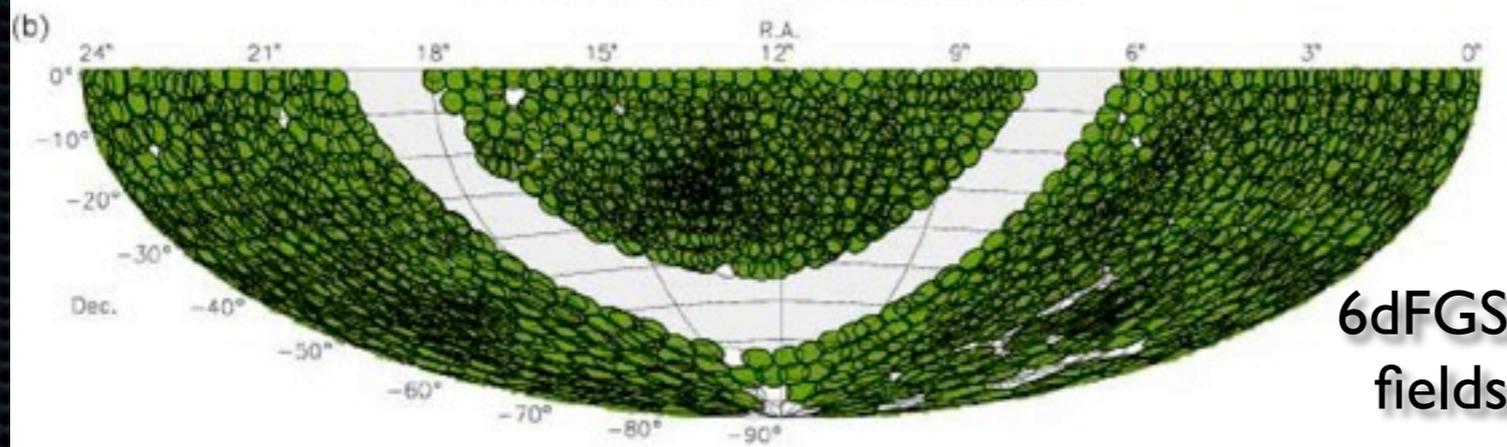
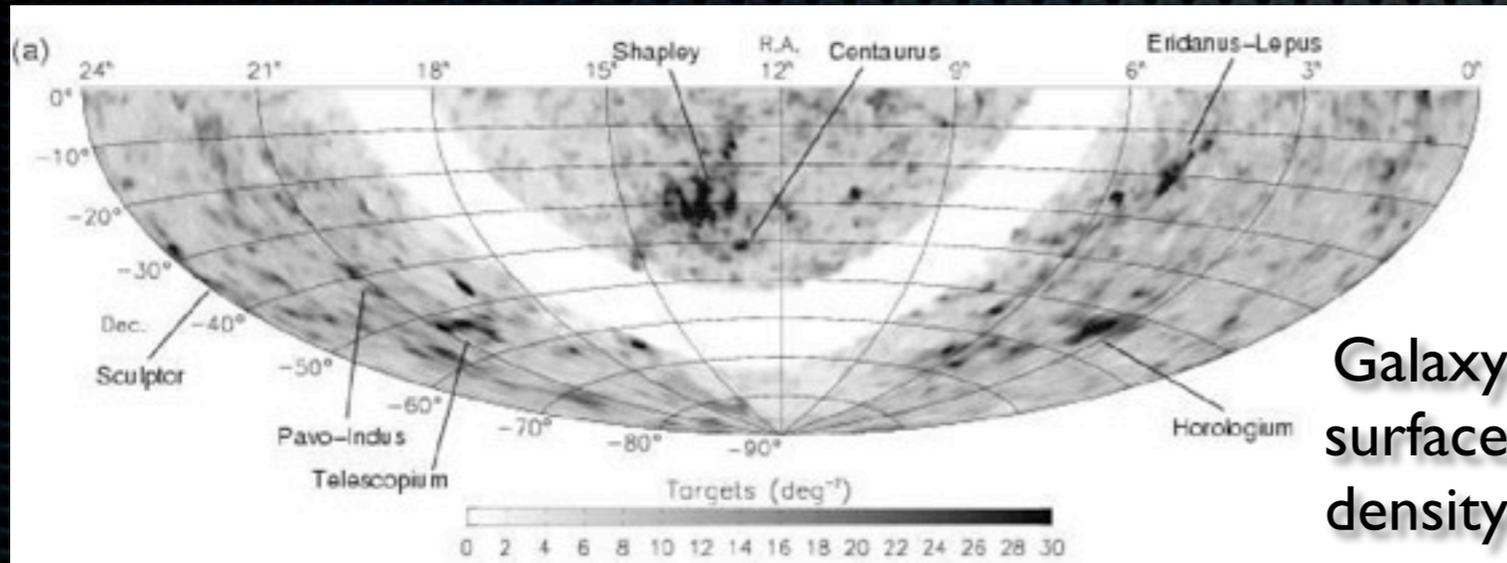
- HERMES will be powerfully complementary to GAIA
- GAIA will give precision astrometry for  $10^9$  stars and radial velocities for  $10^7$  stars (launch date 2011/12)
- For  $V = 14$  GAIA will measure  $\sigma_{\pi} = 10\mu\text{as}$ ,  $\sigma_{\mu} = 10\mu\text{as/yr}$
- So GAIA will give 1% distance errors out to 1 kpc and  $0.7 \text{ km s}^{-1}$  velocity errors out to 15 kpc...
  - ➔ precise transverse velocities and distances for all of the stars in the proposed HERMES survey sample
  - ➔ an accurate colour – absolute magnitude diagram for all survey stars
  - ➔ an independent check that chemically tagged groups have common ages
- **HERMES + GAIA will give precise abundances, positions & motions for  $10^6$  stars, and isochrone ages for  $2 \times 10^5$  subgiant stars - a superb dataset for Galactic archeology**

# The 6dF Galaxy Survey

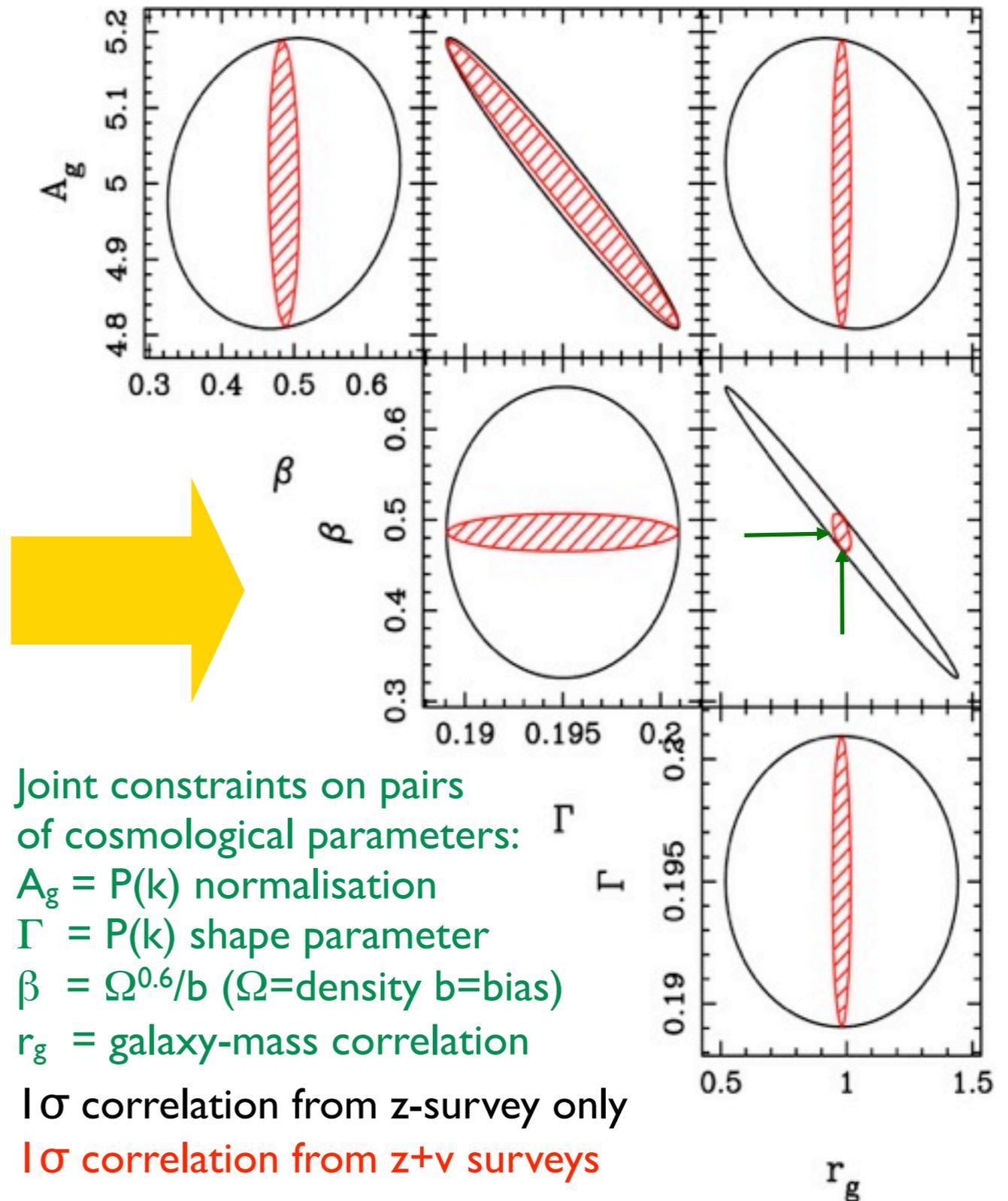
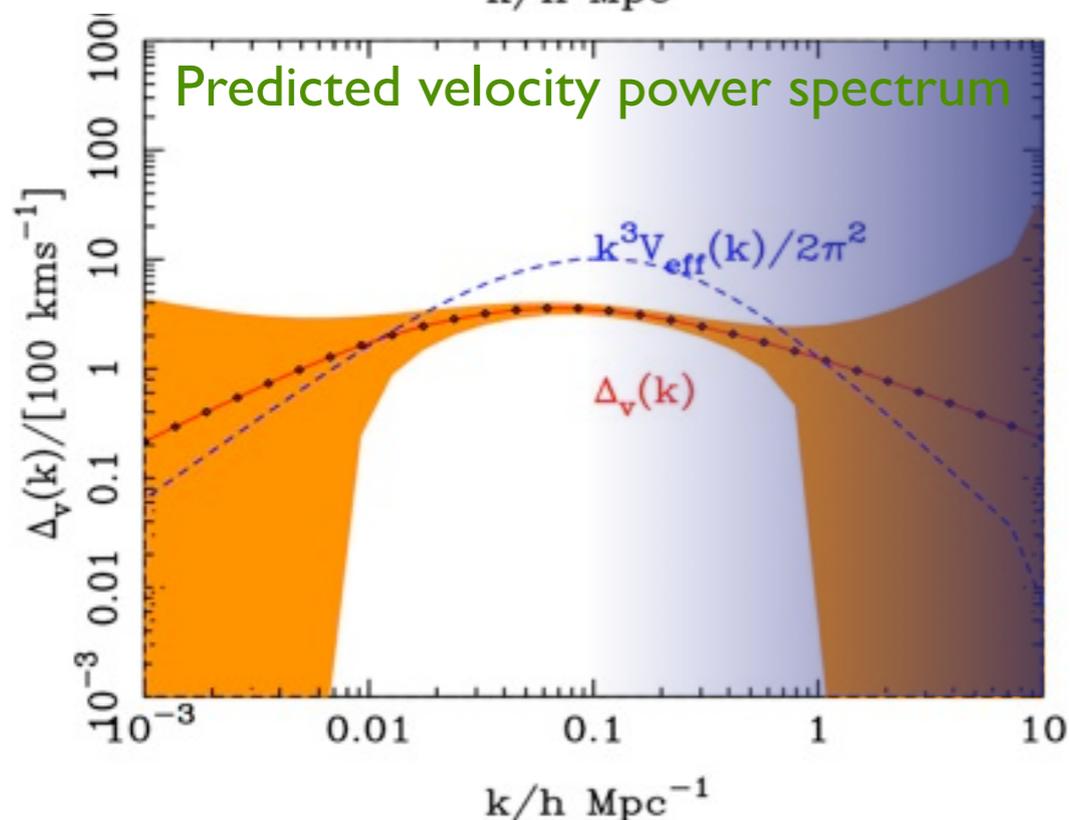
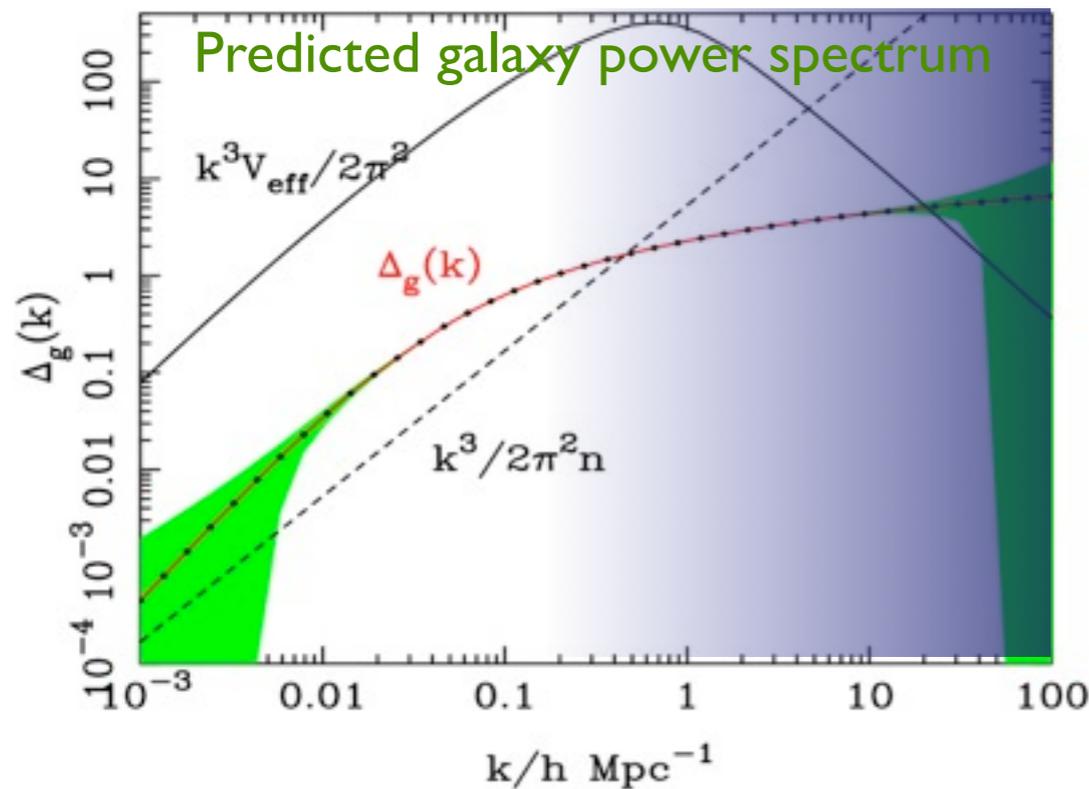
- A redshift and peculiar velocity survey of galaxies in the local universe over the whole southern sky with  $|b| > 10^\circ$
- 2MASS-selected primary galaxy sample with  $K_{\text{tot}} < 12.75$ ; secondary samples to  $H < 13.0$ ,  $J < 13.75$  & to  $r < 15.6$ ,  $b < 16.75$  from SuperCosmos
- Observations carried out using 6dF spectrograph on the UKST over the period May 2001 - Jan 2006
- Database: 137k spectra, 125k redshifts for galaxies over 80% of southern sky
- Peculiar velocity survey for a subset of 10,000 bright early-type galaxies using Fundamental Plane distances
- Data release: Final z-survey data (DR3) made public on 1 April 2009



# 6dFGS sky & redshift coverage

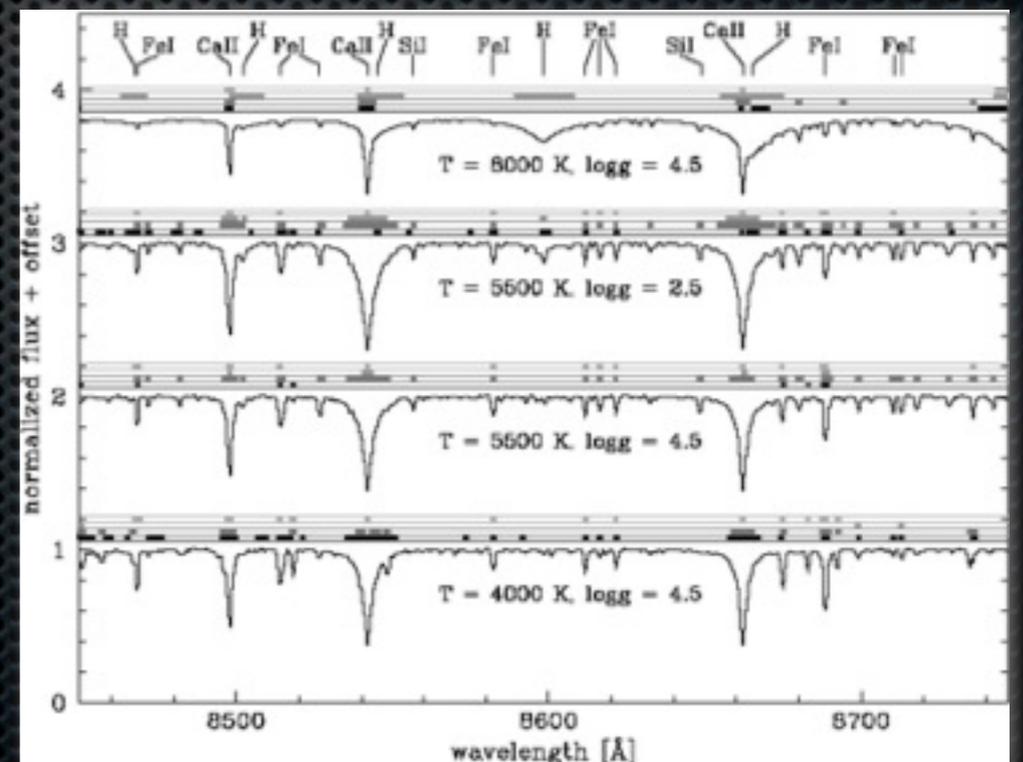


# Cosmology with the 6dFGS



# The RAVE survey

- RAVE is a survey of the dynamics of stellar structure in the Galaxy
- Australian, UK, US, European team
- Using 6dF spectrograph on UKST from 2005 until 2011
- Measures radial velocities, stellar temperatures, surface gravities, metallicities and rotations
- Mapping motions and properties of up to a million stars (currently more than 250,000 observed)
- Aim: to understand the structure of the Galaxy and how it formed



# RAVE survey status

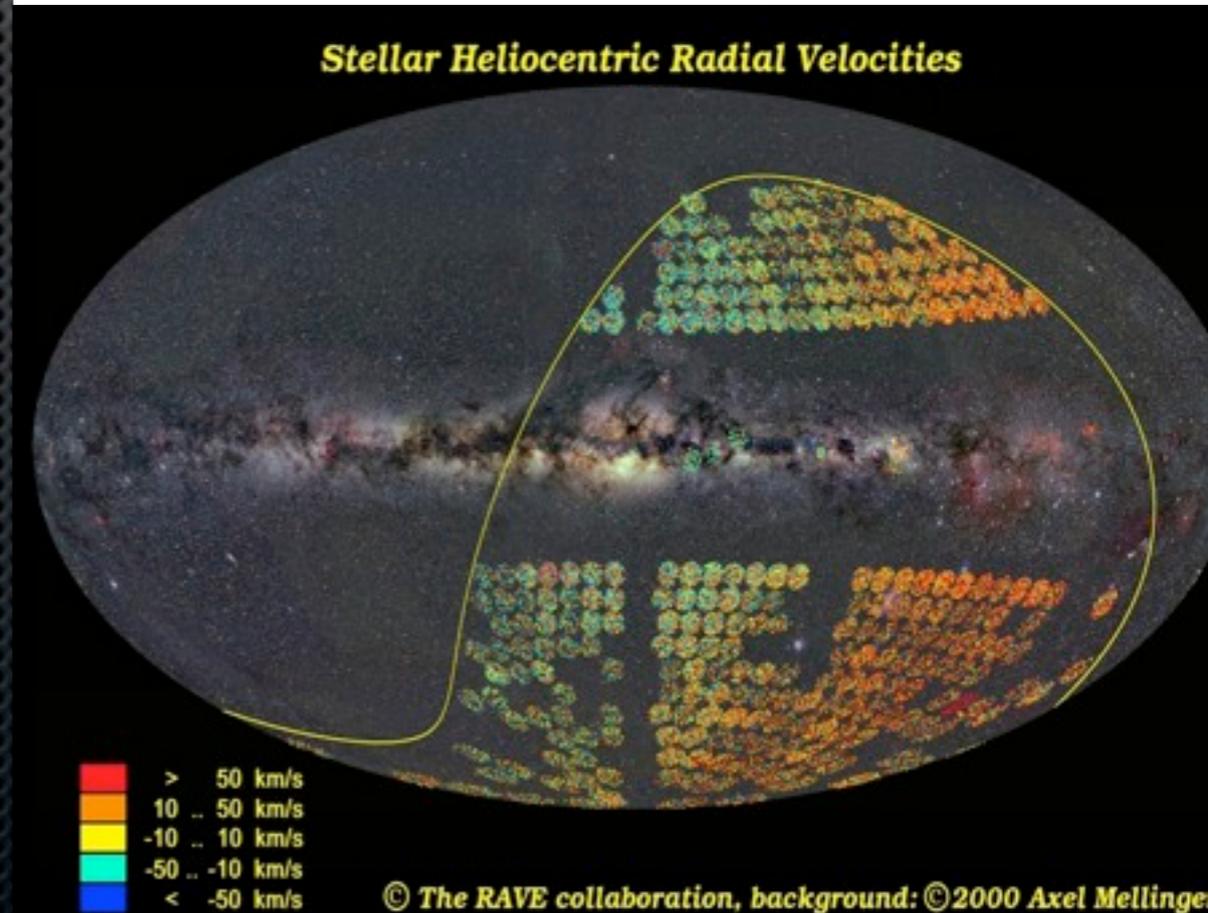
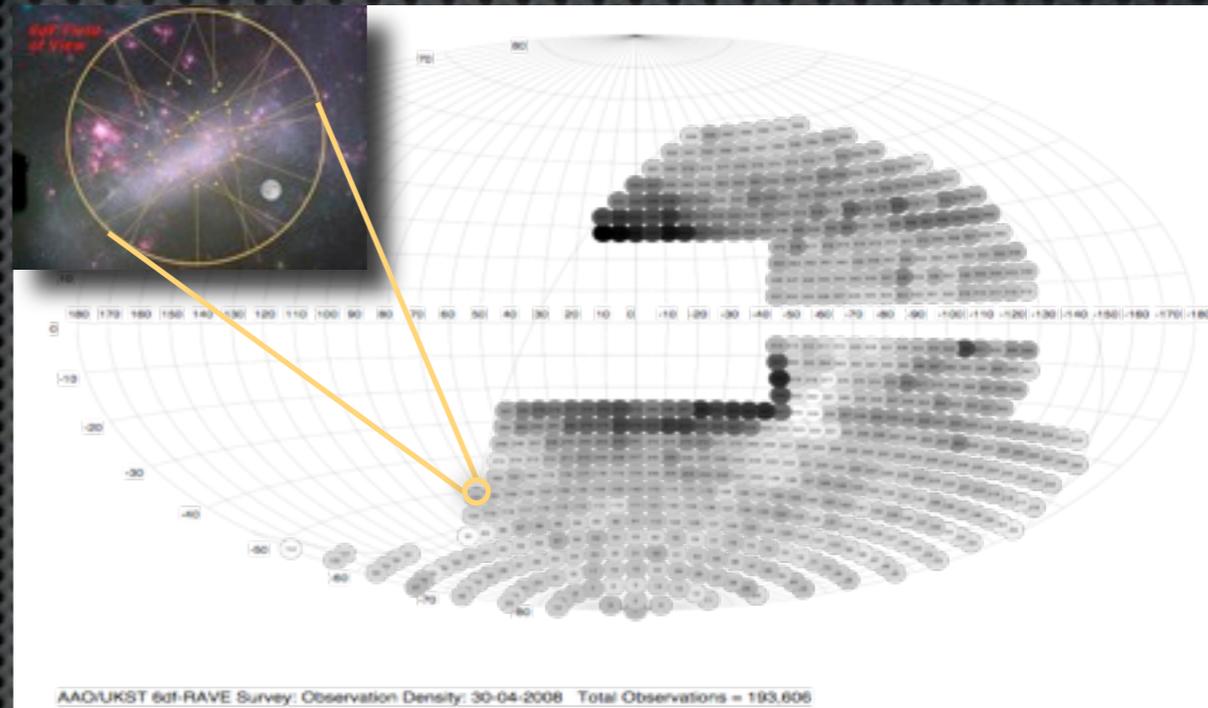
- **RAVE observations to July 2008:**

- Total fields observed = 3247
- Total spectra obtained = 293,656
- Total stars observed = 262,673

- **Second Data Release, July 2008:**

- Year 2 release ~ 25,000 spectra
- Velocities:  $\Delta v_{\text{rad}} \sim 1.3$  km/s
- Temperature:  $\Delta T_{\text{eff}} \sim 300$  K
- Surface gravity:  $\Delta \log g \sim 0.3$  dex
- Metallicity:  $\Delta [\text{Fe}/\text{H}] \sim 0.2$  dex

- **Future releases:  $\Delta v < 1.0$  km/s**



# RAVE science programs

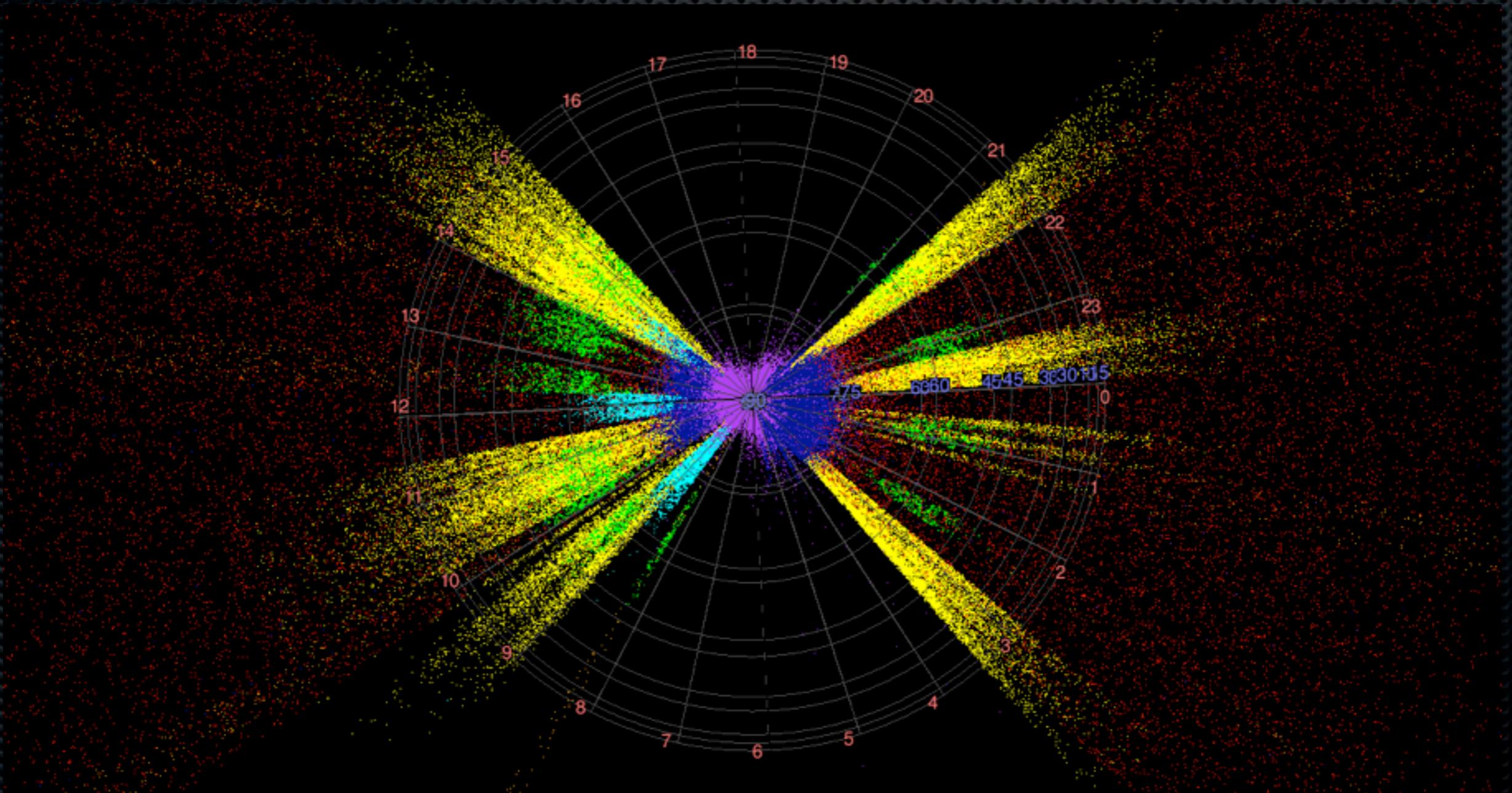
- **Structure and formation of the Galaxy...**
  - **Mass distribution and Galactic potential:** constrain potential via action space;  $K_z$ ; local escape velocity
  - **Dynamical state and structure of the Galaxy:** scale height of thick and thin disks from kinematic analysis and gradients; isothermality of thin disk population; tilt of the velocity ellipsoid; kinematics of thin-thick disk interface; 3D distribution function of the local disk
  - **Galactic chemodynamics:** abundance gradient in Galactic disk; abundance patterns in local disk; age-metallicity-velocity relation; abundances of high-velocity stars; metal-poor stars in disk
  - **Galactic substructure:** the Sagittarius and Arcturus streams; limits on phase space substructure; velocity signatures of spiral structure
- **Stellar and ISM science...**
  - spectral analysis for stellar parameters; spectral classification; stellar photometric parallaxes; cataclysmic variables; emission line stars; binary stars; stellar rotation; diffuse interstellar bands

# UKST opportunities

- There are opportunities for major new surveys on the UKST after the expected end of the RAVE survey in 2011
  - surveys could use **6dF or new instrumentation**
  - deadline for proposals is **30 June 2009**
  - see **[http://www.aao.gov.au/ukst/UKST\\_AO\\_2009.pdf](http://www.aao.gov.au/ukst/UKST_AO_2009.pdf)**
- Proposals should...
  - **lead to significant benefit to Australian science** (i.e. should involve Australian collaborators)
  - **be cost-neutral to the AAO** (cost depends on operational model and instrumentation)
- **N.B. UKST requires refurbishing** for future long-term use

# AAO redshift surveys

- AAT & UKST have measured 600,000  $z$ 's (about 1/3 of all known  $z$ 's)
- WiggleZ & GAMA surveys with AAOmega are rapidly measuring more



AAT & UKST redshift surveys: 6dFGS (purple), 2dFGRS (blue), 2QZ (red), MGC (darkblue), GAMA (cyan), 2SLAQ-LRG (green), 2SLAQ-QSO (orange), WiggleZ (yellow); celestial sphere is at  $z=1.0$ .