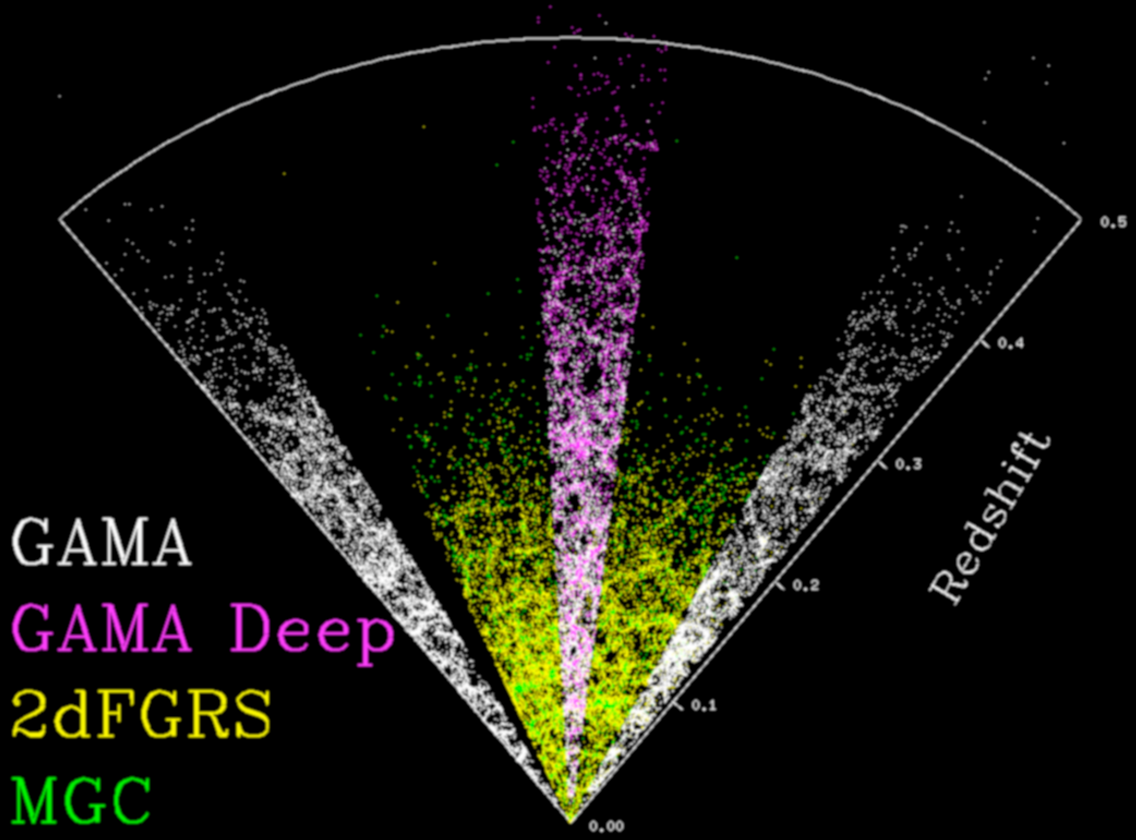
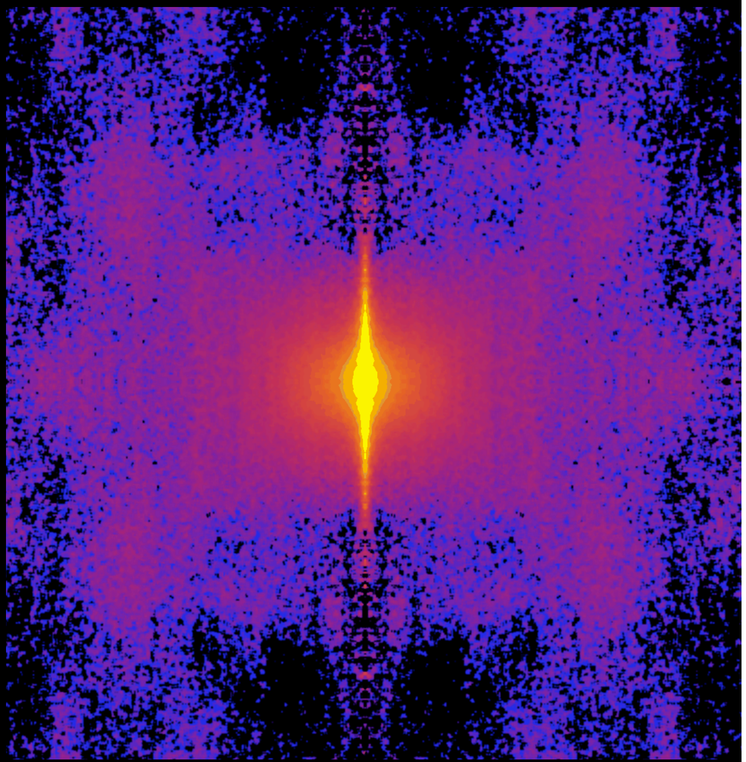
Redshift-space distortions, γ and GAMA

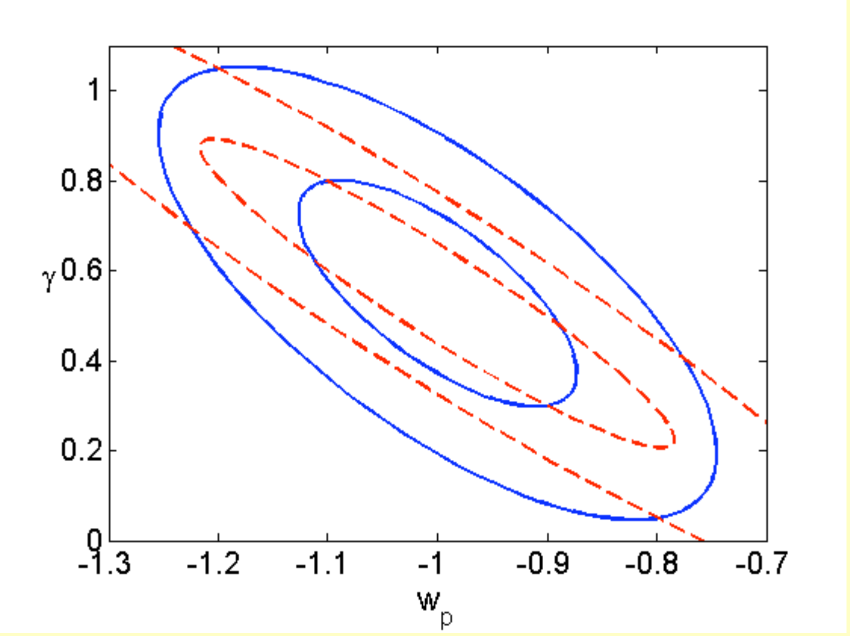




John Peacock
Princeton SUMIRE Workshop
11 Nov 2009

Outline

- Goals: w → DE + modified gravity
- Tools: BAO → BAO + RSD
- Unified treatment (Fergus Simpson + JP 09)
- GAMA: New data from AAOmega



A non-standard universe?

Inference of DE comes from assuming Friedmann:

$$H^2(a) = H_0^2 \left[\Omega_r a^{-4} + \Omega_m a^{-3} + \Omega_k a^{-2} + \Omega_{\mathrm{DE}} a^{-3(1+w)}\right]$$

Extra term

Is DE a physical component, or a failure of Einstein gravity? (not of GR)

$$d\tau^2 = (1+2\Psi)\, dt^2 - (1-2\Phi)\, R^2(t) \left(dr^2 - r^2 d\psi^2\right)$$

Einstein: $\Psi = \Phi;\ \nabla^2\Phi = 4\pi G\bar{\rho}\delta$

$\Rightarrow f_g(a) \equiv d\ln\delta(a)/d\ln a = \Omega_m(a)^\gamma;\ \gamma = 0.55$

Lensing measures sum of potentials; clustering tests perturbation growth law (measure γ)

Observing scales in redshift space

(1) Matter-radiation horizon:

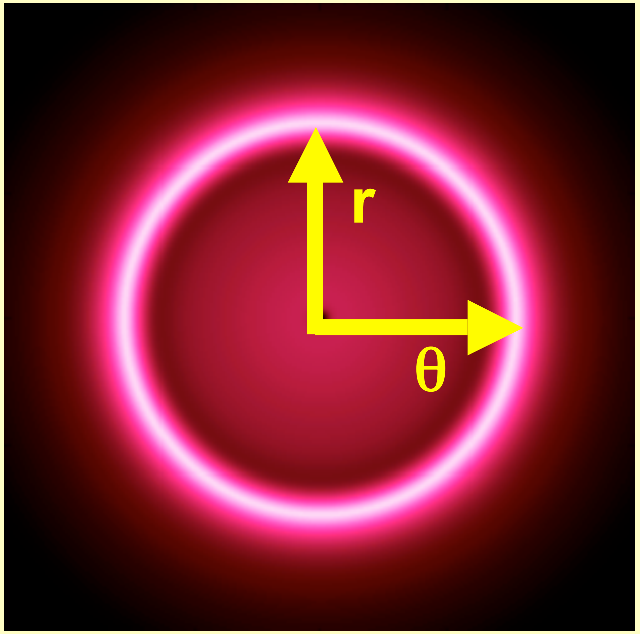
$123\ (\Omega_m h^2 / 0.13)^{-1}$ Mpc

(2) Acoustic horizon at last scattering :

$147\ (\Omega_m h^2 / 0.13)^{-0.25} (\Omega_b h^2 / 0.024)^{-0.08}$ Mpc

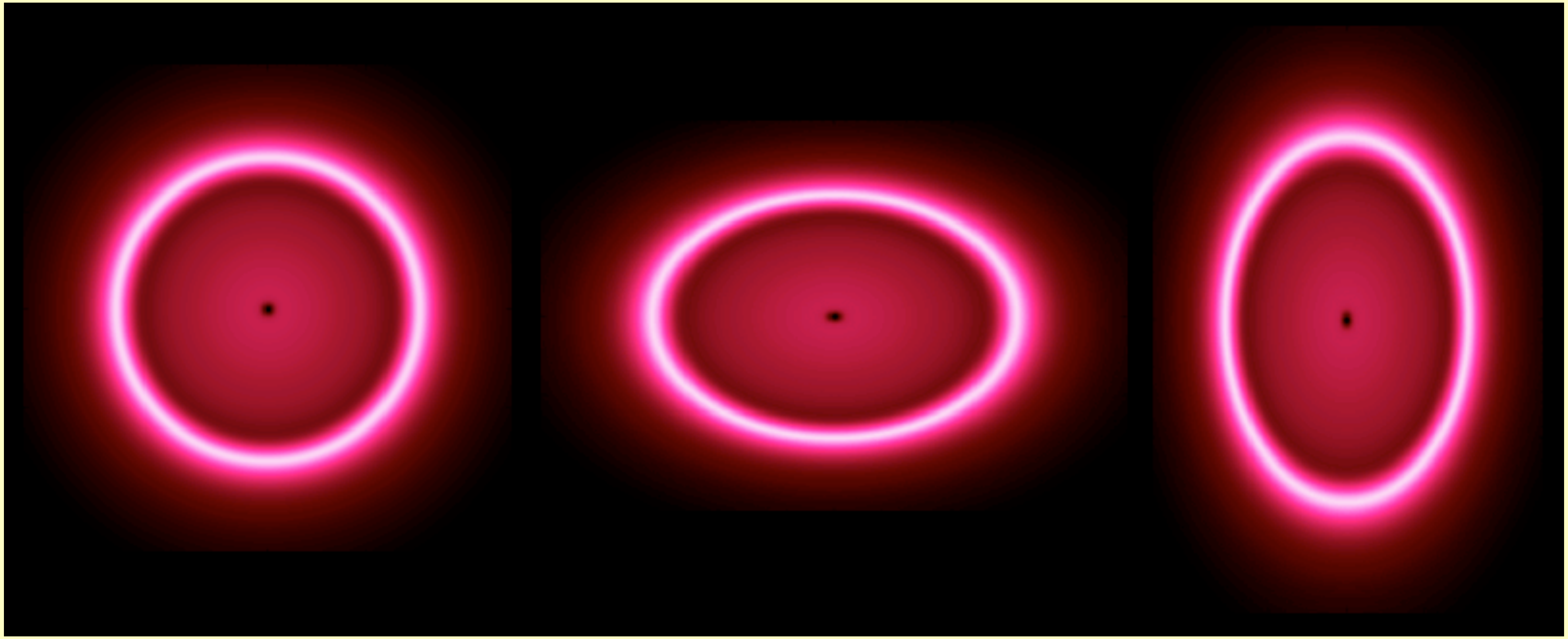
Observe transversely or radially:

$\theta = L / D(z)$ or $dz = L / [c/H(z)]$



Assume average scale depends on $D_V=(D^2[c/H])^{1/3}$

Alcock-Paczynski distortions

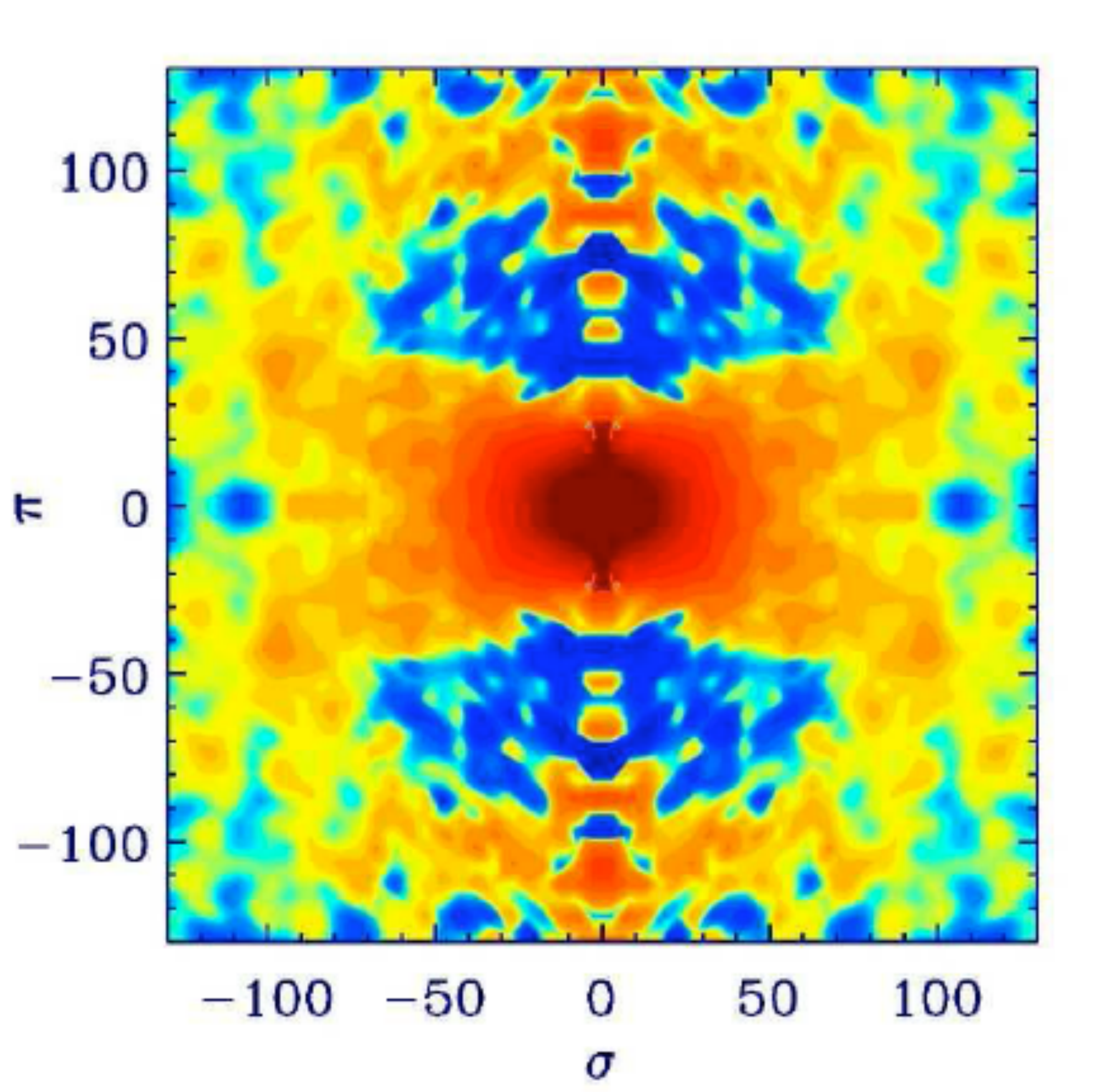


$$H(z) = H_0[\Omega_v(1+z)^{3+3w} + \Omega_m(1+z)^3 + (1-\Omega)(1+z)^2]^{1/2}$$
$$D(z) = \int_0^z \frac{c}{H(z)}\, dz$$

Radial/Transverse scalings: $f_\perp = D/D_{\rm ref}$, $f_\| = H_{\rm ref}/H$

Flattening factor: $F = f_\perp / f_\|$

Combining BAO and RSD

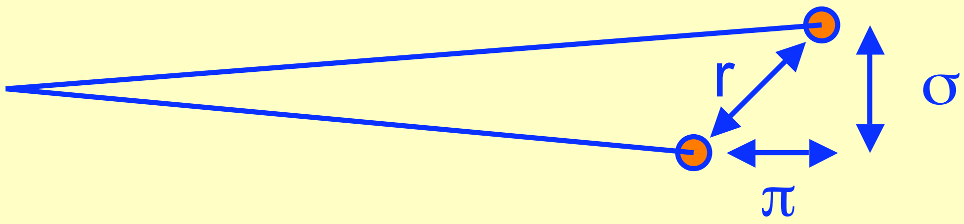


SDSS LRG Redshift-space 2D $\xi(\sigma,\pi)$ Gaztanaga et al. 0807.3551

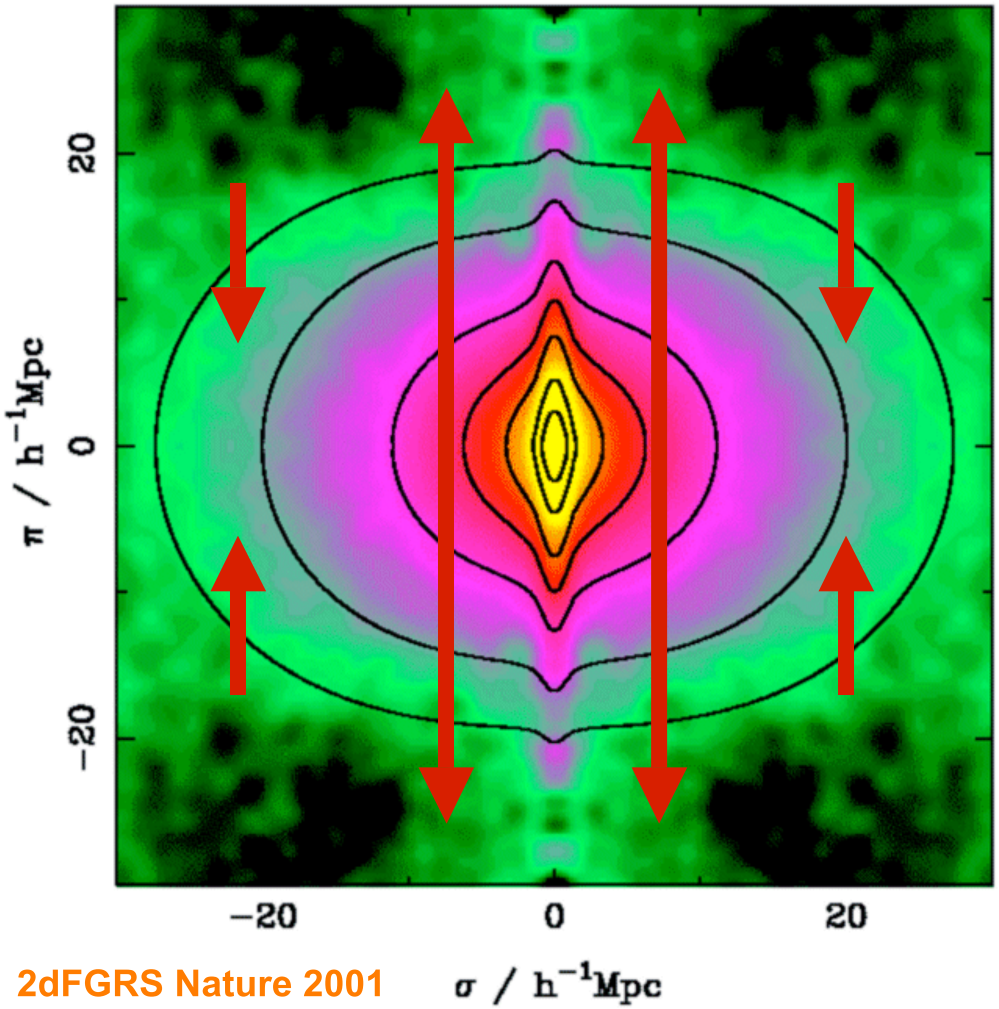
Kaiser flattening at ~ 10-20 Mpc from peculiar velocities.

Little affect on BAO ring

Redshift-Space Distortions



- RSD due to peculiar velocities are quantified by correlation fn ξ(σ,π).
- Two effects visible:
  - Small separations on sky: 'Finger-of-God';
  - Large separations on sky: flattening along line of sight.



2dFGRS Nature 2001

Kaiser and A-P degeneracy

Simple theory (linear + FoG):

$$P_{\rm gal}(k) = b^2 P_m(k)\ \left[1+\beta\mu^2\right]^2 D\left(k\mu\sigma_p\right); \quad \beta \equiv f_g/b$$

But Kaiser dynamical flattening is approximately degenerate with A-P geometrical flattening: β_{eff}=(F-1)/2

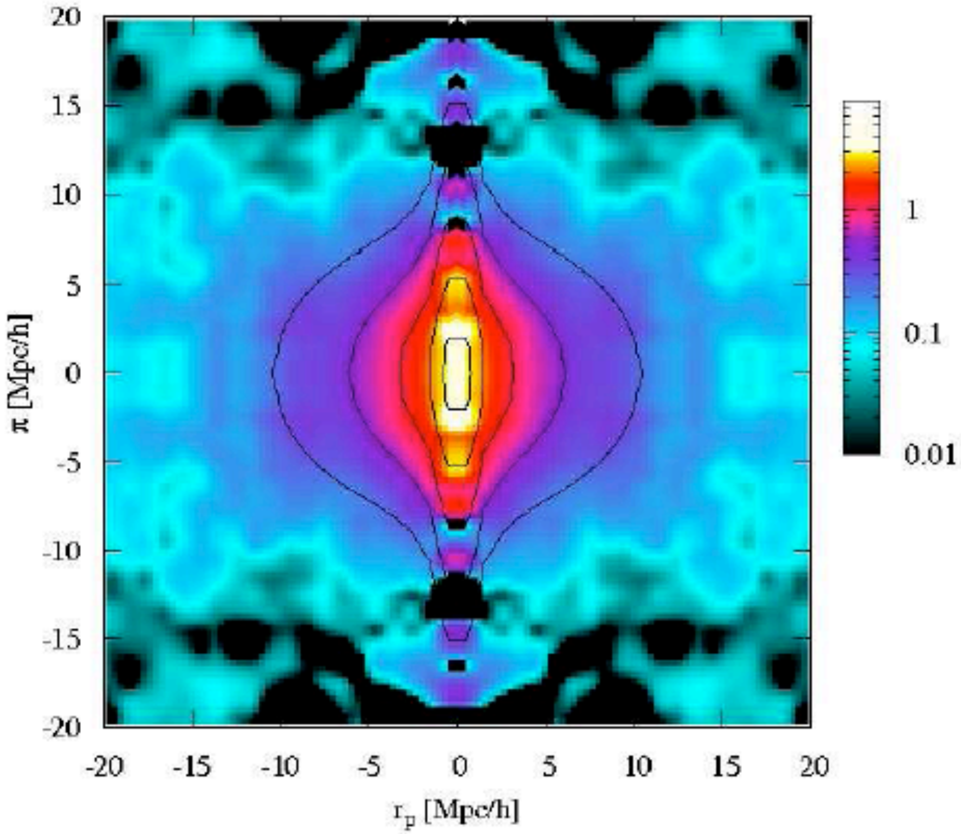
$$P'_{\rm gal}(k') = \frac{1}{f_\perp^2 f_\parallel} b^2 P_m\left(\frac{k'}{f_\perp}\sqrt{1+\mu'^2\left(\frac{1}{F^2}-1\right)}\right) \times \left[1+\mu'^2\left(\frac{1}{F^2}-1\right)\right]^{-2} \times \left[1+\mu'^2\left(\frac{\beta+1}{F^2}-1\right)\right]^2 D\left(\frac{k'_\parallel \sigma_p}{f_\parallel}\right),$$

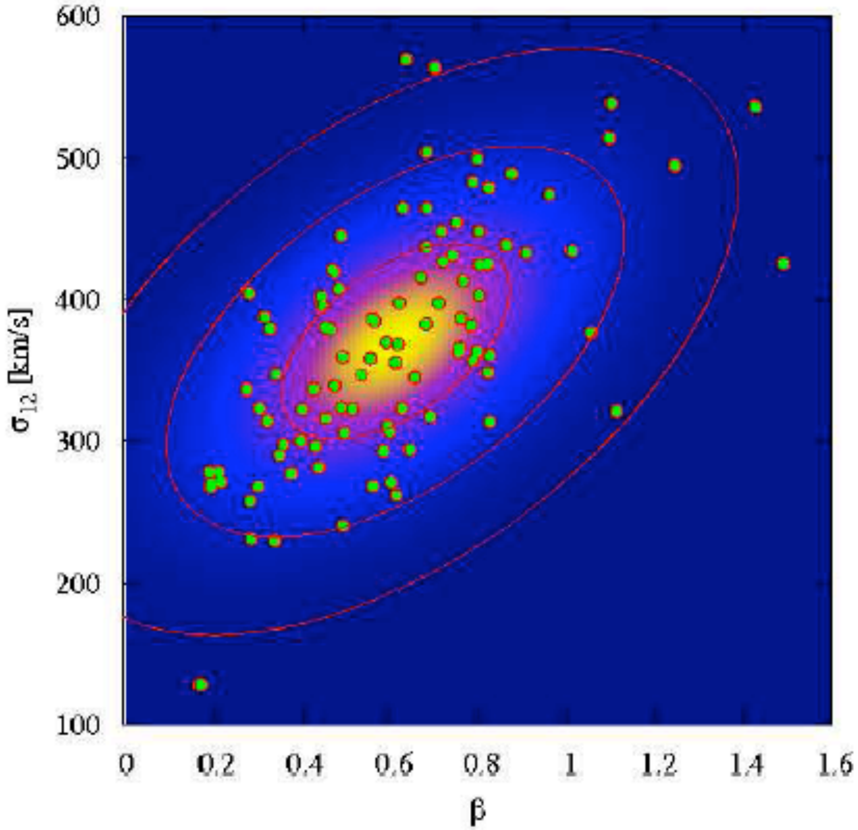
Ballinger et al. 1996

Measuring the growth rate

- Peculiar velocities come from $f_g(a)=d \ln \delta / d \ln a$
- But measure $\beta = f_g / b$
  - b from bispectrum?
- Safer to say $b = \sigma_{gal} / \sigma_m$(CMB | pars)
  - But remember σ_{gal} is affected by A-P

VVDS redshift-space distortions





10k z's: Guzzo et al. Nature 2008

VImos Public Extragalactic Redshift Survey

- New ESO VLT programme
- P.I. Guzzo (Milan)
- 24 deg^2 to $I_{AB} < 22.5$ in CFHTLS fields
- 100k targets at $z > 0.5$, >50% sampling
- 440 VLT hours

- Main aim is to probe modified gravity via RSD

RSD Precision

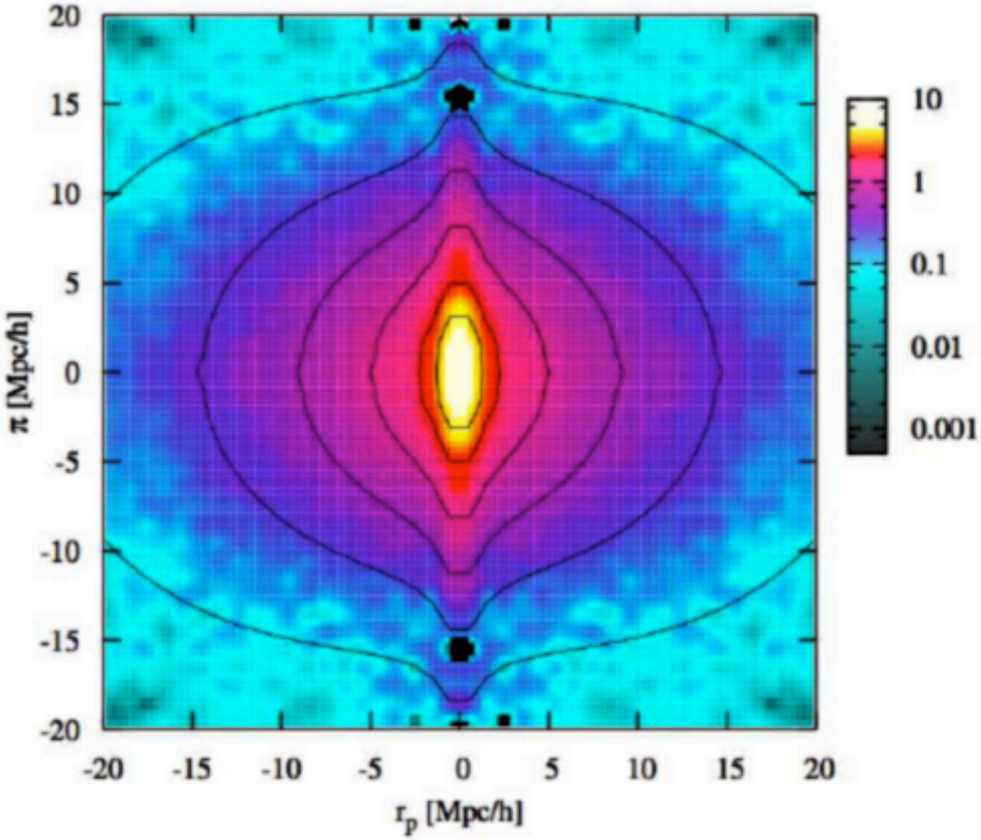
% error in β = (V / 20 h^{-3} $Gpc^3)^{-1/2}$ x (n / 4x10^{-4} h^3 $Mpc^{-3})^{-0.44}$

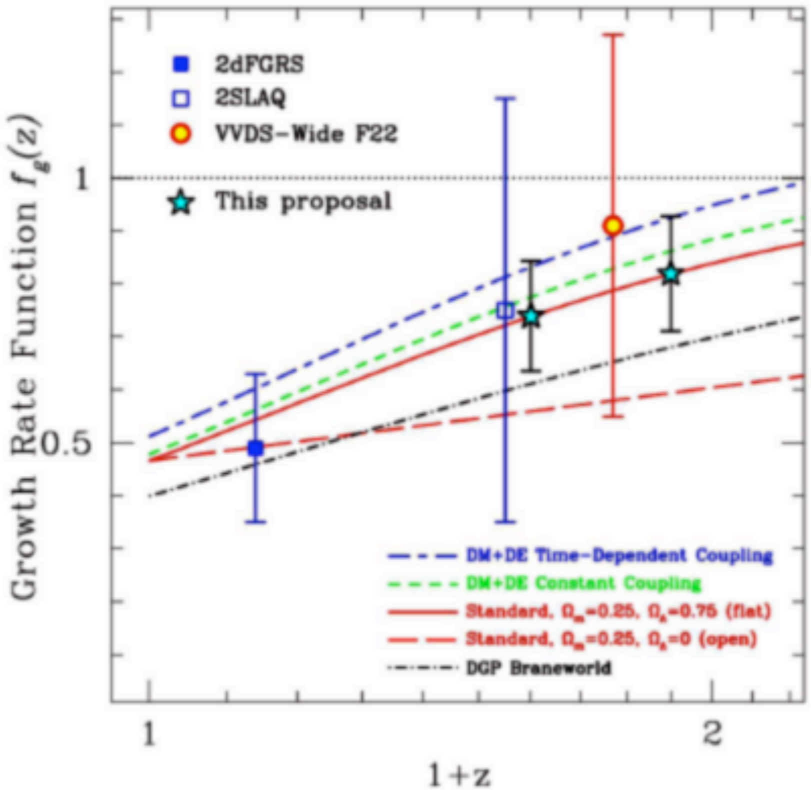
Guzzo et al. 2007; see White & Percival for more accurate Fisher-matrix estimates

Would probably expect a function of V_{eff}:

$$V_{\rm eff} = V \left(\frac{1+nP}{nP} \right)^2$$

RSD predictions for VIPERS



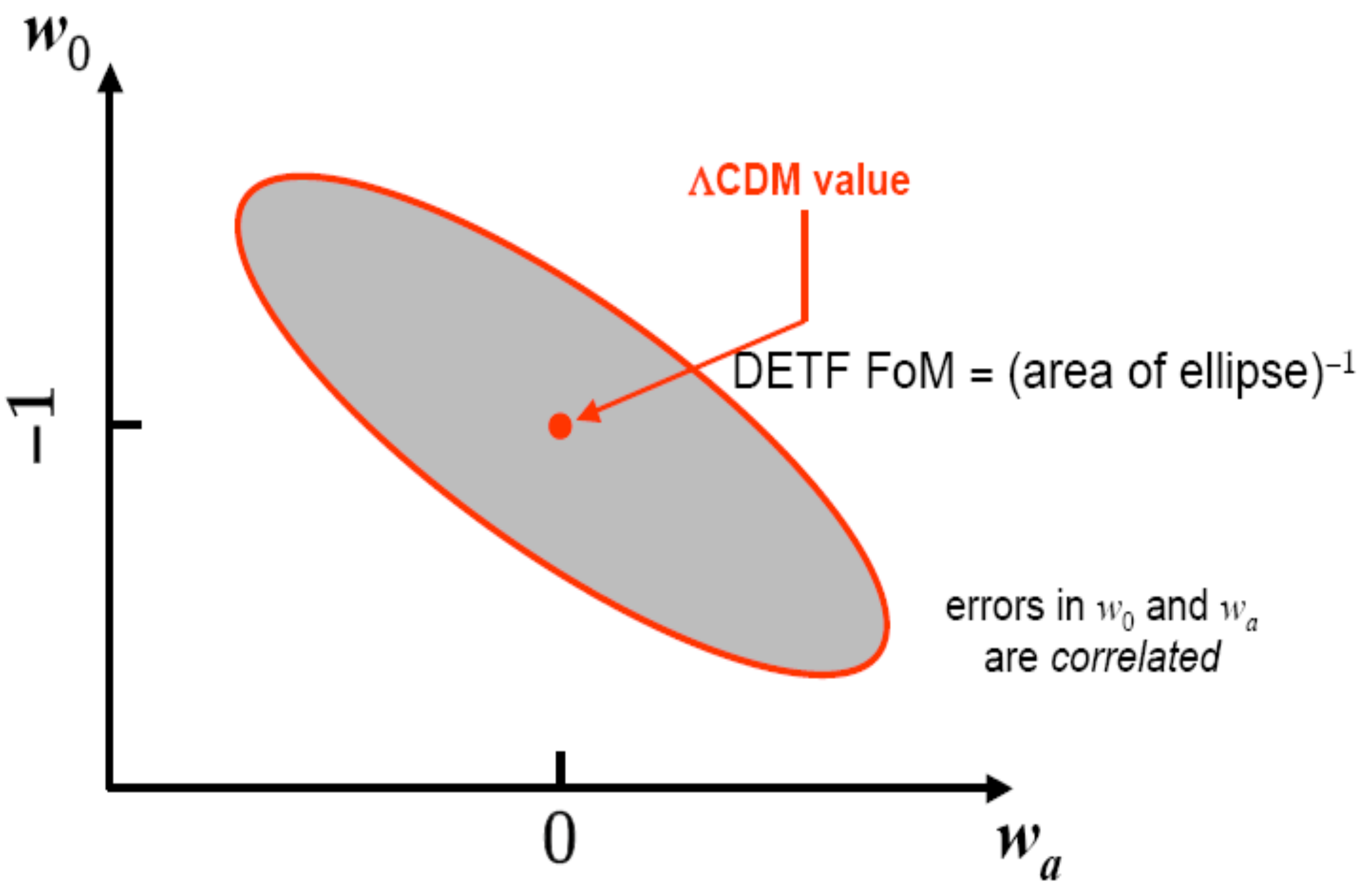


Approved 400h VLT programme: 100k z's over 3 years: predict $\Delta f_g = 0.1$ in 2 bins

DETF figure of merit

$w(a) = w_0 + w_a(1 - a)$: $w = w_0$ today & $w = w_0 + w_a$ in the far past

Marginalize over all other parameters and find uncertainties in w_0 and w_a



2008: add higher order w(a) variations plus quote error on γ

Figures of merit

- DE is just a term in Friedmann: probing non-GR is at least as important as measuring w
- But most people are happy not to consider $\gamma(a)$; thus should avoid too much emphasis on variation in w
- $w = w_0 + w_a (1-a)$ is better regarded as measuring w_p. Rejection of $w = -1$ less likely from poorly measured w_a
- PCA of w(a) interesting, but not a strong driver
- Suggests focus on $\gamma - w_p$ plane

Combining RSD and BAO

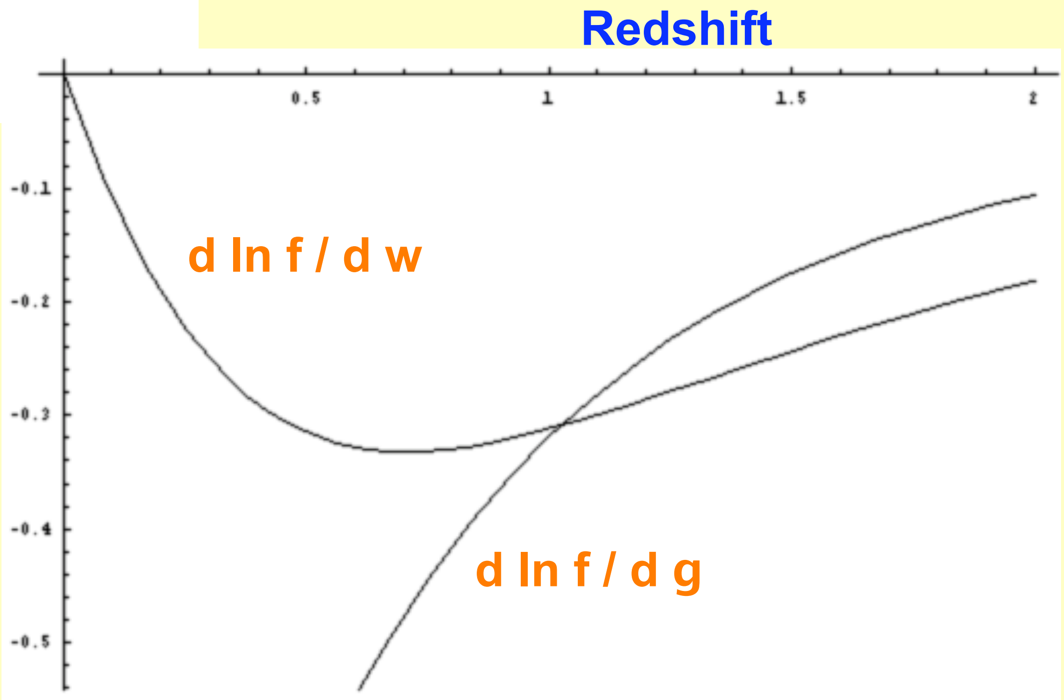
BAO depend on just w if matter content is known (assumed from CMB). RSD depend on both w and γ.

$$f \equiv \frac{d \ln \delta}{d \ln a} = \Omega_m(a)^\gamma \quad \Rightarrow$$

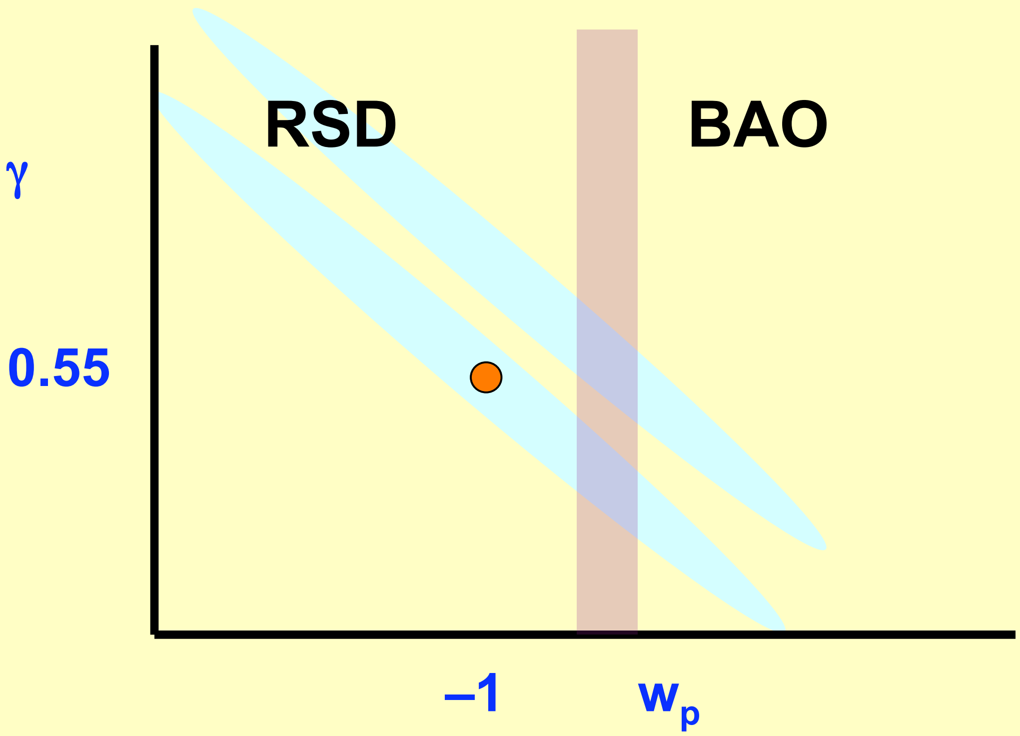
$$\frac{\partial \ln f}{\partial \gamma} = \ln \Omega_m(a)$$

$$\frac{\partial \ln f}{\partial w} = \gamma \frac{\partial \ln \Omega_m(a)}{\partial w}$$

Both derivatives around -0.3 at z = 1



DE-gravity degeneracy



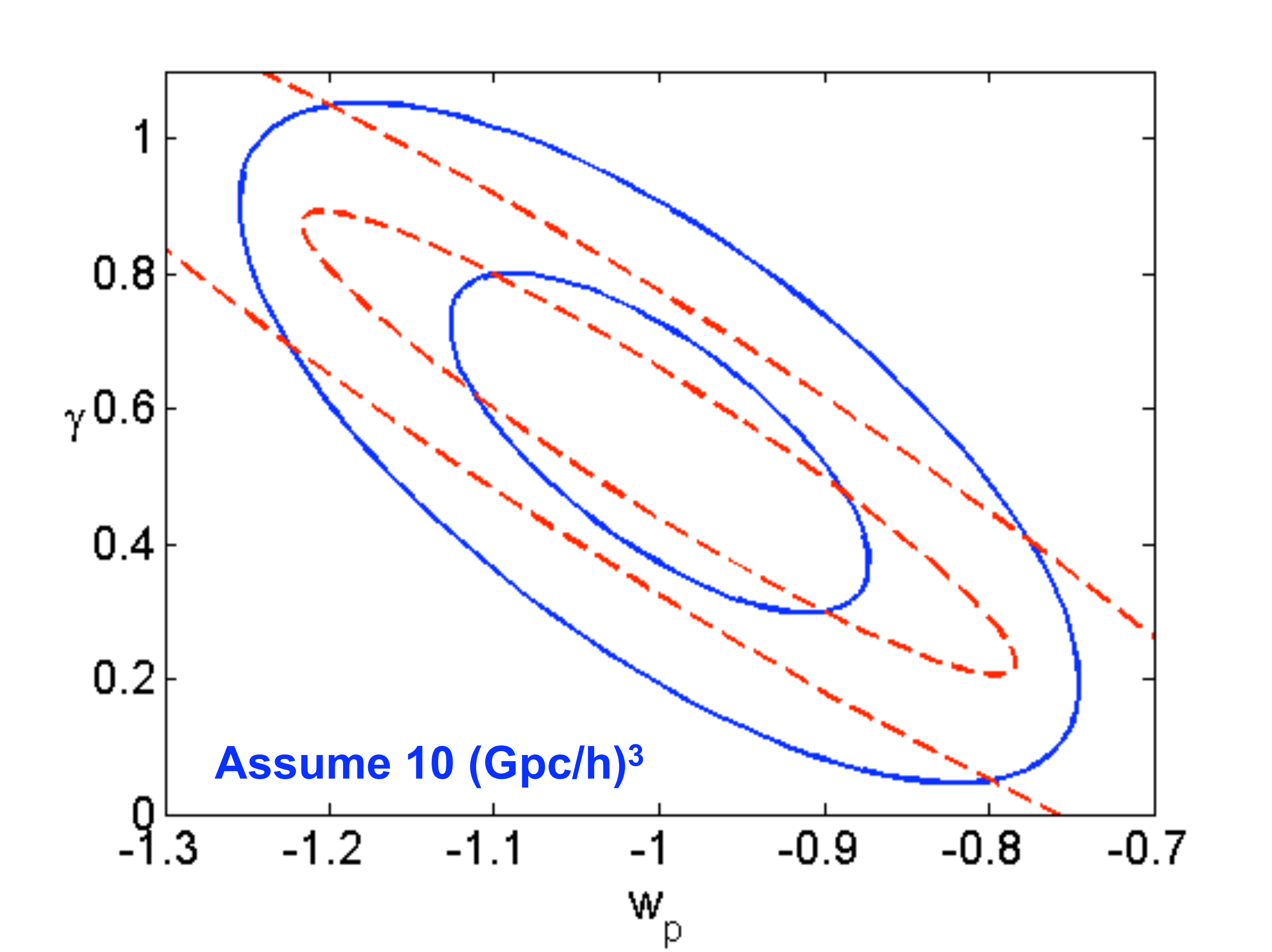
$\gamma + w = x1 \pm y1$

$w = x2 \pm y2$

Good to have both errors comparable.

Good case for FoM based on joint area of confidence ellipsoid in this plane

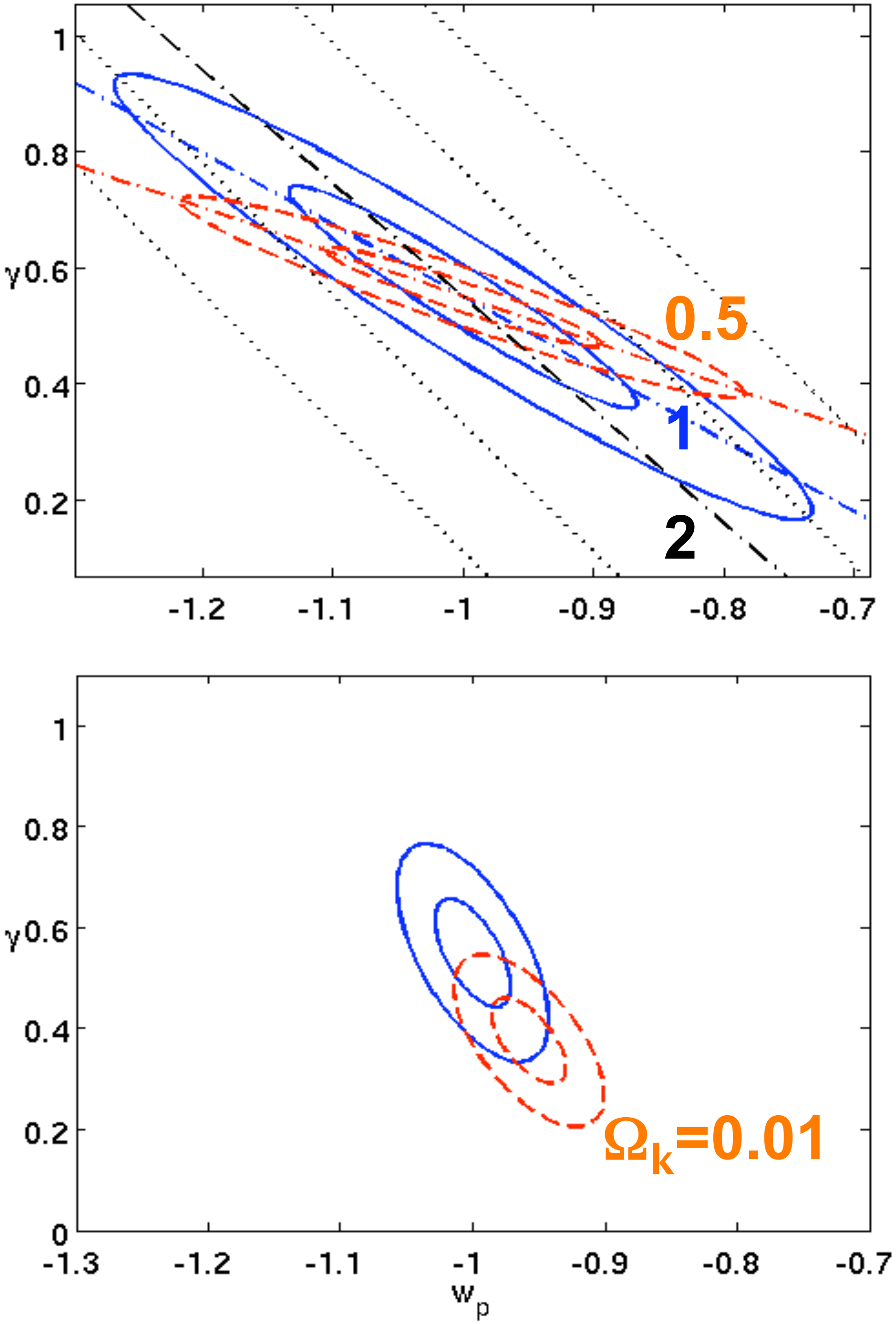
Allowing for Alcock-Paczynski



Fergus Simpson + JAP:

Overall uncertainty in γ can be ~2.5 x figure for w = -1

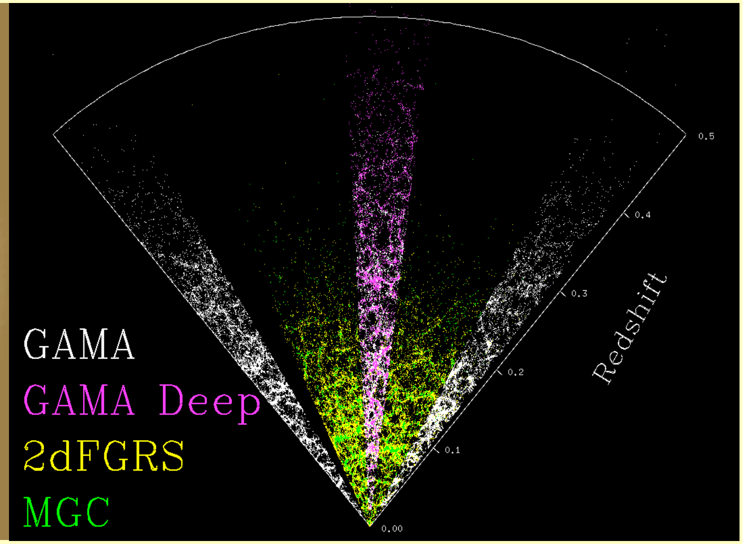
Base FoM on area in γ–w plane



Effect of redshift on degeneracy direction

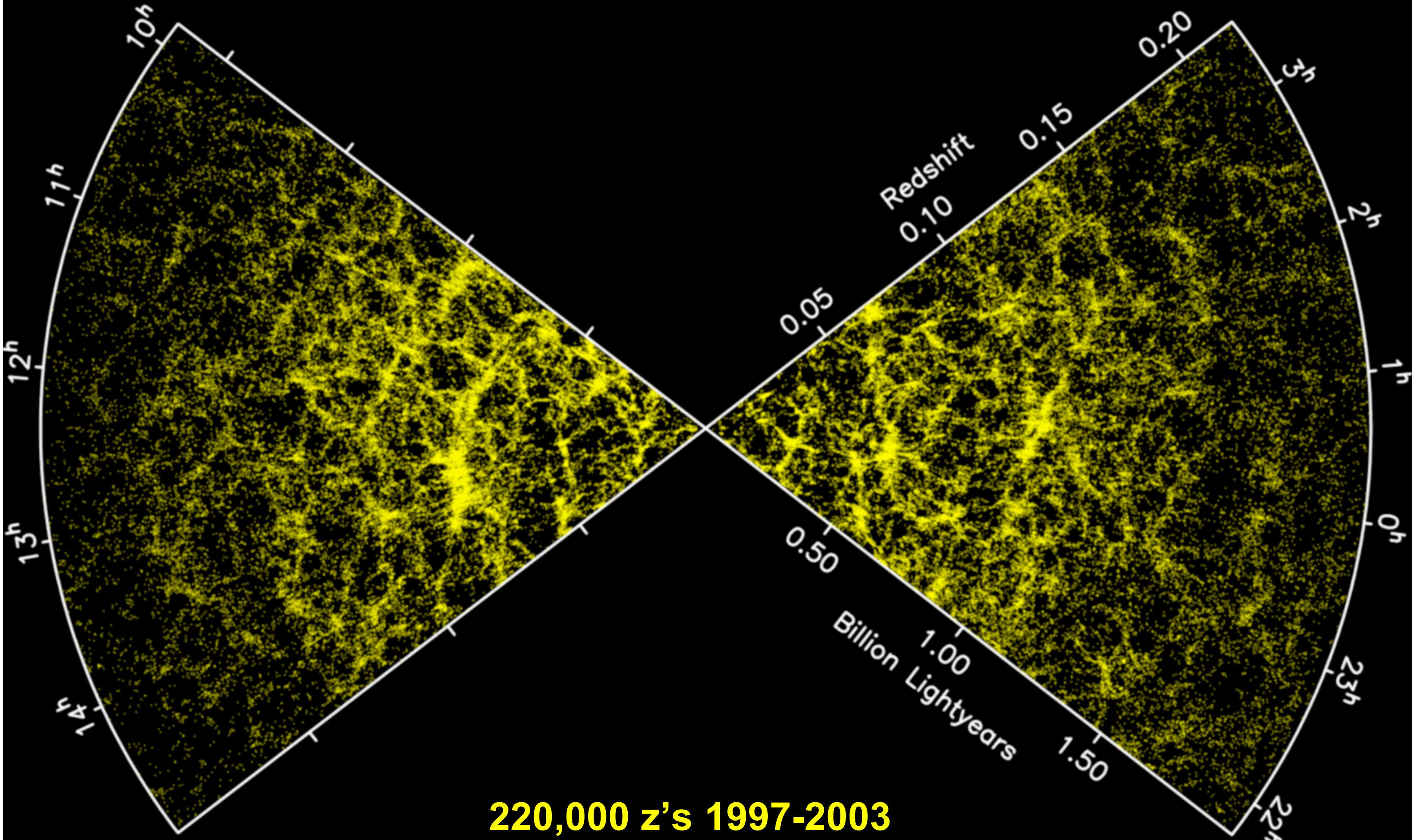
Effect of assuming flat

Galaxy And Mass Assembly – GAMA



- 250 deg^2 in 5 fields
- to r < 19.4 / 19.8 (GAMA deep) in one field – cf. SDSS 17.8
- Aim for >200,000 redshifts
- First 2 observing seasons:
  - 40 AAT nights 08/09 – 80% clear
  - 90k new z's; 96% success
  - Over 100k including 2dFGRS/SDSS

Cosmology after 2dFGRS



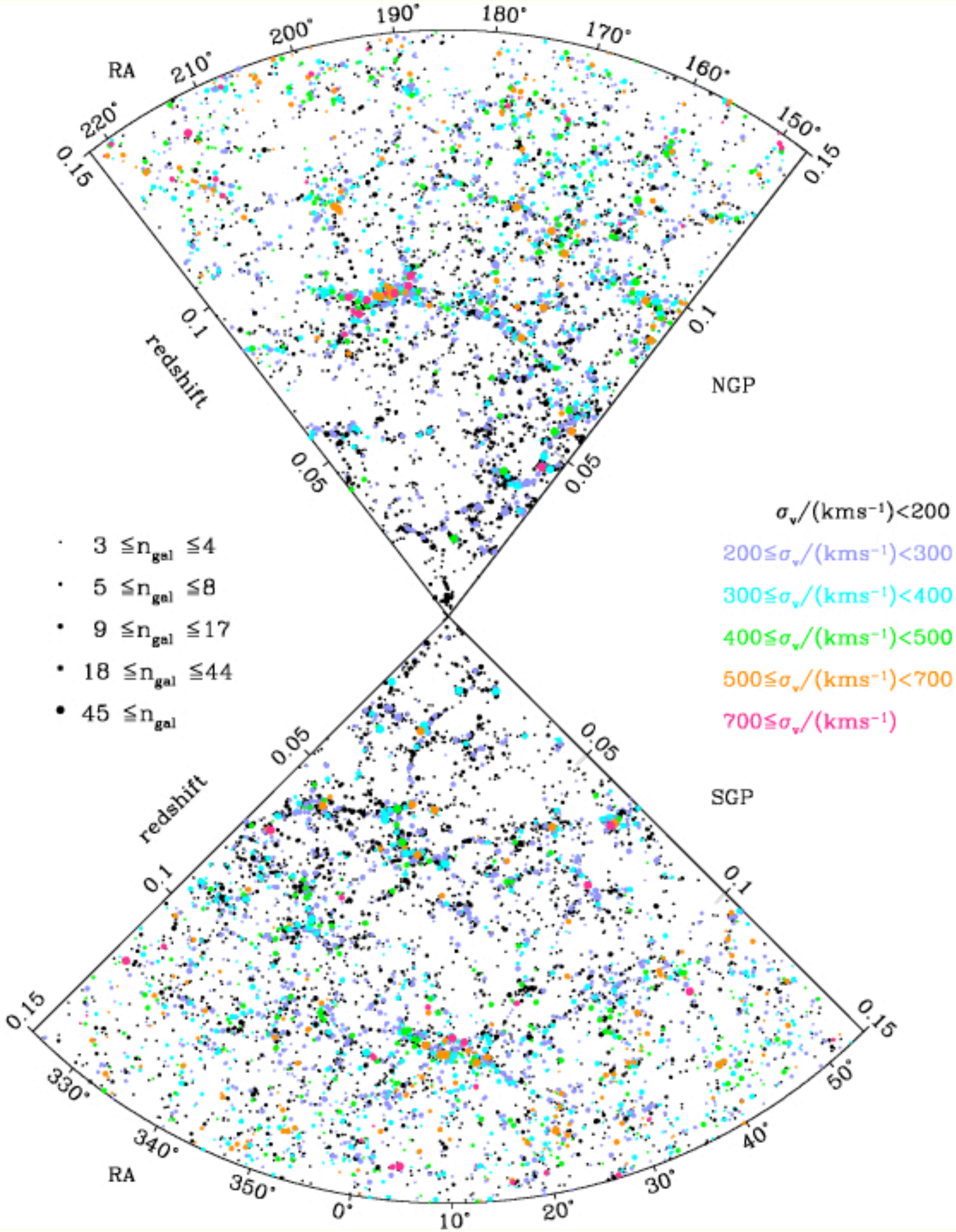
220,000 z's 1997-2003

Open questions

- Fundamental cosmology issues
  - Baryon oscillations
  - Evolution of dark energy
  - Testing modified gravity
- Formation of galaxies and nonlinear structures
  - Hierarchical collapse & nature of DM
  - Feedback and galaxy downsizing
  - Environmental context

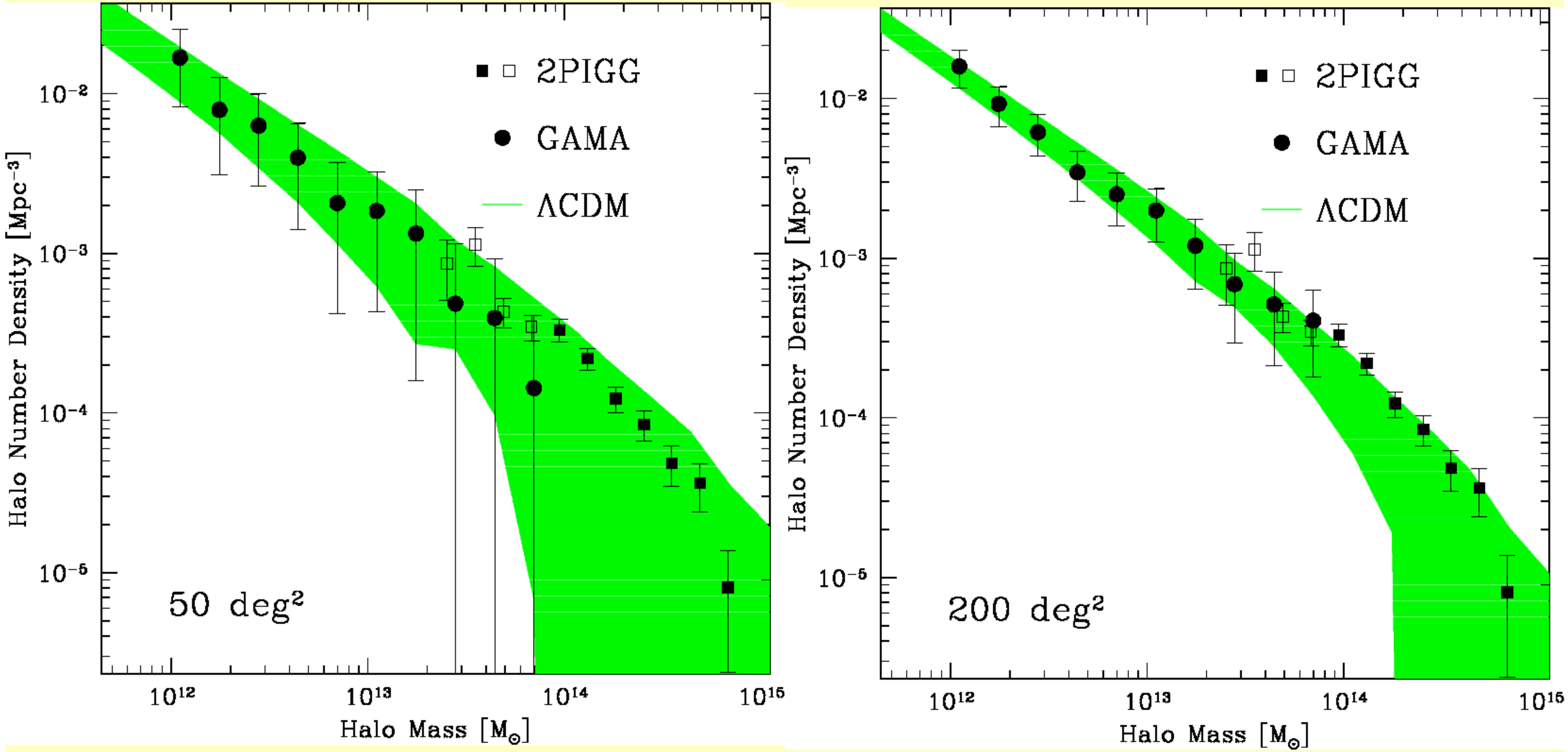
  - Require new deeper survey

2PIGG: Groups in 2dFGRS



Eke + 2dFGRS 2003

Measuring the Halo Mass Function

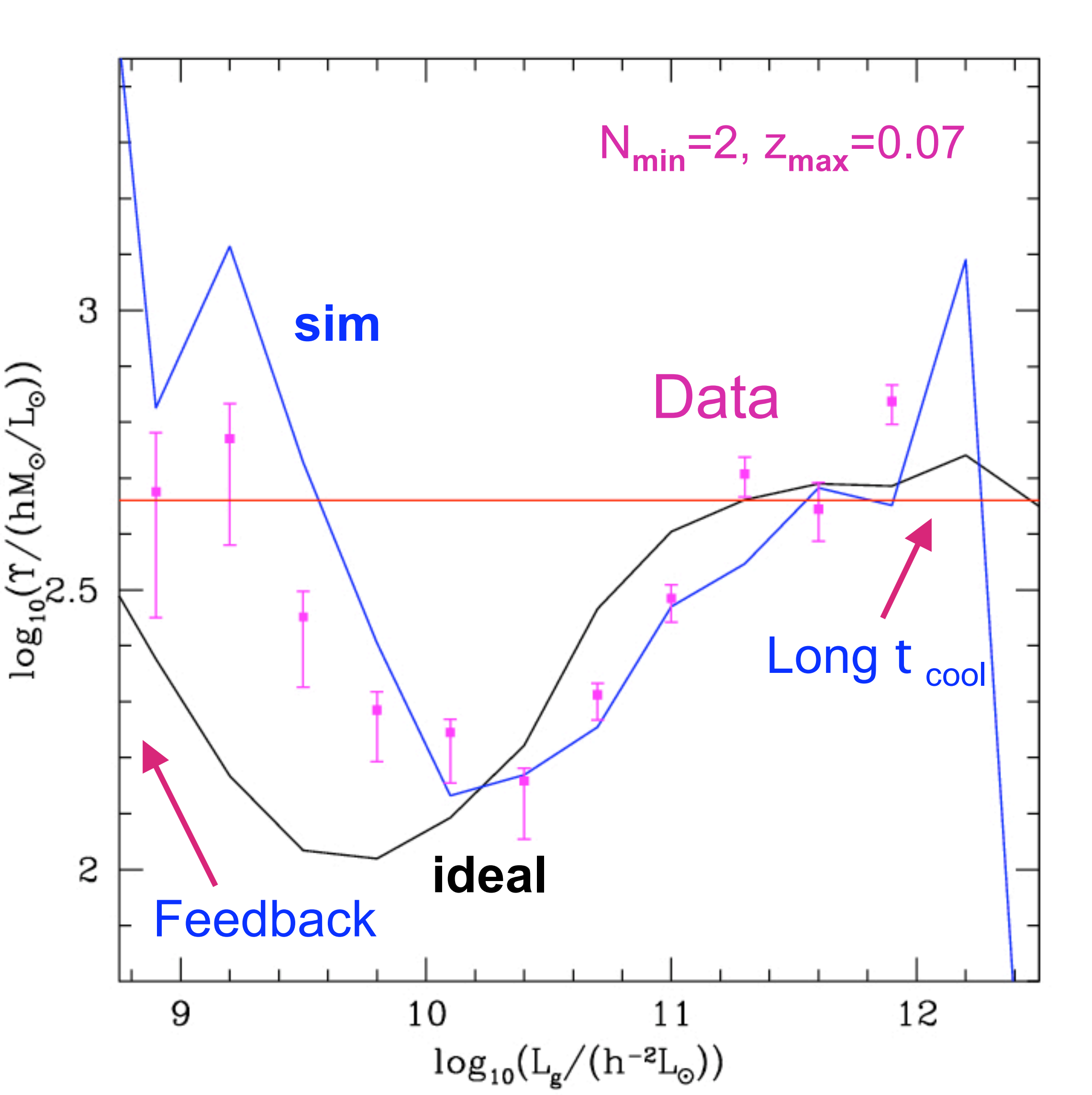


2PIGG: empirical halo galaxy contents

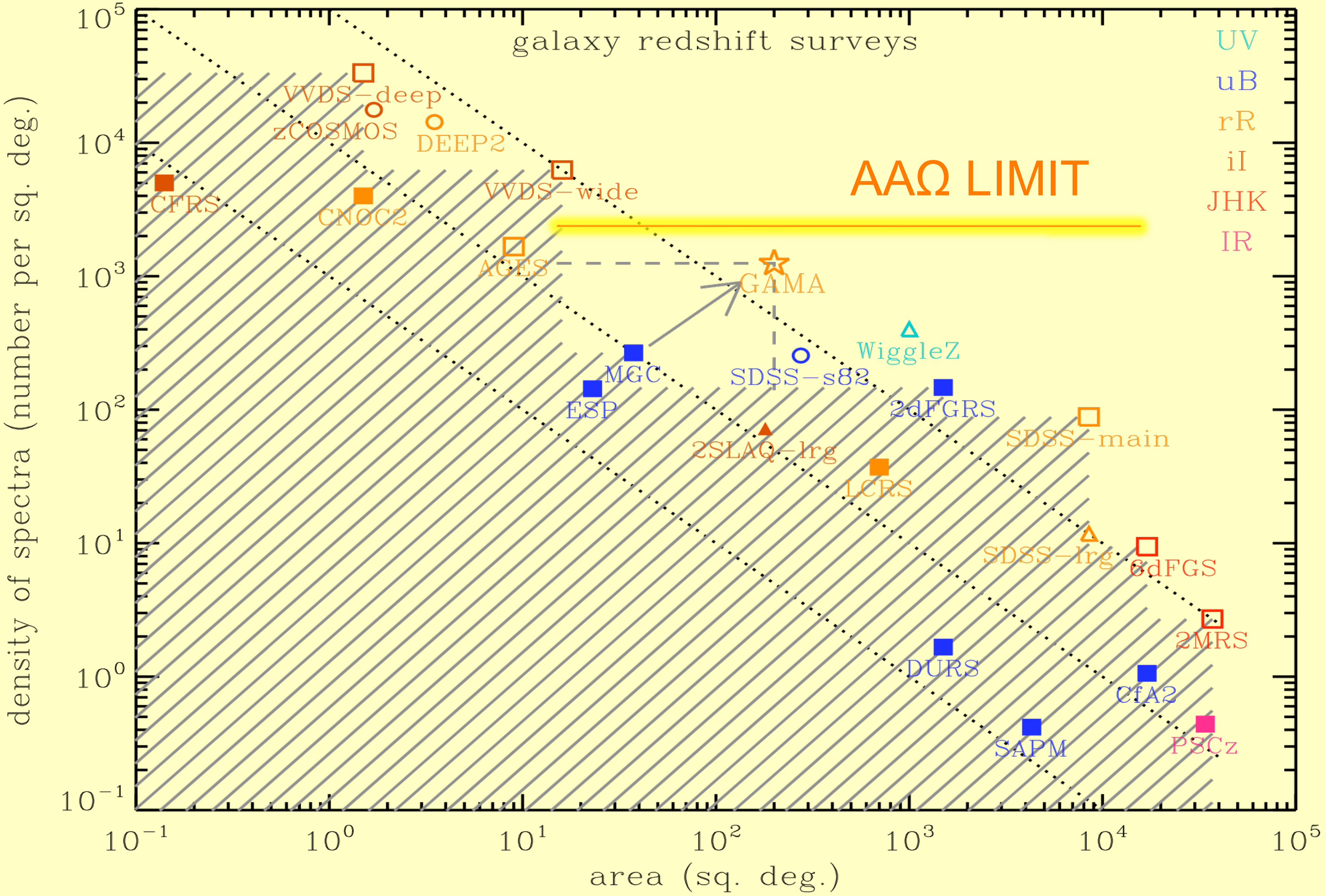
Eke et al. 04:
Factor of 4 decrease in M/L from rich clusters to poor groups

But really want to probe behaviour below total mass M = $10^{12.5}$ M_{sun}

– and evolution

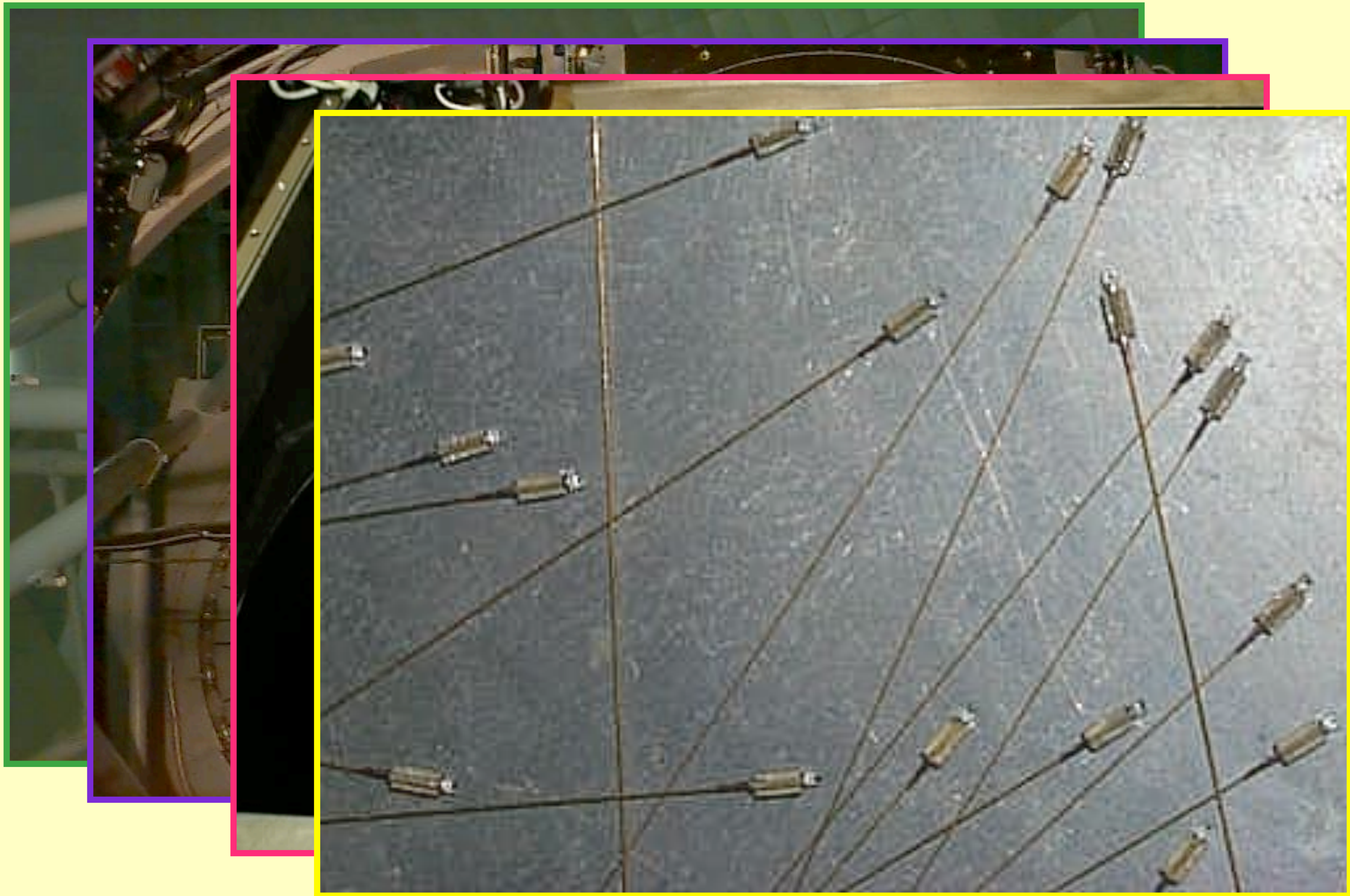


Group luminosity

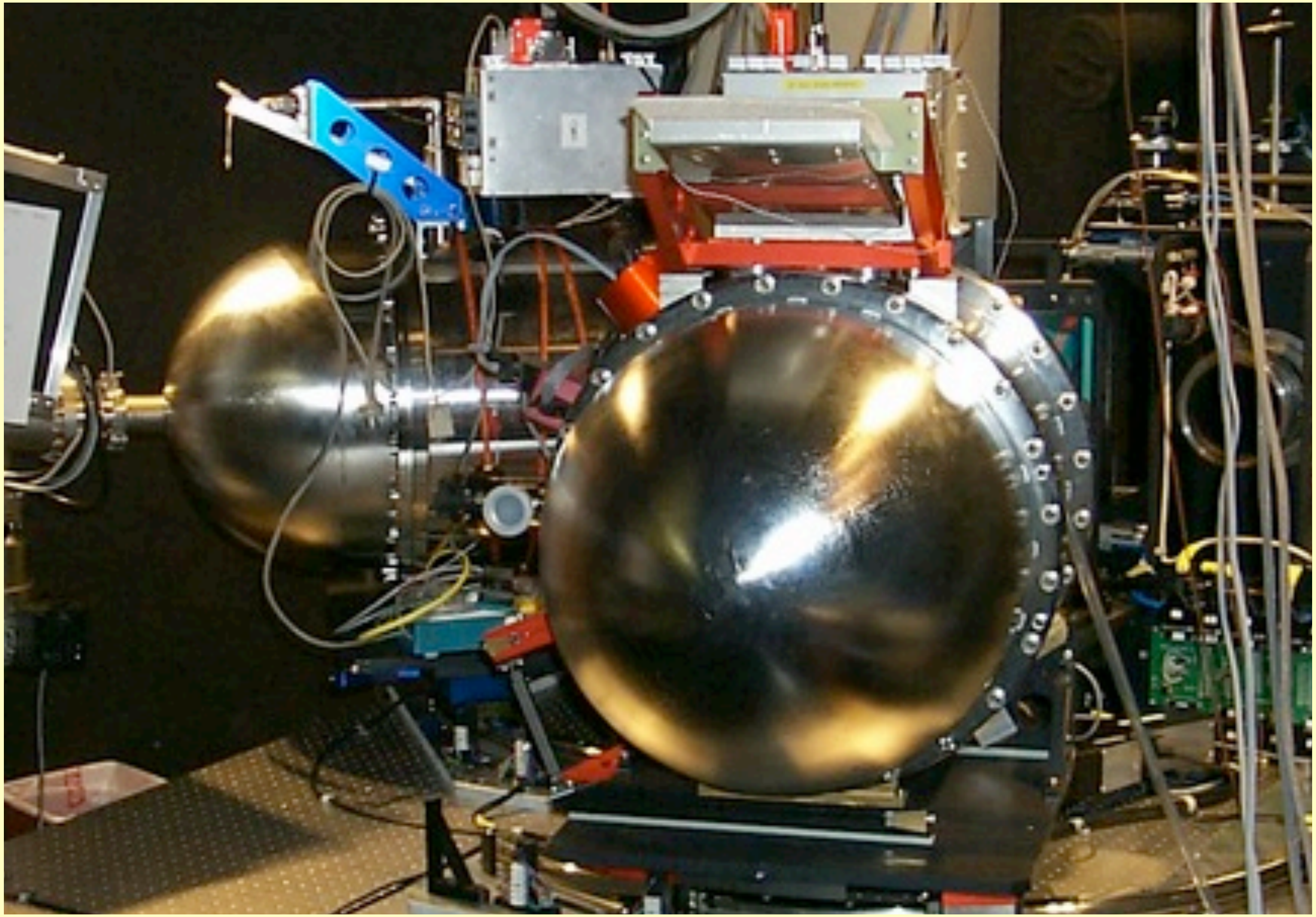


galaxy redshift surveys
UV
uB
rR
iI
JHK
IR
AAΩ LIMIT
VVDS−deep
zCOSMOS
DEEP2
CFRS
CNOC2
VVDS−wide
AGES
GAMA
MGC
ESP
SDSS−s82
WiggleZ
2dFGRS
2SLAQ−lrg
LCRS
SDSS−main
SDSS−lrg
6dFGS
2MRS
DURS
CfA2
SAPM
PSCz
density of spectra (number per sq. deg.)
area (sq. deg.)

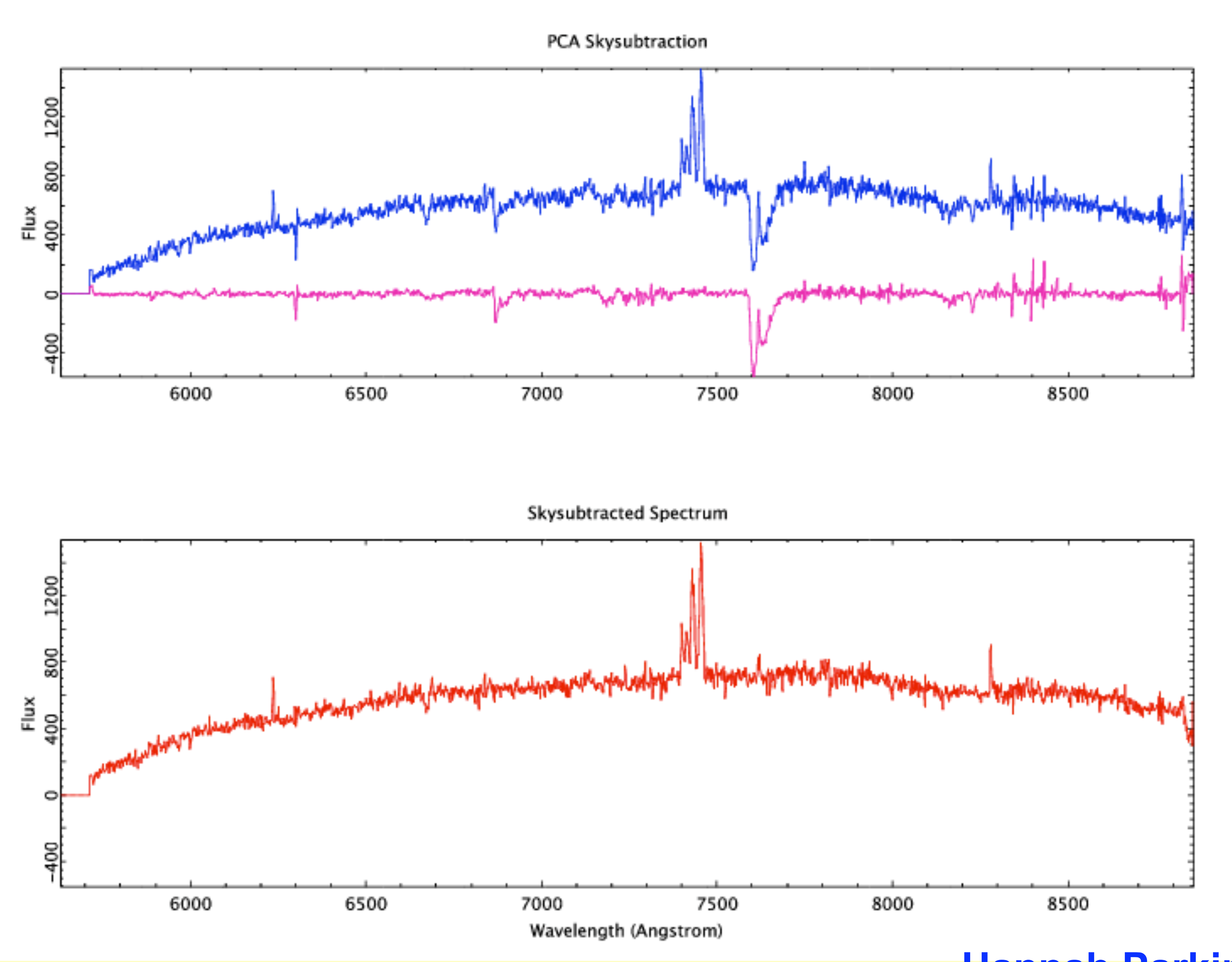
2dF/AAΩ on the AAT



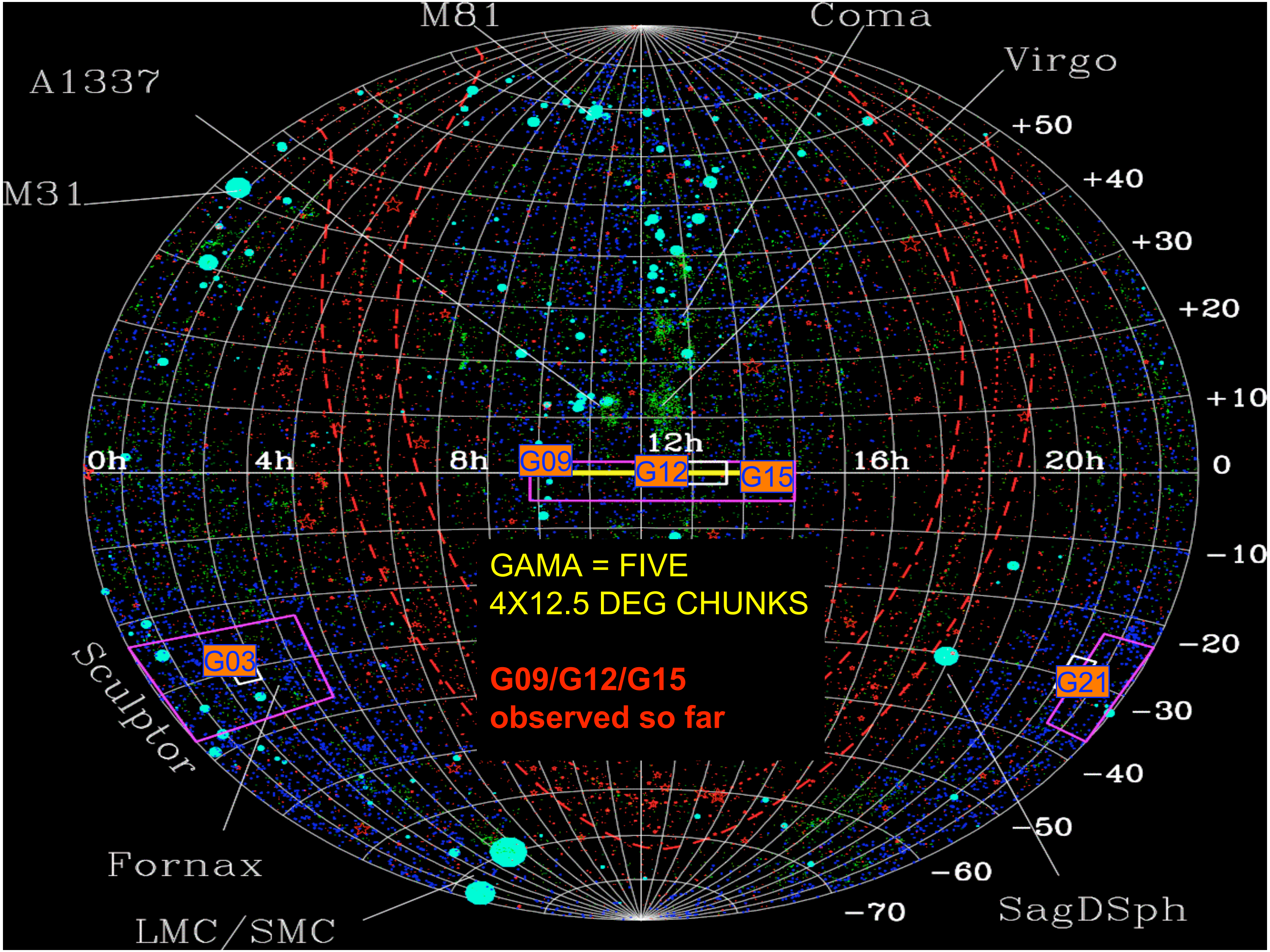
AAΩ: new VPH spectrographs

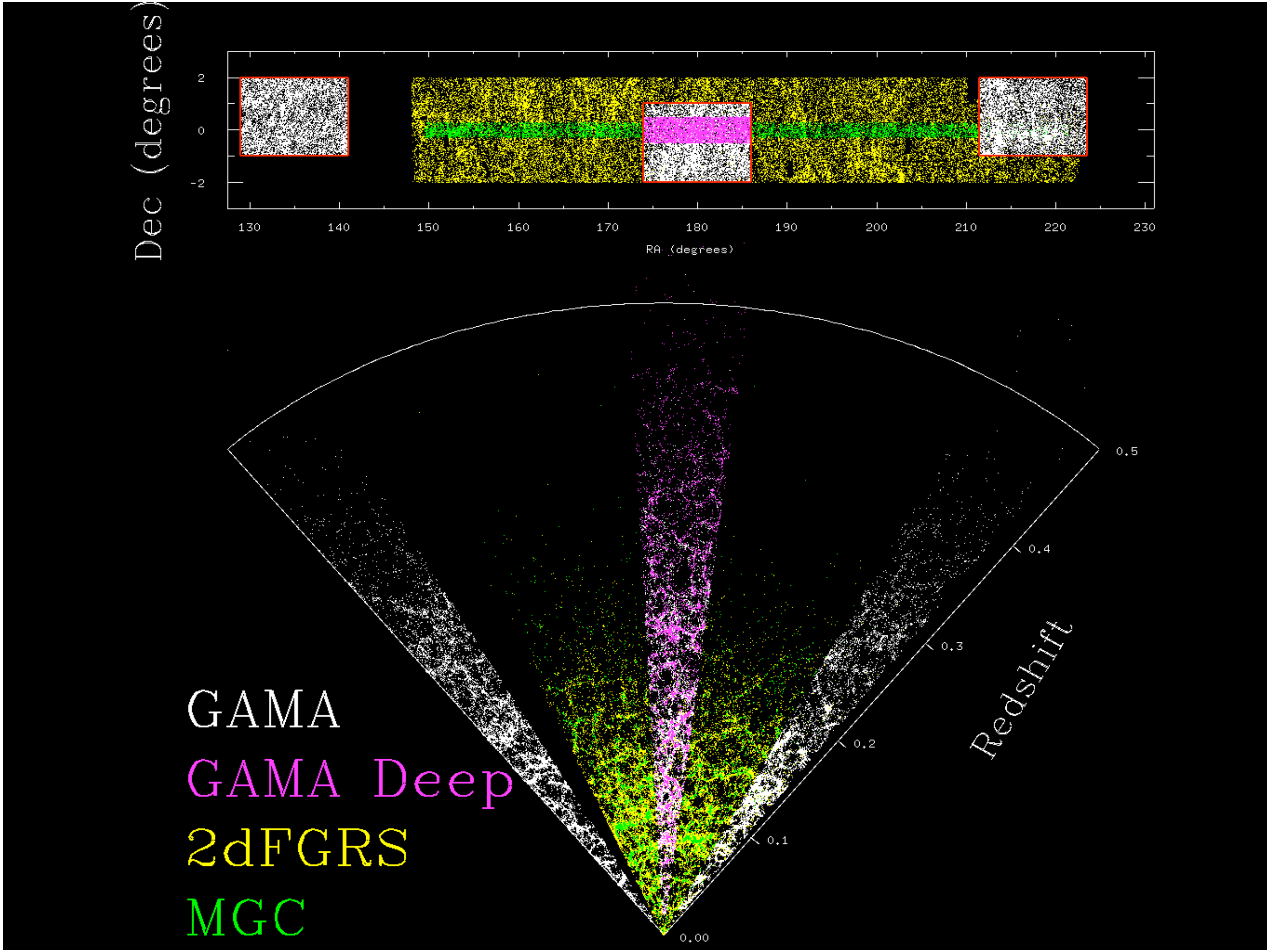


PCA sky subtraction

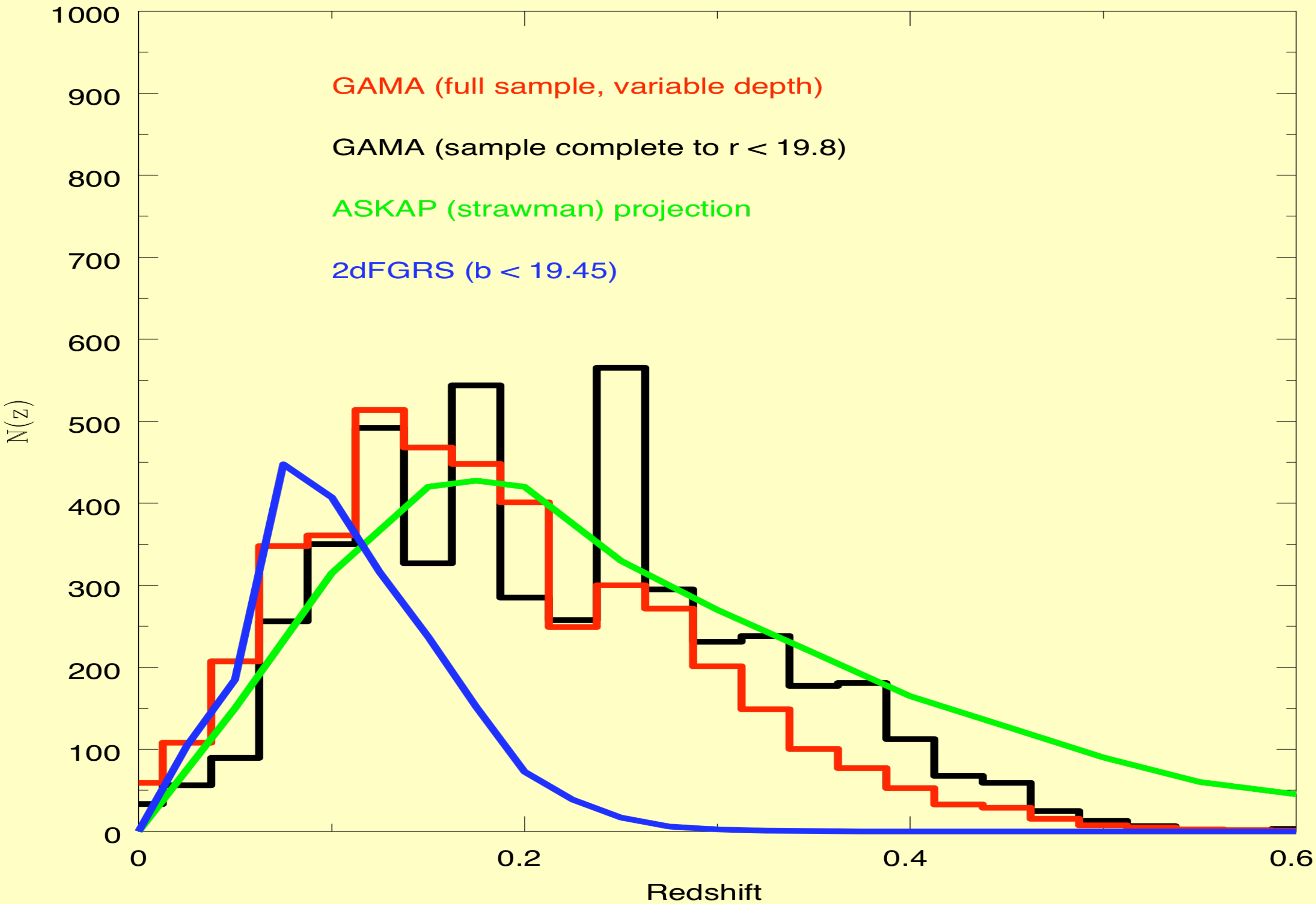


Hannah Parkinson

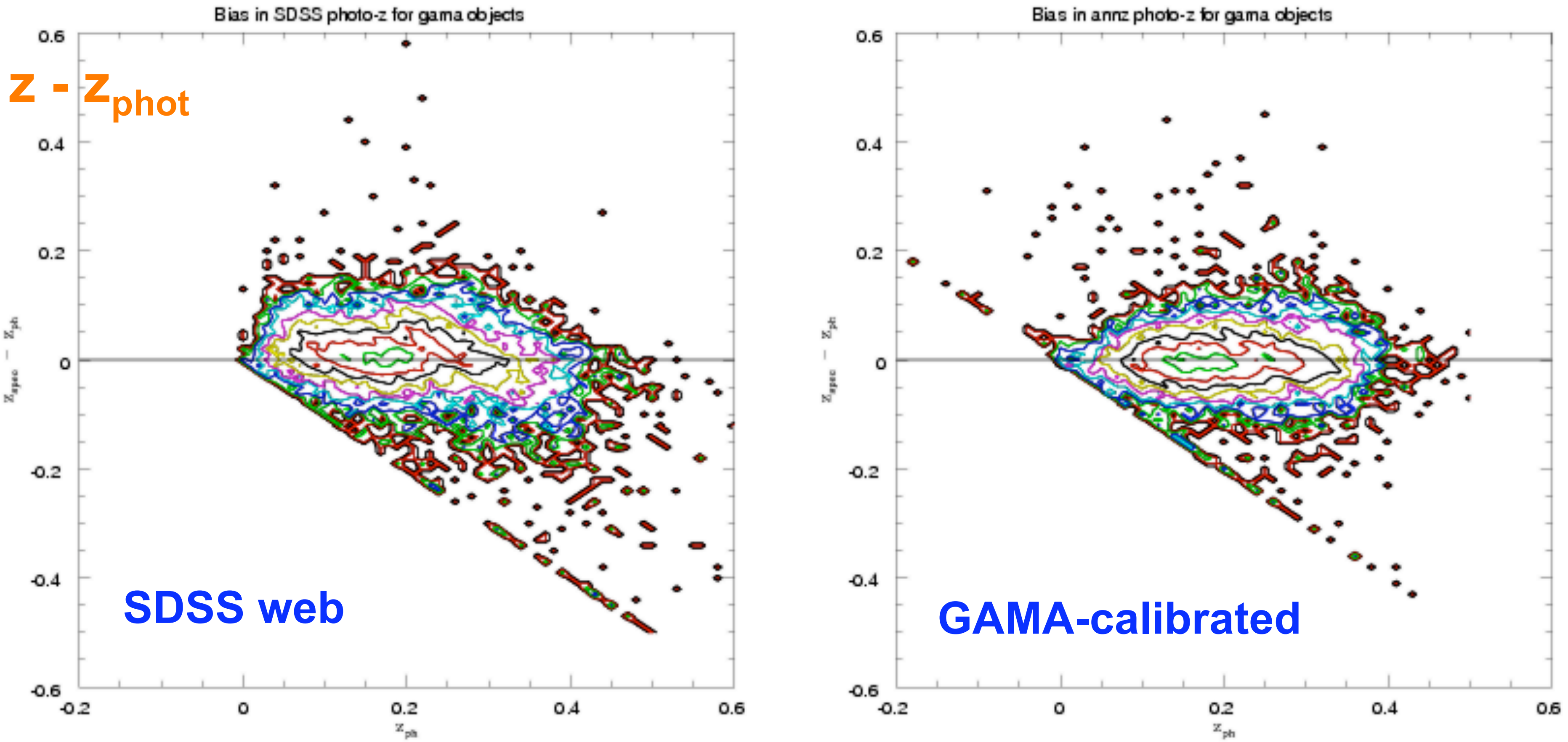

M81
Coma
Virgo
A1337
M31
+50
+40
+30
+20
+10
0
−10
−20
−30
−40
−50
−60
−70
0h
4h
8h
12h
16h
20h
G09
G12
G15
G03
G21
GAMA = FIVE
4X12.5 DEG CHUNKS
G09/G12/G15
observed so far
Sculptor
Fornax
LMC/SMC
SagDSph


Dec (degrees)
2
0
-2
130
140
150
160
170
180
190
200
210
220
230
RA (degrees)
0.5
0.4
0.3
0.2
0.1
0.00
Redshift
GAMA
GAMA Deep
2dFGRS
MGC

GAMA: year-1 N(z)



GAMA-improved SDSS photo-z's



z_{phot}

Hannah Parkinson

GAMA Team

WORKING GROUPS/HEADS

SCIENCE	CATS	DATABASE	OBS	MOCKS	RADIO	SPEC. PIPE.	IMAGE. PIPE.
Peacock	Baldry	Liske	Driver	Norberg	Hopkins	Loveday	Bamford
(ROE)	(LJMU)	(ESO)	(PI, St And)	(ROE)	(USyd)	(Sussex)	(Nott.)

TEAM MEMBERS

Bridges (AAO)	Edmonson (Ports)	Ellis (USyd)
Bland-Haw'n (U.Syd)	Jones (AAO)	Prescott (LJMU)
Cameron (St And)	Kuijken (Leiden)	Proctor (Swin.)
Conselice (Nott.)	Lahav (UCL)	Sharp (AAO)
Couch (Swin.)	Nichol (Ports.)	Staveley-Smith (UWA)
Croom (U.Syd)	Oliver (Sussex)	Sutherland (Camb.)
Cross (Edin.)	Parkinson (Edin.)	Tuffs (MPIK)
Frenk (Durham)	Phillipps (Bristol)	van Kampen (Innsbruck)
Graham (Swin)	Popescu (UCLan)	Warren (Imperial)
Hill (StA)	Eales (Cardiff)	Dunne (Nottingham)

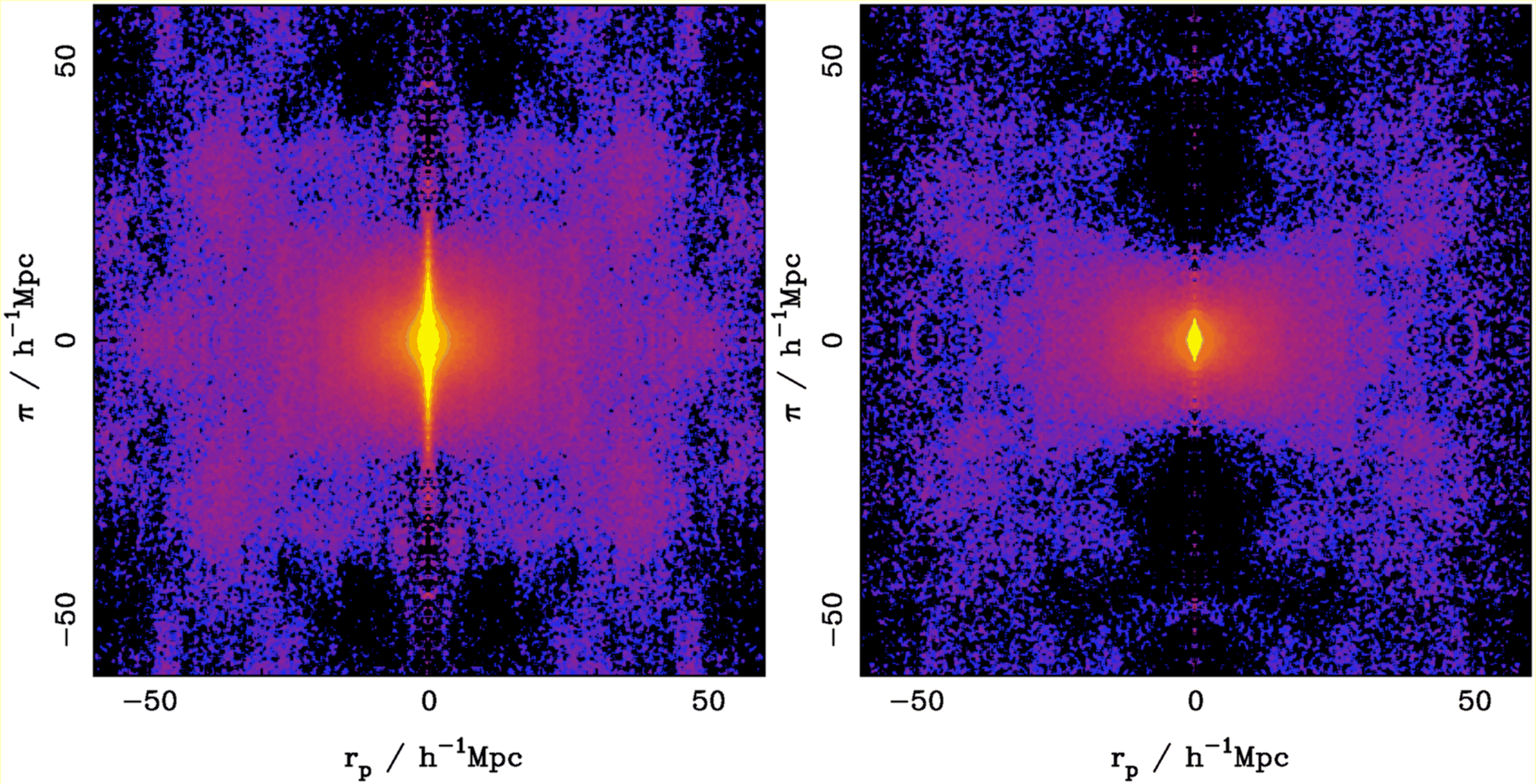
TEAM AFFILIATIONS:

UKIRT/LAS, VST/KIDS, VISTA/VIKING, HERSCHEL-ATLAS, DURHAM ICC

WEBSITE:

http://www.eso.org/~jliske/gama/

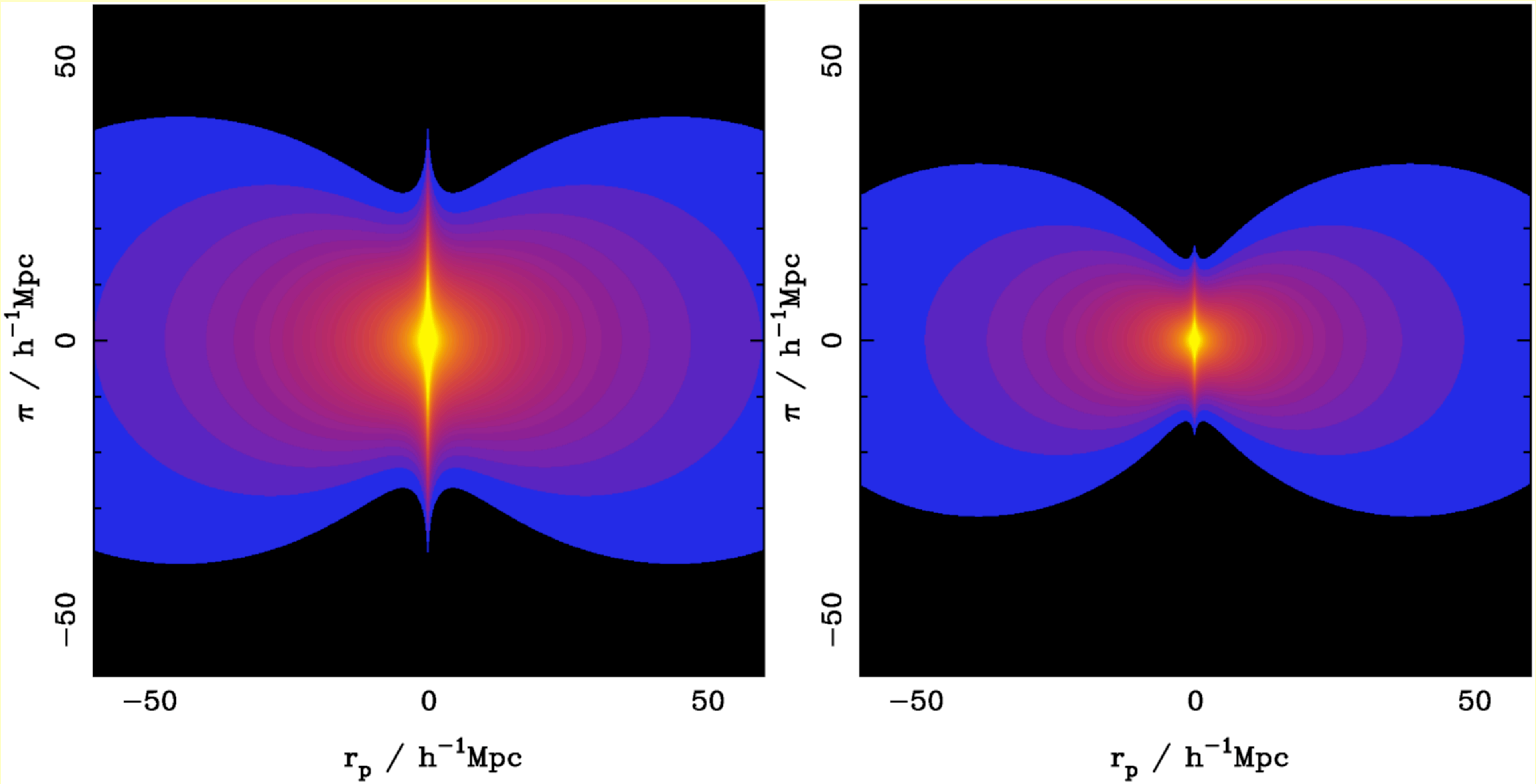
GAMA: redshift-space clustering



Red

Blue

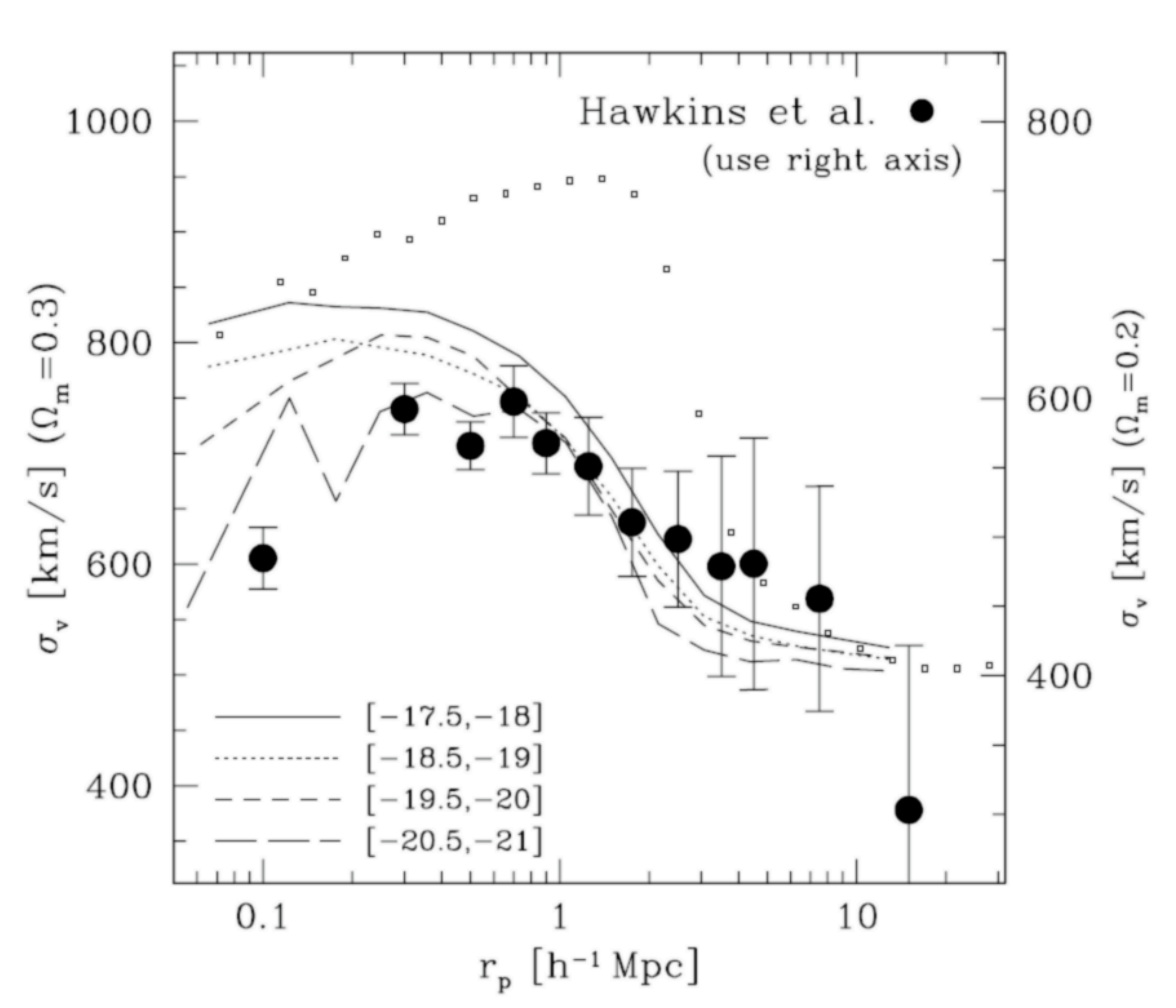
redshift-space models



Red

Blue

Detailed models



Fitting with fixed σ_v changes β by $\simeq$ 0.1. Need to do 10 times better

In Summary

- Must consider exotic DE and modified gravity equally
  - e.g. must not claim new gravity if $w=-1$ is assumed
- Galaxy surveys probe BAO+RSD combination
  - Result is w-γ anticorrelation
- Need to demonstrate robust modelling of RSD as f(galaxy type)
  - GAMA ideal test case at $z<0.4$
  - And interesting in other ways