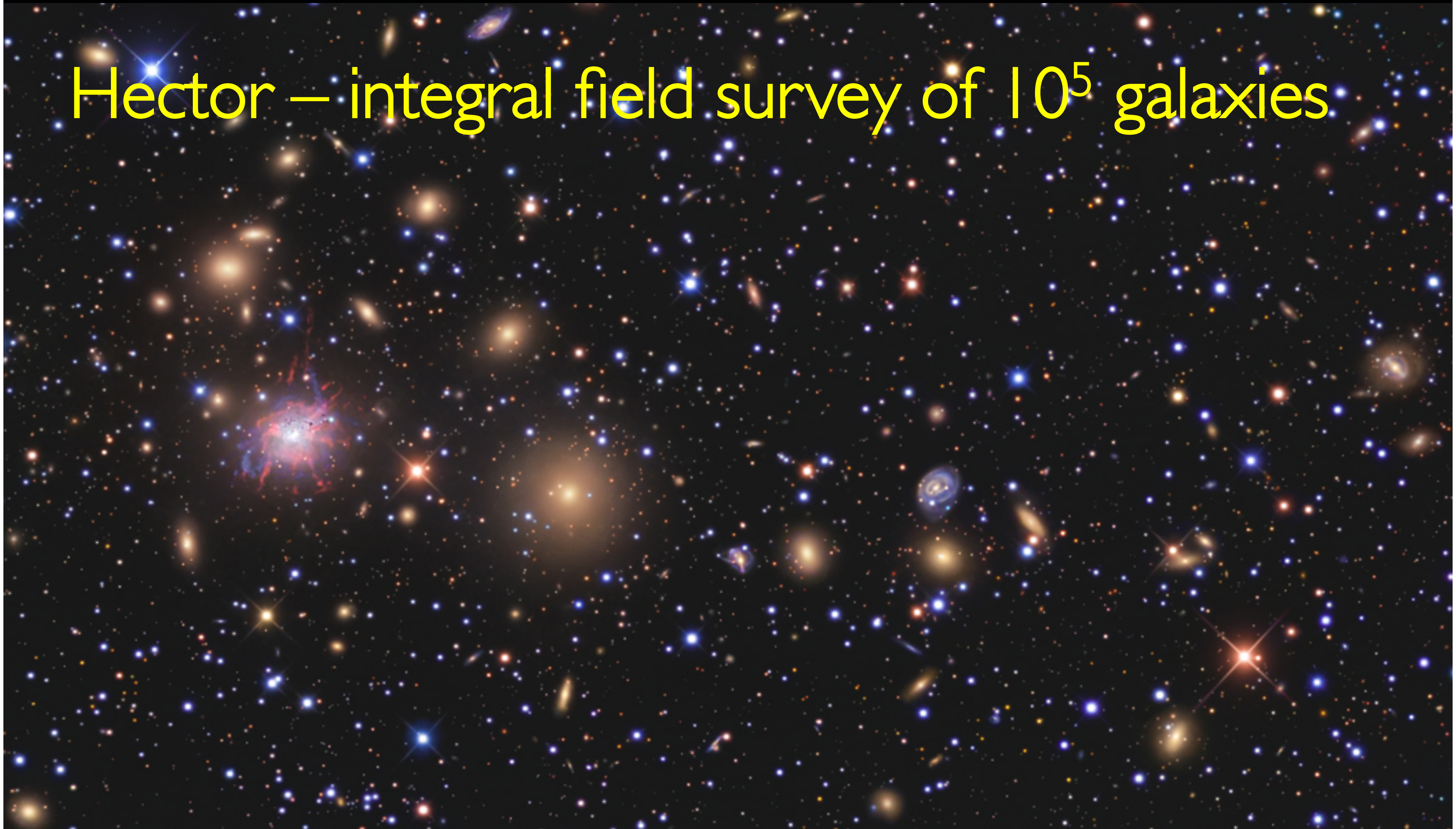
Hector – integral field survey of 10^5 galaxies



Perseus

Joss Bland-Hawthorn
University of Sydney

#aix2015

Why so many galaxies in so much detail ?

Galaxy evolution is the grandest of all environmental sciences.

Are there observed environmental dependencies?

Physical Properties and Environments of Nearby Galaxies

Michael R. Blanton and John Moustakas

Center for Cosmology and Particle Physics, New York University, New York, NY 10003;
email: michael.blanton@nyu.edu

Annu. Rev. Astron. Astrophys. 2009. 47:159–210

They struggle to find a strong environmental dependence beyond cluster vs. field.

Why ?

◆difficulty of defining environment ◆inadequacy of existing data
◆environment effects may be weak ◆need for new "measurables"

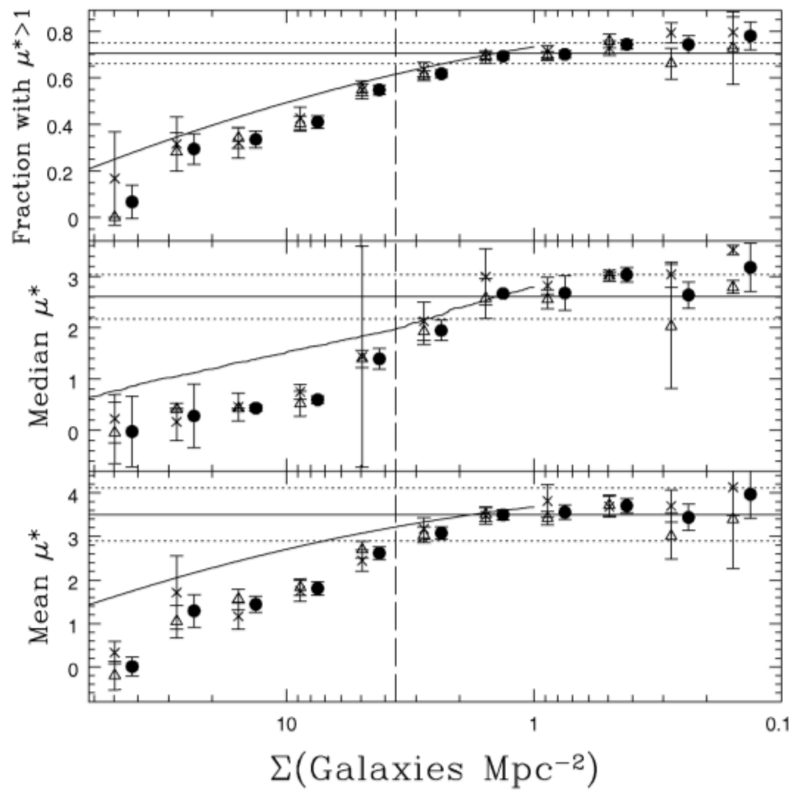
Are there well defined environmental effects over the hierarchy?

Mean star formation rates *appear* to show a trend with environment, but this is mostly a group effect.
Lewis+ 2002; Gomez+ 2003

Scaling relations (e.g. FP) show weak trends with environment.
Blanton & Moustakas 2009

Scatter (e.g. mass-metallicity) may correlate with environment.
Cooper+ 2008

SFR vs. projected local density



- difficulty of defining enviroment

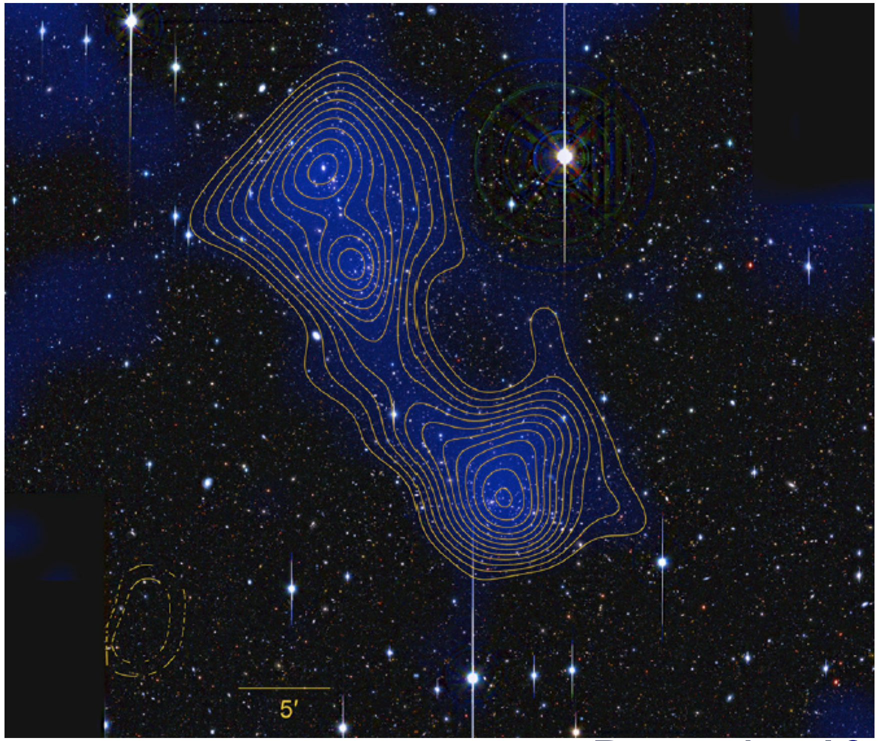
What is environment?

(Haas+ 2011; Muldrew+ 2012; Blanton & Moustakas 2009)

Parameter	Distance-related parameter value	Minimum mass/luminosity	References
From observations			
(Projected) galaxy number density	Average of nearest 10 galaxies	$m_V < 16.5$	1, 2, 3
		$M_V < -20.4$	3
	Group average	$M_B < -17.5$	4
Cluster-/group-centric radius	–	$M_r < -20.5$	5, 6
	–	$M_V < -20.4$	3
	–	$m_V < 16.5$	2
	Scaled to the virial radius	$r < 17.77$	7
Projected galaxy number density out to the Nth nearest neighbour with a maximum radial velocity difference Δv	$N = 3$, $\Delta v = 1000\,\mathrm{km\,s^{-1}}$	$R < 24.1$	8, 9, 10
	$N = 4{,}5$	$M_R < -20$	11 - 16
	$N = 4{,}5$, $\Delta v = 1000\,\mathrm{km\,s^{-1}}$	$M_r < -20$	13, 14
	$N = 4{,}5$, $\Delta v = 1000\,\mathrm{km\,s^{-1}}$	$M_r < -20.6$	16
	$N = 5$, $\Delta v = 1000\,\mathrm{km\,s^{-1}}$	$M_r < -20.6$	11
	$N = 5$, $\Delta v = 1000\,\mathrm{km\,s^{-1}}$	$M_r < -20$	12
	$N = 5$, 10, 20, $\Delta v = 1000\,\mathrm{km\,s^{-1}}$	$I_{AB} < 25$	17
	$N = 10$	$M_V < -20$	18
	$N = 10$	$I < -24$	15
	$N = 10$, in clusters	$M_b < -19$	19
Galaxy number density in sphere of proper radius r	$r \simeq 1\,h^{-1}\,\mathrm{Mpc}$	$r < 17.77$	20
	$r = 8\,h^{-1}\,\mathrm{Mpc}$, $\Delta v \leq 800\,\mathrm{km\,s^{-1}}$	$r < 17.77$	21, 22, 23
Number of neighbours in cylinders with projected radius r	$r = 0.1$–$10\,h^{-1}\,\mathrm{Mpc}$, $\Delta v = 1000\,\mathrm{km\,s^{-1}}$	$M_{0.1r} - 5\mathrm{Log}_{10}\,h < -19$	24, 25
	$r = 0.5$, 1, $2\,h^{-1}\,\mathrm{Mpc}$, $\Delta v = 1000\,\mathrm{km\,s^{-1}}$	$M_r < -20$	26
	$r = 1\,h^{-1}\,\mathrm{Mpc}$, Δv corresponding to 8 Mpc	$r < 17.77$	27
	$r = 1$ - $10\,h^{-1}\,\mathrm{Mpc}$, $\Delta v = 1000\,\mathrm{km\,s^{-1}}$	$I_{AB} < 25$	17
	$r = 2\,h^{-1}\,\mathrm{Mpc}$, $\Delta v = 1000\,\mathrm{km\,s^{-1}}$	$r < 17.77$	28
Mass density due to nearest neighbour ($\rho = 3M_{\rm ngb}/4\pi r^3_{\rm ngb}$)	$N = 1$ or N for which ρ is maximal $\Delta v = 400$, $600\,\mathrm{km\,s^{-1}}$	$M_{r,\rm ngb} \gtrsim M_{r,\rm gal} + 0.5$	29
Projected galaxy number density in annuli	$\{0.5,1,2\} < R/(h^{-1}\,\mathrm{Mpc}) < \{1,2,3\}$	$M_r < -20$	26
	$1 < R/(h^{-1}\,\mathrm{Mpc}) < 3$	$r < 17.77$	28
From simulations			
Halo mass	-	$M > 2.35 \times 10^{10}\,h^{-1}\,\mathrm{M_\odot}$	30
Number of neighbours in spheres of radius R	$R = 2\,h^{-1}\,\mathrm{Mpc}$	$V_{\max} > 120\,\mathrm{km\,s^{-1}}$	31
Mass or density in spheres of radius R	$R = 1$, 2, 4, $8\,h^{-1}\,\mathrm{Mpc}$	–	32, 33
	$R = 5\,h^{-1}\,\mathrm{Mpc}$	–	34, 35
	$R = 5$, $8\,h^{-1}\,\mathrm{Mpc}$	–	36
	$R = 7\,h^{-1}\,\mathrm{Mpc}$	–	30
	$R = 18$, $25\,h^{-1}\,\mathrm{Mpc}$	–	37
Matter density in spherical shells	$2 < R/(h^{-1}\,\mathrm{Mpc}) < 5$	–	38, 39, 40
	$2 < R/(h^{-1}\,\mathrm{Mpc}) < 7$	–	30
	$R_{\rm FOF} < R < 2\,h^{-1}\,\mathrm{Mpc}$	–	30
	$R_{\rm vir} < R < 3R_{\rm vir}$	–	41
Average mass density of surrounding haloes	$N = 7$	$200 < V_{\max}/\mathrm{km\,s^{-1}} < 300$	42

Statistical environment –
a measure of "crowding"

Physical environment – I



Dietrich+ 12

How do we define physical structures?

Ideally these would be defined in terms of EUV/x-ray emissivity, CMB SZ or weak lensing signal.

But while useful for dense groups & cluster mass scales, these are much less sensitive to large-scale structure and low densities.

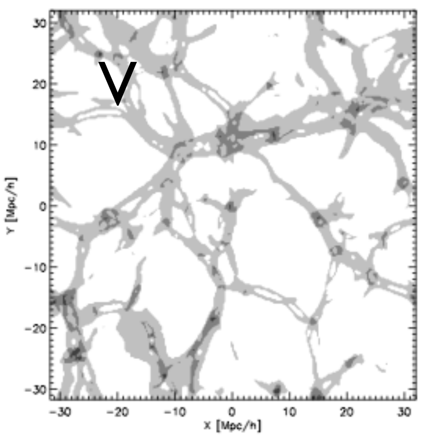
For the foreseeable future, we are limited to **galaxy redshift surveys**.

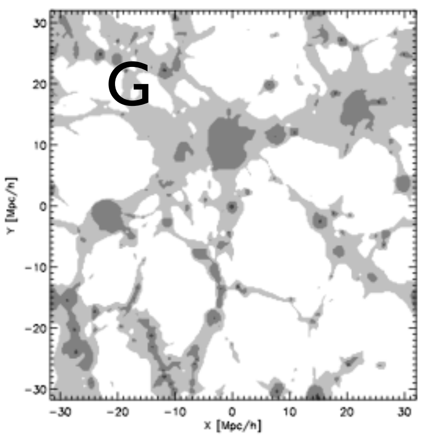
Physical environment – II

"A collection of connected points having the same environmental attributes."

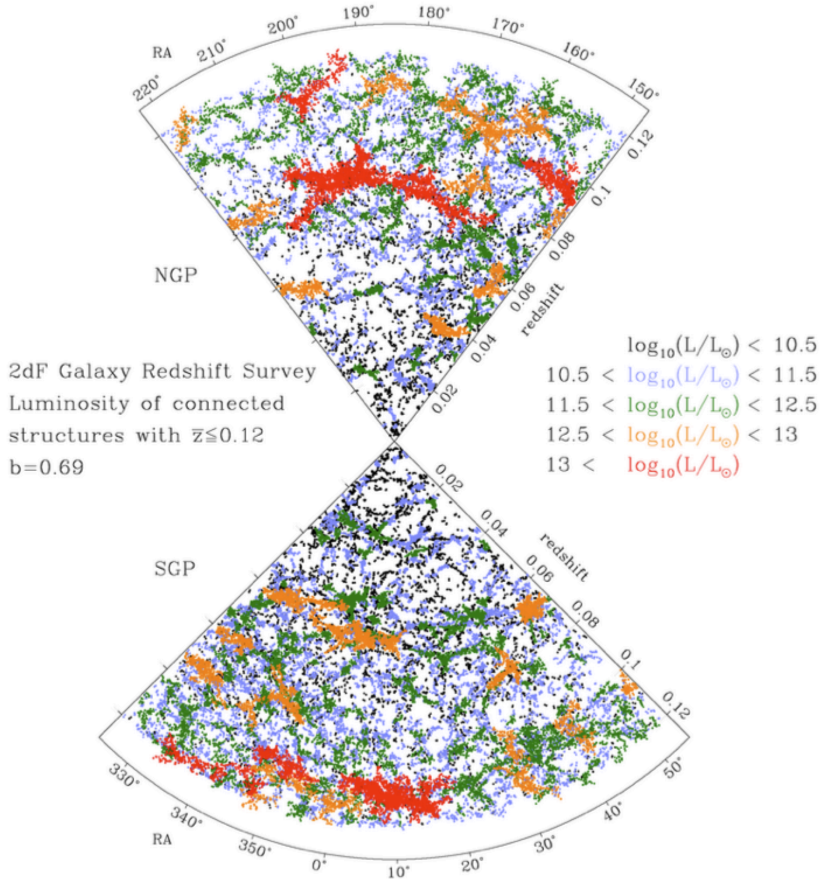
1. **Double pass friends of friends** (Murphy+ 2011)
2. **Multiscale mapping** (Barrow+ 1985; Aragon-Calvo+ 2007; Smith+ 2012)
3. **Geometric classifiers** (Lemson & Kauffman 1999; Sousbie+ 2008)
4. **Dynamic classifiers** (Hahn+ 2007; Hoffman+ 2012)

Dynamic classifiers – **G**ravitational tidal tensor, **V**elocity shear tensor – are the most physical but have not been demonstrated on data yet.





$$\Sigma_{\alpha\beta} = -\frac{1}{2}\left(\frac{\partial v_\alpha}{\partial r_\beta} + \frac{\partial v_\beta}{\partial r_\alpha}\right)/H_0 \qquad T_{\alpha\beta} = \frac{\partial^2 \phi}{\partial r_\alpha \partial r_\beta}$$



- inadequacy of existing data

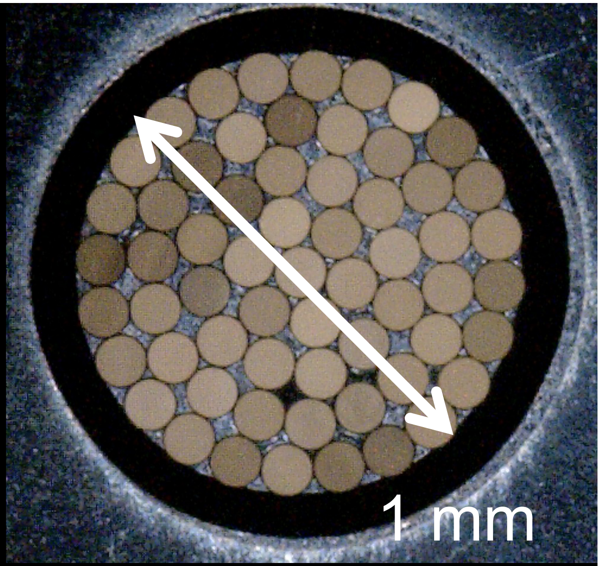
Building on the SAMI legacy

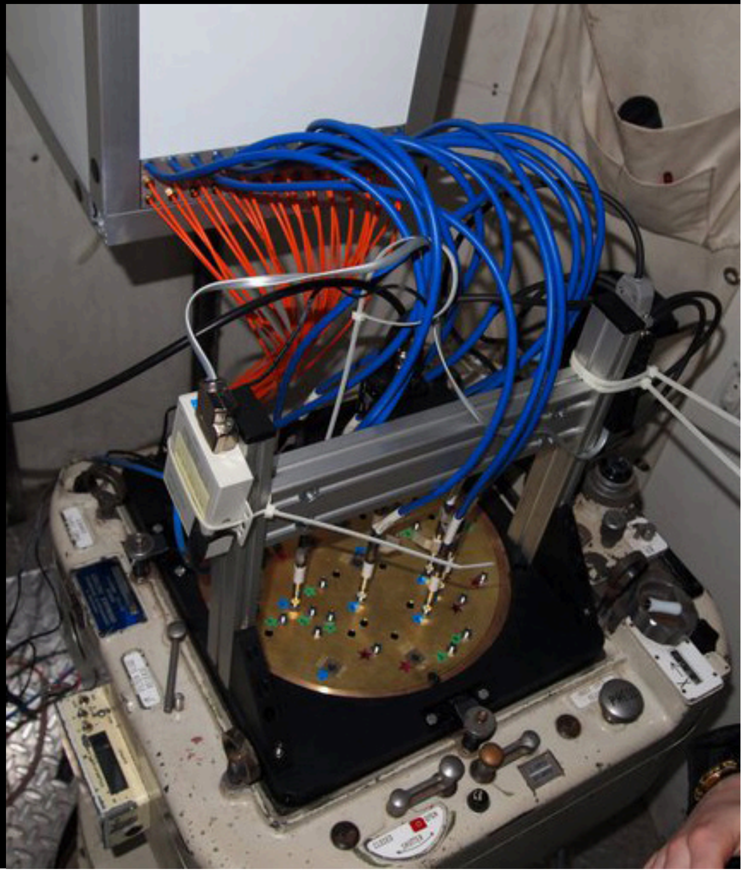
R ~ few x 10^3 (370-550 nm, 620-740 nm)

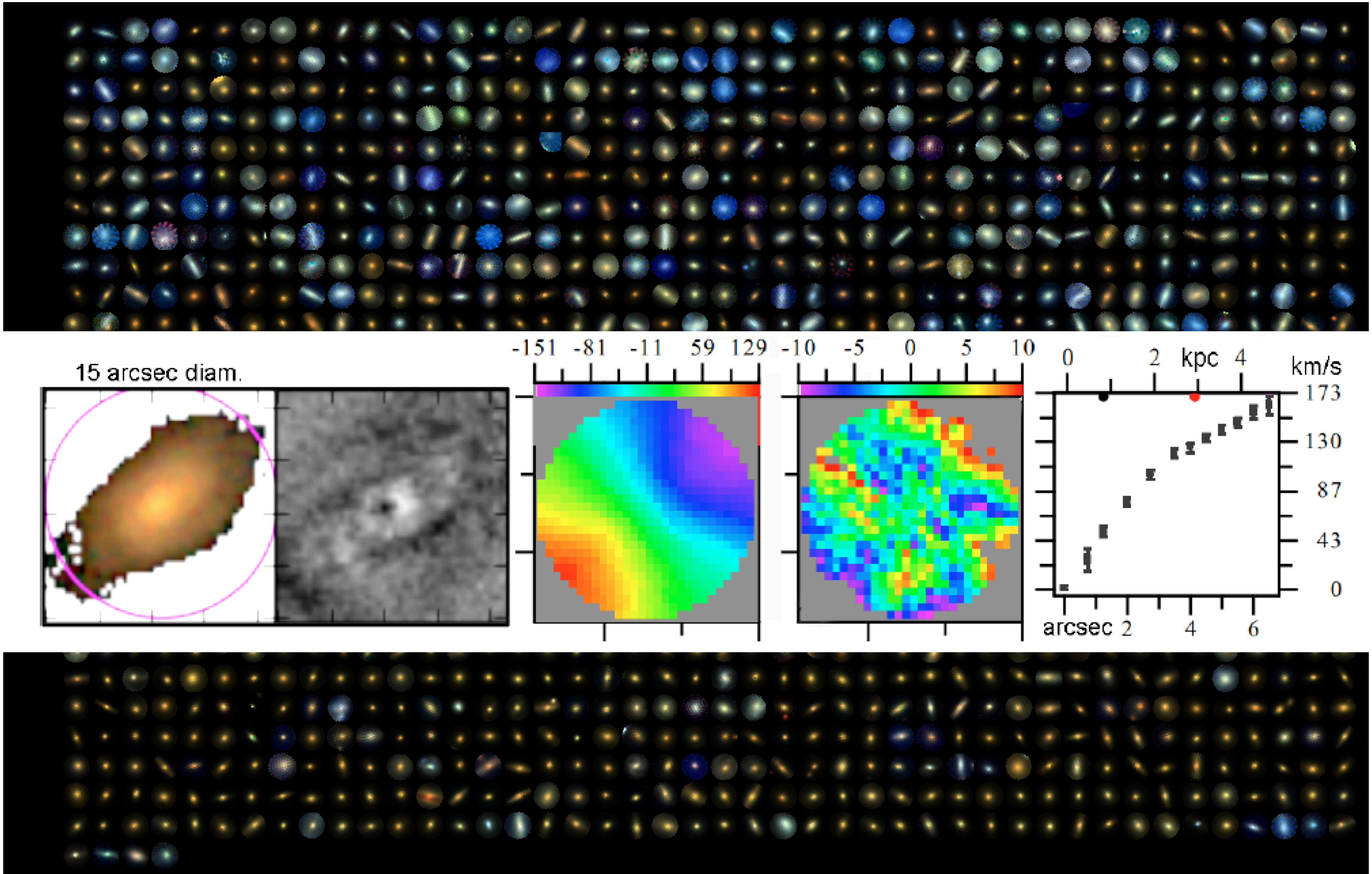
3400 galaxies with integral field spectroscopy

Target GAMA fields to b_J ~ 16.5; mass selected

JBH+ 11; Croom+ 12; Bryant+ 15







SAMI Survey: 1500 galaxies with 3D IFS – 2000 to go !

GAMA: we expect $3x10^4$ groups down to LG mass with complete HI follow-up (2015-18) using Dingo, Wallaby

Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY

Galaxy and Mass Assembly (GAMA): the GAMA galaxy group catalogue (G^{3}Cv1)

A. S. G. Robotham[1,*], P. Norberg[2], S. P. Driver[1,3], I. K. Baldry[4], S. P. Bamford[5], A. M. Hopkins[6], J. Liske[7], J. Loveday[8], A. Merson[9], J. A. Peacock[2], S. Brough[6], E. Cameron[10], C. J. Conselice[5], S. M. Croom[11], C. S. Frenk[9], M. Gunawardhana[11], D. T. Hill[1], D. H. Jones[12], L. S. Kelvin[1], K. Kuijken[13], R. C. Nichol[14], H. R. Parkinson[2], K. A. Pimbblet[12], S. Phillipps[15], C. C. Popescu[16], M. Prescott[4], R. G. Sharp[17], W. J. Sutherland[18], E. N. Taylor[11], D. Thomas[14], R. J. Tuffs[19], E. van Kampen[7] and D. Wijesinghe[11]

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Accepted 2011 June 8.
In original form 2011 June 8.

- environmental effects may be very weak

Environmental signatures – how do baryons enter or leave a galaxy?

"Galactic engine"

Observables:

structural properties

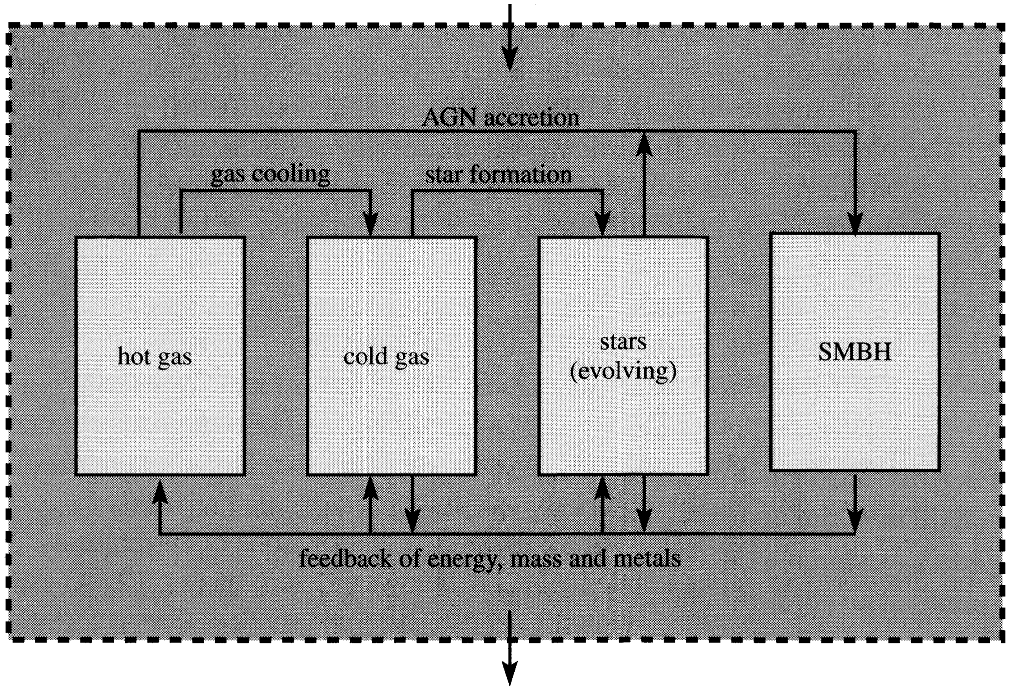
baryon fraction f_b

star formation history

metallicity yield Y_{eff}

Etc.

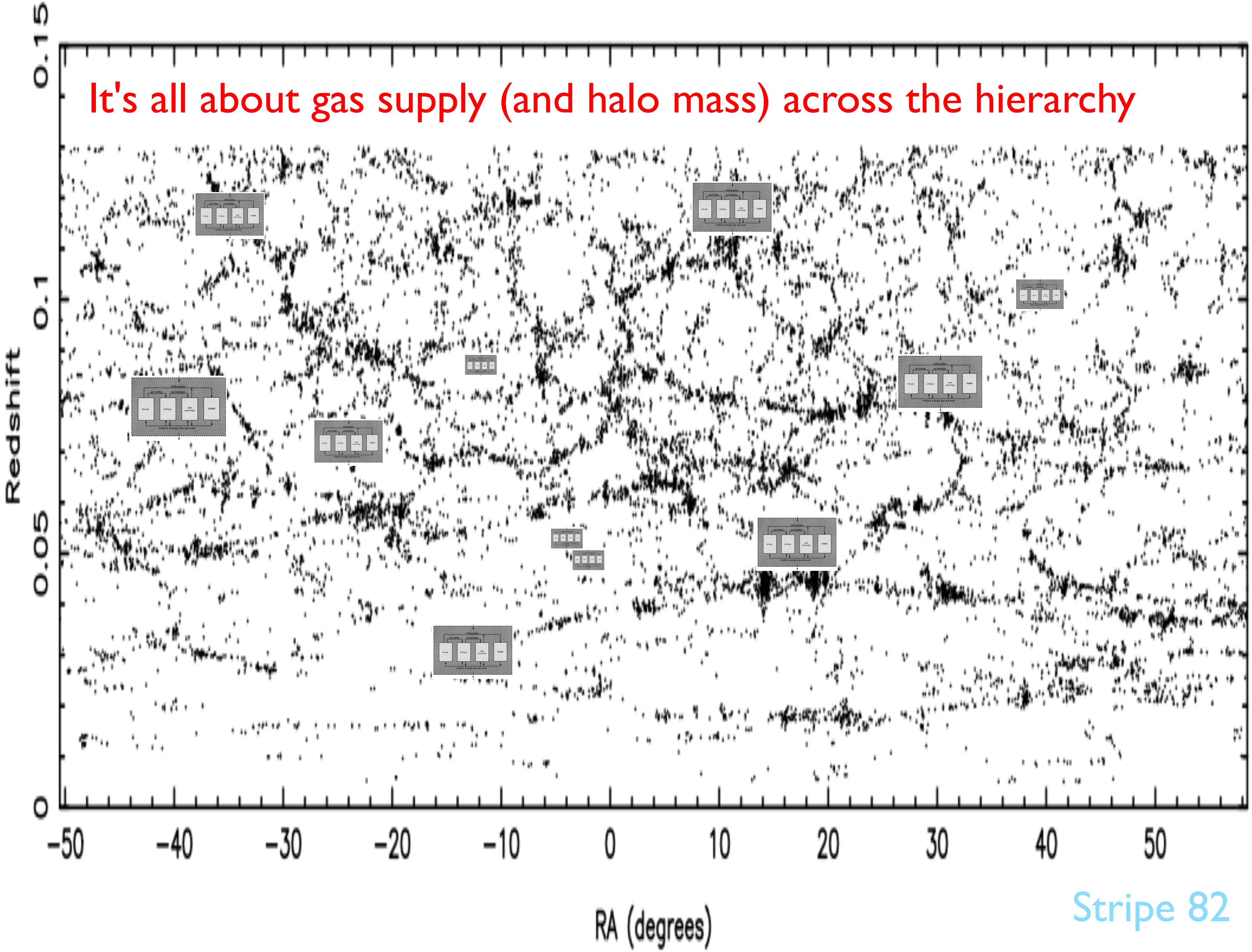
inflow



outflow

Mo, vd Bosch & White 2010

It's all about gas supply (and halo mass) across the hierarchy



Stripe 82

- need for new “measurables” in large surveys

The SAMI Pilot Survey: The Fundamental and Mass Planes in Three Low-Redshift Clusters

Scott et al 2015

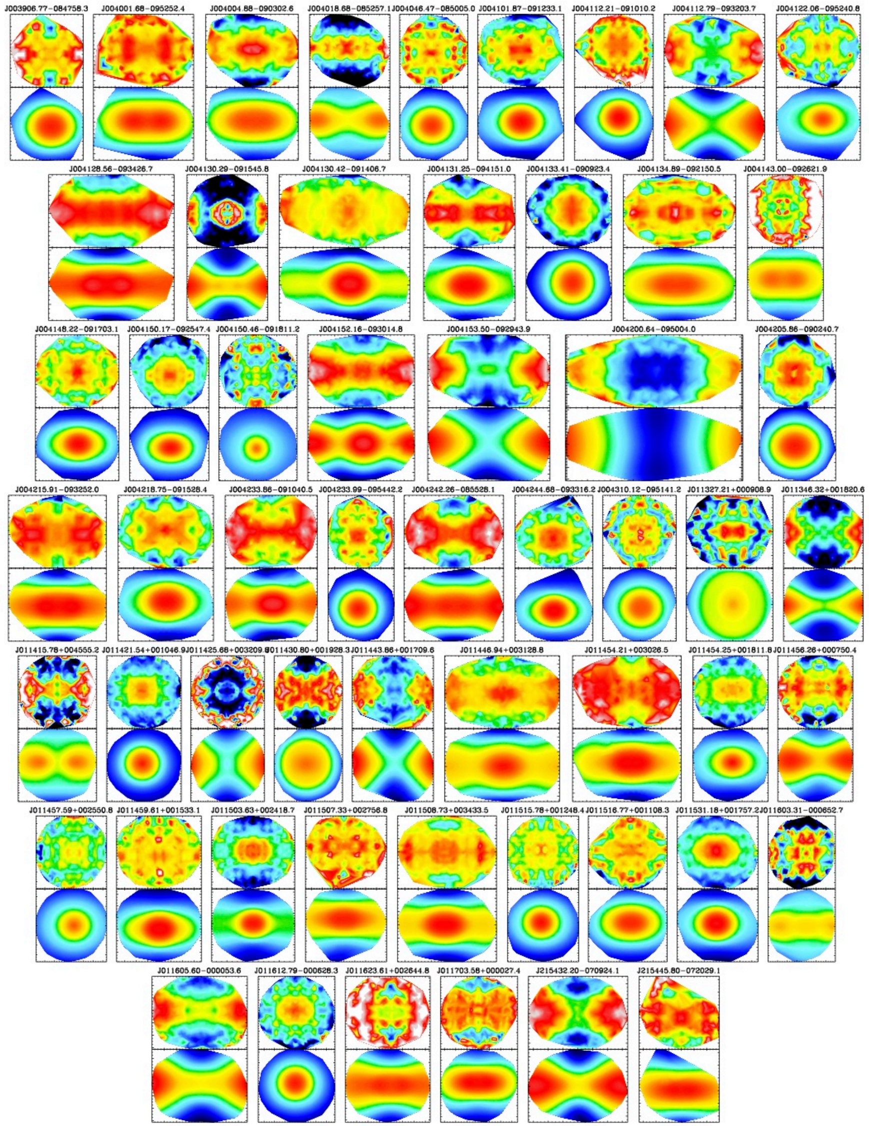


Figure A1. Observed (top) and best-fitting JAM model (bottom) V_{rms} maps for all 105 SAMI Pilot galaxies.

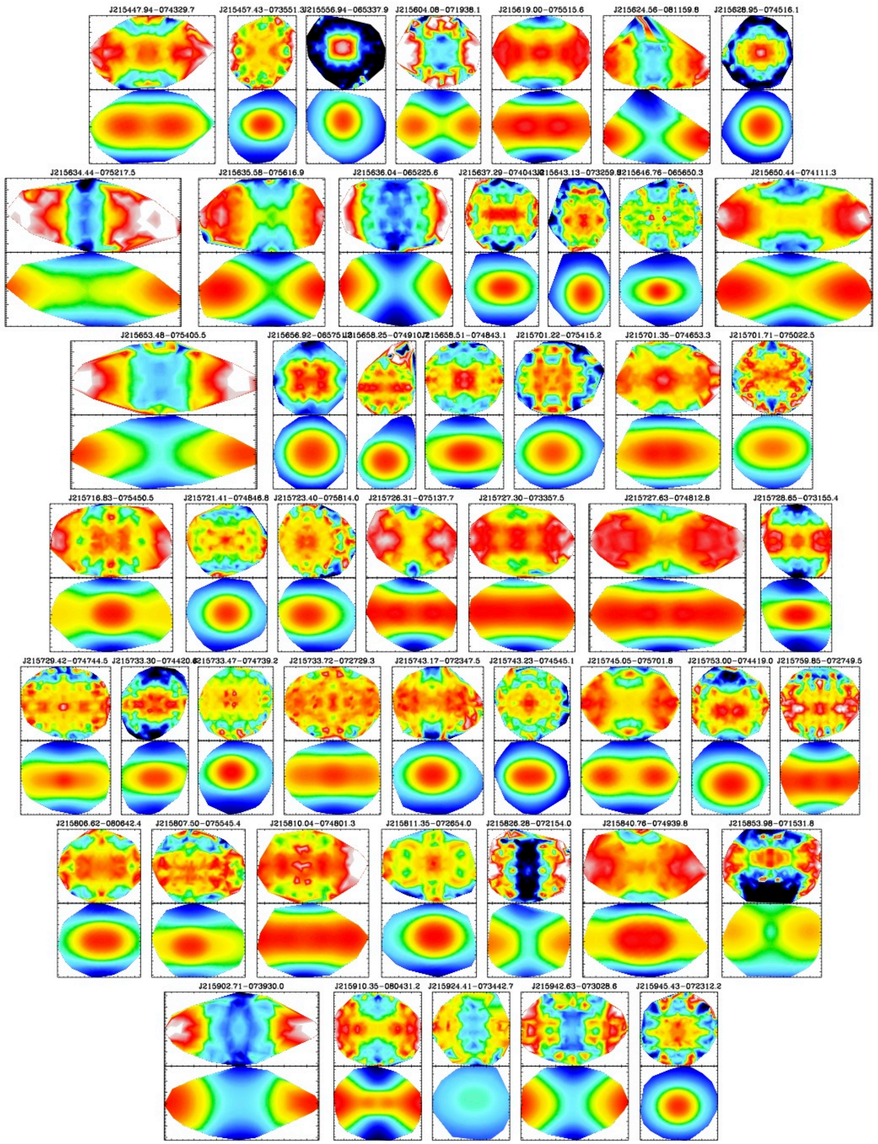


Figure A1 continued.

The SAMI Pilot Survey: The Kinematic Morphology-Density Relation in Abell 85, Abell 168 and Abell 2399

L. M. R. Fogarty[1,2⋆], Nicholas Scott[1,2], Matt Owers[2], S. Brough[3], Scott M. Croom[1,2]
Michael B. Pracy[1], Joss Bland-Hawthorn[1], Matthew Colless[4], Roger L. Davies[5],
D. Heath Jones[6], James T. Allen[1], Julia J. Bryant[1,2], Michael Goodwin[3],
Andrew W. Green[3], Iraklis S. Konstantopoulos[3], J.S. Lawrence[3],
Samuel Richards[1,3], Luca Cortese[7], Rob Sharp[4].

[1] *Sydney Institute for Astronomy, School of cPhysics, University of Sydney, NSW 2006, Australia.*
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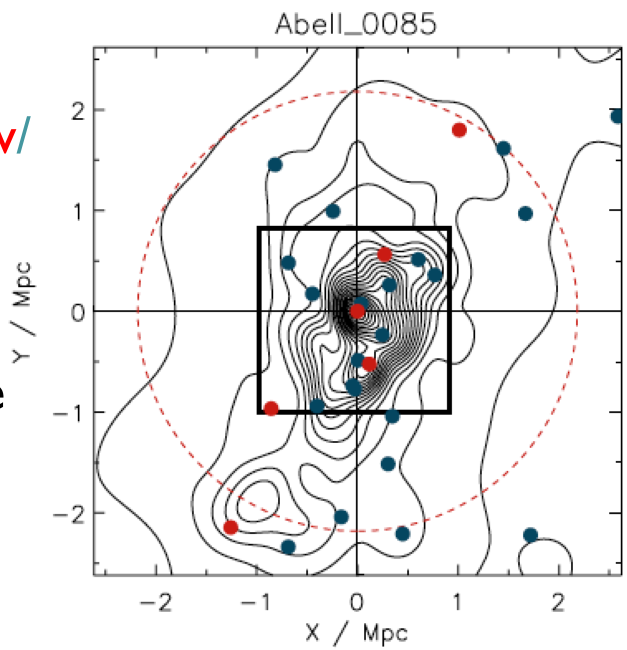
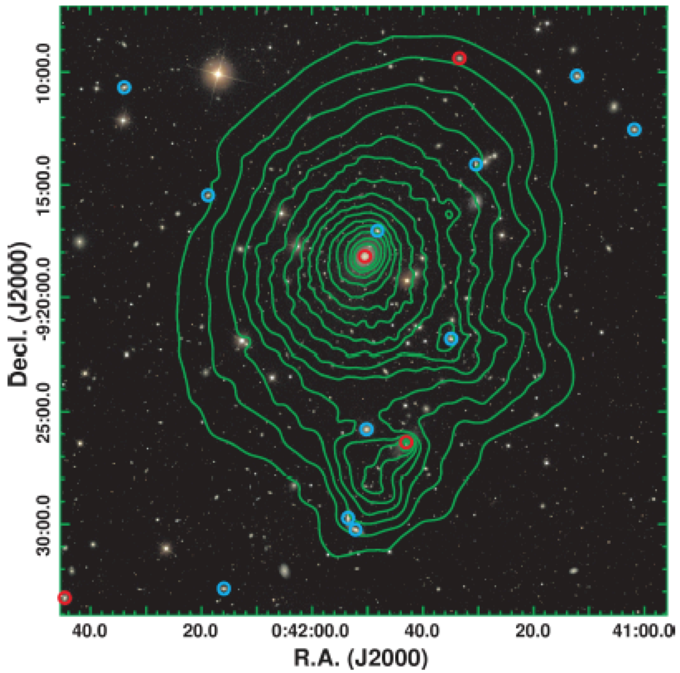
[5] *Astrophysics, Department of Physics, University of Oxford, Denys Wilkinson Building, Keble Rd., Oxford, OX1 3RH, UK.*
[6] *School of Physics, Monash University, Clayton, VIC 3800, Australia.*
[7] *Centre for Astrophysics and Supercomputing, Swinburne University of Technology, Hawthorn, VIC 3122, Australia.*

Clear variations in slow/fast rotator fraction with environment.

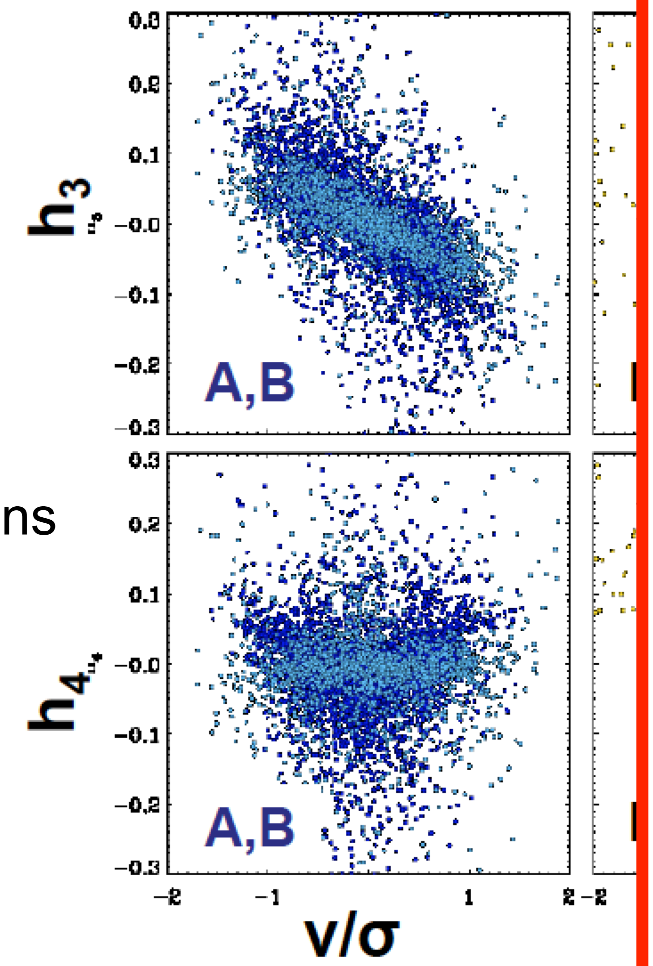
Future papers will have 10x more sources.

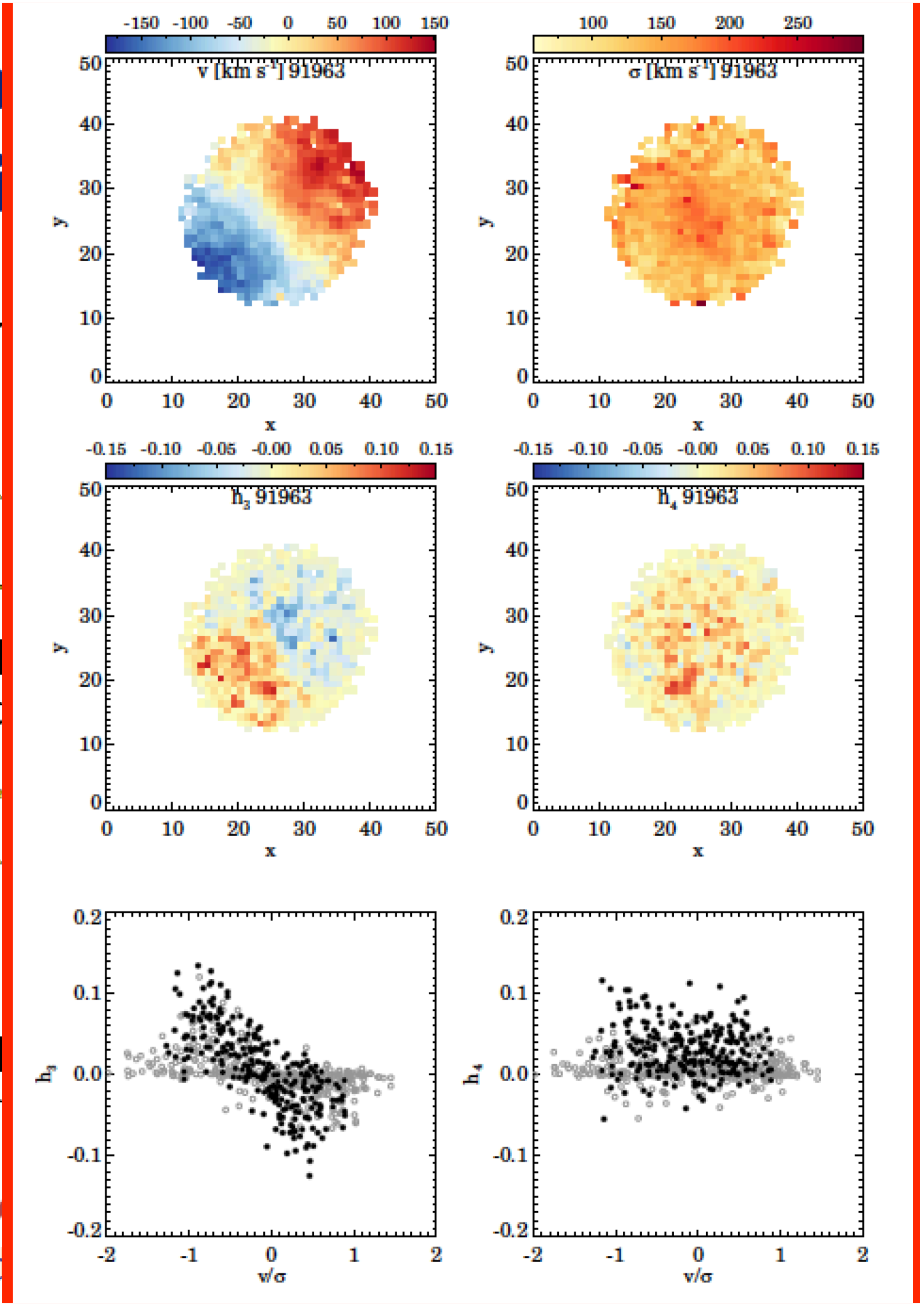




FRs with gas-rich (m
strong h_3-(v/σ) anti

EAGLE
simulations





THE ASTROPHYSICAL JOURNAL, 762:72 (12pp), 2013 January 10 doi:10.1088/0004-637X/762/2/72

THE COSMIC HISTORY OF THE SPIN OF DARK MATTER HALOS WITHIN THE LARGE-SCALE STRUCTURE*

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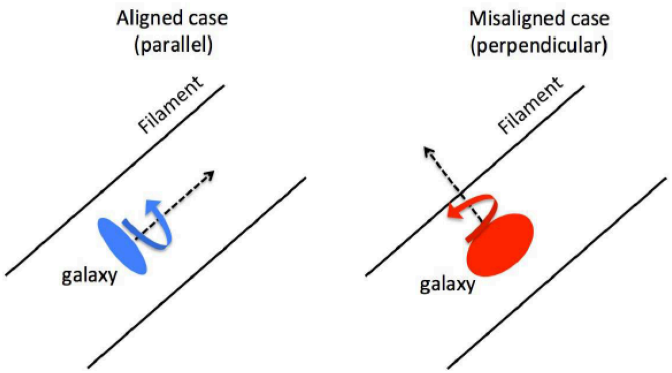
Received 2011 December 1; accepted 2012 November 12; published 2012 December 17

ABSTRACT

We use N-body simulations to investigate the evolution of the orientation and magnitude of dark matter halo angular momentum within the large-scale structure since $z = 3$. We look at the evolution of the alignment of halo spins with filaments and with each other, as well as the spin parameter, which is a measure of the magnitude of angular momentum. It was found that the angular momentum vectors of dark matter halos at high redshift have a weak tendency to be orthogonal to filaments and high-mass halos have a stronger orthogonal alignment than low-mass halos. Since $z = 1$, the spins of low-mass halos have become weakly aligned parallel to filaments, whereas high-mass halos kept their orthogonal alignment. This recent parallel alignment of low-mass halos casts doubt on tidal torque theory as the sole mechanism for the buildup of angular momentum. We see evidence for bulk flows and the broadening of filaments over time in the alignments of halo spin and velocities. We find a significant alignment of the spin of neighboring dark matter halos only at very small separations, $r < 0.3\,\mathrm{Mpc}\,h^{-1}$, which is driven by substructure. A correlation of the spin parameter with halo mass is confirmed at high redshift.

Key words: cosmology: theory – large-scale structure of universe



N ~ 60,000 galaxies to detect spin alignment with LSS

N ~ 150,000 galaxies (Dubois+14)

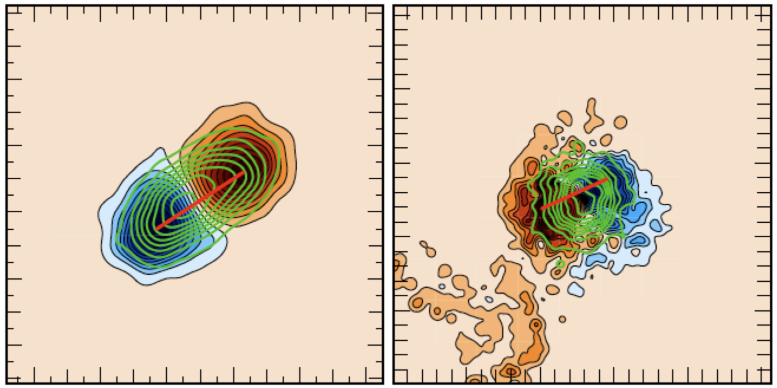
Summary

A case is proposed for **physical environment** over **statistical environment**. We must distinguish between filaments/walls in voids ($\nabla . v > 0$) and filaments in dense regions ($\nabla . v < 0$).

We need to reach down to substantial numbers of (dwarf) **void galaxies** while retaining enough filaments, groups and clusters for intercomparisons. **A full treatment takes us to a survey of ~100,000 galaxies.**

2-4m class telescopes, supported by all-sky HI and photometric surveys, are needed **into the next decade** to tackle these issues. The AAT is building Hector with 3dF, 100 hexabundles, 2019 ff.

We must extract "integral field observations" matched to SAMI of $\sim 10^5$ galaxies and **measure key parameters**. This work has now started (Naab+ 14; Dubois+ 14).



Dubois+ 14