Summary in 20 mins

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In the limited time left, I will concentrate on key issues that were missed before revisiting the baryon census pie chart.

Everyone gets a mention

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Green James	Univ. of Colorado
Stringer Martin	Observatoire de Paris
Anderson Mike	University of Michigan
Sukanya Chakrabarti	Florida Atlantic University
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Stefania Giodini	Leiden Observatory
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Mauro Roncarelli	Univ. Bologna
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Anjali Gupta	Ohio State Univ.
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Ken Sembach	STScI
Alan Duffy	ICRAR (UWA)
Orly Gnat	Hebrew U of Jerusalem
Massimiliano Galeazzi	Univ. of Miami
Joss Bland-Hawthorn	University of Sydney
James Binney	University of Oxford

Summary

15% baryons collapsed (GF is an inefficient & complex process);
85% baryons uncollapsed, half still missing.

We know little about the dynamics of gas flows onto mass structures on any scale, although there may be some evidence that these processes are now being observed. **Most of the action was at high redshift but the same processes are still ongoing.**

1. We need targetted surveys, e.g. MWA, void filaments, differential analysis of inside/outside virial radii (galaxies, groups, clusters).
2. What about a super-deep sightline, hit it with everything.
3. Bright source sightlines look profitable (CGM, CQM).

We need to understand the physical state of each gas phase before talking about a complete inventory (e.g. flow? mixing? fill fraction? baryon fraction? ionization fraction? multiphase? unstable? non-equilibrium?).

We need to avoid double counting; we need to be sure we are comparing like sources over cosmic time, etc.

It's far too soon to claim we have a full census.

Uncollapsed baryons – a different set of problems

How do baryons decouple from dark matter ?

How do baryons move out of voids into filaments and sheets ?

How do baryons get into clusters, groups and galaxies ?

How do galaxy processes mess things up ?

One day, we will be able to answer....

Where are the missing baryons ?

Circumgalactic media – what we did not talk about

1. Galaxies can really mess up their environments.

2. The IGM community needs to embrace environmental classifiers.

3. CGM probes discussed here may be the very best way to probe theories of how baryons get into DM.

4. We need better cosmologically motivated galaxy models.

<u>How galaxies mess things up?</u> The importance of AMR simulations.

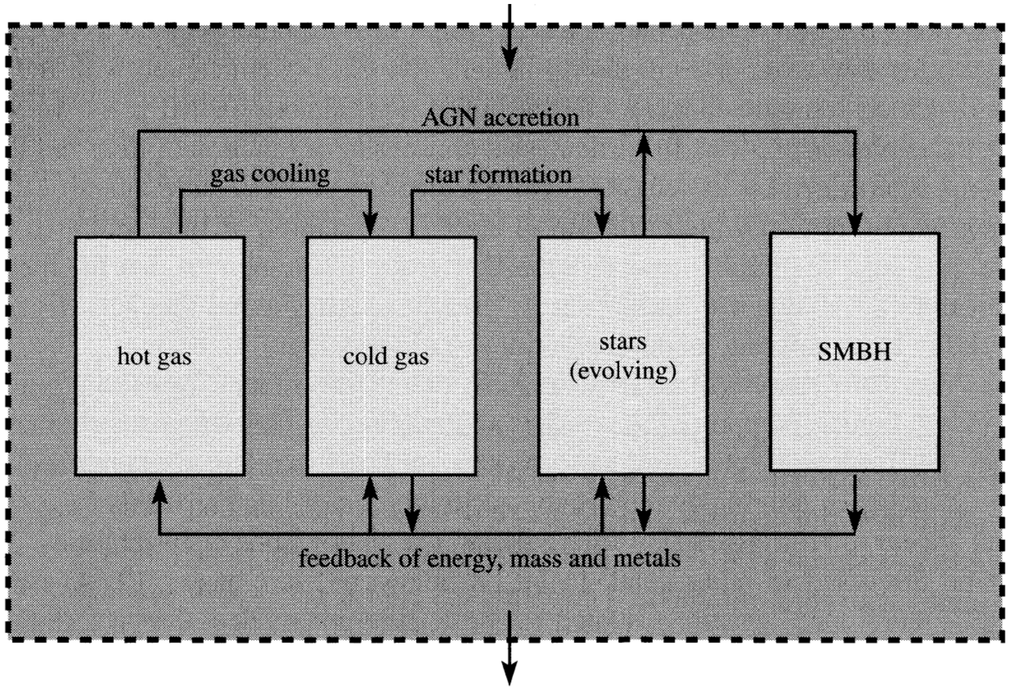
baryon fraction f_b

star formation history b

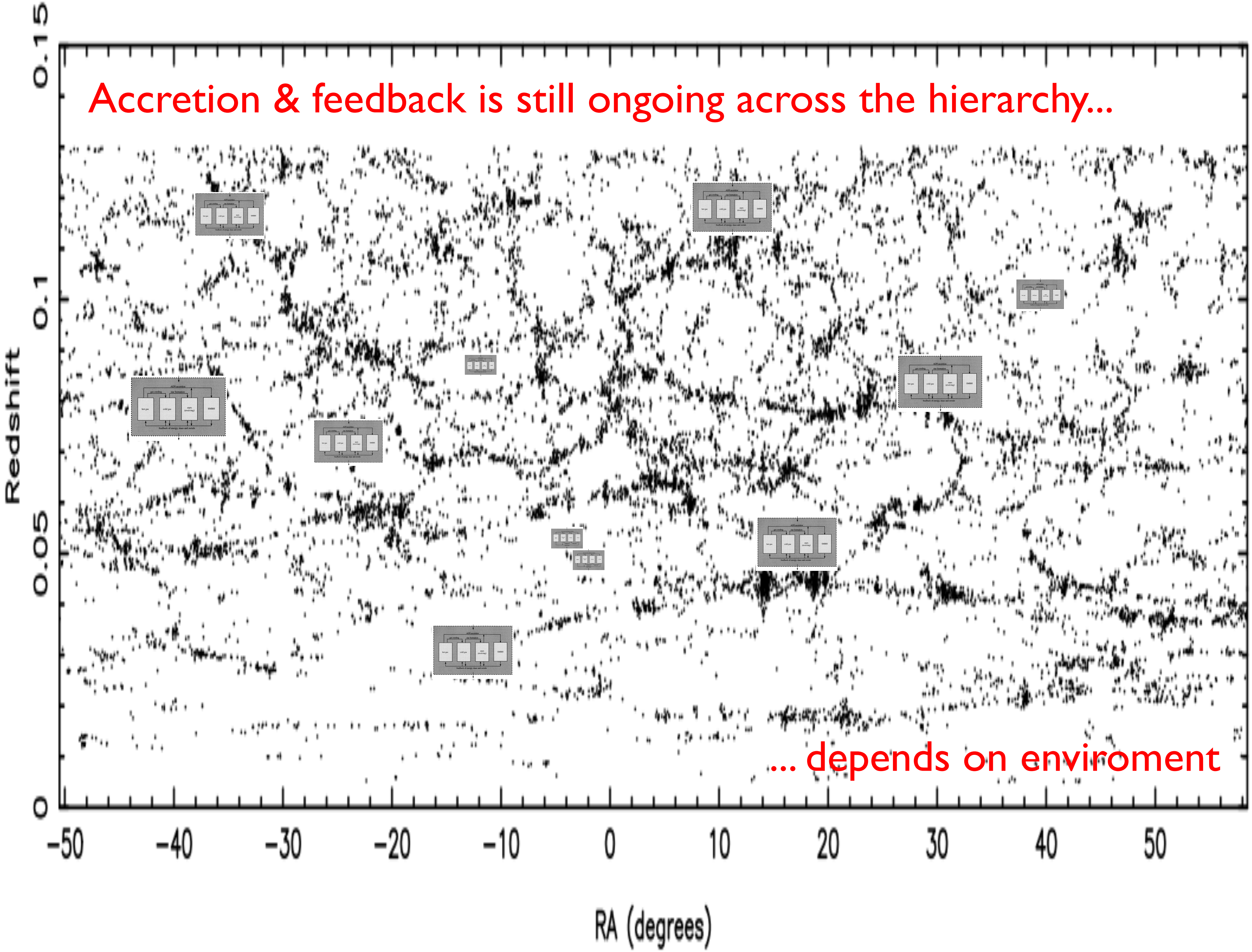
metallicity yield Y_{eff}

structural properties

inflow

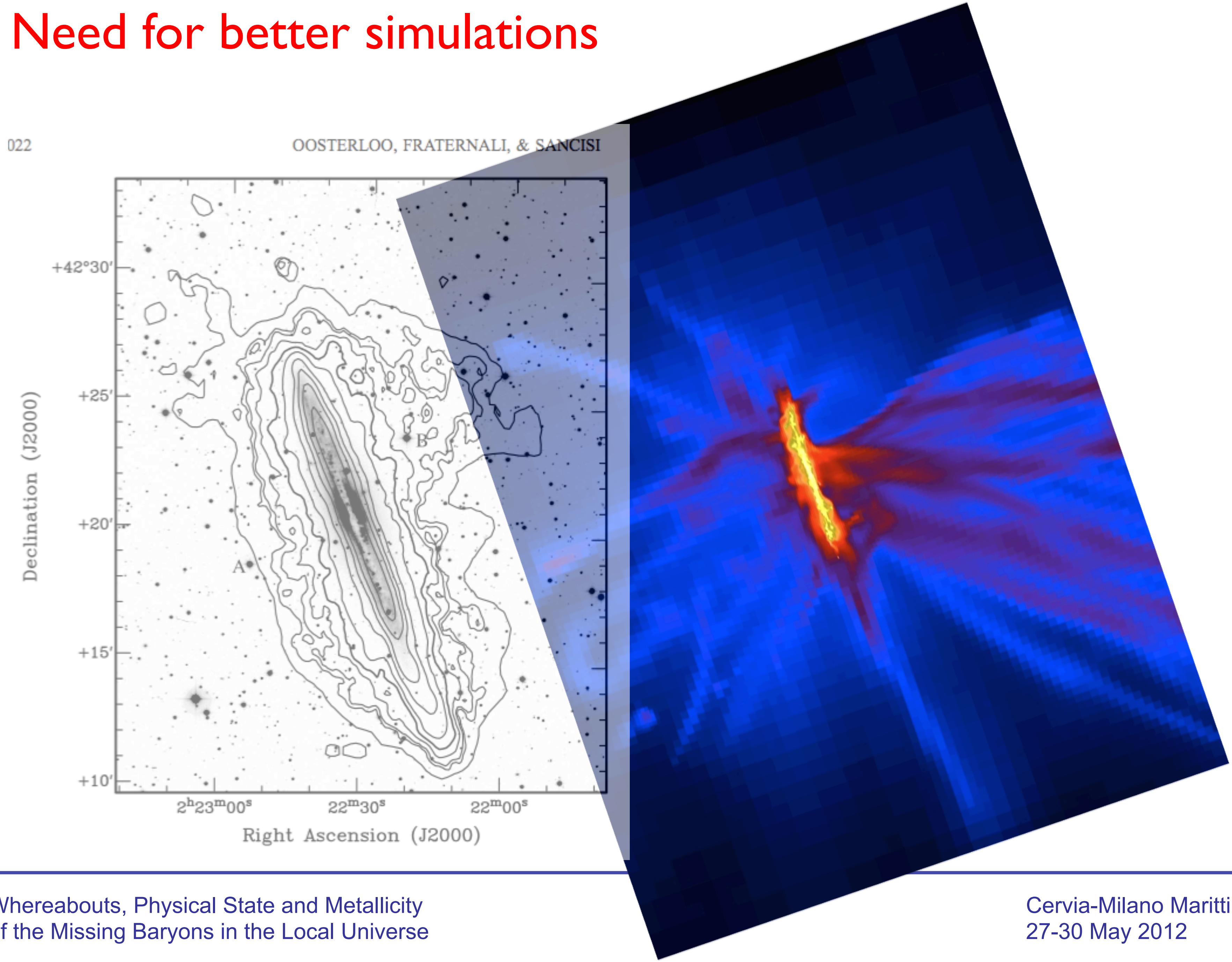


outflow



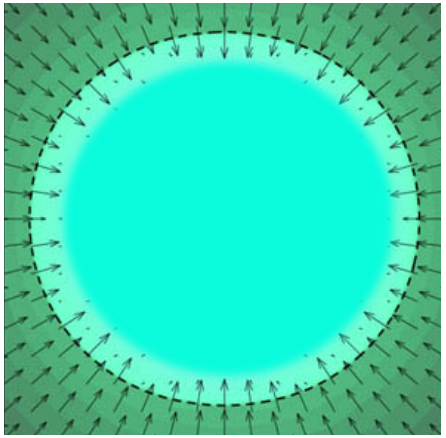
Accretion & feedback is still ongoing across the hierarchy...
... depends on enviroment
Redshift
0
0.05
0.1
0.15
-50
-40
-30
-20
-10
0
10
20
30
40
50
RA (degrees)

Need for better simulations



Current picture of galaxy formation – hot/cold accretion

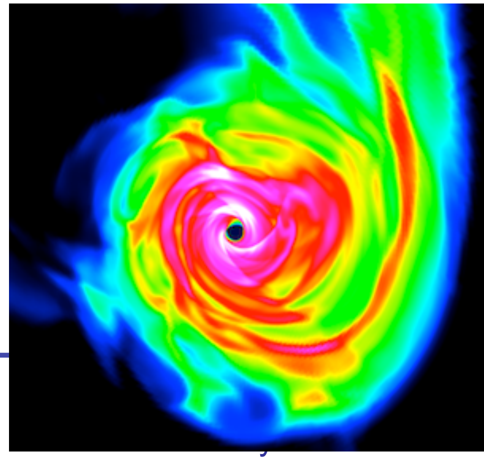
- Gas and DM accrete spherically; gas shock heats to T_{vir} & cools; specific ang. momentum of outer gas ~ dark matter; gas spins up as it cools & moves inwards



Hoyle 1949, 1953; Gunn & Gott 1972
Binney 1977; Rees & Ostriker 1977; Silk 1977
White & Rees 1978; White & Frenk 1991
Fall & Efstathiou 1980; Efstathiou & Silk 1983

- Cold flows ($T_{vir} < 10^{5.5}$ K); gas never heats up, flows in as cool filaments; specific ang. momentum of outer gas > dark matter; complex accretion

Birnboim & Dekel 2003, 2006; Keres+ 2005, 2009
Pichon+ 2011; Kimm+ 2011; Codis+ 2012



CGM studies can help!

Galactic accretion (1950-1990)

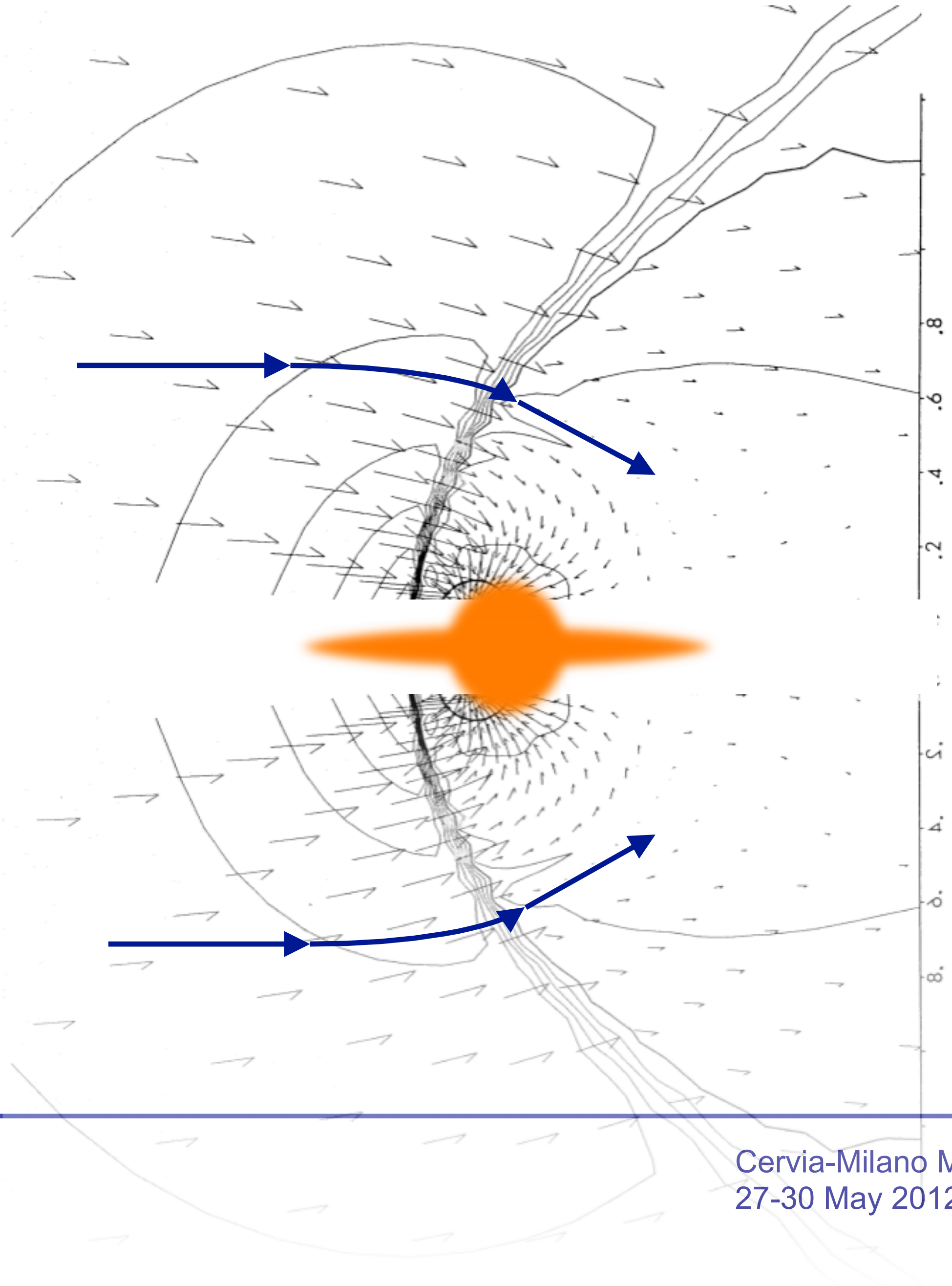
Spiegel 1966; Larson 1969
Ruderman & Spiegel 1971
Hunt 1971, 1979
Shima+ 1985
Portnoy+ 1993

Accretion in three parts:

a. cylindrical (sweeping up)
b. spherical (gravitational)
c. Bondi-Hoyle (tail shock)

$$\dot{m} = \frac{4\pi\rho_{gas}G^2 M_{halo}{}^2}{v_{gas}^3}$$

galaxy not to scale



Bring in concept of 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 ($\rho = 3M_{\mathrm{ngb}}/4\pi r^3_{\mathrm{ngb}}$)	$N = 1$ or N for which ρ is maximal $\Delta v = 400, 600\,\mathrm{km\,s^{-1}}$	$M_{r,\mathrm{ngb}} \gtrsim M_{r,\mathrm{gal}} + 0.5$	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	$R = 2\,h^{-1}\,\mathrm{Mpc}$	$V_{\mathrm{max}} > 120\,\mathrm{km\,s^{-1}}$	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
	$R_{\mathrm{FOF}} < R < 2\,h^{-1}\,\mathrm{Mpc}$	–	30
	$R_{\mathrm{vir}} < R < 3R_{\mathrm{vir}}$	–	41
Average mass density of surrounding haloes	$N = 7$	$200 < V_{\mathrm{max}}/\mathrm{km\,s^{-1}} < 300$	42

Statistical environment –

a measure of "crowding"

The way forward –

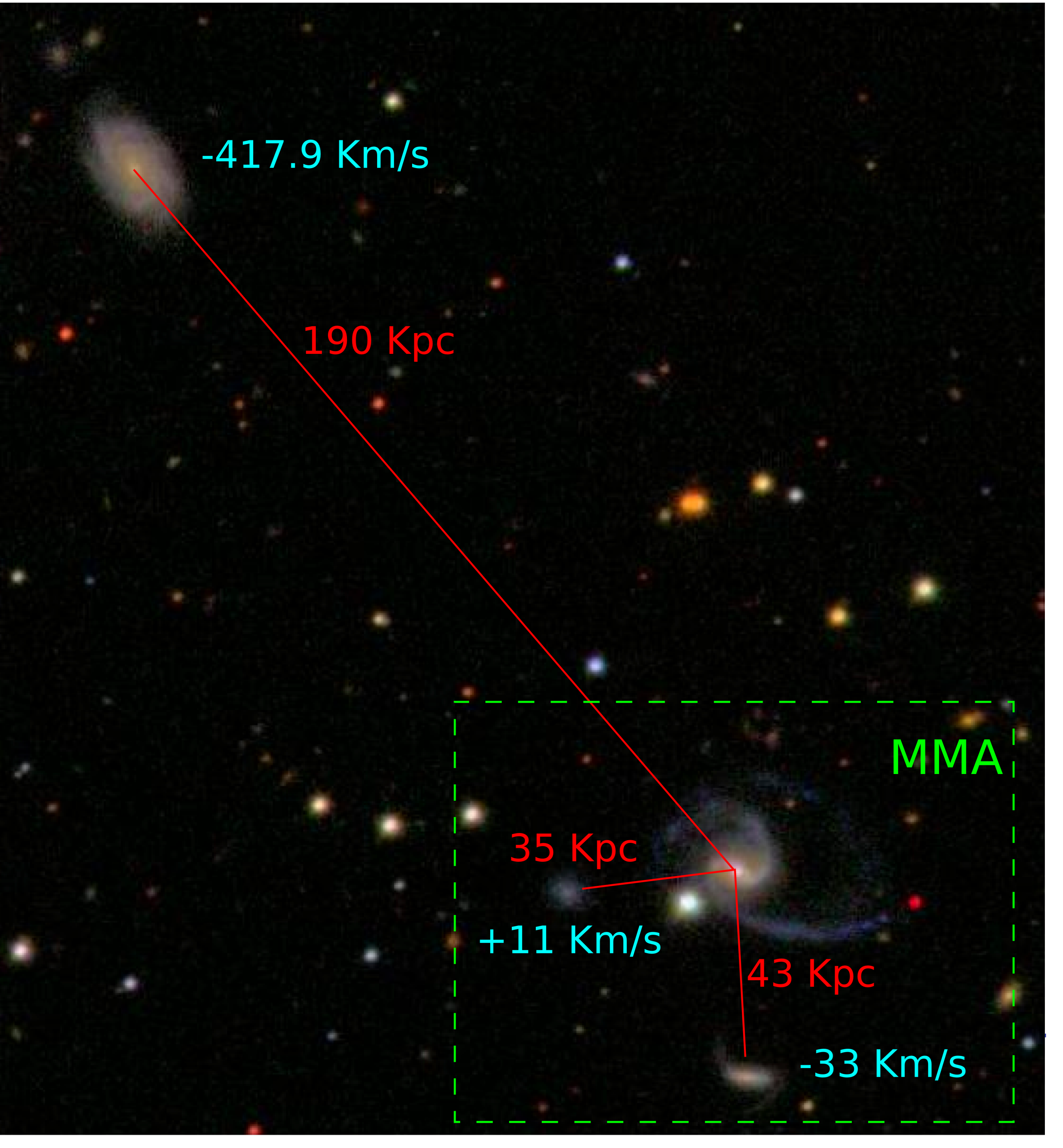
QSOs behind MW anal

Galaxy And Ma
Milky-Way Mag

A.S.G. Robotham[1,2⋆],
P. Norberg[6], A.E. Bau
A.M. Hopkins[7], S. Phi

MWA (+LMC)
MWA (+LMC+SM

Interestingly, most a



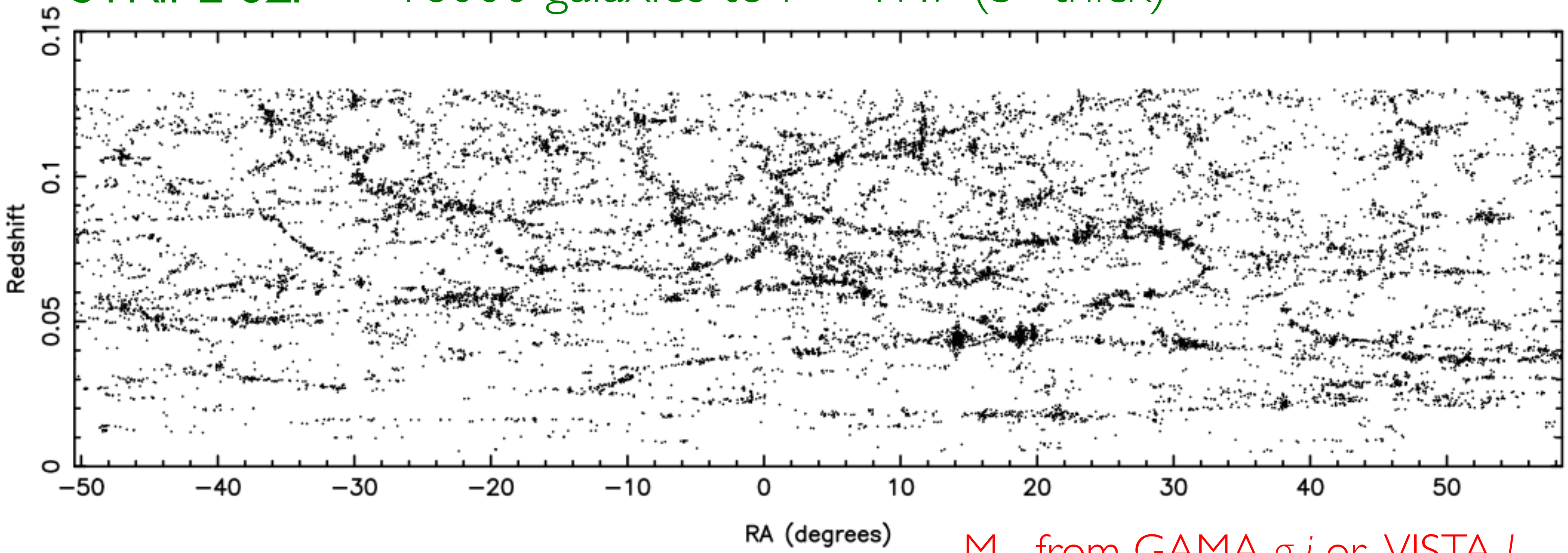
Intergalactic media – what we did not talk about

1. Filaments exist in voids; these should be targetted.

2. 80% of galaxies are collapsing into sheets; these sheets are filled with gas.

Filaments in voids are now seen in redshift surveys

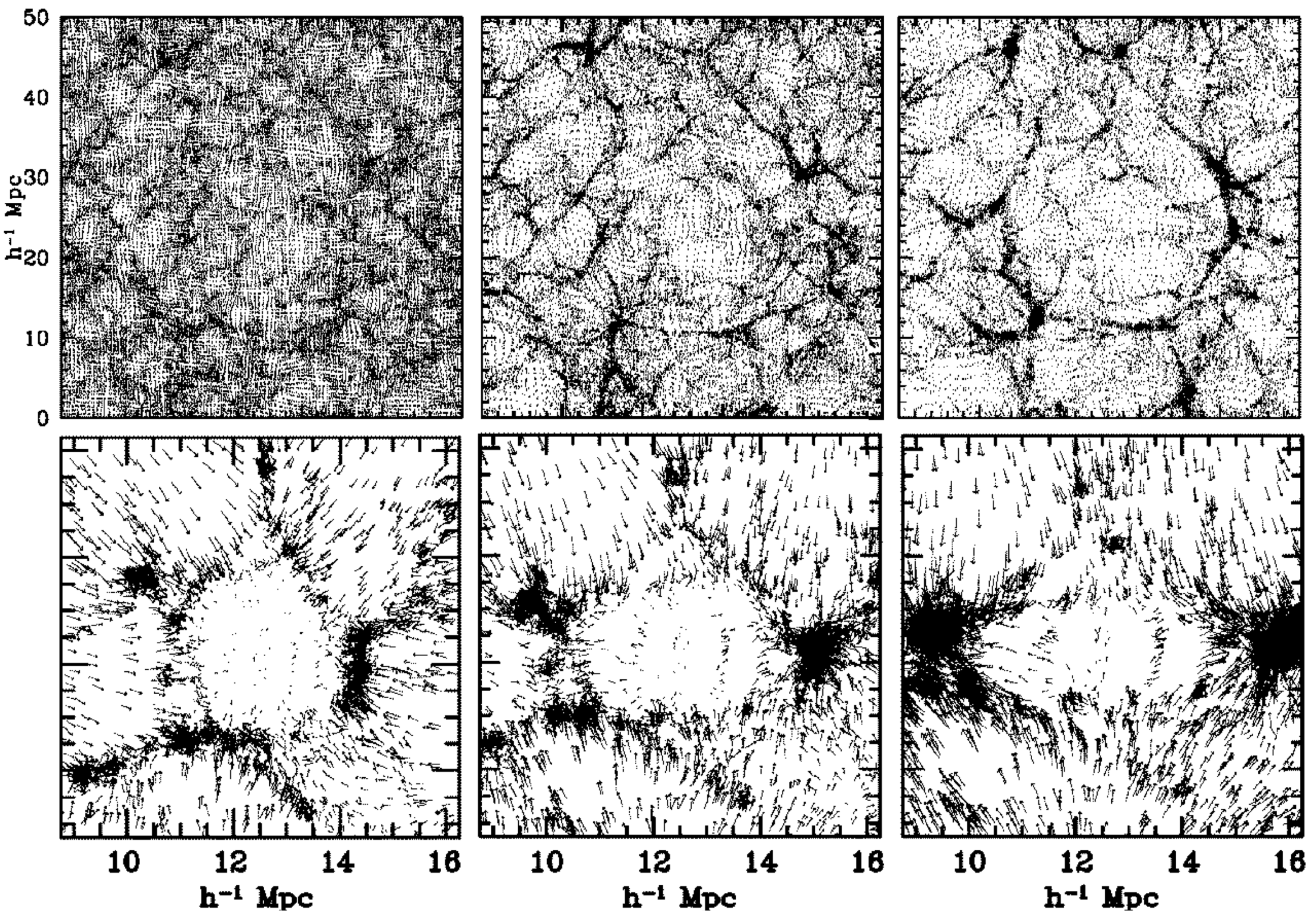
STRIPE 82: 16000 galaxies to r ~ 17.7 (3° thick)



$M_\star$ from GAMA *g-i* or VISTA *J*

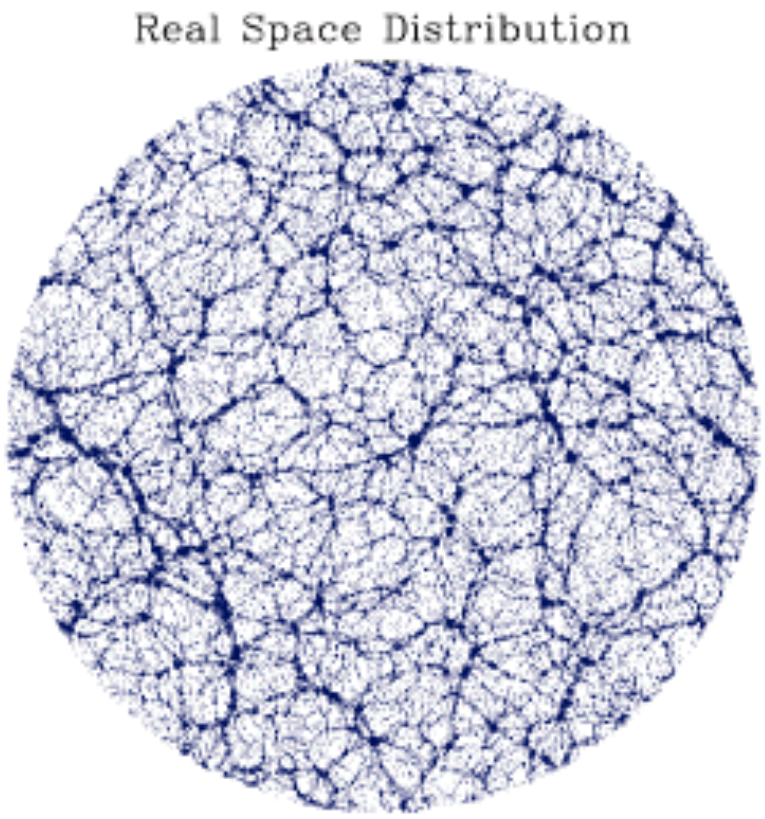
Filaments in voids ($\nabla.v > 0$) are expected to be physically distinct from filaments in dense regions ($\nabla.v < 0$)

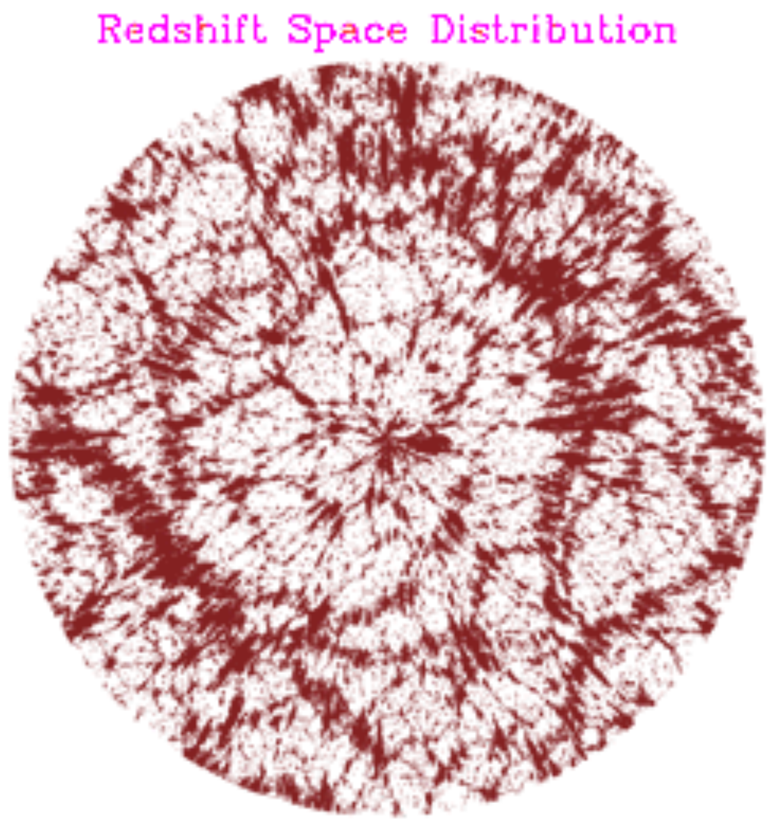
How does gas move out of voids?



Sheth & van de Weygaert 2004

Remember distorted view in z



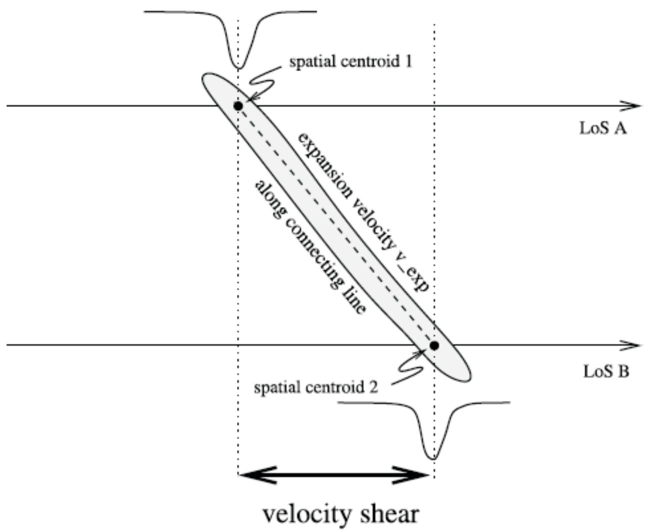


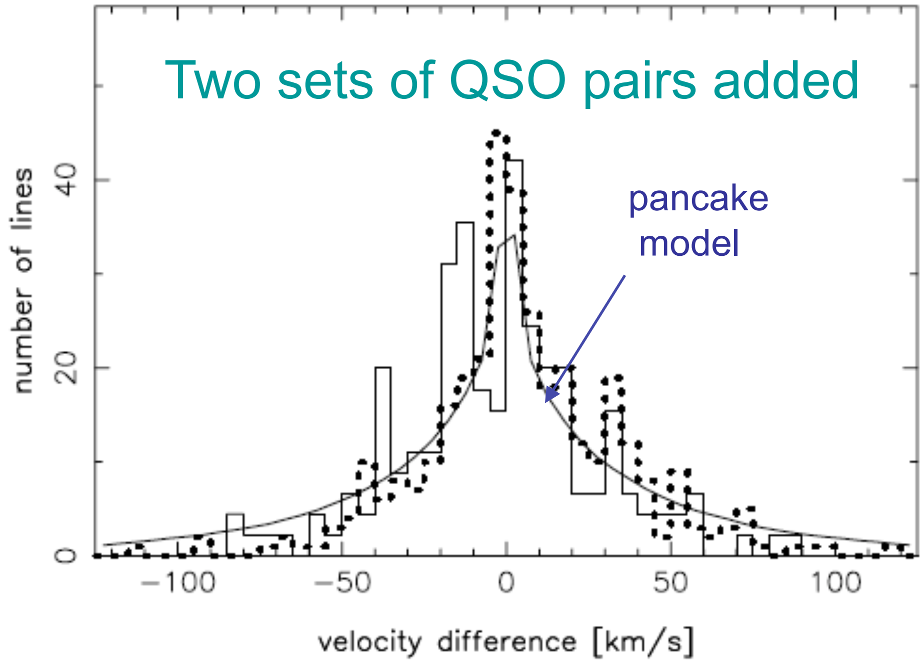
Do collapsing gas sheets really exist?

EXPANSION AND COLLAPSE IN THE COSMIC WEB[1,2]

MICHAEL RAUCH,[3] GEORGE D. BECKER,[4] MATTEO VIEL,[5] WALLACE L. W. SARGENT,[4] ALAIN SMETTE,[6,7]
ROBERT A. SIMCOE,[8] THOMAS A. BARLOW,[4] AND MARTIN G. HAEHNELT[5]

Received 2005 April 2; accepted 2005 May 26





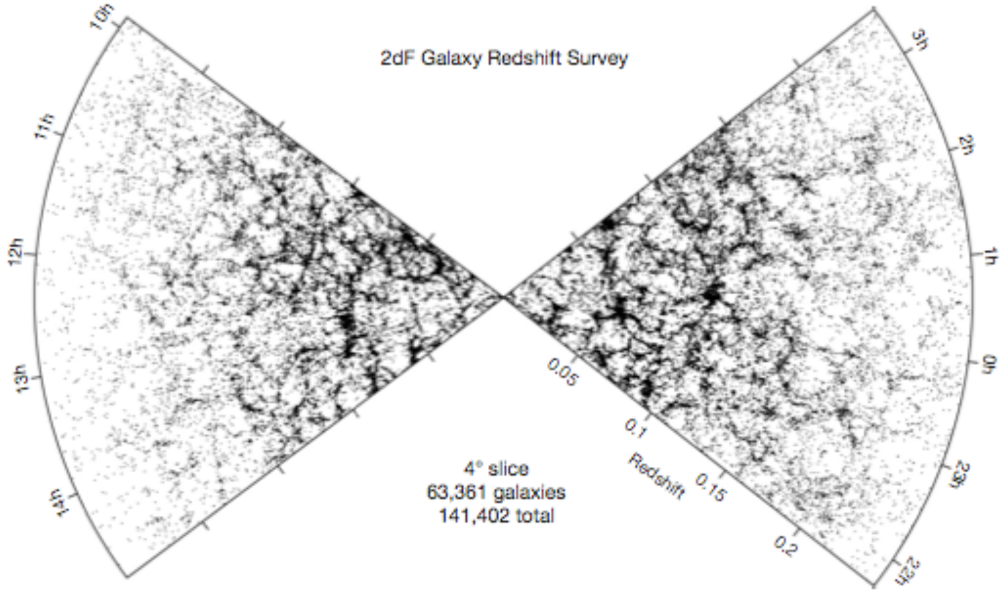
Lyα absorbers along paired z ~ 4 QSO sightlines

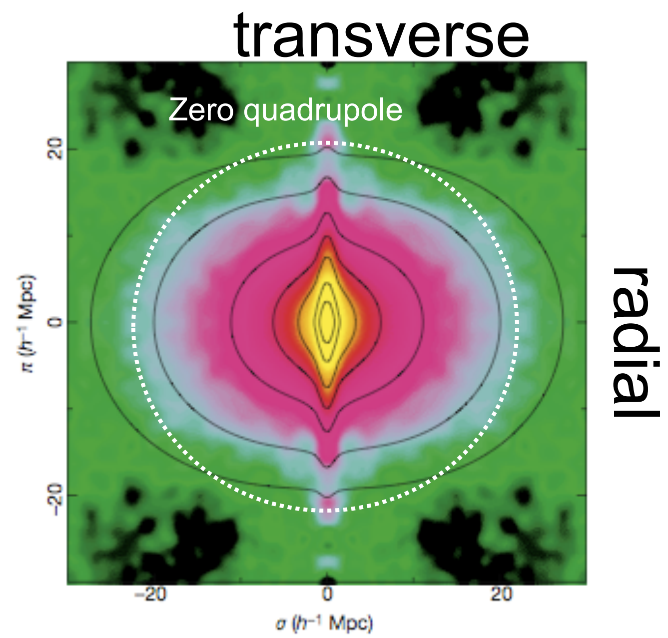
Cosmic infall out to z~0.2

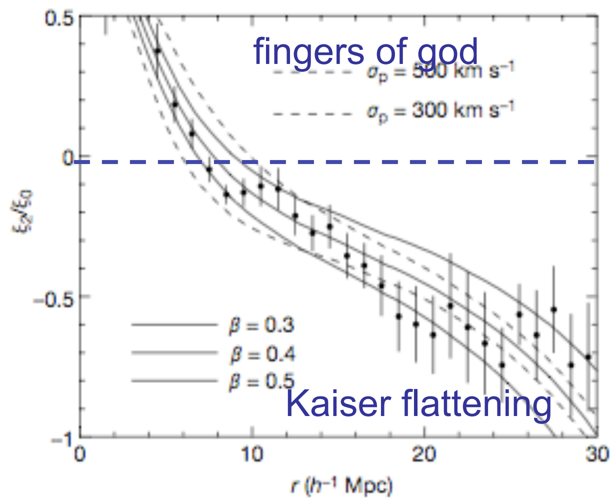
A measurement of the cosmological mass density from clustering in the 2dF Galaxy Redshift Survey

2001

John A. Peacock[1], Shaun Cole[2], Peder Norberg[2], Carlton M. Baugh[2], Joss Bland-Hawthorn[3], Terry Bridges[3], Russell D. Cannon[3], Matthew Colless[4], Chris Collins[5], Warrick Couch[6], Gavin Dalton[7], Kathryn Deeley[6], Roberto De Propris[6], Simon P. Driver[8], George Efstathiou[9], Richard S. Ellis[9,10], Carlos S. Frenk[2], Karl Glazebrook[11], Carole Jackson[4], Ofer Lahav[9], Ian Lewis[3], Stuart Lumsden[12], Steve Maddox[13], Will J. Percival[1], Bruce A. Peterson[4], Ian Price[4], Will Sutherland[1,7] & Keith Taylor[3,10]







Required modifications to BB:

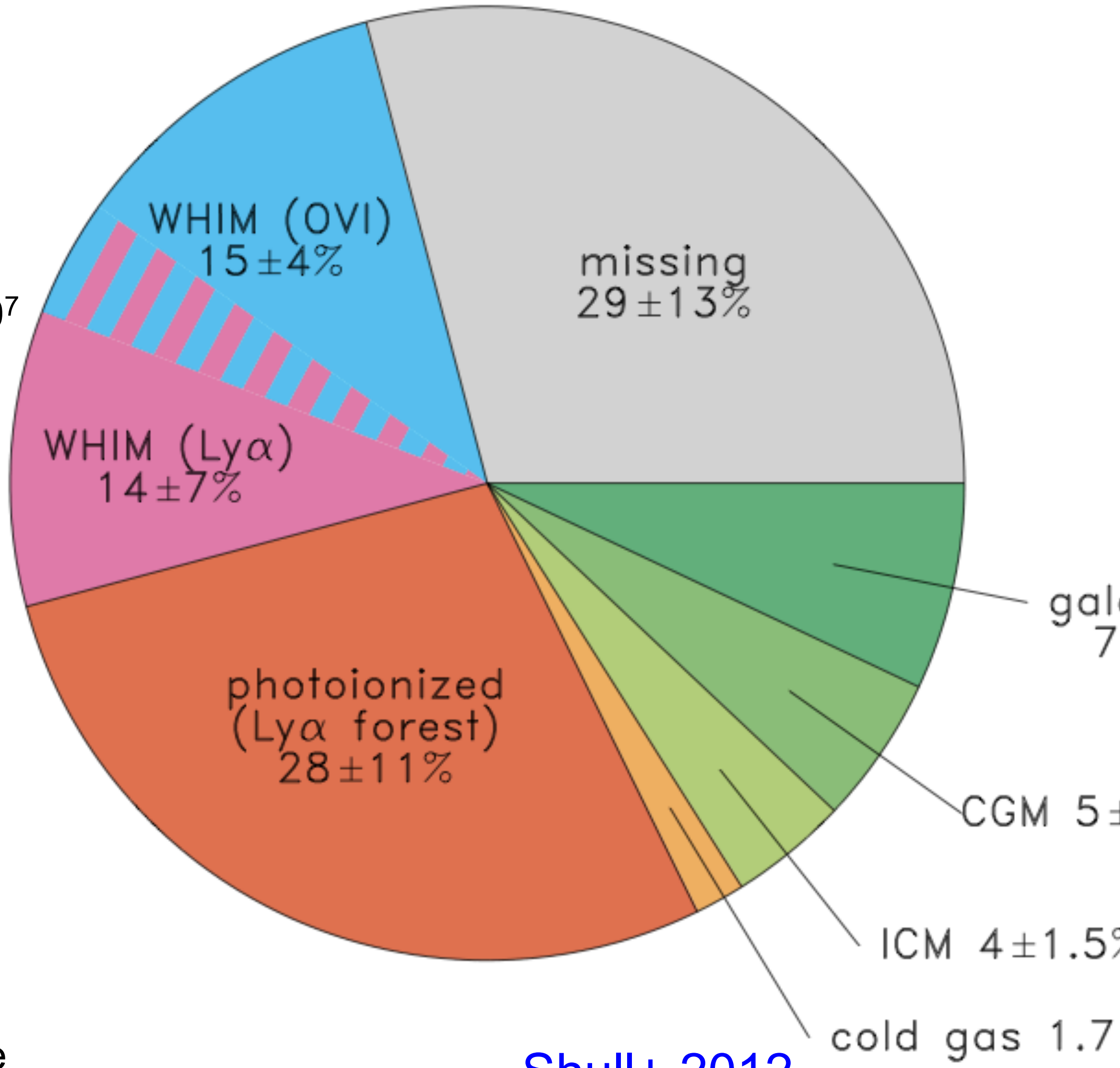
1. Giodini argues that FP04 only consider the most massive clusters. An extra ~5% of BB could be in low mass clusters (10^{13-14} M_o) taking ICM from 4% to 10%.

2. Gnat & Schaye argue for ~10-20% of BB should be in diffuse shock heated IGM ($T > 10^7$ K) that may **not** be seen even in future x-ray missions.

3. Gupta argued that OVII halo absorption & Fermi ϒ-ray background argue for CGM contribution being raised from 5% to 10%.

Recall problems: fixed abundance, ionization correction from simulations, non-equilibrium processes, double counting in overlapping phases, unknown forms of heating (e.g. blazars, GRBs) ?

The "missing baryon problem" may not exist. But like all censuses, we can expect the pie to evolve in the coming decades.



Shull+ 2012

Next meeting?

- Baryons and dark matter – go with the flow
  - Aspen 2013? *Chair:* Chris Martin (Caltech)
- IGM probes and theories of galaxy formation
  - Sydney 2013? *Chair:* Joss Bland-Hawthorn (Sydney)

  Following on from the successful 2009 Missing Baryons meeting at U Sydney, we can now use IGM and CGM probes to study how gas moves in and out of dark matter on all scales (filament flows, cluster flows, galaxy flows). There are now many detailed models of how galaxies form, evolve and interact with their environs (e.g. Shen+ 2012).
- A return to Italy (2014?)
  - Nico, Fabrizio and friends; post Cervia 2012