Observational Cosmology JC

2018/4/16 Taizo Okabe

・Baryon Budget of the Hot Circumgalactic Medium of Massive Spiral Galaxies

Jiang-Tao Li et al. 2018, ApJ, 855, L24

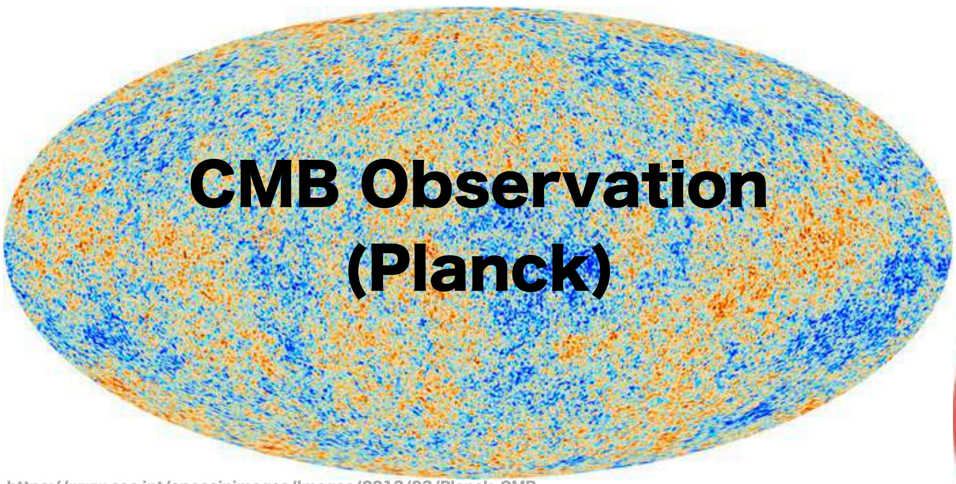
・X-ray and SZ constraints on the properties of hot CGM

Priyanka Singh arXiv:1801.06557

・A VLT/MUSE galaxy survey towards QSO Q1410: looking for a WHIM traced by BLAs in inter-cluster filaments

Ismael Pessa arXiv:1803.09794

Components of the Universe



https://www.esa.int/spaceinimages/Images/2013/03/Planck_CMB

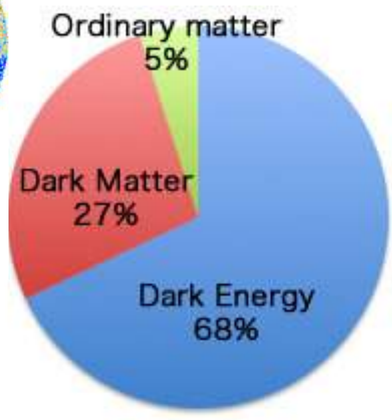


Fig. 1: Components of the Universe

http://www-sk.icrr.u-tokyo.ac.jp/xmass/darkmatter/index-e.html

~95% : Unknown

~5% : known (ordinary matter)

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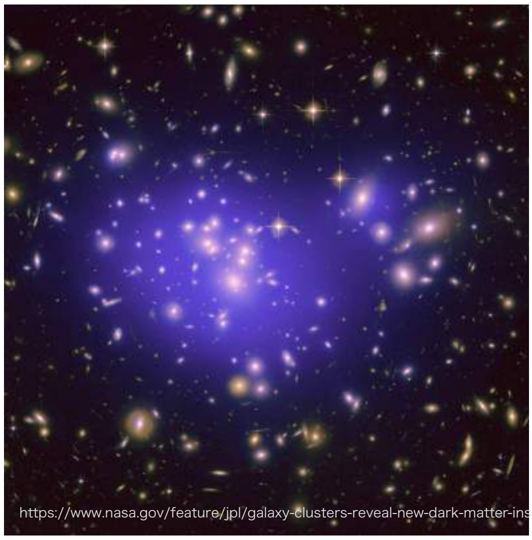
galaxies	galaxy clusters
	

galaxies

dark matter: ~95%
stars : ~2%
neutral gas : ~1%
CGM : ~2%

galaxy clusters

dark matter : ~90%
hot gas : ~10%
galaxies(stars): ~5%

→ Mb/Mtot < 16% (= 5/(25+5))

“missing baryons problem”

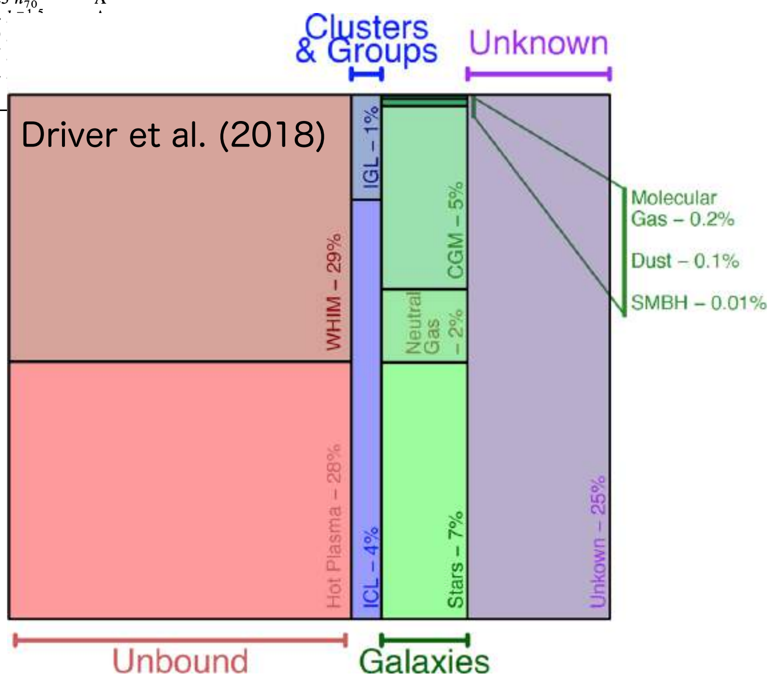
Fukugita, Hogan, & Peebles (1998)

THE BARYON BUDGET

Component	Central	Maximum	Minimum	Grade[a]
Observed at $z \approx 0$				
1. Stars in spheroids	$0.0026\ h_{70}^{-1}$	$0.0043\ h_{70}^{-1}$	$0.0014\ h_{70}^{-1}$	A
2. Stars in disks	$0.00086\ h_{70}^{-1}$	$0.00129\ h_{70}^{-1}$	$0.00051\ h_{70}^{-1}$	A –
3. Stars in irregulars	$0.000069\ h_{70}^{-1}$	$0.000116\ h_{70}^{-1}$	$0.000033\ h_{70}^{-1}$	B
4. Neutral atomic gas	$0.00033\ h_{70}^{-1}$	$0.00041\ h_{70}^{-1}$	$0.00025\ h_{70}^{-1}$	A
5. Molecular gas	$0.00030\ h_{70}^{-1}$	$0.00037\ h_{70}^{-1}$	$0.00023\ h_{70}^{-1}$	A –
6. Plasma in clusters	$0.0026\ h_{70}^{-1.5}$	$0.0044\ h_{70}^{-1.5}$	0.0014	
7a. Warm plasma in groups	$0.0056\ h_{70}^{-1.5}$	$0.0115\ h_{70}^{-1.5}$	0.0029	
7b. Cool plasma	$0.002\ h_{70}^{-1}$	$0.003\ h_{70}^{-1}$	0.0007	
7′. Plasma in groups	$0.014\ h_{70}^{-1}$	$0.030\ h_{70}^{-1}$	0.0072	
8. Sum (at $h = 70$ and $z \simeq 0$)......	0.021	0.041	0.007	

>50% baryons are “missing”

still open question



[1] X-ray and SZ constraints on the properties of hot CGM

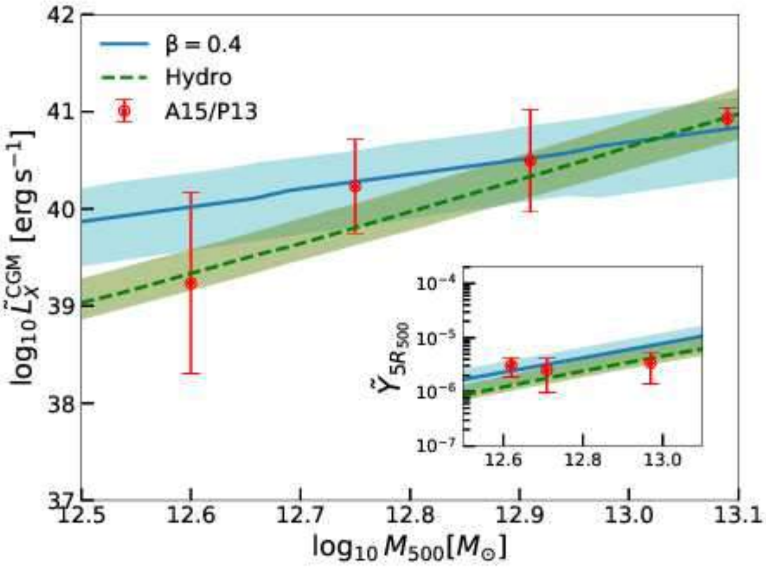
Image stacking analysis of SDSS galaxies ($N \sim 10^5$)

1) X-ray emission

$$L_X^{\rm CGM} = \int_{0.15R_{500}}^{R_{500}} 2\pi r dr \int_r^{R_{500}} \frac{2\, n_e n_i \Lambda(Z, T_e) r' dr'}{\sqrt{r'^2 - r^2}}$$

2) Sunyaev-Zel'dovich (SZ) effect

$$Y_{500} = \frac{\sigma_T}{m_e c^2 D_A^2(z)} \int_0^{R_{500}} P_e dV \qquad P_e = n_e k_{\rm b} T_e$$



[1] X-ray and SZ constraints on the properties of hot CGM

model parameters

$$f_{\rm gas} = \frac{\Omega_B}{\Omega_M}\left(\frac{M_v}{10^{15} M_\odot}\right)^{\alpha_{fg}} \;\&\; f_T = f_{12}\left(\frac{M_v}{10^{12} M_\odot}\right)^{\alpha_T}$$

$$f_{\rm gas} = \frac{4\pi \mu_e m_p}{M_v} \int_0^{R_v} dr\, r^2\, n_e(r)$$

$$T_{\rm gas} = f_T \times T_{\rm vir} \qquad T_{\rm vir} = \frac{\mu m p G M_v}{2 k_b R_v}$$

model I: A power-law model

$$n_e(r) \propto r^{-3\beta} \qquad \beta = 0.4$$

model II: Isothermal hydrostatic equilibrium

$$n_e(r) \propto \exp\left[-\left(\frac{\mu m_p G M_v}{k_b T_{\rm gas} R_s}\right) \frac{1 - \log(1 + r/R_s)/(r/R_s)}{\log(1 + C_v) - C_v/(1 + C_v)}\right]$$

[1] X-ray and SZ constraints on the properties of hot CGM

model I

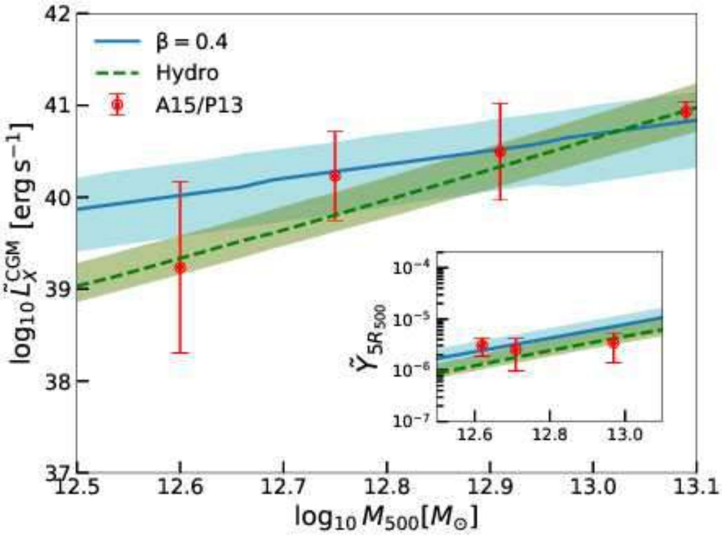
20-30% (of Ωb/Ωm) within Rv,

46-78% within 2Rv (extrapolate)

model II

4-11% of within Rv,

13-24% within 2Rv (extrapolate)

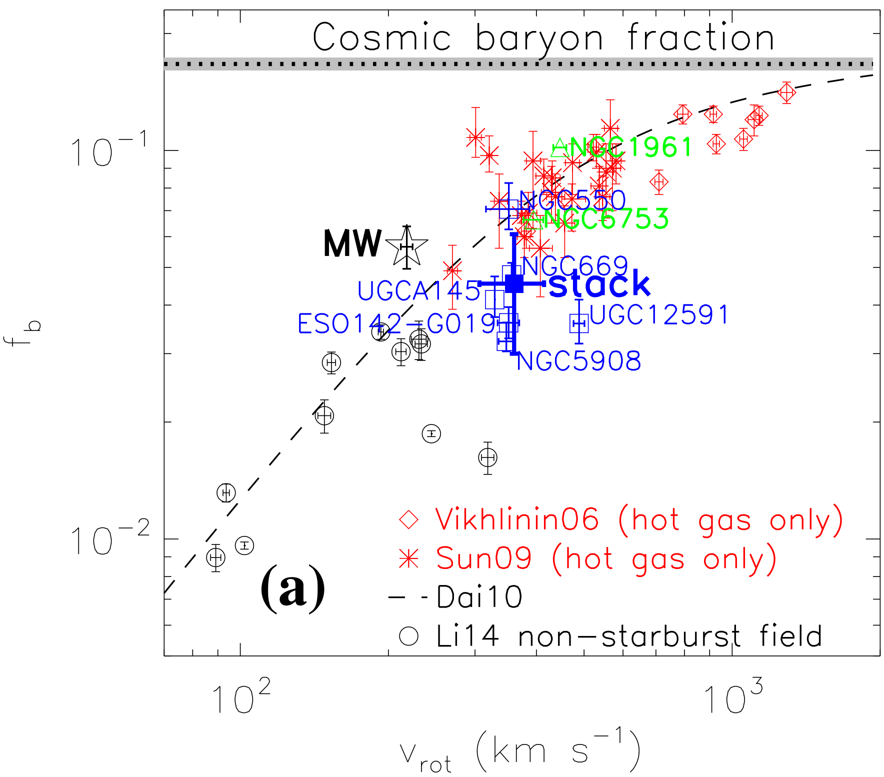


→ insufficient to explain the “missing baryon”

A recent result by Lim et al. (2017) showed that their results are consistent with the CGM containing galactic cosmic baryon fraction within the virial radius of the galaxy. (Oguri-san’s JC)

The signal might be overestimated due to the value of β=0.86 they used

[2] Baryon Budget of the Hot Circumgalactic Medium of Massive Spiral Galaxies

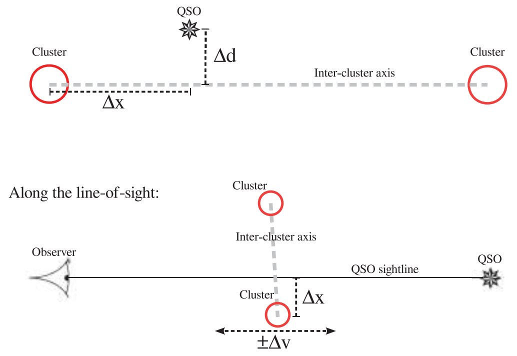


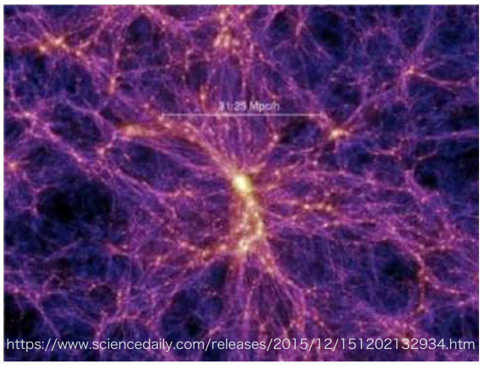
For six local isolated massive spiral galaxies, 4-12% within Rv

(only observations of X-ray emission)

→ insufficient to explain the “missing baryon”

[3] A VLT/MUSE galaxy survey towards QSO Q1410: looking for a WHIM traced by BLAs in inter-cluster filaments





Parameters derived from BLAs

ID	Redshift	b	Column densities		$\log f_{ion}$	Temperature	Gas density		Has galaxy nearby?
							$\Gamma = 0$	$\Gamma = 2$	
		km s^{-1}	$\log(N_{HI}/cm^{-2})$	$\log(N_{HII}/cm^{-2})$		$\log(T/K)$	$\log(\overline{n_H}/cm^{-3})$		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1	0.1606	59±22	13.40±0.11	19.1±0.4	5.68±0.40	5.1±0.3	-6.2±0.4	-6.5±0.4	y
2	0.3422	153±19	13.75±0.05	20.5±0.1	6.72±0.13	6.0±0.1	-4.8±0.1	-5.1±0.1	n
3	0.3502	97±10	14.29±0.09	20.5±0.1	6.22±0.11	5.6±0.1	-4.8±0.1	-5.1±0.1	y
4	0.3689	50±18	13.25±0.11	18.8±0.4	5.50±0.39	5.0±0.3	-6.5±0.4	-6.8±0.4	n
5	0.4118	62±18	13.47±0.09	19.2±0.3	5.74±0.32	5.2±0.3	-6.1±0.3	-6.4±0.3	y
6	0.4202	56±20	13.25±0.12	18.9±0.4	5.63±0.39	5.1±0.3	-6.4±0.4	-6.7±0.4	y
7	0.4547	81±18	13.46±0.08	19.5±0.3	6.03±0.24	5.4±0.2	-5.8±0.3	-6.1±0.3	n

Ωb(filament) ~ 0.01-0.06

consistent with the results of resent works Graaff et al. (2017) & Tanimura et al.(2017) measured by SZ effect ~30% of baryons may be in filaments (Kitayama-san's JC)

→ missing baryons problem may be solved via observations of cosmic web