Clusters of galaxies as a tool in cosmology

Matter to the deepest
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Sylwia Miernik
Aleksandra Piórkowska
Marek Biesiada

University of Silesia, Department of Astrophysic and Cosmology

Outline

I. Clusters of galaxies
II. Obtaining mass and f_{gas}
III. Cosmological parameter fitting
IV. Results
V. Conclusions

Clusters of galaxies

Group of galaxies	• 3< galaxies <=50 • Galaxies are placed in the area < 1 Mpc • Galaxies are bound together by gravity
*Local Group	• ~ 54 galaxies • It includes the Milky Way
Galaxy cluster	• Consist of hundreds to thousands of galaxies bound together by gravity • Typical diameter: 1 – 10 mln ly (2 – 10 Mpc) • Total mass: 10^{14} – 10^{15} solar masses
Galaxy supercluster	• Consist of smaller galaxy groups and galaxy clusters not strongly bound together by gravity

Clusters of galaxies

Arise in the early, hot phase of the Universe from density perturbations in the primordial plasma (photons + baryonic and dark matter)

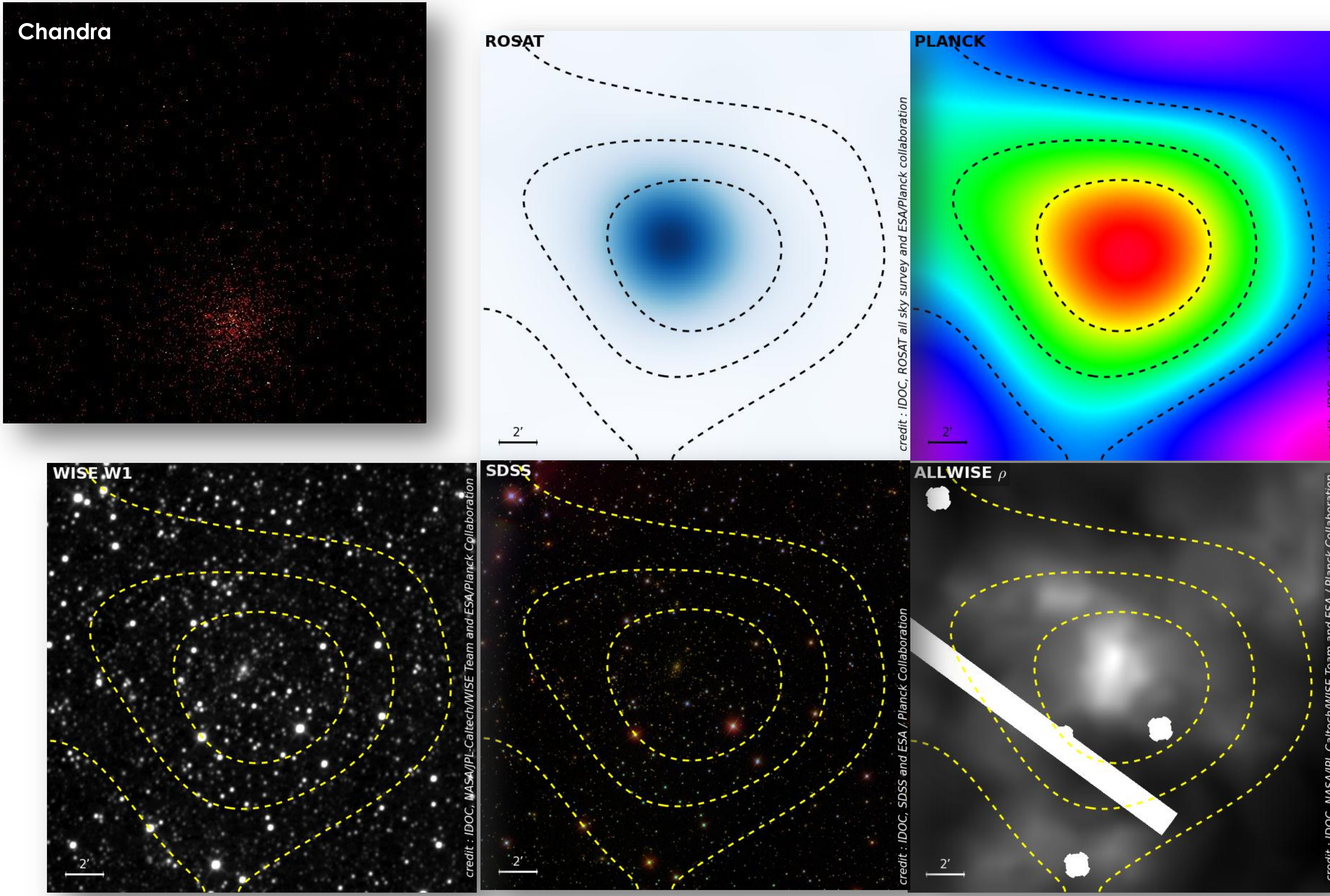
ICM (Intracluster Medium)

- Hot diffuse plasma that fills the intergalactic space
- Electron gas temperatures reaches10^{14} to 10^{15} K
- Mostly emits X-Ray radiation through the bremsstrahlung process

Sunyaev–Zel'dovich effect – small spectral distortion of the cosmic microwave background radiation (CMB) spectrum caused by the scattering of CMB photons off a distribution of hight-energy electrons from ICM

Abell 586 (RXC J0732.3+3137; ACO 586; RMJ073220.3+314120.7; PSZ1 G187.53+21.92)

z = 0.171; Ra 07 32 20.00, Dec +31 37 53.00



Source: SZ CLUSTER DATABASE

Obtaining mass and f_{gas} of the cluster

$$f_{gas} = \frac{M_{gas}}{M_{tot}}$$

The most common model that describes gas density profile is :

- The β model (for cool core clusters)
- Double β model (for non-cool core clusters)
- Mofication of β model

$$n_e(r) = n_{e0}\left[f\left(1+\frac{r^2}{r_{c1}^2}\right)^{-3\beta/2} + (1-f)\left(1+\frac{r^2}{r_{c2}^2}\right)^{-3\beta/2}\right]$$

The total mass of a cluster can be obtained assuming:

- Spherical symmetry of a cluster
- Isothermal gas
- Hydrostatic equilibrium of gas

$$M_{tot}(r) = -\frac{r^2}{\varrho G}\frac{dP}{dr}$$

The temperature profile T(r) of the cluster is also used.

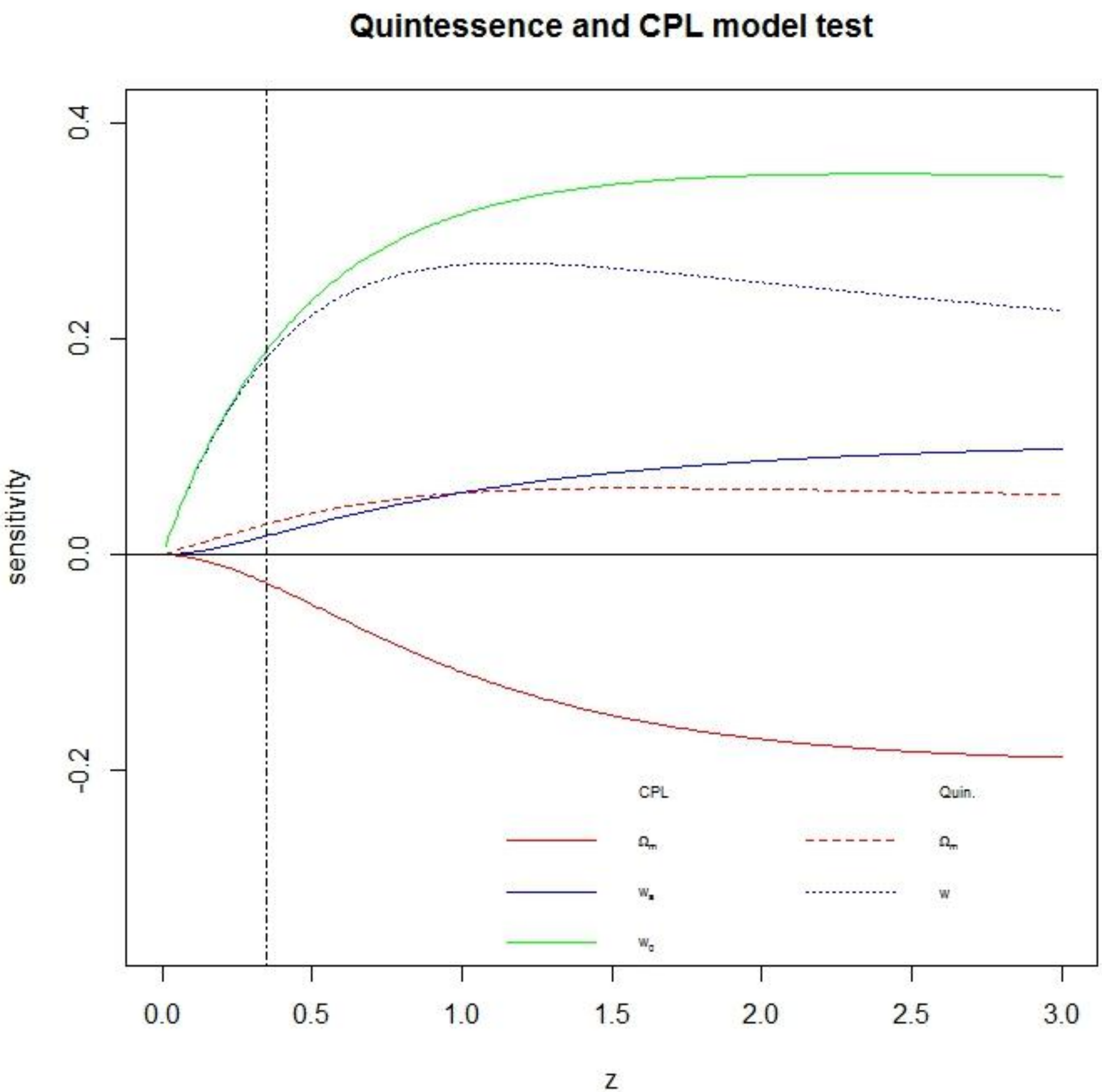
The goal of my work

Fitting the density parameters $\boldsymbol{\Omega_b}$, $\boldsymbol{\Omega_m}$ to f_{gas} data of clusters of galaxies.

$$\boldsymbol{\Omega_b(t)} = \frac{density\ of\ baryonic\ matter\ at\ t}{critical\ density\ at\ t}$$

$$\boldsymbol{\Omega_m(t)} = \frac{density\ of\ \ matter\ (baronic + dark)\ at\ t}{critical\ density\ at\ t}$$

Sensitivity



Allen's [et al. 2008] sample

- 42 very hot and most luminous clusters of galaxies
- z <0.05 ; 1.1 >
- Relaxed
- Doubled time of exposure

M_{tot} was obtained assuming:

- Spherical symmetry of clusters
- Hydrostatic equilibrium
- NFW model to parametrize mass density profile

$$\varrho(r) = \frac{\varrho_c(z)\delta_c}{\frac{r}{r_s}\left(1+\frac{r}{r_s}\right)^2}$$

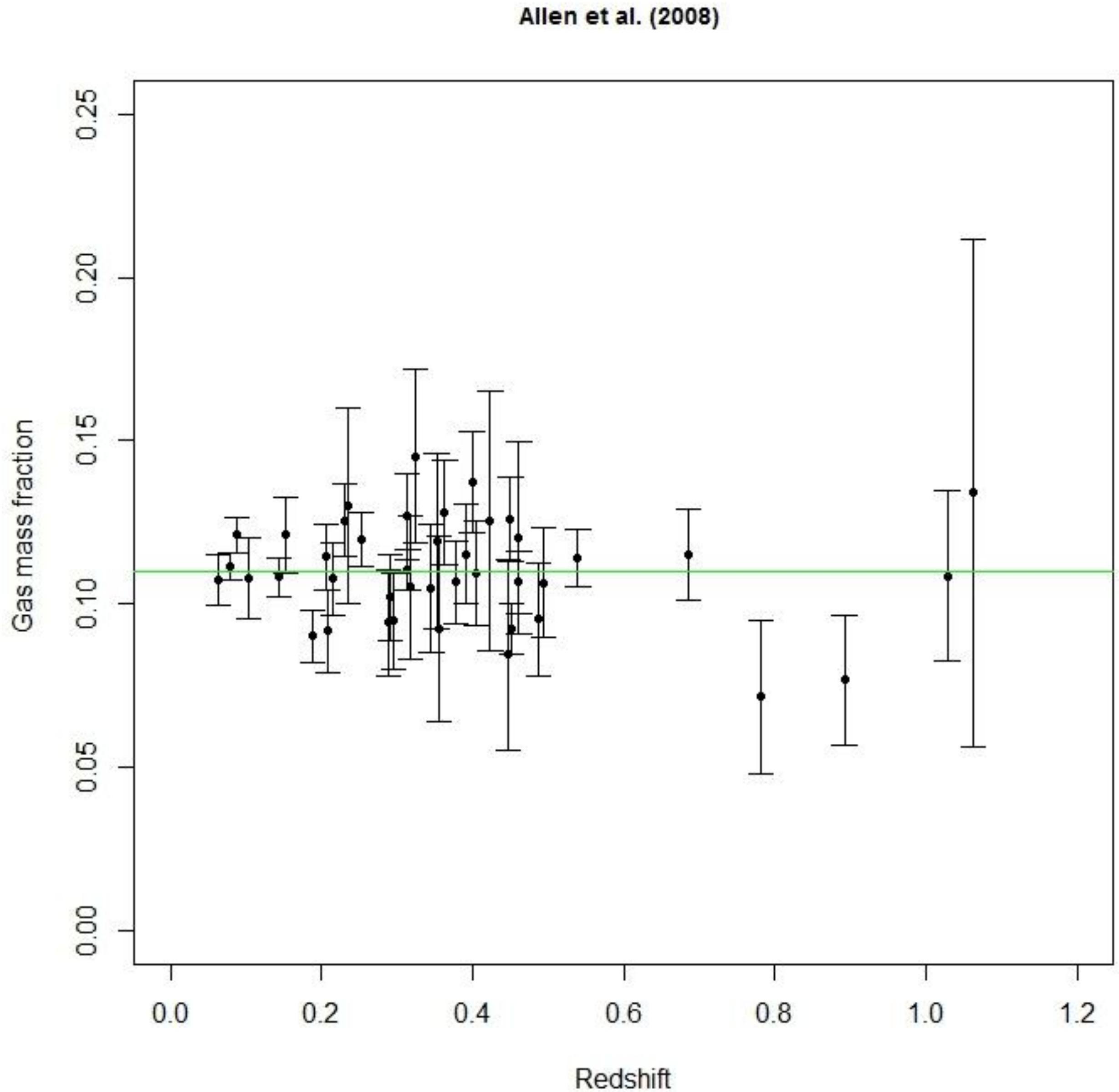
$$\delta_c = \frac{200c^2}{3\left(ln(1+c) - \frac{c}{1+c}\right)}$$

A concentration parameter

$$c = \frac{r_{200}}{r_s}$$

- Other parameters like gas mass density, pressure, mass, entropy, cooling time and f_{gas} was obtained from MC simulation and χ^2 method.

Allen’s [et al. 2008] sample



The method

$$f_{gas}^{th}(z,h,\Omega_m,\tilde{p},\Omega_b) \propto \left(\frac{\Omega_b}{\Omega_m}\right)\left[\frac{d_A^{\Lambda CDM}(z)}{d_A(z)}\right]^{1.5}$$

(Samushia et al. 2008)

where

d_A is an angular diameter distance

$$d_A(z;\ \tilde{p}) = \frac{1}{1+z}\frac{c}{H_0}\int_0^z \frac{dz'}{H(z';\tilde{p})}$$

where

$\tilde{p}$ - the equation of state parameters

Assumed cosmological models

Quintessence $H^2(z',\tilde{p}) = \left[\Omega_m\,(1+z)^3 + \Omega_Q(1+z)^{3(1+w)}\right]$

Chevallier – Polarski – Linder (CPL)

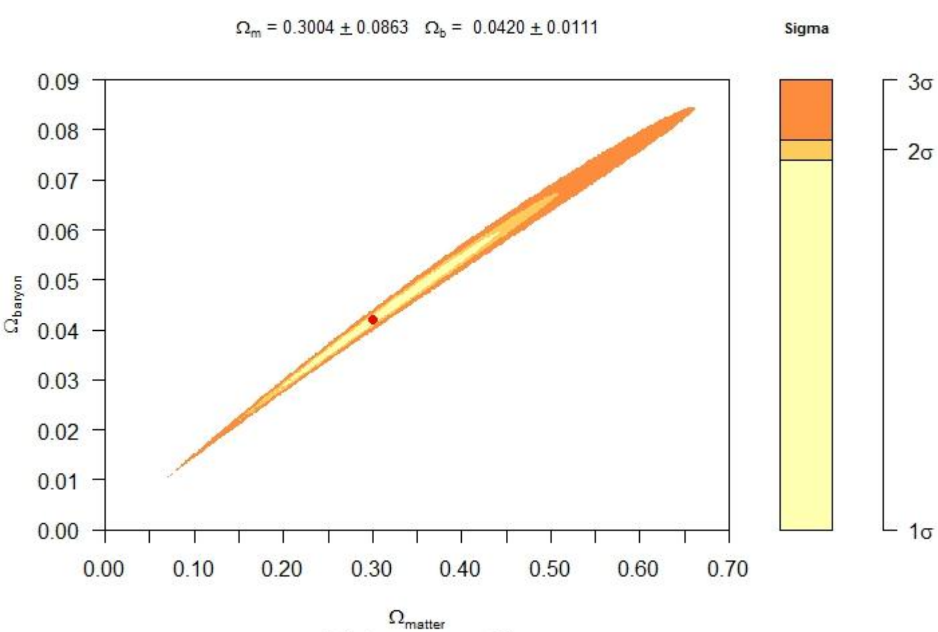
$$H^2(z',\tilde{p}) = \left[\Omega_m\,(1+z)^3 + \Omega_Q(1+z)^{3(1+w_0+w_a)} exp\left(\frac{-3w_a z}{1+z}\right)\right]$$

$$\chi^2 = \frac{\left(f_{gas}^{th}(z,h,\Omega_m,\tilde{p},\Omega_b) - f_{gas}^{obs}(z,h,\Omega_m,\tilde{p},\Omega_b)\right)^2}{\sigma^2}$$

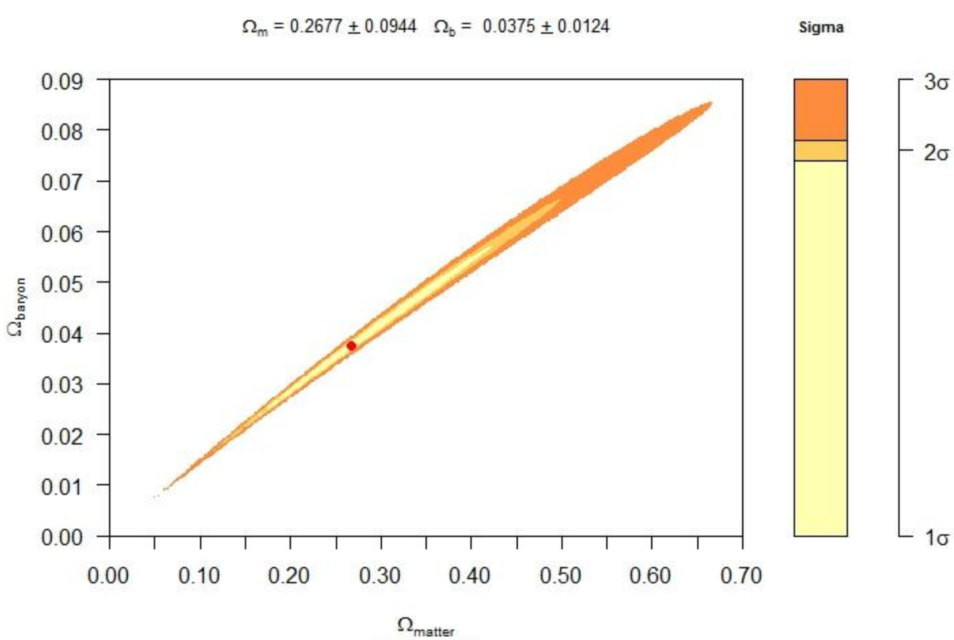
Results

	Quintessece	CPL	Reference values	
Ω_m	0.3005 $\pm$ 0.0863	0.2677 $\pm$ 0.0944	0.315 $\pm$ 0.016	#from Planck (CMB)
Ω_b	0.0420 $\pm$ 0.0111	0.0375 $\pm$ 0.0124	0.0455 $\pm$ 0.00028	#from Planck (CMB)

* Best fit taken from SN as a prior, w = -1.070 ; w_a = 0.609 ; w_0 = -0.993



Quintessence model



CPL model

Conclusions

- ✓ Clusters of galaxies are a good tool for testing cosmology;
- ✓ The density parameters $\boldsymbol{\Omega_b}$, $\boldsymbol{\Omega_m}$ obtained from GC are in a very good agreement with Planck's results;
- ✓ Better results are obtained for the quintessence model;
- ✓ It is worth to constrain the parameters using some other results from a different method eg. gravitational lensing;

Thank you
for your attention