The cluster gas mass fraction as a cosmological probe: *a revised study*

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Gas mass fraction

To constrain the cosmological model

$$\Omega_m + \Omega_\Lambda + \Omega_k = 1$$

We combine a **dynamical** and a **geometrical** method

(see also Allen et al, Blanchard et al., Ettori et al, Mohr et al) :

1. baryonic content of galaxy clusters is representative of the cosmic baryon fraction Ω_b / Ω_m (White et al. 93)
2. f_{gas} is assumed constant in cosmic time in very massive systems (Sasaki 96, Pen 97)

Gas mass fraction: the method

$$\chi^2 = \sum_{i=1}^{N_{dat}} \frac{(\hat{\Omega}_i - \Omega_m)^2}{\varepsilon^2_{\Omega_i}}$$

$$\hat{\Omega}_i = b_i \Omega_b / f_{bar,i}$$

Gas mass fraction: the method

$$\chi^2 = \sum_{i=1}^{N_{dat}} \frac{(\hat{\Omega}_i - \Omega_m)^2}{\varepsilon^2_{\Omega_i}} \qquad \hat{\Omega}_i = b_i \Omega_b / f_{bar,i}$$

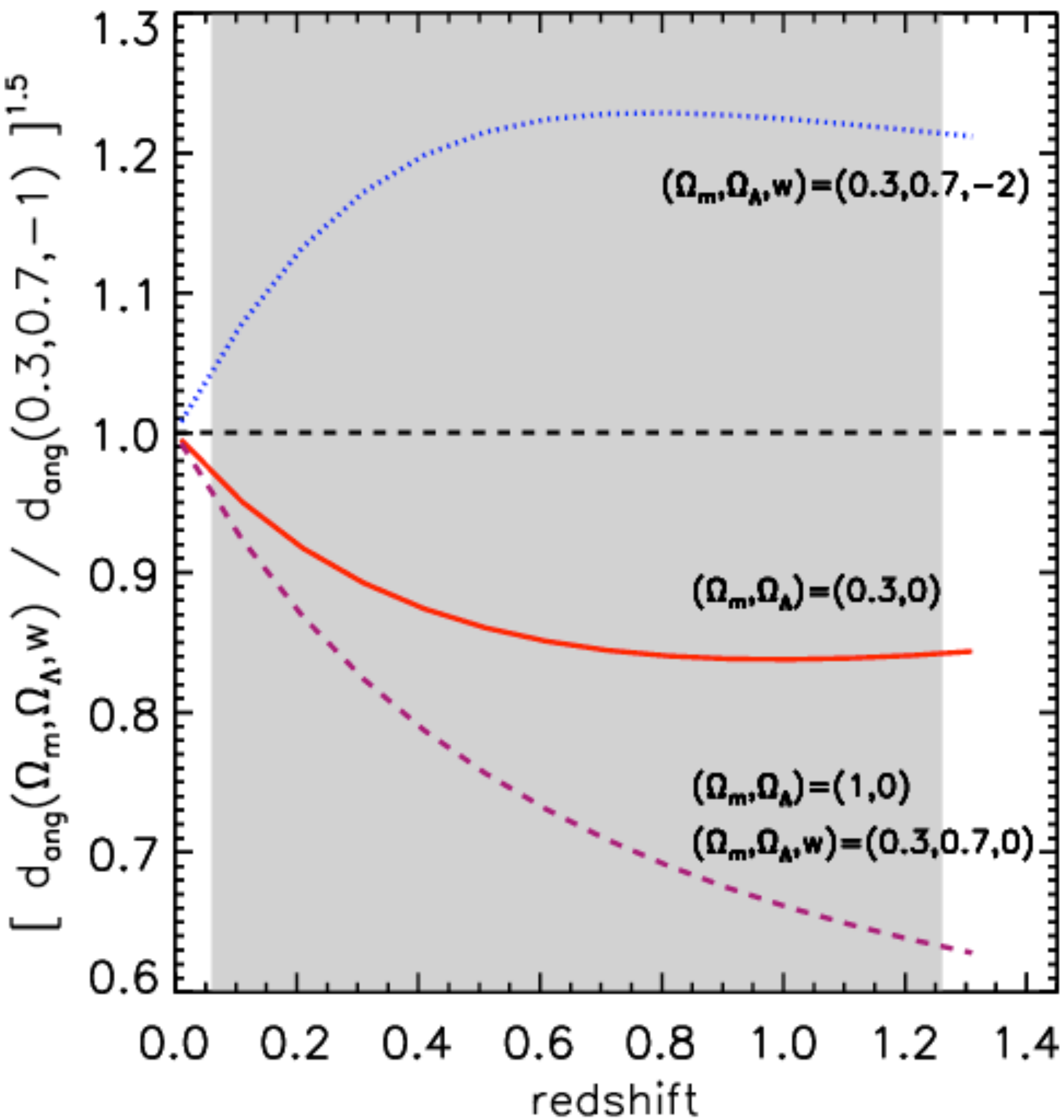
$$f_{bar,\,i} = f_{cold,\,i} + f_{gas,\,i}$$

$$f_{cold} = (0.18 - 0.012\, T_{gas})\, f_{gas} = 0.1\text{-}0.2\, f_{gas}$$

(Lagana et al. 08; Lin et al. 03; White et al. 93)

$$f_{gas}(<r_{500}) = M_{gas} / M_{tot} \propto d_{ang}(\Omega_m, \Omega_\Lambda, w)^{3/2}$$

The cosmological dependence



Gas mass fraction: the method

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$\Omega_b h^2 = 0.0189 \pm 0.0010$ (PN, Burles et al. 01),

$\Omega_b h^2 = 0.0227 \pm 0.0006$ (CMB, Komatsu et al. 08),

$H_0 = 72 \pm 8$ km/s/Mpc (Freedman et al. 2001),

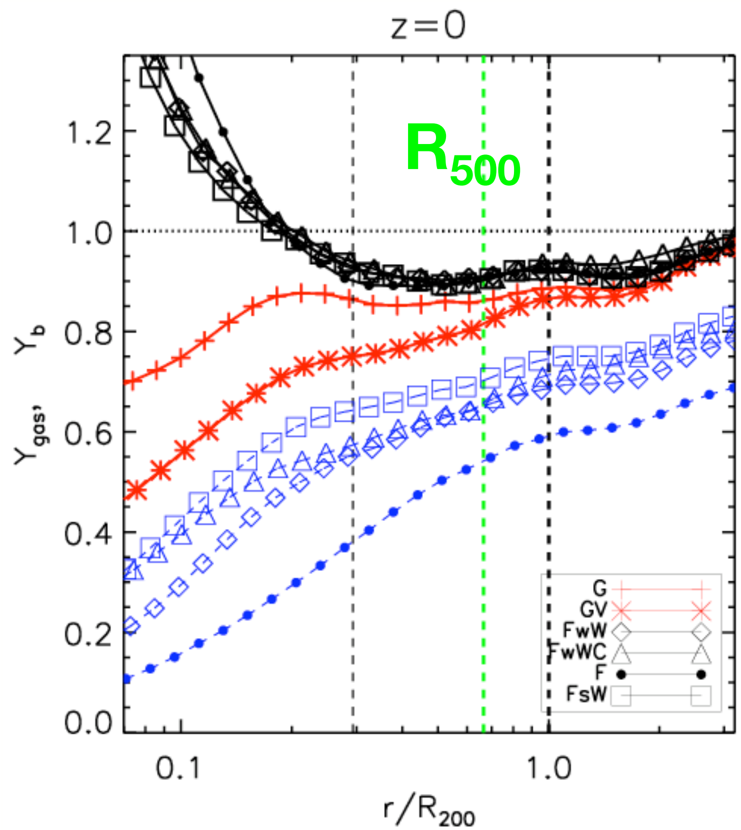
$H_0 = 62 \pm 6$ km/s/Mpc (Sandage et al. 2006),

$H_0 = 70 \pm 1$ km/s/Mpc (Komatsu et al. 2008).

Gas mass fraction: the method

$$\chi^2 = \sum_{i=1}^{N_{dat}} \frac{(\hat{\Omega}_i - \Omega_m)^2}{\varepsilon^2_{\Omega_i}}$$

$$\hat{\Omega}_i = b_i \Omega_b \,/\, f_{bar,i}$$



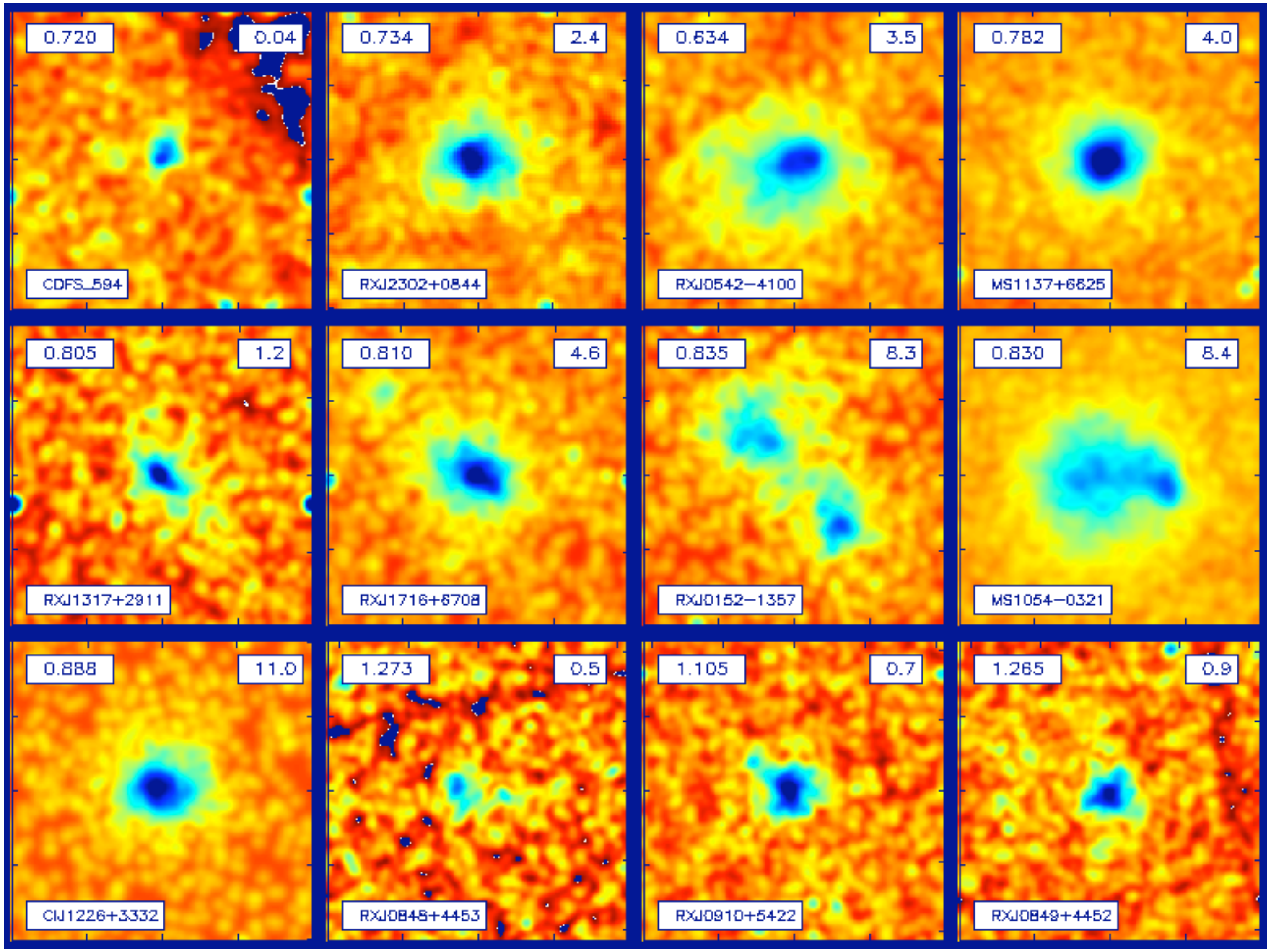
b_{500} = 0.920 (±0.023)

= 0.903 (±0.004) +0.048 (±0.010) z

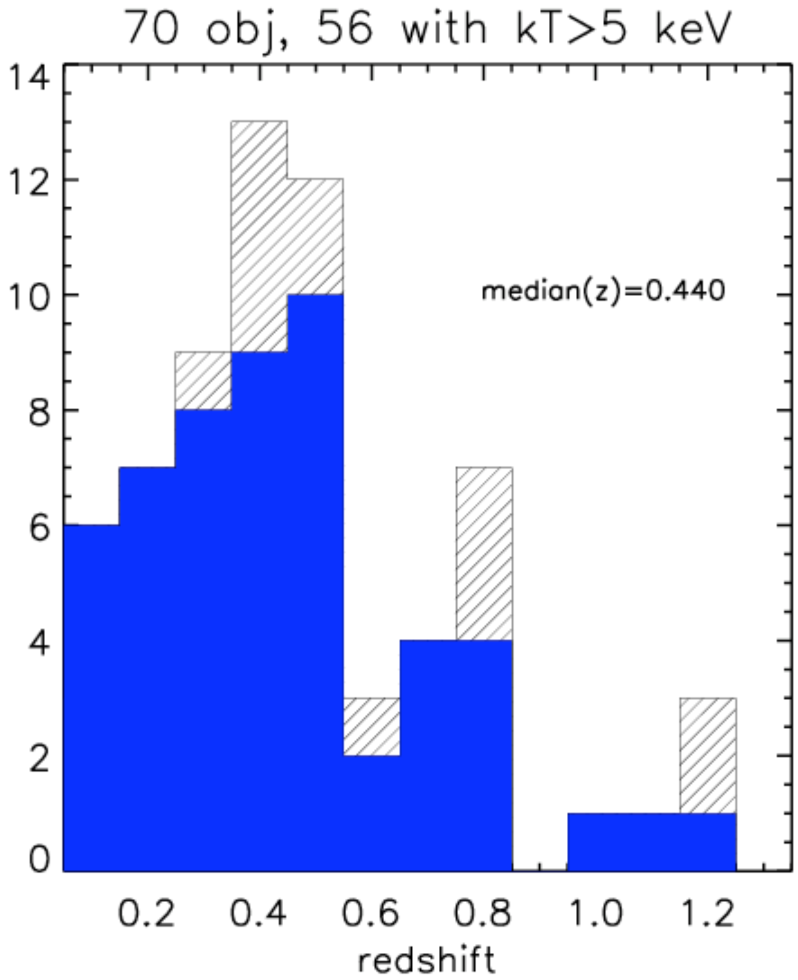
(Ettori et al. 06)

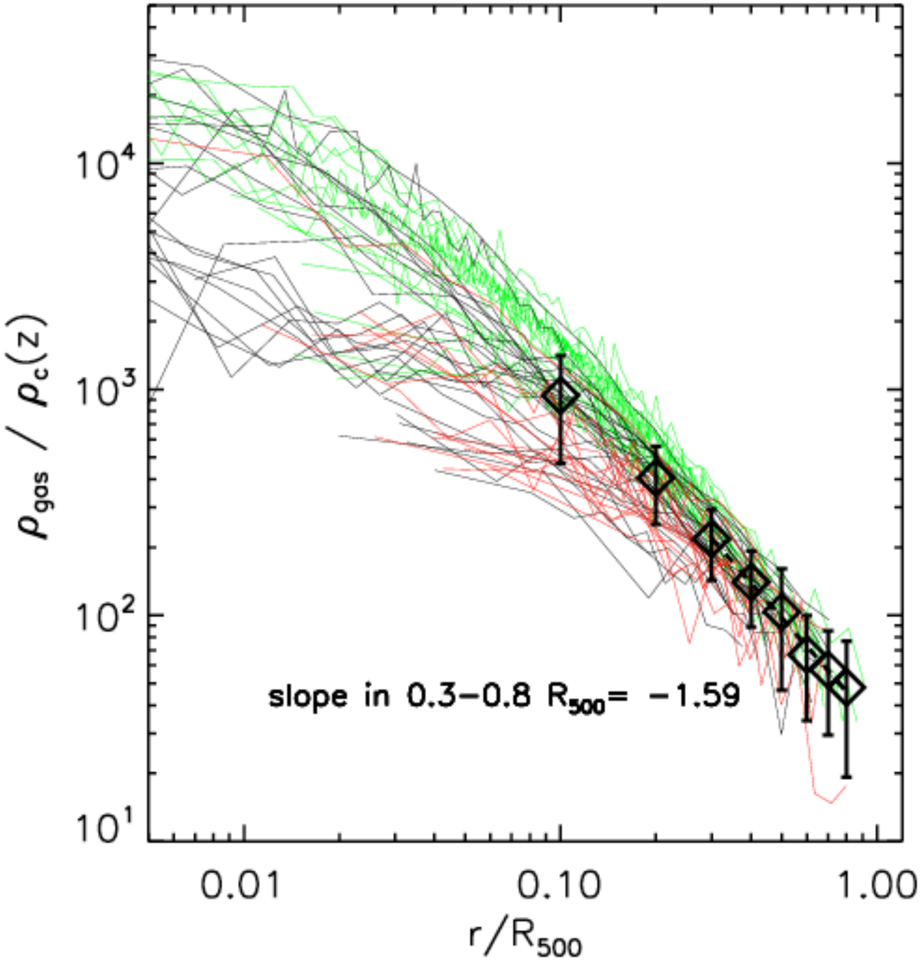
Chandra data for 70 clusters @ 0.06<z<1.27

(Rosati et al 02, Ettori et al 03, 04, Tozzi et al 03, Balestra et al 06, Morandi et al 07)

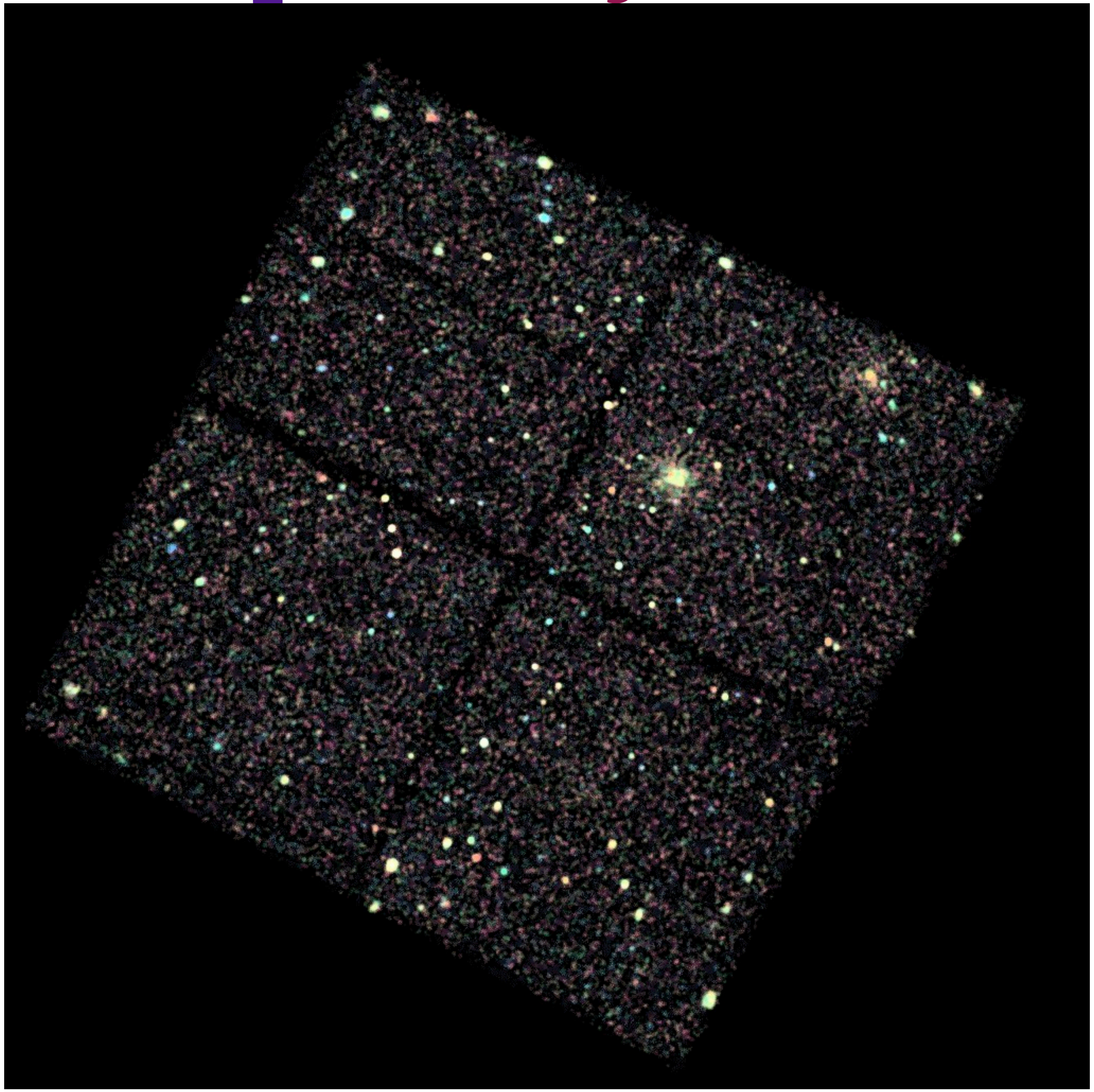


The sample: 56/70 hot clusters





An example: RXJ1252, z=1.235



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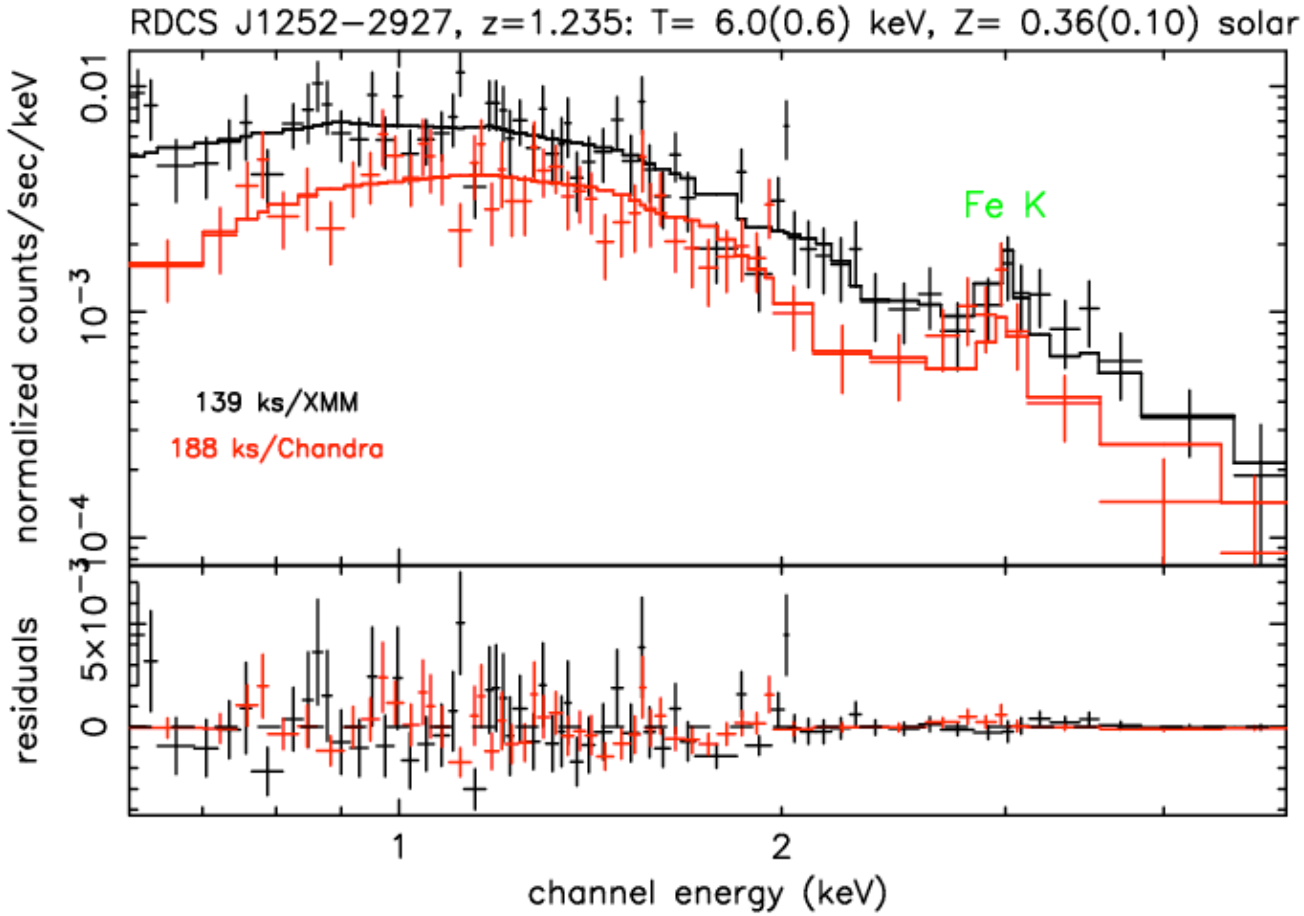
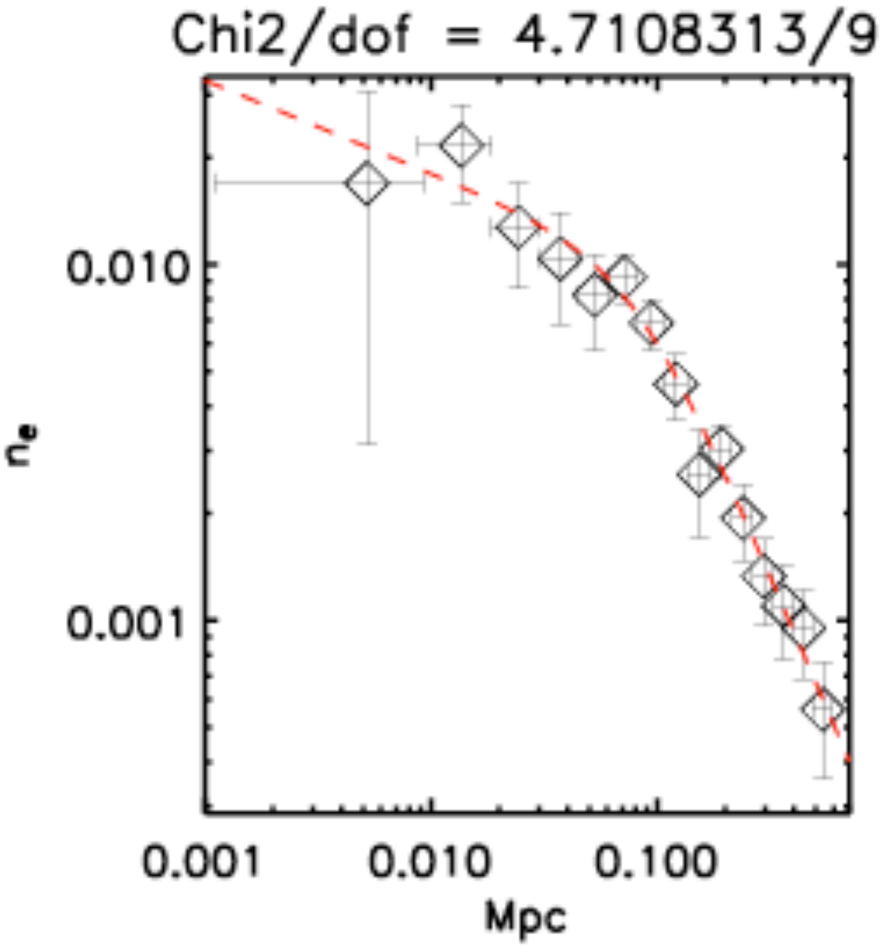


We fit a single absorbed MEKAL to measure T_e

An example: RXJ1252, z=1.237



The **deprojected Sb** provides $\mathbf{n_e}$ that is then fitted with a functional form

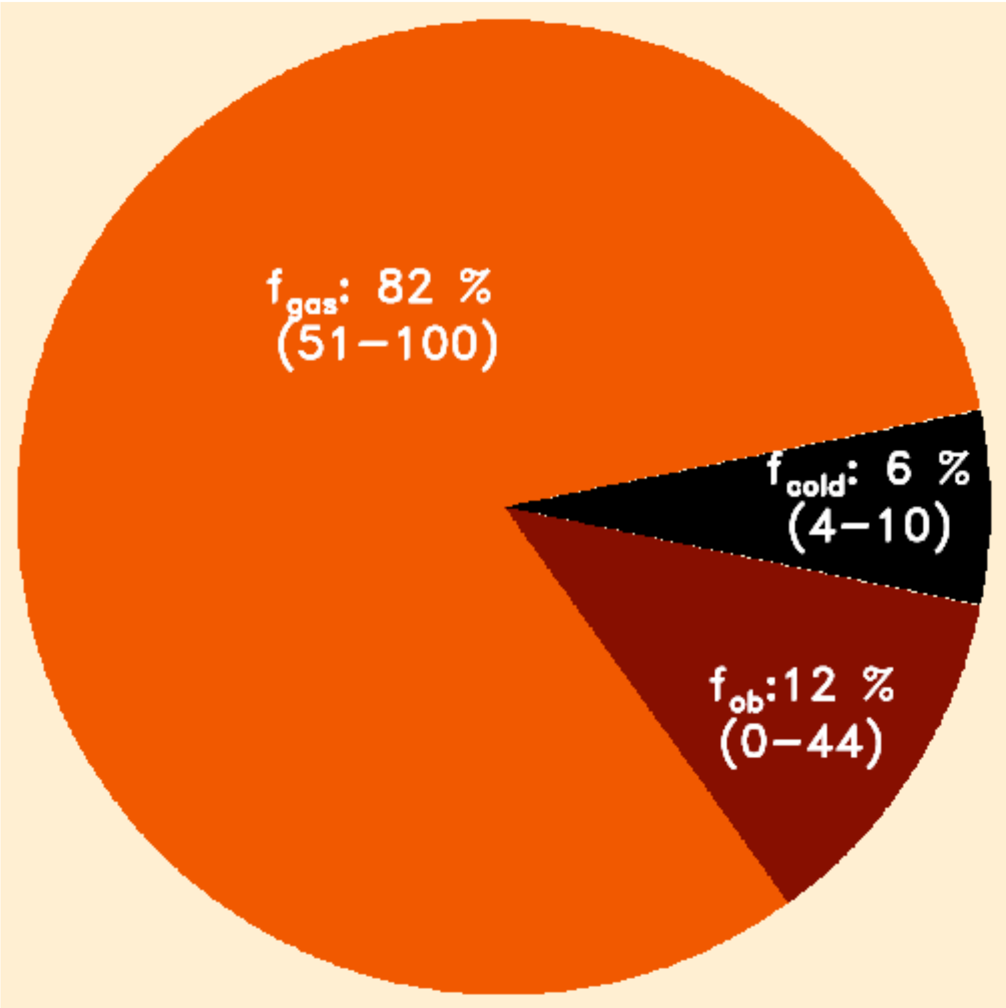
$$M_{tot}(<\mathbf{r}) = -\frac{kT_{gas}\, r}{\mu m_u G}\frac{d\log \mathbf{n_e}(\mathbf{r})}{d\log r}$$

$$R_{500} = \left(\frac{3M_{tot}(<\mathbf{r})}{4\pi 500 \rho_{c,z}}\right)^{1/3}$$

$$M_{gas}(<\mathbf{r}) = \int_0^{R_{500}} 1.155\, m_u\, \mathbf{n_e}(\mathbf{r})\, 4\pi r^2 dr$$

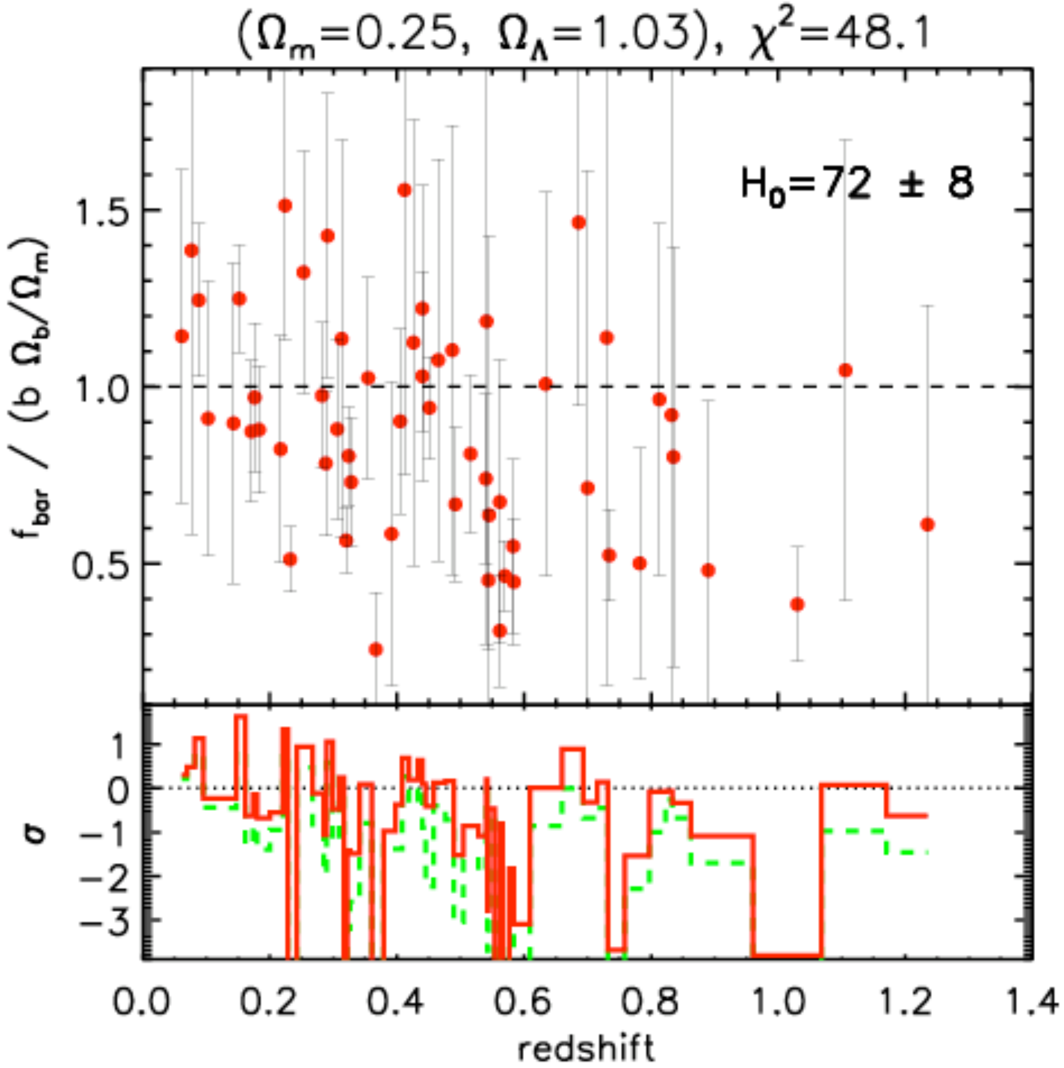
Cluster baryonic pie

(with respect to WMAP-5 yrs; Komatsu et al 08)



$\Omega_b / \Omega_m =$
0.165 ± 0.009

Constraints on Ω_m- Ω_Λ



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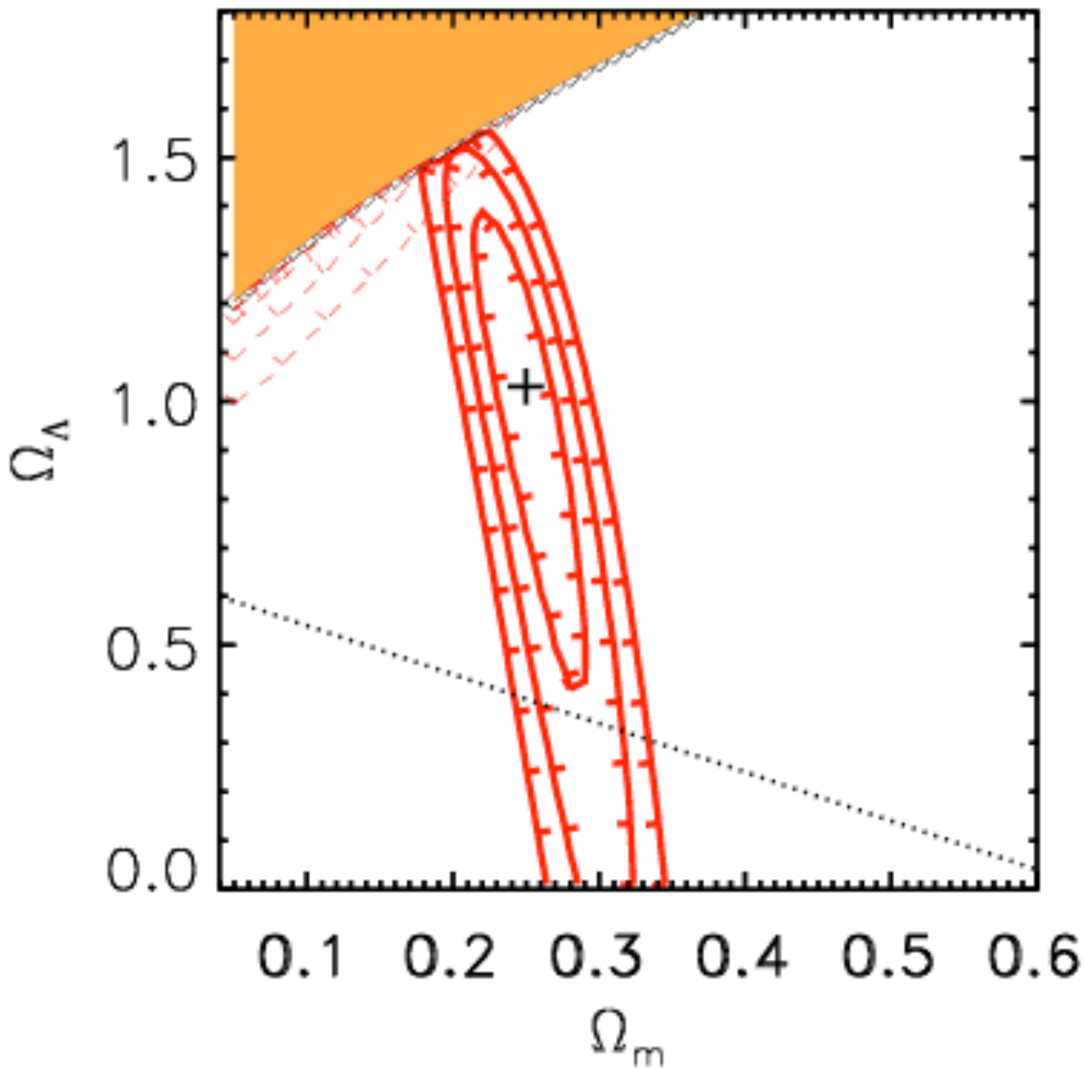
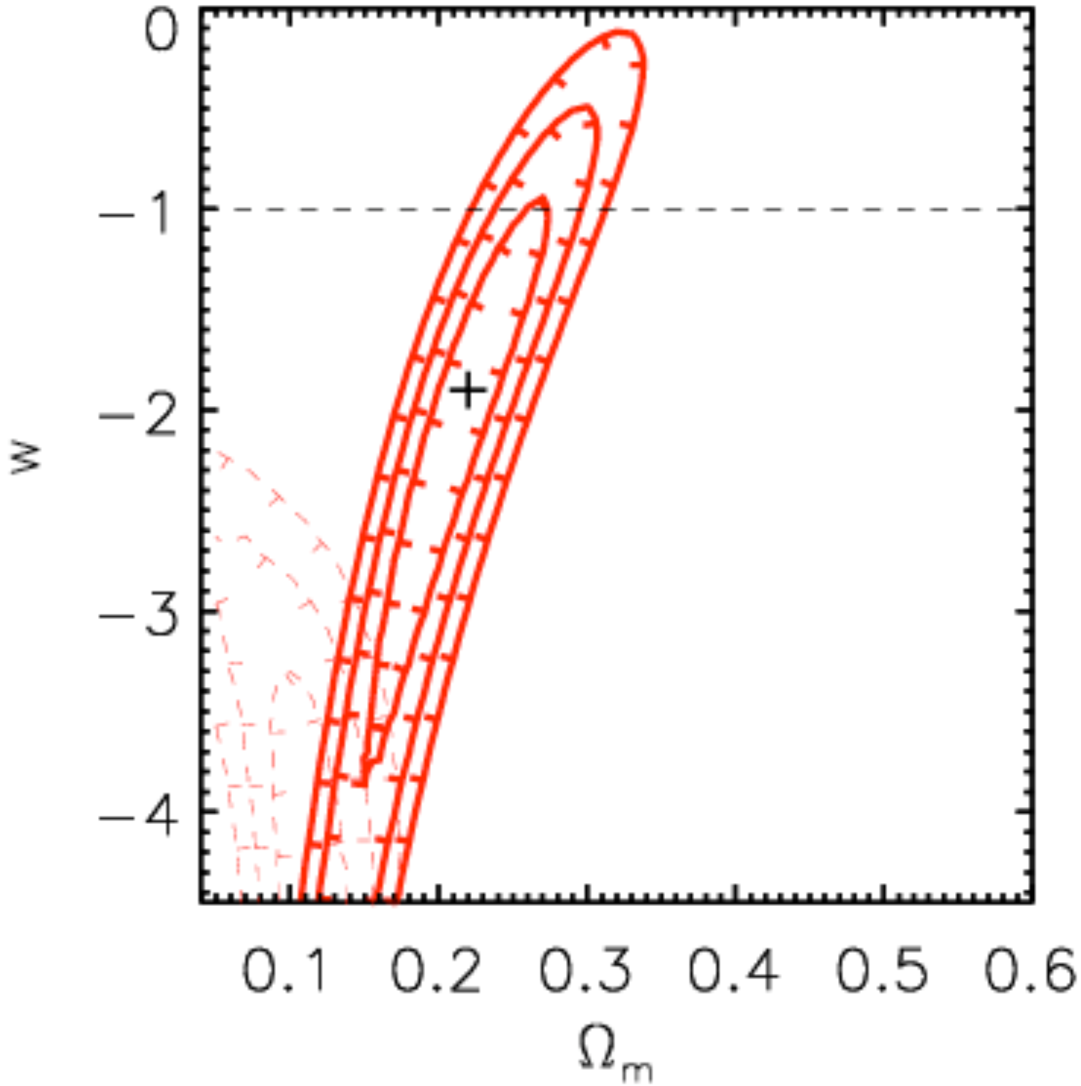


$\Omega_m = 0.25$
(-0.02, +0.03)

$\Omega_\Lambda = 1.03$
(-0.40, +0.24)

(at 1σ on 1 param)

Constraints on Ω_m- w

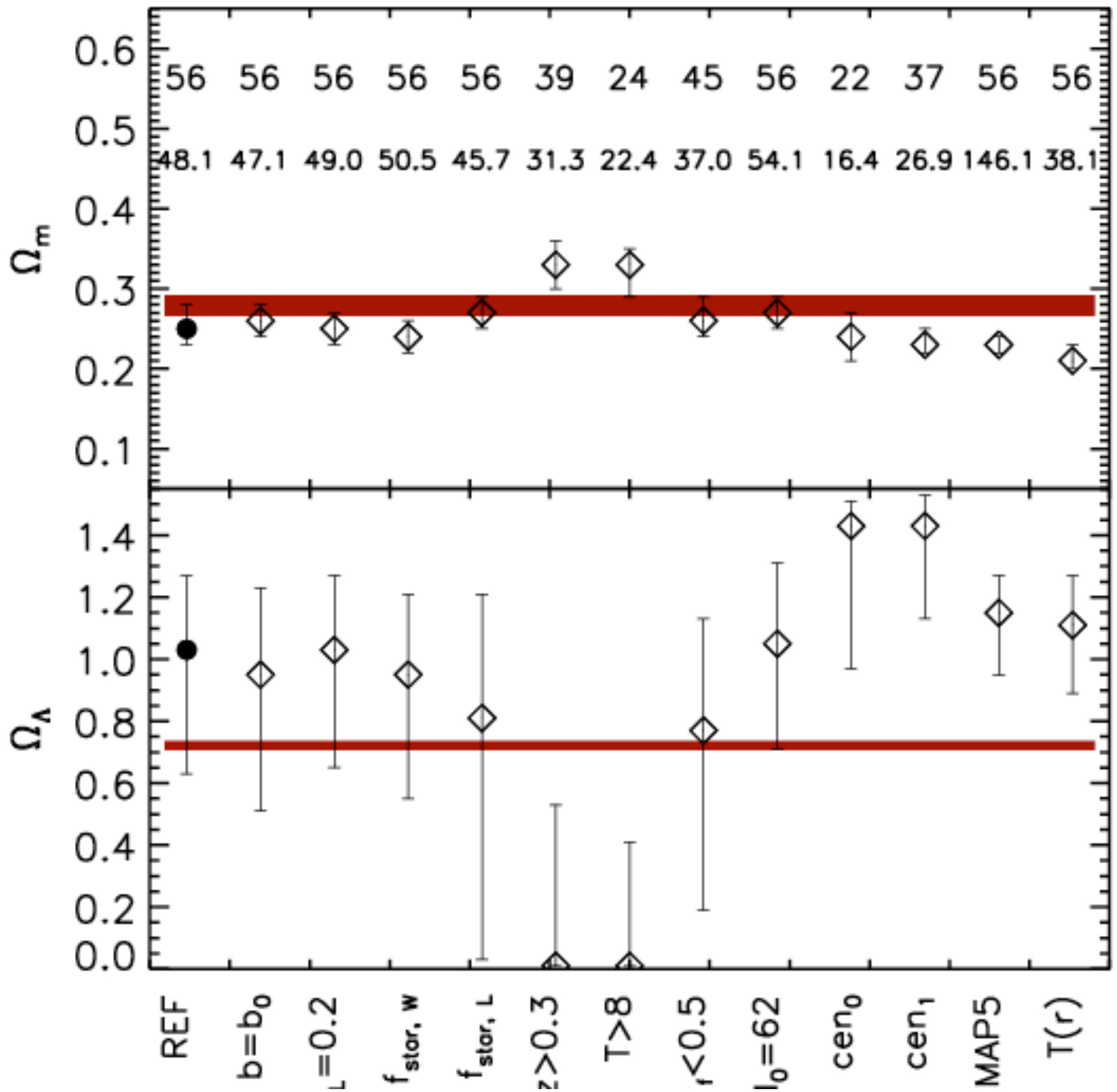


Ω_m= 0.21
(-0.04, +0.04)

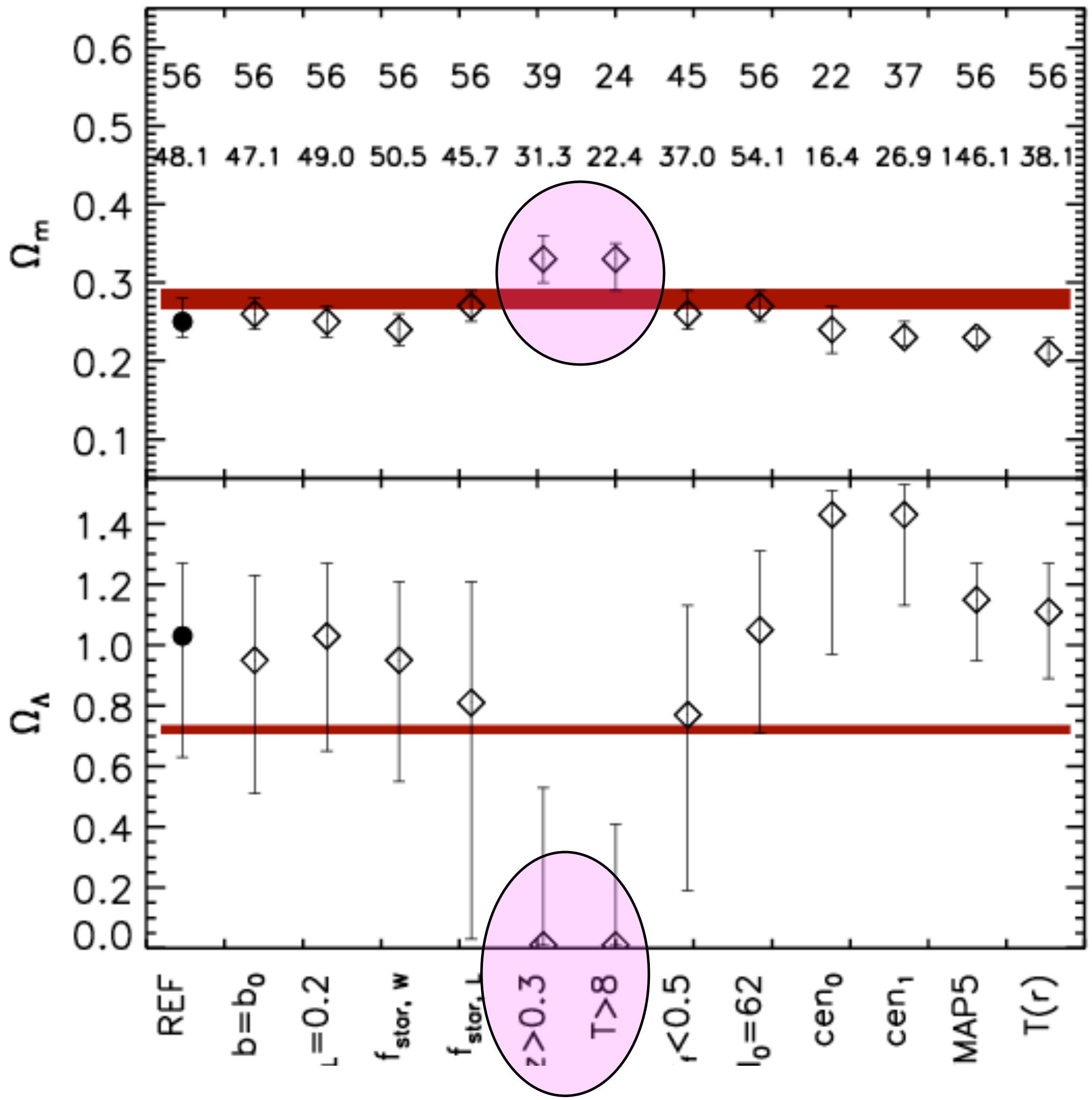
w = -1.8
(-1.0, +0.6)

(at 1σ on 1 param)

Systematics on Ω_m - Ω_Λ (1 σ c.l.)



Systematics on Ω_m - Ω_Λ (1 σ c.l.)



The X-ray Universe, Granada, May 29, 2008: **the cluster gas mass fraction**

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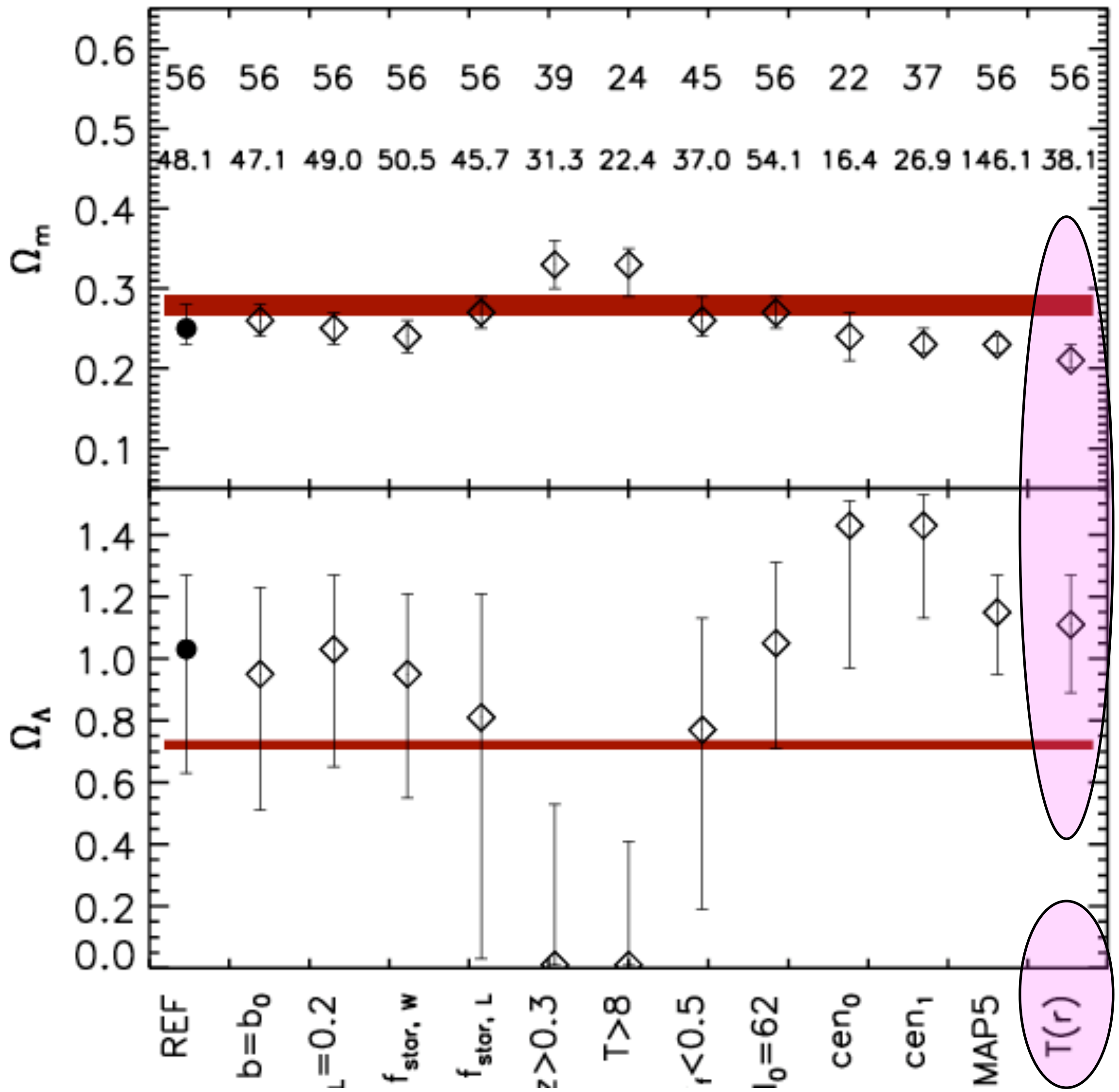

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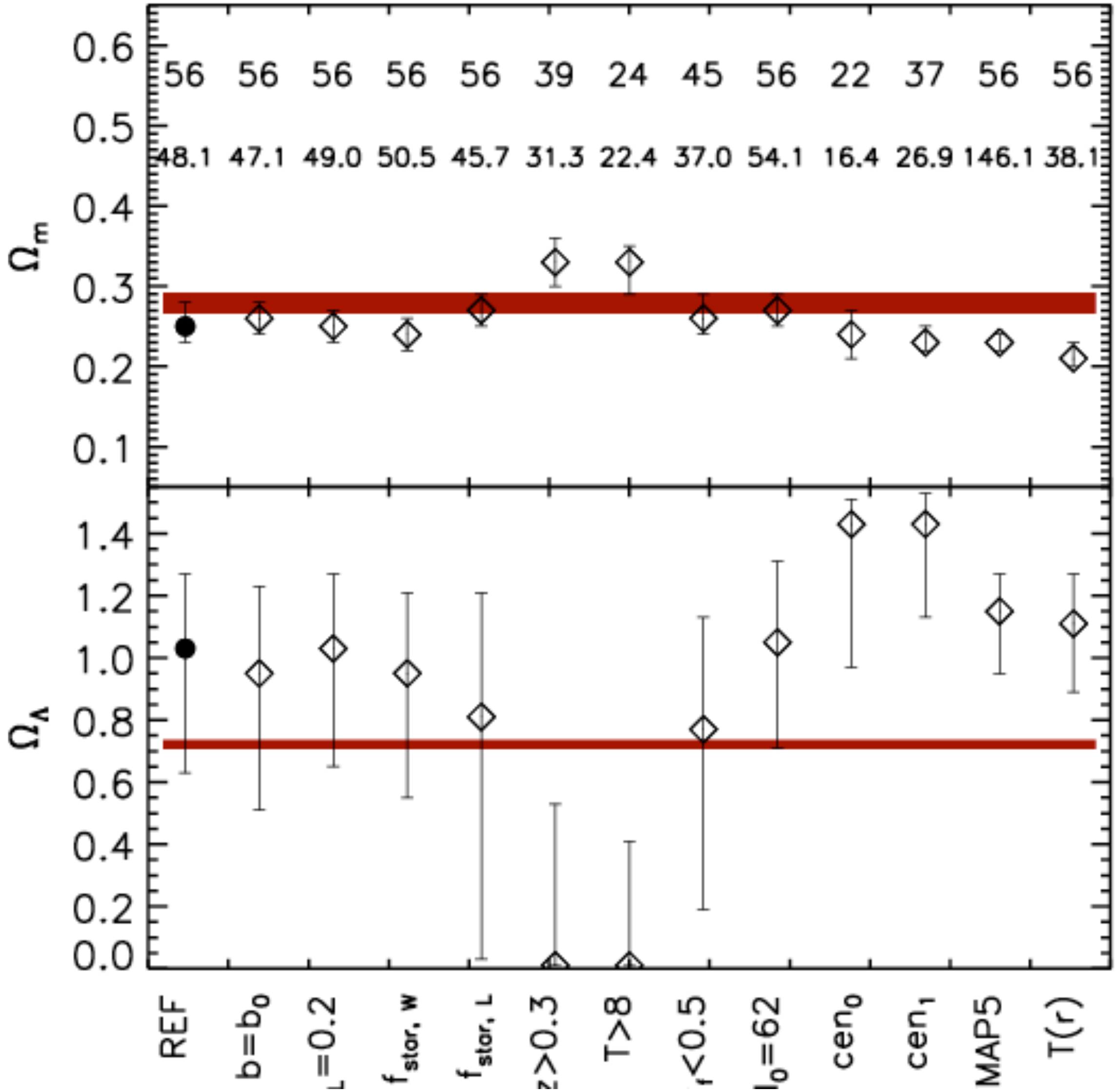

$\Omega_m = 0.25$

(-0.02, +0.03)

(-0.02, +0.03)

$\Omega_\Lambda = 1.03$

(-0.40, +0.24)

(-0.45, +0.18)

Conclusions

• f_{gas} method is good for Ω_m, but…
pay attention to systematics

• cluster baryon budget is consistent with WMAP-5 yrs results
(clumpiness/Non-thermal contribution <20%)