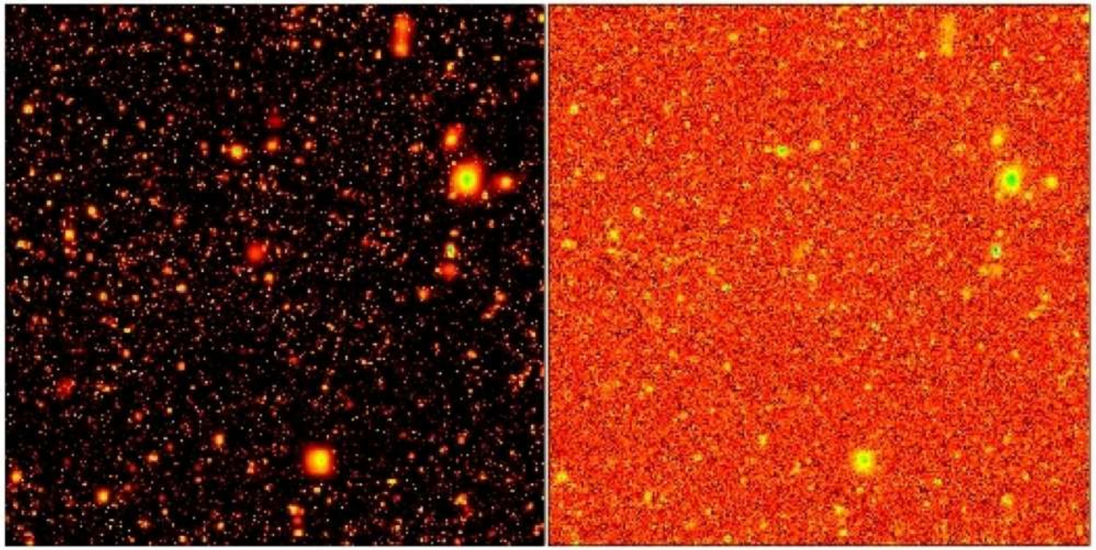
Heidelberg University

Zentrum für Astronomie

Searching for galaxy clusters through weak lensing, X-rays and SZ observations



Matteo Maturi

Overview

- **Galaxy clusters mass function $\Rightarrow$ DE constraints**
- **We search for Galaxy clusters**
- **One method for Four different observables**
- **Numerical simulation and detection analysis**

Galaxy Clusters

Dark-matter halo $+$ gas $+$ stars & galaxies

Mass $M_v \sim 10^{14} - 10^{15}\, M_\odot$

Virial radius $r_v \sim 1 - 3\, Mpc$

ICM Temperature $T \sim 10^7 - 10^8\, K$

X–ray luminosity $L_x \simeq 10^{45}\, erg/s$

tSZ effect (CMB) $\Delta T_{tSZ} \sim 100\, \mu k$

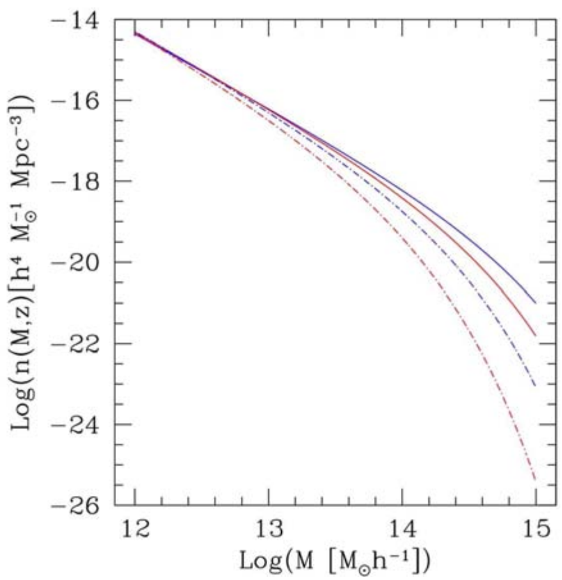
kSZ effect (CMB) $\Delta T_{kSZ} \sim 10 - 30\, \mu k$

Gravitational Lensing $r_E \approx 1'$ + Weak Lensing

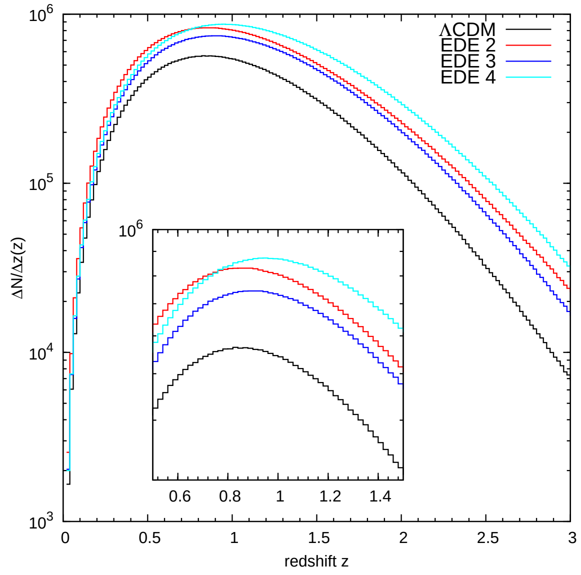
Canada-France-Hawaii Telescope:

Abell 1185

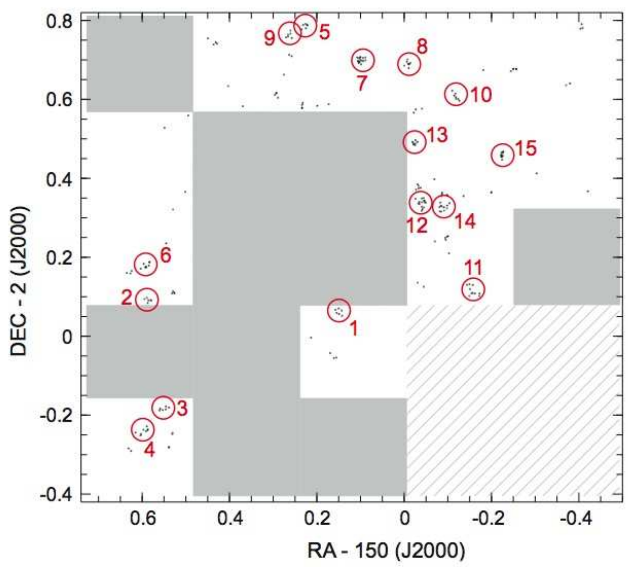
Why galaxy clusters to study cosmology?



Mass function



Redshift distribution

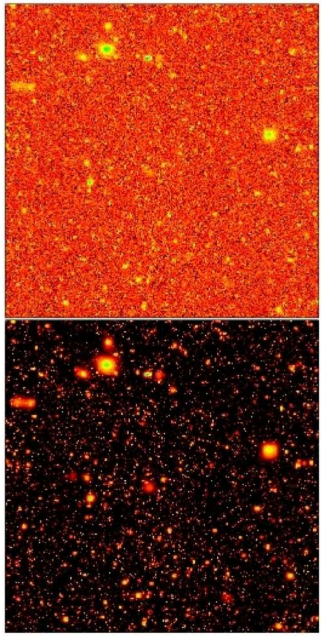


Zatloukal et al. (2007)

- Clusters formation history **depends on cosmology**
- For e.g.. in **early dark energy models** they **form much earlier** than in a Λ-CDM cosmology

How do we search for clusters?

X-rays



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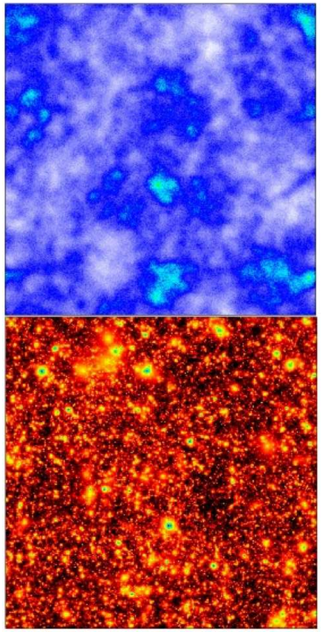
ICM baryons

SZ



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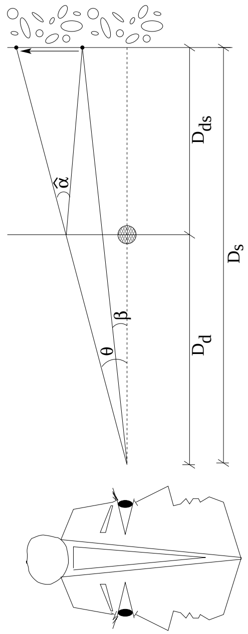
ICM baryons

Weak lensing



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Dark matter

Galaxy 'counting'

Galaxies over-densities

Color distribution

Galaxies morphology

STILL TO COME...

⇓

'Collapsed' baryons

One method for 4 observables

Data $$D_\nu(\boldsymbol{\theta}) = A\tau_\nu(\boldsymbol{\theta}) + N_\nu(\boldsymbol{\theta})$$

Estimate $$A_{\rm est}(\boldsymbol{\theta}) = \sum_\nu \int D_\nu(\boldsymbol{\theta}')\Psi_\nu(\boldsymbol{\theta} - \boldsymbol{\theta}')\, d^2\theta'$$

$$\downarrow$$

$$b \equiv \langle A_{\rm est} - A \rangle$$

Bias to vanish

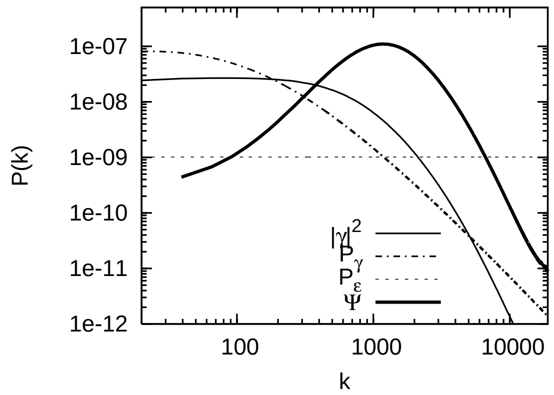
$$\sigma^2 \equiv \left\langle (A_{\rm est} - A)^2 \right\rangle$$

Variance to be minimal

$$\Downarrow$$

Optimal matched filter

$$\hat{\Psi}(\boldsymbol{k}) \propto \boldsymbol{C}^{-1}(k)\boldsymbol{F}(\boldsymbol{k})$$



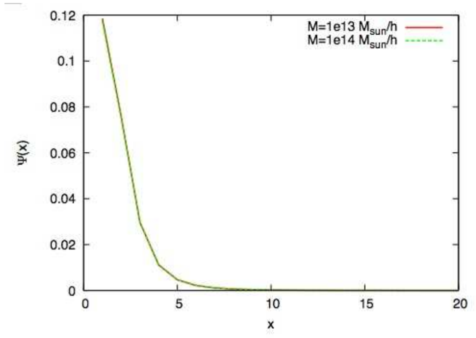
The filter 'face'

X-rays filter:

Photon shot noise (white & uncorrelated)

Instrumental noise (white & uncorrelated)

$\hat{\Psi}(k) \propto \tau(x)$

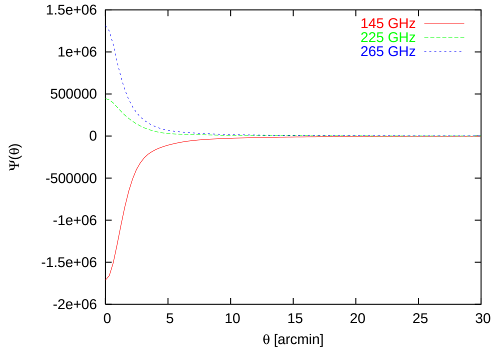


SZ filter:

Noise from CMB (C_l & correlated in all bands)

Instrumental noise (white & uncorrelated)

$\hat{\Psi}(\boldsymbol{k}) \propto \boldsymbol{C}^{-1}(k)\boldsymbol{F}(\boldsymbol{k})$

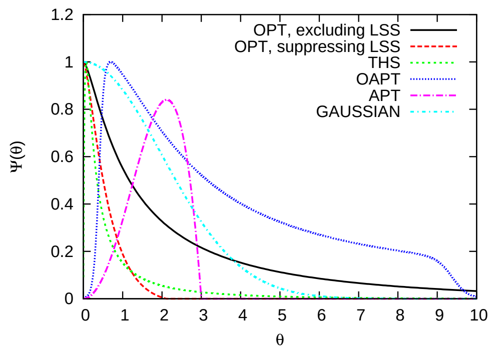


WL filter:

Noise from LSS (P_l)

Intrinsic shape + shot noise of galaxies (white)

$\hat{\Psi}(\boldsymbol{k}) \propto \frac{\hat{\tau}(\boldsymbol{k})}{P_N(k)}$



Testing with Hydro numerical simulations

Cosmology

$\Omega_m = 0.3, \;\; \Omega_\Lambda = 0.7$

$H = 70km/s/Mpc$

$\sigma_8 = 0.8$

Numerics

$L_{box} = 192Mpc/h \quad N = 480^3$

$m_{dm} = 4.6\ 10^9 M_\odot/h$

$m_{gas} = 4.6\ 10^9 M_\odot/h$

Baryon physics

- A hybrid multi-phase model for star formation in the interstellar medium
- Radiative cooling within an optically thin gas consisting of 76% of H and 24% of He by mass
- Supernova feedback to model galactic outflows
- Heating by a time-dependent re-ionization at $z \approx 6$
- Metal lines emission: MeKaL model

Observations

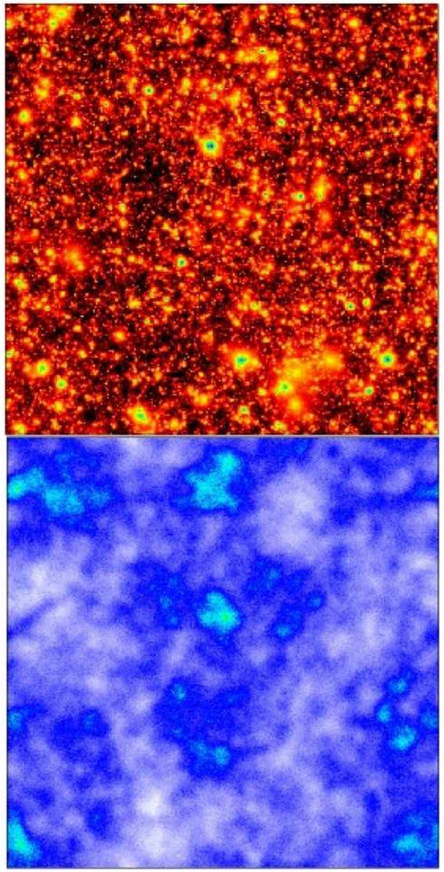
X-rays: XMM & Chandra for 10 ks & 100 ks

SZ: ACT 145 GHz (1'.7, 2 μK), 225 GHz (1'.1, 3.3 μK), 265 GHz (0'.93, 5.7 μK)

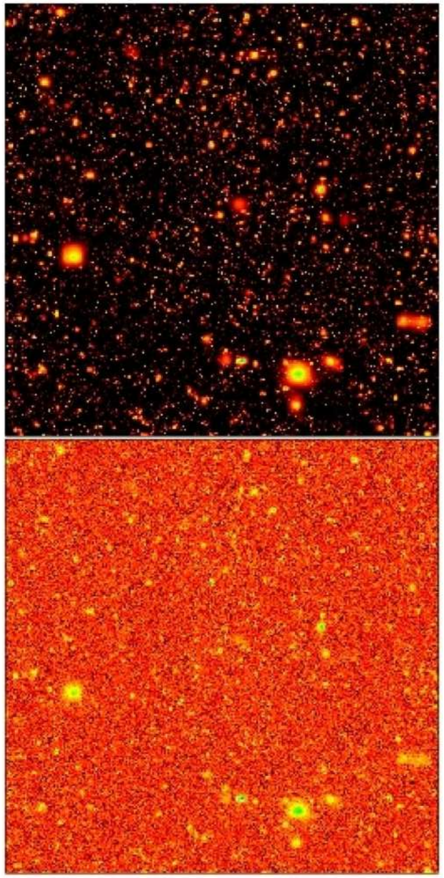
Weak lensing: 30 gal/$arcmin^2$, $\sigma_\gamma = 0.35$, $z_s = 1$ & $z_s = 2$

Simulations ’face’

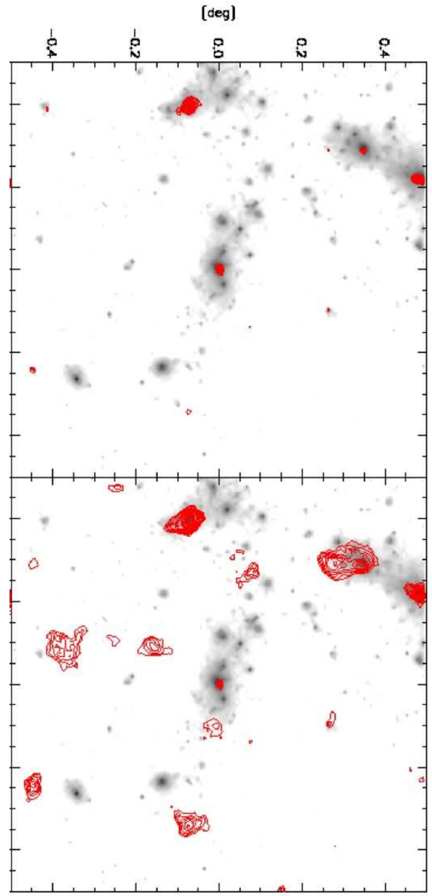
X-rays



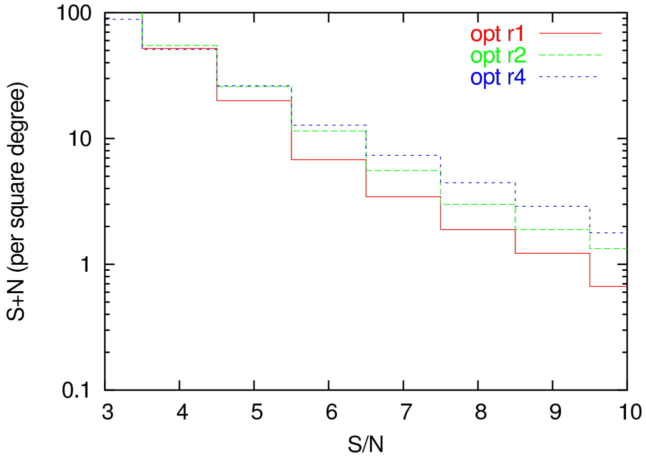
SZ



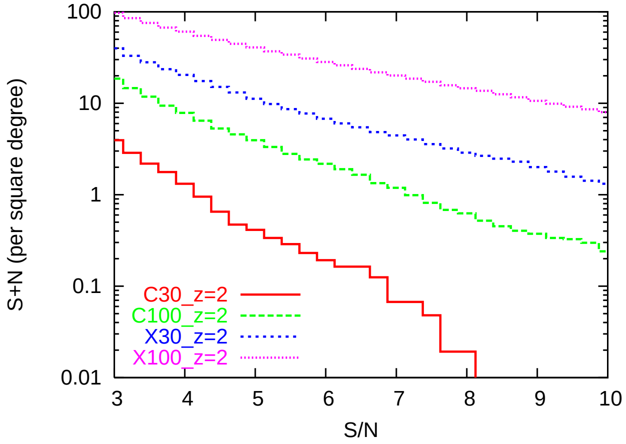
Weak lensing



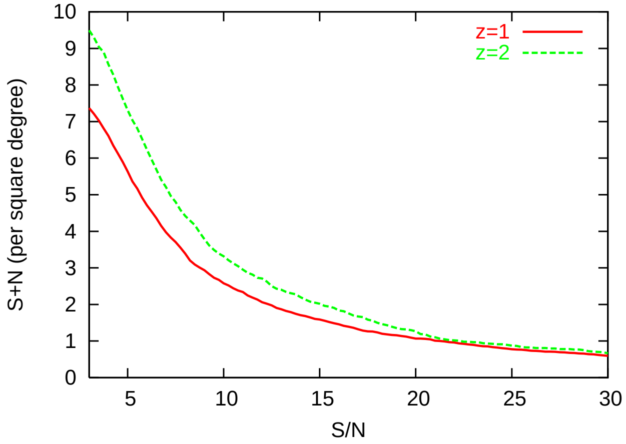
Benchmark: Detections number



Lensing



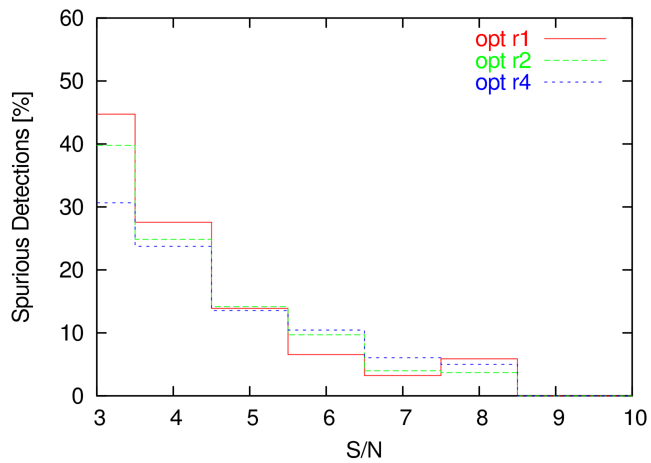
X-rays



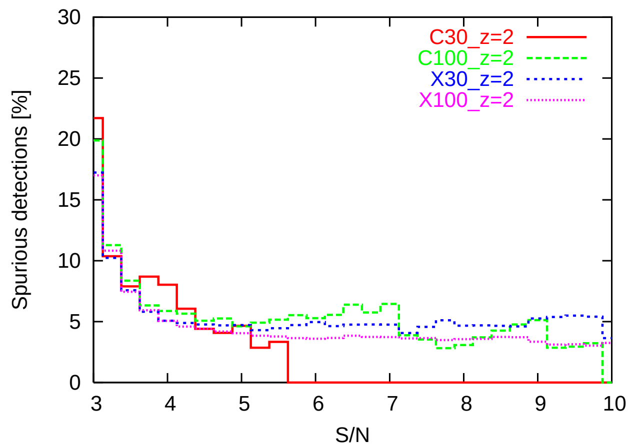
SZ effect

- Weak lensing and X-rays find a comparable number of detections
- SZ detections are less

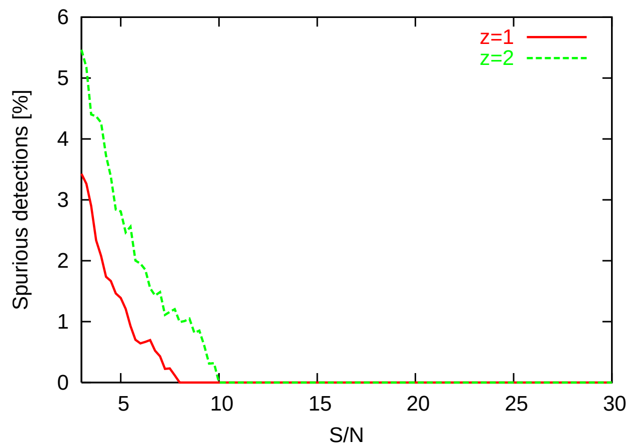
Benchmark: Contamination %



Lensing



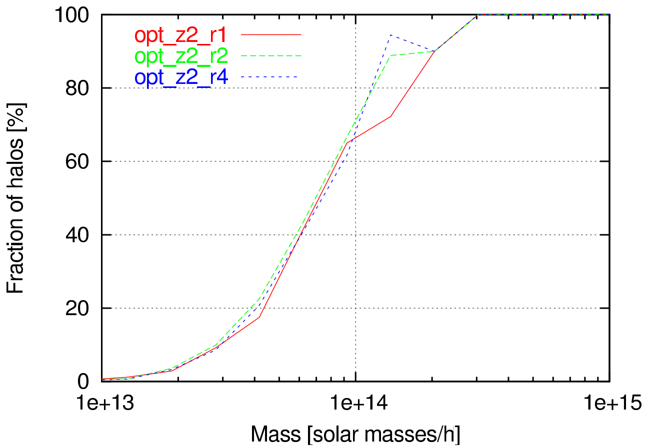
X-rays



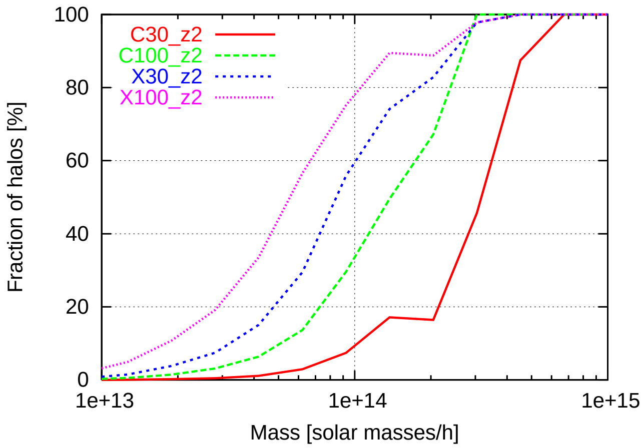
SZ effect

- The WL contamination is larger but comparable to the X-rays one
- The SZ sample has a low contamination

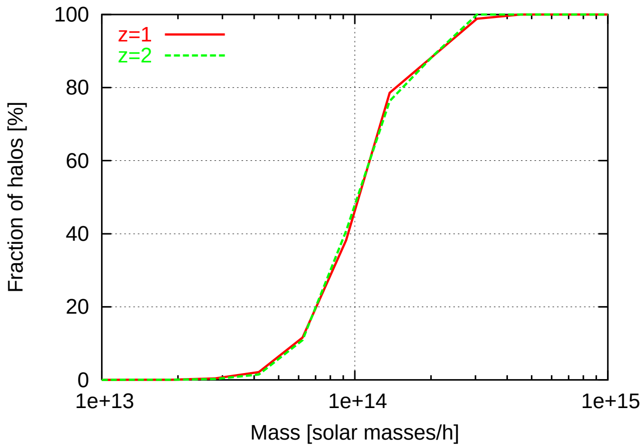
Benchmark: Completeness



Lensing



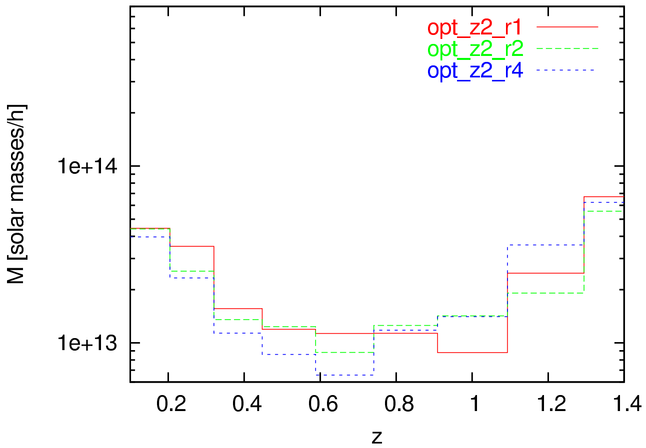
X-rays



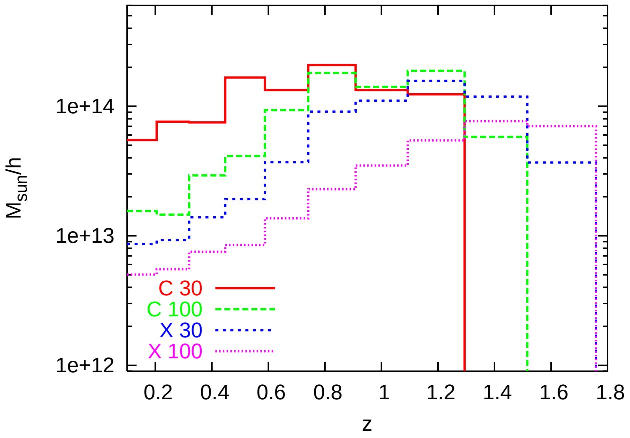
SZ effect

- All three techniques are comparable

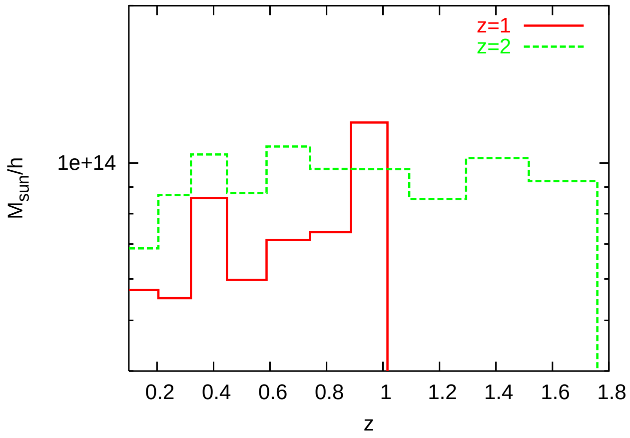
Benchmark: Sensitivity



Lensing



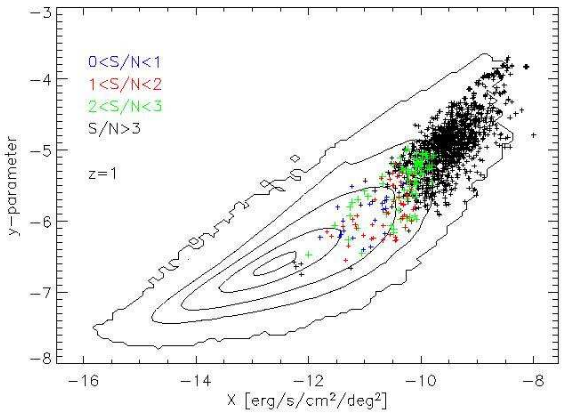
X-rays



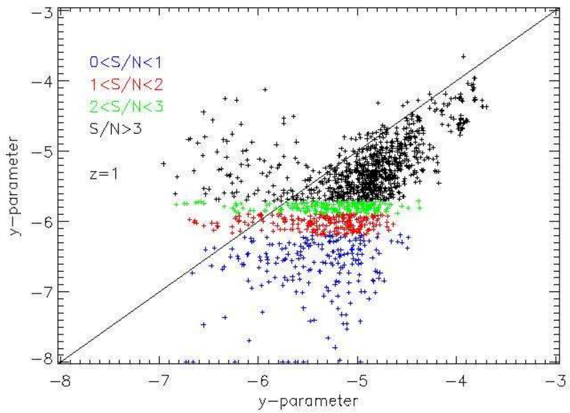
SZ effect

- Smaller masses can be probed with WL

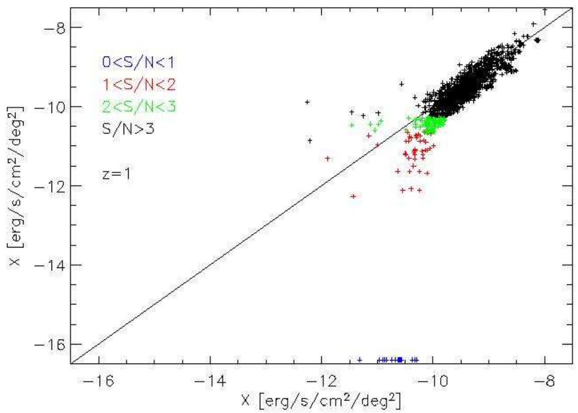
Estimates vs. Simulations



X_rays-Y correlation



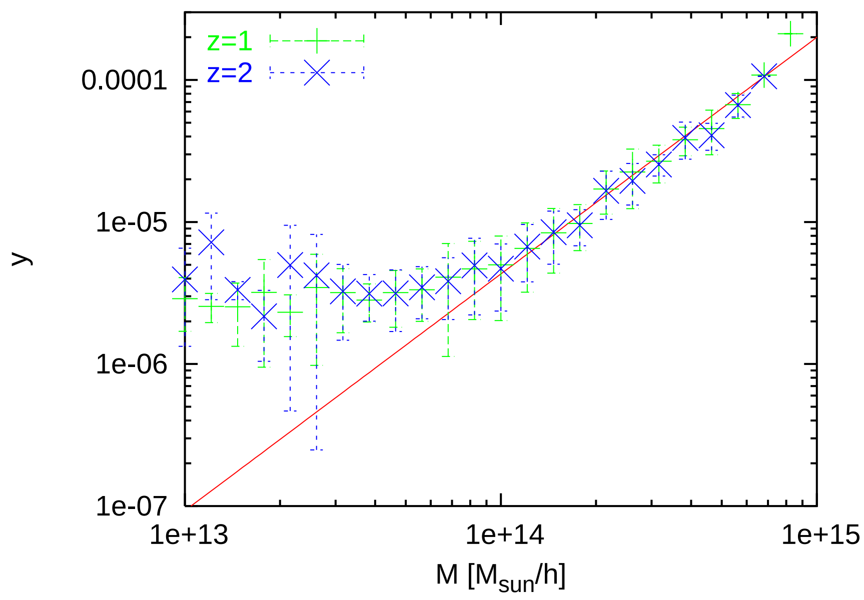
Y parameter



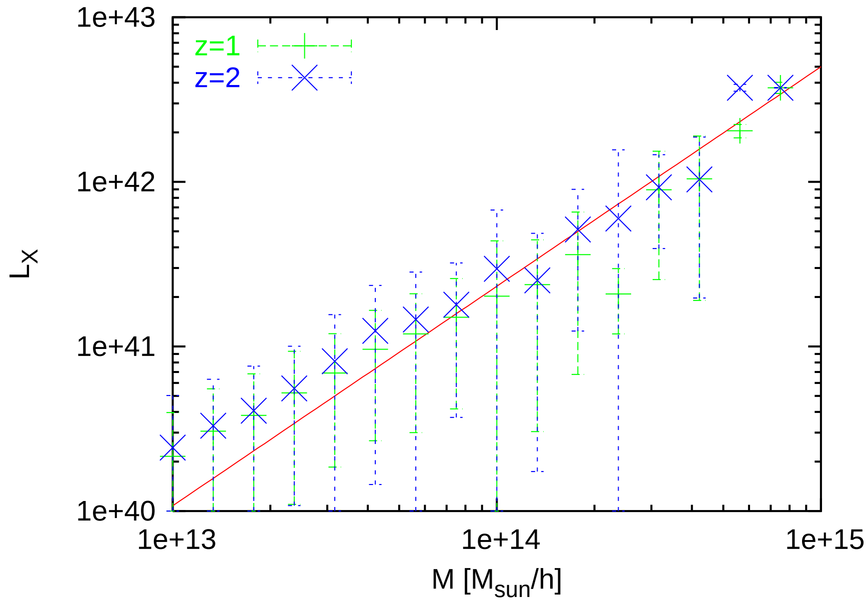
X-rays

- X-rays and SZ are well correlated
- F_x & Y are properly measured

Observables vs. Haloe masses



Central y parameter



Central X-rays luminosity

- Very god fit with the scaling lows
- $Y \propto M^{5/3}$ & $L_X \propto M^{4/3}$

Conclusions

- Galaxy cluster can be used as a **probe for dark energy**
- We aim at detecting galaxy clusters using **all available observables together** (linear filter)
  - ➠ Weak lensing
  - ➠ X-rays
  - ➠ SZ
  - ➠ Galaxy counting (still to come)
- This is optimal to search for clusters as they are expected to be, but unexpected is welcome (X-ray silent clusters?)
- Next step 1: include **galaxy surveys** (with photometric redshifts)
- Next step 2: **combine all observable** in a multi-band filter

Thank you for your attention!

References

- An optimal filter for the detection of Galaxy clusters through weak lensing

  Maturi, Meneghetti, Bartelmann, Dolag & Moscardini, 2005, A&A, 442, 851

- Searching dark-matter haloes in the GABODS survey

  Maturi, Schirmer, Bartelmann, Meneghetti & Moscardini, 2007, A&A, 462, 473)

- Testing the reliability of weak lensing cluster detections

  Pace, Maturi, Meneghetti, Bartelmann, Moscardini & Dolag, 2007, A&A, 471, 731

- Statistical properties of SZ and X-ray cluster multi-band filter detections

  Pace, Maturi, Bartelmann, Cappelluti, Meneghetti, Moscardini, 2007, in prep.