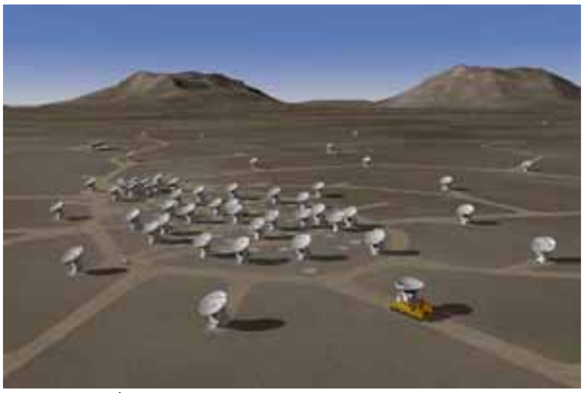
Star an Galaxy Formation - Open Questions:

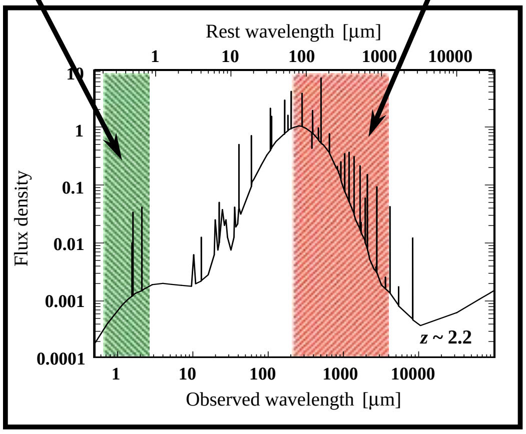
- Mapping the Cosmic Web over time
  - Tracing the evolution of bias of starbursts, spheroids, disks, AGN across the dark matter density field.
- Effect of environment on the physics of galaxy evolution
  - LSS is well modeled by CDM; need to sample the full range of environments to understand the relationship of structure to star formation, black hole formation, AGN-ignition, etc.
- Dominant evolutionary modes?
  - Bulges vs disks
  - Starbursts vs Quiescent
  - Star-formation (nucleosynthesis) vs AGN (accretion) activity
- Mass buildup at high-redshift

  How do we relate high-SFR (submm) sources to formation of massive objects, which are a challenge for CDM models;

  Need large volumes for rare high-mass halos. ($10^{15.5}$ M_o halos)



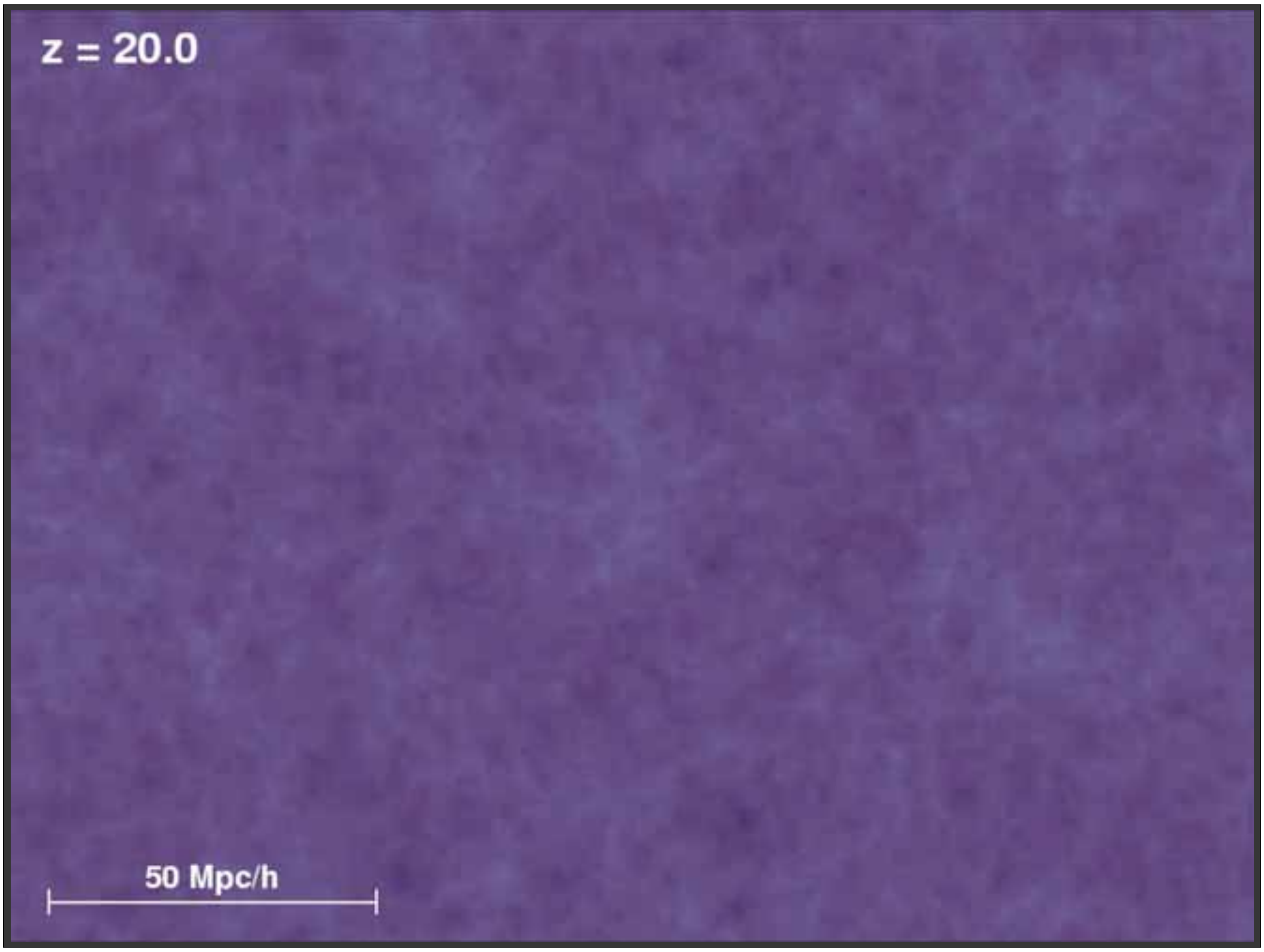
ELTs:
Stars, Black Holes,
Warm ISM

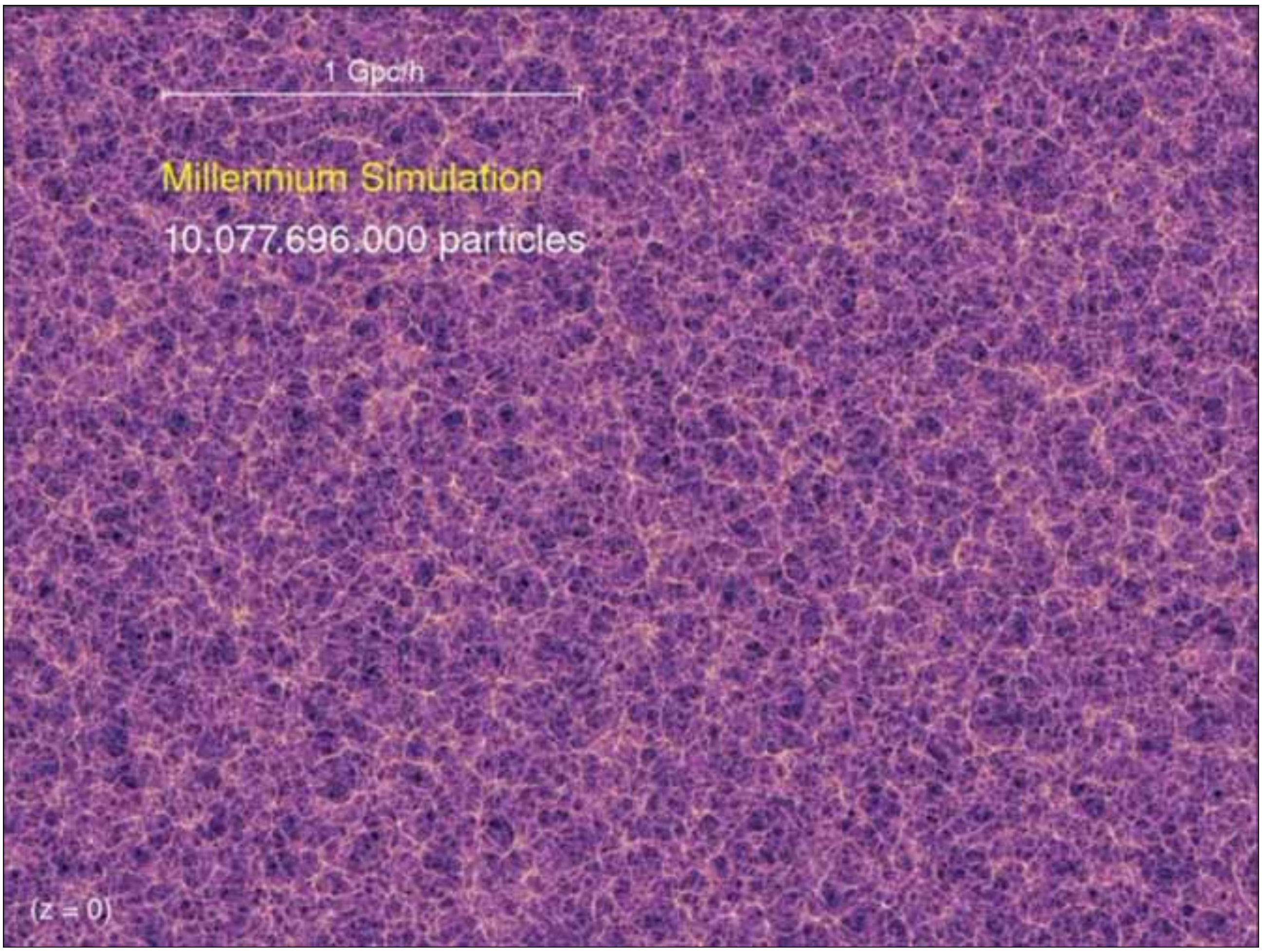


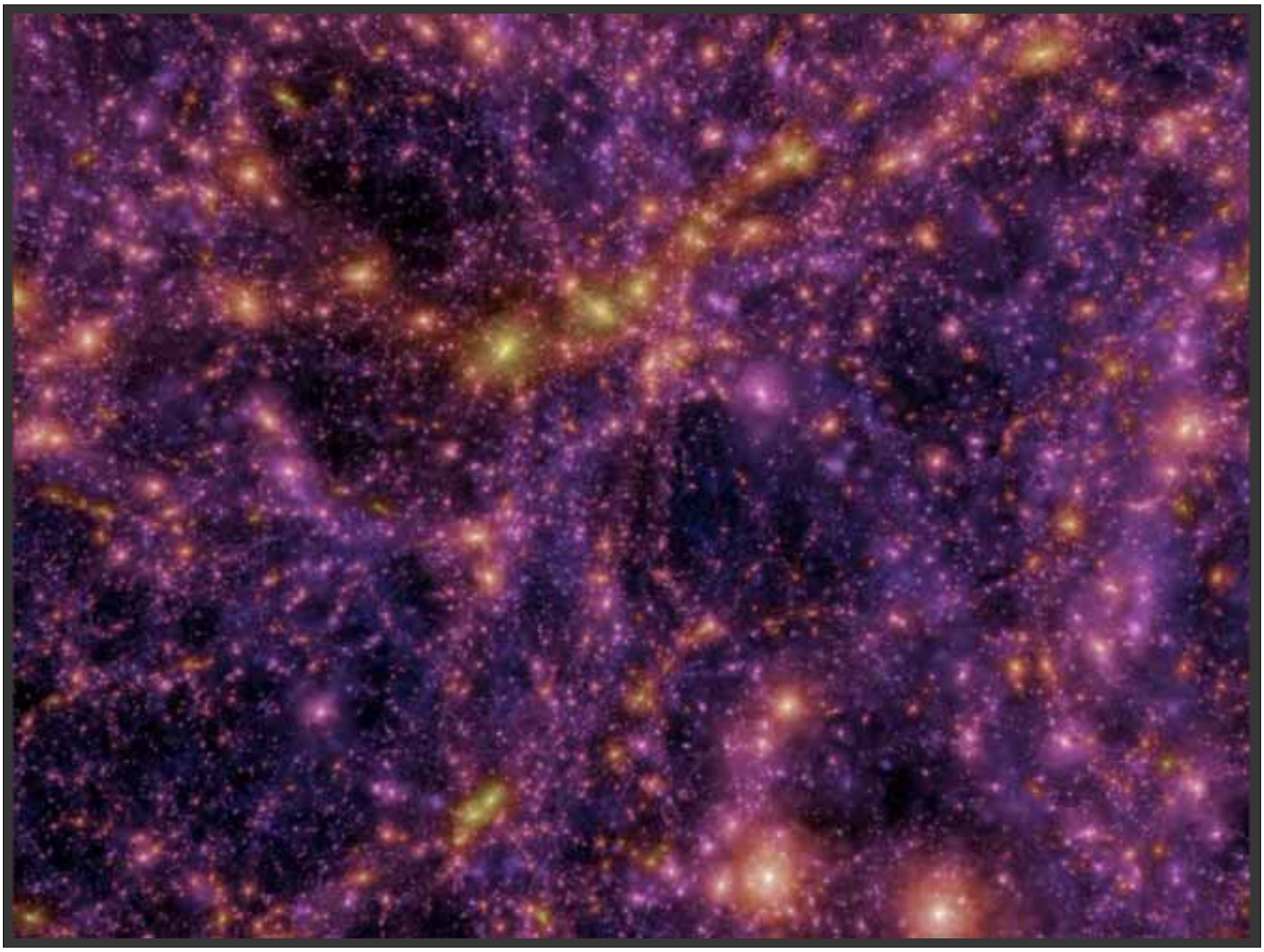
ALMA:
Cold Gas & Dust:
Building Blocks for
Stars & Black Holes,

What ALMA Will Do for Galaxy Evolution:

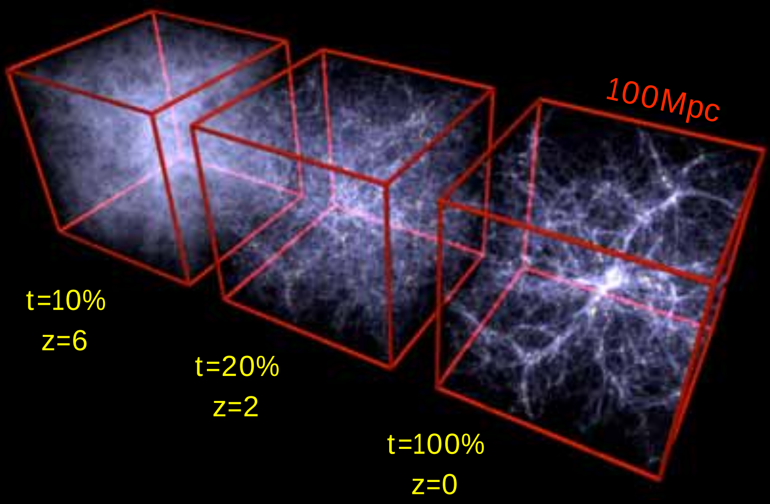
- ➡ Determine robust rotation curves and study velocity fields for distant galaxies as a function of redshift and mass
- ➡ Establish a clean dynamical estimate of galaxy merger fractions as a function of redshift and mass
- ➡ Measure gas fractions as a function of redshift, mass, environment and galaxy morphology; explore the dependence of star formation rates on galaxy properties
- ➡ Resolve clumps, measure dynamical masses, velocity dispersions and gas fractions at ~few hundred pc (~0.03” - 0.05”) resolution; together with ELTs, resolve nature and internal evolution of clumpy high-z galaxies
- ➡ Measure outflow rates of cold gas and test feedback models
- ➡ Together with ELTs, establish M_{BH}/M_{gal} as a function of z, L for obscured and unobscured AGN population


z = 20.0
50 Mpc/h


1 Gpc/h
Millennium Simulation
10.077.696.000 particles
(z = 0)

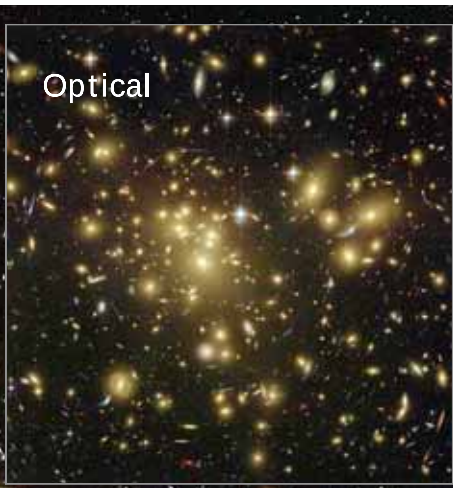


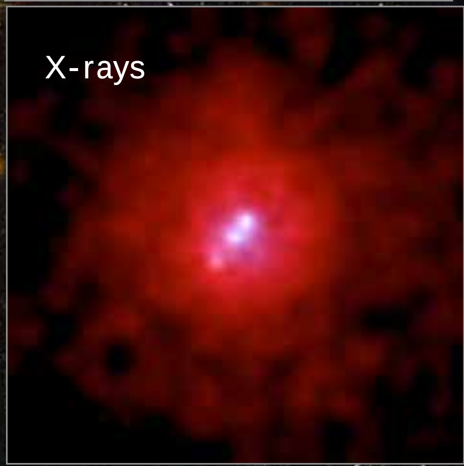
The formation of large-scale sturcture in the universe, as seen through numerical simulations of dark matter evolution.
Here: 100 Mpc comoving volume:



For movies, see http://www.mpa-garching.mpg.de/~hmathis/Galaxien/movies.html

Galaxy Clusters





How to find?

Optical (confusion)
X-ray (sensitivity)
lensing (difficult, confusion)
Sunyeav-Zeldovich (calibration)

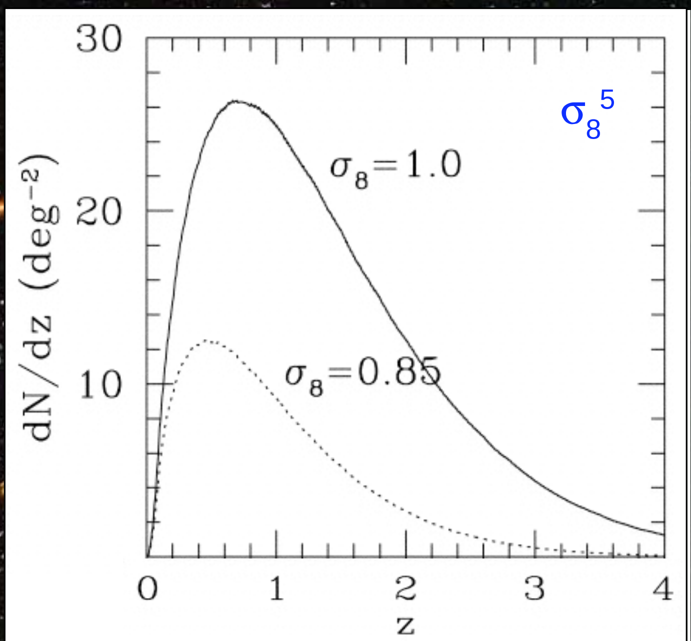
Galaxy Clusters

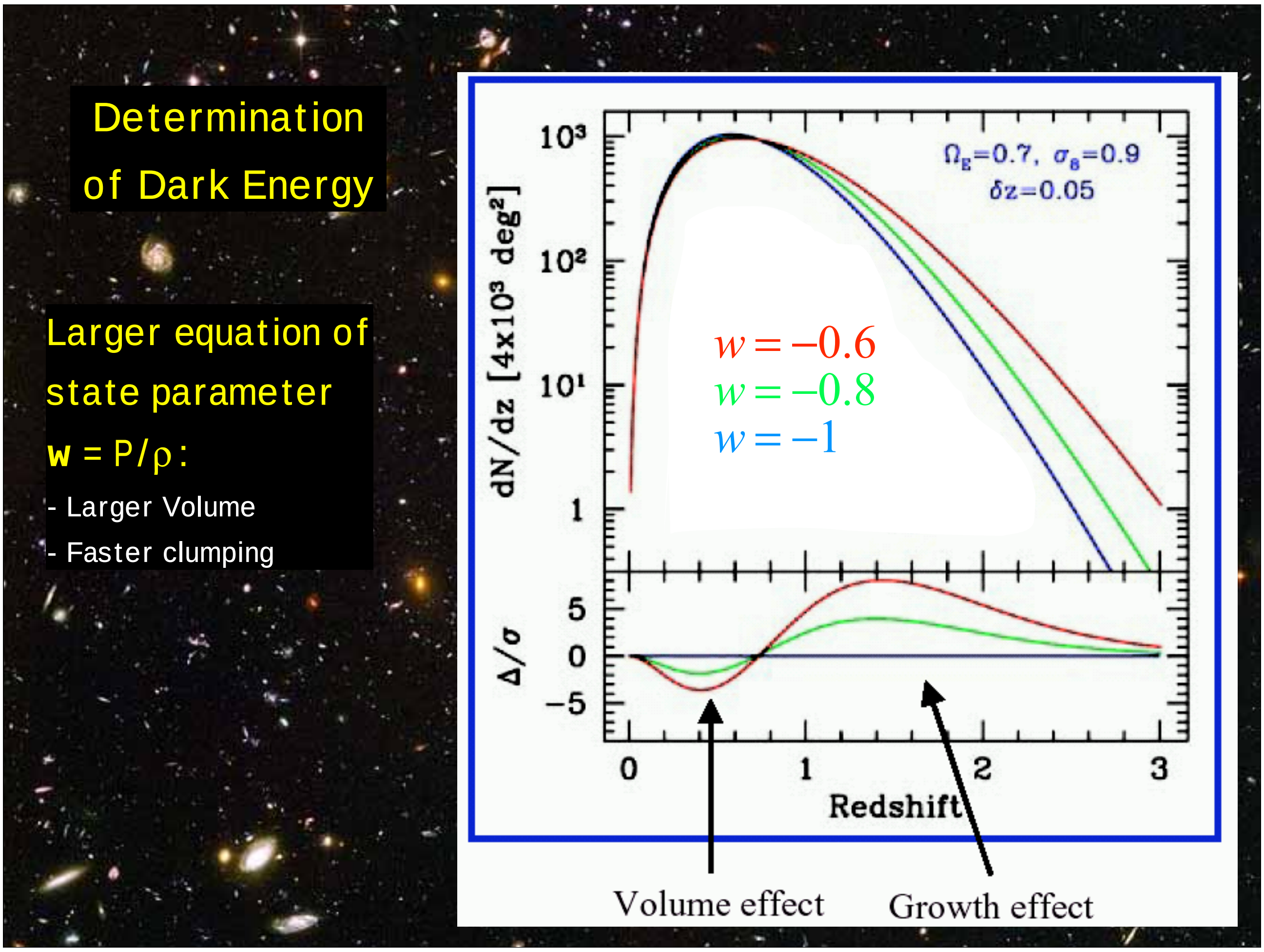
redshift distribution

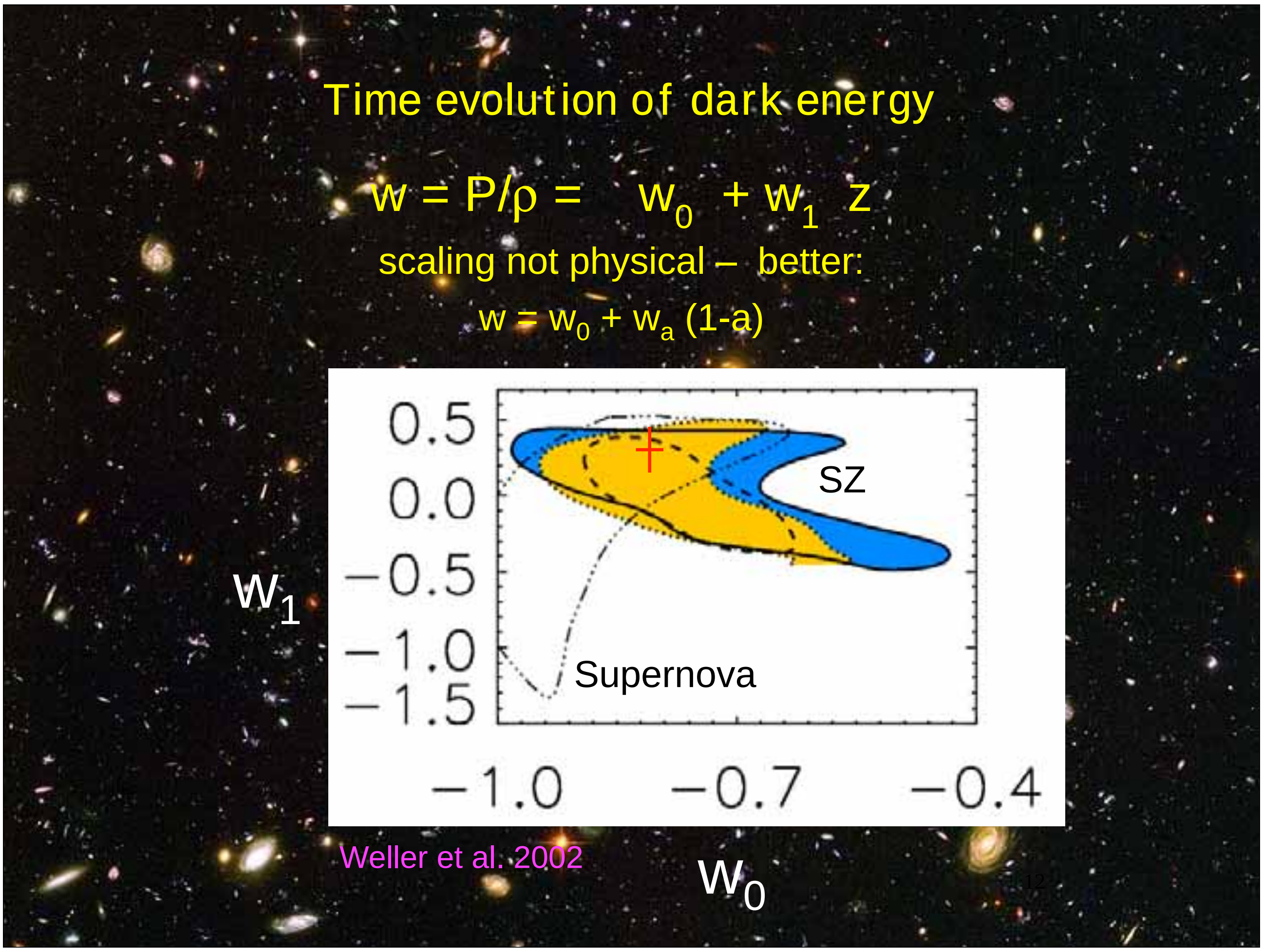
Measure for:

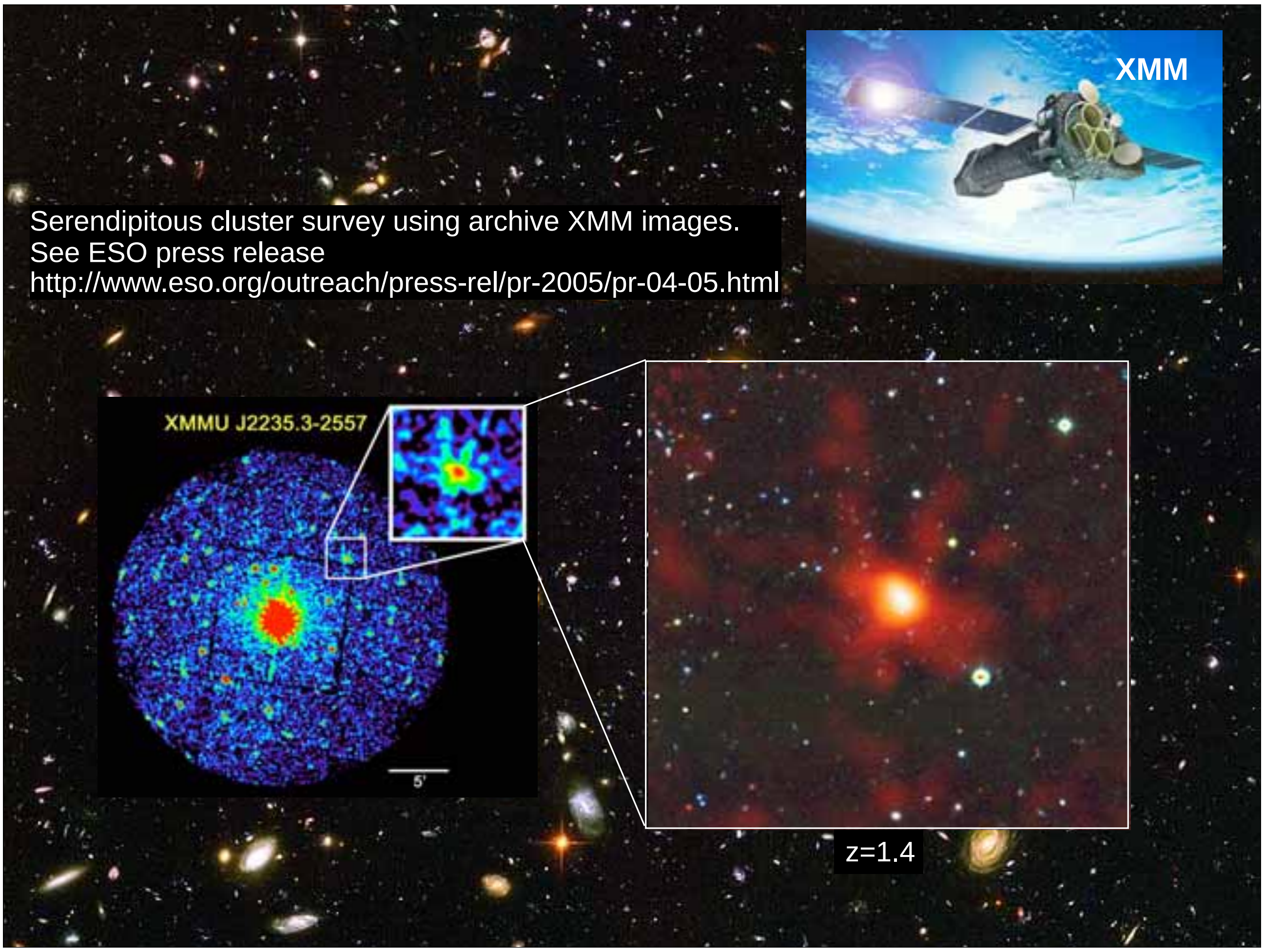
1. Volume-Redshift Relation
2. Speed of structure formation

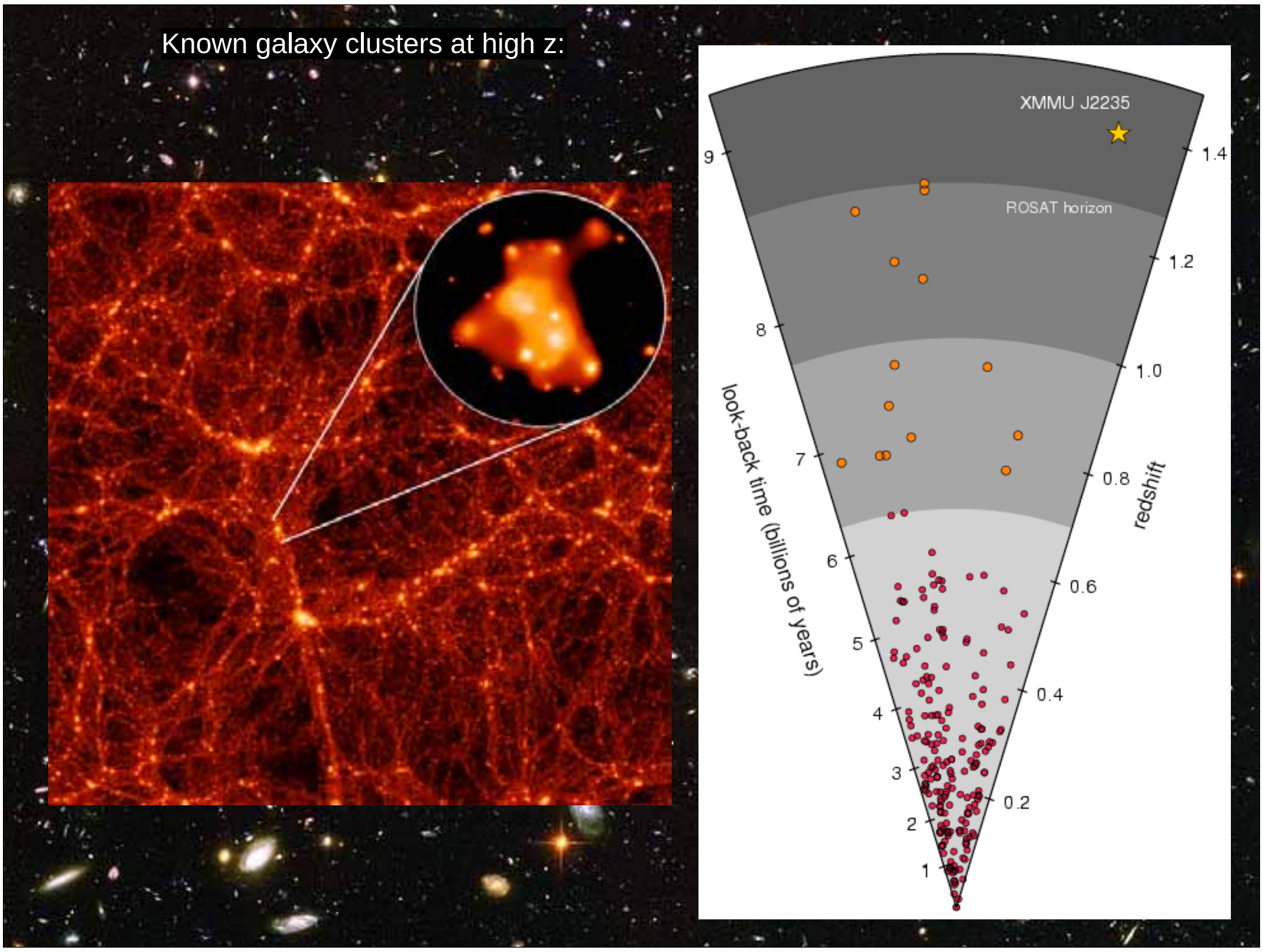
Cluster redshift distribution yields important information on cosmology, complementary to CMB and SN Ia.

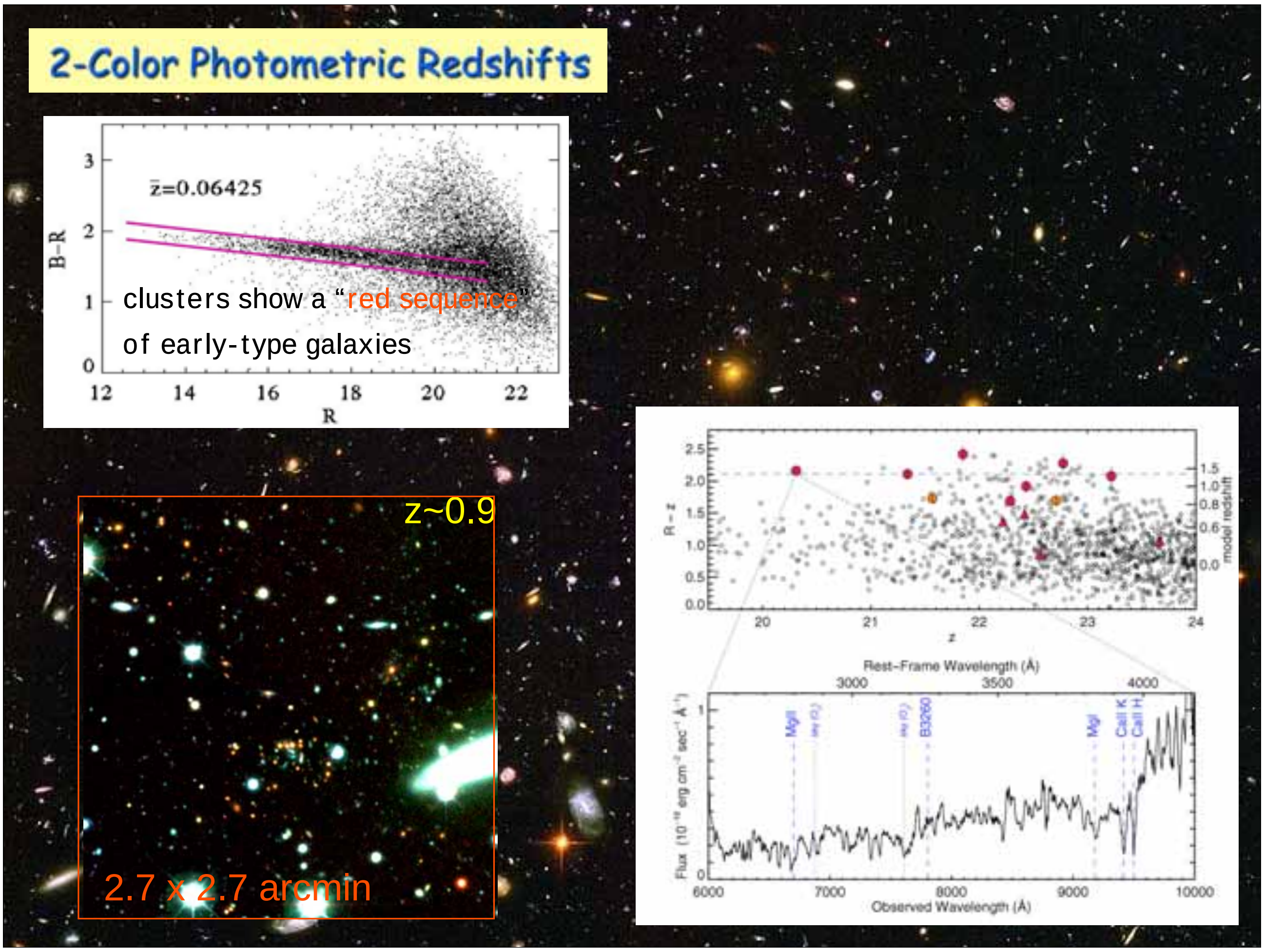


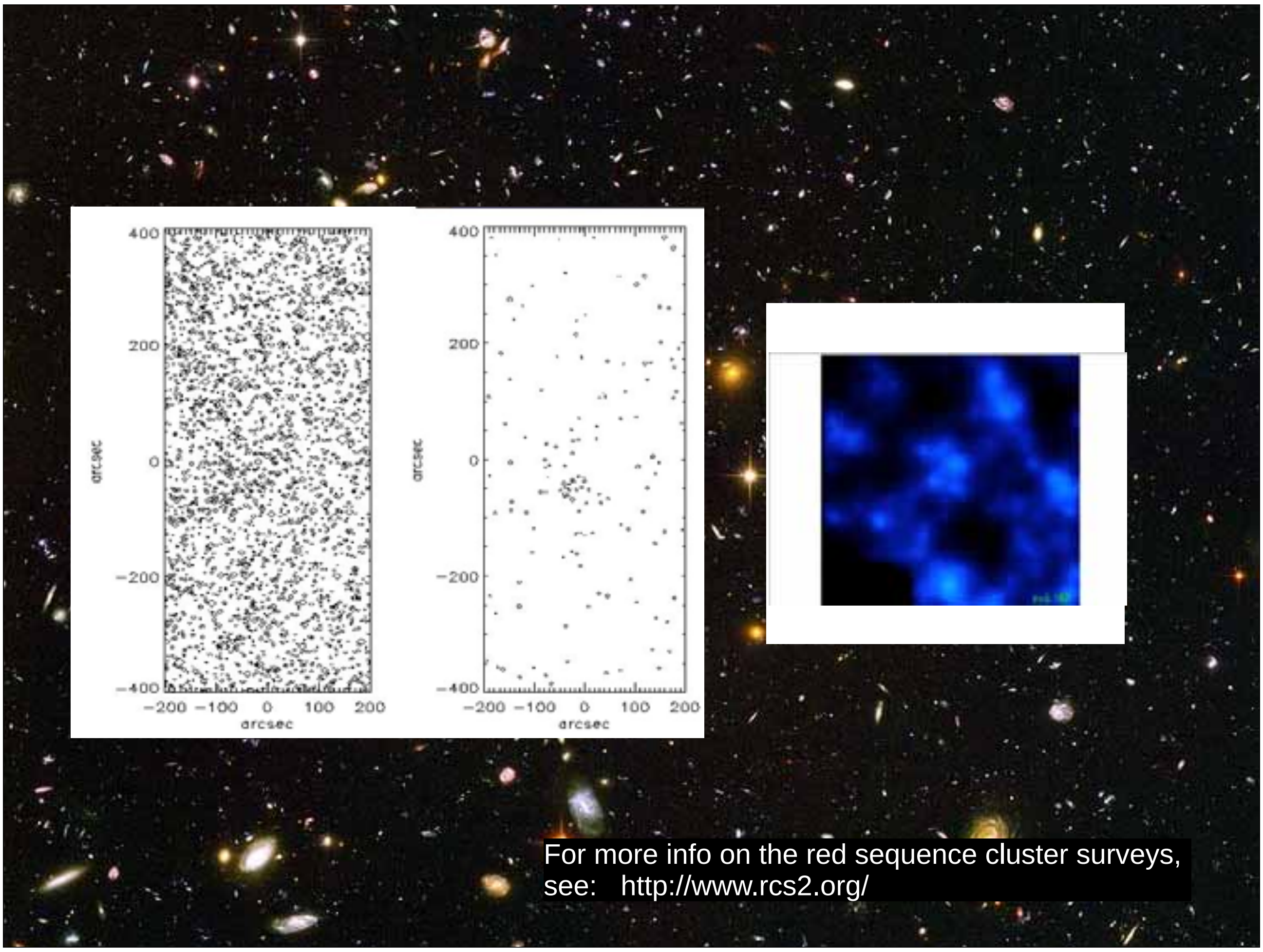

Determination of Dark Energy
Larger equation of state parameter
w = P/ρ:
- Larger Volume
- Faster clumping
10³
10²
10¹
1
dN/dz [4x10³ deg²]
Ω_E=0.7, σ_8=0.9
δz=0.05
w = −0.6
w = −0.8
w = −1
5
0
−5
Δ/σ
0
1
2
3
Redshift
Volume effect
Growth effect


Time evolution of dark energy
w = P/ρ = w0 + w1 z
scaling not physical – better:
w = w0 + wa (1-a)
0.5
0.0
−0.5
−1.0
−1.5
w1
SZ
Supernova
−1.0
−0.7
−0.4
w0
Weller et al. 2002

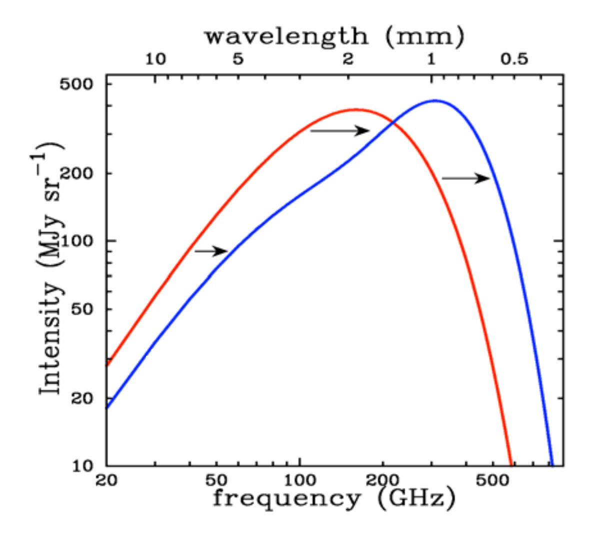

XMM
Serendipitous cluster survey using archive XMM images.
See ESO press release
http://www.eso.org/outreach/press-rel/pr-2005/pr-04-05.html
XMMU J2235.3-2557
5'
z=1.4

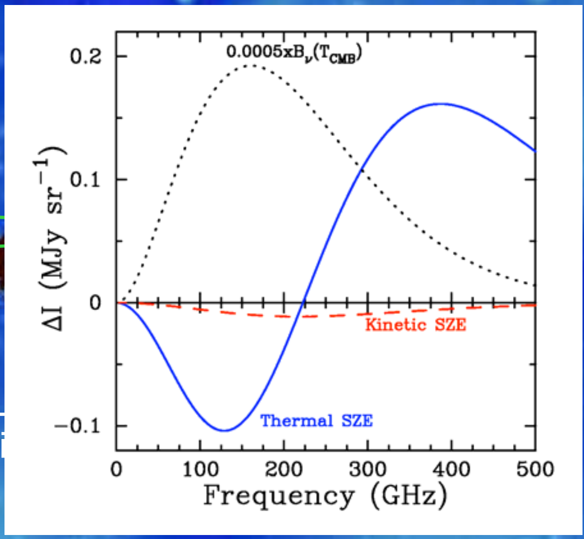

Known galaxy clusters at high z:
XMMU J2235
ROSAT horizon
look-back time (billions of years)
1
2
3
4
5
6
7
8
9
redshift
0.2
0.4
0.6
0.8
1.0
1.2
1.4


2-Color Photometric Redshifts
z̄=0.06425
B−R
R
clusters show a "red sequence"
of early-type galaxies
z~0.9
2.7 x 2.7 arcmin
R − z
z
model redshift
Rest-Frame Wavelength (Å)
Flux
Observed Wavelength (Å)
MgII
B3260
MgI
CaII K
CaII H


arcsec
arcsec
arcsec
arcsec
For more info on the red sequence cluster surveys,
see: http://www.rcs2.org/

The Sunyaev-Zel'dovich Effect





Zhang, Pen, Wang 2002

The Observation of Relic Radiation as a Test of the Nature of X-Ray Radiation from the Clusters of Galaxies

Introduction

The x-ray radiation from a number of clusters of galaxies (Coma, Virgo, Perseus) was discovered recently.[1] It is assumed that clusters of galaxies form an important class of powerful x-ray sources, possibly giving the main contribution to the x-ray background radiation of the Universe.[2] What is the nature of these sources? What physical mechanisms give the observed x-ray radiation?

Most likely this is either the bremsstrahlung radiation of hot intergalactic gas or inverse Compton scattering on the relativistic electrons. Again the question arises—what kind of radiation and where is it scattered? The relic photons in the intergalactic space,[3] or in haloes of massive elliptical galaxies,[4] or infrared radiation in the vicinity of nuclei of galaxies?[5] The observations of small perturbation in angular distribution of relic radiation can give an answer to these questions. These observations enable us to distinguish between hot nonrelativistic electron gas (being a bremsstrahlung source) and a less numer… decrea…

$$\frac{\Delta T}{T_{\mathrm{CMB}}} = g(x) \int dl\, n_e(l)\, \frac{k_B T_e(l)}{m_e c^2}\, \sigma_T$$

Ya. B. Zeldovich
Institute of Applied Mathematics, Moscow

Comments on Astrophysics and Space Physics 1972

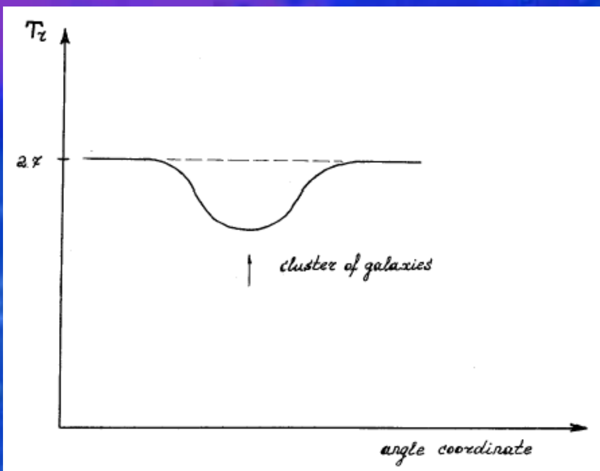
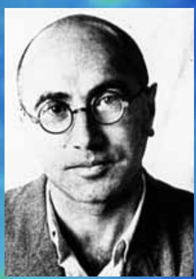


Fig. 1. The "hole" in the microwave background.

Rashid Sunyaev *1943

Yakov Zel'dovich (1914-1987)



Thermal SZE is a small (<1 mK) distortion in the CMB caused by inverse Compton scattering of the CMB photons.

$$\frac{\Delta T}{T_{\rm CMB}} = g(x) \int n_e(l) \frac{k_B T_e(l)}{m_e c^2}\, dl$$

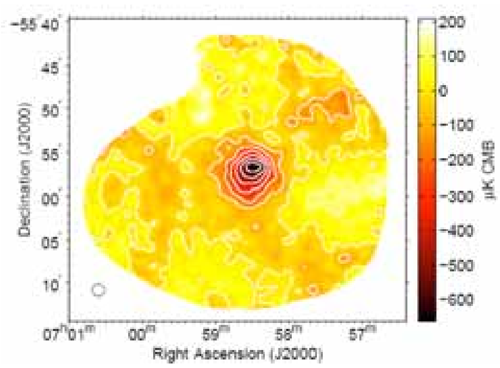
Pressure integrated along line of sight.

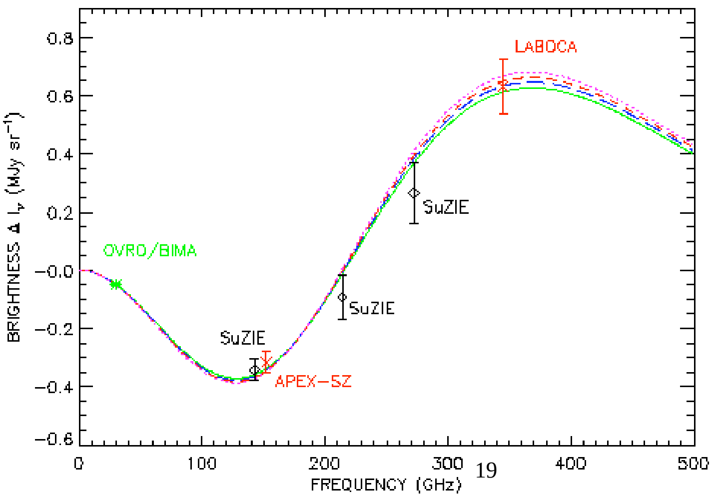
Not a source, therefore redshift independent - great tool for cluster surveys!

Total cluster flux density is independent of redshift!

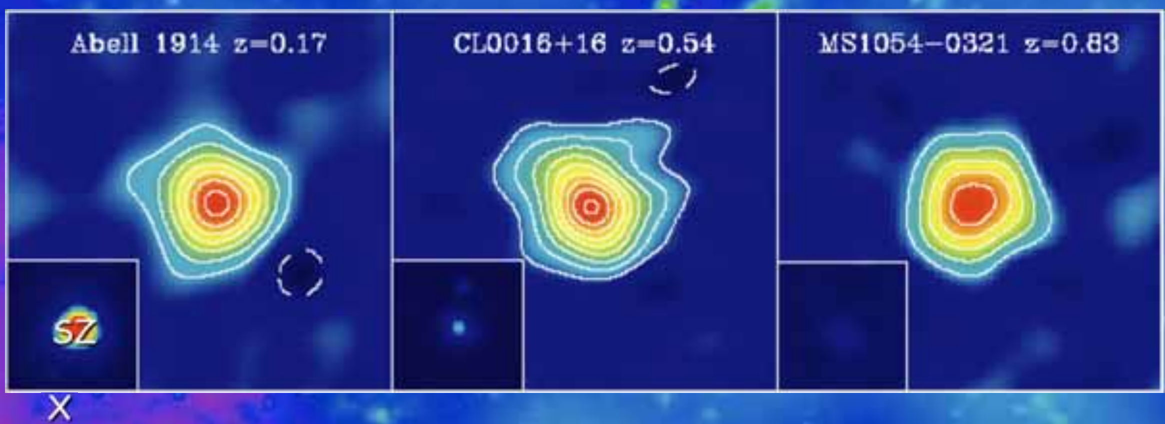
$$\Delta S_\nu = \int \Delta I_\nu \, d\Omega \propto \frac{\int n_e T_e \, dV}{D_A^2} \propto \frac{f_{\rm gas} M_{\rm tot} T_e}{D_A^2}$$

Measures the T-weighted mass = thermal energy



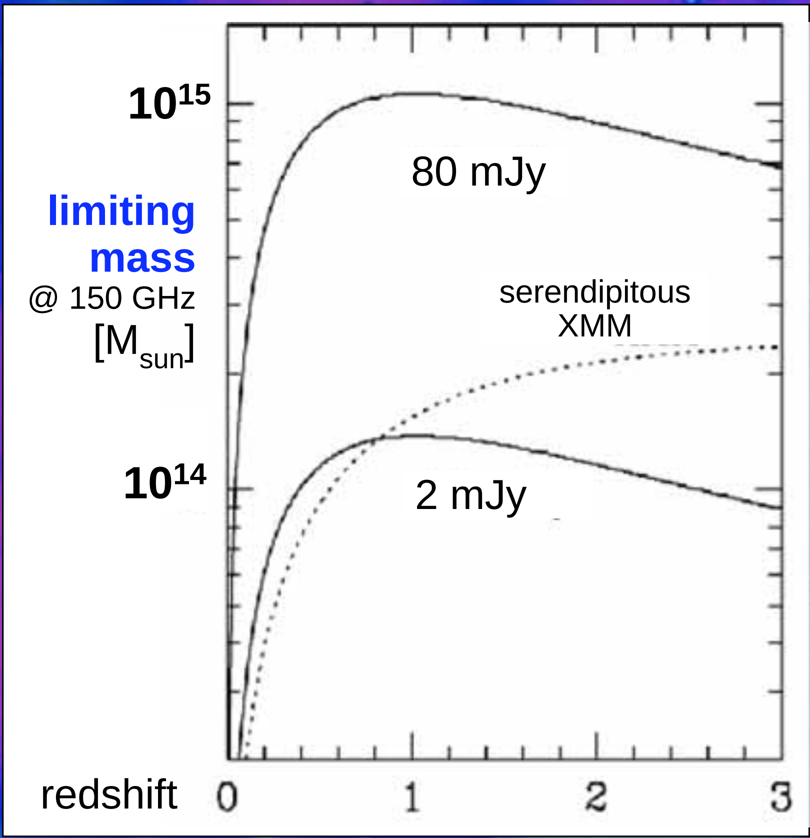


$$\Delta T = f_{(x,T_x)} T_{CMB} D_A \int n_e \sigma_T \frac{k_B T_x}{m_e c^2} d\zeta$$



Compare with X-ray: $D_a{}^2 / D_L{}^2 \propto (1+z)^{-4}$

Limiting Mass of SZE Surveys



well understood selection function

$$\mathbf{D_a^{-2} \propto (1+z)^4/z^2}$$

$$\mathbf{T \propto (1+z)}$$

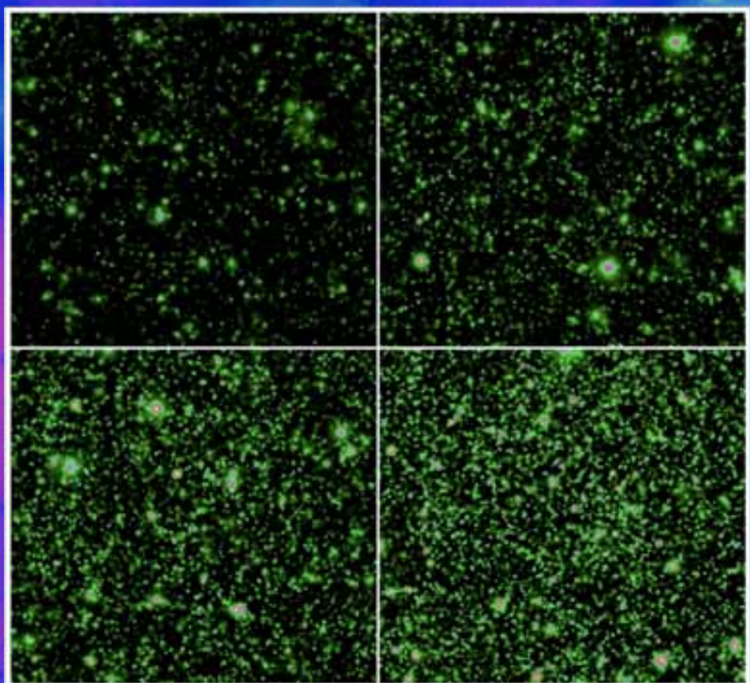
<u>study</u>:

growth of structure

individual clusters

σ_8=0.7

σ_8=0.8



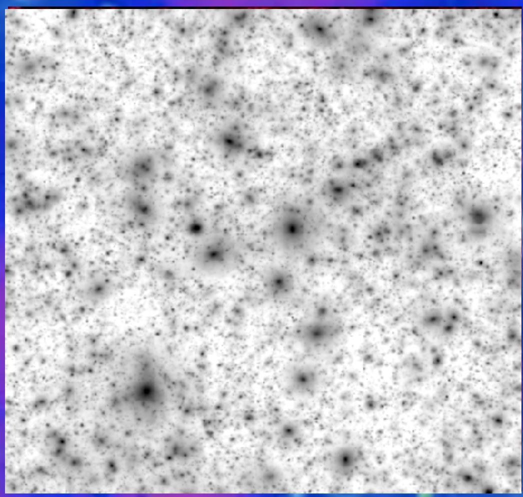
σ_8=0.9

σ_8=1.0

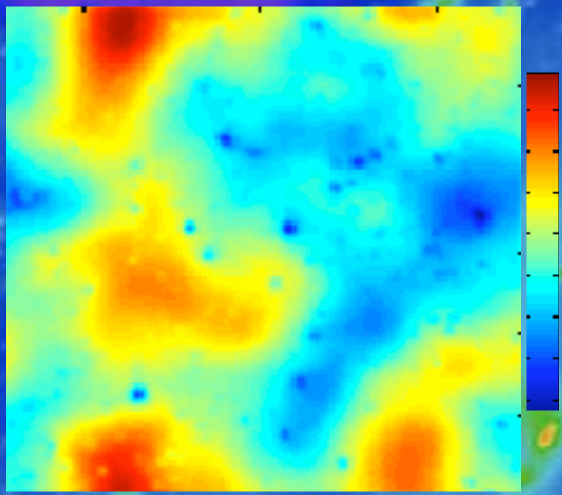
Cluster models from Ian McCarthy

Simulations by M. White

SZ Effect



SZ plus CMB



1 deg

Aim of Sunyaev-Zel'dovich Galaxy Cluster surveys

APEX-SZ

SZ-Array

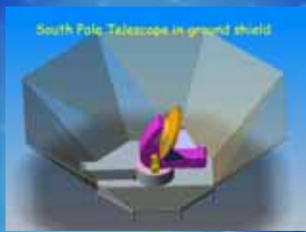
South Pole Telescope
Atacama Cosmology Telescope

- Discovery of thousands of galaxy clusters by mapping of 100 to 4000 sqd to ~50 μK detection limit.
- constrain cosmological parameters, e.g. σ_8 and Dark Energy parameter w.
- Demonstrate new detector technology

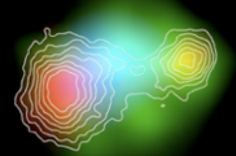
- Find signatures from z>10 supernova-remnants.
- Observe **evolution of structure**, and test theories of structure formation.
- Study **clusters** in detail: structure, evolution, galaxy populations, baryon fraction.
- Study **CMB secondary anisotropies**, weak lensing, Ostriker-Vishniac effect, quadratic Doppler effect, etc.

Current and future SZ surveys

name	type	beam [arcmin]	telescope [m]	clusters	when
ACBAR	Bolo		4	few	?
Bolocam	Bolo 151	1	10	10s	?
SuZIE	Bolo	1	10	?	1997
BIMA	HEMT	?		few	2001
CBI	HEMT 13	4	0.9	?	?
SZA	HEMT 8	0.1	3.5	100	2007
AMiBA	HEMT 19	2	1.2	100s	2006
OCRA	HEMT 100	1.5	32	100s	2006
AMI	HEMT 10	1	3.7	100s	2007
APEX	**Bolo 325**	**1**	**12**	**1,000s**	**2007**
ACT	Bolo 1000	1	6	1,000s	2008
Bolocam-2	Bolo	0.2	40	?	2008?
SPT	Bolo 1000	1	8	20,000	2008
Planck	Bolo	5	2	10,000	2009



SZ @ Bonn 2009: A multi-wavelength look at galaxy clusters



- Overview
- Program
- Participants
- Venue for Workshop
- Travel Information
- Organisers and Contact

SZE workshop in Bonn (July 15-17, 2009)

The last few years have seen tremendous growth in our understanding of the physics of galaxy clusters and their relation to cosmology. One of the latest and most interesting tools in this analysis has been the availability of large-area imaging of galaxy clusters using the Sunyaev-Zel'dovih Effect (SZE), with the help of state-of-the-art multi-pixel bolometer arrays. Several such experiments with new generation of bolometer receivers are now collecting data and producing their first results. The APEX-SZ instrument, commissioned in Spring 2007, is one of the first such experiments and is in the process of announcing its first scientific results.

One particular strength of such large-area SZE maps is to use them in combination with X-ray and weak-lensing data to extend our understanding of the physical and dynamical properties of the intra-cluster gas (ICM) out to a large fraction of the cluster virial radius. The aim of the workshop will be to bring together experts of such multi-wavelength ICM analysis and discuss the recent results from new SZE experiments as well as their combination with other observational probes. Since APEX-SZ is unique in its sensitivity, resolution and ability to track sources, resulting in detailed SZE maps of known galaxy clusters, it is our aim to put current and future APEX-SZ time to its best possible use by developing a joint plan for observation and target selection with a broader community.

As mentioned above, we aim to focus on cluster physics rather than surveys, so the topics will include: cluster ICM modeling combining SZ, X-ray, and possibly weak lensing data; cluster SZE scaling relations; cosmology from cluster baryon fractions; etc. We aim to make possible for every participant to present their latest works.

APEX-SZ Survey

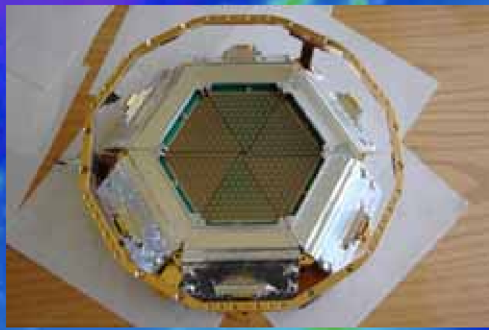
UCB: Lee, Holzapfel ...
Colorado: Halverson, Bender ...
Bonn: Bertoldi, Menten, Basu, Nord, Pacaud ...
MPE: Böhringer
OSO: Horellou

(DFG funding: SPP, Transregio)
optical: ESO/MPG 2.2m with GROND

image at 2mm with 1‘ (45") beam
to rms~2mJy~10µK

sensitivity aim: 500 µK $s^{1/2}$ for 300 channels
1 sqd to 10µK needs ?h
100 sqd need ???h
with 15h/day, ?? days.

see http://bolo.berkeley.edu



12m primary, 16 micron surface rms 125t
optical pointing telescope
chopping secondary (AZ only)
ALMA common software (python)

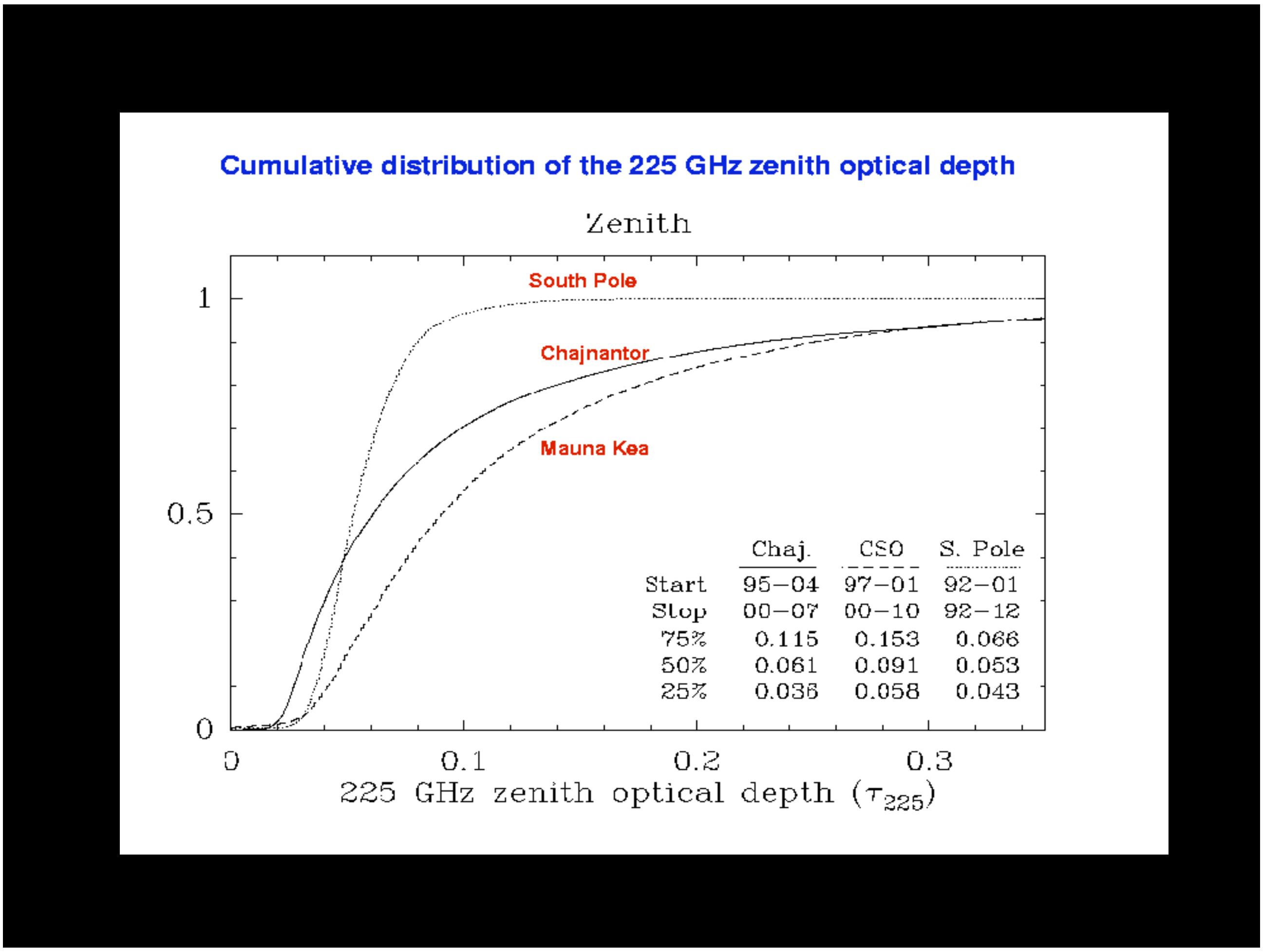
beam 8” at 350 micron,
18” at 870 micron,
45” (60”) at 2 mm

www.apex-telescope.org

ESO

Max-Planck-Institut für Radioastronomie


APEX @5080m
Vicuñas
BOLIVIA
ARGENTINA
SANTIAGO
SOUTH PACIFIC OCEAN
SOUTH ATLANTIC OCEAN
Arica
Iquique
Antofagasta
Coquimbo
Concepción
Punta Arenas


Cumulative distribution of the 225 GHz zenith optical depth
Zenith
South Pole
Chajnantor
Mauna Kea
1
0.5
0
0
0.1
0.2
0.3
225 GHz zenith optical depth (τ_{225})
Chaj. CSO S. Pole
Start 95−04 97−01 92−01
Stop 00−07 00−10 92−12
75% 0.115 0.153 0.066
50% 0.061 0.091 0.053
25% 0.036 0.058 0.043

Instrumentation

Bolometers

- **LABOCA-1**: 295-channel at 870 µm (MPIfR)
  FOV: 11', beam 18" (same as MSX and Herschel 250µm)
- SABOCA: 37-channel at 350 µm (MPIfR)
- 330-channel at 1.4/2 mm for Sunyaev-Zel'dovich survey (UCB, MPIfR)
  new software: BoA (Python/F95) www.openboa.de

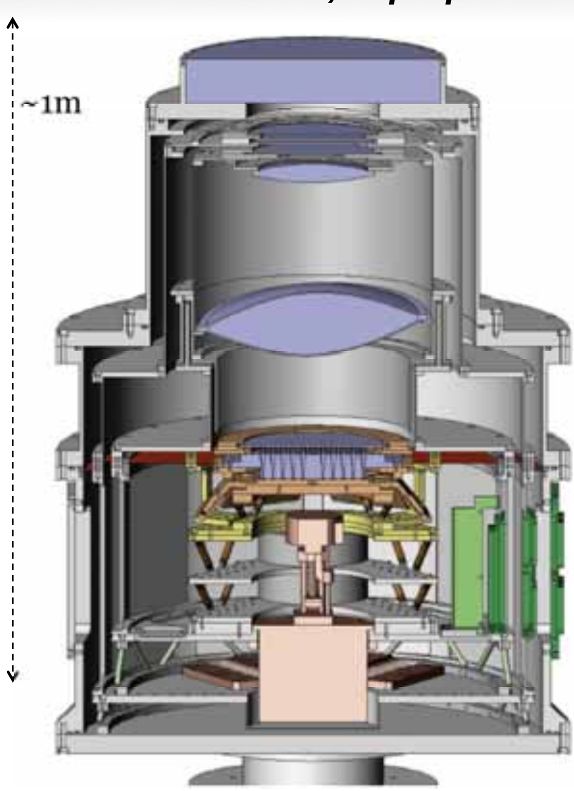
Heterodyne

- 183 GHz water vapour radiometer
- 210-270 GHz (OSO)
- 270-375 GHz (OSO)
- 375-500 GHz (OSO) [currently: 460/810 GHz "FLASH"]
- 800-900 GHz (MPIfR, PI)
- CHAMP+ 600-720/790-920 GHz, 2×7-elements (MPIfR, PI)
- FIR receivers: up to 1.5 THz = 200 micron (OSO, Köln)

APEX-SZ Camera

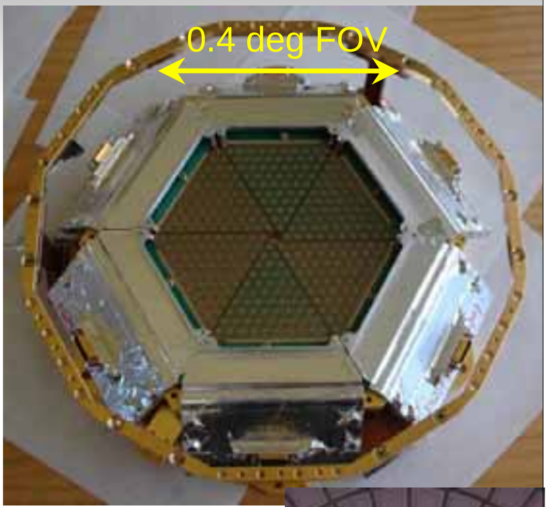
D. Schwan et al., in prep 2009

- PI instrument on APEX
- First light: December 2005
  - 55 detectors, 1 week obs
- 280 TES Bolometer channels @ 150 GHz
  - 2007, 2008 – roughly 1 month/year of which we typically get 2 weeks good observing
- Demonstrates new technologies that are scalable to other experiments, i.e., SPT
  - TES bolometers
  - Frequency domain multiplexed readout
  - Pulse-tube cooler to eliminate liquid cryogens
- Powerful camera for targeted cluster observations
  - Overlaps with northern-hemisphere multi-wavelength observations

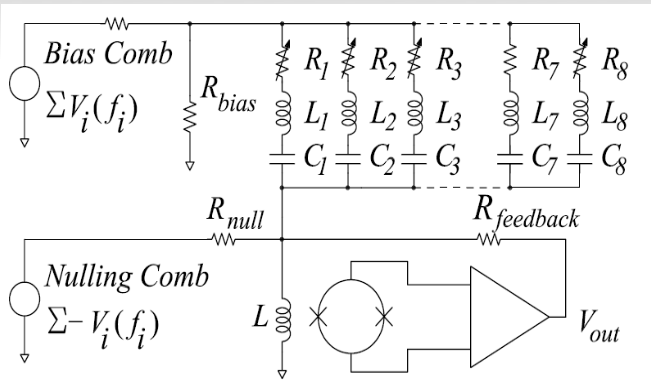


TES Detectors

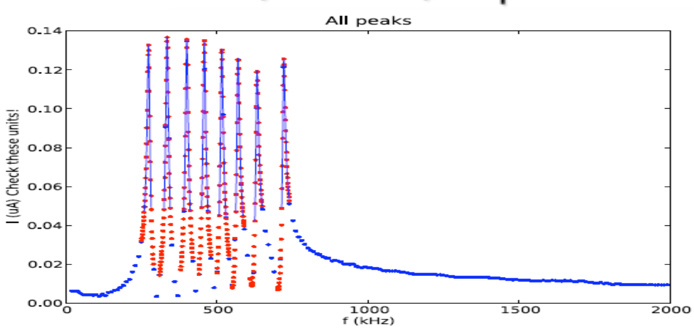
- Fabbed at UC Berkeley by Jared Mehl
- 330 element array – 280 wired
  - 6 wedges of 55 detectors
  - Science results typically use ~150 bolometers.
- March 2009: 2 wedges replaced, optimizing optical coupling, thermal conductivity, bandwidth.
  - $NET_{OLD} = 870\ \mu K_{CMB}\sqrt{s}$
  - $NET_{NEW} \approx 500\ \mu K_{CMB}\sqrt{s}$



Multiplexed Readout



- Analog frequency domain multiplexed readout
- SQUID amplifiers
- First field implementation
- Developed at LBNL/UC Berkeley/ McGill
- Used on APEX-SZ, SPT
- New digital system developed for EBEX, Polarbear, SPTpol



Cryogenics

Mechanical Pulse Tube Cooler (3-4K)

SQUIDs live here.

- ★ No expendable cryogens
- ★ No nasty fills or LHe delivery issues.
- ★ Essential for remote locations

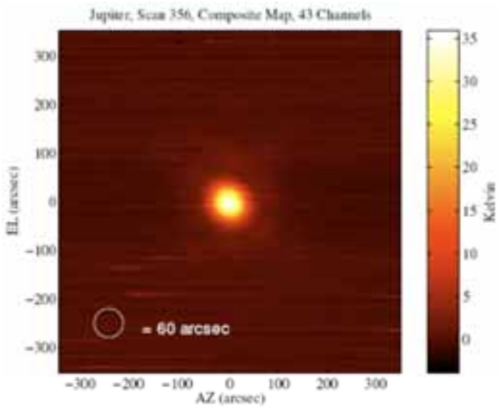
3 stage $He^4He^3He^3$ Absorption fridge (260 mK)

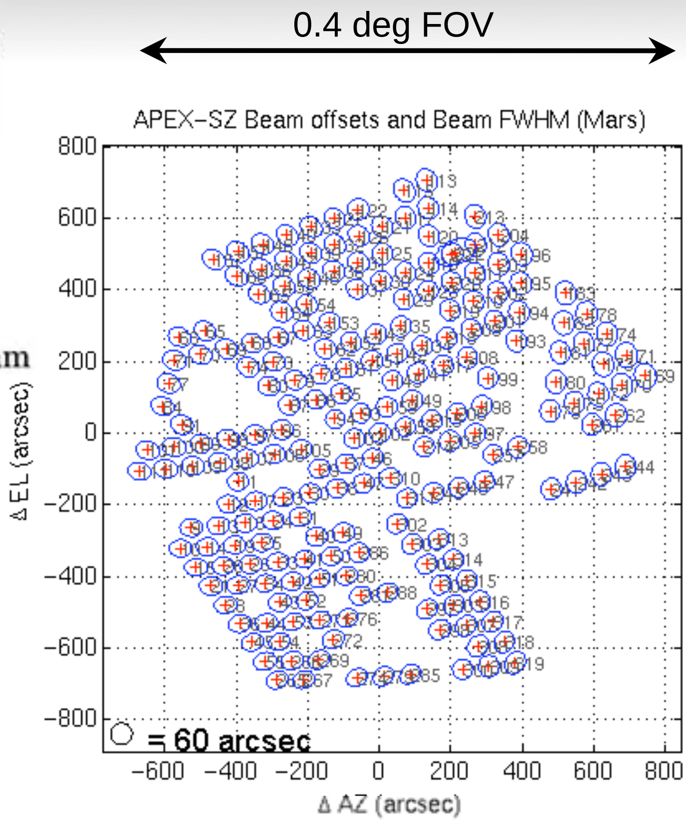
Detectors live here.

APEX-SZ Camera shown mounted in cabin with pulse tube lines & ballasts visible.

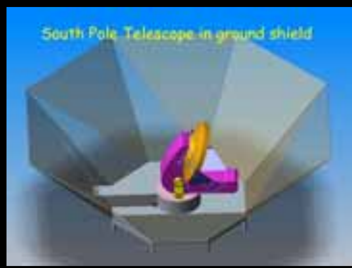
APEX-SZ Beams & Calibration

- Daily mappings of Mars
  - Calibrated against Rudy Model, updated with 1% WMAP data
- Calibration uncertainty 5.5%:
  - 4% from beam area,
  - 3% Mars temporal fluctuations,
  - 1.7% Mars temperature, ..
- Beams:
  - Gaussian main lobe
  - Near sidelobes increase real beam solid angle





SOUTH POLE SPT TELESCOPE



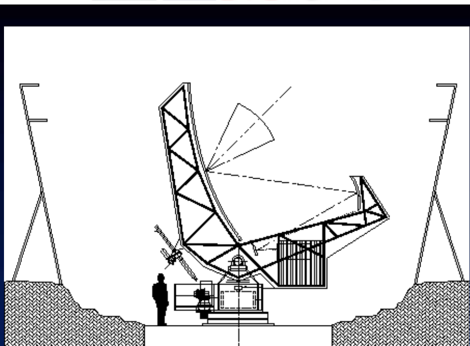
10/8m off-axis

1000-element bolometer

first light 2007

PI: J. Carlstrom

Atacama Cosmology Telescope (ACT)



Goal:

200 deg^2 to 3μK.

Secondary anisotropies.

Less massive clusters.

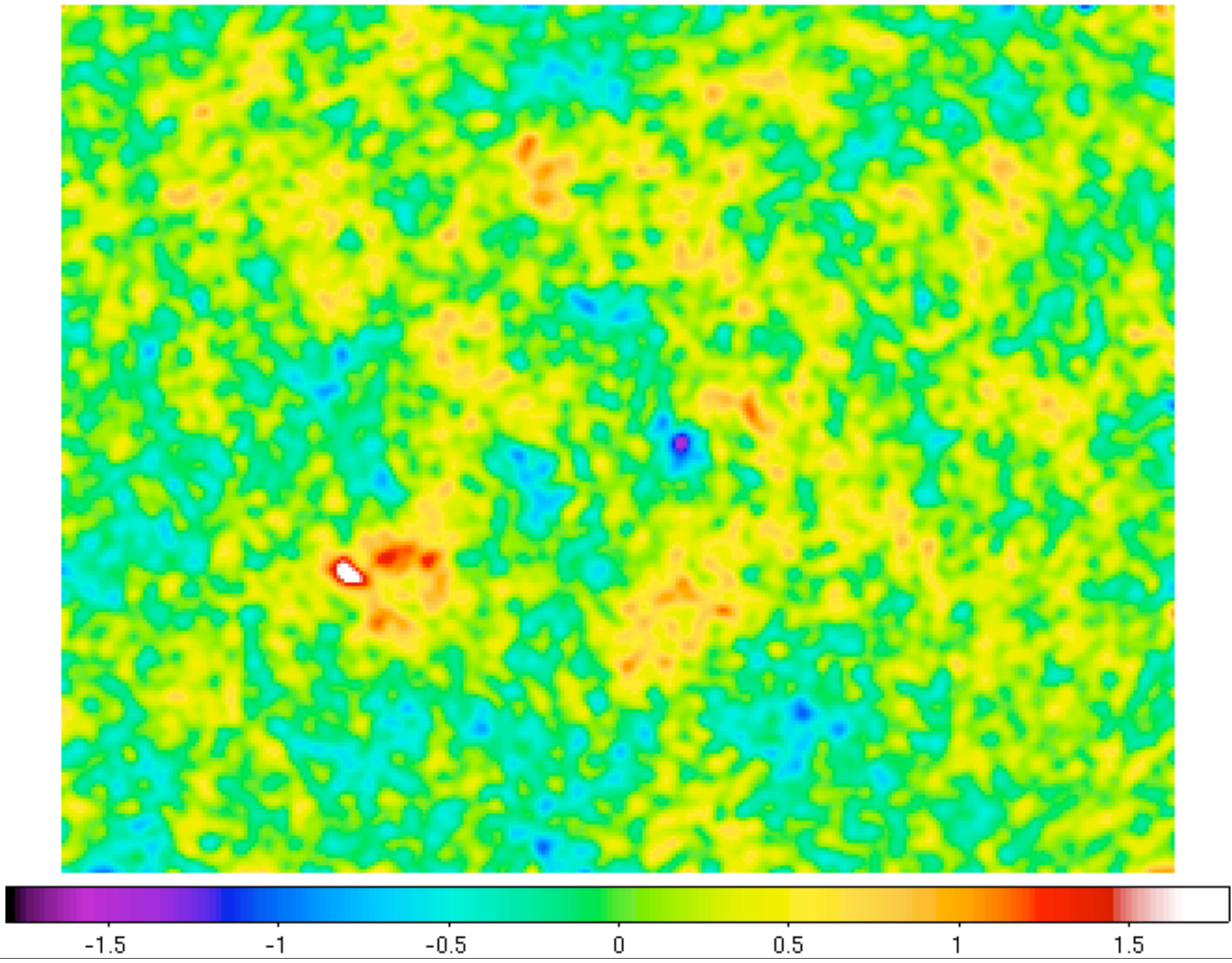
6m off-axis fixed-elevation dish with ground screen.

1000-element pop-up bolometer

first light 2006/7.

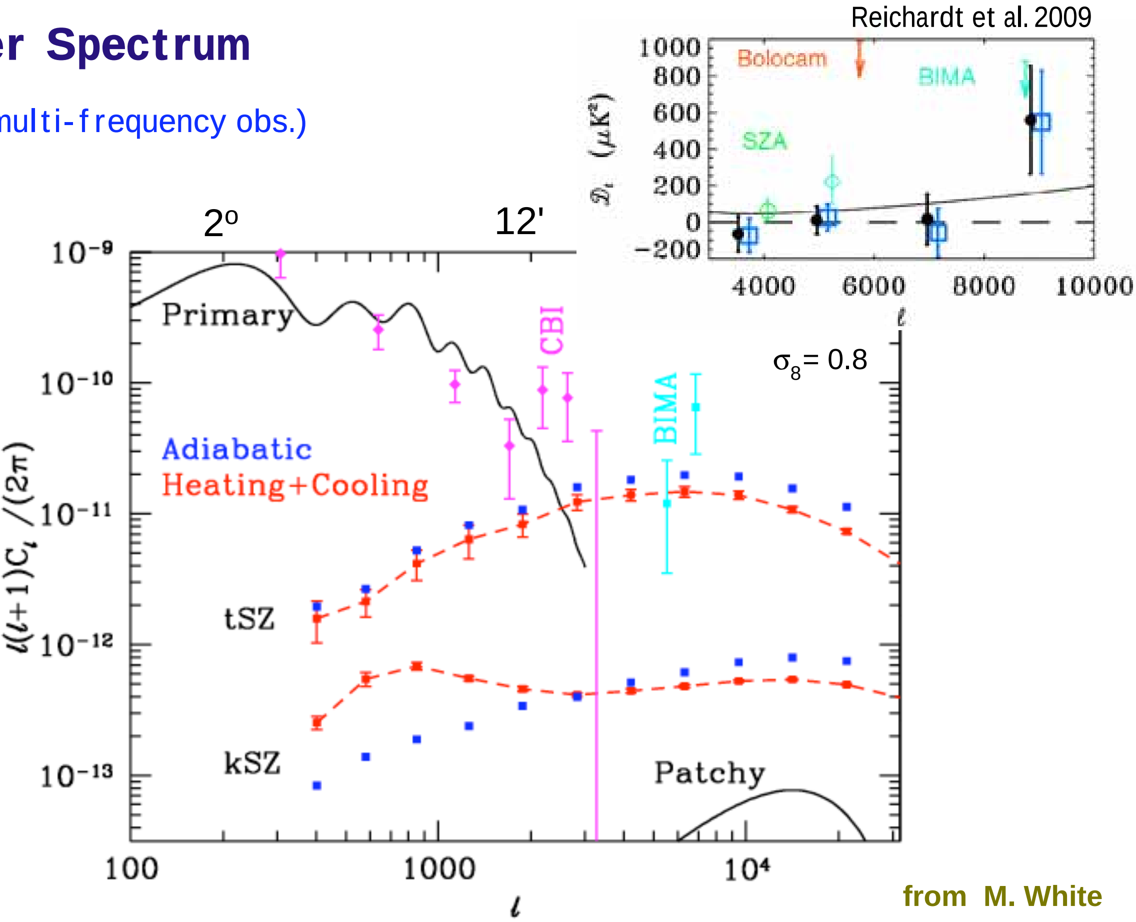
first publication

http://arxiv.org/abs/0907.0461

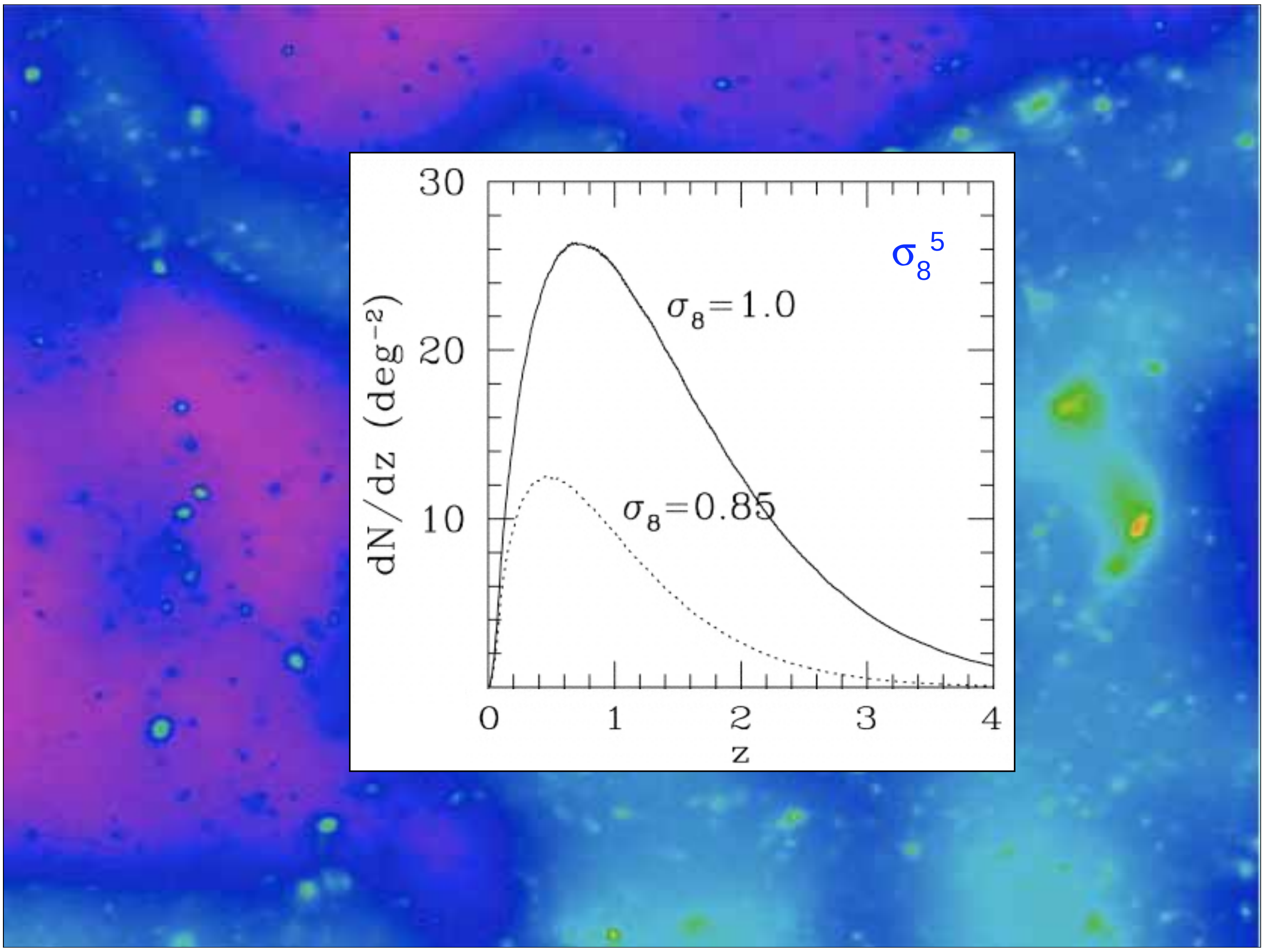


Power Spectrum

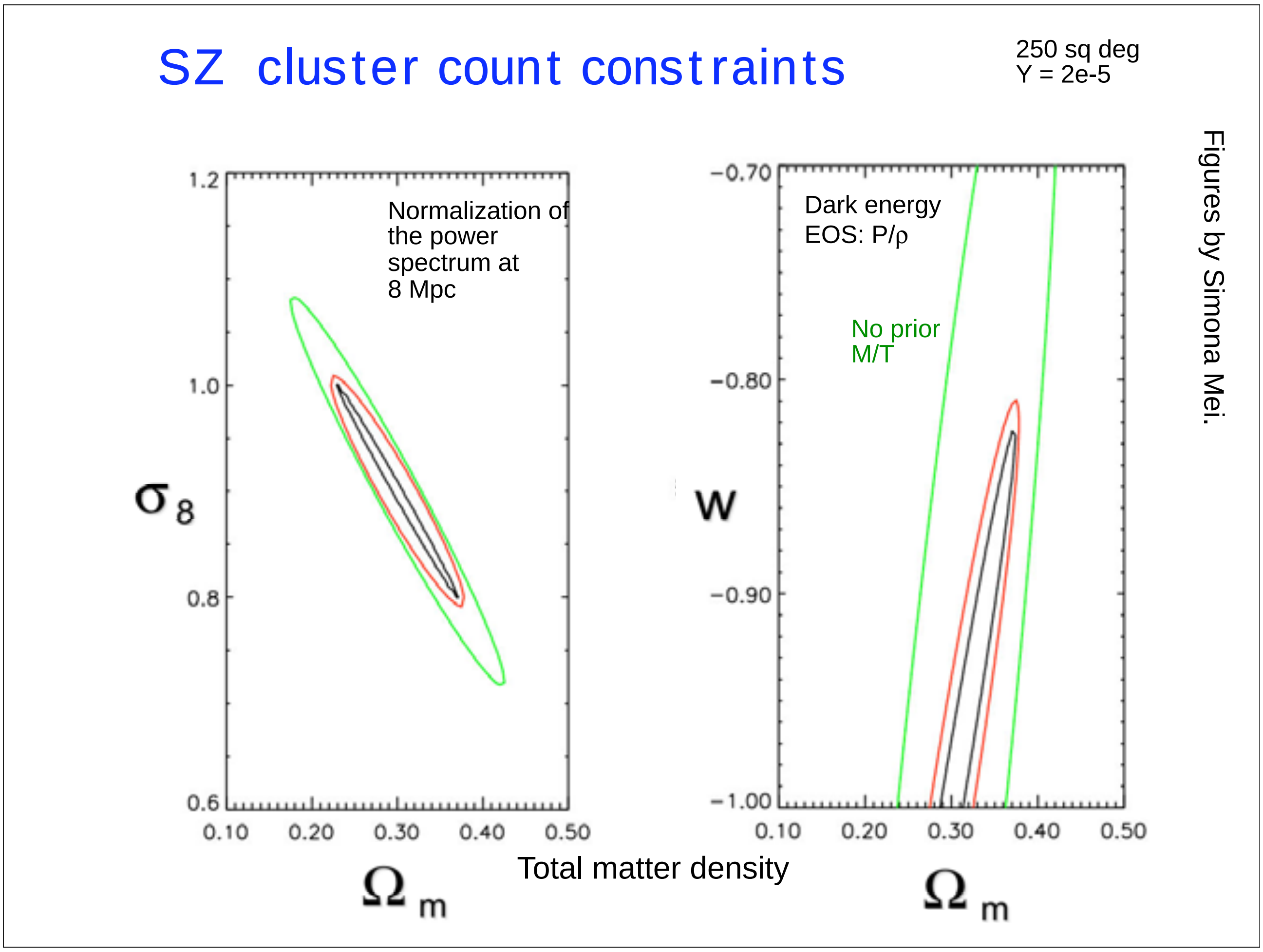
(need multi-frequency obs.)



from M. White



30
20
10
0
1
2
3
4
z
dN/dz (deg^-2)
σ8=1.0
σ8=0.85
σ8^5



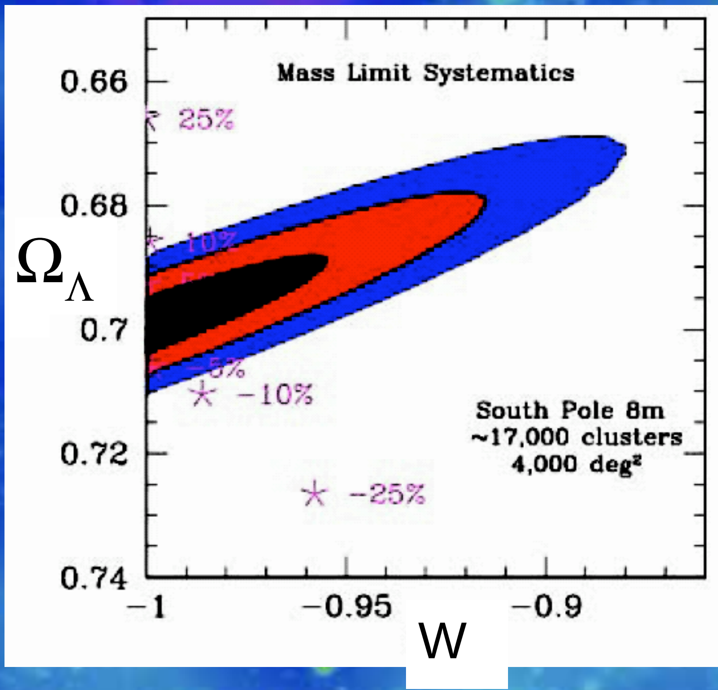
SZ cluster count constraints
250 sq deg
Y = 2e-5
Normalization of
the power
spectrum at
8 Mpc
σ8
Ωm
Total matter density
Dark energy
EOS: P/ρ
No prior
M/T
w
Ωm
Figures by Simona Mei.

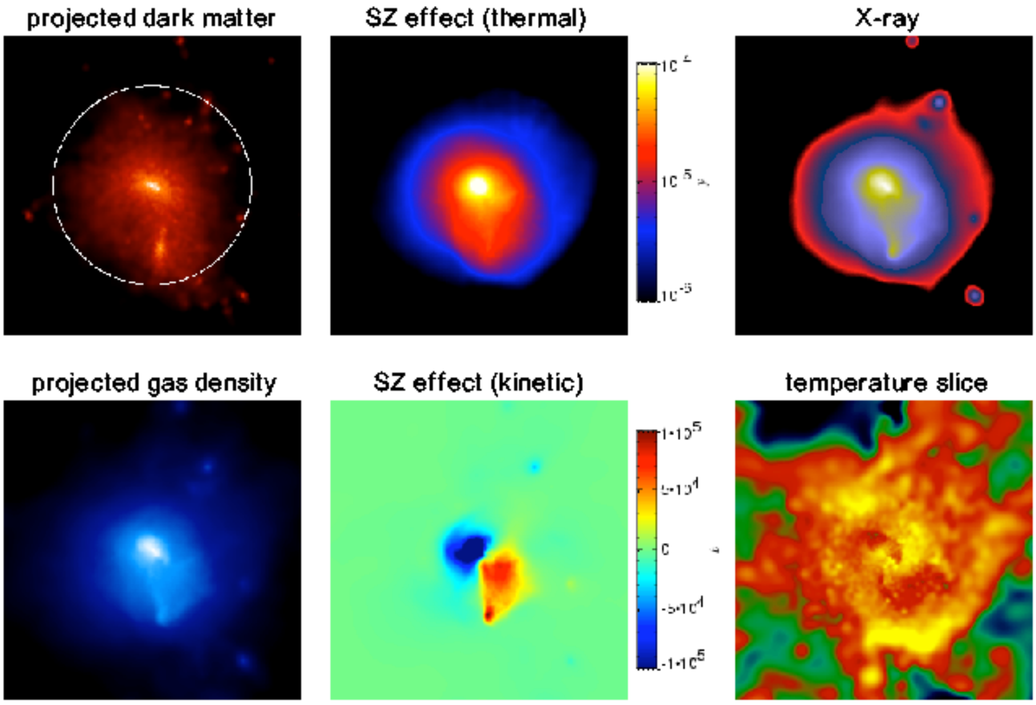
Problem: Systematic Mass Bias

Figure by Joe Mohr

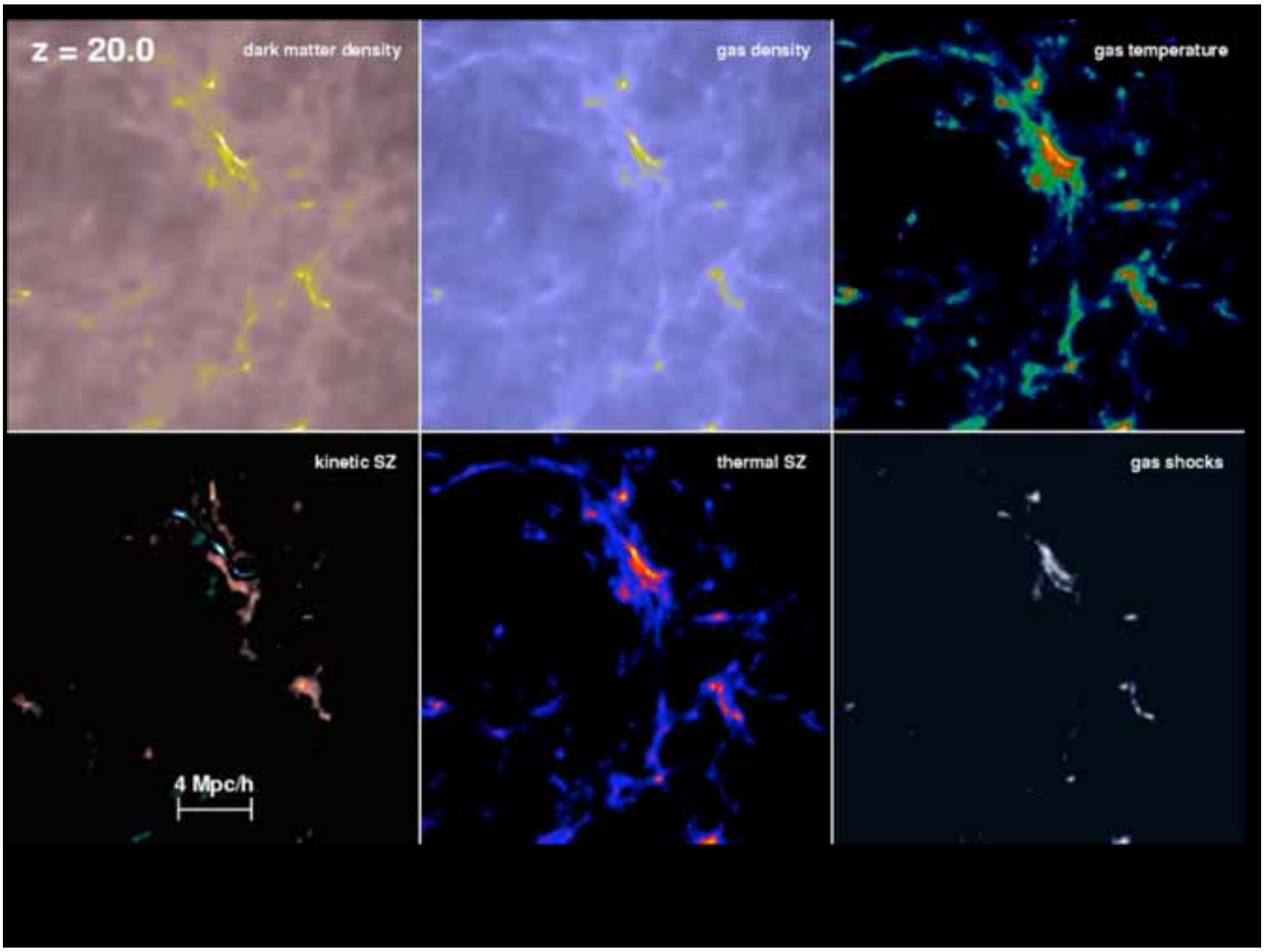
Controlling systematic errors on mass is prime concern !

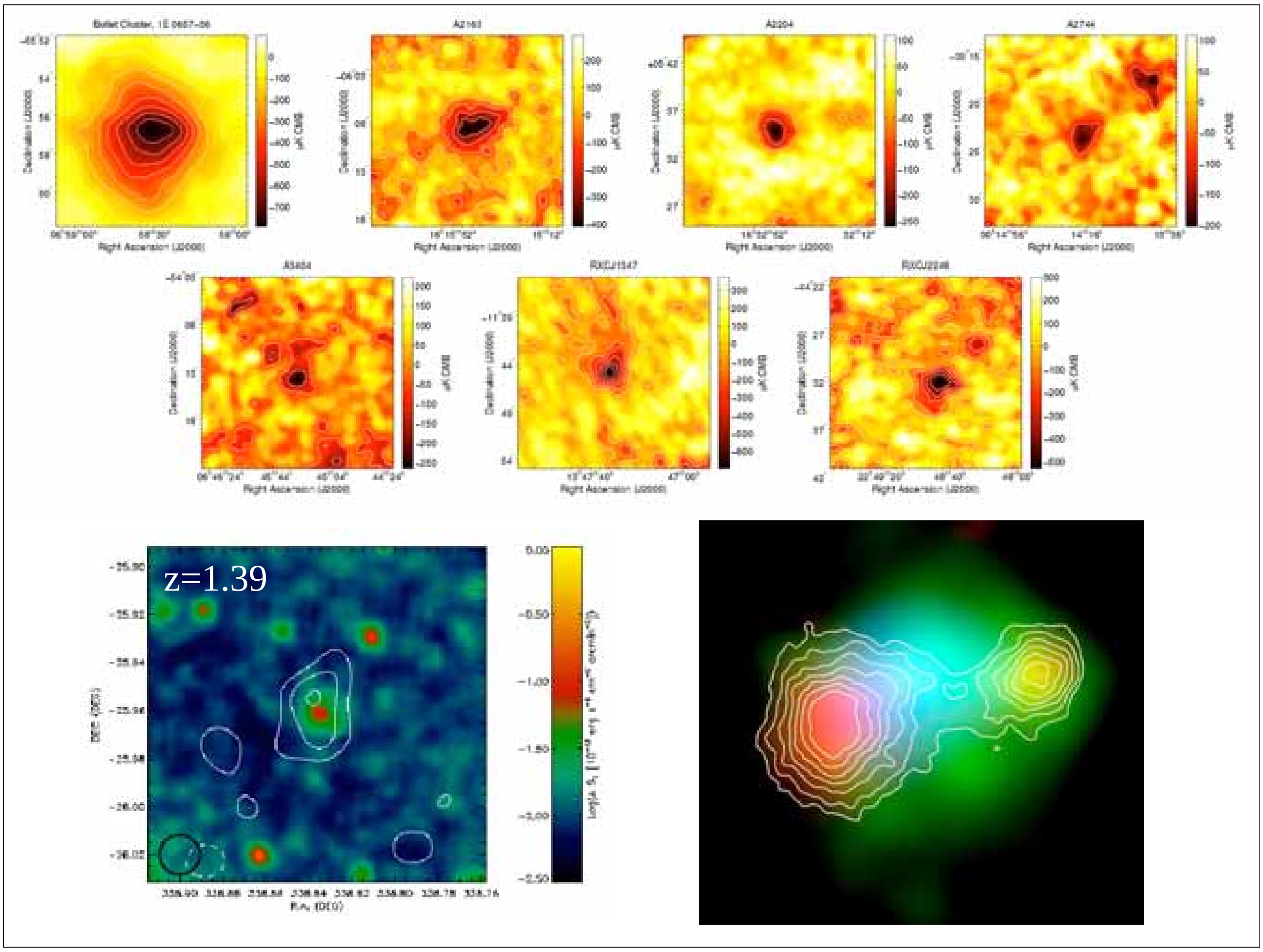
Need multi-wavelength follow-up.

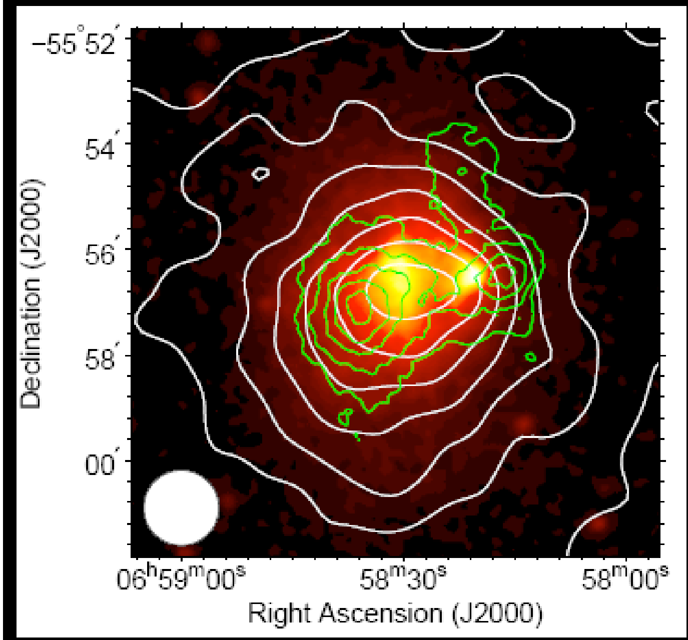




Combined measurement of X-ray, SZ, optical, and weak lensing cosmic shear will become a powerful tool to study structure of galaxy clusters.


z = 20.0
dark matter density
gas density
gas temperature
kinetic SZ
thermal SZ
gas shocks
4 Mpc/h


Bullet Cluster, 1E 0657-56
A2163
A2204
A2744
AS1063
RXCJ1347
RXCJ2248
Right Ascension (J2000)
Declination (J2000)
μK CMB
z=1.39
R.A. (DEG)
DEC (DEG)



The Bullet Cluster

White contours: APEX SZE measurement, 100 µK contours
Green contours: weak lensing surface mass reconstruction (Clowe et al 2006)
Colormap: XMM data, 0.5-2 KeV band

X-ray Surface Brightness

- Clusters are strong X-ray emitters of thermal Bremsstrahlung

$$S_x = \frac{1}{4\pi(1+z)^4} D_A \int n_e n_H \Lambda_{eH} d\zeta \propto \int n_e^2 T_x^{1/2} d\zeta$$

- X-rays give high S/N, high resolution picture of cluster centers
- Can determine T_x from spectra
- Drawbacks: highly sensitive to cluster structure, strong redshift dependence

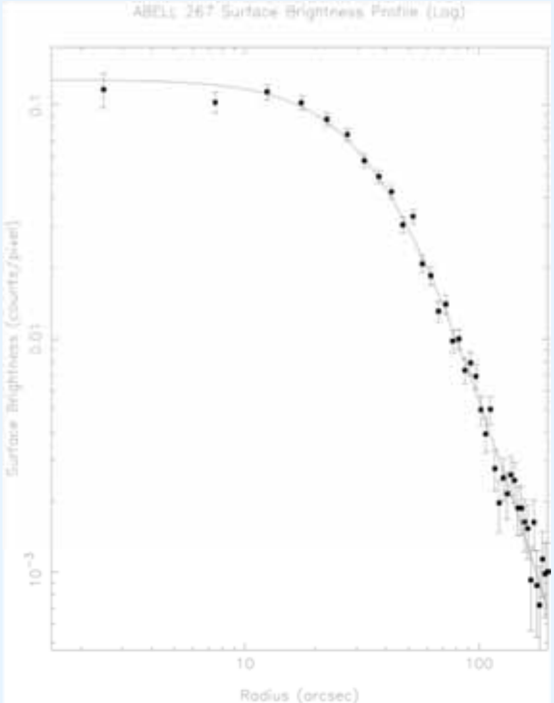
Spherical Isothermal β-Model

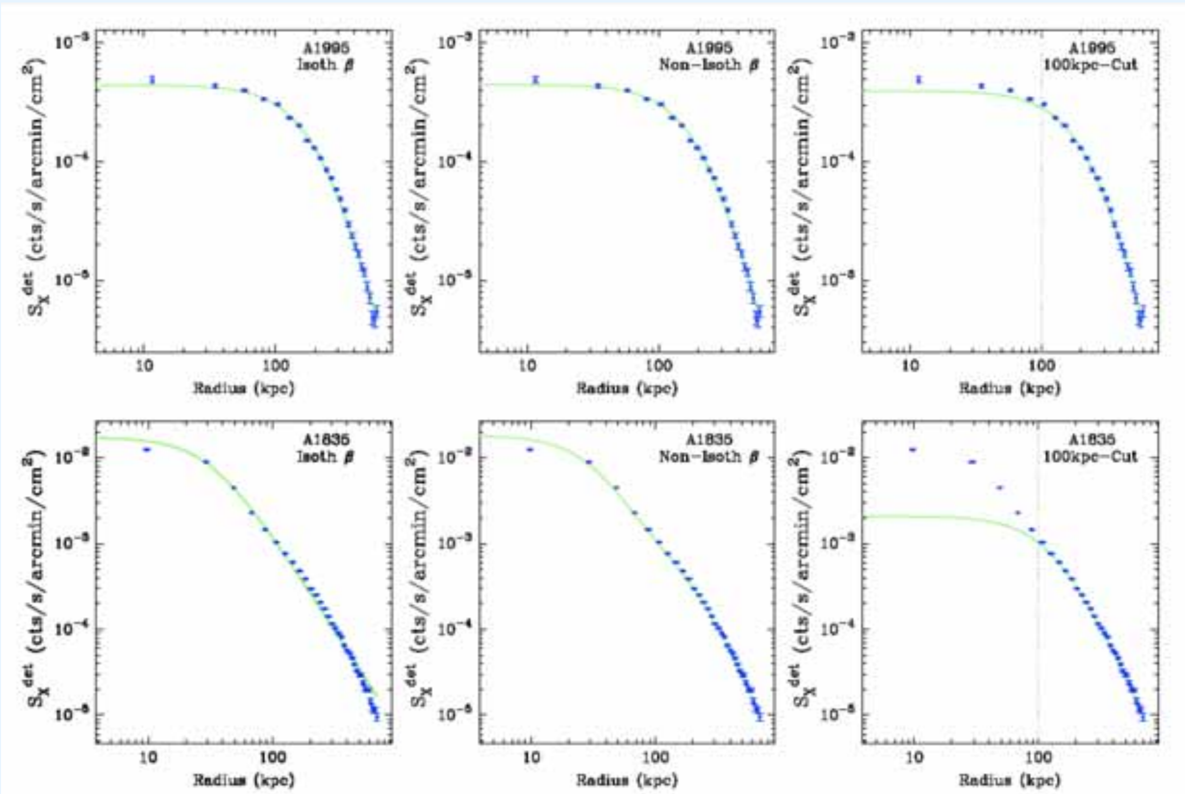
$$n_e(r) = n_{e0}\left(1 + {r^2}/{r_c^2}\right)^{-3\beta/2}$$

- consistently good empirical fit
- SZ and X-ray integrals have analytic solution
- n_{e0} also analytic

However, some clusters have peaked core, then take double-peaked profile:

$$n_e(\mathbf{r}) = n_{e_0}\left[f\left(1+\frac{r^2}{r_{c_1}^2}\right)^{-3\beta/2} + (1-f)\left(1+\frac{r^2}{r_{c_2}^2}\right)^{-3\beta/2}\right]$$





LaRoque et al. 2006, ApJ 652, 917

Calculating Gas Masses

- First solve for n_{e0}:

$$n_{e0} = \frac{\Delta T_0}{f_{(x,T_e)} T_{\mathrm{CMB}}} \frac{m_e c^2}{\sigma_T k_B T_e} \left[D_A \int \left(1 + \frac{\theta^2}{\theta_c^2}\right)^{-3\beta/2} d\theta \right]^{-1} \quad \text{(SZ)}$$

$$n_{e0} = \left\{ \frac{S_{x0} 4\pi (1+z)^4 \mu_H}{\Lambda_{eH} \mu_e} \left[D_A \int \left(1 + \frac{\theta^2}{\theta_c^2}\right)^{-3\beta/2} d\theta \right]^{-1} \right\}^{1/2} \quad \text{(X-ray)}$$

- Then integrate over density distribution to get mass:

$$M_{\mathrm{gas}}(r_0) = 4\pi \mu_e n_{e0} m_p \int_0^{r_0} \left(1 + \frac{r^2}{r_c^2}\right)^{-3\beta/2} r^2 dr$$

Calculating Total Mass

- Total gravitational mass comes from assuming ICM is in hydrostatic equilibrium with dark matter distribution:

$$M_{\mathrm{tot}}(r_0) = \frac{3 k_B T_x \beta}{G \mu m_p} \frac{r_0^3}{r_c^2 + r_0^2}$$

- Same for both SZ and X-ray
- Depends only on *shape* of gas distribution

From Cluster Masses to Ω_M

- Mass composition of clusters reflects universal mass composition:

$$f_g \leq f_B = \frac{\Omega_B}{\Omega_M} \Rightarrow \Omega_M \leq \Omega_B / f_g$$

- Get Ω_B from Big Bang Nucleosynthesis measurements
- Get mean f_g from clusters
- Comparison of SZ and X-ray results sheds light on cluster systematic uncertainties = structure

Results for Ω_M

Assume Ω_B = 0.0205 +- 0.018 h^{-2} (O'Meara et al. 2001)

Assume cluster galaxies contribute 0.20 $h^{3/2}$ M_{gas} to the cluster mass in baryons (White et al. 1993)

Assume 10% of baryons are lost in cluster formation

For h=0.7:

X-ray: $f_g = 0.094 \pm 0.002 \rightarrow \Omega_M \leq 0.36$

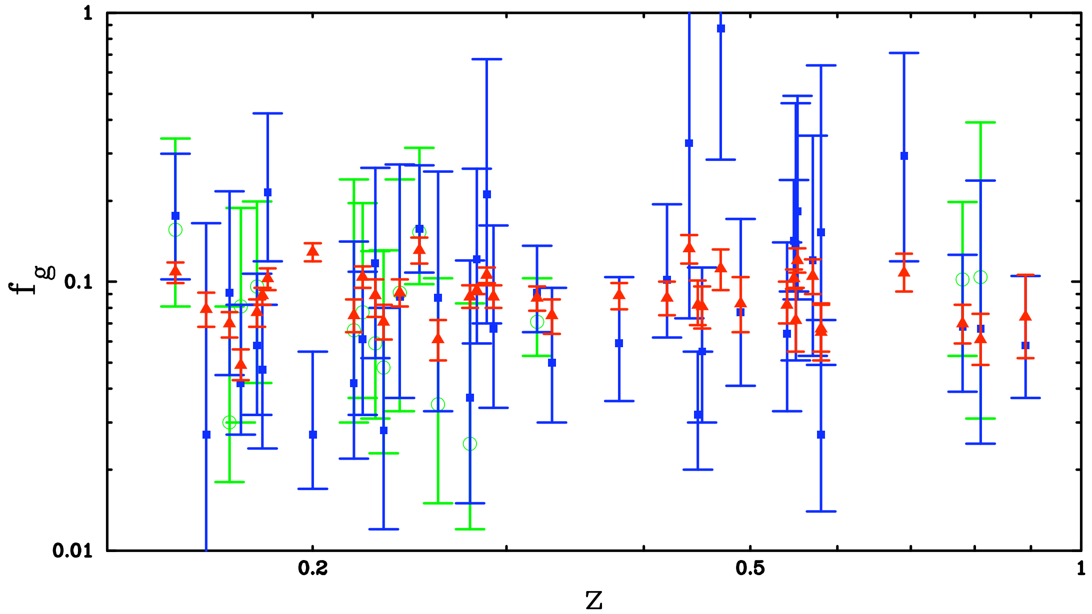
SZ: $f_g = 0.083^{+0.010}_{-0.007} \rightarrow \Omega_M \leq 0.41$

Systematic Uncertainties

- Hydrostatic equilibrium: may be other means of support, like turbulence or magnetic fields
- Clumping: small-scale changes in density field could enhance S_x
- Temperature structure: *Chandra* and *XMM* have shown that clusters are not isothermal

X-Ray and Sunyaev-Zel'dovich Effect Measurements of the **Gas Mass Fraction** in Galaxy Clusters

LaRoque et al. 2006, ApJ 652, 917



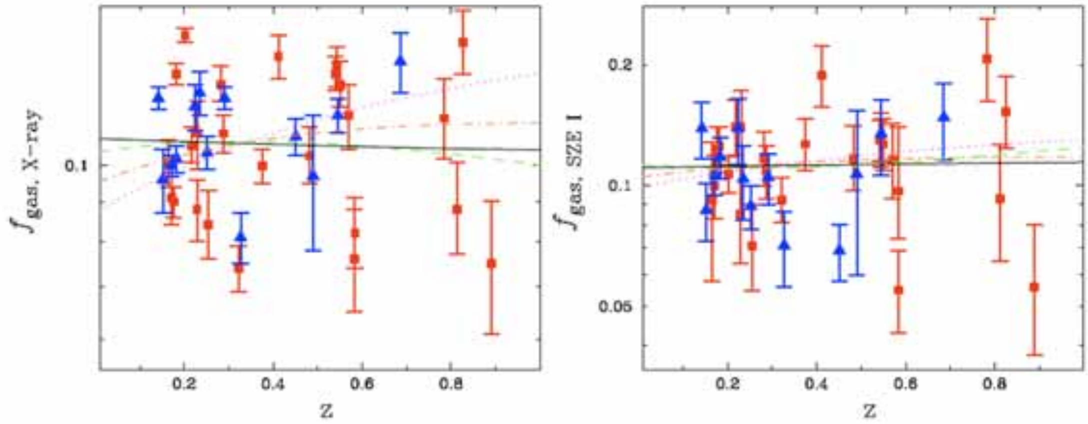


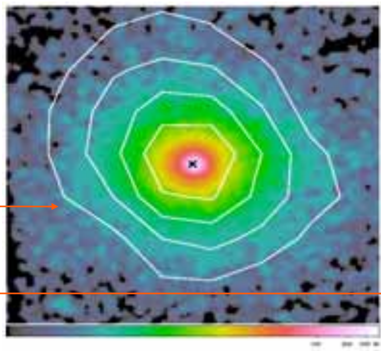
Fig. 4.—: 100 kpc-cut derived gas mass fractions versus redshift for X-ray (left) and SZE I (right) data, showing best fit models for different cosmologies. The solid lines (black) show the best fit cosmologies when the prior $\Omega_M + \Omega_\Lambda = 1.00$ is assumed. The dashed (green) lines show the best fit cosmologies when no prior is assumed. The dash-dotted (orange) lines show the best fit normalization when an Ω_M=0.3, Ω_Λ=0 cosmology is assumed, and the dotted (magenta) line shows the best fit normalization for a cosmology with Ω_M=1.0, Ω_Λ=0.

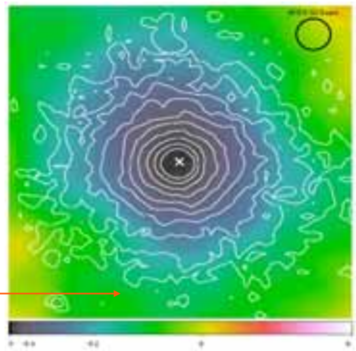
ICM temperature de-projection

Abell 2204:
Prototypical relaxed Cluster

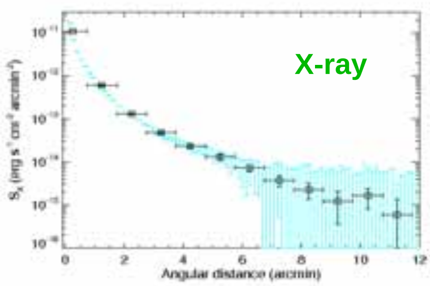
X-ray image with SZ contours

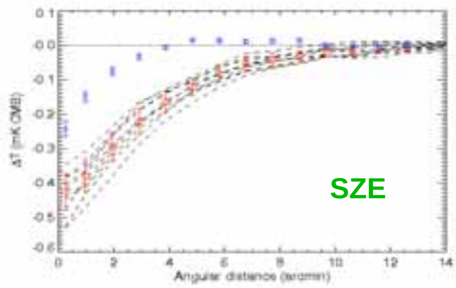
SZ image with X-ray contours





Abell 2204, Basu, Zhang, Nord et al.



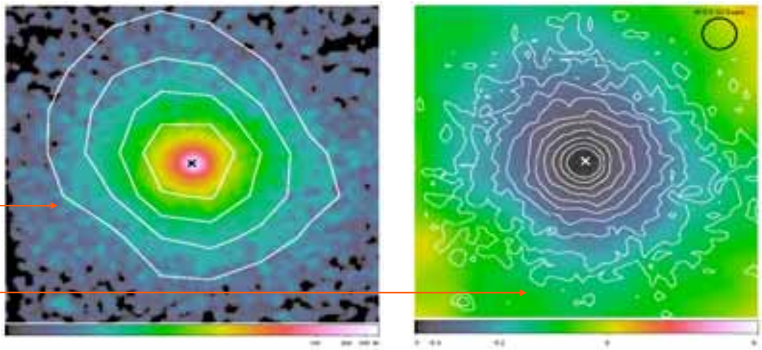


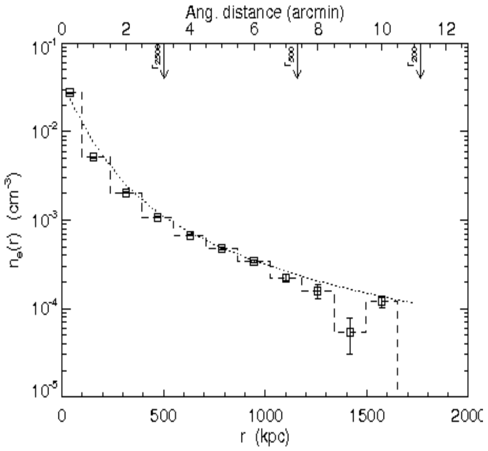
ICM temperature de-projection

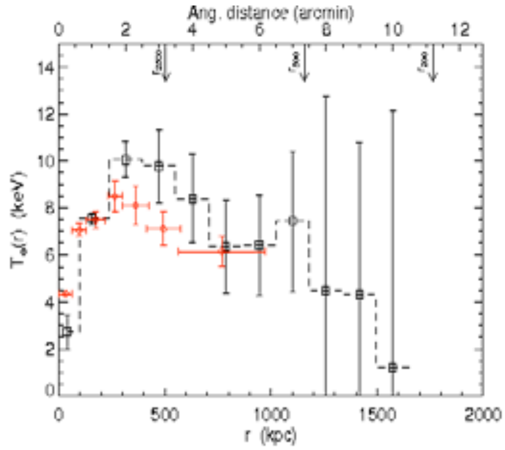
Abell 2204:
Prototypical relaxed Cluster

X-ray image with SZ contours

SZ image with X-ray contours



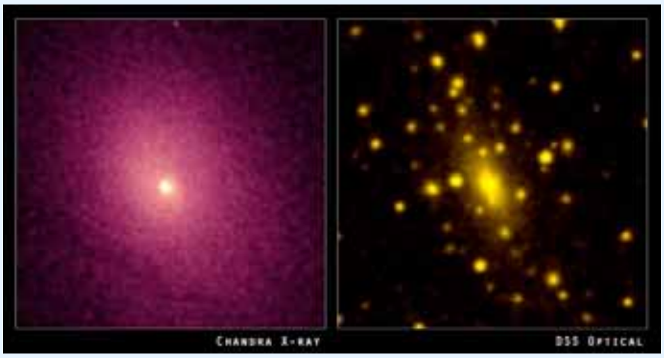




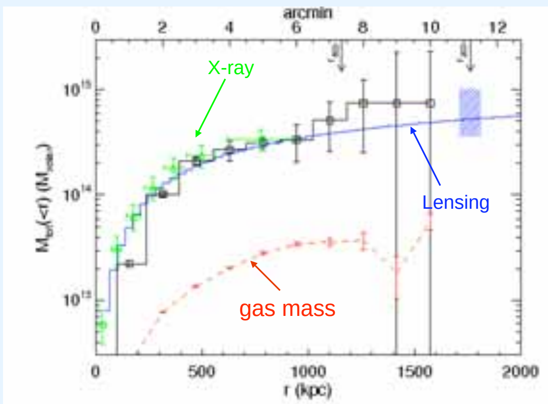
Direct de-projection of density and temperature.
<u>No parametric modeling!</u>

59

Mass profiles



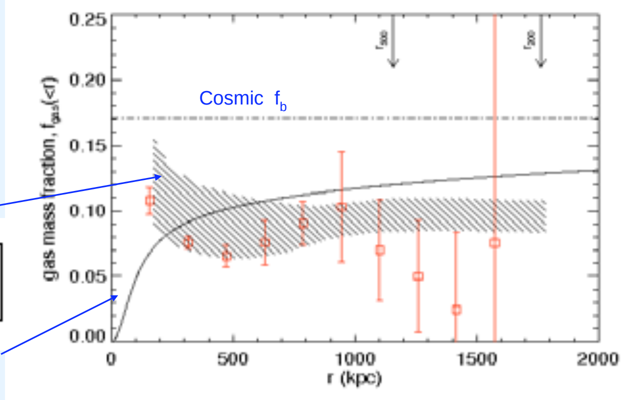
Abell 2204
Basu, Zhang, Nord et al.



Gas in hydrostatic equilibrium inside the dark matter potential well

$$\frac{1}{\rho_g}\frac{dP}{dr} = -\frac{d\phi}{dr} = -\frac{GM(<r)}{r^2}$$

$$M_{tot}(<r) \propto -T_e(r)\left[\frac{d\ln n_e(r)}{d\ln r} + \frac{d\ln T_e(r)}{d\ln r}\right]$$



Prospects:

SZ surveys will produce precision cosmological constraints competitive with SN 1a surveys and CMB anisotropy.

Tasks ahead and along:

- evolution of cluster properties:
  size, temperature, structure, virialization

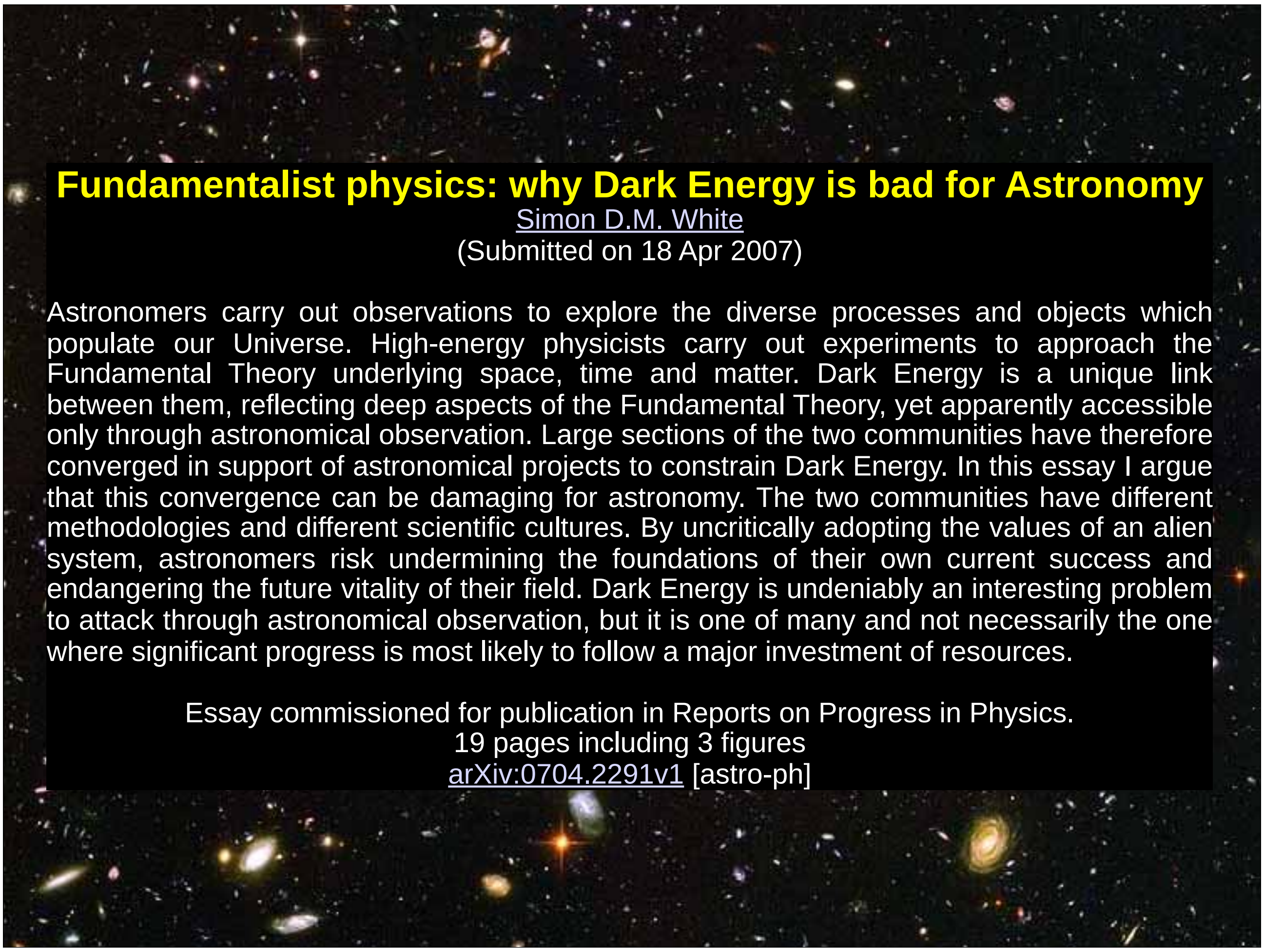
Tune Observable-Mass relation !!

- Non-gravitational heating (star formation) and chemical enrichment.
- Evolution of galaxy populations in clusters (nothing known at z>1)

REPORT OF THE DARK ENERGY TASK FORCE

Dark energy appears to be the dominant component of the physical Universe, yet there is no persuasive theoretical explanation for its existence or magnitude. The acceleration of the Universe is, along with dark matter, the observed phenomenon that most directly demonstrates that our theories of fundamental particles and gravity are either incorrect or incomplete. Most experts believe that nothing short of a revolution in our understanding of fundamental physics will be required to achieve a full understanding of the cosmic acceleration. For these reasons, the nature of dark energy ranks among the very most compelling of all outstanding problems in physical science. These circumstances demand an ambitious observational program to determine the dark energy properties as well as possible.

The Dark Energy Task Force (DETF) was established by the Astronomy and Astrophysics Advisory Committee (AAAC) and the High Energy Physics Advisory Panel (HEPAP) as a joint sub-committee to advise the Department of Energy, the National Aeronautics and Space Administration, and the National Science Foundation on future dark energy research.



Fundamentalist physics: why Dark Energy is bad for Astronomy

Simon D.M. White

(Submitted on 18 Apr 2007)

Astronomers carry out observations to explore the diverse processes and objects which populate our Universe. High-energy physicists carry out experiments to approach the Fundamental Theory underlying space, time and matter. Dark Energy is a unique link between them, reflecting deep aspects of the Fundamental Theory, yet apparently accessible only through astronomical observation. Large sections of the two communities have therefore converged in support of astronomical projects to constrain Dark Energy. In this essay I argue that this convergence can be damaging for astronomy. The two communities have different methodologies and different scientific cultures. By uncritically adopting the values of an alien system, astronomers risk undermining the foundations of their own current success and endangering the future vitality of their field. Dark Energy is undeniably an interesting problem to attack through astronomical observation, but it is one of many and not necessarily the one where significant progress is most likely to follow a major investment of resources.

Essay commissioned for publication in Reports on Progress in Physics.
19 pages including 3 figures
arXiv:0704.2291v1 [astro-ph]

APEX Base Camp near
San Pedro de Atacama
2400m, 76km from APEX