Title: Probing Cosmology and Cluster Structure with the Sunyaevâ€“Zelâ€™dovich Decrement vs. Xâ€“ray Temperature Scaling Relation

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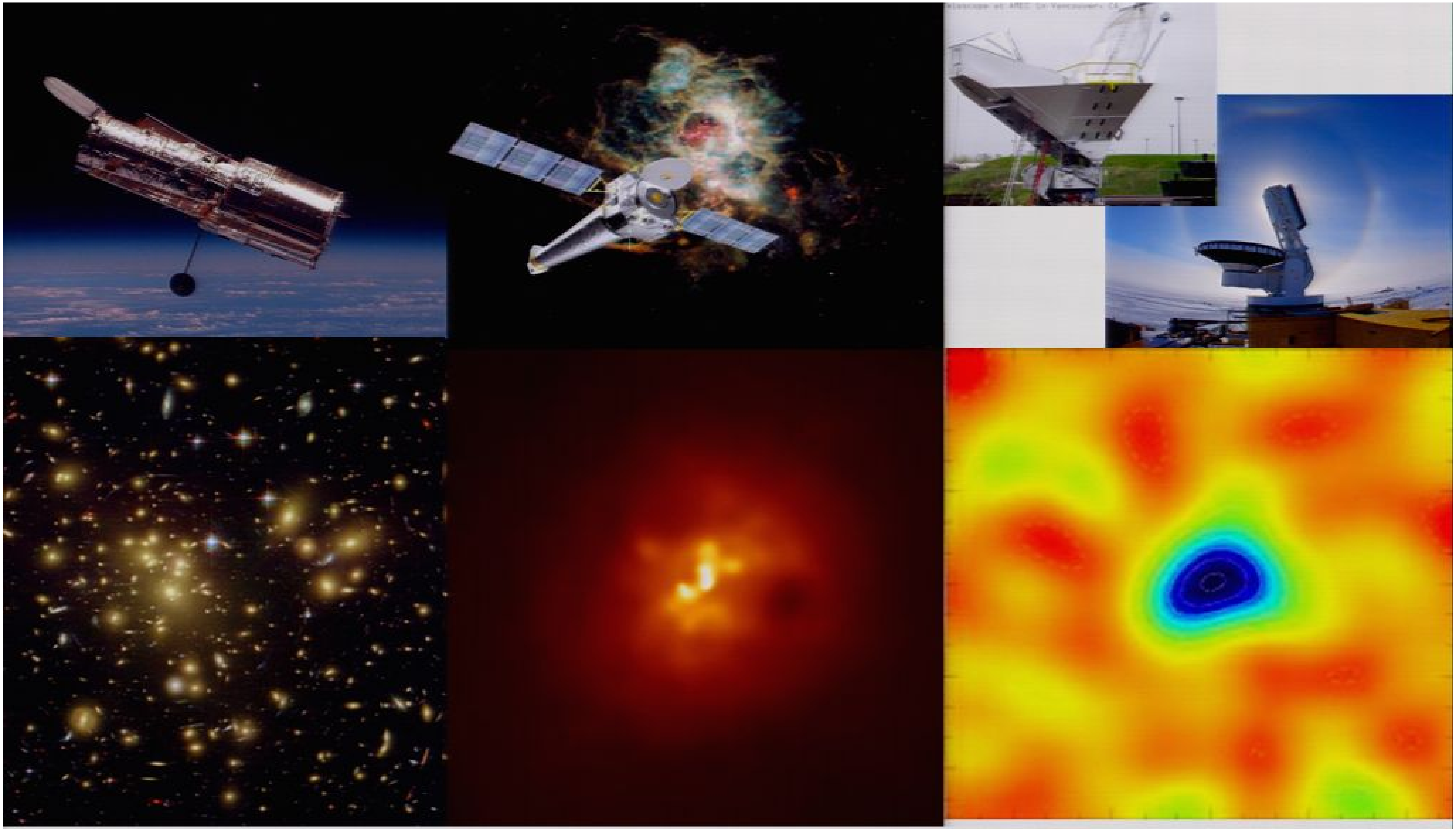
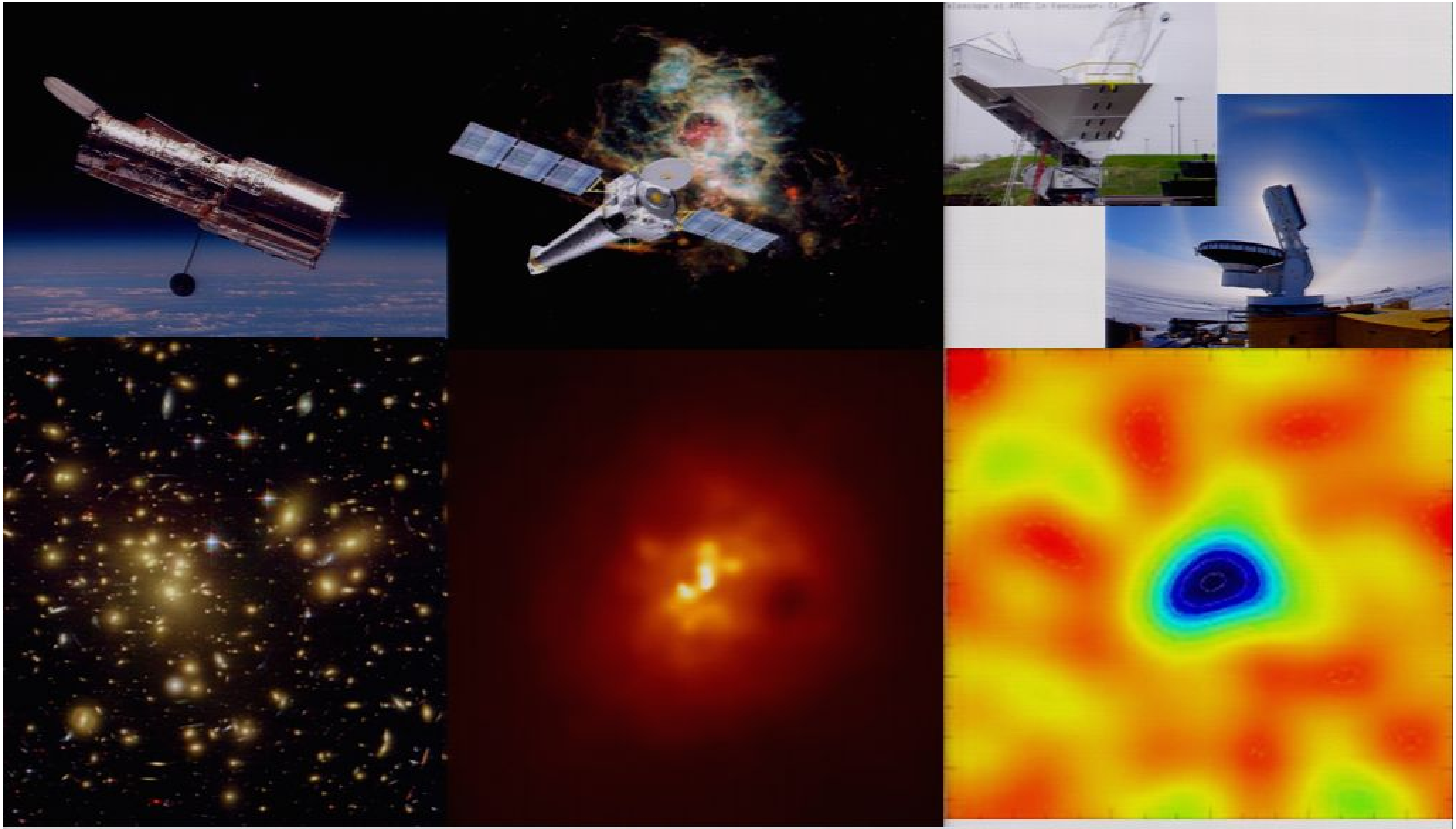
Abstract: Scaling relations among galaxy cluster observables, which will become available in large future samples of galaxy clusters, could be used to constrain not only cluster structure,but also cosmology. I will discuss the utility of this approach, employing a physically motivated parametric model to describe cluster structure, and applying it to the expected relation between the Sunyaev-Zelâ€™dovich decrement (S_{\nu}) and the emissionâ€“weighted Xâ€“ray temperature (Tew). With a suitable choice of fiducial parameter values, the cluster model satisfies several existing observational constraints. A Fisher matrix is employed to estimate the joint errors on cosmological and cluster structure parameters from a measurement of S_{\nu} vs. Tew in a future survey. I will also compare the cosmology constraints from the scaling relation to those expected from the number counts (dN/dz) of the same clusters.

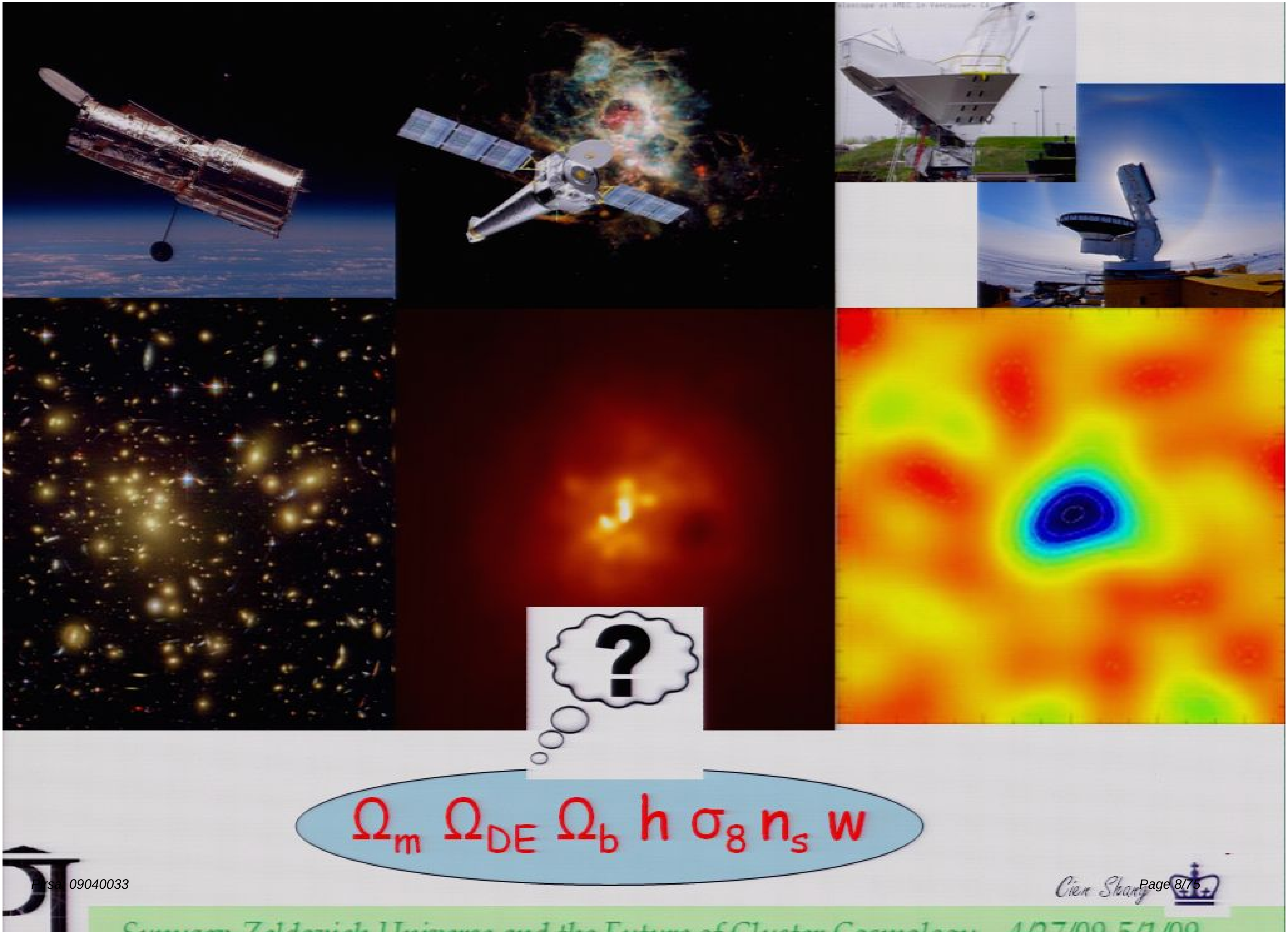
Probe Cosmology with SZ decrement vs T_{xray} Scaling Relation

Shang, Haiman & Verde





$\Omega_m \ \Omega_{DE} \ \Omega_b \ h \ \sigma_8 \ n_s \ w$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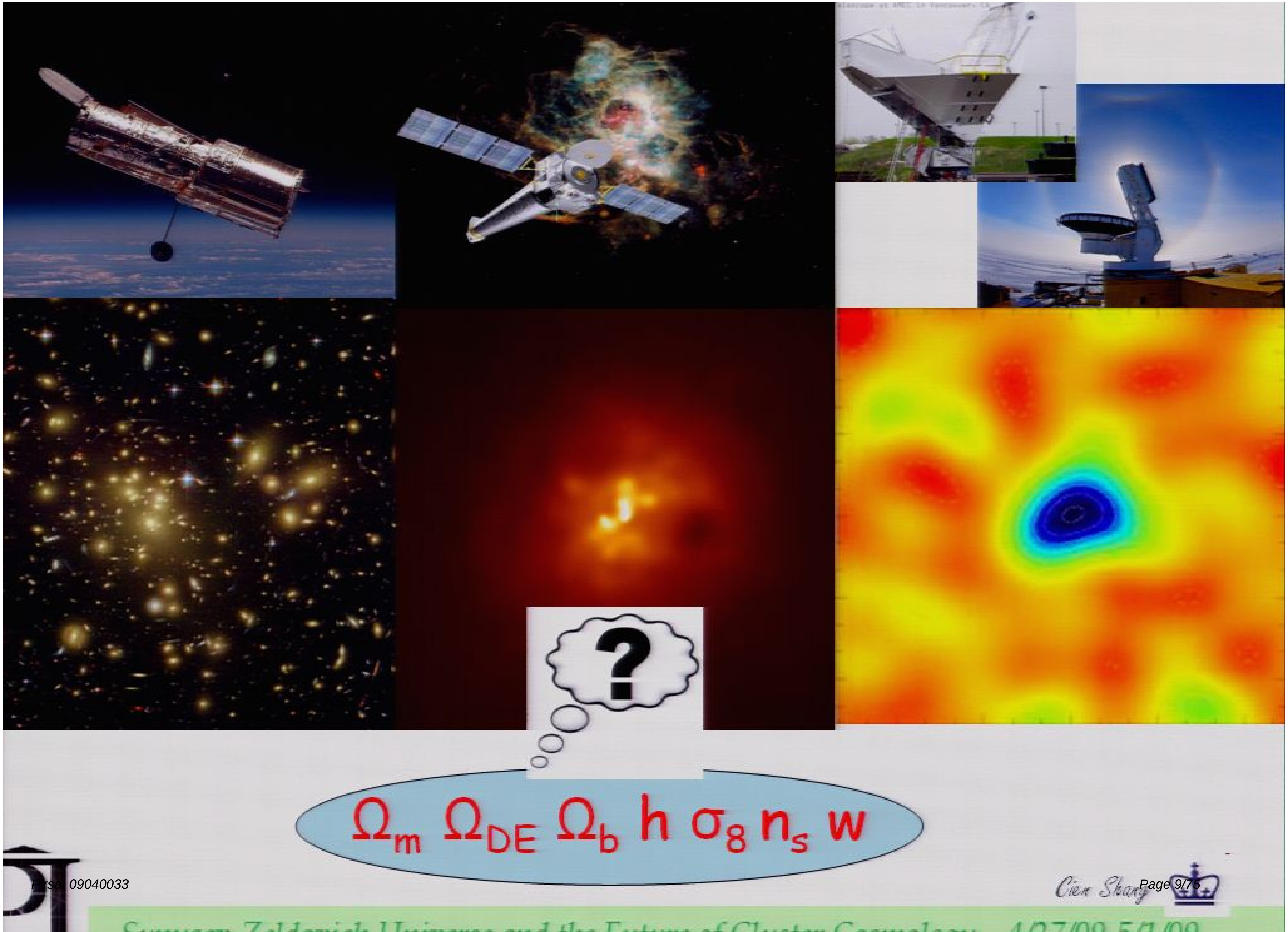
Ω_m Ω_{DE} Ω_b h σ_8 n_s w
Cien Shang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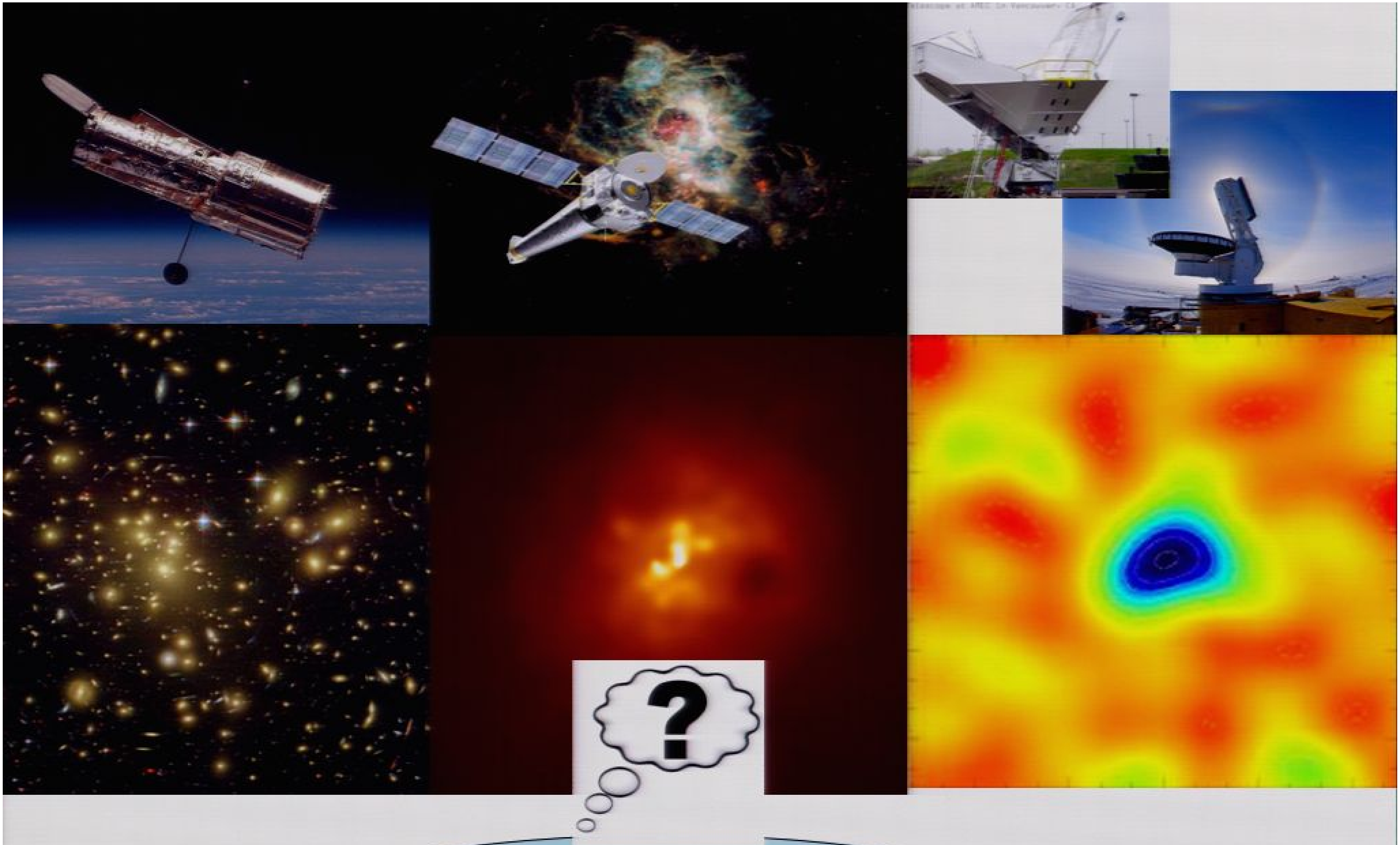
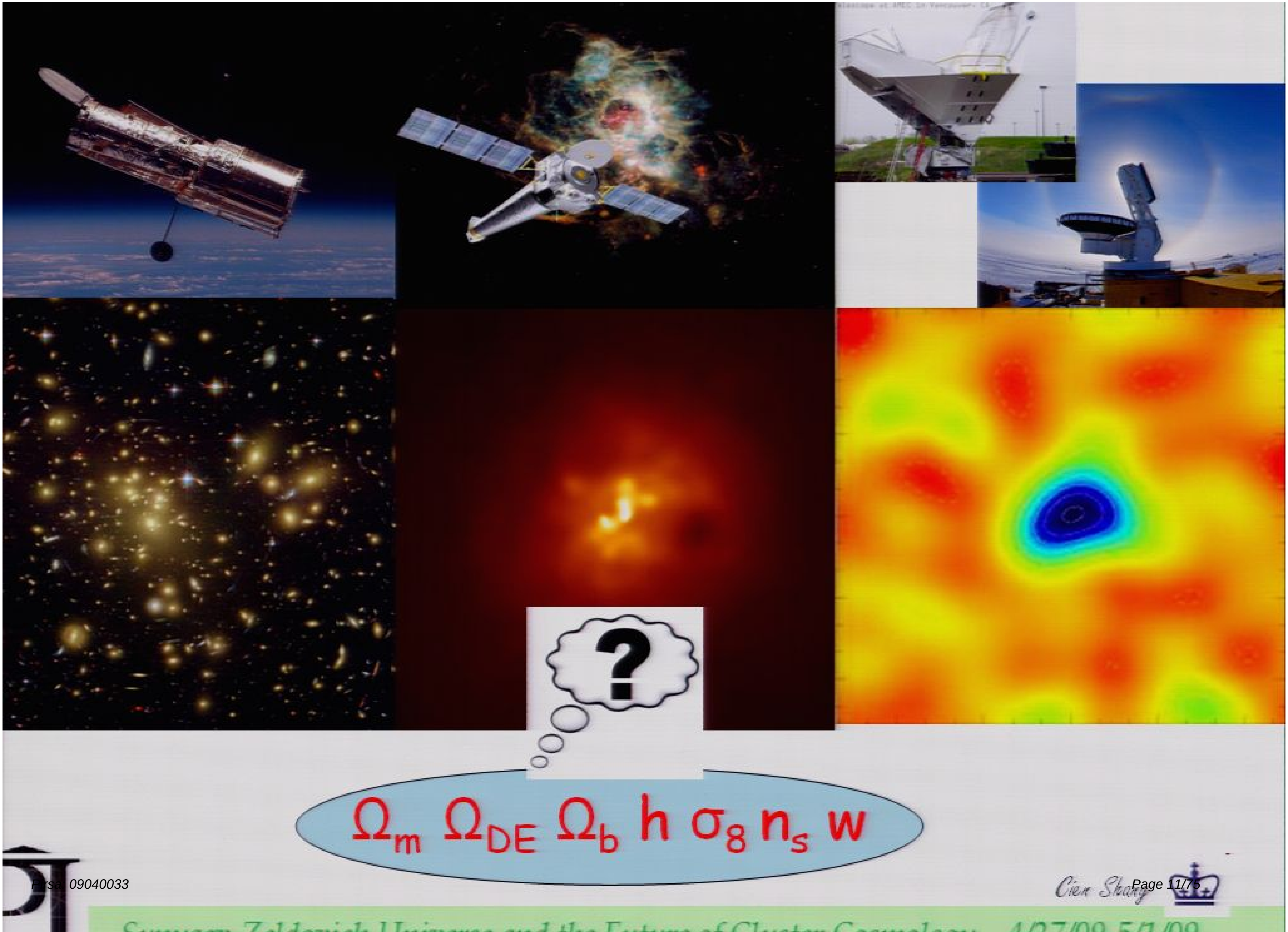
$\Omega_m\ \Omega_{DE}\ \Omega_b\ h\ \sigma_8\ n_s\ w$



$\Omega_m \; \Omega_{DE} \; \Omega_b \; h \; \sigma_8 \; n_s \; w$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Ω_m Ω_{DE} Ω_b h σ_8 n_s w
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Z vs X Ray

1. Count cluster number

XTF, XLF (Vikhlinin et al 2009)

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2. Use cluster as a standard ruler

f_{gas} (Allen et al 2008)

Z vs X Ray

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Maybe scaling relation of
SZ vs X-ray??

Basic Idea

Scaling relations depend on background cosmology. (Verde et al. 2002)

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Why SZ decrement vs X temperature?

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Why SZ decrement vs X temperature?

1. Different dependence on cosmology

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Scaling relations depend on background cosmology. (Verde et al. 2002)

Why SZ decrement vs X temperature?

1. Different dependence on cosmology
2. Robustness to cluster structure

Cluster Model

Z vs X Ray

Cluster Model

In dream: $Y_{sz}=\Omega_m+\Omega_{DE}\times\ \Omega_b/T_x^{ns}-\ h/w^{\sigma 8}T_x$

Cluster Model

SZ vs X Ray

Cluster Model

In reality:

Z vs X Ray

Cluster Model

In reality:

Entropy profile: $K(x)=K\,K_{vir}\,x^{s}$

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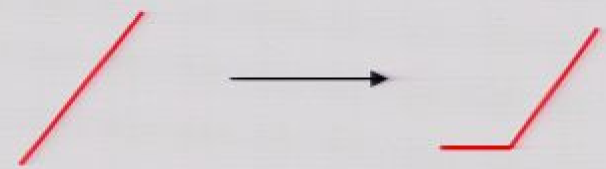

Z vs X Ray

Cluster Model

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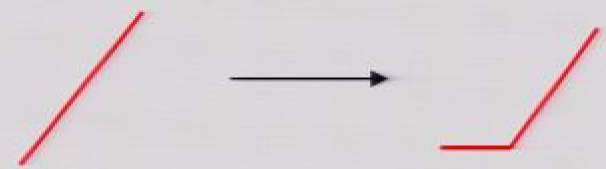

Dark matter halo gravitational potential:

NFW profile $\rho = \dfrac{\delta_c \rho_c}{(r/r_s)(1+r/r_s)^2}$ $c = R_{vir}/r_s$

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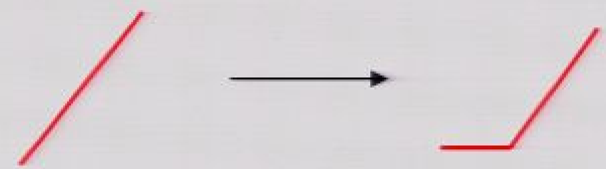

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Equations of hydrostatic equilibrium:

$d\,P(r)/dr = -\eta \rho_g(r) G M_{tot}/r^2$

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K s c η b : 5

Cluster Model

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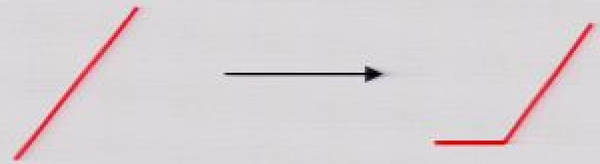

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K s c η b : 5 ⟶ 15

$p = p_{norm}(M/M^*)^{pm}(1+z)^{pz}$

SZ vs X Ray

Cluster Model

Observables:

Cluster Model

SZ vs X Ray

Observables:

$S_\nu = j_\nu Y$

$$Y = \frac{\sigma_T k_B}{m_e c^2 D_A^2} \int n_e T dV_{\text{cluster}}$$

SZ vs X Ray

Cluster Model

Observables:

$S_\nu = j_\nu Y$

$$Y = \frac{\sigma_\mathrm{T} k_\mathrm{B}}{m_e c^2 D_A^2} \int n_e T dV_\mathrm{cluster}$$

T_{ew}

$$T_\mathrm{ew} = \frac{\int_{0.15R_{500}}^{R_{500}} 4\pi r^2 dr \int d\nu \rho_g^2(r) \Lambda(\nu, T) T(r)}{\int_{0.15R_{500}}^{R_{500}} 4\pi r^2 dr \int d\nu \rho_g^2(r) \Lambda(\nu, T)}$$

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10% scatter between Y and T,
T and M

SZ vs X Ray

Cluster Model

Fiducial Values (K s):

s=1.1

K_{norm}=2.4 K_m=-1.2 K_z=0

SZ vs X Ray

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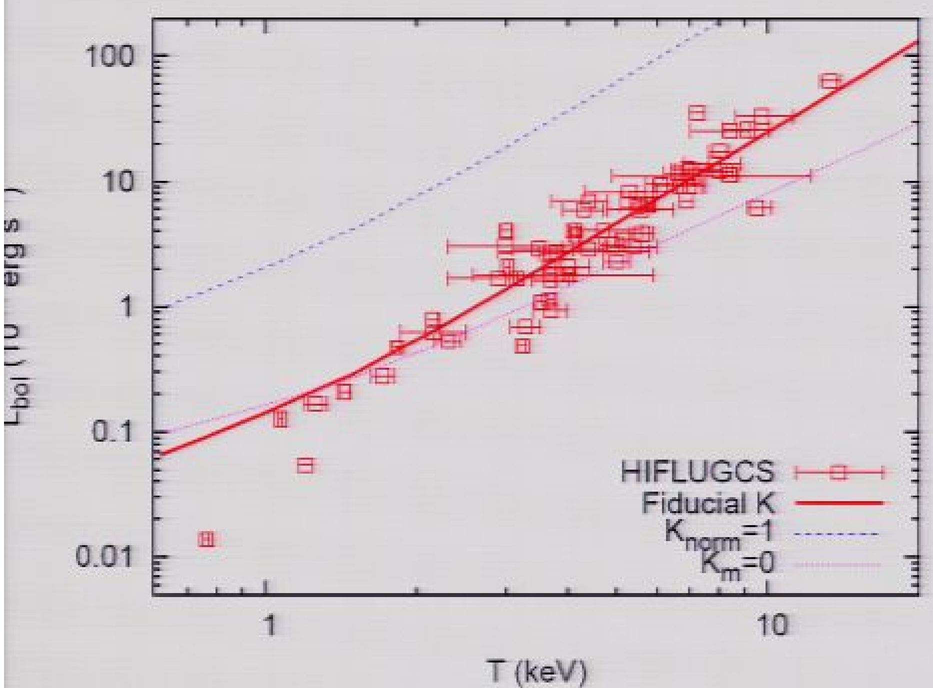

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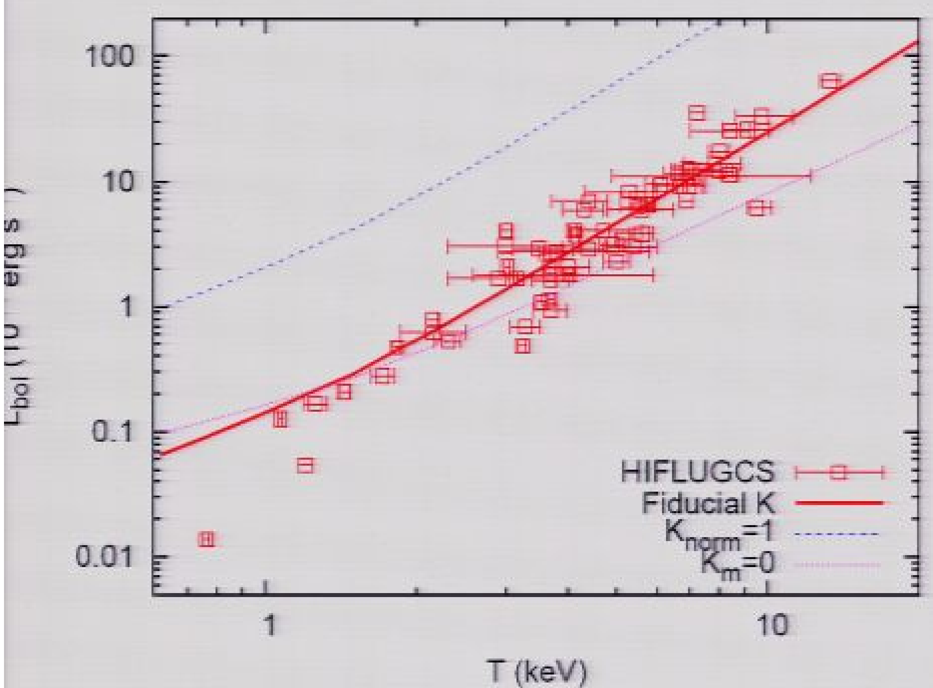

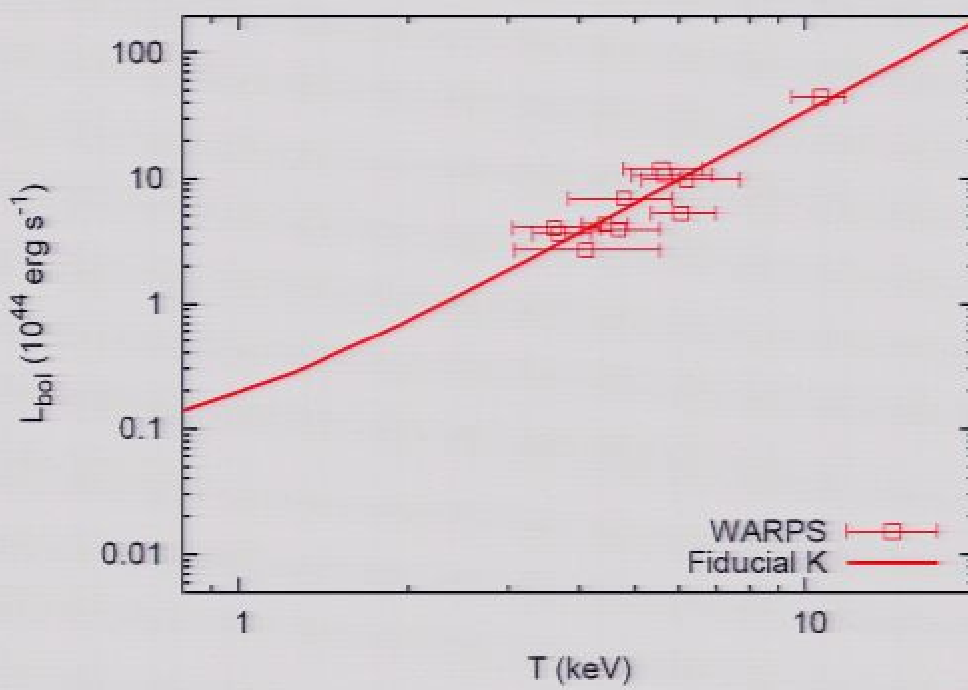

Cluster Model

Fiducial Values (c η b):

$c(M,z)=8.5(M/10^{15}h^{-1})^{-0.086}\,(1+z)^{-0.65}$

$\eta=0.9$ $\qquad$ $b=1$

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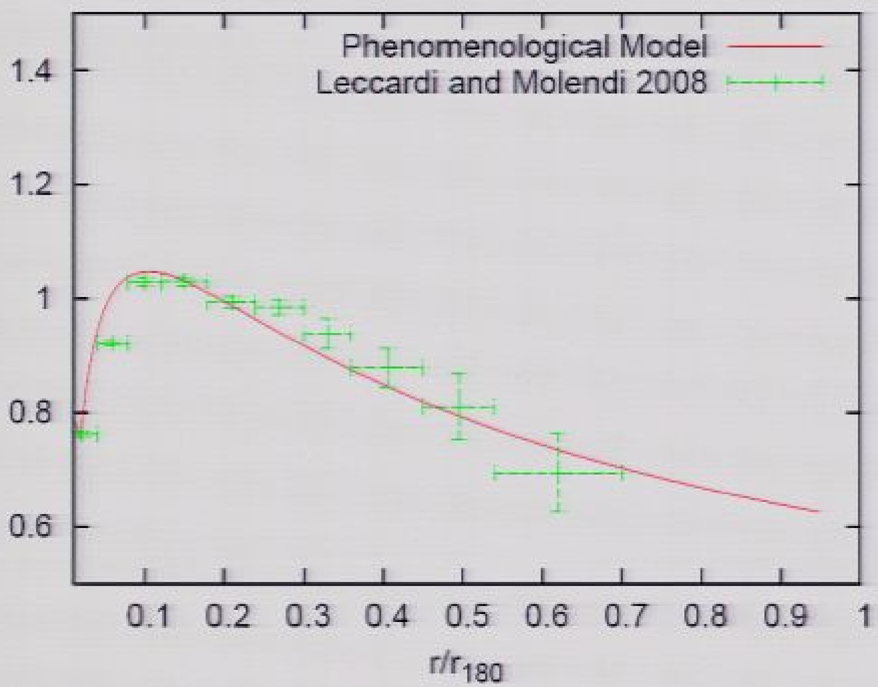

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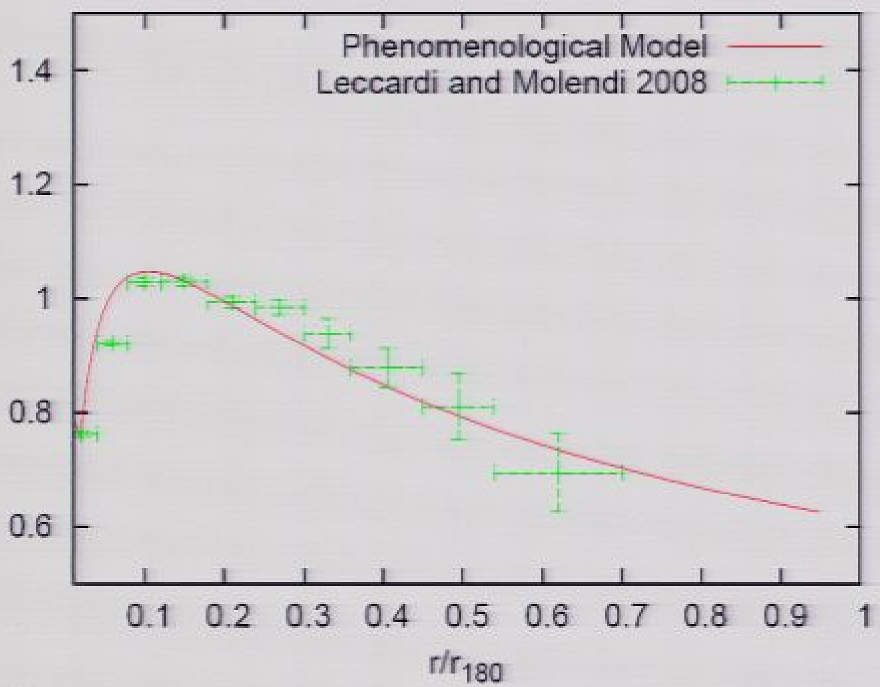

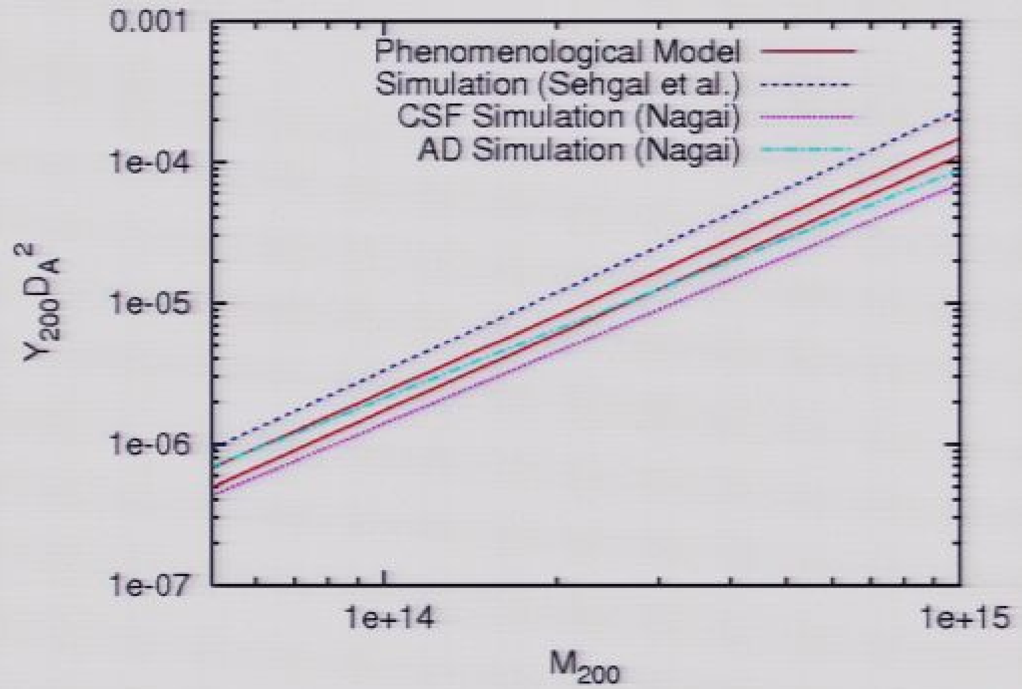

Survey

Sky coverage: 4,000 deg^2

Frequency: 145 GHz

Noise σ: 1mJy

Redshift range: 0-2

Redshift bin width: 0.05

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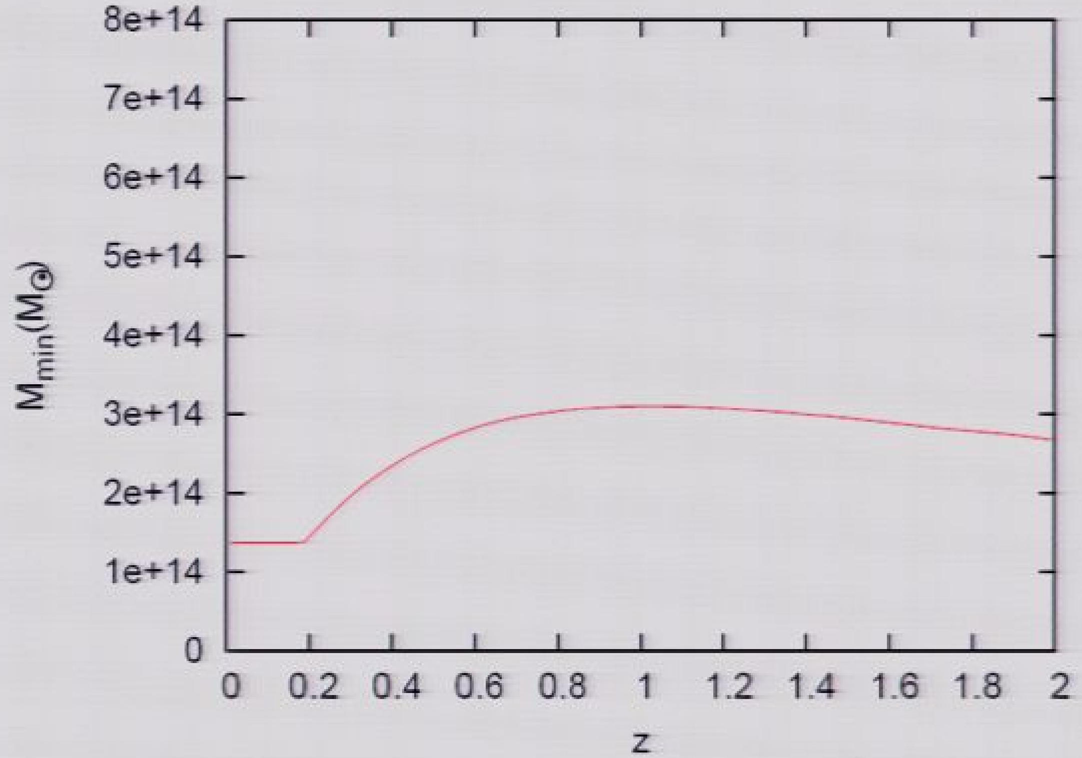
5σ detection



Survey

SZ vs X Ray

Sky coverage: 4,000 deg^2

Frequency: 145 GHz

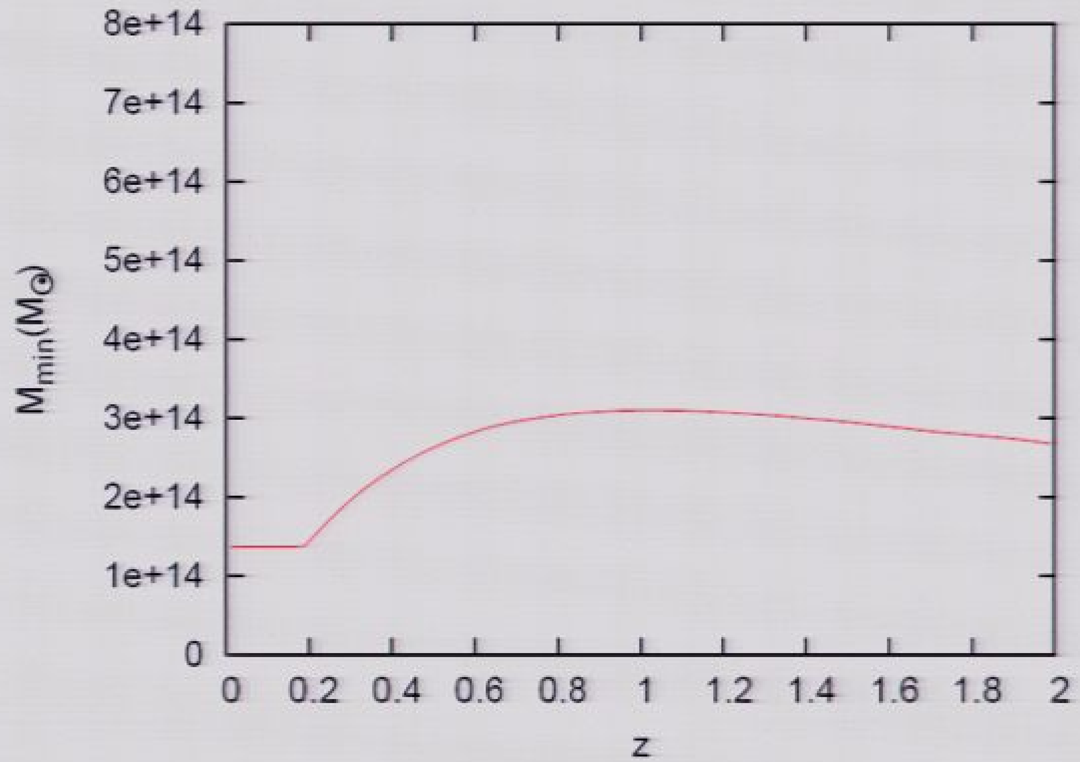
Noise σ: 1mJy

Redshift range: 0-2

Redshift bin width: 0.05

5σ detection

Number of clusters: 6,800



Fisher Matrix

Z vs X Ray

Fisher Matrix

Scaling Relation (SR):

$$F_{ij}^{\mathrm{sr.single}} = \frac{1}{\sigma^2_{Y,T}} \left.\frac{\partial Y}{\partial p_i}\right|_{T_{\mathrm{ew}}} \left.\frac{\partial Y}{\partial p_j}\right|_{T_{\mathrm{ew}}}$$

Z vs X Ray

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$\sigma_{detector}{}^2 + \sigma_{scatter}{}^2$

Fisher Matrix

Z vs X Ray

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$\sigma_{detector}{}^2 + \sigma_{scatter}{}^2$

Number Counts (NC):

$$F_{ij}^{nc.total} = \sum_{\alpha=1}^{N_z} \sum_{\beta=1}^{N_y} \frac{1}{N_{\alpha\beta}} \frac{\partial N_{\alpha\beta}}{\partial p_i} \frac{\partial N_{\alpha\beta}}{\partial p_j}$$

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N_z: # of z bins

N_y: # of Y bins

Z vs X Ray

Fisher Matrix

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N_z: # of z bins

N_y: # of Y bins

Ω_m Ω_{DE} Ω_b h σ_8 n_s w_0 w_a

Z vs X Ray

Constraints

	Ω_m	Ω_{DE}	Ω_b	h	w_0	w_a	σ_8	n_s
Idealized(8):								
SR	0.055	0.20	0.012	0.08	0.037	0.21	-	-
NC	0.023	0.29	0.007	0.11	0.20	1.4	0.016	0.13

Z vs X Ray

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Realistic(8+15):

Z vs X Ray

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SR	0.087	0.28	0.08	0.12	0.53	0.64	-	-
NC	0.068	0.34	0.10	0.14	0.34	1.63	0.055	0.87

Z vs X Ray

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Where constraints come from

Z vs X Ray

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$$Y \propto D_A^{-2} M_{gas} T \sim D_A^{-2} f_{gas} M_{vir} T$$

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$$\sim D_A^{-2} f_{gas} \rho_{vir}^{-0.5} T^{2.5}$$

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$D_A : \Omega_{DE}\ h\ w_0\ w_a$

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D_A : Ω_{DE} h w_0 w_a

f_{gas} : Ω_m Ω_b ($f_{gas} \sim \Omega_b / \Omega_m$)

ρ_{vir} : w_0 w_a (Kuhlen et al 2005)

Z vs X Ray

Where constraints come from

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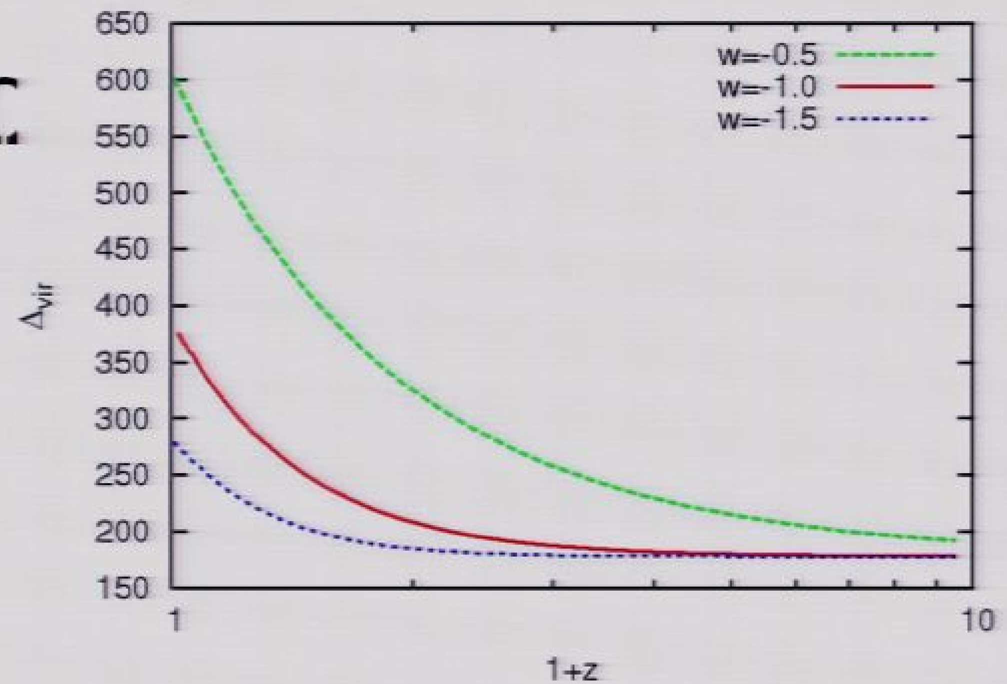

Z vs X Ray

Comparison SR & NC

Cluster abundance is more sensitive to cosmology.

SZ vs X Ray

Comparison SR & NC

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What makes SR competitive:

Z vs X Ray

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- Additional info from T

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- More data points (6800 vs 320)

Comparison SR & NC

Cluster abundance is more sensitive to cosmology.

What makes SR competitive:

- Additional info from T
- More data points (6800 vs 320)
- Smaller error

Z vs X Ray

Combine SR & NC

	Ω_m	Ω_{DE}	Ω_b	h	w_0	w_a	σ_8	n_s
Idealized(8):								
σ	0.009	0.06	0.037	0.05	0.016	0.11	0.007	0.036
	0.17	0.13	0.36	0.62	0.20	0.29	0.19	0.08

$\xi=\sigma^2_{joint}/\sigma^2_{quadrature}$

Z vs X Ray

Combine SR & NC

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Idealized(8):

σ	0.009	0.06	0.037	0.05	0.016	0.11	0.007	0.036
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Realistic(8+15): $\xi=\sigma^2_{joint}/\sigma^2_{quadrature}$

σ	0.038	0.15	0.038	0.075	0.22	0.45	0.033	0.46
	0.50	0.46	0.38	0.70	0.58	0.58	0.36	0.28

Prior of 0.1

	Ω_m	Ω_{DE}	Ω_b	h	w_0	w_a	σ_8	n_s
No prior								
SR	0.087	0.28	0.08	0.12	0.53	0.64	-	-
NC	0.068	0.34	0.10	0.14	0.34	1.63	0.055	0.87

Z vs X Ray

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NC	0.068	0.34	0.10	0.14	0.34	1.63	0.055	0.87
rior of 0.1								
SR	0.064	0.24	0.016	0.089	0.17	0.34	-	-
NC	0.029	0.30	0.012	0.11	0.21	1.45	0.023	0.27

Followup to Z=1

	Ω_m	Ω_{DE}	Ω_b	h	w_0	w_a	σ_8	n_s
Idealized(8):								
σ	0.066	0.23	0.014	0.081	0.050	0.23	-	-
R	1.2	1.1	1.2	1.1	1.4	1.1	-	-

$R=\sigma(z{:}0\text{-}1)/\sigma(z{:}0\text{-}2)$

Z vs X Ray

Followup to Z=1

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σ	0.066	0.23	0.014	0.081	0.050	0.23	-	-
R	1.2	1.1	1.2	1.1	1.4	1.1	-	-
Realistic(8+15):								
σ	0.20	0.32	0.21	0.13	0.92	1.11	-	-
R	2.3	1.1	2.7	1.1	1.7	1.8	-	-

$R=\sigma(z:0\text{-}1)/\sigma(z:0\text{-}2)$

Conclusion

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- We used physically motivated parametric cluster model and Fisher matrix technique to forecast cosmology constraints from SZ vs Xray scaling relation.

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End of talk, work to be continued ...