ATACAMA COSMOLOGY TELESCOPE

Elia Stefano Battistelli

Experimental Cosmology Group
Physics department
"Sapienza" University of Rome

Experimental Cosmology Group
Department of Physics & Astronomy
University of British Columbia

for the ACT collaboration

ACT collaboration

Barcelona ICE (Spain)
UBC (Canada)
University of Cape Town (S. Africa)
Cardiff University (UK)
Columbia (US)
Haverford (US)
INAOE (Mexico)
University of Kwa-Zulu Natal (S. Africa)
University of Massachusetts (US)
NASA/GSFC (US)
NIST (US)
Oxford (UK)
University of Pennsylvania (US)
Princeton (US) PI: Lyman Page
University of Pittsburgh (US)
Pontifica Universidad Catolica (Chile)
Rutgers (US)
CITA/University of Toronto (Canada)

and collaborators at:

Sapienza
Stanford
Miami
CfA
IPMU/Tokyo
MPI
Berkeley
Chicago
LLNL

outline

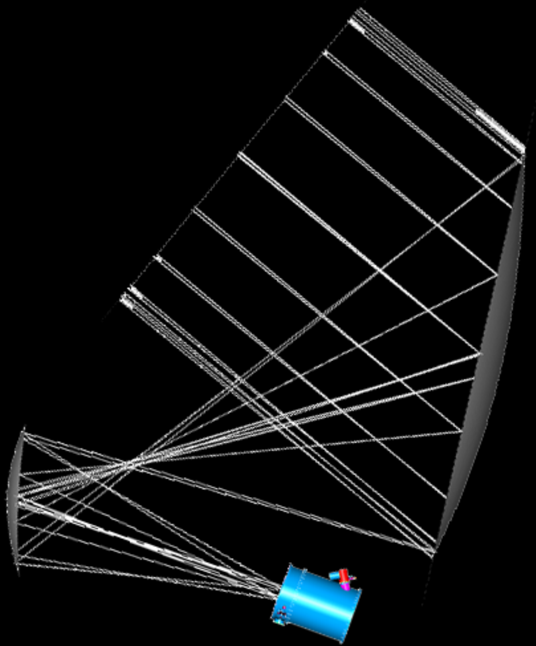
- ACT: instrument and observations
- Maps and power spectrum
- Cosmological parameters
- Gravitational lensing in CMB maps
- point sources
- SZ clusters and follow-up: the case of “El Gordo”

outline

- ACT: instrument and observations
- Maps and power spectrum
- Cosmological parameters
- Gravitational lensing in CMB maps
- point sources
- SZ clusters and follow-up: the case of “El Gordo”

ACT : instrument

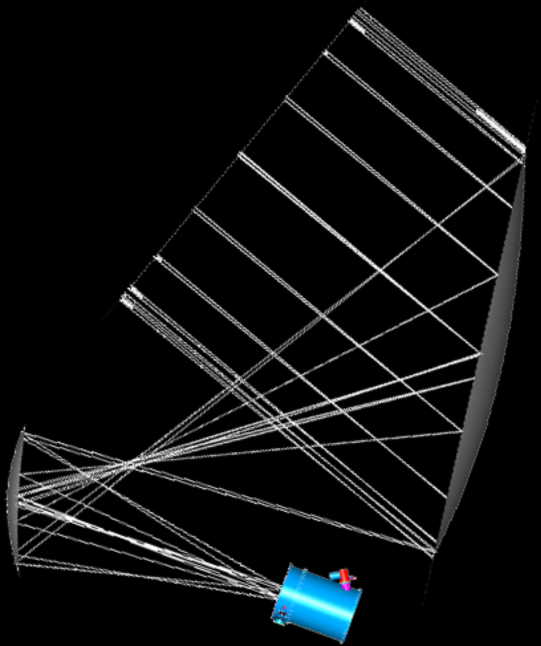
- Gregorian, off-axis telescope with 6m diameter primary mirror, and 2m secondary
- Surrounded by co-moving and fixed ground screens



Fowler et al. App Opt 2007

ACT : instrument

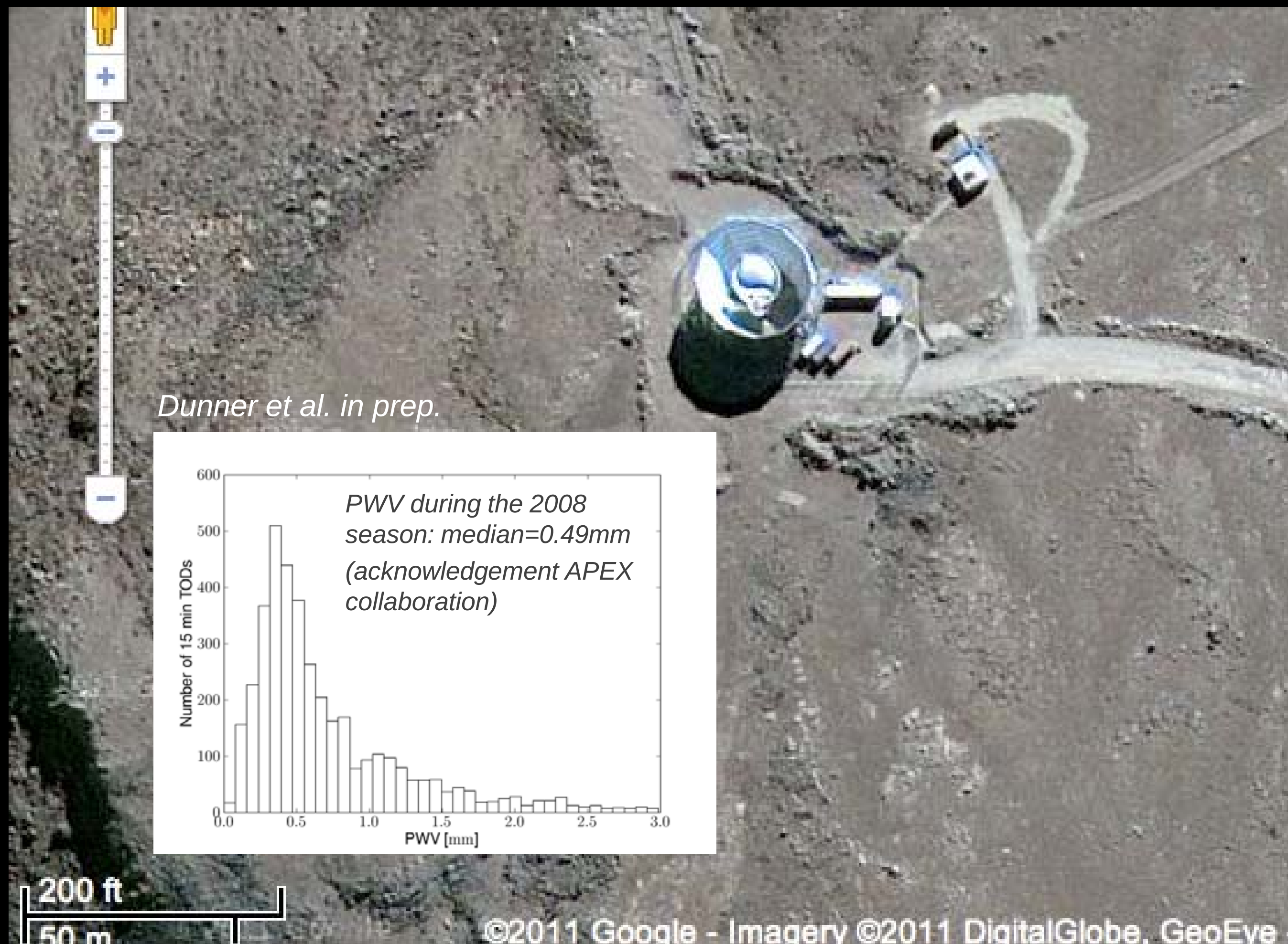
- Gregorian, off-axis telescope with 6m diameter primary mirror, and 2m secondary
- Surrounded by co-moving and fixed ground screens



Fowler et al. App Opt 2007

ACT : location

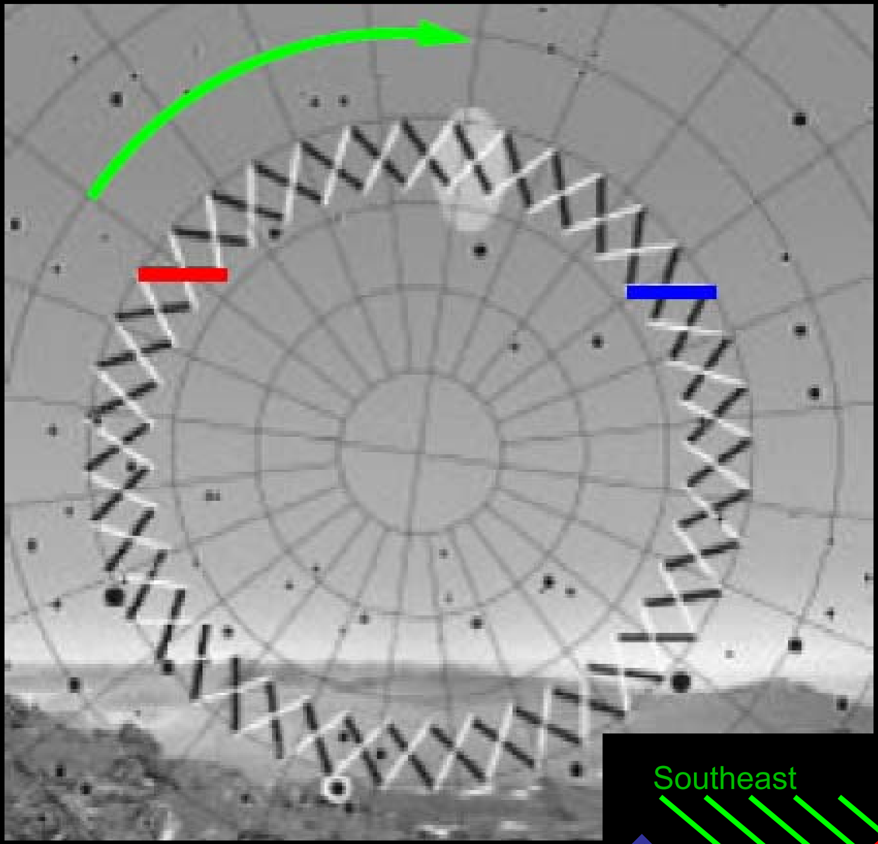
- Location: Cerro Toco, Atacama desert, northern Chile
- Altitude 5200m (one of the highest on earth)
- PWV ~ 0.5mm

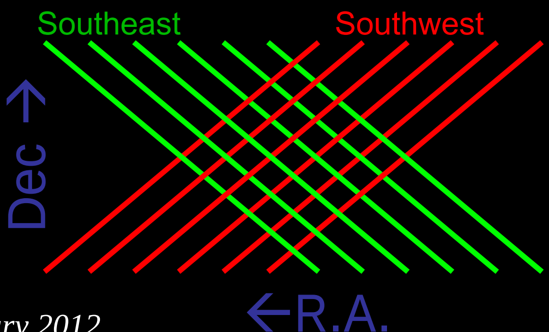


ACT: observations

- First light on October 2007
- 4 seasons completed 2007 (150GHz only), 2008, 2009, 2010. 2 TB per month
- Crosslinked observations in 2 regions opposed wrt SCP az-scanning at 1°.5/s
- Sky coverage:

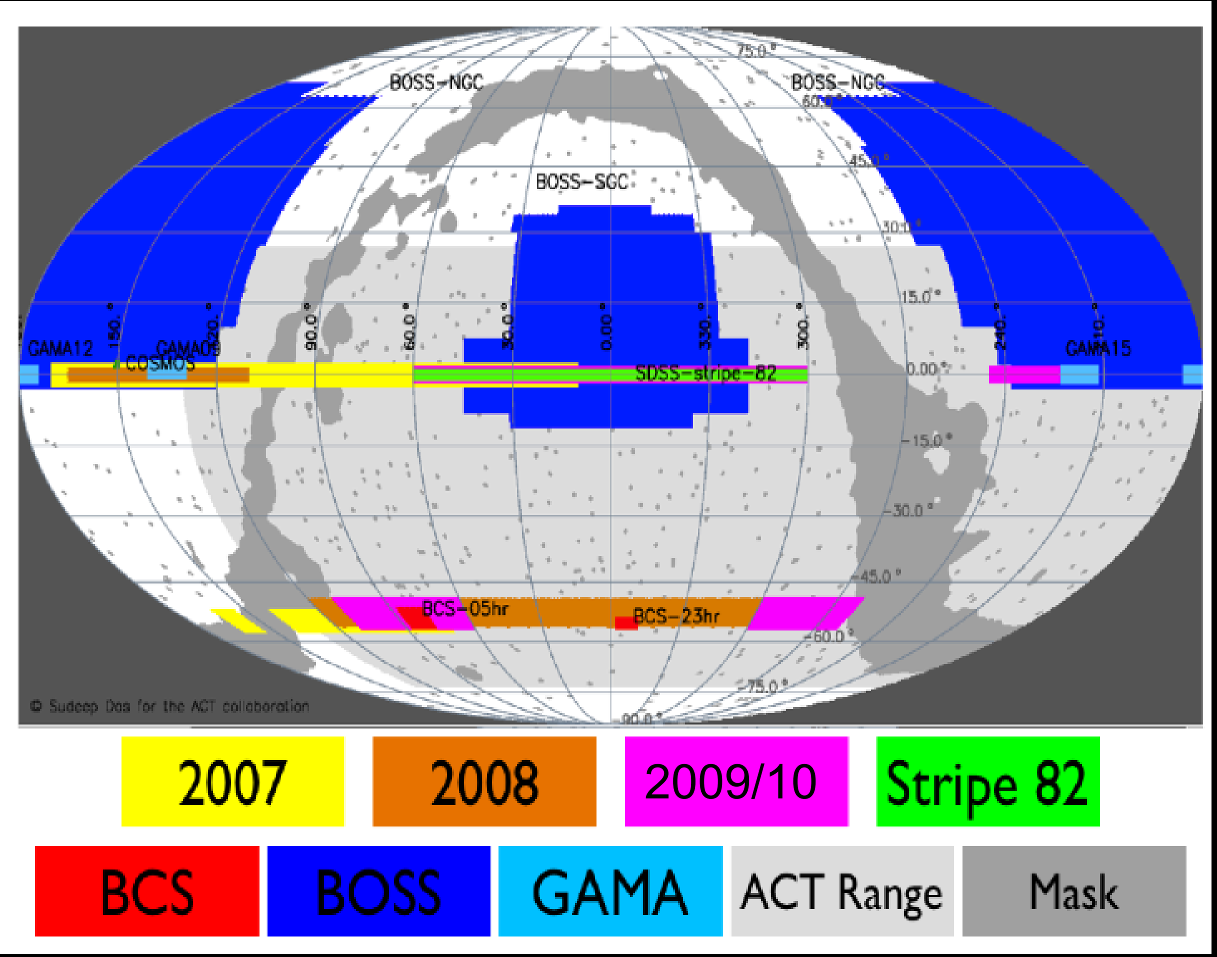
  north and south allowed
- 1000 deg^2 surveyed:
  - South stripe: 9° survey centered at decl. −53°.5
  - Equatorial Stripe: 5° stripe centered on the celestial equator





ACT: observations

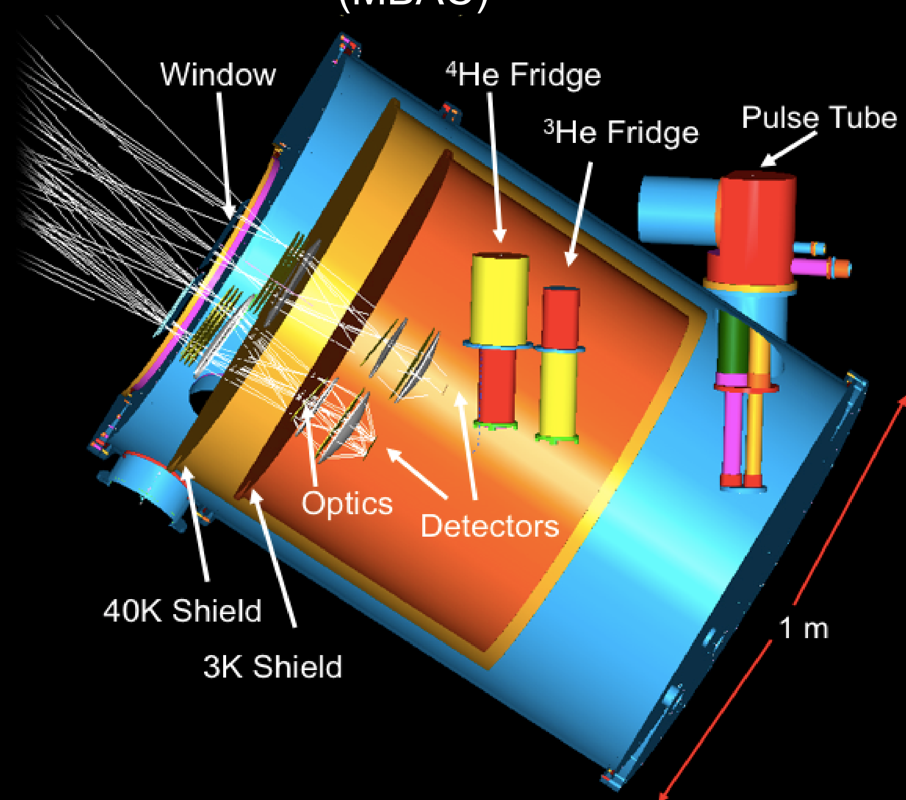
- First light on October 2007
- 4 seasons completed 2007 (150GHz only), 2008, 2009, 2010. 2 TB per month
- Crosslinked observations in 2 regions opposed wrt SCP az-scanning at 1°.5/s
- Sky coverage: →
  north and south allowed
- 1000 deg^2 surveyed:
  - South stripe: 9° survey centered at decl. −53°.5
  - Equatorial Stripe: 5° stripe centered on the celestial equator



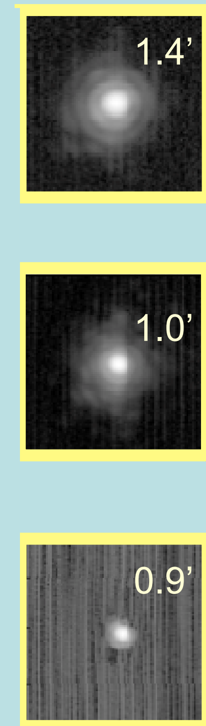
ACT : instrument

Transition Edge Sensors

The Millimeter Bolometric Array Camera (MBAC)



BEAMS

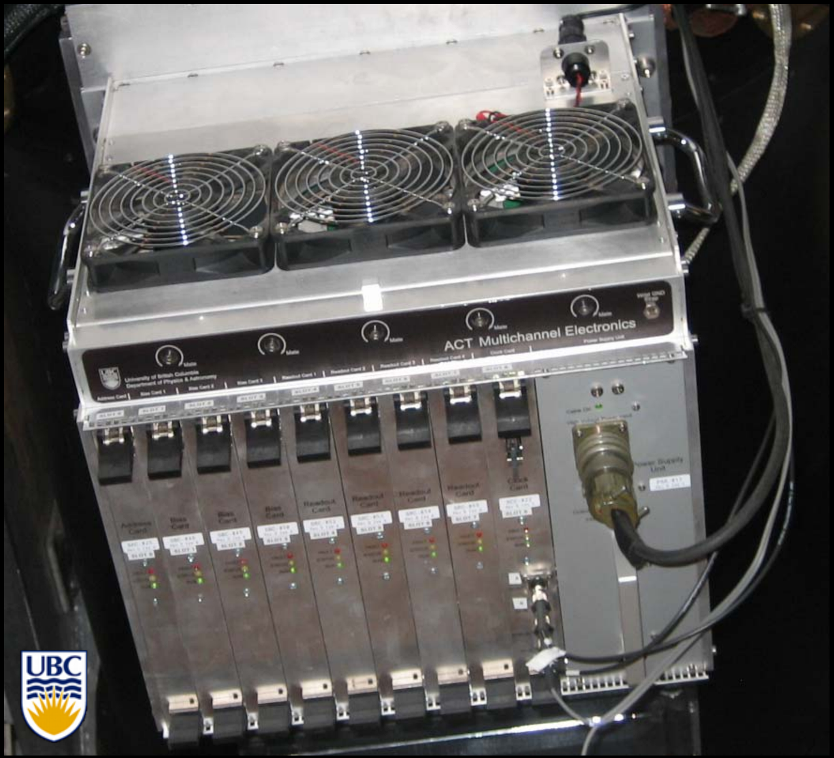


- 3 x 1024 elements TES detectors array at 300mK;
- MBAC: dry/closed criostat with ^{11}He refrigerator;
- Observational frequency: 148, 217, 278 GHz with 1.4', 1.0', 0.9‘ resolution in sky from Saturn;

Swetz et al. ApJS 2011

ACT : instrument

- Pop-up Transition Edge Sensor (TES) developed at NASA GSFC;
- Inductively coupled to NIST SQUIDs;
- More than 3000 pixels → NIST Time Domain Multiplexing;
- 3 SQUID stages
- UBC Read Out/control electronics
- Automatic SQUID tuning procedure: one full and one short autotuning per night



Battistelli et al. JLTP 2008

Battistelli et al. SPIE proc. 2008

outline

- •ACT: instrument and observations
- •Maps and power spectrum
- •Cosmological parameters
- •Gravitational lensing in CMB maps
- •point sources
- •SZ clusters and follow-up: the case of “El Gordo”

ACT: data

•Raw time streams for 6 detectors over 5': atmosphere in common

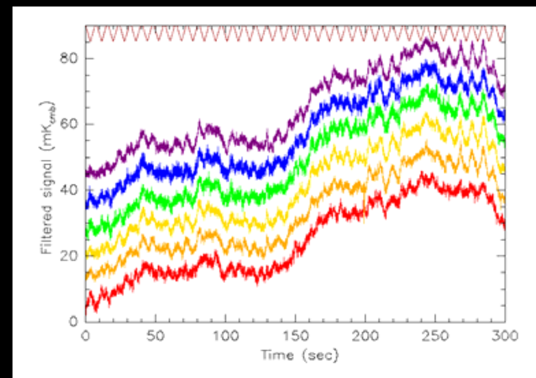
•We use an iterative maximum-likelihood map-making that solves simultaneously for celestial signal and local effects. Removes:

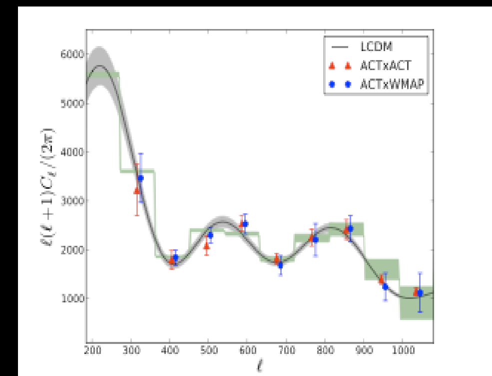
- •atm common mode + gradients
- •detector correlations
- •scan-synchronous effects

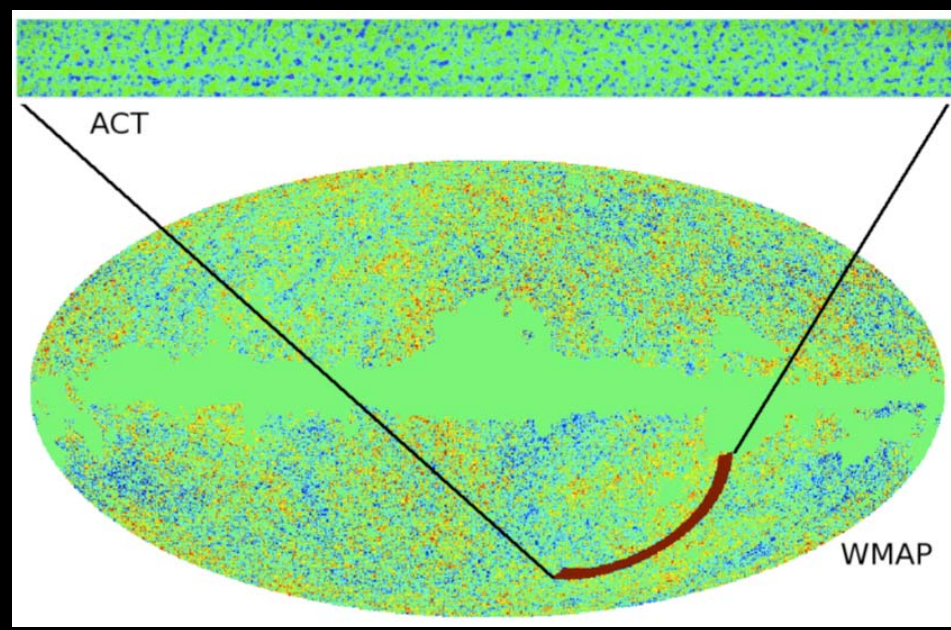
•Calibration:

- •148GHz: 2% with WMAP 7yr by matching power spectrum at 400<l<1000
- •218GHz: Uranus at 7% (6% due to the unknown mm temperature)

Dunner et al. in prep.

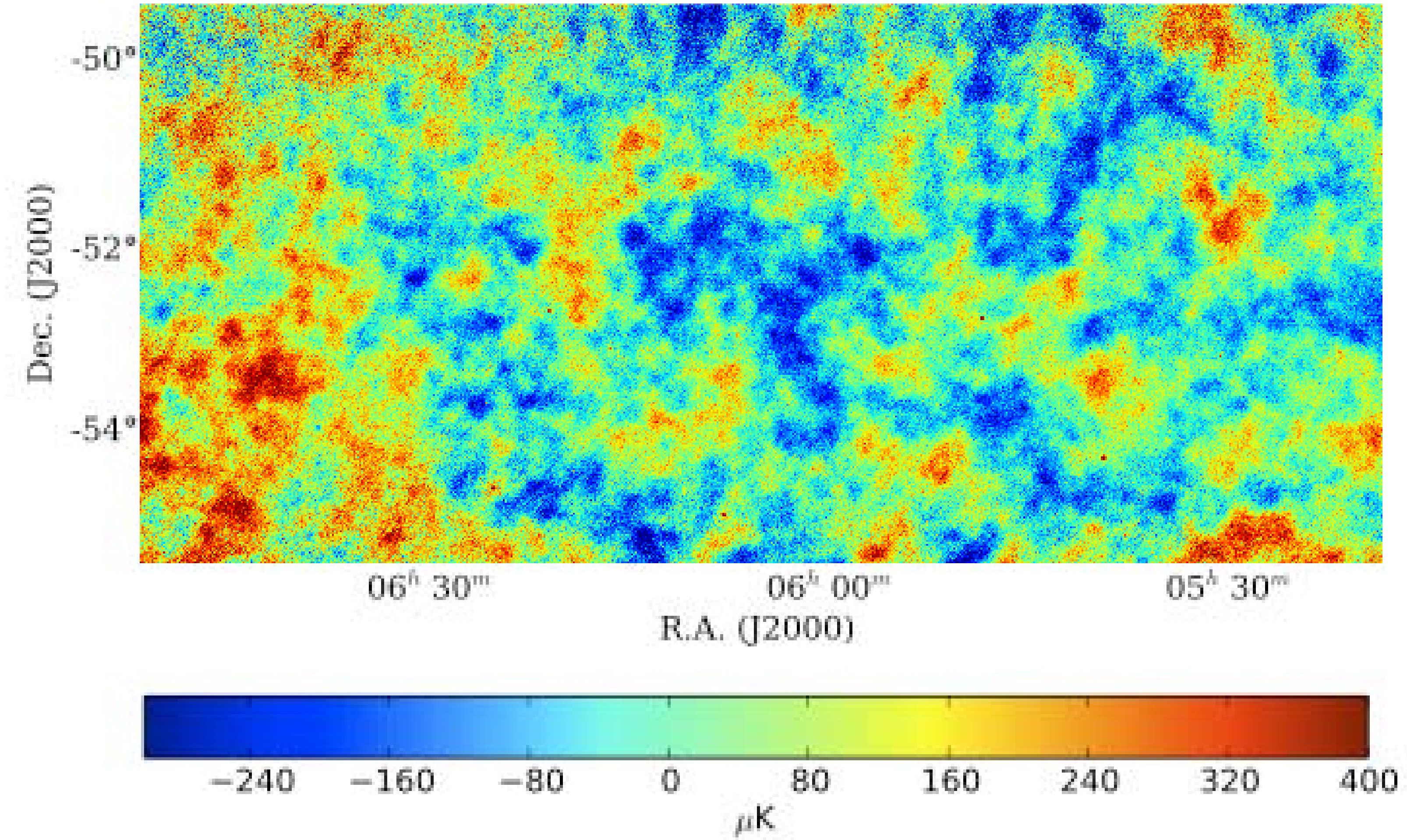






Hajian et al. ApJ 2011

ACT: maps



84 deg^2 compilation map with WMAP data for the largest features, and ACT data to provide high resolution over 84 deg^2

Hajian et al. ApJ 2011

ACT: maps

Unbiased estimate of all modes from *ell* ~ 100 - 10000

Atmosphere: 2 deg
(Filtered Here)

CMB: 1 deg

Clusters*: (>1.4')-4'

Sources*: 1.4'

* Minimum size set by beam

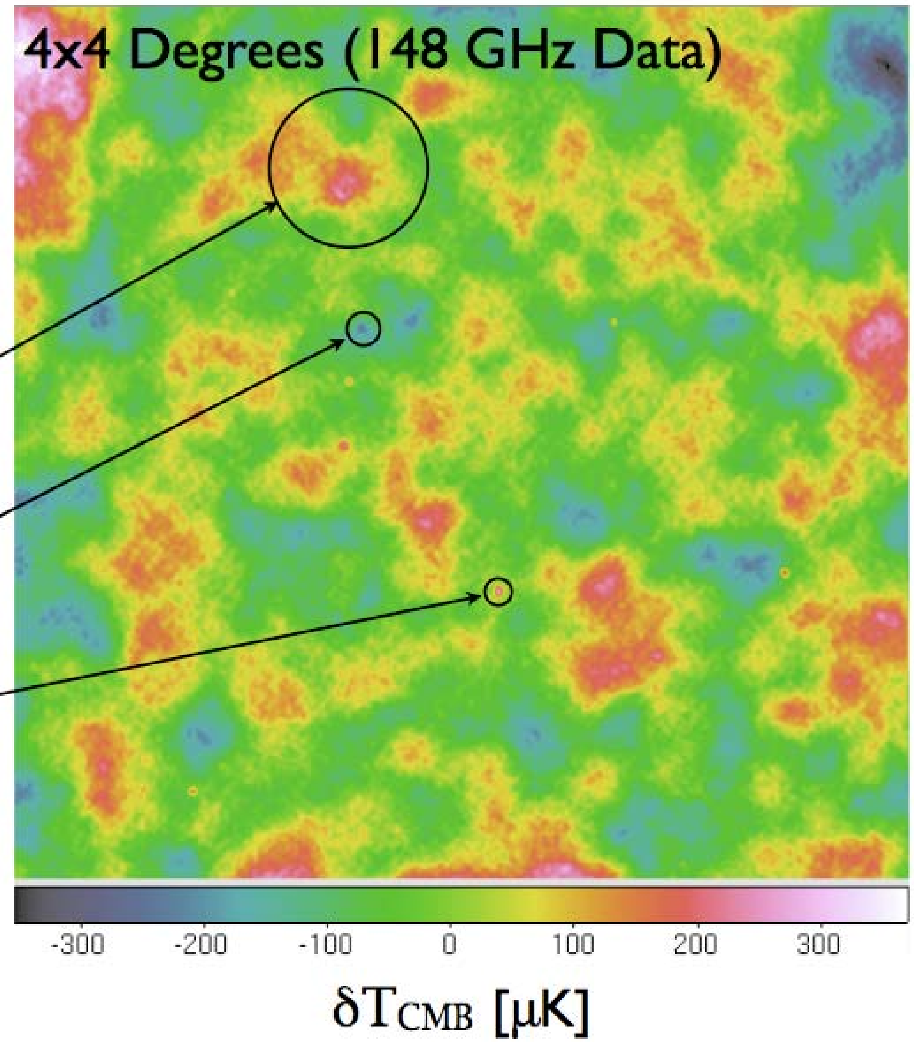
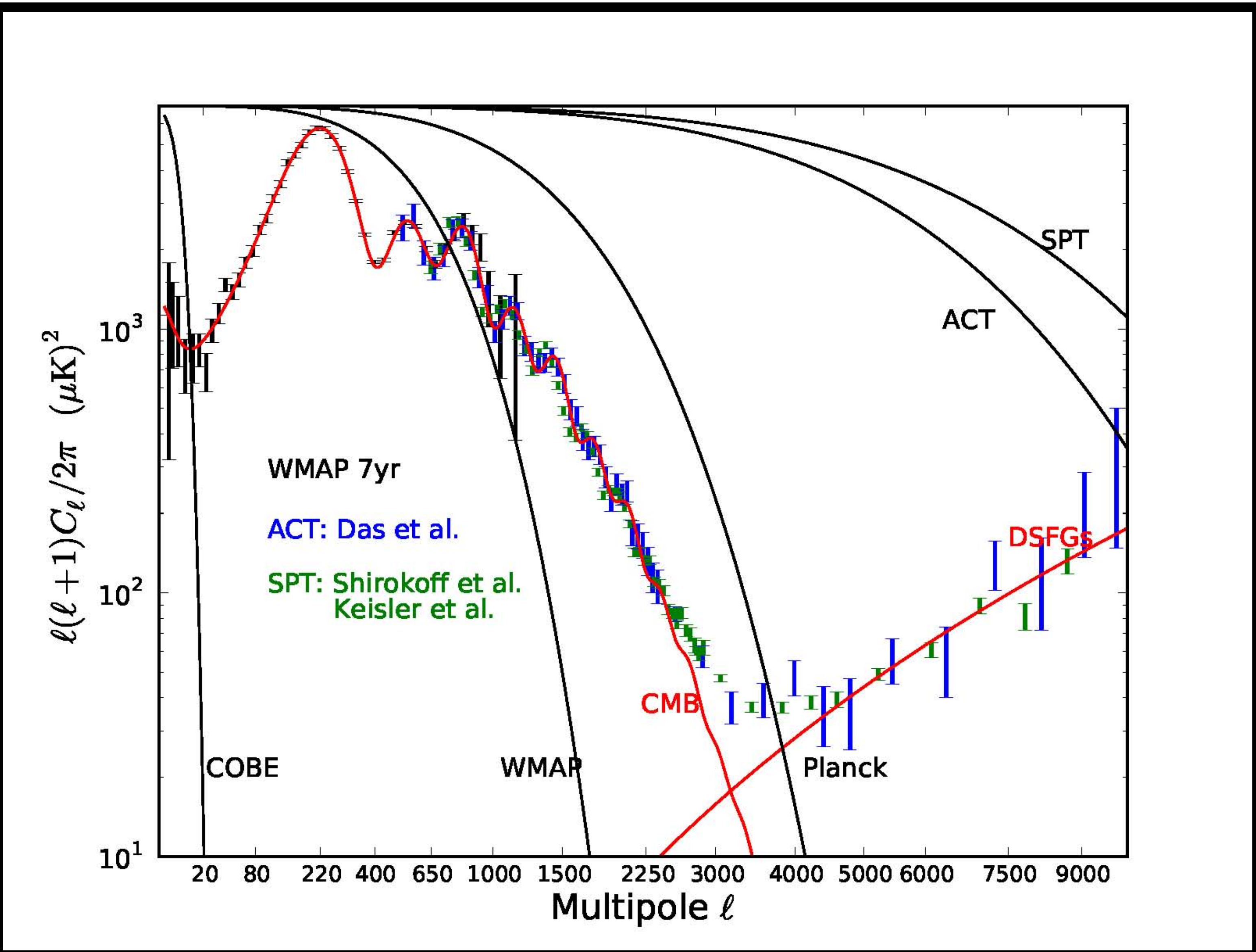


Image courtesy of T. Marriage

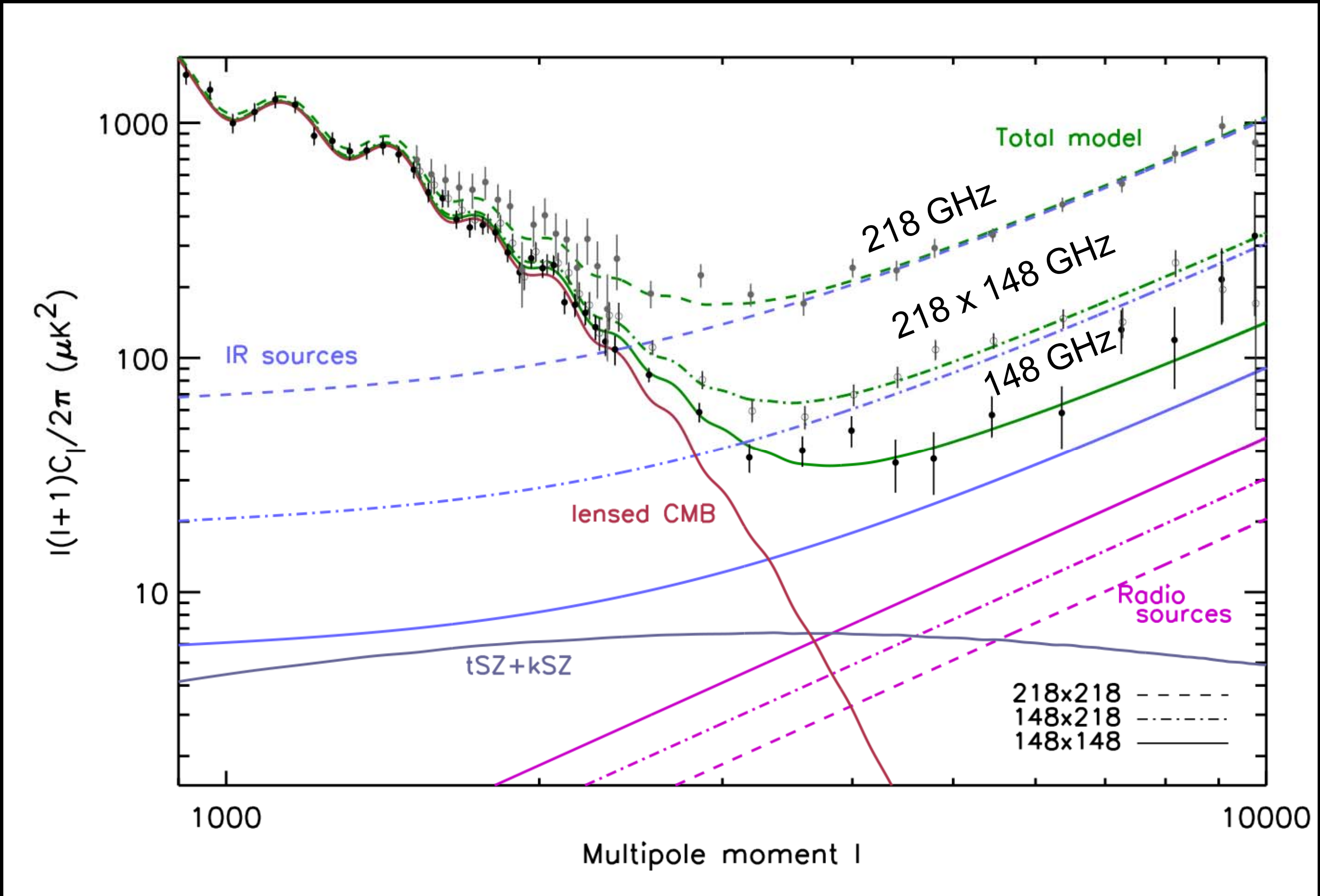
ACT: power spectrum



outline

- ACT: instrument and observations
- Maps and power spectrum
- Cosmological parameters
- Gravitational lensing in CMB maps
- point sources
- SZ clusters and follow-up: the case of "El Gordo"

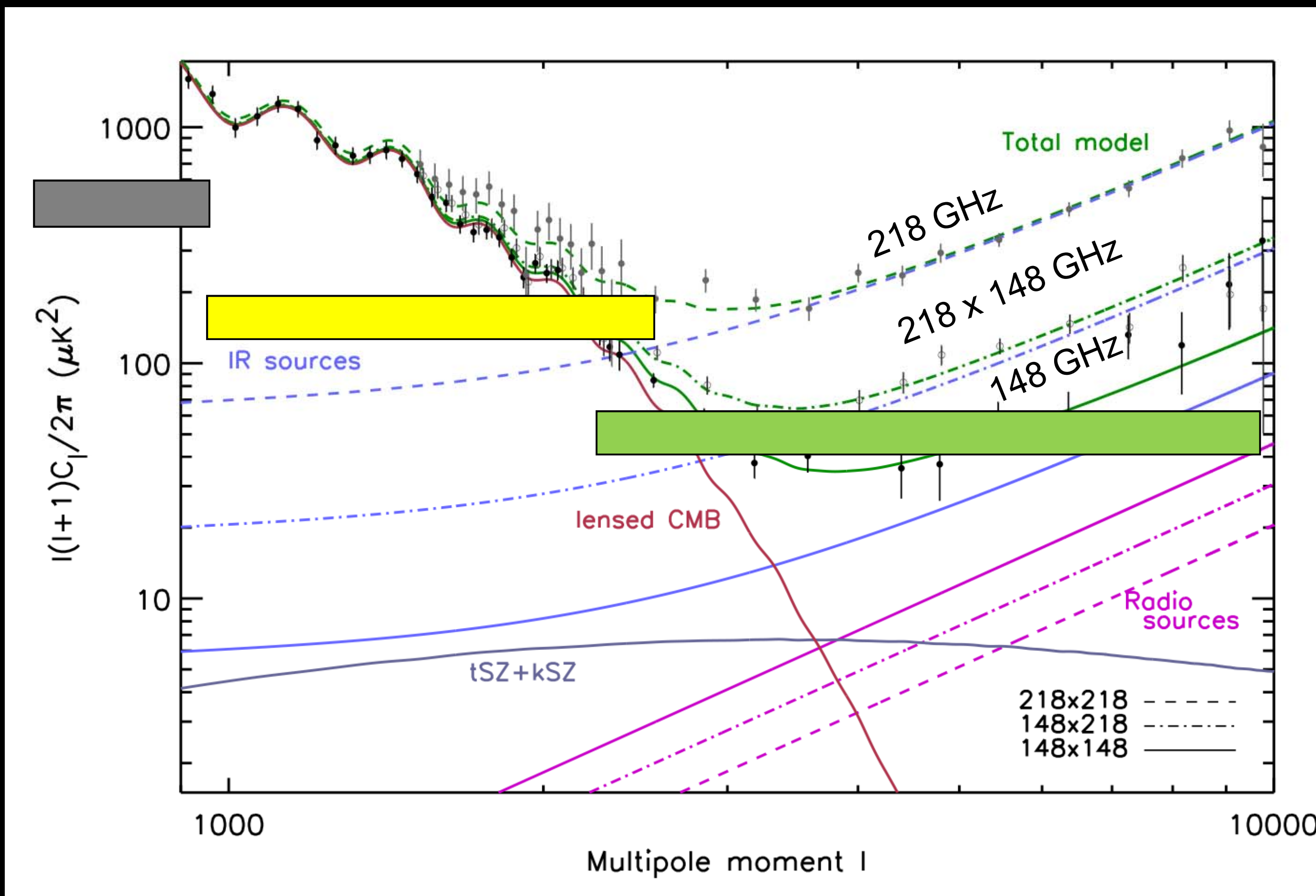
ACT: power spectrum



Dunkley et al. ApJ, 2011

- CMB in good agreements with ΛCDM
- Strong Silk dumping
- No lensing is disfavored
- point sources evident
- SZ contribution

ACT: power spectrum

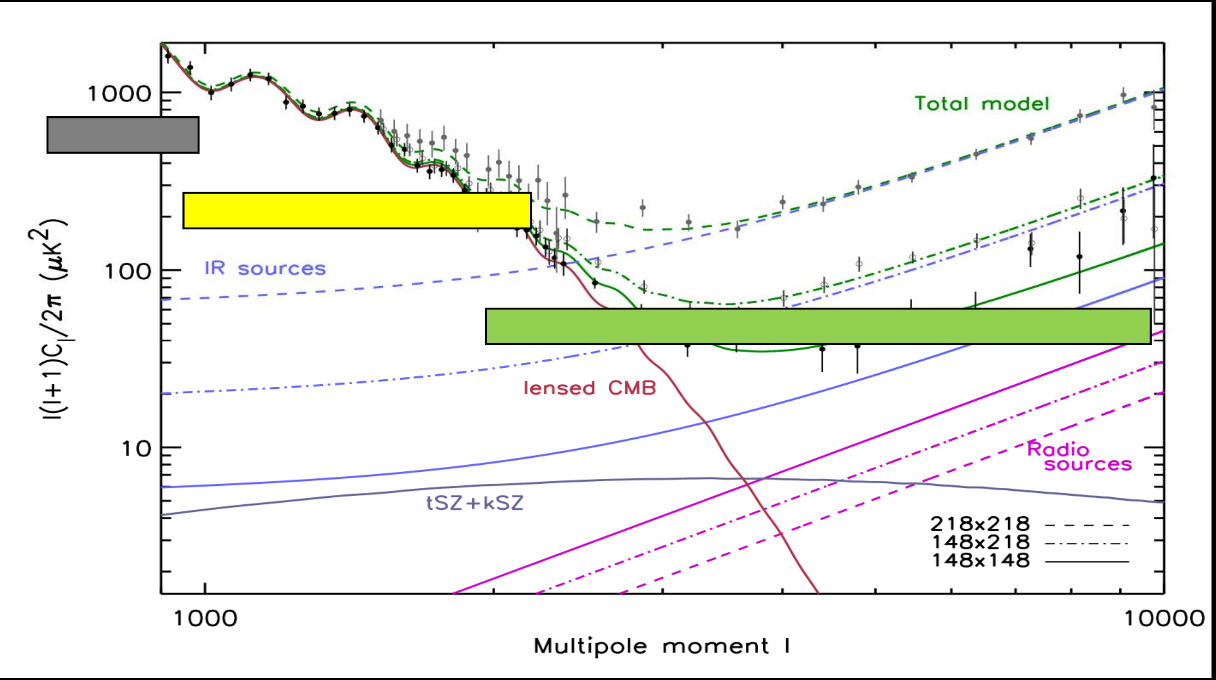


Dunkley et al. ApJ, 2011

- CMB in good agreements with ΛCDM
- Strong Silk dumping
- No lensing is disfavored
- point sources evident
- SZ contribution

ACT: cosmological parameters

Dunkley et al. ApJ, 2011



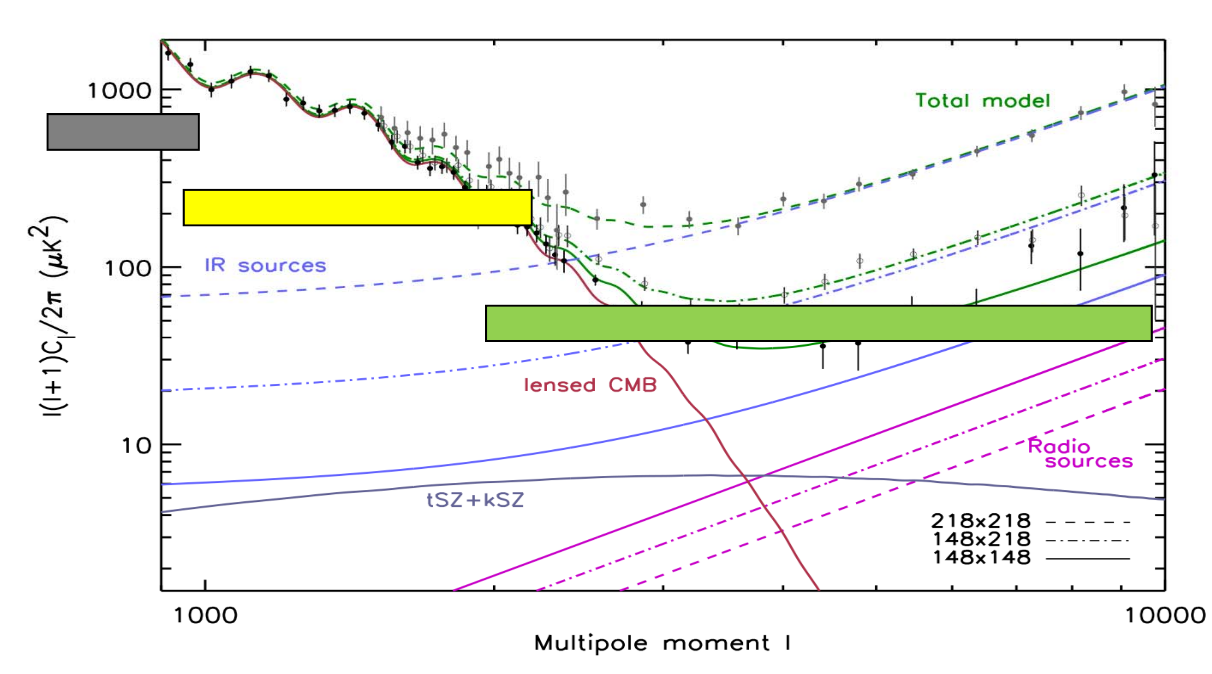
- ΛCDM fits well: $\frac{\chi^2}{Dof} = \frac{29}{46}$

- tSZ power spectrum: $\mathbf{B_{3000}=6.8\pm2.9\mu K^2}$
- tSZ→σ_8**=0.77±0.05** (model dependent)
- kSZ power spectrum: $\mathbf{B_{3000}<8\mu K^2}$ (95%CL)
- IR poisson 148GHz: $\mathbf{B_{3000}=7.8\pm0.7\mu K^2}$

- Prim. pert. sp. index: $\mathbf{n_s=0.962\pm0.013}$ (3σ-away form scl. inv.)
- Running of n_s: $\mathbf{dn_s/d\ln k=-0.034\pm0.018}$
- Tesor-to-scalar ratio: **r<0.19 (95%CL)**
- # rel. species: $\mathbf{N_{eff}=5.3\pm1.3}$ **(68%CL)**
- Prim. He abundance: $\mathbf{Y_p=0.313\pm0.044}$
- Grav. lensing: $\mathbf{A_L=1.3\pm0.5}$
- String pert. (Nambu): $\mathbf{G_\mu<1.6\ 10^{-7}}$ **(95%CL)**

ACT: cosmological parameters

Dunkley et al. ApJ, 2011



- ΛCDM fits well:

$$\frac{\chi^2}{\text{Dof}} = \frac{29}{46}$$

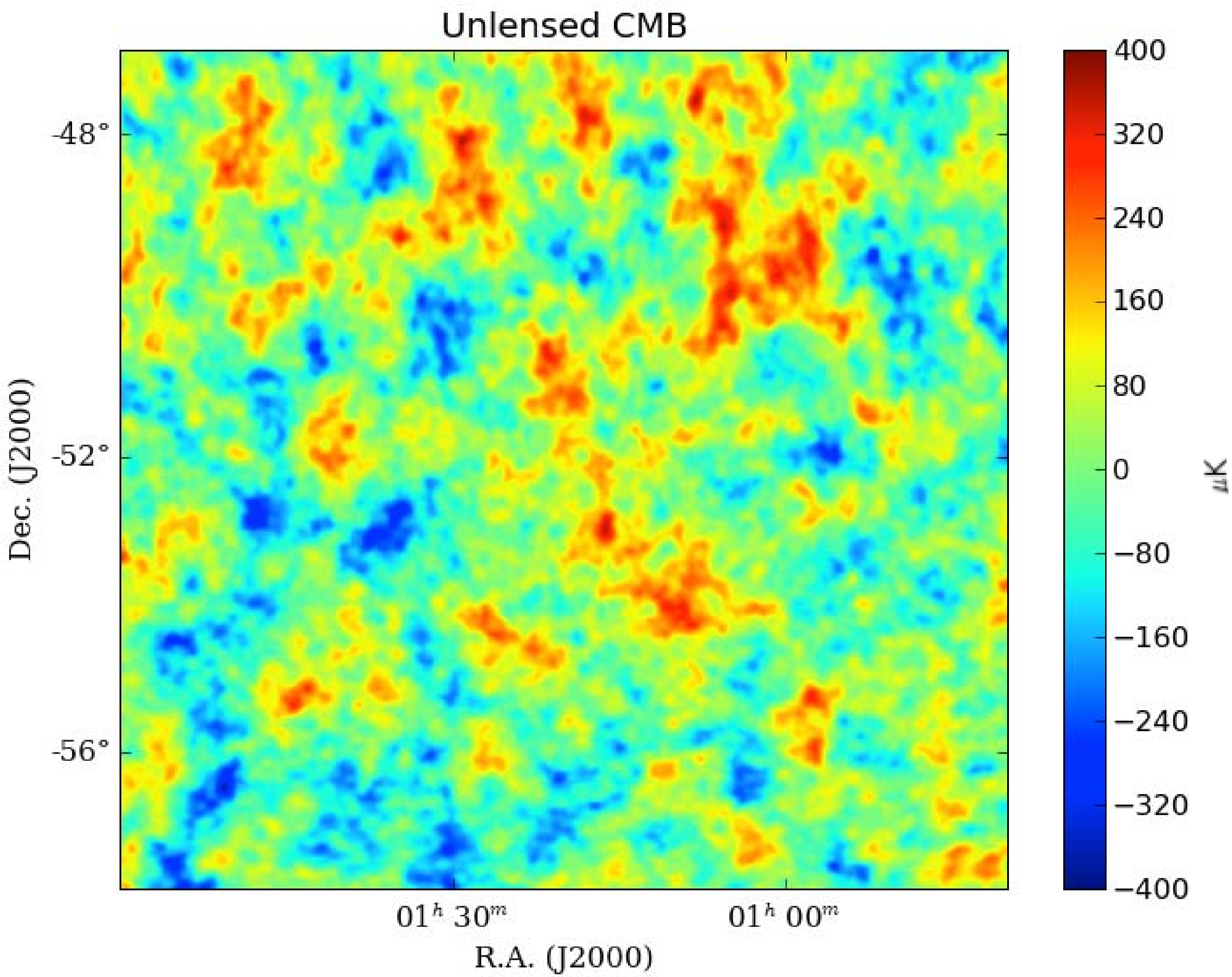
Component		148 GHz	218 GHz
Poisson	$\mathcal{B}_{3000}\ (\mu K^2)^b$	$7.8 \pm 0.7 \pm 0.7$	$90 \pm 5 \pm 10$
	$C_\ell (nK^2)$	$5.5 \pm 0.5 \pm 0.6$	$63 \pm 3 \pm 6$
	$C_\ell\ (Jy^2\ sr^{-1})$	$0.85 \pm 0.08 \pm 0.09$	$14.7 \pm 0.7 \pm 1.8$
Clustered	$\mathcal{B}_{3000}\ (\mu K^2)^c$	$4.6 \pm 0.9 \pm 0.6$	$54 \pm 12 \pm 5$
Total IR	$\mathcal{B}_{3000}\ (\mu K^2)$	12.5 ± 1.2	144 ± 13

- Prim. pert. sp. index:
  n_s=0.962±0.013
  (3σ-away form scl. inv.)
- Running of n_s:
  $dn_s/d\ln k$=-0.034±0.018
- Tesor-to-scalar ratio:
  r<0.19 (95%CL)
- # rel. species:
  N_{eff}=5.3±1.3 (68%CL)
- Prim. He abundance:
  Y_p=0.313±0.044
- Grav. lensing:
  A_L=1.3±0.5
- String pert. (Nambu):
  G_μ<1.6 10^{-7} (95%CL)

outline

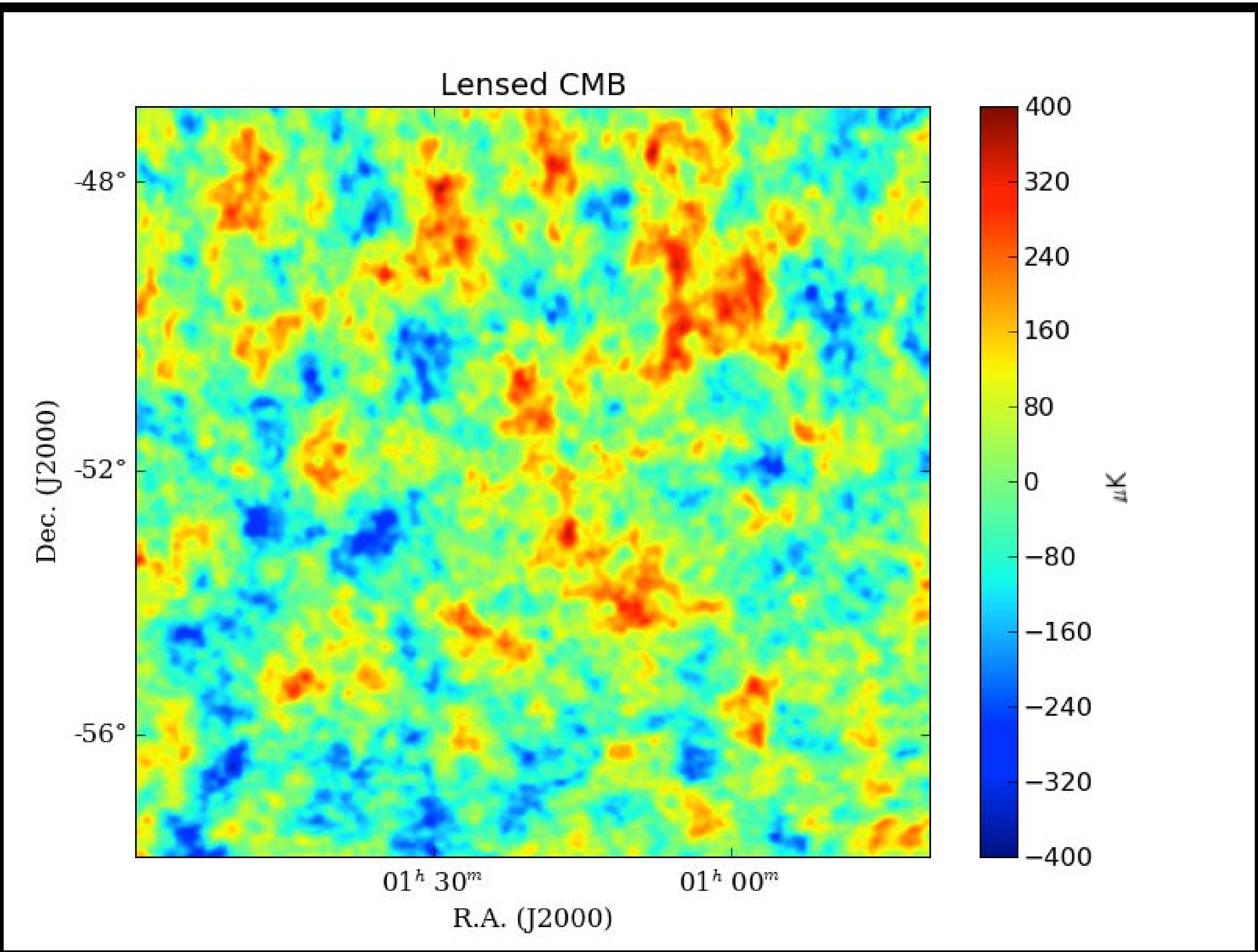
- ACT: instrument and observations
- Maps and power spectrum
- Cosmological parameters
- Gravitational lensing in CMB maps
- point sources
- SZ clusters and follow-up: the case of “El Gordo”

ACT: gravitational lensing



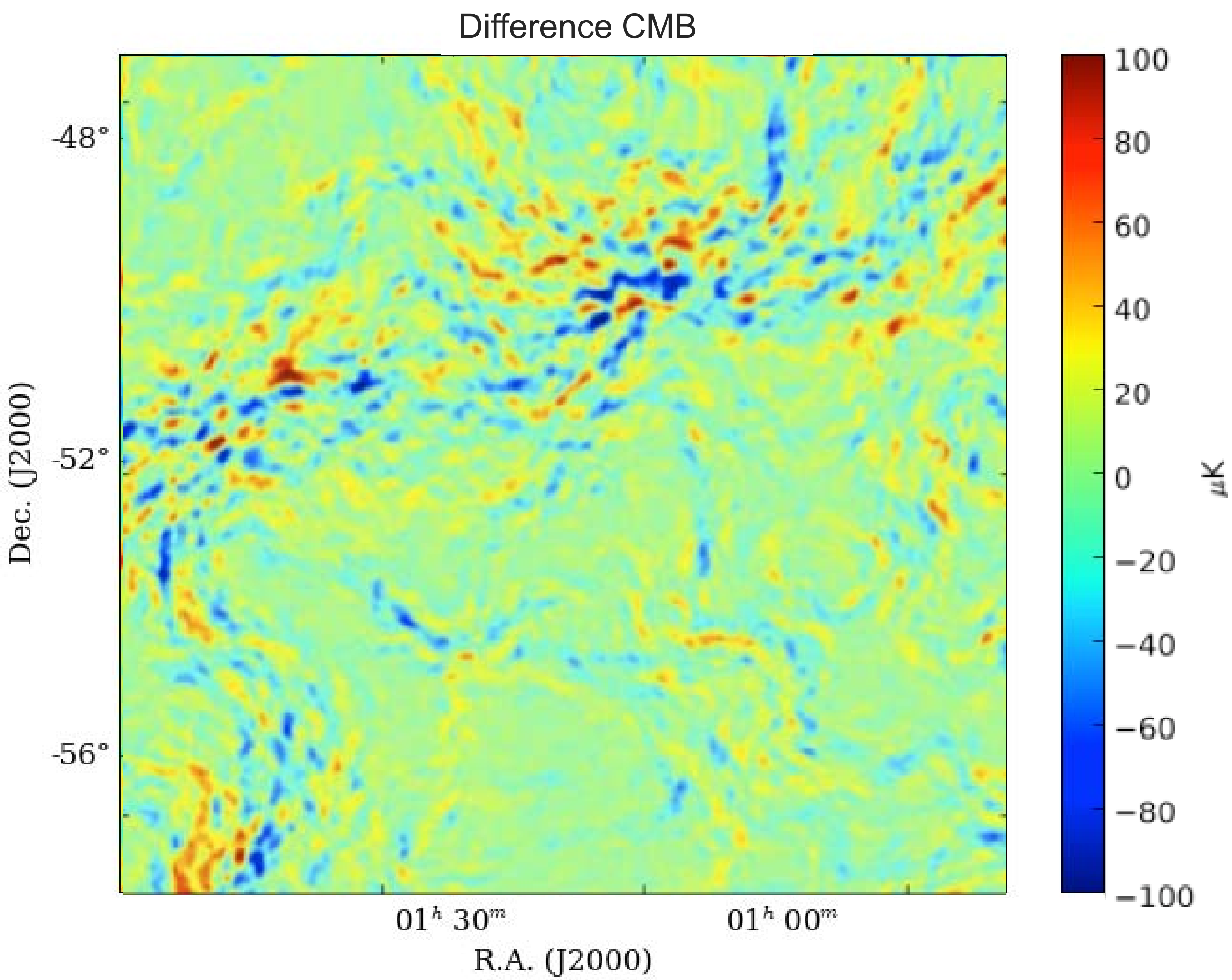
Simulation by S. Das

ACT: gravitational lensing



Simulation by S. Das

ACT: gravitational lensing



Simulation by S. Das

ACT: gravitational lensing

•CMB photons deflected by large scale structures. Typical deflection = 2'.7

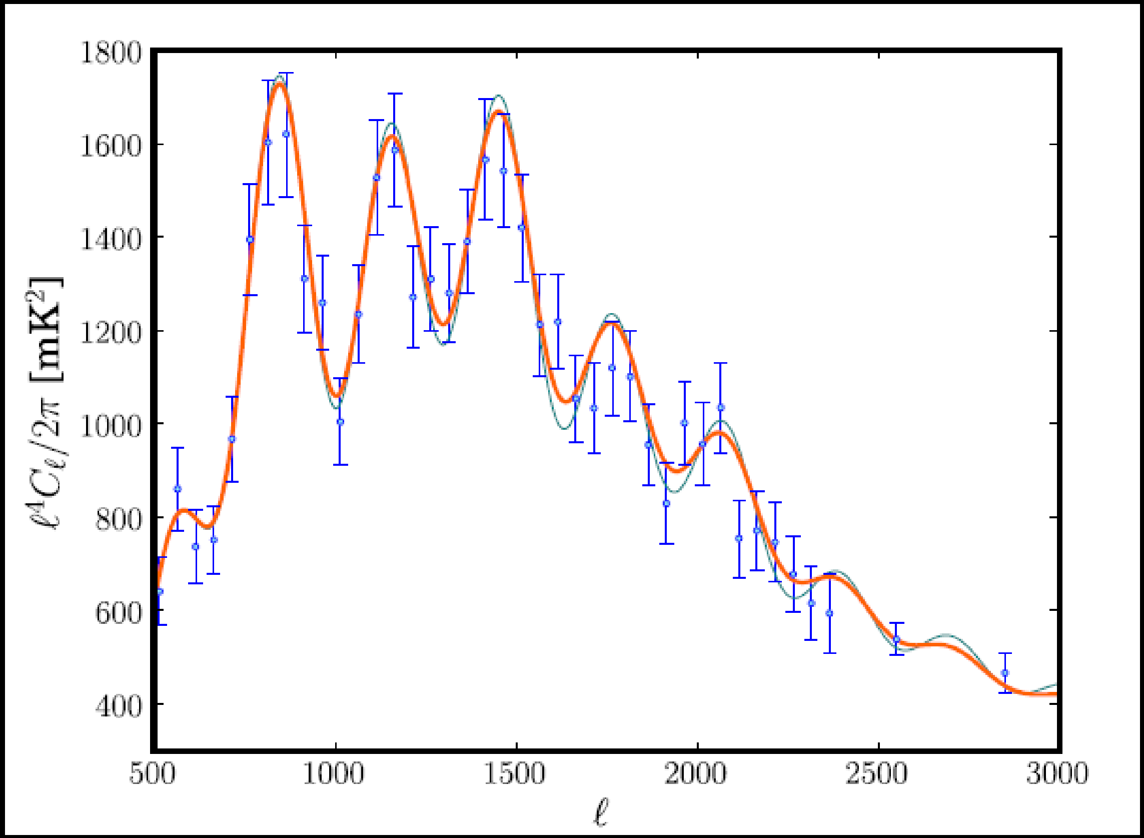
•Gravitational lensing smooths acoustic peaks

•Using four point correlation function, gravitational lensing parameter A_L: A_L=0 → no lensing; A_L=1 → standard lensing:

A_L=1.3±0.5 (68%CL)

↓

2.8σ-away form no lensing universe



Das et al. ApJ 2011

ACT: gravitational lensing

- CMB photons deflected by large scale structures. Typical deflection = 2'.7

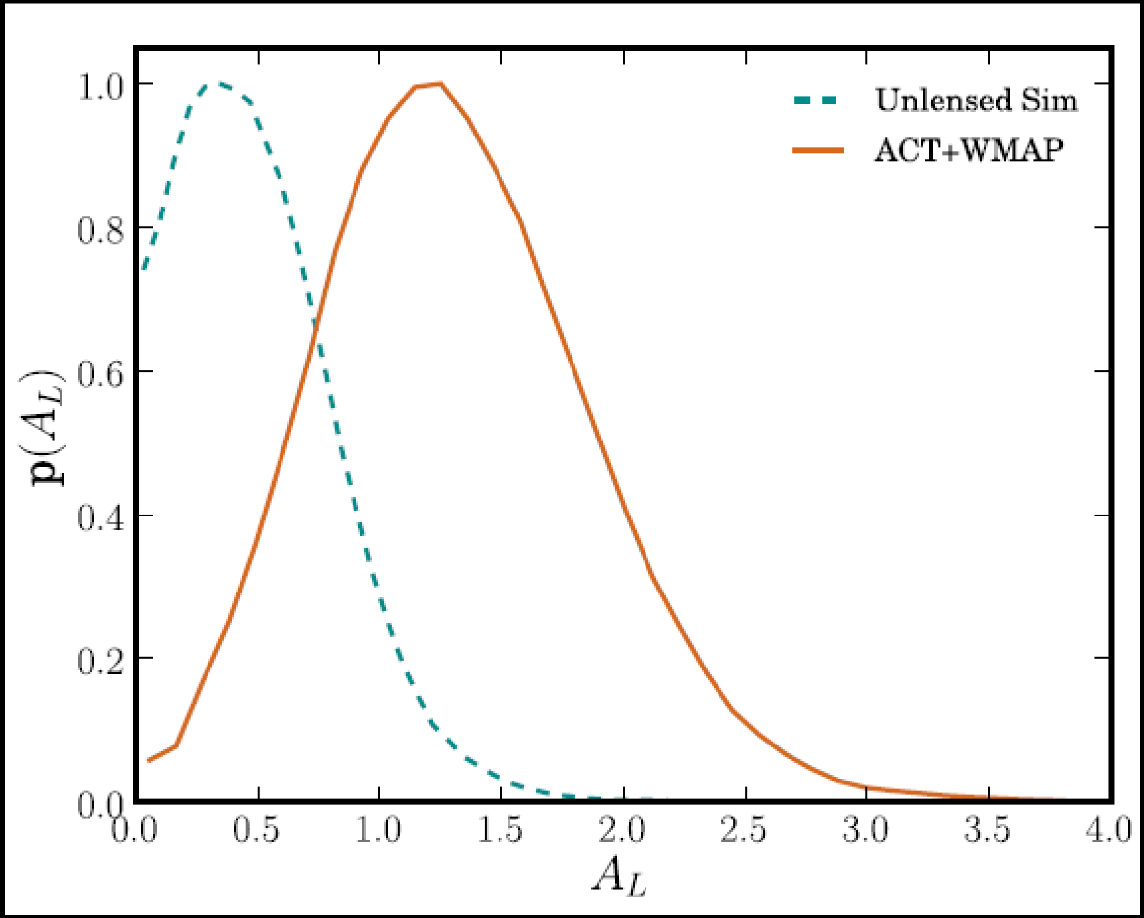
- Gravitational lensing smooths acoustic peaks

- Using four point correlation function, gravitational lensing parameter A_L: A_L=0 → no lensing; A_L=1 → standard lensing:

A_L=1.3±0.5 (68%CL)

↓

2.8σ-away form no lensing universe



Das et al. ApJ 2011

ACT: gravitational lensing

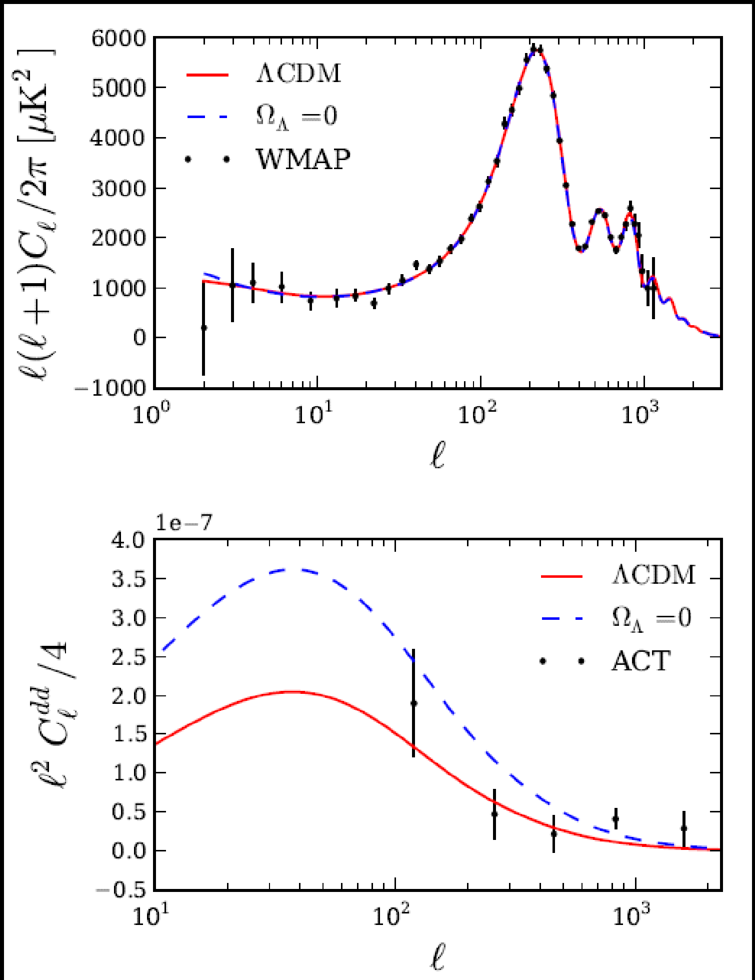
- CMB power spectrum for two geometrically degenerate cosmological models:
  - $\Omega_\Lambda=0$
  - $\Omega_\Lambda=0.73$, $\Omega_m=0.27$

- The 7yr WMAP power spectrum does not significantly favor either model.

- Looking at higher resolution the CMB lensing deflection power spectra are different:
  - If $\Omega_\Lambda=0$, CMB photons spend more time at low z
  - Structures grow more if $\Omega_\Lambda=0$
  - Projection effects

- The $\Omega_\Lambda=0$ universe would produce a larger lensing power spectrum.

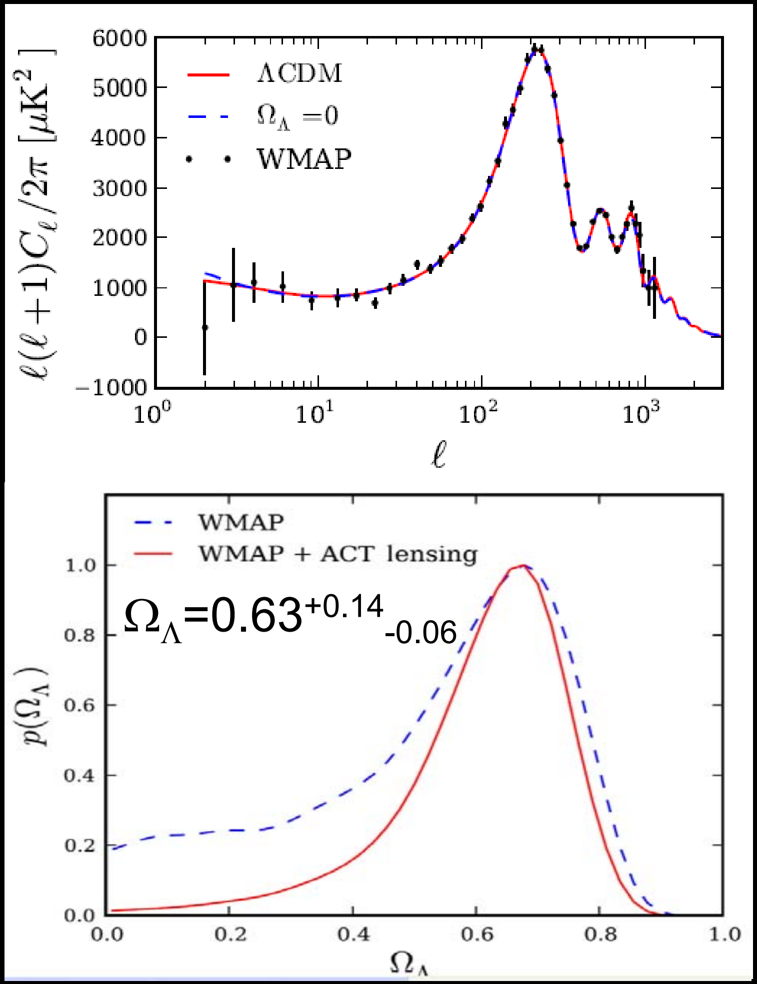
- First CMB-only evidence for Λ



Sherwin et al. Ph.Rev.L, 2011

ACT: gravitational lensing

- CMB power spectrum for two geometrically degenerate cosmological models:
  - Ω_Λ=0
  - Ω_Λ=0.73, Ω_m=0.27
- The 7yr WMAP power spectrum does not significantly favor either model.
- Looking at higher resolution the CMB lensing deflection power spectra are different:
  - If Ω_Λ=0, CMB photons spend more time at low z
  - Structures grow more if Ω_Λ=0
  - Projection effects
- The Ω_Λ=0 universe would produce a larger lensing power spectrum.
- First CMB-only evidence for Λ



Sherwin et al. Ph.Rev.L, 2011

outline

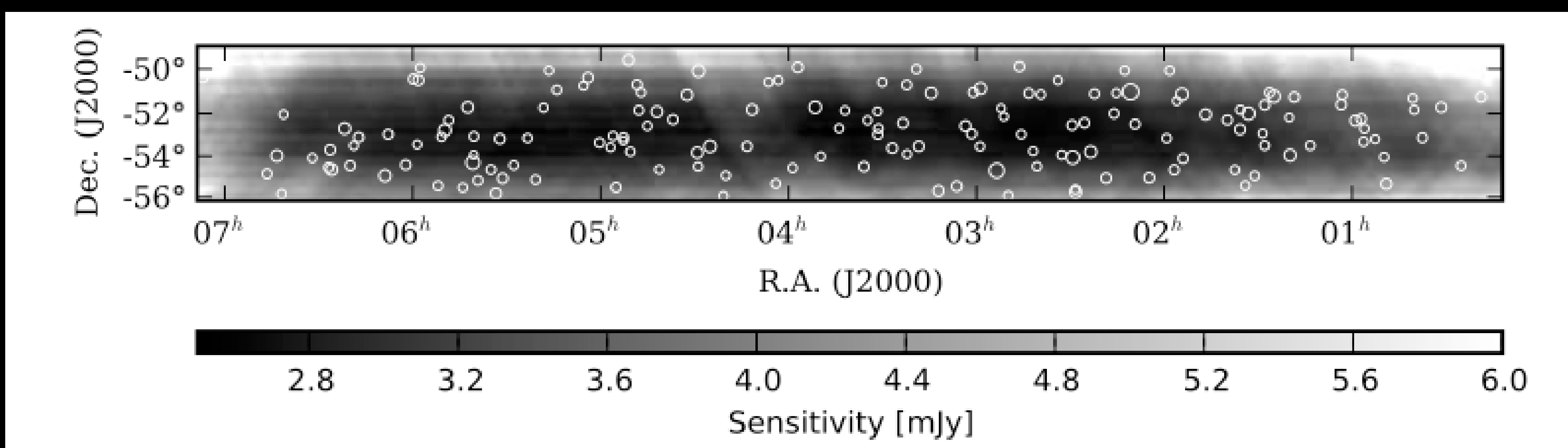
- •ACT: instrument and observations
- •Maps and power spectrum
- •Cosmological parameters
- •Gravitational lensing in CMB maps
- •point sources
- •SZ clusters and follow-up: the case of "El Gordo"

ACT: point sources

- Match-filter for Synchrotron Dominated Radio Galaxies and Dusty Star Forming Galaxies
- *In 455 deg^2 we found, at 148GHz,* 157 sources in the 15 - 1500 mJy range. Nearly all synchrotron dominated. 98% present in low frequency catalogues. Cross identification performed with ATCA at 20GHz of a bright sample yields:

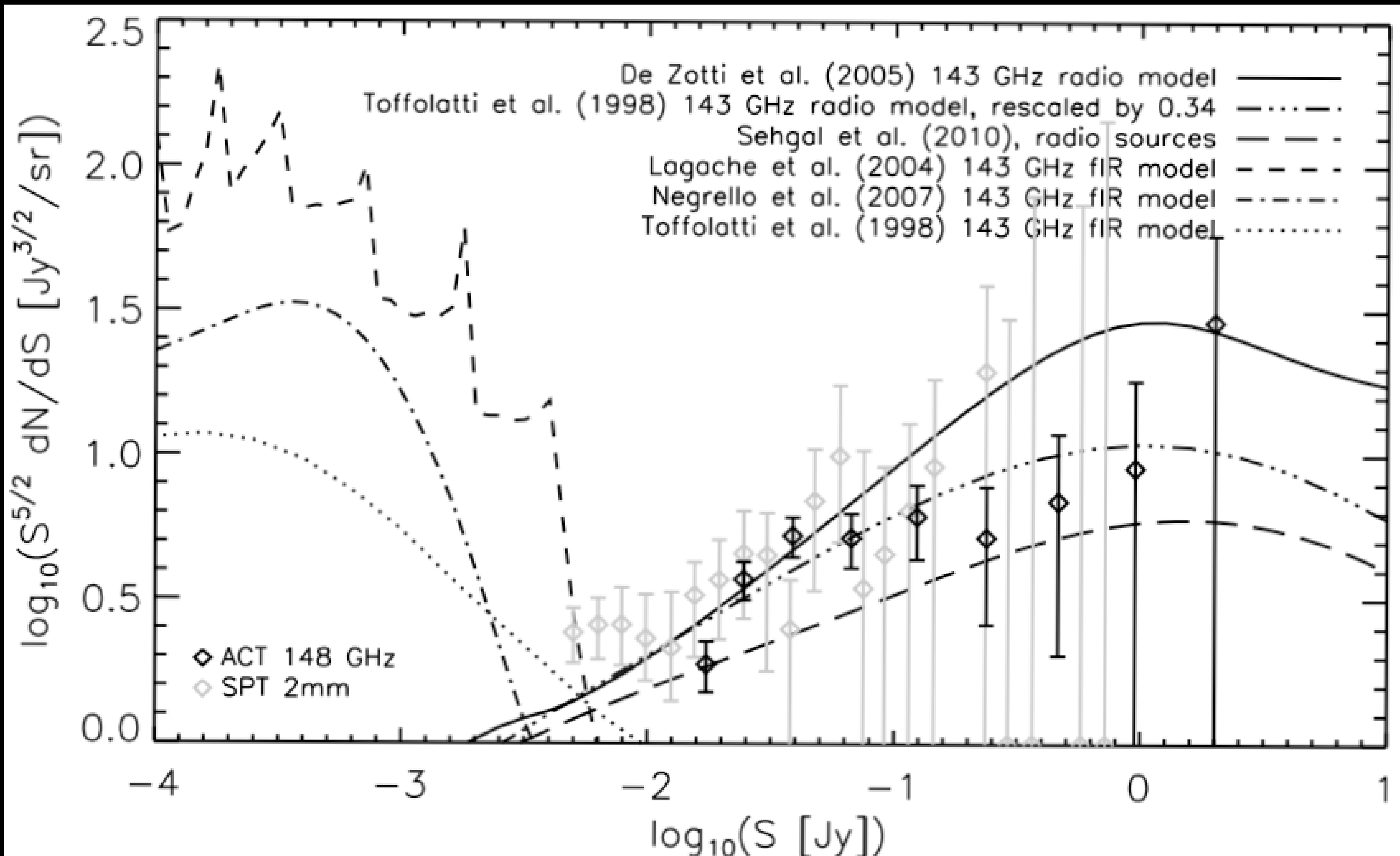
$$\langle\alpha_{20\text{-}148}\rangle = -0.39 \pm 0.04 \text{ (fairly steep)}$$

- *Fundamental importance for SZ detection*



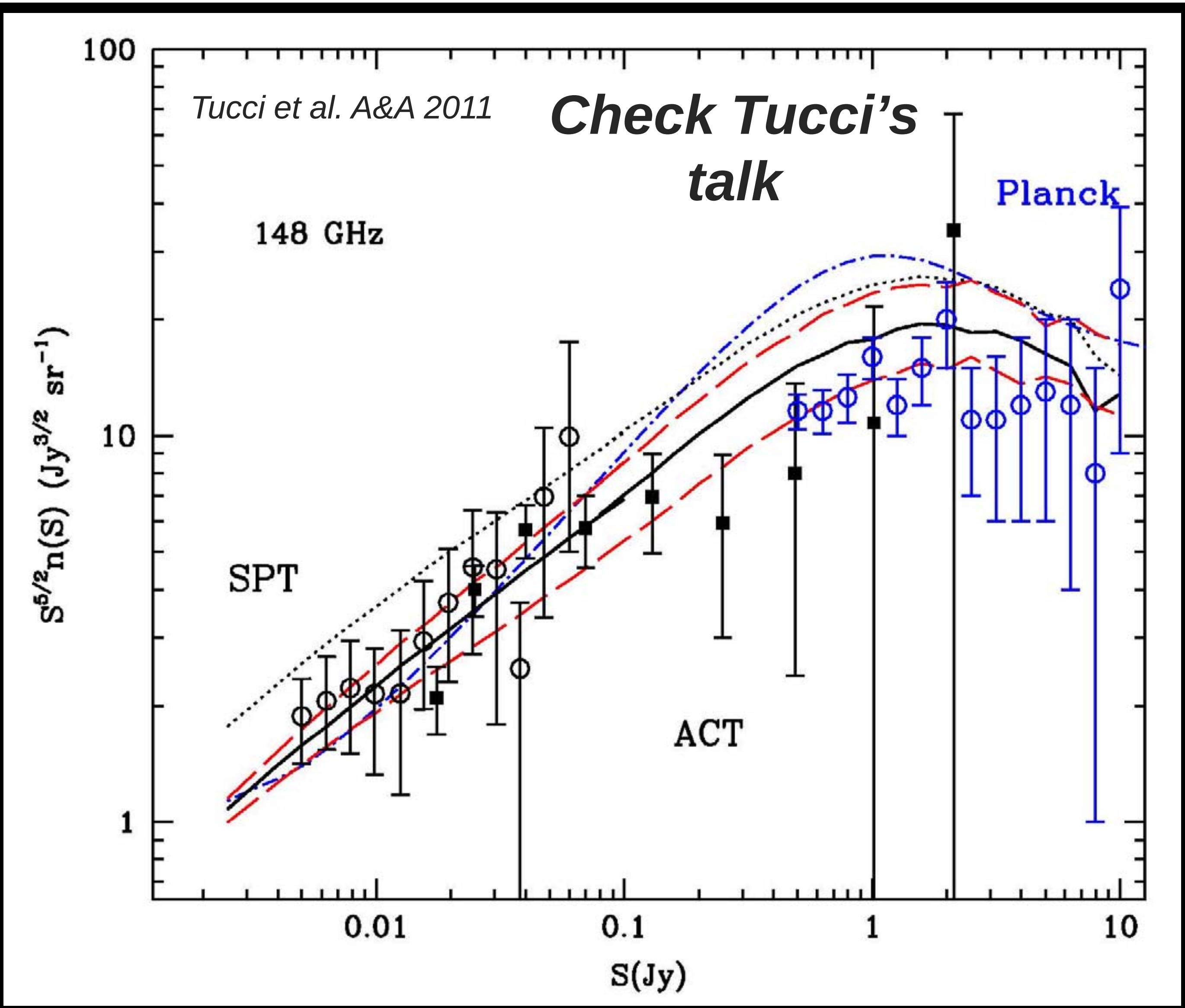
Marriage et al., ApJ 2011

ACT: point sources



Marriage et al., ApJ 2011

ACT: point sources

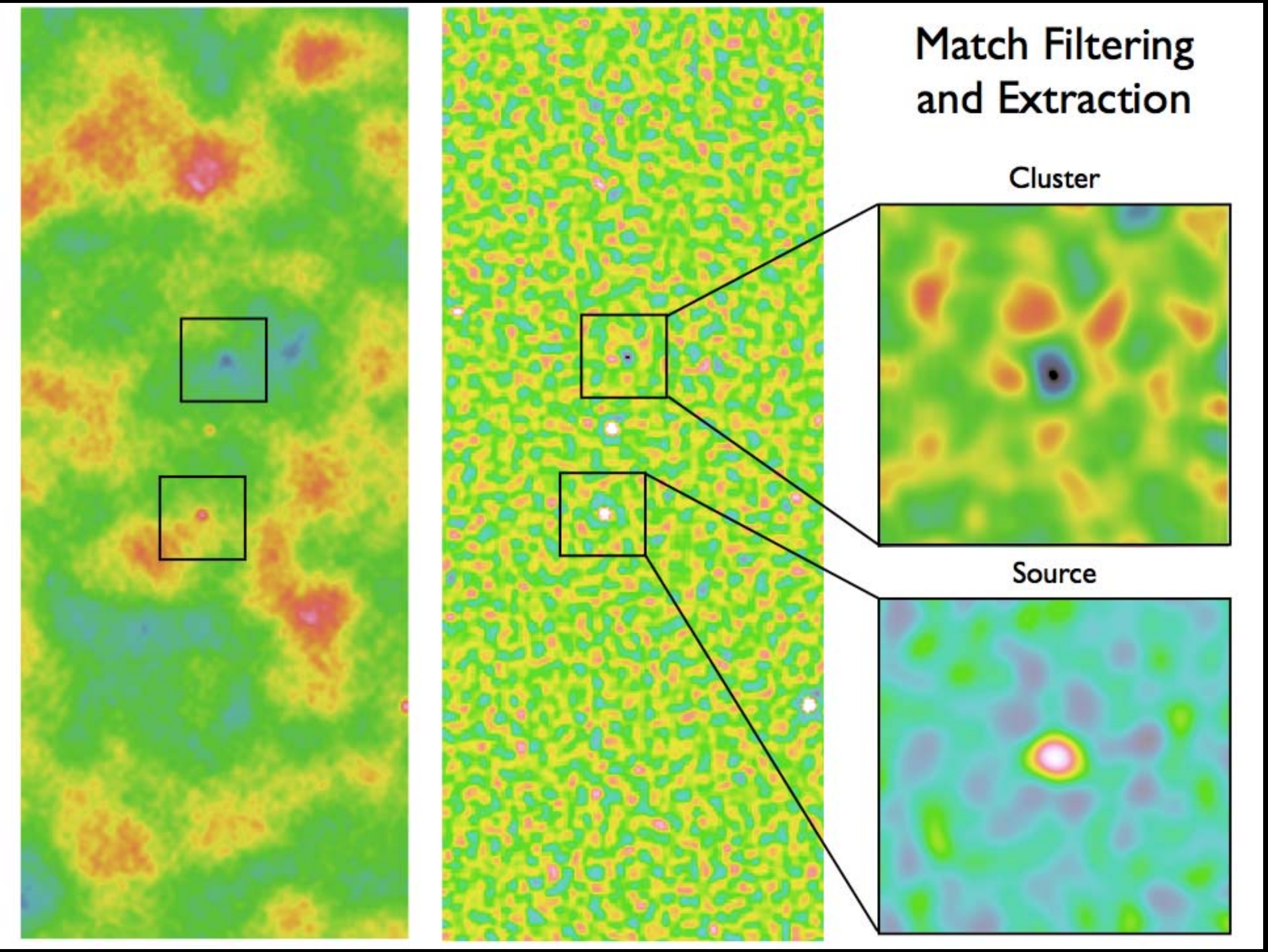


outline

- ACT: instrument and observations
- Maps and power spectrum
- Cosmological parameters
- Gravitational lensing in CMB maps
- point sources
- SZ clusters and follow-up: the case of “El Gordo”

ACT: tSZ

- 455 deg^2 in 2008 data at 148GHz
- Matched filter with β-model profile
- 23 clusters blindly detected
- all have confirmed optical counter part
- 10 are new
- J0102-4915 is among the biggest clusters ever seen



Marriage et al. ApJ, 2011

ACT: tSZ

- 455 deg^2 in 2008 data at 148GHz
- Matched filter with β-model profile
- 23 clusters blindly detected
- all have confirmed optical counter part
- 10 are new
- J0102-4915 is among the biggest clusters ever seen

Table 1
ACT 2008 148 GHz SZ-selected Galaxy Clusters

ACT ID	R.A. (J2000) (hms)	Decl. (° ′ ″)	S/N	θ_c (′)	δT_0[a] (μK)	$\delta T_0'$[b] (μK)	y_0' ($\times 10^{-4}$)	z[c]	Alternative ID
All Candidates S/N > 6									
ACT-CL J0658−5557	06:58:30	−55:57:04	11.5	1.25	-483 ± 42	-734 ± 64	2.98 ± 0.26	0.30	1E0657-56 (Bullet)
ACT-CL J0638−5358	06:38:46	−53:58:45	10.0	1.25	-278 ± 28	-423 ± 42	1.68 ± 0.17	0.22	AS0592
ACT-CL J0245−5302	02:45:33	−53:02:04	9.1	1.00	-198 ± 22	-336 ± 37	1.32 ± 0.15	0.30	AS0295
ACT-CL J0102−4915	01:02:53	−49:15:19	9.0	0.75	-520 ± 58	-1046 ± 116	4.13 ± 0.46	0.75	New
ACT-CL J0438−5419	04:38:19	−54:19:05	8.0	0.50	-214 ± 27	-596 ± 74	2.35 ± 0.29	0.54	New
ACT-CL J0645−5413	06:45:30	−54:13:39	7.1	0.75	-221 ± 31	-444 ± 63	1.75 ± 0.25	0.17	A3404
ACT-CL J0546−5345	05:46:37	−53:45:32	6.5	1.75	-178 ± 27	-240 ± 37	0.95 ± 0.15	1.07	SPT-CL 0547−5345
ACT-CL J0235−5121	02:35:52	−51:21:16	6.2	4.00	-320 ± 51	-363 ± 58	1.43 ± 0.23	0.43	New
ACT-CL J0330−5227	03:30:54	−52:28:04	6.1	1.25	-145 ± 24	-221 ± 36	0.85 ± 0.14	0.44	A3128 (NE)
S/N < 6 and Optically Confirmed									
ACT-CL J0616−5227	06:16:36	−52:27:35	5.9	0.50	-155 ± 26	-431 ± 73	1.70 ± 0.29	0.71	New
ACT-CL J0559−5249	05:59:43	−52:49:13	5.1	2.25	-155 ± 31	-194 ± 38	0.77 ± 0.15	0.61	SPT-CL J0559−5249
ACT-CL J0215−5212	02:15:18	−52:12:30	4.9	0.25	-140 ± 29	-801 ± 164	3.16 ± 0.65	0.51	New
ACT-CL J0509−5341	05:09:21	−53:42:05	4.8	0.50	-115 ± 24	-319 ± 67	1.27 ± 0.27	0.46	SPT-CL 0509−5342
ACT-CL J0641−4949	06:41:35	−49:48:32	4.7	0.25	-283 ± 60	-1625 ± 375	6.41 ± 1.48	0.15	A3402
ACT-CL J0232−5257	02:32:45	−52:57:08	4.7	0.25	-124 ± 26	-710 ± 152	2.80 ± 0.60	0.59	New
ACT-CL J0516−5430	05:16:30	−54:30:30	4.6	1.75	-143 ± 31	-192 ± 43	0.77 ± 0.17	0.29	AS0520/SPT-CL 0517−5430
ACT-CL J0346−5438	03:46:51	−54:38:54	4.4	1.25	-131 ± 30	-198 ± 45	0.78 ± 0.18	0.55	New
ACT-CL J0217−5245	02:17:11	−52:45:20	4.1	1.25	-98 ± 24	-150 ± 37	0.59 ± 0.14	0.34	RXC J0217.2−5244
ACT-CL J0145−5301	01:44:59	−53:01:01	4.0	1.00	-99 ± 25	-167 ± 42	0.65 ± 0.16	0.12	A2941
ACT-CL J0237−4939	02:37:03	−49:39:27	3.9	1.00	-140 ± 36	-236 ± 61	0.93 ± 0.24	0.40	New
ACT-CL J0304−4921	03:04:15	−49:21:42	3.9	1.00	-169 ± 43	-285 ± 74	1.12 ± 0.29	0.47	New
ACT-CL J0707−5522	07:07:13	−55:22:48	3.3	1.75	-218 ± 67	-293 ± 90	1.16 ± 0.35	0.43	New
ACT-CL J0528−5259	05:28:03	−52:59:53	3.1	0.50	-88 ± 28	-244 ± 78	0.94 ± 0.30	0.77	SPT-CL 0528−5300

Marriage et al. ApJ, 2011

ACT: tSZ

- 455 deg^2 in 2008 data at 148GHz
- Matched filter with β-model profile
- 23 clusters blindly detected
- all have confirmed optical counter part
- 10 are new →
- J0102-4915 is among the biggest clusters ever seen

Table 1
ACT 2008 148 GHz SZ-selected Galaxy Clusters

ACT ID	R.A. (J2000) (hms)	Decl. (° ′ ″)	S/N	θ_c (′)	δT_0[a] (μK)	$\delta T_0'$[b] (μK)	y_0' ($\times 10^{-4}$)	z[c]	Alternative ID
All Candidates S/N > 6									
ACT-CL J0658−5557	06:58:30	−55:57:04	11.5	1.25	−483 ± 42	−734 ± 64	2.98 ± 0.26	0.30	1E0657-56 (Bullet)
ACT-CL J0638−5358	06:38:46	−53:58:45	10.0	1.25	−278 ± 28	−423 ± 42	1.68 ± 0.17	0.22	AS0592
ACT-CL J0245−5302	02:45:33	−53:02:04	9.1	1.00	−198 ± 22	−336 ± 37	1.32 ± 0.15	0.30	AS0295
ACT-CL J0102−4915	01:02:53	−49:15:19	9.0	0.75	−520 ± 58	−1046 ± 116	4.13 ± 0.46	0.75	New
ACT-CL J0438−5419	04:38:19	−54:19:05	8.0	0.50	−214 ± 27	−596 ± 74	2.35 ± 0.29	0.54	New
ACT-CL J0645−5413	06:45:30	−54:13:39	7.1	0.75	−221 ± 31	−444 ± 63	1.75 ± 0.25	0.17	A3404
ACT-CL J0546−5345	05:46:37	−53:45:32	6.5	1.75	−178 ± 27	−240 ± 37	0.95 ± 0.15	1.07	SPT-CL 0547−5345
ACT-CL J0235−5121	02:35:52	−51:21:16	6.2	4.00	−320 ± 51	−363 ± 58	1.43 ± 0.23	0.43	New
ACT-CL J0330−5227	03:30:54	−52:28:04	6.1	1.25	−145 ± 24	−221 ± 36	0.85 ± 0.14	0.44	A3128 (NE)
S/N < 6 and Optically Confirmed									
ACT-CL J0616−5227	06:16:36	−52:27:35	5.9	0.50	−155 ± 26	−431 ± 73	1.70 ± 0.29	0.71	New
ACT-CL J0559−5249	05:59:43	−52:49:13	5.1	2.25	−155 ± 31	−194 ± 38	0.77 ± 0.15	0.61	SPT-CL J0559−5249
ACT-CL J0215−5212	02:15:18	−52:12:30	4.9	0.25	−140 ± 29	−801 ± 164	3.16 ± 0.65	0.51	New
ACT-CL J0509−5341	05:09:21	−53:42:05	4.8	0.50	−115 ± 24	−319 ± 67	1.27 ± 0.27	0.46	SPT-CL 0509−5342
ACT-CL J0641−4949	06:41:35	−49:48:32	4.7	0.25	−283 ± 60	−1625 ± 375	6.41 ± 1.48	0.15	A3402
ACT-CL J0232−5257	02:32:45	−52:57:08	4.7	0.25	−124 ± 26	−710 ± 152	2.80 ± 0.60	0.59	New
ACT-CL J0516−5430	05:16:30	−54:30:30	4.6	1.75	−143 ± 31	−192 ± 43	0.77 ± 0.17	0.29	AS0520/SPT-CL 0517−5430
ACT-CL J0346−5438	03:46:51	−54:38:54	4.4	1.25	−131 ± 30	−198 ± 45	0.78 ± 0.18	0.55	New
ACT-CL J0217−5245	02:17:11	−52:45:20	4.1	1.25	−98 ± 24	−150 ± 37	0.59 ± 0.14	0.34	RXC J0217.2−5244
ACT-CL J0145−5301	01:44:59	−53:01:01	4.0	1.00	−99 ± 25	−167 ± 42	0.65 ± 0.16	0.12	A2941
ACT-CL J0237−4939	02:37:03	−49:39:27	3.9	1.00	−140 ± 36	−236 ± 61	0.93 ± 0.24	0.40	New
ACT-CL J0304−4921	03:04:15	−49:21:42	3.9	1.00	−169 ± 43	−285 ± 74	1.12 ± 0.29	0.47	New
ACT-CL J0707−5522	07:07:13	−55:22:48	3.3	1.75	−218 ± 67	−293 ± 90	1.16 ± 0.35	0.43	New
ACT-CL J0528−5259	05:28:05	−52:59:53	3.1	0.50	−88 ± 28	−244 ± 78	0.94 ± 0.30	0.77	SPT-CL 0528−5300

Marriage et al. ApJ, 2011

ACT: tSZ

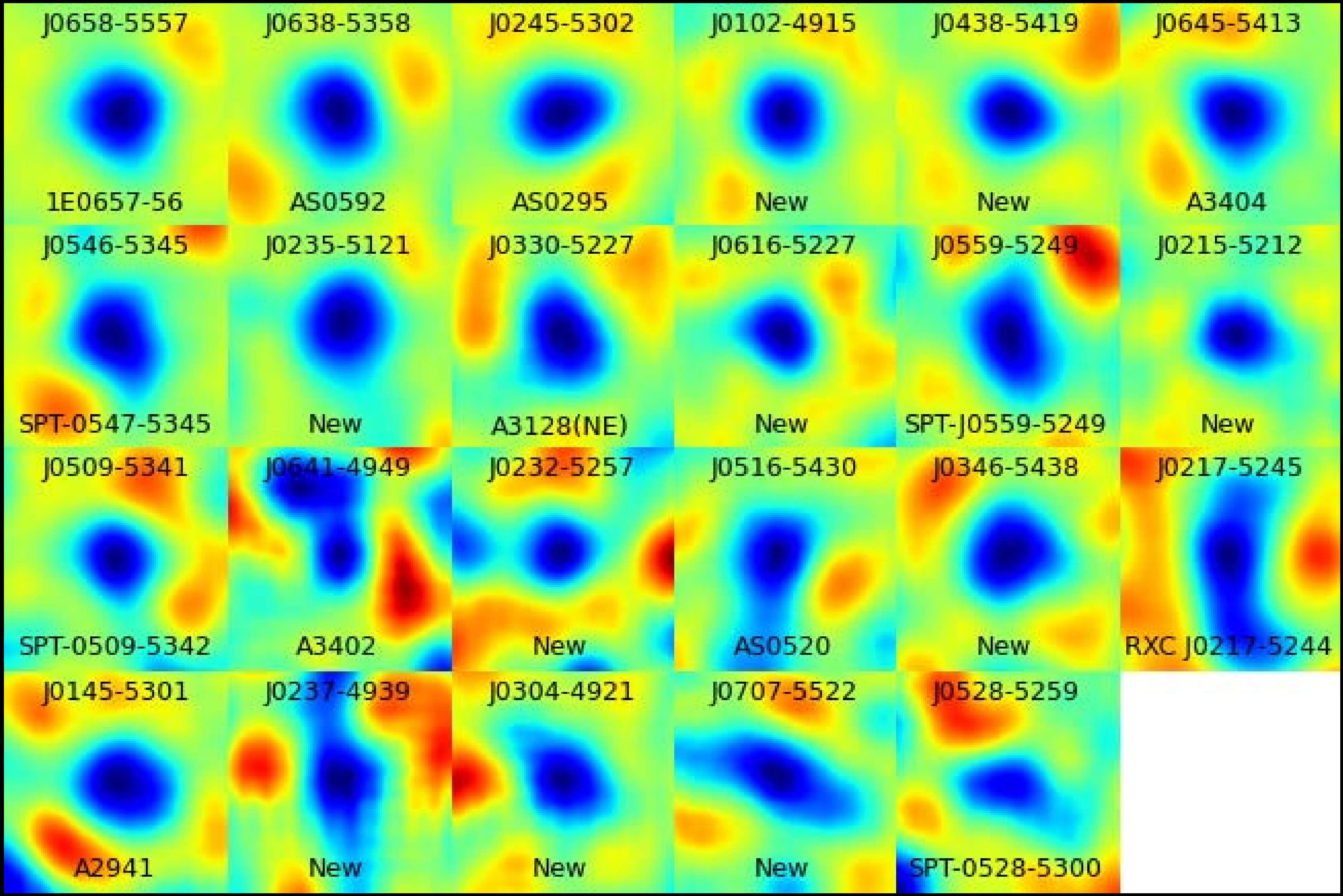
- 455 deg^2 in 2008 data at 148GHz
- Matched filter with β-model profile
- 23 clusters blindly detected
- all have confirmed optical counter part
- 10 are new
- J0102-4915 is among the biggest clusters ever seen

Table 1
ACT 2008 148 GHz SZ-selected Galaxy Clusters

ACT ID	R.A. (J2000) (hms)	Decl. (° ′ ″)	S/N	θ_c (′)	δT_0[a] (μK)	$\delta T_0'$[b] (μK)	y_0' ($\times 10^{-4}$)	z[c]	Alternative ID
All Candidates S/N > 6									
ACT-CL J0658−5557	06:58:30	−55:57:04	11.5	1.25	-483 ± 42	-734 ± 64	2.98 ± 0.26	0.30	1E0657-56 (Bullet)
ACT-CL J0638−5358	06:38:46	−53:58:45	10.0	1.25	-278 ± 28	-423 ± 42	1.68 ± 0.17	0.22	AS0592
ACT-CL J0245−5302	02:45:33	−53:02:04	9.1	1.00	-198 ± 22	-336 ± 37	1.32 ± 0.15	0.30	AS0295
ACT-CL J0102−4915	01:02:53	−49:15:19	9.0	0.75	-520 ± 58	-1046 ± 116	4.13 ± 0.46	0.75	New
ACT-CL J0438−5419	04:38:19	−54:19:05	8.0	0.50	-214 ± 27	-596 ± 74	2.35 ± 0.29	0.54	New
ACT-CL J0645−5413	06:45:30	−54:13:39	7.1	0.75	-221 ± 31	-444 ± 63	1.75 ± 0.25	0.17	A3404
ACT-CL J0546−5345	05:46:37	−53:45:32	6.5	1.75	-178 ± 27	-240 ± 37	0.95 ± 0.15	1.07	SPT-CL 0547−5345
ACT-CL J0235−5121	02:35:52	−51:21:16	6.2	4.00	-320 ± 51	-363 ± 58	1.43 ± 0.23	0.43	New
ACT-CL J0330−5227	03:30:54	−52:28:04	6.1	1.25	-145 ± 24	-221 ± 36	0.85 ± 0.14	0.44	A3128 (NE)
S/N < 6 and Optically Confirmed									
ACT-CL J0616−5227	06:16:36	−52:27:35	5.9	0.50	-155 ± 26	-431 ± 73	1.70 ± 0.29	0.71	New
ACT-CL J0559−5249	05:59:43	−52:49:13	5.1	2.25	-155 ± 31	-194 ± 38	0.77 ± 0.15	0.61	SPT-CL J0559−5249
ACT-CL J0215−5212	02:15:18	−52:12:30	4.9	0.25	-140 ± 29	-801 ± 164	3.16 ± 0.65	0.51	New
ACT-CL J0509−5341	05:09:21	−53:42:05	4.8	0.50	-115 ± 24	-319 ± 67	1.27 ± 0.27	0.46	SPT-CL 0509−5342
ACT-CL J0641−4949	06:41:35	−49:48:32	4.7	0.25	-283 ± 60	-1625 ± 375	6.41 ± 1.48	0.15	A3402
ACT-CL J0232−5257	02:32:45	−52:57:08	4.7	0.25	-124 ± 26	-710 ± 152	2.80 ± 0.60	0.59	New
ACT-CL J0516−5430	05:16:30	−54:30:30	4.6	1.75	-143 ± 31	-192 ± 43	0.77 ± 0.17	0.29	AS0520/SPT-CL 0517−5430
ACT-CL J0346−5438	03:46:51	−54:38:54	4.4	1.25	-131 ± 30	-198 ± 45	0.78 ± 0.18	0.55	New
ACT-CL J0217−5245	02:17:11	−52:45:20	4.1	1.25	-98 ± 24	-150 ± 37	0.59 ± 0.14	0.34	RXC J0217.2−5244
ACT-CL J0145−5301	01:44:59	−53:01:01	4.0	1.00	-99 ± 25	-167 ± 42	0.65 ± 0.16	0.12	A2941
ACT-CL J0237−4939	02:37:03	−49:39:27	3.9	1.00	-140 ± 36	-236 ± 61	0.93 ± 0.24	0.40	New
ACT-CL J0304−4921	03:04:15	−49:21:42	3.9	1.00	-169 ± 43	-285 ± 74	1.12 ± 0.29	0.47	New
ACT-CL J0707−5522	07:07:13	−55:22:48	3.3	1.75	-218 ± 67	-293 ± 90	1.16 ± 0.35	0.43	New
ACT-CL J0528−5259	05:28:03	−52:59:53	3.1	0.50	-88 ± 28	-244 ± 78	0.94 ± 0.30	0.77	SPT-CL 0528−5300

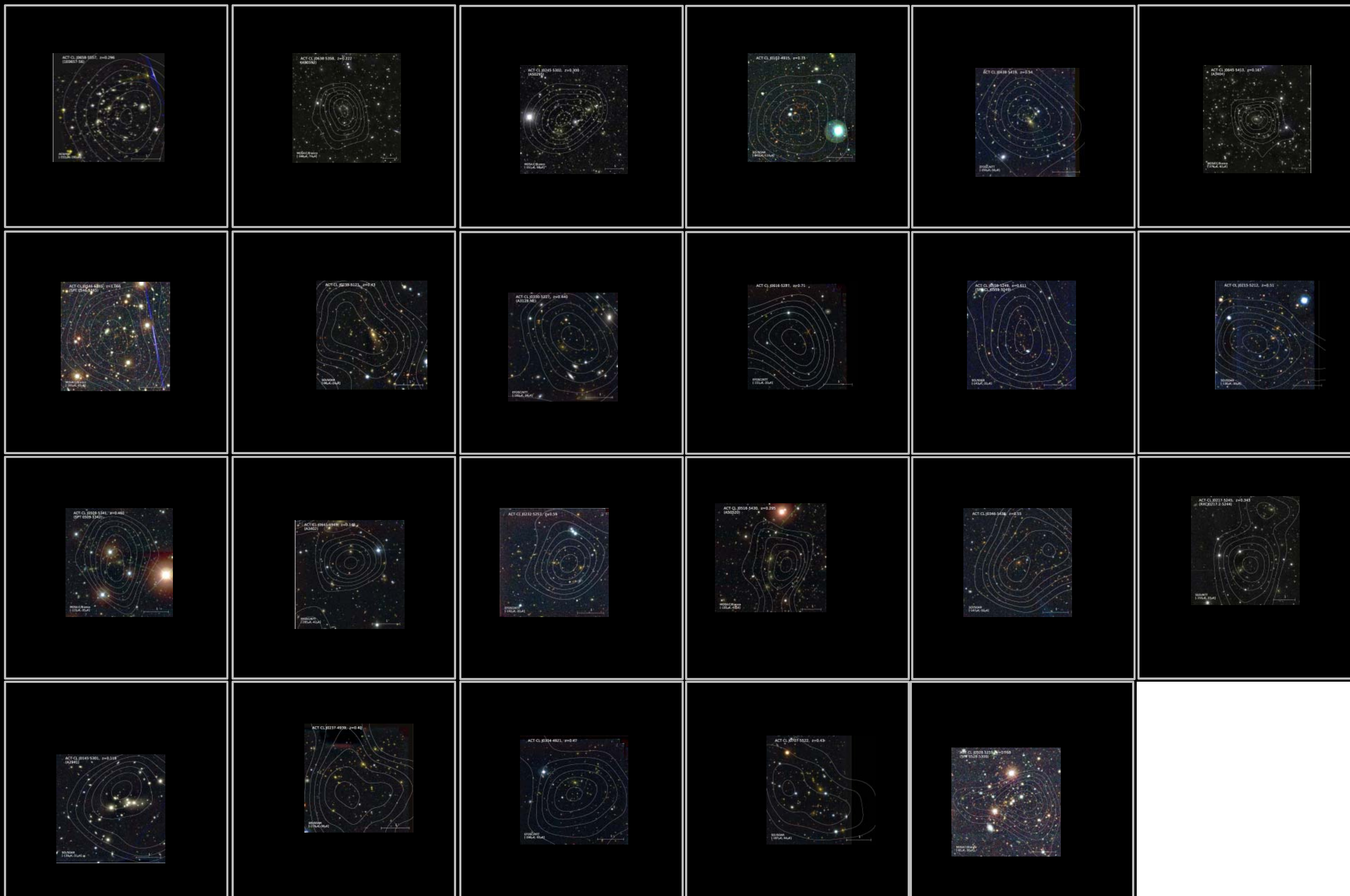
Marriage et al. ApJ, 2011

ACT: tSZ



Marriage et al. ApJ, 2011

ACT: tSZ



Menanteau et al. ApJ, 2010

Marriage et al. ApJ, 2011

ACT: tSZ –the case of ”El Gordo”

- ACT:
  - ACT-CL J0102-4915: new discovery
  - ~1mK decrement
  - y $\cong 5\ 10^{-4}$
- Optical follow-up (SOAR/SOI + VLT/FORS2):
  - 89 spectra → z=0.870
  - σ_{gal}=1321 km/s
  - Strong lensing arc
- SPITZER:
  - < 1% stellar mass
- X-ray: Chandra
  - Integrated T_x=14.5±1.0 keV
  - Temp. variation from 6 to 22 keV
  - Cometary shape…even a double tail
- Combined mass: $M_{200}=(2.16\pm0.32)\ 10^{15}\ h^{-1}_{70}\ M_{sun}$; on the edge of the mass distribution produced with simulations
- Major merger with 2÷1 components
- High redshift Bullet cluster?

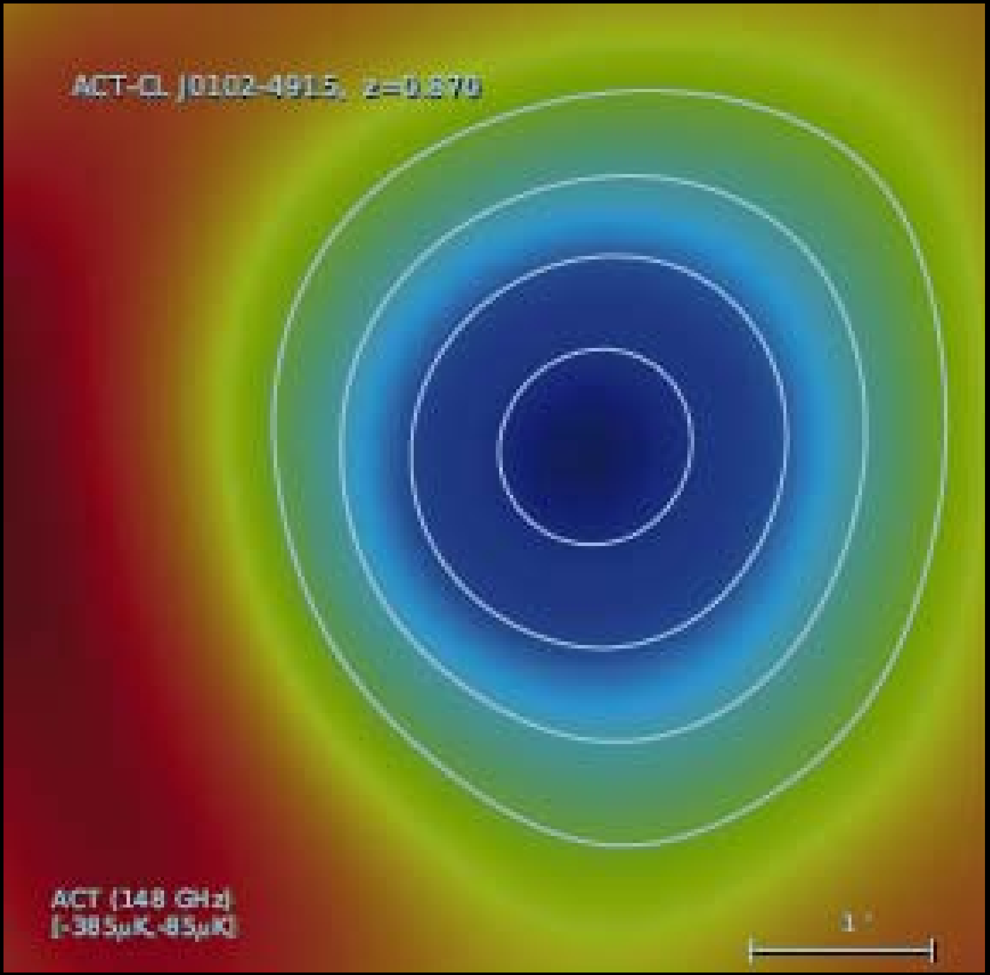


Image courtesy of F. Menanteau

Marriage et al. ApJ, 2011
Menanteau et al. ApJ 2012

ACT: tSZ –the case of ”El Gordo”

- ACT:
  - ACT-CL J0102-4915: new discovery
  - ~1mK decrement
  - y $\cong$ 5 10^{-4}
- Optical follow-up (SOAR/SOI + VLT/FORS2):
  - 89 spectra → z=0.870
  - σ_{gal}=1321 km/s
  - Strong lensing arc
- SPITZER:
  - < 1% stellar mass
- X-ray: Chandra
  - Integrated T_x=14.5±1.0 keV
  - Temp. variation from 6 to 22 keV
  - Cometary shape…even a double tail
- Combined mass: $M_{200}=(2.16\pm0.32)\ 10^{15}\ h^{-1}_{70}$ M_{sun}; on the edge of the mass distribution produced with simulations
- Major merger with 2÷1 components
- High redshift Bullet cluster?

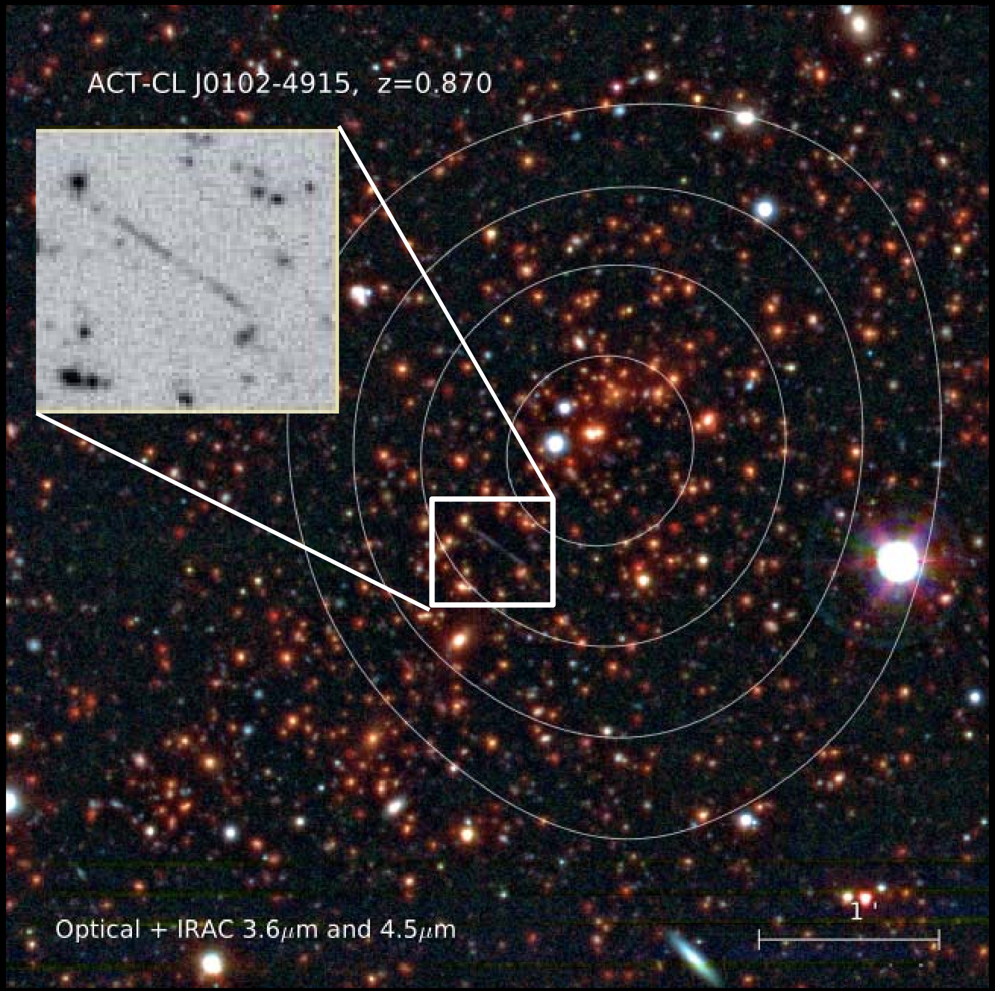


Image courtesy of F. Menanteau

Marriage et al. ApJ, 2011
Menanteau et al. ApJ 2012

ACT: tSZ –the case of ”El Gordo”

- ACT:
  - ACT-CL J0102-4915: new discovery
  - ~1mK decrement
  - y $\cong$ 5 10^{-4}
- Optical follow-up (SOAR/SOI + VLT/FORS2):
  - 89 spectra → z=0.870
  - σ_{gal}=1321 km/s
  - Strong lensing arc
- SPITZER:
  - < 1% stellar mass
- X-ray: Chandra
  - Integrated T_x=14.5±1.0 keV
  - Temp. variation from 6 to 22 keV
  - Cometary shape…even a double tail
- Combined mass: M_{200}=(2.16±0.32) 10^{15} h^{-1}_{70} M_{sun}; on the edge of the mass distribution produced with simulations
- Major merger with 2÷1 components
- High redshift Bullet cluster?

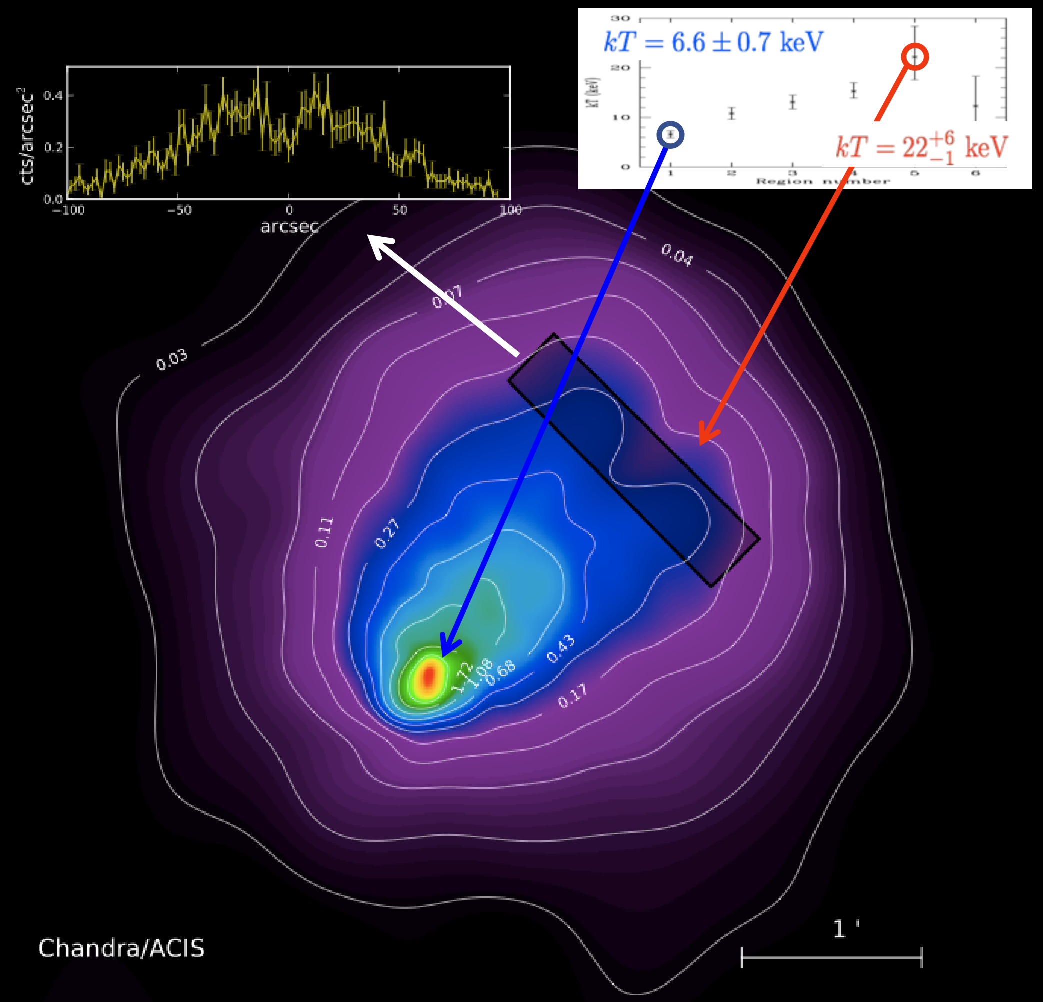


Image courtesy of F. Menanteau

Marriage et al. ApJ, 2011
Menanteau et al. ApJ 2012

ACT: tSZ –the case of ”El Gordo”

- ACT:
  - ACT-CL J0102-4915: new discovery
  - ~1mK decrement
  - y ≅ 5 10^{-4}
- Optical follow-up (SOAR/SOI + VLT/FORS2):
  - 89 spectra → z=0.870
  - σ_{gal}=1321 km/s
  - Strong lensing arc
- SPITZER:
  - < 1% stellar mass
- X-ray: Chandra
  - Integrated T_x=14.5±1.0 keV
  - Temp. variation from 6 to 22 keV
  - Cometary shape…even a double tail
- Combined mass: $M_{200}=(2.16\pm0.32)\ 10^{15}\ h^{-1}{}_{70}\ M_{sun}$; on the edge of the mass distribution produced with simulations
- Major merger with 2÷1 components
- High redshift Bullet cluster?

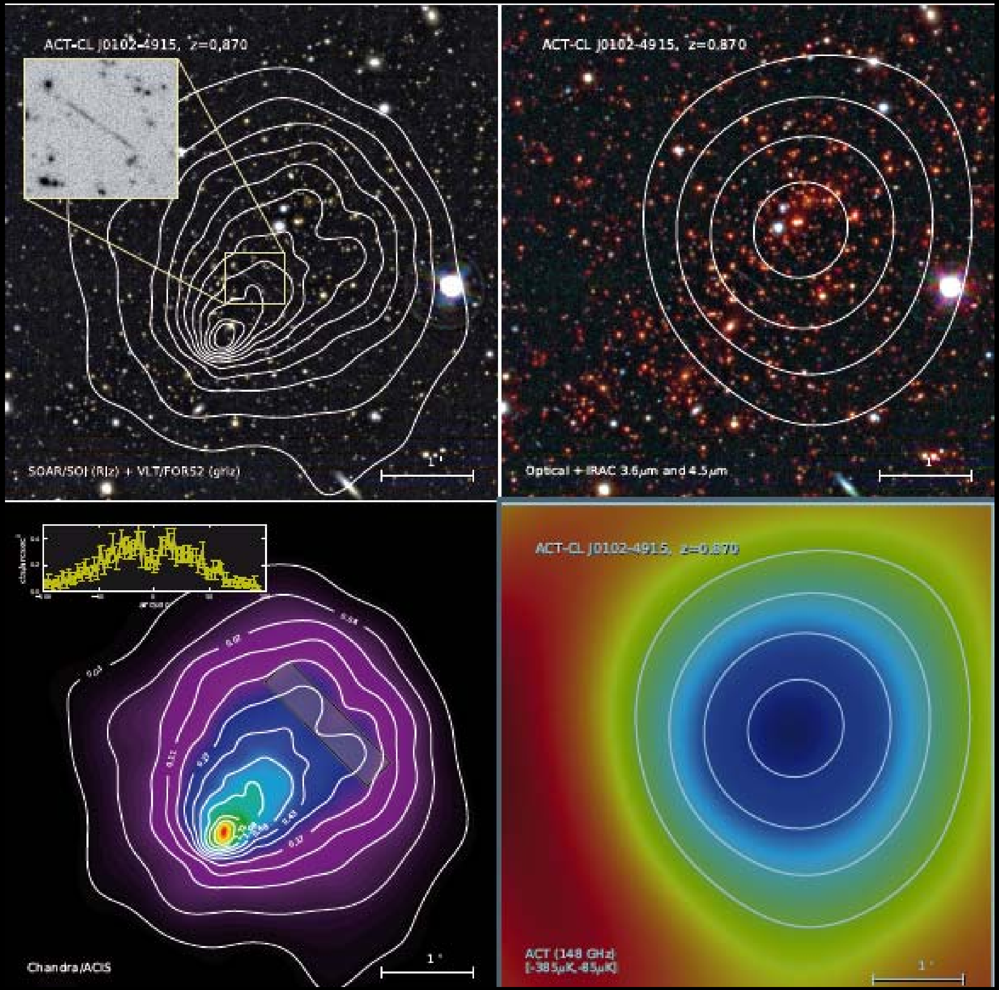


Image courtesy of F. Menanteau

Marriage et al. ApJ, 2011
Menanteau et al. ApJ 2012

ACT: tSZ –the case of "El Gordo"

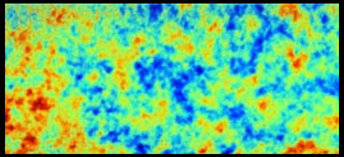
- ACT:
  - ACT-CL J0102-4915: new discovery
  - ~1mK decrement
  - y $\cong$ 5 10^{-4}
- Optical follow-up (SOAR/SOI + VLT/FORS2):
  - 89 spectra → z=0.870
  - σ_{gal}=1321 km/s
  - Strong lensing arc
- SPITZER:
  - < 1% stellar mass
- X-ray: Chandra
  - Integrated T_x=14.5±1.0 keV
  - Temp. variation from 6 to 22 keV
  - Cometary shape…even a double tail
- Combined mass: M_{200}=(2.16±0.32) 10^{15} h^{-1}_{70} M_{sun}; on the edge of the mass distribution produced with simulations
- Major merger with 2÷1 components
- High redshift Bullet cluster?

Marriage et al. ApJ 2011

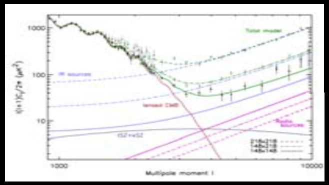
Menanteau et al. ApJ 2012

Summary

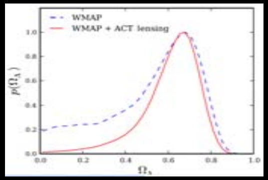
•ACT: instrument and observations



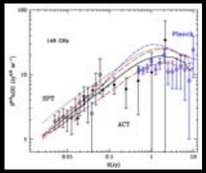
•Maps and power spectrum



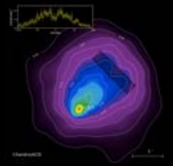
•Cosmological parameters



•Gravitational lensing in CMB maps



•point sources



•SZ clusters and follow-up: the case of “El Gordo”

The end: thank you!

Barcelona ICE (Spain)
UBC (Canada)
University of Cape Town (S. Africa)
Cardiff University (UK)
Columbia (US)
Haverford (US)
INAOE (Mexico)
University of Kwa-Zulu Natal (S. Africa)
University of Massachusetts (US)
NASA/GSFC (US)
NIST (US)
Oxford (UK)

University of Pennsylvania (US)
Princeton (US) PI: Lyman Page
University of Pittsburgh (US)
Pontifica Universidad Catolica (Chile)
Rutgers (US)
CITA/University of Toronto (Canada)

and collaborators at:

Sapienza
Stanford
Miami
CfA
IPMU/Tokyo

MPI
Berkeley
Chicago
LLNL