XMM-Newton mosaic mode: First results from the XMM-BCS cluster survey

Róbert Šuhada

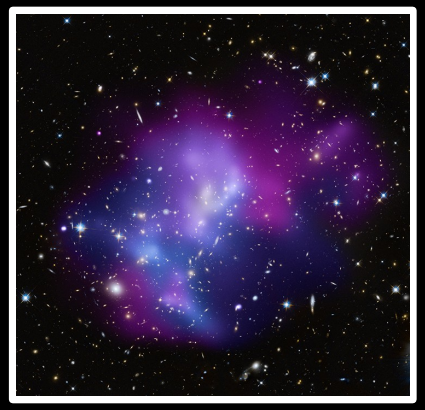
with
H. Böhringer, J. Song, J. Mohr, B. Benson, R. Fassbender,
A. Finoguenov, G. Chon, et al.

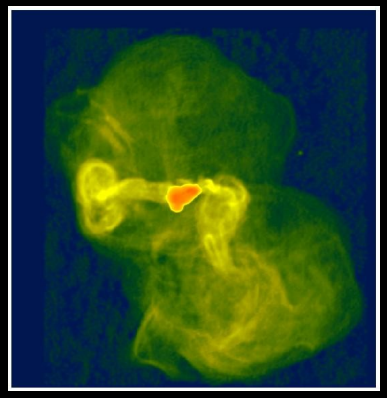
1. Clusters and their cosmological context

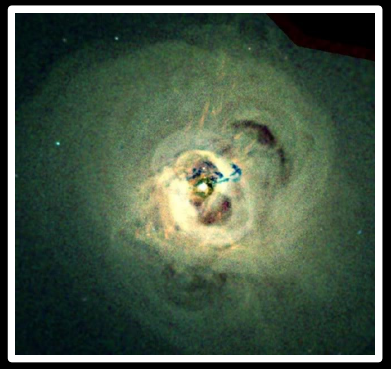
2. The XMM-BCS survey

3. The SZE connection

A beautiful, unique snowflake



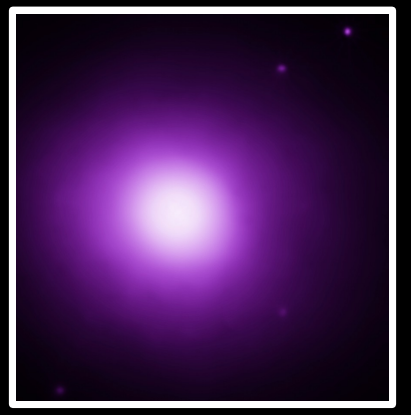


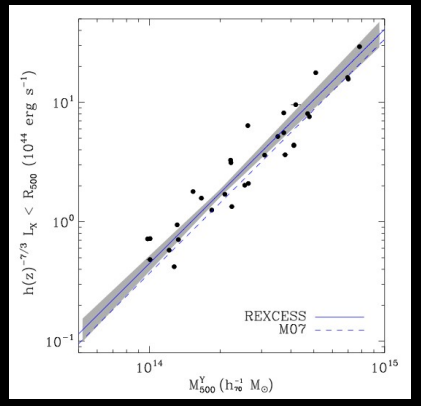


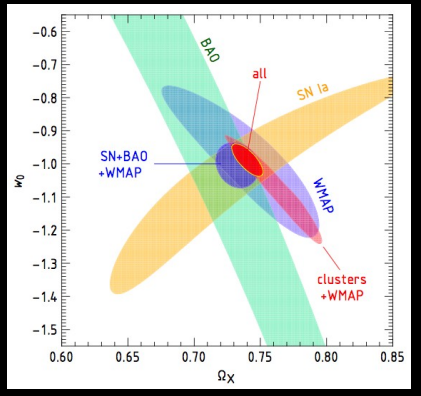
Cosmology

Physics

Just another brick in the wall







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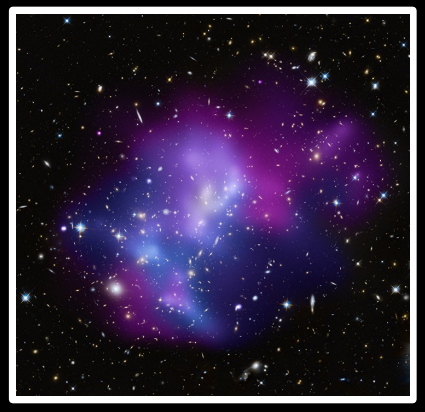
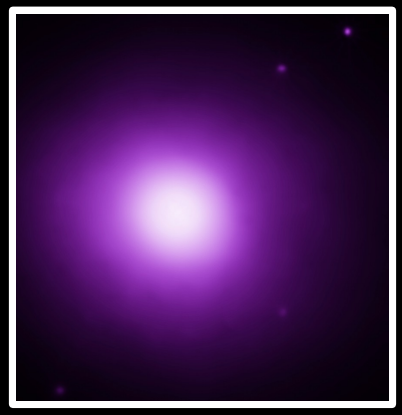
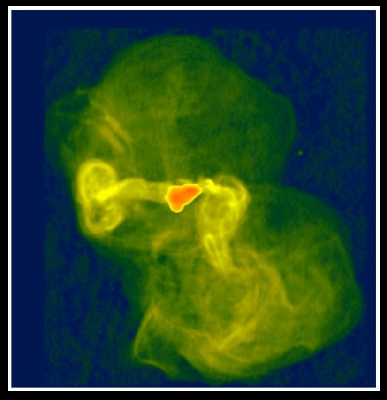
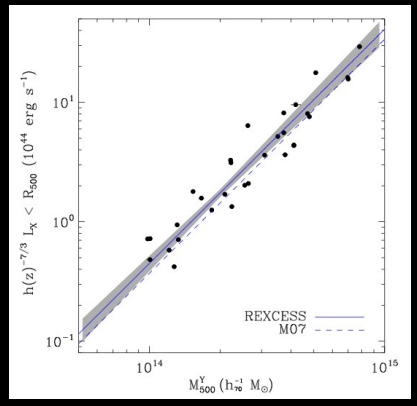


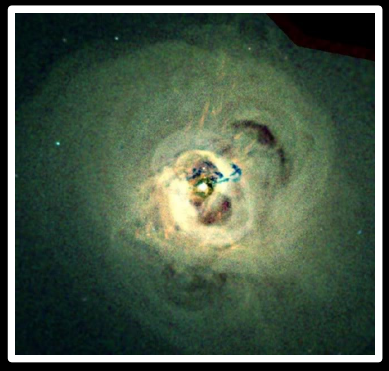
Thermodynamical state of the ICM
Gas cooling/heating
Metal enrichment
AGN feedback



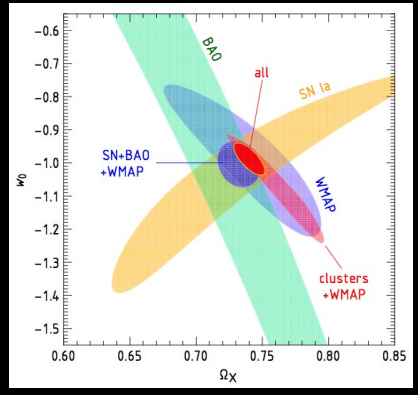


Scaling relations and their evolution
D_A, f_{gas} ...
Selection function





Hierarchy of the LSS
Cluster environment
Background cosmology



1. Clusters and their cosmological context

2. The XMM-BCS survey

3. The SZE connection

Aims

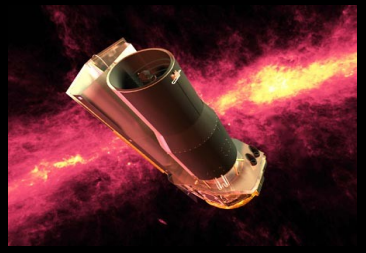
Multi-wavelength survey

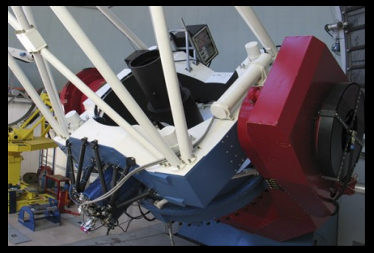
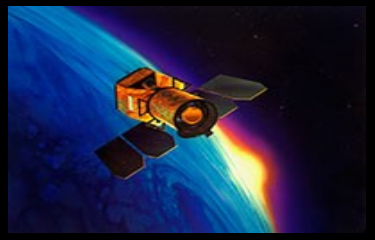
- bring together both established and new techniques for cluster selection: X-ray, optical+NIR, IR and SZE
- study and compare the selection functions
- multi-wavelength characterization of newly discovered clusters up to z~1

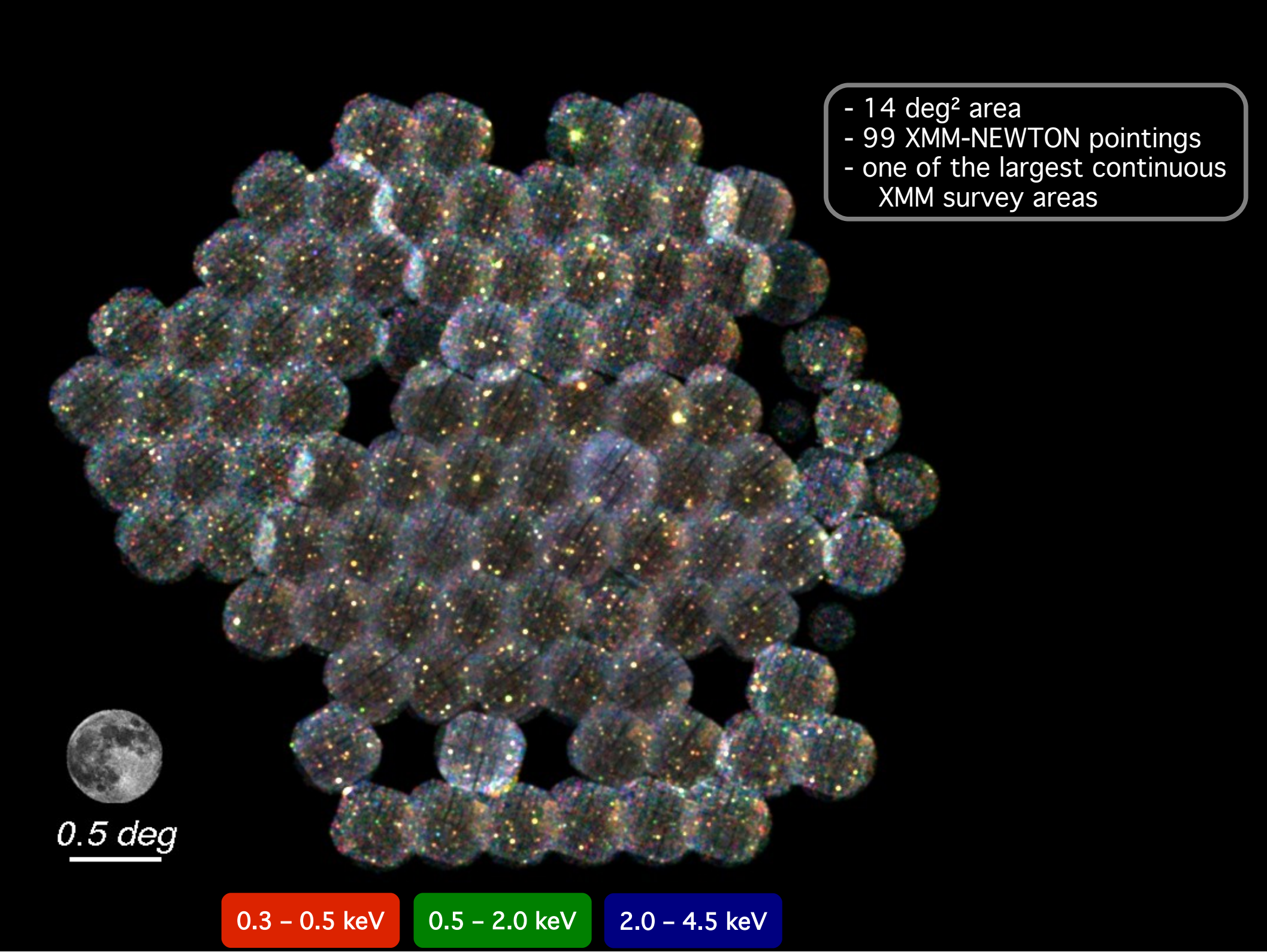
X-ray part of the survey

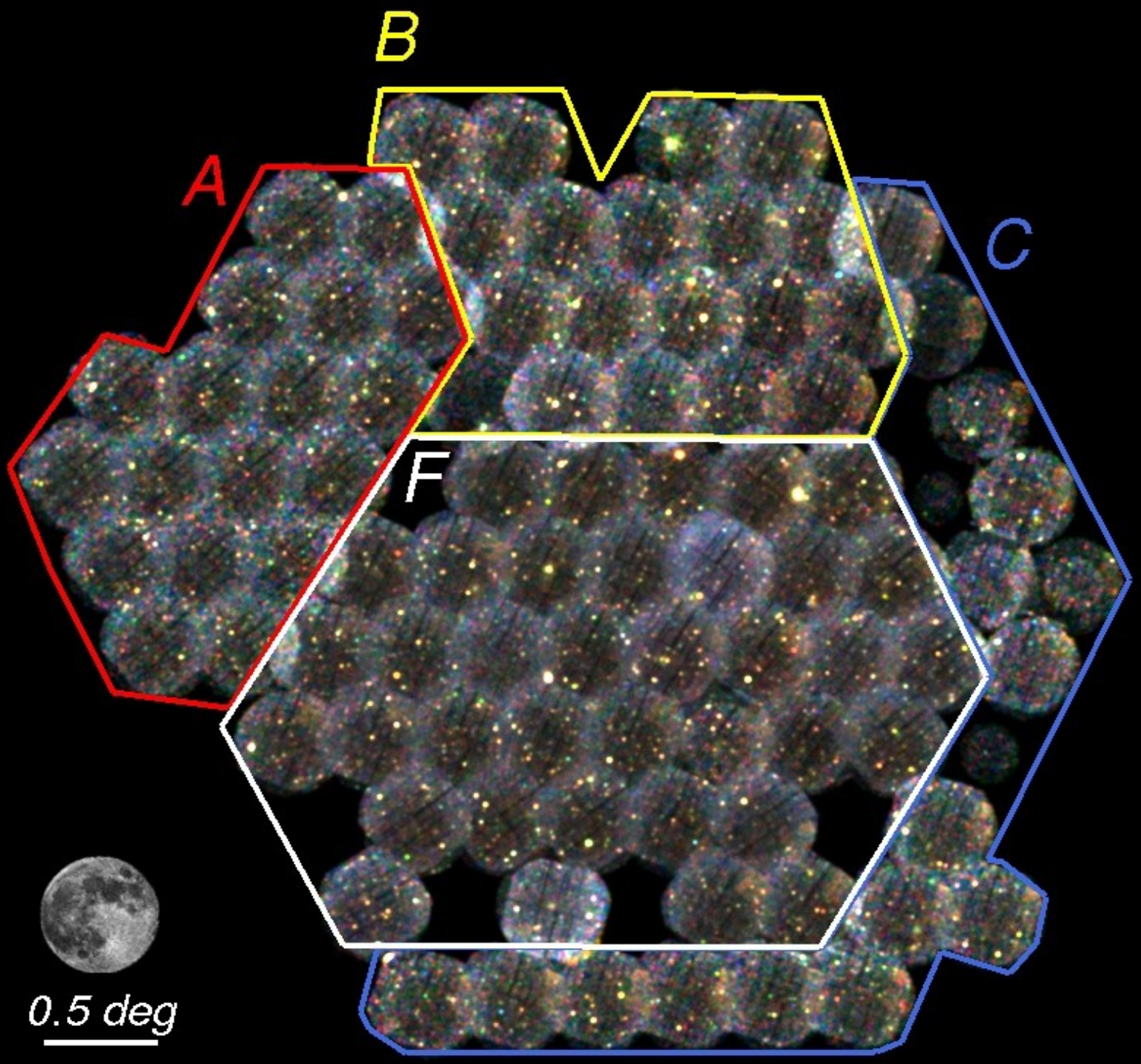
- Detect and study clusters in the field
- Cluster evolution and cosmological modeling
- Get (modest) constraint on cosmological parameters
- Find and study AGN, AGN clustering properties
- Help calibrating the SZ surveys

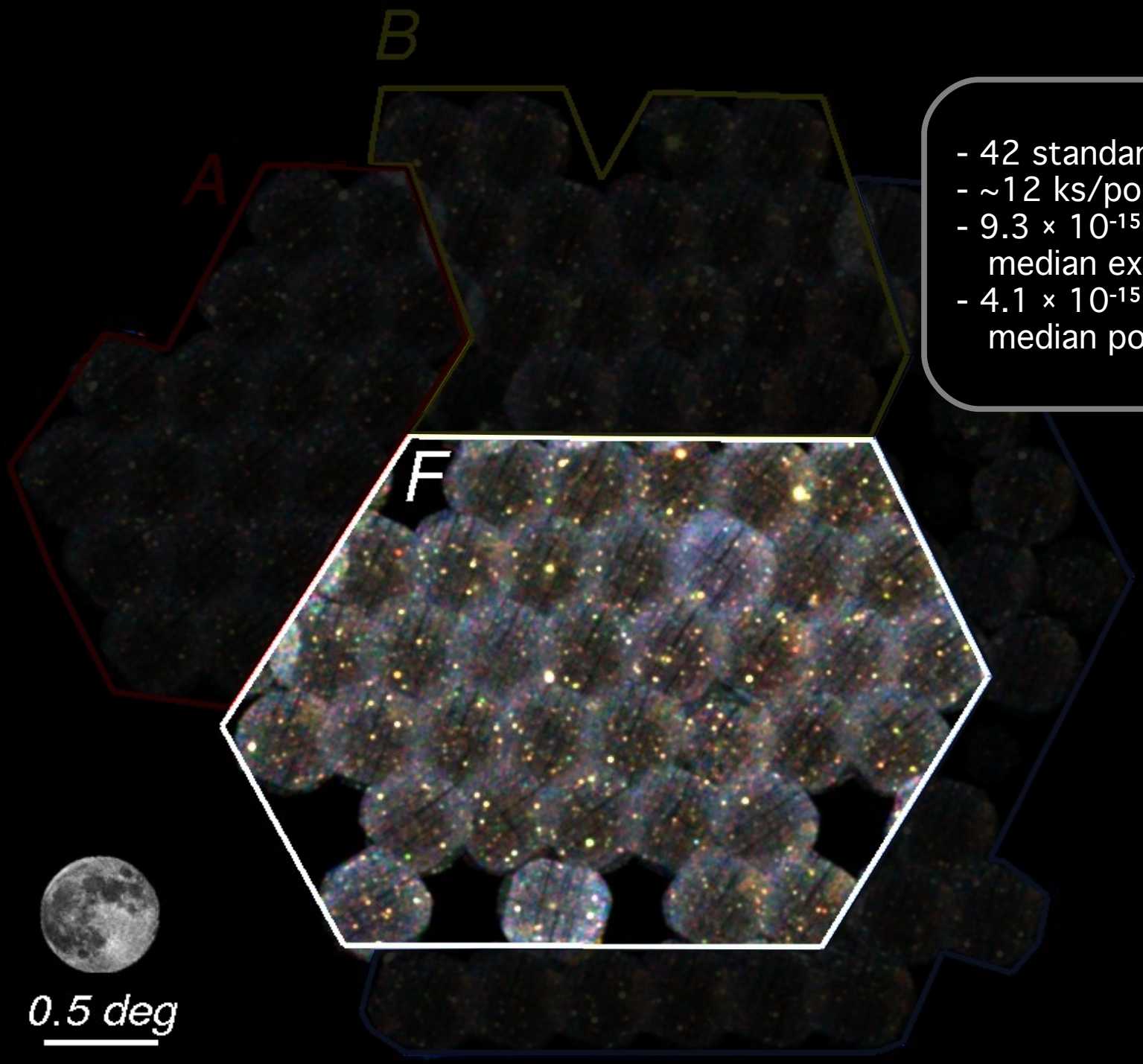




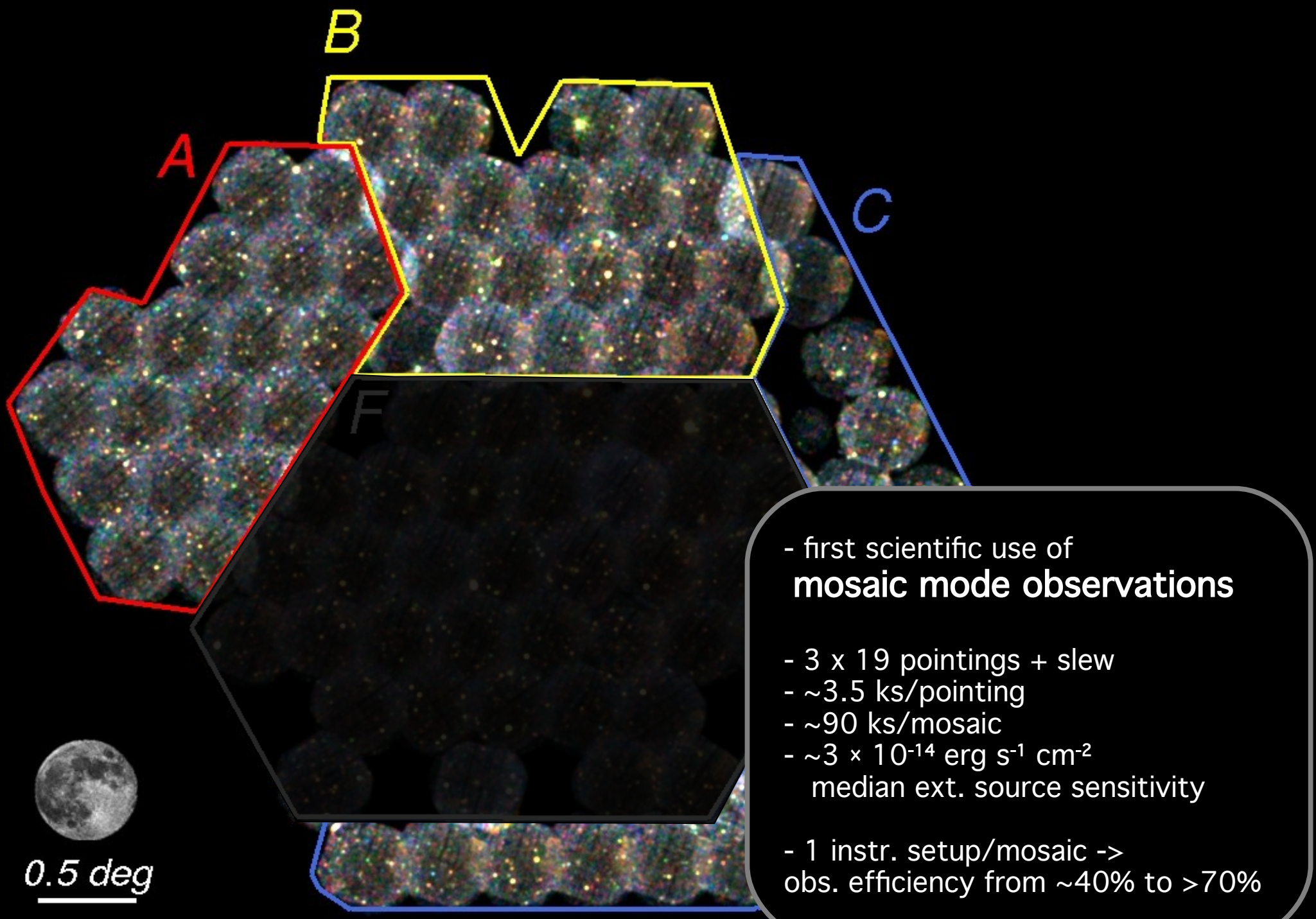


- 14 deg² area
- 99 XMM-NEWTON pointings
- one of the largest continuous XMM survey areas
0.5 deg
0.3 – 0.5 keV
0.5 – 2.0 keV
2.0 – 4.5 keV


B
A
C
F
0.5 deg
0.3 – 0.5 keV
0.5 – 2.0 keV
2.0 – 4.5 keV



- 42 standard pointings
- ~12 ks/pointing
- 9.3×10^{-15} erg s^{-1} cm^{-2} median ext. source sensitivity
- 4.1×10^{-15} erg s^{-1} cm^{-2} median point source sensitivity

0.3 – 0.5 keV | 0.5 – 2.0 keV | 2.0 – 4.5 keV

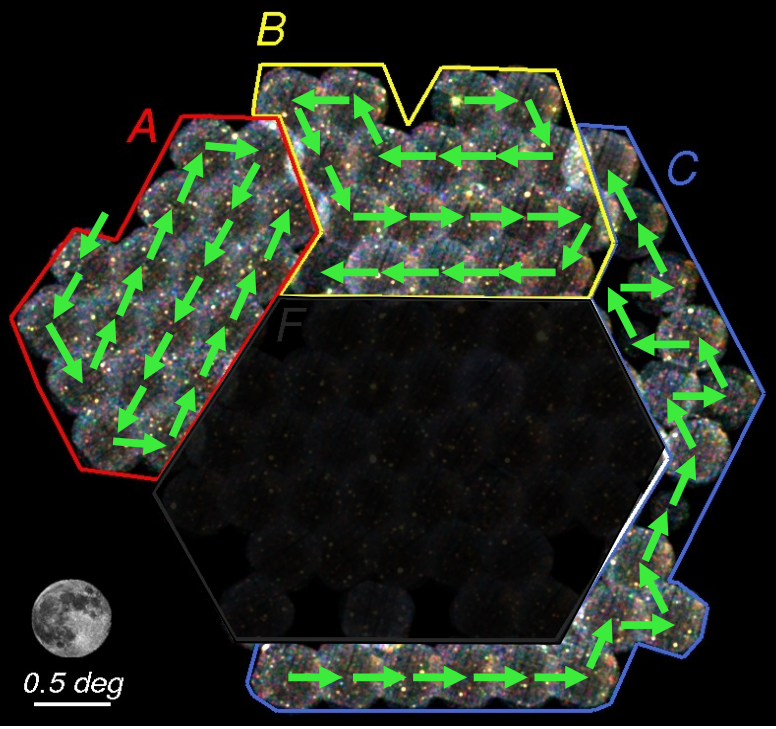


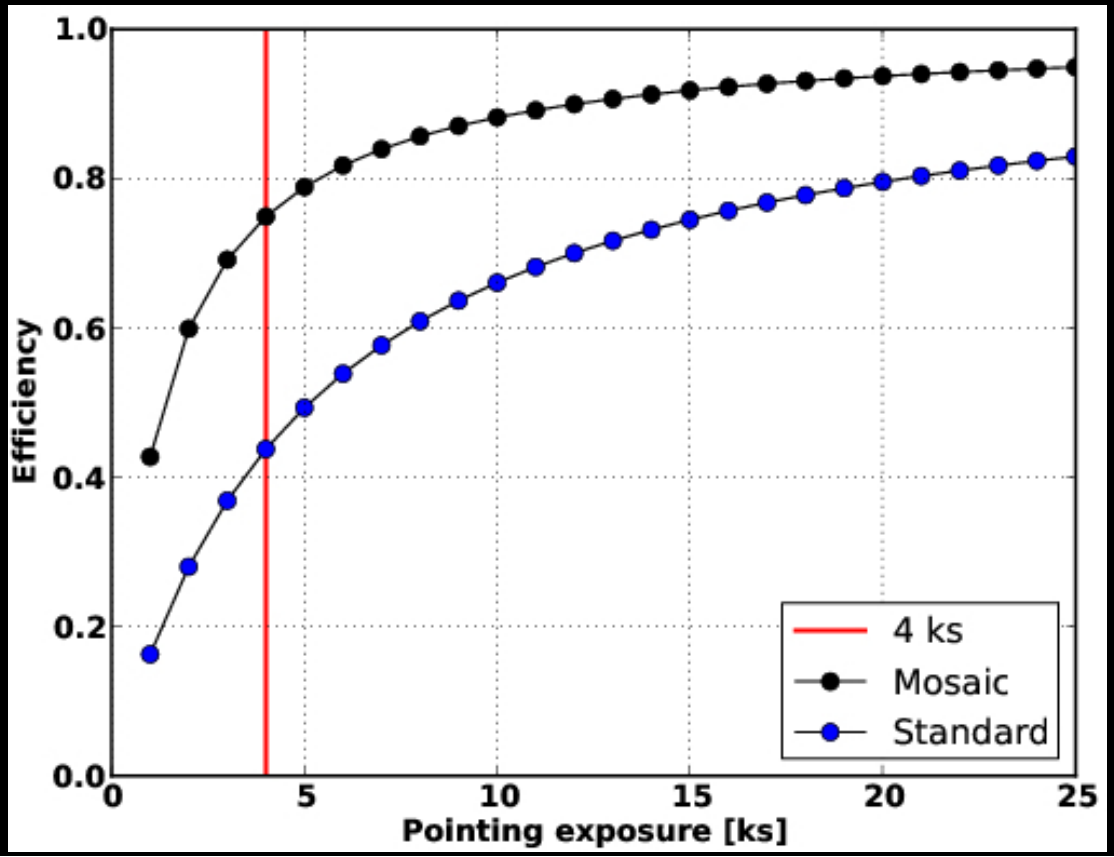
- first scientific use of
mosaic mode observations

- 3 x 19 pointings + slew
- ~3.5 ks/pointing
- ~90 ks/mosaic
- ~3 × 10^{-14} erg s^{-1} cm^{-2}
  median ext. source sensitivity

- 1 instr. setup/mosaic ->
obs. efficiency from ~40% to >70%

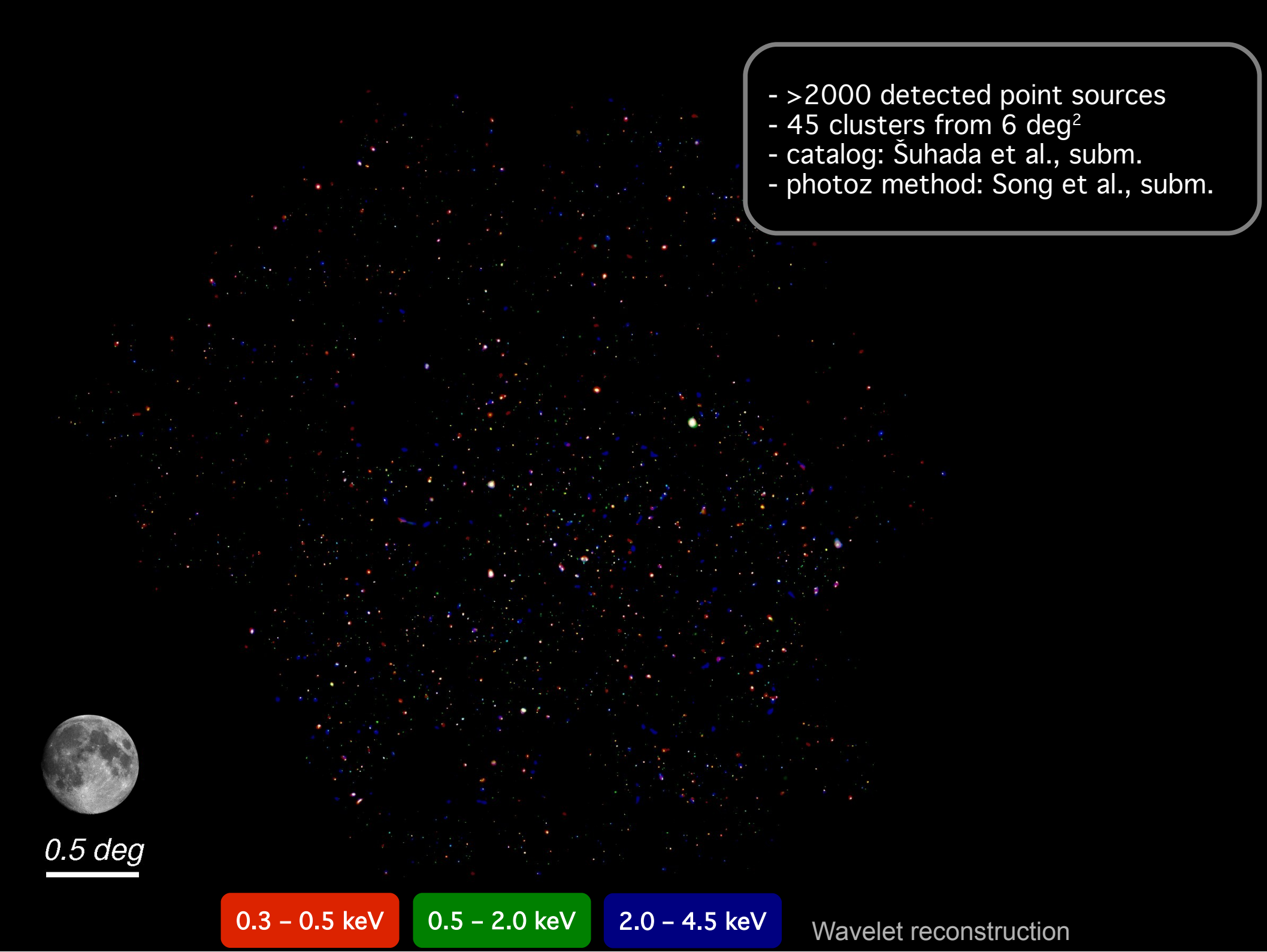
0.3 – 0.5 keV | 0.5 – 2.0 keV | 2.0 – 4.5 keV





The Mosaic Mode

- suppress the EPIC offset table calculation for every pointing beyond the first observation
- slight decrease in zero-charge level precision
- avoid brighter stars
- pointing offsets (12”, 1 deg)
- exp. time (2, ~4) ks/pointing


- >2000 detected point sources
- 45 clusters from 6 deg^2
- catalog: Šuhada et al., subm.
- photoz method: Song et al., subm.
0.5 deg
0.3 – 0.5 keV
0.5 – 2.0 keV
2.0 – 4.5 keV
Wavelet reconstruction

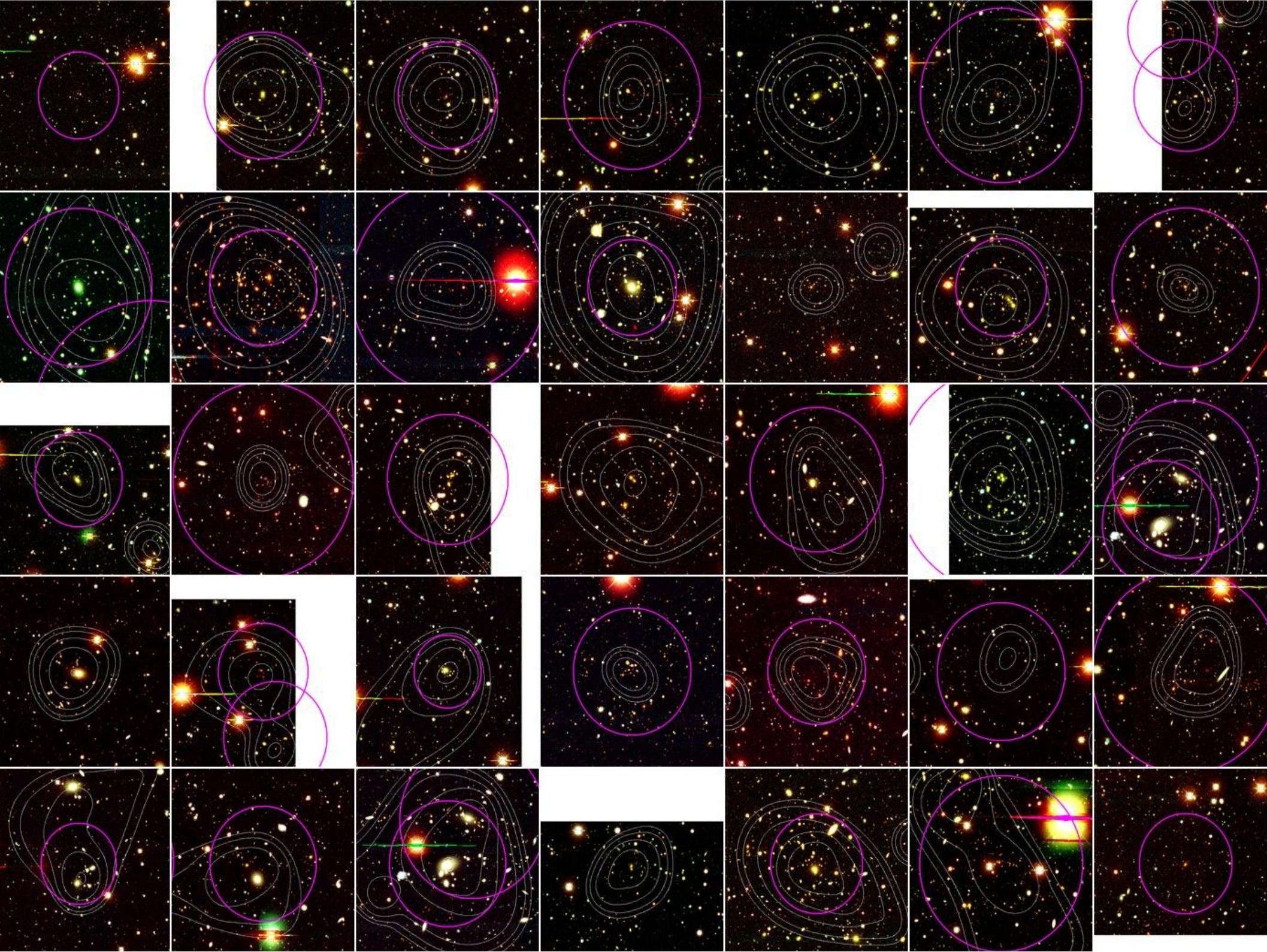
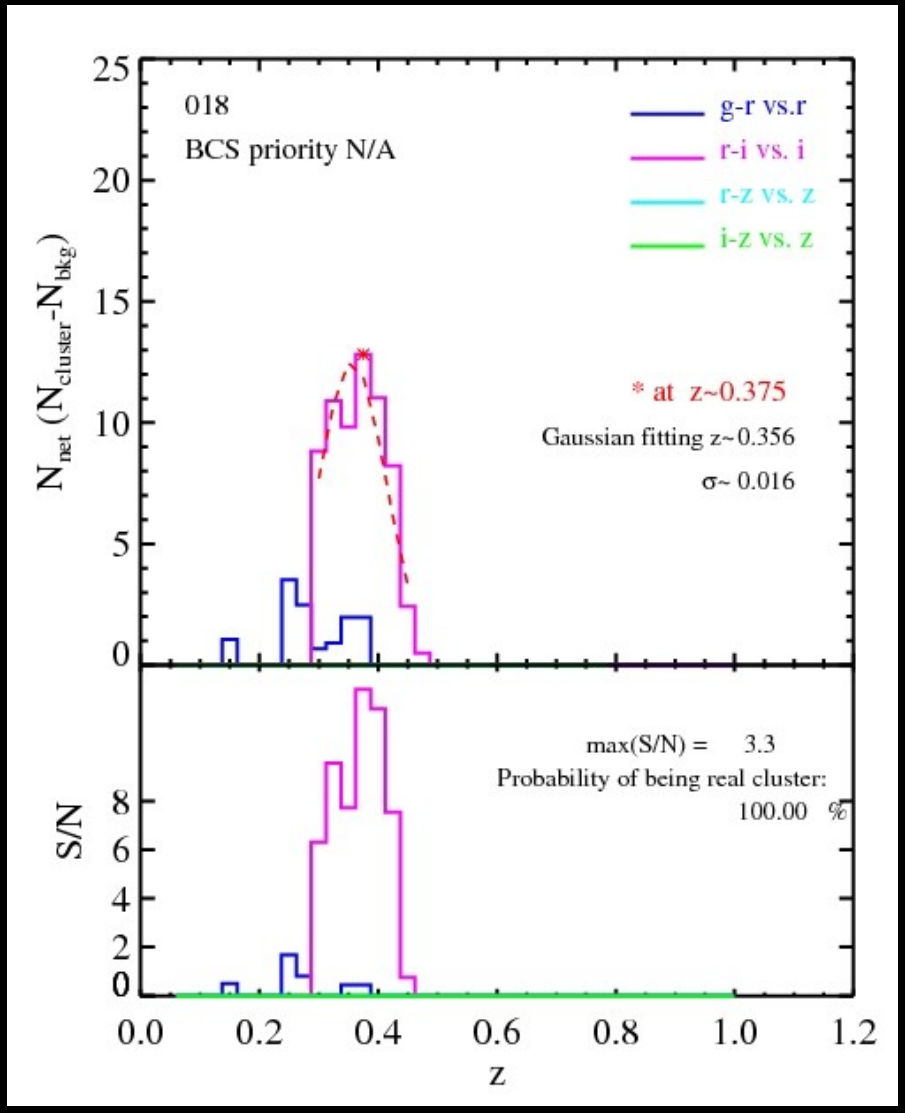
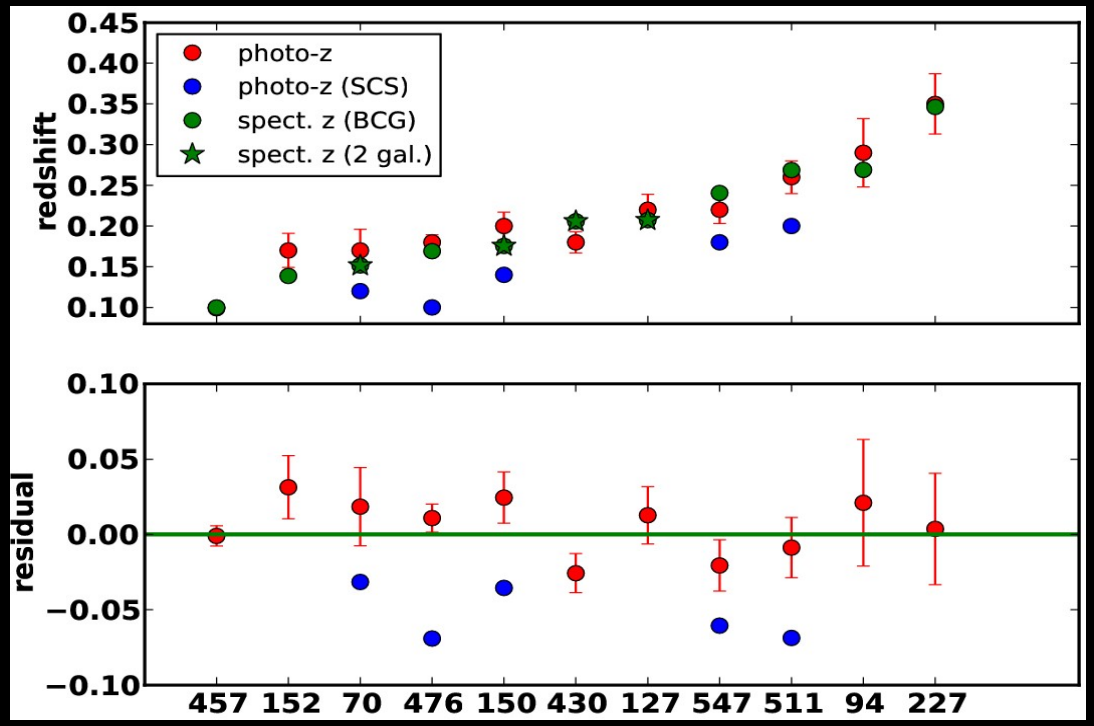
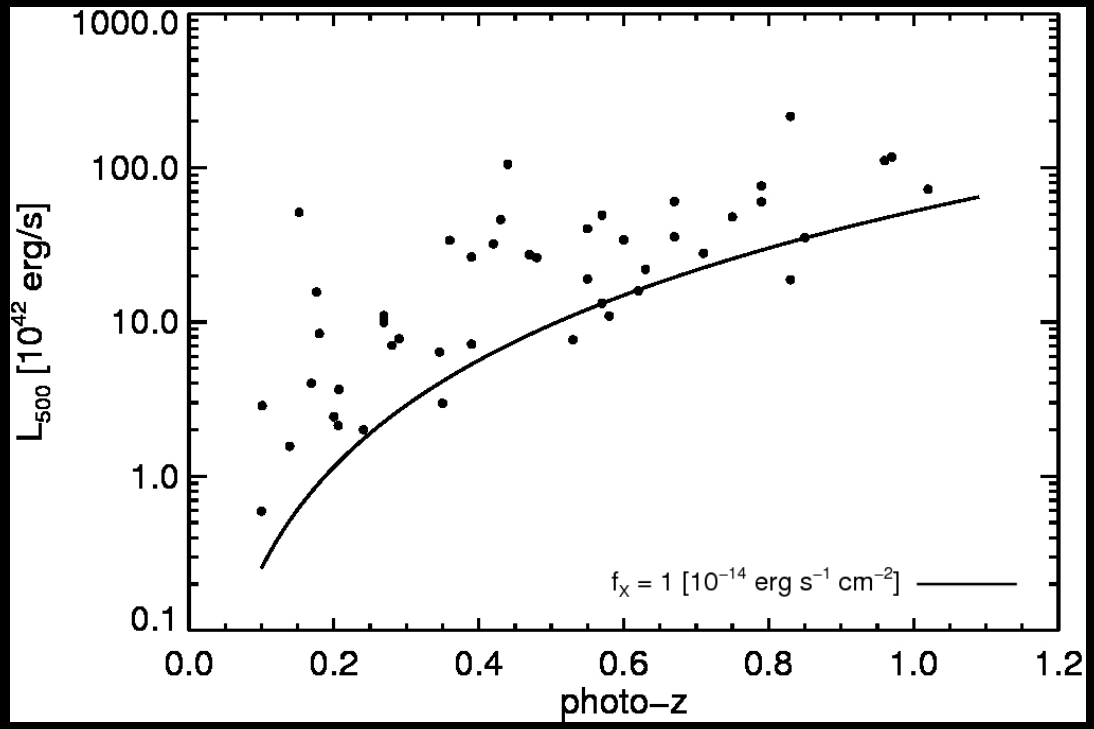


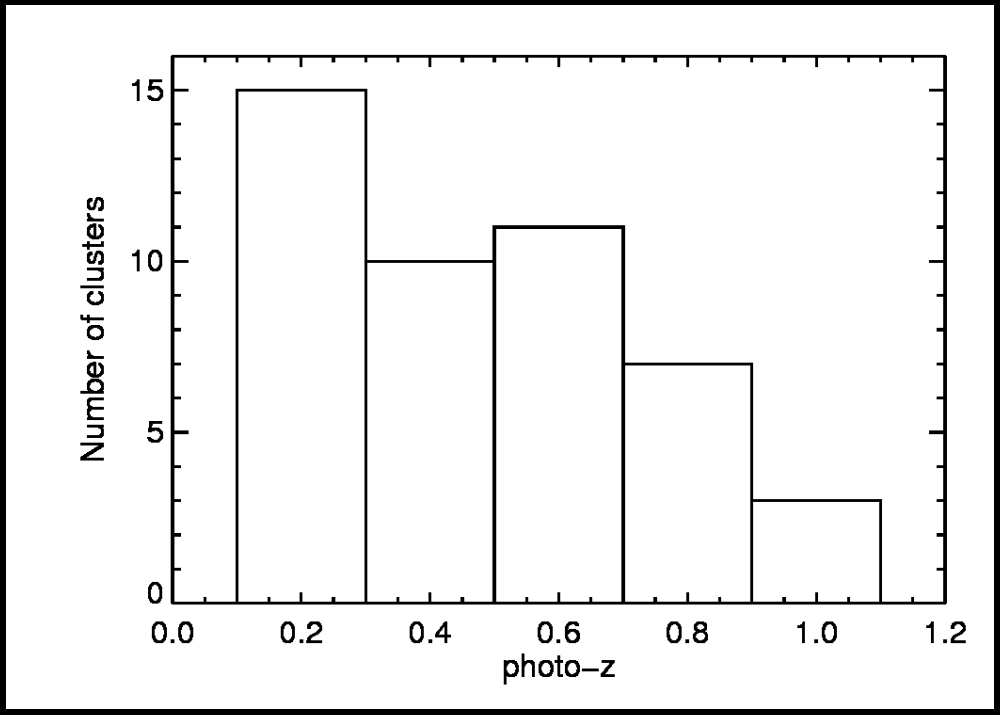
Photo-z estimation

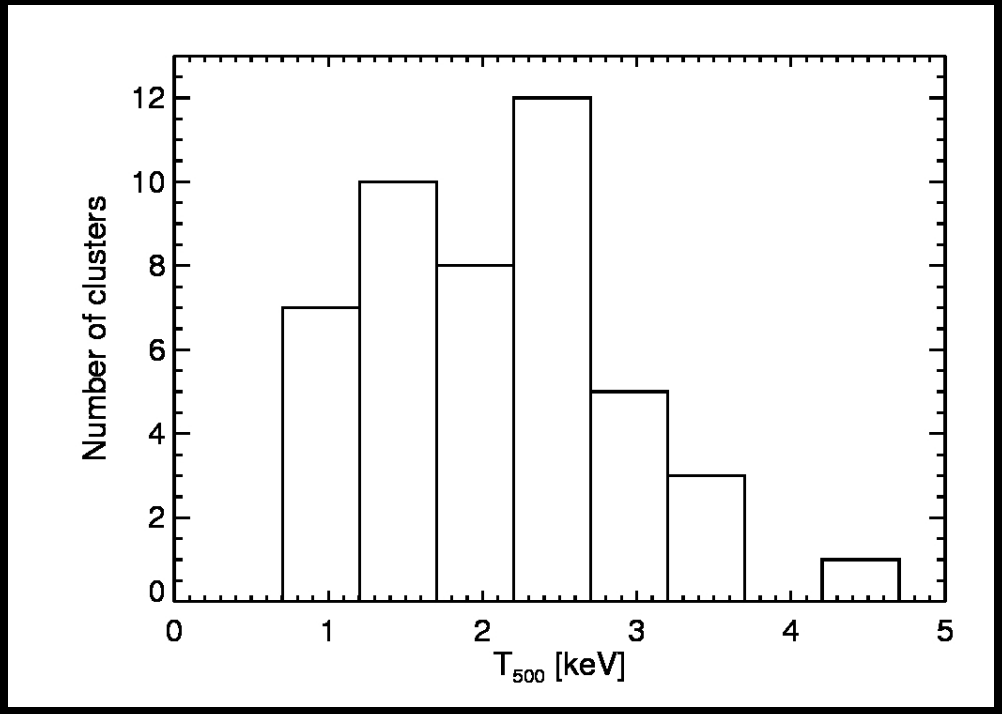


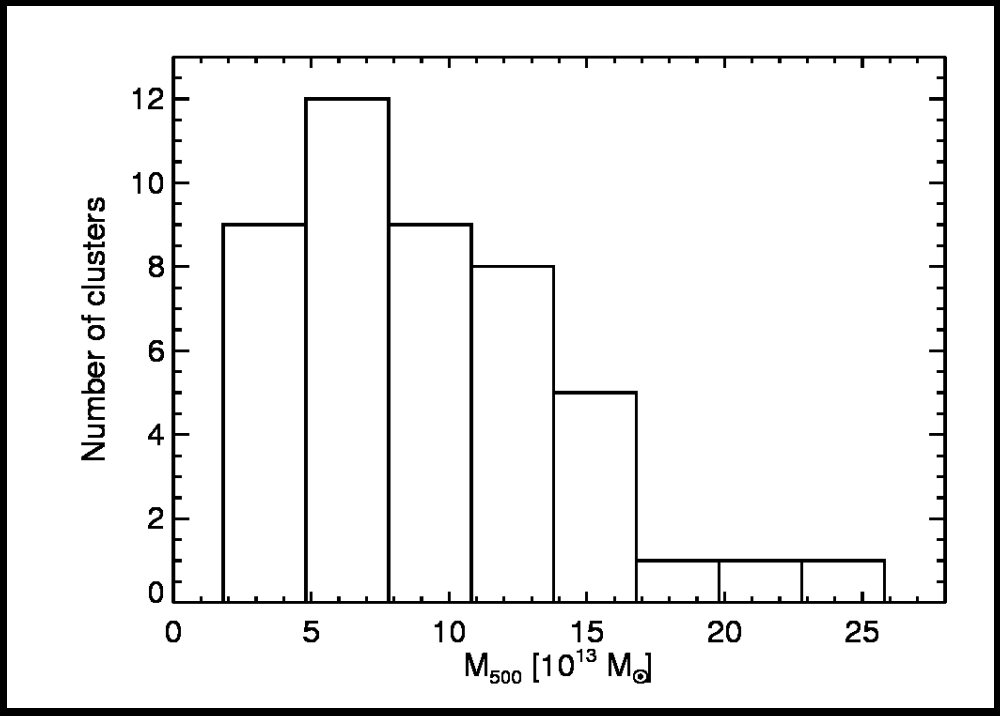




BCS PI: J. Mohr
NTT spectra: H. Böhringer, G. Chon







Total number of clusters: 45

Šuhada+11, subm.

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Behind the Iron Curtain
deep in the Cold War era...

"*...toiling behind the Iron Curtain under a tough mentor, a Russian astrophysicist uncovered secrets of the universe that have led to discoveries 4 decades later*" (Bhattacharjee, 2010)

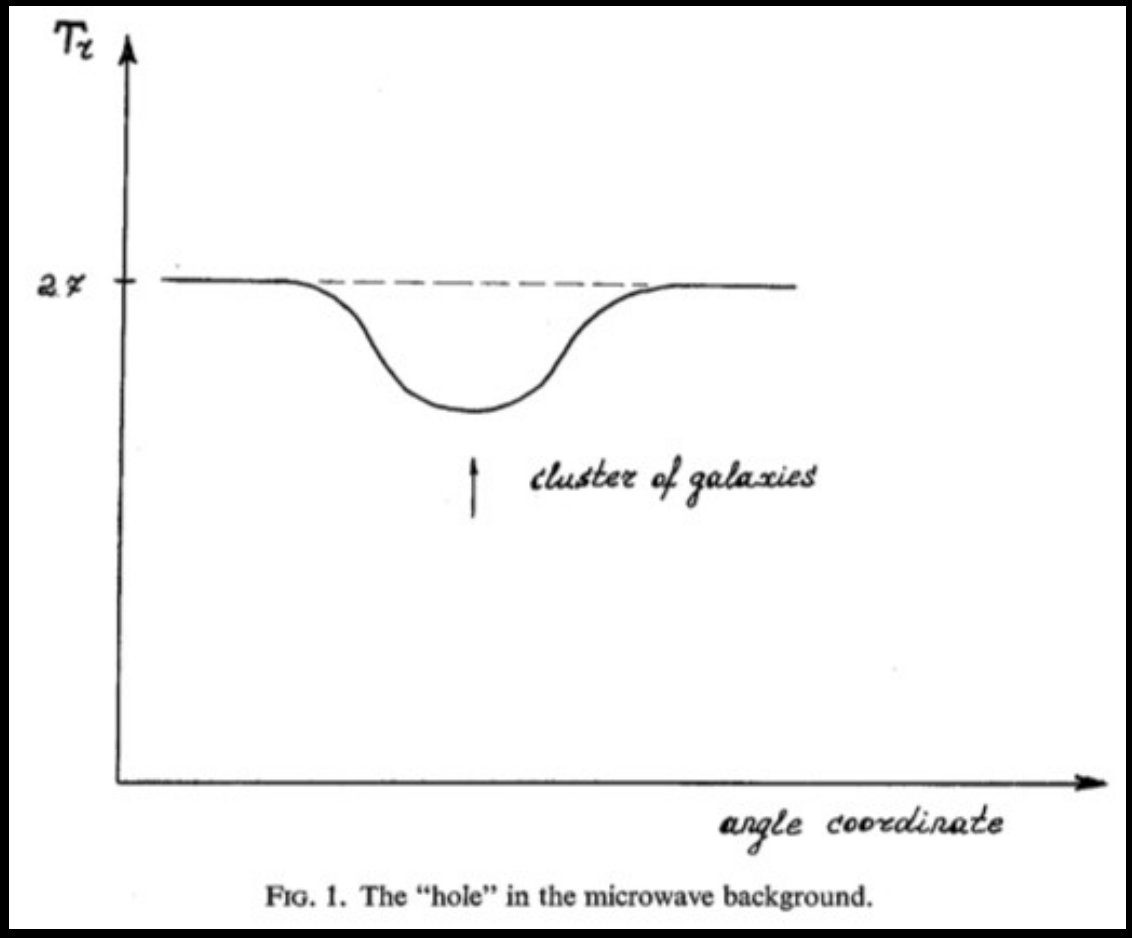


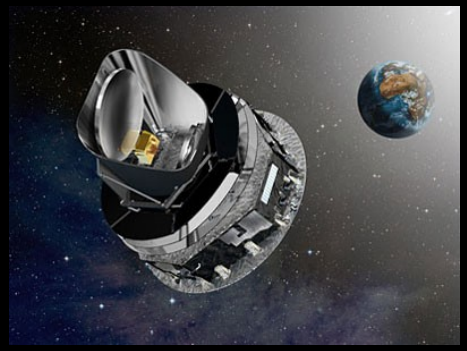
FIG. 1. The "hole" in the microwave background.

Sunyaev & Zel'dovich, 1969, 1970, 1972

...4 decades later

iCompton era

...4 decades later



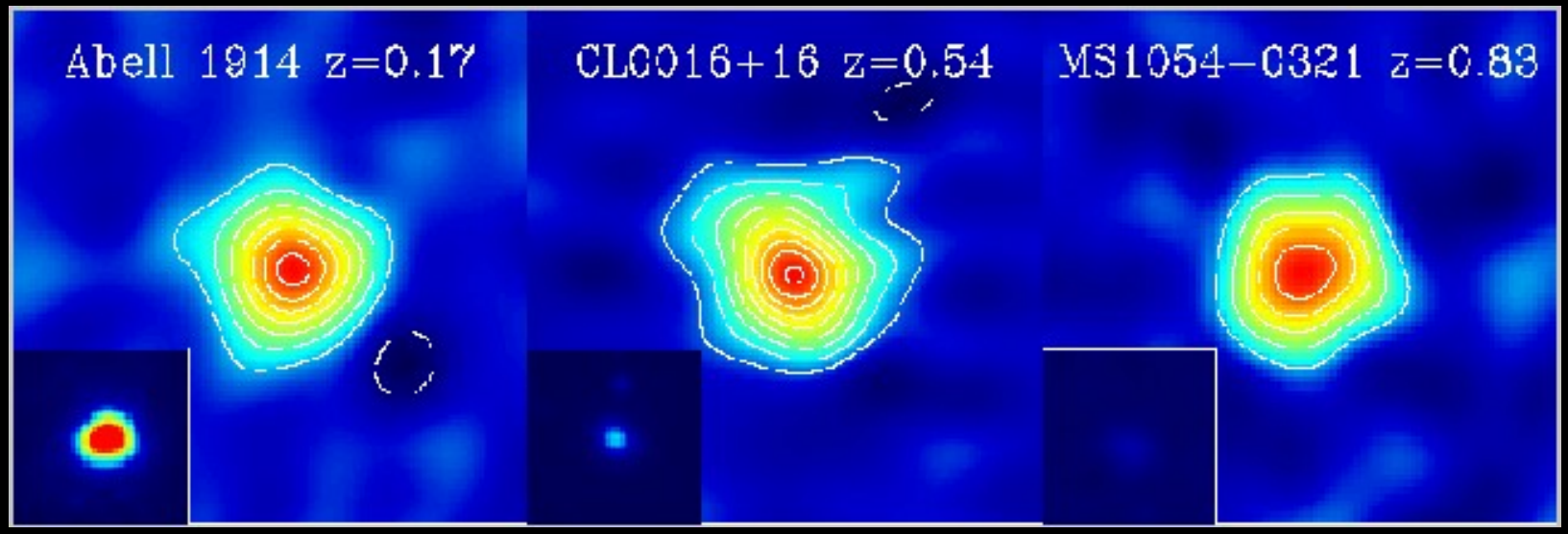
Planck

South Pole Telescope

Atacama Cosmology Telescope

Atacama Pathfinder Experiment

+ interferometer arrays

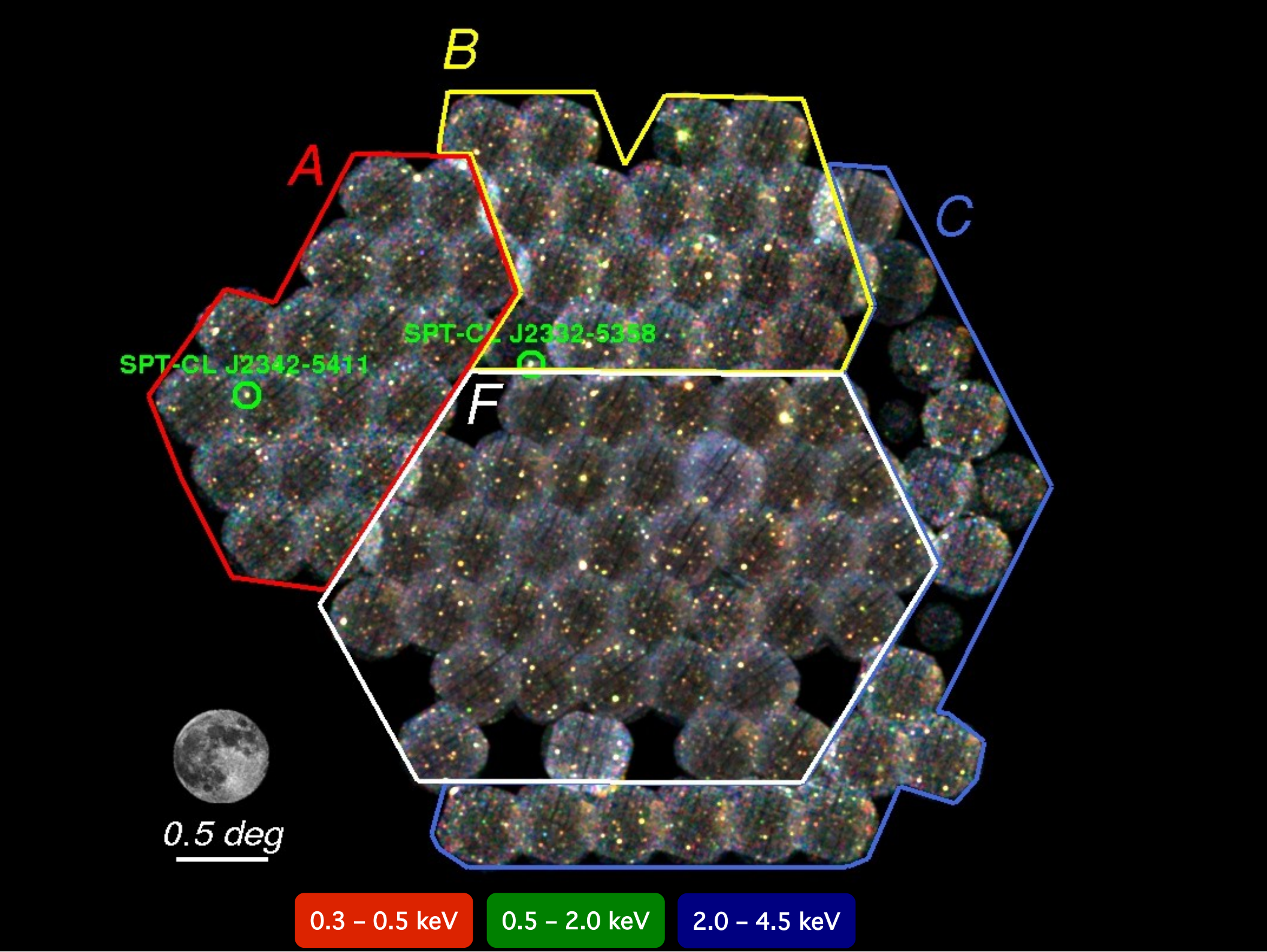


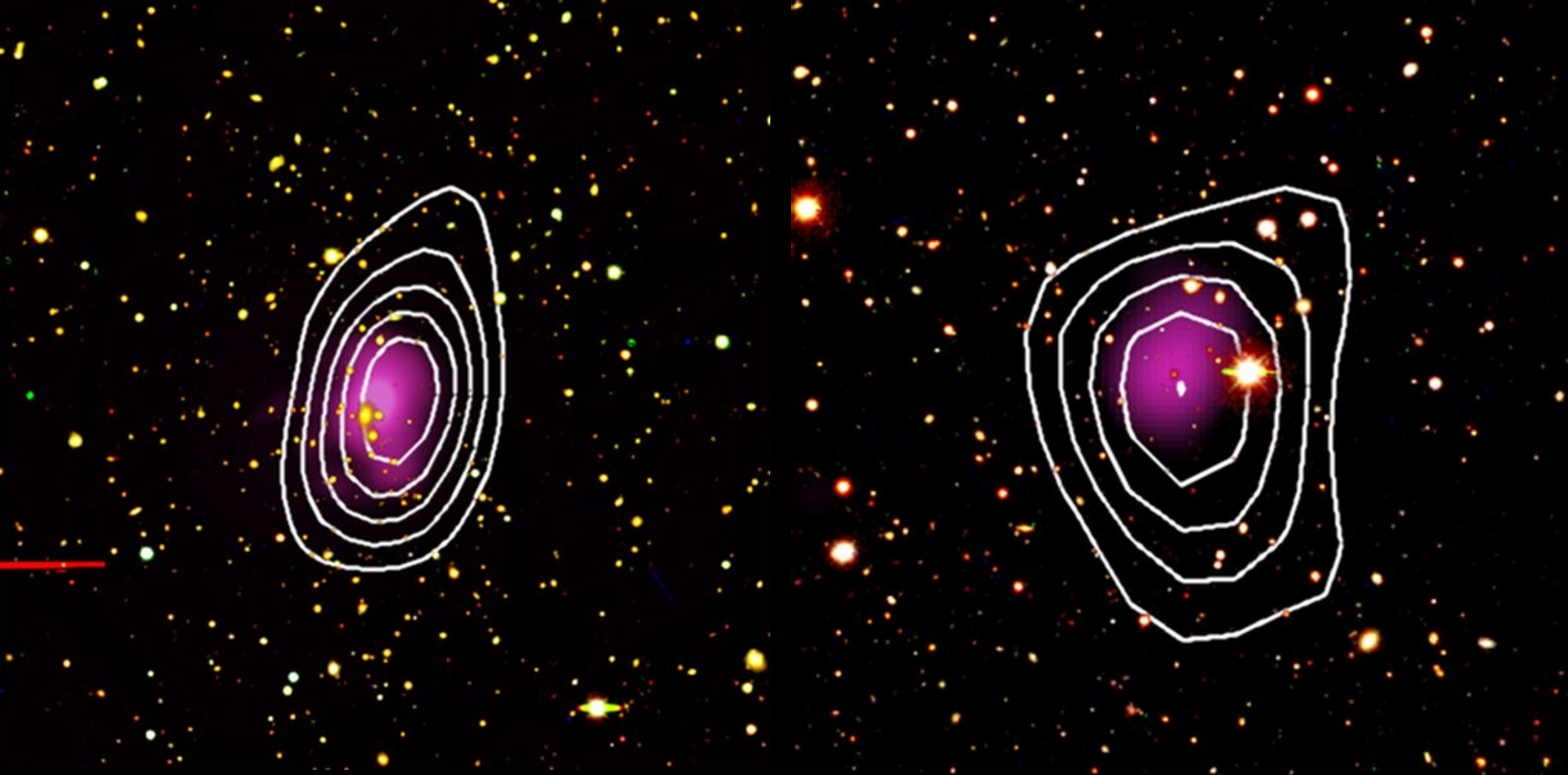
J. Carlstrom and
J. Mohr, 2002

$$y = \int \mathrm{d}l \, n_e \sigma_T \frac{k_B T_e}{m_e c^2}$$

- no redshift dimming
- simple selection close to mass-limited selection at any redshift
- low-scatter mass proxy

→ Sensitive only to the rarest, most massive systems


B
A
C
F
SPT-CL J2342-5411
SPT-CL J2332-5358
0.5 deg
0.3 – 0.5 keV
0.5 – 2.0 keV
2.0 – 4.5 keV

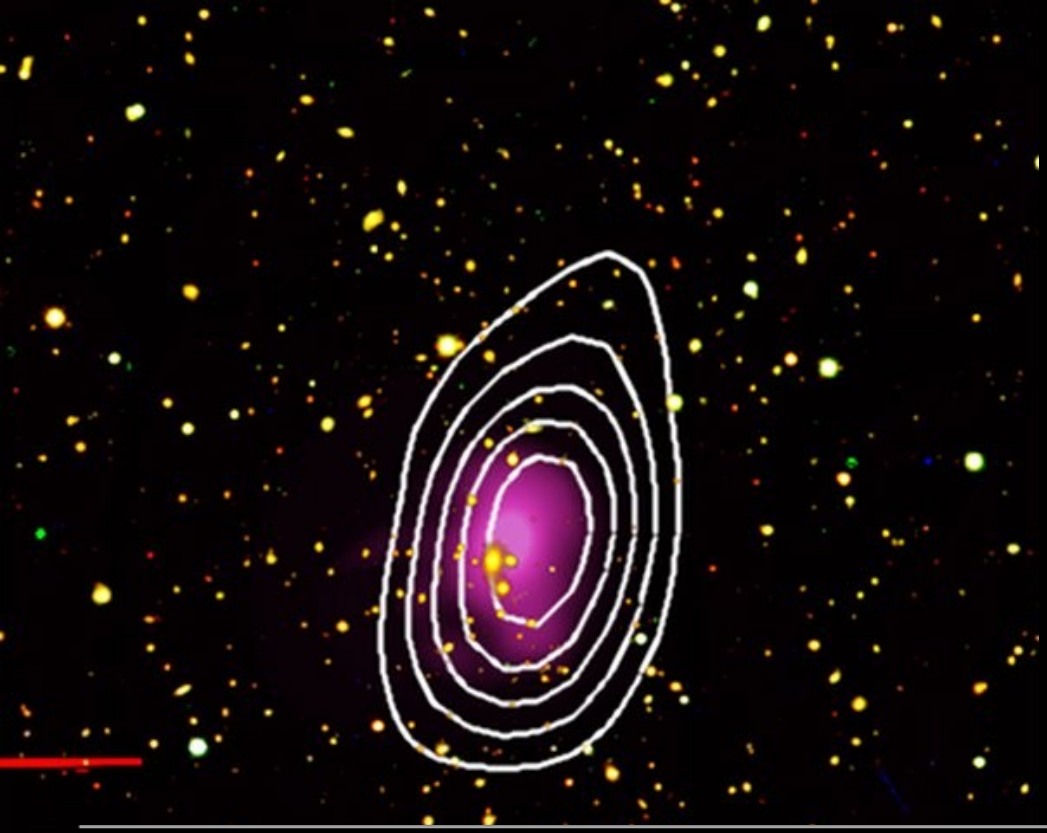


gri optical image, pink: X-rays, white contours: SZE (SPT)

First common X-ray/SZE detected cluster in survey conditions!

SZE detection:
Vanderlinde+10

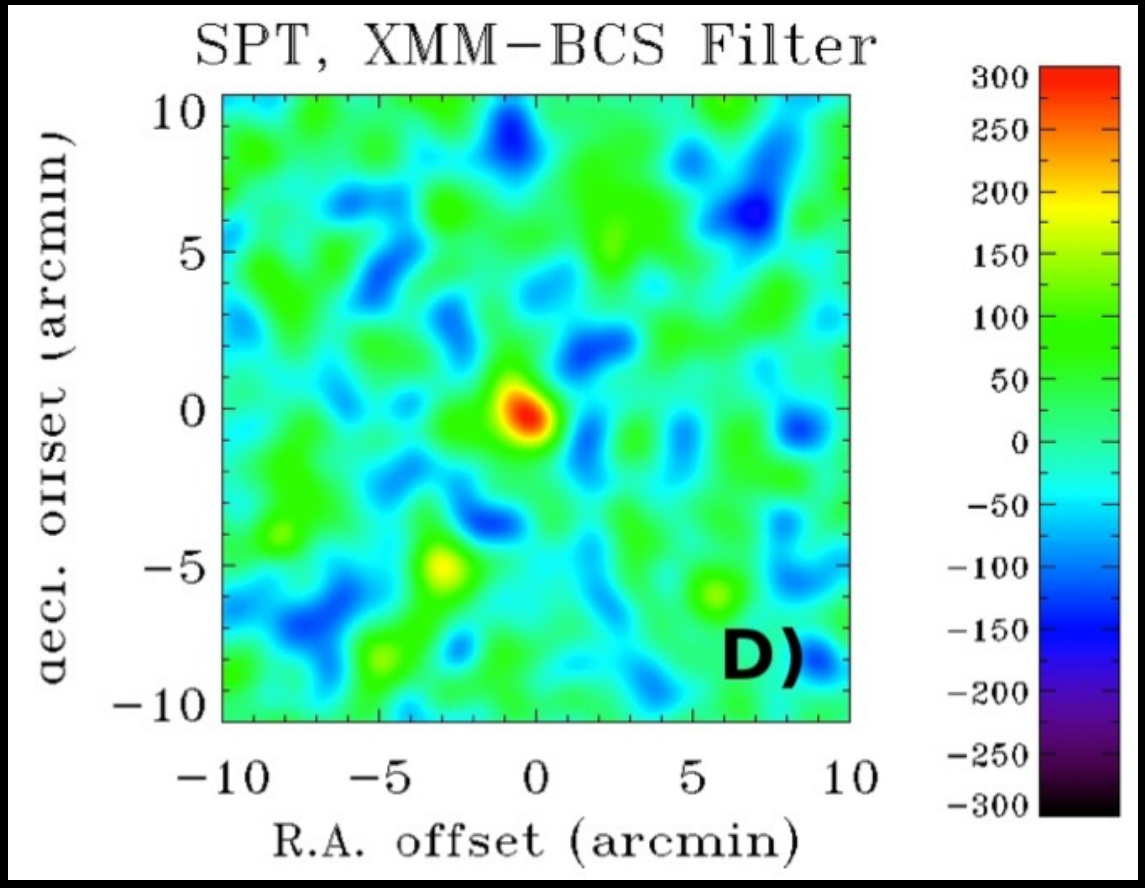
X-ray and optical prop.:
Šuhada+10
Andersson+10



parameter	SPT-CL J2332-5358	SPT-CL J2342-5411	units
α (J2000)[a]	$23^{\rm h}\,32^{\rm m}\,26.7^{\rm s}$	$23^{\rm h}\,42^{\rm m}\,45.8^{\rm s}$	
δ (J2000)[a]	$-53^\circ\,58'\;\;20.4''$	$-54^\circ\,10'\;\;59.2''$	
photometric redshift	0.32[b]	1.08[b]	
F_{500} $[0.5-2.0$ keV$]$	9.52 ± 0.51	0.58 ± 0.06	10^{-13} erg cm^{-2} s^{-1}
L_{500} $[0.5-2.0$ keV$]$	2.71 ± 0.15	2.86 ± 0.29	10^{44} erg s^{-1}
T_{500}	9.3 ± 2.6[c]	4.5 ± 1.3[f]	keV
r_{500}	1.3 ± 0.2[d]	0.6 ± 0.1[d]	Mpc
M_{500}	8.8 ± 3.8[d]	1.9 ± 0.8[d]	10^{14} M$_\odot$
$Y_{X,500}$	11.6 ± 9.7[e]	1.1 ± 0.7[g]	10^{14} M$_\odot$ keV
r_{200}	2.0 ± 0.3[d]	0.9 ± 0.1[d]	Mpc
M_{200}	12.4 ± 5.4[d]	2.7 ± 1.2[d]	10^{14} M$_\odot$

The SPT cross-comparison

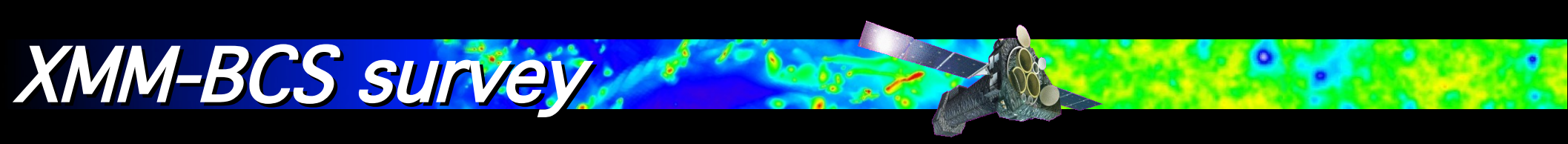
- follow-up of lower significance SPT detection
- another direct detection at ~4.2 sigma
- stacking analysis in both directions



SPT stack of 11 most massive X-ray detected clusters: >6 σ

with B. Benson

XMM-BCS survey



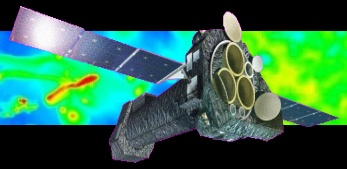
1) XMM-BCS is currently one of the largest contiguous areas covered by XMM-Newton

2) Includes the historically first use of mosaic mode observations

3) First catalog includes ~45 clusters for cluster science (scal. relations, cosmology tests, prep. for upcoming surveys)

4) First common X-ray/SZE detected clusters in a survey

Prospects:
- extension to full 14 deg² (up to ~100 clusters in total)
- lower significance SZE detections and stacking
- optical properties – mass estimators for PanSTARRS/DES?
- add *SPITZER* data



Thank you