



The MERGHERS survey

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Rhodes University / SARAO

Synergies in Non-thermal Astrophysics in Southern Africa
1 August 2024



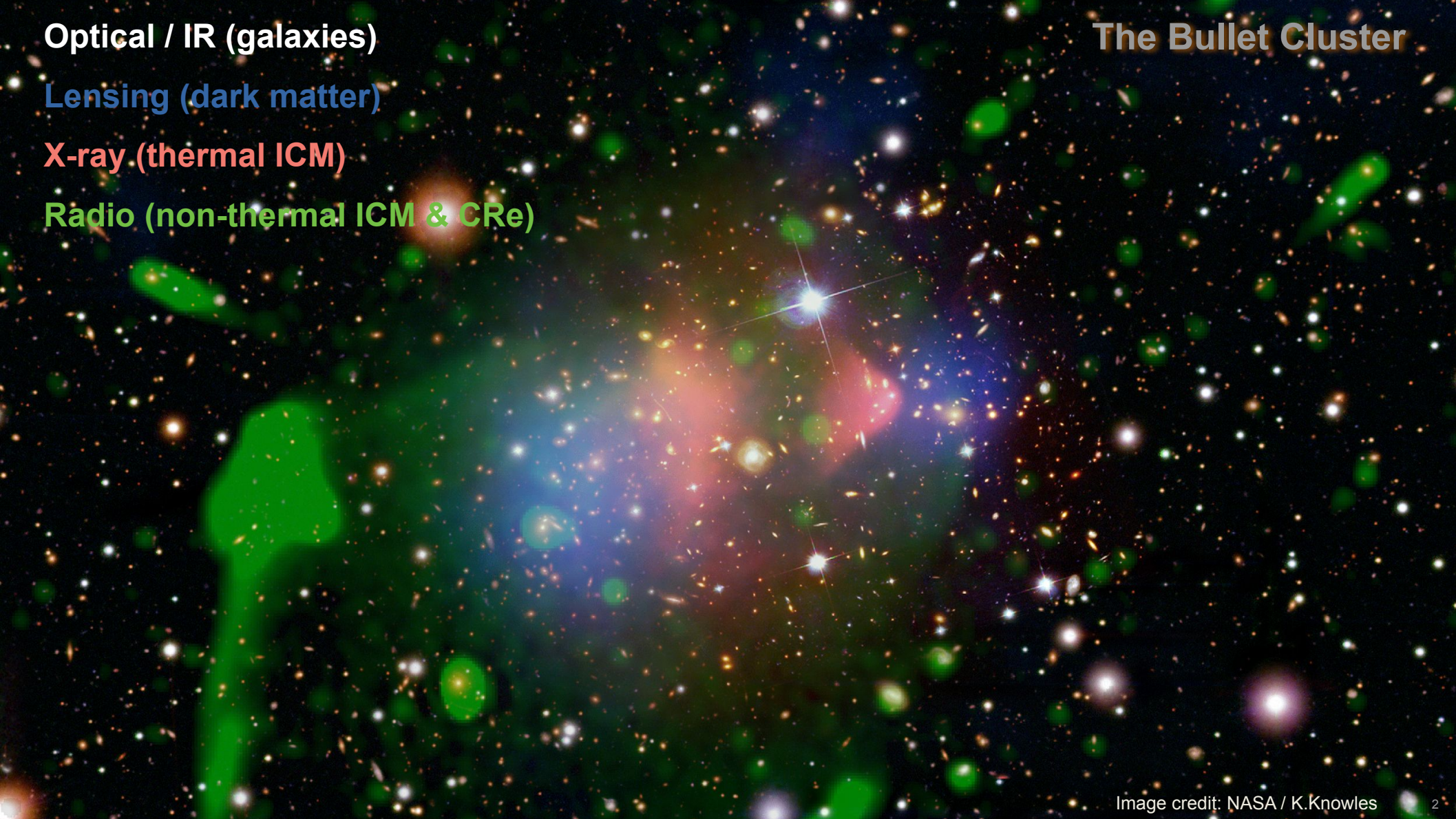
Optical / IR (galaxies)

Lensing (dark matter)

X-ray (thermal ICM)

Radio (non-thermal ICM & CRe)

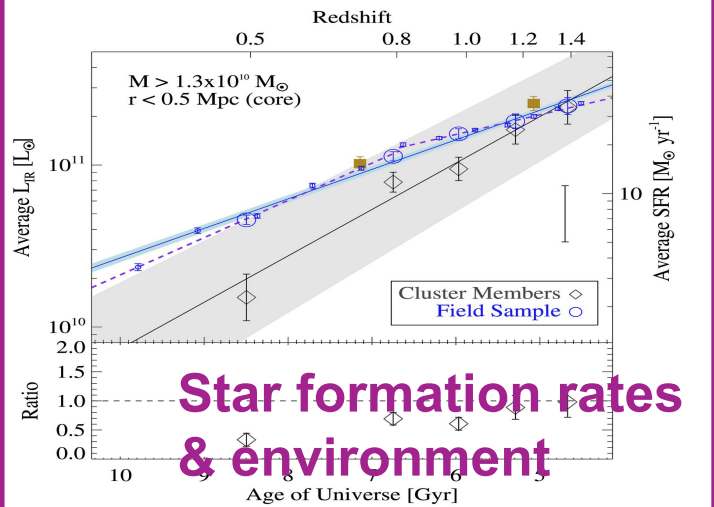
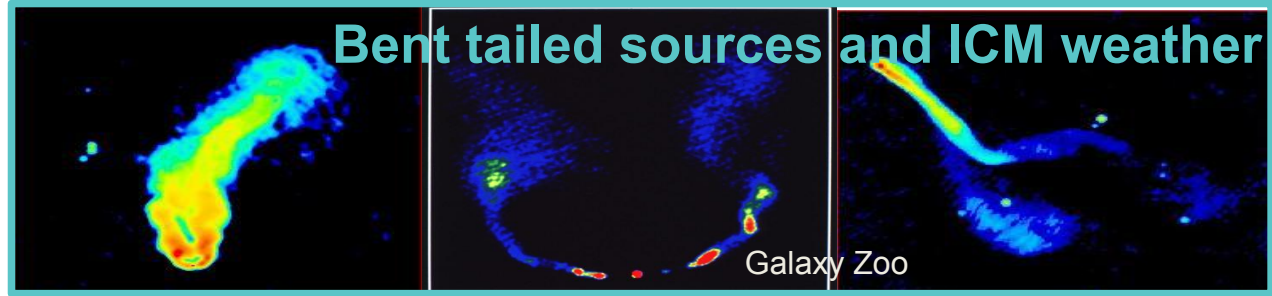
The Bullet Cluster



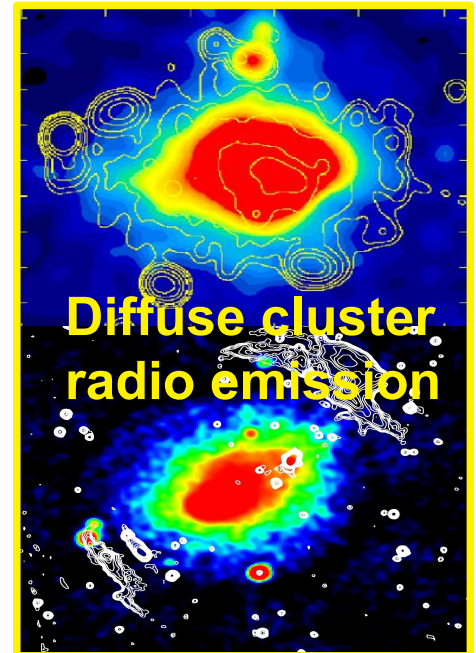
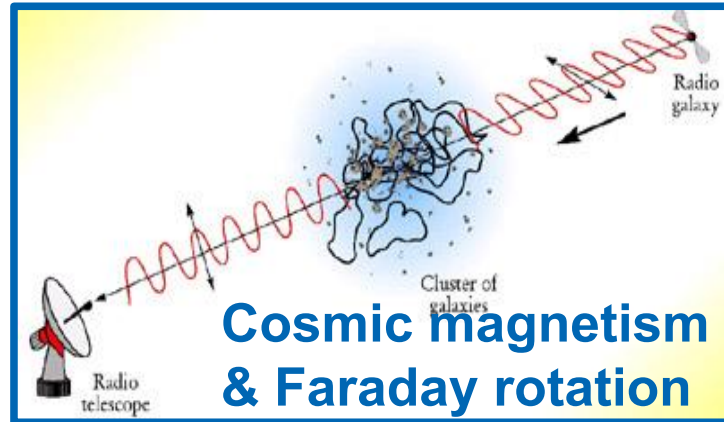
Clusters in the radio

AGN Feedback

NASA/ESA, McNamara



Alberts+2014



Diffuse Cluster Radio Emission

- ★ Faint (μJy @ GHz)
- ★ Large (0.1 – 2+ Mpc)
- ★ Steep spectrum ($S_\nu \propto \nu^{[\alpha < -1]}$)
- ★ Rare (*maybe*)

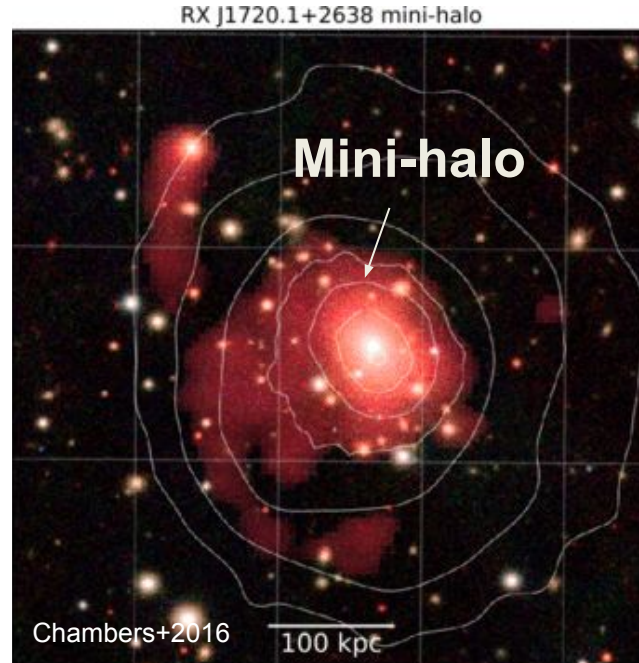
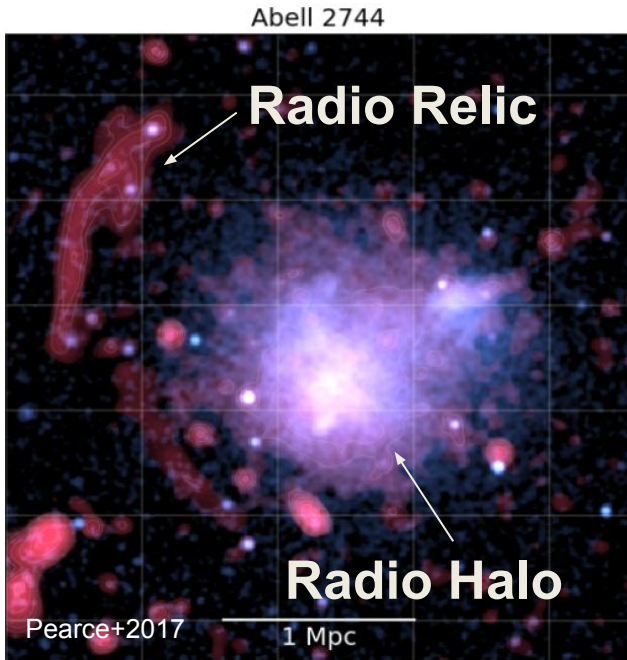
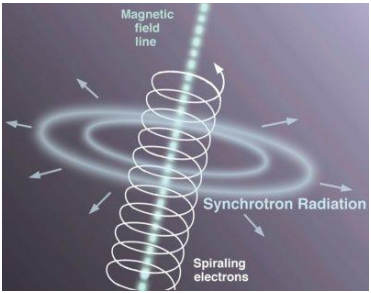
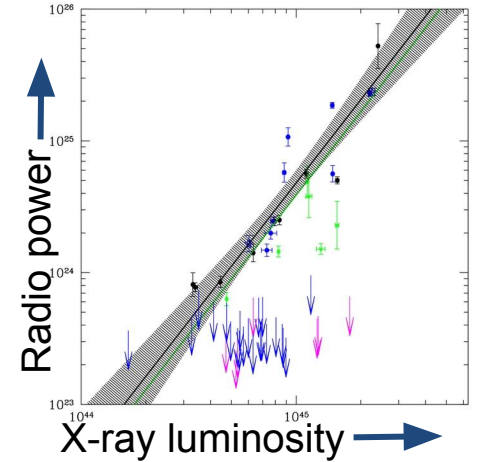
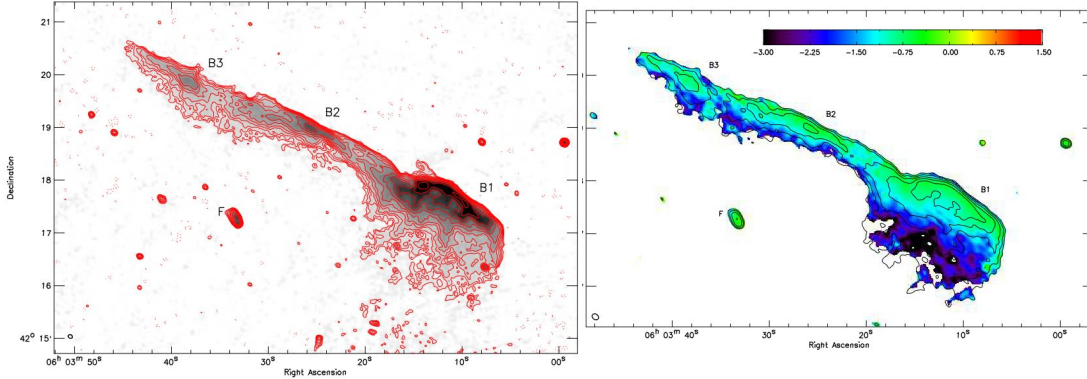


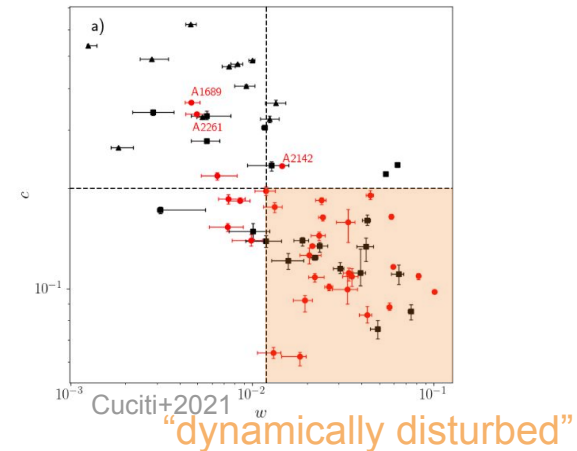
Image credits: R. van Weeren, F. de Gasperin 4

Both individual and statistical studies useful

van Weeren+2012

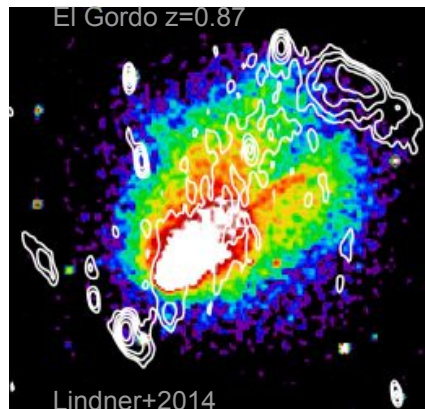
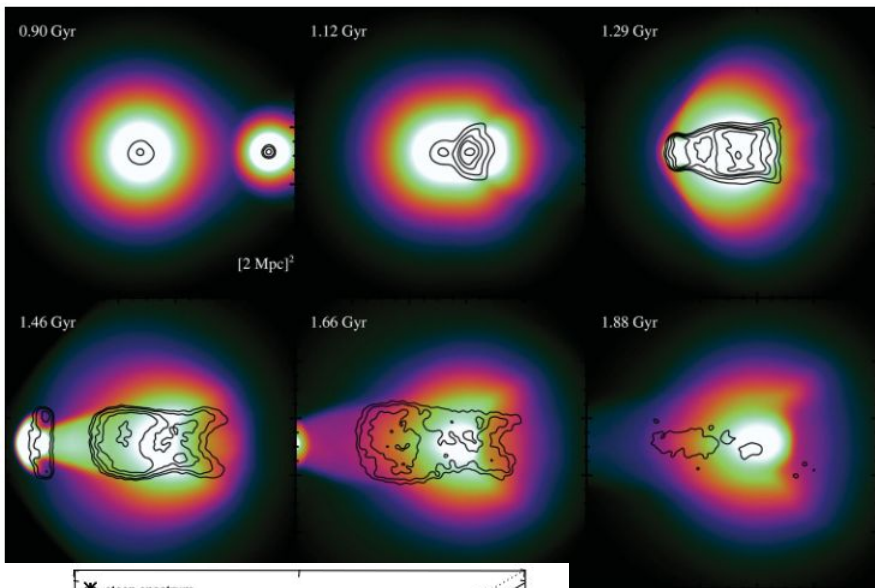
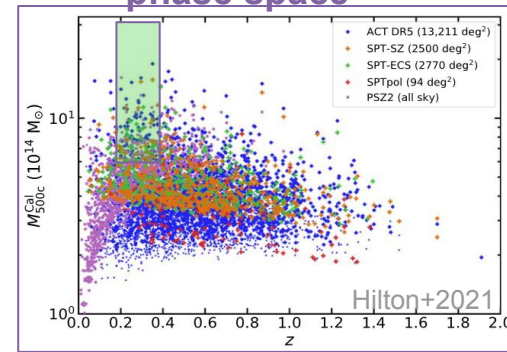


- ★ Deep, multi-frequency/resolution observations of individual, bright, resolved sources → test models in ‘poster child’ setting
- ★ Statistical samples → radio power correlated with cluster properties; helps to constrain theories behind formation mechanisms on population basis

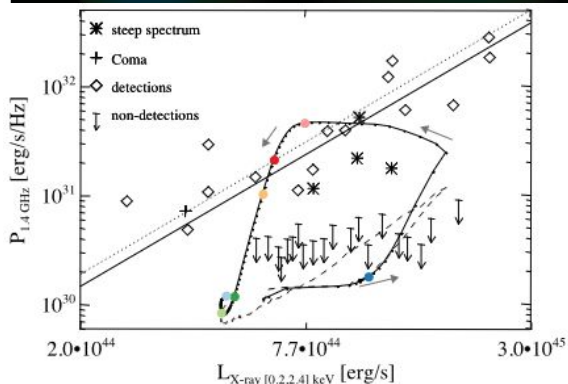


Many open questions

Small portion of the statistical phase space

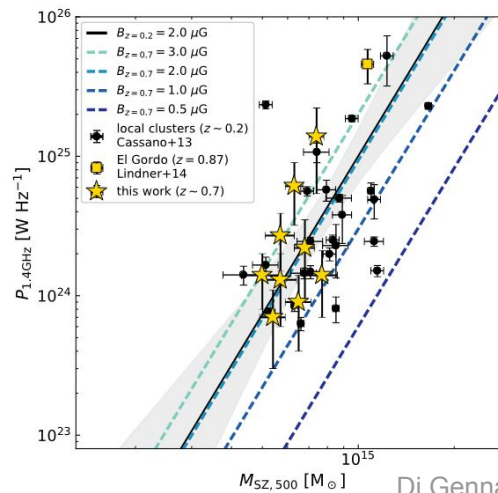


High- z observations aren't as predicted

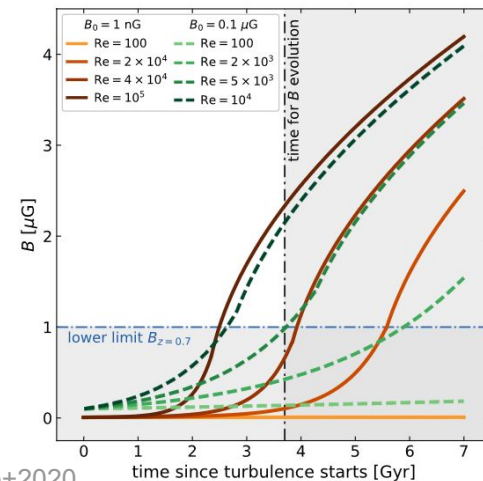


Donnert+2013

Merger timescale component

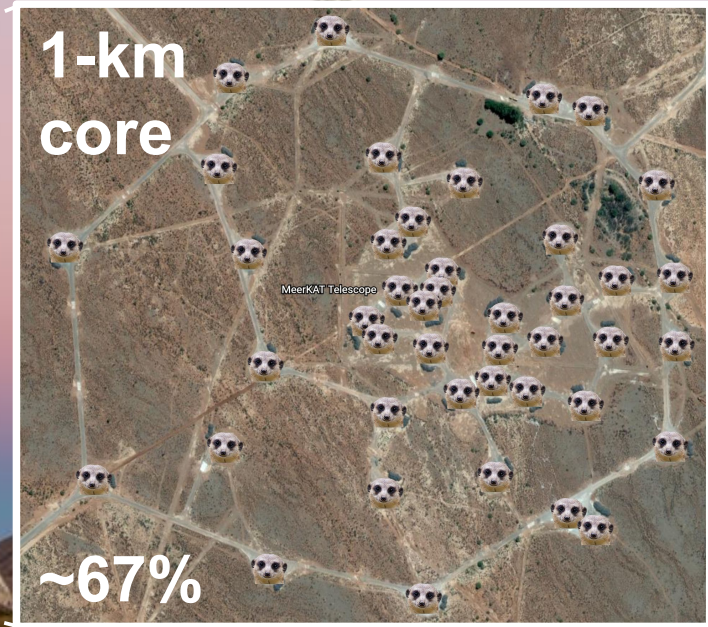
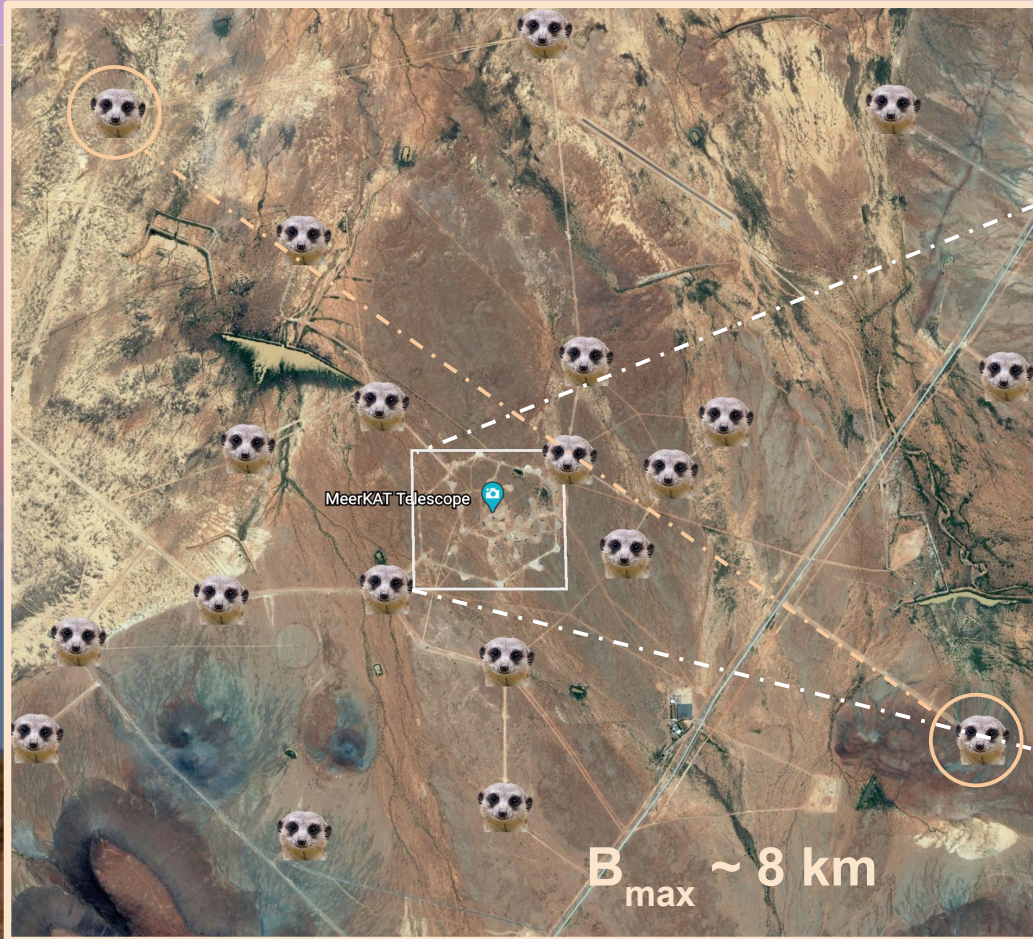


Di Gennaro+2020



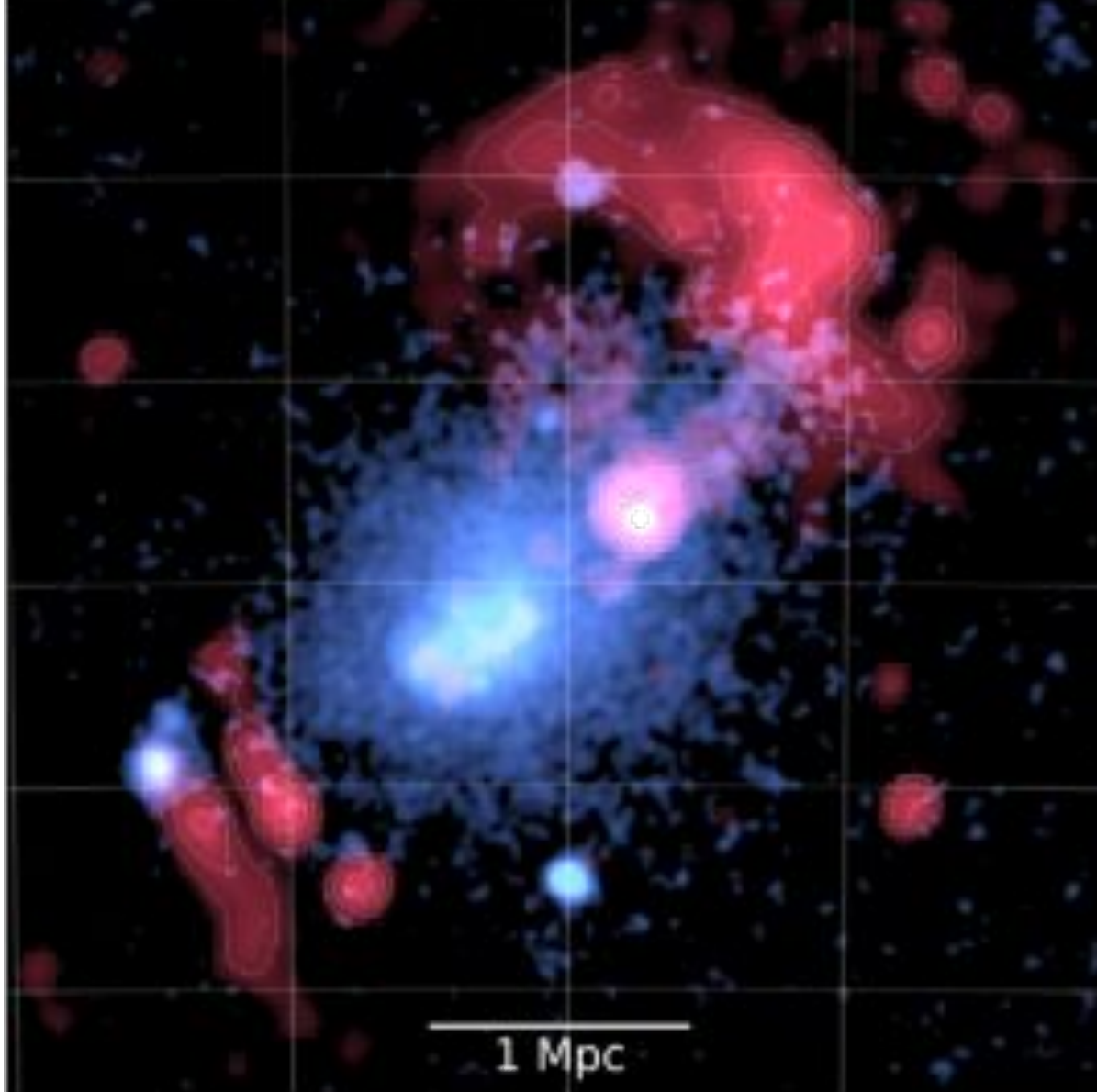
The MeerKAT array configuration

~8" resolution @ 1.28 GHz



Dense core for sensitivity to large scale emission

Abell 3667
SUMSS
45"



Abell 3667
MeerKAT L
8"



The MERGHERS survey

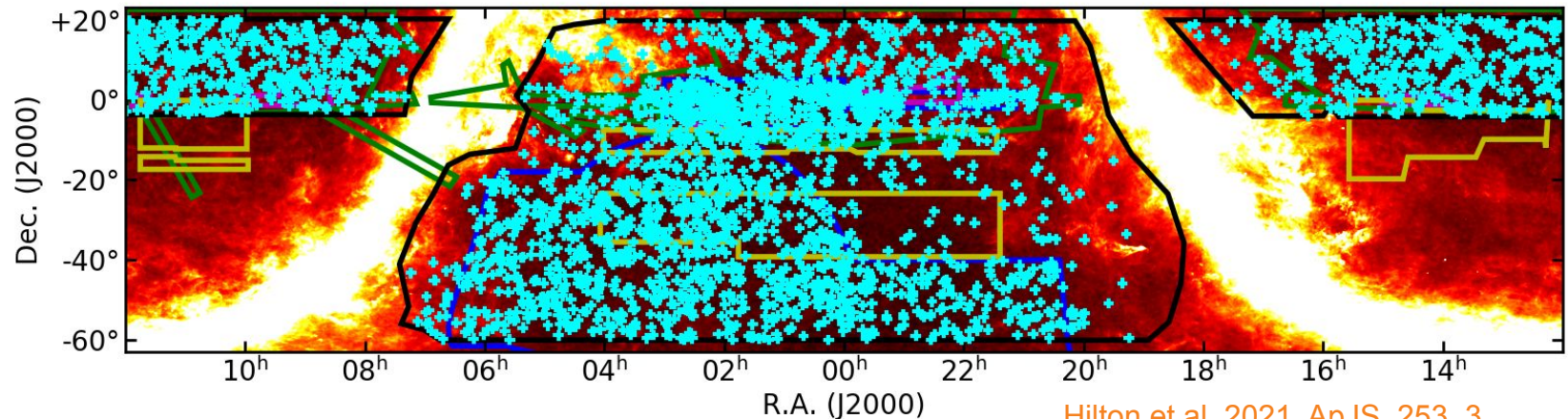
Knowles et al. 2016, POS, 30

*MeerKAT Exploration of Relics, Giant Halos,
and Extragalactic Radio Sources*



- ★ Statistical studies over wide z , M ranges
 - Diffuse cluster emission
 - Cluster magnetic fields
- ★ Well-selected cluster sample: ACT-DR5
 - 4000+ confirmed SZ clusters

Short track
(~1–3 hr on source)



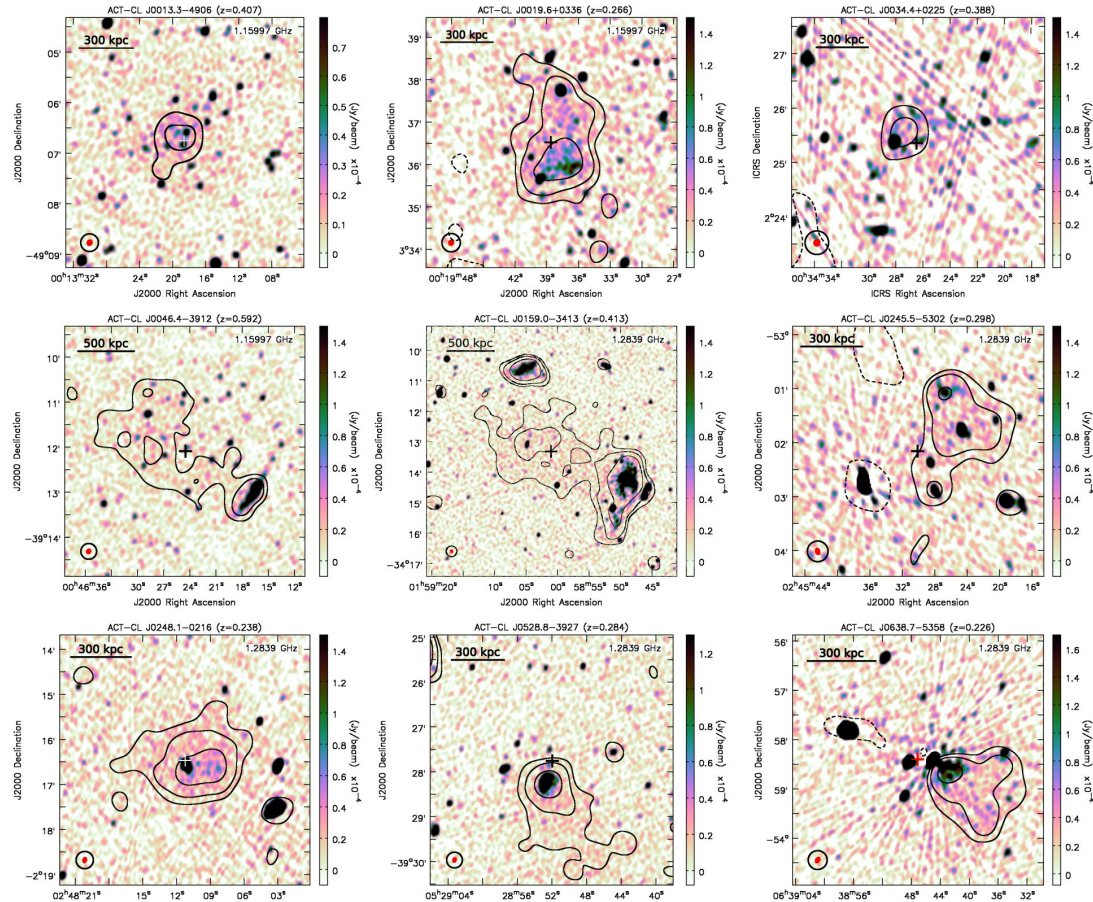
Hilton et al. 2021, ApJS, 253, 3

MERGHERS Pilot

Knowles et al. 2021, *MNRAS*, 504, 1749

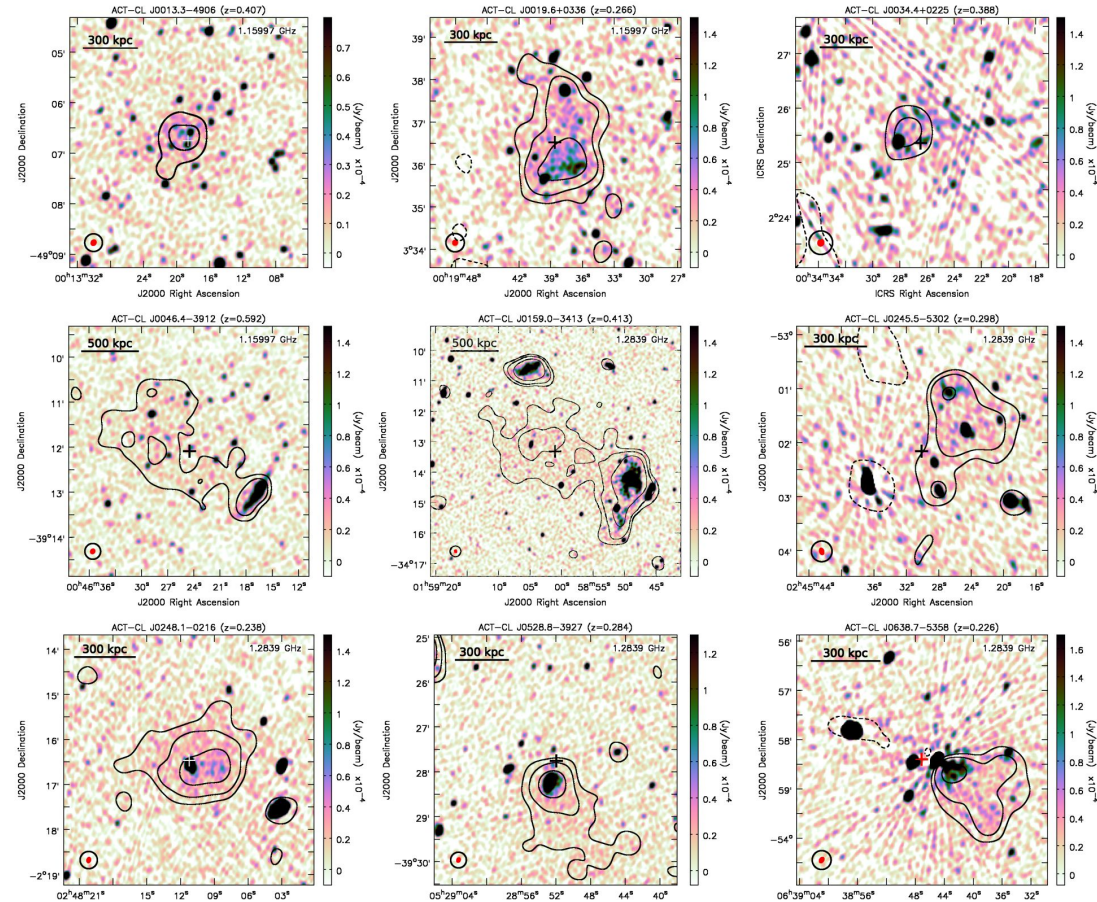
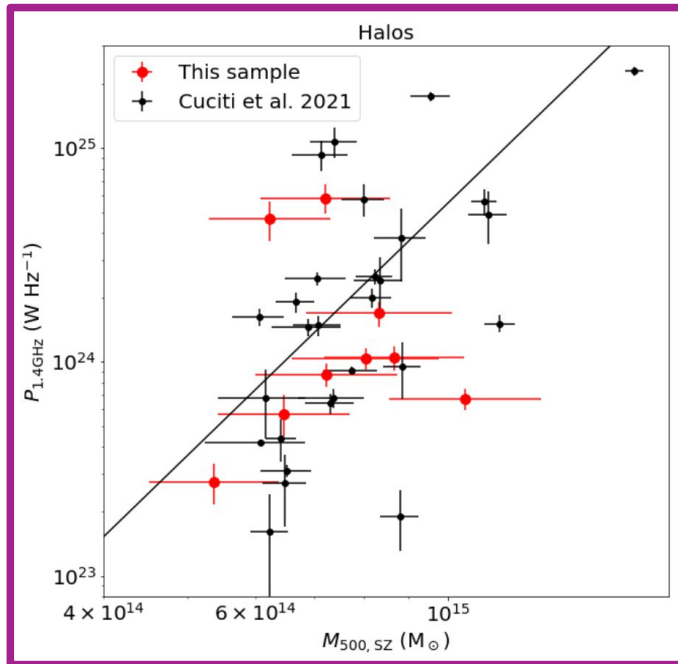
- ★ 13 cluster targets @ L-band
 - Preliminary ACT DR5
 - ACT SNR > 10
 - $z < 0.6$
 - $M_{500,SZ} > 6 \times 10^{14} M_{\odot}$
 - Candidate mergers

70% detection rate!
11 new diffuse
emission detections



MERGHERS Pilot

Knowles et al. 2021, *MNRAS*, 504, 1749



Still to do:

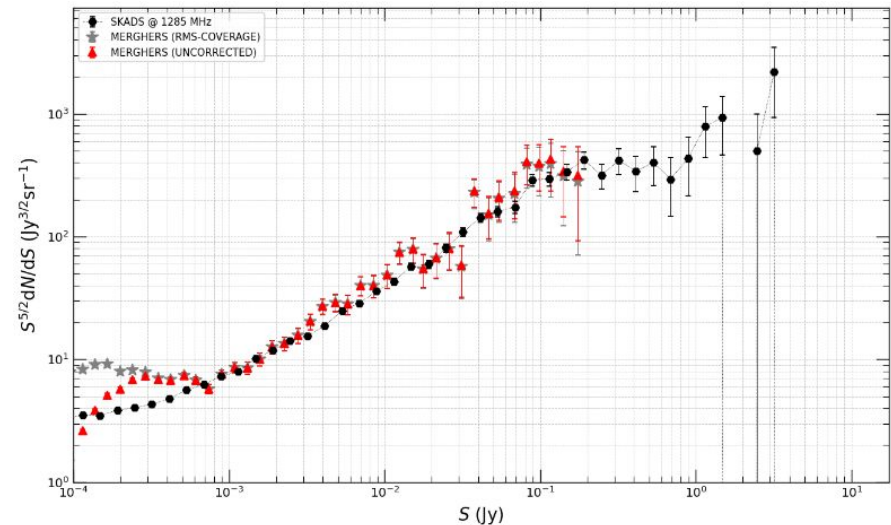
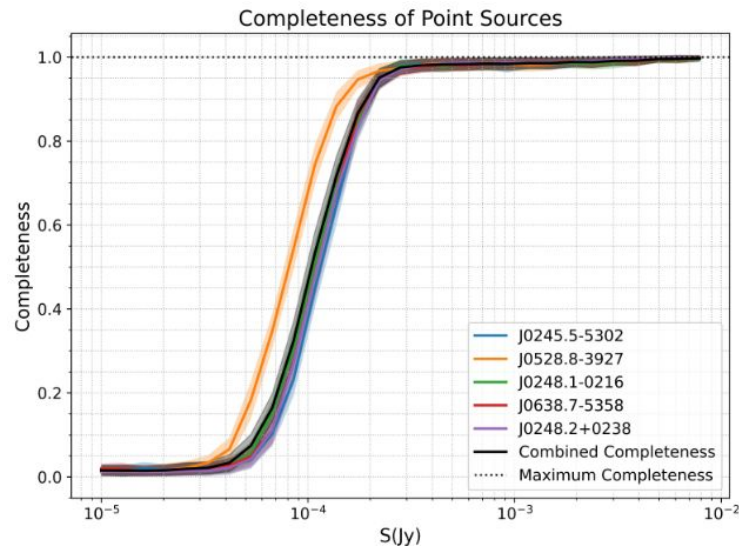
- ★ spectral index studies
- ★ dynamical state studies
e.g., Pillay et al. 2021, *Galaxies*, 9, 97
- ★ full-field source catalogues

Cataloguing and source science

Courtesy: Brenda Homera
(2024 MSc,
paper in prep.)



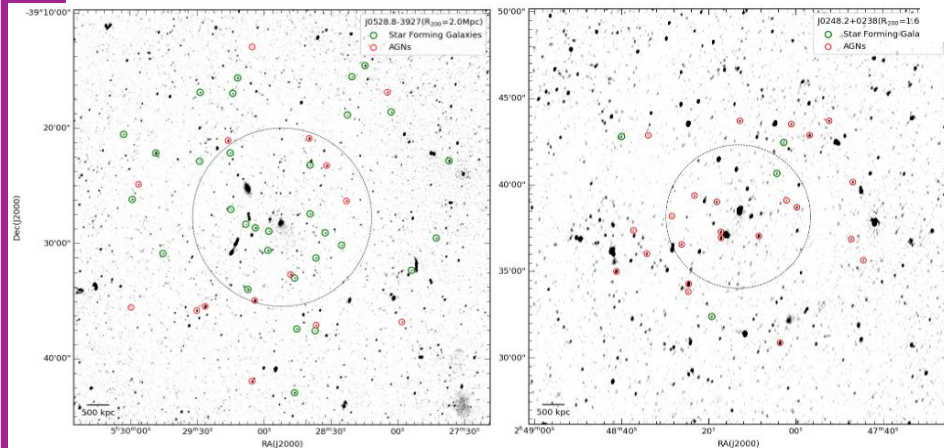
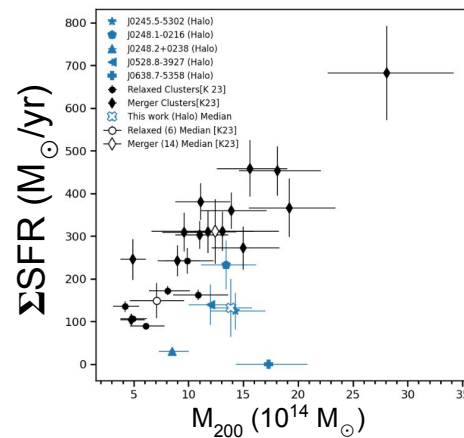
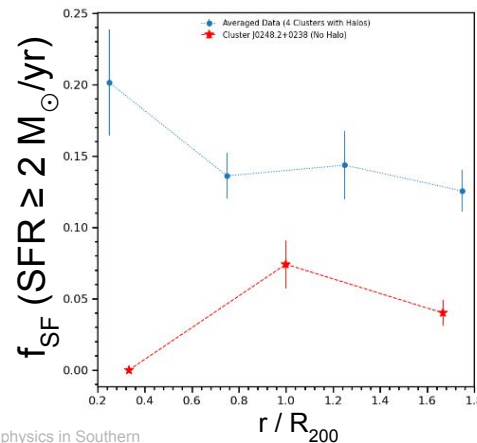
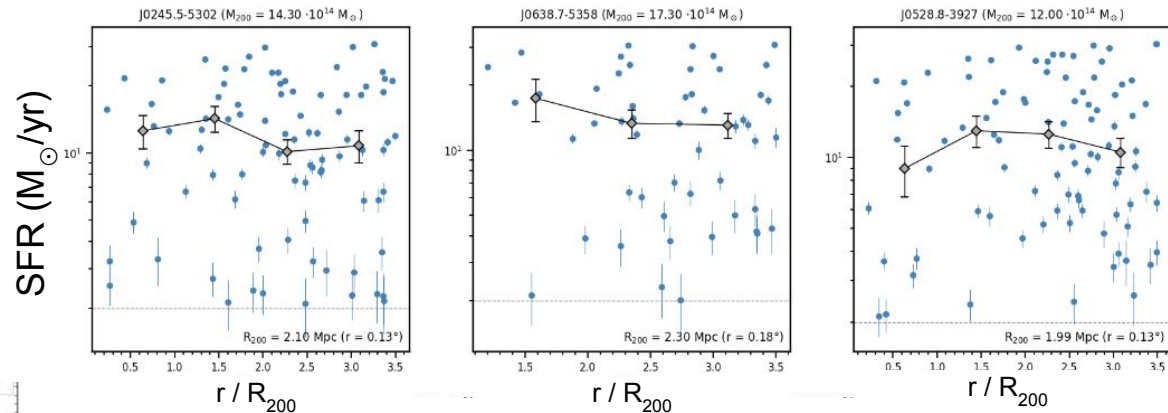
- ★ Student-driven work to catalogue the radio sources in the pilot fields
 - Reprocessed 5 targets and created radio source catalogues
 - Completeness, flux density, astrometry checks
- ★ All catalogues 80% complete above ~ 0.15 mJy



Cataloguing and source science

- ★ Initial star formation rate study shows similar trends in terms of clusters with vs without diffuse cluster emission
- ★ X-matched w/ DECaLS

Courtesy: Brenda Homera (2024 MSc, *paper in prep.*)

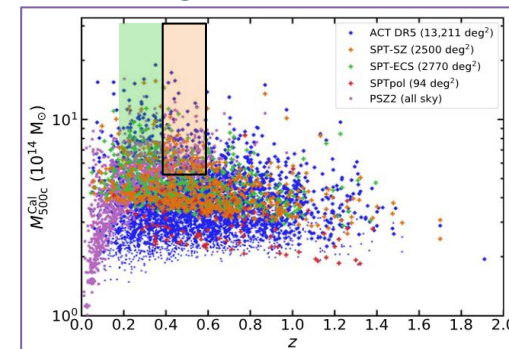


MERGHERS Tier 1

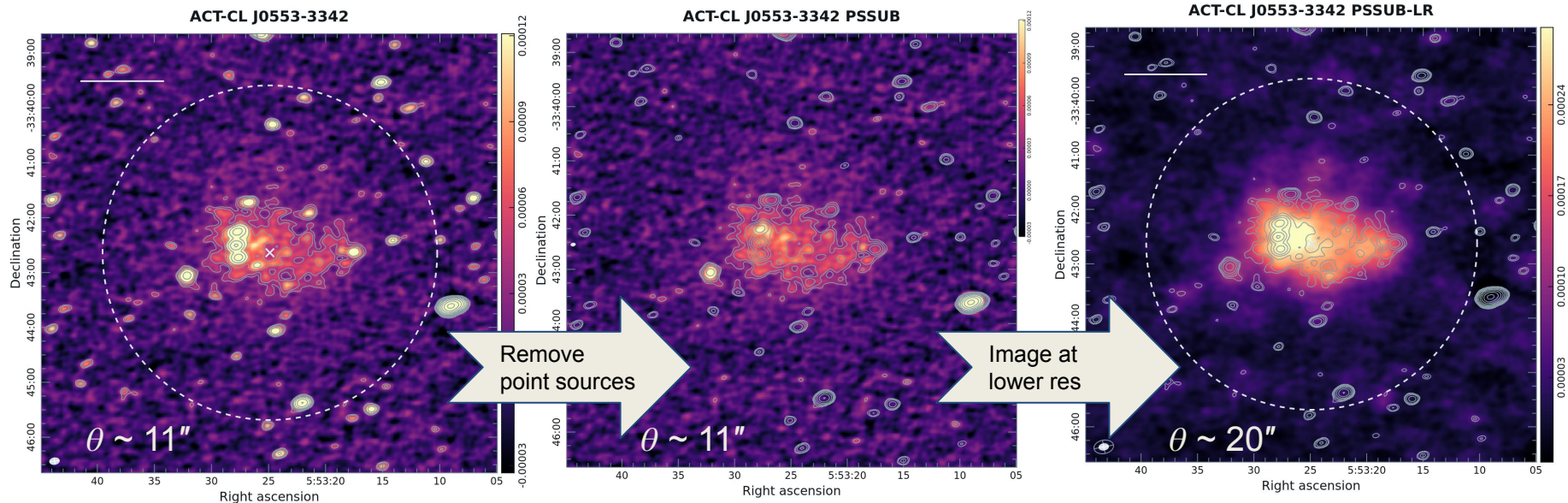
25 clusters

★ Focus on building a statistical sample in the mid- to high-redshift range

- Published ACT DR5
- DES region
- $0.4 < z < 0.6$
- $M_{500,SZ} > 5.5 \times 10^{14} M_{\odot}$



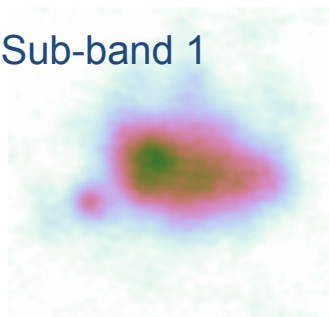
Extracting the extended emission



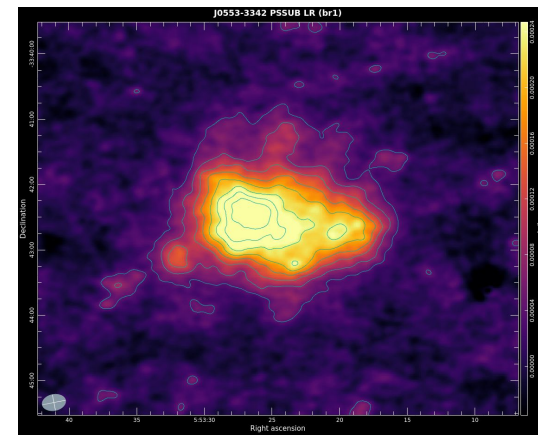
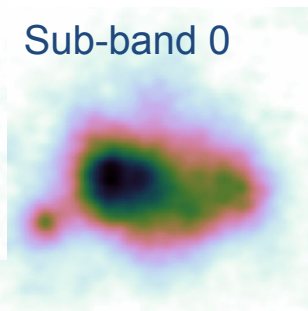
In-band spectral index
(possibly maps too)

- ★ Split BW into two
- ★ Match uv -range
- ★ Match resolution $\gtrsim 25''$

Sub-band 1

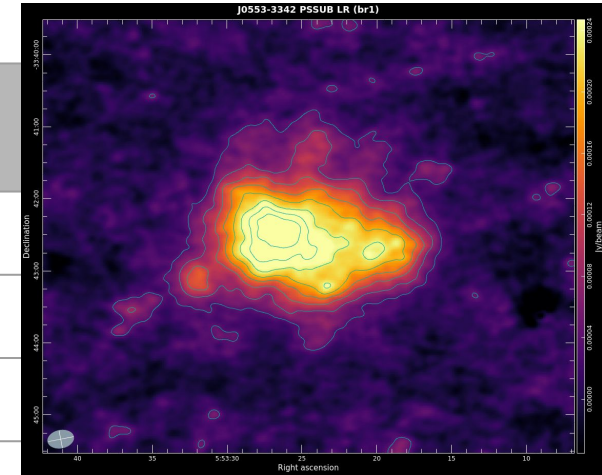


Sub-band 0



Final post-processing mostly complete

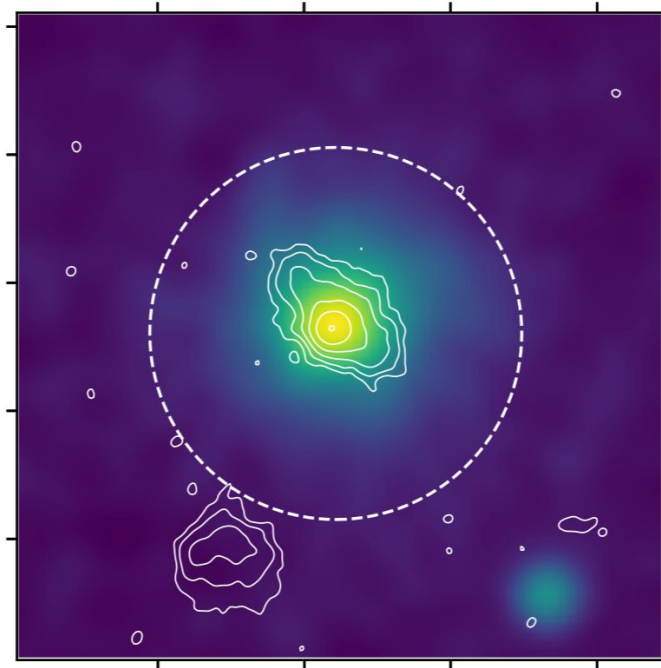
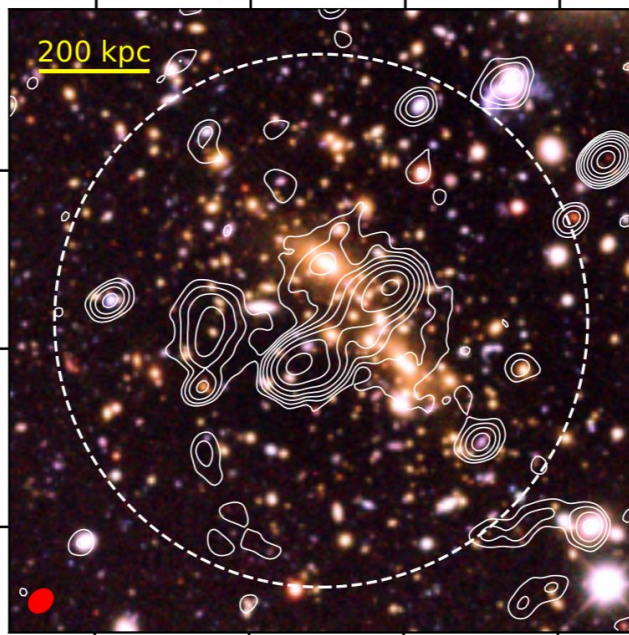
ACT-CL Target	$S_{1.28 \text{ GHz}}$ (mJy)	LLS (Mpc)	α (in-band)	Type
J0553	9.8	1.18	-1.32	Halo
J0243	0.5	0.60	-1.36	AGN?
J0234	8.6	0.55	...	Halo / MH?
J0259	—	—	—	Non-detection
J0203	3.9	0.82	...	Halo (elongated)
J2131	2.4	0.67	-1.46	Uncertain
J2116	—	—	—	Non-detection
+ ...				



**12 of 25 clusters
~48% detection rate
for diffuse emission**

Multiwavelength information

- ★ DES / DECaLS – Optical imaging + photo-z's
- ★ **SALT** – spec-z's (but difficult to get!)
- ★ *XMM-Newton / Chandra* – X-ray imaging



Dynamical state

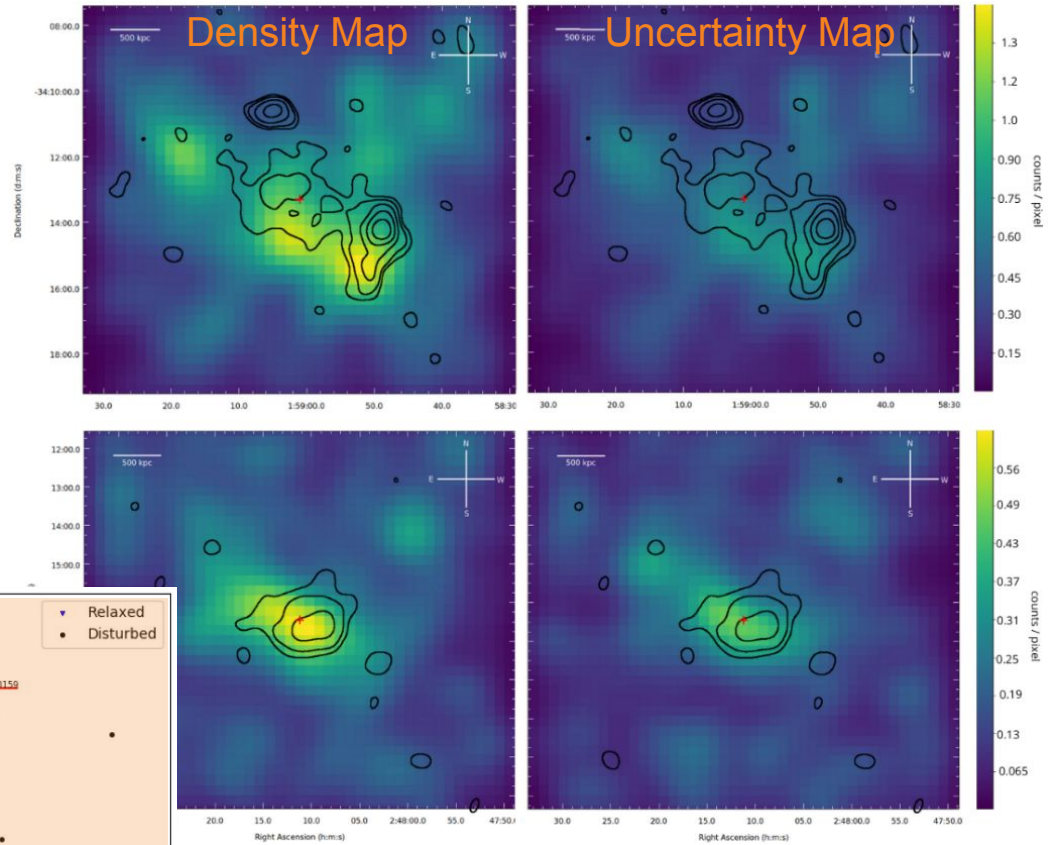
★ DES → optical density maps

- Centre shift

$$CS = \sqrt{(x_m - x_0)^2 + (y_m - y_0)^2} \times 0.2$$

- Asymmetry parameter

$$A^2 = \frac{\sum(I_0 - I_\phi)^2}{\sum(2I_0^2)}$$



Courtesy: Denisha Pillay (MSc Thesis 2021)

Dynamical state

★ XMM-Newton → **morphological parameters**

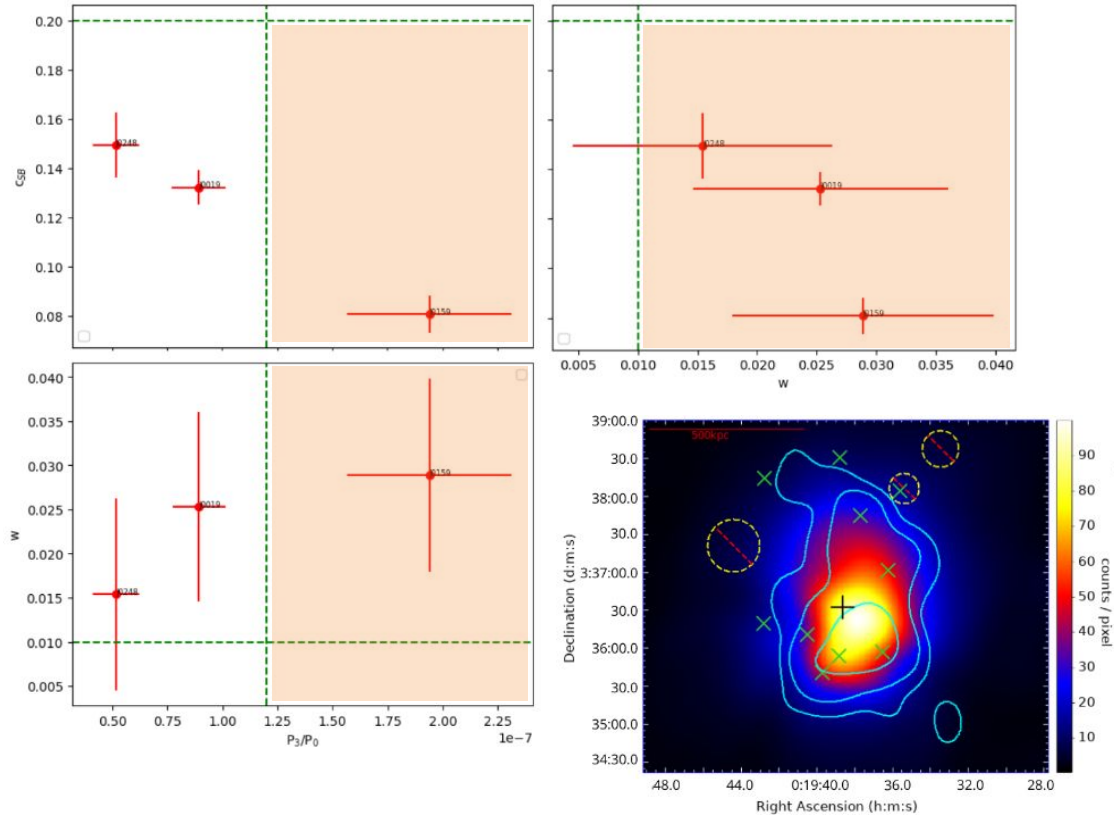
- Concentration

$$c_{SB} = \frac{S < (100 \text{ kpc})}{S < (500 \text{ kpc})}$$

- Centroid shift

$$w = \left[\frac{1}{N-1} \sum (\Delta_i - \langle \Delta \rangle)^2 \right]^{1/2} \times \frac{1}{R_{ap}}$$

- Power ratio

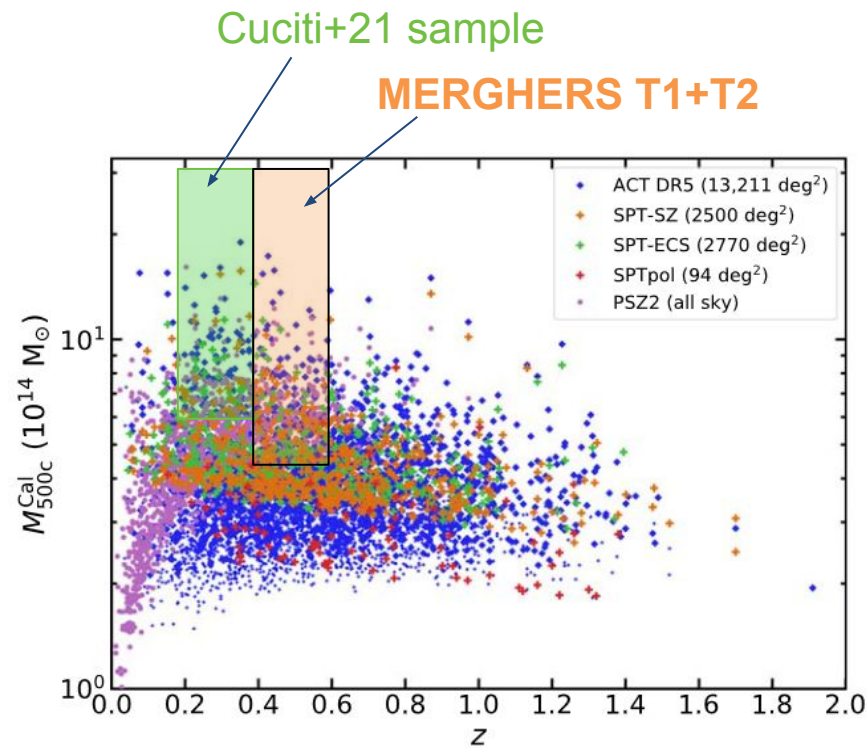


Courtesy: Denisha Pillay (MSc Thesis 2021)

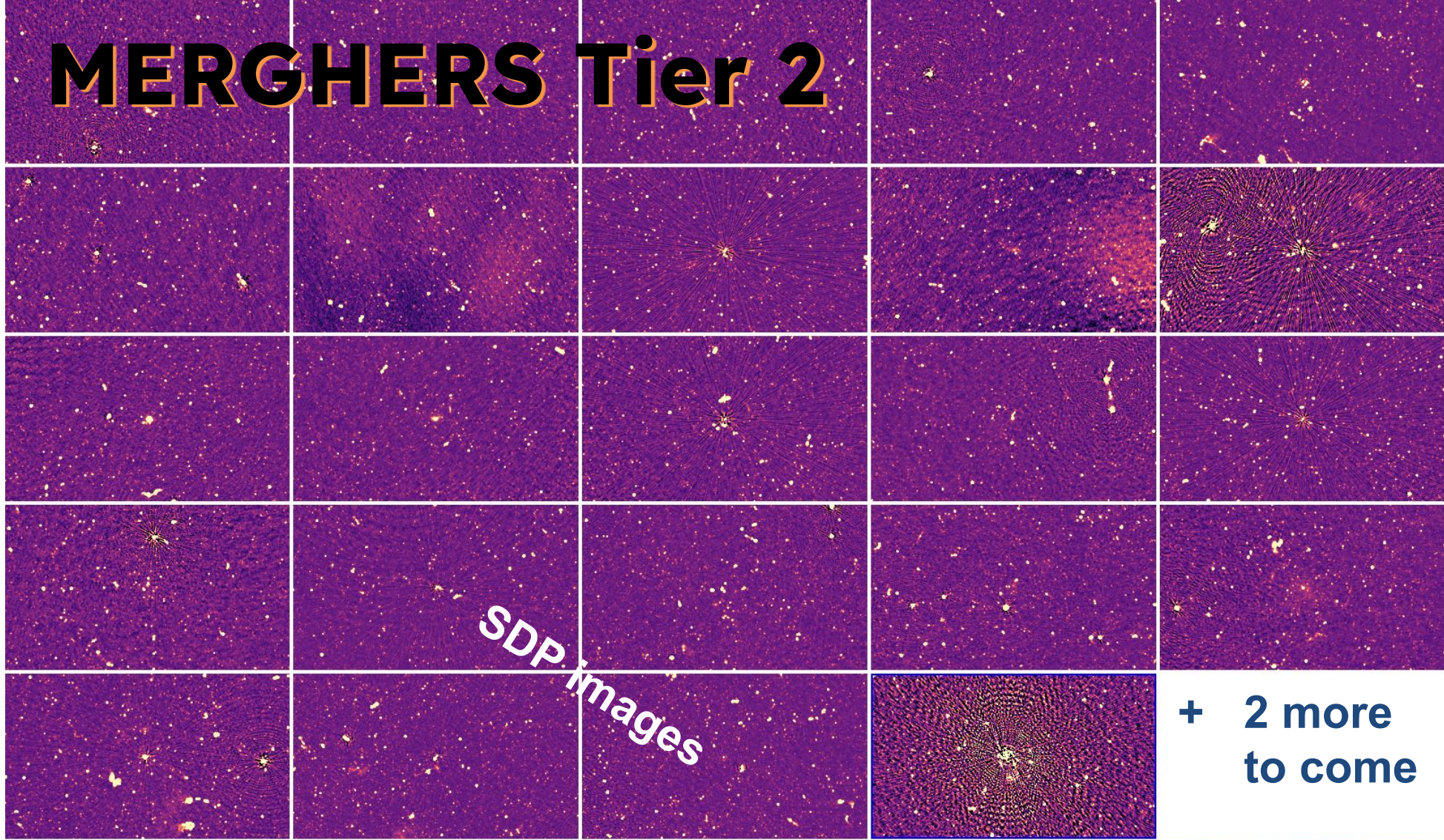
MERGHERS Tier 2

- ★ Complete the T1 sample and extend it to lower mass
 - Published ACT DR5
 - **UHF**
 - $0.4 < z < 0.6$
 - $M_{500,SZ} > 4.5 \times 10^{14} M_{\odot}$

Brings the statistical sample up to 55 clusters



MERGHERS Tier 2



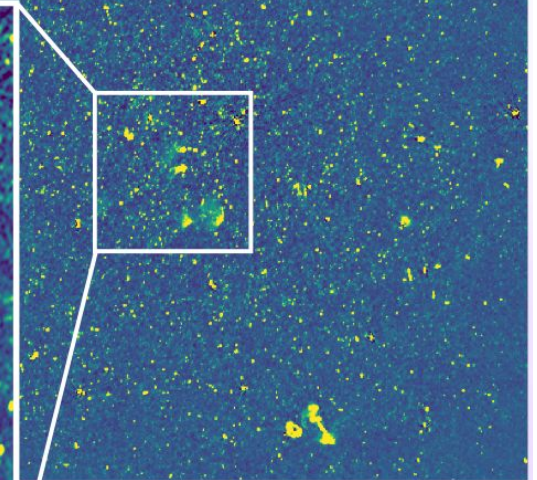
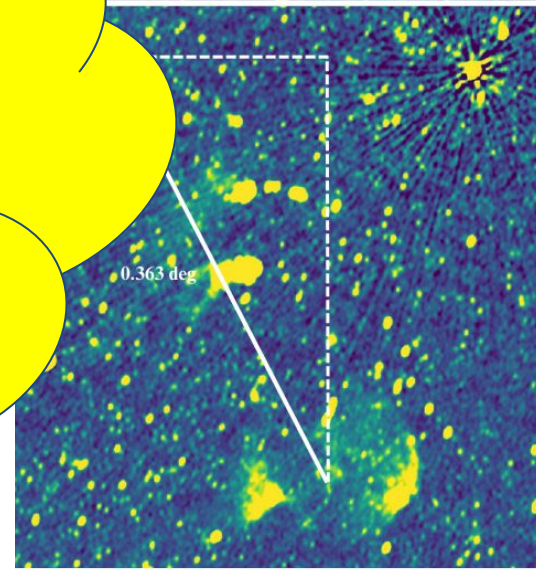
-0.0001 -5E-05 0 5E-05 0.0001 0.00015 0.0002

Some puzzles being found

★ Diffuse emission
south of the

★
See talk by Mikaela Webber
from Wednesday!

Courtesy: Mikaela Webber
(MSc Thesis, *in prep.*)



MERGHERS: Next steps

- ★ Radio analysis of T1 and T2 clusters
 - Complete intensity + spix analysis
 - Calibrate + image in Stokes Q & U



- ★ Dynamical state analysis
 - eRosita IEC
 - DES data
 - SALT spectroscopy



- ★ Spectral studies of diffuse emission using newly obtained GMRT band 4 data



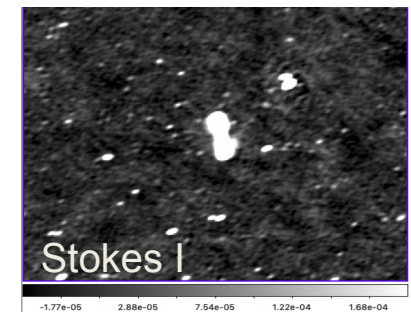
- ★ Individual follow-ups of interesting systems



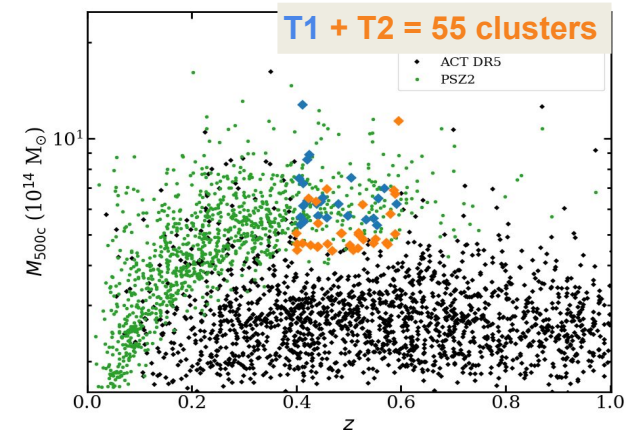
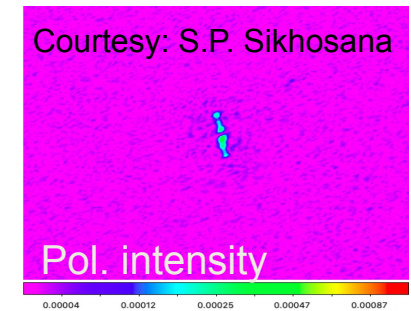
- ★ Studying field radio galaxies



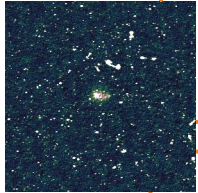
- ★ Developing mock catalogues for machine learning (RadioClusters project with EPFL)



Courtesy: S.P. Sikhosana

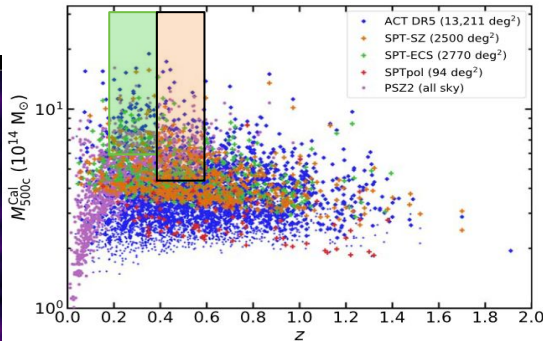
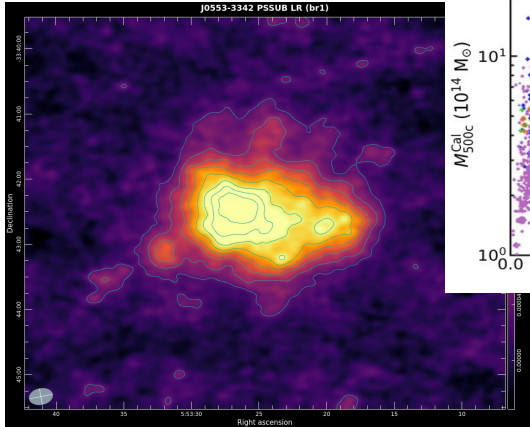


Summary



MERGHERS is the first homogeneous cluster study with $z > 0.4$ above 150 MHz

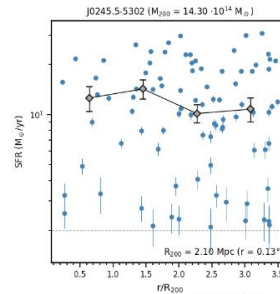
Several new diffuse emission detections, with analysis still ongoing



MeerKAT is providing excellent data for a wide range of science



Known synergies with SALT
– What about HESS and AMT?



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Thank you