Relics and Halos from the MWA GLEAM Survey

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Gabriel Pratt, Andre Offringa

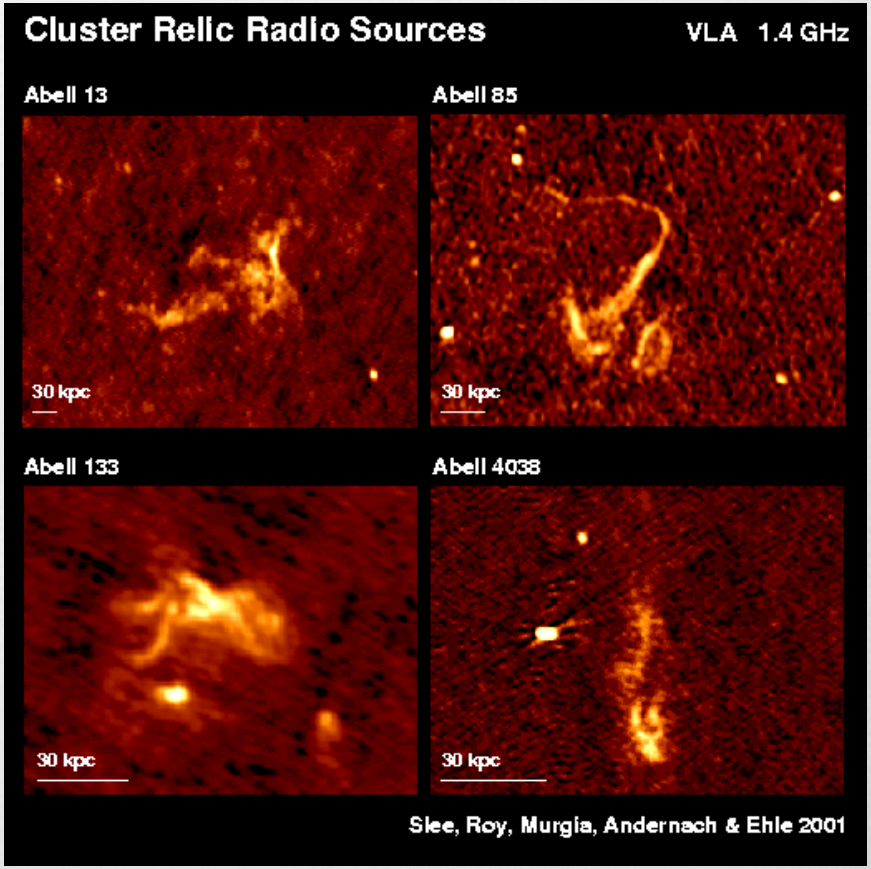
Current Taxonomy is out of Date!

- We discuss relics, halos, mini halos, phoenixes, dead radio galaxies… definitions largely associated with a morphological classification (see eg Kempner et al. 2004)
- In the era of low frequency telescopes we are finding these things are more plentiful and harder to define based purely on morphology (eg Macario et al. 2014, Shimwell et al. 2017)
- Need a new taxonomy based on physics eg morphology + energetics
- Doing scaling relations for halos at 1.4 GHz is not what we should be doing. Should all be redone at 150 – 200 MHz

A3888: Radio halo from Shakouri et al (2016)

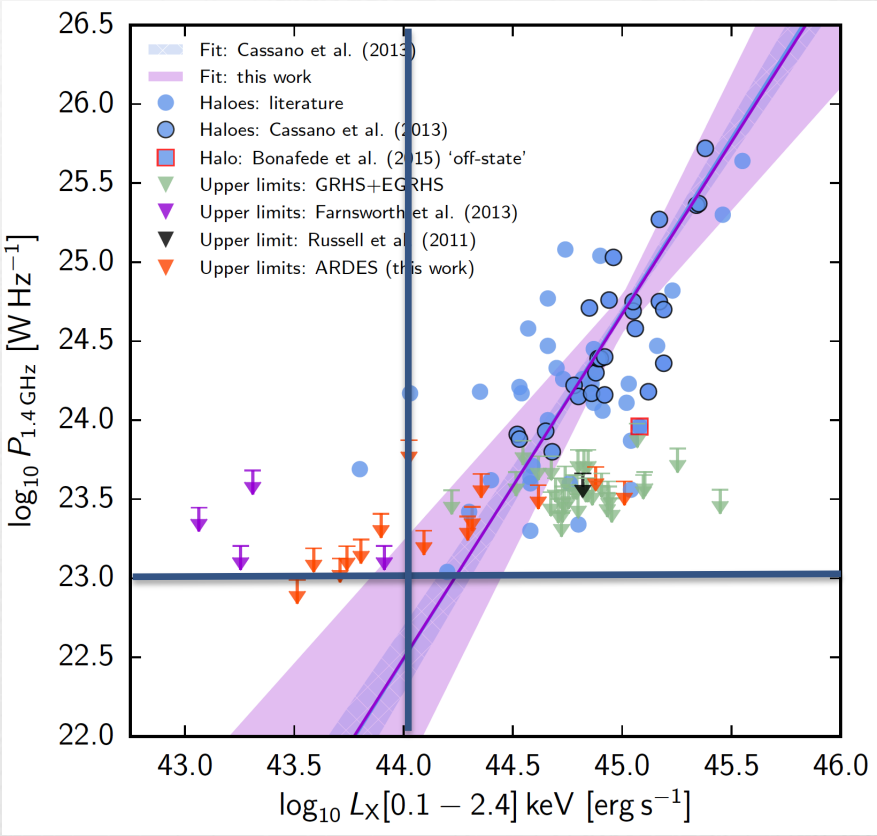
Split in Relic Classification

- Observations of 4 clusters which appeared to have only small relics (Slee et al. 2001) prompted a split in the classification of relics into two classes.
- Mpc-scale relics which had to be generated in cluster mergers (eg A3667) and 'relics' or 'radio phoenix' where were kpc-scale emission regions (Kempner et al. 2004)



Searches for Relics and Halos

- Most searches to date for such emission has been biased to higher mass/Lx systems.
- Carried out at non-optimal frequencies (mostly 1.4 GHz) via individual pointings
- Takes a long time and doesn't give you results (eg 4 years for ARDES cluster sample to get 1 halo and 14 upper limits)



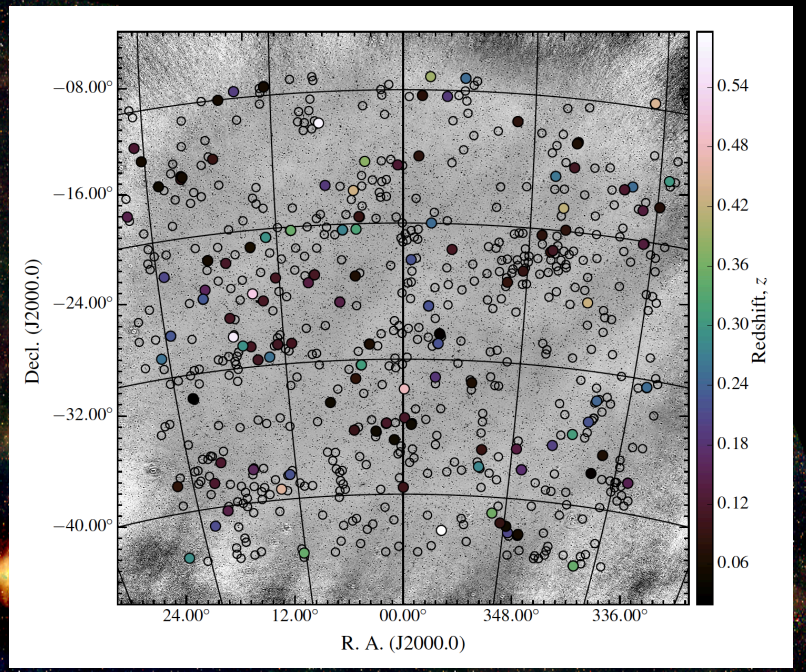
ARDES II – Shakouri, Johnston-Hollitt, Pratt (to be submitted today)

Current Status

- There are currently ~65 radio halos known
- Similar number of relics including ~20 double relic systems.
- Given the current models we have for halo and relic generation, there should be many, many more. Due to the steep spectral index these should be most easily seen at low frequencies. Eg Cassano et al. 2012, predicted 500 halos in the LOFAR Tier 1 survey.

GLEAM +EoR0 field

- 72 – 231 MHz
- South of +30 degrees
- Divided into 20 sub-bands of 7.5 MHz
- 2-3’ resolution



- 168 MHz, deepest MWA image ever. See Offringa et al. (2017)
- 2-3’ resolution

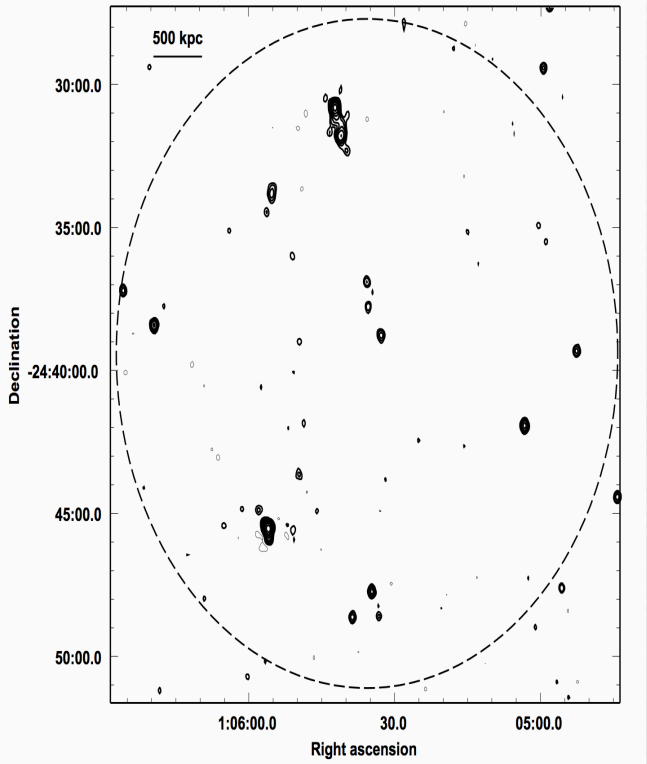
Relics and Halos in GLEAM

- Two searches for diffuse emission in clusters have been performed:
  - Searched ~1,100 MCXC clusters covered by GLEAM for relics and halos
  - Searched the remaining 4200 known galaxy clusters from major catalogues (ACO, SPT, Planck, etc)
- Full cross match comparison to all existing radio surveys, comparison to X-ray and optical.

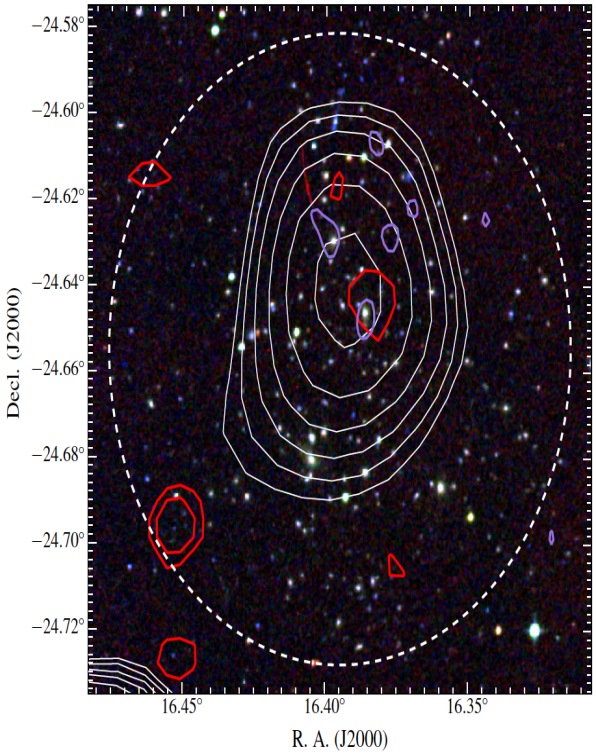
Relics and Halos in GLEAM

- In total 950 diffuse source candidates found. Many of which are difficult to classify.
- For the MCXC search: a new catalogue of ~190 diffuse sources: including 41 halos and 46 new candidate halos, 40 relics and 25 candidate relics and ~50 diffuse sources that are not easily classified.
- For second catalogue we have 25 unambiguous halos, 20 unambiguous relics and LOTS of things which demonstrate our taxonomy is not sufficient.
- The highest redshift candidate is at z =0.68 but due to the resolution issues the highest redshifts I'm confident about are to z = 0.45
- Many of the new radio halos have 1.4 GHz radio powers below 10^{22} W/Hz assuming a spectral index of -1.3. Many are ultra steep. Steepest is -3.4

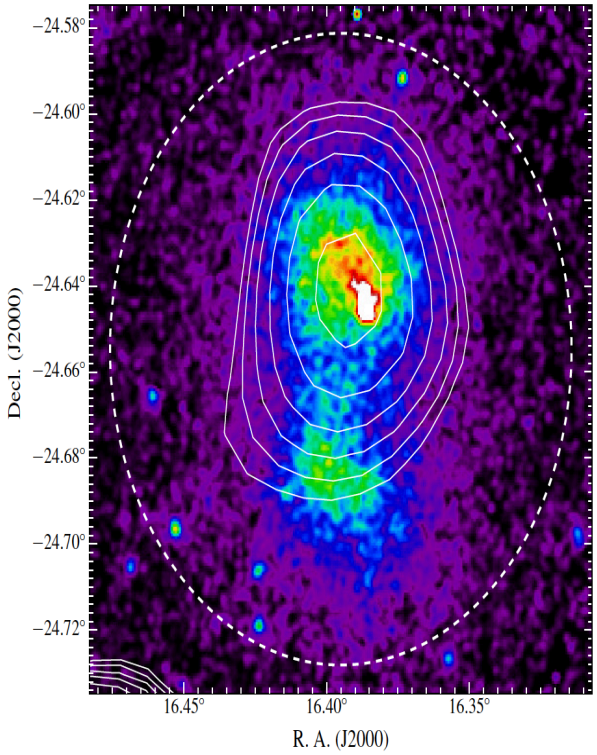
610 MHz - GMRT



168 MHz MWA



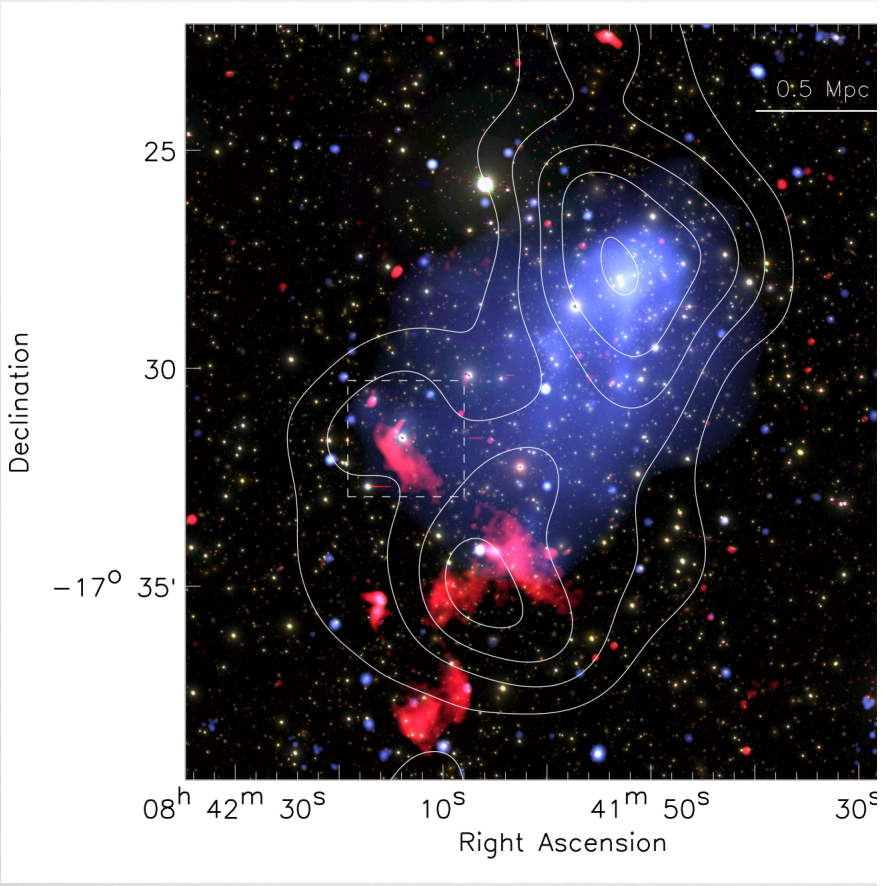
X-ray

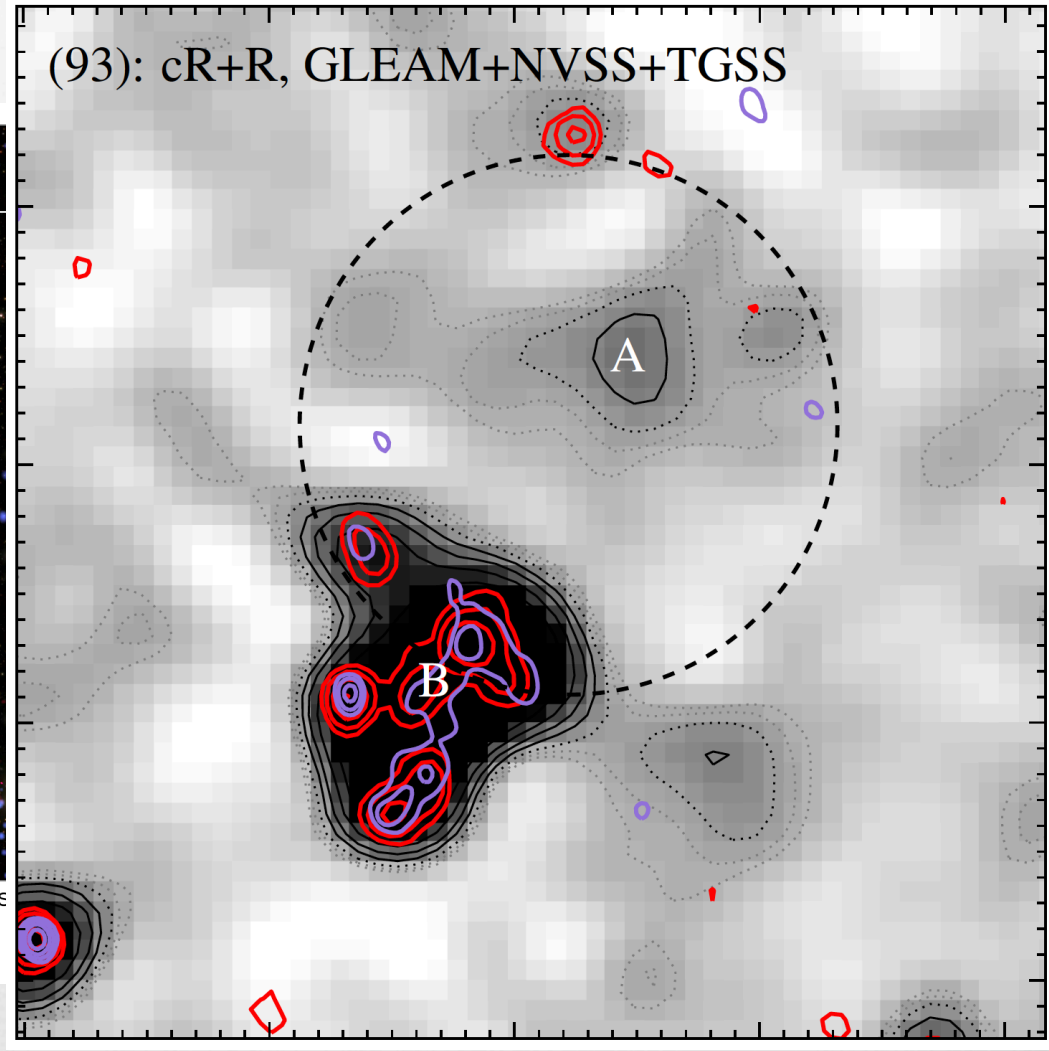


Halo steeper than -2.1

Credit: Venturi et al. (2007)

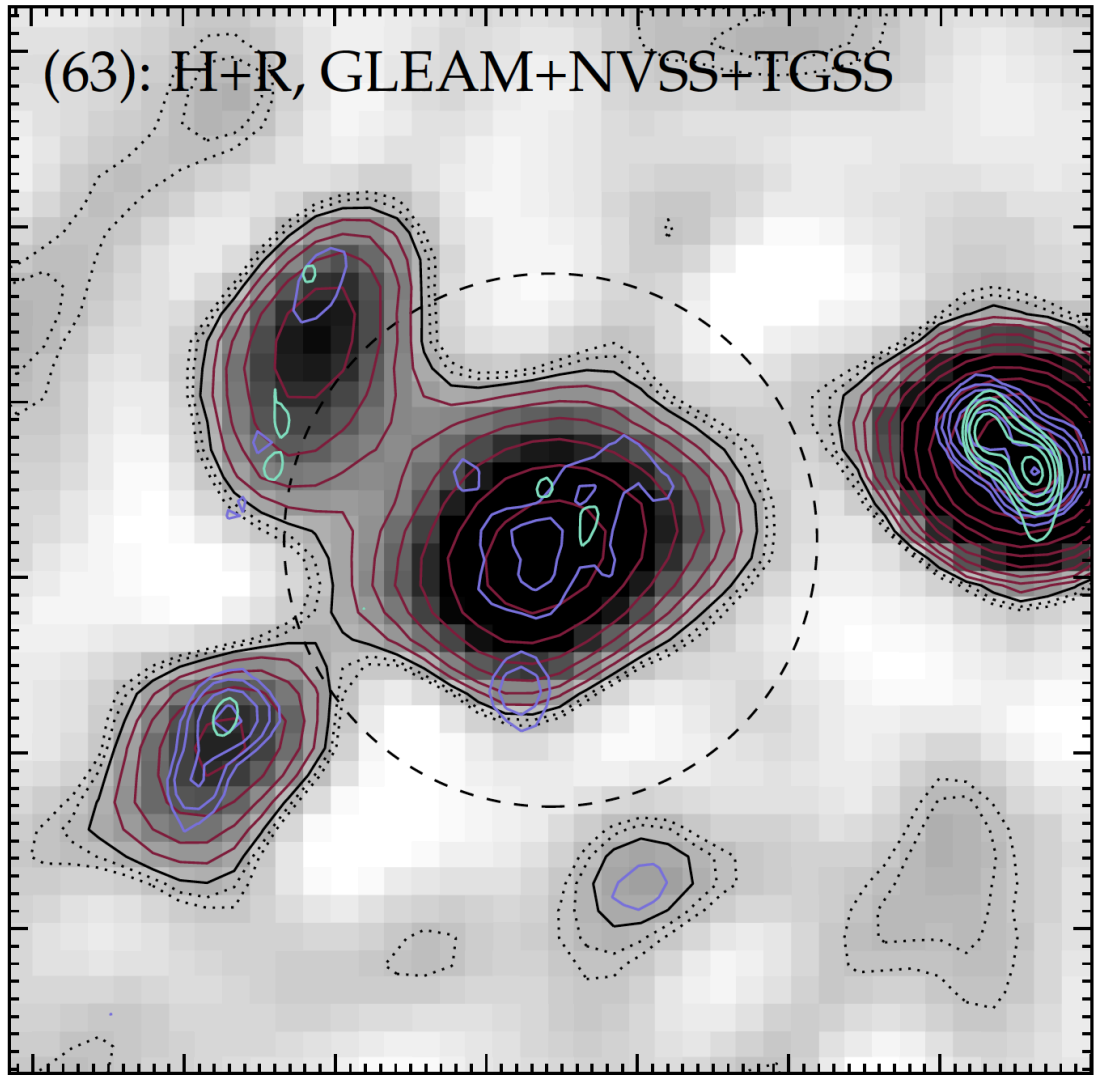
Credit: Duchesne et al. (2017)



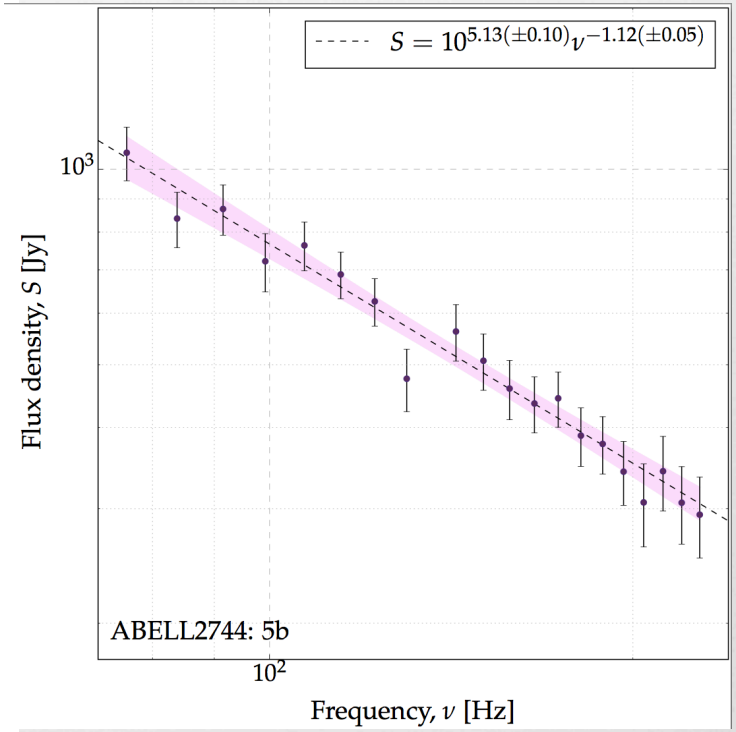


Credit: van Weeren et al. (2017)

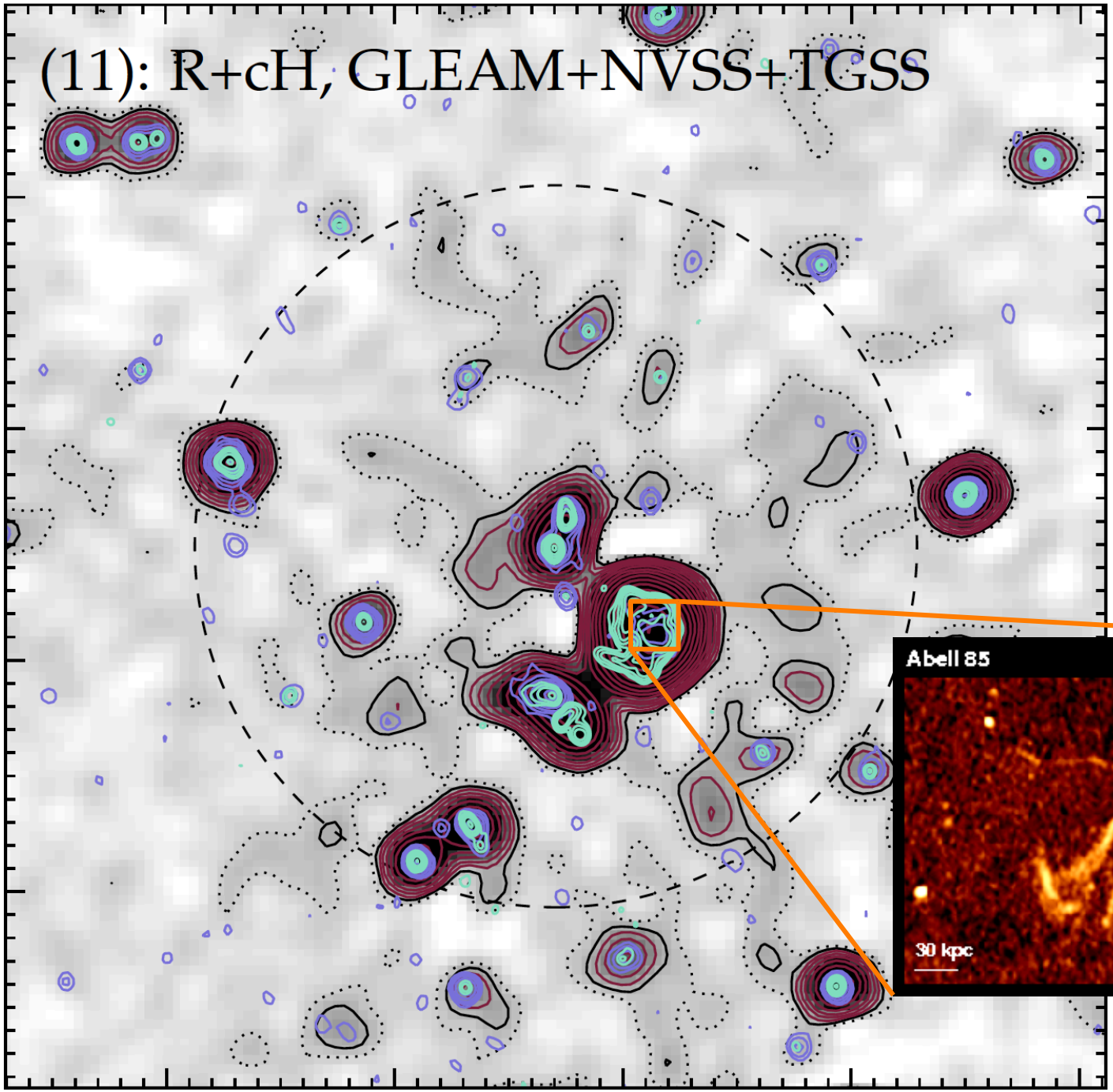
Credit: Johnston-Hollitt et al. (in prep)



A2744: known relic and halo, but halo is larger.



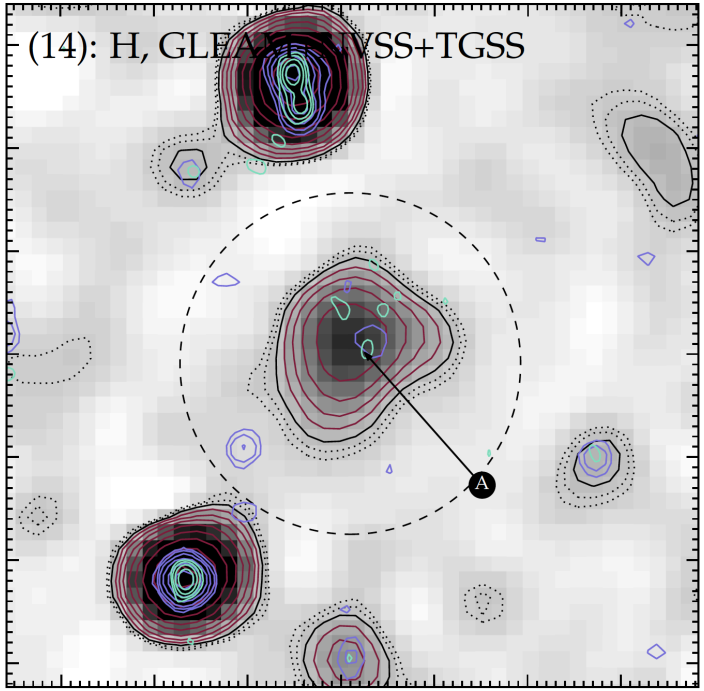
TGSS 150 MHz 20” data in aqua
NVSS in purple
maroon and black contours are GLEAM, green circle is r500

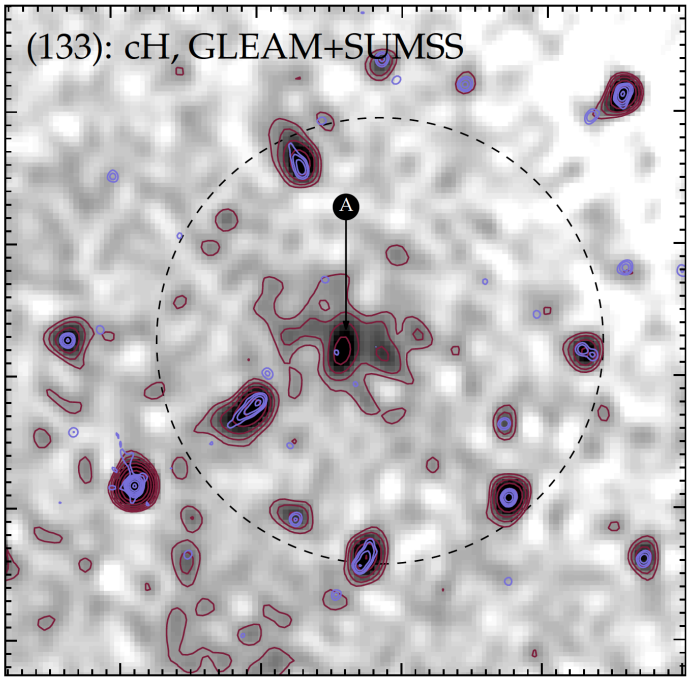


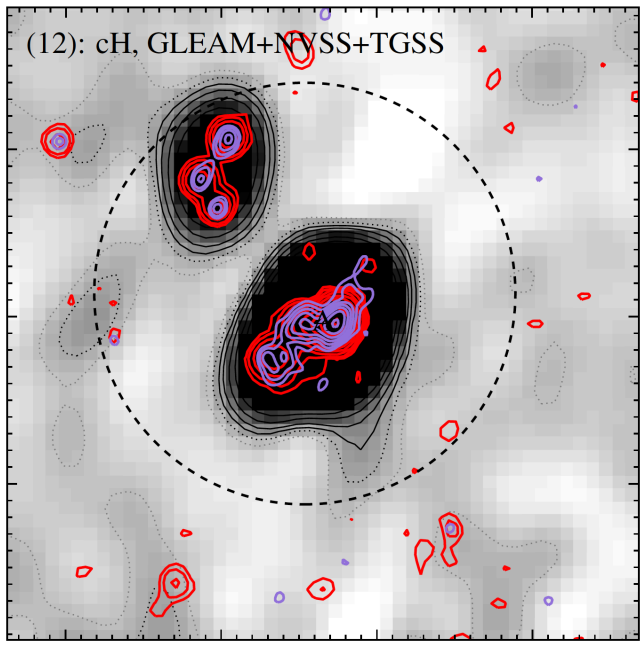
Abell 85

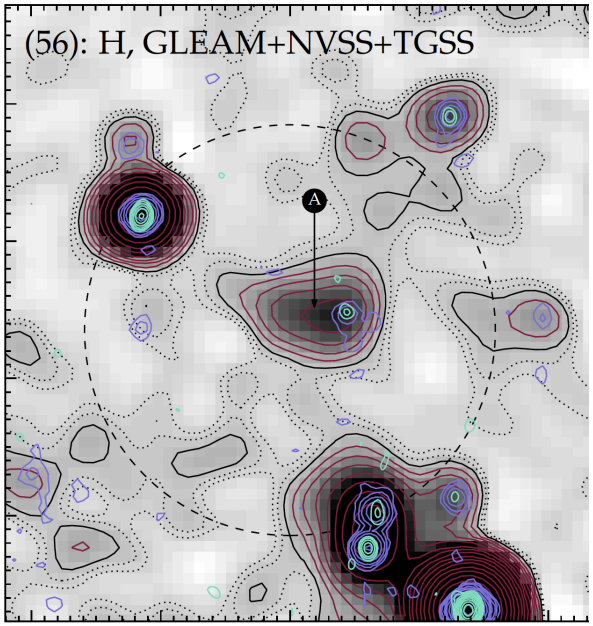
Relic is not a kpc-scale relic! This relic is full size AND the cluster is full of diffuse emission.

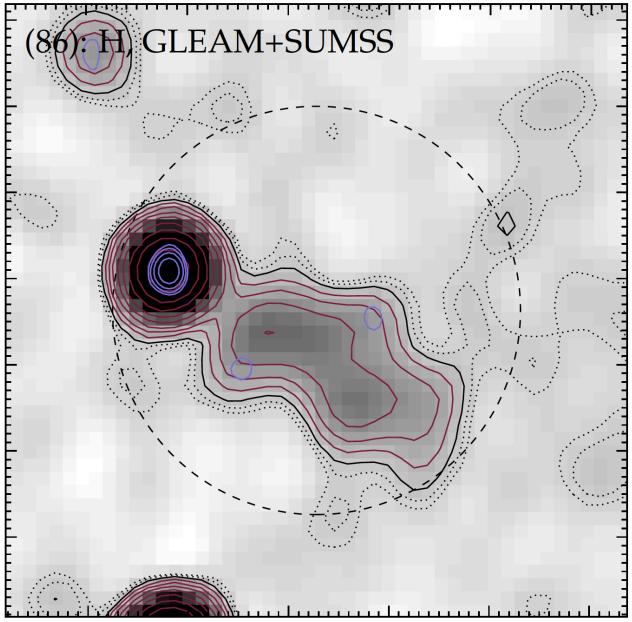
Examples of some of the new halos



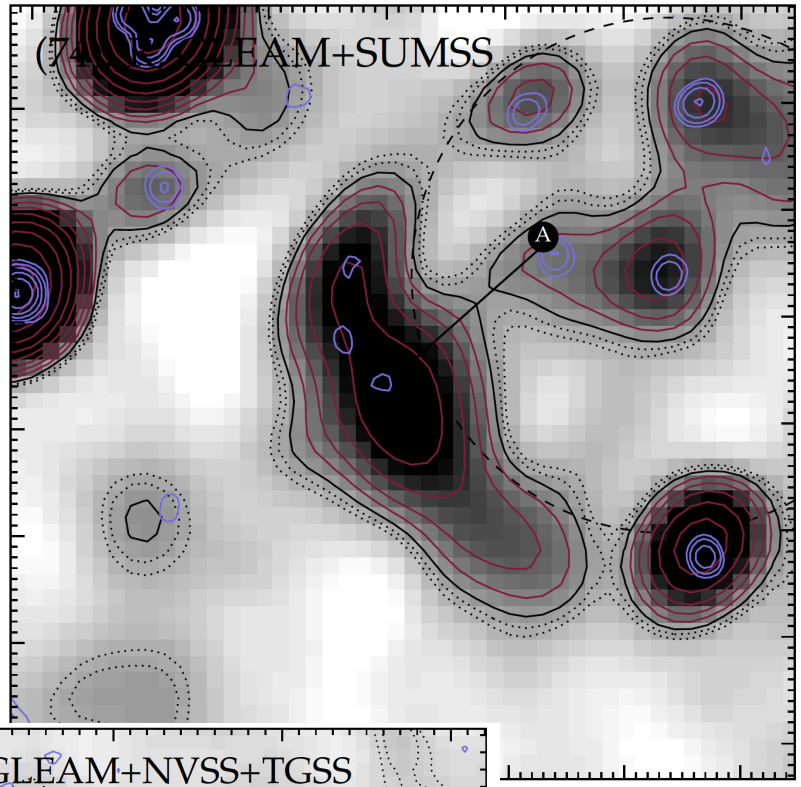


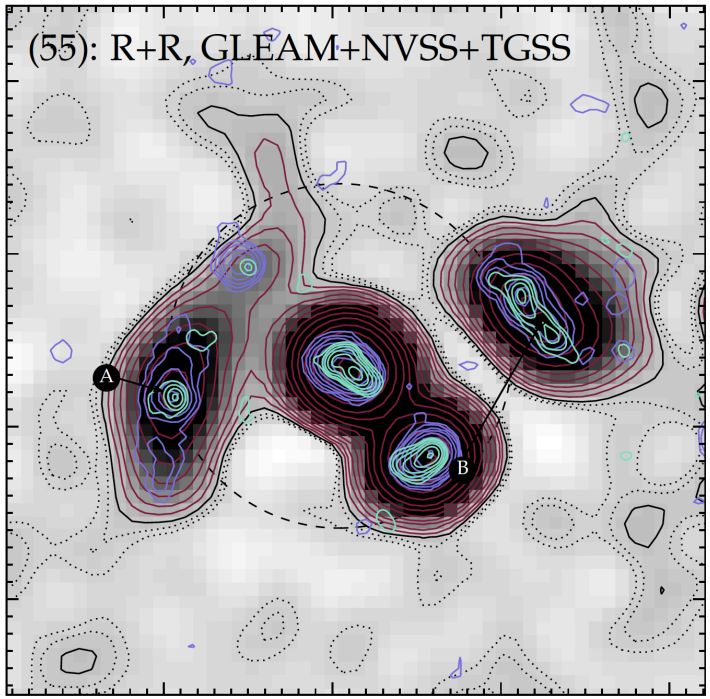


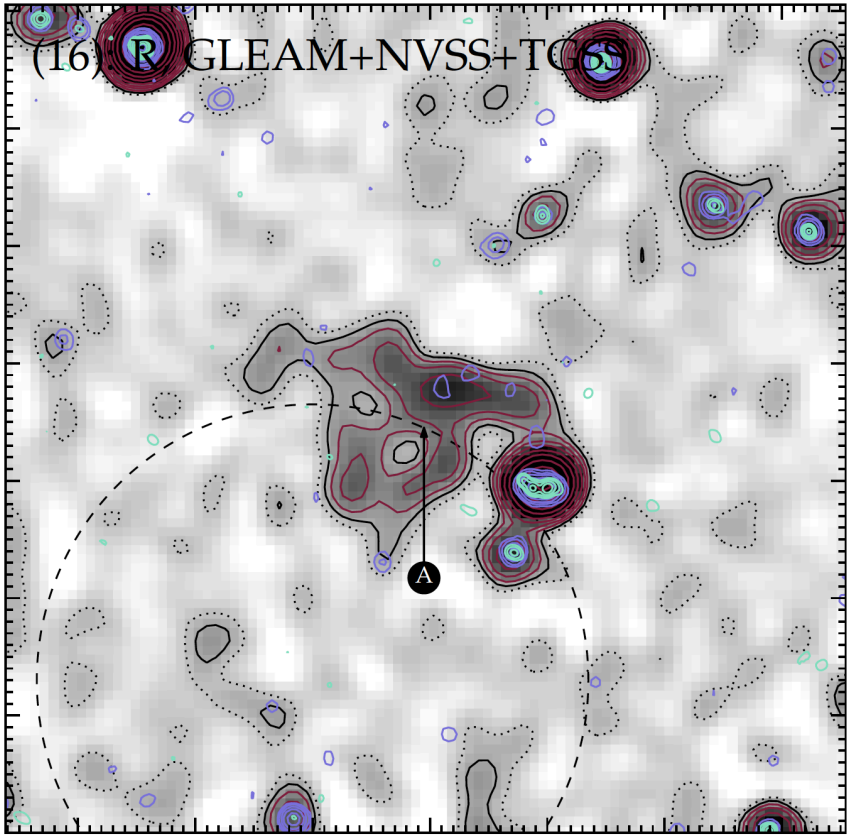


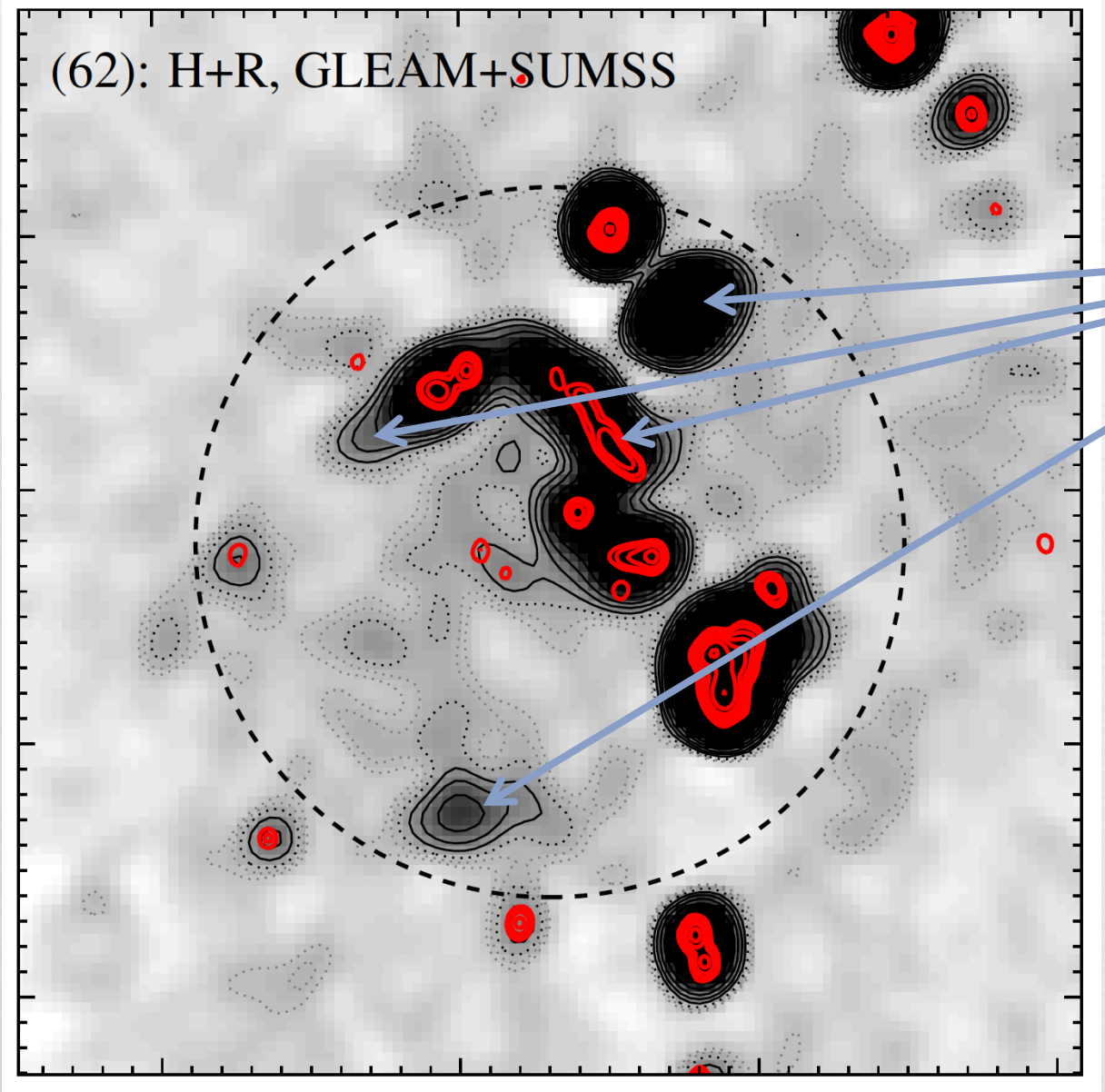


Examples of some of the new relics





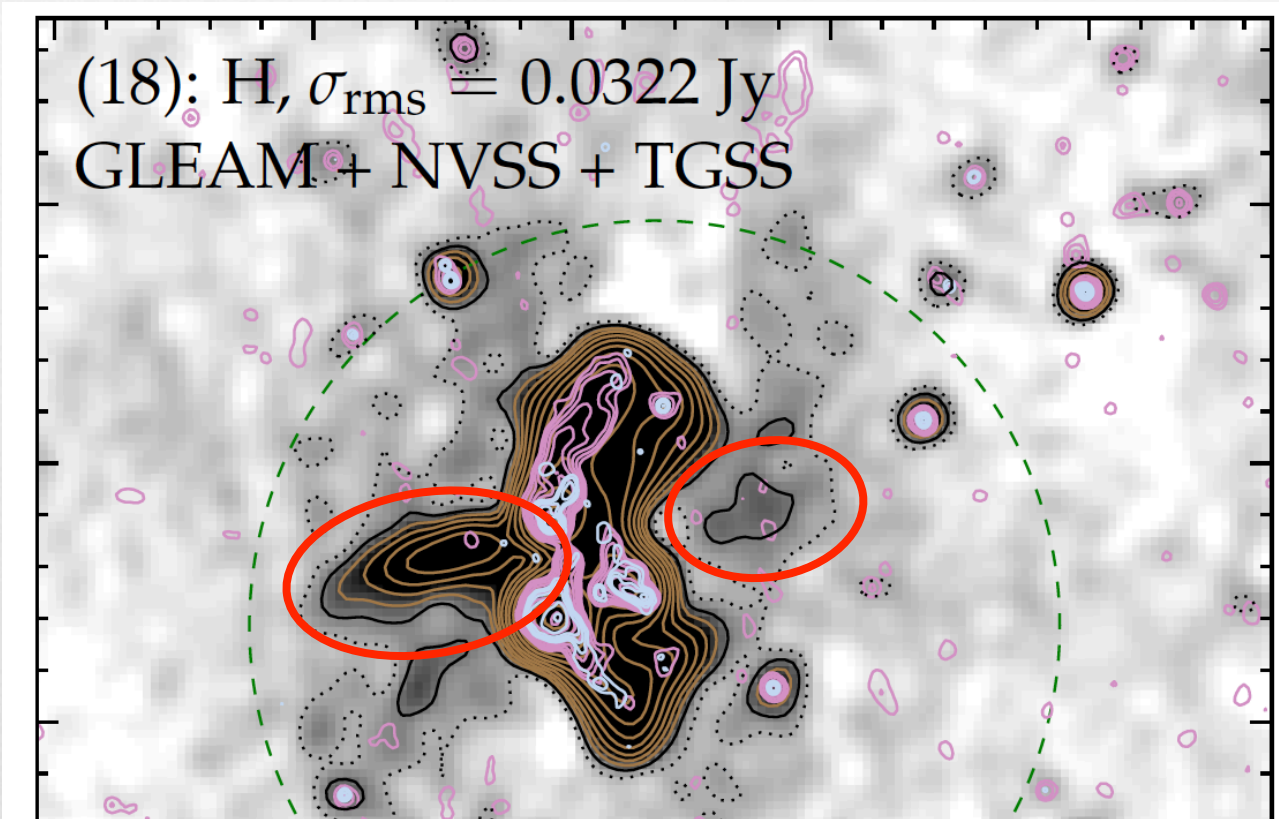




First 4 relic system

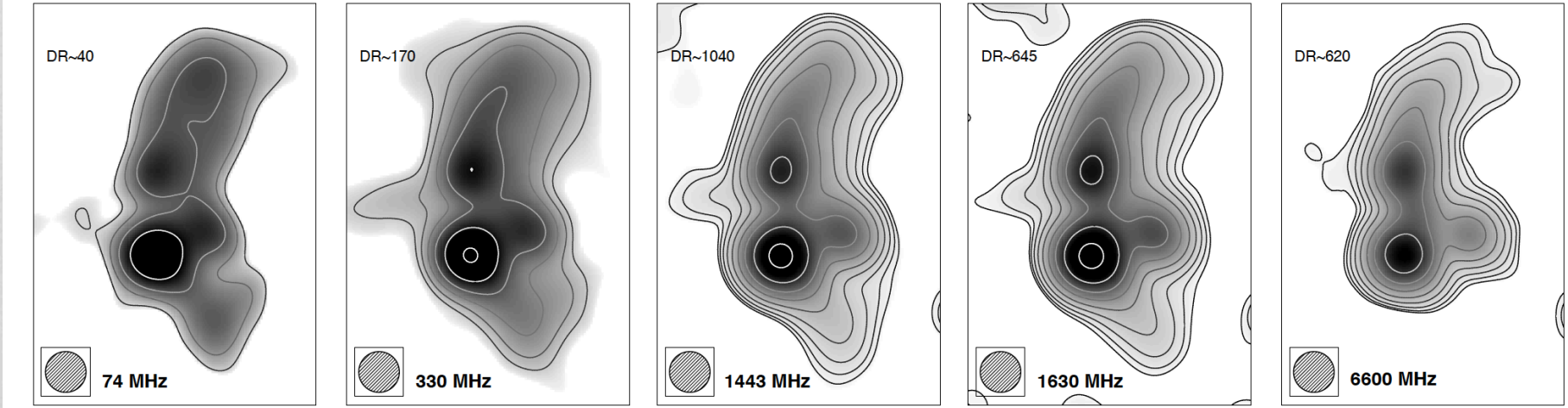
Relics

We have deep ATCA 1.4 GHz imaging and 1300 spectroscopic redshifts have done a full dynamical analysis of this in optical (Dehghan et al. in press) very complex multi-merger system

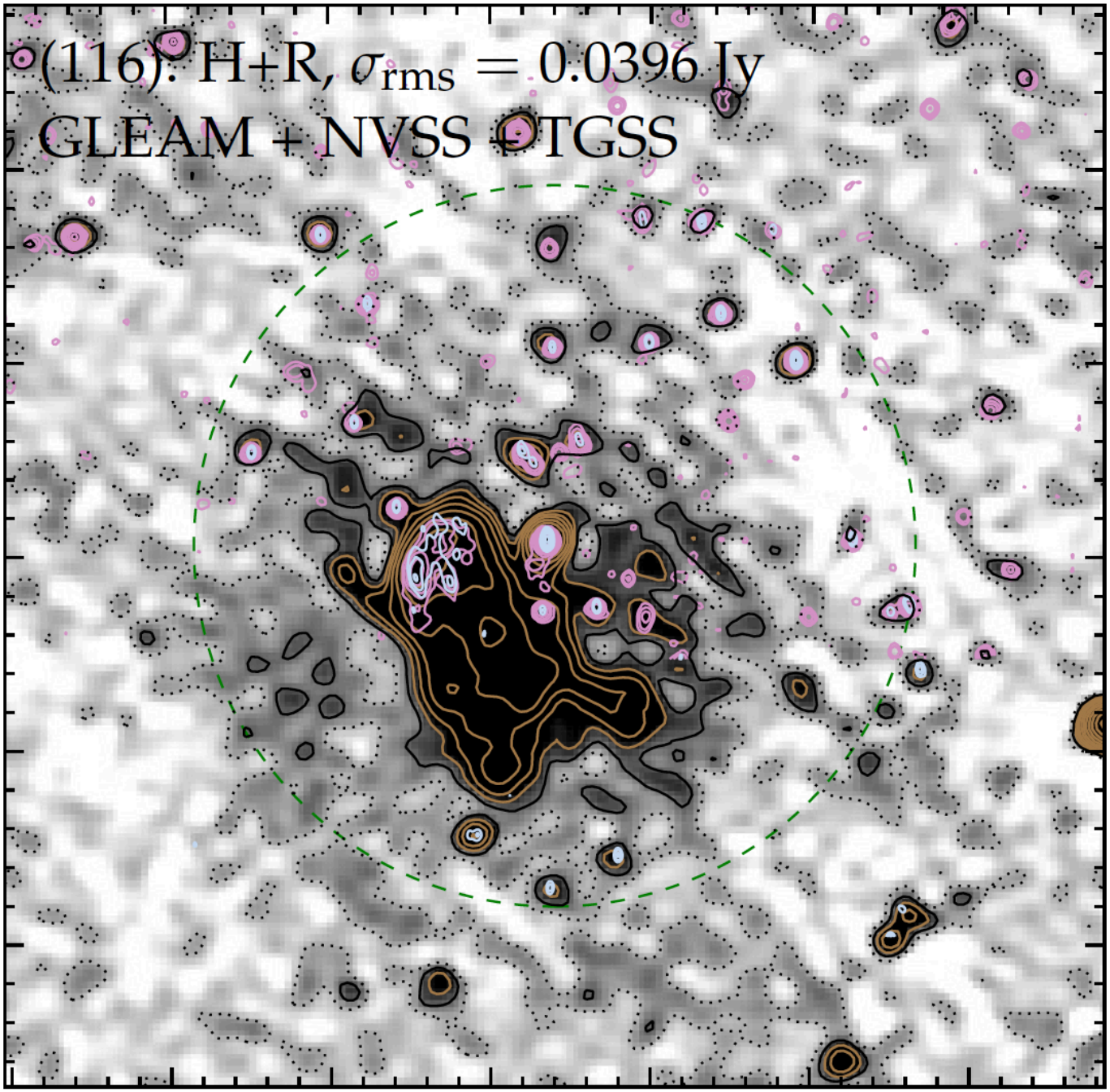


Abell 194
Minkoski's Object

Known AGN, but full extent not known. Evidence of rotation of the jet axis

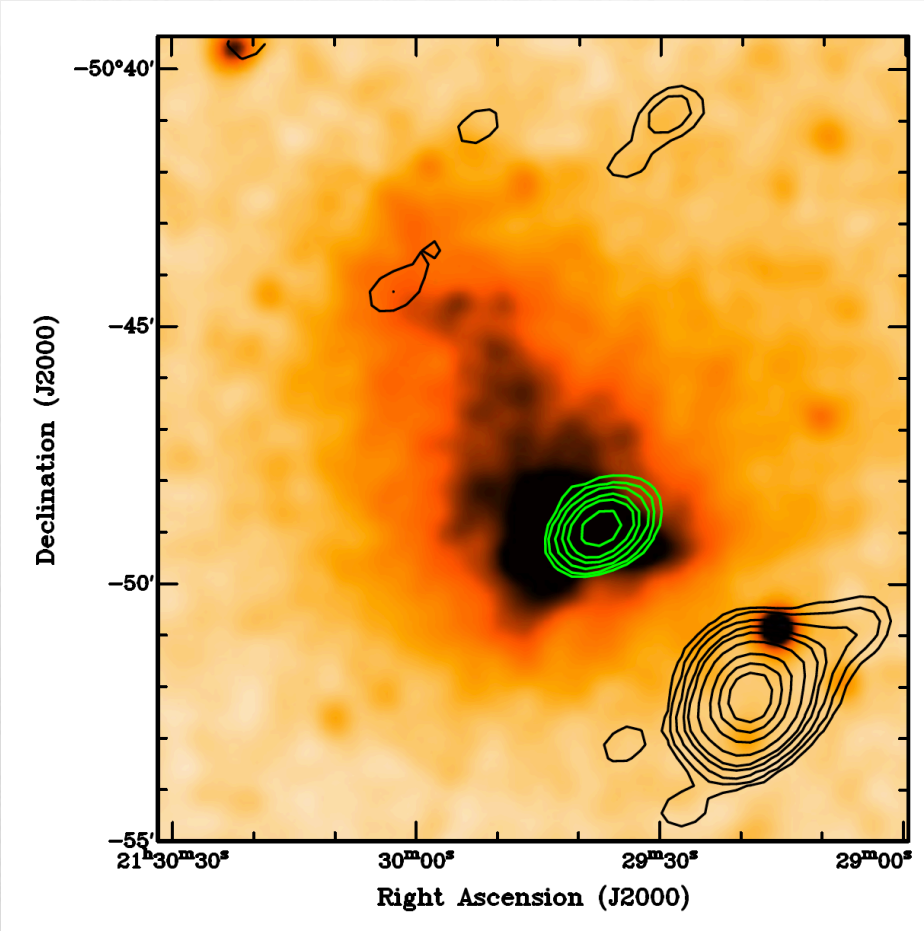


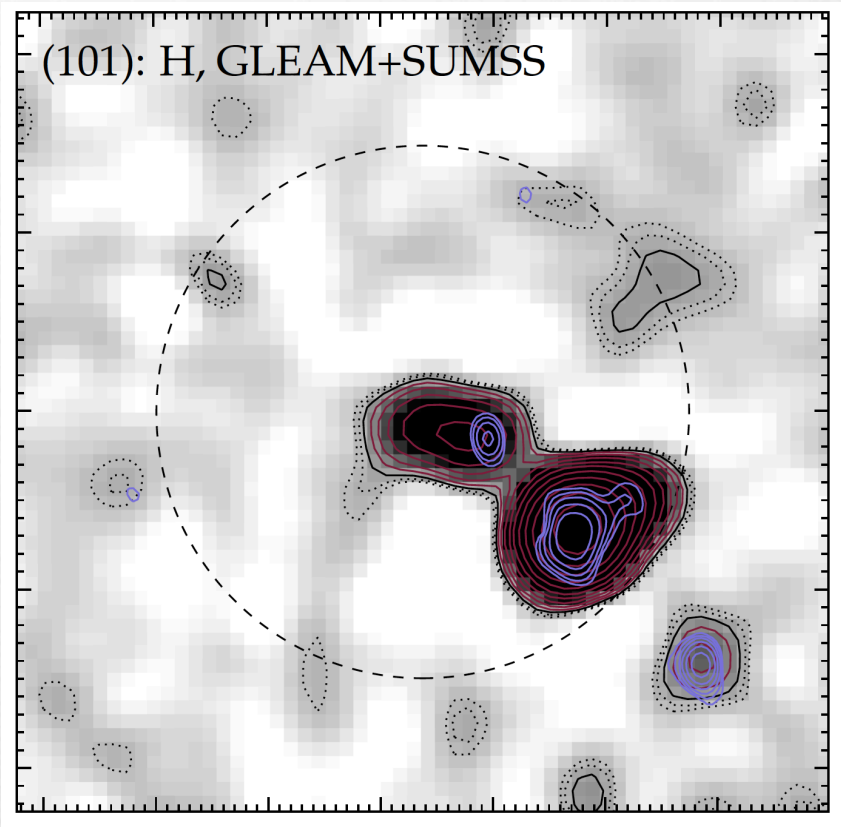
Govoni et al. (2017)



No idea!

A3771



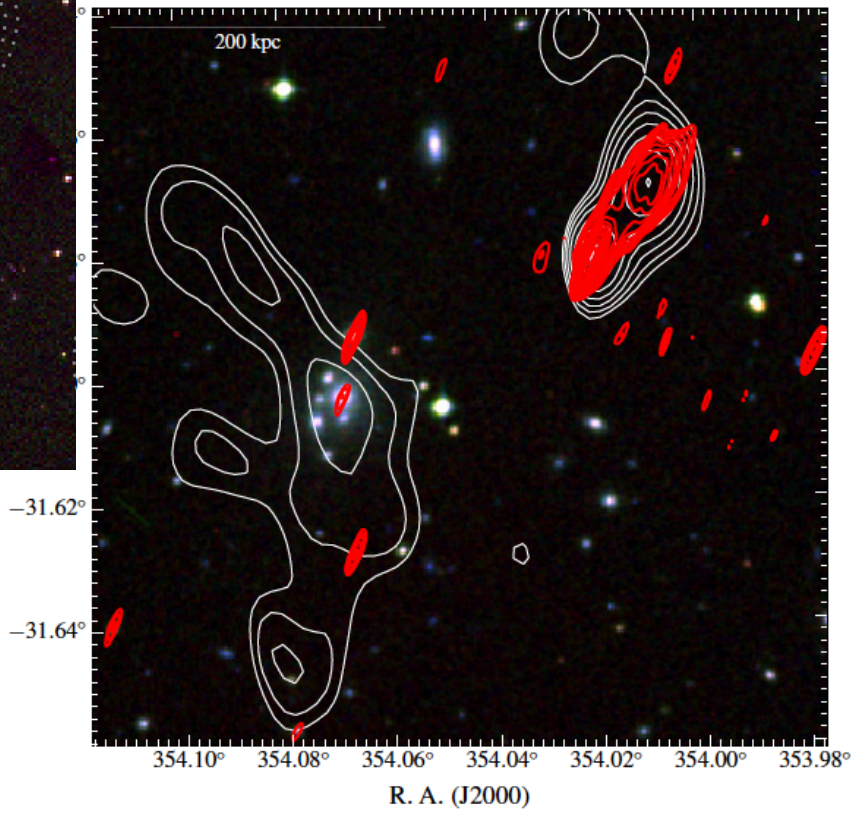


Highly disturbed X-ray
Deep ATCA imaging finds no halo
(Shakouri, Johnston-Hollitt, Pratt)

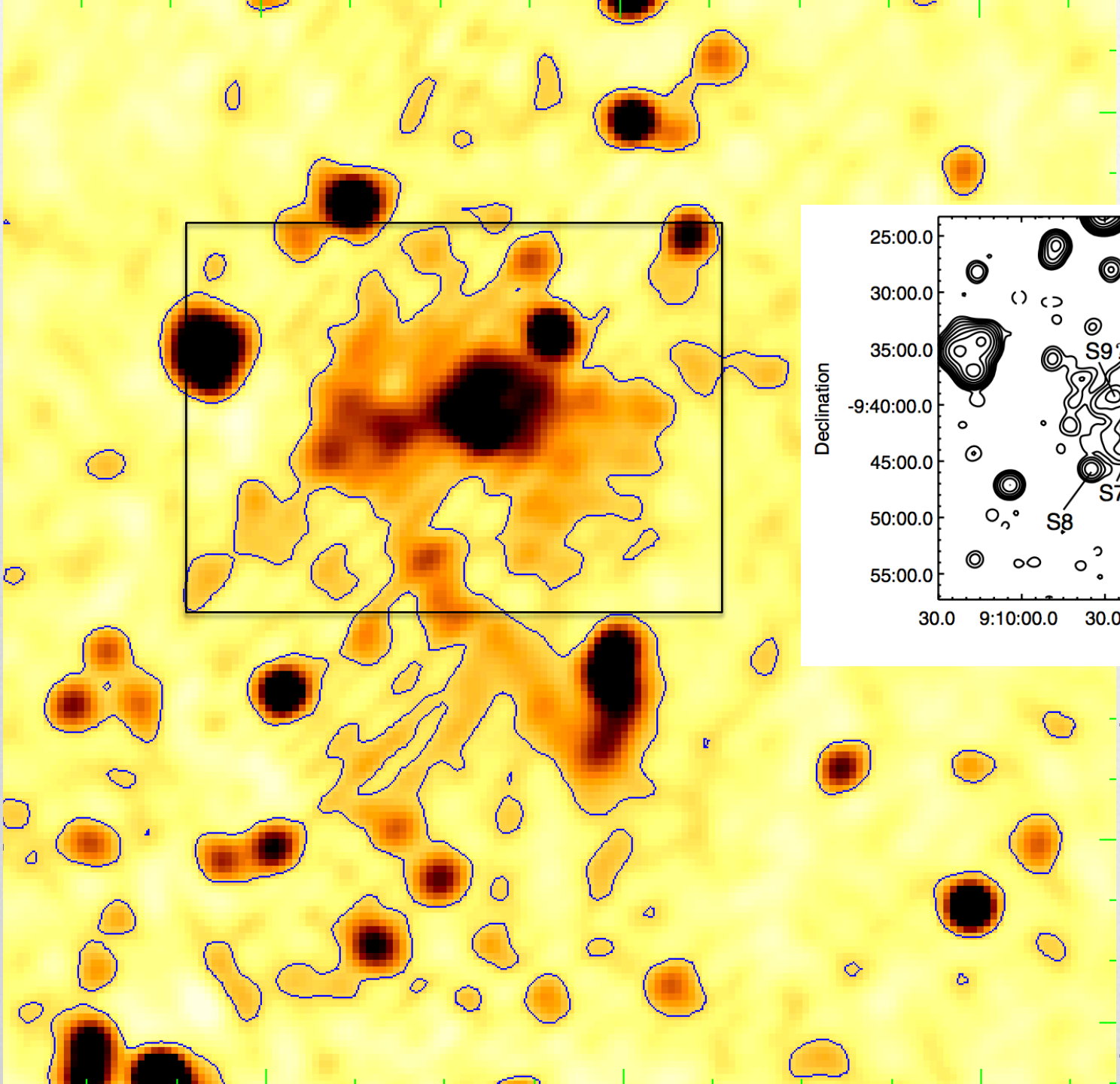
GLEAM easily finds the halo!
So we really shouldn't be doing this at 1.4 GHz!!

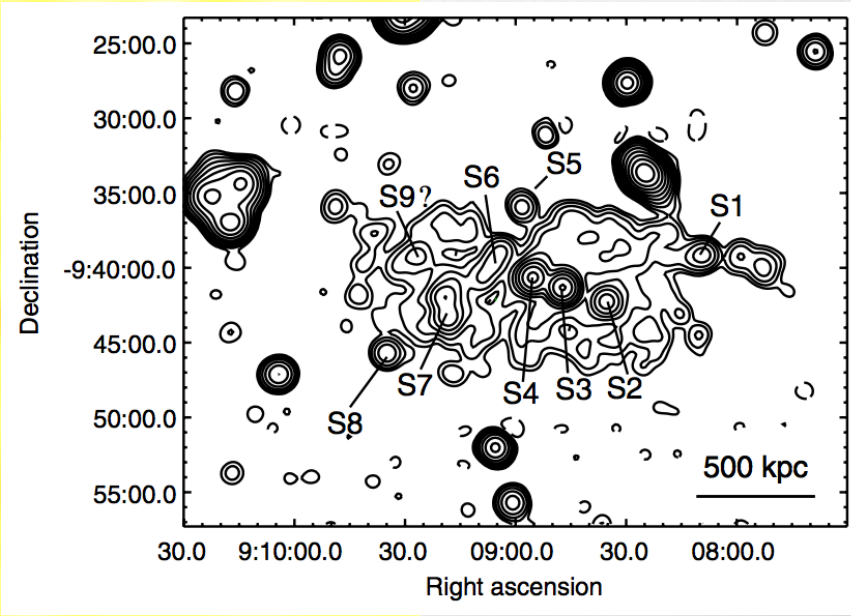
GLEAM (white), TGSS (purple), NVSS (red)

Deep 2.1 GHz ATCA (red), TGSS (white)



Duchesne et al. in prep



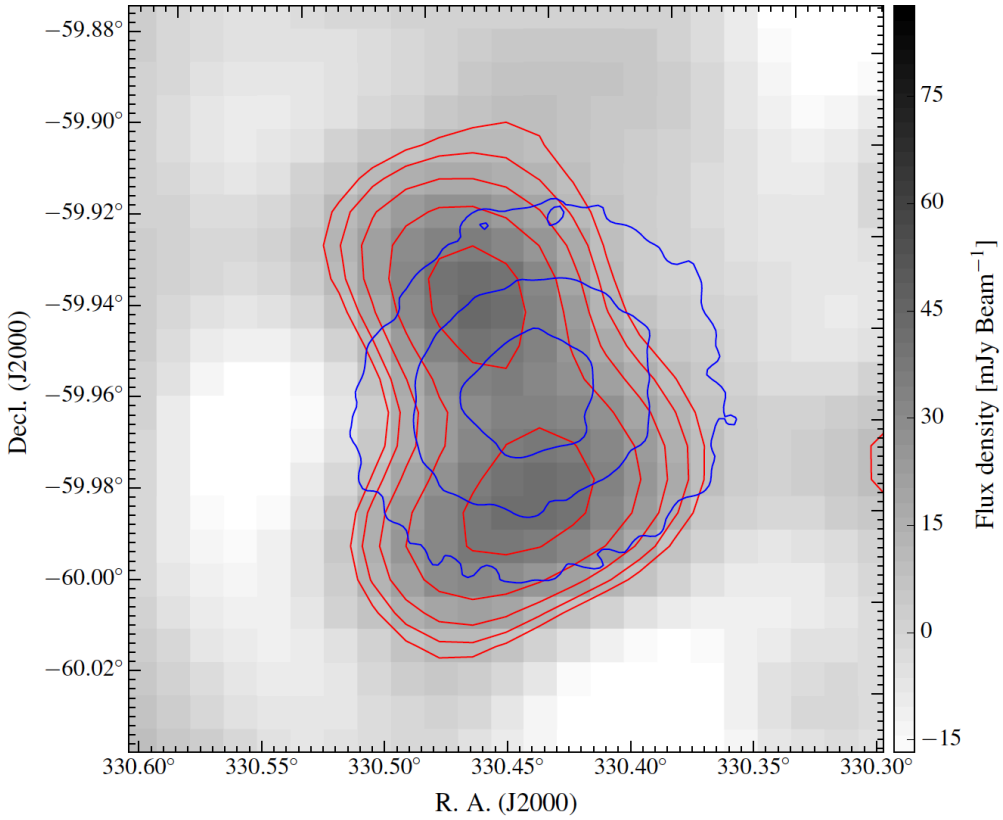


1.4 GHz VLA at
70” resolution
Macario et al. 2011

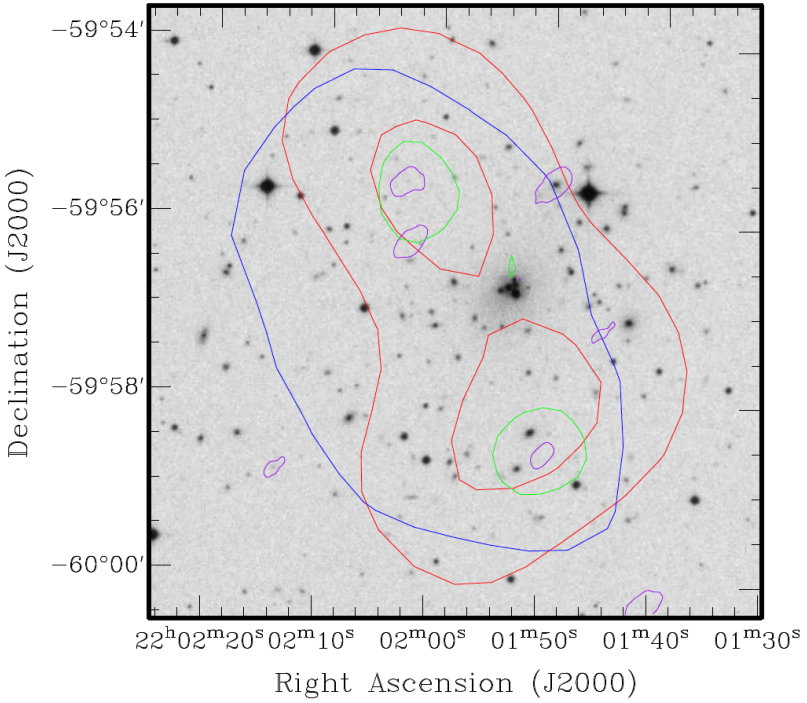
150 MHz GLEAM
RMS = 9 mJy/b
~2.5’ resolution

SPT J2201-5956

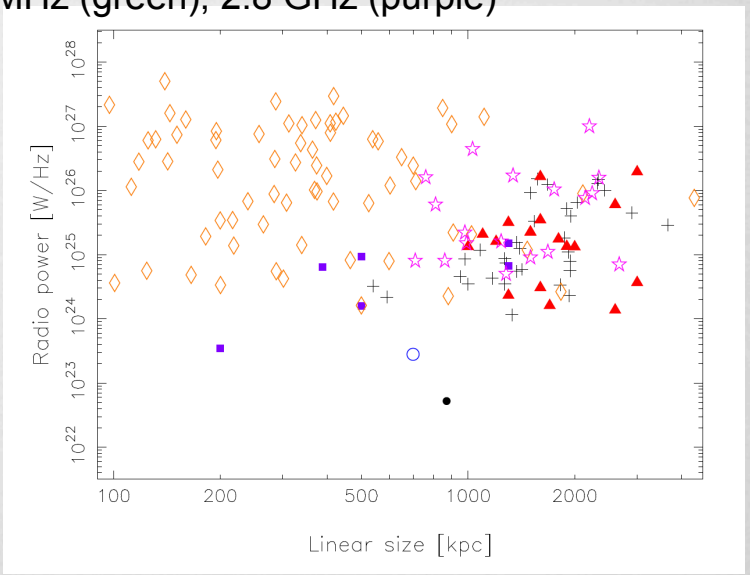
Diffuse emission in this cluster is another example of a dead RG. There's no re-acceleration, just dead lobes.



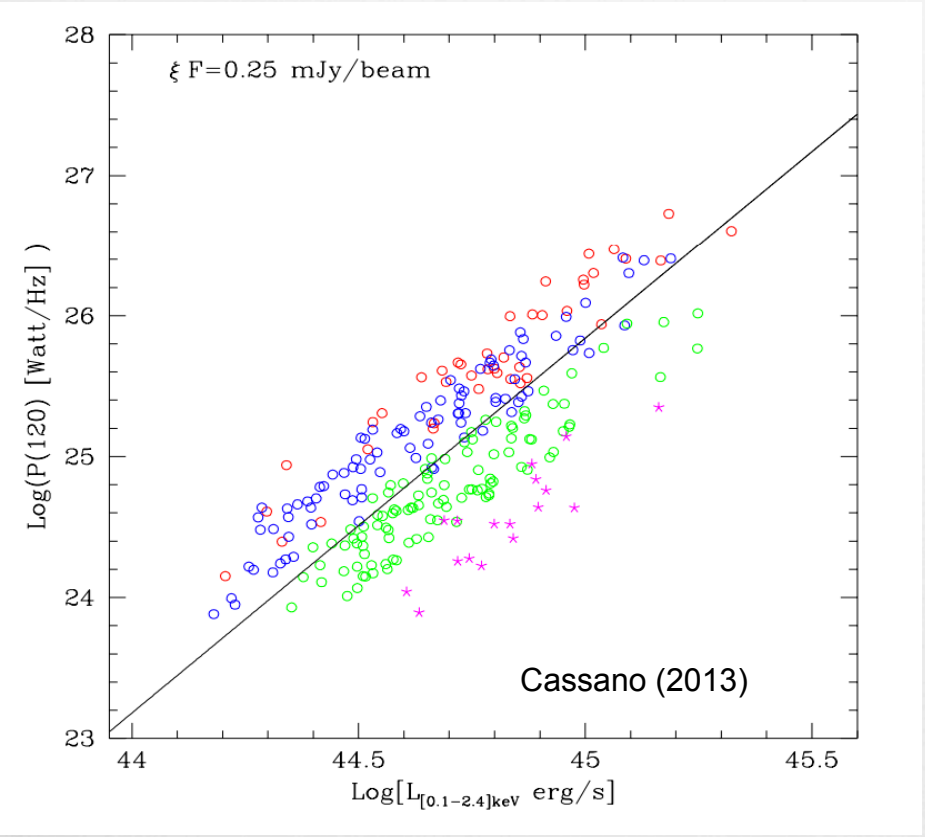
Red 200 MHz MWA, Blue XMM

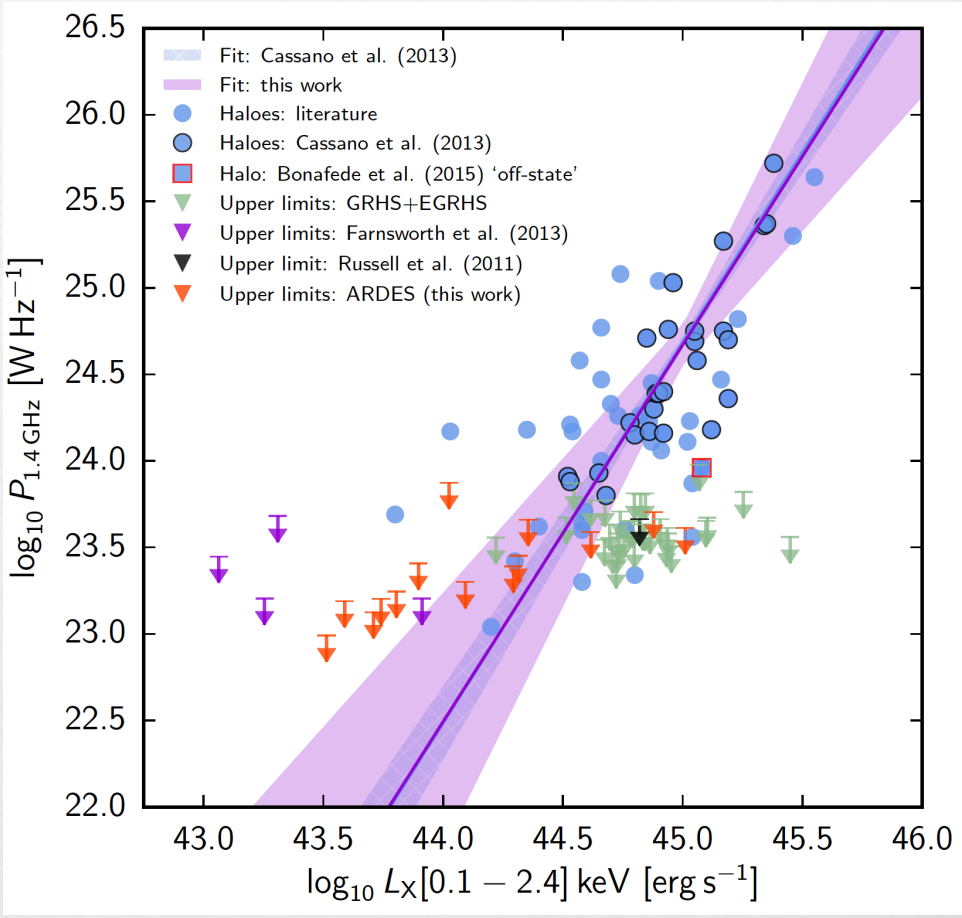


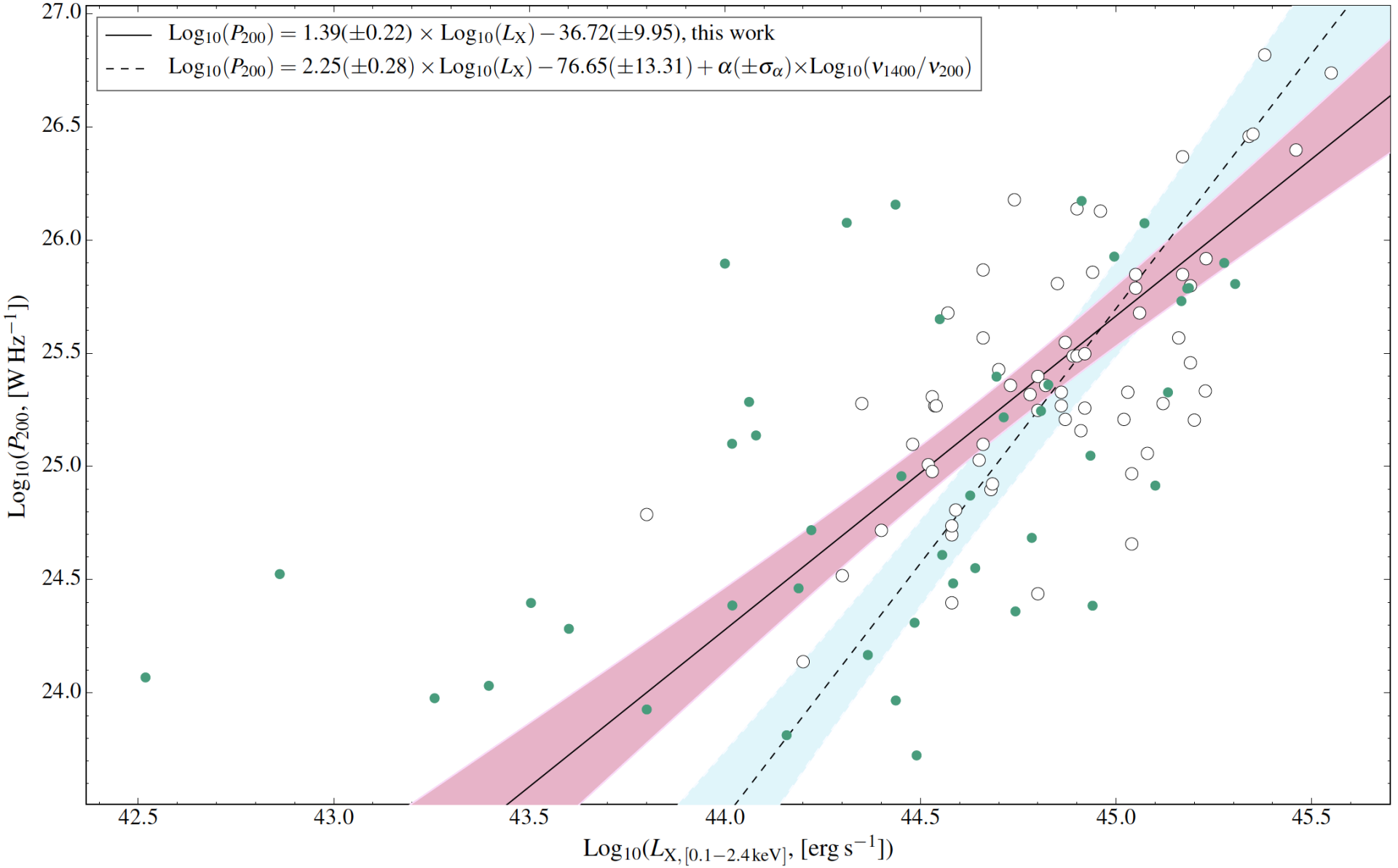
200 MHz MWA (red), 408 MHz (Blue), 843 MHz (green), 2.8 GHz (purple)



Zheng et al. in prep

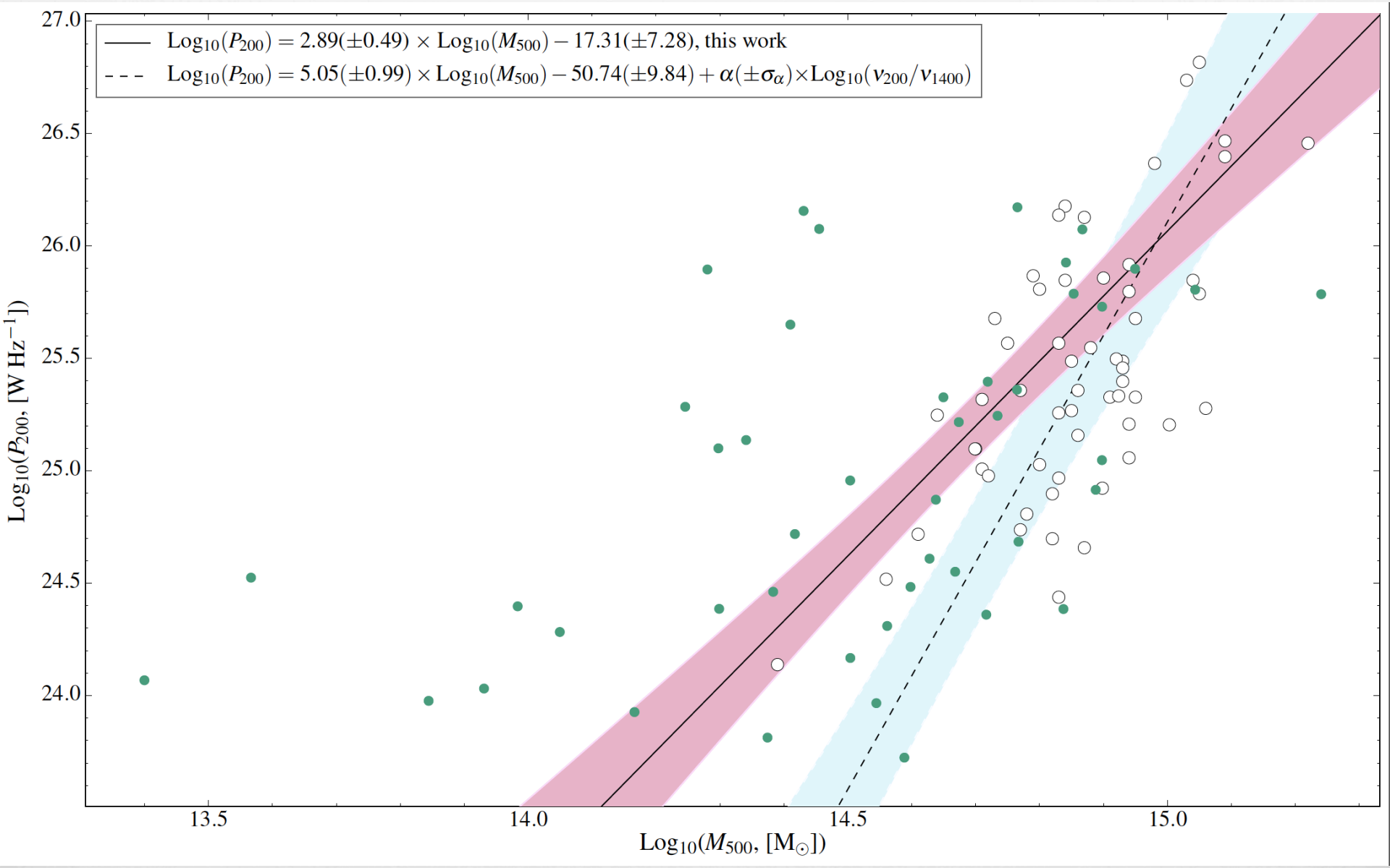

ξ F=0.25 mJy/beam
Cassano (2013)
Log(P(120) [Watt/Hz])
Log[L[0.1−2.4]keV erg/s]
28
27
26
25
24
23
44
44.5
45
45.5


Fit: Cassano et al. (2013)
Fit: this work
Haloes: literature
Haloes: Cassano et al. (2013)
Halo: Bonafede et al. (2015) 'off-state'
Upper limits: GRHS+EGRHS
Upper limits: Farnsworth et al. (2013)
Upper limit: Russell et al. (2011)
Upper limits: ARDES (this work)
log10 P1.4 GHz [W Hz−1]
log10 LX[0.1 − 2.4] keV [erg s−1]
26.5
26.0
25.5
25.0
24.5
24.0
23.5
23.0
22.5
22.0
43.0
43.5
44.0
44.5
45.0
45.5
46.0



Scatter in Lx not a surprise.

Johnston-Hollitt, Duchesne et al



1.4 GHz is not the frequency to do this!!
Lots of extrapolation here.

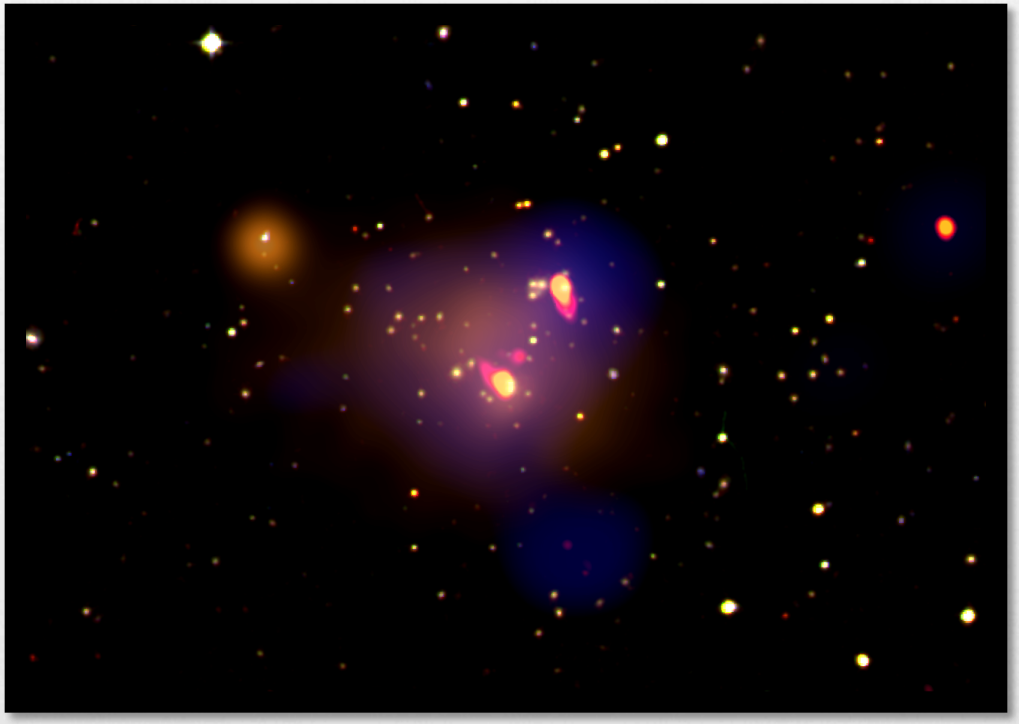
Johnston-Hollitt, Duchesne et al

Summary I

- Clusters are full of diffuse emission! Of the 950 diffuse sources we've found the vast majority are RGs, many of which are dead.
- From 1100 clusters in MXCX have ~200 diffuse sources properly categorised including more than double the number of know halos and relics. From over 5400 clusters over 500 hundred candidates to be classified.
- Now filling the bottom part of the P1.4 vs Lx diagram, but can also test the difference between steep and ultra steep halo populations.
- RGs associated with the cD galaxy possibly more common in clusters in the past, dead RGs appear to be the source of electrons to be accelerated in relics and halos. Many current RGs also see conjoined to relics and halos.

Summary II

- Our taxonomy is no longer sufficient
- We need to stop doing scaling relations at 1.4 GHz
- We have the following papers associated with this work to appear very soon:
  - Catalogue of new halos and relics I – the MXCX sample and II the rest of the sky, Johnston-Hollitt et al.
  - Diffuse Radio Emission in the EoR0 field: Duchesne et al..
  - Several papers on individuals clusters led by postdocs, Cathie Zheng & Siamak Dehghan
- So lots of exciting stuff, plus MWA is being upgraded so can push out further than 0.45 very soon!



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