Why are the radio sources missing in the Fornax cluster?

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The Northern lights – also known as the aurora borealis – dancing across the night sky in Alaska.

The Fornax cluster – optical

Credit: Mikel Martinez 2020

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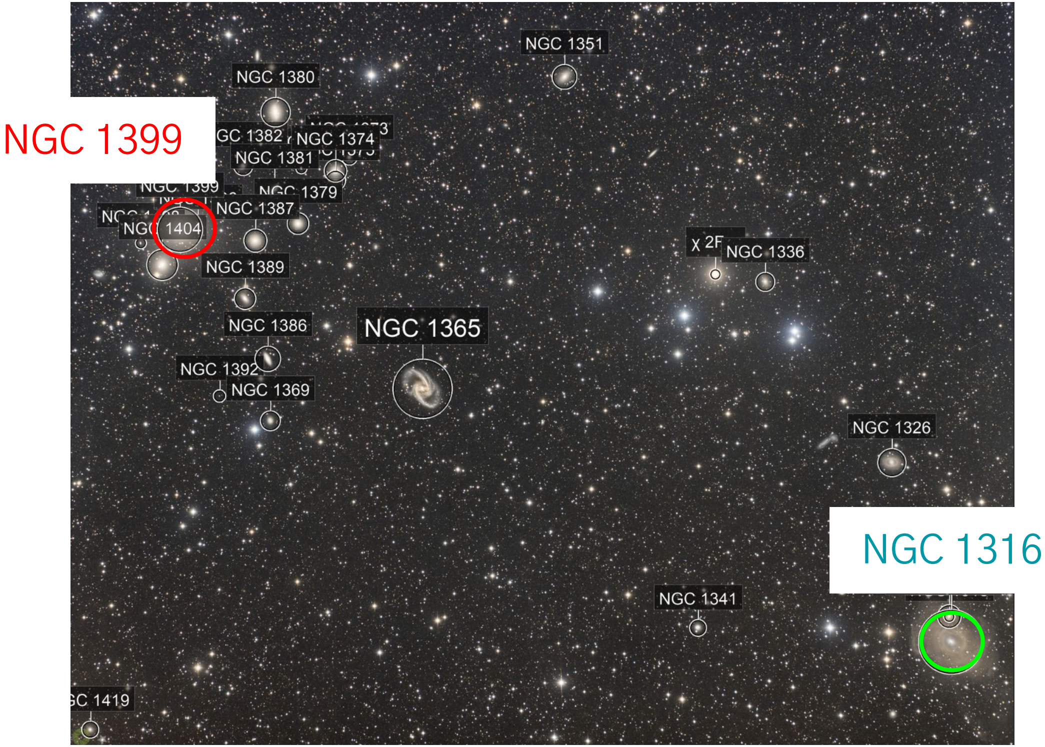

Credit: Mikel Martinez 2020

- nearby, $z \approx 0.0046$
- ~ 390 member galaxies
- low total ~ 10^{13} solar masses
- cD–type central galaxy NGC 1399
- Fornax A: NGC 1316
- core: early–type galaxies – virialised and well–evolved?

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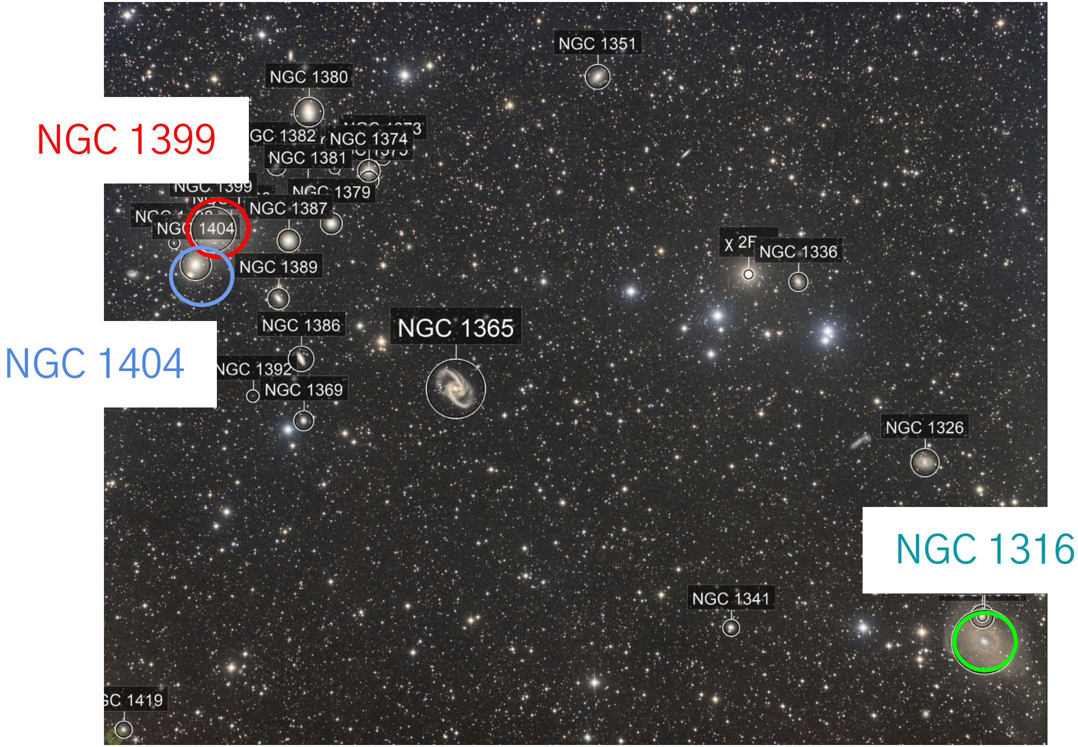

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However, recent studies indicated that the cluster is still assembling mass through a series of on–going mergers:
NGC 1399 + NGC 1316
NGC 1399 + in–falling NGC 1404

The Fornax cluster – radio linear polarised intensity

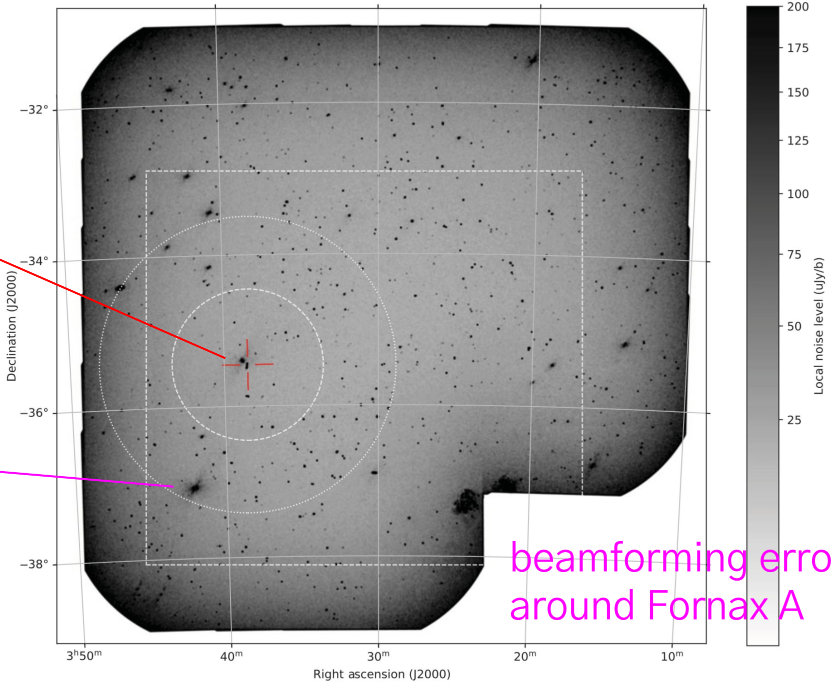
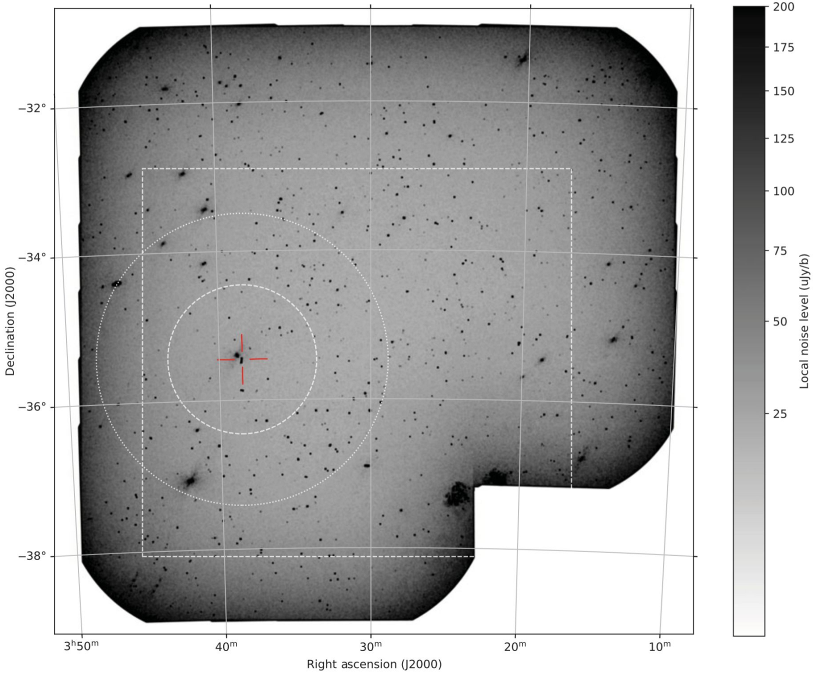


Figure 3. The local root-mean-squared (RMS) noise in the peak-*P* map. This is supplied in lieu of the peak-*P* map itself, which renders point sources effectively invisible for our high-resolution, large area map. This RMS map was generated by running a square sliding window of width and height both equal to five synthesised beamwidths over the peak-*P* map and calculating the RMS values of the pixels inside the window. The image shown here has a square root stretch applied. Linearly polarised radio sources are visible as a marked increase in the local RMS value. In source-free regions, the RMS is typically ~30 μJy beam^{-1}, except at the mosaic edges, and in the vicinity of bright sources, where the faint imprint of the synthesised beam manifests as narrow, diagonal fan-like structures. The centre of the Fornax cluster is indicated with a red cross-hair. Fornax A is partially visible in the bottom-right corner of the map, where six beams are missing due to beamforming errors. The white dashed box approximately indicates the region shown in Figure 8. The white dashed line indicates an angular radius of 1°, while the white dotted line indicates the 705 kpc (1.96°) virial radius of the cluster.

- ASKAP POSSUM survey
- “polarised intensity” map 747 – 1027 MHz
- ~ 25 RMs per square degree
- ~ 870 linearly polarised background sources (black dots) with a median fractional polarisation 4.8%
- white box: analysis region
- inner circle: 1–degree angular radius
- outer circle: 705 kpc virial radius of cluster

(Anderson+ 2021)

The Fornax cluster – “missing” polarised sources?



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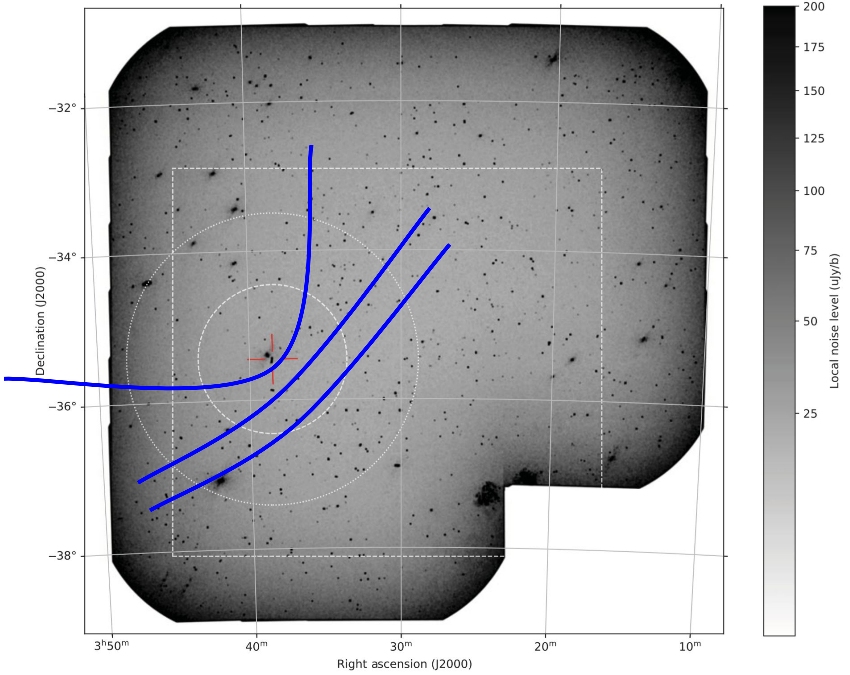
The Fornax cluster – “missing” polarised sources?

empty “patches”
by eye



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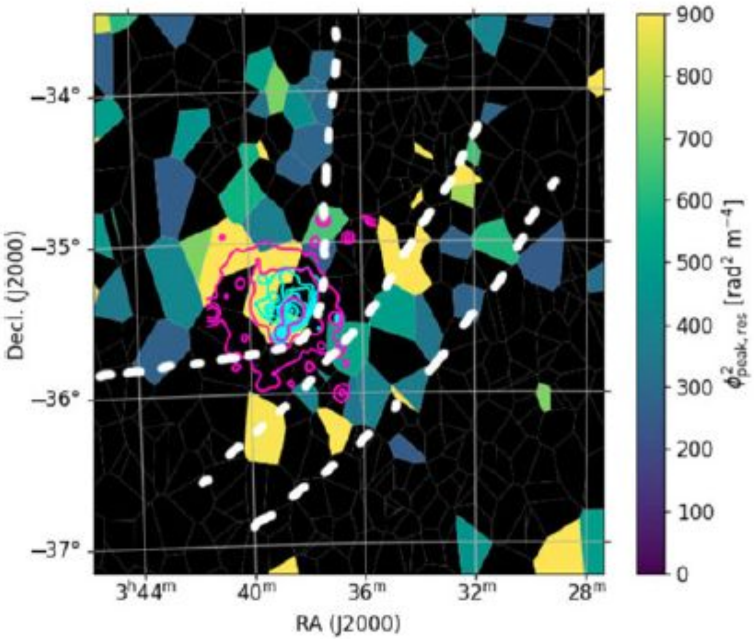
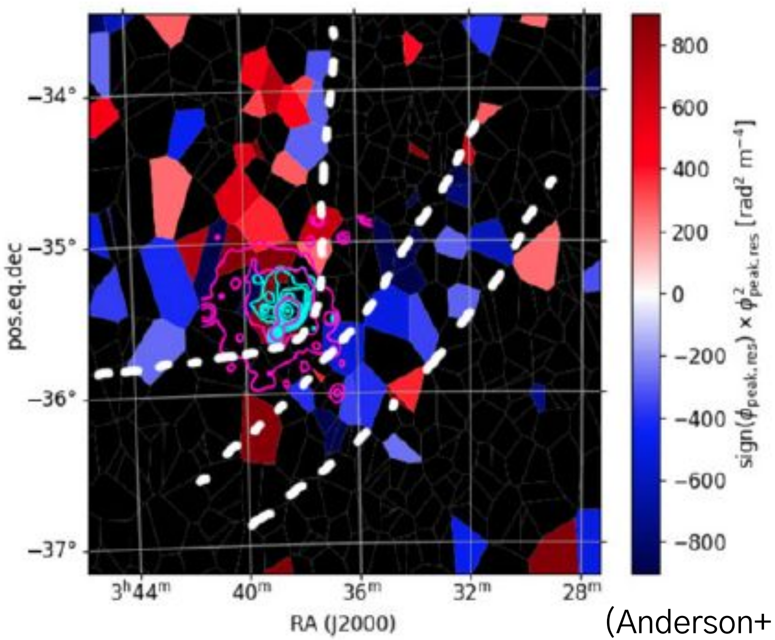
(Anderson+ 2021)

The Fornax cluster – X-rays and RMs

Contours: X-rays
light blue: Chandra (0.3 – 1.5 keV)
magenta: ROSAT (1 – 2.4 keV)

Colours: RMs
(anything < 200 rad^2 m^{-4} masked as black)





(Anderson+ 2021)

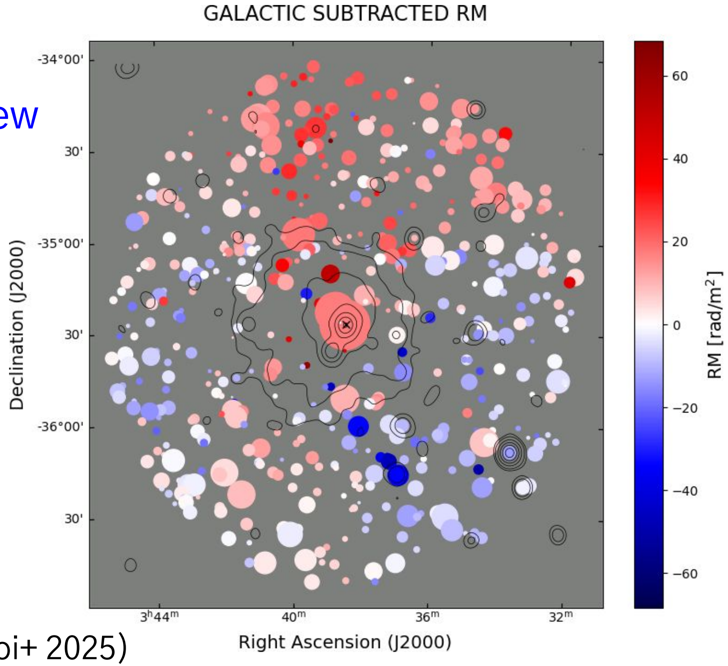
Is there truly a deficit of polarised sources?

Comparing the RM grids – MeerKAT vs ASKAP surveys

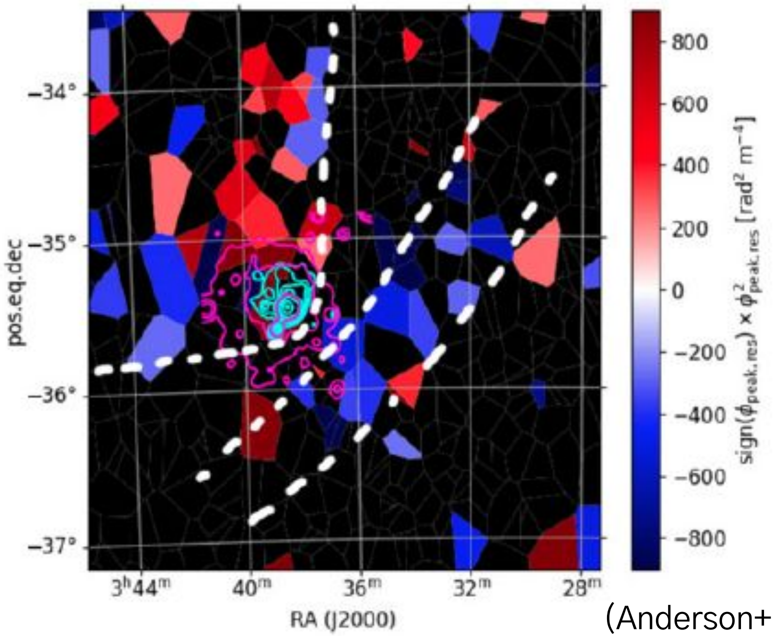
Contours: X-rays
e-ROSITA (0.2 – 2.3 keV)
extended radio sources included

Colours: RMs

New



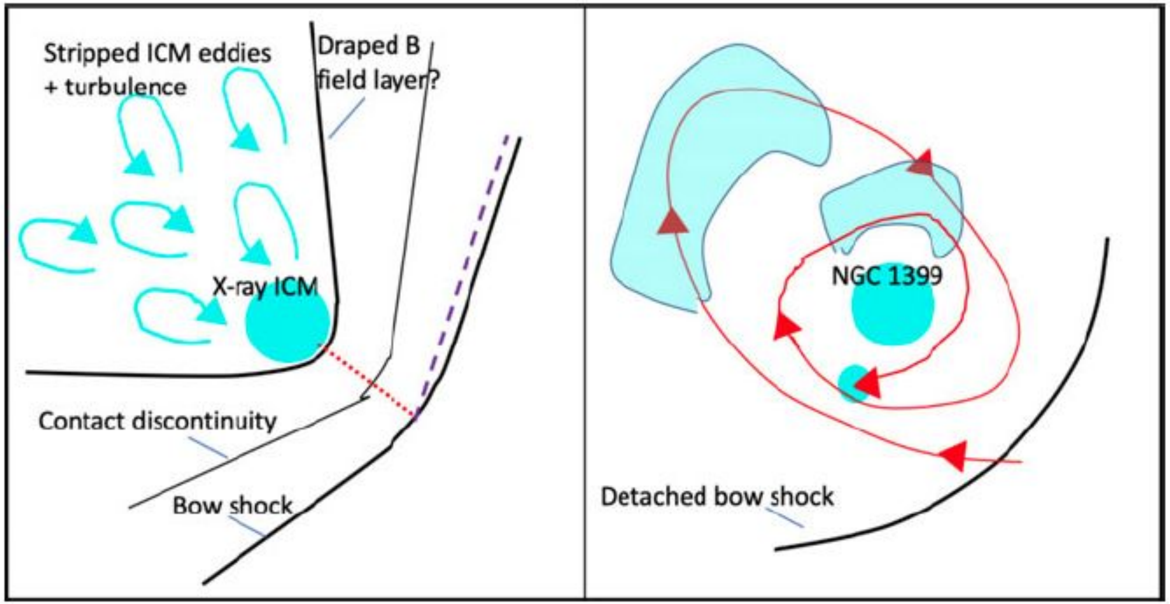
(Loi+ 2025)



(Anderson+ 2021)

Possible scenarios for Mpc–scale depolarisation

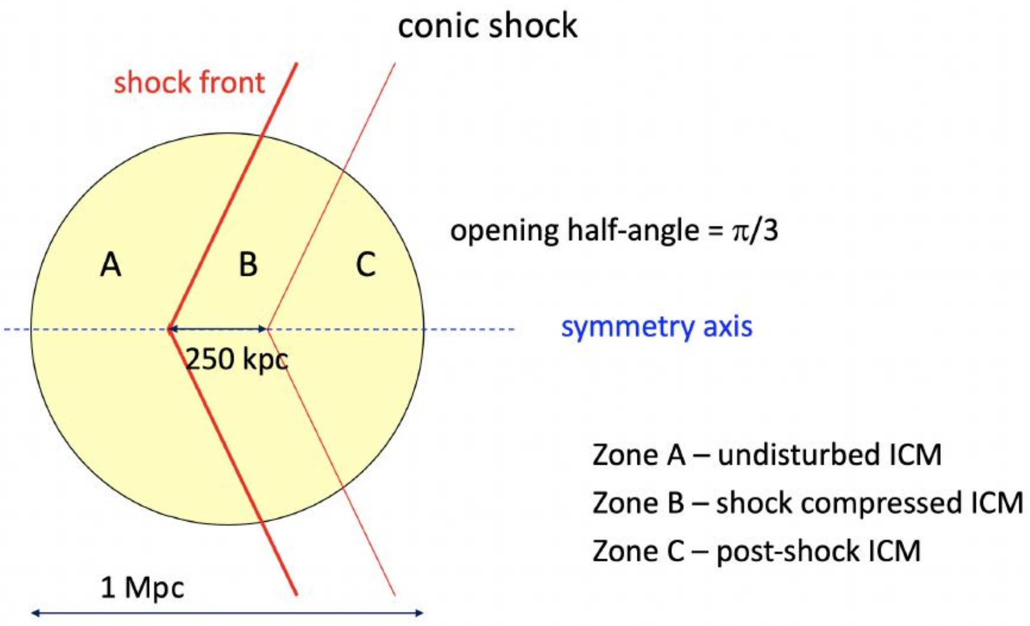
shock passage | sloshing motion



(Anderson+ 2021)

Building a conic shock model

The large–scale shock compresses the gas and amplifies the B–field.



thermal electron number density follows a beta model

B–field strength in B is twice of A

A and C have the same number of thermal electrons

C has twice the number of non–thermal electrons than A

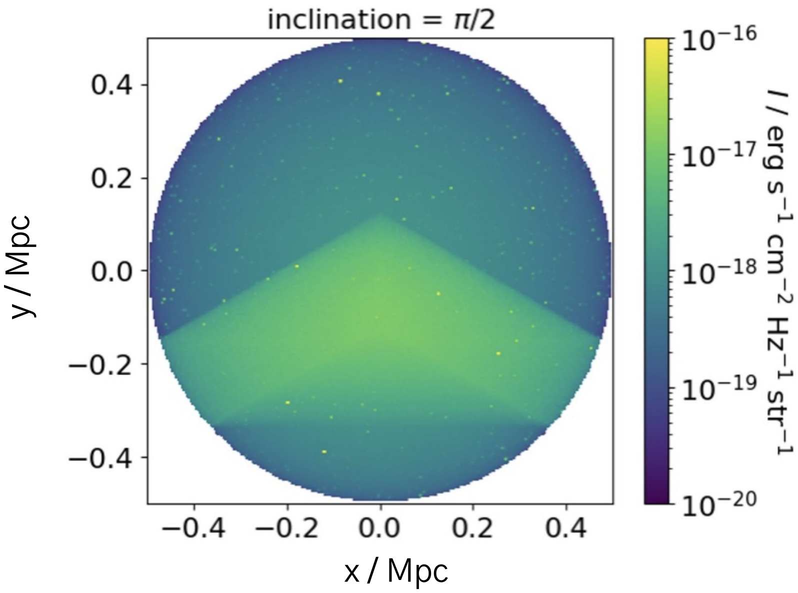
cluster temperature 10^7 K

(**On,** Chan, Lai and Wu, under review)

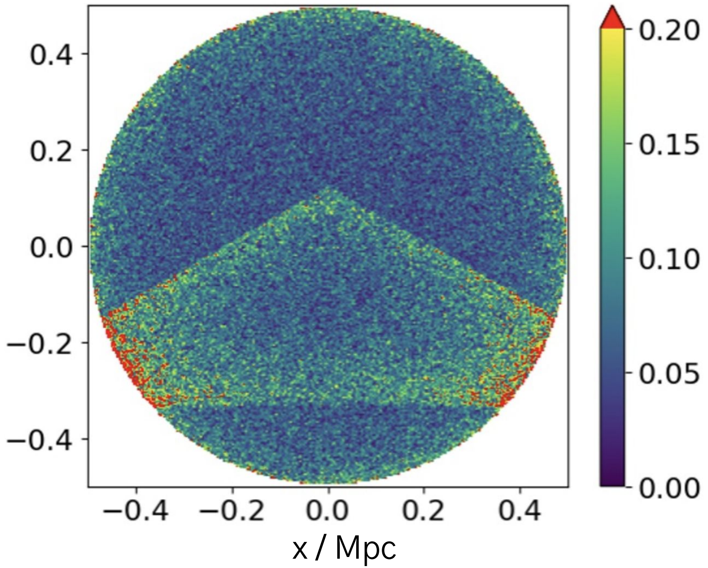
Synthetic radio maps of our shock model

Full polarised radiative transfer calculations; 1024 background point sources

total intensity



fractional linear polarisation



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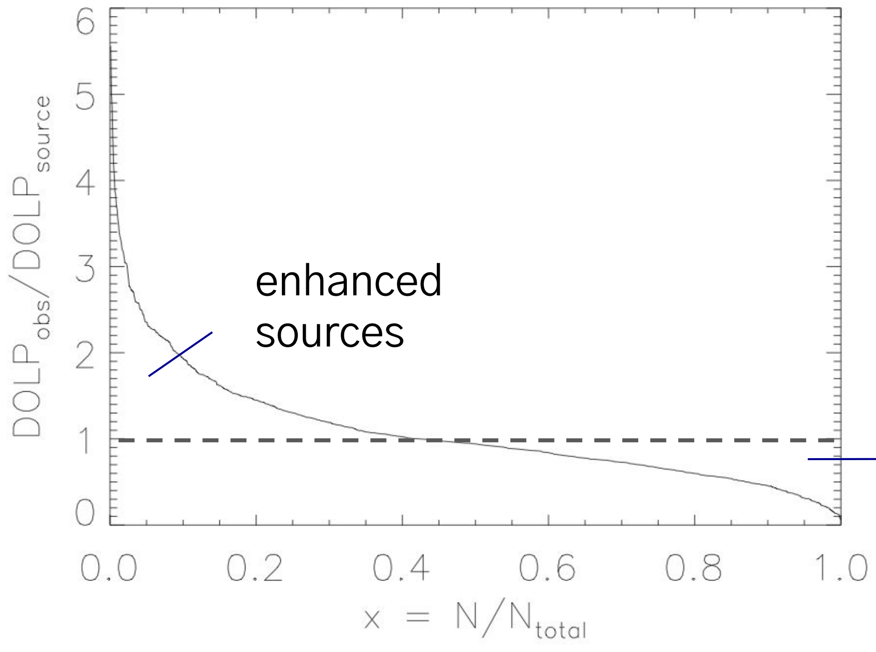
Not all point sources are created equal

Bright sources barely experience any significant changes in linear polarisation
Dim sources either get severely depolarised or enhanced



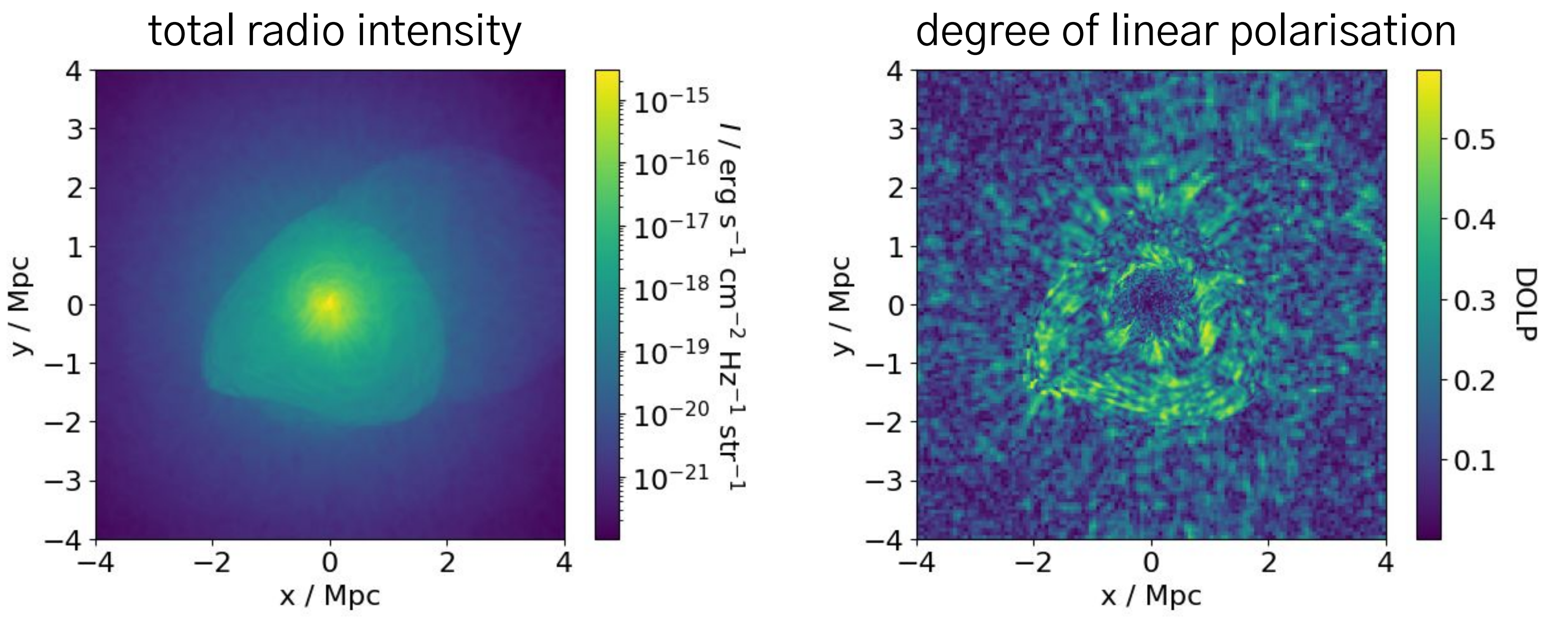
a larger number of point sources have their polarisation enhanced behind the shock than its outskirts

reason: shock has a larger degree of linear polarisation

(**On,** Chan, Lai and Wu, under review)

Changes in polarisation after shock and slosh

FLASH MHD simulations of a cluster merger scenario



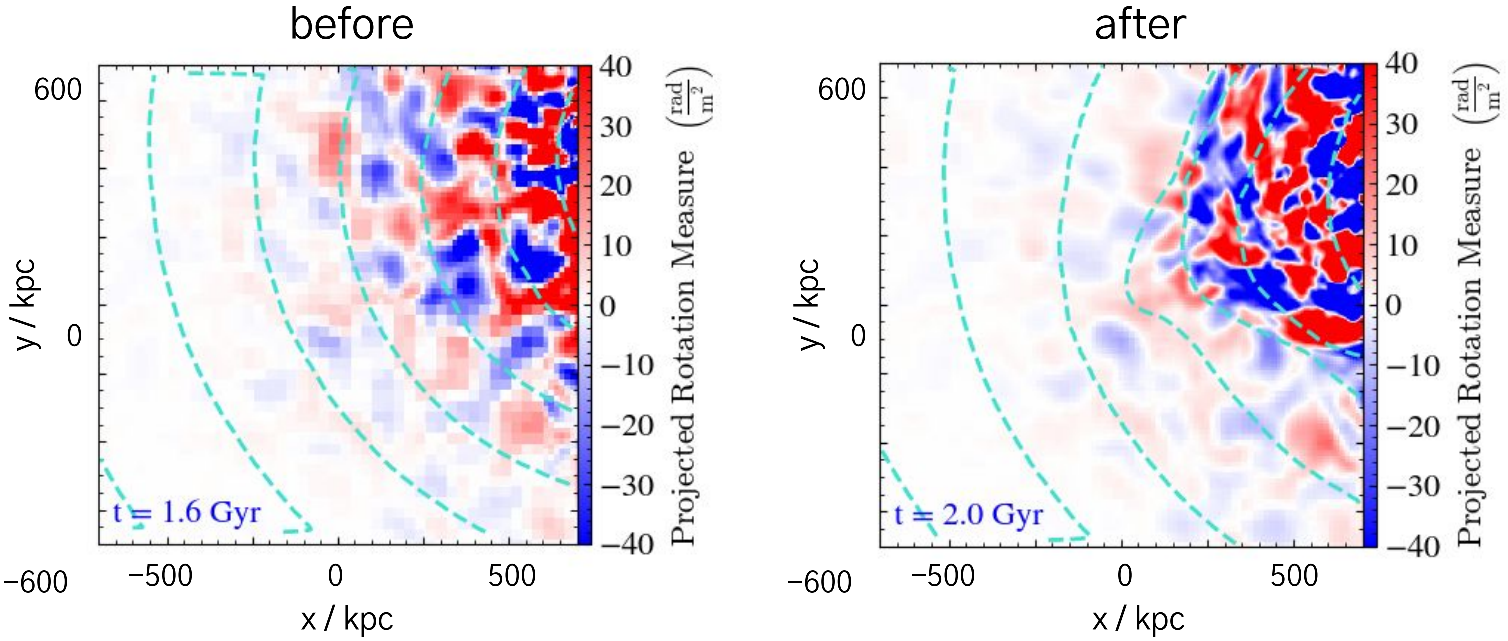
(Liou, **On** and Yang, in prep)

Enhancement in RM after a shock passes by

FLASH MHD simulations of a cluster merger scenario

colours: RM

cyan contours: projected X-ray emission



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Summary

- The polarisation of extragalactic radio sources can be used to constrain the properties of the intracluster medium.
- Intrinsically polarised point sources can appear to be unpolarised in an observation.
- The observed degree of linear polarization of radio point sources in the field of a galaxy cluster does not always truly indicate the intrinsic degree of linear polarization.

Wishlist:

Keep the (full) Stokes polarisations

Search for any radio halo/relic in the Fornax cluster