Giant probes of large-scale structure

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The many facets of extragalactic radio surveys
Bologna, October 2015

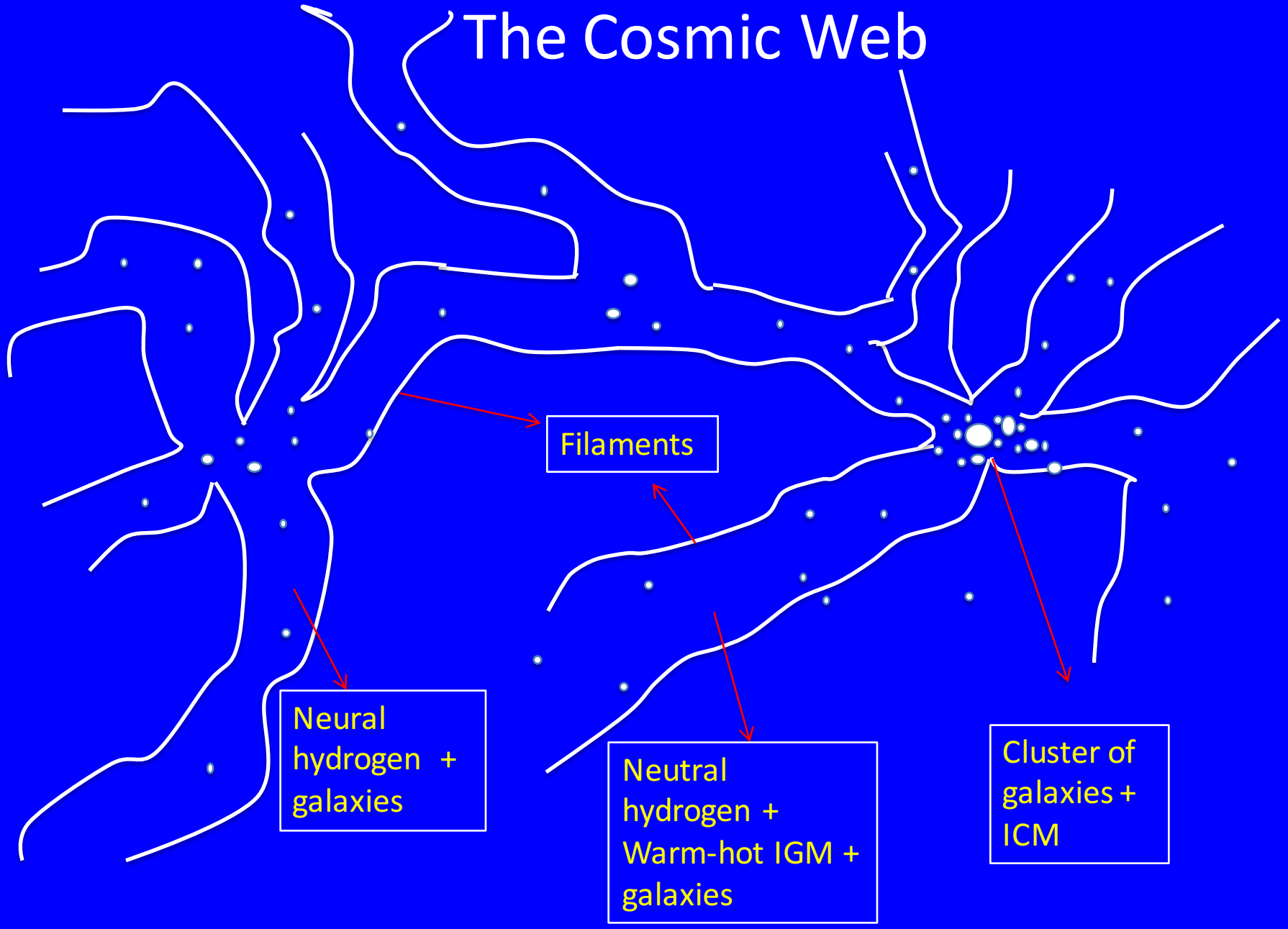
- Jurek Malarecki (UWA)

- Lister Staveley-Smith (UWA)
- Heath Jones (Macquarie/Monash University)
- Ravi Subrahmanyan (RRI)
- Lakshmi Saripalli (RRI)

Talk outline

- Motivation and approach
- Sample used
- Results, implications

The Cosmic Web



Local Cosmic Web

- Galaxies, cool diffuse IGM (mostly neutral hydrogen), warm-hot IGM (WHIM; ionized gas)

- Local diffuse IGM mostly detected as Ly-α forest; in HI emission with great effort (Braun and Thilker, 2004; Popping and Braun, 2011)

- WHIM – difficult to detect

The elusive WHIM

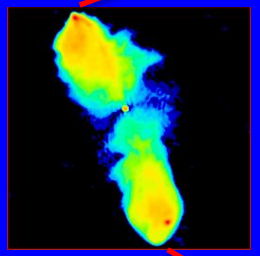
- Traditional tools such as neutral hydrogen absorption, Ly-α absorption features – *not* available

- Difficult to detect in X-ray *emission* – tentative (stacking) detection reported (Fraser-Mckelvie et al, 2011)

- Available tools: sparse metal ions; discrete LoS

An ongoing project using Giant Radio Galaxies to study WHIM and large-scale galaxy distribution

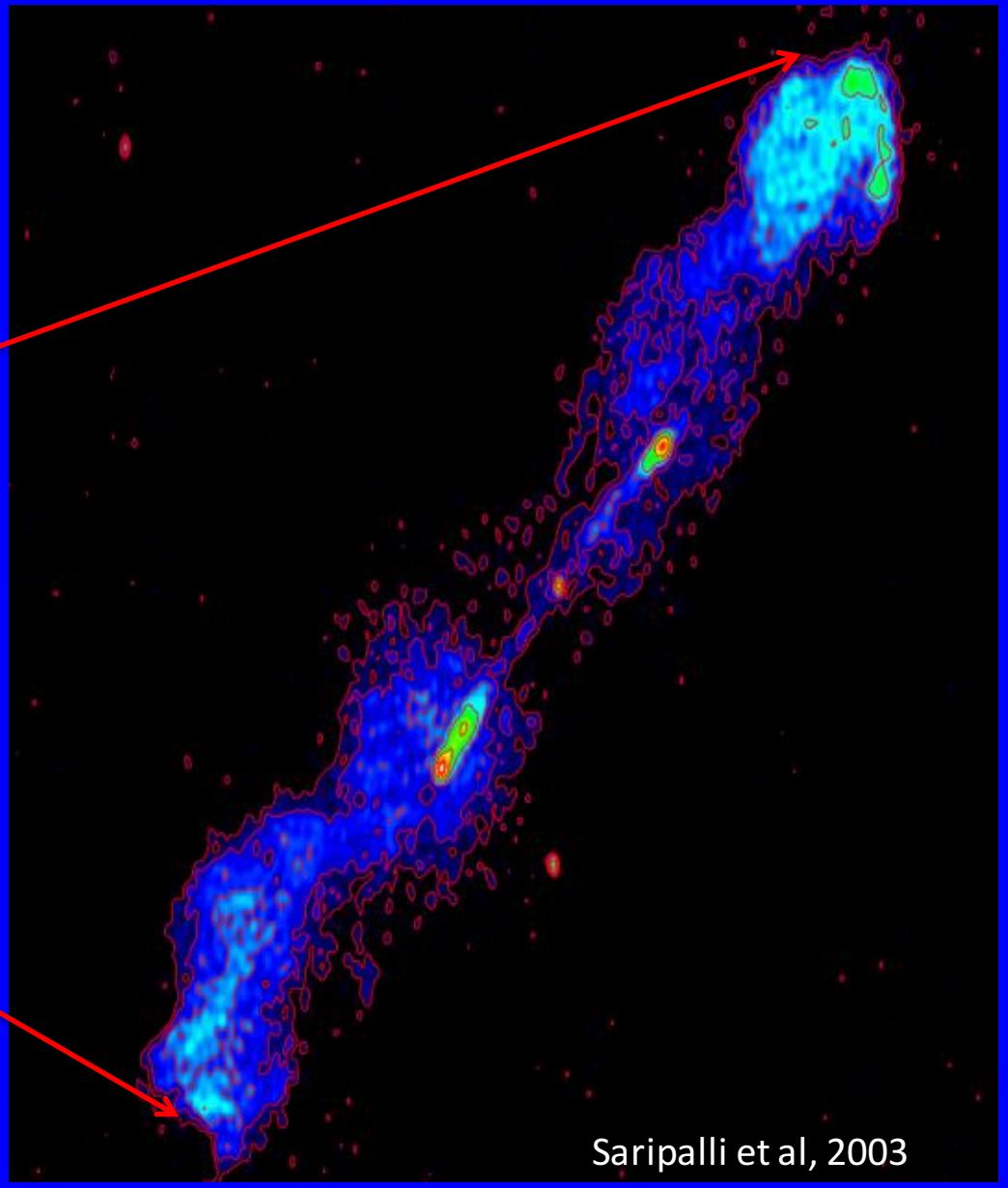
Median sizes of radio galaxies ~ 200 Kpc (Singal, 1993…corrected for H_o)



3C 98 Size= 193 kpc

3CRR Atlas

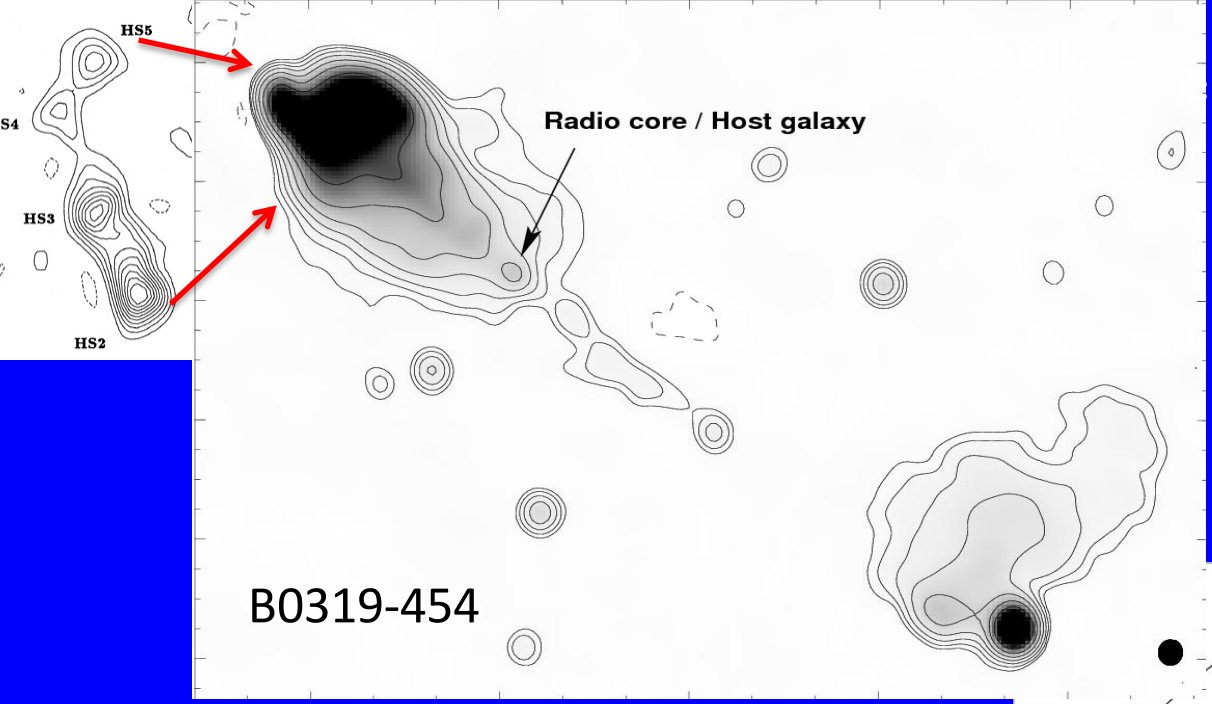
B1545-321 Giant Radio Galaxy Size ~1000 kpc



Saripalli et al, 2003

Using GRGs to probe large-scale environments

- Can we explore potential of GRGs to constrain parameters of WHIM ambient environments?
- A much traversed path but today sophisticated simulations available with which to compare
- A ring-side view of IGM and large-scale galaxy distribution



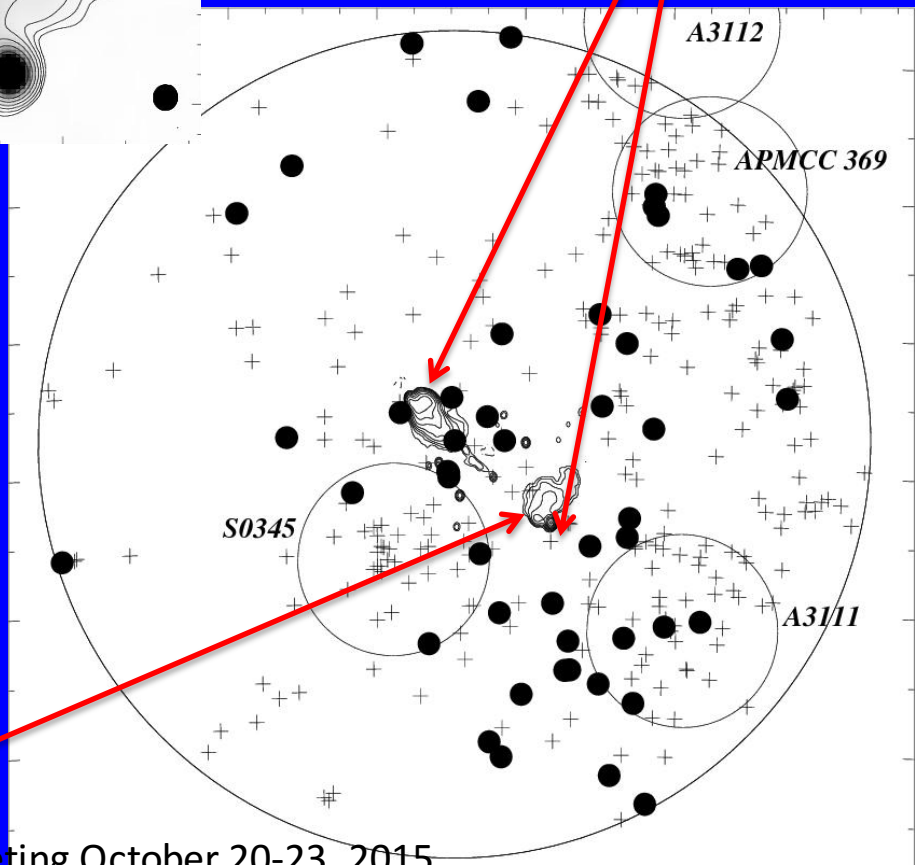
26’ D= 1.9 Mpc, z = 0.0622

Smoothed to 1.25 Mpc galaxy density ratio=3.3:0.9

Safouris et al, 2009

Highly asymmetric source

--Different lobe extents
--Different lobe surface brightnesses
--Different lobe structures
--Emission gaps



Factor 2 difference in galaxy density on the two sides

Subrahmanyan et al, 2008

MSH J0505-2835

LAS=40', D=1.8 Mpc, z=0.038

Source at centre in all panels

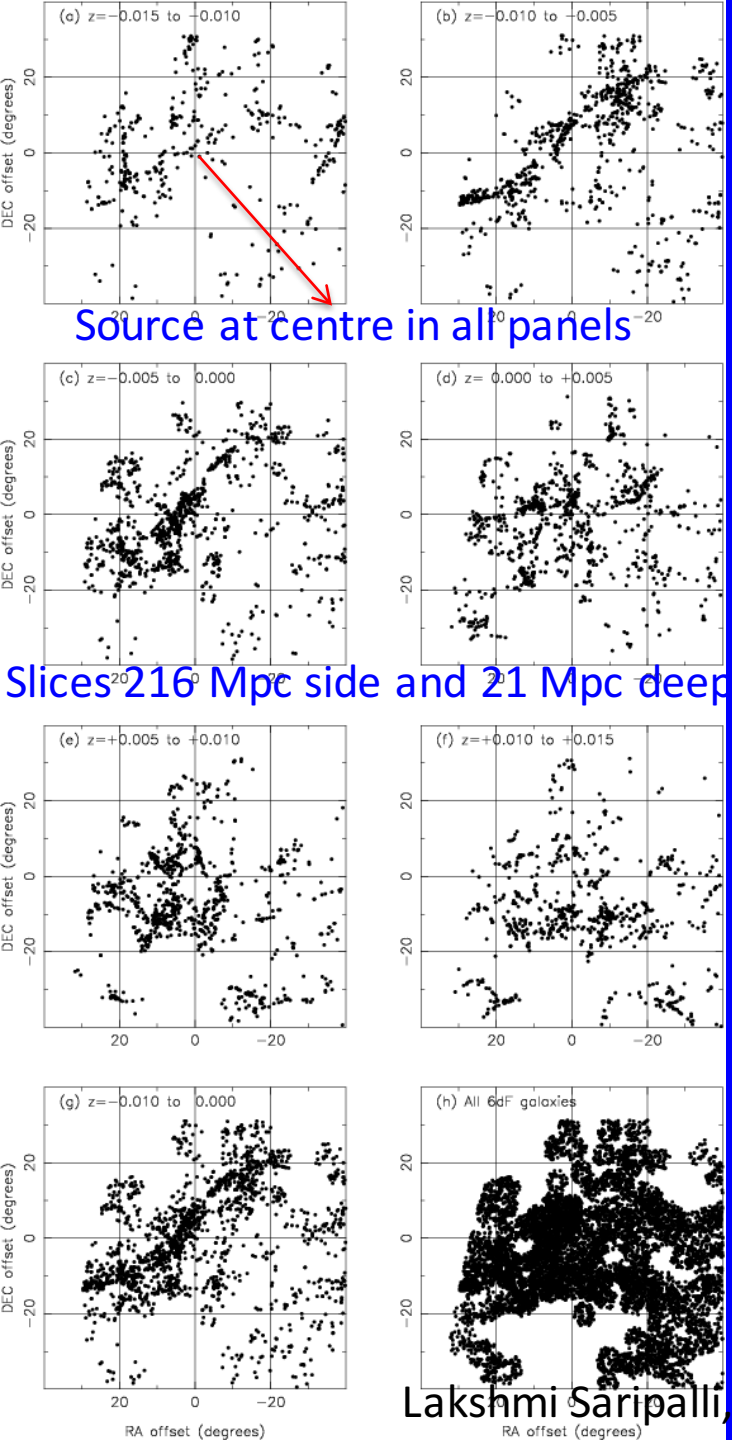
Slices 216 Mpc side and 21 Mpc deep

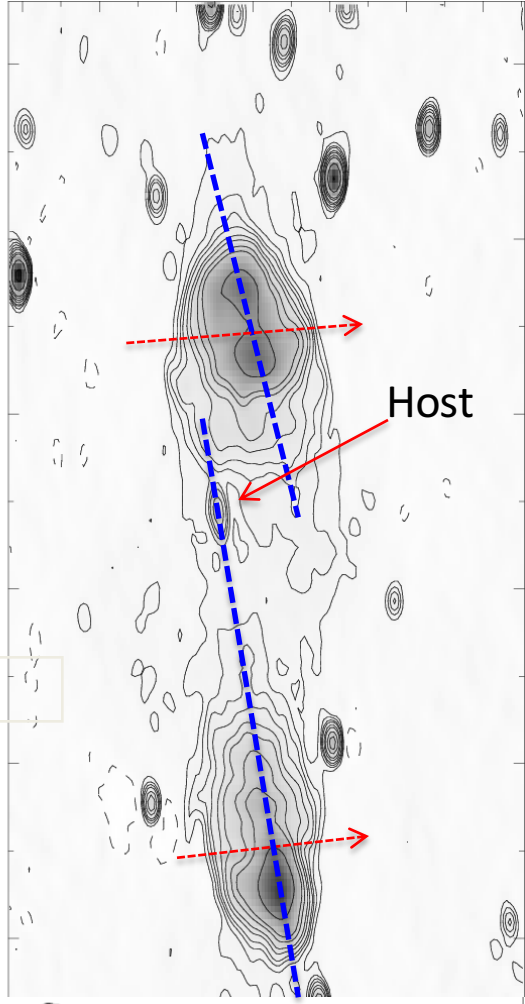
Source is asymmetric

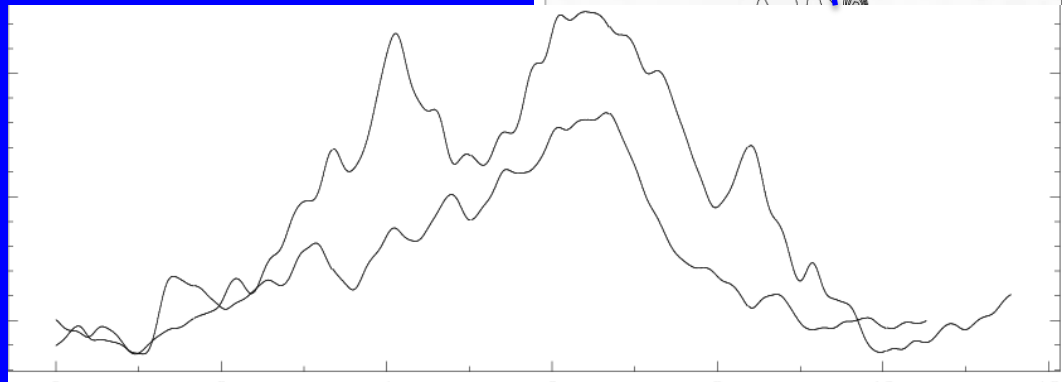
--1:1.6 lobe length ratio
--N lobe is off axis to W

No Hotspots

Radio lobes not sharply bounded

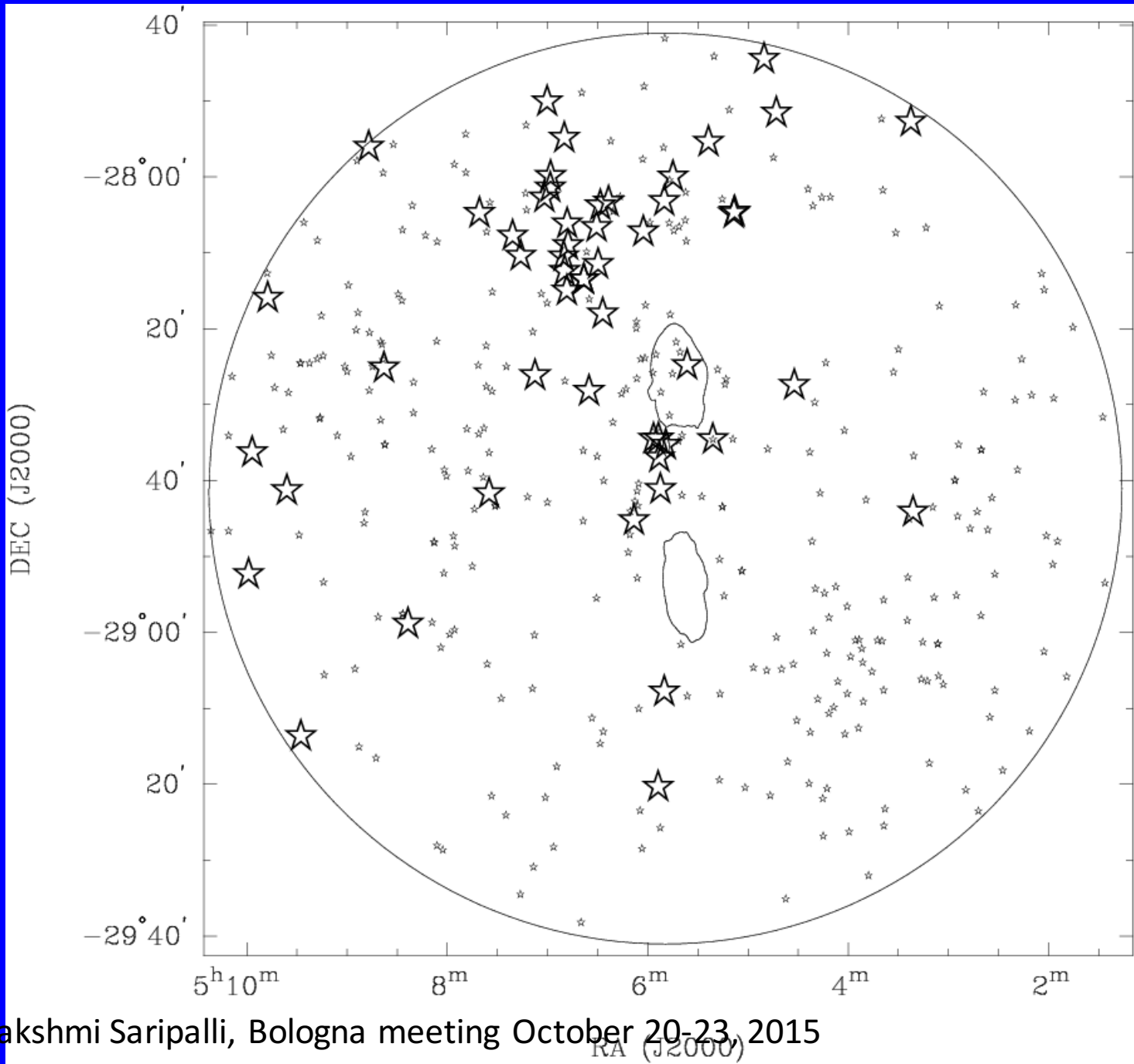






Galaxies within
$z = 0.03 - 0.05$

Large stars
Δz = +/- 0.003

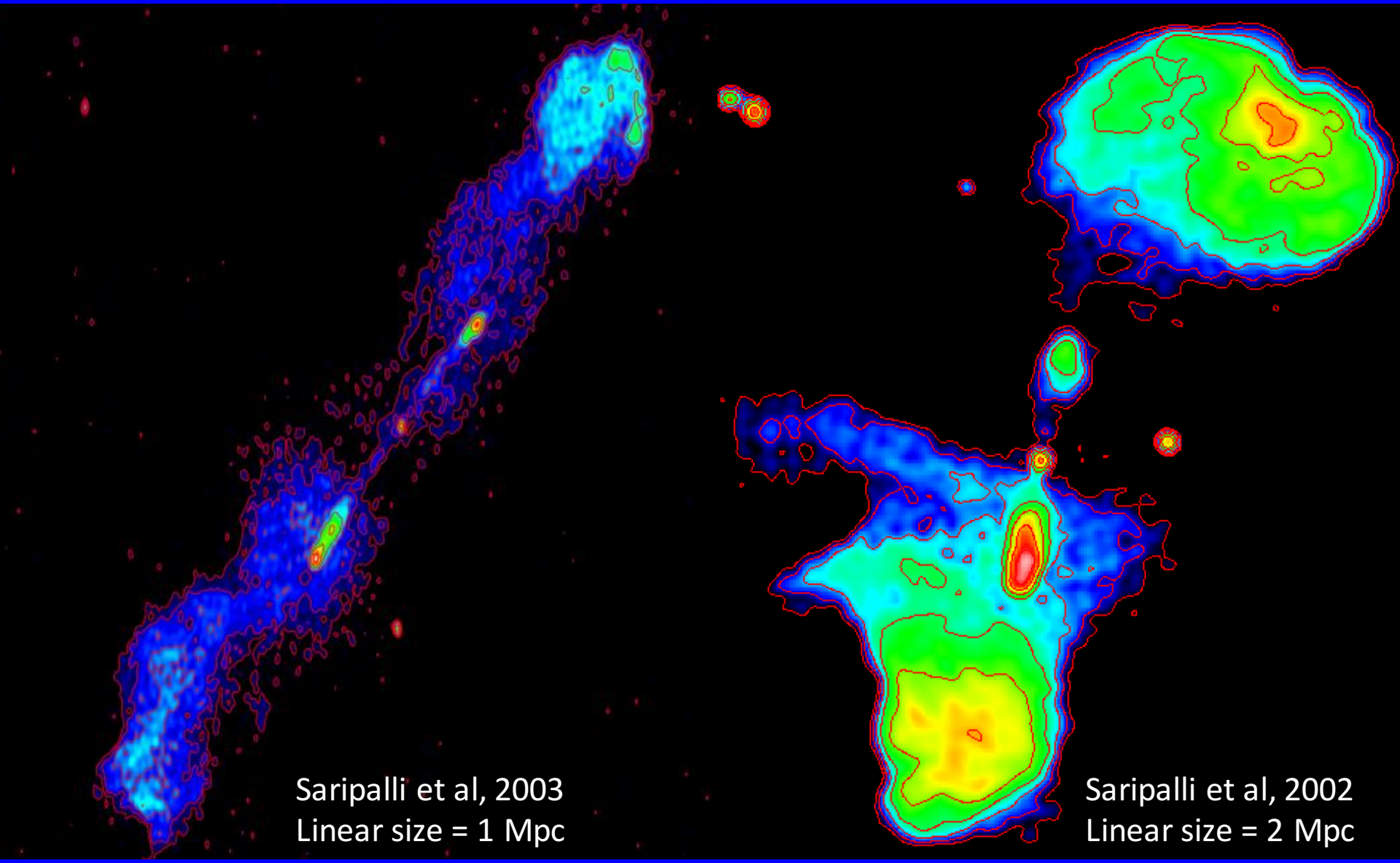


GRGs and large-scale environments-I

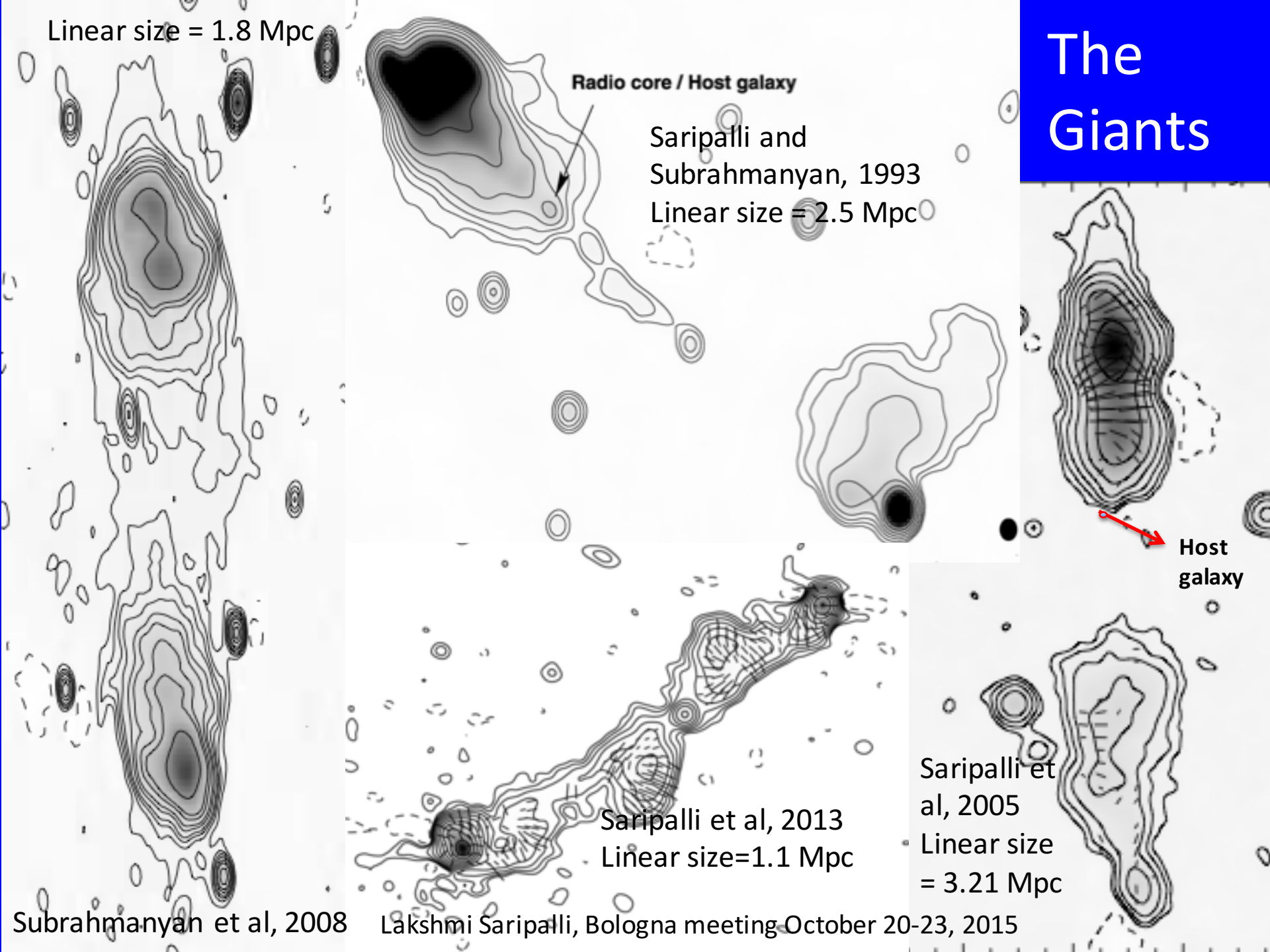
- Large sample of 19 southern GRGs
- Linear sizes 0.8 – 3.2 Mpc
- Radio continuum imaging at L/S-2-GHz wide band
- Compared lobe component pressures with models for WHIM components from simulation studies

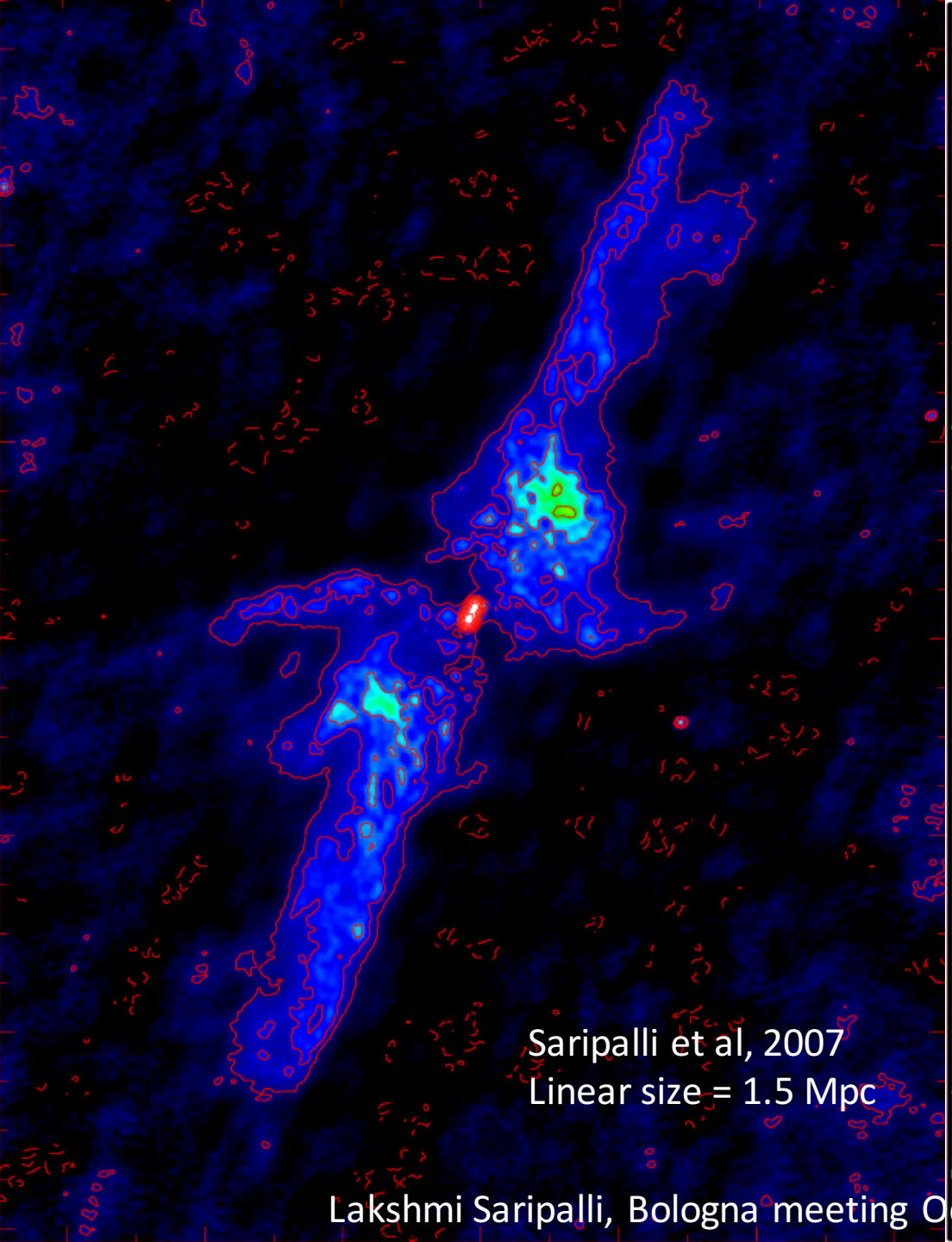
Malarecki, Staveley-Smith, Saripalli, Subrahmanyan, Jones 2013

The Giants


Saripalli et al, 2003
Linear size = 1 Mpc
Saripalli et al, 2002
Linear size = 2 Mpc

The Giants


Linear size = 1.8 Mpc
Radio core / Host galaxy
Saripalli and
Subrahmanyan, 1993
Linear size = 2.5 Mpc
Host
galaxy
Saripalli et al, 2013
Linear size=1.1 Mpc
Saripalli et
al, 2005
Linear size
= 3.21 Mpc
Subrahmanyan et al, 2008


Saripalli et al, 2007
Linear size = 1.5 Mpc


Saripalli et al, 2013
Linear size = 2 Mpc

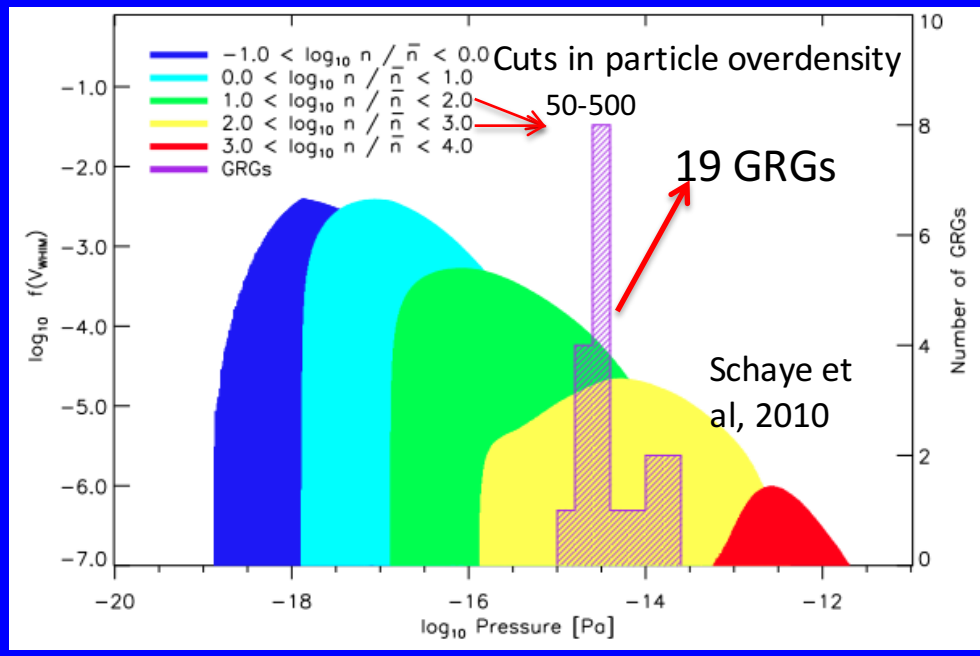
Using GRG sample to probe WHIM

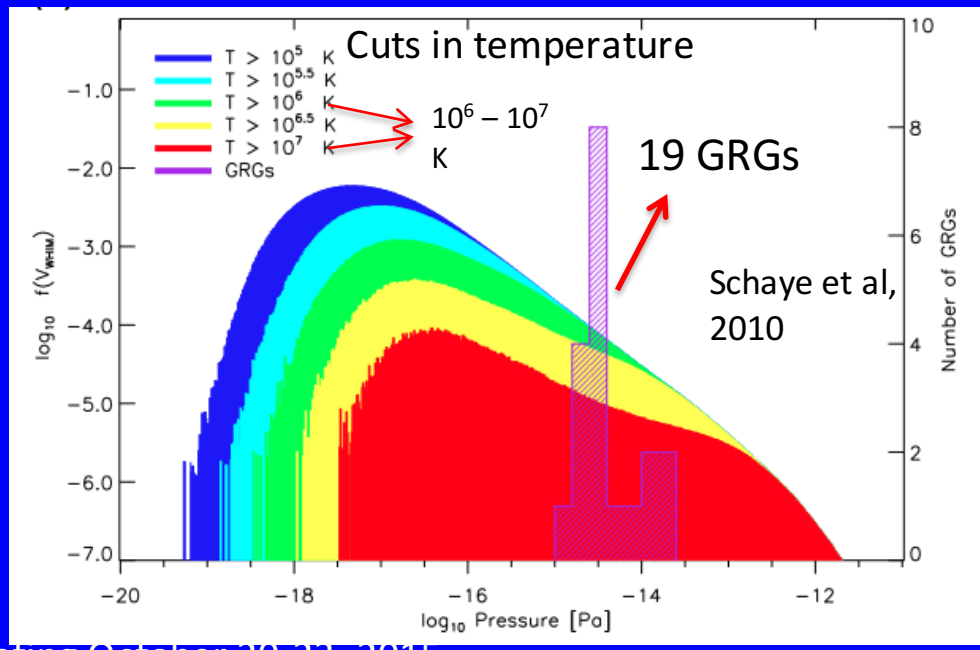
WHIM in pressure balance with the radio lobes has

(1) temperature in excess of ~10^6 K or

(1) particle overdensity in the range 50–500

(2) Such temperature (density) regions account for only 6 (1) % of WHIM by volume or 18 (23) % of WHIM by mass





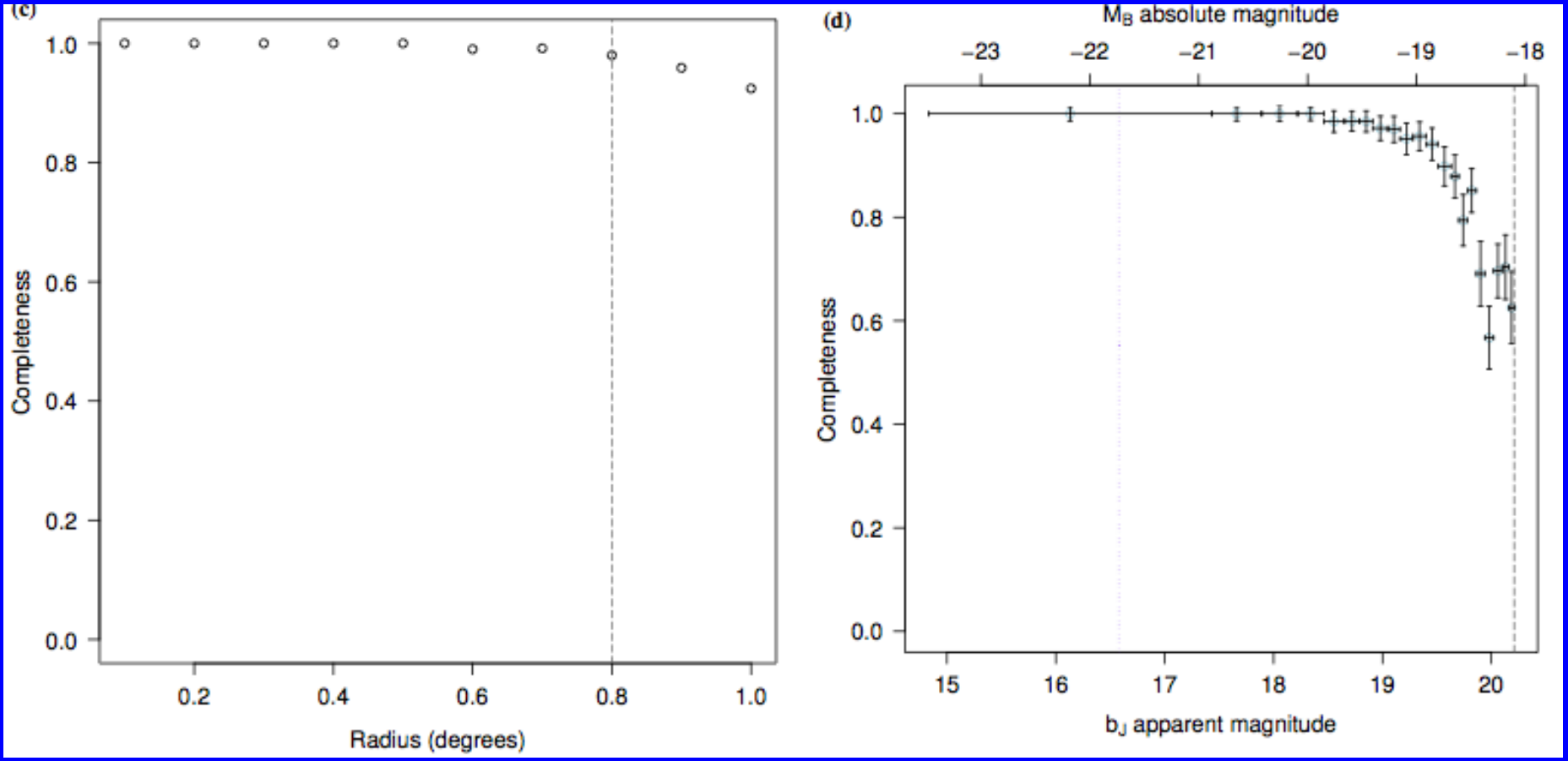
Perfect exercise with LOFAR, MWA etc

- While some GRGs may be in pressure balance others may be over-pressured.
- Hunt for low surface brightness GRGs that are more likely in pressure balance with the WHIM
- Great potential for using GRGs as probes of the WHIM
- Giant Relic radio galaxies

Determining galaxy density fields around GRGs-II

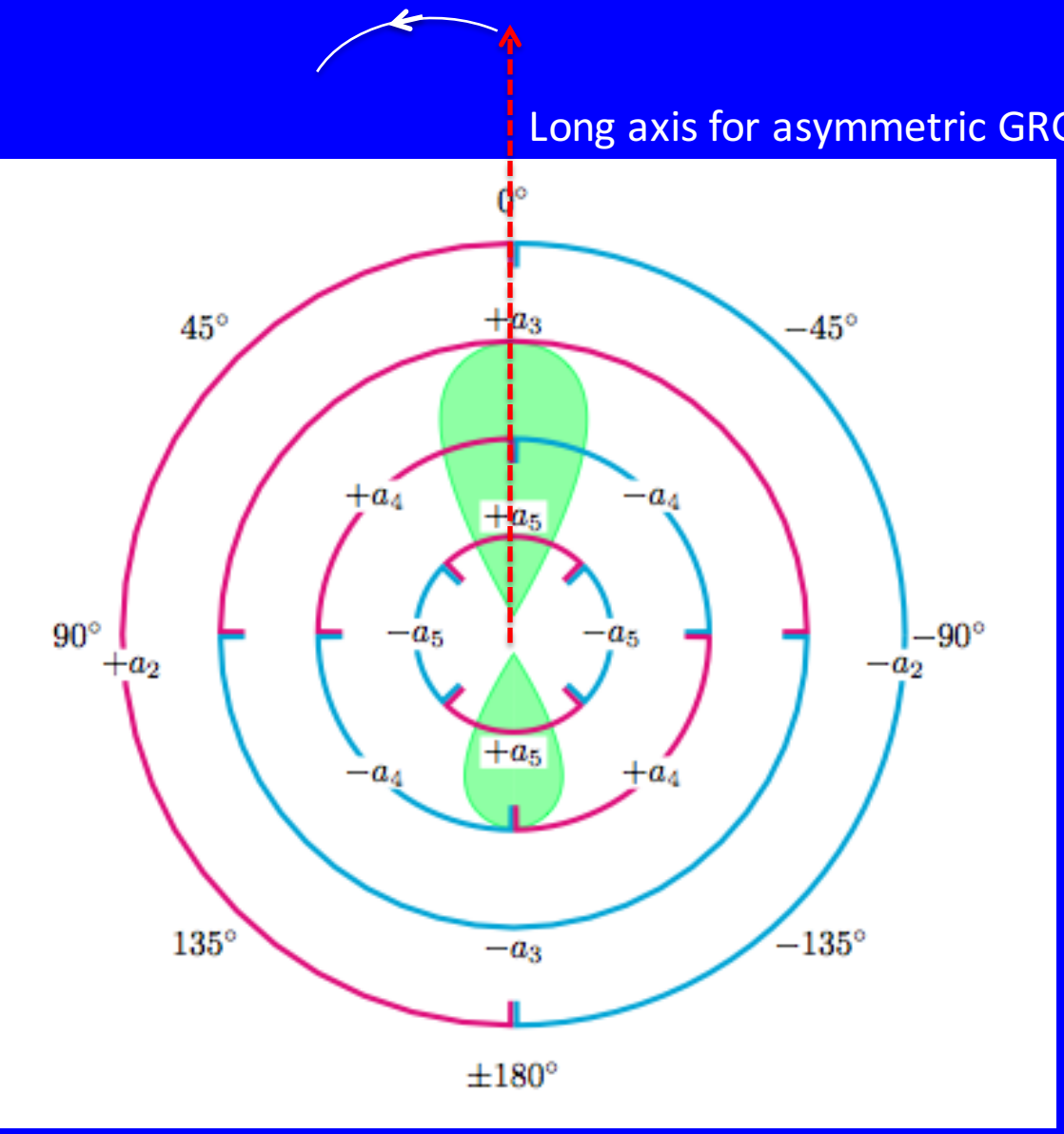
- Obtained optical spectra of 24742 objects in 2-deg fields around 19 GRGs ($0 < z < 0.15$)
- Measured redshifts for 9080 galaxies
- Overlays of radio maps and galaxy distributions
- Fourier component analysis used to quantify the anisotropy in the surrounding galaxy distribution
- Malarecki, Jones, Saripalli, Subrahmanyan, Staveley-Smith, 2015

Completeness



- complete to radius = 0.8 deg
- complete to absolute magnitude = -19 to -20

Relating environment to radio structure



$$a_k = \frac{\sum_{i=1}^{n}(w_i\ f_k(\theta_i))}{\bar{\alpha}_1}$$

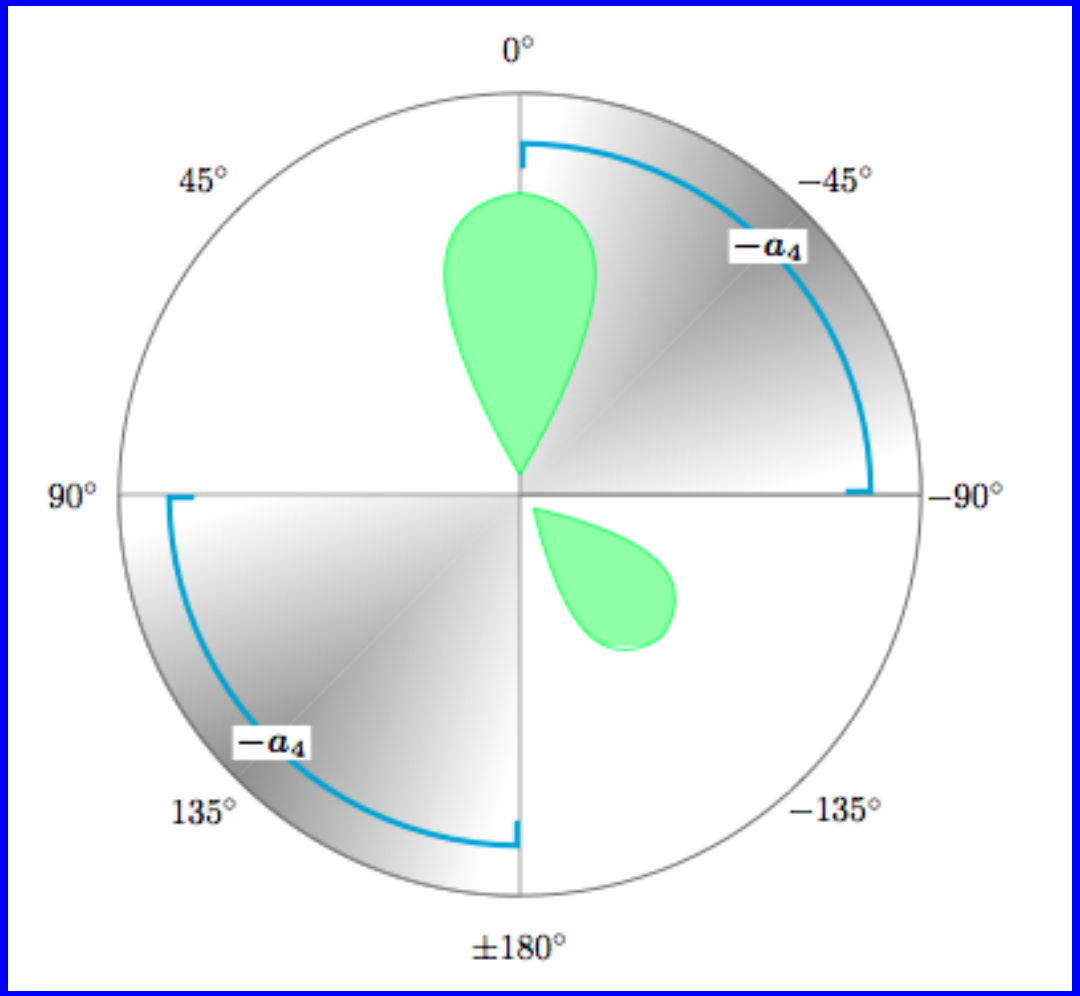
$f_k(\theta_i)$ are terms equal to 1, sin (θ_i), cos (θ_i), sin ($2\theta_i$) and cos ($2\theta_i$) for k = 1, 2, 3, 4 and 5, respectively.

$\bar{\alpha}_1$ is a normalization factor applied to each Fourier component term.

- The mean galaxy number overdensity in volumes of ~700 Mpc^3 near GRG host galaxies is ~70

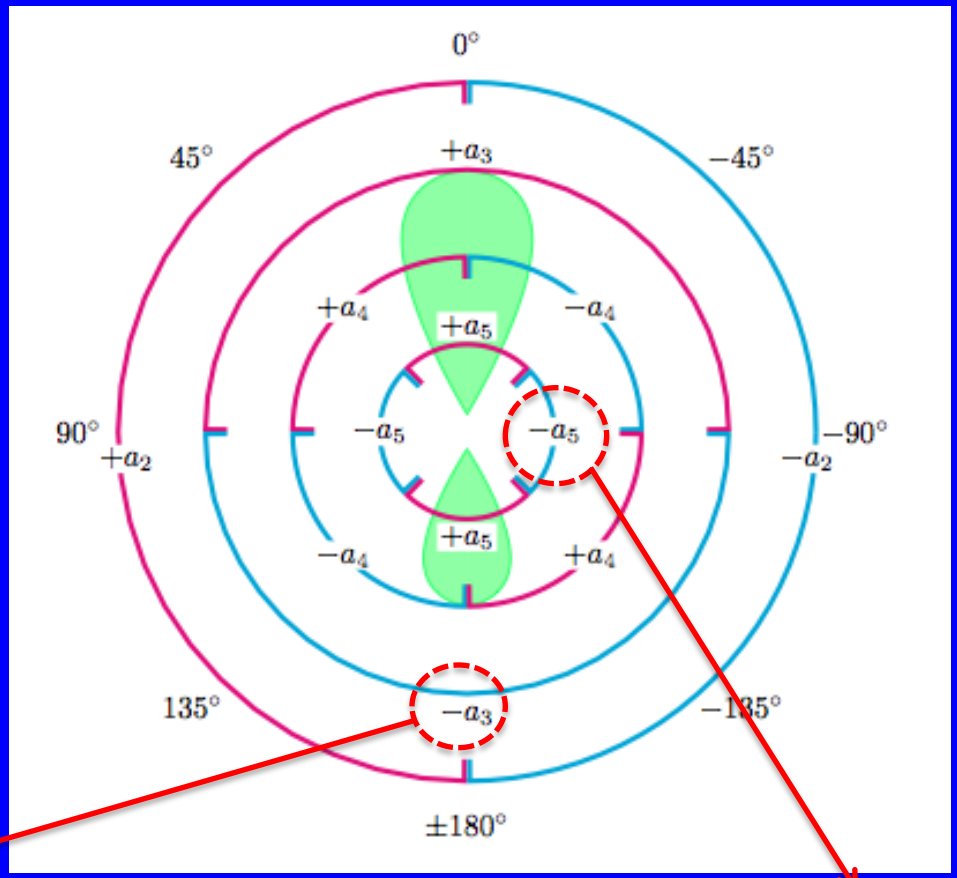
- Indicates overdense but non-virialized environment.

Relating environment to radio structure



Strong influence of environment seen

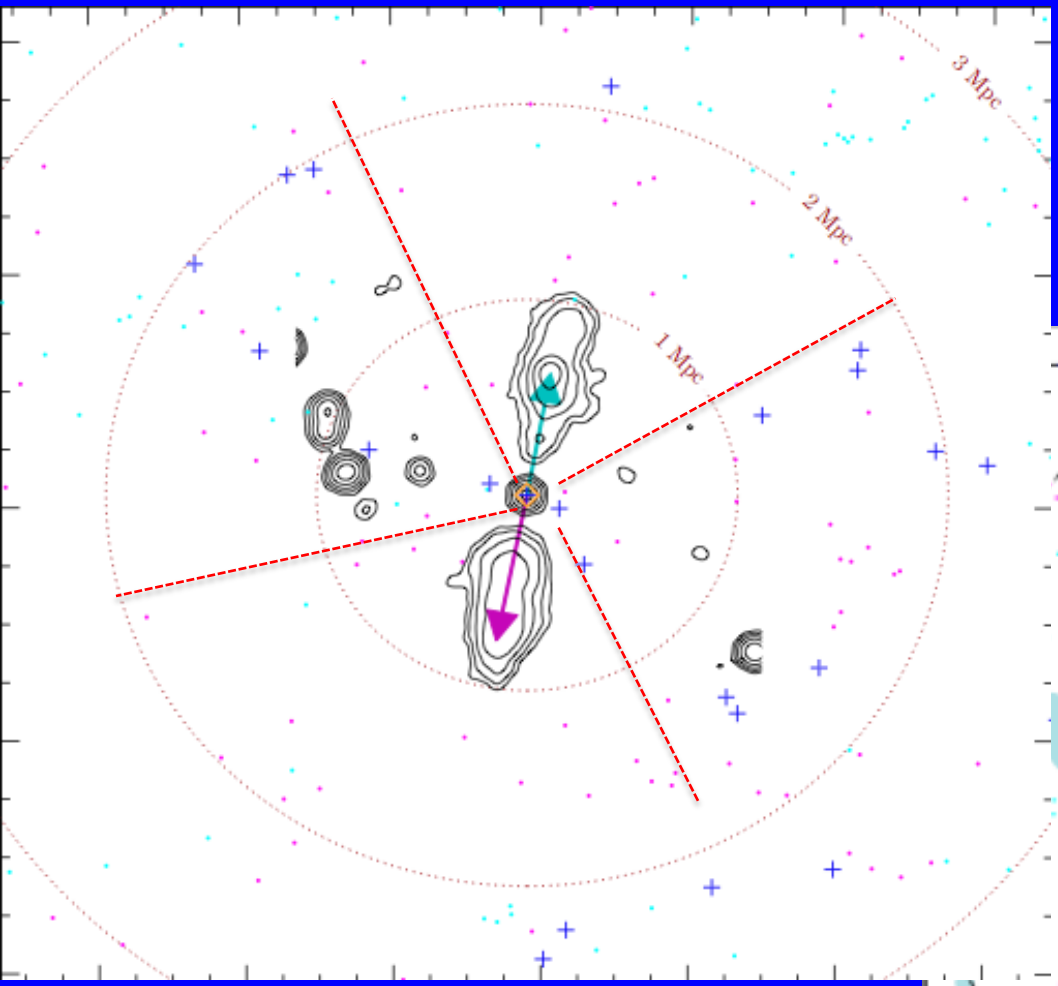
Relating environment to radio structure

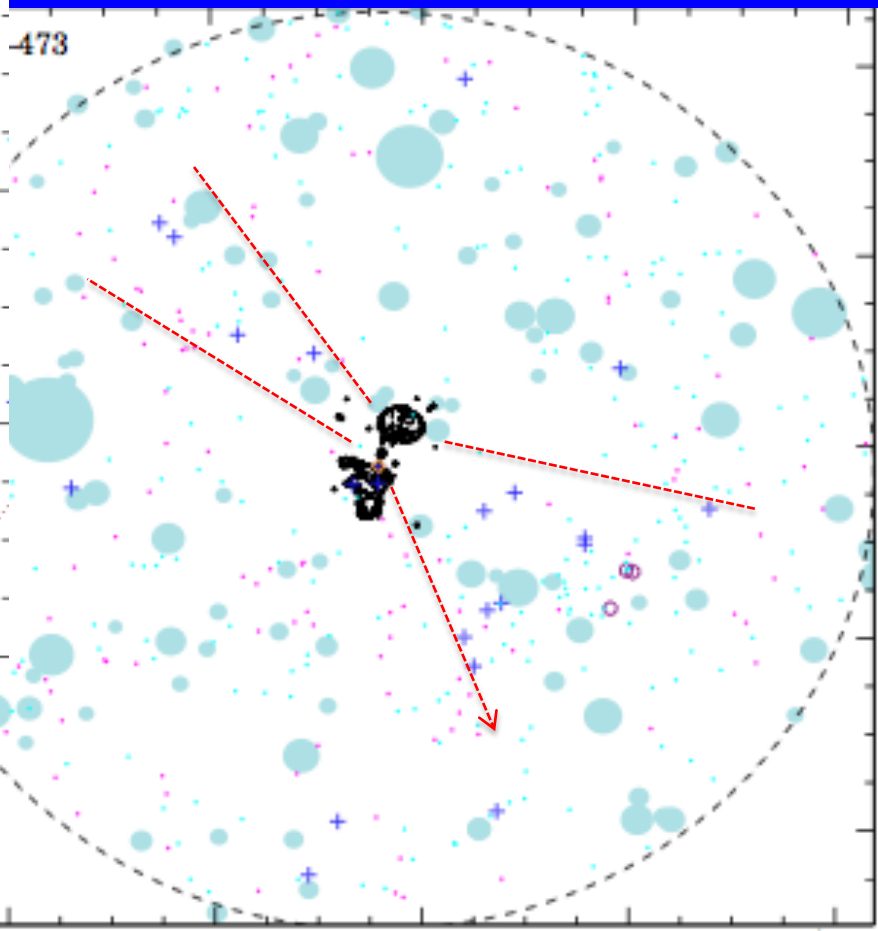


'a_3' negative for asymmetric sources: *higher galaxy over-density on side of shorter lobe*

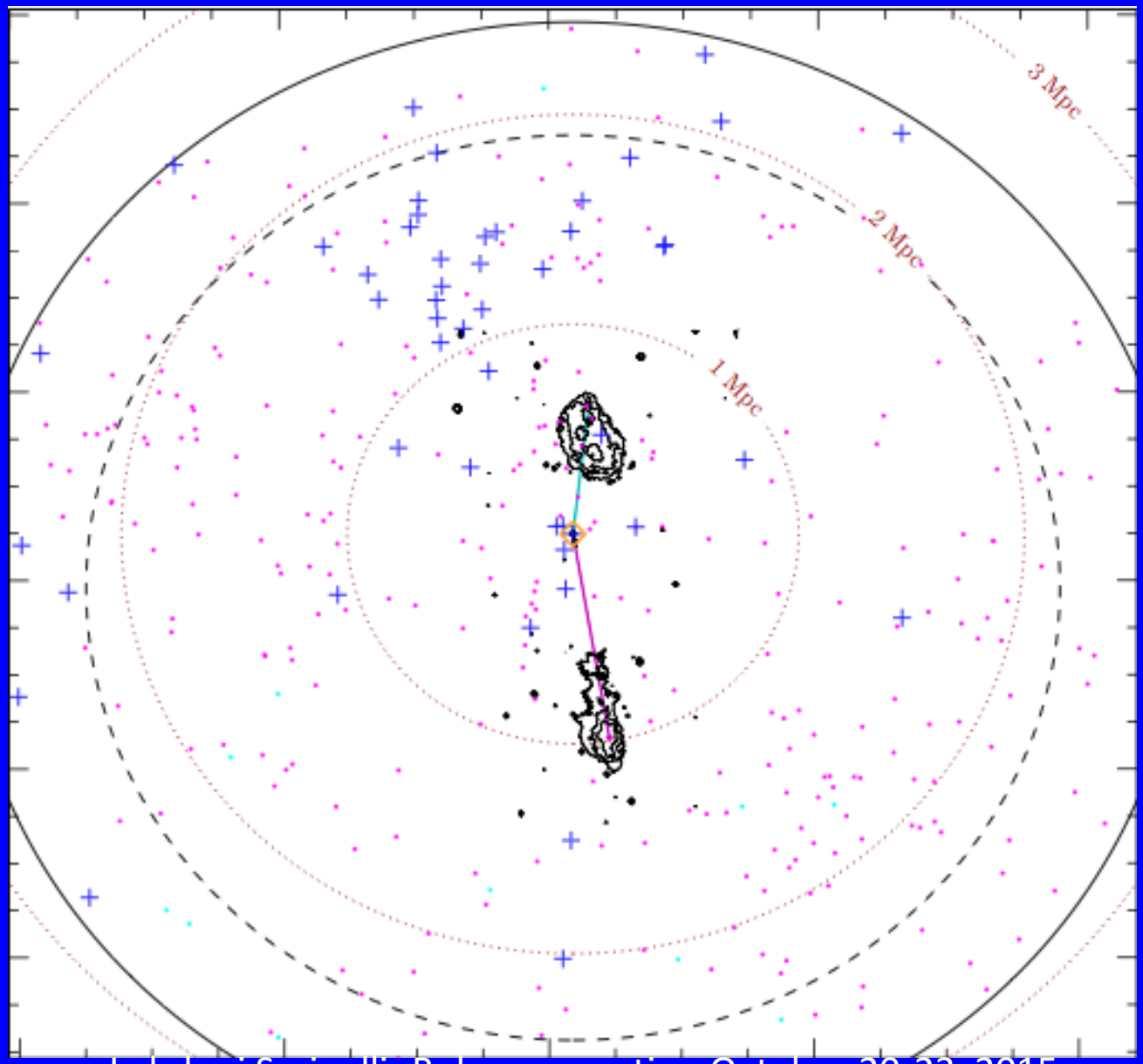
'a_5' negative for several sources: *higher galaxy over-density in direction perpendicular to radio source axis*

GRGs and large-scale galaxy distribution

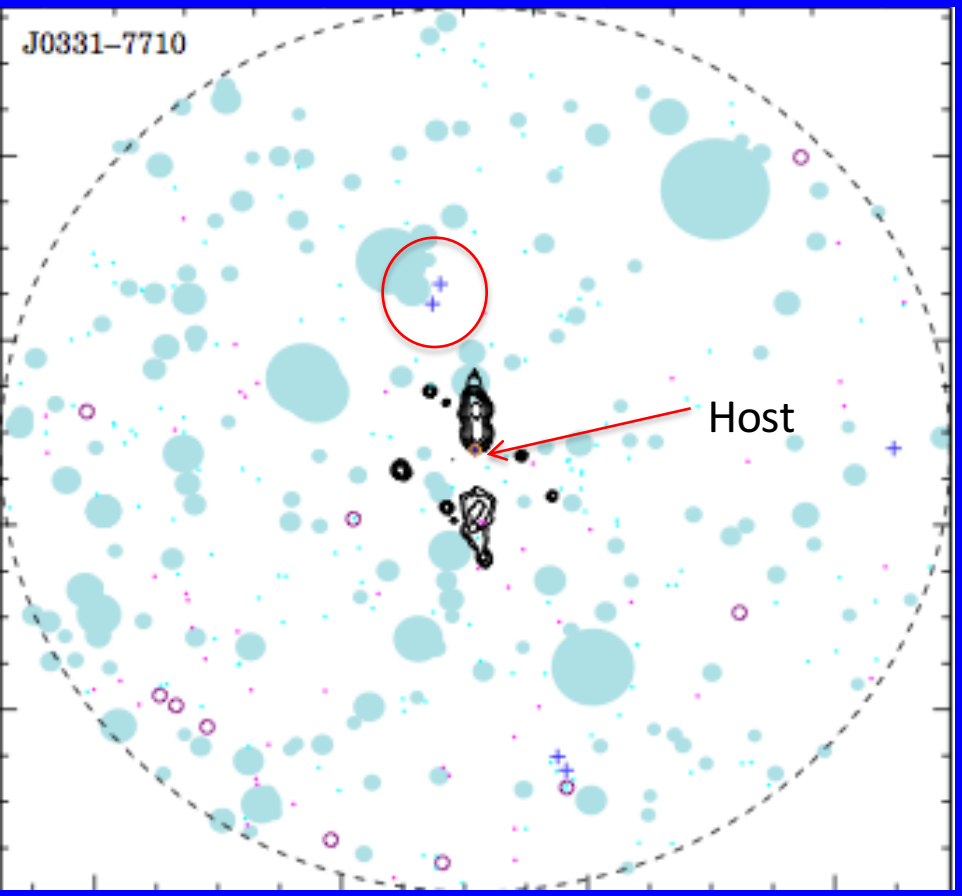


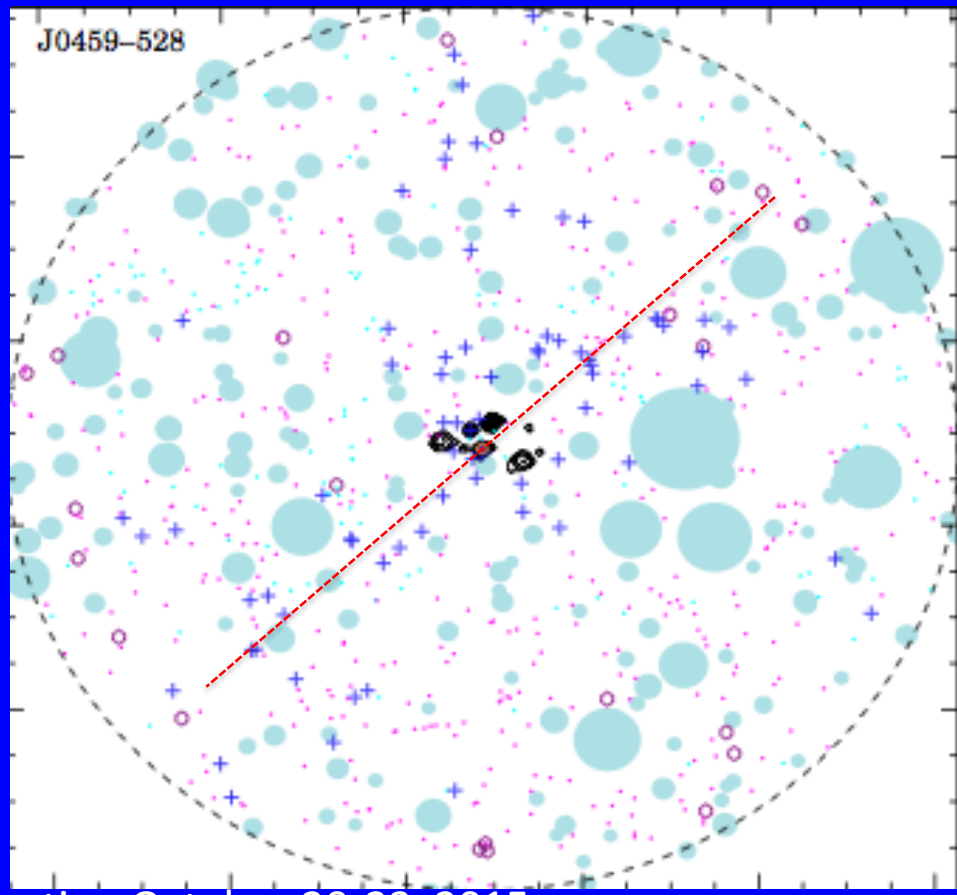


GRGs and large-scale galaxy distribution

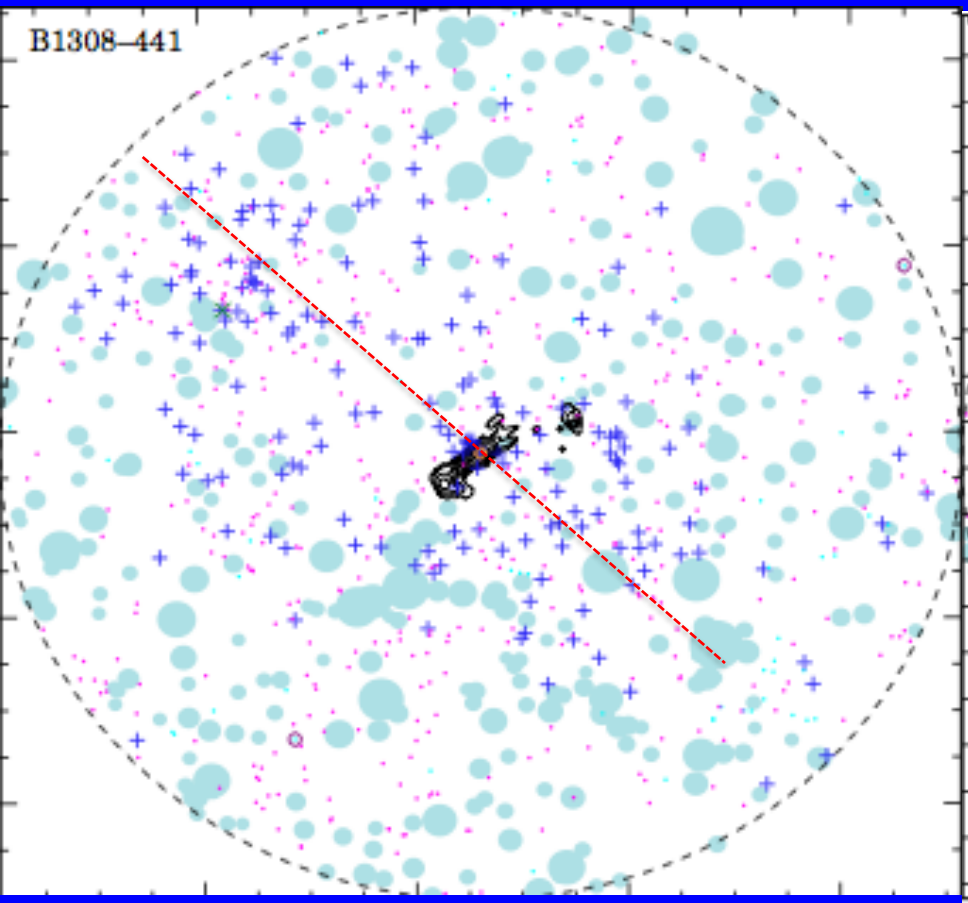


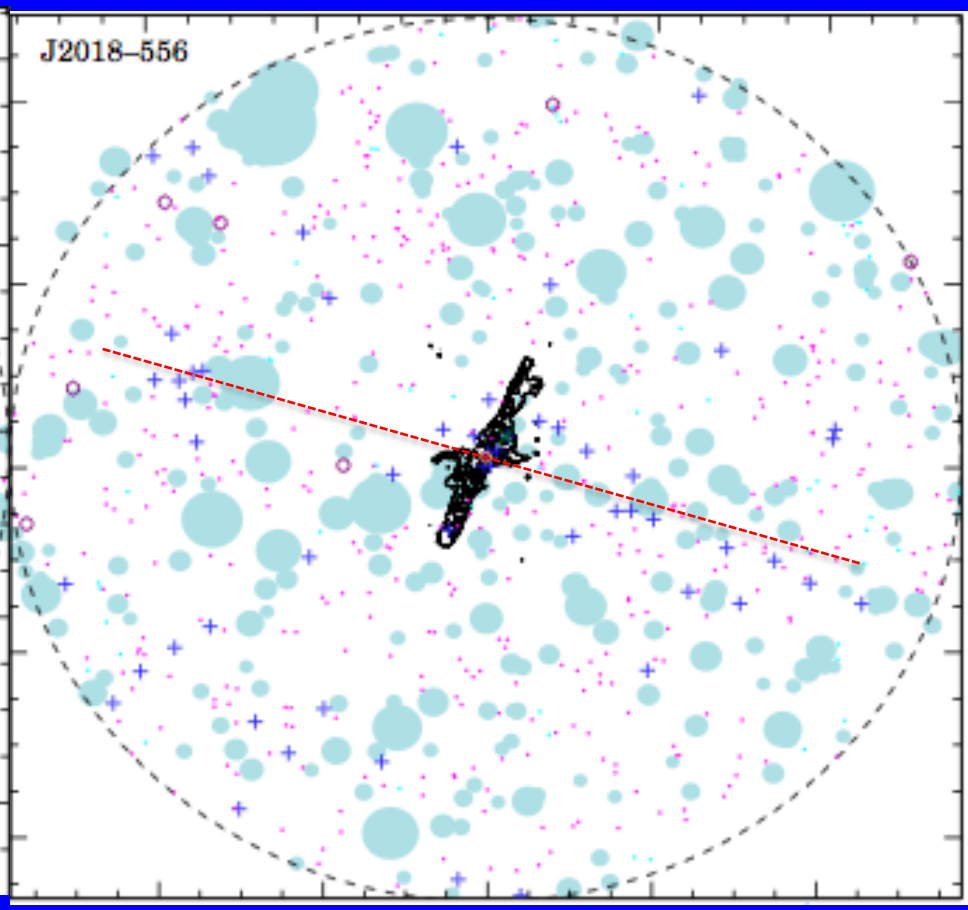
GRGs and large-scale galaxy distribution



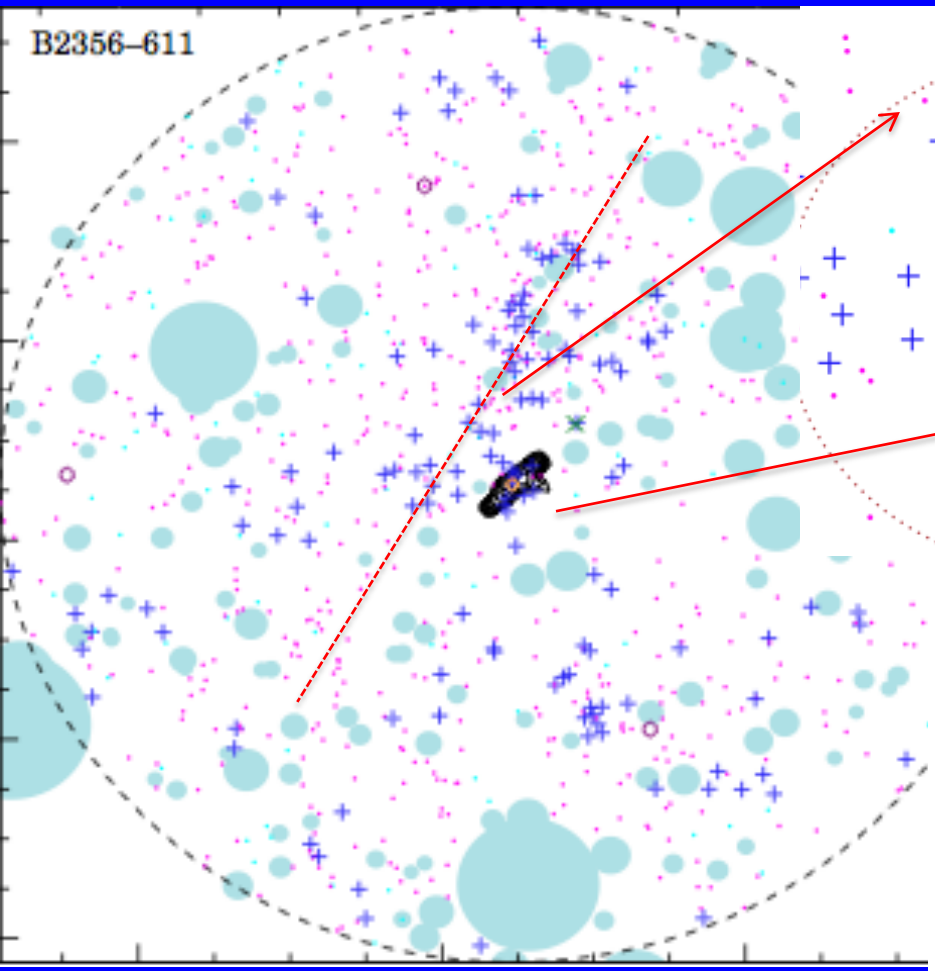


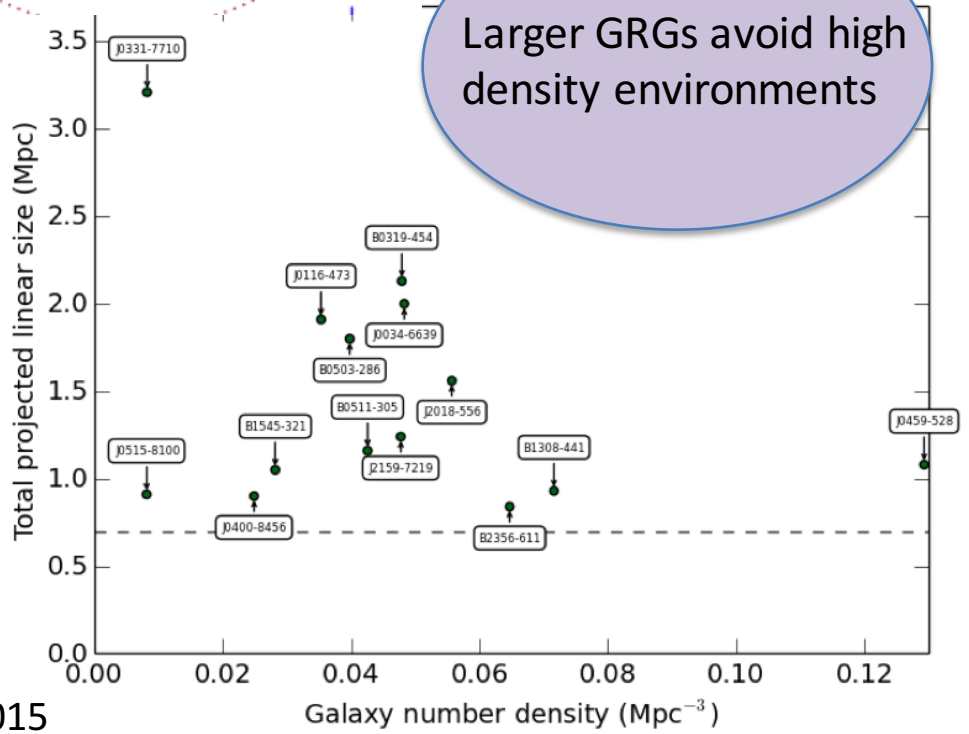
GRGs and large-scale galaxy distribution





GRGs and large-scale galaxy distribution





Larger GRGs avoid high density environments

GRGs and large-scale galaxy distribution

- Clear influence of galaxy environment seen
- GRG lobes are shorter in directions of greater galaxy over-density
- GRG lobes deflected away from greater galaxy over-density
- GRGs grow in sparse environments *or* perpendicular to galaxy chains and filaments
- GRG jets preferentially seek void regions

Work in continuation

- Encouraged by clear signs of interaction between galaxy distributions and GRG jets and lobes

- Currently using large-scale environments around GRGs to model gas environments in GRG vicinities

Thank you