Giant probes of large-scale structure

Lakshmi Saripalli
Raman Research Institute
Bangalore, India

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

Neural hydrogen + galaxies

Filaments

Neutral hydrogen + Warm-hot IGM + galaxies

Cluster of galaxies + ICM

Lakshmi Saripalli, Bologna meeting October 20-23, 2015
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 $H_0$)

B1545-321 Giant Radio Galaxy Size ~1000 kpc

3C 98  Size= 193 kpc

3CRR Atlas

Lakshmi Saripalli, Bologna meeting October 20-23, 2015
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
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

B0319-454

Safouris et al, 2009

26’ D= 1.9 Mpc, z = 0.0622

Smoothed to 1.25 Mpc galaxy density ratio=3.3:0.9

Lakshmi Saripalli, Bologna meeting October 20-23, 2015
Source is asymmetric
-- 1:1.6 lobe length ratio
-- N lobe is off axis to W

No Hotspots
Radio lobes not sharply bounded

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

Lakshmi Saripalli, Bologna meeting October 20-23, 2015
Galaxies within $z = 0.03 - 0.05$

Large stars
$\Delta z = +/- 0.003$
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

Lakshmi Saripalli, Bologna meeting October 20-23, 2015
The Giants

Saripalli et al., 2003
Linear size = 1 Mpc

Saripalli et al., 2002
Linear size = 2 Mpc

Lakshmi Saripalli, Bologna meeting October 20-23, 2015
The Giants

Saripalli and Subrahmanyan, 1993
Linear size = 2.5 Mpc

Saripalli et al, 2005
Linear size = 3.21 Mpc

Saripalli et al, 2013
Linear size = 1.1 Mpc

Subrahmanyan et al, 2008
Lakshmi Saripalli, Bologna meeting October 20-23, 2015
Saripalli et al., 2007
Linear size = 1.5 Mpc

Saripalli et al., 2013
Linear size = 2 Mpc

Lakshmi Saripalli, Bologna meeting October 20-23, 2015
Using GRG sample to probe WHIM

WHIM in pressure balance with the radio lobes has

1. temperature in excess of $\sim 10^6$ K or

2. particle overdensity in the range 50–500

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

Lakshmi Saripalli, Bologna meeting October 20-23, 2015
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

Lakshmi Saripalli, Bologna meeting October 20-23, 2015
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

Lakshmi Saripalli, Bologna meeting October 20-23, 2015
Relating environment to radio structure

$f_k(\theta_i)$ are terms equal to 1, \(\sin(\theta_i)\), \(\cos(\theta_i)\), \(\sin(2\theta_i)\) 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.

Lakshmi Saripalli, Bologna meeting October 20-23, 2015
The mean galaxy number overdensity in volumes of $\sim 700 \text{ Mpc}^3$ near GRG host galaxies is $\sim 70$.

Indicates overdense but non-virialized environment.
Relating environment to radio structure

Strong influence of environment seen

Lakshmi Saripalli, Bologna meeting October 20-23, 2015
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*

Lakshmi Saripalli, Bologna meeting October 20-23, 2015
GRGs and large-scale galaxy distribution
GRGs and large-scale galaxy distribution
GRGs and large-scale galaxy distribution

Lakshmi Saripalli, Bologna meeting October 20-23, 2015
GRGs and large-scale galaxy distribution

Lakshmi Saripalli, Bologna meeting October 20-23, 2015
GRGs and large-scale galaxy distribution

Larger GRGs avoid high density environments

Lakshmi Saripalli, Bologna meeting October 20-23, 2015
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

Lakshmi Saripalli, Bologna meeting October 20-23, 2015
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