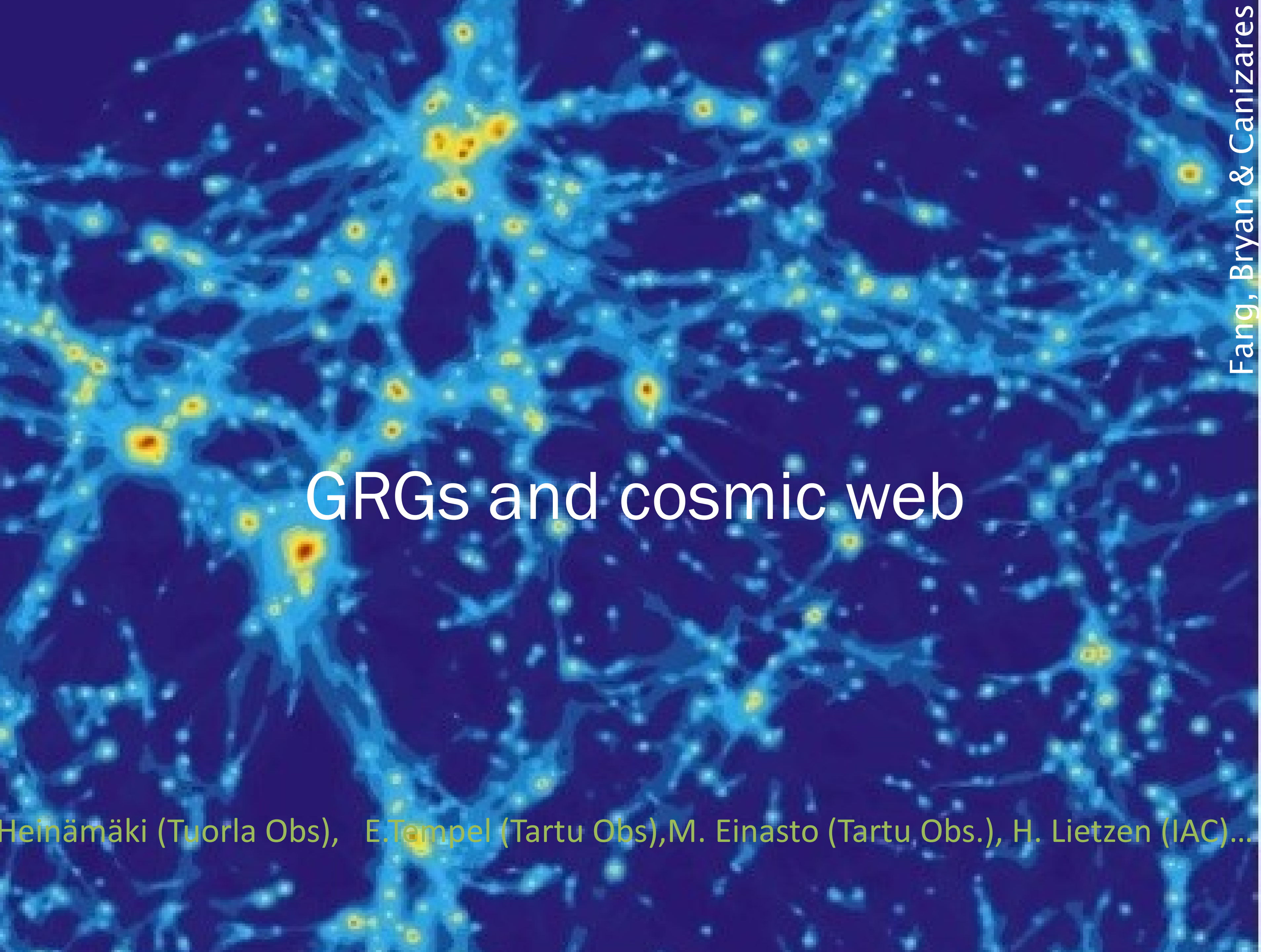
GRGs and cosmic web



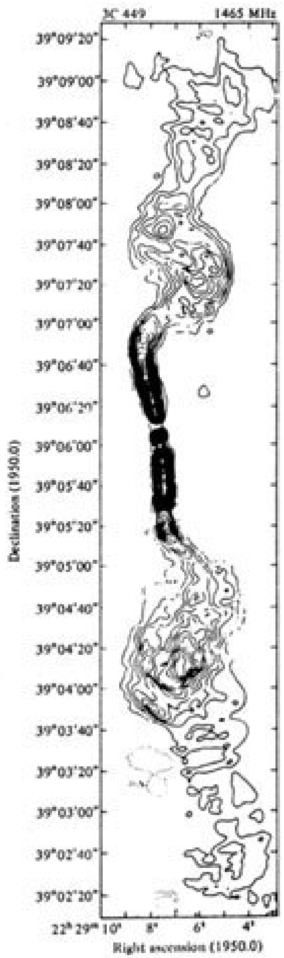
Heinämäki (Tuorla Obs), E.Tempel (Tartu Obs),M. Einasto (Tartu Obs.), H. Lietzen (IAC)…

- Radio galaxies : two classes according to their radio structure:
  FR I and FR II (Fanaroff & Riley 1974) radio sources

- Classification correlates strongly with luminosity

- Dividing radio luminosity $L_{175MHz\ FR} = 5x10^{25}$ W/Hz

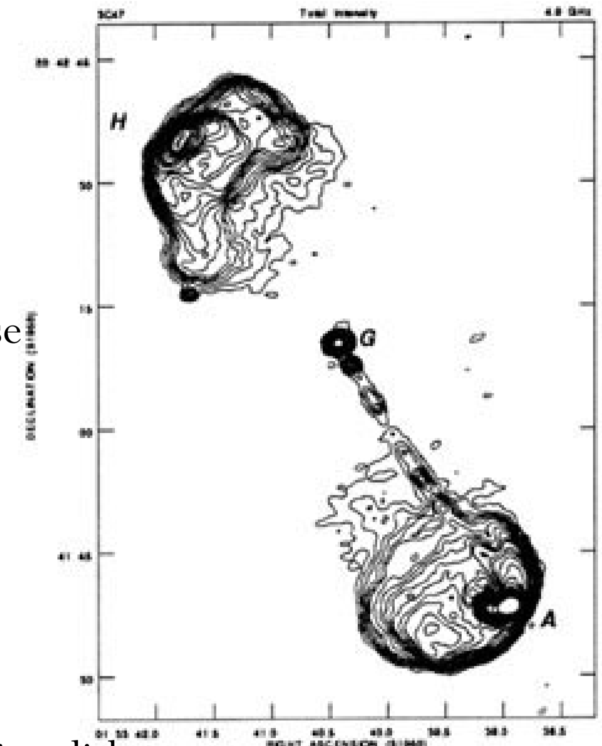
Morphology



VLA map of the FR-I galaxy 3C 449 at 1465 MHz. Perley, Willis and Scott (1979).

-Core-dominated, edge-darkened
-jets fading, dissipating short distance from centre

VLA map of the FR-II quasar 3C 47 (Bridle et al. 1994)

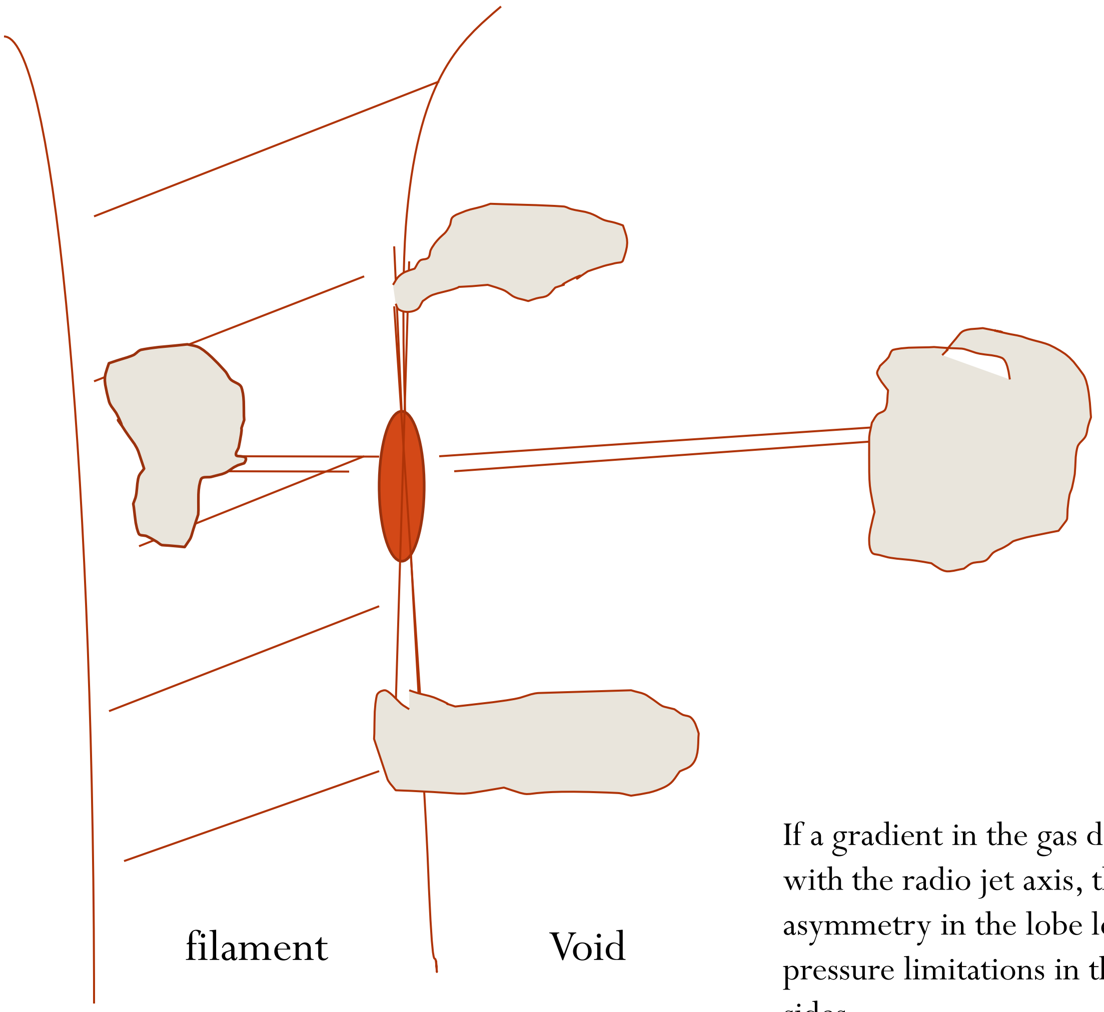


-Edge-brightened with highly collimated jets
-Largest individual structures in the Universe
-Elliptical/disturbed host galaxies
-Avoid clusters and high density regions

Radio synchrotron emission,
collimated radio jets powered by accretion disk around supermassive blackhole (Blandford&Rees 1976).

GRGs

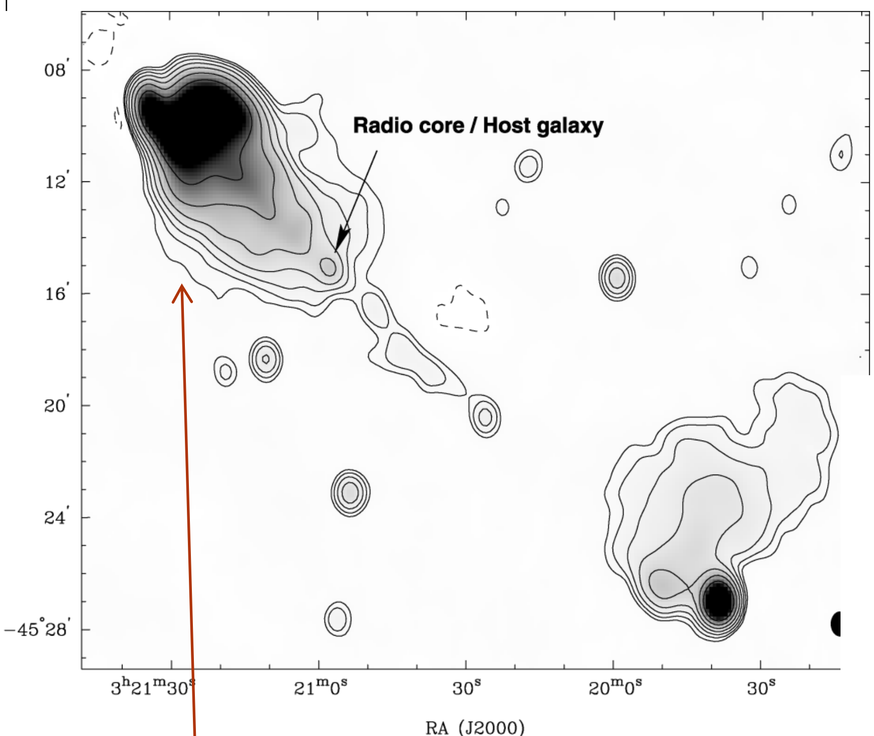
- Giant radio sources (GRG) linear projected size > 0.7 Mpc (definition not clear sometimes), the largest individual objects in the universe. Minimum projection effect
- Giant radio galaxies tend to reside outside of rich clusters
- They tend to populate regions with low galaxy density, corresponding to galaxy filamentary structure
- Lobes extend well beyond the interstellar media and host galaxy halo
- Lobes plasma interact with intergalactic medium (IGM)
- If galaxies are a reliable tracer of the IGM gas, than we expect the distribution of gas around a GRG to depend on the position of the host galaxy relative to LSS in the IGM.
- Thus if the evolution of the radio lobes may depend on interaction with this ambient gas -->LSS is also expected to determine lobe dynamics in giant radio sources (Safouris et al. 2009).



If a gradient in the gas density is aligned with the radio jet axis, then we would expect an asymmetry in the lobe lengths due to differing ram-pressure limitations in the ambient gas on the two sides.

If gradient is transverse to the jet axis lobes evolve transverse to the jet axis and in the direction of decreasing ambient density and pressure due to buoyancy

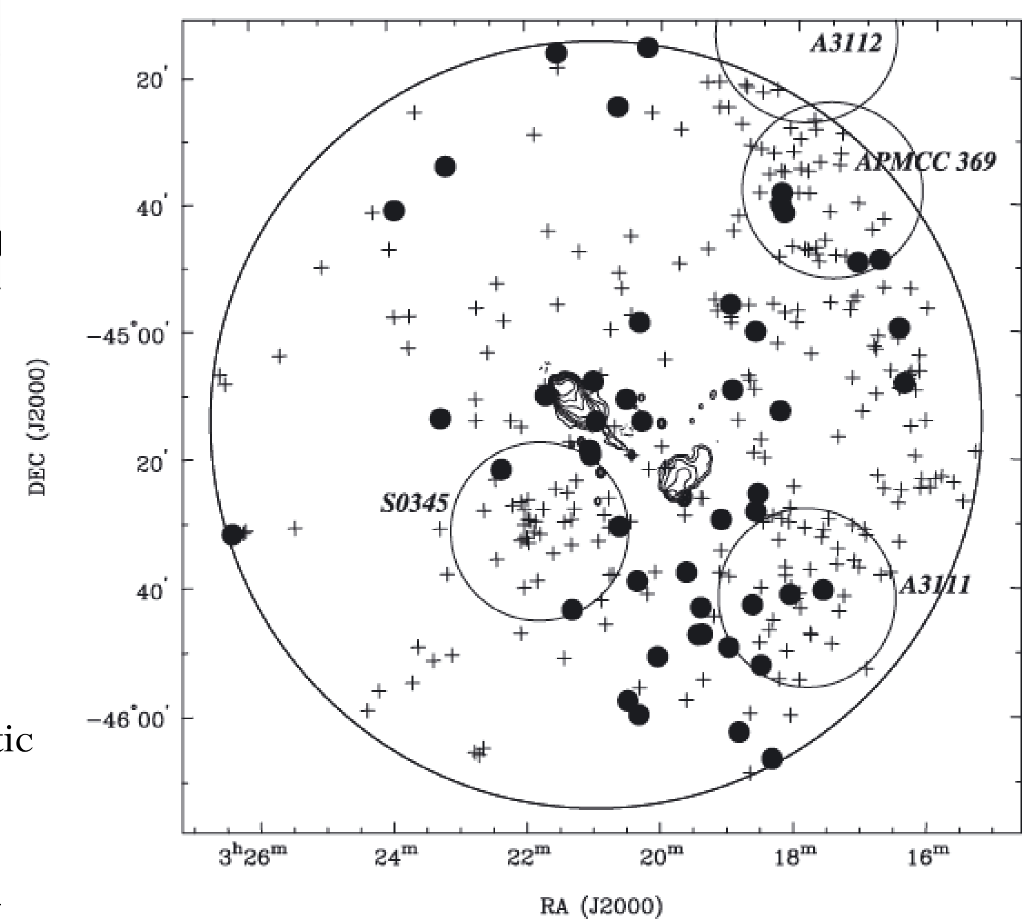
MRCB0319-454 is 2.5 Mpc radio source is located within a galaxy filament of the Horologium-Reticulum supercluster at z~0.06



Most striking feature : side to side asymmetry
Overdensity in the galaxy distribution
North of the radio core.

Safouris et al. 2009 concluded that MRCB0319-454 probing the large-scale structure : galaxies trace the ambient intergalactic gas and the evolution of the radio structures are ram-pressure limited by this associated gas.

Black dots at host galaxy redshift



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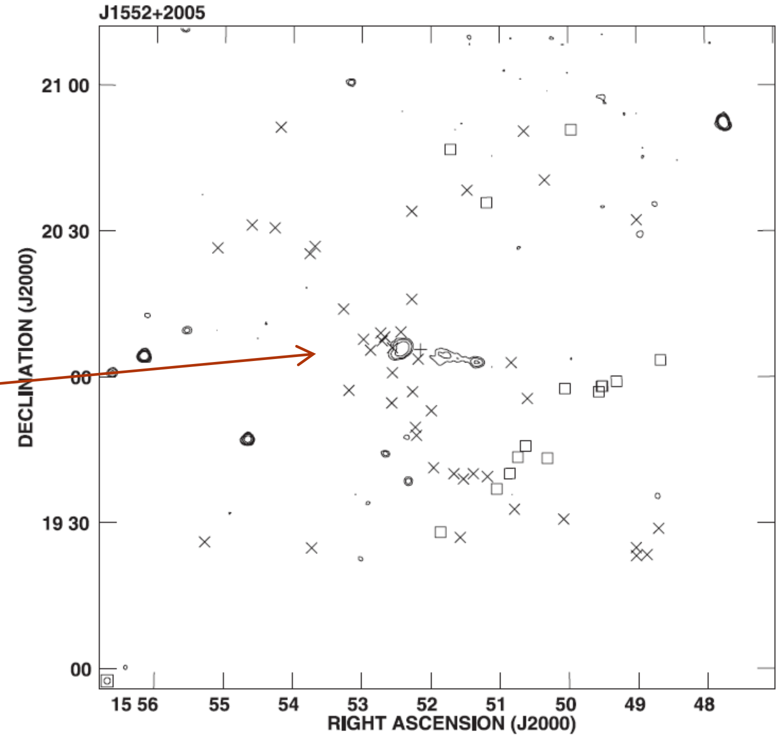
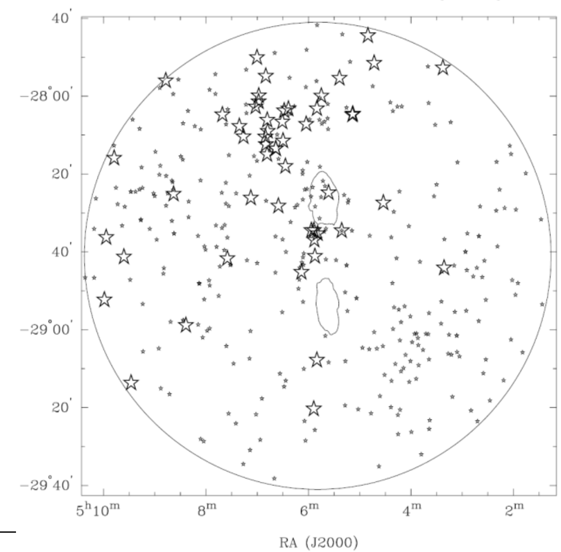
A study of the environments of large radio galaxies (GRS) using SDSS (Pirya et al. MNRAS, 2012).
-16 large radio sources in SDSS.
-Regions of low galaxy density
-JI552+2005 shorter arm is found to interact with a group of galaxies which forms part of filamentary structure



Also Subrahmanyan et al. 2008 studied MSH 05-22 (linear size 1.8 Mpc). Observed asymmetry seems to related to an ansiotropy in the local galaxy distribution. MSH 05-22 is associated with small group that lies close the boundary of sheetlike and filamentary density enhancements.
It is probable that radio lobes interact with the more diffuse IGM associated with the large-scale filament and not thermal intragroup gas



Malarecki et al. 2013:

- sample of 12 giant radio galaxies
- >0.7 Mpc, z<0.15
- Anglo-Australian Telescope and Australia Telescope Compact Array (ATCA)
- A comparison of the lobe pressures (assumptions: old objects, equilibrium, pressure balance between ambient and lobe) derived for the GRG sources with the WHIM gas properties in the OWLS simulation indicates that the corresponding IGM would have a temperature in excess of $10^{6.5}$ K.

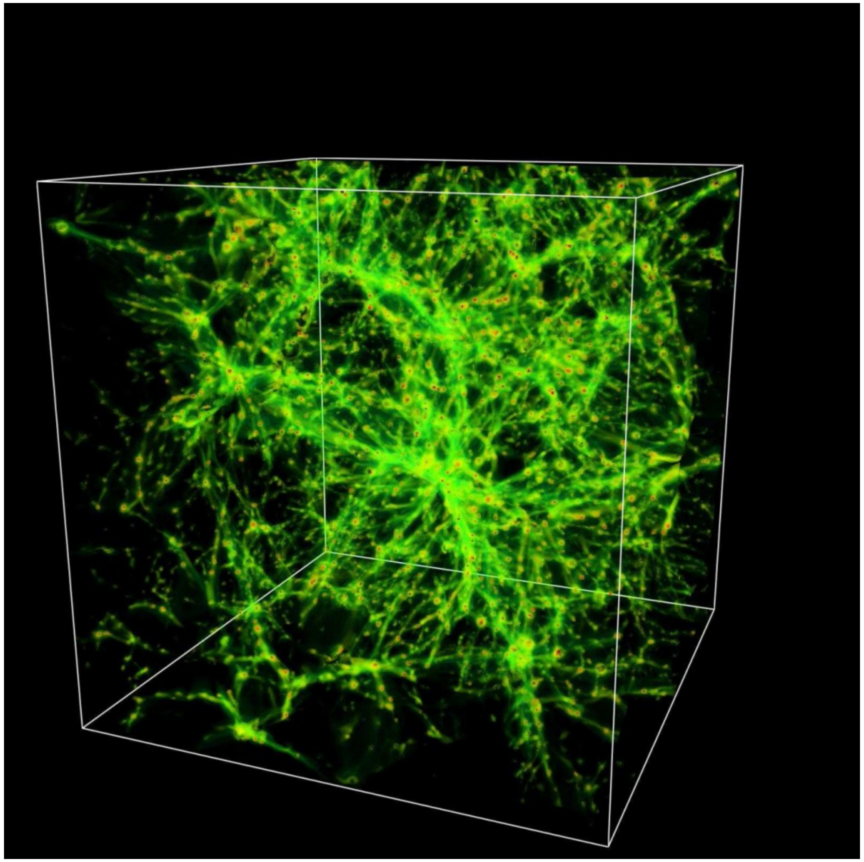
Malarecki et al. 2013 concluded that GRGs may be useful probes of the warm-hot intergalactic medium believed to be associated with moderately over dense galaxy distribution .

Need of the galaxy density field .

-Relatively little is known a gas associated with galaxy filaments.

At z>2 almost all baryons are found in the Ly-alpha forest, but about 50% of the baryons z<2 are missing (infered from stars,atomic and molecular gas, dust, plasma in clusters)

According to simulations and theoretical predictions the majority of the missing *baryons* are hidden in **low-density plasma** called WHIM (warm-hot intergalactic medium: **10^5 and 10^7 K**) that traces the cosmic large-scale web, consisting of superclusters and filaments between them (Cen & Ostriker 1999, 2006).



The diffuse gas in the environs of giant radio galaxies, outside of rich clusters, most likely pertains to the warm-hot phase (WHIM) of the IGM.

Methods to search WHIM:

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1) Several detections of WHIM have come from O VI absorption lines in the FUV band showing that a small part of the WHIM plasma seems to exist in a low temperature $T<3*10^5$K phase (Savage et al. 1998; Tripp et al. 2006, and references there in). 40 O VI systems at $z< 0.15$.

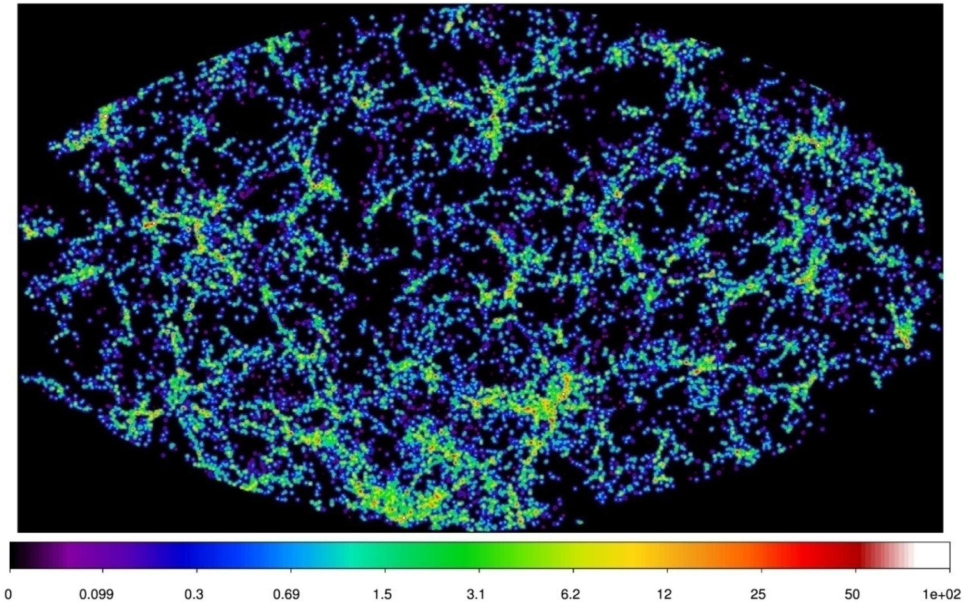
2) Alternatively, one can try to search for the diffuse X-ray emission that could allow to study the spatial distribution of WHIM. Unfortunately, this is difficult due to a low surface brightness of the WHIM gas and to galactic contamination.

3) One possibility to detect WHIM is to search for the Thermal Sunyaev-Zeldovich effect (SZ) signals from WHIM at supercluster scales.

4) One of the most promising technique is to search for WHIM in the X-rays along those lines of sight toward bright background X-ray sources that intercept large-scale structure concentrations (this is “blind”-search)

5) An alternative strategy is to focus on known foreground structures that may contain WHIM. In that case the redshift of the absorber is known a priori from the redshift of the superclusters traced by its galaxies (Fang et al. 2010). → Liivamägi et al. → currently *WBANG project (Nevalainen et al.)*

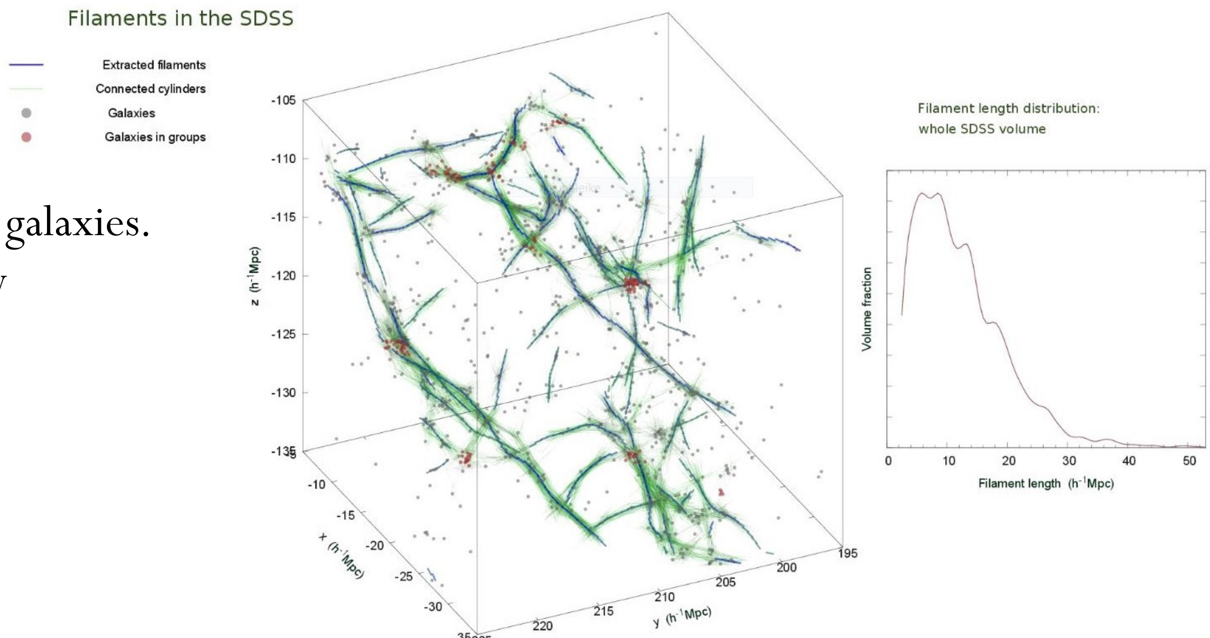
Luminosity density filed (Liivamägi et al.)



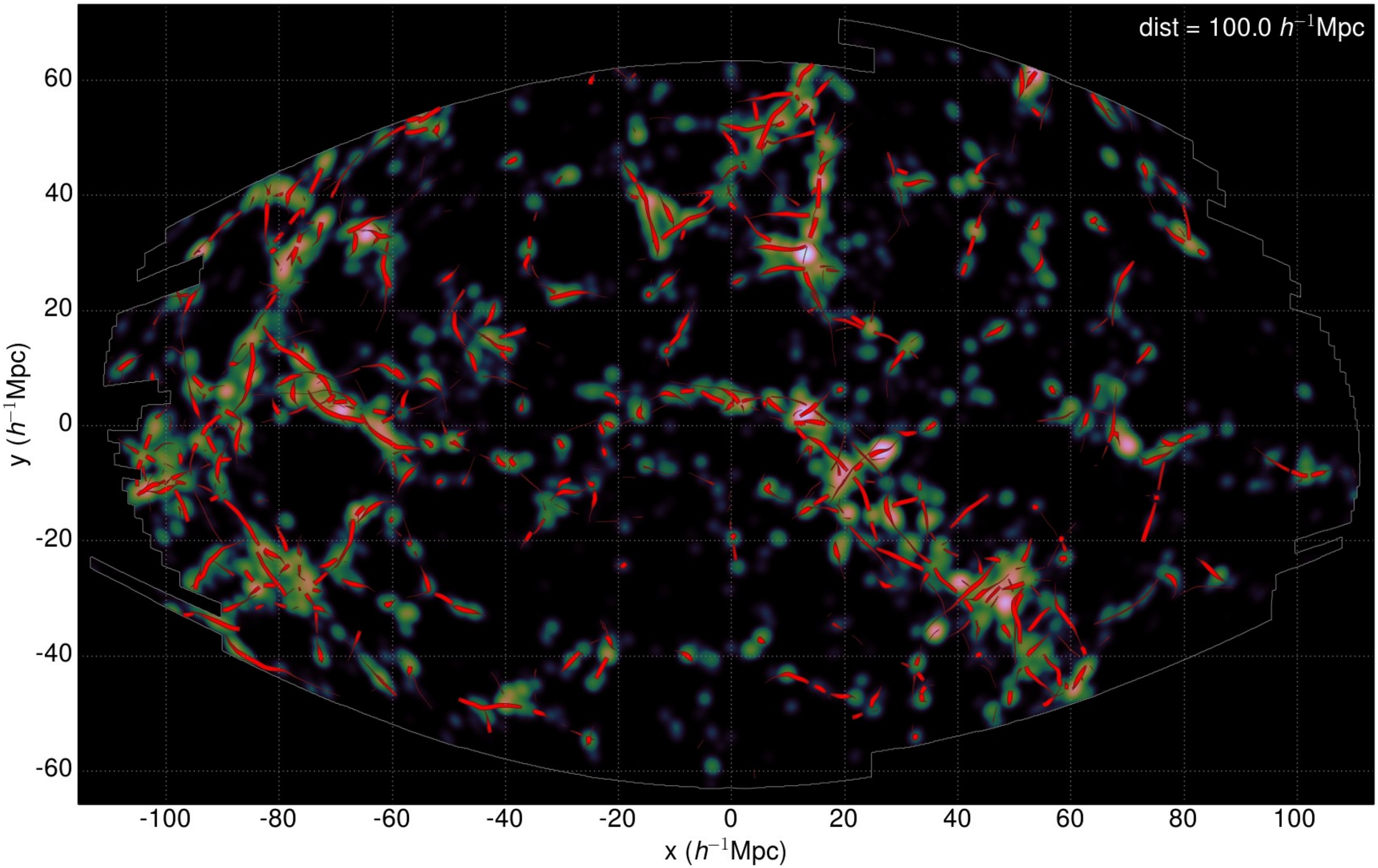
SDSS galaxies
(Einasto et al.)

LD assumes that luminosity density is proportonial to dark matter density and gas follows galaxies. Differs from numerical density

Elmo Tempel et al. 2014
filament machine



Filament +luminosity density field



Tempel et al. (2014, MNRAS 438) filament catalogue based on MCMC and Bisous model (Stoica et al. 2005). This catalogue is extracted from the SDSS-DR8 contains 3D mapping of 15421 filaments including their properties (e.g. galaxy richness, luminosity, length). Radius of the filaments in this catalogue is fixed at 0.5 Mpc/h. FILM

Using Tempel et al. filament machine and luminosity density approach to map regions of the GRG filaments can be traced with accuracy which in allow to study environments of GRG.

Are GRG in filaments?

How orientation and environment effect to the lobe stucture, size, assymetry etc. ?

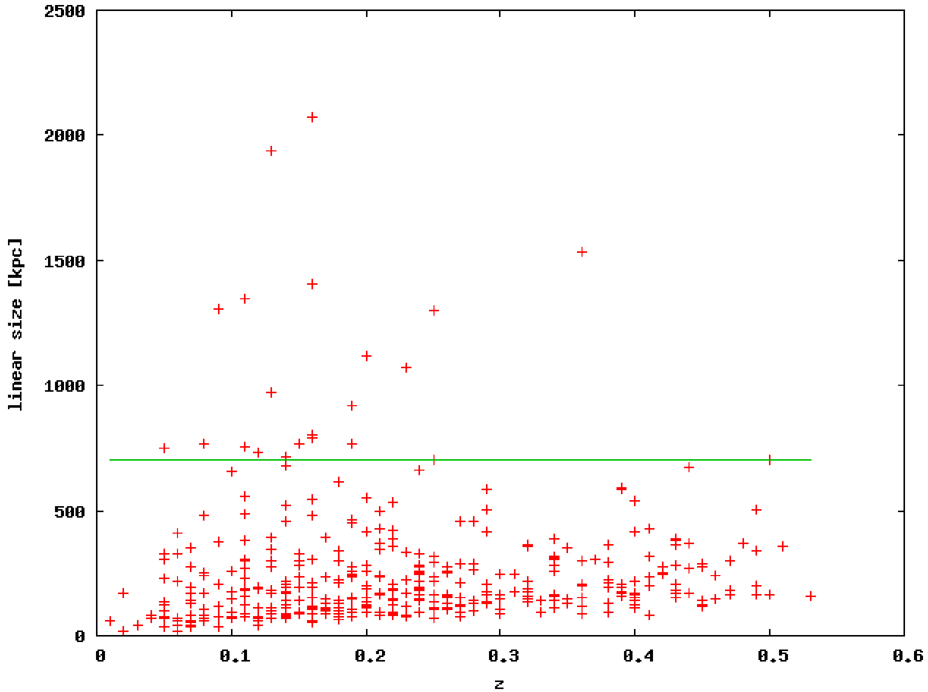
If GRG lobes are in filaments and filaments are prominent regions of the WHIM gas → GRGs might be good parometers of the WHIM gas. GRG shows up surrounding gas in IGM.

Using hydrodynamical simulations -> relation between observed WHIM gas and luminosity density (Nevalainen et al.)

Map environments around GRG using luminosity density field –> radio-lobe properties / WHIM

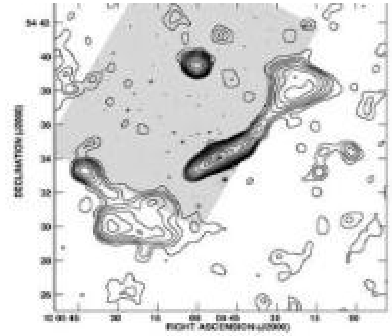
Koziel-Wierzbowska et al. (2011) analyzed FR II radio sources (Cambridge Catalogues of Radio sources: 3C-9C) and their counterparts in SDSS DR7, finding in total 401 FR II sources.

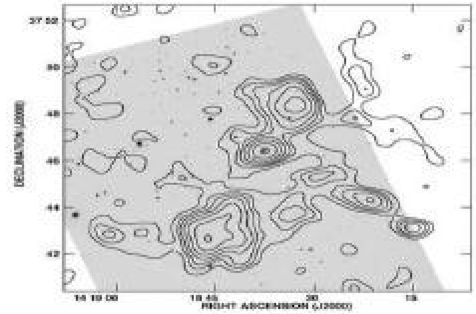
Among these sources we found 22 GRGs

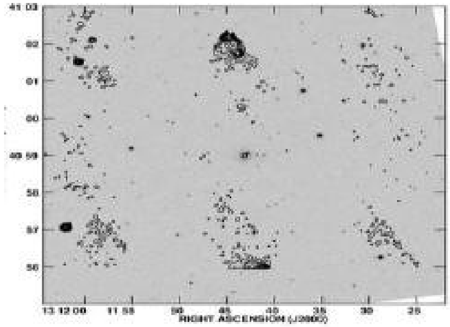


Filament data extends up to z=0.155 which reduce the number of GRGs to 9.

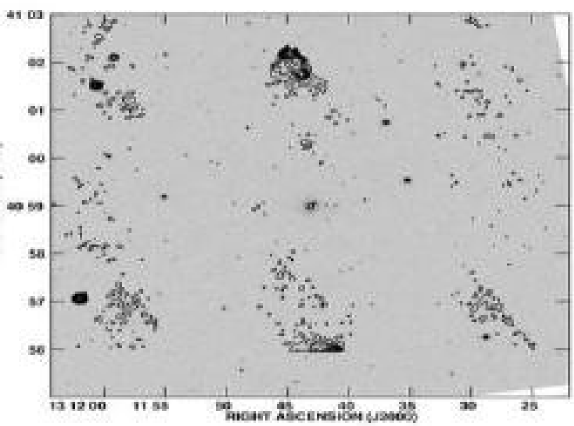
[1]	[2]	[3]	[4]	[5]	[6]
30	0.108	1348	1	3.4	
32	0.124	733	2	>20	-
129	0.150	769	1	6.9	
136	0.048	751	43	1.0	2.6
248	0.135	973	6	0.76	8.1
273	0.110	754	4	0.27	9.1
282	0.137	712	2	9.6	
299	0.131	1940	11	>20	-
317	0.140	714	1	>20	-

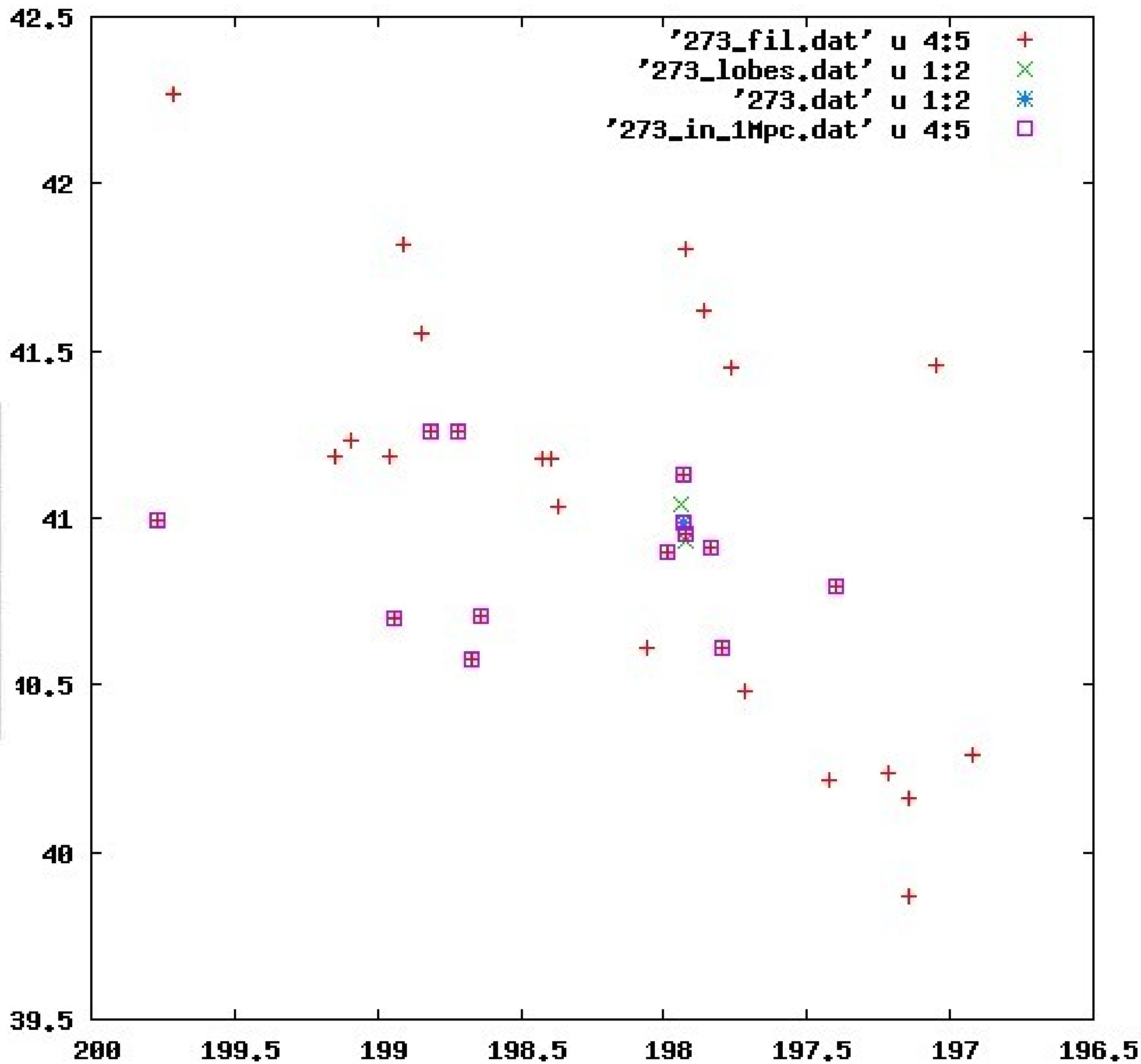






Columns contain following information: [1] GRG identification number, [2] GRG redshift, [3] GRG linear size (kpc), [4] Richness of the group where GRG host galaxy belongs , [5] GRG host distance from the nearest filament axes (Mpc/h), [6] Length of the filament (Mpc/h).


RIGHT ASCENSION (J2000)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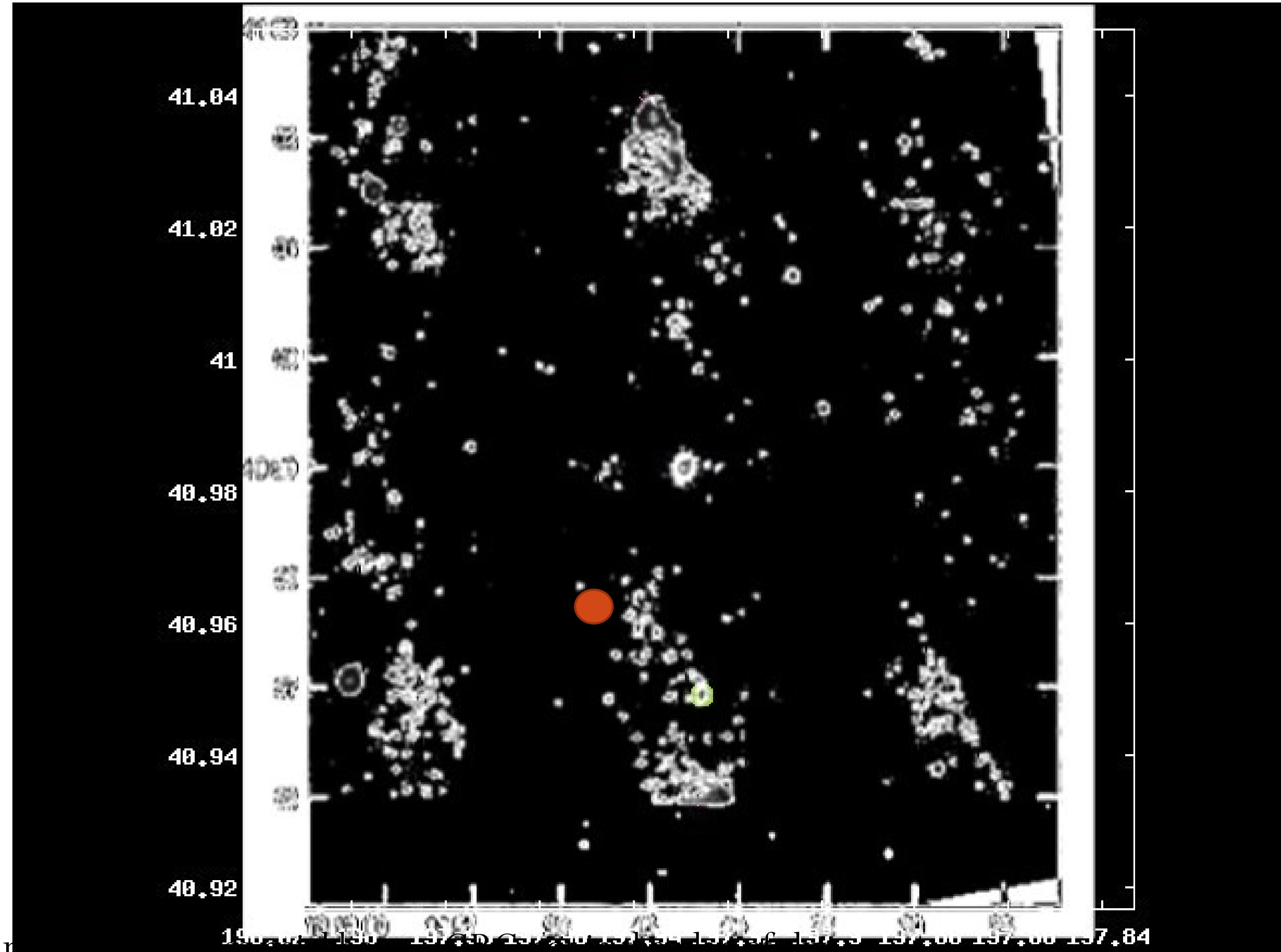
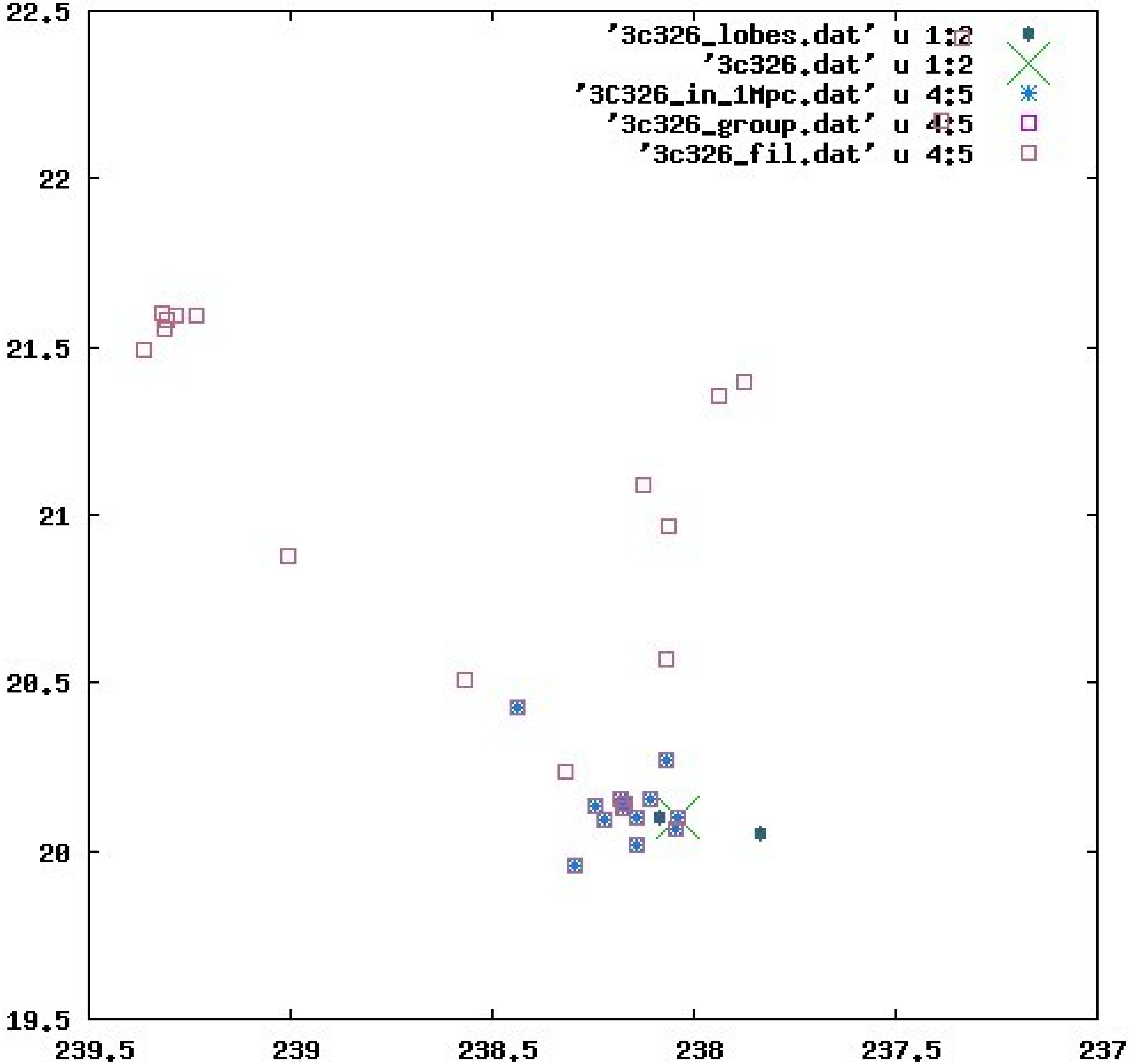


Symm



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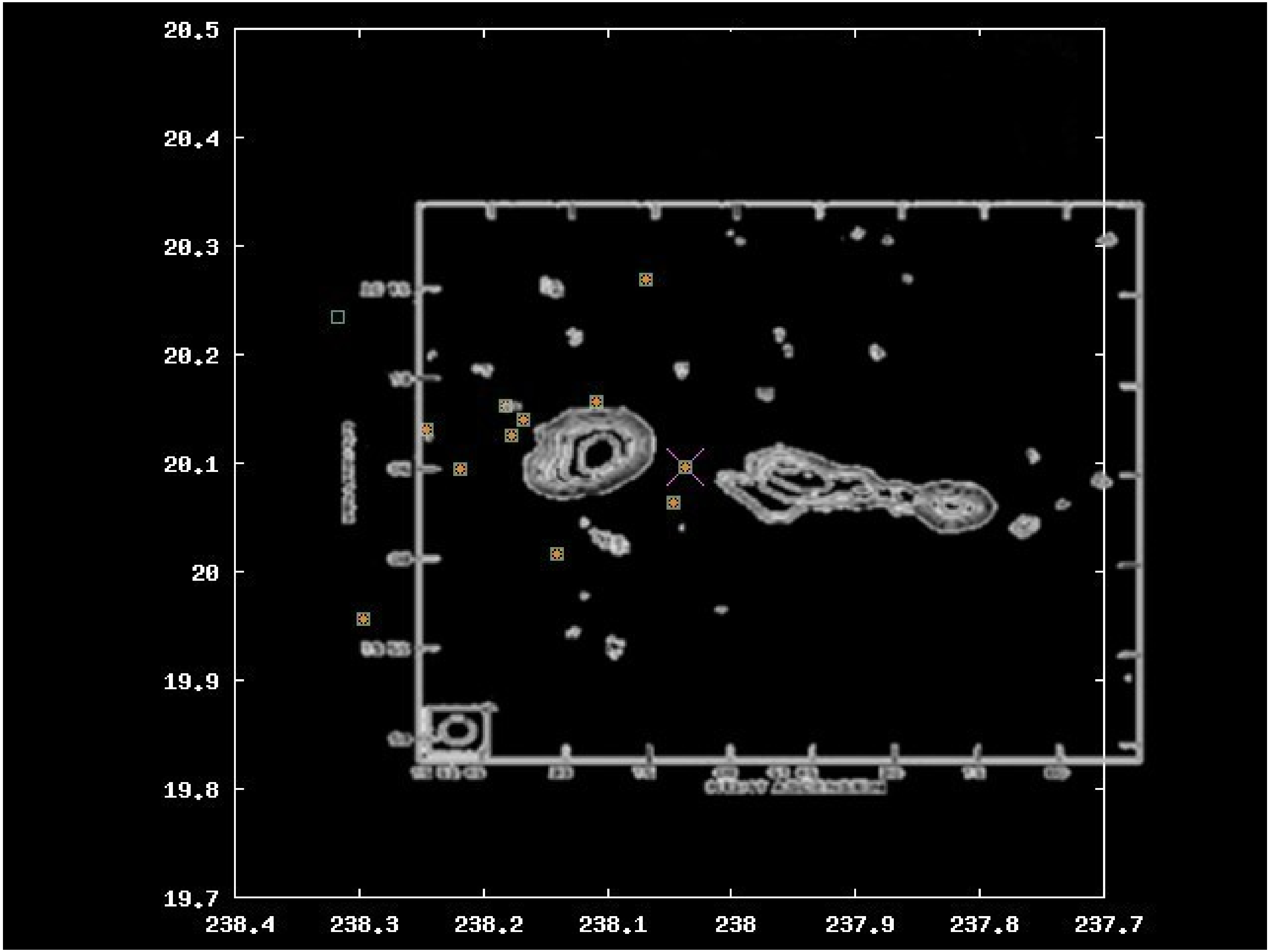

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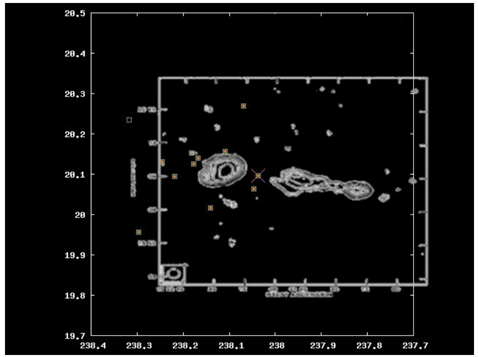
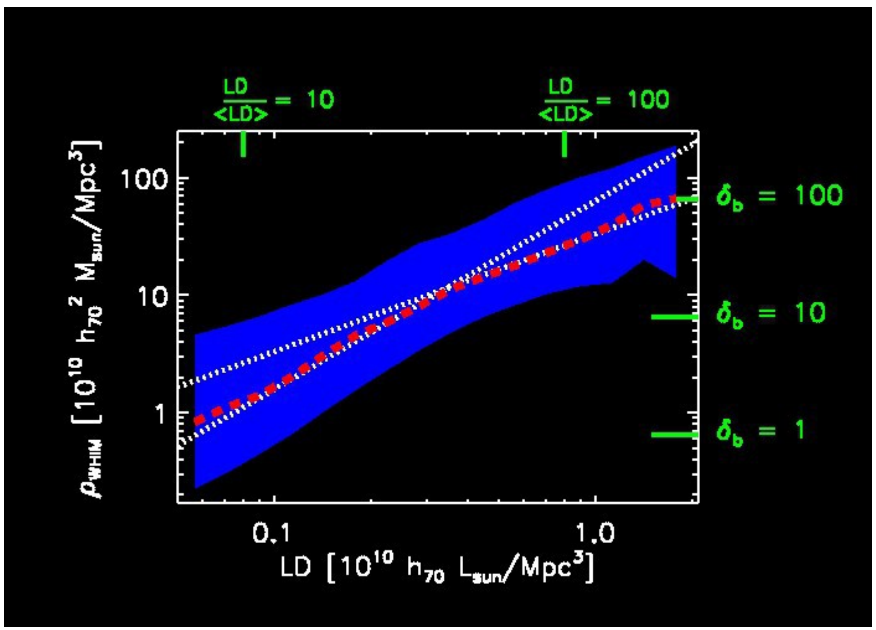
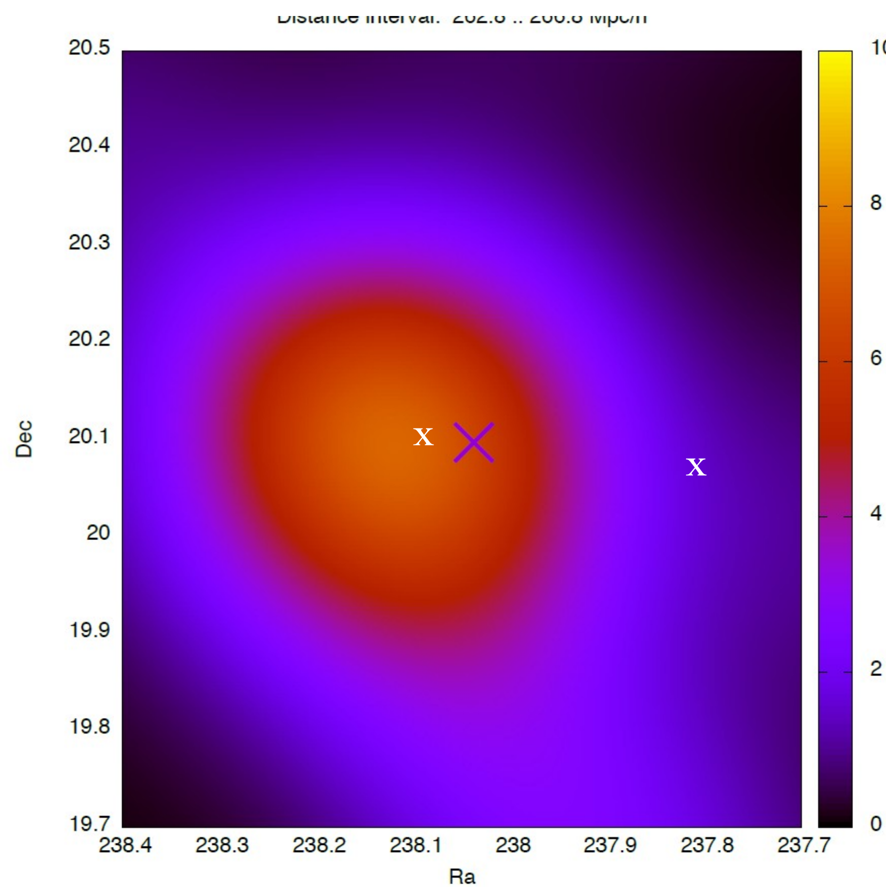
Tested against Sculptor and Blazar H2356-309



It is probable that radio lobes interact with the more diffuse IGM associated with the large-scale filament and not thermal intragroup gas (Subrahmanyan et al. 2008). BUT …





Thermal pressure ∝ (density contrast, T and some cosntants).If equipartition is assumed thermal pressure minimun has minimum value → estimation of the IGM temperature T (Subrahmanyan et al.2008)

Current project is at very preliminary stage. It is starting point for more detailed forthcoming analysis of the relations between GRG, filaments and density field. We are planning to add more GRGs outside SDSS to our analysis (using 2dF and GAMA).

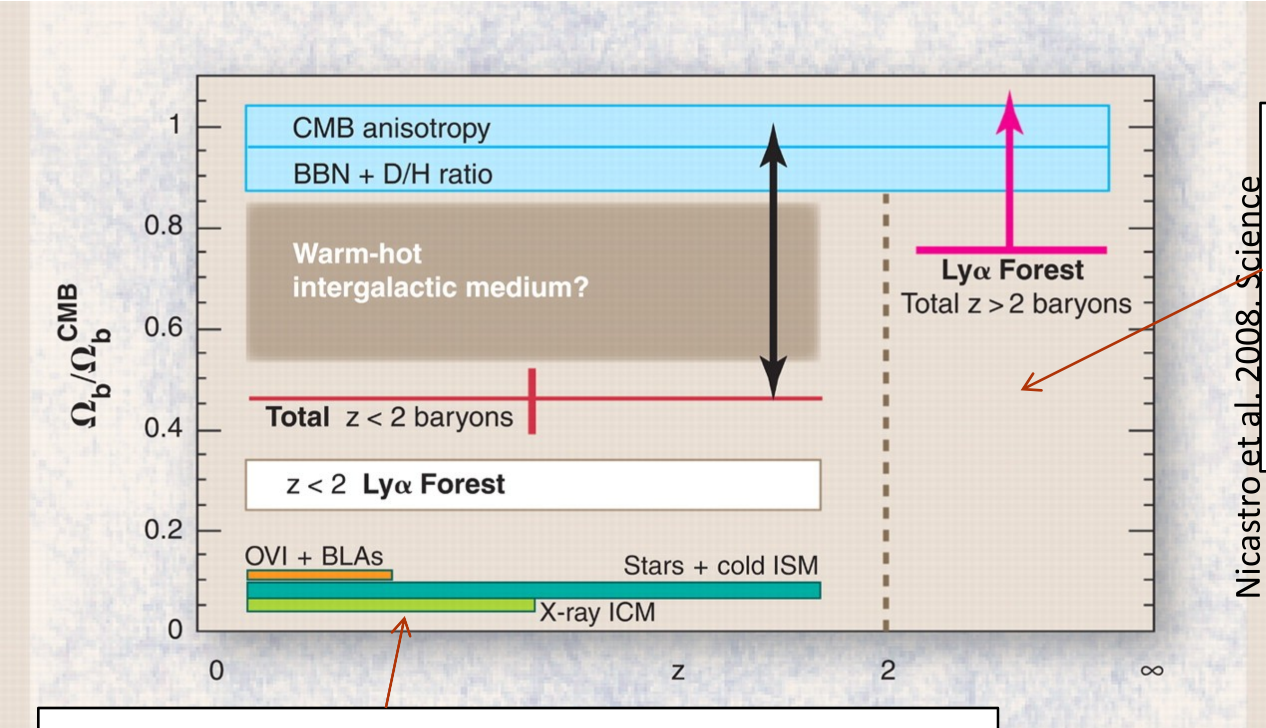
- Our preliminary analysis (using Koziel-Wierzbowska et al. (2011) catalogue) shows that only 3 case out of these 9 GRGs has host galaxy are more or less inside the filament (note, despite that it's morphology seems to be quite symmetric). At least six cases host galaxies and radio lobes are too far away from the filaments to have interaction with filament ambient

- Case by case study using large GRG, filament definition prosedure and luminosity density field

- Together with knowledge of the filamentary structure and radio data we will can also map in detail the luminosity density field in the vicinity of radio lobes aiming to an opportunity to investigate the physical state of the gas in these regions of moderate overdensities.

감사합니다 KIITOS

At z>2 almost all baryons are found in the Ly-alpha forest, but about 50% of the baryons z<2 are missing (infered from stars,atomic and molecular gas, dust, plasma in clusters)



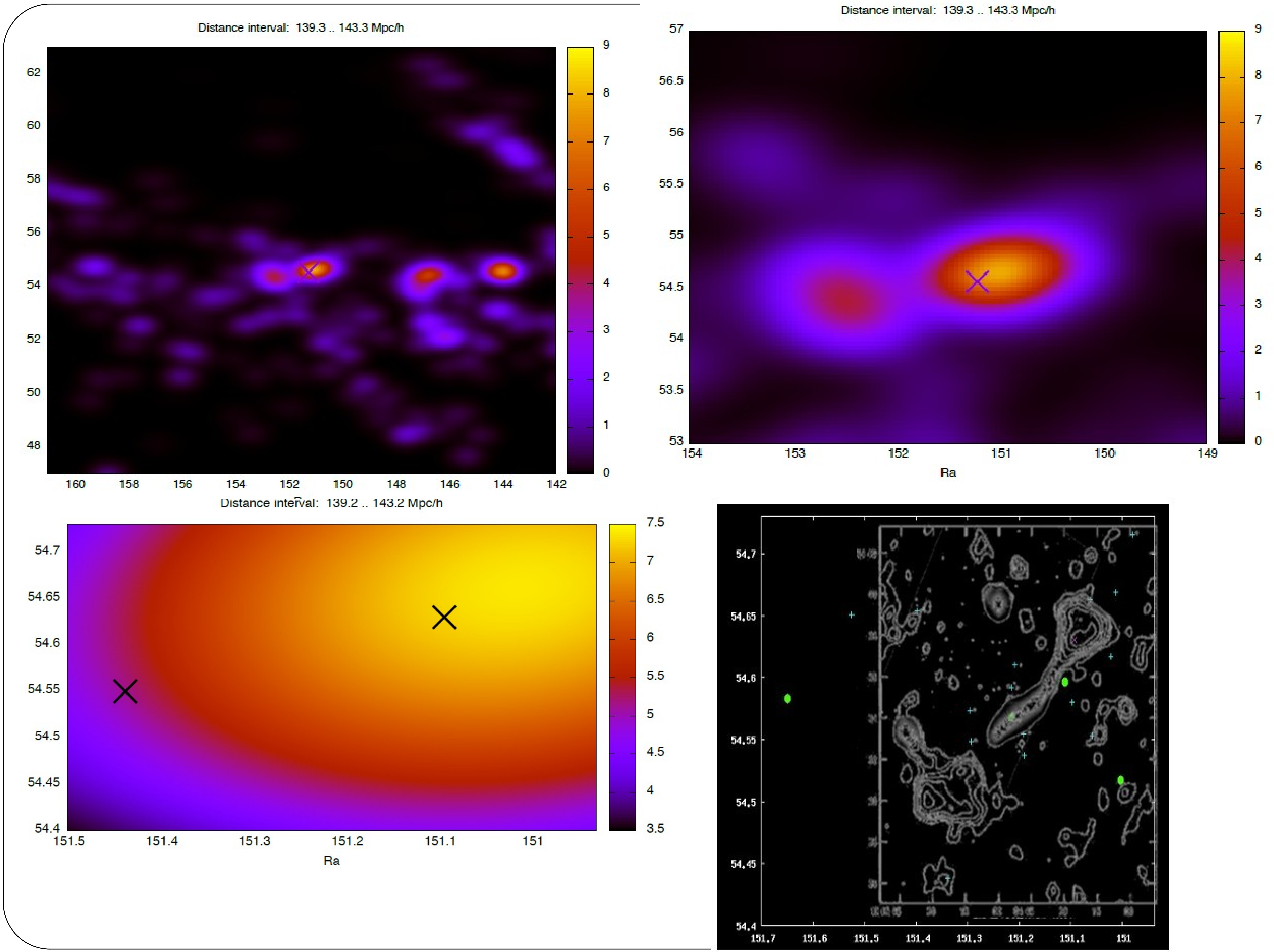
Nicastro et al. 2008, Science

At $z > 2$ most of the baryons are thought to reside in the diffuse, photoionised intergalactic medium (IGM) with $T \sim 10^4$–10^5 K, *traced by the Lyα forest*

(stars, cold interstellar medium in galaxies, low-z Lya forest, OVI and BLA absorbers, X-ray hot gas in clusters of galaxies)

Less than 10% of the ordinary matter appears in collapsed objects (stars, galaxies, groups; Fukugita & Peebles 2004).

- Current project is very preliminary stage and this poster discripe more like the idea and the starting point for more detail analysis of the GRG and filaments. Next step is to study how radiolobes are alingned with filaments. Moreover we are planning to add more GRGs outside Koziel-Wierzbowska et al. (2011) catalogue to our analyzis.
- Together with knowledge of the filamentary structure and radio data we will also map in detail the luminosity density field in the vicinity of radio lobes aiming to an opportunity to investigate the physical state of the gas in these regions of moderate overdensities.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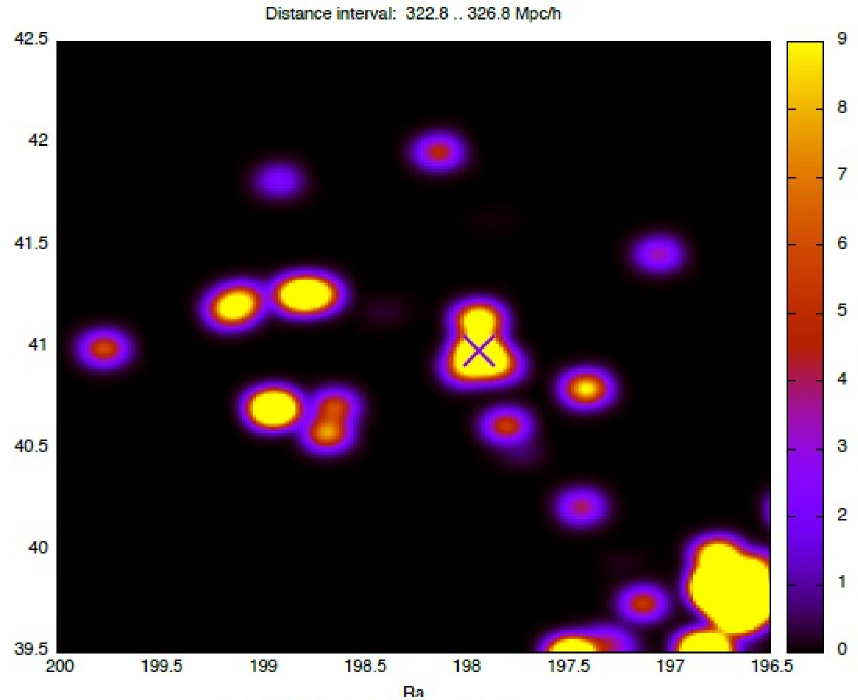
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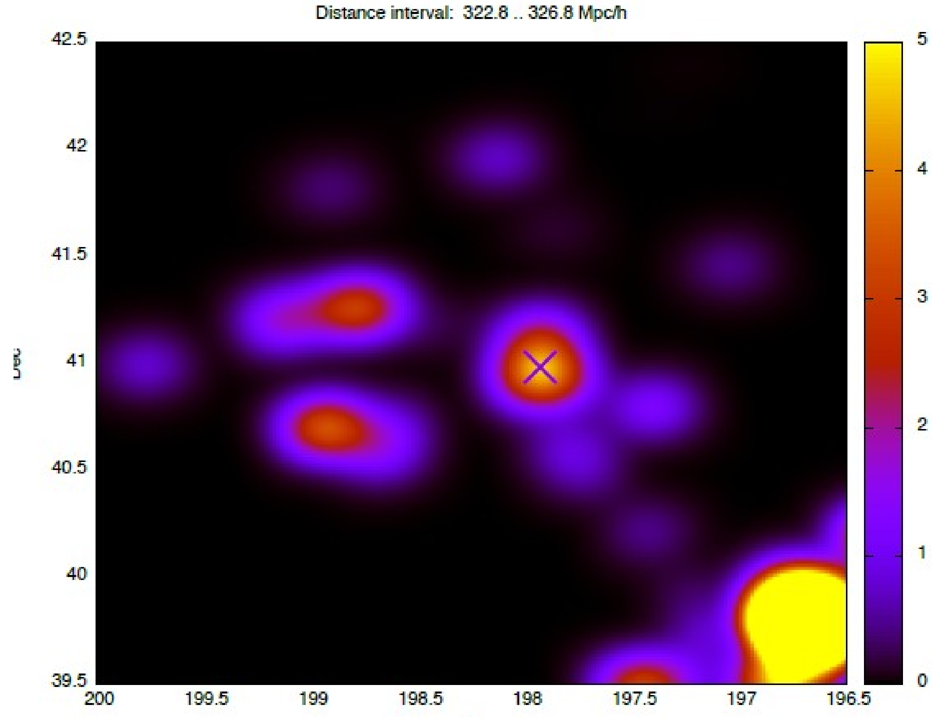
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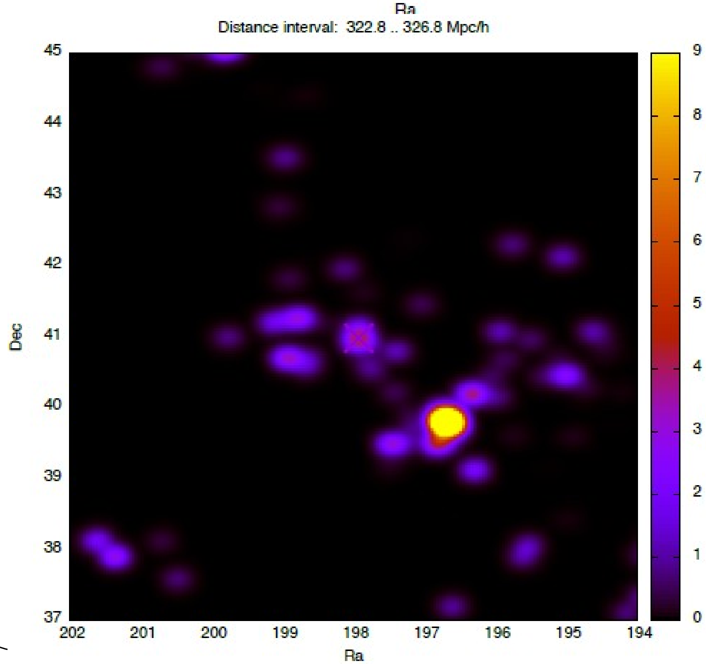
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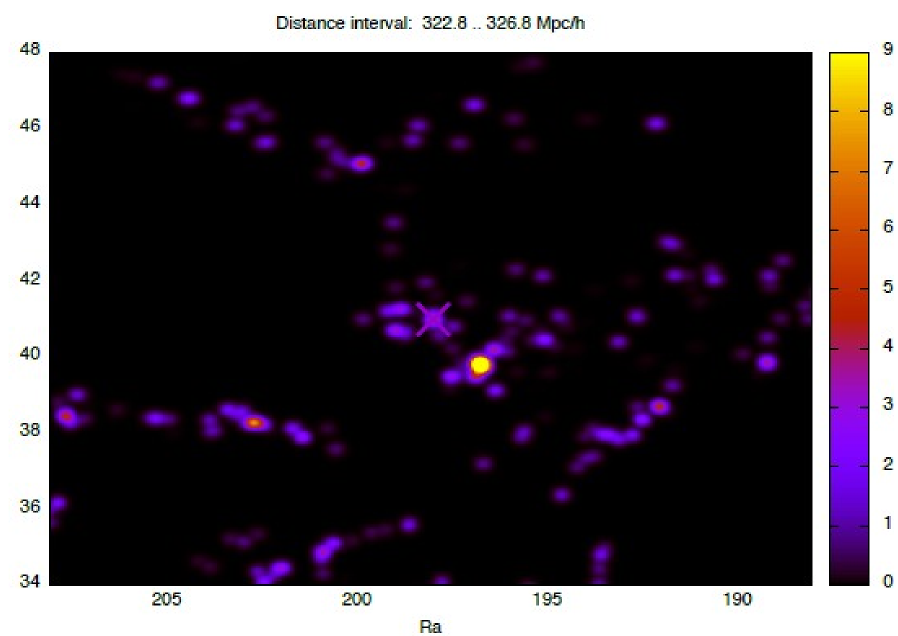
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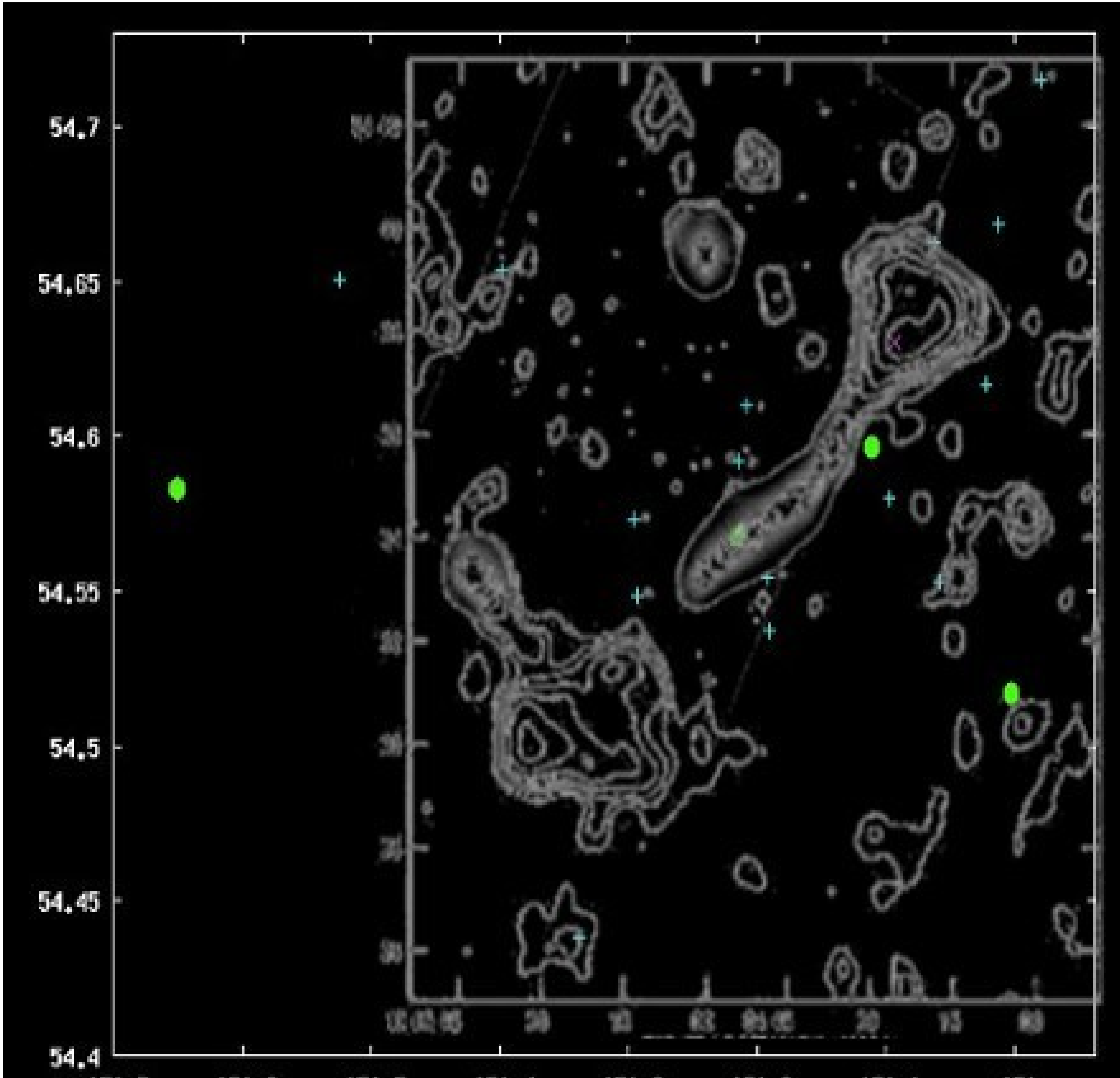
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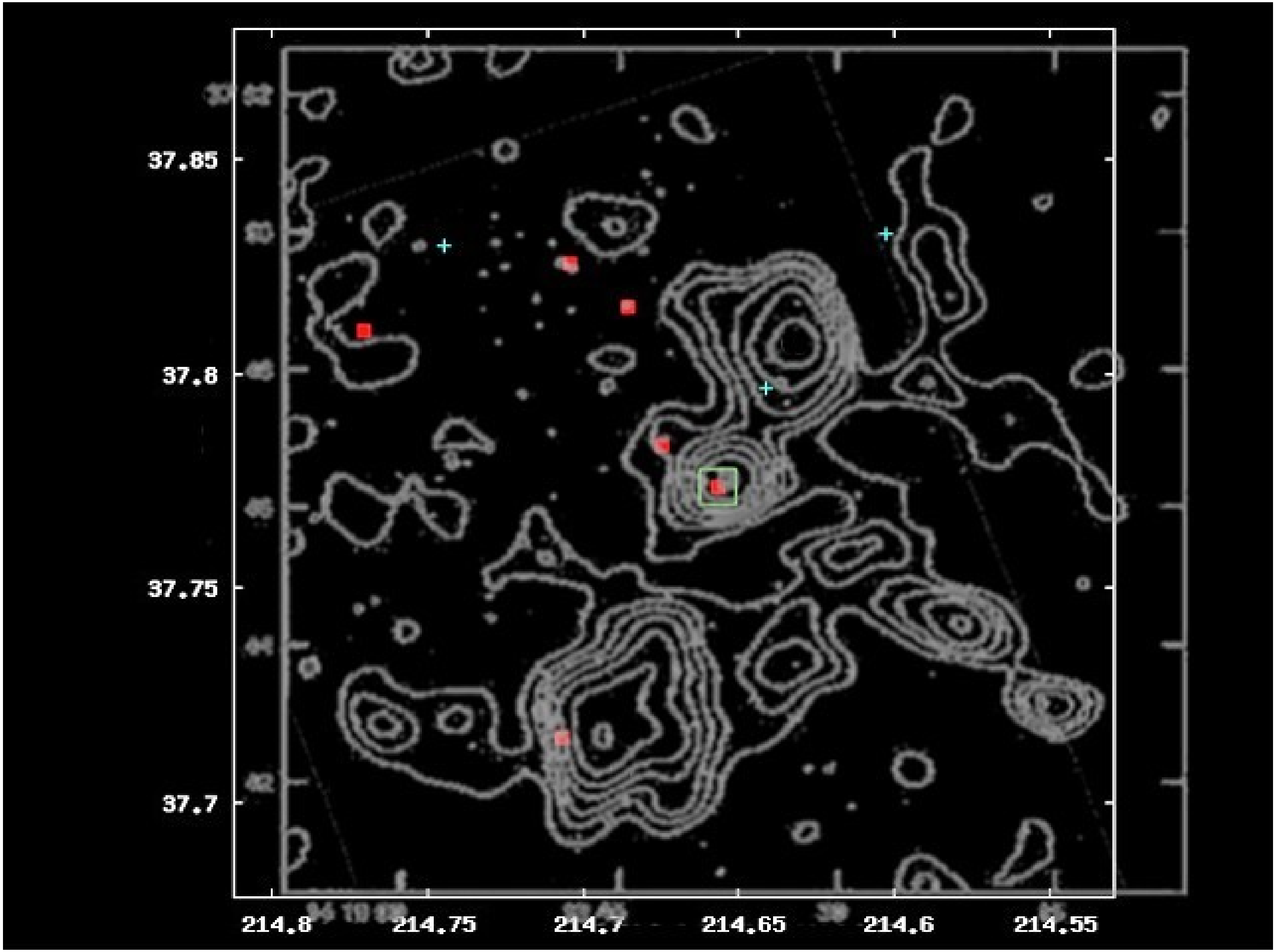
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