A High Resolution, Unobscured View of the Active Regions in (Ultra) Luminous Infrared Galaxies from a VLA 33 GHz Survey

Loreto Barcos-Muñoz[1], Adam K. Leroy[2,3], Aaron S. Evans[1,3], et. al

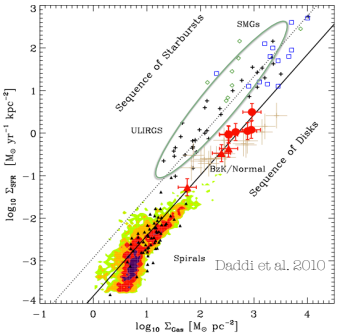
[1]University of Virginia, [2]Ohio State University, [3]National Radio Astronomy Observatory

MOTIVATION:

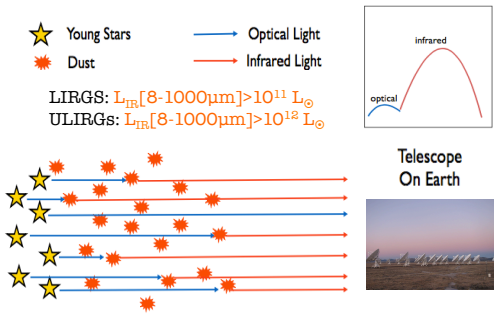
U/LIRGs are extreme starbursts with high L_{IR}, high dust obscuration, and are very compact. High resolution radio observations will help us address the following questions:

- How compact are these extreme systems ?
- What are the physical conditions in such extreme systems?
- What is the nature of their radio emission?
- Are they maximal starbursts?

UNDERSTADING STAR FORMATION AT ITS EXTREME REGIME

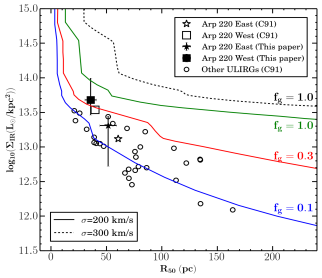


Star formation is more efficient for extreme starbursts



High amounts of dust => High IR luminosity

Radiation pressure on dust as main feedback mechanism in dusty systems



Eddington Limit for starbursts ~ 10^{13} $L_\odot kpc^{-2}$

Thompson et al. 2005; Barcos-Muñoz et al. 2015

The balance between star formation and feedback depends on the size of the star forming region

EXPERIMENT:

Main Issues

Compactness → Interferometer

Dust obscuration → Radio frequencies

Karl G. Jansky Very Large Array

- VLA observations combining A, B, C and D array configurations
- 22 local (z < 0.065), most luminous U/LIRGs
- Observed at C (4 -8 GHz) and Ka (26.5 – 40 GHz) band
- ~40 min total on source
- High resolution: 0.08" (40 pc @ 100 Mpc) and 0.4"
- High sensitivity: 30 and 10 μJy/beam

FIRST SURVEY OF ITS KIND!

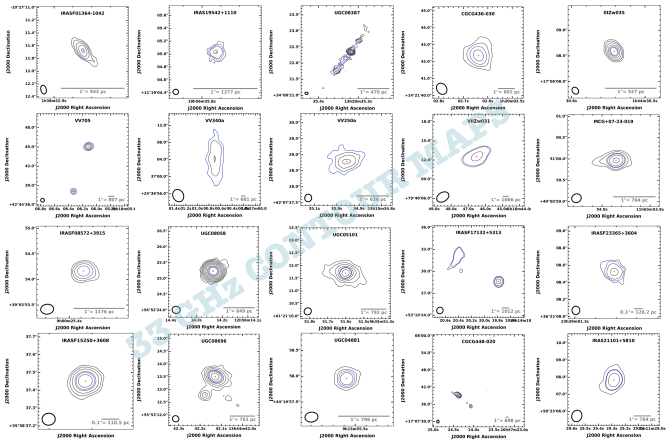


TABLE 1
CHARACTERISTICS OF THE SAMPLE GALAXIES

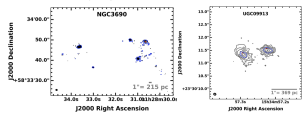
Galaxy Name (1)	Alternate Name (2)	R.A. (J2000) (3)	Decl. (J2000) (4)	$\log_{10}(L_{IR})$ (5)	D_L (6)	Id. number (7)
CGCG 436-030	MCG +02-04-025	$01^h20^m02.722^s$	+14°21′42″.94	11.64	127	1
IRAS F01364-1042	2MASXJ01385289-1027113	$01^h38^m52.921^s$	−10°27′11″.42	11.81	201	2
III Zw 035		$01^h44^m30.500^s$	+17°06′05″.00	11.58	111	3
VII Zw 031		$05^h16^m46.096^s$	+79°40′13″.28	11.95	229	4
IRAS 08572+3915		$09^h00^m25.390^s$	+39°03′54″.40	12.13	254	5
UGC 04881	Arp 55	$09^h15^m55.100^s$	+44°19′55″.00	11.70	169	6
UGC 05101		$09^h35^m51.595^s$	+61°21′11″.45	11.97	168	7
MCG +07-23-019	Arp 148	$11^h03^m53.200^s$	+40°50′57″.00	11.61	149	8
Arp 299	NGC 3690/IC 694[a]	$11^h28^m32.300^s$	+58°33′43″.00	11.82	45.2	9
UGC 08058	Mrk 231	$12^h56^m14.234^s$	+56°52′25″.24	12.52	181	10
VV 250a	UGC 08335 NED02	$13^h15^m34.980^s$	+62°07′28″.66	11.77	132	11
UGC 08387	Arp 193	$13^h20^m35.300^s$	+34°08′21″.00	11.65	101	12
UGC 08696	Mrk 273	$13^h44^m42.111^s$	+55°53′12″.65	12.15	162	13
VV 340a	UGC 09618 NED02	$14^h57^m00.826^s$	+24°37′04″.12	11.67	144	14
VV 705	I Zw 107	$15^h18^m06.344^s$	+42°44′36″.69	11.87	172	15
IRAS 15250+3608		$15^h26^m59.404^s$	+35°58′37″.53	12.02	238	16
UGC 09913	Arp 220	$15^h34^m57.116^s$	+23°30′11″.47	12.16	77.2	17
IRAS 17132+5313		$17^h14^m20.000^s$	+53°10′30″.00	11.90	217	18
IRAS 19542+1110		$19^h56^m35.440^s$	+11°19′02″.60	12.07	277	19
CGCG 448-020	II Zw 096	$20^h57^m23.900^s$	+17°07′39″.00	11.79	148	20
IRAS 21101+5810	2MASX J21112926+5823074	$21^h11^m30.400^s$	+58°23′03″.20	11.74	162	21
IRAS F23365+3604	2MASX J23390127+3621087	$23^h39^m01.273^s$	+36°21′08″.31	12.16	273	22

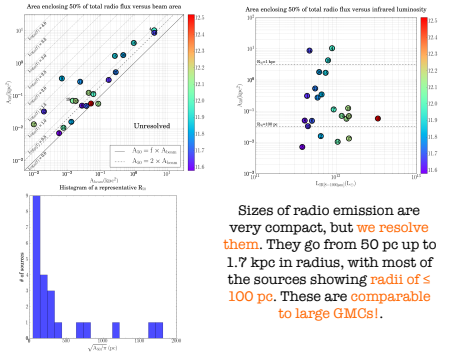
NOTE. — Column 1: Name of the galaxy; Column 2: alternate name; Column 3: Source right ascension (J2000) from NED; Column 4: Source declination (J2000) from NED; Column 5: total infrared luminosity in $\log_{10}$ Solar units computed from the IRAS flux densities from Sanders et al. (2003) and following the equation from Sanders & Mirabel (1996); Column 6: luminosity distance from NED; Column 7: Number used to identify each system in some of the figures presented in this paper.

[a]Arp 299 has two components, NGC 3690 (west) and IC 694 (east)

RESULTS: FROM 33 GHz OBSERVATIONS

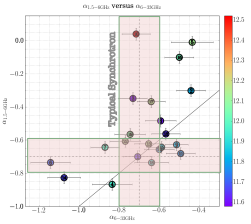
Barcos-Muñoz et al. in prep



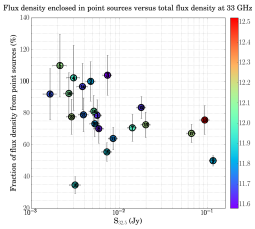


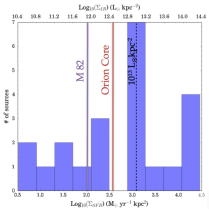
Sizes of radio emission are very compact, but we resolve them. They go from 50 pc up to 1.7 kpc in radius, with most of the sources showing radii of ≤ 100 pc. These are comparable to large GMCs!.

The nature of the radio emission for most of the sources is synchrotron, and some of them show a curvature in their spectrum due to change in optical depth between 1.5 and 33 GHz.



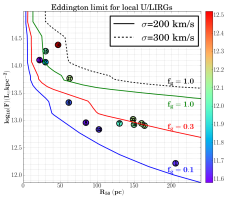
For the majority of our systems, the radio emission is originated in point sources, which is consistent with the compactness observed.





Even though we observe the brightest U/LIRGs there is wide range of environments with 4 dex in S_{SFR} (and S_{IR})

Most extreme systems are at least 2 – 100 times more extreme than Orion core



Most systems show $\Sigma_{IR} \geq 10^{13}$ $L_\odot kpc^{-2}$, the dusty Eddington limit, but are not maximal starbursts

AGN emission is not required to explain the high values of Σ_{IR} that we derive

CONCLUSIONS:

- First high resolution, high sensitivity, 33 GHz survey of local U/LIRGs.
- The size of the active regions are very compact (≤ 100 pc). Comparable to large GMCs!.
- The nature of the emission is mostly synchrotron, and originated in point sources.
- Very extreme systems, but still not maximal starbursts.

MORE EXCITING RESULTS: ASK ME!