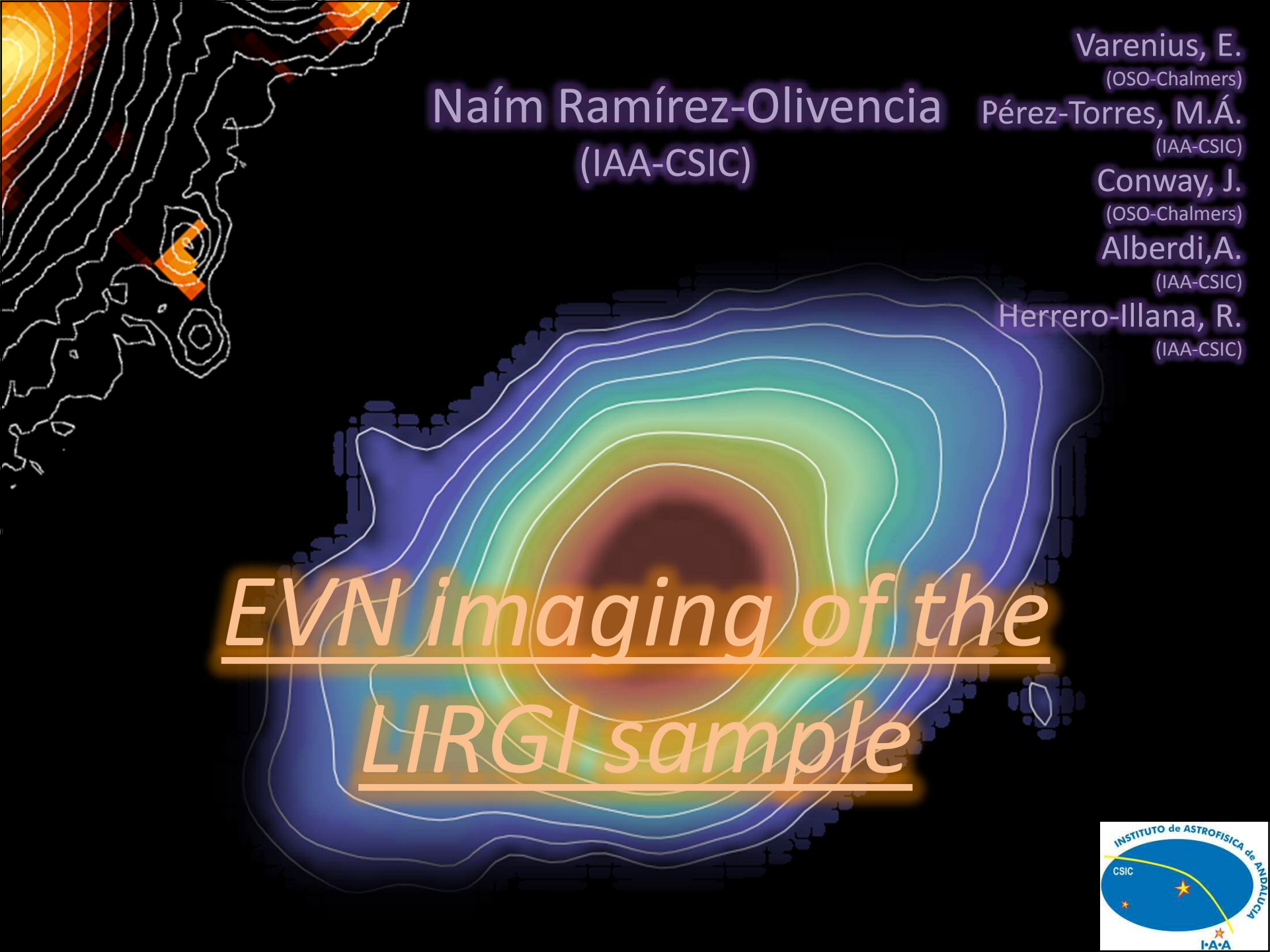


EVN imaging of the LIRGI sample

Naím Ramírez-Olivencia
(IAA-CSIC)

Varenius, E.
(OSO-Chalmers)

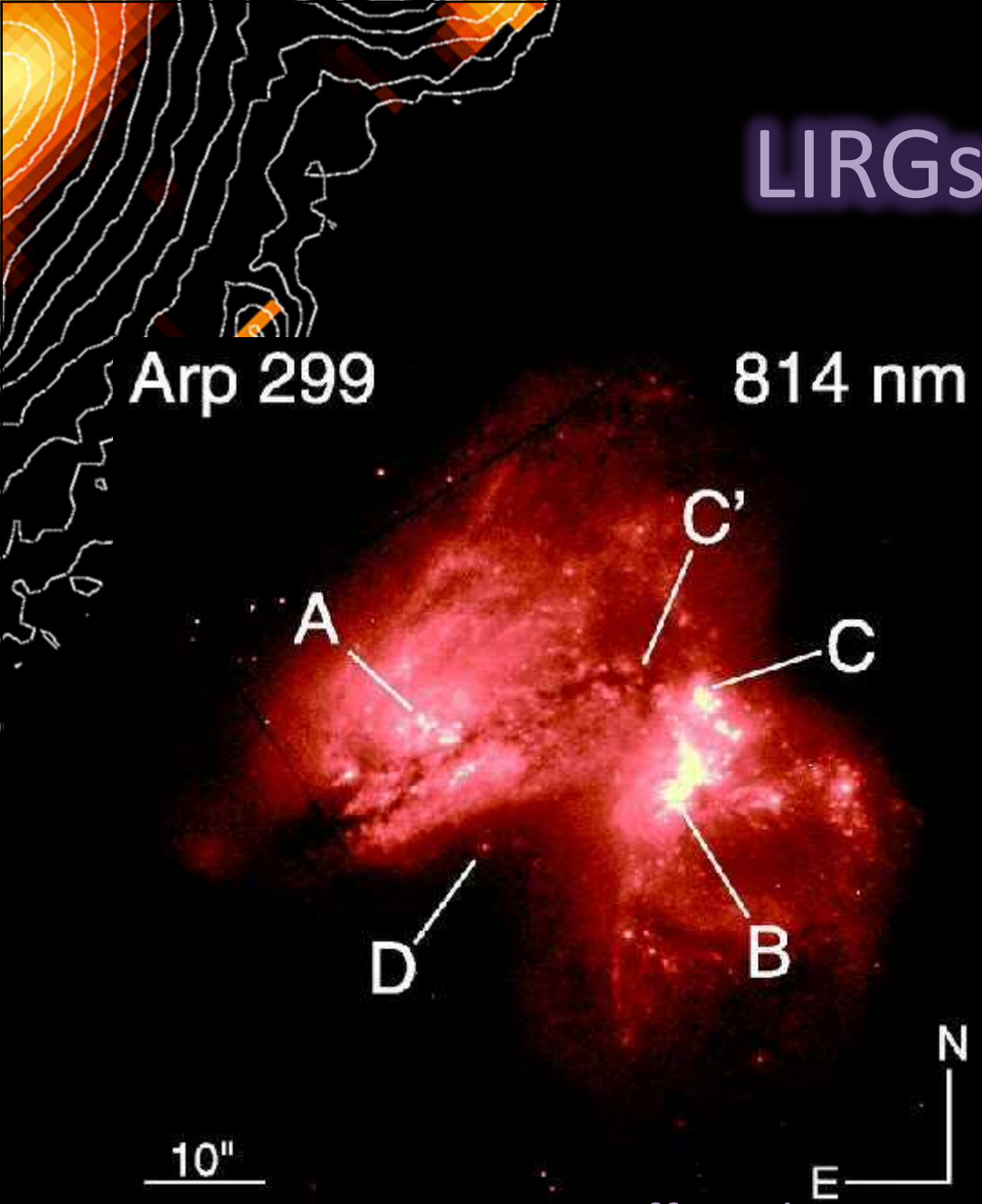
Pérez-Torres, M.Á.
(IAA-CSIC)

Conway, J.
(OSO-Chalmers)

Alberdi,A.
(IAA-CSIC)

Herrero-Illana, R.
(IAA-CSIC)

LIRGs



Neff et al. 2004

LIRGs

$10^{11} L_{\odot} < L_{IR} < 10^{12} L_{\odot}$

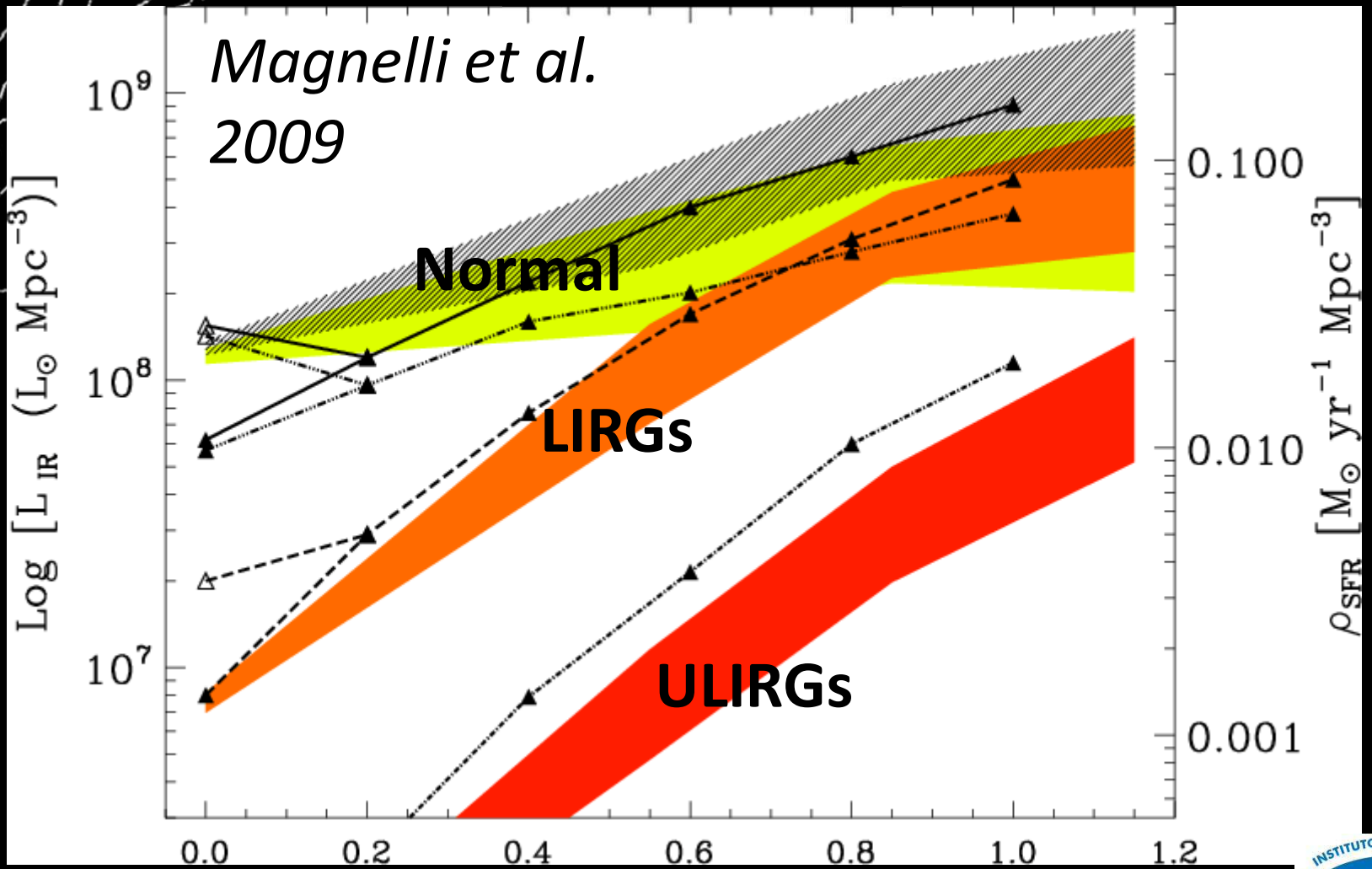
ULIRGs

$L_{IR} > 10^{12} L_{\odot}$

Interacting galaxies

AGN vs. starburst

LIRGs


Magnelli et al.
2009
Normal
LIRGs
ULIRGs
10^9
10^8
10^7
Log [L_{IR} ($L_\odot$ Mpc^{-3})]
0.100
0.010
0.001
ρ_{SFR} [$M_\odot$ yr^{-1} Mpc^{-3}]
0.0
0.2
0.4
0.6
0.8
1.0
1.2
Redshift

Luminous InfraRed Galaxies Inventory (LIRGI)

eMERLIN legacy survey

J.Conway **&** **M.Á. Pérez-Torres**

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Lu xies

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Antxon Alberdi	IAA-CSIC, Granada, Spain
Phil Appleton	NASA Herschel Science Center, Caltech, USA
Willem Baan	ASTRON, The Netherlands
Fabien Batejat	Onsala Space Observatory, Chalmers, Sweden
Rob Beswick	JBCA, Manchester, UK
Luis Colina	DAMIR, Madrid, Spain
John Conway	Onsala Space Observatory, Chalmers, Sweden
Francesco Costagliola	IAA-CSIC, Granada, Spain
Phil Diamond	JBCA, Manchester, UK
Denise Gabuzda	University College Cork, Ireland
Simon Garrington	JBCA, Manchester, UK
Rubén Herrero-Illana	IAA-CSIC, Granada, Spain
Hans-Rainer Klockner	Oxford, UK
Colin Lonsdale	MIT, Cambridge, USA
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Sebastien Muller	Onsala Space Observatory, Chalmers, Sweden
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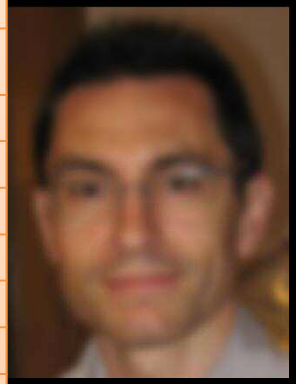
Ray Norris	CSIRO, Australia
Miguel Ángel Pérez-Torres	IAA-CSIC, Granada, Spain
Naím Ramírez-Olivencia	IAA-CSIC, Granada, Spain
Rodrigo Parra	ESO, Chile
Ylva Pihlström	University of New Mexico, USA
Mónica Rodríguez	IAA-CSIC, Granada, Spain
Cristina Romero-Cañizales	IA, Pontificia Universidad Catolica, Chile
José-María Torrelles	CSIC-IEEC, Barcelona, Spain
Eskil Varenius	Onsala Space Observatory, Chalmers, Sweden



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Luminous InfraRed Galaxies Inventory (LIRGI)

eMERLIN legacy survey

J.Conway **&** **M.Á. Pérez-Torres**

42 (7 already observed) of the most Luminous northern LIRGs
(8 ULIRGs)

Luminous InfraRed Galaxies Inventory (LIRGI)

Luminous InfraRed Galaxies Inventory (LIRGI)

eMERLIN legacy survey

J.Conway **&** **M.Á. Pérez-Torres**

42 (7 already observed) of the most Luminous northern LIRGs
(8 ULIRGs)

$$\log(L_{IR}/L_{\odot}) > 11.4$$

D < 250 Mpc

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Luminous InfraRed Galaxies Inventory (LIRGI)

$\delta > 8°$

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Luminous InfraRed Galaxies Inventory (LIRGI)

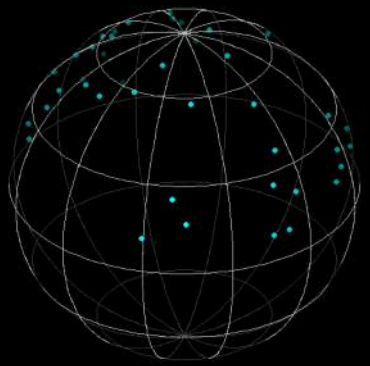
eMERLIN legacy survey

J.Conway & **M.Á. Pérez-Torres**

http://lirgi.iaa.es

42 (7 already observed) of the most Luminous northern LIRGs
(8 ULIRGs)

$\log(L_{IR}/L_{\odot}) > 11.4$



D < 250 Mpc

$\delta > 8°$

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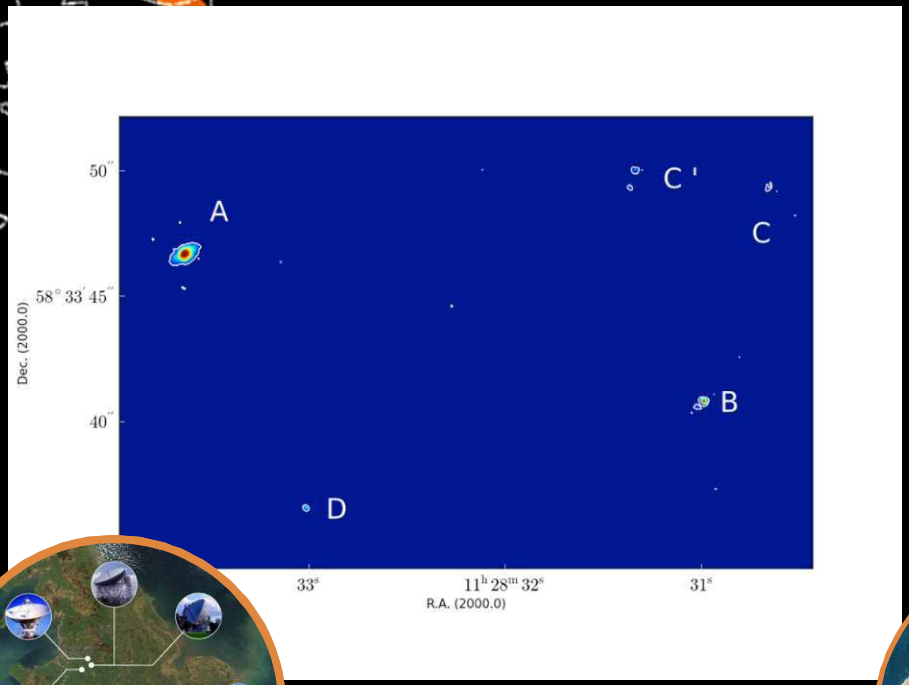
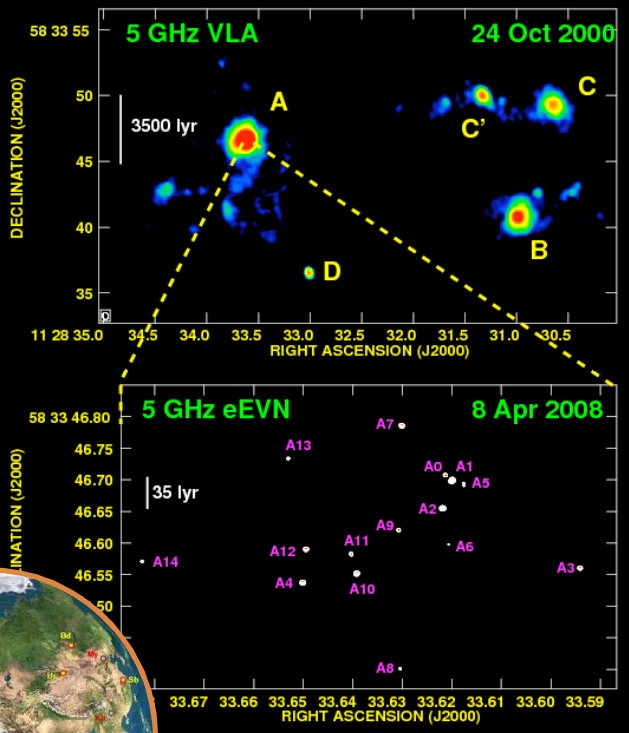
LIRGI observations

Diffuse emission



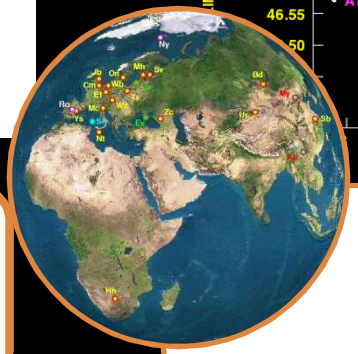
Herrero-Illana et al. 2013 - ATel

Compact Sources

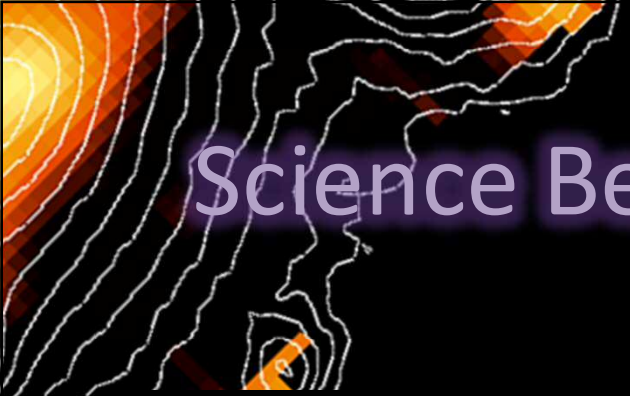


Pérez-Torres et al. 2009

eMERLIN

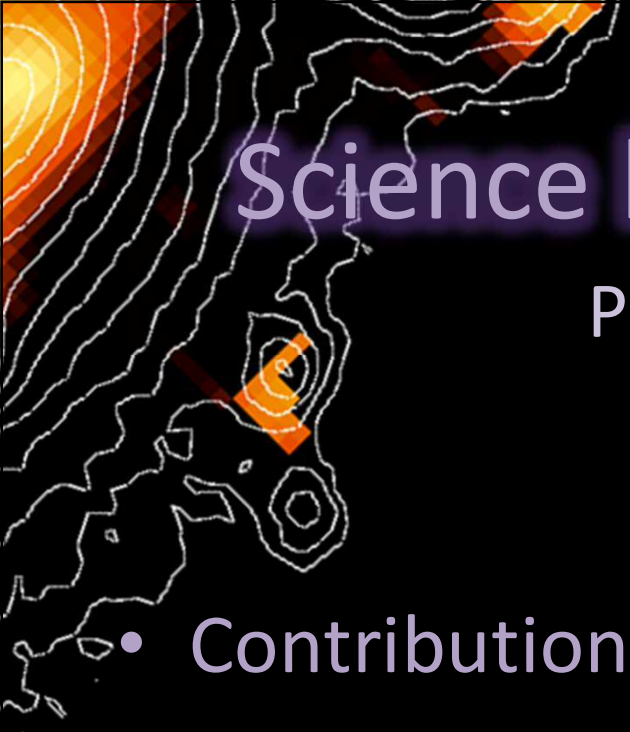


EVN



Science Behind LIRGI with eMERLIN

- Map **diffuse radio emission**
- Trace the **free-free absorption** with high resolution
- Measure **magnetic field** strengths
- Obtain **dynamical masses**
- Spatial variations in **chemistry** and **physical** conditions

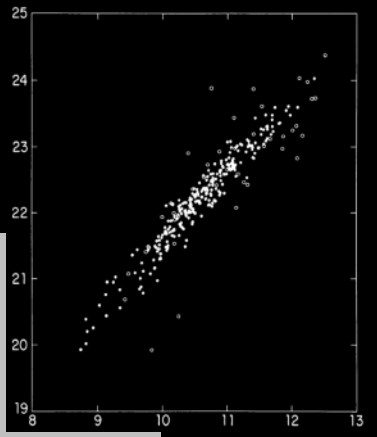


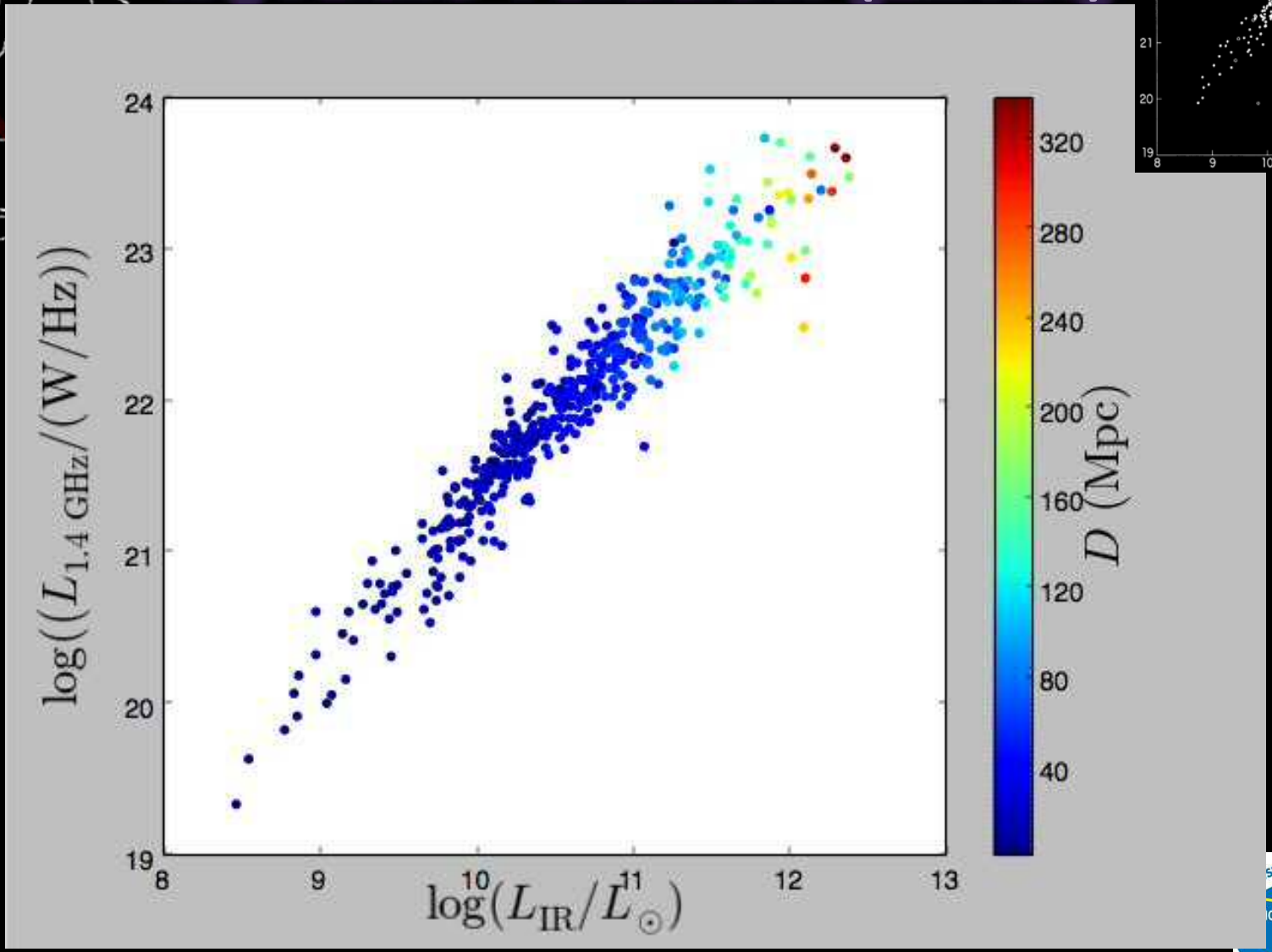
Science behind LIRGI with EVN

PI: M.Á.Pérez-Torres

- Contribution of **AGNs** and **starbursts**
- Detection and measurement of Supernova Remnants (**SNRs**)
- Core Collapse Supernova (**CCSN**) rate

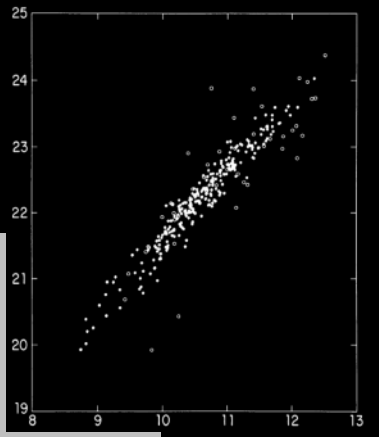
IR/radio relation (LIRGI)

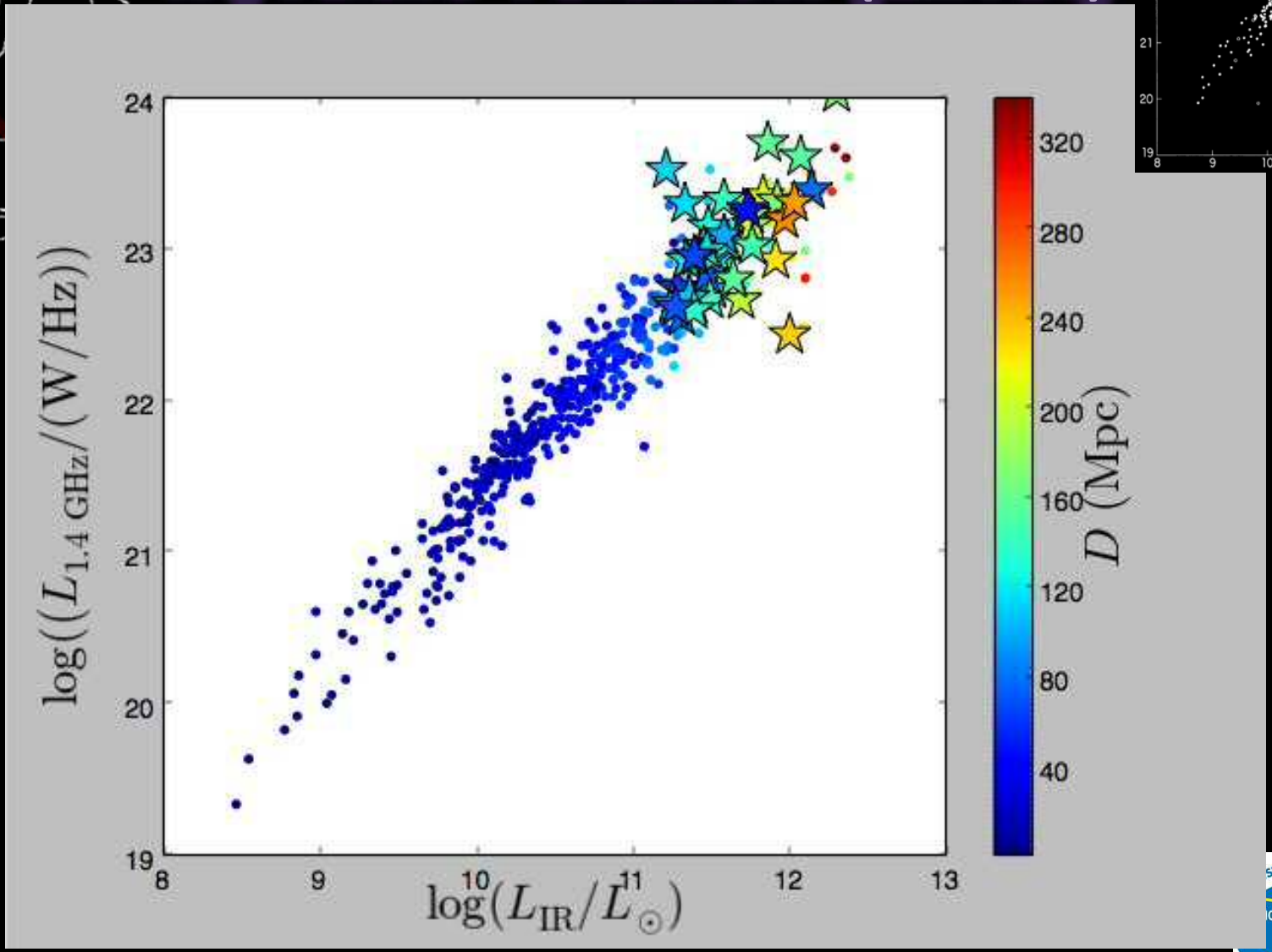




Yun et al. 2001

IR/radio relation (LIRGI)





Yun et al. 2001

LIRGI observing requests for EVN

- Contemporaneous C- and L-band
- 1 Gb/s
- Off source rms$\leqq$10 $/beam$ both bands
- Integration time $\simeq 80m$
- Mutiple pointings, multiple correlations

LIRGI observations with EVN

- Experiments: EP076 (A,B,C,D) and EP088(A,B,C,D).
- Incoming EP088(E,F)
- EP088(G,H) to observed this October
- Antennas observing :

Effelsberg
Westerbork
Jodrell Bank (Lovell)
Onsala
Medicina
Torun
Yebes (Cband)

Svetloe
Zelenchukskaya
Badary
Urumqui
Shangai
Hartebeesthoek

LIRGI observations with EVN

- Sources obtained:

18/35 LIRGs in LIRGI!
(12 reduced)

MRK0331
MCG+12-02-00
III ZW035
IRAS03359+15
IC5298
NGC2623
NGC5256
NGC7674
IRASF17132
IRAS10565
VV340
CGCG448
IRASF15250
NGC6090
NGC6670
NGC0695
VV250
VV705

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LIRGI observations with EVN

- EP076 (A,B,C,D)(session 3, 2012)

Galaxy	Distance	L_{IR}	$L_{1.7GHz}$	$rms_{1.7GHz}$	L_{5GHz}	rms_{5GHz}
	$[Mpc]$	$[L_\odot]$	$\left[\times 10^{26} erg \cdot s^{-1} Hz^{-1}\right]$	$\mu Jy/beam$	$\left[\times 10^{26} erg \cdot s^{-1} Hz^{-1}\right]$	$\mu Jy/beam$
IC5298	108	11.54	15.70	25	2.12	26
MRK0331	106	11.56	17.8	71	27.6	42
III ZW035	107	11.56	15.1	22	68.4	31
IRAS03359+15	137	11.47	15.6	20	33.0	25
MCG+12-02-00	64	11.44	13.0	28	15.5	31
NGC2623	77.43	11.54	1235.6	454	2557.8	269
NGC5256A,B,C	116	11.49	67	64.23	38.1	43

LIRGI observations with EVN

- EP088 (C ,D)(session 1, 2014)

Galaxy	Distance	L_{IR}	$L_{1.7GHz}$	$rms_{1.7GHz}$	L_{5GHz}	rms_{5GHz}
	$[Mpc]$	$[L_\odot]$	$\left[\times 10^{26} erg \cdot s^{-1} Hz^{-1}\right]$	$\mu Jy/beam$	$\left[\times 10^{26} erg \cdot s^{-1} Hz^{-1}\right]$	$\mu Jy/beam$
IRASF10565	176	12.02	2441.2	395	2380.7	77.66
VV340A	139	11.67	18.46	20	36.6	18
CGCG448	144	11.87	27.4	22	26.3	17
NGC6670A	118	11.6	15.7	15	15.36	20
IRASF15250	223	12.02	176.3	45	595.0	20

LIRGI observations with EVN

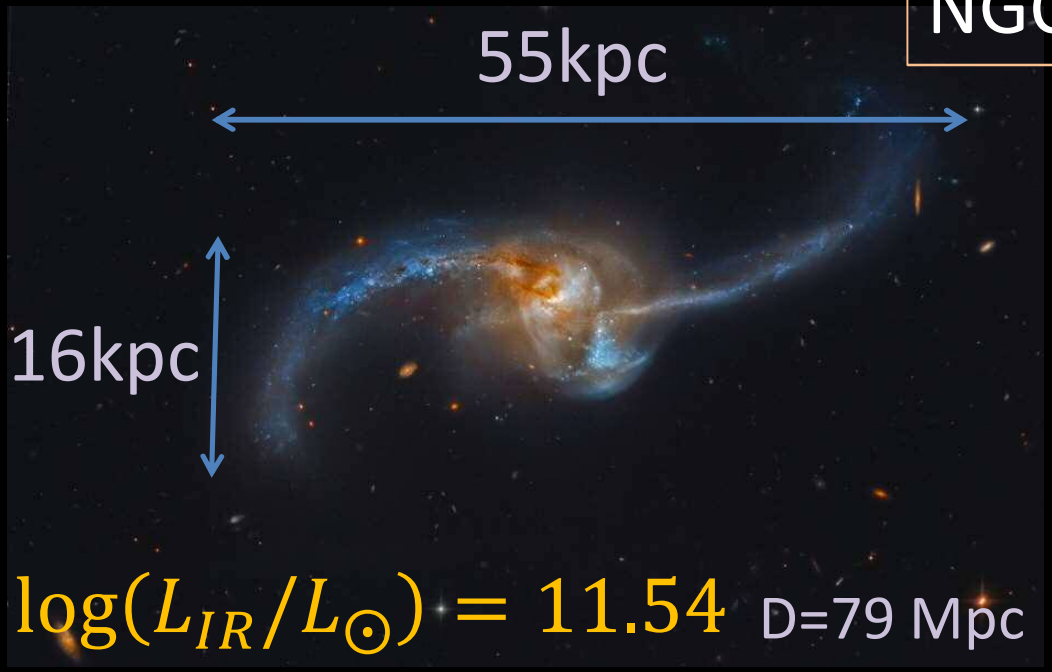
Galaxy	L-band	C-band
IRASF10565	✓	✓
VV340A	✓	
CGCG448		
NGC6670		
IRASF15250	✓	✓
IC5298		✓
MRK0331		✓
III ZW035		✓
IRAS03359+15		
MCG+12-02-00		
NGC2623	✓	✓
NGC5256A	✓	

Typical values: $10^{27} - 10^{28}\ erg \cdot s \cdot Hz^{-1}$

Associated luminosity with rms: $< 5 \cdot 10^{25} erg \cdot s \cdot Hz^{-1}$

LIRGI observations with EVN

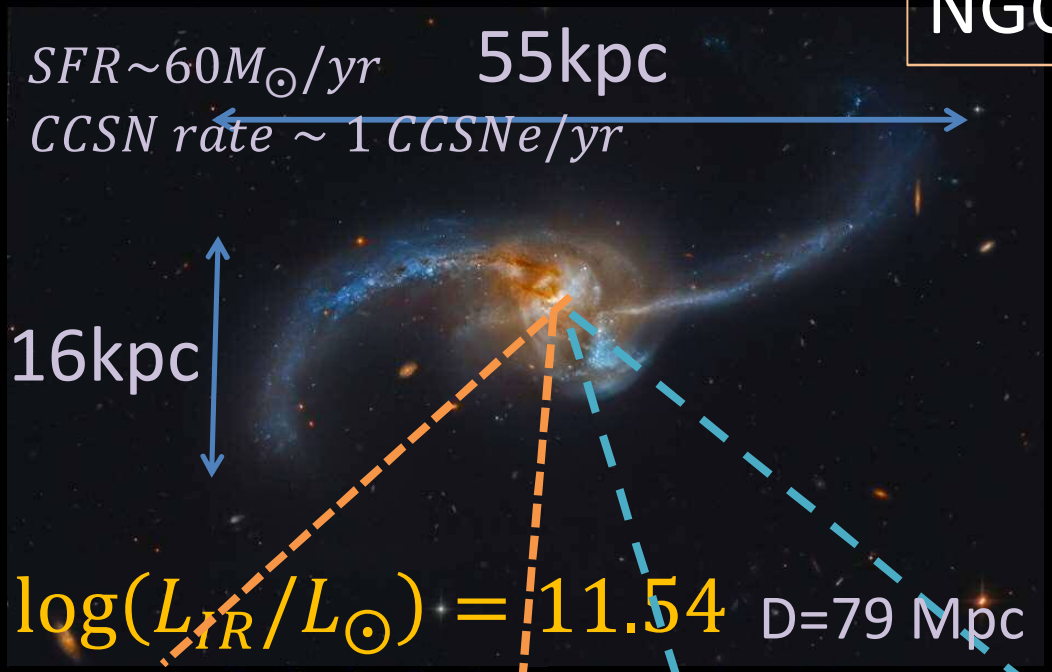
NGC2623



$\log(L_{IR}/L_{\odot}) = 11.54$ D=79 Mpc

LIRGI observations with EVN

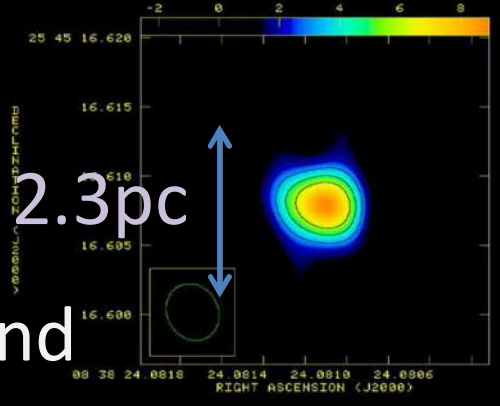
NGC2623



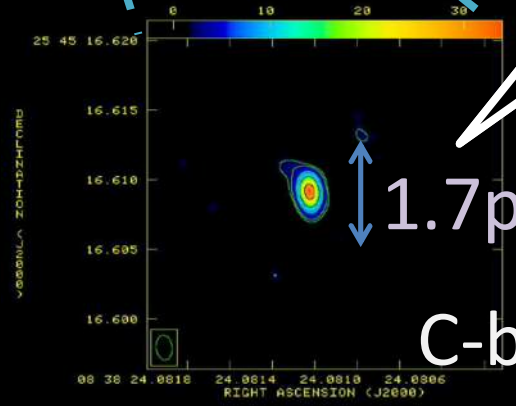
$\alpha_L^C = 0{,}67$

$L_{1.7GHz} = \mathbf{1{,}2 \cdot 10^{29}} erg \cdot s^{-1} \cdot Hz^{-1}$

$L_{5GHz} = \mathbf{2{,}6 \cdot 10^{29}} erg \cdot s^{-1} \cdot Hz^{-1}$



L-band



C-band

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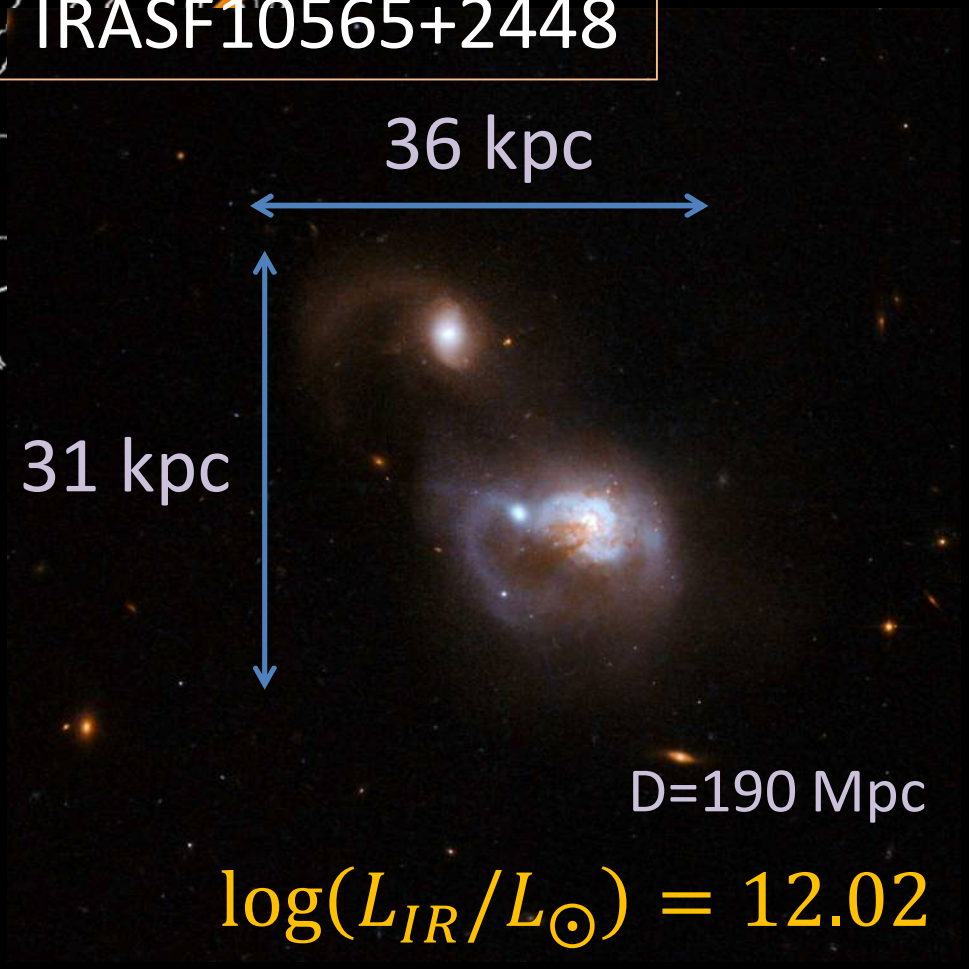
LIRGI observations with EVN

IRASF10565+2448



$$\log(L_{IR}/L_{\odot}) = 12.02$$

LIRGI observations with EVN

IRASF10565+2448

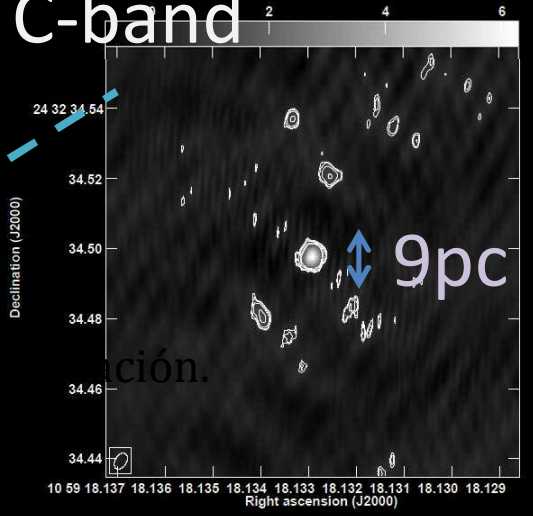
36 kpc

31 kpc

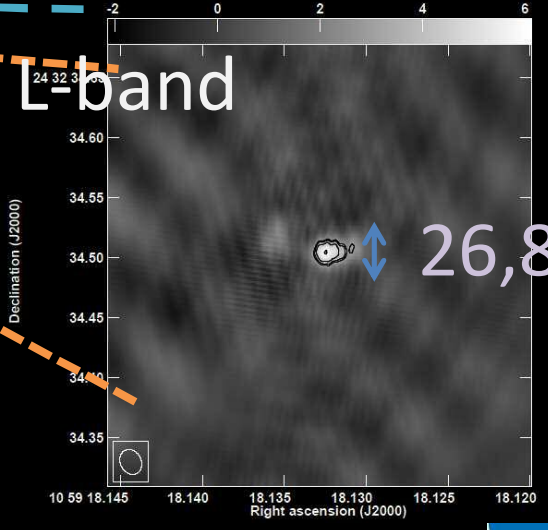
D=190 Mpc

$\log(L_{IR}/L_{\odot}) = 12.02$

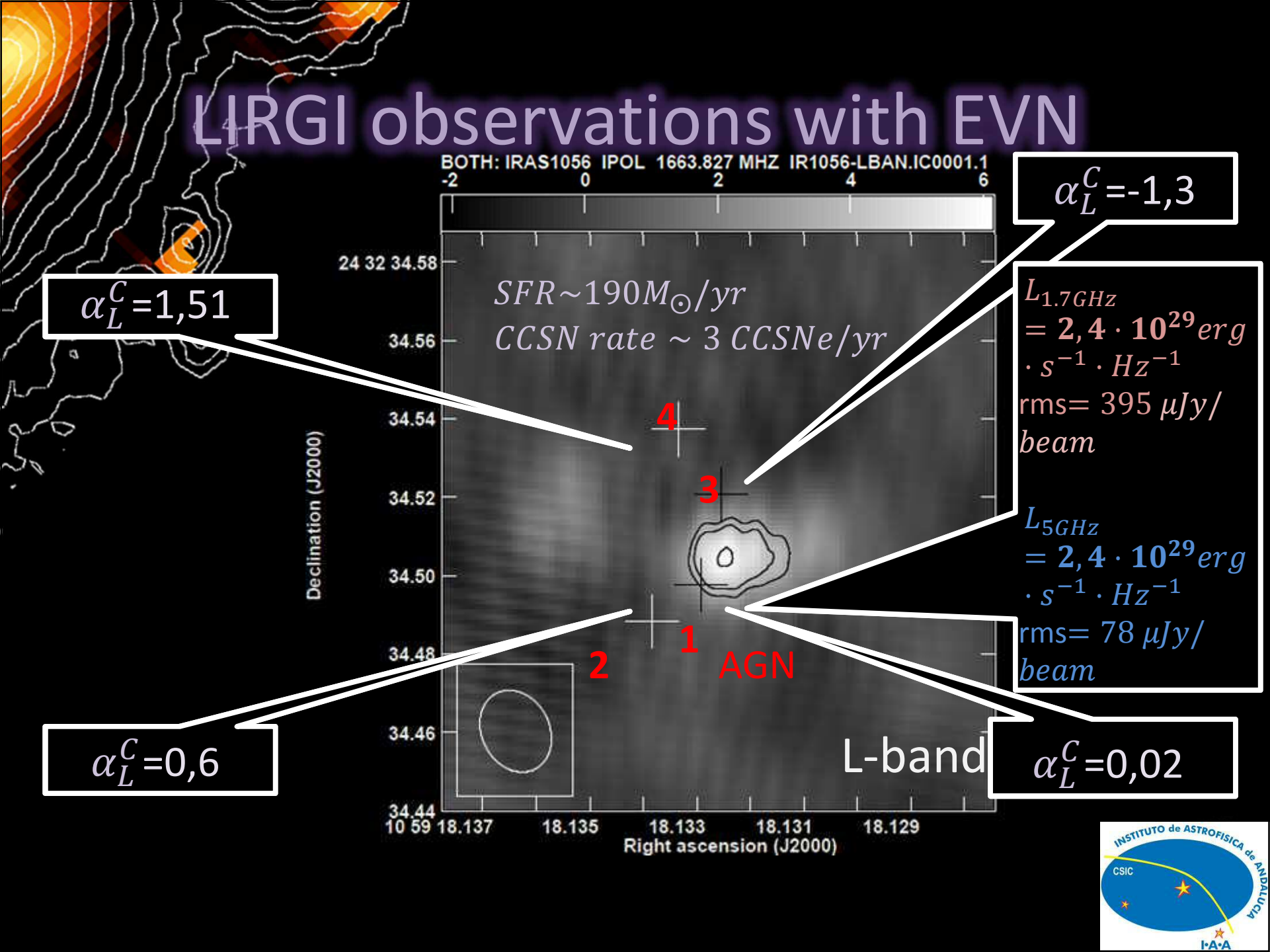
C-band



L-band

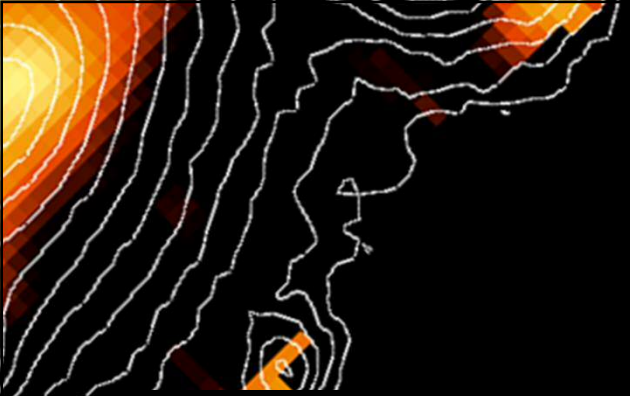


LIRGI observations with EVN



Summary

- Observations of high resolution at radio wavelenghts of 18/35 LIRGs of the LIRGI survey
- Detections at both bands:
  - L band: 2
  - C band: 3
  - Both bands: 3
- rms ~25-30 μJy/b, about twice the expected value
- Detection of compact components with lower limits (3-sigma) of ~ $10^{27} erg \cdot s \cdot Hz^{-1}$, typical of supernovae and/or supernova



Summary

- In good agreement with the expected CCSN rate
- Good detection of at least 2 AGNs (evidence both in the espectral index and luminosity)
- Overall, our current EVN observations show evidence for:
  - AGN dominated nuclear sources (e.g. NGC 2623)
  - Mixing of SB and AGN activity (e.g., IRAS10565+2448)
  - SB-dominated sources (several non-detections => diffuse synchrotron emission)

Future Work with LIRGI

- Remaining 17 U/LIRGs.
- Incoming observations with eMERLIN
- Improvement of the last epoch images
- Complete the catalog with new information (SNRs, AGN (yes/no), spectral index)
- **Offer the complete legacy project for the scientific community**


THANK YOU!