LIRGS and (U-)LIRGs with eMERLIN and the EVN

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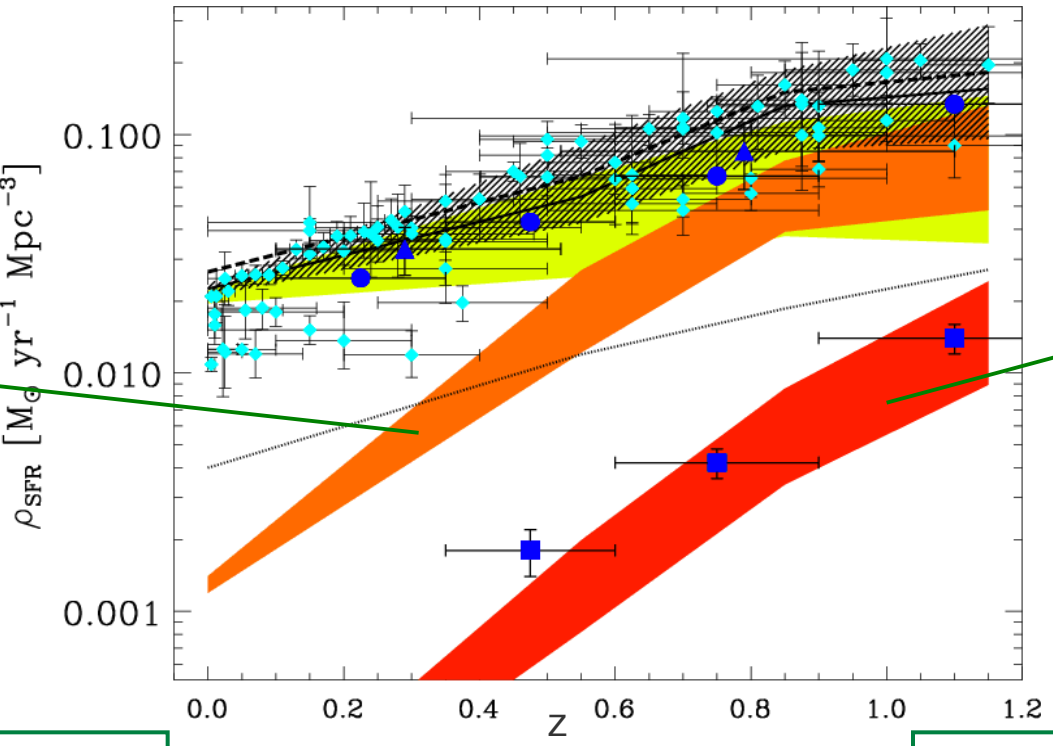
+ R. Beswick + M.Argo+ C. Romero-Cañizales,
+ LIRGI Team ...)

"JBO in the SKA era"
Manchester, 15 September 2016

(U)LIRGs: scaled up starbursts

LIRGs



ULIRGs

- $L_{IR} > 10^{11}$ L_{sun}
- z~1 (Le Floc'h +05)

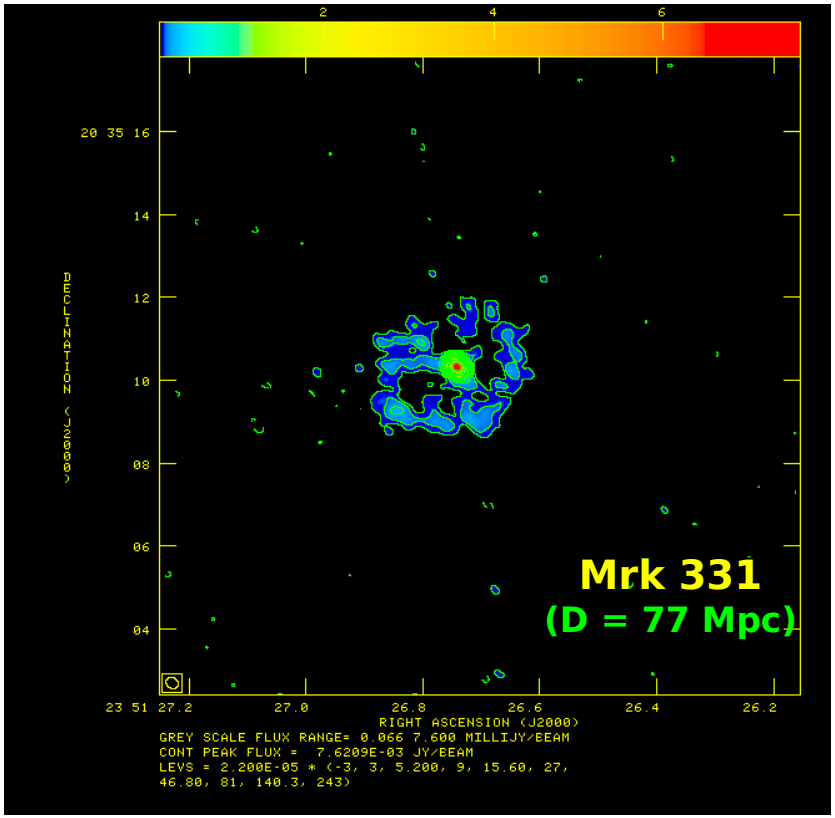
- Significant fraction of the SF at high-z took place in (U-)LIRGs
- Detection of SNe crucial for revising CCSN rates both locally and at high-z

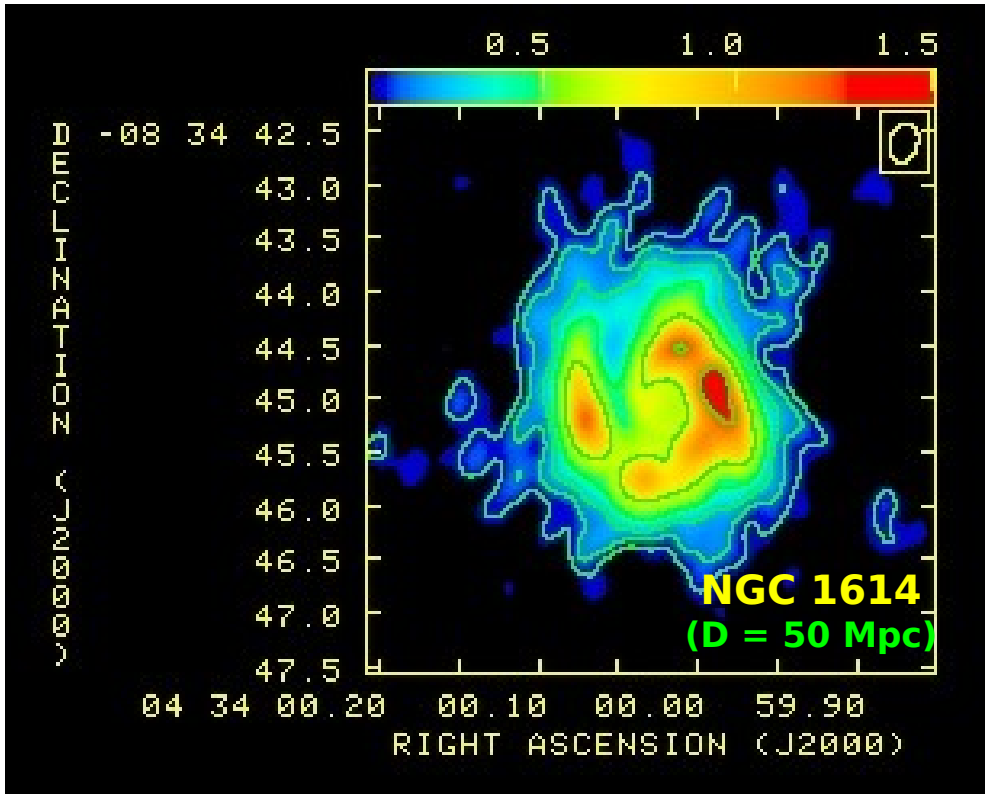
- $L_{IR} > 10^{12}$ L_{sun}
- z~2 (Caputi +07)

(Magnelli et al., 2009)

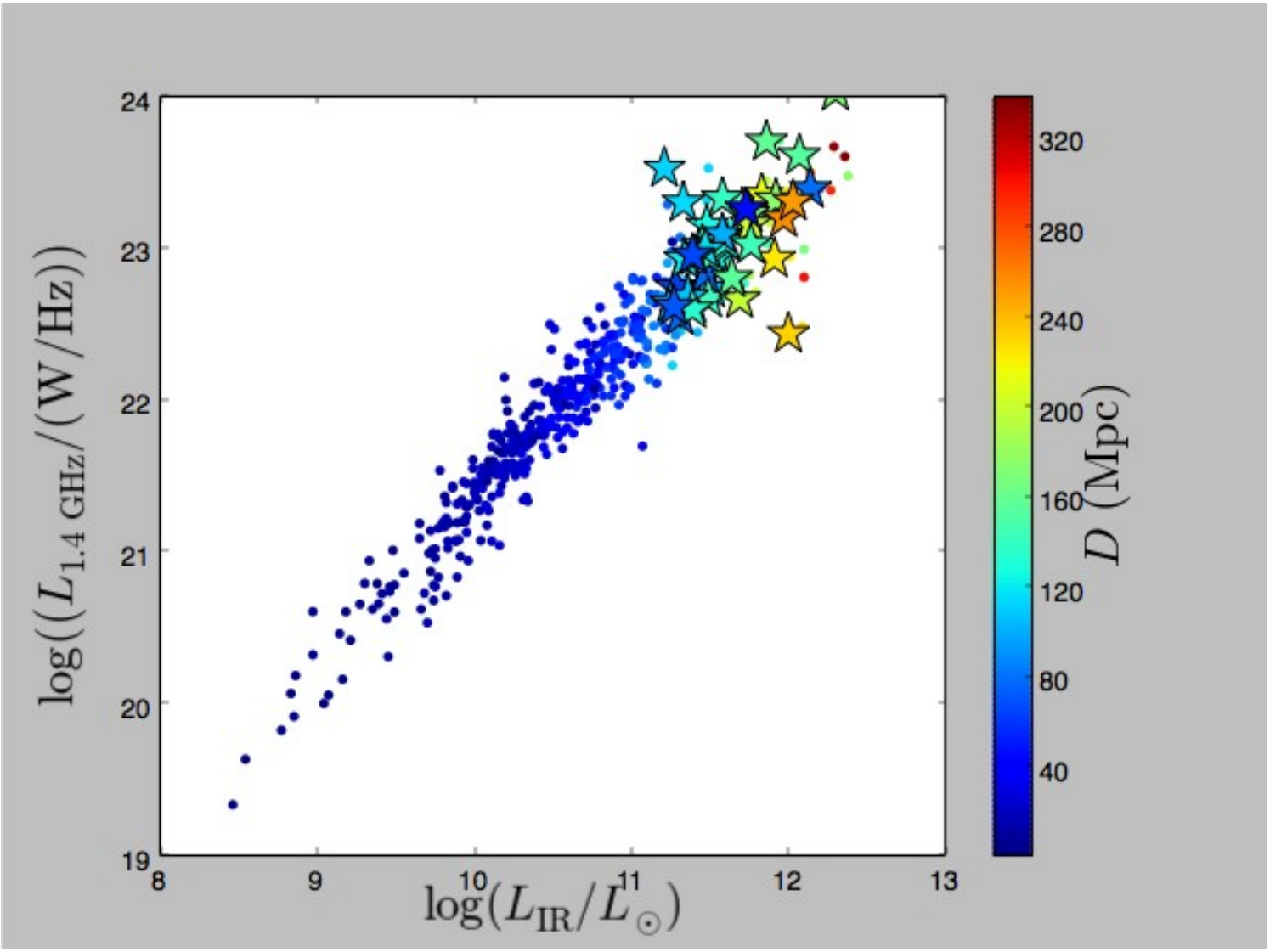
Radio Observations of Starburst Galaxies

- **Compact (≤150 pc) high surface brightness ($T_b \geq 10^3$ K)** central radio source → generated by a point-like source (AGN) and/or by the combined effect of SNe and RSNe
- **Low surface brightness circumnuclear halo** → ongoing burst of star formation





LIRGI: eMERLIN Legacy Project



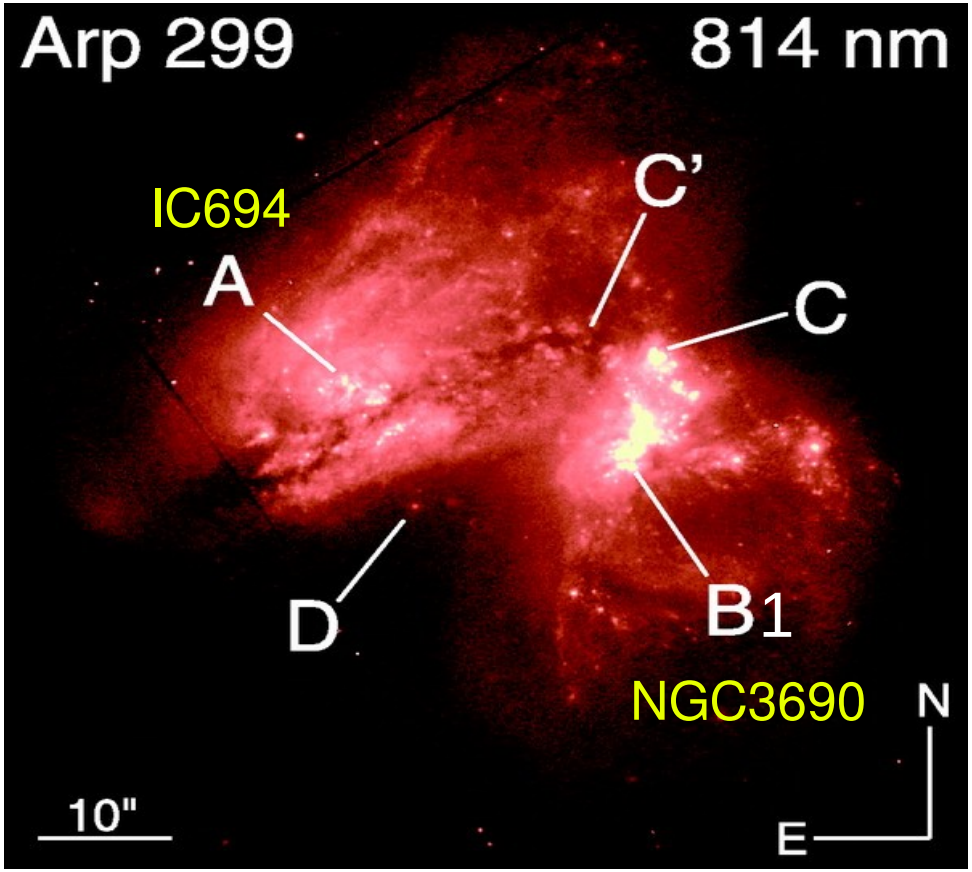
LIRGI: Science with eMERLIN

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

LIRGI: Science with the EVN

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

Arp299



HST -**WFPC2** 814nm image (Neff et al., 2004)

Early stage merger

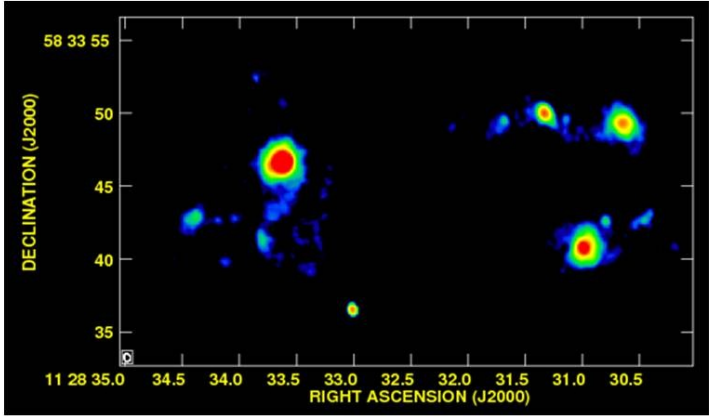
- D ~ 45 Mpc → 1 mas ~ 0.2 pc

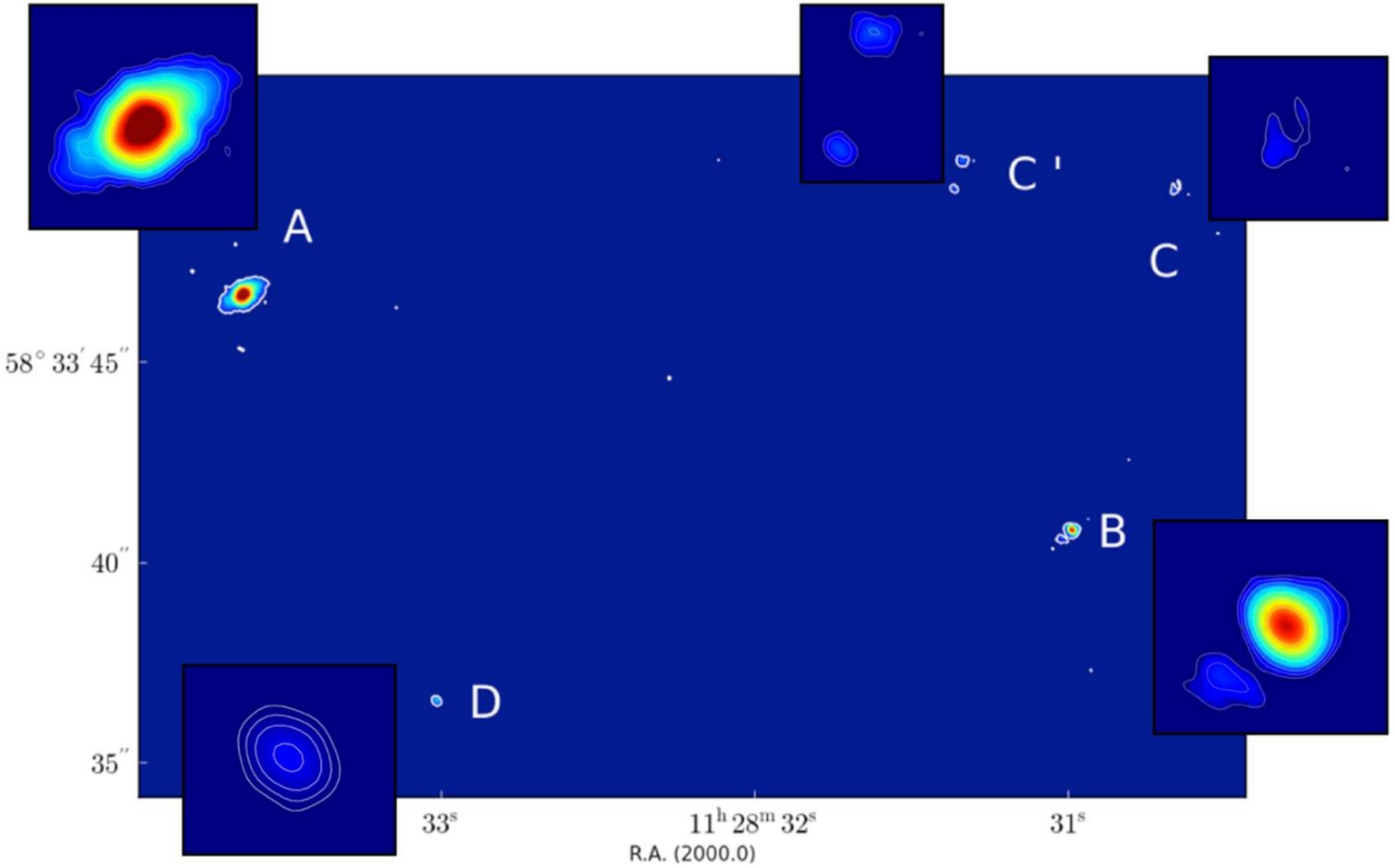
- L_{IR} ~ 6.7 x 10^{11} L_{sun}

  ~ 40% in A → $\nu_{CCSN} \approx 0.8\ yr^{-1}$

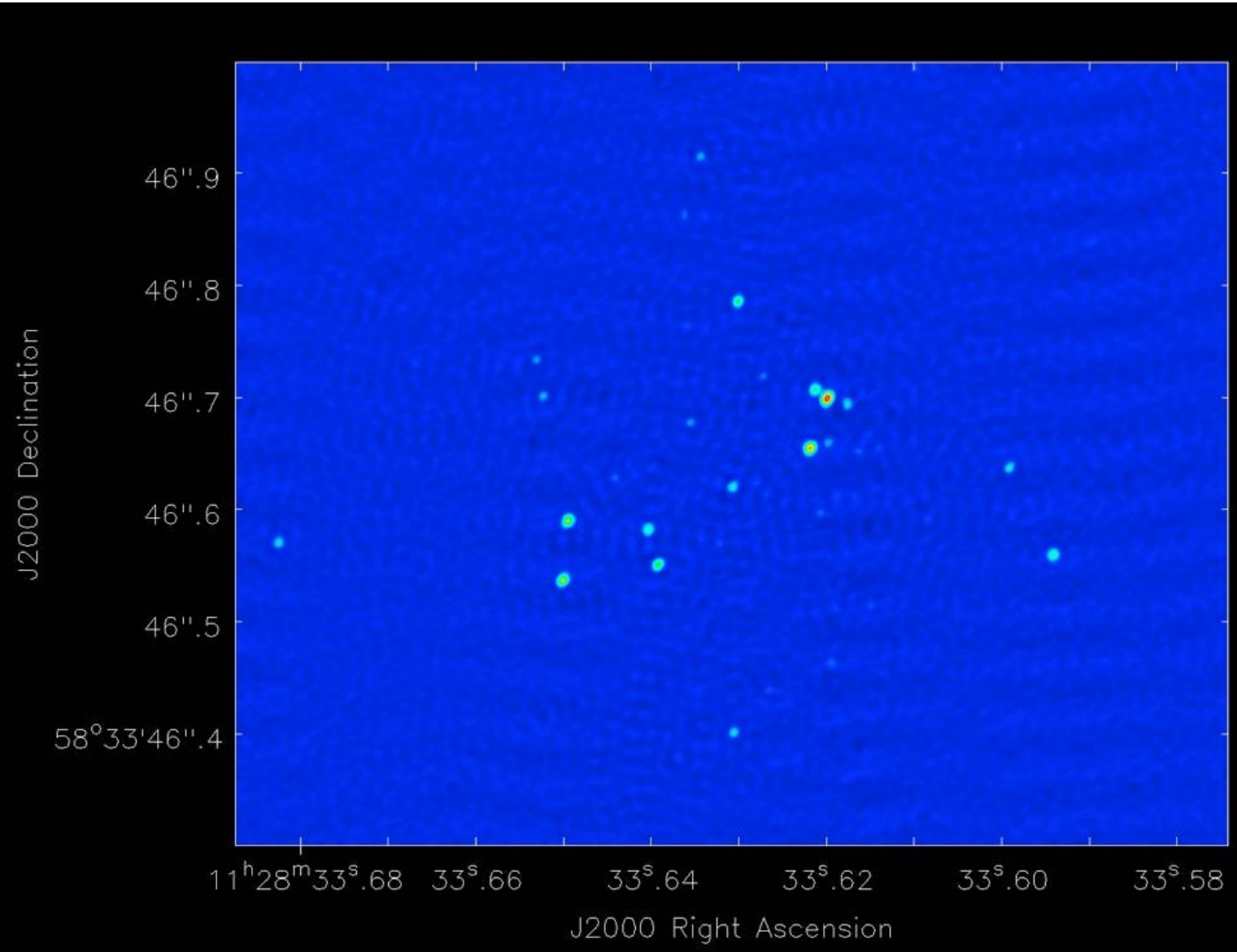
  ~ 20% in B1 → $\nu_{CCSN} \approx 0.4 yr^{-1}$

Arp 299: eMERLIN Image

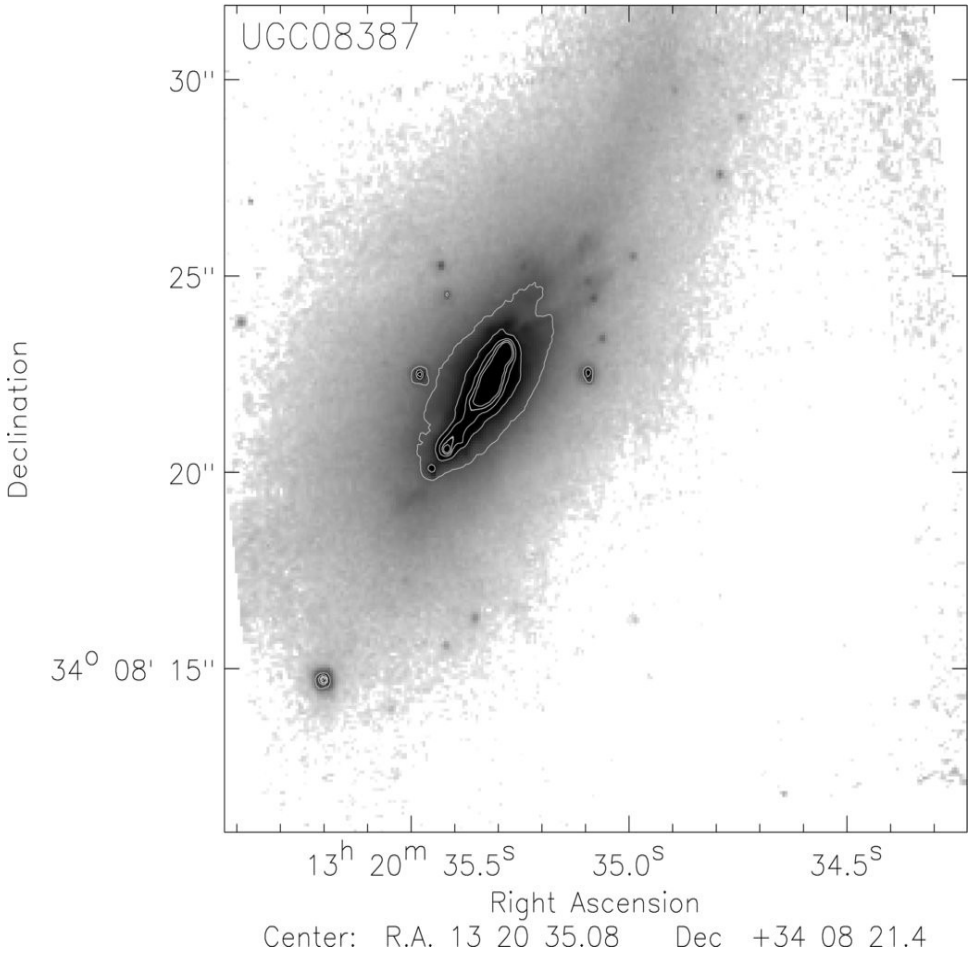




The Arp 299-A lab: Summary



IC883



Advanced stage merger (starburst-AGN composite)

- D ~ 100 Mpc → 1 mas ~ 0.5 pc
- $L_{IR} \sim 4.7 \times 10^{11} L_{sun}$ →

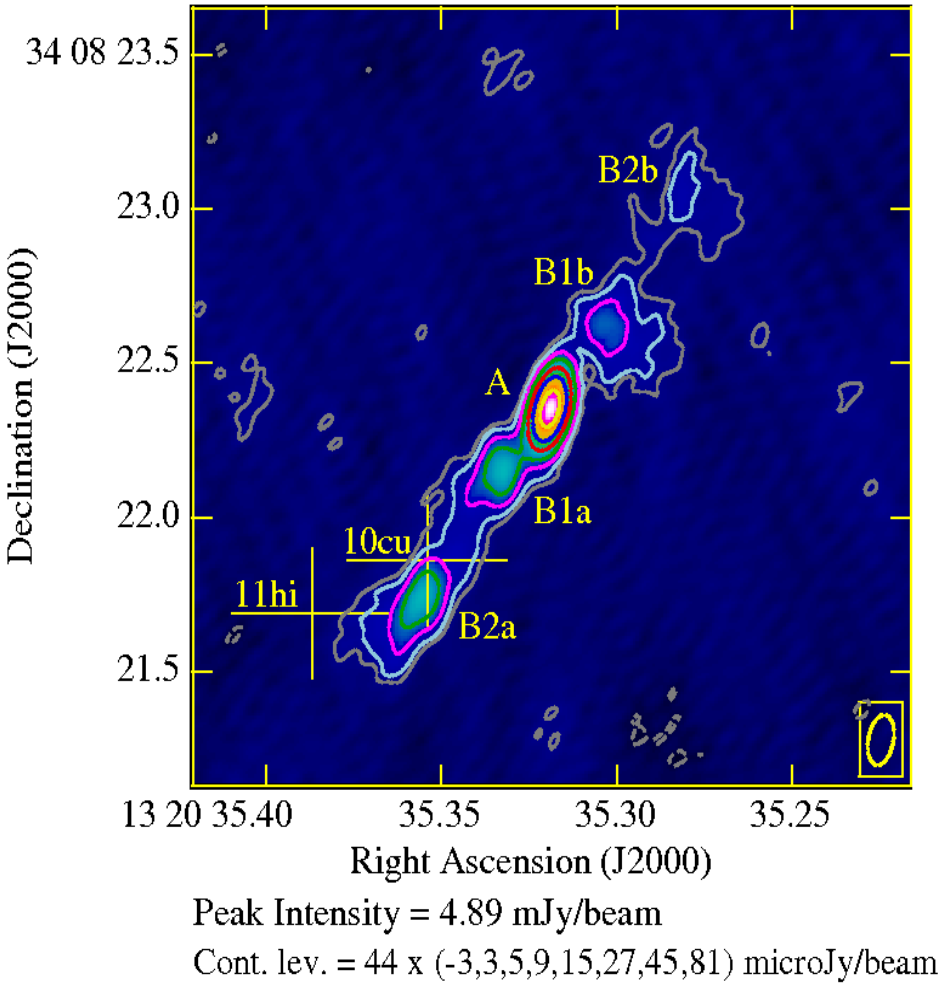
$\nu_{CCSN} \approx 2.4\ yr^{-1}$

Two new SNe discovered: SN 2010cu (Ryder et al., 2010) & SN 2011hi (Kankaré et al. 2011)

$\nu_{CCSN} \approx 2_{-1.3}^{+2.6} yr\text{-}1$

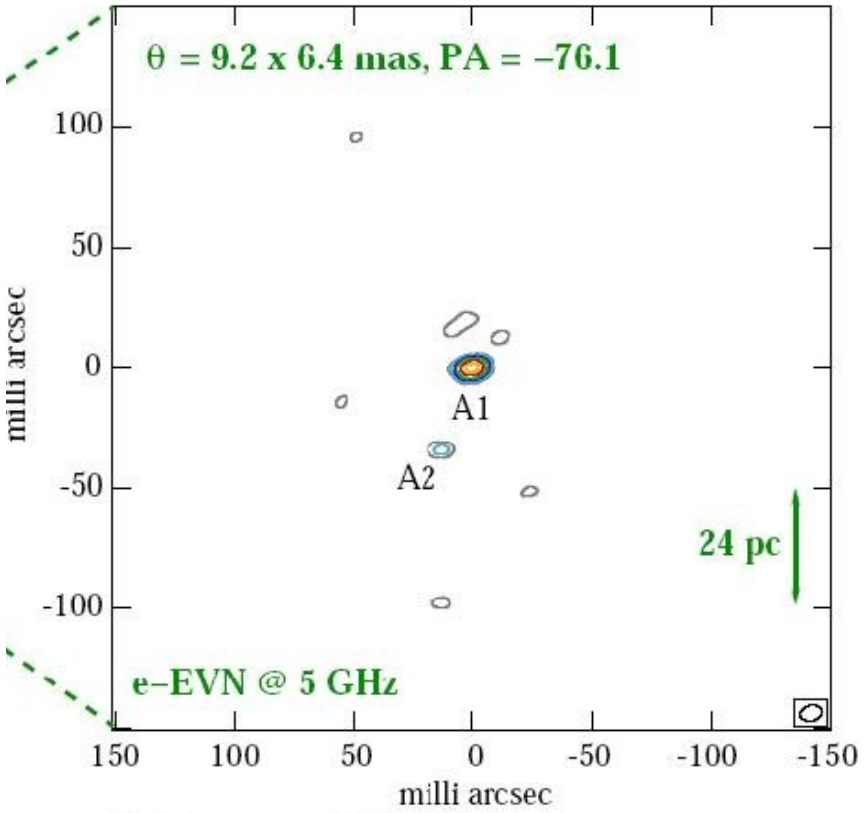
HST -**NICMOS** 1.6 μm image (Haan et al., 2011)

IC 883: e-MERLIN + e-EVN observations



Peak Intensity = 4.89 mJy/beam

Cont. lev. = 44 x (-3,3,5,9,15,27,45,81) microJy/beam



Peak Intensity = 3.82 mJy/beam

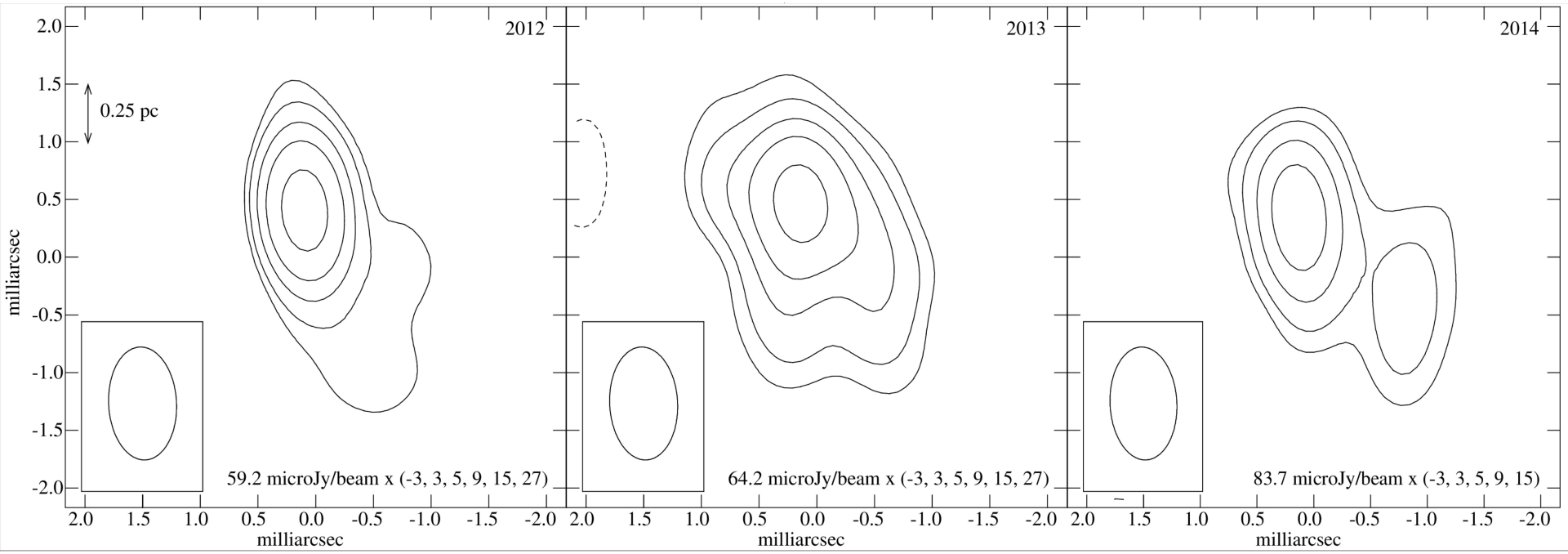
Cont. lev. = 66 x (-3,3,5,9,15,27,45) microJy/beam

~ 1 kpc structure at 144º, showing components of a warped rotating ring

Romero-Cañizales et al., 2012

IC883: nuclear region

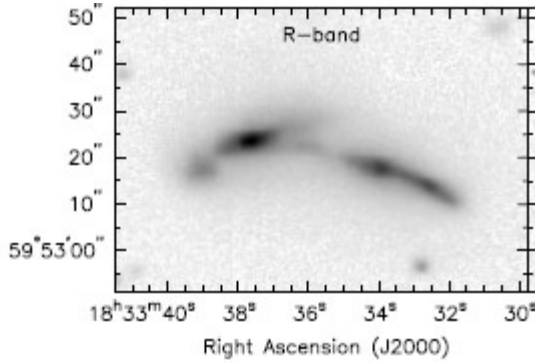
8.4 GHz (θ=1x0.6 mas, PA=3 deg)



New ejected component at 8.4 GHz: not present in VLBA observations from 15.05.2011 at the same frequency (although at poorer resolution).

- The jet-like component was probably ejected sometime between May 2011 and November 2012 ⇒ it has moved at $0.6\,c < v < 1.1\,c$
- The jet dies out fast? No signs of it at θ>2 ...

NGC 6670



(Wang et al., 2012)

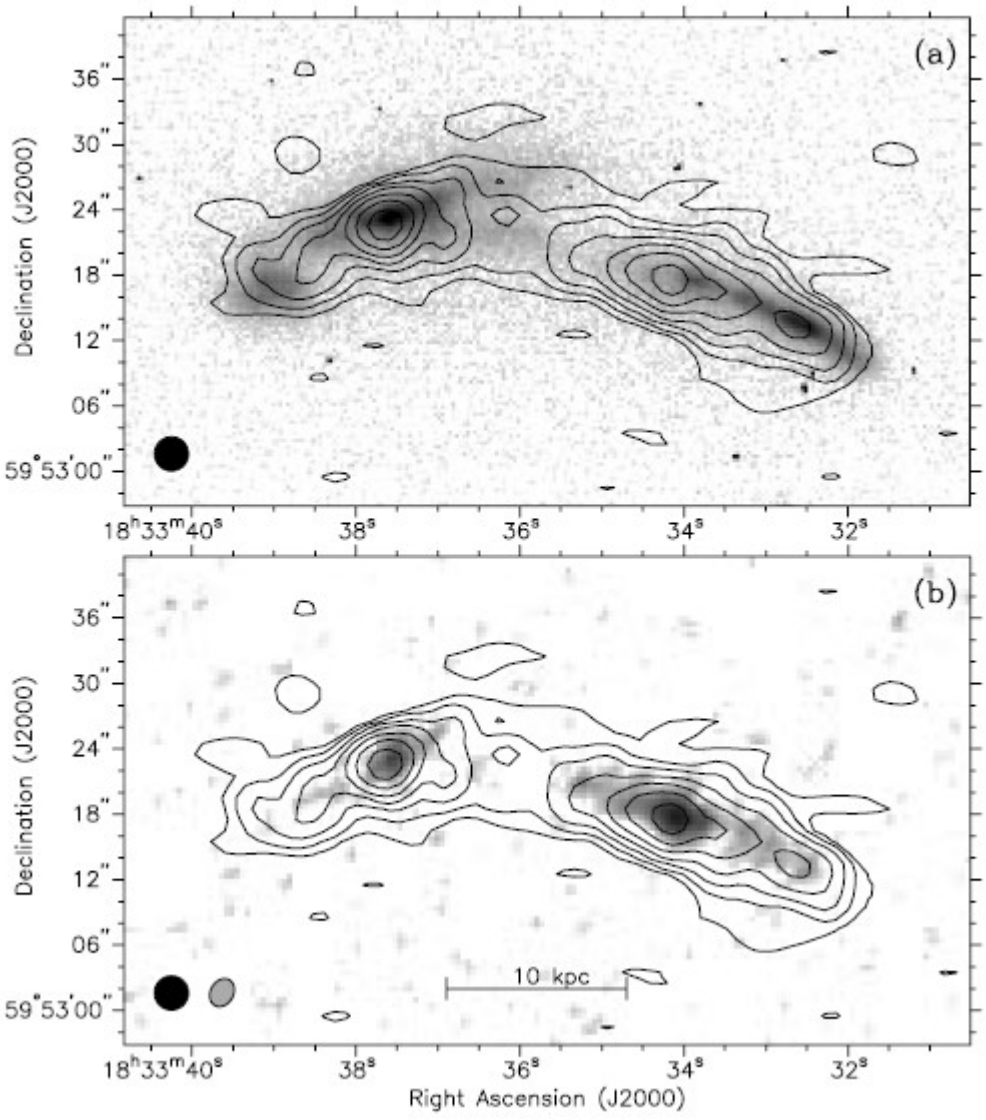
Two edge-on disk galaxies, in early stage of interaction.

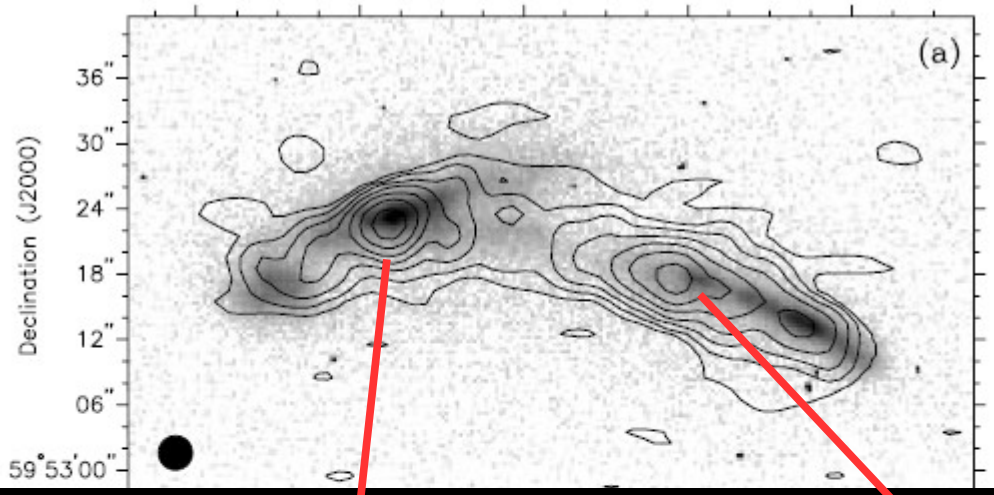
- D ~ 120 Mpc → 1 mas ~ 0.55 pc
- $L_{IR} \sim 4.7 \times 10^{11} L_{sun}$ →

$\nu_{CCSN} \approx 2\ yr^{-1}$

Enhanced SF in the nuclear region of both galaxies → Nuclear Starbursts

NGC 6670


(a)
(b)
Declination (J2000)
36"
30"
24"
18"
12"
06"
59°53'00"
18h33m40s
38s
36s
34s
32s
10 kpc
Right Ascension (J2000)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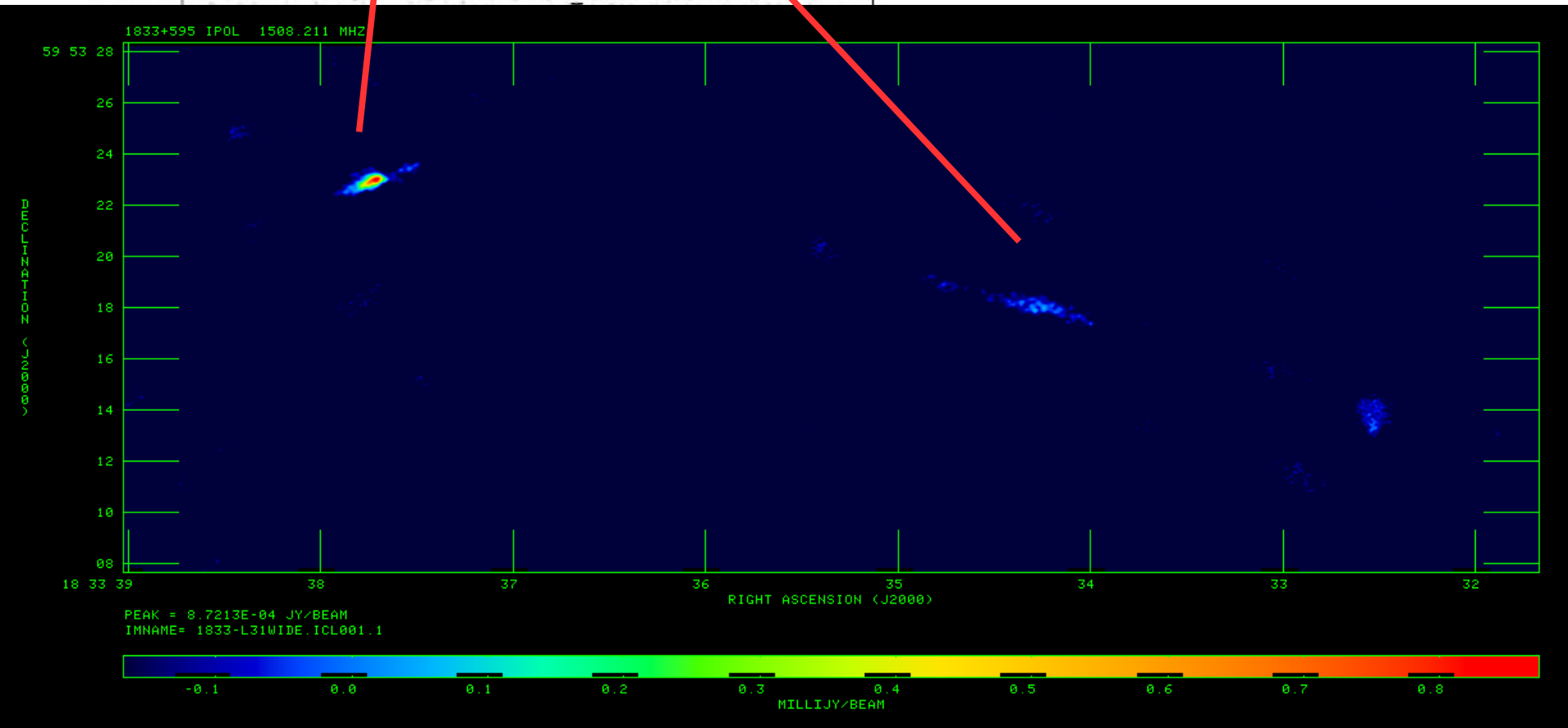
NGC 6670

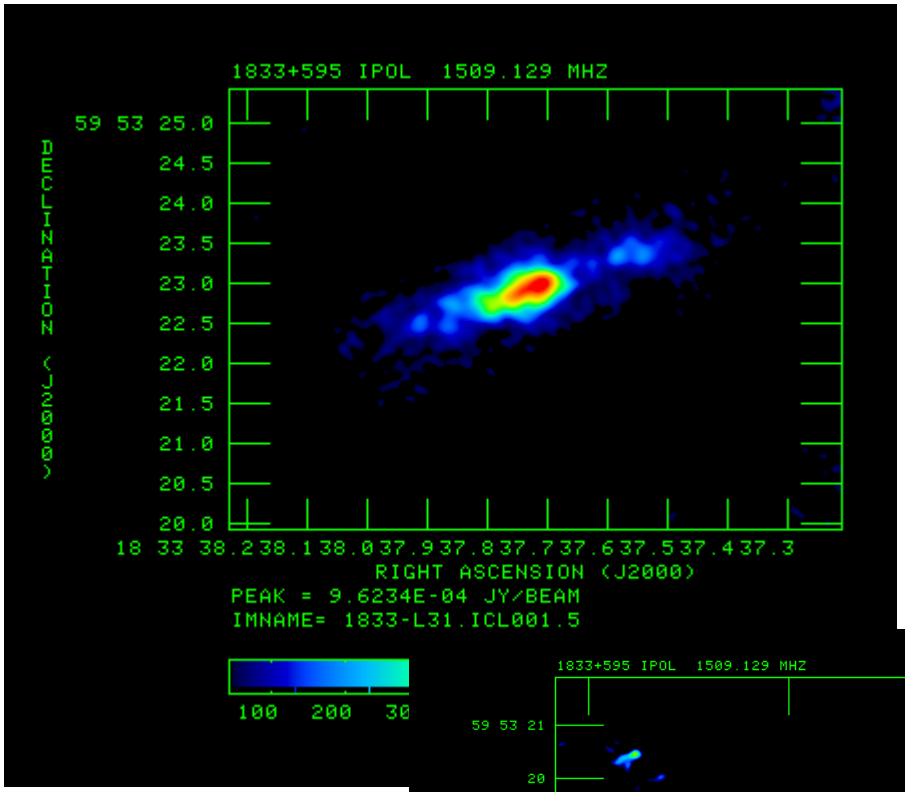

1833+595 IPOL 1508.211 MHZ
59 53 28
26
24
22
20
18
16
14
12
10
08
DECLINATION (J2000)
18 33 39
38
37
36
35
34
33
32
RIGHT ASCENSION (J2000)
PEAK = 8.7213E-04 JY/BEAM
IMNAME= 1833-L31WIDE.ICL001.1
-0.1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
MILLIJY/BEAM

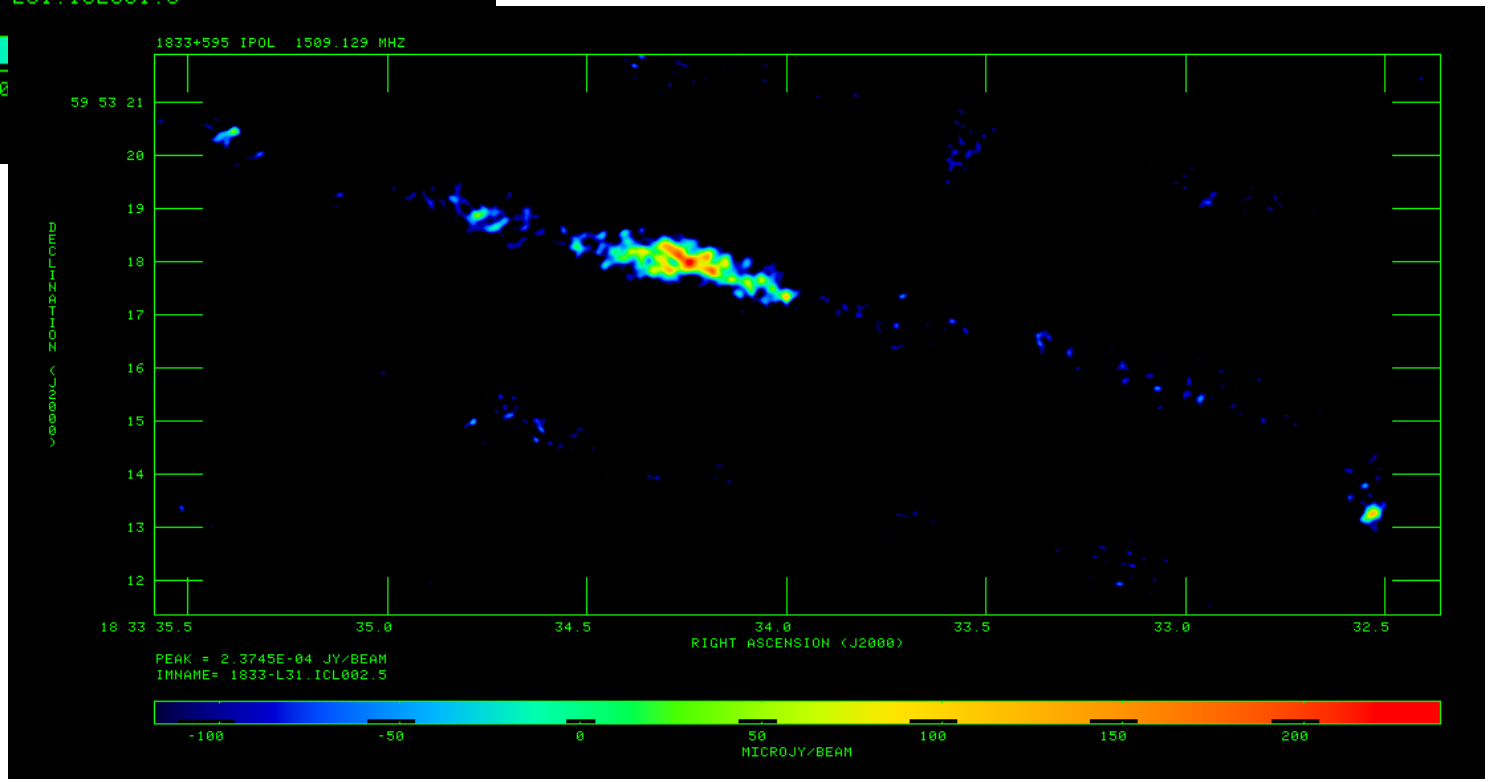
NGC 6670

-eMERLIN L-band

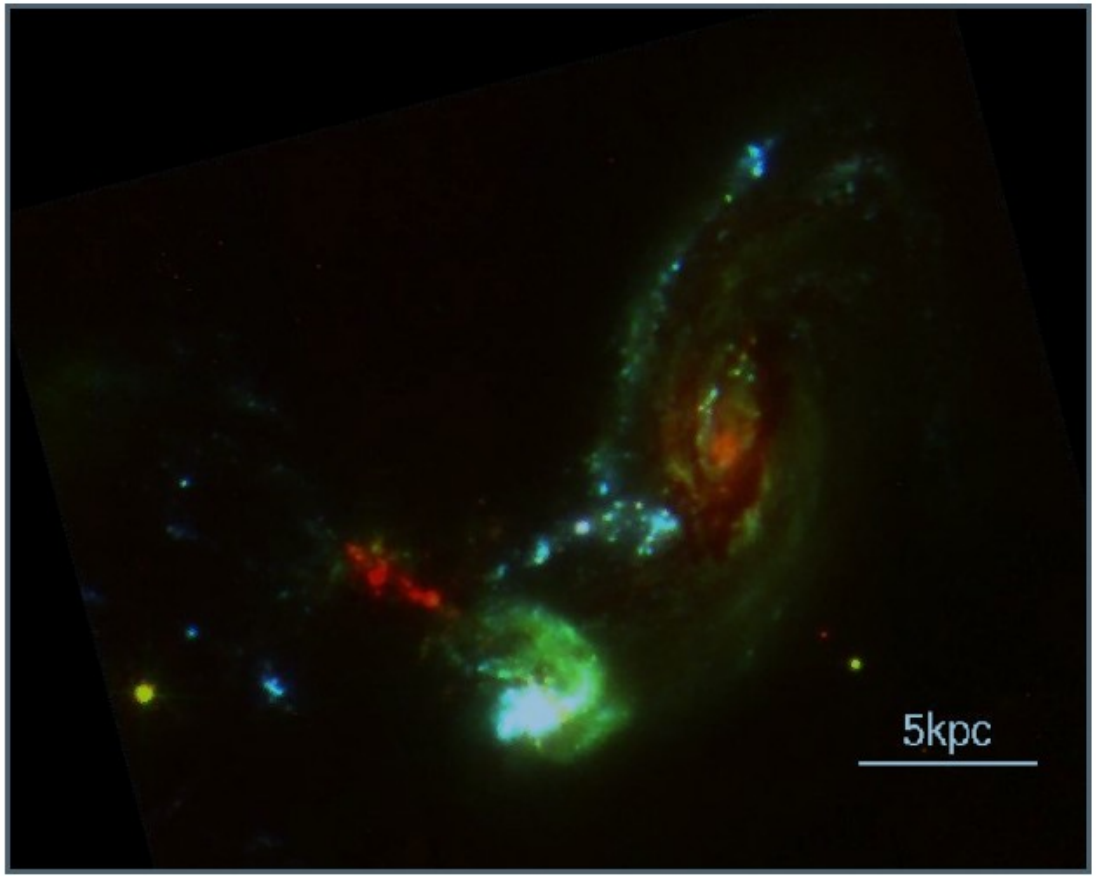
- Sensitivity: 14 microJy/b

- Angular Resolution: 150 mas





CGCG 448-020



- Merger of a two gas-rich spirals → large number of super-star clusters, with at least tow age-population

- D ~ 161 Mpc → 1 mas ~ 0.72 pc

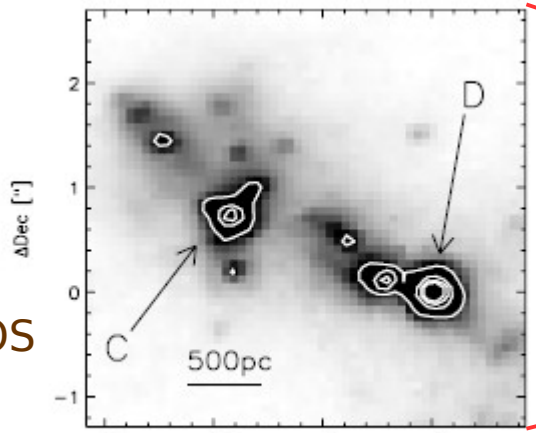
- $L_{IR} \sim 10^{11,94}\ L_{sun}$

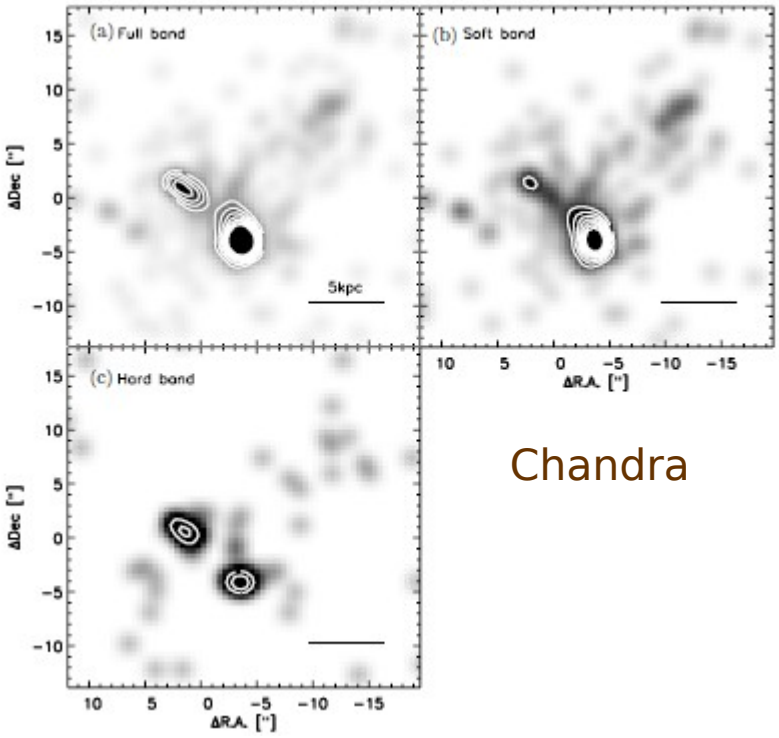
- Most of the IR emission comes from a compact off-nuclear starburst → SFR ~ 120 Msun/yr

(Inami et al., 2010)

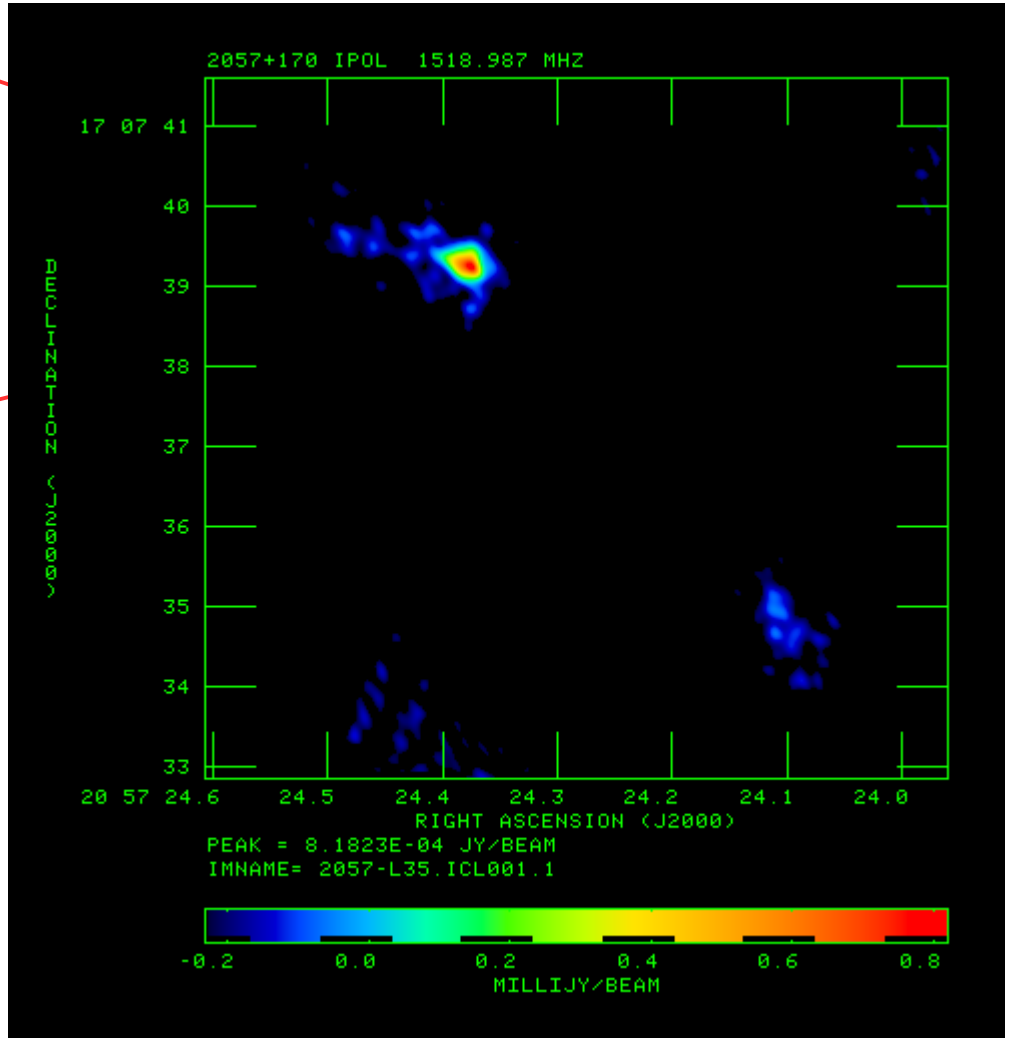
CGCG 448-020

NICMOS

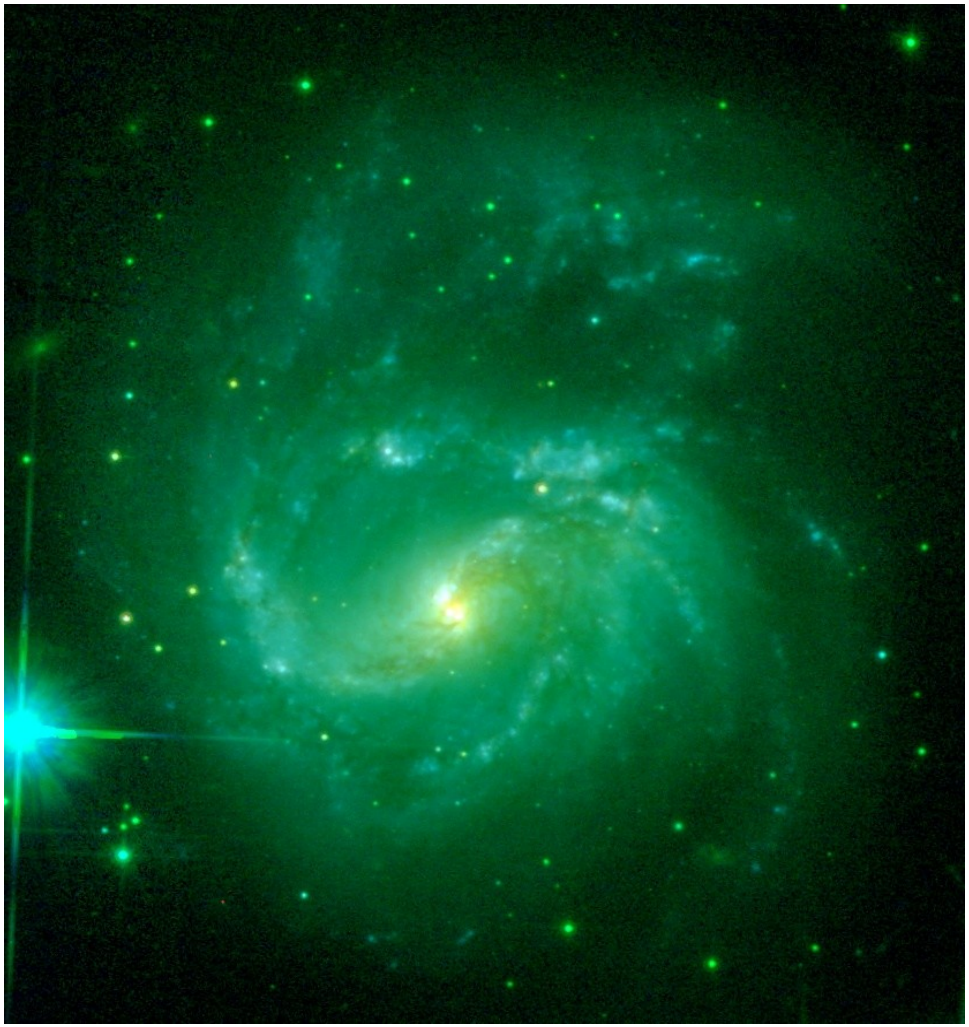




Chandra



IRAS 20351+2521



(GOALS Sample)

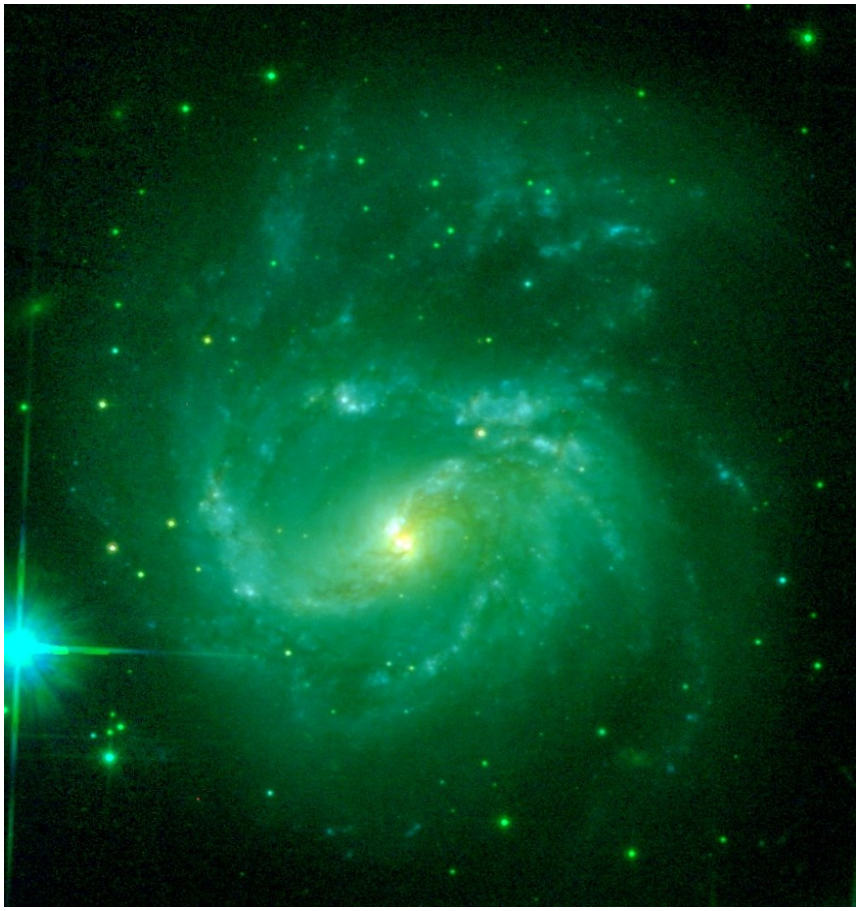
- Nearly merged pair of galaxies

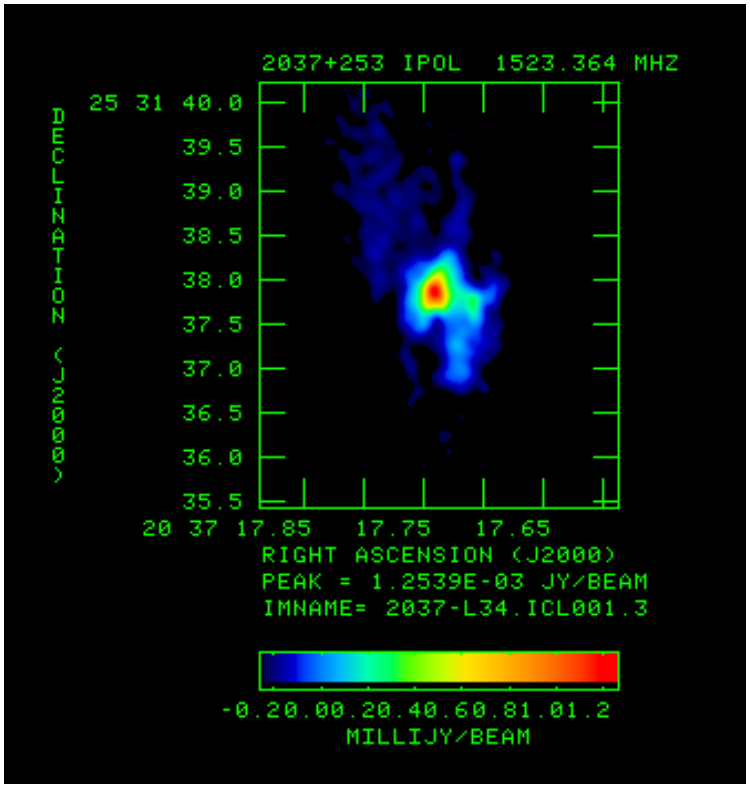
- $D \sim 150$ Mpc → 1 mas ~ 0.627 pc

- $L_{IR} \sim 10^{11,56}$ L_{sun}

- Numerous blue star knots

IRAS 20351+2521





(GOALS Sample)

Summary

☑ Radio observations of (U)LIRGs at the highest resolution and sensitivity are extremely useful to: (i) **discern SB from AGN driven activity** in the innermost regions; (ii) determine their **CCSN rate**; and (iii) **test the IMF** of the massive stars.

Summary

☑ EMERLIN + VLBI radio searches on large samples needed to get meaningful statistical results (=> LIRGI: It will allow to establish a **phenomenological sequence and timescale for the evolution of a nuclear starburst** for a statistically significant sample of (U)LIRGs in the local universe).

Some notes of interest about eMERLIN (and probably SKA)

- **Lack of short baselines** → Loss of sensitivity
- At 18cm, the PB is of around 15 arcmin: you can find a point-like source in the FoV of the target source → **Phase-Selfcal on the target** can be possible.
- On the other hand, **strong sources**, with a flux density of the order of the phase-calibrator, can be **within the PB** → Difficulties for the amplitude selfcal
- When the **interferometric array is not homogeneous,** the PB for different dishes can be different. If there are sources close to the PB boundaries, the selfcalibration has to be done in different steps.

Some notes of interest about eMERLIN (and probably SKA)

- **Reprocessing** can be necessary in many cases: Splitting the FoV in different facets; shifting the phase-reference position; ...
- **eMERLIN could be a good laboratory**: visibilities can be stored, reprocessed, algorithms for image reconstruction can be tested ...
- Extension to **X-band** (Band 5) and **S/X** (Spectral Information) can be extremely interesting for LIRGI