Resolved radio continuum studies with the VLA and e-MERLIN of IC10

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Collaborators

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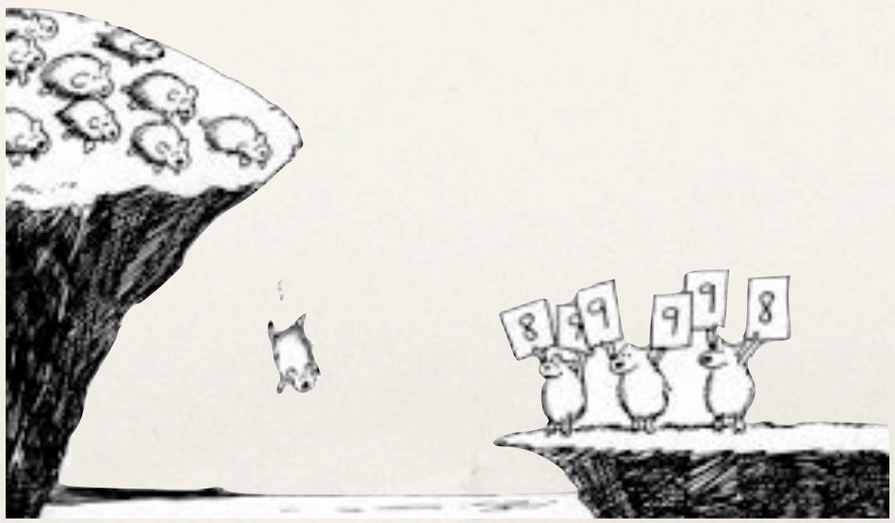
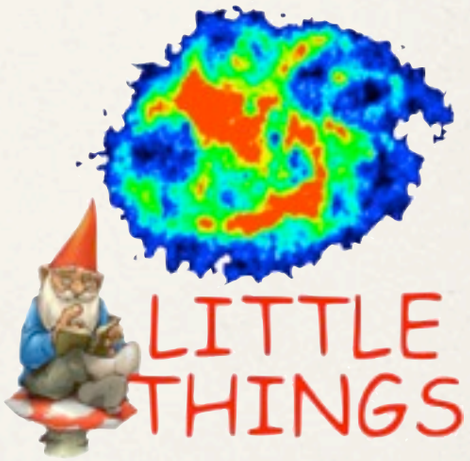
Volker Heesen (Southampton)

Rob Beswick & Pierre-Emmanuel Belles (Manchester)

LITTLE THINGS consortium

LeMMINGs





Content

- Motivation
- Multi-band, multi-configuration VLA observations of IC10
- First e-MERLIN results on IC10

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Poster by Jonathan Westcott

Motivation

- Star formation (SF) drives galaxy evolution
- UV/optical tracers suffer uncertainty due to extinction
- MIR extinction correction or FIR SF tracers require high resolution satellite observations
- refurbished e-MERLIN & VLA, plus SKA precursors, have boosted radio continuum (RC) capabilities
- thermal RC (33GHz; Murphy et al. 2012) is a virtually extinction-free proxy for the SFR, but at T~10^4 K is weak.
- instead, explore synchrotron-dominated 1.5-6 GHz regime

Motivation

- (non-thermal) RC has potential to be a dust-free star formation rate (SFR) probe via RC-SFR (Condon) and the RC-FIR relation

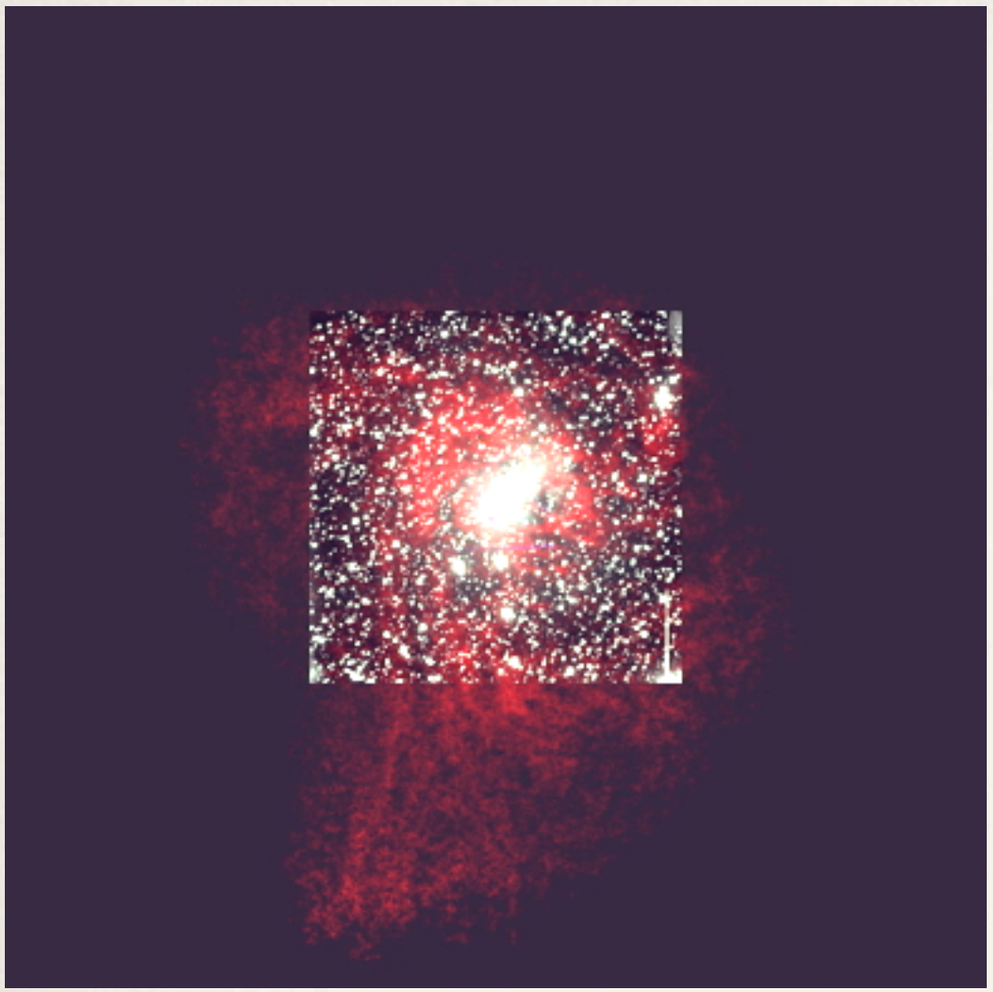
- Heesen et al. (2014): RC-SFR study in spirals

- Kitchener PhD: RC-SFR & RC-FIR relation of dwarfs with VLA (~40 dIrr galaxies)

- Case study: IC10 multi-band, multi-configuration spatially resolved VLA study (Heesen et al. 2011)

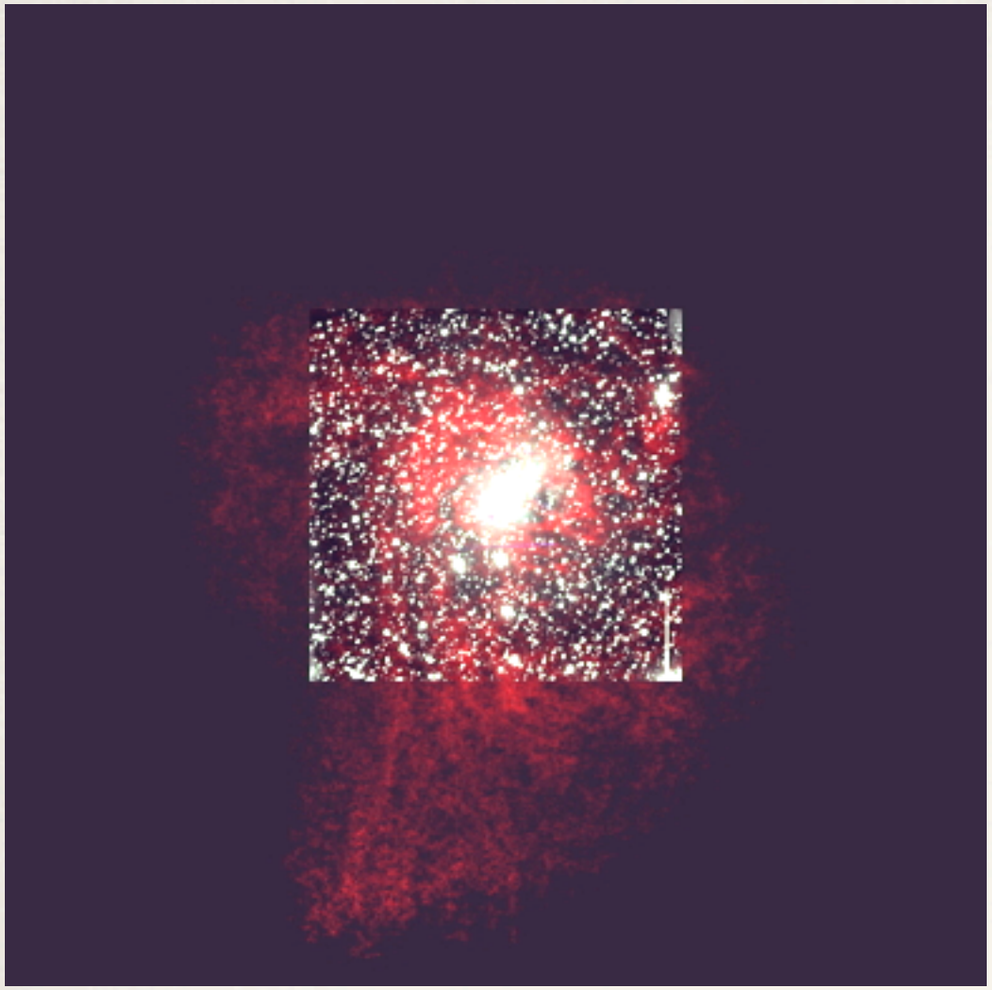
- Westcott MSc: IC10 20cm e-MERLIN study, head count of SNR and (ultra-)compact HII regions → SFR

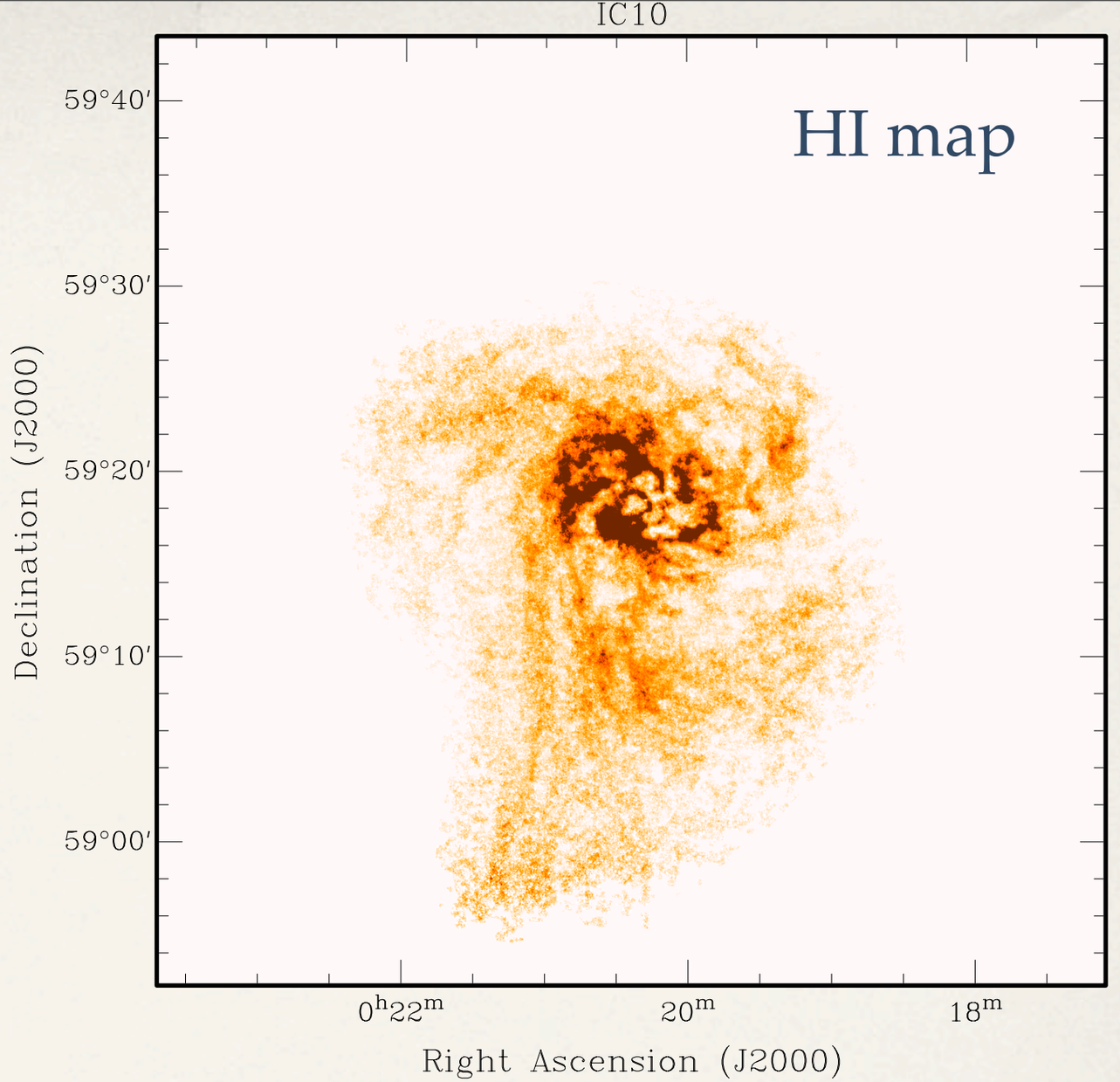
IC10



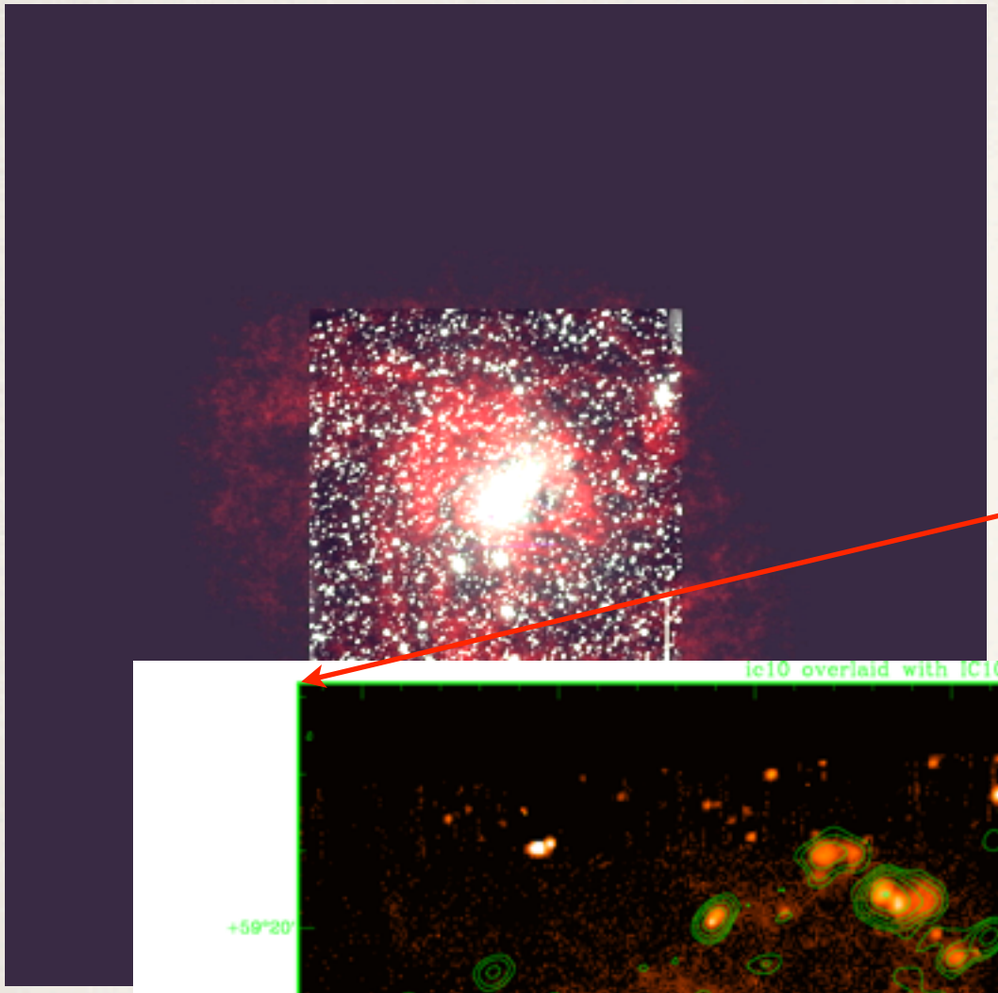
- RA, Dec = $0^h20^m17.3^s$, $+59^o18'14''$
- l,b = $118.^o96$, $-3.^o33$
- D = 0.7 - 1.0 Mpc (member of M31 sub-group)
- ISM dominated by HI/Hα shells
- non-thermal radio continuum bubble (Yang & Skillman 1993)

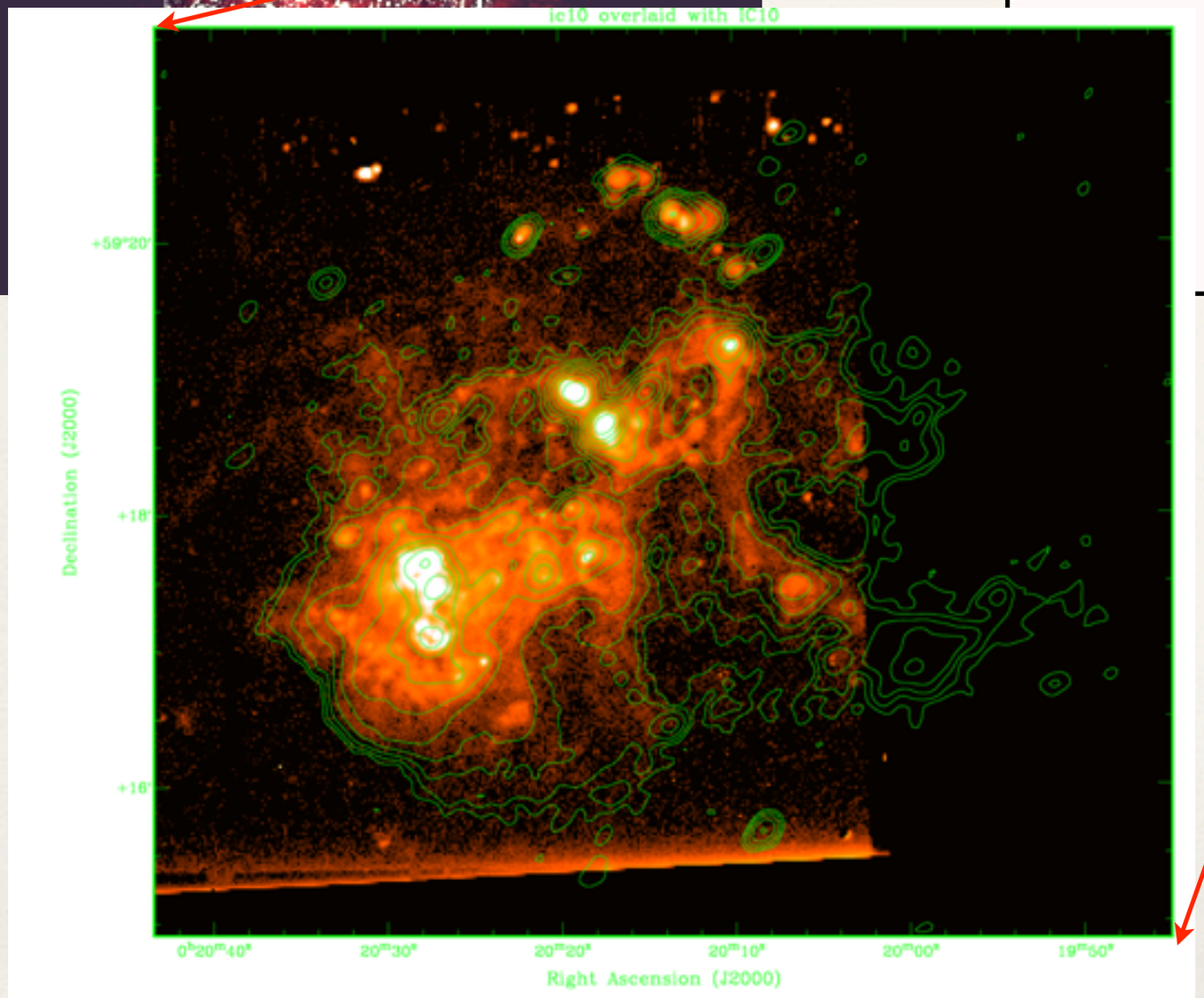
B-band on HI map

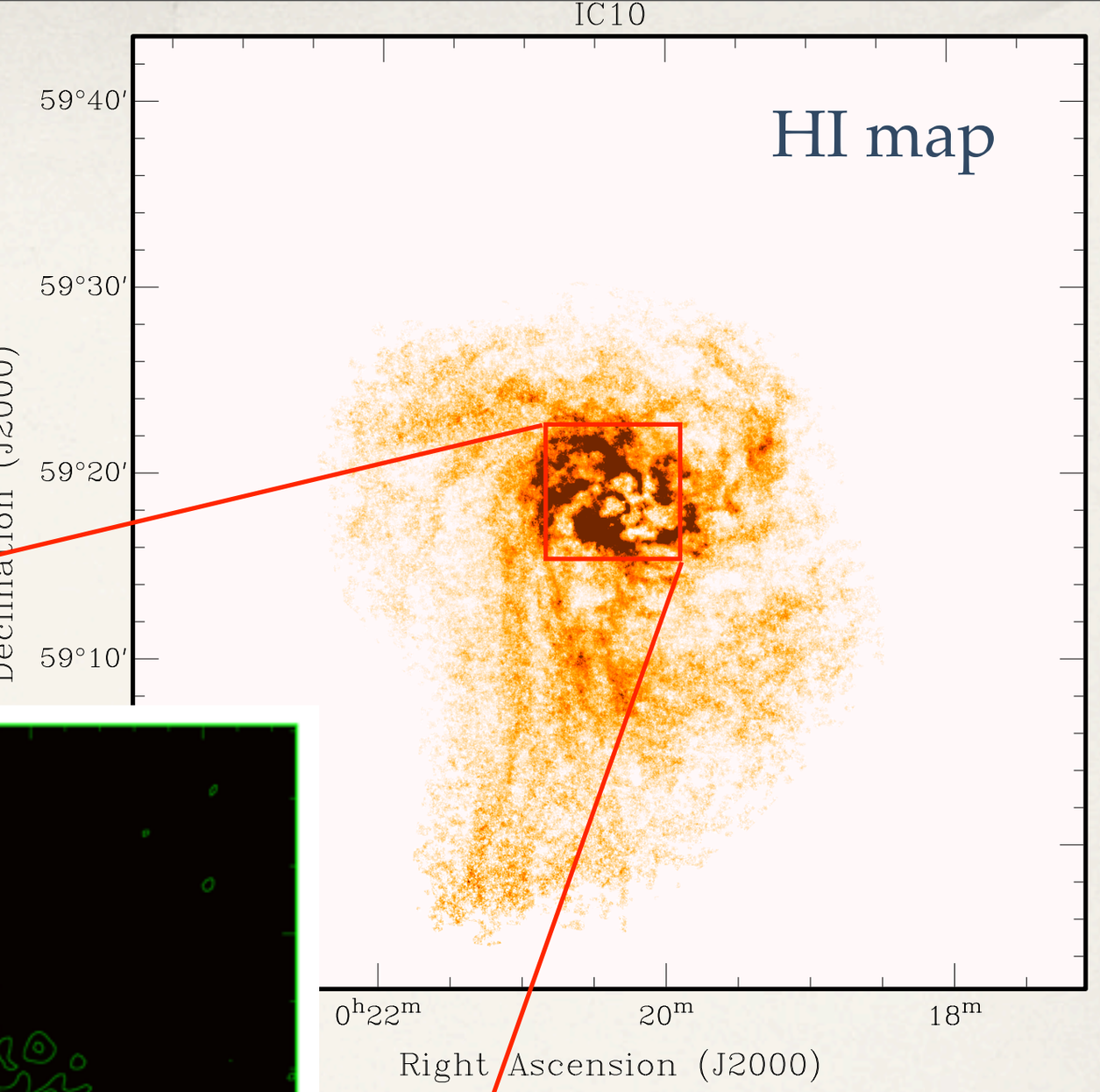




B-band on HI map

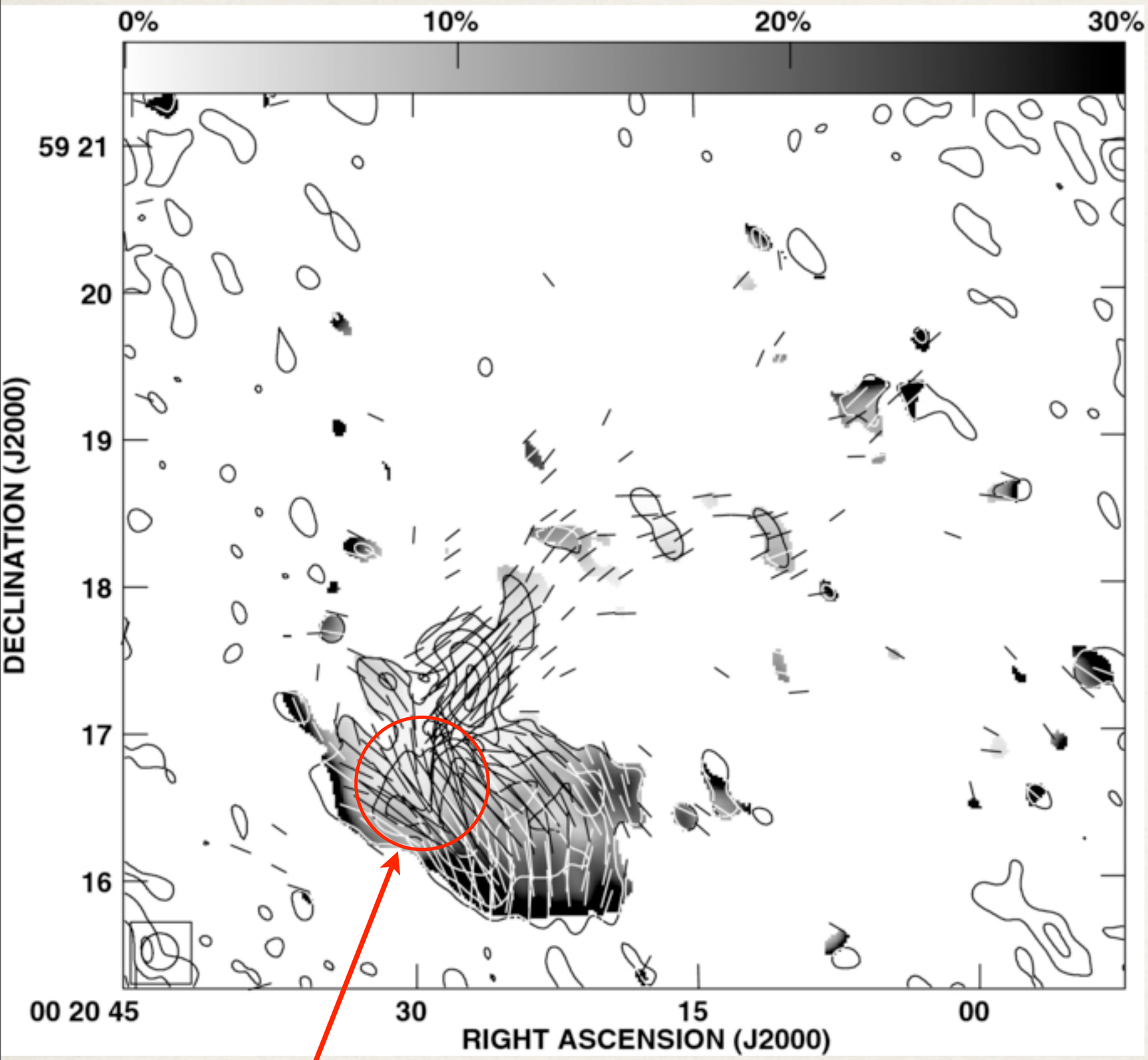






6cm on Hα

- Heesen et al. 2011, ApJ Lett., 739, L23
- ~4 hr, Full Stokes, C-array, 2 GHz @ C-band (6.2 GHz)
- 5 μJy rms @ I, Q, & U (expected thermal noise 4 μJy)
- ~2000:1 dynamic range
- MS-MFS mapping (Rau & Cornwell 2011)
- 9.4″ x 7.3″ resolution (~ 47 x 36 pc)

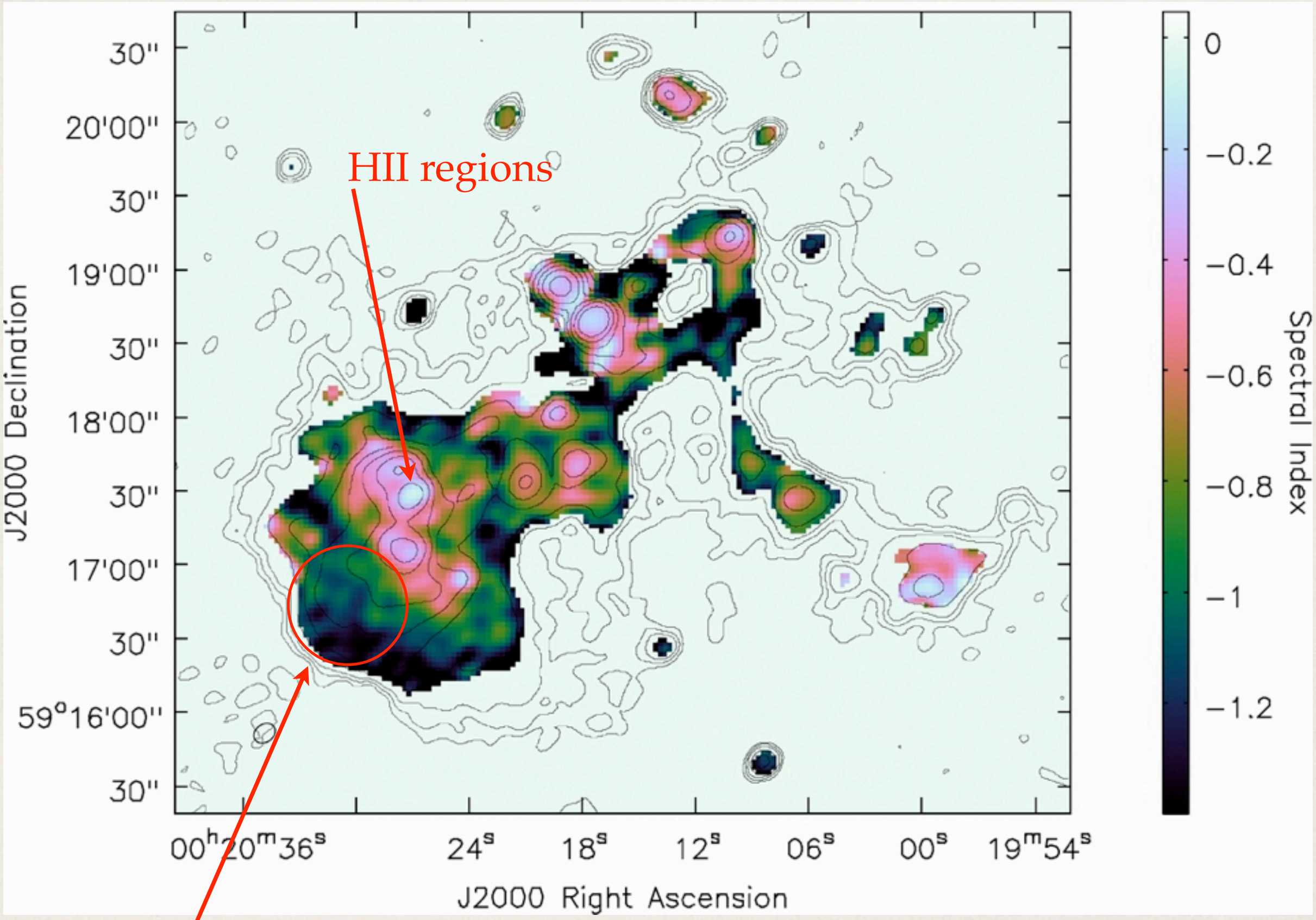


- No galaxy-wide B-field
- Compression by shock waves?

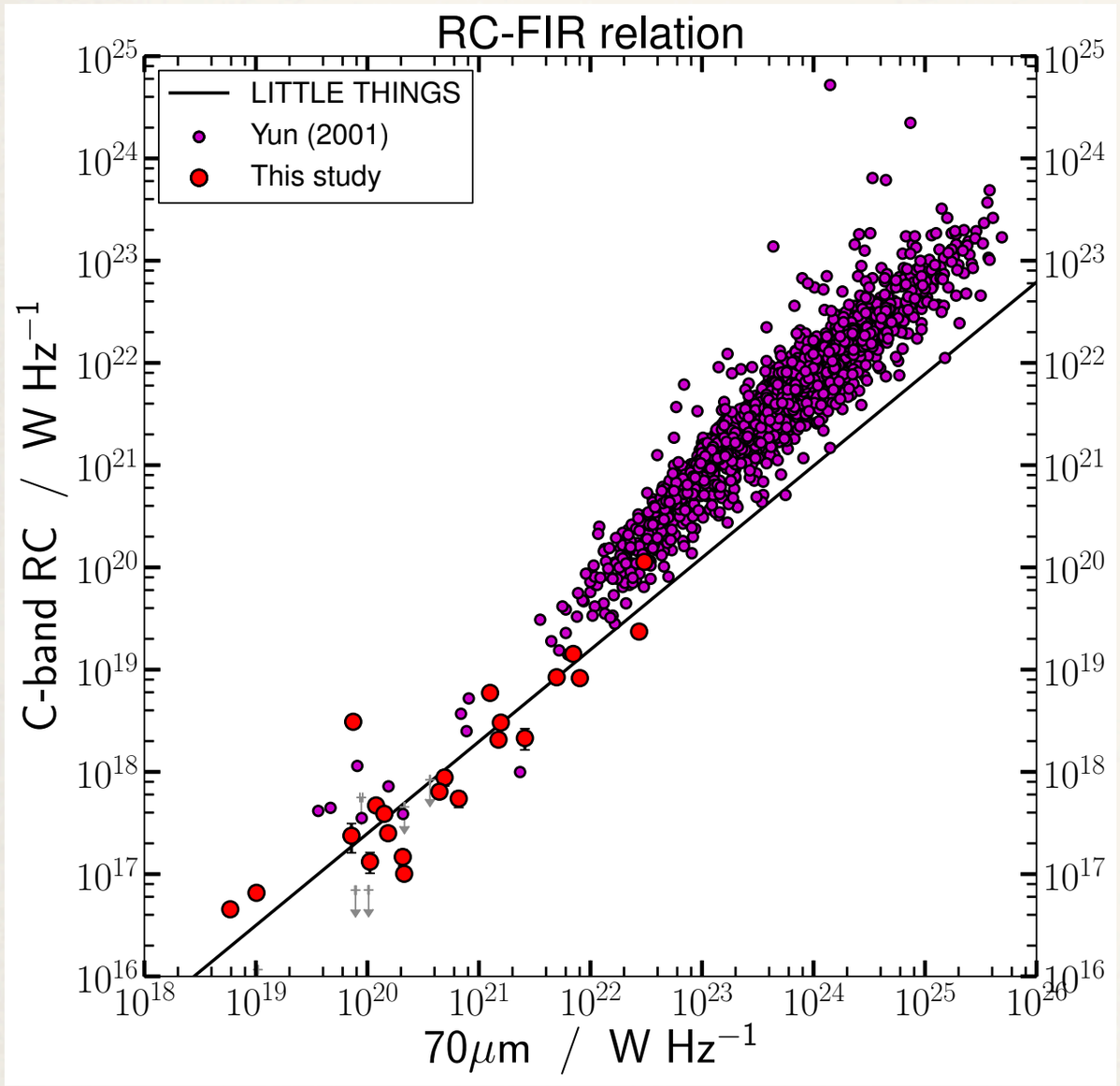
Polarised intensity and magnetic field orientation overlaid on the fractional polarisation (grey scale) at 15″ resolution. Polarised intensity contours are at 3, 6, 10, and 20 × 7 μJy beam^{-1} .

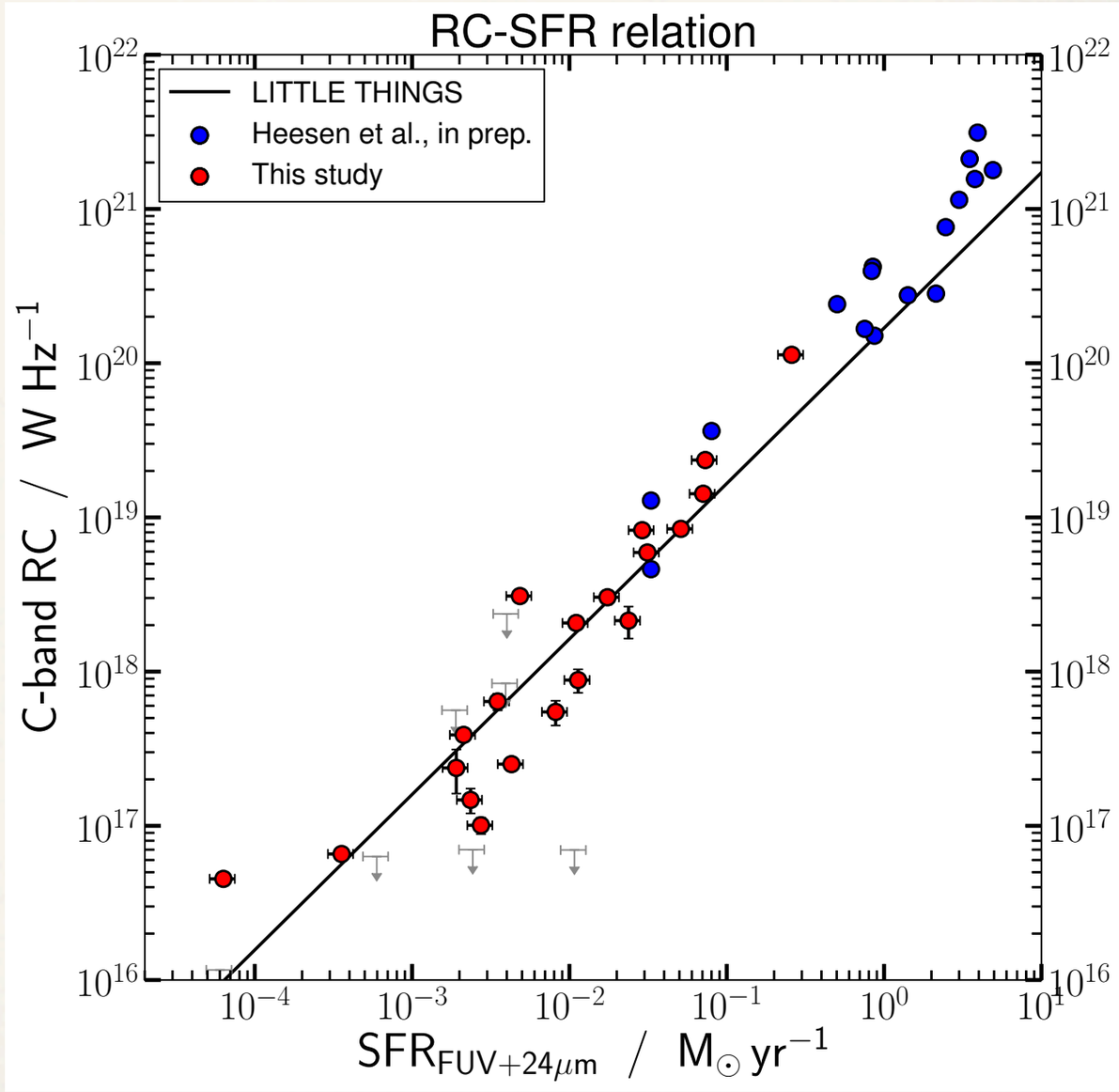
non-thermal bubble

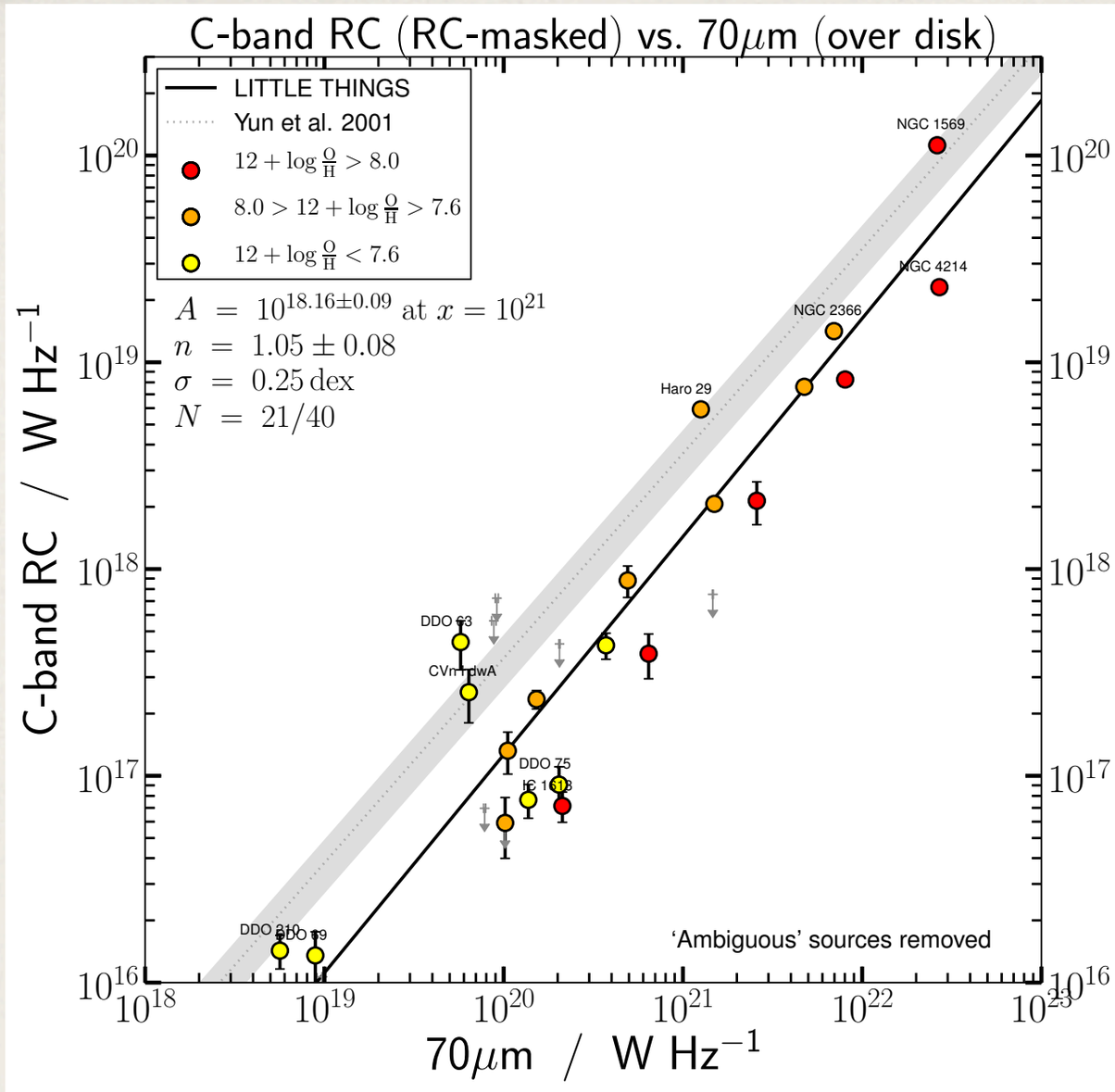
in-band spectral index on 6cm

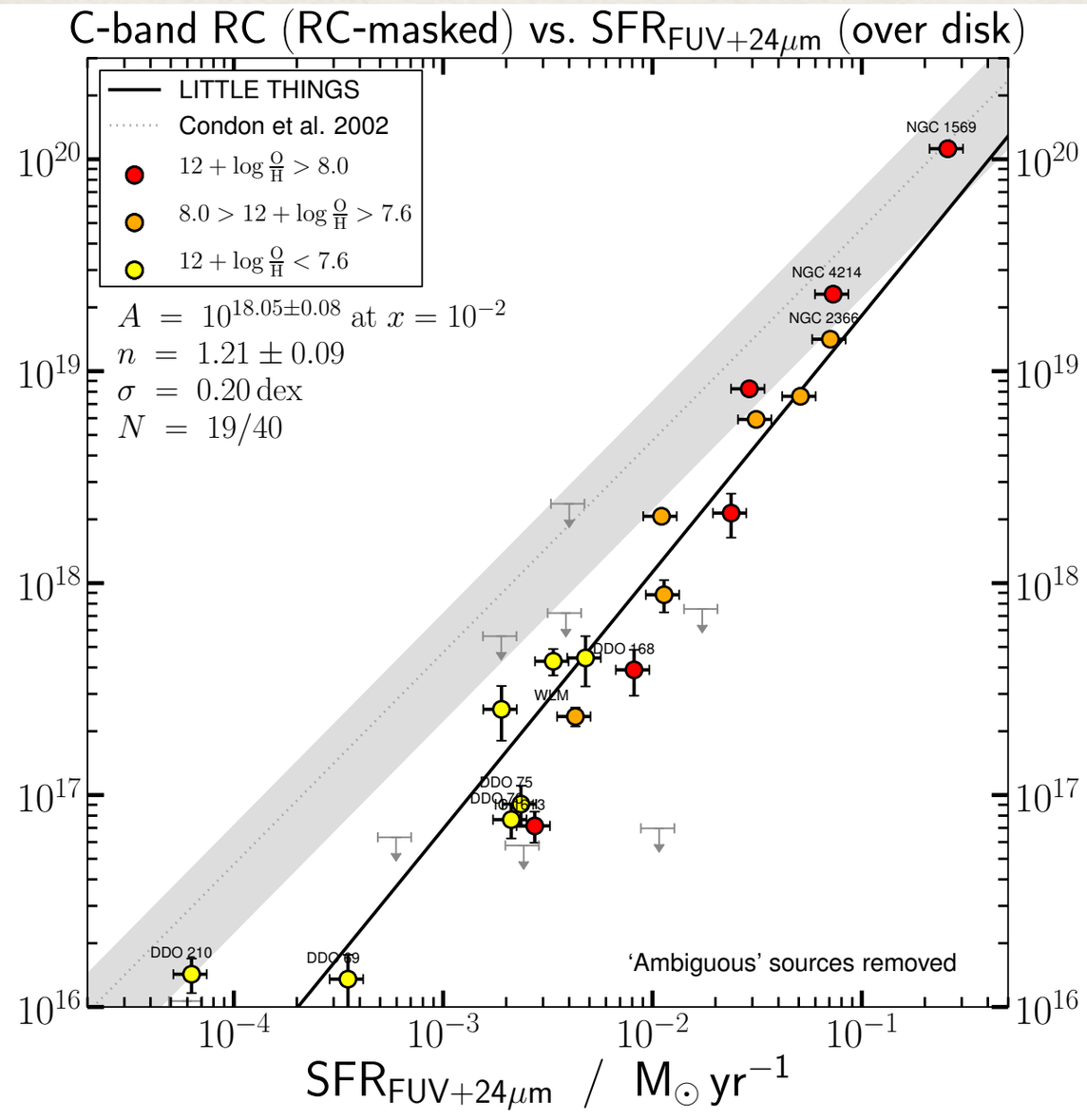


RC-FIR & RC-SFR relations





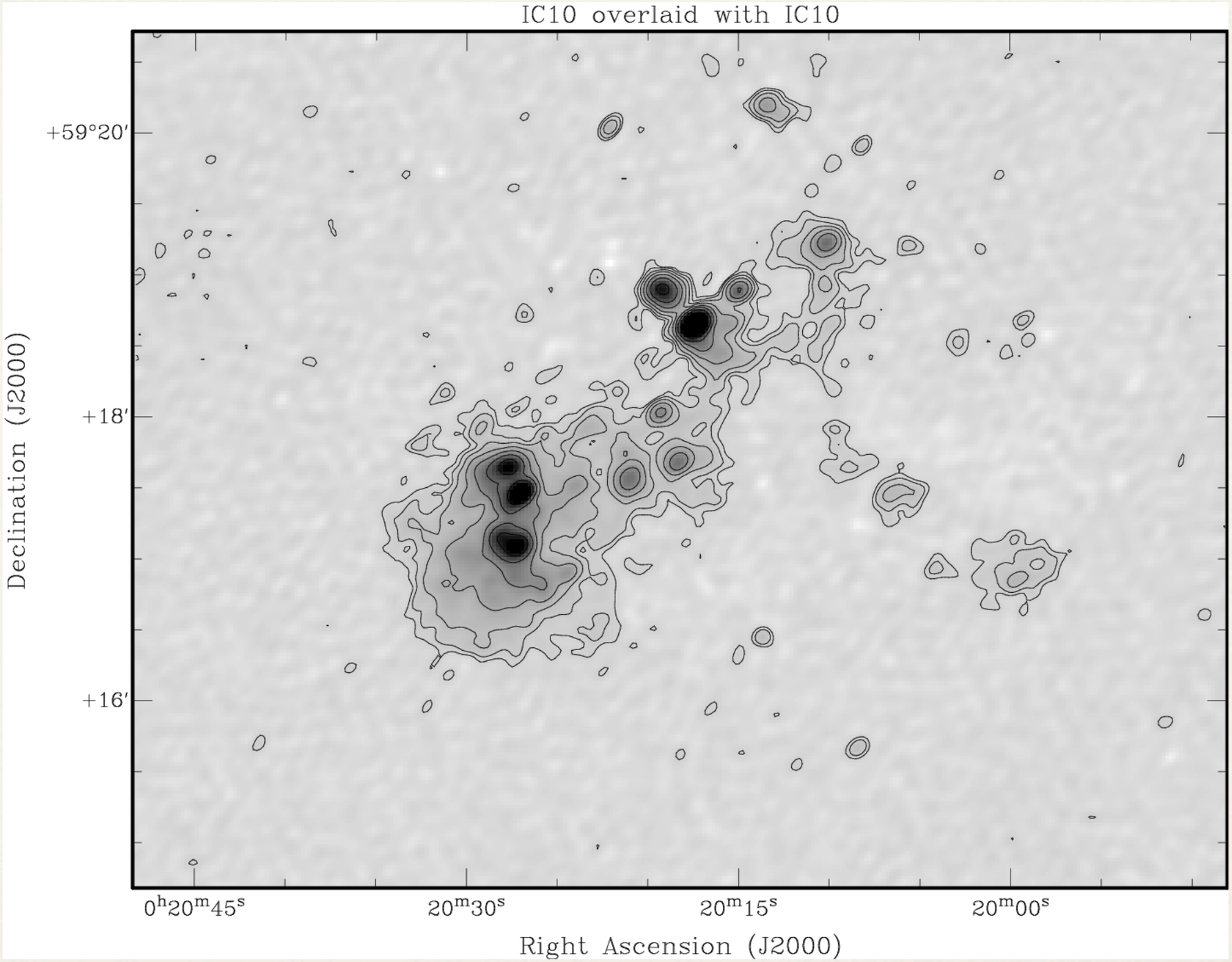




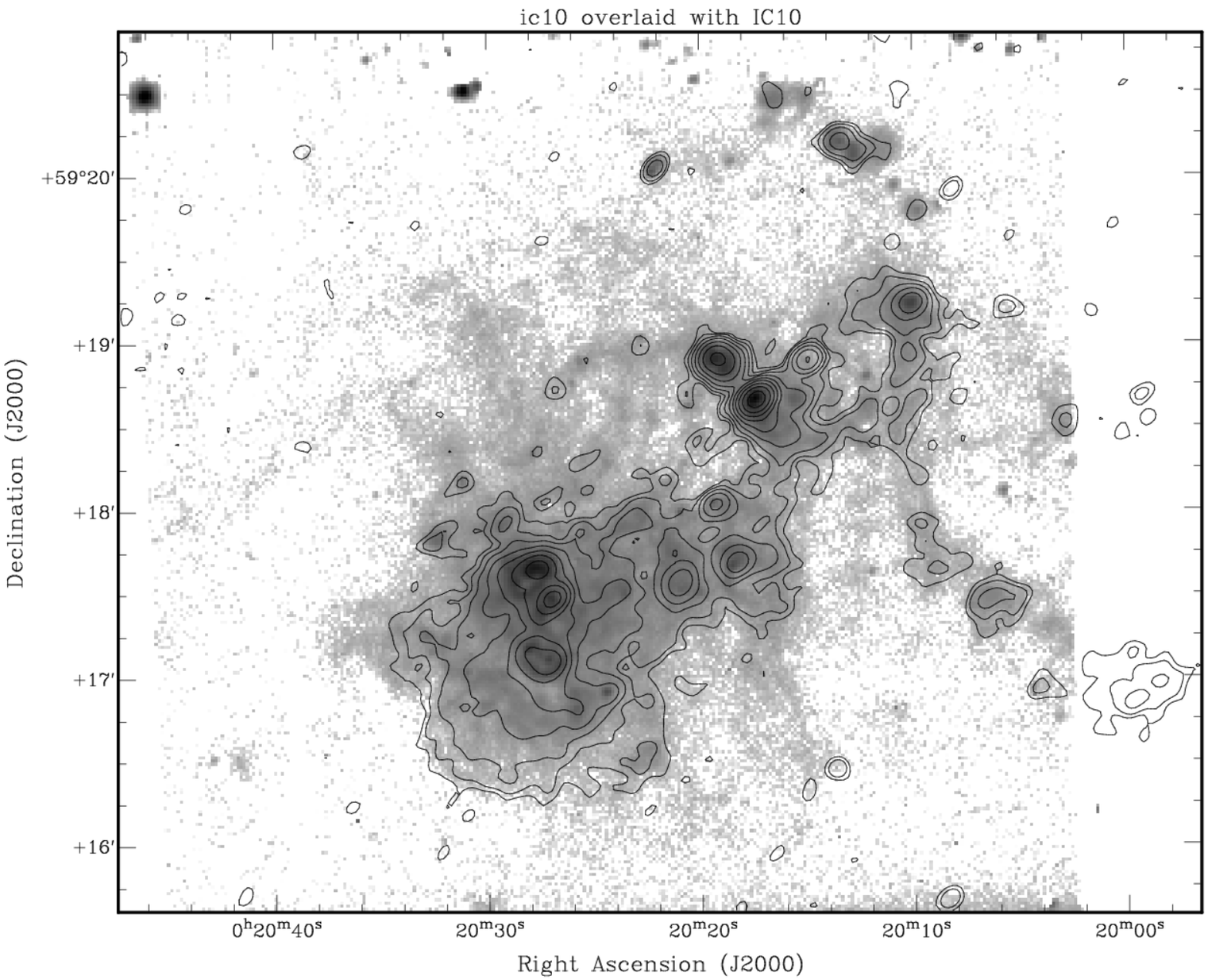
- RC-FIR slope 1.05 ±0.08 (large spirals 0.99±0.01, Yun et al. 2001)
- dispersion 0.25 dex
- factor of 2 below Yun et al. (2001)
- RC-FIR "conspiracy"

- RC-SFR slope 1.21 ±0.09
- dispersion 0.2 dex
- deviates from Condon-relation below SFR < 0.1 $M_\odot$ yr^{-1}
- both thermal & synchrotron are down

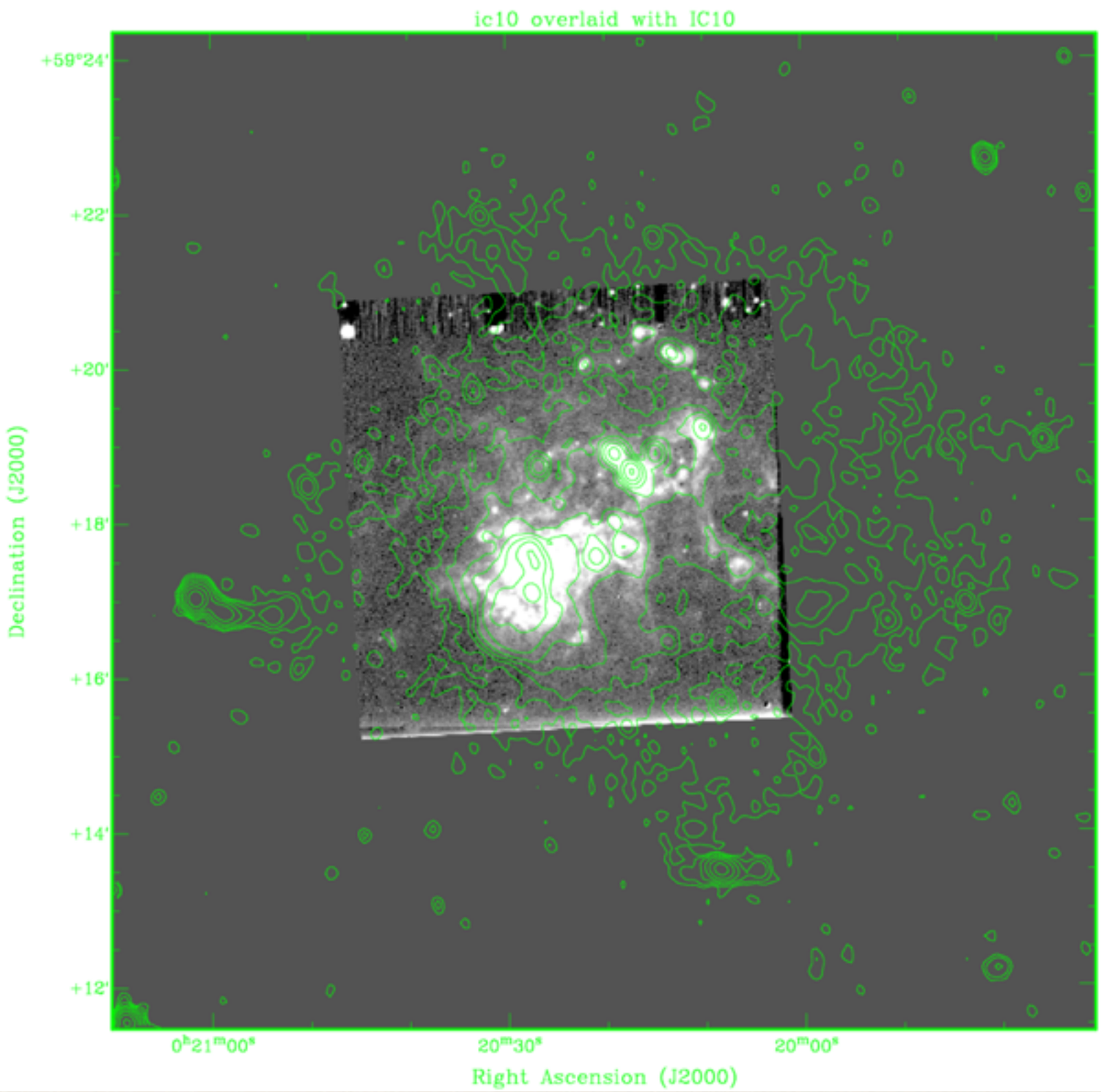
3cm D-array


IC10 overlaid with IC10
+59°20′
+18′
+16′
Declination (J2000)
0h20m45s
20m30s
20m15s
20m00s
Right Ascension (J2000)

Contours: 3cm D-config
Grey-scale: Halpha



L-band C+D-array on Hα



Measuring Cosmic Ray aging

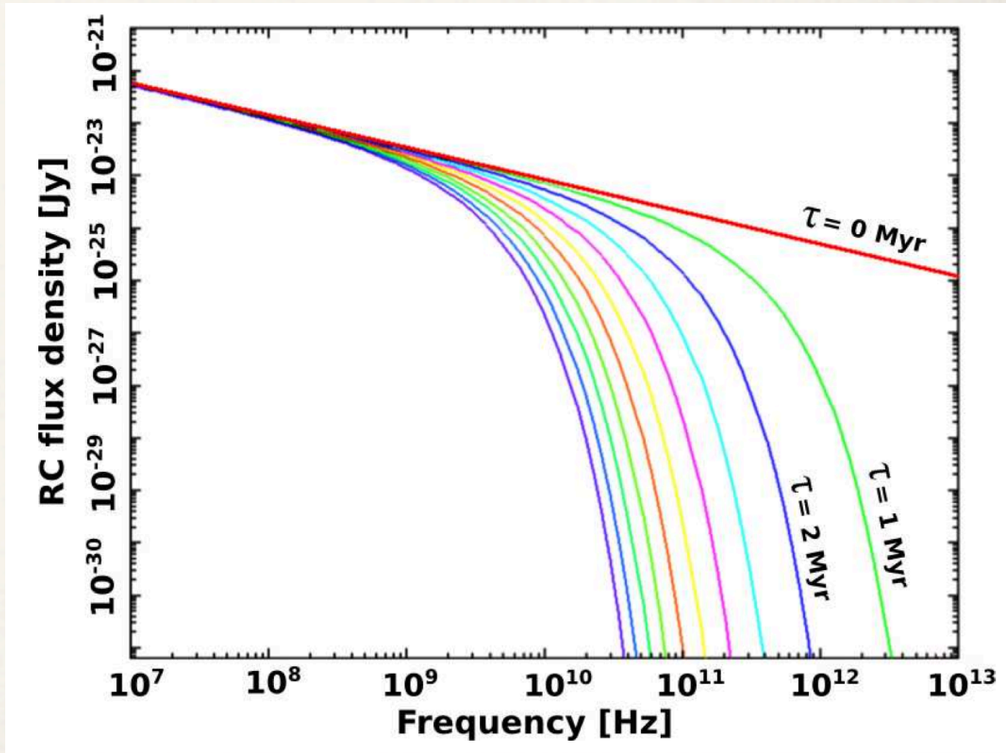
- Power-law "injection" spectrum breaks at $\nu_{brk}(t)$

$$\nu_{\rm brk} = 2.52\times10^3 \frac{[B/10\,\mu{\rm G}]}{([B/10\,\mu{\rm G}]^2 + [B_{\rm CMB}/10\,\mu{\rm G}]^2)^2[\tau/{\rm Myr}]^2}\ {\rm GHz}$$

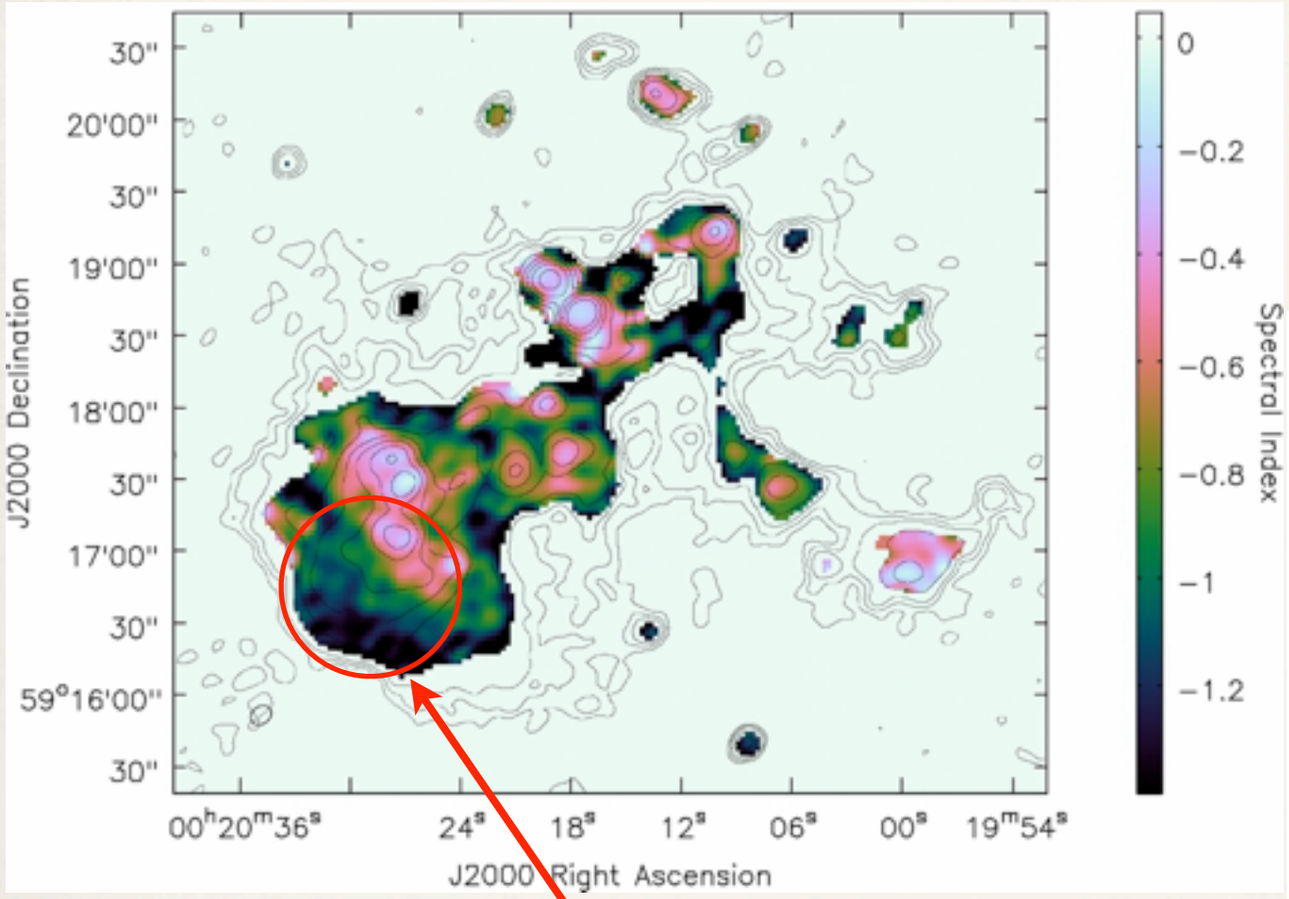
- Above ν_{brk}, spectrum depends on model assumptions (e.g. pitch angle scattering): Jaffe & Perola 1973, Kardashev 1962 & Pacholczyk 1970

- More complex models exist (e.g. Tribble 1993)

- But radio spectral ages have a number of limitations….



Non-thermal superbubble

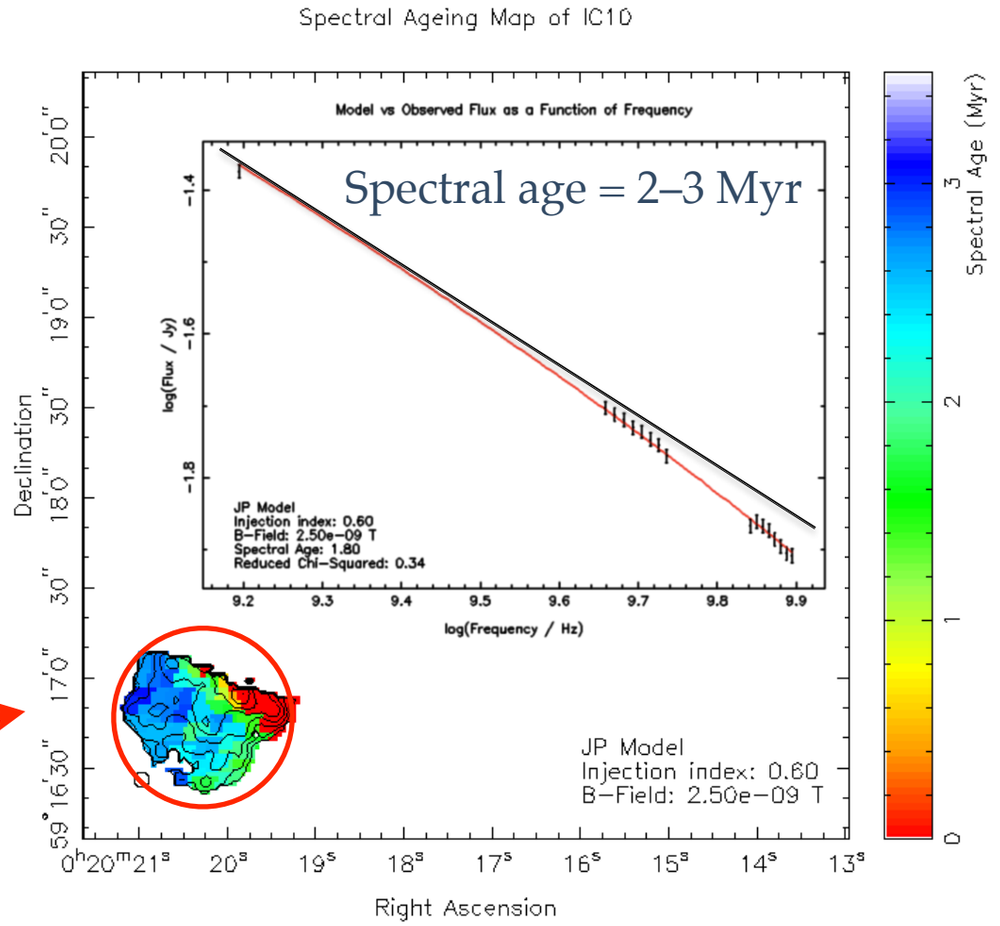


Some details:

– Subtract thermal RC based on Hα

– Correct for missing spacings with Effelsberg (not crucial)

– Estimate B from energy equipartition

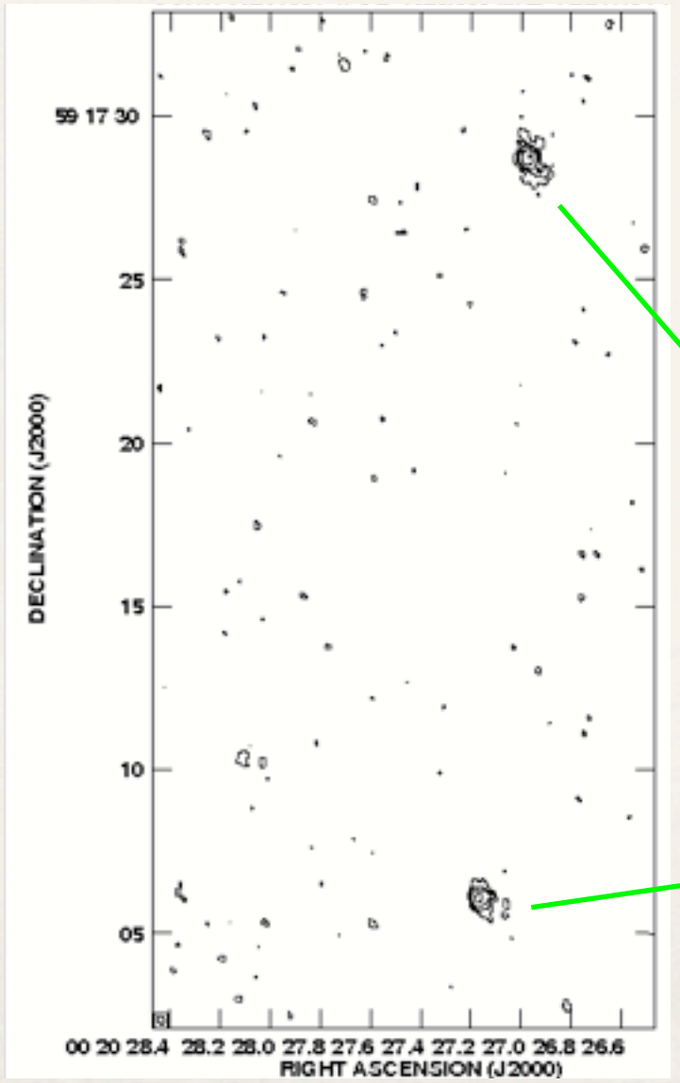


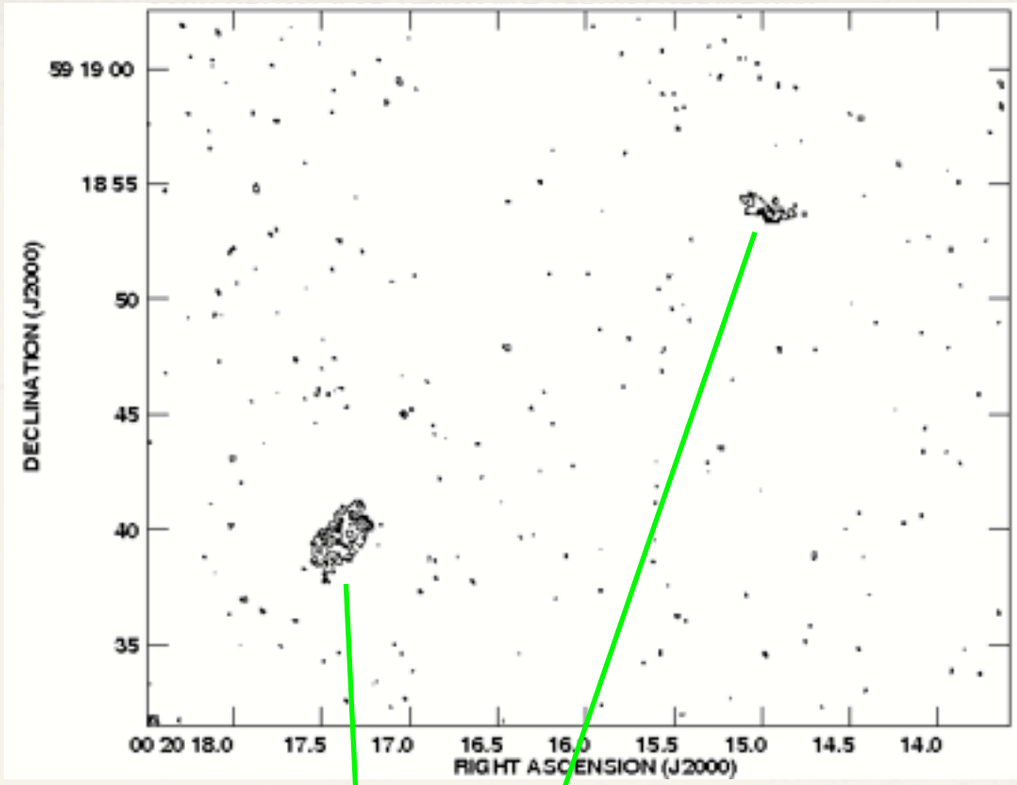
non-thermal bubble

Using BRATS (Harwood et al. 2013)

L-Band e-MERLIN observations of IC10 [LeMMINGs] Feb & Nov 2013

$\sigma \lesssim 30\ \mu Jy$





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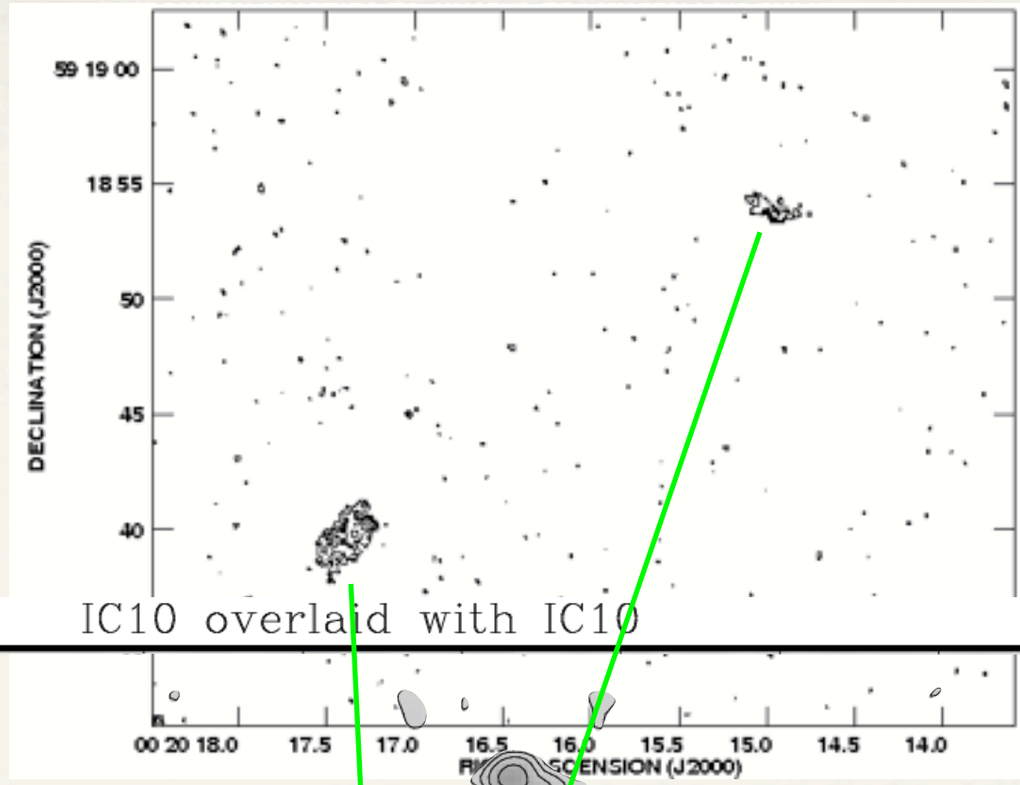
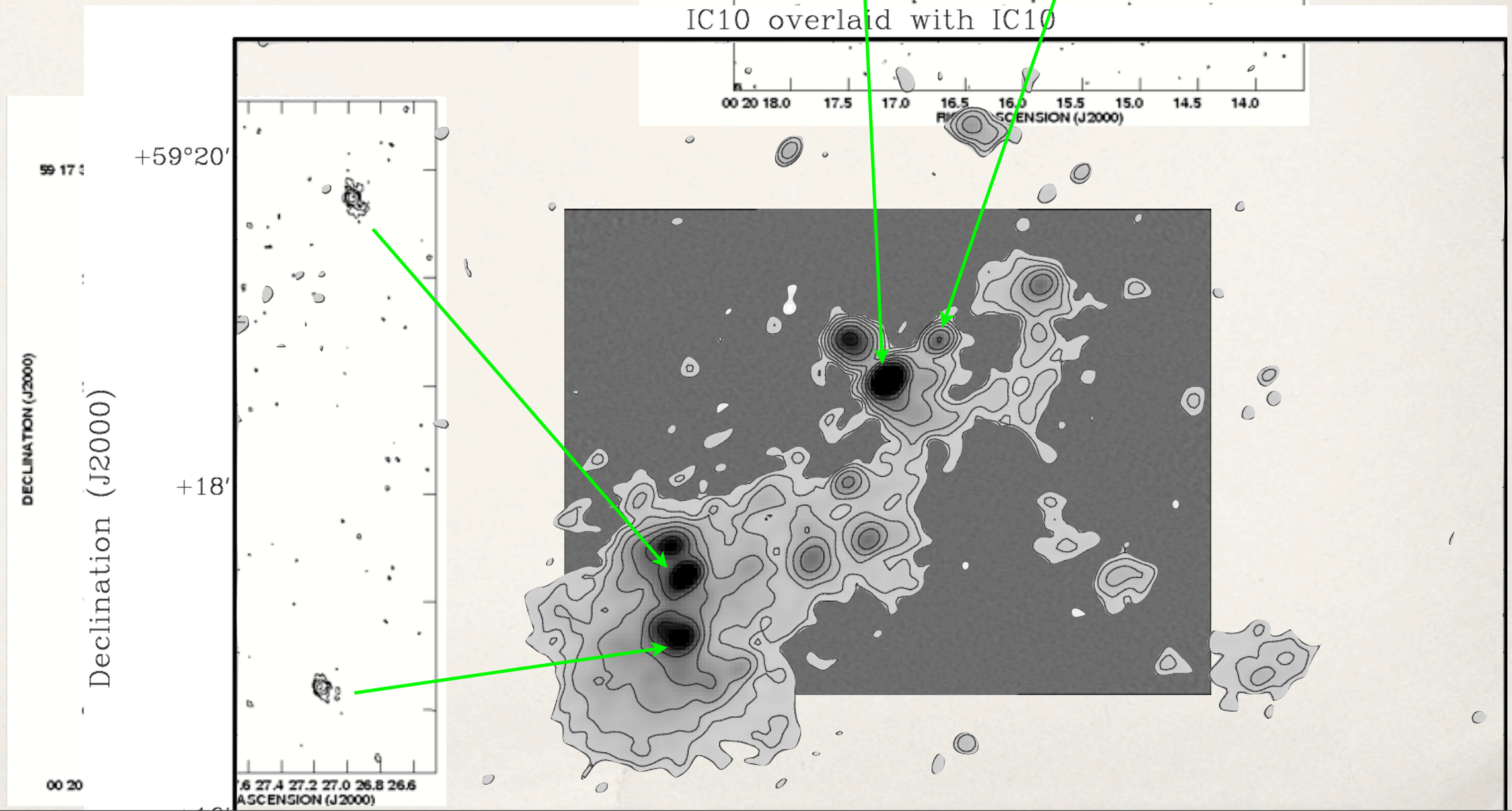


IC10 overlaid with IC10



First e-MERLIN IC10 Results

- ~ dozen sources related to IC10 (morphology; spatial correlation)
- ratio SNR/HII about 50/50
- Work in progress:
  - will be looking for variability between Feb & Nov 2013 epochs
  - proper ID using ancillary data
  - create SNR luminosity function
  - investigate Σ-D relation for SNR

Summary: IC10

- Radio continuum correlates with Hα; RC is 30–50% thermal
- Radio continuum falls 2–3x below RC–SFR relation (truncated IMF? loss of CR electrons)
- Non-thermal bubble:
  - Fractional polarisation 10–20%
  - shock origin?
  - spectral age ~2-3 Myr
- e-MERLIN finds ~dozen compact sources, 50% SNR, 50% HII region

The End