

M. A. Perez Torres

An extremely prolific SN factory in the buried nucleus of Arp 299A

The central kiloparsec of many local luminous infrared galaxies are known to host intense bursts of massive star formation, leading to numerous explosions of core-collapse supernovae. However, the dust-enshrouded regions where those supernovae explode hamper their detection at optical and near-infrared wavelengths.

We investigated the nuclear region of the starburst galaxy IC 694 (=Arp 299-A) at radio wavelengths, aimed at discovering recently exploded core-collapse supernovae, as well as determining their rate of explosion, which carries crucial information about star formation rates, the initial mass function, and the starburst processes in action.

We used the electronic European VLBI Network (eEVN) to image with milliarcsecond resolution the 5.0 GHz compact radio emission of the innermost nuclear region of IC 694. Our observations detected a rich cluster of 26 compact radio emitting sources in the central 150 pc of the nuclear starburst in IC 694. The high brightness temperatures observed for the compact sources are indicative of a non-thermal origin for the observed radio emission, implying that most, if not all, of those sources are young radio supernovae and supernova remnants. We found evidence of at least three relatively young, slowly evolving, long-lasting radio supernovae that appear to have unusual CCSN properties, suggesting that the conditions in the local circumstellar medium (CSM) play a significant role in determining the radio behaviour of expanding SNe. Their radio luminosities are typical of normal RSNe, which result from the explosion of type IIP/b and type IIL SNe. All of these results provide support for a recent (less than 10-15 Myr) instantaneous starburst in the innermost regions of IC 694, and confirm that the inner regions of Arp 299-A are an extremely prolific supernova factory.

The (Radio) SN factory in Arp 299-A

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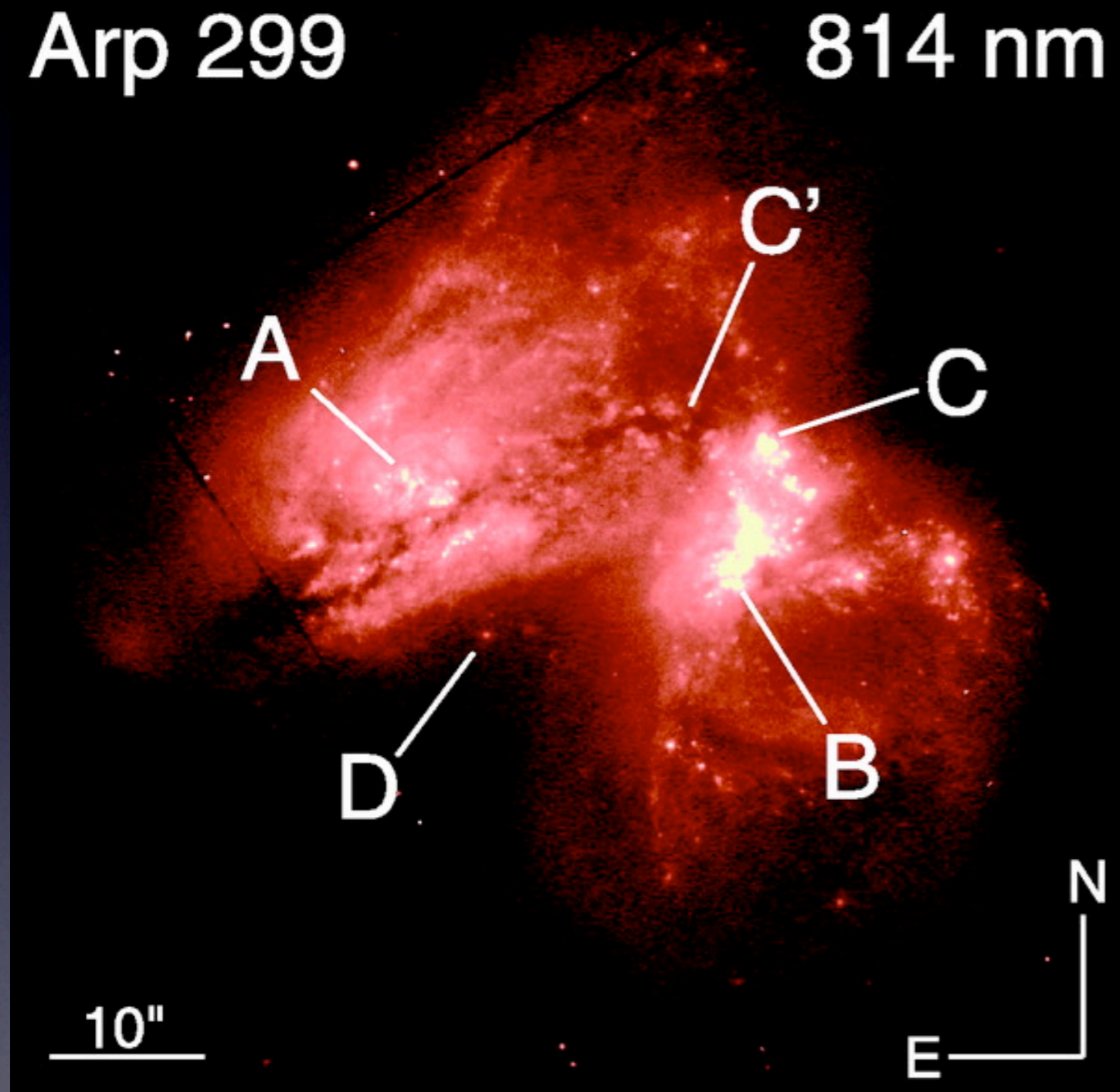
Cristina Romero-Cañizales (IAA-CSIC)
Antxon Alberdi (IAA-CSIC)



The supernova factory in Arp 299

Arp 299

814 nm



Merger in an early state.

$D \sim 45 \text{ Mpc}$

$1'' \sim 220 \text{ pc}$

$L_{\text{IR}} \sim 6.5 \times 10^{11} L_{\text{sun}}$

No evidence for AGN

About half of this Luminosity is in component A. Corresponding CCSN rate is about 0.9 SN/yr

The radio “prehistory” of IC 694 (=Arp 299A)

The Prehistory of Arp 299A

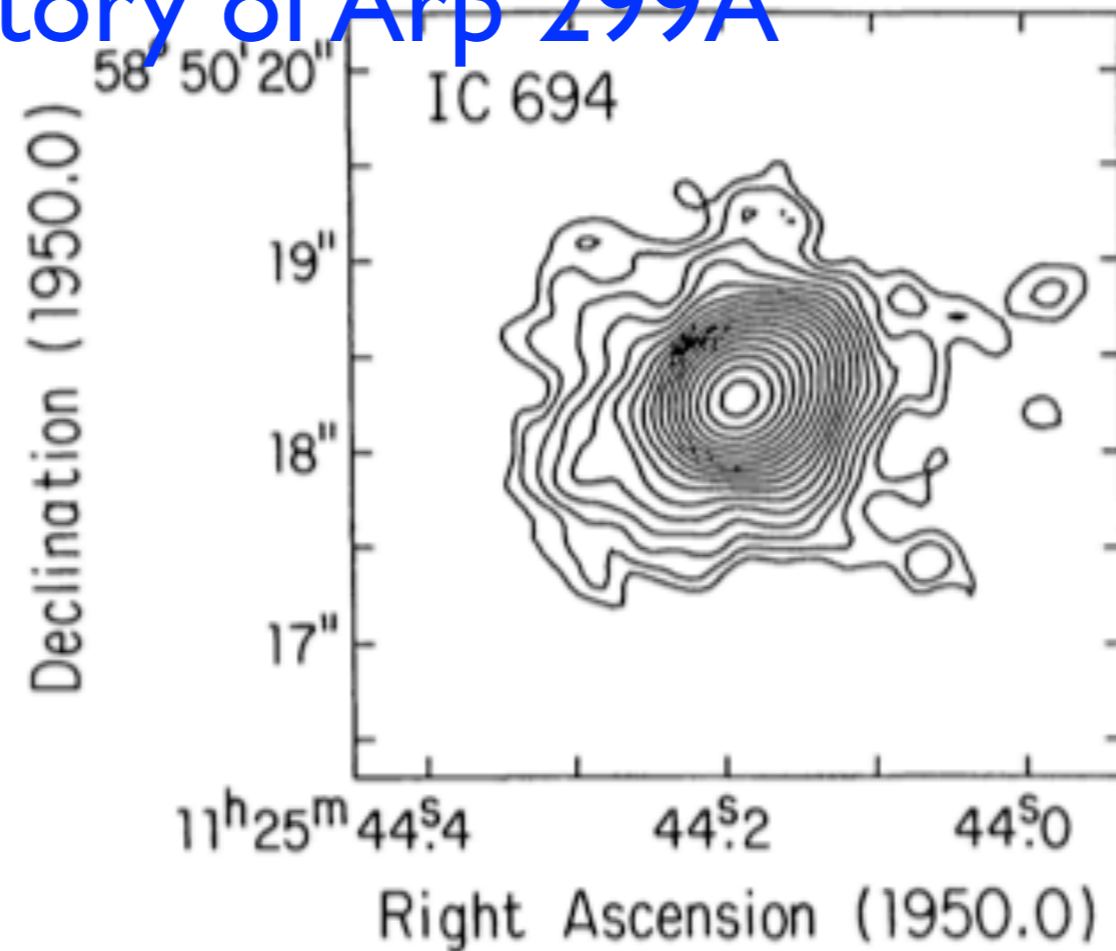


Figure 5 The nucleus of IC 694 is typical of the brightest and most compact sources found in “normal” galaxies. Its 8.44 GHz brightness temperature is only $\sim 10^4$ K, so its relatively flat radio spectrum indicates free-free absorption by thermal electrons with temperature $T_e \sim 10^4$ K, not synchrotron self-absorption by relativistic electrons with kinetic temperature $T_r > m_e c^2/k \sim 10^{10}$ K. The logarithmic contours are separated by factors of $2^{1/2}$ in brightness, and the lowest contour is $0.1 \text{ mJy beam}^{-1} \sim 28 \text{ K}$.

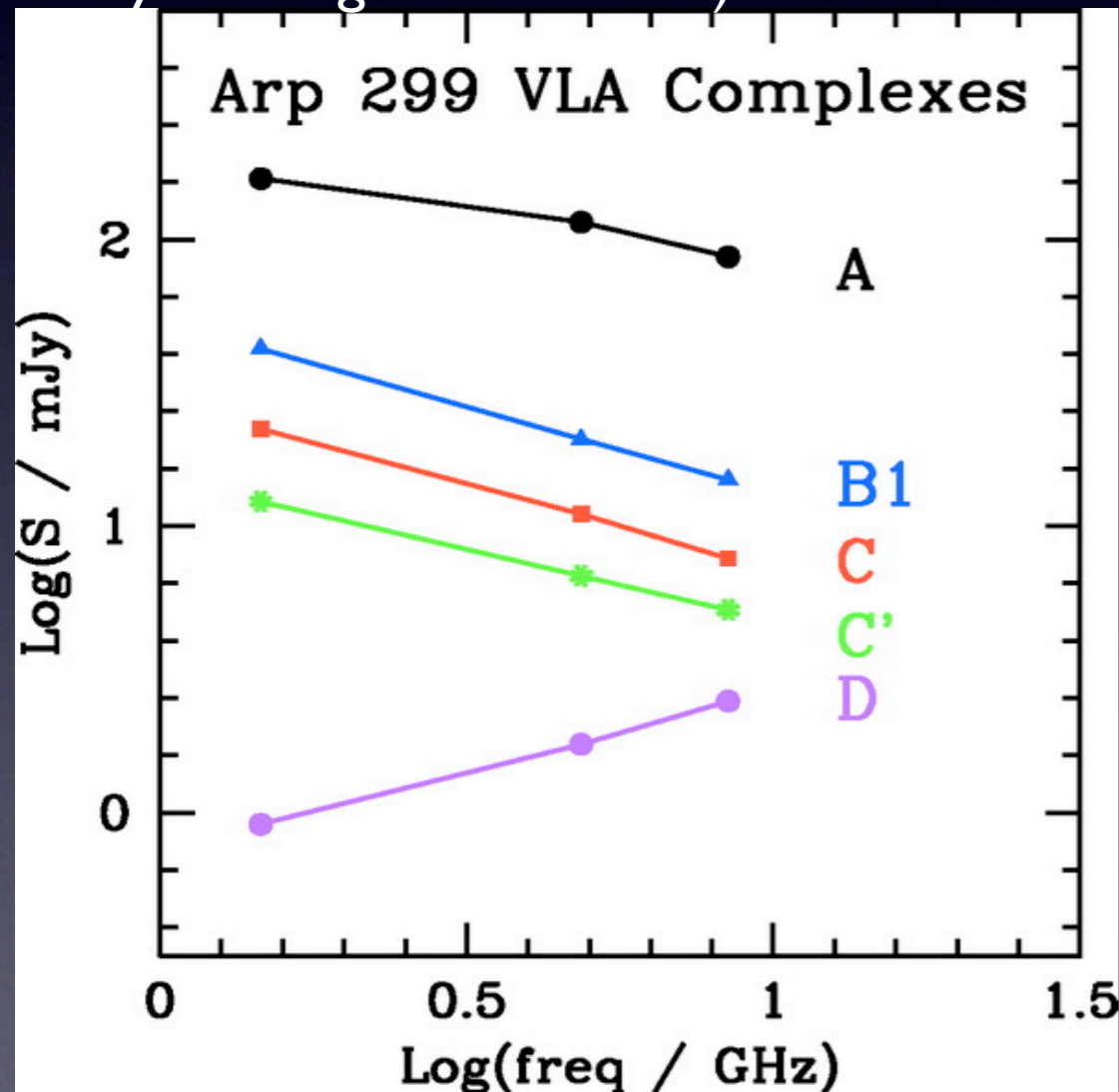
From Condon (ARA&A, 1991)

Radio components in Arp 299

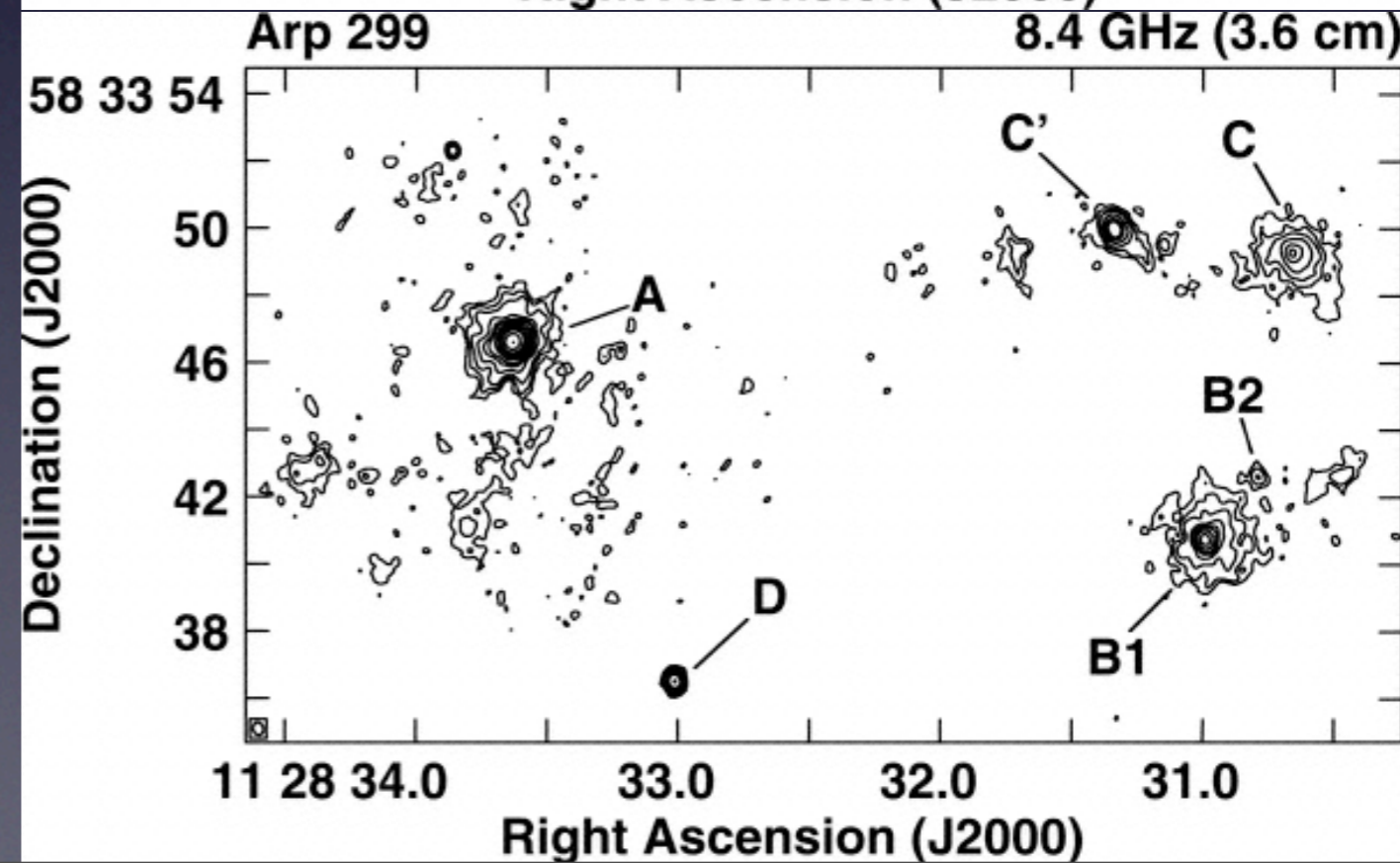
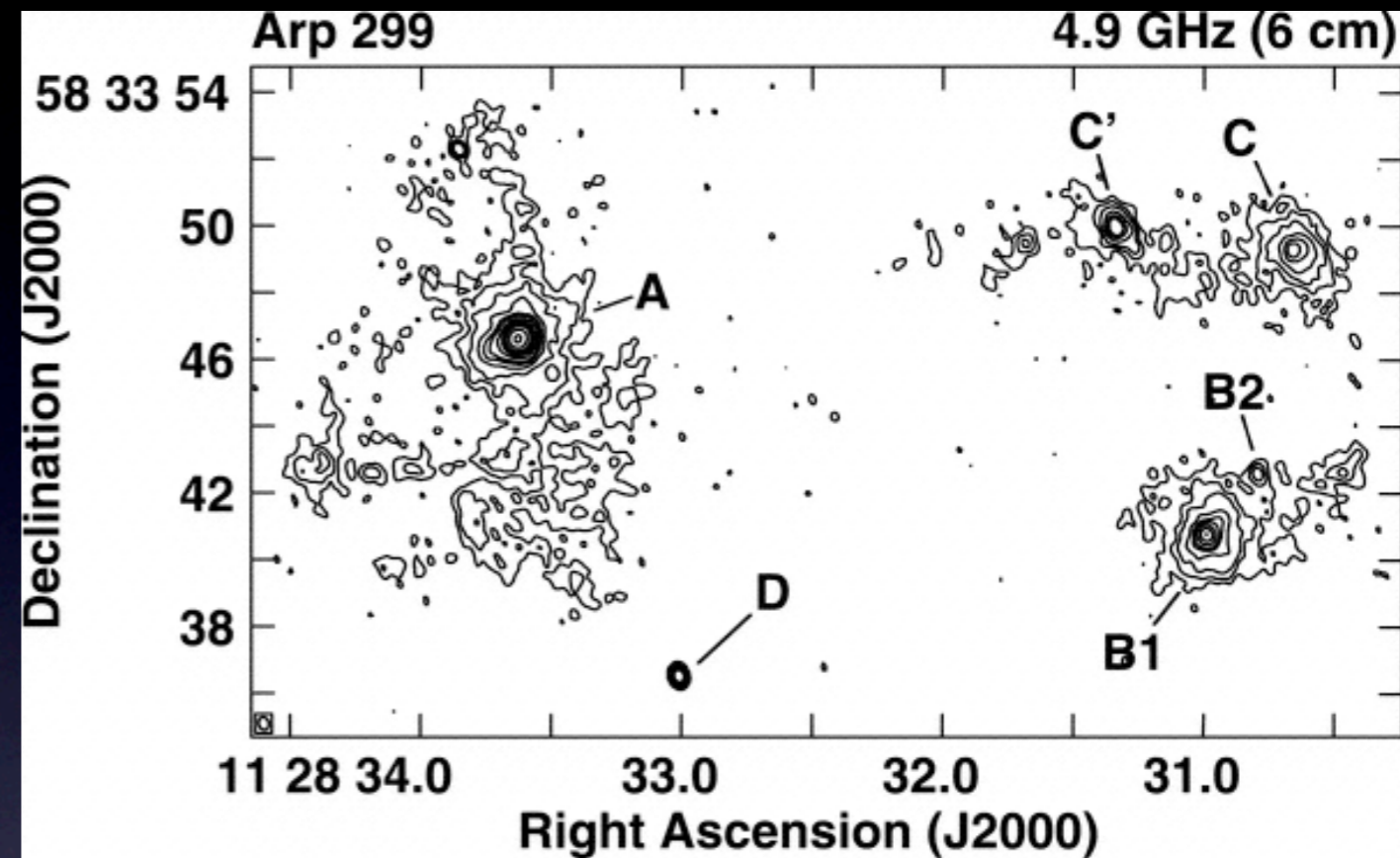
The arcsecond scale structure consists of five compact radio sources within diffuse emission

A, B, C, C' show steep spectra

D displays an inverted spectrum (it is likely a background source)

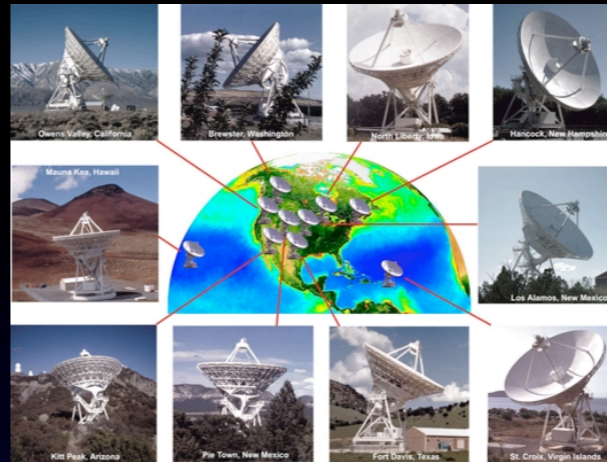


Neff et al. (ApJ, 2004)

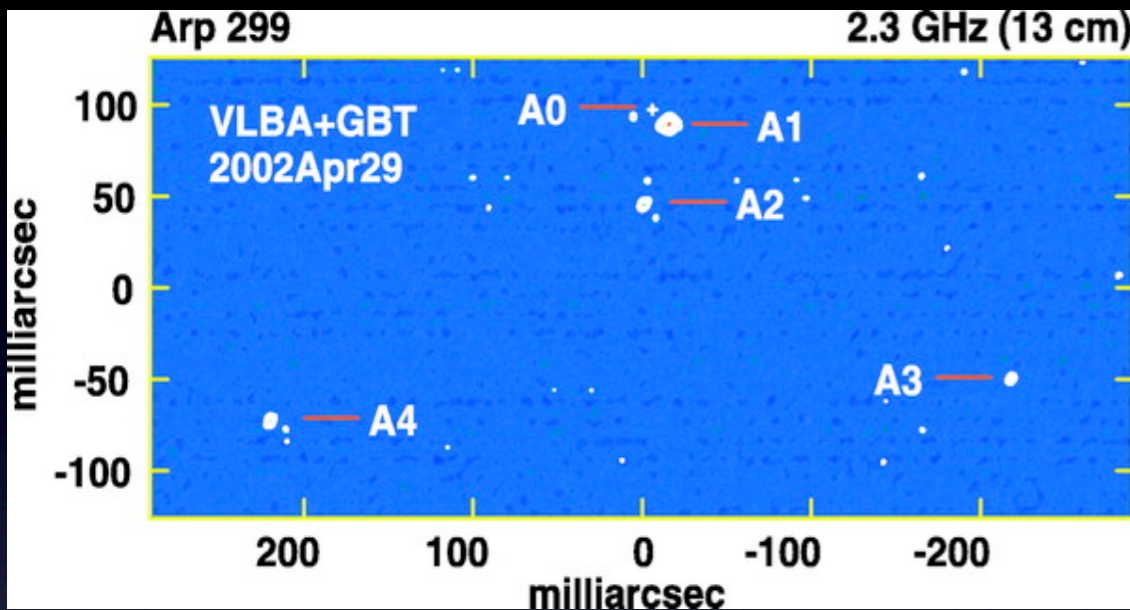


VLBA+GBT obs-ns of Arp 299

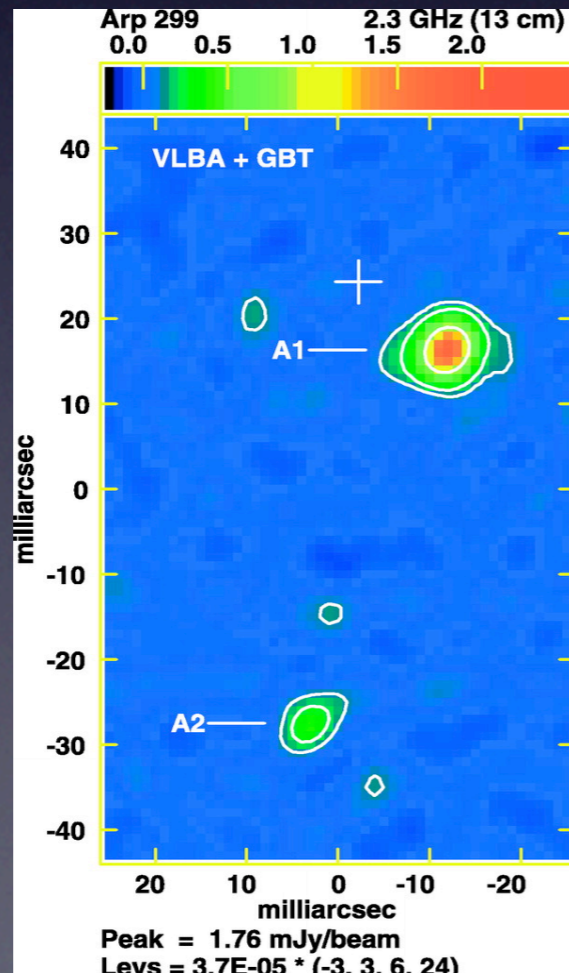
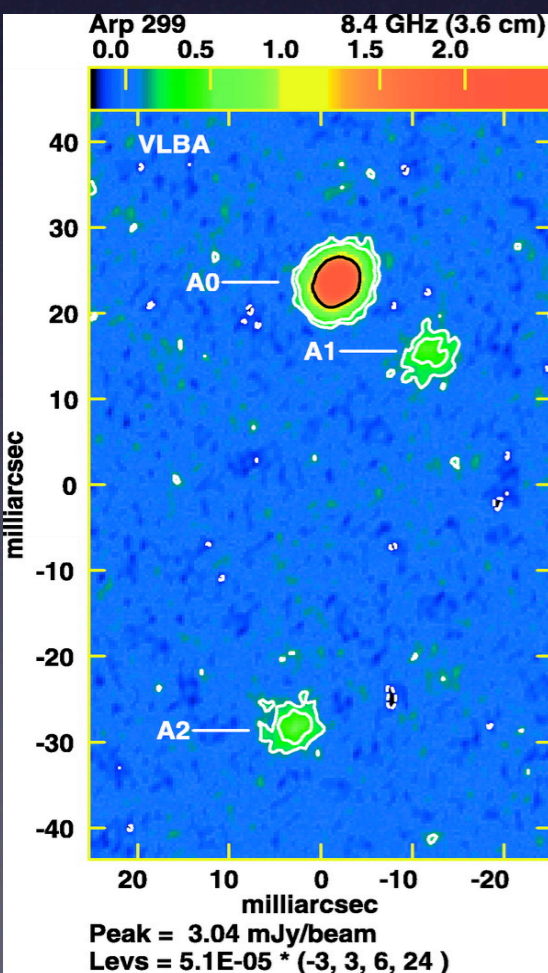
Neff et al. (ApJ, 2004)



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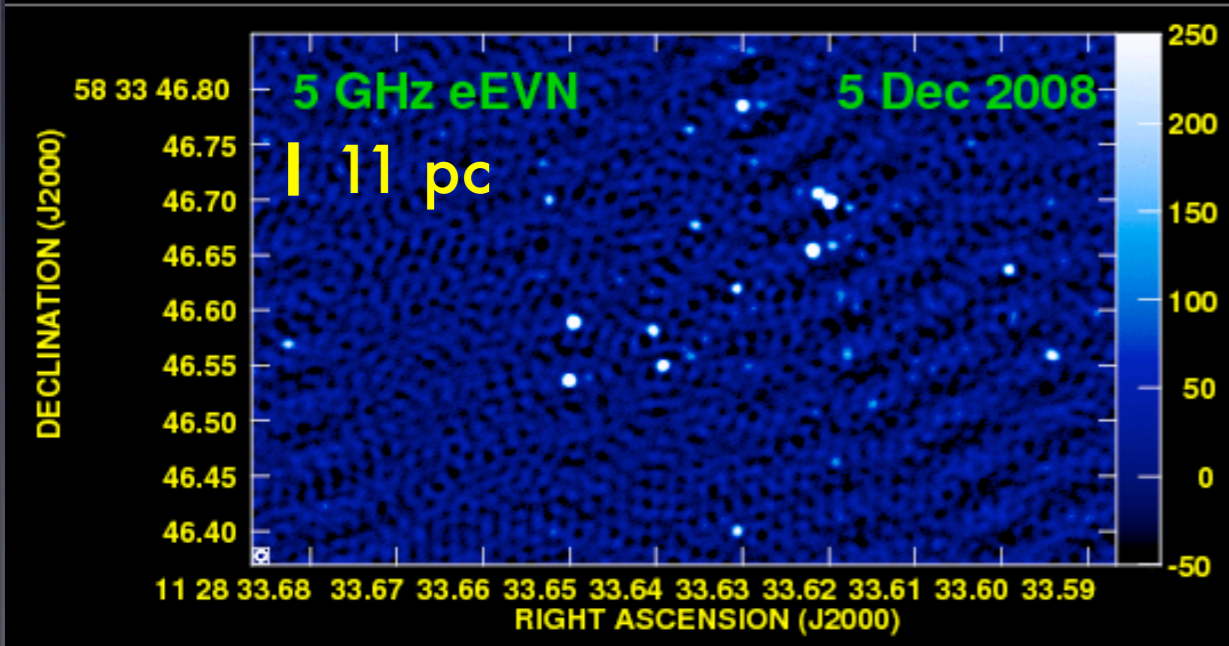
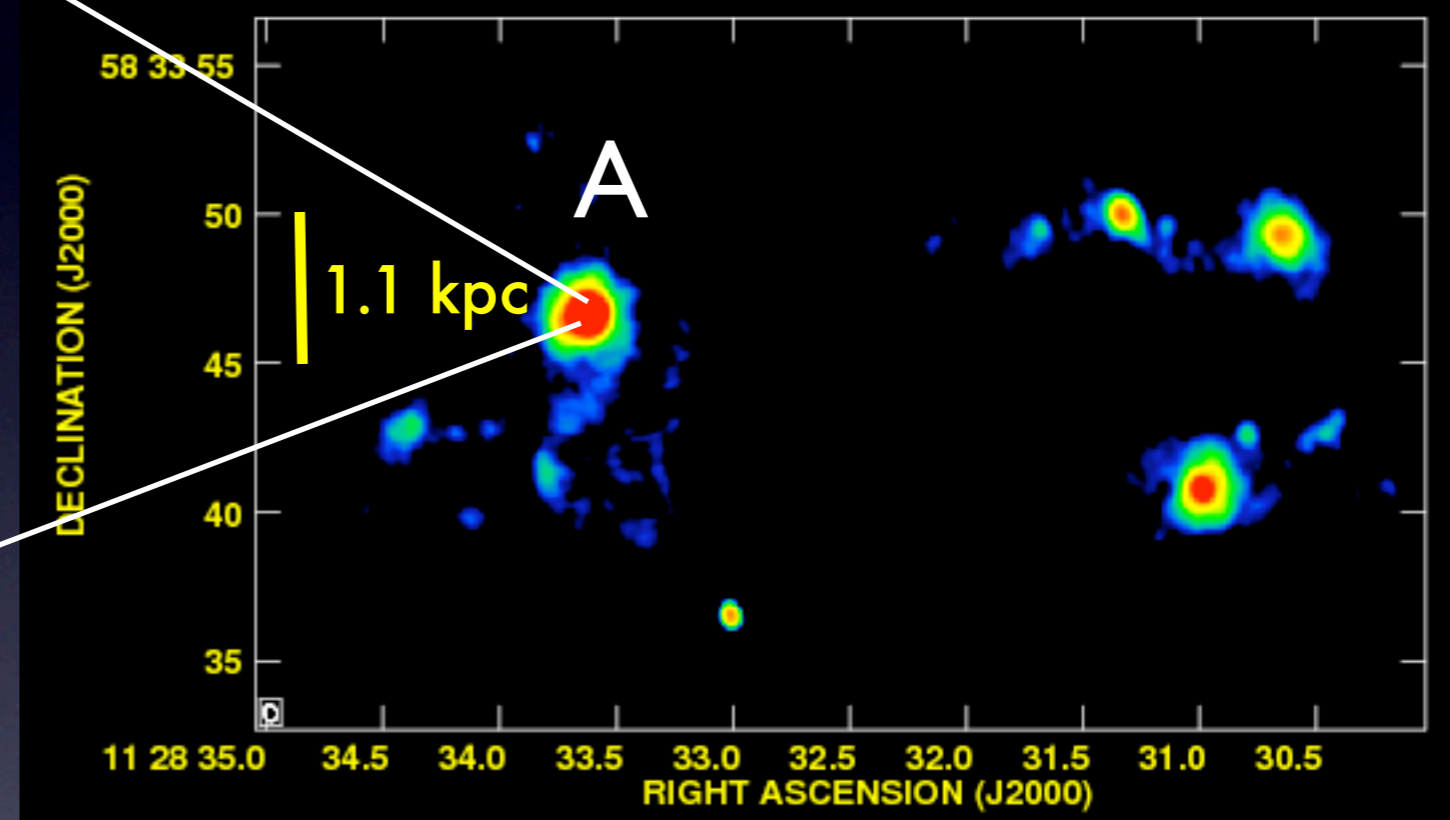
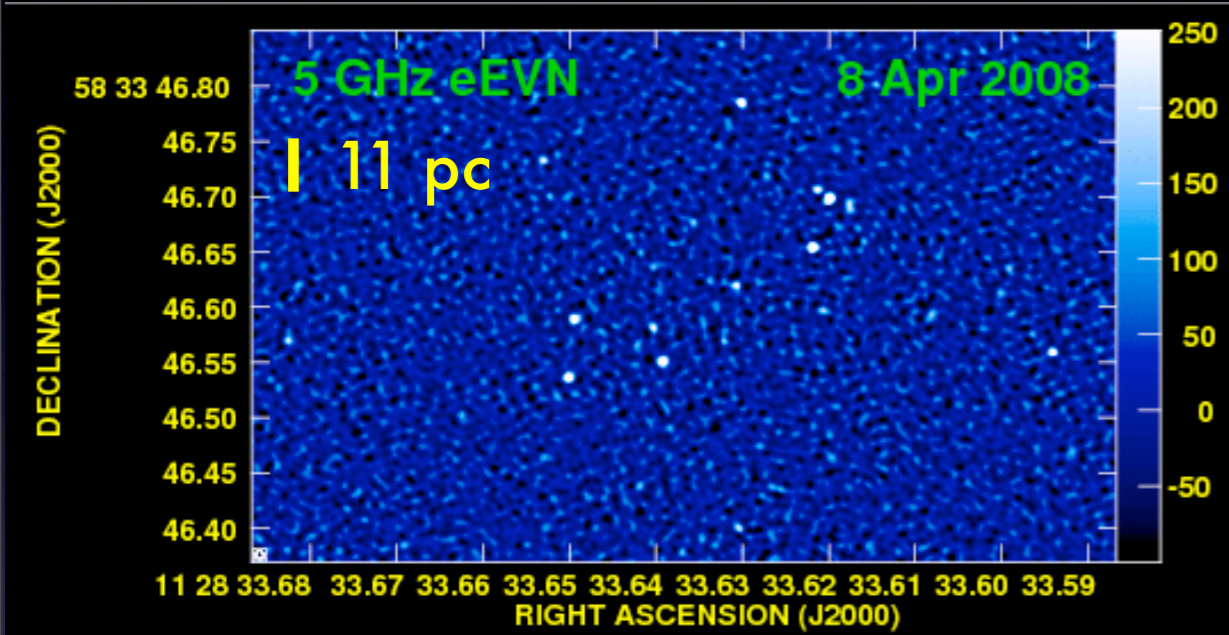


- 5 compact radio sources in A. Luminosities between 8×10^{19} and 7×10^{20} Watt/Hz
- A0 - A new RSN
- A0, A1 and A2 located within a 10pc-region (probably all of them exploded within the same super-star cluster)
- Star formation rate for A is in the range 0.5-1.0 SN/yr, in agreement with previous results (e.g., Alonso-Herrero et al. 2000)



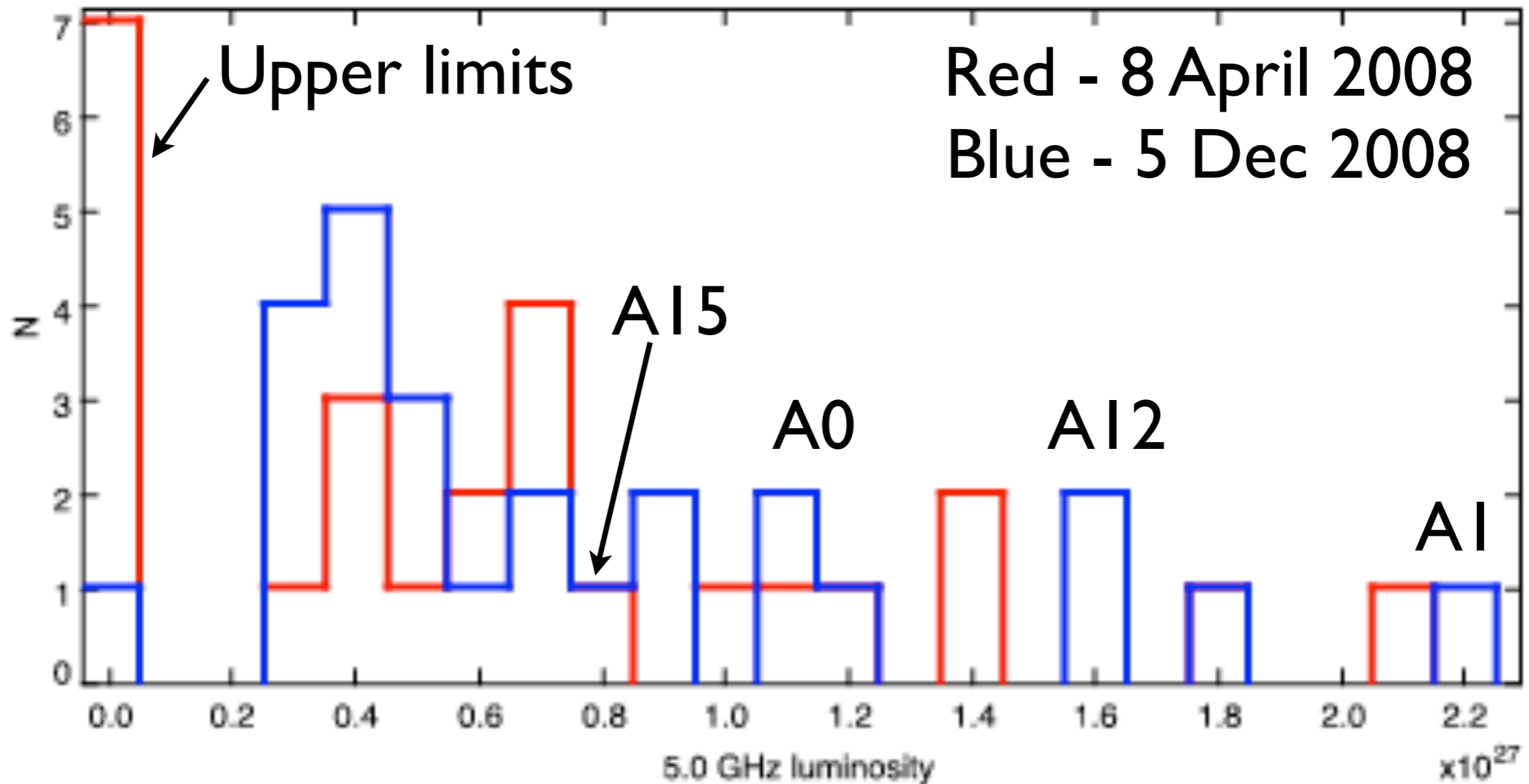
An extremely prolific SN factory in Arp 299-A revealed with the eEVN

Pérez-Torres et al. (Letters to A&A, 507, L17, 2009)



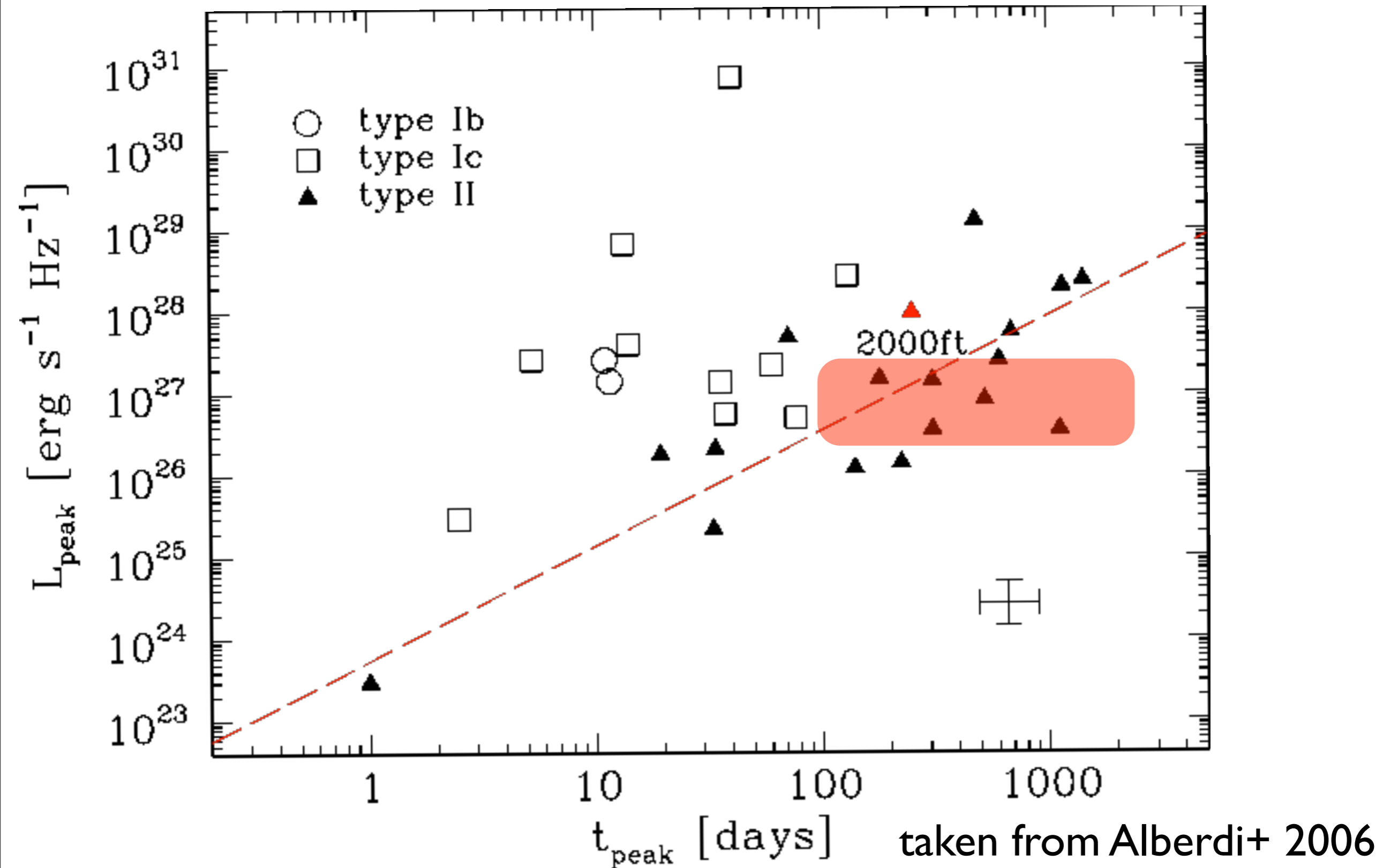
★ Discovery of a rich cluster of compact radio emitting sources in the central (150 x 80) pc of the nuclear starburst in IC 694.

5.0 GHz luminosity histogram of the VLBI components



Radio emission levels are moderate to high,
and typical of Type II RSNs

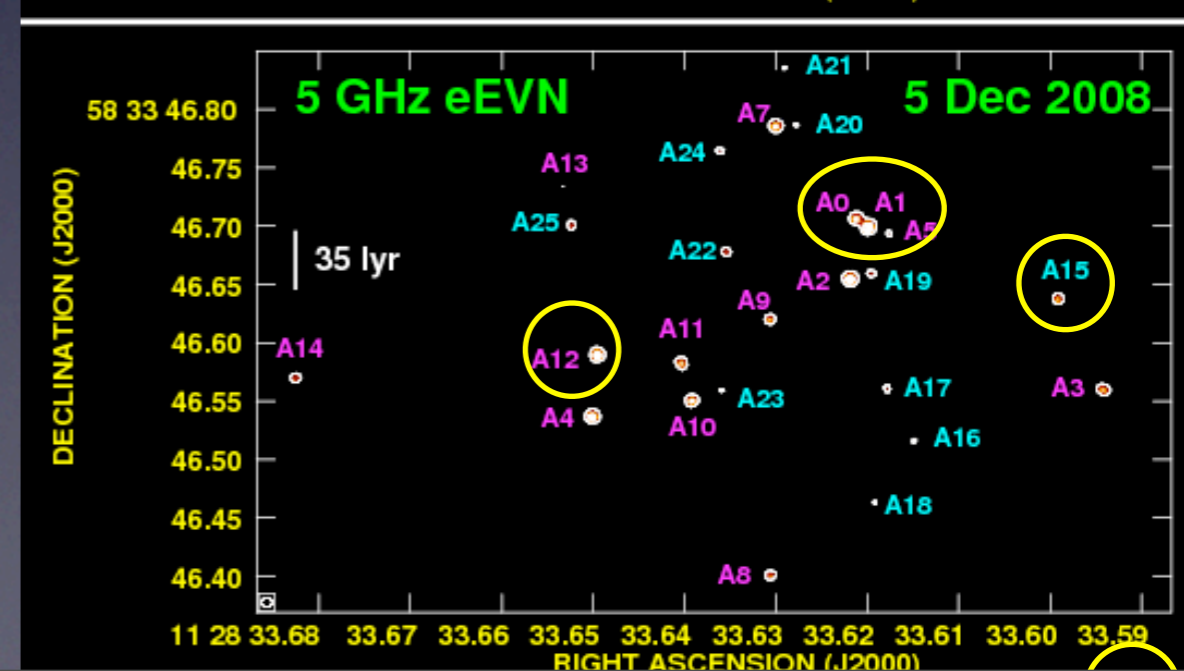
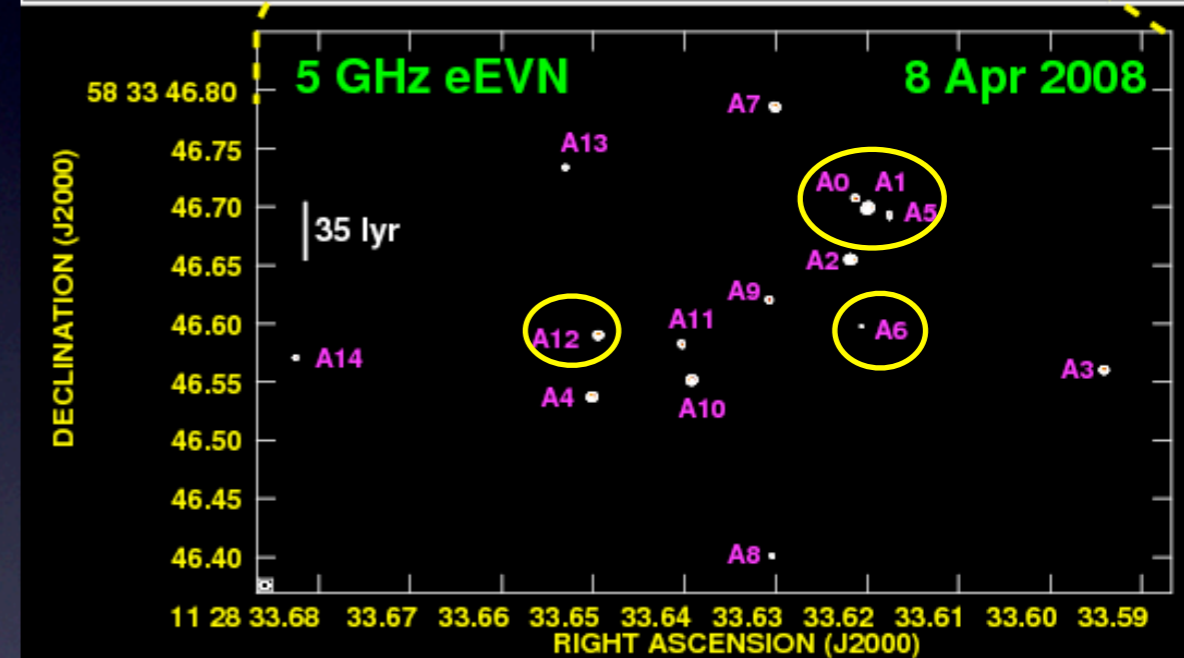
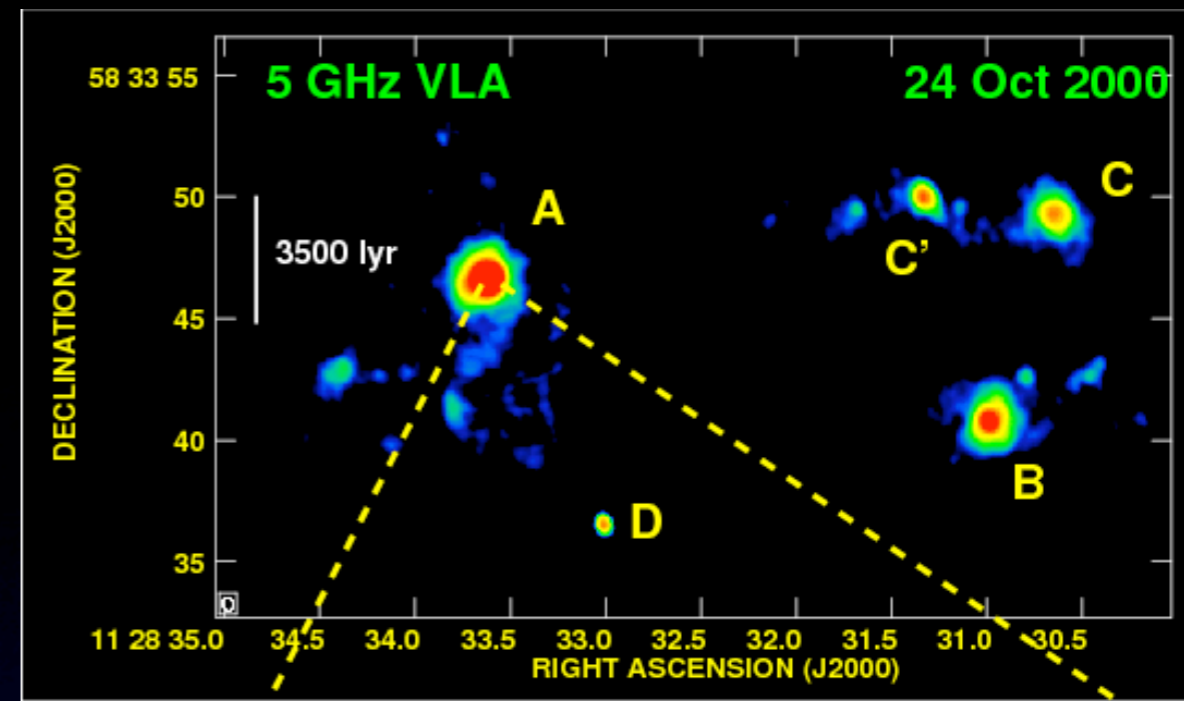
Peak luminosity vs. time to peak for RSNs



An extremely prolific SN factory in Arp 299-A revealed with the eEVN

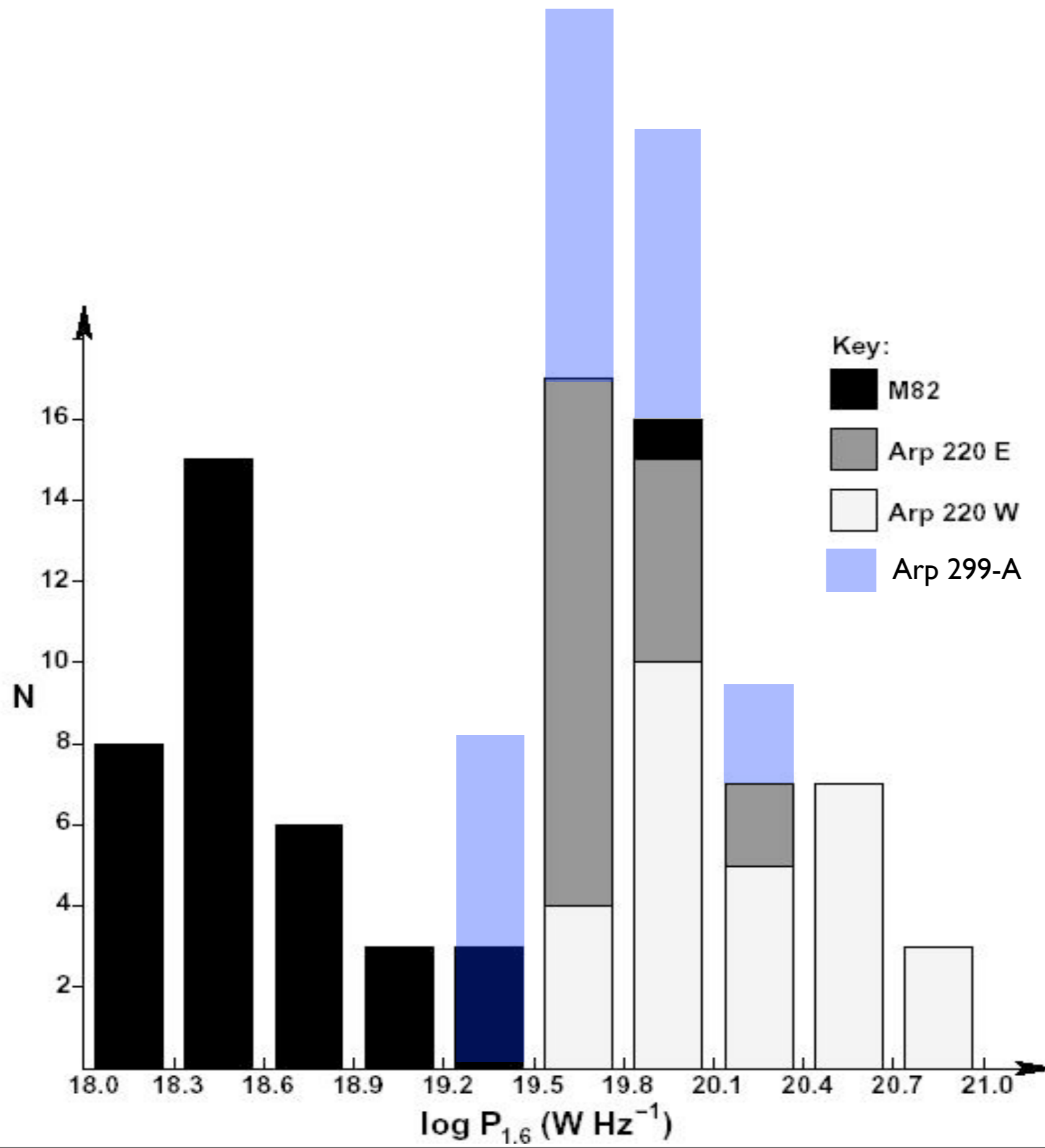
- ★ SNe and/or SNRs, likely embedded in SSCs.
- ★ Evidence of at least three RSNs (A0, A12 and A15), plus a likely one (A6, although it could be an X-ray binary).
- ★ All of the three RSN are relatively young, slowly evolving, long-lasting SNe.
- ★ Very suggestive of the local CSM playing a main role in shaping the radio behaviour of RSNs.
- ★ Moderate to high radio emission levels (typical of Type II SNe)
- ★ All of these results provide support for a recent (< 10-15 Myr) instantaneous starburst in the inner 150 pc of IC 694

Pérez-Torres et al. (Letters to A&A, 2009)



Arp 299-A in context

Arp 299-A starburst vs. M82 and Arp 220



Summary

- Arp 299-A is of moderate IR luminosity, yet it seems to show an extremely prolific RSN factory.
- Large number of compact radio sources found in 6/18 cm observations of Arp 299-A with the EVN. Must be SN and SNRs, likely embedded in SSCs. Radio obs-ns give further evidence for a recent, short-duration SB.
- Possible microquasar detection (A6) and at least two new RSNe in the last few years (A12 and A15). Radio luminosities indicate these must be Type IIb/P, or Type IIL SNe.
- Other young (but less recent) RSNe indicate that we are witnessing a population of long-lasting, slowly evolving RSNe in Arp 299A.
- Confirmation for a very bright (and also long-lasting, slowly evolving) RSN detected in the nucleus of B1. Where's the AGN?
- Bottom line: The Arp 299-A starburst nicely fills a gap between M82-like starbursts and monster, Arp 220-like starbursts in the local Universe.
- Stay tuned for news on this spectacular object!