The sub-parsec structure of the nuclear region of the LIRG NGC7469

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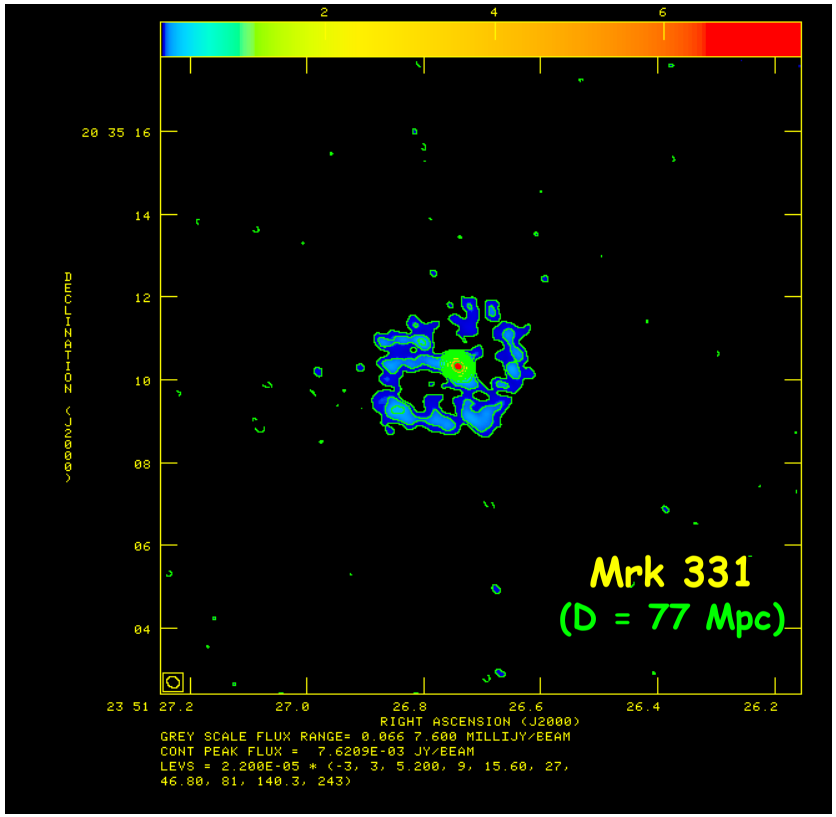
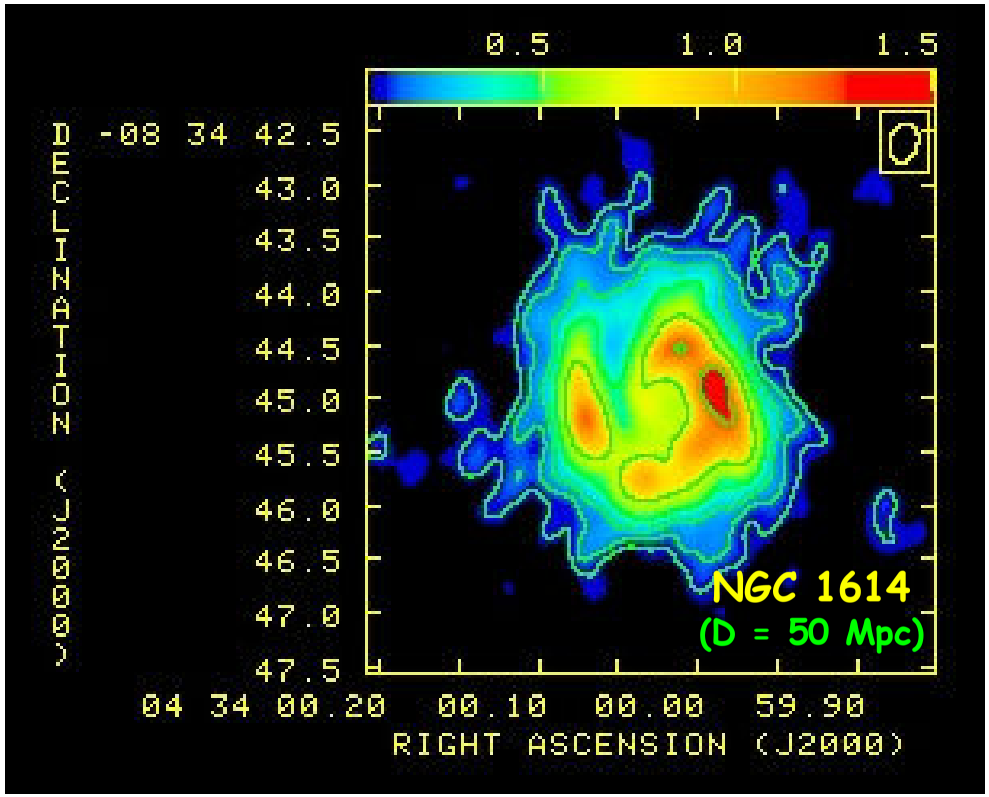
Radio Observations of Starburst Galaxies

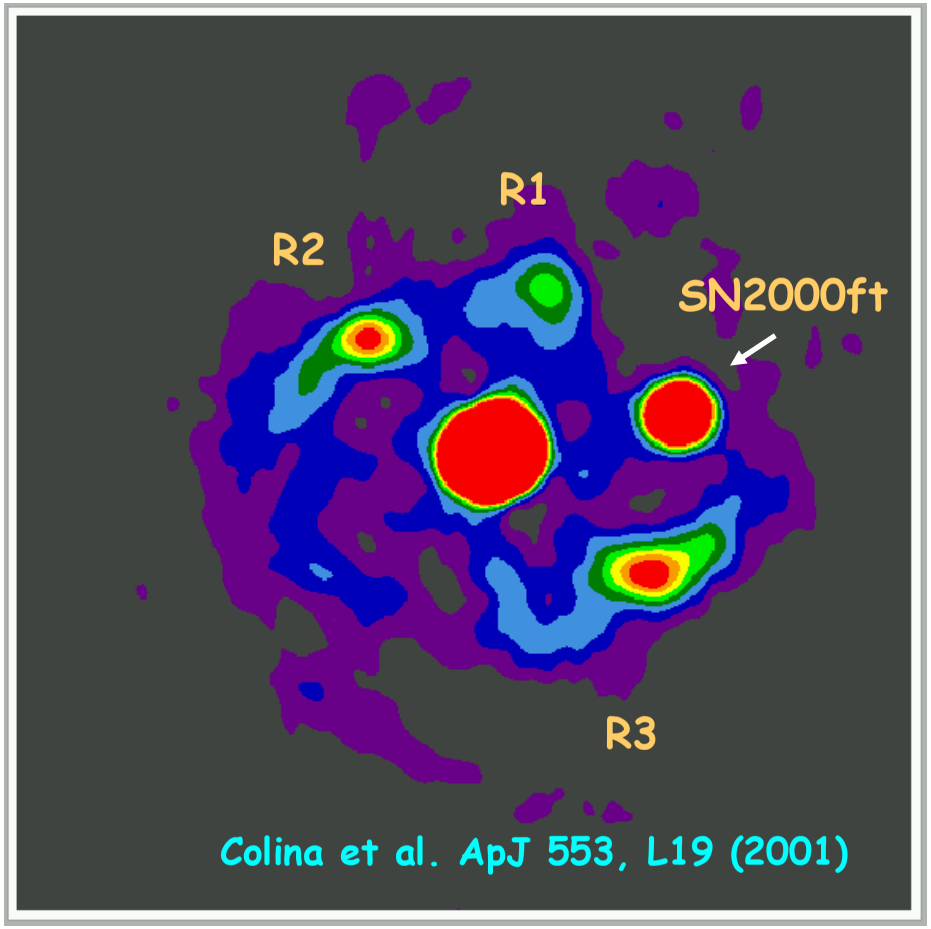
- Compact (≤150 pc) high surface brightness ($T_b \geq 10^3$ K) central radio source → generated by a point-like source (AGN) or by the combined effect of SNe and RSNe
- Low surface brightness circumnuclear halo → ongoing burst of star formation





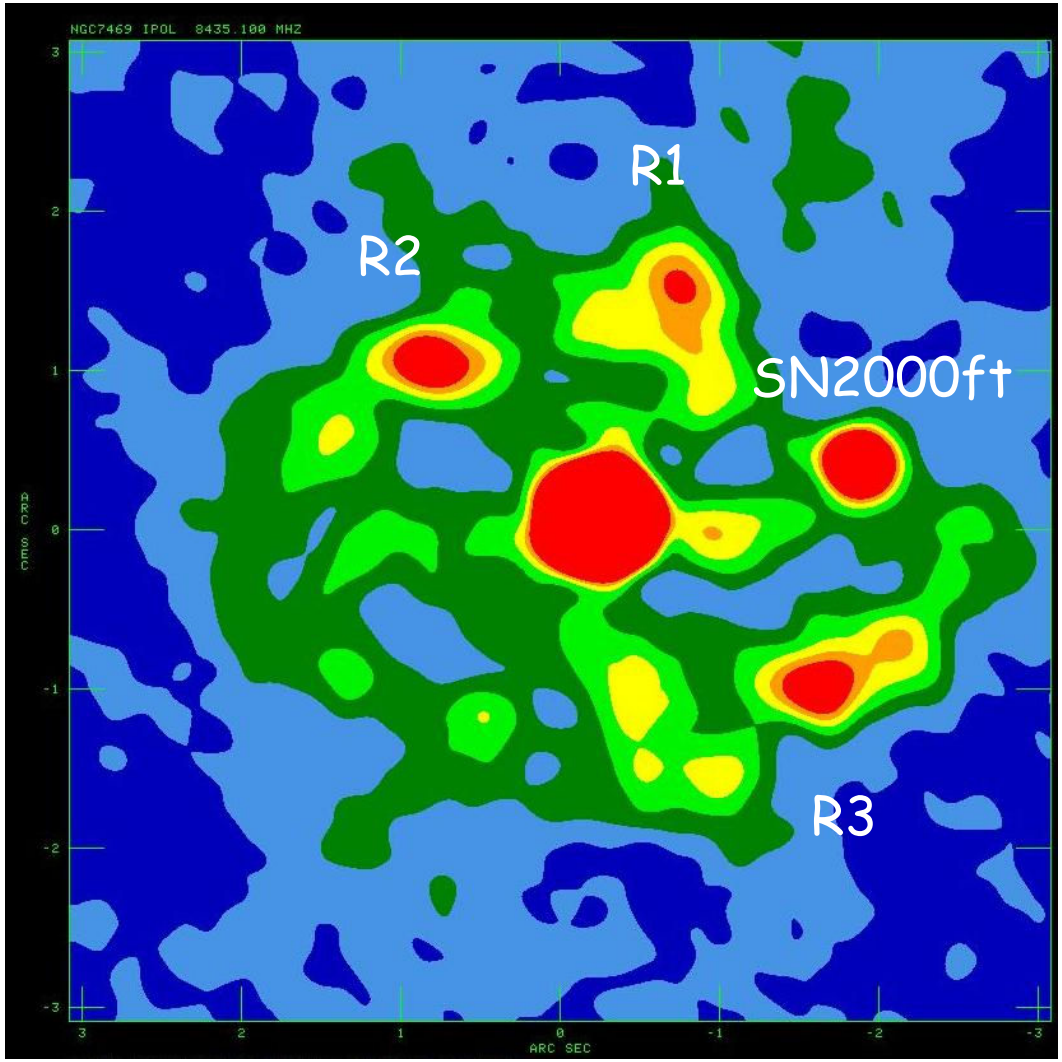
SN 2000ft in NGC 7469

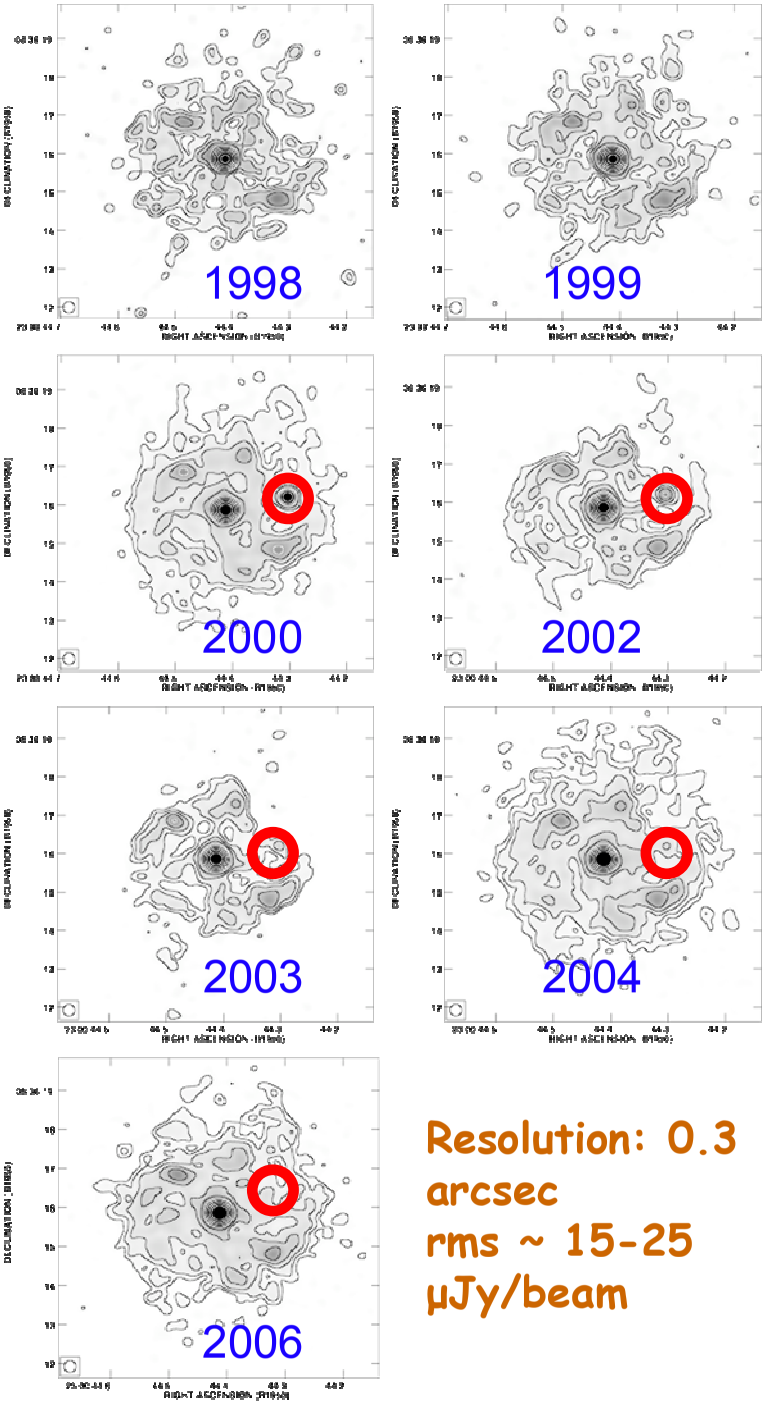
- NGC 7469 is a highly luminous infrared, QSO-like, galaxy.
- There is evidence for a 10^7 M_{sun} BH
- L_{IR} ~ 5 x 10^{11} L_{sun} ; D: 70 Mpc; 1 mas= 0.32 pc



- Ring: 1 Kpc
- SN 2000ft is located in the circumnuclear starburst, at a distance of 600 pc of the nucleus.
- $L_{SN2000ft}$ = 1.1 x 10^{21} W/Hz, very luminous

SN 2000ft in NGC 7469: X-band evolution (8 years)

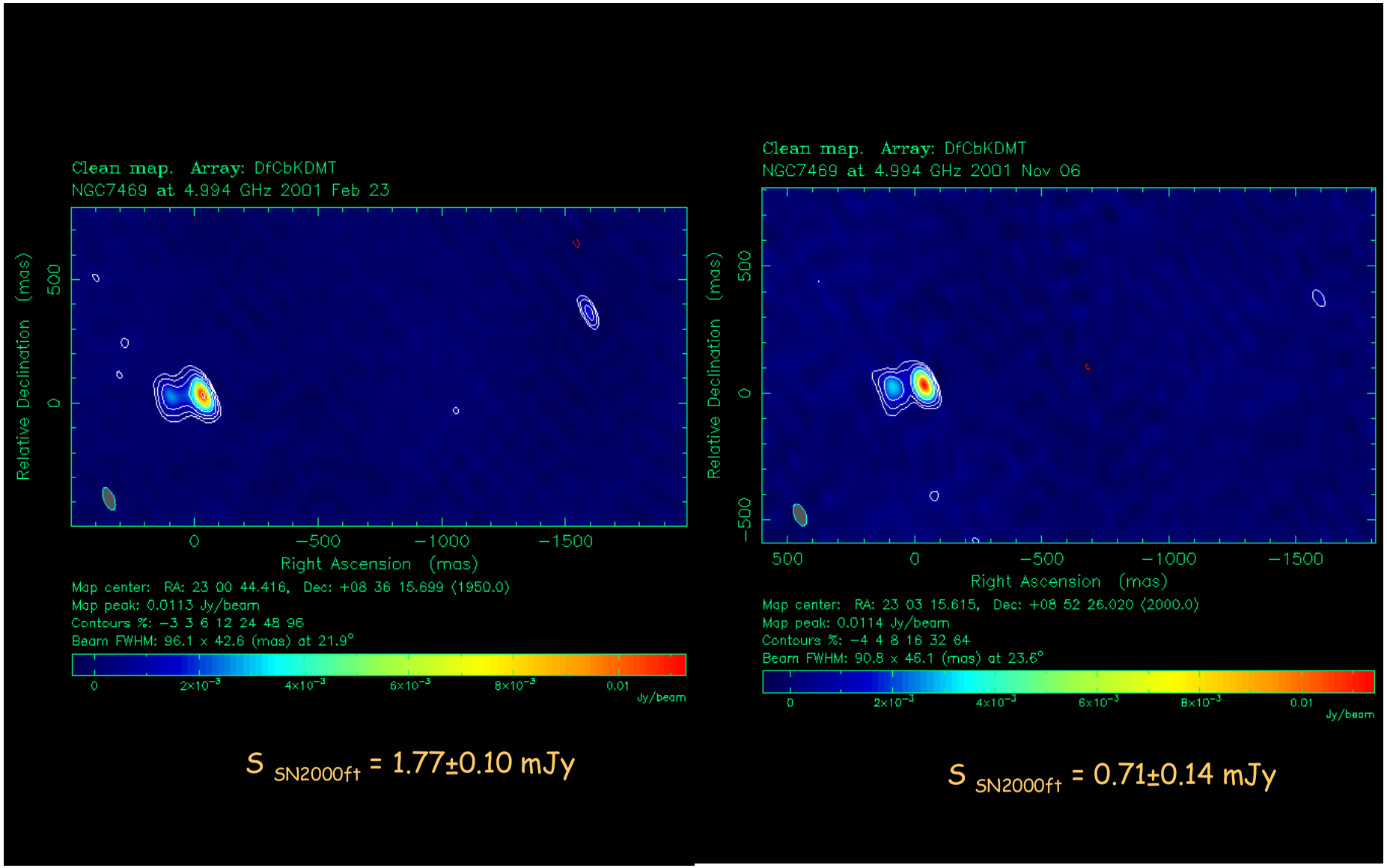




Resolution: 0.3 arcsec
rms ~ 15-25 μJy/beam

Alberdi et al. ApJ 638, 938 (2006) Pérez-Torres et al. MNRAS 399, 1641 (2009)

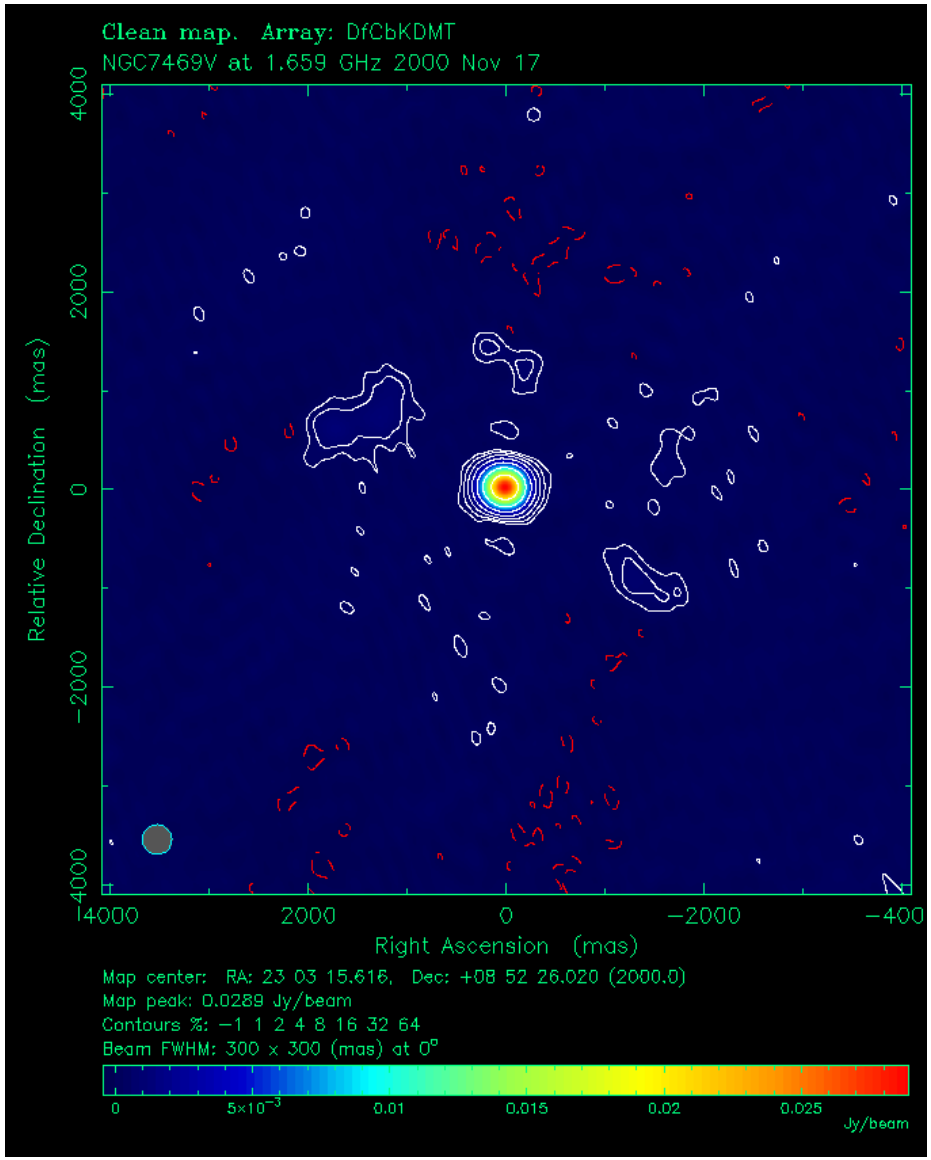
SN 2000ft in NGC 7469: C-band evolution



$S_{SN2000ft}$ = 1.77±0.10 mJy

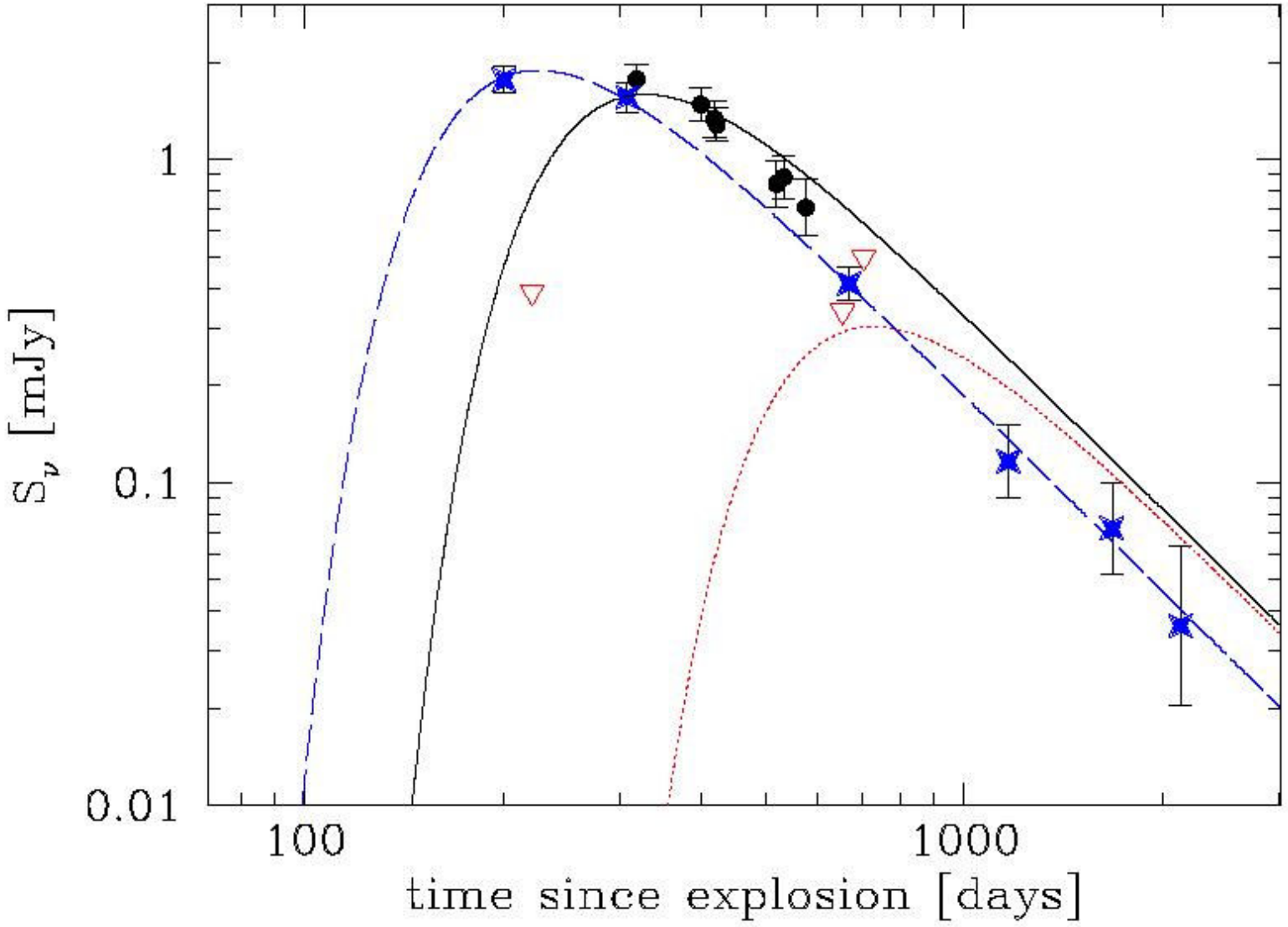
$S_{SN2000ft}$ = 0.71±0.14 mJy

SN 2000ft in NGC 7469: L-band evolution



No detection at 18 cm

SN 2000ft in NGC 7469: Radio Light Curve



Alberdi et al. ApJ 638, 938 (2006); Pérez-Torres et al. MNRAS 399, 1641(2009)

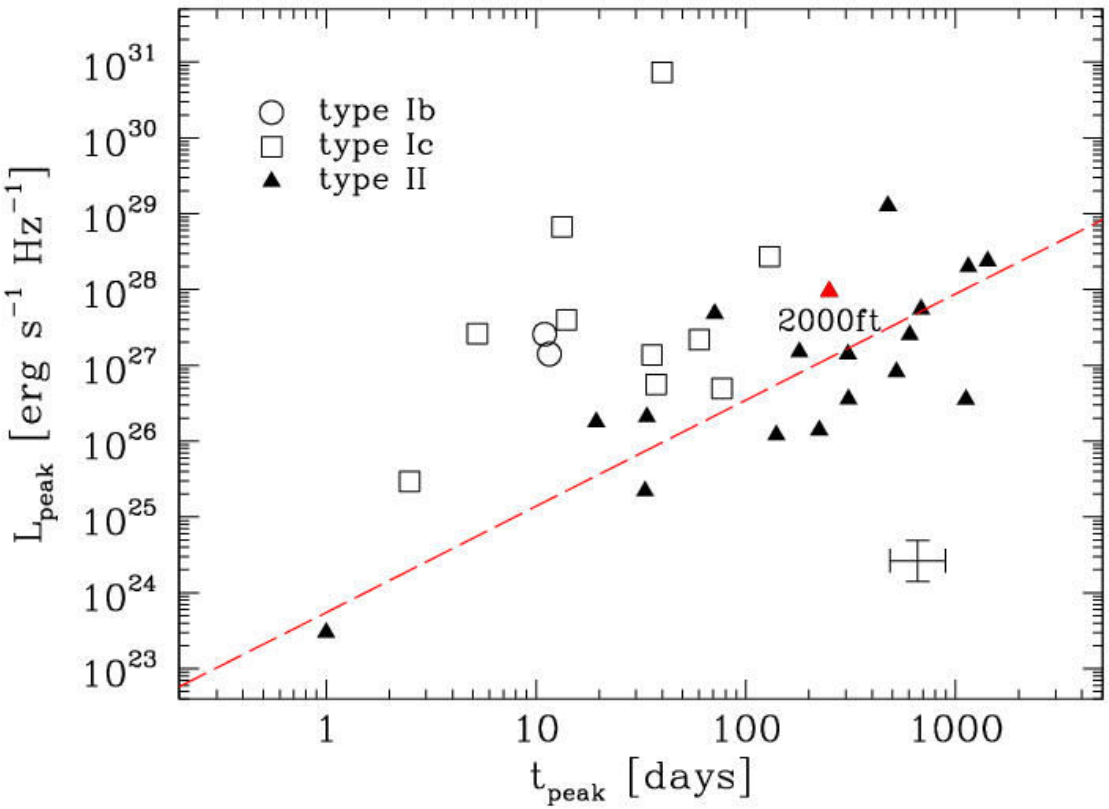
SN 2000ft in NGC 7469: Radio Light Curve

$$S(\mathrm{mJy}) = K_1 \left(\frac{\nu}{5\ \mathrm{GHz}}\right)^{\alpha} \left(\frac{t-t_0}{1\ \mathrm{day}}\right)^{\beta} e^{-\tau_{\mathrm{external}}} \left(\frac{1-e^{-\tau_{\mathrm{CSM_{clumps}}}}}{\tau_{\mathrm{CSM_{clumps}}}}\right) \left(\frac{1-e^{-\tau_{\mathrm{internal}}}}{\tau_{\mathrm{internal}}}\right) \qquad (1)$$

- Fitted time of the explosion: 10 May 2000
- Fitted spectral index: α = -1.27
- Fitted power-law time decay: ß = -2.02
- Fitted 5 GHz flux at 1 day: K_1 =4.45e5 mJy
- $\tau_{external}$ = τ_{CSM} (fitted 5 GHz RSG stellar wind τ_{ff} at 1 day, K_2 = 1.67e7) + $\tau_{distant}$ (associated with a foreground HII region: $K_4 \geq 0.17$). This value of the opacity implies the presence of an ionized layer along the LOS with an Emission Measure, EM= 1.60 x 10^7 cm^{-6} pc)

Alberdi et al. ApJ 638, 938 (2006); Pérez-Torres et al. MNRAS 399, 1641 (2009)

SN 2000ft in NGC7469: A bright type-II RSN



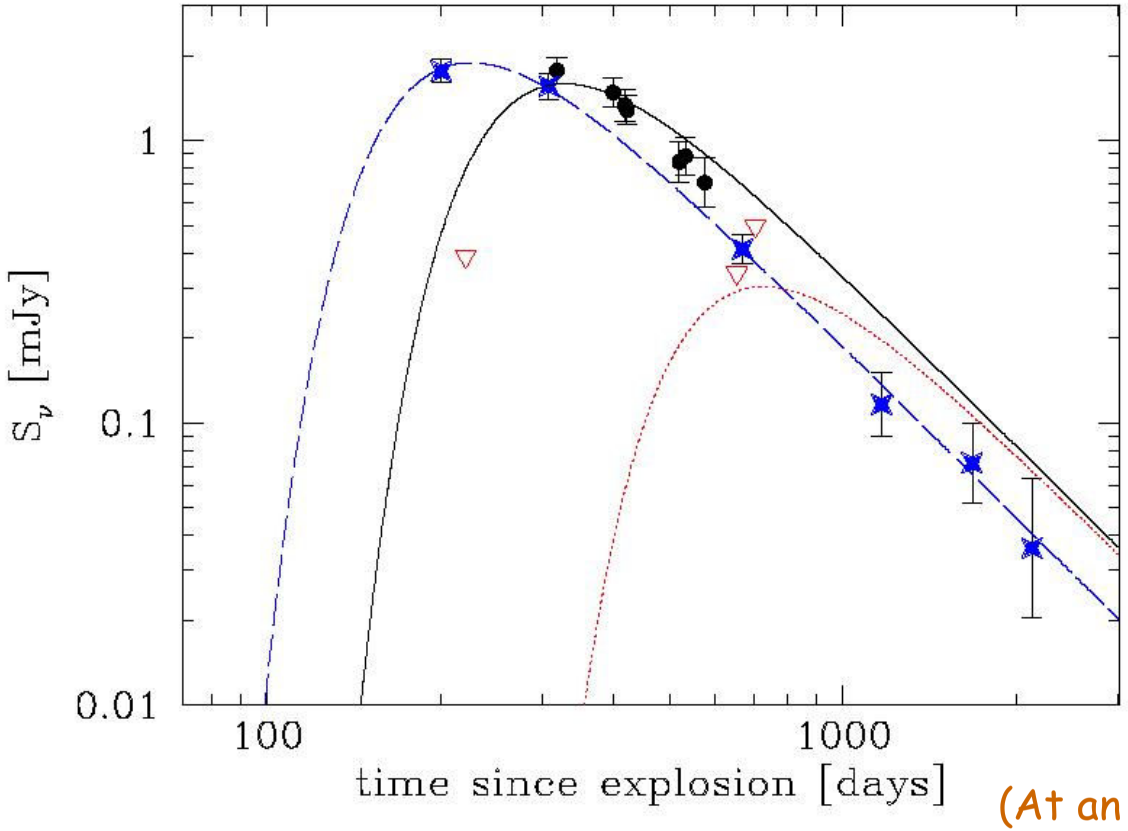
- It is a extremely luminous radio supernova (1.1×10^{28} erg s^{-1} Hz^{-1}), like SN79C, SN86J, SN88Z

- Fitting parameters are typical of type-II radio supernovae

- Mass loss rate $\leq (4.7\text{-}5.1) \times 10^{-5}$ M_{sun} / yr, typical of a RSG-progenitor

SN2000ft: CSM vs. ISM interaction (I)

First ~2100 days radio emission powered by circumstellar interaction. In the future, departure from standard behaviour will indicate radio emission is being powered by interaction with ISM



ram pressure of wind $\rho_w v_w^2$

radio SN phase ends when

$$P_{\rm ISM} \approx \rho_w v_w^2$$

for a steady, spher. symmetric wind

$$\rho_w \propto r^{-2}$$

$$r_w \approx 0.18 \dot{M}_{-4}^{1/2} v_{w1}^{1/2} p_7^{-1/2}$$

Assuming V_{sh} = 10000 km/s

r ~ 0.06 pc < r_w

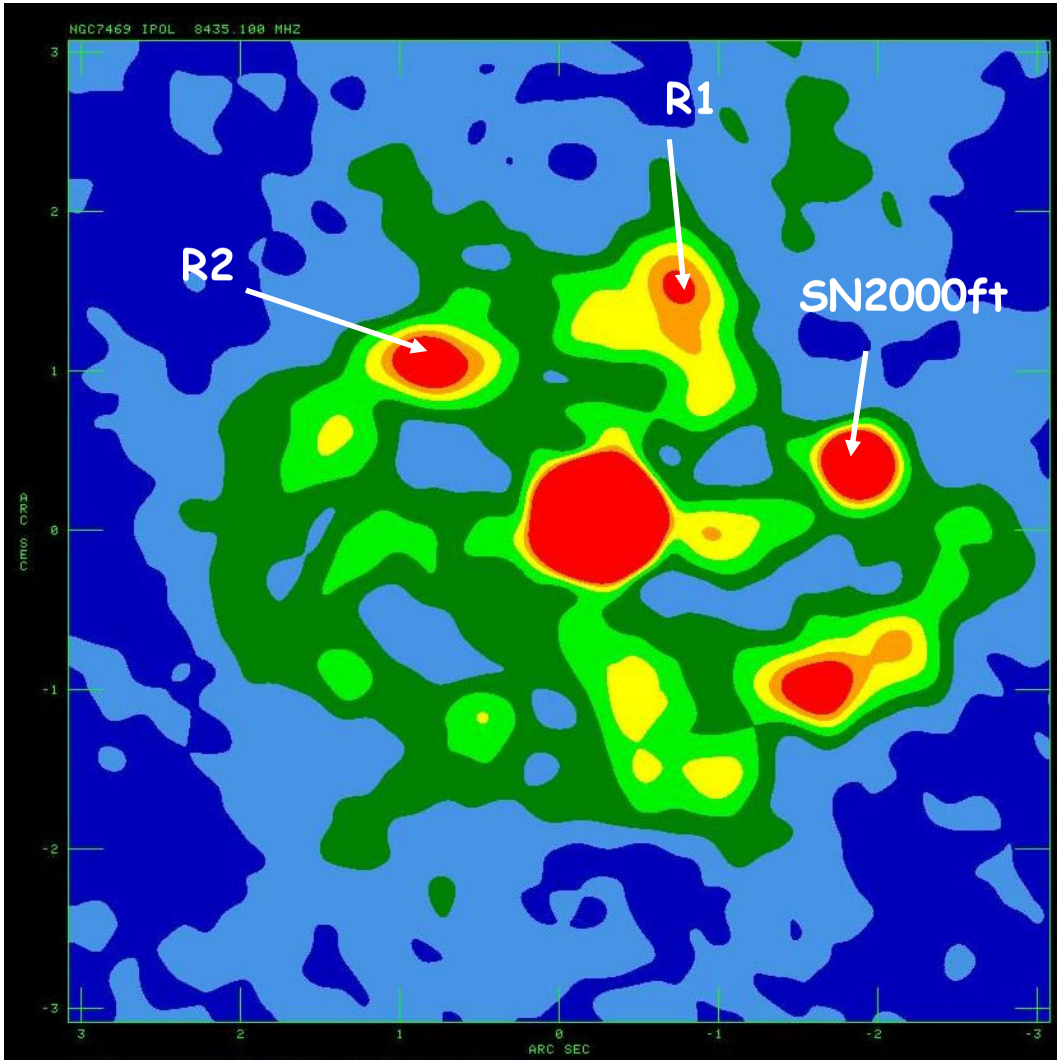
(At an age of 2147 days, the ram pressure of the wind is ~7.6 × 10^{-9} dyn cm^{-2}, still very high to be overcome by P_{ISM})

Pérez-Torres et al. 2009, MNRAS 399, 1641

The circumnuclear starburst in NGC 7469

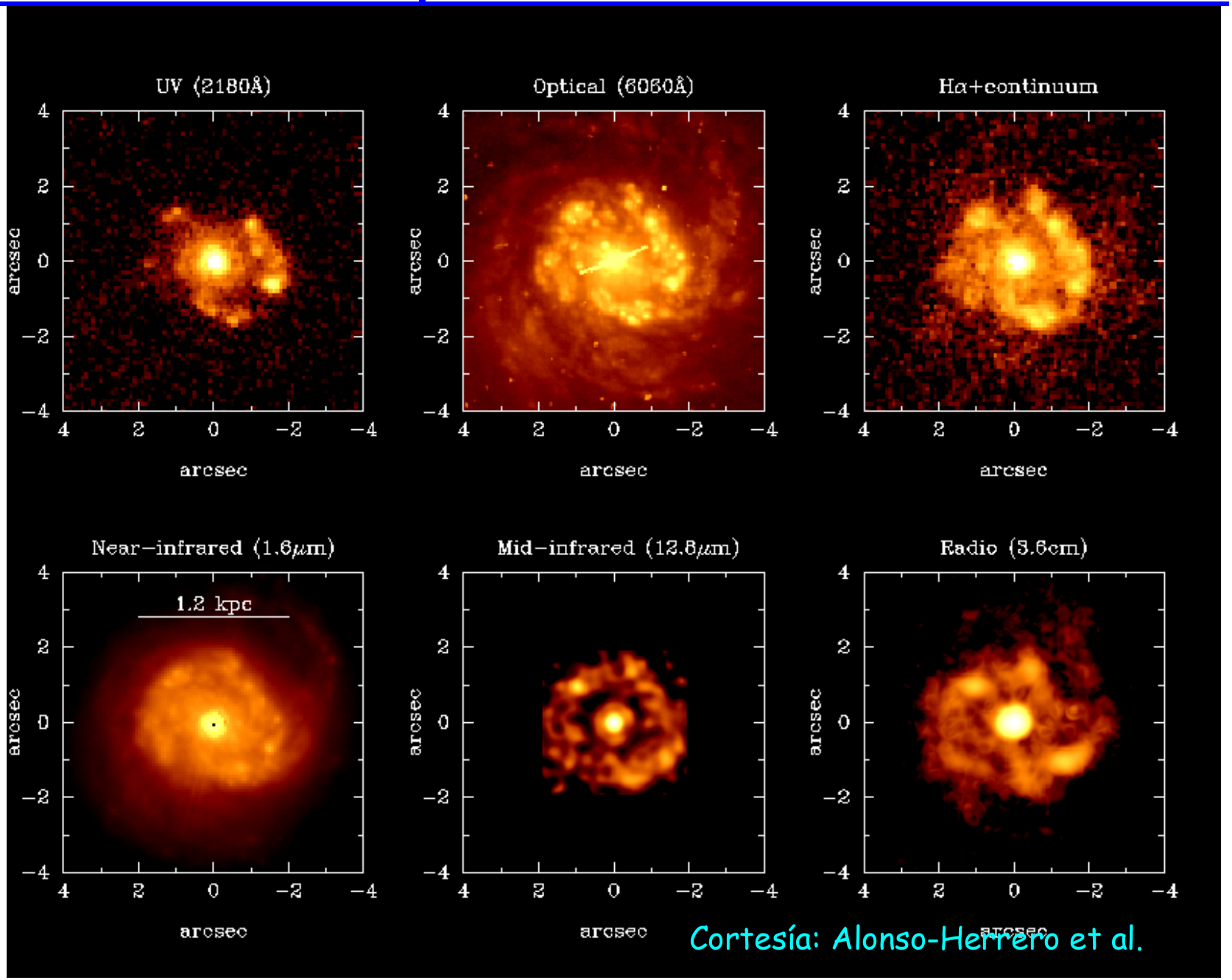
Apart from SN 2000ft, there is no evidence for RSNe more luminous than about $L_{peak} \sim 6 \times 10^{26}$ erg s^{-1} Hz^{-1}, suggesting that no other Type IIn SN has exploded since 2000 in the nuclear starburst of NGC 7469.

CCSN rate is ≤ 0.13 #/yr, in contrast with the CCSN rate = 2.7e-12 * L_fir → 0.81 #/yr



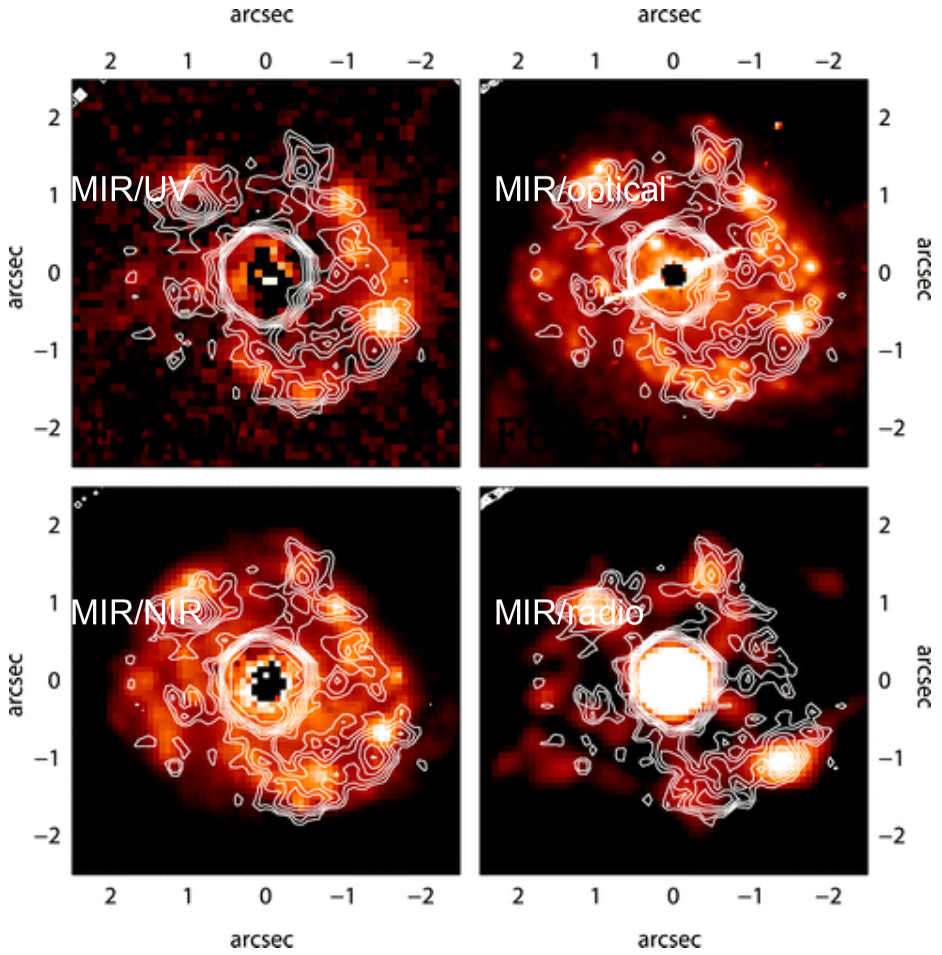
Pérez-Torres et al. 2009, MNRAS 399, 1641

NGC 7469: A 0.2 μ to 3.6 cm view at 0.2" resolution



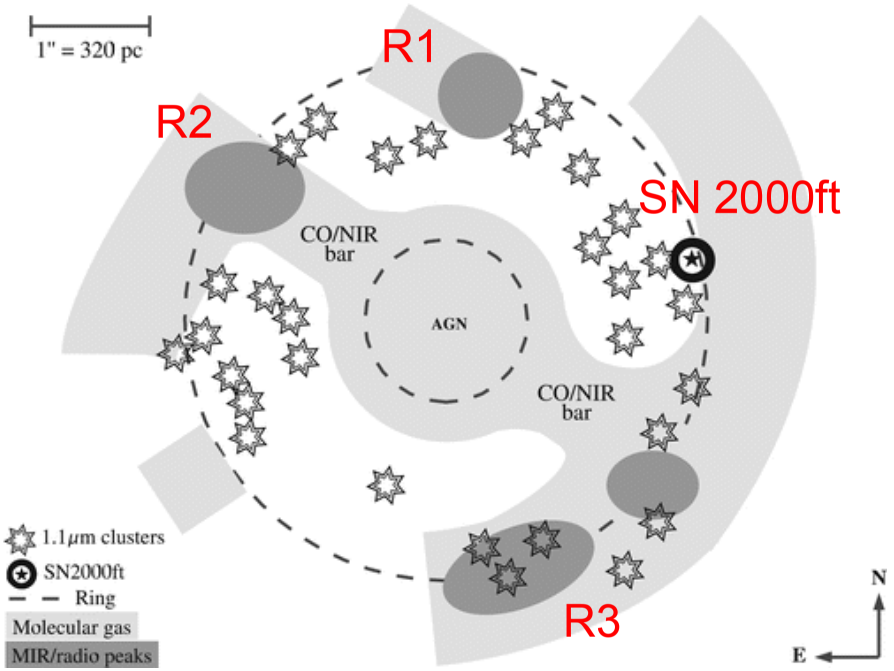
Cortesía: Alonso-Herrero et al.

Stellar Populations in the Stb of NGC 7469



Sketch of the nuclear region of NGC 7469

(CO-data: Davies et al. 2004 ApJ 602, 148)

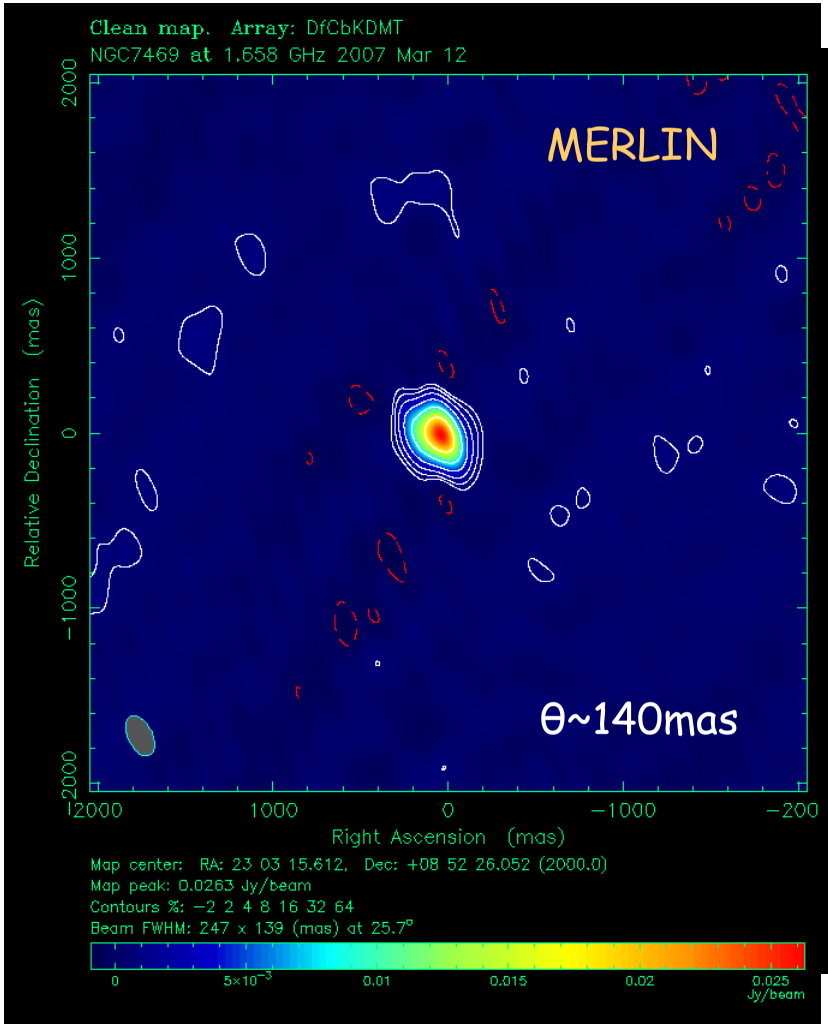


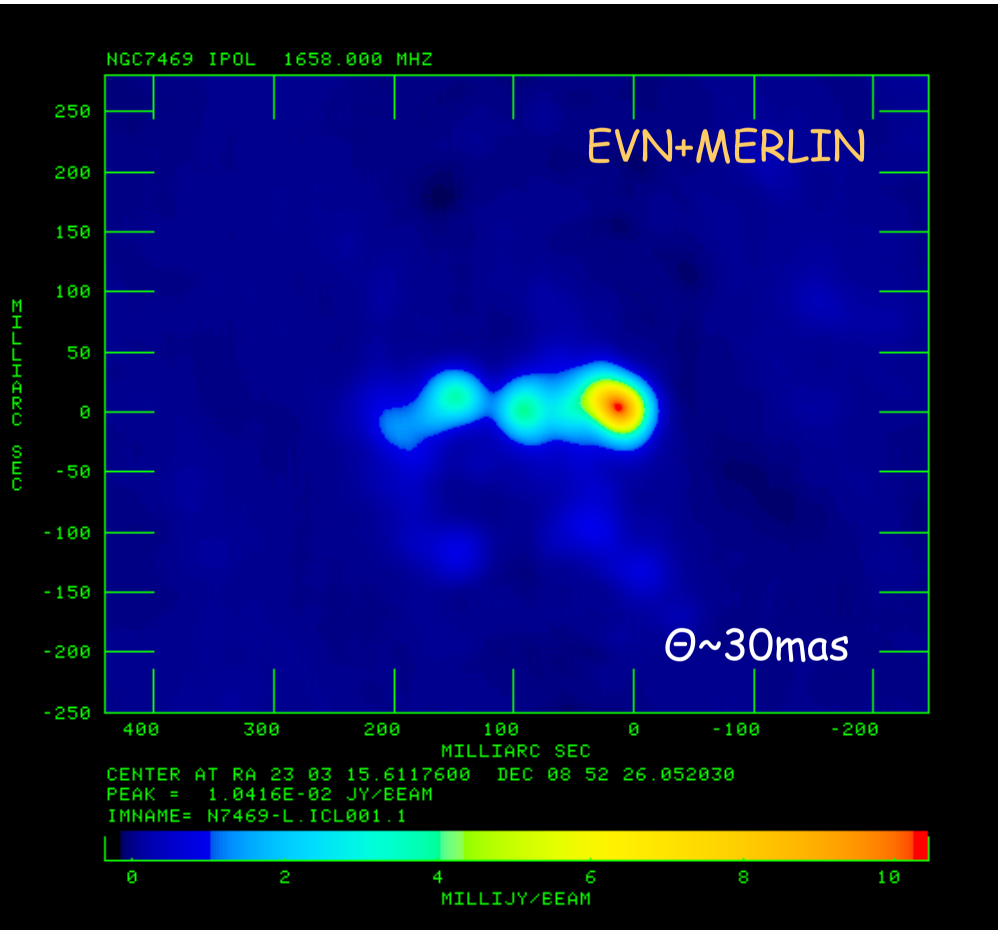
- The UV-optical-NIR continuum: intermediate age (14-35 Myr)

- The MIR+Radio: young (5-6 Myr), highly obscured population (Av ~ 7-13 mag)

(Díaz-Santos et al. ApJ, 661, 149 (2007))

The nuclear region of NGC 7469 at very high angular resolution

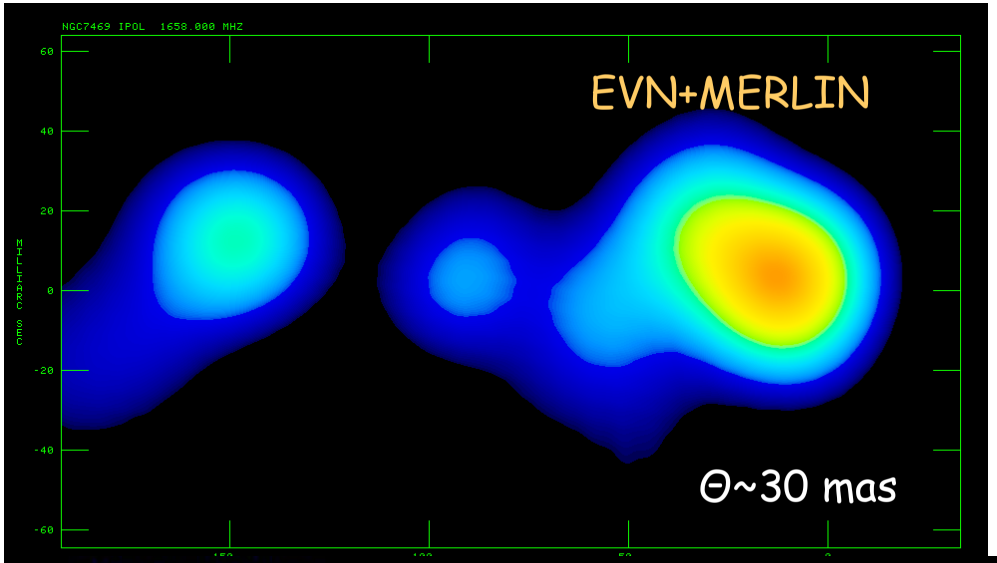


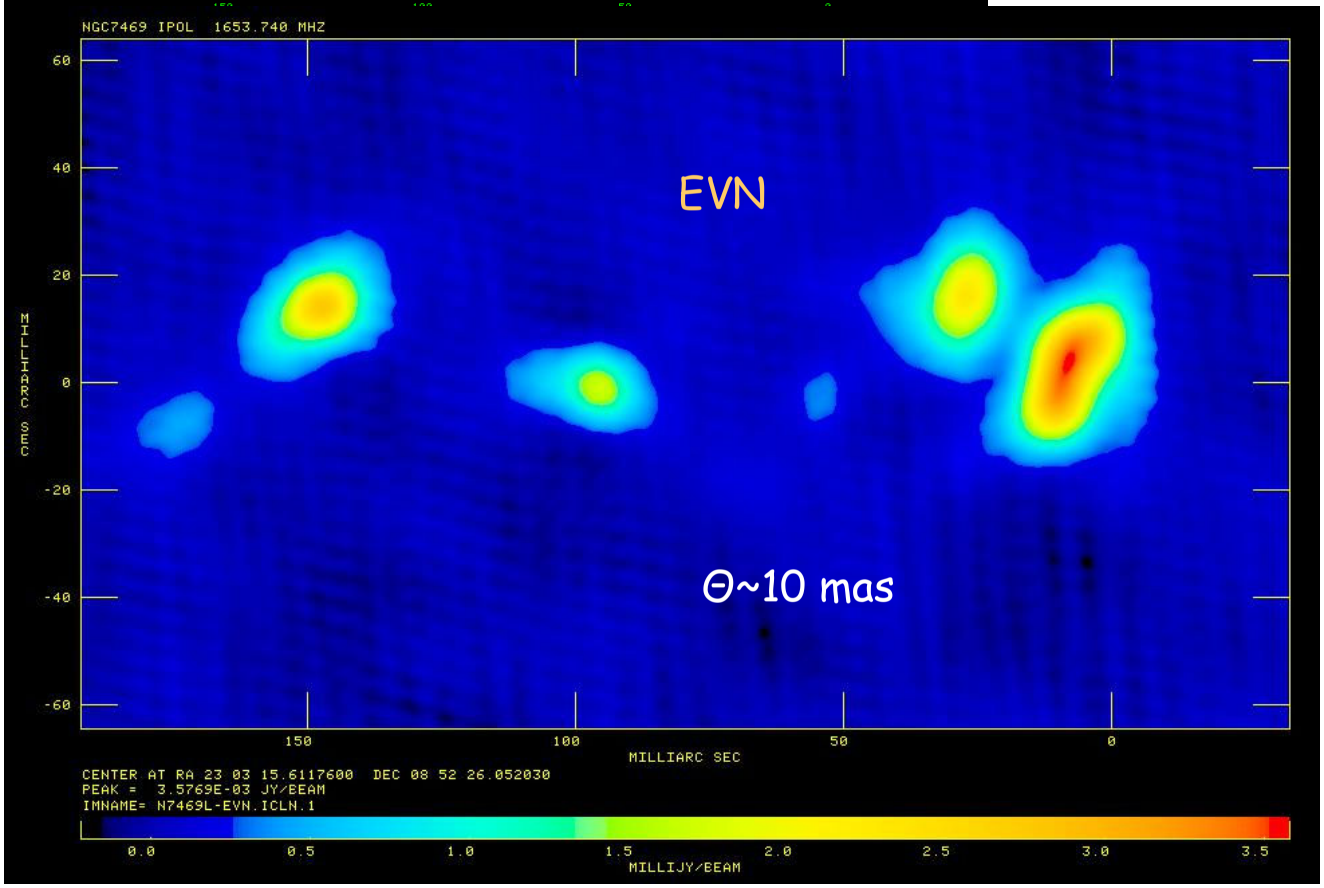


EVN + MERLIN at λ18cm - March 2007

1 mas = 0.32 pc

Alberdi et al. 2010 (in prep.)





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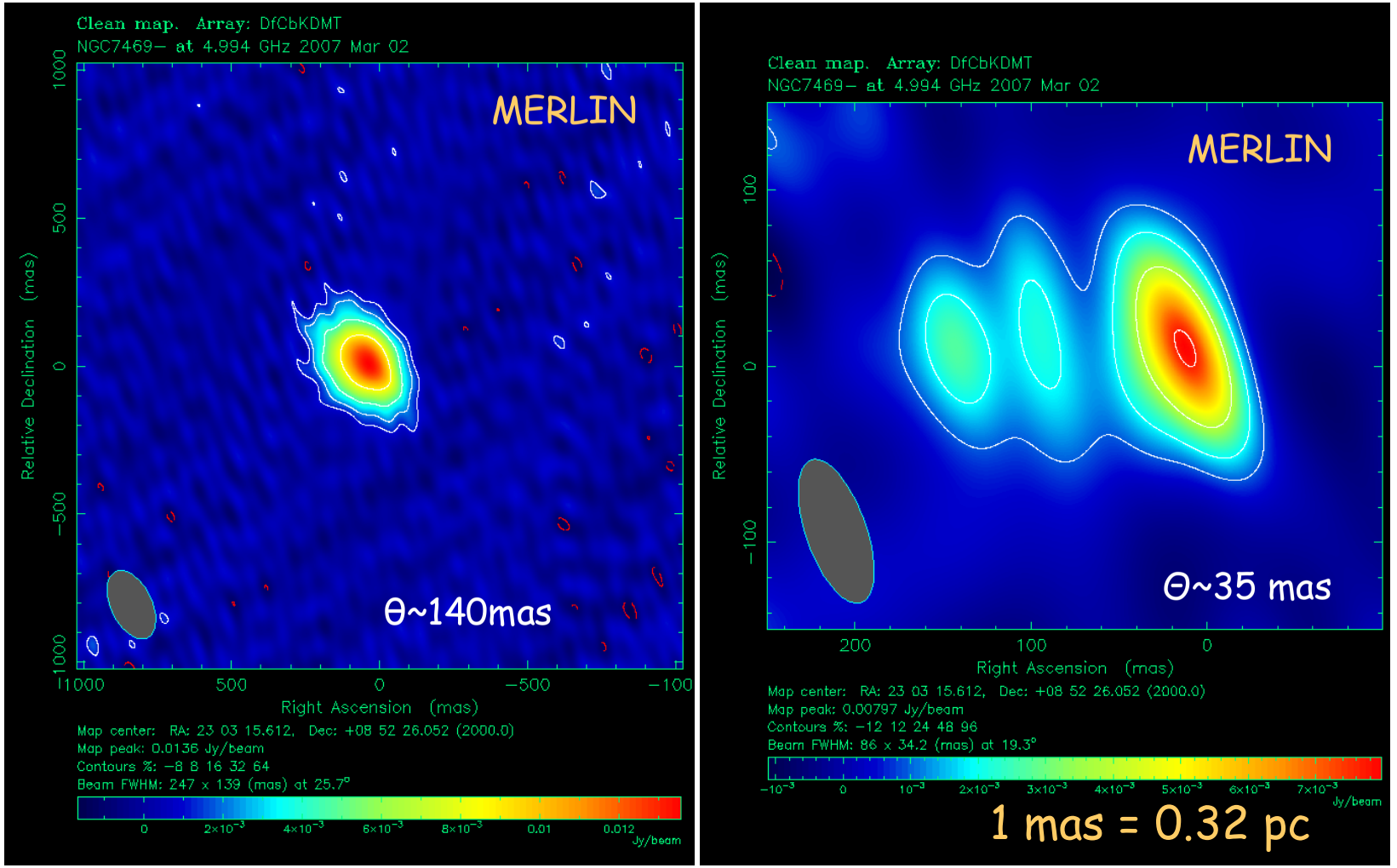
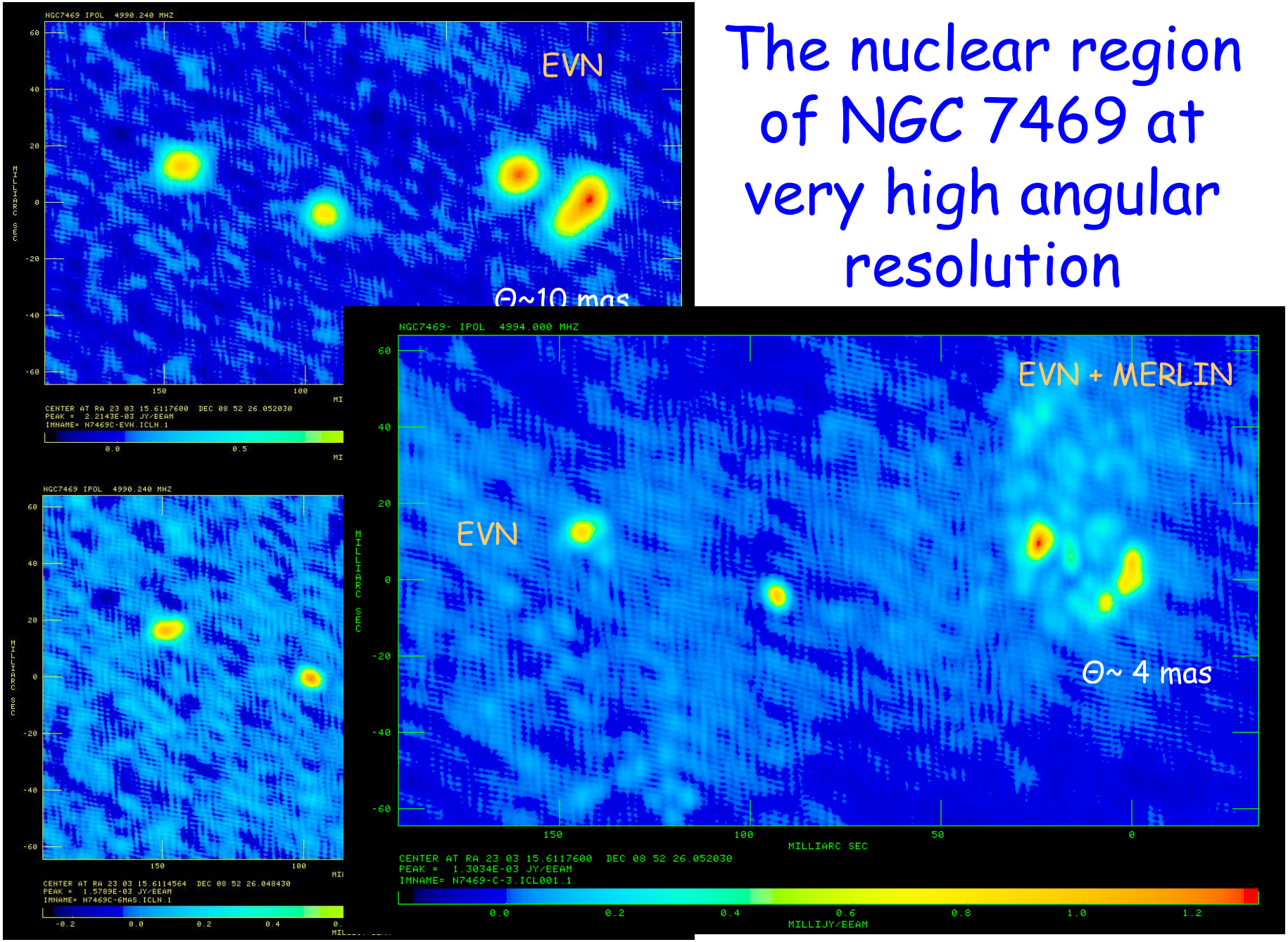


EVN + MERLIN at λ 6cm - March 2007

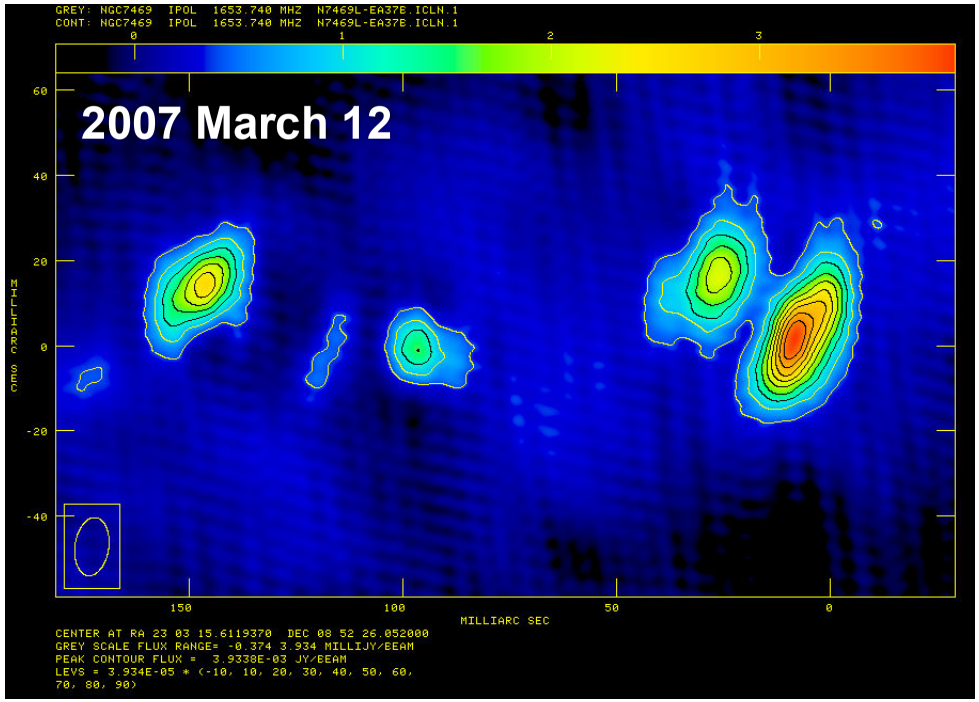
Alberdi et al. 2010 (in prep.)

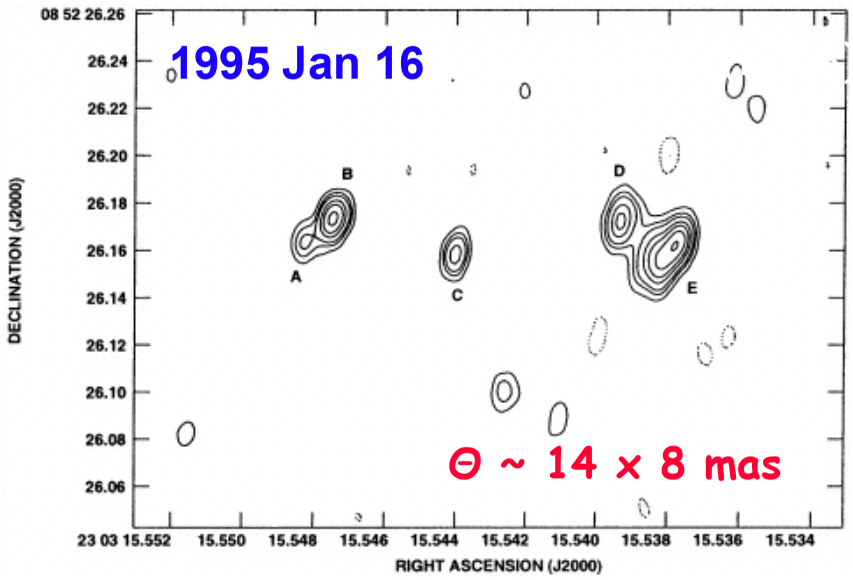
The nuclear region of NGC 7469 at very high angular resolution



EVN + MERLIN at λ 6cm - March 2007 Alberdi et al. 2010 (in preparation)

Structure Variability of the nucleus of NGC 7469: i) λ 18cm

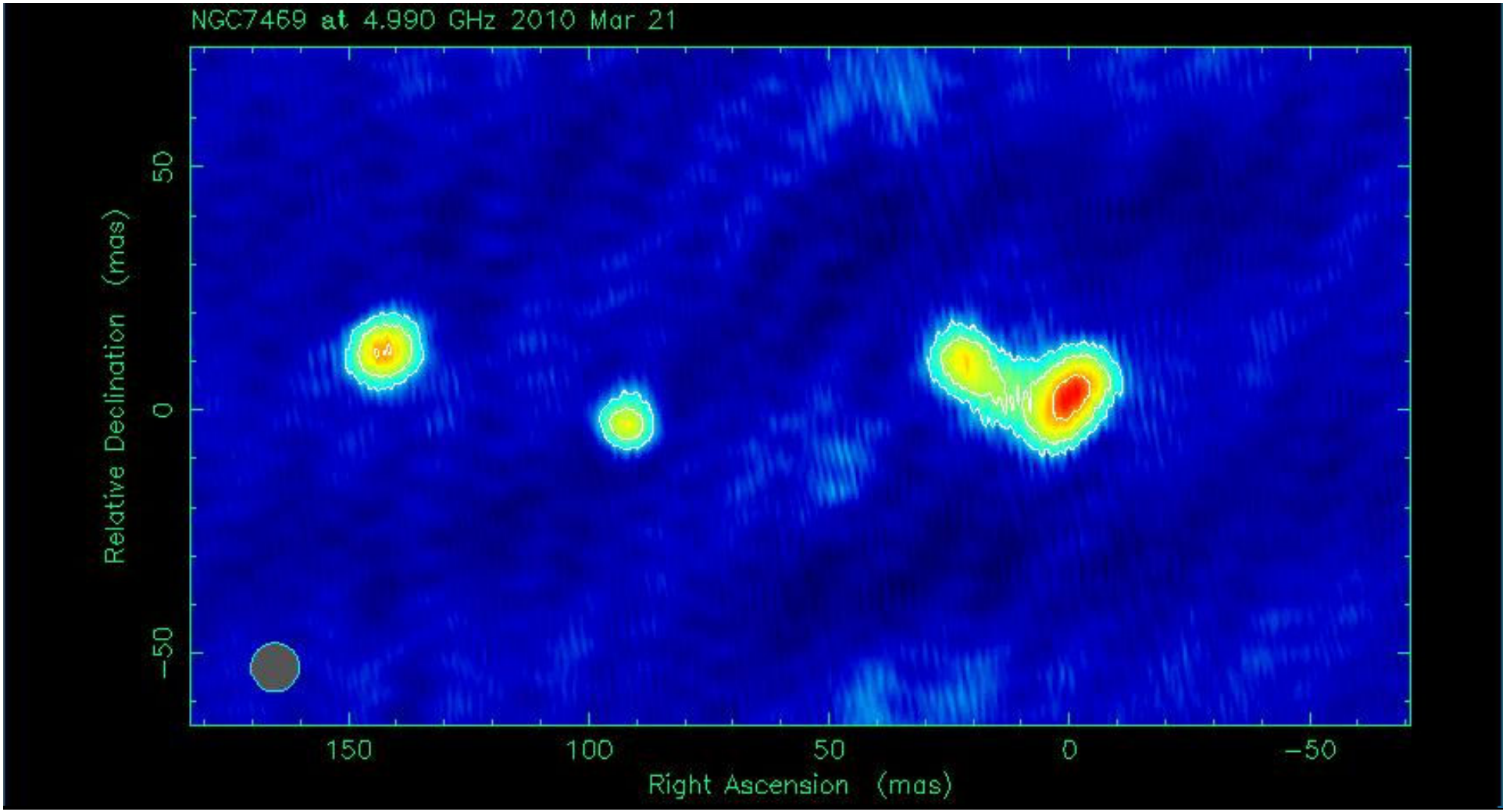




For almost 12 yrs, the structure has remained very similar; there are hints of flux density variability

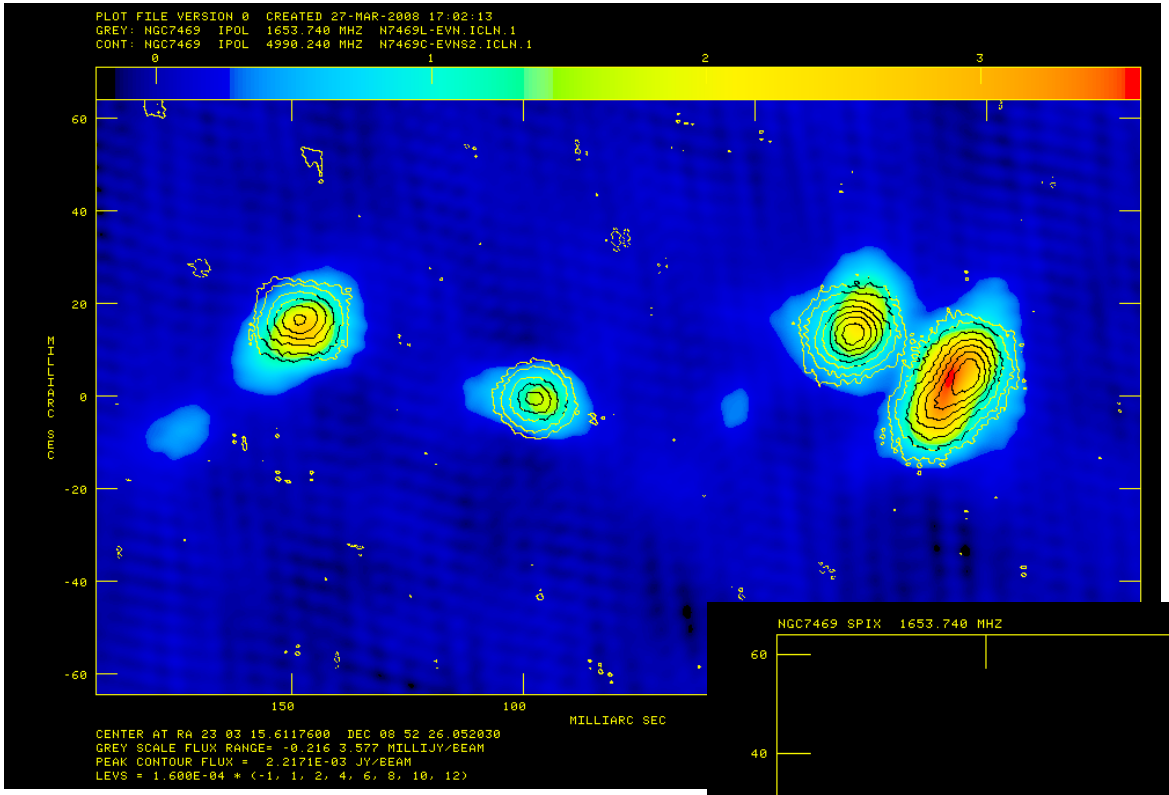
Alberdi et al. 2010 (in preparation)

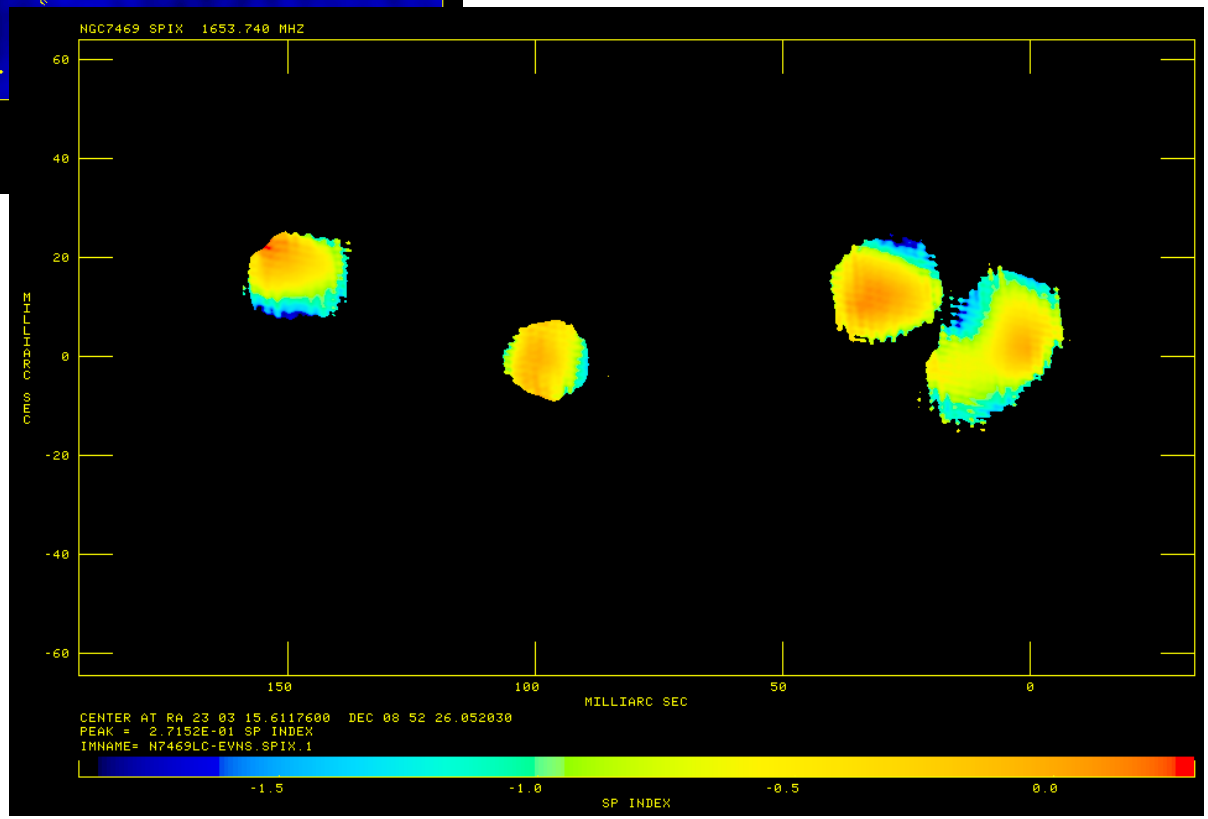
Structure Variability of the nucleus of NGC 7469: ii) λ 6cm



Alberdi et al. 2010 (in preparation)

Radio spectrum of the nucleus of NGC 7469





Alberdi et al. 2010 (in preparation)

The nuclear region of NGC 7469 at very high angular resolution

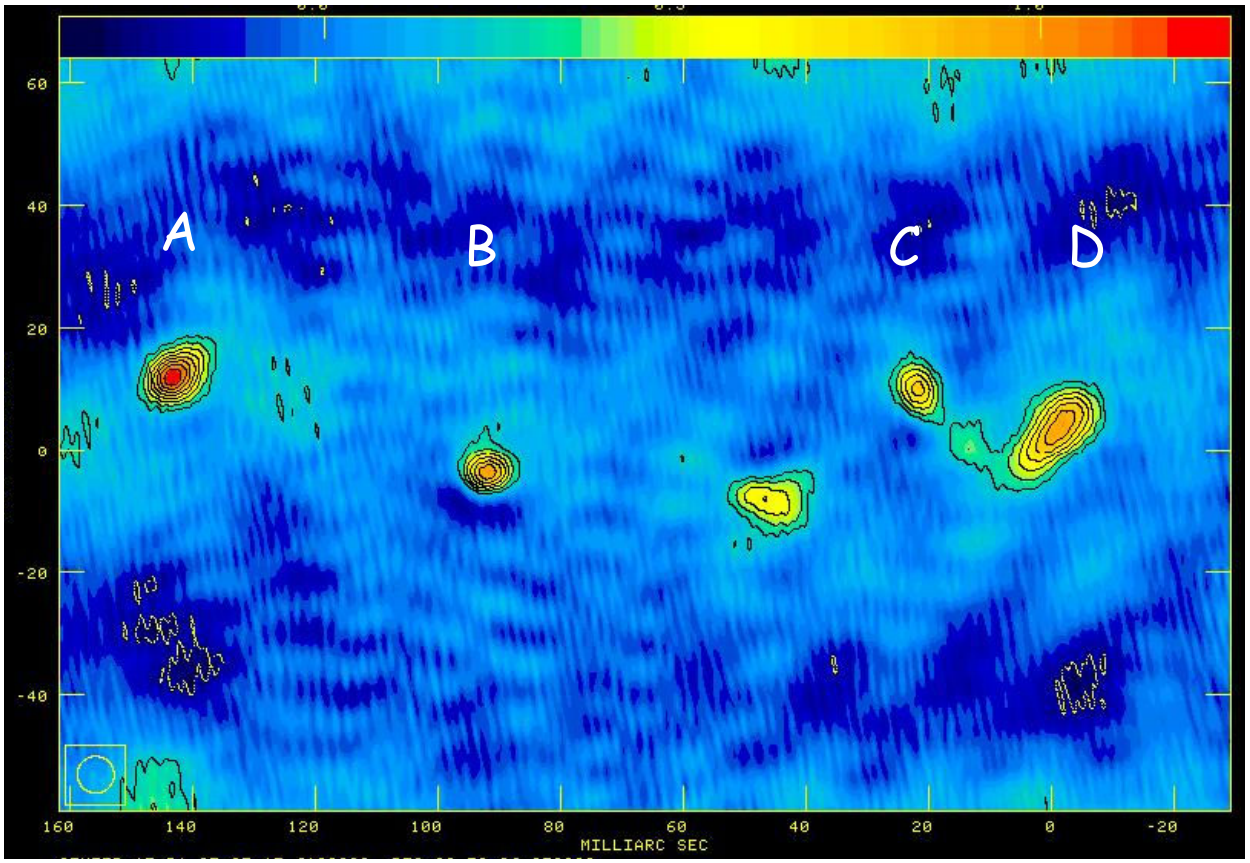
It is still unclear whether these components trace a core-jet structure of an AGN or, alternatively, we are seeing compact starforming regions where individual, or clumps of supernovae, are exploding:

- in favour of an AGN: i) a well-defined east-west orientation, consistent with MERLIN; ii) a low supernova rate (based on the infrared luminosity); iii) a kind of jet-like structure in some of the components; iv) it is a Seyfert 1 galaxy (BH mass from reverberation mapping).

- in favour of young starforming regions, where core-collapse supernovae are currently exploding: i) all the nuclear components show steep spectra, with values between -1 and -0.2; ii) all the VLBI sources are within an area of 50 pc, which is also the size of the nuclear starburst (Davies et al. 2004; ApJ 602, 148); iii) for all the components, $T_b > 10^6$ K; $L \sim 10^{27}$ erg s^{-1} Hz^{-1}.

Alberdi et al. 2010 (in prep.)

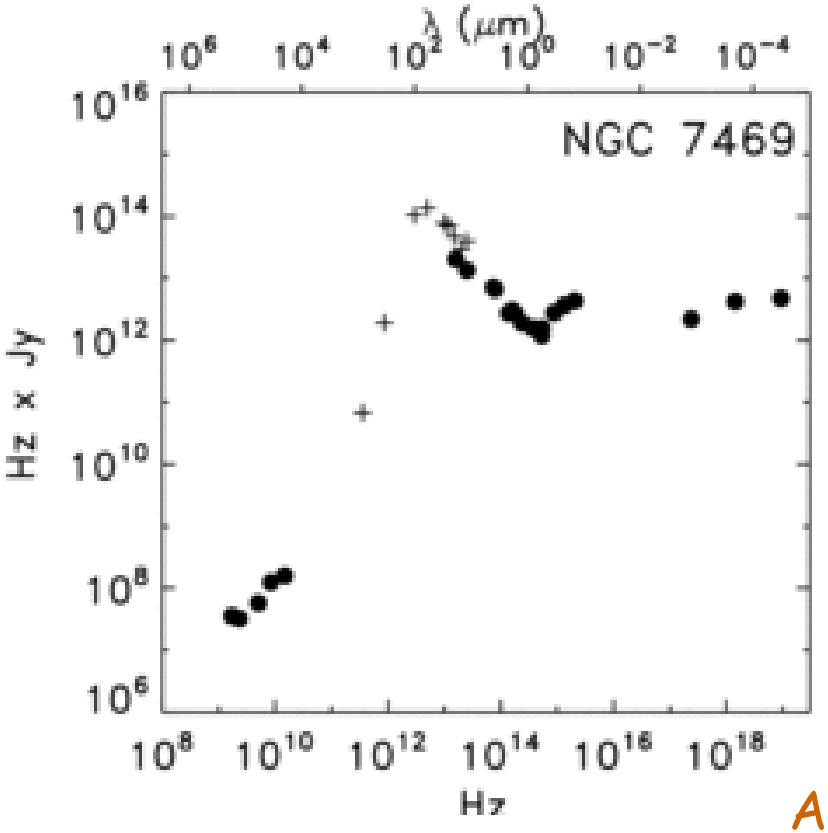
The nuclear region of NGC 7469

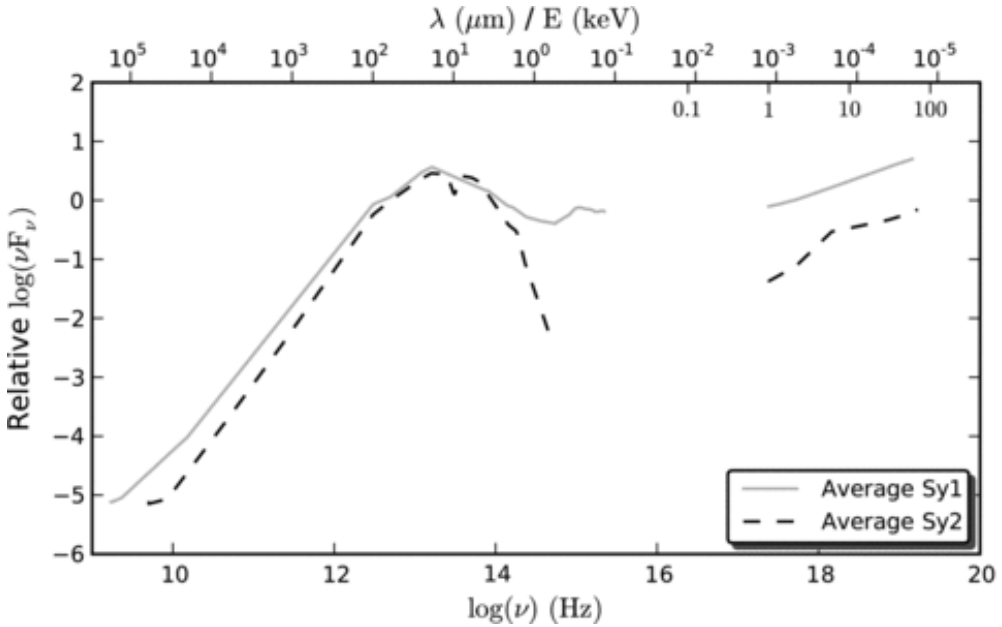


Alberdi et al. 2010 (in preparation)

- Component D: AGN emission ($L = 3\times10^{38}$ erg/s) → flux density and structural variability;
- Component A: flux density variability; compact source within extended flux (steep spectral index, $\alpha\sim1$);
- Component B: very compact ($\theta<3$mas; $T_B>5\times10^6$ K) + quite steady in flux + ($\alpha\sim0.5$) → Long-lasting SNR candidate?
- Component C: rather compact + flux density variability + α-variable

NGC 7469: the SED of the central parsecs

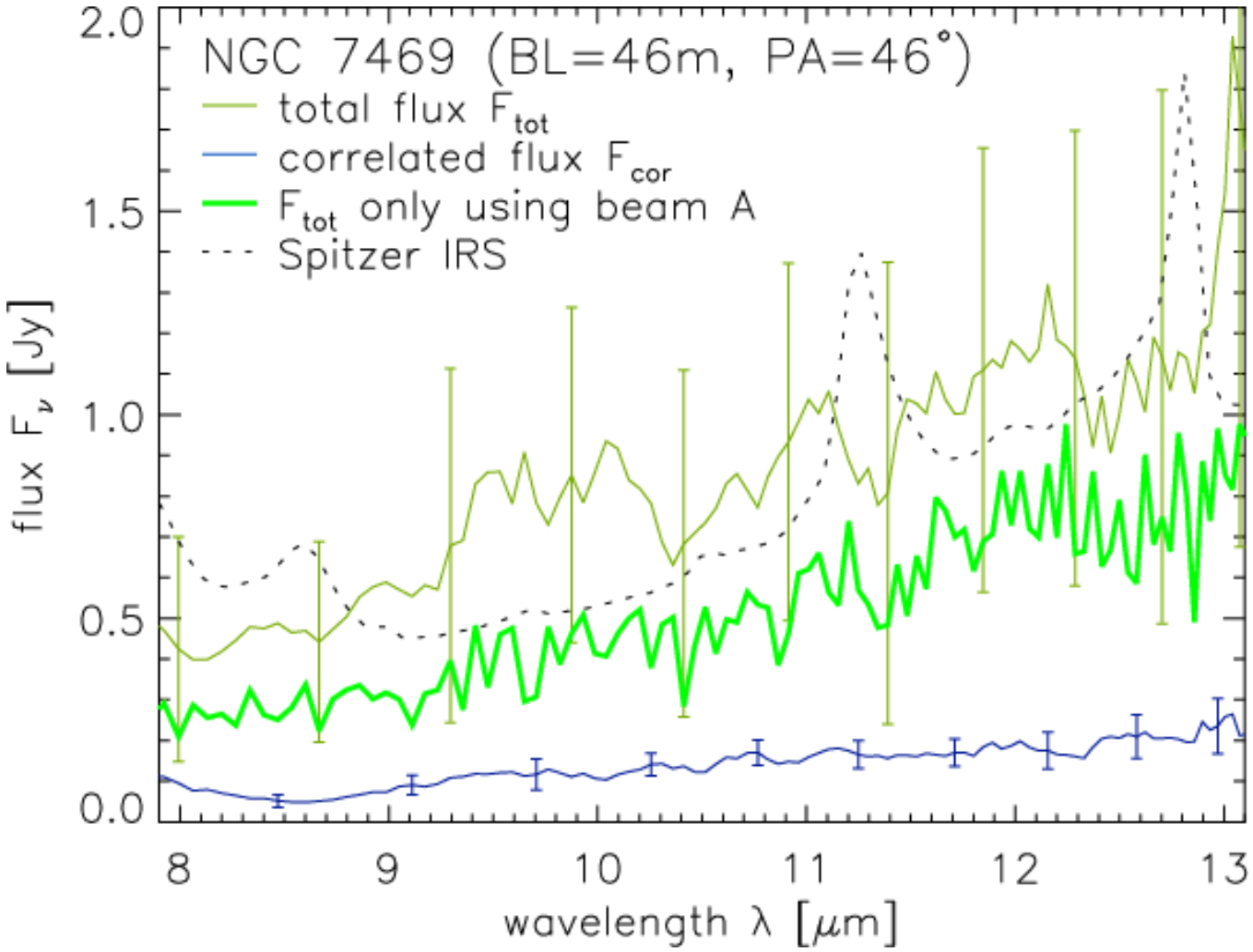




At the scales of a few tens of parsecs from the central engine, the bulk of the IR emission can be reconciled with pure dust emission → NACO upper limit of 26 pc

Prieto et al. MNRAS 402, 724 (2010)

The nuclear region of NGC 7469 at MIR: MIDI observations (8-13 μm)



- The correlated flux spectrum is lower than the total one;
- Fringe spacing of 25 mas → the source is resolved, the size of the dust distribution is of the order of 10 pc (warm dust T=300K)

Tristram et al. A&A 502, 67-84 (2009)

Summary

- Circumnuclear star-forming ring (diameter of 1 kpc): evidence of a type IIn RSN: SN 2000ft
- We find evidences for a low-luminosity AGN in the nuclear region of NGC 7469, probably coexisting with recent bursts of starformation. Are both a starburst and AGN associated phenomena?