Cores and jets in extremely high-redshift quasars as seen in radio and X-ray domains

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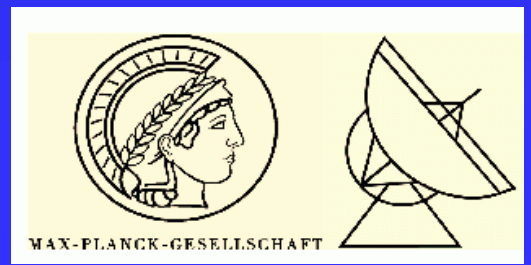
RadioNet Workshop
Multiband Approach to AGN
MPIfR, Bonn, Germany
30 Sept – 02 Oct 2004

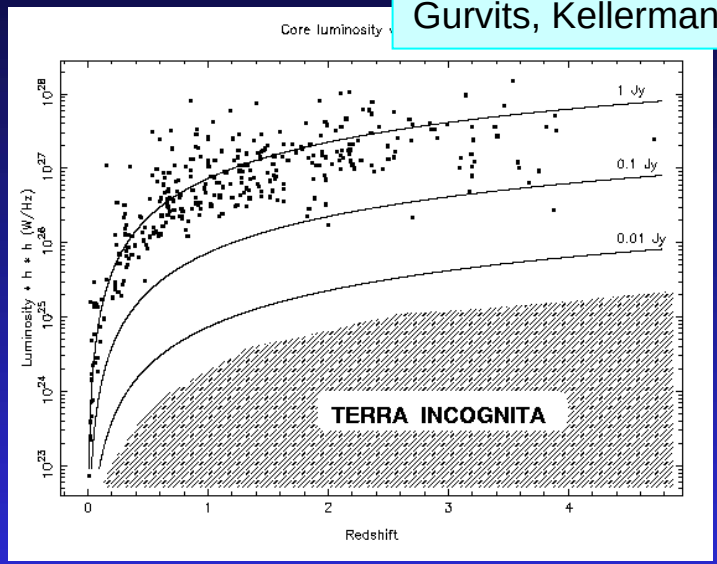


Compact sources at z > 4: venturing into unknown

The aim:

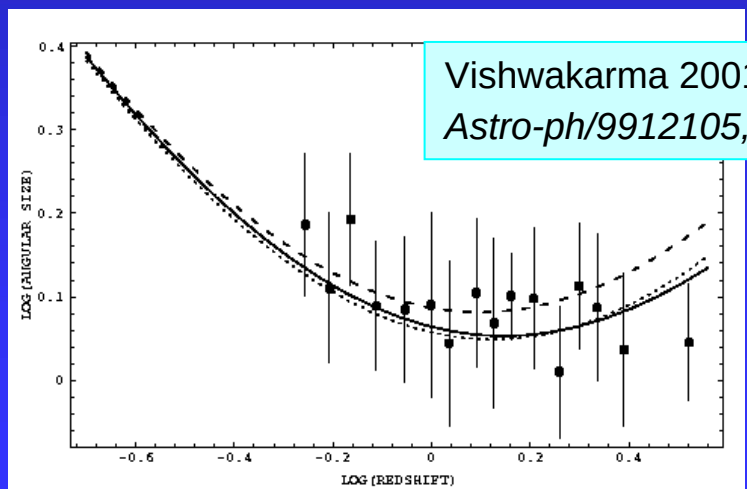
- To search for and study footprints of high activities in AGN at earlier cosmological epochs, especially in combination with X-ray data (ROSAT, Chandra, XMM-Newton);

Gurvits, Kellermann, Frey 1999



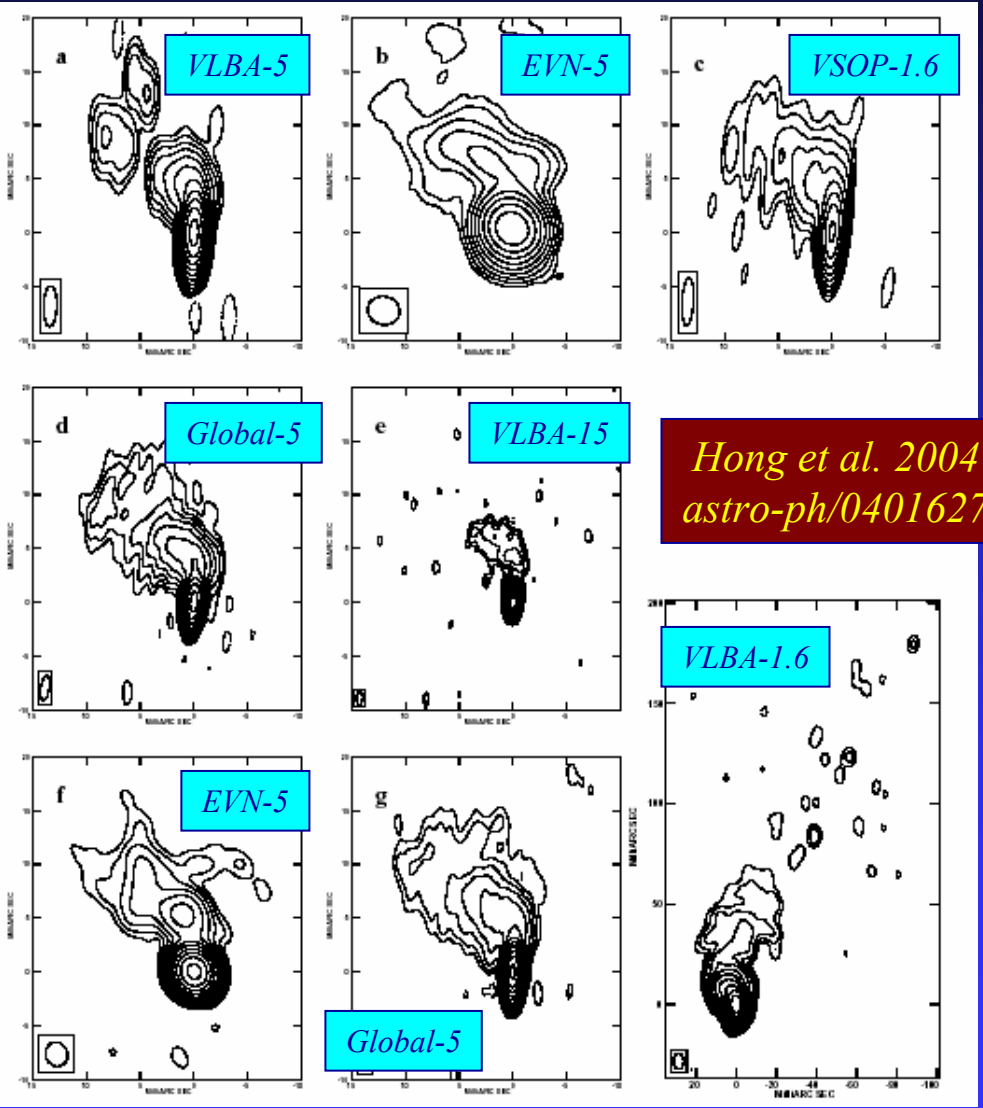
- To establish high-redshift sub-sample of mas-scale radio morphologies for z-dependent statistics (θ-z, μ-z, T_B-z, etc. tests)

Vishwakarma 2001
Astro-ph/9912105, -/0012492

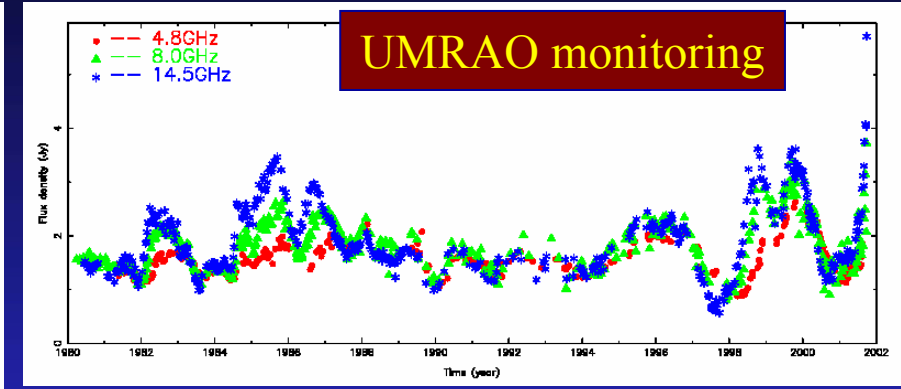


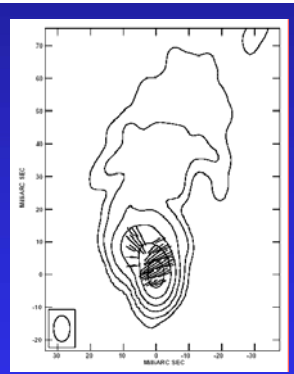
Sample "selection":
ALL VLBI-observable sources at z > 4

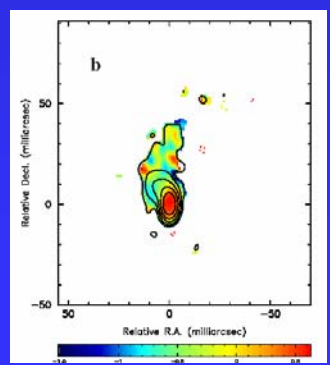
1156+295: a show case of helical jet (HPQ at z=0.729)

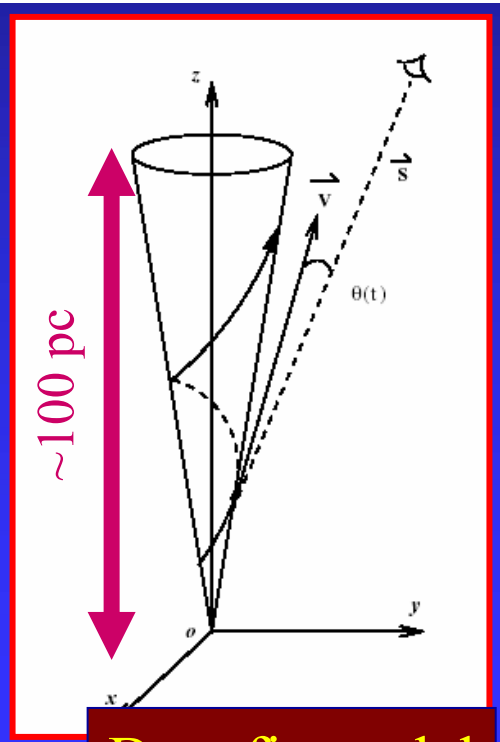


Hong et al. 2004
astro-ph/0401627





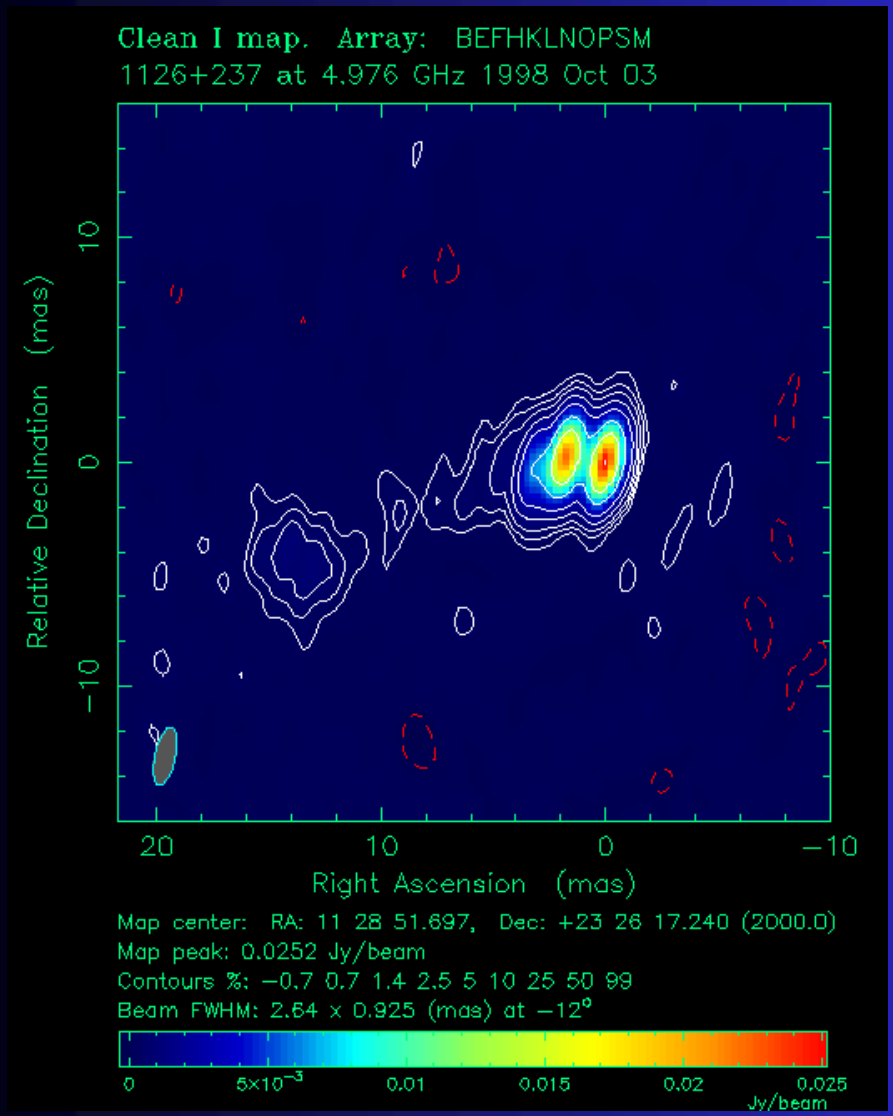


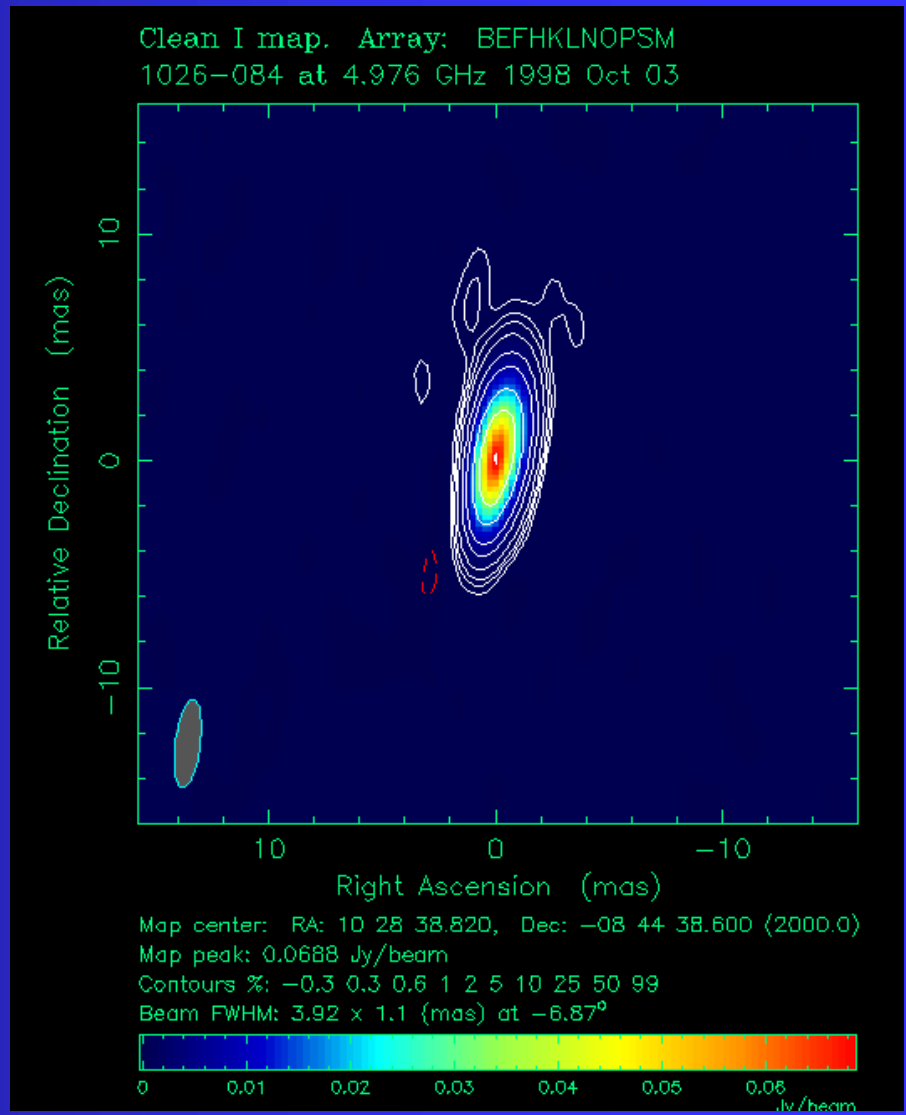


Best-fit model

J1128+2326 (z=3.04) *J1028-0844 (z=4.28)*

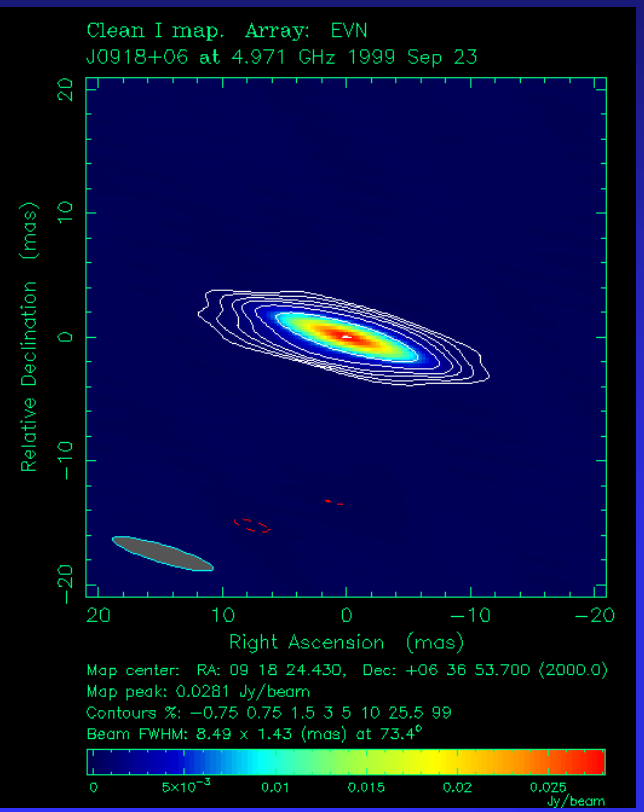
X-ray sources (Moran et al. 1996 and Kaspi et al. 2000, AJ 119, 2031)





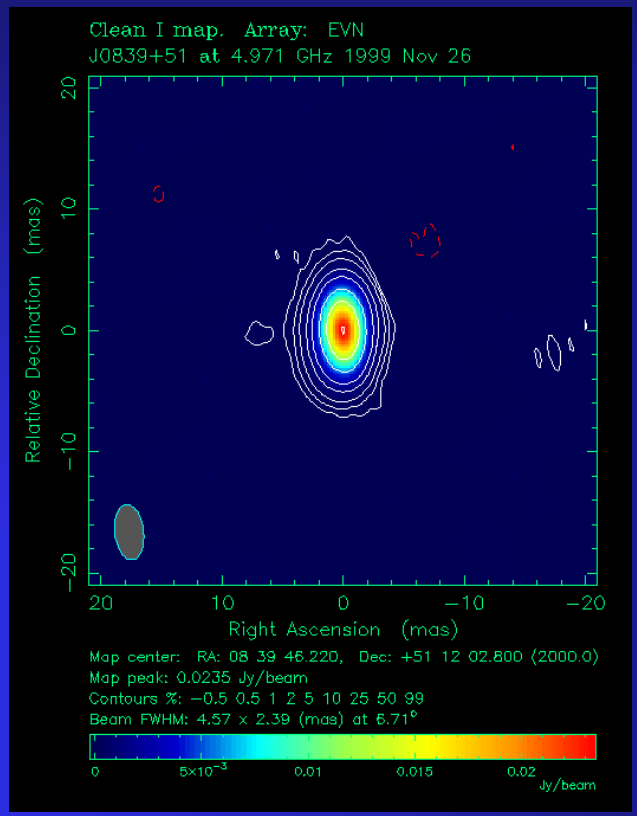
Resolved featureless mas-scale structures

J0918+0636



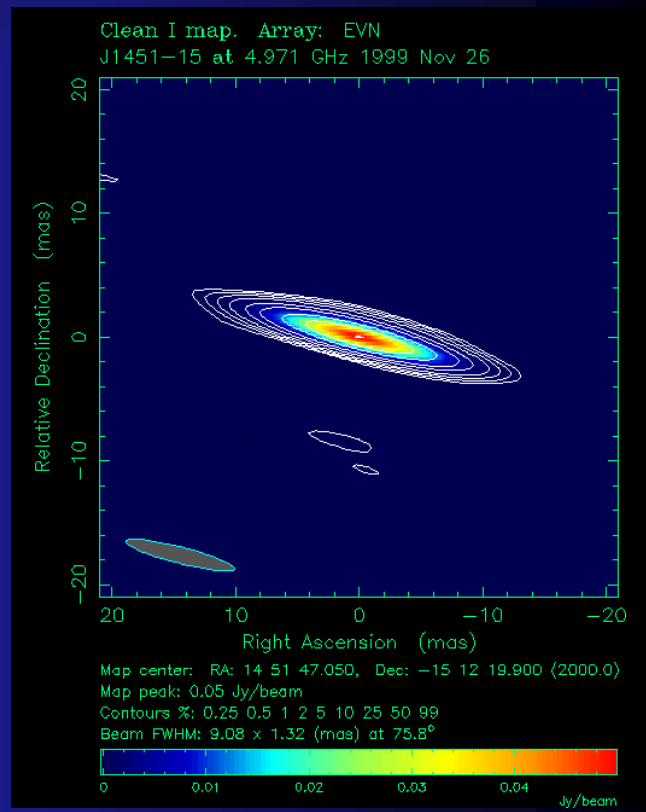
z=3.19

J0839+5112



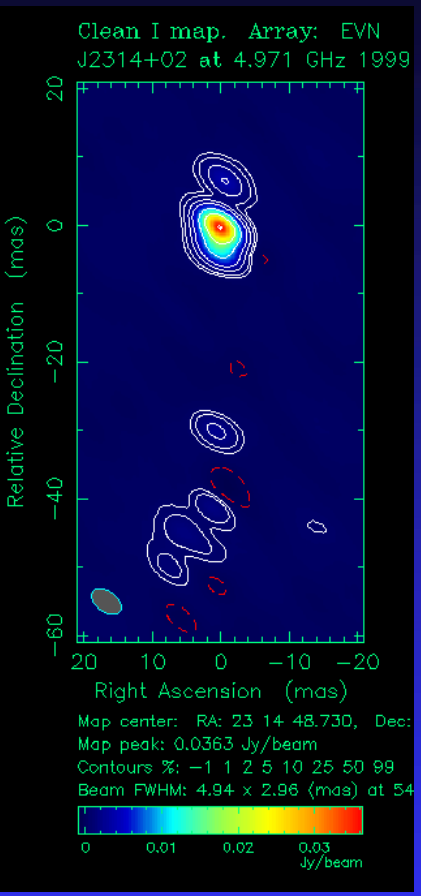
z=4.41

J1451-1512



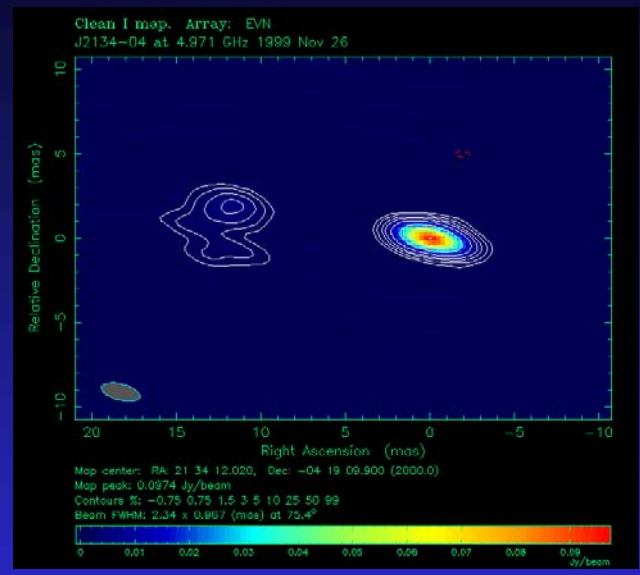
z=4.76

“Traditionl” core-jet structures

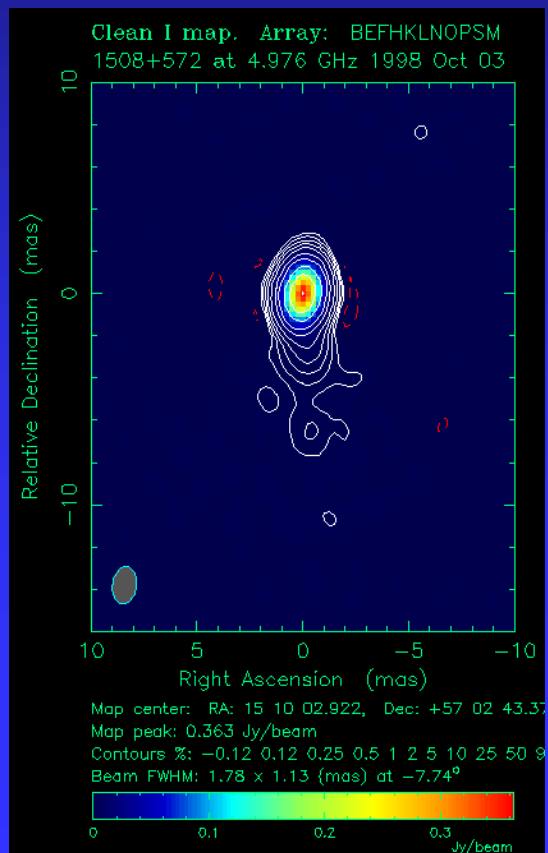


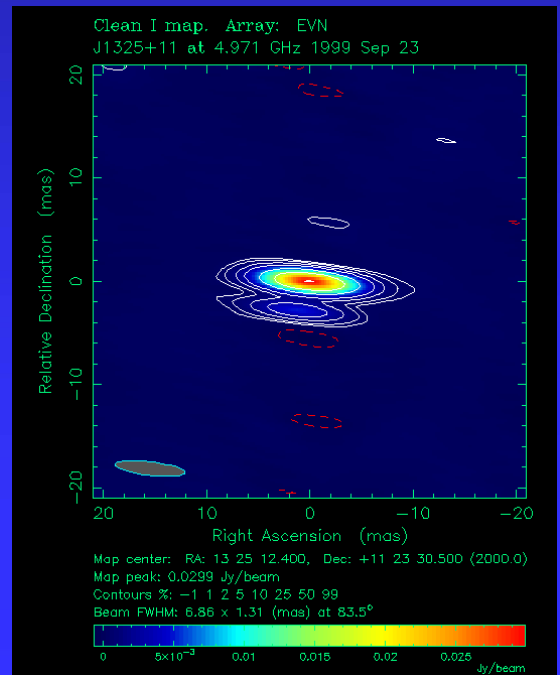
J2314+0201
z=4.11

J2134-0419, z=4.35



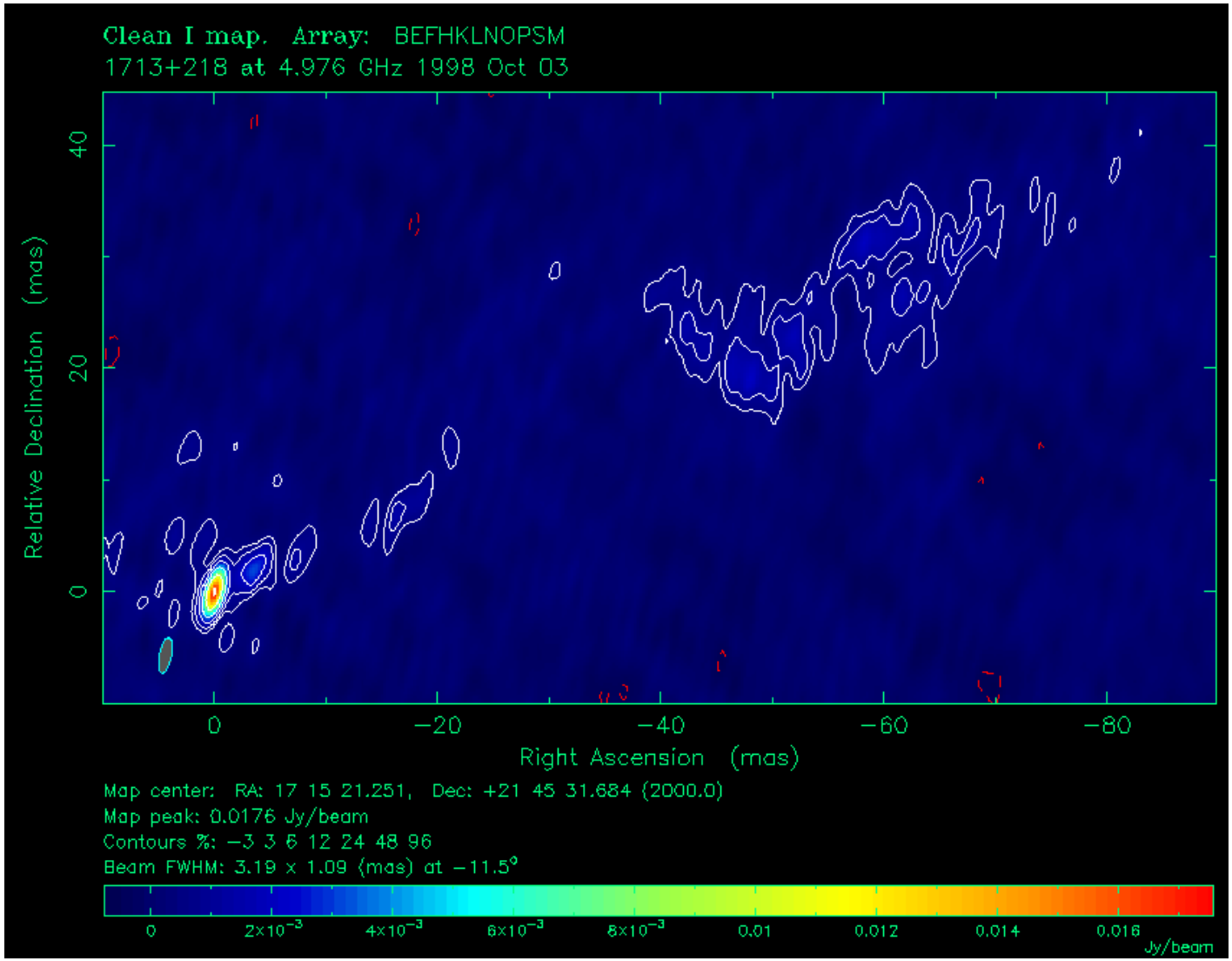
J1510+5702
z=4.30





J1325+1123
z=4.40

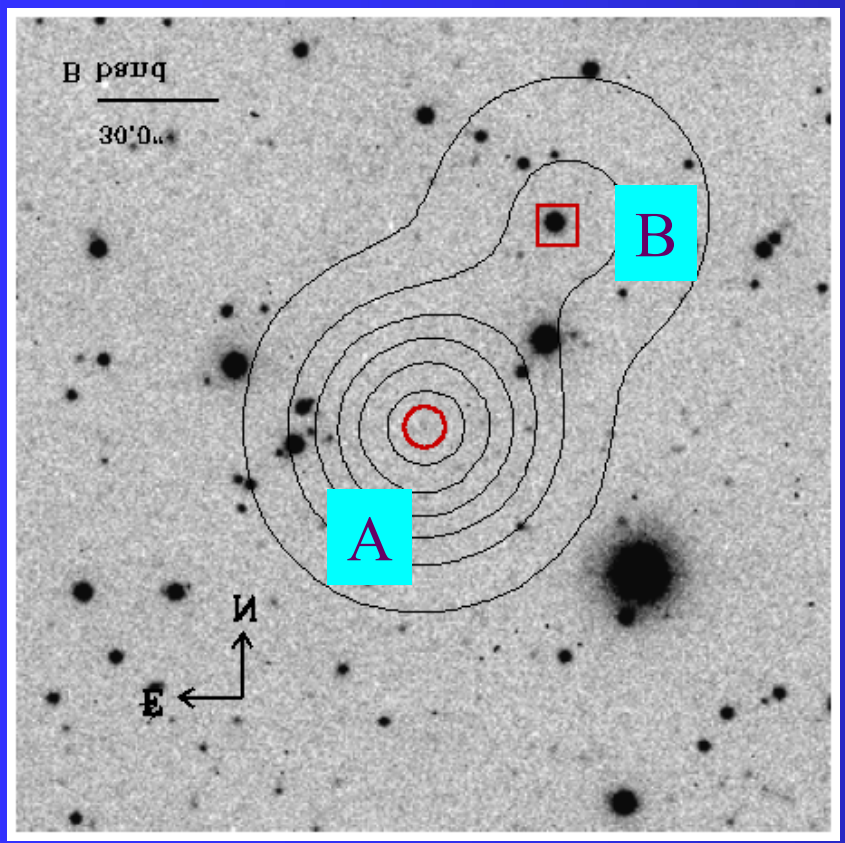
J1715+2145 (1713+218): an unexpected jewel at z=4.01

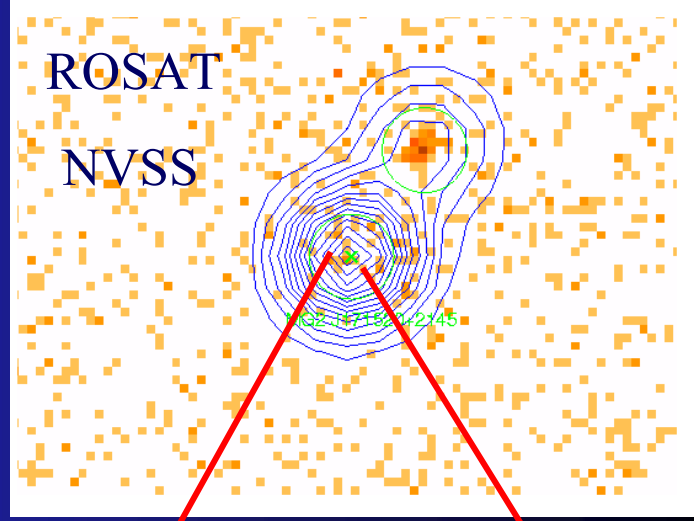


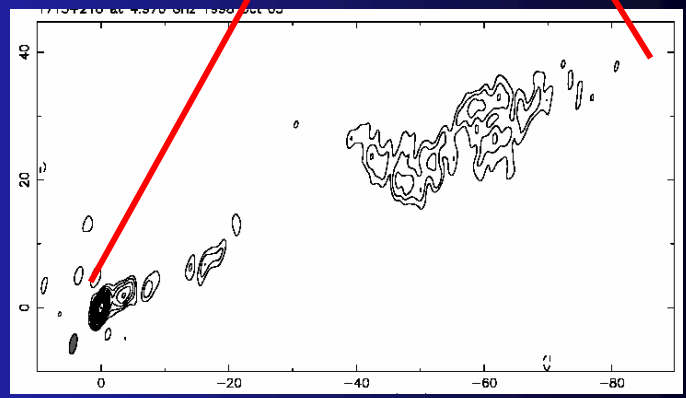
Exceptionally prominent VLBI-scale jet at 25 GHz (rest-frame)

J1715+2145 across the EM-spectrum

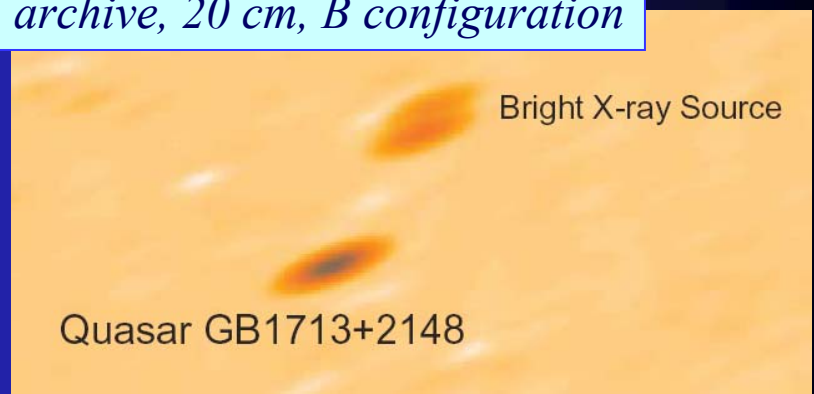
"A" – z=4.01 QSO, "B", 61 " NW - ???





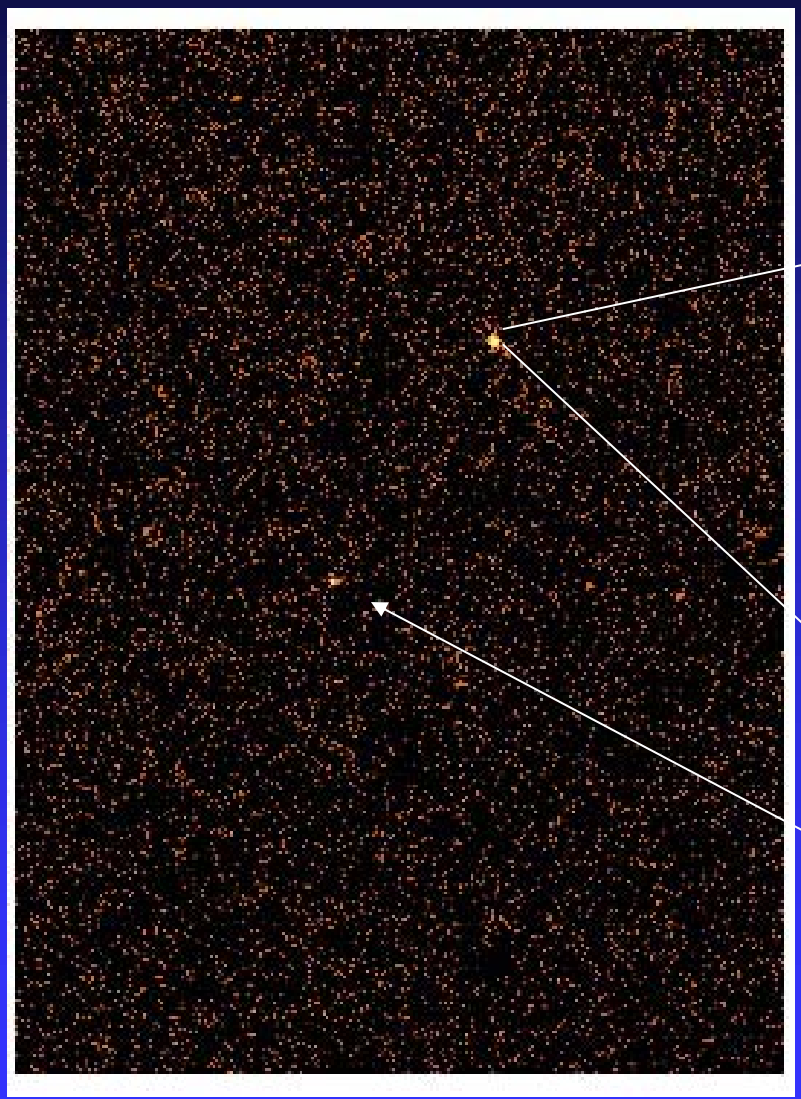


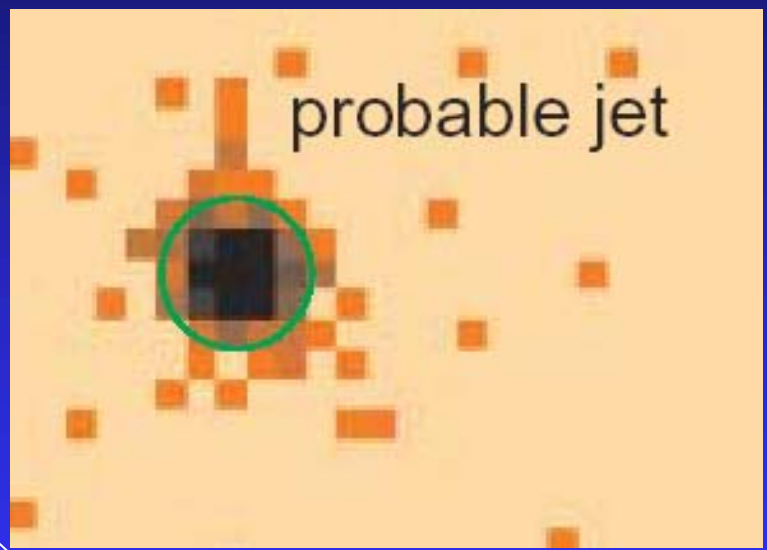
VLA archive, 20 cm, B configuration



Optical (gray-scale, B-band, left), X-ray (ROSAT, color, upper right) and radio (contours, NVSS, both panels) images of the field around J1715+2145

Chandra observation, 3 ks, June 2004: iC-CMB case?



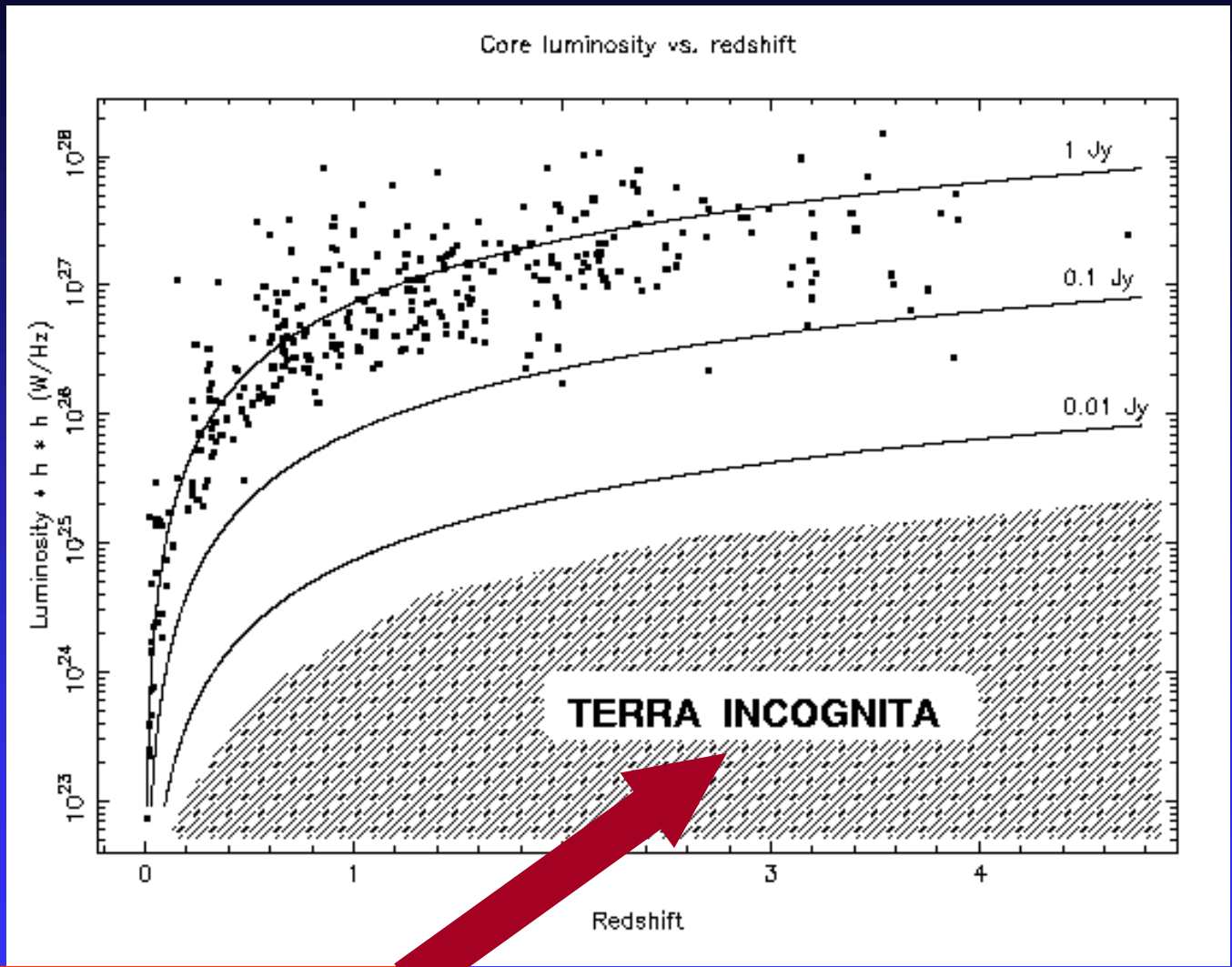


1713+218 at z=4.01

Toward 10,000 sources

Data points: 300 AGN
Imaged @ 5 GHz
(ad-hoc) with mas
angular resolution
(Gurvits et al. 1999)

De-facto flux density selection!



New territory for new radio telescopes, especially "Global" SKA!

Need to observe mJy-level sources with 10^{23} – 10^{25} W/Hz objects at z>0.5

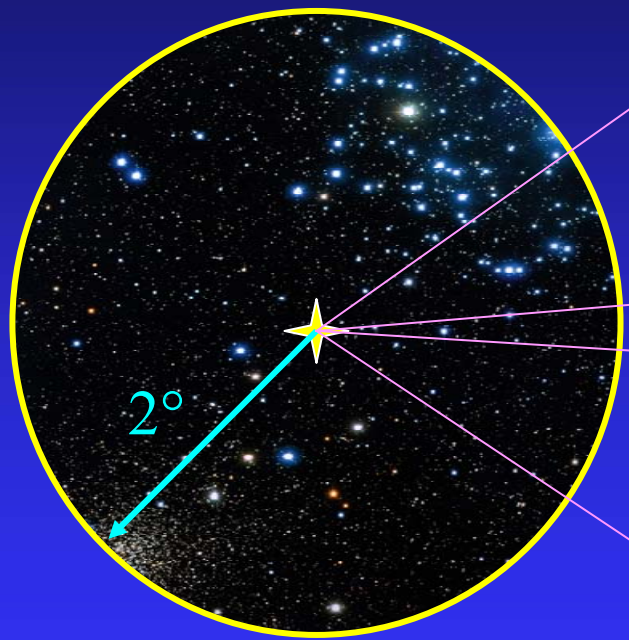
Deep Extragalactic VLBI-Optical Survey (DEVOS): the approach

- To observe weak compact sources around bright ones using phase-referencing technique (Garrington, Garrett, Polatidis 1999 – he field around 1156+295);
- To select targets using multi-step filtering:
  - Overlay of optical and radio surveys; e.g. FIRST VLA and the Sloan Digital Sky Survey (SDSS) can provide 10^5 targets
  - MERLIN observations filter out sources too resolved for further VLBI observations

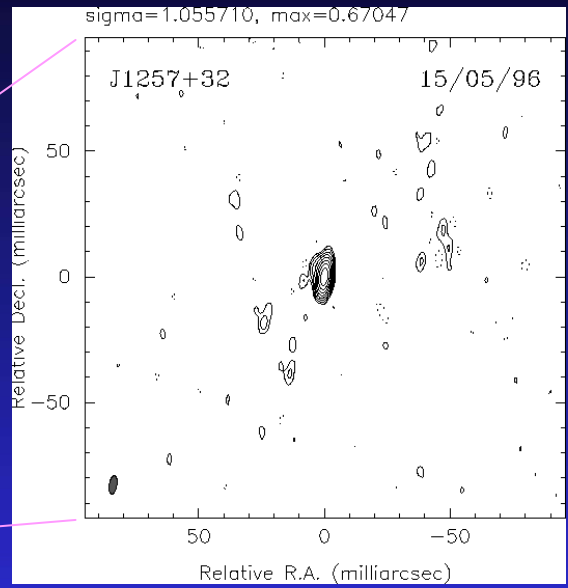
- **DEVOS (Deep Extragalactic VLBI-Optical Survey) criteria:**
  - SLOAN-identified quasars (other types of AGN) detected as FIRST sources with $S_{1.4} > 30$ mJy (Note: NO spectral index criteria)
  - MERLIN detection of compact components brighter than ~2 mJy/beam

The sky area of DEVOS NGP (North Galactic Pole)

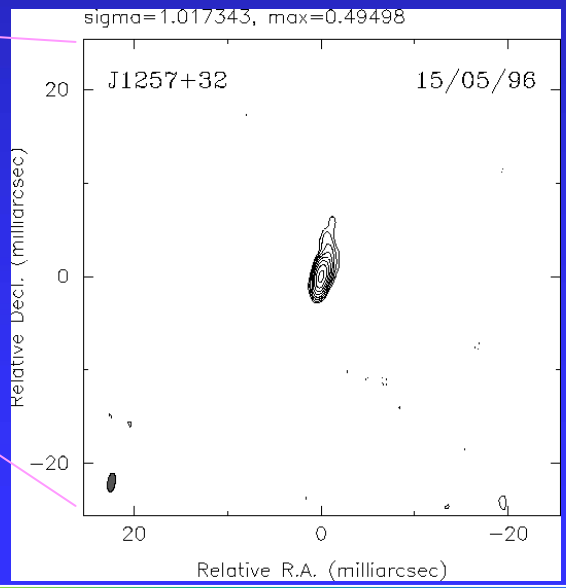
The reference source: J1257+3229
VLBA Calibrator source



2.3 GHz



8.4 GHz

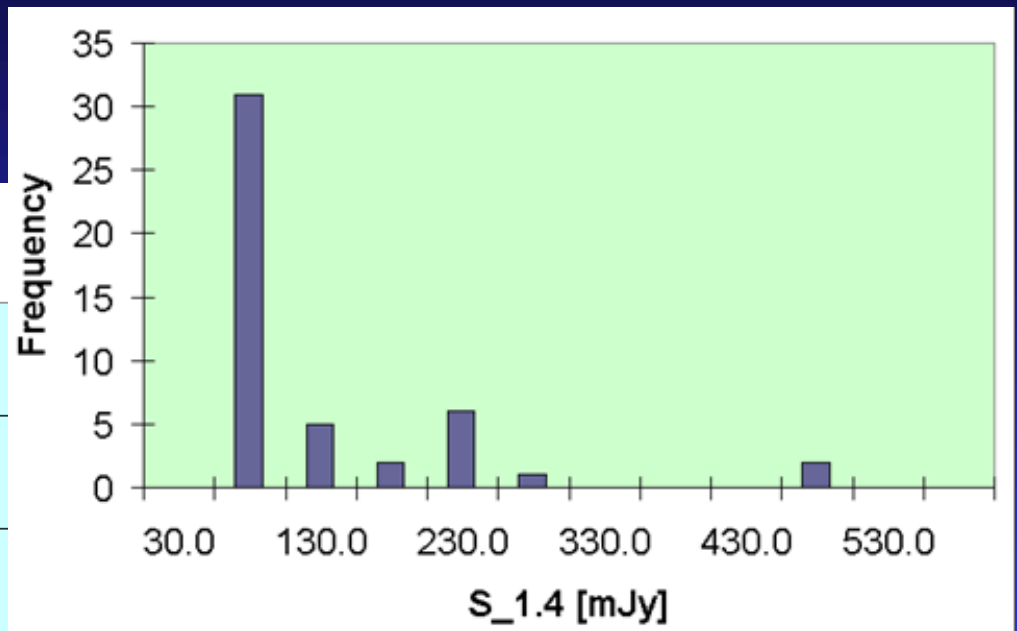


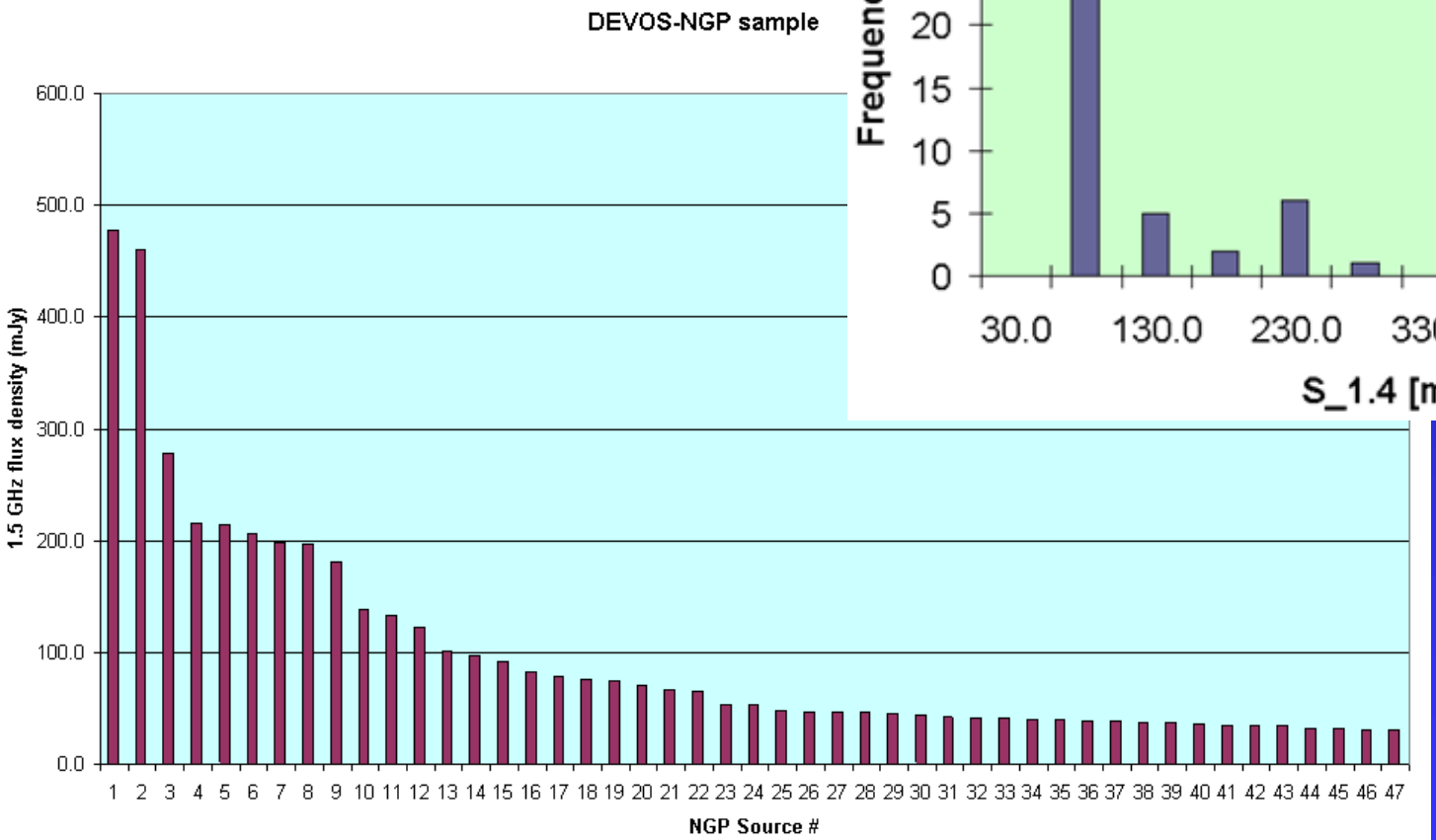
47 FIRST/SDSS sources within 2°
from J1257+3229

DEVOS NGP – the sample of 47 sources

FIRST data:

$30 < S_{1.4} < 490$ mJy





MERLIN filter for DEVOS NGP

Observed at 5 GHz,
24 March 2001

J1257+3229, 2 min

↓

NGP target, 4.5 min

↓

J1257+3229, 2 min

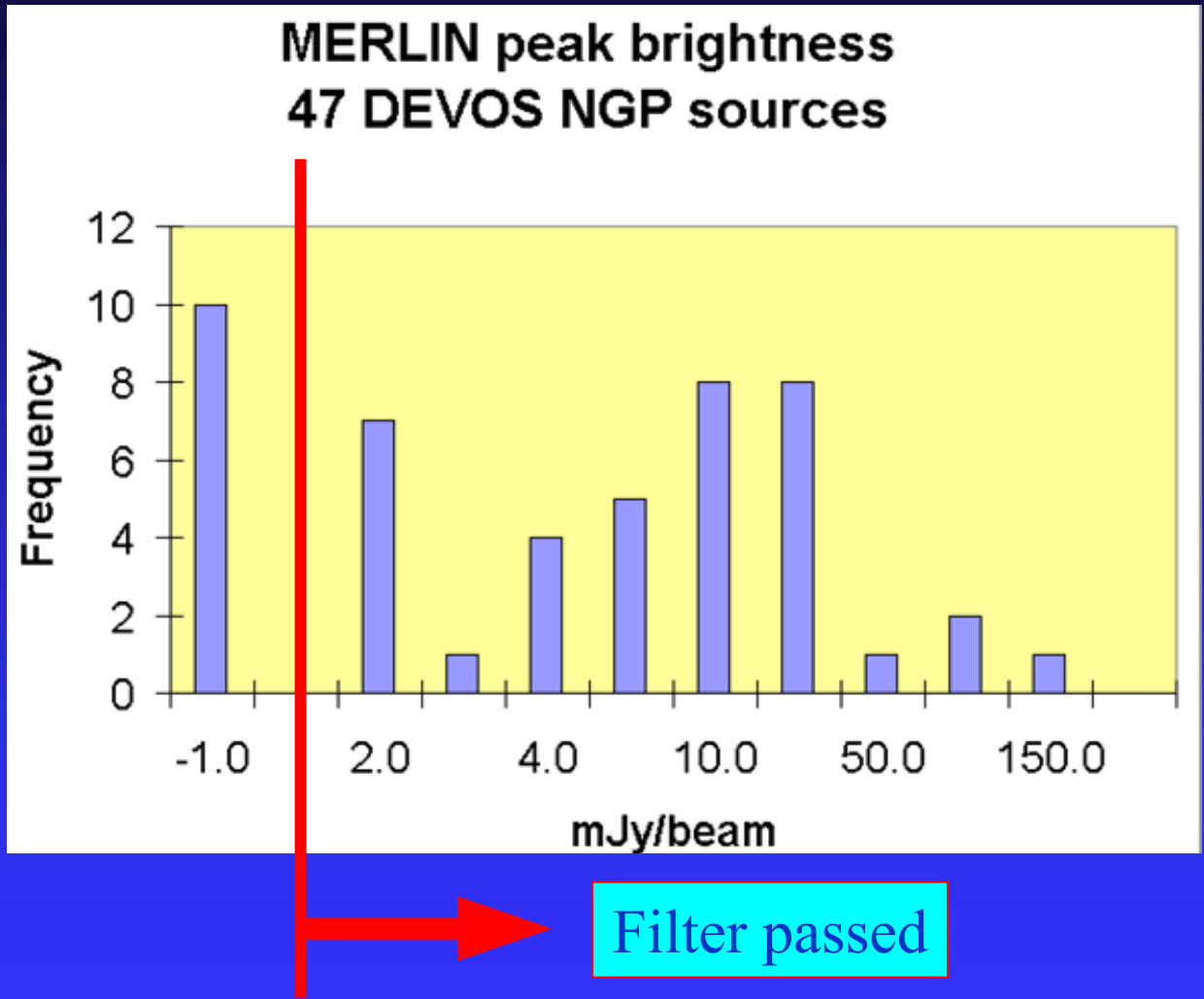
↓

NGP target, 4.5 min

↓

…

Total: 15h 18m



+ improved astrometry for VLBI φ-ref !

Global VLBI filter for DEVOS NGP

Observed at 5 GHz,
30 May 2001

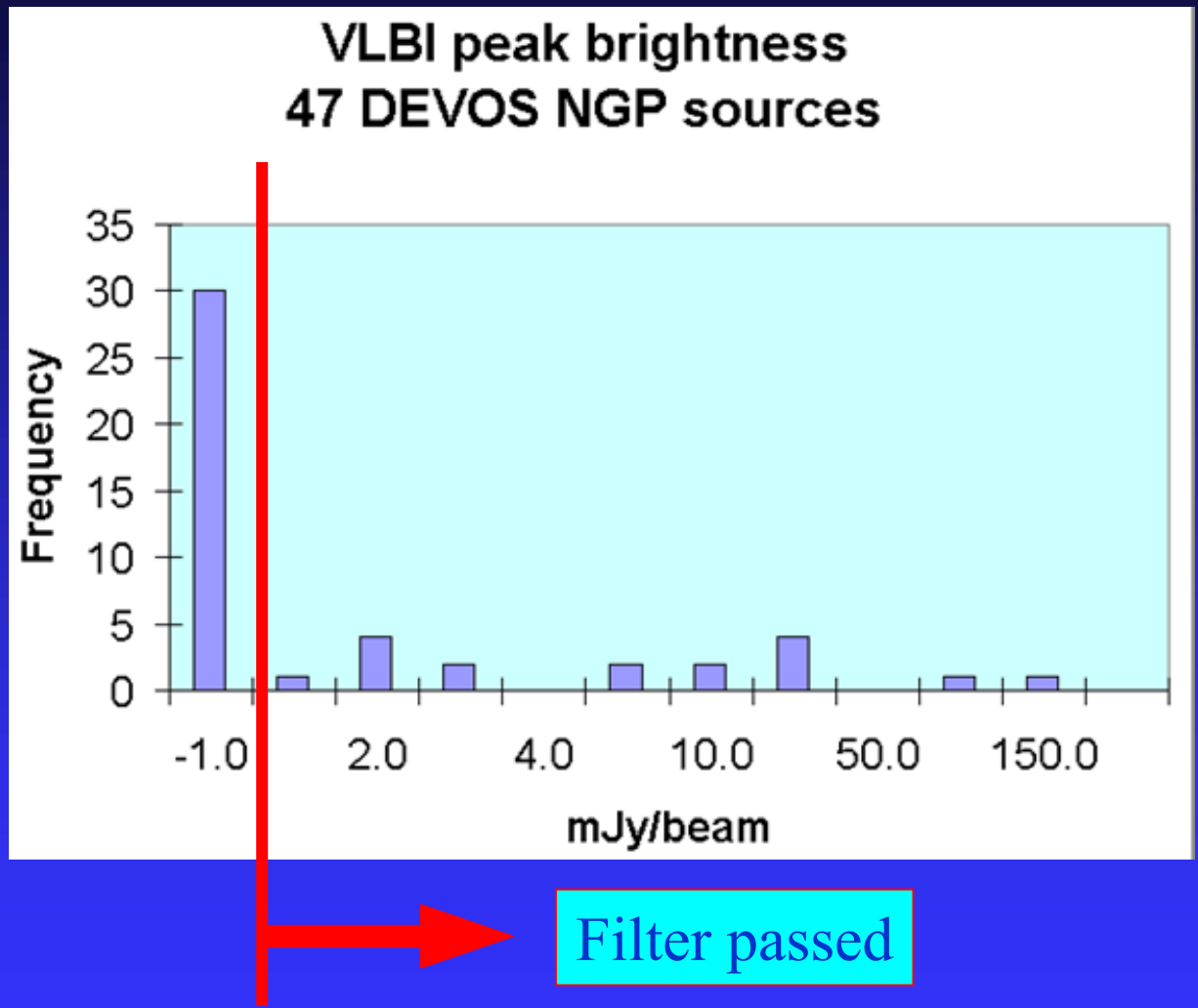
J1257+3229, 2 min

NGP target, 2 min

NGP target, 2 min

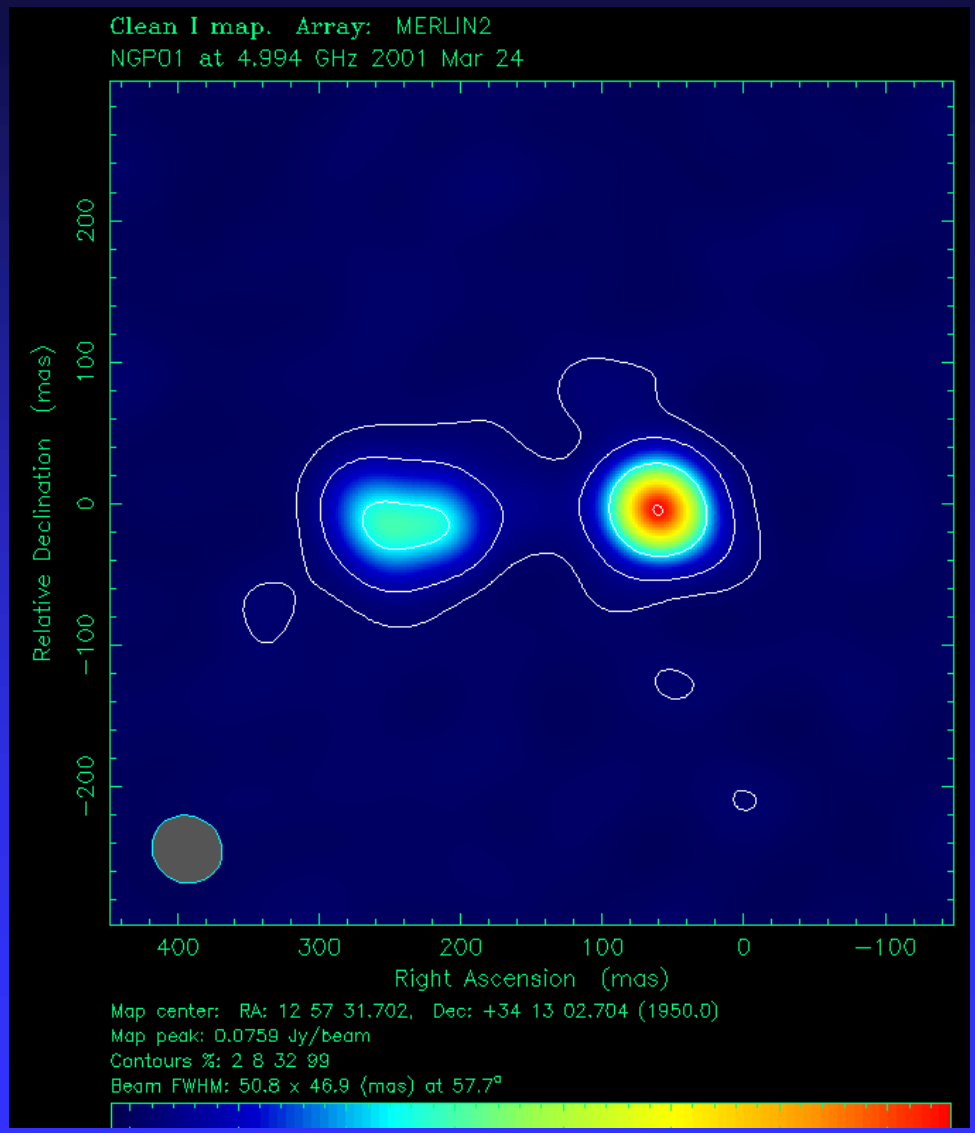
J1257+3229, 2 min

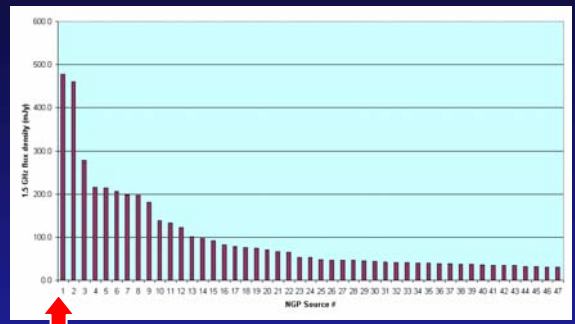
…

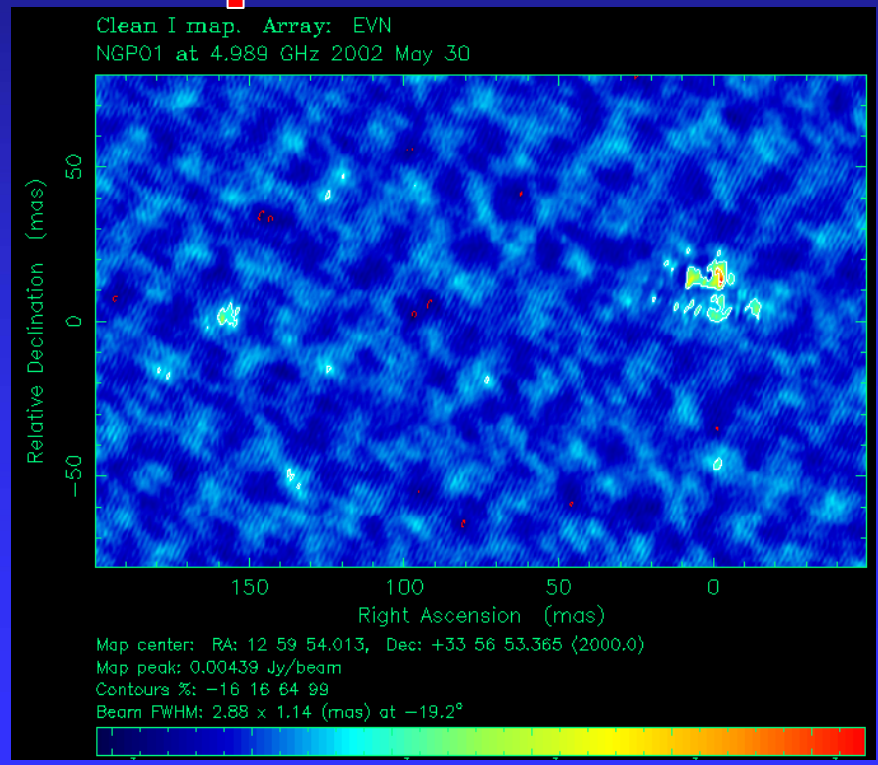


Total: 21 hr (7 hr global), 12-14 min/target, $1\sigma_{thermal}$ = 200 μJy/beam

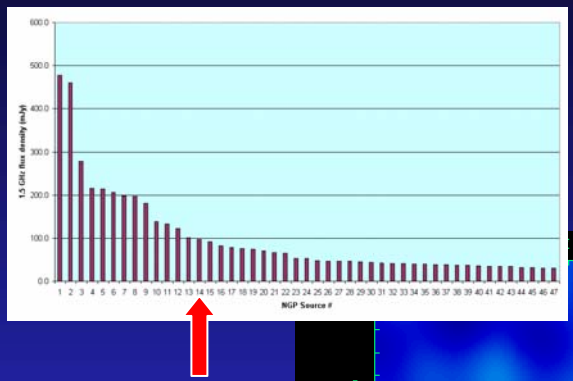
NGP01: VLBI detection at 4.4 mJy/beam

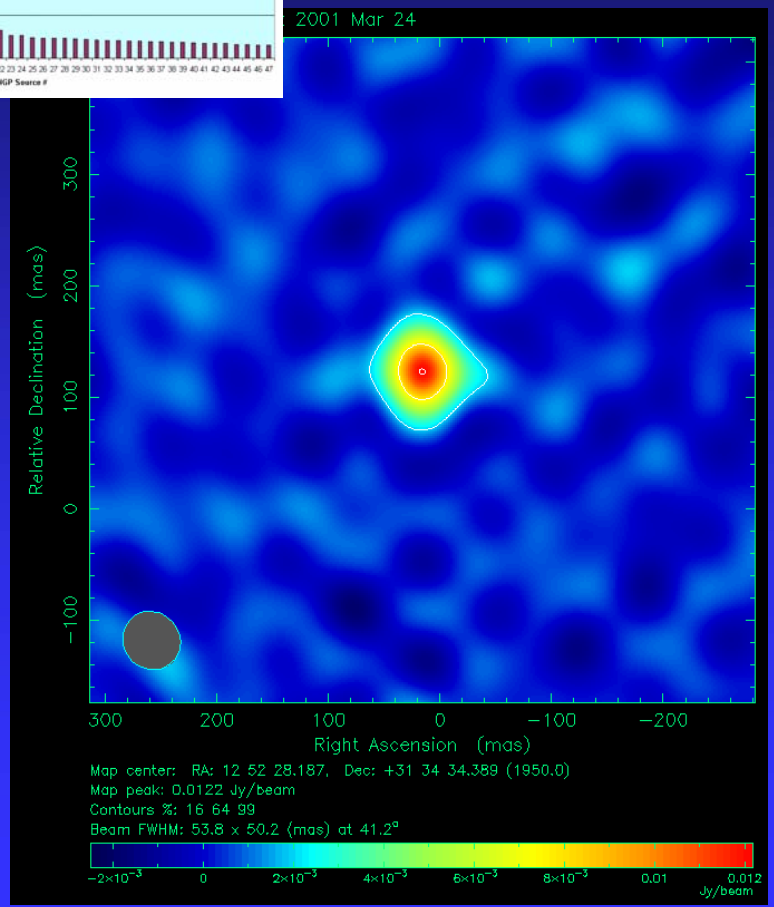


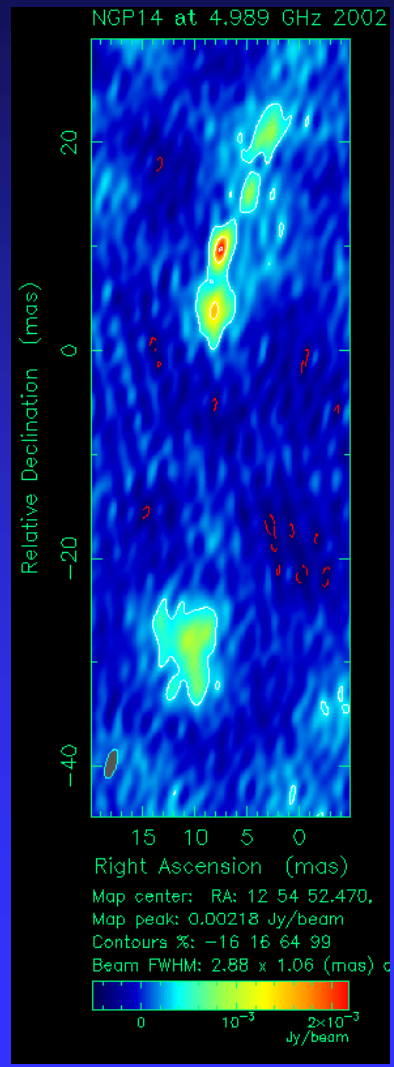




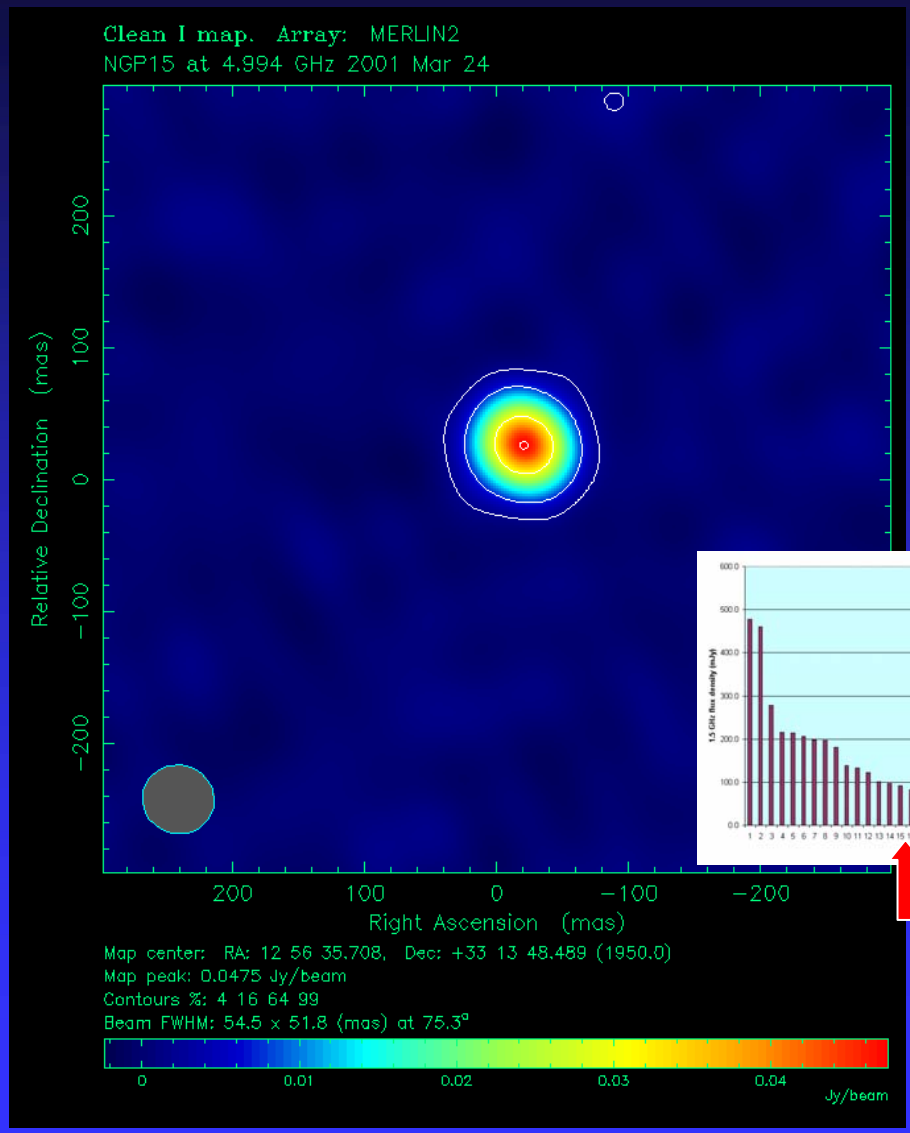
NGP14: 12.2 (MERLIN) and 2.2 (VLBI) mJy/beam

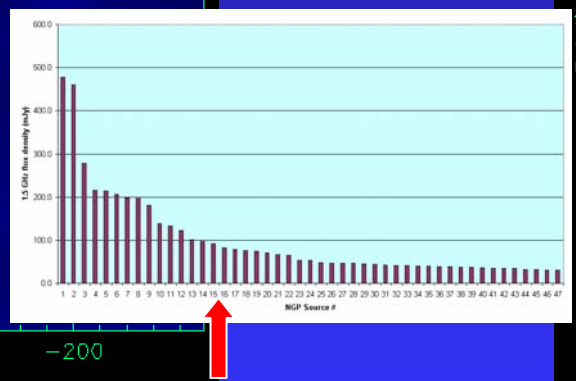


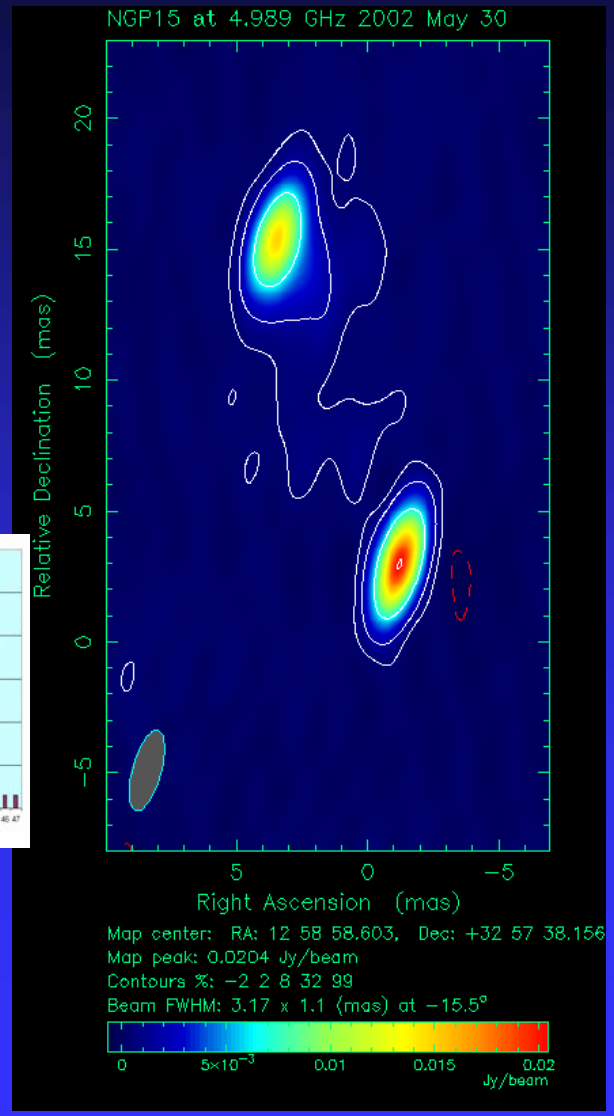




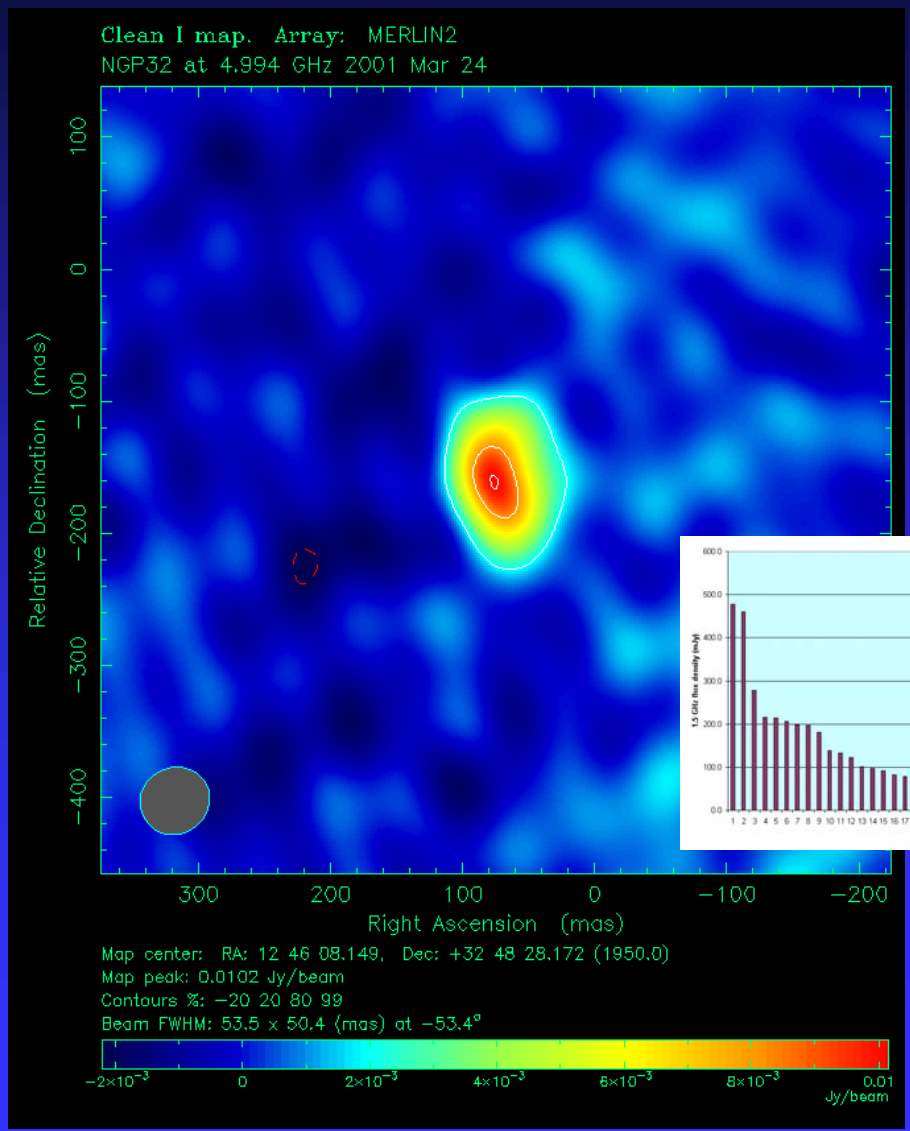
NGP15: 47 (MERLIN) and 20 (VLBI) mJy/beam

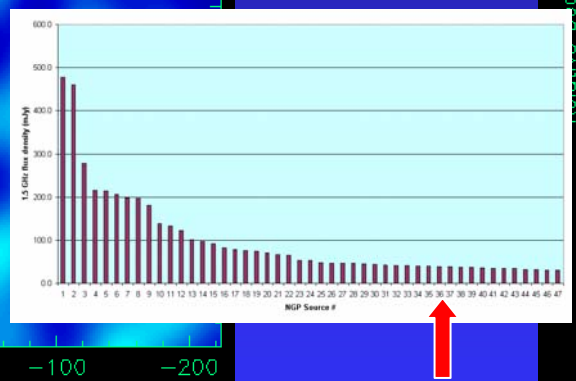


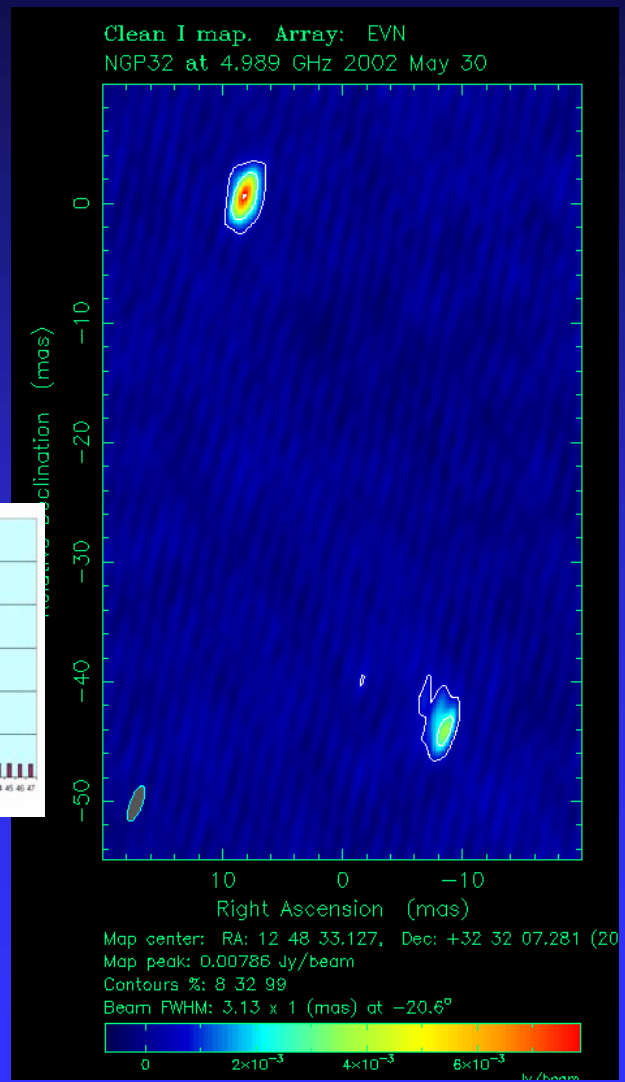




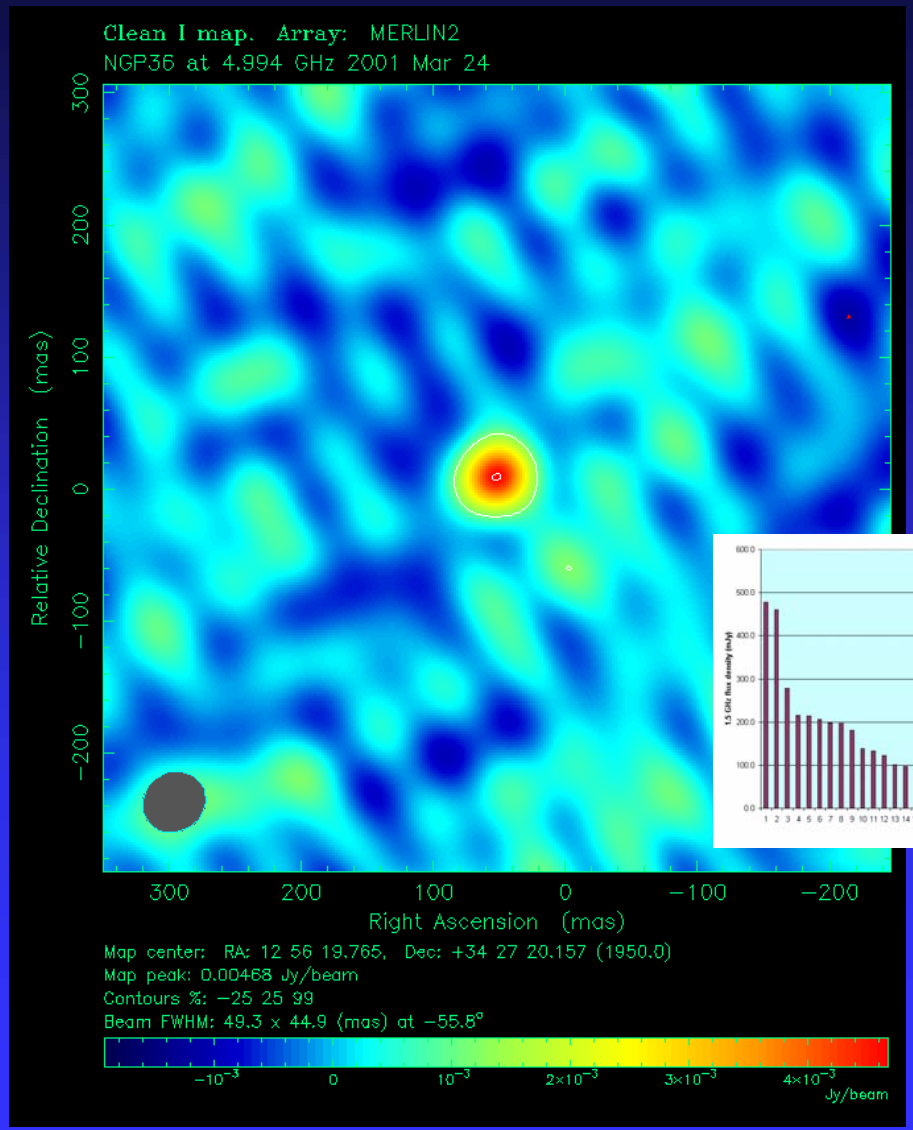
NGP32: 10 (MERLIN) and 7.9 (VLBI) mJy/beam

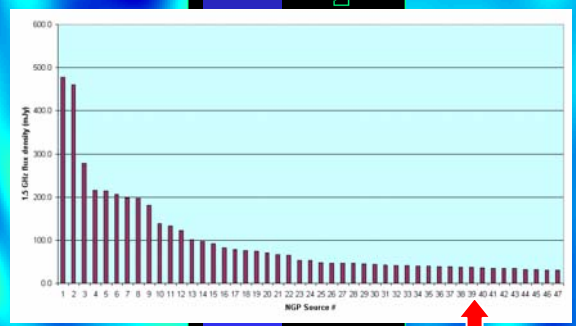




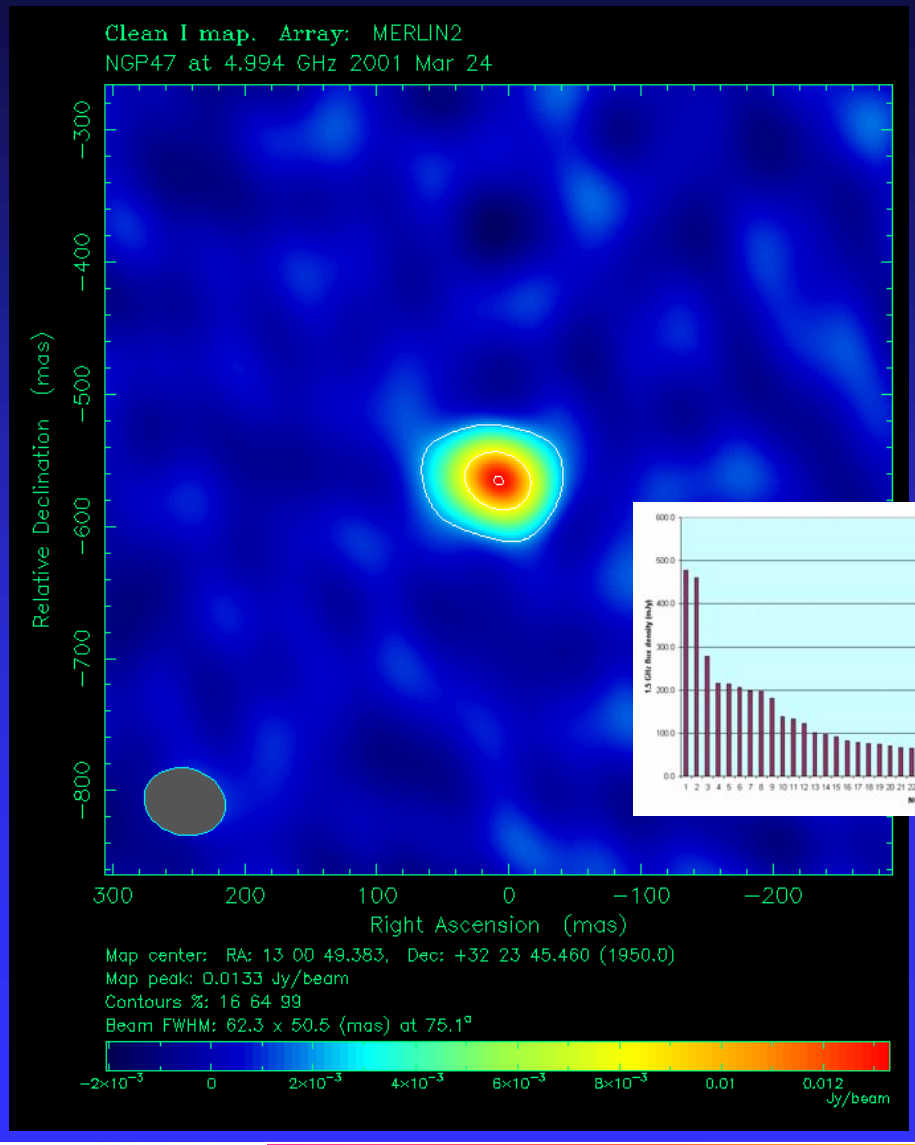


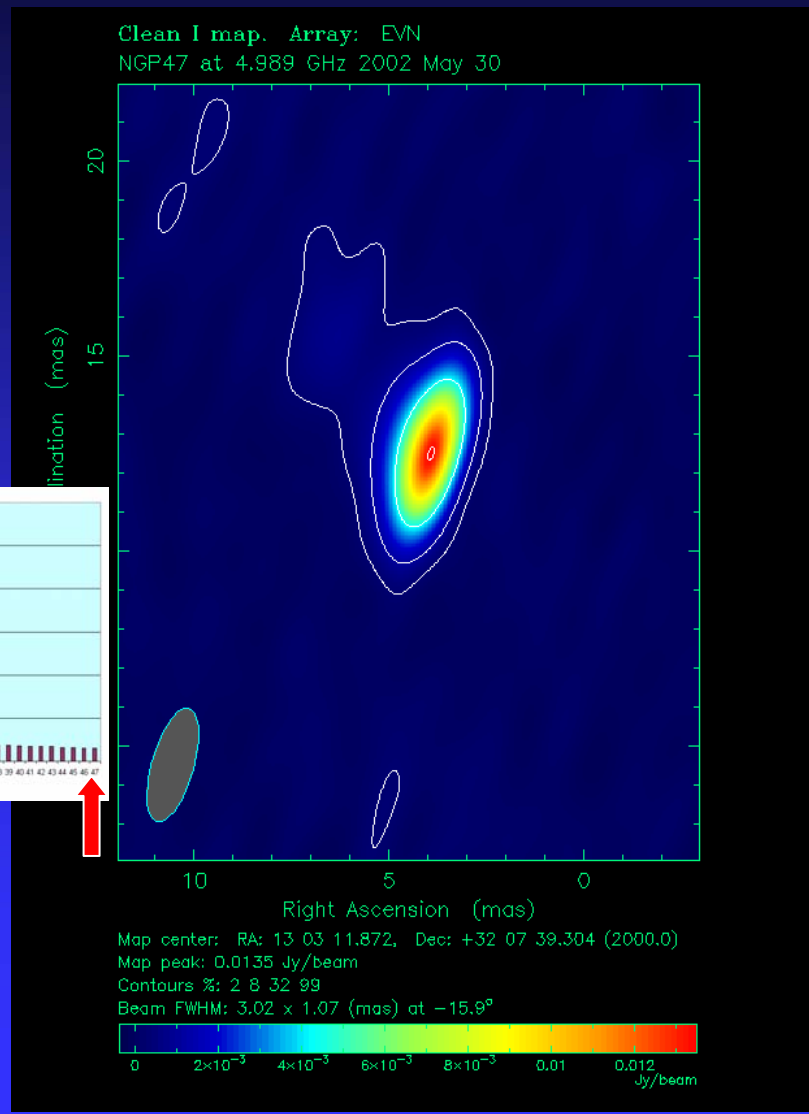
NGP36: 13.3 (MERLIN) and 1.4 (VLBI) mJy/beam





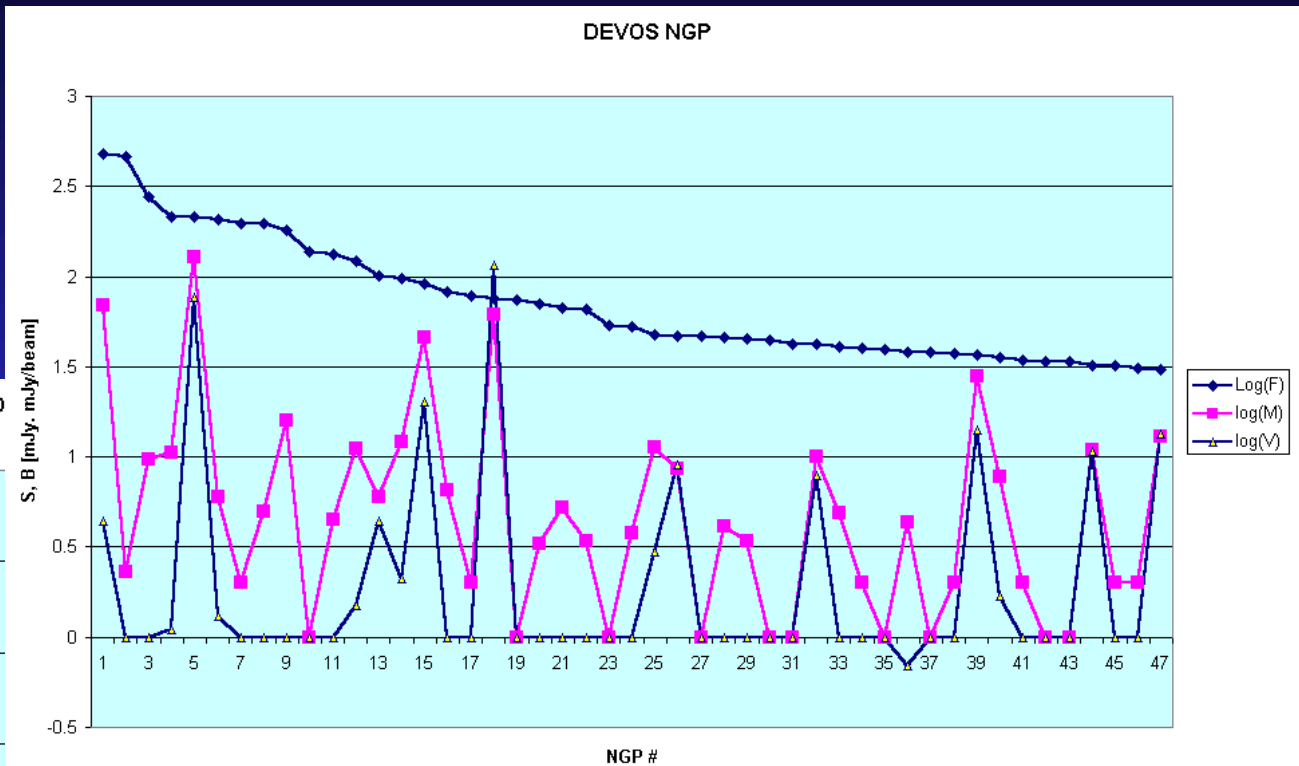
NGP47: 13.3 (MERLIN) and 13.5 (VLBI) mJy/beam

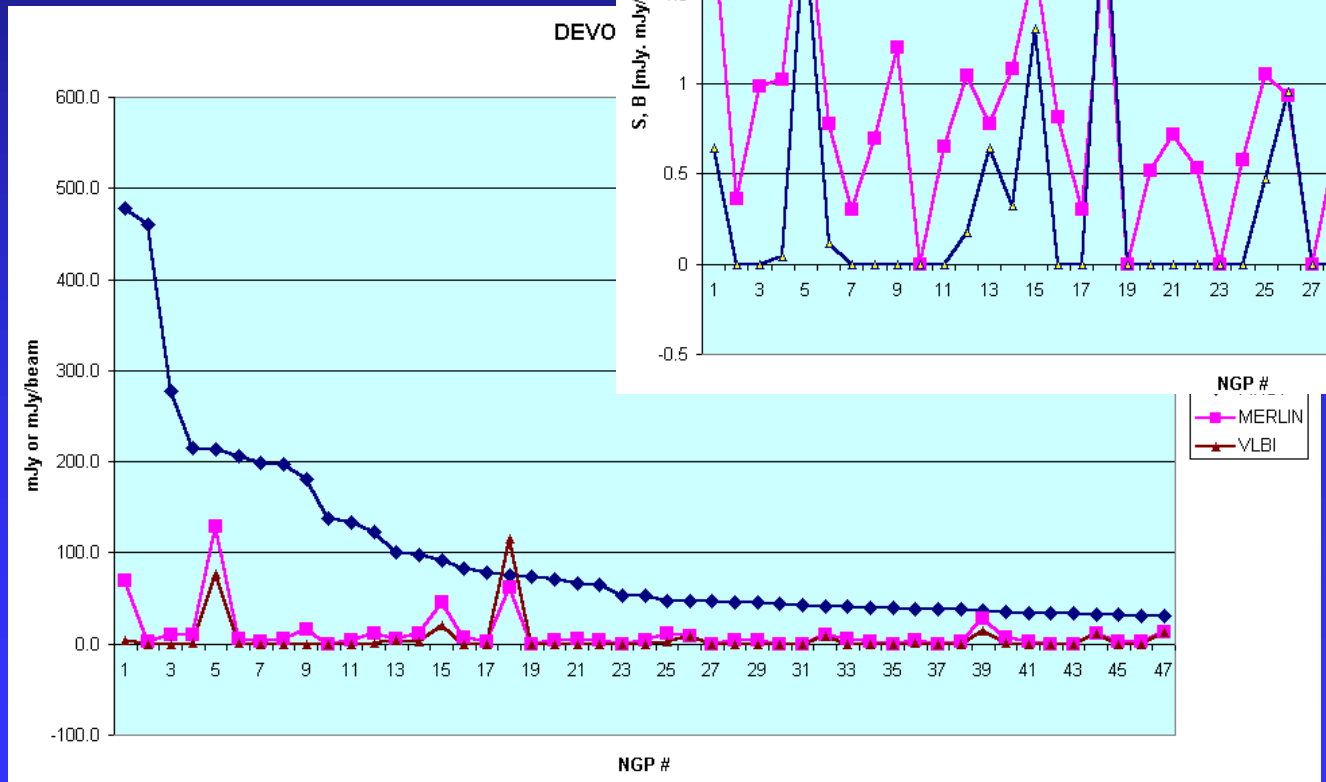




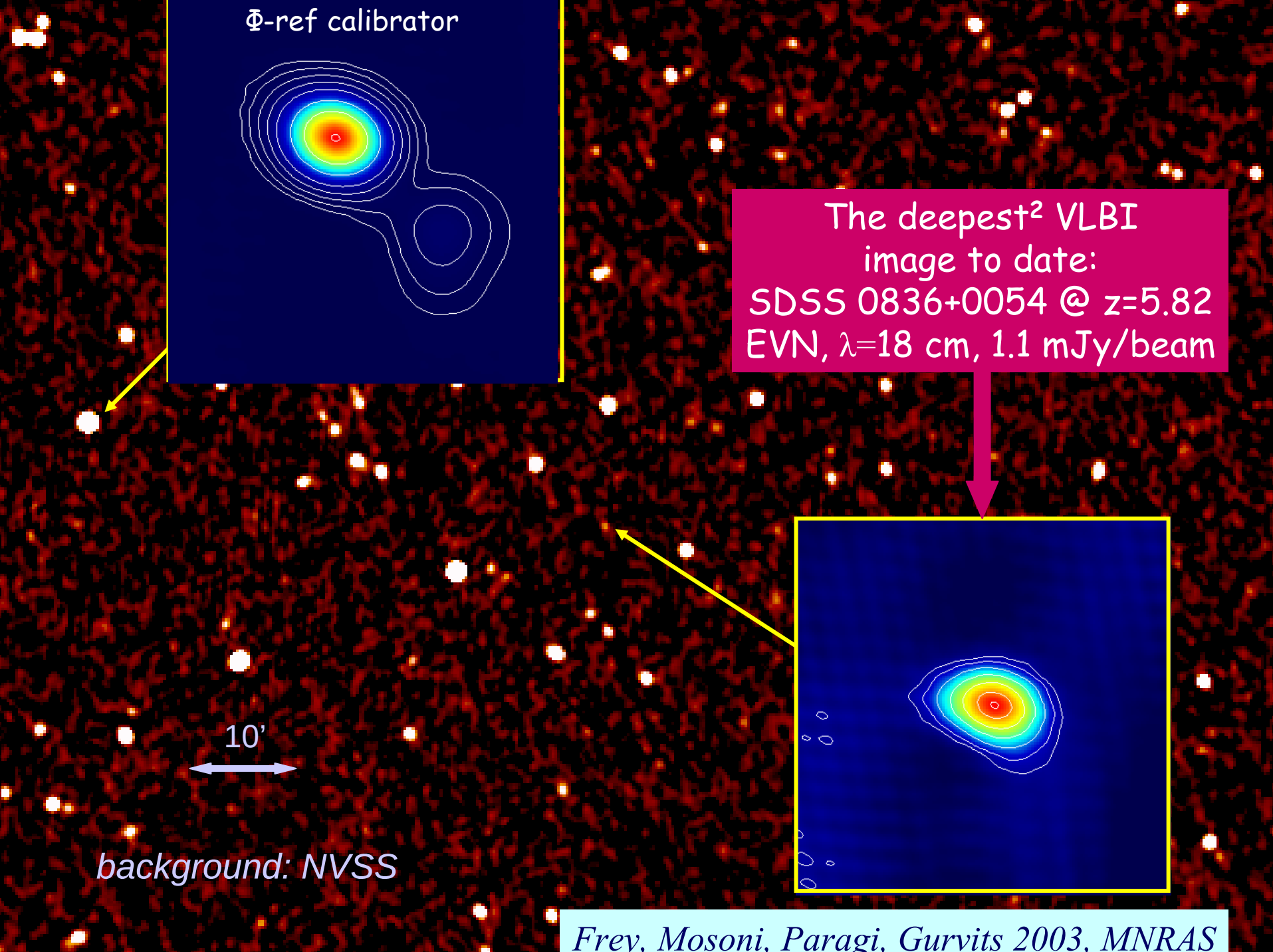
DEVOS NGP: the final yield

16/47 NGP sources detected with VLBI





30%


Φ-ref calibrator
The deepest² VLBI image to date:
SDSS 0836+0054 @ z=5.82
EVN, λ=18 cm, 1.1 mJy/beam
10'
background: NVSS
Frey, Mosoni, Paragi, Gurvits 2003, MNRAS

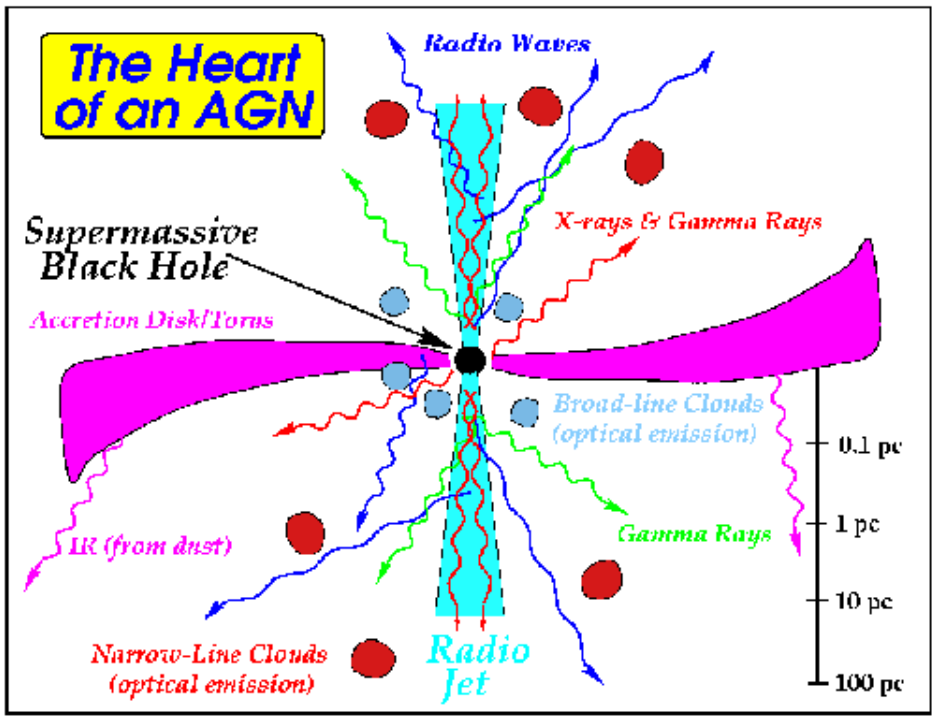
Conclusions: what to expect next

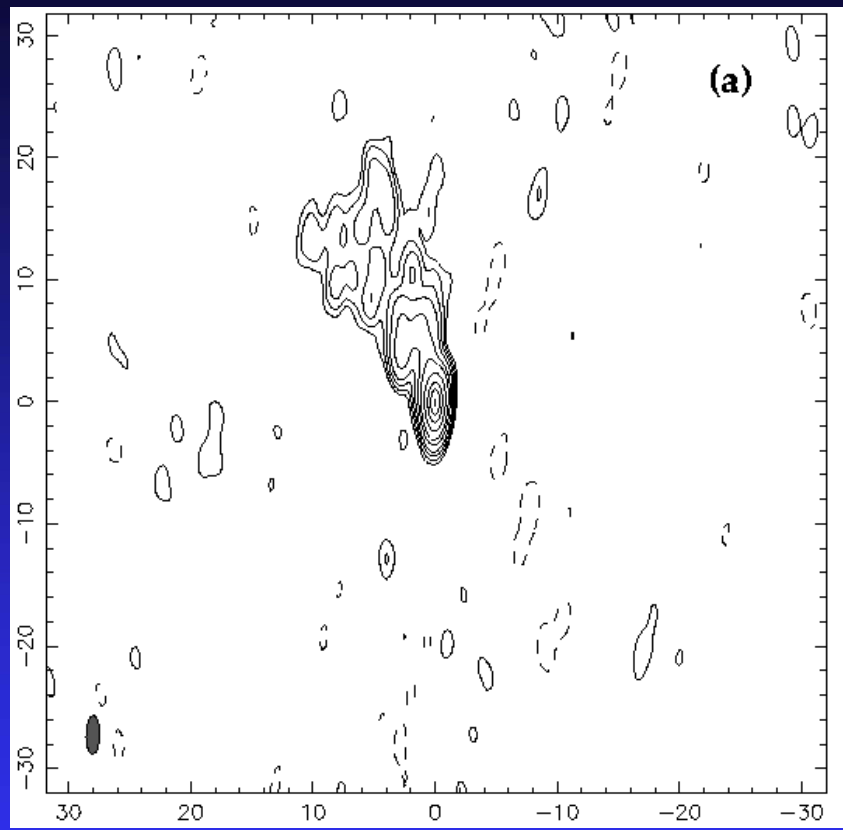
- **Quarter of the sky (~10,000 deg^2) would result in ~15,000 mJy-level detections!**

  Important for fore-ground studies and techniques?

- **Things to be sorted out:**
  - Optimum "yield – filter threshold" relation
    - *At least one more pilot required (lower declination field, in preparation)*
  - Observing and man-power resources
    - *Higher recording data rate (e.g. 1 Gbit/s) reduces integration required*
    - *Pipelining helps to keep post-docs alive and smiling*
- **New instruments ("e"-Radio Astronomy) and "Global configuration SKA" will make mJy-level VLBI surveys inevitable**

Expectations versus observational facts





ARISE, 1999, JPL Publ. 99-14

- **What is the correspondence between the two pictures (jets, cores, etc.)?**
- **How much deeper in the "core" can one go (a hunt for the highest T_B)?**

What are jets made of?