Global eVLBI observations of PMN J0948+0022

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Outline

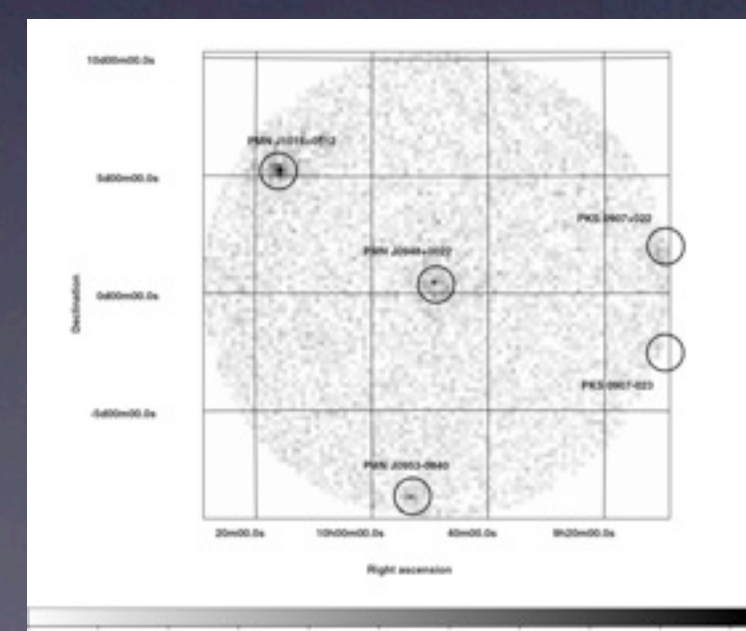
- This project - PMN J0948+0022
  - background: detection of 1st gamma-ray RL NLS1
  - support MWL campaign to assess identification and construct simultaneous, time resolved SED
  - characterization of the radio jet with highest angular resolution ever
- open problems in PMN J0948+0022 and RL-NLS1 in general
- comparison to RQ-NLS1

Introduction

- Only a small fraction of NLS1 are radio loud (~7%, Komossa et al. 2006). These sources show the hallmarks of relativistic blazar-like jets (Doi et al. 2006, Zhou et al. 2003)
  - large core dominance
  - high brightness temperature
  - flat spectral index
- Blazar jets make gamma-rays... how about RL-NLS1s?

Gamma-ray discovery of PMN J0948+0022

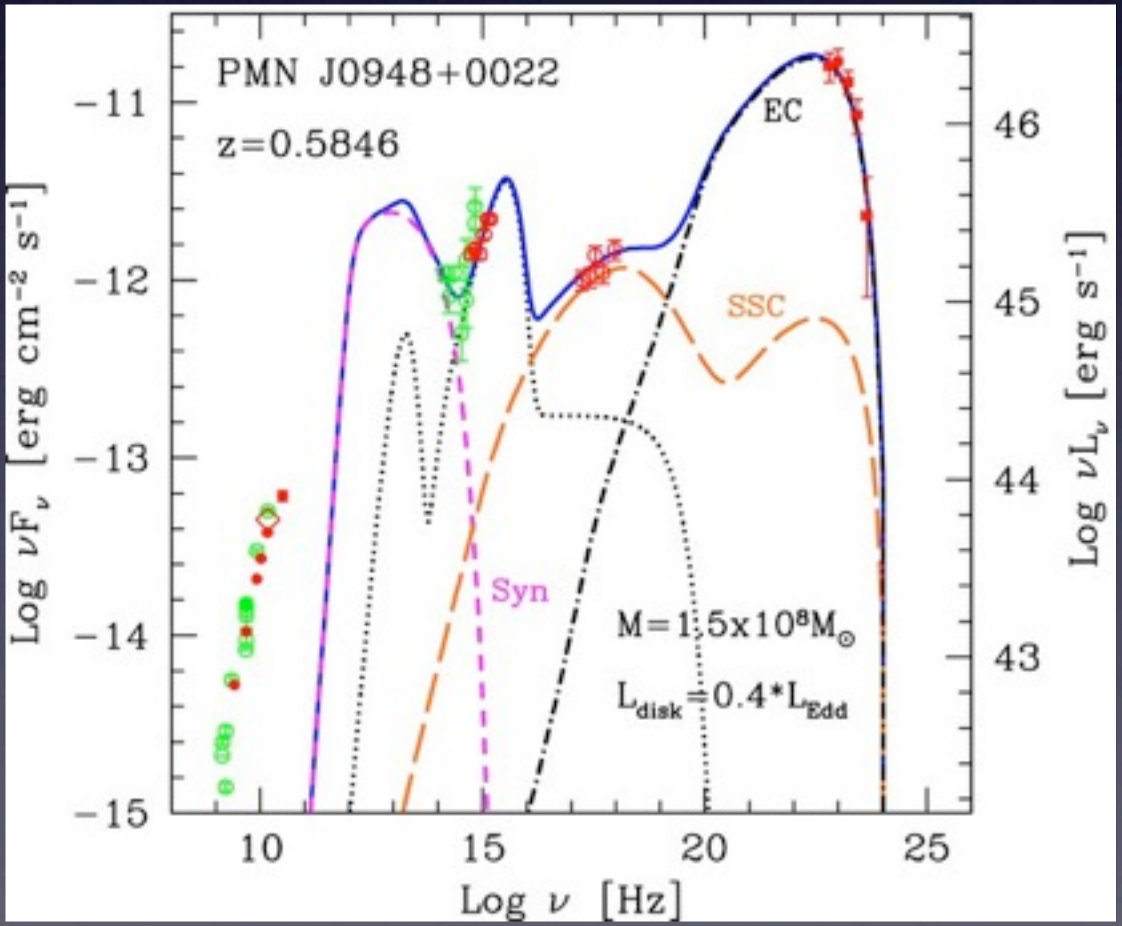
- Just few weeks after its launch, the Large Area Telescope on board Fermi reveals gamma-ray emission positionally consistent with the NLS1 PMN J0948+0022 (Abdo et al. 2009, ApJ 699 976)
  - z=0.58
  - Flux [E>100 MeV] = $(12.1 \pm 2.2) \times 10^{-8}$ ph cm^{-2} s^{-1}
  - Photon Index = 2.60 ± 0.14



MWL observations: archival data and the 2009 campaign

- Multiwavelength archival data have initially been used to clarify the details of the emission processes at work in PMN J0948+0022
- SED parameters typical of FSRQs (bulk Γ, viewing angle, luminosity, magnetic field, γ electrons)
- However, a new observational campaign was immediately set up to obtain better, simultaneous data

Luigi's talk



2009 MWL campaign: the radio observations

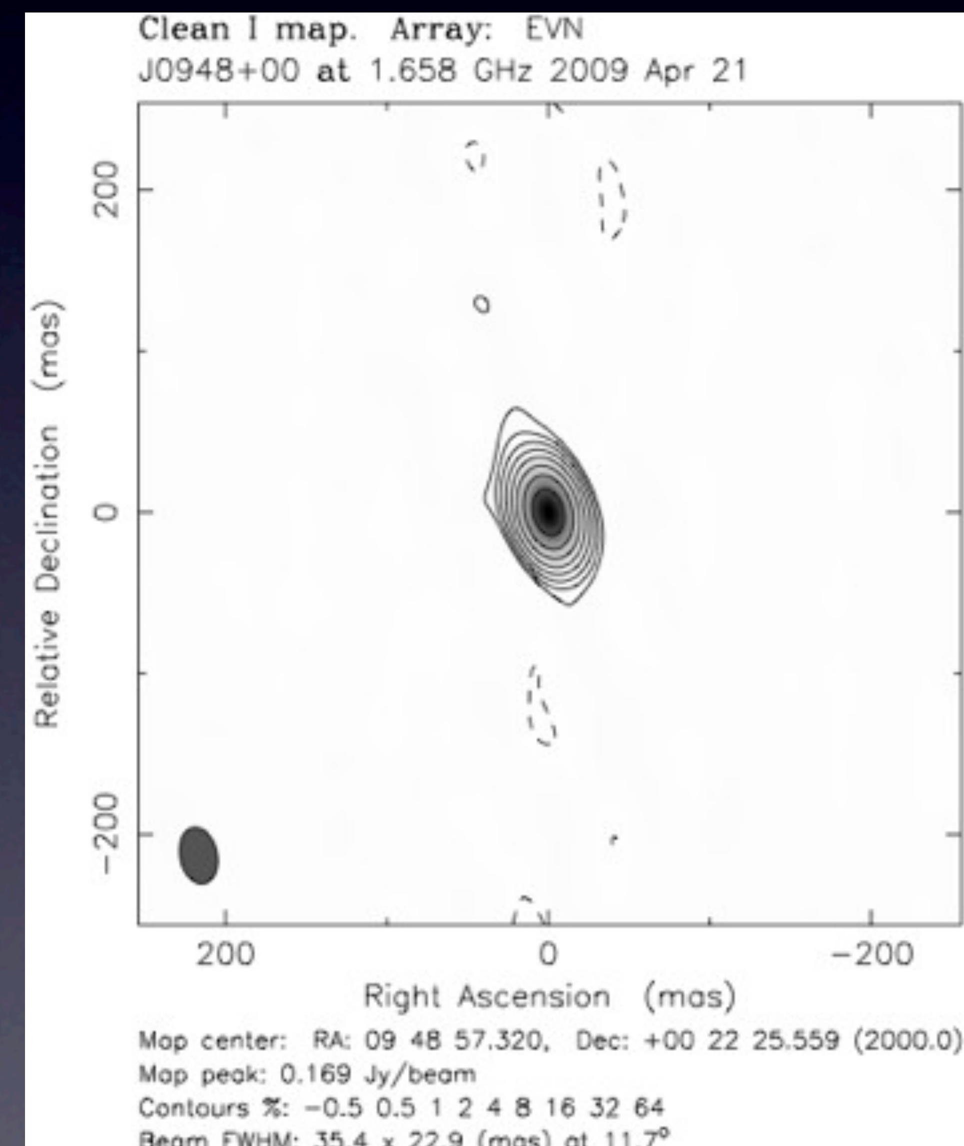
- Radio emission is generally detected somewhat out of the gamma-ray zone, but VLBI observations can still provide
  - complementary information on correlated variability
  - independent constraints on Doppler factor and viewing angle
  - highest angular resolution imaging

How: global e-VLBI observations

- More and more telescopes are becoming connected with optical fibers sustaining high data rates
- Advantages both scientific and practical
  - fast delivery of results
  - possibility to test setups in real time
  - no need to store data on disks
- The European VLBI Network (EVN) operates in e-VLBI mode about once per month since 2008
  - but never done before on a global scale

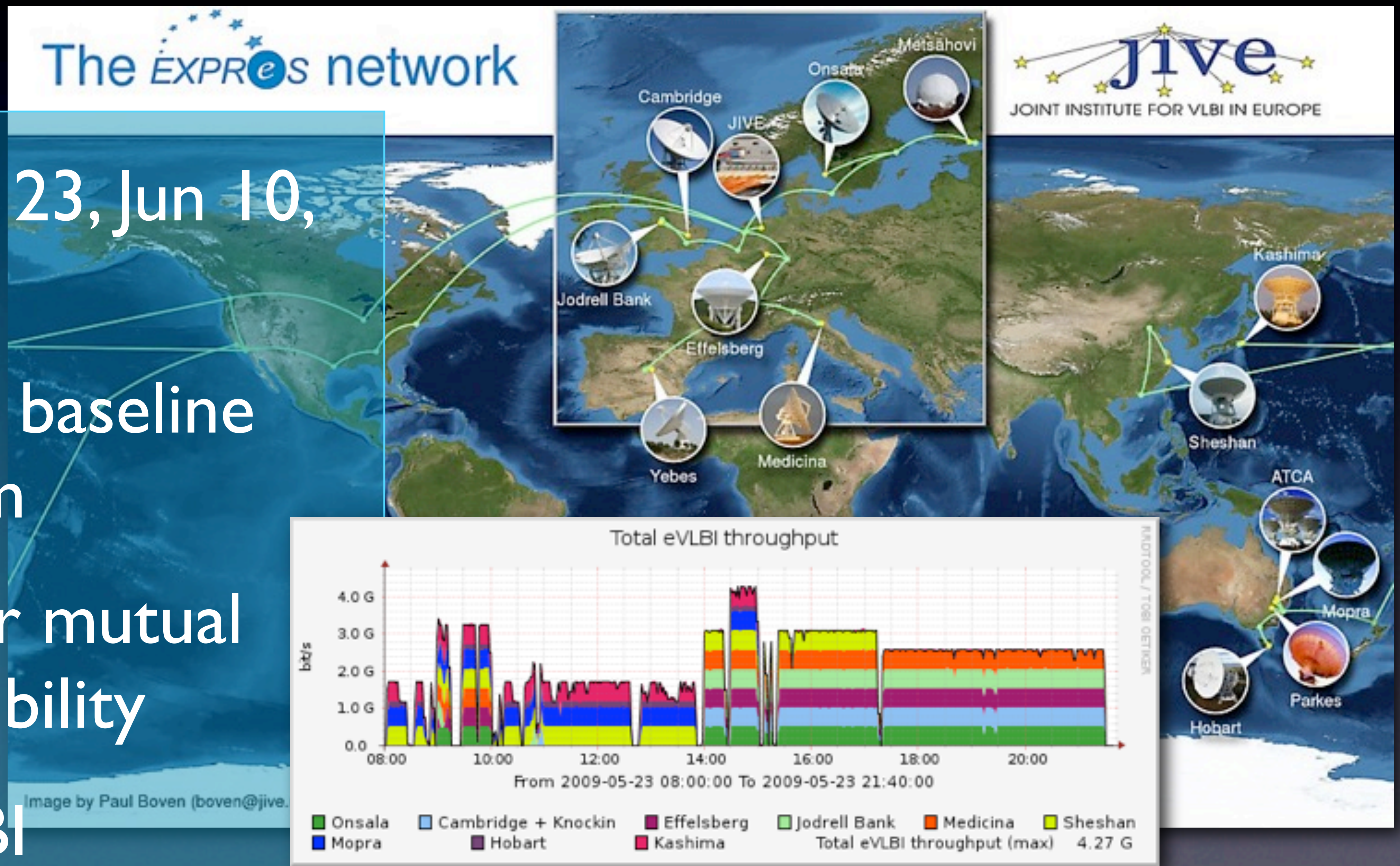
e-VLBI and PMN J0948+0022

- Intra-European test at 1.6 GHz succeeded in revealing the source on Apr 21
  - organization of a full-size campaign
- Known facts: inverted spectrum, Dec~0deg, very compact structure
  - go for maximum resolution with global high-frequency observations: **Eu+Ch+Jp+Au at 22 GHz, three epochs**



Observations: details

- 2009 May 23, Jun 10, July 3
- Maximum baseline ~12500km
- about 1 hr mutual Eu-Au visibility
- max eVLBI throughput ~4.5 Gbps



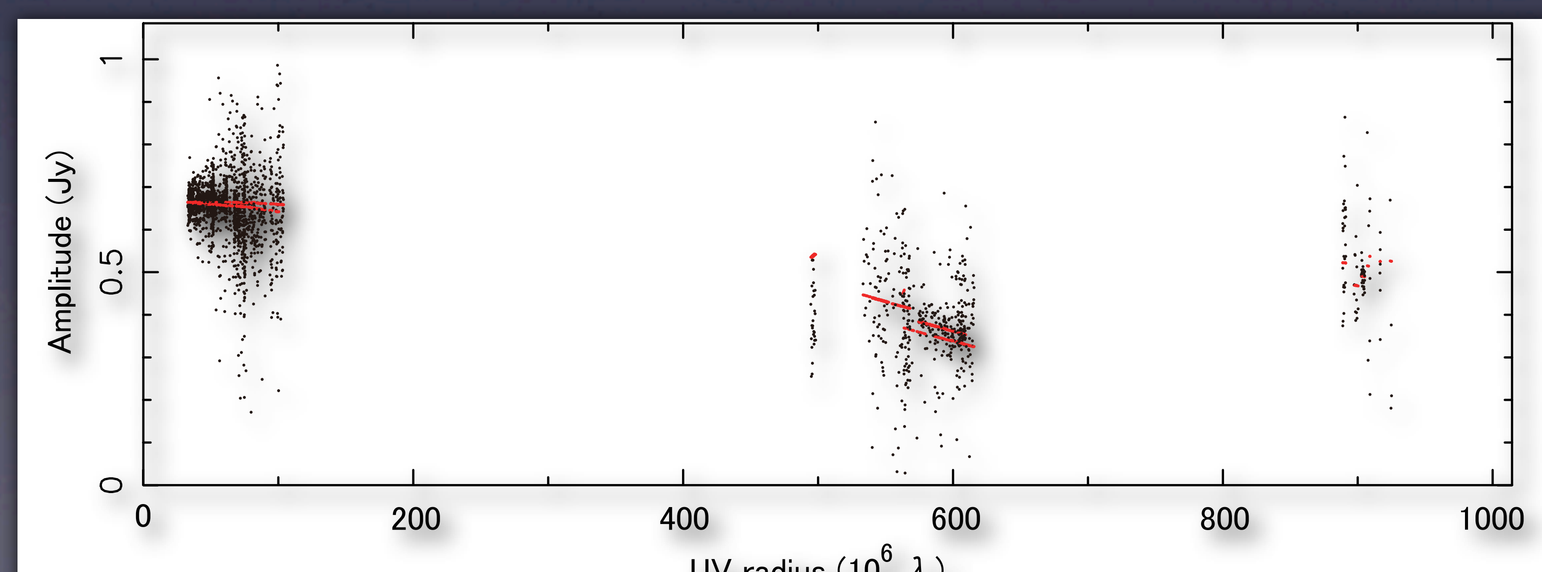
Results

- source detected at all epochs, with a flux density varying between 300 and 700 mJy
- Angular resolution as good as 0.15x0.38 mas, corresponding to brightness temperature $T_B>3.4\times10^{11}$ K

Day of 2009	Freq. (GHz)	Longest baseline (km)	beam *FWHM* (mas × mas, °)	*S* (mJy)
Apr. 21	1.6	Jb-Tr, 1388	35.4 × 22.9,11.7	173 ± 20
May 23	22.2	Ef-Ho, 12359	0.38 × 0.15,39.1	665 ± 130
Jun. 10	22.2	Ys-Mp, 12458	0.43 × 0.14,43.3	345 ± 70
Jul. 04	22.2	Ks-Mc, 8811	0.42 × 0.35,39.5	445 ± 90

$M_{BH}=1.5\times10^8\ M_{sun}$ - $1R_S=5\times10^{-5}$ pc

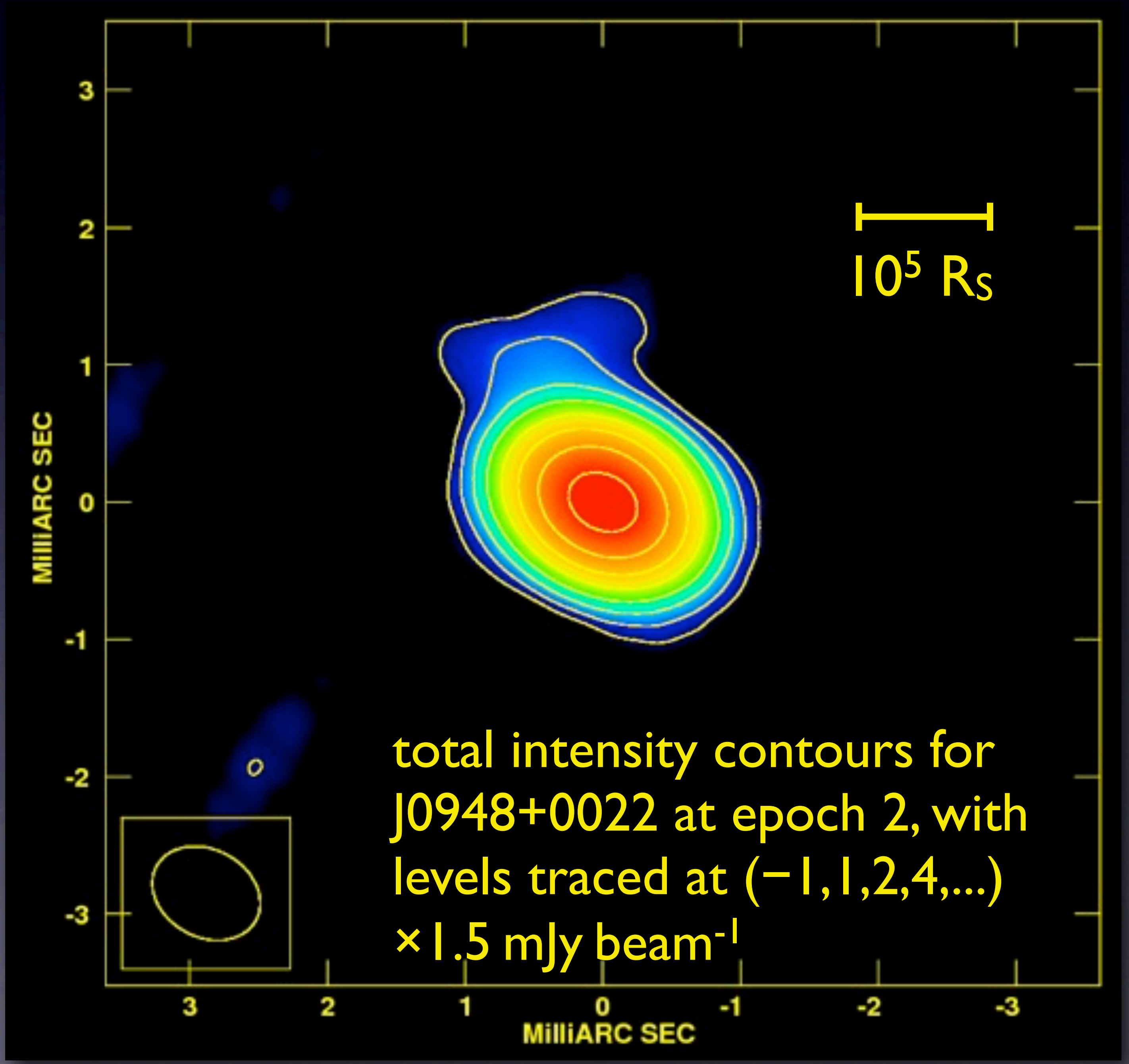
$z=0.585$ - 0.1 mas $=0.6$ pc $=10^4\ R_s$



Revealing the sub-mas jet

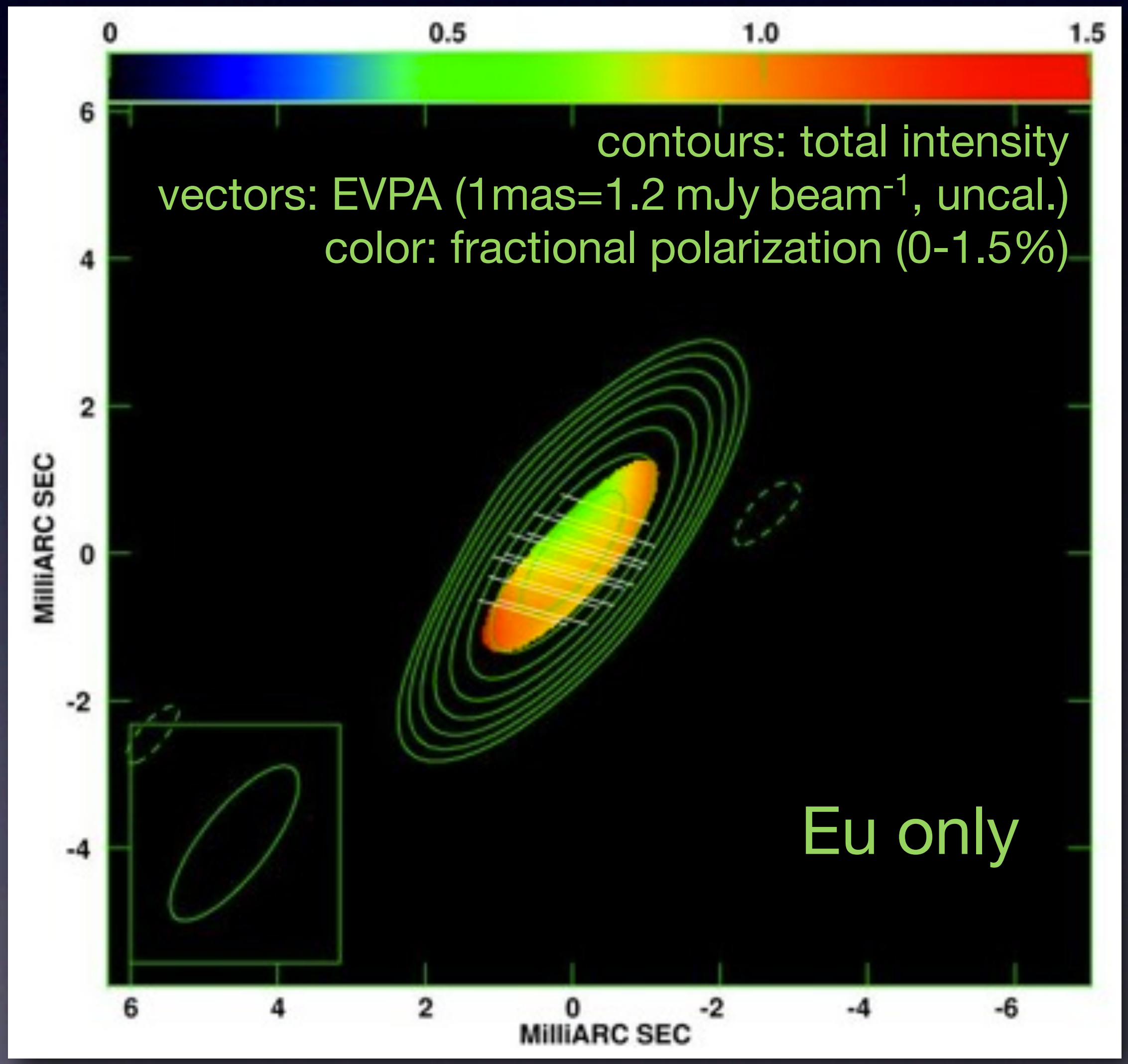
- The compact core dominates the structure

- However, a jet component is found at r=0.86 mas from the core in PA θ=35.4°, well aligned with the lower frequency structure, which shows a resolved jet feature in PA ~ 30°−40° (Doi et al. 2006, Abdo et al. 2009, Foschini et al. 2011)



How about polarization?

- Polarization traces magnetic field structure (shocks?)
- changes in polarization intensity and position angle often related to gamma-ray events
- on average, Fermi detected blazar jets are more polarized (Hovatta et al. 2010)
- Our result: polarization detected at epoch 2, mean 0.9% (peak of 1.3%), barely in excess of the VLBA at 15 GHz for the same epoch



The 2009 Global e-VLBI campaign: results and open problems

Results

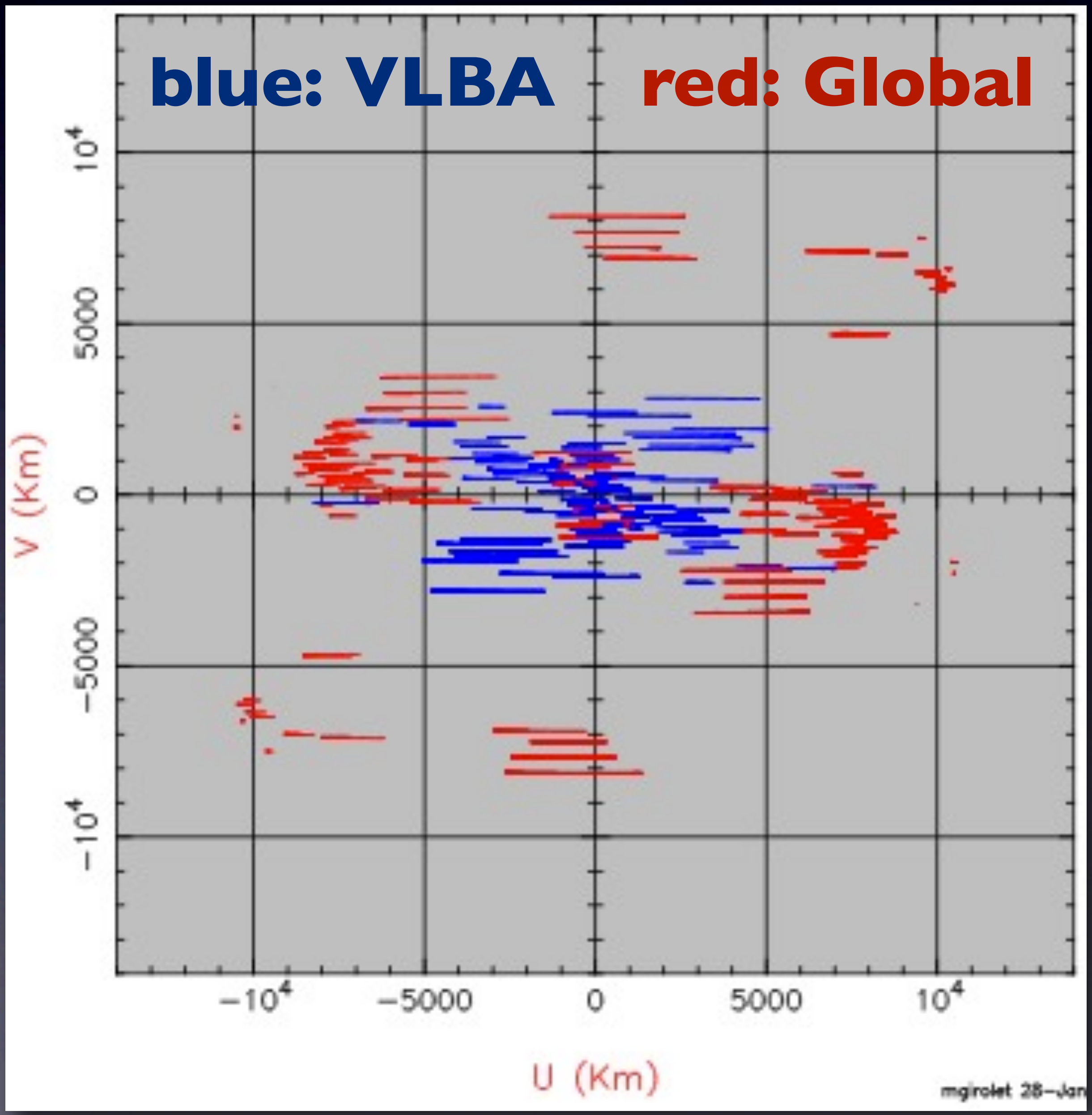
- source is detected
- variable (300-600 mJy), unresolved <10^4 R_S core: **relativistic jet base**
- faint one-sided jet knot
- ~1% fractional pol.

Open problems

- still not possible to trace proper motion of jet knot
- why do J0948 and other RL-NLS1 lack extended emission?
- connection between gamma-ray activity and polarization
  - Even more interesting after gamma-ray flare and VLBA data reported by Foschini et al. 2011

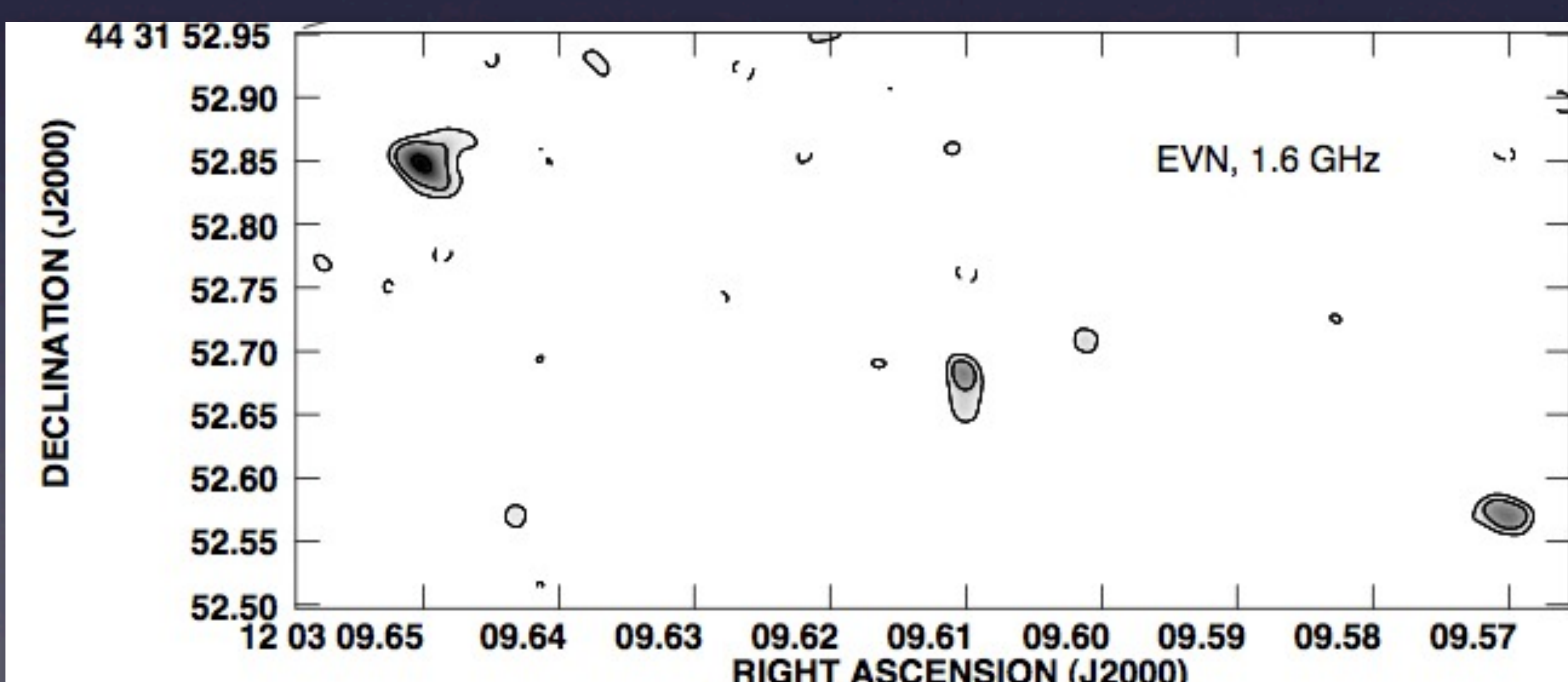
A new (2011-2012) global VLBI campaign

- 22-24 GHz VLBA+EVN observations: improve angular resolution by factor ~3 over VLBA
- 3 epochs separated by 4 months: suitable to reveal proper motions in the range β~10-30
- large bandwidth: good for polarization & RM study (clues on medium)
- one epoch simultaneous with XMM-Newton (PI D'Ammando)



RL vs RQ NLS1?

- RL-NLS1 have bright compact cores
- What about RQ NLS1?
- They have compact cores too, but not as bright



NGC 4051
(Giroletti&Panessa 2009)

T_B =10^5 K
linear size<0.3pc

$L_{5\ GHz}$ = 18.8 W Hz^{-1}
$L_{2\text{-}10\ keV}$ = 40.8 erg s^{-1}

Jet base? Thermal emission from outflow/wind/molecular disk

Summary

- Global e-VLBI is a reliable technique to image AGN jets and constrain their physical properties
- PMN J0948+0022 exhibits most features of relativistic jets - compactness, brightness, polarization
- Future VLBI observations are fundamental for
  - the details of this source
  - more RL NLS1
  - and RQ NLS1 too