Millimeter VLBI of NGC1052: Pinpointing a Supermassive Black Hole

Anne-Kathrin Baczko [1,2,3]

In Collaboration with:

R. Schulz [2,3,4], E. Ros [3,4], M. Kadler [1], M. Perucho [4], J. Wilms [1]

[1] *MPIfR, Bonn;* [2] *Remeis Obs. Bamberg & ECAP Erlangen;* [3] *Univ. Würzburg;* [4] *Univ. València;*

[5] *ASTRON, Dwingeloo, NL*

May 31, 2016

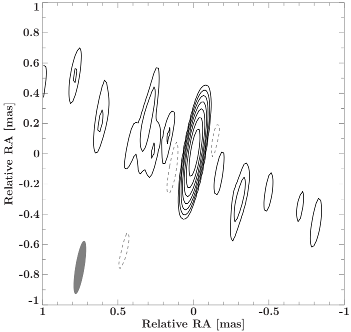
Max-Planck-Institut
für
Radioastronomie

ASTRO WÜRZBURG

Table of Contents

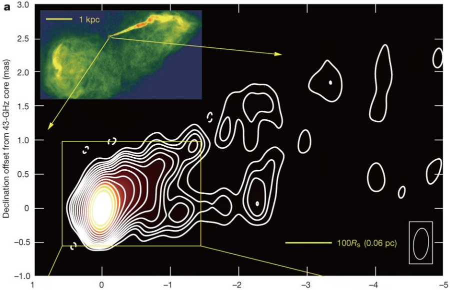
	NGC1052	M87
Distance	$\sim$20 Mpc	$\sim$ 16.7 Mpc
BH mass	$M \sim 10^{8.2}\,M_\odot$	$M \sim 10^{9.8}\,M_\odot$ $^{(*)}$
Inclination angle	close to 90°	$15 - 25°$ $^{(**)}$

$^{(*)}$ *Gebhardt & Thomas 2009 (ApJ 700,1002)*, $^{(**)}$ *Acciari et al. 2009 (Science 325,444)*



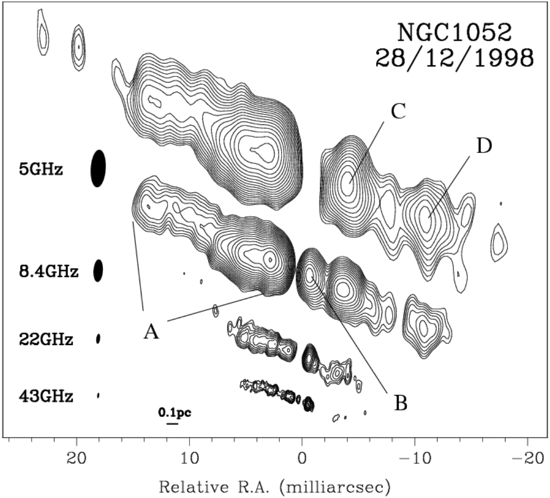
Baczko et al. 2016 (A&A in press, ArXiv 1605.0700)

Emission region $<$ 200 R_S



Hada et al. 2011 (Nature 477,185): Central engine within 14–23 R_S of the 7mm-core

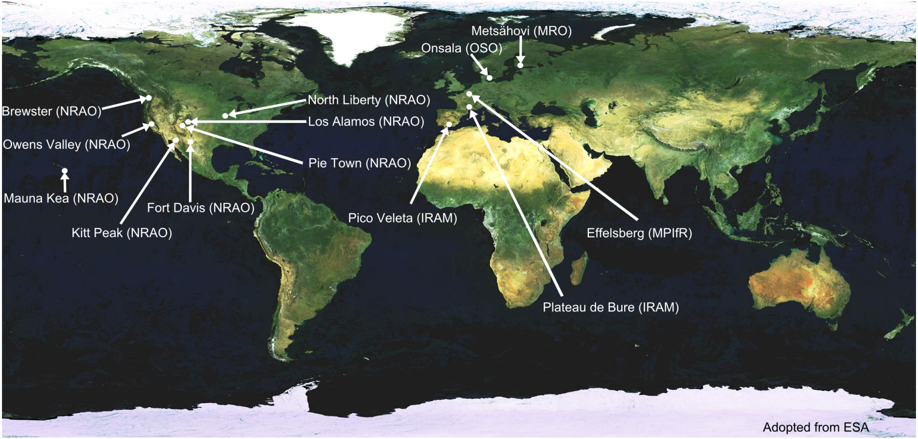
Radio properties of NGC 1052



Kadler et al. 2004 (A&A 426, 481)

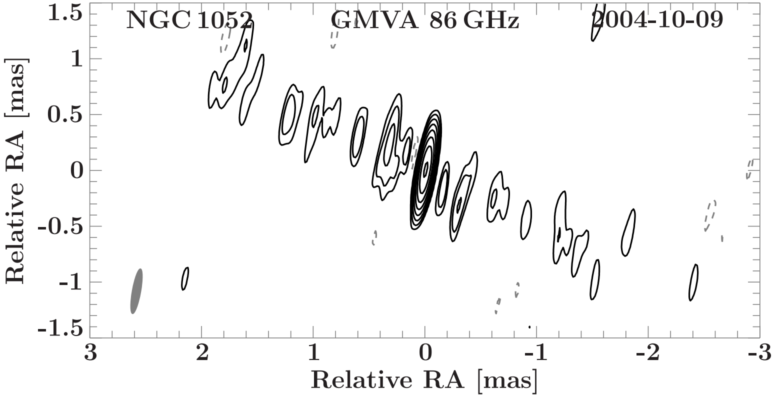
The Global mm-VLBI Array (GMVA)

Observation on 9/10 October 2004



First detection of the twin-jet system of NGC 1052 at 86 GHz

Baczko et al. 2016 (A&A in press)

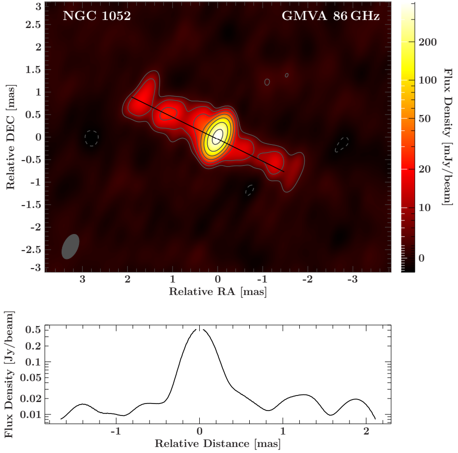


Uniform weighted beam: (353 $\times$ 58) μas^2

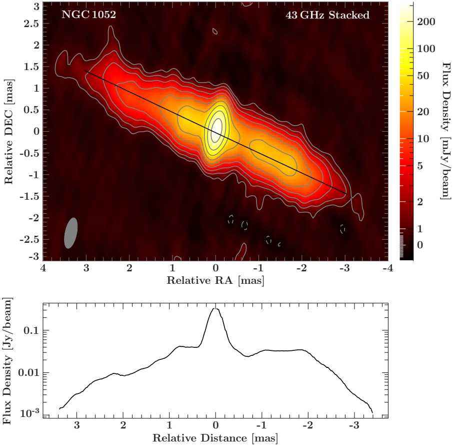
$\rightarrow$ **resolution in east-west direction: 6.5 ltd**

The Morphology at 86 and 43 GHz

Tapered image at 86 GHz October 2004

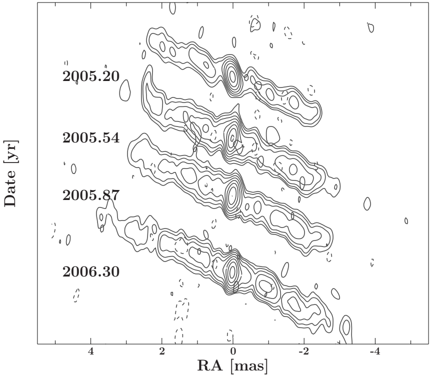


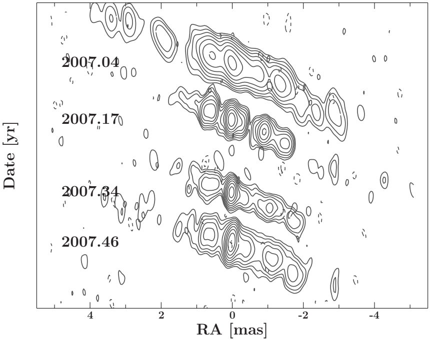
Stacked image at 43 GHz 2005-2009



Detailed analysis at 43 GHz

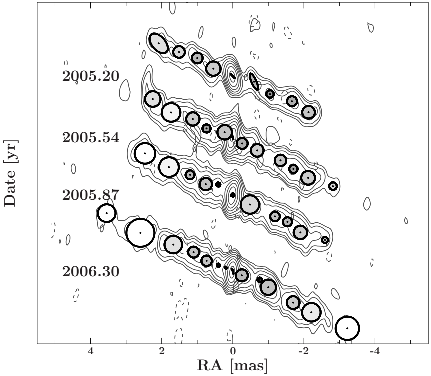
Examples from 4 years of observation with the VLBA (2005-2009)

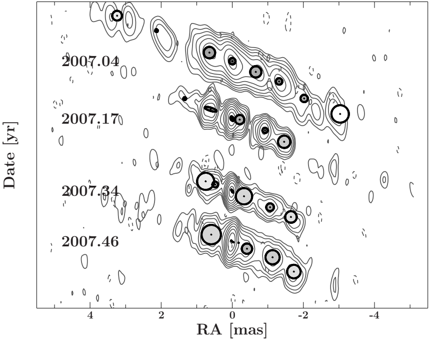




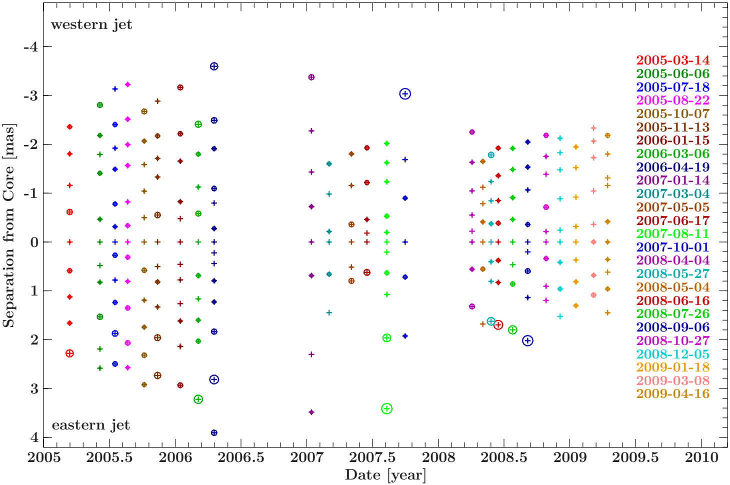
Detailed analysis at 43 GHz

Examples from 4 years of observation with the VLBA (2005-2009)

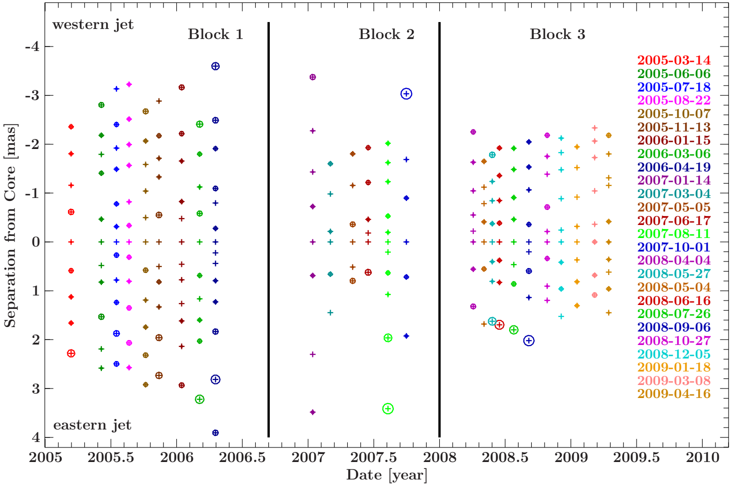




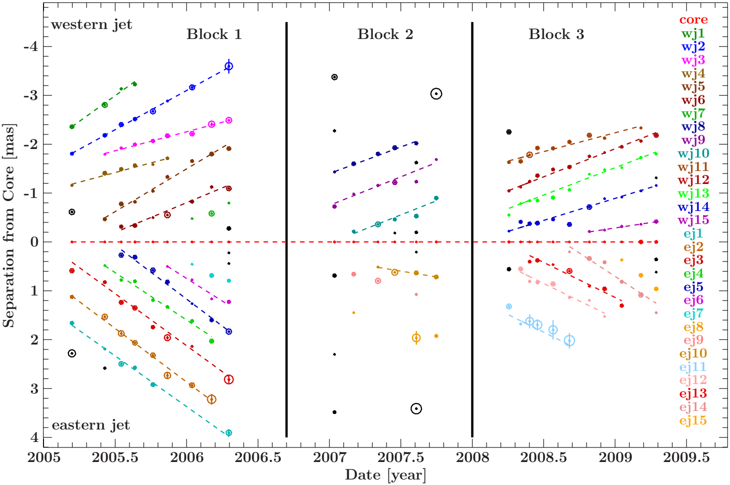
Tracking Moving Emission Features



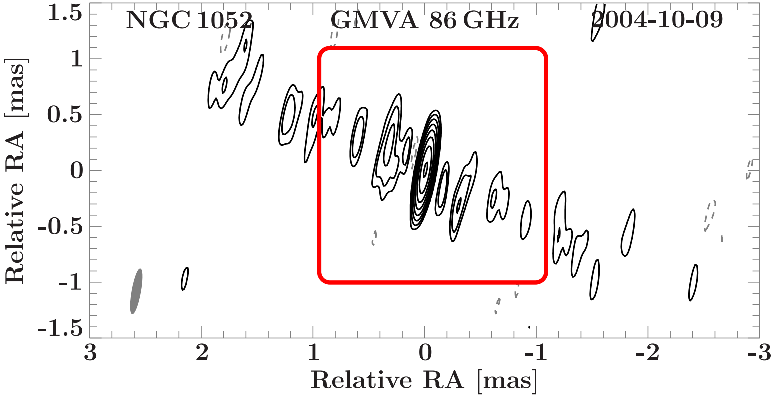
Tracking Moving Emission Features

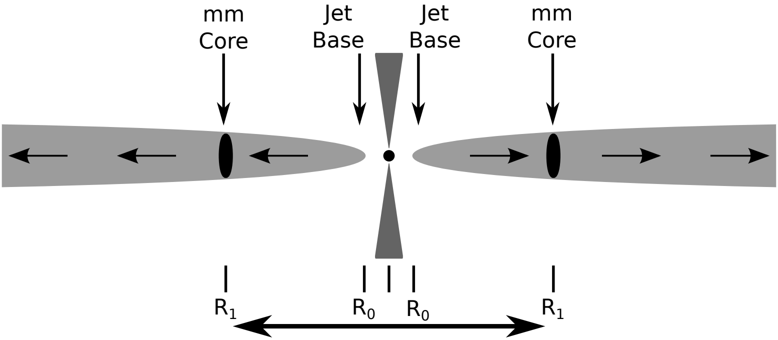


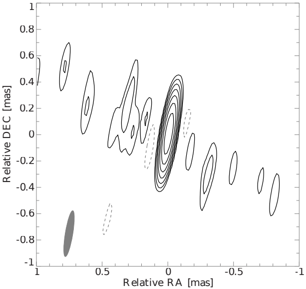
Tracking Moving Emission Features

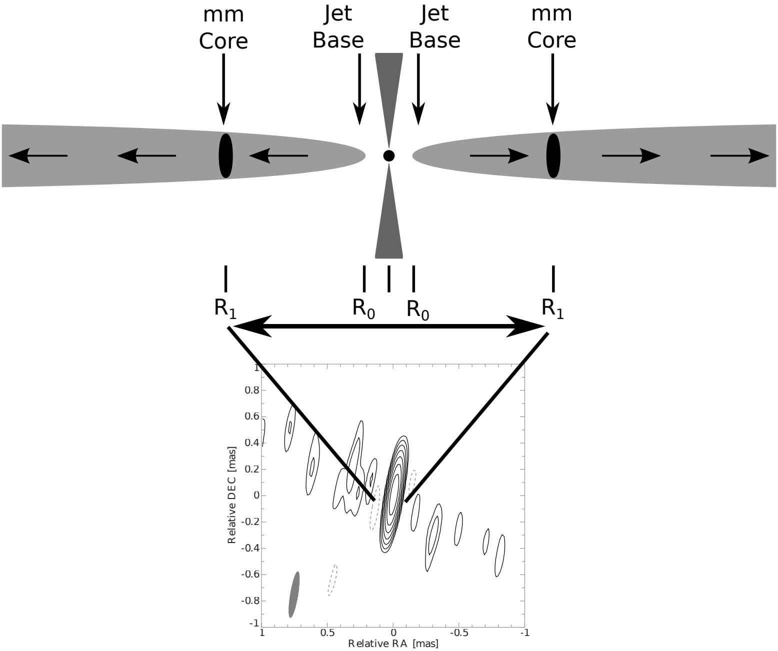


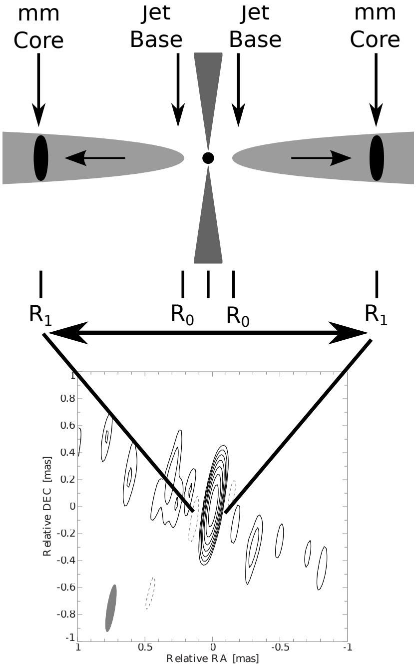
Mean jet velocities: $\beta_{\text{western}} = 0.36 \pm 0.03$, $\beta_{\text{eastern}} = 0.56 \pm 0.03$


NGC 1052
GMVA 86 GHz
2004-10-09
1.5
1
0.5
0
-0.5
-1
-1.5
Relative RA [mas]
3
2
1
0
-1
-2
-3
Relative RA [mas]


mm
Core
Jet
Base
Jet
Base
mm
Core
R1
R0
R0
R1

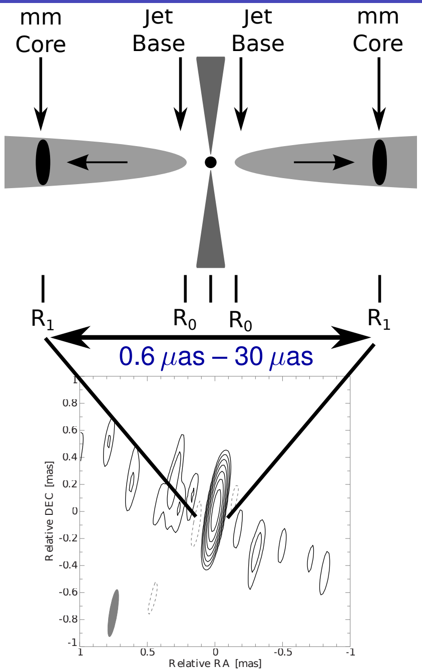

Relative DEC [mas]
Relative RA [mas]
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
1
0.5
0
-0.5
-1


mm
Core
Jet
Base
Jet
Base
mm
Core
R1
R0
R0
R1
Relative DEC [mas]
Relative RA [mas]
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
1
0.5
0
-0.5
-1



Core size estimate

- Modelfit unresolved



Core size estimate

- Modelfit unresolved
- $1/2$ th beam: 30 μas
- $1/5$ th beam: 12 μas
- Based on SNR: 8 μas Lobanov (2005)
- Smallest possible: 4 R_S = 0.6 μas

Magnetic field estimates (0.6 μas $< 2\,d <$ 30 μas)

Electrons loose energy while radiating: $\rightarrow$ synchrotron losses

$$\left(\frac{\mathrm{d}\gamma}{\mathrm{d}t}\right) = -\frac{4}{3}\sigma_T \frac{u_B}{m_e \cdot c}\,\gamma^2\beta^2\,, \tag{2.1}$$

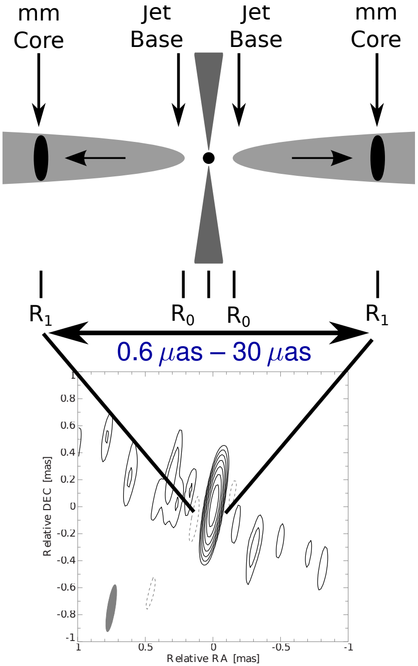
$\rightarrow$ Gives cooling time of electrons : $t_c = 5.4 \times 10^6 \times B^{-3/2}[\mathrm{G}^{-2/3}]\,s$

Magnetic field needed for observed synchrotron cooling

$$B_{\mathrm{sc},\,d} = \left(\frac{d[\mathrm{cm}]}{\beta\,[\mathrm{cm\,s^{-1}}] \times\ 5.4\ \times 10^6\ \mathrm{s}}\right)^{-2/3}\ \mathrm{G}, \tag{2.2}$$

Assuming $B \propto r^{-1}$ for $d > 2\,R_\mathrm{S}$ & $B \propto r^{-2}$ for $d < 2\,R_\mathrm{S}$

$$B_{\mathrm{Sc},\,1R_\mathrm{S}} \propto d^{1/3} \tag{2.3}$$

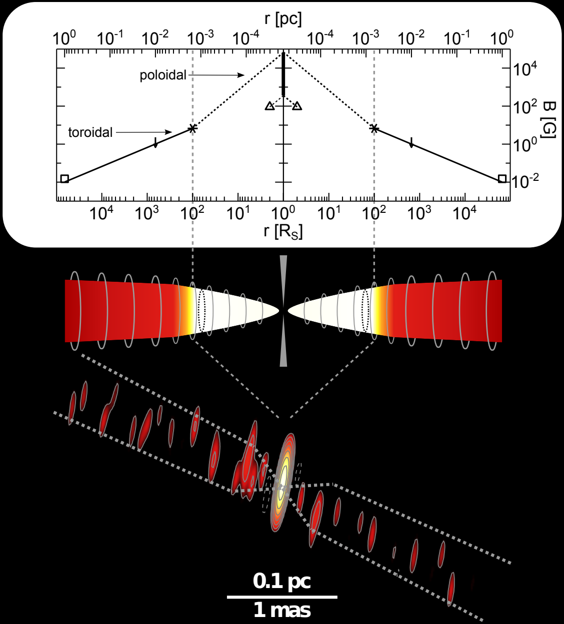


Core size $\rightarrow$ Magnetic field

- $1/2$ th beam: 30 μas
- $1/5$ th beam: 12 μas
- Based on SNR: 8 μas Lobanov (2005)
- Smallest possible: $4\,R_\mathrm{S}$ = 0.6 μas

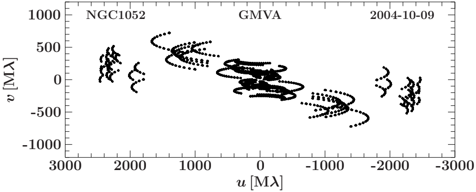
At $1\,R_\mathrm{S}$: $B_{\mathrm{Sc},\,1R_\mathrm{S}} \propto d^{1/3}$

$\Rightarrow$ $\mathbf{200\,G} < \boldsymbol{B_{\mathrm{Sc},\,1R_\mathrm{S}}} < \mathbf{8 \times 10^4\,G}$



Baczko et al. 2016 (A&A in press, ArXiv 1605.0700)

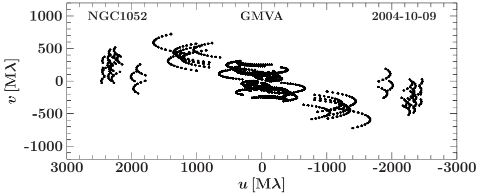
Outlook – including ALMA – including space VLBI



- Good resolution in E-W direction
- Adding baselines in N-S direction

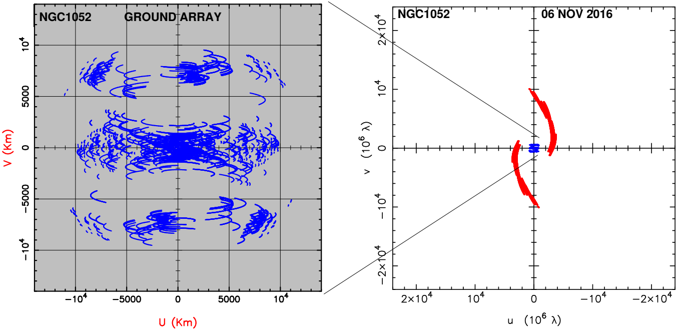
$\Rightarrow$ Better transversal resolution

Outlook – including ALMA – including space VLBI



- Good resolution in E-W direction
- Adding baselines in N-S direction

⇒ Better transversal resolution

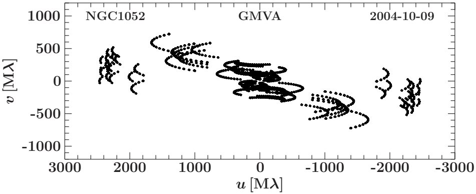


1.3 cm

EVN
VLBA
GBT
VLA
LBA

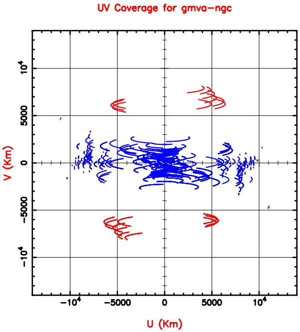
RadioAstron

Outlook – including ALMA – including space VLBI



- Good resolution in E-W direction
- Adding baselines in N-S direction

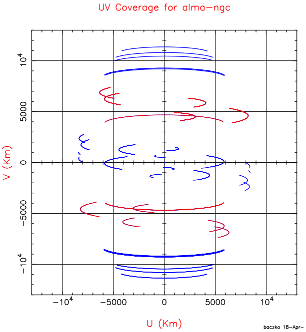
$\Rightarrow$ Better transversal resolution



3.6 mm

VLBA
EFLSBERG
PDFBURE
PICOVEL
ONSALA
METSAHOVI
YEBES
GBT

ALMA

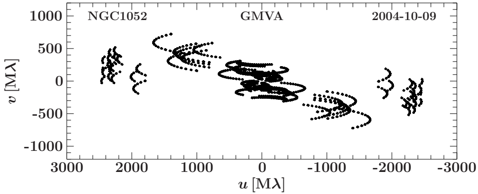


1.3 mm

APEX
JCMT
LMT
SMTO
PdBure
Pico Veleta
SMA
SPT

ALMA

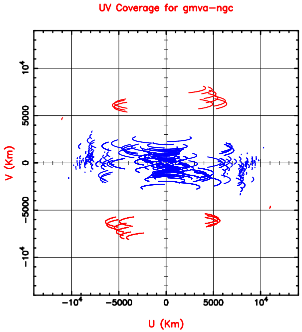
Outlook – including ALMA – including space VLBI



- Good resolution in E-W direction
- Adding baselines in N-S direction

⇒ Better transversal resolution

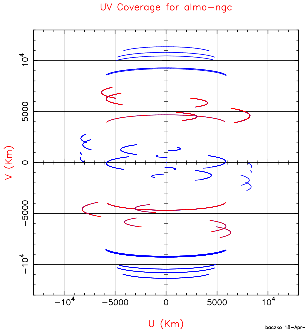
⇒ Test jet formation and collimation on scales of lightdays



3.6 mm

VLBA
EFLSBERG
PDFBURE
PICOVEL
ONSALA
METSAHOVI
YEBES
GBT

ALMA



1.3 mm

APEX
JCMT
LMT
SMTO
PdBure
Pico Veleta
SMA
SPT

ALMA