The innermost AGNs with future mm-VLBI

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mm-VLBI, astronomy at the highest resolution:

More than 40 years from their discovery, the AGNs continue being one of the most intriguing objects in the Universe. Still today, we have not a complete knowledge about the physics in the surroundings of their central super-massive black holes. The physics and dynamics of their relativistic jets, in particular the mechanisms through which they are formed, accelerated and collimated are still unknown (Meier et al. 2001). mm-VLBI offers the best tool to observe the innermost regions of the jets (Krichbaum 2003). At present, the most sensitive mm-VLBI instrument is the Global 3mm-VLBI Array (see Table 1 and http://www.mpifr-bonn.mpg.de/globalmm). The Global mm-VLBI array is able to achieve maximum baseline sensitivities of 38 mJy (adopting 20s coherence time, 100s segmentation time and a sampling rate of 512 Mbps [2bits]). This yields an image sensitivity of ~0.85 mJy (for 12h of observation and a duty cycle of 0.5). With these characteristics the number of sources which could be imaged with high dynamic ranges (≥500) is larger than ~100 (Lobanov et al. 2002).

Figure 1 represents some of our maps from recent 3mm-VLBI observations (work in progress). The images demonstrate the capability of the Global 3mm-VLBI Array to study the innermost jet structures with an angular resolution better than 50 μas. For better maps and larger number of sources, however, an increase in sensitivity is still needed. The most direct way to do it, is to increase the collecting area.

Table 1. List of the Global mm-VLBI Array antennas and their main characteristics.

Station	Country	Diameter(m)	Zen Tsys (K)	Gain (K/Jy)	App Eff (%)	SEFD (Jy)
Effelsberg	Germany	100	130	.137	8	952
Plateau de Bure	France	6x15	120	.180	65	667
Pico Veleta	Spain	30	120	.140	55	857
VLBA(8)	USA	25	120	.030	17	4000
Onsala	Sweden	20	250	.053	45	4717
Metsähovi	Finland	14	300	.017	30	17647

Table 2. List of possible future phased arrays and antennas, and their characteristics, suitable to participate in mm-VLBI.

Station	Country	Diameter(m)	Zen Tsys (K)	Gain (K/Jy)	App Eff (%)	SEFD (Jy)
ALMA	Chile	64x12	100	1.82	70	55
GBT	Va, USA	100	100	.996	35	100
LMT	Mexico	50	100	.285	40	351
CARMA	Ca, USA	6x10.4+10x6.1	100	.174	50	574
Yebes	Spain	40	150	.182	40	824
Nobeyama	Japan	45	150	.173	30	868
Noto	Italy	32	350	.044	15	8009

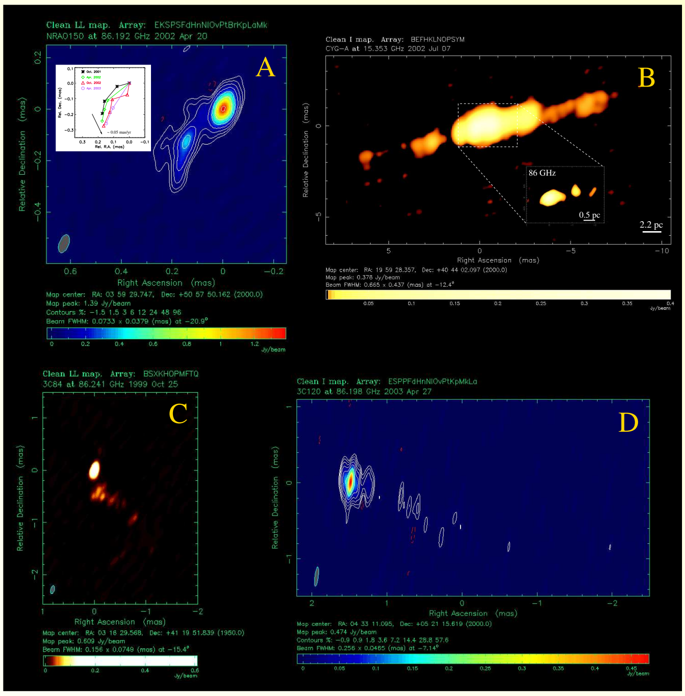

Figure 1.

A) Global 3mm-VLBI Array image of NRAO150. The analysis of our 3mm-VLBI monitoring of NRAO150 shows a clear change of the ejection direction within the innermost 0.2 mas of the jet (Agudo et al. 2004, in preparation).

B) The inset shows the first 3mm-VLBI image of Cygnus A compared to a 2cm map. At 3mm, the brightest component is still compact and its spectrum remains flat up to this wavelength. Further Global 3mm-VLBI Array observations should also show the origin of the counter-jet and a possible gap between the two jets (Bach et al. 2004, in preparation).

C) Global 3mm-VLBI Array image of 3C84. This array allows to study the acceleration of the jet fluid in the innermost region of this Seyfert Galaxy with a spatial resolution of ~2×10^3 R_S.

D) 3mm-VLBI image of the radio galaxy 3C120, which follows the jet towards its origin on linear scales of $\leq10^4$ R_S. Combination of this with observations in other spectral bands can provide an accurate estimate of the distance from the central black hole at which the jet becomes radio visible (Marscher et al. 2002).

Table 3. 7σ baseline sensitivities for future global mm-VLBI assuming 1 Gbit/s recording rate and 100 s segmented integration time.

[mJy]	Plateau de Bure	Pico Veleta	VLBA	Onsala	Metsähovi	ALMA	GBT	LMT	CARMA	Yebes	Nobeyama	Noto
Effelsberg	28	31	68	74	142	8	11	20	26	31	32	96
Plateau de Bure		27	57	62	121	7	9	17	22	26	27	81
Pico Veleta			65	71	137	8	10	19	25	30	30	92
VLBA				153	295	16	22	42	53	64	66	199
Onsala					321	18	24	45	58	69	71	216
Metsähovi						35	47	87	112	134	138	418
ALMA							3	5	6	7	8	23
GBT								7	8	10	10	31
LMT									16	19	19	59
CARMA										24	25	75
Yebes											30	90
Nobeyama												93

The future of mm-VLBI: higher sensitivity and image fidelity:

Table 2 summarizes some of the most sensitive antennas suitable to participate in mm-VLBI in the near future. This future array can achieve baseline sensitivities of up to 3 mJy (an improvement by a factor of 13!), see Table 3, and image sensitivities better than 0.07 mJy (also an increase by a factor of 13!). In addition, continuous development of VLBI will provide standard recording rates of at least 2 Gbps (Garret 2003). This will increase the sensitivity by an extra factor ≥ √2.

But the possible future array, will not only increase the sensitivity. New stations will also largely improve the UV-coverage. The addition of ALMA will not only largely improve the sensitivity, but also the UV-coverage for sources with low declination (less than 20°). ALMA will also facilitate the VLBI imaging of the Galactic Center source SgrA*.

If the proposed improvements are performed, dynamic ranges of several thousands could be easily obtained. This will place mm-VLBI at a similar level of sensitivity than present day cm-VLBI.

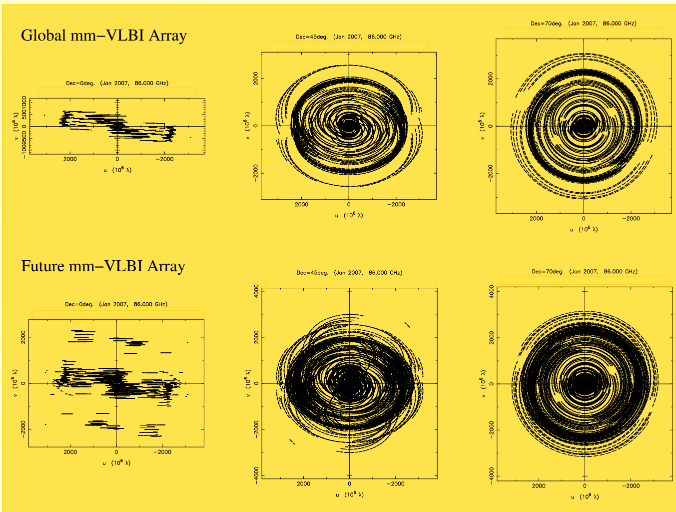

Figure 2. Simulation of the present UV coverages of the Global 3mm-VLBI Array (top) and those for the proposed future mm-array (bottom) for source declinations of 0°, 45° and 70° (from left to right).

Scientific goals:

The proposed improvements would have an enormous impact on our knowledge of the physics of jets in AGNs and hence of their central engines. It will be possible to obtain high quality images of the innermost regions in the jets. This will facilitate to:

- Investigate the MHD physics close to strong gravitational fields
- Study the relativistic jets formation, initial acceleration and collimation
- Probe their initial magnetic field configurations (via polarimetry)
- Infer the properties of their super-massive black holes and its immediate vicinity

... for several hundreds or even thousands of compact sources

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