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Netherlands Institute for Radio Astronomy

E-MERLIN and the European VLBI Network some remarks

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The European VLBI Network is a joint facility of independent European, African, Asian, and North American radio astronomy institutes.

The European VLBI Network (EVN)

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20+ possible antennas Involving the Big Dishes in Europe

Ef, Mc, On, Jb, Nt, Tr, Wb, Sh, Ur, Hh, Ar,

Mh, Ys, Sv, Ro, Ku, My, Wz, Sm, Ny, Ka

Ran by 14 different organizations

Covering range of frequencies

Workhorse wavebands 18cm, 6cm. Also available: 90, 5, 3.6, 1.3, 0.7 cm

Reaching mas resolutions

From 15mas for 1.4 GHz EVN

To 1 mas at 5GHz (with Asian, African or American baselines)

Collaboration provides even longer baselines: NRAO, LBA, RadioAstron

Sensitivity of 5μJy in 8hr at 1.4 GHz

Combination of Big Antennas and 1 Gbps bandwidth

Big antennas also vital for spectroscopy

User cases for combined e-MERLIN and EVN observations

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- High fidelity imaging of complex sources: superb resolution as well as surface brightness sensitivity for extended structures
  - Probing regions of different brightness temperatures in complex sources
  - Accurately imaging structure on a range of angular scales is key in understanding the relationship between star formation and AGN activity
  - Studying the relation between compact and diffuse (mega)Maser components
- Pinpointing and tracking variable components in dynamically changing, complex radio sources requires simultaneous observing

e-MERLIN improvement to EVN only

(example plot 12 hrs; DEC+45; C-band)

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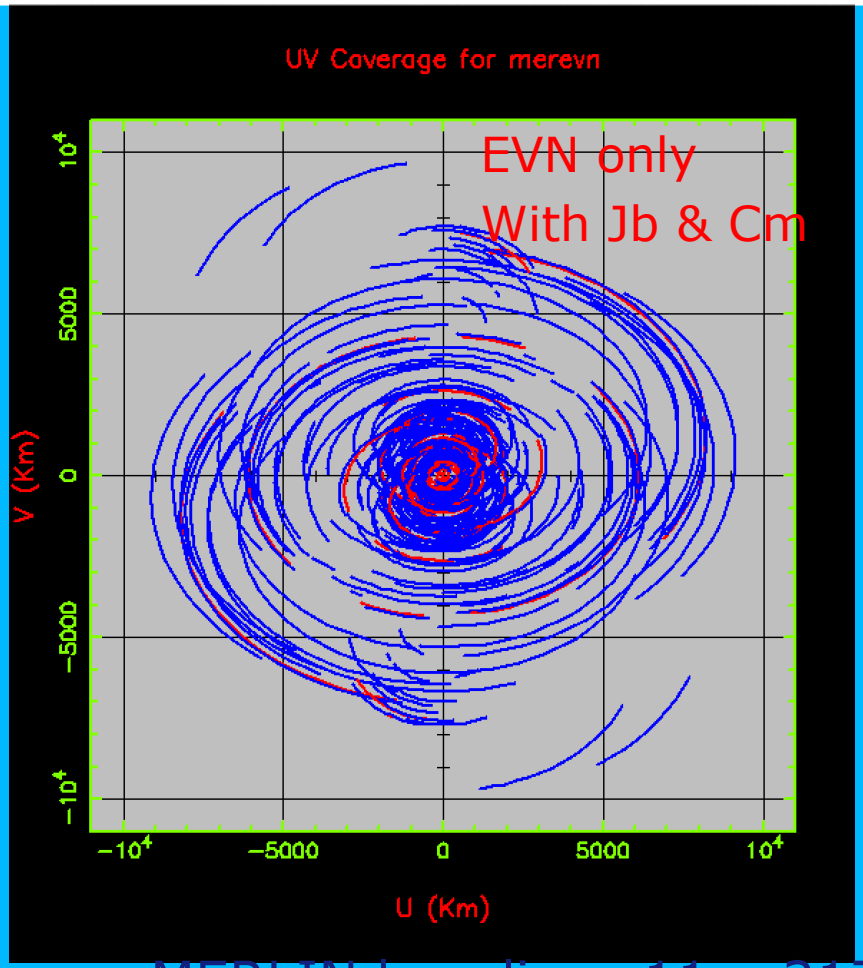

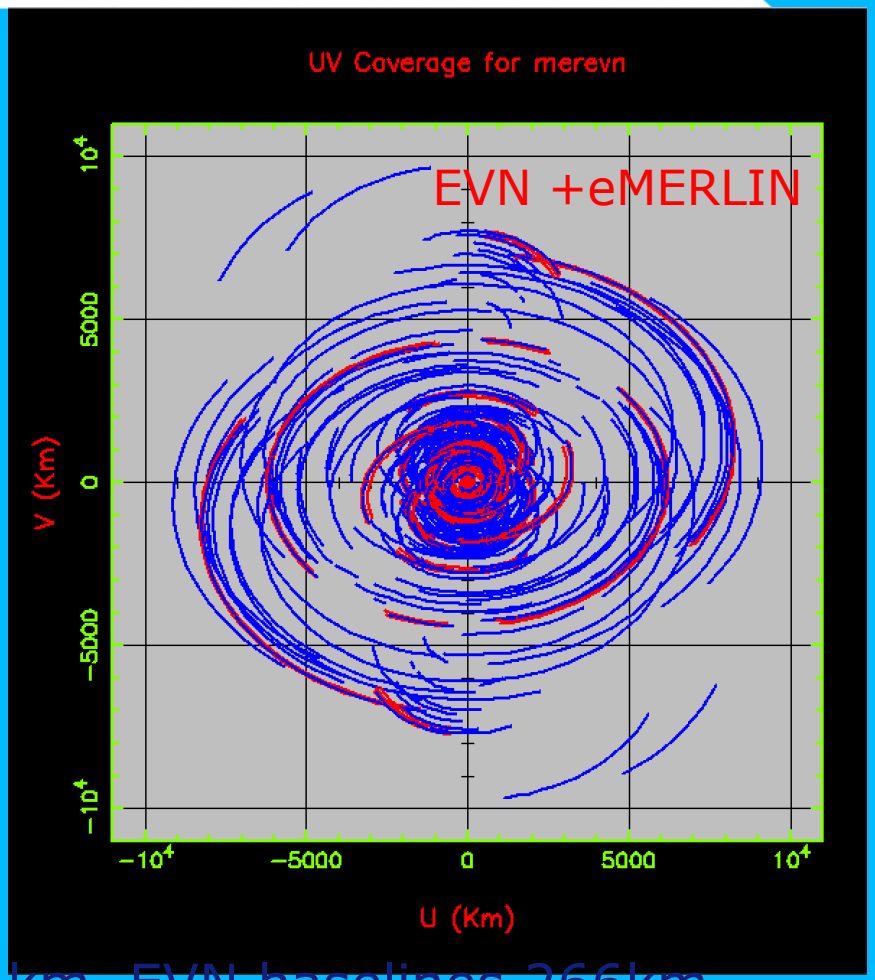

- e-MERLIN baselines 11 – 217 km, EVN baselines 266km - ~10000 km
- Sensitivity improvement ~20 %

e-MERLIN improvement to EVN only

(example plot 12 hrs; DEC+45; C-band, inner 2000km)

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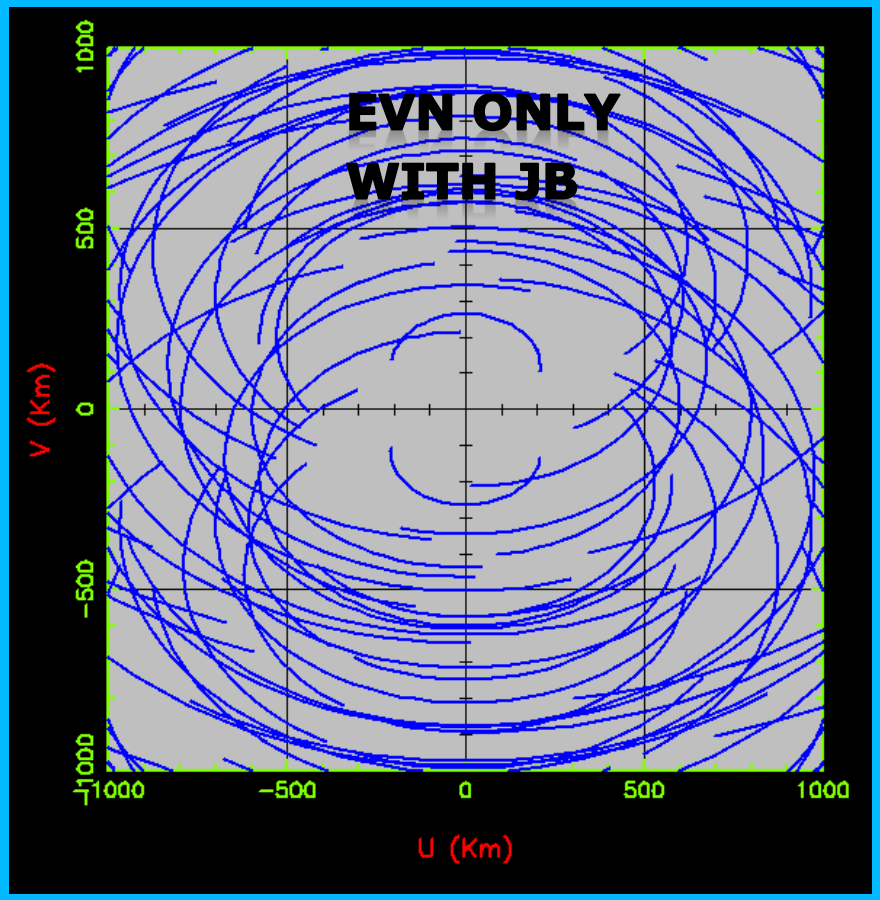

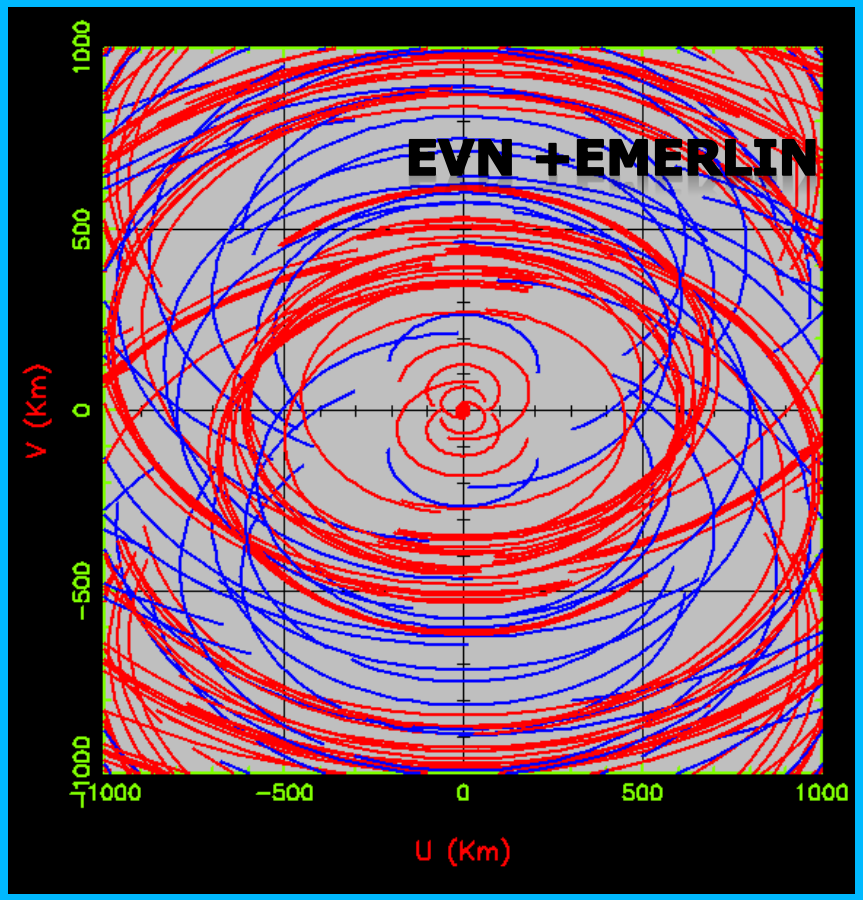

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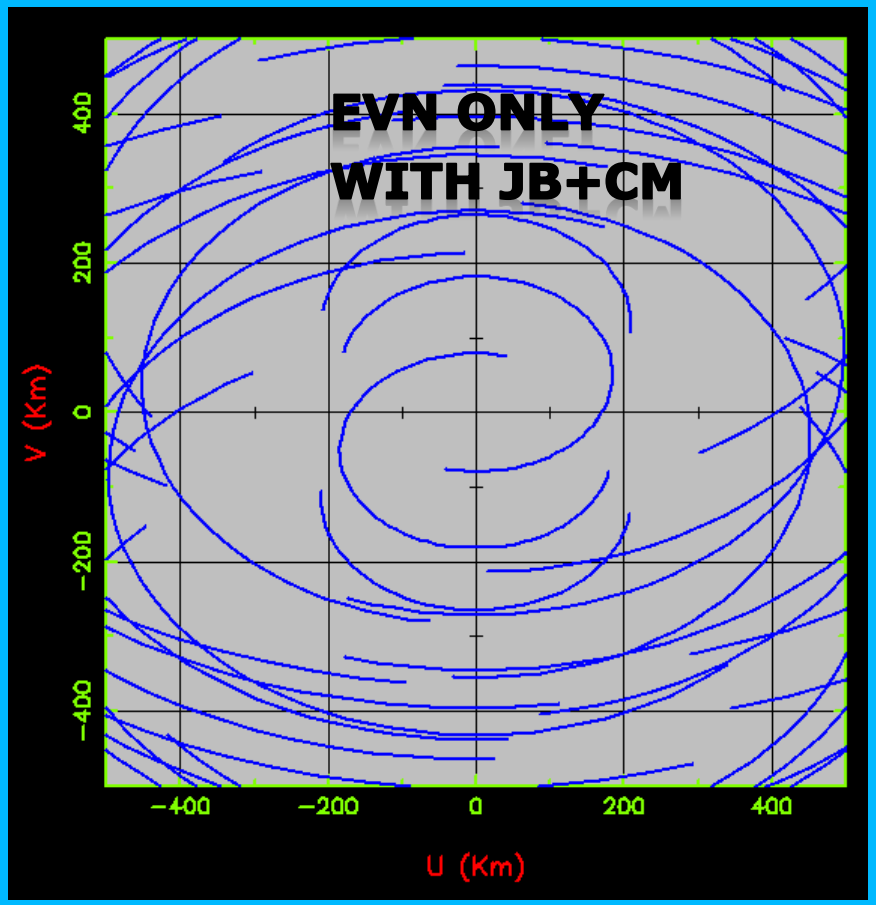

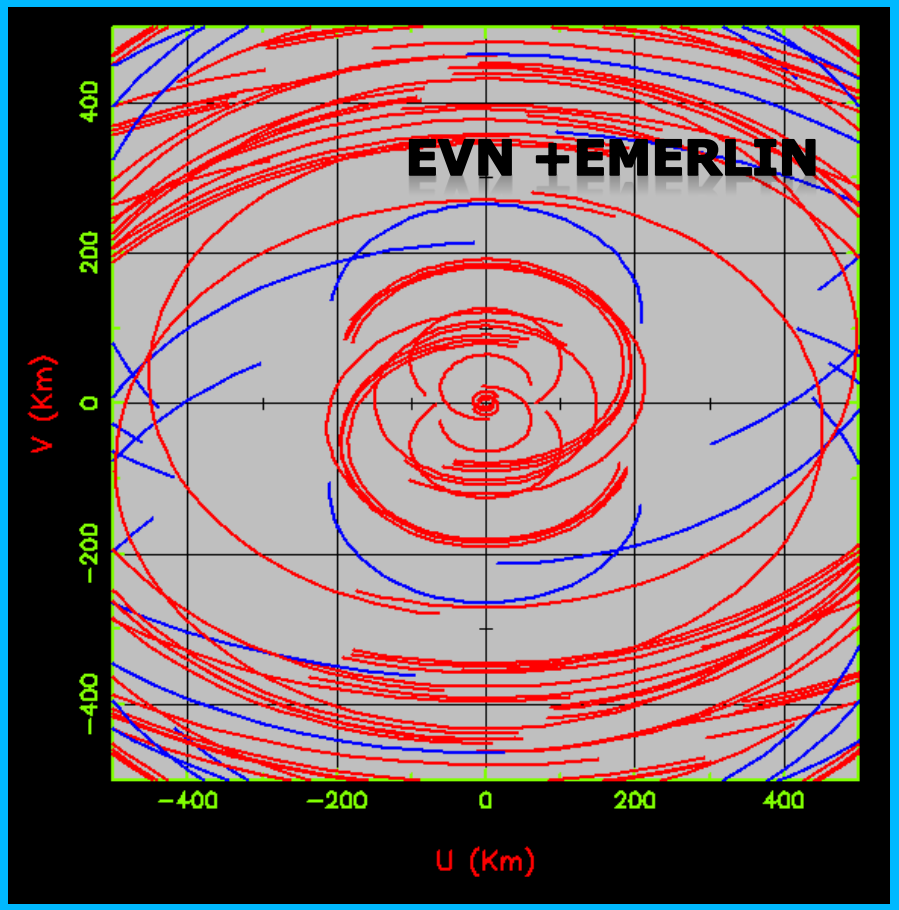

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(e-)MERLIN & EVN Synergy

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Since their start, combining the arrays has appealed to scientists

- In late-80s & early-90s up to 4 outstations recorded & correlated at VLBI correlators (Mark 2, 2MHz BW, 1 pol).
- 90s and 00s, a home station and Cm correlated in the EVN and simultaneous MERLIN observations correlated at JBO.

  Datasets calibrated separately, concatenated & imaged later.
- Early e-MERLIN era: Jb1/Jb2 and/or Cm correlated in the EVN; contemporaneous e-MERLIN observations.

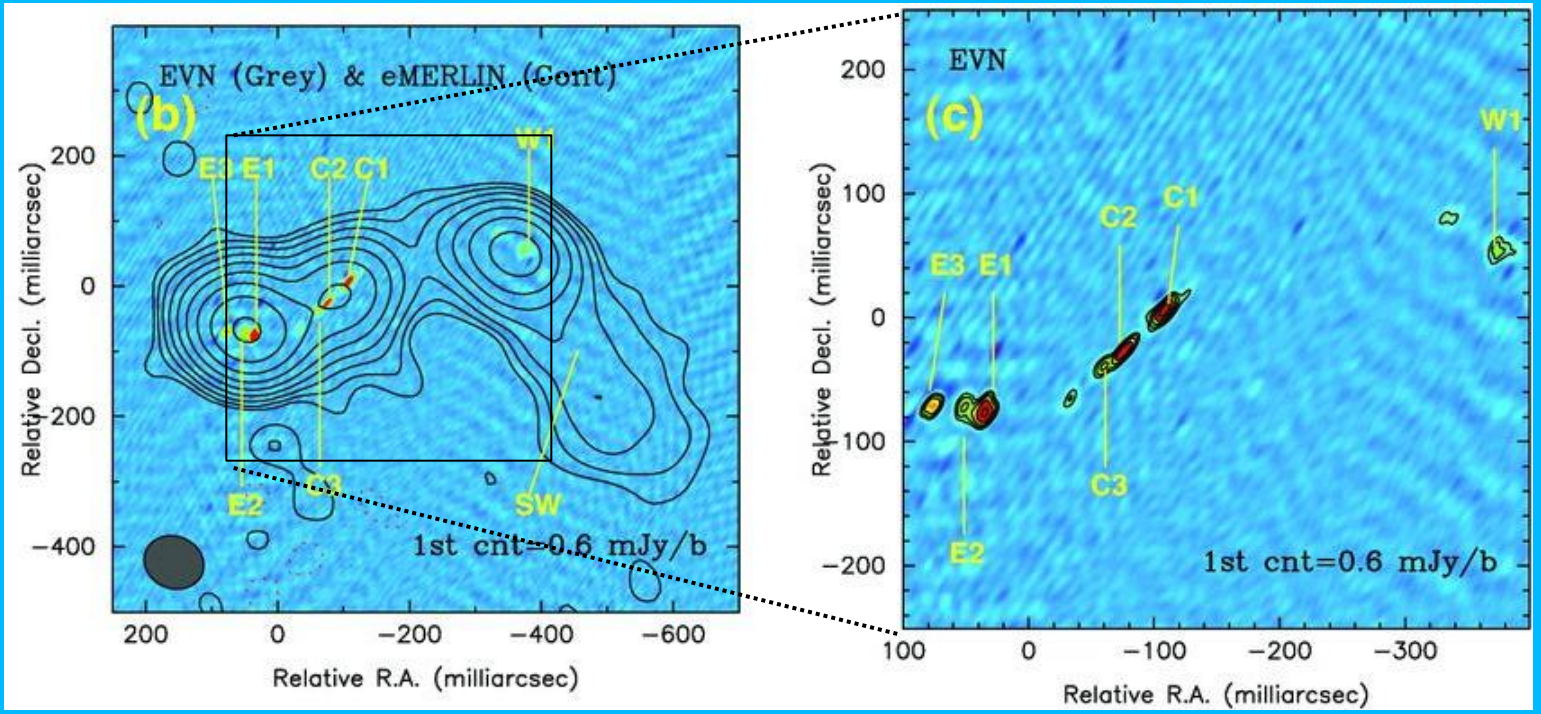
Concatenation and imaging not straight-forward

Needs good calibration and carefully chosen weighting schemes

However, impressive scientific results achieved.

The central region of 3C216 at 5GHz

T. An et al. MNRAS 2013;433:1161-1171



5GHz Quasi simultaneous observations (3 weeks difference)

Left: the e-MERLIN image (thick contours) overlaid on EVN (colour) image

Right: The EVN image

The nuclear and circumnuclear regions of LIRG IC883

C. Romero-Cañizales et al 2012, A&A, 543, A72

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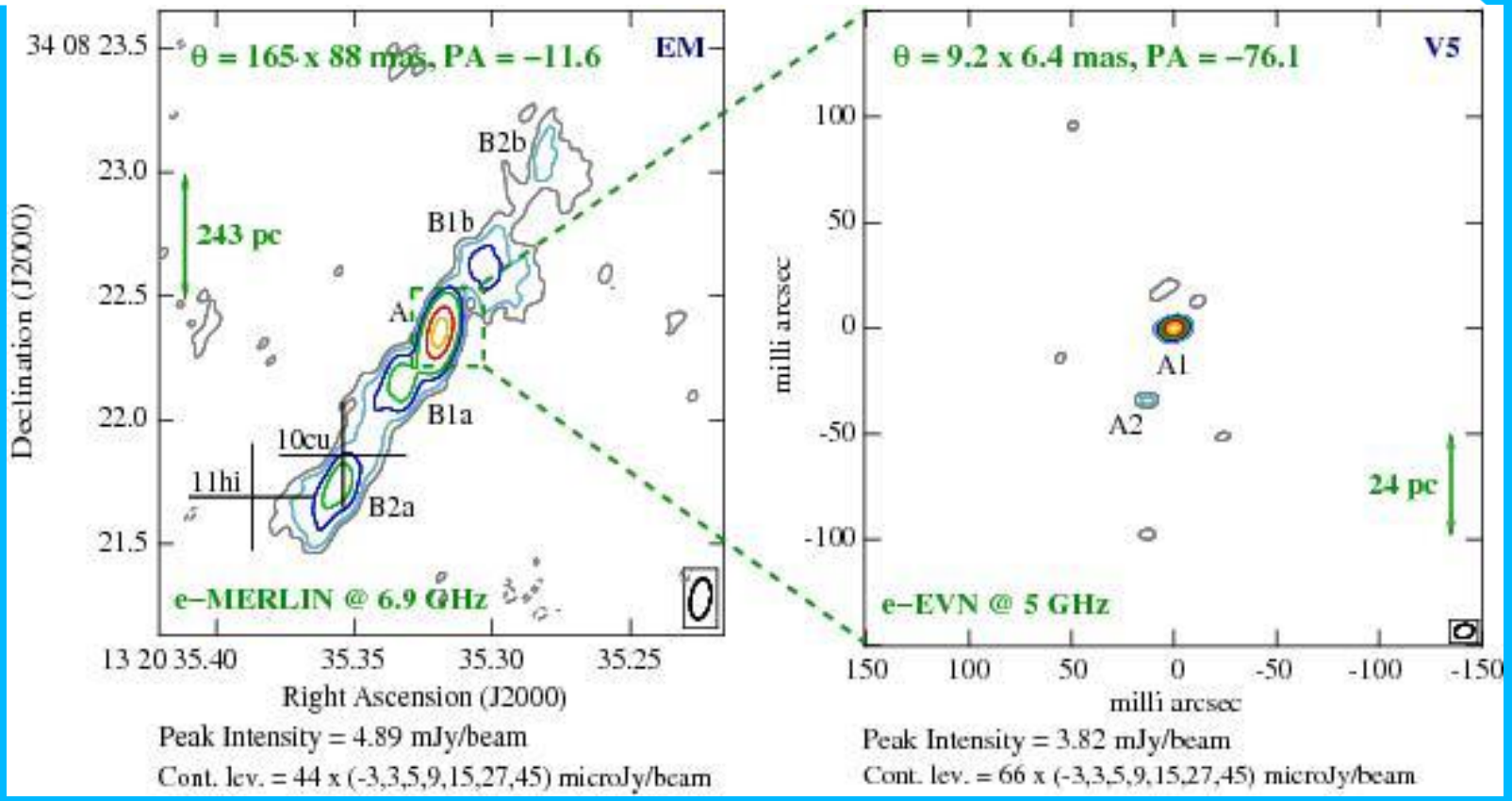

e-MERLIN observations: a striking double-sided structure, likely a warped disc/ring.

EVN observations:4 non-thermal components:

- 3 are transient sources
- A1, is a long-lived, variable compact source, likely an AGN.

J123642+621331 – GOODS-N (e-MERGE legacy)

Radcliffe et al, 2015, PoS *EXTRA-RADSUR2015, 24*

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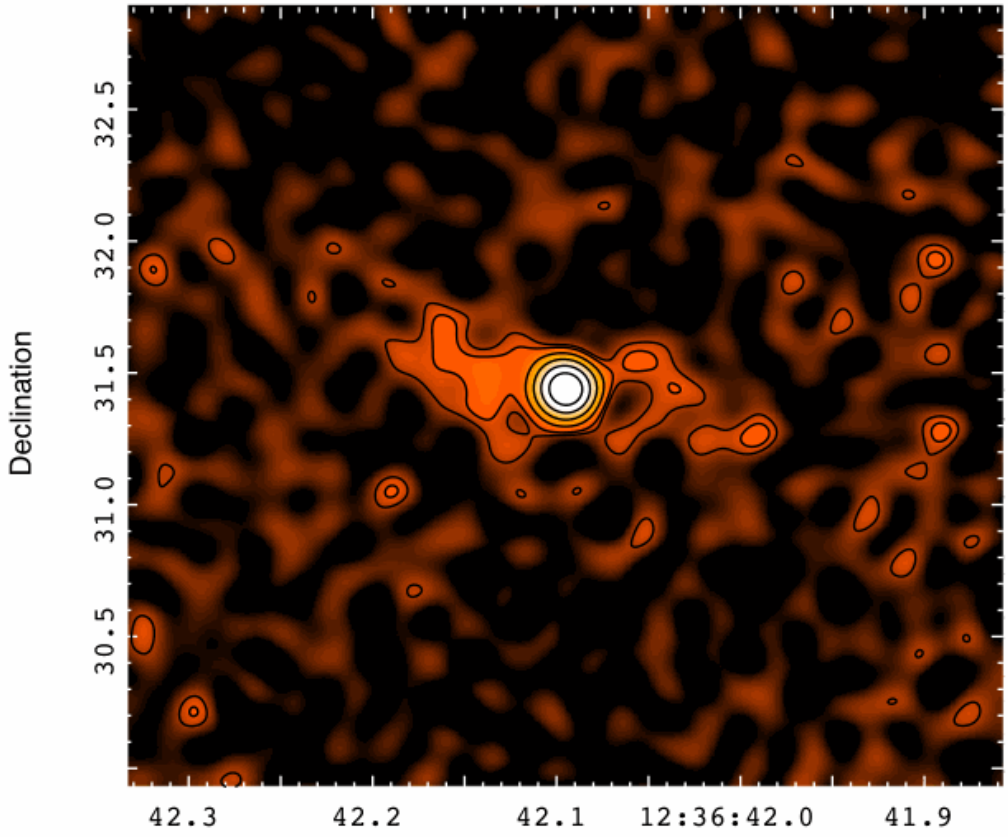
it A: SF+AGN - J123642+621331



J123642+621331: high-z (4.4) AGN/starburst composite source
e-MERLIN (150mas) to EVN resolution scales (10mas).

III Zw 35: Starburst continuum and OH megamasers

Pihlstroem et al, 2001, A&A, 377, 413

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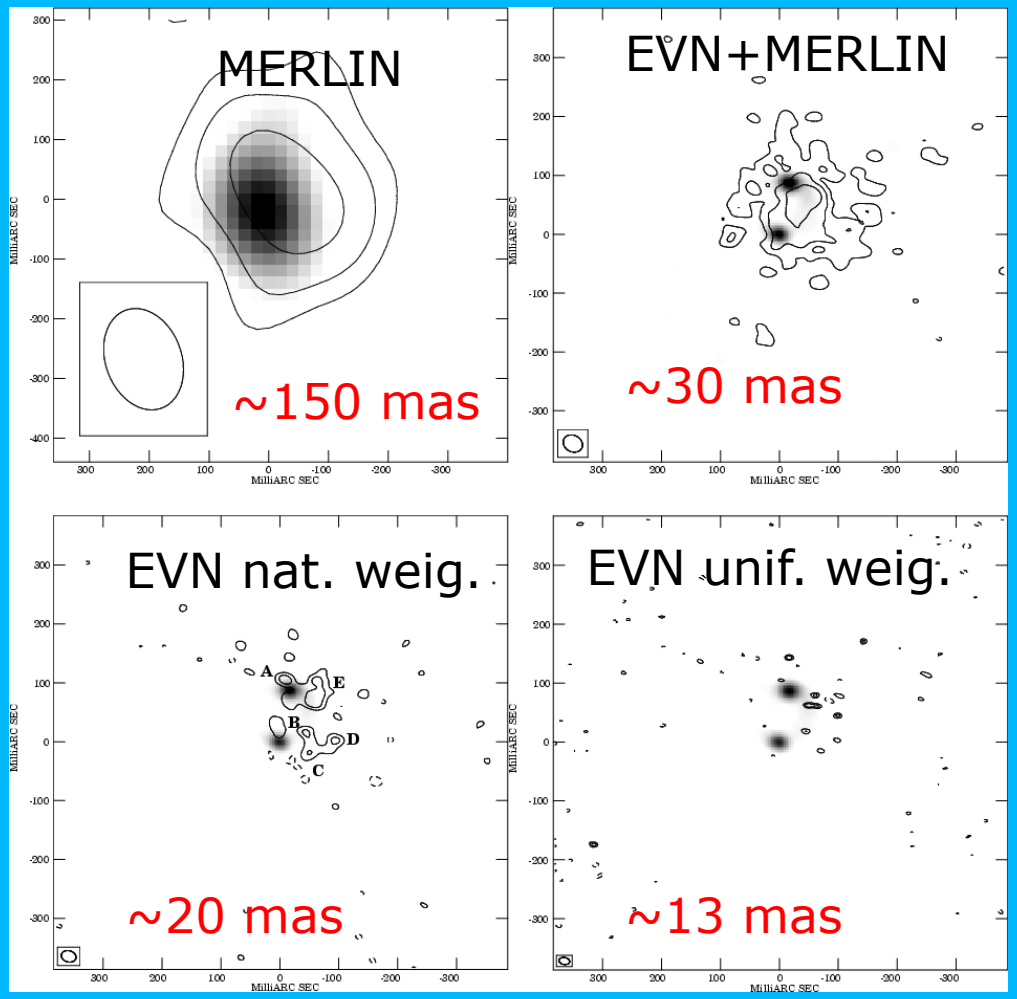

"Classical" MERLIN + EVN

Continuum = Contours

Grey = OH masers

- Continuum is starburst, with both diffuse and compact components.
- OH maser emission in a thick rotating disk.

MERLIN baselines allowed to constrain the geometry of the diffuse maser emission, resolved out in the long EVN baselines.

Combined global VLBI + MERLIN imaging of M82
Fenech et al 2010, MNRAS 408, 607 & on-going programme

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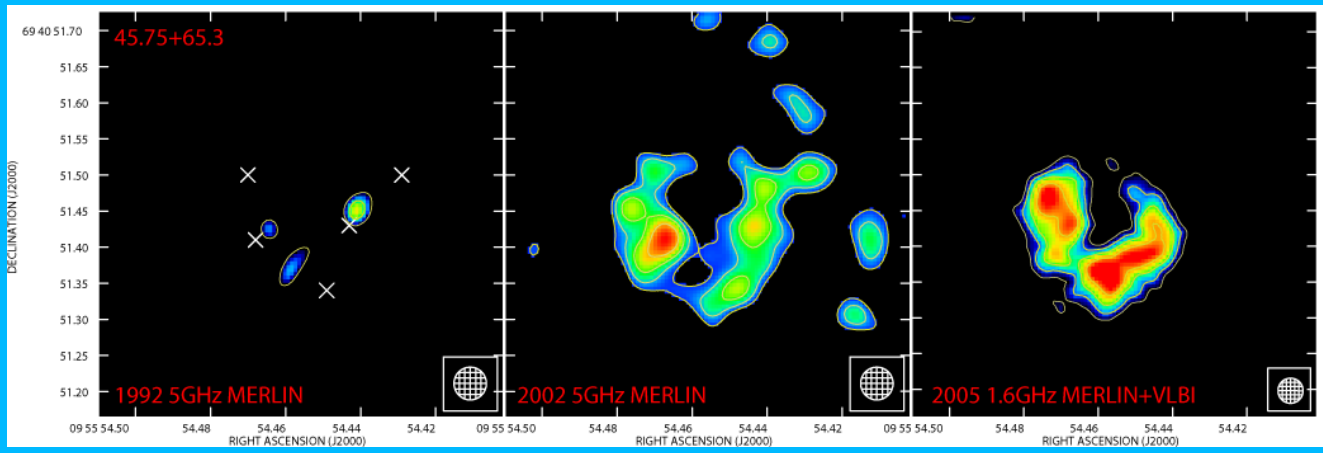
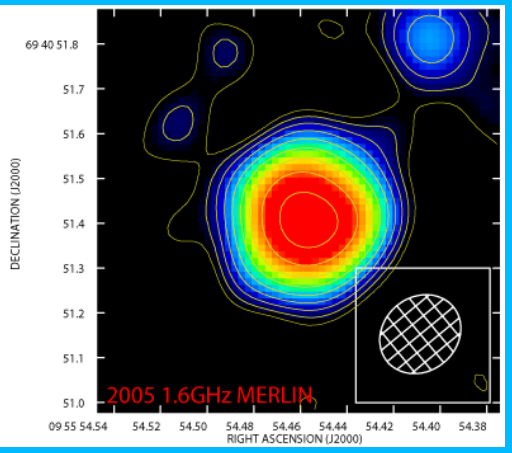
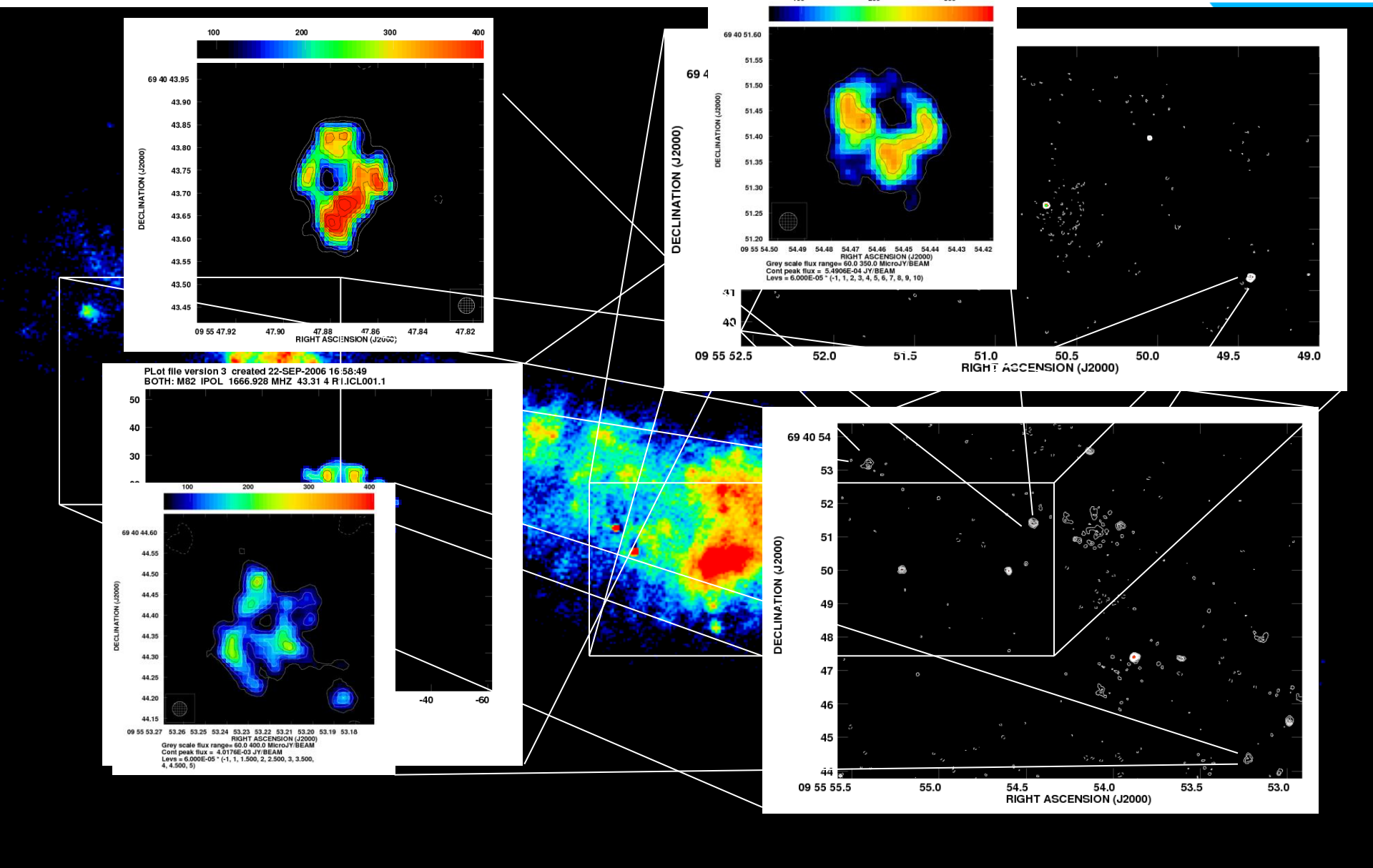
- Simultaneous observations of M82 using MERLIN and VLBI. Successfully combined two datasets - produced images with resolutions from ~5-100 mas
- Now have repeated simultaneous observations at L-band and C-band Some calibrator issues…





Combined VLBI + MERLIN imaging of M82



(e-)MERLIN & EVN Synergy now and the future

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In the current decade typically 10-20% of EVN proposals have stipulated that combining with e-MERLIN was required for the science

The combination of resolution and surface brightness sensitivity, with

- Modern-day (>1 Gbps and better) bandwidths
- High quality, routine calibration
- "Instant" response through e-VLBI techniques

gives e-MERLIN + EVN unrivalled, cutting-edge capabilities well into the future

Let's make it happen!

(e-)MERLIN & EVN Synergy now and the future

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Since 2016 e-MERLIN outstations can be correlated at JIVE

Current capacity: max of 1 Gbps distributed over outstations.

Expressed aim is to achieve seamless integration of all e-MERLIN stations into EVN observing at multiple Gbps.

- JIVE correlator capable of mixed data-rate mode
- 1Gbps (soon 2Gbps) standard for EVN, working towards 4Gbps at appropriate frequency ranges

Discussion

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e-MERLIN with long baselines

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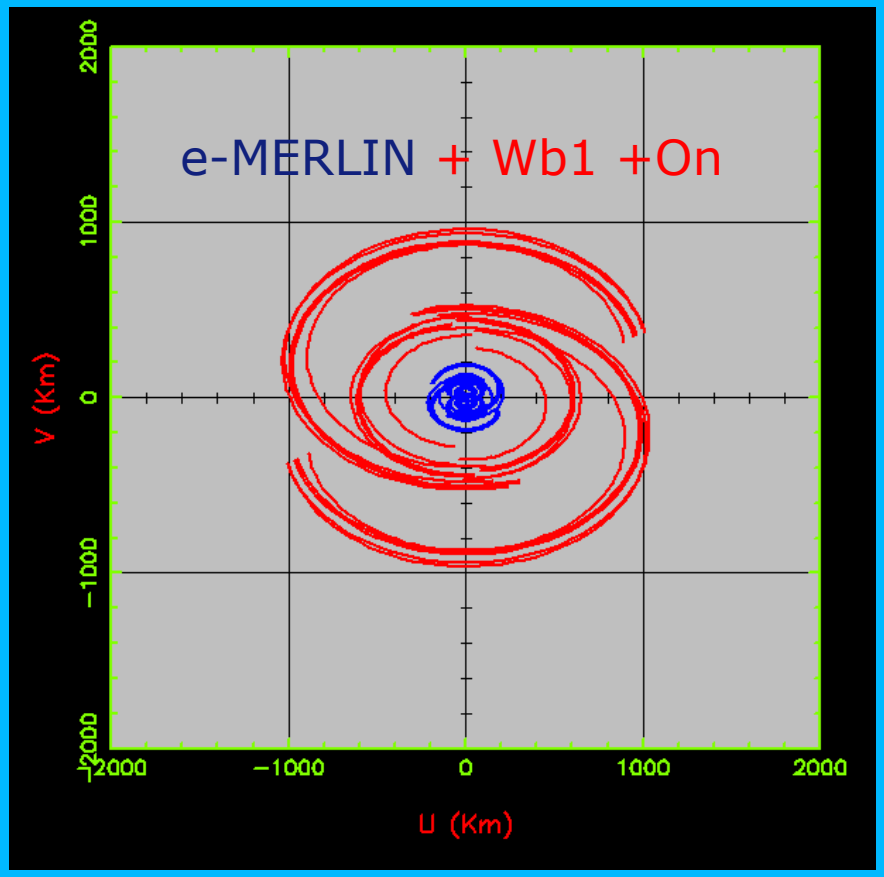
- Further possibilities to explore is to add WSRT and Onsala to e-MERLIN.

- **Wb** baselines: 454km-648km

Resolution ~20 mas (C-band)

- **On** baselines: 601km-1076km

Resolution ~11 mas (C-band)



Discussion

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(e)MERLIN a considerable addition to EVN capabilities

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- Proposal Statistics background

Semester	Ask M	All	EVN	eMERLIN	eVLBI	Global	% MER of All	%MER of EVN
16B		11		0				
16A		26	20	6	3	7	23	30
15C		19	18	1	4	1	5	6
15B		16	12	1	6	4	6	8
15A		18	13	0	1	5	-	-
14C		10	9	1	4	1	10	11
14B		19	11	2	1	8	11	18
14A		28	21	4	3	4	14	19
13C		19	15	1	3	4	5	7
13B		19	16	3	2	3	16	19
13A		31	23	2	5	8	6	9
12C		22	16	2	2	4	9	13
12B		24	20	2		4	8	10
12A		25	23	4	7	2	16	17
11C		22	20	1	2	0	5	5
11B		28	21	2	6	1	7	10
11A		26	19	3	5	7	12	16