The University of Manchester
Jodrell Bank Observatory

4th International VLBI Workshop
eMERLIN (+ VLBI)
Current Status & News

23 November 2015

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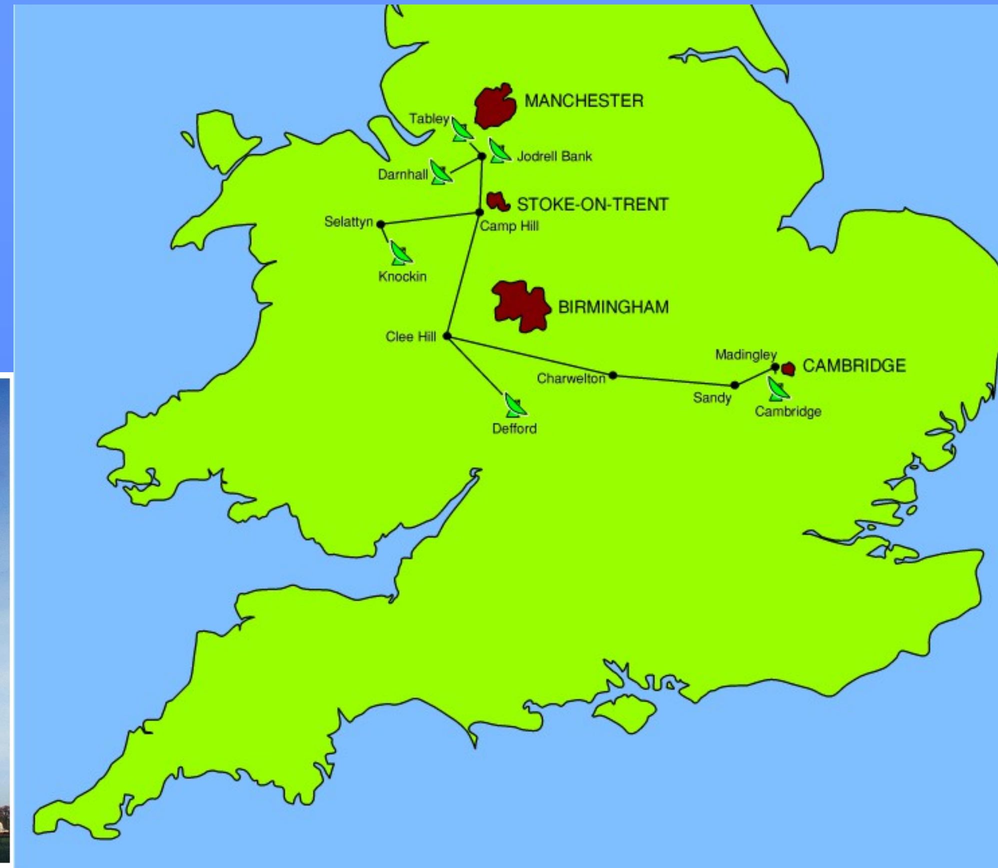
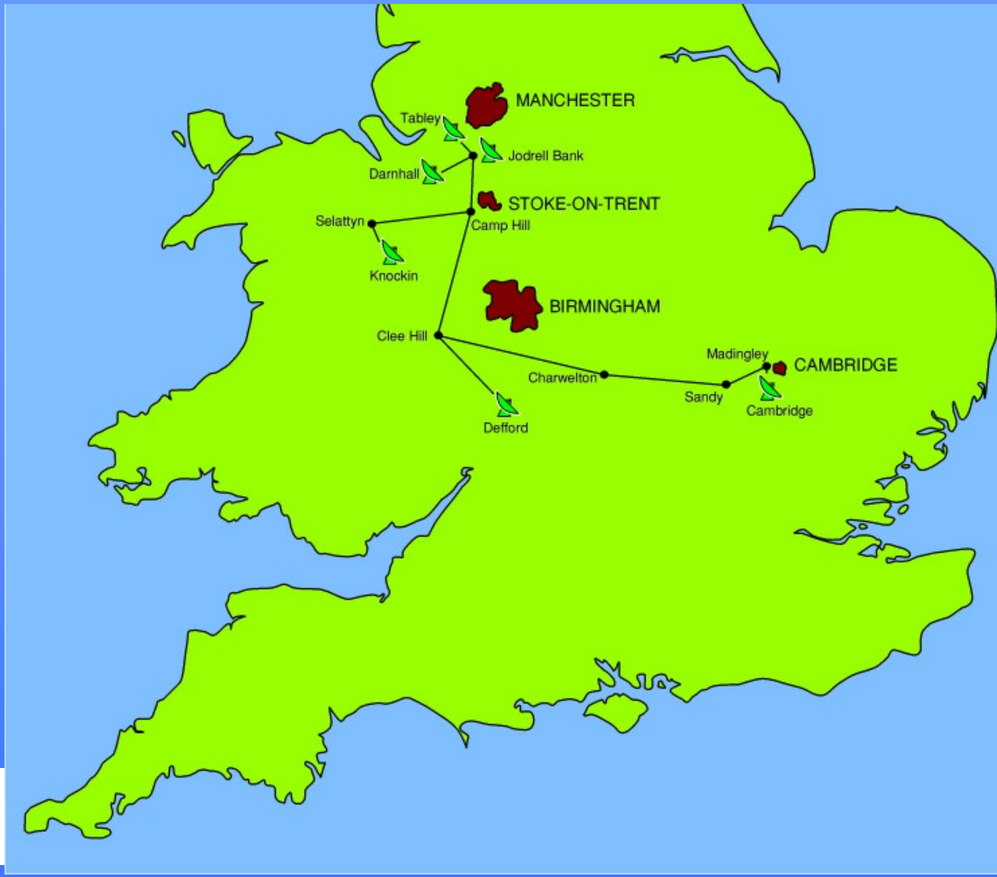
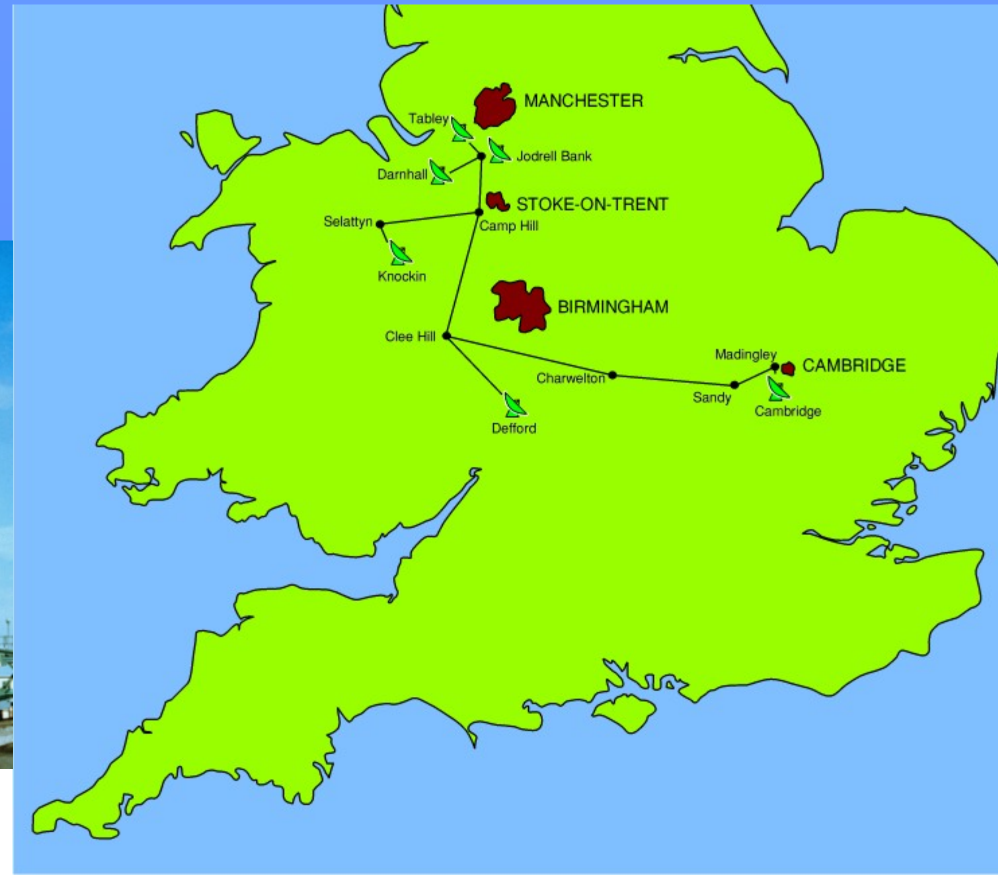
e-MERLIN





Improve Sensitivity with:.



Improve Sensitivity with:

- Improve Tel. Gains – Improve Lovell & Defford surfaces & **tracking**.

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e-MERLIN

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Current sensitivity ~0.5 desired maximum at C-Band

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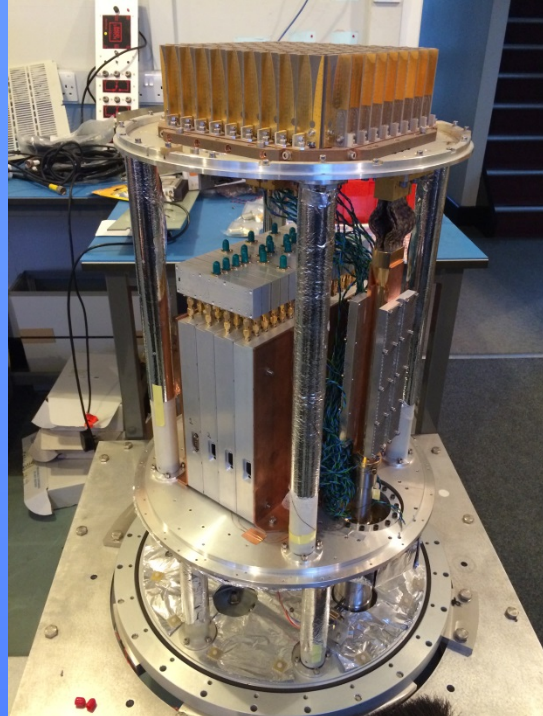
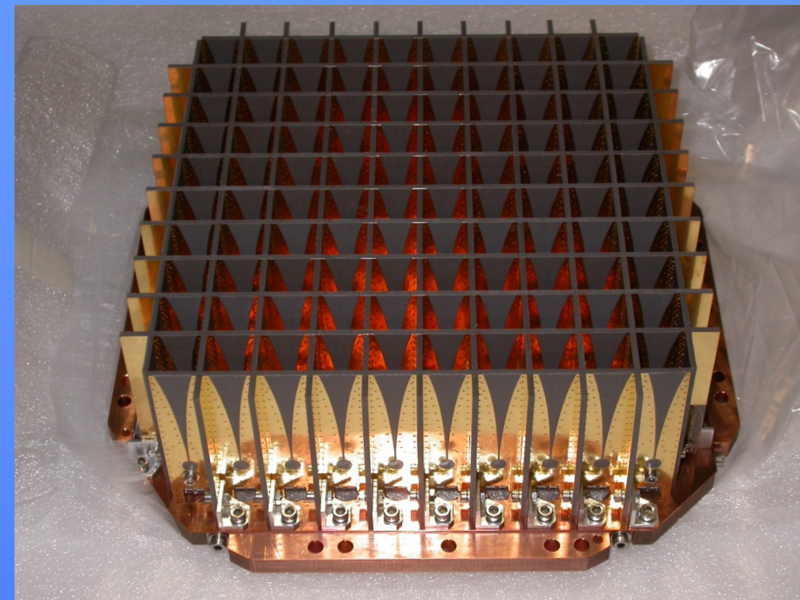
eMERLIN





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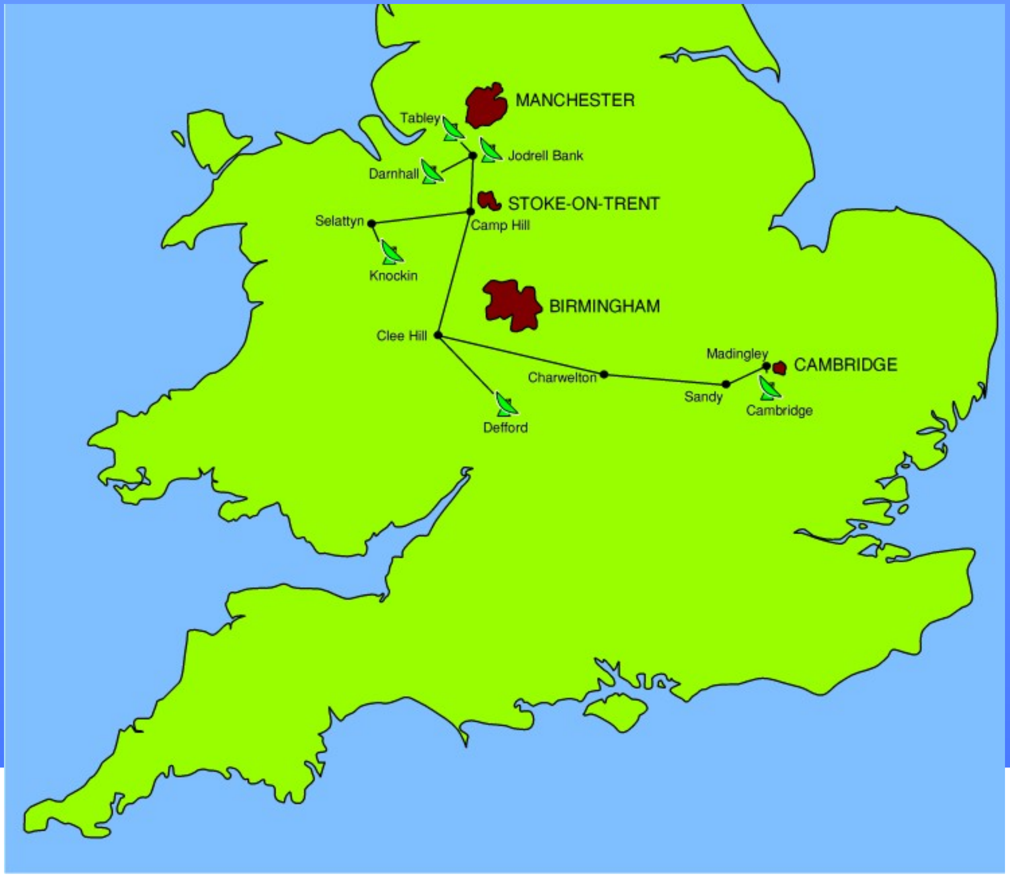
eMERLIN



Improve Sensitivity with:

- Improve Tel. Gains – Improve Lovell & Defford surfaces **& tracking**
- Improved System Noise Temperatures. (Some possibility).

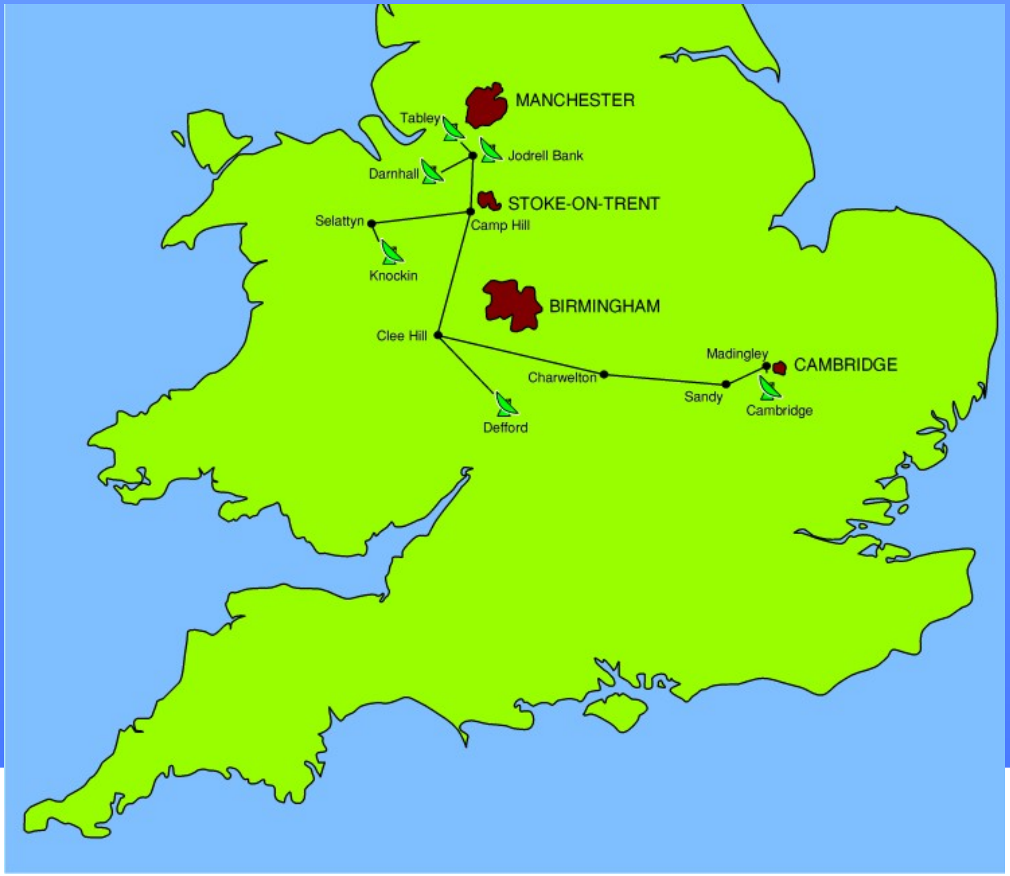
Receivers:	L-Band	C-Band	K-Band
Freq. Range (GHz)	1.25 – 1.75	4.0 – 8.0 (7.5)	20.0 – 25.0
T (Rx)	30K (10K)	40K (<40K)	35 – 40 K
Tamp	4K	4K	?

L-Band – New cryogenic filters to stop cross-mod. with 1.8 GHz

C-Band – Amp. Gains & Phases matched so that hybrid can come after LNAs.

Result: Lower noise & gains and phases flat across bands.

K-Band – Not fully tested yet, but previous system noise was ~130K



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- Increase Bandwidths (16 MHz per pol. - Definitely).

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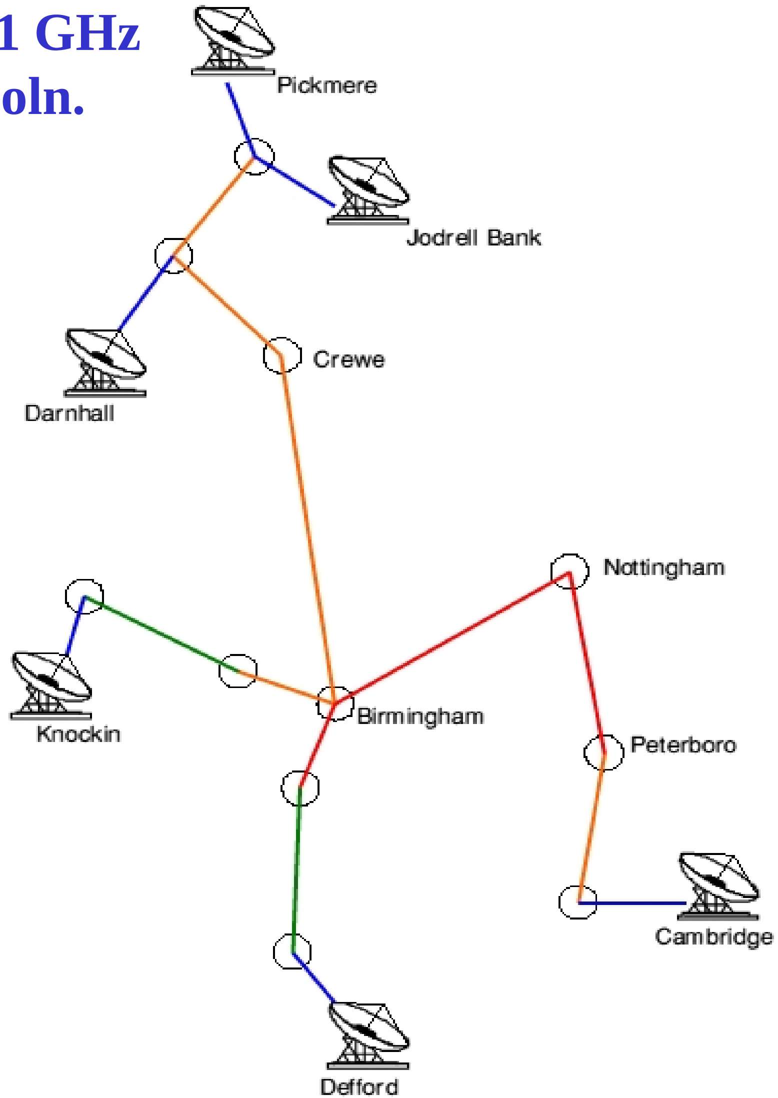
a) **2 GHz bandwidth = 4GHz sampling with 3 bits / poln.**

b) **500 MHz bandwidth – 1 GHz sampling with 8 bits / poln.**

Data Transmission Network Solution

Fujitsu (FTEL,UK) installed & tested 90km new fibre alongside minor roads to connect to…



Dark fibre trunks provided mainly by Global Crossing (UK) - ~600 km

Maintenance contract for entire network

Amplifiers/Regeneration at Peterborough, Nottingham, Birmingham, Crewe, designed and installed by JBO

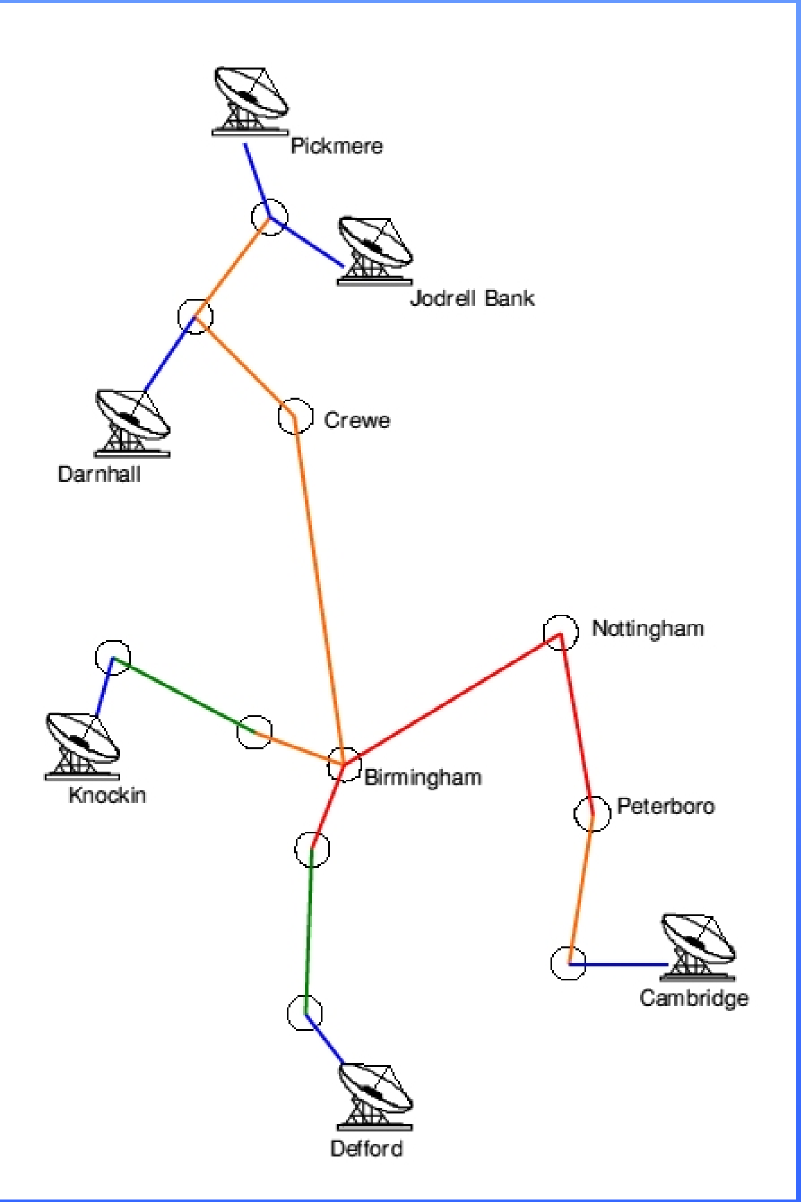
Require 30 Gb/s from each telescope to correlator at Jodrell Bank (2 GHz/pol @ 3bits = 24G)

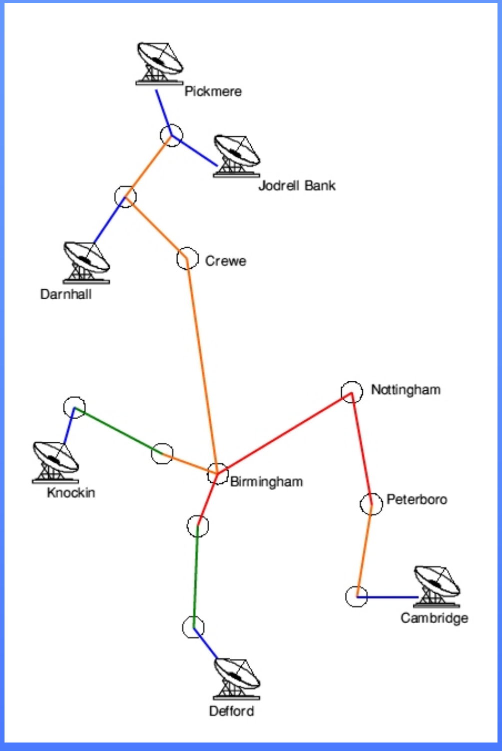
Own dark fibre - e-MERLIN uses 3 x 10.0G

L-Band link system initially continued ‘through the air’

The L-Band link system is now fully operational along the fibre network, including the single fibre leg from Peterboro to Nottingham.

Much greater path length variations along fibres than through the air.





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- Increase Bandwidths (16 MHz per pol. - Definitely)
- Include all MERLIN telescopes in EVN & other VLBI observations.

Ability to record data for e-MERLIN + (e-)VLBI lost except for Jodrell Lovell & Mk2 telescopes !!
Digital sampled data (from telescope focus boxes) goes along fibres directly into the WIDAR correlator.

Initial idea: Use VSI chip on WIDAR correlator station-board to tap off signal directly. IBOB project, which required FPGA programming. Person working on it left. Idea dropped.

Work-around: Can use 'phased array' functionality of the baseline boards to effectively phase-up a single telescope to retrieve the baseband data for that telescope as a VDIF stream. (32 byte header & 8000 byte payload.)

First fringe: Obtained ~3 years ago when correlated at JIVE from tests after switching off delay models in the WIDAR correlator.

Success ! Sadly NO !!! Could not switch off phase rotation and (unluckily) observations made close to zero fringe rate.

Took > 18 months to obtain firmware from NRAO which enabled us to switch off the fringe rotation.

Now found fringes internally between e-MERLIN telescopes, but still could not find fringes to external VLBI telescopes.

In the meantime, major software job by Paul Harrison to enable us to configure the correlator using scripts rather than manually setting the configuration board by board with a GUI (easy to make mistakes).

Became clear that the delay between the ‘phased’ VDIF through the WIDAR correlator and the standard VLBI route was greater than a few hundred nanoseconds.

Also note that during this lengthy period of time trying to obtain fringes, we had obtained copies of the DiFX & SFXC software correlators and installed them and got them running on our servers.

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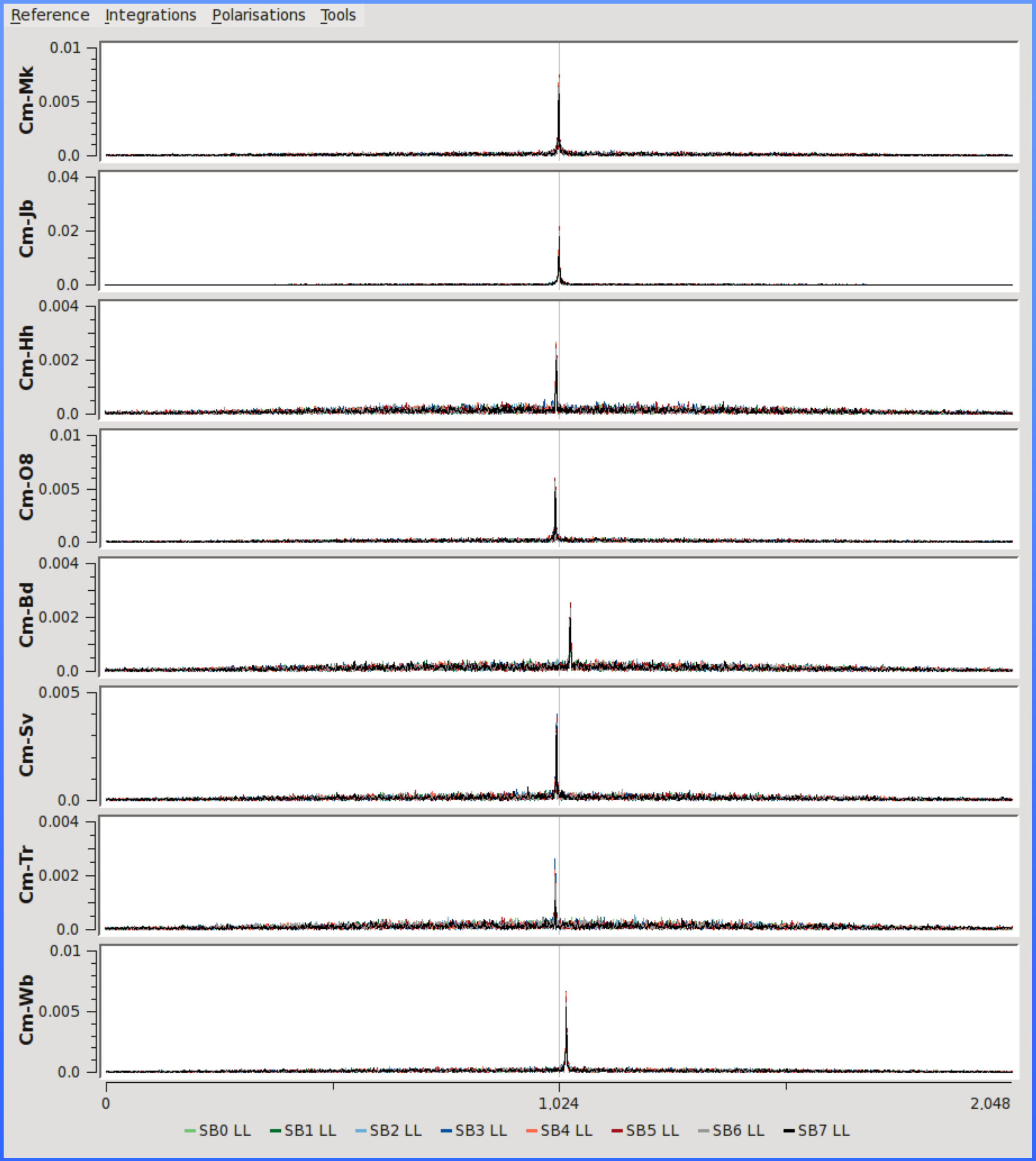
The pulsar B0329+54 and recorded the data both using the VDIF route and the standard VLBI route.

The Jodrell pulsar group were given the data for a full timing analysis using their powerful machines, and they determined that the VDIF route data was delayed relative to the standard VLBI route by ~112 millisecs !!

Paul Harrison now made a fortuitous mistake and typed into the system 121 millisecs and a fringe appeared at 121.933millisecs.



Reference
Integrations
Polarisations
Tools
Cm-Mk
Cm-Jb
Cm-Hh
Cm-O8
Cm-Bd
Cm-Sv
Cm-Tr
Cm-Wb
0.01
0.005
0.0
0.04
0.02
0.004
0.002
0
1,024
2,048
SB0 LL
SB1 LL
SB2 LL
SB3 LL
SB4 LL
SB5 LL
SB6 LL
SB7 LL

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Paul Harrison now made a fortuitous mistake and typed into the system 121 millisecs and a fringe appeared at 121.933millisecs.

This is a very large delay difference, but why we do not know. However, interestingly, this is approximately half the total delay buffer

Should now be able to offer 2 * 64 MHz e-MERLIN and 16 * 8 MHz for VLBI for EVN session 1 next year.

However, significant work still needs to be done for this.

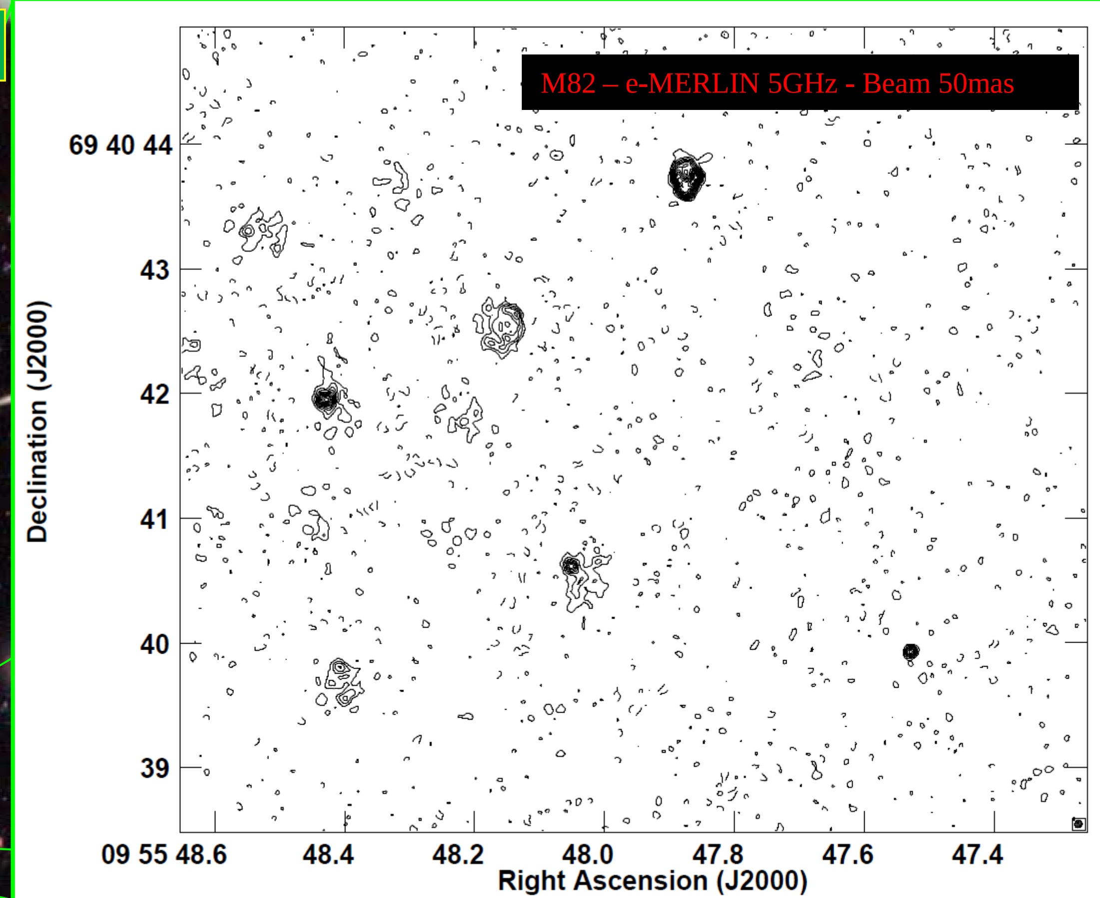
e.g.

a) Variable fibre delay needs to be removed
b) WIDAR correlator needs to be driven from the VLBI Field System
c) Reworking of internal networking / data storage to be able to cope with larger bandwidth data rates

Additional VLBI equipment development.

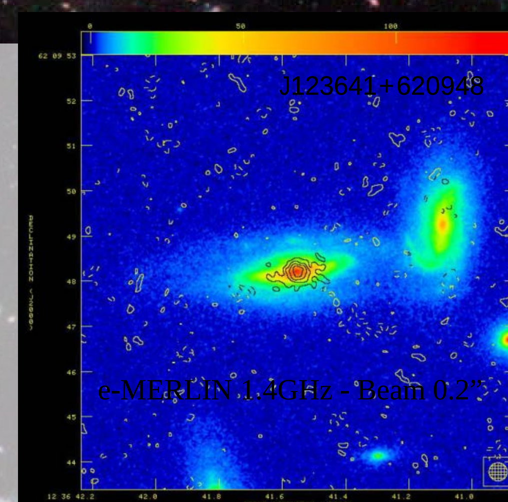
a) Moved to DBBC as operational backend
b) Purchased 2 more Core 2 boards for DBBC, which will double the number of IFs available.
c) Intend to upgrade one of our Mk5B recorders with an Amazon card to make it a Mk5C

Star-formation Across Cosmic Time



Calibrate star-formation rate derivation on nearby galaxies like M82

Extend to distant galaxies 1000 times further away and 1 million times fainter
e-MERGE Survey (0.2 sq arcmin field) >5000 galaxies to edge of visible Universe

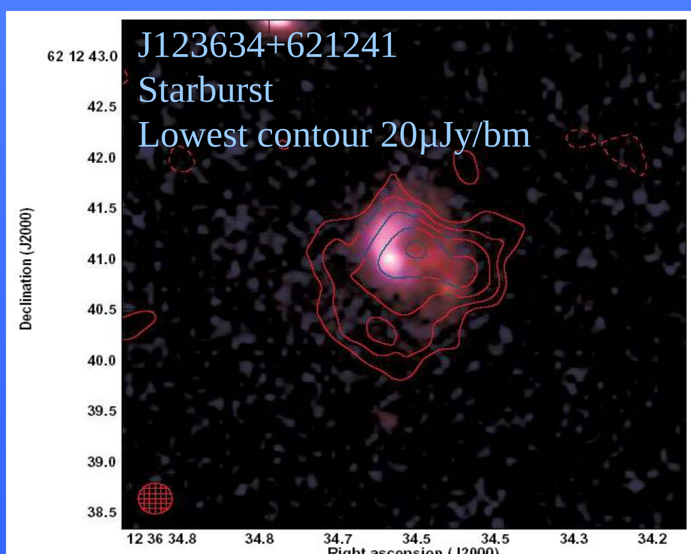


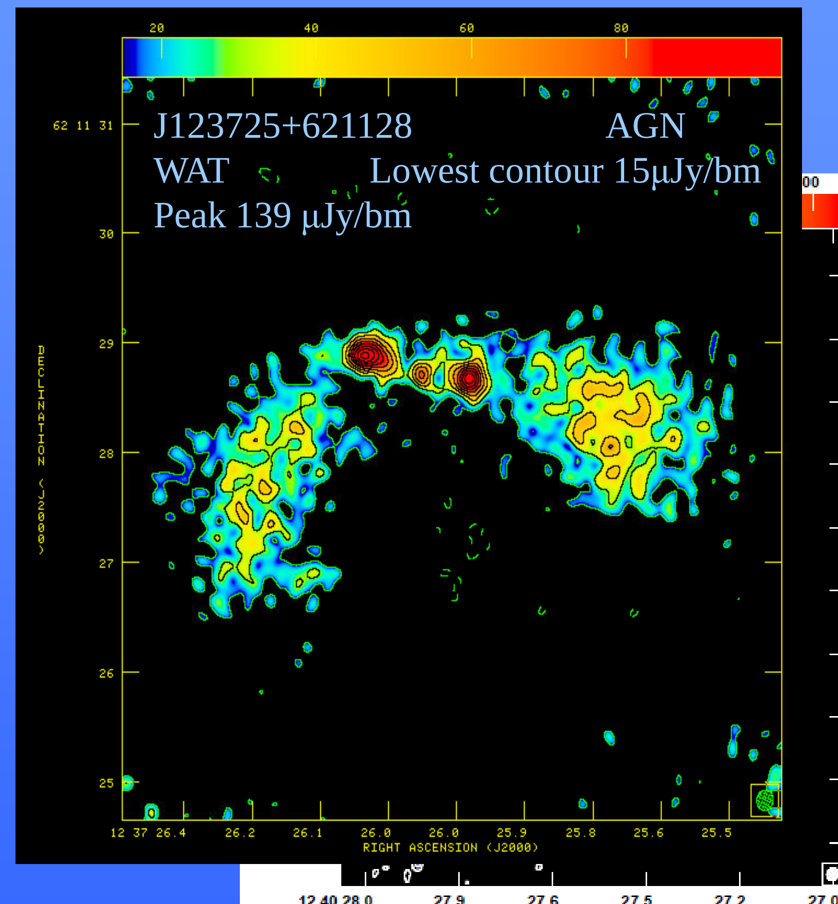
Seyfert-2 at z=0.5186 ($S_{1.4}$ = 76μJy)

Extended + nuclear starburst emission (no VLBI AGN detection) S-R rate ~40 $M_{\odot}$/yr

Deep field imaging
(GOODS-N : e-MERGE project)
Muxlow/Smail/McHardy

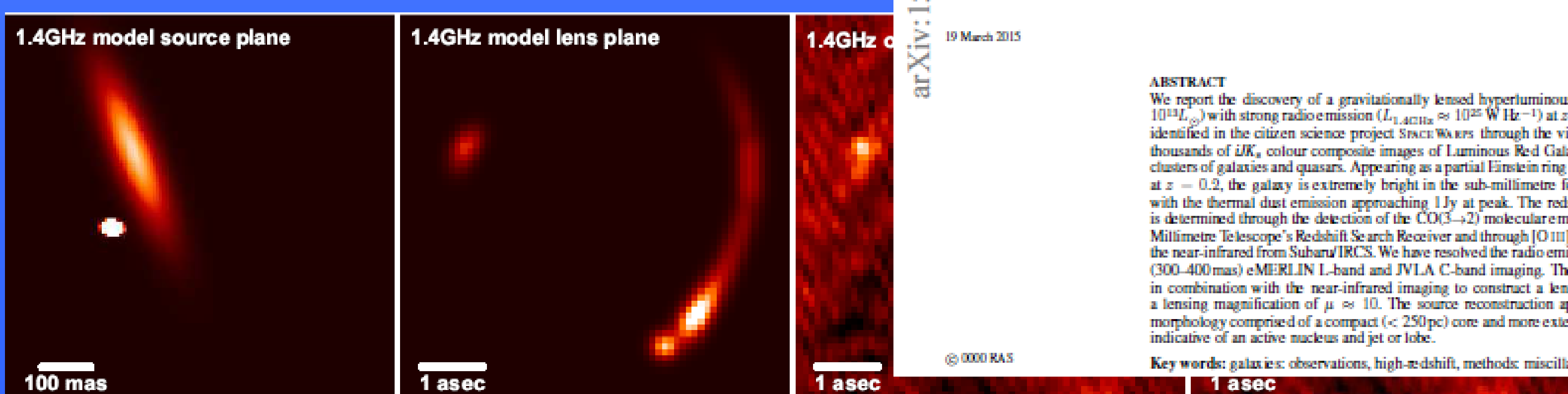
- Recent deep L-band imaging – 2 day test
  - 6.6uJy/bm
  - Full imaging of field underway.





A red radio ring: stargazing-live (Geach et al)

- Stargazing live discovery lens
- z=2.553 lens discovered through citizen scie during live BBC broadcast
- See astro-ph/1503.05824 MNRAS



arXiv:1503.05824v1 [astro-ph.GA] 19 Mar 2015

The Red Radio Ring: a gravitationally lensed hyperluminous infrared radio galaxy at z=2.553 discovered through citizen science

J. E. Geach[1], A. More[2], A. Verma[3], P. J. Marshall[4], N. Jackson[5], P.-E. Belles[5], R. Beswick[5], E. Baeten[6], M. Chavez[7], C. Cornen[6], B. E. Cox[8], T. Erben[9], N. J. Erickson[10], S. Garrington[5], P. A. Harrison[5], K. Harrington[10] D. H. Hughes[7], R. J. Ivison[11,12], C. Jordan[5], Y.-T. Lin[13], A. Leauthaud[2], C. Lintott[3], S. Lynn[15], A. Kapadia[14], J.-P. Kneib[15,16], C. Macmillan[6], M. Makler[17], G. Miller[6], A. Montaña[7], R. Mujica[7], T. Muxlow[5], G. Narayanan[10], D. Ó Briain[18], T. O'Brien[5], M. Oguri[19], E. Paget[14], M. Parrish[14], N. P. Ross[11], E. Rozo[20,21], E. Rusu[22], E. S. Rykoff[4], D. Sanchez-Argüelles[7], R. Simpson[3], C. Snyder[14], F. P. Schloerb[10], M. Tecza[3], L. Van Waerbeke[23], J. Wilcox[6], M. Viero[4], G. W. Wilson[10], M. S. Yun[10], M. Zeballos[7]

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[23]Department of Physics and Astronomy, University of British Columbia, 6224, Agricultural Road, Vancouver, B.C., V6T 1Z1, Canada

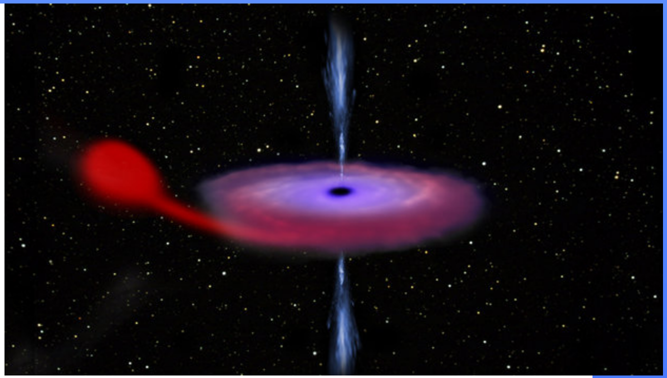
19 March 2015

ABSTRACT

We report the discovery of a gravitationally lensed hyperluminous infrared galaxy ($L_{IR} \approx 10^{13} L_\odot$) with strong radio emission ($L_{1.4GHz} \approx 10^{25}$ W Hz^{-1}) at $z = 2.553$. The source was identified in the citizen science project SpaceWarps through the visual inspection of tens of thousands of iJK_s colour composite images of Luminous Red Galaxies (LRGs), groups and clusters of galaxies and quasars. Appearing as a partial Einstein ring ($r_e \approx 3''$) around an LRG at $z = 0.2$, the galaxy is extremely bright in the sub-millimetre for a cosmological source, with the thermal dust emission approaching 1 Jy at peak. The redshift of the lensed galaxy is determined through the detection of the CO(3→2) molecular emission line with the Large Millimetre Telescope's Redshift Search Receiver and through [O III] and Hα line detections in the near-infrared from Subaru/IRCS. We have resolved the radio emission with high resolution (300–400 mas) eMERLIN L-band and JVLA C-band imaging. These observations are used in combination with the near-infrared imaging to construct a lens model, which indicates a lensing magnification of $\mu \approx 10$. The source reconstruction appears to support a radio morphology comprised of a compact (< 250 pc) core and more extended component, perhaps indicative of an active nucleus and jet or lobe.

Key words: galaxies: observations, high-redshift, methods: miscellaneous

V404Cyg – June 2015 outburst



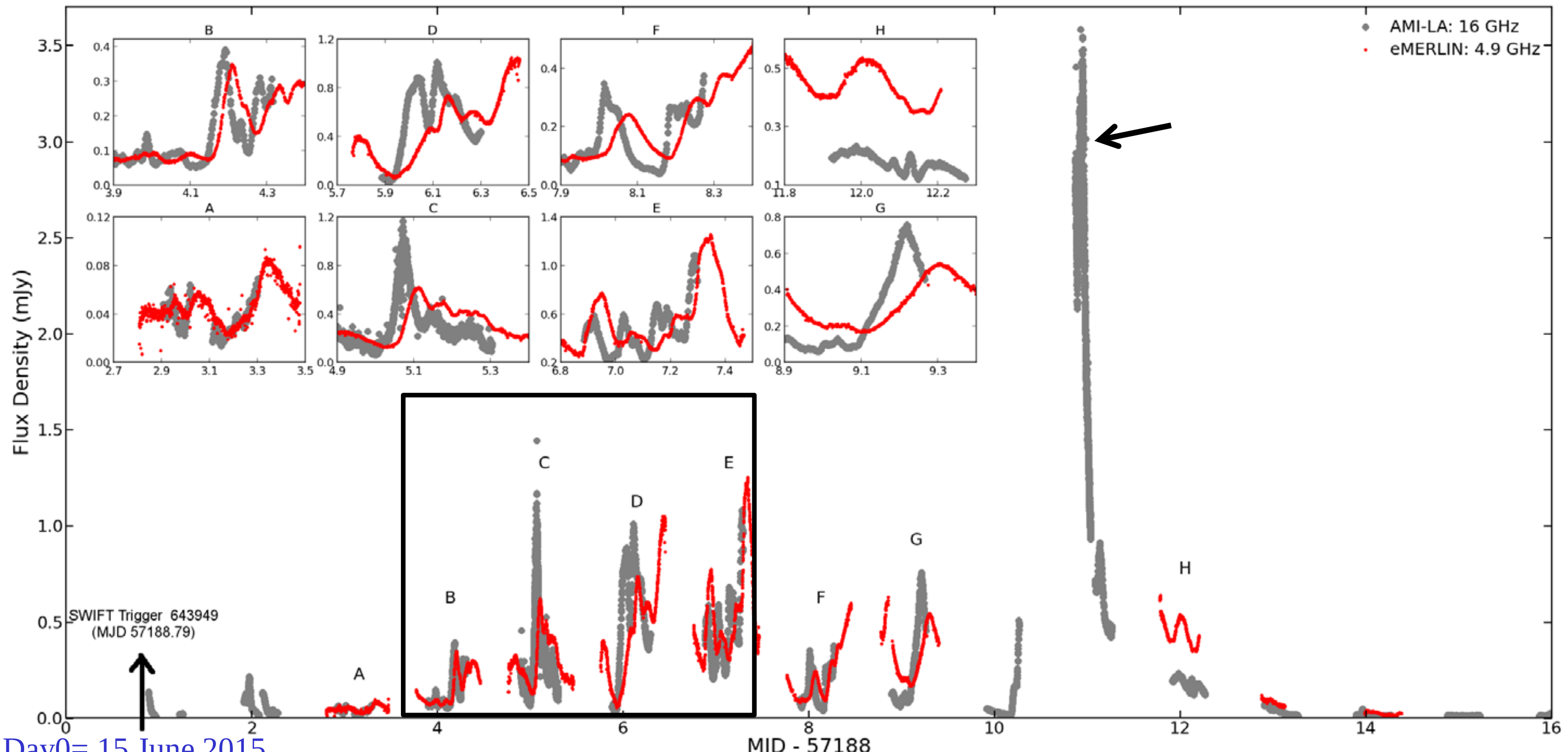
V404Cygni

- Low Mass X-ray Binary system comprising of a Black-hole (~12Msun) and a (G-type) star

- Very nearby ~2.39+/-0.14kpc
- ➔ eMERLIN resolution scale of 30mas~70AU
- First major outburst since 1989 was detected by Swift on 15th June 2015, then Integral etc.
  - Triggered extensive global multiwavelength monitoring of the source
  - Detailed radio monitoring from e-MERLIN (from 17th June) and AMI (from 15th June) at 4.8-5.3GHz and 15GHz.

'Hot-off-the-correlator'

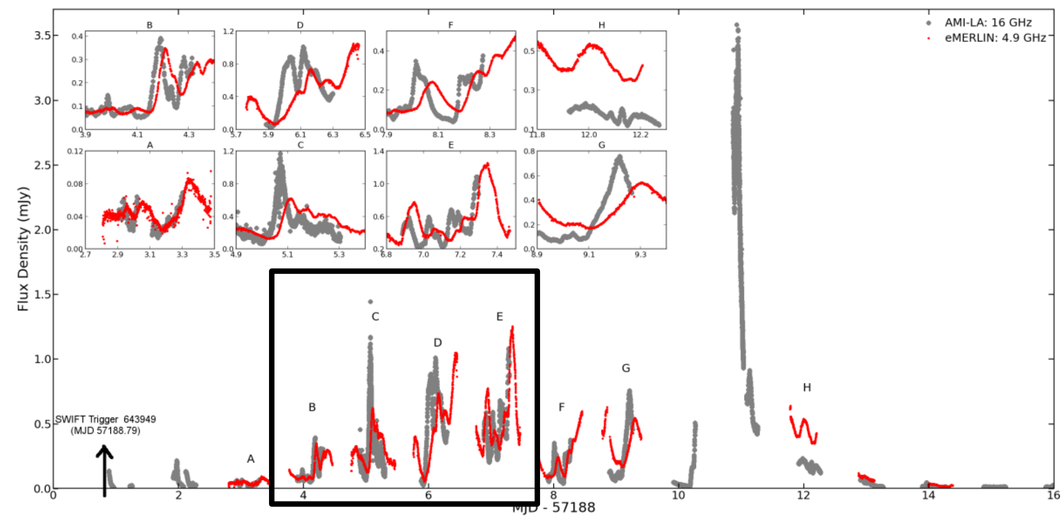
V404Cyg – June 2015 outburst



Day0= 15 June 2015

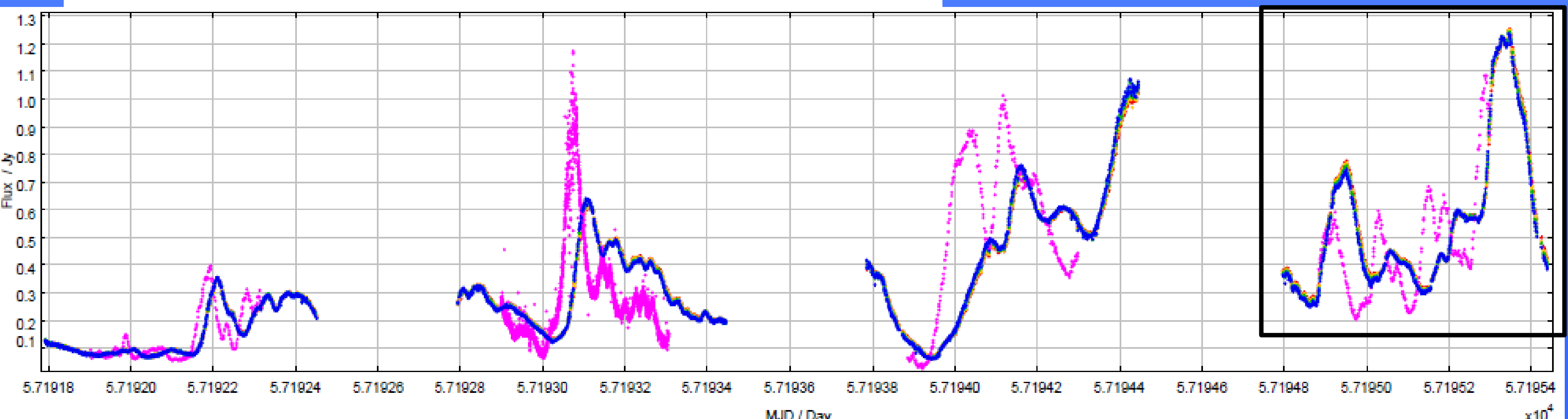
Simultaneous rapid multi-frequency monitoring from
e-MERLIN (4.8-5.3GHz) and AMI (15GHz – via 4PI SKY project PI Fender)
Ongoing programme inc JVLA, EVN, VLBA, AMI & e-MERLIN

V404Cyg – June 2015 outburst



V. Preliminary analysis:
~40min time lag between 15-5GHz
~few min lag across 500MHz
e-MERLIN band

Source remains ‘unresolved’



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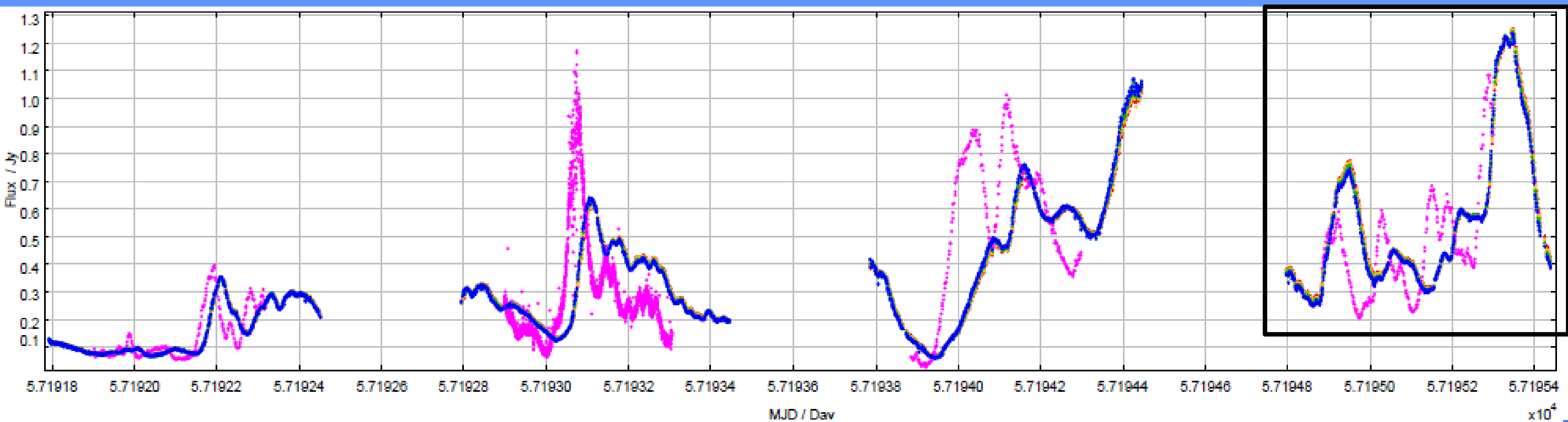
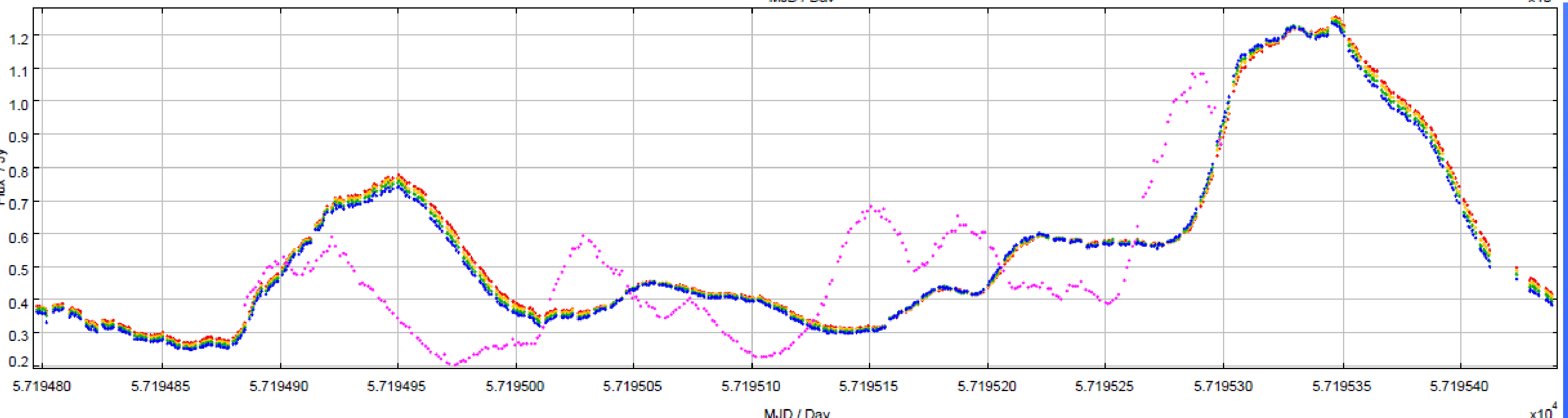
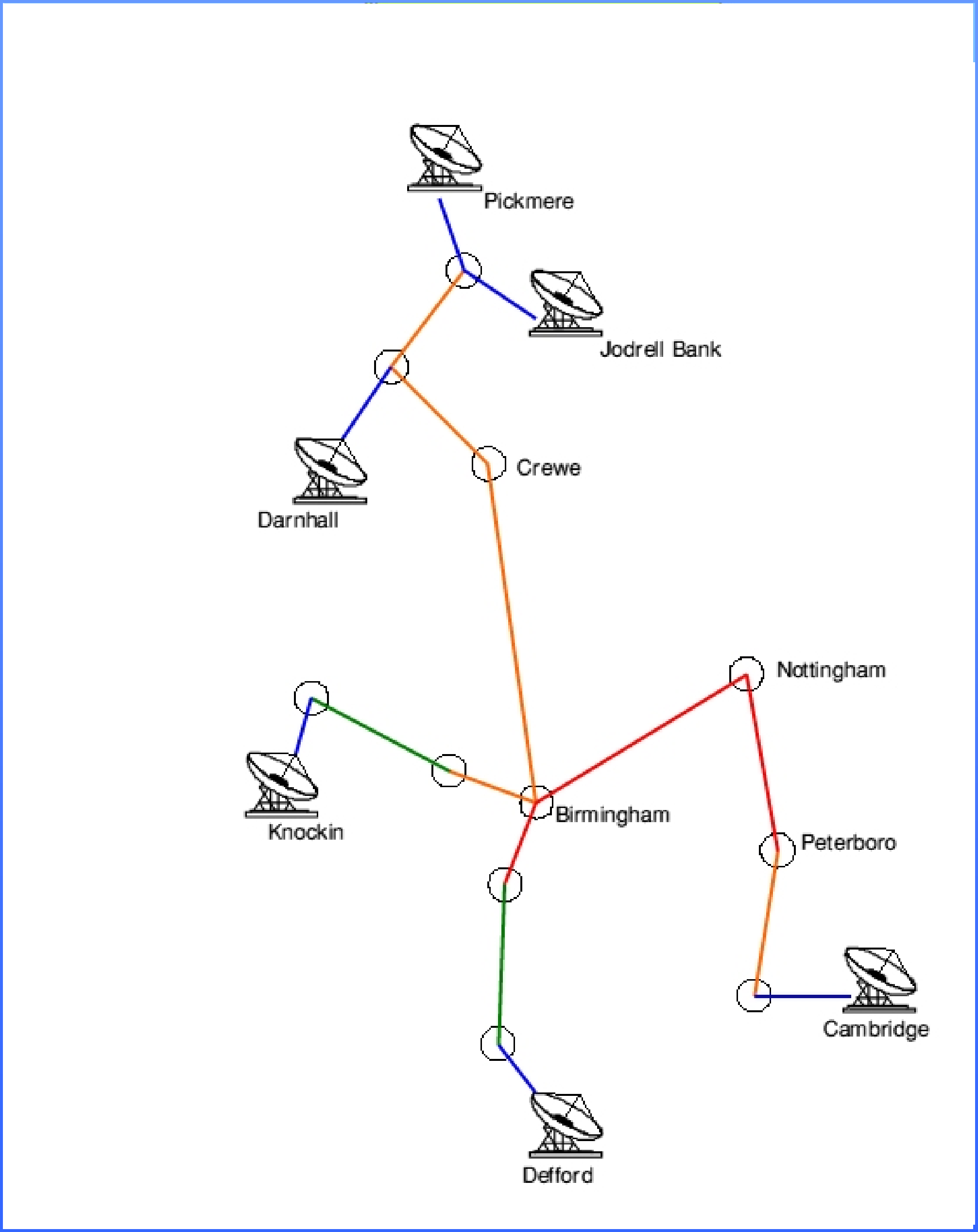




Differing peak profile as function of frequency – full analysis pending

Thank You


Pickmere
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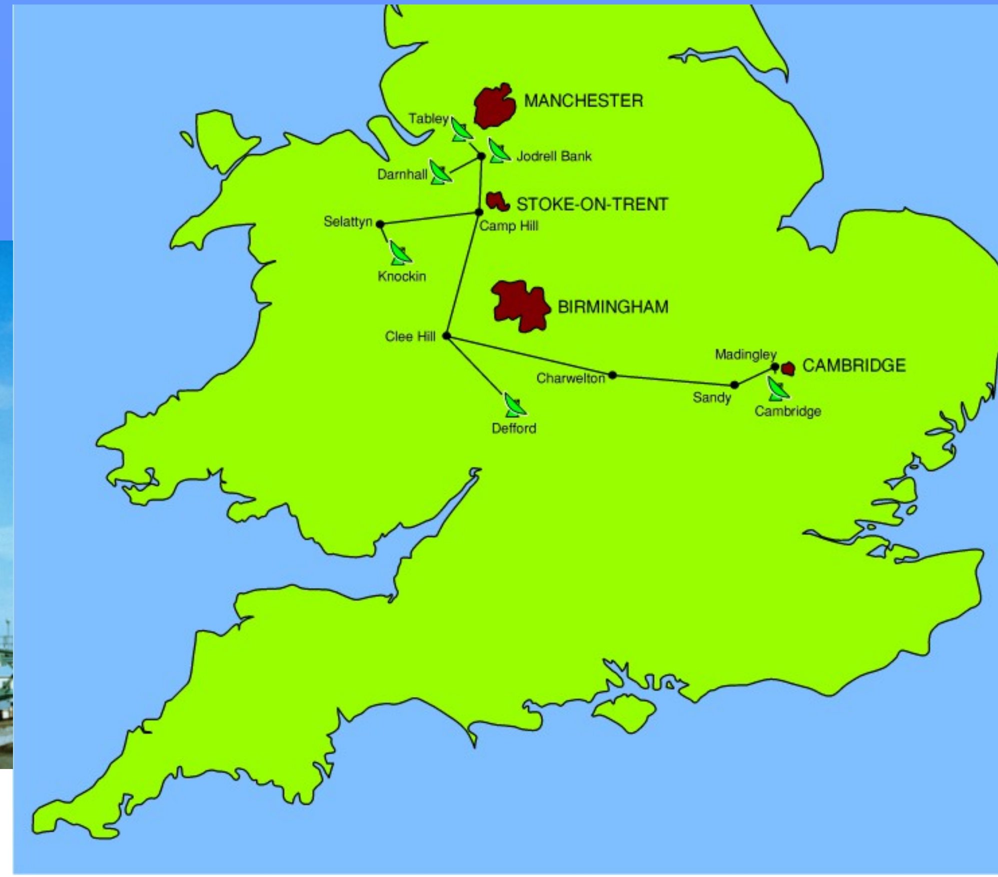
Darnhall
Crewe
Nottingham
Knockin
Birmingham
Peterboro
Cambridge
Defford



Improve Sensitivity with:

- Improve Tel. Gains – Improve Lovell & Defford surfaces & tracking
- Improved System Noise Temperatures. (Some possibility)
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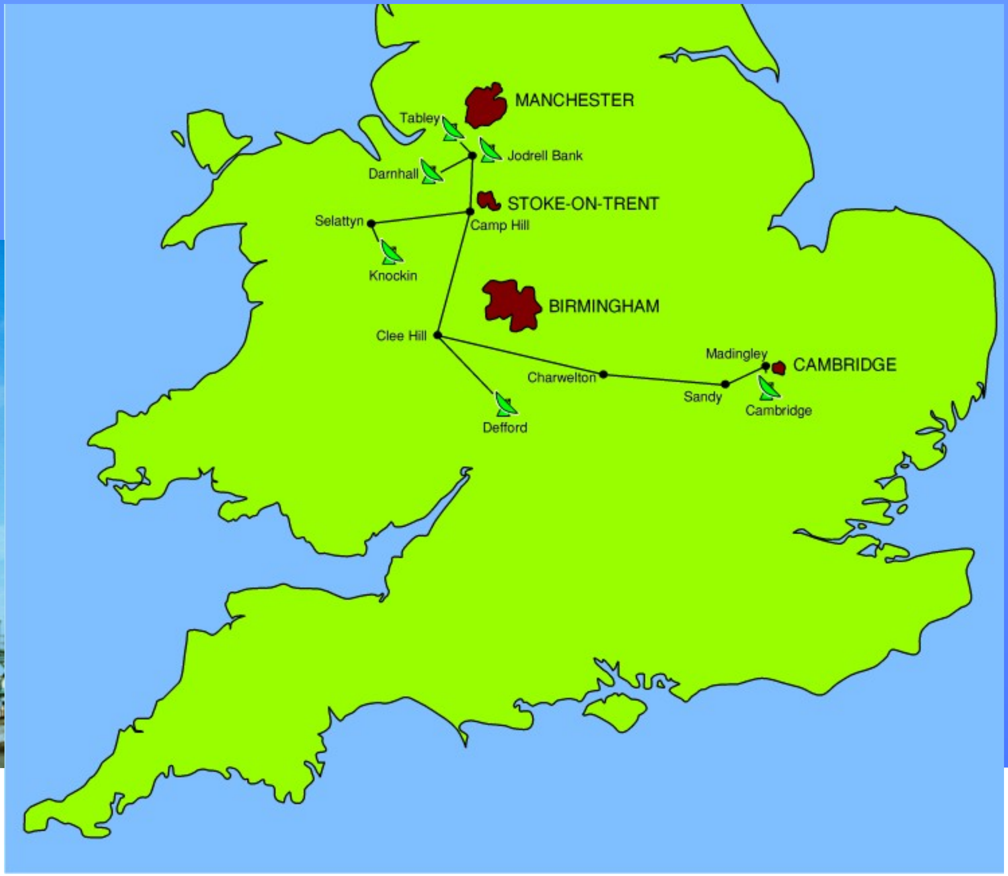

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76-m Lovell Telescope
October 2002

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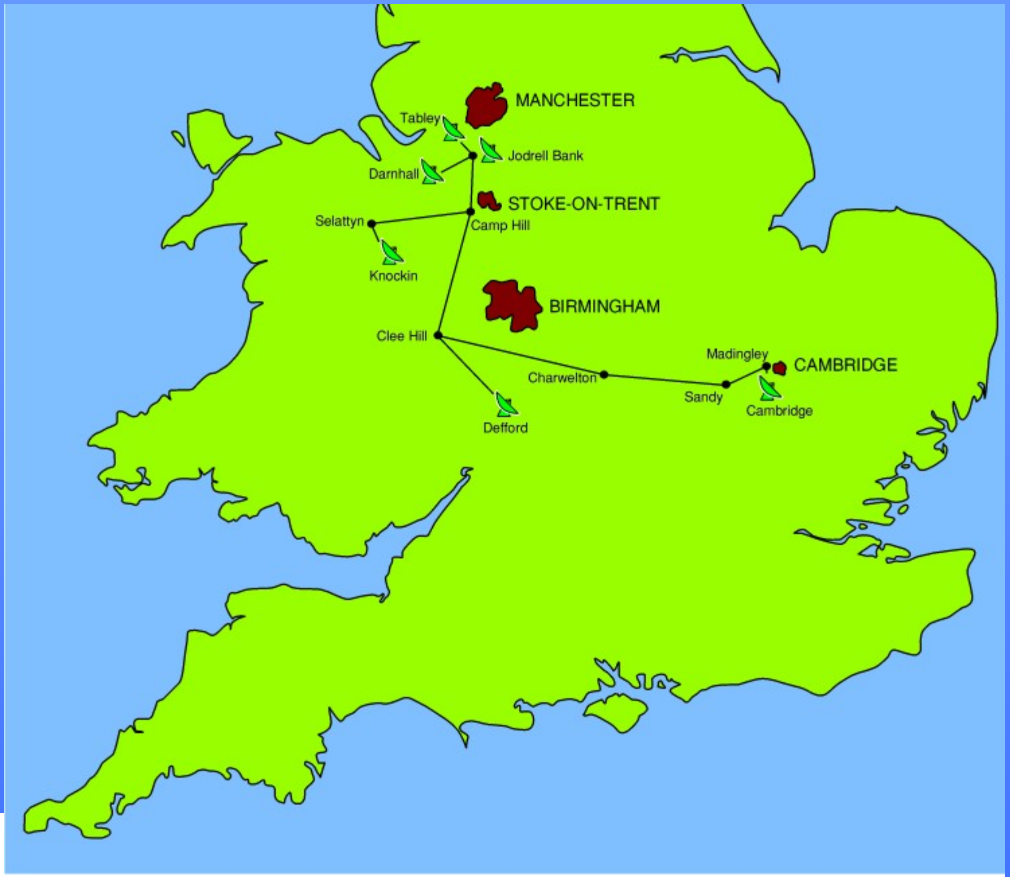
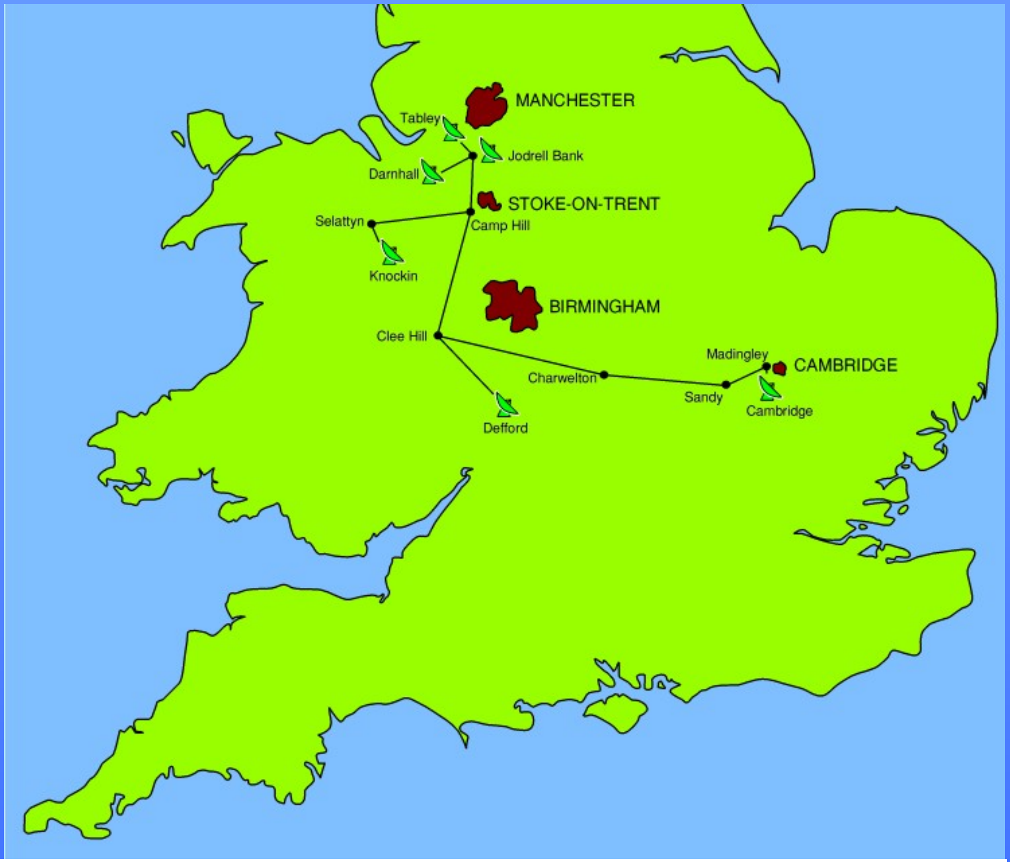


Improve Sensitivity with:

- More, Larger and More Efficient Telescopes (Yes / No)
- Improved System Noise Temperatures. (Some possibility)
- Increase Bandwidths (16 MHz per pol. - Definitely)



Improve Sensitivity with:

Increase Bandwidths - requires optical fibre connections;

- completely new wideband IFs, Feeds & L.O. system;
- new correlator;
- L-Band link down fibres

Data Transmission Network Solution

Fujitsu (FTEL,UK) installed & tested 90km new fibre alongside minor roads to connect to…

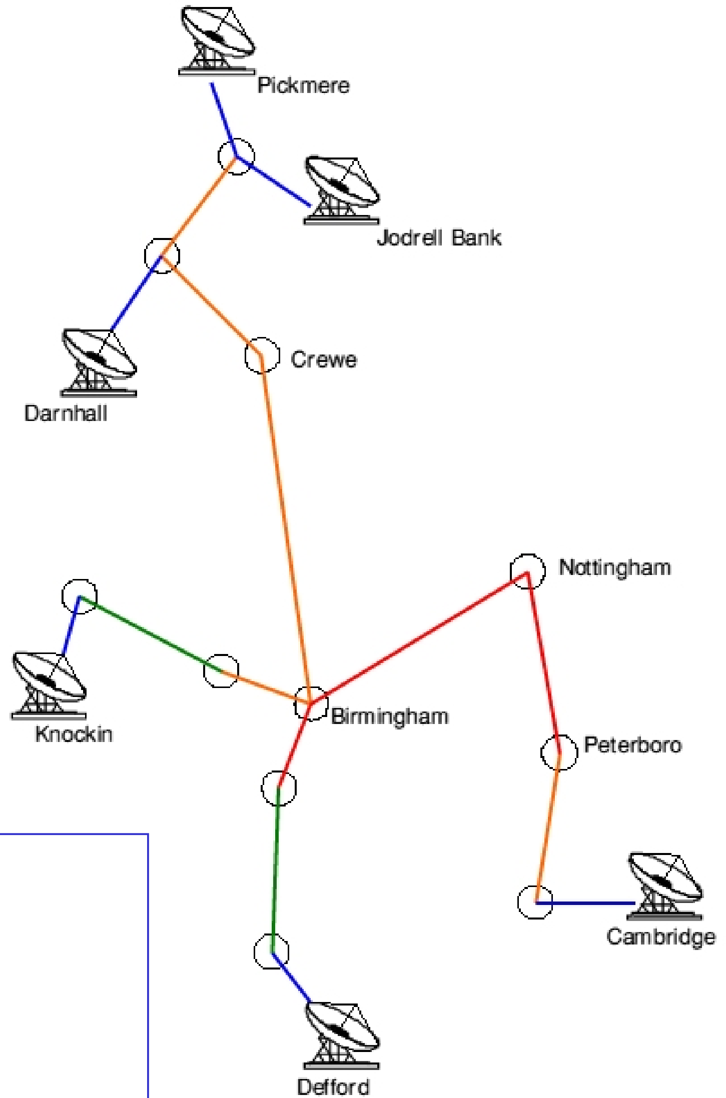
Dark fibre trunks provided mainly by Global Crossing (UK)

Maintenance contract for entire network

Amplifiers/Regeneration at Peterborough, Nottingham, Birmingham, Crewe, designed and installed by JBO

Require 30 Gb/s from each telescope to correlator at Jodrell Bank (2 GHz/pol @ 3bits = 24G)

Own dark fibre - e-MERLIN uses 3 x 10.0G



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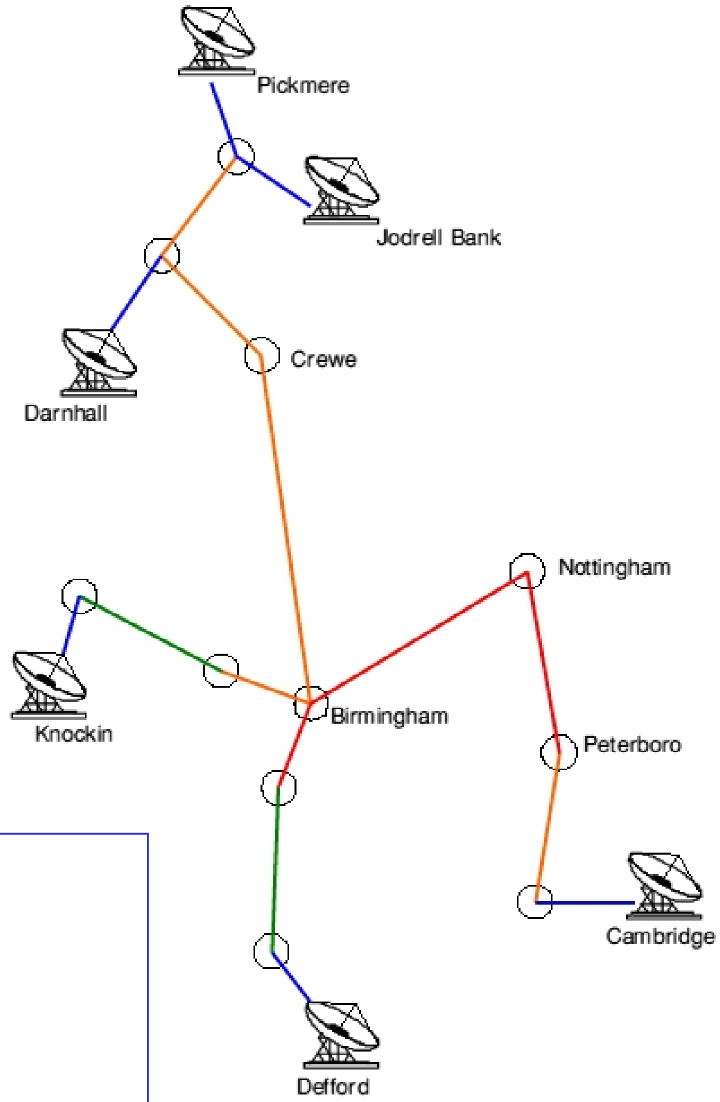


Legacy programme allocations

GALACTIC PROJECTS:

• e∏ - Pulsar interferometry – Vlemmings/Stappers et al.	160hrs **
• PEBBLES – Greaves et al.	72hrs **
• Feedback processes in Massive SF – Hoare/Vlemmings et al.	450hrs
• Thermal jets from low mass stars - Rodriguez et al	180hrs
• COBRaS – Prinja et al.	294hrs

EXTRA-GALACTIC PROJECTS:

• LEMMINGS – Beswick/McHardy et al.	810hrs
• LIRGI – Conway/Perez-Torres et al.	353hrs
• Extragalactic Jets – Laing/Hardcastle et al	375hrs
• AGATE – Simpson/Smail et al	330hrs
• e-MERGE – Muxlow/Smail/McHardy et al	918hrs
• Gravitational lenses – Jackson/Serjeant et al	228hrs **
• *SuperCLASS – Battye et al **NEW***	*832hrs*

- **** Remaining 830hrs to be allocated to these projects pending initial results**

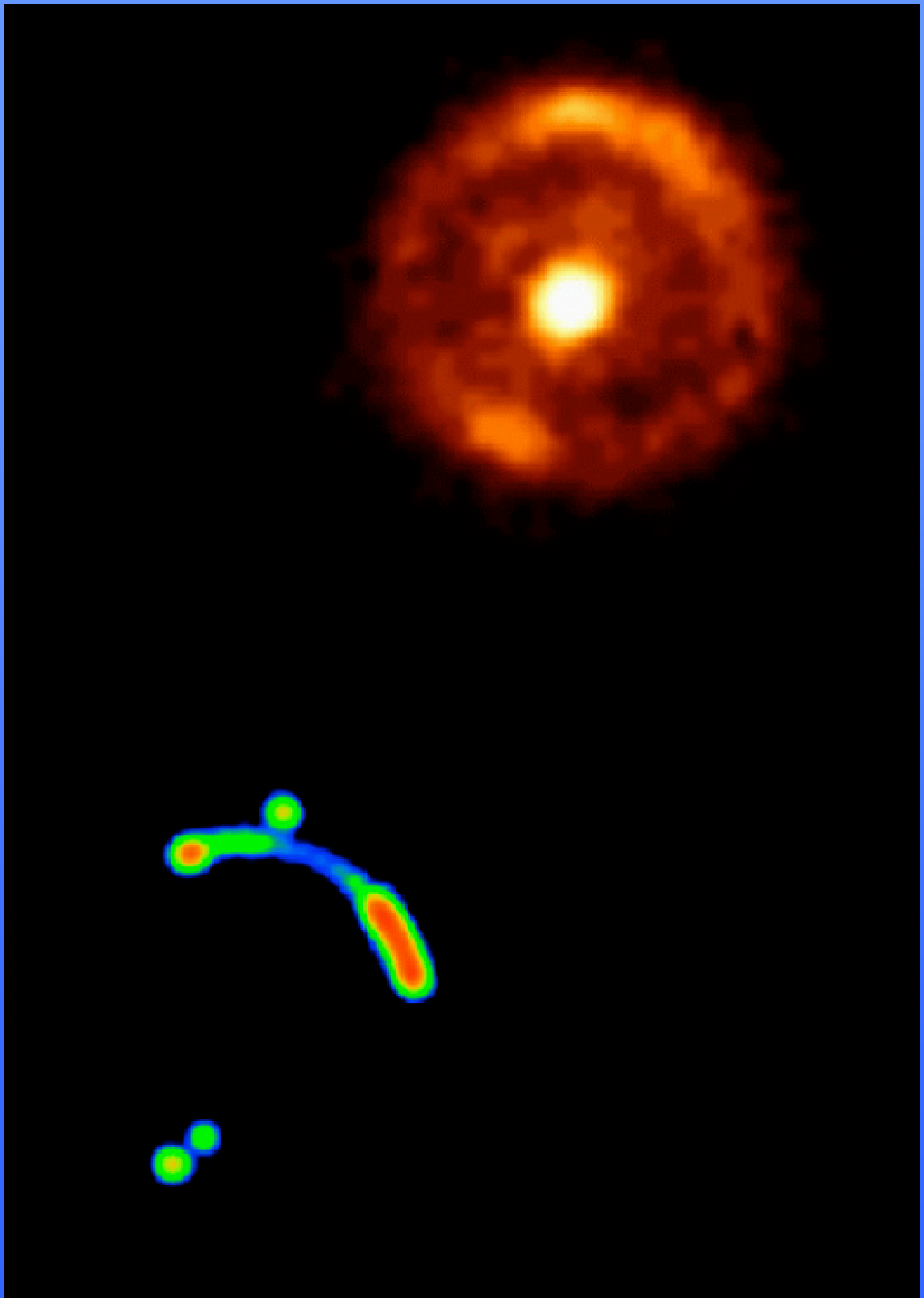
Legacy programme commissioning & contributions

- To-date commissioning various observations have been made for 7/11 of the legacy teams
  - eMERGE, LIRGI, LeMMINGs, Grav lens, CoBRAS, exgal-jets, Pebbles
  - Objective to involve teams (help with commissioning and data reduction developments)
    - significant visits to Manchester of scientists from 6 teams
    - 3 long-term visits (2*3months from LIRGI team, 1 eMERGE – 3months) from PDRAs & students (training & commissioning work)
    - Several 'busy weeks' (>4 visitors from individual teams) working on legacy commissioning data
  - Various teams (eg CoBRAS/LeMMINGs/eMERGE/Grav Lens) are committing effort to help development of data reduction pipelines and tools under auspices of technical working group (core of this group).
  - Automatic RFI flagging software – LIRGI/LeMMINGs group contributions

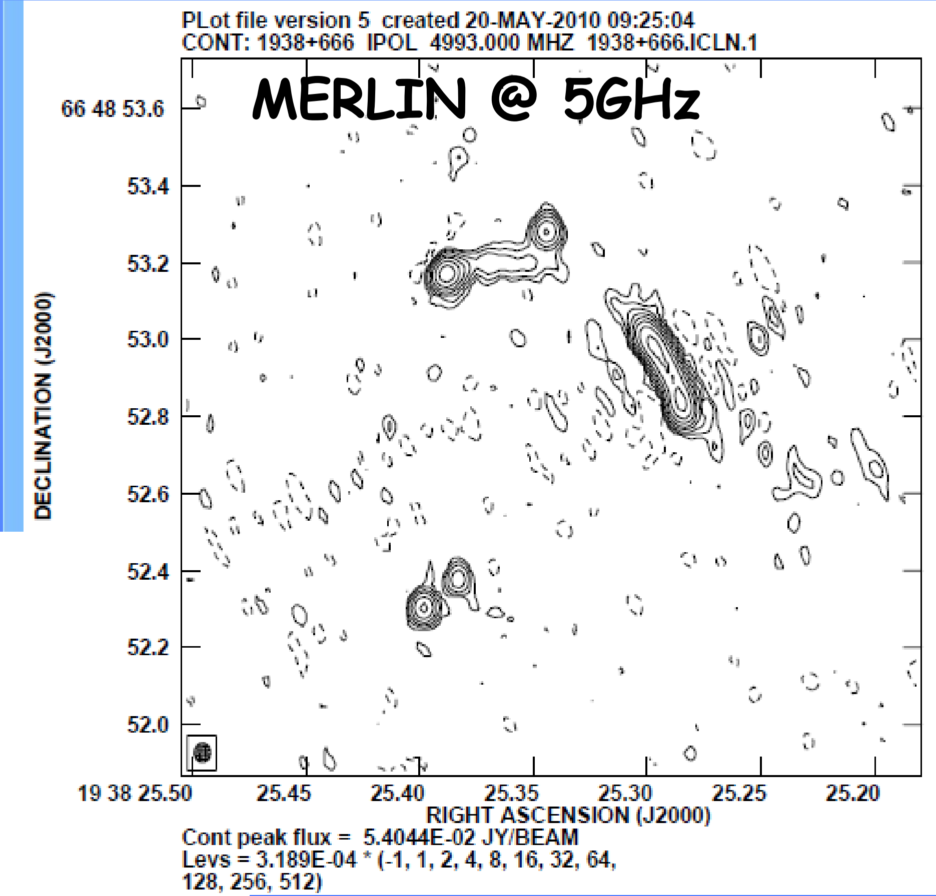
Initial Test Observations

- All observations have been observed as 'shared-risk' and as part of commissioning.
- Nearly all data has been at C-Band & all has had a reduced bandwidth of 512MHz.
  - Centre frequencies between 4.4 and 6.7GHz
  - Since March 2011, no Cm telescope available; also, before March old IF system & single polarisation
- Data reduced in either AIPS or CASA
  - Preliminary pipelines exist in both CASA and AIPS (ParselTounge)

An Einstein Ring

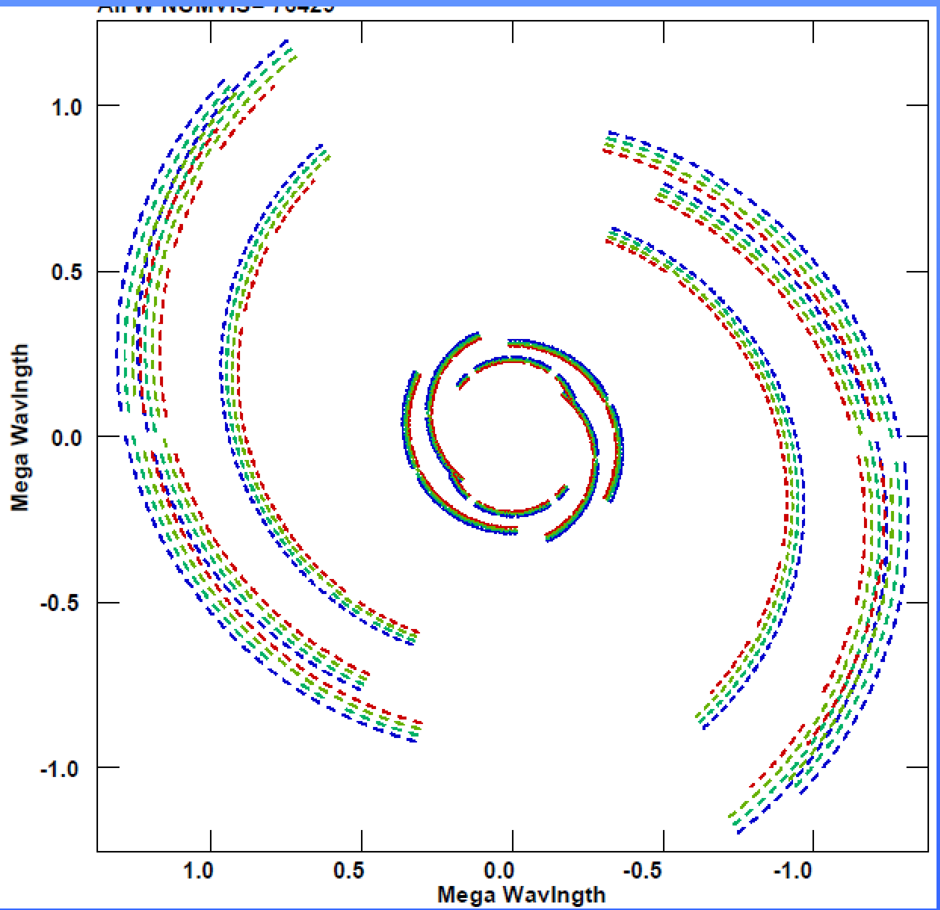


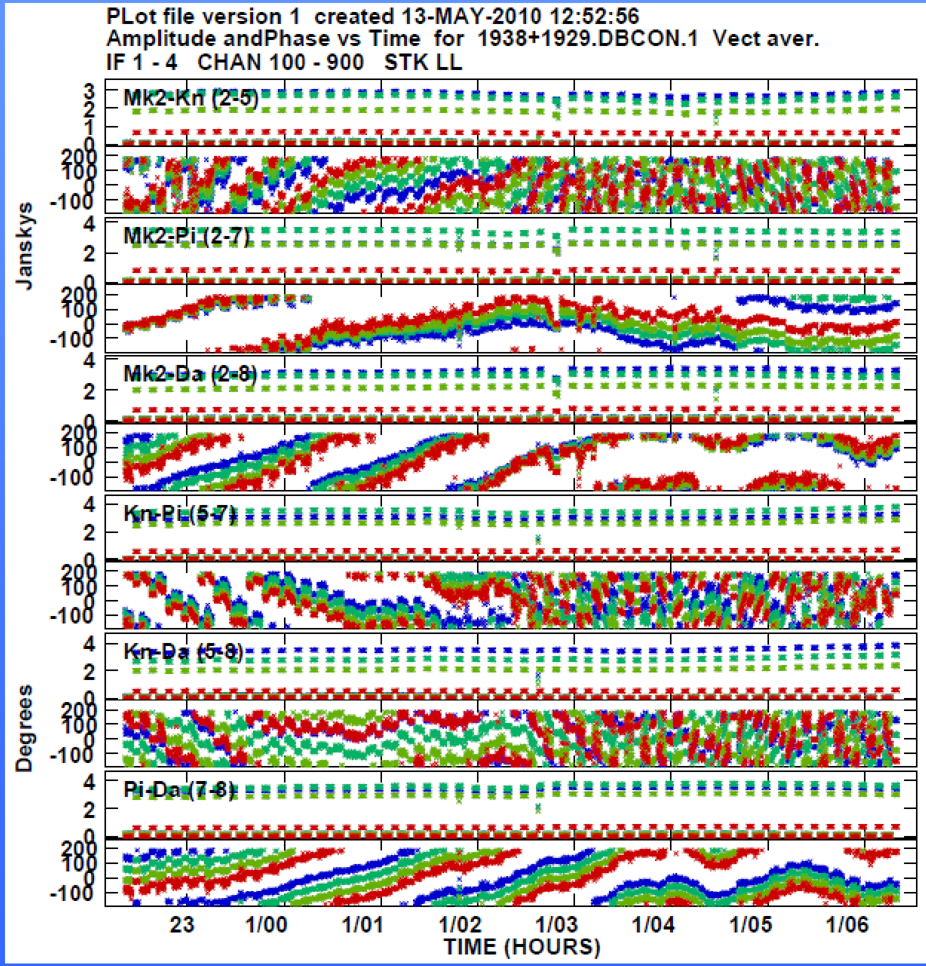
HST and MERLIN images of the lens 1938+666



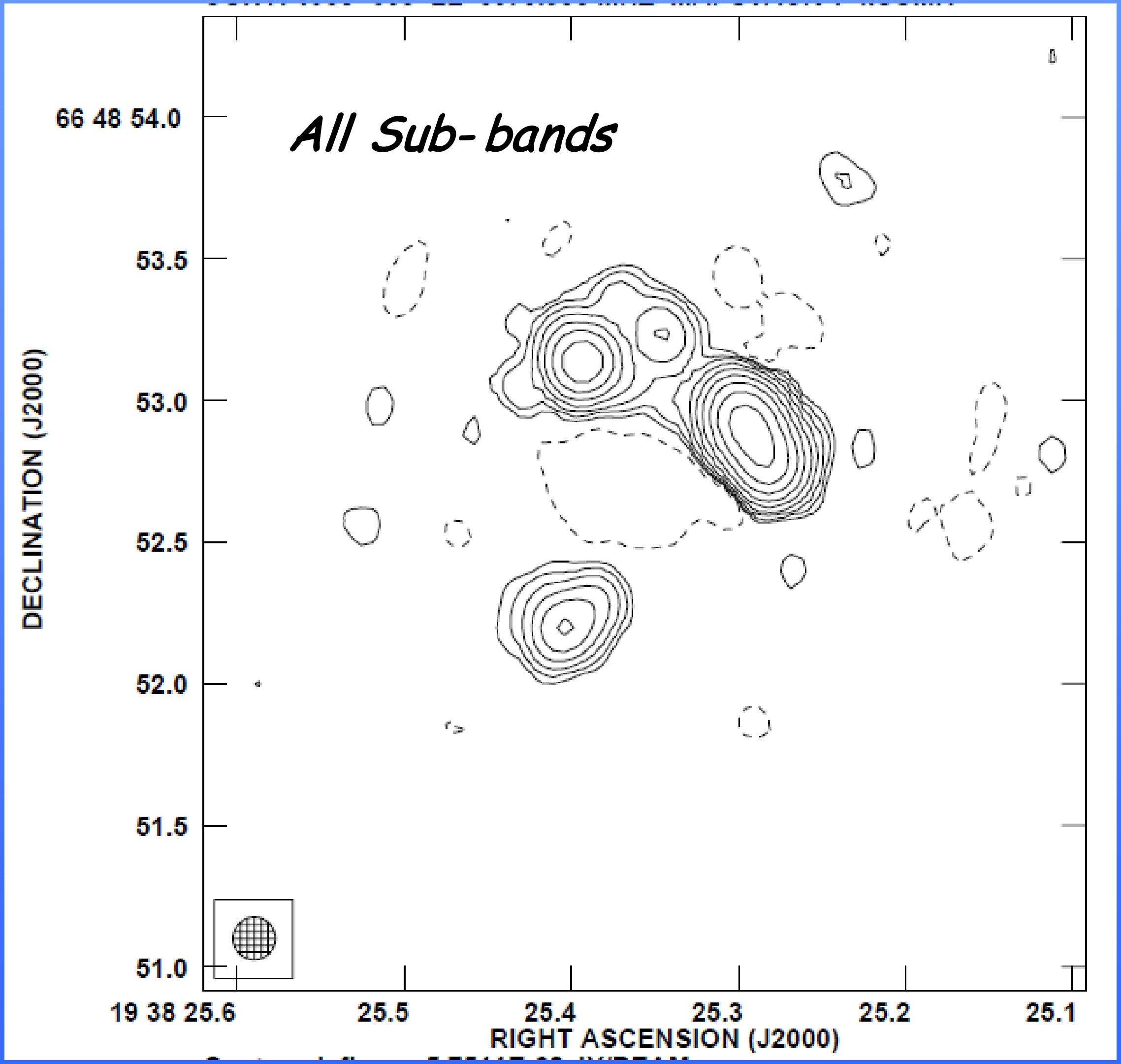
- Test data – 4 stations
  - 4 stations (MK2, Pi, Da, Kn)
  - 4 * 128MHz sub-bands (ie. 25%
  - of final B/w)
    - 6.064 → 6.576GHz
    - 1024 channels/sub-band
    - Single polarisation (LL)
  - Run for ~8hrs with phase referencing
    - Target source : 1938+668
    - Phase ref : 1927+739 (bright ~2Jy point)

UV-Coverage & Data





Combined sub-bands

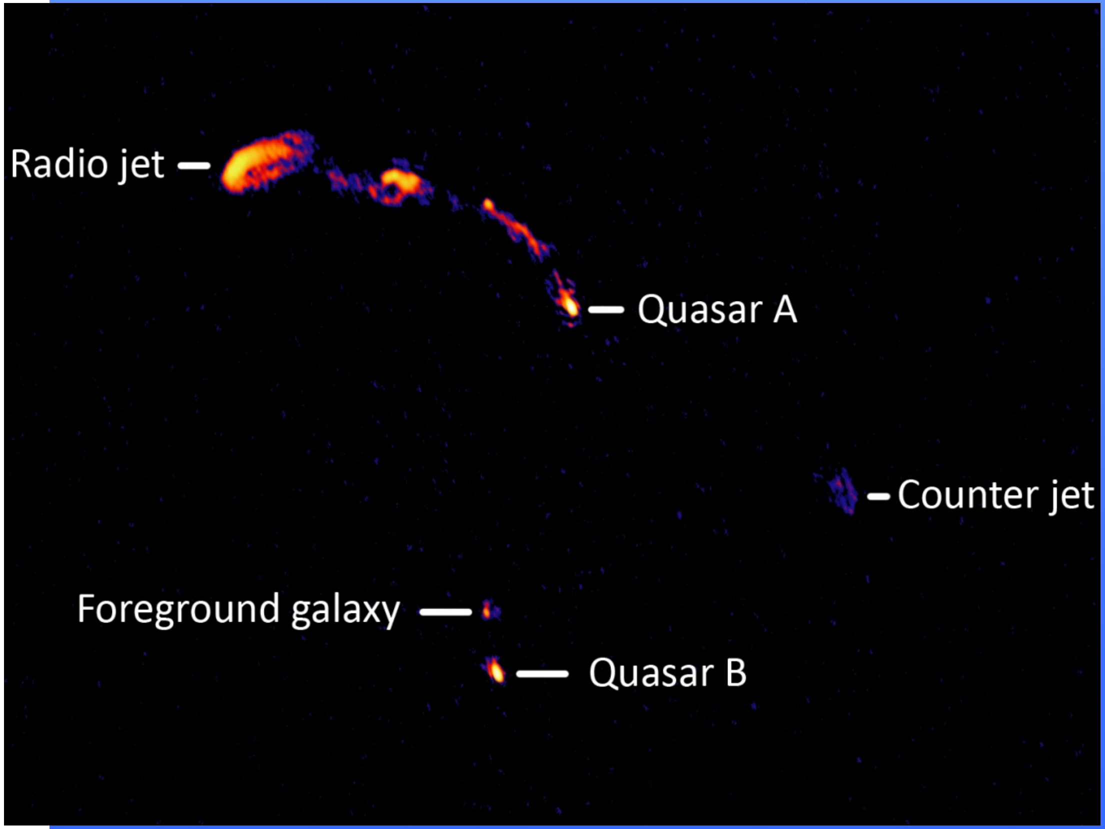


Test / Commissioning Observations

- Double Quasar
- Hubble Deep Field
- Luminous IR gals
  - (Arp299 & IC883)
- Nearby Galaxies
  - (IC342 & M82)
- Protoplaentary disks
  - (DG –TAU)

First 6-telescope data & image: 2010

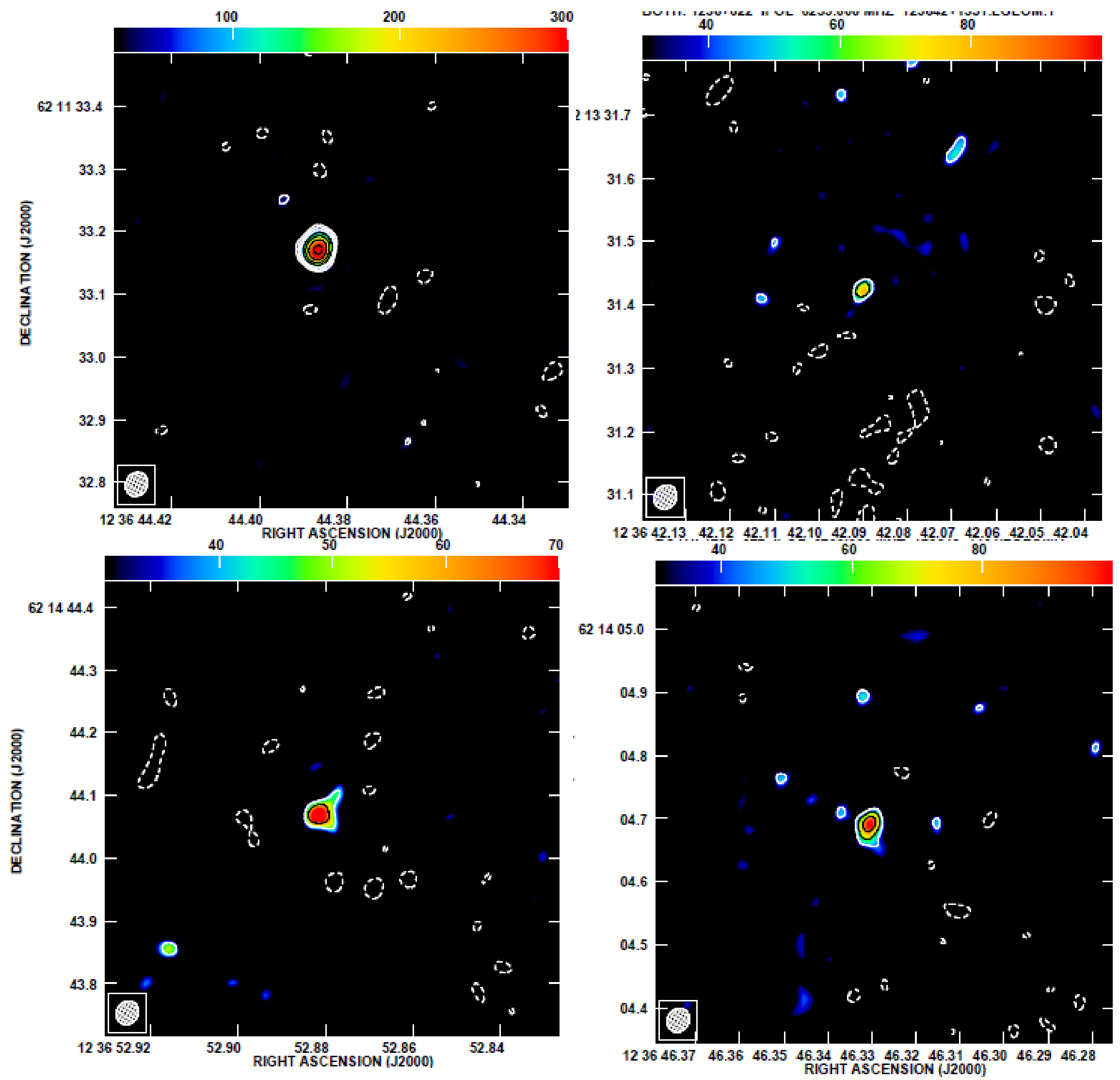
- Double Quasar – gravitational lens
- 6.7 GHz
- 12hrs data
- 50 mas resolution



GOODS-N field

New 6.75GHz images

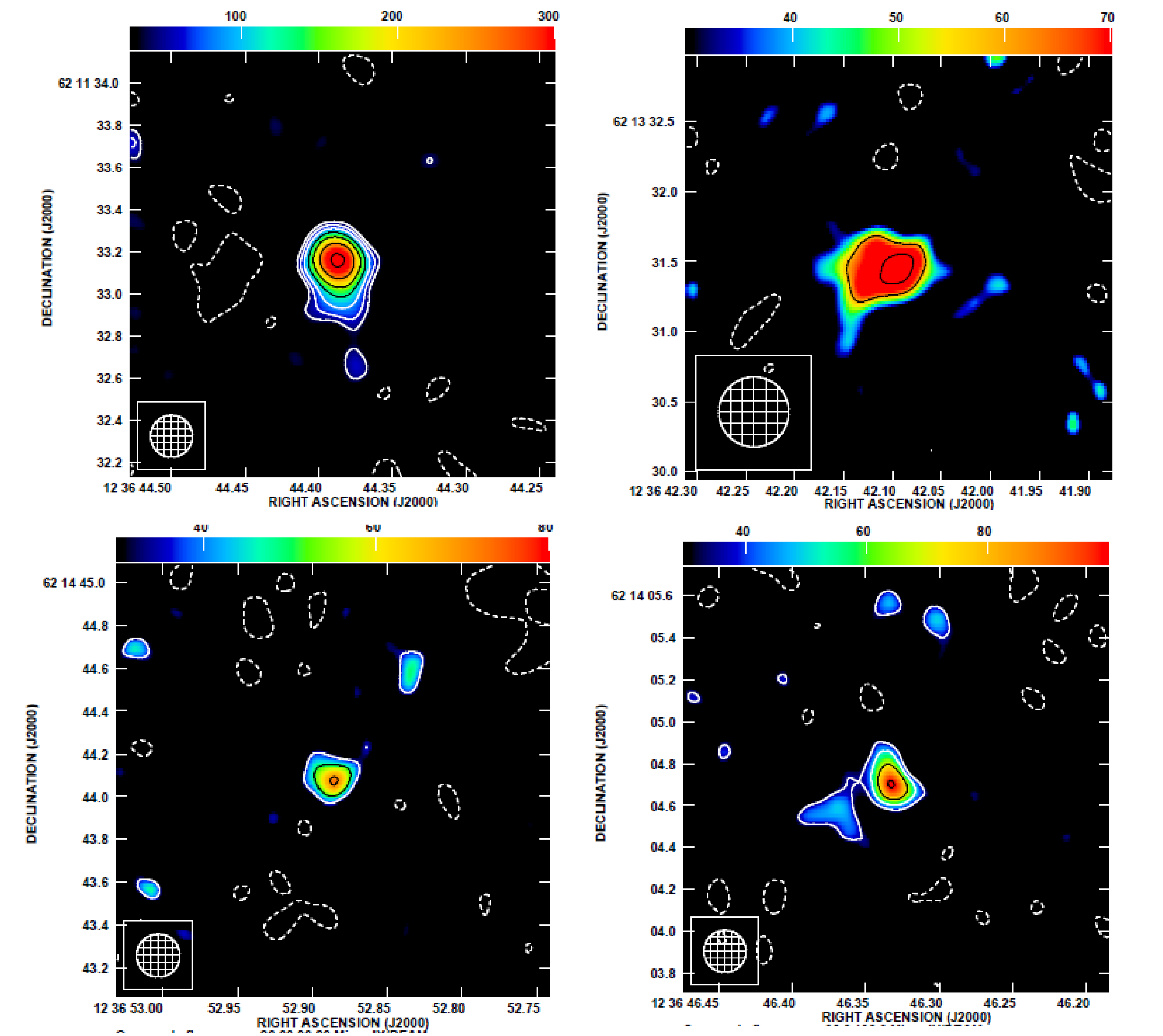
- 6.75GHz
  - Rms= 12μJy/bm
- 4.75GHz
  - Rms =16μJy/bm
- Detection of multiple high-z systems
  - AGN cores & SB systems



GOODS-N field

New 4.7 GHz images

- 6.75GHz (1 pol)
  - Rms= 12μJy/bm
- 4.75GHz (no cm)
  - Rms =16μJy/bm
- Detection of multiple high-z systems
  - AGN cores & SB systems

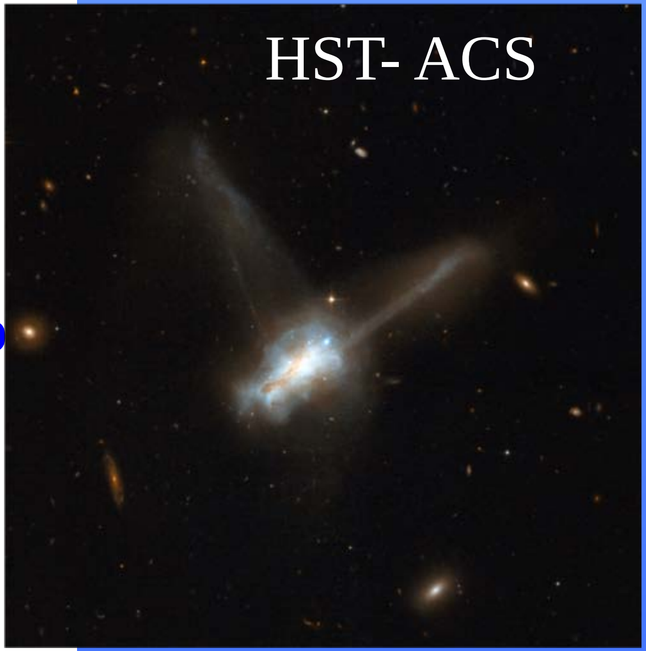


Luminous IR Galaxies

- Various commissioning observations undertaken for the LIRGI legacy project inc.:
  - IC883 – observed for Perez-Torres/Romero-Canizales
  - Arp299 – Observed for Perez-Torres/Herrero-Illana
  - Arp220 – Observed for Conway
- Significant man-power and effort provide by the team
  - 2 times 3 Month long PhD student visits to Manchester
  - Plus multiple visits by multiple senior team members

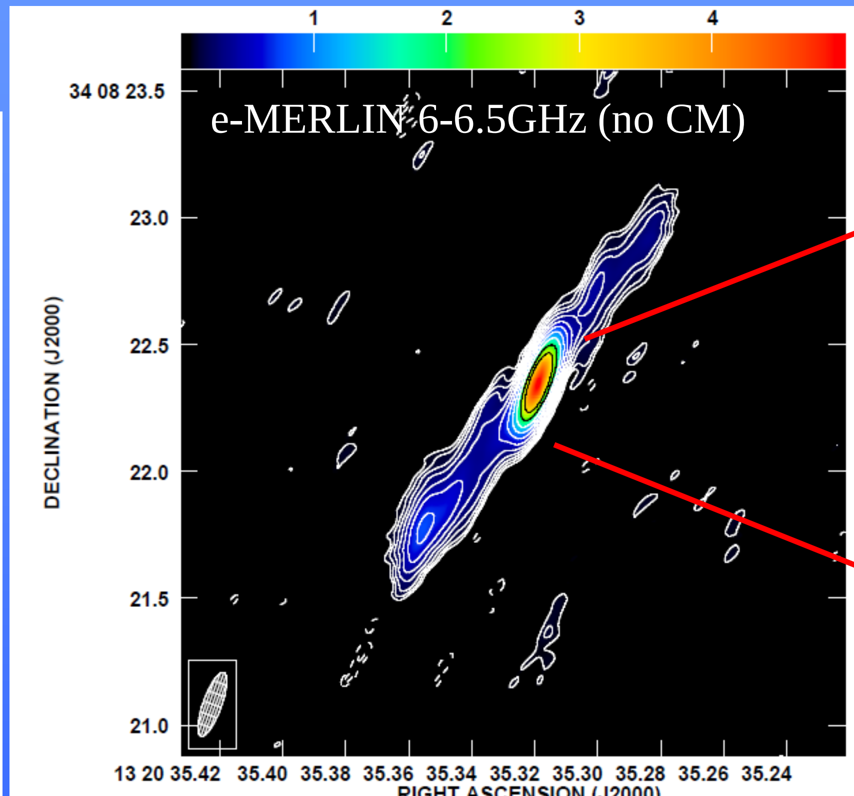
Starburst-AGN nucleus of IC883

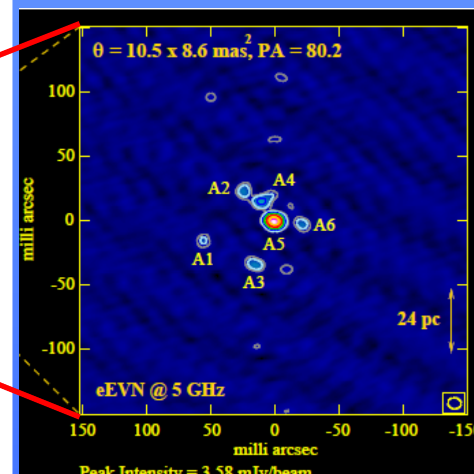
- IC883 nearby (100Mpc) LIRG (SB/LINER galaxy)
  - Large amount of recent SF
  - Kpc scale radio Sne factory (akin to Arp220/Arp299)
    - CCSNe rate ~1.3/yr
  - Multiple recently reported optical Sne
- ~8hr e-MERLIN observation at 6.5-7.0GHz
  - Aim: to image the extended nuclear region



IC883 (cont)

- e-MERLIN & eEVN results reveal central SNe factory
- e-MERLIN uniquely images the extended radio structure (tracing the optical nucleus)
- Search for optical SNe in radio
  - Non-detection help to reveal their nature
- Rms ~30uJy/bm (no CM, full track)

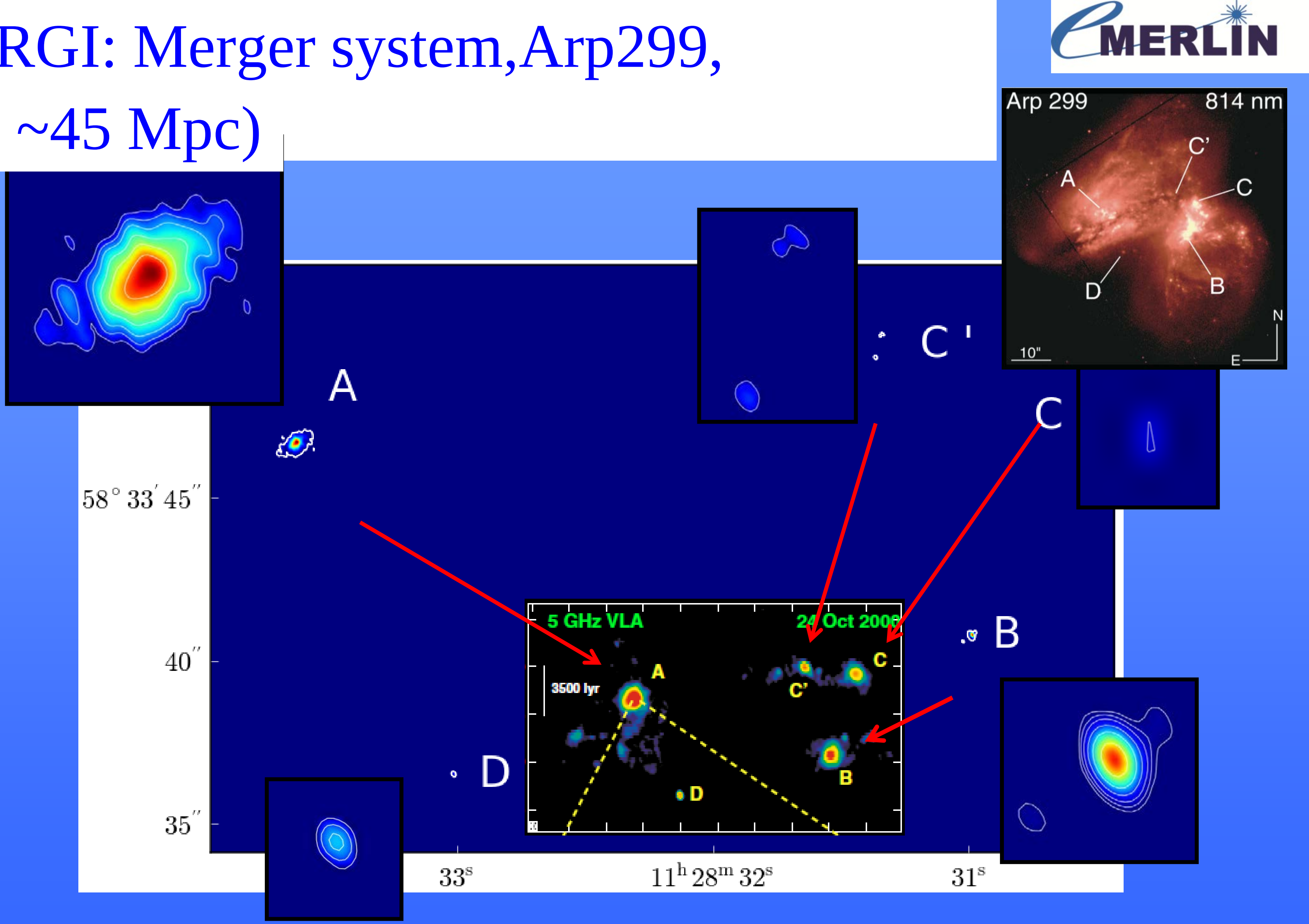




Recent e-EVN image RSNe in core

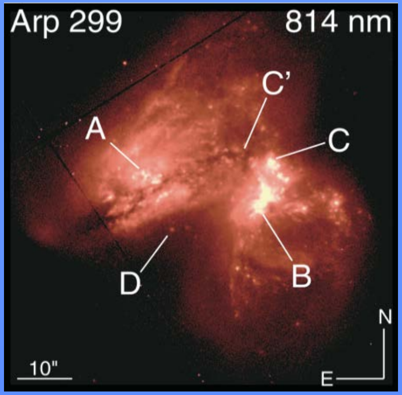
(Romero-Canizales A&A submitted – e-MERLIN + eEVN results, plus part of Romero-Canizales PhD)

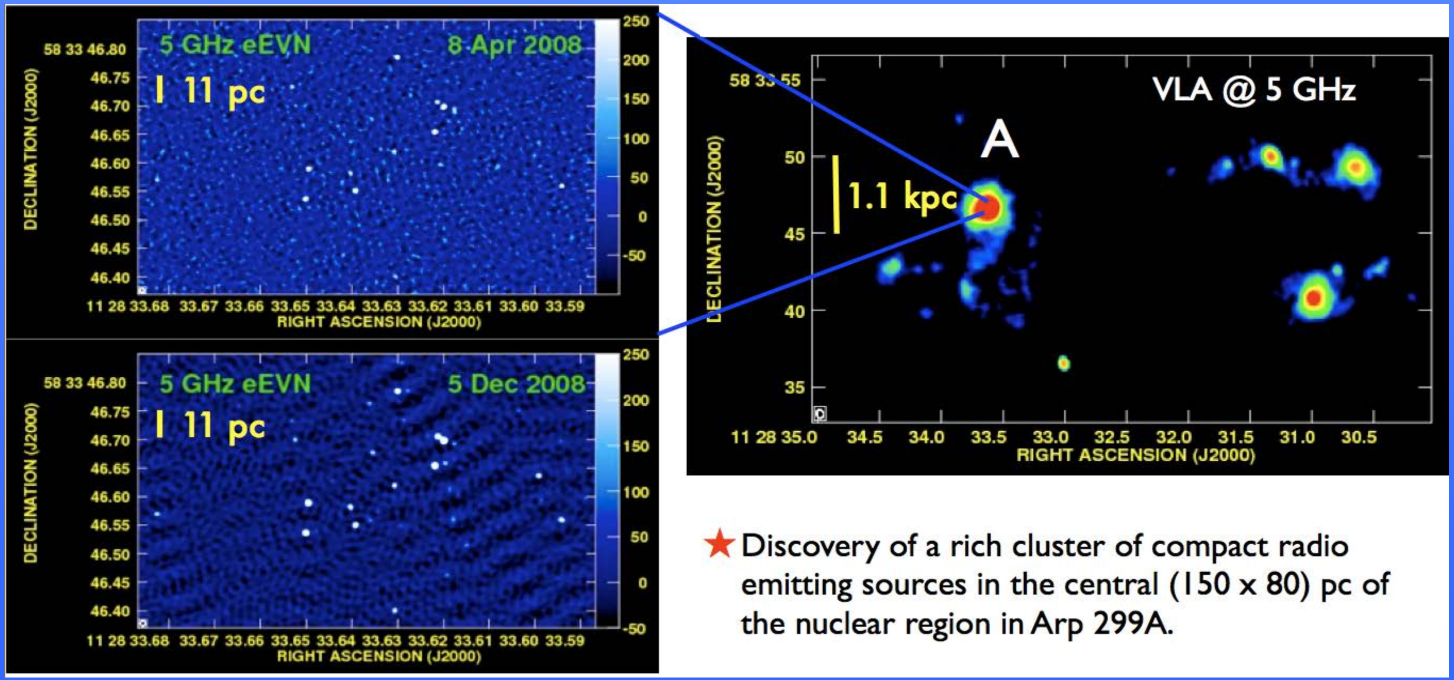
LIRGI: Merger system,Arp299, (D ~45 Mpc)



Data reduction by Herrero-Illana (PhD student) work ongoing

LIRGI: Merger system,Arp299, (D ~45Mpc), with a prolific SNe factory.





★ Discovery of a rich cluster of compact radio emitting sources in the central (150 x 80) pc of the nuclear region in Arp 299A.

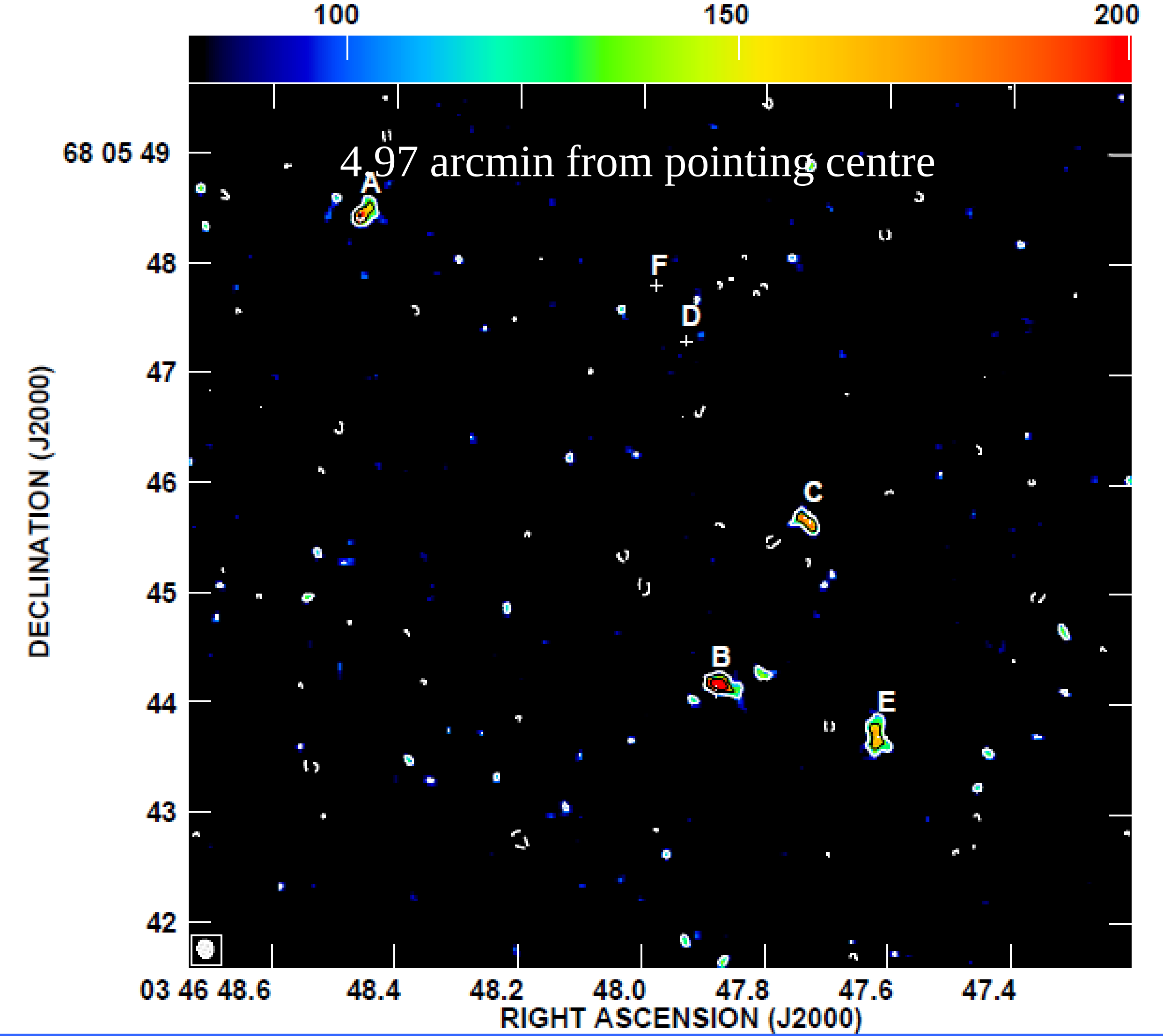
(Perez-Torres 2009 A&A)

Other Nearby Galaxies – IC342

- IC342 nearby (3.93Mpc) spiral galaxy
  - Part of LeMMINGs legacy survey (PI: Beswick)
  - Observations part of a campaign by Stephane Corbel (CEA, France)
- Major radio emission of galaxy ~5arcmin from target pointing (IC342-X1)
- IC342 X-1 = 10^4 $M_\odot$ ULX source IC342-X1 (Cseh et al 2011)
  - No radio detection at x-ray position of X1

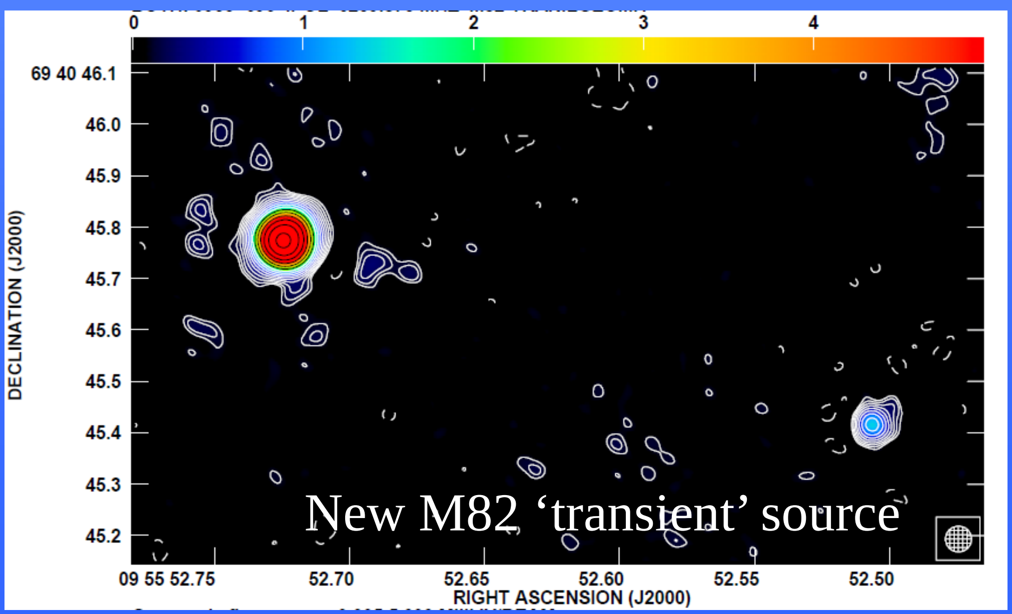
  >100uJy/bm (3σ)

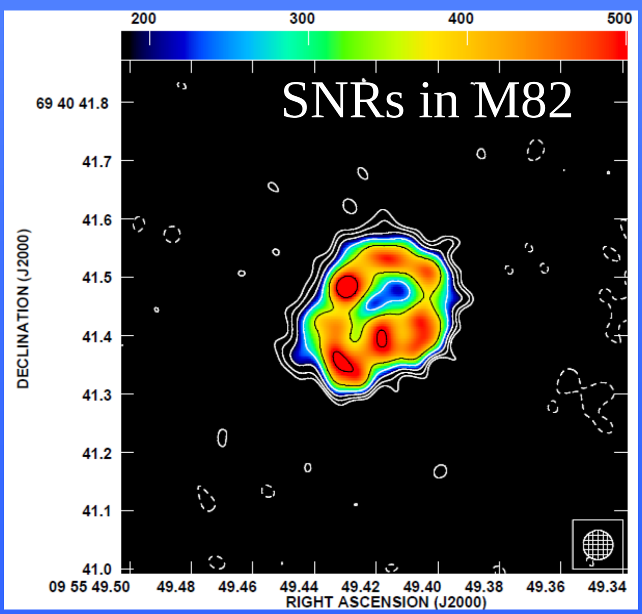
  (Variable/compact?)



M82 – a nearby SNR laboratory

- Continued monitoring of SNRs in M82 (Muxlow/Beswick/Fenech/Gendre) – part of long term MERLIN+e-MERLIN flux monitoring campaign (Gendre et al MNRAS in prep) – Part of LeMMINGs legacy project
- High fidelity e-MERLIN images of individual SNR shells
  - Tracking the evolution of new M82 Transient source (Discovered by Muxlow et al 2010)



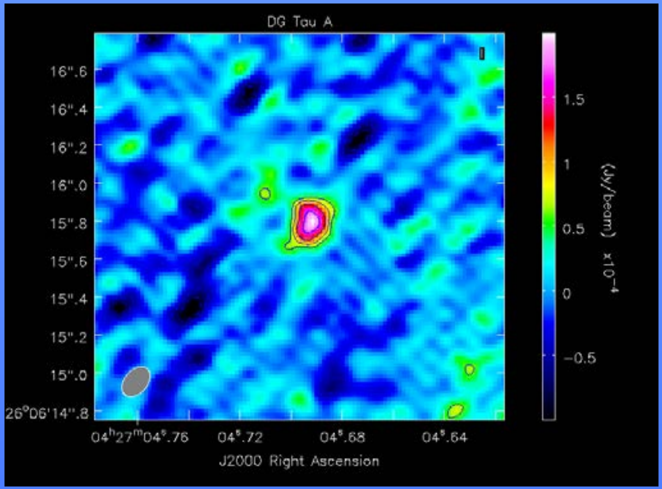


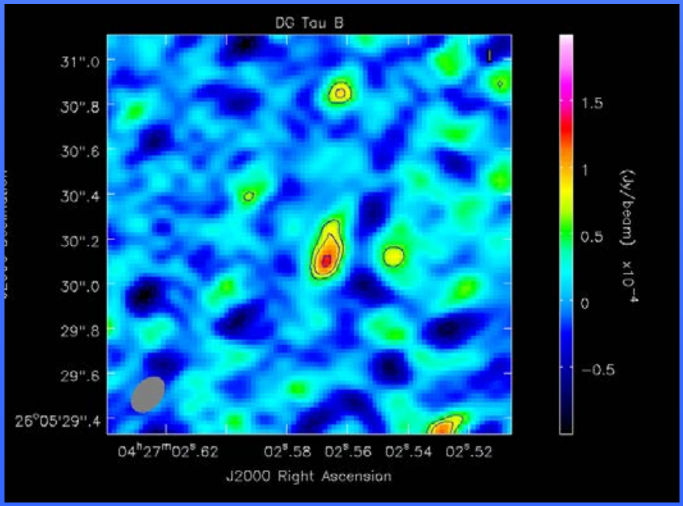
Protoplanetary disk – DG Tau

- Exploratory obs of DG Tau field
  - Part of Pebbles legacy program (Greaves et al)
    - Search for Planetary building blocks
  - Also commissioning request T. Ray (related to stellar jets legacy project)
- Observation at 4.5-5GHz (No CM)
- Imaging of both DG Tau A & B
  - Central star emission combination of thermal and dust emission
  - Jet emission from DG Tau A

(Multi-scale imaging in CASA)

DG Tau A

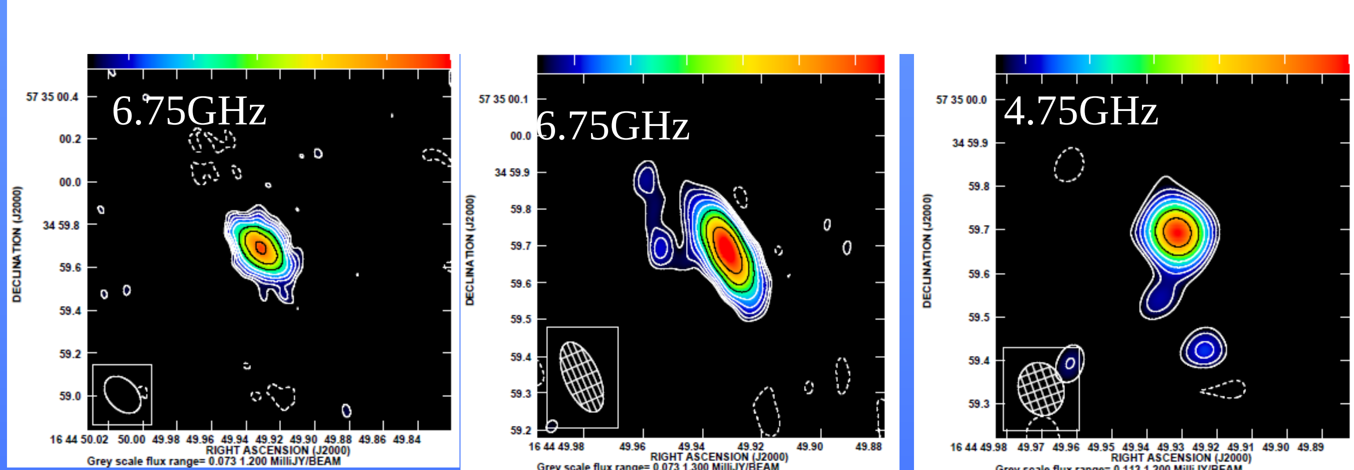




DG Tau B

GRB 110328A/Swift J164449.3+573451

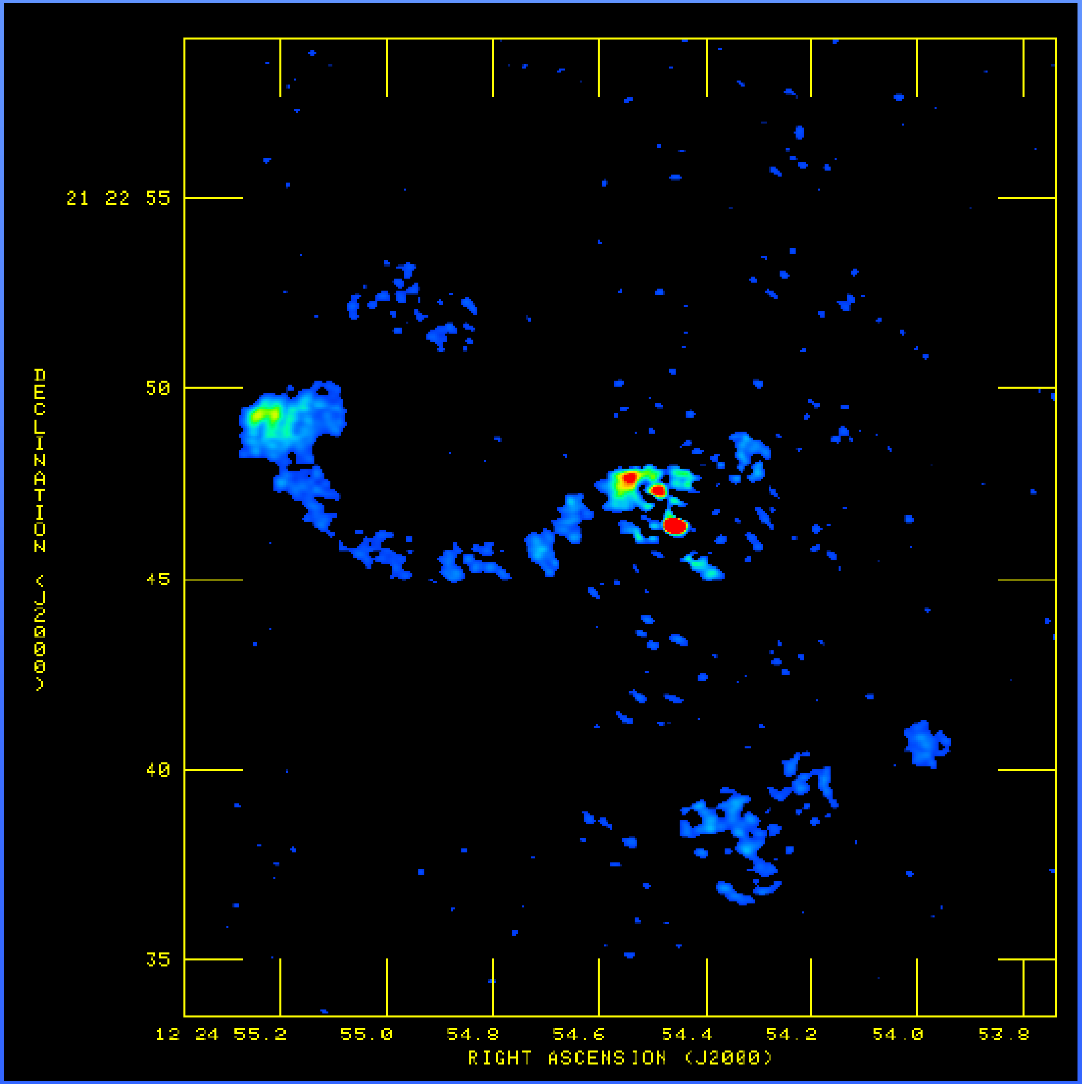
March 31st 2011 April 3rd 2011 April 5th 2011



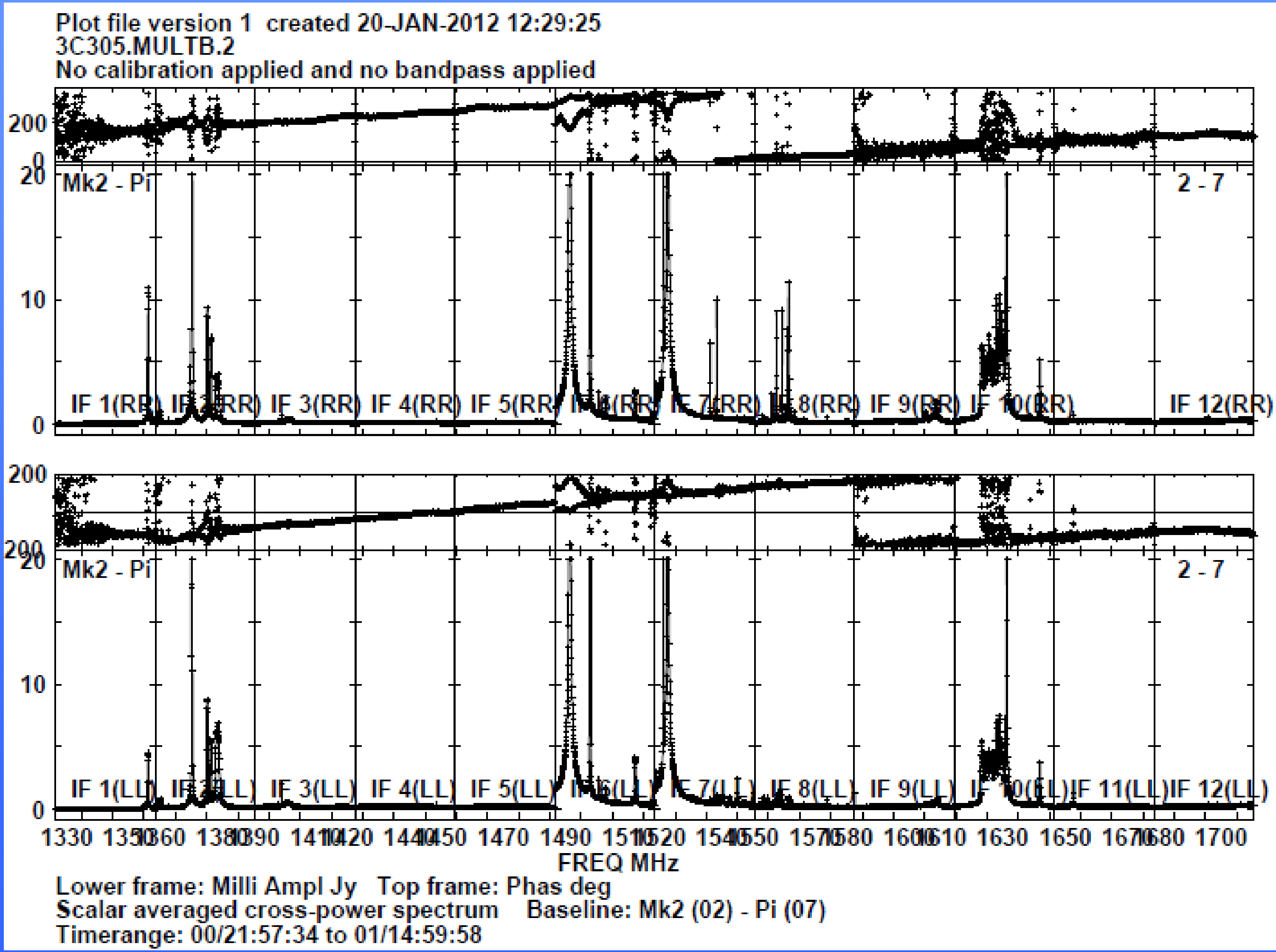
- GRB 110328A/Swift J164449.3+573451 – powerful, persistent x-ray source flared at γ-rays on 28th March 2011
- Rapid response observation detected radio emission – consistent with eVLA/VLBA/WSRT monitoring
- (Zaunder et al., 2011,Nature & Levan et al., 2011, Nature)
- Source located in z=0.35 galaxy
- Origin of emission likely to be tidal disruption of star plunging into SMBH (Bloom et al 2011, Sci)
  - e-MERLIN detection and radio monitoring at 5-7GHz

First L-Band Observations

- 1Jy core, DR limited image at present.
- Single sub-band image



Raw baseline spectra (Jan 2012)



PATT Proposals for Semester 12A

65 proposals received
Huge oversubscription

1/3 time Test observations / commissioning
1/3 time Legacy programmes
1/3 time PATT allocated programmes

Thank you

Thank You

The Resolution of a Telescope is dependent upon its SIZE & the WAVELENGTH at which it is used.

Hubble Space Telescope
Diameter = 2.4 m.

Green Light = ~ 5000 Å

Resolution = ~ 50 milliarcsecs

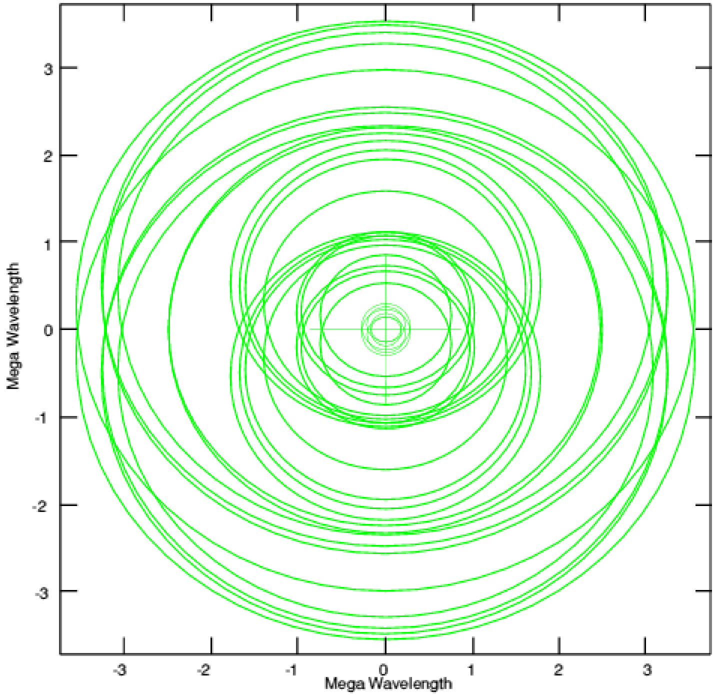
For an equivalent resolution at 6 cm, need ~ 200 km telescope

6 / 7 Telescopes

Maximum Spacing ~ 217 km. (Ca – Kn)

Minimum Spacing ~ 12 km (JB – Ta)

Resolution ~ 45 milliarcsecond at 5 GHz.

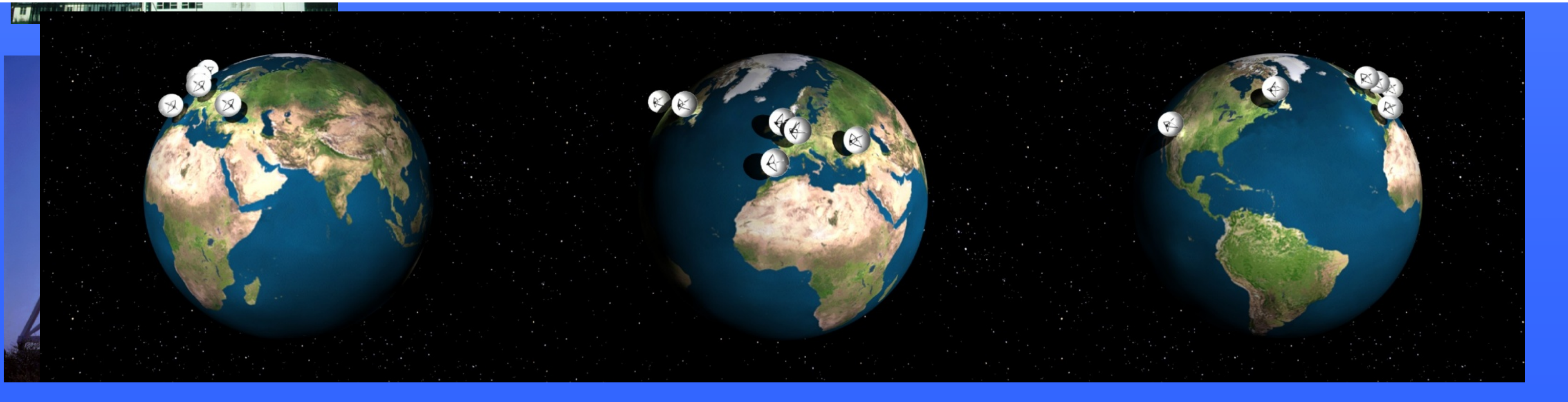


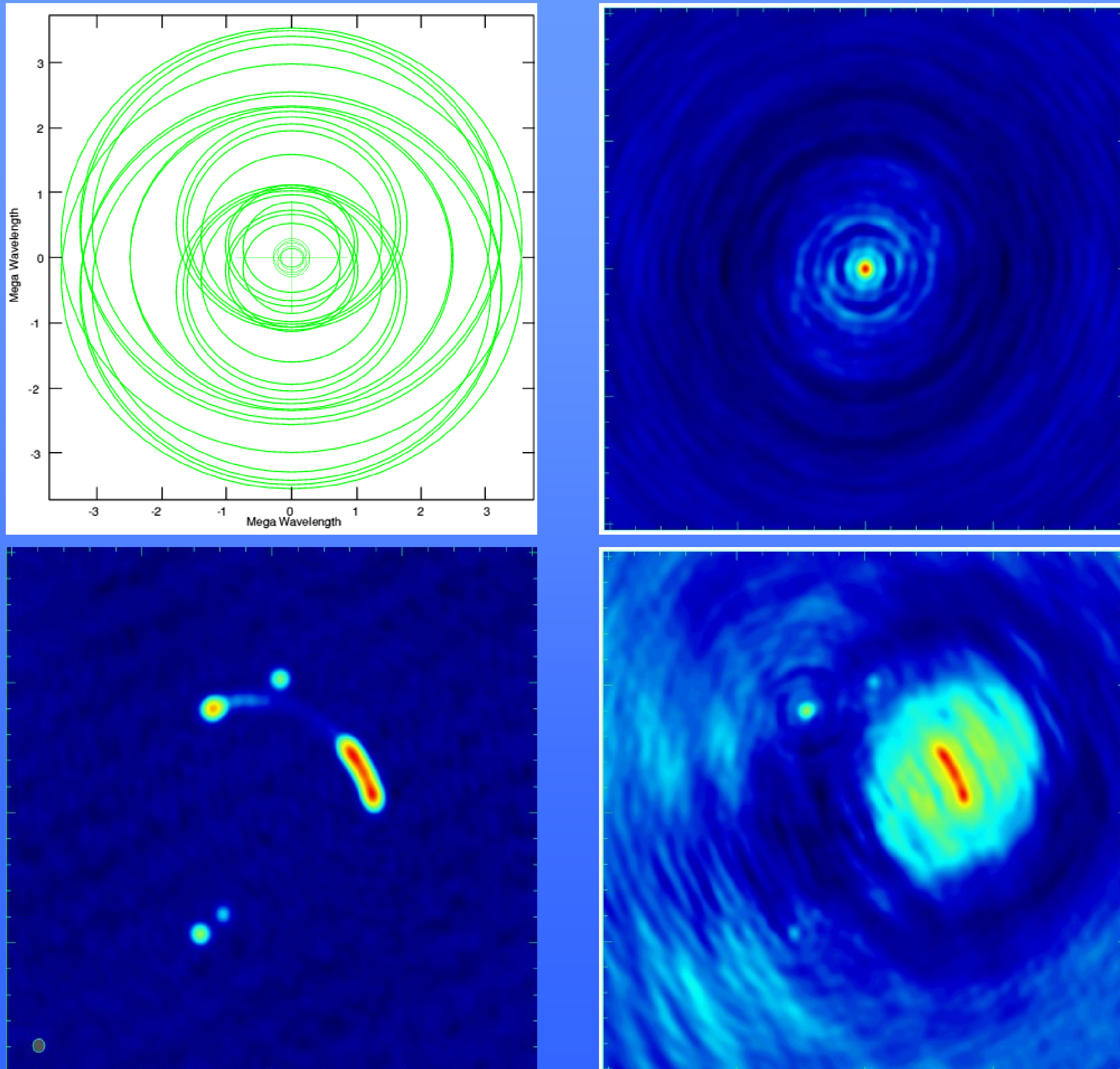
Radio Links for:-

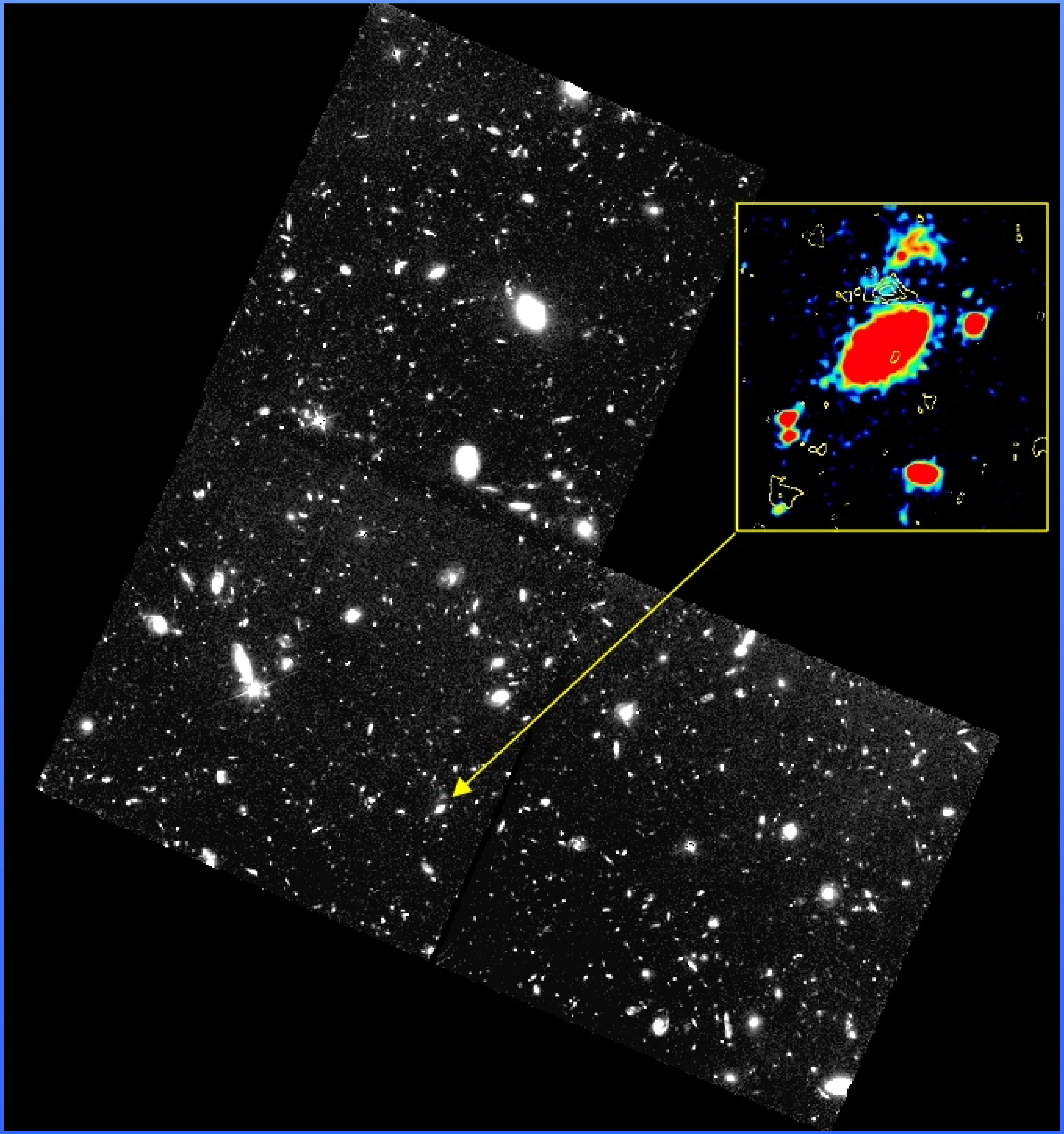
a) Data (Microwave link)

b) Frequency locking & time (L-Band link)

Computer Link (‘Own’ telephone lines)

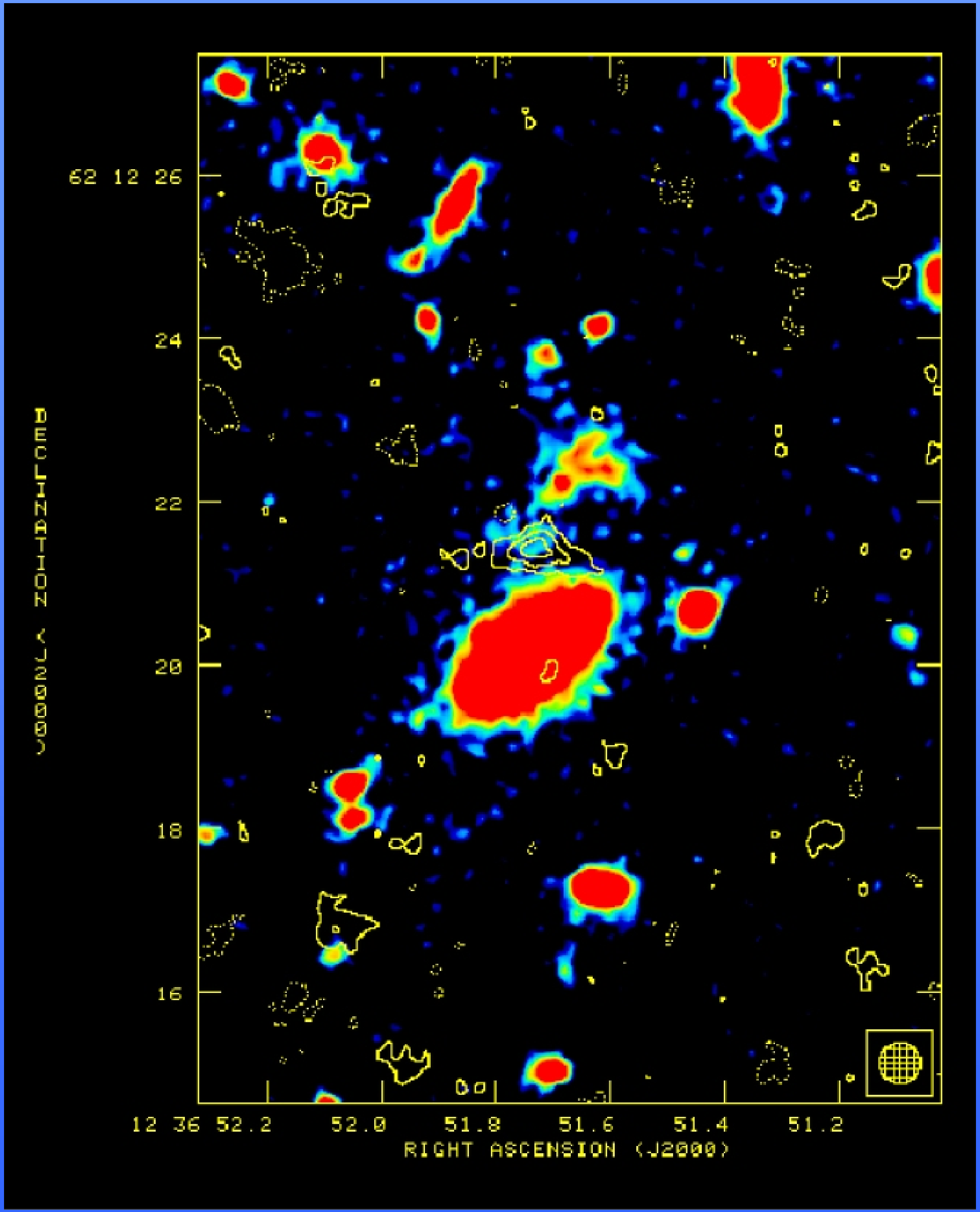



Mega Wavelength
Mega Wavelength
3
2
1
0
-1
-2
-3
-3
-2
-1
0
1
2
3

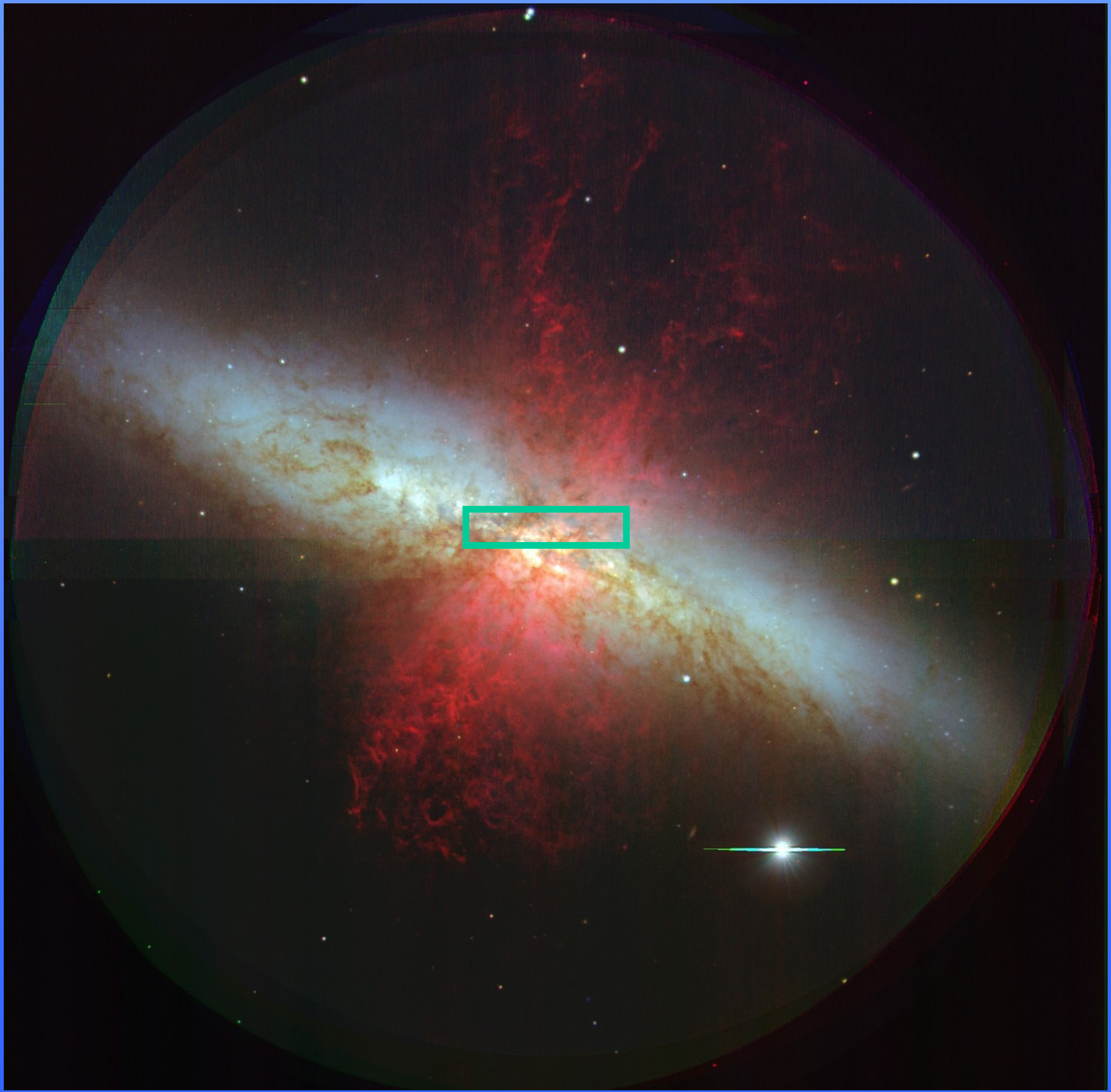


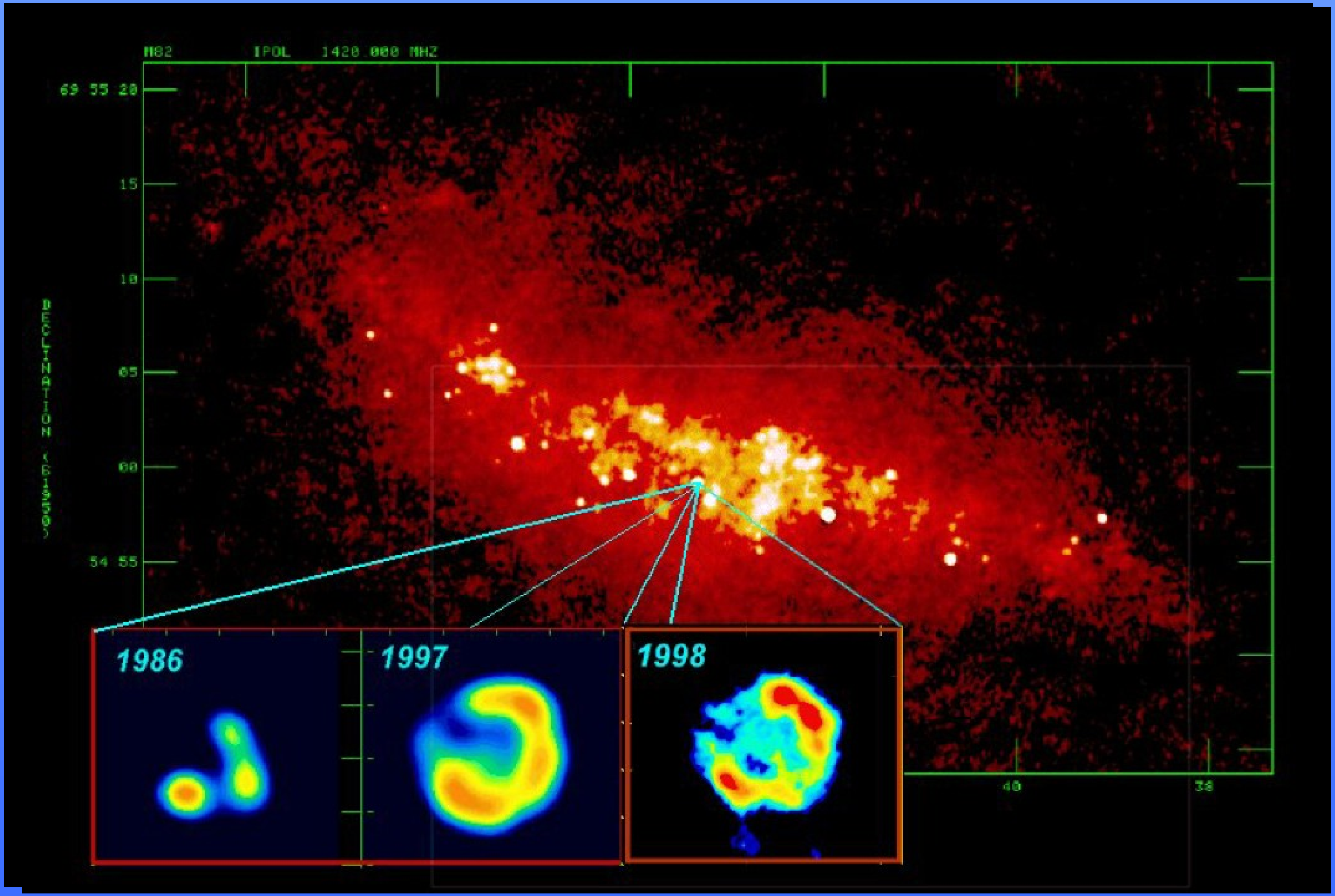
MERLIN Astrometry is extremely good

We told the HST observers where they were pointing.



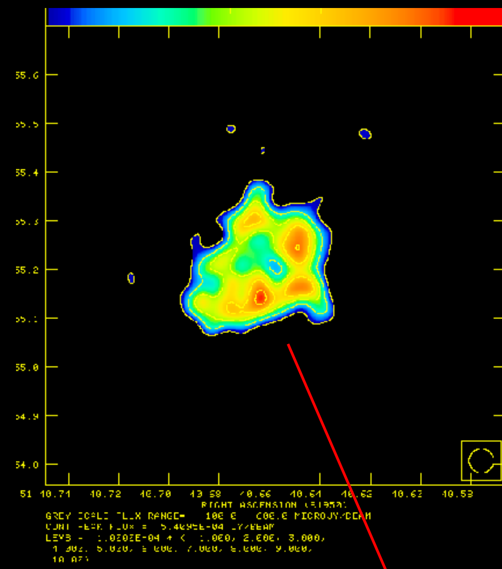
Object associated with the radio source is a galaxy with a redshift >4

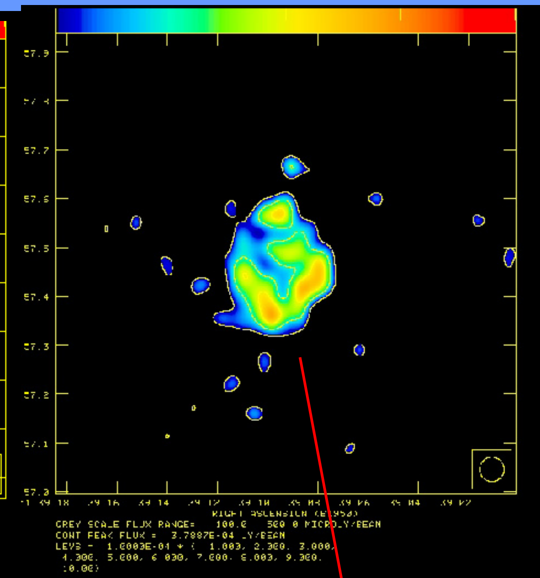


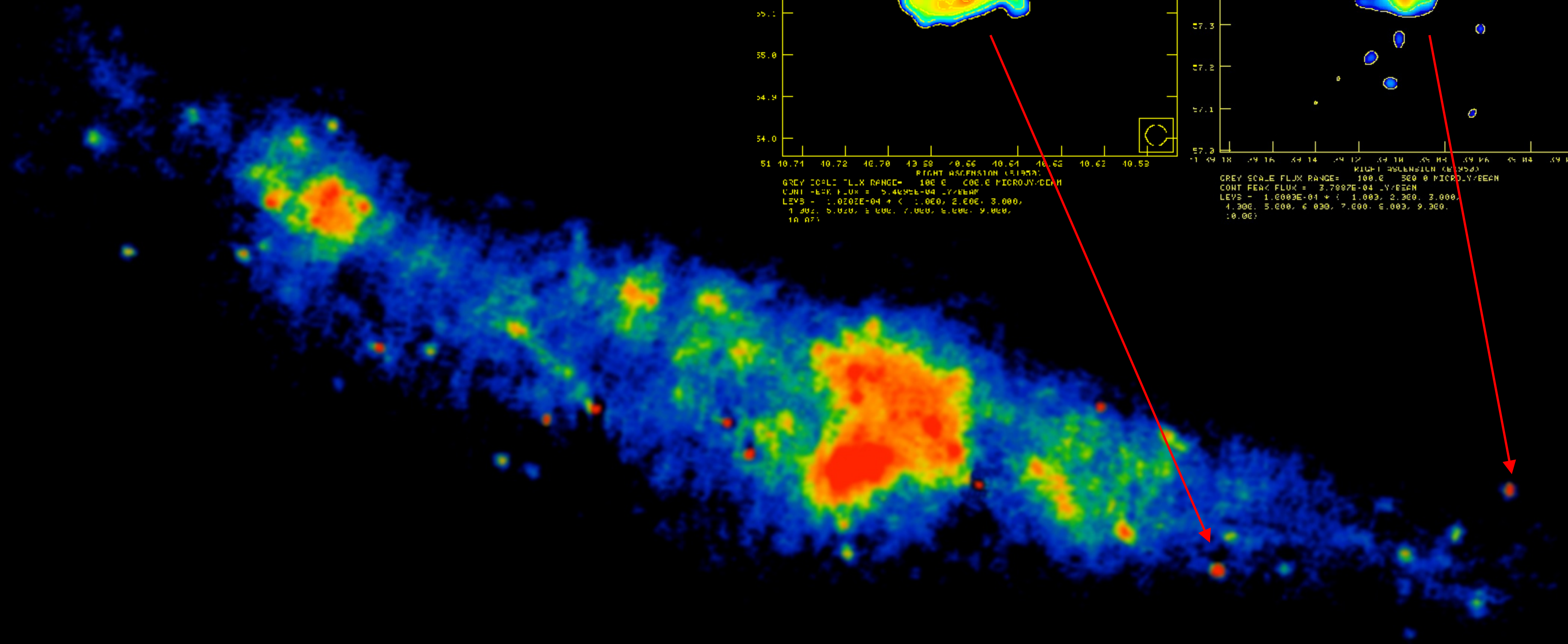


MERLIN + VLA Image of M82 at L-Band
showing supernova remnants

MERLIN resolves all the SNR visible in M82 – derive size distribution







MERLIN (MFS) +VLA 1995

MERLIN Operating Frequencies & Sensitivity

151 MHz	408 MHz	1.33 – 1.43 GHz 1.57 – 1.73 GHz	4.5 – 5.2 GHz	(6.0 – 7.0 GHz)	22.0 – 24.0 GHz
7000µJy/b	700µJy/b	60µJy/b (30µJy/b)	50µJy/b (30µJy/b)	Tsys ~ 70 K	400µJy/b

Improve Sensitivity with:

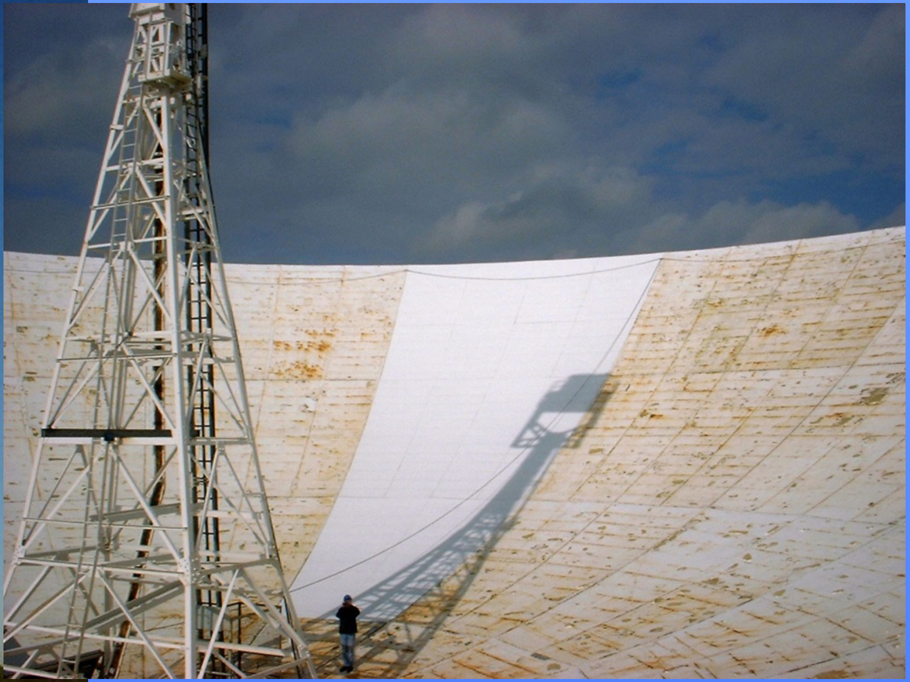
- More, Larger and More Efficient Telescopes (Yes / No)
- Improved System Noise Temperatures. (Some possibility)
- Increase Bandwidths (16 MHz per pol. - Definitely)

1. Improve the gain of our telescope.
   (New surface & drive system for the Lovell 76m telescope.)

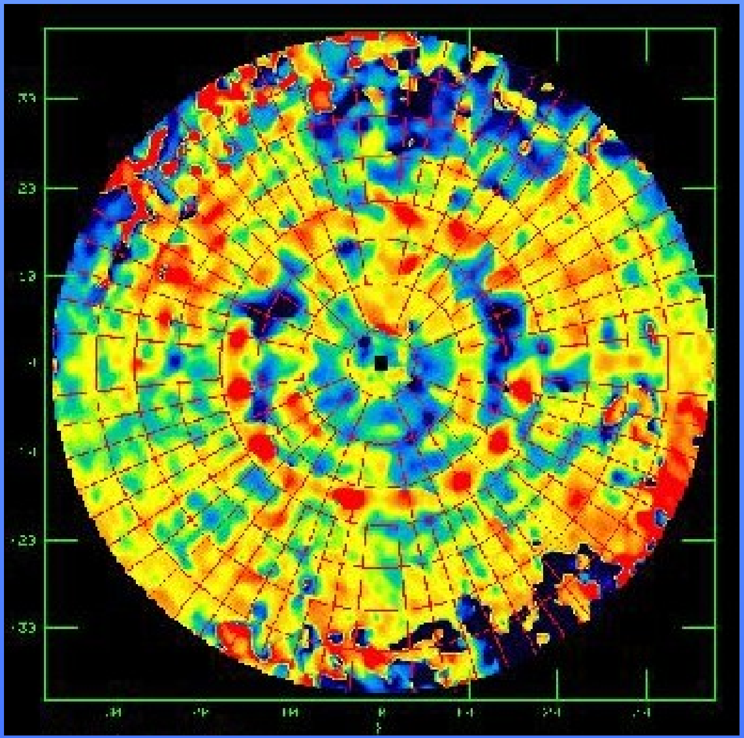
2. Increased bandwidth means wider bandwidth receivers.
   (Develop new very low noise receivers and feeds with very low polarization residuals across the whole band – frequency range at C-Band = 4 – 8 GHz)

3. JBO has developed optical fibre Tx / Rx system for ALMA

2 & 3 are required for the SKA

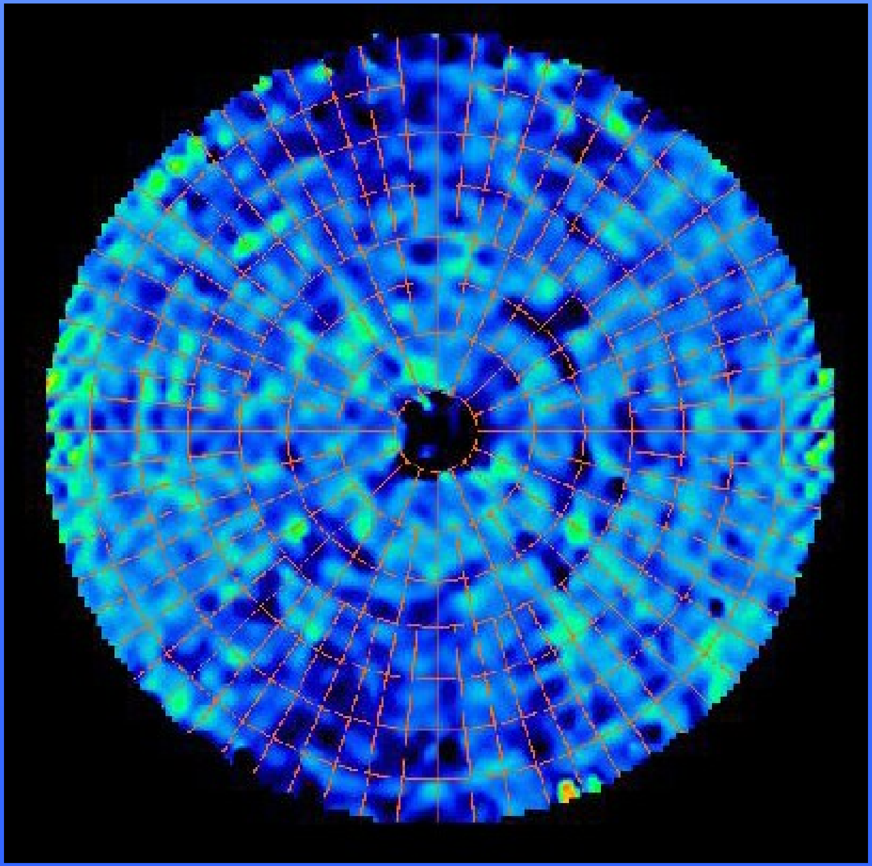




Lovell Telescope Surface Holograms



OLD

NEW

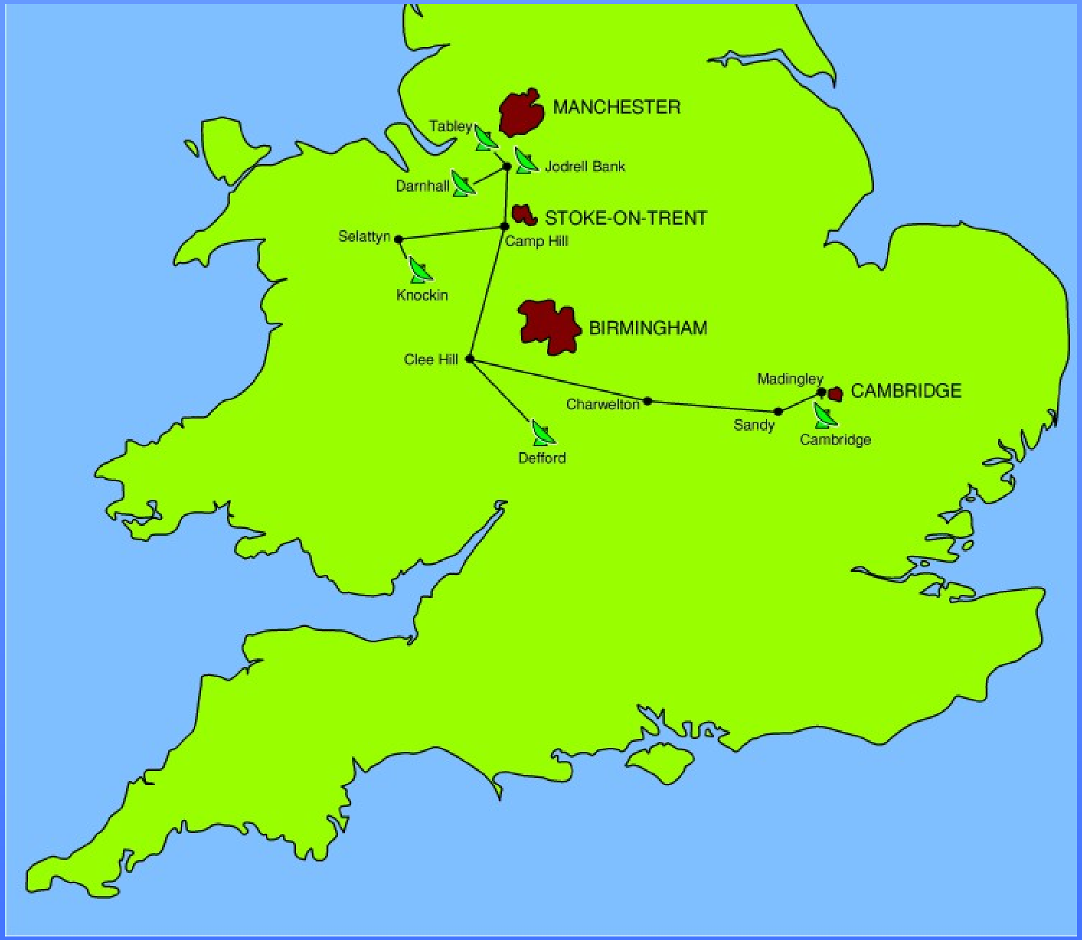


Now at 5 GHz, the sensitivity is within a factor of 2 of its maximum – i.e. a factor of 5 better than it was before.

e-MERLIN

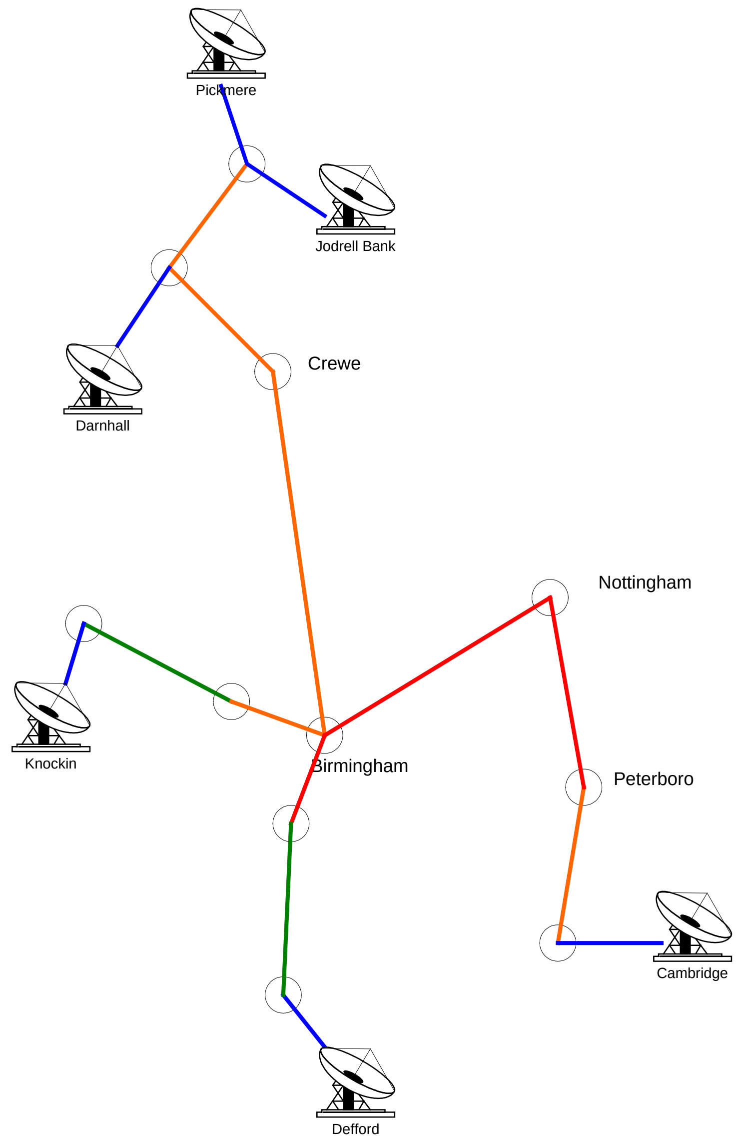
- Replace Microwave Data Link with optical fibres
- For a 2 GHz bandwidth (4 GHz sampling)
- Require 30 Gb/s from each telescope to correlator at Jodrell Bank

  (2 GHz/pol @ 3bits = 24G)
- Tx/Rx design developed at JBO (12 x 10 Gb/s) for ALMA use.
- Own dark fibre - e-MERLIN uses 3 x 10.0G
- Some digging required … biggest single cost in project.


MANCHESTER
Tabley
Jodrell Bank
Darnhall
STOKE-ON-TRENT
Selattyn
Camp Hill
Knockin
BIRMINGHAM
Clee Hill
Madingley
CAMBRIDGE
Charwelton
Sandy
Cambridge
Defford

Data Transmission Network Solution

- Fujitsu (FTEL,UK) installed & tested 90km new fibre alongside minor roads to connect to…
- Dark fibre trunks provided mainly by Global Crossing (UK)
- Maintenance contract for entire network
- Amplifiers/Regeneration at Peterborough, Nottingham, Birmingham, Crewe, designed and installed by JBO



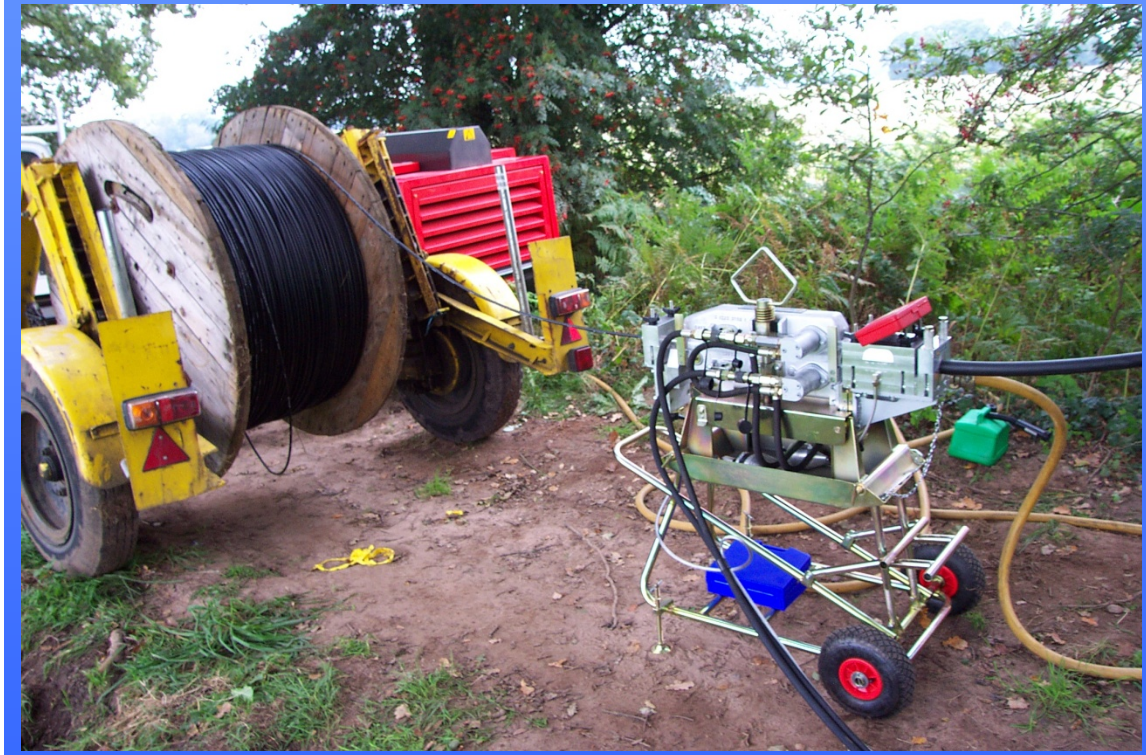
Optical fibre connections Installation

- Digging uses a variety of techniques,
- Directional drilling
- 90-km total dig

MOVIE

Cable blowing

- Cable ‘blown in’ using specialised equipment
- Avoids snagging, reduces forces (load is distributed)
- Installed in 2-4 km lengths



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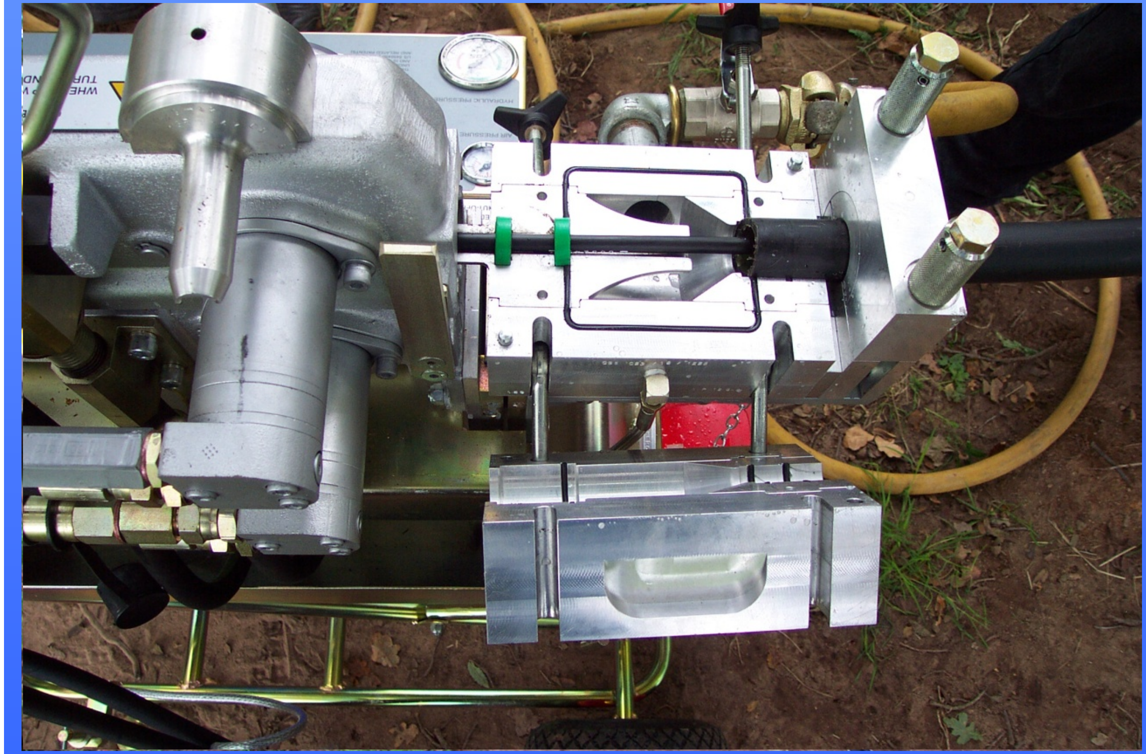
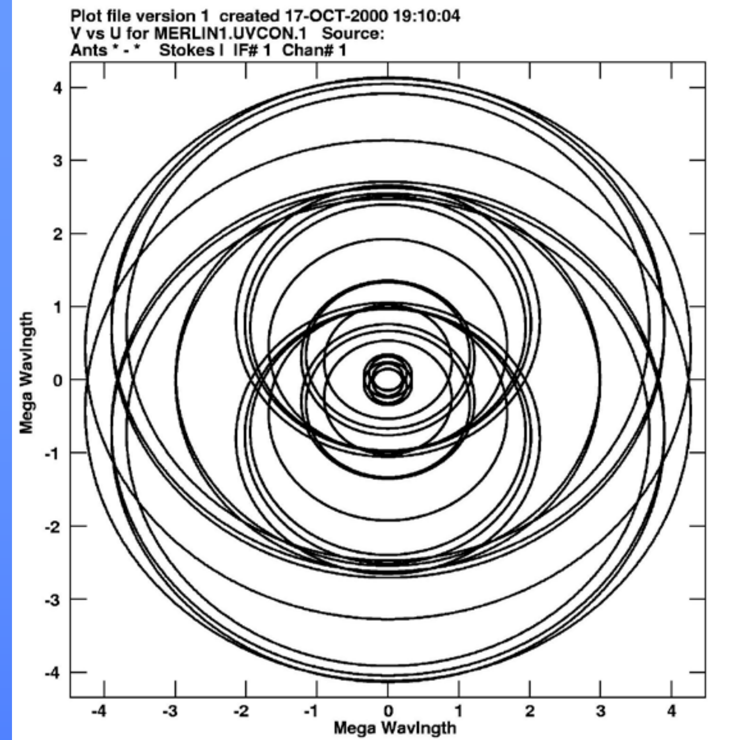
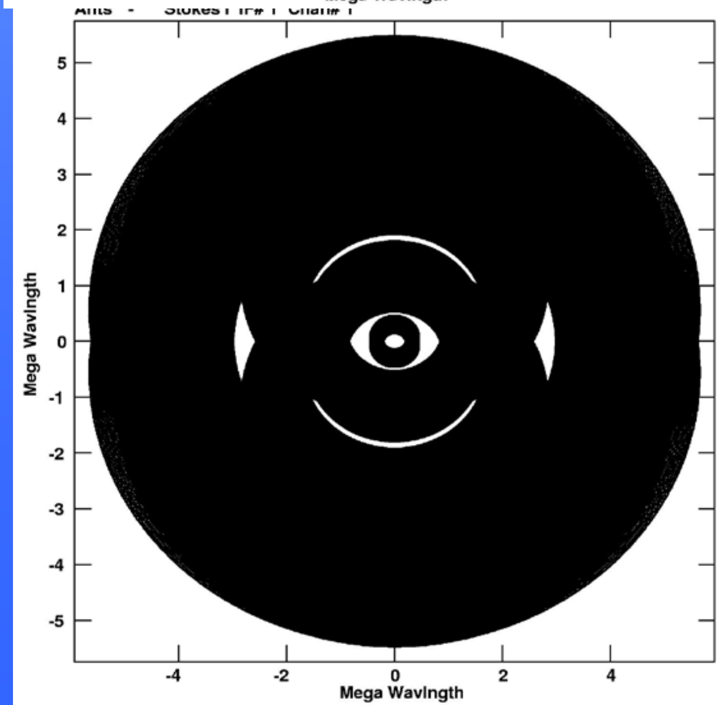


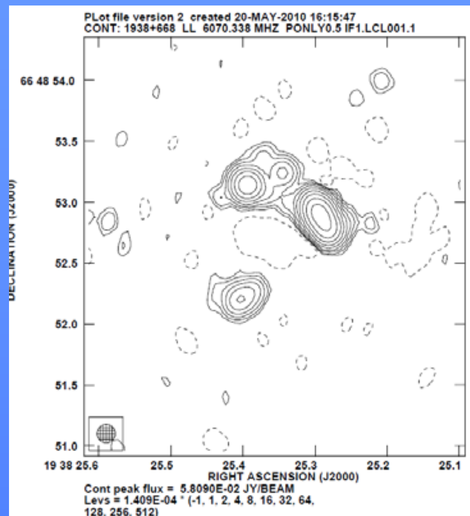
e-MERLIN

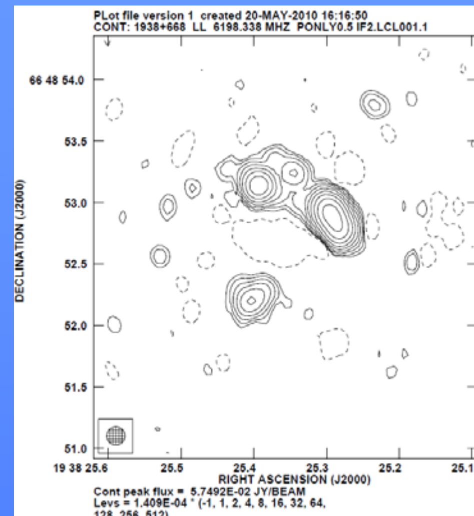
- 100x bandwidth (■>4GHz)
  - Optical fibres
  - B/W fills aperture plane
- New receivers
- Lovell now good to <~12GHz
- 10 - 30 x sensitivity
- FOV limited by primary beam: 15' at 1.4 GHz
  - 18kx18k pixel potential images
- ICRF mas astrometry
  - fainter reference sources
- Multi-line spectral imaging + continuum + polarization

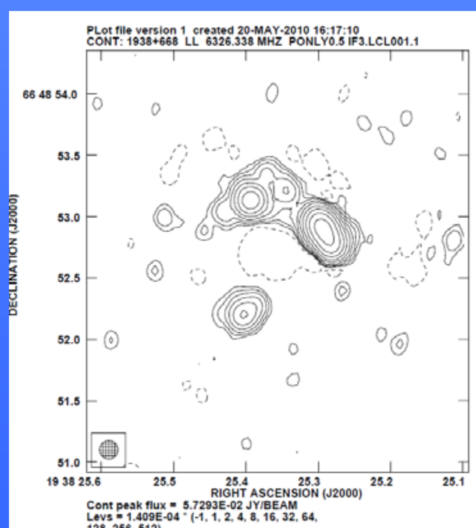


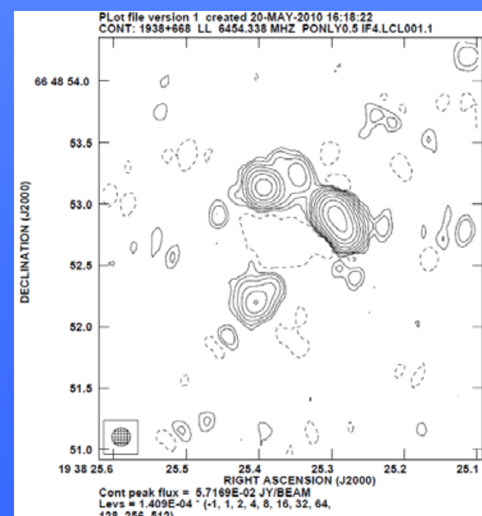


Individual sub-bands









Combined sub-bands

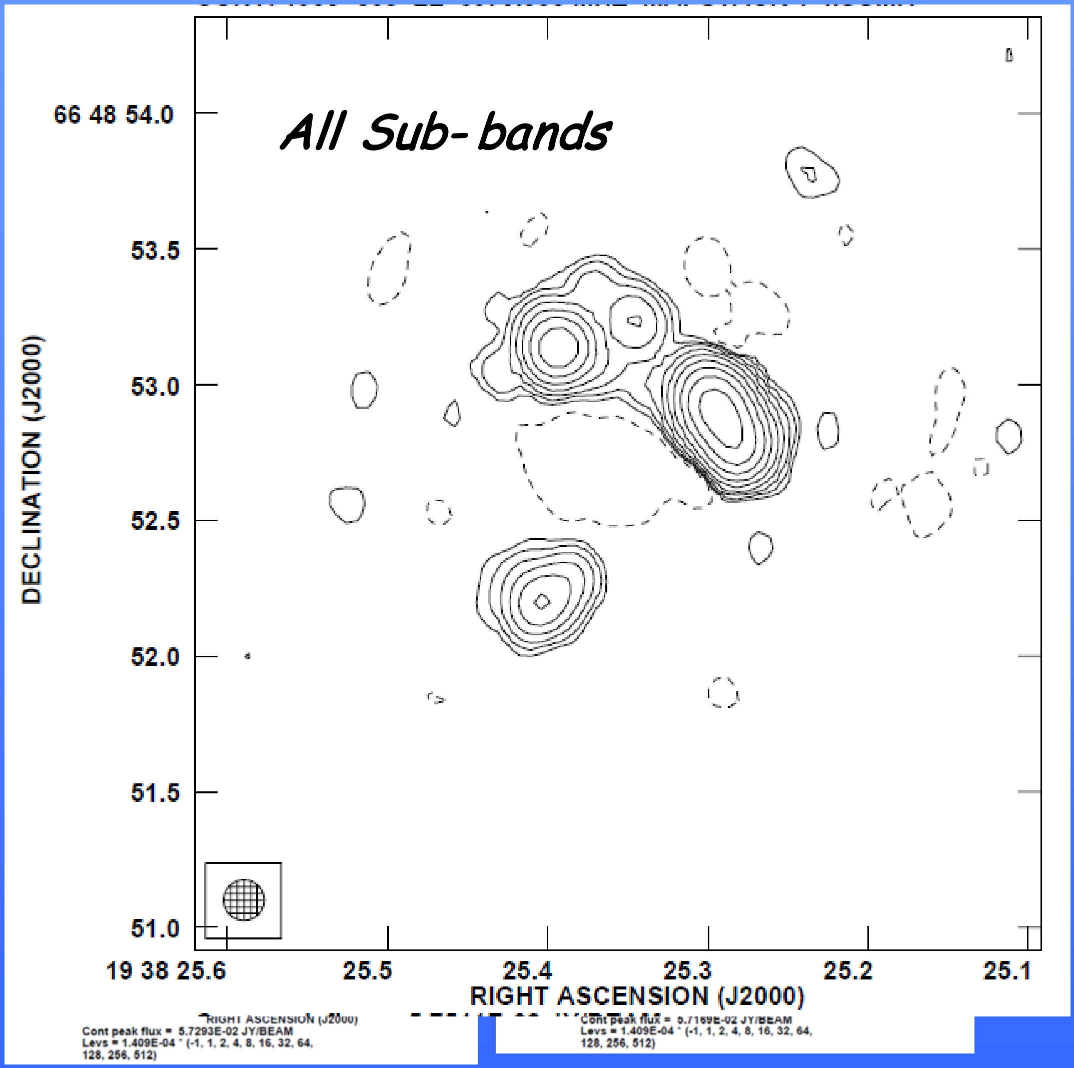


Image noise/quality

- Final noise in image ~30uJy/b
  - Dynamic Range only ~few thousand:1
  - Expected noise levels
    - ~4 hrs data on-source
      - 1 pol, 1/4 final B/w, 4tels only
      - Compared with a full eMERLIN 12hr data set
      - These data should be less sensitive by a factor of

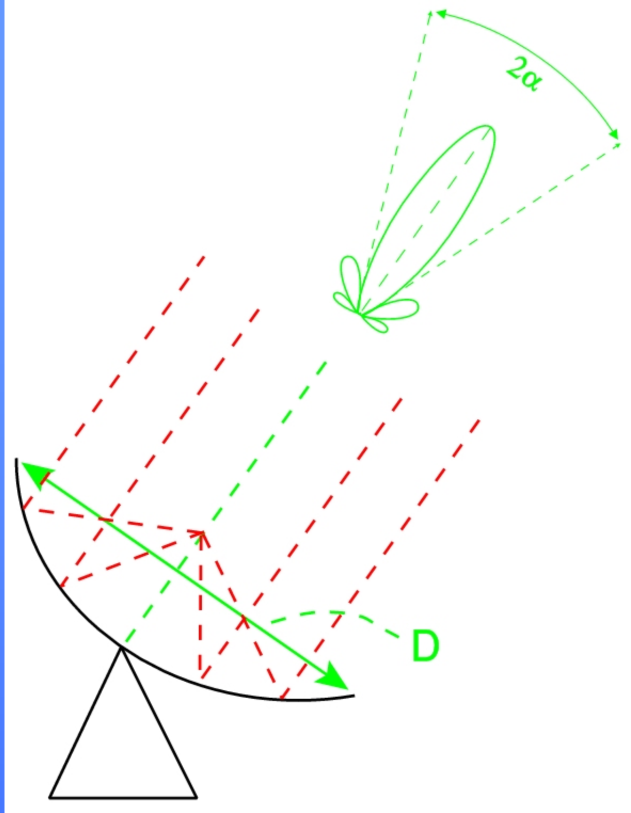
~2(B/W)*2(Pols)*√2 (telescopes)*√3(time on source) ~10

~10 compared with a full-track eMERLIN run (~2.5uJy/b expected)

➔Field noise ~30uJy/b (ie. Approaching expected)

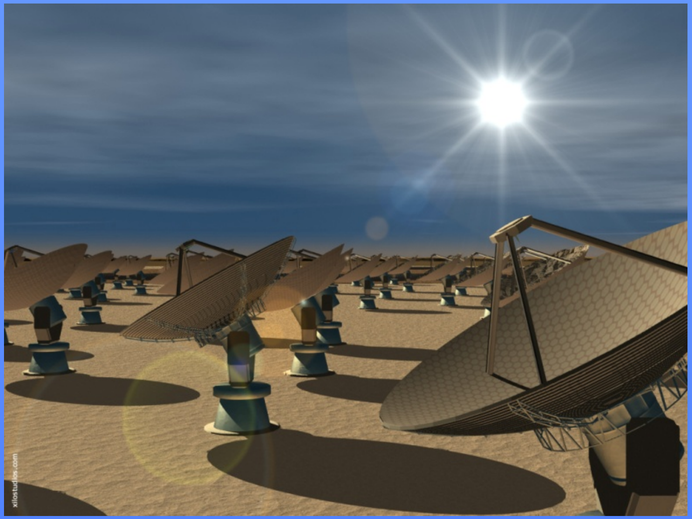
➔i.e. expect ~25uJy/b

- Image clearly has some Dynamic Range issues remaining.



$$\alpha \sim \frac{1.22\,\lambda}{D}$$

ASKAP



36 * 12m dishes (wide FOV)

Frequency range 0.7 to 1.8 GHz

30 Independent beams each ~1 sq. deg.

Instantaneous Bandwidth – 300 MHz

Maximum Baseline – 6km

2-PAD

Dual Polarization All Digital Phased Array

Frequency Range 0.3 to 1 GHz

Two Antenna designs

a) Bunny Ear Combine Antenna Array

b) Octagon Ring Antenna Array

32 signal paths

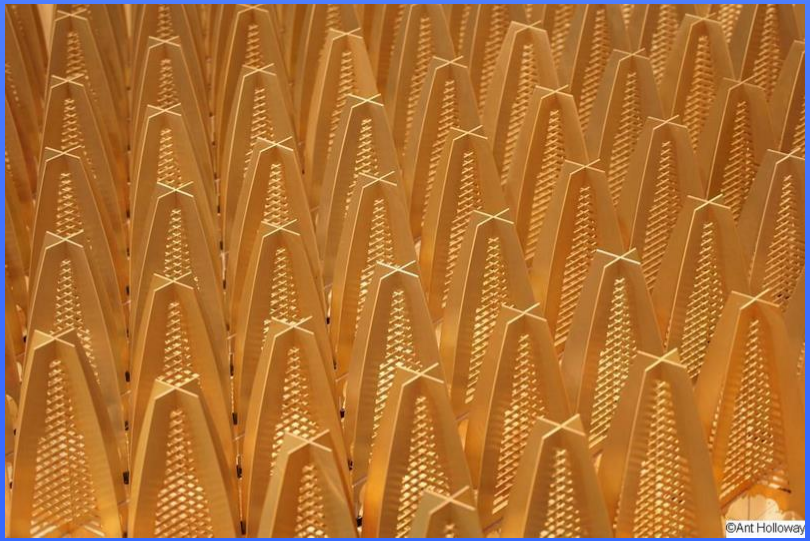
= 4 x 4 x 2 array

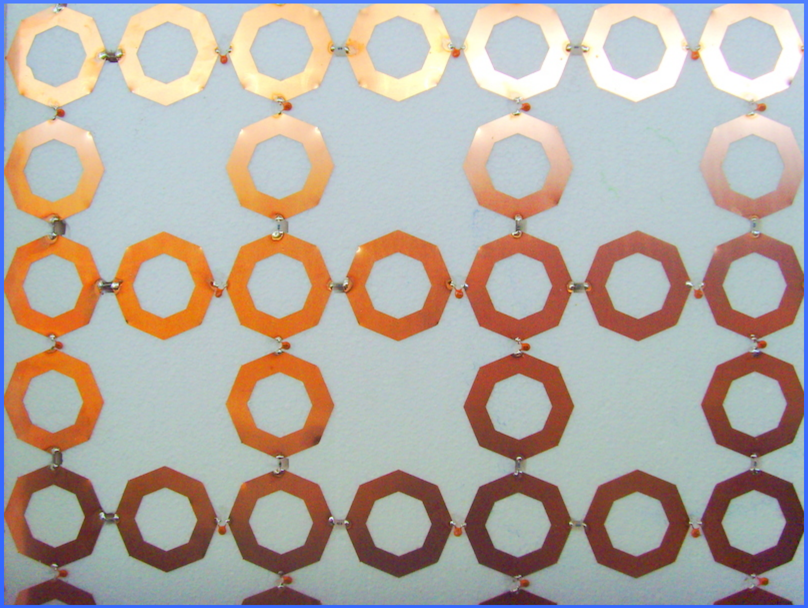
Software Beam-forming

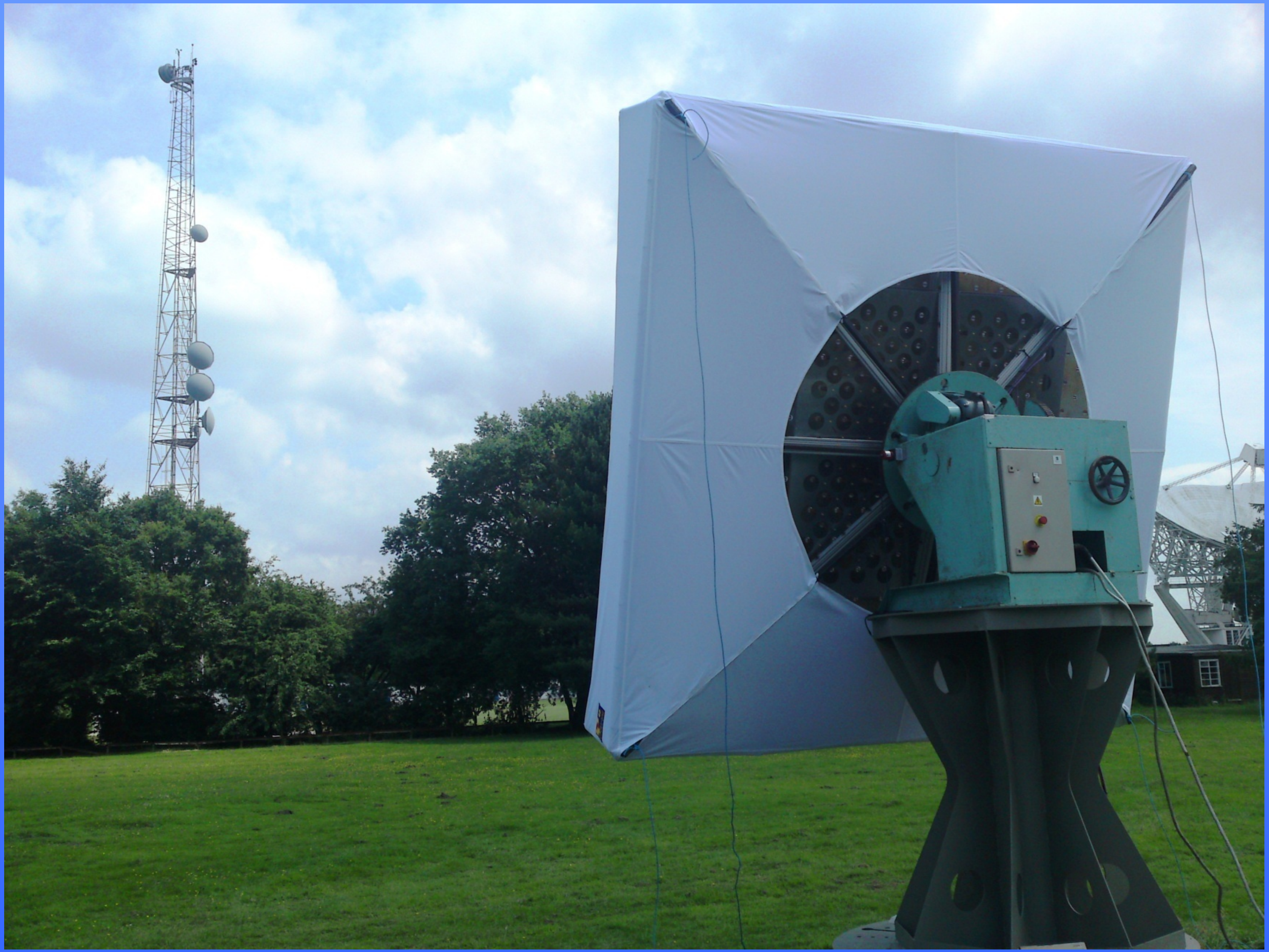
Digitisation

Channelisation

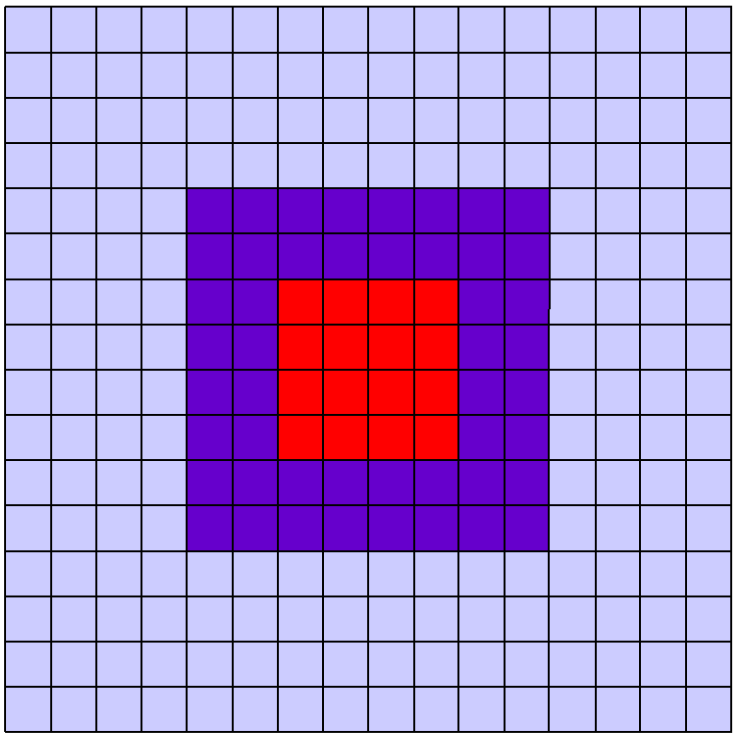
Beam-forming ?



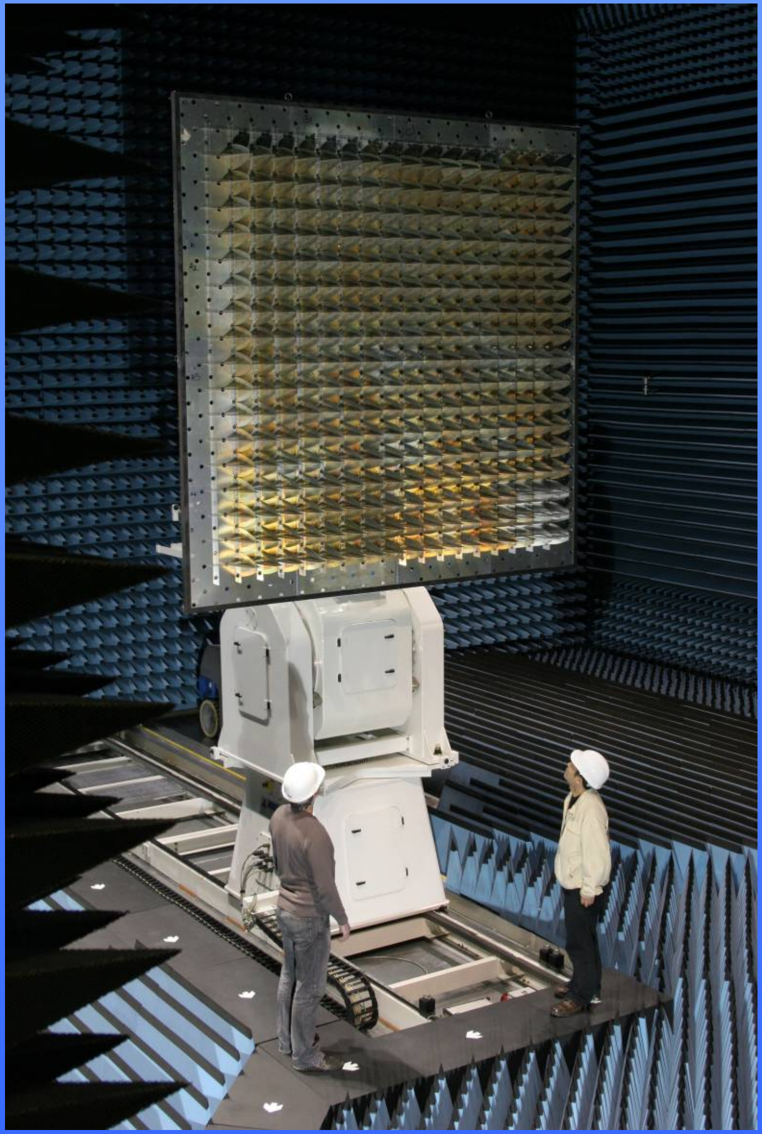


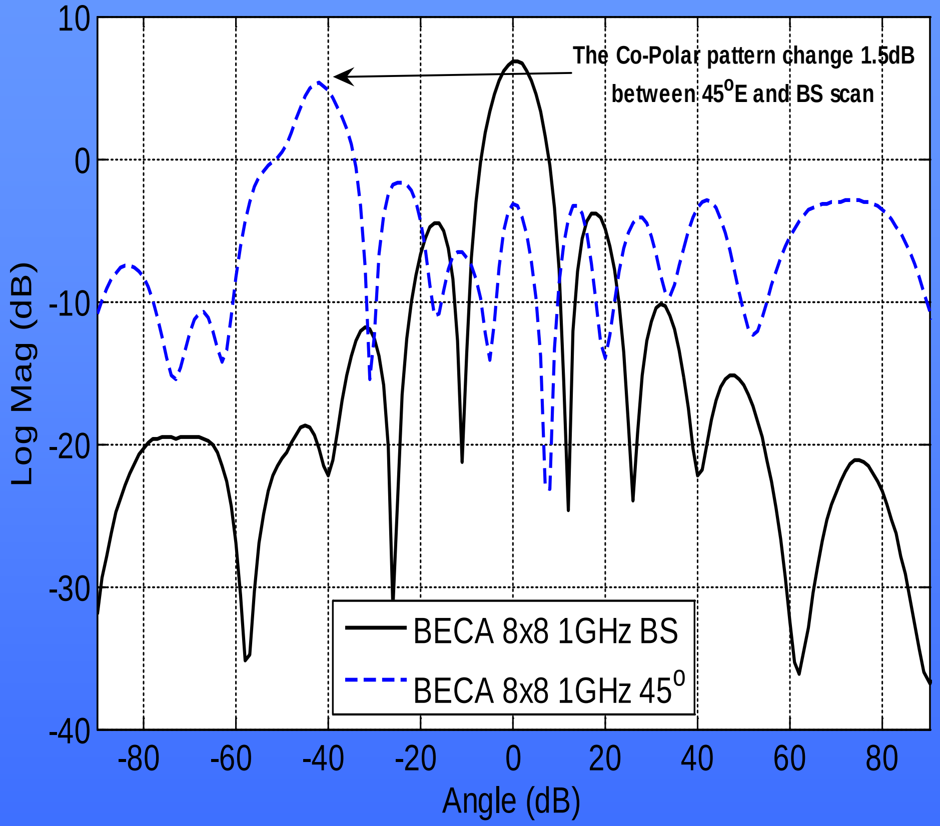


2-PAD: The Antennas

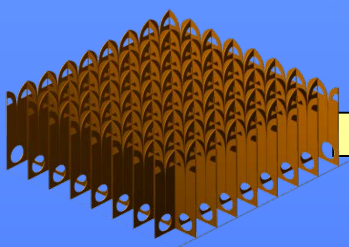


- 16 x 16 dual polarisation elements
- **RF Testing – 8 x 8 dual pol**
- **2-PAD V1 – 4 x 4 dual pol**
- **2-PAD V2 - 8 x 8 dual pol**
- Antennae at the edges are dummy loaded




The Co-Polar pattern change 1.5dB
between 45^{0}E and BS scan
BECA 8x8 1GHz BS
BECA 8x8 1GHz 45^{0}
Log Mag (dB)
10
0
-10
-20
-30
-40
-80
-60
-40
-20
0
20
40
60
80
Angle (dB)

2-PAD Simplified System Overview



LNA → Analogue Signal Transport → Digitiser Subsystem → Digital Signal Transport → Digital Beam-forming Processor →

Various

BECA
ORA
FlowPAD

Various

To suit
Antenna
Options

Gain Chain

CAT7
Cable

Sig Cond
Card

Midplane

DAQ Card

Clock
Distribution

CX4 10Gb/s

4x3.125Gb/s

8b10
Encoding

Streaming
Channel

No Transport
Overhead

Berkeley
FPGA
Board
Based
System

Or

IBM 20
Node
C64
“Cyclops”
Based
System

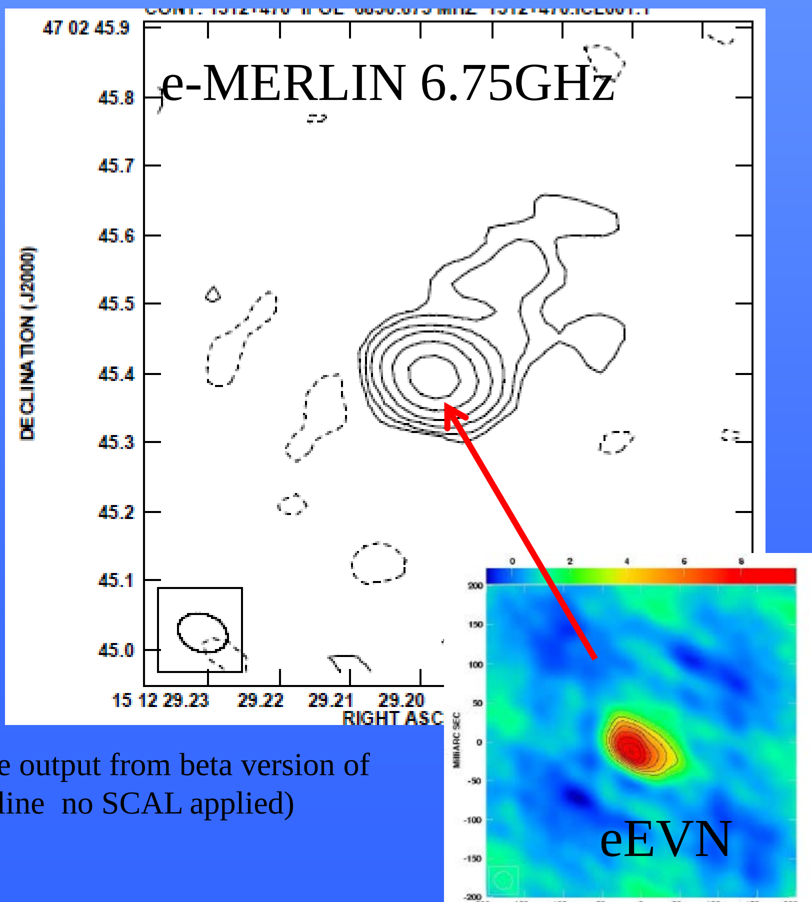
DELL Quad
Core ZEON
Server

2TB
Storage

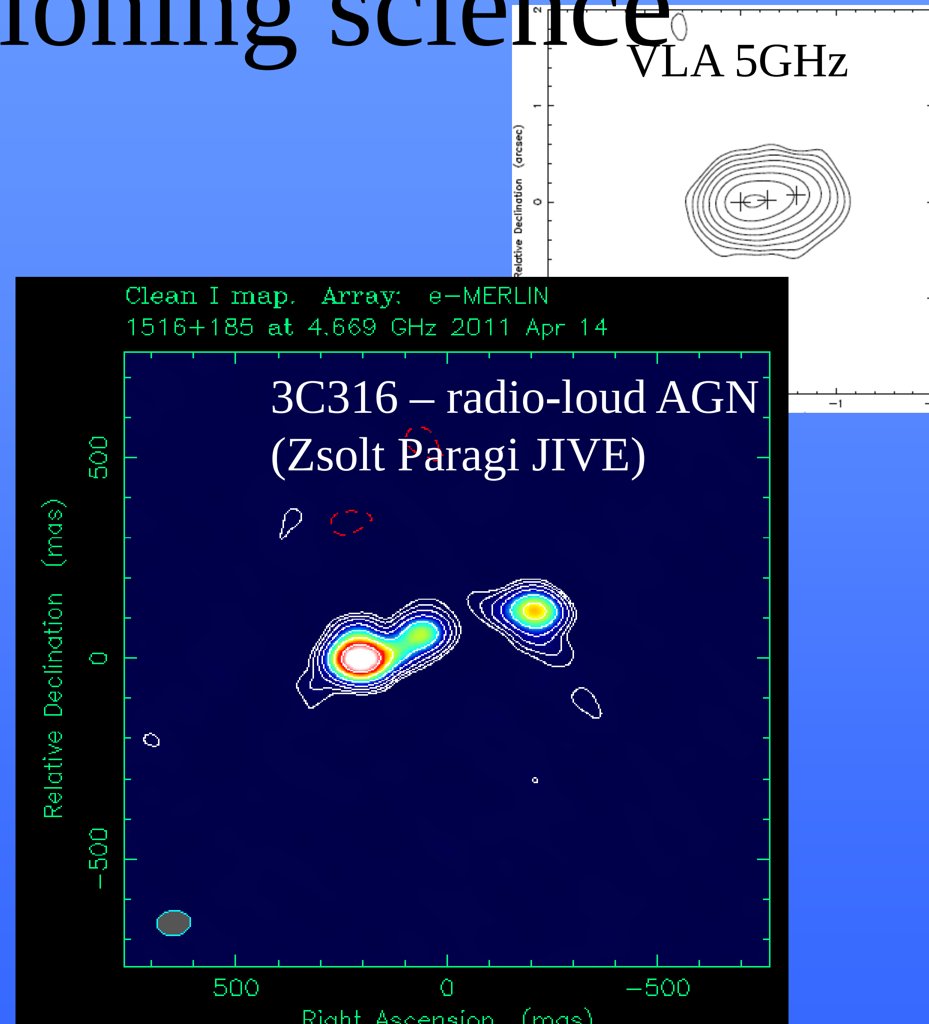
RHEL

More commissioning science

1512+470 – high redshift USS ($\alpha = -1.49$) – Mahmud (JIVE)



(Pure output from beta version of pipeline no SCAL applied)



(ongoing work)