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E-MERLIN and EVN/e-VLBI Capabilities, Issues & Requirements

- e-MERLIN: capabilities, expectations, issues
- EVN/e-VLBI: capabilities, development
- Requirements
  - Achieving sensitivity
  - Dealing with bandwidth, wide fields, dynamic range

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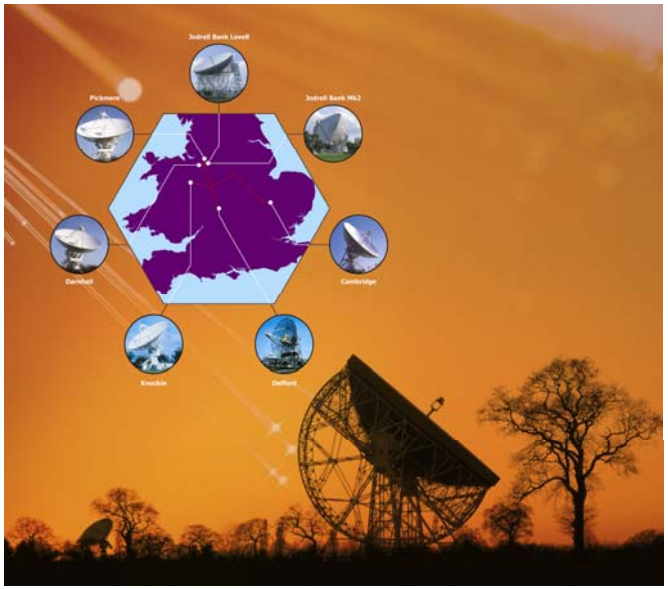
e-MERLIN

- Major upgrade to MERLIN
  - 7 antennas; 220km max baseline
  - 50 mas resolution at 5 GHz
- 4 GHz bandwidth
  (2x2GHz or 2+2 GHz)
- New optical fibre network installed
  - 30 Gb/s per tel
- New/upgraded receivers
  - 1.3-1.8 GHz, 4-8 GHz, 21-24 GHz
- New IF, samplers,...
- New correlator (DRAO)
  - Starting to commission now



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Northwest Regional Development Agency
University of Cambridge
Science & Technology Facilities Council
liverpool JMU

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e-MERLIN Capabilities

- uJy sensitivity in 12 hrs
- 10 – 150 mas resolution
- L (1.3-1.8 GHz), C (4-8 GHz) K (21-24 GHz)

  Tsys 25-40K

  Rapid change (1 min) between bands

  But do not anticipate much fast switching
- 16 sub-bands
  - 0.25 MHz channels at all Stokes,

    full bandwidth (128 MHz)
  - <kHz resolution; mix bandwidths

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e-MERLIN Science

Open Time + 'Legacy Programme'

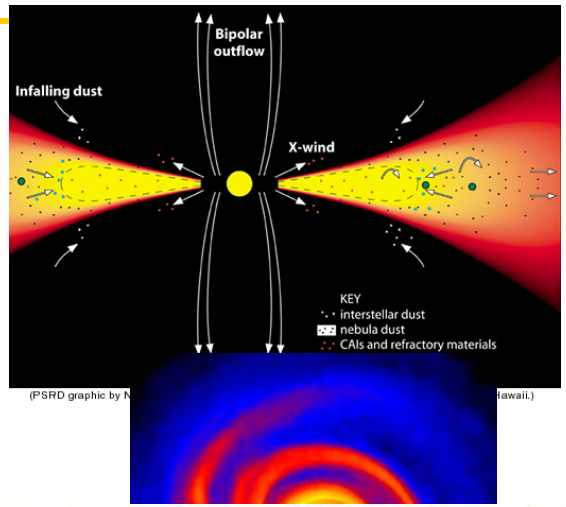
- Stellar magnetic fields
- Massive star formation
- Stellar mass loss
- Pulsar astrometry
- Planet-forming disks
- YSO jets
- XRBs; transients
- Jet physics
- Galaxy substructure, environments
- Starformation & AGN in nearby galaxies
- Galaxy evolution

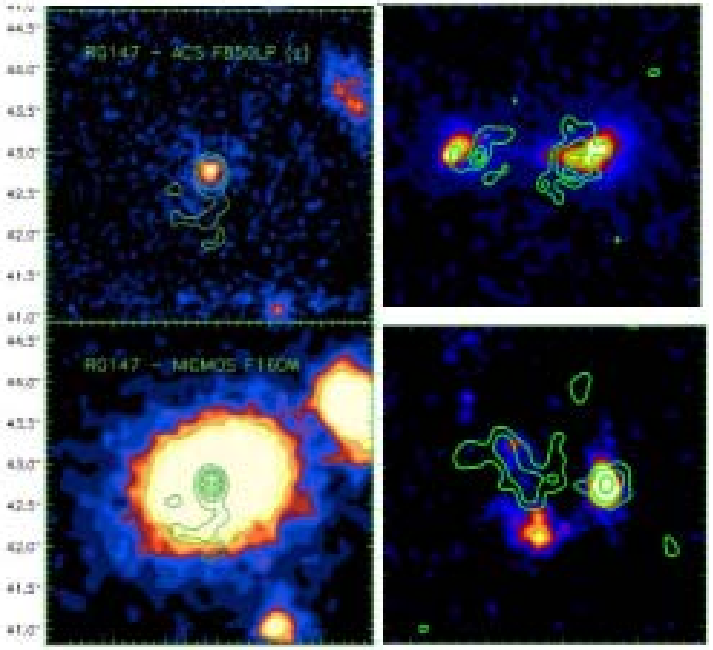
Proposals being evaluated now

3x oversubscribed; >300 scientists

Programme to be put to Steering Committee

Projects should remain open





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e-MERLIN Expectations (eventually…)

- Straightforward to approach noise in 12-24hr observations of faint targets
  - Heroic efforts may be required for the very deepest integrations
- Lovell telescope easily incorporated
- Free wide-field images
- Free spectral information from wide band
- Mosaicing for surveys of few sq. degrees
- Significant improvement in image fidelity from multi-frequency synthesis
  - At least 'VLA-quality' for full synthesis
  - Multi-snapshots as good as current full synthesis
- High dynamic range for sources containing bright features – eg extragalactic jets
  - 10^6:1 Problem appreciated
- Polarisation mapping across wide bands → RM mapping
- Interest in using 4-8 GHz (single pol)
- (Improved astrometry)

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e-MERLIN Issues

- Fractional bandwidth
  - ν_2 / ν_1 ~ 1.3-2
  - multi-frequency synthesis
- RFI …
  - (populated areas, but well spaced telescopes)
- Range of telescopes
  - Lovell (76-m), Mk2 (24*30m;prime), Defford (25-m prime; offset feeds) 3 x E-sys (Cassegrain; on-axis; L-band lens); Cambridge (32-m Cassegrain on-axis)
- Very different primary beams on different baselines
  - Yet to characterise new horn/lens systems in detail, f(ν)
- Sparse aperture coverage
  - (without MFS)
- Lack of short baselines
  - 20:1 (physical baseline ratio)

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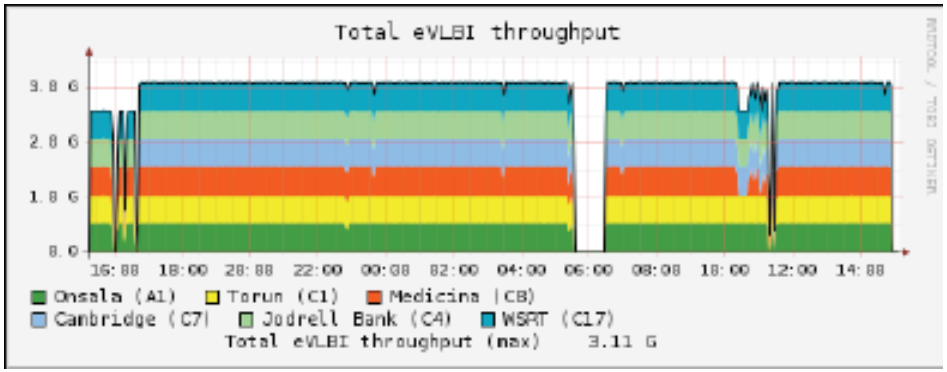
EVN/e-VLBI

- 1 Gb/s disk recording now routine with EVN
- ~1 Gb/s real-time demonstrated through EXPReS and will soon be routine
- > 1 Gb/s actively being pursued
- Large telescopes: Ef,JB,WSRT, (Ar) and more being added (Yb, SRT)
- Increasing number of telescopes available (China, Russia,...) increasing sensitivity and resolution



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EVN Capabilities

- Few uJy sensitivity
  at 1 Gb/s in 12h
- 0.25s correlator dump time
  → 5 arcmin FOV
  (5000km baselines 1.4 GHz)
- Bandwidth expansion
  - DBBC, e-VLBI
  - 4 … 10 Gb/s
  - New correlator, new IF
  - 4 Gb/s → ~1 uJy/beam
  - Similar fractional bandwidth to e-MERLIN, EVLA at 1.5 GHz

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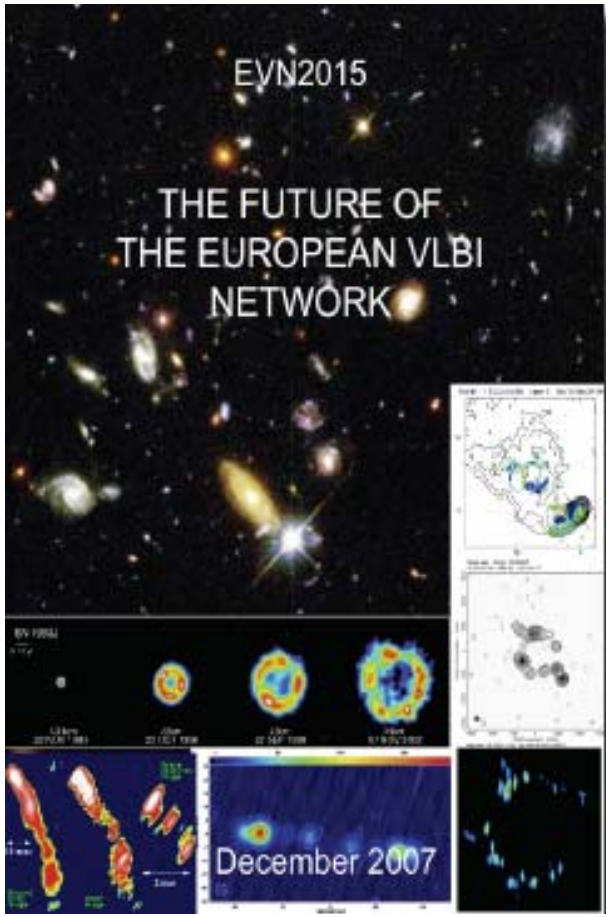
EVN Science

- See EVN2015 Document
  - History of star-formation & accretion
  - Gravitational lenses: substructure
  - Physics of relativistic jets close to event horizon
  - Molecular gas feeding AGN
  - 3D kinematics of star-formation
  - SNe, SNR, XRB, ULX in local group
  - Fundamental astrometry; pulsars
  - Spacecraft tracking



http://www.evlbi.org/publications/publications.html

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EVN/e-VLBI issues

- Wide range of telescope types and phased arrays
  - Telescope & feed geometries
  - Some need characterisation
- Data volumes for wide-field imaging
- Calibration & fringe-fitting
  - Uncorrelated atmospheres, independent clocks, a priori amplitude cal
- Model accountability for astrometry
- Evolving sources
- Can add/incorporate e-MERLIN for short baselines

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General requirements

- Achieving ~ uJy sensitivity on faint targets
  - (Assuming perfect correlator etc)
  - 'Confusing' sources:
  - L-band: ~20 sources > 1 mJy within 25-m beam
    - ~10 compact on longer baselines
    - Range of spectral indices
    - Need to be subtracted to 1-10,000:1
      - Ionosphere
      - Primary beam
        - » Different telescopes (Lovell, EVN)
      - Direction & frequency dependent calibration
        sub-band peeling
    - ~ 200 sub-mJy sources to be dealt with at 100-1000:1
      - Not bright enough to peel
      - use default/nearest/interpolated cal?
    - ? Brighter sources
  - C-band: ~1-2 mJy sources
    - Compact fraction ~ 30%

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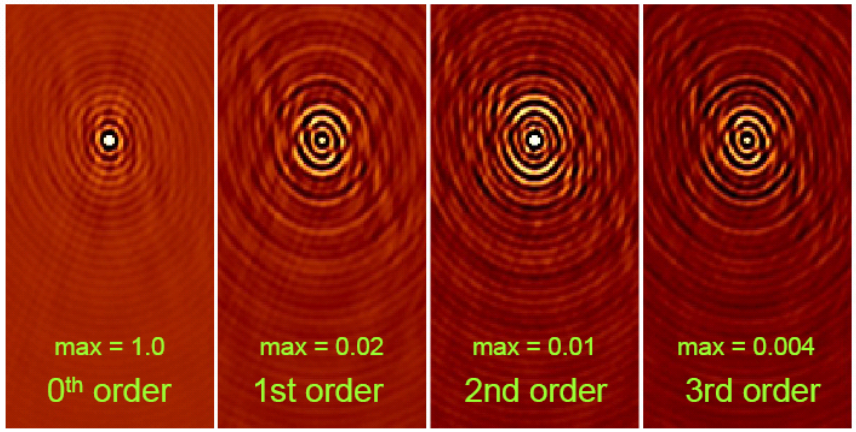
General requirements



- Wide-band imaging
  - $I' = I*B_0 + I\alpha*B_1 + \ldots$
  - Artefacts at $\Delta\alpha/100$
  - Sault-Wieringa and extensions
  - Range of flat & curved spectra for targets & confusing sources
- Wide-band calibration
  - Expect to work in sub-bands
  - Using in-beam/faint reference sources will require fitting across whole band
  - May want to fit for dispersive delay across sub-band
    - Cf Brunthaler

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General requirements

- Wide-field imaging
  - Expect this to be common: ~ TB data sets
  - Low resolution/reduced band search; subtraction
  - Faceted imaging
    - Image sizes, not just w-term
    - e-MERLIN: 72k x 72k
    - e-VLBI: ~200k x 200k
  - Imaging the full field?
  - Strategies for distributed processing

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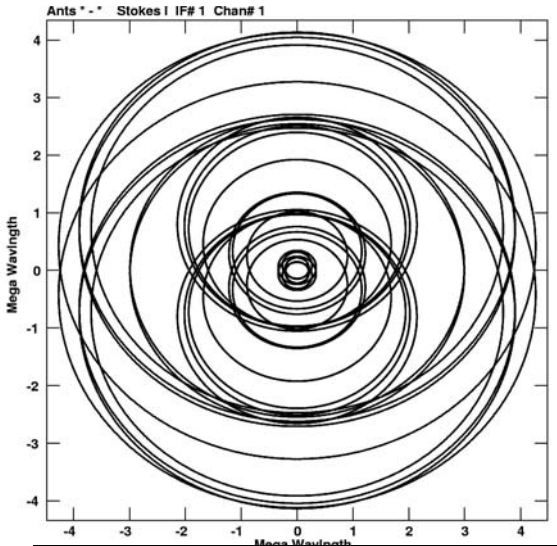
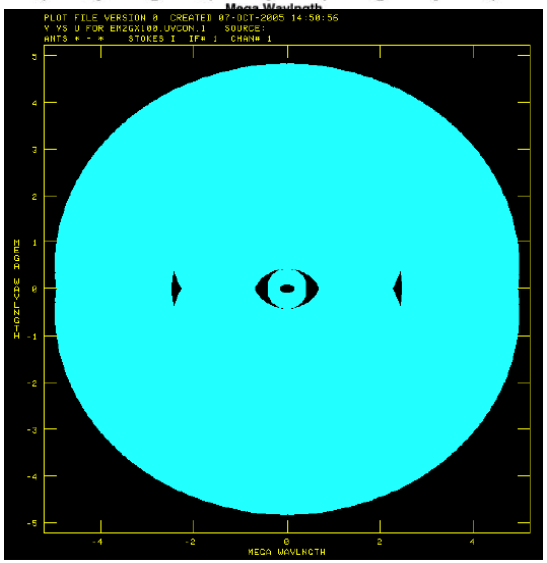
General requirements

- High dynamic range (narrow field)
  - Calibration at that sky position
    - Frequency & time-dependent terms
    - Polarisation terms
    - Baseline-dependent terms
  - Imaging & deconvolution
    - Gridding
    - Weight-smoothing
    - Source fitting
- Image fidelity
  - Deconvolution should be significantly improved by wide band
    - Need MFS
  - Sensitive to wider range of scales
    - Multi-scale CLEAN
    - MEM,...





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Summary

- Main issues for e-MERLIN and EVN/e-VLBI expected to be
  - Accurate subtraction of mJy sources towards edge of field requiring direction- and freq.-dependent cal
    - 1-10,000:1
    - Exacerbated by wide range of telescope beams and pointing performance
  - Wide-field imaging at 1000:1
    - Direction-dep cal across whole band?
  - Mosaicing with different telescope beams
  - Gaining benefit of full/improved aperture coverage through MFS for high DR imaging
  - High dynamic range on-source
    - Low-level freq. & time-dep effects
- Some of the tools already in place
  - Mix & match; Distributed processing in AIPS
  - Parallel wide-field imaging

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