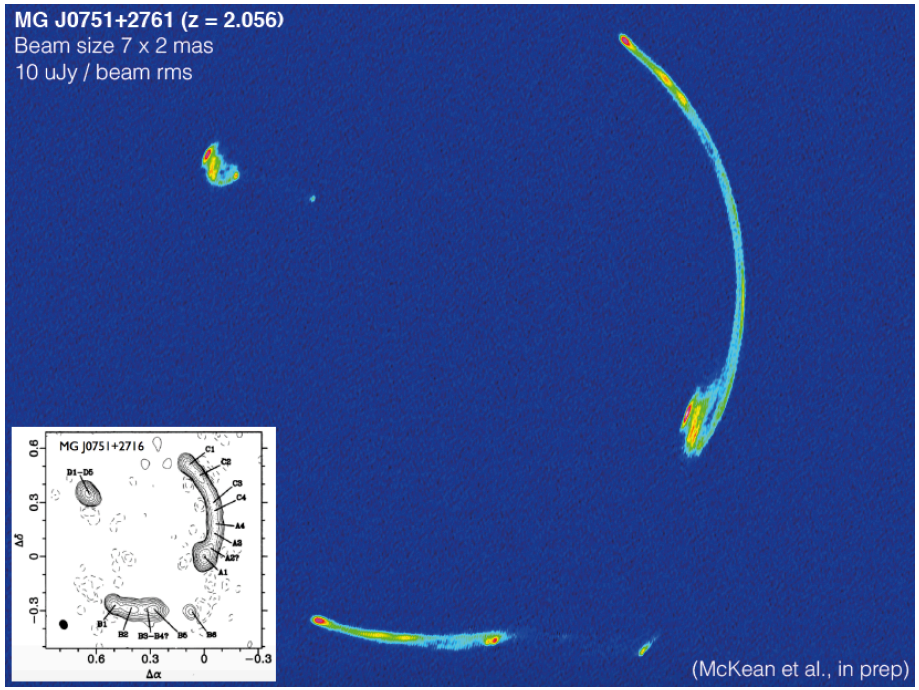
The present status and the future of the European VLBI Network



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Outline

- Introduction
- Description of the EVN
- Science examples
- Future directions and possibilities
- Summary

THE QUEST FOR RESOLUTION

Resolution = Observing wavelength / Telescope diameter

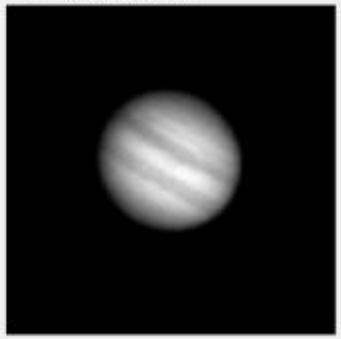
Angular Resolution	Optical (5000A) Diameter	Optical (5000A) Instrument	Radio (4cm) Diameter	Radio (4cm) Instrument
1′	2mm	Eye	140m	GBT+
1″	10cm	Amateur Telescope	8km	VLA-B
0.″05	2m	HST	160km	MERLIN
0.″001	100m	Interferometer	8200km	VLBI

Atmosphere gives 1″ limit without corrections which are easiest in radio

Jupiter and Io as seen from Earth

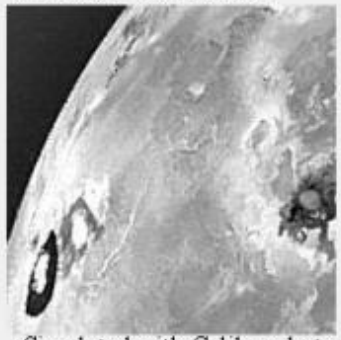
1 arcmin

1 arcsec



0.05 arcsec

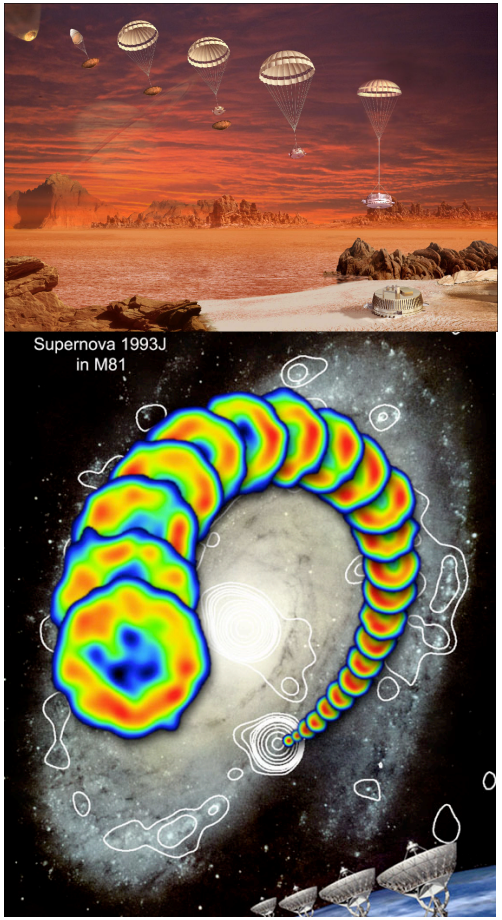
0.001 arcsec



Simulated with Galileo photo

VLBI Science - extremely varied

- VLBI continuum observations generally observe high brightness temperature radio emission from synchrotron processes
- Radio spectral lines are observable in maser emission and in absorption against bright continuum sources (mainly in HI, OH, and H_2CO)
  - Radio jet & black hole physics
  - Radio source evolution
  - Astrometry
  - Galactic and extra-galactic masers
  - Gravitational lenses
  - Supernovae and gamma-ray-burst studies
  - Nearby and distant starburst galaxies
  - Nature of faint radio source population
  - HI absorption studies in AGN
  - Space science VLBI



Description of the EVN

- The European VLBI Network (EVN) was formed in 1980. Today it includes 15 major institutes, including the Joint Institute for VLBI ERIC, JIVE
- The overall governance and policy is set by the EVN Consortium Board of Directors, CBD
- The EVN operates about 21 individual telescopes, including some of the world's largest and most sensitive radio telescopes. Today, the EVN has grown into the most sensitive VLBI array in the world
- The EVN operates an “open sky” policy. Only the PC grants access to the facility and it does this on the basis of scientific merit and technical feasibility only
- There is no standing centralised budget for the EVN. The EVN is thus a classical example of a distributed European facility

EVN and e-VLBI

- From tape reel to intercontinental light paths
- Pieces falling into place around 2003:
  - Introduction of Mark5 recording system (game changer) by Haystack Observatory
  - Emergence of high bandwidth optical fibre networks

e-VLBI

- The development of e-VLBI has been spearheaded by the EVN
- In this way, the EVN/JIVE is a recognized SKA pathfinder

EUROPEAN VLBI NETWORK

JIVE
Joint Institute for VLBI ERIC

Image by Paul Boven (boven@jive.nl). Satellite image: Blue Marble Next Generation, courtesy of Nasa Visible Earth (visibleearth.nasa.gov).

Current status

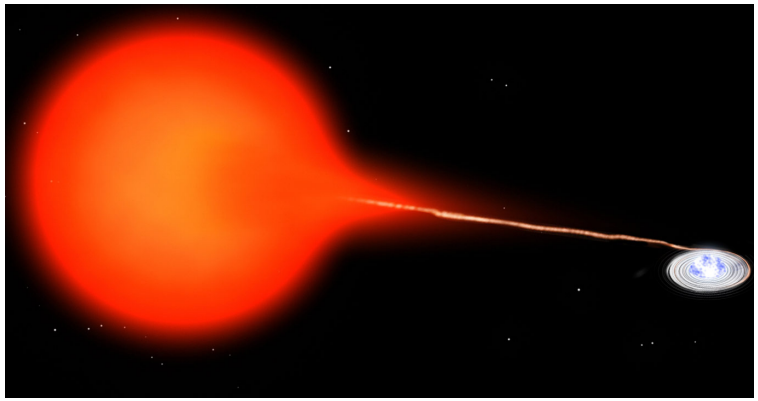
- **Call for proposals:** 3 times per year
- **Number of proposals:** 70-80 per year
- **Oversubscription:** ~ 2.2
- **Not a full time array, the EVN observes during "sessions":**
  - 3 EVN disk sessions (3x3 weeks)
  - 10 e-VLBI sessions (10x24 hours)
  - Target of Opportunity
- **Maximum data rate:** 1 Gbps, 2x128 MHz (from October 2015, 2 Gbps)
- **Most data is correlated at JIVE**
- **Cooperation:** NRAO (VLBA, GBT, VLA), LBA, RadioAstron, …

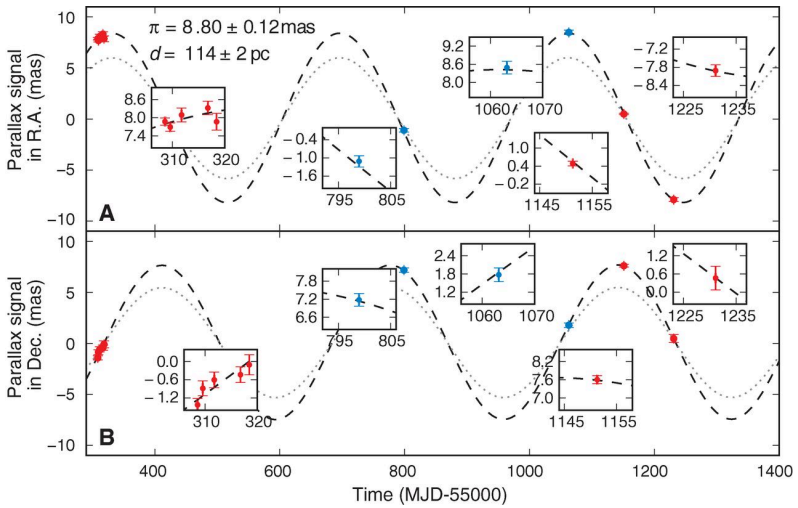
Current status

Maximum Angular Resolution in milliarcseconds

Array	90 cm	18 cm	6 cm	3.6 cm	1.3 cm	0.7 cm
EVN	-	15	5	3	1	0.6
EVN (inc. SH/Ur)	30	5	1.5	1	0.3	0.15
EVN+VLBA	19	3	1	0.7	0.25	0.13

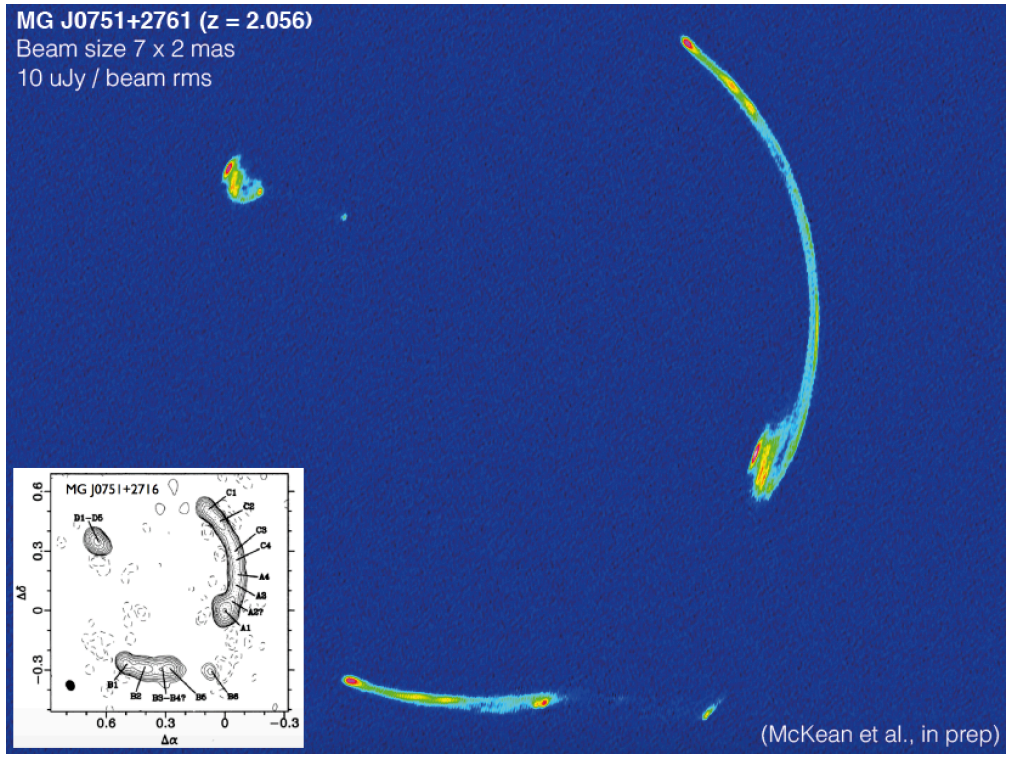
The dwarf nova SS Cygni





- SS Cyg is perhaps the prototype dwarf nova, the outbursts result from changes in the rate at which matter moves through the disk onto the white dwarf
- Using VLBA and the EVN, Miller-Jones et al (2013) were able to accurately measure the distance to SS Cyg
- VLBI data places SS Cyg substantially closer, 114±2 pc, than HST data, 159±12 pc
- The new distance measurement has solved the puzzle of SS Cygni's brightness, it fits the theories after all

Cosmology



McKean et al, in prep.

- Project aimed to image gravitationally lensed radio jets in order to detect dark matter substructure
- It is an innovative and potentially powerful technique using deviations in the brightness distribution of gravitationally lensed arcs as tracers of sub-haloes around lensing galaxies
- Important for CDM models of galaxy formation
- Largest global program ever correlated at JIVE, 23 stations

Enhancing EVN capabilities

- **Feedback from the community**
  - Improved uv-coverage (more telescopes, more short spacings)
  - Increased bandwidth to improve sensitivity
  - Improved resolution (more long baselines)
- **New observing modes**
  - EVN+LBA
  - Triggered/interrupted e-VLBI observations
- **New telescopes and collaborations**
  - e-Merlin with all out stations at 1 Gbps (and beyond)
  - China, AVN, MeerKAT, …
  - Sub-arrays, more observing time with smaller telescopes (EVN light)

Enhancing EVN capabilities

- **e-VLBI/e-transport – not all telescopes are connected**
  - Disk recording and e-VLBI simultaneously
  - 100 Gbps technology rolled out

- **Next generation receivers, backends and recording systems**
  - Summary: More bandwidth (2x4 GHz)

- **Next generation correlators**
  - The EVN Software Correlator at JIVE (SFXC): Fantastically flexible. "Easy" to modify, improve, extend, expand, upgrade
  - UniBoard, based on FPGA:s: Perfect for "simple" operations

Enhancing EVN capabilities

- **SKA1**
  - the two instruments are complementary because the spatial resolution of the EVN is better
  - EVN also observes at shorter wavelength not available to SKA1
  - Very-high-sensitivity VLBI observations will be possible using SKA1-MID acting as a single phased-up element (Paragi et al. 2014)
  - The EVN has a bright future as an instrument for VLBI in the coming decade and through the SKA era

Summary

- Development: bottom-up or top-down? EVN does both
- Communication and scientific interaction between engineers and scientists involved in the development and operation of radio astronomical instruments, such as the EVN, is very important
- EVN is making use of and drive technical progress
- The future for the EVN is looking bright also when we enter the SKA era

The EVN is producing excellent science

Thank you for your attention! Any questions?