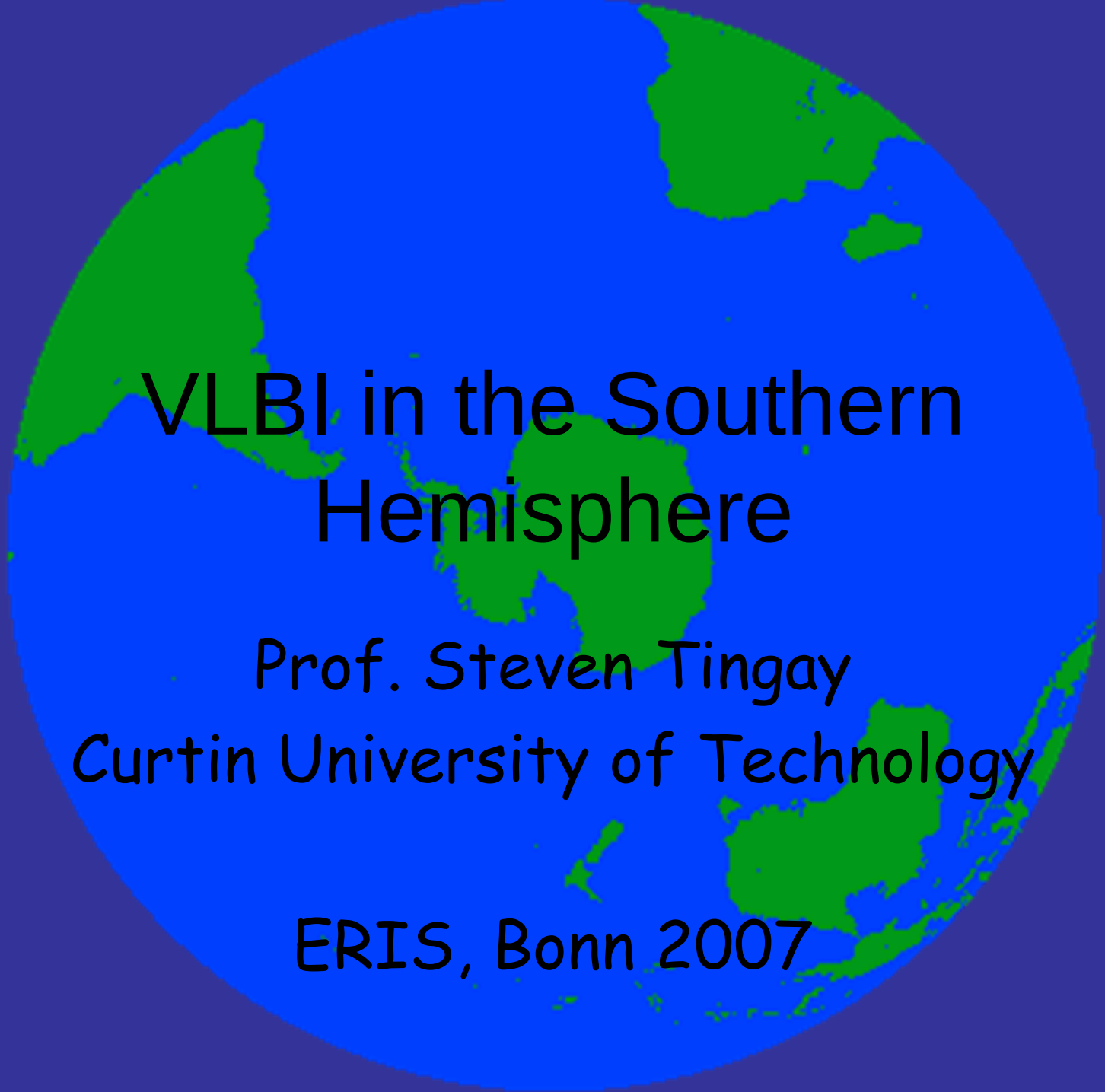


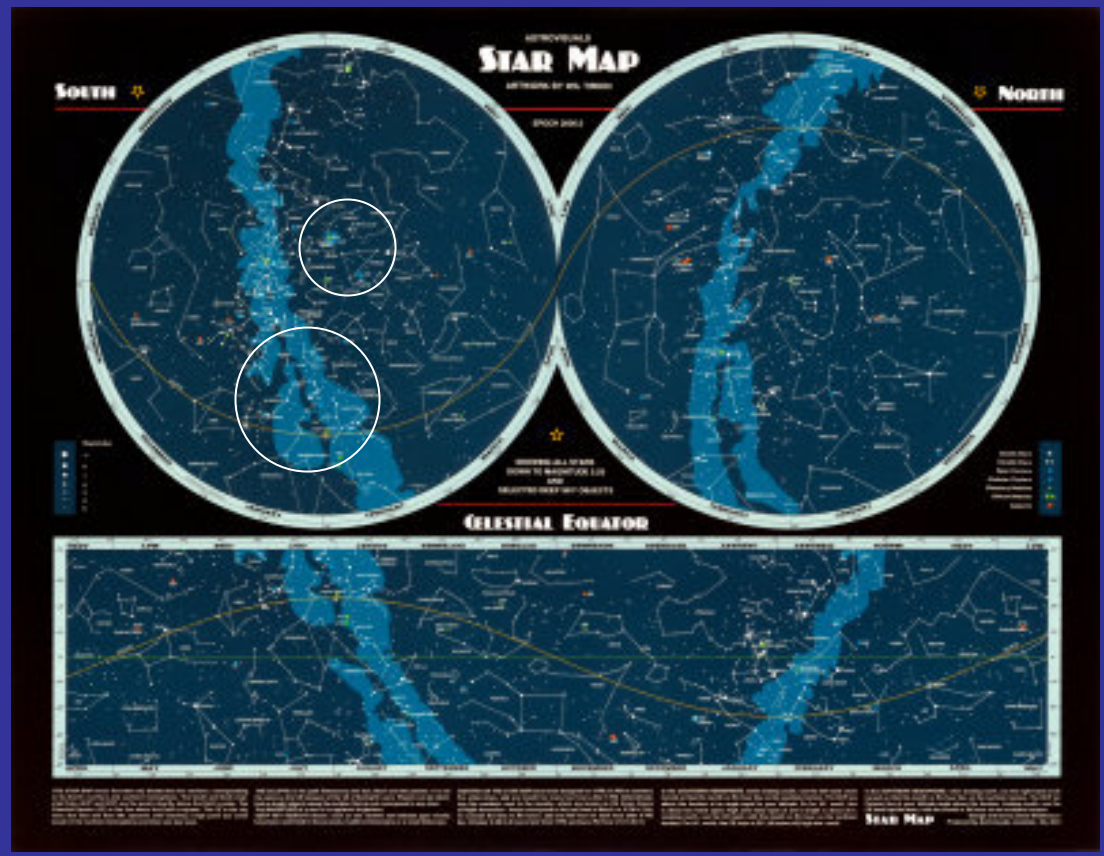
VLBI in the Southern Hemisphere

Prof. Steven Tingay
Curtin University of Technology

ERIS, Bonn 2007

Why Southern Hemisphere VLBI?

- Half the sky in the south!
- Many interesting objects south of -30 degrees:
  - Centre of our galaxy, -30;
  - SMC/LMC, -80;
  - Vela pulsar, -45;
  - Centaurus A/Pictor A, -45.



Australian Long Baseline Array (LBA)

- Consists of 6 antennas;
- Baseline lengths: 100 km - 1700 km;
- Frequencies: 1.4, 1.6, 2.3, 4.8, 6.7, 8.4, 22 GHz;
- Data rates up to 1024 Mbps;
- Data processed using software correlator;
- e-VLBI capabilities;
- International partners;
- Extensions to the array in the medium term

Distribution of antennas

64 m

6 x 22 m

Narrabri

Mopra

22 m

Parkes

Ceduna

30 m

Tidbinbilla

70 m

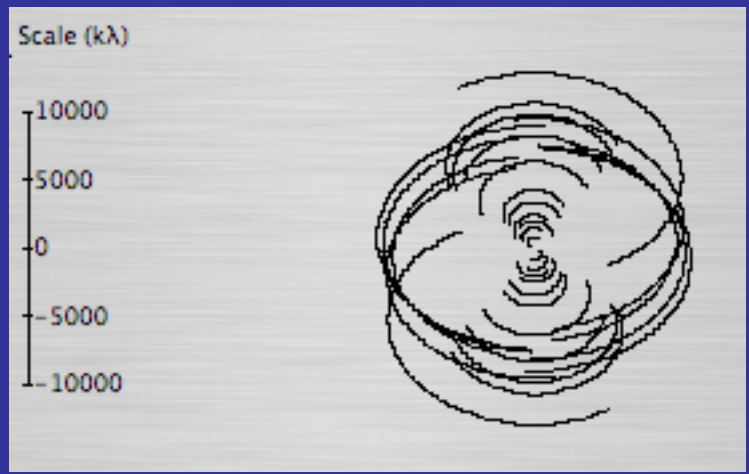
Hobart

26 m

(u,v) coverage and sensitivity

- LBA sensitivity calculator at:
  - http://www.atnf.csiro.au/vlbi/calculator;
  - http://www.atnf.csiro.au/vlbi (Tsys lists, etc…)

- 6 hr integration time at 2.3 GHz with full array and maximum data rate gives 1σ image RMS of 48 uJy/beam (natural weighting)

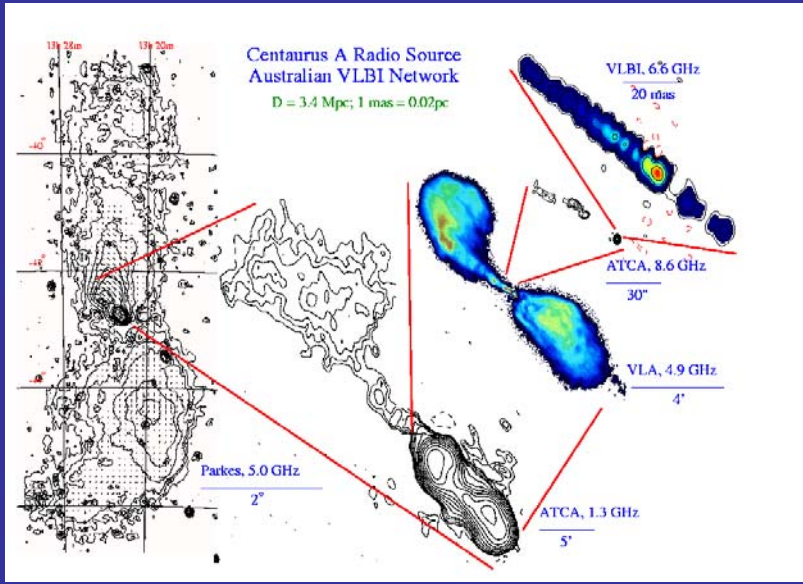


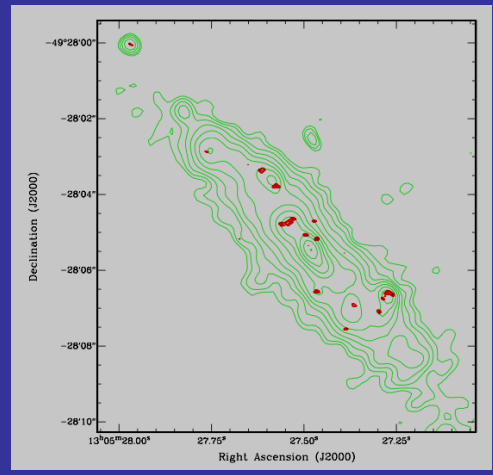
Recording system

- Based on COTS approach developed in Europe;
- Uses PC with DMA card to capture digital time series data and write to an external raid5 disk (Apple Xraid);
- Allows datarates of up to 1024 Mbps;
- System interfaces seamlessly to software correlation system on medium sized computer clusters.

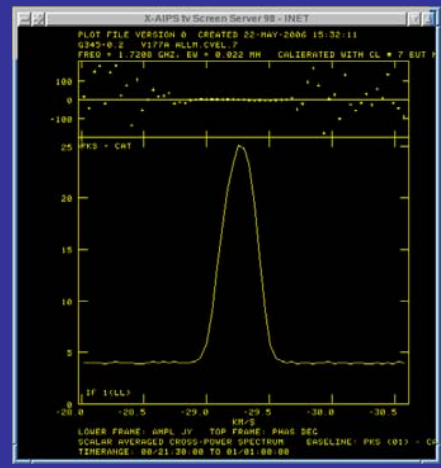
Software correlator

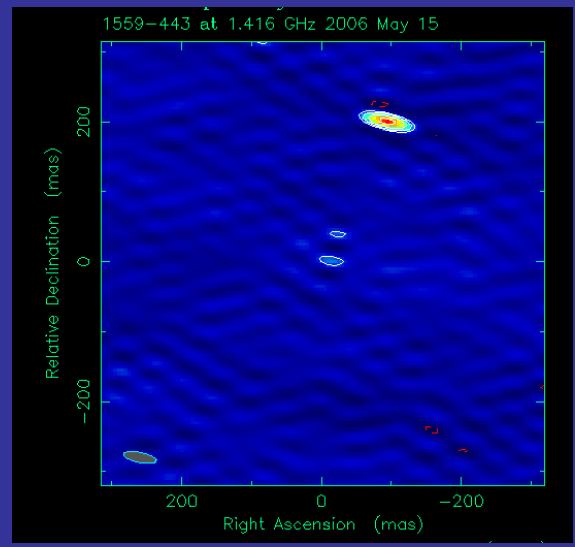
- DiFX (Distributed FX correlator), developed by Mr Adam Deller;
- C/C++ and IPP (Intel Performance Primitives), Java GUI;
- Runs on Intel-based and AMD-based machines, easily ported to other architectures;
- Software is ultimately flexible and allows:
  - Almost arbitrary spectral and temporal resolution;
  - Almost arbitrary and optimal pulsar binning modes;
  - Full control over systematics (fringe-rotation, fractional sample error);
- Can be obtained from:
  - http://astronomy.swin.edu.au/~adeller/software/DiFX
- See full description in:
  - Deller, Tingay, Bailes & West 2007, PASP, 119, 318

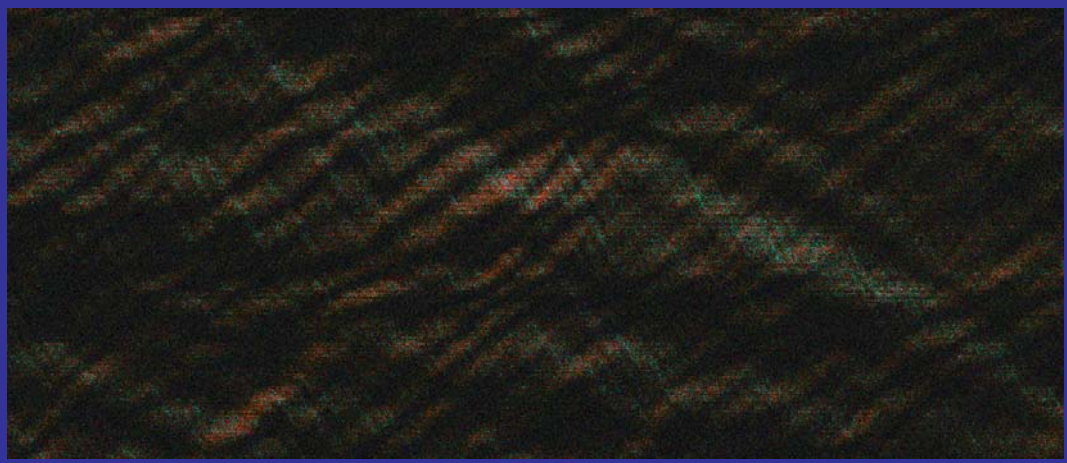




Examples





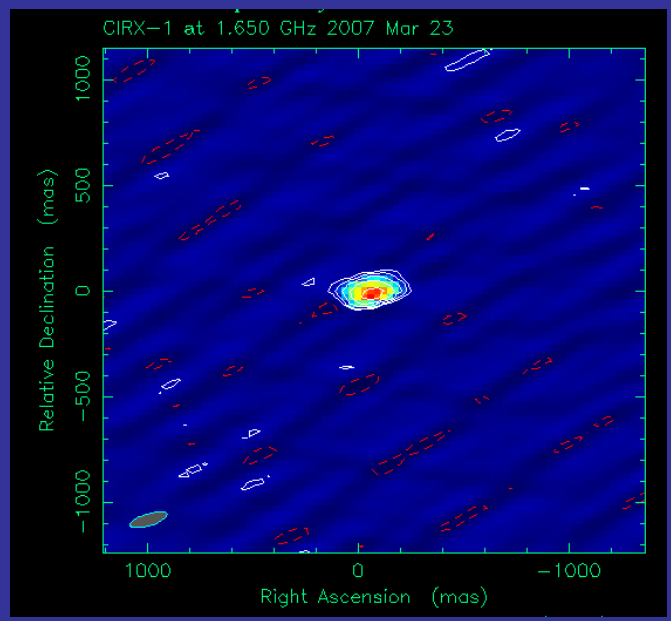


Time

Frequency

e-VLBI

- Real-time transport of digital data from telescopes to correlator - no recording of signals - instant production of visibility datasets;
- Operates for four antennas (Parkes, ATCA, Mopra, Hobart) at data rates of up to 256 Mbps (soon to be 512 Mbps);
- First science for X-ray transient Circinus X-1 (Phillips et al. 2007, MNRAS, 380, L11).
- Excellent for fast response "Target of Opportunity" observations.



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Detection of compact radio emission from Circinus X-1 with the first Southern Hemisphere e-VLBI experiment

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ABSTRACT

Circinus X-1 has recently returned to a state of strong radio flaring. Here we report on the first VLBI observations, and detection, undertaken in the 25 years since the 1975-1985 period of strong recurrent flaring activity. We detected Circinus X-1 with the first observations conducted by a recently developed Southern Hemipshere e-VLBI array, at both 1.6 and 8.4 GHz, over a three day period. At 1.6 GHz, the compact source has a total flux density of 11 mJy and a size of 60±15 milliarcseconds (Gaussian model FWHM). At 8.4 GHz, the compact source is less than 60 milliarcseconds. The size variation with frequency is consistent with a broadened image due to scattering in the turbulent, ionised interstellar medium of our Galaxy. However, these size measurements appear inconsistent with the $\lambda^{2.2}$ variation expected for strong interstellar scattering and previous VLBI observations made at 2.3 GHz in the early 1980s. To explain this apparent inconsistency, we suggest that Circinus X-1 supports a weak, non-varying component of 35 milliarcseconds extent (175 AU at 5 kpc distance), corresponding to compact structure in the extended radio nebula. No significant variation in the flux density at 1.6 GHz is evident between two observations 24 hours apart. No jet-like structures are evident on scales of tens of milliarcseconds, a single scatter broadened source, presumably coincident with the binary system.

Key words: instrumentation: interferometers, techniques: interferometric, X-rays: stars, radio continuum: stars, X-rays: individual (Circinus X-1)

1 INTRODUCTION

Recently the galactic X-ray binary Circinus X-1 (Cir X-1) has returned to a high flaring state at radio wavelengths, last seen in the period 1975 − 1985. Flares as strong as ∼1 Jy at 3.5 cm wavelength have been observed in the period 2006 Aug 03 - Nov 26 with the Hartebeesthoek Radio Astronomy Observatory 26 m antenna (?). The Cir X-1 flares follow a 16.6 day period (?), and the source has been modelled as an eccentric binary system with a compact object in orbit around an OB supergiant, where the flares result from the high mass transfer near periastron (??). One member of the binary system is presumed to be a neutron star (???) and the companion from which material is accreted has recently been suggested to be a supergiant of spectral type B5 − A0 (?).

During the period 1996 - 2007, ? and ? have shown that Cir X-1 has persistently flared, but at mJy levels, not the Jy levels seen in 1975 - 1985 and again recently (?).

At radio wavelengths, several comprehensive studies of Cir X-1 have been undertaken. An arcminute-scale radio nebula surrounds Cir X-1 (???), powered by an arcsec-scale jet originating at the binary system and aligned with our line of sight to within 5° (??). The most compact radio structure in Cir X-1, near the site of acceleration of the particles injected into the jet seen on larger scales, has been previously

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International partners/future extension

- Co-observe with 26 m antenna in South Africa;
- Co-observe with VLBA antennas;
- Three new antennas planned for Australia + SKA demonstrator telescope in Western Australia;
- Three new antennas planned for New Zealand.
- 2010 - 2012: 12 antenna array in Australia/New Zealand at 1.4 - 8.4 GHz and 6000 km maximum baseline.

Proposal and scheduling information

- Proposal preparation and submission information from:
  - http://www.atnf.csiro.au/observers
- Observations scheduled typically in 3 x ~week long blocks during the year;
- Plus several 24 - 48 hour observations outside these blocks for time critical or monitoring observations;
- Interested/Questions? Come and ask me this week, or via email (s.tingay@ivec.org)